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Joint Edition of the Newsletter of the Climate Variability and Predictability Project (CLIVAR) Exchanges and the CLIVAR Variability of the American Monsoon Systems Project (VAMOS)

VAMOS !

Exchanges

CLIVAR is an international research programme dealing with climate variability and predictability on time-scales from months to centuries. CLIVAR is a component of the World Climate Research Programme (WCRP). WCRP is sponsored by the World Meteorological Organization, the International Council for Science and the Intergovernmental Oceanographic Commission of UNESCO.

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Editorial

I am writing this from Antalya, Turkey where the 31st session of the Joint Scientific Committee (JSC) for WCRP is meeting this week (15-19 February). The meeting is taking place alongside the WMO Commission for Climatology's (CCl's) 15th Technical Conference on "Changing climate and demands for climate services for sustainable development" with which there will be a joint one-day session with the JSC. WCRP visioning on the long-term functions and structure of WCRP for supporting climate research and, following World Climate Conference-3 last year, climate services form important elements of the JSC's discussions this year. In addition, the JSC will receive reports summarising the accomplishments over the past year and issues and future challenges of the four core projects (CliC, CLIVAR, GEWEX and SPARC) and of the WCRP Panels, Working Groups and Task Teams. A summary of the outcomes of this year's JSC will be included in the next edition of Exchanges. In the meantime you may wish to take note of the dates for the WCRP Open Science Conference that will take place in Denver, Colorado, USA from 24-28 October 2011. Further information on this important event can be found at www.wcrp-climate.org/conference2011.

As you will see, this edition of Exchanges is joint with the annual VAMOS (Variability of the American Monsoon System) Newsletter that describes some of the latest developments under the CLIVAR VAMOS programme. We also include a short report on the Global Synthesis and Observations Panel meeting held at JAMSTEC, Tokyo last November and a report on last September's Working Group on Coupled Modelling (WGCM) meeting. The latter summarizes the developments in the planning for phase 5 of the Climate Modelling Intercomparison Project and progress with other coordinated modelling activities. One of the issues being discussed at the JSC meeting this week is how to interface with end users including human dimension aspects and so it is timely that we include also an article on "Making climate science useful" from the Humanitarian Futures Programme in the UK.

Finally we include a flyer re-advertising the post of the ICPO Director, the closing date for applications for which is 29 March 2010. Please could you display the vacancy prominently in your institutions.

Howard Cattle

Report of the Fourth Global Synthesis and Observations Panel meeting

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Following the success of OceanObs'09 Conference, which had more than 600 participants from 36 nations, it is now time to work towards the implementation of the Conference's Vision and Statement published at http://www.oceanobs09.net/statement/index.php. The CLIVAR Global Synthesis and Observations Panel (GSOP) was one of the drivers for OceanObs'09 and its members and invitees met at the JAMSTEC Tokyo Office, Japan, on 11-13 November 2009 for the panel's fourth meeting. This meeting focused on the best ways to move forward the discussions that took place during that conference and how GSOP can contribute to realizing its outcomes.

The implementation of a Global Ocean Observing System is now a realizable goal and the OceanObs'09 conference called upon nations to complete the initial phase by 2015. The technologies are in hand, the initial design is in place, and our community is prepared to build and sustain an observing system which is needed for the benefit and the future of our global society. One of the actions from GSOP's meeting was to develop a document (in preparation) which will show that (1) the ocean observing system for climate has great value and must be sustained, (2) our international community achieved a consensus at OceanObs'09 on the enhancements to the initial system that are needed and (3) there is a practical plan for moving forward. A key part of the document will be to identify what are currently seen as "endangered" observations and enhancements needed for understanding ocean phenomena in global climate and variability.

GSOP is the CLIVAR framework for its ocean basin panels to meet and discuss issues on global scales and across-basin boundaries including how to fit to global issues. A highlight of this meeting was the discussion of overarching problems and synergies of basin and global activities. This was facilitated at the meeting by the attendance of representatives (three of them were panel co-chairs) of all four CLIVAR basin panels. They reported on the status of the existing observational activities in the ocean basins highlighting opportunities to enhance or develop the observing system in those regions, as well as problems with its present configuration.

CLIVAR's Data Policy (http://www.clivar.org/data/data_policy.php) was written by GSOP members in 2006 and was widely advertised to all CLIVAR panels and projects seeking CLIVAR endorsement. However, during the discussion about data management, the group felt that it was necessary to review CLIVAR's Data Policy in order to reflect current changes in data management. It is also important to note that CLIVAR is a strong advocate of quick data release, which can be used for validation and assimilation purposes. The group also addressed data quality control and, in particular, strongly supported activities to coordinate quality control schemes of ocean profile data, including a follow up of the first XBT fall rate workshop, which is already being planned.

With regard to ocean synthesis activities the Indian Ocean Panel has already promoted studies on the consistency of Indonesian Throughflow transport estimated by ocean data assimilation products, and all basin panels were encouraged to set up small teams centered around key oceanic regions to exploit the use of ocean synthesis products. In addition, global ocean synthesis intercomparison activities were encouraged to continue under the guidance of GSOP.

Report from the Thirteenth Session of the Working Group on Coupled Modelling (WGCM) 28–30 September, 2009

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WGCM
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The 13th Session of the CLIVAR/WCRP Working Group on Coupled Modelling (WGCM) was hosted by the Program for Climate Model Diagnosis and Intercomparison (PCMDI) in Sausalito, San Francisco, USA. PCMDI celebrated its 20th anniversary in 2009, having been established in 1989 at the Lawrence Livermore National Laboratory (LLNL) in Livermore, California. WGCM was extremely grateful for the welcome and organization provided by K. Taylor, P. Gleckler and P. Drumtra of PCMDI that made this meeting so successful.

The two main topics of this meeting were the progress of the Coupled Model Intercomparison Project: Phase 5 (CMIP5) and the theme of model evaluation and improvement. WGCM's partners (including CLIVAR, GEWEX, SPARC, CliC, WGNE, WOAP, IDAG) and the global modelling centres reported on their activities of relevance to CMIP5, including associated coordinated experiments, and progress in model development. Additional WGCM discussion topics included air quality and climate and a proposal for a coordinated geoengineering experiment. The third day of the meeting was held jointly with the Scientific Steering Committee of the IGBP Earth System modelling project, Analysis, Integration and Modelling of the Earth System (AIMES). The mini-workshop addressed the current status of Earth System Model (ESM) development and future directions.

CMIP5 and Coordinated Modelling Activities

Over 20 global modelling groups are in the process of starting to generate their contributions to the Climate Modelling Intercomparison Project, Phase 5 (CMIP5). The PCMDI CMIP5 website (http://cmip-pcmdi.llnl.gov/cmip5/) is in place and includes the full set of forcings for CMIP5 (emissions and concentrations) and the list of fields to save from the simulations.

The Representative Concentration Pathways (RCP) database currently includes harmonized and consolidated data for three of the four RCPs (RCP2.6, RCP4.5 and RCP8.5).

The database will include historic and harmonized future land use/land cover data as well as further spatial detail for historical emissions. The data for RCP 6.0 is undergoing internal review within the Integrated Assessment Modelling (IAM) community and will be made available as soon as possible. Registered users of the database will receive information about further developments and updates of the database.

The AC&C/SPARC Ozone Database is available from the CMIP5 website and has the goal of providing a merged tropospheric/stratospheric ozone time series from 1850 to 2100 for use in CMIP5 simulations by models without interactive chemistry.

The inclusion of the Cloud Feedback Model Intercomparison Project, Phase 2 (CFMIP2) experiments in CMIP5 has created a direct link between the process and climate communities. The CFMIP component of CMIP5, both experiments and outputs, has been finalized. CFMIP has developed the CFMIP Observations Simulator Package (COSP), a community tool for facilitating the comparison of model with satellite data (www.cfmip.net). Observations consistent with COSP diagnostics are available on http://climserv.ipsl.polytechnique.fr/cfmip-obs.html. COSP V1.2 will be compliant with CMIP5 data format requirements.

The Paleoclimate Modelling Intercomparison Project, Phase 3 (PMIP3) is contributing to the CMIP5 list of simulations on the last glacial maximum (LGM), the Mid-Holocene and the last millennium. The experimental design of the experiments has been finalized (http://pmip3.lsce.ipsl.fr/). The last millennium simulations will assess the relative role of external forcing and internal variability in shaping the climate on interdecadal to multi-centennial time scales, ensuring continuity with the CMIP5 control integrations. The PaleoCarbon Modelling Intercomparison Project (PCMIP) focuses on the coupling between climate and the carbon cycle on Quaternary time scales and is a Tier 2 experiment for CMIP5. PMIP recommends that groups use the same model version as is being used for simulations of the current and future climate, though recognizing that the stress on resources may mean that different resolutions are used.

The Task Force on Regional Climate Downscaling (TF-RCD) was formed in 2008 and its main outcome has been to organize the Coordinated Regional Climate Downscaling Experiment (CORDEX) that is aimed at fostering coordination between regional downscaling efforts around the world, and at assessing and understanding the sources of uncertainty in RCD-based projections. CORDEX has a model evaluation framework consisting of a set of simulations at 50 km resolution using ERA-Interim reanalyses as boundary conditions over the period 1989-2007, and a climate projection framework related to the RCP 4.5 and 8.5 CMIP5 simulations, contributing to the near-term, decadal runs. CORDEX will evaluate the added value of downscaling and address issues of uncertainty at small scales. The aim is to look at the regional changes in climate and air quality associated with the evolution of GHGs, aerosols, land use changes etc. and to assess their possible impacts. The initial focus will be on Africa. A CORDEX website is being developed, there is commitment from global modelling groups to provide the necessary output, hosted by PCMDI, and results will be held in CORDEX databanks.

A framework to facilitate the use of observations alongside CMIP5 model data has been proposed, initially for NASA, but hopefully for expansion to other agencies and data centres (a discussion about this is underway within WOAP). The proposal aims to identify observational datasets that are pertinent for CMIP5 analysis, something never done before, engaging the observational community directly. A strategy is being developed to provide the community of researchers that will access and analyze CMIP5 model results access to analogous sets of observational data in a common and convenient format. The need to inform modellers about observations, uncertainties and differences across algorithms has been raised.

Model Development and Evaluation

Now that CMIP5 is underway, WGCM and the wider modelling community has the opportunity to start the process necessary to achieve major improvements to develop the next generation of models, with an eye on a future CMIP6. WGCM will be strengthening its partnership with the WCRP Working Group on Numerical Experimentation (WGNE) that is also aiming to drive this process, working on parameterization development, metrics, organizing focused workshops, etc. As part of this partnership, a joint WGNE-WGCM initiative (named Transpose-AMIP) aiming at evaluating climate models in a numerical weather prediction mode has been endorsed.

Model errors and biases are key limitations of the skill of model predictions over a wide range of time and space scales. This is not a new story and the increases in resolution and in model complexity have not solved the problem. In an effort to reinvigorate the discussion of how to improve and evaluate models, a bottom-up community-wide consultation has been initiated within WCRP and its core project working groups and panels, WWRP, THORPEX and IGBP. The groups surveyed range from the process study, theoretical and observational communities to the NWP and climate modelling communities. The fact that WCRP is undergoing a period of evolution in its structure is an opportunity to put the recommendations from the survey into action.

More than 100 responses have been received so far, many of which are group, lab or project-wide responses. The survey recommendations and outcomes will be available on a dedicated website and the results will be synthesized for the WCRP, WWRP and THORPEX steering committees. The survey outcomes will help to provide advice regarding where international coordination and efforts need to be strengthened. The results will also be published in the peer-reviewed literature.

Joint WGCM-AIMES SSC Meeting on Earth System Modelling

The final day of the WGCM meeting was held jointly with the AIMES SSC and included updates on the state of the art of ESMs in Japan, Europe and the USA as well as a discussion on what the increasing complexity of ESMs means for evaluating uncertainties, feedbacks and climate sensitivities. There will be new issues emerging with CMIP5 now that some modelling groups are running ESMs, with new questions arising on how to evaluate them. The need to coordinate efforts on the process-oriented analysis and evaluation of ESMs across the different MIPs (C4MIP, CFMIP, CCMVal, etc.) has been recognized.

The meeting addressed the future directions for Integrated Assessment Models (IAMs), including the prospects for coupling IAMs to ESMs, and adding human dimensions. There have been three major transformations in the human population over time, the last being since the industrial

Front row, left to right: Gerald Meehl, Gokhan Danabasoglu, Natalie Mahowald, Pascale Bracannot, Peter Gleckler; second row: Marco Giorgetta, Amy Solomon, Sybil Seitzinger, Ken Sperber, Ron Stouffer; third row: Tony Hirst, George Boer, Ayako Abe-Ouchi, Ghassem Asrar; Fourth row: John Mitchell, Masa Kimoto, Greg Flato, Sandrine Bony; Fifth row: Colin Jones, Jiping Liu, Karl Taylor, Renu Joseph, Ben Santer, Anna Pirani, Cath Senior; back row: David Legler, Joao Teixeira, Filippo Giorgi, Kathy Hibbard, Jean-Francois Lamarque, Curt Covey, Christian Jakob.
See the meeting report for a full list of participants.

revolution. From an IAM perspective, there will be a new change over the next century. This will be in part intentional, due to policies and choices in development paths, and in part dependant on natural processes and climate. This gives the motivation for coupling the IAM and ESM disciplines. Integrated 'Anthropocene' (human and Earth) System Models (IASMs) could couple human well being and earth systems in an internally consistent way by coupling emissions, land-use and land-cover, carbon and nitrogen cycles, energy, industry, transport, settlement patterns, agriculture and forestry.

The model and data needs of predicting biogeochemistry and biology in the Earth System were discussed together with a presentation of the National Ecological Observatory Network (NEON), an observing system in the USA with 20 eco-climatic zones. NEON data is being integrated to produce analyses and forecasts, for example, of the suitability of habitats for invasive species. Long-term observations of relevant quantities are necessary to assess and develop models.

The closing discussion of the joint meeting focused on the common interests between the WCRP and IGBP in pursuing a coordinated strategy to Earth System Modelling. For example, what are the key questions that should be addressed by a suite of ESMs and how to best develop the models needed to address these questions, including what are the climate related questions and what additional dimensions could be included into ESMs? The idea is to think ambitiously on where ESMs are going in the future and whether other collaborations are necessary that are outside the traditional WCRP-IGBP partnership. Future plans should also include a 'deliverables' dimension on how observations and model improvements lead to capabilities for those investing in the fundamental research as well as users of the output products.

Isaac Newton Institute for Mathematical Sciences: Mathematical and Statistical Approaches to Climate Modelling and Prediction 11 August –22 December 2010
http://www.newton.ac.uk/programs/CLP/index.html

A six-month research programme is to be held in Cambridge, UK which will bring together world-leading researchers in climate modelling, mathematics and statistics in order to make progress in solving some of the major issues facing climate prediction. Our best estimates of future climate are based on the use of complex computer models that do not explicitly resolve the wide variety of spatio-temporal scales making up Earth's climate system. The non-linearity of the governing physical processes allows energy transfer between different scales, and many aspects of this complex behaviour can be represented by stochastic models. However, the theoretical basis for so doing is far from complete. Many uncertainties remain in predictions derived from climate models, yet governments are increasingly reliant on model predictions to inform mitigation and adaptation strategies. An overarching aim of climate scientists is to reduce the uncertainty in climate predictions and produce credible assessments of model accuracy. This programme will focus on themes that require the close collaboration of mathematicians, statisticians and climate scientists in order to improve climate models and the interpretation of their output.

Further information on the programme activities and the people taking part can be found on http://www.newton.ac.uk/programmes/CLP/index.html.

Making climate science useful

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While governments are making significant resources available for climate change research and adaptation programmes, limited funding or efforts have, to date, been devoted to ensuring that those most likely to be adversely affected by climate change are able to understand, use and inform the climate science produced. There are, currently, significant mismatches between the climate information which is available and that which could effectively inform efforts to address the impacts of climate change.

With the aim of strengthening dialogue about the types of climate information required for humanitarian and development planning, the Humanitarian Futures Programme (HFP) supported a series of pilot exchanges in 2009 between scientists from the Universities of Exeter, Liverpool, London and Oxford, the Met Office Hadley Centre, and the humanitarian organizations: CAFOD, Christian Aid, Oxfam and Save the Children UK.

Based at King's College, London, HFP aims to strengthen the capacities of organisations engaged in prevention, preparedness and response to prepare for the changing nature, scale and locality of future crises. The programme's Futures Group aims to strengthen the dialogue between scientists and humanitarian and development policy makers on issues of future human vulnerability. In building understanding of how humanitarian and development organisations take on issues of scientific uncertainty and establish the capacity to take on evolving scientific learning within their planning processes, the Group has recently adopted a thematic focus on climate change.

While HFP has produced a fuller briefing paper (Climate Change Exchange, 2009), this article seeks to highlight some of key findings of the pilot exchanges, including the areas of climate science support identified by exchange participants, together with the views of some of the exchange partners, with a perspective from one of the participating scientific bodies and another from a policy maker in a humanitarian and development organisation.

The exchanges resulted in a number of immediate benefits, including: heightened understanding amongst partner humanitarian organisations of the difficulties of effectively using climate information and the different forms of climate information available, and, amongst partner scientists, increased awareness of the level of climate science understanding within partner humanitarian organisations and the climate science required within humanitarian planning processes. The exchanges also made very clear the need for more sustained, contextualized and cross-disciplinary dialogue on climate change.

The exchanges have highlighted the need for a new discourse more relevant to the climate information needs of end users, but who are the end users of climate information?

There is a wide range of end users of climate information within the humanitarian and development sector, from ministers to those communities extremely vulnerable to changes in climate, encompassing a huge diversity of levels of education, cultural backgrounds, perceptions and interests. The exchanges highlighted the need to disaggregate the intended group encompassed within the term 'end users', and challenge assumptions regarding commonly employed terminology. Climate information needs to be provided in formats that are accessible and useful, with different types of information likely to be required to support humanitarian and development programming, advocacy and campaigning.

There are important opportunities for climate scientists to more directly inform the various stages of policy and planning. Within this process, policy makers require greater clarity regarding those areas where scientific understanding can usefully inform humanitarian and development policy and where it remains, at present, too uncertain. Yet even where understanding currently remains uncertain, issues which may have a significant impact on future human vulnerability must remain on the humanitarian and development radar.

Each of the exchanges underlined the importance of contextualising climate change alongside other drivers of vulnerability. Such a process inevitably requires strengthening multi-disciplinary approaches and reaching agreement on shared measurements of risks, together with the development of frameworks to enable the comparison and prioritisation of issues with potential to heighten future human vulnerability.

Areas of required climate science identified by exchange participants were:

- Undertaking a broad-based assessment of the existing levels of understanding of climate science within the humanitarian and development community and their climate information needs;
- Assessing how existing climate products could be used by, or adapted for, humanitarian and development planning purposes;
- Identifying critical climatic thresholds and how these link with economic and social tipping points;
- Assuring quality control of climate information and climate tools, and assessing how these have been employed by humanitarian and development organisations;
- Providing climate science training, including how to both assess the quality of and use climate products;
- Strengthening the credibility of national and local disseminators of climate information;
- Supporting linkages between universities and national science academies in 'developed' and 'developing countries';
- Building multi-disciplinary approaches to climate change;
- Identifying relevant fora for enhancing the dialogue between humanitarian and development policy makers and climate scientists, such as the World Meteorological Organisation (WMO)'s Regional Climate Outlook Forum (RCOF);

- Creating channels for community concerns to directly inform climate scientists;
- Establishing clearing houses for climate-related activities to promote coordination and collaboration; and
- Exploring the role of humanitarian and development organisations as gatherers, disseminators and translators of climate information.

Proposed next steps

HFP continues to seek support for the extension of the pilot exchanges in time, place and scope. Exchange partners have indicated their interest in undertaking longer exchanges between climate research institutions, humanitarian and development organizations, and their programmes and partners in other countries and regions, as well as developing cross-disciplinary approaches, bringing in scientific expertise on issues of future vulnerability beyond climate change.

Accrued understanding from these efforts to support an effective dialogue between climate scientists and humanitarian and development policy makers will be channeled to a range of relevant ongoing fora, including the WMO's recently agreed initiative to develop a Global Framework for Climate Services, the IPCC's Special Report on 'Managing the Risks of Extreme Weather Events and Disasters' and the Department for International Development's support for a Climate and Development Knowledge Network. Most immediately, HFP has proposed a Royal Society Policy Lab on 'Preparing for extreme weather events' anticipated for early 2010.

Perspectives from one of the scientific partners to the pilot exchanges:

Dr Andy Morse, (A.P.Morse@liv.ac.uk), and Dr Cyril Caminade (cyril.caminade@liverpool.ac.uk), School of Environmental Science, University of Liverpool

The development and production of weather and climate information is, by definition, driven by the needs of, and potential benefits which it can bring to, society, whether this be at the level of an individual citizen, a government at local, national or pan-national level, or indeed commercial and industrial interests. It is therefore surprising that the community that produces this information have invested few resources in strengthening links with the user-base in an attempt to exchange knowledge and understanding on a tailored and long term partnership building basis. There are, of course, exceptions and ongoing partnerships but as the interest in climate change grows and the number of organizations that are climate aware increases, there are not scalable solutions to addressing needs at the interface between provider and user of climate information. This exchange programme was a first step to identify these gaps and look for both generic and specific solutions for non-expert use of climate information, encompassing observations, initial condition predictions - especially from ensemble prediction systems running from days to seasons, or longer term climate change projections.

Unfortunately the meteorological community has, on the whole, lacked a real vision for engaging with, or growing a base of, interested parties beyond its own discipline or established allied discipline groupings e.g. hydrology and agricultural impact groups. In many parts of the developing world there is lack of capacity within the National Meteorological Services themselves to use the type of information produced by state of the art climate prediction systems. Meteorologists in these National Meteorological Services need to be trained, but there are also a series of further connections that need to be made between forecasting centres, forecast developers and national and regional humanitarian and development organisations in order that the latter can employ the best climate information available to inform their decision making operations and development policies.

It is essential that climate scientists from a range of climate and weather sub-disciplines become actively engaged in knowledge exchange. Knowledge exchange is a two way process and both sides learn and improve their current practices following carefully organised interactions. With a few exceptions, knowledge exchange is currently generally left to the media or non-main stream climate scientists. Humanitarian and development organisations have been seen to rely on secondary sources or intermediary translators of climate information. Where they do take the information direct from plots or archives, they do not always understand how to process or interpret the data sets. Past attempts of knowledge exchange have been more statements of position and current expertise rather than a genuine and active partnership where equal working relationships are accorded the time and resources required to develop.

Currently we can find naïve interpretation of climate information by potential users and, at times, gross misunderstanding of the techniques used to make prediction and projections and their inherent uncertainties. Without the knowledge of common model biases, for example, the large frequency of drizzle days or systematic problems for certain parts of the world - such as the simulated rainbelt location in West Africa, it is impossible for a user of climate data from outside the climate science community to make use of important data sets. When there is an ensemble of values, the non-community user will often reduce the result to a multi-model mean and miss the rich information surrounding the uncertainty of that prediction or projections. There is a strong need to educate potential users about multi-model ensemble prediction systems and climate projections, especially as they reach into decadal time scales.

The current state of affairs makes maladaptation to climate change a distinct possibility. Such maladaptation, due to incomplete understanding of climate projections, could be devastating to those living in the poorer regions of the world that are likely to be hit the hardest by climate change where people are already living in areas that are climatically marginal or, at best, entirely reliant on rainfall for their agricultural systems, such as most of Africa.

Current understanding amongst, and collaboration with, the users of the data sets is far from the potential for engagement outlined above. There is an initial stage of training that needs to take place, before interaction surrounding climate model data sets can be discussed. Before presenting outputs from models, there is a strong need to develop portable, simple, but informative, basic climate system information and training. What is often required is an informed narrative that accompanies data sets and an easy to pick up discussion. It is likely that we should develop voice over for visuals to explain the key points in a chart or graph. It is our duty to engage with the users of our datasets to make sure that they are not used inappropriately or commented on in a misleading way by people with some perceived authority, but who do not have the expertise to make such judgments.

The exchange programme has confirmed that the use of worked examples, even if not fully developed, is essential for showing appropriate ways to analyse climate model data and tailor it to specific user requirements. In our exchange with CAFOD we looked briefly at a rapid study of climate variability and the production of maize in Bolivia. The annual maize production over Bolivia experienced a significant increasing trend over the last 50 years and shows large interannual variability (Fig1a). The production trend can be mainly related to globalisation. This is due to increasing demand for maize for the animal food market and especially for exportation. The interannual maize production variability can be associated with climate variability. Indeed, there is a robust relationship between the El Niño Southern Oscillation (ENSO) pattern and maize production in Bolivia at an interannual time scale (Fig1b). Significant positive correlations between maize production and rainfall are highlighted over the Bolivian highlands, especially over the southwestern part of Bolivia (Fig1c). During El Niño, western wind anomalies at 200hPa are observed over the tropical Andes that prevent the advection of moist air from the Amazonian region to the Altiplano (Ronchail and Gallaire, 2006). This consistently leads to decreased rainfall, and thus to decreased maize production over southwestern Bolivia. As the ENSO is now relatively well represented by the ensemble seasonal forecasts (Weisheimer et al., 2009), discussions between the involved climate scientists and the NGO partners have highlighted the use of this climate information in order to build local adaptation strategies at seasonal time scales.

Climate projections based on coupled ocean-atmosphere climate models from the CMIP3 IPCC archive simulate a significant rise in temperature over Bolivia for the 21st century (Fig2a) with, however, a large spread in the projected magnitude (between 1.8°C and 5°C around 2070, based on the SRESA1B emission scenario. However, future projections of rainfall (Fig2b) have high uncertainty over Bolivia and to some extent over the whole tropics (Solomon et al., 2009). Given these large uncertainties and the need for humanitarian and development policy makers to develop and implement adaptation strategies for the next decades (particularly the next 10 or 20 years for which the projected climate change signal is relatively small), it appeared that this "raw" climate information could have limited operational use for them. This is partly why the next IPCC exercise (AR5) will concentrate on these issues, including an extensive ensemble decadal prediction exercise.

Long-term progress in an exchange exercise only occurs where the collaboration is facilitated over months and years. Initial progress works best when a real world problem is tackled as a learning and collaborative exercise, as is shown above. It is only through such a try and see approach that progress in forming understanding and ideas can be developed in an incremental, but rapid way. The exchange has led to an ongoing relationship that will continue in funded projects. Most importantly we feel that, given a fully supported programme, we could produce tailored climate products that would be useful operationally and inform humanitarian and development policy and planning at all levels; whilst at the same time

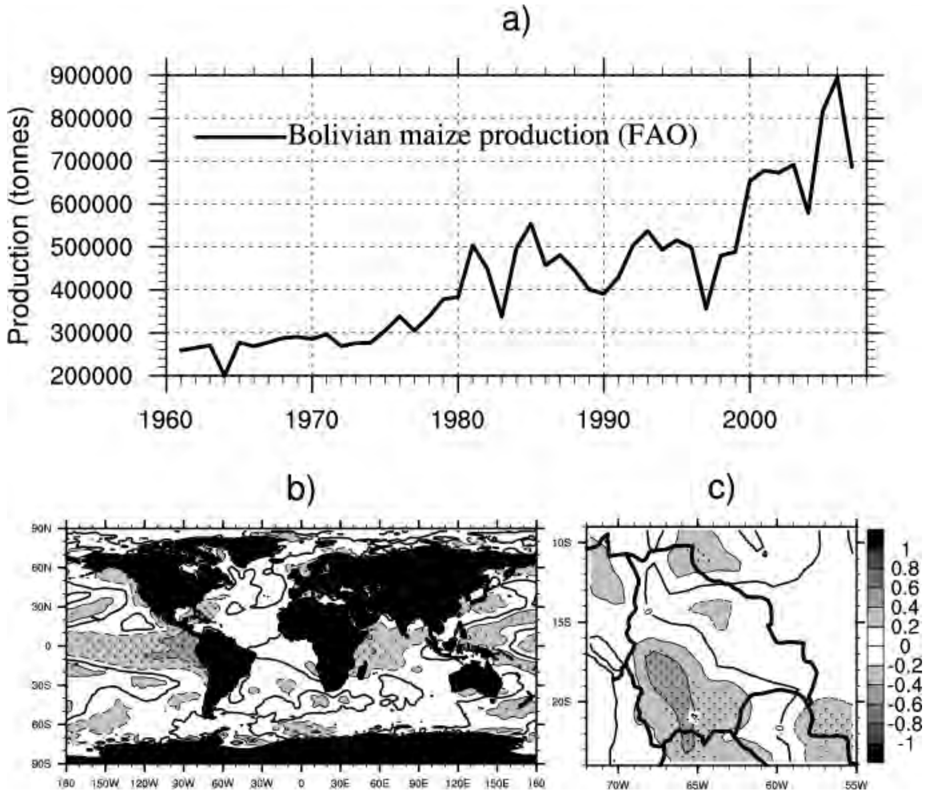

Figure 1: a) Annual maize production (tonnes) over Bolivia (FAO dataset). Correlation between annual maize production and b) annual global sea surface temperatures and c) annual rainfall. For the correlations the data have been detrended using a high pass filter with an 8year cut-off. Dotted areas depict significant correlations at the 95% confidence interval, as estimated by a student t-test. Dashed (solid) contours show negative (positive) correlations. The SST are from the ERSST dataset (Smith and Reynolds, 2004), rainfall is based on the CRUTS2.1 dataset (Mitchell and Jones, 2005).

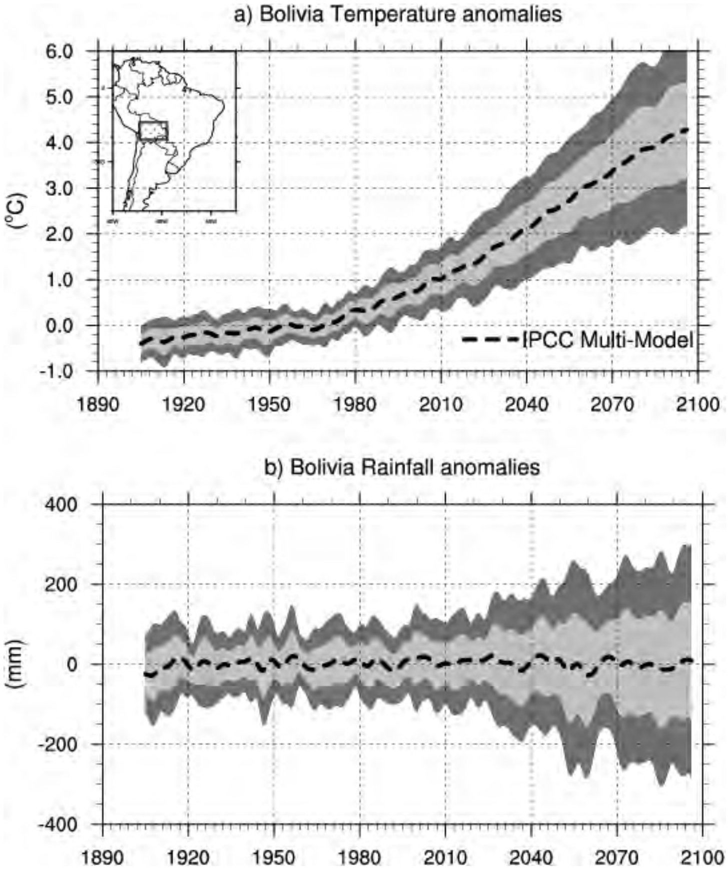

Figure 2: a) Annual Temperature (°C) and b) Rainfall (mm) projections for the CMIP3-IPCC model ensemble (based on 23 climate models). The future scenario is based on the SRESA1B emission scenario, the current climate is based on the 20C3M experiments (historical runs). The light (dark) grey envelope depicts the spread within the model ensemble defined by one (two) standard deviation of the models with respect to the ensemble mean. The area to compute the indices fits the Bolivian domain: 21°S-14°S, 69°W-58°W

improving or even constructing a feedback loop on the inherent real-world quality of the forecasting system to the forecasting centers. Ideally the forecast centre, forecast developer and forecast user (in this case a partner from the humanitarian and development community) should all be equal partners in a programme spanning research development to strengthening operational capability.

Perspective from a humanitarian policy maker partner to the pilot exchanges:

Dr Mike Edwards (medwards@cafod.org.uk), Climate Change Programme Development Officer, CAFOD.

The prospect of human-induced climate change is going to lead to changes in the threat profile of all countries and regions around the world. If we are to believe some of the more catastrophic predictions of climate change, then the humanitarian sector is going to be very busy in the coming decades. The problem is, how does the humanitarian sector engage with an issue that is couched in such uncertainty? It is, for example, impossible for the humanitarian sector to plan for the future impacts of climate change using only the output of general circulation models (GCMs). To make sense of the threat of climate change, it is essential to have some idea of how the impacts of climate change will manifest at a local level. Even if local scale information is not yet available, it is essential that the humanitarian sector is aware of the types of climate information that are currently available to reduce people's vulnerability to climate variability.

This is why the pilot exchange has proved to be so important. It has shown the humanitarian sector that there are many existing climate-tailored products, developed by scientists, that will allow the humanitarian sector a much greater understanding of the impacts of climate change. Indeed, it has become clear that we no longer have to be paralysed by the uncertainty of the course resolution of GCMs; we can start to make use of climate information in new and exciting ways that will help us find appropriate responses to the threat of climate change. Without the exchange, many humanitarian actors would be scratching their heads trying to make use of generic information provided by bodies such as the Intergovernmental Panel on Climate Change (IPCC). It is interesting to note that most humanitarian actors who took part in the exchange agreed that 'generic' climate change information of the type produced by the IPCC is next to useless for strategic planning in the humanitarian sector.

Perhaps one of the most interesting outcomes of the exchange was the fact that many scientists were concerned that the humanitarian sector (and wider development community) was making assumptions about climate change that could not be backed up by the science. There are understandable reasons for this: the humanitarian sector wants action to be taken at an international level to address the potentially catastrophic threats of future climate change. However, this often results in statements being made about climate change that cannot be substantiated by science. This undermines the important message which the humanitarian sector is trying to convey. The importance of the exchange is that increasingly the humanitarian sector will be able to call on scientists to help them deliver the message appropriately.

One issue that was raised during the exchange was the very real possibility that the humanitarian sector could, inadvertently, make people more vulnerable to climate change by supporting inappropriate adaptation. The possibility exists that a humanitarian intervention with regard to climate change based upon 'perceived' impacts may actually increase vulnerability. It is interesting to note that predictions of the impacts of climate change for Uganda, for example, show both the possibility of a major increase in precipitation and the possibility of a major decrease. In these situations the humanitarian sector could choose to respond assuming a decrease in precipitation by installing rain water harvesting structures, only to discover that flood protection measures are needed. Examples such as these show how important it is to use reliable information and to be willing to be guided by the existing scientific expertise.

At present, most climate change related information is not in a format useable by, or accessible to, practitioners. One of the principal accolades for many scientists is the number of papers published in peer-reviewed academic literature. It would be a brave researcher who would dedicate his or her time to producing climate change related information of a more accessible nature. Hopefully, this situation is changing as the major academic funding bodies are realising the importance of applied research and stipulating the importance of making information accessible to a less 'traditional' end user. It is hoped that this will make it more appealing for academics to spend time making climate change related information useable. It is also hoped that, as more and more resources are put into climate change adaptation strategies, that beneficiaries and practitioners from the humanitarian and development sector will be able to directly inform the direction of relevant strands of climate change research.

Finally, it became starkly clear from the exchange that the humanitarian sector, with the support of both climate scientists and scientists focusing on a range of issues concerning future vulnerability, need to be able to contextualize climate change i.e., they need to be able to rank or rate the importance of the threat posed by climate change in different regions of the world. Unless this contextualisation is undertaken, we risk ranking the threat of climate change too high or too low and perhaps helping people to adapt to climate change when the most important threat to human security may be of a different nature. It would appear that the humanitarian sector has not yet grasped the importance of this contextualisation and are not yet fully employing rigorous scientific analysis to decide where and when they undertake climate change adaptation initiatives.

From a humanitarian perspective, the exchange has proved invaluable. However talking about the need for greater communication and collaboration between climate scientists and humanitarian actors is different from actually doing something tangible. In the future it is hoped that some pilot projects will be instigated to explore how these two communities can work together in practice. The exchange has proved invaluable but it is only the first step on a long journey. While there is still a degree of suspicion between the two communities, there is increasing realization that most of us are using different approaches to achieve similar aims – the improvement of peoples' lives. This realization provides a firm footing for closer future partnership.

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Director, International CLIVAR Project Office

International CLIVAR Office, National Marine Facilities Division, National Oceanography Centre, Southampton (NOCS)

The World Climate Research Programme (WCRP) and the UK's National Oceanography Centre, Southampton (NOCS) invite applications for the position of Director of the International CLIVAR Project Office (ICPO), located at NOCS.

The Climate Variability and Predictability (CLIVAR) project is one of four core projects of the WCRP. CLIVAR coordinates and facilitates national and international activities that contribute to our understanding and prediction of climate variability and change on seasonal, decadal and centennial time scales. The Director of the Project Office takes a leading role in the development and implementation of CLIVAR under the general guidance of the CLIVAR Scientific Steering Group.

The successful applicant will provide science and administrative leadership of the ICPO and of the CLIVAR programme. Your role will be to oversee and manage the implementation of the plans and activities of each of the project elements of CLIVAR in support of the overall mission and strategy of WCRP. You will maintain active links between CLIVAR and the wider science community stimulating and organizing scientific meetings, workshops and conferences and ensuring the timely flow of information on CLIVAR. You will be responsible for the management of the Project Office staff budget and operations and for maintaining and developing its funding base.

You will have a Ph.D or equivalent in a relevant field and considerable experience of working in climate-science. A proven ability in science management including winning external funding is essential and you should have demonstrated the ability to conceive, organize and manage interdisciplinary and international science activities and initiate and sustain international cooperation.

This post is currently funded by the Natural Environment Research Council to 31 March 2013 and the salary is in the range of £47,630 to £60,420 per annum. Benefits include RCUK pension scheme and up 30 days leave and 10 ½ public/privilege days. The role will include periods of travel both within the UK and internationally.

Enquiries regarding CLIVAR and its international role should be directed to Dr. Howard Cattle on +44 (0)23 8059 6208 or email hyc@noc.soton.ac.uk.

It is proposed that interviews will take place on 29 April 2010.

For further information on this post and to download an application pack, please visit http://www.oceanography.ac.uk/jobs or alternatively contact Lorraine Taylor, Human Resources, NOCS, European Way, Southampton SO14 3ZH (Telephone +44 (0) 23 8059 6604 or e-mail: loraya@noc.soton.ac.uk).

The closing date for completed applications is 29th March 2010.

Please quote reference number NOCS 119/10 on all correspondence.

VAMOS !

Newsletter of the Variability of the American Monsoon Systems Panel

Editorial

Another year has passed and another edition of the VAMOS! Newsletter is being distributed. Our newsletter is a means to report the news and activities carried out by the VAMOS Panel, but we would also like to hear from you, the reader. Beginning on next issue, we will dedicate a section to letters with comments about previous articles and differing views on issues that have been addressed. In addition, we will have a new section listing recently published papers or chapter of books relevant to VAMOS programs. We welcome suggestions to promote this "two-way" interaction.

During the past year VAMOS has continued to be active, and there is plenty to report. Our annual meeting (VPM-12) took place in Puerto Rico, with the objective of reaching out to the Caribbean region at a time in which IASCLIP, the Intra-Americas Study of Climate Processes, is being consolidated. As usual, the VPM-12 received reports from the different science components, and invited speakers discussed issues that are relevant for the advancement of VAMOS objectives. The panel heard presentations on the International Geosphere-Biosphere Programme (IGBP), the North American Regional Climate Change Assessment Program (NARCCAP), on land-atmosphere feedbacks in the North American Monsoon, and on anthropogenic climate change in the South American Monsoon.

The CLIVAR SSG has now fully endorsed the IASCLIP as a component of VAMOS. In doing so they stressed the importance of IASCLIP liaison with WGSIP (through the VAMOS modeling plan) and with the Atlantic Panel where appropriate. The IASCLIP Science Steering Group has met to plan implementation aspects of the Project. The project is co-chaired by David Enfield, and since this year, Arthur (Art) Douglas. We welcome Art as new co-chair. He is well known to VAMOS for his contributions to NAME, and his commitment to promote international collaborations. IASCLIP has its own web site, http://www.eol.ucar.edu/projects/iasclip/, where the reader will find additional information on the project.

Another VAMOS science component, VOCALS (VAMOS Ocean-Cloud-Atmosphere-Land Study), has continued its activities following the extremely successful Field Campaign that took place in October 2008. VOCALS has had a PIs meeting this last July and a special session at the American Geophysical Union (AGU) Fall Meeting in San Francisco. This issue of the VAMOS! Newsletter is dedicated mostly to report their progress during and after the Field Campaign.

The AGU is planning its Meeting of the Americas, to be held for the first time in Foz do Iguassu (Brazil) in August 2010. In making this decision, AGU shows its commitment

Pasó otro año y estamos distribuyendo un nuevo número de la Revista VAMOS!. Nuestra revista es un medio para informar acerca de las novedades y actividades que lleva a cabo el Panel de VAMOS, pero también nos gustaría saber de ti, lector. A partir de la próxima edición, iniciaremos una sección de cartas con comentarios sobre los artículos anteriores y diferentes visiones de los temas que fueron tratados. Además, contaremos con una nueva sección que presentará los trabajos o capítulos de libros publicados recientemente y relacionados con los programas de VAMOS. Todas las sugerencias para promover esta interacción "en dos direcciones" son bienvenidas.

El año pasado, VAMOS continuó sus actividades y hay mucho para informar. Nuestra reunión anual (VPM-12) se realizó en Puerto Rico, con el objetivo de extenderse hacia la región Caribe en un momento en que se está consolidando IASCLIP, el Estudio Intra-Americano de Procesos Climáticos. Como de costumbre, en VPM-12 hubo presentaciones de los diferentes componentes científicos, y oradores invitados debatieron temas relacionados con el avance de los objetivos de VAMOS. También hubo presentaciones del Programa Internacional de la Geósfera y la Biosfera (IGBP), el Programa Regional para la Evaluación del Cambio Climático de América del Norte (NARCCAP), sobre las interacciones tierra-atmósfera en el Monzón Norteamericano, y el cambio climático antrópico en el Monzón de Sudamérica.

El Grupo Director Científico (SSG) de CLIVAR ya aprobó enteramente a IASCLIP como componente de VAMOS. Al hacerlo, pusieron de relieve la importancia del vínculo entre IASCLIP y WGSIP (a través del plan de modelado de VAMOS) y con el Panel del Atlántico donde correspondiera. El Grupo Directivo Científico de IASCLIP se ha reunido para planificar aspectos de la puesta en marcha del proyecto, cuyos co-presidentes son David Enfield y, a partir de este año, Arthur (Art) Douglas. Le damos la bienvenida a Art como nuevo co-presidente. Se trata de una persona muy conocida en VAMOS por su contribución con NAME, y su compromiso en la promoción de la cooperación internacional. IASCLIP tiene su propio sitio web, http://www.eol.ucar.edu/projects/iasclip/, donde el lector podrá hallar información adicional del proyecto.

Otro componente científico de VAMOS, VOCALS, ha continuado con sus actividades luego de un muy exitoso Trabajo de Campo que se realizó en octubre de 2008. VOCALS mantuvo una reunión de PIs en julio y una sesión especial en la Reunión de Otoño de la AGU en San Francisco. Este número de VAMOS! está dedicado principalmente durante y después de dicha campaña.

La Unión Geofísica Americana (AGU) está planeando su Reunión de las Américas, que tendrá lugar por primera vez en Foz do Iguaçu (Brasil) en agosto de 2010. Con la toma de esta decisión, AGU demuestra su compromiso con la promoción de la ciencia en una comunidad aún más amplia que la que habitual-

to promote science for an even a larger community than that usually served in its meetings. For VAMOS, it is an opportunity to be seized to showcase our activities and achievements. Our members have been active in proposing sessions that will focus on IASCLIP, VOCALS, LPB, and the South American Monsoon. Therefore, at least four sessions of the AGU meeting will involve VAMOS activities. In addition, many other sessions are following the cross-cut approach promoted from VAMOS that involves science topics being developed for the Americas, not North, South or Central, but the Americas as a whole. We welcome this approach and look forward to a meeting that will help promote the vision and objectives of the VAMOS community.

mente participa en sus reuniones. Para VAMOS, es una oportunidad que debe aprovecharse para mostrar nuestras actividades y logros. Nuestros miembros participaron proponiendo sesiones que se concentrarán en IASCLIP, VOCALS, LPB y el Monzón Sudamericano. Es decir que se tratarán temas relacionados con las actividades de VAMOS en al menos cuatro sesiones de la reunión de la AGU. Además, muchas otras sesiones seguirán el enfoque transversal que se promueve desde VAMOS y que incluye temas científicos que se están desarrollando para América, no del Norte, del Sur o Central, sino en su conjunto. Damos la bienvenida a este enfoque y esperamos que la reunión contribuirá a promover la visión y objetivos de la comunidad de VAMOS.

Hugo Berbery
Department of Atmospheric and Oceanic Science, University of Maryland, USA, Co-chair of VAMOS Panel / Copresidente del Panel VAMOS
José Marengo
CPTEC/INPE, Brasil, Co-Chair of VAMOS Panel / Copresidente del Panel VAMOS

VAMOS Panel

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José Marengo (co-chair), CPTEC, INPE, Brazil

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The ICPO contact for the CLIVAR VAMOS Panel is Carlos Ereño.

VOCALS – REx

VOCALS is an international VAMOS/CLIVAR program that aims to develop and promote scientific activities leading to improved understanding, model simulations, and predictions of the climate system. The focus is on the southeastern Pacific (SEP), a region characterized by extensive decks of low-level clouds, cold ocean temperatures, and strong oceanic productivity. The program is ultimately driven by a need for improved numerical model simulations of the coupled climate system, which have large errors in the SEP and over the wider tropics and subtropics. At the root of VOCALS scientific strategy is the encouragement of synergies among numerical experimentation, empirical analysis, and fieldwork. During October and November 2008 some 150 scientists from 40 institutions in 8 nations took part in the program field campaign, called VOCALS-REx. A total of five aircraft including the NSF C-130, the DoE G-1, the CIRPAS Twin Otter, and two aircraft from the UK, and two research vessels (the NOAA Ronald H Brown [RHB] and the Peruvian IMARPE José Olaya) sampled the lower atmosphere and upper-ocean during the campaign. Two land-based sampling sites at locations in Chile complemented these platforms. The following papers present some of the many exciting results that are coming from VOCALS.

VOCALS es un programa internacional de VAMOS/CLIVAR que tiene por objeto desarrollar y promover actividades científicas conducentes a mejorar la comprensión, las simulaciones por modelos y las predicciones del sistema climático. El foco está puesto en el Pacífico Suroriental (SEP), una región que se caracteriza por sus extensas zonas de nubes bajas, bajas temperaturas del océano y una gran productividad oceánica. En última instancia, el programa está conducido por la necesidad de mejorar las simulaciones del sistema climático acoplado hechas con los modelos numéricos, que tienen grandes errores en el SEP y en regiones más amplias de los trópicos y los subtrópicos. La raíz de la estrategia científica de VOCALS es la promoción de sinergias entre los experimentos numéricos, los análisis empíricos y el trabajo de campo. En octubre y noviembre de 2008 cerca de 150 científicos de 40 instituciones de 8 países participaron en el trabajo de campo del programa, que se llamó VOCALS-REx. Durante la campaña, un total de cinco aviones, el NSF C-130, el DoE G-1, el CIRPAS Twin Otter, y dos aviones del Reino Unido, así como dos buques de investigación (el Ronald H Brown [RHB] de la NOAA y el José Olaya del IMARPE, en Perú) tomaron mediciones en la atmósfera baja y la capa superior del océano. Dos estaciones de tierra ubicadas en Chile complementaron las observaciones. Los siguientes artículos presentan algunos de los muchos resultados apasionantes de VOCALS.

C. R. Mechoso, VOCALS Chair
R. Wood, VOCALS-REx PI

PreVOCA: Comparing models in the VOCALS Region

PreVOCA: Comparación de modelos en la región de VOCALS

The Southeast Pacific (SEP) is a region of extensive persistent low-level clouds, whose sensitivity to climate change is of great interest. The region also hosts large contrasts in aerosol concentrations, from extremely clean remote maritime conditions to highly polluted conditions downstream of large coastal point sources such as copper smelters.

Despite advances in observing and understanding the SEP atmosphere-ocean system, general circulation models (GCMs) typically do not represent this region well. The SEP is also the focus of VOCALS (VAMOS Ocean-Cloud-Atmosphere-Land Study). In preparation for the VOCALS Regional Experiment (REx) which took place from mid-October through mid-November 2008, we organized an assessment of current atmospheric modeling capability with a particular focus on the marine boundary layer (MBL). PreVOCA (the Preliminary VOCALS model Assessment) compares a large and diverse collection of models simulating the SEP during the period of October 2006. Archived model output and new model output from fourteen modeling centers was collected. Global forecast models and global climate models made daily forecasts, while regional models were run continuously for the study period, initialized and forced at the boundaries with global model analyses. The following questions motivated our study: Do the models simulate the

El Pacífico Sudoriental (SEP, por sus siglas en inglés) es una región cubierta extensamente por nubes bajas persistentes, cuya sensibilidad al cambio climático resulta de gran interés. En la región también se ven grandes contrastes en las concentraciones de aerosoles, desde condiciones marinas lejanas extremadamente limpias hasta las altamente contaminadas corriente debajo de grandes fuentes puntuales costeras como las fundiciones de cobre.

Pese a los avances en la observación y comprensión del sistema atmósfera-océano del SEP, los modelos de circulación general (GCMs, por sus siglas en inglés) no suelen representar adecuadamente esta región. El SEP es también el foco de VOCALS (Estudio de los Océanos-Nubes-Atmósfera-Tierra de VAMOS). En preparación para el Experimento Regional (REx, por sus siglas en inglés) de VOCALS, que tuvo lugar desde mediados de octubre hasta mediados de noviembre de 2008, organizamos una evaluación de la capacidad actual de modelización de la atmósfera con particular foco en la capa límite marina (MBL). PreVOCA (Evaluación Preliminar de modelos de VOCALS) compara una gran y variada colección de modelos que simulan el SEP durante el período de octubre de 2006. Se recolectaron salidas de modelos archivadas y nuevas de catorce centros de modelización. Los modelos globales de pronóstico y los modelos climáticos globales se utilizaron para los pronósticos diarios, mientras que los modelos regionales se corrieron de forma continua durante el período de estudio, inicializados y forzados en large scale conditions adequately? Do the models agree on the vertical structure of the MBL? Do the models capture the basic cloud regimes and the MBL sufficiently well? Are the simulation and predictions of such a quality that will justify the models use in studies of climate change, aerosol and chemical transport, aerosol indirect effects, and aerosol-cloud interactions? For a more complete discussion of the PreVOCA experiment than is given here, see Wyant et al. (2009).

Experiment
PreVOCA includes global operational forecast models, regional models and global climate models. Global operational models including ECMWF, NASA GMAO, NCEP, Japan Meteorological Agency, and UK Met Office typically involve a data assimilation system. Regional models including Naval Research Laboratory COAMPS, COLA, IPRC Reg-CM, WRF (UCLA and University of Chile), WRF-Chem (PNNL), and LMDZ are run over a more limited area at higher horizontal resolution. They rely on boundary conditions provided by other models, and are most frequently used for mesoscale research. Climate models include CAM, GFDL and the ECMWF coupled climate ensemble. Typical horizontal resolutions are about 50 km for regional and operational models, and 250 km for climate models. Some models use nested grids over the study region with as low as 15 km resolution. The number of vertical levels varies from 24 to 91, and all models except for CAM 3.5, have 8 or more levels in the boundary layer. There are two simulation modes among the runs presented here: forecast and continuous. In forecast mode, models make daily forecasts initialized using operational analysis, with a few models making more frequent forecasts. For these runs, a specified subset of forecast hours for each daily run is selected, and these are stitched together to provide a continuous month of model output for comparison with other models. For each simulation, we expect the vertical structure of the MBL to drift away from the initial analysis towards a model-dependent preferred state, while other supporting features of the forecast do not deviate far from analysis, highlighting biases in the MBL. This approach to identifying parameterization biases applied to GCMs is described in Phillips et al. (2004).

In continuous mode, the model fields are initialized by global analysis, and then run for the entire month from initial conditions provided by analysis datasets, which also provide time dependent boundary conditions at the edges of the domain. Because the model fields are not re-initialized regularly, greater model biases are expected than in the forecast-mode runs. Nearly all runs were made with specified SST.

The study region extends from 70^{o}W to 110^{o}W and 40^{o}S to the equator and is dominated by the eastern part of the South Pacific subtropical high. Surface southeasterly winds with speeds of 5-9 m s^{-1} prevail over most of the northern half of the region, with southerly winds along the coast influenced by the high coastal topography. The winds over most of the study region blow from colder to warmer water promoting surface sensible and latent heat flux into the MBL. In the eastern part of the domain, the lower tropospheric stability is large and is typically associated with very strong inversions at the top of the MBL. Surface precipitation, as estimated by AMSR-E, is light (< 0.5 mm day^{-1}) across the study region, except south of 30^{o}S where mid-latitude disturbances pass, and the modeled surface precipitation is similarly weak (< 1 mm day^{-1}) for most models. The model monthly-mean surface winds generally show excellent agreement with the observed surface winds. The mean position

los contornos con análisis de modelos globales. Nuestro estudio estuvo motivado por los siguientes interrogantes: ¿los modelos simulan adecuadamente las condiciones de gran escala? ¿hay acuerdo entre los modelos respecto de la estructura vertical de la MBL? ¿los modelos captan los suficientemente bien los regímenes básicos de las nubes y la MBL? ¿Tienen las simulaciones y las predicciones una calidad tal que justifique el uso de modelos en estudios del cambio climático, el transporte químico y de aerosoles, el efecto indirecto de los aerosoles y las interacciones aerosol-nubes? Podrá encontrar un debate acerca del experimento PreVOCA, más completo que el que aquí se presenta en Wyant et al. (2009).

Experimento
PreVOCA incluye modelos operativos globales de pronóstico, modelos regionales y modelos climáticos globales. Los modelos operativos globales, entre los que se cuentan el ECMWF, NASA GMAO, NCEP, el de la Agencia Meteorológica del Japón y el de la Oficina Meteorológica del Reino Unido, típicamente incluyen un sistema de asimilación de datos. Los modelos regionales, incluyendo el COAMPS del Laboratorio de Investigaciones Navales, COLA, IPRC Reg-CM, WRF (UCLA y Universidad de Chile), WRF-Chem (PNNL) y LMDZ se corren sobre un área más limitada y con una resolución horizontal mayor. Ellos se apoyan en condiciones de contorno provistas por otros modelos, y se los utiliza más frecuentemente en investigaciones de mesoescala. Los modelos climáticos son CAM, GFDL y el conjunto climático acoplado ECMWF. Las resoluciones horizontales típicas son de alrededor de 50 km para los modelos regionales y operativos, y 250 km para los modelos climáticos. Algunos modelos utilizan grillas anidadas en la región de estudio con una resolución de hasta 15 km. La cantidad de niveles verticales varía entre 24 y 91, y todos los modelos excepto CAM 3.5 tienen 8 o más niveles en la capa límite. En las corridas que se presentan aquí hay dos modos de simulación: continua y de pronóstico. En este último modo, los modelos realizan pronósticos diarios inicializados utilizando análisis operativos. Unos pocos modelos realizan pronósticos más frecuentes. En estas corridas, se selecciona un subconjunto específico de horas de pronóstico para cada corrida diaria. Luego, se unen los pronósticos para obtener un mes seguido de salidas del modelo para su comparación con otros modelos. En cada simulación se espera que la estructura vertical de la MBL se aleje del análisis inicial hacia un estado preferencial dependiente del modelo, mientras que otras características de apoyo del pronóstico no se alejan demasiado de los análisis, poniendo de relieve los desvíos en la MBL. Este acercamiento a la identificación de tendencias en las parametrizaciones aplicadas a los GCMs se describe en Phillips et al. (2004).

En el modo continuo, los campos del modelo se inicializan con análisis globales, y luego se corren para todo el mes partiendo de condiciones iniciales provenientes de conjuntos de datos de análisis, que también proporcionan condiciones de contorno dependientes del tiempo en los bordes del dominio. Como los campos de los modelos no se re-inicializan de forma regular, se espera tener mayores desvíos que en las corridas en modo pronóstico. Casi todas las corridas se hicieron con SSTs especificadas.

El área de estudio se extiende desde 70^{o}W hasta 110^{o}W y desde 40^{o}S hasta el ecuador y está dominada por la parte oriental del alta subtropical del Pacífico Sur. En la mayor parte de la mitad norte de la región prevalecen vientos del sudeste en superficie con velocidades de 5-9 m s^{-1}, mientras que a lo largo de la costa soplan vientos del sur influenciados por la alta topografía costera. En la mayor parte de la zona de estudio, los vientos soplan desde aguas más frías a más cálidas promoviendo un flujo superficial de calor sensible y latente hacia la MBL. En la parte oriental del dominio, la estabilidad de la tropósfera baja es alta y está típicamente asociada con inversiones muy fuertes en el tope de la MBL. La precipitación en superficie, según la estimación del AMSR-E es escasa (< 0.5 mm día^{-1}) en la región de estudio, excepto al sur de 30^{o}S donde pasan las perturbaciones of the surface anticyclone is also well agreed upon by the models. Broad subsidence is associated with the South Pacific high. Mean weak subsidence (~0.03 Pa s^{-1} or ~25 hPa day^{-1}) at the 850-hPa level prevails across most of the study region, with stronger subsidence (> 0.05 Pa s^{-1}) near the Chilean coast at about 30ºS.

Despite the generally close agreement among the horizontal wind, vertical velocity, and static stability fields averaged over the month, the models show a large disagreement in their cloud properties. The mean-monthly cloud fraction from MODIS and low-cloud fraction for a selection of models is shown in Figure 1. The MODIS cloud fraction is based on liquid-water retrieval and mostly represents low cloud. It excludes ice cloud which is primarily found south of 30ºS associated with passing synoptic disturbances. Model low cloud fractions are typically computed from the surface to 700 or 800 hPa.

The MODIS cloud fraction is 0.8-0.9 near the coast except for a relatively clear region between 30ºS and 40ºS associated with strong subsidence. Mean cloud fraction decreases moving away from the cloudy part of the coast, but is still around 0.7 near the stratus buoy, dropping off to 0.4 in the peripheral parts of the study region. The models show a large disparity in cloud fraction over the region despite the similarity in forcing. A common model problem is too little low cloud near the coast from 30ºS to the equator, as exemplified in the IPRC and GFDL. The models also vary greatly in the amount of cloud in the north central and northwest part of the study region where trade-cumulus convection is more significant, with many models producing too much cloud compared to MODIS (e.g. PNNL-P), and several models too little cloud in this region (e.g. IPRC). Overall the ECMWF family of models and the UK Met Office model do fairly well in matching the mean MODIS cloud fraction in the region.

de latitudes medias, y la precipitación en superficie modelada en la mayoría de los modelos es similarmente baja (< 1 mm $día^{-1}$). Los vientos medios mensuales en superficie generalmente concuerdan con los vientos medidos en superficie. La ubicación media del anticiclón de superficie también coincide entre los modelos. Existe una amplia subsidencia asociada al alta del Pacífico Sur. En el nivel de 850-hPa prevalece una subsidencia media débil (~ 0.03 Pa s^{-1} o ~25 hPa $día^{-1}$) a través de la mayor parte de la región de estudio, y una subsidencia más fuerte (> 0.05 Pa s^{-1}) cerca de la costa de Chile, alrededor de 30ºS.

A pesar de que en general coinciden en las estimaciones del promedio mensual de los campos de viento horizontal, velocidad vertical y estabilidad estática, se ve en los modelos una gran divergencia en su representación de las propiedades de las nubes. En la Figura 1 se muestra la fracción de nubes media mensual de MODIS y la fracción de nubes bajas de un grupo de modelos. La fracción de nubes de MODIS se basa en la recuperación del agua líquida y representa mayormente las nubes bajas. Excluye las nubes de hielo que se encuentran principalmente al sur de 30ºS asociadas al pasaje de perturbaciones sinópticas. La fracción nubosa de los modelos se calcula típicamente desde la superficie hasta 700 u 800 hPa.

La fracción de nubes MODIS es 0,8-0,9 cerca de la costa, excepto en una región relativamente libre entre los 30ºS y los 40ºS asociada a una fuerte subsidencia. La fracción media de nubes decrece al alejarse de la parte nubosa de la costa, pero sigue valiendo alrededor de 0,7 cerca de la boya de estratos, decreciendo hasta 0,4 en las áreas periféricas de la región de estudio. Los modelos muestran una gran disparidad en la fracción nubosa de la región, pese a la similitud en el forzamiento. Un problema común a los modelos son las pocas nubes cerca de la costa desde 30ºS al ecuador, como se ejemplifica en el IPRC y GFDL. La cantidad de nubes en la parte centro norte y noroeste de la región de estudio también presenta grandes variaciones entre los modelos. En esa parte, la convección alisios -cúmulos es más significativa, y muchos modelos generan demasiadas nubes en comparación con MODIS (por ejemplo,

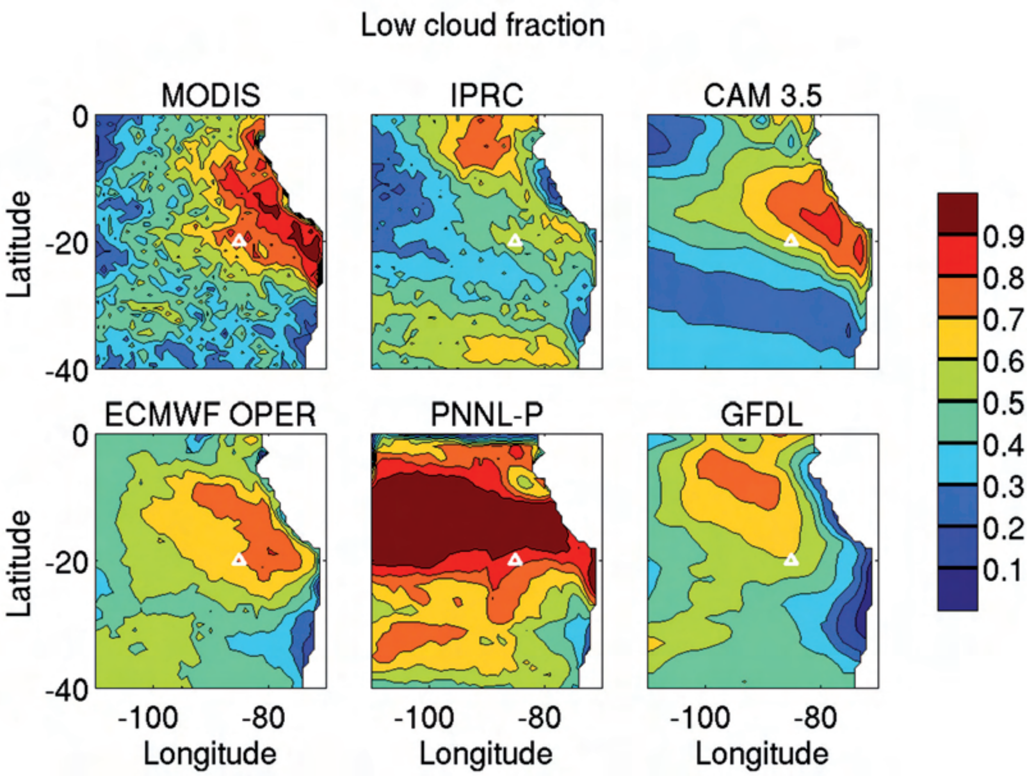

Figure 1: Monthly-mean MODIS total cloud fraction (upper left) and modeled low-cloud fraction. The white triangle indicates the location of the stratus buoy at 85ºW 20ºS. // Figura 1: Fracción total de nubes media mensual MODIS (arriba, izquierda) y fracción modelada de nubes bajas. El triángulo blanco indica la ubicación de la boya de estratos en 85ºW 20ºS

There are also large model-to-model discrepancies in monthly-mean liquid water path and large biases compared with microwave satellite retrievals (AMSR-E, TMI, and SSM/I). The biases in cloud fraction and liquid water path have substantial implications for the surface energy budget, especially the downwelling shortwave radiation at the surface, a major driver of the SST spatial distribution and seasonal cycle. For each model, geographical biases in downward shortwave radiation compare very closely to those in cloud fraction. While there are clearly many factors influencing the shortwave radiation reaching the surface, cloud fraction plays a major role. In many models, the substantial under-prediction of clouds from the buoy region eastwards to the South American coast results in very large positive biases (sometimes larger than 100 W m^{-2}) in downwelling SW compared to ISCCP. Biases such as these would substantially increase regional SSTs in coupled simulations.

The models also widely disagree in the mean boundary layer depth. We plot the model-estimated MBL depths along 20°S together with a number of observational climatologies in Figure 2. For each model, the model boundary layer depth is estimated as the top of the highest model level where the relative humidity exceeds 60%. The climatologies used include COSMIC boundary layer depths derived from retrieved soundings and averaged from 15-25°S, CALIPSO boundary-layer depths averaged from 17-23°S (Wu et al., 2008), and MODIS derived cloud-top heights from 19-21°S (Zuidema et al., 2009). We also plot the mean and standard deviation of boundary layer depth as estimated from 30 soundings taken in Octobers from 2001-2007, also using the height where the RH = 60%. East of 90°W, the various observational climatologies agree to within 300 m. West of 90°W COSMIC heights are about 300-500 m higher than the other observed estimates, possibly because cloud-top height begins to diverge from inversion base height in the trade-wind MBL. The discrepancy between model and observation is largest near the coast, with the typical modeled MBL depth significantly shallower than satellite estimates. It is unclear why GCMs and other models consistently underestimate this and why the underestimate is especially strong near the coast. Further investigation of the models' diurnal

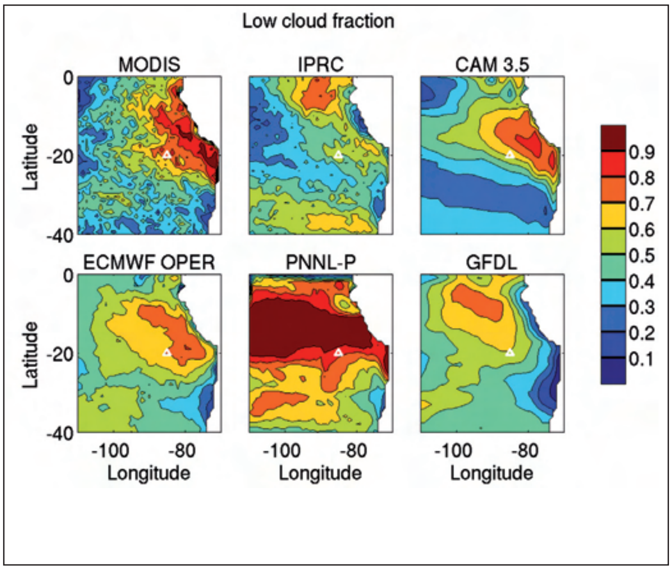

Figure 2: Model boundary layer depth compared with observations of boundary layer depth and cloud-top height. // Figura 2: Profundidad modelada de la capa límite comparada con observaciones de la profundidad de la capa límite y la altura de tope de nube.

PNNL-P), y varios otros demasiado pocas para esta región (por ejemplo, IPRC). En general, la familia de modelos ECMWF y el modelo de la Oficina Meteorológica del Reino Unido ajustan bastante bien a la fracción media de nubes MODIS en la región.

Existen también grandes discrepancias entre los modelos en cuanto a la media mensual del recorrido de agua líquida y grandes desvíos si se la compara con las observaciones satelitales de microondas (AMSR-E, TMI y SSM/I). Las desviaciones en la fracción de nubes y el recorrido de agua líquida tienen implicancias sustanciales en el balance de energía en superficie, particularmente la radiación de onda corta descendente en superficie, un importante forzante de la distribución espacial y el ciclo estacional de la SST. En cada modelo, los desvíos geográficos en la radiación de onda corta descendente son muy cercanos a los de la fracción de nubes. Mientras existen claramente numerosos factores que influyen en la radiación de onda corta que llega a la superficie, la fracción de nubes tiene un papel trascendente. En muchos modelos, la sustancial subestimación en la predicción de las nubes desde la región de la boya al este hacia la costa sudamericana resulta en desviaciones positivas muy grandes (a veces superiores a 100 W m^{-2}) en la radiación descendente de onda corta en comparación con el ISCCP. Desviaciones como esas harían aumentar significativamente la SSTs regional en simulaciones acopladas.

Los modelos también difieren mucho en la profundidad media de la capa límite. En la Figura 2 graficamos las profundidades de la MBL estimadas con los modelos a lo largo de los 20°S junto con una serie de climatologías observadas. En todos los modelos, la profundidad de la capa límite del modelo se estima como el tope del nivel más alto del modelo donde la humedad relativa supera el 60%. Las climatologías utilizadas incluyen las profundidades de capa límite COSMIC derivadas de los sondeos y promediadas entre los 15 y los 25° S, las profundidades de la capa límite CALIPSO promediadas en 17-23° S (Wu et al., 2008), y las alturas de tope de nubes derivadas de MODIS entre 19 y 21°S (Zuidema et al., 2009). Graficamos también la desviación media y estándar de la profundidad de la capa límite calculadas a partir de 30 sondeos realizados en los meses de octubre de 2001-2007, y utilizando la altura donde RH = 60%. Al este de los 90°W, las diferentes climatologías observadas concuerdan hasta dentro de los 300 m. Al oeste de los 90°W las alturas COSMIC son unos 300-500 m superiores a las otras estimaciones observadas, posiblemente porque la altura del tope de nube comienza a divergir desde la altura de base de la inversión de la MBL de los vientos alisios. La discrepancia entre los modelos y las observaciones es máxima cerca de la costa, y la profundidad típica modelada de la MBL es significativamente menor que las estimaciones satelitales. No está claro por qué los GCMs y otros modelos subestiman de forma consistente esta característica y por qué la subestimación es particularmente grande cerca de la costa. Wyant et al. (2009) profundizan la investigación del ciclo diurno de los modelos y el manejo de la variabilidad sinóptica durante el período de estudio.

Conclusiones

La evaluación de modelos PreVOCA analizó la habilidad de una gran variedad de modelos atmosféricos actuales para simular la región del SEP cercana a la costa de Chile durante octubre de 2006. Los modelos operativos y climáticos se usaron para realizar pronósticos diarios de corto plazo en el período de interés, mientras que con cada modelo regional se realizaron simulaciones de un mes de duración continuamente forzadas con análisis meteorológicos. En general, los modelos simulan bien los vientos anticiclónicos de superficie observados. También presentan similares campos medios de subsidencia, aunque son difíciles de evaluar por comparaciones observacionales. No obstante, las propiedades de las nubes y la capa límite producidas por los modelos son bastante diversas, especialmente en cuanto a la fracción de nubes, la profundidad de la MBL y el recorrido del agua líquida. Los desvíos de la fracción de nubes contribuyen primordialmente cycle and handling of synoptic variability during the study period is discussed in Wyant et al. (2009).

Conclusions

The PreVOCA model assessment surveyed the ability of a wide range of contemporary atmospheric models to simulate the SEP region near the Chilean coast during October 2006. Operational and climate models performed daily short-term forecasts for the period, while regional models each ran month-long simulations forced continuously by meteorological analysis. Overall the models do a good job of simulating the observed anticyclonic surface winds. They also share similar mean subsidence patterns, though these are difficult to evaluate by observational comparison. However, the cloud and boundary layer properties produced by the models are quite diverse especially in cloud fraction, MBL depth, and liquid water path. Cloud fraction biases are primary contributors to very large biases in the downward shortwave flux at the surface. There is not a clear relationship between model skill at predicting MBL height or cloud properties and model vertical resolution.

A very common model problem to the east of the stratus buoy is the under-prediction of the MBL depth, especially near the coast. This problem has important implications for modeling surface fluxes and cloud properties such as thickness and cloud fraction, though there is no clear connection between mean MBL depth bias and mean cloud fraction bias among these models.

A major focus of VOCALS is the interaction between aerosols and clouds. The cloud and boundary-layer modeling errors demonstrated here pose substantial challenges to modeling aerosol and gas concentrations and transport, as well as aerosol source and sink processes. A follow on inter-comparison of a similar suite of models for October-November 2008 during REx will be performed with a particular focus on aerosol-cloud interactions. This future study, the VOCALS Assessment or VOCA, will benefit from a large array of *in-situ* aircraft and ship measurements, and will no doubt provide further insights to improve the modeling of this region.

a muy grandes desvíos en el flujo descendente de onda corta en superficie. No hay una relación clara entre la capacidad del modelo para predecir la altura de la MBL o las propiedades de las nubes y la resolución vertical del modelo.

Un problema muy común de los modelos, que se observa al este de la boya de estratos, es la subestimación de las predicciones de la profundidad de la MBL, especialmente cerca de la costa. Este problema tiene importantes implicancias para la modelización de los flujos de superficie y las propiedades de las nubes como su grosor y fracción, aunque no hay una vinculación clara entre el desvío en la profundidad de la MBL y el de la fracción media de nubes entre estos modelos.

Un importante objetivo de VOCALS es la interacción entre los aerosoles y las nubes. Los errores de modelización de las nubes y la capa límite aquí mostrados, plantean retos sustanciales a la modelización de las concentraciones y transporte de aerosoles y gases, así como para los procesos de las fuentes y sumideros de los aerosoles. Se realizará una intercomparación de un conjunto similar de modelos para octubre-noviembre de 2008, período de realización del REx, con especial énfasis en las interacciones entre aerosoles y nubes. Este estudio futuro, la Evaluación de VOCALS o VOCA, se beneficiará con un gran conjunto de mediciones in-situ *de aviones y barcos, y sin duda brindará más conocimientos para mejorar la modelización de esta región.*

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The UK Contribution to VOCALS-REx

A UK Consortium consisting of the Universities of Manchester, Leeds and Reading, the National Centre for Atmospheric Science (NCAS) and the Met Office is making a significant contribution to VOCALS through both VOCALS-Mod, the VOCALS modelling programme, and VOCALS-REx. The UK participation in the intensive field programme during VOCAS-REx involved two UK research aircraft, a BAe-146 and a Dornier 228, which made in situ and remote sensing measurements of the cloud and aerosol fields in the South-East Pacific (SEP) region during October and November 2008. These activities were supported by forecast information from the Met Office Unified Model at 17 and 40 km resolution, which was also used to provide pollution forecasts using the NAME model.

One of the aims of VOCALS-UK is analysing the large-scale relationships between the climate of the SEP and the wider tropical Pacific, identifying the controlling mechanisms, and eventually highlighting processes which need to be improved in general-circulation models (GCMs). Until recently, climate models failed to adequately capture stratocumulus clouds, the effects of the Andes on the atmospheric circulation, and the thermodynamic structure of the upper ocean, and uncertainties arising from the sensitivity of the global climate system to the radiative balance of the SEP region have remained significant. VOCALS-UK is making extensive use of in-site data, satellite data, reanalysis products, forecast models, and GCMs to address these questions. On the GCM front specifically, VOCALS-UK is taking advantage of recent advances in high resolution coupled climate modelling achieved in the UK-HiGEM programme (UK-HiGEM - High resolution Global Environment Modelling). HiGEM is an Atmosphere-Ocean GCM with a resolution of approximately 90 km in the atmosphere and 1/3º globally in the ocean. It has, to date, been used to study the scale interactions between weather and climate and between the atmosphere and the ocean, and their effects on the mean climate and on the ENSO (Shaffrey et al., 2009). Its multi-decadal, stable simulation of the global climate is very faithful in the SEP, with a realistic representation of the surface energy fluxes, ocean upwelling and, to some extent, ocean eddies (Toniazzo et al., 2009). HiGEM offers a unique contribution to the modelling activities within VOCALS.

VOCALS-UK activity during VOCALS-REx

Two aircraft facilities from the UK were involved in VOCALS-REx - the Facility for Airborne Atmospheric Measurements (FAAM), which operates a BAe-146-301, and the Airborne Remote Sensing Facility (ARSF), which operates a Dornier-228. FAAM is a joint facility of the National Environment Research Council and the Met Office. The BAe-146 is capable of flying up to a crew of 22 (of whom 18 may be scientists) and 1,000-4,000 kg of instrumentation for flights of up to 5¼ hours – typically flying at groundspeeds of 100-170 ms^{-1} and at altitudes from 15 m above the surface to 10.7 km pressure altitude. The ARSF Dornier-228 is supported by the National Environment Research Council. It is a twin turbo-prop powered, non-pressurised, monoplane that can carry a crew of five, 3 of which may be scientists and is typically configured for remote sensing at groundspeeds of around 120 ms^{-1} with a 4 km operational ceiling.

Contribución del Reino Unido a VOCALS-REx

Un Consorcio del Reino Unido conformado por las Universidades de Manchester, Leeds y Reading, el Centro Nacional de Ciencias Atmosféricas (NCAS) y el Servicio Meteorológico está haciendo importantes aportes a VOCALS a través de VOCALS-Mod, el programa de modelización VOCALS y VOCALS-REx. El Reino Unido aportó dos aviones de investigación (un BAe-146 y un Dornier 228) para el programa intensivo de campo realizado durante VOCAS-Rex. Los aviones realizaron mediciones in situ y remotas de los campos de nubes y aerosoles de la región del Pacífico Suroriental (SEP) en octubre y noviembre de 2008. Estas actividades contaron con el apoyo de los pronósticos del Modelo Unificado del Servicio Meteorológico con resolución de 17 y 40 km. Esos pronósticos también se utilizaron para realizar pronósticos de contaminación con el modelo NAME.

Uno de los objetivos de VOCALS-UK es analizar las relaciones de gran escala entre el clima del SEP y el Pacífico tropical, identificar los mecanismos que las controlan y eventualmente los procesos que deben mejorarse en los modelos de circulación general (GCMs). Hasta recientemente, los modelos climáticos no podían captar de manera adecuada los estratocúmulos, el efecto de los Andes en la circulación atmosférica y la estructura termodinámica de la capa superior del océano, y han sido significativas las incertidumbres que surgen de la sensibilidad del sistema climático global al balance radiativo de la región del SEP. VOCALS-UK está realizando un amplio uso de datos in-situ, *satelitales, productos de reanálisis, modelos de pronóstico y GCMs para abordar estos interrogantes. Específicamente en lo que se refiere al GCM, VOCALS-UK está aprovechando los recientes avances en modelización acoplada del clima en alta resolución que se lograron en el programa UK-HiGEM (UK-HiGEM – Modelización Ambiental Global en Alta Resolución). HiGEM es un GCM océano-atmósfera con una resolución de aproximadamente 90 km en la atmósfera y 1/3º globalmente en el océano. Hasta ahora, se ha utilizado para estudiar las interacciones de escalas entre el tiempo y el clima y entre la atmósfera y el océano, así como sus efectos en el clima promedio y en el ENOS (Shaffrey et al., 2009). Su estable simulación multidecenal del clima global en el SEP es muy fiel, y representa de forma realista los flujos de energía en superficie, las surgencias oceánicas y hasta cierto grado, los vórtices oceánicos (Toniazzo et al., 2009). HiGEM constituye un aporte único a las actividades de modelización de VOCALS.*

Actividades de VOCALS-UK durante VOCALS-REx

Dos aviones del Reino Unido participaron en VOCALS-Rex, equipados con la Facilidad para Mediciones Atmosféricas desde el Aire (FAAM, por sus siglas en inglés), que opera en un BAe-146-301, y la Facilidad Aérea de Percepción Remota (ARSF), que funciona en un Dornier-228. FAAM pertenece conjuntamente al Consejo Nacional de Investigaciones Ambientales y al Servicio Meteorológico. El BAe-146 puede llevar una tripulación de hasta 22 personas (de los que unos 18 pueden ser científicos) y 1.000-4.000 kg de instrumental en vuelos de hasta 5¼ horas – volando típicamente a velocidades de 100-170 ms^{-1} respecto de tierra y altitudes de 15 m sobre la superficie hasta un techo de 10,7 km. El Dornier-228 equipado con el ARSF es mantenido por el Consejo Nacional de Investigaciones Ambientales. Se trata de un monoplano bimotor turbopropulsado no presurizado, que puede llevar una tripulación de cinco personas, 3 de los cuales pueden ser científicos y está típicamente configurado para la percepción remota a velocidades absolutas de alrededor de 120 ms^{-1} con un techo operativo de 4 km.

Durante VOCALS-Rex, el avión FAAM se equipó con una gran variedad de instrumental para medir las propiedades físicas y químicas de los aerosoles y de los parámetros microfísicos de las

The VOCALS-UK team in front of the FAAM aircraft at Arica// El equipo de VOCALS-UK frente al avión FAAM en Arica.

During VOCALS-Rex, the FAAM aircraft was fitted with a payload that included a wide range of instrumentation for measuring the physical and chemical properties of aerosol particles, as well as cloud microphysical parameters including liquid water content and droplet and drizzle number size distributions from a range of under-wing probes. The aircraft regularly launched dropsondes and also made measurements of both directional and hemispherically integrated radiation using a range of broadband and spectrally resolving instruments covering visible, infra-red and microwave wavelengths that can provide information on cloud properties and sea surface brightness temperature. The ARSF aircraft carried a payload of two hyperspectral imagers, a backscatter lidar, and could also measure aerosol number size distributions and 3-dimensional winds. The hyperspectral imagers are nadir viewing with spectral resolutions of a few nanometers between 400 and 2400 nm, having a swath of several hundred metres in the cross-track direction with a spatial resolution of a few metres. The backscatter lidar was capable of detecting cloud top height and the presence of elevated aerosol layers across the region.

The FAAM aircraft worked closely with the US National Center for Atmospheric Research C-130, flying 13 missions during VOCALS-REx. A key strategy was to use both these aircraft to provide a series of flight observations along a 20ºS transect from the Chilean coast towards the IMET buoy at 85ºW. The range of the FAAM aircraft limited this transit to around 80ºW, whereas the C130 could reach the IMET buoy. On several days the aircraft operated independently so that data were obtained at intervals of approximately 3-4 days throughout the intensive period. On other occasions the FAAM aircraft took off a few hours behind the C-130 so that its return leg was closely coincident in time but at a higher altitude, providing remote sensing measurements and a curtain of drop sondes approximately every 1º of longitude from 80ºW to 72ºW. On several occasions, the FAAM aircraft was used to sample developing open cell structures, or pockets of open cells (POCs), which were identified from satellite images. Other flights included overpasses of the RV Ron Brown so as to provide *in-situ* validation of its remotely-sensed microphysical and dynamical observations, and survey flights to investigate pollution outflow and smelting along the coast.

The Do-228 conducted 14 missions during VOCALS-REx. Flights plans were focussed on the investigation of elevated aerosol layers advected from sources along the Pacific rim of the Andes over the VOCALS region. These flights used a combination of high altitude surveys to identify pollution layers using the lidar and a series of profiles to determine the in situ characteristics of the

nubes, incluyendo el contenido de agua líquida y las distribuciones cantidad-tamaño de las gotas y llovizna medidas con una gama de sondas ubicadas debajo de las alas. El avión lanzó radiosondas con paracaídas en forma regular y realizó mediciones de radiación integrada tanto direccional como hemisféricamente utilizando una variedad de instrumentos de banda ancha y resolución espectral que cubren longitudes de onda visible, infrarrojo y microondas y que pueden brindar información acerca de las propiedades de las nubes y la temperatura de brillo de la superficie del mar. El avión ARSF llevaba dos sensores hiperespectrales, un lidar de dispersión de retorno, y también midió distribuciones cantidad-tamaño de los aerosoles y vientos en tres dimensiones. Los sensores hiperespectrales tienen visión nadiral, resoluciones espectrales de algunos nanómetros -entre 400 y 2400 nm- y una franja de visión de varios cientos de metros en la dirección transversal a la trayectoria con una resolución espacial de unos pocos metros. El lidar de dispersión de retorno pudo detectar la altura de tope de nube y la presencia de capas de aerosoles en niveles altos en la región.

El avión FAAM, que trabajó en forma coordinada con el C-130 del Centro Nacional de Investigaciones Atmosféricas de EE.UU., voló en 13 misiones durante VOCALS-REx. Una estrategia clave fue la utilización de ambos aviones para obtener una serie de observaciones a lo largo de una transecta a lo largo de 20ºS desde la costa de Chile hacia la boya de IMET en 85ºO. La autonomía del avión FAAM sólo alcanzó hasta cerca de los 80ºO, mientras que el C130 pudo llegar a la boya IMET. Durante varios días los aviones operaron de forma independiente, por lo que los datos fueron obtenidos en intervalos de aproximadamente 3-4 días durante el período intensivo. En otras oportunidades, el FAAM despegó pocas horas después del C-130 de manera que su pierna de retorno se realizó casi simultáneamente, pero a una mayor altura, realizando mediciones de percepción remota y una cortina de radiosondas con paracaídas lanzadas aproximadamente cada 1º de longitud desde los 80ºO hasta los 72ºO. En varias oportunidades, se utilizó el avión FAAM para muestrear las estructuras de las celdas abiertas en desarrollo, o bolsas de celdas abiertas (POCs, por sus siglas en inglés), que fueron identificadas a partir de imágenes satelitales. También se sobrevoló varias veces el RV Ron Brown de manera de poder contar con validaciones in-situ *de sus mediciones microfísicas y dinámicas por percepción remota. Además se realizaron vuelos para investigar el flujo saliente de contaminantes y fundiciones a lo largo de la costa.*

El Do-228 realizó 14 misiones durante VOCALS-REx. Los planes de vuelo se concentraron en la investigación de capas de aerosoles de altura advectadas de fuentes ubicadas a lo largo de la costa Pacífica de los Andes en la región de VOCALS. En estos vuelos se utilizó una combinación de reconocimientos de altura para identificar capas de contaminantes utilizando lidar y una serie de perfiles para determinar las características in situ *de las capas de aerosoles. En varias ocasiones se observaron múltiples capas de aerosoles relativamente finas, pero al este de 75ºO no se vio que éstas existieran inmediatamente por encima de la capa de nubes, más bien, ese aire se caracterizó mayormente por ser muy limpio y seco. En otros casos, los sondeos se realizaron en conjunción con el FAAM o el C-130. Varios de esos vuelos se hicieron a lo largo de la transecta de 20ºS donde se utilizaron datos lidar para determinar la altura de la capa límite a partir de la dispersión de retorno del tope de las nubes. Estos datos muestran la variabilidad en la profundidad de la capa límite marina, que en ocasiones mostró poca variación con la longitud, aunque algunos días hubo un gradiente notable, que se reducía hacia la costa. El equipo VOCALS-UK está estudiando la influencia de la dinámica de mayor escala sobre estas variabilidades y sus efectos sobre la fracción de nubes. Estos vuelos también se utilizaron para obtener imágenes hiperespectrales de la radiación del tope de nube. Actualmente, se está trabajando con esta información para obtener información acerca de las propiedades volumétricas* aerosol layers. On several occasions multiple, relatively thin aerosol layers were observed but to the east of 75ºW these were not seen to exist immediately above the cloud layer, rather this air was often characterised by being very clean and dry. On other flights, survey work was carried out, often in conjunction with either the FAAM aircraft or the C-130. Several of these flights were along the 20ºS transect where lidar data was used to determine boundary layer height from cloud top backscatter. These data show the variability in the marine boundary layer depth, which at times displayed little variation with longitude but on other days there was an appreciable gradient, reducing towards the coast. The influence of larger scale dynamics on these variabilities and their influences on cloud fraction are being investigated by the VOCALS-UK team. These flights were also used to obtain hyperspectral imaging information of radiation from the cloud top. Currently, work is underway to use this information to retrieve cloud bulk property information for comparison with satellites and concurrent in situ measurements from the other aircraft platforms.

Since the end of the field programme, a considerable amount of effort has been given to quality assurance of the data. Several comparison flights were conducted between the FAAM, C130 and G-1 aircraft to compare thermodynamic measurements, aerosol probes and cloud microphysical parameters. Such comparisons are particularly important in order to provide synthesised data sets along the 20ºS transect that are capable of describing both the mean and variability of the measurements. These data show a marked decrease in aerosol accumulation mode number concentration from approximately 250 particles cc^{-1} near the coast to around 100 particles cc^{-1} towards 76ºW. Westwards of this longitude the concentrations are low in general although plumes of pollution from the Santiago region were observed intermittently as far west as 80ºW. Cloud properties show similar trends with decreasing droplet number from greater than 200 drops cc^{-1} in the coastal bight to less than 100 drops cc^{-1} west of 76ºW. Work is ongoing to characterise these properties in terms of the variability of the marine boundary layer and the influence of changes in the larger scale dynamical features of the region.

Pockets of Open Cells

Several POCs were observed by both the FAAM aircraft and the C-130 and in at least two cases these were sampled by both aircraft in a quasi-Lagrangian fashion separated by several hours. This will enable the study of their development as the features were advected to the north and west of the region. POC formation and development is thought to involve linkages between aerosols, cloud droplets, drizzle and dynamics but the relative importance of each at different stages in the lifecycle of these structures is not yet understood. VOCALS-REx data will play an important role in resolving some of these issues.

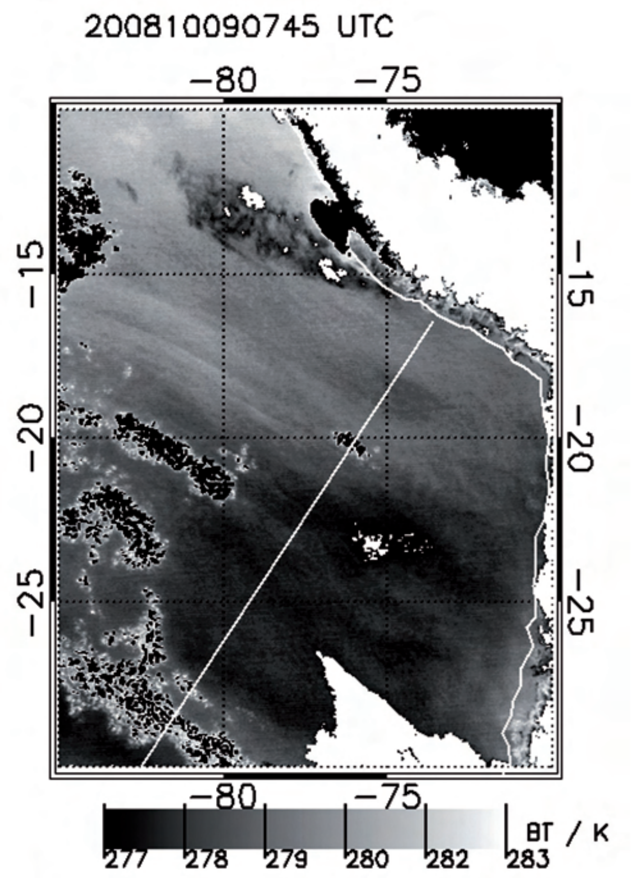
These POCs showed significant differences in aerosol properties and cloud microphysics from the surrounding cloudy regions. A marked gradient in accumulation mode aerosol number concentration existed often falling to less than 30 particles cc^{-1} or less in the sub-cloud layer inside the POC region from greater than 100 cc^{-1} in the surrounding region. However, the total aerosol number was at times greatly enhanced by large numbers of small particles inside the POC indicating a source of ultrafine particles. The POC boundaries were often identifiable by a line of cumuliform cloud whose cloud top was elevated relative to the surrounding cloud field. These clouds were observed to be producing significant drizzle. Inside the POC, the boundary layer

de las nubes para ser comparada con imágenes satelitales y mediciones simultáneas in situ desde los otros aviones.

Desde el final del trabajo de campo, se ha invertido un considerable esfuerzo en garantizar la calidad de los datos. Se realizaron varios vuelos comparativos entre los aviones FAAM, C130 y G-1 para comparar las mediciones termodinámicas, de aerosoles y los parámetros microfísicos de las nubes. Estas comparaciones son particularmente importantes para lograr conjuntos de datos sintetizados a lo largo de la transecta de 20ºS que sean capaces de describir tanto la media como la variabilidad de las mediciones. Estos datos muestran un marcado descenso en la concentración del número acumulado de aerosoles desde alrededor de 250 partículas cc^{-1} cerca de la costa hasta unas 100 partículas cc^{-1} hacia los 76ºO. Hacia el oeste de esta longitud, las concentraciones son en general bajas, si bien las plumas de contaminación provenientes de la región de Santiago pudieron observarse intermitentemente hacia el oeste, llegando a los 80ºO. Las propiedades de las nubes muestran tendencias similares con un número decreciente de gotas desde más de 200 gotas cc^{-1} en la ensenada costera hasta menos de 100 gotas cc^{-1} al oeste de los 76ºO. Se estás trabajando en la caracterización de estas propiedades en términos de la variabilidad de la capa límite marina y la influencia de los cambios en las características dinámicas de mayor escala en la región.

Bolsas de celdas abiertas

Varios POCs fueron observados por ambos aviones, el FAAM y el C-130; en al menos dos casos fueron muestreados por ambos de un modo quasi-Lagrangiano con un intervalo de varias horas.



Gravity waves propagating to the north-east during 9th October 2008. A number of pockets of open cells can be seen to have developed behind the gravity waves. The image shows the channel 4 cloud brightness temperature from the GOES satellite // Ondas gravitatorias propagándose hacia el noreste el 9 de octubre de 2008. Puede verse una serie de bolsas de celdas abiertas que se desarrollaron detrás de las ondas de gravedad. La imagen muestra la temperatura de brillo de las nubes en el canal 4 del satélite GOES was often decoupled. Clouds, when present, were characterised by low droplet number concentrations (<30 droplets cc^{-1}), compared to 100 to 300 droplets cc^{-1} in the surrounding cloud. The corresponding mean volume diameters were also enhanced inside the POC and hence drizzle was often observed.

GOES Cloud products have been analysed for the VOCALS-REx period by the VOCALS-UK team. These are being used to test the capability of Met Office Numerical Weather Prediction (NWP) version of the Unified Model (UM) to predict boundary layer stratocumulus cloud together with the aircraft and ship data. The GOES analysis has also revealed the presence of gravity waves arising from the storm track to the south of the SEP VOCALS region which propagate through the region and are diagnosed by changes in the retrieved cloud properties. Case studies are showing examples of such waves that induce changes in boundary layer depth and correspondingly liquid water path which can induce the formation of open cells, which once formed persists during its migration through the VOCALS region.

VOCALS-UK is conducting a range of modelling activities in support of the experimental phase of VOCALS-Rex. Cloud scale modelling is being conducted with the Met Office Large Eddy Model (Connolly et al., 2006) using 2D and 3D simulations where the cloud droplet number is being considered as a prognostic variable. The simulations are presently being run as a sensitivity study to investigate the impact of including a number of different processes such as drizzle precipitation and cloud droplet scavenging on the cloud microphysical and radiative properties. Future simulations will investigate the impact of propagating gravity waves on cloud evolution and case studies will be compared with statistics of cloud top spatial structure that can be derived from the lidar and hyperspectral imagers.

A Lagrangian cloud particle model driven by and interacting with an LES dynamical simulation that includes a specific treatment of activation (Andrejczuk et al., 2008) is being used to assess the effects of entrainment of dry air into the stratocumulus deck. Two dimensional idealized simulations are currently being carried out with mean profiles derived from observations. Both high and low initial aerosol concentrations, derived from measurements are being used to initialise the model. WRF simulations are being conducted to investigate cloud properties across the SEP and in future WRF-CHEM simulations will also be carried out to this end.

Within the Met Office, there are plans to repeat the global and regional-scale forecasts at higher resolution in both the horizontal and vertical. Studies will include the impact of such resolution changes on the forecasting of inversion strength, cloud top height and liquid water path. The impact of aerosols on drizzle formation will be studied by incorporating the aerosol schemes from the Hadley Centre climate configuration of the UM into trial NWP simulations.

To link the VOCALS-Mod activities with VOCALS-REx, HiGEM (initialised from global analyses) is being used to examine how well high resolution climate models predict conditions during VOCALS-REx and to investigate the way the initial tendencies of a high resolution climate model develop. A listing of available VOCALS-UK data sets can be found at the NCAR-EOL website. The VOCALS-UK data is now available through the British Atmospheric Data Centre (http://www.badc.ac.uk) or by contacting the VOCALS-UK Coordinator, Dr Grant Allen (grant.allen@manchester.ac.uk).

Esto permitirá el estudio de su desarrollo ya que las características fueron advectadas hacia el norte y el oeste de la región. Se cree que la formación y desarrollo de los POC involucra vínculos entre los aerosoles, las gotas de nubes, la llovizna y la dinámica, pero la importancia relativa de cada uno de ellos en las diferentes etapas del ciclo de vida de estas estructuras sigue sin comprenderse. Los datos de VOCALS-REx tendrán un papel importante en la resolución de algunas de estas cuestiones.

Se observaron grandes diferencias en las propiedades de los aerosoles y la microfísica de las nubes entre estos POCs y las regiones nubosas circundantes. A menudo se vio un marcado gradiente en la concentración del número acumulado de aerosoles llegando hasta 30 partículas cc^{-1} o menos en la capa que se encuentra debajo de las nubes en la región de POC y habiendo partido de más de 100 cc^{-1} en la región aledaña. Sin embargo, el número total de aerosoles a veces se vio incrementado en gran medida por grandes cantidades de partículas pequeñas dentro de los POC, indicador de una fuente de partículas ultra finas. A menudo, los límites de los POC podían identificarse por una línea de nubes cumuliformes cuyo tope se encontraba más alto respecto del campo de nubes circundante. Se observó que esas nubes producían una garúa significativa. Dentro de los POC, la capa límite se encontraba a menudo desacoplada. Las nubes, cuando las hubo, se caracterizaron por tener pequeñas concentraciones de número de gotas (<30 gotas cc^{-1}), comparadas con los 100 a 300 gotas cc^{-1} en la nube circundante. Los diámetros correspondientes al volumen medio también estaban aumentados dentro de los POC por lo que a menudo se observó llovizna.

El equipo VOCALS-UK analizó los productos GOES Cloud para el período VOCALS-REx. Los análisis se están utilizando para probar la capacidad de la versión de Predicción Numérica del Tiempo (NWP, por sus siglas en inglés) del Modelo Unificado (UM) perteneciente al Servicio Meteorológico, para predecir la capa límite de estratocúmulos junto con datos de los aviones y el buque. El análisis GOES reveló también la presencia de ondas gravitatorias que surgen de las trayectorias de las tormentas al sur de la región SEP VOCALS que se propagan a través de la región y se diagnostican mediante los cambios observados en las propiedades de las nubes. Los estudios de caso muestran ejemplos de ondas que inducen cambios en el grosor de la capa límite y consecuentemente en el recorrido de agua líquida que puede inducir el desarrollo de celdas abiertas, que, una vez formadas, persisten durante su migración a través de la región de VOCALS.

VOCALS-UK está realizado una variedad de actividades de modelización para apoyar la fase experimental de VOCALS-REx. Se están realizando modelizaciones en escala de nubes utilizando el Modelo de Grandes Vórtices del Servicio Meteorológico (Connolly et al., 2006) utilizando simulaciones 2D y 3D en las que la cantidad de gotas en las nubes está siendo considerada como una variable de pronóstico. Actualmente, se están corriendo las simulaciones como estudio de sensibilidad para investigar el impacto de la inclusión de diferentes procesos como la llovizna y el barrido de las gotas de las nubes en las propiedades microfísicas y radiativas de las nubes. Las próximas simulaciones estudiarán el impacto de la propagación de las ondas gravitatorias en la evolución de las nubes y se compararán los estudios de caso con las estadísticas de la estructura espacial del tope de nube que puede obtenerse de las mediciones lidar e hiperespectrales.

Se está utilizando modelo Lagrangiano de partículas de nubes, que funciona con una simulación dinámica LES, con la que también interactúa. Esta simulación cuenta con un tratamiento de activación específico (Andrejczuk et al., 2008) y se la está utilizando para evaluar los efectos de arrastre de aire seco en la cubierta de estratocúmulos. Actualmente se están llevando a cabo simulaciones idealizadas en dos dimensiones con los perfiles medios obtenidos de las observaciones. Las concentraciones altas y bajas de aerosoles, derivadas de las mediciones se están

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utilizando para inicializar el modelo. Se están realizando simulaciones de WRF para estudiar las propiedades de las nubes en el SEP y en el futuro también se realizarán simulaciones WRF-CHEM con el mismo fin.

El Servicio Meteorológico planea repetir los pronósticos globales y regionales con una mayor resolución vertical y horizontal. Se estudiará también el impacto de tales cambios de resolución en el pronóstico de la fuerza de inversión, la altura del tope de nube y el recorrido de agua líquida. Se estudiará el impacto de los aerosoles en la formación de llovizna mediante la incorporación de esquemas de clasificación de aerosoles de la configuración climática del UM del Centro Hadley en las simulaciones de prueba de NWP.

Para vincular las actividades de VOCALS-Mod con VOCALS-REx, se está utilizando el HiGEM (inicializado con análisis globales) para examinar cuán buenas son las predicciones de las condiciones VOCALS-REx realizadas con modelos climáticos de alta resolución y para investigar cómo se desarrollan las tendencias iniciales en un modelo climático de alta resolución.

En el sitio de NCAR-EOL hay una lista de los datos disponibles de VOCALS-UK. Además, ahora estos datos están disponibles en el Centro Británico de Datos Atmosféricos (http://www.badc.ac.uk) o pueden solicitarse al Coordinador de VOCALS-UK, Dr. Grant Allen (grant.allen@manchester.ac.uk).

VOCALS-REx Coastal Component

Within the broad framework of VOCALS, researchers from Peru, Chile, France, Sweden and United States undertook a number of atmospheric and oceanographic measurement activities in the near-shore region of western South America during the spring of 2008. This Regional Coastal Component of VOCALS-REx was aimed at improving our capability to understand regional environmental variability directly related to a sustainable management of natural resources (e.g. fisheries, solar and wind energy, fresh water from coastal clouds) while contributing to the international effort to understand the processes responsible for the maintenance and variability of the stratus cloud cover and cold tongue in the tropical-subtropical South-eastern Pacific (SEP) as a key factor in the global climate.

There were two major scientific motivations driving VOCALS-REx Coastal Component. First, the Humboldt Current System (HCS) is one of the four most prominent wind-driven Eastern Boundary Upwelling System (EBUS). Along South-America, the Andes Cordillera forms a sharp barrier to the zonal atmospheric flow, forcing the south-east trade winds to blow parallel to the coasts of Chile and Peru (Strub et al., 1998). That results in strong coastal wind jets near 15ºS (Moody et al., 1981; Stuart, 1981) and 35ºS (Garreaud and Muñoz, 2005), which generate an offshore flow in the surface layer (10-30 m). To compensate this divergent westward flux at the surface, intense upwelling cells and filaments of deep, cold and nutrient-rich water take place along the coast driving a high biological productivity. As a result, the coastal ocean of the HCS is characterized by low surface temperatures and high rates of primary production. The Andes cordillera and the prominent coastal topography also lead to complex, diurnally varying, mesoscale circulations in the nearshore region (Garreaud and Muñoz, 2005; Muñoz, 2008).

Componente costero de VOCALS-REx

En el amplio marco de VOCALS, investigadores de Perú, Chile, Francia, Suecia y Estados Unidos emprendieron una serie de mediciones atmosféricas y oceanográficas en la región cercana a la costa occidental de América del Sur durante la primavera de 2008. Este Componente Costero Regional de VOCALS-REx tuvo por objeto mejorar nuestra capacidad de comprender la variabilidad ambiental regional relacionada directamente con el manejo sustentable de los recursos naturales (por ejemplo, pesquerías, energía solar y eólica, agua dulce de nubes costeras) al tiempo que contribuía con el esfuerzo internacional dirigido a comprender los procesos responsables del mantenimiento y variabilidad de la capa de estratos y la lengua fría del Pacífico Suroriental tropical-subtropical (SEP) como factor clave del clima global.

Dos importantes motivaciones científicas guiaron al Componente Costero de VOCALS-REx. En primer lugar, el Sistema de la Corriente de Humboldt (HCS, por sus siglas en inglés) es uno de los cuatro Sistemas de Surgencias del Límite Oriental (EBUS, por sus siglas en inglés). A lo largo de América del Sur, la Cordillera de los Andes forma una marcada barrera para el flujo atmosférico zonal, forzando a los vientos alisios del sudeste a moverse paralelos a la costa de Chile y Perú (Strub et al., 1998). Esto provoca fuertes corrientes costeras en chorro cerca de los 15ºS (Moody et al., 1981; Stuart, 1981) y los 35ºS (Garreaud y Muñoz, 2005), que generan un flujo mar adentro en la capa superficial (10-30 m). Para compensar este flujo divergente en la superficie hacia el oeste, se general intensas celdas y filamentos de surgencia de aguas profundas, frías y ricas en nutrientes a lo largo de la costa dando lugar a una alta productividad biológica. Como resultado, el área costera del océano del HCS se caracteriza por tener temperaturas de superficie bajas y altos ritmos de producción primaria. La cordillera de los Andes y la prominente topografía costera también generan complejas circulaciones de mesoescala, de variación diaria, en la región cercana a la costa (Garreaud and Muñoz, 2005; Muñoz, 2008).

Secondly, the subduction of the Nazca plate under the Andes and the South American continent induces an area of distinct volcanic activity where numerous volcanoes show persistent fumarolic activity (e.g., Mather et al., 2004), which in connection with downslope winds may supply effective cloud condensation nuclei (CCN) over the stratocumulus deck. Furthermore, there is evidence of a potential perturbation of the subtropical stratocumulus deck due to anthropogenic emissions of oxidized sulfur (SOx) that occur mainly due to copper smelting along the continental strip of Chile and Peru (Kuang and Yung, 2000; Huneeus et al., 2006). Anthropogenic sulfate aerosols emitted from smelters located uphill the Andes and inland urban centers, as well as dust from the coastal desert, would reach the stratus deck in connection with strong easterly wind events, whereas coastal emissions would be advected by trade winds.

Focal areas

The VOCALS-REx Coastal Component focused in two well defined areas: (a) Pisco-San Juan (13°-15°S) in the southern coast of Peru and (b) Paposo (25°S) in the northern coast of Chile. The Pisco-San Juan region concentrated most of the efforts of the Peruvian contribution. It was selected for the study of the coupled processes at the mesoscale due to the presence of intensified alongshore wind occasionally stronger than 16 m s^{-1} (Stuart, 1981), persistent cloud clearing extending from around 15ºS, 300 km to the northwest, a large upwelling plume of relatively cold and fresh coastal water, separated from warmer and saltier offshore water of subtropical origin by a strong thermal front. This region also exhibits relatively high levels of oceanic eddy kinetic energy and corresponds to the most propitious location for the generation of mesoscale eddies (Chaigneau et al., 2008; 2009). Finally, the selected area encompasses one of the most intense and extended oxygen minimum zone of the World Ocean (e.g. Fuenzalida et al., 2009), contributing to ~50% of oceanic N_2O production (Nevison et al., 2004), a potent greenhouse gas that influences Earth's heat budget and depletes stratospheric ozone.

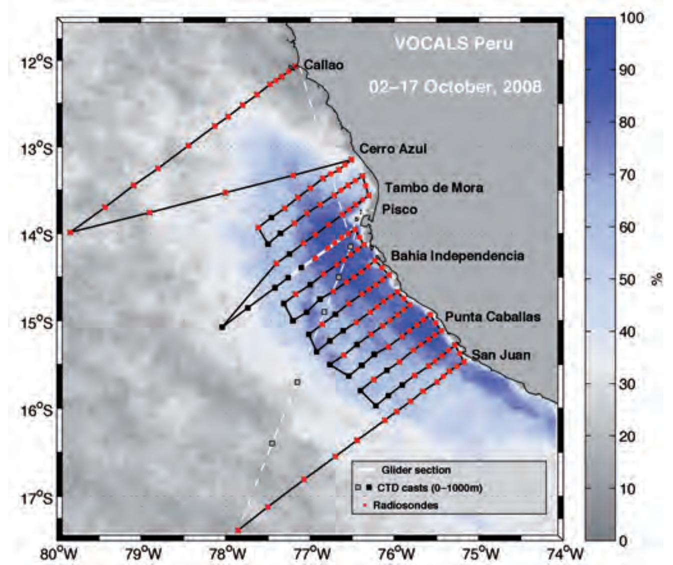

Figure 1. VOCALS-Peru cruise track. Color shading indicates the percentage of time that weekly maps from SeaWIFs satellite data (1998-2008) are cloud free. Regions in blue correspond to cloud clearing area. // Figura 1. Trayectoria del crucero VOCALS-Perú. El sombreado indica el porcentaje de tiempo en que los mapas semanales de datos del satélite SeaWIFs (1998-2008) están libres de nubes. Las regiones azules corresponden al área sin nubes.

En segundo lugar, la subducción de la placa de Nazca bajo los Andes y el continente sudamericano da lugar a un área volcánica definida, donde se ve una importante y persistente actividad fumarólica (por ejemplo, Mather et al., 2004), que en conjunción con los vientos ladera abajo pueden proveer núcleos efectivos de condensación de nubes sobre la capa de estratocúmulos. Además, hay evidencia de una perturbación potencial en la capa subtropical de estratocúmulos causada por emisiones antrópicas de óxidos de azufre (SOx) que se deben principalmente a las fundiciones de cobre ubicadas a lo largo de la franja continental de Chile y Perú (Kuang y Yung, 2000; Huneeus et al., 2006). Los aerosoles de sulfato de origen antrópico emitidos por las fundiciones ubicadas en los Andes y centros urbanos tierra adentro, así como el polvo proveniente del desierto costero, alcanzarían la capa de estratos vinculados con eventos de intensos vientos del este, mientras que los vientos alisios advectarían las emisiones costeras.

Áreas focales

El Componente Costero de VOCALS-REx se concentró en dos áreas bien definidas: (a) Pisco-San Juan (13°-15°S) en la costa sur de Perú y (b) Paposo (25°S) en el norte de la costa de Chile. La mayor parte de los esfuerzos en la región Pisco-San Juan correspondieron al aporte de Perú. Esa área fue seleccionada para el estudio de procesos acoplados de mesoescala debidos a la presencia de la intensificación de los vientos paralelos a la costa, que en ocasiones superan los 16 m s^{-1} (Stuart, 1981), un persistente claro de nubes que se extiende desde alrededor de 15ºS, 300 km al noroeste, una gran pluma de surgencia de agua costera relativamente fría y dulce, separada de las aguas de origen subtropical más cálidas y salinas que se encuentran mar adentro por un fuerte frente termal. Esta región también muestra niveles relativamente altos de energía cinética de los torbellinos oceánicos y es la ubicación más propicia para la generación de torbellinos de mesoescala (Chaigneau et al., 2008; 2009). Finalmente, el área elegida abarca una de las zonas más extensas de mínimos de oxígeno, que son los más intensos del Océano Mundial (por ejemplo, Fuenzalida et al., 2009), y que contribuyen ~50% de la producción oceánica de N_2O (Nevison et al., 2004), un poderoso gas de invernadero que afecta el balance de calor de la Tierra y reduce el ozono estratosférico.

Paposo es un pequeño pueblo pesquero alrededor del que se concentró la mayor parte de los esfuerzos del equipo chileno. Como se describirá después, en Paposo se instaló instrumental para mediciones meteorológicas y de la química del aire. Este lugar también fue llamado súper sitio en tierra de VOCALS-REx. El sitio fue elegido por ser representativo de las condiciones meteorológicas prevalecientes a lo largo de la costa del desierto de Atacama. El cordón costero se eleva a más de 1000 m snm dentro de los 10 kilómetros desde la línea de costa, seguido por un suave aumento de la altura del terreno y finalmente el rápido ascenso de la cordillera de los Andes con picos que superan los 5 km snm. En esta latitud (25°S) la línea de costa, el cordón costero y la cordillera de los Andes tienen mayormente una orientación norte-sur, lo que facilita el análisis de la circulación atmosférica. Además, el sitio se encuentra relativamente aislado de centros urbanos y grandes fundiciones de cobre, aunque al momento de la campaña hubo un aumento en el tránsito de camiones e incremento en las emisiones de una planta de energía cercana.

La fase experimental: Crucero del R/V Olaya

Entre el 2 y el 17 de octubre de 2008, el R/V José Olaya perteneciente al IMARPE (Instituto del Mar del Perú) realizó 113 estaciones CTD en las que 78 tomaron muestreos biogeoquímicos (oxígeno, nutrientes, pH y clorofila-a) y biológicos (fito y zooplancton) y 132 radiosondeos (Figura 1) para un muestreo exhaustivo de la capa límite marina (MBL, por sus siglas en inglés). La traza del crucero de mesoescala y alta resolución tuvo en cuenta además, observaciones en movimiento de la meteorología en superficie, la temperatura del agua y salinidad de la superficie del mar, la velocidad de las corrientes, la presión par-

Paposo is a small fishing village around which most of the efforts from the Chilean team were concentrated. As described later, several meteorological and air chemistry instrumentation was installed in Paposo, which is also referred as VOCALS-REx land super site. The location was selected because it is representative of the meteorological conditions that prevail along the coast of the Atacama desert. The coastal range rises to more than 1000 m ASL within 10 kilometers of the coastline, followed by a gentle increase in terrain height and finally the rapid rise of the Andes cordillera with peaks in excess of 5 km ASL. The coastline, coastal range and Andes cordillera are mostly oriented north-south at this latitude (25°S) facilitating the analysis of the atmospheric circulation. Furthermore, the site is relatively isolated from urban centers and major copper smelters, although by the time of the campaign a few there was an increase in truck traffic and increased emission from a nearby power plant.

The experimental phase: R/V Olaya cruise
From October 2nd to 17th 2008, the IMARPE (Instituto del Mar del Perú) R/V Jose Olaya occupied 113 CTD stations among which 78 considered biogeochemical (oxygen, nutrients, pH and chlorophyll-a) and biological (phyto and zooplankton) sampling and 132 radiosoundings (Figure 1) for an extensive sampling of the marine boundary layer (MBL). The high-resolution mesoscale cruise track considered in addition, underway observations of surface meteorology, water temperature and salinity at the sea surface, current velocities, partial pressure of carbon dioxide and hydroacoustic estimations to document fish (in particular anchovy) abundance and patterns of distributions and its relationship to the physical environment. A cluster of 8 surface drifters were deployed across the upwelling front in order to study advective and diffusive processes inside this feature.

Additionally, the high resolution structure and variability of the upwelling plume and thermal front off Pisco were investigated using an autonomous underwater vehicle (glider) from October 3rd to November 24th, 2008. The glider completed nine consecutive sections perpendicular

cial de dióxido de carbono y las estimaciones hidroacústicas para documentar la abundancia de peces (en particular anchoas) y sus patrones de distribución y su relación con el ambiente físico. Se lanzó un grupo de 8 sondas Xbt de superficie a través del frente de surgencias con el fin de estudiar los procesos advectivos y difusivos dentro de esta característica.

Además, desde el 3 de octubre hasta el 24 de noviembre de 2008 se investigaron la estructura en alta resolución de la pluma de surgencias y el frente térmico así como su variabilidad mar adentro de Pisco utilizando un vehículo subacuático autónomo (glider). El glider realizó nueve secciones consecutivas y perpendiculares al talud continental desde alrededor de los 10 km hasta los 100 km desde la costa, tomando alrededor de 1300 perfiles, hasta una profundidad de 200 m. Se obtuvieron datos físicos y biogeoquímicos de alta resolución para caracterizar la estructura y la dinámica del frente de surgencias.

El súper sitio de Paposo
En el sitio costero de Paposo (25º0'S, 70º27'W, 700 m snm) se realizaron mediciones in situ *de viento, temperatura, radiación, concentraciones de aerosoles y núcleos de condensación de las nubes, la composición y distribución de tamaño. Hubo dos sitios primarios (Figura 2): el inferior (a unos pocos metros de la costa y 20 m snm) y el superior (estación CONAF, 680 m snm, ubicado en la escarpa costera).*

Durante VOCALS-REx se instaló en el sitio inferior una estación meteorológica automática completa (EMA), un LIDAR polarimétrico (Fochesatto et al., 2005) y un cielómetro láser. En julio de 2008 se agregó una segunda estación automática en el sitio superior. En el sitio inferior, se lanzaron radiosondas 3-4 veces por día durante el transcurso de la campaña, lo que posibilitó una descripción detallada de las características de la MBL y la circulación troposférica cerca de Paposo. Los radiosondeos en Paposo cubrieron el vacío de observaciones entre los sondeos regulares que realiza la Dirección Meteorológica de Chile en Antofagasta (23°S) y Santo Domingo (33°S).

Además de las mediciones meteorológicas en superficie y en altura, se instalaron varios equipos para medir la química del aire y los aerosoles en Paposo. Entre ellos: (a) núcleos de condensación

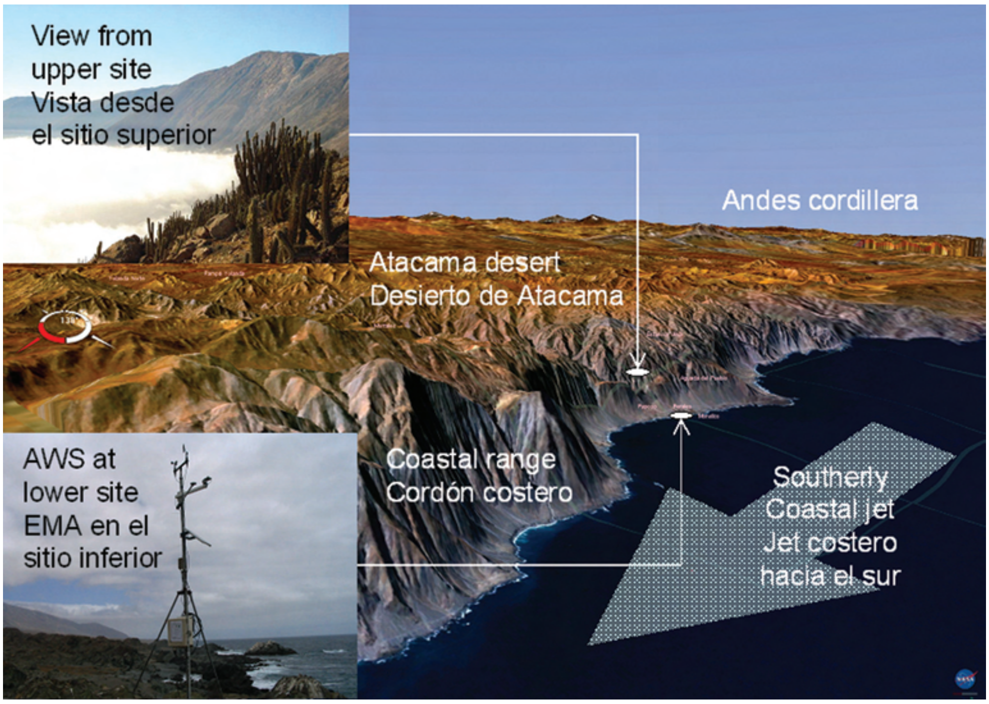

Figure 2. Paposo area (25°S) viewed from the north, along with snapshots of the upper and lower sites. Note the Sc cloud deck capped by a strong inversion off Paposo. //
Figura 2. Área de Paposo (25°S) vista desde el norte, junto con fotografías de los sitios superior e inferior. Nótese cómo una fuerte inversión mar adentro de Paposo limita la capa de Sc.

System / Measurements Sistema / mediciones	Project Proyecto	Leading institution Institución principal	Researchers Investigadores	Location(s) Ubicación(es)	Associated Instruments Instrumental Asociado
Meteor. Soundings Sondeos meteorológicos		Dirección Meteorológica de Chile	J. Carrasco, J. Aravena	Paposo lower site Sitio inferior en Paposo Cerro Moreno Airport Aeropuerto Cerro Moreno	Radiosonde Receiver Receptor de radiosonda
Surface Meteorology Meteorología de superficie	ACT-19	Departamento de Geofísica Universidad de Chile	J. Rutllant	Paposo lower site Paposo upper site Sitios superior e inferior en Paposo	AWS, data logger, solar panel EMA, registrador de datos, panel solar
Cloud base and frequency Bese de nubes y frecuencia	ACT-19	Departamento de Geofísica, Universidad de Chile	R. Muñoz, R. Garreaud	Paposo lower site Sitio inferior en Paposo	Vaisala CL-31 Ceilometer Telémetro Vaisala CL-31
Volcanic emissions Emisiones volcánicas Volcanic emissions Emisiones volcánicas		Departamentos de Geofísica & Geología - Universidad de Chile	A. Amigo, A. Pavez	Láscar and Lastarria volcanoes Volcanes Láscar y Lastarria	MiniDOAS FLYSPEC
Cloud Condesation Nuclei Núcleos de condensación de nubes	IAI 2017	Department of Applied Environmental Science, Stockholm University	R. Krejci	Paposo upper site Sitio superior en Paposo	PSAP, CVI
Aerosol loading, distribution and radiative properties Carga, distribución y propiedades radiativas de los aerosoles	NSF-ATM 0839872	Geophysical Institute, University of Alaska, Fairbanks	J.Fochesatto	Paposo Lower site (Lidar) Sitio inferior en Paposo (Lidar) Paposo Upper site (rest) Sitio superior en Paposo (resto)	Lidar, Aerosol samplers, column optical instruments LIDAR, muestreadores de aerosoles, instrumental óptico
Observations of aerosol physical, chemical and optical properties Observaciones de las propiedades físicas, químicas y ópticas de los aerosoles		Atmospheric Sciences, University of Washington, Seattle, USA	R. Wood, J.Thornton, D. Chand	Paposo upper site Sitio superior en Paposo	Climet OPC Impactor filters Nephelometer Nefelómetro, filtros Climet OPC
Black carbon observations at upper site Observaciones de hollín en el sitio superior	SAEMC	Universidad de Valparaíso / Universidad de Chile	L. Gallardo, A. Córdova	Paposo upper site Sitio superior en Paposo	Aethalometer, model AE42-2 “Portable”, Sharp-cut Cyclone Inlet Aetalómetro, modelo portátil AE42-2

Table 1: Synthesis of instruments, measurements and teams operating in Paposo Super-site during VOCALS-Rex ||
Tabla 1: Resumen del instrumental, mediciones y equipos que trabajaron en el Súper Sitio de Paposo durante VOCALS-Rex

to the continental slope from about 10 km to about 100 km from the coast collecting about 1300 profiles, down to 200 m depth. High resolution physical and biogeochemical data were obtained to characterize the structure and the dynamics of the upwelling front.

Paposo Super Site

In situ measurements of wind, temperature, radiation, aerosol and cloud condensation nuclei concentrations, composition and size distribution were performed in the Paposo coastal site (25º0'S, 70º27'W, 700 ma.s.l). There were two primary sites (Figure 2): lower (within a few meters from the shore at 20 m ASL) and upper (CONAF station, 680 m ASL on the coastal escarpment).

A full automatic weather station (AWS), a polarimetric LIDAR (Fochesatto et al., 2005) and a laser ceilometer were installed in the lower site during VOCALS-REx. A second AWS was installed in the upper site in July 2008. In the lower site, radiosondes were launched 3-4 daily during the field campaign, allowing a detailed description of the MBL characteristics and tropospheric circulation near Paposo. The radiosondes at Paposo filled the observational gap between the regular soundings performed by the Chilean Weather Service at Antofagasta (23°S) and Santo Domingo (33°S).

In addition to the surface and upper-air meteorological data, several aerosol and air-chemistry instrumentation was installed in Paposo, which included: (a) cloud condensation nuclei in the upper site (usually within the cloud), (b) Aerosol loading, distribution and radiative properties, (c) observations of aerosol physical, chemical and optical properties, and (d) black carbon observations at upper site. Table 1 lists the instruments, projects and researchers involved in these measurements. Further details on the sub-projects, catalog of datasets, and access to data are available on-line at: http://www.dgf.uchile.cl/VOCALS_PAPOSO/

Modeling efforts

Model studies are being carried out for understanding the physical (atmospheric and oceanographic) and biological processes, as well as validating the models with the observations. These efforts are based on a suite of different atmospheric, oceanic, biogeochemical and biological models. Modeling activities within VOCALS-REx builds upon several on-going projects within the research institutions. The Instituto Geofísico del Perú (IGP) runs a high-resolution MM5 nested model configuration, and the Department of Geophysics, Universidad de Chile (DGF-UCH) runs a mesoscale WRF model over the whole SEP. On-going work has been also devoted to the comparison of WRF and MM5 simulation against the unprecedented dataset generated during VOCALS-REx.

The air-chemistry and meteorological data collected in Paposo will be further analyzed and put into a regional framework by means of high resolution regional- and meso-scale simulations using a weather forecast model (e.g., WRF-Chem) as well as dispersion simulations including natural and anthropogenic oxidized sulfur sources. Satellite data (e.g., cloud droplet radii, cloud cover, liquid water path, SO_2 loading, etc.) will also complement these analyses.

IMARPE and IRD are running several configurations of the ROMS models at 1/9° and 1/6° resolutions (Penven et al., 2005; Belmadani et al., 2009). It is planned to perform downscaling experiments at higher-resolution (1/18° and 1/27°) for the duration of the cruise using the AGRIF software, which enables efficient and straightforward downscaling from a regional model to a higher resolution

de nubes en el sitio superior (generalmente dentro de las nubes), (b) concentración de aerosoles, distribución y propiedades radiativas, (c) observaciones de las propiedades físicas, químicas y ópticas de los aerosoles, y (d) mediciones de hollín en el sitio superior. En la Tabla 1 se presenta el instrumental, proyectos e investigadores involucrados en las mediciones. En http://www.dgf.uchile.cl/VOCALS_PAPOSO/ pueden hallarse más detalles sobre los sub-proyectos, un catálogo de los conjuntos de datos y el acceso a los mismos.

Actividades de modelización

Se están realizando estudios de modelización para comprender los procesos físicos (atmosféricos y oceanográficos) y biológicos, así como la validación de los modelos con las observaciones. Estos esfuerzos se apoyan en un conjunto de diferentes modelos atmosféricos, oceánicos, biogeoquímicos y biológicos. Las actividades de modelado de VOCALS-REx se articulan en varios proyectos que se están desarrollando en las instituciones de investigación. El Instituto Geofísico del Perú (IGP) utiliza una configuración de modelos MM5 anidados de alta resolución, y el Departamento de Geofísica de la Universidad de Chile (DGF-UCH), un modelo WRF de mesoescala en toda la región del SEP. El trabajo en curso también compara las simulaciones WRF y MM5 con el conjunto de datos sin precedentes generado durante VOCALS-REx.

Se continuará con el análisis de los datos meteorológicos y de la química del aire recolectados en Paposo y se los incorporará a un marco regional mediante simulaciones regionales y de mesoescala de alta resolución utilizando un modelo de pronóstico del tiempo (por ejemplo, el WRF-Chem) y simulaciones de dispersión incluyendo fuentes antrópicas y naturales de óxidos de azufre. Estos análisis también se complementarán con datos satelitales (por ejemplo, el radio de las gotitas de nubes, la cobertura de nubes, el recorrido de agua líquida, la concentración de SO_2, etc.).

El IMARPE y el IRD están corriendo diferentes configuraciones de los modelos ROMS con resoluciones de 1/9° y 1/6° (Penven et al., 2005; Belmadani et al., 2009). Se planea realizar experimentos de reducción de escala con mayor resolución (1/18° y 1/27°) para el período de duración del crucero, utilizando el programa AGRIF, que permite una reducción de escala eficiente y sencilla desde un modelo regional a uno costero de más alta resolución. Para ese mismo período, las condiciones iniciales y de contorno abierto para la grilla más gruesa serán provistas por el modelo global de MERCATOR GLORYS1V1 con 1/4°, en el que se asimilan de forma rutinaria datos de ARGO y satelitales. Finalmente, se acoplará un modelo biogeoquímico (PISCES) con el modelo físico (ROMS) utilizando las mismas grillas anidadas (1/9° y 1/27°). Las condiciones iniciales y de borde (nutrientes, oxígeno, concentraciones de plancton) para el modelo acoplado ROMS/ PISCES serán provistas ya sea por una simulación global de gran escala realizada con el ORCA/PISCES (2° de resolución) o por productos con resolución de 1/4° del proyecto francés "MERCATOR-vert" (http://www.legos.obs-mip.fr/projets/bionuts/).

Los resultados del modelo se confrontarán con las mediciones tomadas durante el crucero. Las simulaciones regionales del modelo y el producto MERCATOR servirán también como herramienta para estudiar el contexto regional del crucero, es decir, la circulación regional previa al crucero y la influencia de las ondas de Kelvin ecuatoriales. La confrontación de los resultados del modelo con las observaciones biogeoquímicas permitirán mejorar las parametrizaciones de los procesos biogeoquímicos. Una vez optimizado, se utilizará la plataforma del modelo para estudiar procesos en escalas intraestacionales a interanuales.

coastal model. For the duration of the cruise, initial and open boundary conditions for the coarse grid will be provided by the global MERCATOR model GLORYS1V1 at 1/4°, in which satellite and ARGO data are routinely assimilated. Finally, a biogeochemical model (PISCES) will be coupled to the physical model (ROMS) using the same nested grids (1/9° and 1/27°). The initial and boundary conditions (nutrients, oxygen, plankton concentrations) for the coupled ROMS/ PISCES model will be provided either by a large scale global simulation performed with ORCA/PISCES (2° resolution) or by products at 1/4° resolution delivered by the French project "MERCATOR-vert" (http://www.legos.obs-mip.fr/projets/bionuts/).

The model results will be confronted to the observations collected during the cruise. The regional model simulations and the MERCATOR product will also serve as a tool to study the regional context of the cruise, i.e. the regional circulation before the cruise and the influence of the equatorial Kelvin waves. The confrontation of the model results with the biogeochemical observations will allow improving the parameterizations of the biogeochemical processes. Once optimized, the model platform will be used to study processes at intraseasonal to interannual time scales.

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Progress on Understanding Land–Atmosphere Interactions and Surface Hydrology during the North American Monsoon

Land surface processes have been considered to play an important, yet poorly understood, role on the evolution of the North American Monsoon System (NAMS). In summarizing the results of the NAME Process Study, Higgins and Gochis (2007) indicated that surface flux, vegetation and soil moisture measurements taken during NAME could potentially help constrain estimates of land-atmosphere interactions and moisture recycling. To understand these land surface-atmosphere feedbacks involves observations and modeling of the land phase of the hydrological cycle. As indicated by Vera et al. (2006), only the major hydrologic features of the NAMS, such as the seasonal march of precipitation and streamflow at coarse spatial scales, have been quantified. Motivated by these studies, several efforts by a team of U.S. and Mexico scientists were carried out during 2006-2009 in the NAMS region.

Process Studies

Activities during the NAME Process Study were continued in Sonora, Mexico. Precipitation, soil moisture and surface flux monitoring was carried out in the Rio Sonora Observatory (RSO) and the Rosario de Tesopaco Flux Site.

Avances en el conocimiento de las interacciones tierra–atmósfera y la hidrología en superficie durante el Monzón de Norteamérica

Se considera que los procesos en la superficie terrestre cumplen un papel importante, aunque escasamente conocido, en la evolución del Sistema Monzónico Norteamericano (NAMS, por sus siglas en inglés). En su síntesis de los resultados del Estudio de Procesos de NAME, Higgins y Gochis (2007) señalaron que las mediciones del flujo en superficie, la vegetación y la humedad del suelo realizadas durante NAME podrían ayudar potencialmente a ajustar las estimaciones de las interacciones tierra-atmósfera y el reciclado de la humedad. Para comprender estas retroalimentaciones entre la superficie de la tierra y la atmósfera se requieren observaciones y modelizaciones de la fase tierra del ciclo hidrológico. Como indicaron Vera et al. (2006), sólo se han cuantificado las principales características hidrológicas del NAMS, como la marcha estacional de la precipitación y el caudal en escalas espaciales grandes. Motivado por estos estudios, un equipo de científicos de EE.UU. y México llevó a cabo varios trabajos entre 2006 y 2009 en la región del NAMS.

Estudios de proceso

Las actividades durante el Estudio de Proceso de NAME se continuaron en Sonora, México. El monitoreo de la precipitación, la humedad del suelo y el flujo en superficie se llevó a cabo en el Observatorio del Río Sonora (RSO) y en el Sitio de medición de

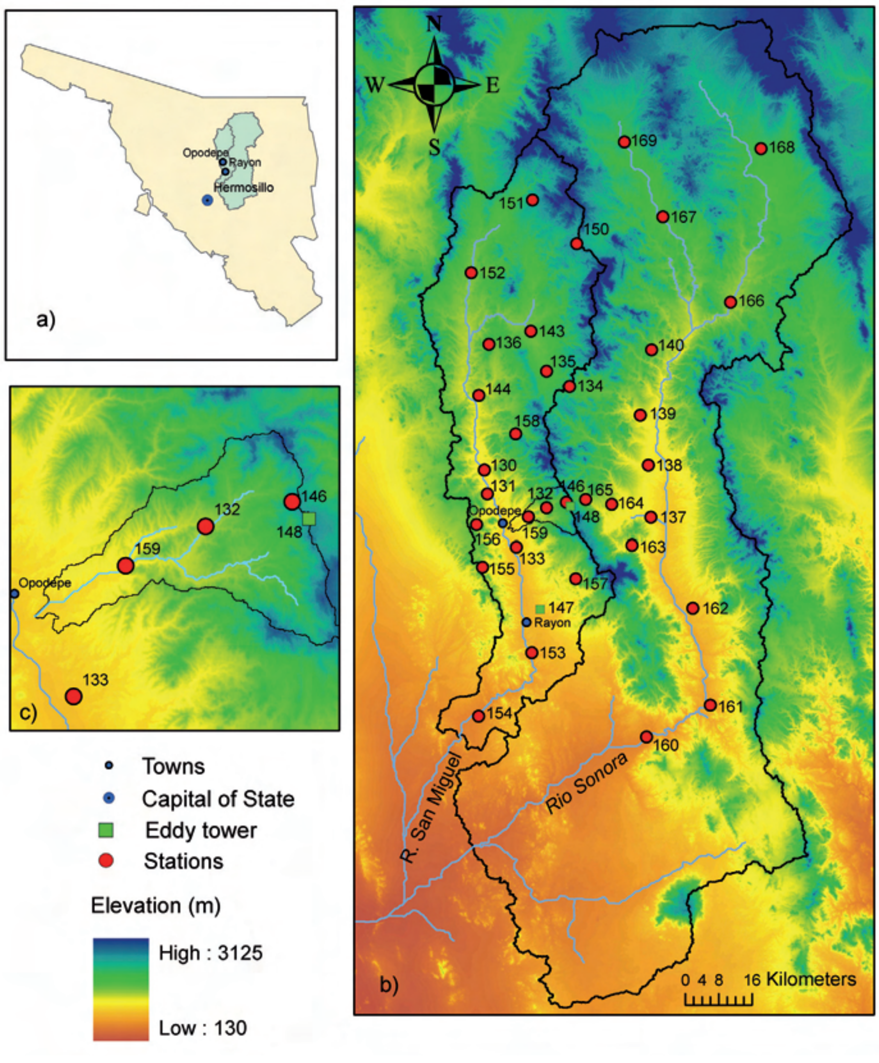

Figure 1. Rio Sonora Observatory (RSO) with locations of hydrometeorological stations.
Figura 1: Observatorio del Río Sonora (RSO) y ubicación de las estaciones hidrometeorológicas

The RSO is a network of two eddy covariance sites (Rayon Subtropical Scrubland and Sierra Los Locos Oak Savanna) and thirty-five continuous precipitation and soil moisture stations (Fig. 1). The instrument network affords an unprecedented opportunity to study the linkage between precipitation, soil moisture, evapotranspiration and vegetation dynamics in the NAMS region. For example, Vivoni et al. (2008) utilized eddy covariance observations at Rayon, Rosario de Tesopaco and two sites in Arizona to identify how vegetation dynamics influence the evolution of the evapotranspiration-soil moisture relationship, a critical parameterization in land surface models. This study clearly indicates that dynamic ecosystem greening needs to be represented in studies that attempt to quantify land-atmosphere interactions and moisture recycling.

Remote Sensing Analyses

The RSO instrument network also provides a rich data sets for relating ground-based data to remotely-sensed observations of precipitation and surface characteristics from various satellite platforms. For example, Mendez-Barroso et al. (2009) related the seasonal and interannual variations in vegetation greenness obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS) to hydrologic conditions at 14 continuous stations over 2004-2007. The authors found that the different ecosystems in the NAMS region have varying strategies to cope with the interannual variability of the NAMS, with large seasonal changes in net primary productivity related to concurrent soil moisture and cumulative precipitation. The study showed that the land surface responses to the NAMS contains information that can be used to understand the land-atmosphere feedbacks that may lead to moisture recycling during periods of limited synoptic-scale moisture convergence.

Hydrologic Modeling

While useful, ground and remote sensing observations are limited by their spatial and/or temporal resolutions. To overcome this limitation, a distributed hydrological model was tested for the Sierra Los Locos basin in the RSO by Vivoni et al. (2009). In their study, the authors utilized NAME data to build confidence in the simulated soil moisture and evapotranspiration. A key finding was that the model reproduced the evapotranspiration-soil moisture relation at Rayon significantly better than the North American Regional Reanalysis (NARR) dataset. Applications over the Sierra Los Locos basin were

flujos en Rosario de Tesopaco. El RSO es una red de dos sitios de covarianza de vórtices (el Matorral Subtropical de Rayón y la Sabana de Robles de Sierra Los Locos) y treinta y cinco estaciones continuas de precipitación y humedad del suelo (Fig. 1). La red de instrumentos ofrece una oportunidad sin precedentes para estudiar la relación entre la precipitación, la humedad del suelo, la evapotranspiración y la dinámica de la vegetación en la región del NAMS. Por ejemplo, Vivoni et al. (2008) usaron observaciones de la covarianza turbulenta de Rayón, Rosario de Tesopaco y de dos sitios en Arizona para identificar cómo afecta la dinámica de la vegetación a la evolución de la relación evapotranspiración-humedad del suelo, una parametrización crítica en los modelos de superficie. Este estudio indica claramente que el enverdecimiento dinámico de los ecosistemas debe representarse en estudios que busquen cuantificar las interacciones tierra-atmósfera y el reciclado de humedad.

Análisis de Detección Remota

La red de instrumentos del RSO también ofrece un rico conjunto de datos para relacionar observaciones en tierra con mediciones remotas de la precipitación y de las características de superficie desde diferentes plataformas satelitales. Por ejemplo, Mendez-Barroso et al. (2009) relacionaron las variaciones estacionales e interanuales en el verdor de la vegetación obtenidas con el Espectroradiómetro de Imágenes de Resolución Moderada (MODIS) con las condiciones hidrológicas de 14 estaciones continuas en el período 2004-2007. Los autores hallaron que los diferentes ecosistemas de la región del NAMS tienen variadas estrategias para enfrentar la variabilidad interanual del NAMS, con grandes cambios estacionales en la productividad primaria neta en relación simultánea con la humedad del suelo y precipitación acumulada. El estudio mostró que las respuestas de la superficie de la tierra al NAMS contienen información que puede ser utilizada para comprender las retroacciones tierra-atmósfera que pueden llevar al reciclado de humedad durante períodos de limitada convergencia de humedad a escala sinóptica.

Modelización de la Hidrología

Si bien son útiles, las observaciones en superficie y por detección remota son limitadas por sus resoluciones espaciales y/o temporales. Para superar esta limitación, Vivoni et al. (2009) probaron un modelo hidrológico distribuido para la cuenca de Sierra Los Locos en el RSO. En su estudio, los autores utilizaron datos del NAME para realizar simulaciones confiables de la humedad del suelo y la evapotranspiración. Un hallazgo clave fue que el modelo reprodujo sustantivamente mejor la relación evapotranspiración-humedad del suelo en Rayón que el conjunto de datos del Reanálisis Regional de América del Norte

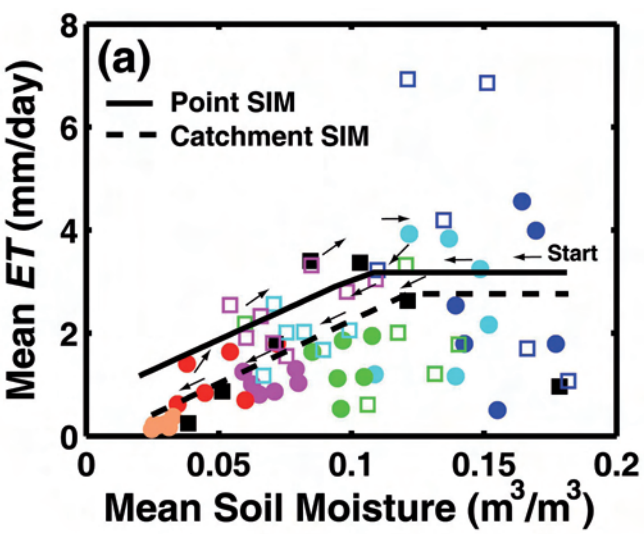

Figure 2. Relation between evapotranspiration (ET) and soil moisture at the point and catchment scales.
Figura 2: Relación entre la evapotranspiración (ET) y la humedad del suelo en escalas de punto y captación

subsequently used to explore how the evapotranspiration-soil moisture relation varied at the catchment scale due to the aggregation of underlying spatial patterns induced by the variability in topography, soil moisture and vegetation (Fig. 2). The mismatch between the point and catchment scale relations indicates that capturing the spatial patterns within river basins is important for predicting the effective surface fluxes that play a role in moisture recycling in the NAMS region. Furthermore, the relation between evapotranspiration and soil moisture exhibits hysteresis that requires carefully depicting the temporal evolution of hydrologic conditions.

Conclusions

In addition to the cited studies, a special issue in the Journal of Arid Environments is under preparation on the topic of "Land Surface Ecohydrology of the North American Monsoon System", to be published in early 2010. The twelve papers in the special issue address a range of topics including: (1) characterizing the precipitation and runoff seasonality in the NAMS region, (2) quantifying the land surface expression of a vegetation-rainfall feedback mechanism, (3) identifying the controls of soil depth on the hydrologic response at two eddy covariance sites, (4) exploring the albedo, land surface temperature and vegetation greenness changes across a large transect of sites in the NAMS region, and (5) quantifying the statistical features of soil moisture for improving hydrologic simulations at the regional scale, among others. These papers will jointly make an important contribution to extending our current knowledge of land-atmosphere interactions and hydrology of the NAMS.

Despite recent advances, a complete understanding of the role of land-atmosphere interactions, mediated by the hydrologic response in catchments, on the evolution of the NAMS has still not been achieved. To fully address this issue will require regional-scale climate modeling of the NAMS evolution with dynamically-updated vegetation conditions. The simulations should be tested against the field observations at the RSO and other eddy covariance sites in the NAMS region, in particular with respect to surface fluxes and their relation to soil moisture and vegetation states. Given a well-tested regional model simulation, the effects of land surface conditions on the NAMS evolution through local moisture recycling can be carefully evaluated relative to other forcing mechanisms.

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(NARR). Las aplicaciones en la cuenta de la Sierra Los Locos se usaron posteriormente para explorar cómo variaba la relación evapotranspiración-humedad del suelo a escala de captación debido a la agregación de los patrones espaciales subyacentes, inducidos por la variabilidad de la topografía, la humedad del suelo y la vegetación (Fig. 2). El desajuste entre la relación de escalas del punto y la zona de captación de la cuenca indica que la interpretación de los patrones espaciales en las cuencas fluviales es importante para predecir los flujos de superficie efectivos, que tienen un papel en el reciclado de la humedad en la región del NAMS. Además, la relación entre la evapotranspiración y la humedad del suelo muestra una histéresis que requiere una descripción cuidadosa de la evolución temporal de las condiciones hidrológicas.

Conclusiones

Además de los estudios citados, se está preparando un número especial del Journal of Arid Environments sobre "Ecohidrología de la superficie de la tierra del Sistema Monzónico Norteamericano", que se publicará a comienzos de 2010. Los doce trabajos de ese número especial tratan una gran variedad de temas: (1) la caracterización de la estacionalidad de la precipitación y la escorrentía en la región del NAMS, (2) la cuantificación de la expresión de la superficie de la tierra de un mecanismo de retroalimentación vegetación-precipitación, (3) identificación de los controles de profundidad del suelo en la respuesta hidrológica en dos sitios de covarianza de vórtices, (4) exploración del albedo, la temperatura en superficie y los cambios en el índice de verdor a través de un largo perfil de sitios en la región del NAMS, y (5) cuantificar las propiedades estadísticas de la humedad del suelo para mejorar las simulaciones de la hidrología en escala regional, entre otras. Estos trabajos en conjunto serán un importante aporte al avance de nuestro conocimiento actual de las interacciones tierra-atmósfera y la hidrología del NAMS.

Pese a los recientes avances, aún no se ha logrado comprender completamente el papel de las interacciones tierra-atmósfera, mediadas por la respuesta hidrológica en las cuencas, en la evolución del NAMS. Para poder abordar este tema de forma completa se necesita el modelado climático a escala regional de la evolución del NAMS con actualización dinámica de las condiciones de la vegetación. Las simulaciones deberían probarse contra las observaciones de campo del RSO y otros sitios de covarianza de vórtices de la región del NAMS, especialmente en lo referente a los flujos de superficie y su relación con los estados de la humedad del suelo y de la vegetación. Dada una simulación bien probada de un modelo regional, los efectos de las condiciones en superficie sobre la evolución del NAMS a través del reciclado local de humedad pueden evaluarse cuidadosamente en relación con otros mecanismos forzantes.

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