

Regional Modeling at DGF – Universidad de Chile

Current work and VOCALS perspectives

René Garreaud(*), Ricardo Muñoz, Mark Falvey, Rodrigo Sanchez

* The Mesoscale Model of the 5th Generation (**MM5**) and the Weather and Research Forecast (**WRF**), two widely-used, regional atmospheric models, have been used at Department of Geophysics – Universidad de Chile, to study several features of the weather/climate of the South-east Pacific (SEP) region.

* Particular emphasis has been put on the adequate simulation of the Sc-capped marine boundary layer (MBL) in the SEP, since the distribution of low level coastal clouds, the intensity and direction of coastal winds and the amplitude of coastal temperatures are strongly modulated by the dynamics of this MBL.

* More recently, and in collaboration with LEGOS (France), we began to run **ROMS** (Regional Ocean Modeling System) forced by WRF to study the atmosphere-ocean interaction off north-central Chile.

MM5 / WRF Typical configuration in our studies:

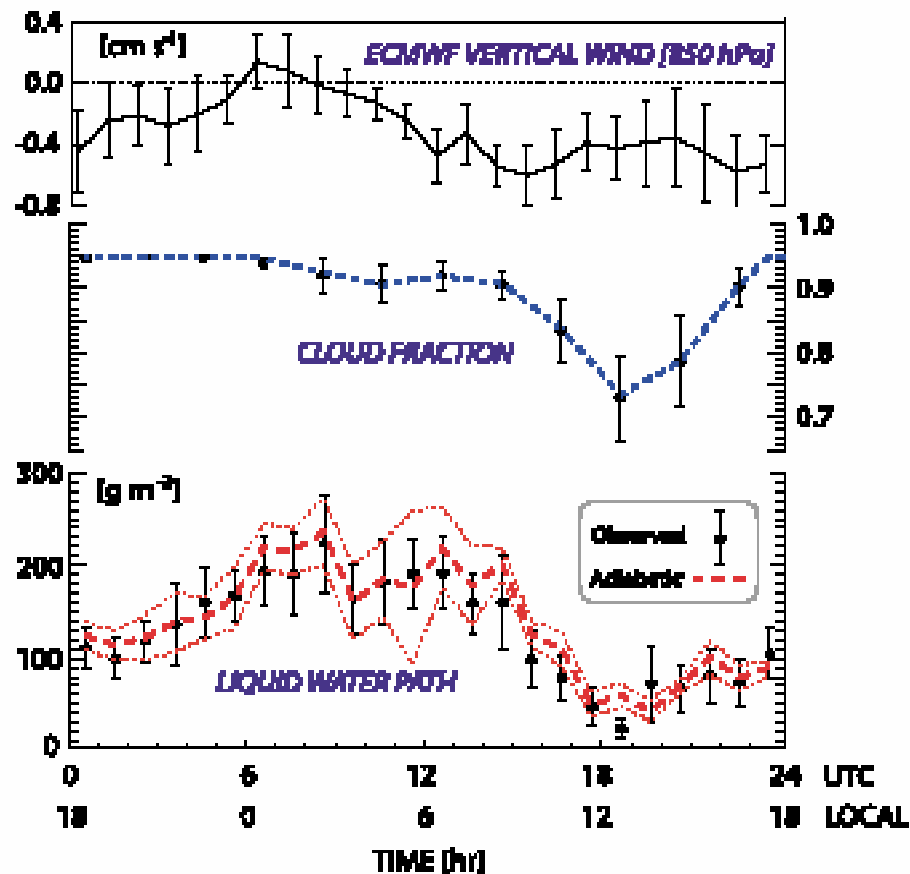
- Integration time: 2 weeks up to 3 months
- Inner Domain: 15°-35°S / 90°-60°W (about 1500 km off the coast)
- IC and Lateral BC: NCEP-NCAR Reanalysis
- Horizontal resolution: 10-50 Km
- Vertical resolution: 27-30 sigma levels (100 m in the lowest 2 km)
- High vertical resolution: 60 sigma levels (25 m in the lowest 2 km)
- PBL-turbulence parameterization:
 - Gayno-Seaman [1.5-order turbulence scheme with a prognostic eqn. for TKE (with an all-or-nothing treatment of the saturation effects) and diagnosis of the mixing and dissipation length scale].
 - MRF scheme has also been used.

Past research includes:

- Atmospheric gravity waves propagating from the coast of southern Perú – Northern Chile into the SEP, and their effect on the diurnal cycle of the Sc (Garreaud and Muñoz 2004)
- Structure, variability and dynamics of the coastal jet off central-Chile (Garreaud and Muñoz 2005, Muñoz and Garreaud 2005)
- Structure and dynamics of the coastal lows, coastally trapped disturbances often observed in North-central Chile (Garreaud and Rutllant 2003).

For each line, we present now some observational wonder-figure(s) and few results from regional simulations.

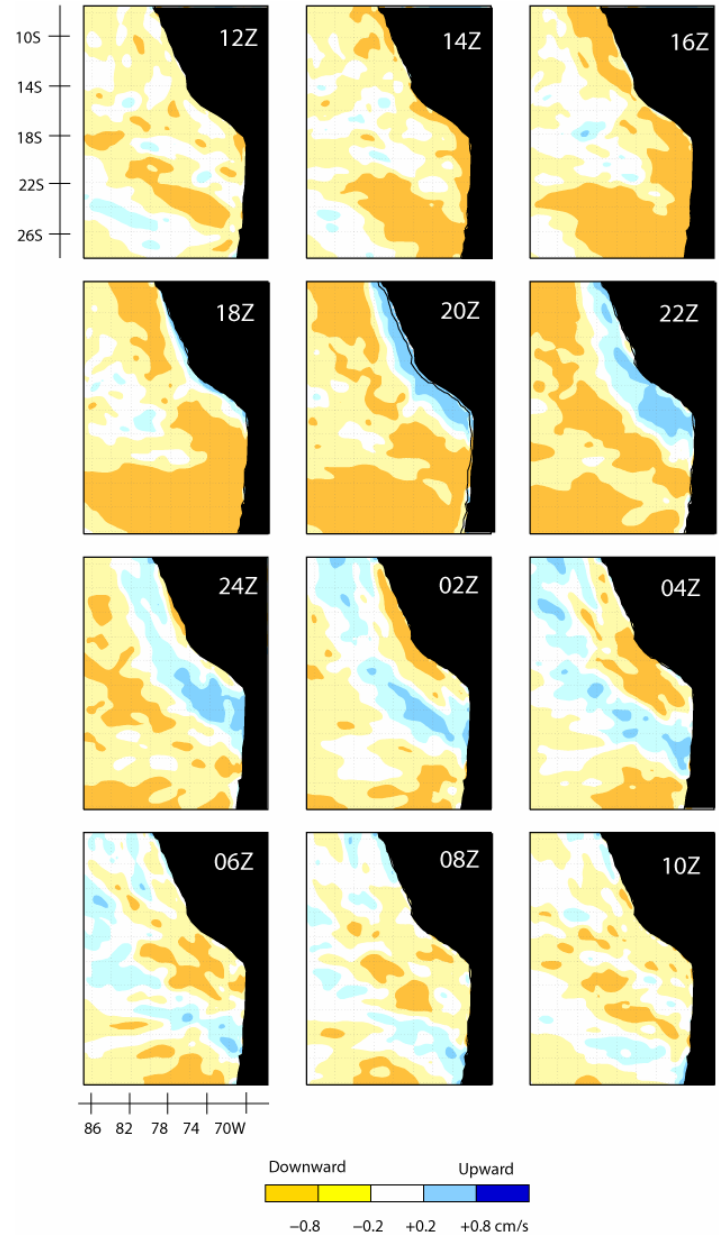
A distinctive feature of this Sc deck is its particularly pronounced diurnal cycle in cloud amount (Minnis and Harrison 1984; Rozendaal et al. 1995) and LWP (Bretherton et al. 2003; Wood et al. 2002), that is highly relevant to the quantification of the true impact of Sc on climate (Bergman and Salby 1997).



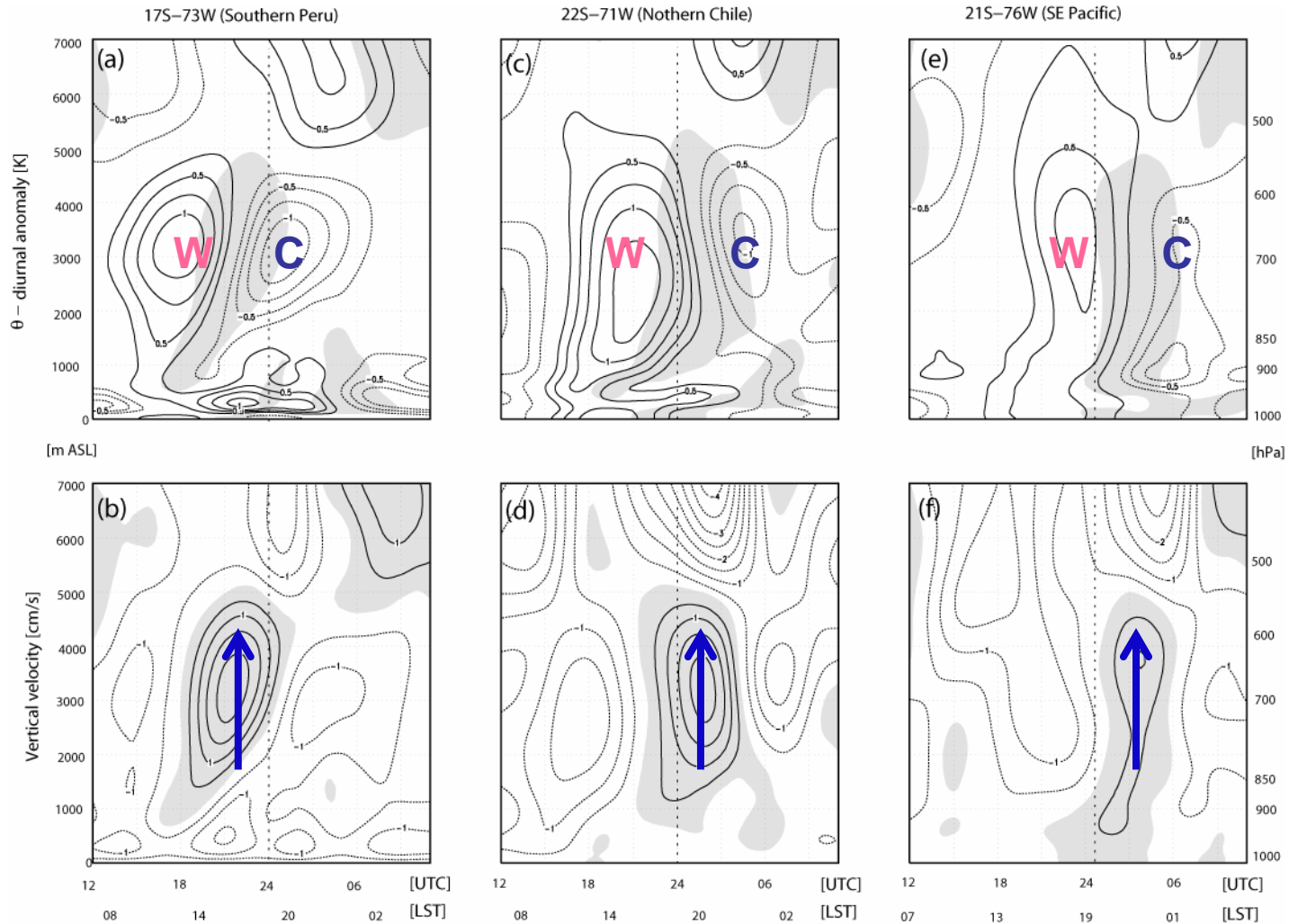
MM5 results. SON simulation.

Mean diurnal cycle of vertical velocity at 800 hPa ▶

Note the “upsidende wave” originated along the peruvian coast.

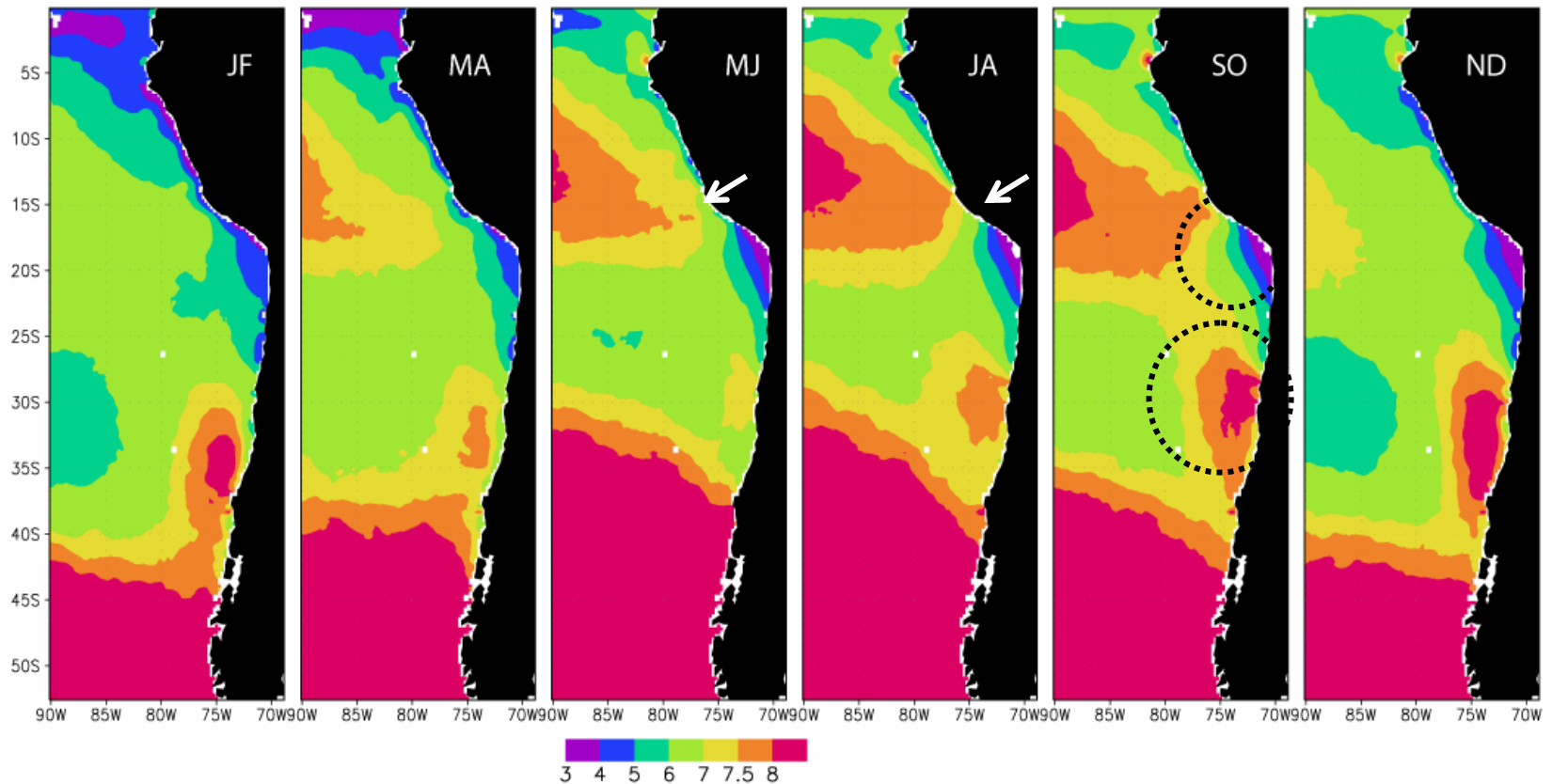


MM5 results. SON simulation.



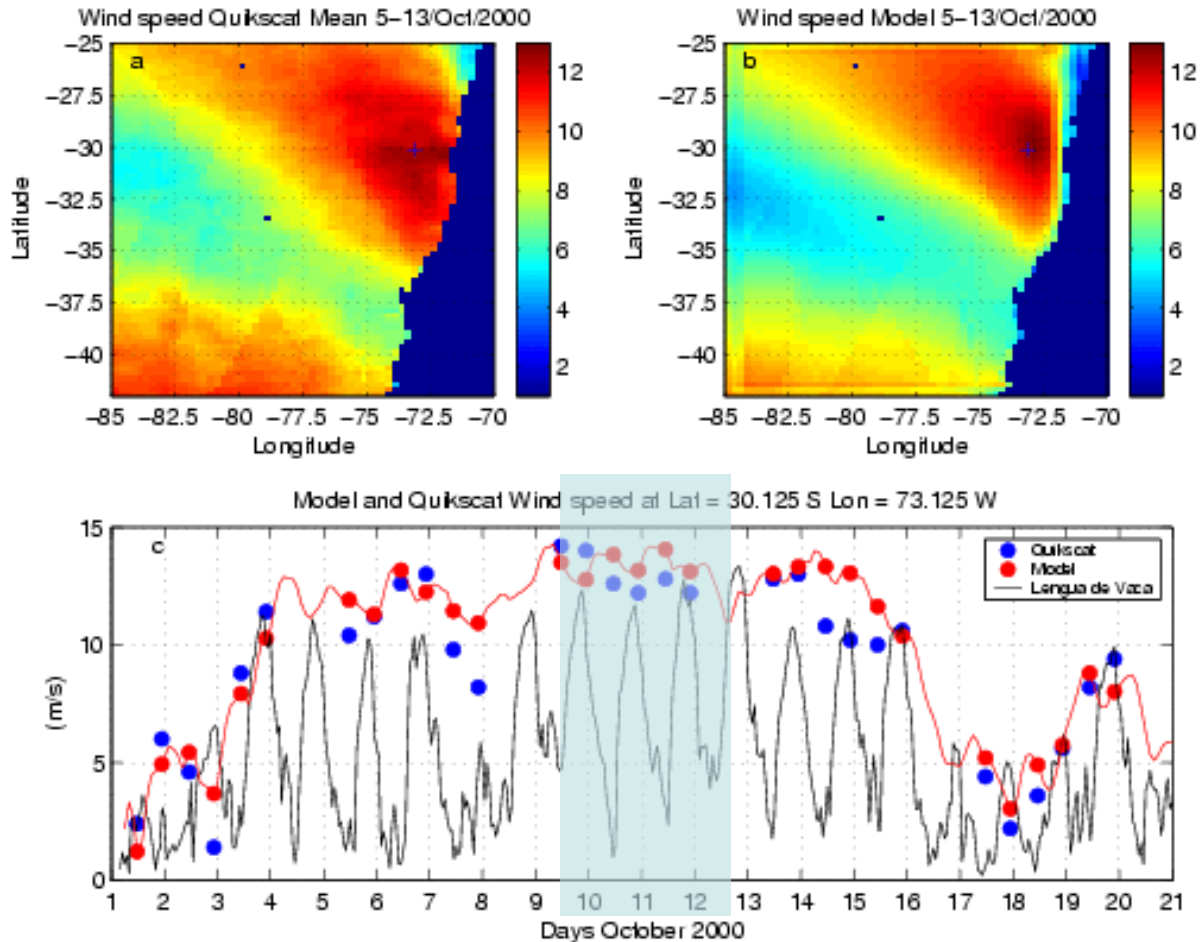
- Significant diurnal cycle in θ up to 5 km ASL
- Subsidence interrupted by period of upward motion
- Cooling largely produced by vertical advection

QuikScat surface wind speed climatology (2000-2005)

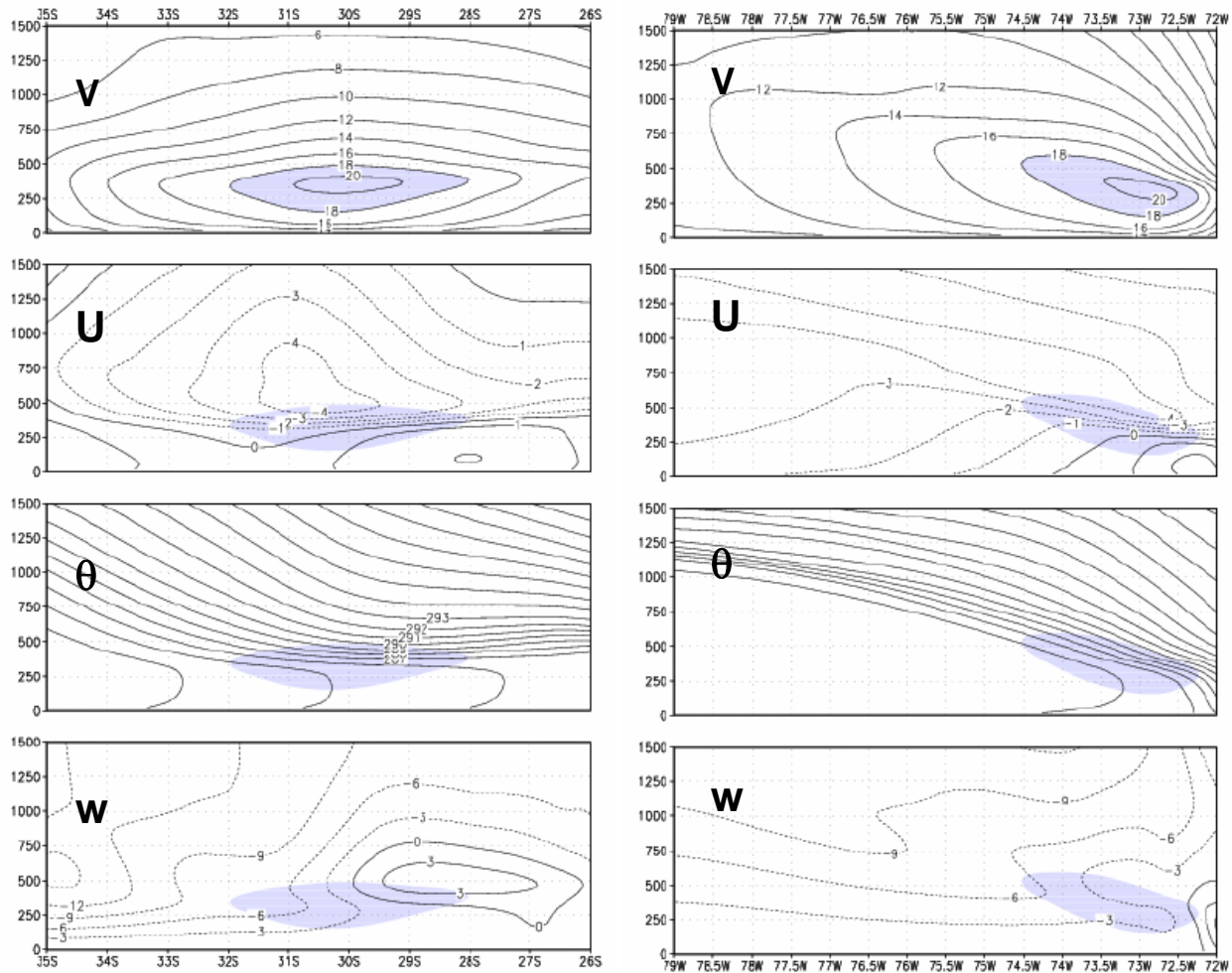



Among several interesting features of the sfc. ws field, we focus on the **coastal jet off central Chile and the low-speed area around 18°S**. Also notice the wind maximum @ 15°S only present during JJA

MM5 results. October 2000 simulation of a well defined jet events



Simulated (MM5) structure of the coastal jet

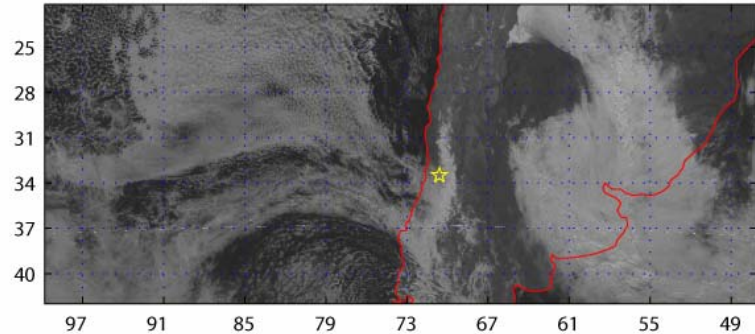


 V > 18 m/s

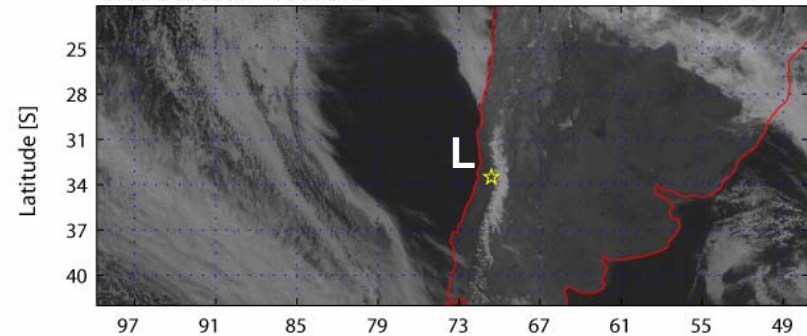
Coastal lows in central Chile

- * Quasi-weekly occurrence
- * During winter they can reach northern Chile
- * During developing phase, extensive cloud clearing off the coast and eventual advection of continental air over the SEP.

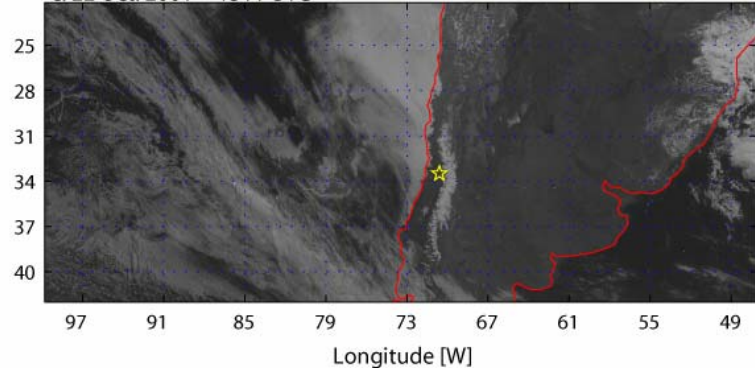
a. 18 Oct. 2001 – 1644 UTC



b. 20 Oct. 2001 – 1644 UTC



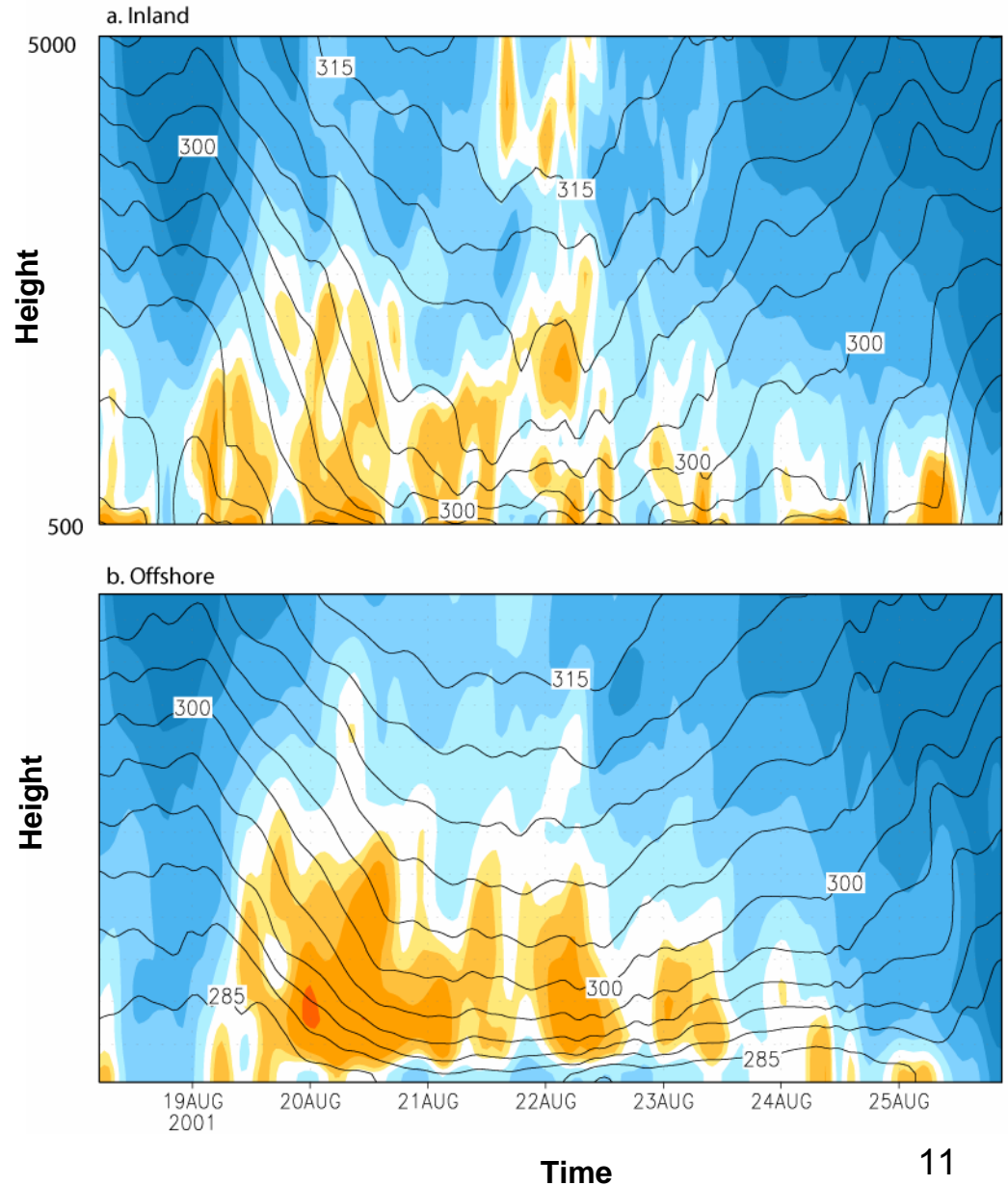
c. 22 Oct. 2001 – 1511 UTC



MM5 results for a case study (August 2001)

Zonal wind (shaded, blue: westerly / yellow: easterly) and θ (contours)

Warming associated with easterly (offshore) flow but also with enhanced subsidence

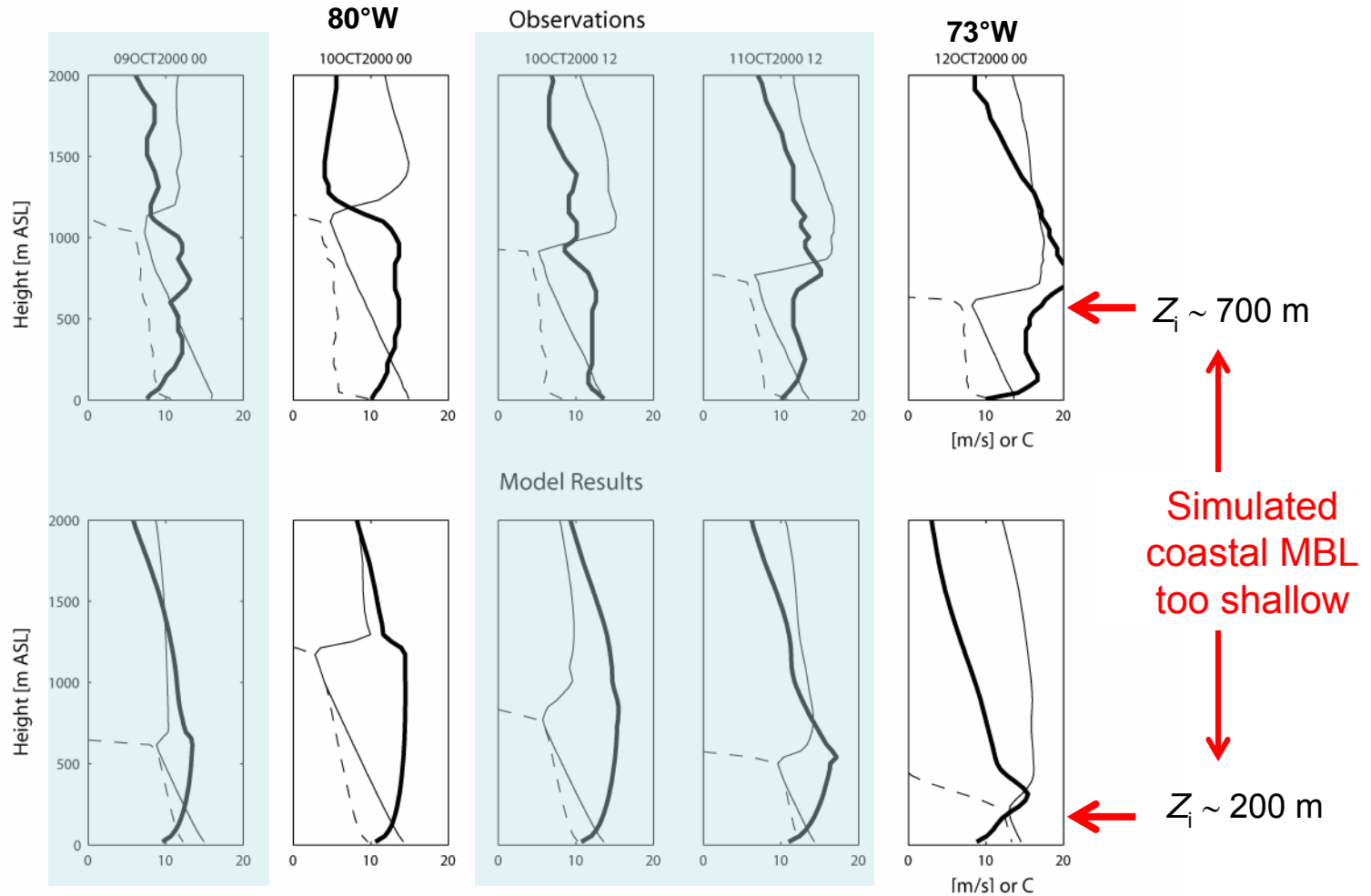


Ongoing research includes:

- Improving representation of the MBL near the coast (**our main problem in regional simulations**)
- Revisiting the diurnal cycle of the MBL, clouds and winds near the coast off northern Chile
- Trajectory analysis over the SEP, to assess the origin of air masses arriving to different MBL locations
- Effects of atmospheric forcing (spatial and temporal features) and ROMS-horizontal resolution in resolving the upwelling patterns off central Chile

For each line, we present now some observational wonder-figure and few results from regional simulations.

Bad representation of the MBL in MM5/WRF



Vertical profiles of temperature (thin lines), dew point temperature (dashed lines) and wind speed (thick lines) along 27°S.

**Bad representation of the MBL in MM5/WRF (too shallow)
it can be caused by:**

- Insufficient vertical resolution
- Insufficient horizontal resolution
- MBL-Turbulence parameterization (Gayno-Seaman & MRF)
- Wrong SST
- Too much subsidence
- Other causes

Work are underway (R. Muñoz) to diagnose and correct this crucial problem, using 3-D and 1-D MM5 simulations.

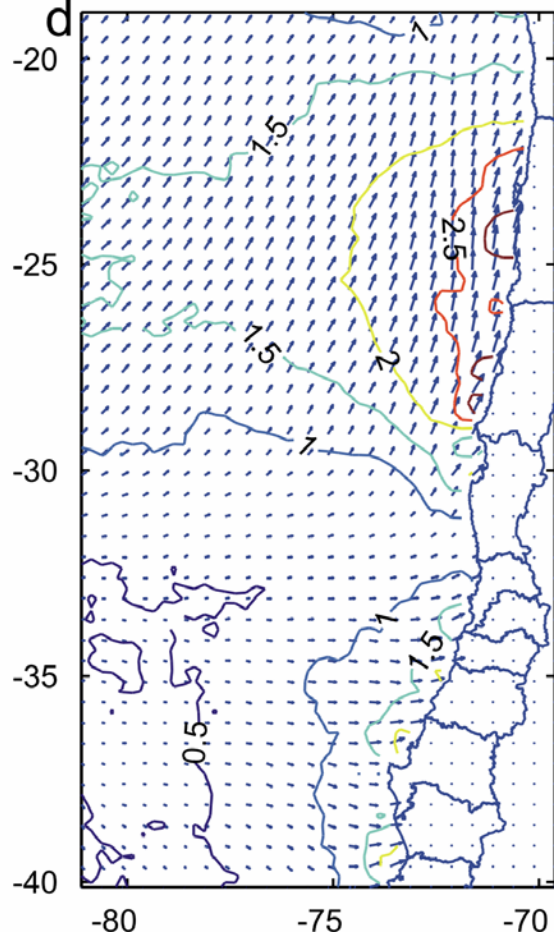
Furthermore, there is little data in coastal-offshore area to compare with...a situation that can be remedied during VOCALS.

Key features of diurnal cycle I:

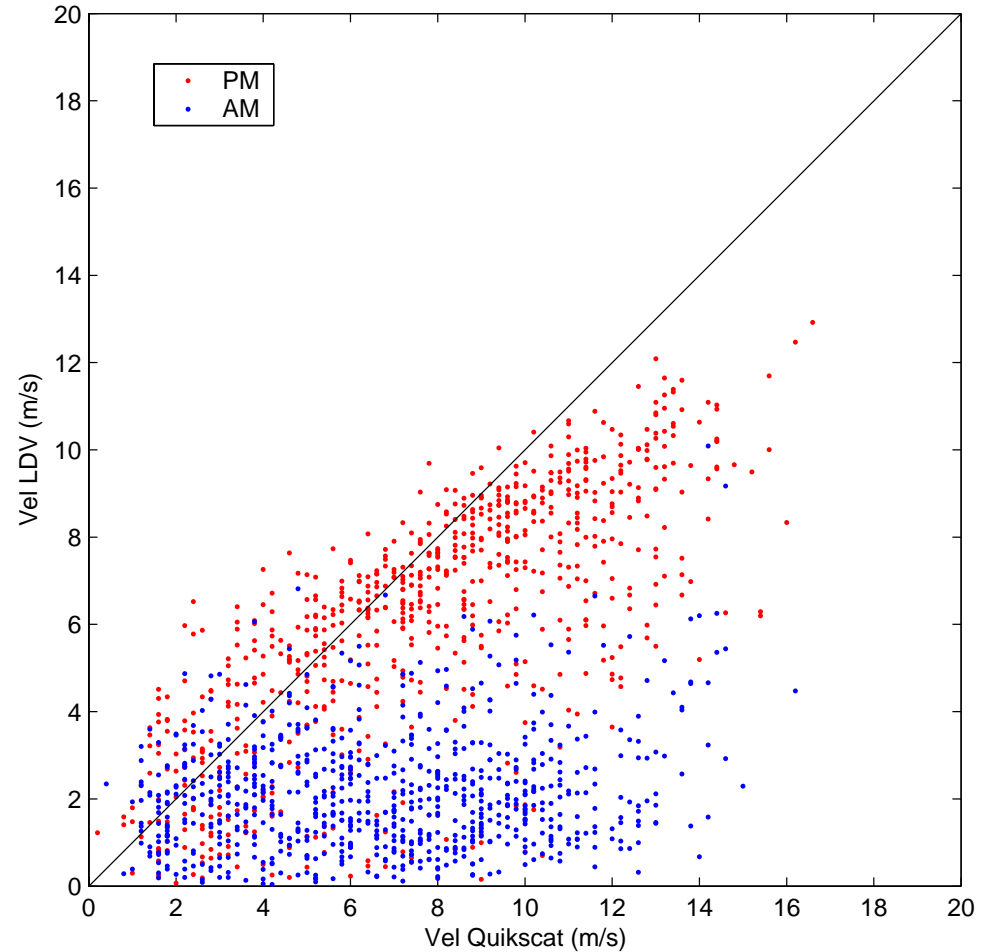
Max. amplitude of V-wind off northern Chile

Nocturnal decoupling of wind on coastal strip

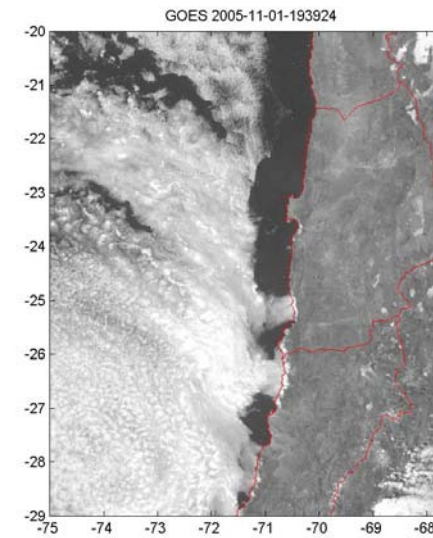
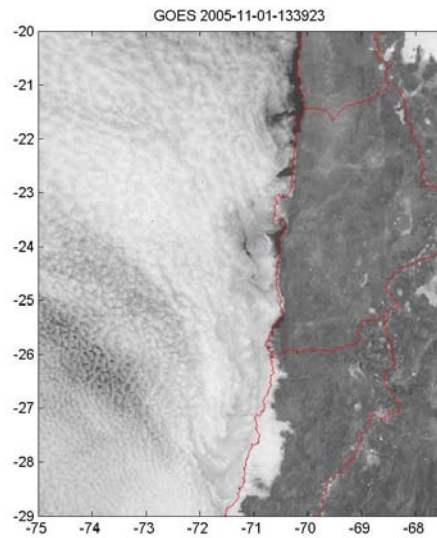
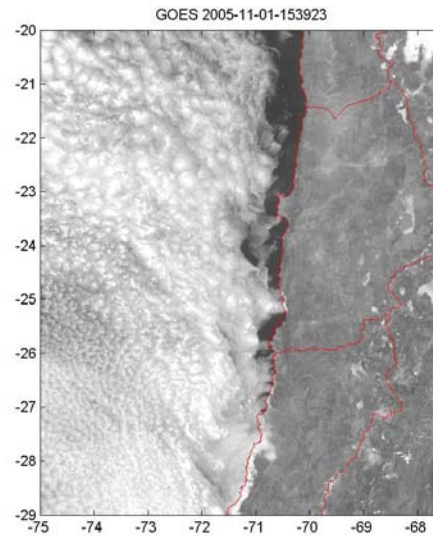
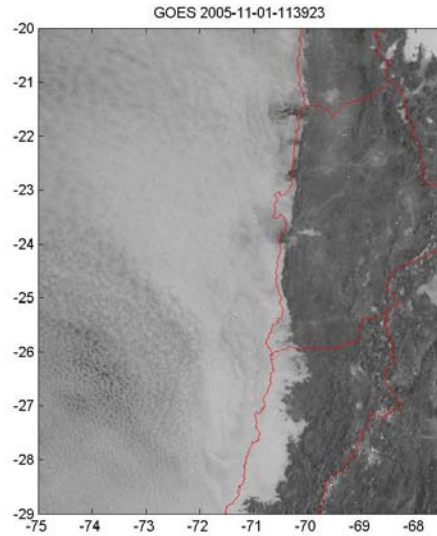
QS VEL PM-AM OCT-MAR 2000-2004



Velocidad LDV versus Quikscat



Key features of diurnal cycle II: Diurnal Coastal clearing, most marked during spring-summer



On the basis of **limited inland observations**, it has been suggested that coastal clearing can be related to continental circulation over the western slope of the Andes.

This hypothesis can be tested by performing experiments (varying topography) in MM5/WRF.

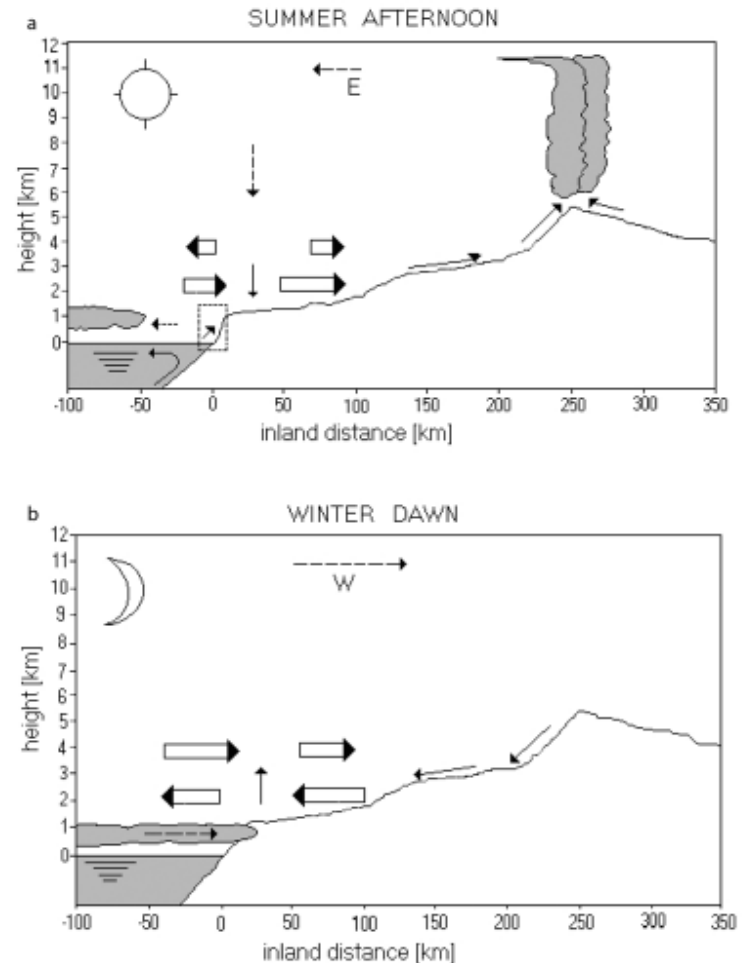
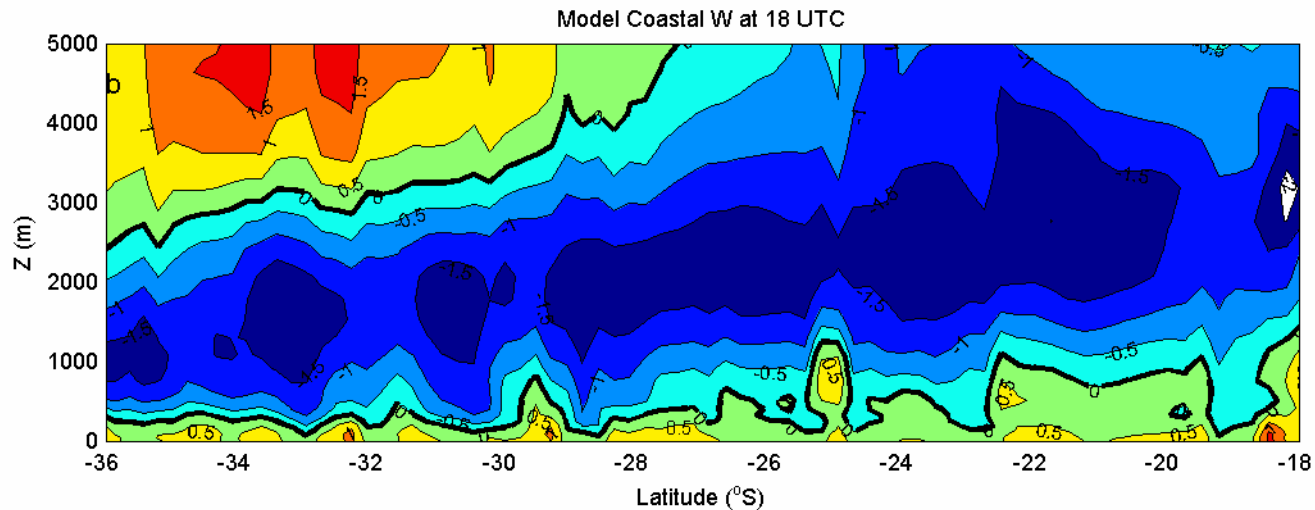
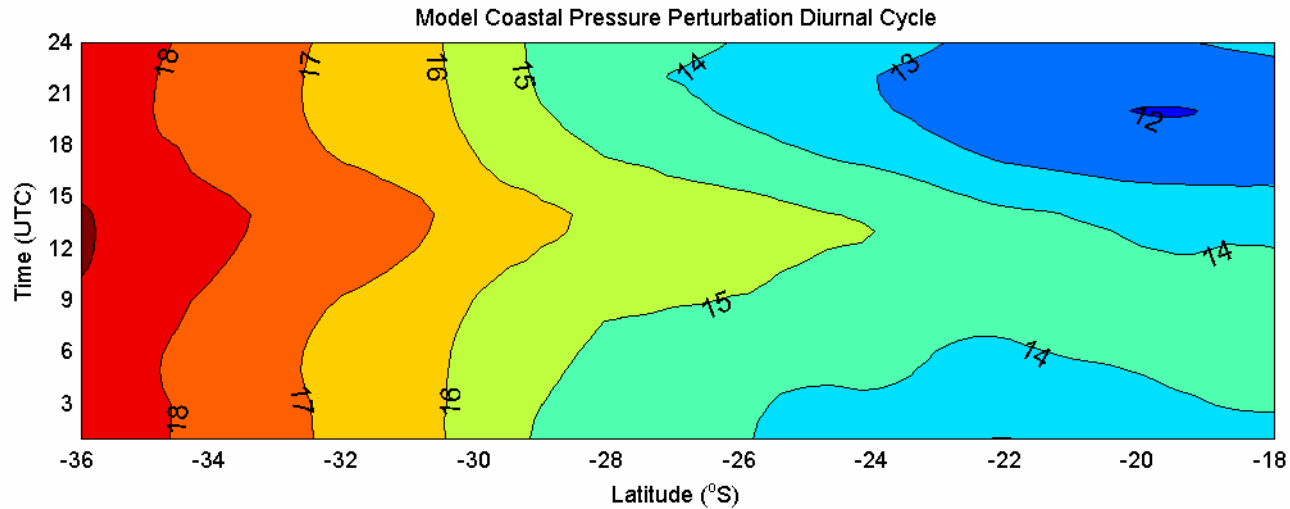
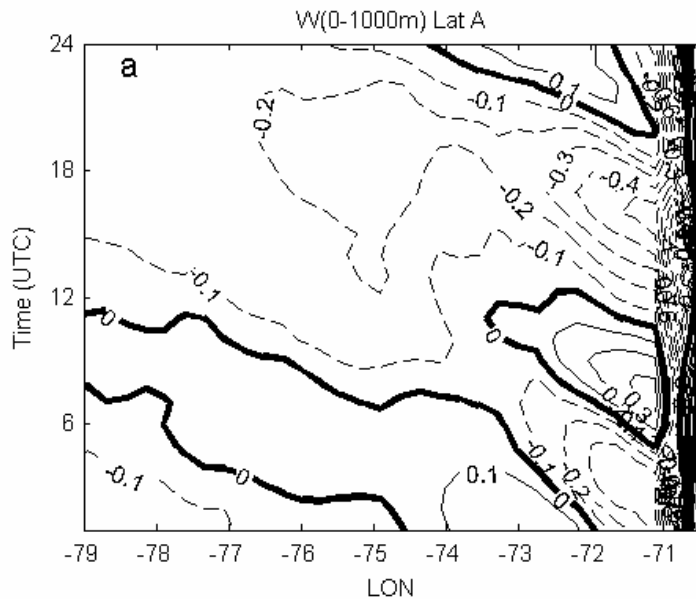


Figure 9. Schematic diagrams of the zonal mass flux (thick arrows) and zonal flow (thin arrows) across the arid northern coast of Chile: (a) austral summer afternoon conditions and (b) austral winter early morning conditions. The dashed rectangle in Figure 9a represents the cross section depicted in Figure 8.

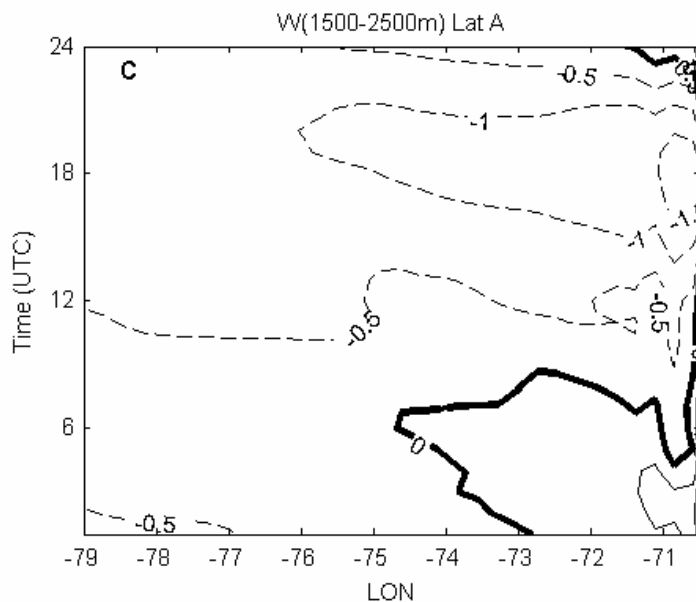
MM5 Model Results for Sep-Oct 2003 (Muñoz 2007)



Coastal gradient of pressure exhibits a large diurnal cycle off N. Chile
Afternoon decrease in sfc. pressure associated with subsidence diurnal cycle
How the ABL reacts to the diurnal cycle of W?



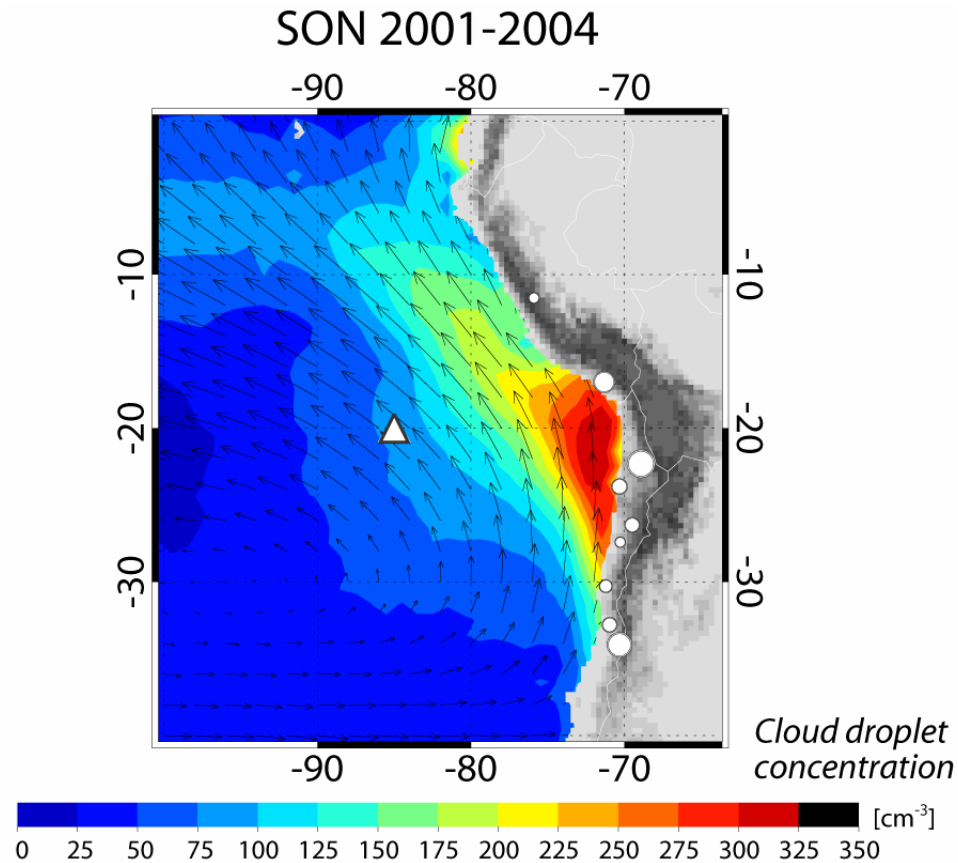
Mean vertical velocity within (upper panel) and above (lower panel) the MBL at 22°S as function of longitude, based on MM5 results from a simulation that spans SO 2003.



Coastal MBL exhibits a prominent **semi-diurnal** cycle in response to the **diurnal** cycle of W aloft...why is that?

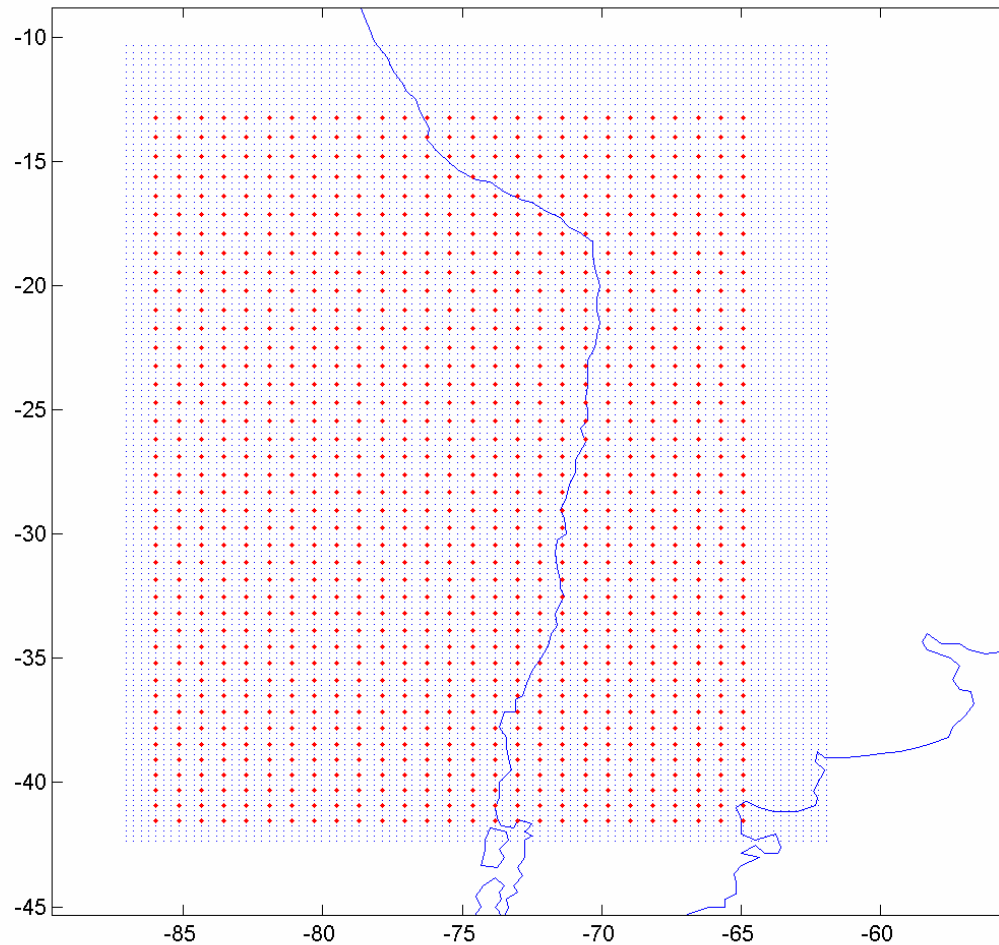
Modeling and analytical studies underway...(R. Muñoz)

Near-stagnation zone at 18°S Collocated with maximum in CDC
Topographically induced? How deep? Sometime flush?

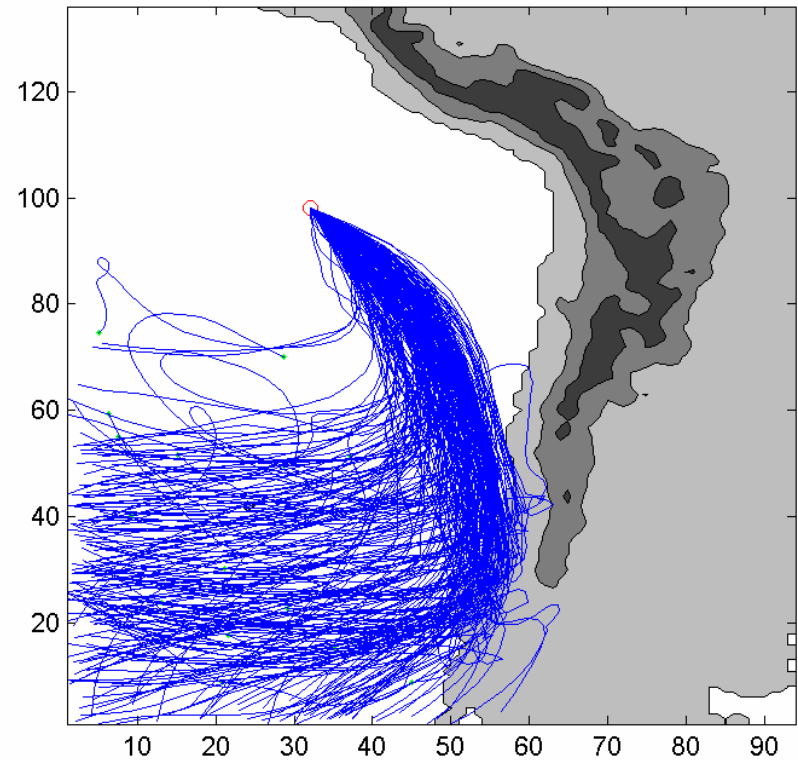
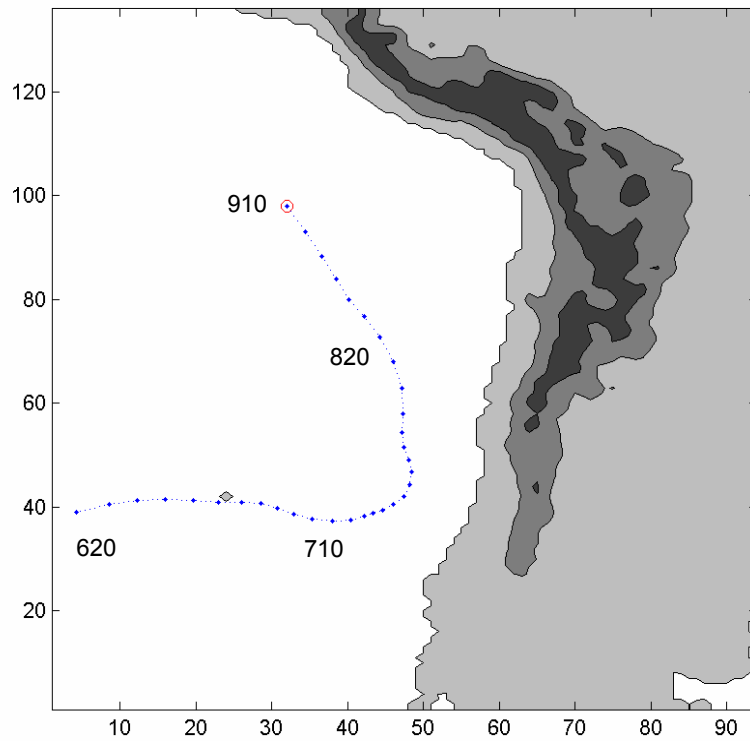


MM5 simulation, Sep-Oct 2003, single domain, 30 km hor. res. (blue dots)

120-hr backward and forward 3-D trajectories were calculated for 920 selected points (red dots), every 6 hr at 6 vertical levels (990, 950, 900, 860, 830, 800 hPa aprox.)



Trajectory information (lat,lon,pres,temp,rh) was saved every 3 hours.
Quite a bit of data: $6 \times 920 \times (24/6) \times 50 \times (120/3) \times 5 = 220 \text{ Mill !!}$

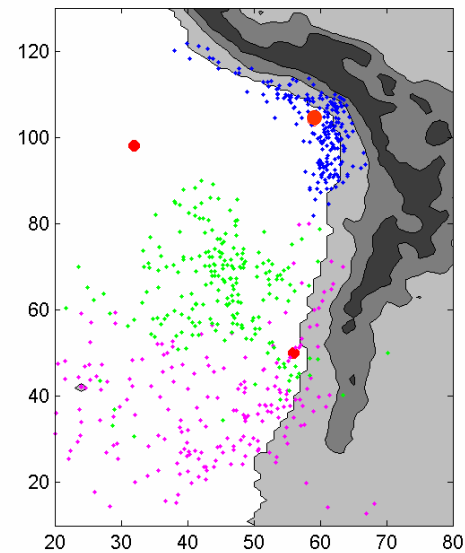
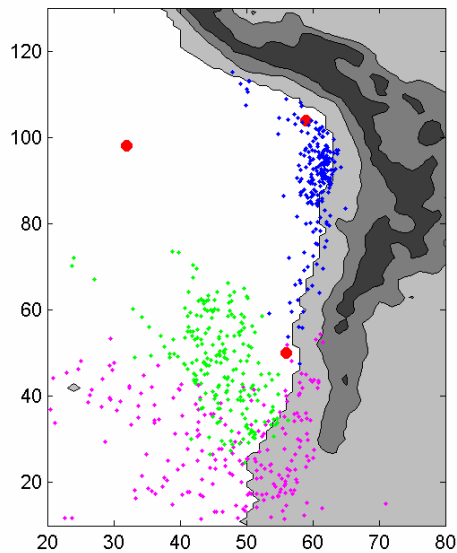
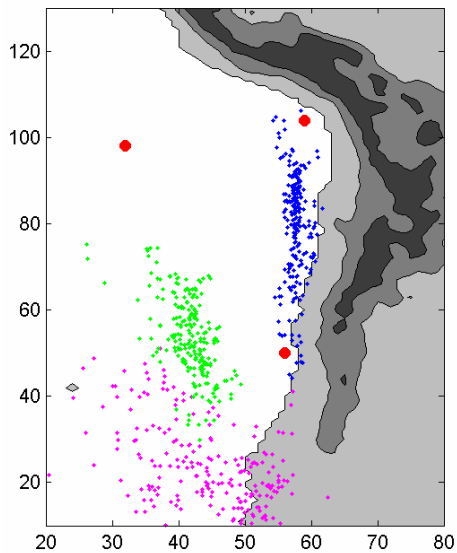


$P_0=995$ hPa
(near surface)

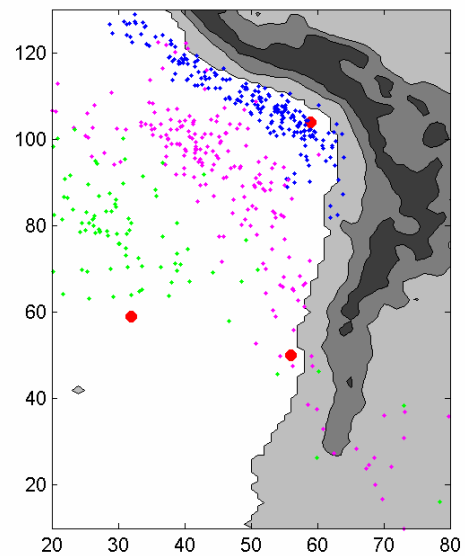
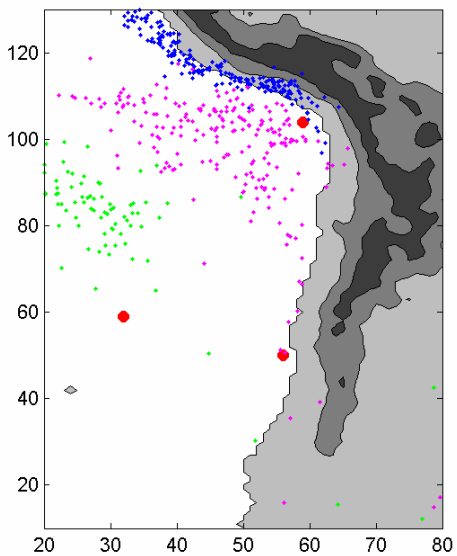
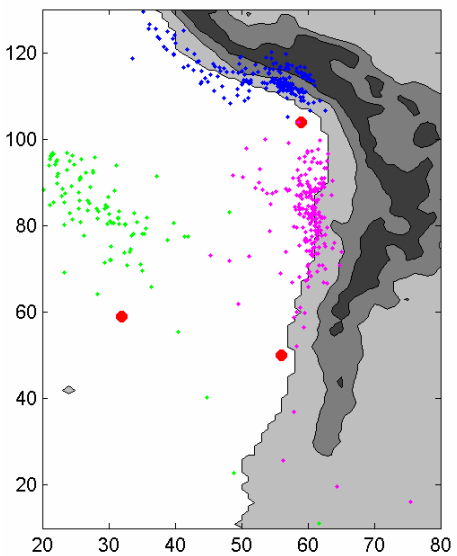
$P_0=950$ hPa
MBL

$P_0=850$ hPa
Inversion

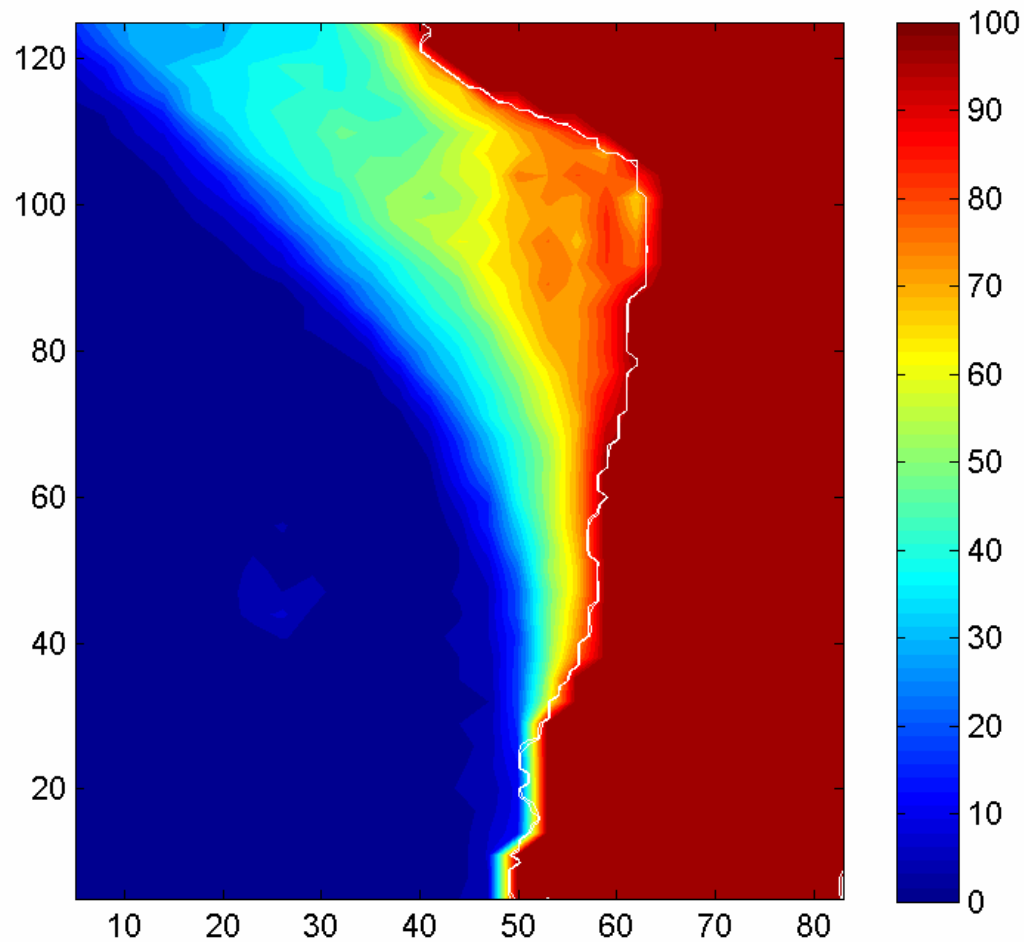
-36 hr



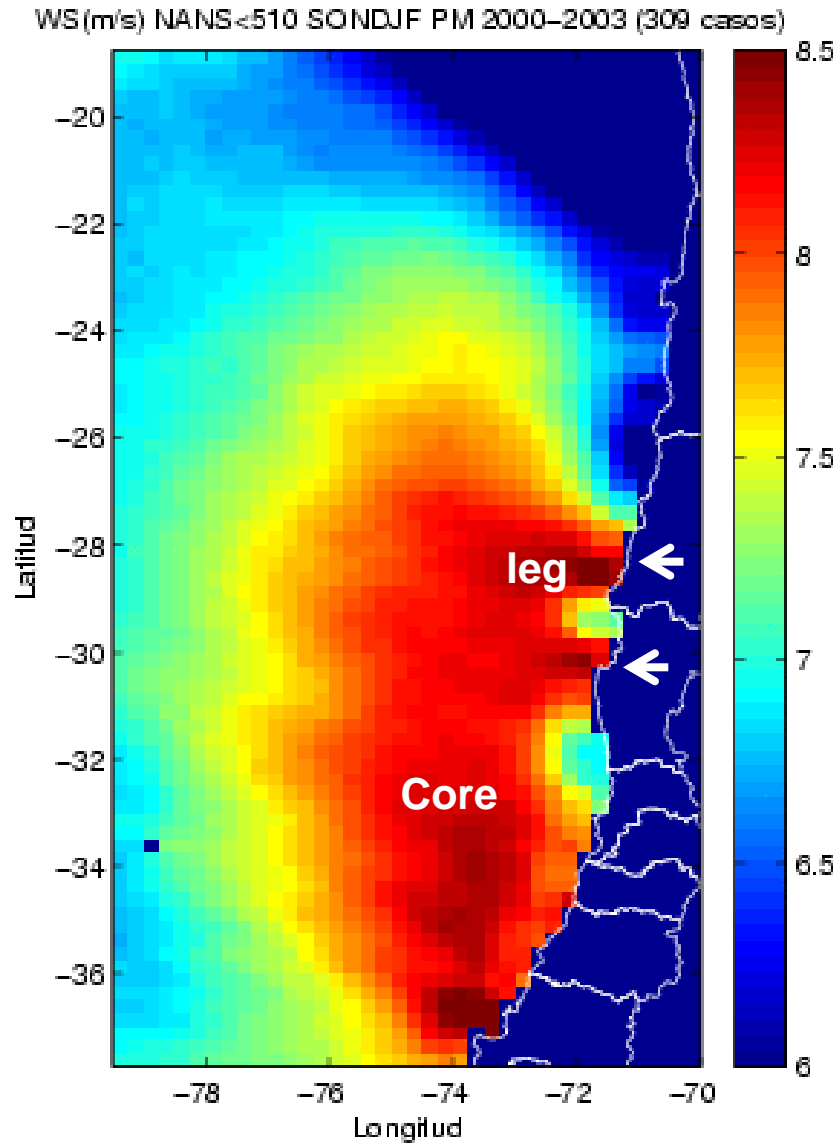
+36 hr

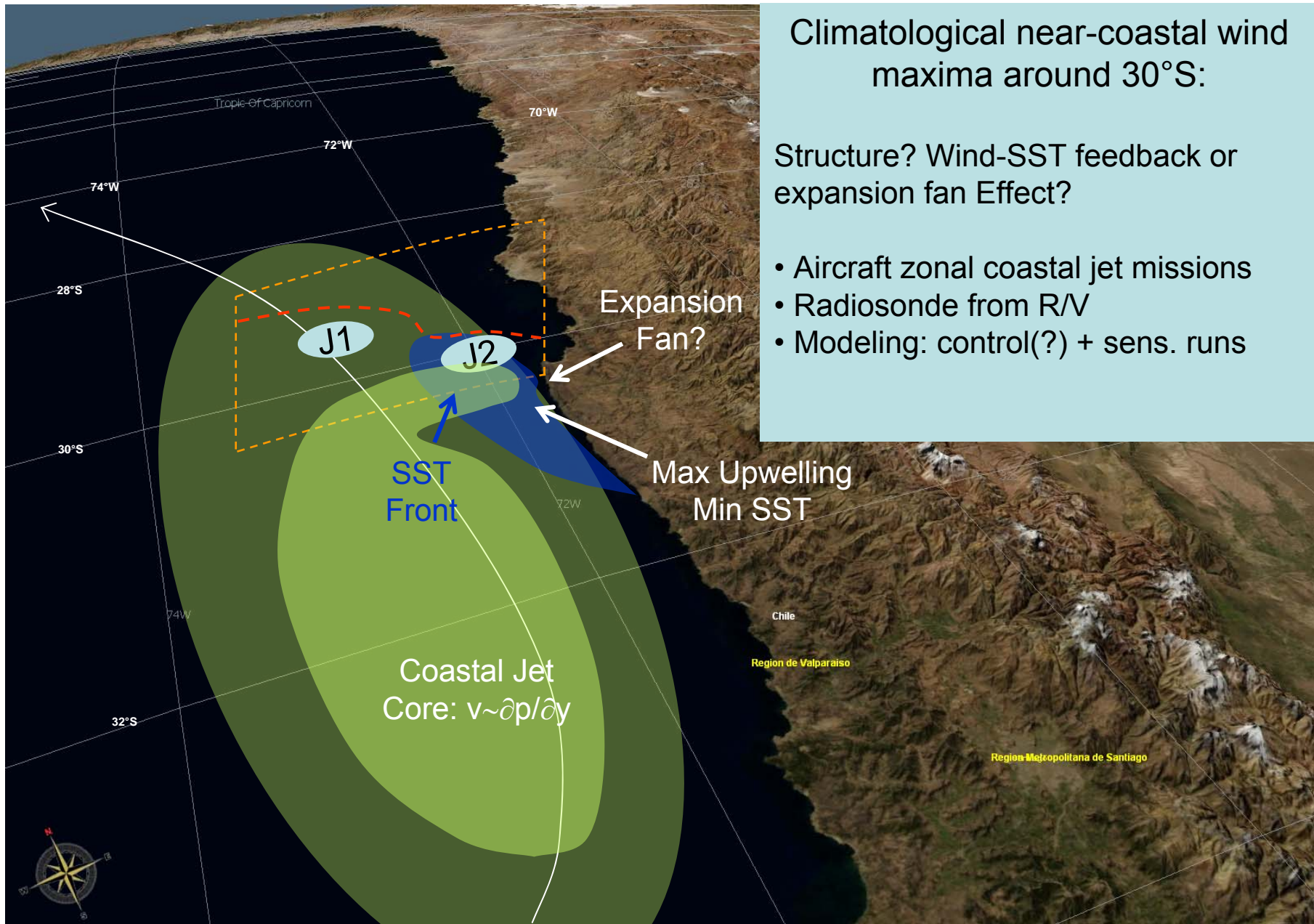


Show for each starting point ($p_0=900$ hPa), the proportion of trajectories that have passed over continental topography at above surface altitudes of less than 2000 m



Climatological near-coastal wind maxima around 30°S (*jet legs*)





Climatological near-coastal wind maxima around 30°S:

Structure? Wind-SST feedback or expansion fan Effect?

- Aircraft zonal coastal jet missions
- Radiosonde from R/V
- Modeling: control(?) + sens. runs

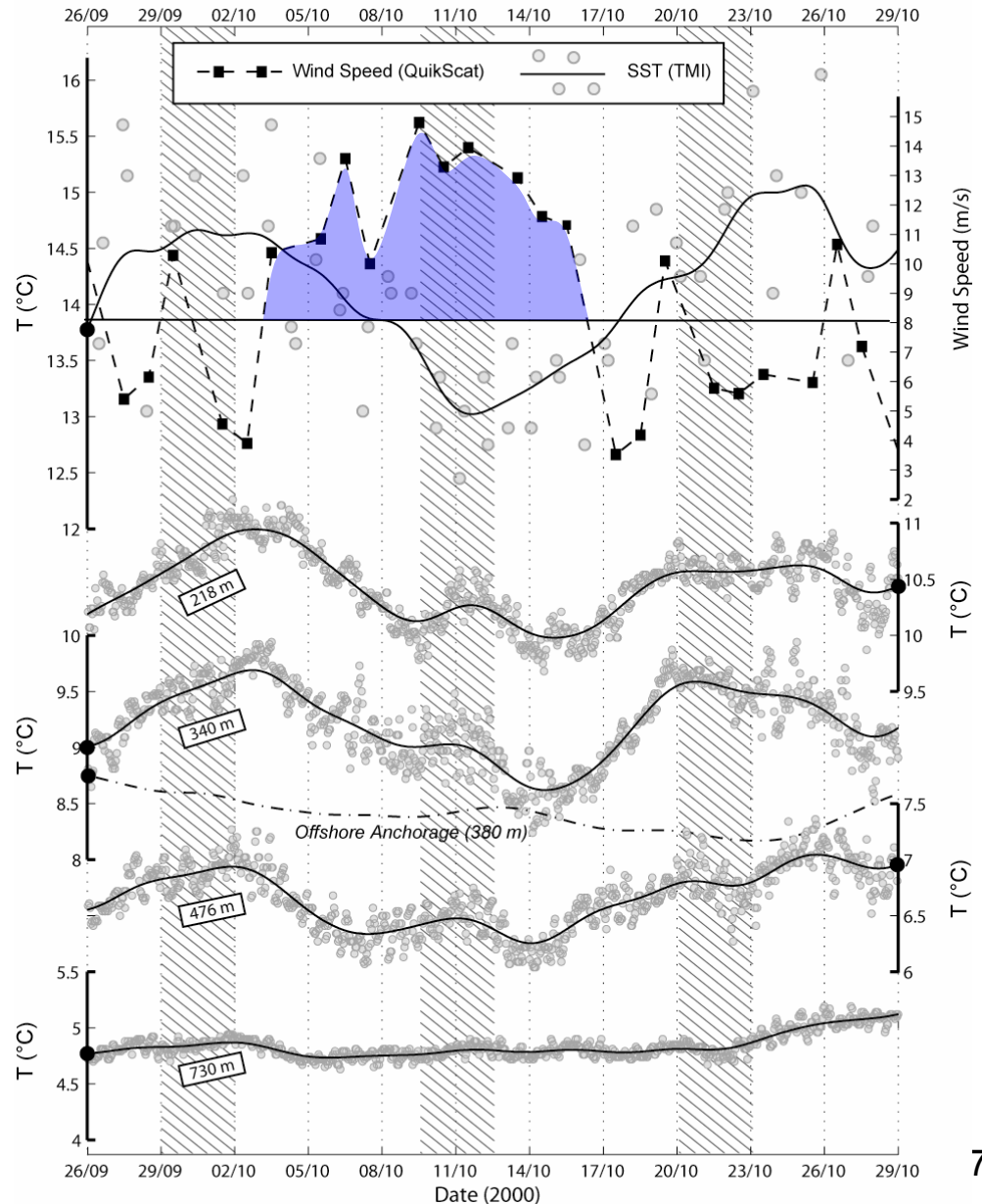
Impacts of Jet Events on SST.

Ok, stronger winds, more upwelling, cooler water...but how does the processes really occurs?

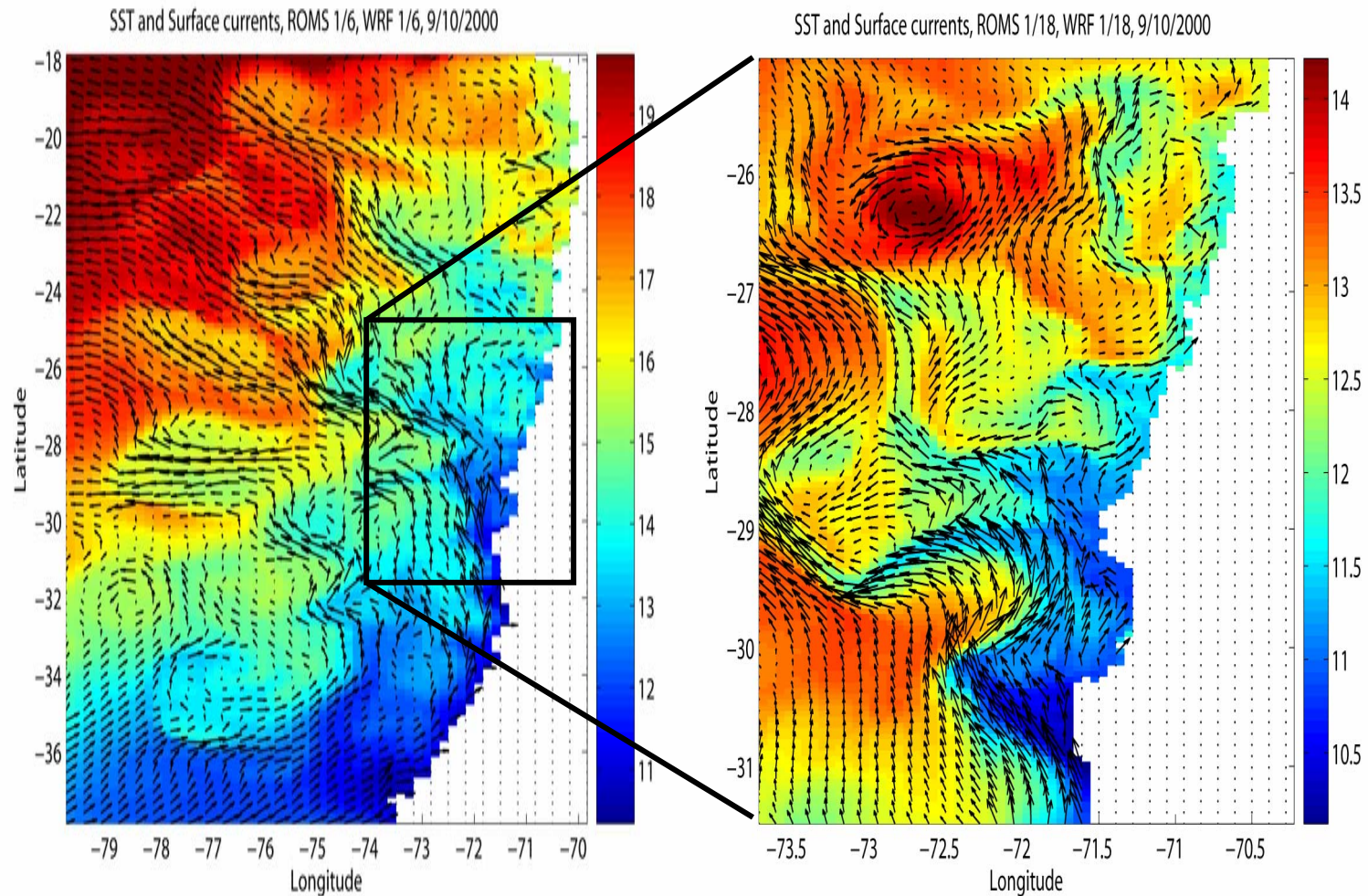
Can we simulate them?

What resolution do we need in the ocean/atmos models?

Renault et al. 2006



To understand / quantify the response of the surface ocean to coastal jet events we propose ship-borne observations, aircraft observations (at onset, height and demise of the event), as well as modeling experiments (in progress, WRF+ROMS)



Within the context of VOCALS-REX, we envision a major synergy among regional modeling and field observations.

* During VOCALS field campaign, *in-situ* observations will give us an unprecedented dataset of the 3-D atmospheric structure over the coastal SEP, with temporal and spatial resolution comparable with (or better than) those obtained from regional modeling. This will allow us to perform detailed inter-model (e.g., MM5-WRF-RAMS), inter-parameterization comparison and validation.

* **MM5/WRF** (and eventually **ROMS**) will be run at DGF-UCH in real-time over the SEP region before, during and after VOCALS-Rex. Outputs from these regional models (including trajectory analysis) can serve as guidance for field operations