Avances en Precipitación Orográfica

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Seminarios DGF, 12-10-2016

Avances en Precipitación Orográfica

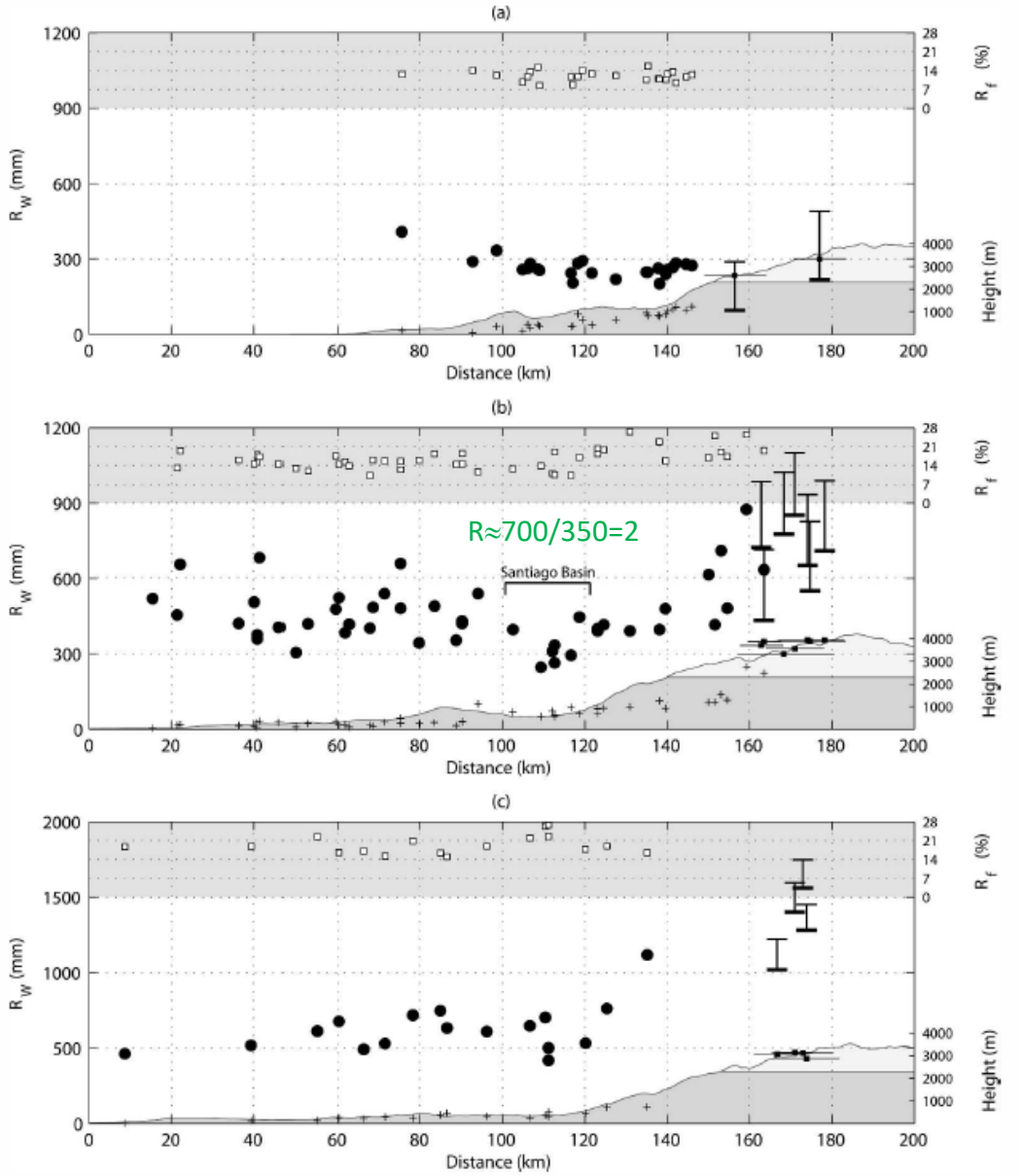
Revisitando el **Gradiente de Precipitación Orográfica** (GOP) a lo largo de los Andes (Falvey and Garreaud 2007; Viale and Garreaud 2015)

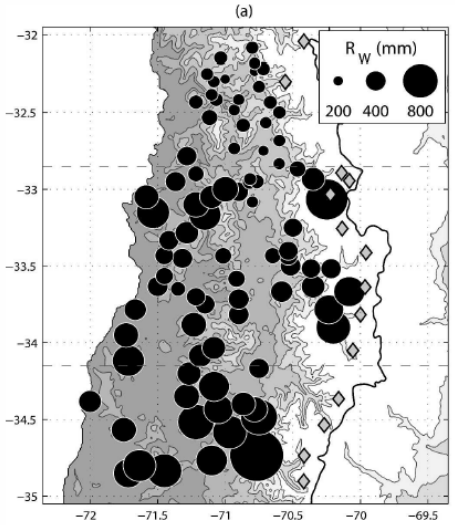
Tormentas de verano en los Andes subtropicales (Garreaud and Rutllant 1997; Viale and Garreaud 2014; Garreaud and Viale 2015)

Precipitación en Nahuelbuta y el experimento AFEX: Una prueba para modelos lineales (Garreaud, Falvey and Montecinos 2016)

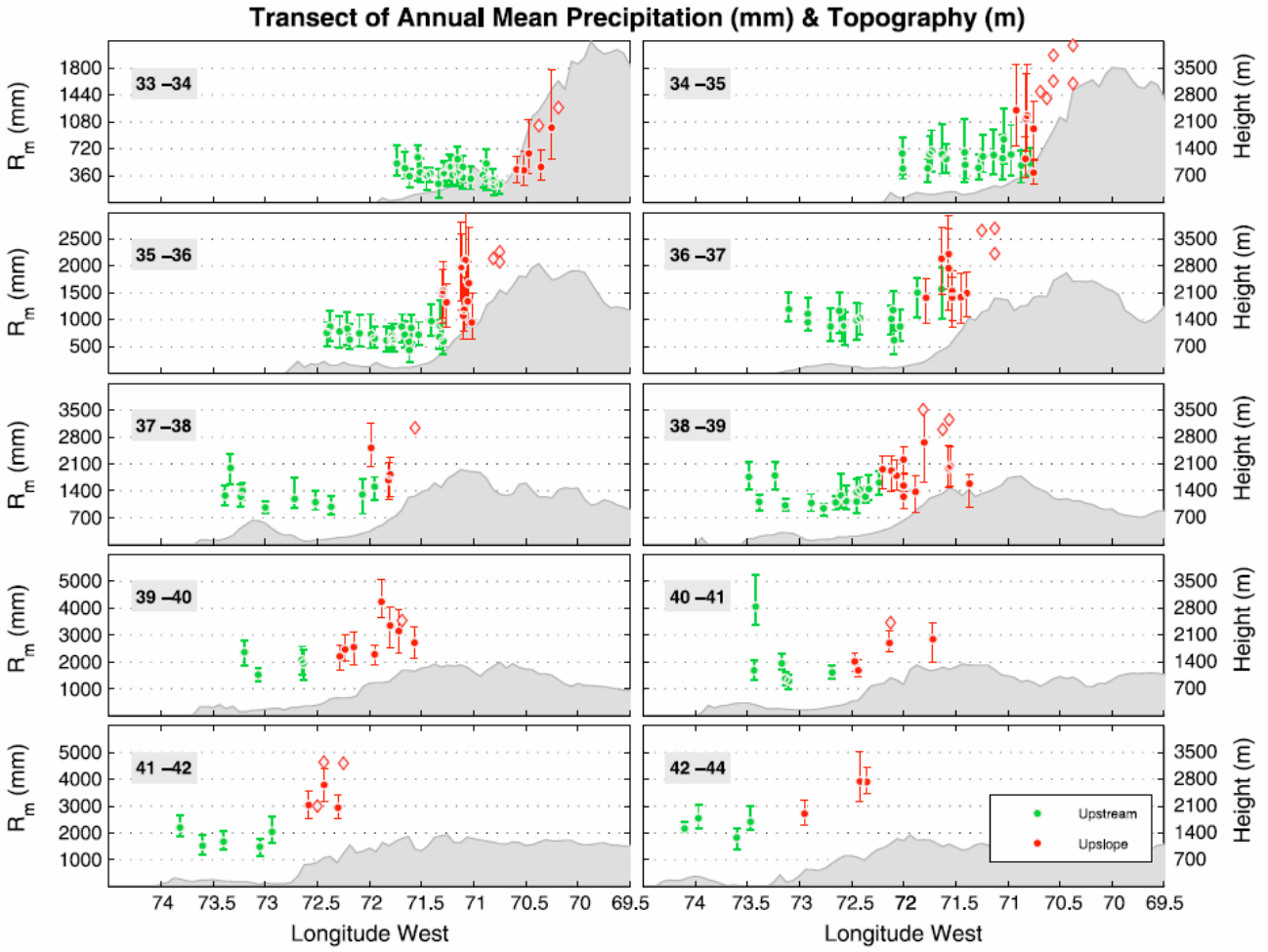
Regímenes de precipitación en Nahuelbuta y el expermiento CCOPE (Masman, Minder and Garreaud 2017; Tesis de Cinthya Bravo)

Control orográfico de la precipitación en **Patagonia** (Garreaud et al. 2013; Garreaud and Nicora 2014; actual investigación con Sergio Gonzalez).





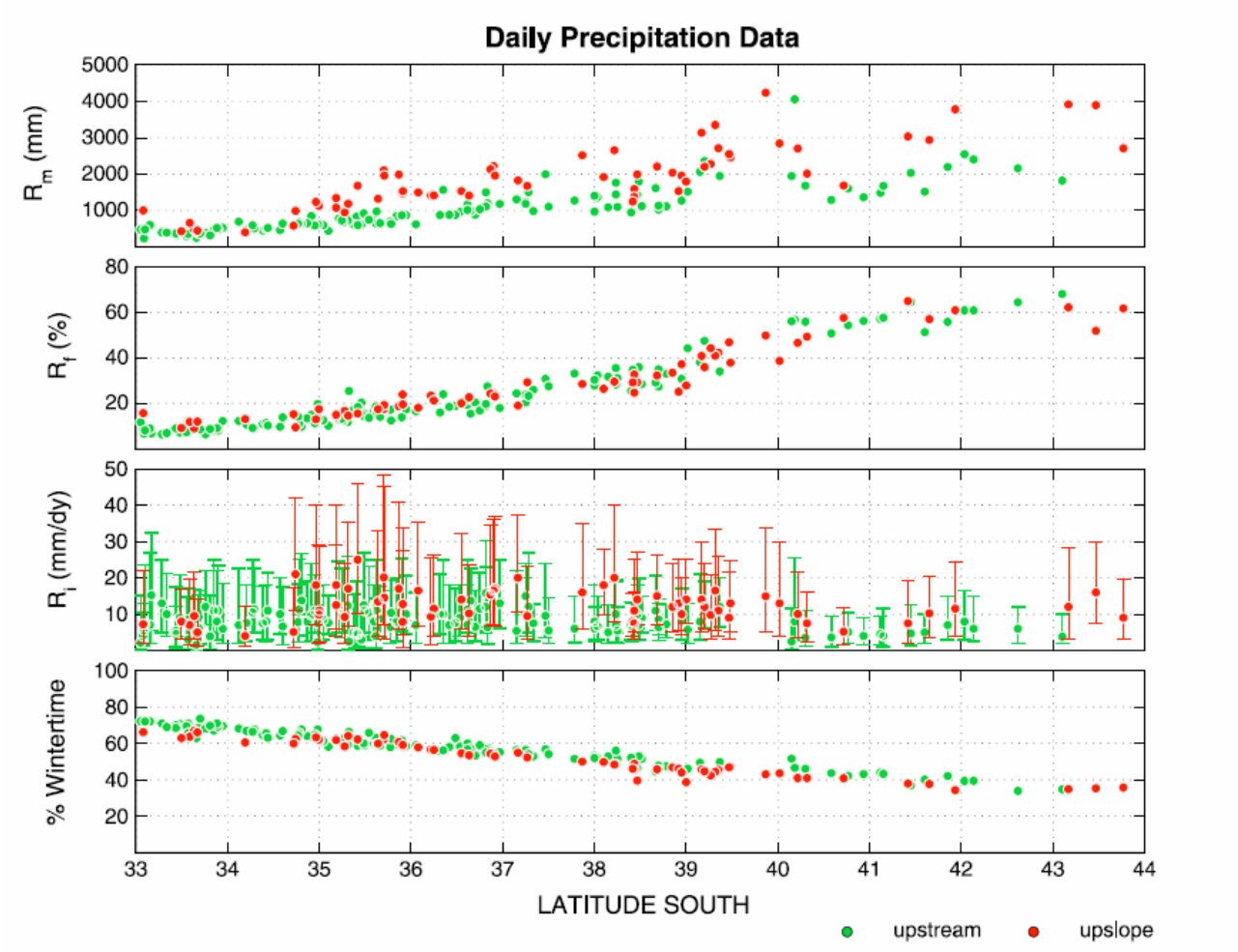
Falvey and Garreaud 2007



Enhancement rate is more or less uniform (~2) across a wide range of latitudes, despite changes in synoptic forcing and Andes height!

Upstream enhancement…more rainy days or more intense storms?

Viale and Garreaud 2015



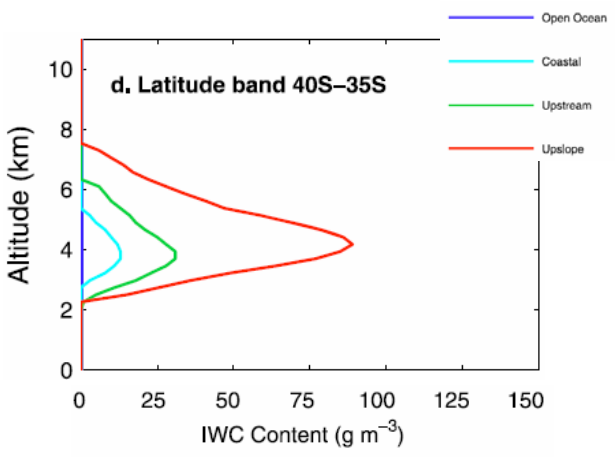
Frequency of rainy days doesn't change much between upstream and upslope sectors.

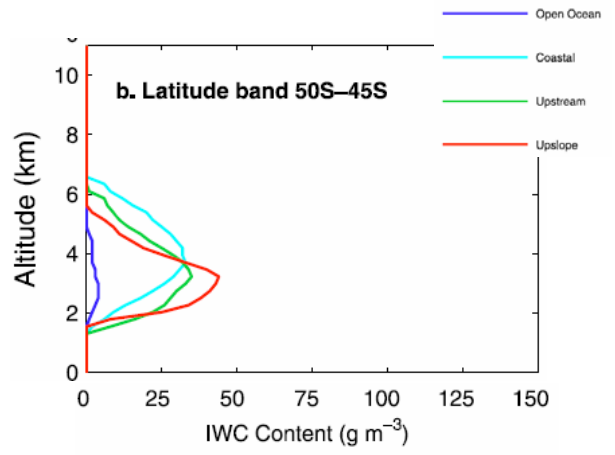
BUT…At subdaily scales, both higher intensity and longer rainy periods explain upslope enhancement.

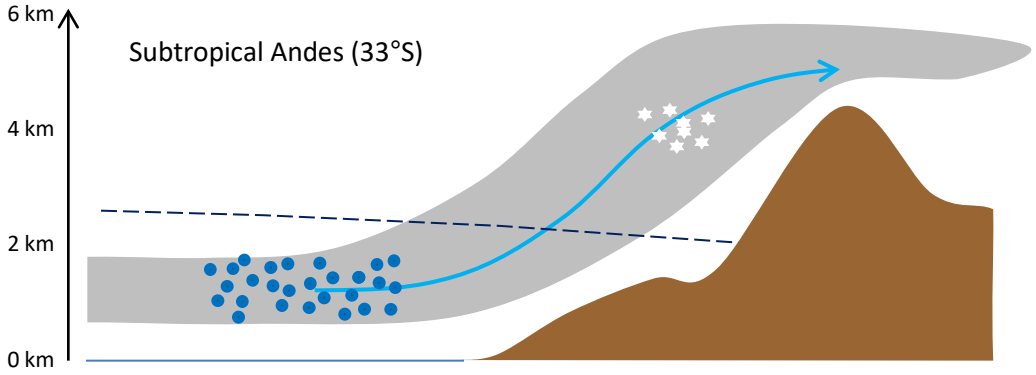
Viale and Garreaud 2015

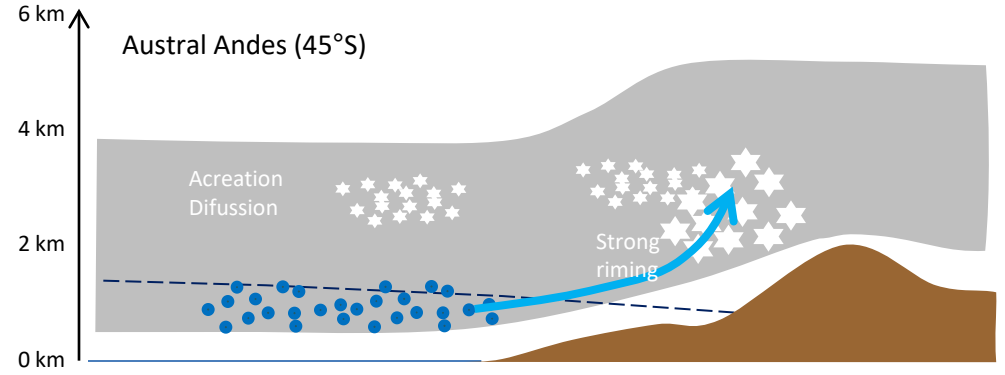
CALIPSO data

Ice Water Content



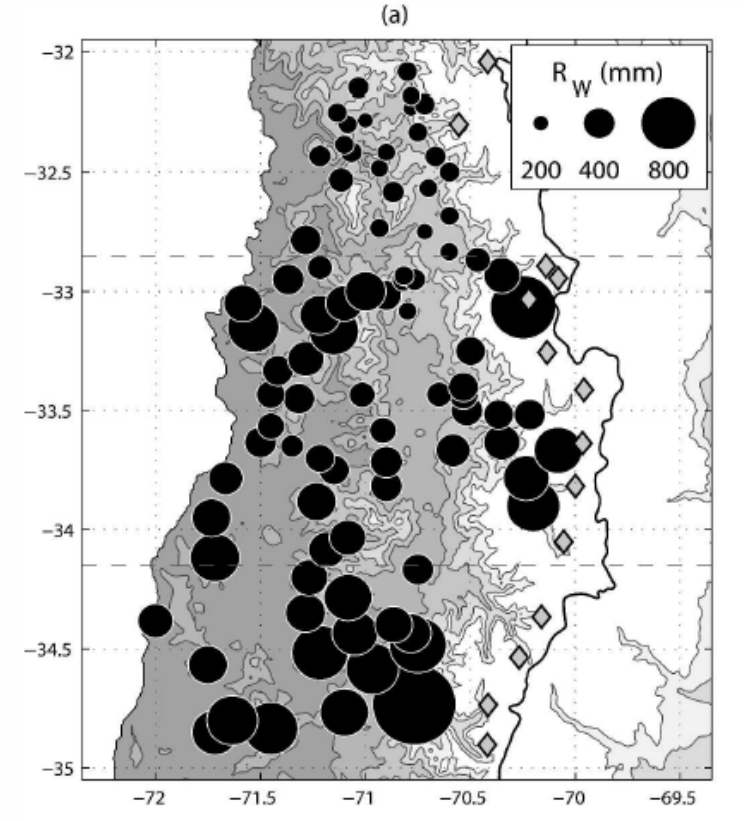


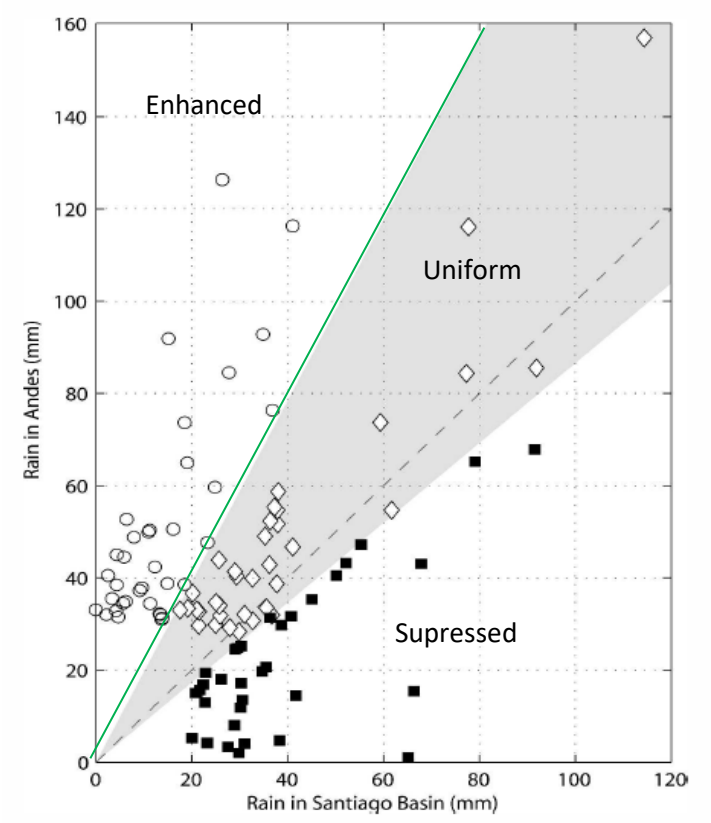




Viale and Garreaud 2015

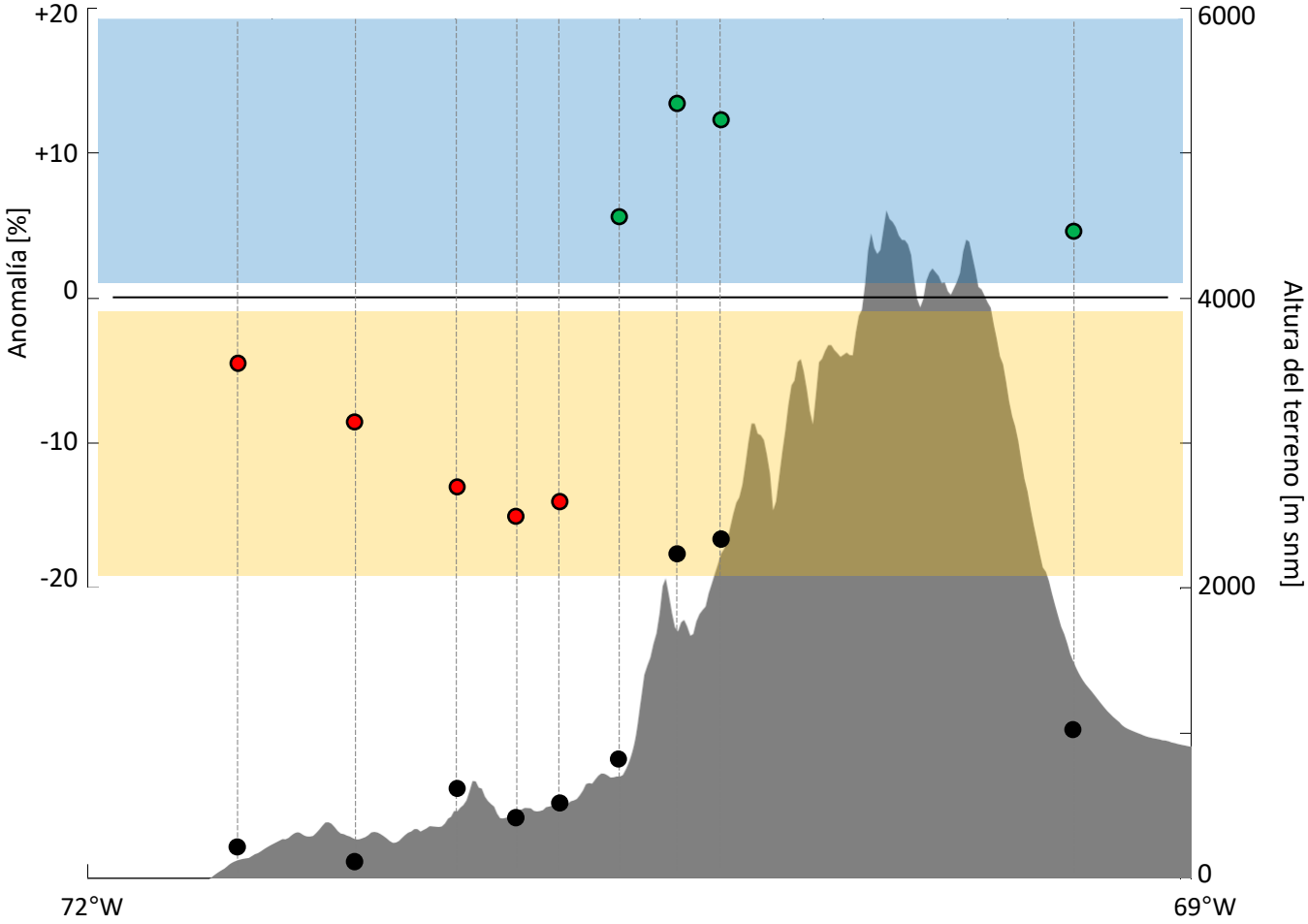
Pregunta pendiente (y muy relevante)
Que controla el GOP en entre/intra tormentas?





Falvey and Garreaud 2007

Anomalía de precipitación Enero-Agosto 2016
Estaciones entre 33-34°S
(% relativo a climatología 1970-2010)



Pregunta pendiente…
Que controla el GOP en entre/intra tormentas?

Estuctura y evolución de la tormenta

Estabilidad del flujo (Fr=U/Nh))

Estabilidad termodinámica (convección?)

Contenido de humedad (IWV)

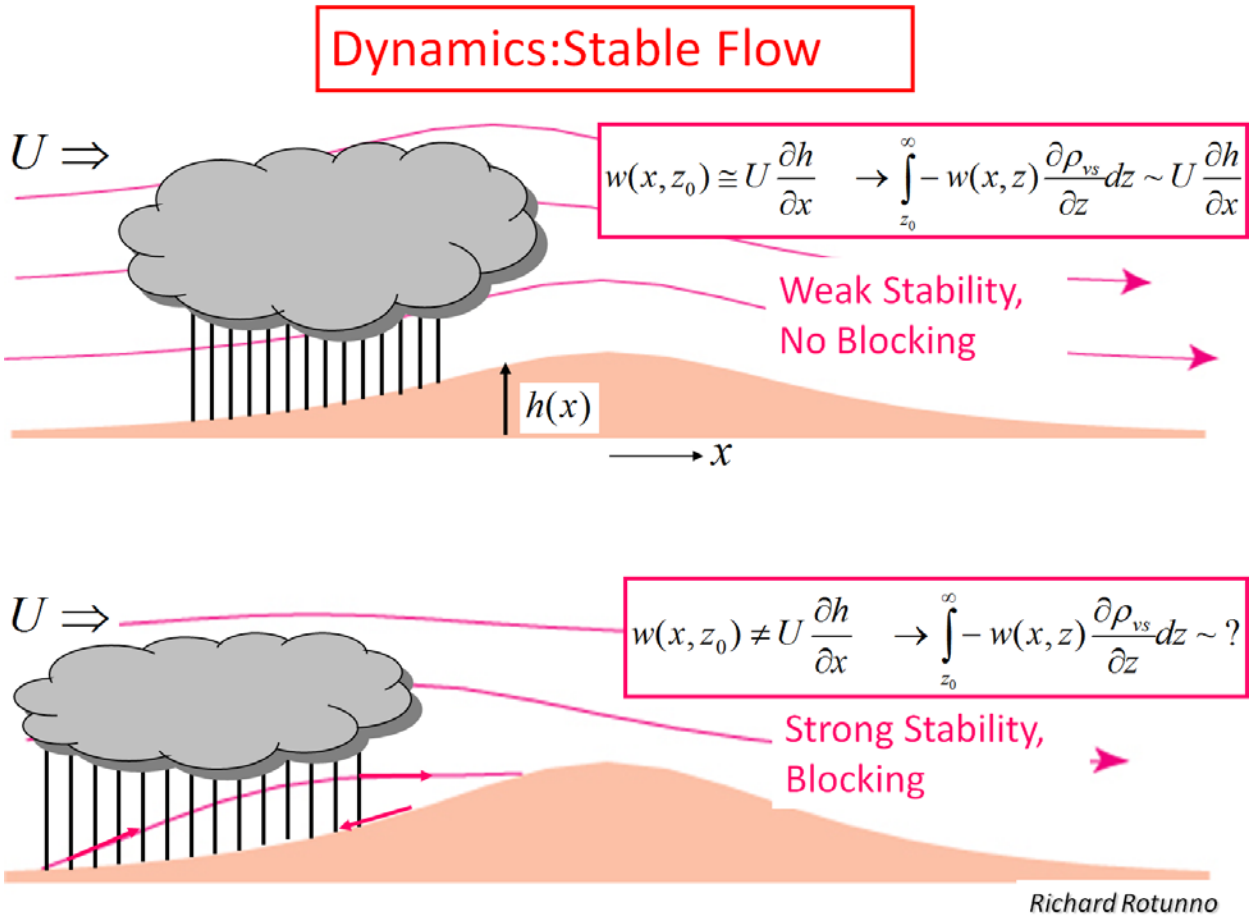
Microfisica (τrain < τadv =L/U)

Bloqueo orográfico

El numero de ***Froude*** determina flujo sobre/flujo alrededor de la montaña

Fr=U/(Nh); Fr<1 flujo alrededor; Fr>1 flujo sobre
Si N=0.01, U=10, h=1 km es el limite

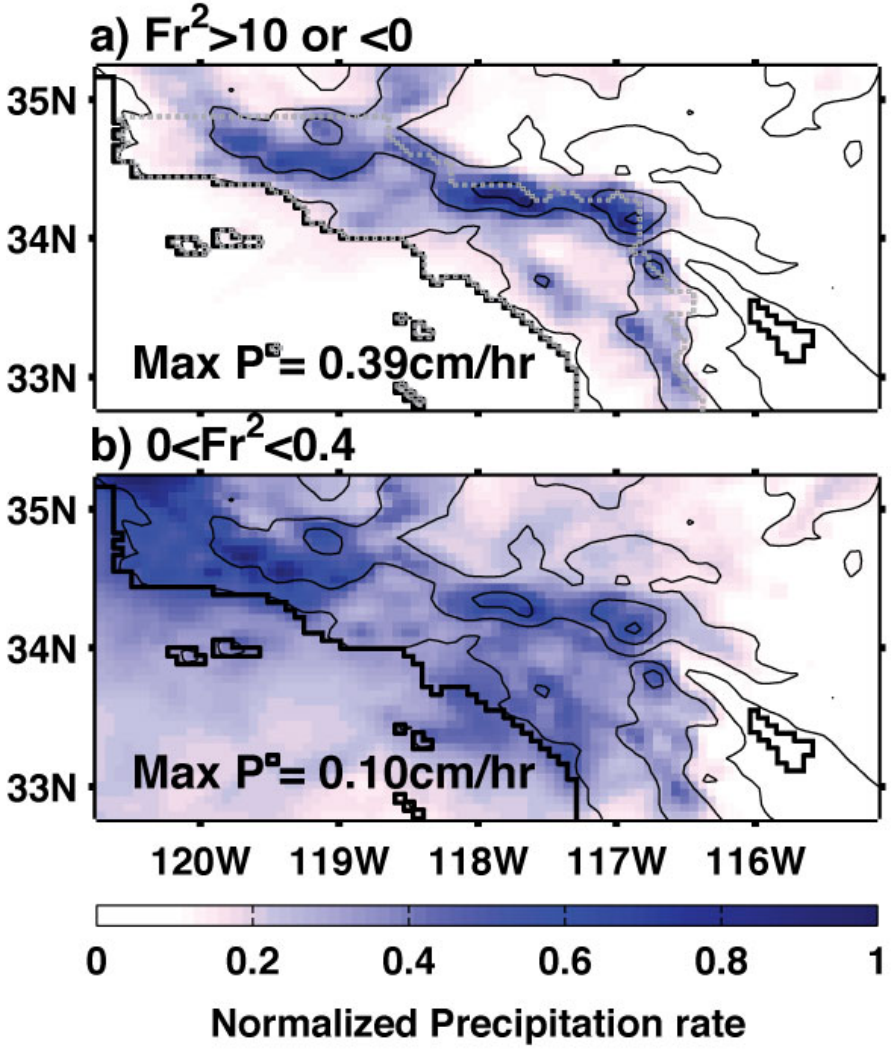
En caso saturado se emplea N_m<N lo cual favorece ascenso sobre la montaña



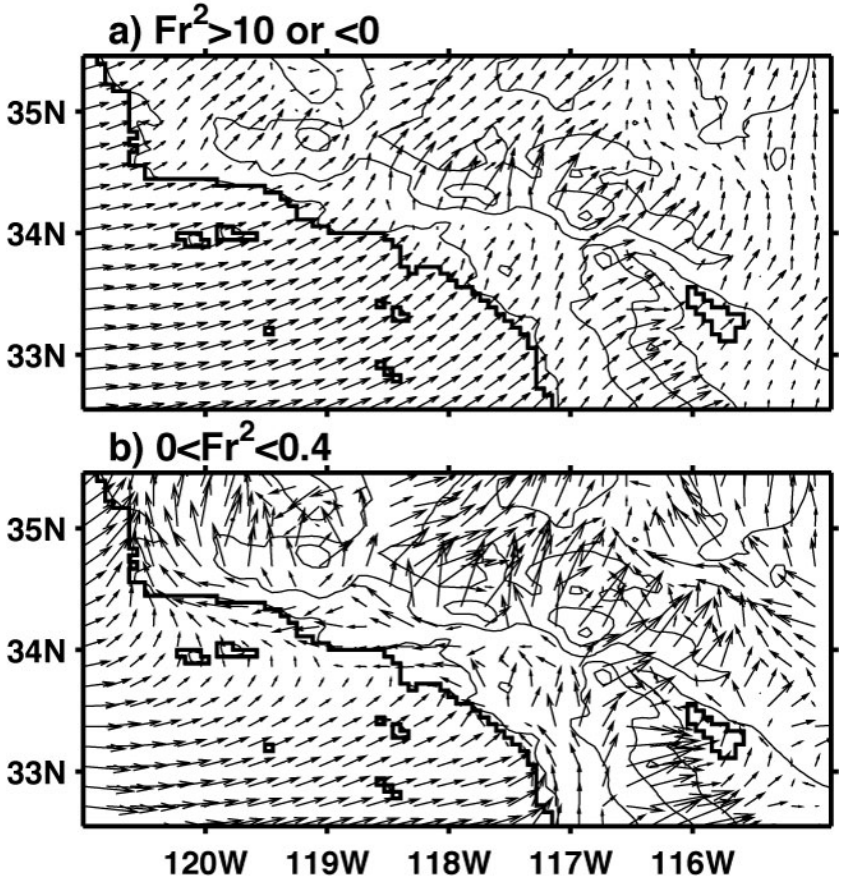
Blocking in Areas of Complex Topography, and Its Influence on Rainfall Distribution

MIMI HUGHES, ALEX HALL, AND ROBERT G. FOVELL

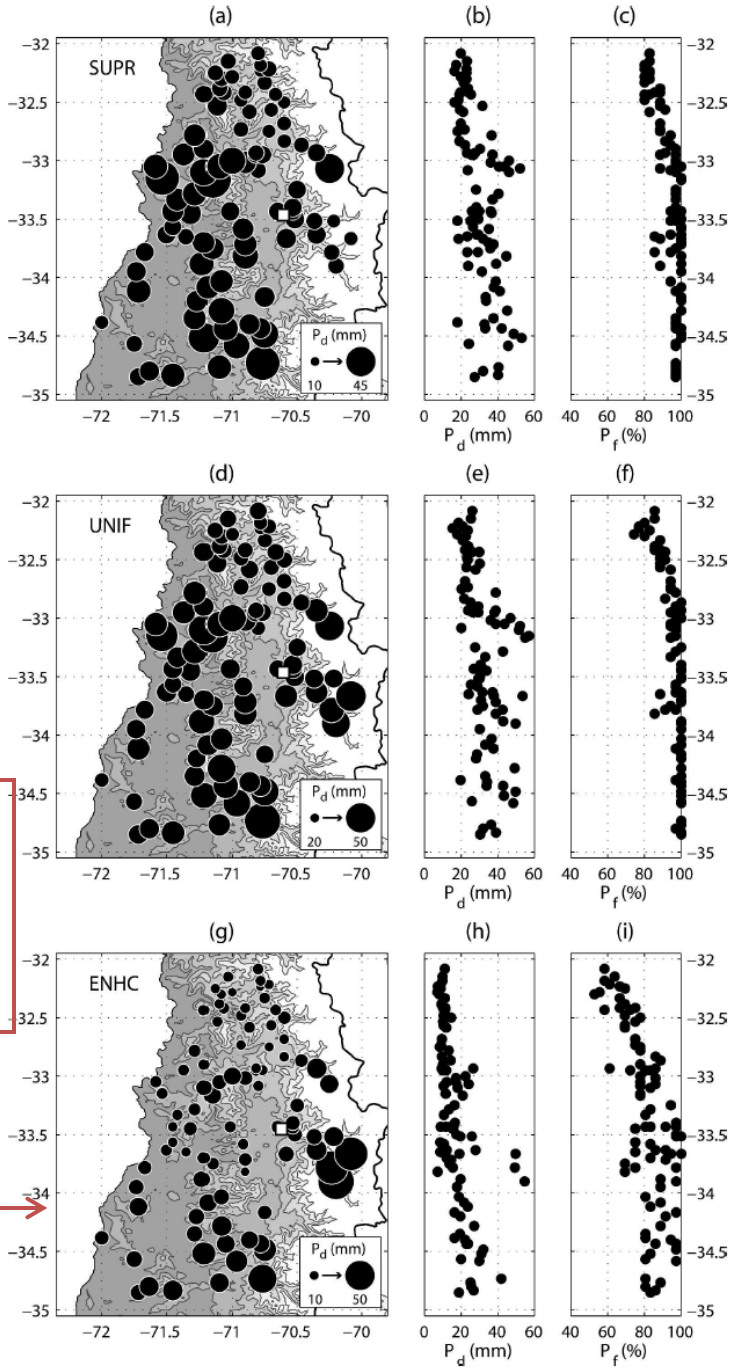
$$Fr^2 = \frac{U^2}{N^2 h^2}$$



Composite maps of normalized precipitation rate for rainy hours binned by Fr^2.



Vectors show sfc wind speed and direction, normalized by open-ocean speed.



Uniform Precipitation Group exhibits colder conditions (H0 = 1900 m)

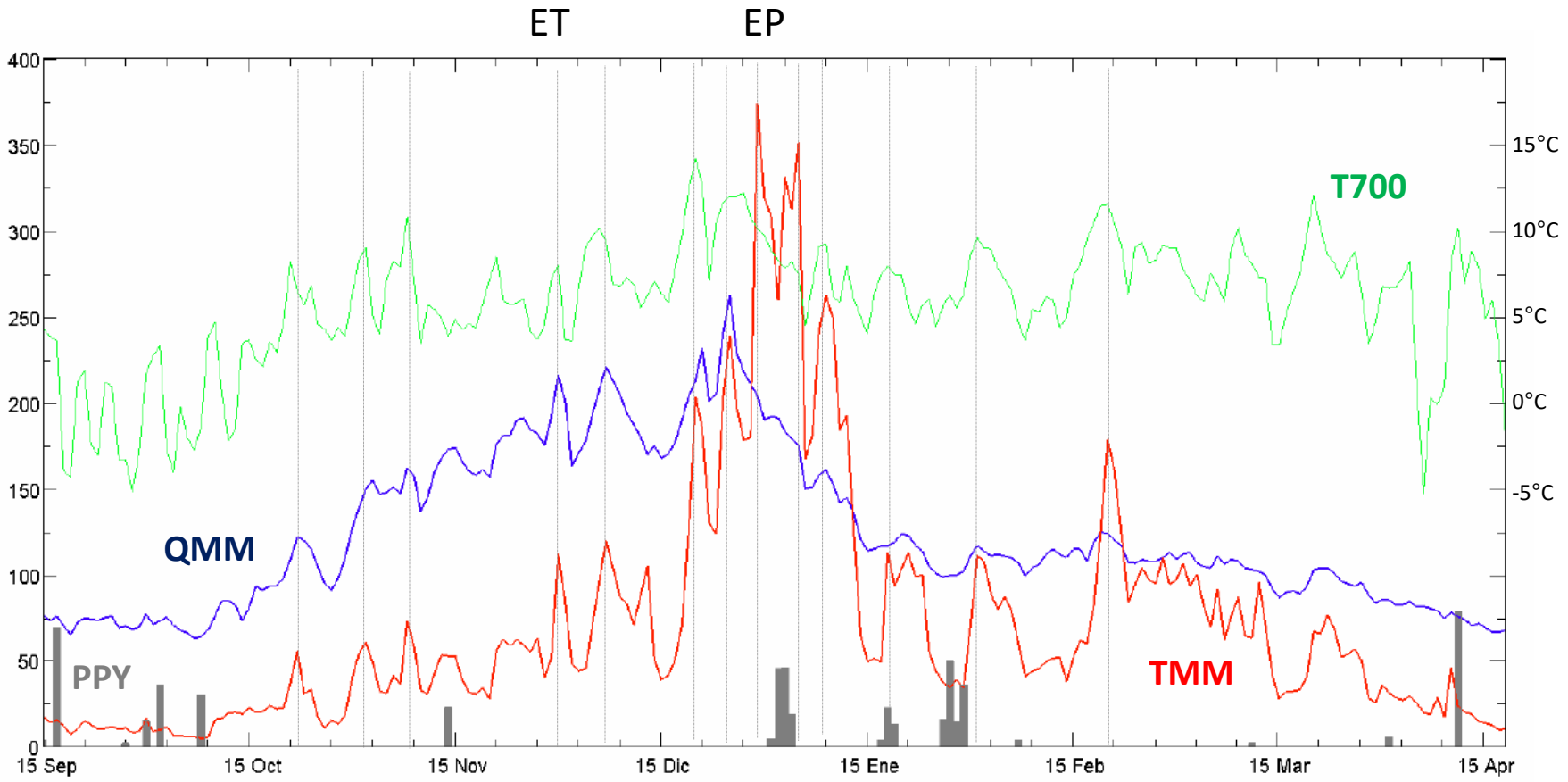
Mountain Enhanced Precipitation Group exhibits warmer conditions (H0 = 2900 m)

Falvey and Garreaud 2007

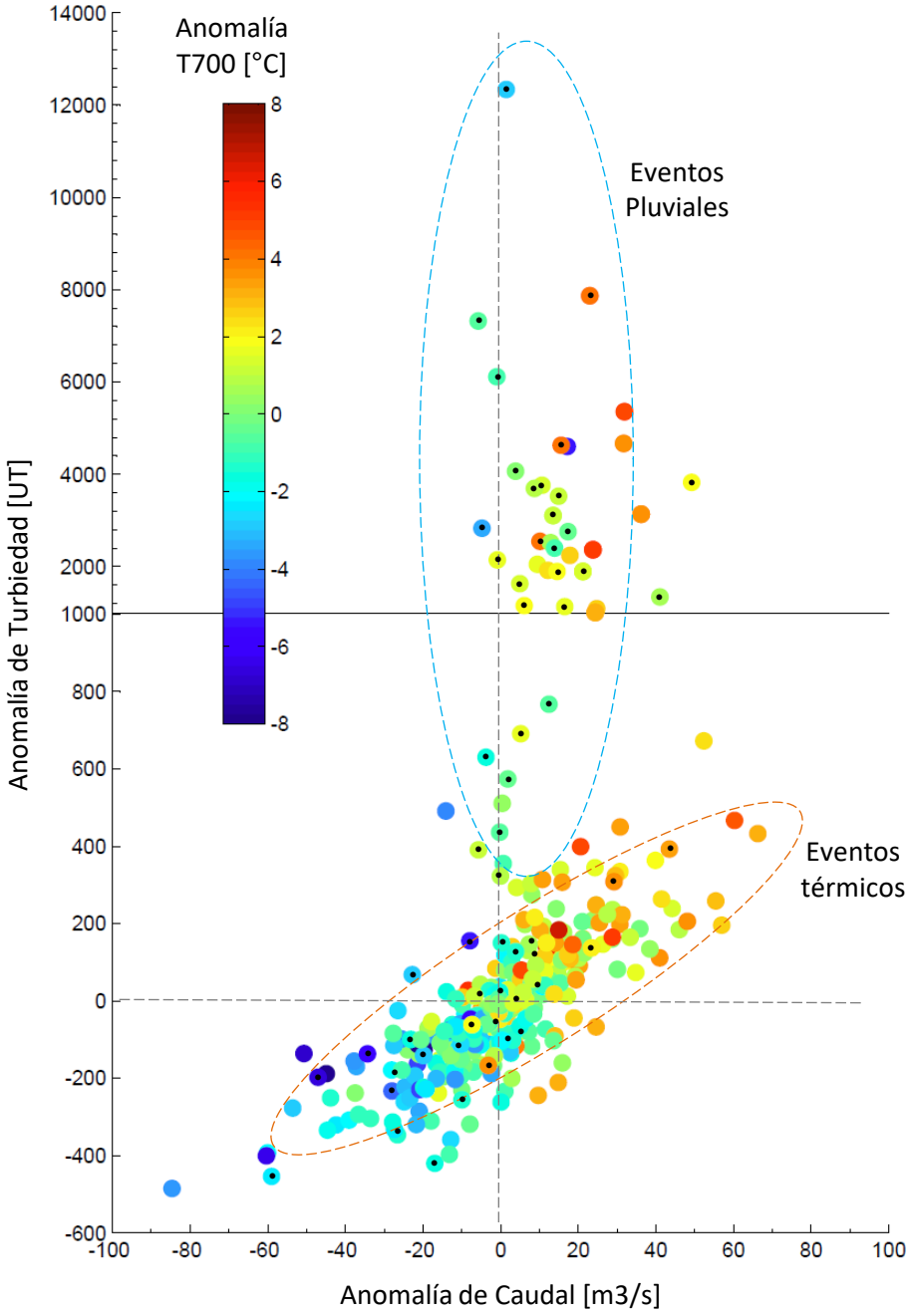
Postales del verano 2013

Río Maipo en el Manzano

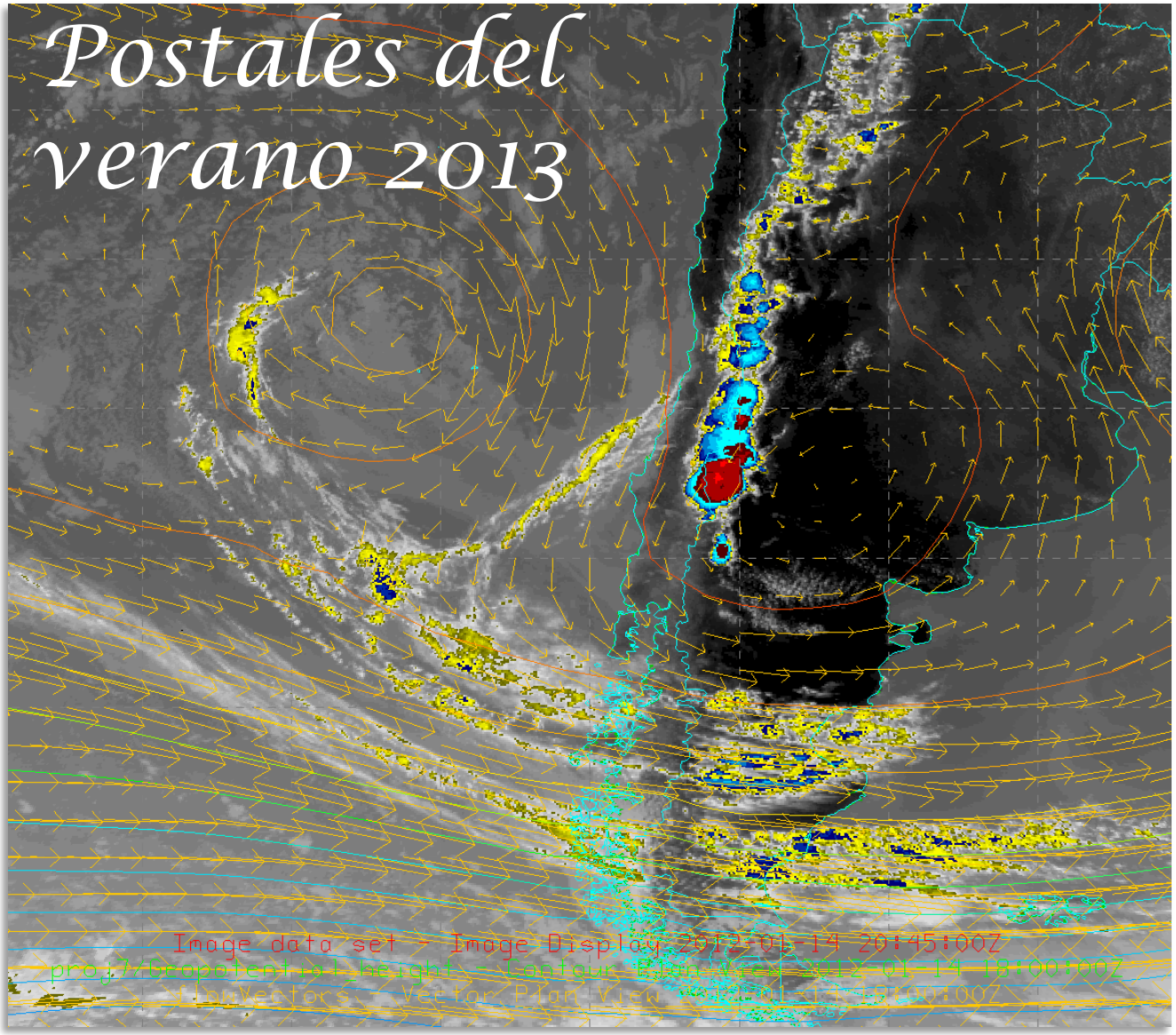
Promedios diarios de caudal, turbiedad, temperatura del aire y precipitaciones (2010-11)



Garreaud and Viale 2015



Garreaud and Viale 2015


Postales del
verano 2013

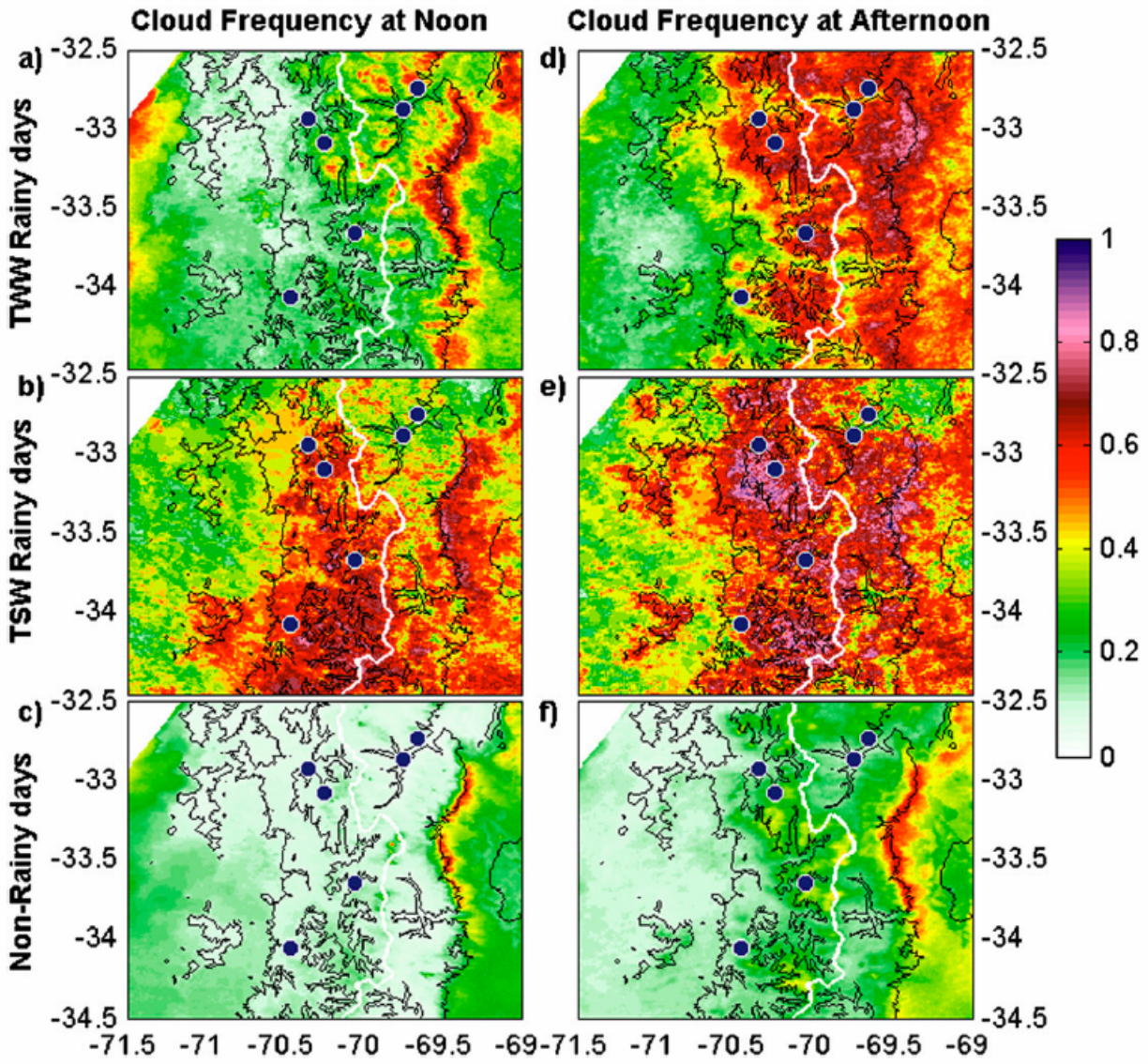
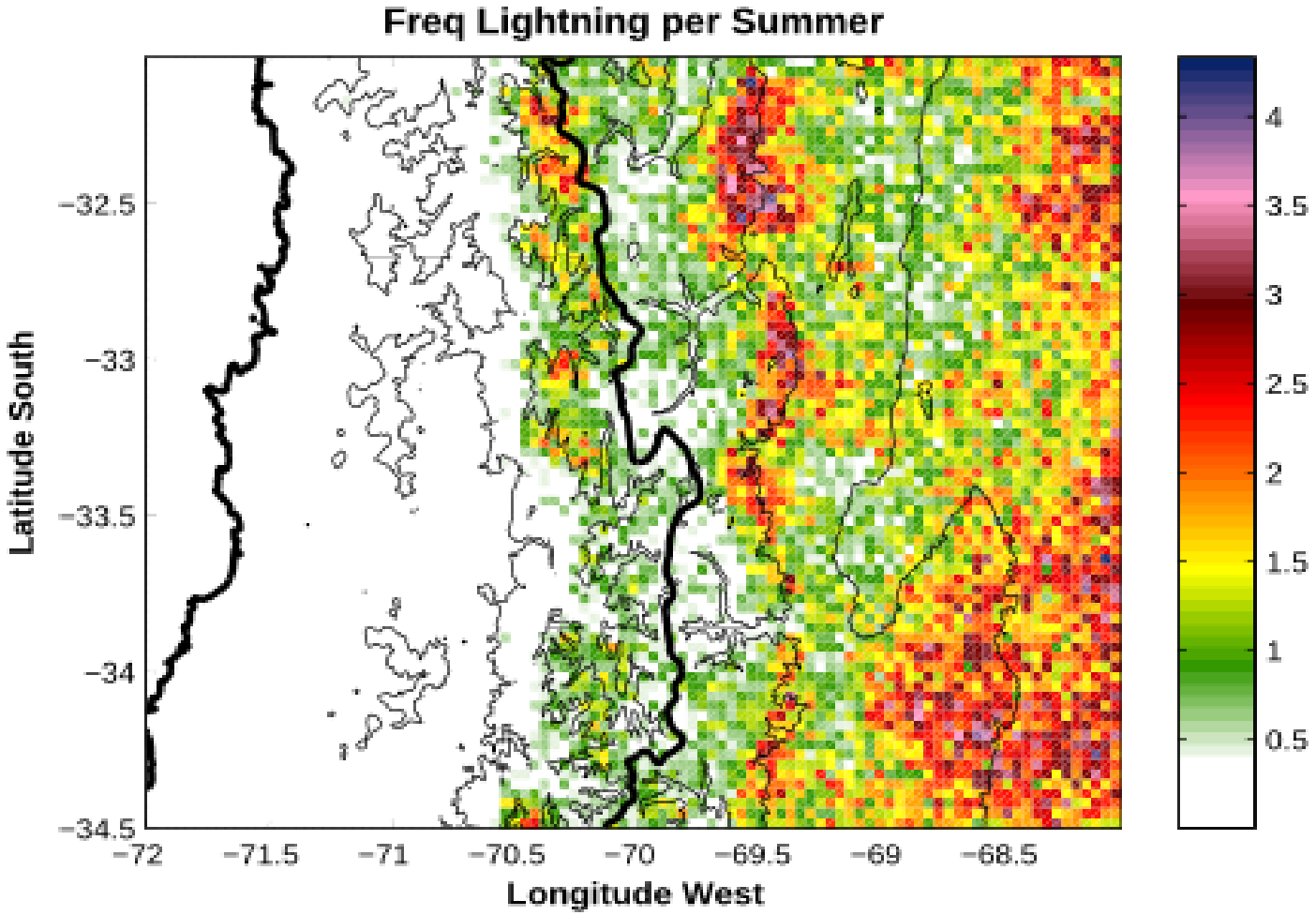
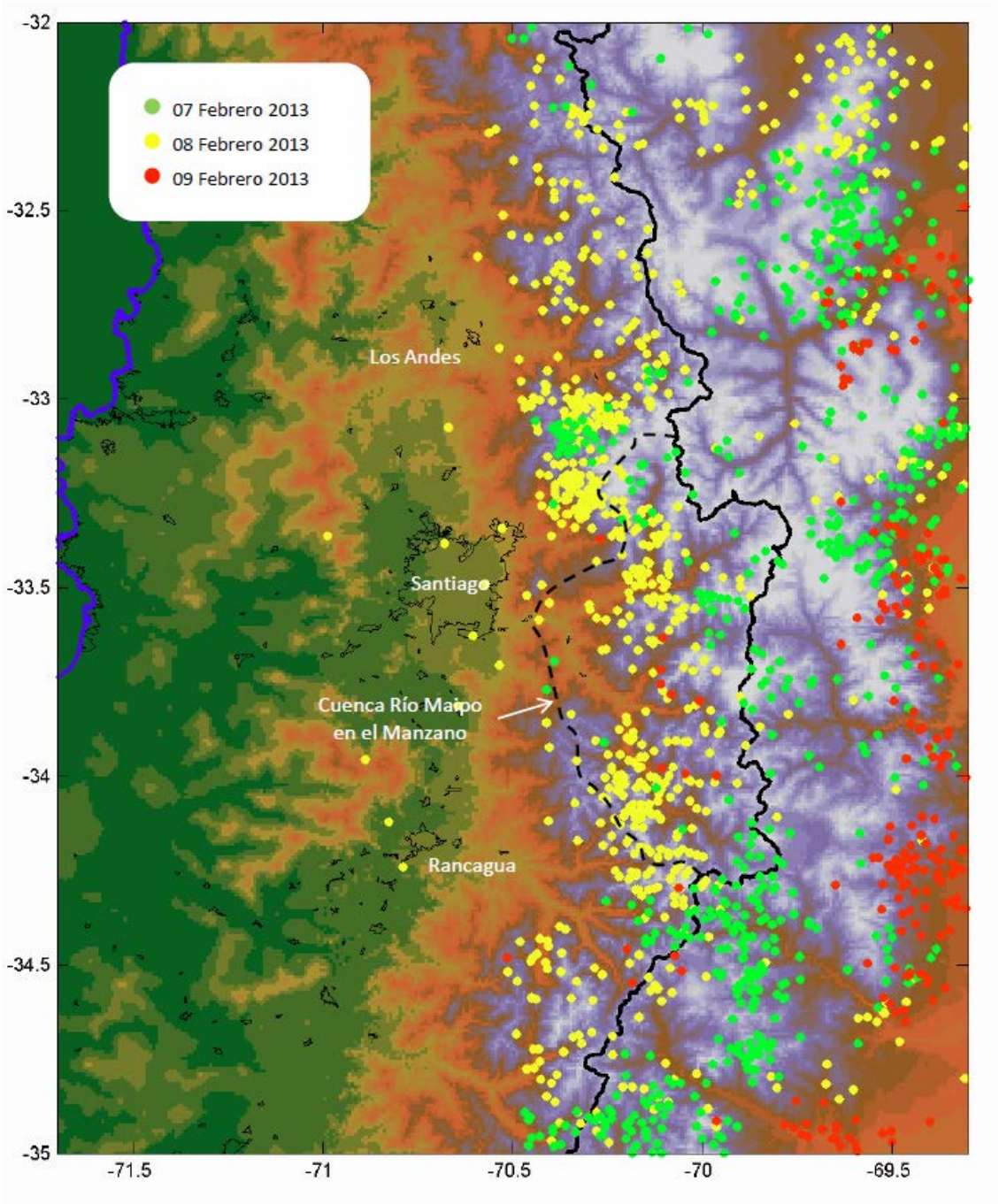


FIG. 10. Summer (DJF) cloud frequency for (a),(d) the TWW rainy days, (b),(e) the TSW rainy days, and (c),(f) the nonrainy days obtained from MODIS data on board (left) *Terra* and (right) *Aqua*, which pass over western South America at noon and afternoon hours, respectively. In each panel, the white line corresponds to the Argentina–Chile border (representative of the crest line), the black lines correspond to the topography height of 1000 and 3000 m, and the blue circles represent the mountain weather station locations.

Viale and Garreaud 2015



Viale and Garreaud 2015



Garreaud and Viale 2015

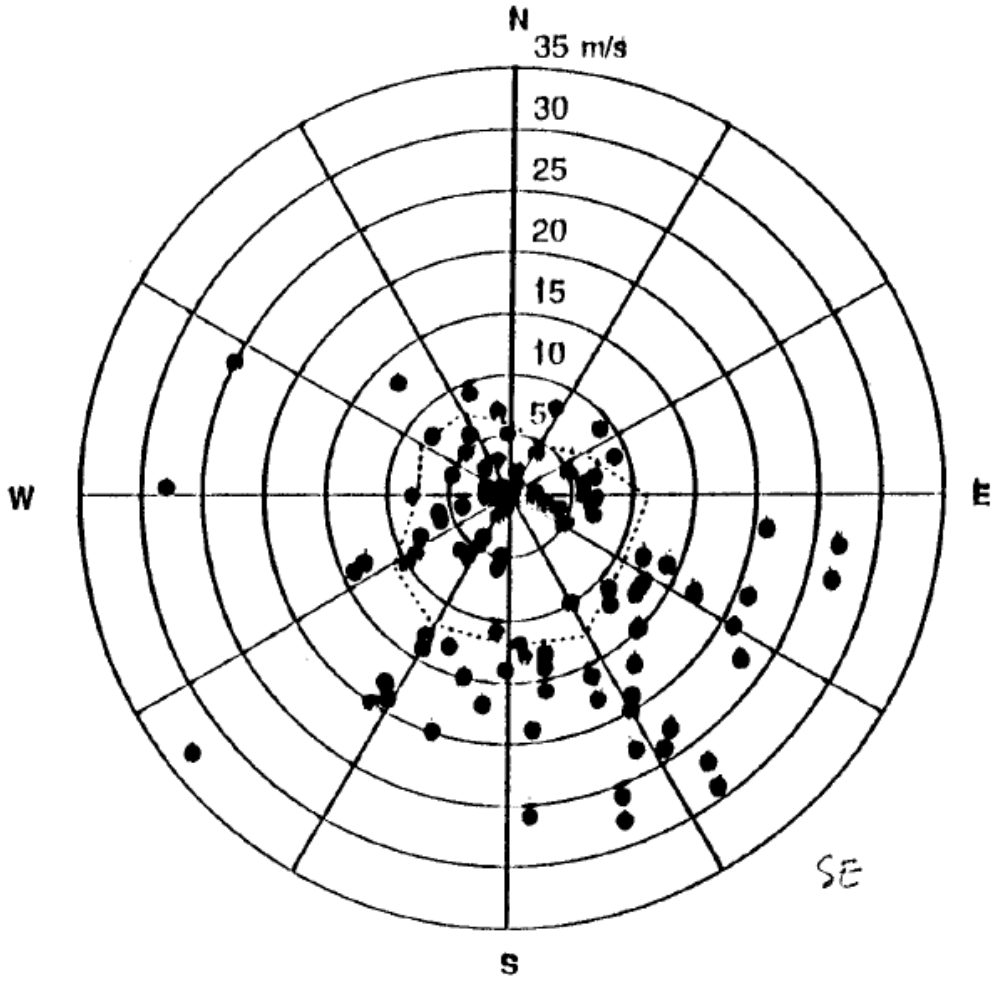


Fig. 9: Representación polar del viento en 500 hPa (Quintero) durante los días con precipitación estival. La línea segmentada corresponde a la magnitud climatológica en cada dirección.

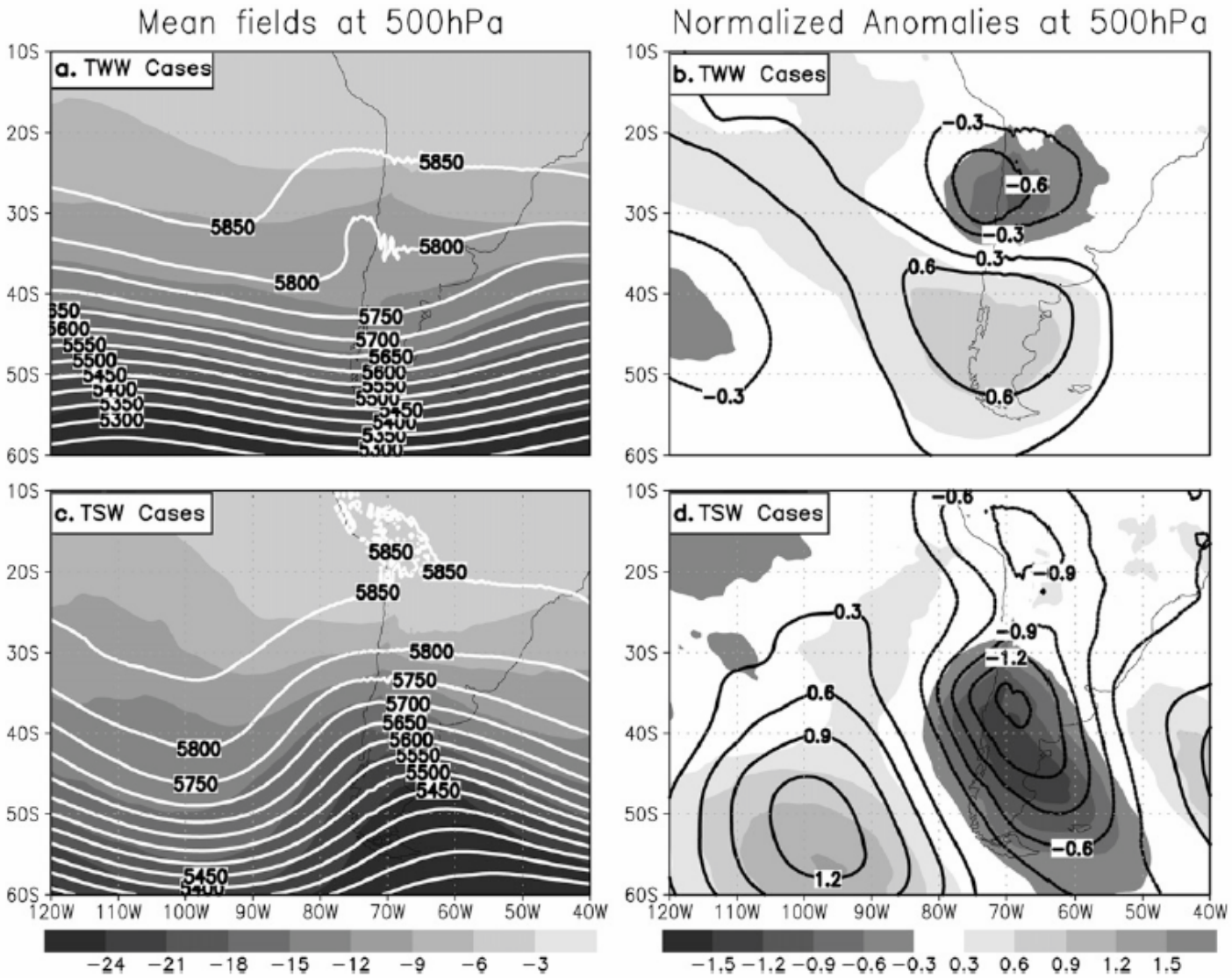
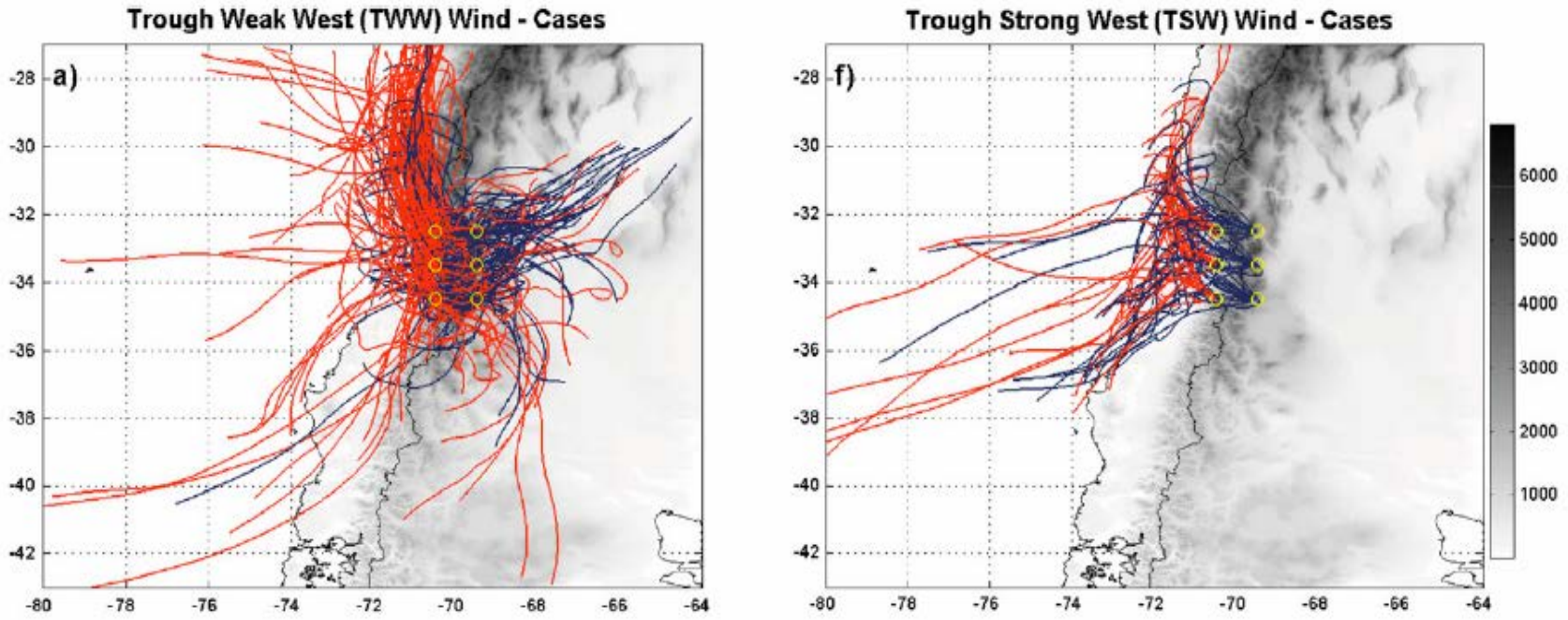


FIG. 5. (left) Mean and (right) normalized anomalies of 500-hPa temperature and geopotential height for the (top) TWW and (bottom) TSW cases. (a),(c) Temperature is shaded every 3°C and geopotential height is contoured every 50 m. (b),(d) Normalized anomalies of temperature is shaded every 0.3σ and of geopotential height is contoured every 0.3σ.

Viale and Garreaud 2015



Viale and Garreaud 2015

How Linear is Orographic Precipitation?
Insights from Nahuelbulta Mountains in Southern Chile

René D. Garreaud, Mark Falvey, Aldo Montecinos

Departamento de Geofísica
Universidad de Chile-Universidad de Concepción

Orographic Precipitation

Upstream precipitation enhancement/downstream rain shadow is a very **consistent meteorological pattern** produced by seemingly simple atmospheric physics.

The **quantitative distribution** of **precipitation** over **mountainous** terrain is, however, a significant **challenge in meteorology**, especially as one considers shorter time scales (e.g., daily or hourly accumulations). On the other hand, precipitation distribution is a critical input for water resource and risk management over complex terrain.

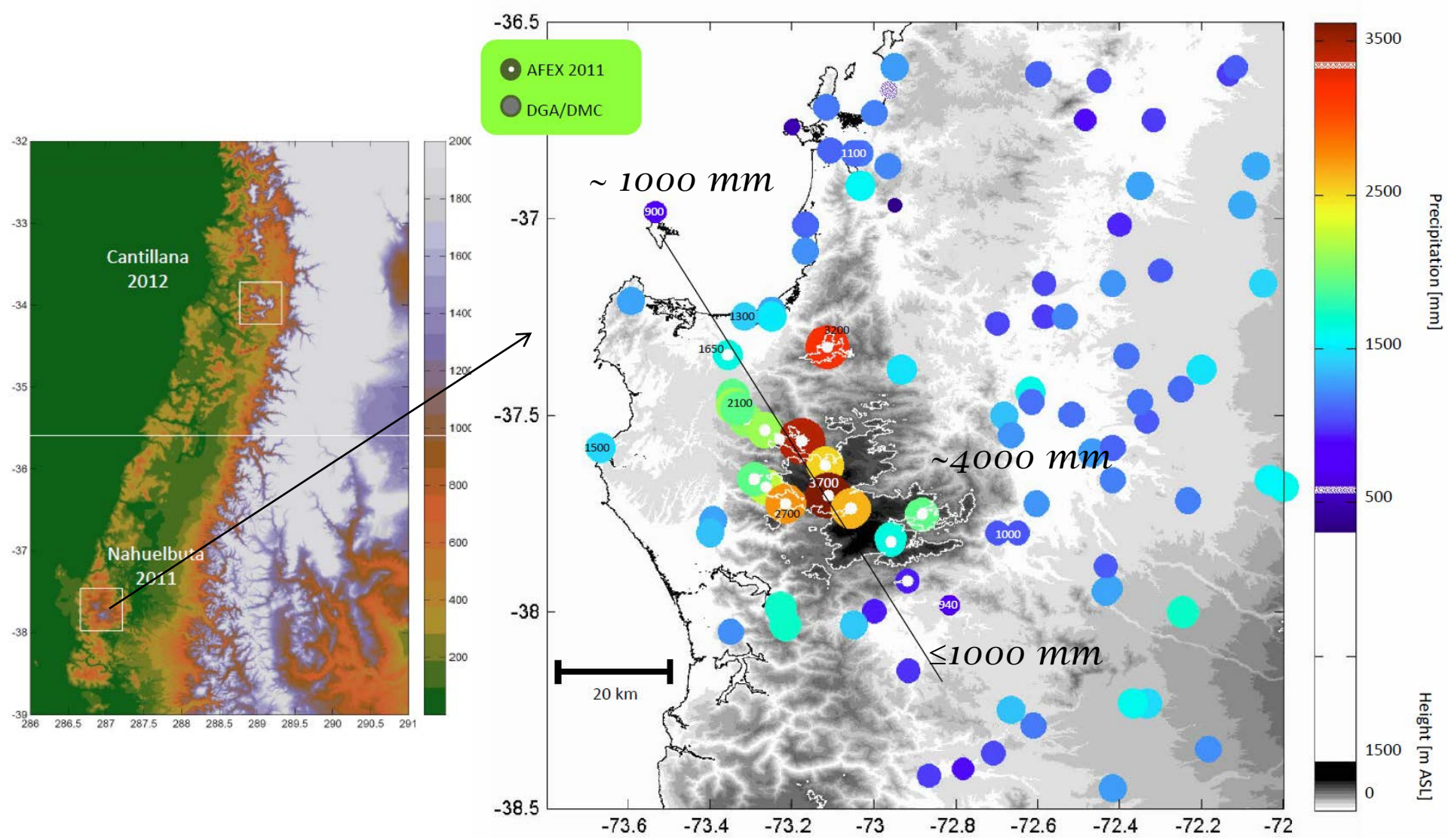
Several methods have been used to obtain the precipitation distribution over mountains:

- **Geo-statistical methods (e.g., PRISM) (need lot of obs.)**
- **Full meteorological models (e.g., WRF) (expensive to run at high resolution)**
- **Linear precipitation models (need to tune a few parameters, fast to run)**

Widely used to force other models…but is it realistic?

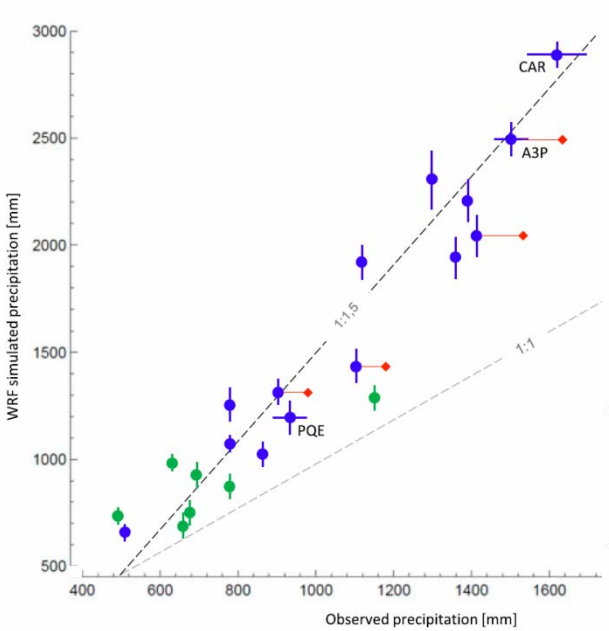
Results from AFEX: Andean frontal Experiment

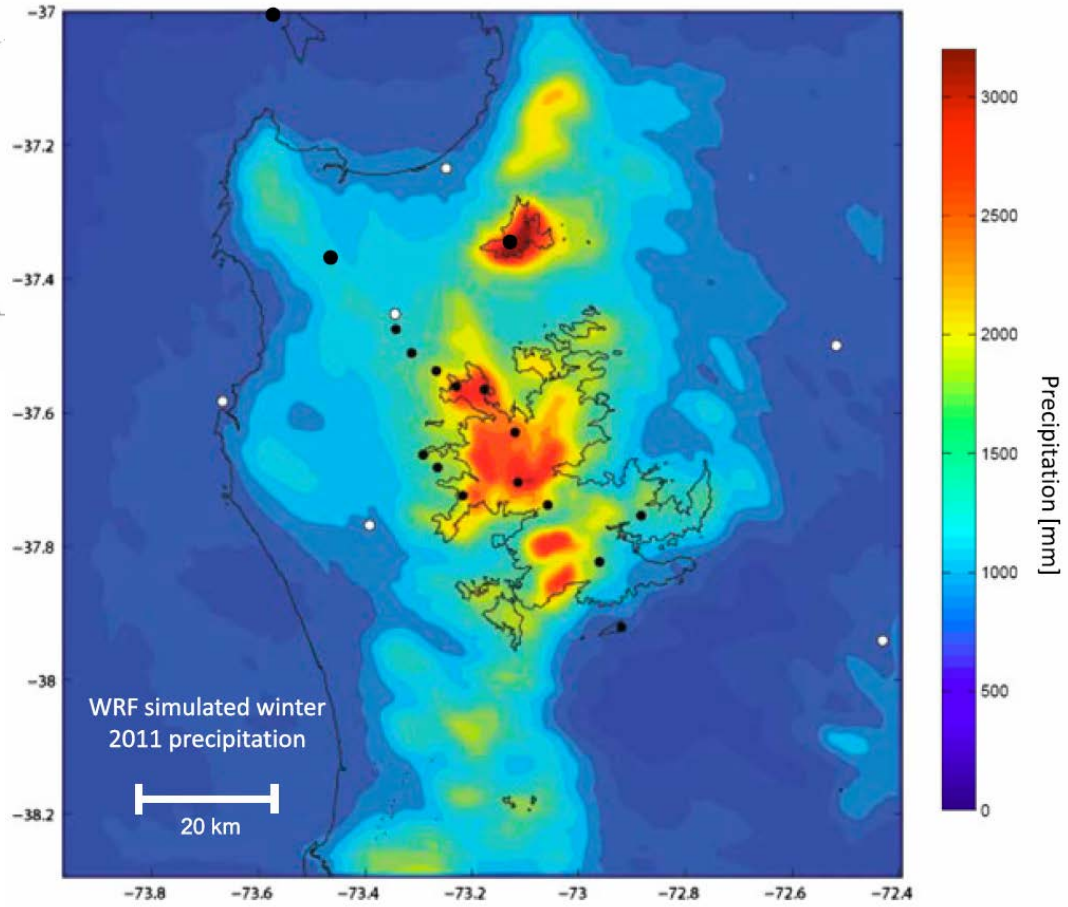
15 raingauges. 2011-2013. Estimated annual mean precipitation [mm]



WRF (1 km) continuous run during winter 2011 (May-Sep) forced by GFS

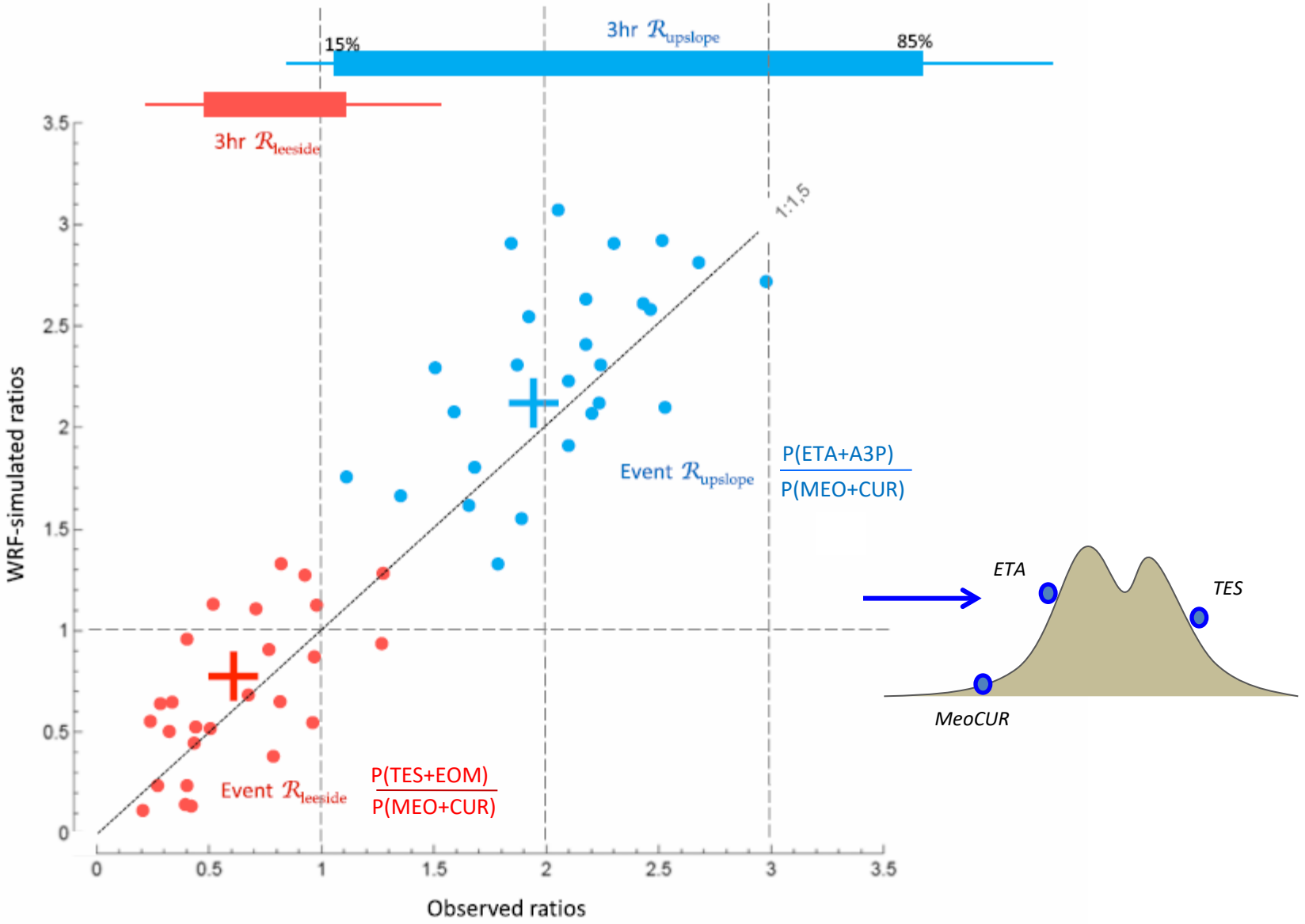
Several weeks of computation in high performace computer…and a lot of pain.





Orographic modification ratios

For each of the 27 events….

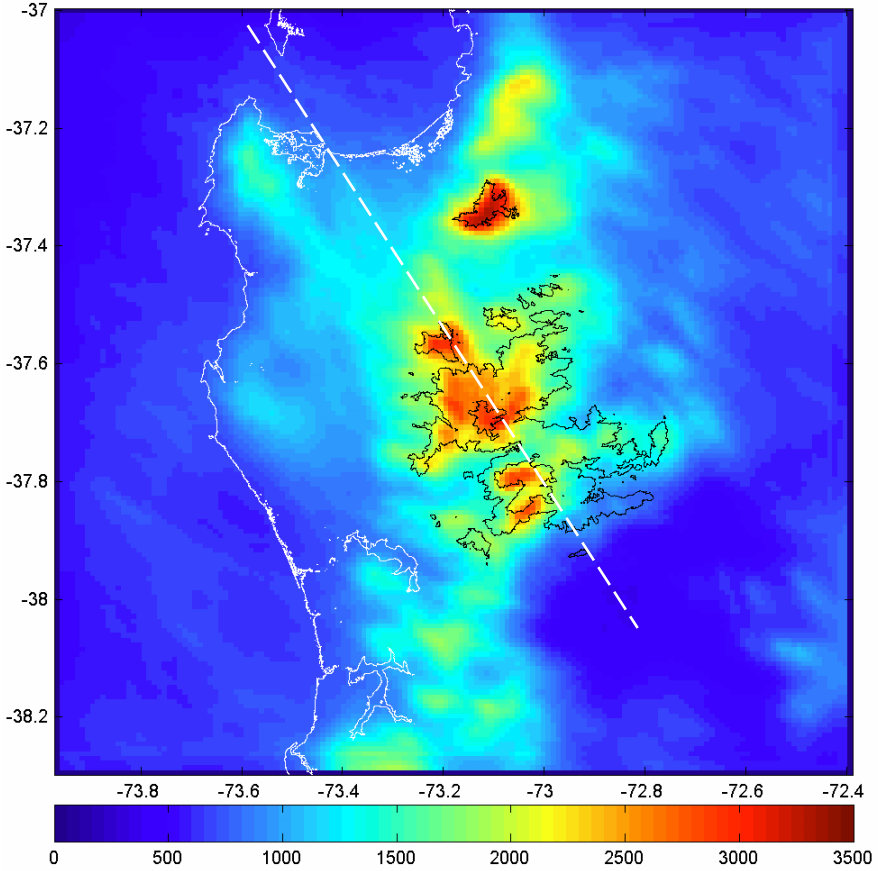


Multi storm statistics (28 frontal cases)

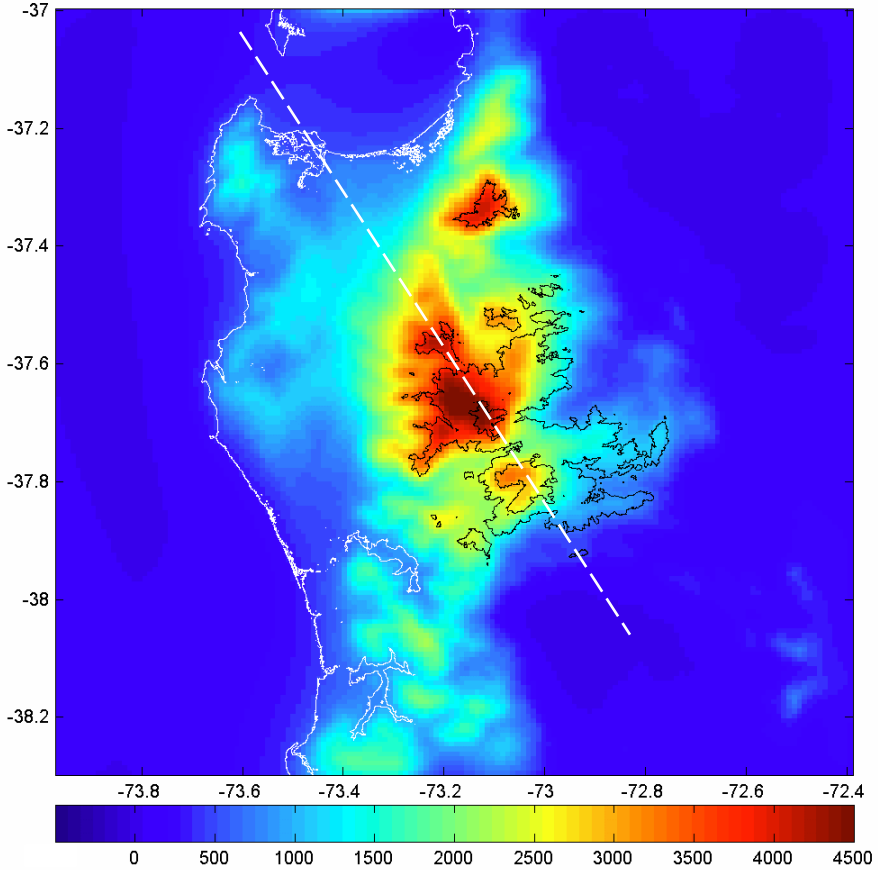
Parameter	Prefrontal stage	Frontal stage	Postfrontal stage
Duration (hr)	17±5	3	10±6
Foothill accumulation (%)	45±9	28±9	27±9
Foothill rain rate (mm/hr)	1.2±0.7	4.7±1	0.5±0.4
Mnt. rain rate (mm/hr)	2.2±0.8	6.9±1.2	1.6±0.5
Leeside rain rate (mm/hr)	0.5±0.3	3.6±0.7	0.3±0.3
Upslope enhancement	5.1±0.4	1.4±0.5	5.5±0.9
Lee side suppression	0.3±0.2	0.8±0.5	0.5±0.3

Simulated 2011 winter (May-Sep) Precipitation [mm]

(a) WRF (Full physics)



(b) LT Model (var. Wind and moisture from WRF)

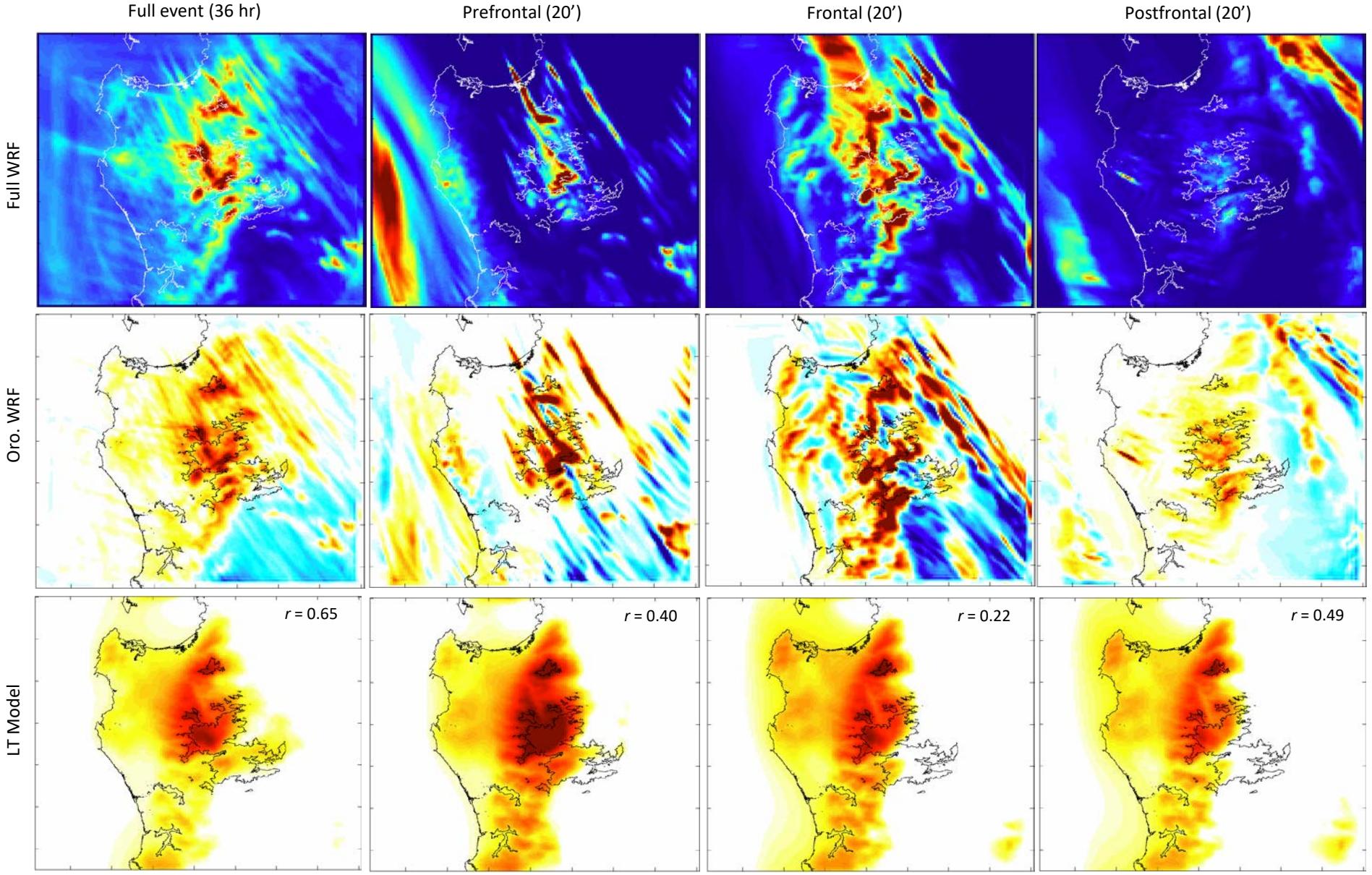


(*) Linear Theory Model by Smith and Barstad (2004)

$\tau_c = \tau_f = 1000$ s, $P_\infty = 0$

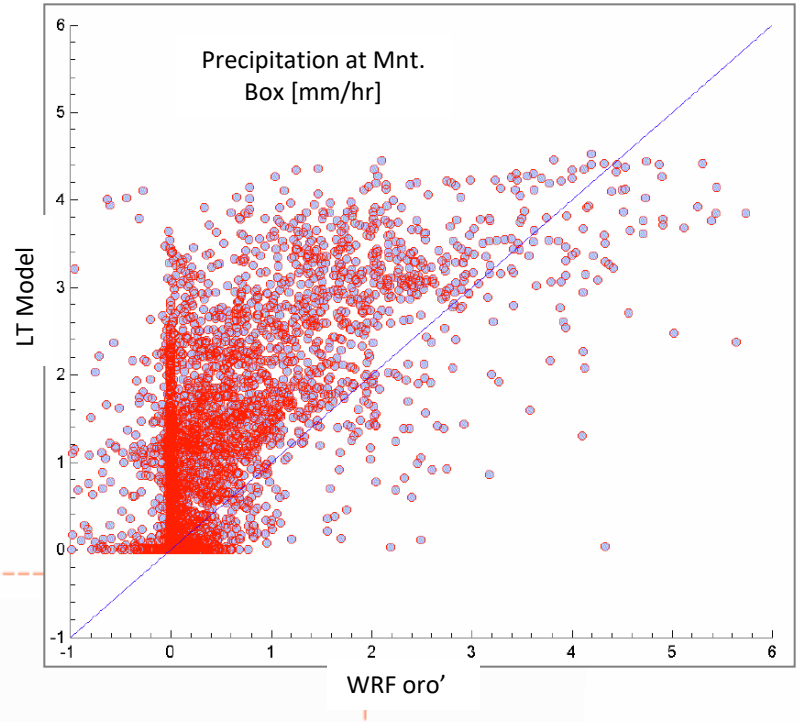
30 min of calculation in domestic PC

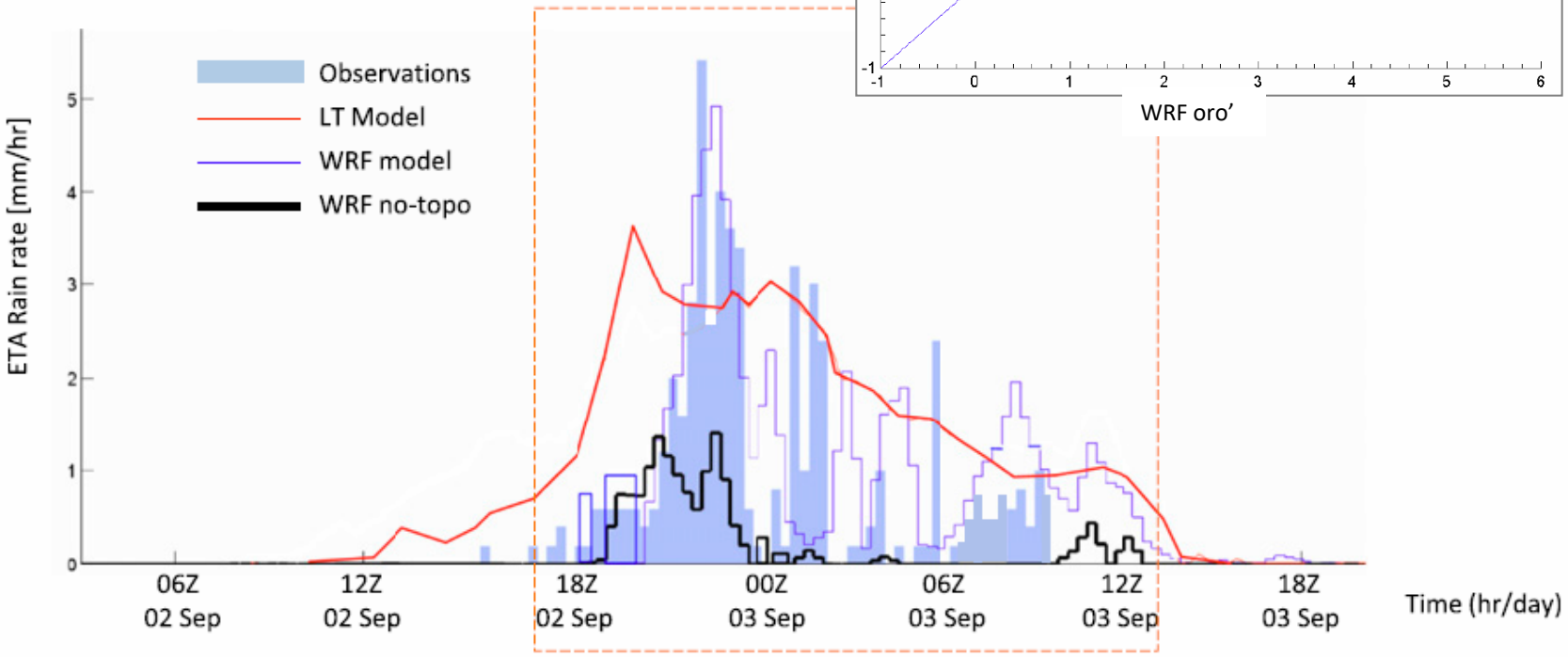
How similar are WRF and LT precipitation pattern at individual events?



Orographic WRF: Full topo – No topo

How similar are the WRF and LT-Model precipitation pattern at individual events?





Conclusions

✓WRF model does a good job in simulating the seasonal mean and event rainfall accumulation. WRF itself partially linear.

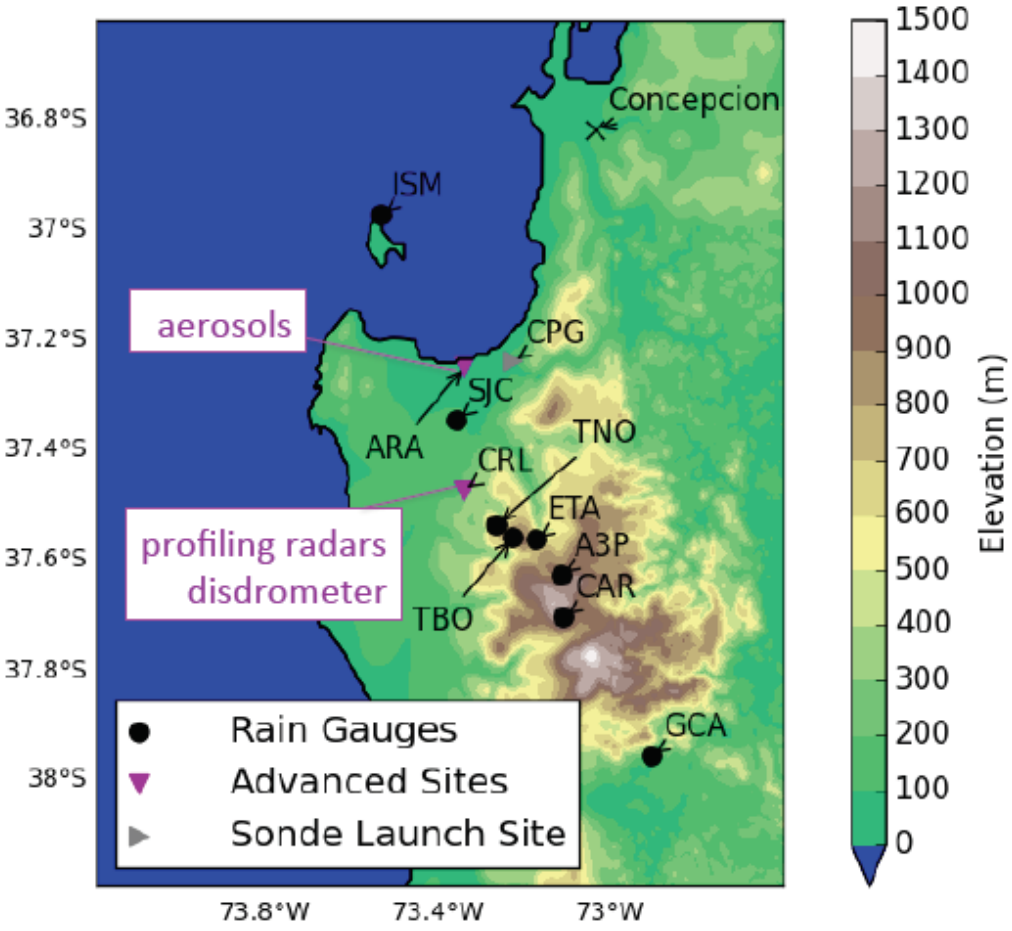
✓ Linear model does capture the seasonal rainfall distribution of precipitation over the Nahuelbuta mountains, although it overestimate accumulation in the windward side and produce a too strong rain shadow effect.

✘ Over/under estimations in the LT model can be reduced by tuning their parameters and filtering out many periods of light precipitation that the model produce before actual rainfall began.

✘ LT model can't resolve intense, short-lived (less than an hour) rainfall episodes that are associated with non-linear effects during frontal passage. This episodes are highly variable in time and space, so they smooth when considering daily or longer periods.

The Chilean Coastal Orographic Precipitation Experiment Pilot Project (CCOPE-2015)

Minder, Massman; Geerts, Fults, Sneider; Kingsmill, Valenzuela; Garreaud, Falvey



Massman et al. 2015

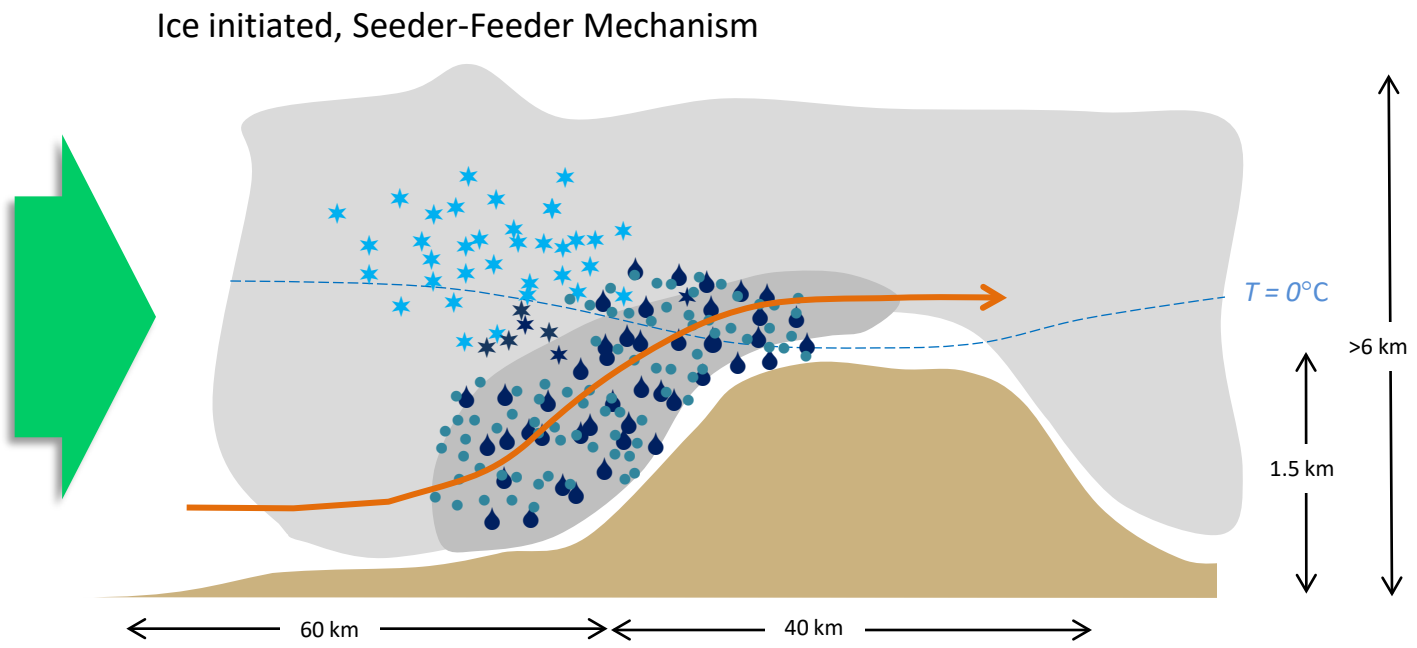
Que controla el GOP en entre/intra tormentas?

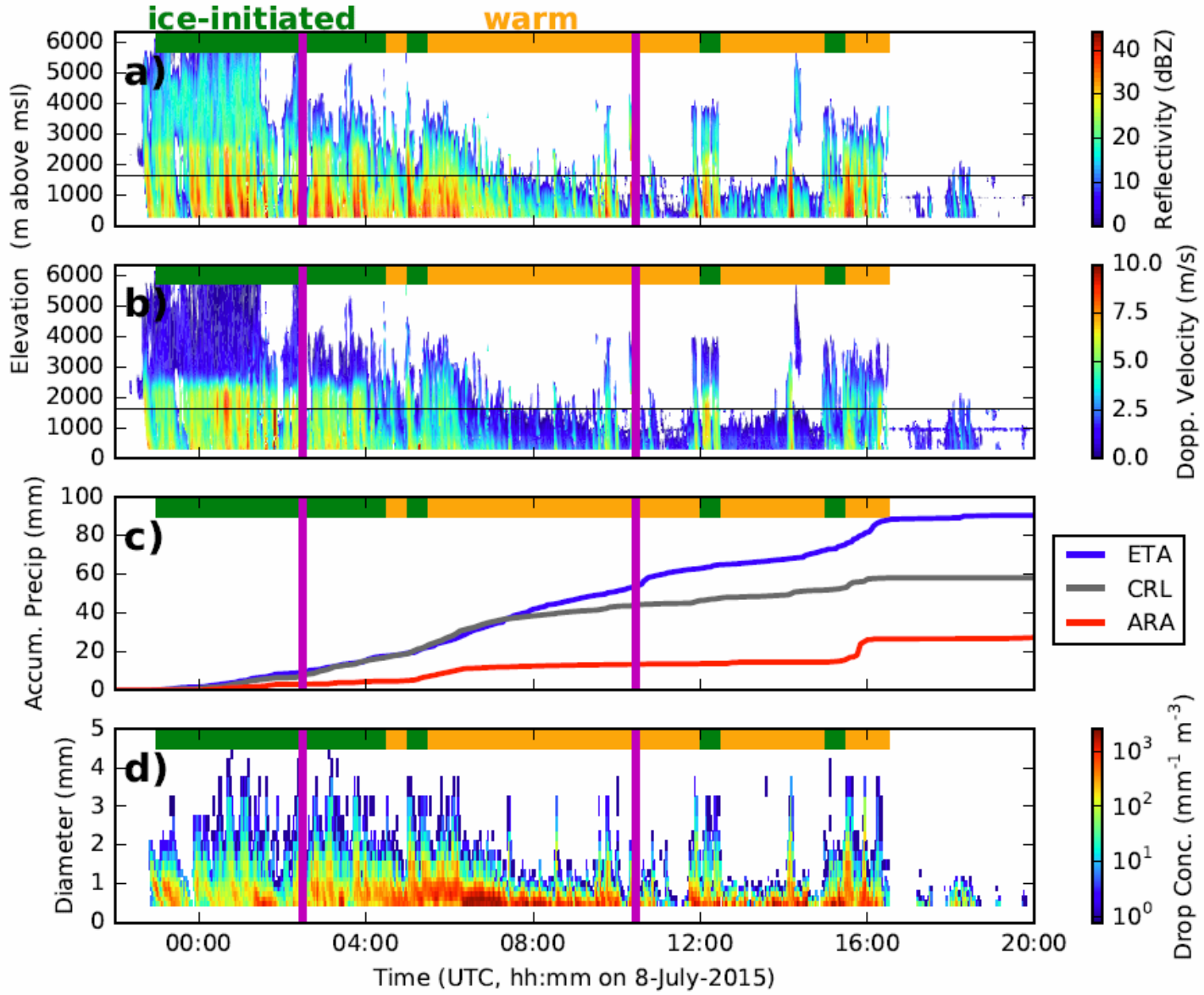
Estabilidad del flujo (Fr=U/Nh))

Estabilidad termodinámica (convección?)

Contenido de humedad (IWV)

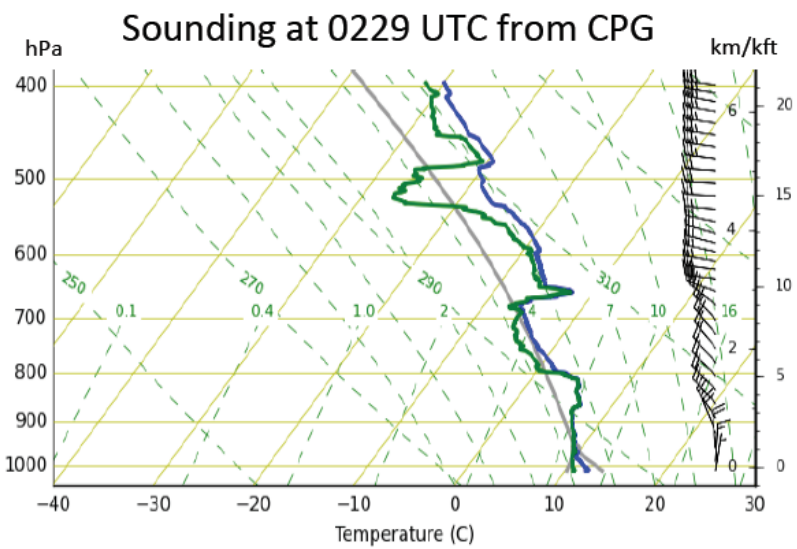
Microfisica ($\tau rain < \tau adv = L/U$)

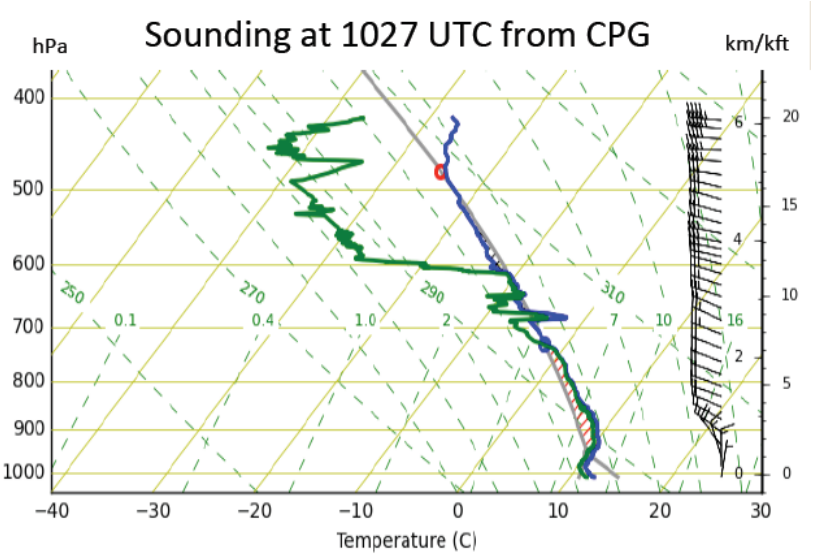


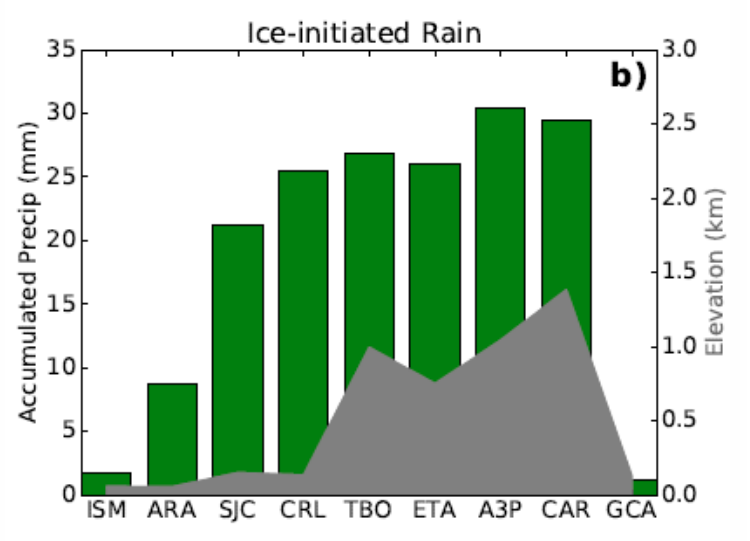


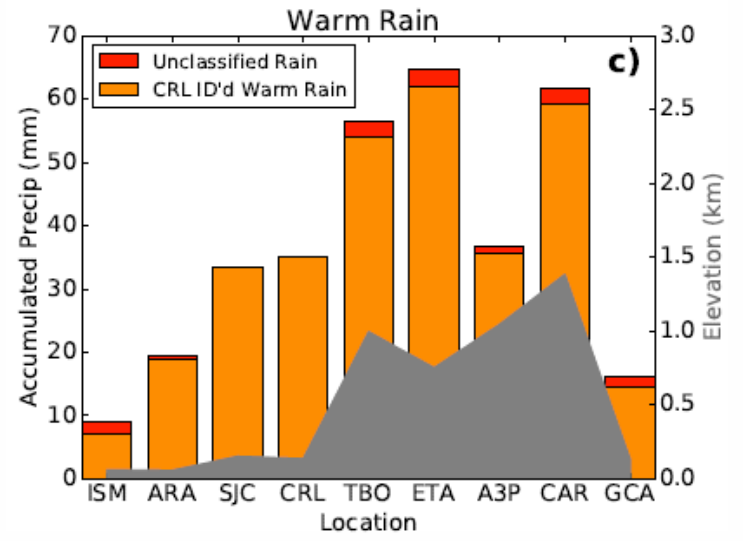
Massman et al. 2016

Minder et al. 2015



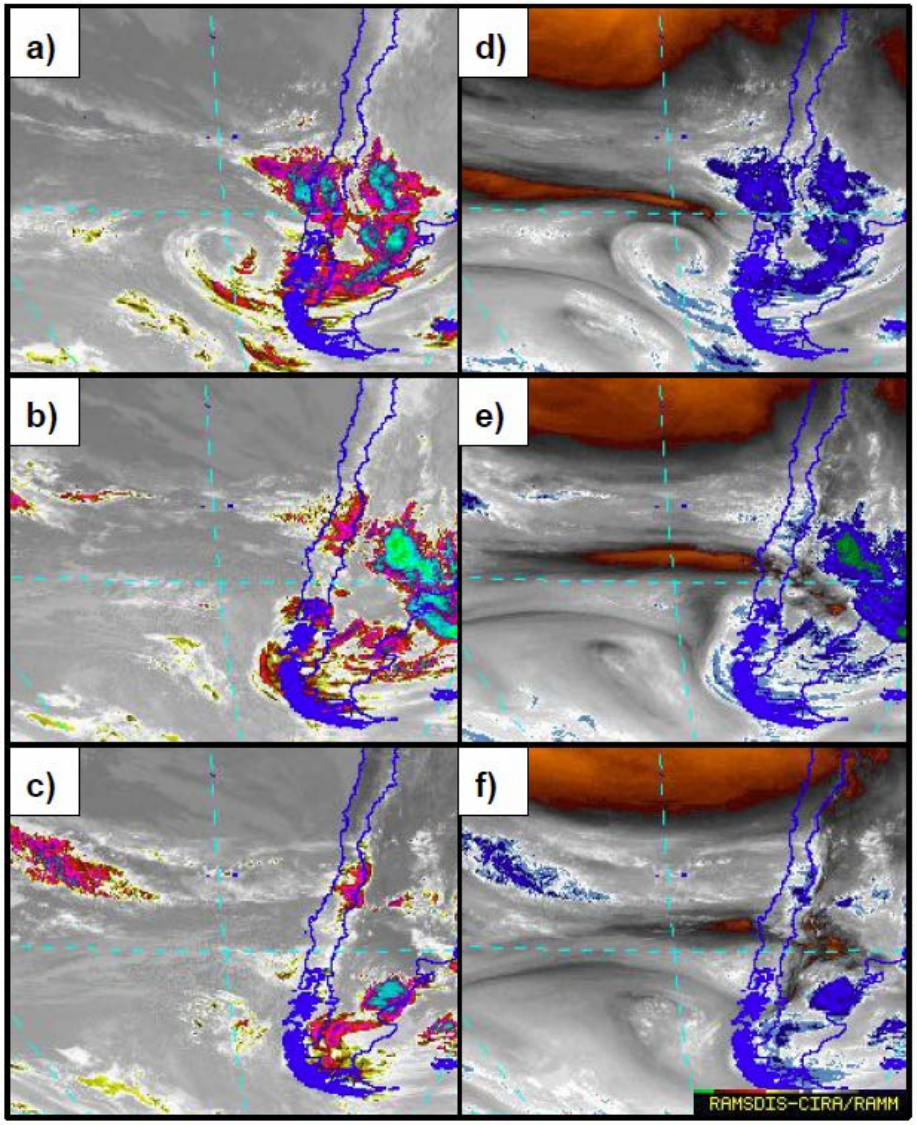




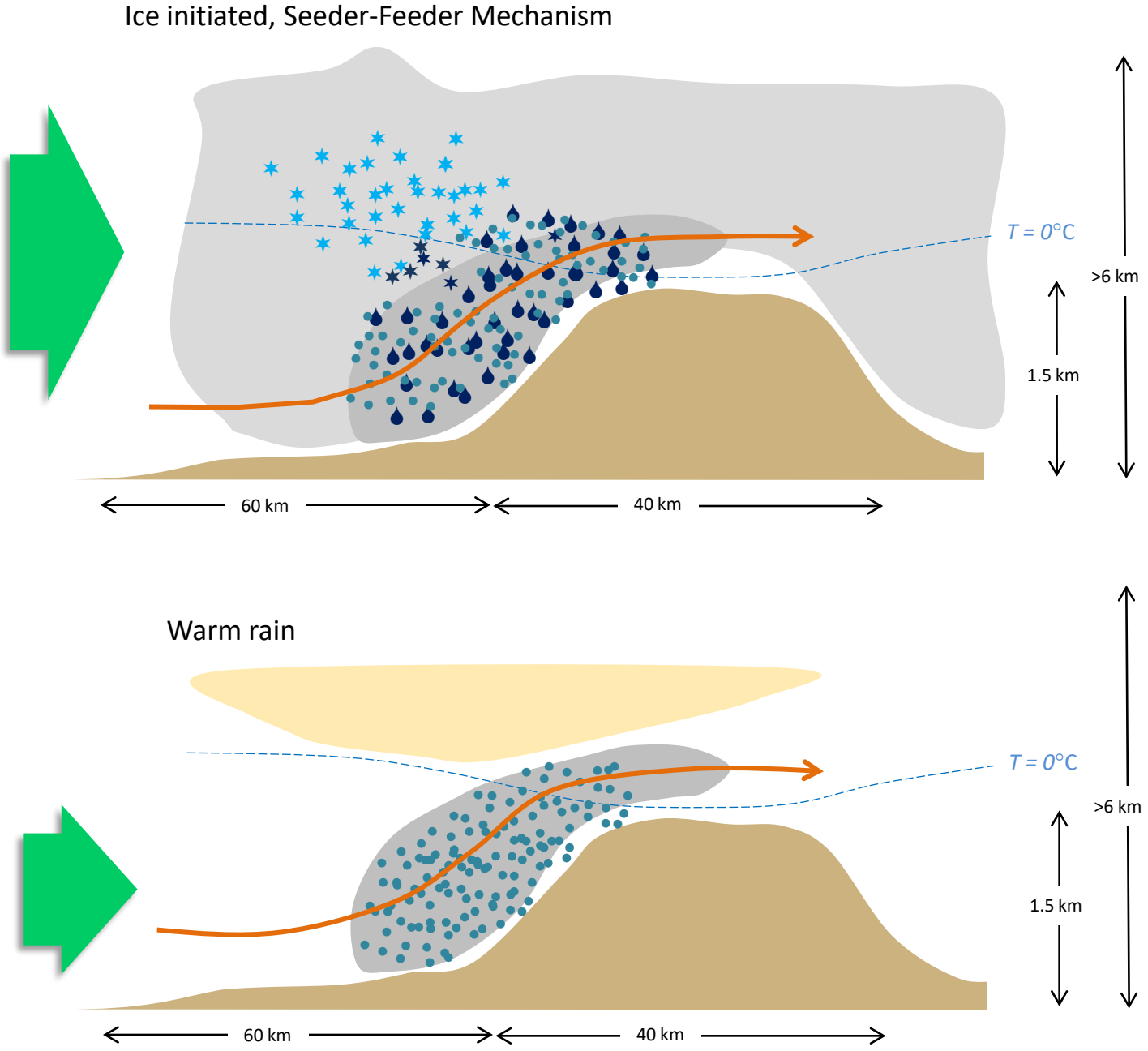


Massman et al. 2016

Transition from ice-initiated to warm rain controlled by synoptic evolution



Massman et al. 2016


Ice initiated, Seeder-Feeder Mechanism
T = 0°C
>6 km
1.5 km
60 km
40 km
Warm rain
T = 0°C
>6 km
1.5 km
60 km
40 km

Preguntas pendientes

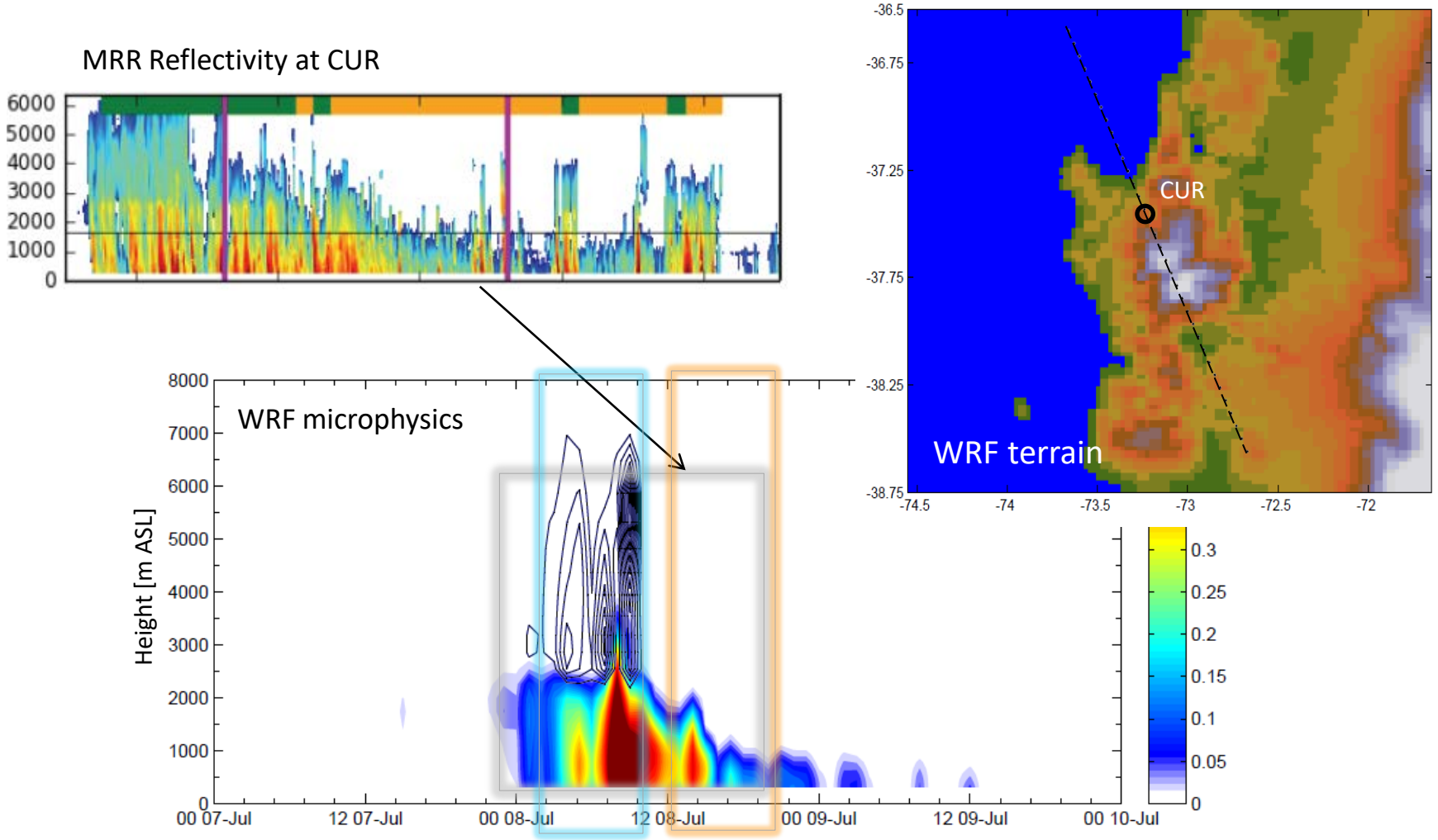
En que régimen (WR/Ice) es mayor el GOP?
(Obs + Simulaciones numéricas: Tesis Cinthya Bravo)

Que parametrización de WRF captura estos regímenes?

Detección satelital?

Evidencia de convección durante WR?

WRF-UCh simulations in support of CCOPE-2015
Inner domain (3km)
IOP3. Initial time: 2015-07-07 00:00 UTC



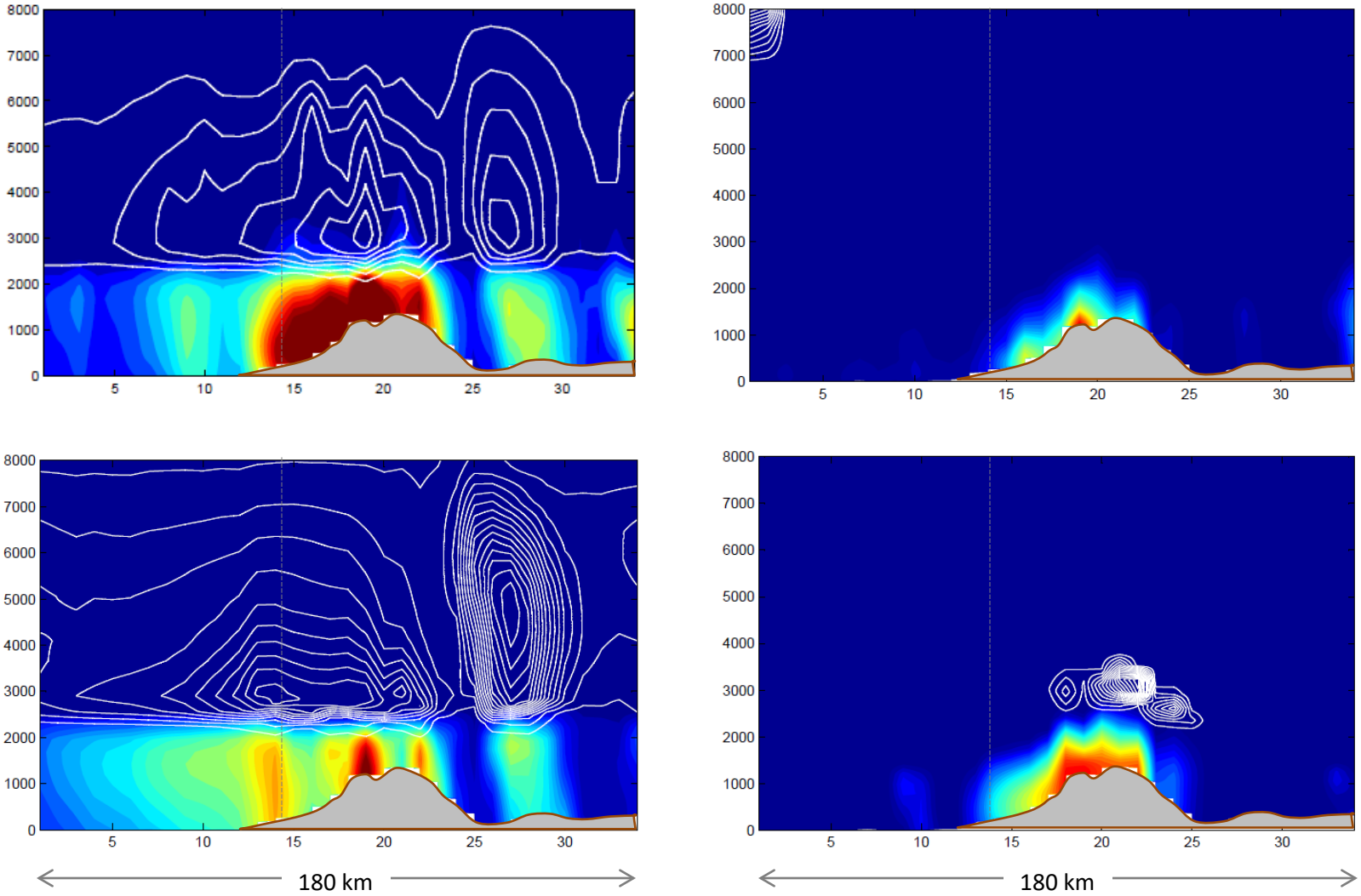
High-distance cross-section along the NW-SE direction of q_{rain} and q_{frozen}

Ice initiated rain period

Warm rain period

10 hour average

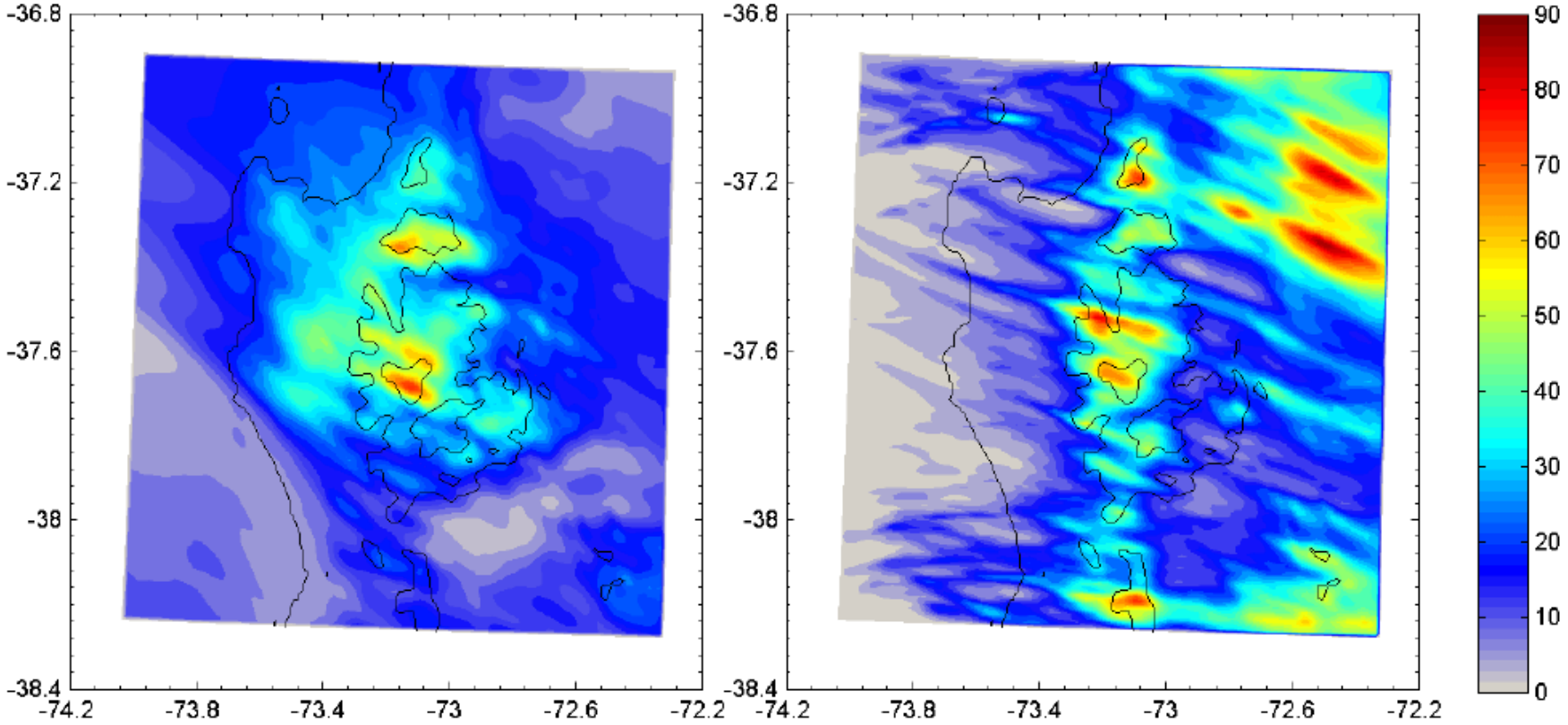
Snapshot



IOP 3, July 7, 8 2015
WRF 1 km
Accumulated rainfall (mm)

Ice initiated rainfall period (12 hr)

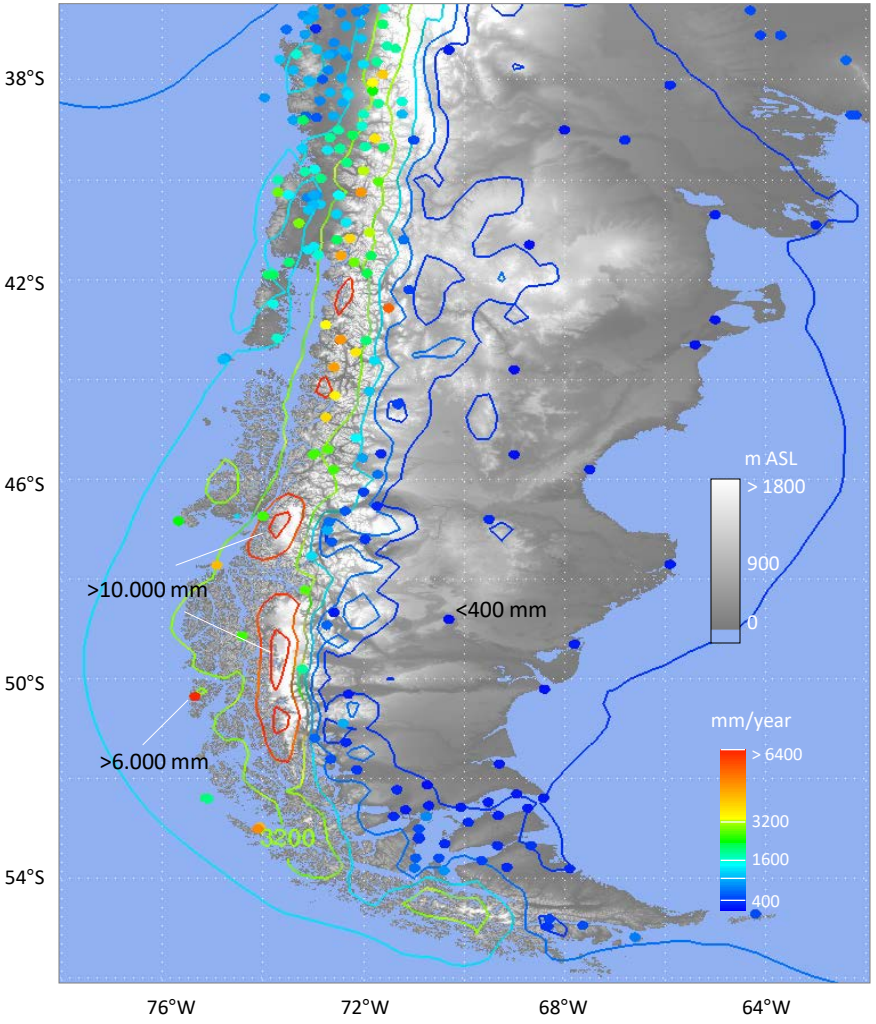
Warm rainfall period (24 hr)



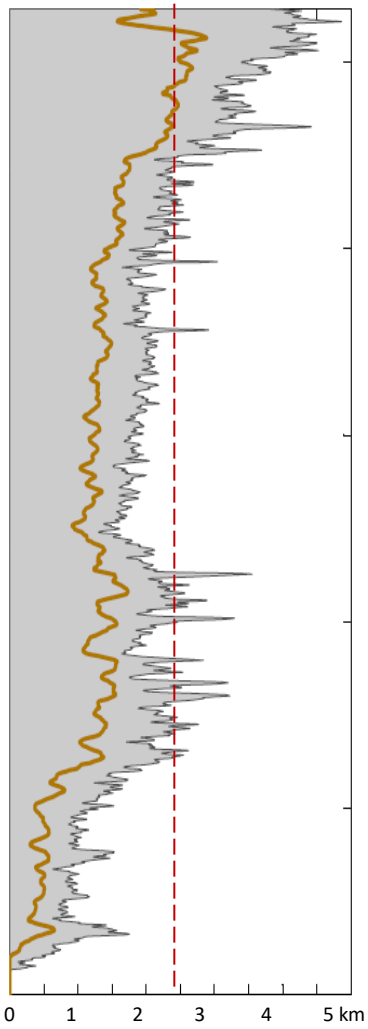
precip10min.txt

Patagonia 101: Precipitation

Mean Annual Rainfall (everybody guess)



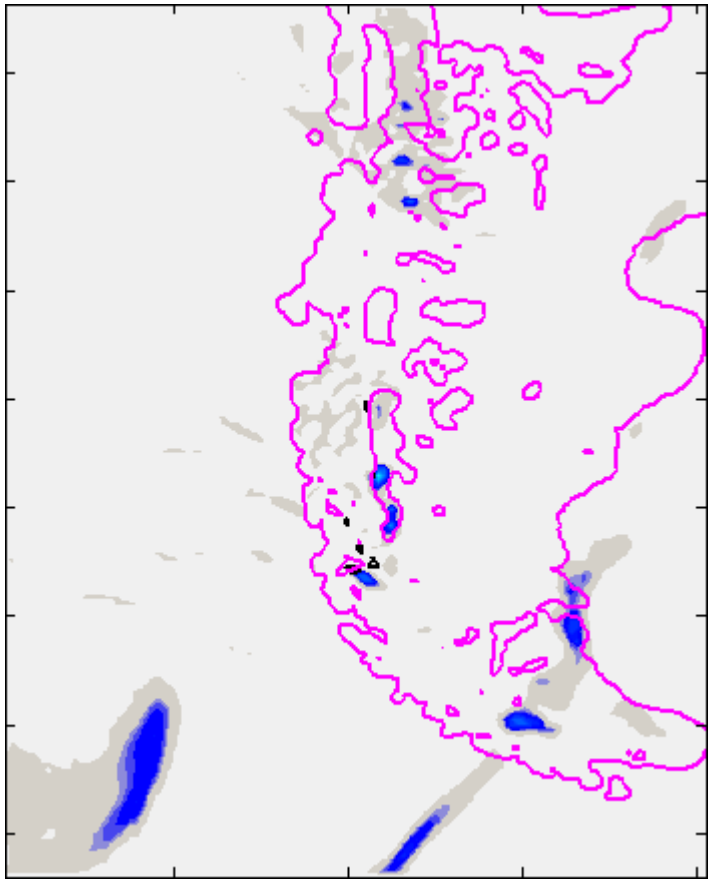
Height (max, 90%)



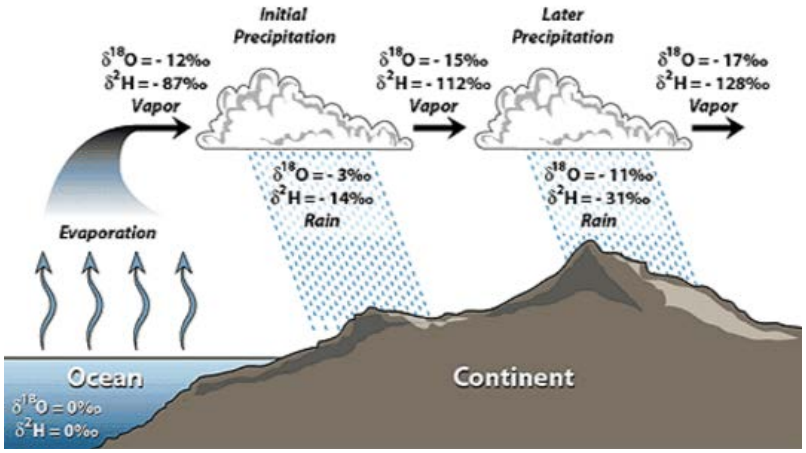
Garreaud and Nicora 2014

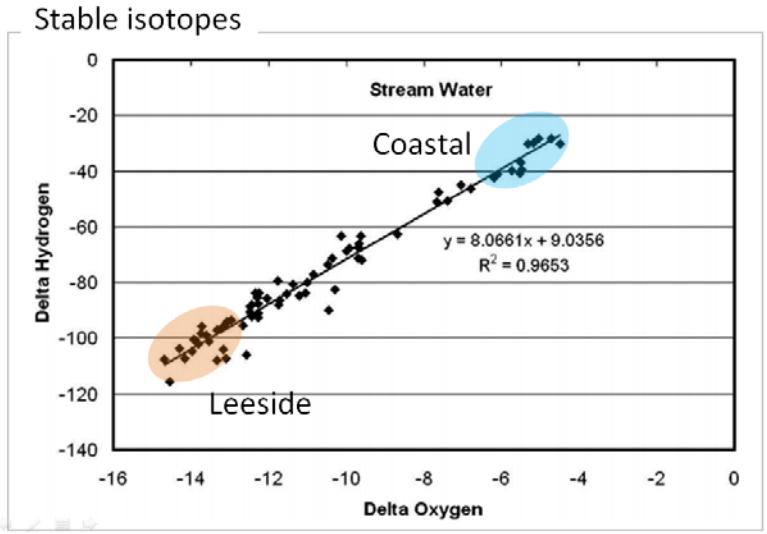
One (typical) storm simulation (WRF)

Hourly results during a 3 day period. Resolved precipitation (colors), Convective rainfall (contours) and topography

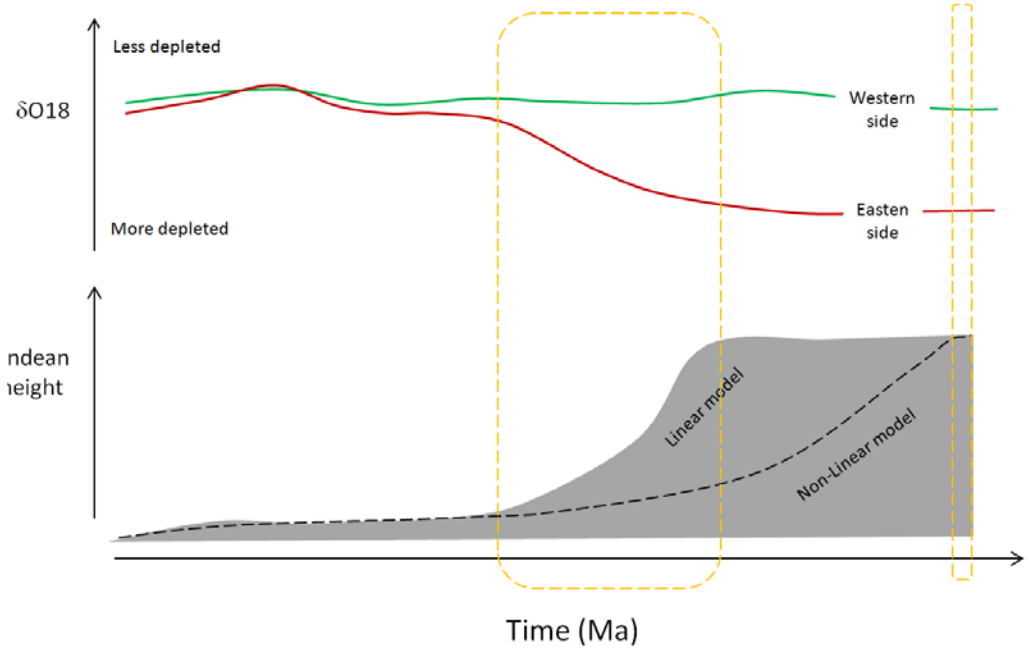


Salient features: Rainfall enhancement over the Andes windward slope, Rain shadow, Convective rainfall along the coast



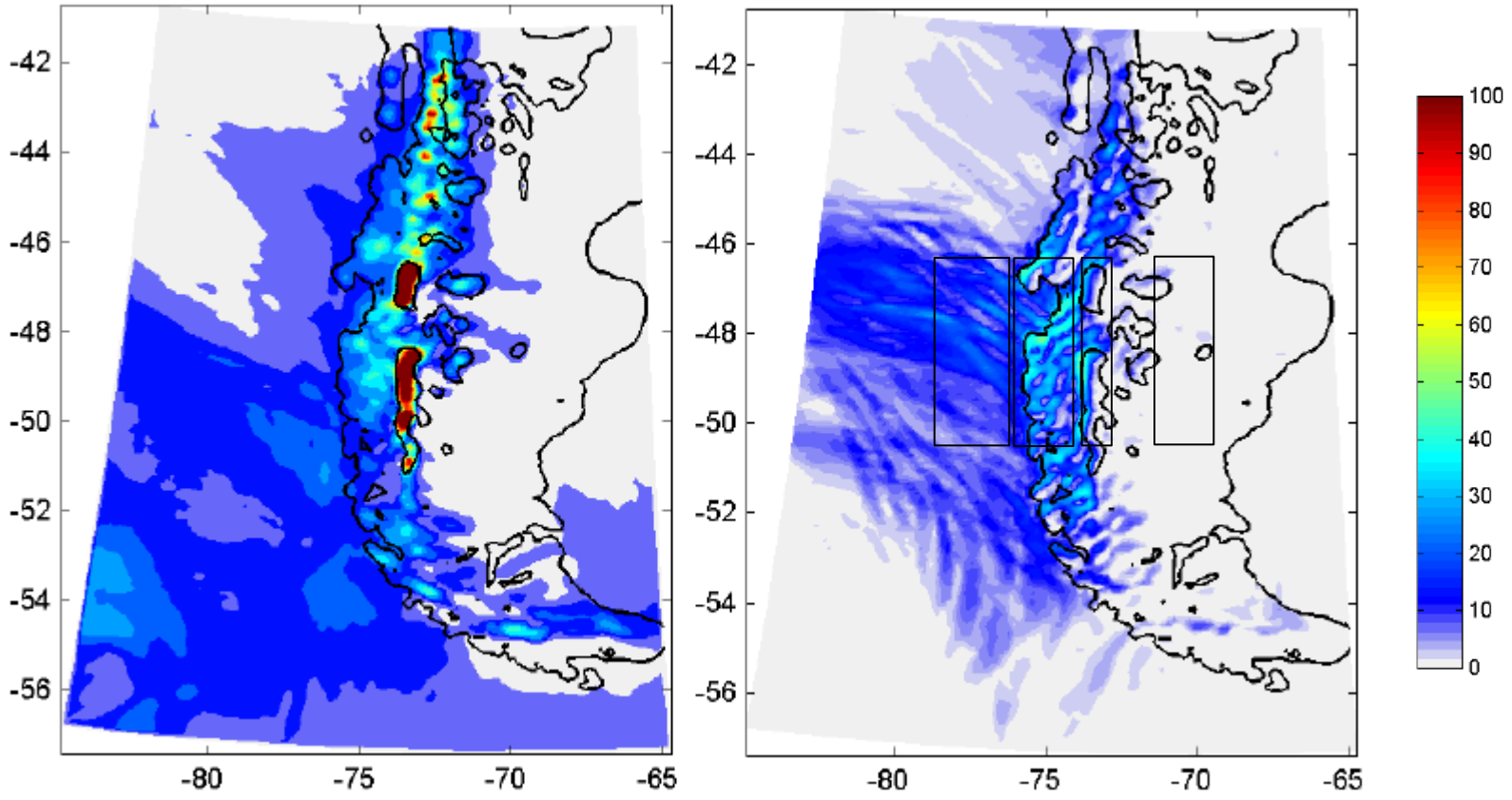


Smith and Evans 2007



Control topográfico
(relevante para el clima del pasado muy remoto)

48 hr Accumulated Precip - Control Simulation

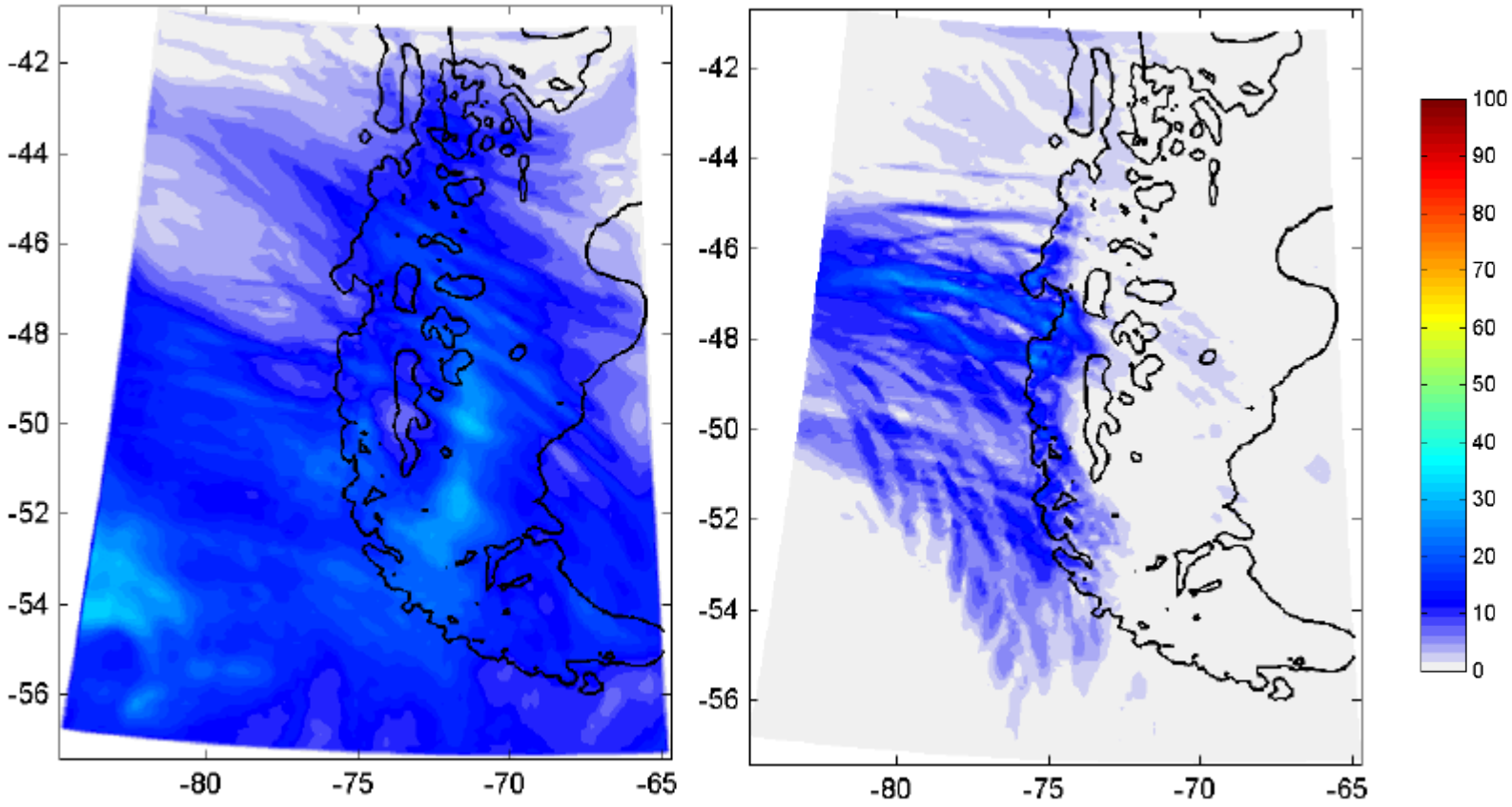


Resolved

Convective

Control topográfico
(relevante para el clima del pasado muy remoto)

48 hr Accumulated Precip – No Topo Simulation

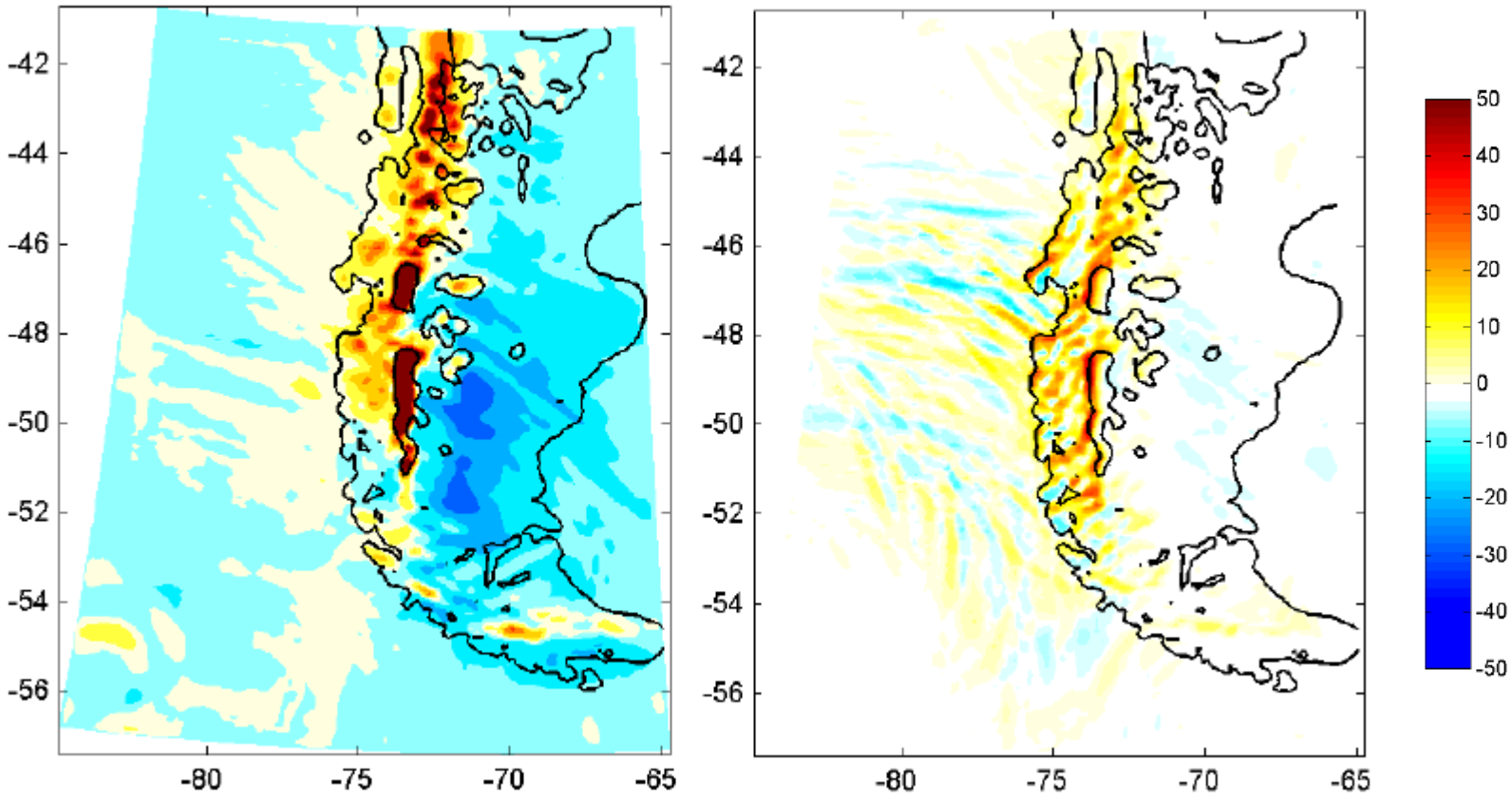


Resolved

Convective

Control topográfico
(relevante para el clima del pasado muy remoto)

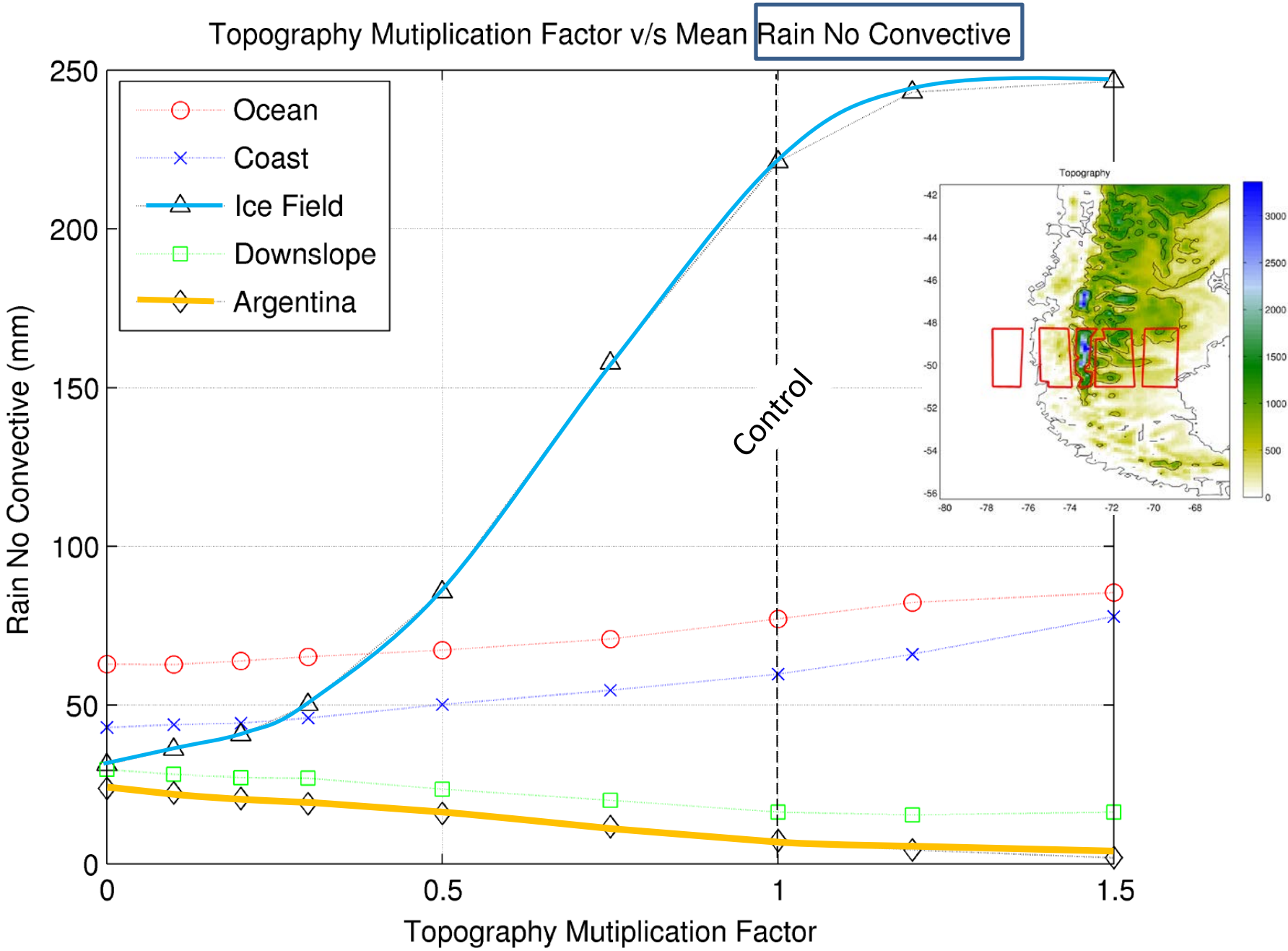
48 hr Accumulated Diff Precip (CTR-Ntopo)



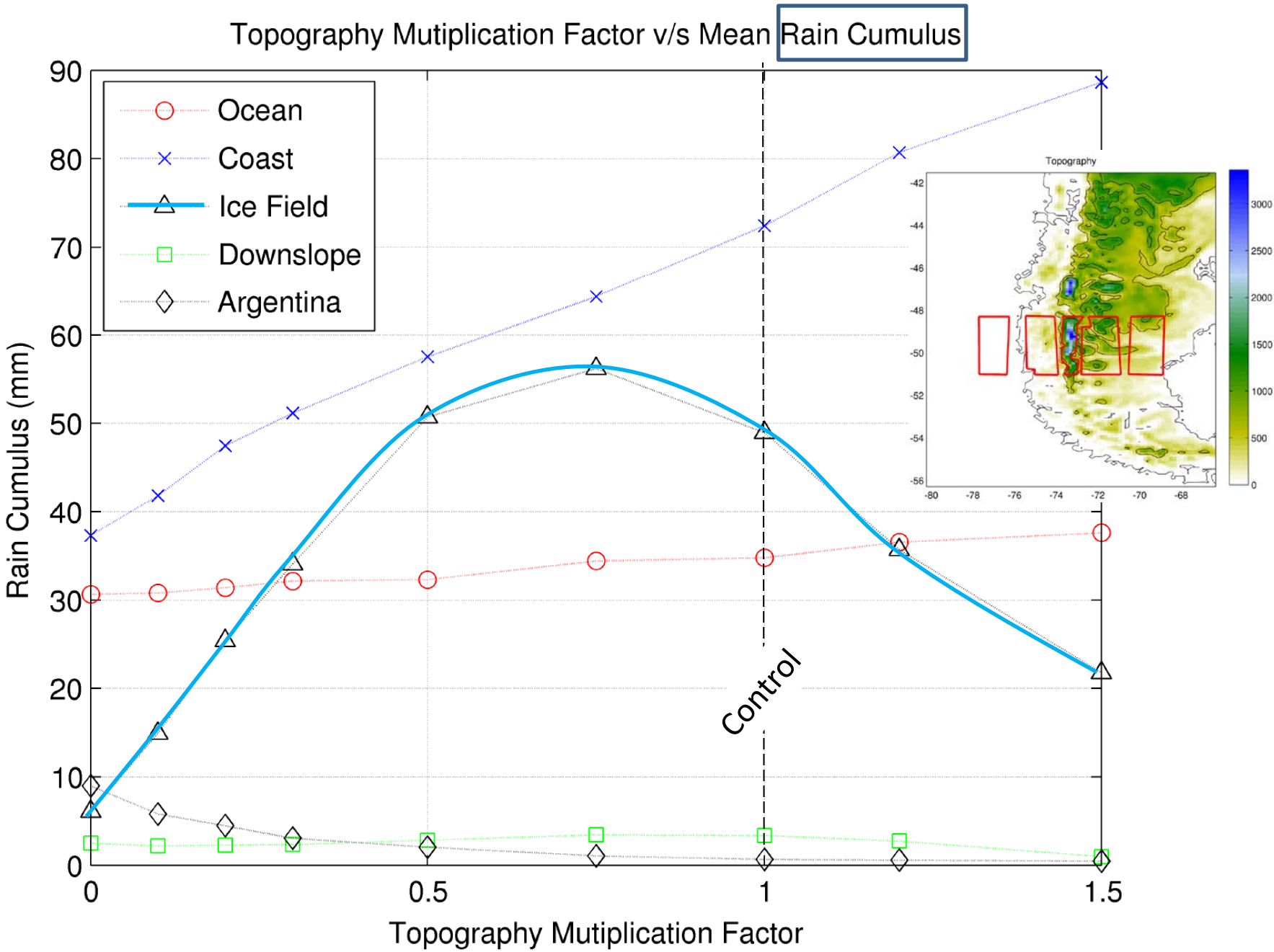
Resolved

Convective

Gonzalez and Garreaud 2017?



Gonzalez and Garreaud 2017?

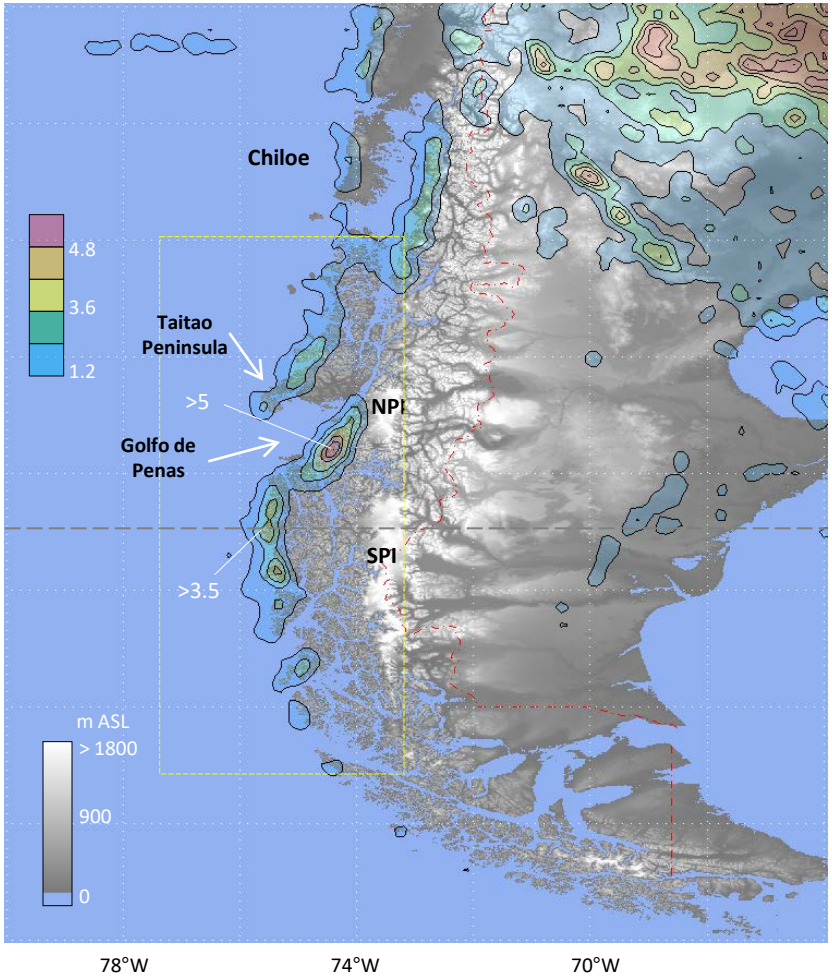


Gonzalez and Garreaud 2017?

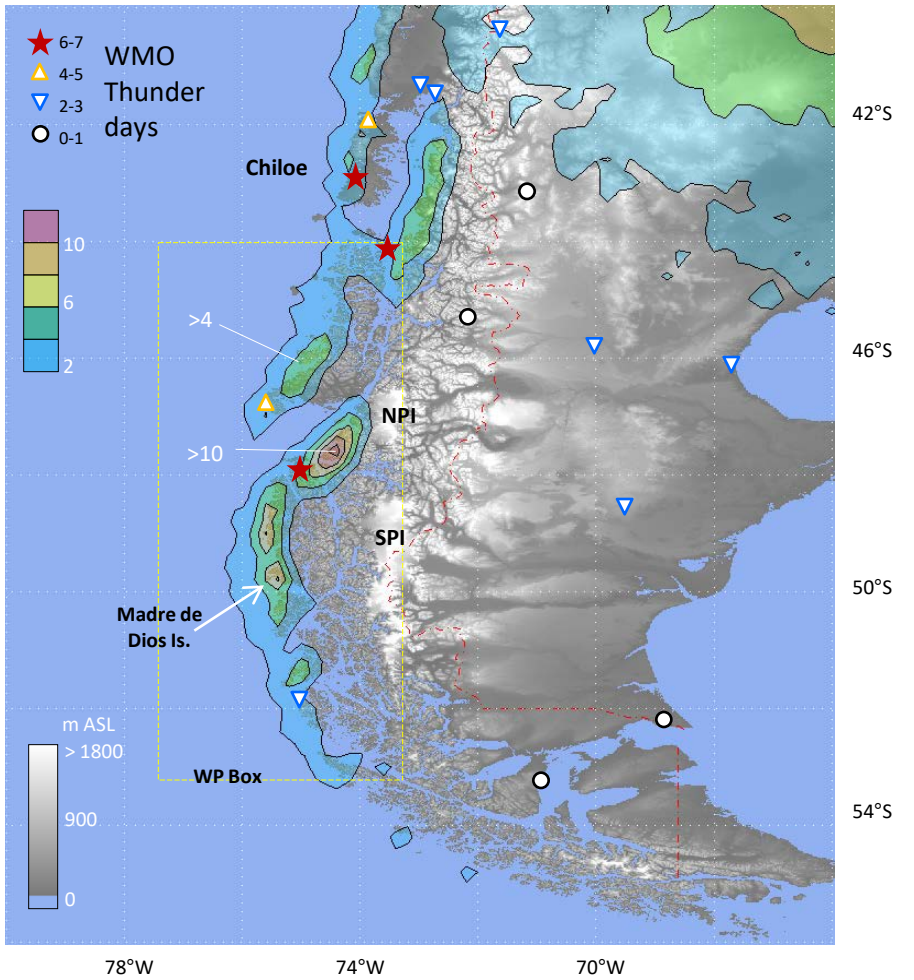
Distribución Espacial

Patrón de densidad similar entre años (pese a cambio de ED)

Lightning density, 0.1×0.1 lat-lon boxes



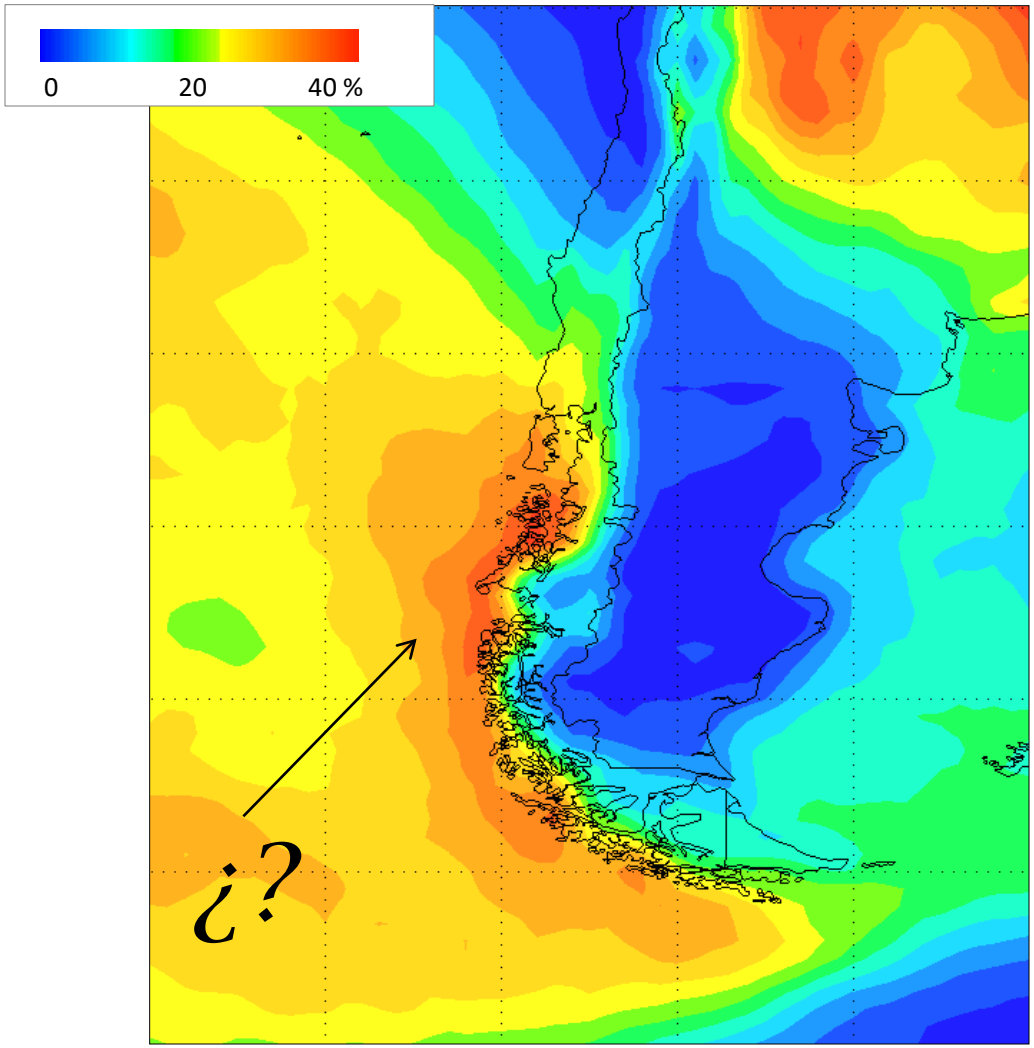
Number of lightning-days, 0.2×0.2 lat-lon boxes



Garreaud and Nicora 2014

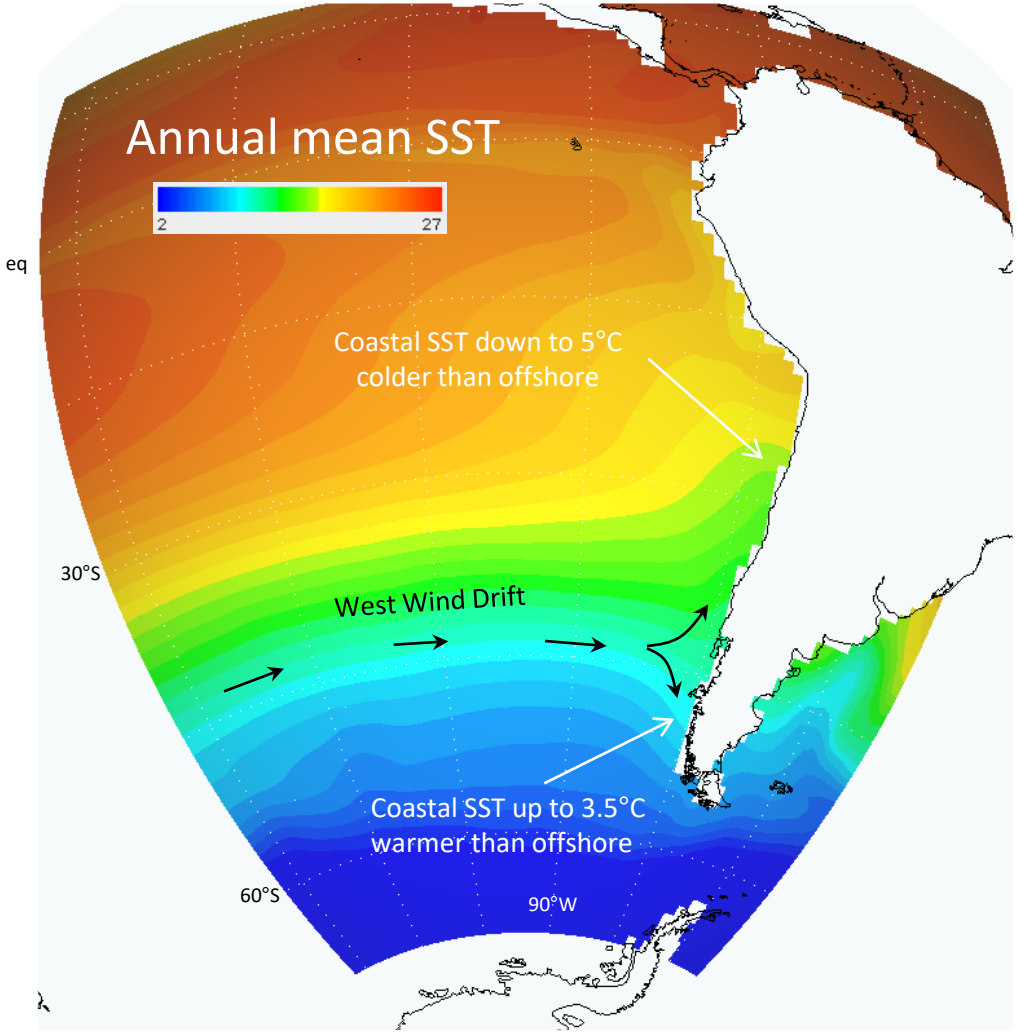
Frecuencia de días con LI≤0.5…similar a CAPE>0

Datos CFSR. Notar máximo de cond. Inestables sobre Patagonia Oeste…



Garreaud and Nicora 2014

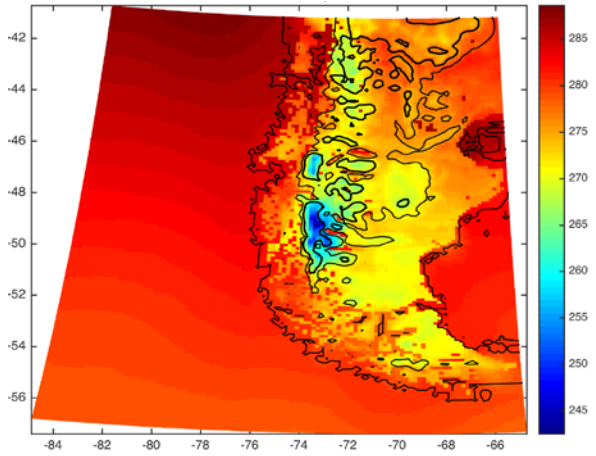
El máximo de ocurrencia de cond. Inestables sobre Patagonia podría estar asociado a mayor TSM en esta región



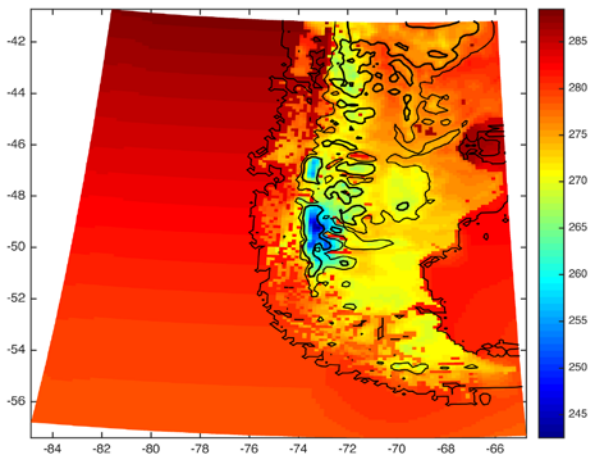
Garreaud and Nicora 2014

SST Experiments

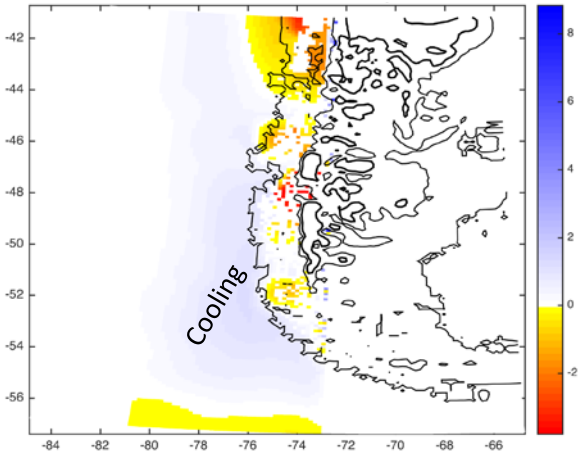
Observed SST



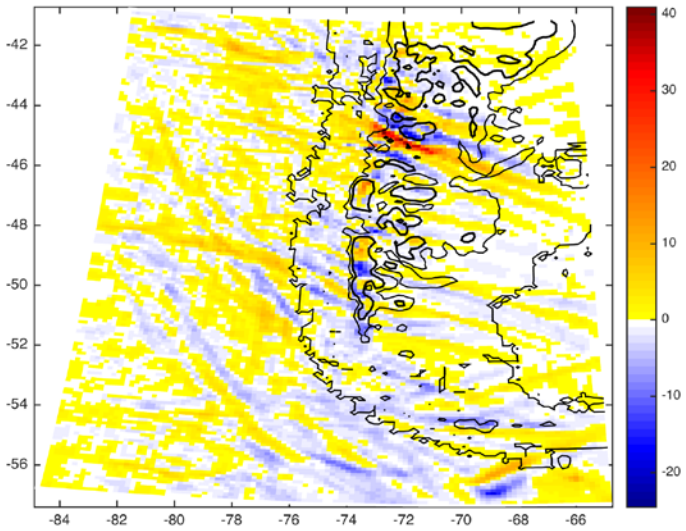
Modified SST



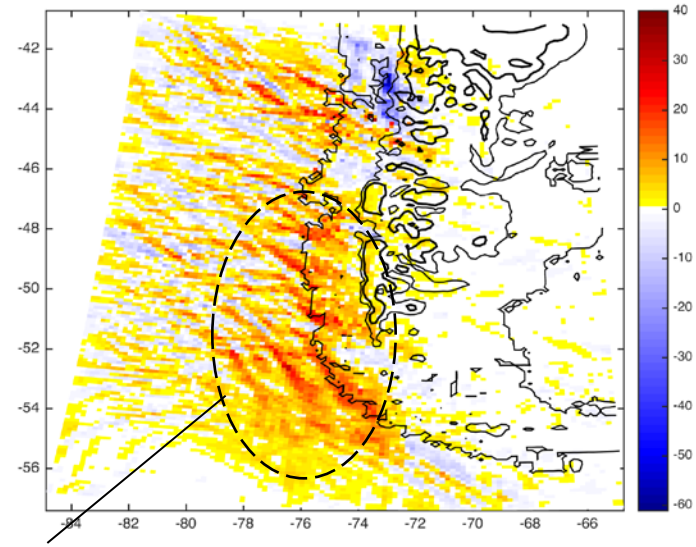
Difference



ΔP(grid-scale): CTR-MOD



ΔP(Convective): CTR-MOD



Warm anomaly increases rainfall (up to 70%)

Gonzalez and Garreaud 2017?

Avances en Precipitación Orográfica

Muchas preguntas pendientes

Necesitamos mas mediciones…muy bien pensadas

Necesitamos simulaciones para probar hipótesis