Cut-off lows in the Southern Hemisphere
Climatology and two cases of study

René D. Garreaud
Departament of Geophysics
Universidad de Chile
Santiago, Chile

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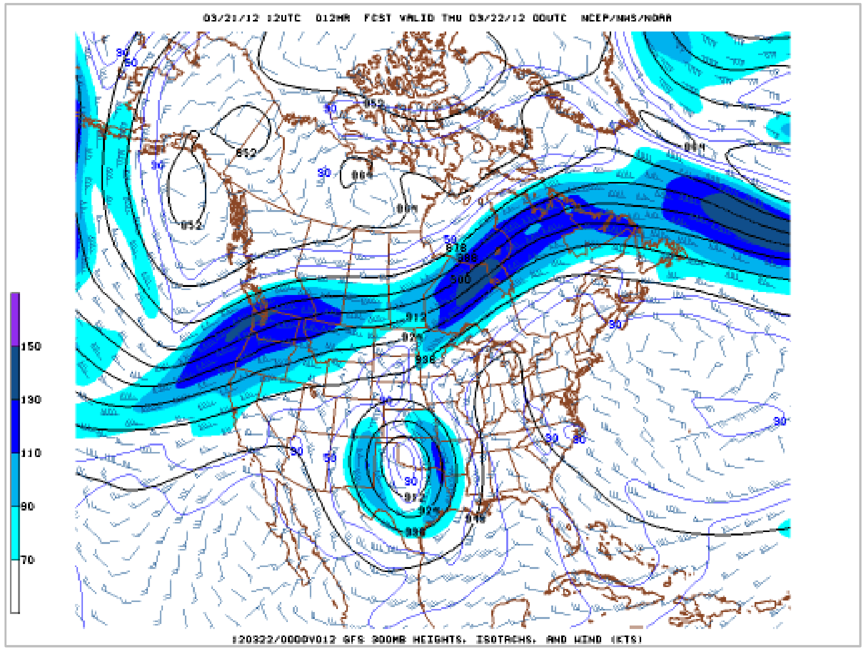
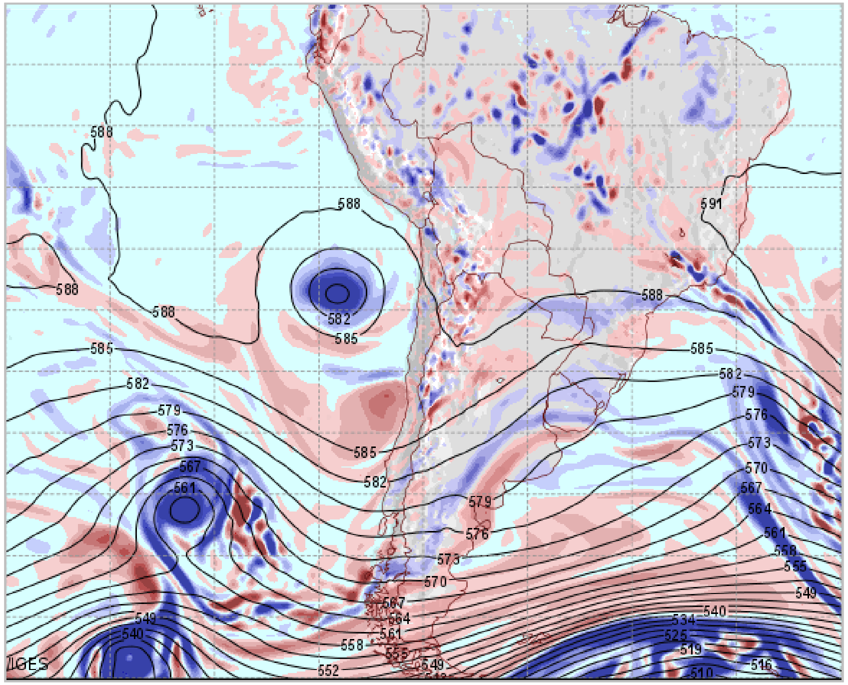
University at Albany - SUNY

Outline

- Structure and evolution
- Climatological distribution
- Why COLs are so frequent/persistent off western South America
- The March 2015 Atacama rainstorm

Cut off Lows…

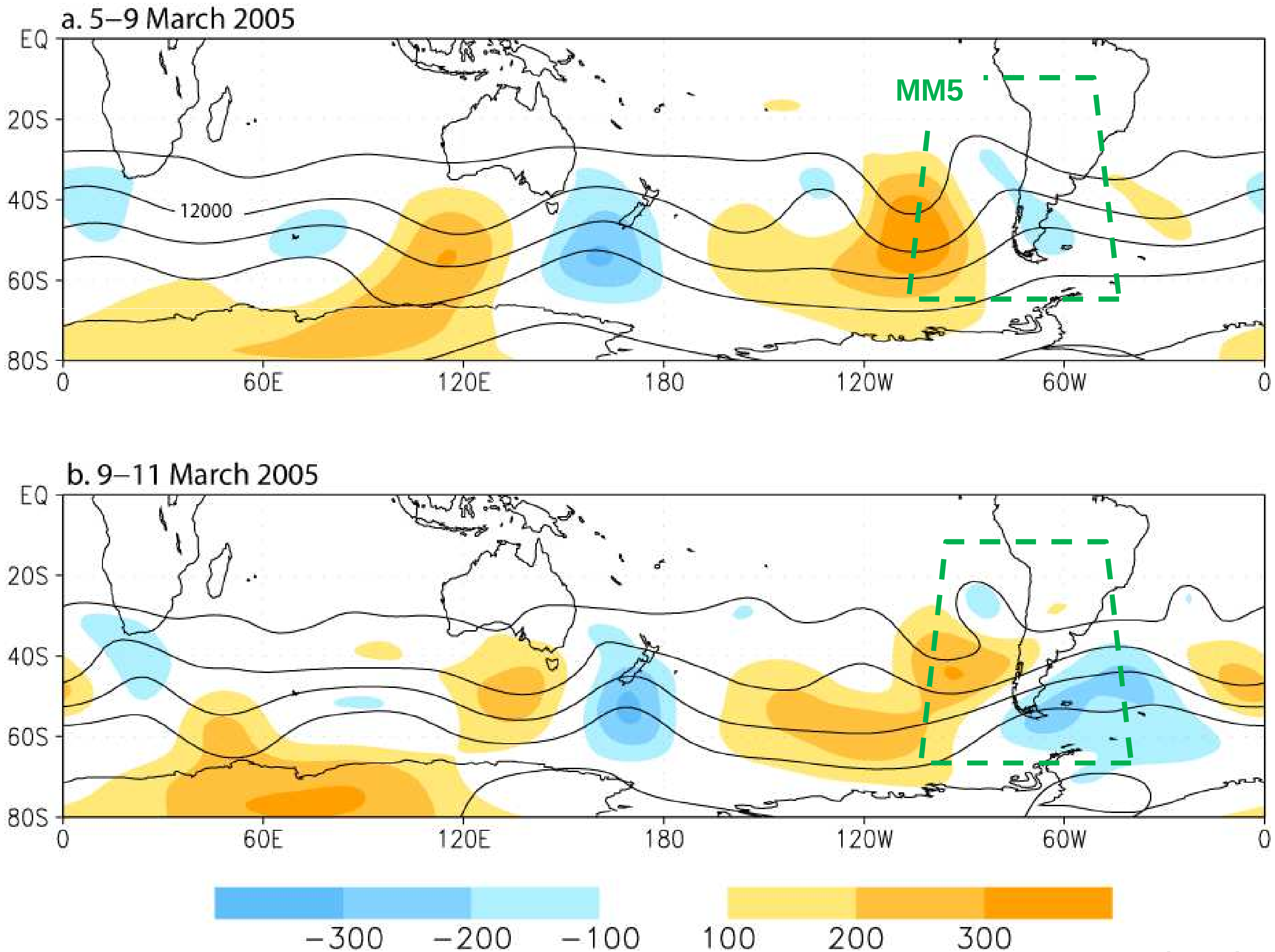




- Horizontal scale of a few hundred km.
- Lifecycle of several days
- Erratic displacement, hard to predict.
- Can cause deep convection and intense precipitation (case study 2)
- Can also bring strong winds, heavy snowfall, and unusual cold onditions to high-elevation regions (e.g., Vuille and Ammann 1997)
- Increase stratosphere–troposphere exchange (STE) of trace gases

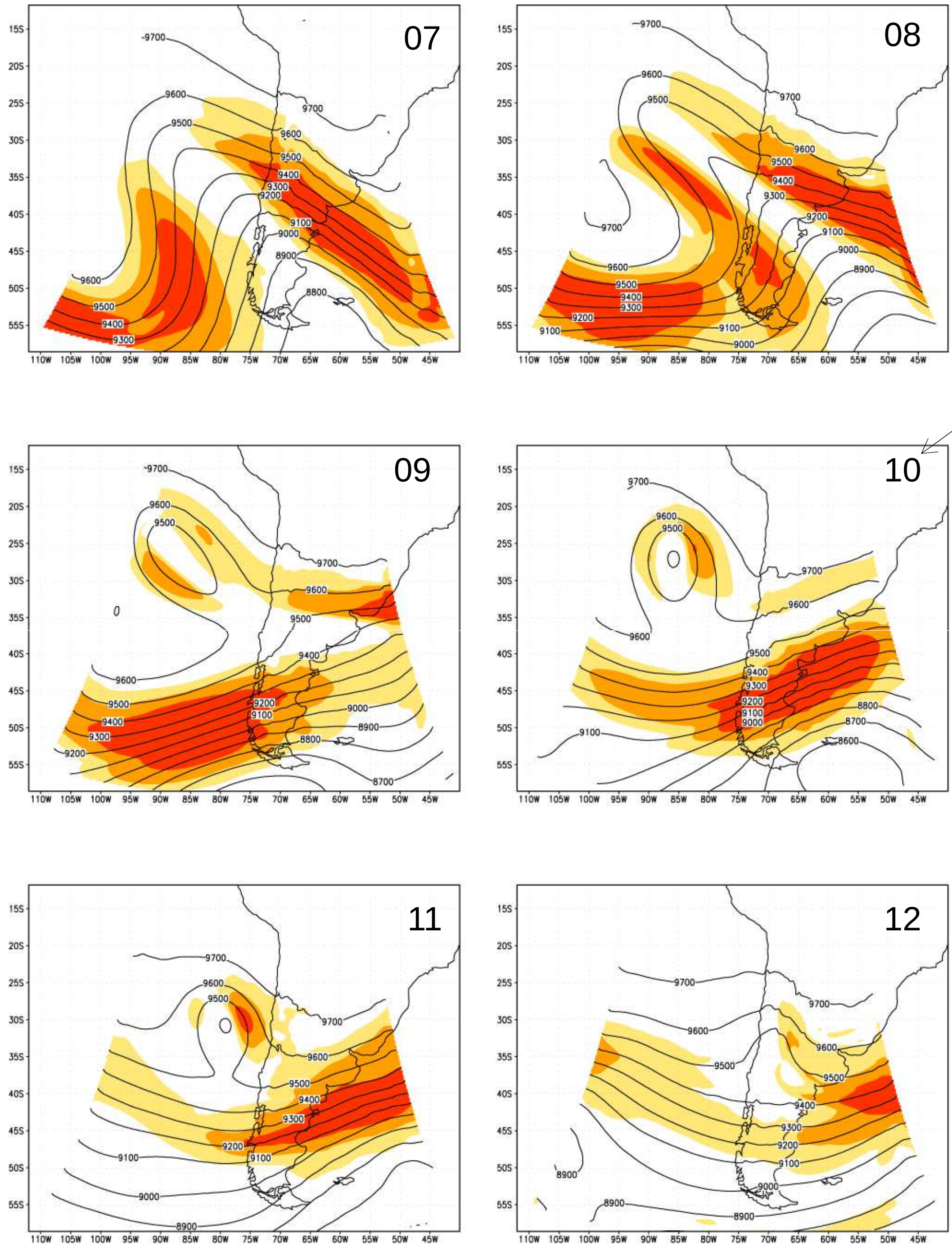
COL structure and evolution

To illustrate the structural evolution of a typical COL in the SH we integrated MM5 (25 km resolution) for a 6 day period forced by NCEP-NCAR Reanalysis (2.5x2.5 lat-lon) in their lateral boundaries. Full topography and standard parameterizations.



Garreaud and Fuenzalida 2007

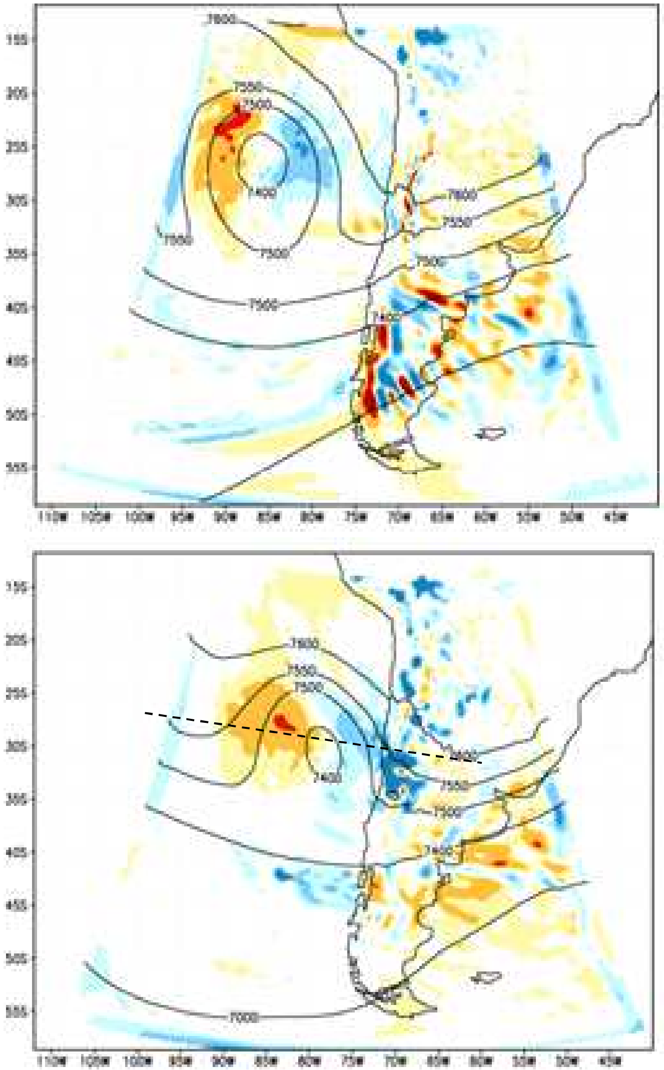
Geopotential height and wind speed at 300 hPa



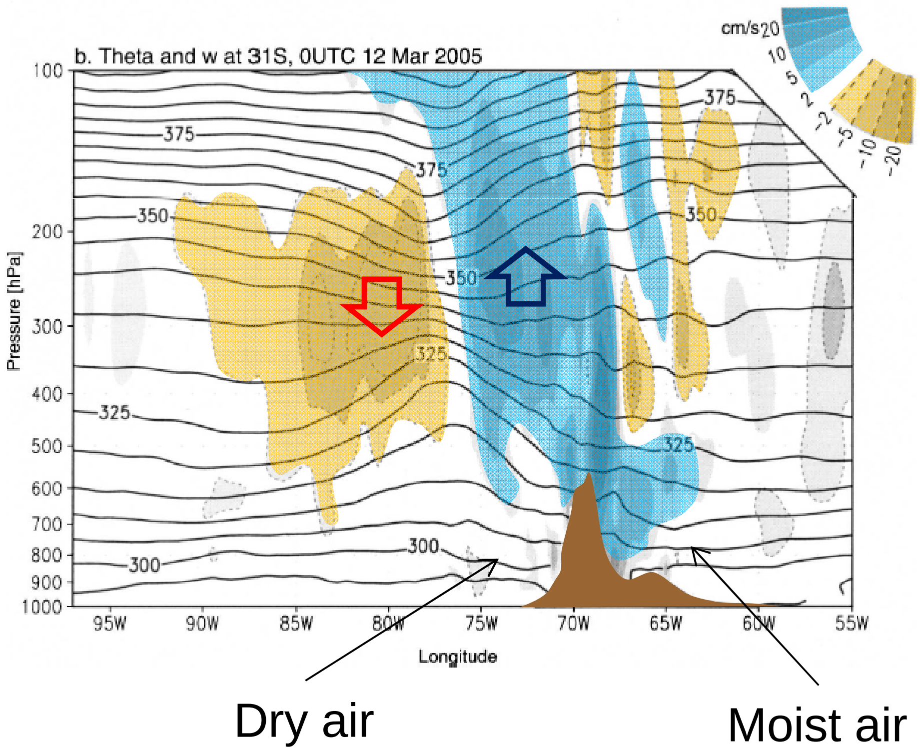
Day of March 2005
18:00 UTC

Garreaud and Fuenzalida 2007

COL structure and evolution

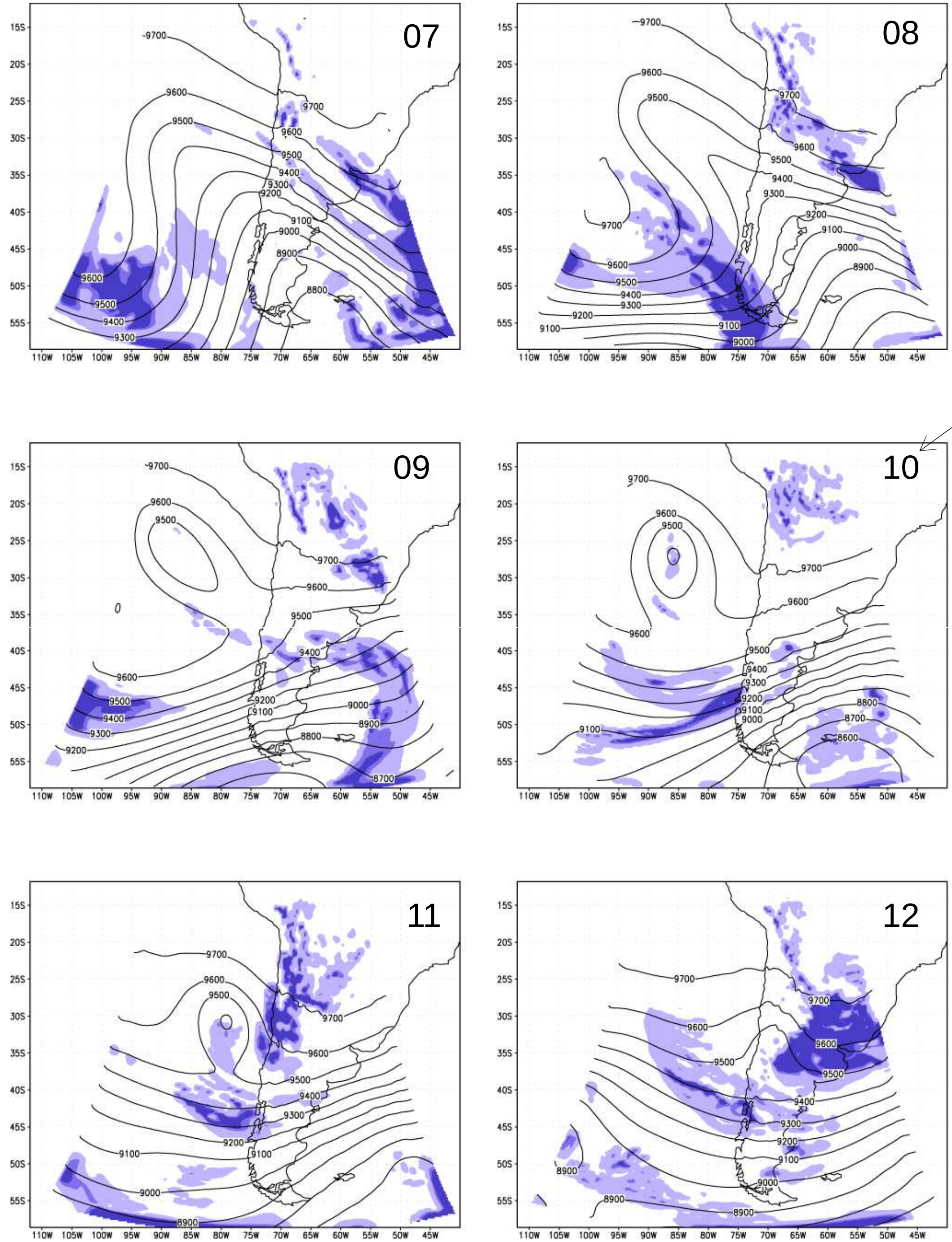


300 hPa geopotential height
and vertical velocity



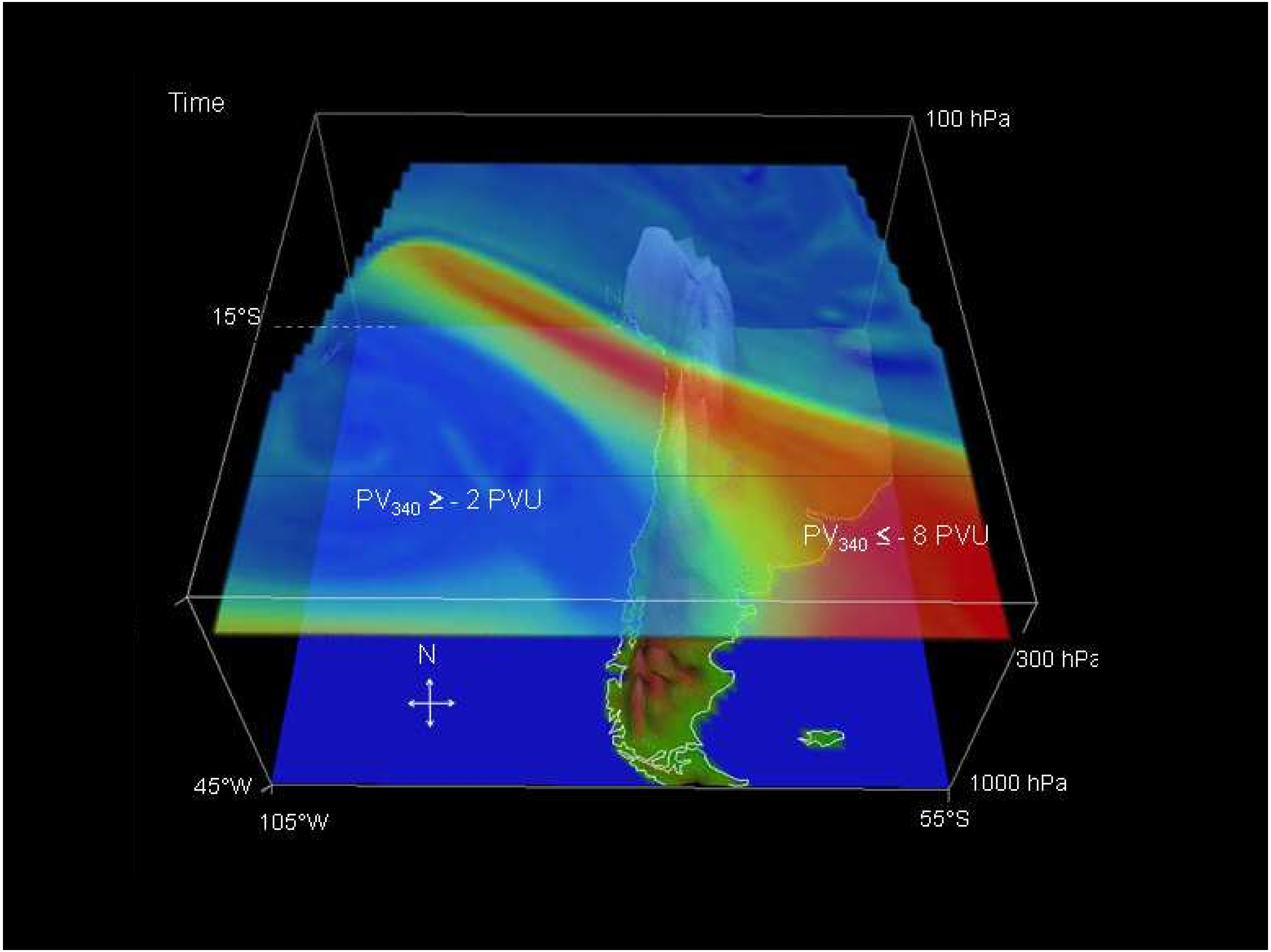
Garreaud and Fuenzalida 2007

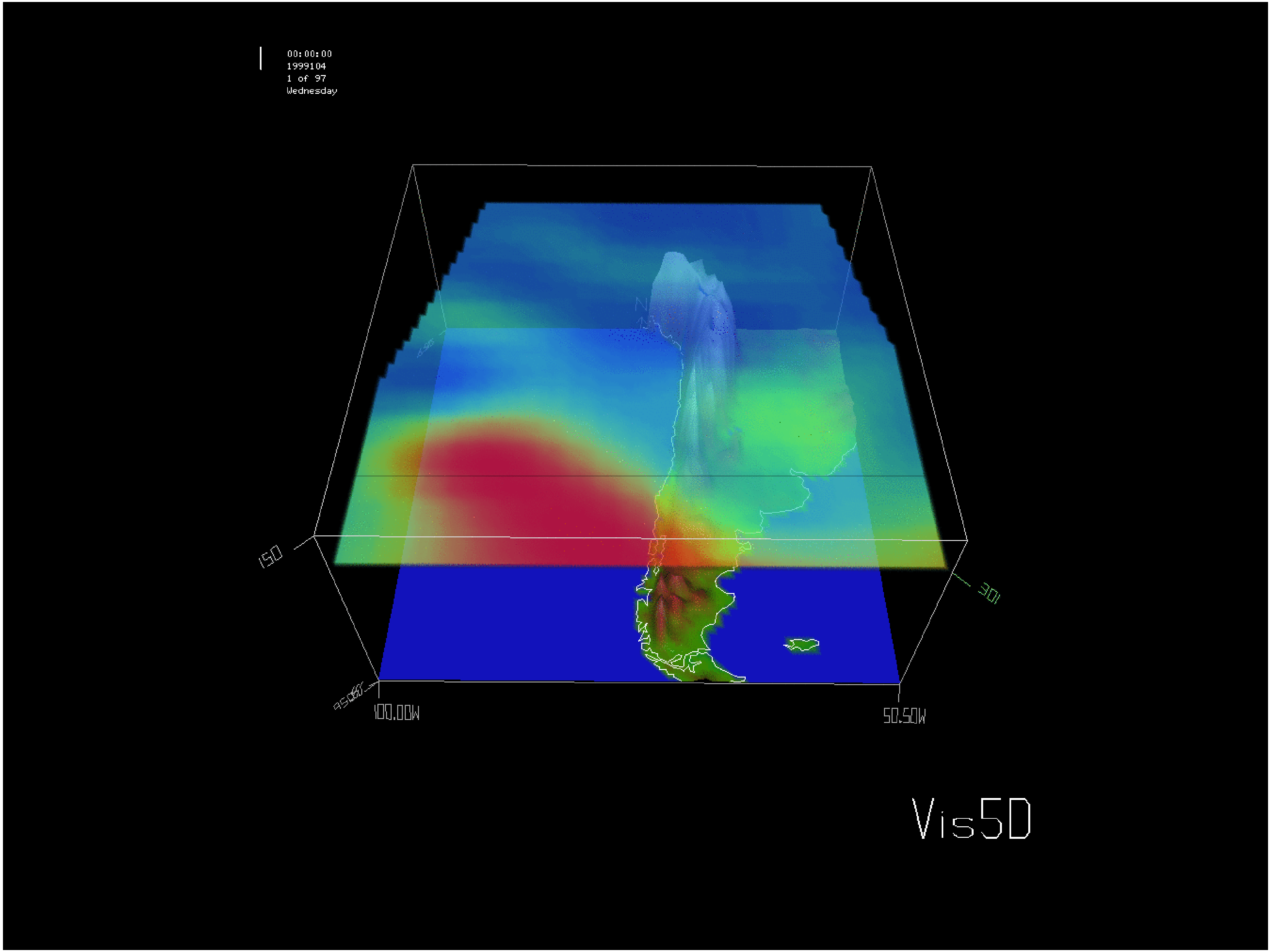
Z(300 hPa) and mid level clouds



Day of March 2005
18:00 UTC

Garreaud and Fuenzalida 2007


Time
100 hPa
15°S
PV340 ≥ - 2 PVU
PV340 ≤ - 8 PVU
N
300 hPa
1000 hPa
45°W
105°W
55°S


00:00:00
1999104
1 of 97
Wednesday
150
30
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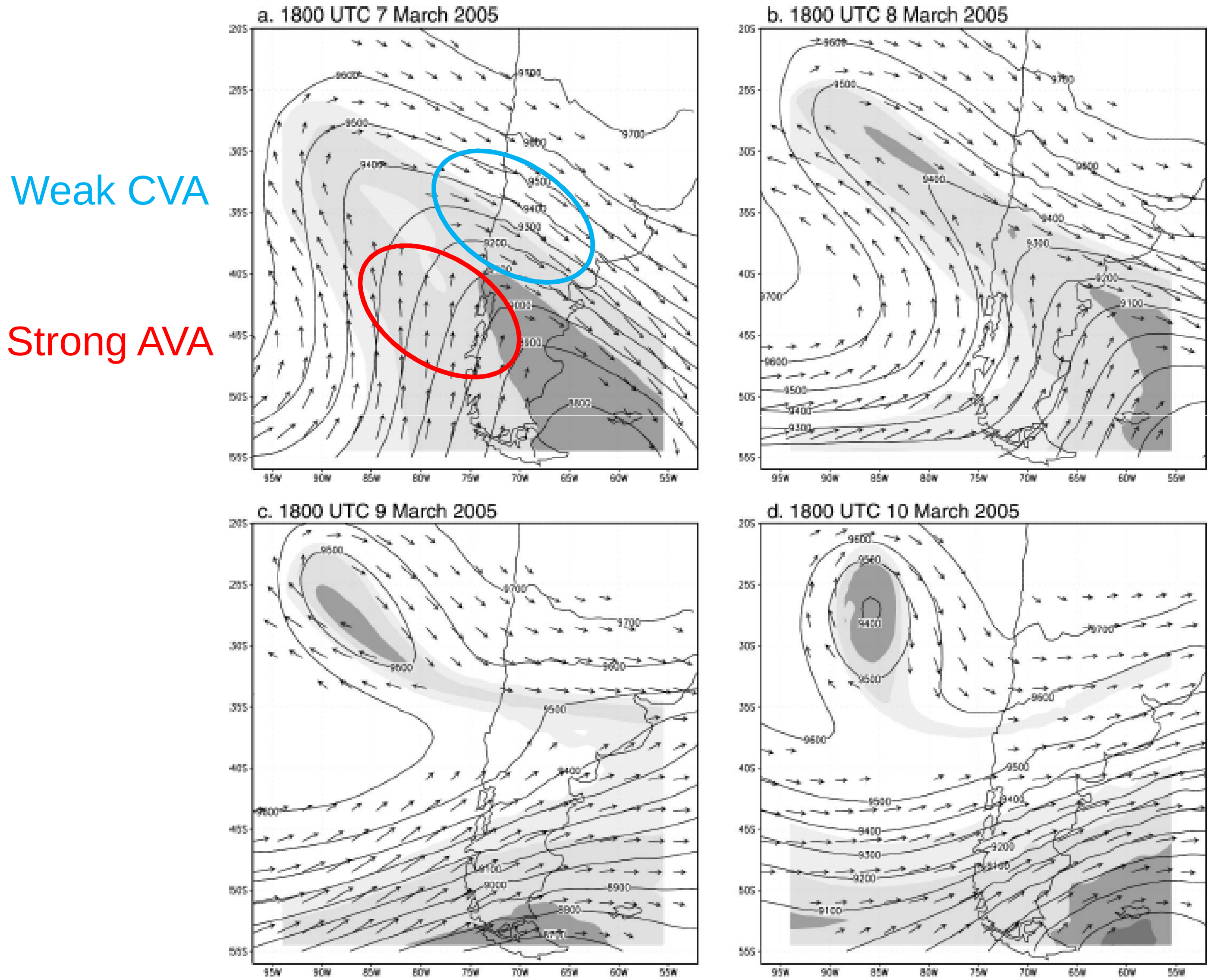
50.50W
Vis5D

COL structure and evolution

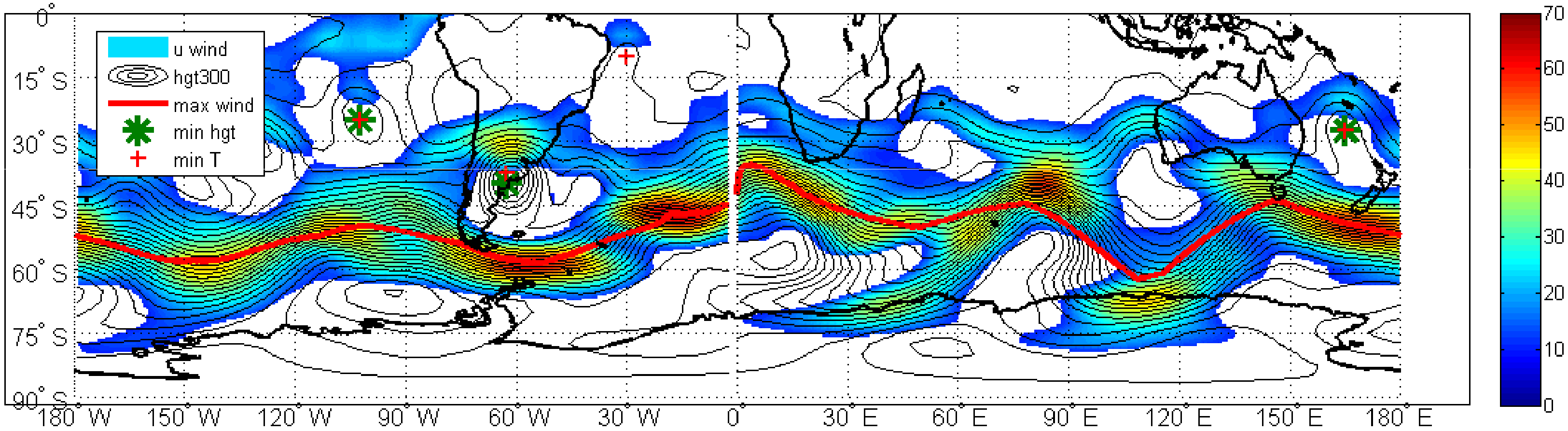
300 hPa geopotential height. Wind vectors and potential vorticity at 340 K



Garreaud and Fuenzalida 2007

Long-term mean distribution of COLs

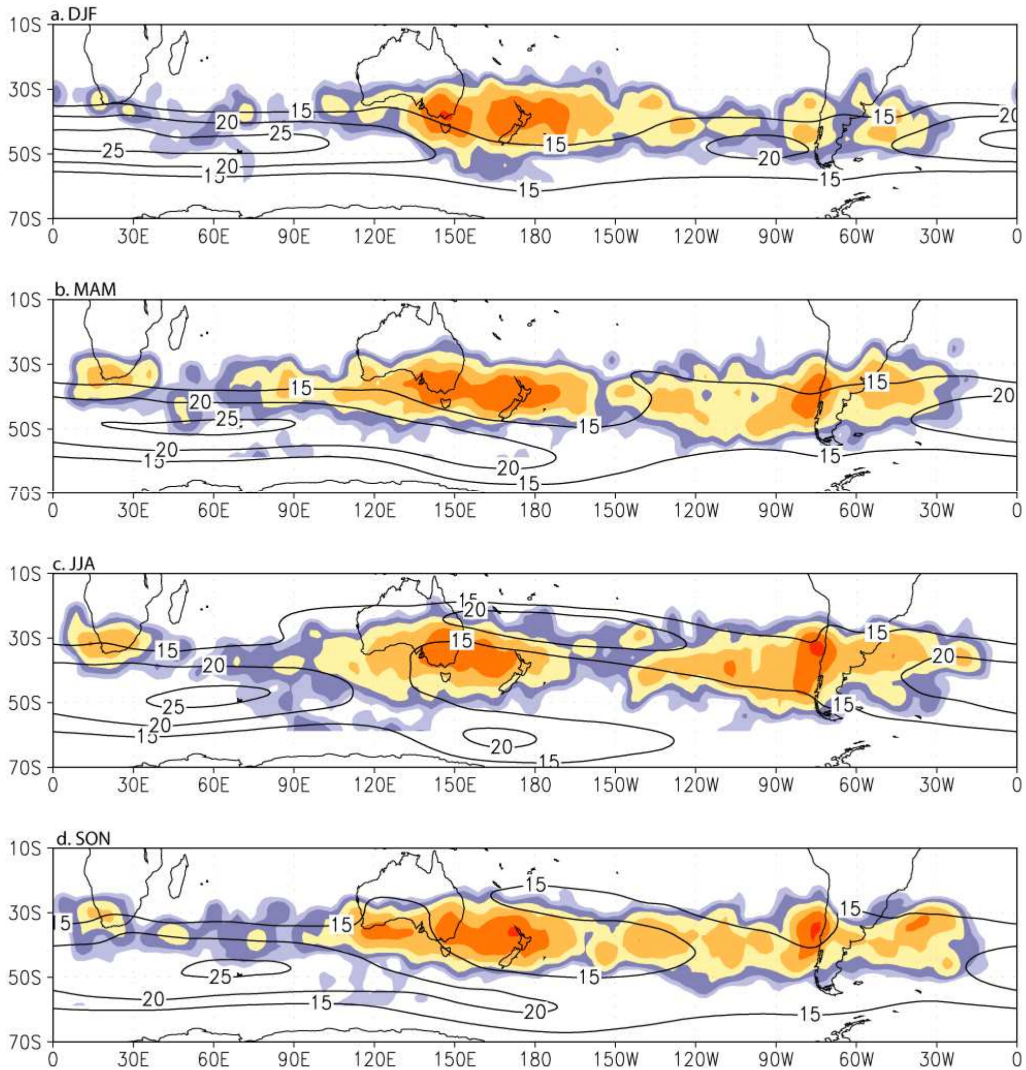
Dataset: NCEP-NCAR Reanalysis (6 hourly, 2.5x2.5 lat-lon grids). 1979-2000, 2015
Search and track(*) closed lows at 300 hPa equatorward of the main westerly jet.
Lows must satisfy criteria of intensity, duration (>1 day) and cold-core at upper levels.



(*) Tracking algorithm following Murray and Simmonds, 1991

Long-term mean distribution of COLs

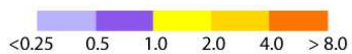
Most COLS in three subtropical regions: Australia, South America and South Africa



Austral Summer
(SA, SAF min)

Austral Winter
(SA max)

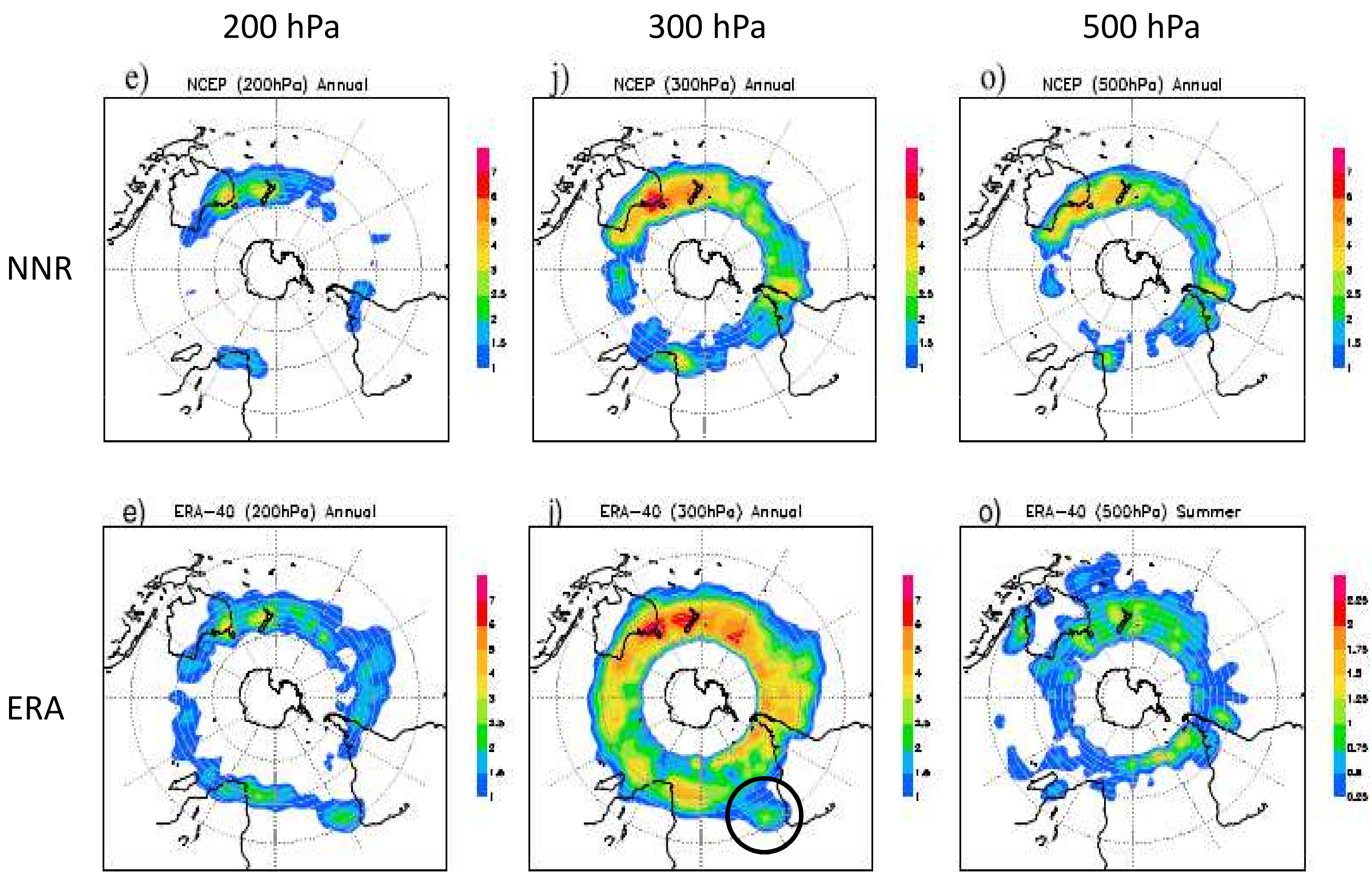
Number of COL centers in 2.5 lat x 2.5 lon boxes (colors) and 500 hPa winds (contours)



Fuenzalida et al. 2005

Annual mean COL distribution

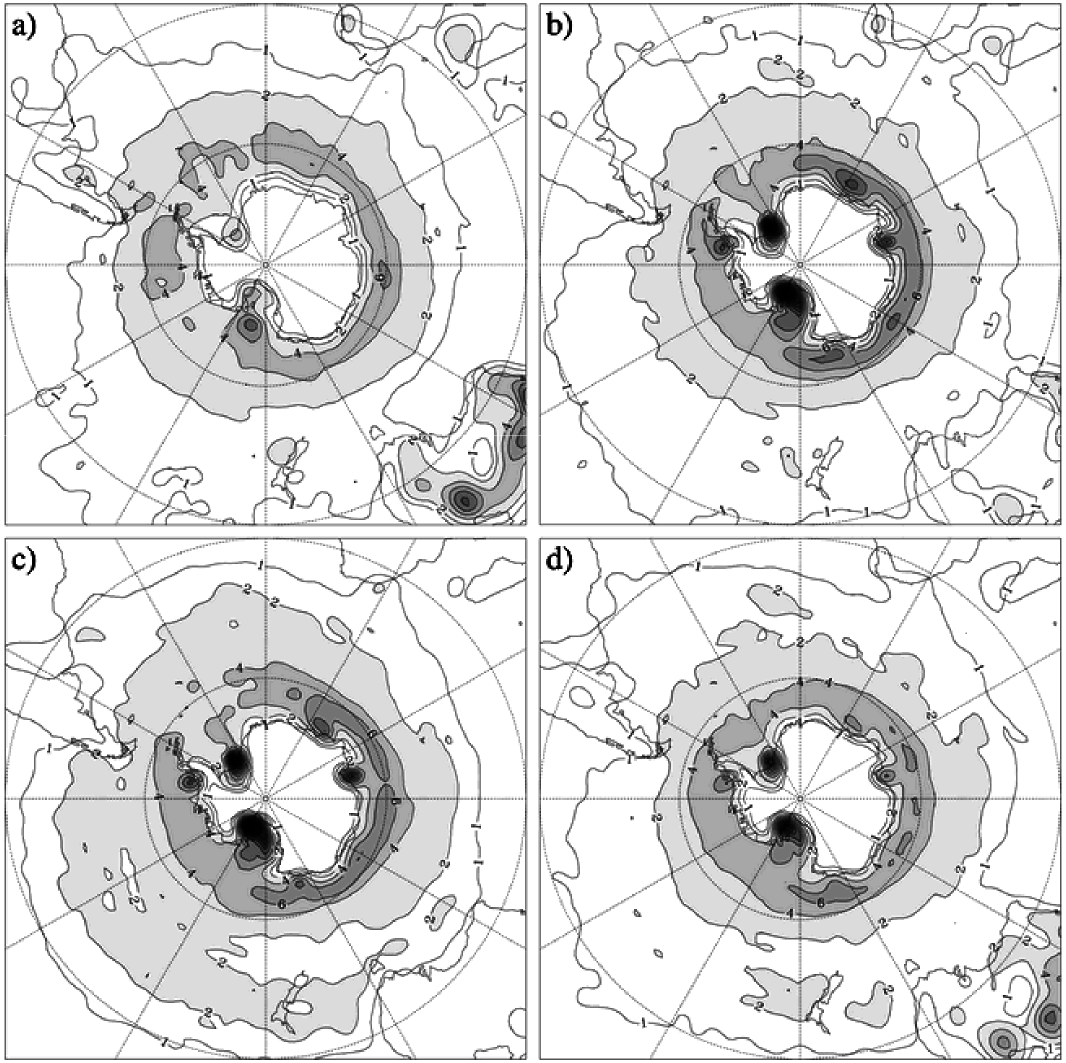
Some changes depending on level of identification and dataset



Reboita et al. 2007

Seasonal distribution of surface cyclones

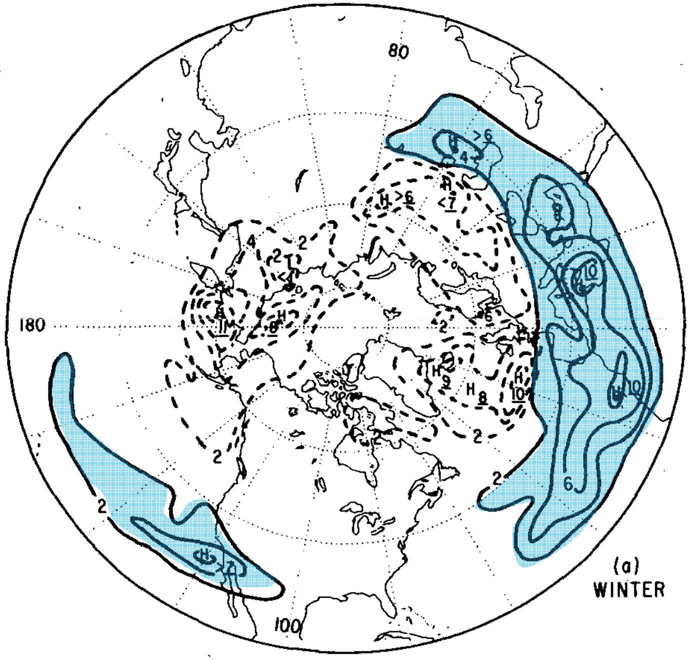
In contrast to COL distribution, surface cyclone density maximizes in a circumpolar band at 60° with less asymmetry



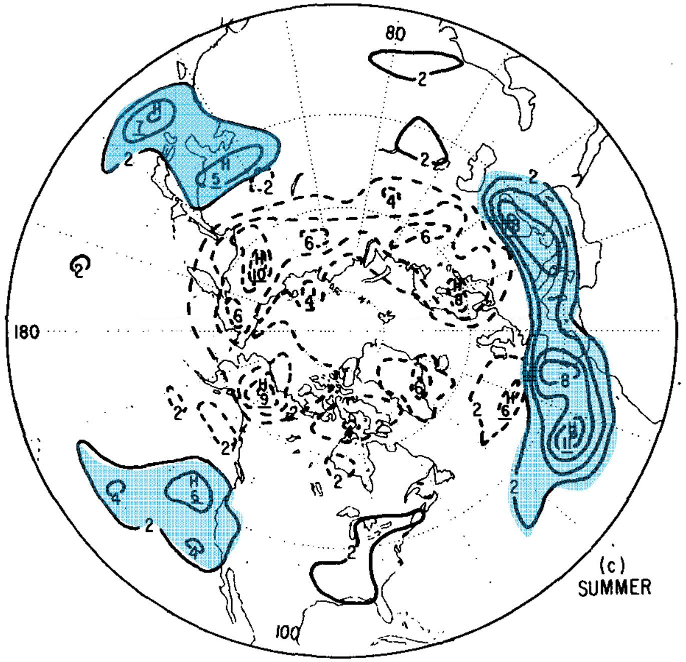
Simmonds and Keay 2000

Annual mean COL distribution in the NH

DJF (NH Winter)



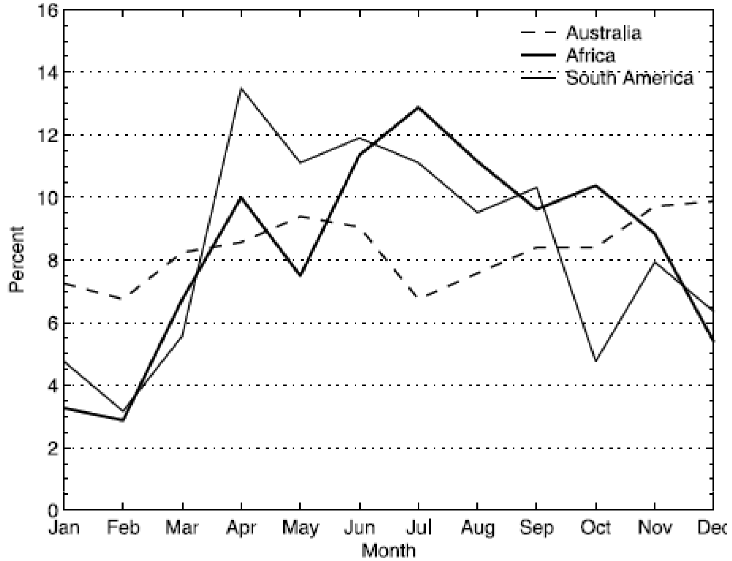
JJA (NH Summer)

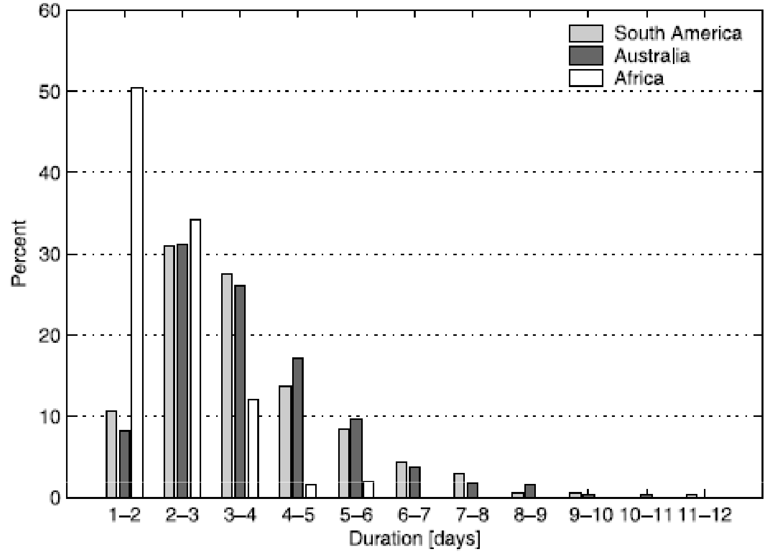


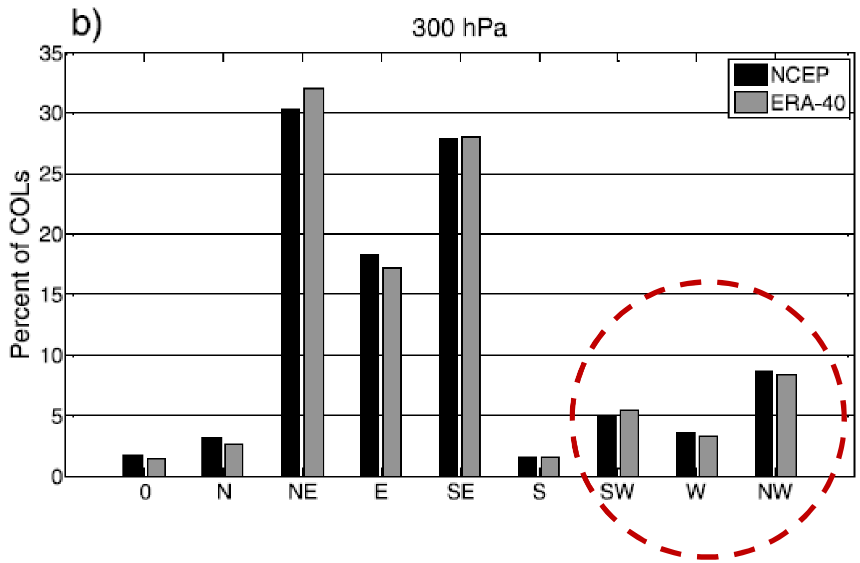
500 hPa closed lows to the south of the Jet (from Bell and Bosart 1989)

Bell and Bosart 1989

Others aspects of COLs in the SH





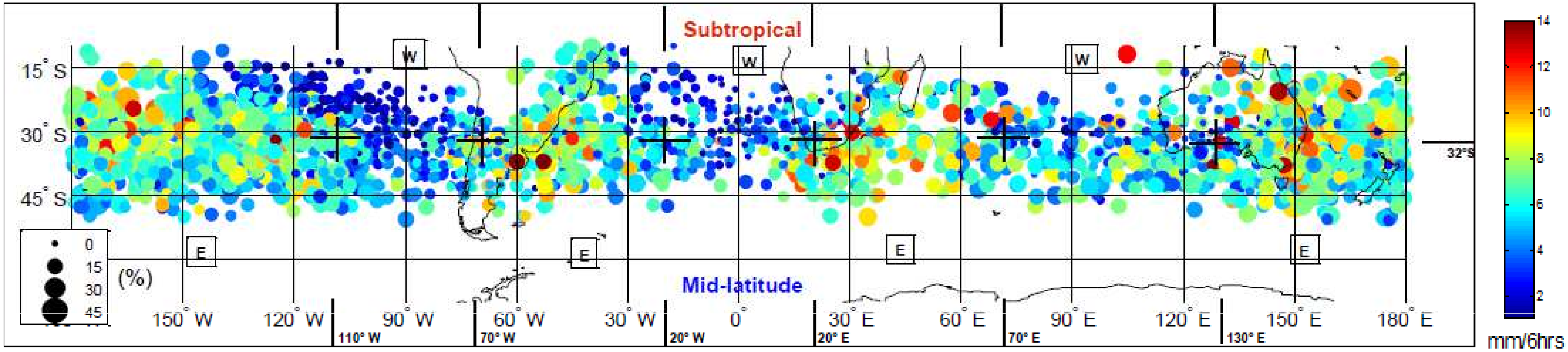


Fuenzalida et al. 2005
Reboita 2008

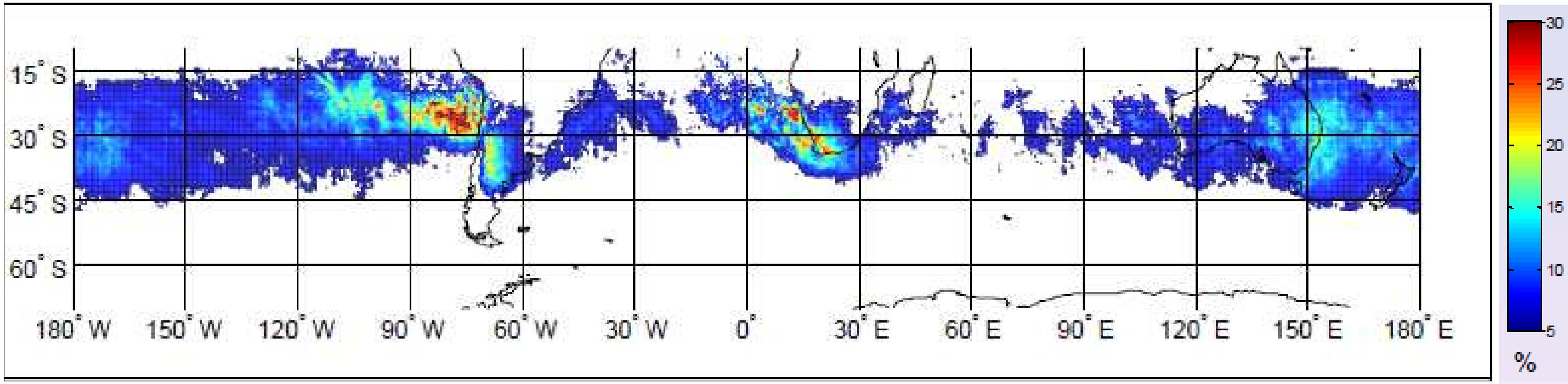
Others aspects of COLs in the SH

For each COL we calculate the precipitation (TRMM) in a 10°×10° lat-lon box around the COL center.

Area (size) and Intensity (colors) of mean precipitation for each COL



Percentage annual of precipitation accounted by COLs

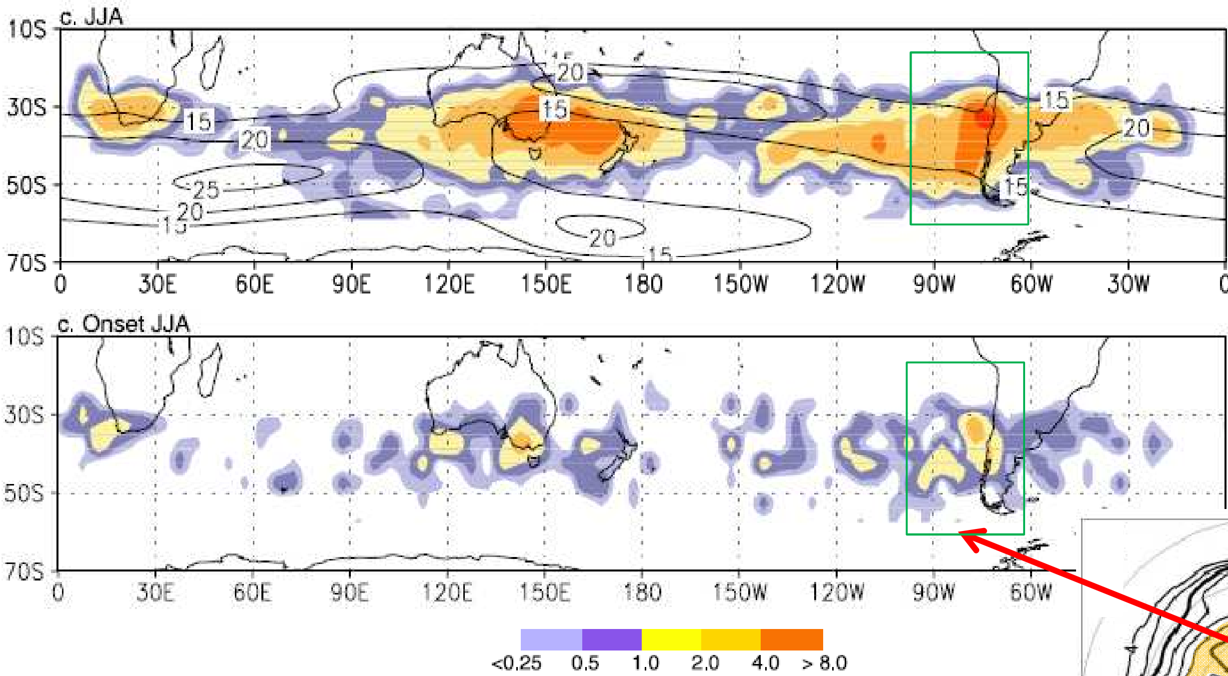


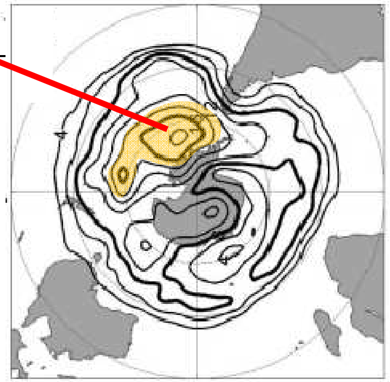
Barahona et al. 2015

COL distribution in the SH

High frequency of COL off the west coast of South America (but in summer) due to:

Dry conditions over the SE Pacific → little diabatic heating → COLs tend to be last longer
Dynamical forcing enhance their genesis (jet exit region, frequent blocking farther south, Andes cordillera)





Blocking anticyclone distribution

Renwick 2005

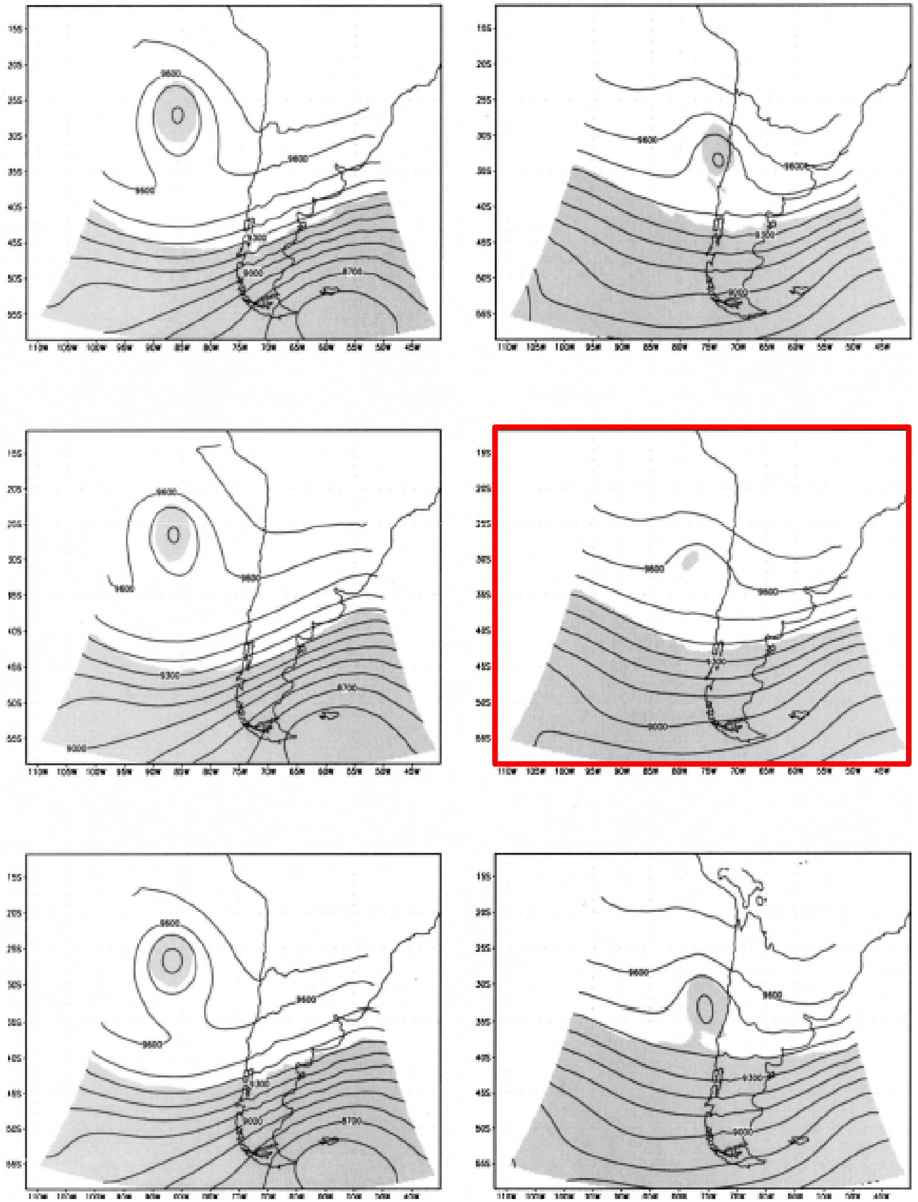
Numerical experiments using WRF

12 UTC 10 March 2005 | 06 UTC 12 March 2005

CTR

*Red Topo (0.2*H)*

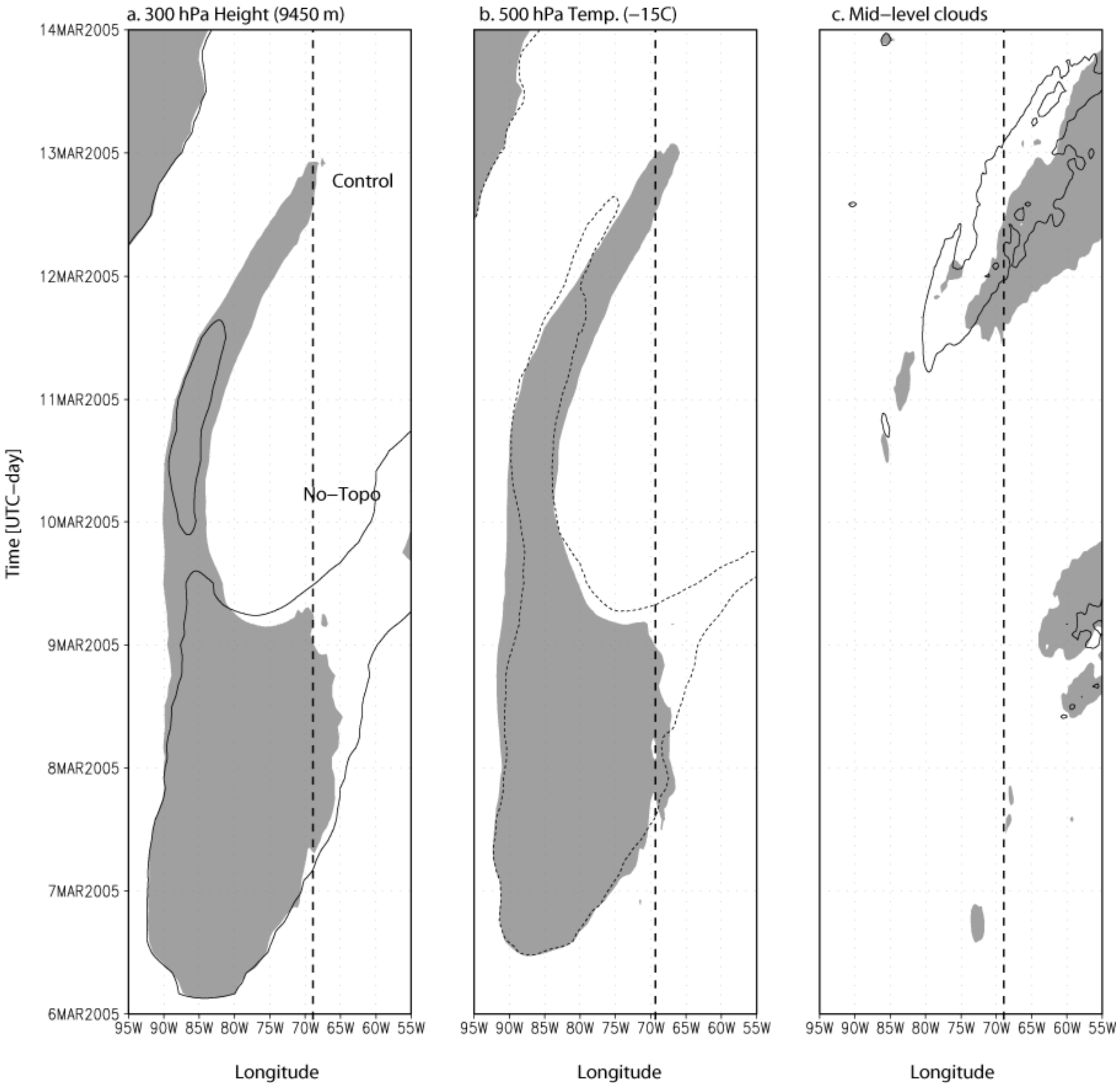
Dry (No SH)



Garreaud and Fuenzalida 2007

Numerical experiments using WRF

Time–longitude diagram of 300-hPa geopotential height averaged between 28° and 32°S.

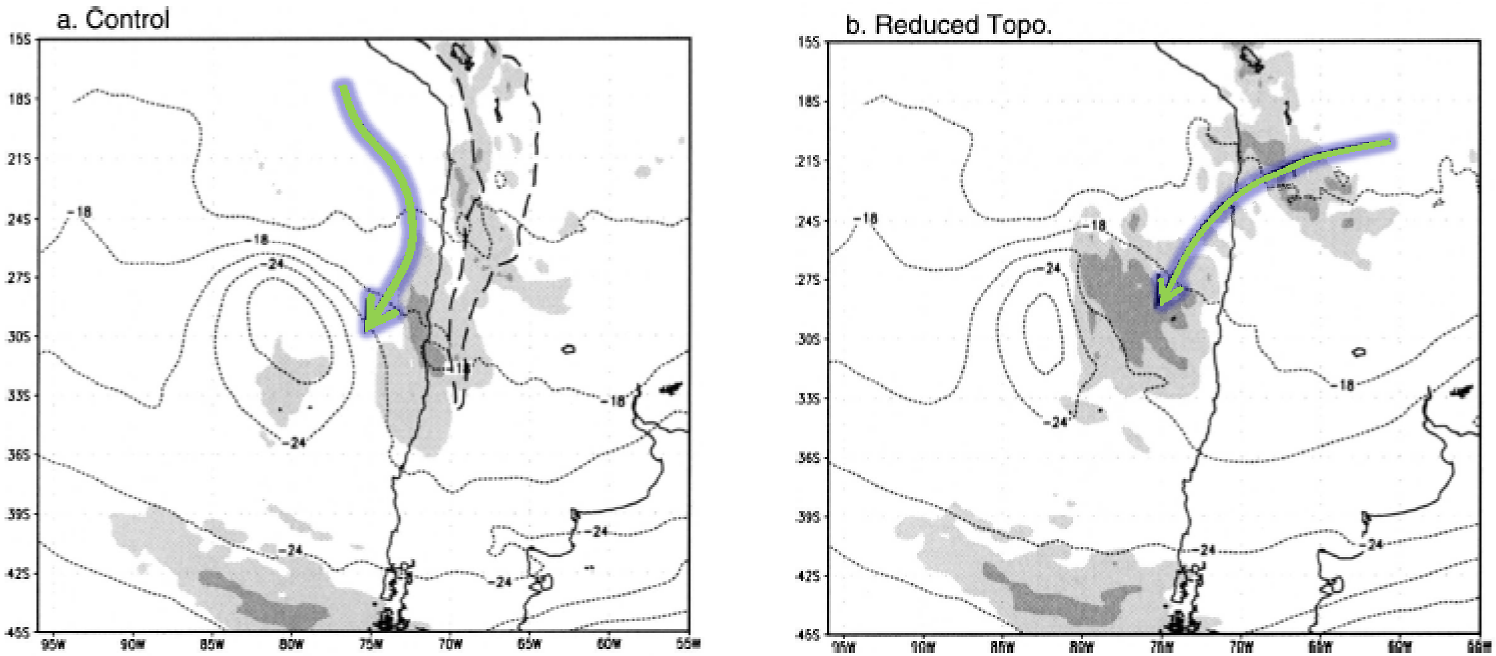


Garreaud and Fuenzalida 2007

Numerical experiments using WRF

400-hPa air temperature and cloud mixing ratio integrated between 600 and 300 hPa at 1800 UTC 11 Mar 2005 in CTR.

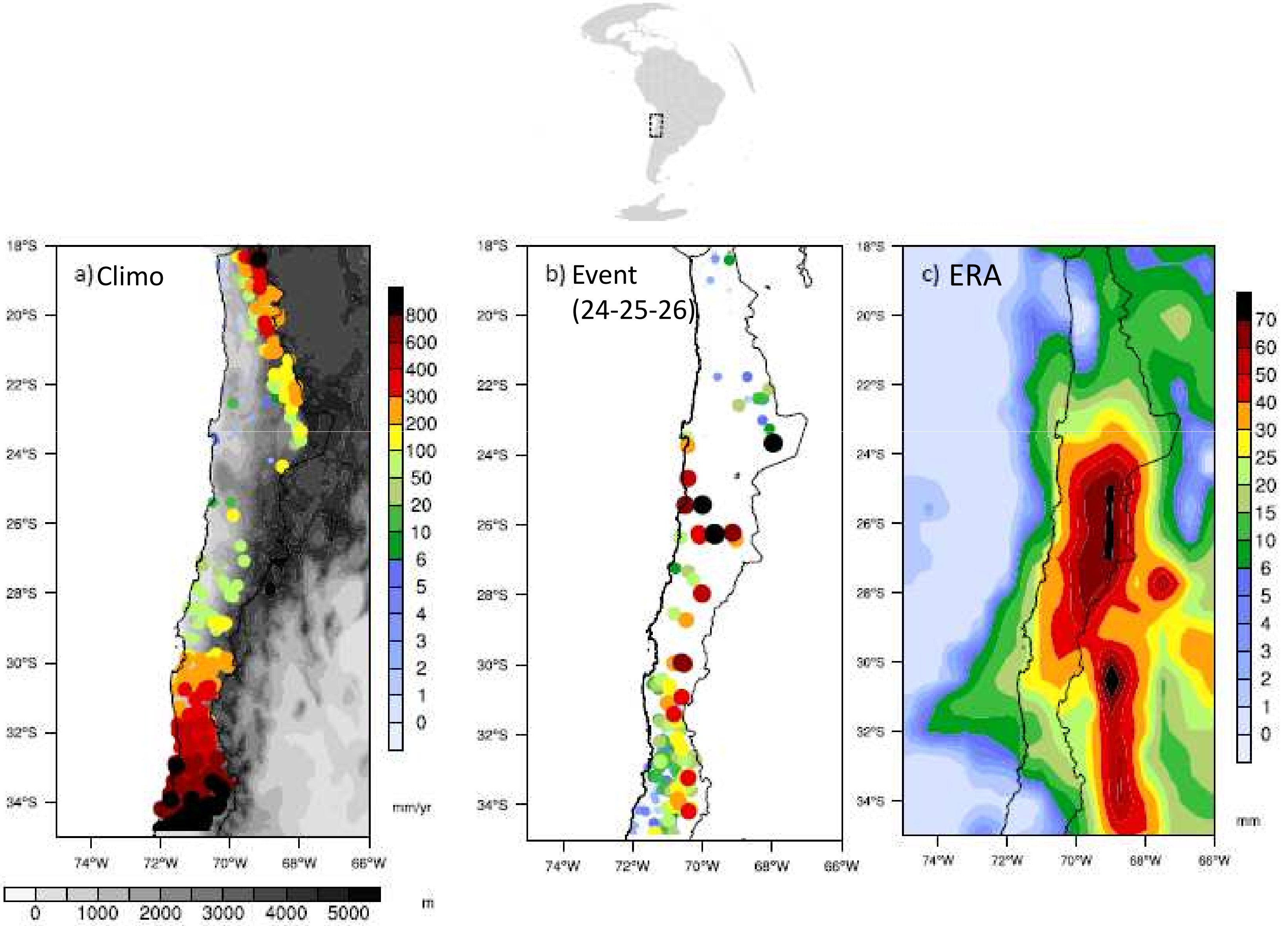
Green arrows are 36 hr back trajectories arriving at the 500 hPa level



Garreaud and Fuenzalida 2007

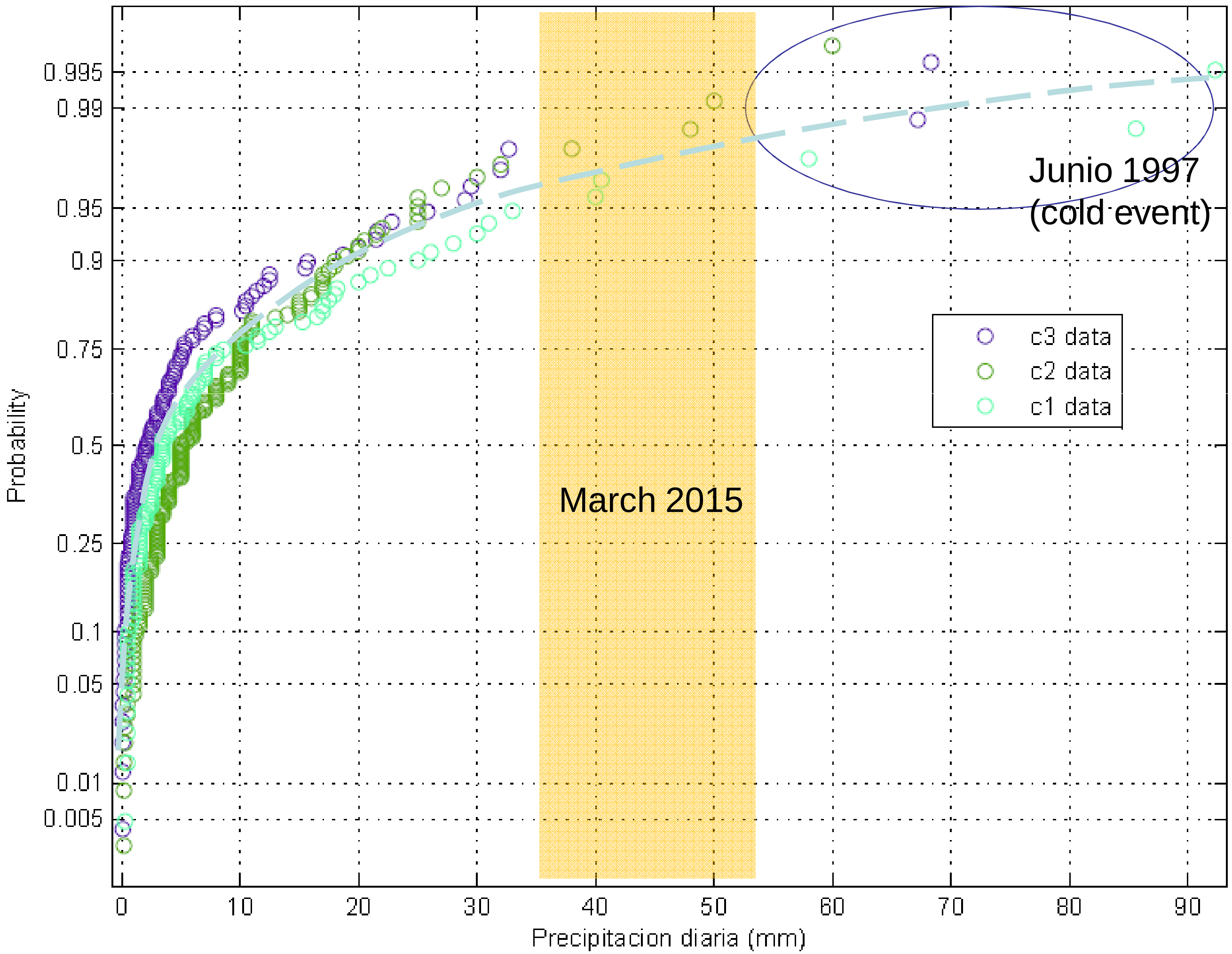
The March 2015 Atacama Storm. Three days of intense rainfall triggered landslides and widespread flooding. More than 80 causalities and major damage to public and private infrastructure. Most acute impact during the event but many problems (e.g. public health) in subsequent months.

Precipitation during the Event

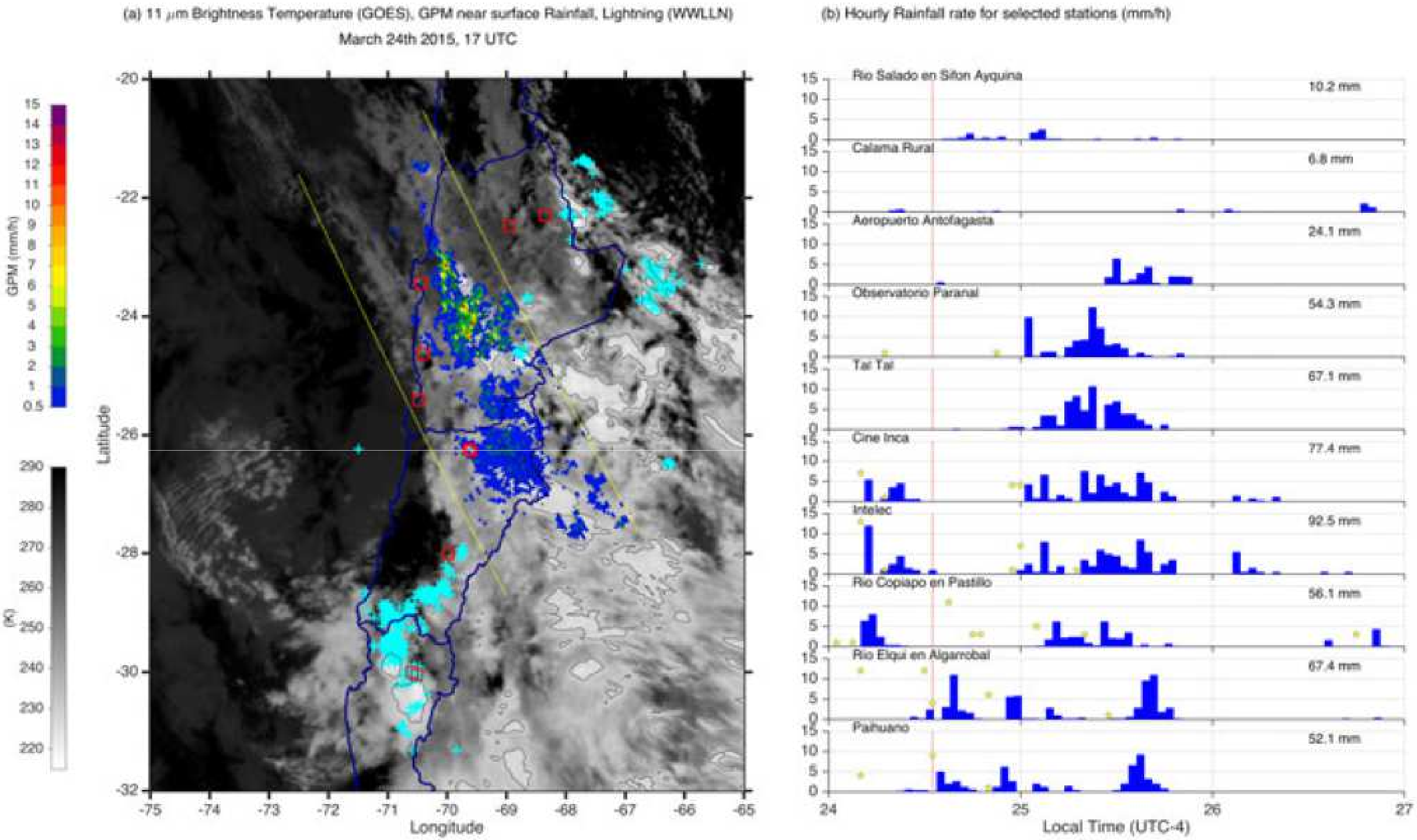


Distribución observada de la Precipitación diaria en estaciones DGA zona de Copiapo (1970-2013)

Precipitación media anual ≈ 15 mm



Precipitation during the Event

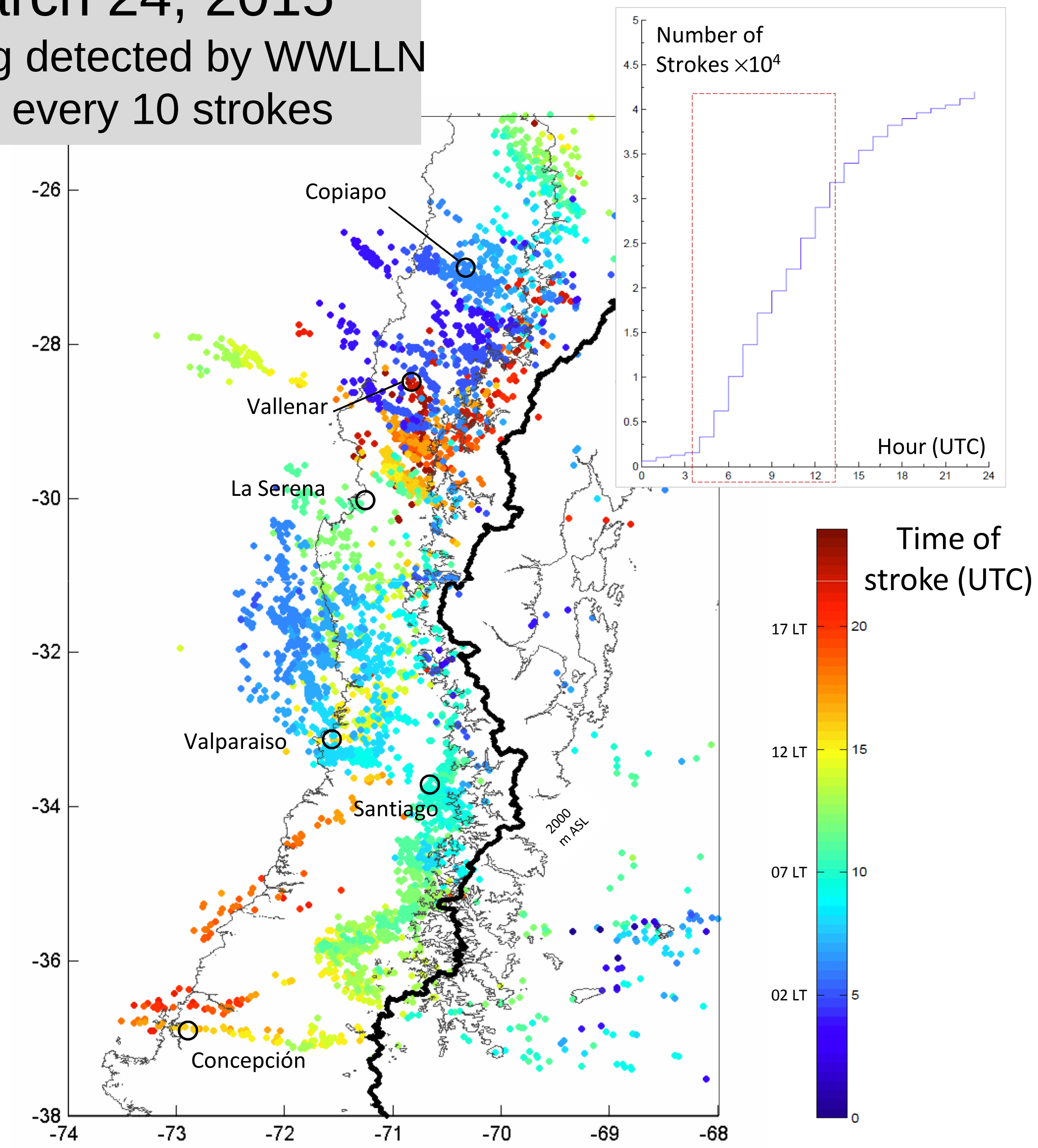


It was a warm storm. Freezing level during the storm remained above 4000 m ASL…much of the Andean slope receive rain instead of snow

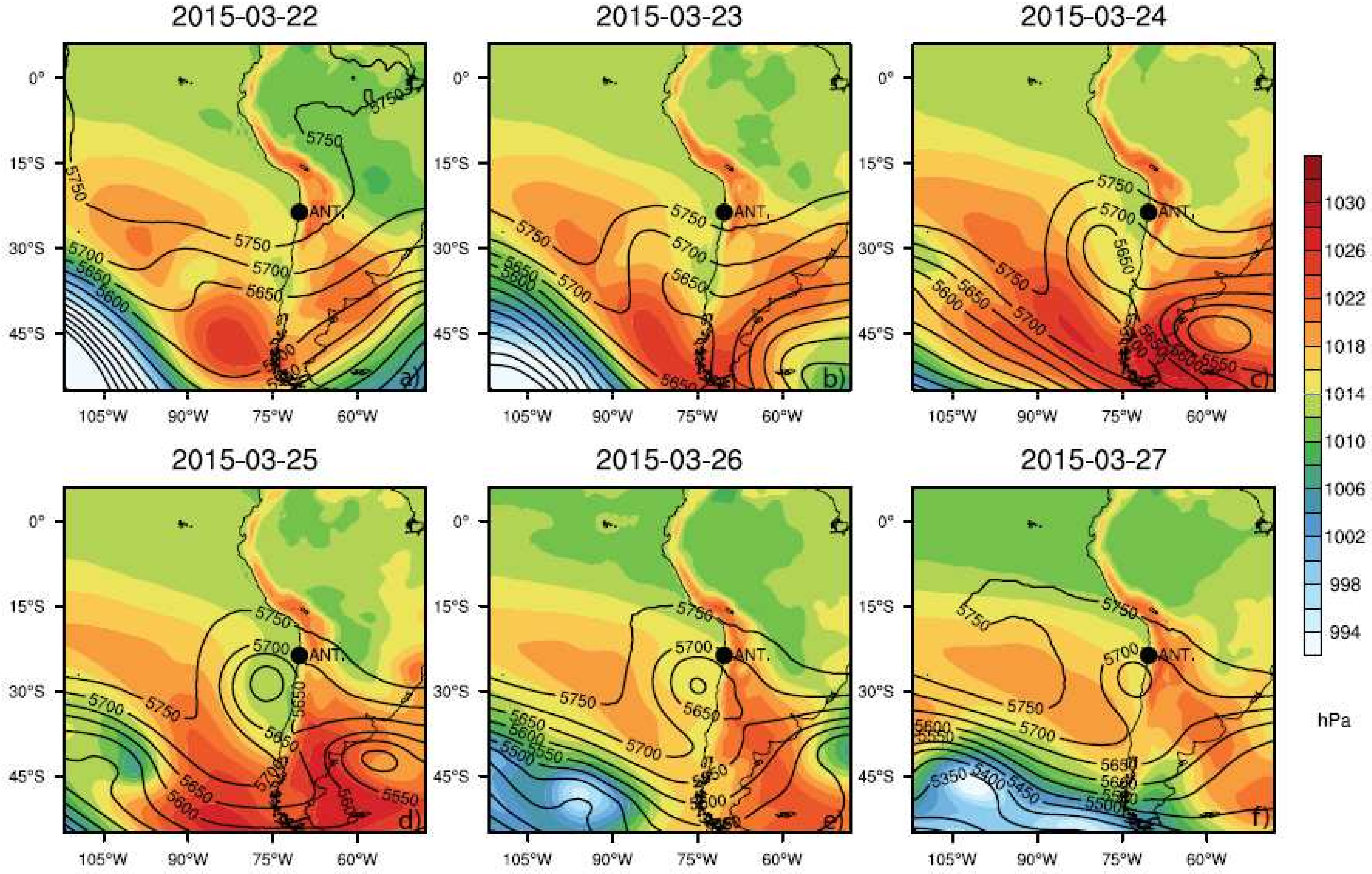
March 24, 2015

Lightning detected by WWLLN

One every 10 strokes

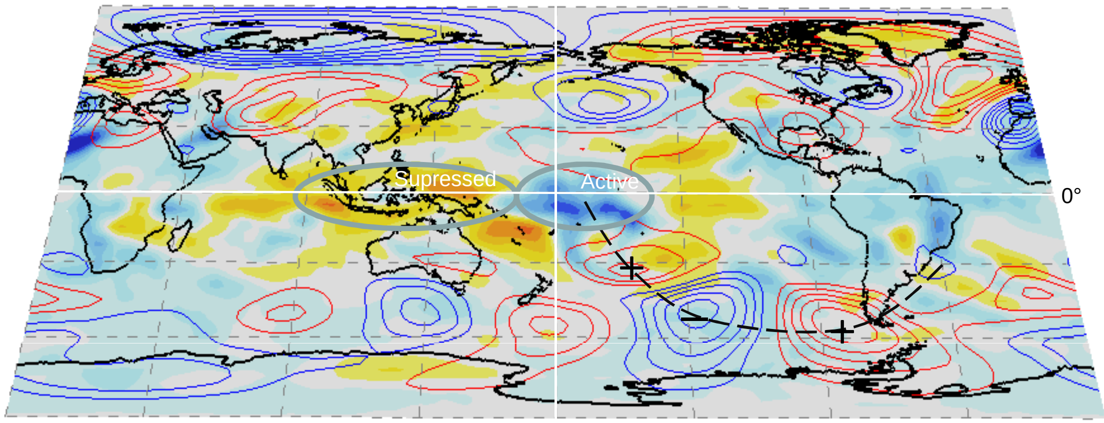


Synoptic environment I: Z500 and SLP



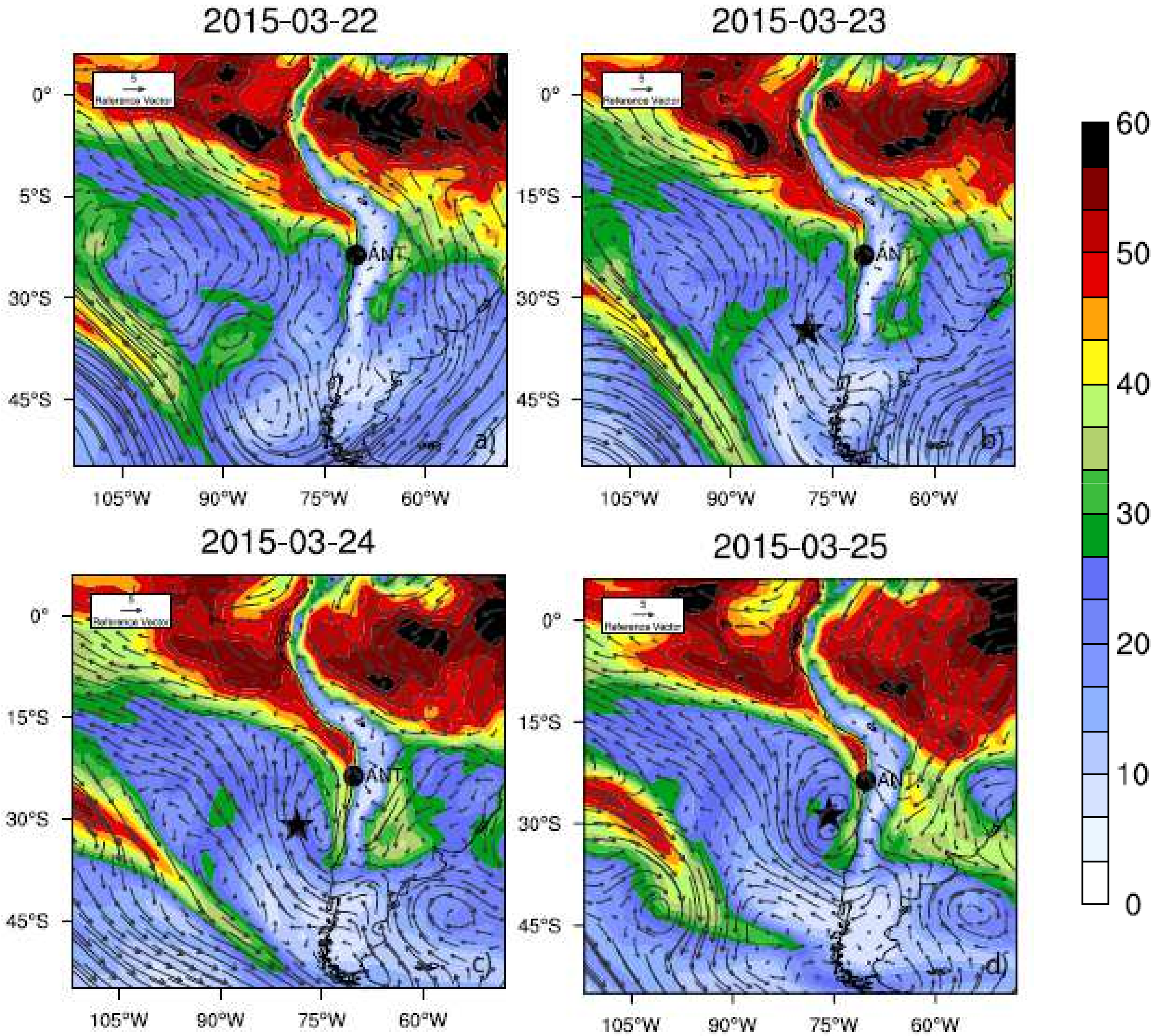
Large scale context

OLR & H250 19-22 Mar 2015



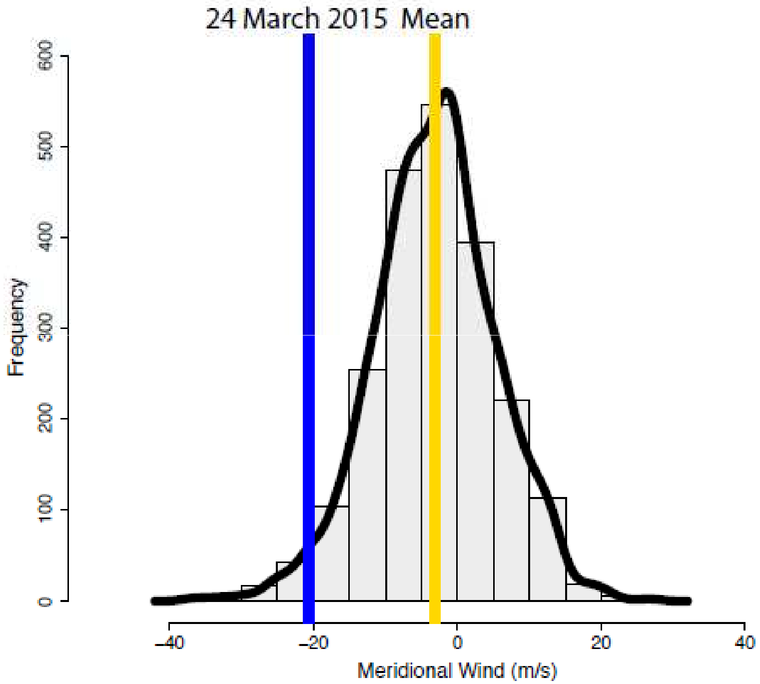
COL developed off northern Chile in connection with a large-scale ridge over the South Pacific that in turn growth from energy propagating from the tropics by the PSA mode….

Synoptic environment I: PW and 850 winds

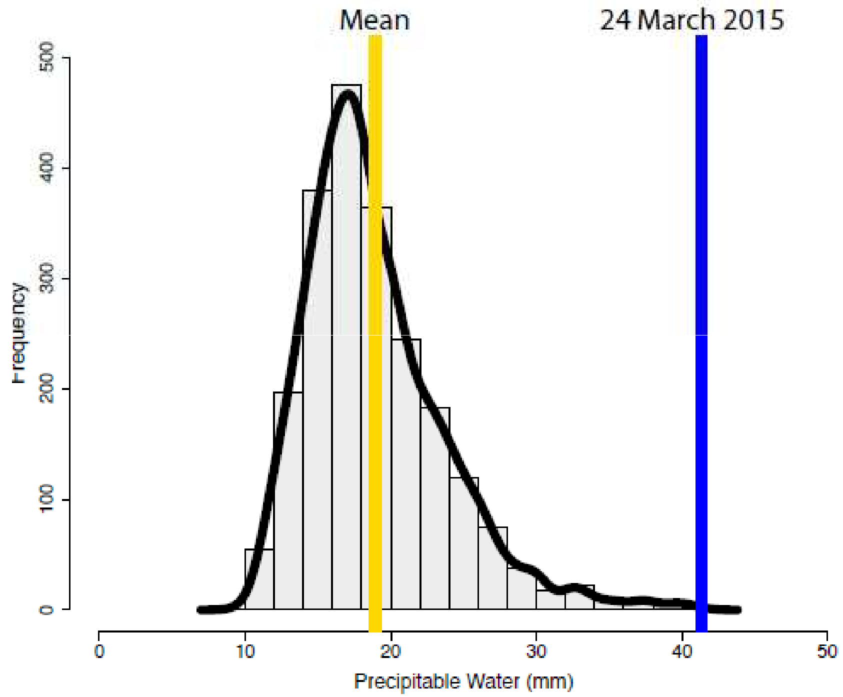


What caused such a intense storm over Atacama?

Dynamic features

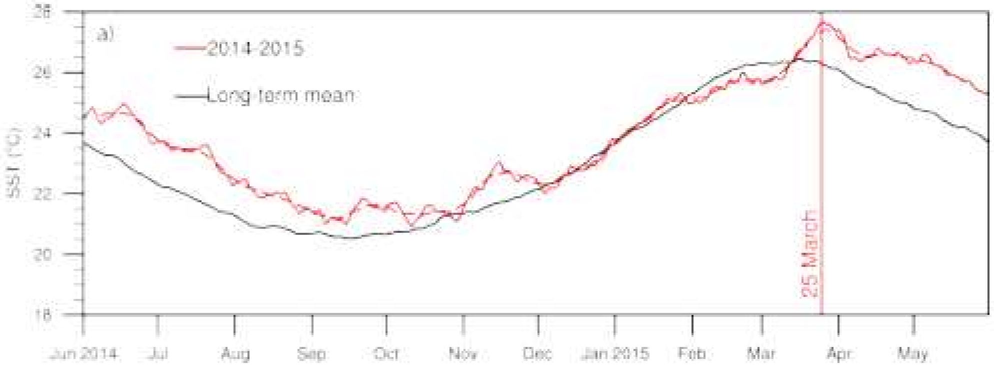


Thermodynamic features

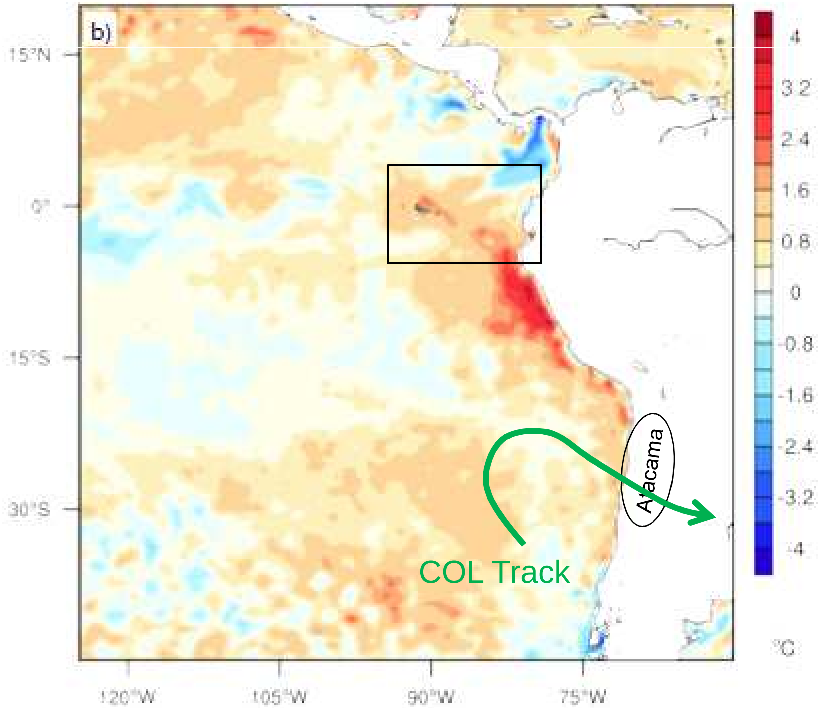


Plausible suspect: marked, sudden SST warming off South America (EN 2015)
Destabilize the atmosphere and provide extra moisture

Niño 1-2
SST

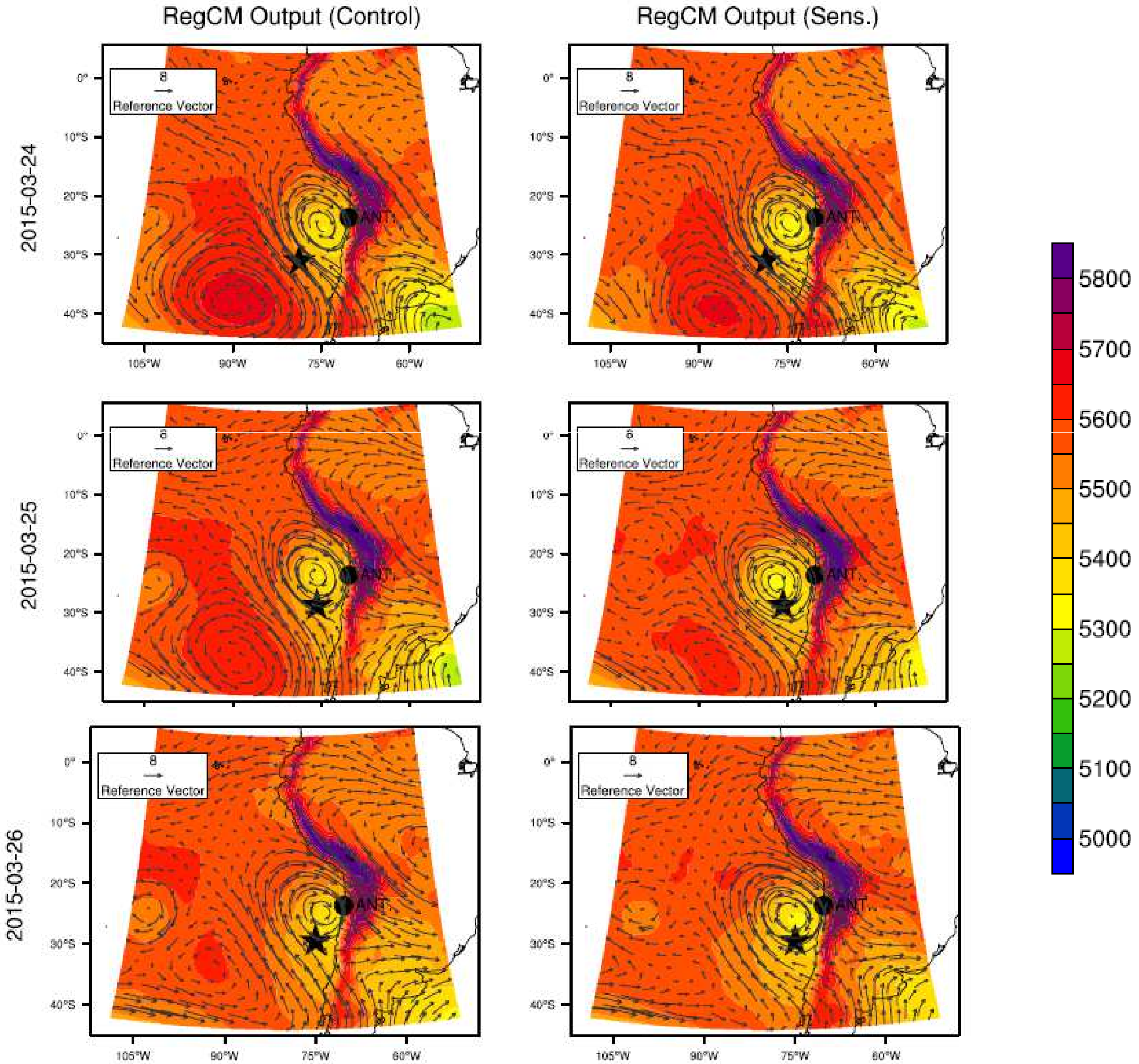


SST anomaly
23 March 2015

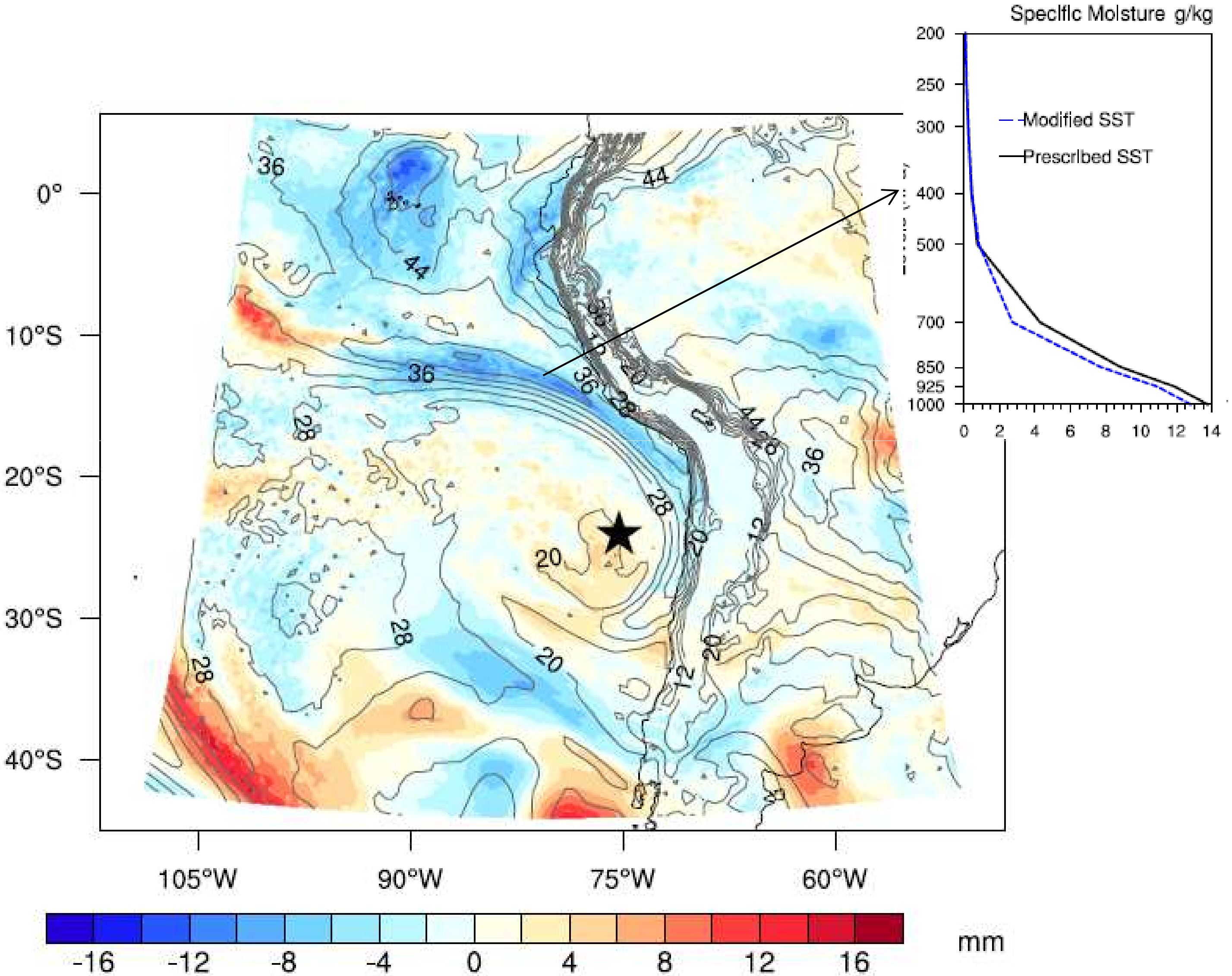


Numerical experiment using RegCM (forced by ERA)

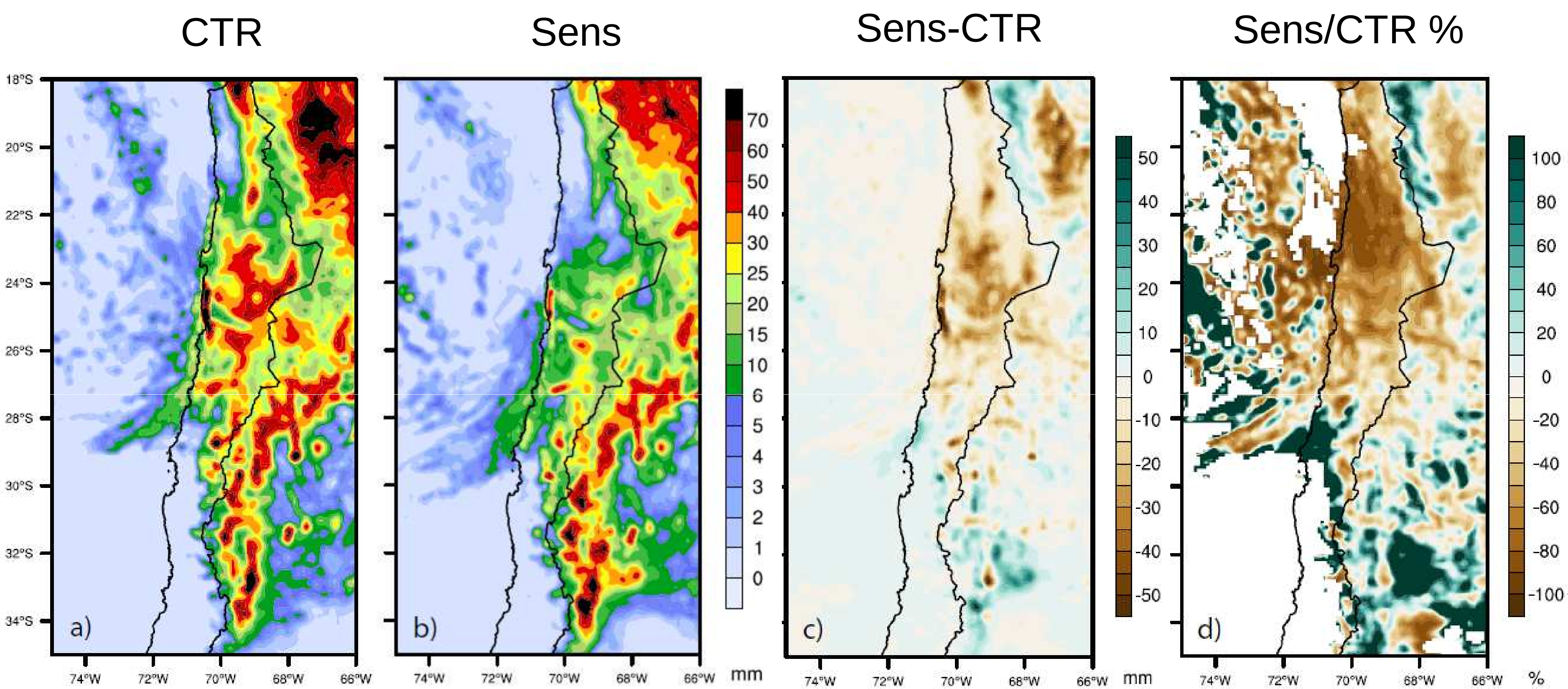
In a sensitivity run the SST was keep equal to the field at March 10 (prior to the warming) thus causing a sfc BC cooler than the control run



CTR PW (contours) and SENS-CTR PW (colors)



RegCM simulated precipitation



Conclusions

* COLs in the SH have similar structure and characteristics than their NH counterparts

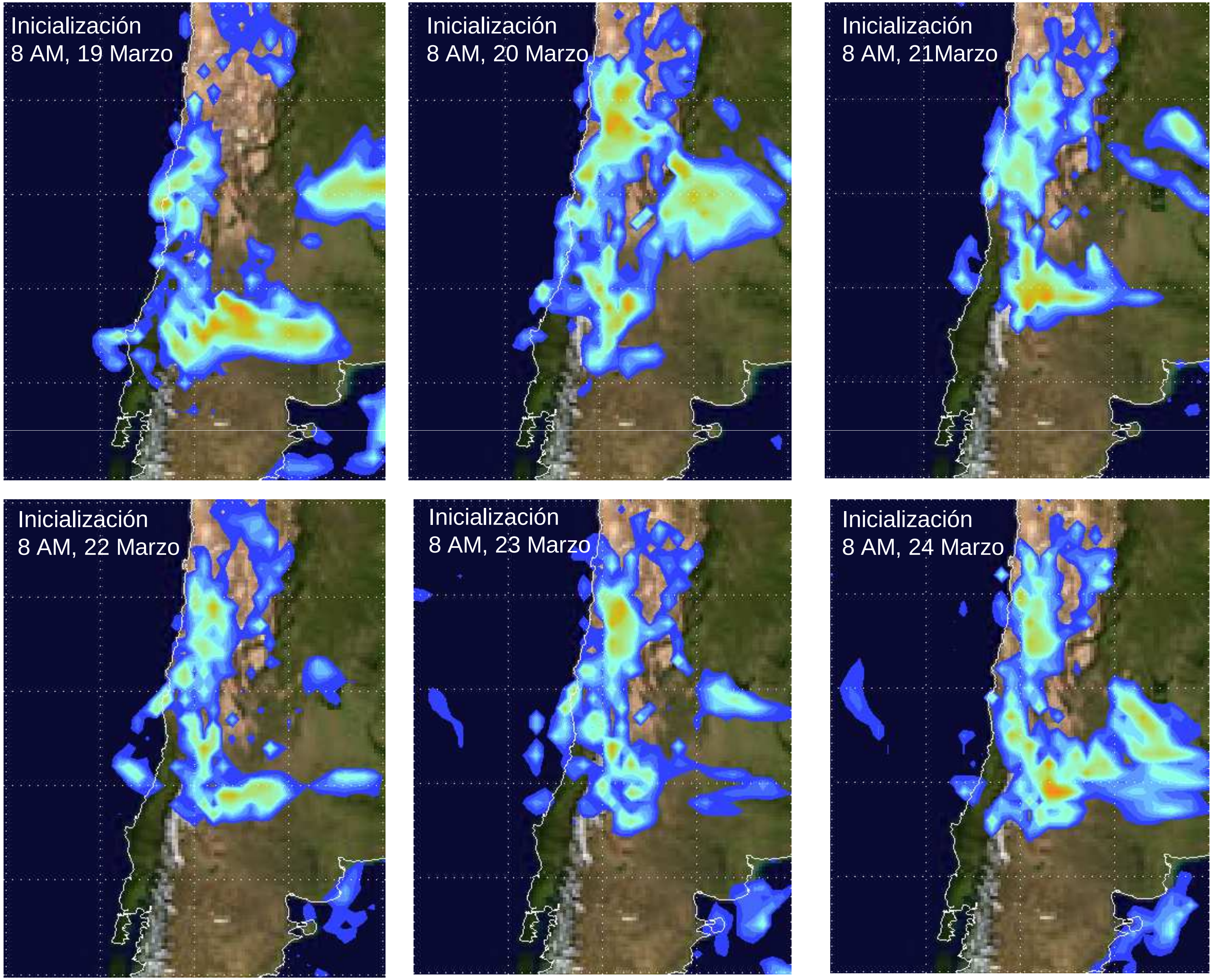
* COLs in the SH tends to cluster in three subtropical areas: Australia, South America and Africa, away from baroclinically active regions

* The Andes cordillera has little influence on the COL formation and intensification. Rather, the cyclone segregation appears mostly driven by the large-scale, upper-level circulation.

* The Andes delays the COL demise by blocking the inflow of warm, moist air from the interior of the continent that would otherwise initiate deep convection.

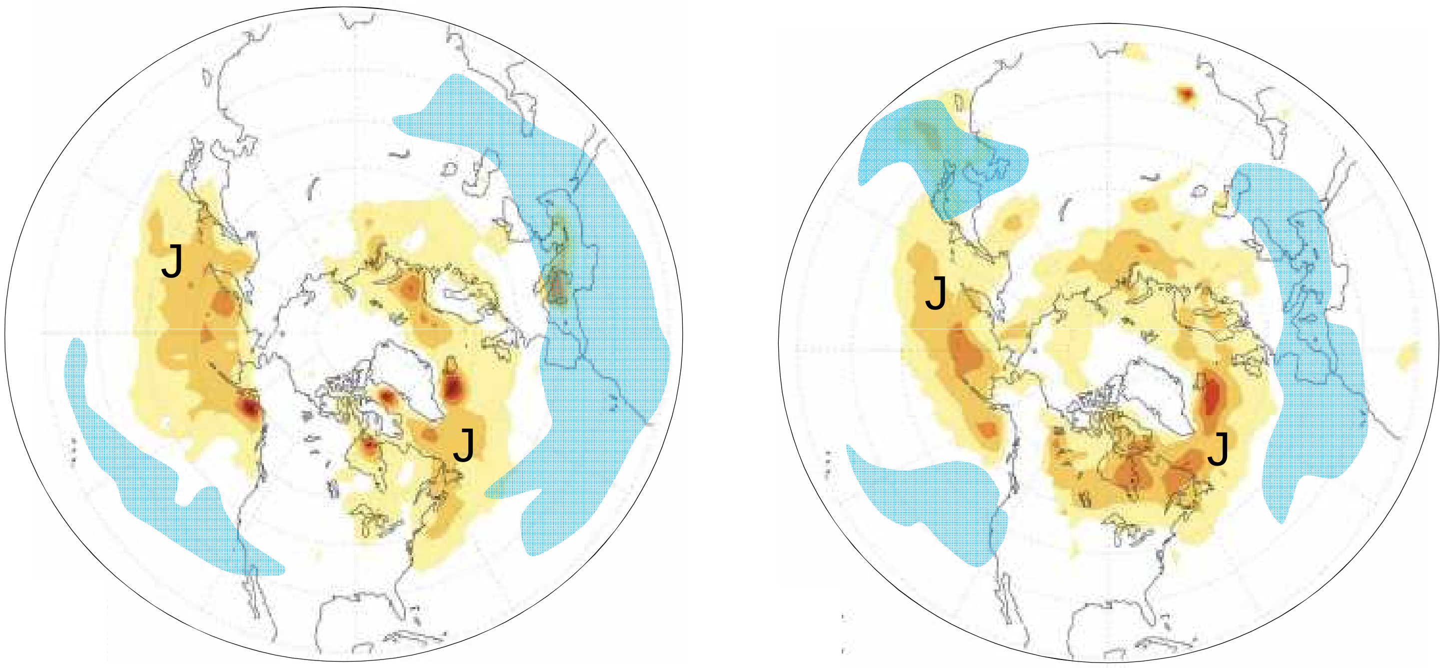
* Given enough moisture, COLs can cause heavy precipitation even in the driest place on earth (Atacama dessert)

Precipitación acumulada en 6 horas
Pronóstico valido a las 18 hrs, 24 Mar 2015



Annual mean COL distribution in the NH

DJF (NH Winter) JJA (NH Summer)



Light blue shading: 500 hPa closed lows to the south of the Jet (from Bell and Bosart 1989)
Warm colors: Surface cyclones density (from Raible et al. 2008)