The highest temperature for the Antarctic continent: local-scale phenomena forced by large-scale anomalies

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UNIVERSIDAD DE CHILE

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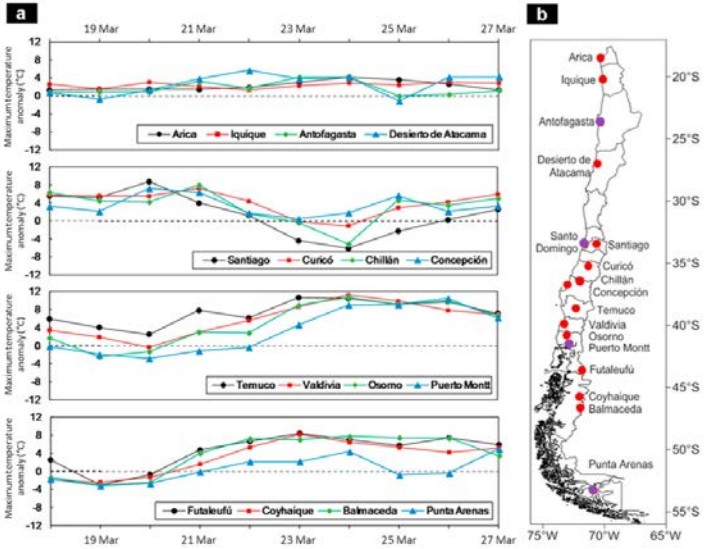
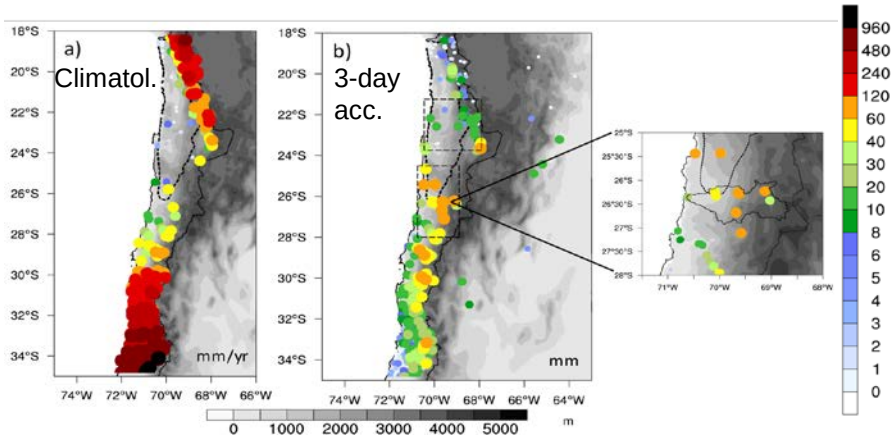
Between 18 and 27 March 2015, northern, central, and southern Chile as well as the Antarctic Peninsula experienced a series of extreme hydrometeorological events just at the beginning of the austral fall:

Extreme temperature events in Chile



Barrett et al., (2016), Extreme temperature and precipitation events in March 2015 in central and northern Chile, J. Geophys. Res., doi: 10.1002/2016JD024835

The March 2015 Atacama Storm



Bozkurt et al., (2016), Impact of warmer eastern tropical Pacific SST on the March 2015 Atacama floods, Mon. Wea. Rev., DOI: 10.1175/MWR-D-16-0041.1

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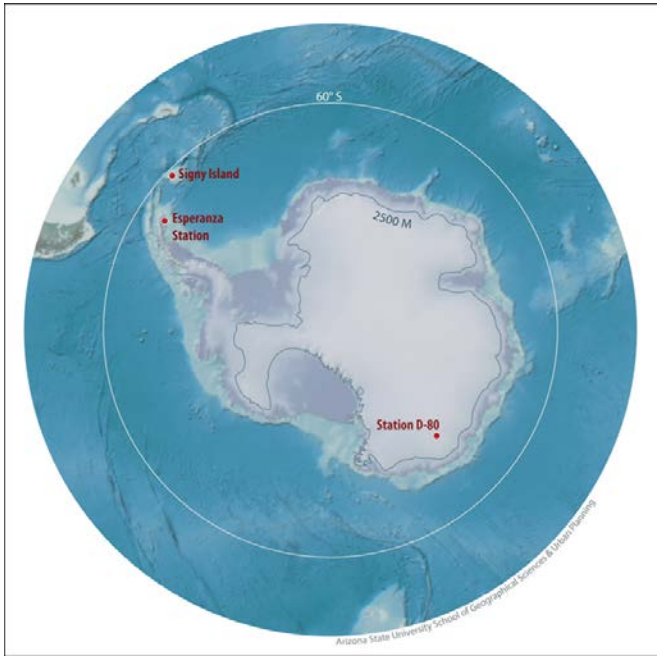
24 March 2015: The highest temperature on the Antarctic continent

Highest Temperature on the Continent: 17.5°C, Esperanza Research Base, 24 March 2015

Consequently, after careful evaluation of the evidence with regard to quality of observation, type and calibration of equipment, and site placement, as well as foehn occurrence, the committee recommended unanimously to accept the observation of 17.5°C (63.5°F) made on 24 March 2015 at the Argentine research base Esperanza as the highest temperature recorded for the Antarctic continent.

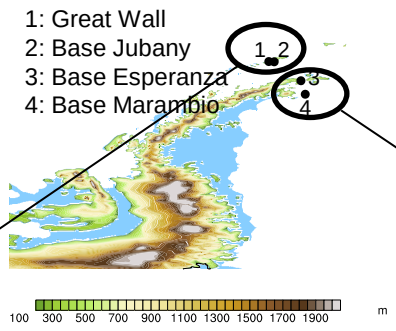


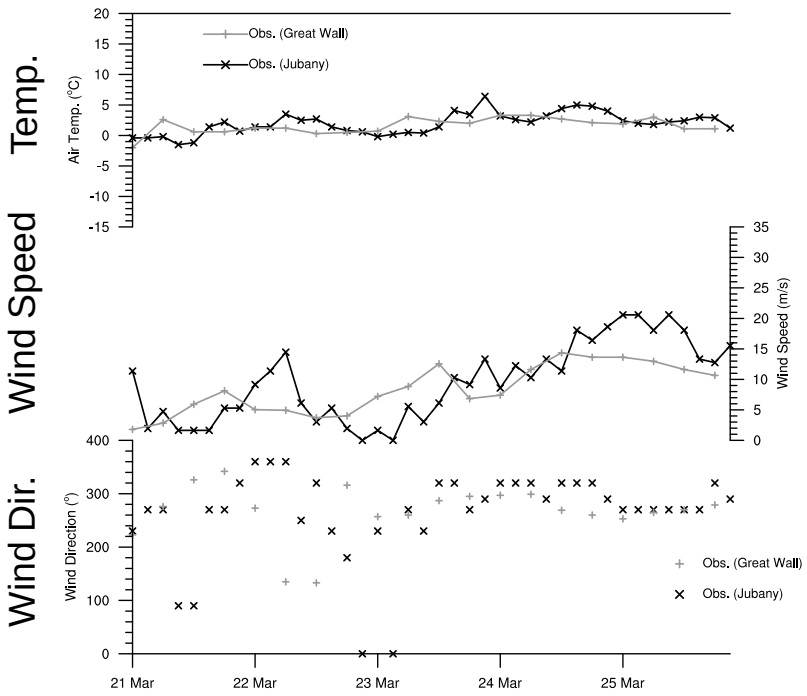
Skansi, M. d. L. M., et al. (2017), Evaluating highest-temperature extremes in the Antarctic, *Eos, 98,* https://doi.org/10.1029/2017EO068325.

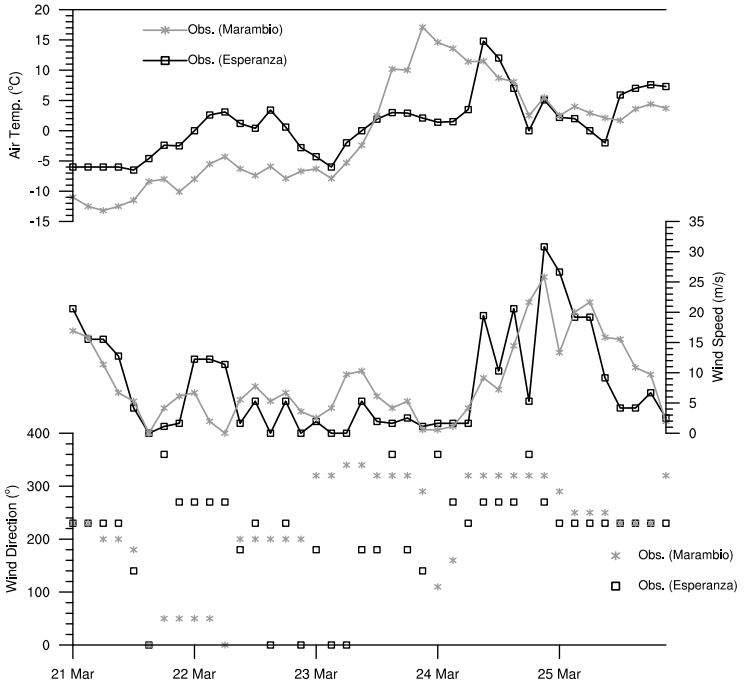
- The March 2015 event:
  - Event overview
  - Synoptic description
  - Numerical simulations
- Conclusions and outlook

The March 2015 event over the Antarctic Peninsula: Event overview

- 3-hr temperature, wind speed and wind direction for Base Esperanza, Base Jubany (Carlini) and Base Marambio
- 6-hr temperature, wind speed and wind direction for Great Wall







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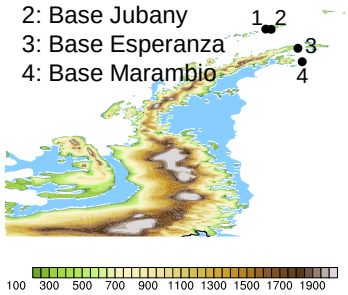
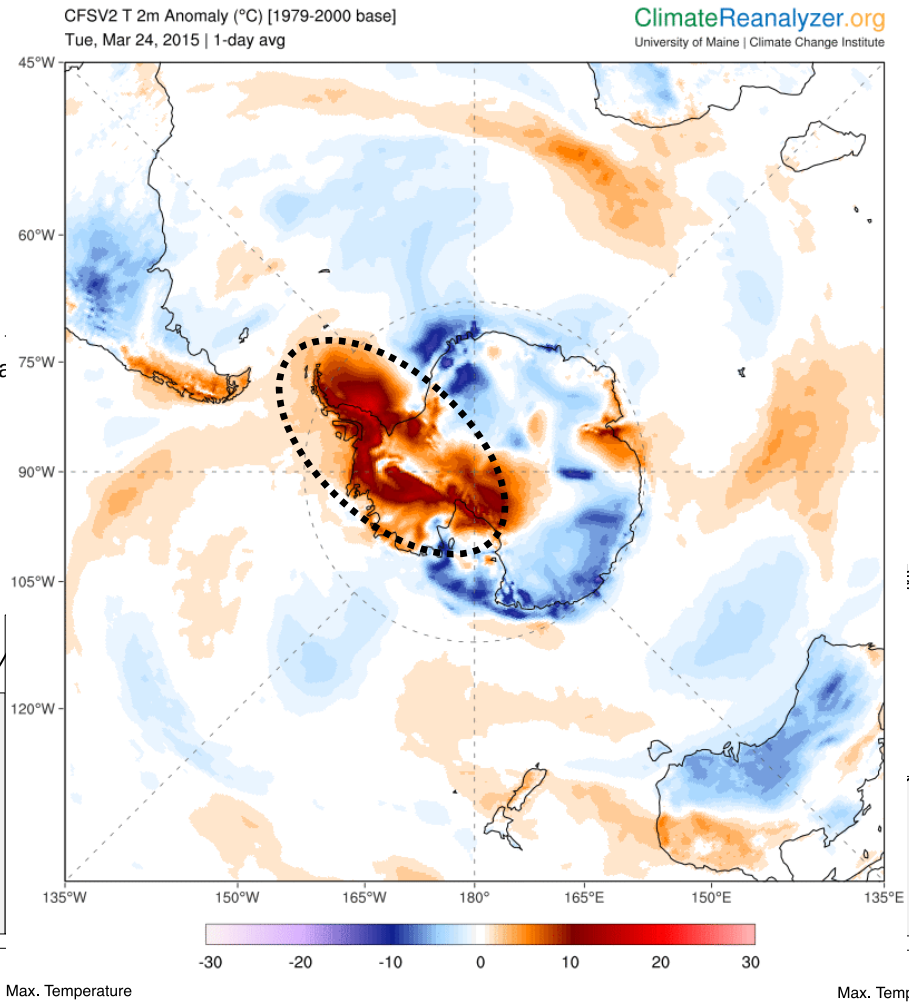
The March 2015 event over the Antarctic Peninsula: Event overview

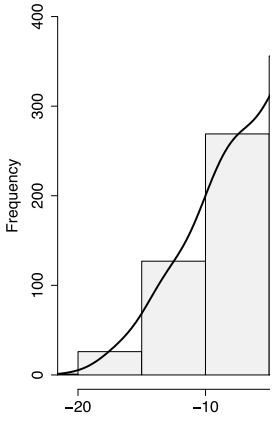
1: Great Wall
2: Base Jubany
3: Base Esperanza
4: Base Marambio

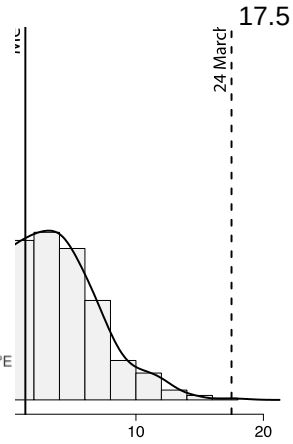


Daily maximum temperature record
1971-2015 (Base Esperanza and Ba
1989-2015 (Base Jubany)



Base Marambio





Record breaking anomalies on the leeward!

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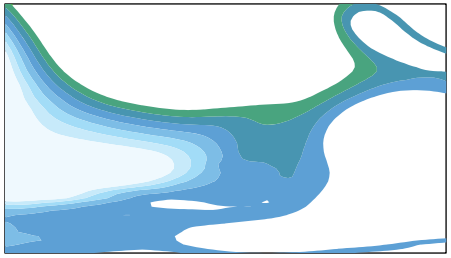
The March 2015 event over the Antarctic Peninsula: Synoptic conditions

21-25 March 2015 MSLP & 500hPa geopotential heights (ERA-Int)



1030

1024

1018

1012

1006

1000

994

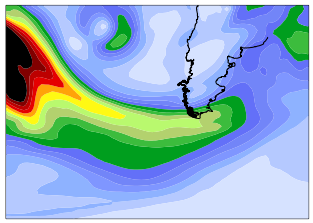
988

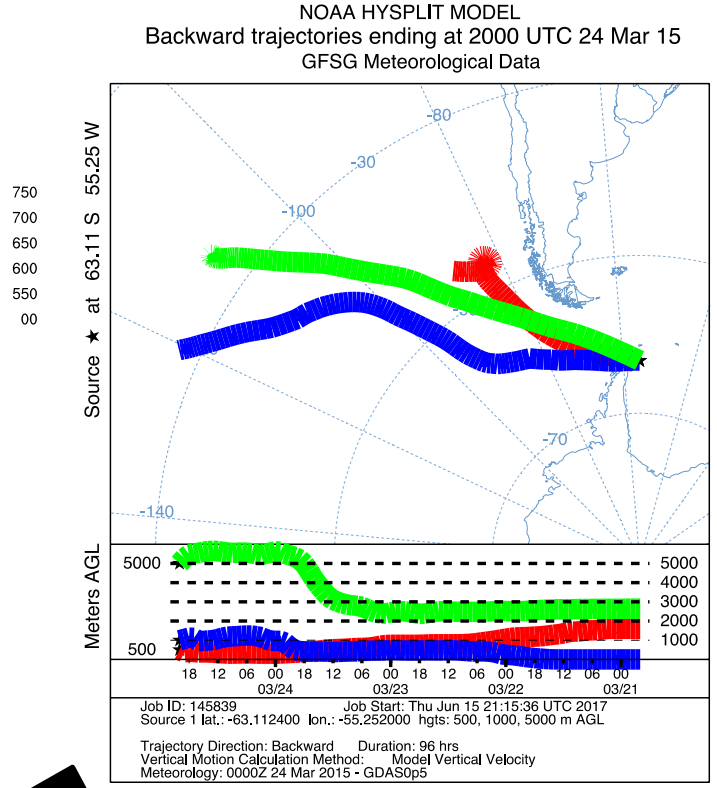
82

Anomalous northwest-southeast midlevel ridge and surface anticyclone stretched from higher latitudes over the South Pacific towards the Antarctic Peninsula

The March 2015 event over the Antarctic Peninsula: Synoptic conditions

21-25 March 2015 IVT (ERA-Int)

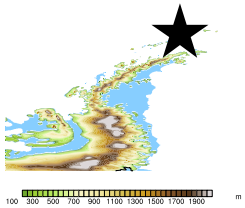




Large scale advection of warm and moist air
Within an atmospheric river activity

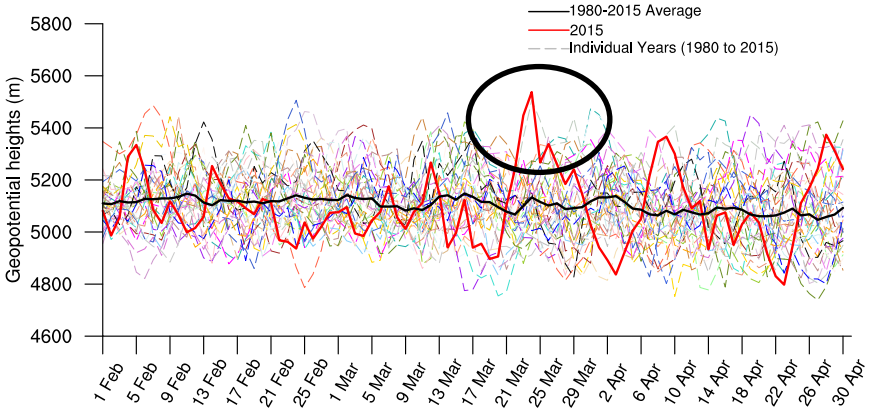
Moist-laden air masses
resided over the subtropical
Pacific

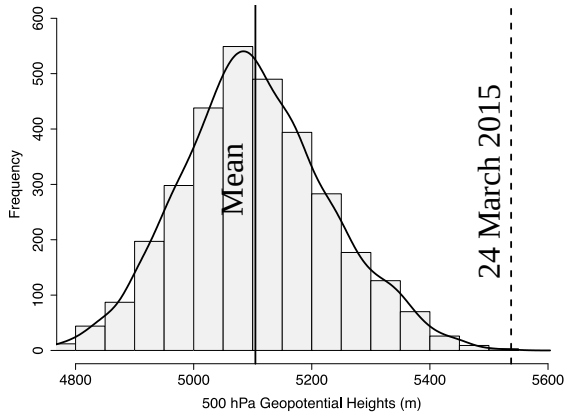
The March 2015 event over the Antarctic Peninsula: Synoptic conditions



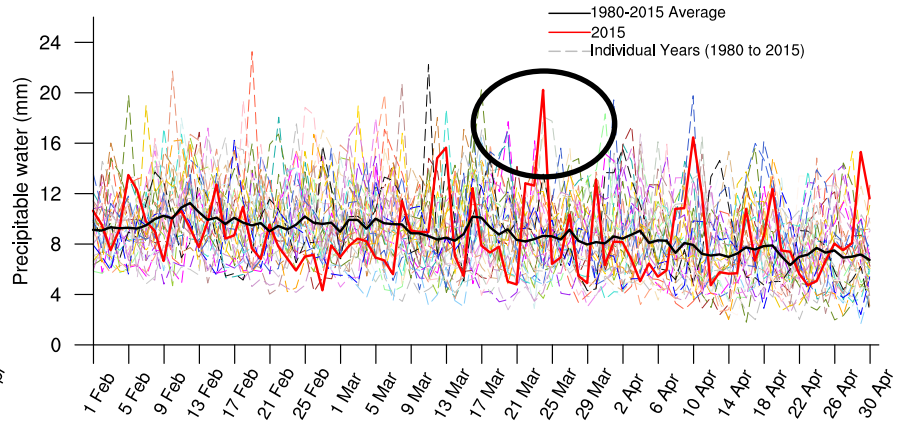
Feb–April daily time series from ERA-Int for each year between 1980 and 2015 as well as their long-term mean

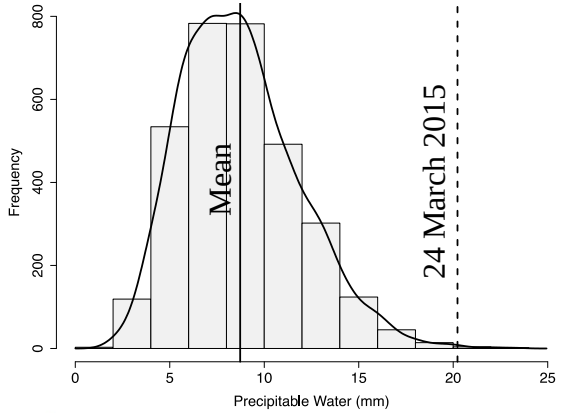
500 hPa geop. heights





Precipitable water





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Numerical simulations

Objective: To further investigate the large scale and local scale forcings during the event through regional climate model simulations covering a large, continental-scale domain to resolve the time-evolution of the large-scale forcings and their far-reaching impacts

Method :

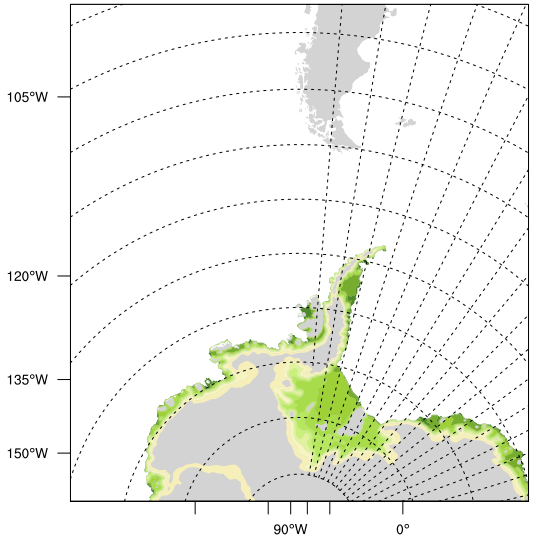
i) To apply a regional climate model (hydrostatic) at 10 km spatial resolution

ii) To validate the model with the observations and reanalysis

iii) To investigate local scale changes during the event

iv) To further comparison of hydrostatic simulations with non-hydrostatic simulations at 6-km spatial resolution

Numerical simulations



Experiemental setup	
Number of grids and simulation period	*512x472* *15-31 March 2015*
Spatial and vertical resolution	*10km and 23 pressure levels*
Radiation and convective scheme	*NCAR-CCSM3, Grell+Emanuel*
Land surface	*BATS*
Initial and boundary conditions	
Pressure levels	*ERA-Interim (0.75ºx0.75º, 37 level., 6hr)*
SST& Ice concentration	NOAA OISST.V2 (*1ºx1º*)
Land use and vegatation	*GLCC (30-sec)*

ICTP-RegCM4 (dynamical core is based on the hydrostatic version of the MM5)

The ICTP regional climate model system

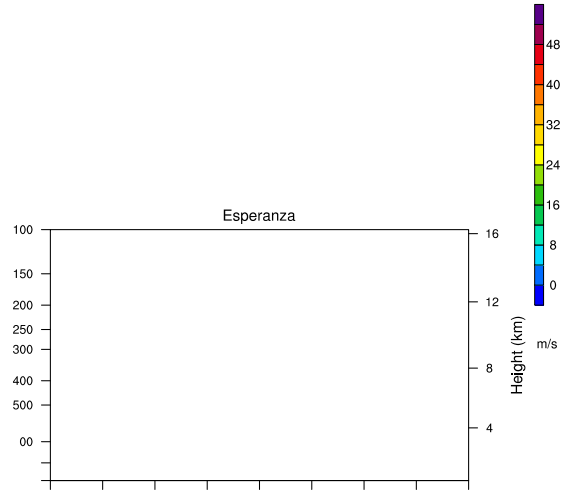
RegCM4 (Giorgi et al. 2012, CR SI 2012)

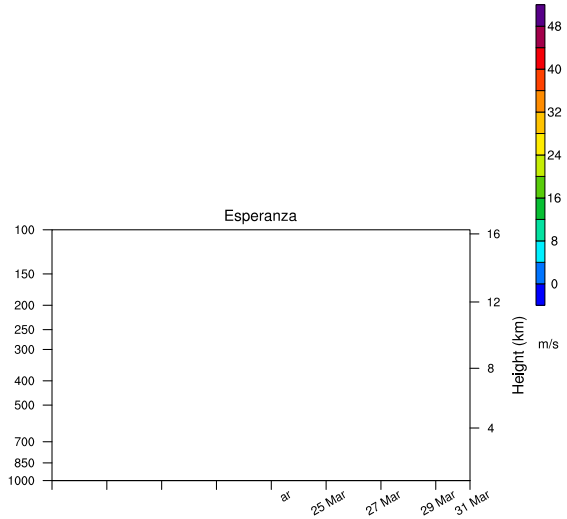
- **Dynamics:**
  - Hydrostatic (Giorgi et al. 1993a,b)
  - Adaptable to any region
- **Radiation:**
  - CCM3 (Kiehl 1996)
  - **RRTM (Solmon)**
- **Large-Scale Precipitation:**
  - SUBEX (Pal et al 2000)
- **Cumulus convection:**
  - Grell (1993)
  - Anthes-Kuo (1977)
  - MIT (Emanuel 1991)
  - **Mixed convection**
  - **Tiedtke**
  - **Betts-Miller (never really worked)**
- **Planetary boundary layer:**
  - **Modified Holtslag**, **Holtslag (1990)**
  - **UW-PBL (O' Brien et al. 2011)**
- **Land Surface:**
  - BATS (Dickinson et al 1993)
  - SUB-BATS (Giorgi et al 2003)
  - **CLM3.5 (Steiner et al. 2009)**
- **Ocean Fluxes**
  - BATS (Dickinson et al 1993)
  - Zeng (Zeng et al. 1998)
  - **Diurnal SST**
- **Configuration**
  - Adaptable to any region
  - **Tropical belt configuration**
- **Extensive code remake**

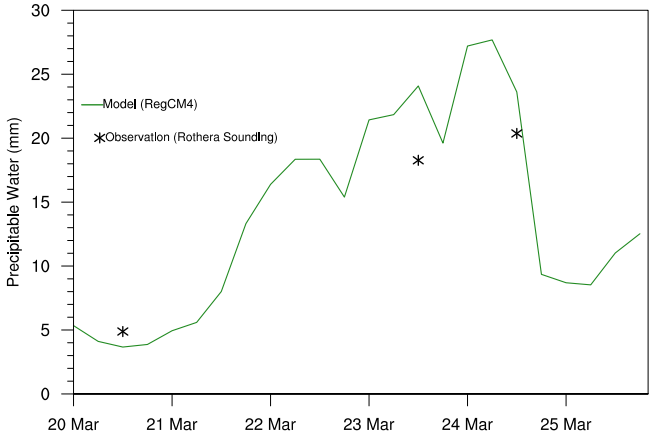
Model validation

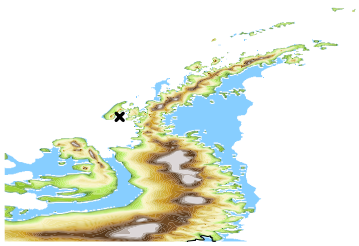
ERA-Int (Q_{as} & Wind Speed)

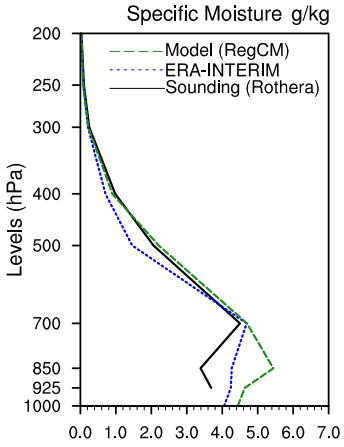
Model (Q_{as} & Wind Speed)





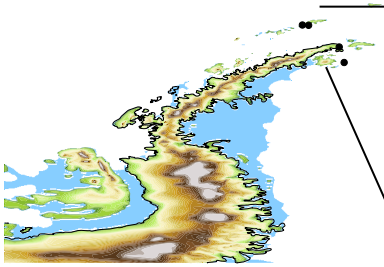




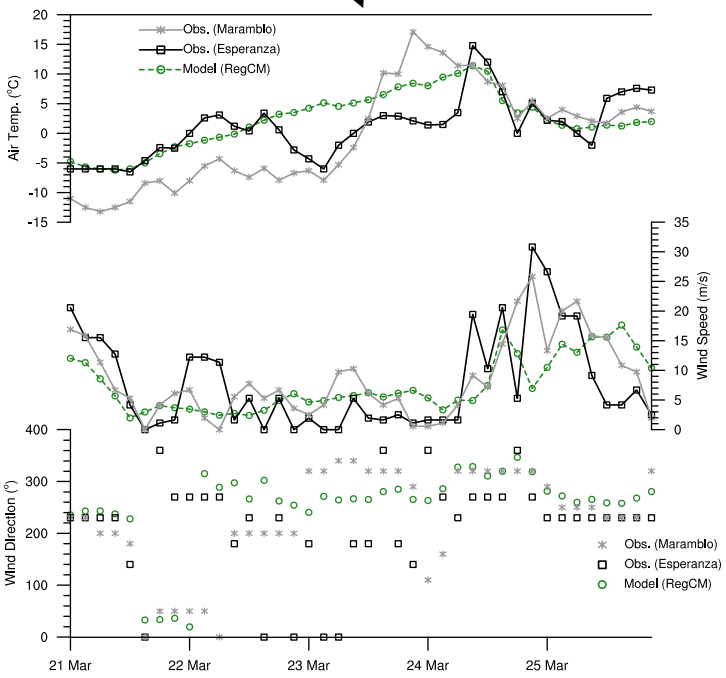


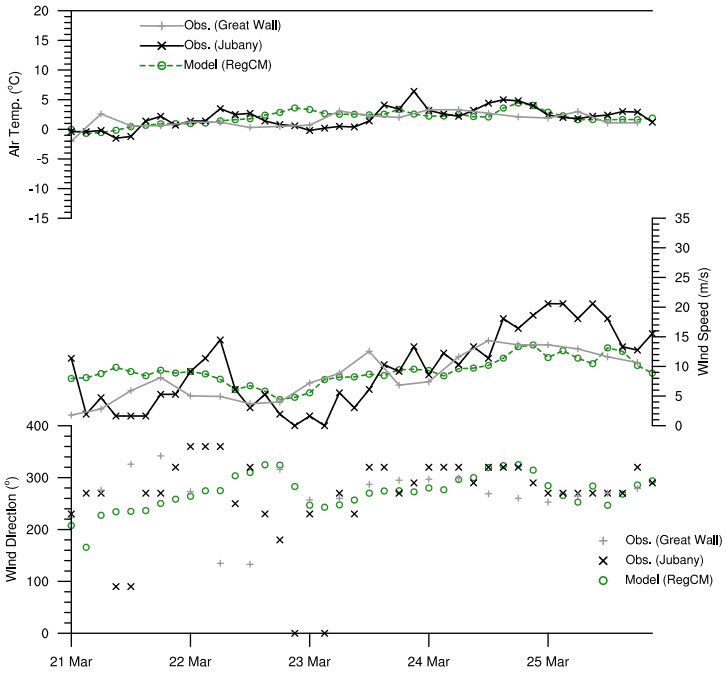
More moist and warmer conditions in the simulation at near-surface and mid-levels

Model validation



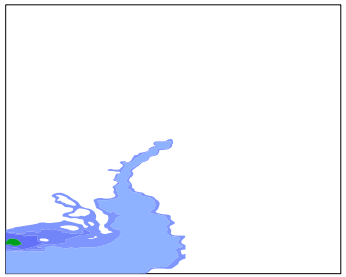
- 3-hr temperature, wind speed and wind direction for observations and model





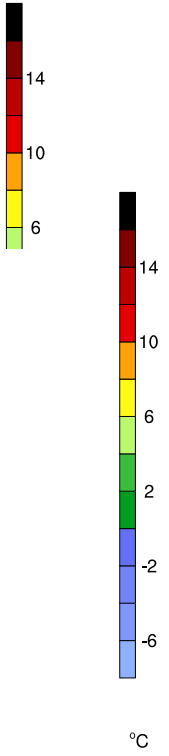
Simulation results

21-25 March 2015, 850 hPa wind vectors & daily max. T_{2m}



ERA-Int

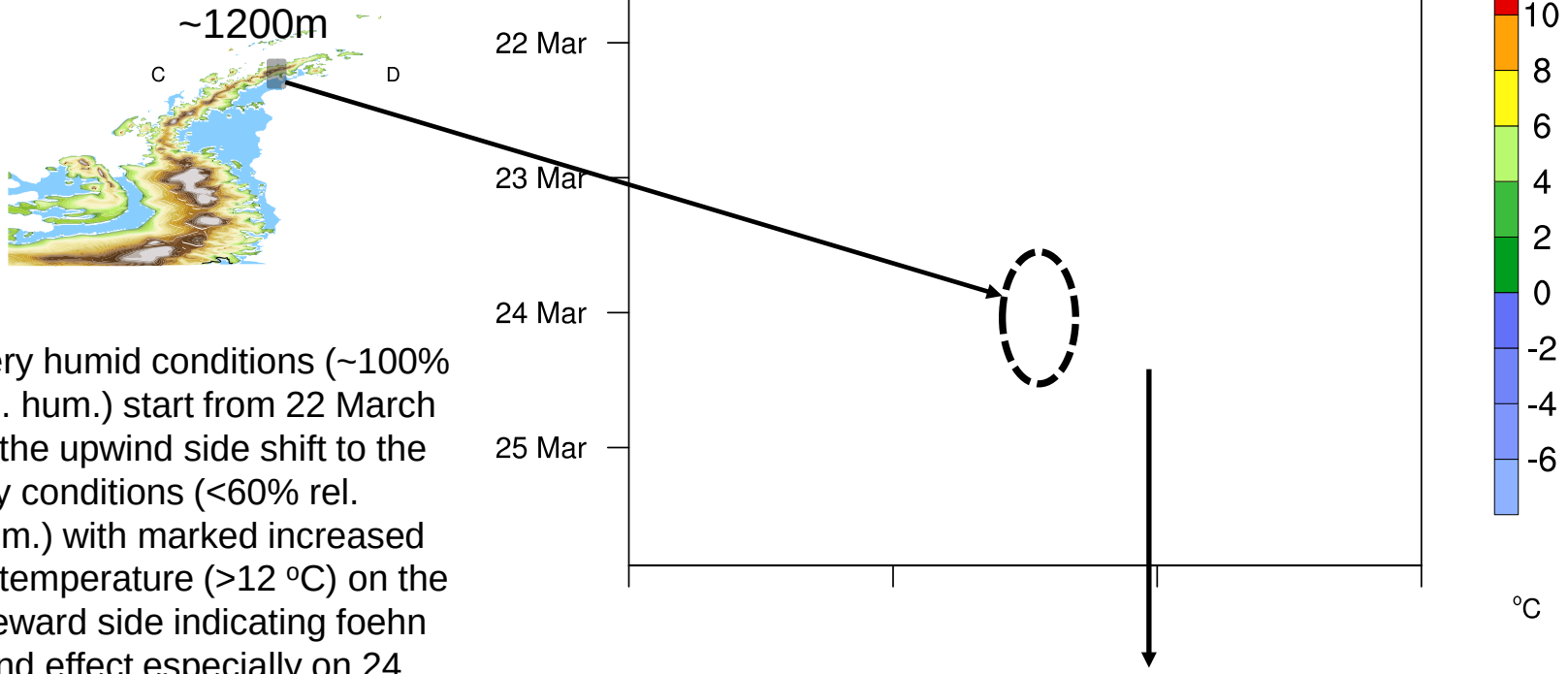
Model



Marked increase in maximum temperatures in the leeward starting from 22 March

Simulation results

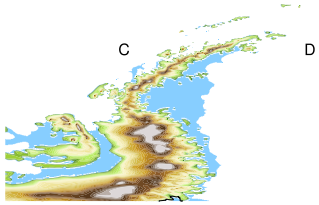
3-hr temporal and longitudinal evolution of T2m & Relative humidity



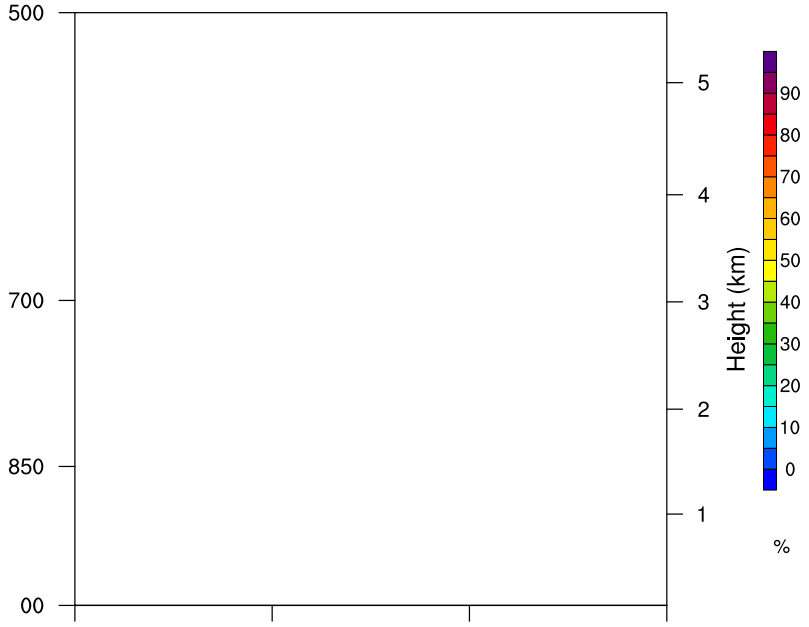
Very humid conditions (~100% rel. hum.) start from 22 March in the upwind side shift to the dry conditions (<60% rel. hum.) with marked increased in temperature (>12 °C) on the leeward side indicating foehn wind effect especially on 24 March 2015

Simulation results

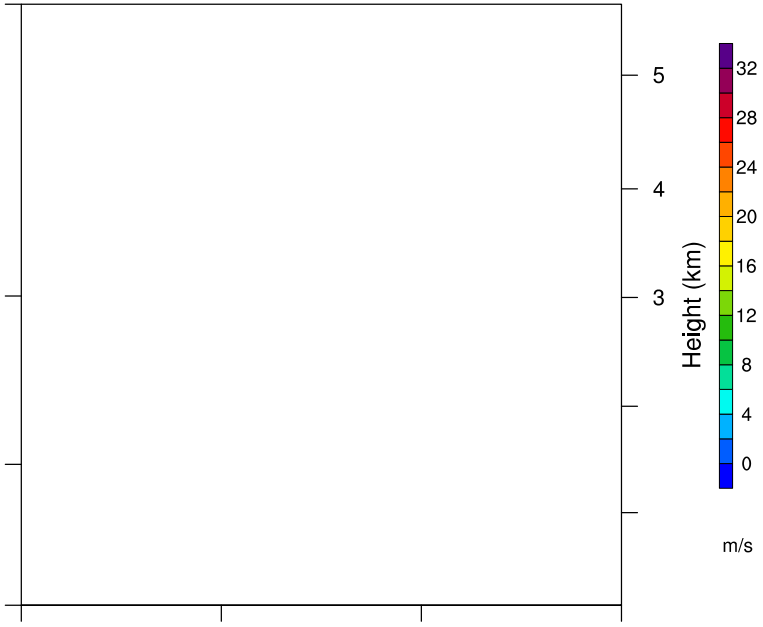
24 March 2015, 12:00



3-hr relative humidity & potential temperature & wind barbs



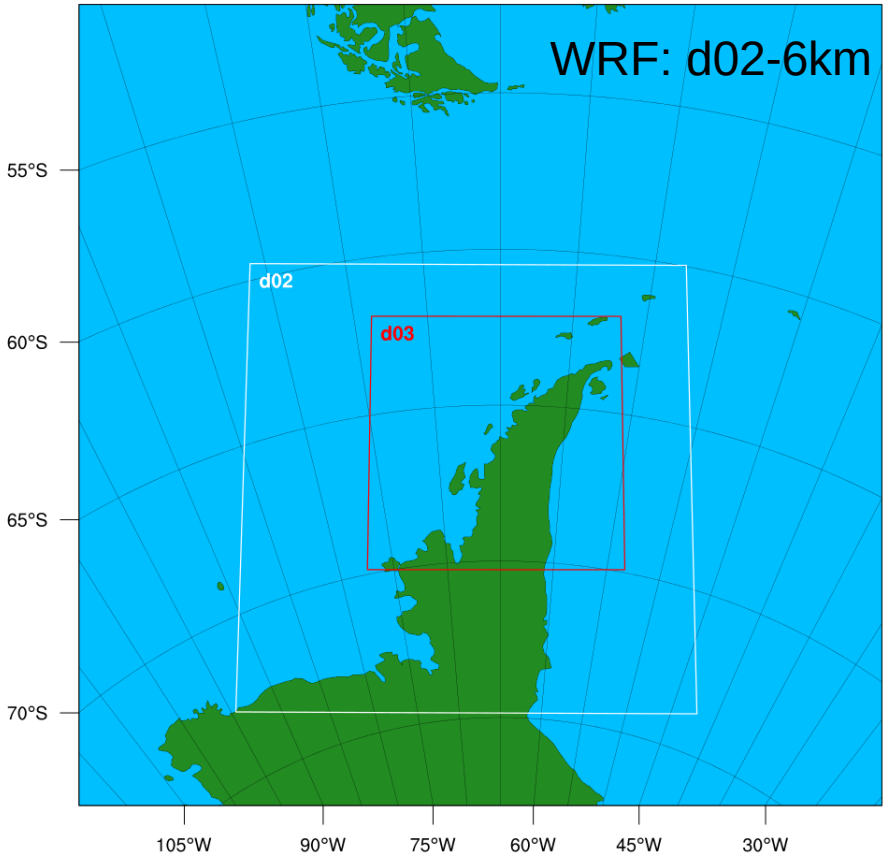
3-hr wind speed & air temperature



Low-level blocking and mountain wave activity, with warm air aloft advected down toward the surface

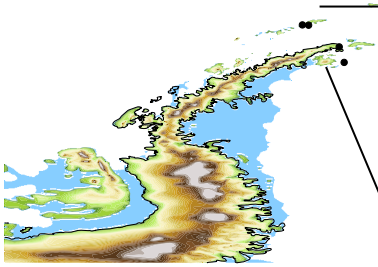
Elevated near surface wind velocities with marked increase in air temperature along the lee slope

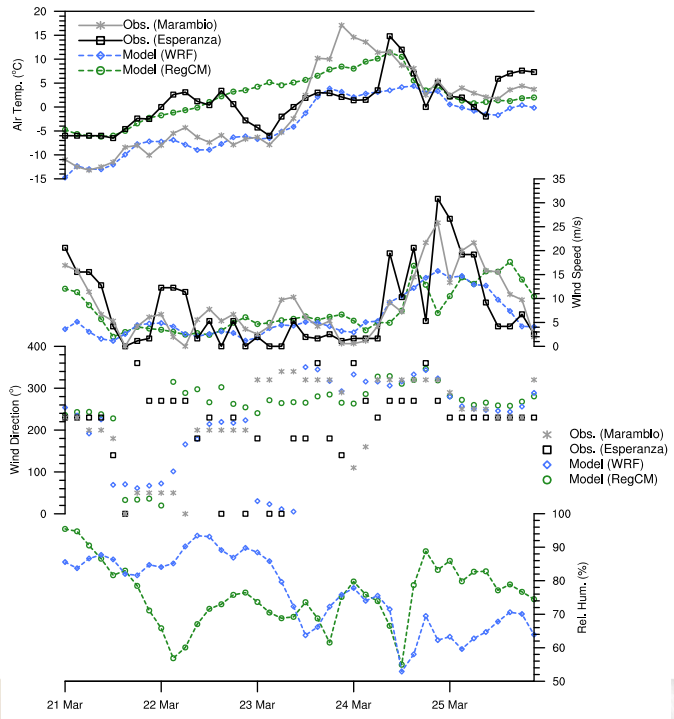
Comparison of the simulations with non-hydrostatic simulations

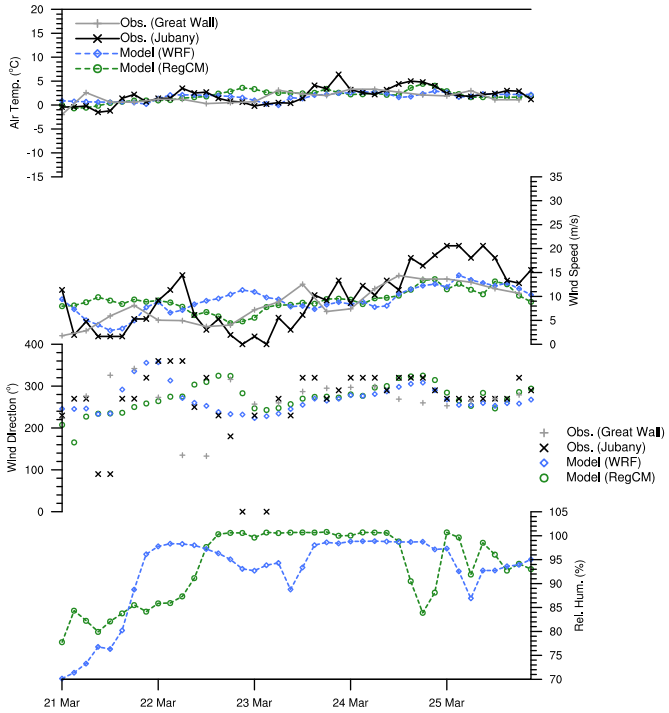


- Initial and boundary condition: CFSR (0.5ºx0.5º)
- Microphysics: WRF Single-Moment 6-class
- Radiation: RRTMG scheme
- PBL: MYNN scheme
- Land-surface: *5-layer thermal diffusion scheme*
- Convective: Kain-Fritsch cumulus scheme

Comparison of the simulations with non-hydrostatic simulations







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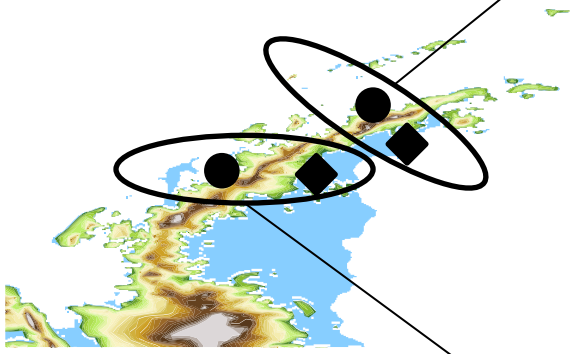
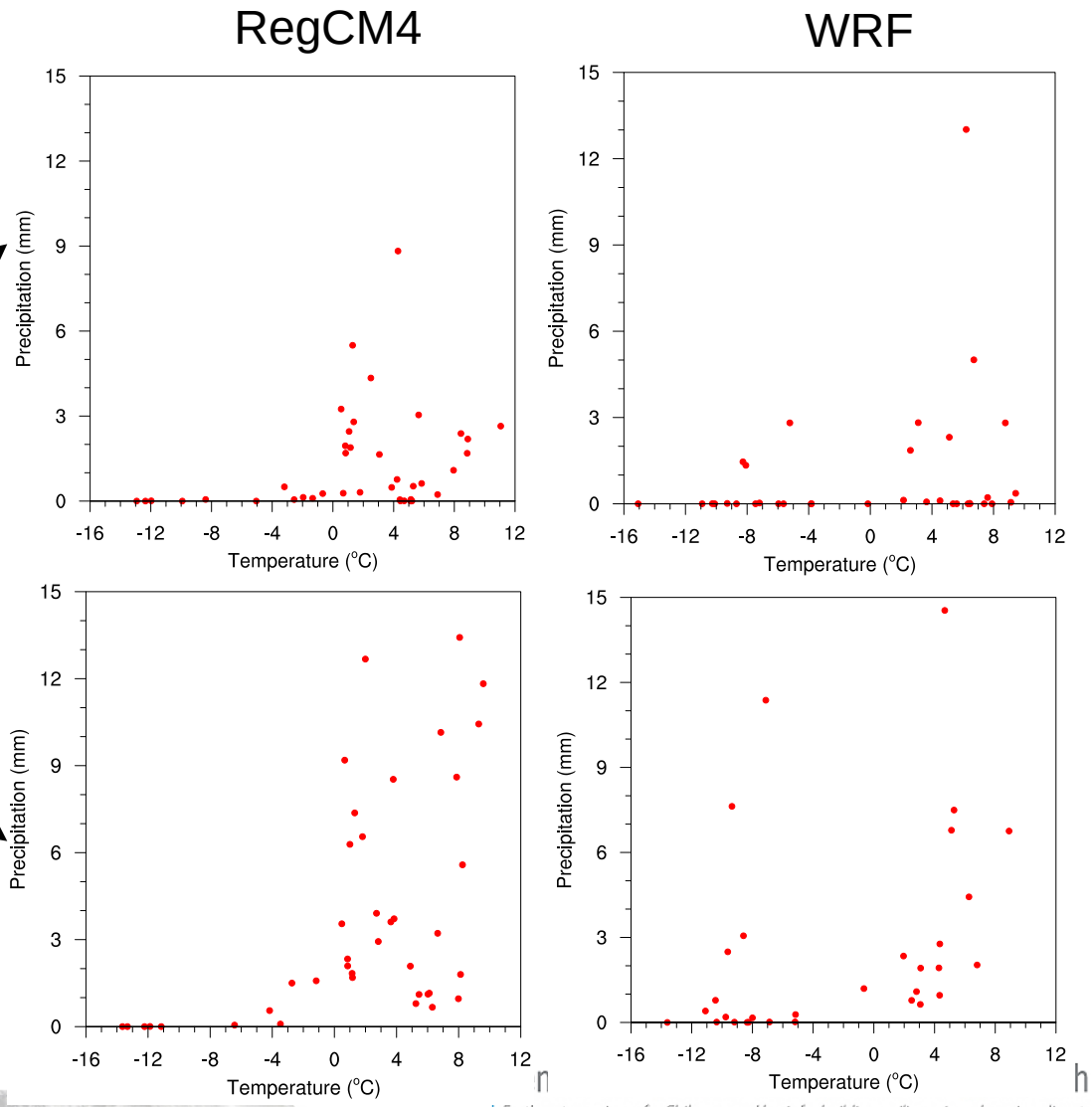
Comparison of the simulations with non-hydrostatic simulations

- Windward precipitation
- Leeward surface temperature



The accuracy of model estimations of temperature on the leeward side is somehow dependent on the precipitation estimation on the windward direction



Conclusions

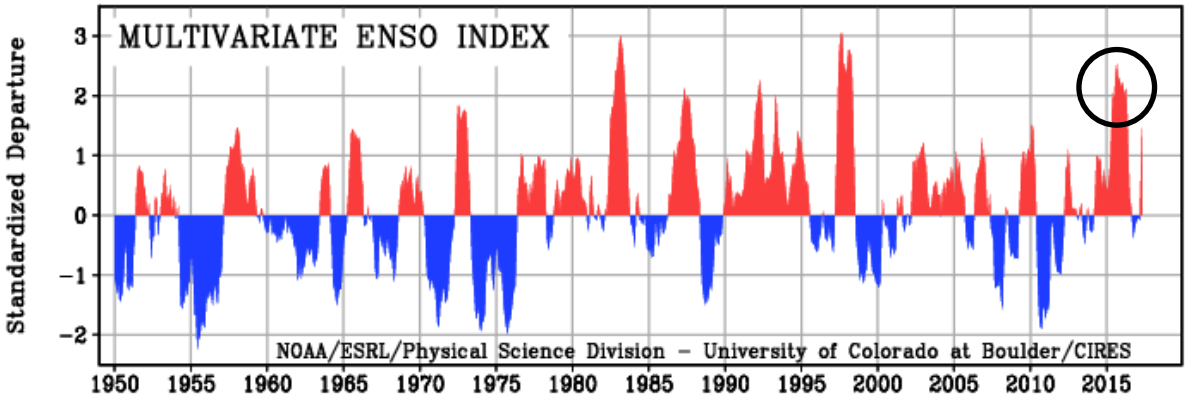
- Extreme dynamical (500 hPa geopotential heights) and thermodynamical (precipitable water) conditions before and during the event, resulted in moist air provided by the large scale advection of the atmospheric river

- Foehn wind event occurred on the lee of the mountain ranges in the Antarctic Peninsula resulting in extreme temperatures

- Modeling experiment indicates that the model captures the synoptic conditions as well as the rapid increase in the temperature on the lee of the mountain ranges albeit with an underestimation of magnitude of temperature increase

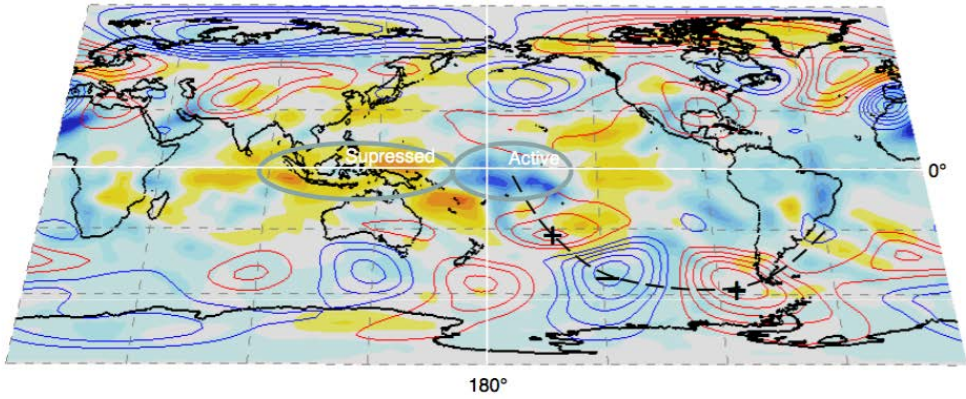
- The accuracy of model estimates (both hdyrostatic and non-hydrostatic) for surface heating on the leeward side (foehn effect) somehow depends on the precipitation estimation on the windward side

Outlook: Large scale context



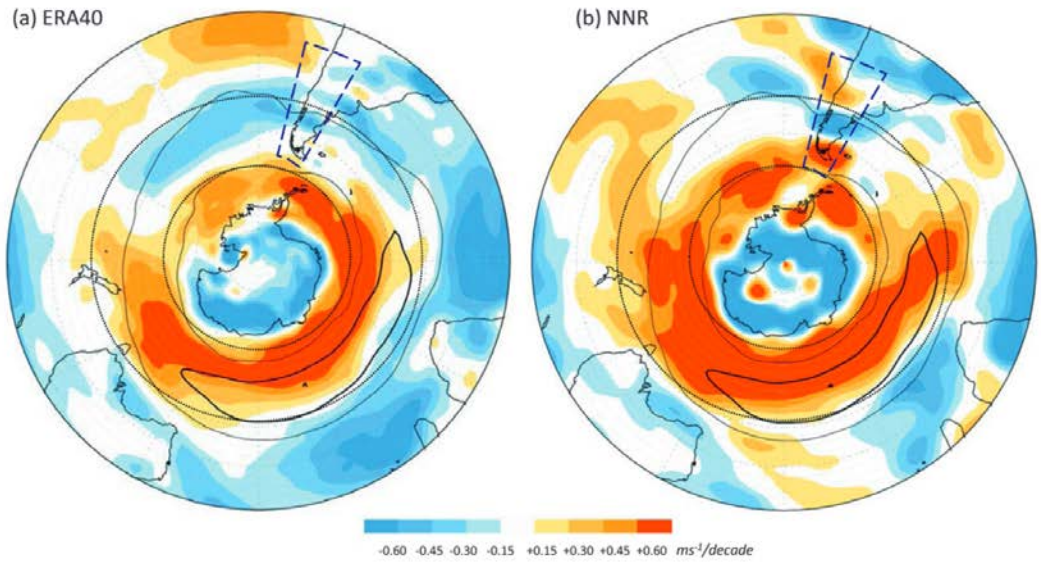
2015/2016

OLR & H250 19-22 Mar 2015



Induced atmospheric teleconnections by ENSO and Rosby wave propagation?

Outlook: Large scale and local scale context



Linear trend in the annual mean 850-hPa zonal wind using ERA-40 and NNR for the period 1968–2001

Garreaud et al., 2013

An increased tendency of westerlies → Possibility of increased foehn effects together with increased moisture content of the atmosphere (due to anthropogenic climate change) → More rapid melting events

?

Cuernos del Paine, Chile

El Chalten, Argentina

Thank you!

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