

Antarctic boundary layers: challenges for atmospheric models beyond Dome C

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GABLS4 workshop
Toulouse, 12-14 September 2018





Why should we continue to study the Antarctic boundary layer ?

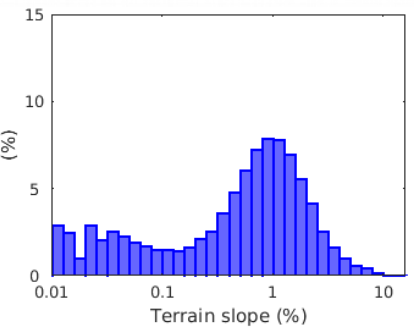
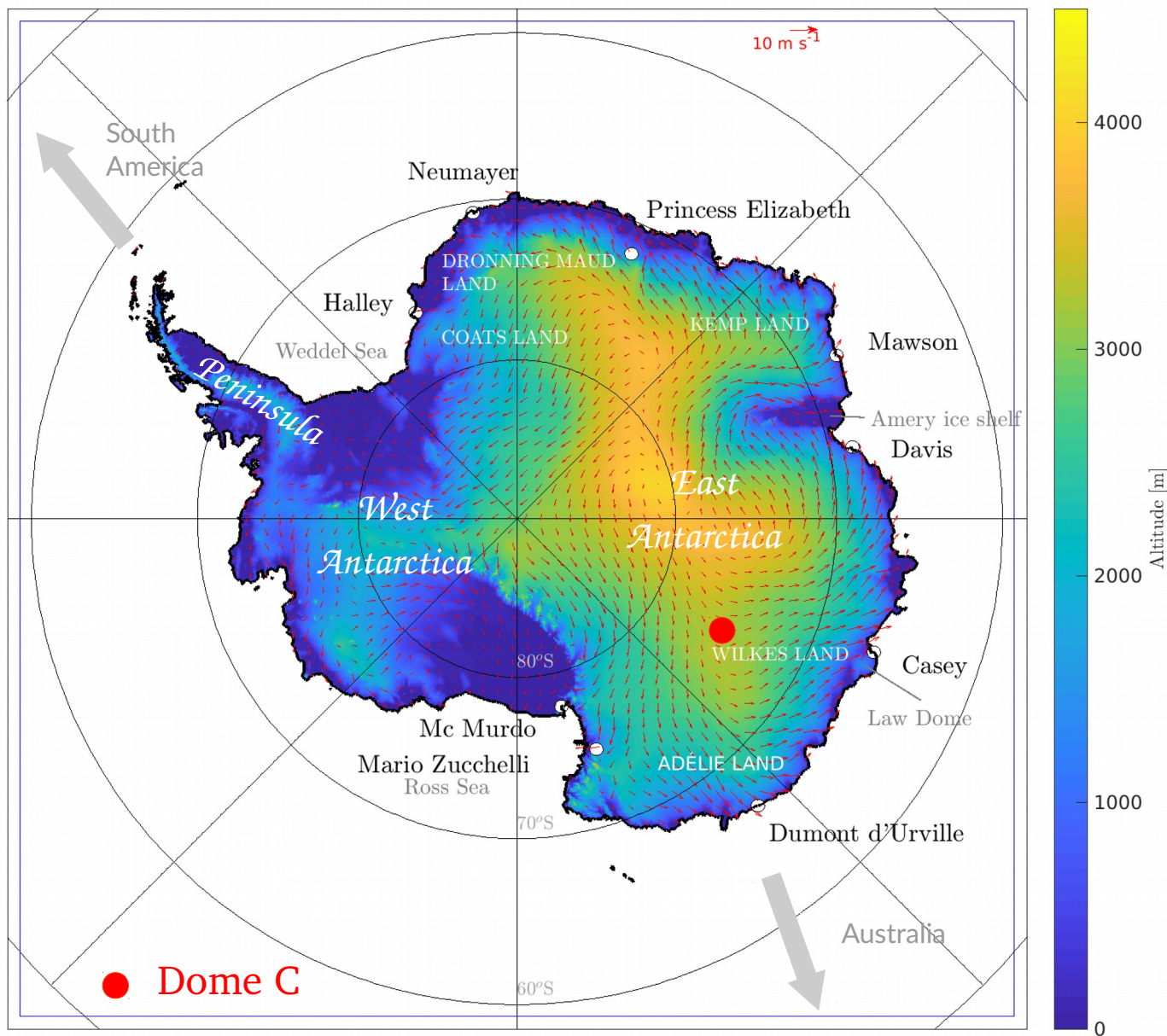
(subjective answers)



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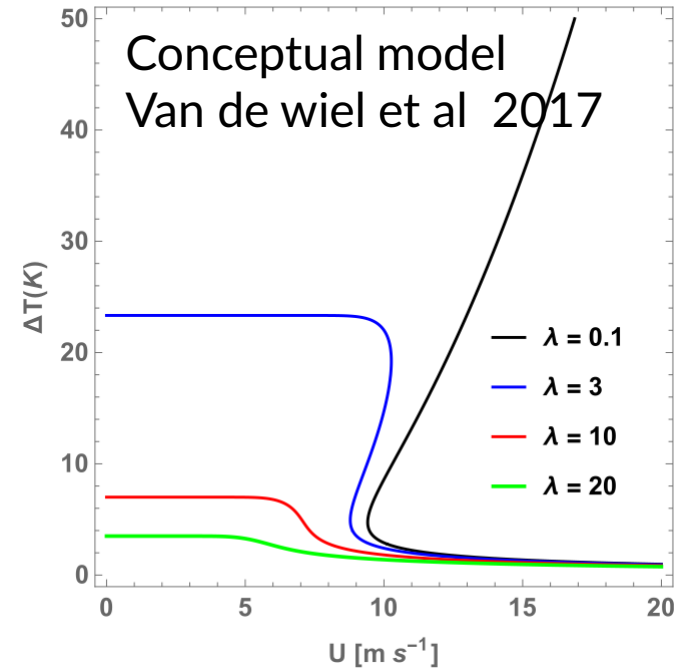
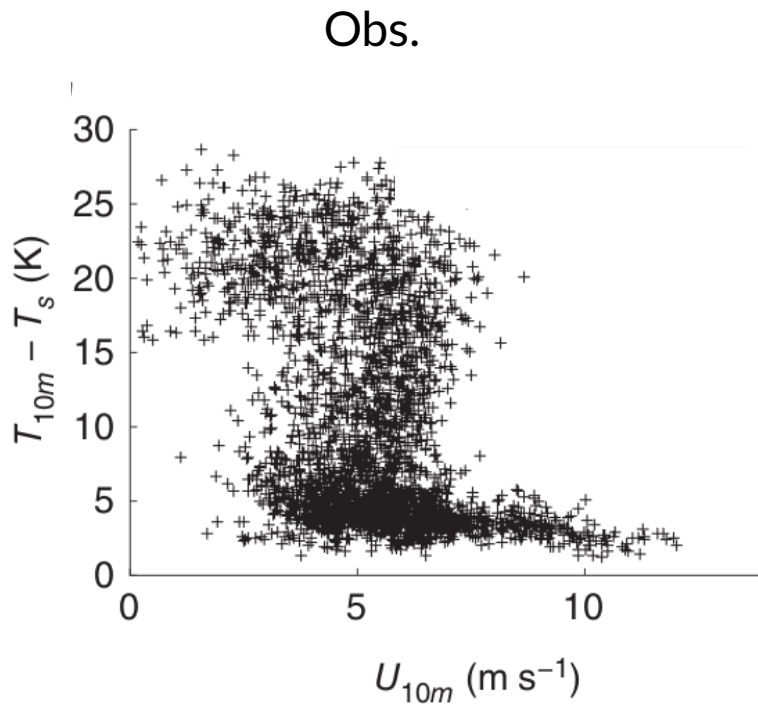
(subjective answers)

- **Dome C is a very particular location (flat terrain)**



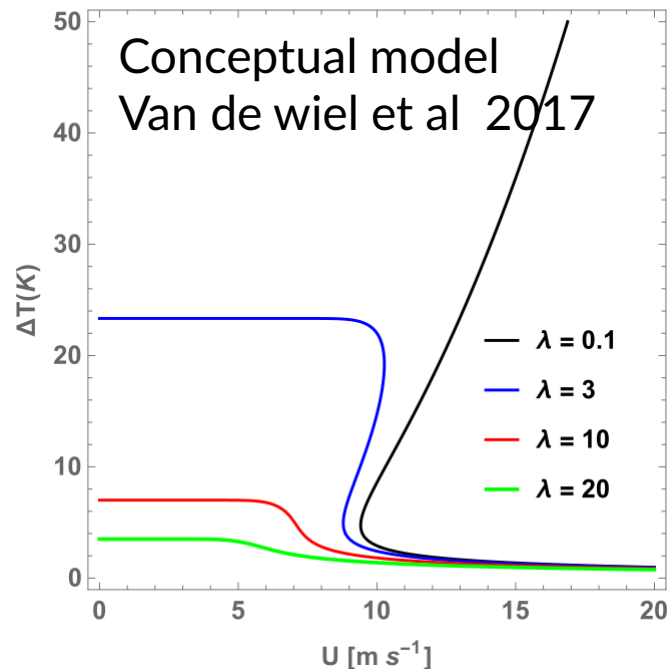
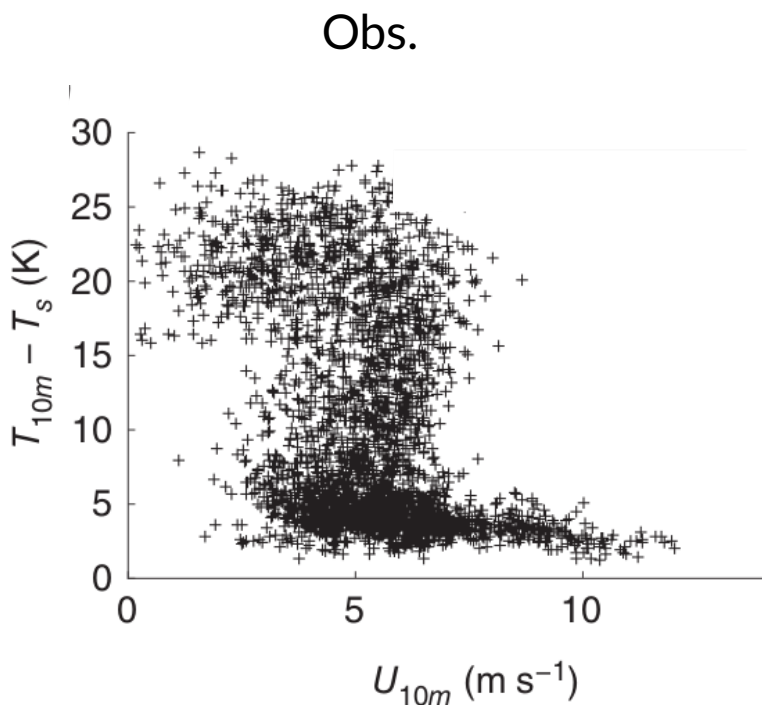


Dome C



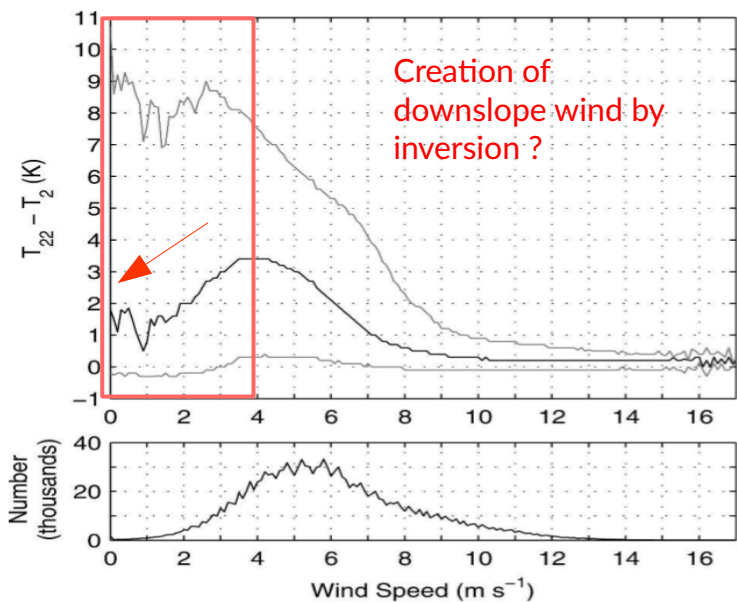


Dome C



South Pole

With a very gentle slope



?



3 main types of boundary layer in Antarctica (King and Turner 1997)

- Boundary layers over the Plateau (gentle or no slopes e.g., Dome C) ← **GABLS4**
- Boundary layers over ice shelves and sea ice (interaction with austral ocean)
- Boundary layers over coastal and escarpment regions
→ katabatic winds + interaction with ocean air masses



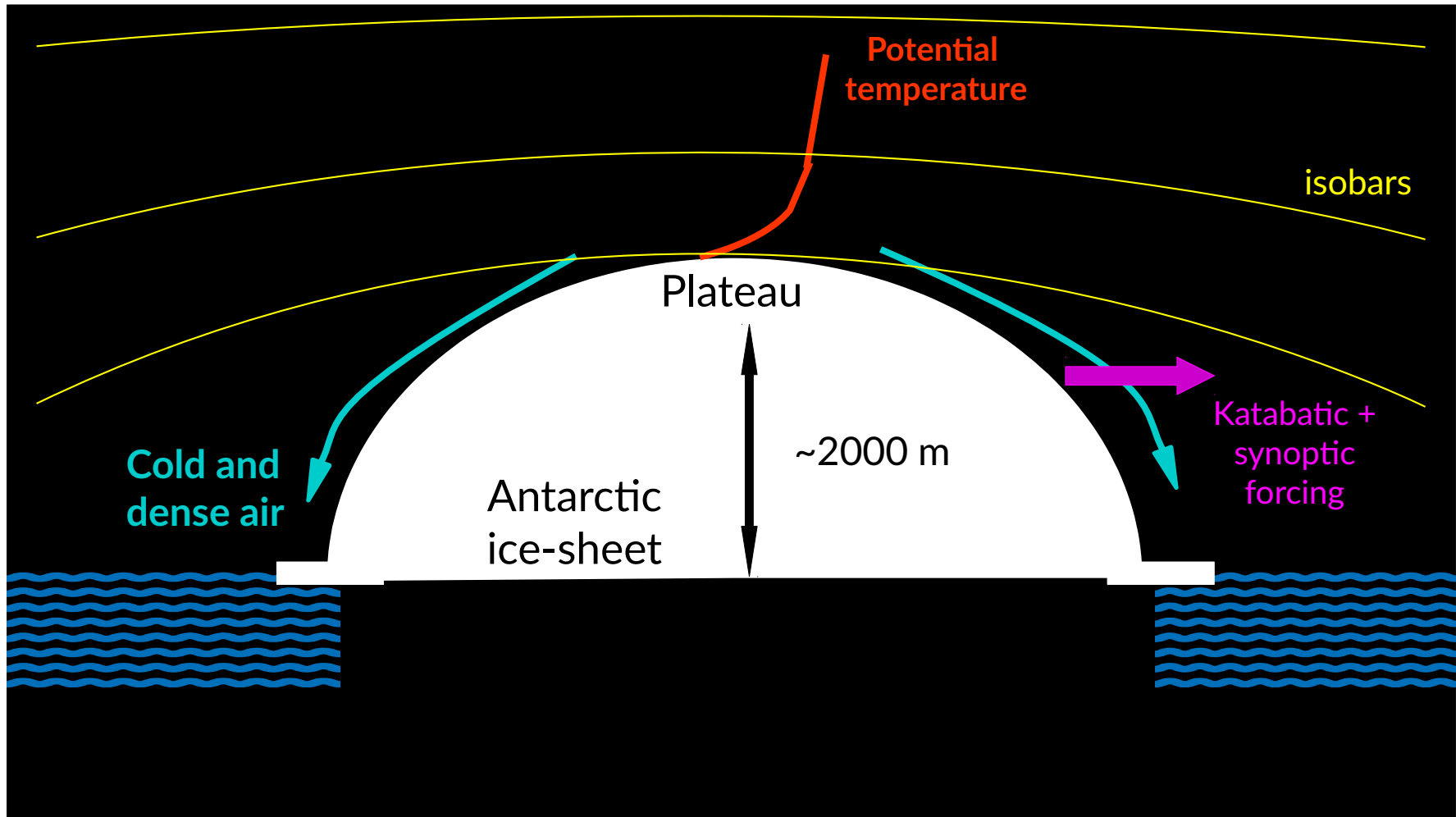
Why should we continue to study the Antarctic boundary layer ?

(subjective answers)

- Dome C is a very particular location (flat terrain)
- **The Antarctic boundary layer is very important for the Antarctic climate system**



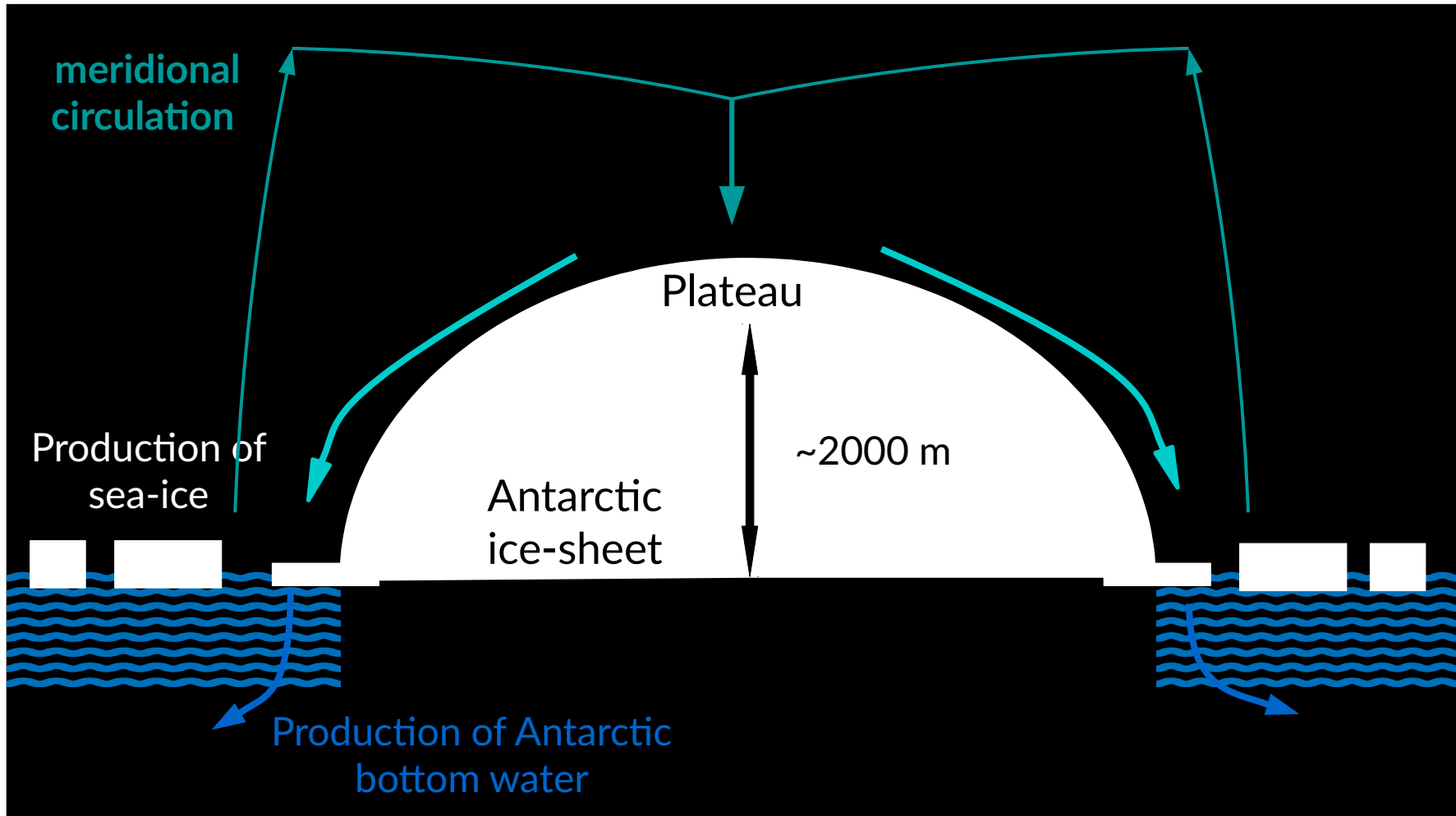
Sketch of the Antarctic meridional circulation





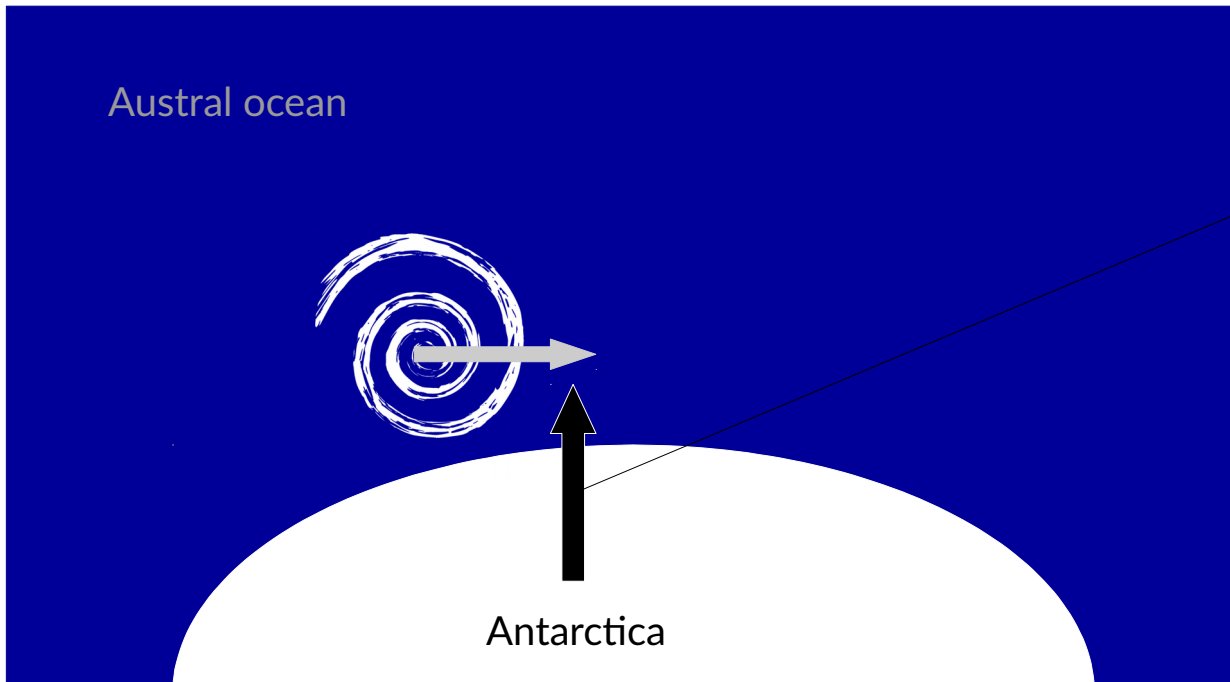
Drainage flow

(James 1989, Parish and Bromwich 1991)





« Antarctic katabatic winds »
Interaction with synoptic weather systems

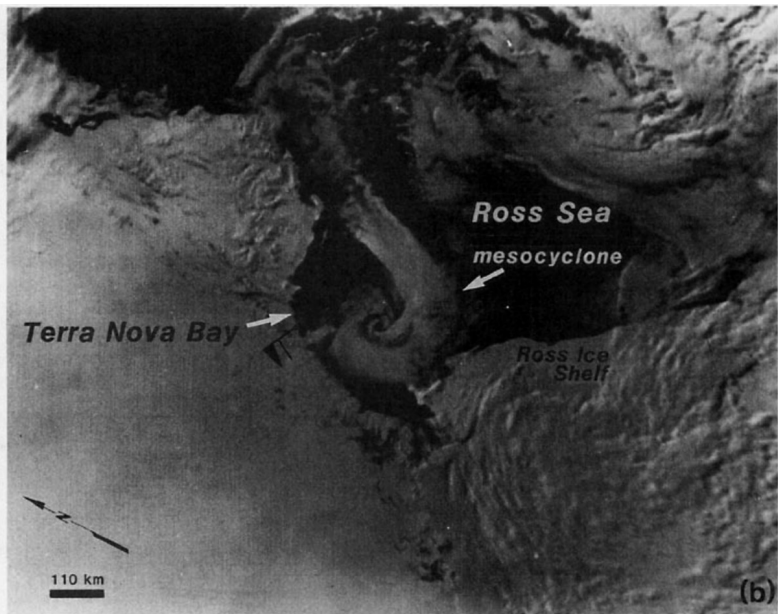
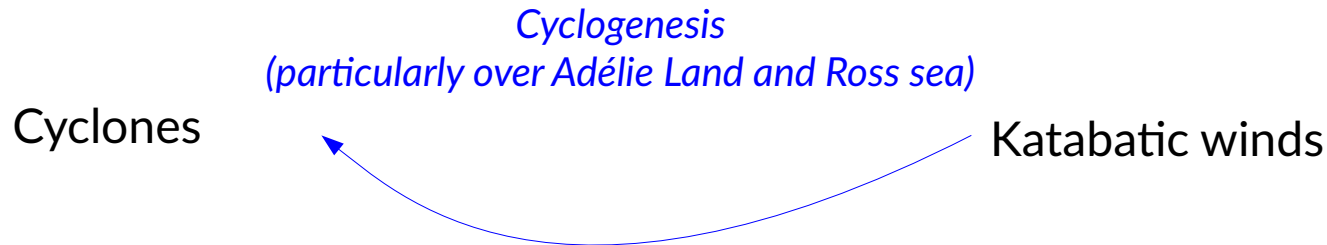


Increase in continent-ocean
pressure gradient

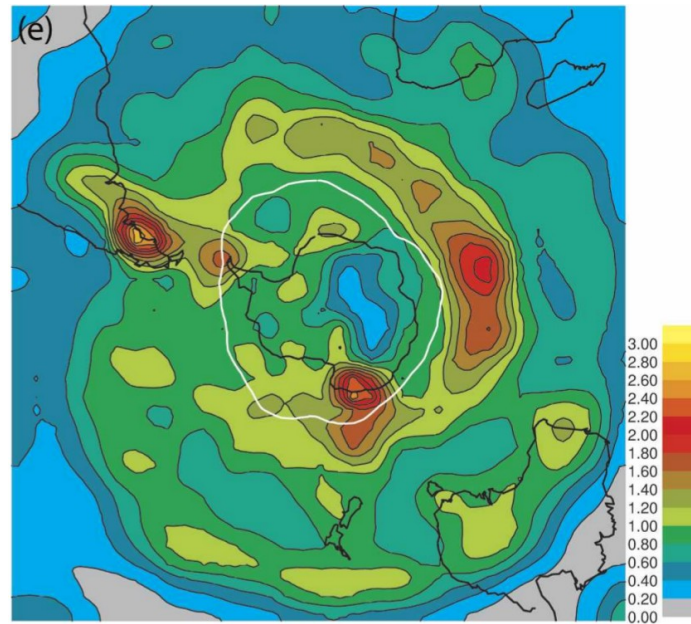
→ acceleration of katabatic
winds (and drainage flow)

Parish et al 1993, 1998
Naithani et al 2002, 2003

« Antarctic katabatic winds » Interaction with synoptic weather systems



Visible image of meso-scale cyclogenesis over the Ross sea, Bromwich et al 1991



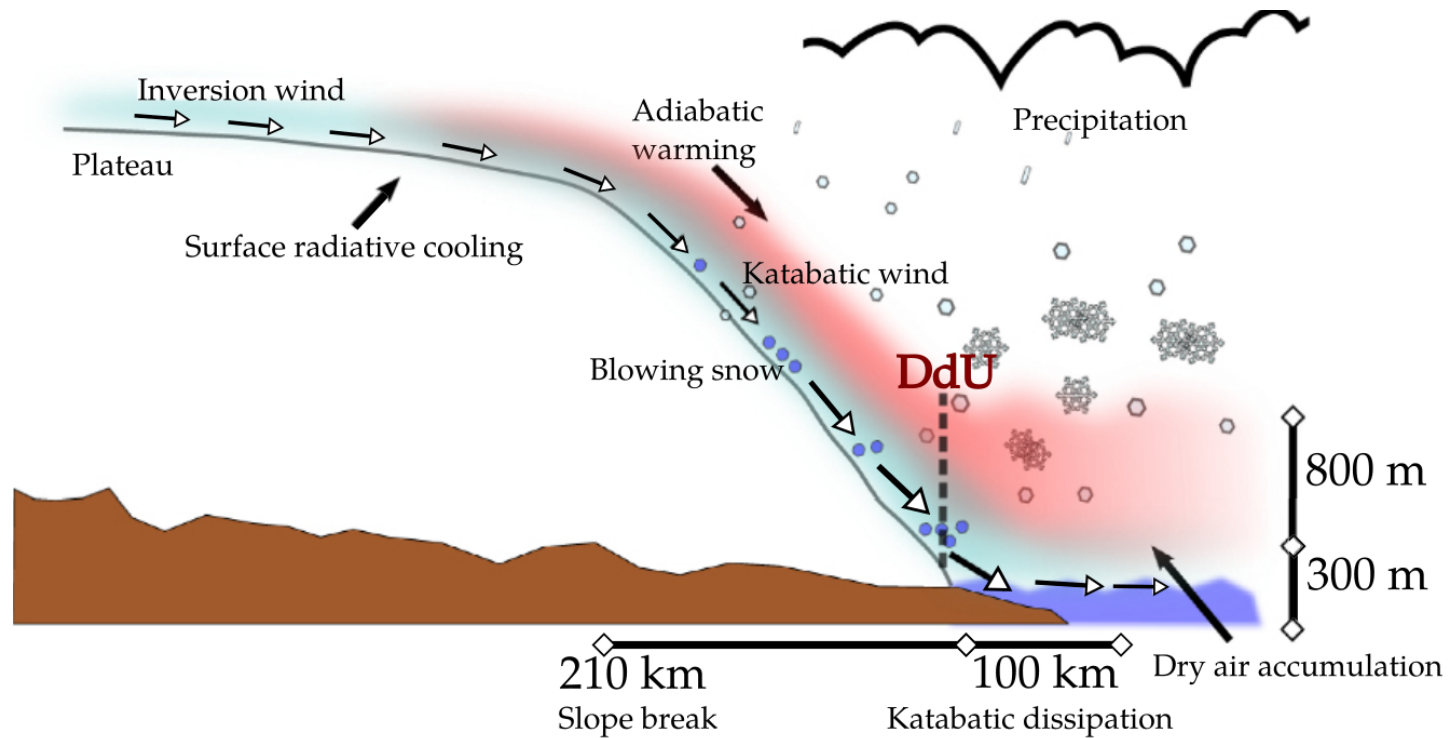
Density of winter cyclogenesis (per month per unit area), Hoskins et al 2005

Several mechanisms involved :

- secondary development
- enhanced baroclinicity
- barrier winds
- vortex stretching
- vorticity generation at the lee side of katabatic jets

Bromwich et al 1991, 2011
Gallee et al 1995, 1996
Turner et al 1993, 1998
Carrasco et al 1997

« Antarctic katabatic winds »
Sublimation of precipitation





Antarctic boundary layer and katabatic winds over
Antarctica are critical for :

- Large scale circulation : drainage flow, export of mass at low levels,
import of potential energy at high levels
- Production of sea-ice and oceanic bottom waters
→ *importance of horizontal extent of continental flows*
- Surface mass balance (blowing snow + sublimation of precipitations)
→ *vertical structure*
- Interaction with synoptic weather systems





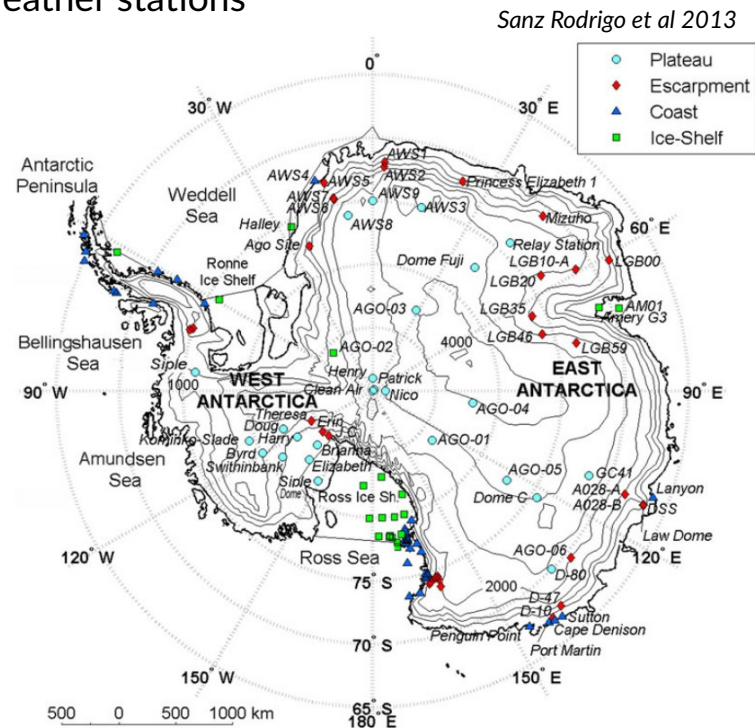
Why should we continue to study the Antarctic boundary layer ?

(subjective answers)

- Dome C is a very particular location (flat terrain)
- The Antarctic boundary layer is very important for the Antarctic climate system
- **Significant biases in reanalyses and climate models**

Wind biases at the surface

Network of automatic weather stations



Evaluation of wind speed in ERA-Interim and RACMO in Sanz Rodrigo et al 2013

« The highest errors are found in escarpment areas [...] **the bias can be more than 10 m s^{-1}** in the reanalysis databases. Regional climate models reduce the bias in these areas significantly but are still far from being bias free. »

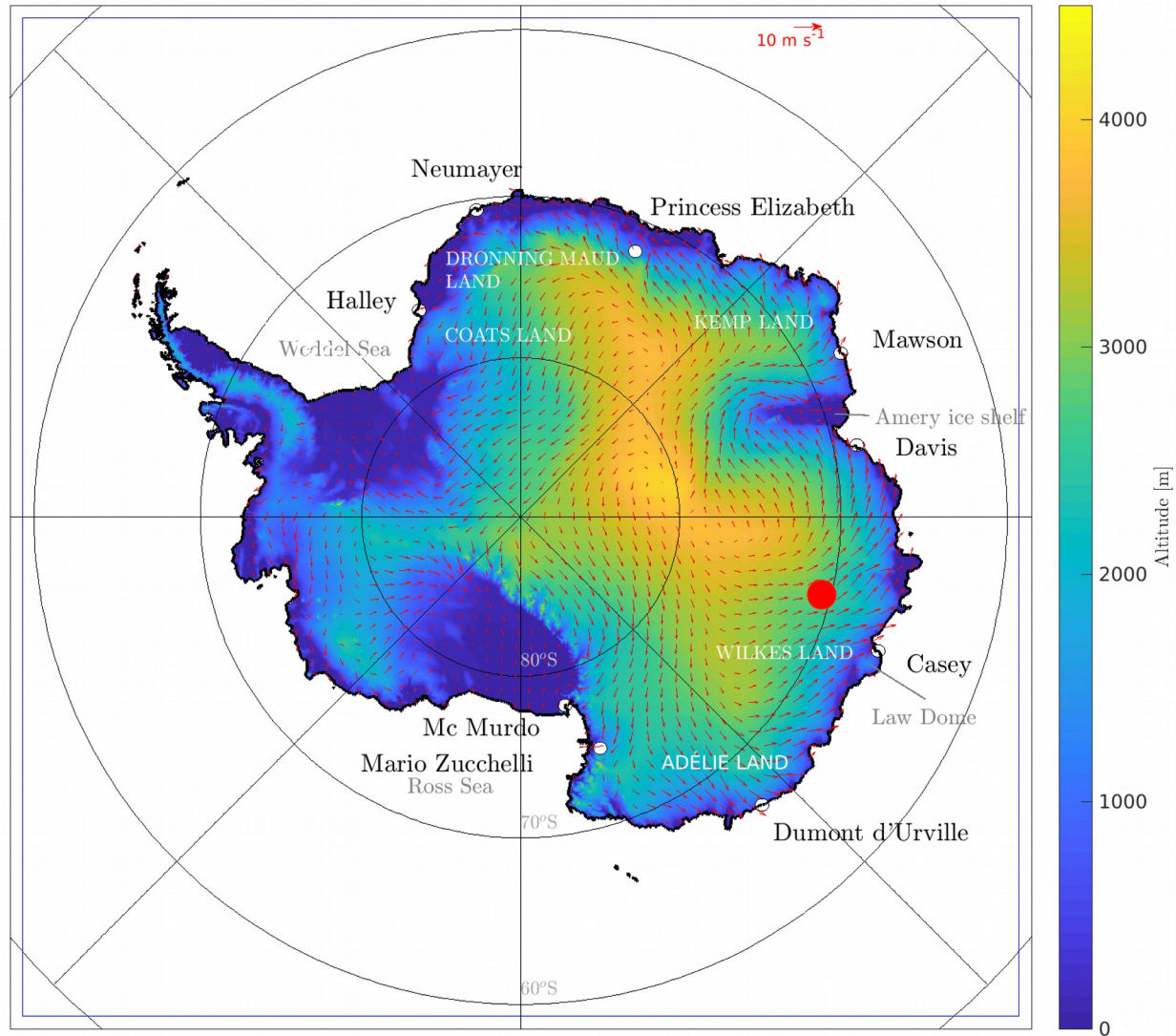
Evaluation of wind speed in EC-Earth global climate model in Bintanja et al 2014

« Simulated surface winds are generally underestimated with respect to observations, in particular the strongest winds (occurring over steep slopes), and **especially in low resolution.** »



What about the vertical structure ?

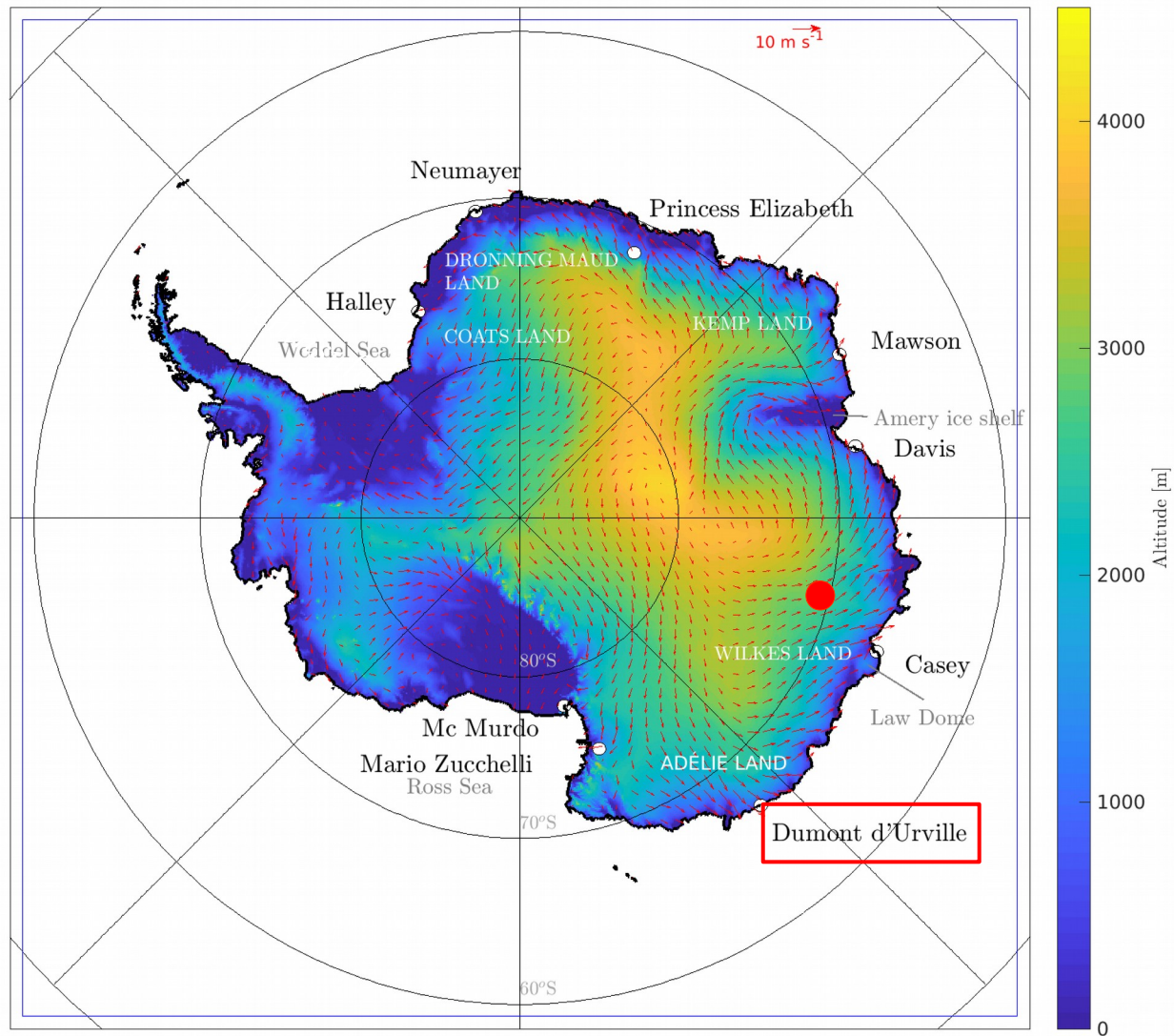
Daily Radiosoundings

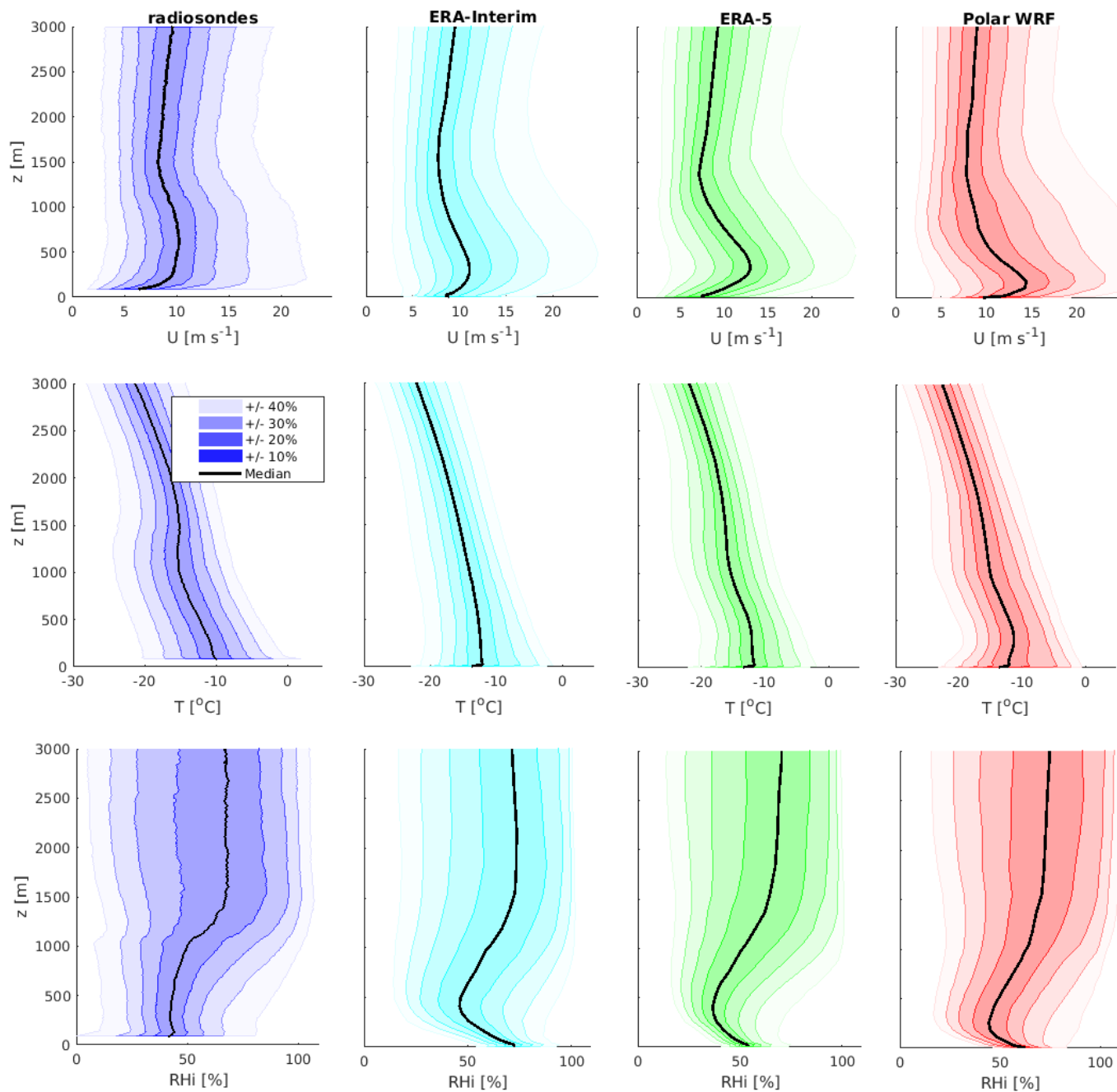




What about the vertical structure ?

Daily Radiosoundings





ERA-Interim :

Assimilates radiosondes
 ~78 km resolution
 17 vertical levels in the first 3000m
 K-gradient turbulent scheme (Louis)

ERA5 :

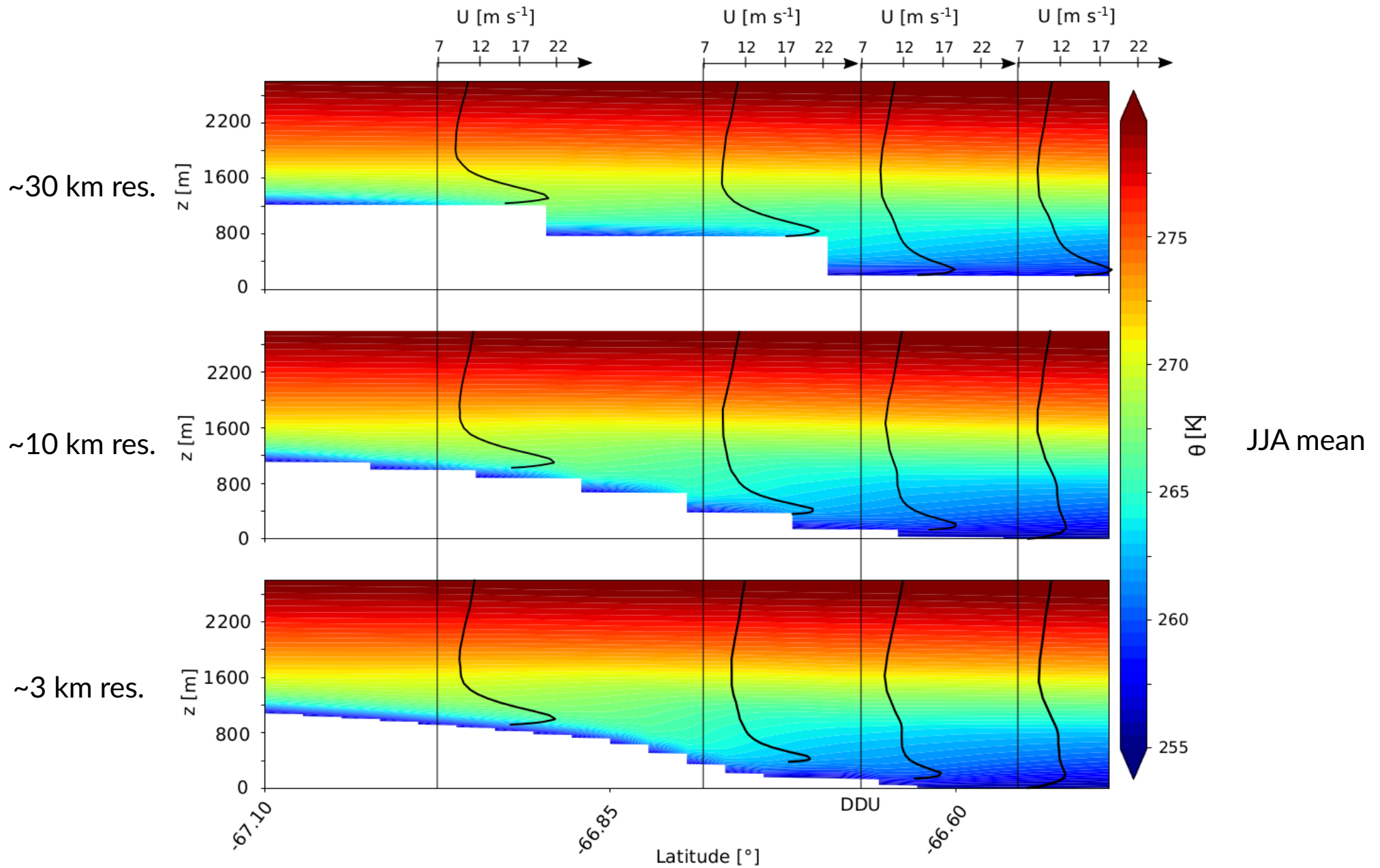
Assimilates radiosonde
 ~31 km of resolution
 33 vertical levels in the first 3000m
 K-gradient turbulent scheme (Louis)

Polar-WRF :

free climate model simulation over the whole Antarctic continent, laterally forced with ERA5, 30 km resolution, 23 vertical levels in the first 3000m
 Mellor and Yamada TKE-I scheme



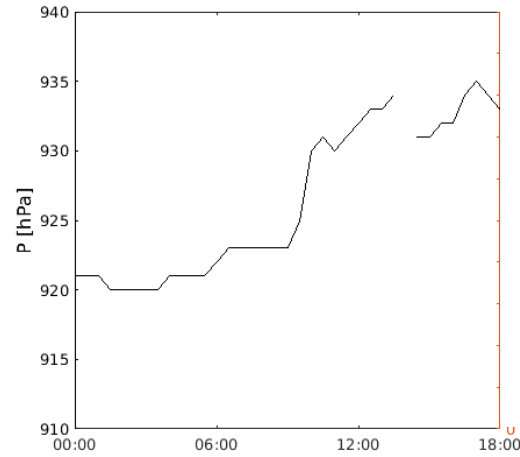
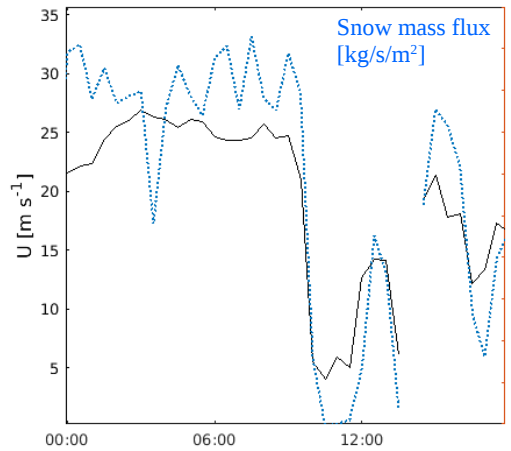
Effect of the « bump » of cold air



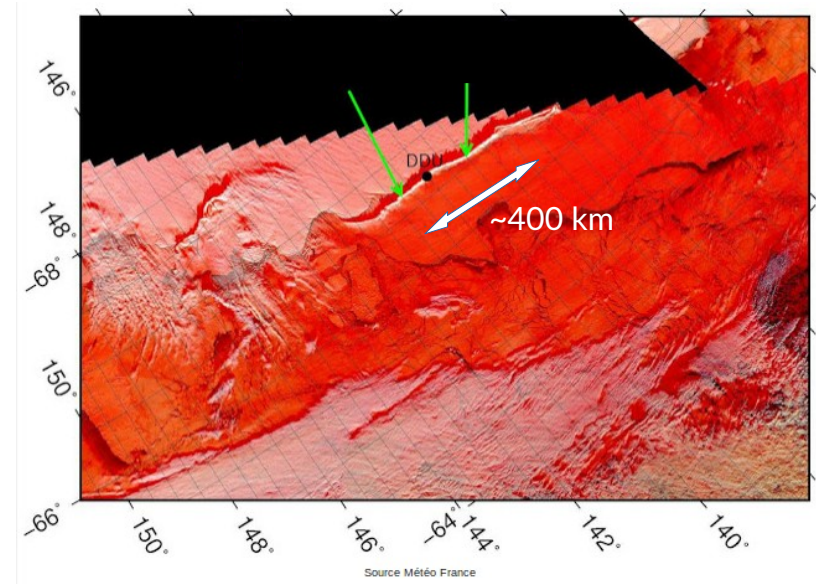


Wind speed transition can be abrupt : « Katabatic jumps »

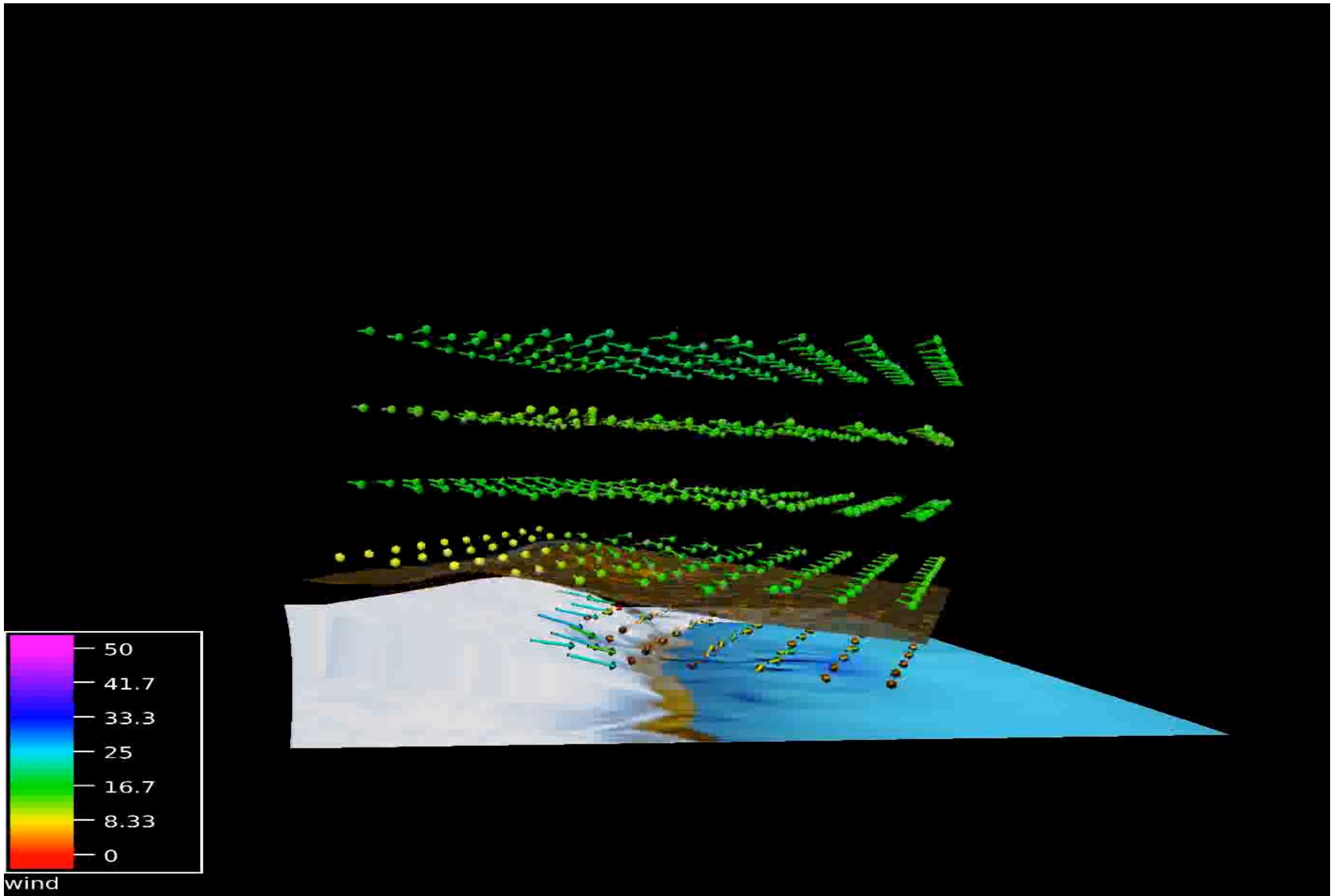
Example : 10/08/2017 at
Dumont d'Urville



Credits : F. Mariotti



Source : Météo France



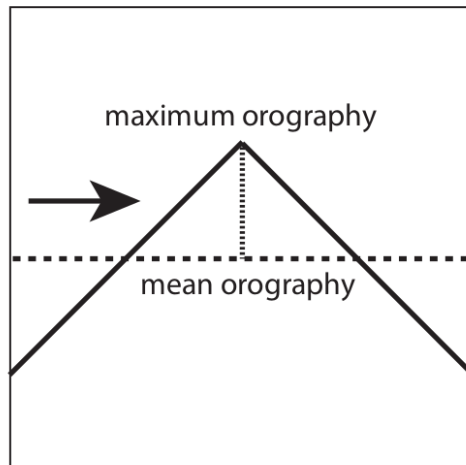


- Evaluating and improving the modeling of stable boundary layers over **slopes** of escarpment regions (katabatic winds)
Need to account for subgrid slope (original approach by *Pettré 1990*) ?

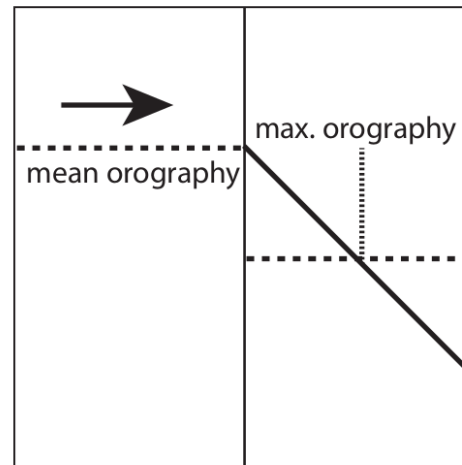


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! Classical subgrid-scale orographic drag based on standard deviation of subgrid orography over Greenland and Antarctica (*Pithan et al 2015*)



Situation for which subgrid orography drag schemes are often developed



Ice-sheet edges

- Evaluating and improving the modeling of stable boundary layers over **slopes** of escarpment regions (katabatic winds)
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- At the **Antarctic coast**, what is the ability of models to represent :
 - the **vertical structure** of the boundary layer
 - the **horizontal extent** of katabatic winds
(cold air bump, sea breeze, katabatic jumps, wave generation)
model studies but no evaluation
critical for the formation of sea-ice and ocean bottom water in coupled models

Need for additional measurements ?

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Prospects : Year of Polar Prediction – Southern Hemisphere

Special Observing Period : Nov. 16, 2018 - Feb. 15 , 2019

(extra radiosonde launches, model simulations, additional AWS, buoys...)

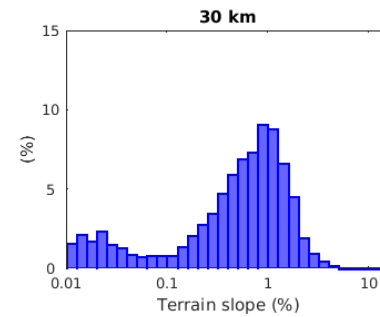
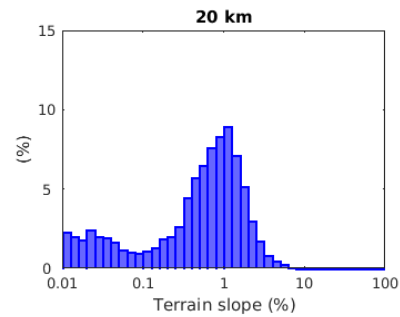
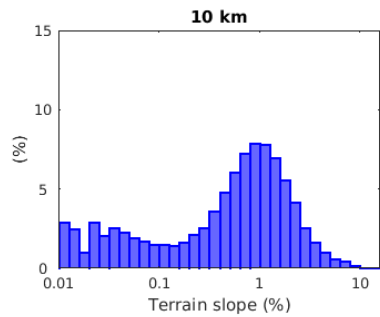
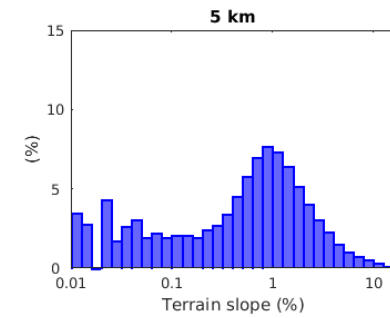
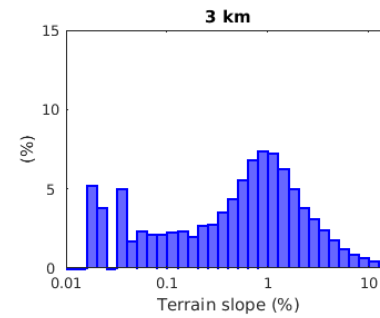
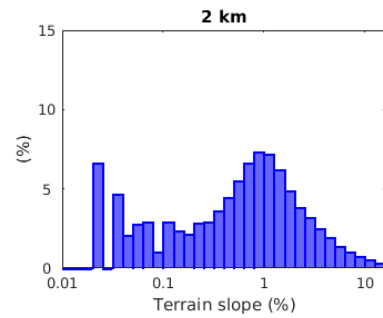
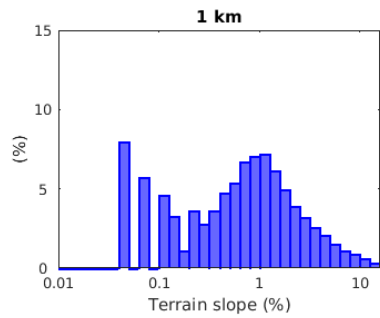
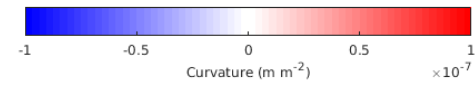
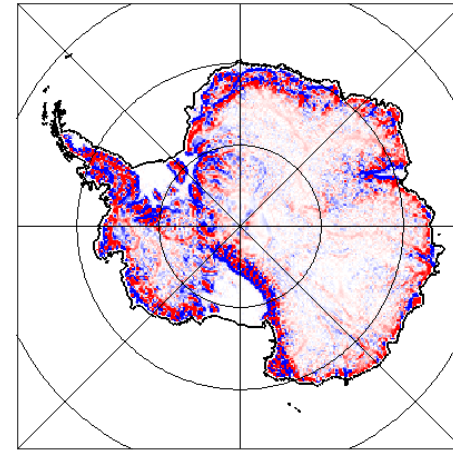
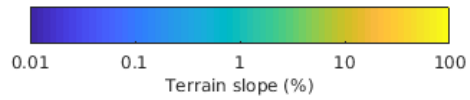
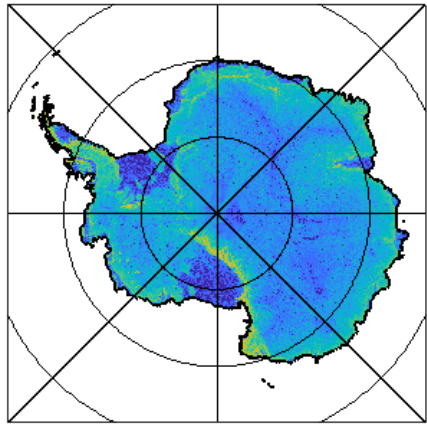
<http://polarmet.osu.edu/YOPP-SH>

Thank's for your attention



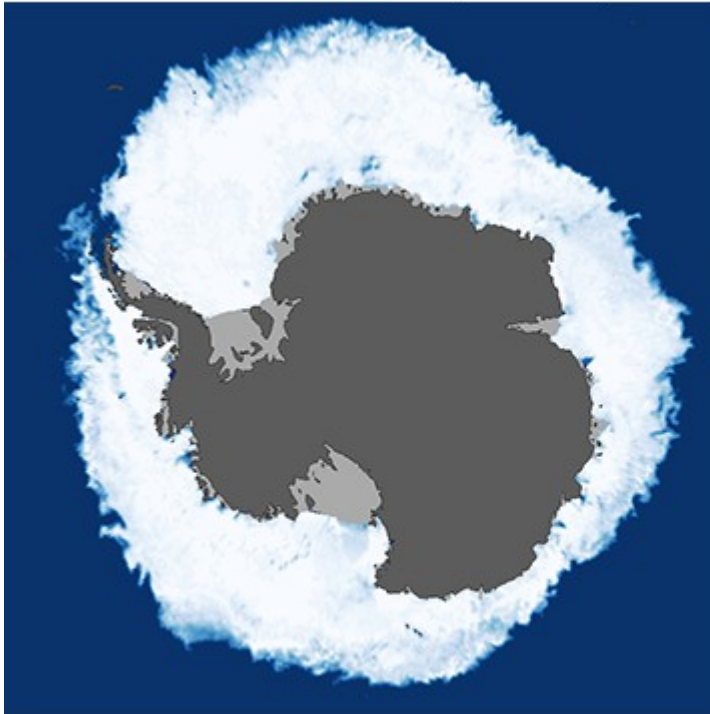
Scientists challenging the Antarctic boundary layer

Challenges

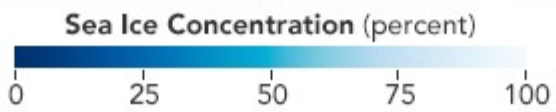




2015 Antarctic Maximum (October 6)

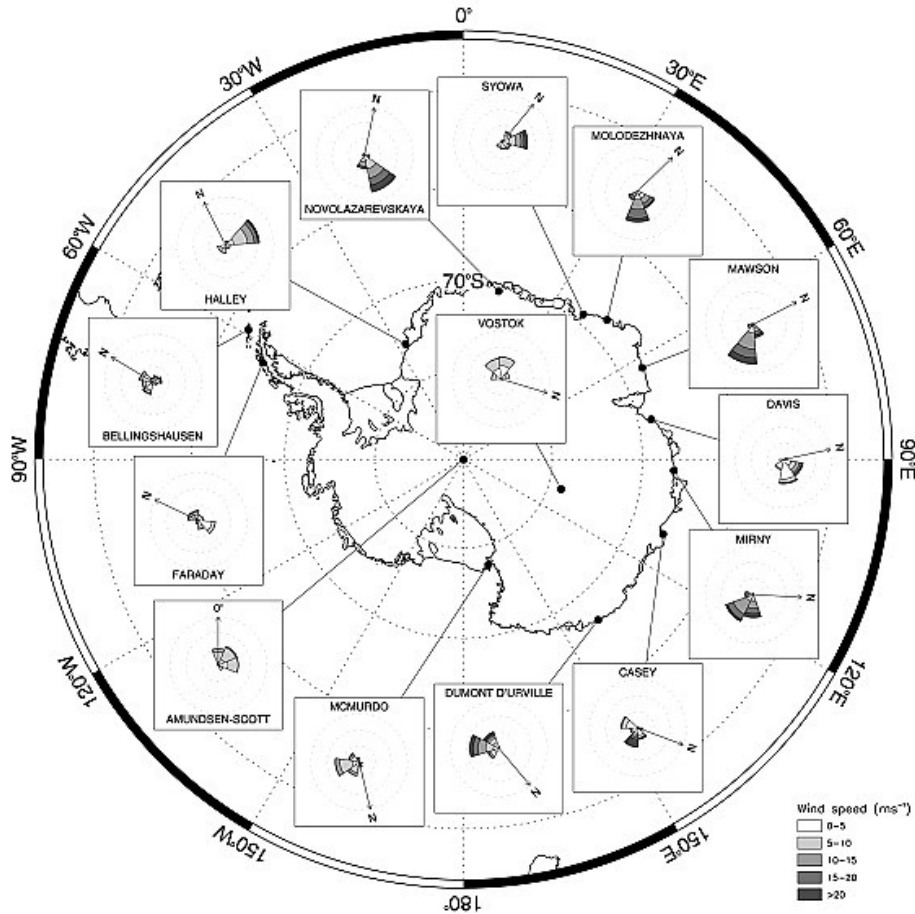


2016 Antarctic Minimum (February 19)



Source : NASA

« Antarctic katabatic winds » Export of mass and humidity from the continent



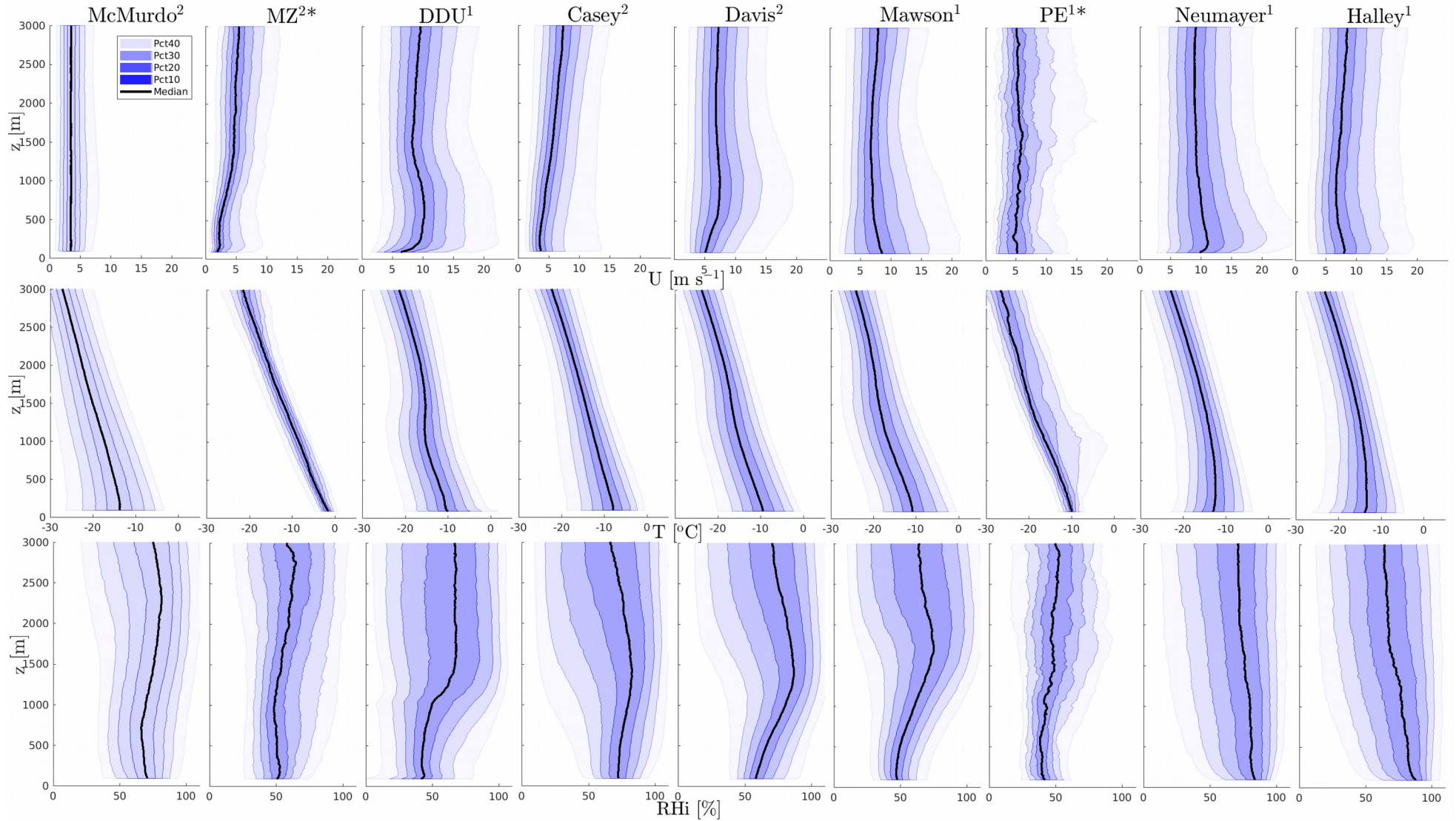
Winter wind roses at Antarctic stations,
Turner et al 2009

Record near Dumont d'Urville station : 90.8 m/s



Blowing snow affecting penguins

Evaluation of models



Evaluation of models

