



## Antarctic boundary layers: challenges for atmospheric models beyond Dome C

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V. Favier, C. Genthon and A. Berne



GABLS4 workshop  
Toulouse, 12-14 September 2018





**Why should we continue to study the Antarctic boundary layer ?**

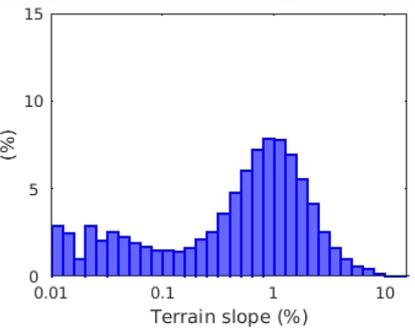
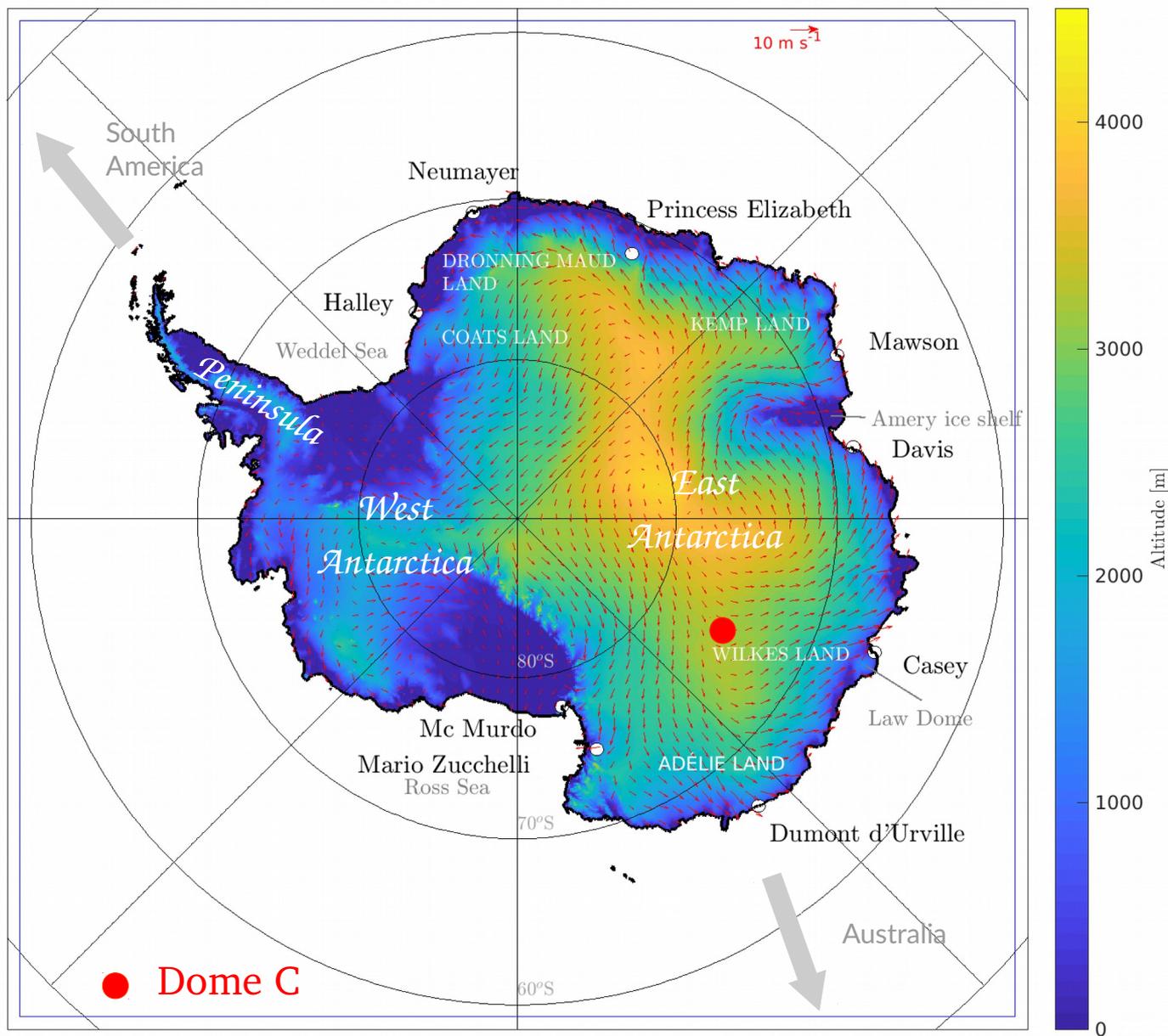
(subjective answers)



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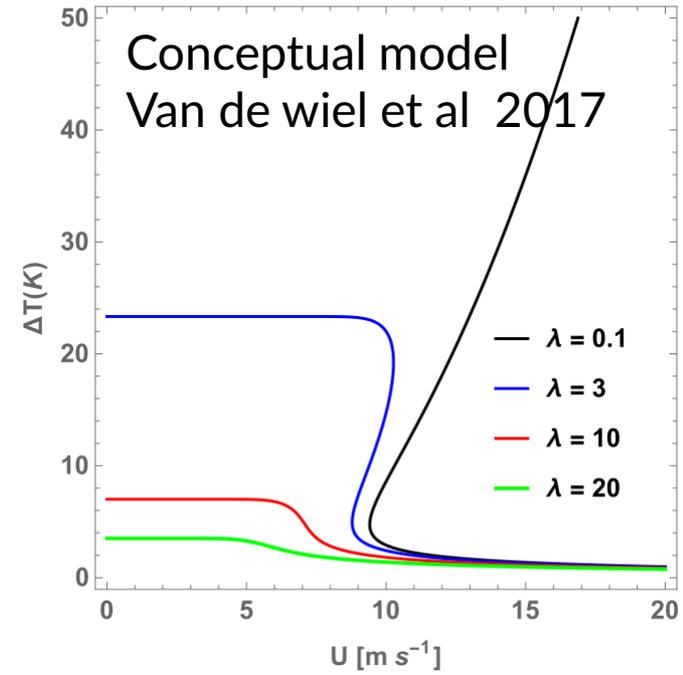
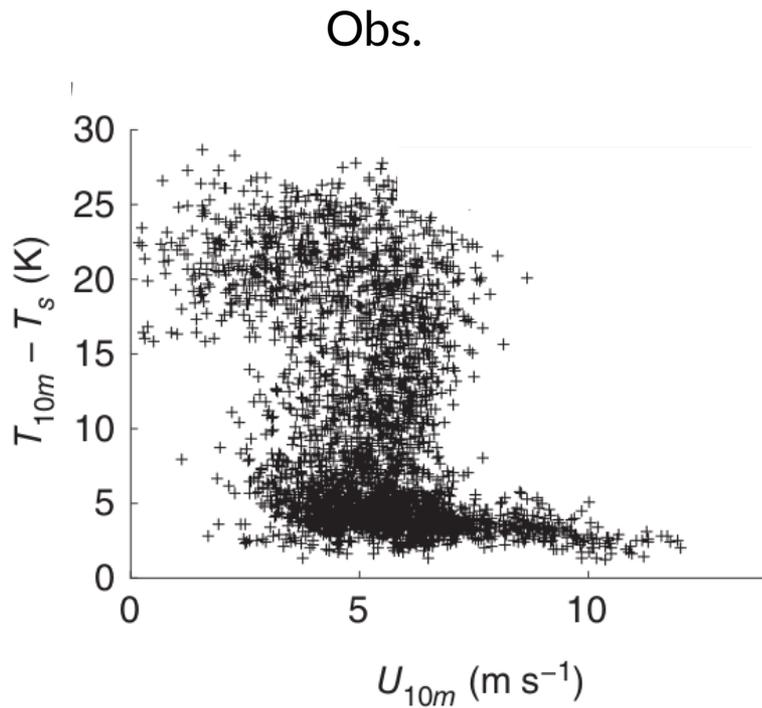
(subjective answers)

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



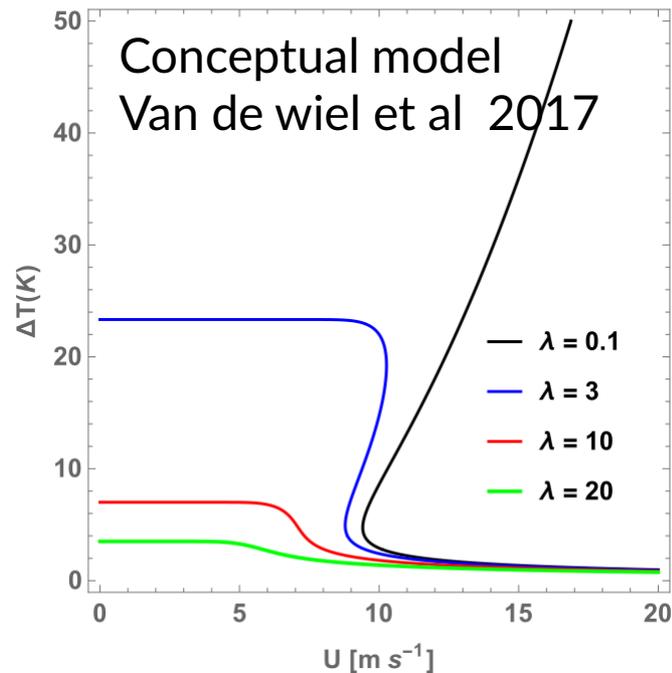
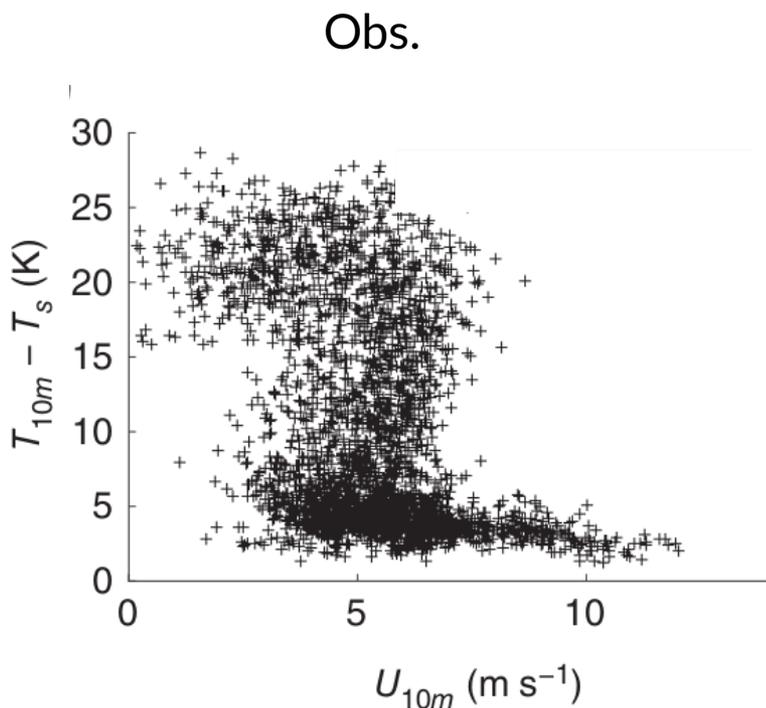


Dome C



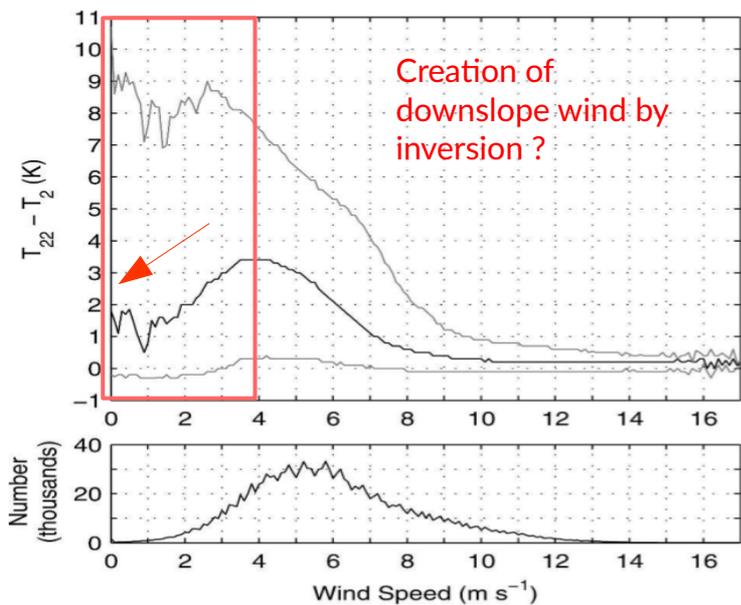


Dome C



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



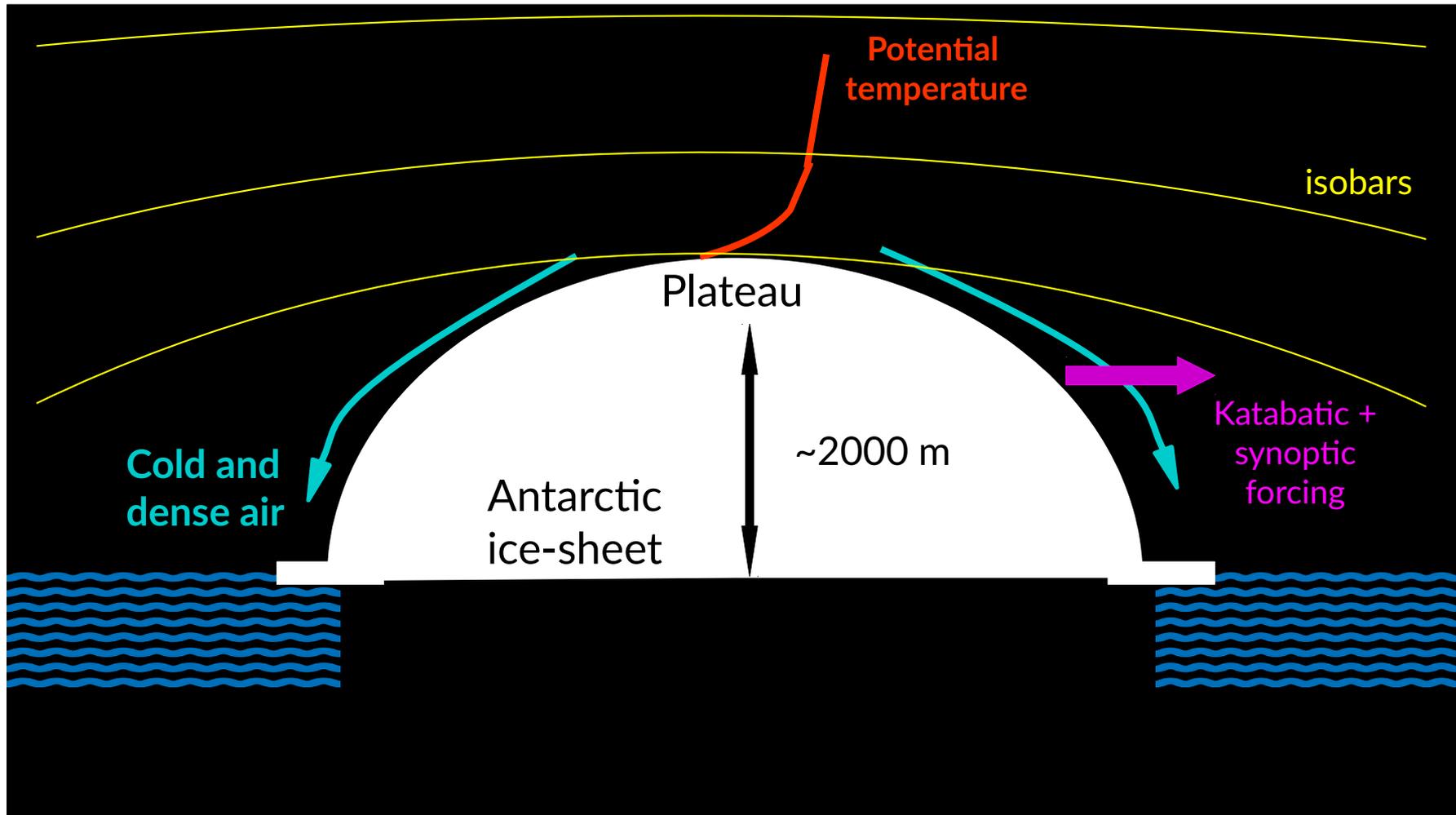
**Why should we continue to study the Antarctic boundary layer ?**

(subjective answers)

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



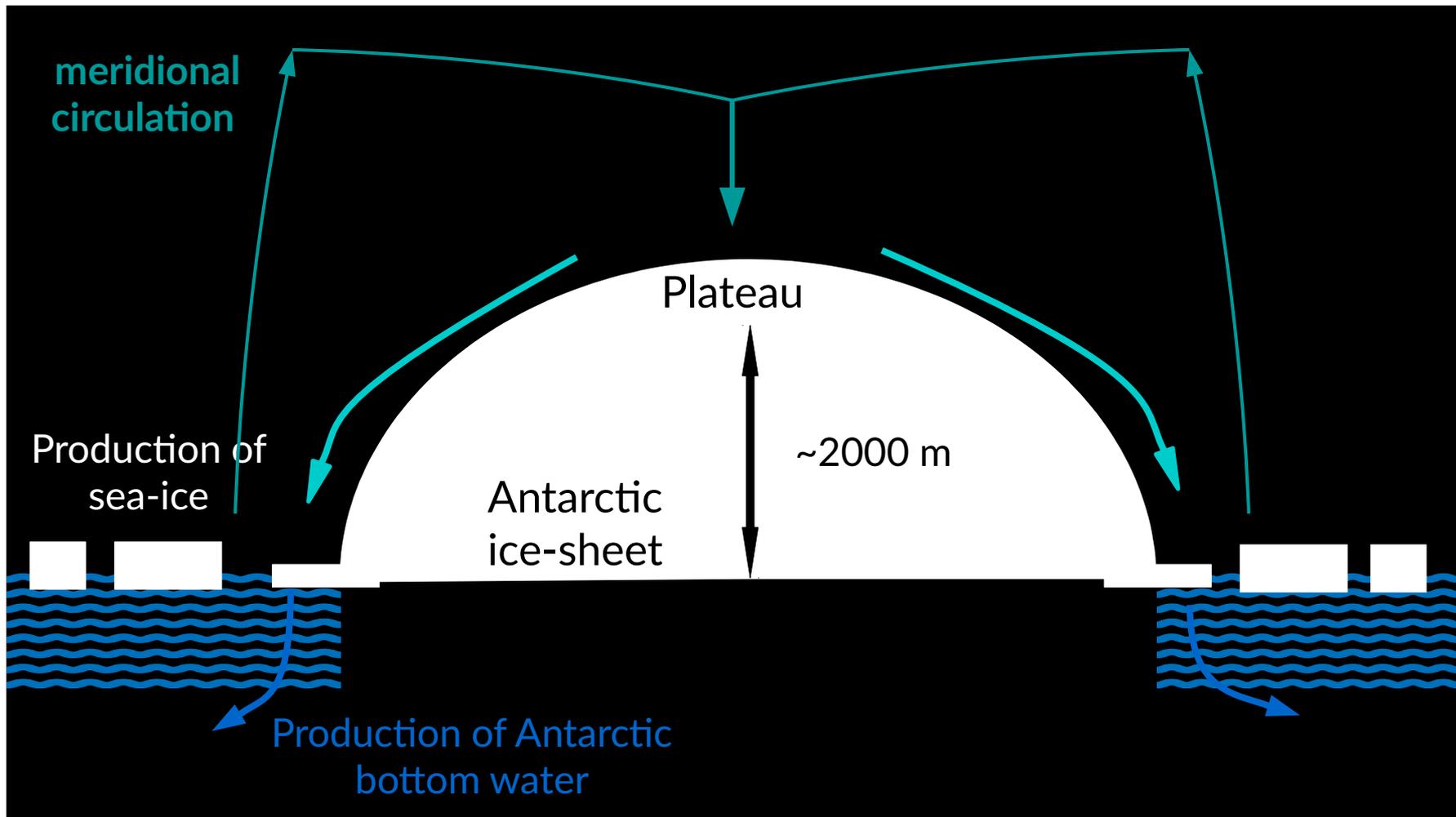
Sketch of the Antarctic meridional circulation





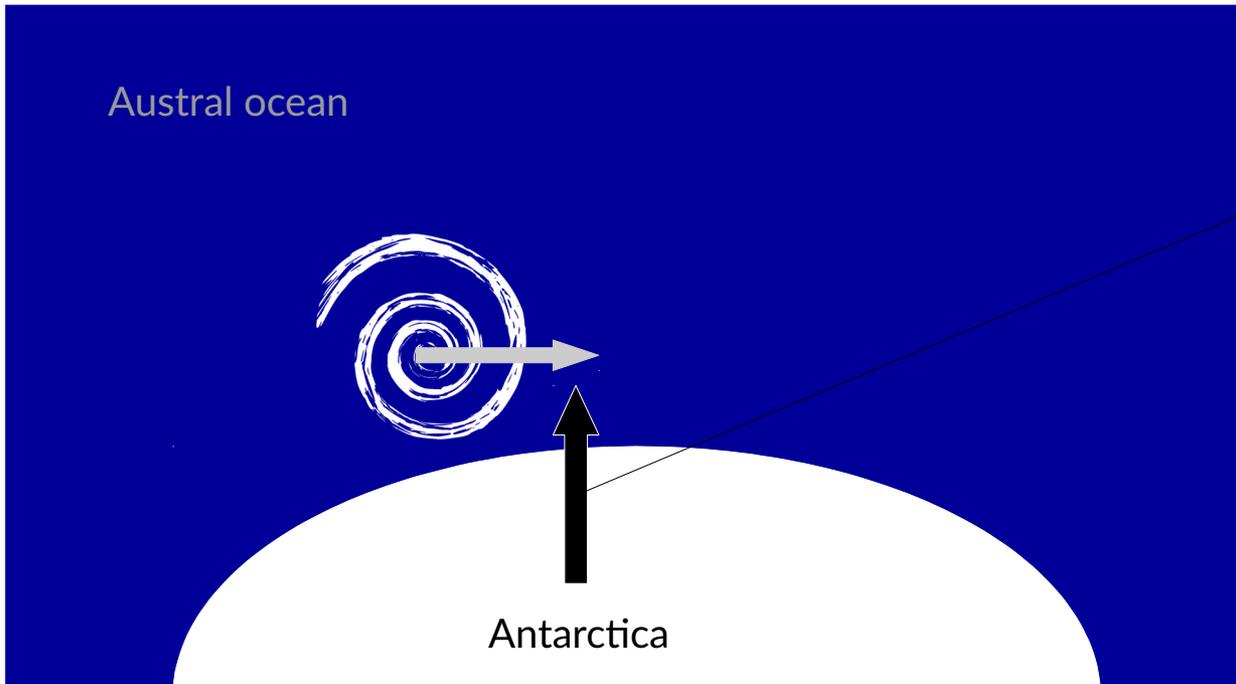
## Drainage flow

(James 1989, Parish and Bromwich 1991)





« Antarctic katabatic winds »  
Interaction with synoptic weather systems

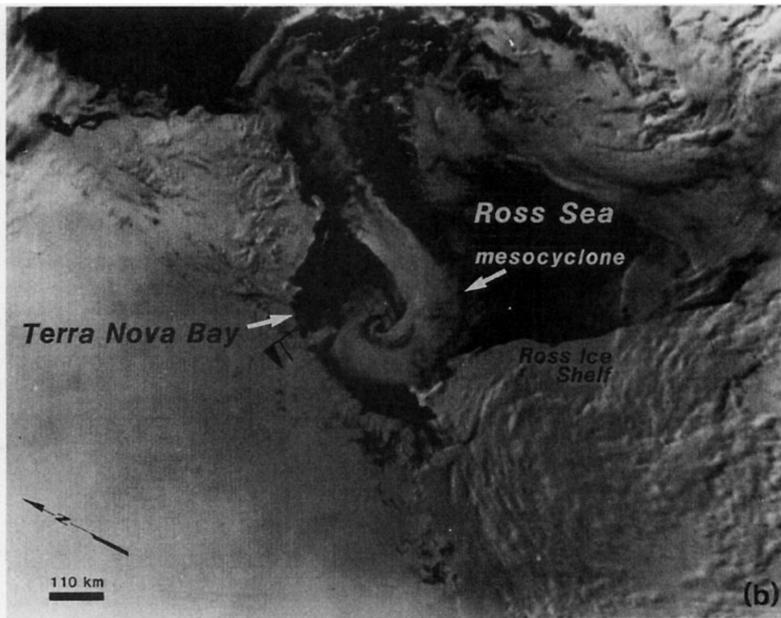
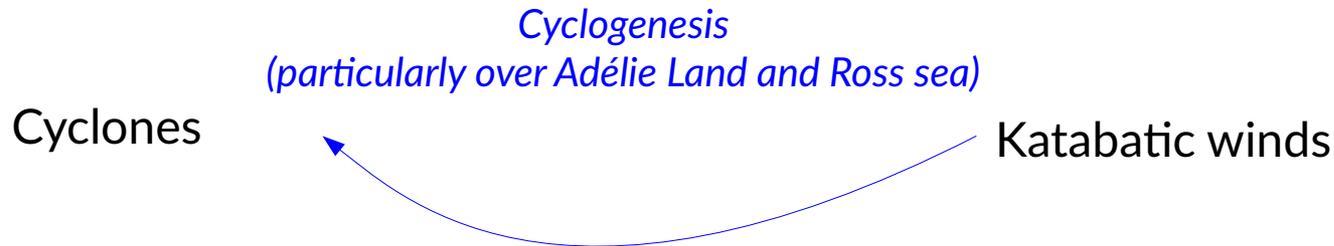


Increase in continent-ocean  
pressure gradient

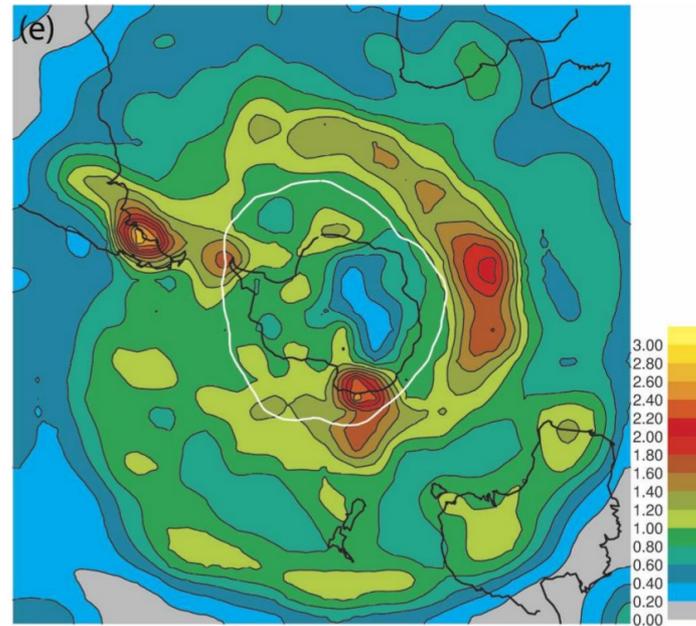
→ acceleration of katabatic  
winds (and drainage flow)

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



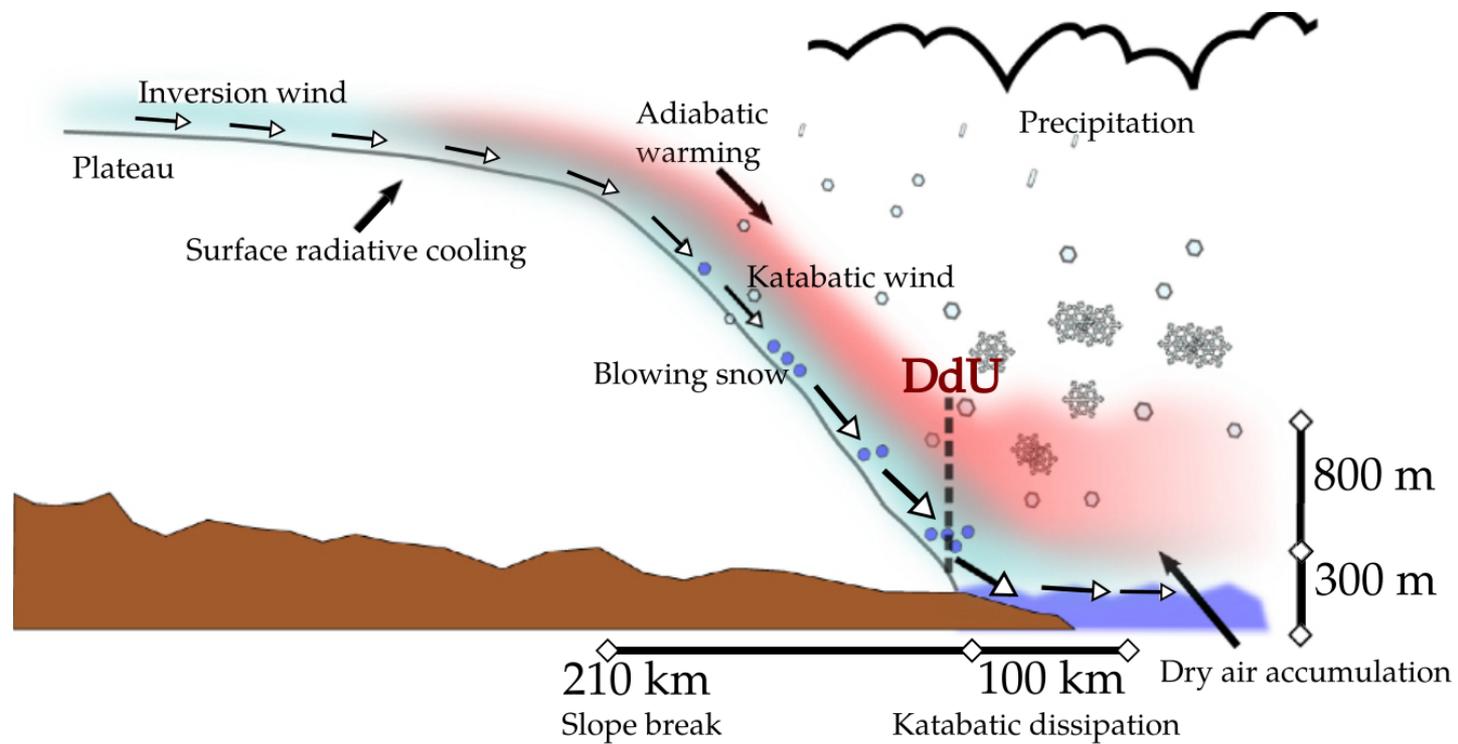
Density of winter cyclogenesis (per month per unit area), Hoskins et al 2005

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



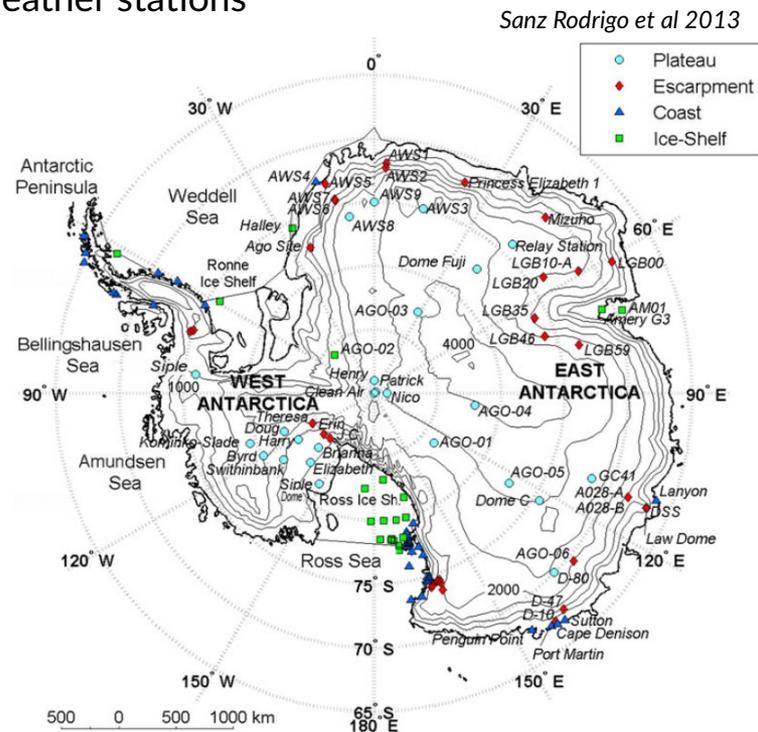
**Why should we continue to study the Antarctic boundary layer ?**

(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  $10 \text{ m s}^{-1}$**  in the reanalysis databases. Regional climate models reduce the bias in these areas significantly but are still far from being bias free. »

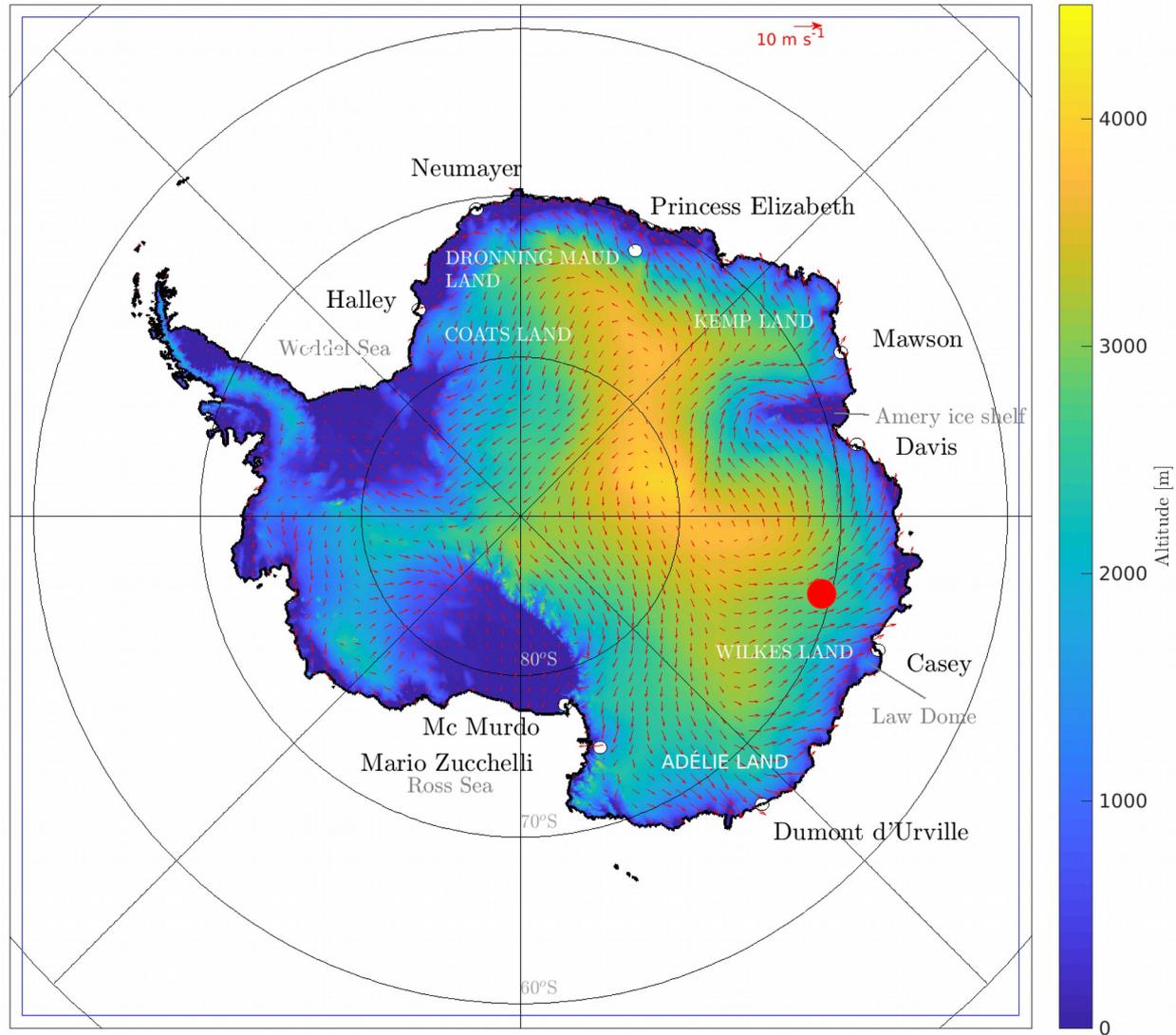
### Evaluation of wind speed in EC-Earth global climate model in Bintanja et al 2014

« 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 ?

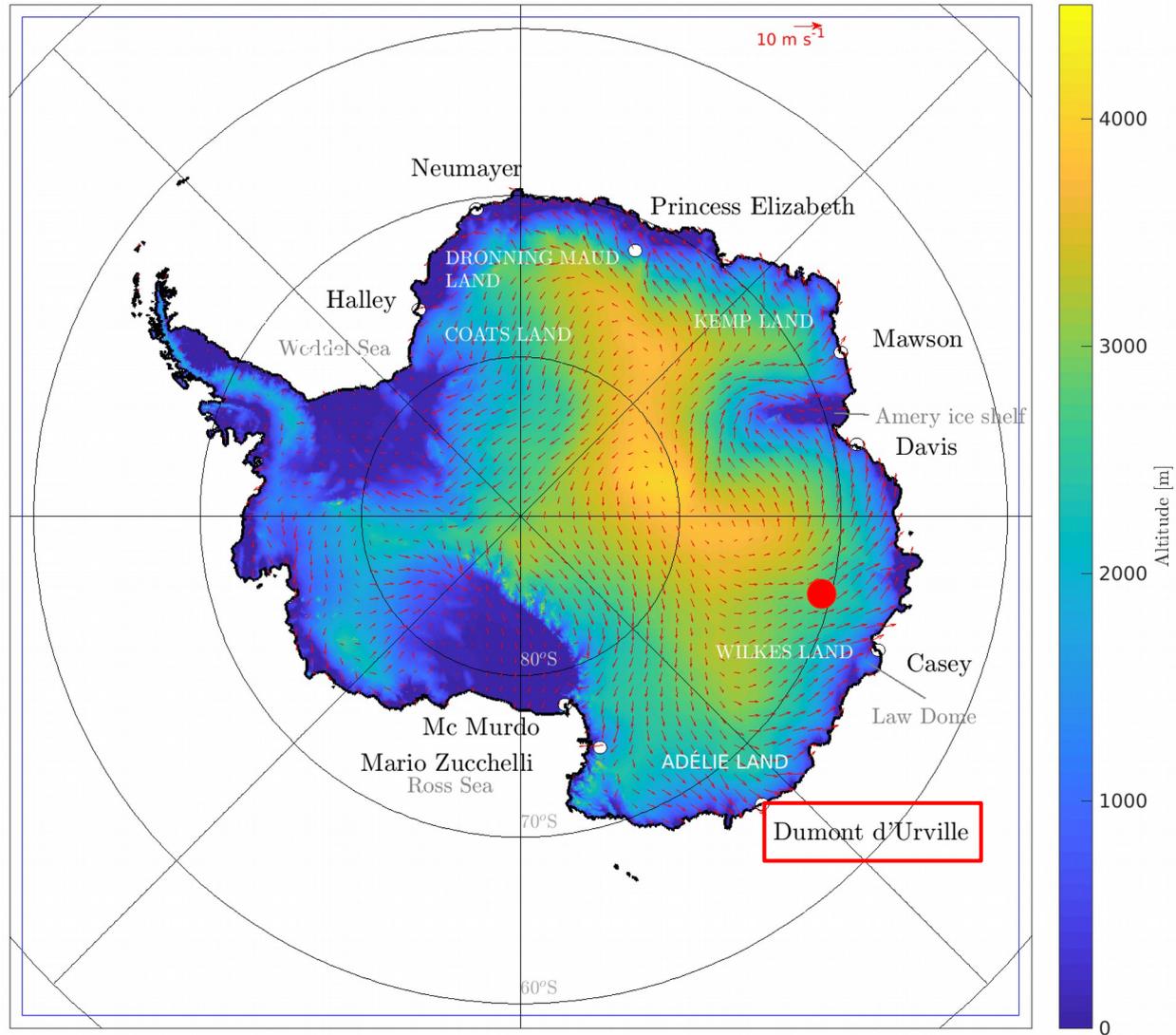
### Daily Radiosoundings

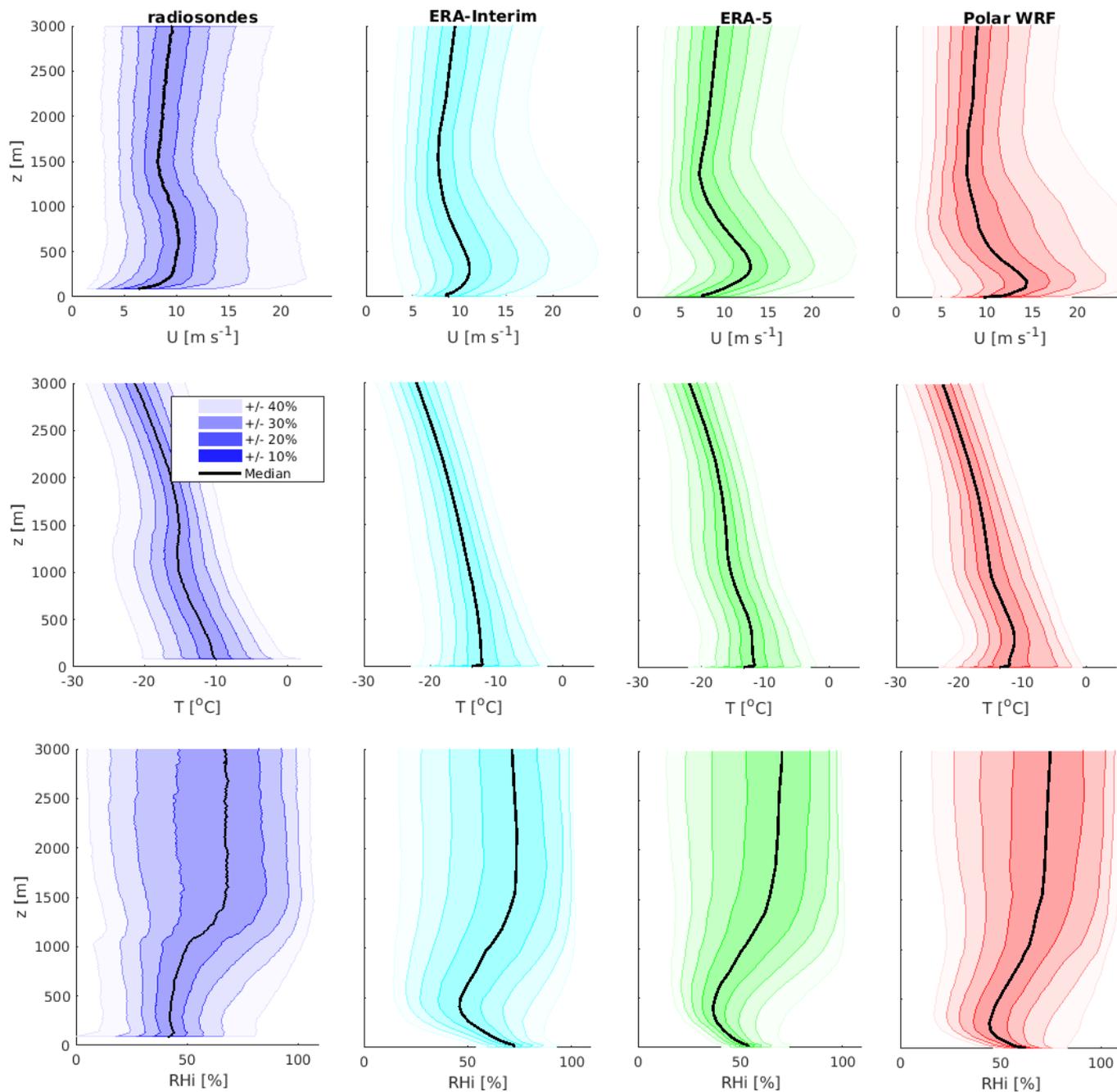




## What about the vertical structure ?

### Daily Radiosoundings





## ERA-Interim :

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

## ERA5 :

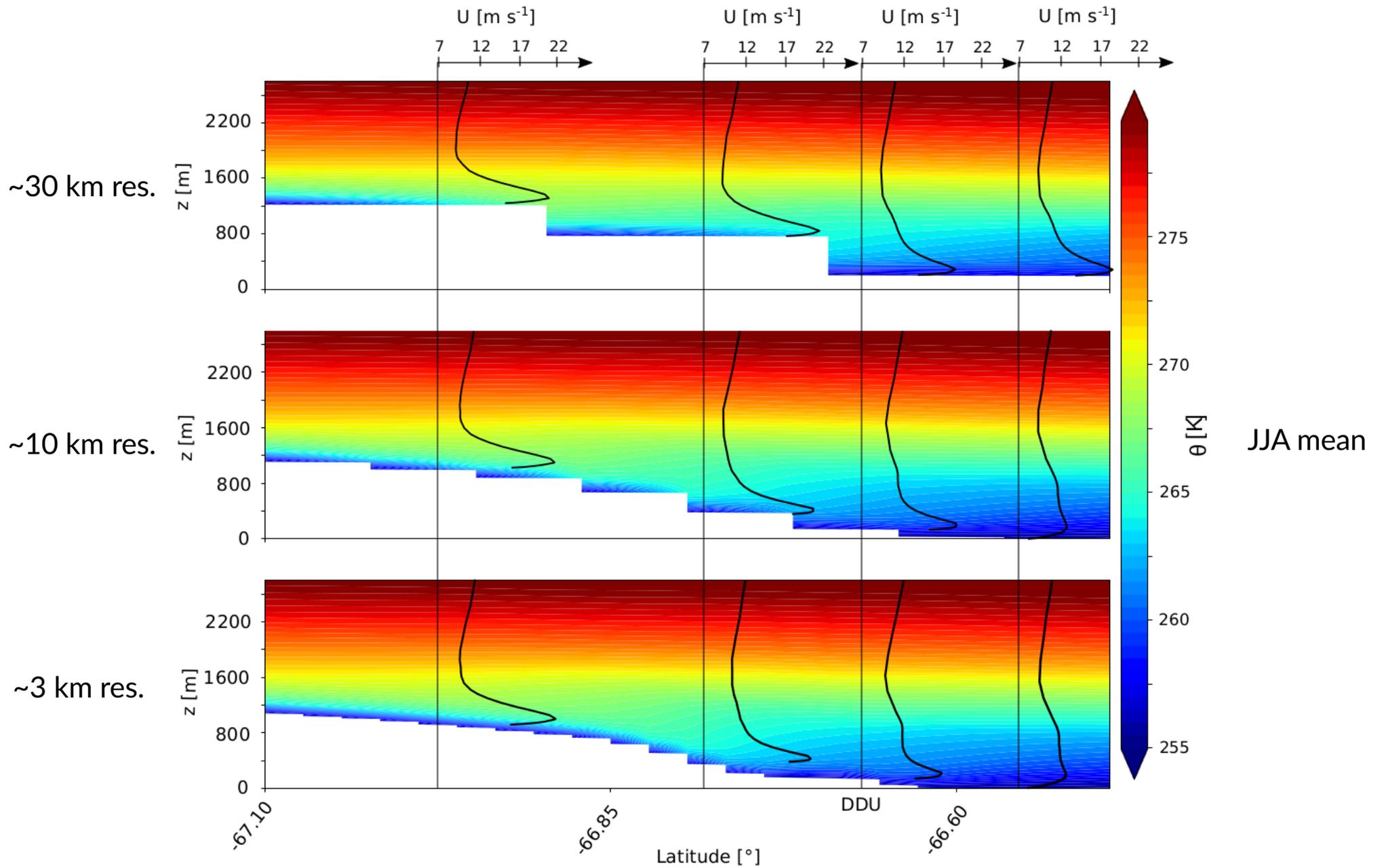
Assimilates radiosonde  
 ~31 km of resolution  
 33 vertical levels in the first 3000m  
 K-gradient turbulent scheme (Louis)

## 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



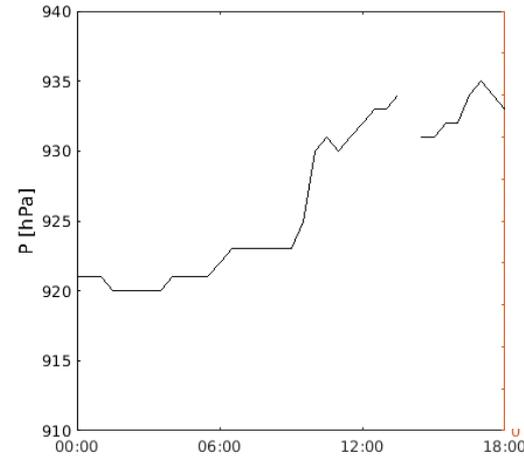
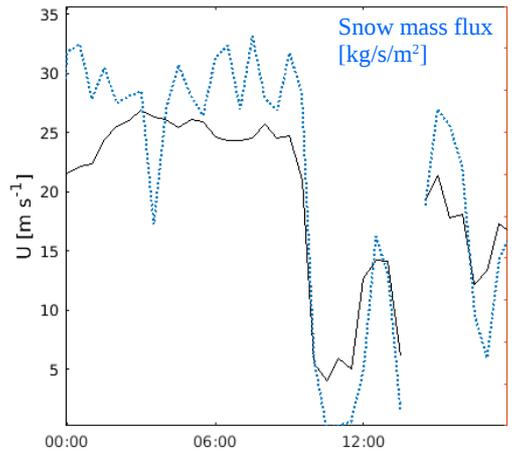
Effect of the « bump » of cold air



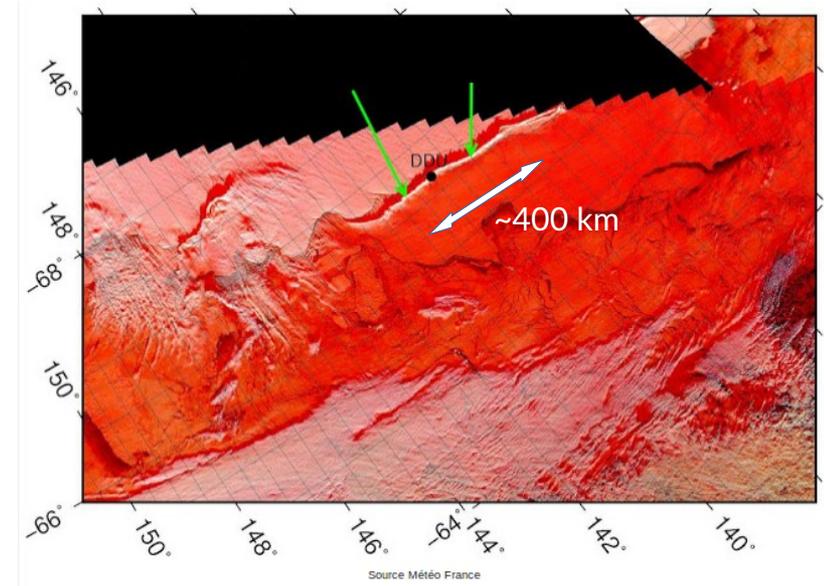


## Wind speed transition can be abrupt : « Katabatic jumps »

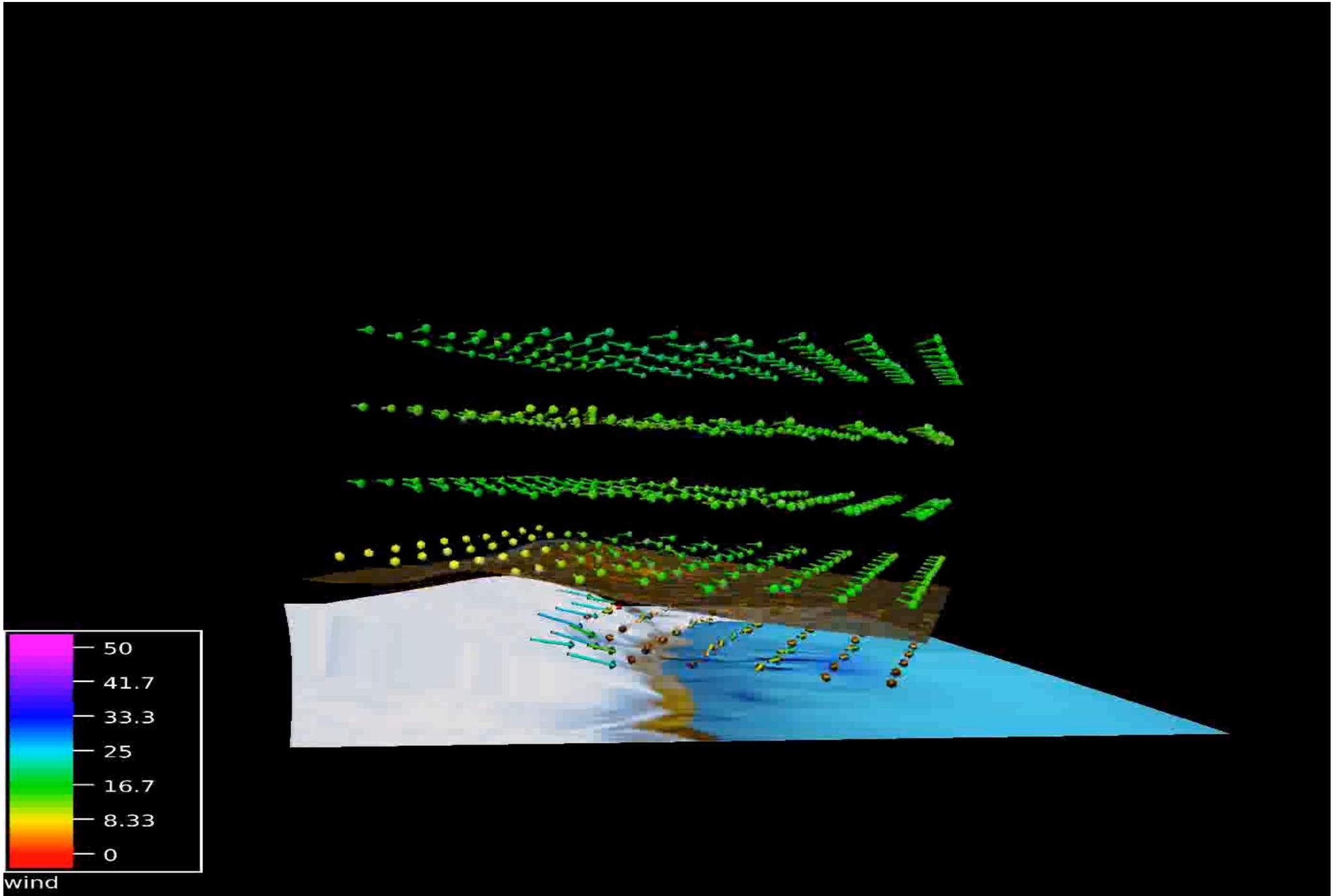
Example : 10/08/2017 at  
Dumont d'Urville



Credits : F. Mariotti



Source : Météo France



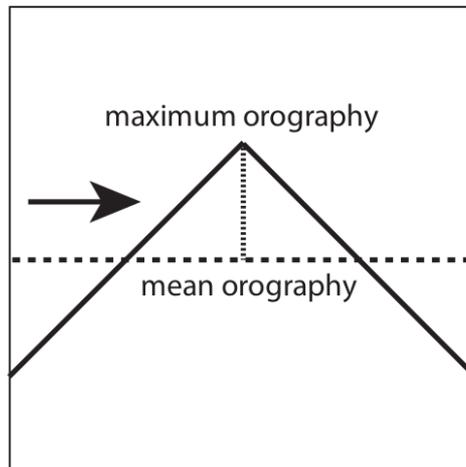


- Evaluating and improving the modeling of stable boundary layers over **slopes** of escarpment regions (katabatic winds)  
Need to account for subgrid slope (original approach by *Pettré 1990*) ?

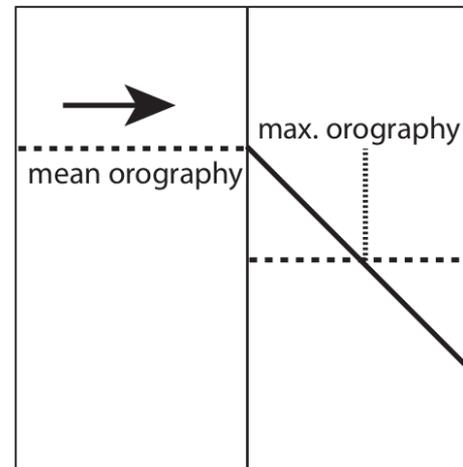


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! Classical subgrid-scale orographic drag based on standard deviation of subgrid orography over Greenland and Antarctica (*Pithan et al 2015*)



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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- **Blowing snow** (e.g. Gallee et al 2001, Lenaerts et al 2012) and near-surface humidity

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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...)

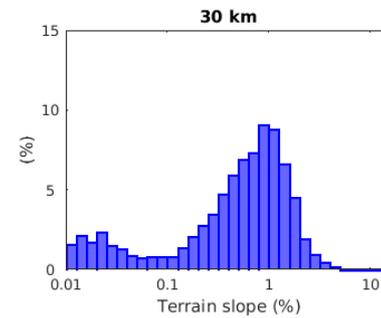
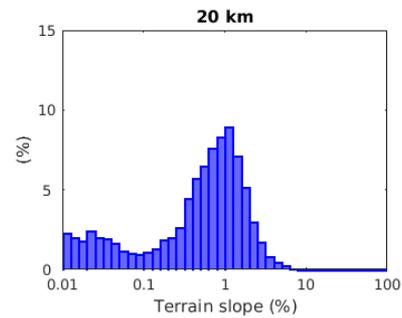
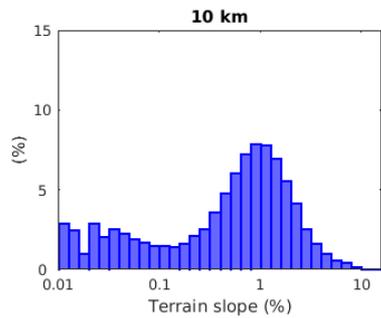
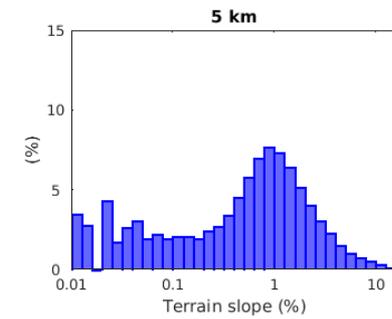
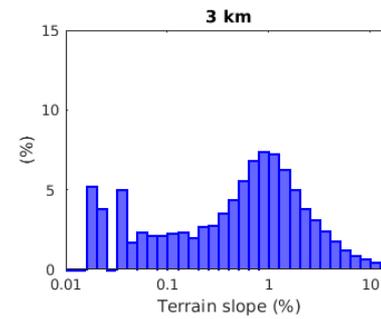
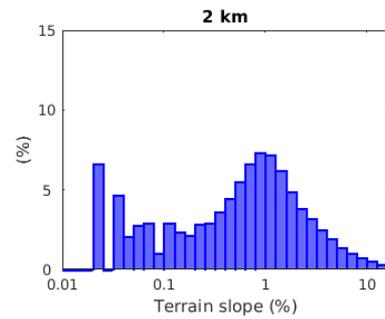
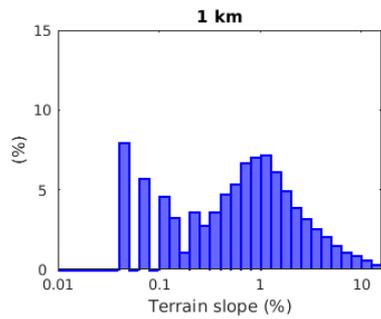
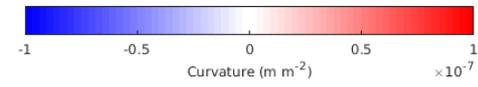
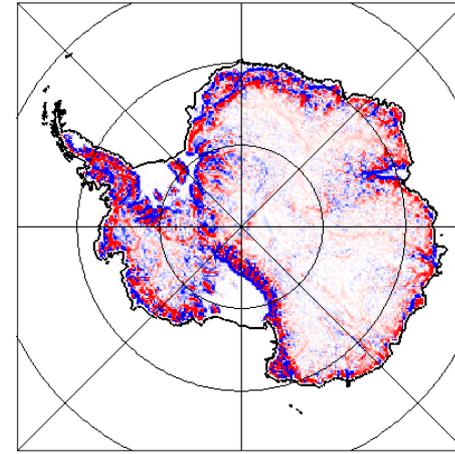
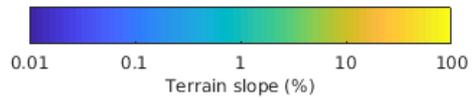
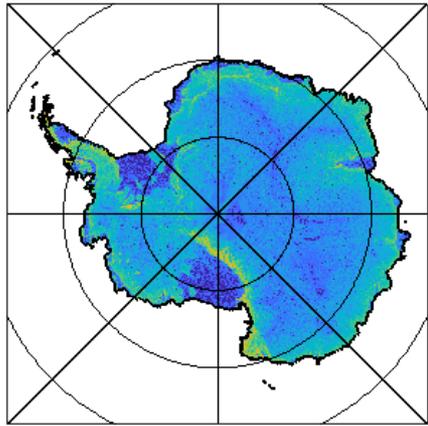
<http://polarmet.osu.edu/YOPP-SH>

Thank's for your attention



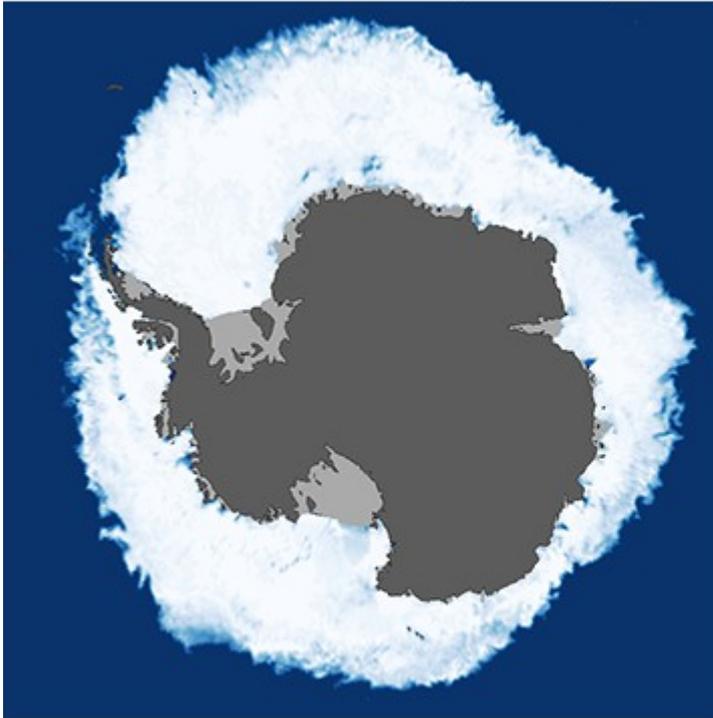
*Scientists challenging the Antarctic boundary layer*

# Challenges

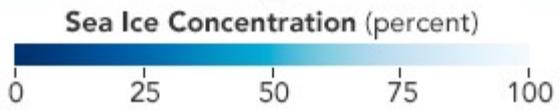




2015 Antarctic Maximum (October 6)

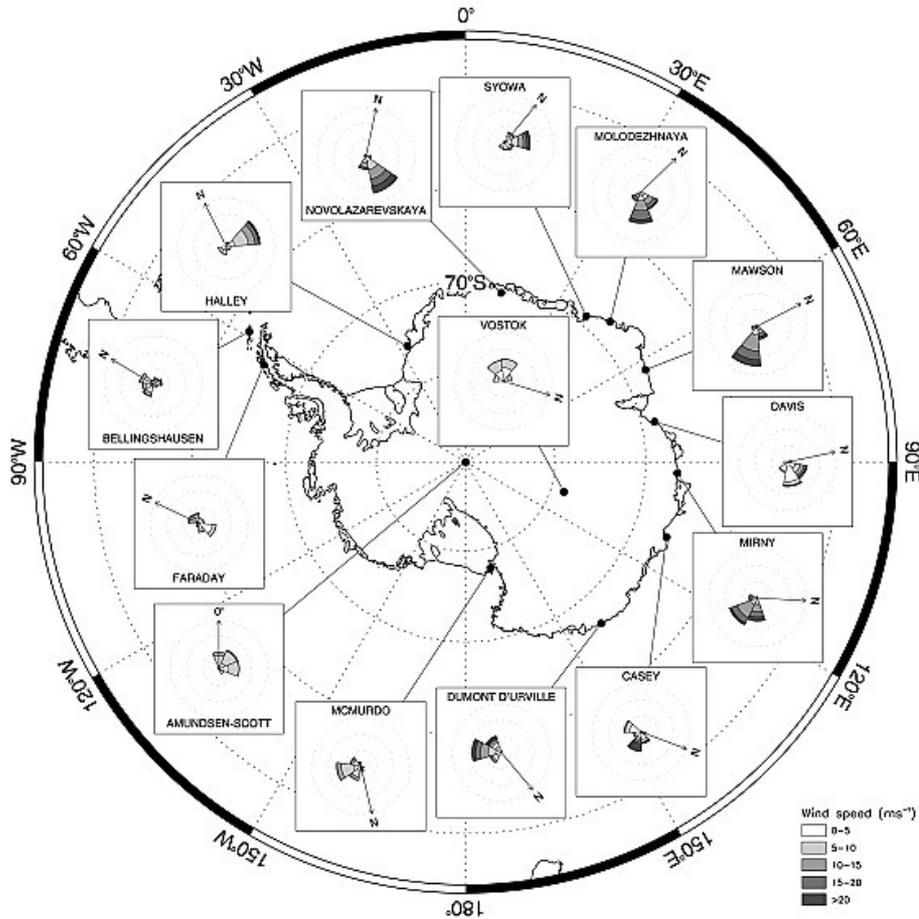


2016 Antarctic Minimum (February 19)



Source : NASA

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



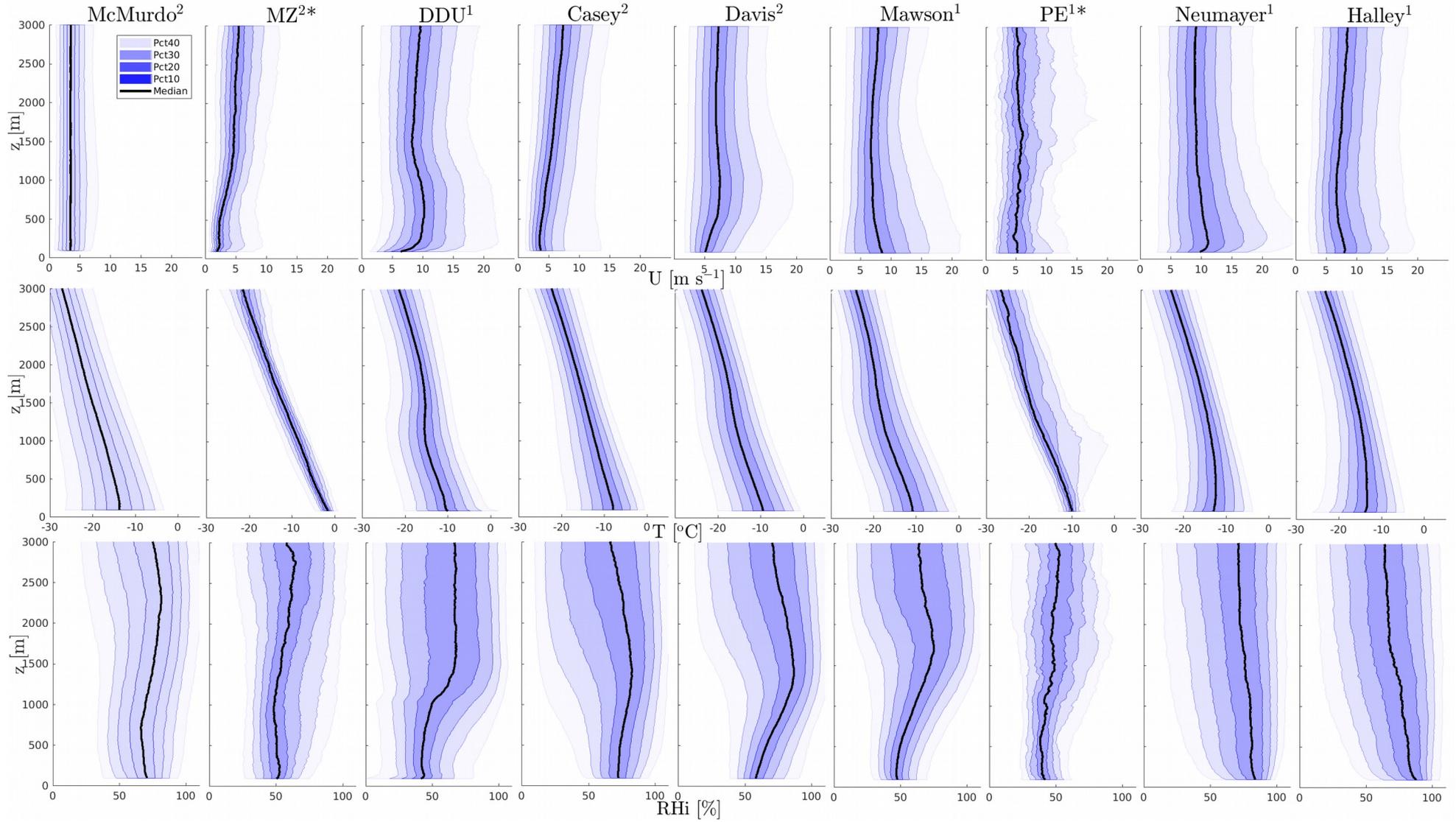
Winter wind roses at Antarctic stations,  
Turner et al 2009

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



Blowing snow affecting penguins

# Evaluation of models



# Evaluation of models

