Drivers of surface winds variability in Antarctica

This presentation participates in OSPP

Outstanding Student & PhD candidate Presentation contest

Cécile Davrinche[1], Cécile Agosta[1], Charles Amory[2], Christoph Kittel[2], Anaïs Orsi[3]

[1]Laboratoire des Sciences du Climat et de l'Environnement, IPSL, [2]Université Grenoble Alpes, CNRS,[3]University of British Columbia

EGU, 2022 May 26th

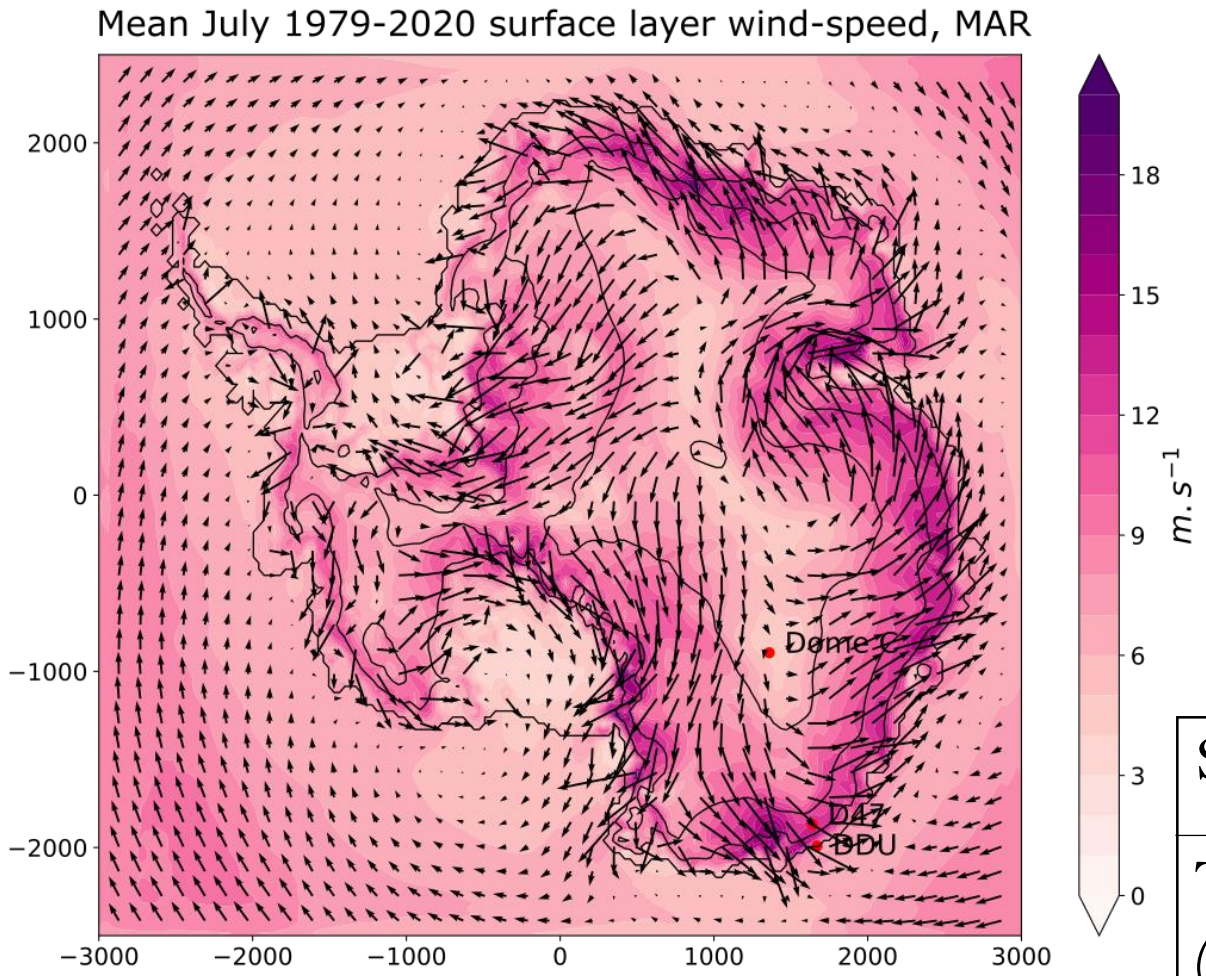
1st year PhD student

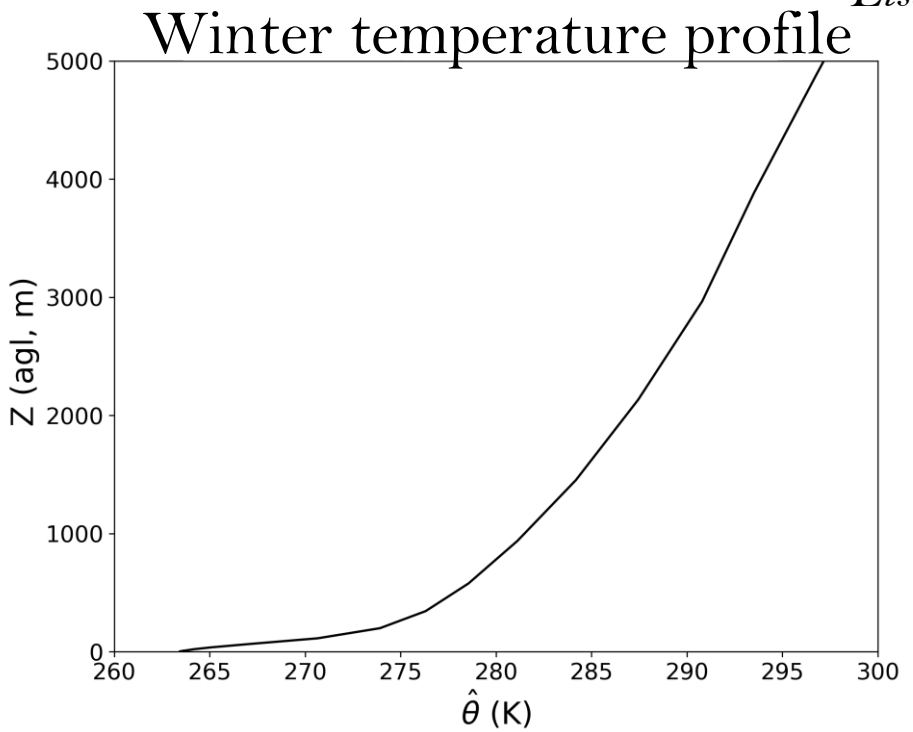
CR7.2 – Polar Meteorology and Climate and their Links to the Rapidly Changing Cryosphere

Guy Clavel, AFP

Surface winds in Antarctica

Lisa Strachan, 2013

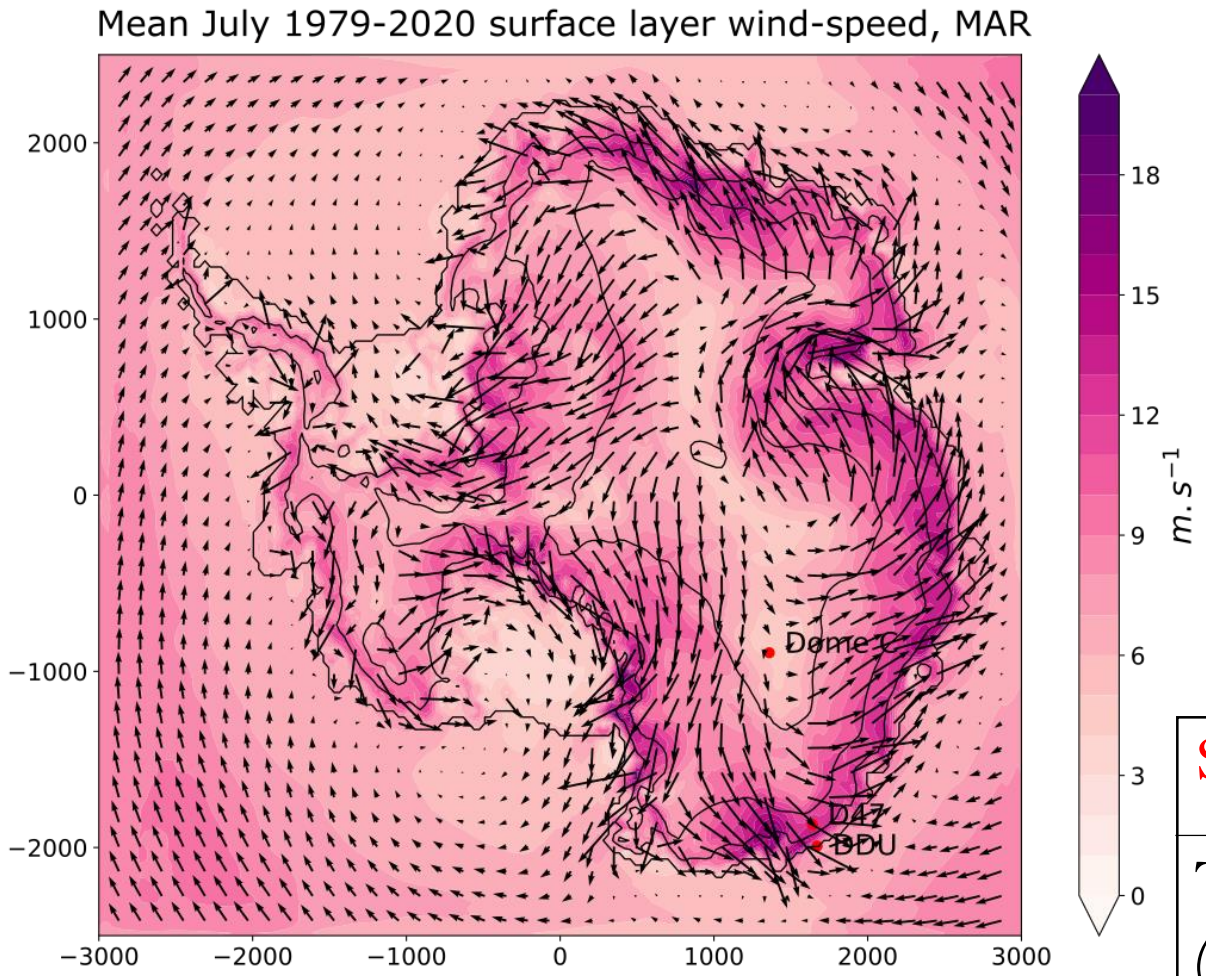


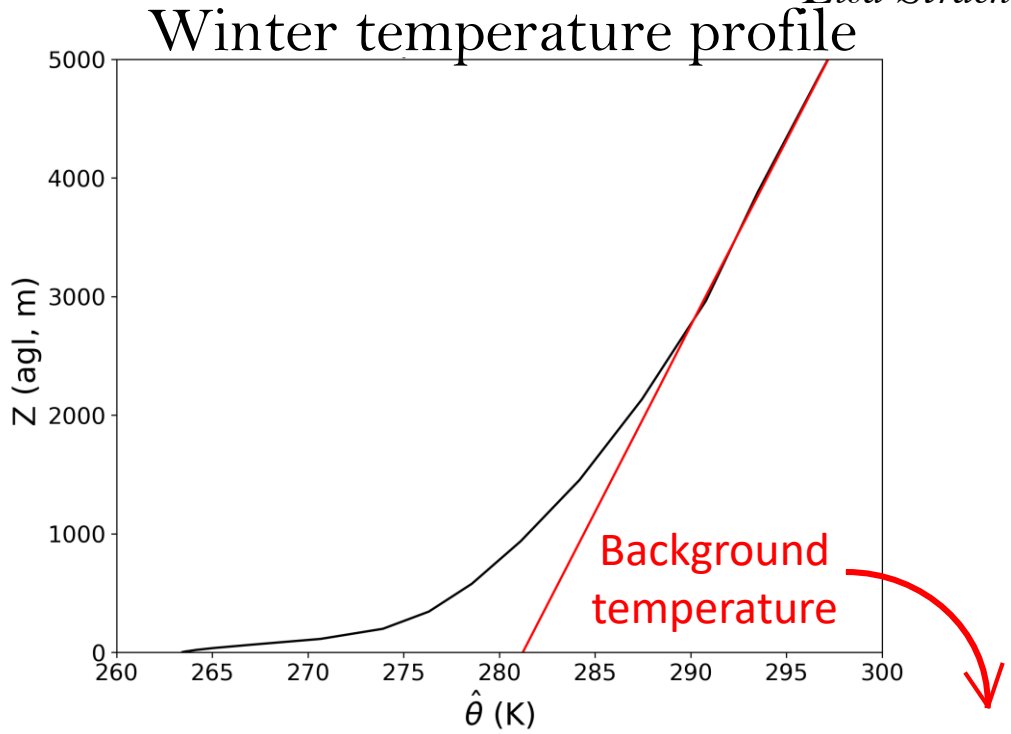


Synoptic	Large-scale (LSC)
Temperature inversion (Boundary layer)	Katabatic (KAT) Thermal wind (THWD)

Surface winds in Antarctica

Lisa Strachan, 2013

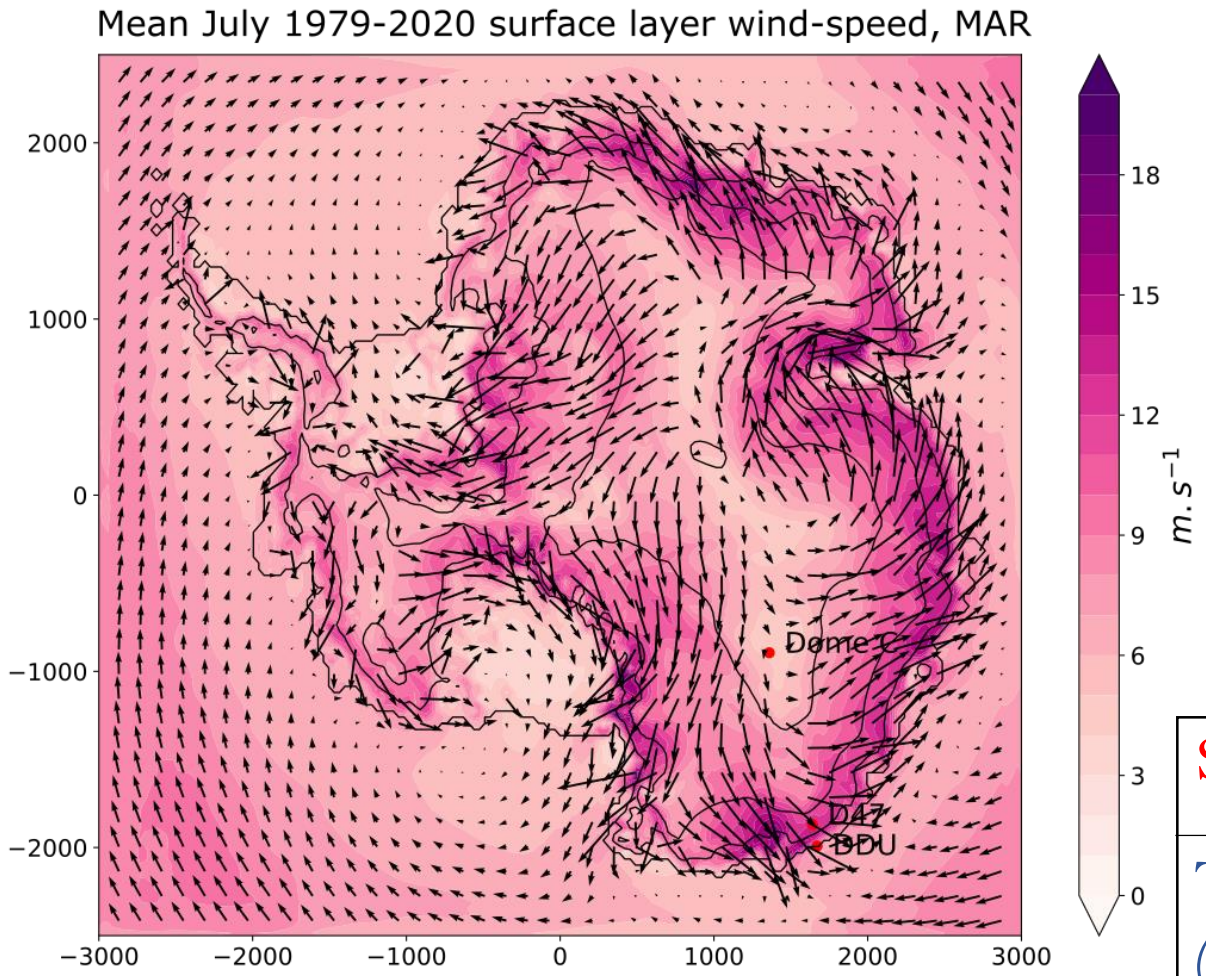


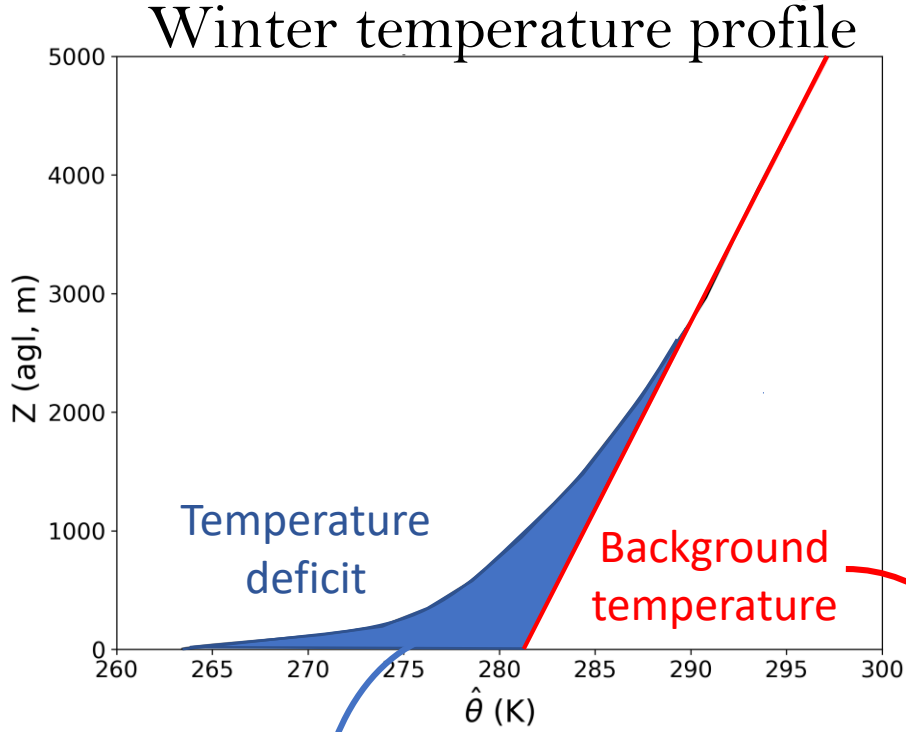


Synoptic	Large-scale (LSC)
Temperature inversion (Boundary layer)	Katabatic (KAT) Thermal wind (THWD)

Surface winds in Antarctica

Lisa Strachan, 2013





Synoptic	Large-scale (LSC)
Temperature inversion (Boundary layer)	Katabatic (KAT) Thermal wind (THWD)

Use of the momentum budget

How will climate change drive modifications of these winds?

STATE OF THE ART

According to model projections from CMIP:

- slight **weakening** of the temperature inversion
- Winter **strengthening** in large-scale synoptic forcing, associated with SAM increasing trend

→ Uncertain future trends …

Marshall, 2003, Bintanja, 2014, Hazel, 2019, Neme, 2020

CHALLENGES

CMIP boundary layer physics is not well modeled

GCM slope under-estimated

GOALS

1. What processes drive the momentum budget?

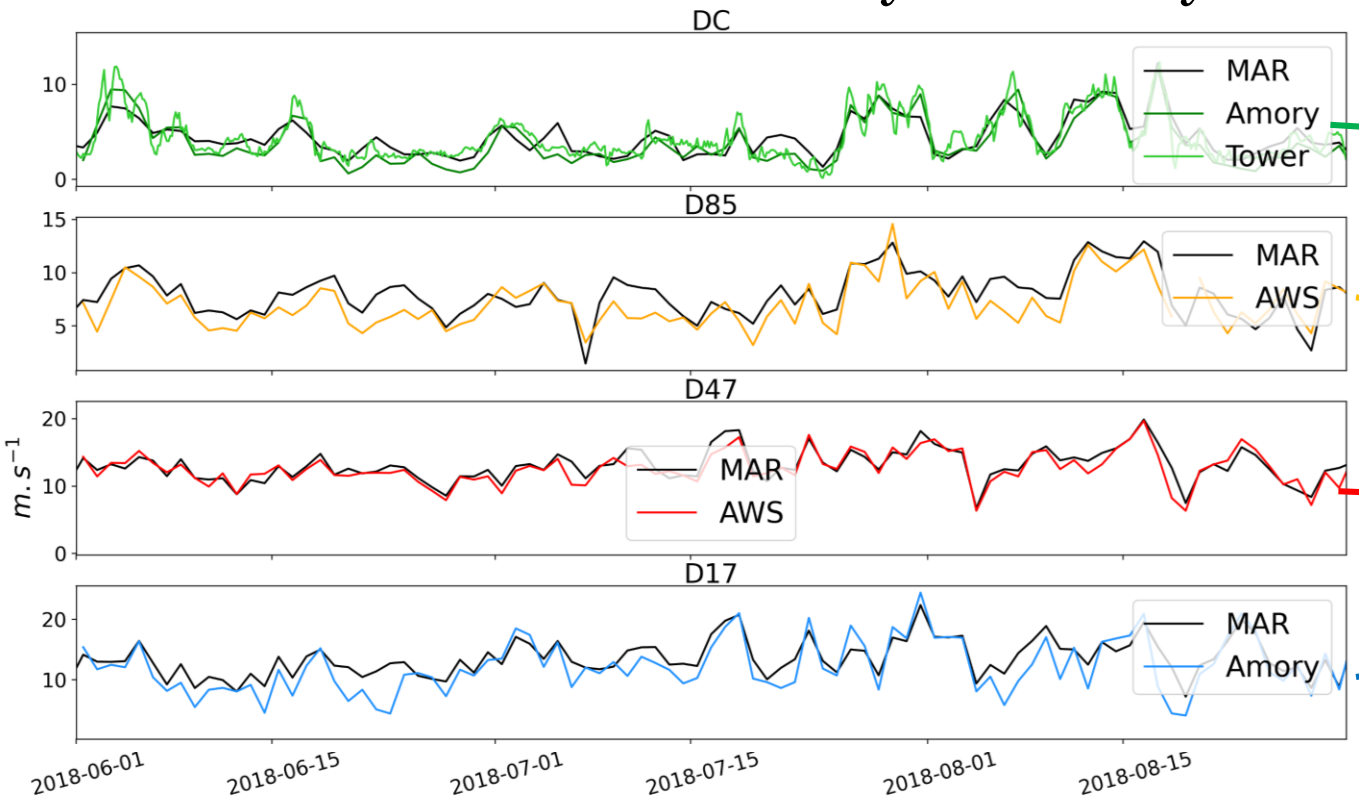
2. Are there any feedbacks stabilizing or amplifying changes in wind?

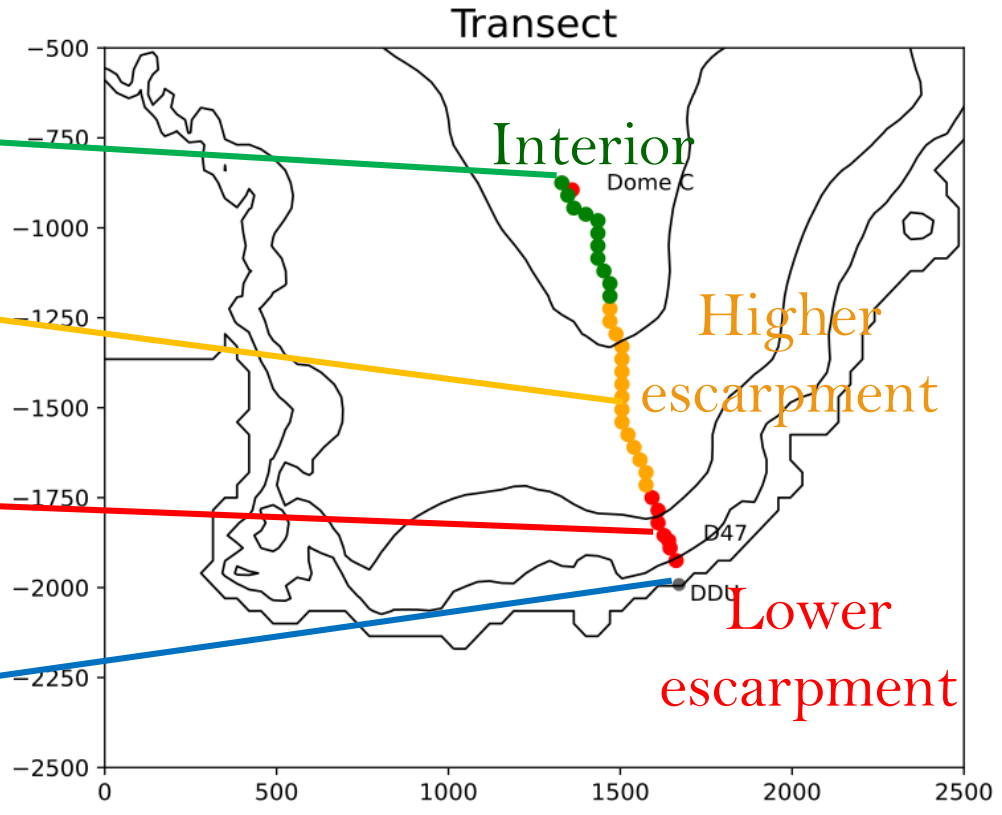
Model: MAR on a transect running through Adélie land

MAR: Polar-oriented regional atmospheric model

Agosta & al. 2019, Kittel & al. 2021, Amory & al. 2021

Comparison surface wind-speed MAR/measurements, July 2018, daily





Dominant terms are Katabatic, large-scale and thermal winds

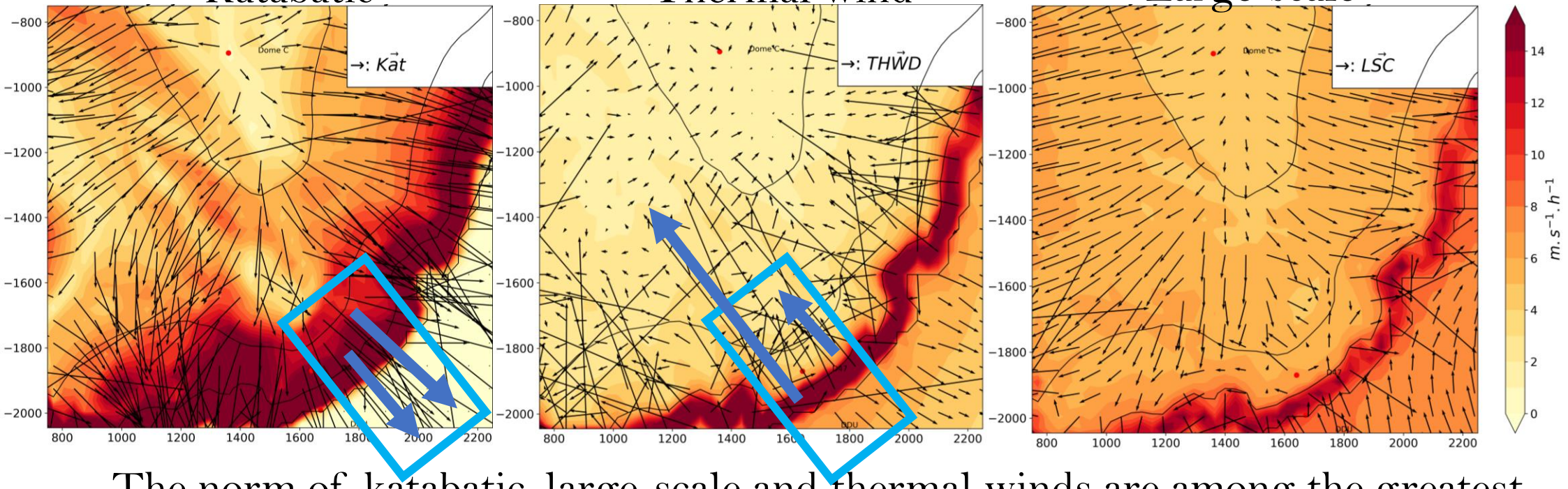
At equilibrium, $\vec{f} \times \vec{V} = -\Sigma \overrightarrow{accelerations}$

Dominant terms are Katabatic, large-scale and thermal winds

At equilibrium, $\vec{f} \times \vec{V} = -\Sigma\, \overrightarrow{accelerations}$

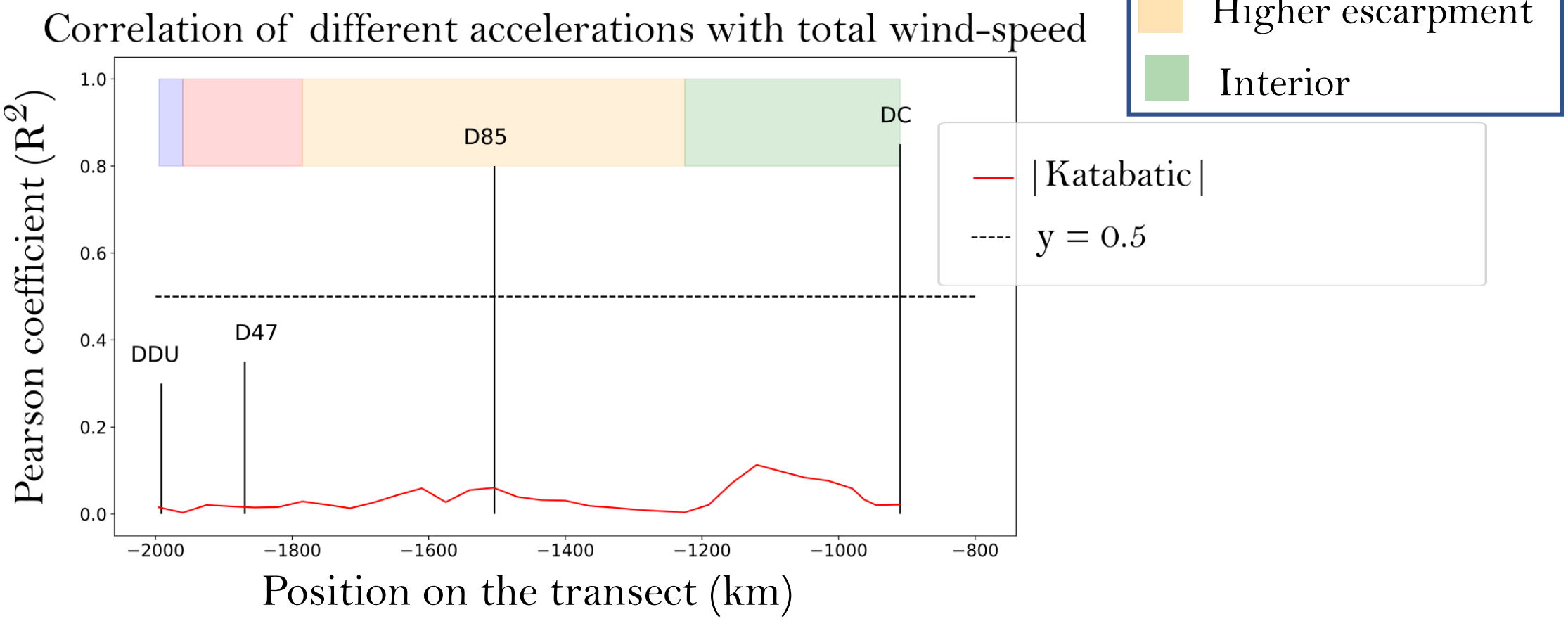
Accelerations in the surface layer, July 1979-2020, MAR daily

Katabatic | Thermal wind | Large-scale



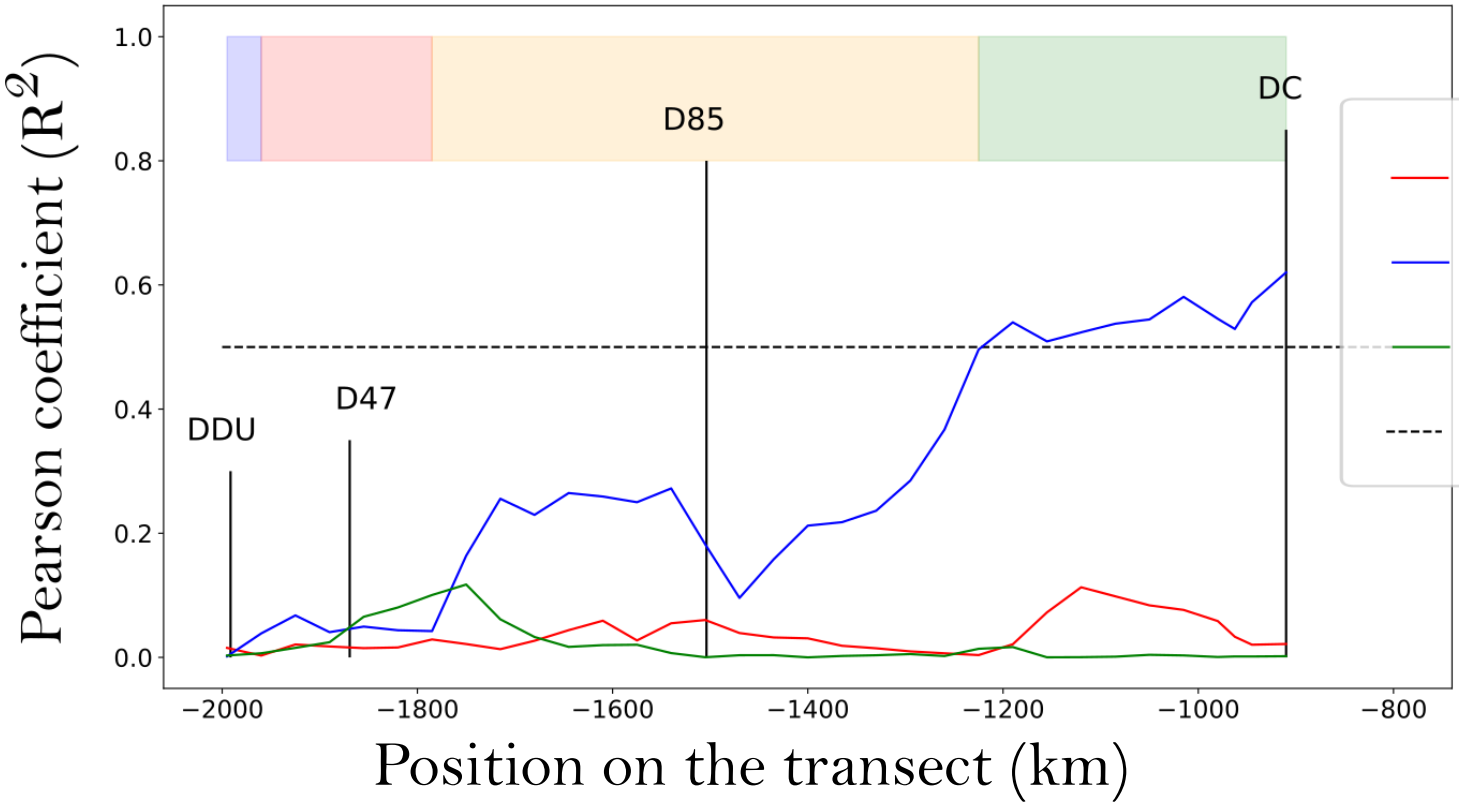
The norm of katabatic, large-scale and thermal winds are among the greatest.
Highest values are concentrated on a belt following the coastline.

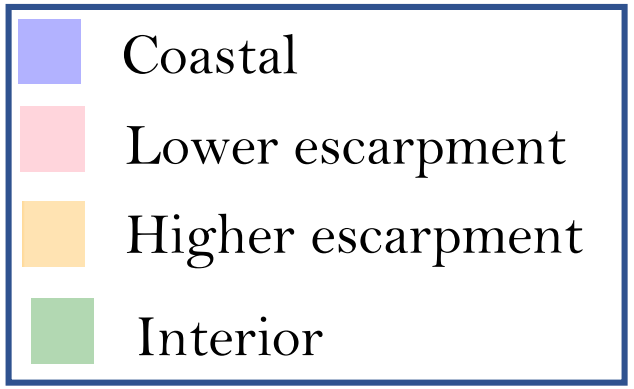
Dominant terms are Katabatic, large-scale and thermal winds and they are correlation patterns with the WS

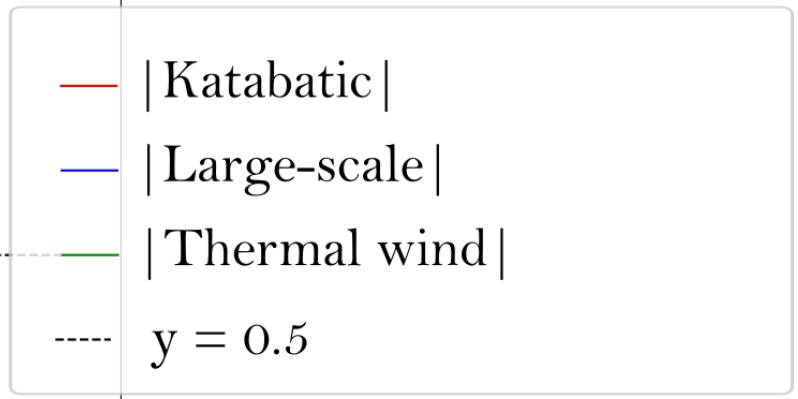


Dominant terms are Katabatic, large-scale and thermal winds and they are correlation patterns with the WS

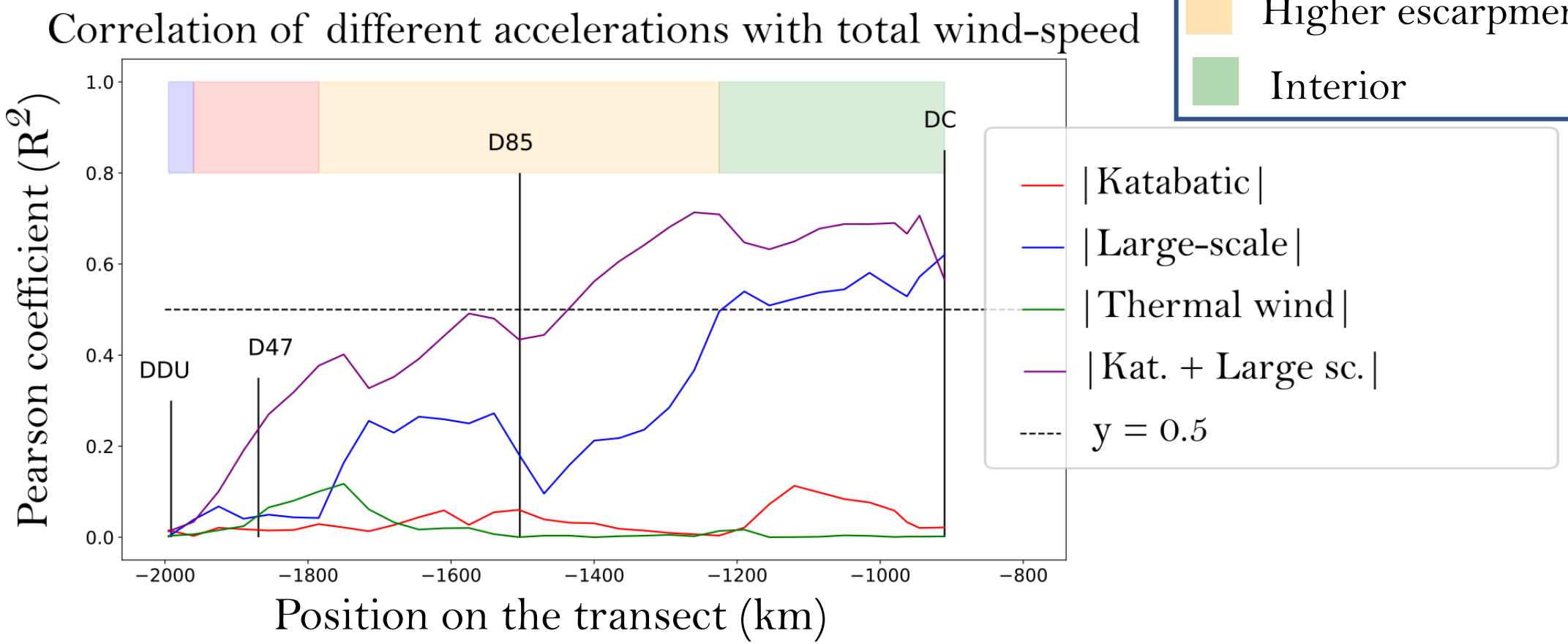
Correlation of different accelerations with total wind-speed



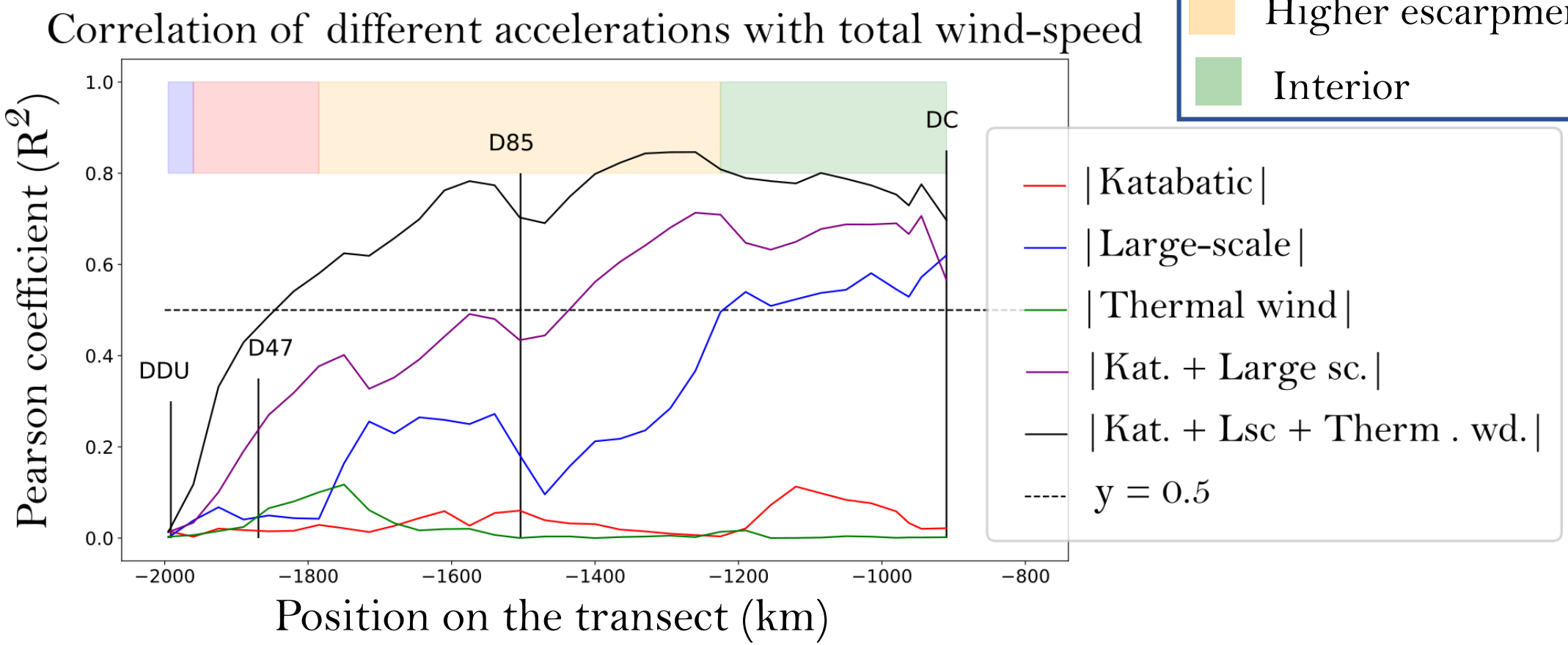




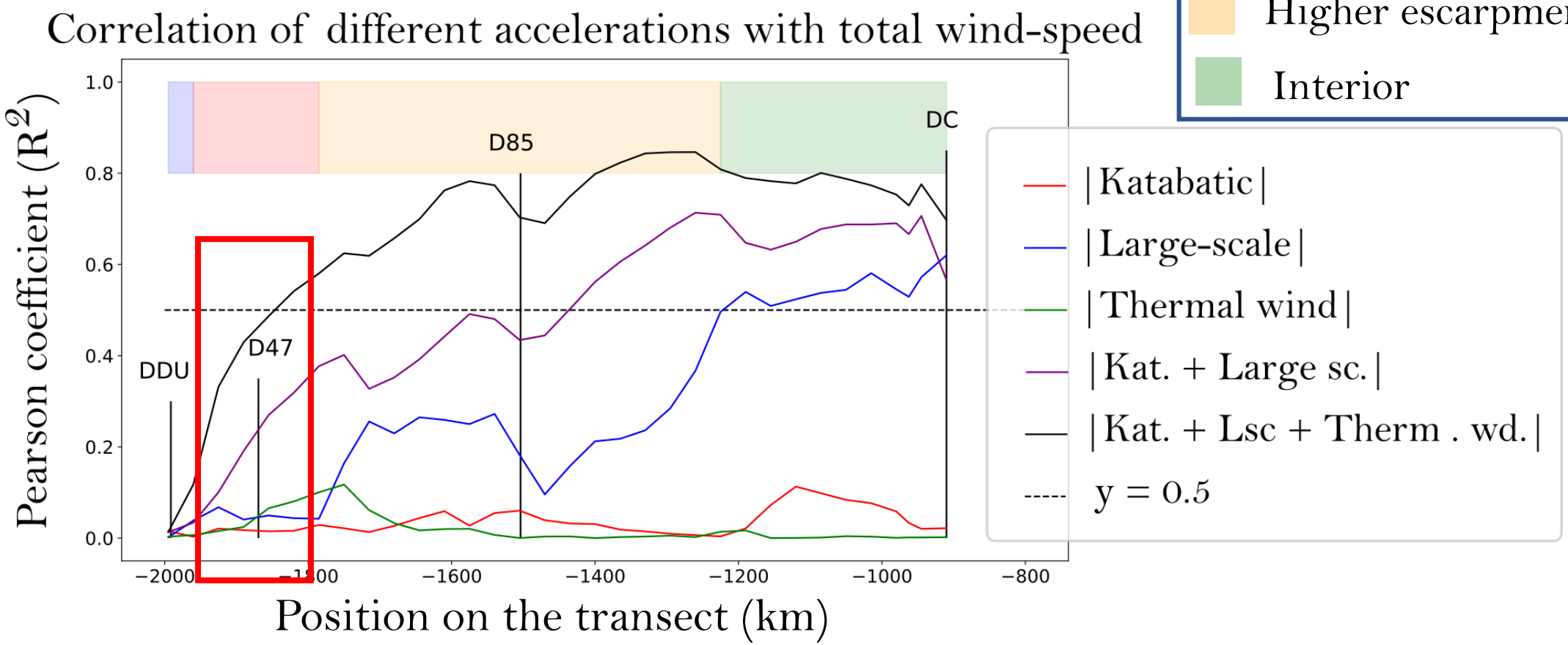
Dominant terms are Katabatic, large-scale and thermal winds and they are correlation patterns with the WS



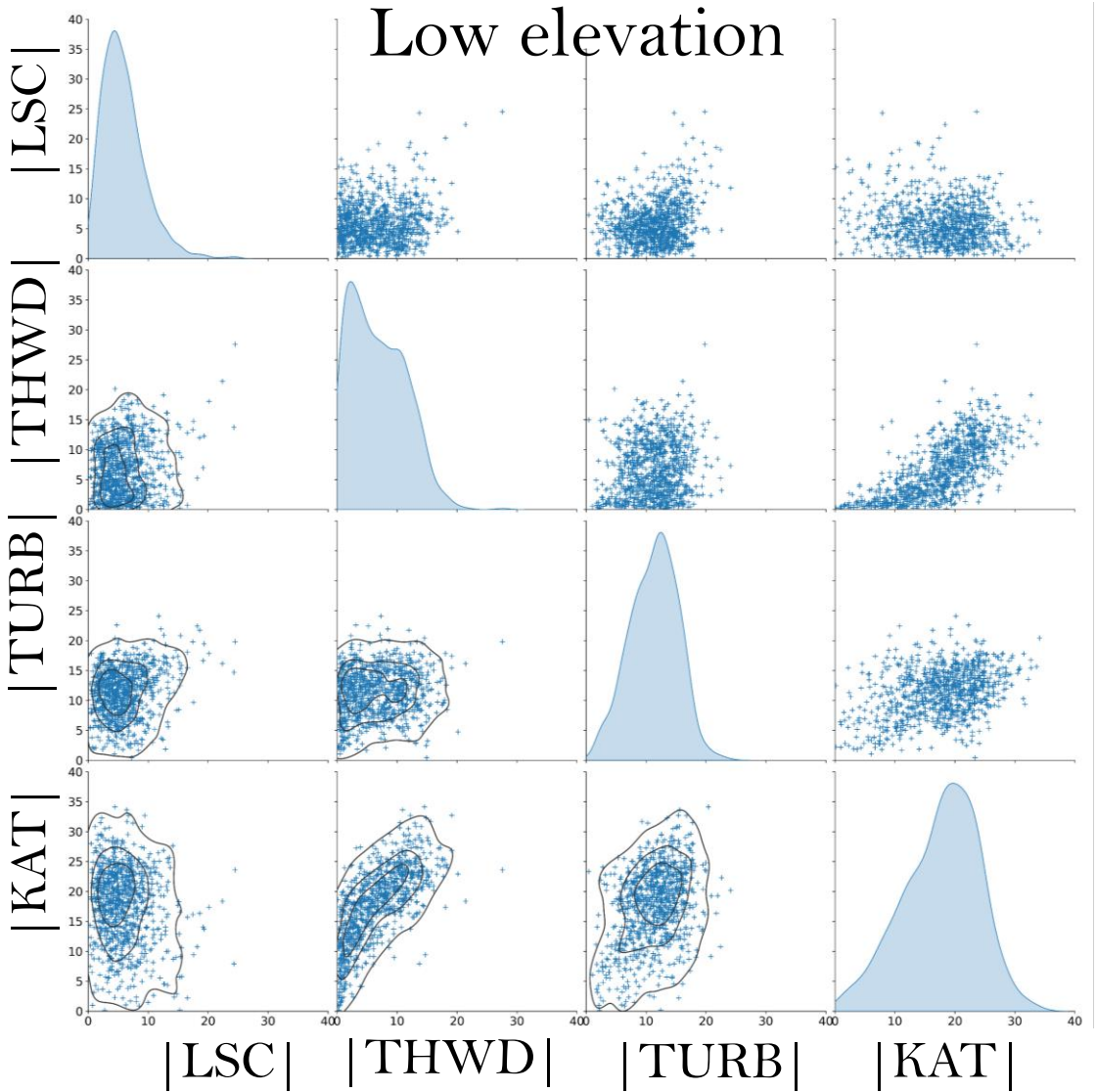
Dominant terms are Katabatic, large-scale and thermal winds and they are correlation patterns with the WS

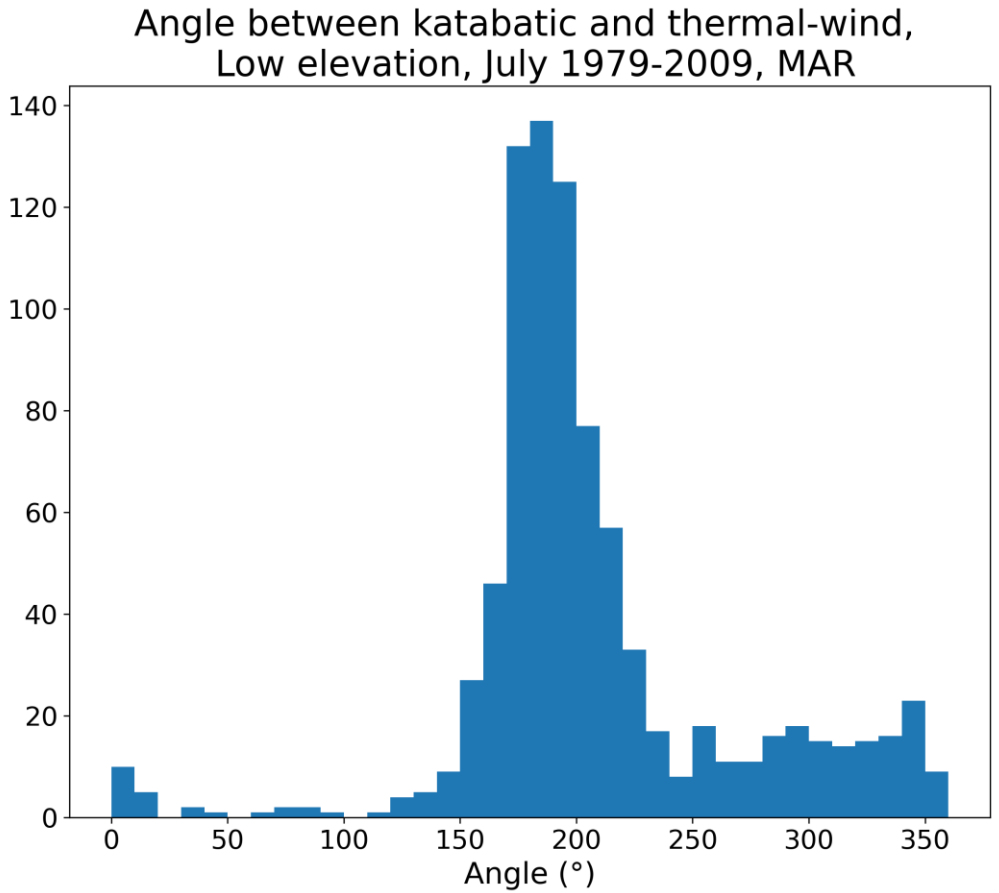


Dominant terms are Katabatic, large-scale and thermal winds and they are correlation patterns with the WS



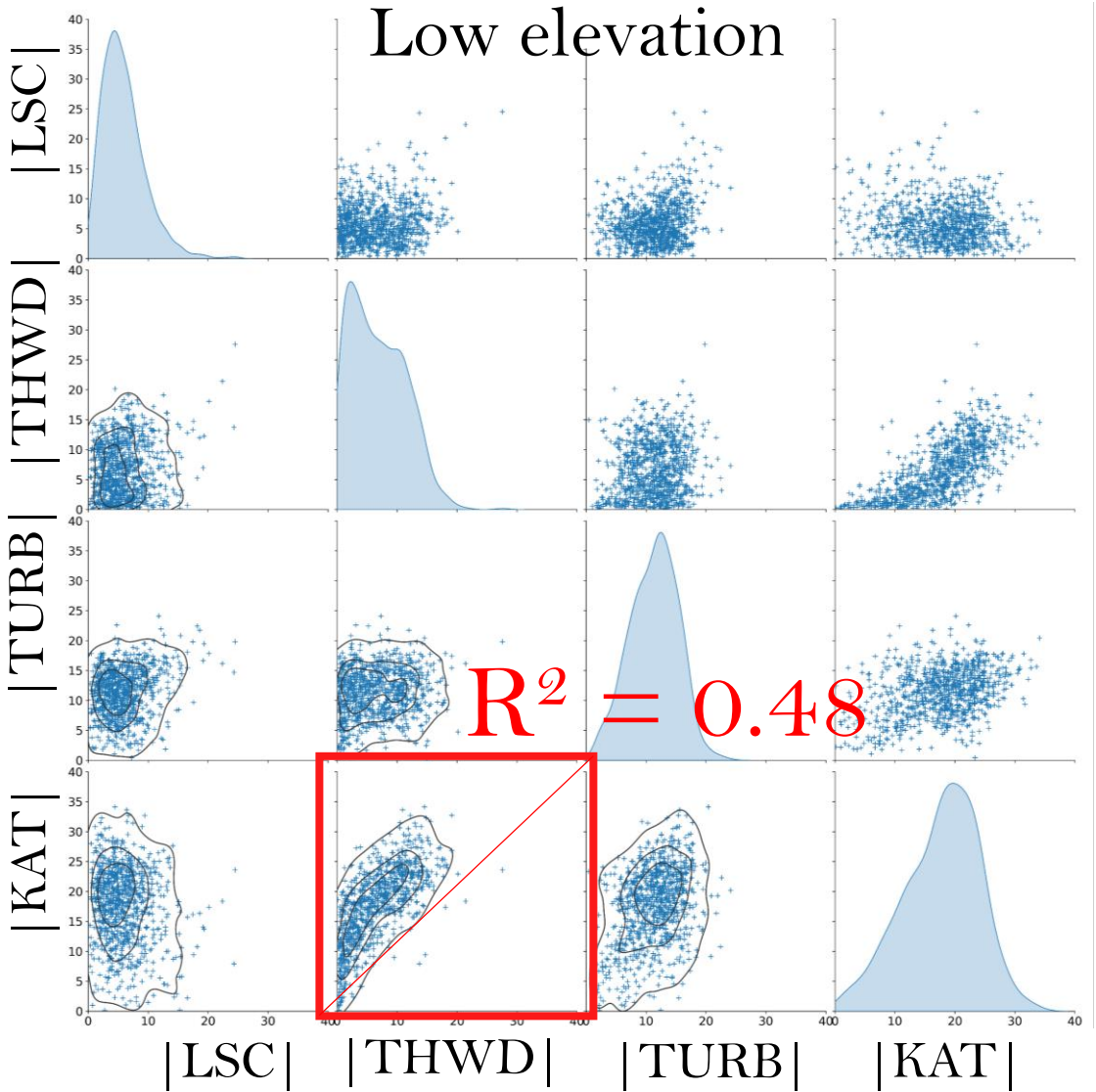
Thermal wind and katabatic are not independent

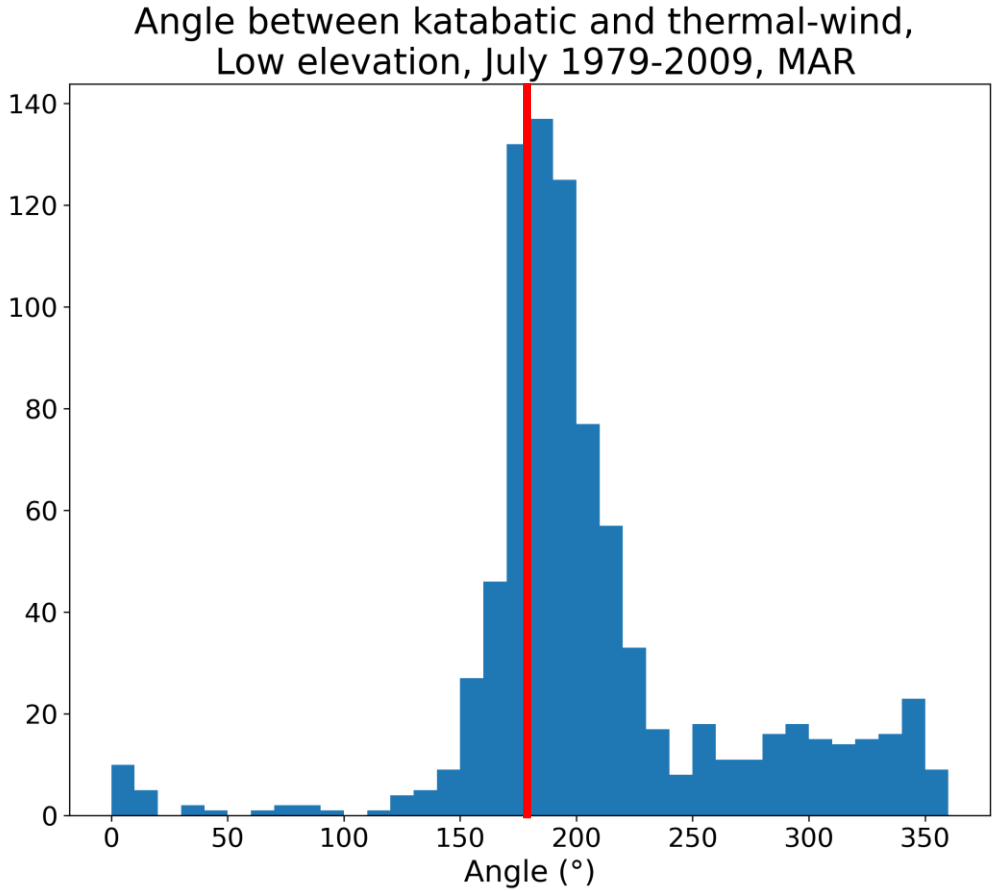




Katabatic and thermal wind are correlated.
However, they act in opposite direction

Thermal wind and katabatic are not independent





Katabatic and thermal wind are correlated.
However, they act in opposite direction

Take-home messages

- Highest accelerations result from **large-scale pressure gradient** (LSC) and **inversion layer** (Kat, THWD)
- Interior: momentum budget **dominated by LSC**
- Katabatic term alone does NOT correlate to total wind-speed
- |Kat + LSC| or |Kat + LSC + THWD| depending on the zone are good proxys for the total wind-speed
- Katabatic and Thermal wind stabilizing each others, will it continue ?

Thanks for your attention!

If you have any question, feel free to contact me:
cecile.davrinche@lsce.ipsl.fr

This presentation participates in OSPP

EGU

Outstanding Student & PhD candidate Presentation contest

LSCE

RAID ICORDA KATABATIC

Emmanuel Lepage, La Lune est blanche

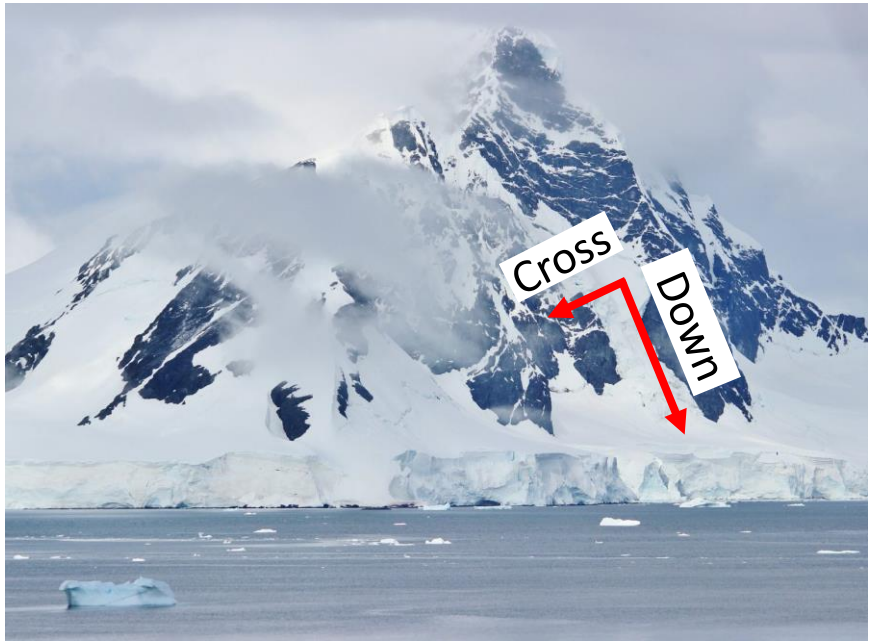
Supplement: Equations

Advection Thermal wind Large-scale

Cross-slope

$$\frac{\partial U}{\partial t} = -U\frac{\partial U}{\partial x} - V\frac{\partial U}{\partial y} - W\frac{\partial U}{\partial z} - \frac{\partial \overline{uw}}{\partial z} + \frac{g}{\theta_0}\frac{\partial \hat{\theta}}{\partial x} + fV - fV_{LSC}$$

Turbulence Coriolis



Downslope

$$\frac{\partial V}{\partial t} = -U\frac{\partial V}{\partial x} - V\frac{\partial V}{\partial y} - W\frac{\partial V}{\partial z} - \frac{\partial \overline{vw}}{\partial z} + \frac{g}{\theta_0}\frac{\partial \hat{\theta}}{\partial y} - fU + fU_{LSC} + \frac{g}{\theta_0}\Delta_\theta \sin(\alpha)$$

Advection Thermal wind Large-scale Katabatic

van den Broeke, 2003

Supplement: References

C. Agosta, C. Amory, C. Kittel, A. Orsi, V. Favier, H. Gallée, M. R. van den Broeke, J. T. M. Lenaerts, J. M. van Wessem, W. J. van de Berg, and X. Fettweis. Estimation of the antarctic surface mass balance using the regional climate model mar (1979–2015) and identification of dominant processes. *The Cryosphere*,2019.

C. Amory. Drifting-snow statistics from multiple-year autonomous measurements in adélie land, east antarctica. *The Cryosphere*, 2020.

R. Bintanja, C. Severijns, R. Haarsma, and W. Hazeleger. The future of antarctica's surface winds simulated by a high resolution global climate model: 2. drivers of 21st century changes. *Journal of Geophysical Research*: Atmospheres,2013.

J.E. Hazel, A.L. Stewart. Are the Near-Antarctic Easterly Winds Weakening in Response to Enhancement of the Southern Annular Mode?. J*ournal of Climate*, 2019

C. Kittel, C. Amory, C. Agosta, N. C. Jourdain, S. Hofer, A. Delhasse, S. Doutreloup, P.-V. Huot, C. Lang, T. Fichefet, and X. Fettweis. Diverging future surface mass balance between the antarctic ice shelves and grounded ice sheet. *The Cryosphere*, 2021.

G. Marshall. Trends in the Southern Annular Mode from Observations and Reanalyses. *Journal of Climate*, 2003

J. Neme, M. England, A. McC. Hogg. Projected changes of surface winds over the Antarctic continental margin. *Geophysical Research Letters*, 2022

M. Van den Broeke and N. van Lipzig. Factors controlling the near-surface wind field in Antarctica. *Monthly Weather Review*, 2003