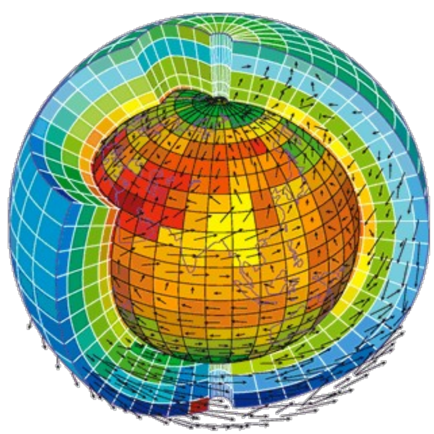
Sensitivity experiments with the LMDZ model on the GABLS4 exercise

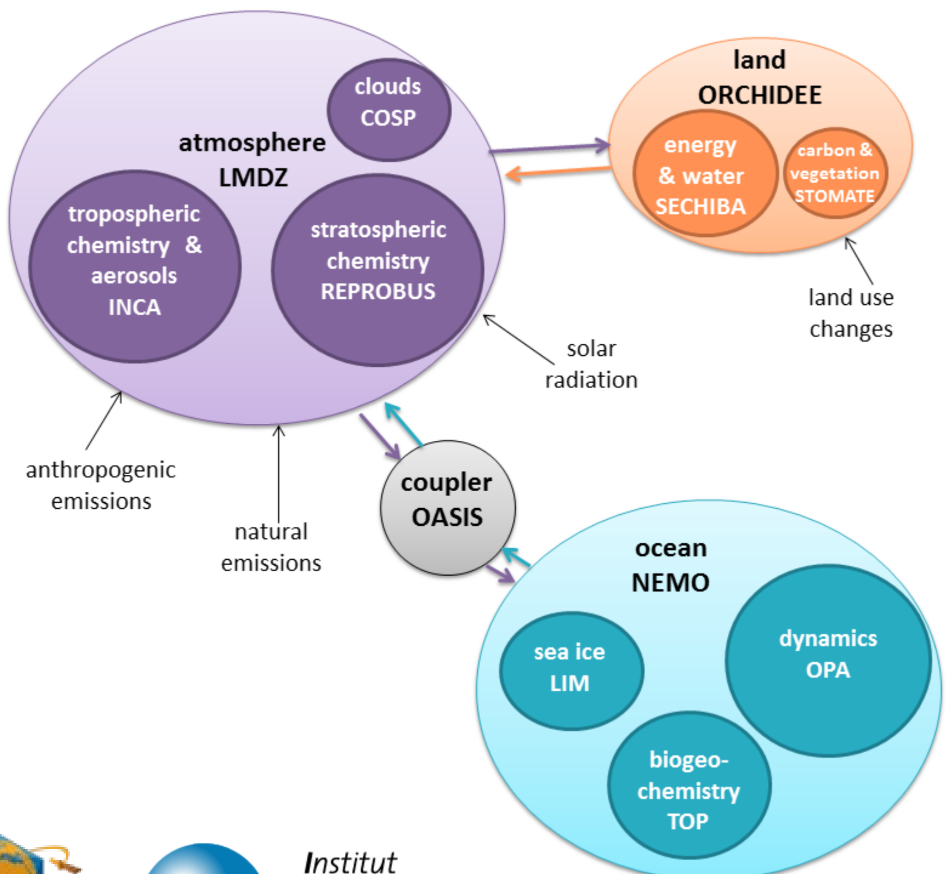


E. Vignon, C. Genthon, F. Hourdin, E. Bazile, H. Gallée, M.-P. Lefebvre, J.-B. Madeleine and B. van de Wiel

LMDZ ?

LMDZ ?

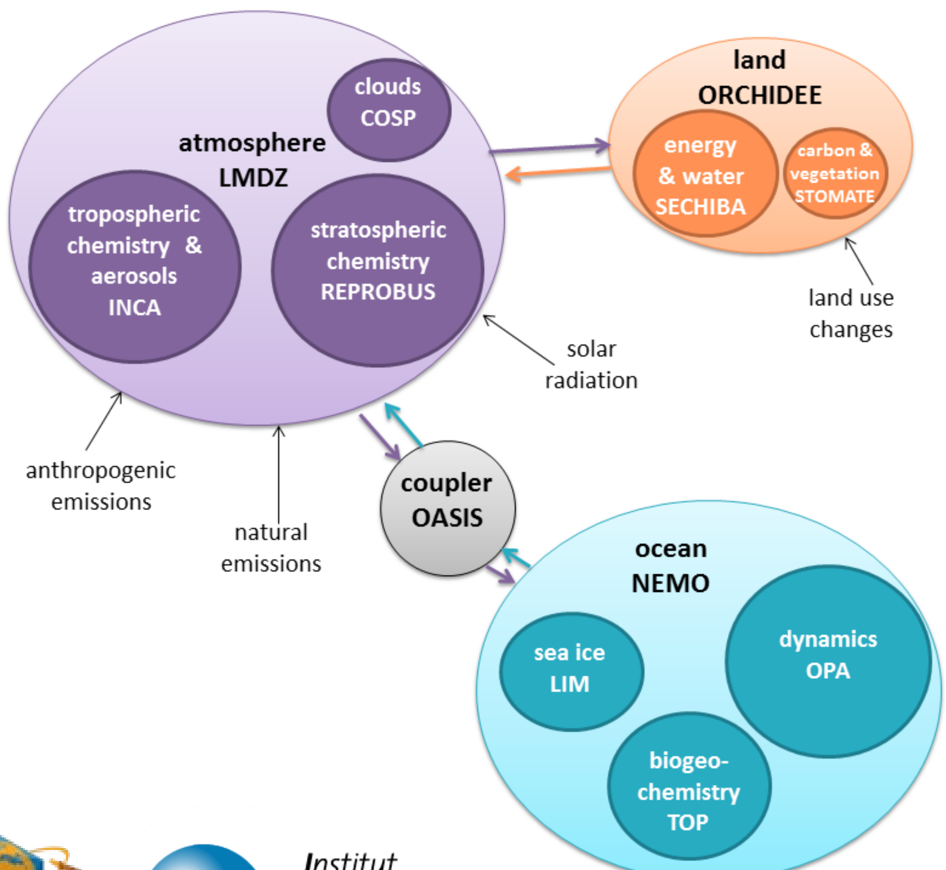
IPSL EARTH SYSTEM MODEL



LMDZ ?

PARIS

IPSL EARTH SYSTEM MODEL



5th version of LMDZ and IPSL

↓

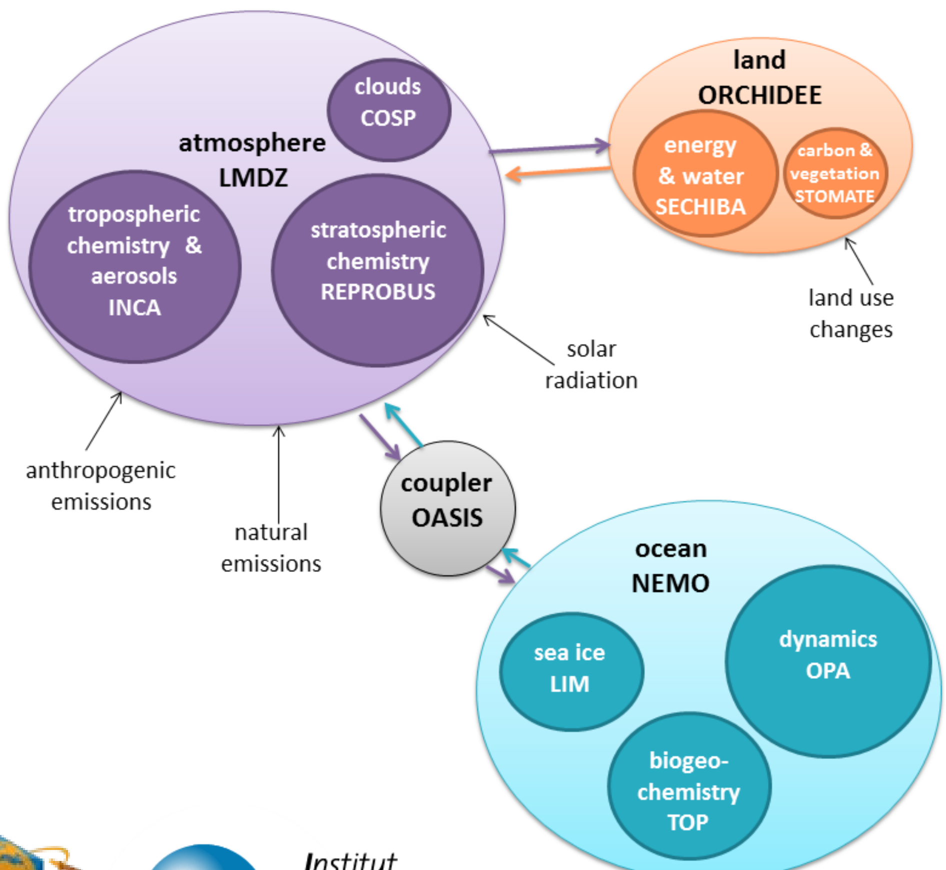
5th IPCC report in 2013

LMD

Sciences de l'environnement
Institut Pierre Simon Laplace

LMDZ ?

IPSL EARTH SYSTEM MODEL



5th version of LMDZ and IPSL

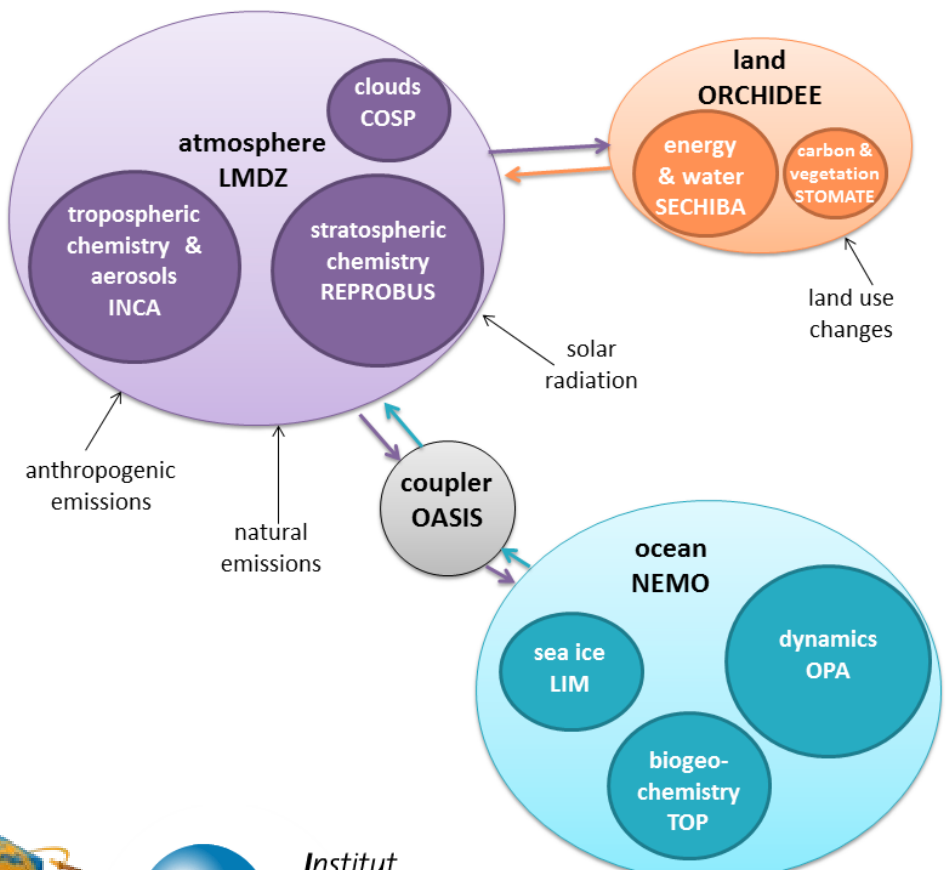
5th IPCC report in 2013

6th version of LMDZ and IPSL

First simulations August 2018

LMDZ ?

IPSL EARTH SYSTEM MODEL



5th version of LMDZ and IPSL

5th IPCC report in 2013

GABLS4

6th version of LMDZ and IPSL

First simulations August 2018

Outline

1) From standard LMDZ5 version to "GABLS4 version"
→ effect of prescribed surface parameters

2) Diurnal convective boundary layer
→ importance of the mass flux scheme

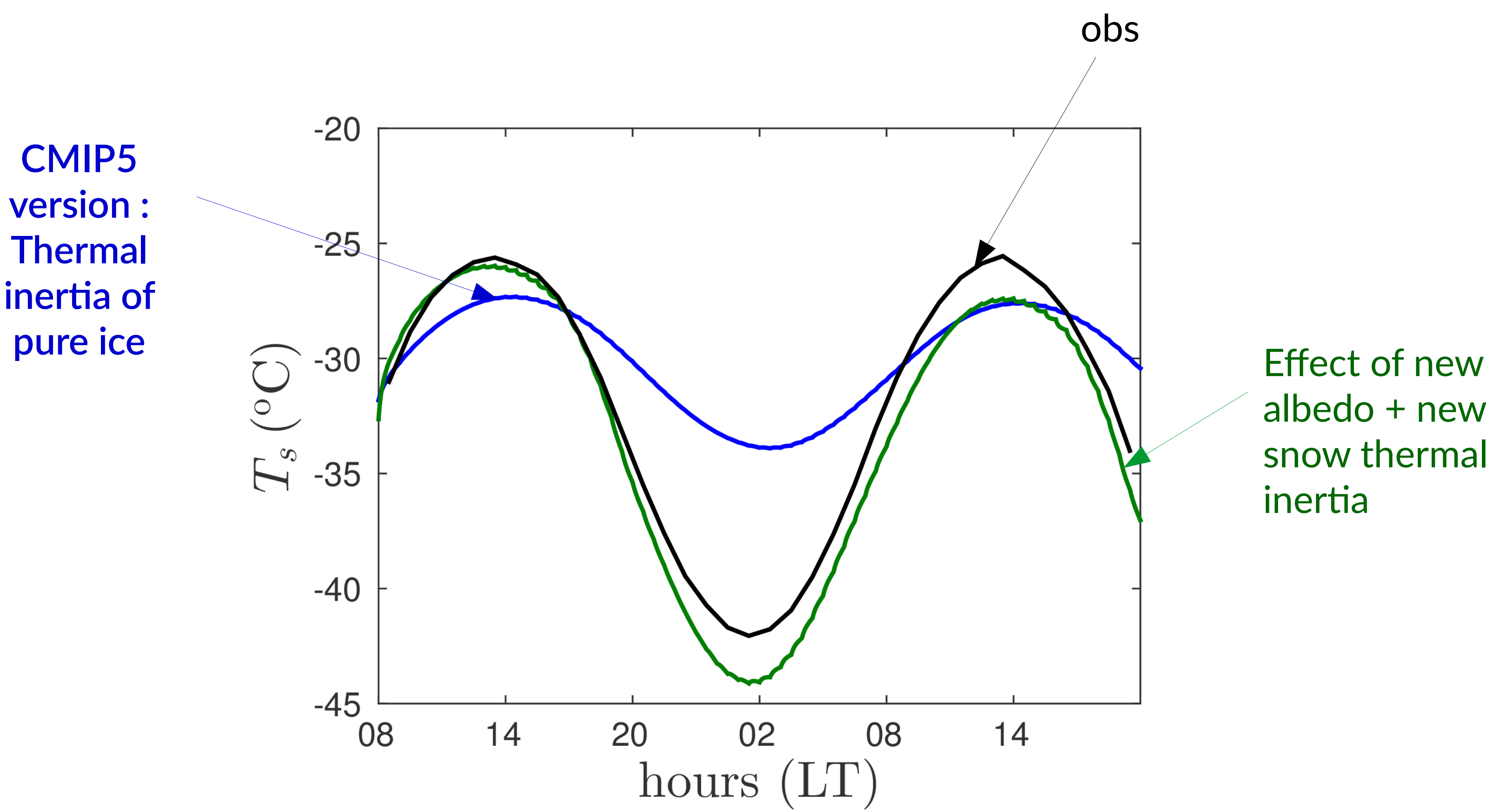
3) "Nocturnal" stable boundary layer
→ surface layer scheme
→ turbulence scheme
→ radiation vs turbulence
→ vertical resolution

4) Discussion on external forcings

5) Conclusion

1) From standard LMDZ5 version to "GABLS4 version"

Prescriptions after the first GABLS4 workshop:		**LMDZ5 (advanced)**
- albedo= 0.81 and emissivity = 0.98		- albedo=0.77
- z0m = 0.001 m and z0h/q = 0.0001m		- z0m=z0h=0.001 m
- a snow density rho_snow=300Kg/m^3		
- a prescribed thermal coefficient Csnow	*Thermal inertia of snow*	- Thermal inertial of ice
- snow height = 5cm		
- prescribed 90-level vertical grid		- 79-level grid

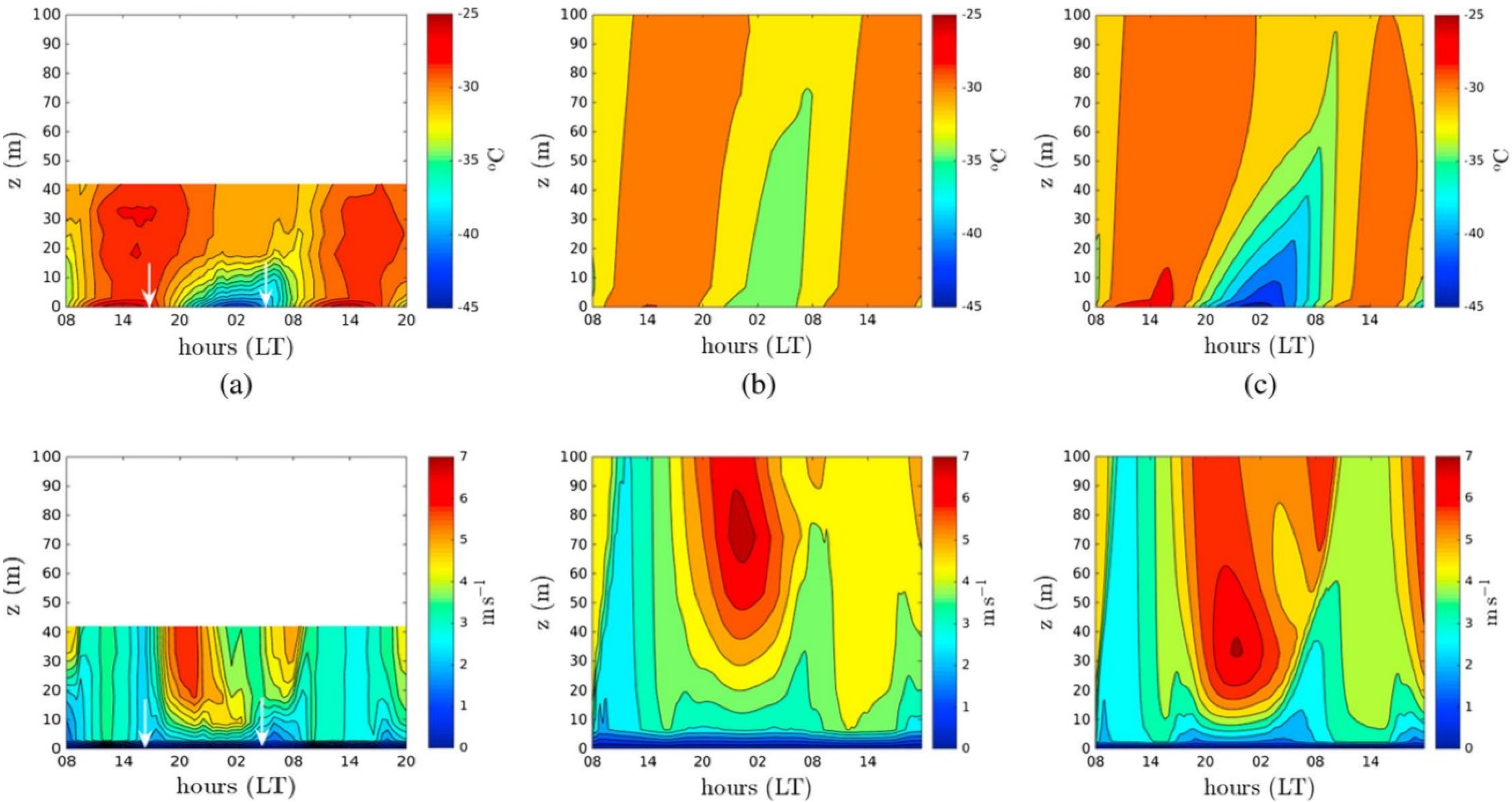


→ Dome C: very reactive snow surface (low inertia)

Obs

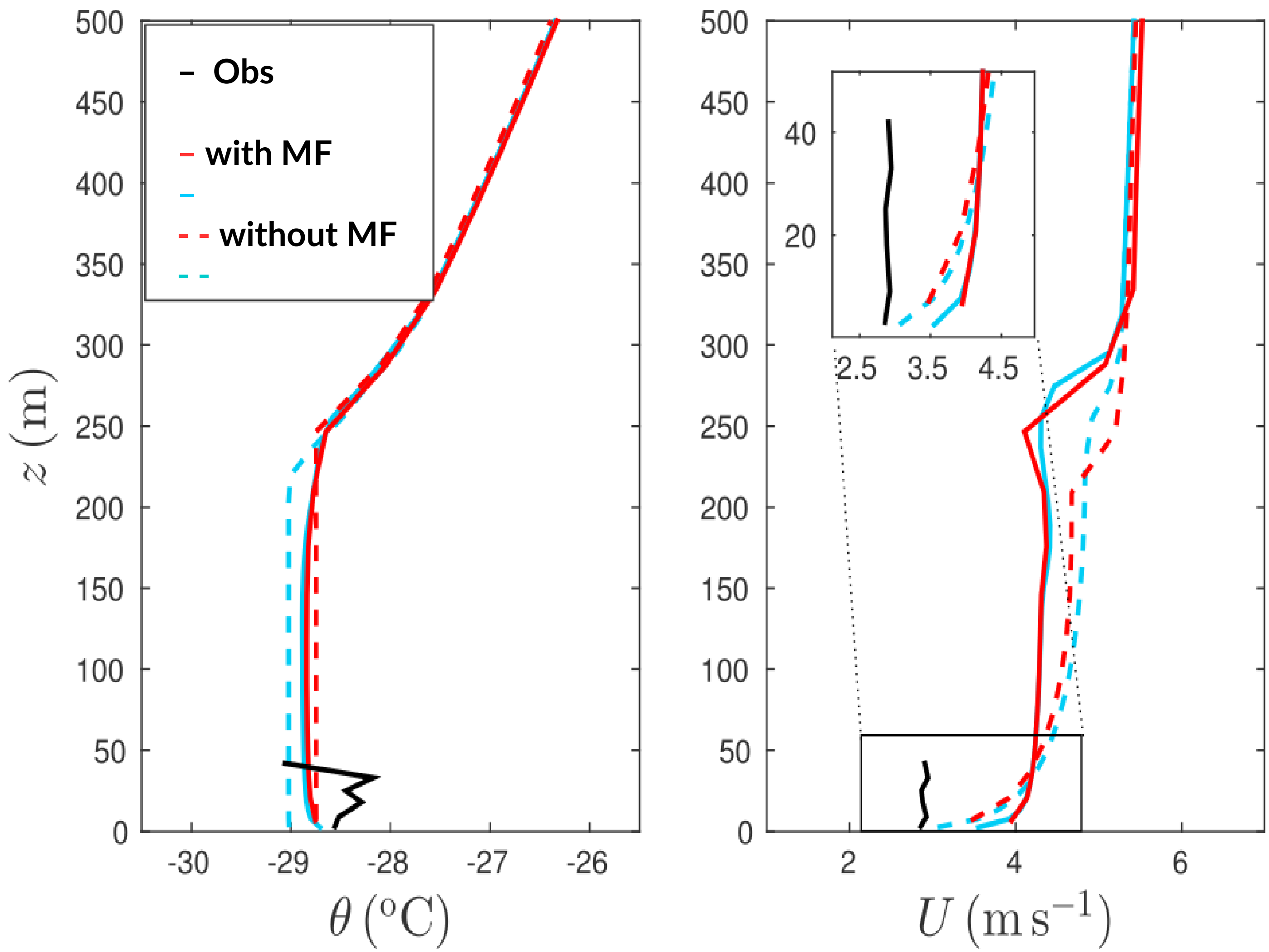
LMDZ (CMIP5)

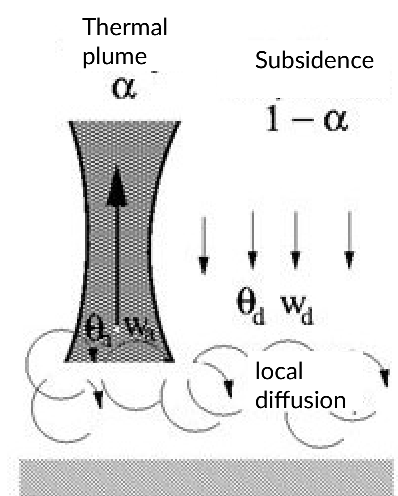
LMDZ (after GABLS4 prescriptions)



2) Diurnal convective boundary layer

Effect of using a Mass Flux (MF) scheme or “thermal plume model”
(Hourdin et al 2002, Rio et al 2010, Couvreux et al 2009)





The LMDZ Mass Flux Scheme accounts for the mixing of momentum.

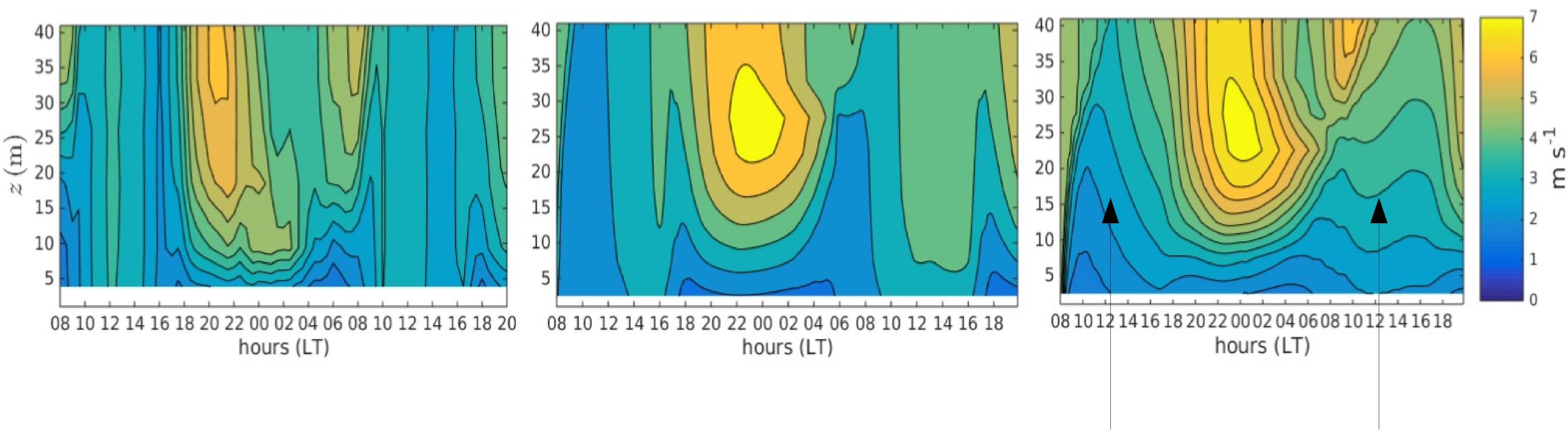
This is not the case for all models !

Wind speed: height-time plot

OBS

LMDZ
with MF scheme
with mixing of momentum

MAR regional model
with MF scheme
with no mixing of momentum



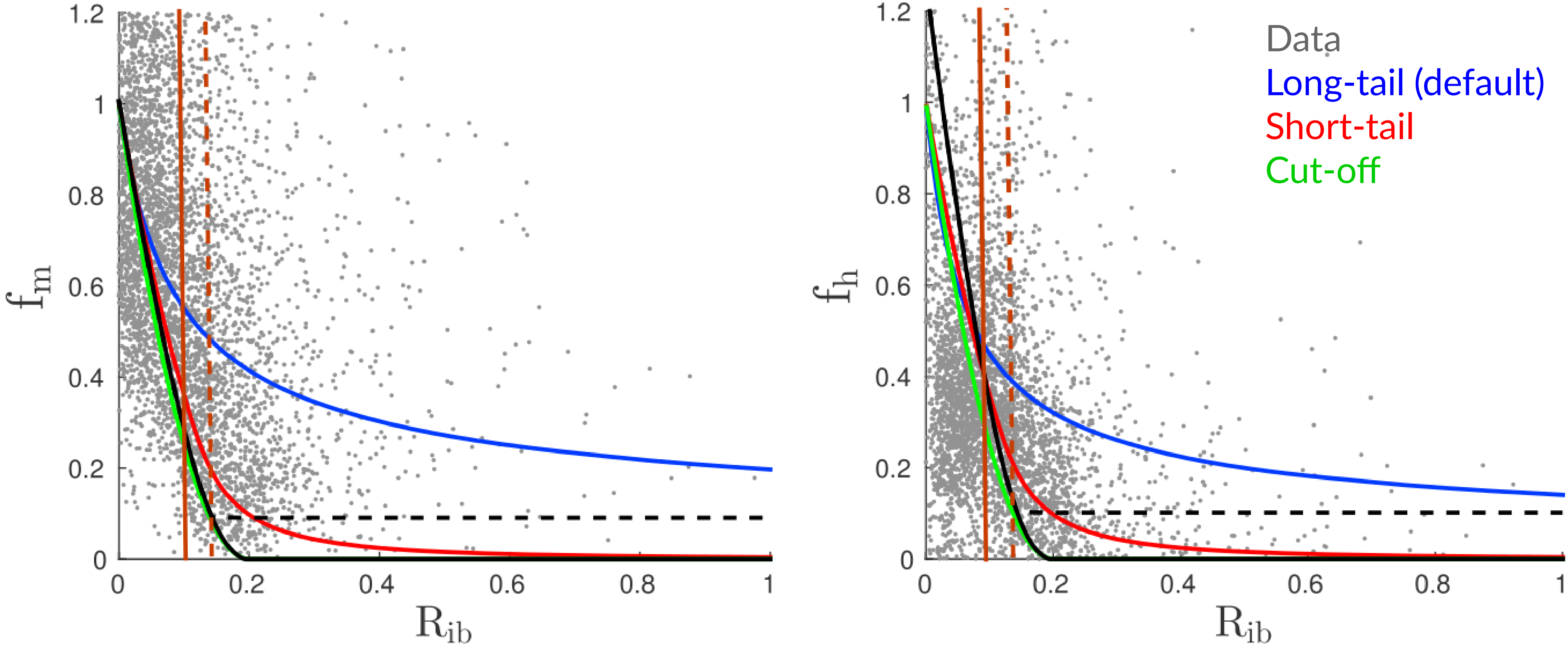
unrealistic gradient

3) "Nocturnal" stable boundary layer

Sensitivity to the surface Layer scheme

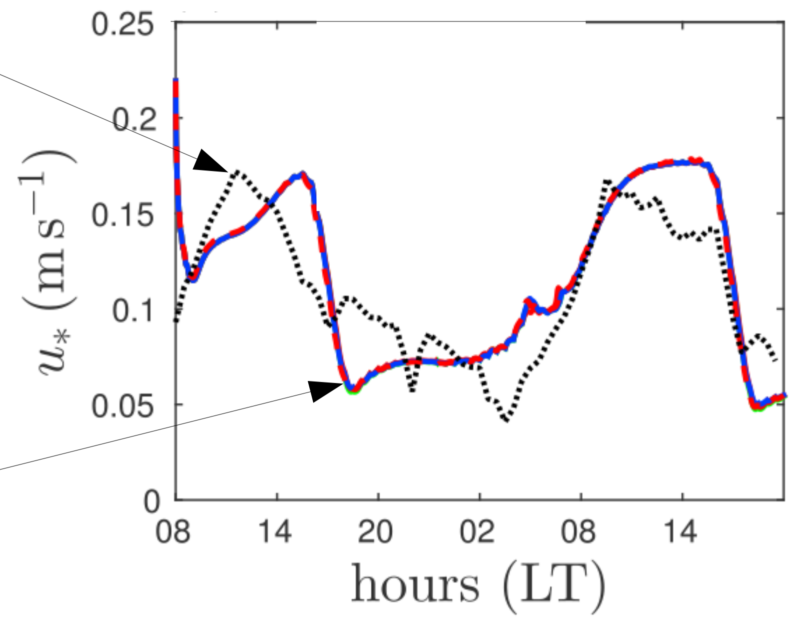
$$C_d = \frac{\kappa^2}{\ln(z_1/z_0)^2} \times f_m$$

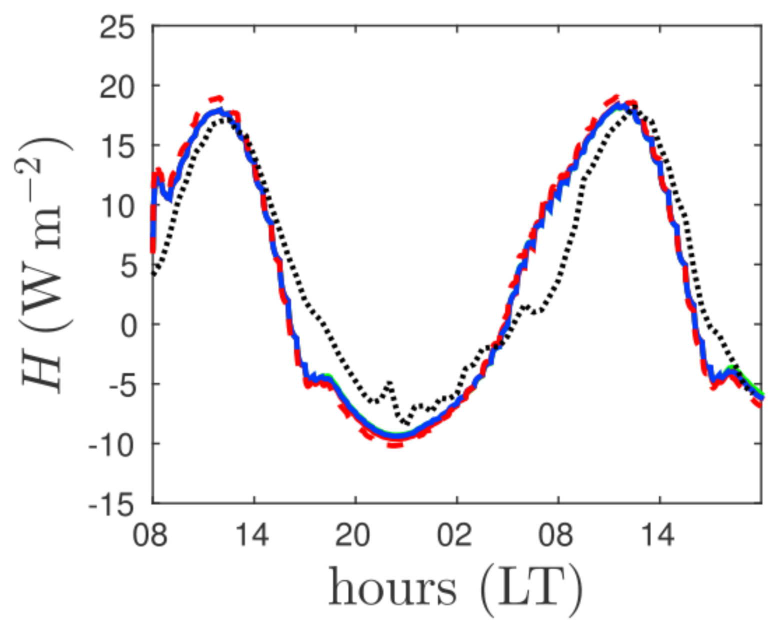
$$C_h = \frac{\kappa^2}{\ln(z_1/z_0)\ln(z_1/z_{0t})} \times f_h$$



Estimation from obs

Colors: simulations with different fm, fh





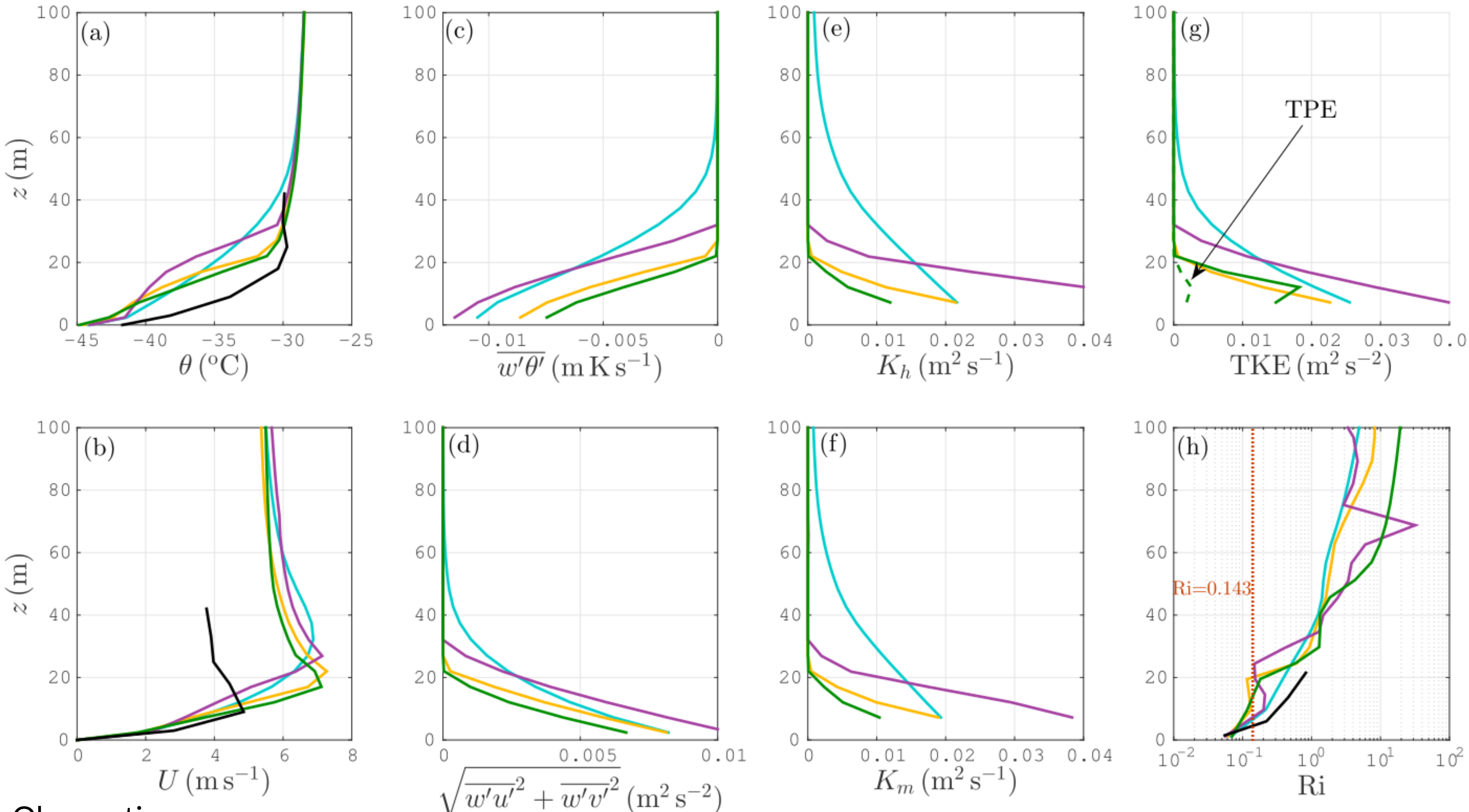
No sensitivity to the stability functions in stable conditions

max(Ri)=0.1

Results weakly sensitive to turbulence scheme

Sensitivity increases when first model level from 3m to 8m

Sensitivity to the turbulence scheme



Observation

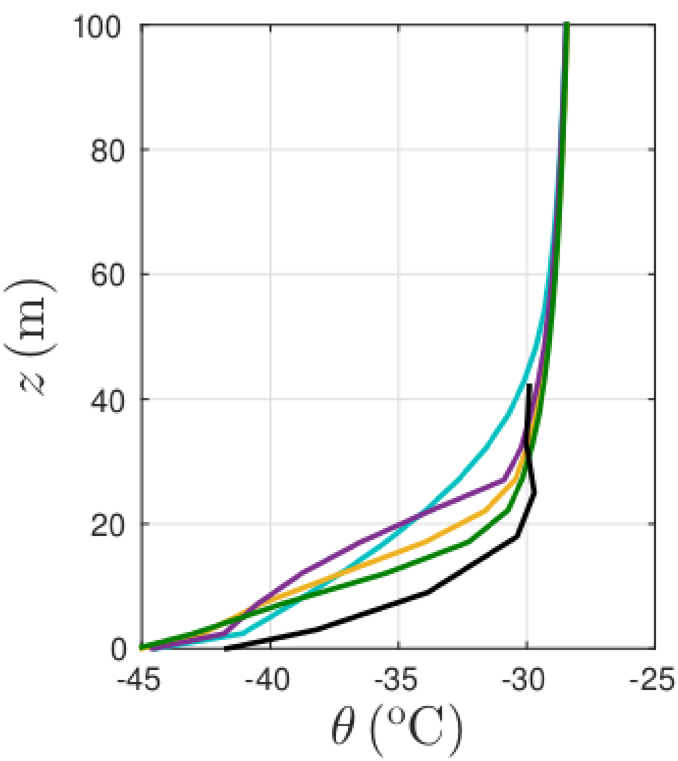
TKE-l scheme (Mellor and Yamada) + enhanced mixing (long-tail) = CMIP5 config.

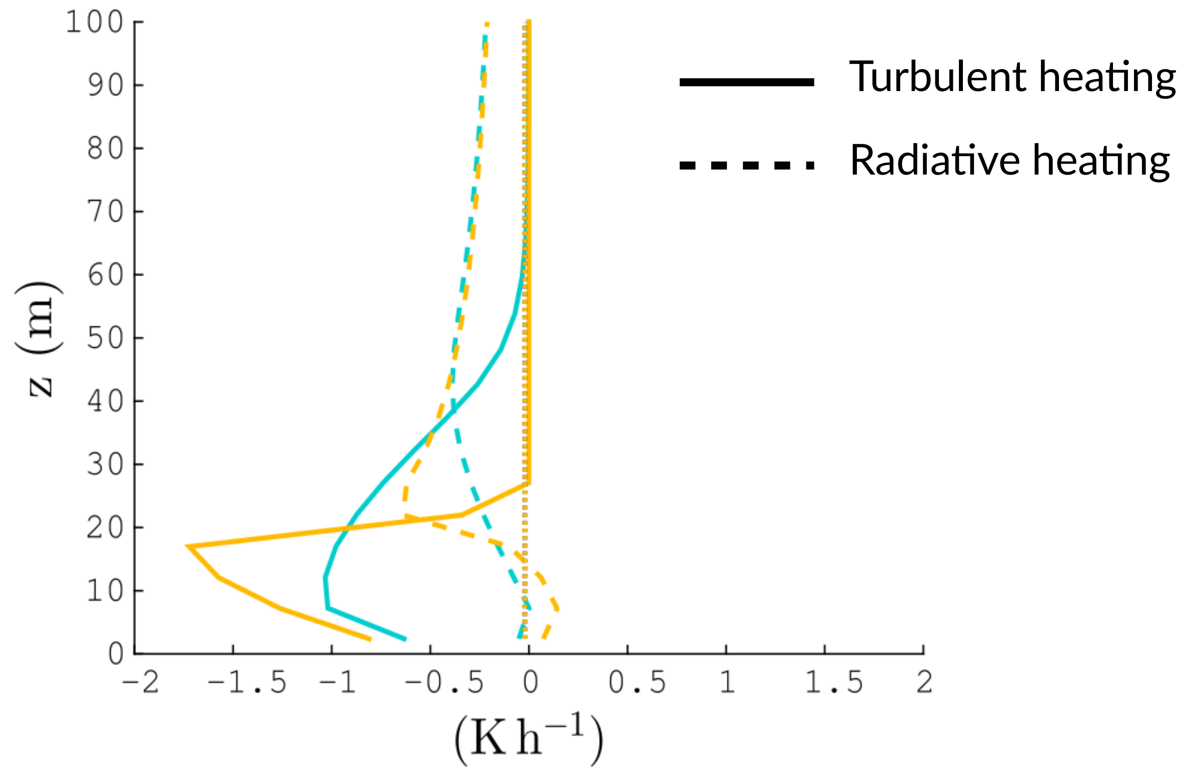
TKE-l scheme (Mellor and Yamada) = CMIP6 config.

K-ε scheme (Duynkerke 1988) = MAR RCM

Energy-Flux-Budget scheme (Zilitinkevich et al 2013)

Role of radiation





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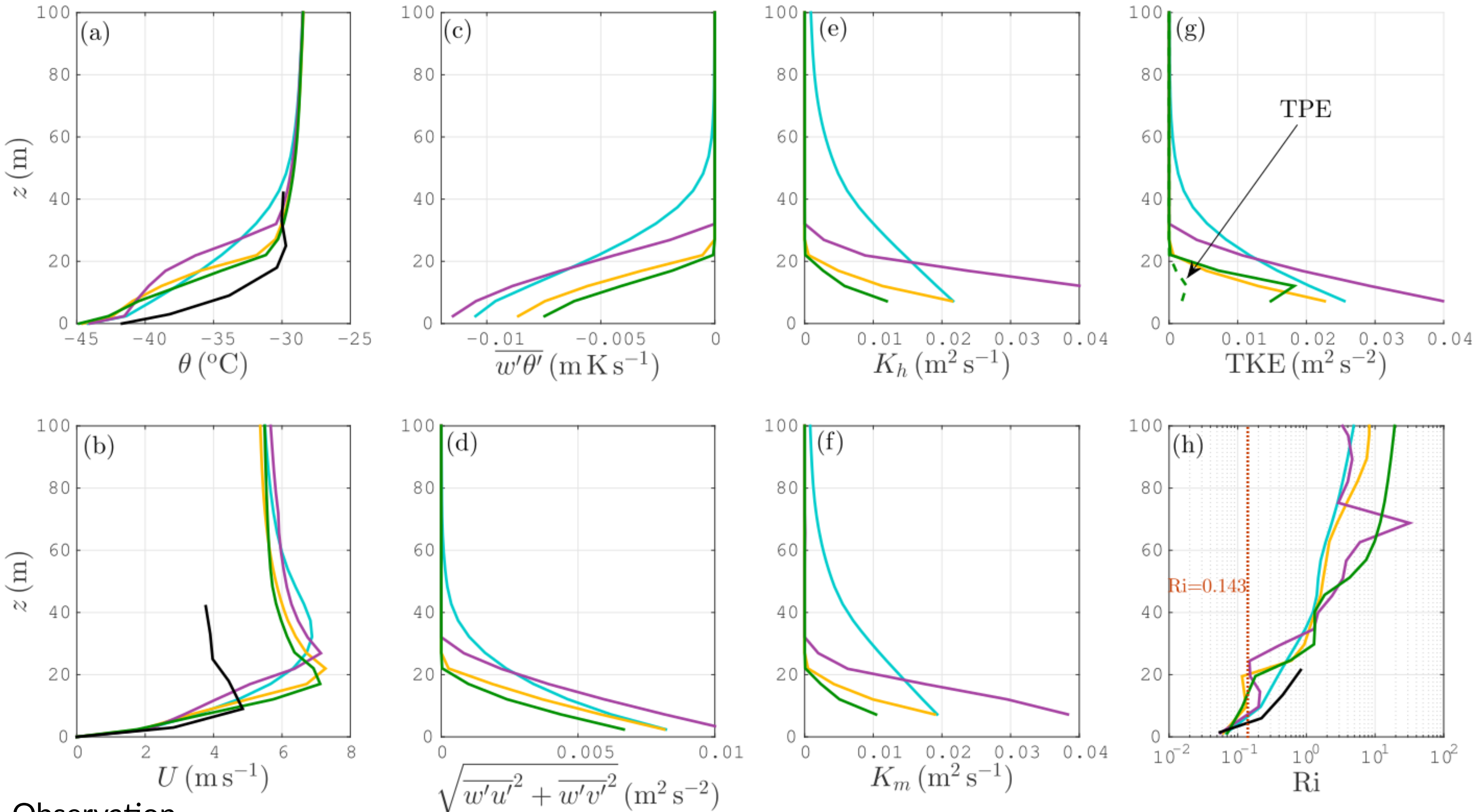
Sensitivity to the turbulence scheme



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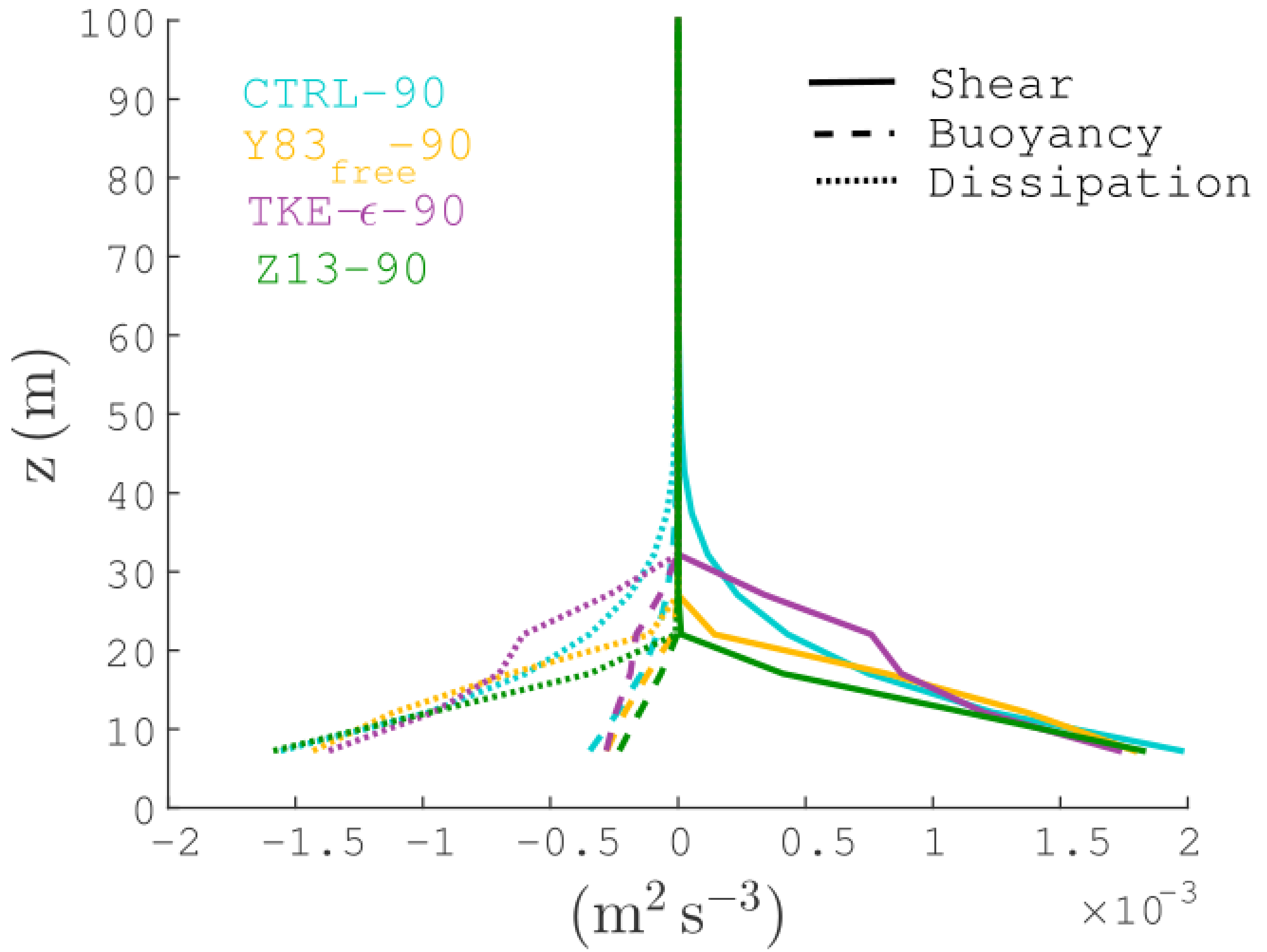
TKE budget

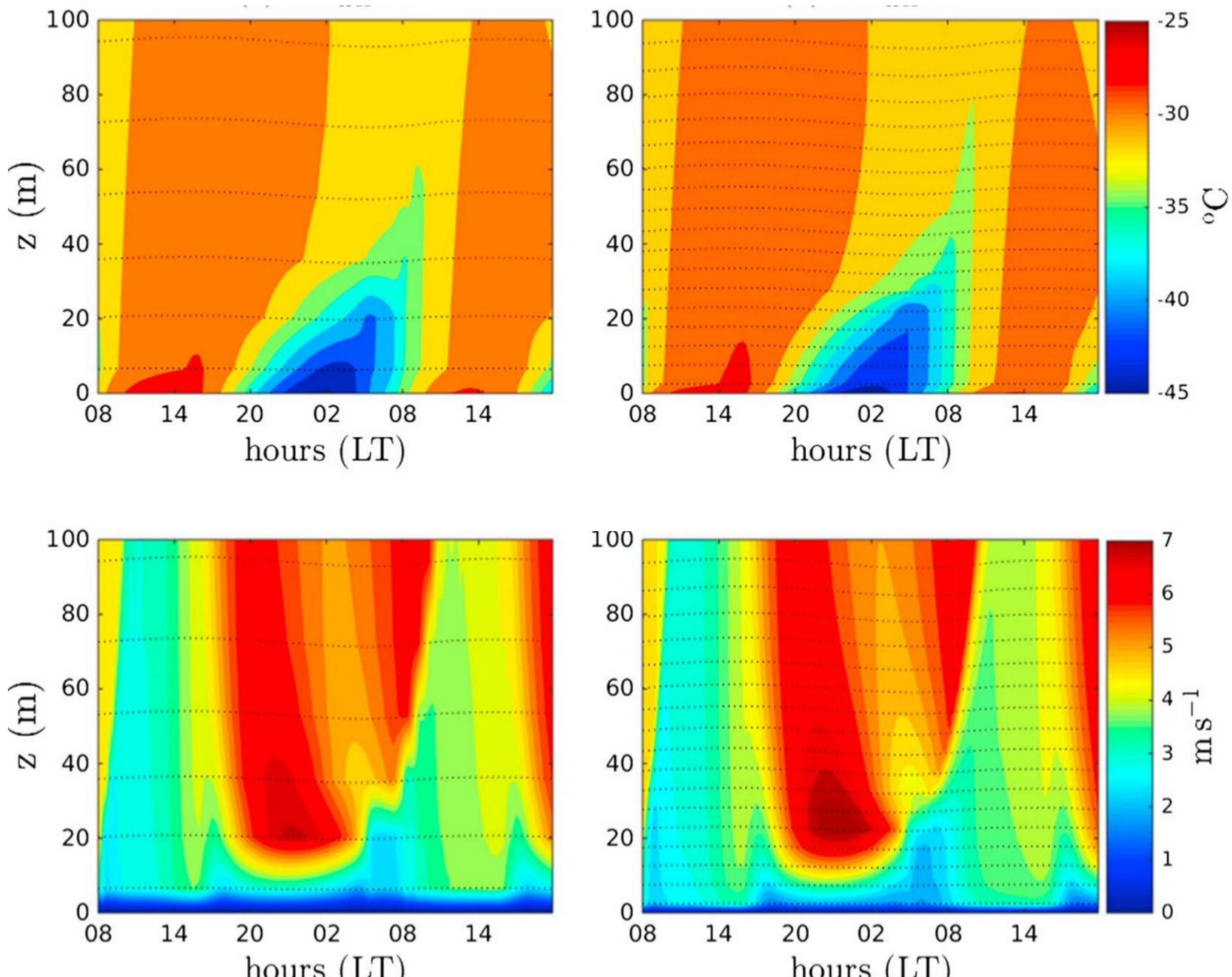


CTRL−90
Y83free−90
TKE−ϵ−90
Z13−90
Shear
Buoyancy
Dissipation
z (m)
100
90
80
70
60
50
40
30
20
10
0
−2
−1.5
−1
−0.5
0
0.5
1
1.5
2
(m² s⁻³)
×10⁻³

Sensitivity to the vertical resolution

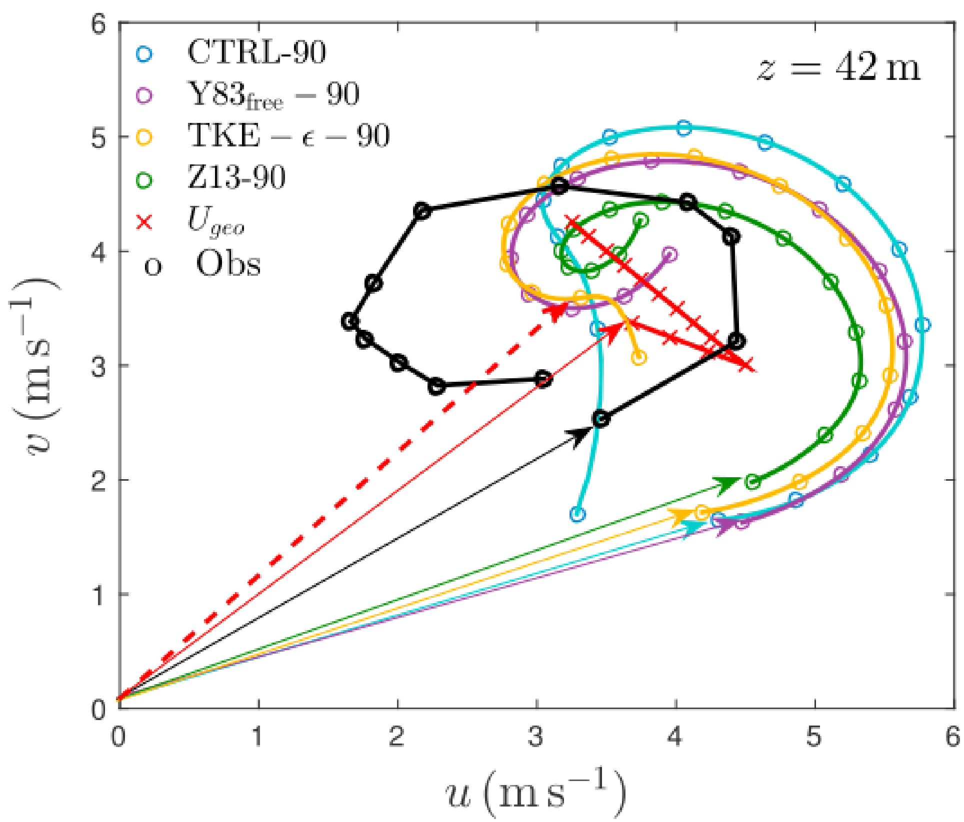
Standard 79-level grid

GABLS4 90-level grid



4) Discussion on external forcings

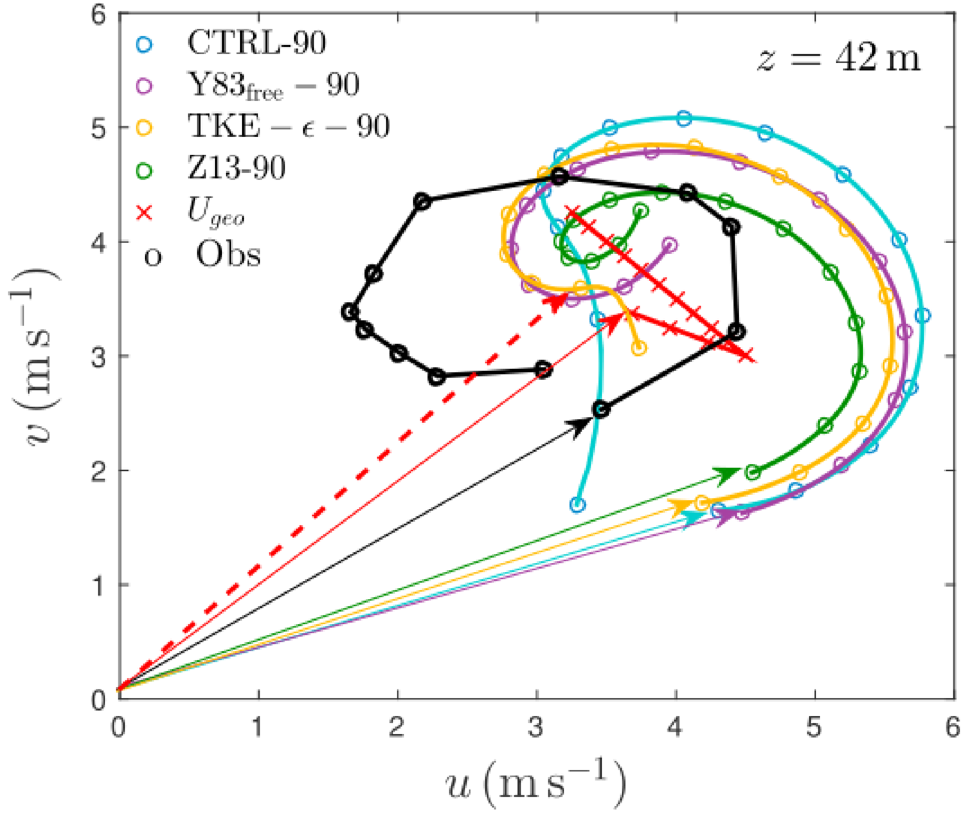
Strength of the geostrophic wind



Hodograph from 18:00 LT (arrows) to 07:00 LT

4) Discussion on external forcings

Strength of the geostrophic wind



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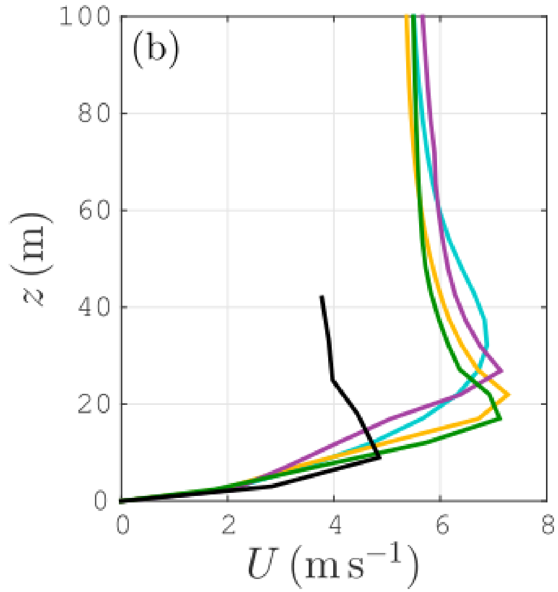
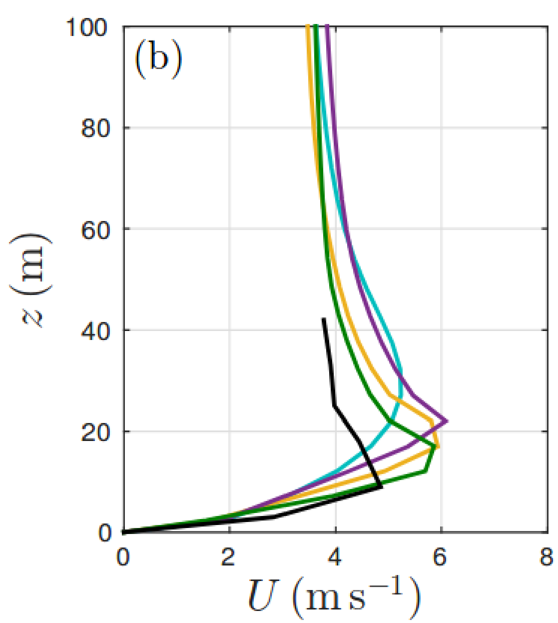
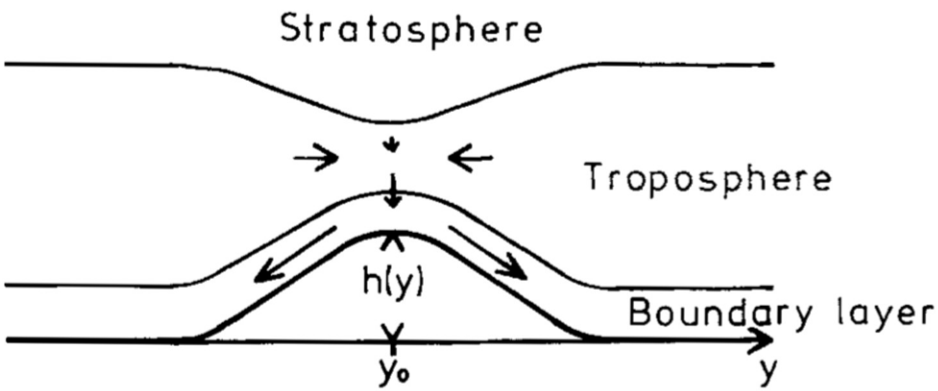




Impact of large scale subsidence

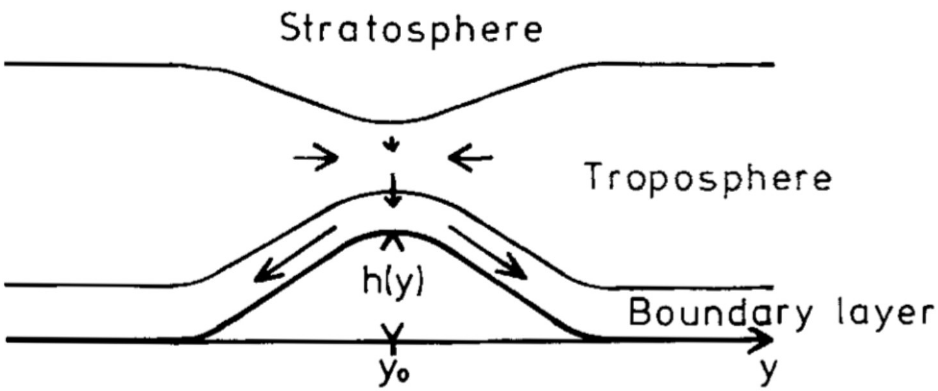


Antarctic drainage flow, James 1989

Van de Berg et al 2008
Vignon et al 2018
Baas et al 2018

→ Importance of subsidence term in heat budget of the Antarctic SBL

Impact of large scale subsidence



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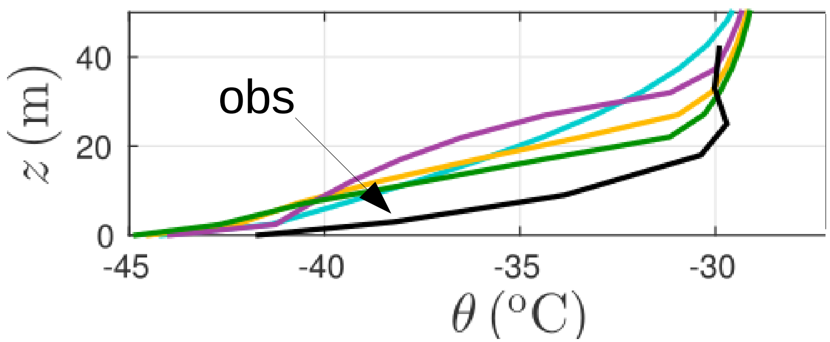
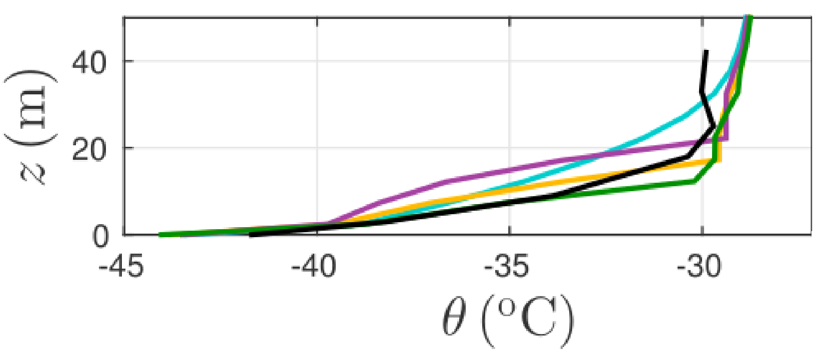


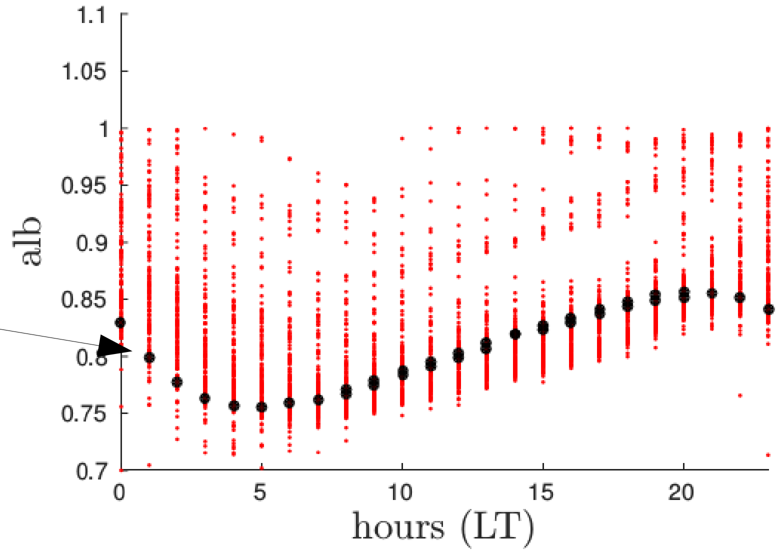
Additional subsidence =10^{-3} m s^{-1}
(linear decrease → 0 below 100m)



Albedo time-evolution

Diurnal cycles from same instrument

GABLS4 days



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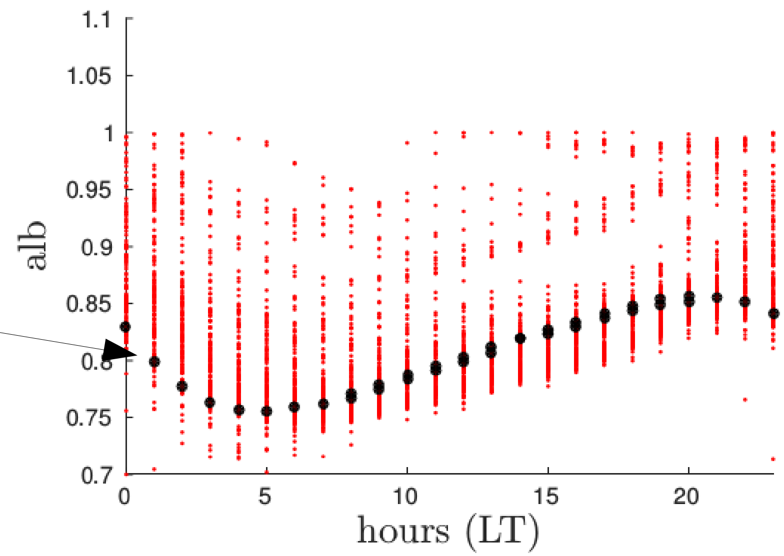
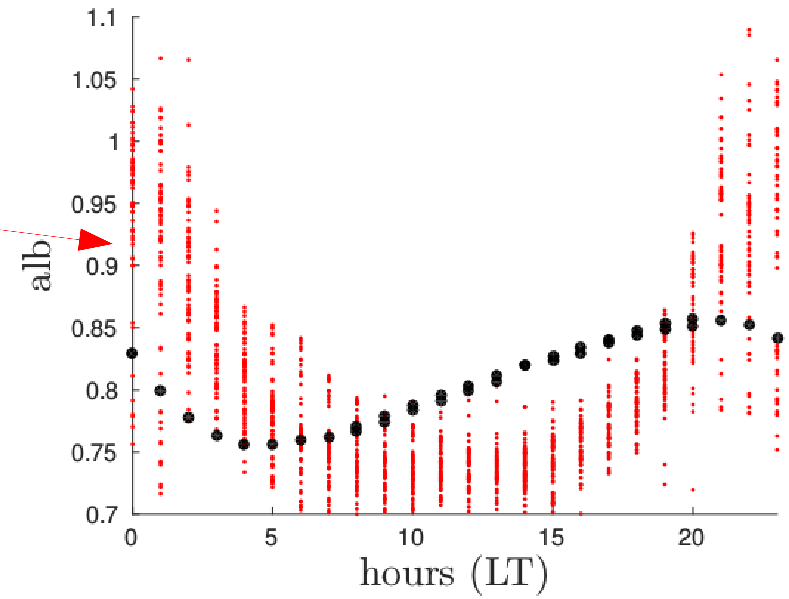


Diurnal cycle from instrument 200 m north



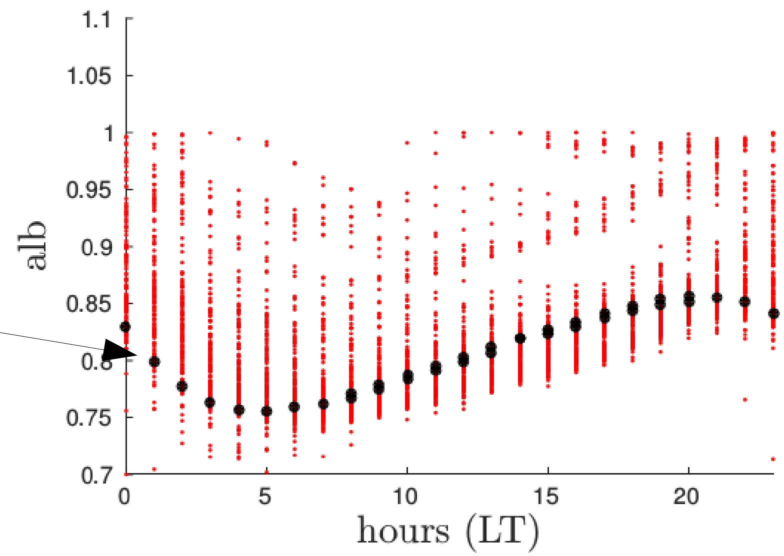
More consistent with the expected dependence on solar zenith angle

External forcings

Albedo time-evolution

Diurnal cycles from same instrument

GABLS4 days



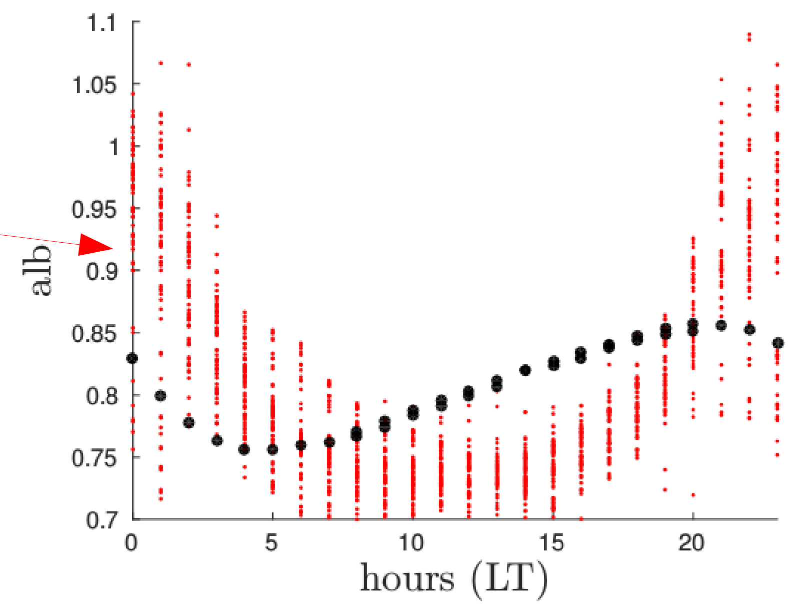
Observers report a small dune below the instrument

→ effect on the diurnal cycle of albedo (Dumont et al 2017)

Simulations with Marie Dumont's snow albedo model (CEN, Grenoble, France)

→ snow surface tilted by 1-2°

Diurnal cycle from instrument 200 m north



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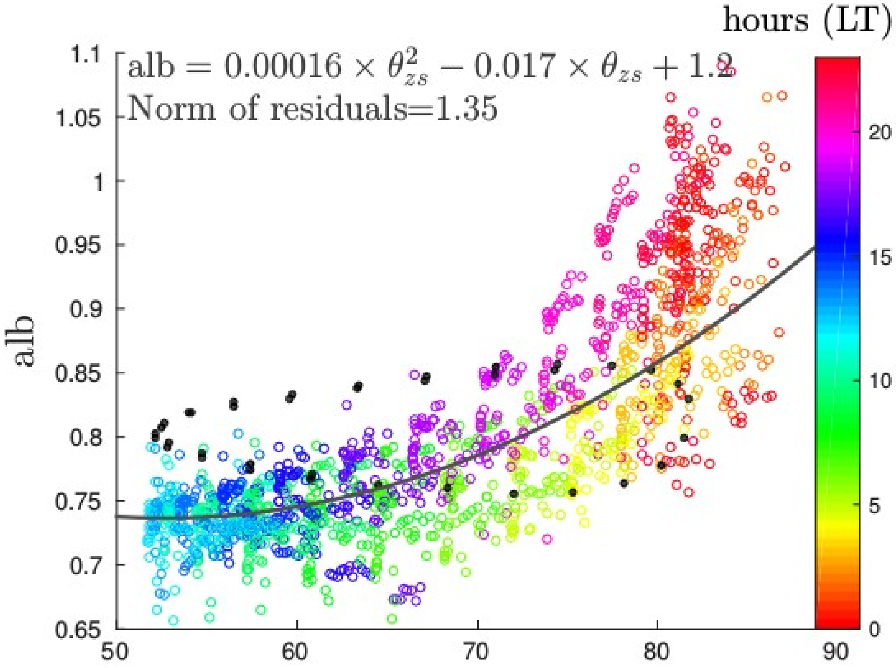
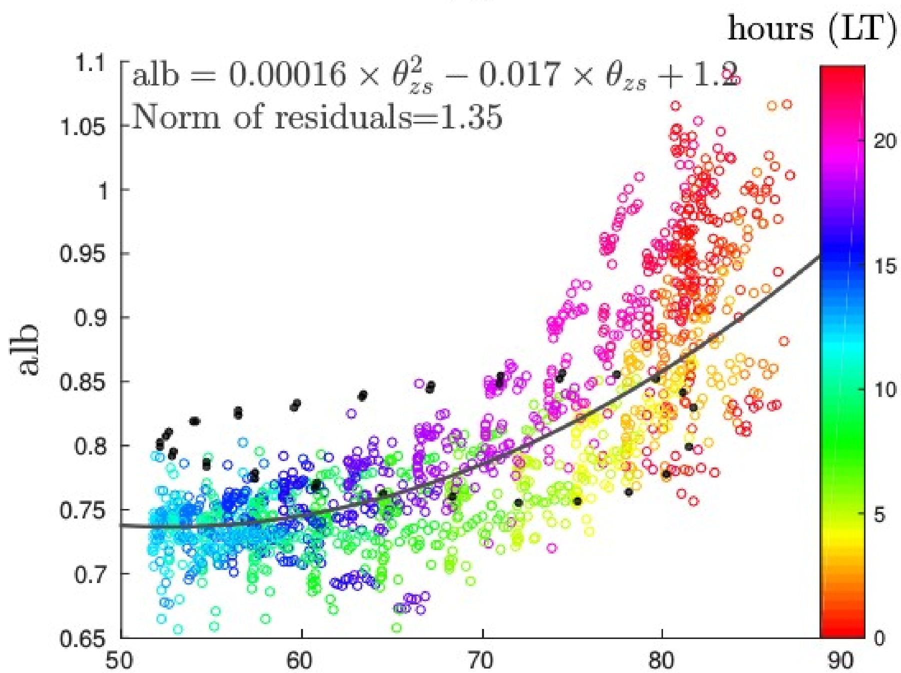


Solar zenith angle (°)

Albedo time-evolution



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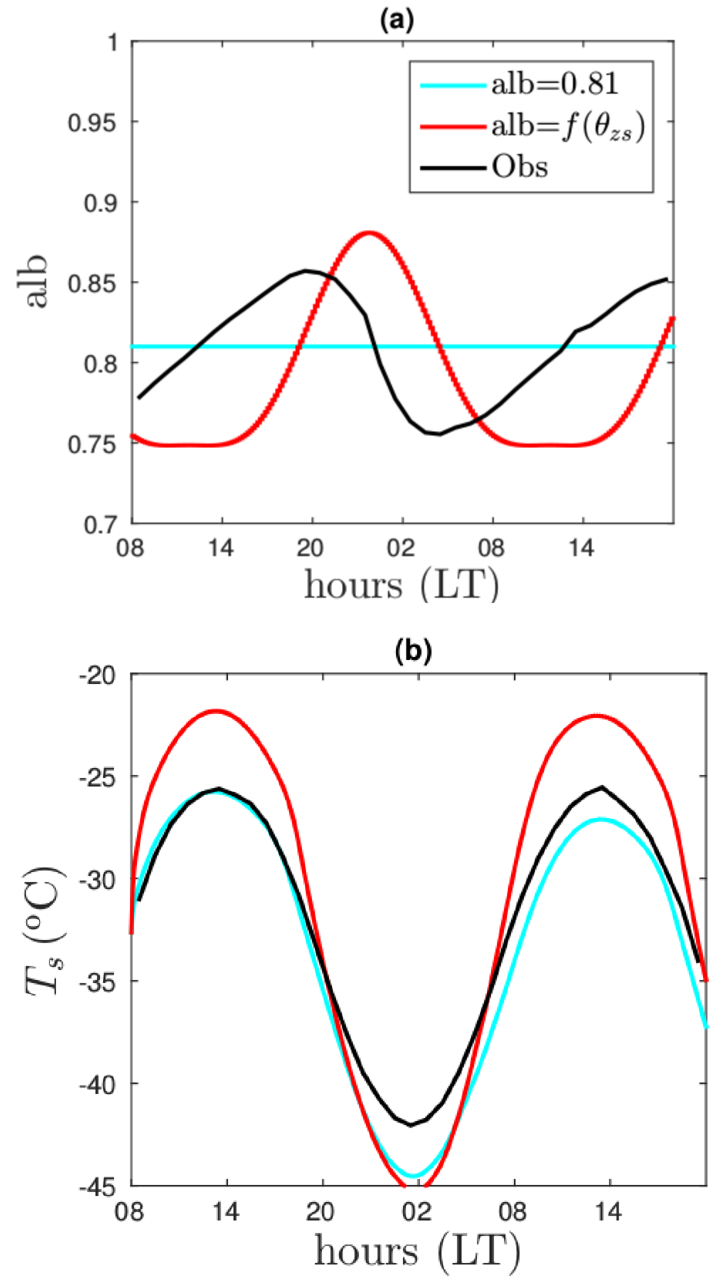


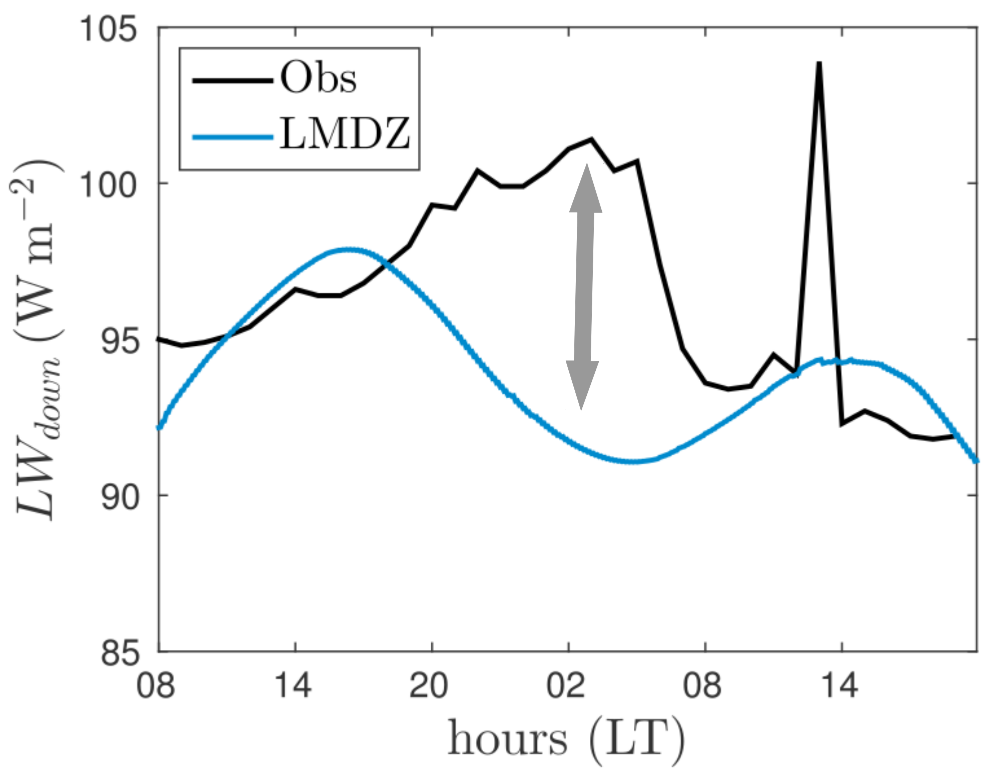
5) Conclusions

- GABLS4 helped in setting the new configuration of LMDZ for CMIP6

5) Conclusions

- GABLS4 helped in setting the new configuration of LMDZ for CMIP6
- Prescribed surface parameters for GABLS4 → clear improvement
- Importance of mass flux scheme accounting for mixing of momentum
- Weak sensitivity to vertical grid and surface layer scheme in stable conditions
- Enhanced mixing formulations deteriorates the structure of the Dome C SBL
- TKE-l scheme and EFB scheme give the best results
- Likely slight overestimation of geostrophic wind + absence of subsidence in the forcings → be careful with direct comparison with Obs
- Comment on diurnal cycle of albedo
- Remaining cold nocturnal bias at the surface despite new LW scheme → high thin clouds?


Thank you for your attention
etienne.vignon@epfl.ch
- Vignon et al 2017, Antarctic boundary layer parametrization in a general circulation model: 1-D simulations facing summer observations at Dome C. J Geophys Res: Atm, 122, 6818–6843. https://doi.org/10.1002/2017JD026802



Explains a surface temperature cold bias between 0.4 and 2.4 K