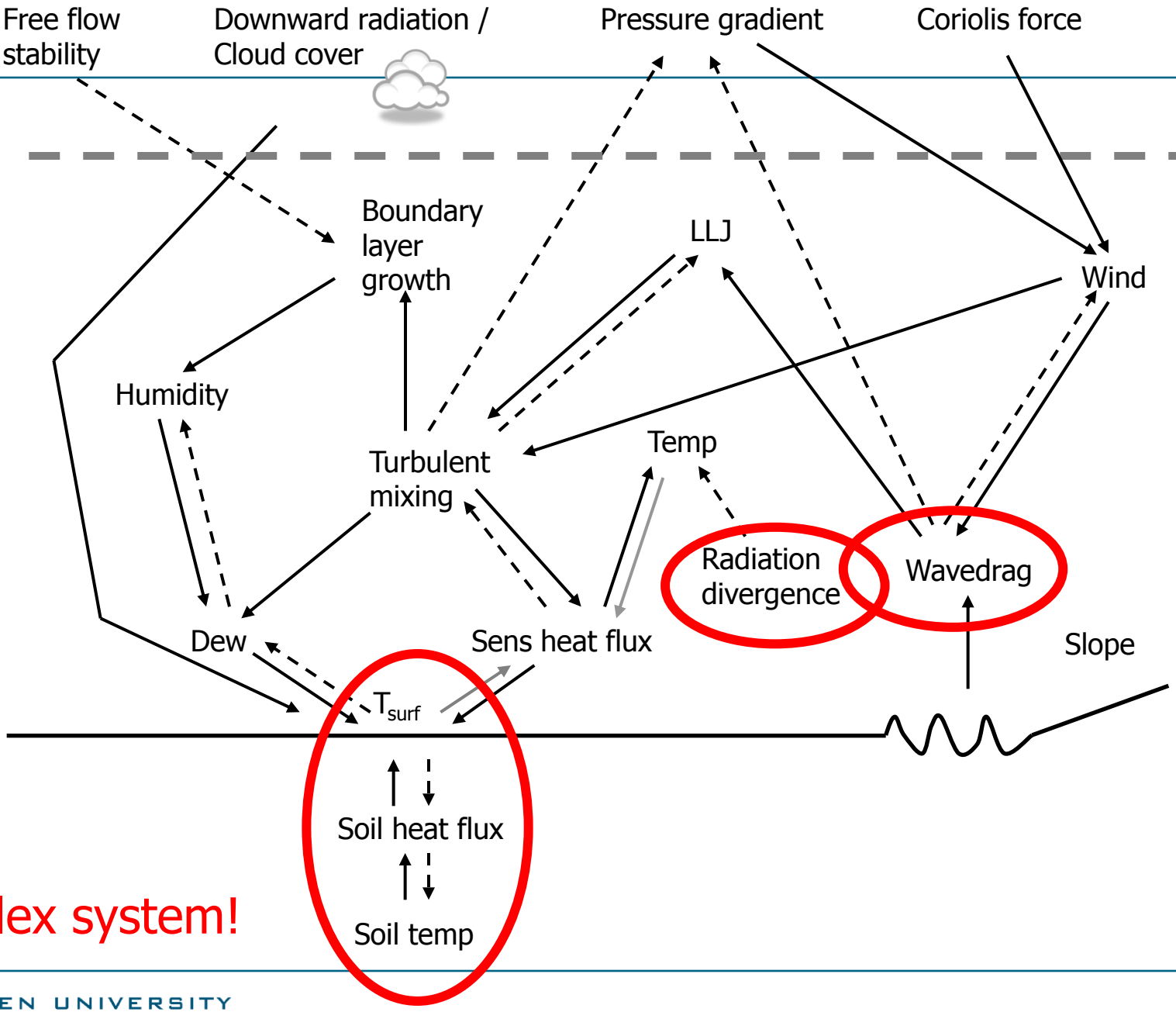
Stable boundary layer issues

Gert-Jan Steeneveld
GABLS workshop Nov 2011, ECWMF

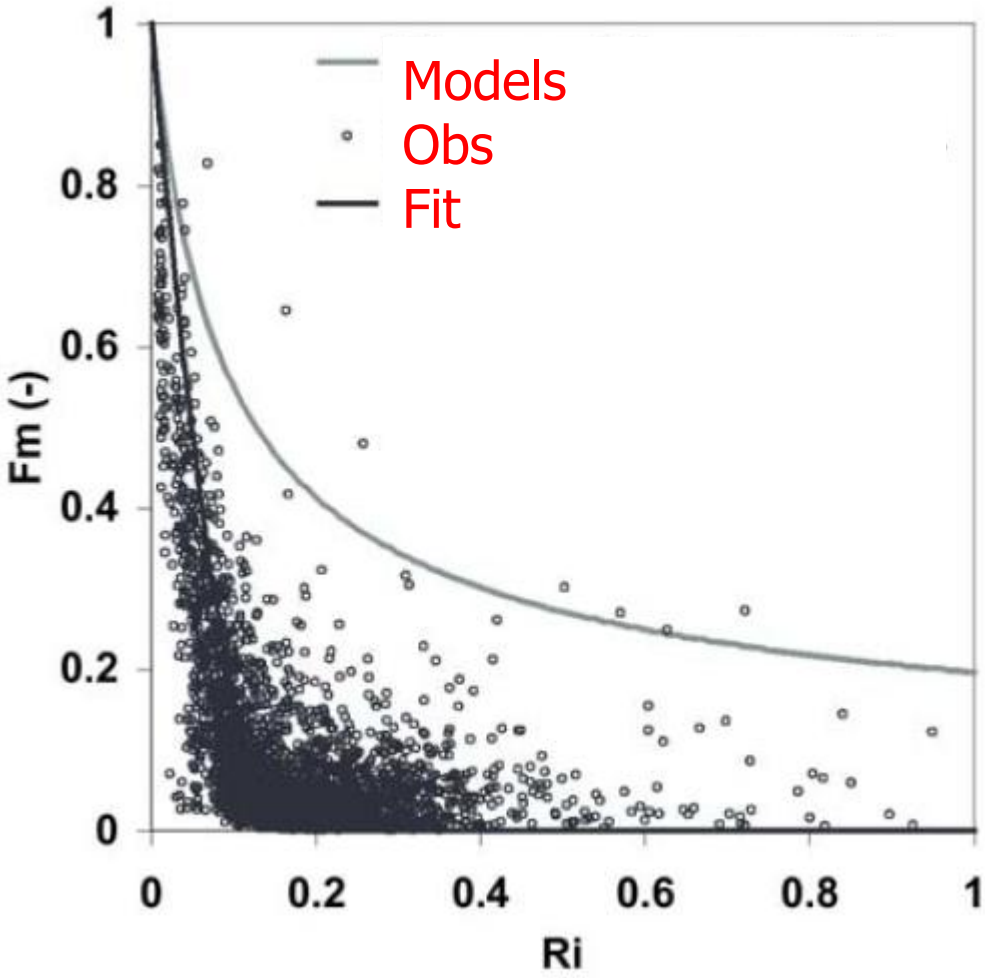
Ex.drivers



It is a complex system!

Idea borrowed from Mike Ek

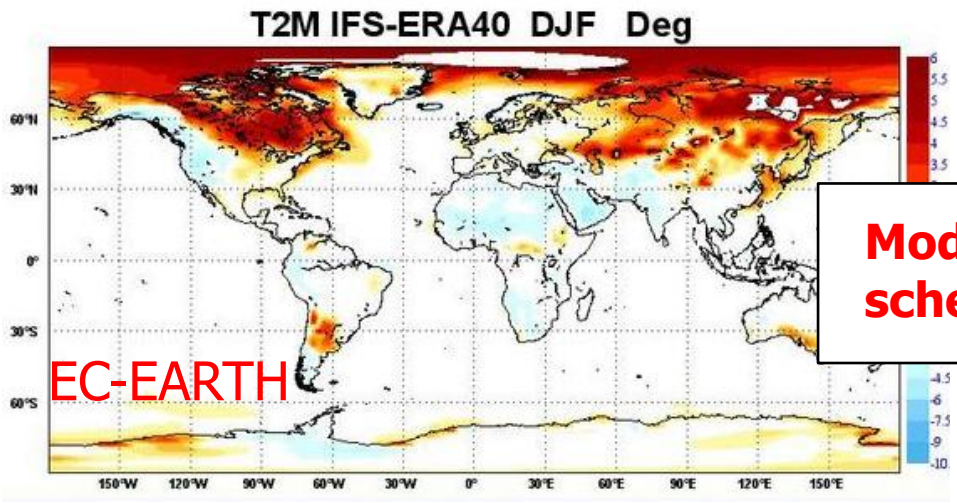
Turbulent mixing (CASES-99)



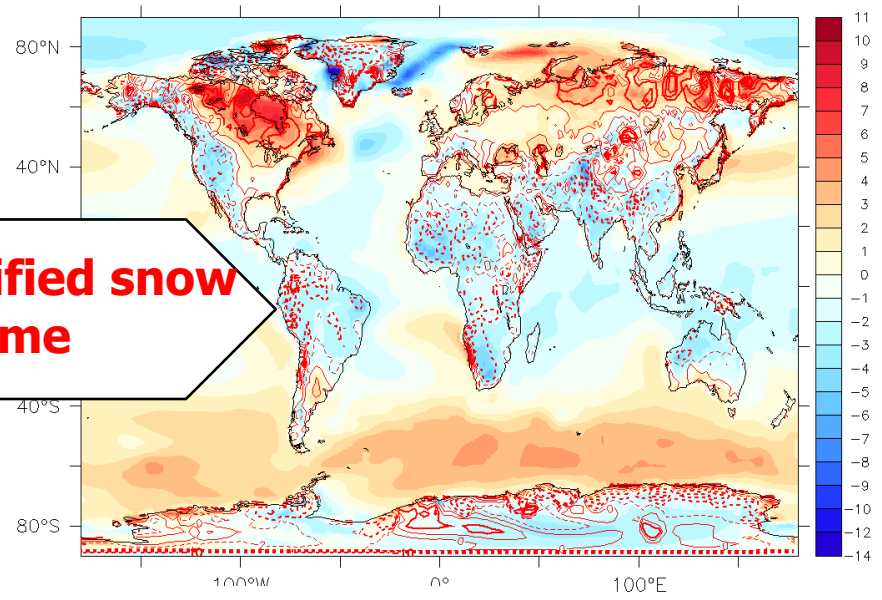
Do models still need long tail formulations?

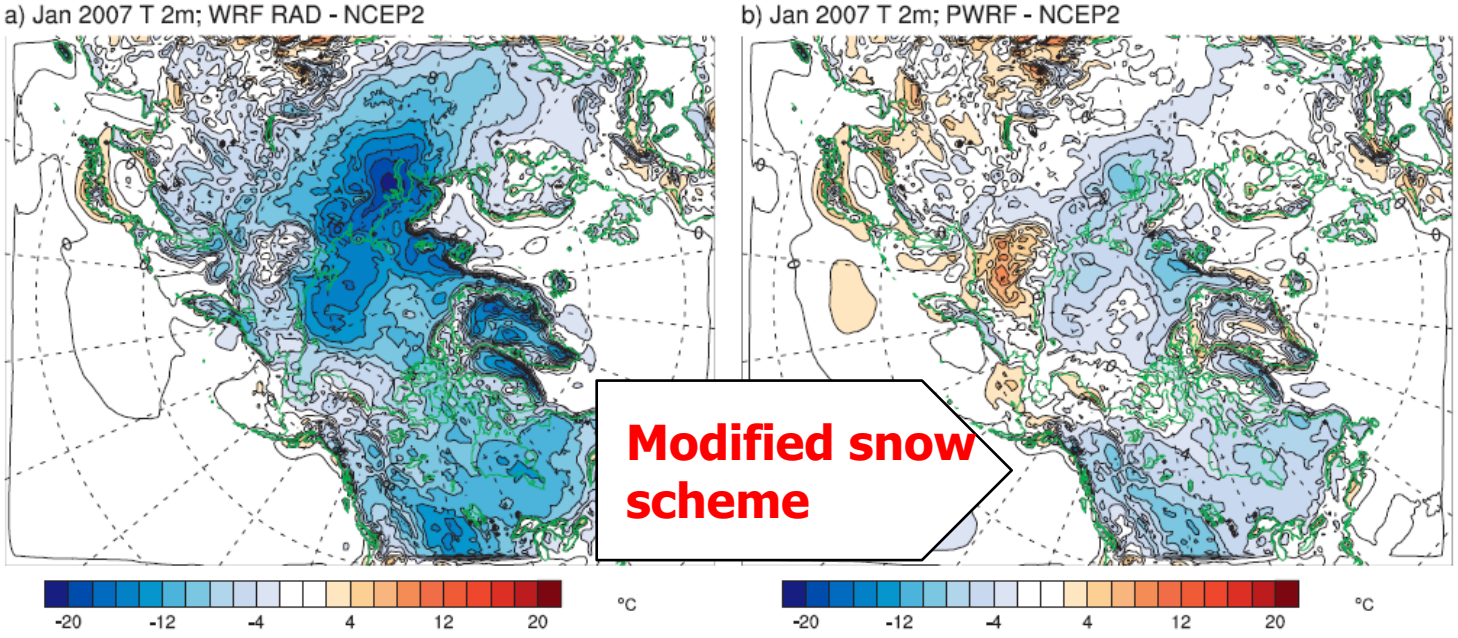
Over land only?

Role of land surface description



Modified snow scheme

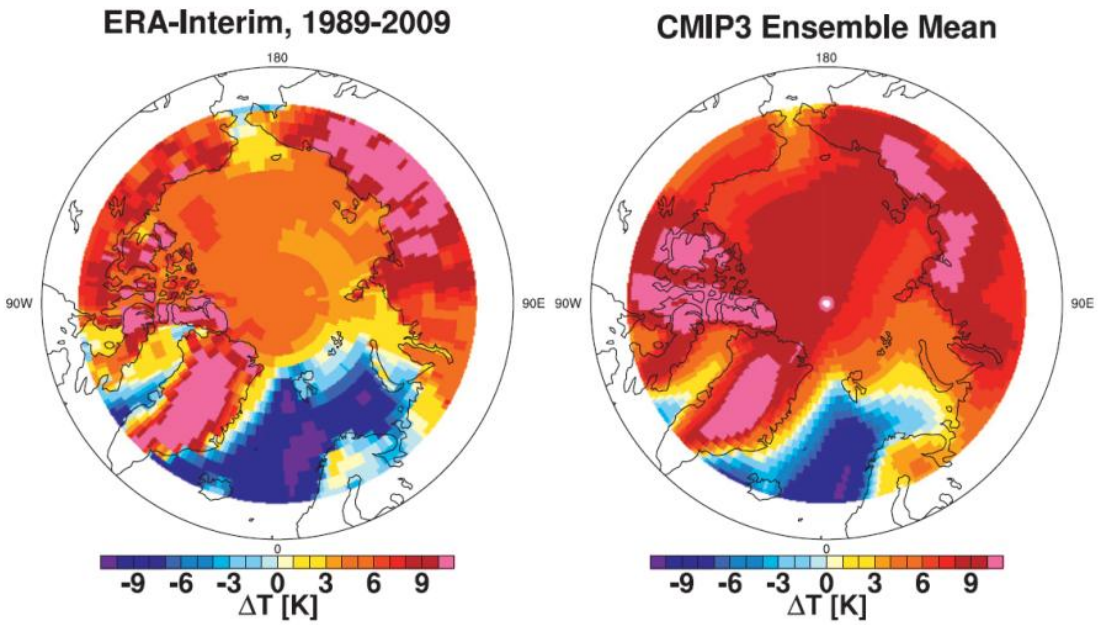


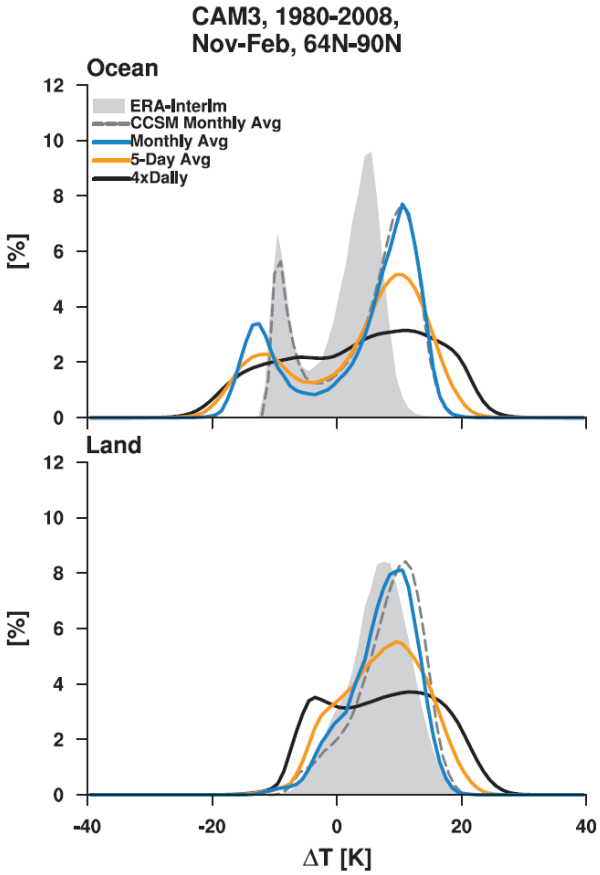


Modified snow scheme

WRF

Arctic climate





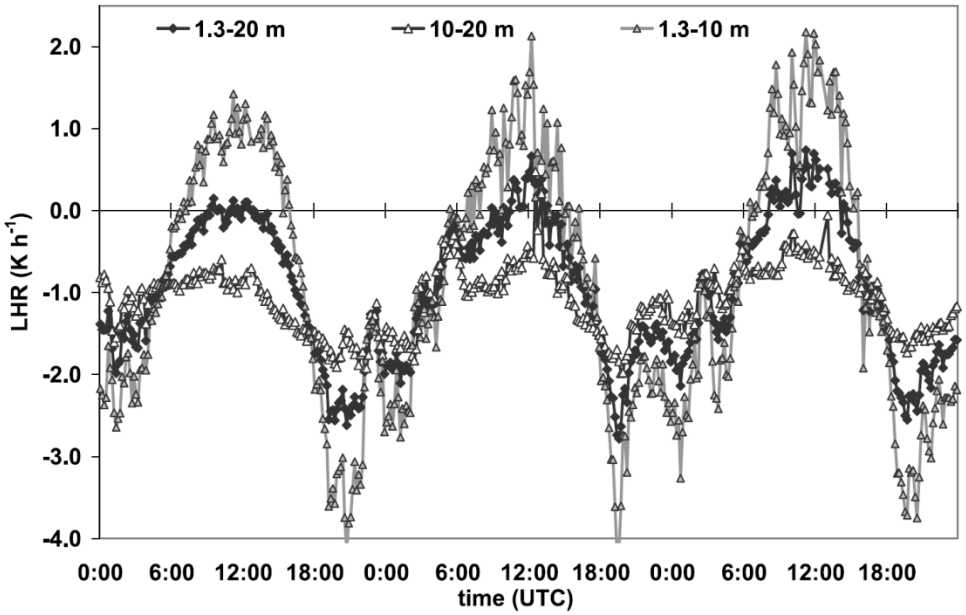
Inversion strength *over*estimated

Medeiros, Brian, Clara Deser, Robert A. Tomas, Jennifer E. Kay, 2011: Arctic Inversion Strength in Climate Models. J. Climate, 24, 4733–4740. doi: 10.1175/2011JCLI3968.1

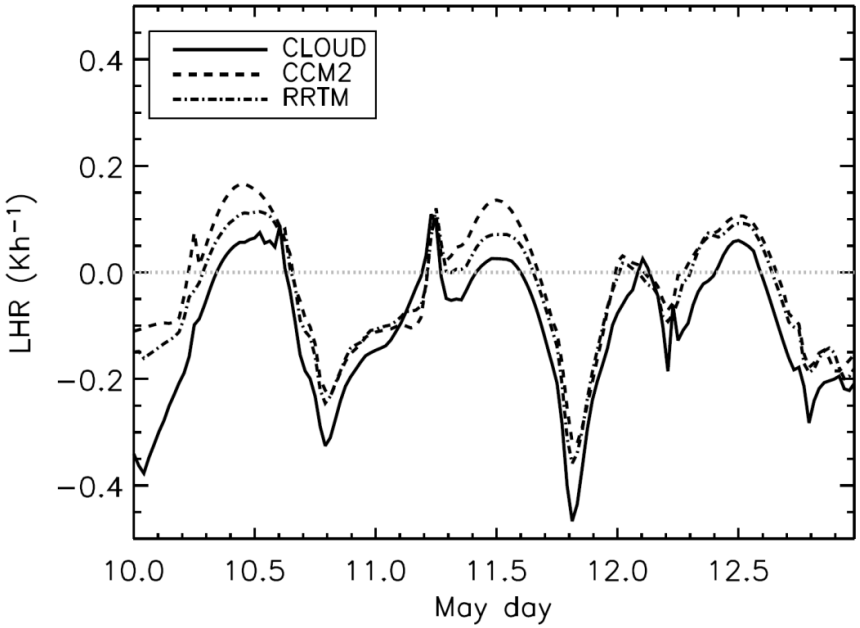
Radiation

$$\frac{\partial \theta}{\partial t} = -\frac{\partial \overline{w\theta}}{\partial z} - \frac{1}{\rho C_p}\frac{\partial L^*}{\partial z}.$$

OBS



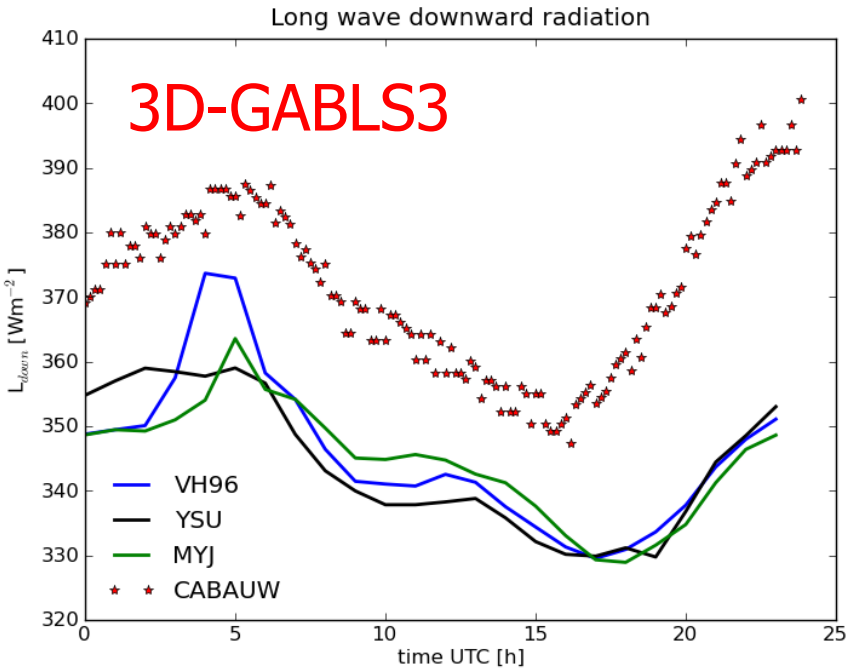
MODEL

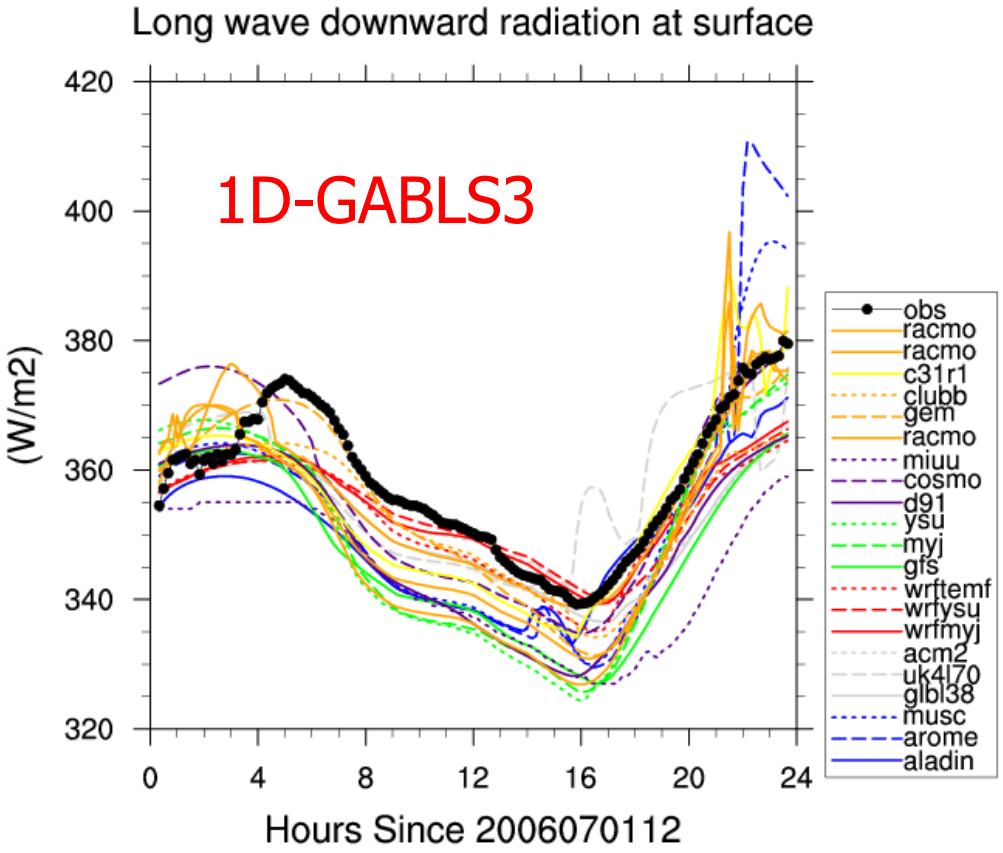


In weak wind conditions, radiation divergence is substantial contributor in nature, but not in atmospheric models. How to diagnose T2m?

Steeneveld, G.J., M.J.J. Wokke, C.D. Groot Zwaaftink, S. Pijlman, B.G. Heusinkveld, A.F.G. Jacobs, A.A.M. Holtslag, 2010: Observations of the radiation divergence in the surface layer and its implication for its parametrization in numerical weather prediction models. J. Geophys Res., 115, D06107, doi:10.1029/2009JD013074.
See also: Edwards et al 2009a,b

Long wave downward rad. systematically underestimated?

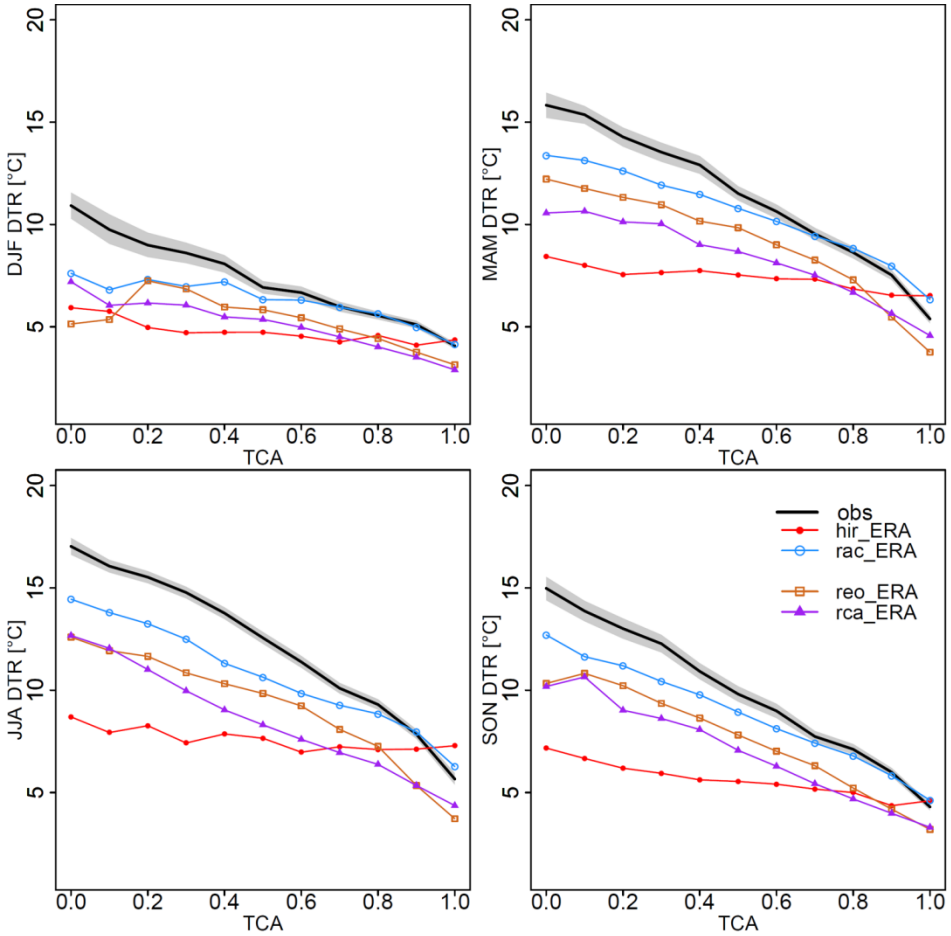




See poster Michal Kleczek

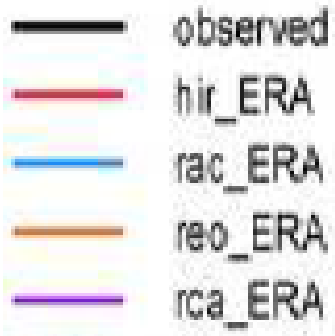
Also reported elsewere

Diurnal Temperature Range

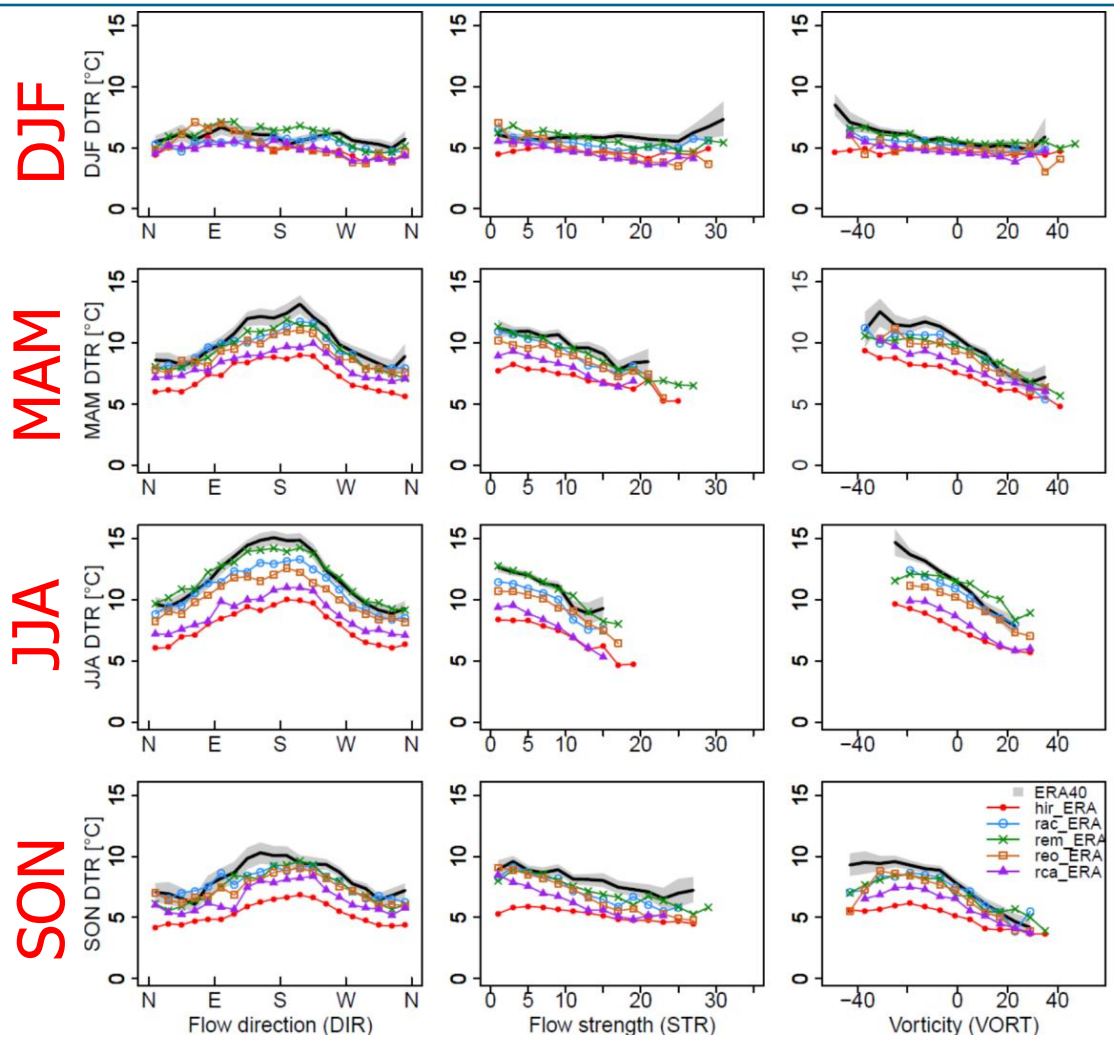


Cloud cover

DTR usually, substantially underestimated by models
(in this case for central Europe)



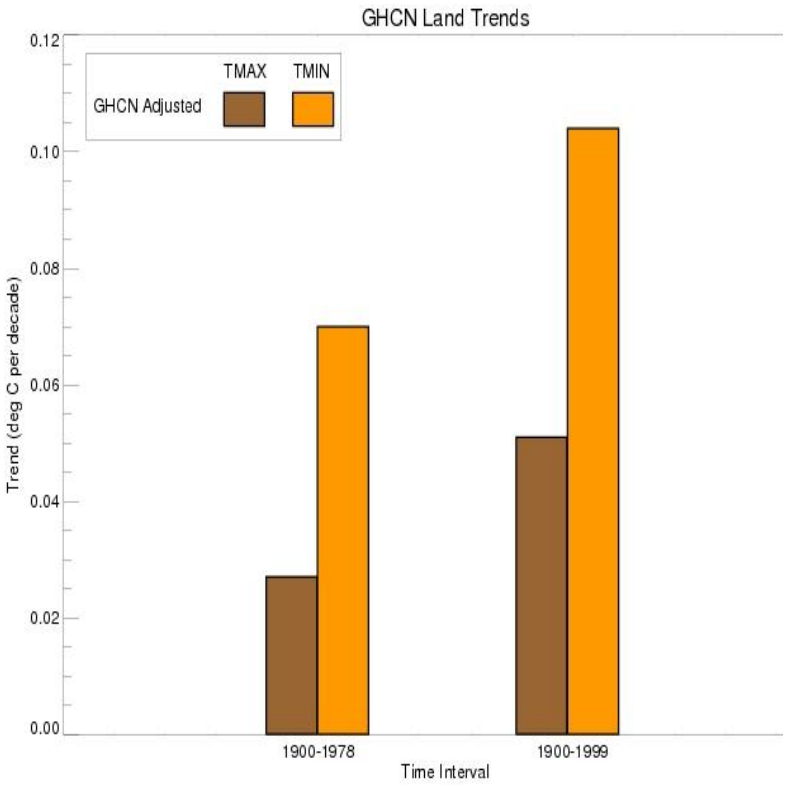
DIRECTION STRENGTH VORT



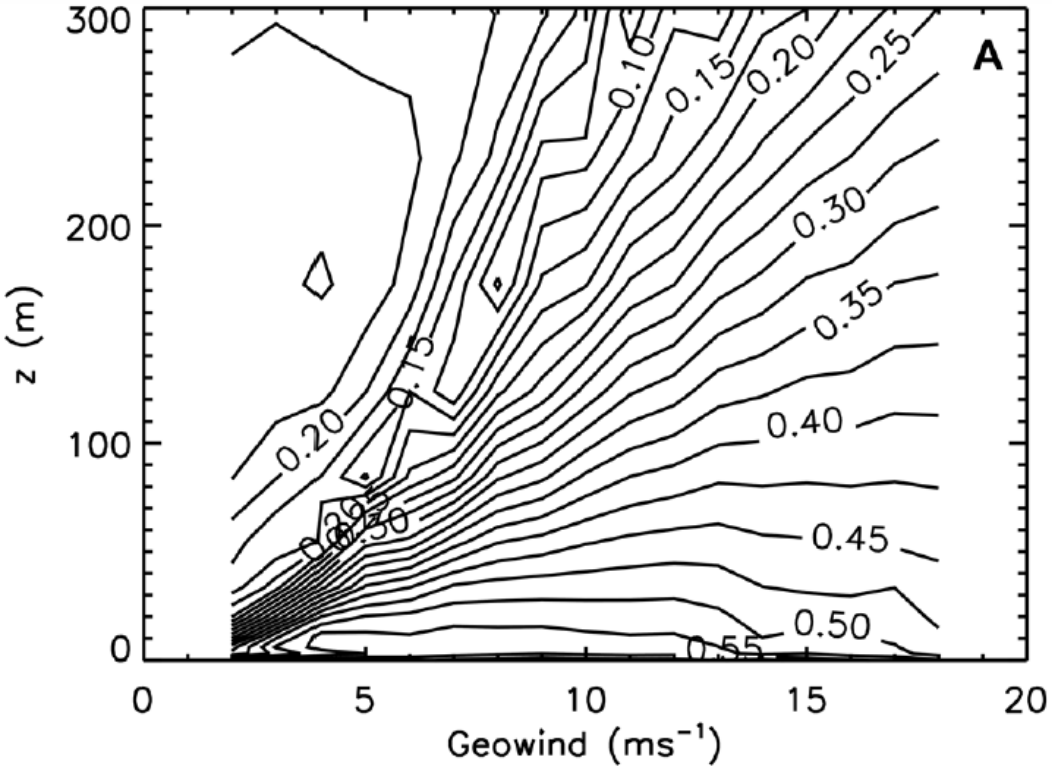
Underestimation DTR
Strongest for
-anticyclonic flow
-weak winds

Kyselý, J., and E. Plavcová, 2011: Biases in the diurnal temperature range in Central Europe in an ensemble of regional climate models and their possible causes. *Clim. Dyn.*, in press.

Role of Stable Boundary Layer in climate change



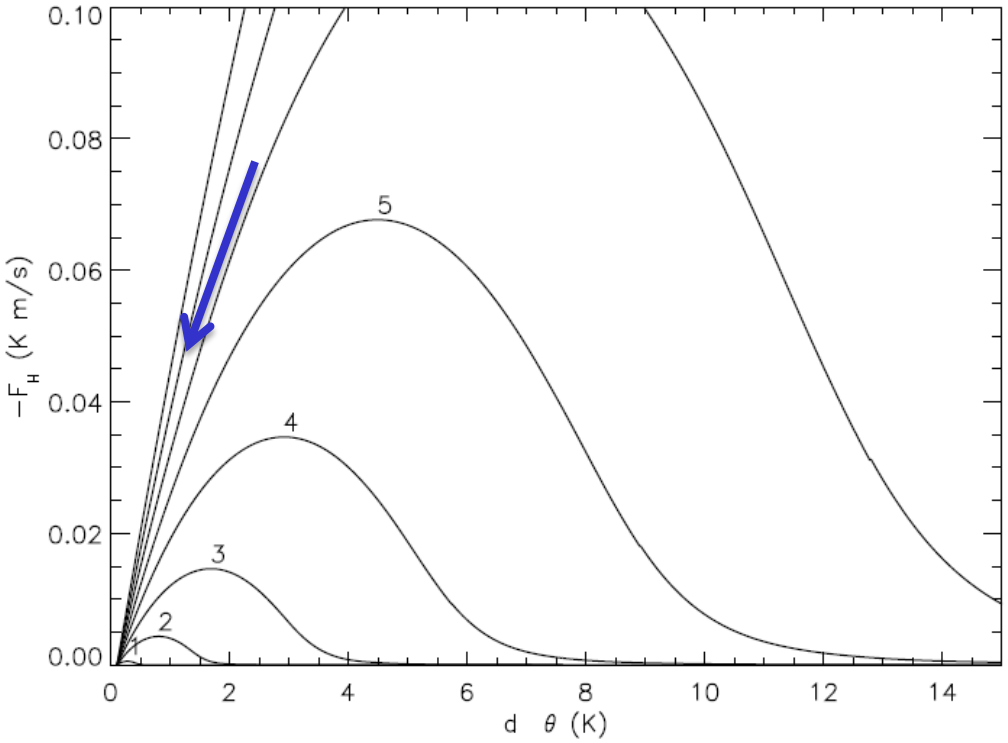
40% extra CO2

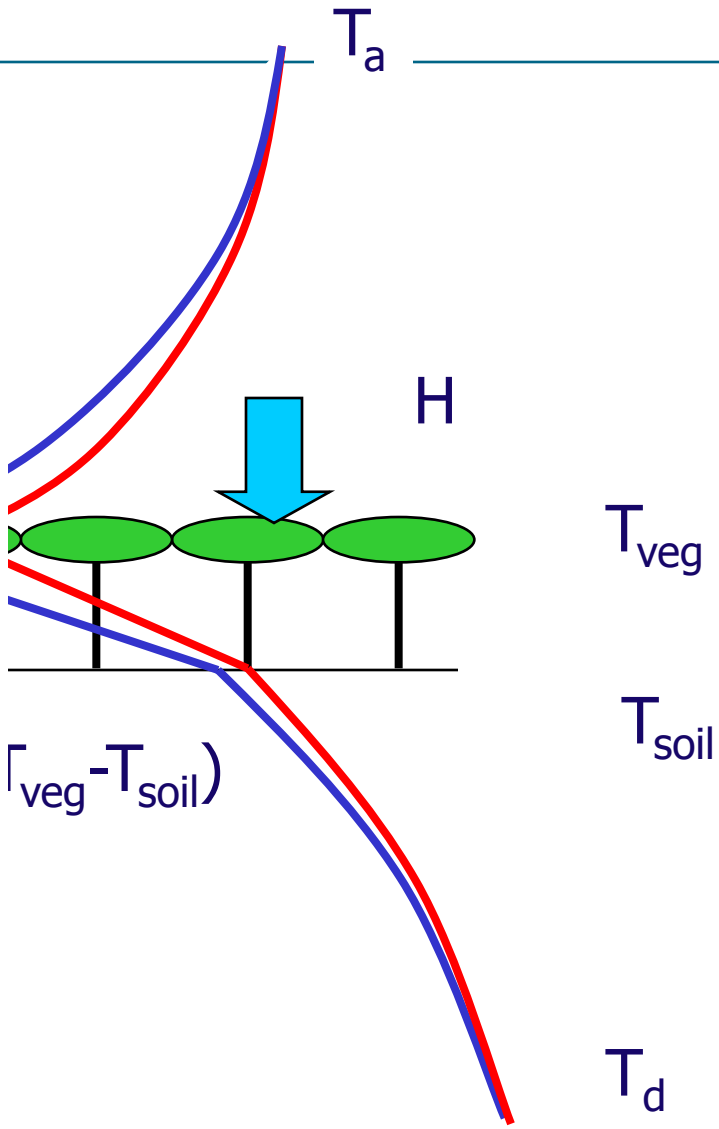


At what level do we find temperature change?

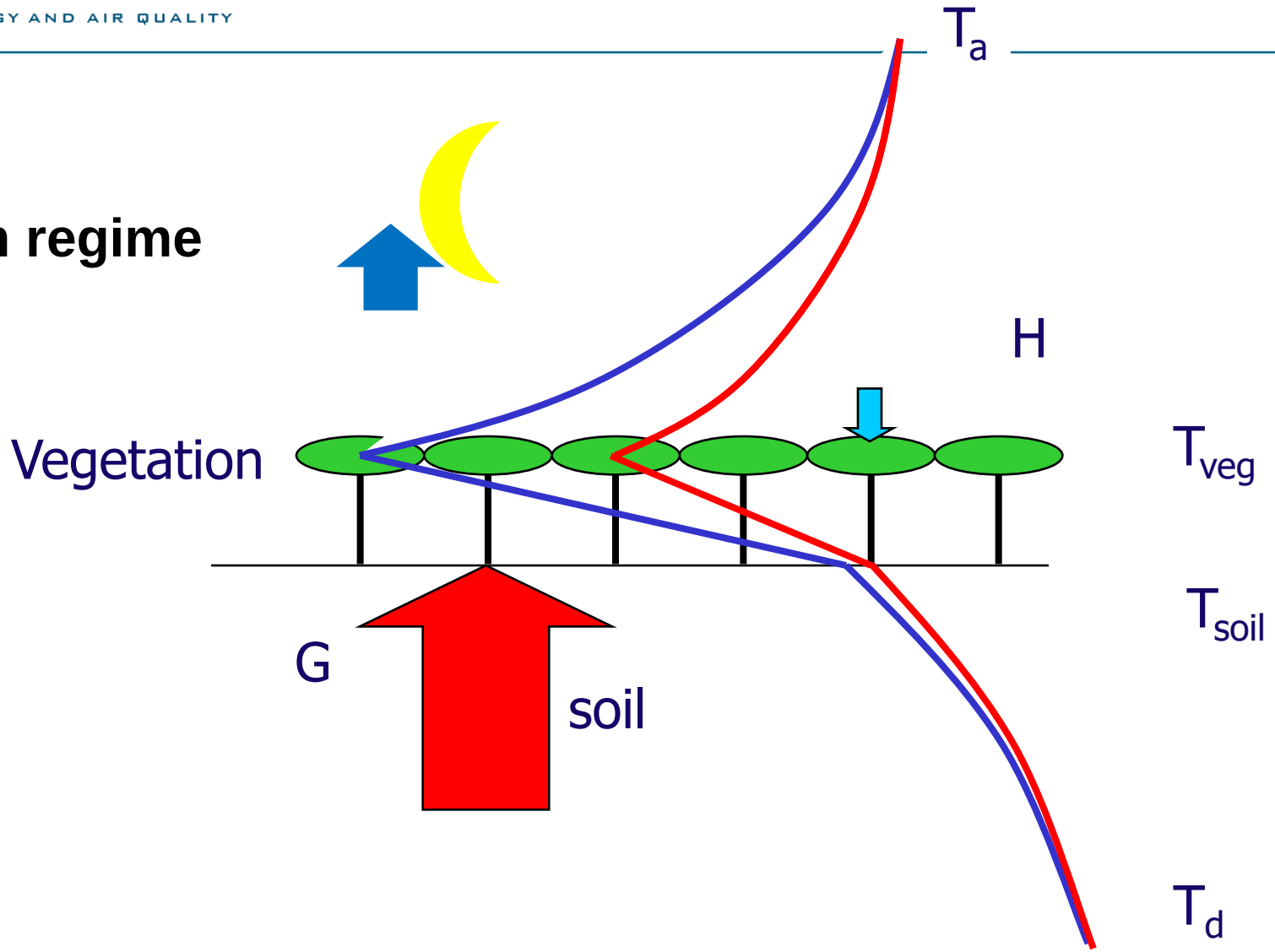
Steeneveld et al, 2011; McNider et al, in prep

Windy regime

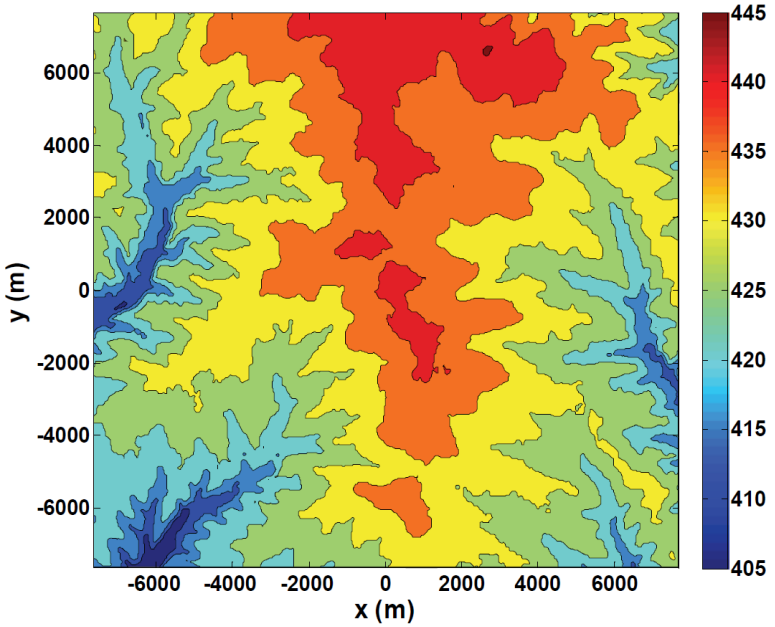


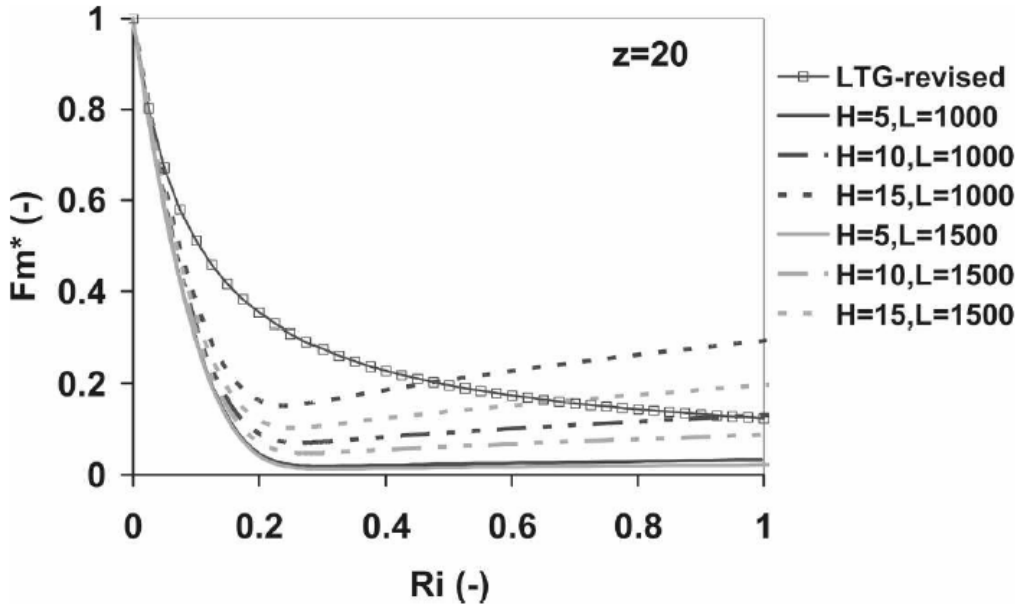


Calm regime

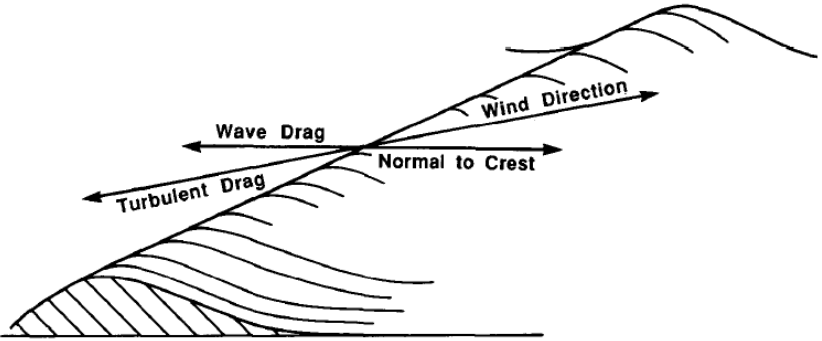


Wave drag



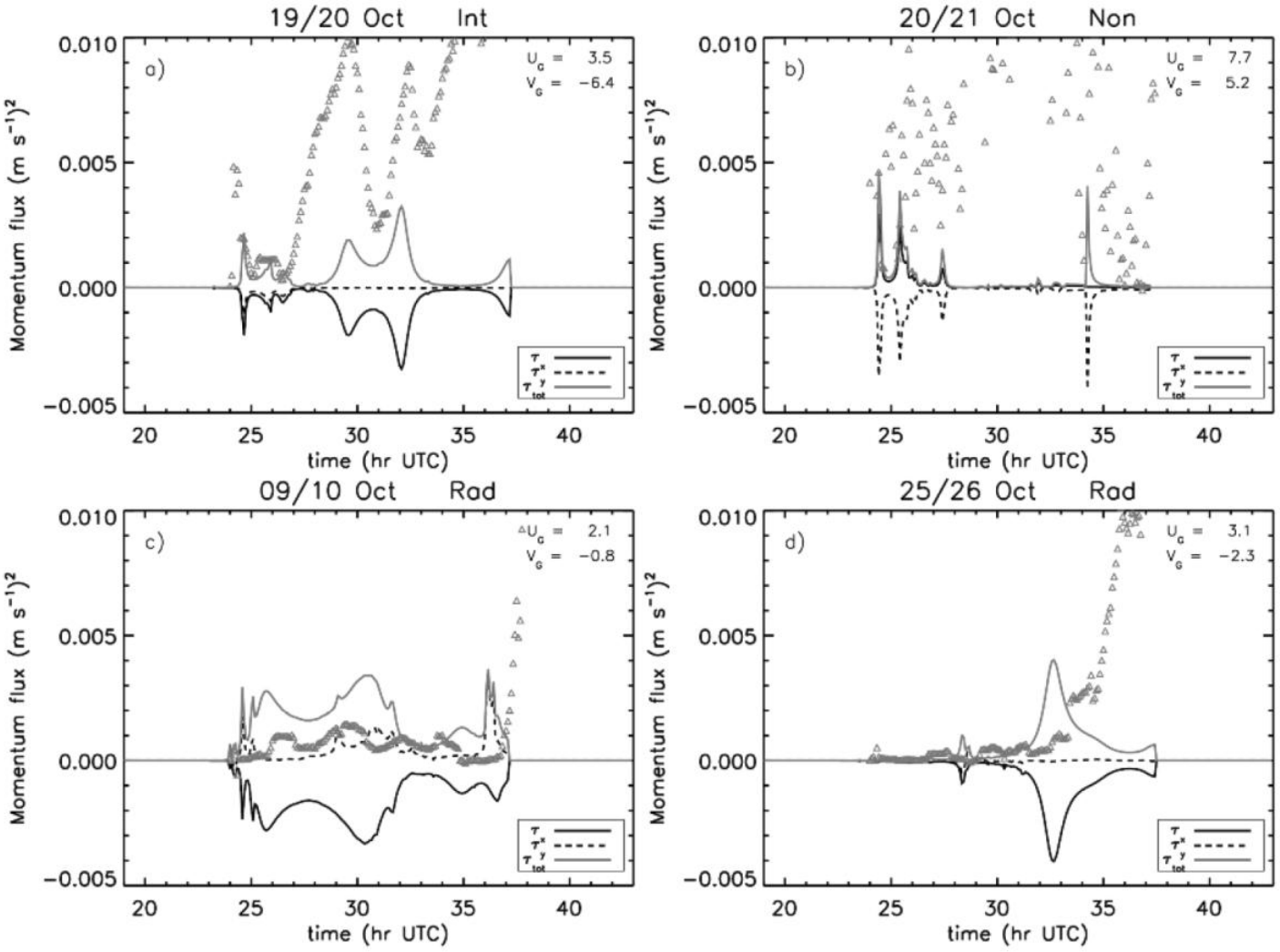


$$\tau_{\text{wave}} = \frac{1}{2}\rho_0 k_s (UH_{\text{oro}})^2 \sqrt{N^2/U^2 - k_s^2}$$



$$F_m^* = \frac{(\tau_{\text{turb}} + \tau_{\text{wave}})/\rho}{(\kappa z)^2\left(\frac{\partial U}{\partial z}\right)^2} = \frac{\tau_{\text{turb}}/\rho}{\left(\kappa z \frac{\partial U}{\partial z}\right)^2} + \frac{\tau_{\text{wave}}/\rho}{\left(\kappa z \frac{\partial U}{\partial z}\right)^2}$$

Wave drag climatology in CASES-99



Test role wave drag in 3D WRF

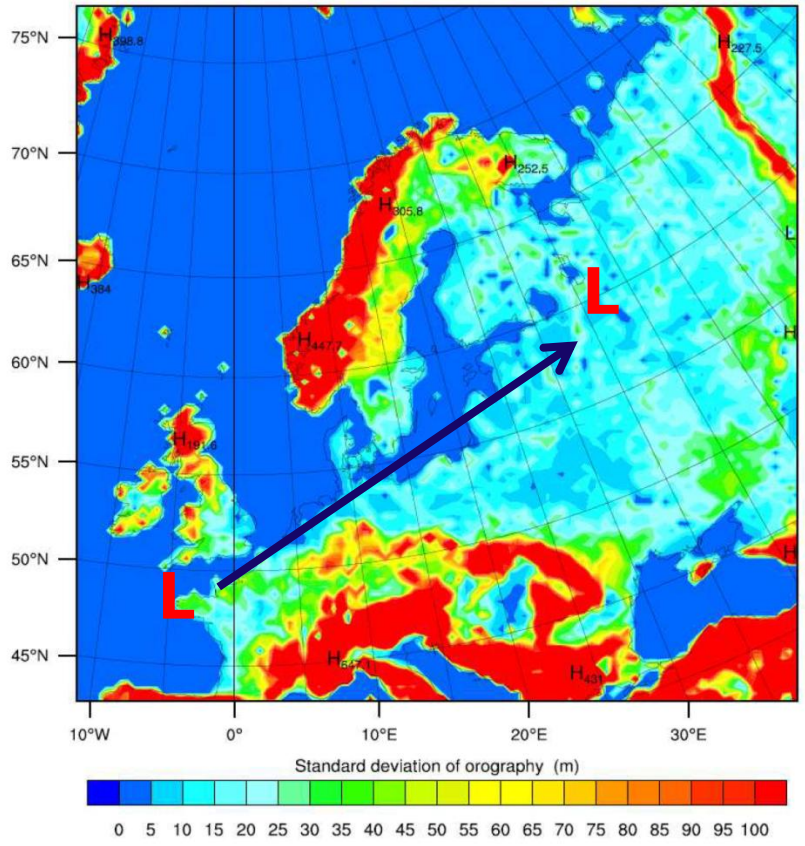


Figure 1: standard deviation of the orography [m] over Europe according to the USGS 2'x2' database.

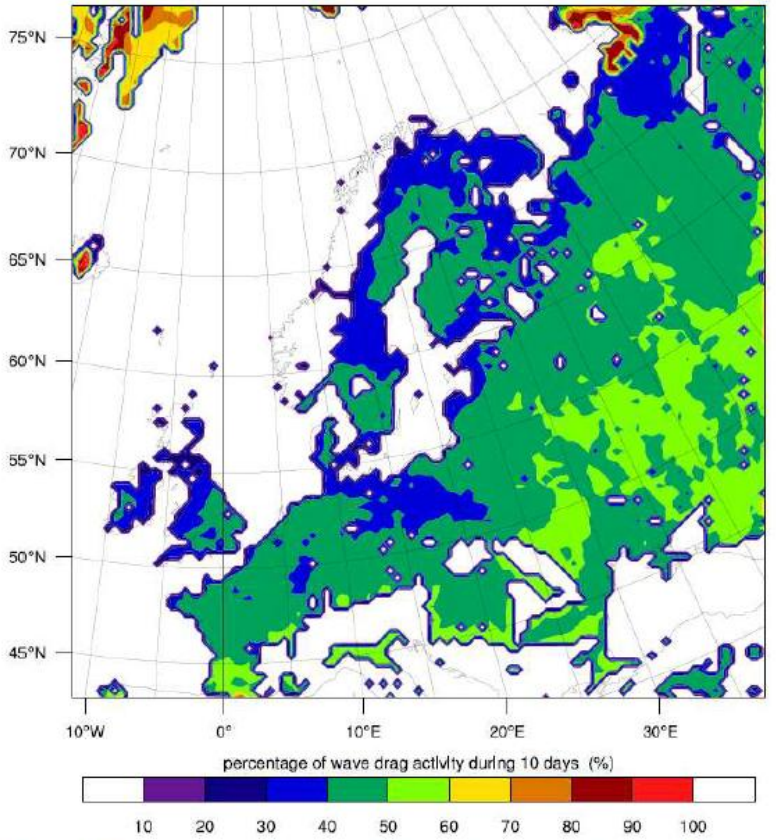


Figure 4: Percentage of orgoraphic gravity wave drag activity per location, during ten days. Areas with a standard deviation larger than 100 [m] are excluded.

Diurnal cycle of wind

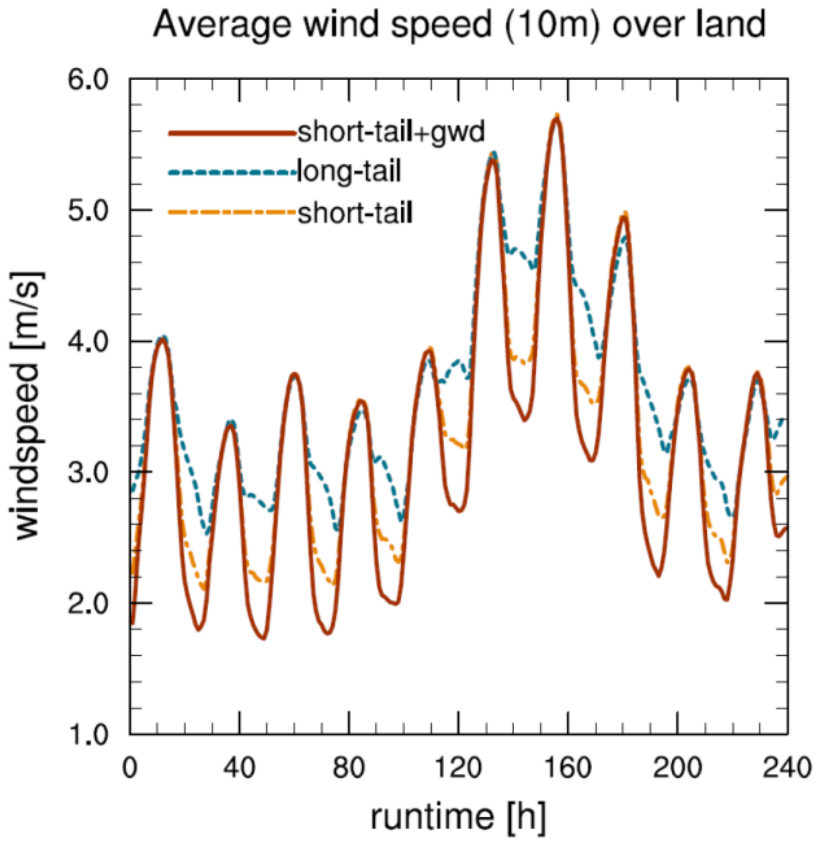


Figure 7: Average horizontal wind speed [ms^{-1}]at 10 m. over land during the different runs.

PBL depth

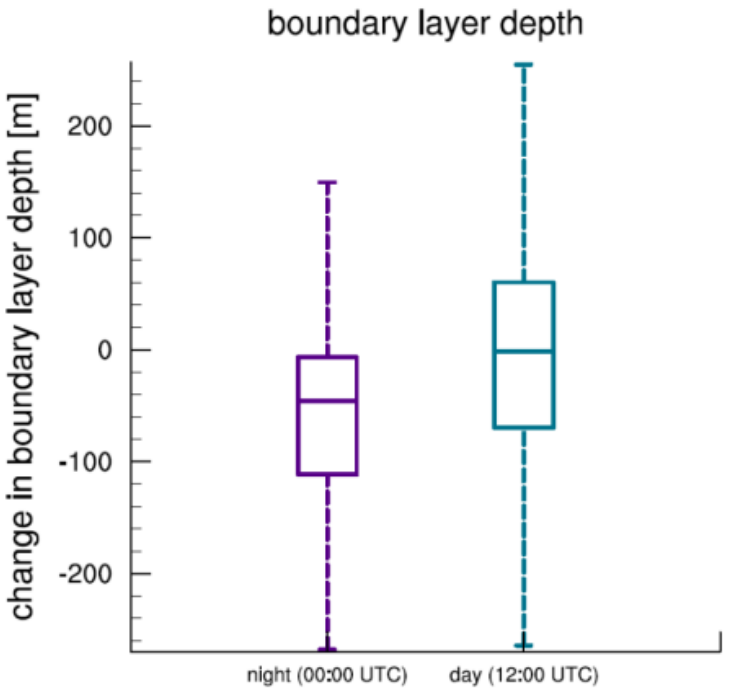
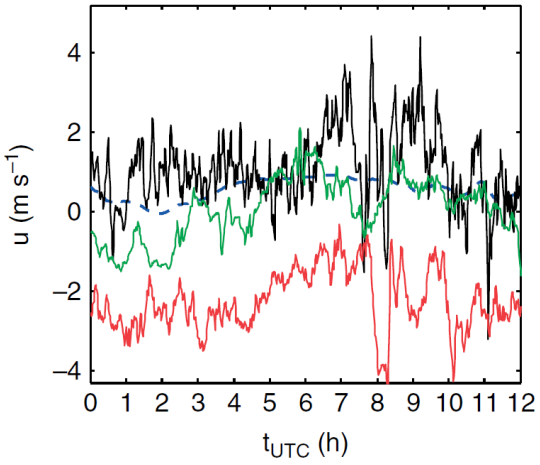
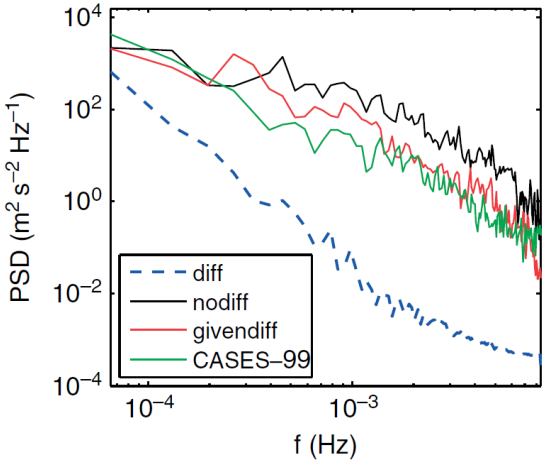


Figure 9: Change in boundary-layer depth [m] between LT run and ST+GWD run, during the night (left) and during the day (right).

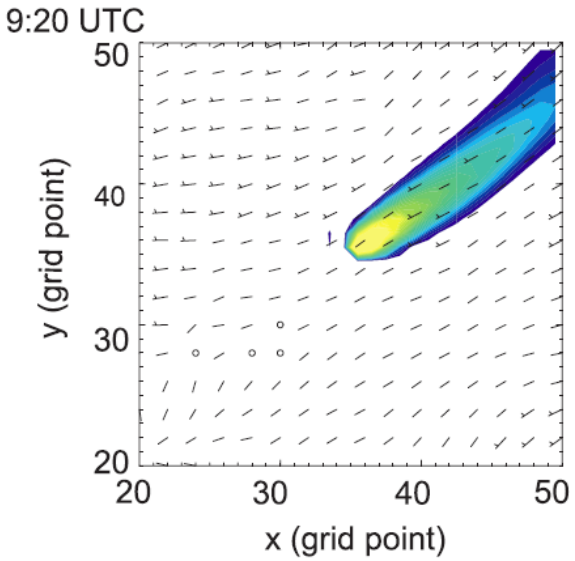
Need further confirmation!

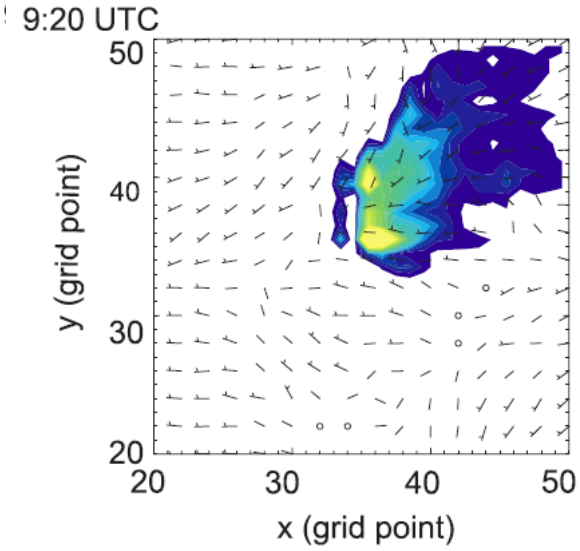
Horizontal diffusion





Parametrization of horizontal diffusion very important to allow for small scale motions and meandering





Modelled CO concentration

Belusic, D., and I. Guttler, 2010: Can mesoscale model reproduce meandering motions?, *Quart J. Roy Meteor. Soc.*, 136, 553-565.

Not covered, though relevant

Observational issues

Drainage flows

Submeso motions

Intermittent turbulence

Land surface heterogeneity

Issues…

Long tails vs short tails

Land surface coupling

Arctic climate

Mainly for low winds speeds:

- Diurnal cycle of temperature
- Radiation divergence
- Small scale wave drag
- Horizontal diffusion

Further reading

Steeneveld, G.J., A.A.M. Holtslag, C.J. Nappo and L. Mahrt, 2008: Exploring the role of small-scale gravity wave drag on stable boundary layers over land, *J. Appl. Meteor. Clim.*, 47, 2518–2530.

Steeneveld, G.J., M.J.J. Wokke, C.D. Groot Zwaaftink, S. Pijlman, B.G. Heusinkveld, A.F.G. Jacobs, A.A.M. Holtslag, 2010: Observations of the radiation divergence in the surface layer and its implication for its parametrization in numerical weather prediction models. J. Geophys Res., 115, D06107, doi:10.1029/2009JD013074.

Steeneveld, G.J., C.J. Nappo, and A.A.M. Holtslag, 2009: Estimation of Orographically Induced Wave Drag in the Stable Boundary Layer during CASES99,Acta Geophys.,57,857-881.

Kyselý, J., and E. Plavcová, 2011: Biases in the diurnal temperature range in Central Europe in an ensemble of regional climate models and their possible causes. Clim. Dyn., in press.

Medeiros, Brian, Clara Deser, Robert A. Tomas, Jennifer E. Kay, 2011: Arctic Inversion Strength in Climate Models. J. Climate, 24, 4733–4740. doi: 10.1175/2011JCLI3968.1

Edwards, J.M., J.R. McGregor, M.R. Bush, F.J.A. Bornemann, 2011: Assessment of numerical weather forecasts against observations from Cardington: Seasonal diurnal cycles of screen-level and surface temperatures and surface fluxes, Quart. J. Roy. Meteorol. Soc., 137, 656-672, doi:10.1002/qj.742.

Cuxart, J. and M.A. Jiménez, 2011: Deep Radiation Fog in a Wide Closed valley: Study by Numerical Modeling and Remote Sensing, Pure Appl. Geophys., in press, doi: 10.1007/s00024-011-0365-4.

Stoll, Rob, Fernando Porté-Agel, 2009: Surface Heterogeneity Effects on Regional-Scale Fluxes in Stable Boundary Layers: Surface Temperature Transitions. J. Atmos. Sci., 66, 412–431.

Velde, I.R. van der, G. J. Steeneveld, B.G.J. Wichers Schreur, and A.A.M. Holtslag, 2010: Modeling and Forecasting the Onset and Duration of Severe Radiation Fog under Frost Conditions, Mon. Wea. Rev., doi: 10.1175/2010MWR3427.1.

Prabha, T.V., Hoogenboom, G., Smirnova, T.G., 2011: Role of land surface parameterizations on modeling cold-pooling events and low-level jets, Atmos. Res., 99, 147-161.

What are the issues

Turbulence
Radiation
Land-surface interaction
Waves
Complex terrain
DTR
Meandering motions
Horizontal diffusion (Belusic & Guttler paper)
Intermittency?
Predictability issues?