Experience with the representation of stable conditions in the ECMWF model

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1. Stable conditions: current issues

2. Land-atmosphere coupling

3. Turbulent diffusion

4. Conclusions

Stable conditions: current issues

Unrealistically strong turbulent diffusion is generally used in NWP for stable conditions in order to compensate for other errors

- benefits:
  - ✓ avoid night time runaway cooling
  - ✓ avoid a too slow decay of cyclones

- detriments:
  - ✓ too deep boundary layer
  - ✓ smearing out of low level jets
  - ✓ underestimation of the wind turning in the boundary layer
  - ✓ too weak inversions/too much diffusion of warm and dry air from above into the boundary layer, resulting in underestimation of stratocumulus decks
  - ✓ despite too strong diffusion, often cold and dry biases close to the surface

1. Stable conditions: current issues

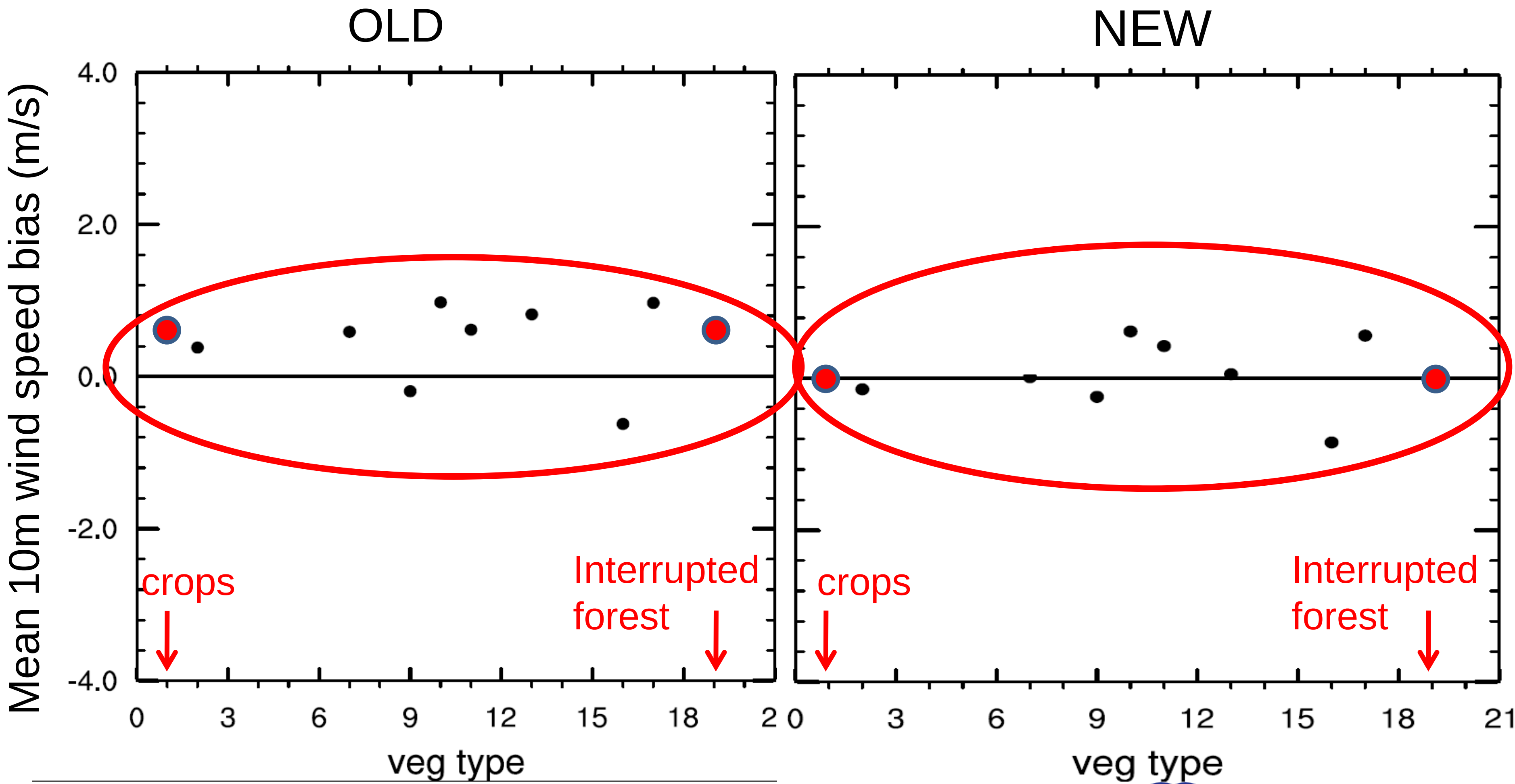
2. Land-atmosphere coupling, or turbulent diffusion is not the only bad guy: two examples of atmosphere-land coupling parameters playing an important role in PBL representation

3. Turbulent diffusion

4. Conclusions

Revision of the roughness length table for momentum

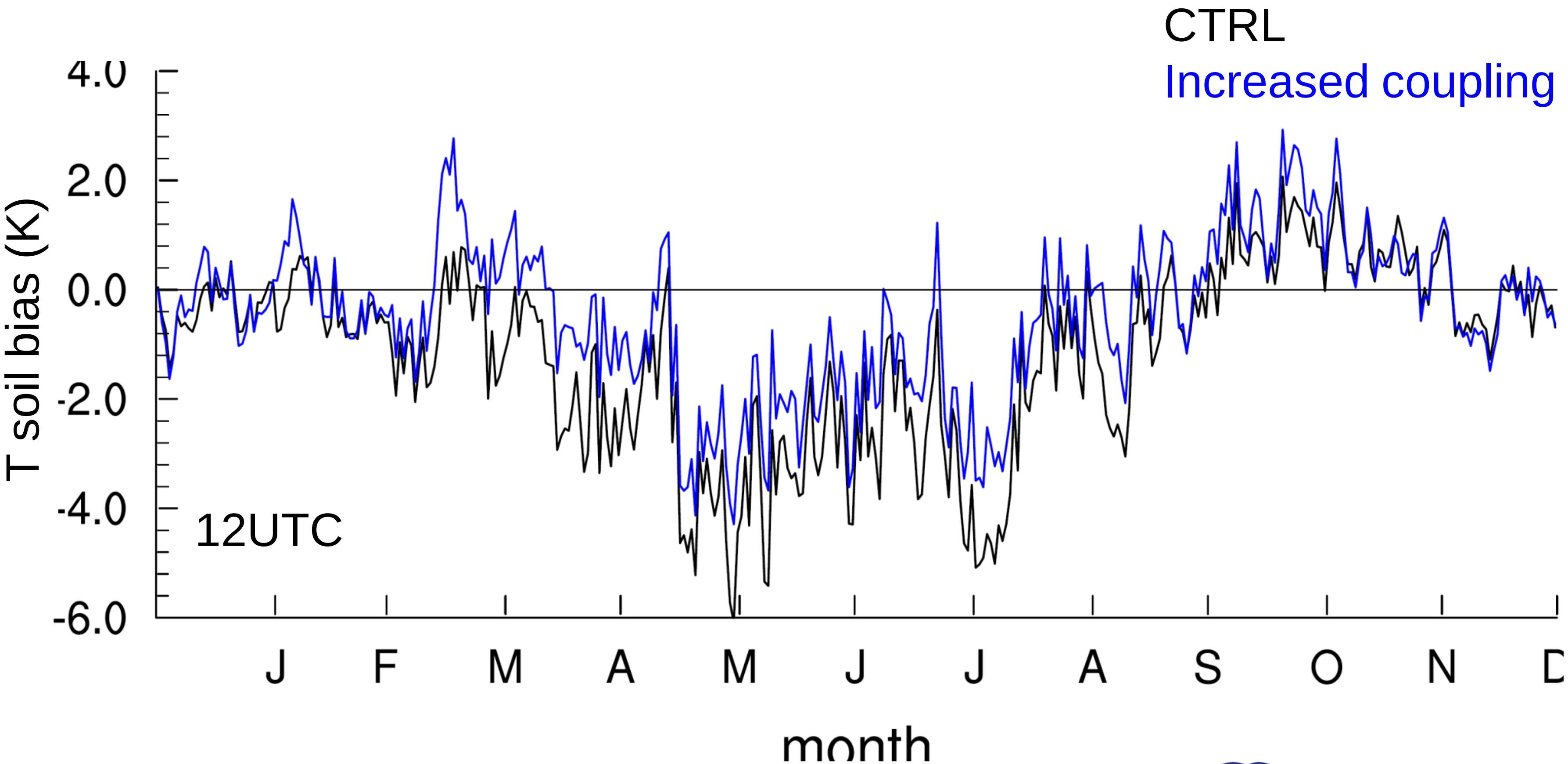
The 10m winds are mainly controlled by the momentum roughness length values and are generally overestimated by the model. Based on 10m wind observations, the roughness length for momentum was increased for 10 vegetation types.



Model sensitivity to the skin layer conductivity (λ_{sk})

Stronger coupling:

- smaller Tsoil errors during daytime, smaller T2m errors during nightime
- better diurnal cycle of Tsoil, T2m



1. Stable conditions: current issues

2. Land-atmosphere coupling

3. Turbulent diffusion

- Current representation in the IFS
- Experiments
- Impacts of reducing the diffusion on PBL
- Impacts of reducing the diffusion on large-scale circulation

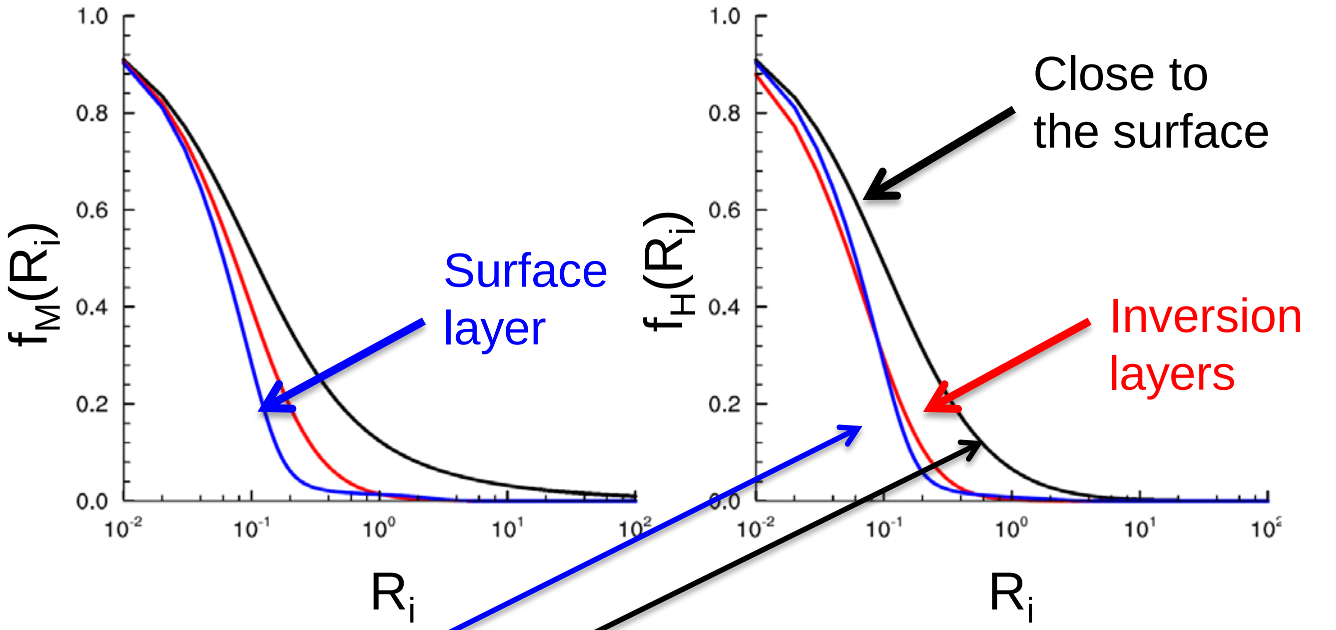
4. Conclusions

Stable conditions : current formulation in IFS

$$K_{M,H} = \left|\frac{\partial U}{\partial Z}\right| l^2 f_{M,H}(R_i)$$

$$\frac{1}{l} = \frac{1}{kz} + \frac{1}{\chi}$$

$$\chi = 150\ m$$



Stable conditions: current formulation in UKMO

Short tails over ocean

Long tails over land

λ=40m away from the surface

No vertical diffusion above 3 km

Stable conditions : current formulation in IFS

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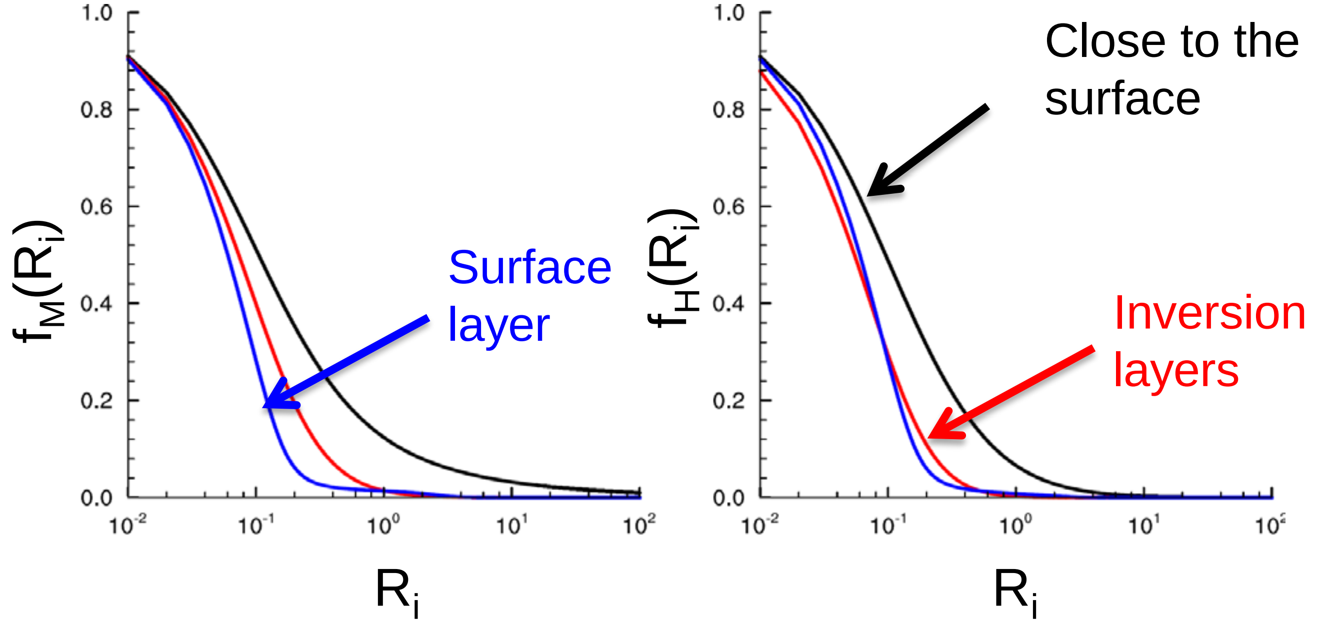


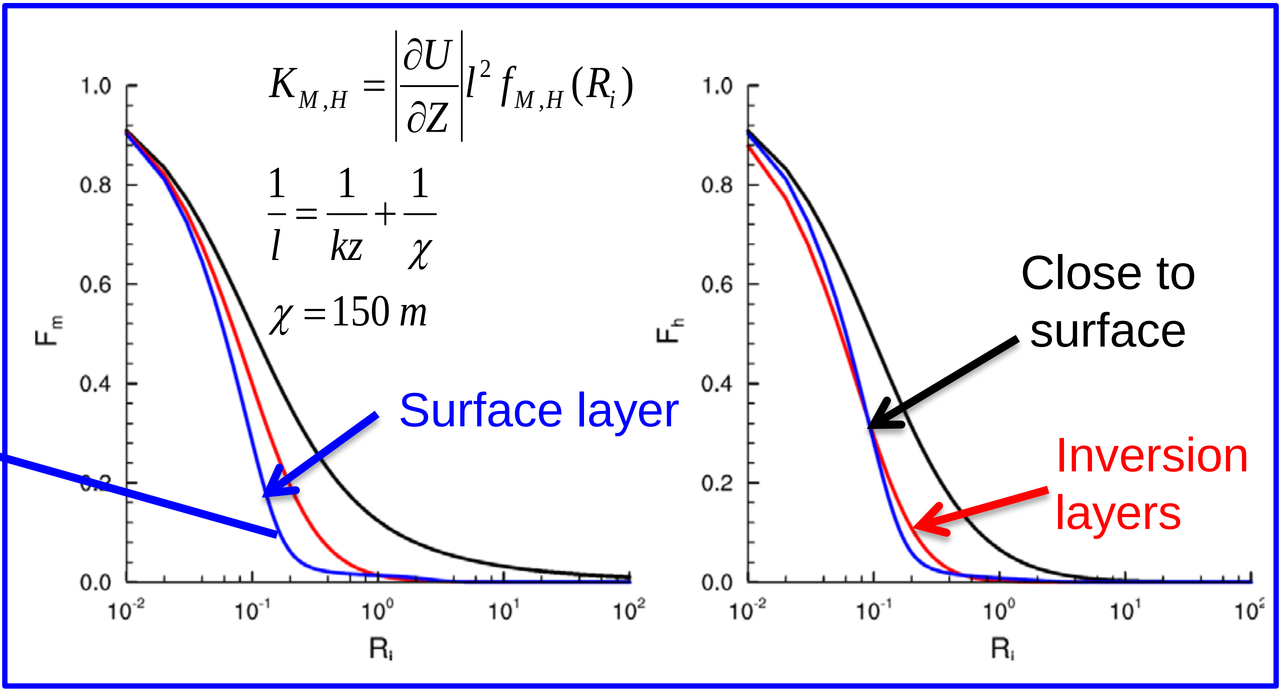
Stable conditions : our wish list

An unique (less diffusive) pair of stability functions above the surface layer combined with adjusted parameters of the land – atmosphere coupling that would allow to:

- increase the wind turning, better represent the low level jet
- reduce the cold and dry bias close to the surface
- correct the 10m winds
- improve the diurnal cycle of T2m

Sensitivity experiments to the representation of the turbulent diffusion in stable conditions

Current representation of stable conditions

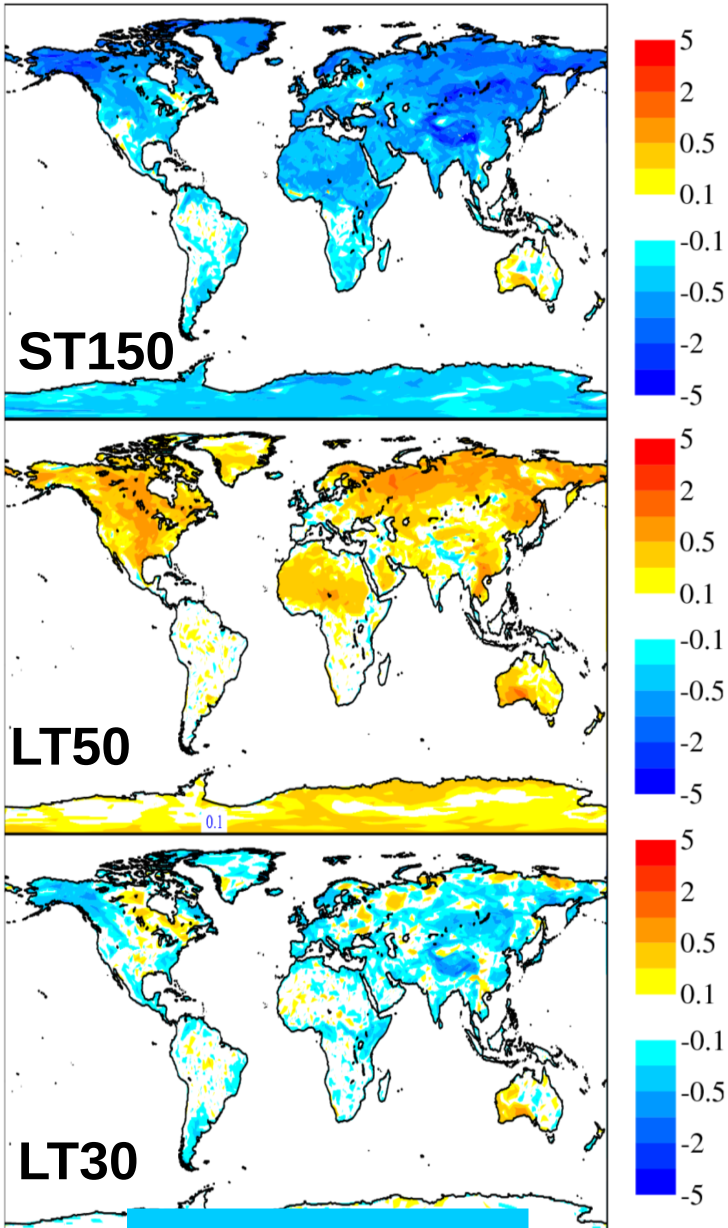


A set of T511L91 FC experiments
with modified f(Ri), **λ** :

- **short tails + λ=150m : (ST150)**
- **long tails + λ=50, 30 m (LT50, LT30)**

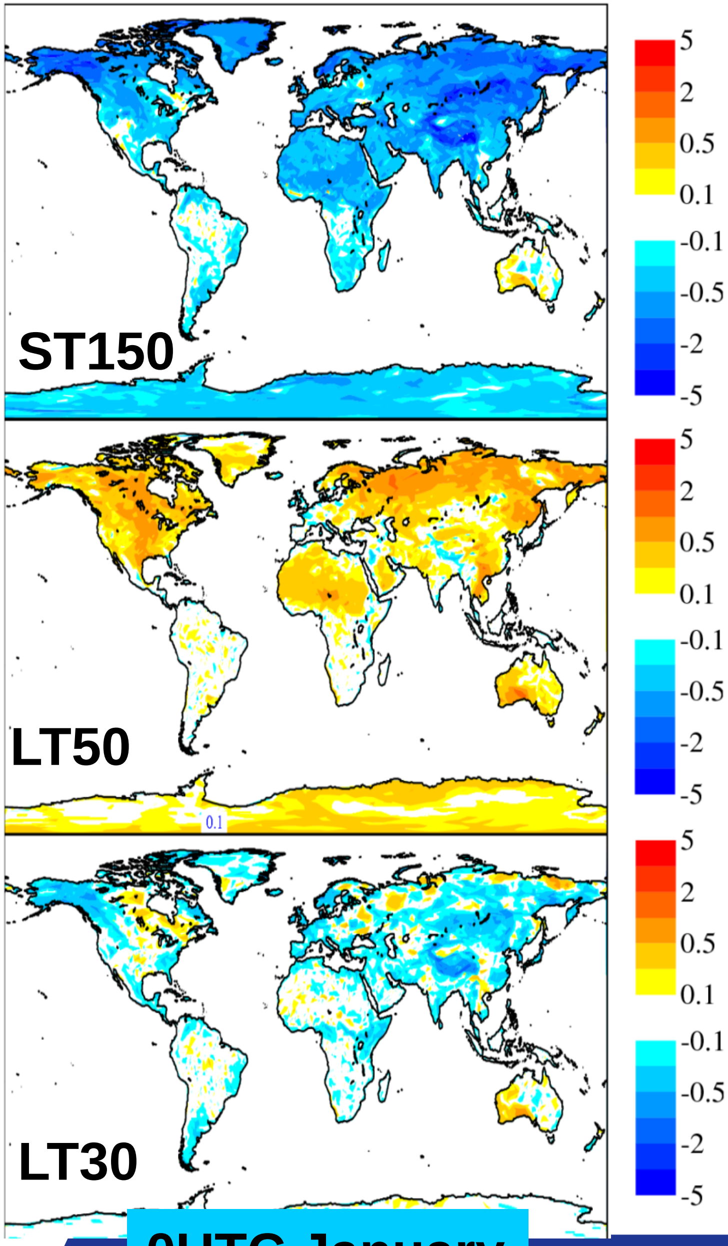
Pretty complete picture of how the modification of the turbulent exchange coefficients acts on the different aspects of the system (BL structure – profiles of T, U, Q, W; BL height, stratocumulus cover, Z bias, RMSE)

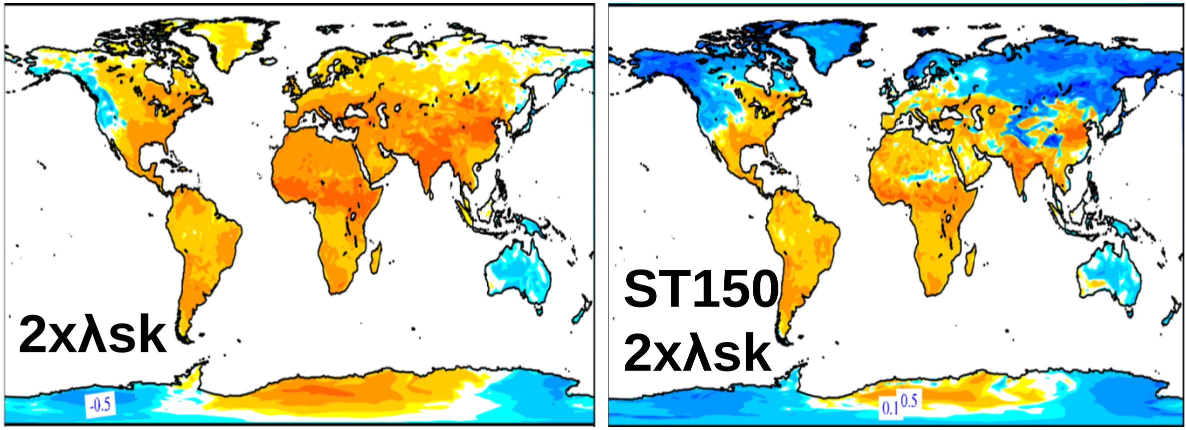
T2m change



0UTC January

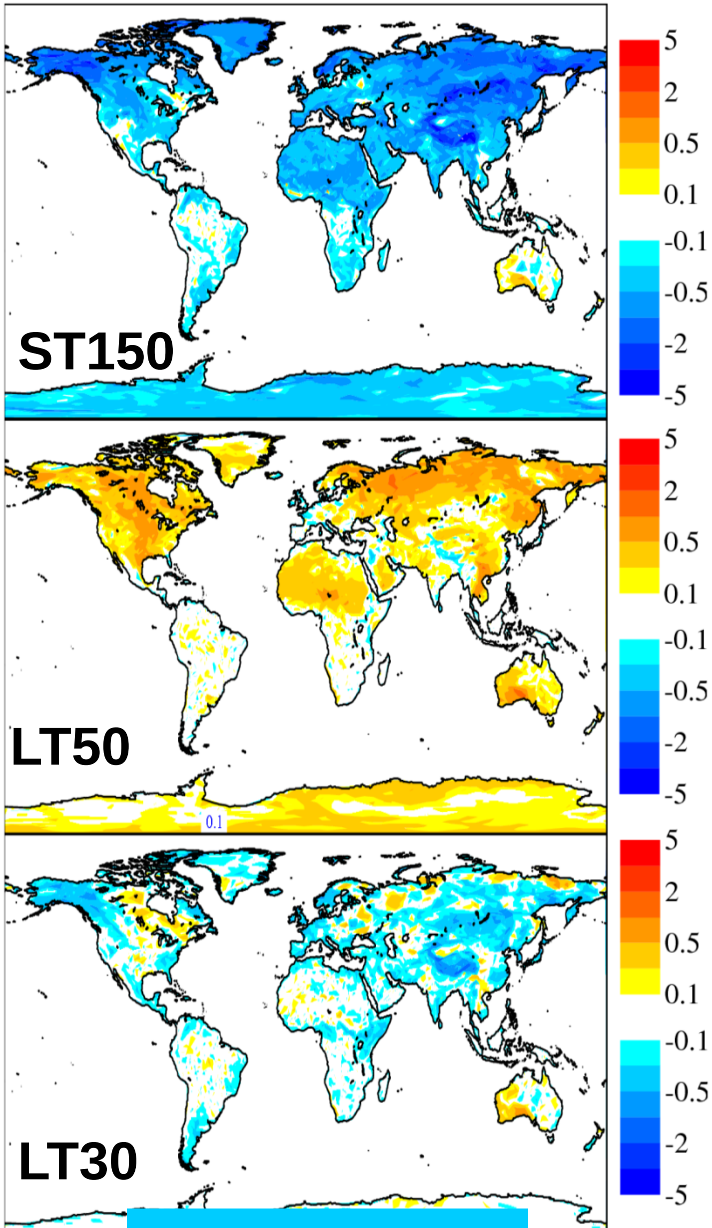
T2m change



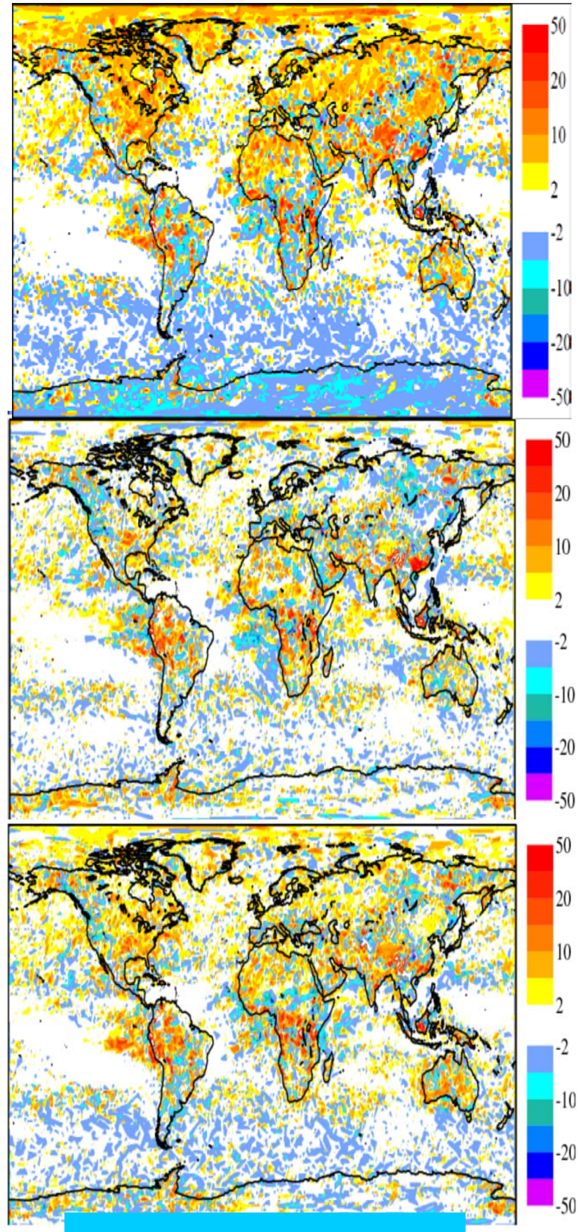


how can one calibrate these coupling coefficients in a sensible way?

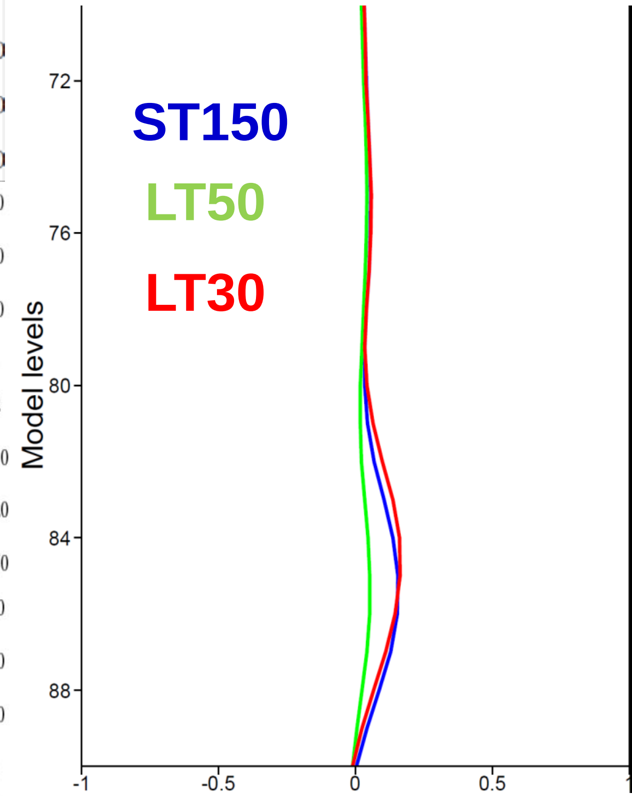
T2m change



Wind turning change



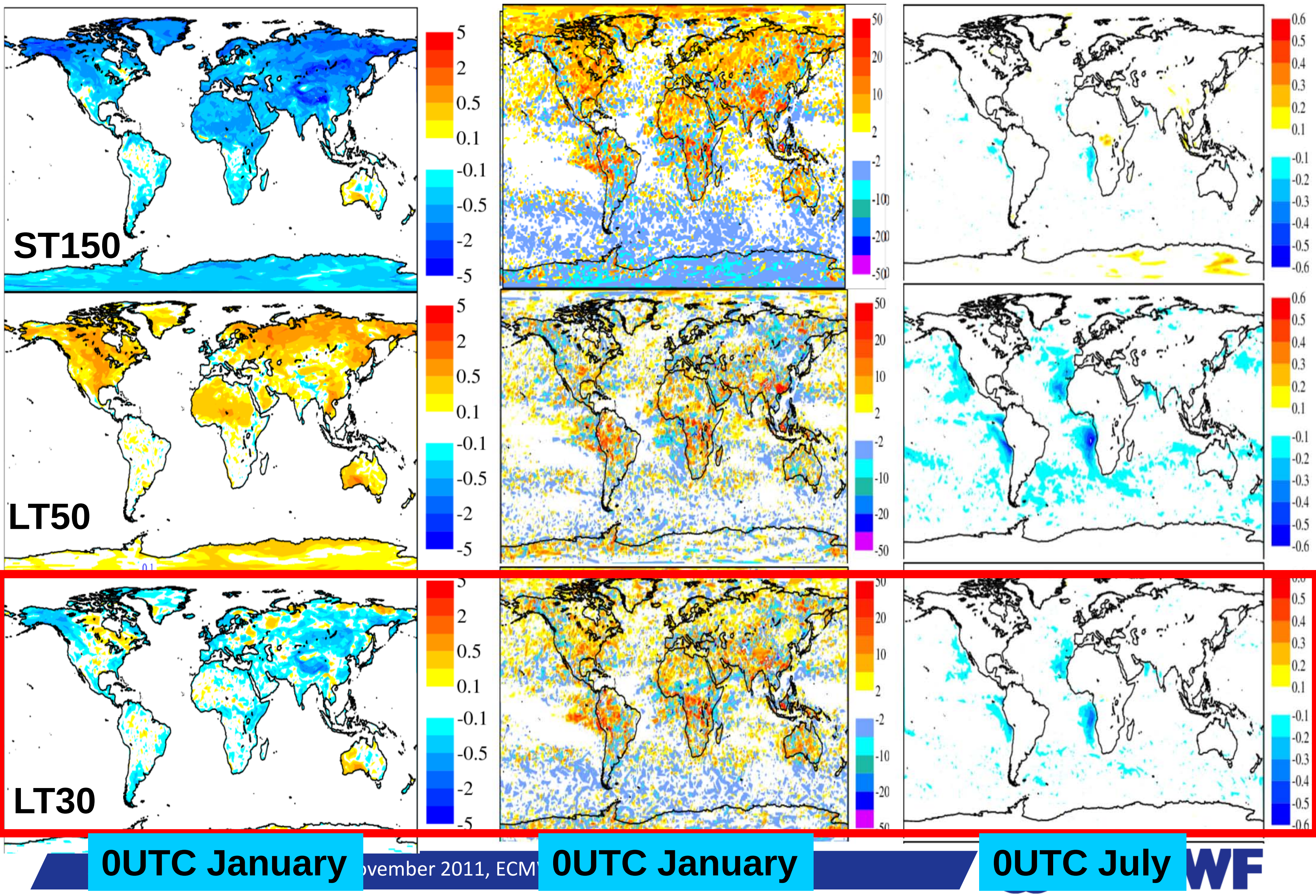
Change in wind speed, Europe, 0UTC, January



0UTC January

0UTC January

T2m change Wind turning change LCC change



Impact of turbulent diffusion on the large-scale circulation

Score wise, reducing the diffusion has:

- ✓ always positive impact in summer hemisphere
- ✓ but negative in winter hemisphere

Why?

Impact of turbulent diffusion on the large-scale circulation

Score wise, reducing the diffusion has:

- ✓ always a positive impact in the summer hemisphere
- ✓ but a negative impact in the winter hemisphere

Why?

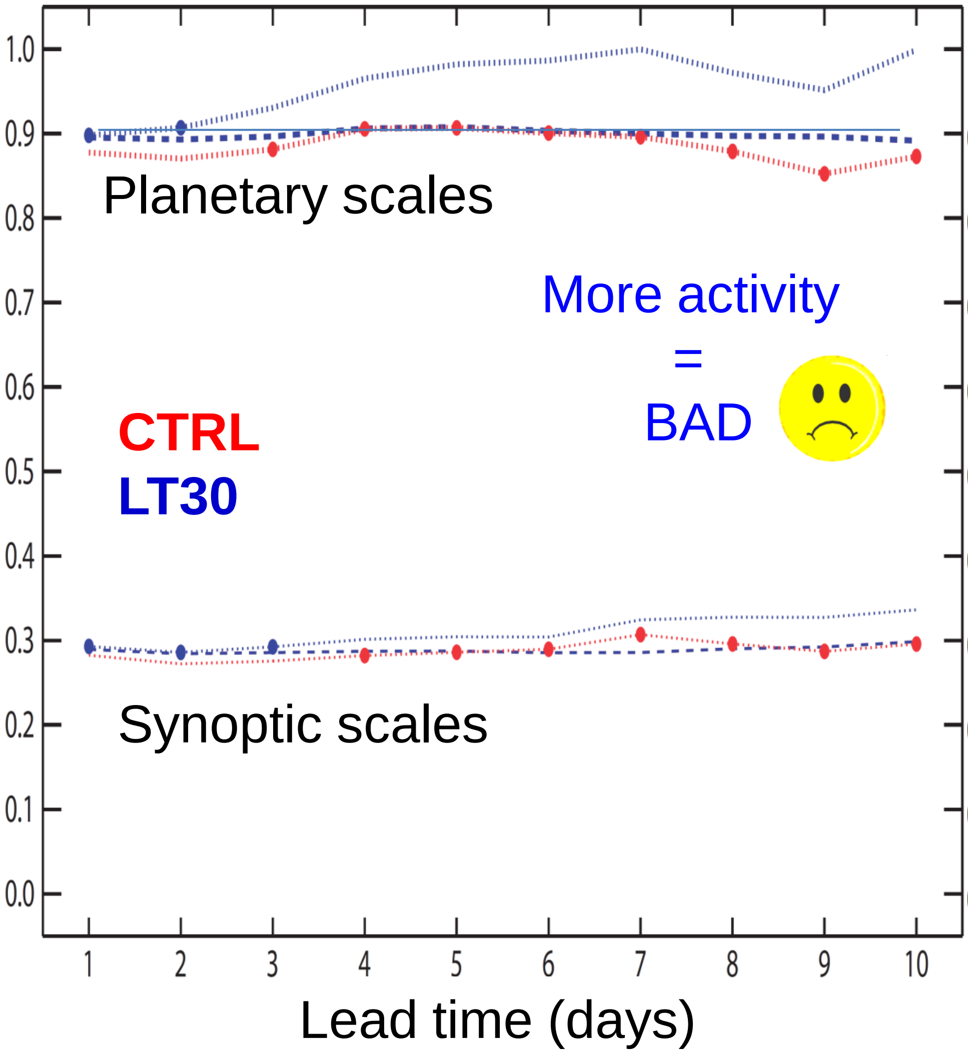
Reduced diffusion → weaker Ekman pumping → slower filling of cyclones (stronger cyclones)

↘ also slower weakening of the anticyclones (stronger anticyclones)

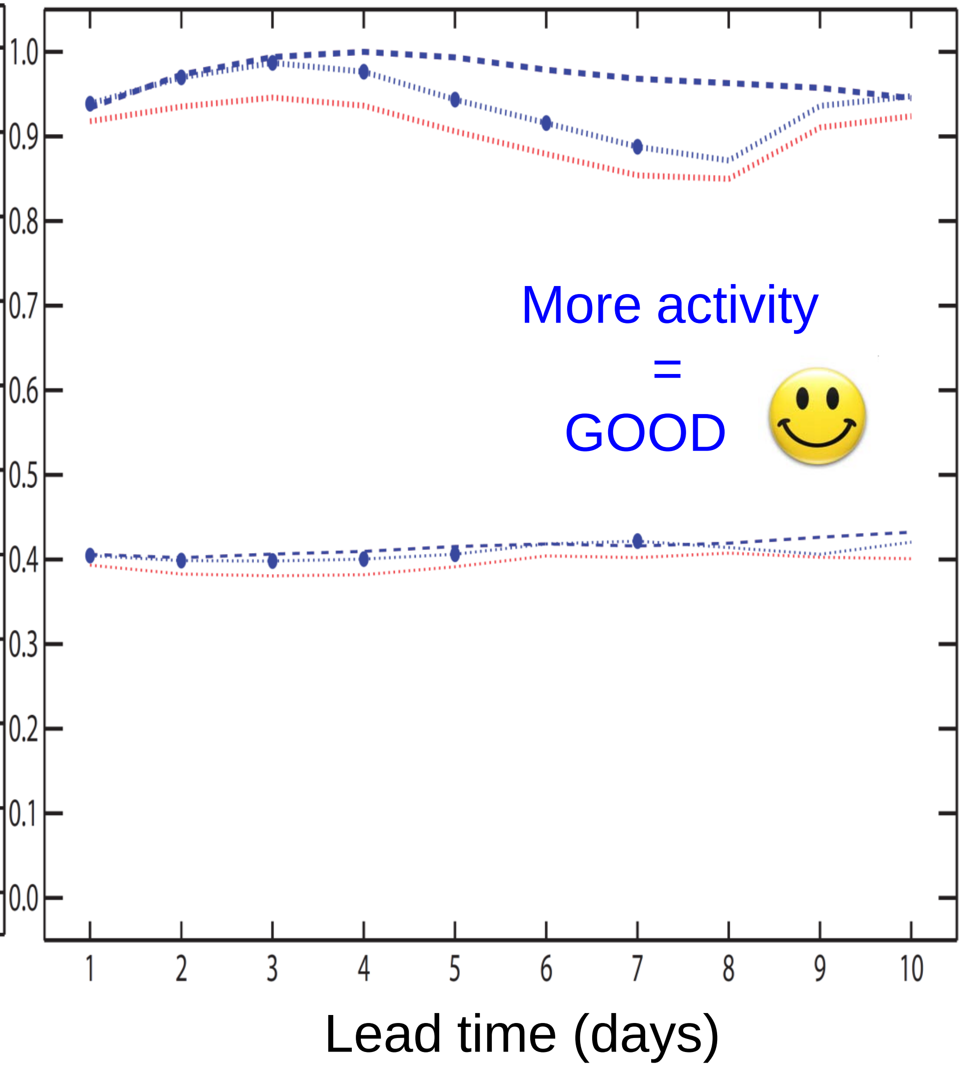
Changes to the turbulent diffusion entrain changes to the amplitude of low/high pressure systems, hence to the model's activity

Model’s activity for 1 - 31 January 2011

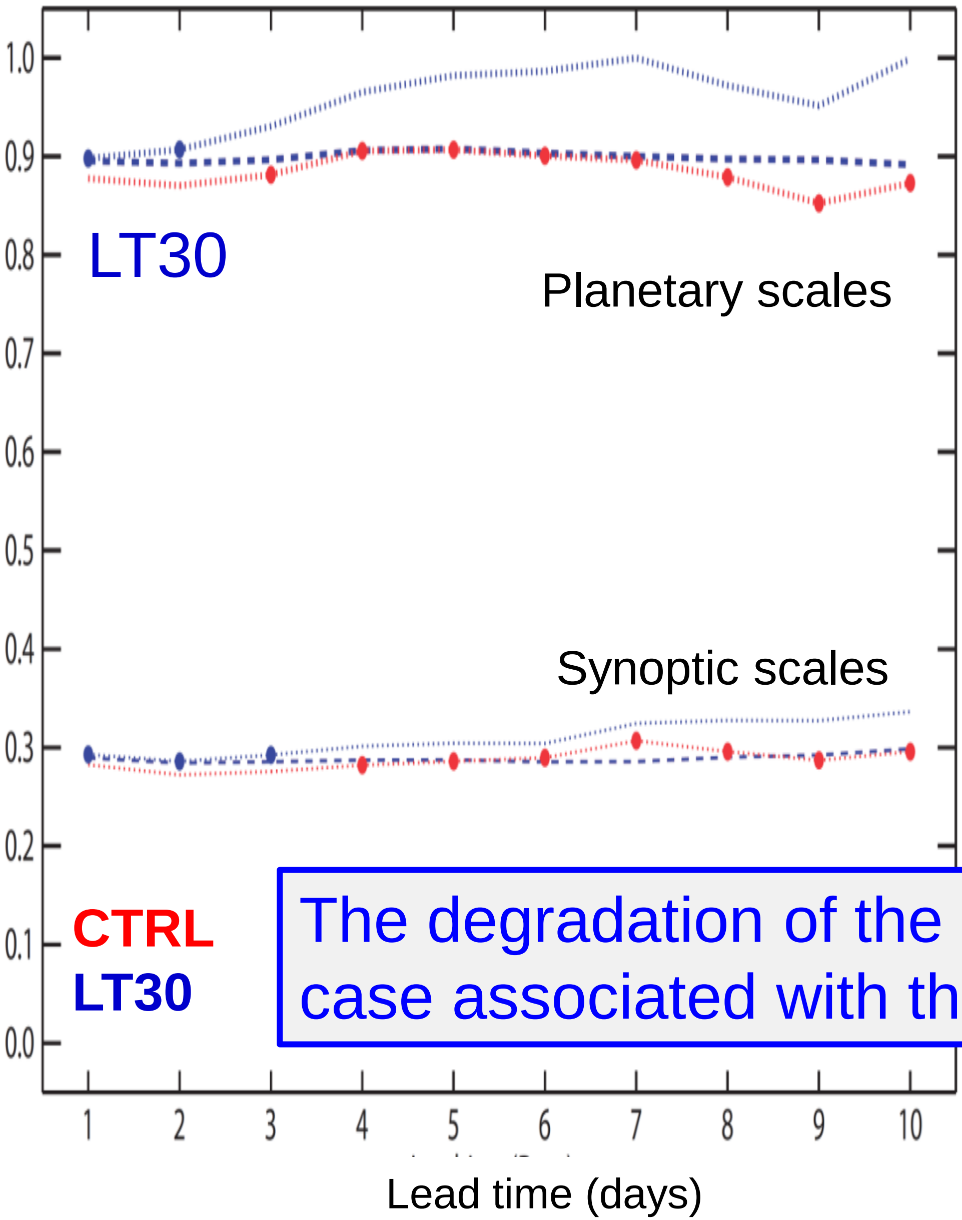
Z1000 hPa – North Hemisphere

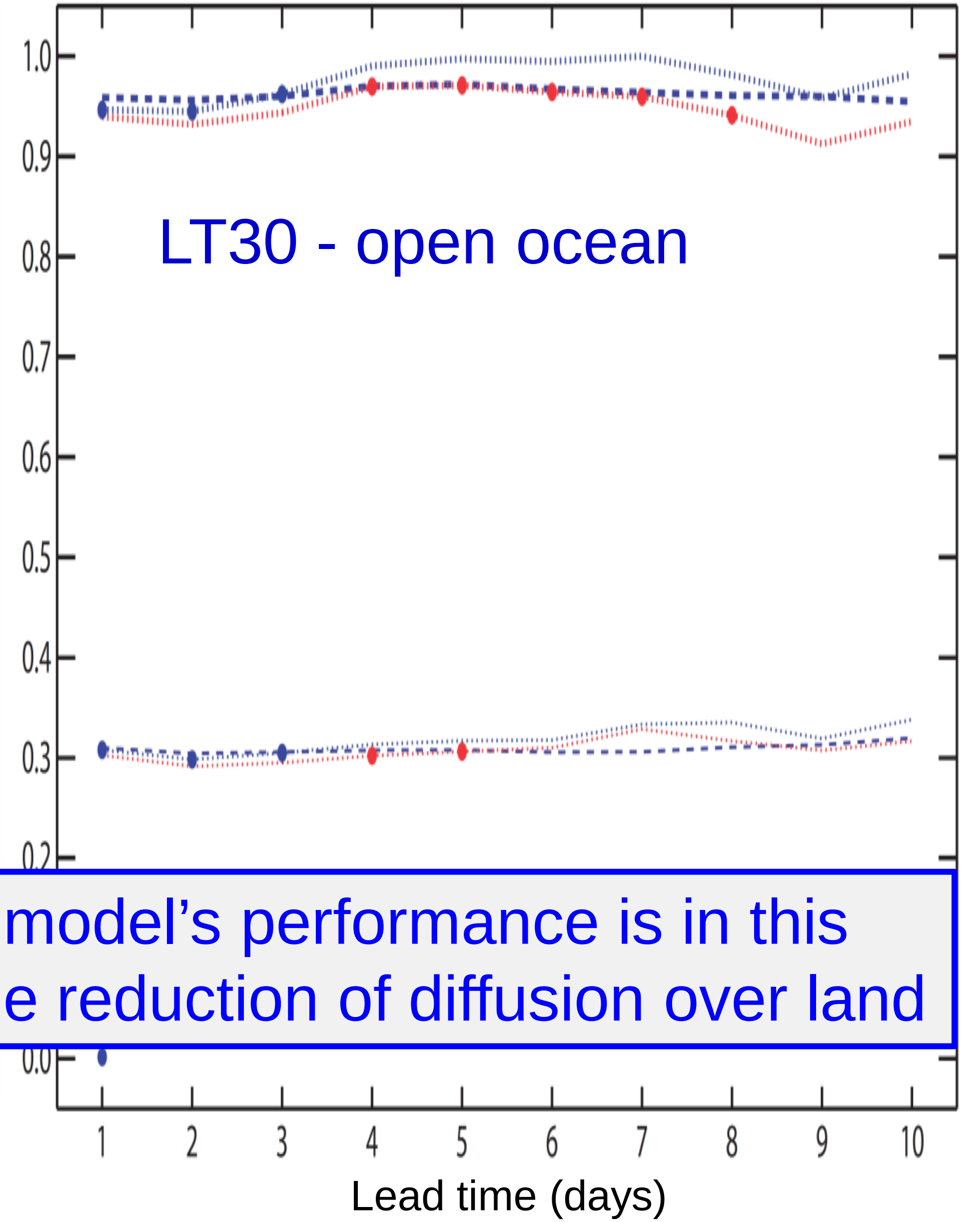


Z1000 hPa – South Hemisphere



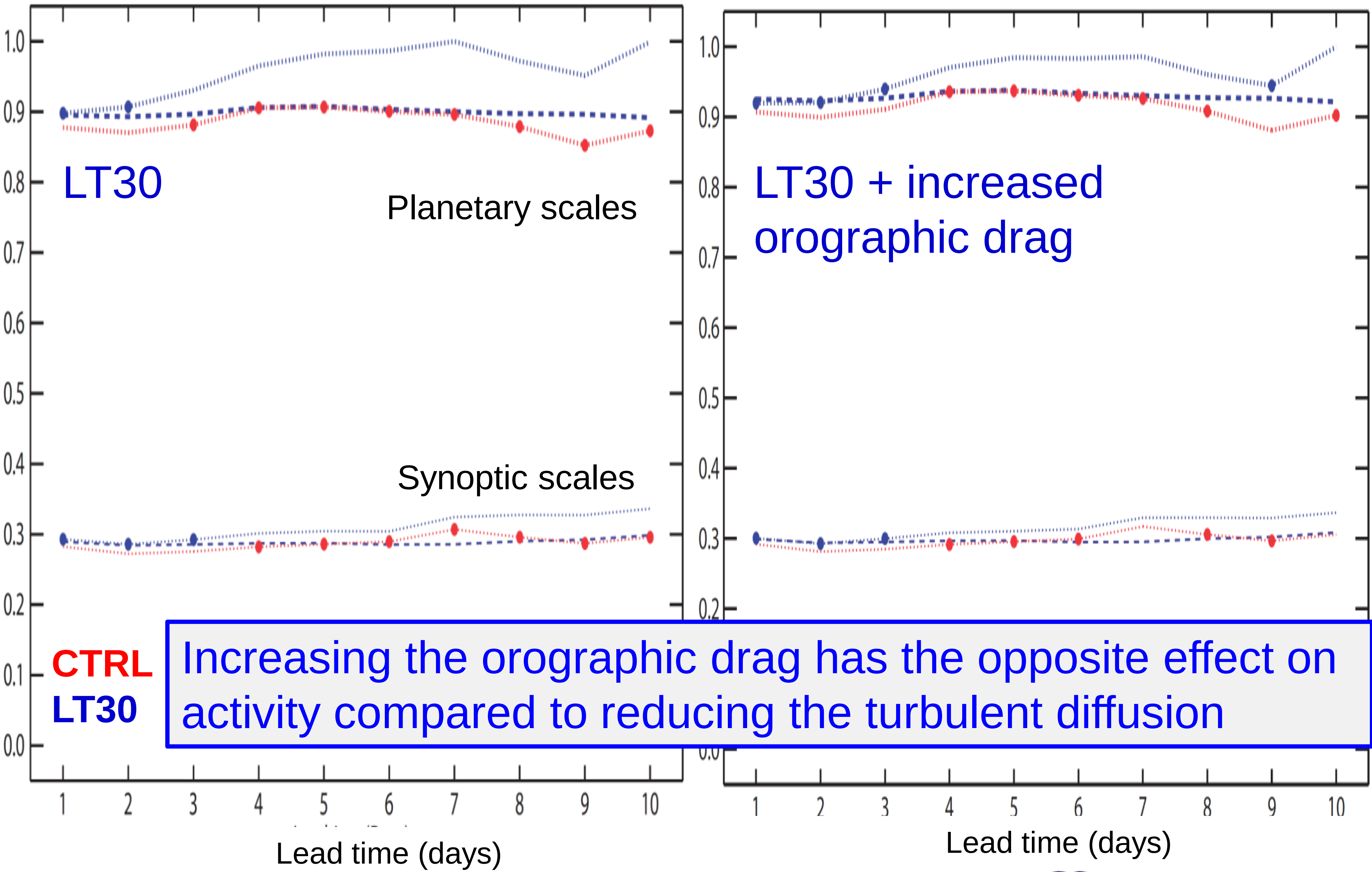
N. Hemisphere, Z1000hPa, January – decomposition of errors





The degradation of the model's performance is in this case associated with the reduction of diffusion over land

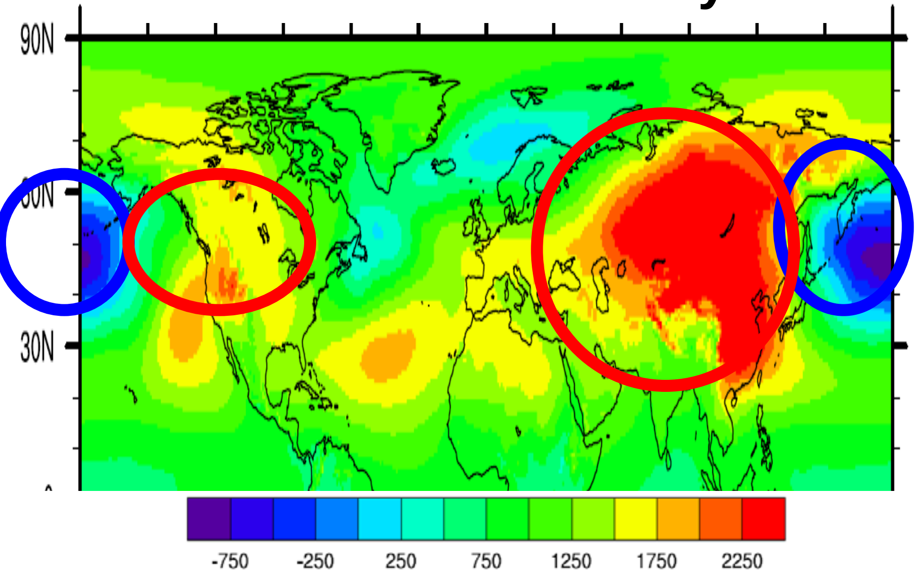
N. Hemisphere, Z1000hPa, winter – decomposition of errors

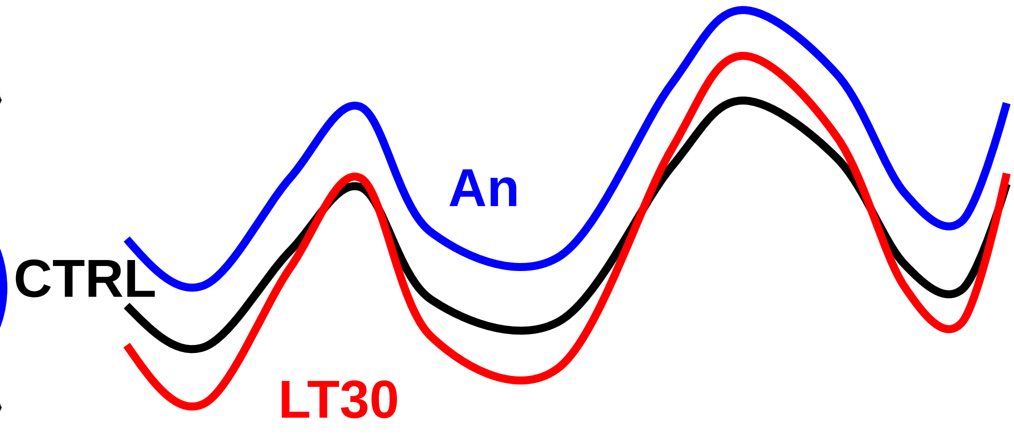


Increasing the orographic drag has the opposite effect on activity compared to reducing the turbulent diffusion

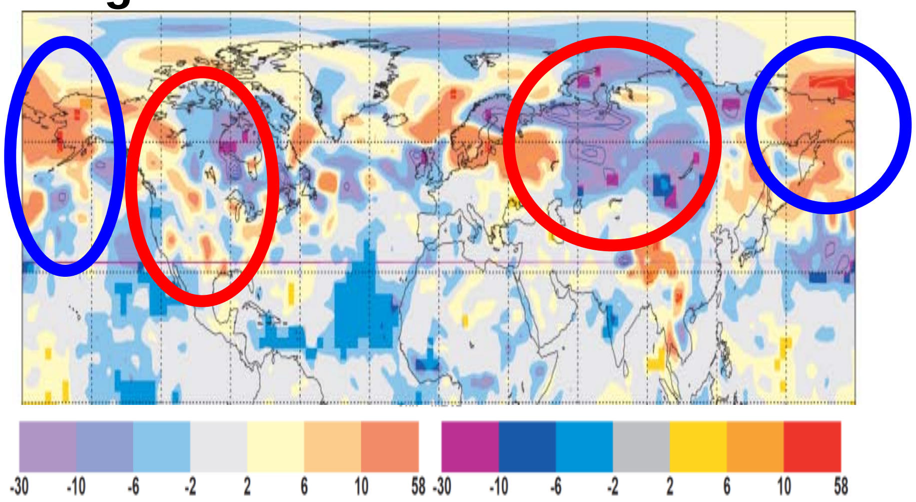
N. Hemisphere winter – decomposition of errors

Mean Z1000hPa - analysis





Change in Z1000hPa RMSE: LT30-CTRL



N. Hemisphere winter – decomposition of errors

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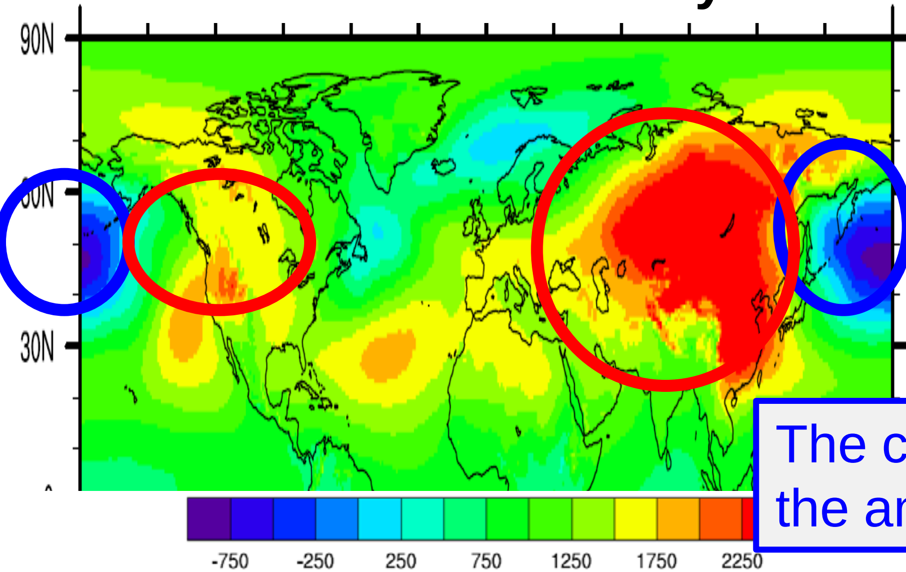
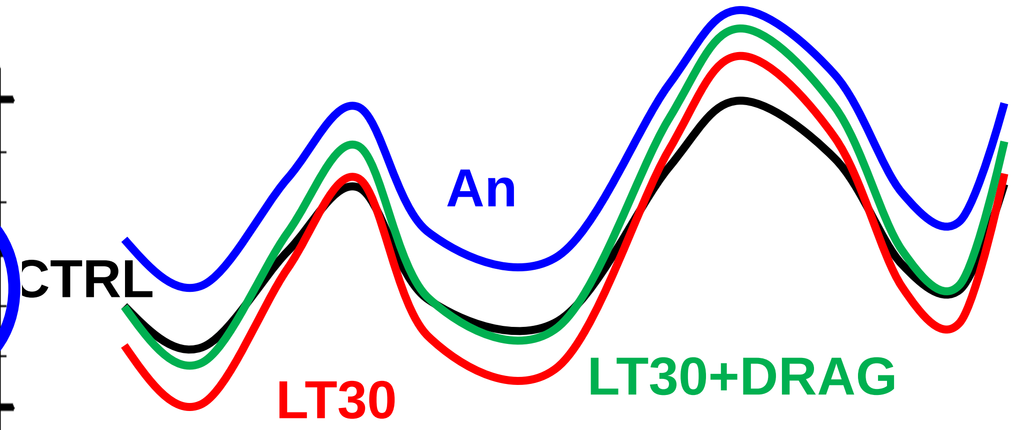
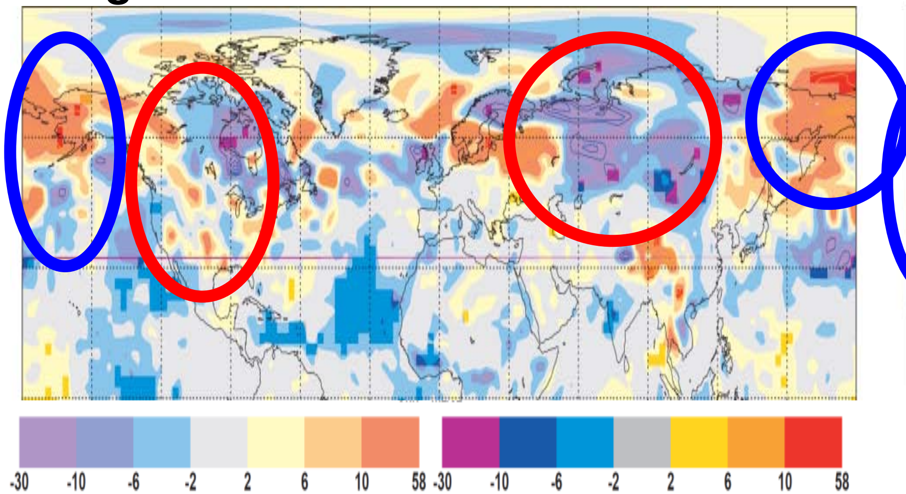


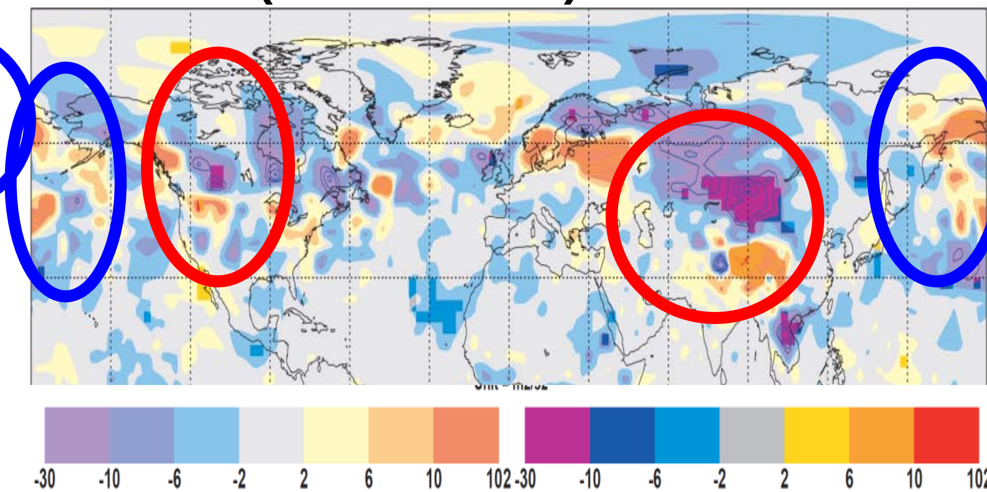


The change in drag over orography modulates the amplitude of the planetary waves

Change in Z1000hPa RMSE: LT30-CTRL



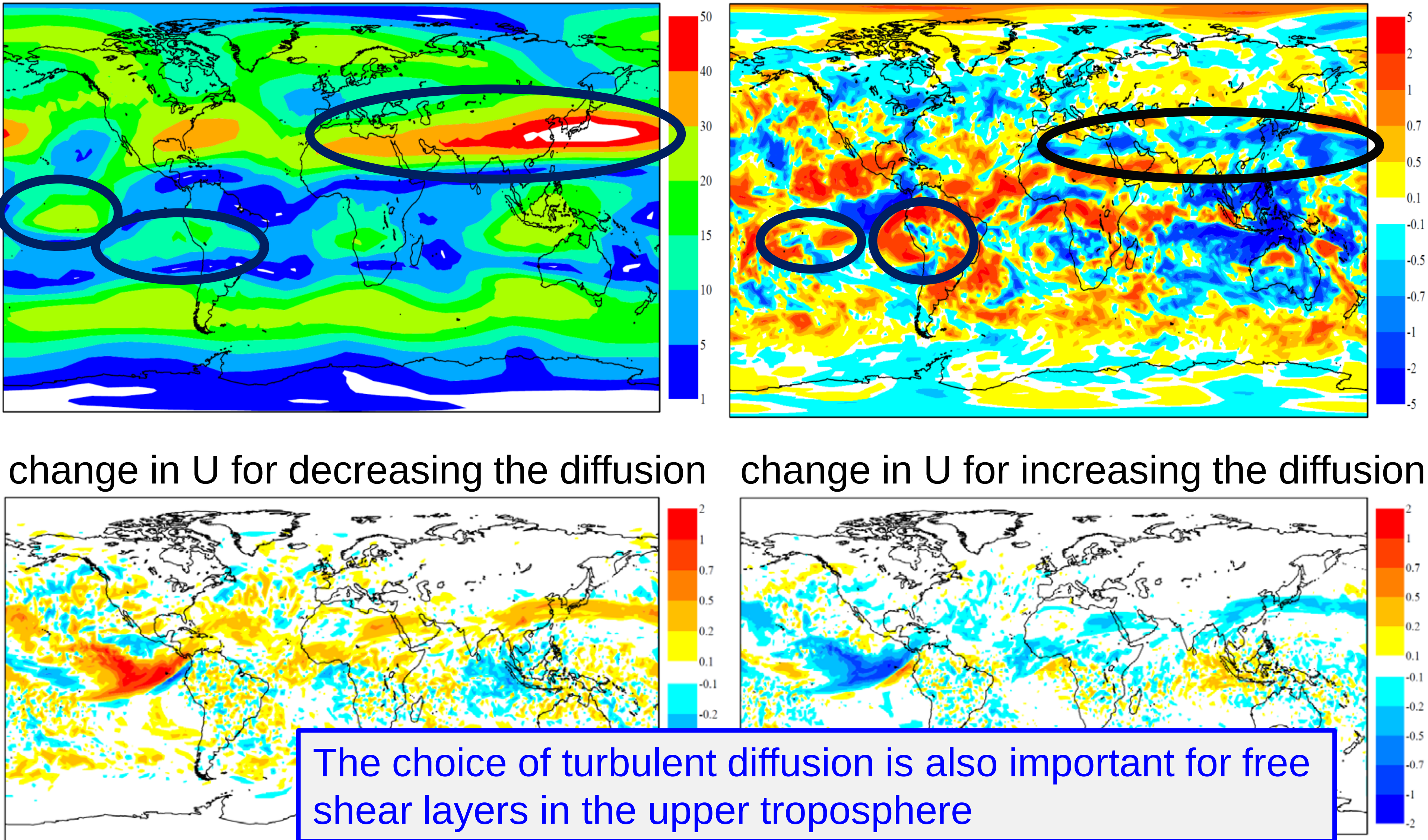
(LT30+DRAG)- CTRL



Tropics (e.g. for January 200hPa)

U in CTRL forecast (step 24) | U bias compared to the analysis

change in U for decreasing the diffusion | change in U for increasing the diffusion



The choice of turbulent diffusion is also important for free shear layers in the upper troposphere

Main conclusions so far....

- ➢ It is not all about vertical diffusion: the coupling with the surface plays a major role
- ➢ Reducing the diffusion has negative and positive impacts
  - ✓ better low level jets, wind turning
  - ✓ better amplitude of T2m diurnal cycle
  - ✓ further lowering of nighttimeT2m
  - ✓ worse scores in winter, better/neutral in summer
  - ✓ worse tropical winds/scores
- ➢ The choice of the orographic drag is crucial for the level of activity of the model
- ➢ The intensity of the diffusion plays an important role not only for the PBL but also for the upper troposhere jets.

Open questions

- Can we assess the skin conductivity from observations?

- Is there a sensible way of calibrating the orographic drag?

- How to chose a value for the asymptotic mixing length?

- Can we use a stability dependent mixing length without using a TKE scheme?