The Effects of Turbulent Mountain Stress (TMS) on the Boundary Layer in CAM

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Diurnal cycle in CAM4 and CAM5

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- Aim is to compare the two very different PBL schemes
- CAM4 and CAM5 5-year climatological SST simulations
- Coupled to the land model which is the same in both simulations
- We analyse hourly output at locations with observations of turbulent fluxes

Flux stations used in the study

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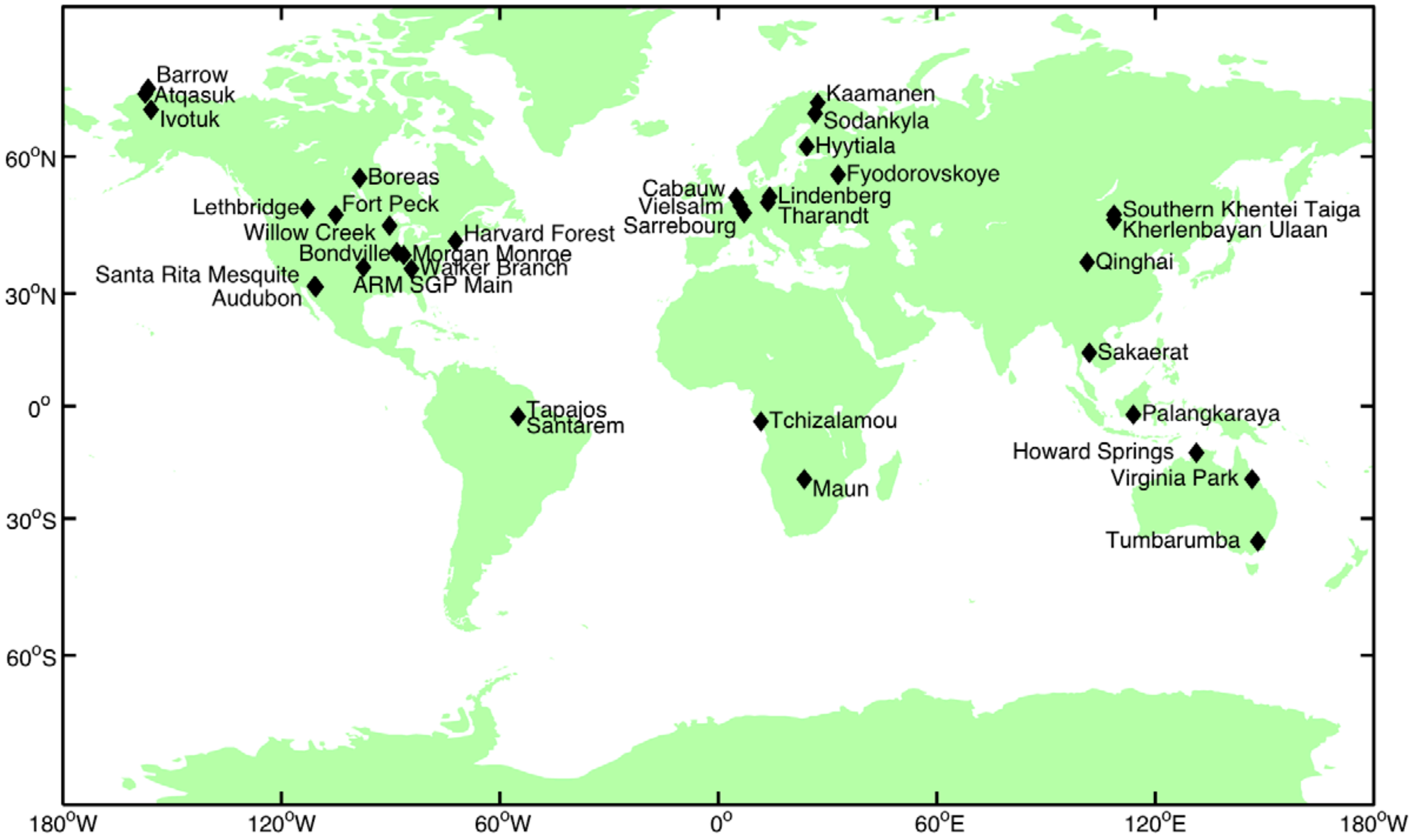
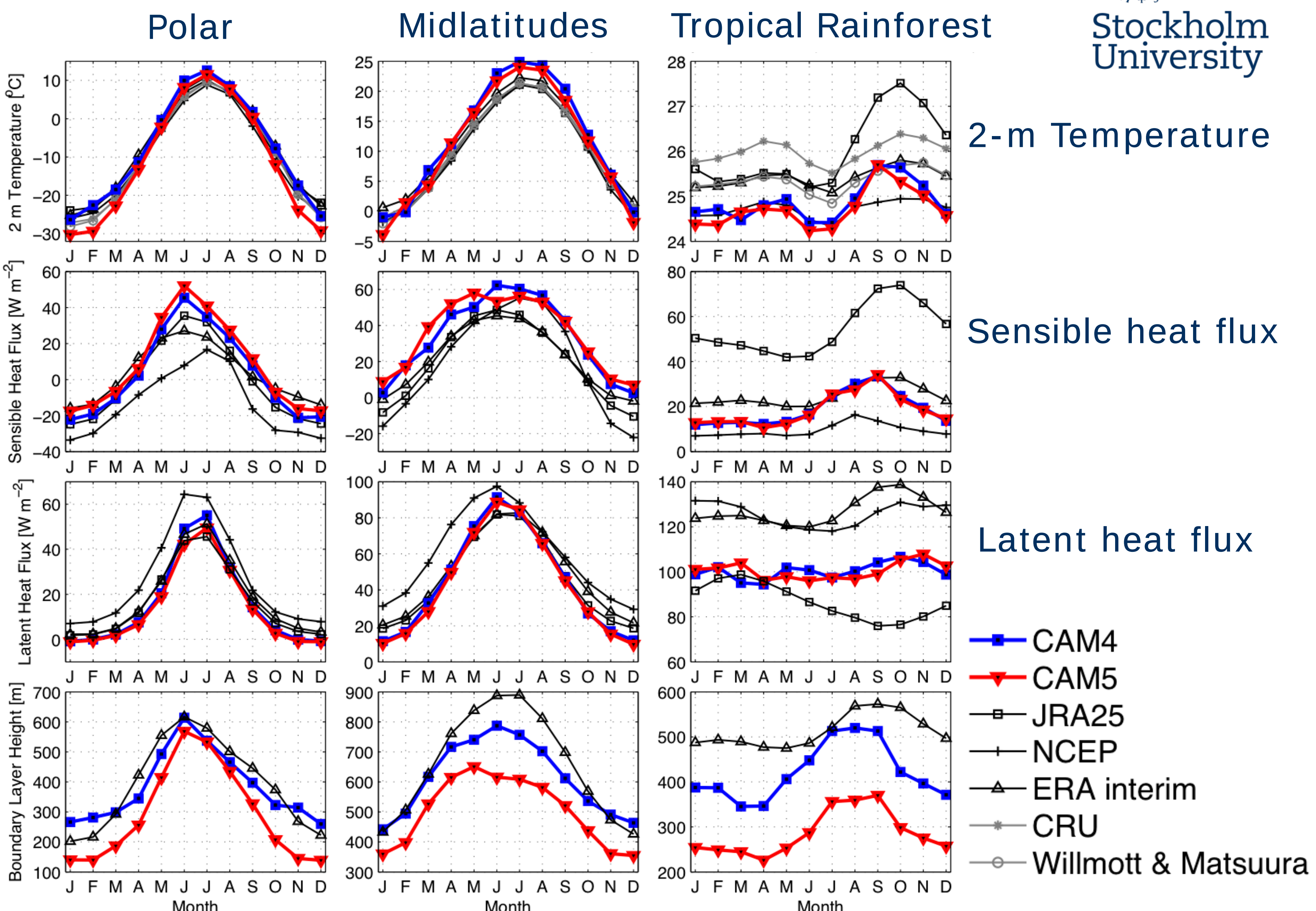


Annual cycle



Diurnal cycle

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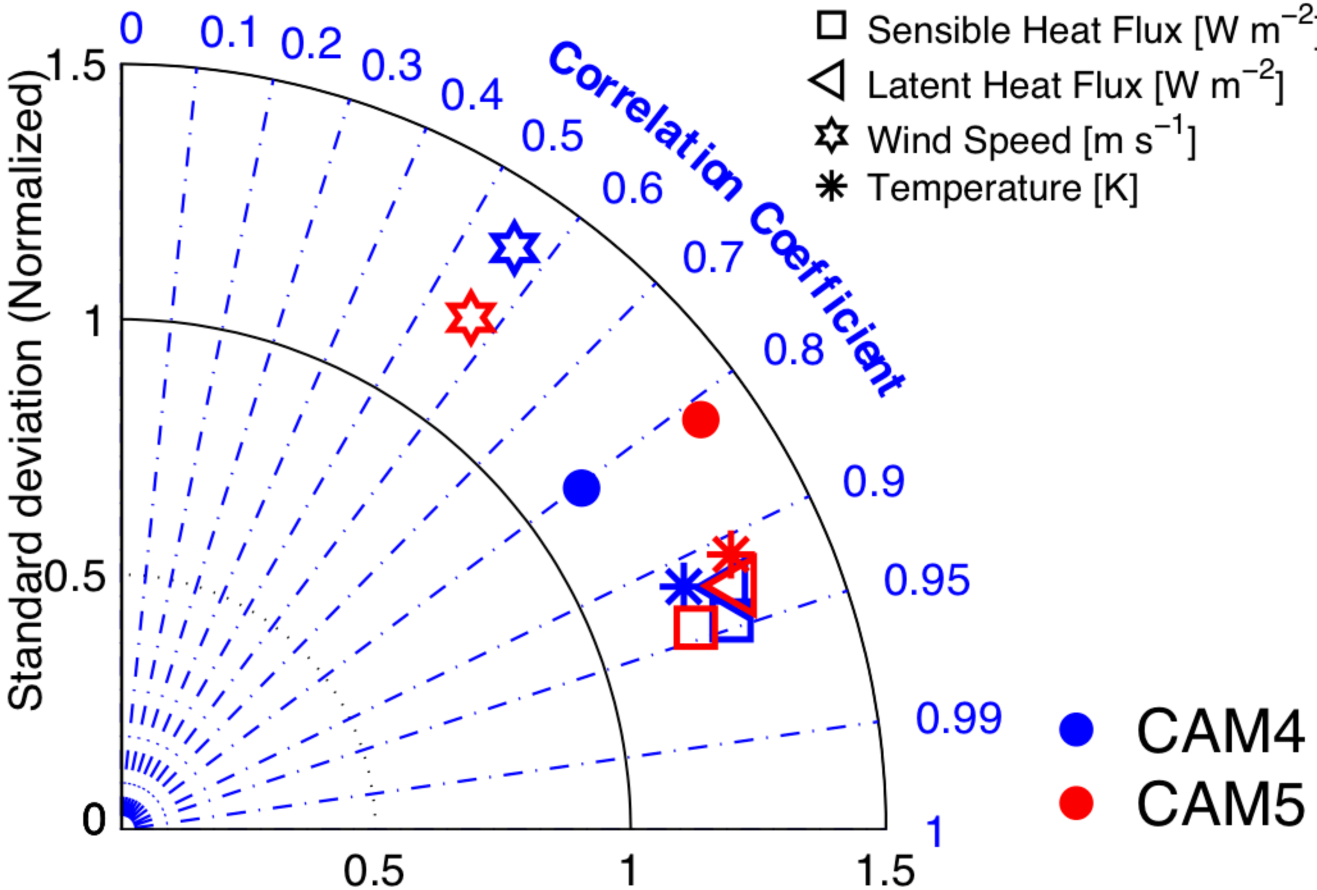
	RMSE CAM4	RMSE CAM5
● Friction Velocity [m s^{-1}]	0.106	0.15
□ Sensible Heat Flux [W m^{-2}]	27.4	27.4
◁ Latent Heat Flux [W m^{-2}]	23.7	23.9
✡ Wind Speed [m s^{-1}]	1.31	0.728
✳ Temperature [K]	2.77	2.97



Observed and simulated median monthly diurnal cycles

ARM SGP site

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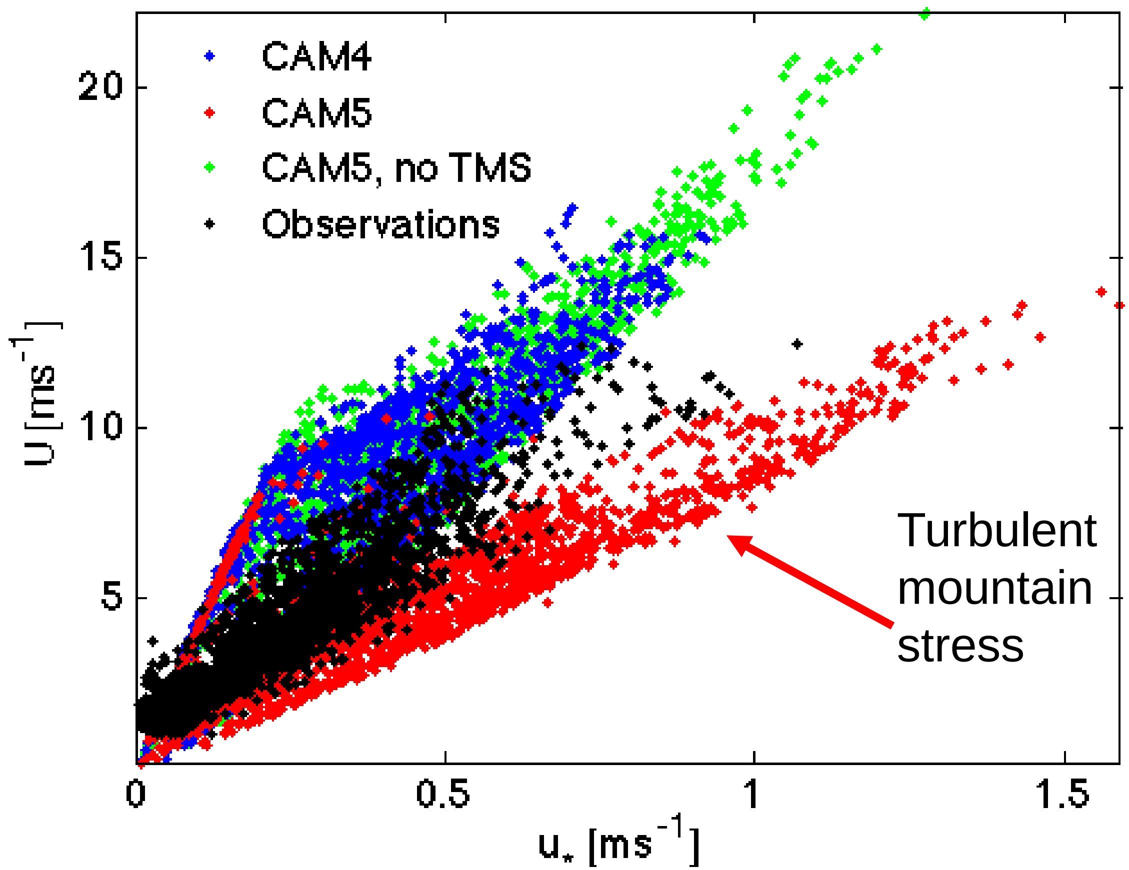

Data from January, February and March

CLM and CAM interactions

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CAM4

- CLM calculates turbulence fluxes at the surface
- Used as boundary conditions for the PBL scheme
- Same stability functions in CLM as in PBL scheme

CAM5

- CLM calculates turbulence fluxes at the surface
- TMS adds surface stress in CAM, thus a larger surface stress is used as boundary condition
- This extra drag reduces the wind speed in lowest layer
- Not the same stability functions in CLM, PBL and TMS

Turbulent Mountain Stress (TMS)

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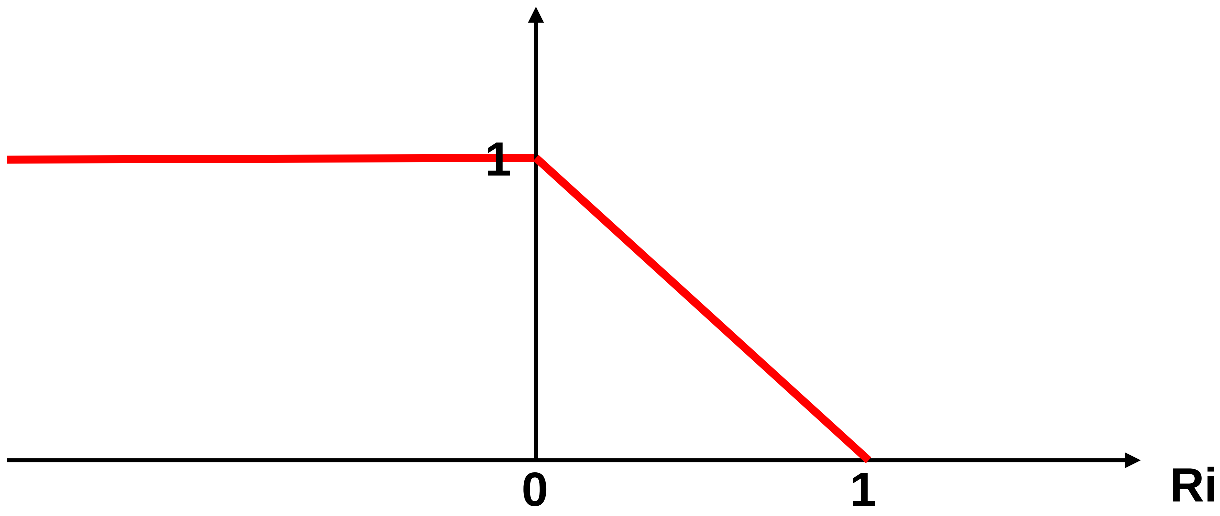
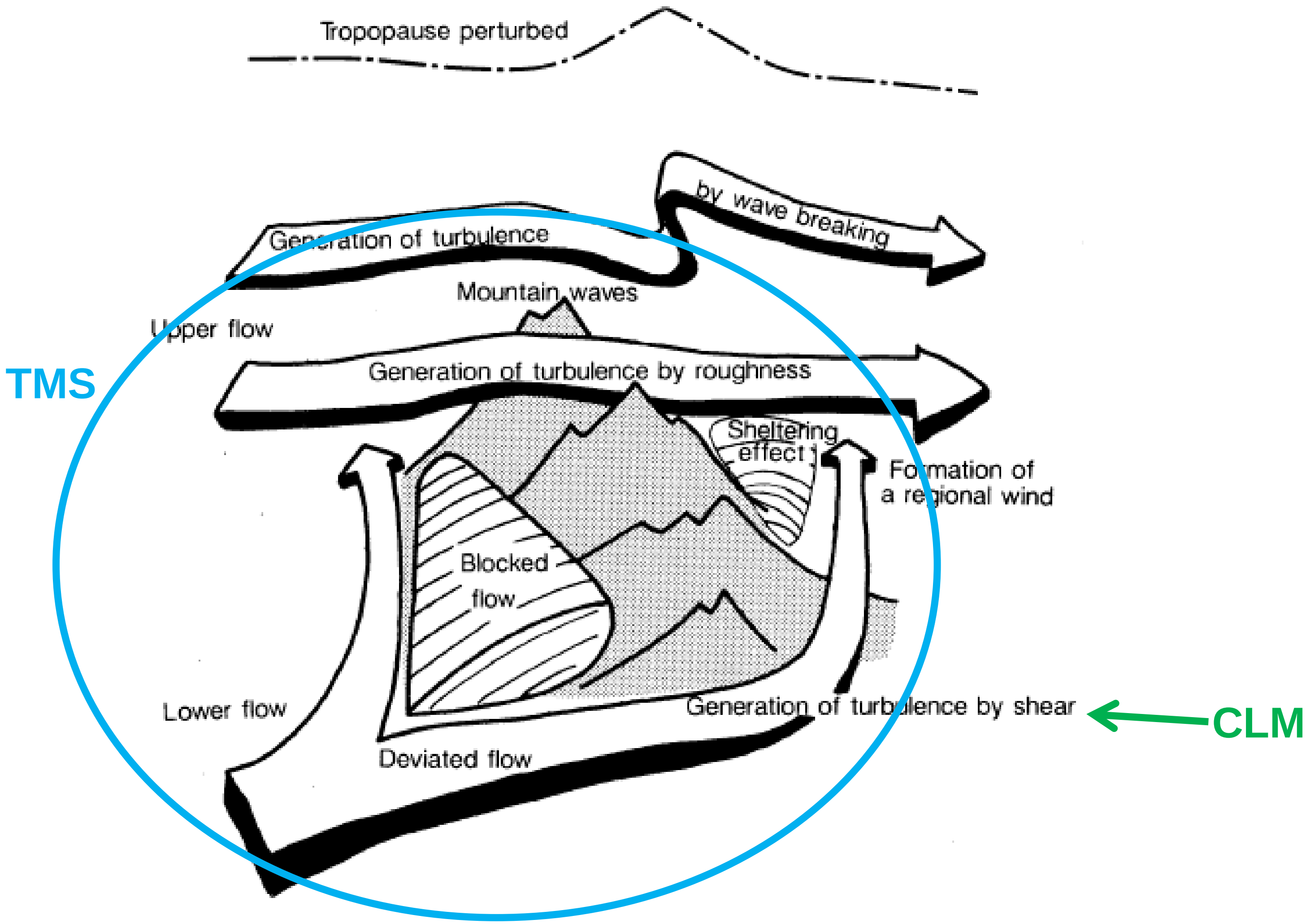
- Added to improve the general circulation
- Enhancement of the surface drag due to subgrid-scale terrain, basically increases surface rougness to z_{0_oro}
- Applied when Ri < 1 based on function below



Subgrid scale orographic drag



Subgrid scale orography

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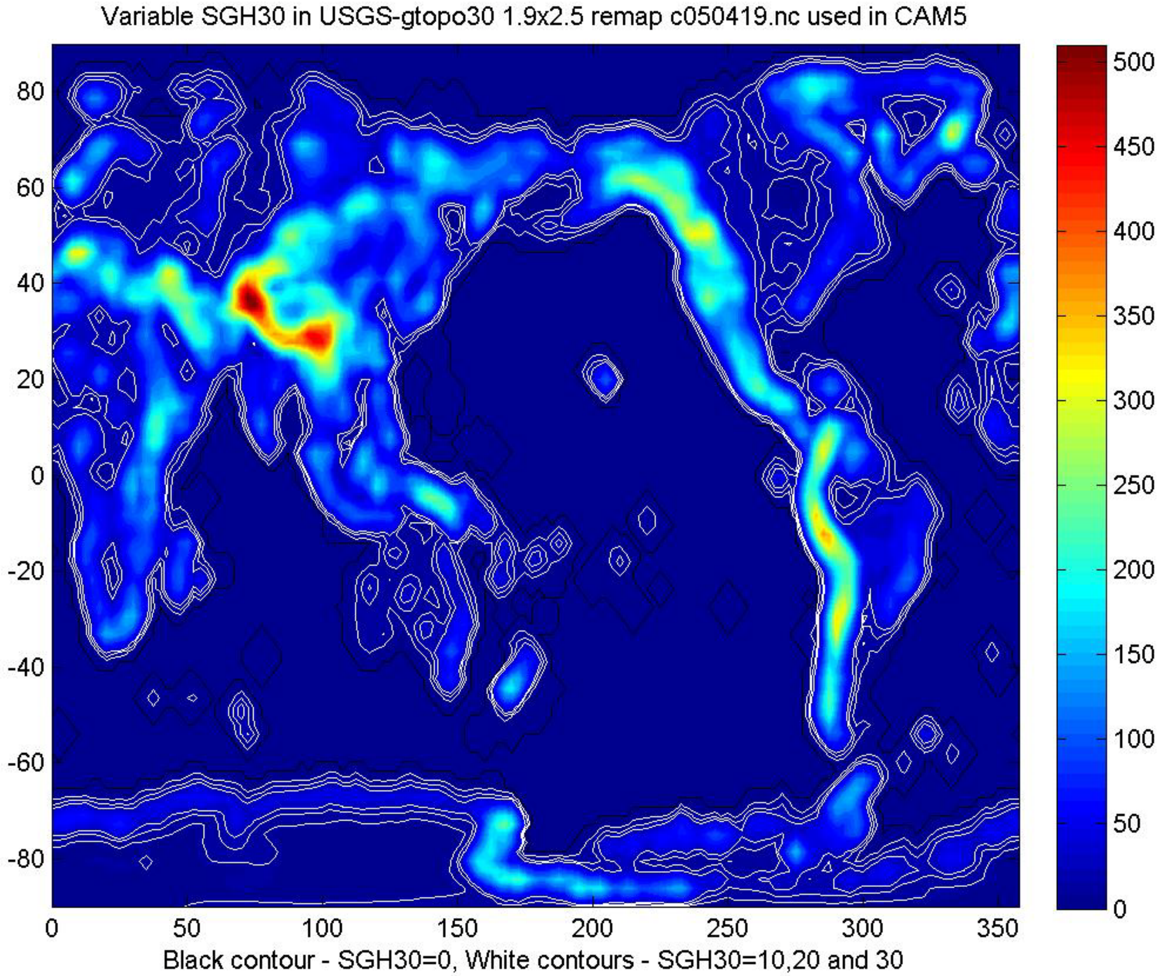
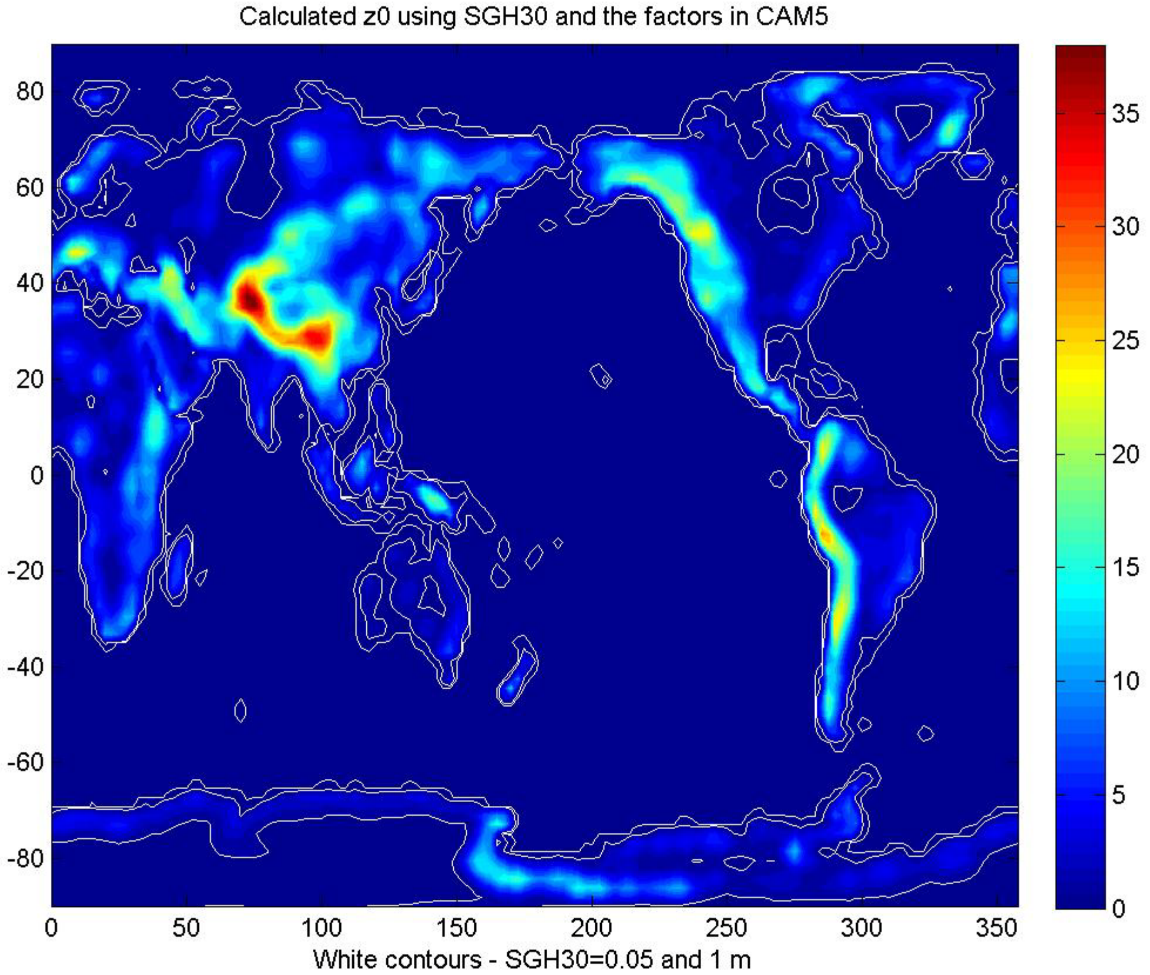


At SGP:

SGH30=23 m

Calculated z_{0_oro}



At SGP:

z_{0_oro} = 1.7m

z_0 = 0.06 m

Neutral drag law

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$$u_*^{\ 2} = C_{DN} U_{ref}^{\ \ 2}$$

$$U_{ref} = \frac{u_*}{k} \ln\left(\frac{z_{ref}}{z_0}\right)$$

⇓

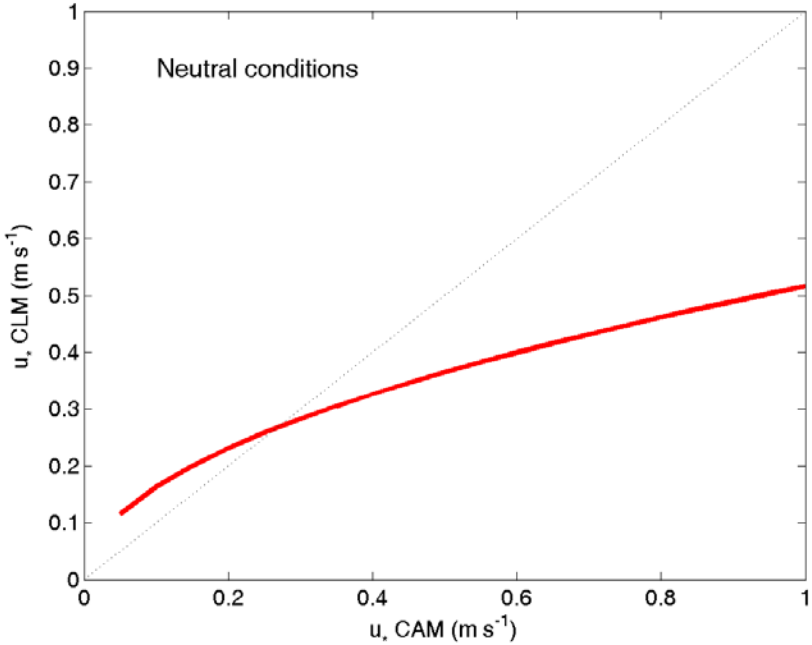
$$C_{DN} = \frac{k^2}{\ln\left(\frac{z_{ref}}{z_0}\right)^2}$$

Applied to the Southern Great Plains where

$z_0 = 0.06$ m

$z_{0\_oro} = 1.7$ m

$u_{*CAM} \rightarrow U_{ref} \rightarrow u_{*CLM}$



Neutral drag coefficient for SGP

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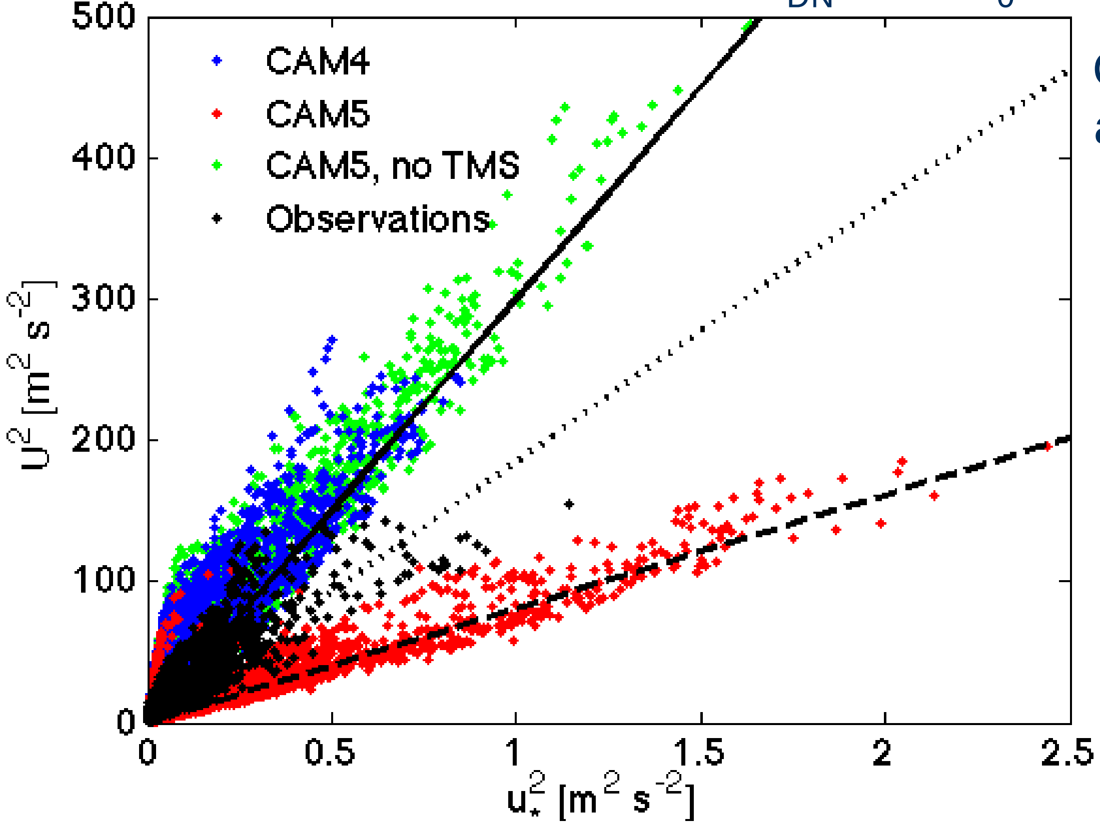
C_{DN} with z_0=0.06 m

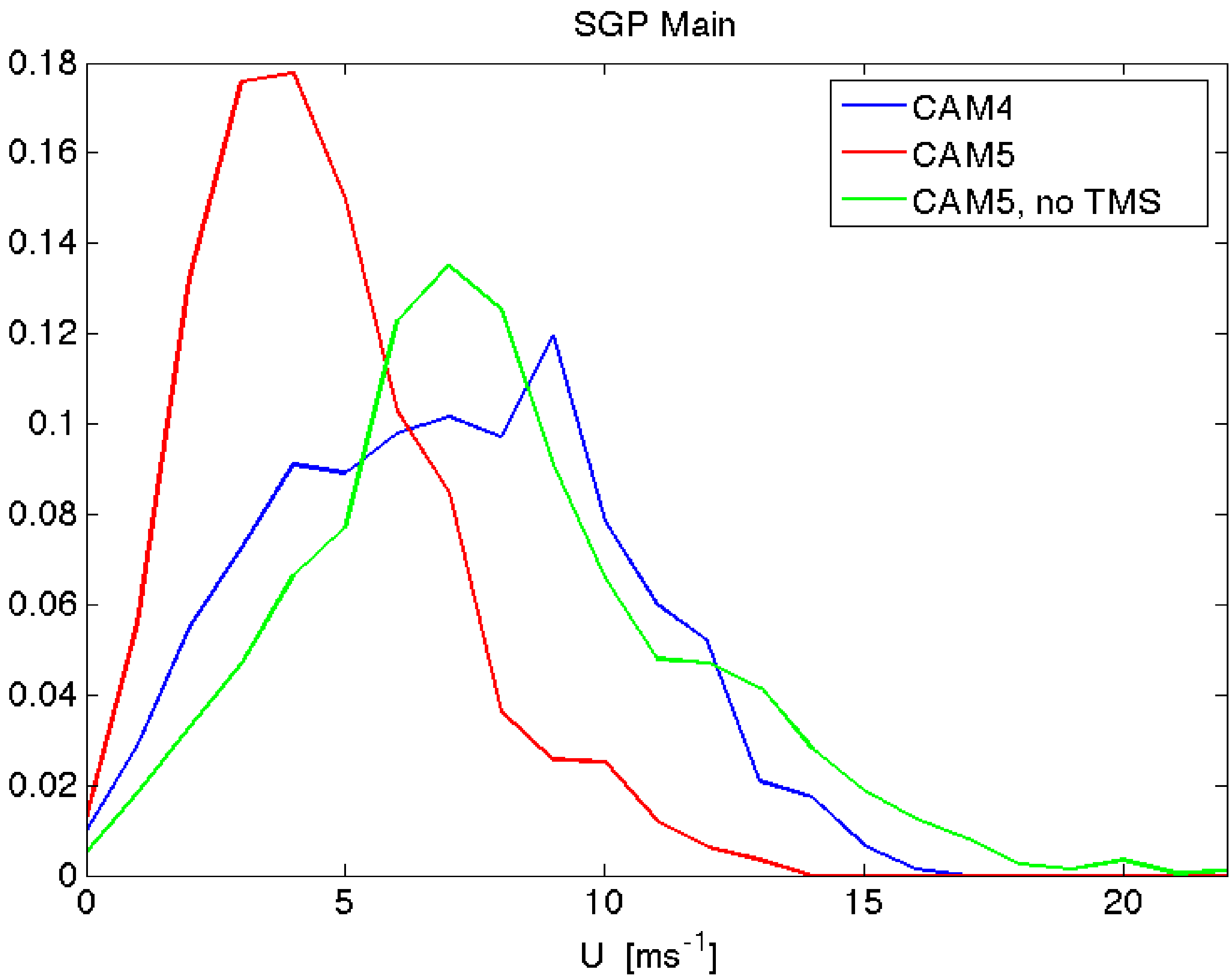


C_{DN} with z_0=0.06 m and ref height for obs

C_{DN} with z_0=1.7 m

$$C_{DN} = \frac{k^2}{\ln\left(\frac{z_{ref}}{z_0}\right)^2}$$

Wind speed is reduced…



Temperature gradients increase

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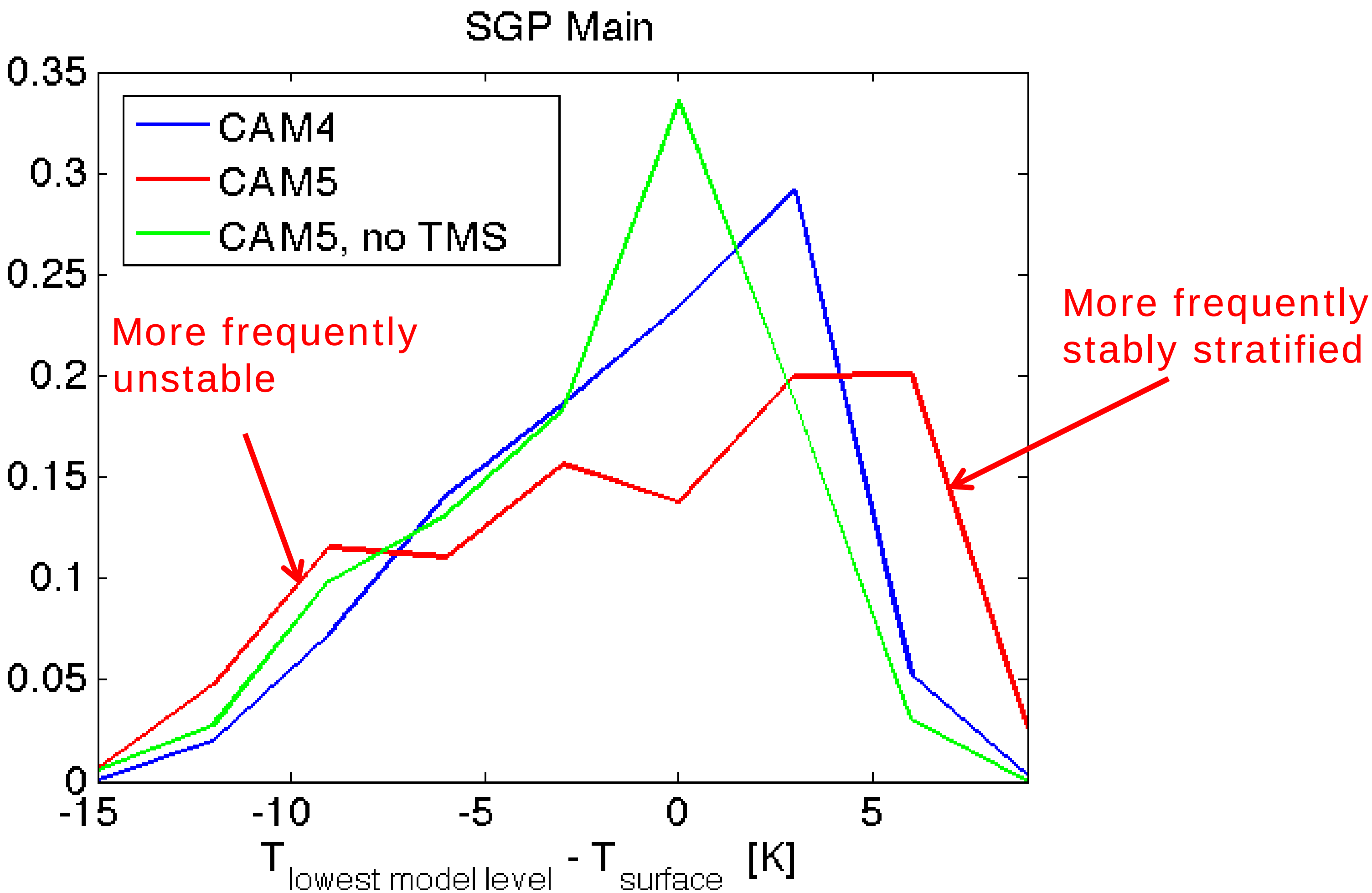

Surface heat fluxes almost the same

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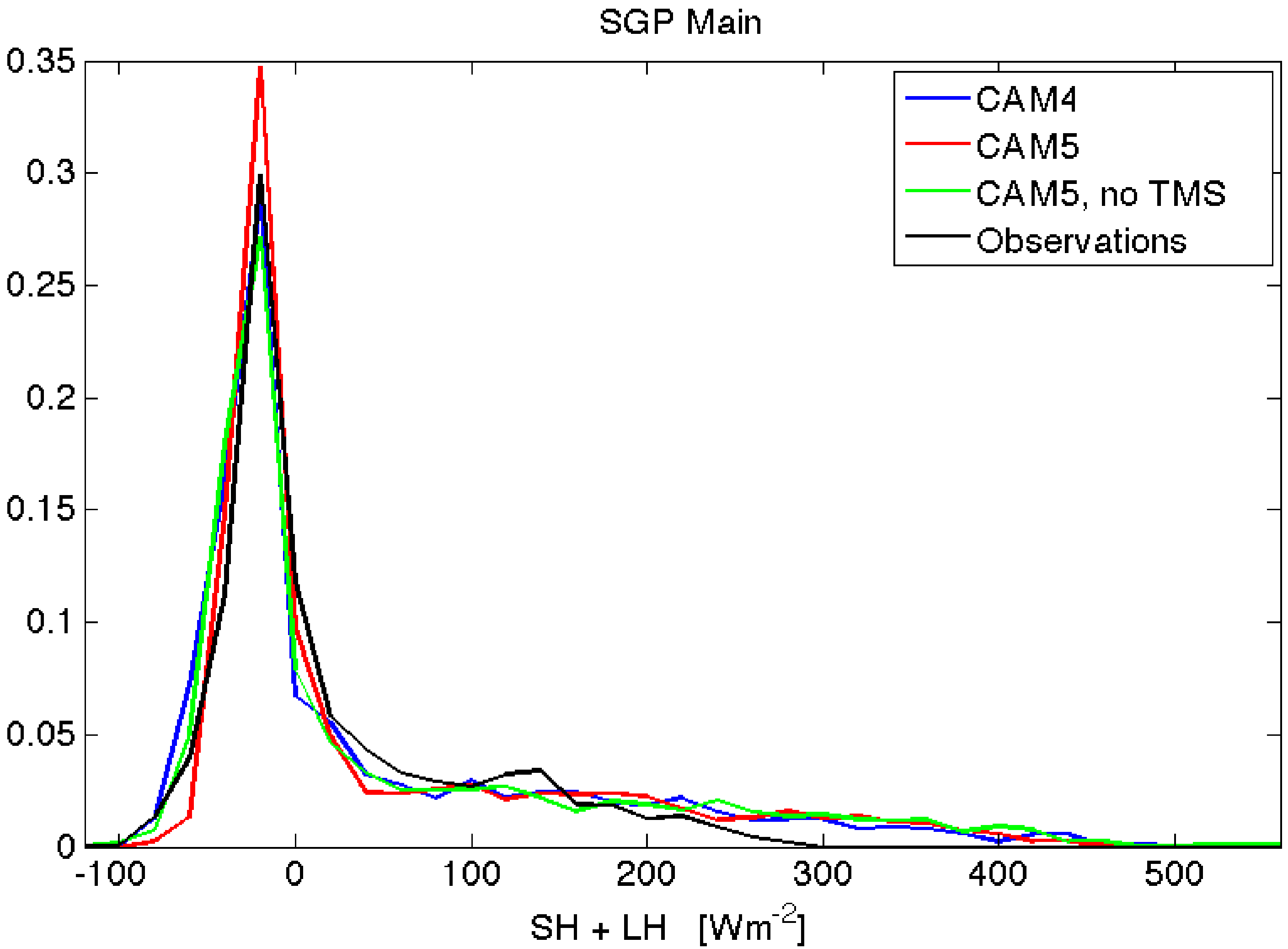
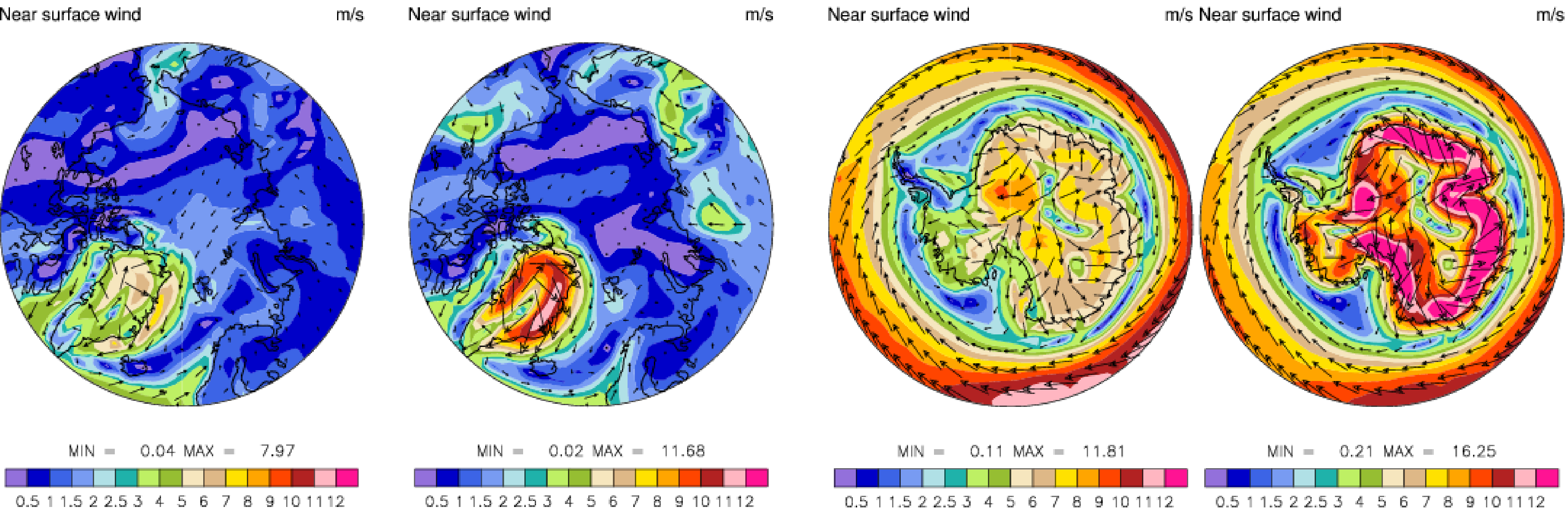
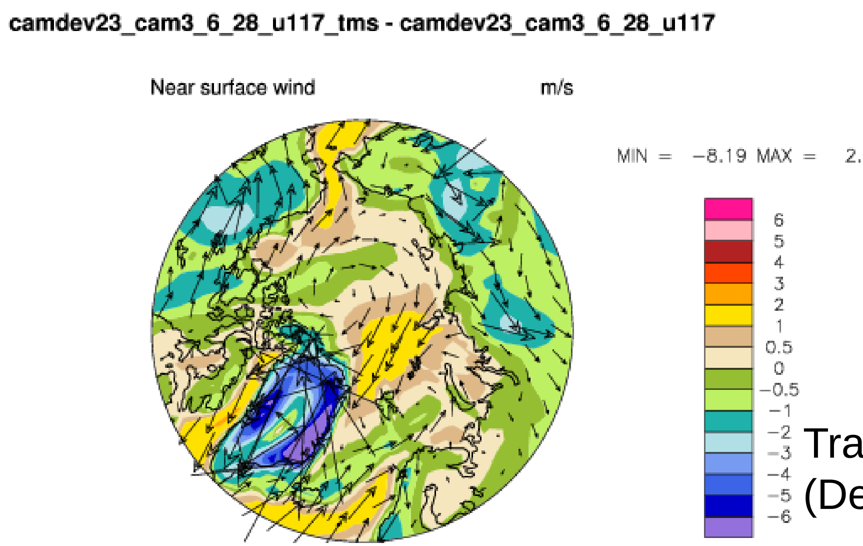


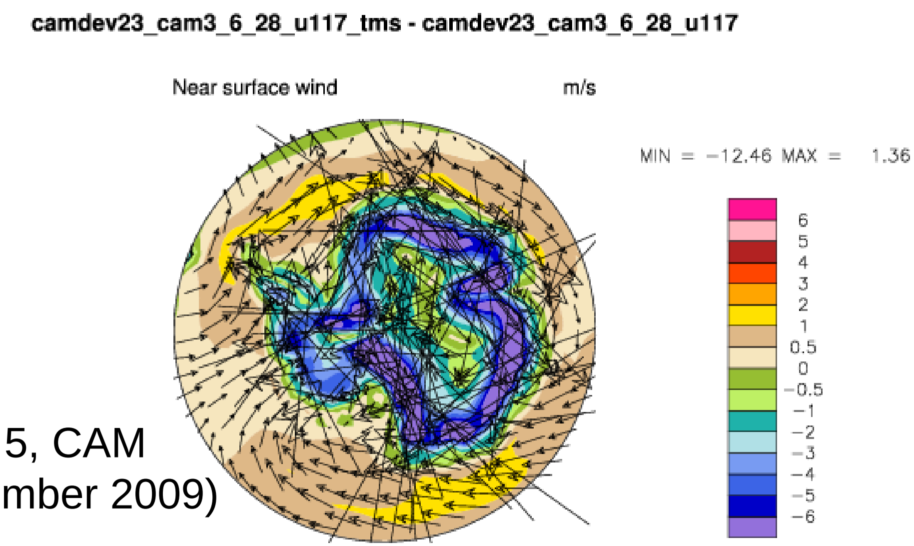
Effect of turbulent mountain drag

TMS | No TMS | TMS | No TMS





Track 5, CAM (December 2009)



Summary

- The Turbulent Mountain Stress is needed for CAM5 to have ”enough” momentum extracted at the surface
- Climatolological surface turbulent heat fluxes are similar in CAM4 and CAM5 even though the winds are much reduced in CAM5
- The model compensates the lower wind gradients with larger temperature gradients
- A more sophisticated parameterisation that does not intefere with the surface driven turbulence is preferable
- Problematic since there are no observational datasets to compare with...