The impact of changes in parameterizations of surface drag and vertical diffusion on the large scale circulation and boundary layer wind turning in CAM5

Gunilla Svensson
Jenny Lindvall and Rodrigo Caballero

Department of Meteorology and
Bolin Centre for Climate Research

Investigating the role of surface friction

The Community Atmosphere Model (CAM5.3)

Stockholm University

How is the boundary layer and the general circulation affected by added drag (Turbulent Mountain Stress, TMS) at the surface?

Do surface drag and turbulent diffusion affect the general circulation in a similar way?

Wind turning over the PBL is important for interaction with the large scale

Overall goal is to describe the local boundary-layer turbulence ***and*** the general circulation well

Subgrid-scale orographic drag

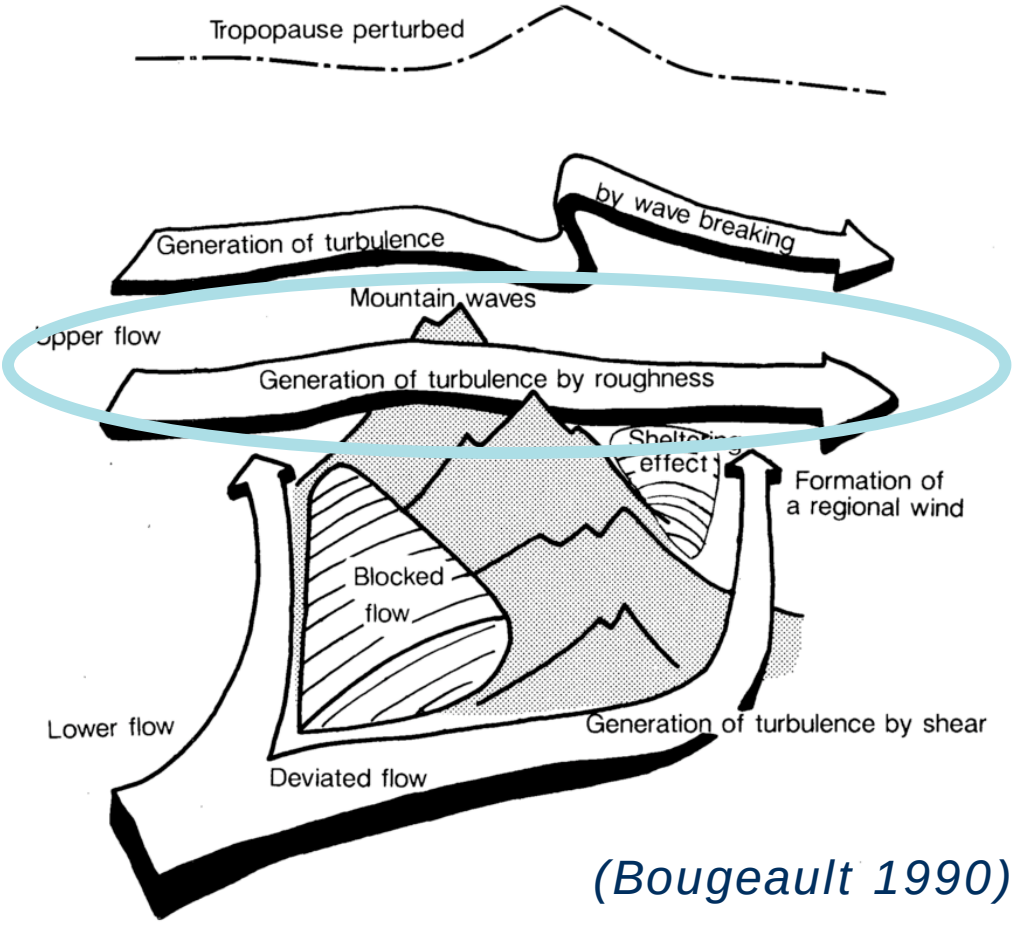
Stockholm University

Sub-grid scale momentum transfer are done by several parameterizations

Subgrid-scale orographic drag is parameterized as an **additional surface stress** (TMS)

The size of the TMS is dependent on the stability and the variance of orography in a gridbox

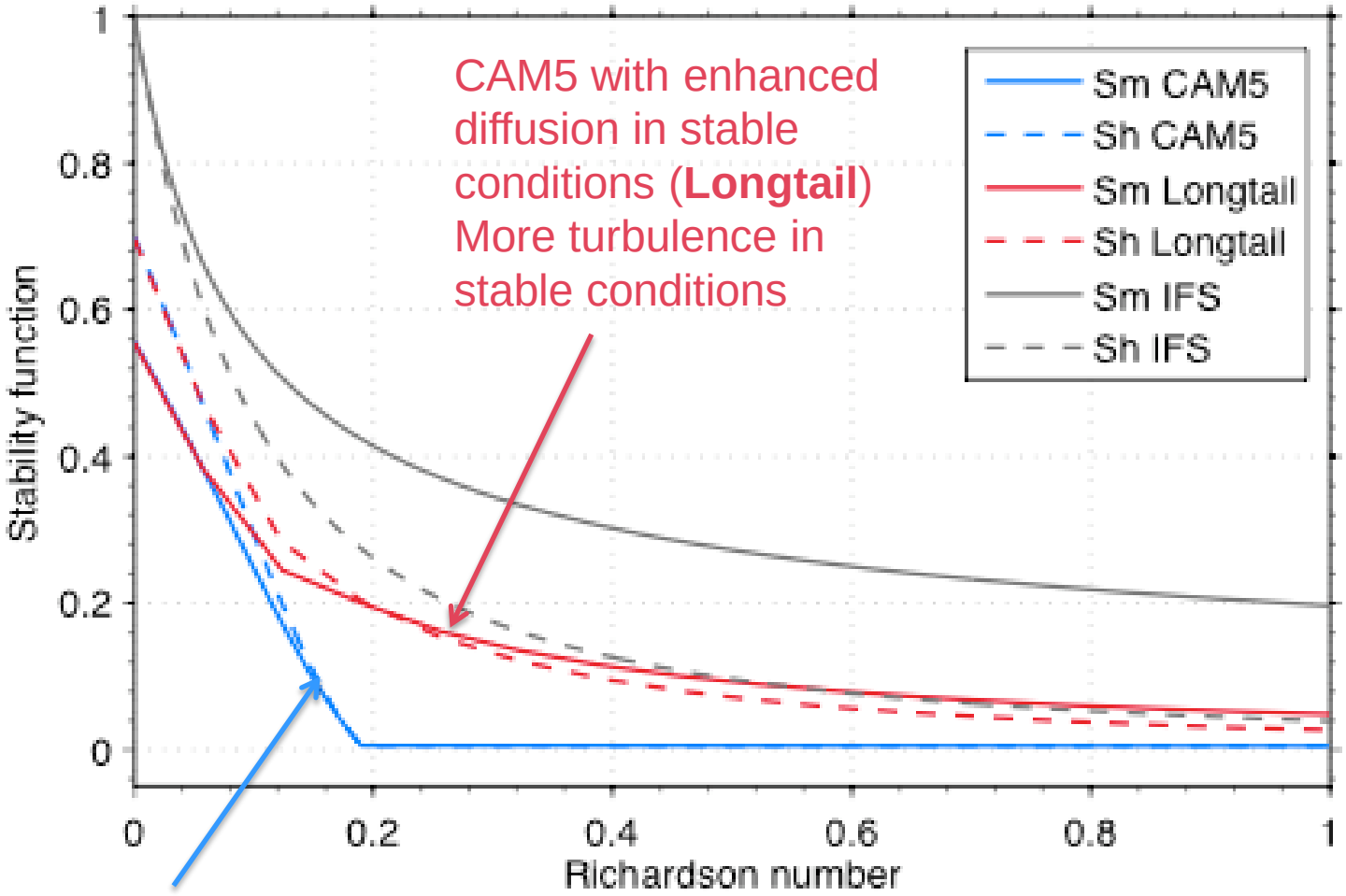
The PBL is parameterized using a diagnostic TKE scheme (*Bretherton and Park, 2009)*



(Bougeault 1990)

Changing turbulent diffusion

Stockholm University



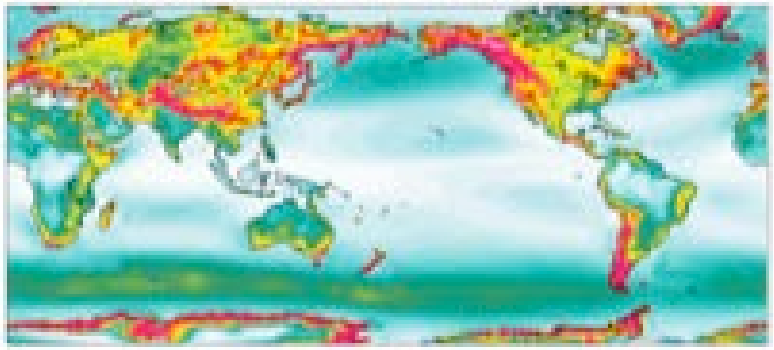
Default CAM5 (**CONTROL**)
No turbulence when Ri > 0.19

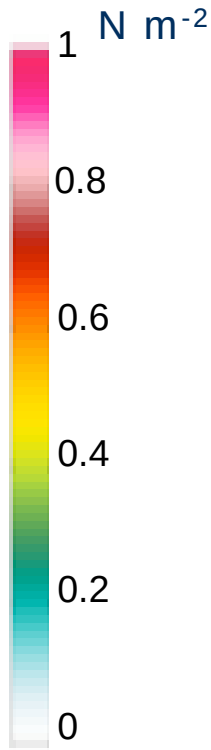
(Lindvall et al. 2013; 2014)

Magnitude of total surface stress

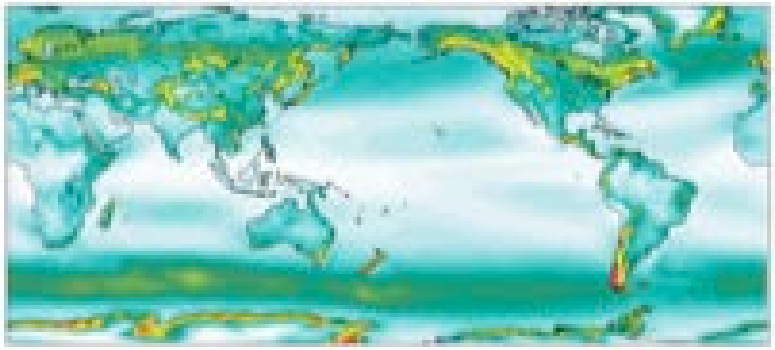
Stockholm University

CONTROL

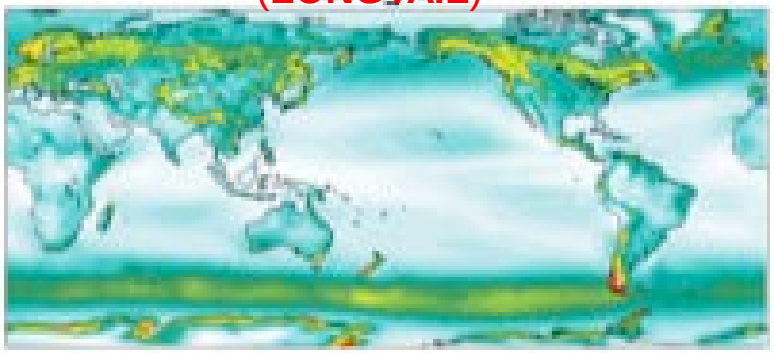




Without subgrid scale turbulent orographic drag (**NoTMS**)



Higher diffusivity in stably stratitified conditions + no turbulent orographic drag (**LONGTAIL**)

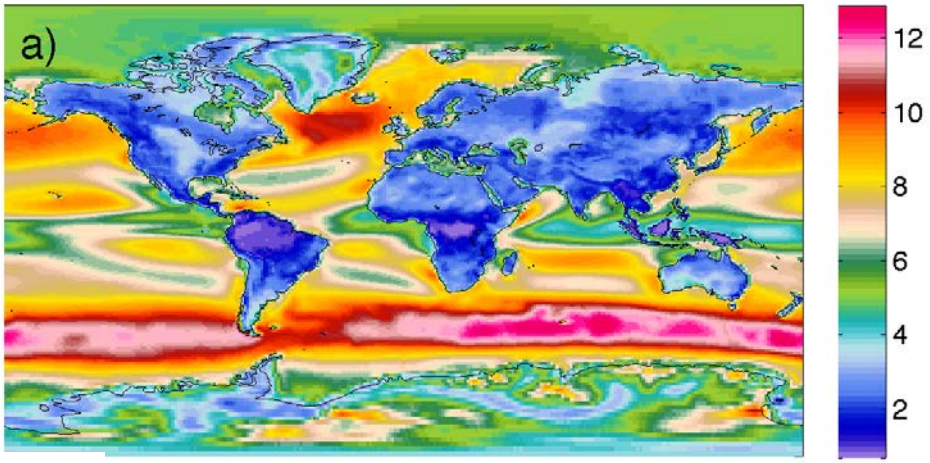


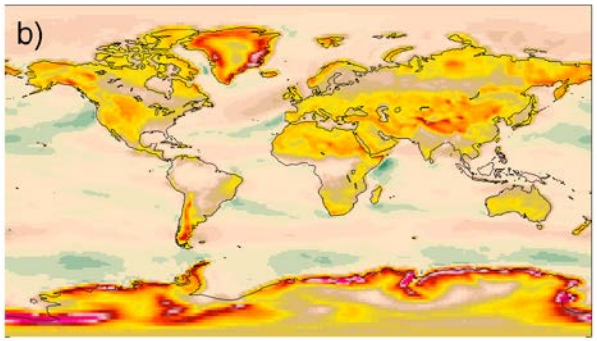
Large differences in the annual mean magnitude of the surface stress

Near surface wind field

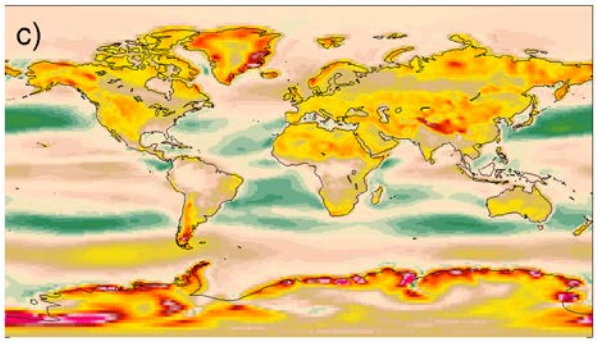
Stockholm University

CONTROL

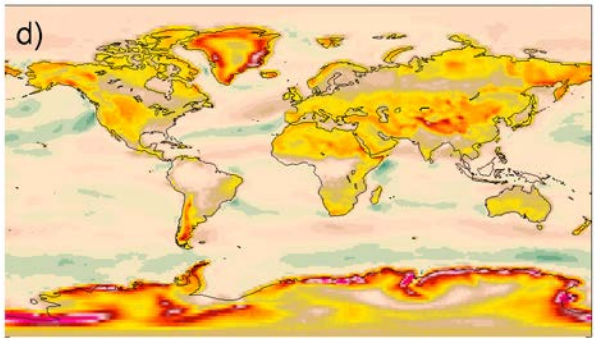




NoTMS – CONTROL



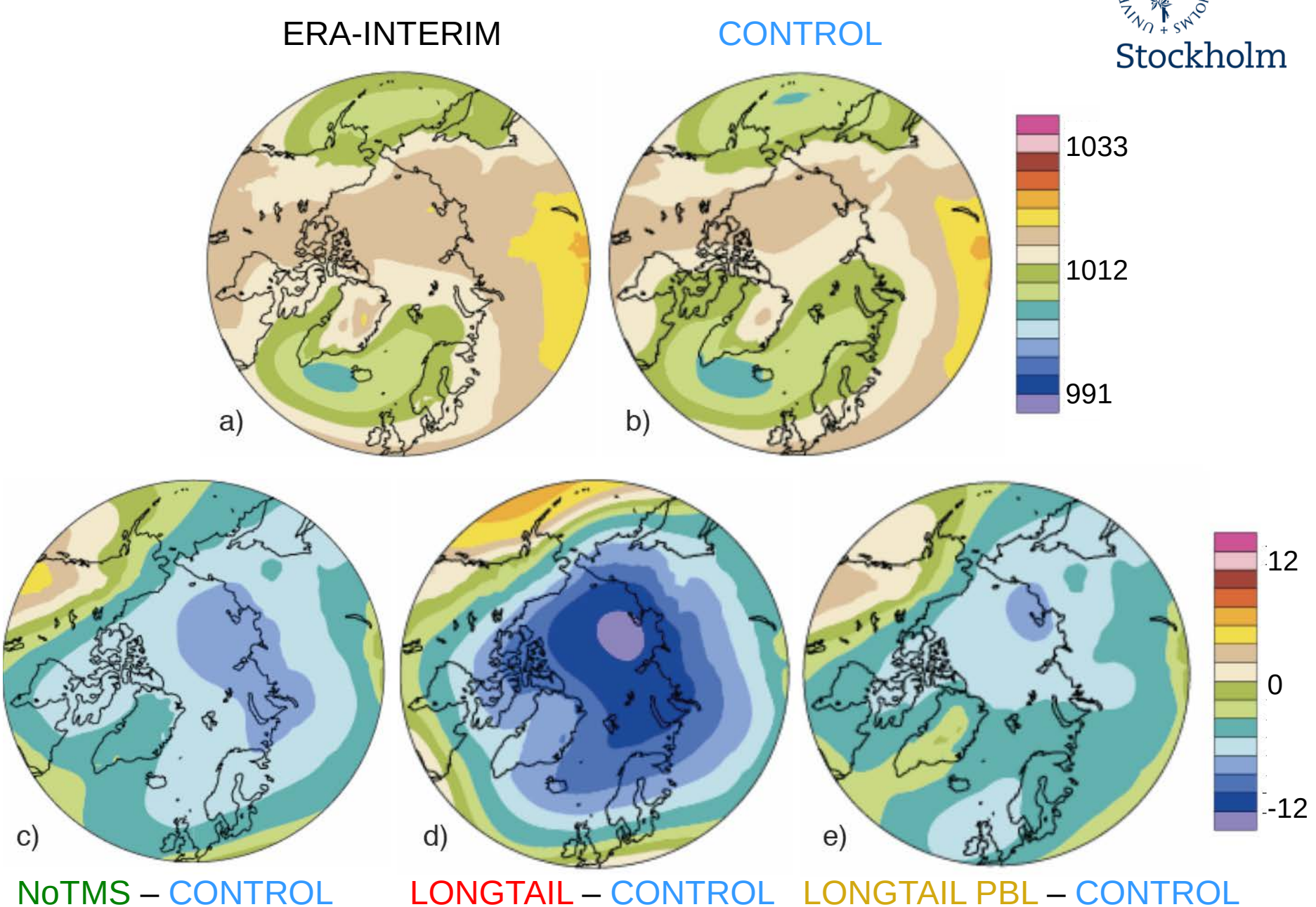
LONGTAIL – CONTROL



LONGTAIL PBL – CONTROL

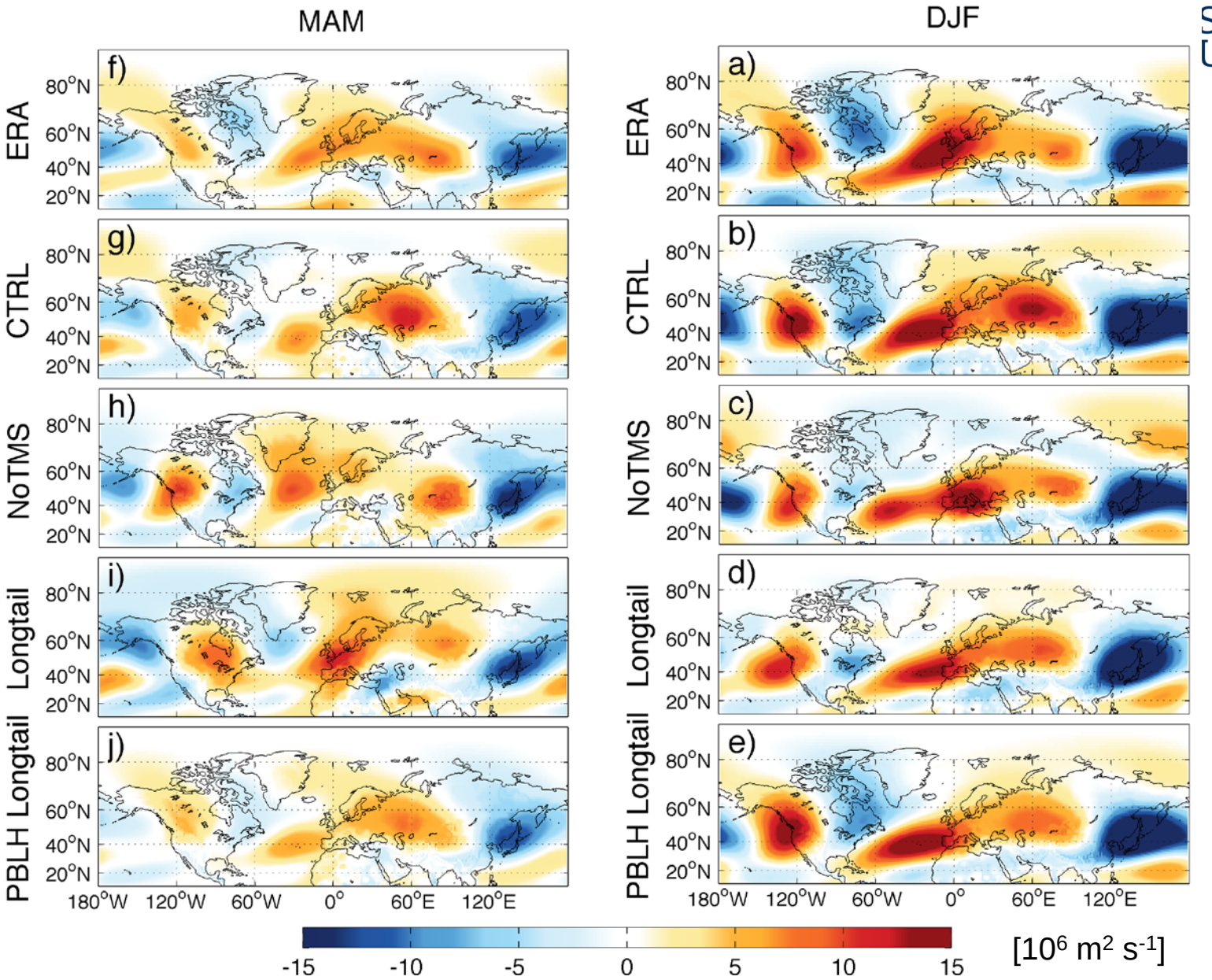
Lindvall et al, 2015

Arctic annual mean sea level pressure



500 hPa streamfunction
Zonal anomaly

Stockholm University

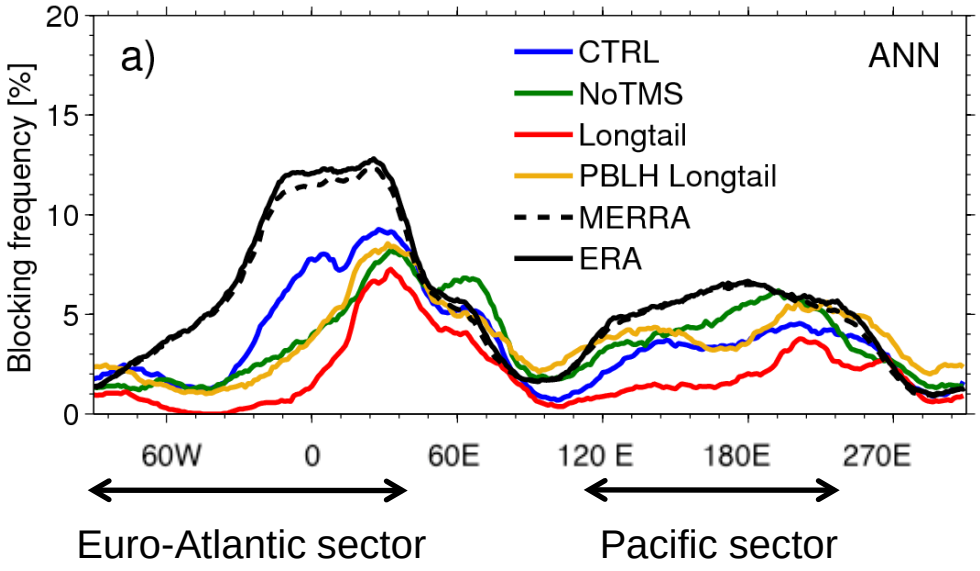


Blocking frequencies in CESM

Different sub-grid scale parameterisations of the surface drag

Stockholm University

All model versions have too few blockings, specially for the Euro-Atlantic sector

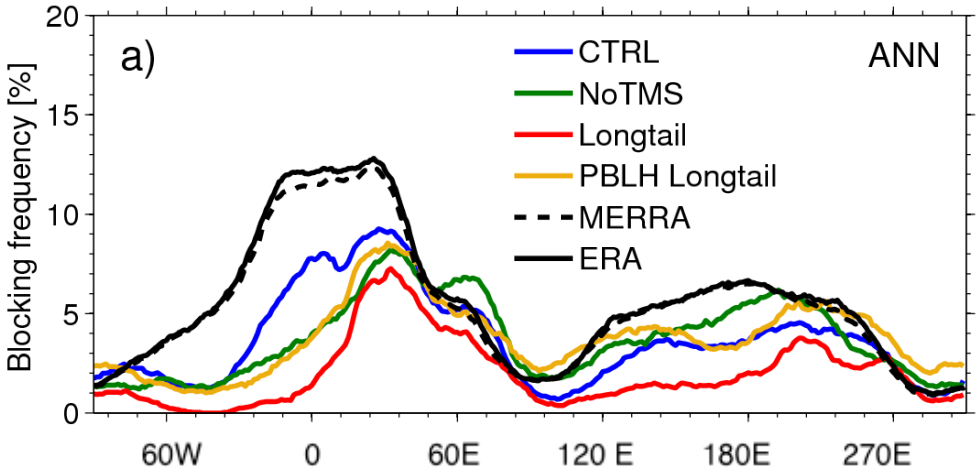


Blocking frequencies in CESM

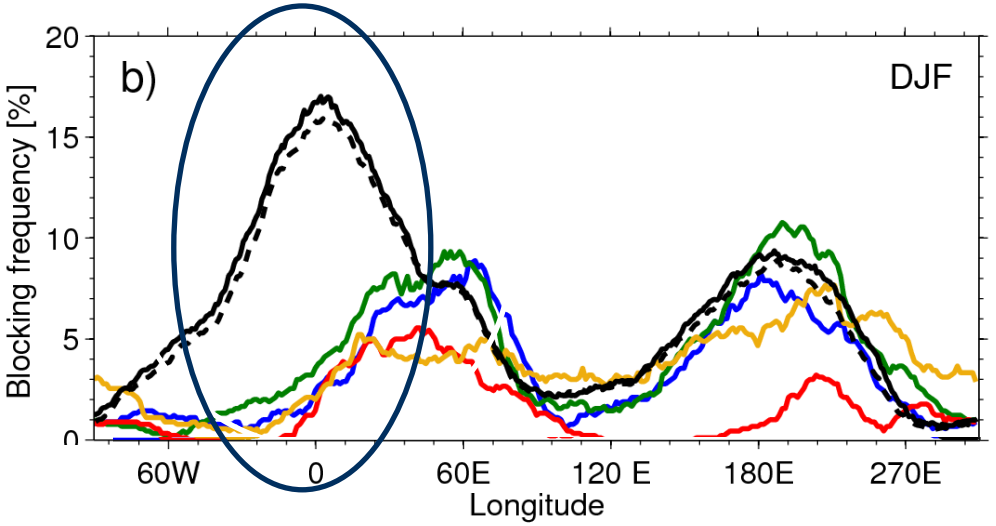
Different sub-grid scale parameterisations of the surface drag

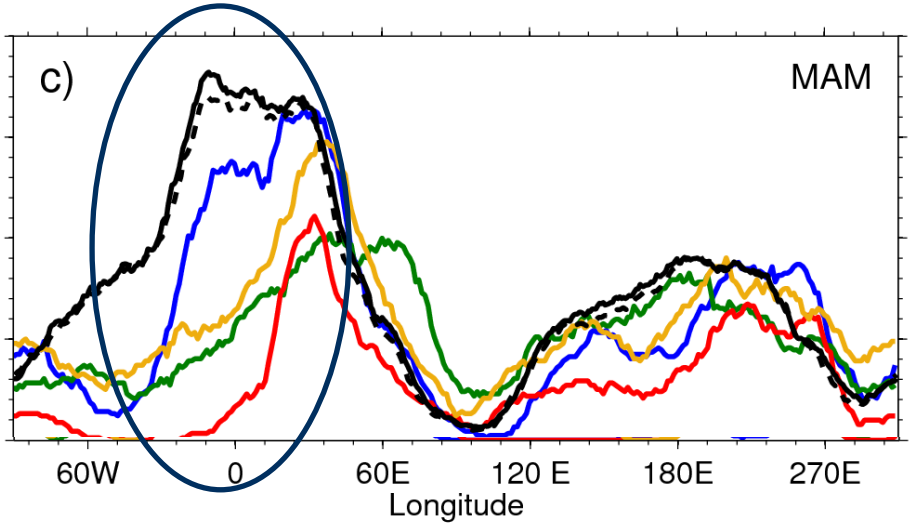
Stockholm University

No version captures the Atlantic blockings in winter



Control is closest to observations

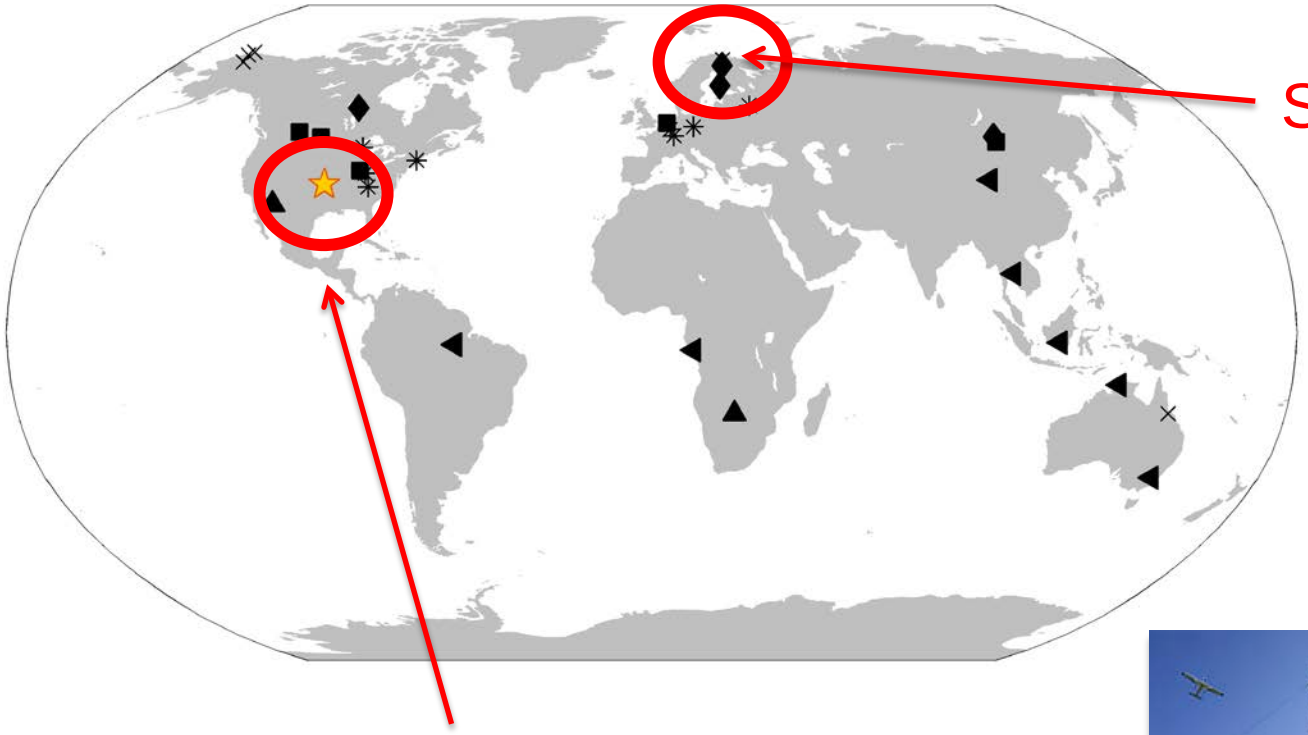




Lindvall et al, 2015

Tower data combined with sounding information

Stockholm University



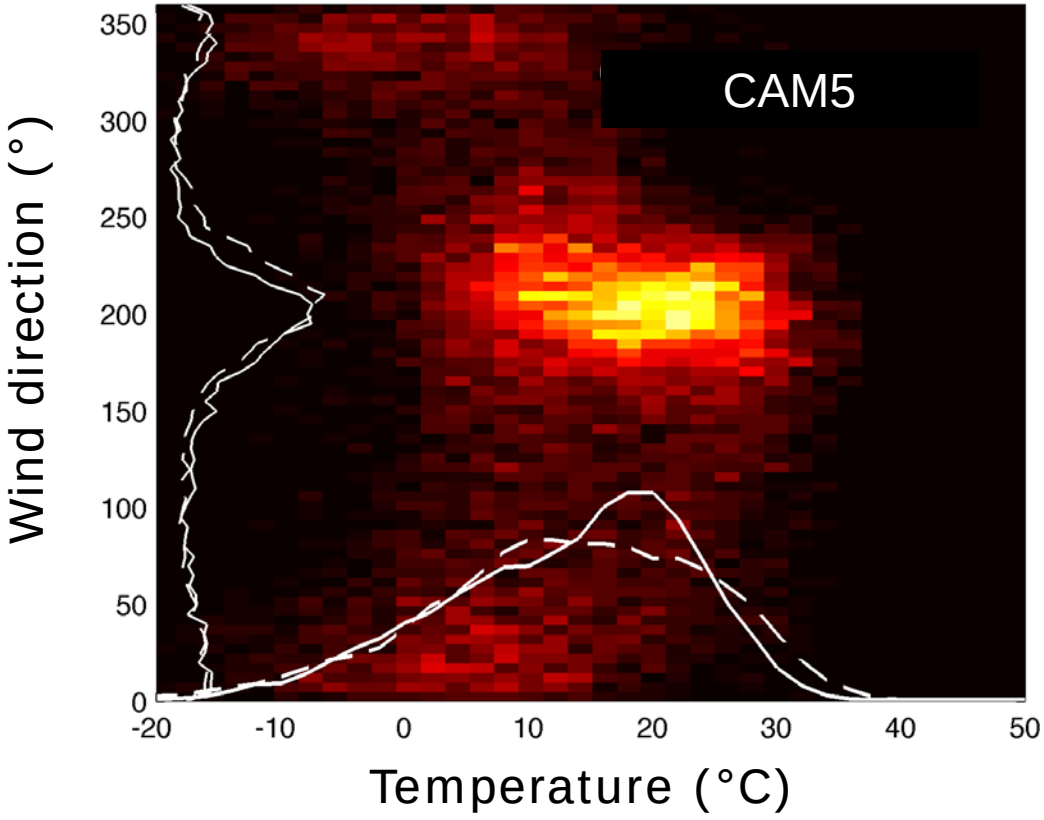
Sodankylä

ARM Southern Great Plain site

Radiosondes are released four times daily
Use a RI based PBL height combined with surface stress observations

Large-scale circulation @SGP

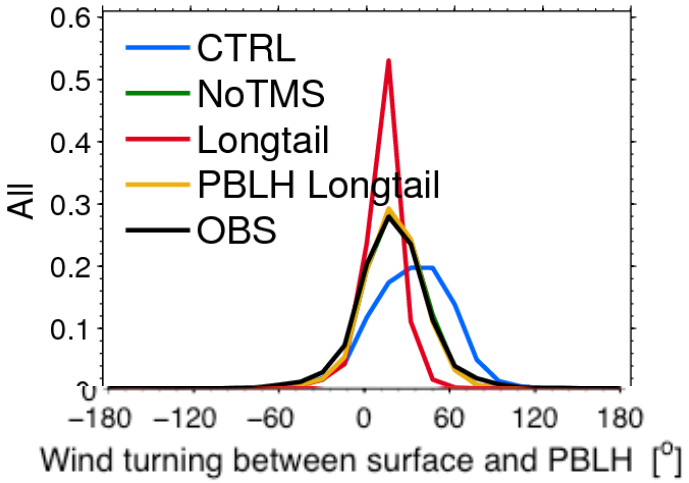
Stockholm University



Density scatter plots, as well as individual PDFs, of wind direction (°) and temperature (°C) just above the PBL

(Lindvall and Svensson 2015)

Boundary layer wind turning SGP



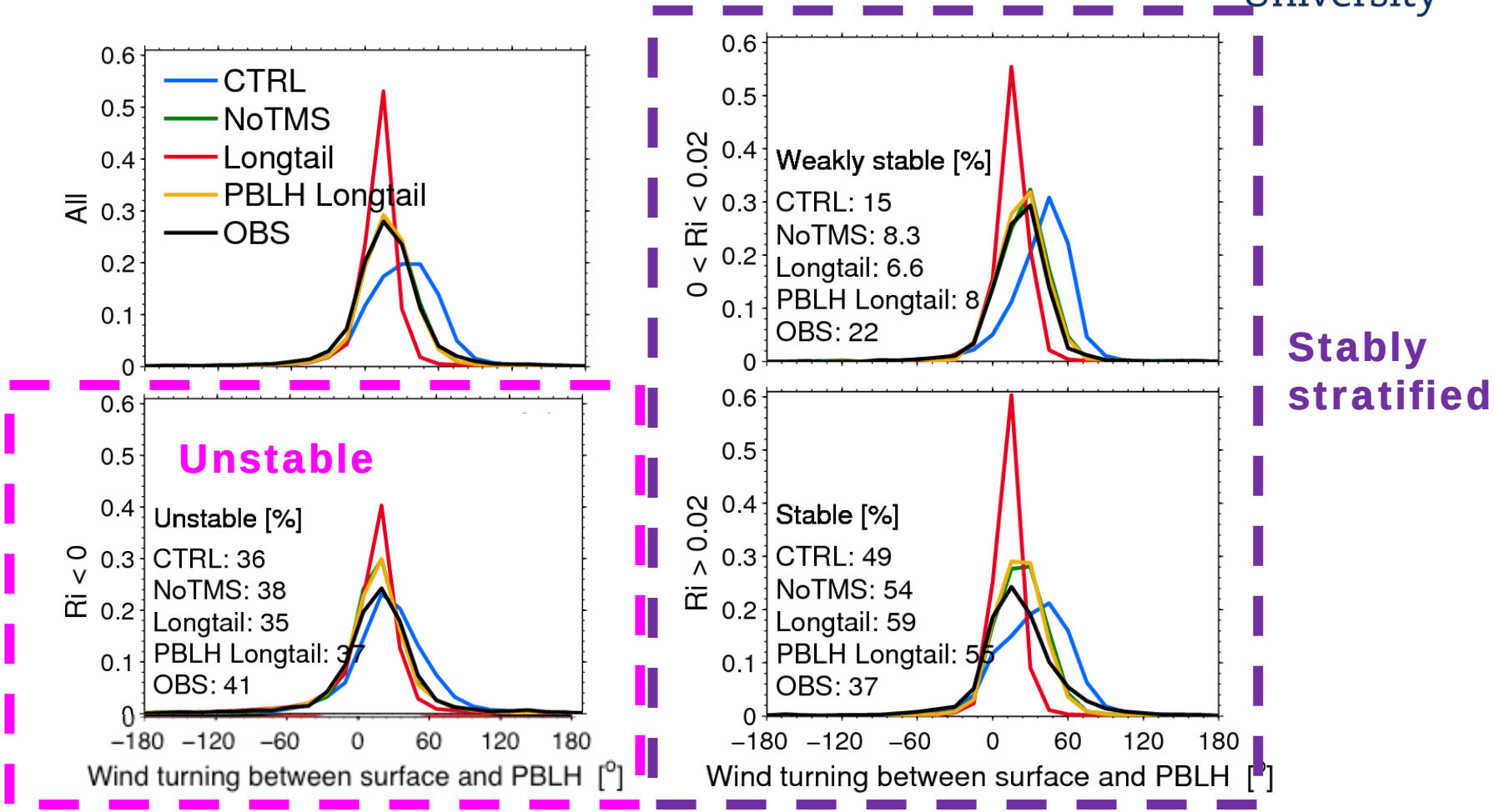
The TMS in the CONTROL run gives too large wind turning over the boundary layer

Longtail has the smallest wind turning

No TMS and PBLH Longtail are very close to observations

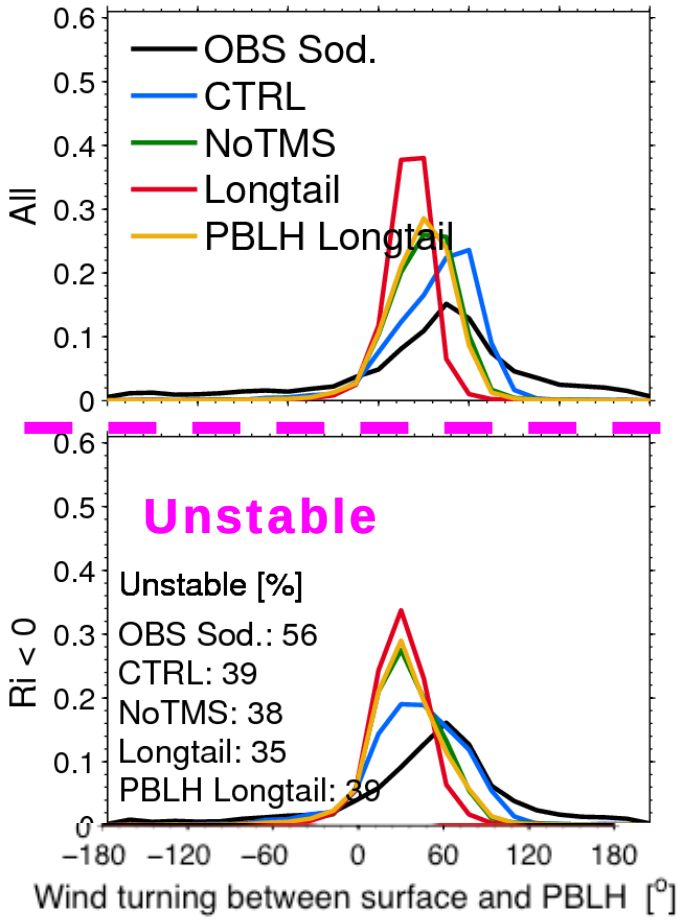
Boundary layer wind turning SGP

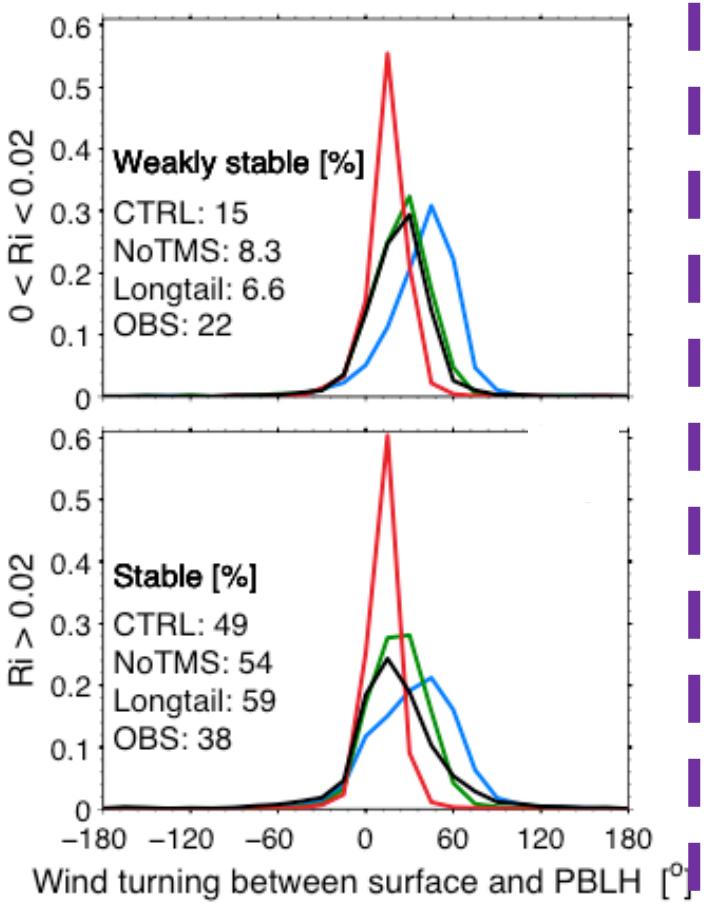
Stockholm University



Boundary layer wind turning Sodankylä

Stockholm University



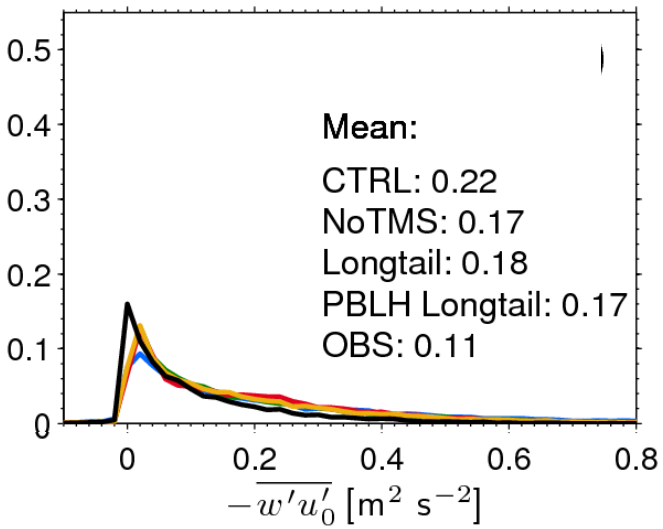


Stably stratified

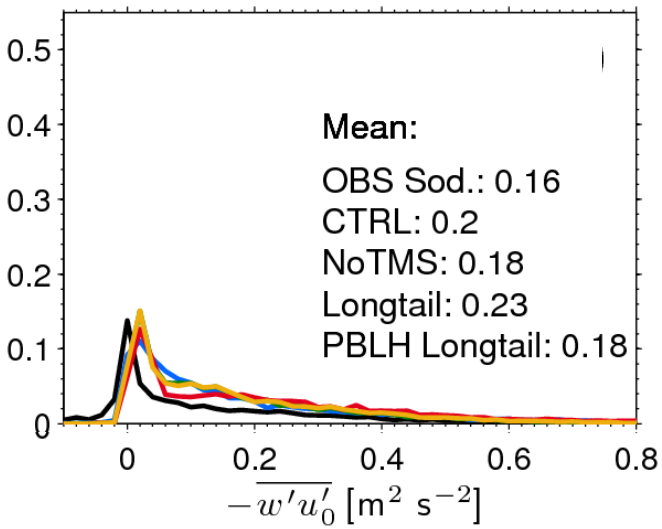
PBL cross-isobaric flow

Stockholm University

SGP



Sodankylä



All simulations have more cross-isobaric flow than the observations at the Southern Great Plains site

At Sodankylä the CONTROL and Longtail have too much, the other two compares well with observations

Summary

Stockholm University

Comparing the control simulation with experiments without turbulent orographic drag and with more turbulent diffusivity (longtail), we conclude:

- The orographic surface drag (TMS) has a substantial impact on both the boundary layer (wind turning over the PBL) and the general circulation (blocking frequency, stream functions, surface pressure)
- Increasing the turbulent diffusivity has not the same effect as the turbulent orographic surface drag in CAM5
- Only two sites are examined regarding the wind turning and cross-isobaric flow so far