Further developments to parameterized orographic drag in CAM

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Overview

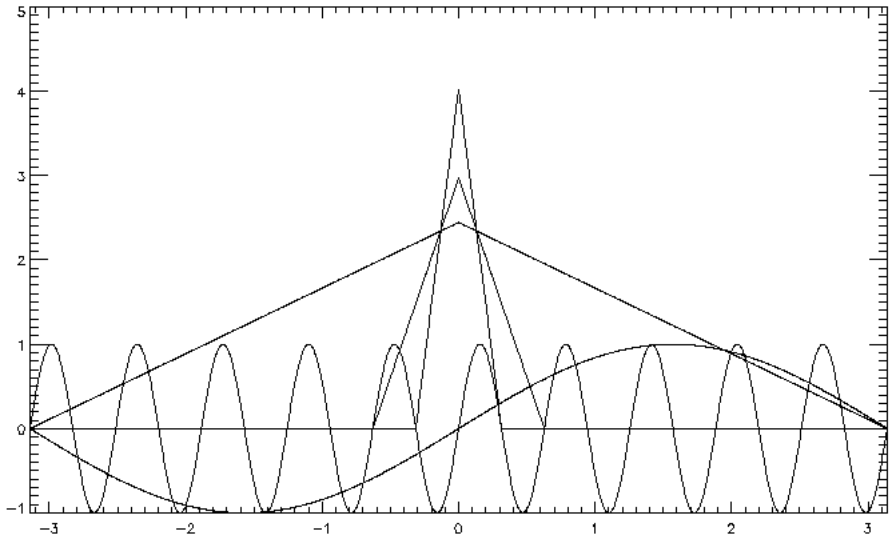
- Background
- Anisotropic/blocking scheme description
- Results
  - AMIP results
    - Isotropic vs Ridge schemes
    - TMS vs no-TMS
  - CAPT
- Future work

Ridge-based orographic drag scheme

- Anisotropy
- Low-level processes (blocking)
- Multiple ridges

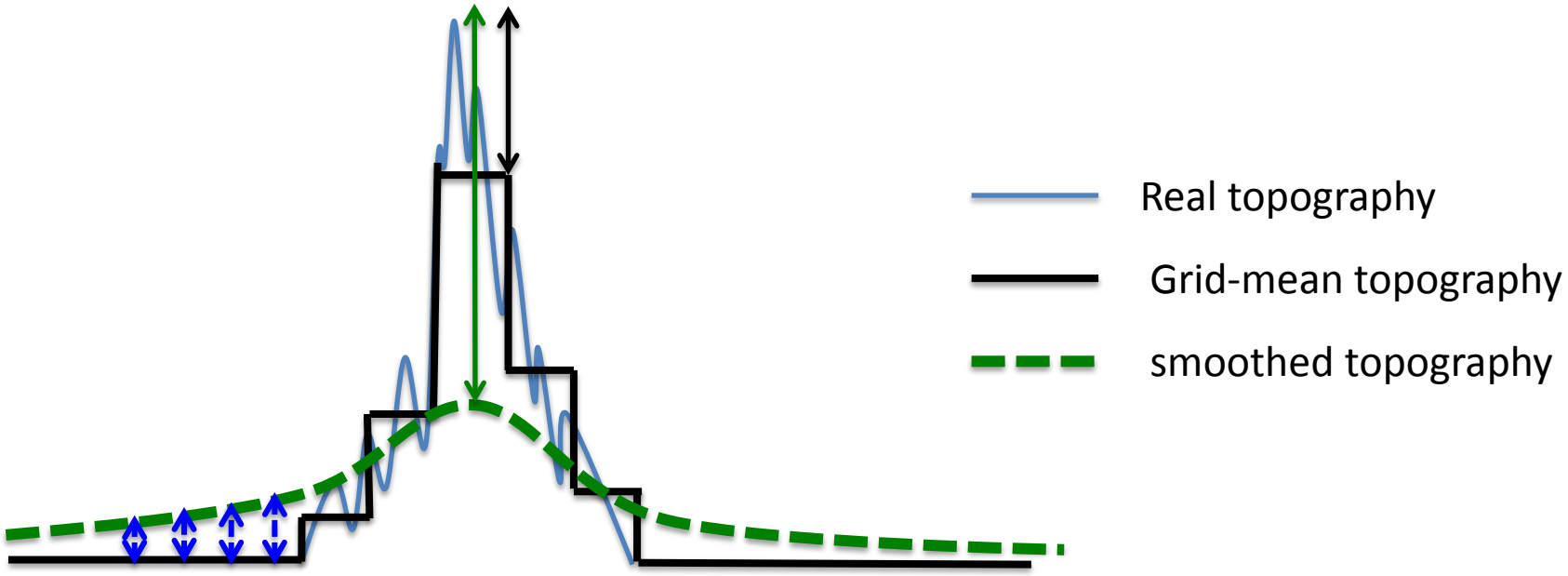
- *Soon: trapped lee waves from meso-γ ridges (L<20km)*

Subgrid variance may not be a good way to diagnose forcing for orographic gravity waves



Cross-sections with approximately equal variances

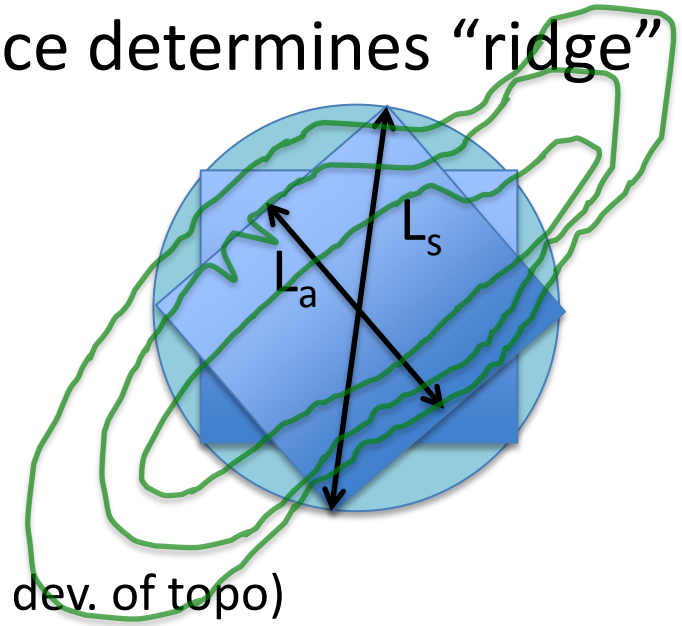
Sub-grid vs. unresolved



Most models smooth topography. What should be parameterized, e.g.: Figure above – green arrow or black arrow? What about blue arrows?

Feature-based ridge identification

- Smooth (Bandpass) topography (scale ~ L_s)
- Calculate variances of mean cross-sectional profiles at 16 different orientations on L_axL_a domains
- Maximum 1D vs 2D variance determines “ridge” angle

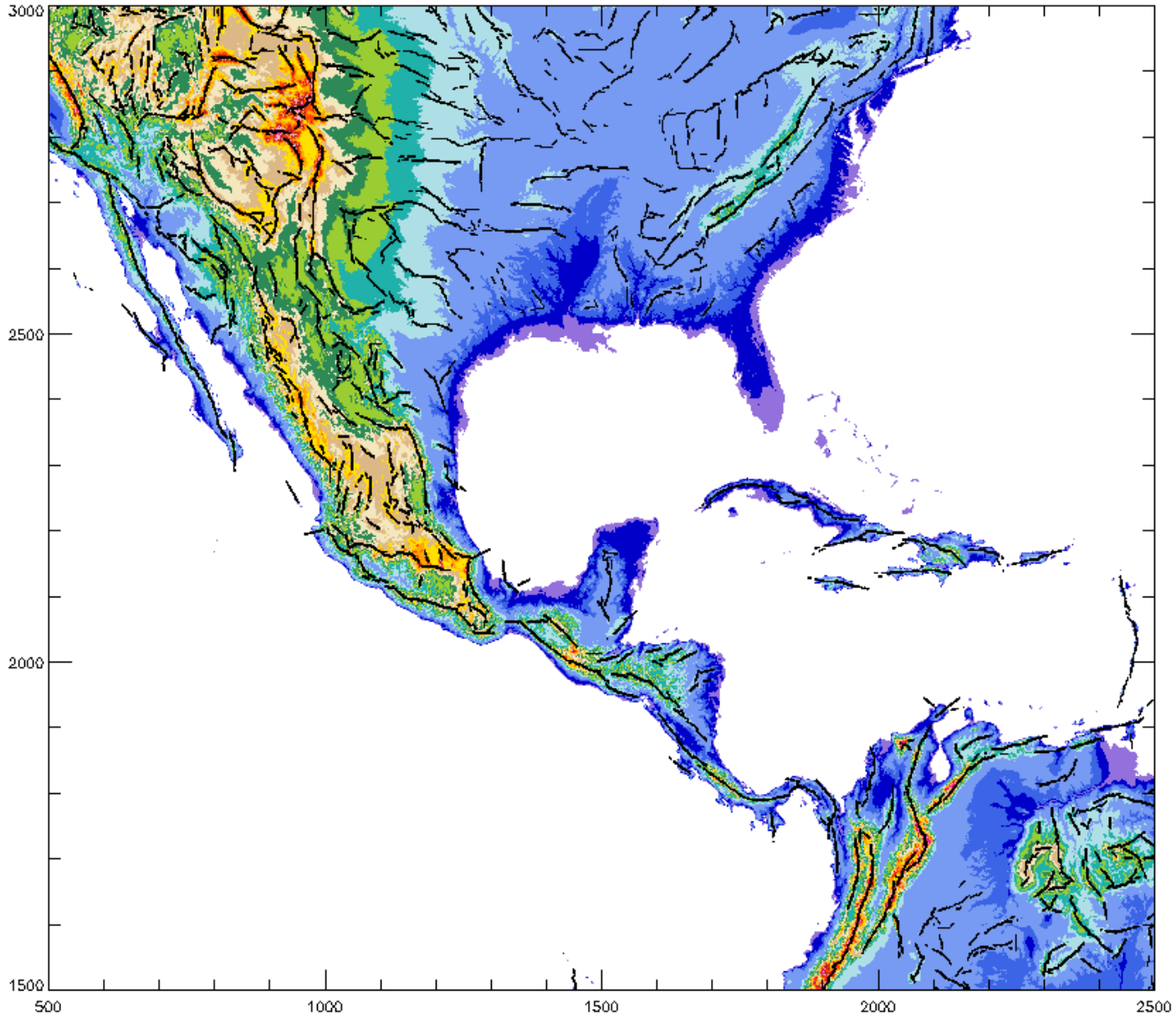


- Outputs
  - Orientation
  - Ridge height (different from std. dev. of topo)
  - Geographically-based estimate of “effgw_oro”
  - Estimate of ridge width
  - “quality” ratio of 1D/2D variance

Feature-based ridge identification

Feature scale
~125km

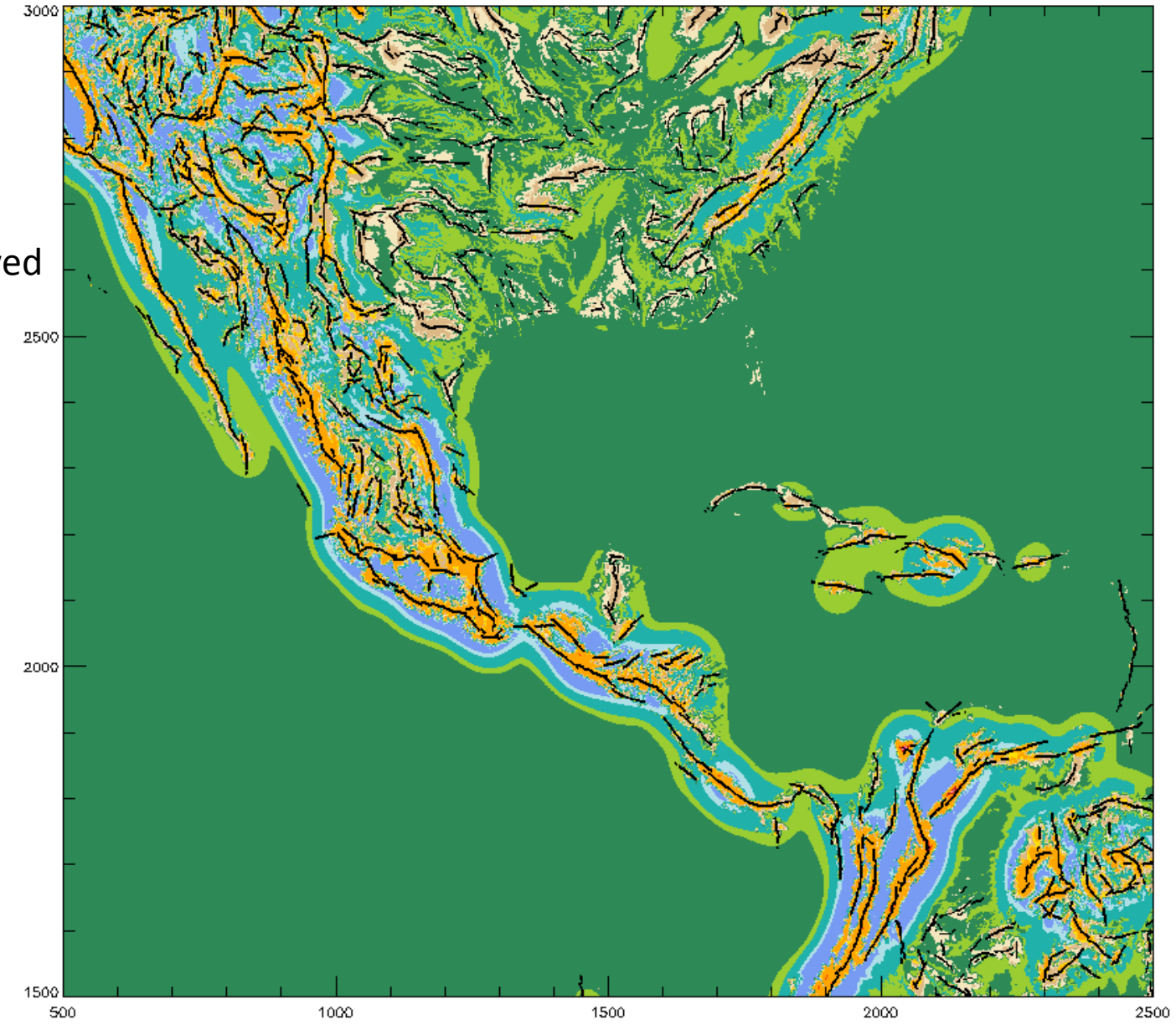
Plotted over raw 3km
topography data



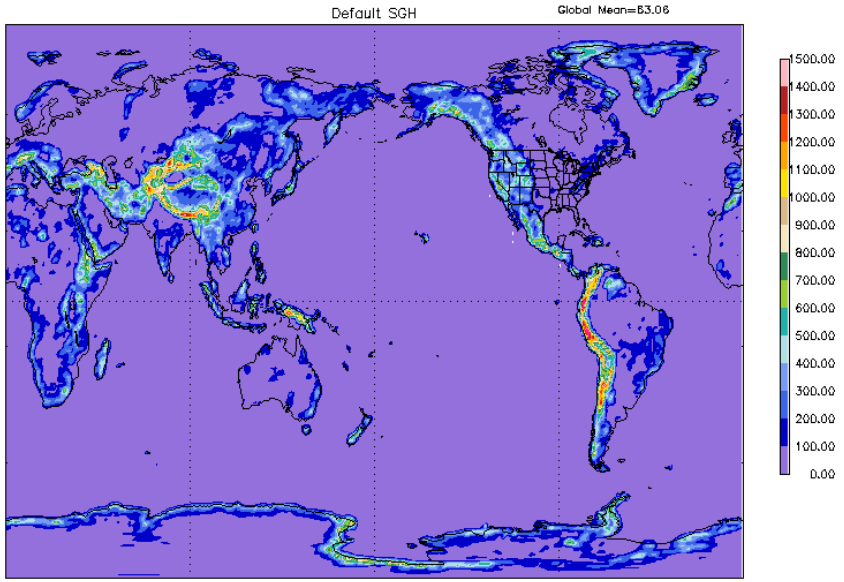
Feature-based ridge identification

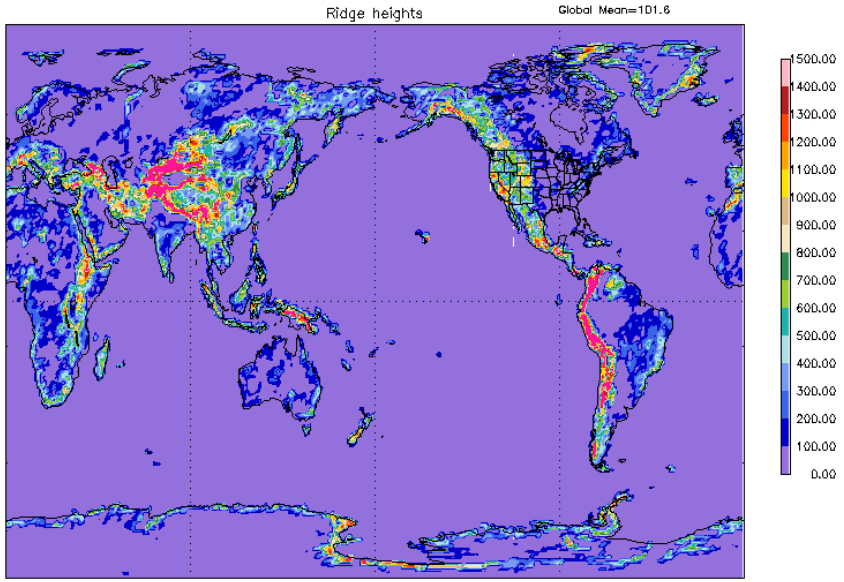
Feature scale
~125km

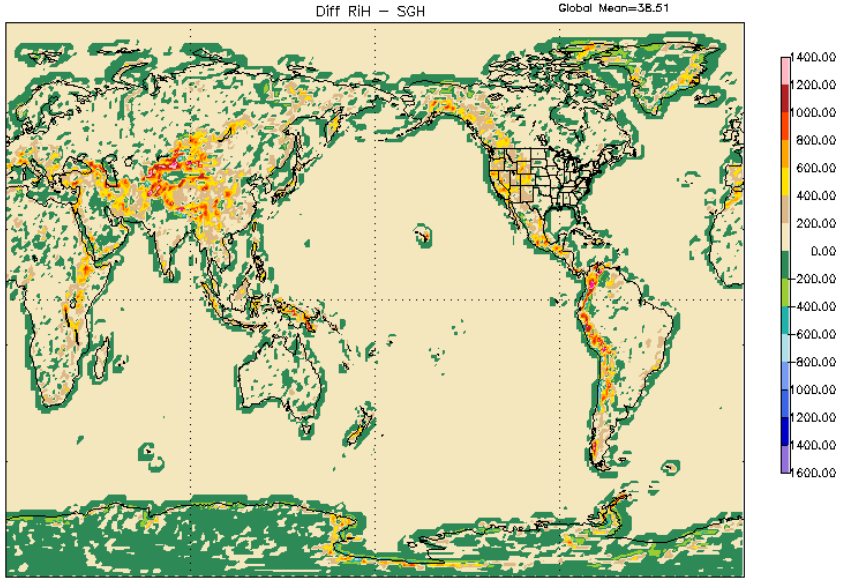
Plotted over unresolved topography:
Raw-Smooth(180km)



Feature-based ridge identification







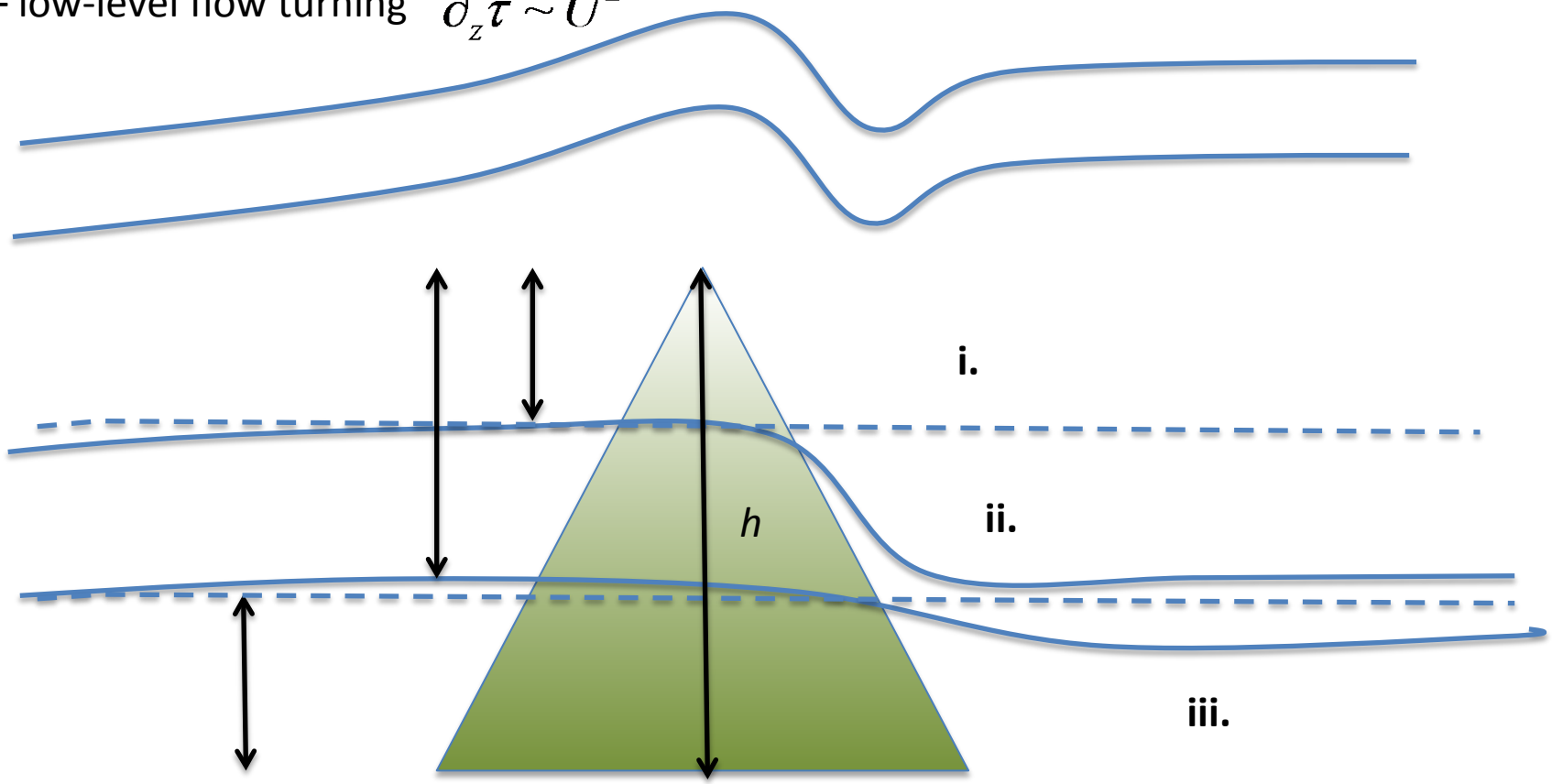
Blocking, low-level turning

(follows Scinocca&McFarlane 2000)

i – vertically propagating waves $\partial_z \tau$ via saturation

ii - downslope wind layer $\partial_z \tau \sim (\tau_{dsw} - \tau_{sat}) / H_{dsw};\ \tau_{dsw} = \alpha \tau_{sat}$

iii – low-level flow turning $\partial_z \tau \sim U^2$

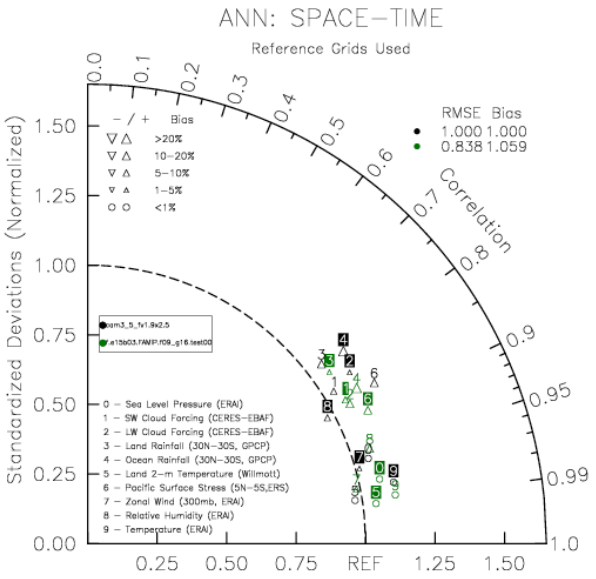


AMIP runs 1/1979-1/2000

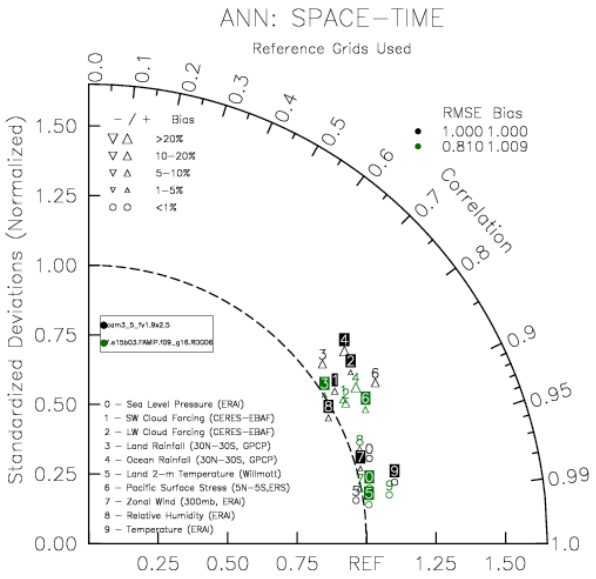
- FV 0.9x1.25 *(Ridge Scheme is ready for SE as well)*
- 8 runs
  - Default GW scheme (4): CAM5.4/CLUBB; TMS/No-TMS
  - Ridge-based scheme(4): CAM5.4/CLUBB; TMS/No-TMS
- *A PI-1850 coupled run has started with Ridge-based scheme, CLUBB, No-TMS. 20-years done*

- *All use GTOPO30 not GMTED due to apparent errors in GMTED over Antarctic Peninsula*

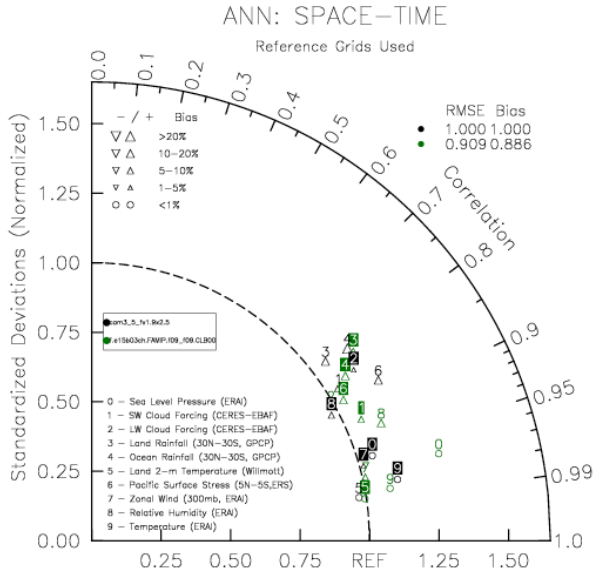
CAM5.4 +IsoGWD +TMS



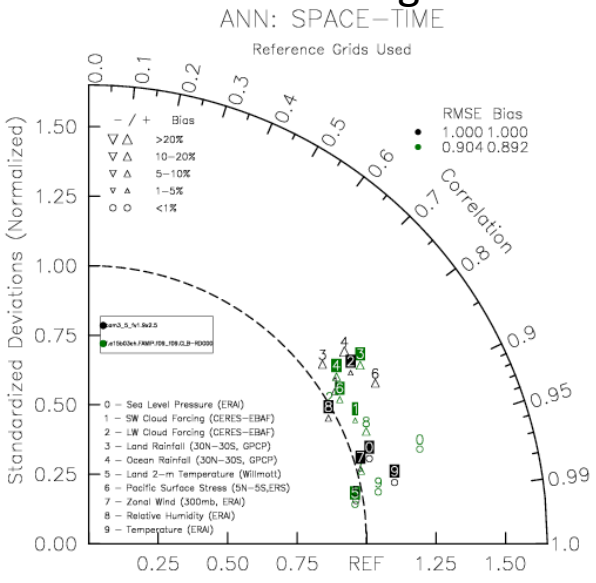
CAM5.4 +Ridge -TMS



CAM-CLUBB +IsoGWD +TMS



CAM-CLUBB +Ridge -TMS

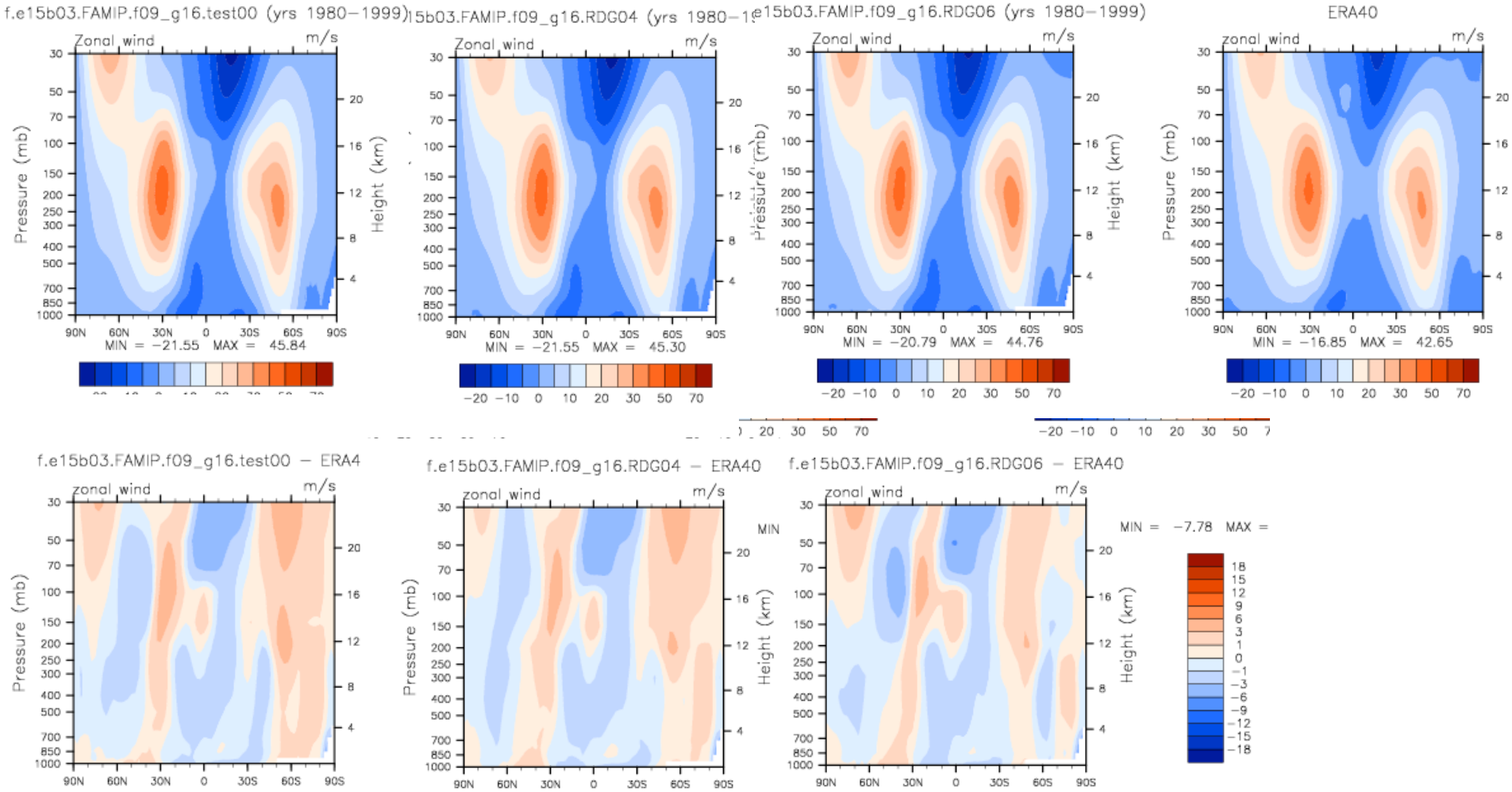


DJF Zonal mean winds (CAM5.4)

Isotropic GWD

Ridge-based GWD

Ridge-based GWD ***w/out TMS***

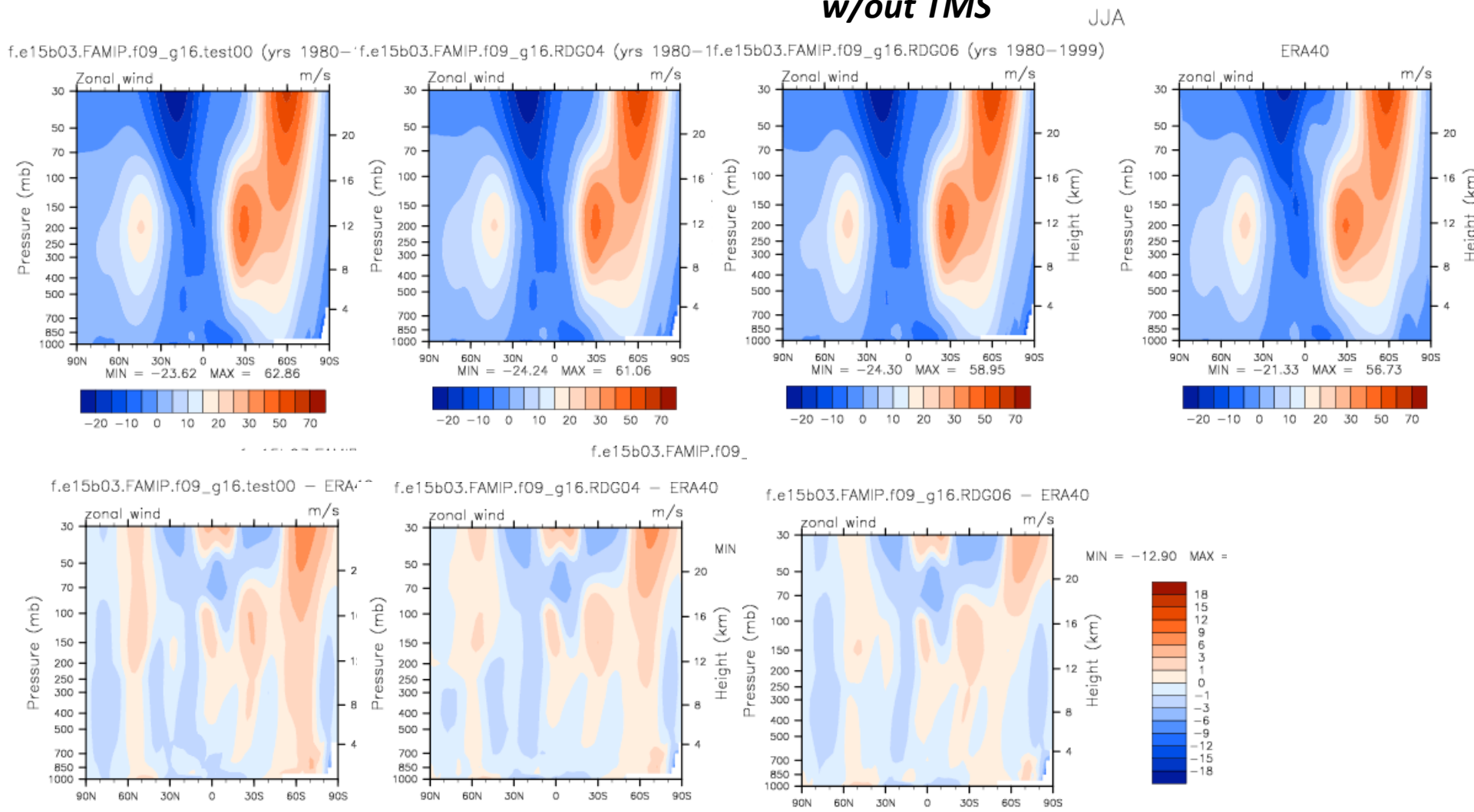


JJA Zonal mean winds (CAM5.4)

Isotropic GWD

Ridge-based GWD

Ridge-based GWD ***w/out TMS***

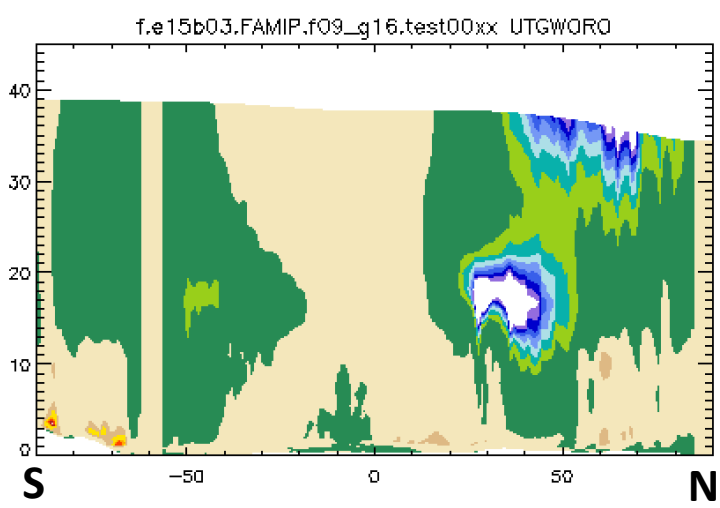


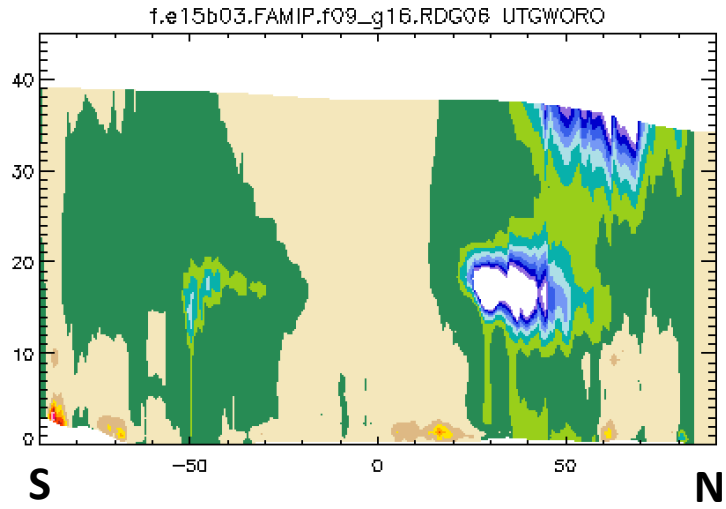
Zonal mean GW zonal wind tendencies

Isotropic GWD

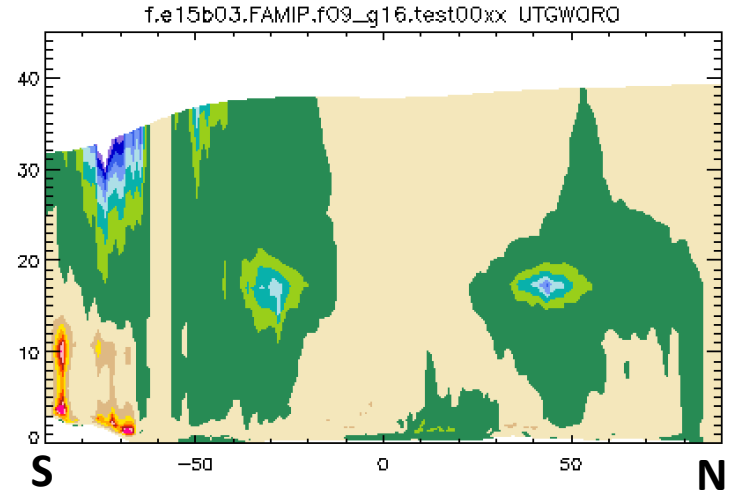
Ridge-based GWD
w/out TMS

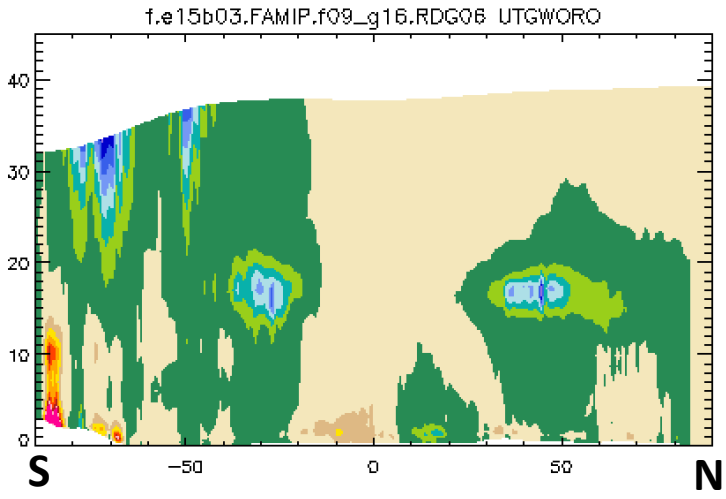
DJF





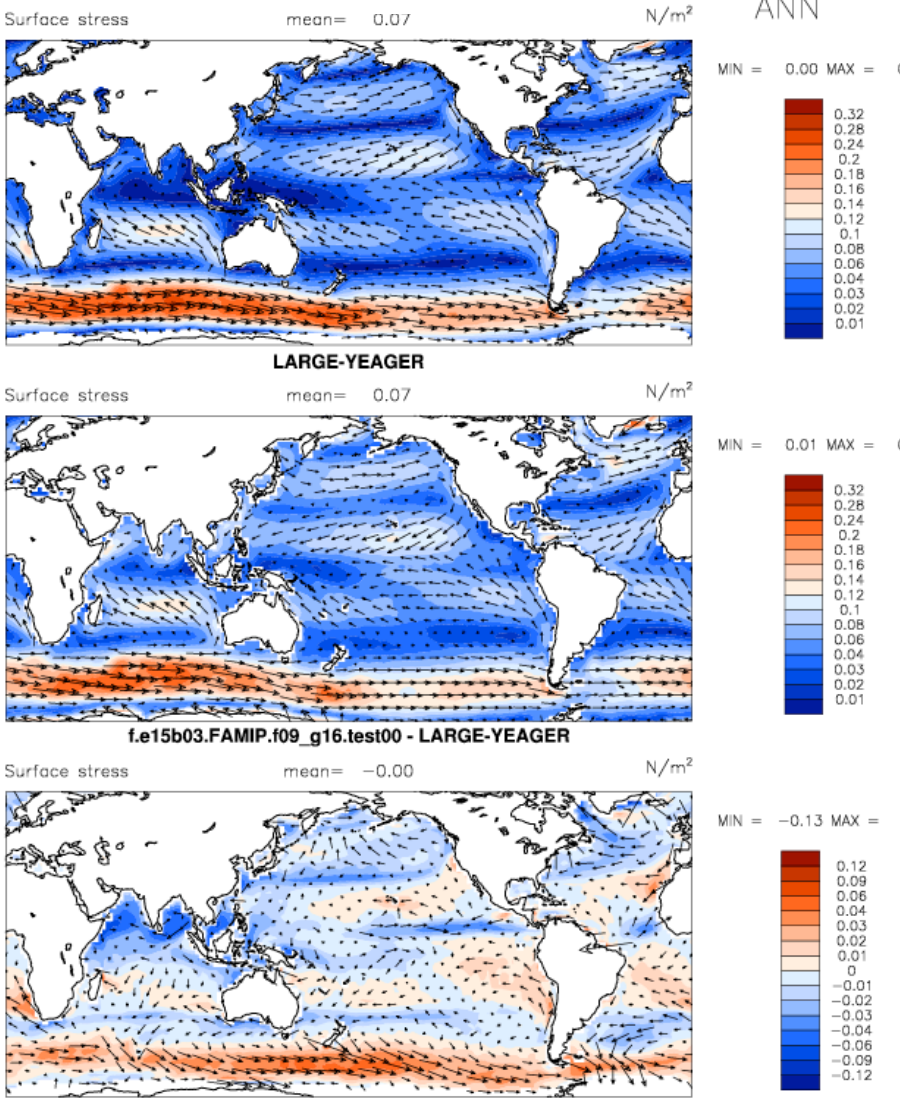
JJA





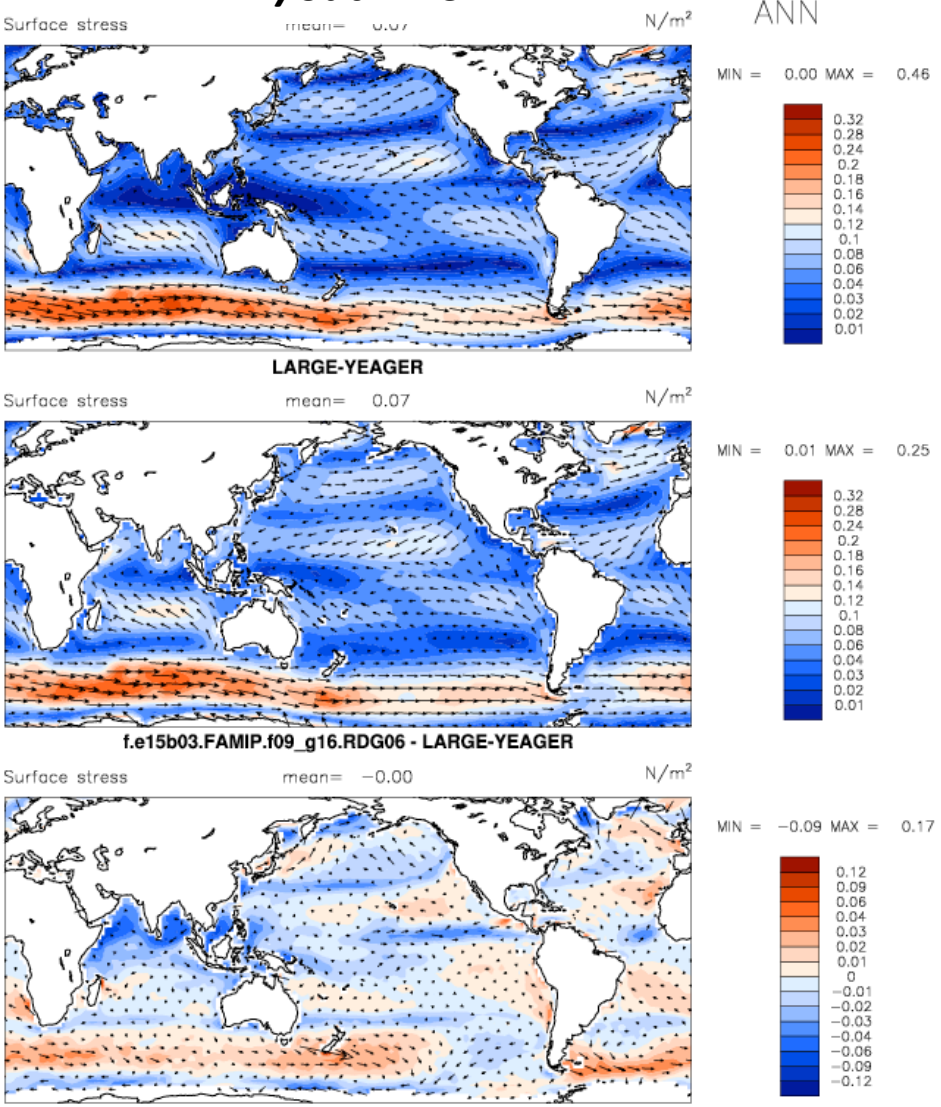
Annual mean wind stress (CAM5.4)

Isotropic GWD



Ridge-based GWD

w/out TMS



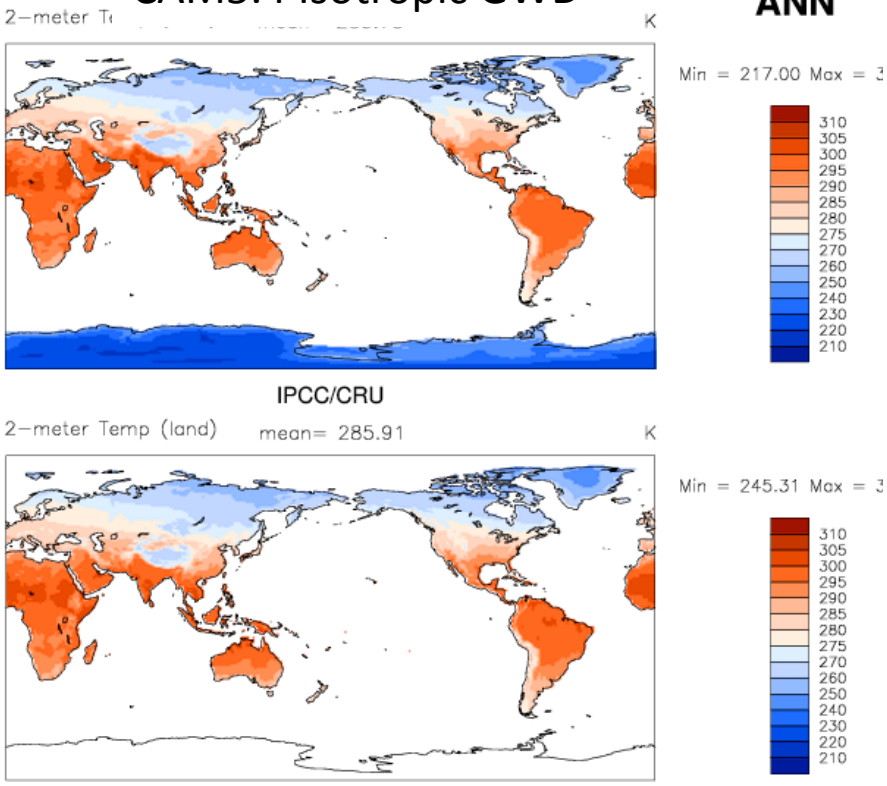
- Ridge based scheme improves SH without detrimental effects on NH
- Overall improvements in wind-stress

- With CAM-CLUBB – more mixed results

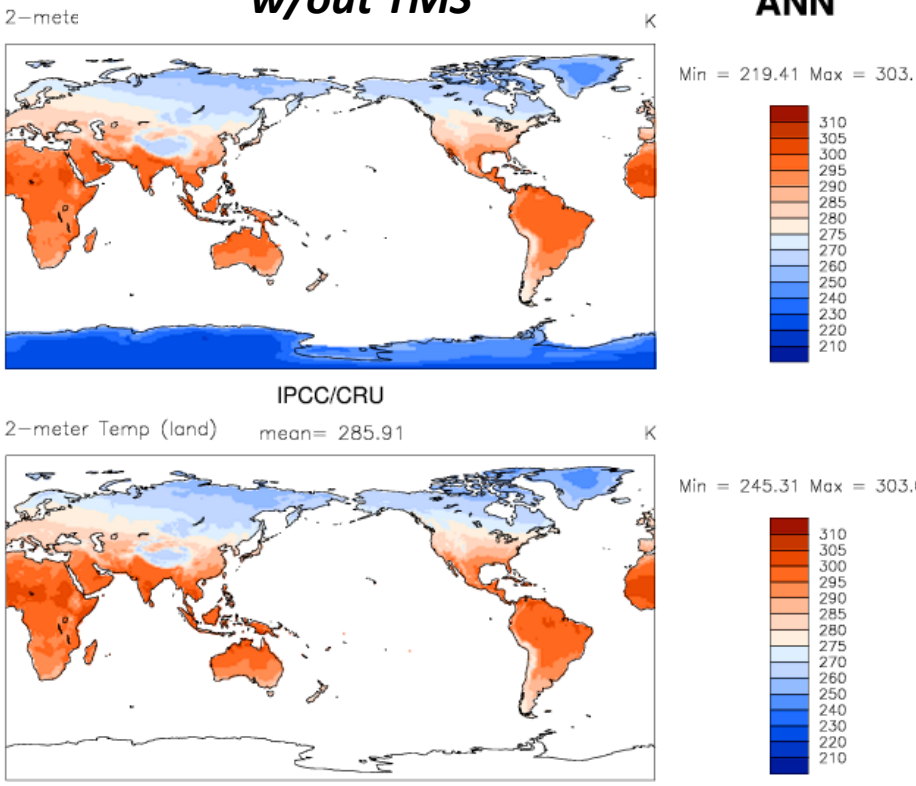
More effects of Turbulent Mountain Stress (TMS)

Annual mean 2m Temperatures

CAM5.4 Isotropic GWD

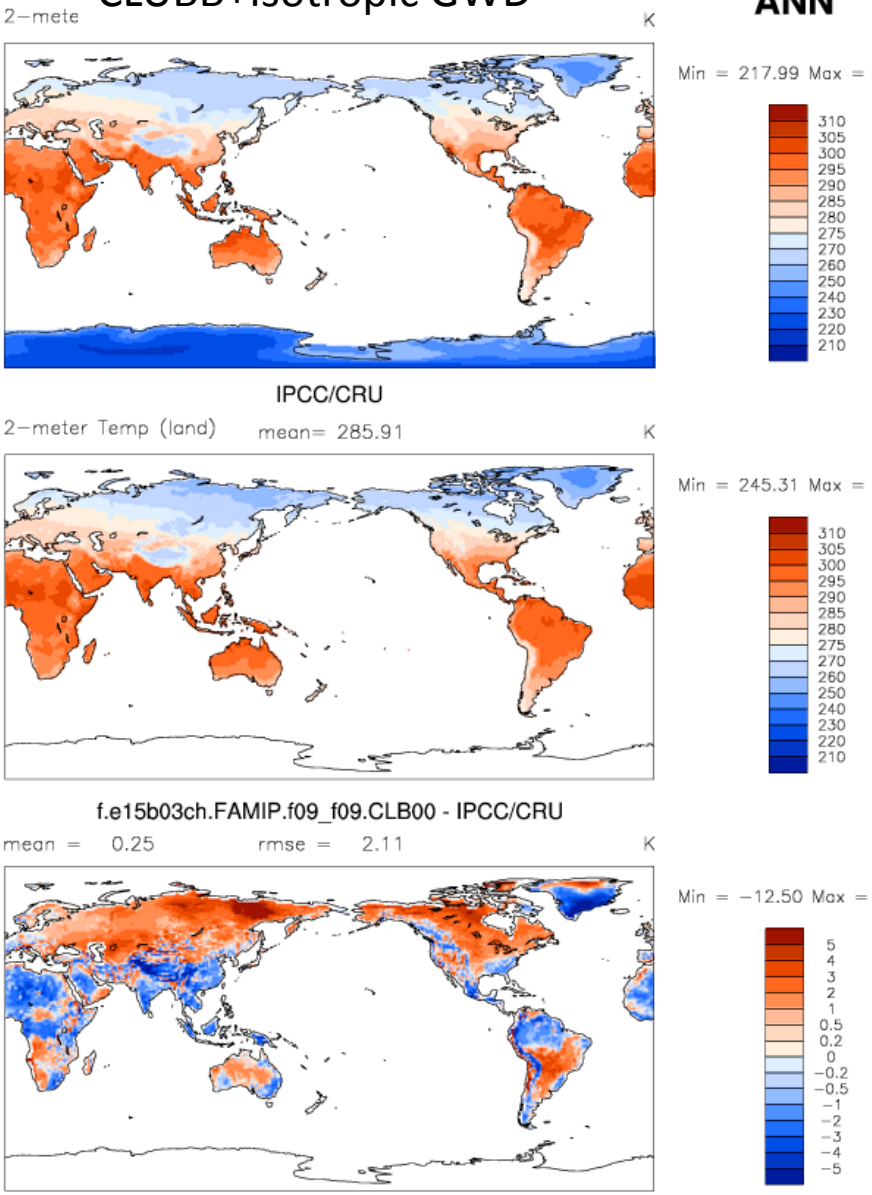


CAM5.4 Ridge-based GWD ***w/out TMS***

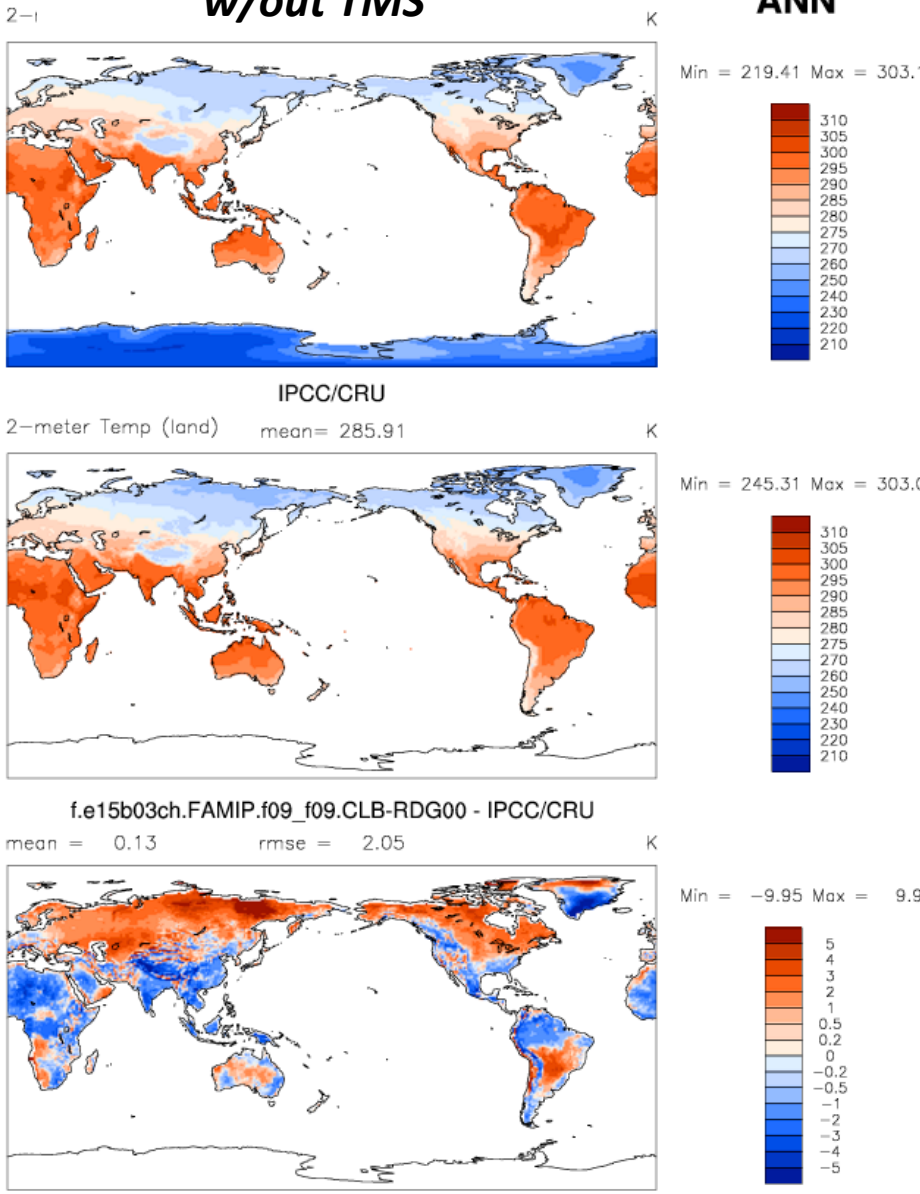


Annual mean 2m Temperatures

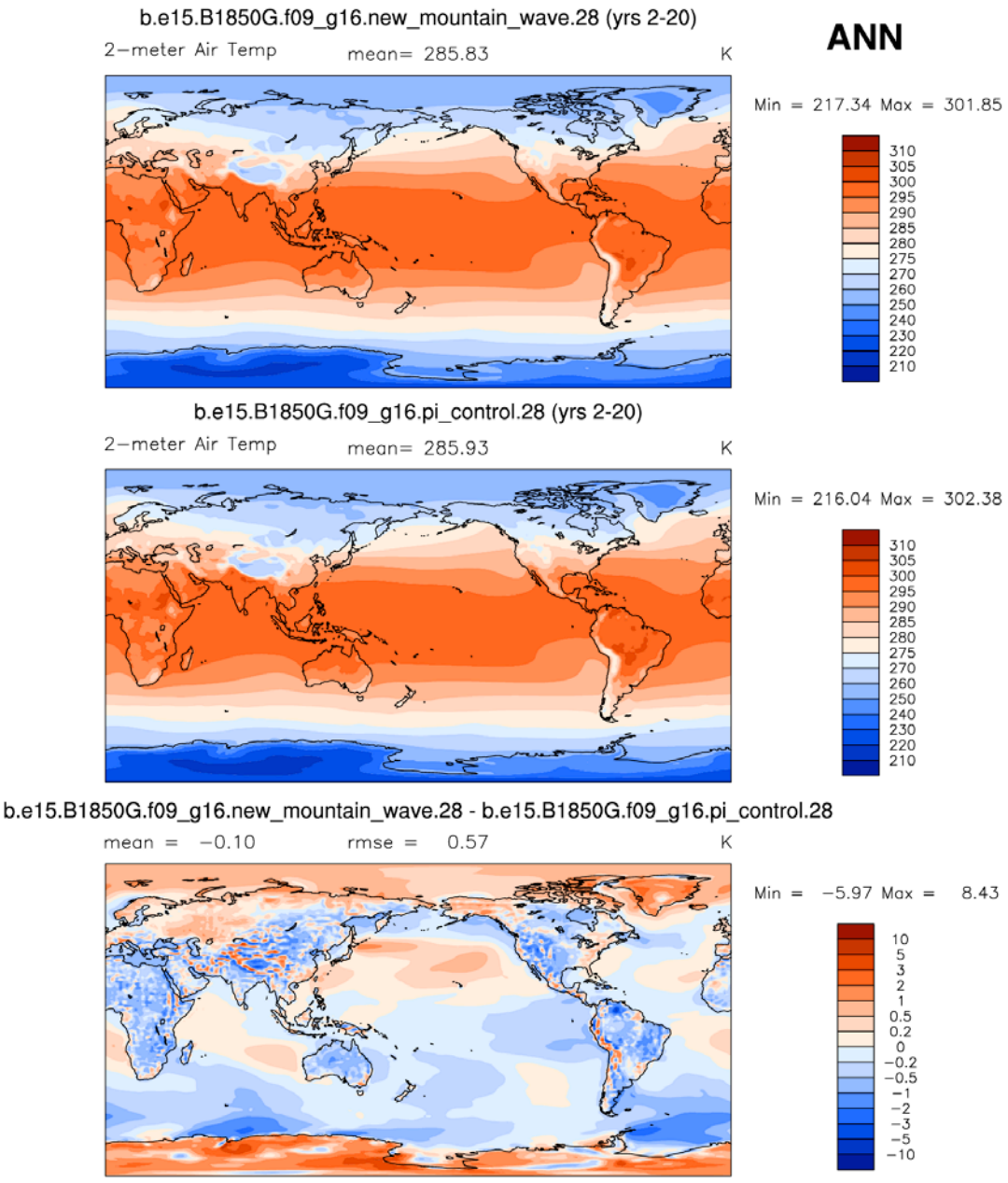
CLUBB+Isotropic GWD



CLUBB+Ridge-based GWD ***w/out TMS***



Annual mean 2m Temperatures (coupled runs)

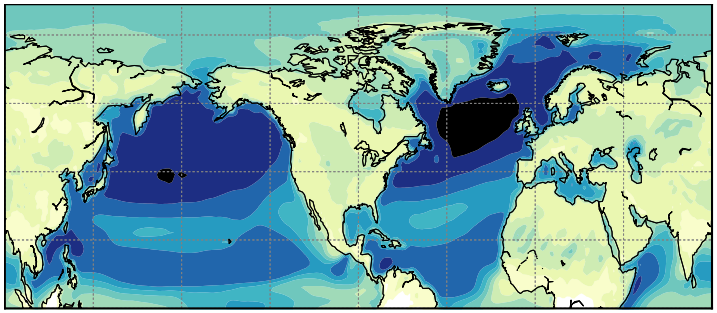


CLUBB+Ridge-based GWD
w/out TMS

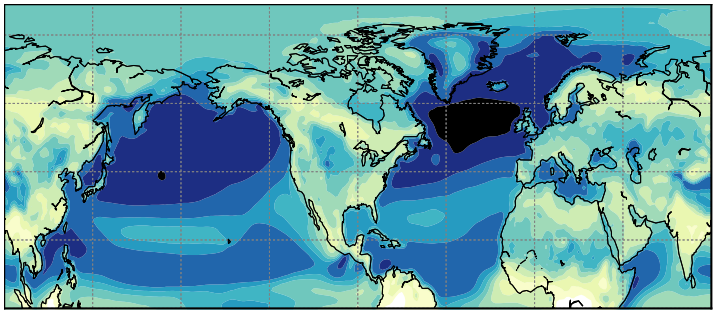
CLUBB+Isotropic GWD

DJF 10m Winds

Ridge-based GWD
including TMS



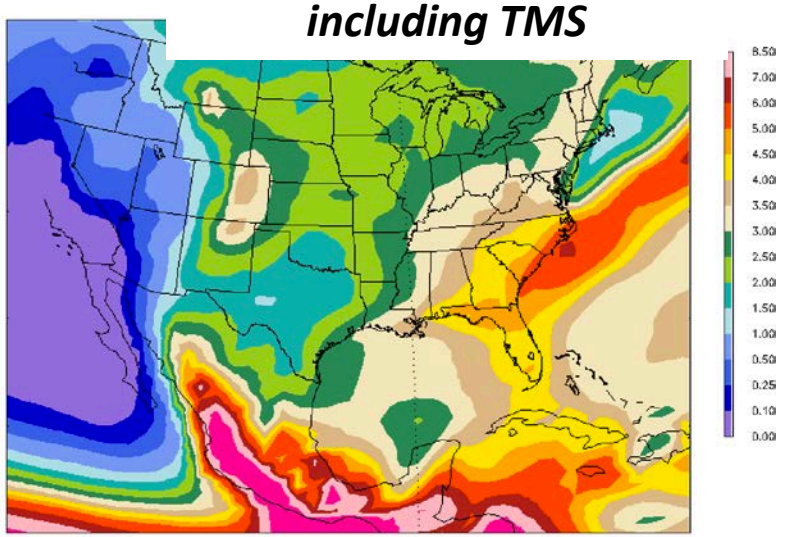
Ridge-based GWD
w/out TMS



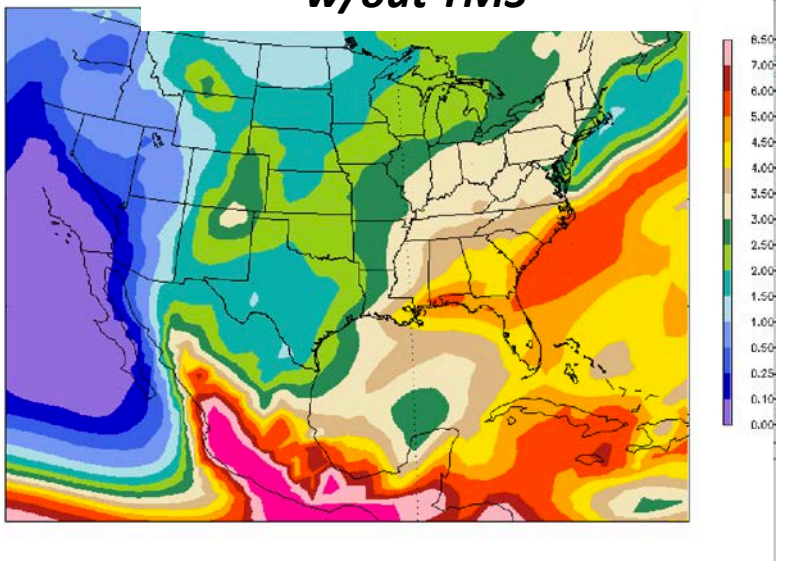
Courtesy of Marcus Löfverström

JJA Precipitation

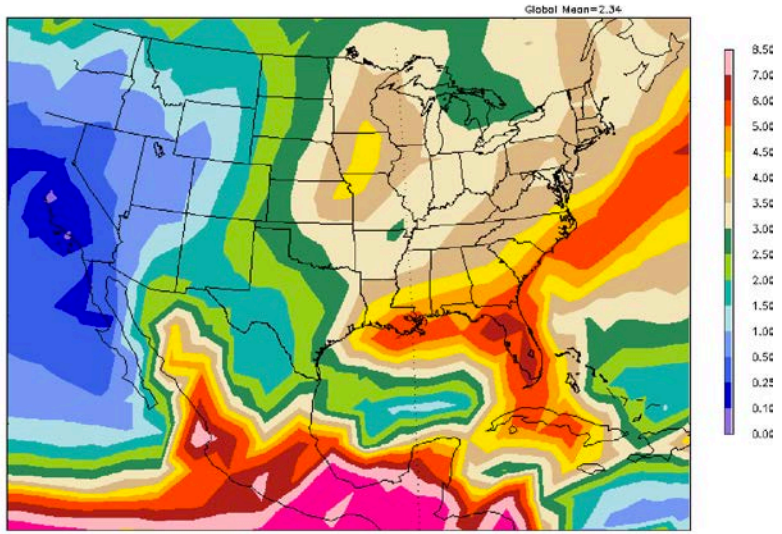
CAM5.4 w/ Isotropic GWD
including TMS



CAM5.4 w/Isotropic GWD
w/out TMS

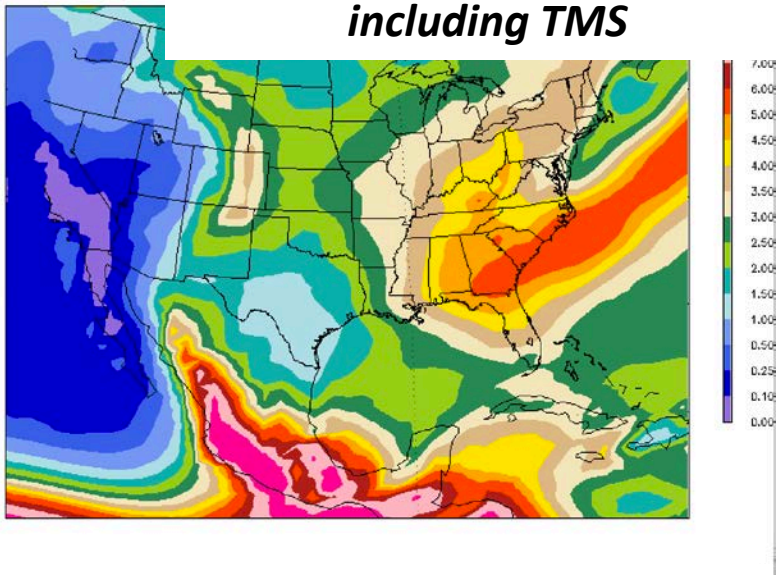


GPCP

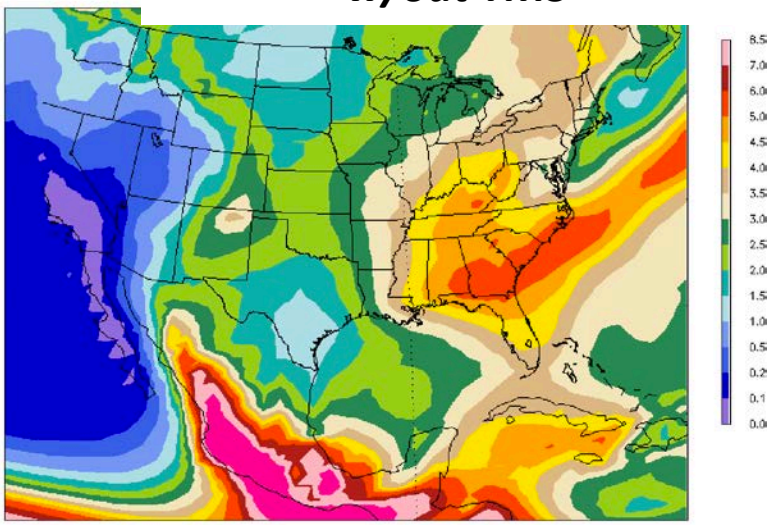


JJA Precipitation

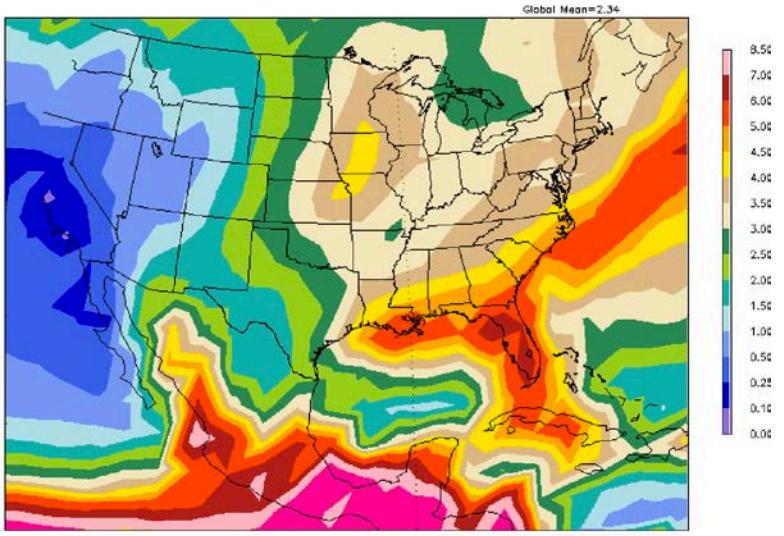
CAM-CLUBB w/ Isotropic GWD
including TMS



CAM-CLUBB w/Isotropic GWD
w/out TMS



GPCP



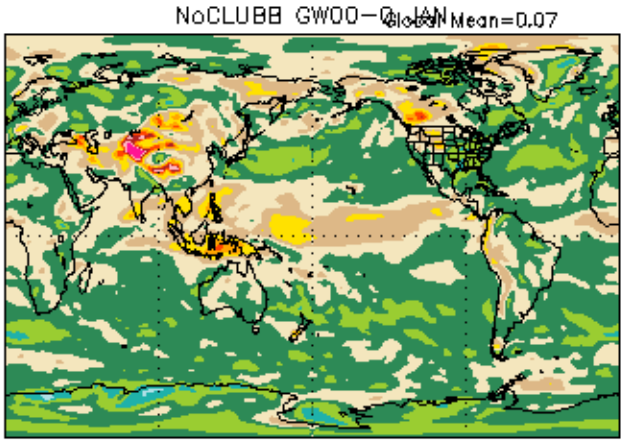
- TMS may lead to biases in 10m, 50m winds
- TMS exacerbates JJA Rocky Mtn precip bias
- TMS could contribute to warm bias in central US

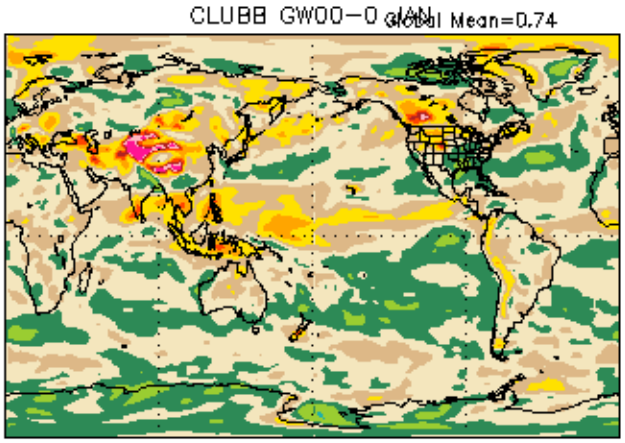
CAPT forecasts 12/2005-3/1/2006

- Forecasts initialized from ERA-I reanalyses
- 4-times per day 00,06,12,18Z run for 15 days

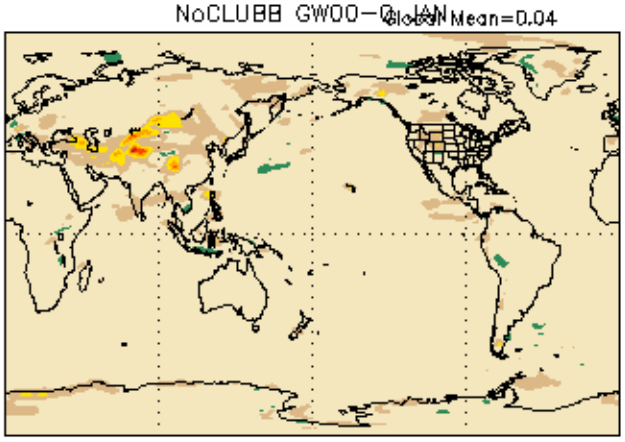
January mean 900-700 hPa wind-speed errors at day 3 00Z

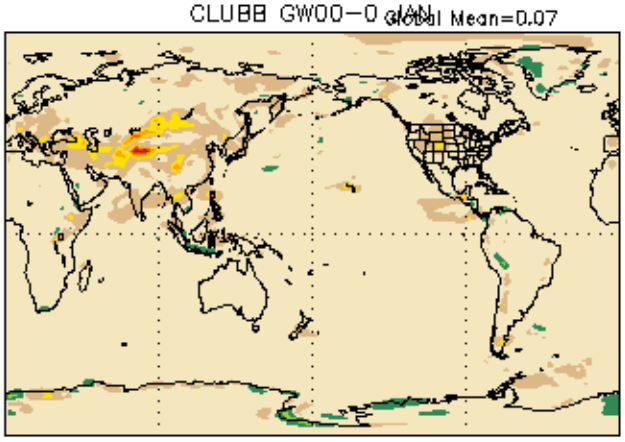
Validated against ERA-I





Change in error w and w/out Ridge based scheme

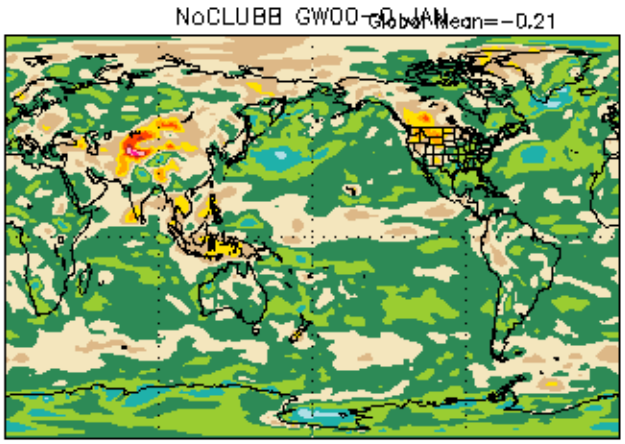


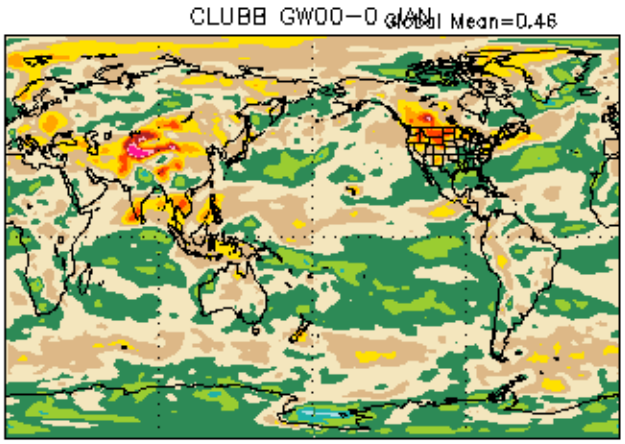


Yellow-red ➔improvement with Ridge-based scheme

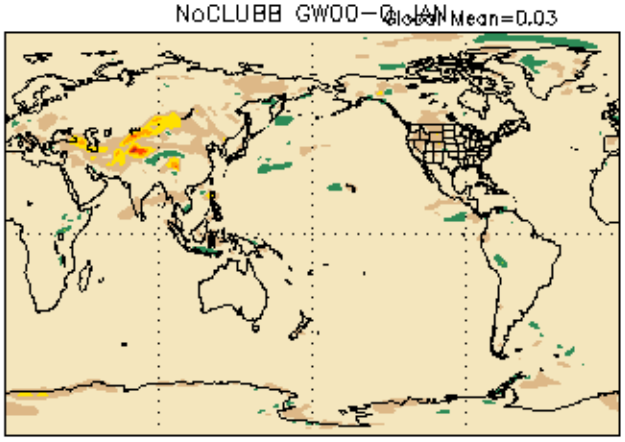
January mean 900-700 hPa wind-speed errors at day 3 00Z

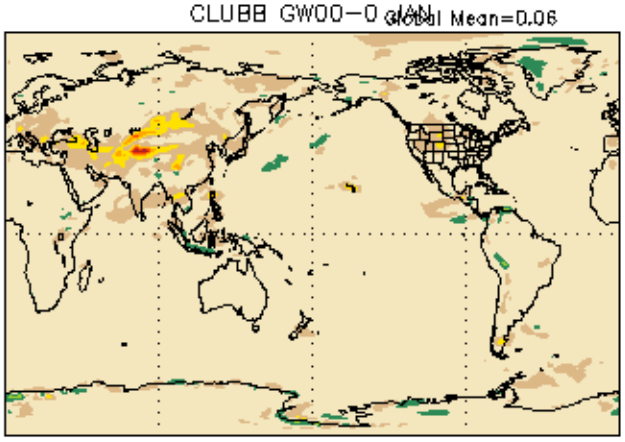
Validated against MERRA



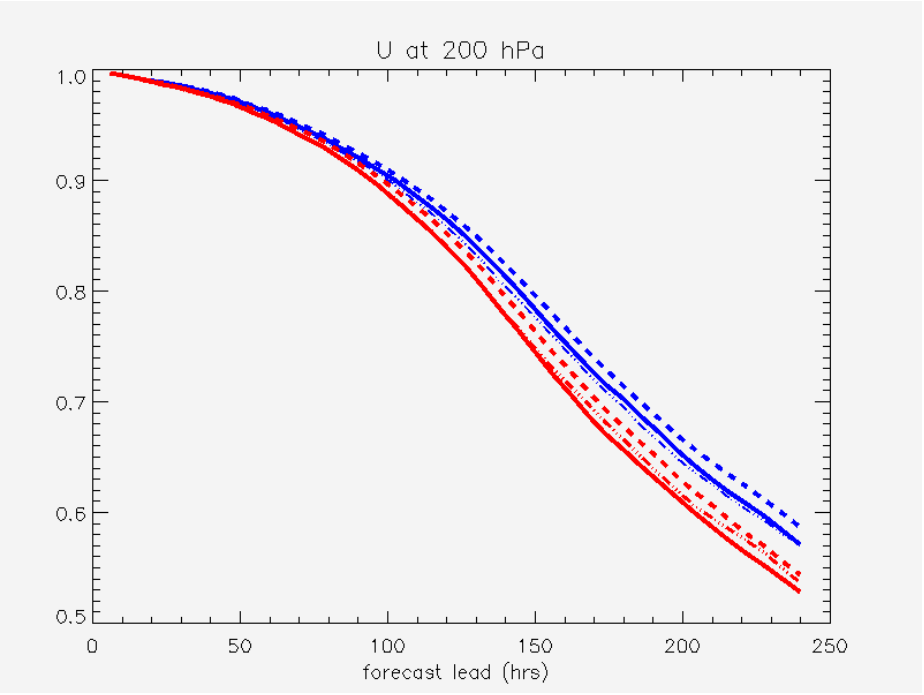


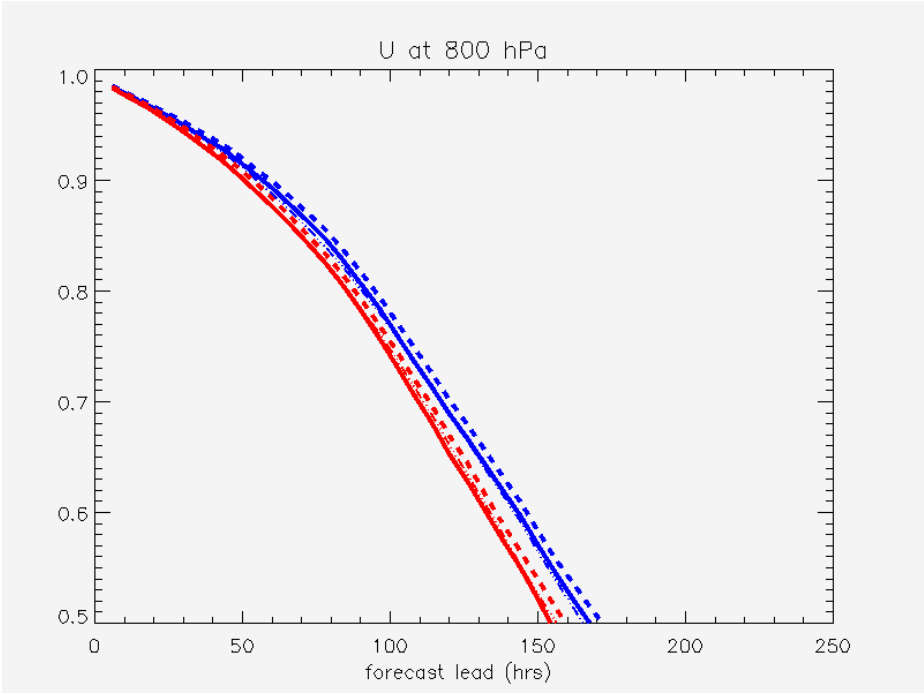
Change in error w and w/out Ridge based scheme





January mean NH anomaly correlation in Zonal wind





CAM5.4

CAM5.5 (CAM-CLUBB)

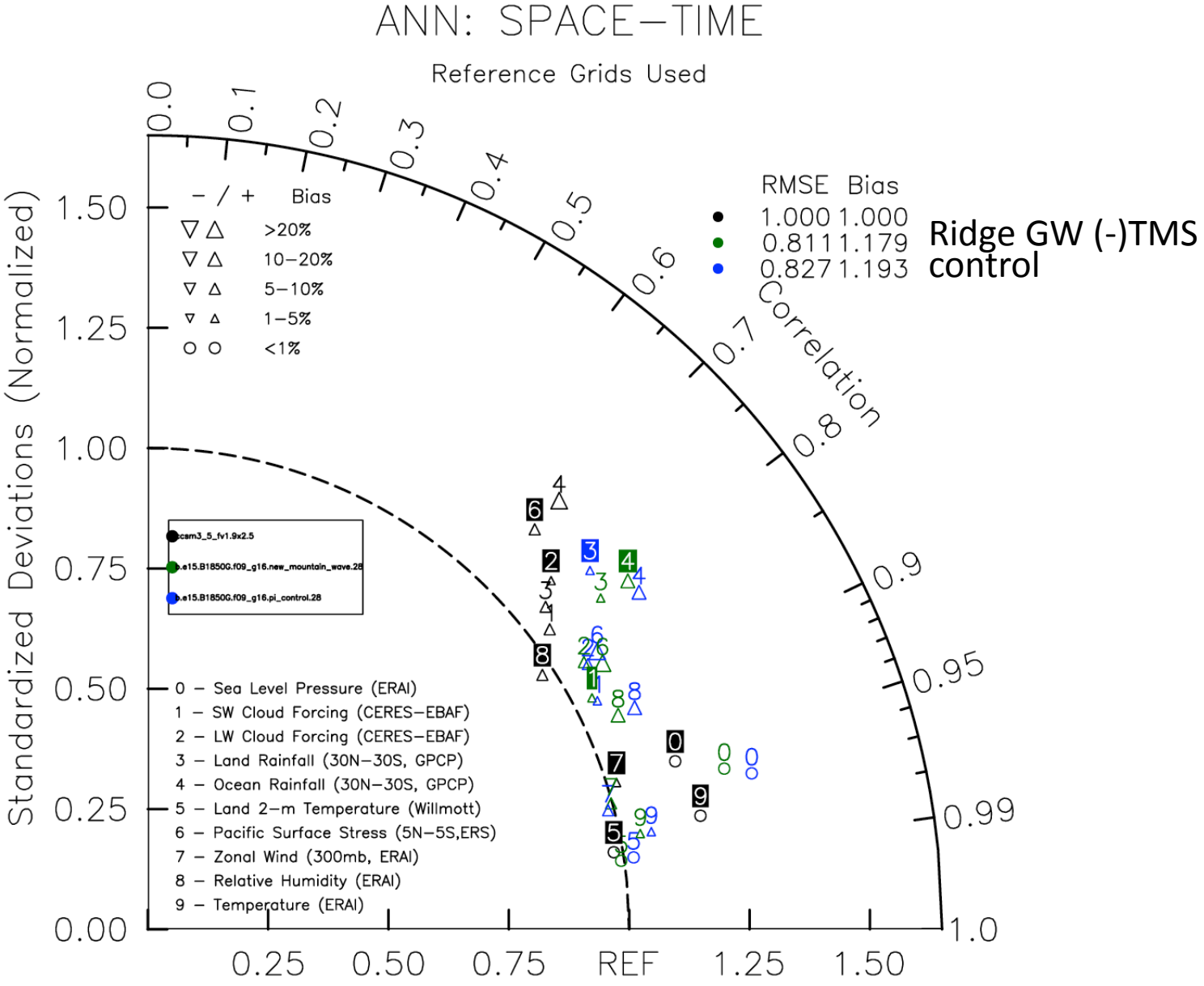
Isotropic GWD +TMS

Ridge GWD +TMS

Ridge GWD -TMS

Future work

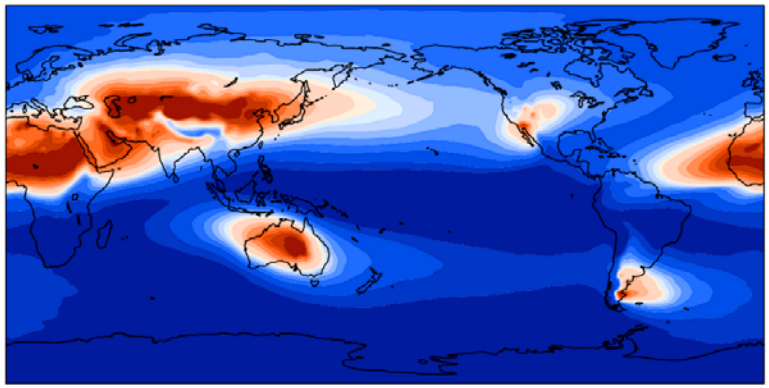
- Diagnose momentum processes in CAM
  - Low-level flow parameterization in Ridge GW
  - Lee-waves/retune TMS/Beljaars
  - Momentum mixing in CLUBB
  - Sub-cycle drag processes
  - Comparisons with *U, V* in radiosonde data
  - DART
- WACCM simulation to see effects of Ridge GW on SSWs
- Anisotropic TMS
- Topography data set quality control (e.g. missing Antarctic Peninsula in GMTED)
- *Couple to microphysics (w/ Xiaohong Liu)*


ANN: SPACE–TIME
Reference Grids Used
Standardized Deviations (Normalized)
Correlation
RMSE Bias
1.000 1.000
0.811 1.179
0.827 1.193
Ridge GW (-)TMS
control
– / + Bias
>20%
10–20%
5–10%
1–5%
<1%
0 – Sea Level Pressure (ERAI)
1 – SW Cloud Forcing (CERES–EBAF)
2 – LW Cloud Forcing (CERES–EBAF)
3 – Land Rainfall (30N–30S, GPCP)
4 – Ocean Rainfall (30N–30S, GPCP)
5 – Land 2–m Temperature (Willmott)
6 – Pacific Surface Stress (5N–5S,ERS)
7 – Zonal Wind (300mb, ERAI)
8 – Relative Humidity (ERAI)
9 – Temperature (ERAI)
REF

b.e15.B1850G.f09_g16.new_mountain_wave.28 (yrs 2-20)

ANN

Total dust optical depth mean= 0.06 dimensionless



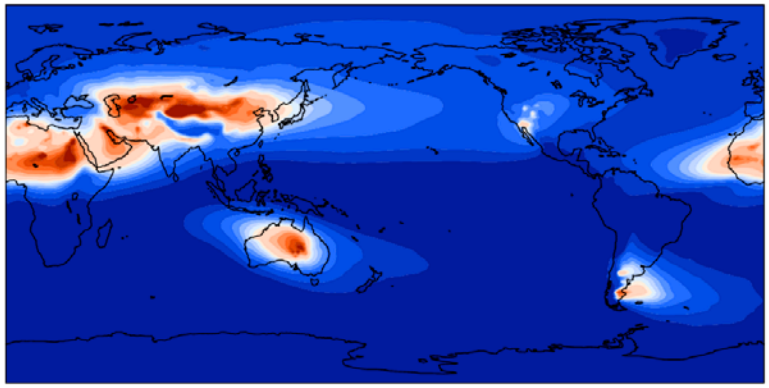
Min = 0.00 Max = 3.29

0.4
0.3
0.25
0.2
0.15
0.12
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.005

Ridge GW (-)TMS

b.e15.B1850G.f09_g16.pi_control.28 (yrs 2-20)

Total dust optical depth mean= 0.02 dimensionless



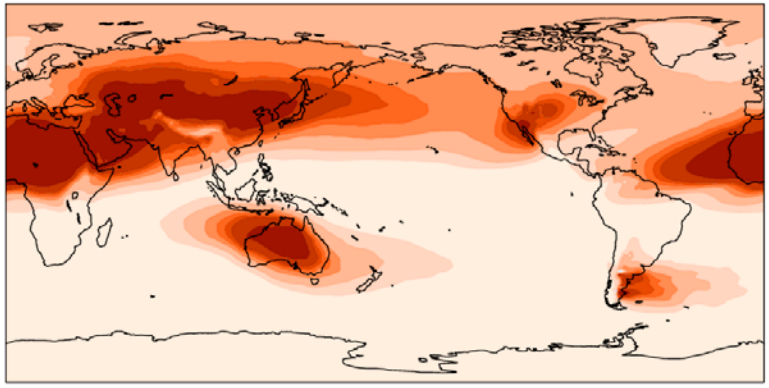
Min = 0.00 Max = 1.59

0.4
0.3
0.25
0.2
0.15
0.12
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.005

control

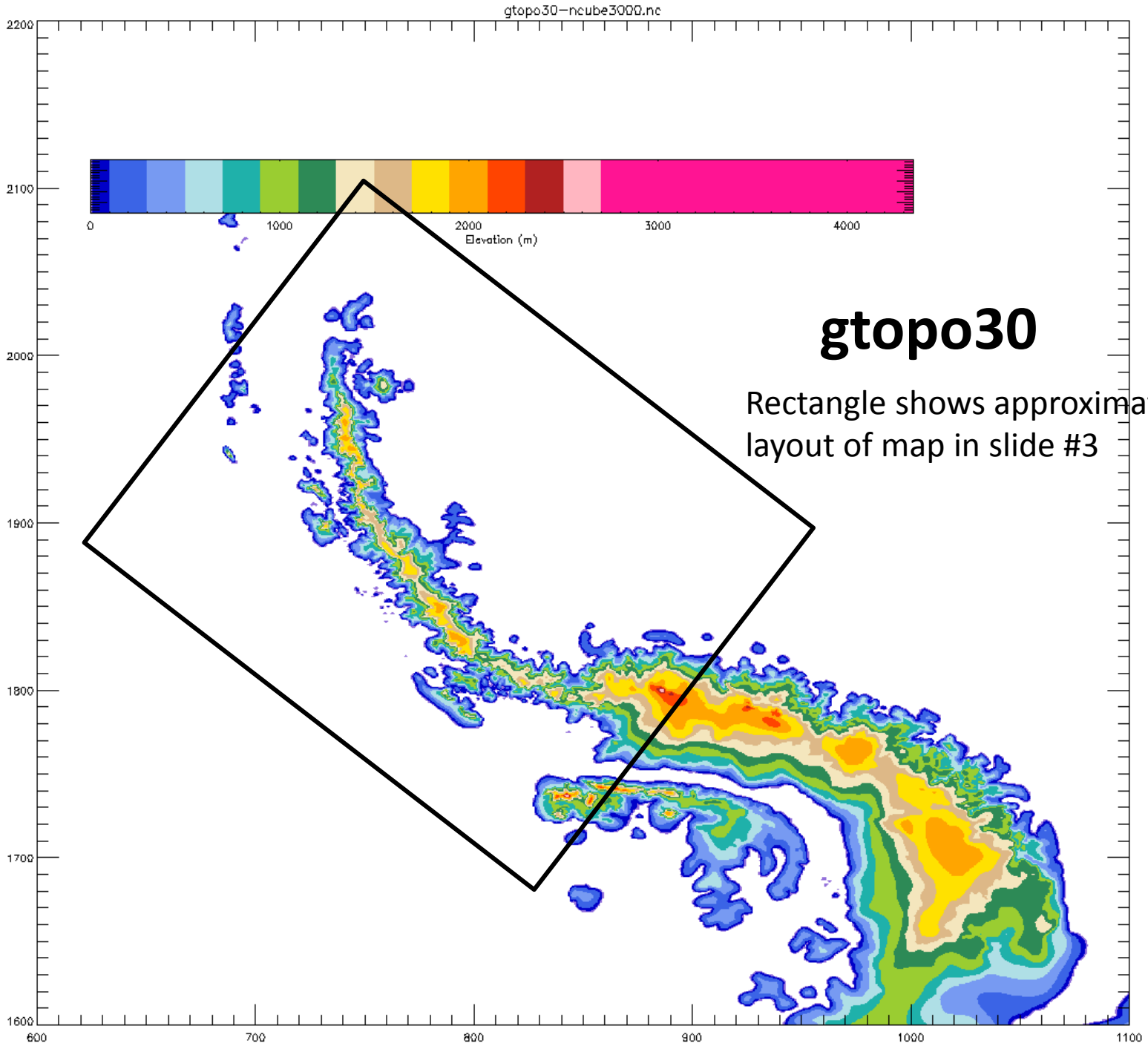
b.e15.B1850G.f09_g16.new_mountain_wave.28 - b.e15.B1850G.f09_g16.pi_control.28

mean = 0.03 rmse = 0.09 dimensionless



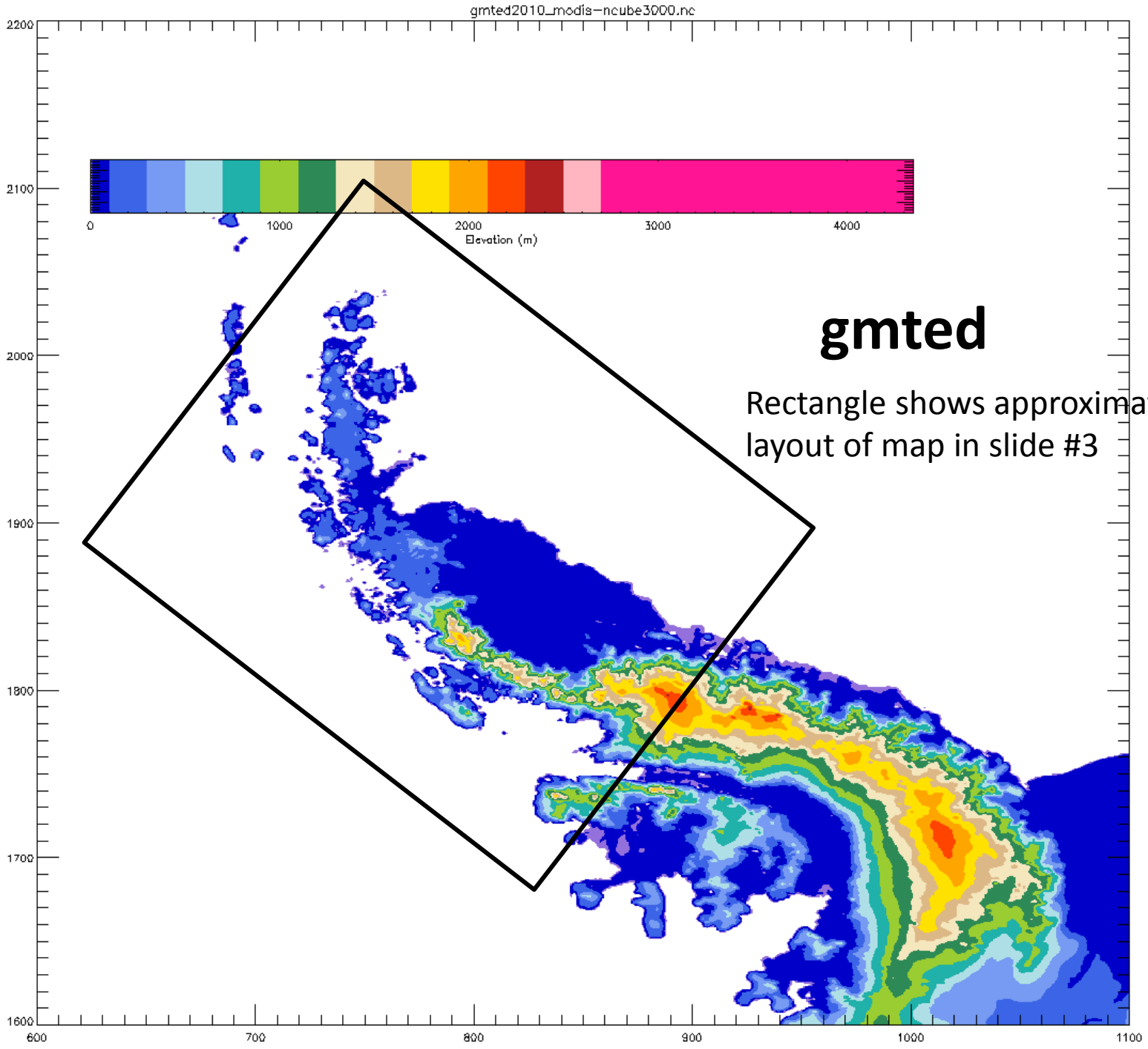
Min = −0.02 Max = 1.71

0.1
0.05
0.04
0.03
0.02
0.01
0.005
0
−0.005
−0.01
−0.02
−0.03
−0.04
−0.05
−0.1



gtopo30

Rectangle shows approximate layout of map in slide #3

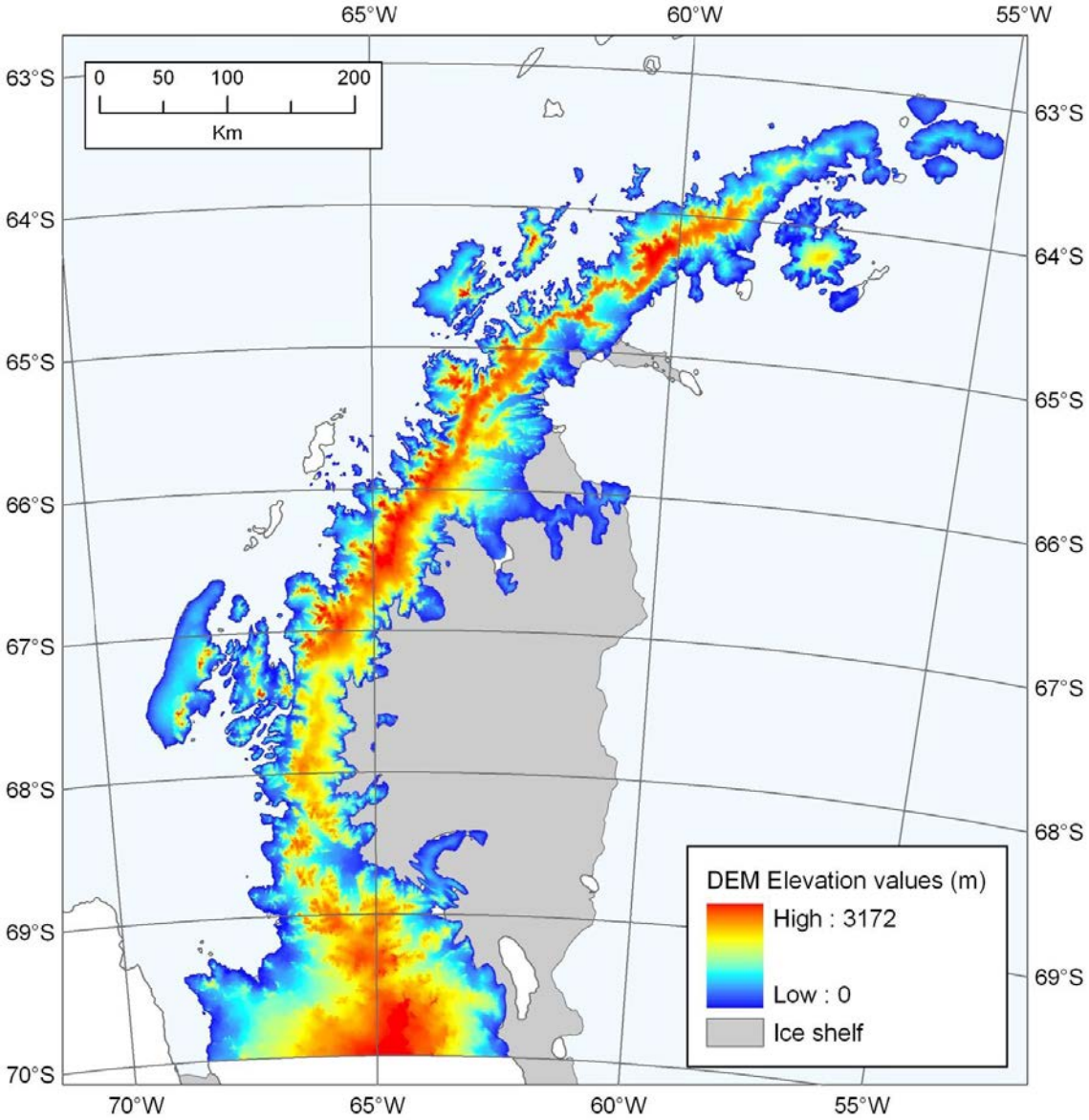


gmted

Rectangle shows approximate layout of map in slide #3

Antarctic Peninsula 100 m Digital Elevation Model Derived from ASTER GDEM

National Snow and Ice Data Center



http://nsidc.org/data/docs/agdc/nsidc0516-cook/