Drag project: part 2

Contributions from

SPARC, QBOi, ISSI

WGNE-30 Meeting, College Park MD, USA, 25 March 2015

Interesting drag/momentum Activities

- SPARC GW activity (Kaoru Sato)
  - Surface drag, TEM diagnostic MIP in CMIP6
  - Surface drag fields added to HighResMIP
- ISSI momentum budget intercomparison (Joan Alexander, Naftali Cohen)
  - High-latitude focused study
- QBOi (Scott Osprey, Lesley Gray)
  - Kick-off meeting Victoria BC March 16-18 2015
  - Initial focus on QBO dynamics, but later on impacts as well

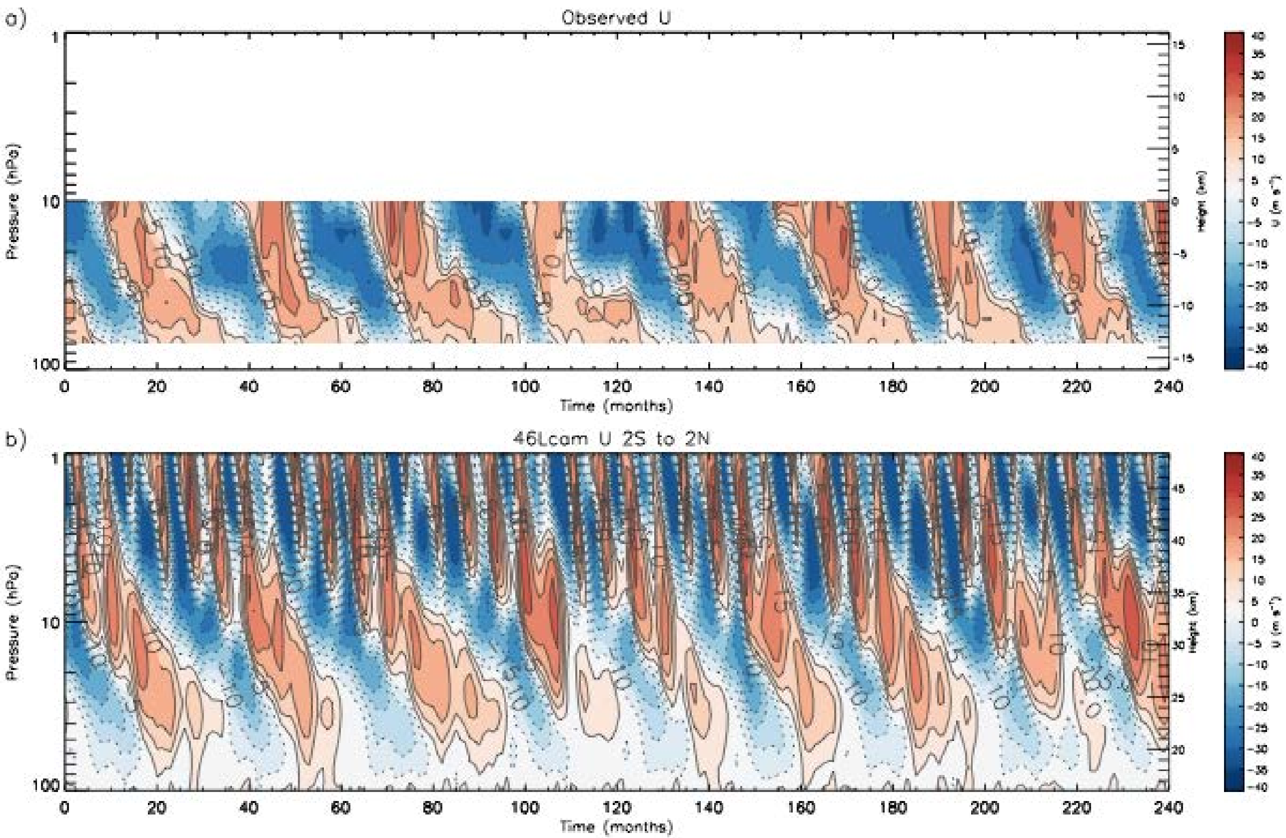
QBO*i*

- QBO could provide a source of predictability
  - 26 month period, direct tropical as well as extratropical impacts.
- Many models now have a QBO
  - Generally too regular, don’t penetrate deep enough, too confined in latitude
  - In all but 1 model, parameterized GW provide more momentum forcing than resolved waves
  - Vertical resolution important, but no agreement across models
- Glaring lack of observations to constrain wave momentum fluxes in the tropics

Observed and simulated QBOs

OBS

46L CAM



Observed and simulated QBOs

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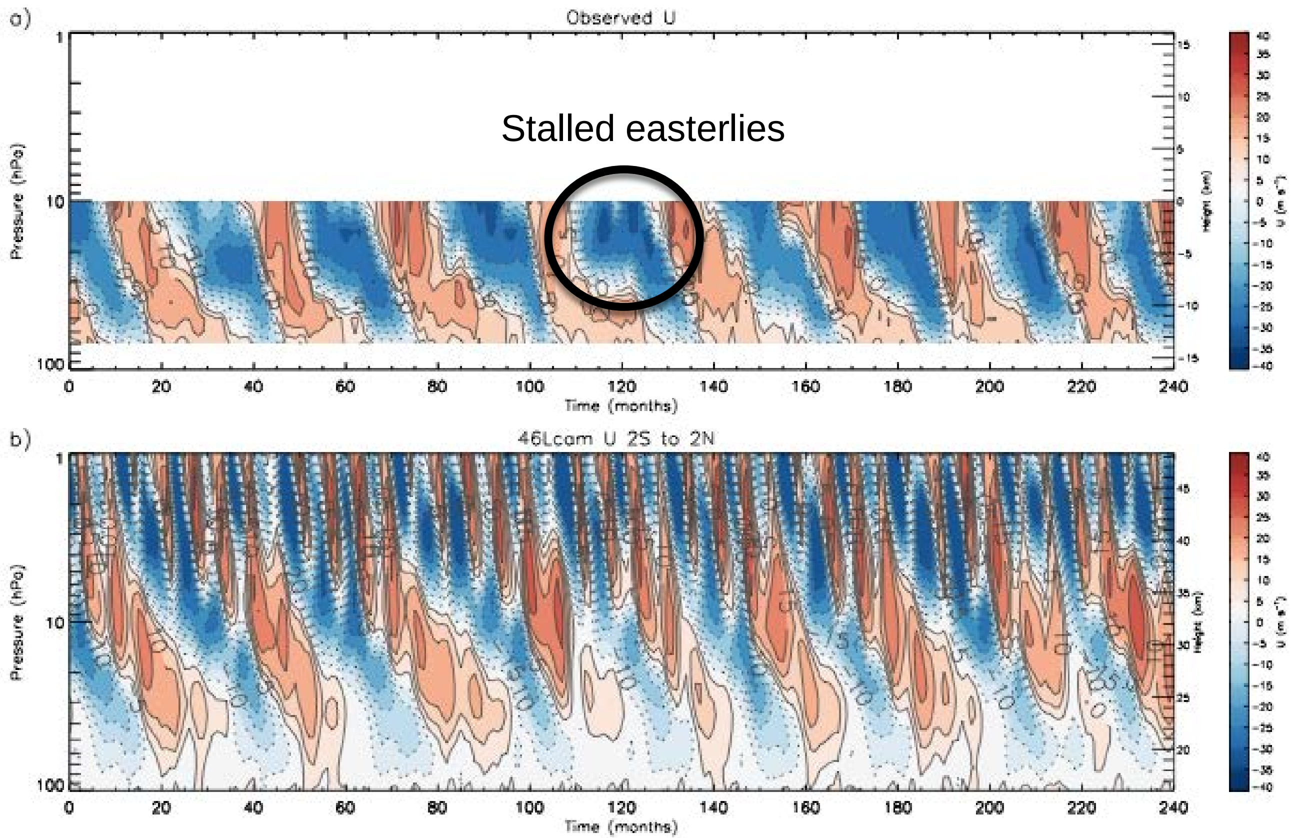

Extratropical Impact of QBO

(1000 hPa Z)

W-E QBO Composite of 1964-96 1000-hPa Z

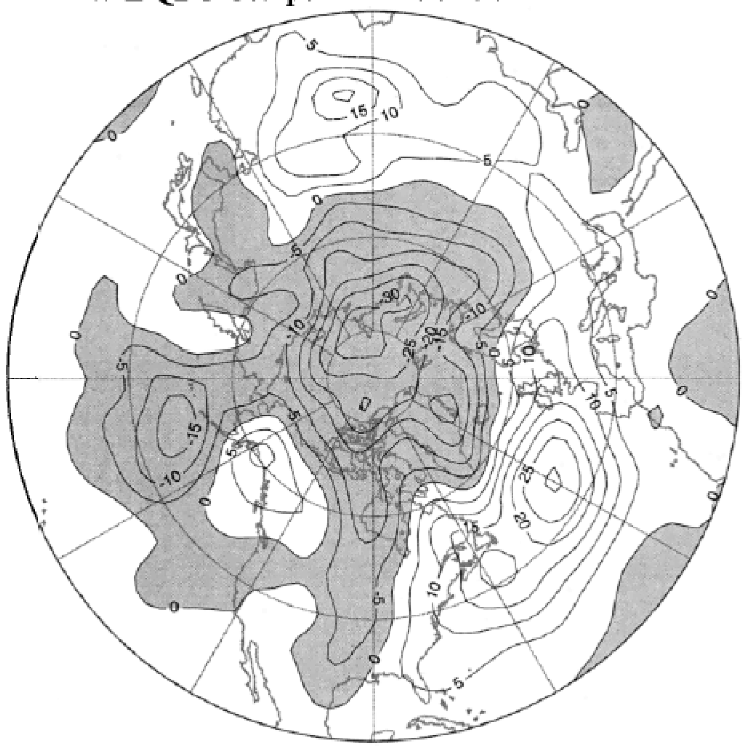

Figure 31. Difference in 1000-hPa geopotential height composites (meters) between westerly and easterly QBO composites. December–February monthly-mean National Centers for Environmental Prediction data for 1964–1996 were used.

From ***Baldwin et al. 2001***

QBO*i*

- Initial experimental protocols
  - ~30 year AMIP simulation+corresponding simulation with climatological SSTs
  - 20 or so 6-12 month seasonal forecast runs with same models initialized with observations
  - Nudging runs – exact nature TBD – tropics only?, zonal-mean only?
- Output/diagnostics
  - A number of detailed QBO characterizations
  - Zonal mean TEM momentum budgets ***(with residuals)*** In all but
  - High frequency outputs (hourly) to calculate resolved wave characteristics

Observations to constrain wave momentum flux ***Albert Hertzog LMD …. McMurdo Antarctica 2005(VORCORE), 2010 (CONCORDIASI)***

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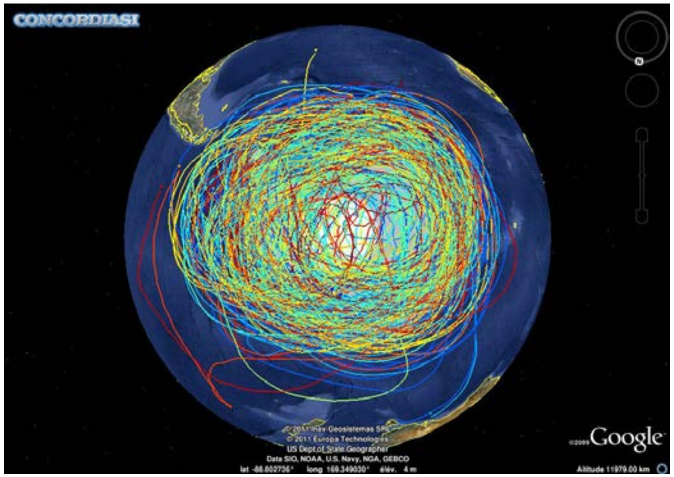
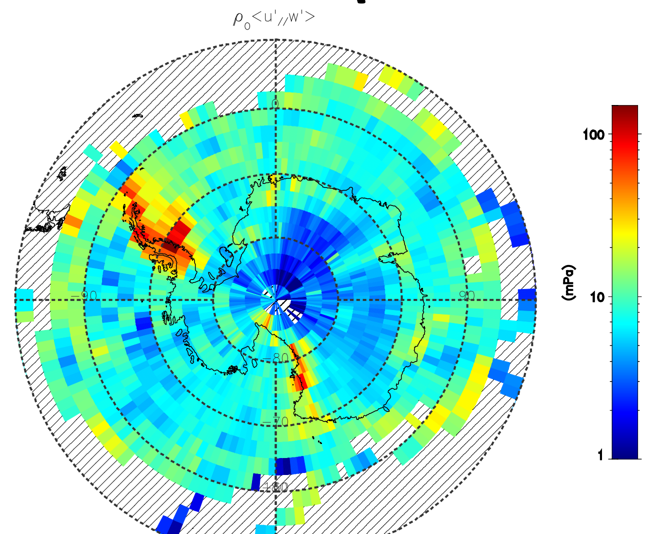
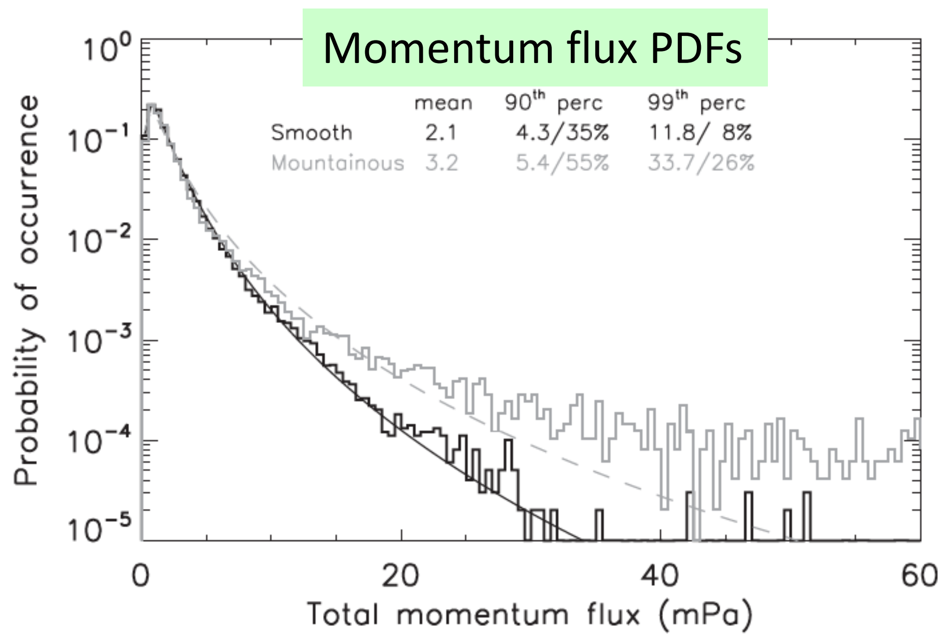


Concordiasi
19 flights, Sept-Jan 2010



Concordiasi gravity-wave momentum flux

Constant pressure balloons:
Remain between 18 and 20km altitude



Stratéole 2
A long-duration balloon campaign to study the equatorial UTLS

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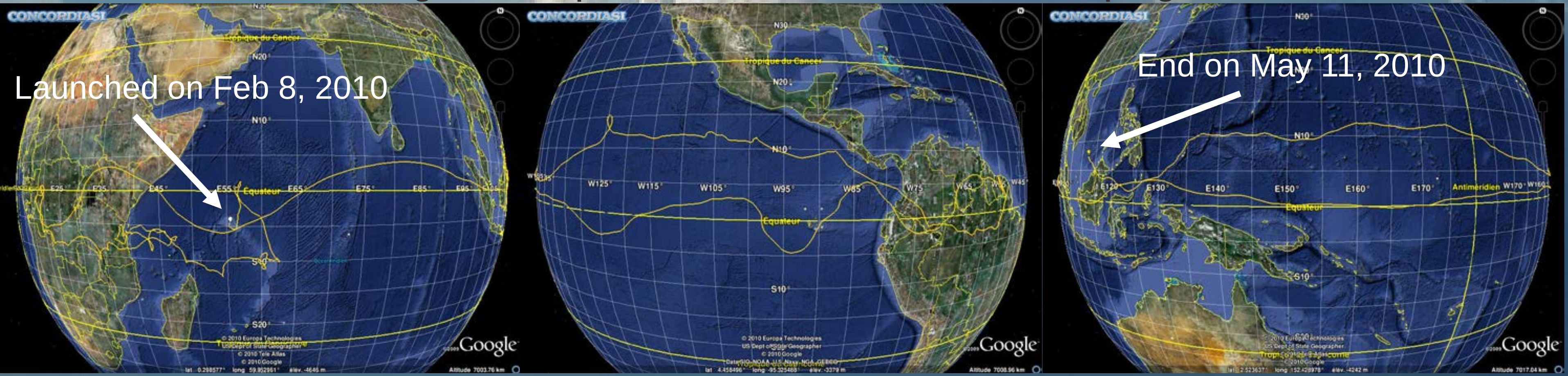
Flight example: 2010 Pre-Concordiasi campaign



Flight duration: 92 days

2 separate long-duration balloon campaigns

- 2018 and 2019 (to sample both phases of the QBO)
- About 20 flights per campaign

Scientific objectives

- Dynamics of the equatorial middle atmosphere: driving of the QBO (role of planetary/gravity waves),wave generation by deep convection, gravity-wave parameterization
- Transport and dehydration in the TTL: occurrence of penetrating convection, cirrus, supersaturation, cloud/dynamics interaction(long-duration balloons are quasi-Lagrangian tracers)
- Operational meteorology: accuracy of analyzed winds in the tropics, assimilation of balloon-borne observations
- Satellite validation (ADM/Aeolus, IASI on Metop)

WGNE Action Item:

Letter of support for STRATEOLE2
“would be very helpful”

Decision point at the end of the year

Google "google stratospheric balloons"

Extensions to parameterized orographic drag in CAM

- Scheme
- Evaluation in forecast mode and climate mode
- Future studies using DAS

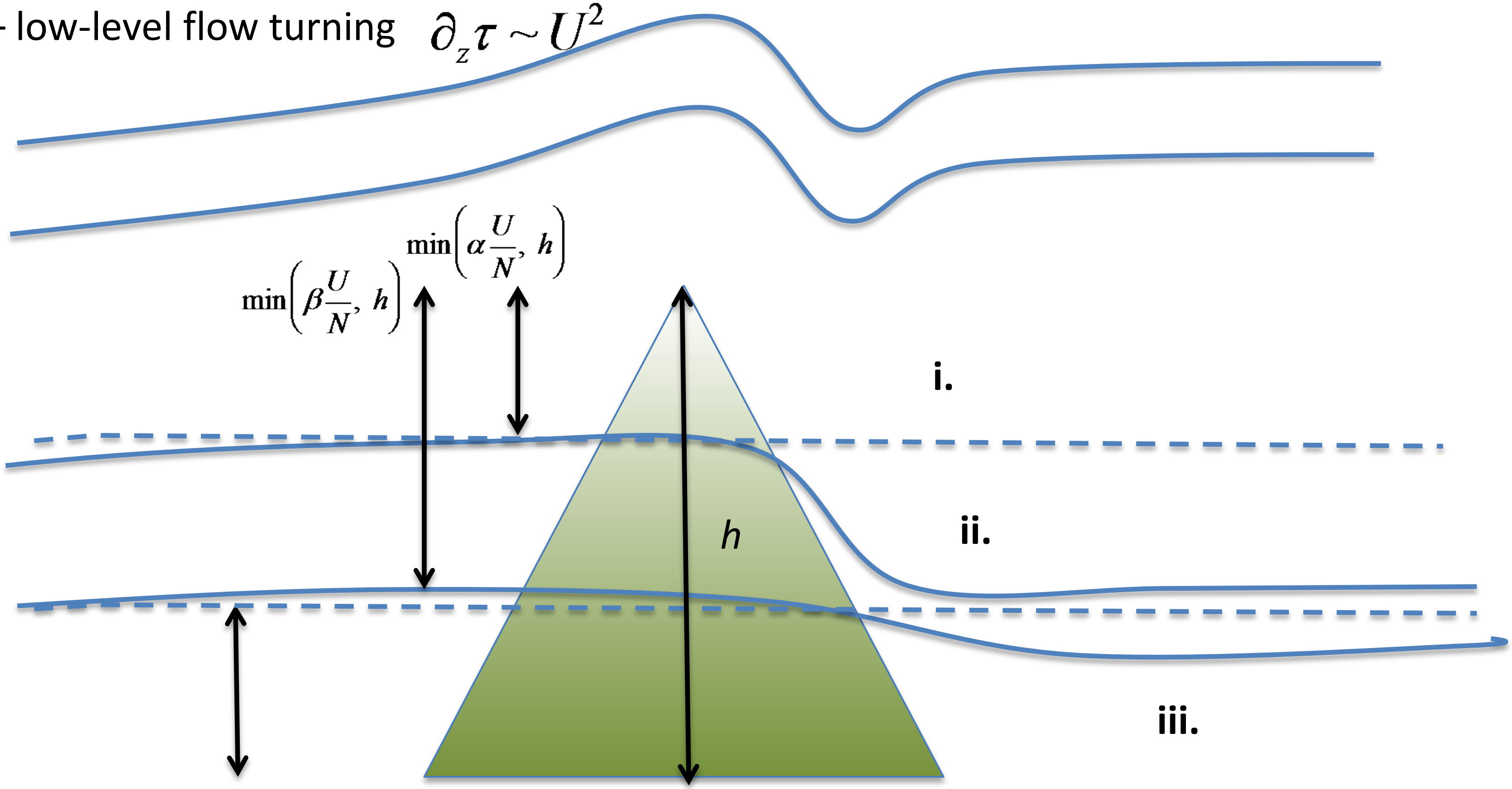
Blocking, low-level turning

(follows Scinocca&McFarlane 2000)

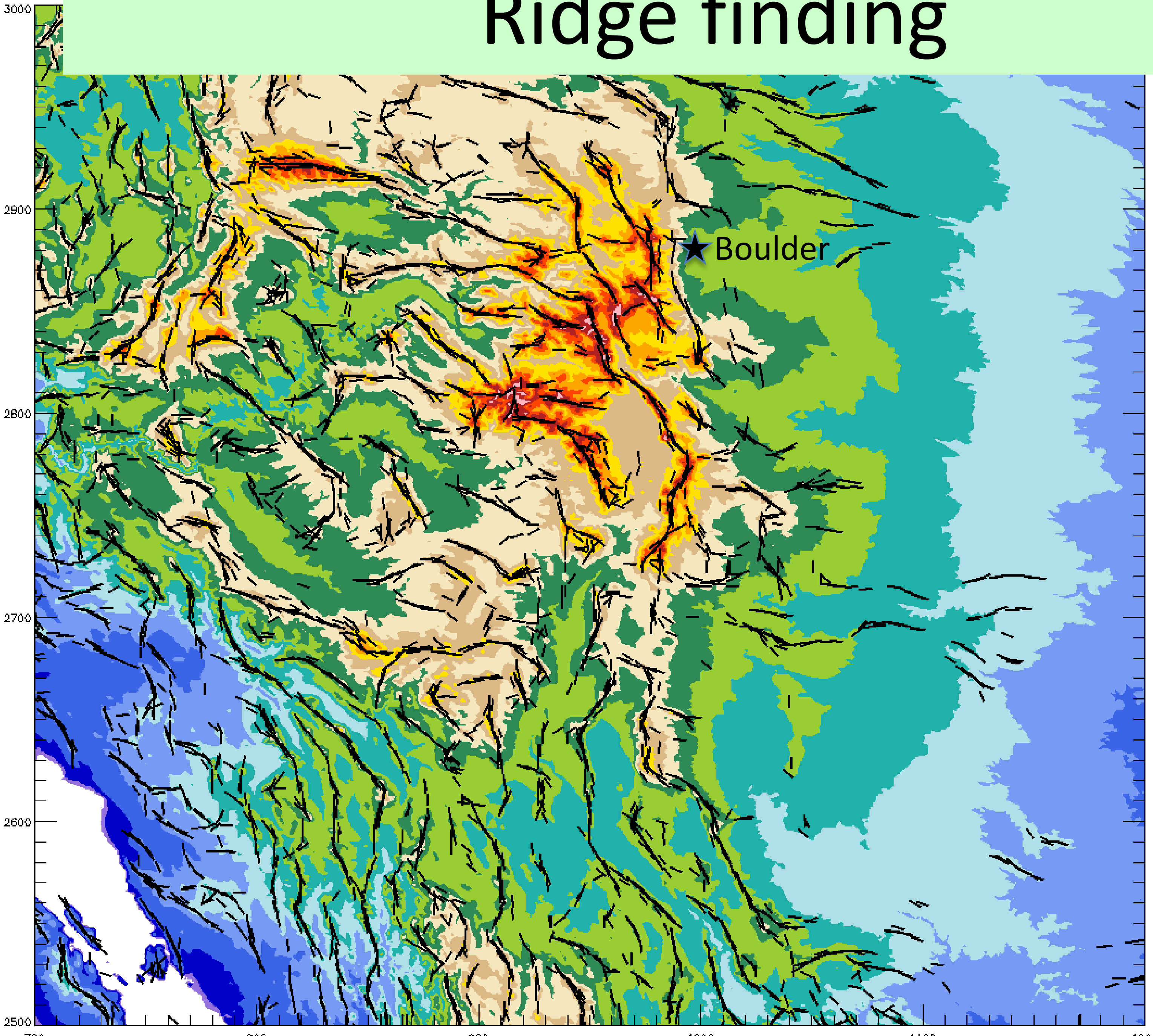
i – vertically propagating waves $\partial_z \tau$ via saturation

ii - downslope wind layer $\partial_z \tau \sim \partial_z \tau \big|_{sat} (1+\gamma)$

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



Ridge finding

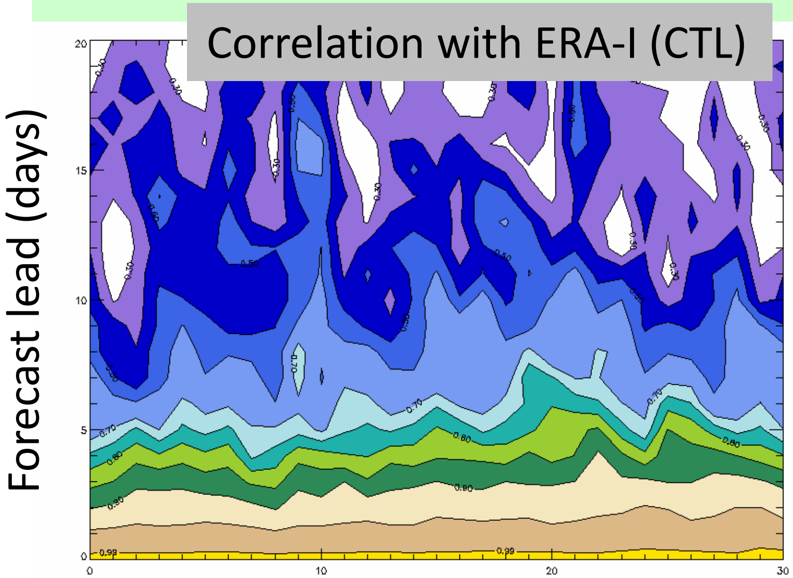


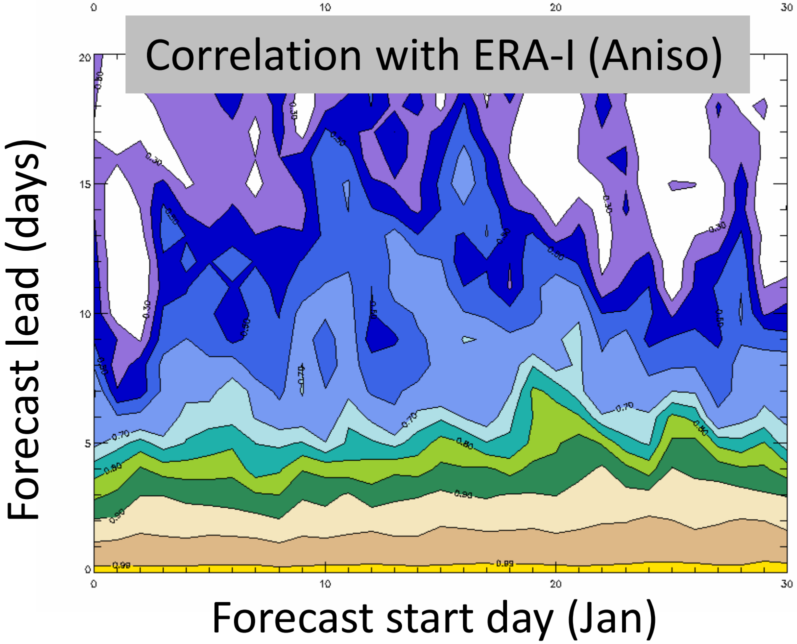
L_s~80km

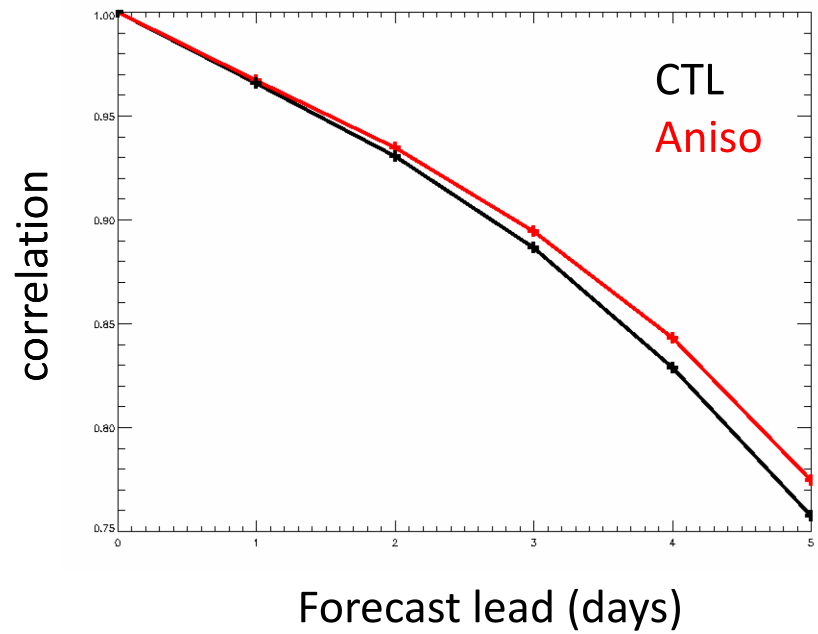
CAPT forecasts 1/2003

- Forecasts initialized from ERA-I reanalyses
- Once per day 00Z (1/1-1/31) run for 20 days
- Validation against ERA-I *(could be a problem)*

Forecasts of U at 700 hPa 1/2003



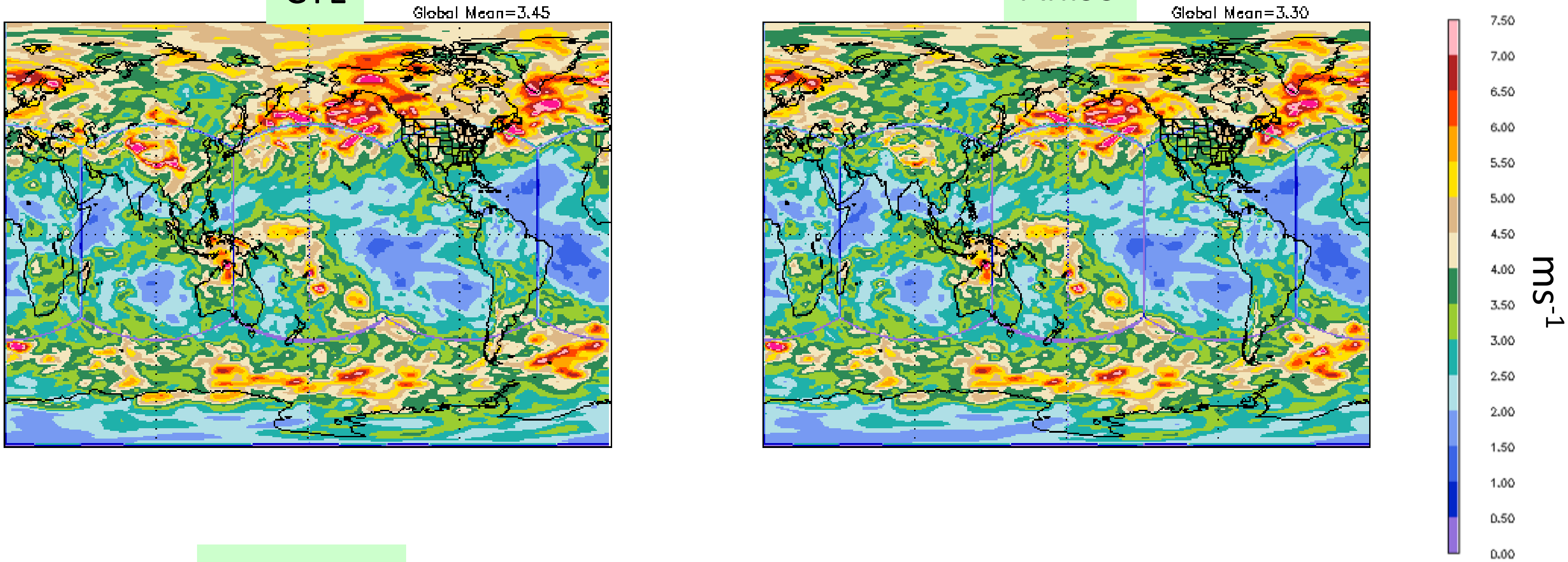




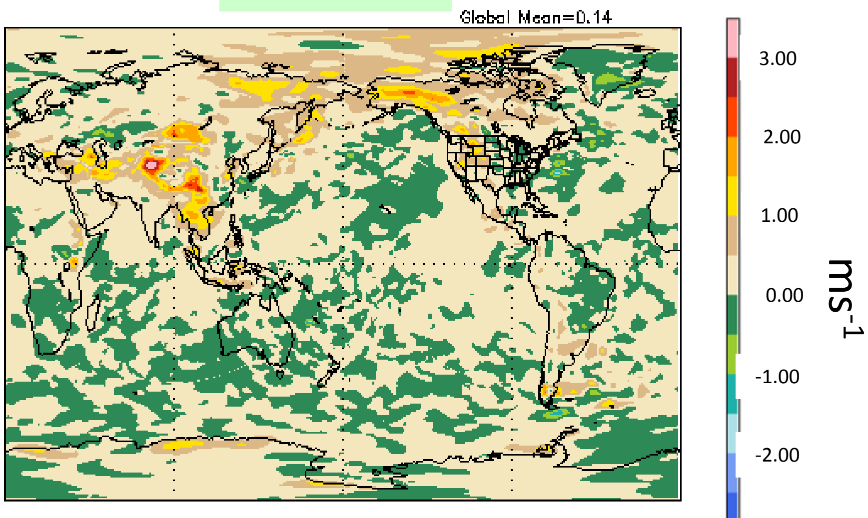
Mean errors in 0.7-0.95 σ–lev *U* at Day 3

CTL

Aniso



CTL-Aniso



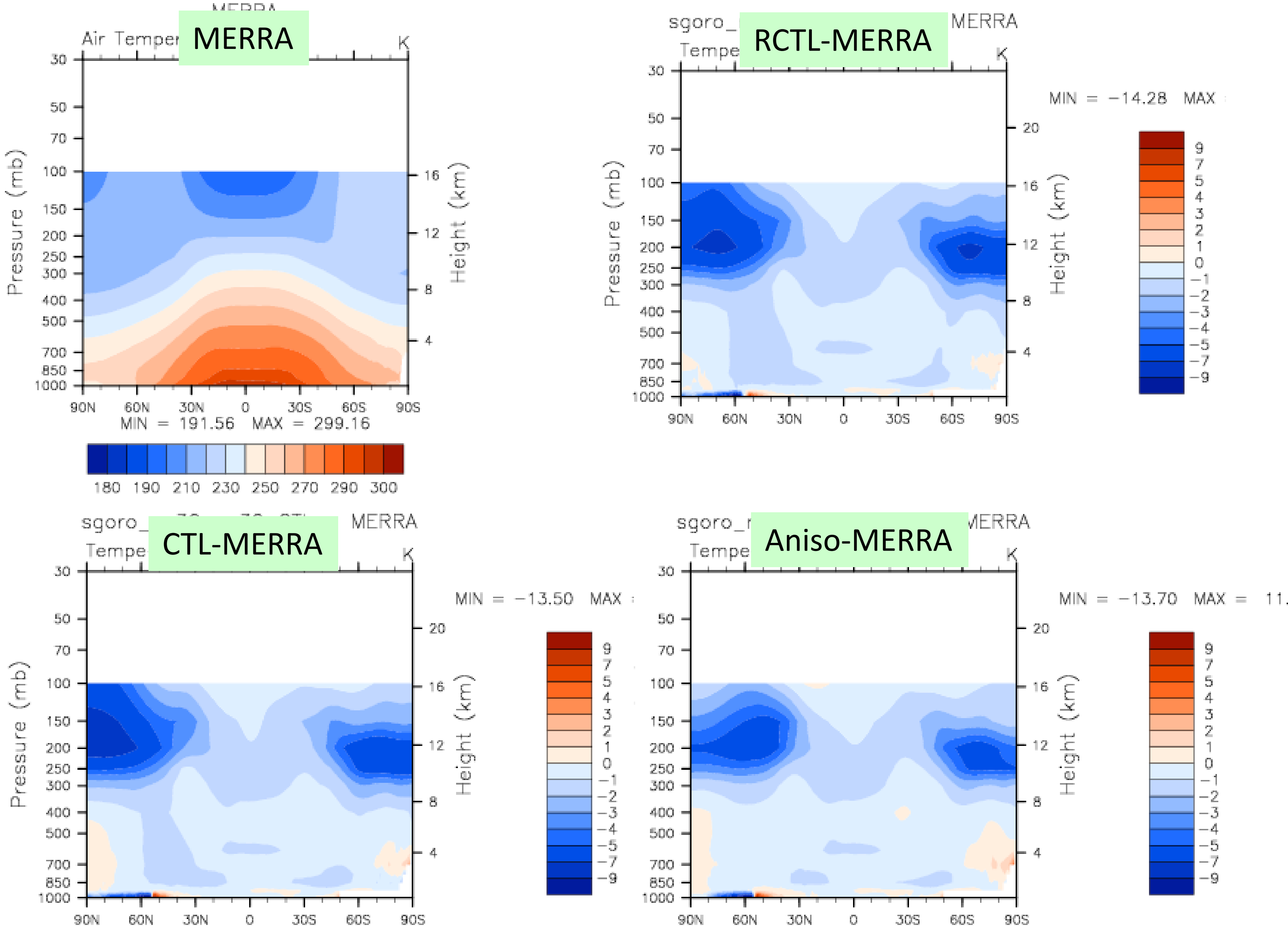
Aniso better

CTL better

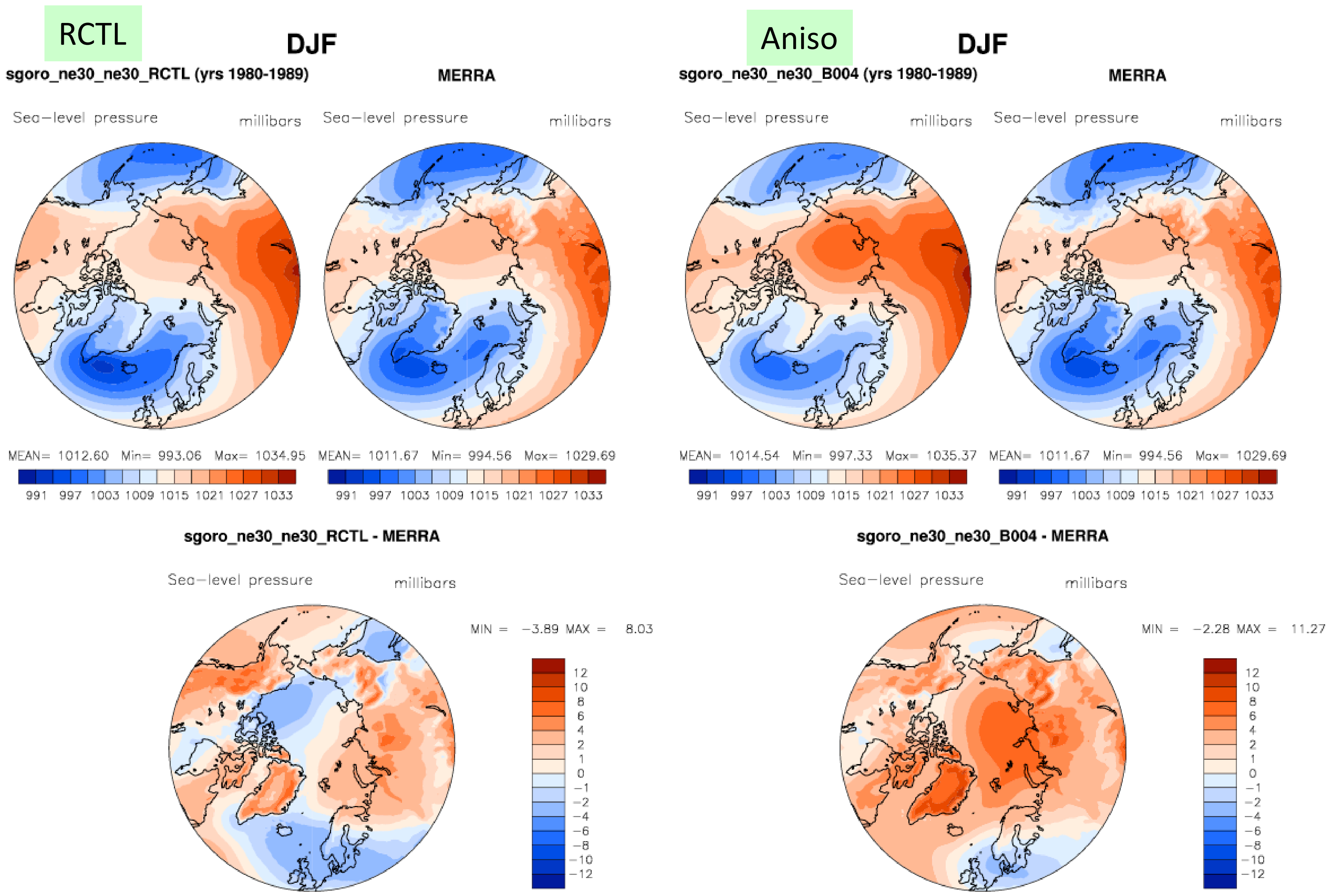
Encouraging, but does this just show that EC's model also has an anisotropic OGW scheme?

10-year AMIP simulations

DJF Zonal mean temperatures



DJF mean sea-level pressure



Future work

Use full data assimilation system, e.g. DART, to examine scheme's impact on corrections/innovations …

smaller=better

Extend this approach to evaluation of other schemes in CAM/CESM

Thank You

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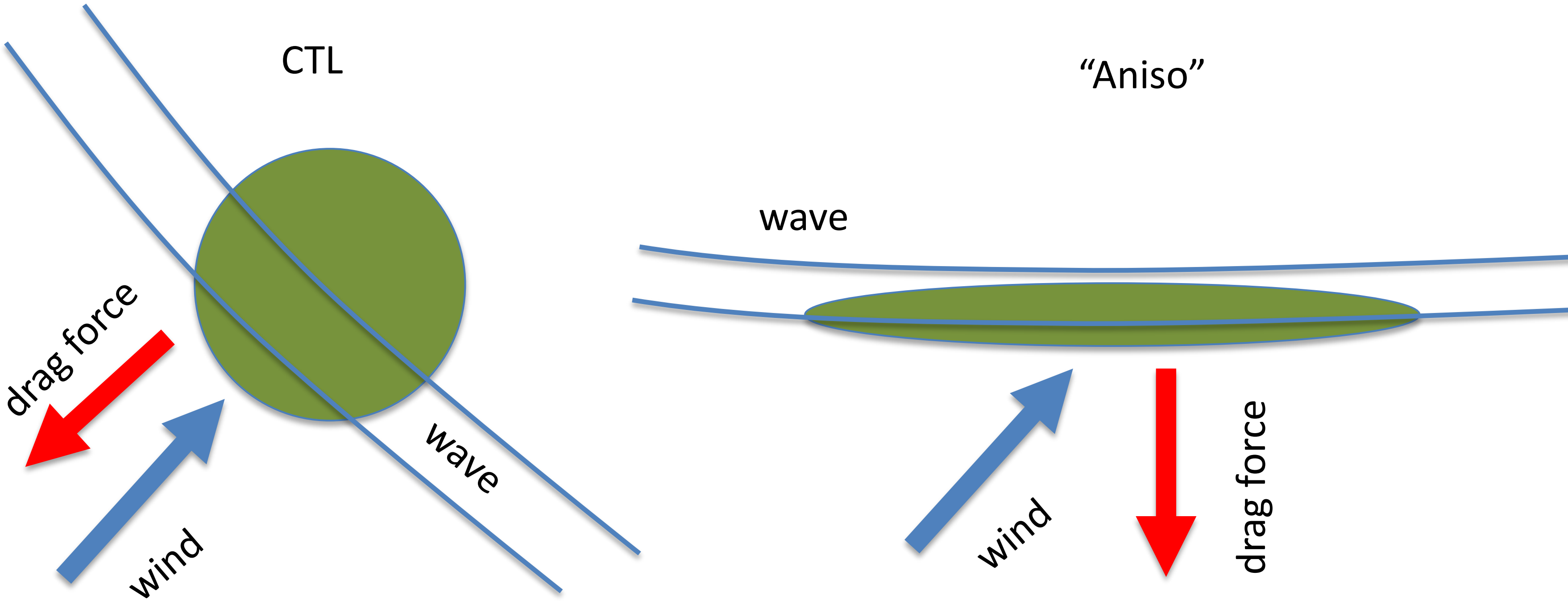
Scientific Discovery through Advanced Computing

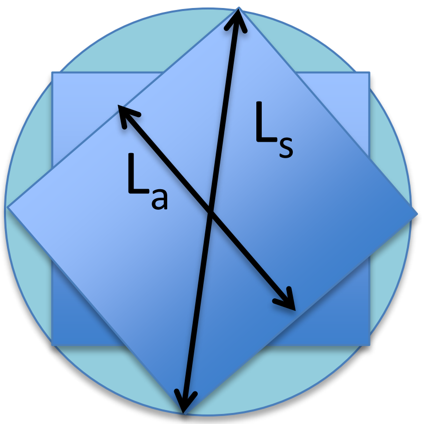
Extra Slides

Anisotropy



Ridge finding

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



- Outputs
  - Orientation
  - Ridge height (different from std. dev. of topo)
  - "quality" ratio of 1D/2D variance
  - Width

Further innovations/complications

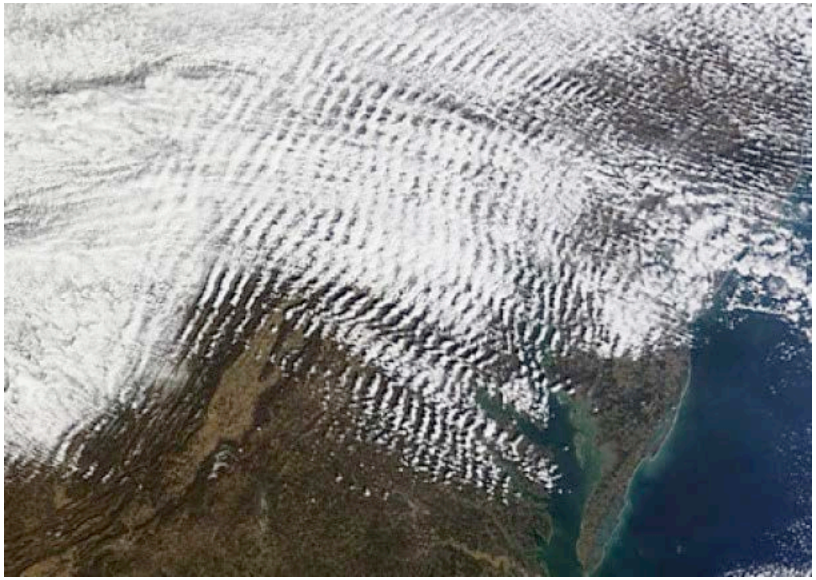
Multiple ridges possible in any AGCM gridbox depending on remapping from topo grid

2 families of ridges:

- Meso β 800km-80km
- Meso γ 80km-3km

Trapped lee wave parameterization. Uses width estimate to calculate

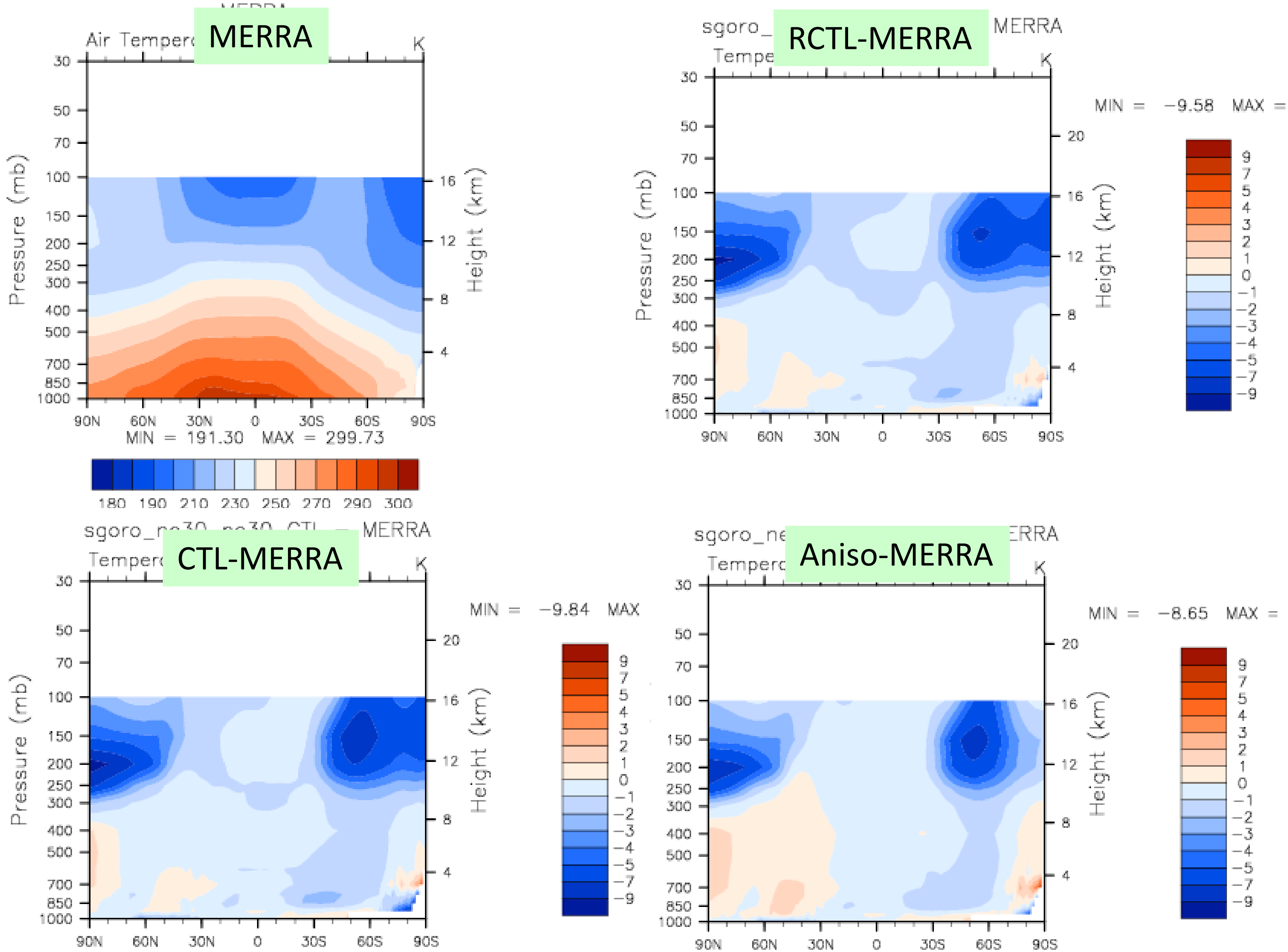
$$m^2 = \frac{N^2}{U^2} - k^2$$



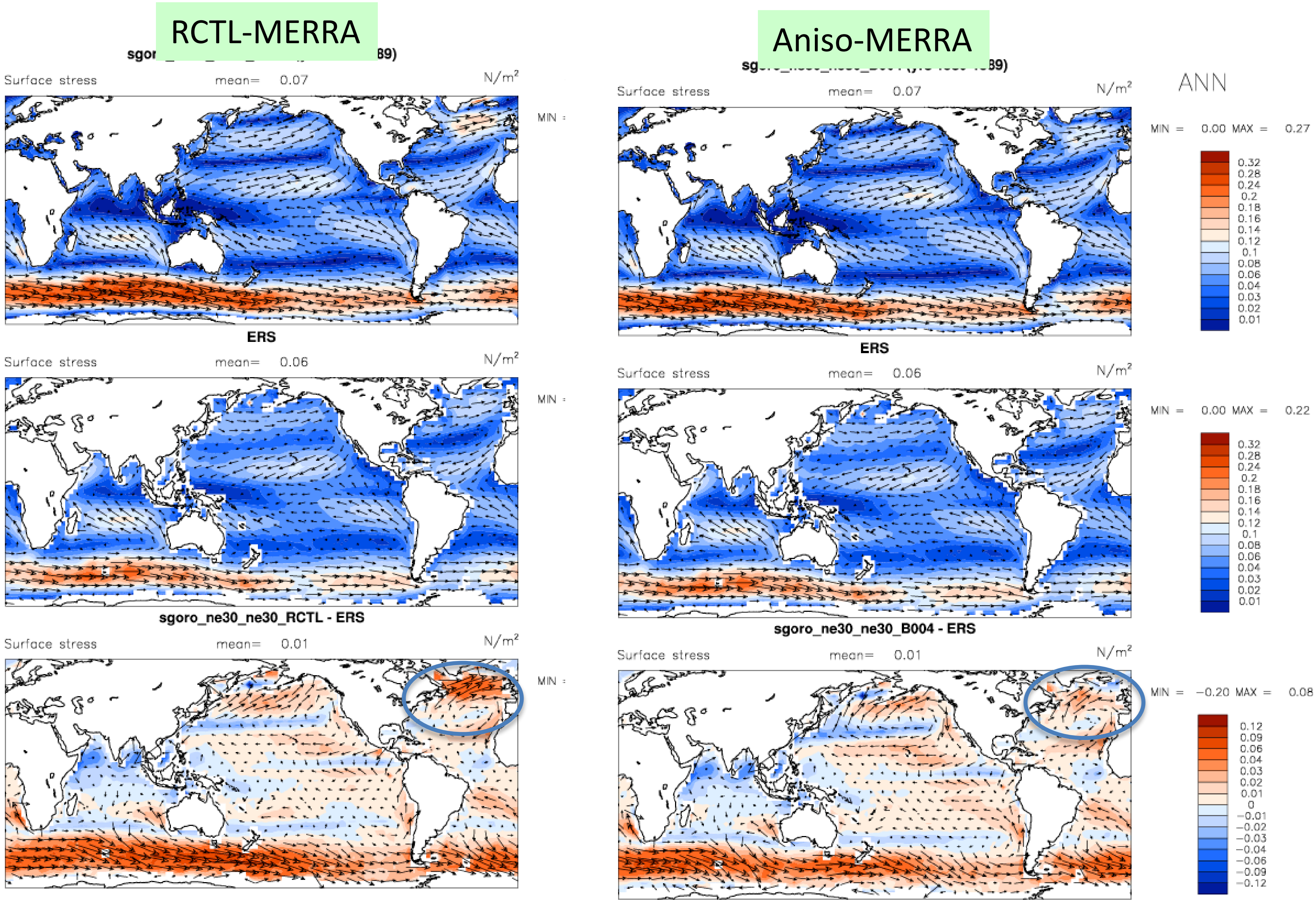
AMIP runs 1/1979-1/1990

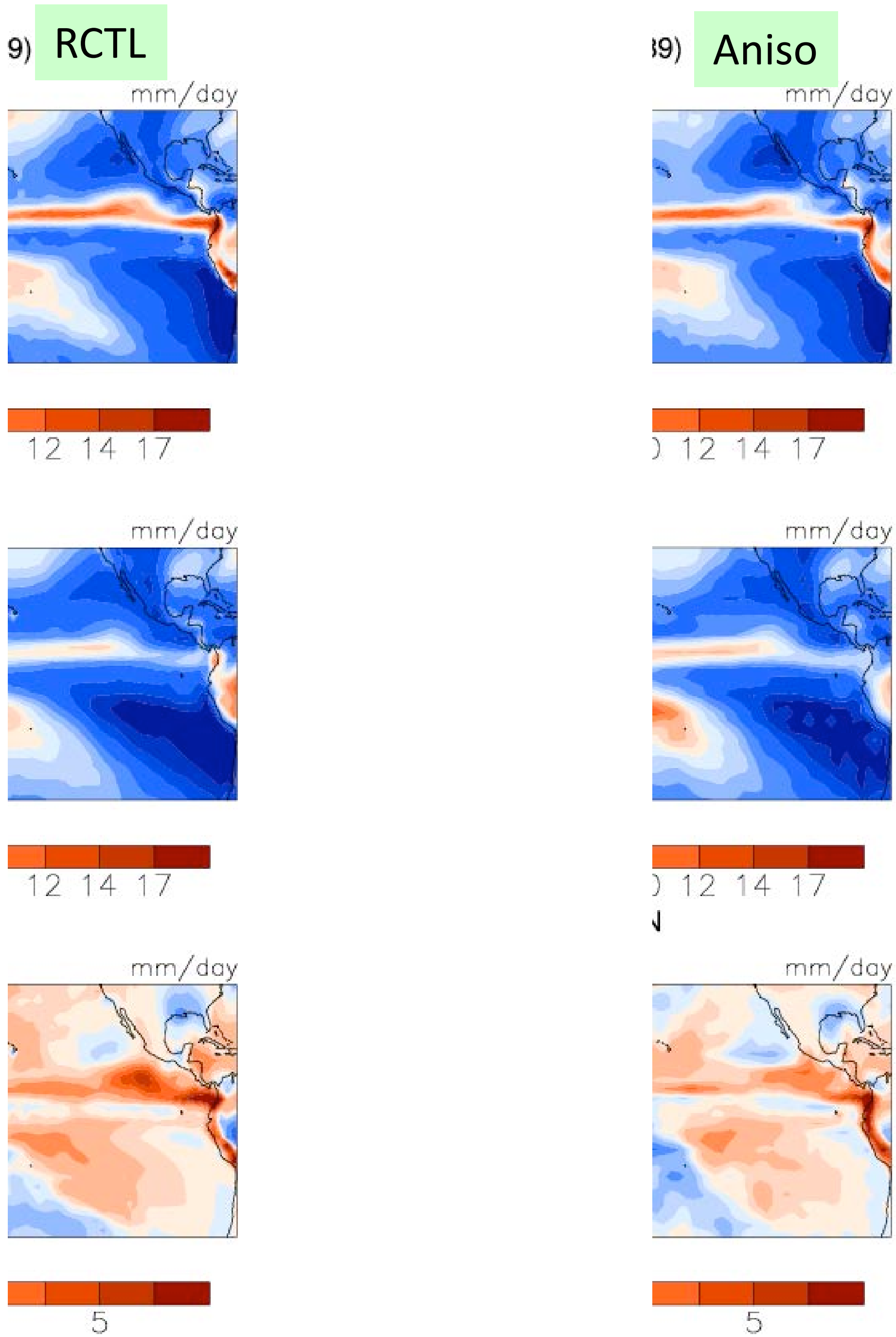
- ne30
- 3 runs
  - **RCTL** - “rough” control. Rougher topo (L<400km) w/ old istropic OGW scheme
  - **CTL** - control. Smoother topo (L<800km) w/ isotropic
  - **Aniso** – new anisotropic scheme w/ blocking, lee-waves etc..
- All still use TMS
- All use *low* value for divergence damping

JJA Zonal mean temperatures



Annual mean wind stress





1980-90 DJF mean Precipitation

New orographic drag scheme

- Anisotropy
- Low-level processes (blocking)
- Lee-wave trapping
- Multiple ridges and scales

EXTRA SLIDES

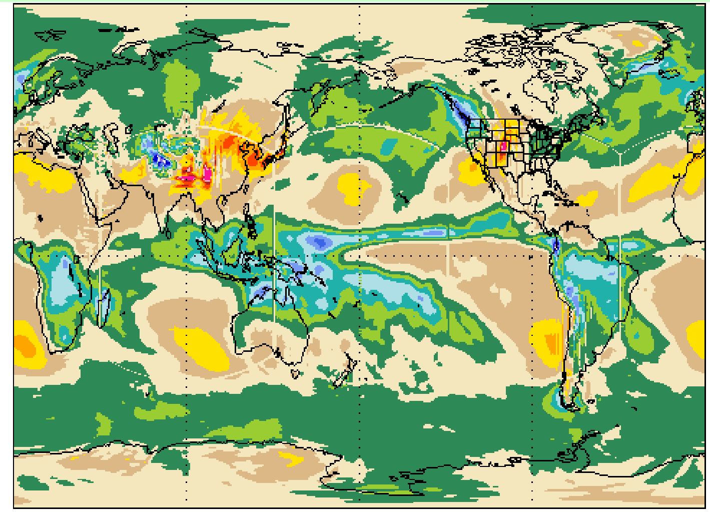
1980-81 DJF mean ω fields ne30~100km

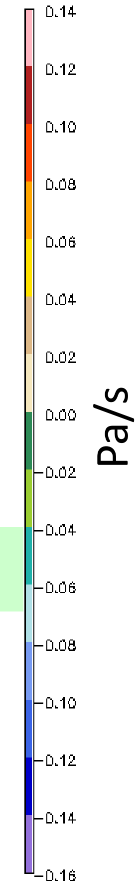
CAM-SE is noisy

2 approaches to mitigate this

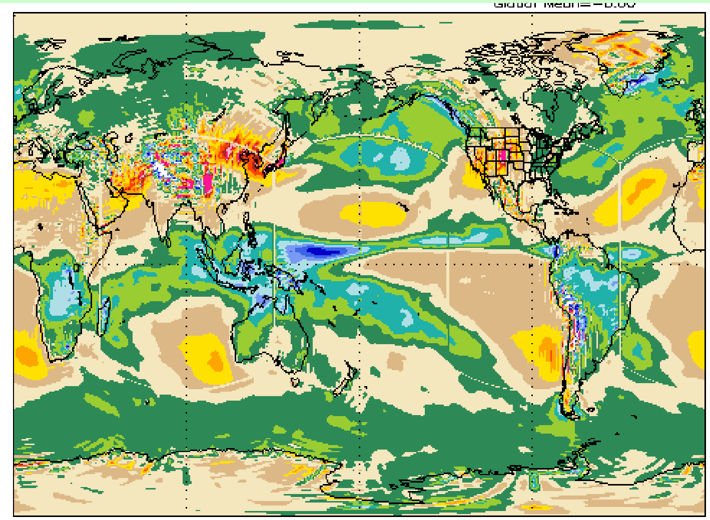
- smoother topo
- increased divergence damping

Smooth topo (smoothing scale~800km)

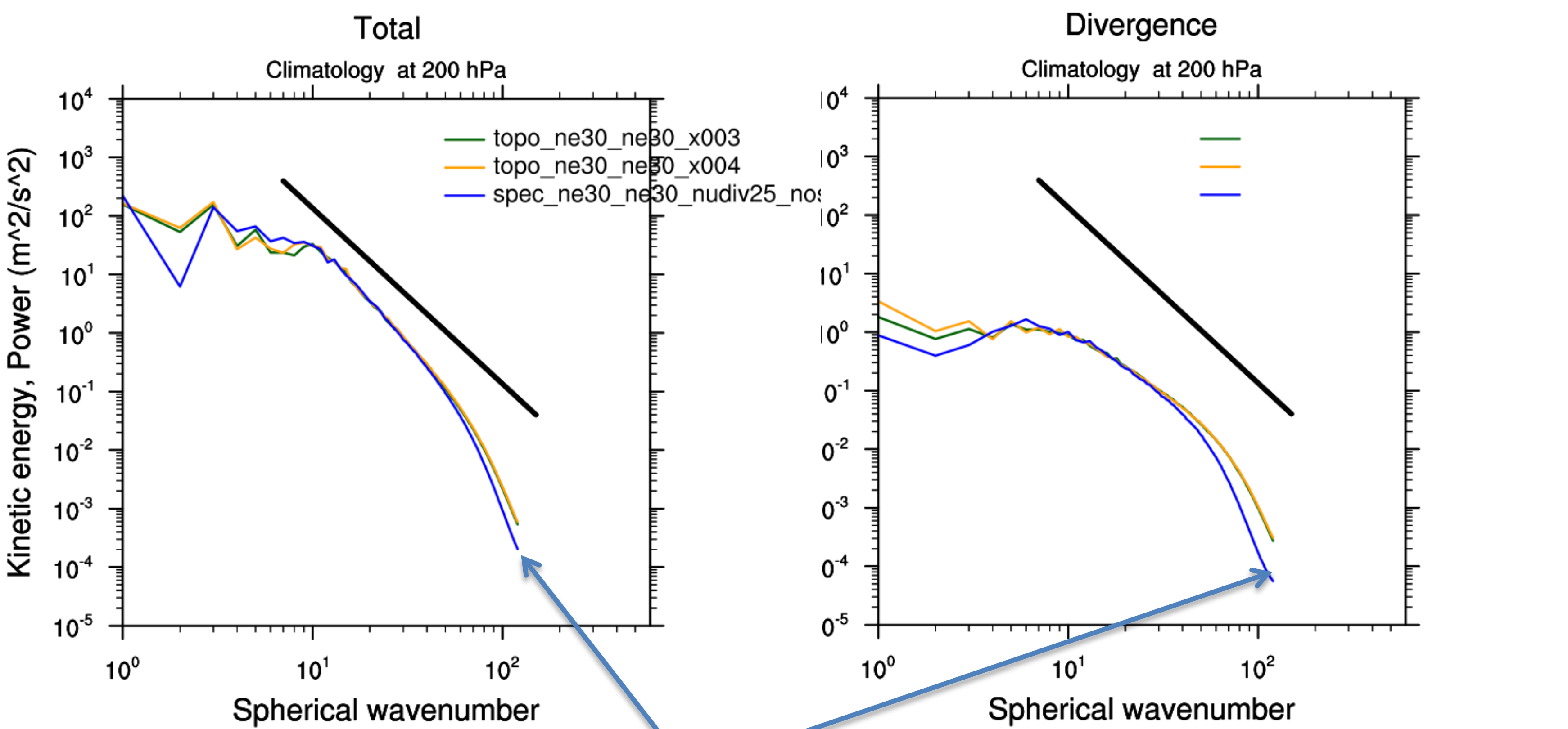




“Rough” topo (smoothing scale~400km)

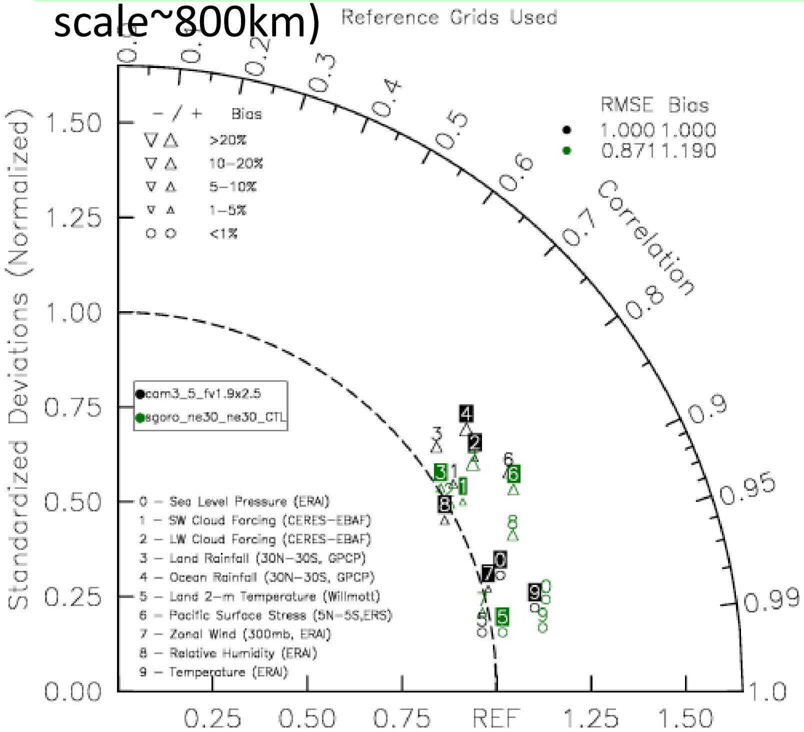


Energy spectra



increased divergence damping impacts spectra

Smooth topo (smoothing scale~800km)



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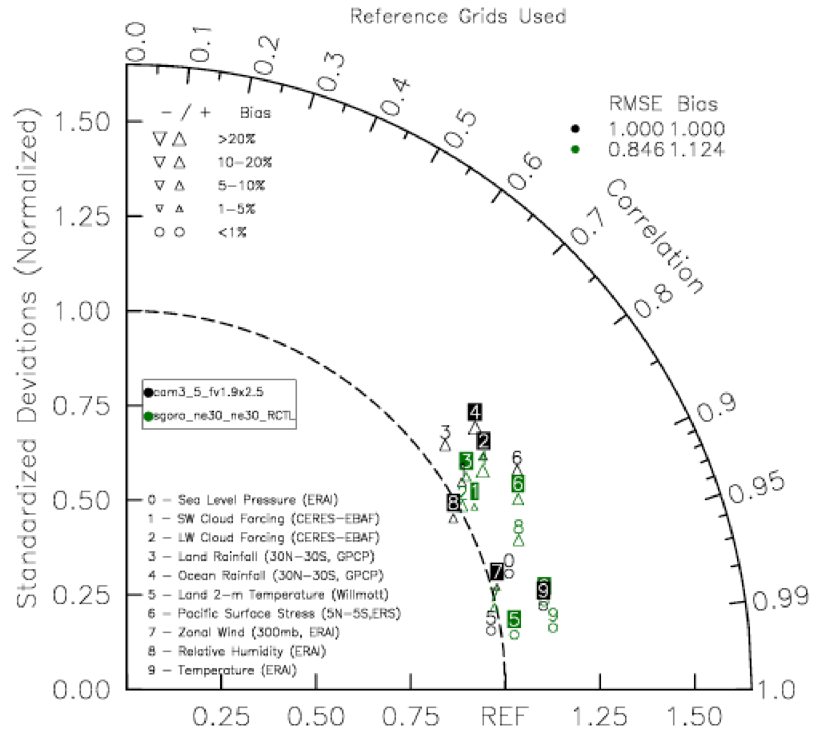
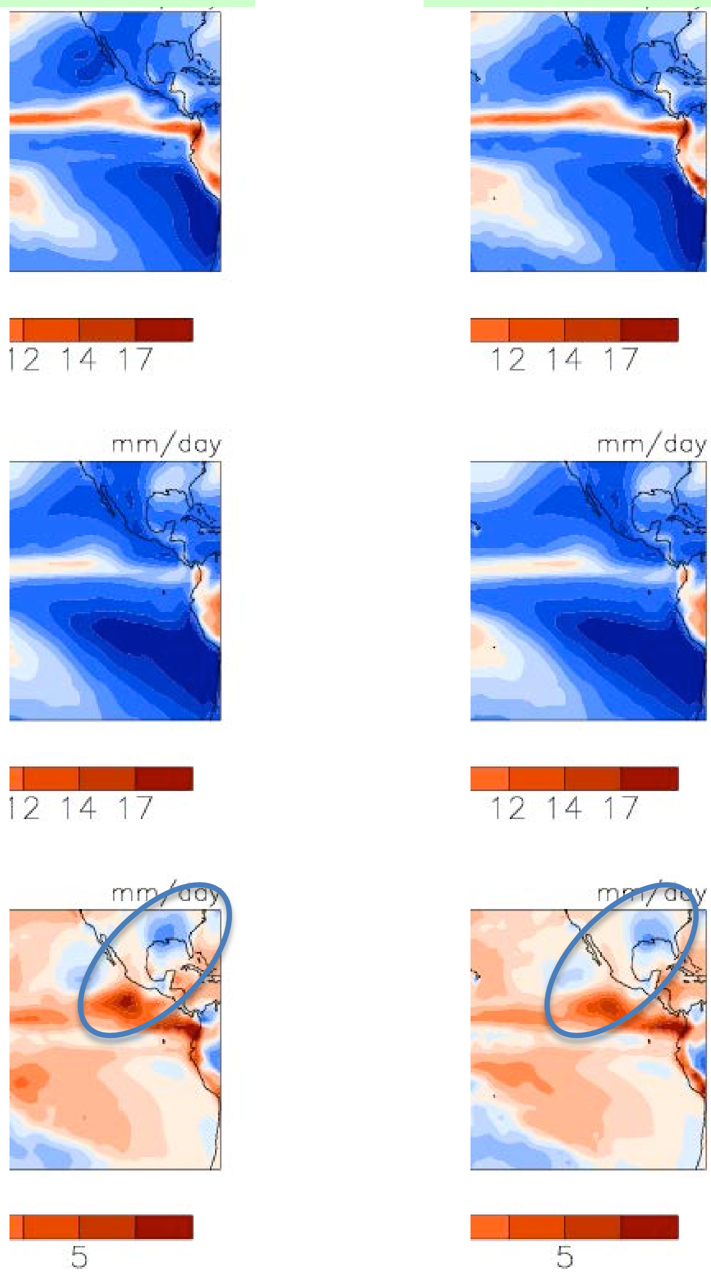


Climate somewhat better overall with rougher topography

Smooth topo

"Rough" topo



1980-90 DJF mean Precipitation

Annual mean surface stress 1980-1990