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Evaluating the impact of localized grid refinement on global climatology in CAM

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Sandia National Laboratories

Variable-resolution CAM-SE

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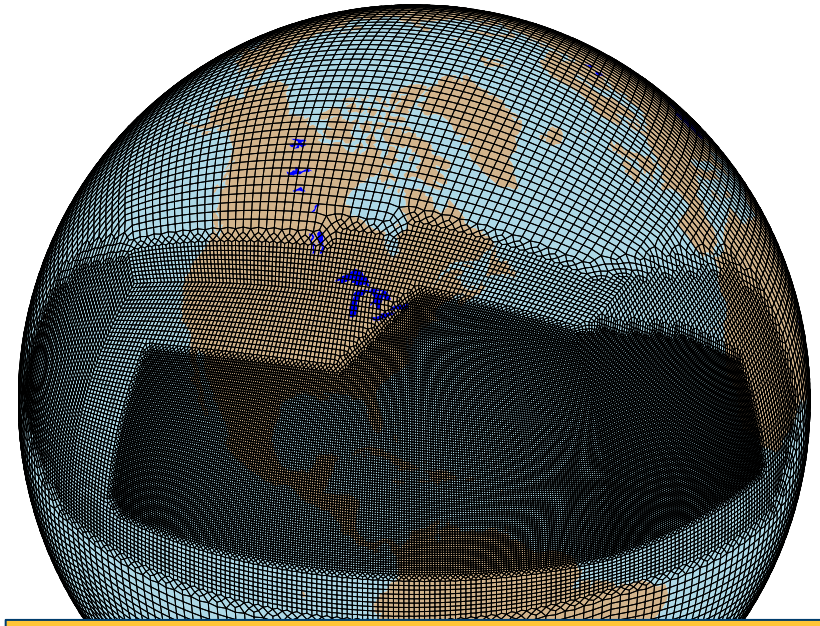
- Mesh refinement
  - Conforming
  - Quadrilateral
- Explicit diffusion (hyperviscosity) varies with element size
- Timestep globally restricted to finest scale
- Model runtime scales essentially linearly with number of elements
  - V-R grid; 1/8° refined patch with 1/10 cells runs 10x faster



- Can the use of variable-resolution global models…
  - A) improve the representation of regional climate while…
  - B) not harming global solution

CESM AMIP simulations

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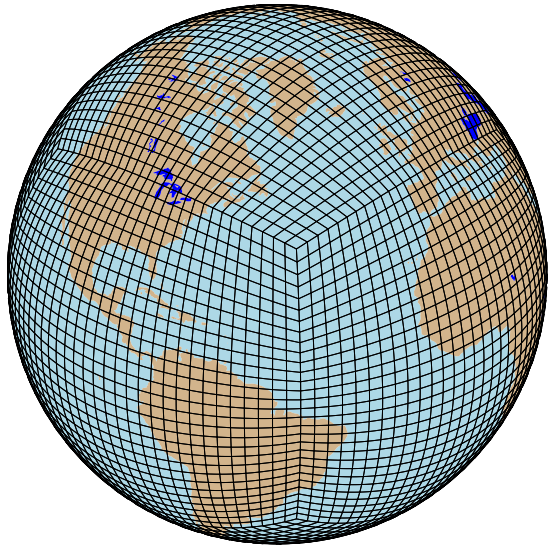
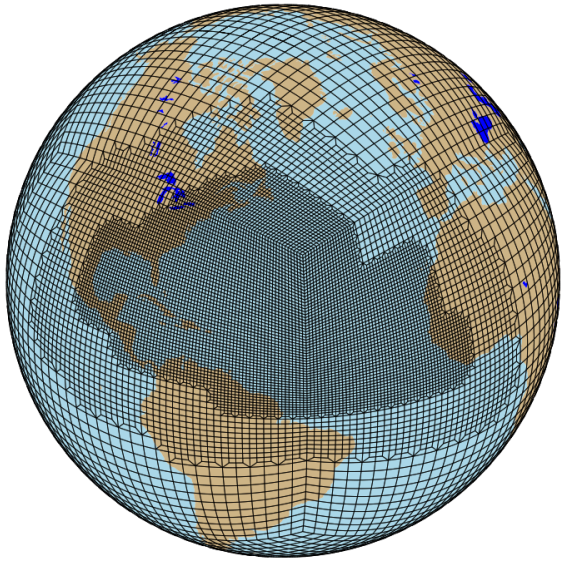
- CESM framework
  - Land: **FV0.9°x1.25°** - active
  - Ocean/Ice: **gx1v6 (~1°)** – prescribed
- AMIP protocols
  - 1980-2002 (23 years)
- Two different CAM grids
  - Globally uniform 1° (**UNI**) (~110 km)
  - Variable-resolution (**VR**) (~110 km base grid, ~26 km refinement over Atlantic)
- CAM5 physics
  - Aquaplanet simulations -> CAM5 much less scale sensitive than CAM4 Zarzycki *et al.*, 2014, J.Clim. (see AMWG-32 poster)





CESM AMIP simulations

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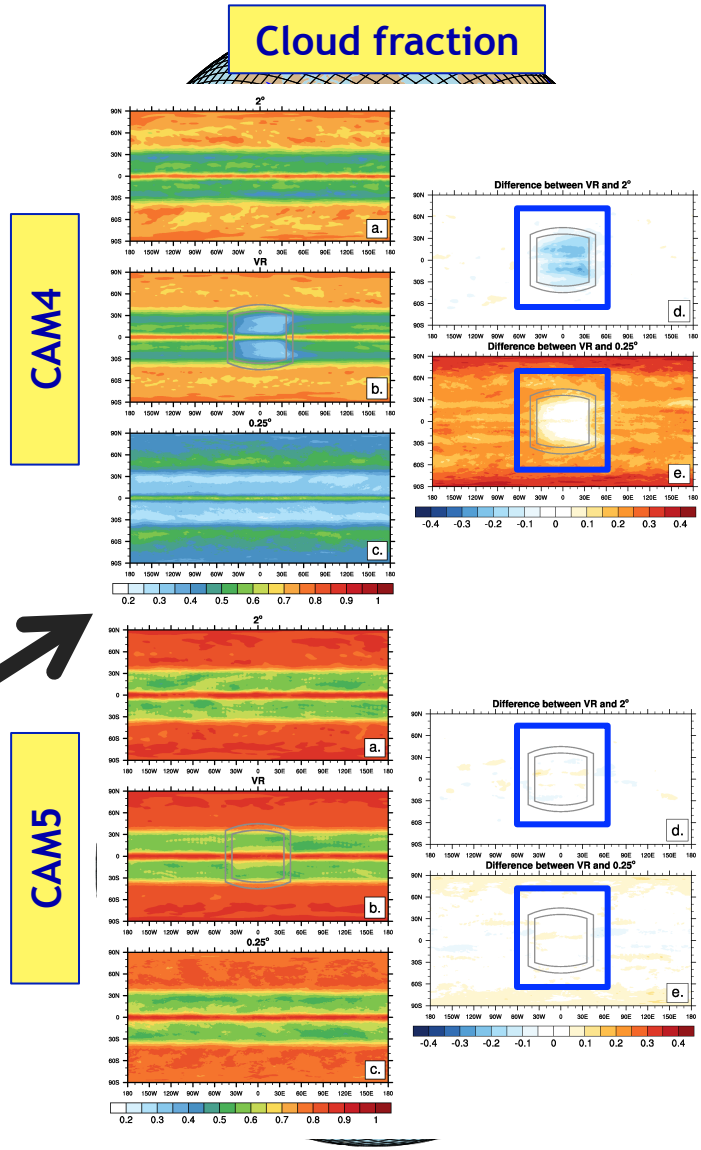

Uniform global simulation

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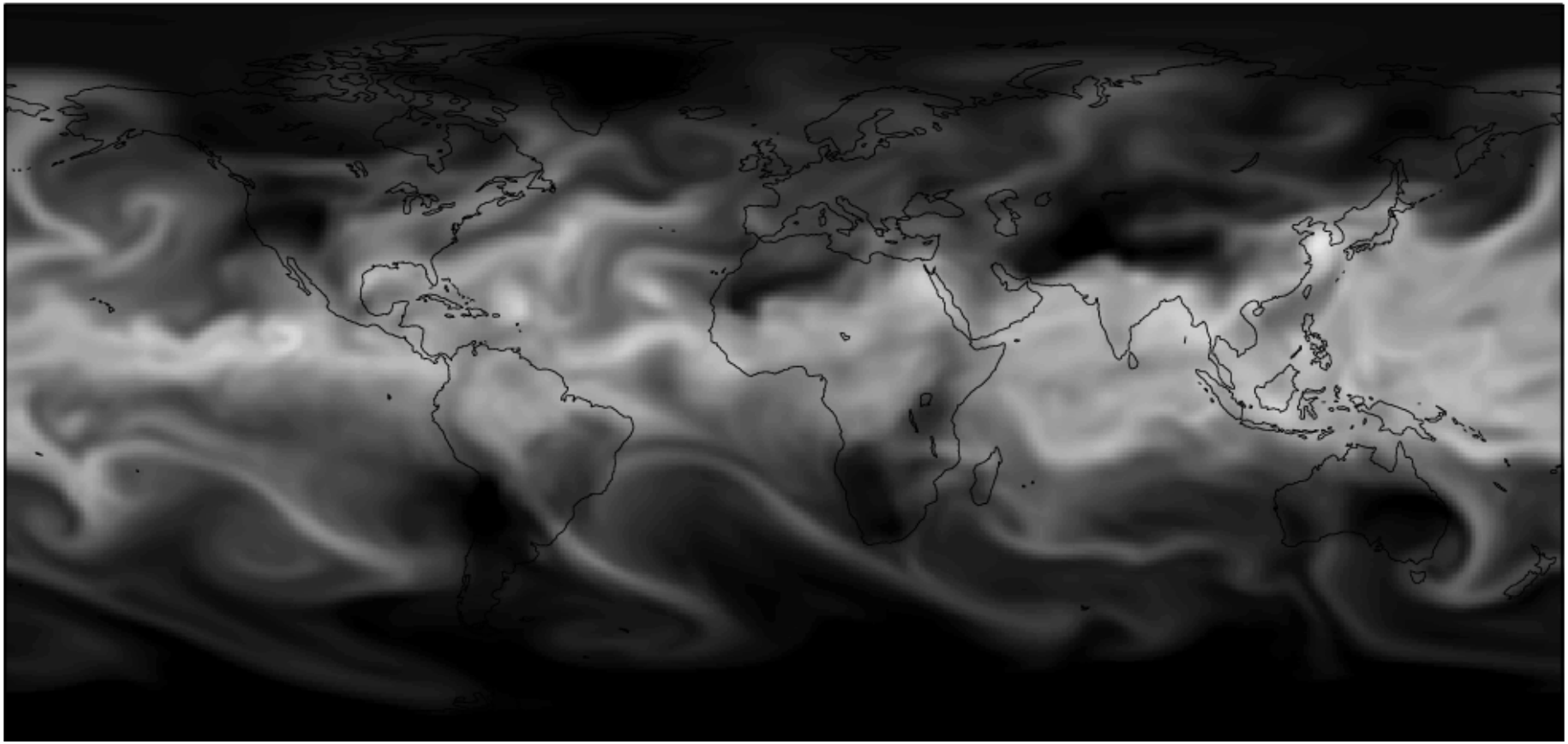

TPW, Sept 1-16

Multi-resolution global circulation

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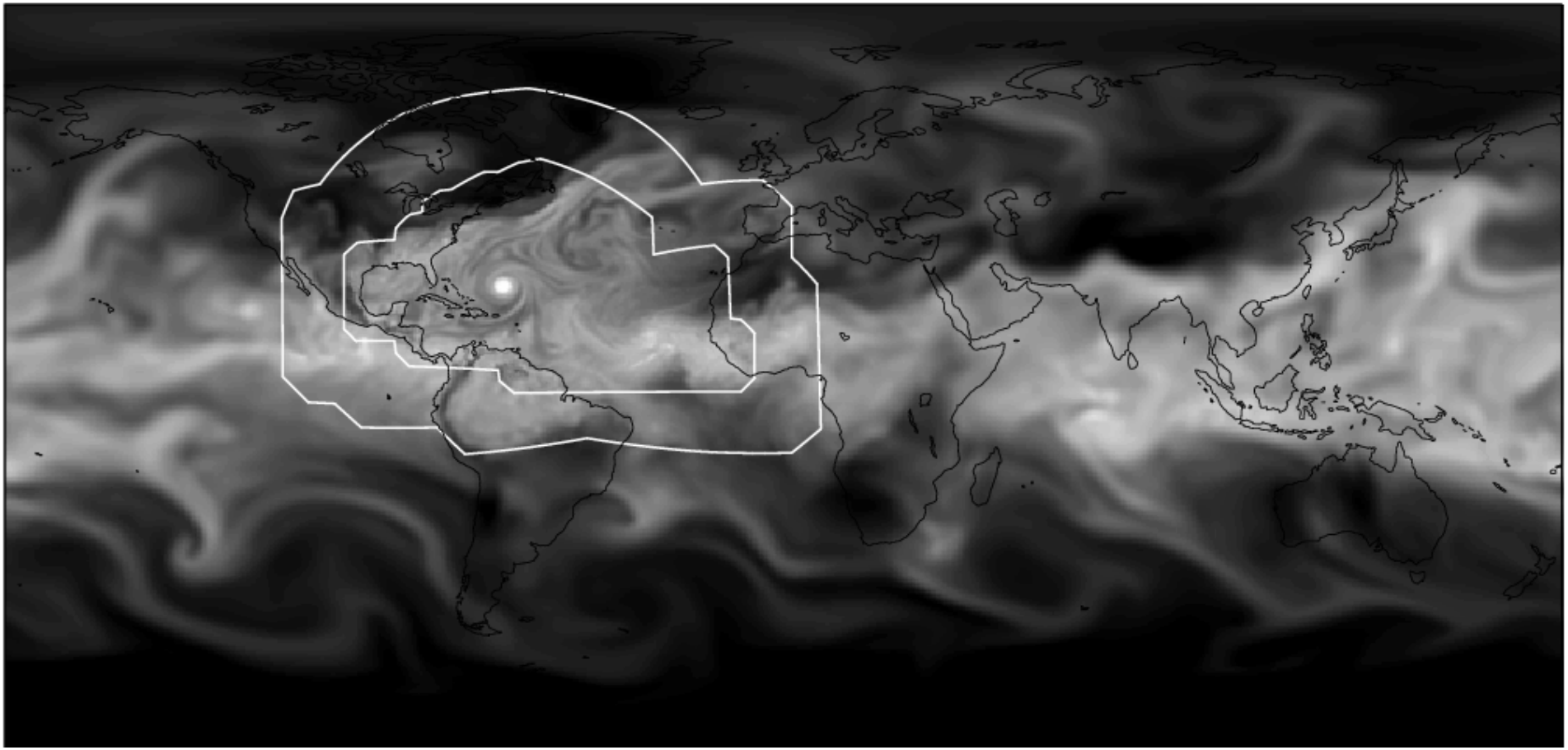

TPW, Sept 1-16

Global climate

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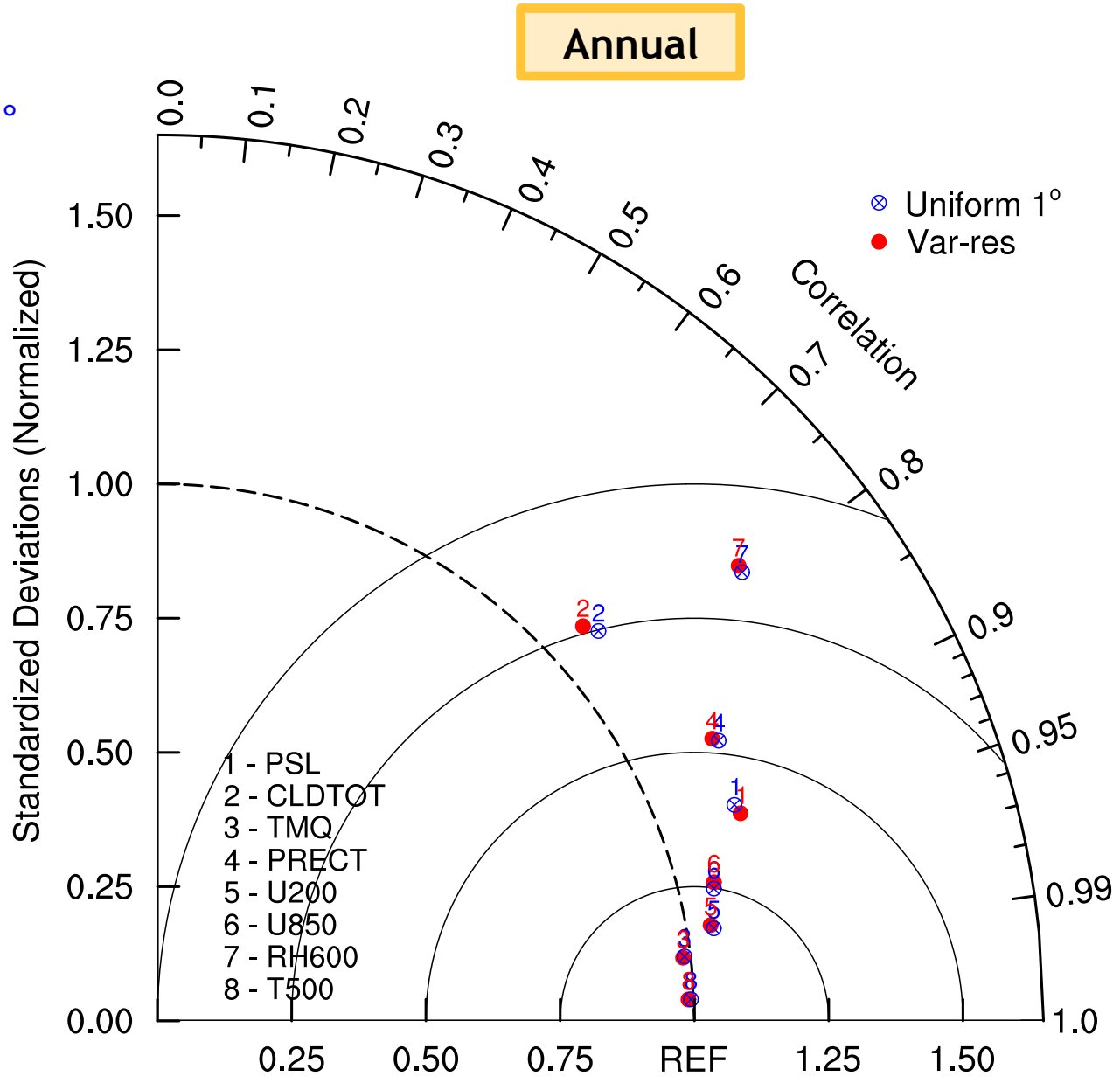
Global 1°
Var-res



Effect of refinement on NH jet

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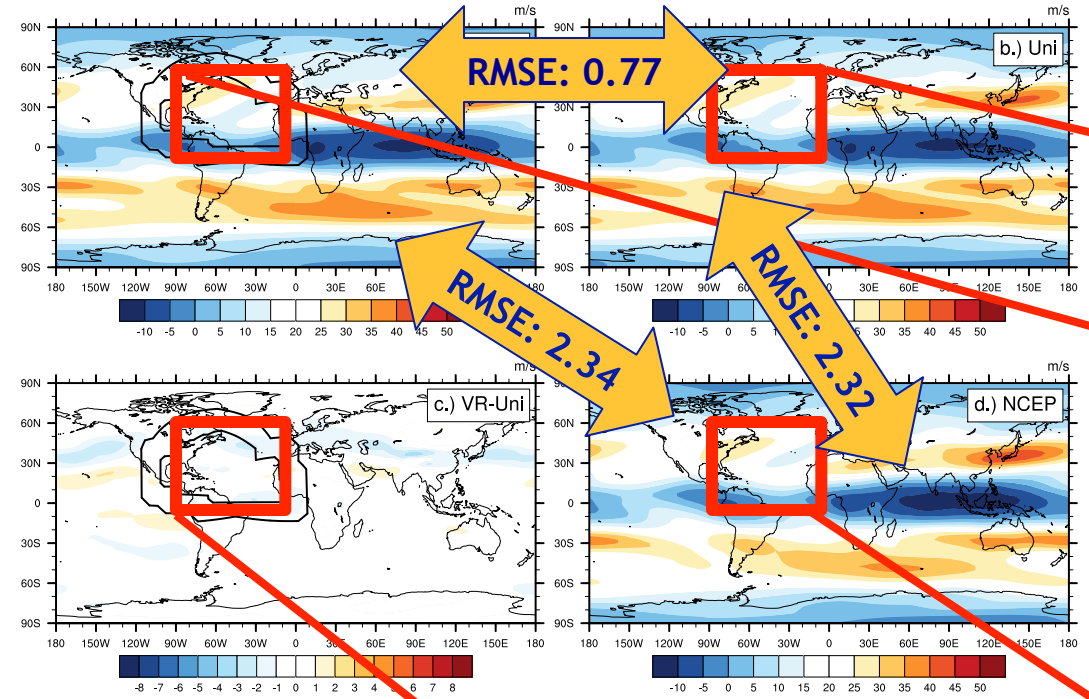
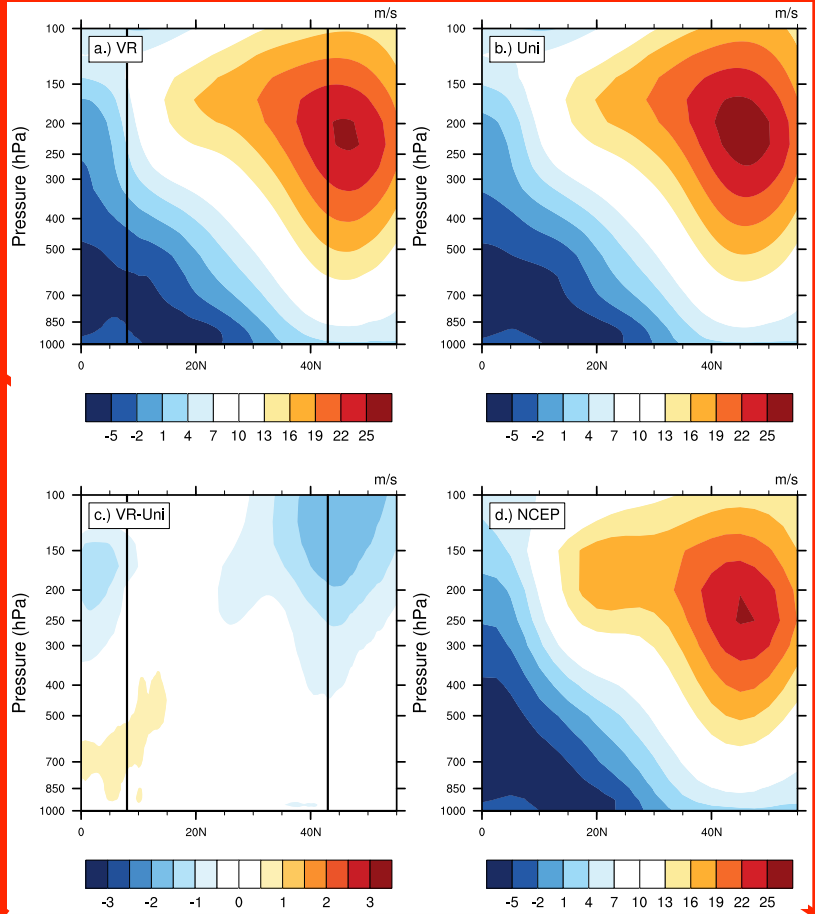


U200



Differential topography smoothing

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Hyperviscosity order

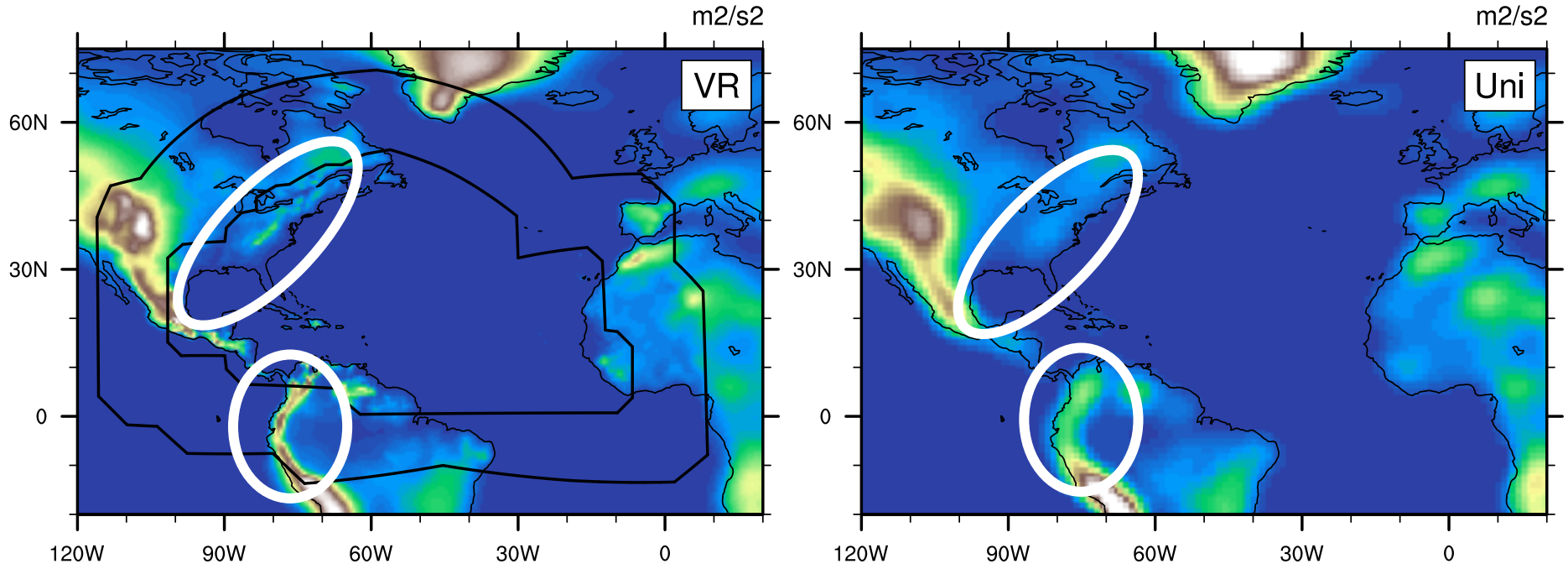
$$\Phi_{VR} = \Phi_U + cK_o(\Delta x)\nabla^o\Phi_U$$

Var-res topo

High-res topo

Tunable constant

Diffusion coefficient (scale selective!)



Topographical effects

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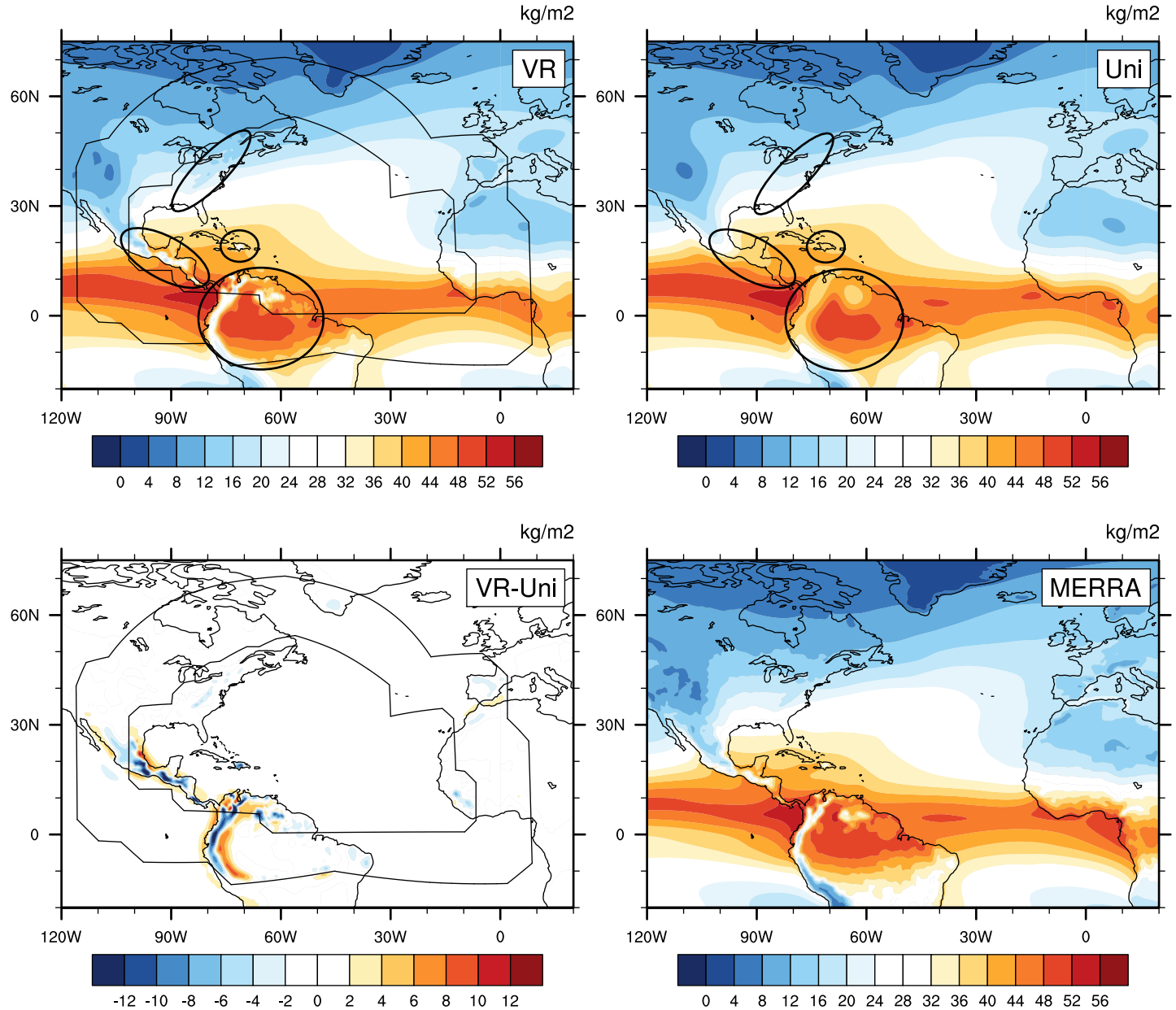
Total Preciptable Water



Regional climate

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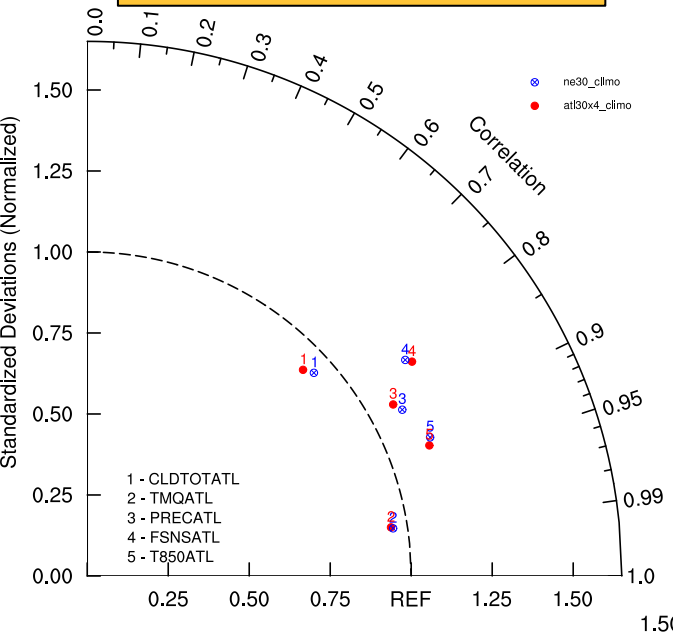
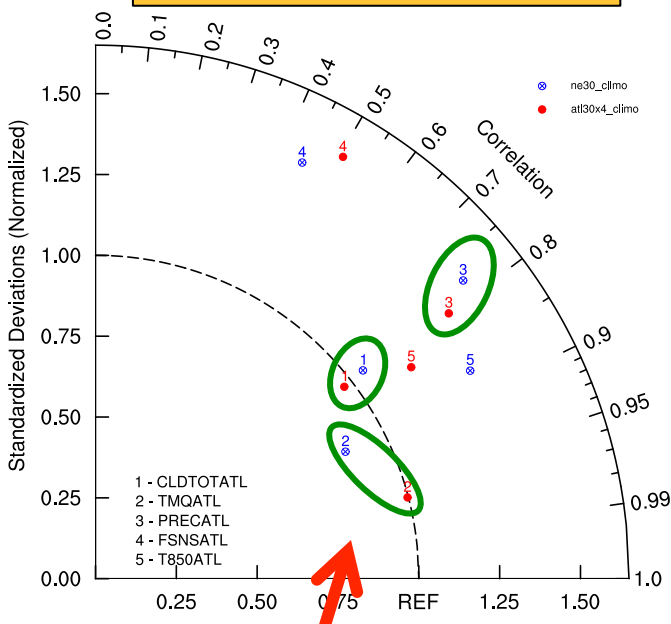
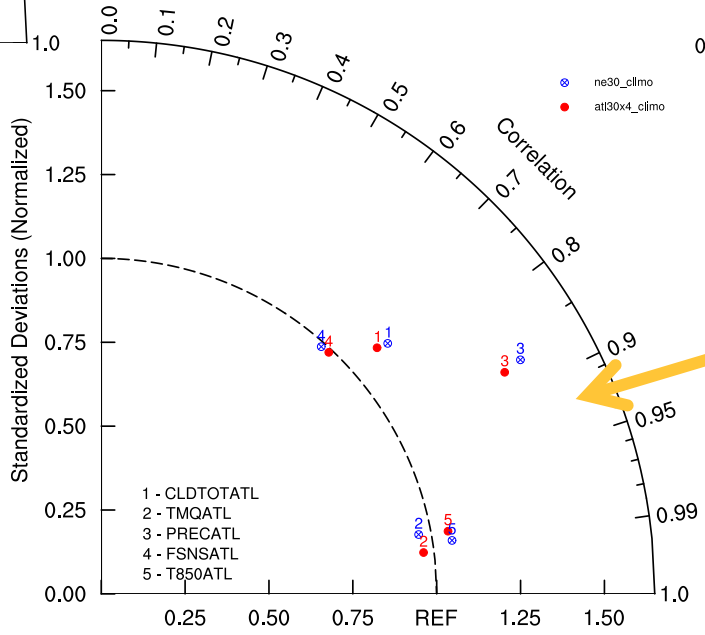
Global

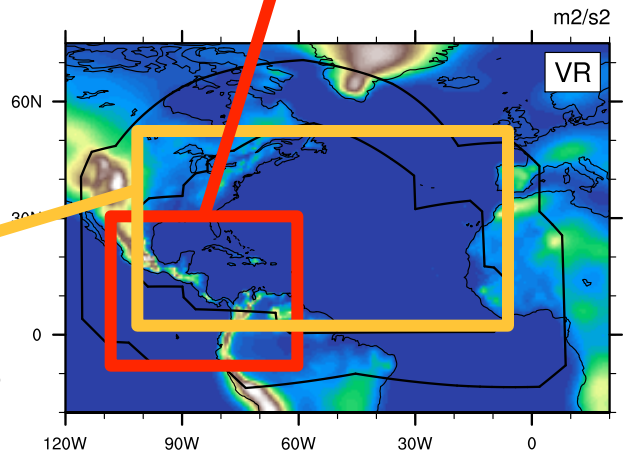


C./North S. America



Atlantic Basin





Global 1°
Var-res

1 – CLDTOT
2 – TMQ (TPW)
3 – PRECT
4 – Net surface SW flux
5 – T850

African Easterly Wave activity

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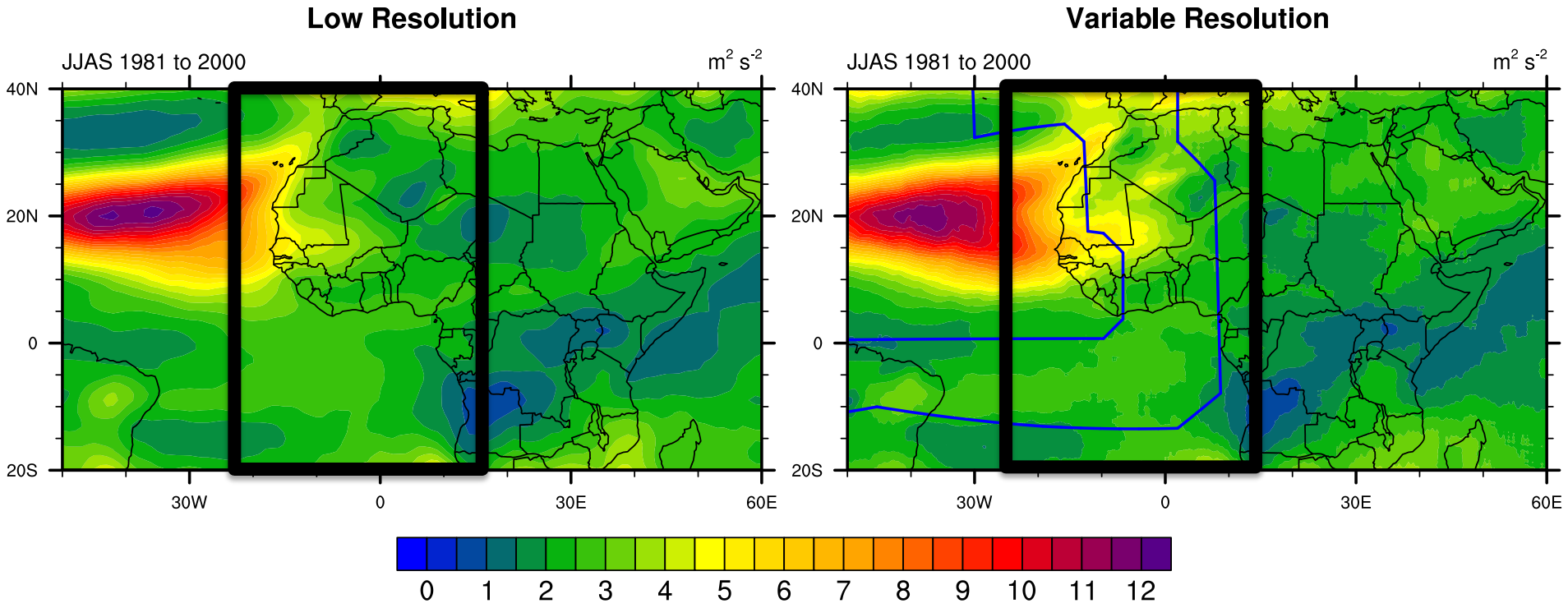
CAM-SE Meridional Wind Variance at 700 hPa



Figures from *Diana Thatcher* (UMich), technique from *Skinner and Diffenbaugh*, 2013

African Easterly Jet

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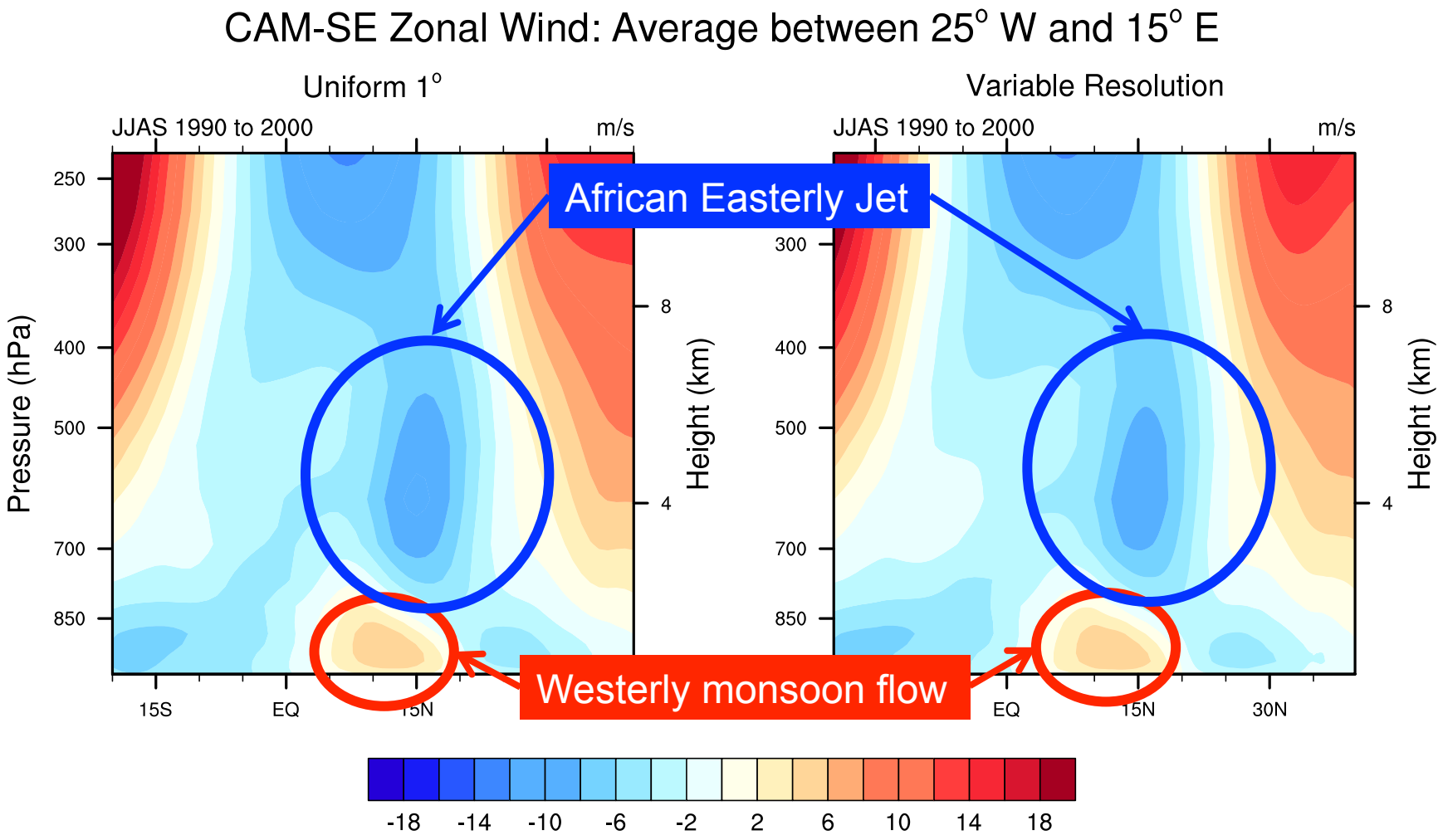

Figures from *Diana Thatcher* (UMich)

Regional climate - TCs

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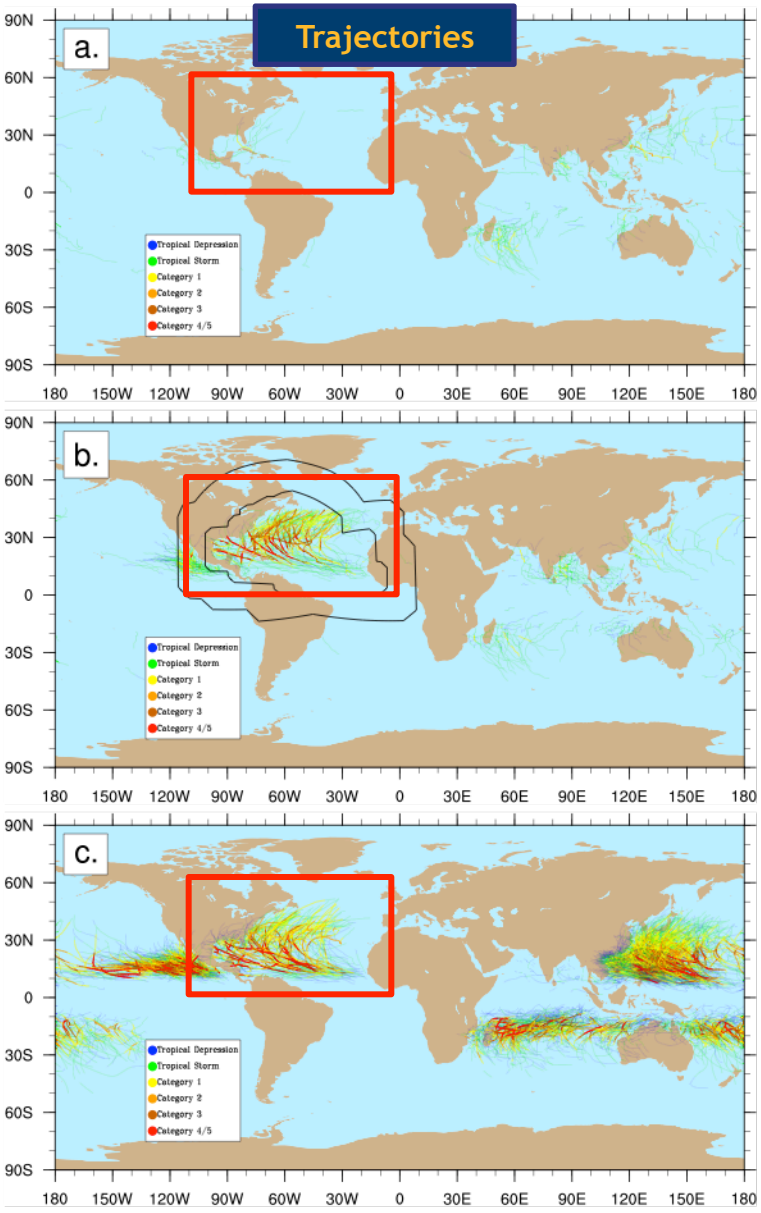
Uniform 1°

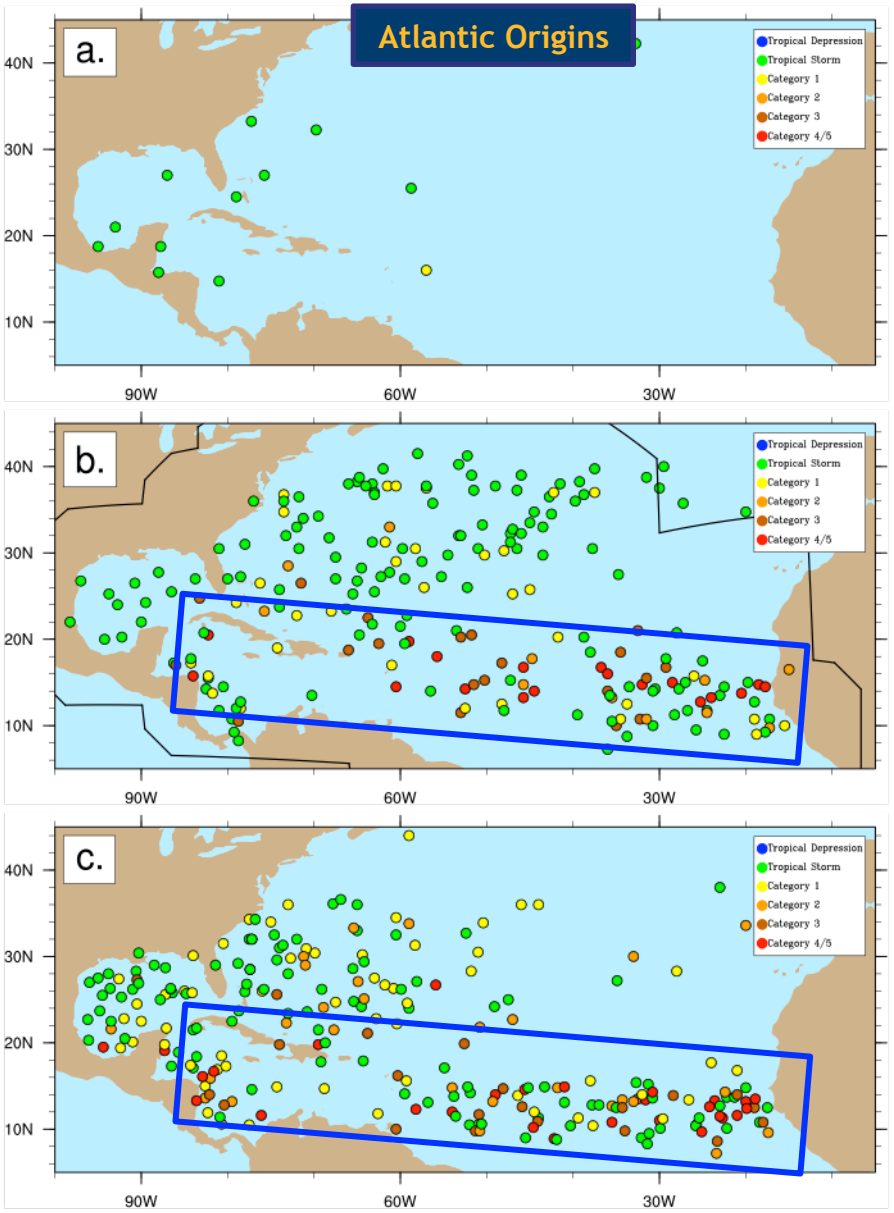
Var-res

Obs

Trajectories

Atlantic Origins





Regional climate - Mountain gap winds

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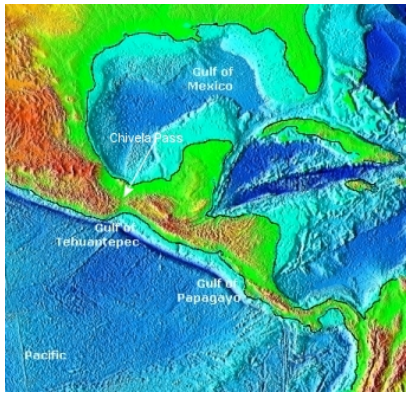
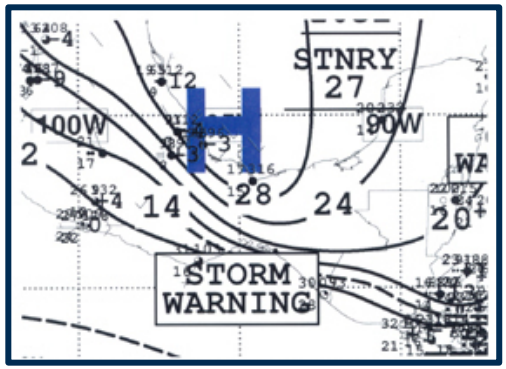
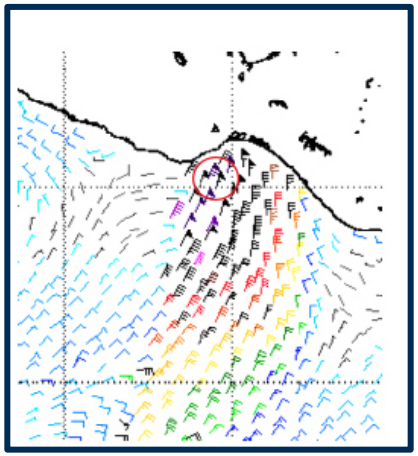
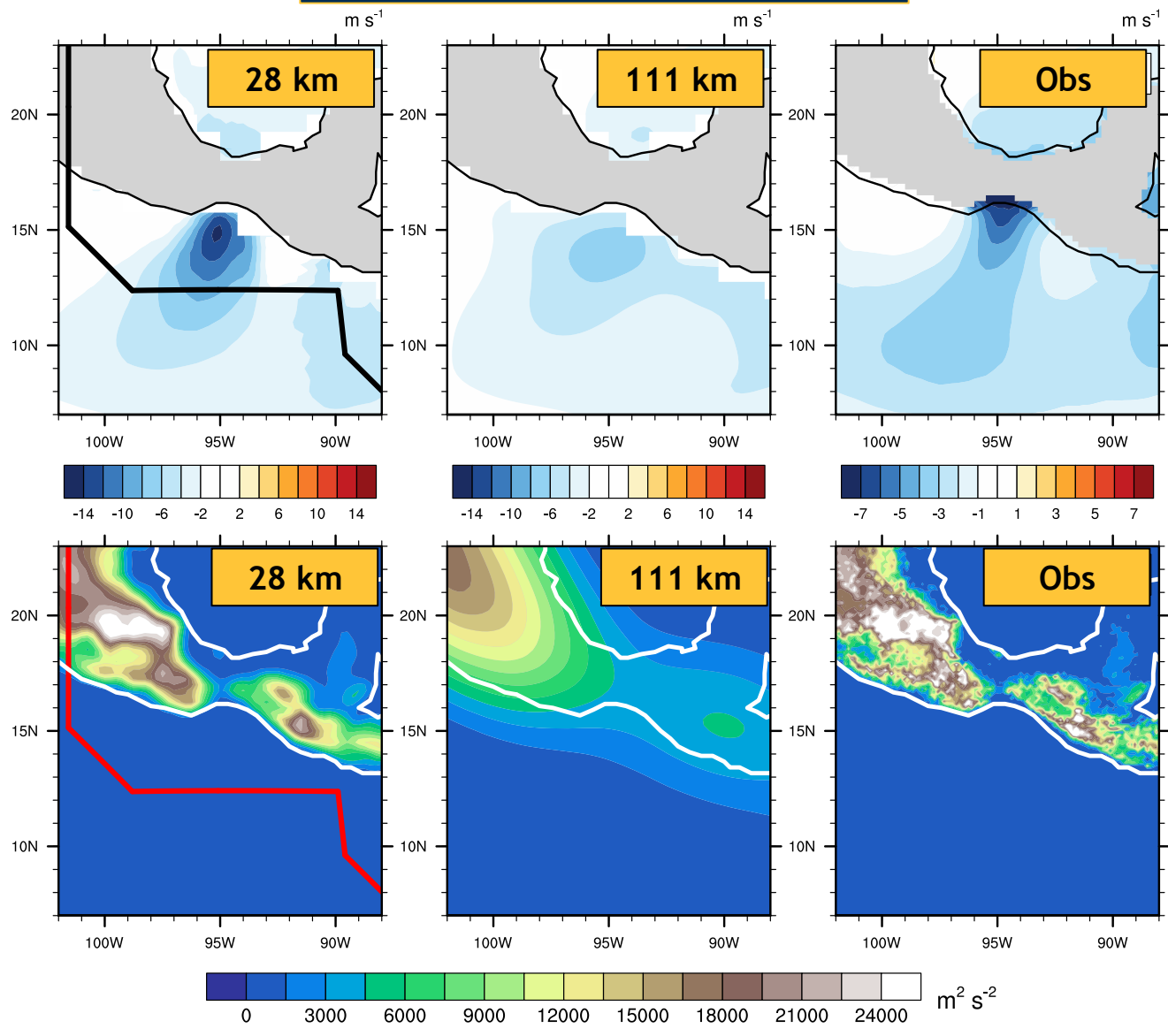






NOAA March 30-31, 2003

January Average Surface Wind



Regional climate – Western US snowpack

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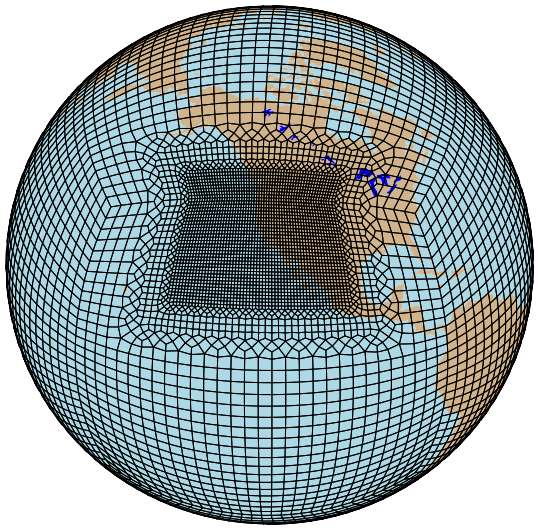
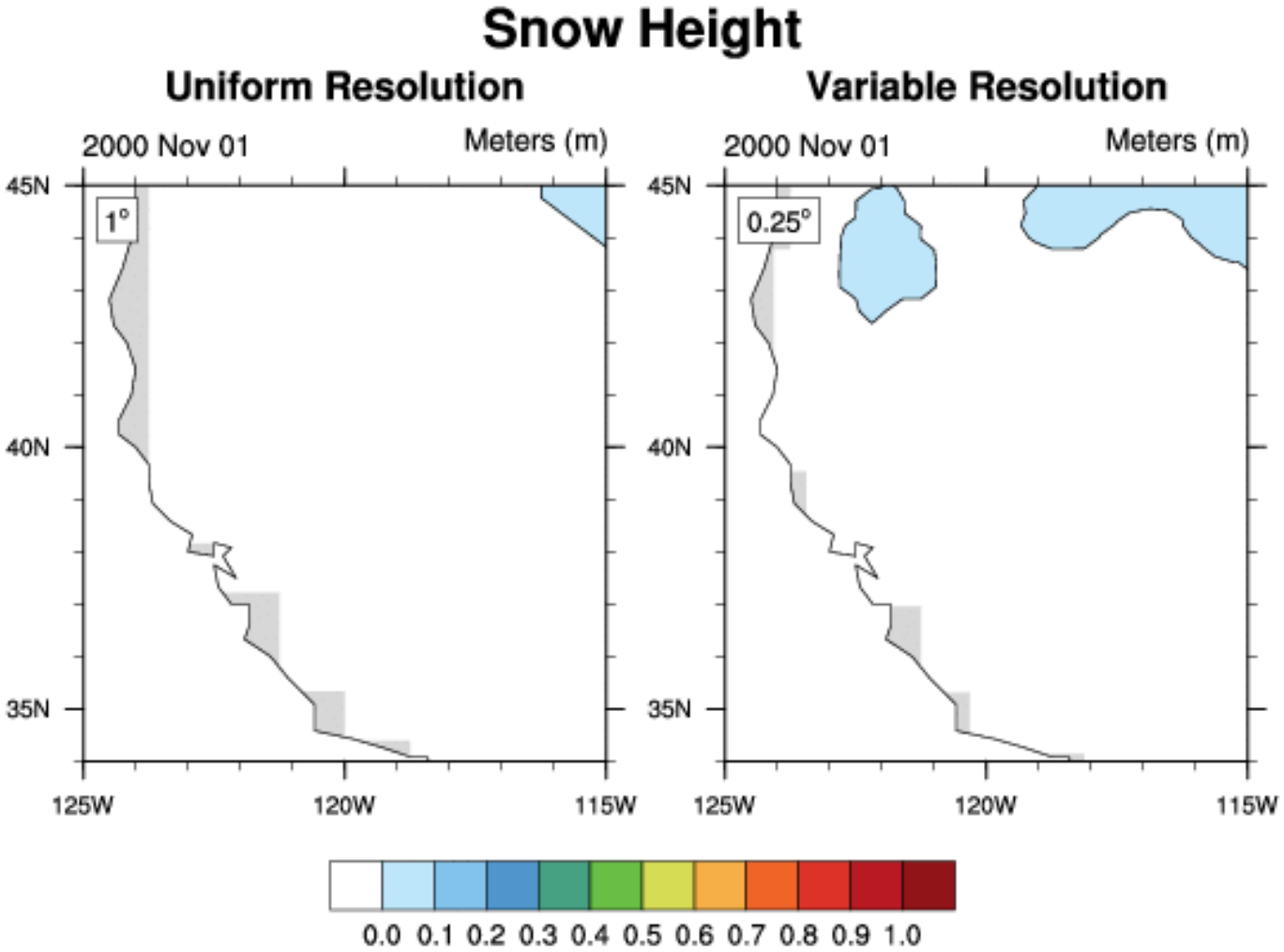
- California snowpack (Alan Rhoades + Paul Ullrich, UCDavis)
- Preliminary results show var-res effective mechanism to target topographically-induced effects





"Upscale" effects?

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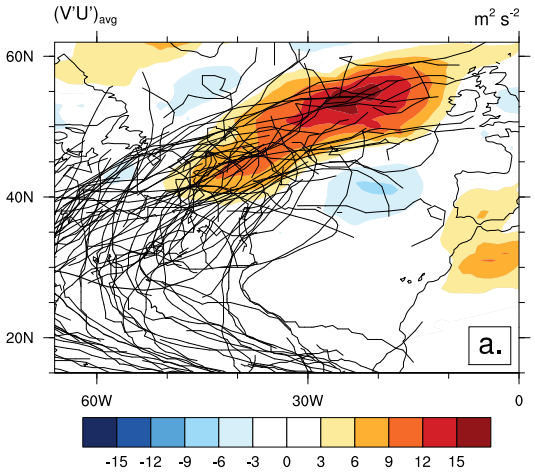
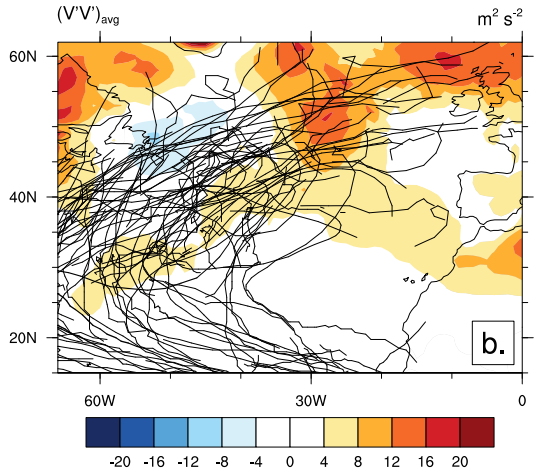
- ASO transient meridional fluxes due to eddies
  - Var-res minus coarse
- Extratropical transition signature?

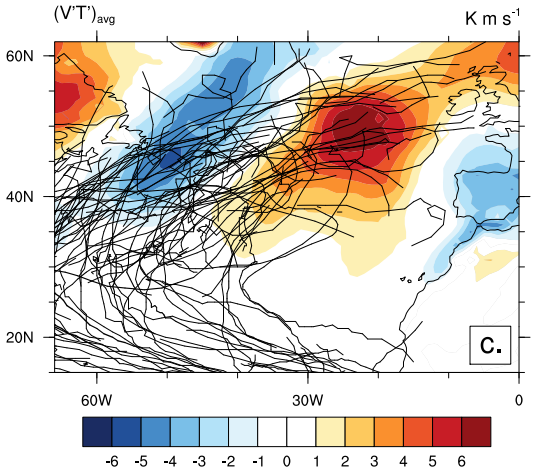
Zonal momentum

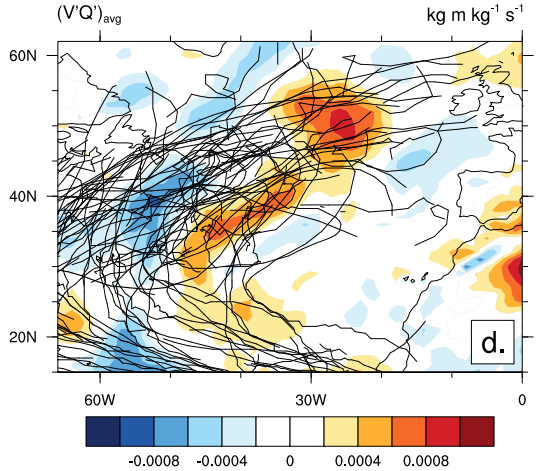




Meridional momentum

Temperature





Moisture

Summary

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- Global climate
  - Overall CAM-SE CAM5 var-res climate resembles that of globally-uniform simulation
  - Large scales do not appear to be significantly harmed by addition of resolution
    - No overt issues found in dynamical fields (yet) in/near grid transition regions
- Regional climate
  - Topographical representation in time-averaged climatology improved
    - Dynamics (upslope/downslope, gap winds)
  - Tropical cyclones significantly more realistic with refinement