A Hierarchical Framework for Evaluating Regional Climate Simulations

L. Ruby Leung and Samson Hagos
Pacific Northwest National Laboratory

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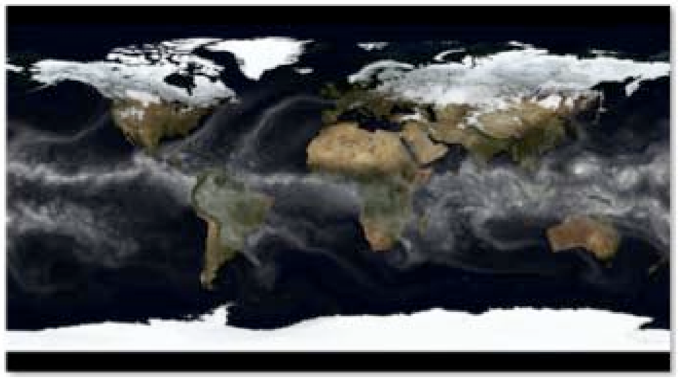
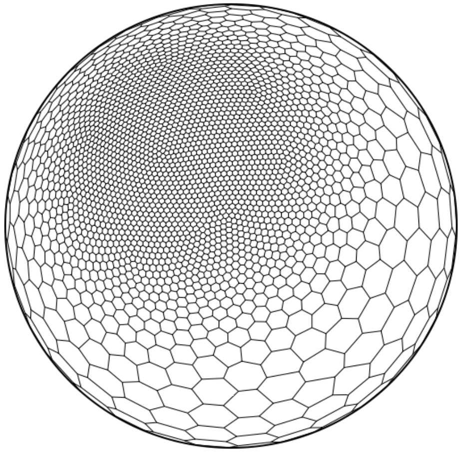
Robust regional climate modeling

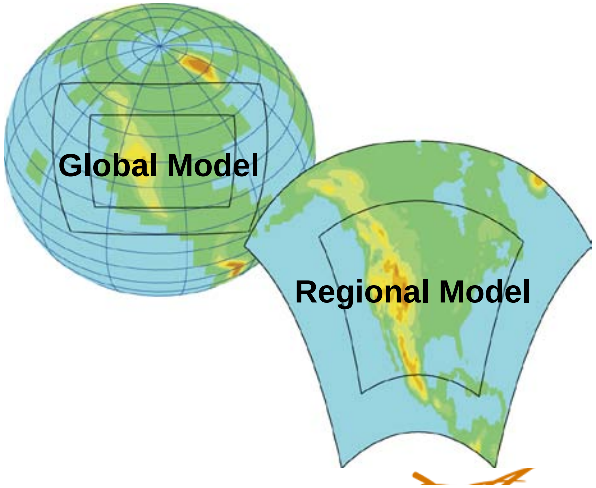
- Objective: To reduce the uncertainty of regional climate simulations through comparison of different modeling approaches
- Project team: Leung (PNNL), Ringler (LANL), Bader (ORNL), Collins (LBNL)
- Approach: Apply a hierarchical evaluation approach to different dynamical frameworks to identify the sources of and quantify uncertainties in regional climate simulations



Global high resolution model



Global variable resolution model



Nested regional climate model

Participating climate models

- Community Climate System Model (CCSM)
  - Atmospheric component
    - CAM-spectral (spherical harmonic discretization)
    - CAM-HOMME (spectral finite element)
    - MPAS-A (variable resolution finite volume)
  - Ocean component
    - POP (finite difference)
    - MPAS-O (variable resolution finite volume)
- Nested regional climate models
  - Weather Research and Forecasting (WRF) Model
    - Atmospheric component: WRF driven by CAM-spectral
    - Ocean component: ROMS driven by POP
  - RegCM3
    - Atmosphere only (*different physics)

Approach

- The hierarchical framework will evaluate simulations progressing from simple to complex and from idealized to real world (no physics or same physics)
  - Idealized no physics simulations
    - Shallow water test case
  - Idealized full physics simulations
    - Aqua-planet simulation
    - Channel flow simulation
  - Real world single component simulations (North and South America)
    - Real world atmosphere simulations
    - Real world ocean simulations
  - Real world coupled simulations
    - Real world coupled atmosphere-ocean simulations

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Aqua-planet simulations

- Does nested regional model preserve the large-scale intra-seasonal waves as they propagate across the domain (both in amplitude and phase)?
- How are the power spectrum and frequency distribution of precipitation affected by the increased resolution and nesting?
- In the absence of regional forcing, what is gained from high resolution regional modeling?

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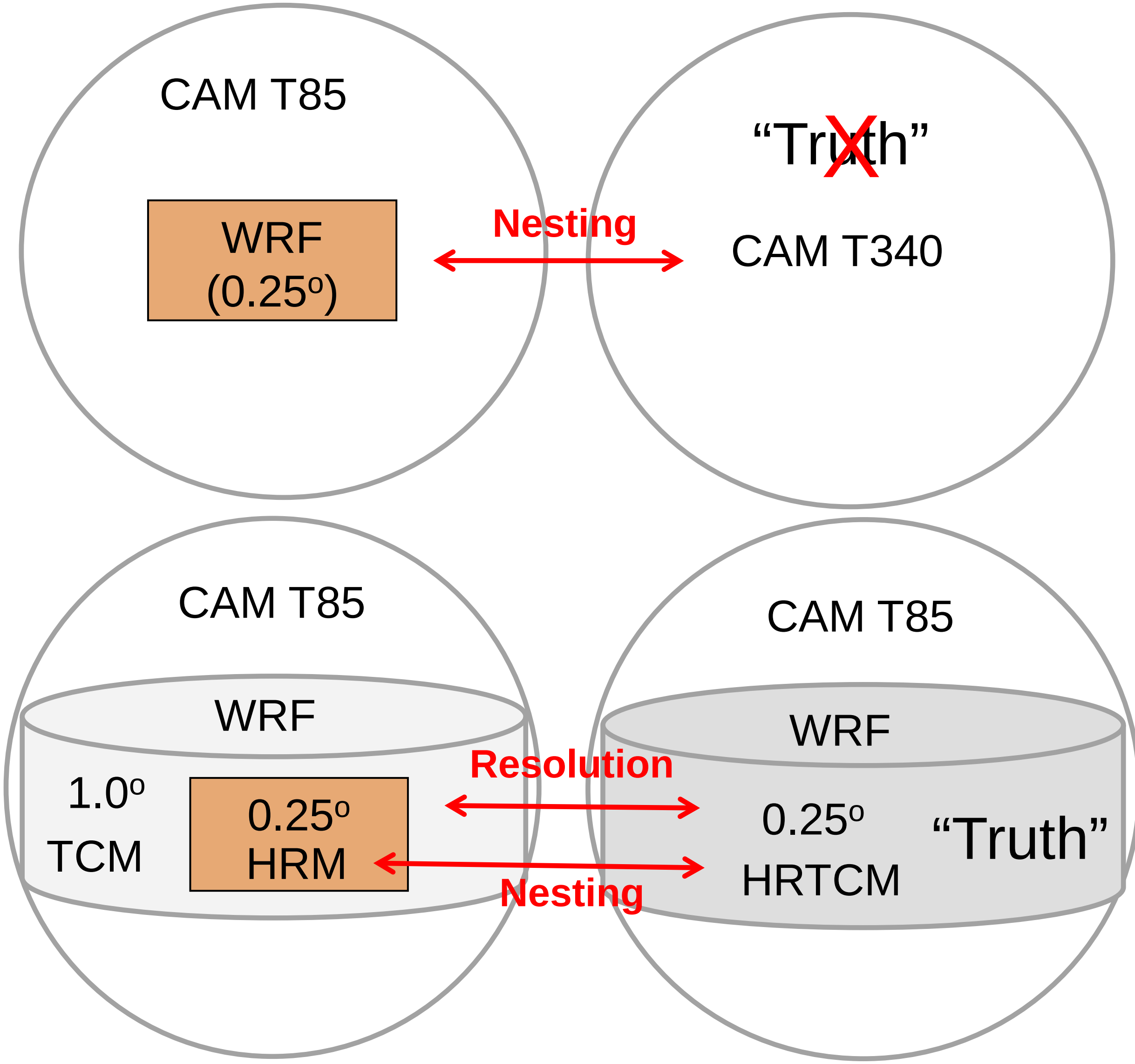
APE experimental design



- The CAM4 physics package is used in both CAM and WRF simulations
- Even with the same physics, differences between CAM and WRF dynamical cores matter – CAM T340 cannot be treated as the "truth" for evaluating WRF
- WRF is configured as TCM and run at 1° with a nested domain at 0.25° for comparison with the TCM at 0.25°

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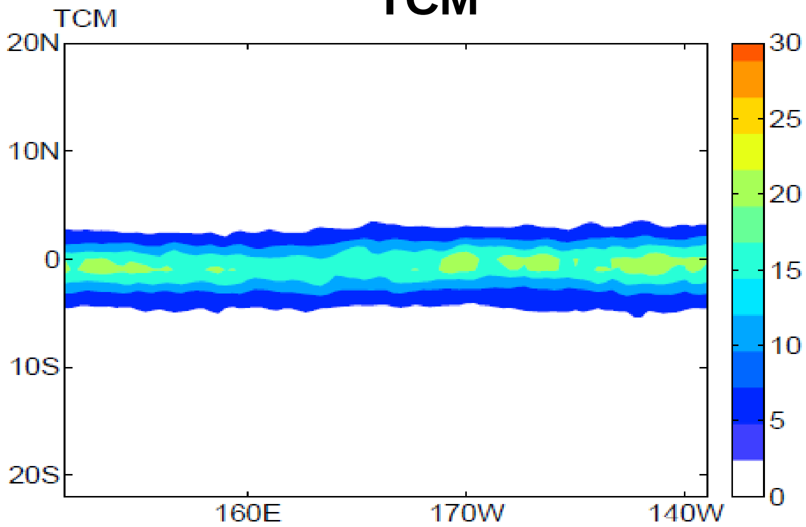
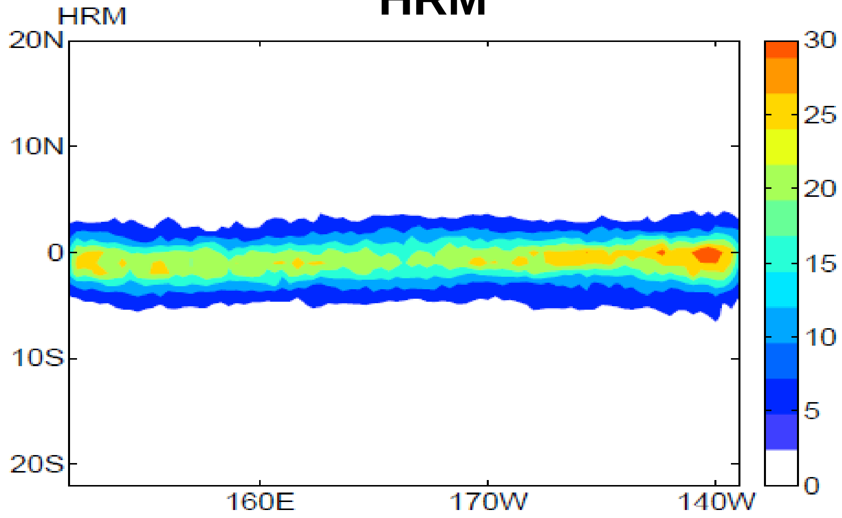
Spatial distribution of precipitation

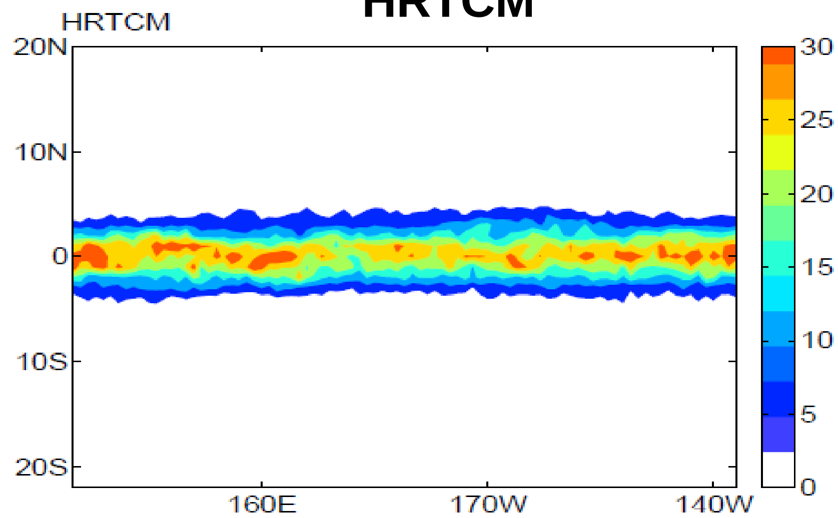
TCM



HRM



HRTCM



- Mean precipitation in the ITCZ is enhanced with grid resolution
- Some effects of nesting are felt in the eastern boundary of the regional domain (zonal asymmetry)

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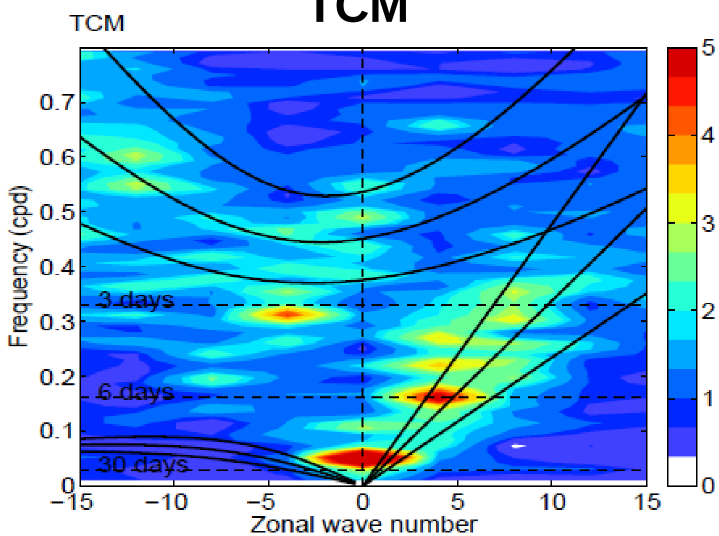
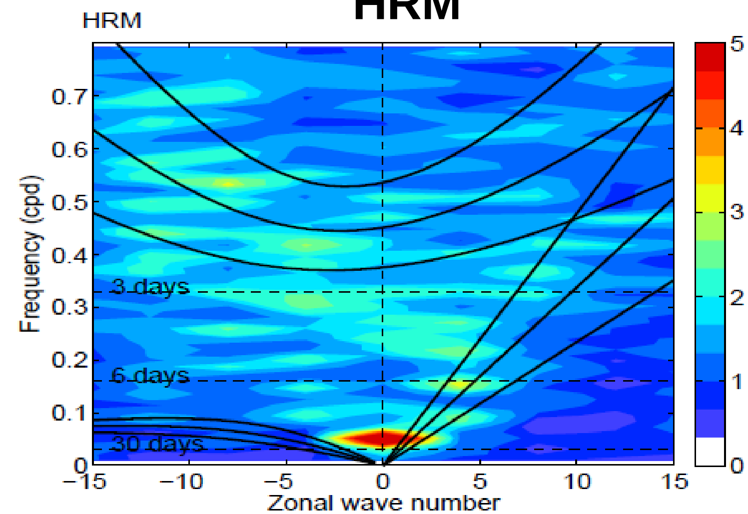
Space-time spectra (symmetric mode)

TCM

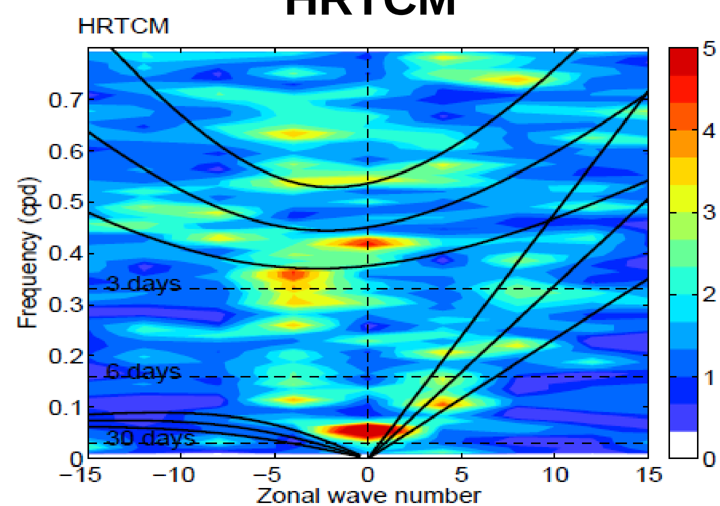


HRM



- Long Kelvin waves are preserved, but shorter waves are weaker in HRM and HRTCM
- WIG and EIG are weakened by nesting compared to HRTCM

HRTCM



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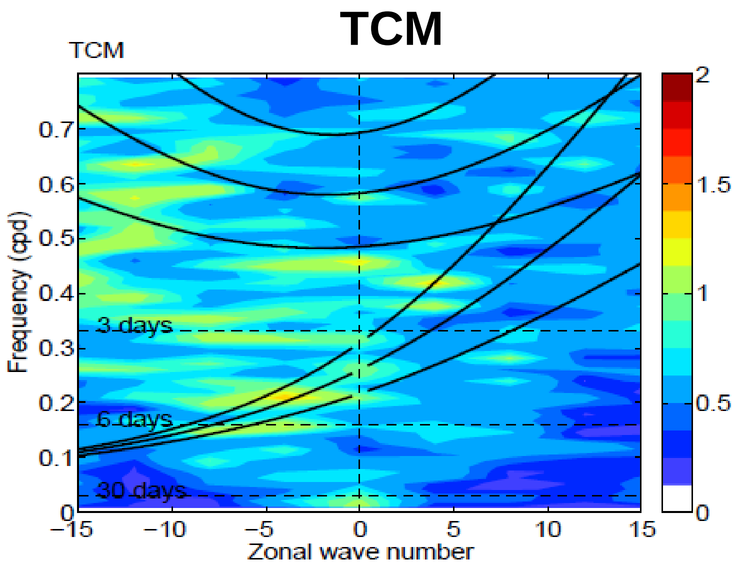
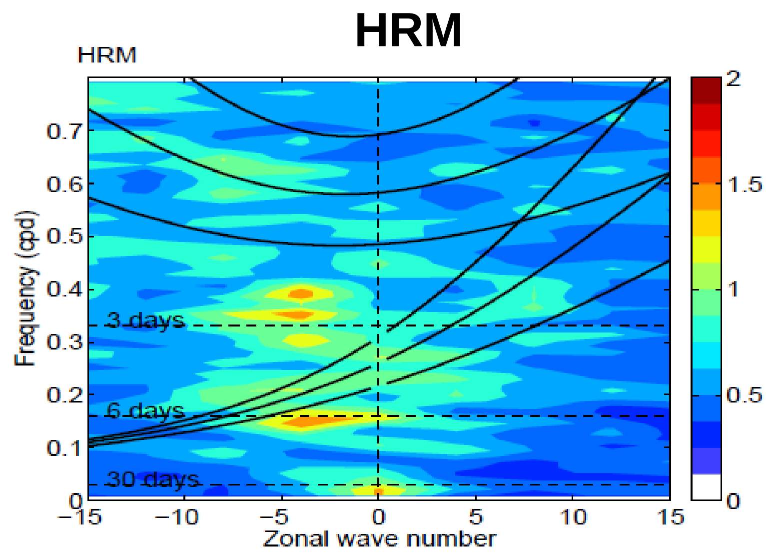
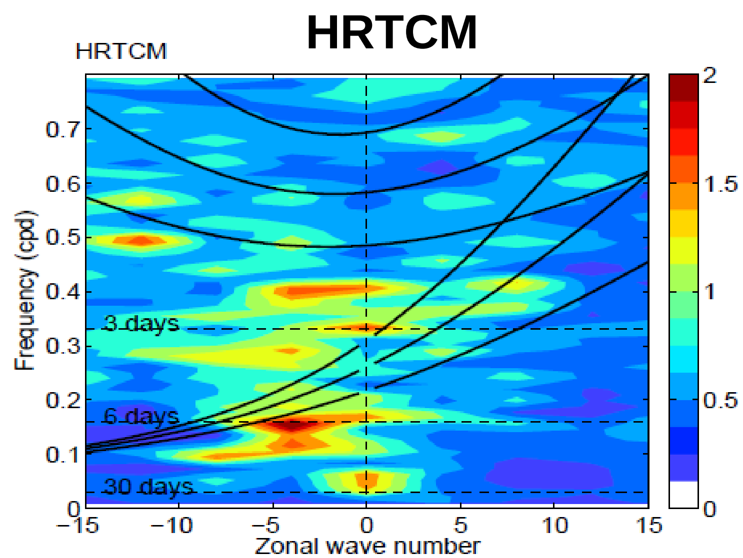
Space-time spectra (anti-symmetric mode)





- Nesting weakens MRG and EIG compared to HRTCM
- MRG and WIG in HRM are present and somewhat stronger than TCM



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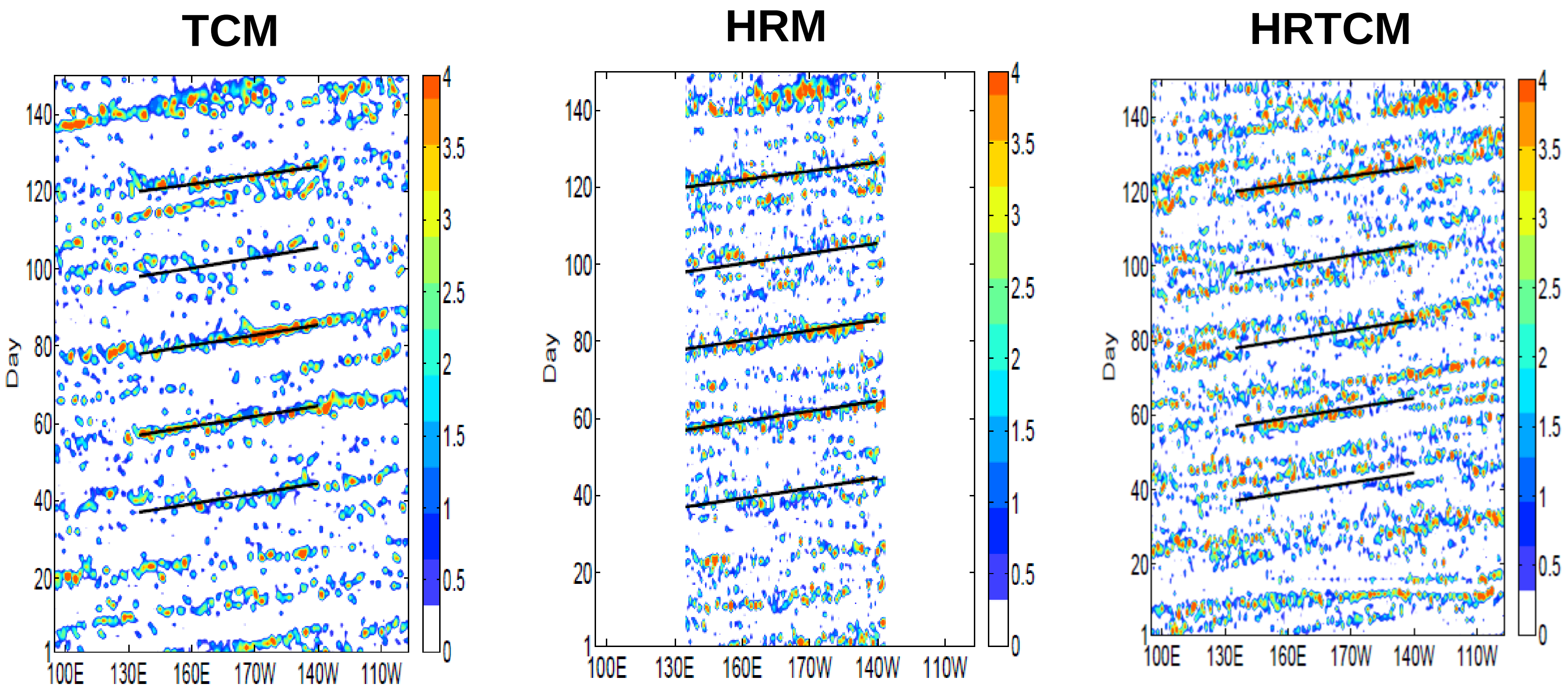
Propagating features and phase speed



Raw precipitation averaged between 10S and 10N in mm/day – black lines mark the propagation speed of about 23 m/s

- The precipitation signal is dominated by 20-day Kelvin waves that maintain their amplitude and phase as they propagate through the boundaries of the regional domain

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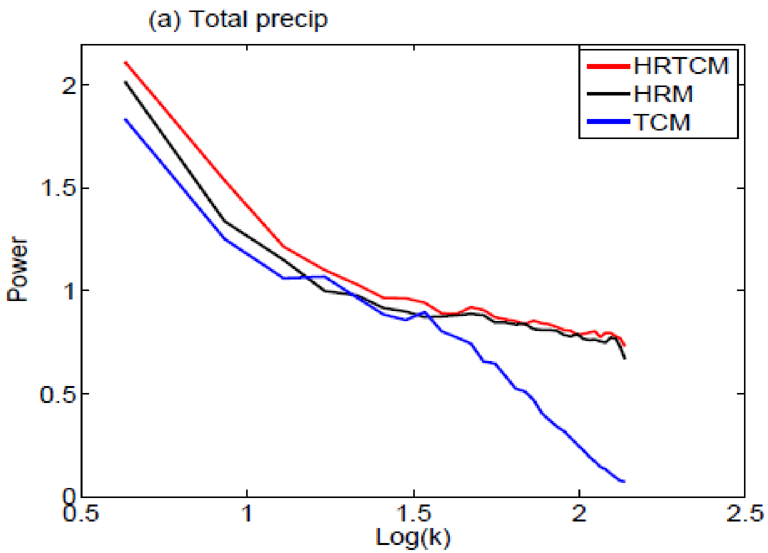
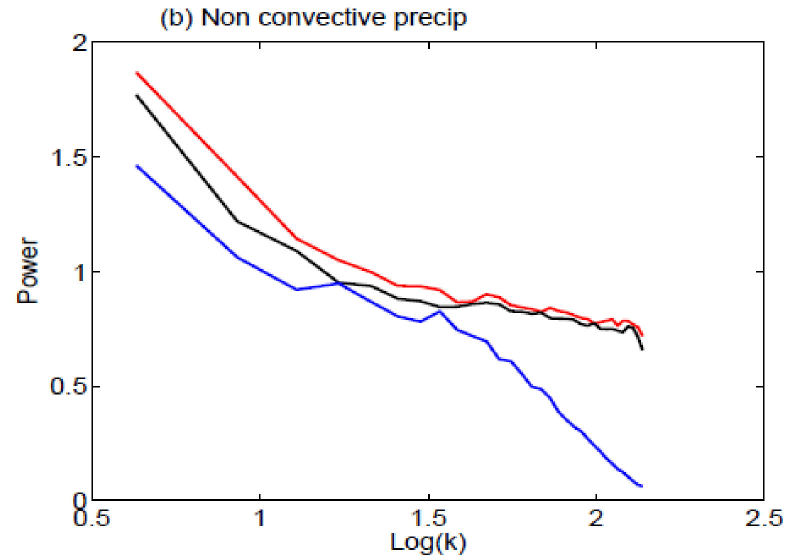
Precipitation spectra

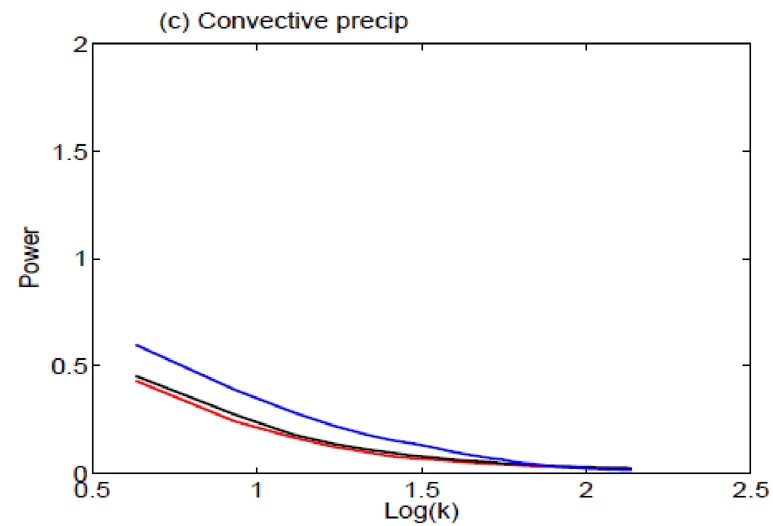
Total precipitation



Non-convective precipitation

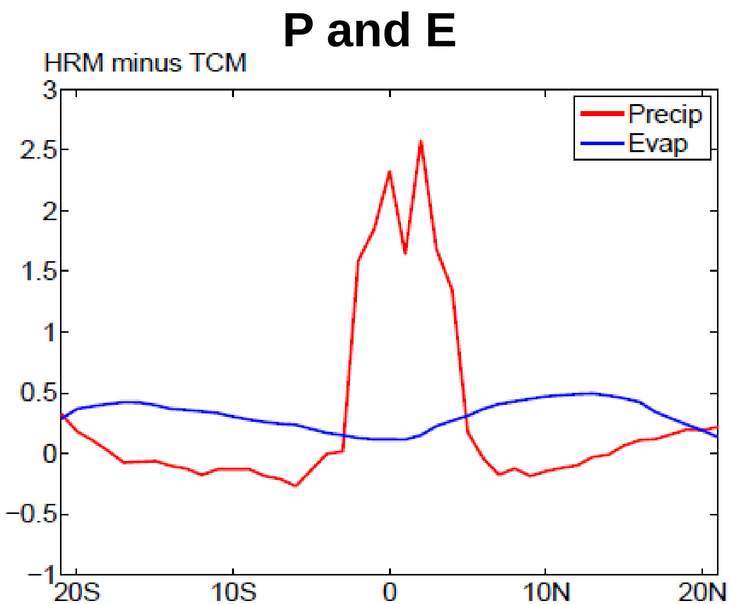


Convective precipitation

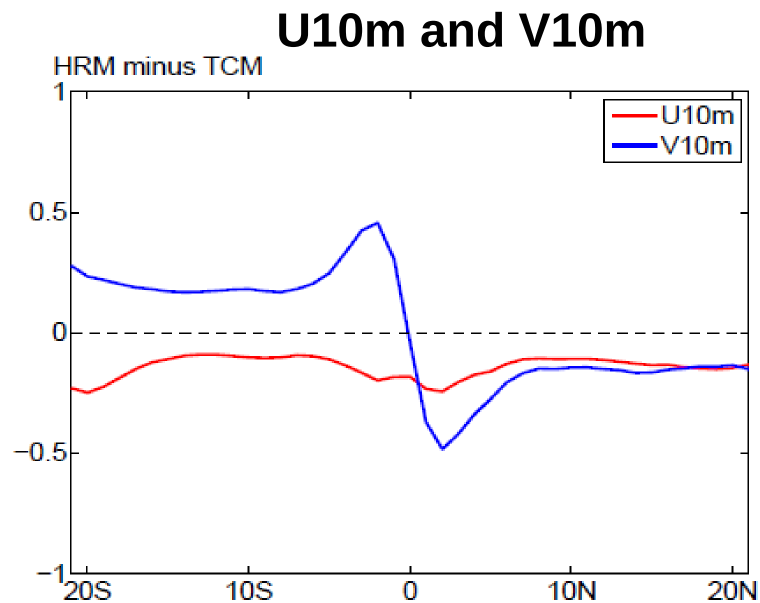


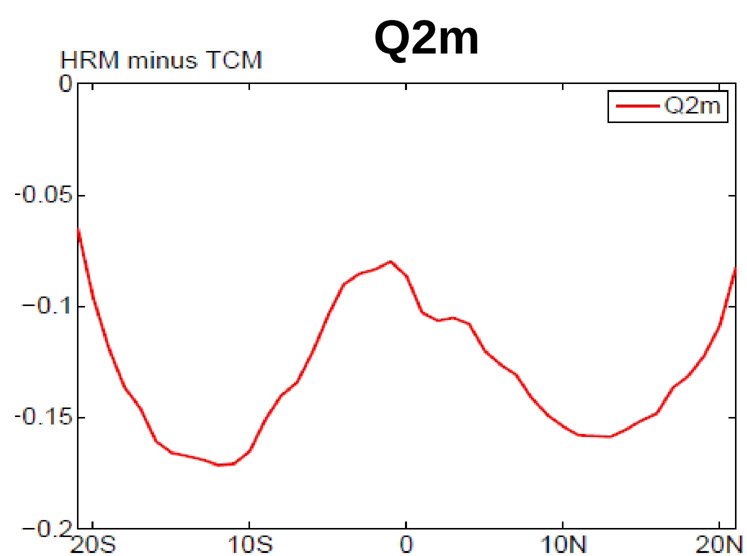
- More eddies of scale < 1000 km (log(k) > 1.5) are resolved by HRM and HRTCM
- Convective precipitation is reduced but compensated by the resolved precipitation at finer scales

How does a change in resolution affect precipitation?



HRM minus TCM

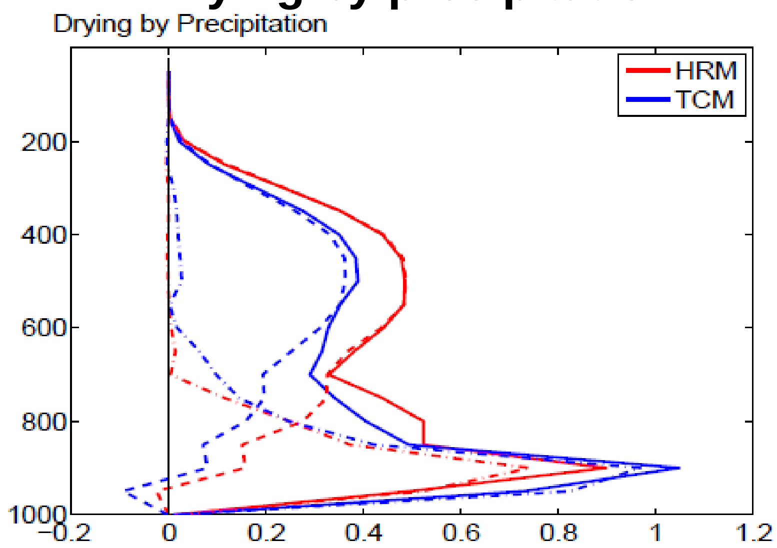




- Evaporation is enhanced due to:
  - Stronger surface winds
  - Dryer boundary layer

Resolution effects on moisture budget

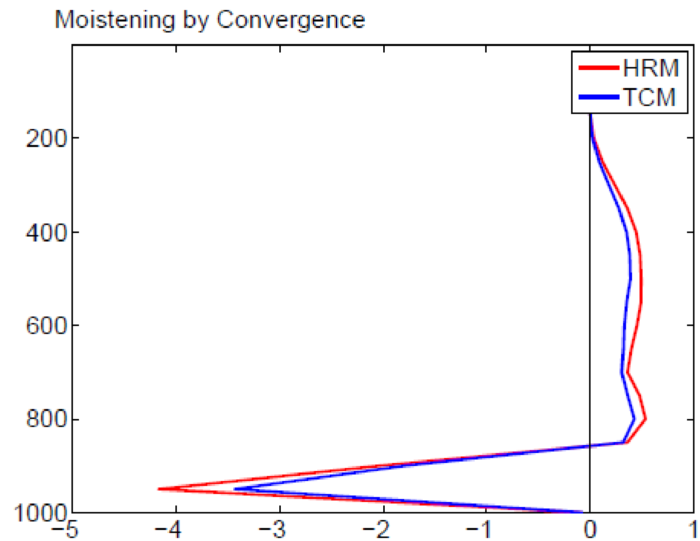
Drying by precipitation



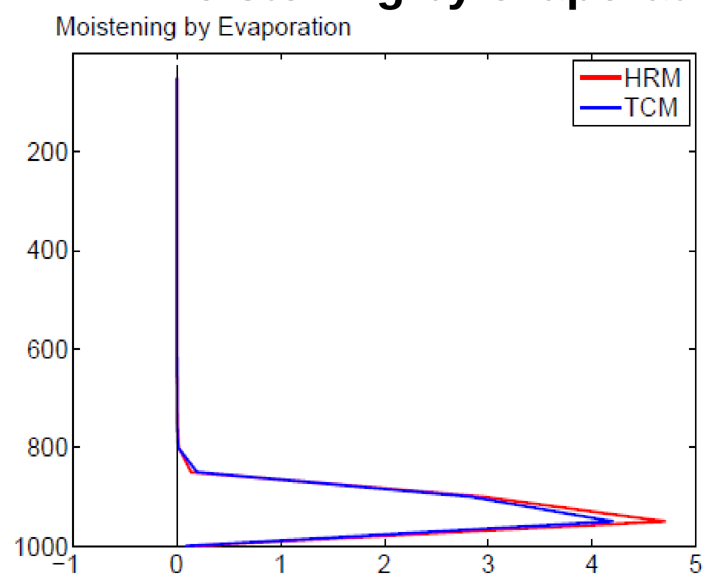
Total precip (solid); Non-convective (dashed); Convective (dash-dot)

- Increased resolution enhances the top-heavy profile of drying by precipitation (i.e., more non-convective like)
- This enhances upward moisture transport, circulation, and evaporation

Moistening by convergence



Moistening by evaporation



Summary

- A hierarchical framework is being used to quantify the effects of resolution and nesting on the hydrological cycle of the tropics in an aqua-planet setting
- Resolution:
  - Preserves the large-scale waves and adds variability at scales less than 1000 km
  - Changes the profile of drying by precipitation, which feeds back into moisture fluxes to increase precipitation and evaporation (strengthening of the hydrological cycle)
- Nesting:
  - Allows propagation of long waves, but weakens MRG and EIG modes compared to HRTCM
  - HRM reproduces many features of HRTCM
- Future work:
  - Other idealized simulations using WRF
  - Comparison across dynamical frameworks and dynamical cores
  - Real world simulations …

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