Parametric Sensitivity to Regional Mesh Refinement in the Community Atmosphere Model

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Community Earth System Model (CESM) Regional Refinement

Regional refinement within global climate simulations represents a unique opportunity to target regions where high resolution is required to resolve circulation features important to forecast and climate simulations. This approach represents a significant cost and speed savings over an equivalent global high resolution configuration.

However, significant uncertainties remain as to the applicability of current physics packages operating across resolution within the same domain.
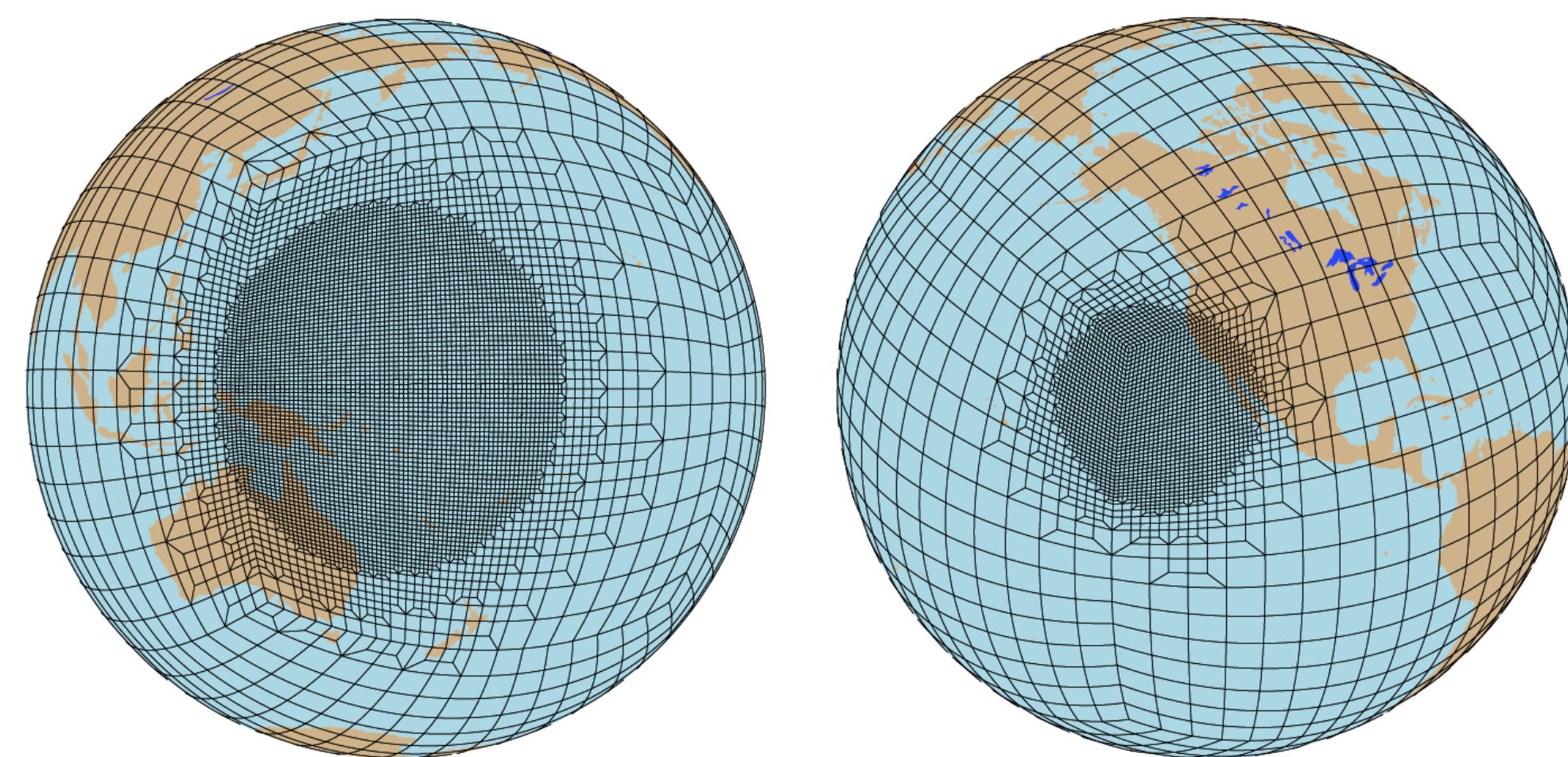

Figure 1: Regional refinement masks over tropical and sub-tropical domains.

Aqua-Planet Simulations with CESM

A series of global aqua-planet simulations are performed using the spectral element version of CESM. They are intended to demonstrate simulation characteristics in the presence of regional refinement. Simulations vary by:

Mask: Tropical and sub-tropical as defined in Figure 1.
Resolution: Global uniform (ne16/2º and ne120/0.25º) and regionally refined from ne16->ne120)
Physics: CAM4 and CAM5 physics
Configuration: Control: Standard physics package
tau300: Deep convection timescale reduced from 3600 to 300s
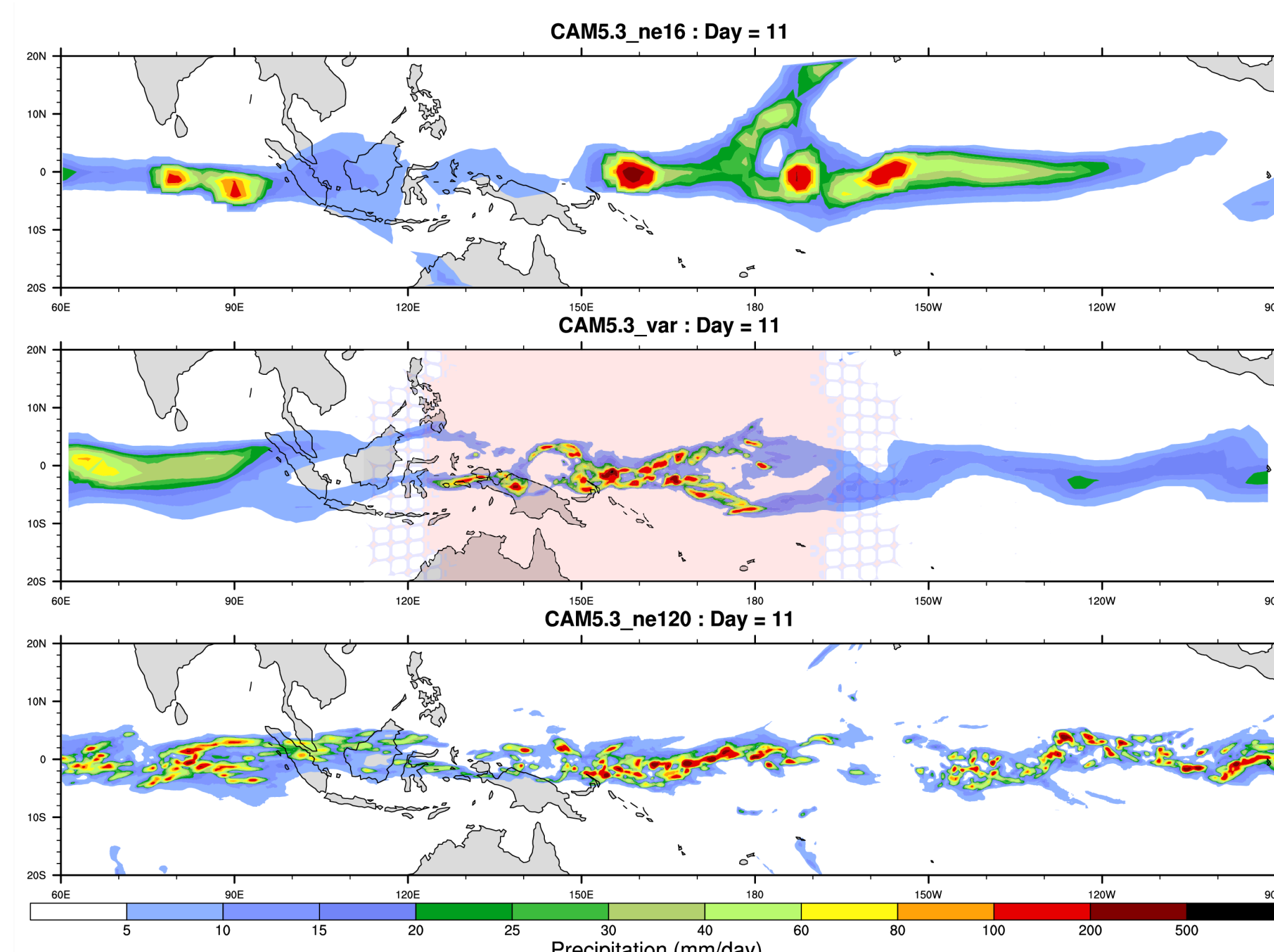ZMoff: Deep convection scheme turned off

Figure 2: Daily snapshot of rainfall in a uniform 2 deg (top) regionally refined 2 deg->0.25 deg (center) and uniform 0.25 deg (bottom) aqua-planet simulation.

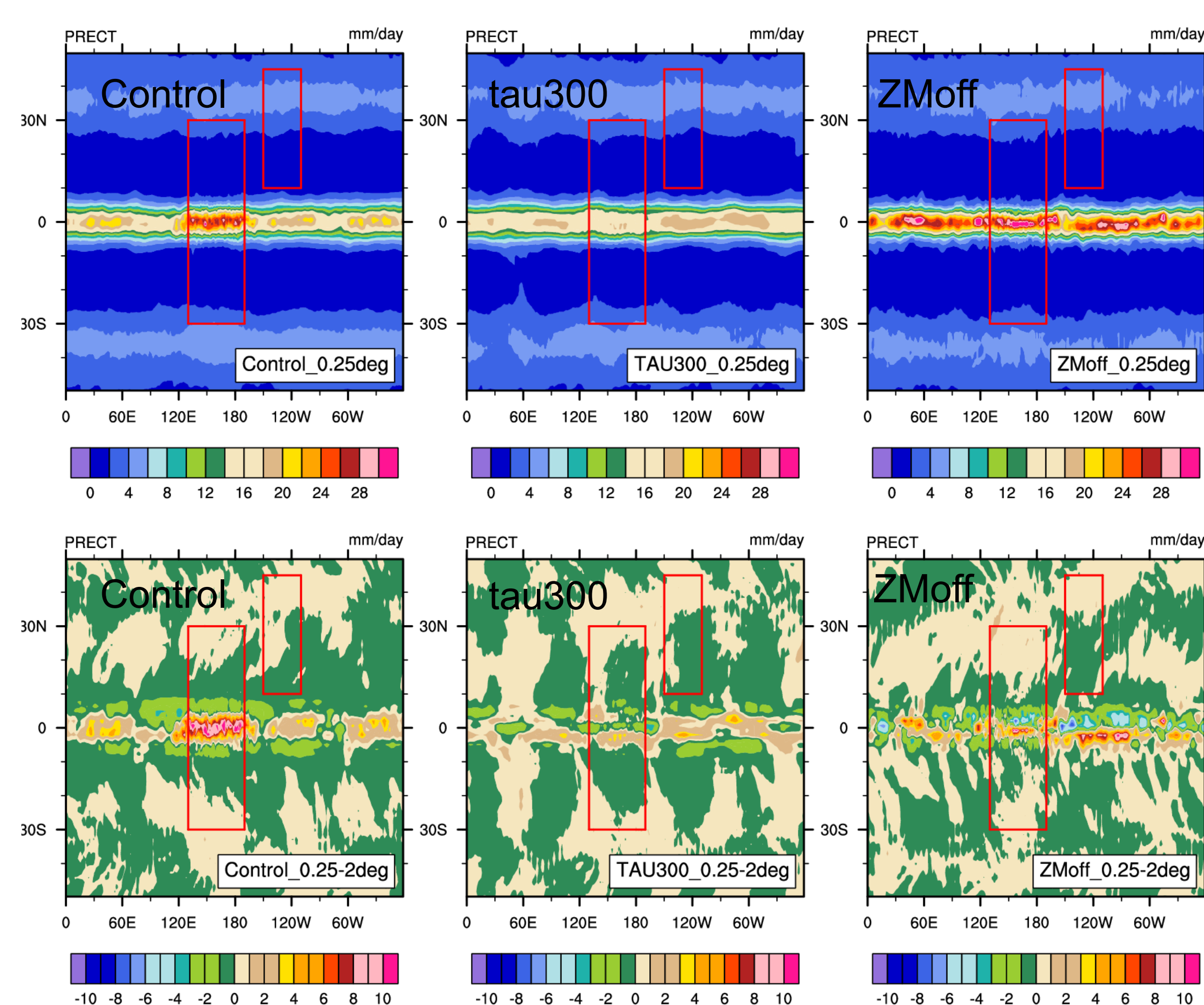## Regional Refinement Sensitivity

Figure 3: Precipitation means (top) and zonal anomalies from the equivalent control (bottom) for CAM5 regionally refined simulations testing the physics parameter settings.d

Main Conclusions

- Regional refinement is potentially a cost effective tool for high-resolution climate and forecast simulations.
- Simulation sensitivities exist across uniform resolution sensitivities and within regionally refined simulations
- Parameter settings can both reduce and amplify these sensitivities
- Sensitivities manifest as differences in vertical distribution of parameterization tendency terms
- Deep convection dominates the sensitivity to tropical regional refinement.
- Modulation of tropical wave activity is dependent on the propagating wave scale and parameterization settings

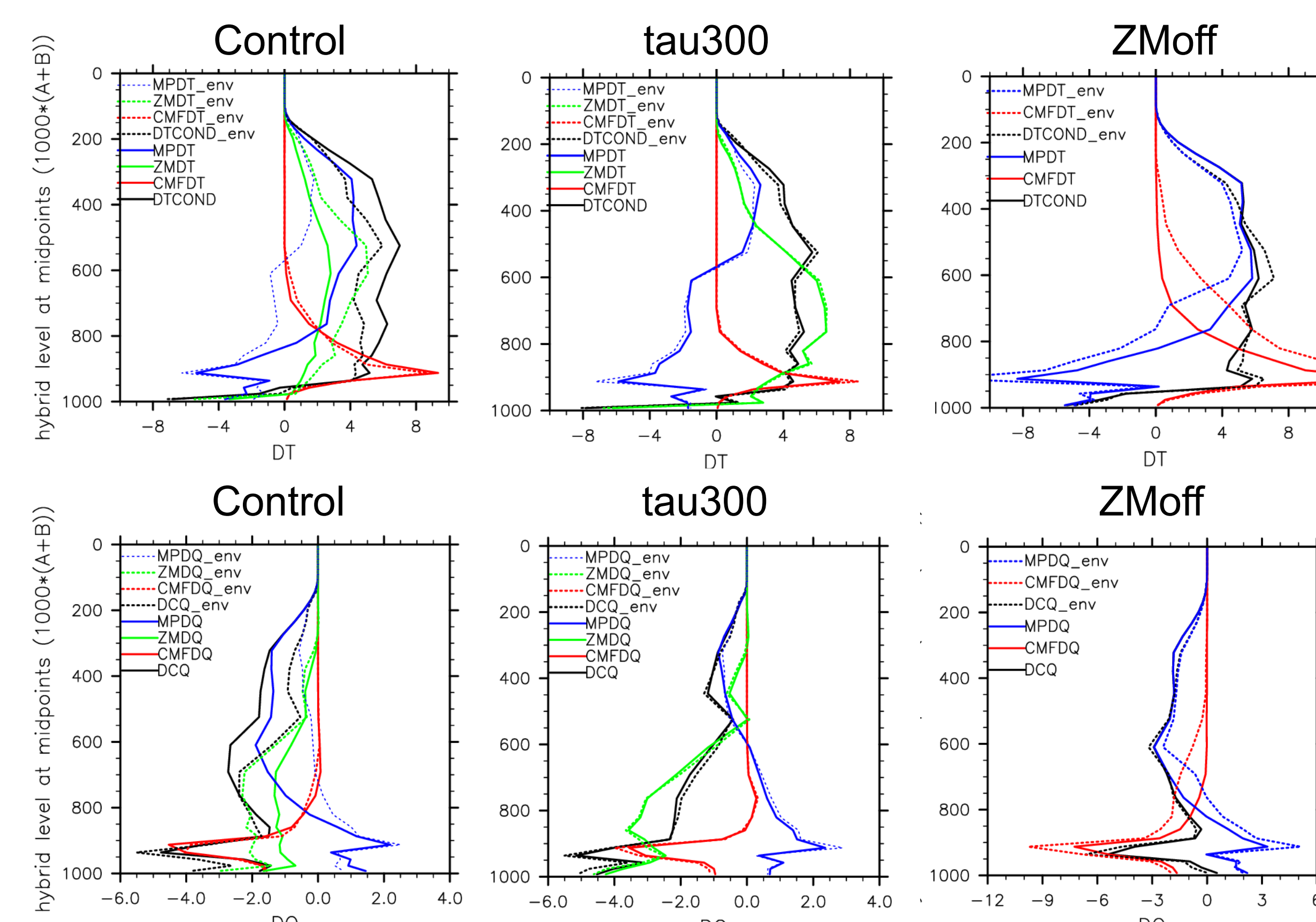## Resolution Sensitivity of Individual Parameterization Tendencies

Figure 4: Vertical heating (top) and moistening (bottom) profiles for parameterization budget terms from CAM5 regionally refined experiments. Solid lines are for averages within the refinement, dotted line are for averages outside the refinement. **Terms:** DTCOND/DCQ: Total Moist Processes; ZMDT/ZMDQ: Deep convection; CMFDT/CMFDQ: Shallow Convection; MPDT/MPDQ: Large-scale+microphysics

Resolution Sensitivity of Precipitation/Profile Relationships
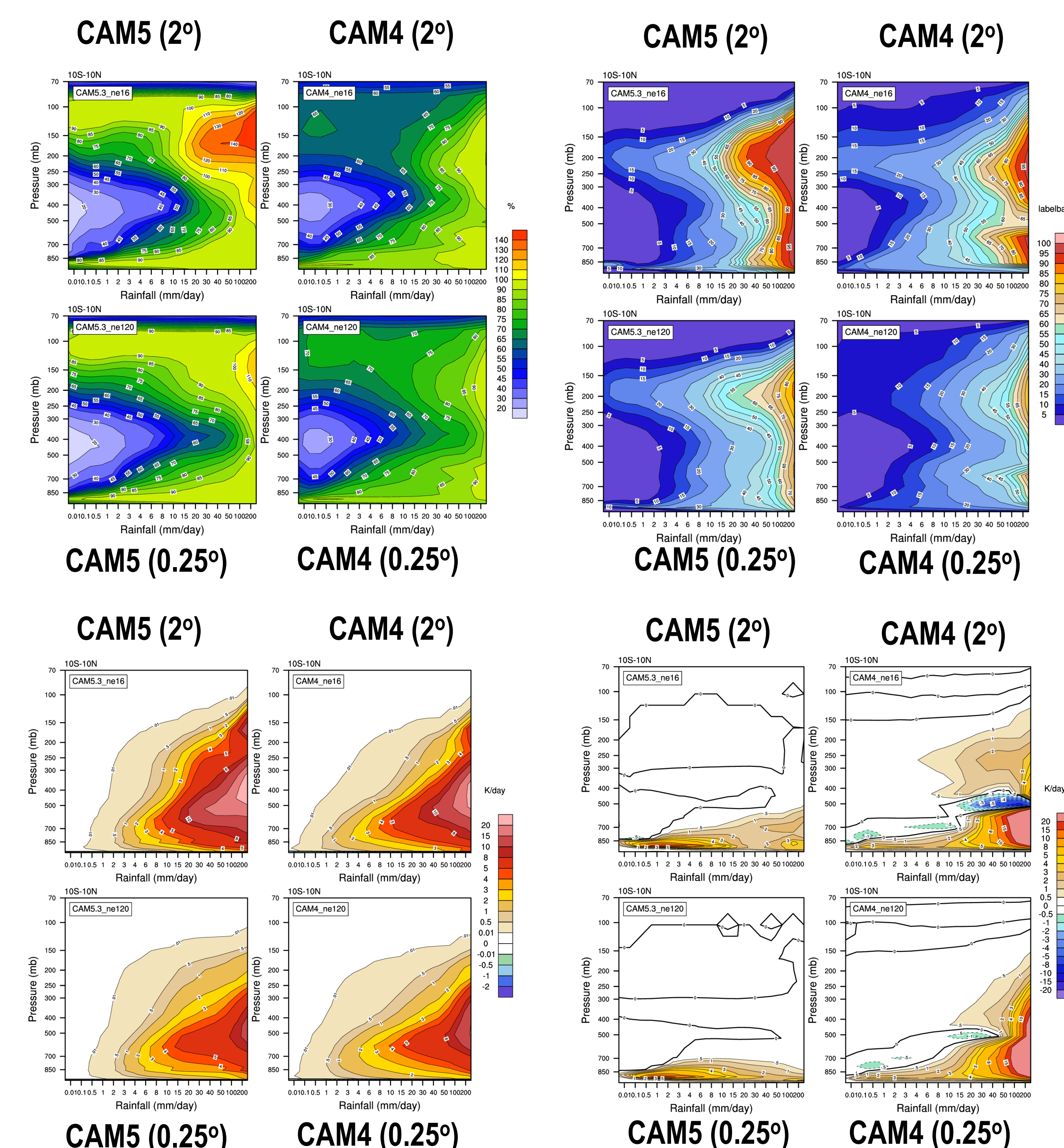

Figure 5: Precipitation rate (mm/day), vertical profile relationships for tropical daily data showing relative humidity (top left), cloud fraction (top right), deep convection heating rate (bottom left) and shallow convection heating rate (bottom right).

Consistency of Resolution Dependence with Regional Refinement
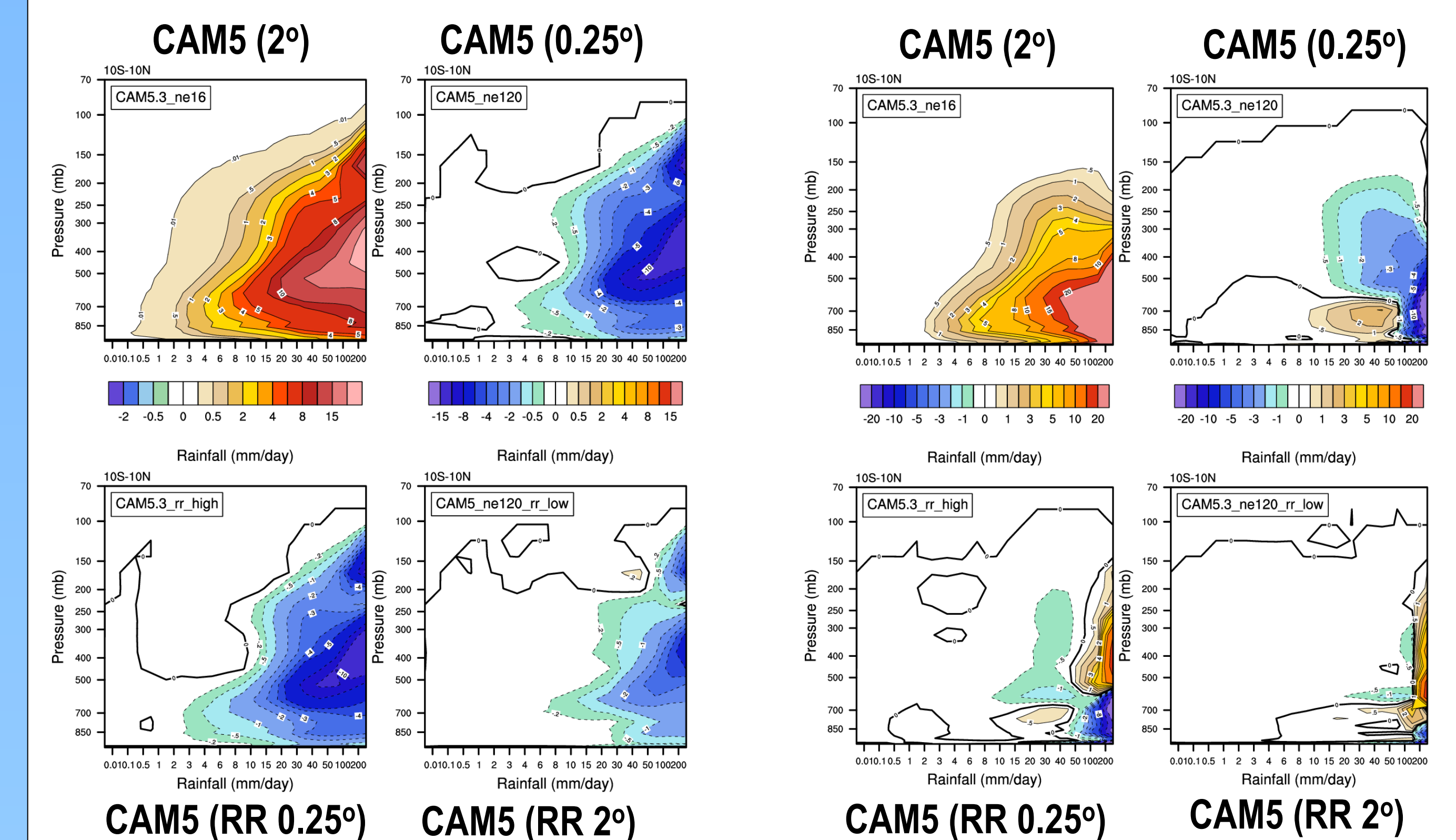

Figure 6: Precipitation binned deep convection temperature tendencies from the CAM5 control (left set) and tau=300 (right set) experiments. Each set shows the 2º control. with differences from the 0.25º control, inside the area of regional refinement (RR 0.25º) and outside the area of regional refinement (RR 2º).
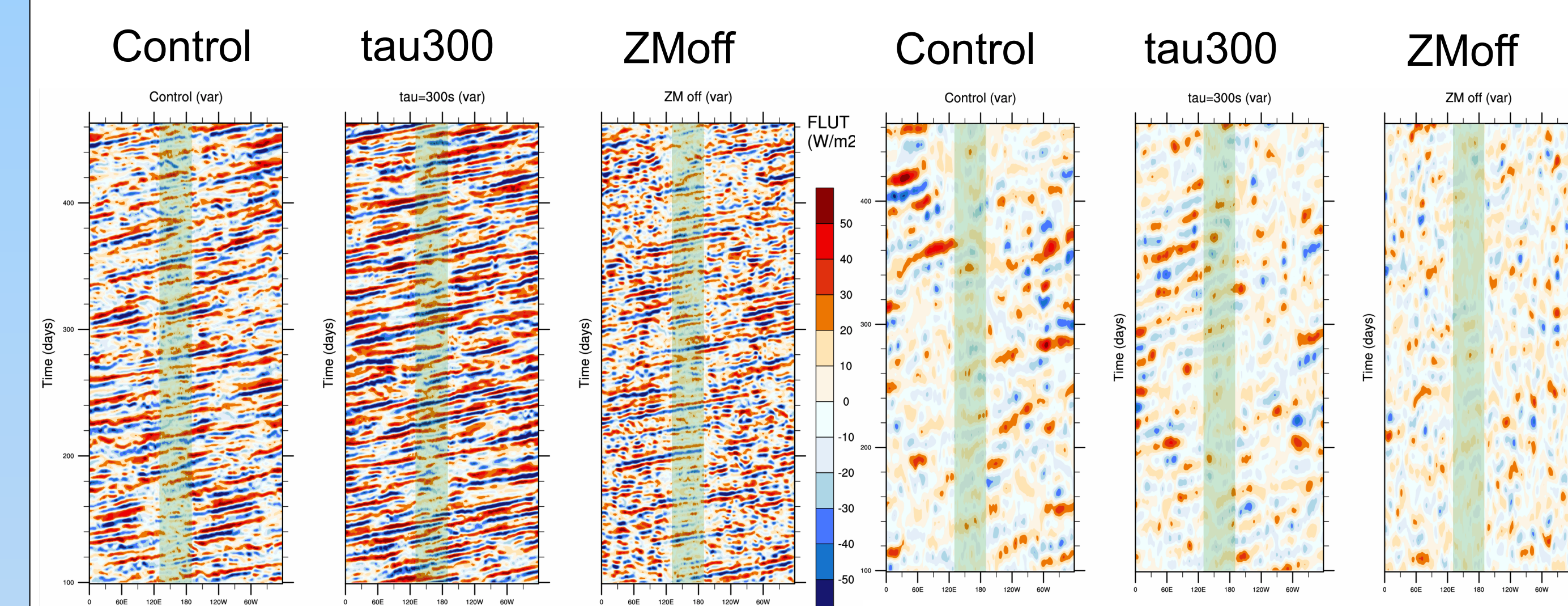
Tropical Wave Propagation

Figure 7: Hovmoller diagrams of outgoing long-wave radiation (OLR/FLUT) in CAM5 regionally refined simulations (high res. within green region) separated by 5-20-day band pass filtering (left) and 20-100-day band pass filtering (right).

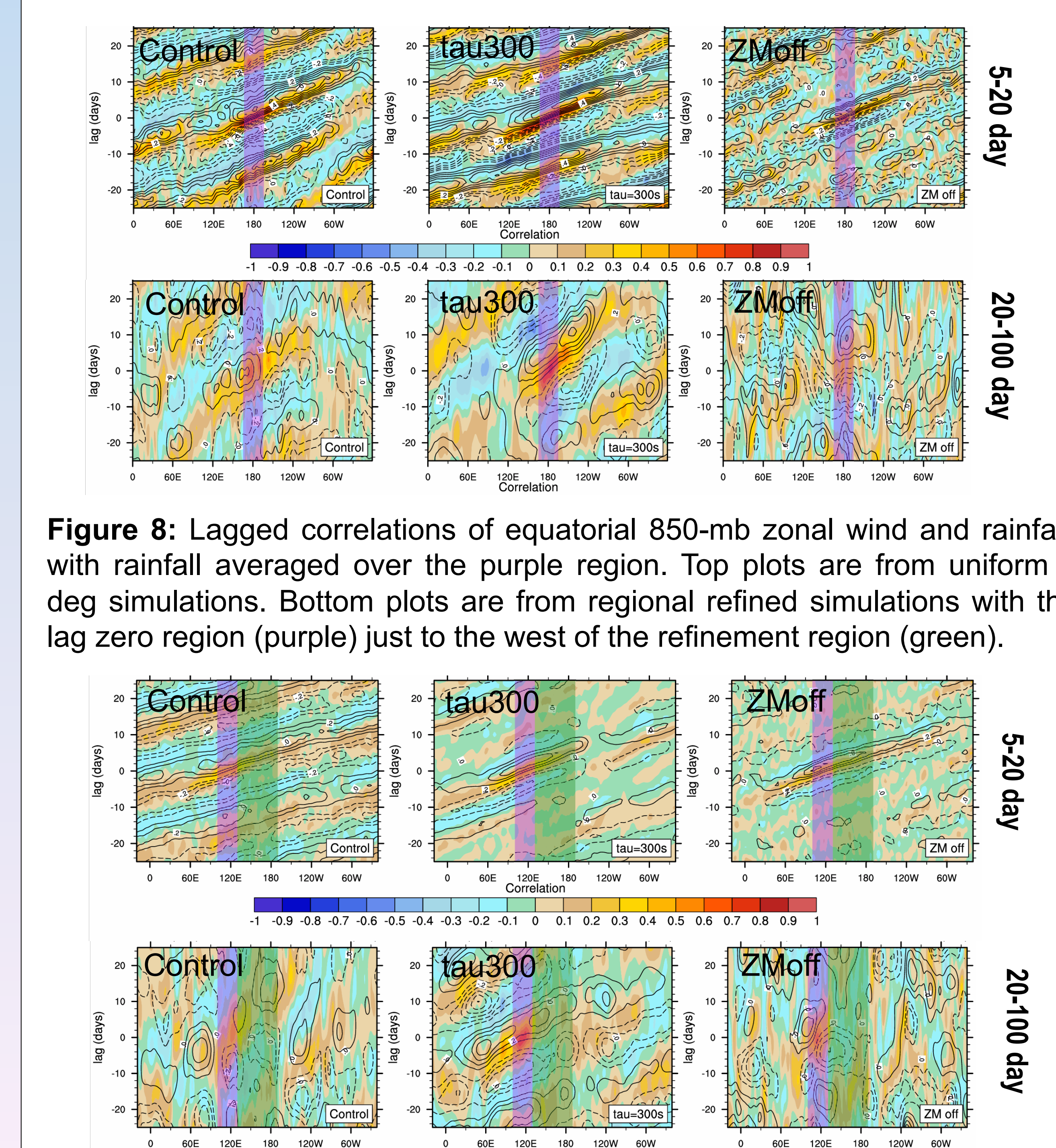## Tropical Wave Propagation Modulation

Figure 8: Lagged correlations of equatorial 850-mb zonal wind and rainfall, with rainfall averaged over the purple region. Top plots are from uniform 2 deg simulations. Bottom plots are from regional refined simulations with the lag zero region (purple) just to the west of the refinement region (green).