6.1 ANALYSIS OF THE MPAS CONVECTIVE-PERMITTING PHYSICS SUITE IN THE TROPICS WITH DIFFERENT PARAMETERIZATIONS OF CONVECTION

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REMARKS AND MOTIVATIONS

1. If we want to use variable-resolution meshes for regional NWP and climate predictions, it is essential that the parameterization of "deep" convection works at ALL scales, particularly in the coarse area of the mesh where it does most of the work.

2. It may be important to focus on one suite to provide the details of the interactions between the parameterization of convection and the other parameterizations (detrainment of cloud condensates to microphysics, subgrid scale convective cloud feedbacks to radiation, …)

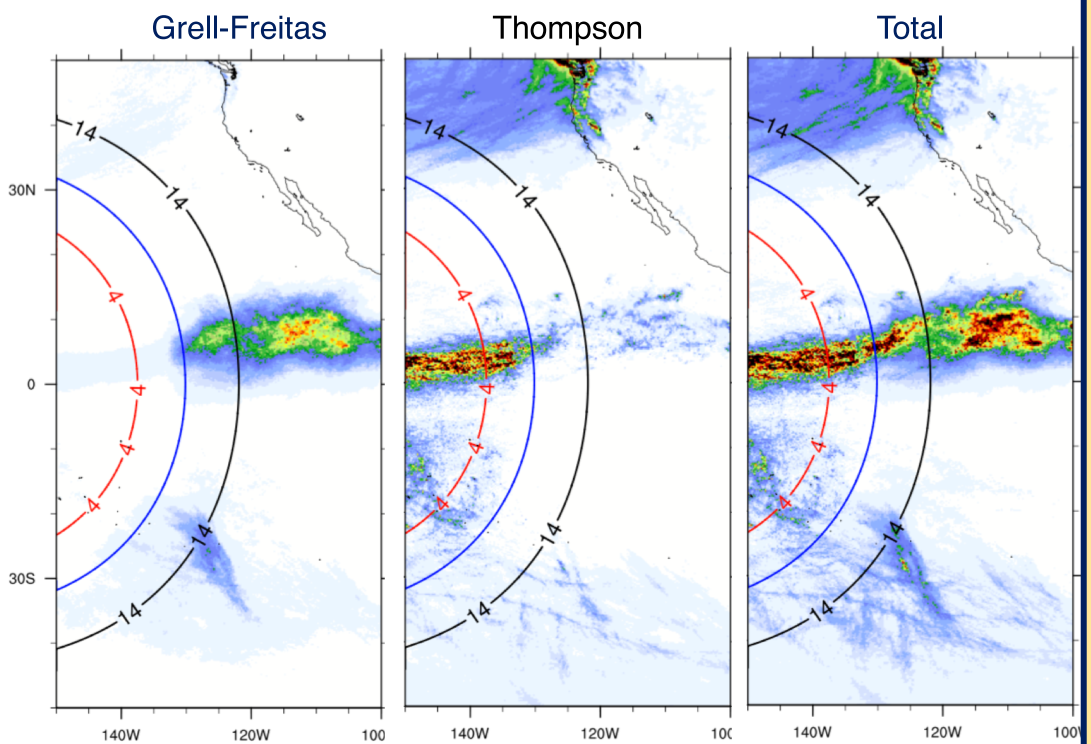
3. In the spirit of unification, it is important to improve condensation/deposition processes, and precipitation in convective cloud models to be consistent with the grid-scale cloud microphysics.

JOINT WRF/MPAS USERS' WORKSHOP (11-15 June 2018), Boulder, Colorado.

DESCRIPTION OF THE CONVECTION-PERMITTING SUITE

- Because the suite includes the scale-aware Grell-Freitas (GF) parameterization of deep convection, the suite was originally designs for use with variable-resolution meshes.
- Most of MPAS forecasts with the convection-permitting suite have used the 15km down to 3 km variable-resolution mesh with mesh refinement centered over CONUS (Weather Hazard Testbed experiments, ensemble prediction forecasts).

15-3 km VARIABLE MESH CENTERED OVER THE TROPICAL PACIFIC OCEAN



Partitioning between the convective and grid-scale precipitation across the transition zone between the refined and coarse areas of the mesh.

CONVECTION AND GRID-SCALE MOIST PROCESSES

- Convection: Grell-Freitas (WRF 3.8.1).
- Microphysics: Thompson (WRF 3.9.1.1) with scale-aware aerosols turned off.

As spatial resolution increases, the Grell-Freitas scheme reduces to a precipitating shallow convection scheme, so that:

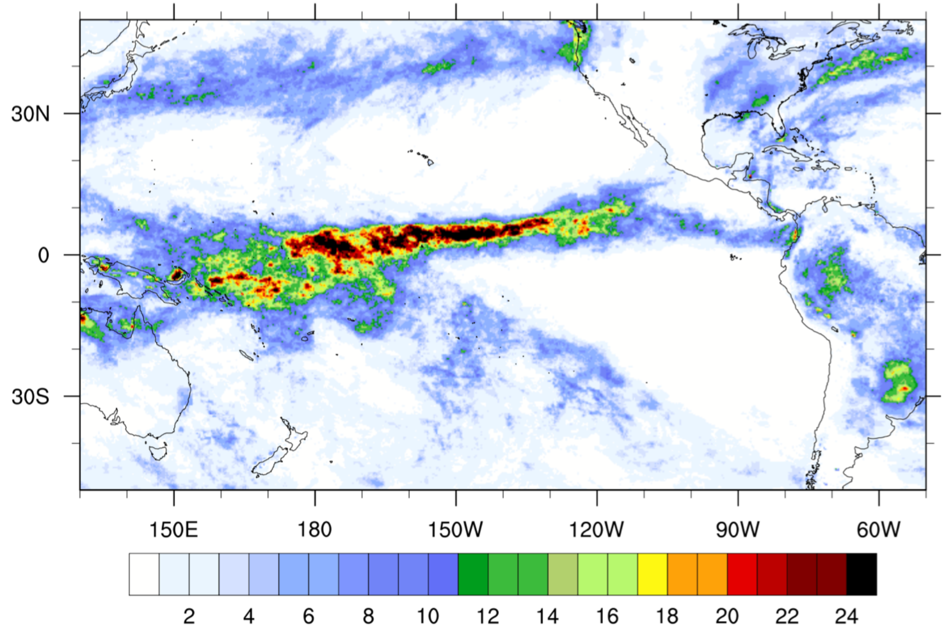
- Inside the refined mesh, grid-scale explicit microphysics processes (Thompson) dominate.
- Outside the refined mesh, parameterized convective processes (Grell-Freitas) dominate.

OTHER PARAMETERIZATIONS

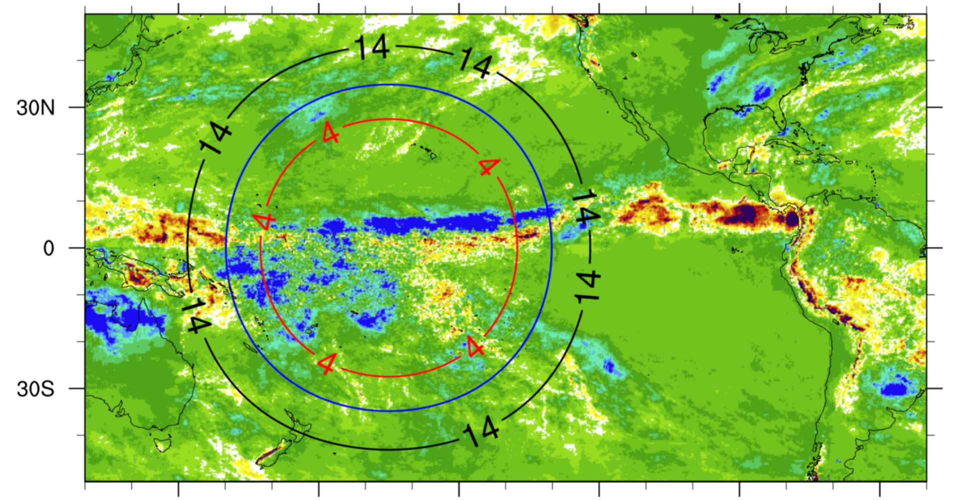
- Gravity wave drag over orography: GWDO (WRF 3.6.1).
- Long- and short-wave radiation: RRTMG (WRF 3.9.1), except for climatological aerosols.
- Horizontal cloud fraction: Function of relative humidity (WRF 3.9.1).
- PBL and surface layer: MYNN (WRF 3.9.1).
- Land model: NOAH (WRF 3.9.1).

DECEMBER 2015 – PRECIPITATION RATE DIFFERENCE (mm day^{-1})

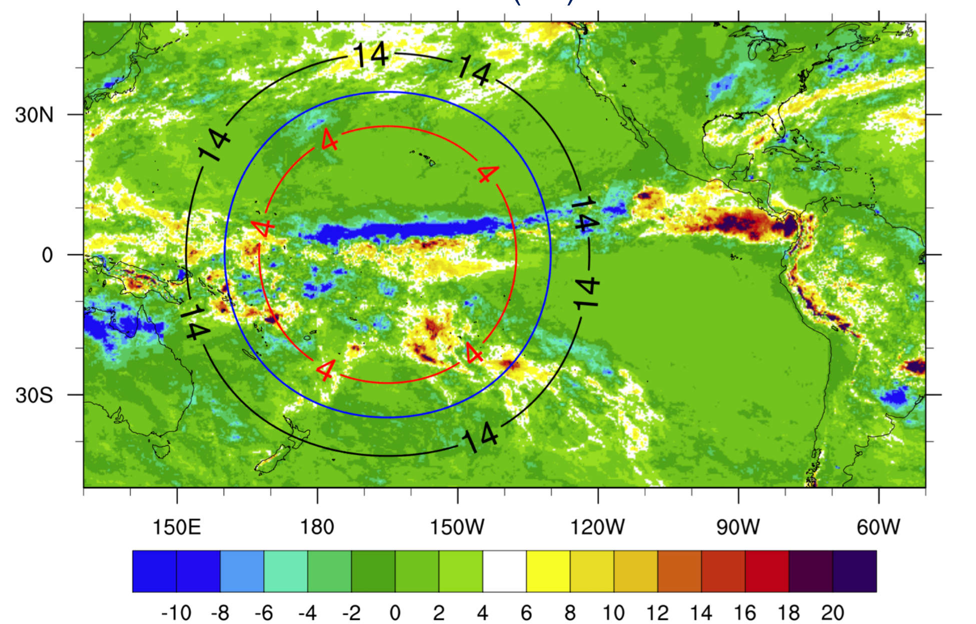
TRMM-3B42



15-3 km VARIABLE MESH (GF) – TRMM difference



15 km UNIFORM MESH (GF) – TRMM difference



The variable (top) and uniform (bottom) meshes display similar biases relative to TRMM data:

- Overestimation of precipitation in the Eastern Pacific Ocean.
- Underestimation of precipitation along the ITCZ in the Central Pacific Ocean.
- The location of the ITCZ is located southward of its actual observed location.

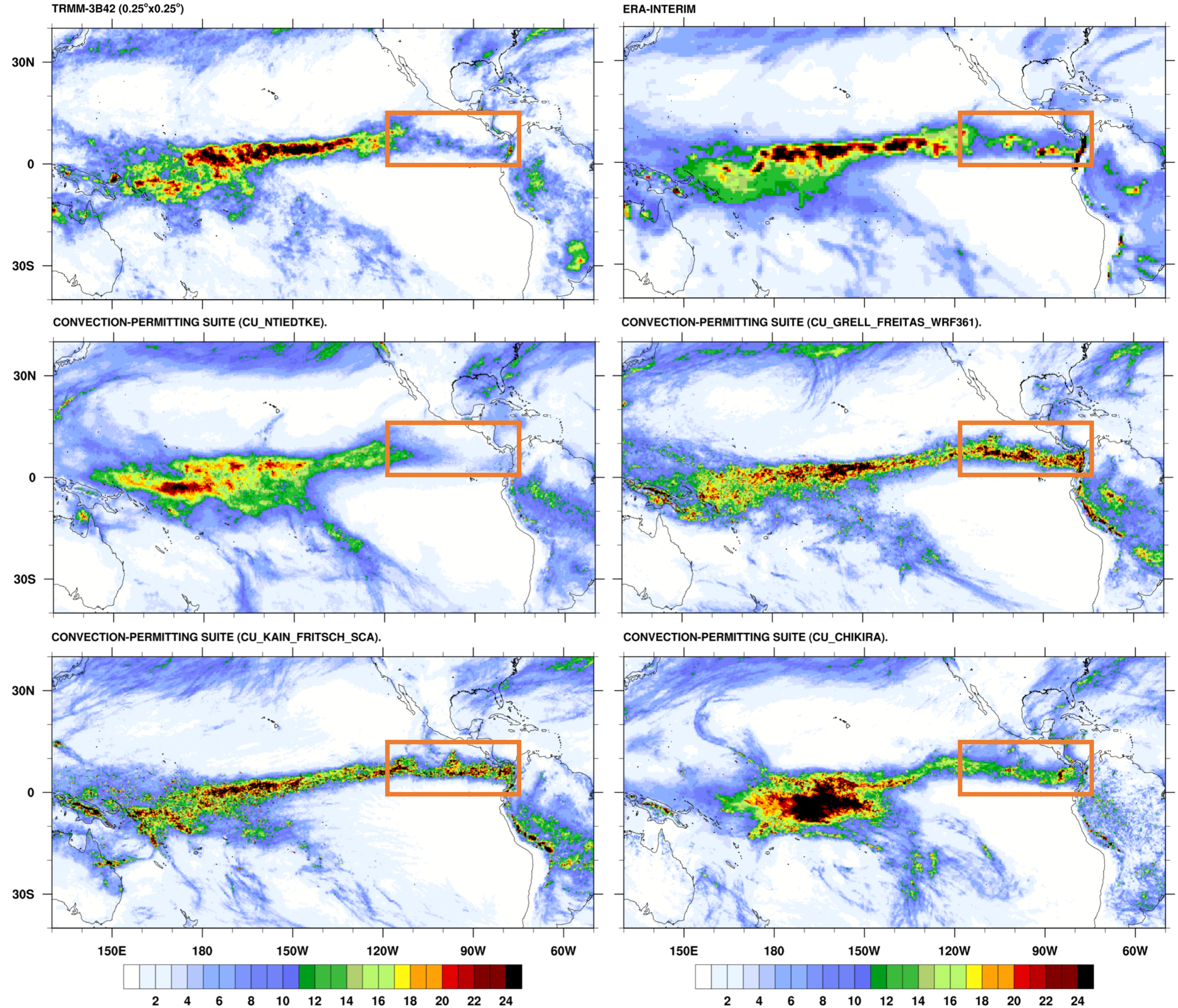
CONVECTIVE PARAMETERIZATIONS WITH THE CONVECTION PERMITTING SUITE

- EXPERIMENTS:
  - 33-day experiments initialized on 29th November 2015 with ERA-Interim data with time-varying sea-surface temperatures, and 2-day spin up
  - Use the 30 km uniform mesh because major biases seen at higher resolutions are also obvious at lower resolutions.
  - Results are December 2015 monthly-means.

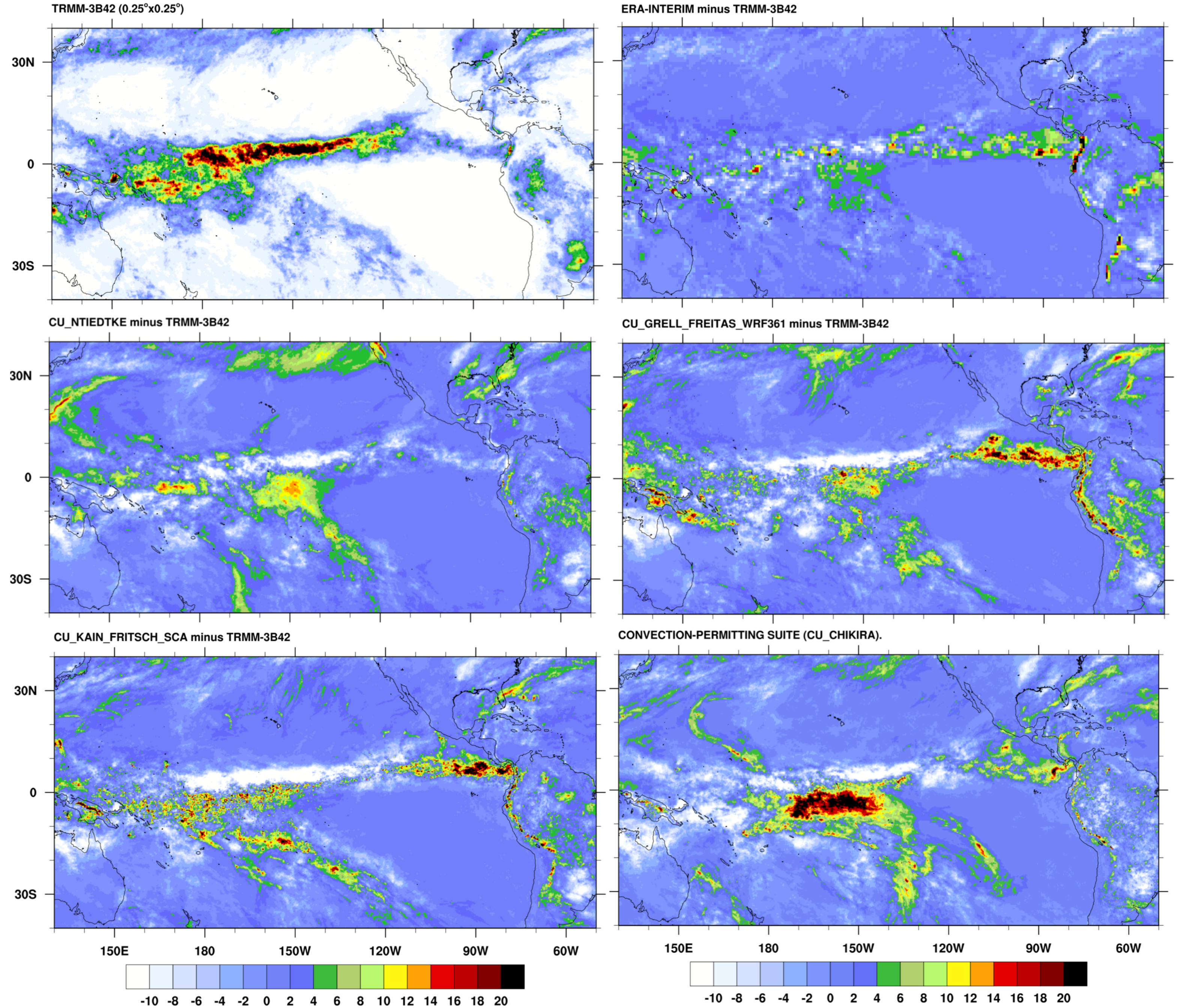
- Four parameterizations:
  - **CU_GRELL_FREITAS_WRF361**: from WRF 3.8.1, Grell and Freitas (2014), Fowler et al. (2016), scale insensitive, following Arakawa and Wu (2013).
  - **CU_KAIN_FRITSCH_SCA (MSKF)**: from WRF 3.9.1, Alapaty et al. (2014), scale insensitive through 1) adjustment time-scale; 2) ”Tokioka” parameter in the formulation of the entrainment.
  - **CU_NTIEDTKE**: from WRF 3.9.1, Tiedtke (1989), and Wang et al. (2007).
  - **CU_CHIKIRA**: just been implemented in the stand-alone MPAS. Currently tested in MPAS-CAM at CSU, and based on Chikira and Sugiyama (2010), scale insensitive following Randall (2014).

- The four parameterizations are mass-flux based, but different in terms of:
  - Formulation of the entrainment rate.
  - Formulation of the convection closure, to determine the cloud base mass flux.
  - Formulation of condensation and precipitation processes in the cloud model, particularly handling of the ice phase.
  - Formulation of the partitioning between the detrained cloud liquid water and cloud ice to the grid-scale microphysics.

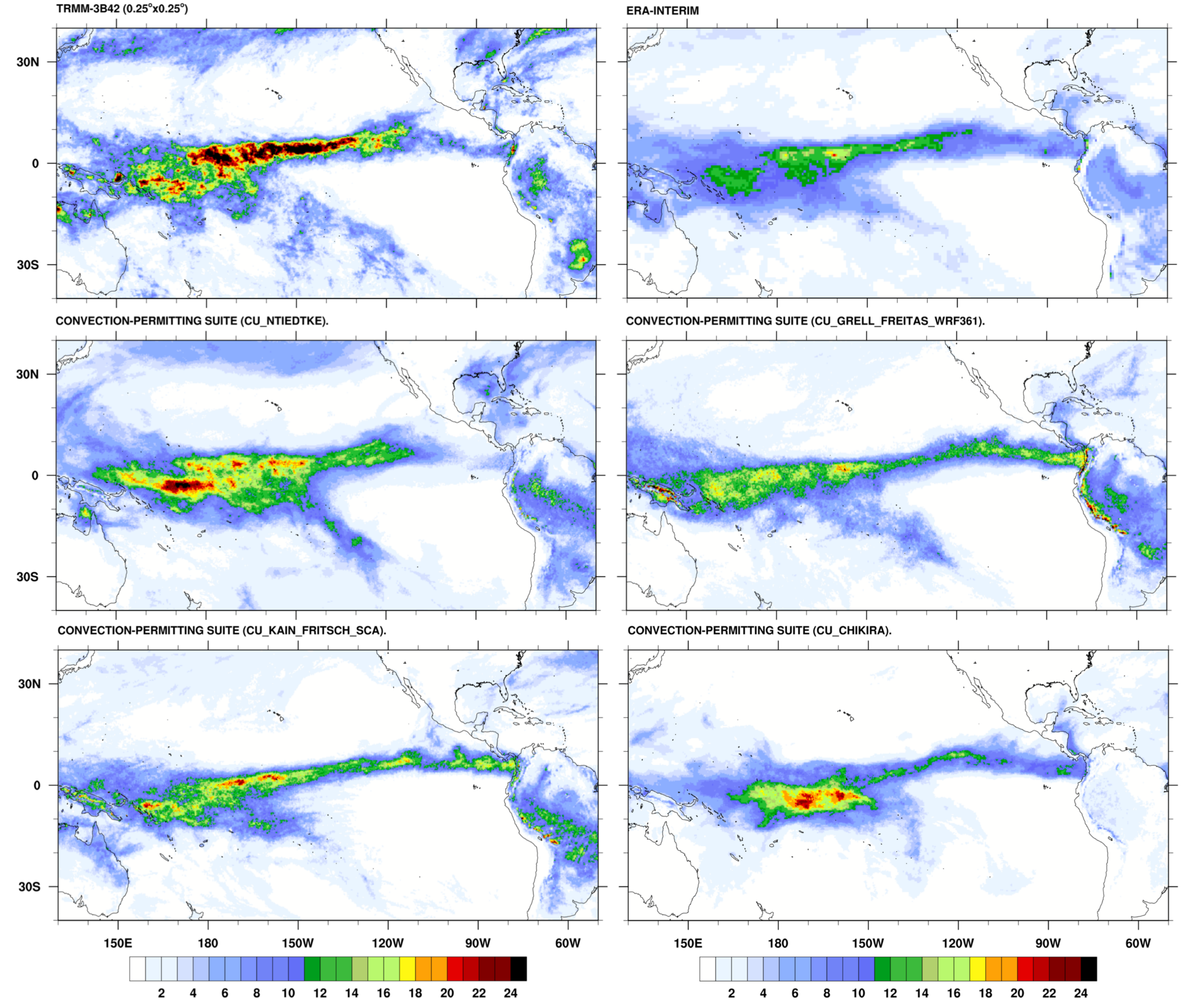
DECEMBER 2015 – TOTAL PRECIPITATION RATE (mm day^{-1})



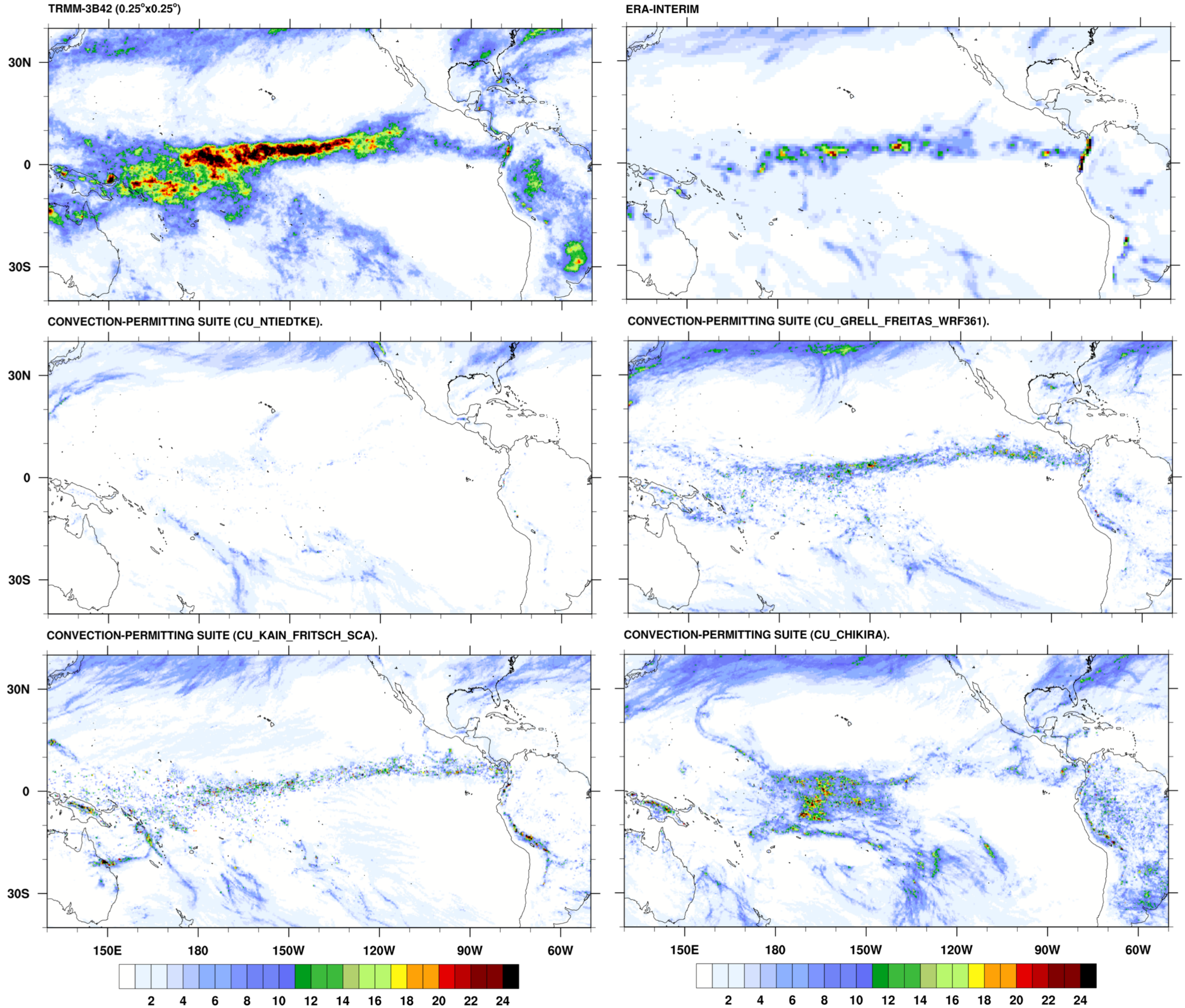
DEC. 2015 – TOTAL PRECIPITATION RATE DIFFERENCE (mm day^{-1})



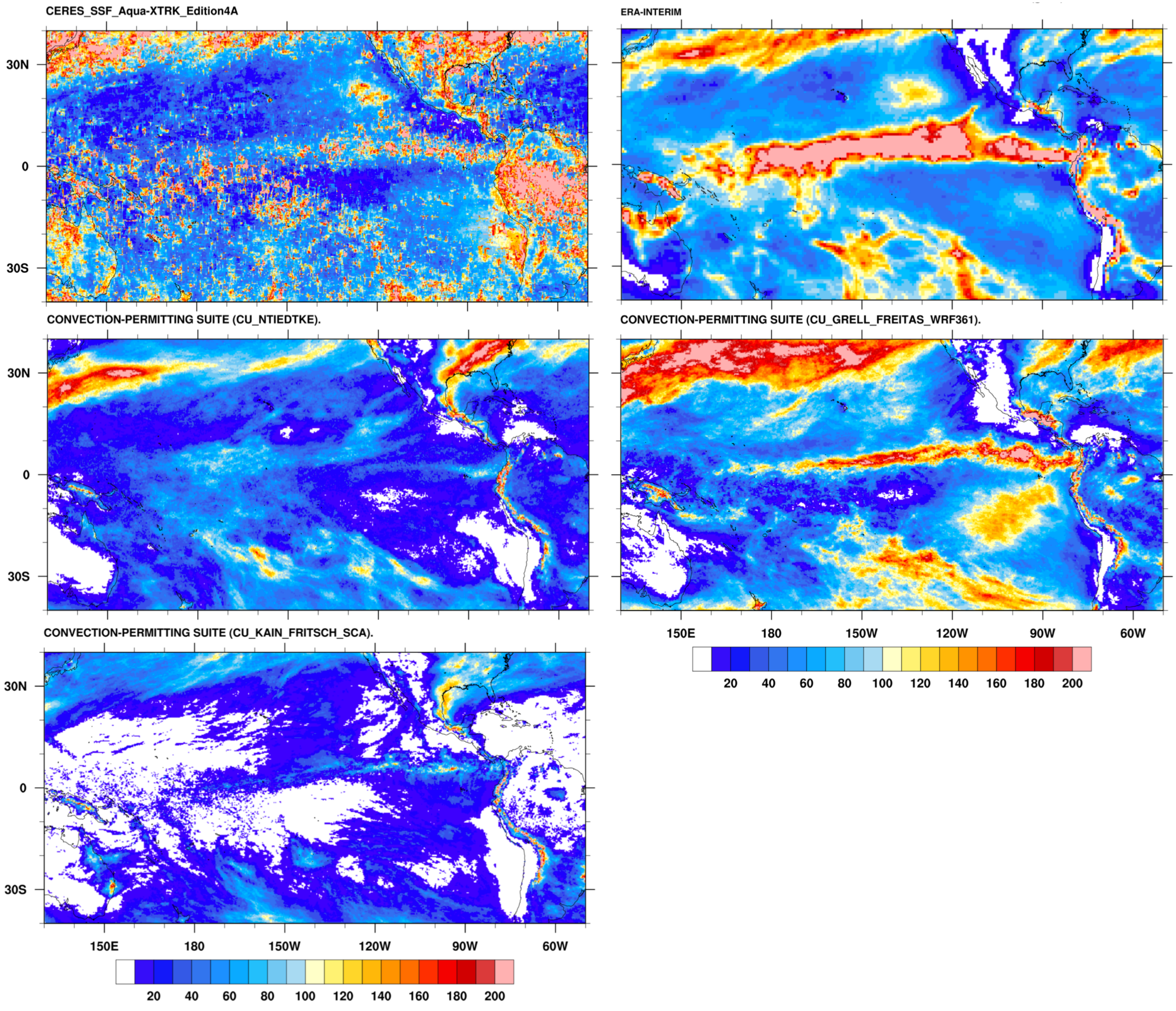
DECEMBER 2015 – CONVECTIVE PRECIPITATION RATE (mm day^{-1})



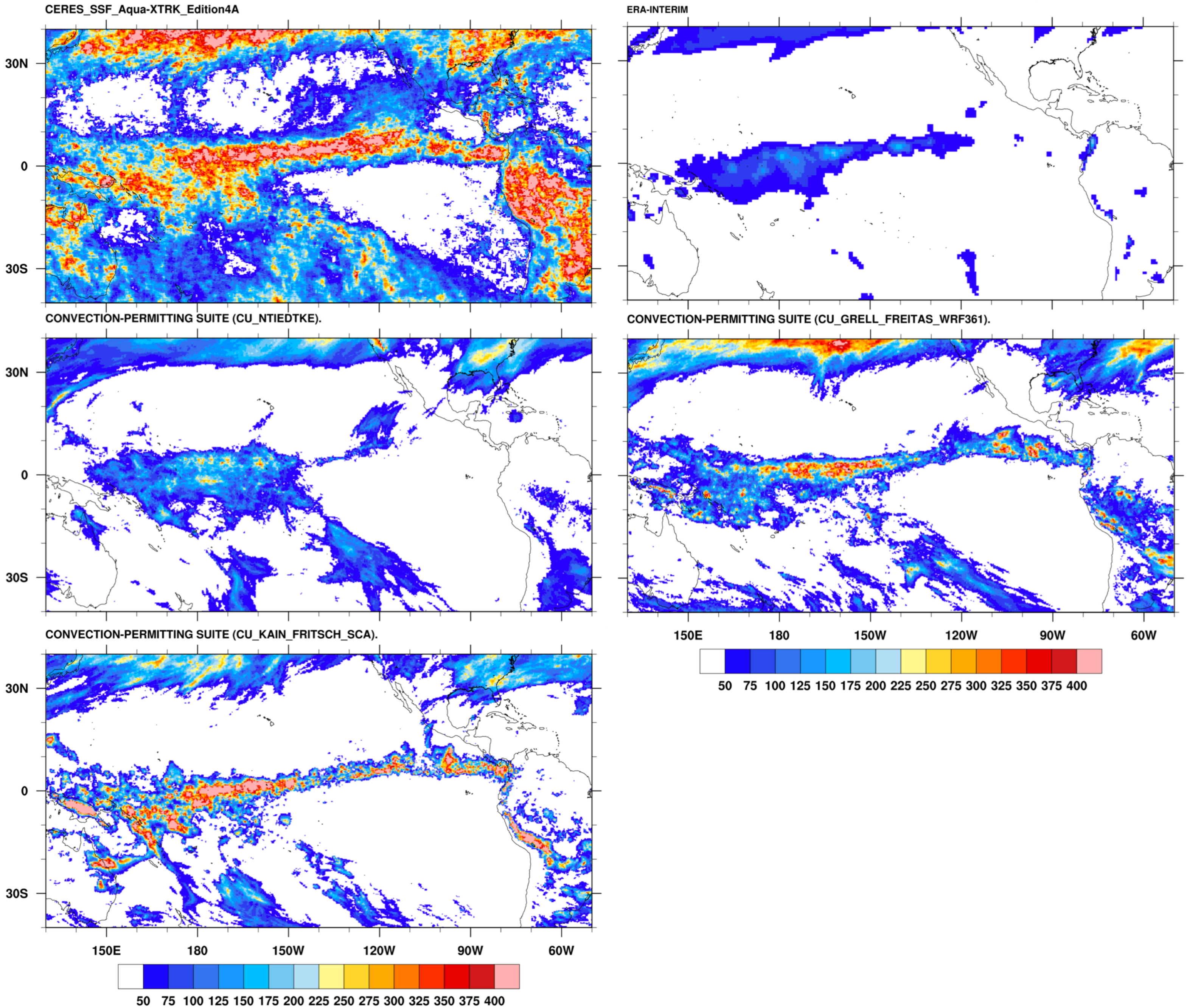
DECEMBER 2015 – GRID-SCALE PRECIPITATION RATE (mm day^{-1})



DECEMBER 2015 – CLOUD WATER PATH (g m^{-2})



DECEMBER 2015 – CLOUD ICE PATH (g m^{-2})



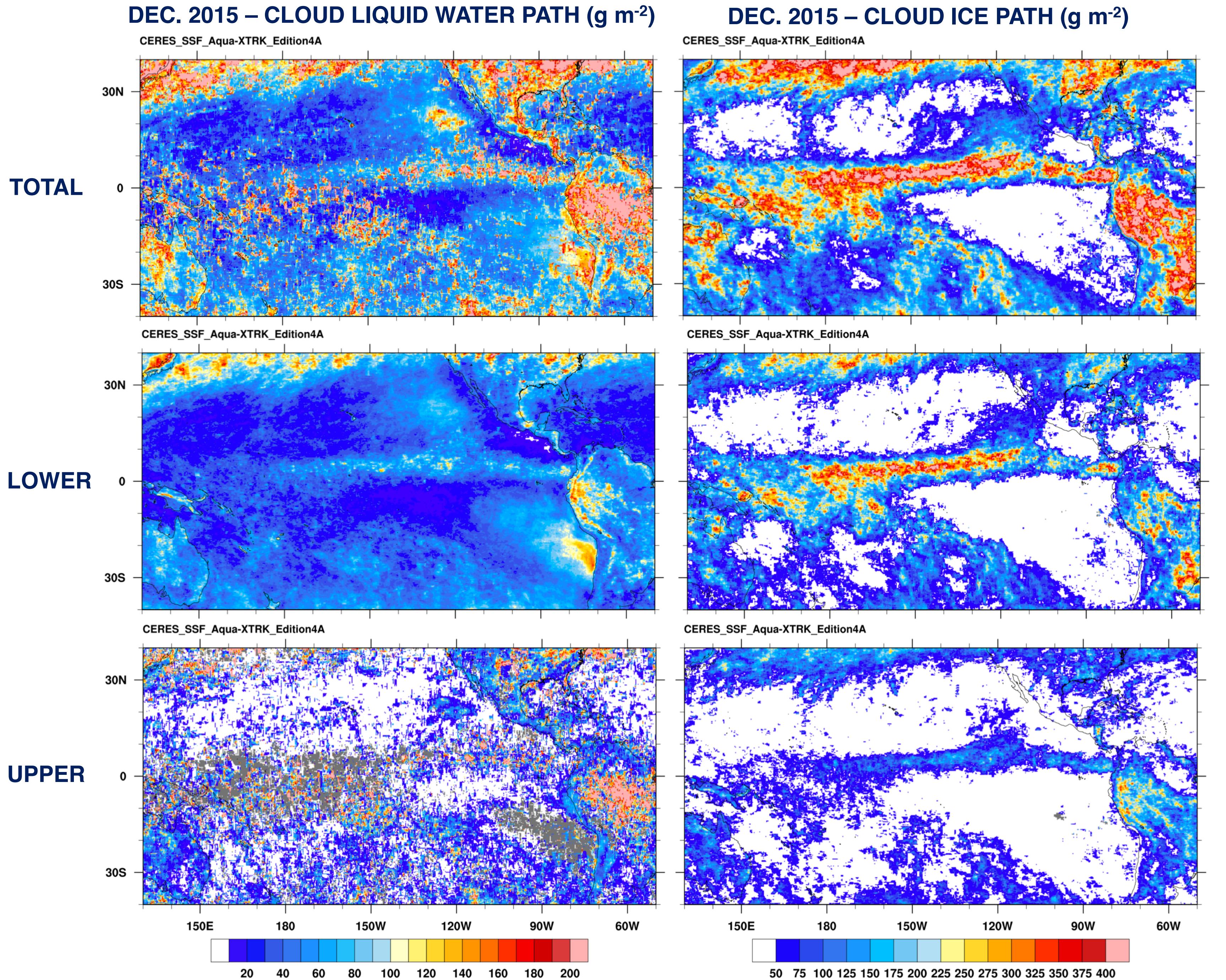
SUMMARY

- There are significant biases in the distributions of precipitation, and cloud liquid water and ice paths in all four simulations relative to observations:
    - A parameterization of convection cannot be simply substituted with an other one without important re-tuning of the parameterization and understanding of its interactions with the other physics schemes.
    - Results suggest the importance of focusing and improving one physics suite, for studies of tropical convection.

- Focus should be given to improve microphysics and precipitation processes in convection schemes.

- Focus should be given on improving interactions between the convective and cloud microphysics parameterizations to ensure a seamless distribution of the liquid and ice water paths at all scales.

- Using variable-resolution meshes, focus should be given on the impact of the “scale-awareness” of the convection schemes in the transition zones.



DEC. 2015 – CLOUD LIQUID WATER PATH (g m-2)
DEC. 2015 – CLOUD ICE PATH (g m-2)
TOTAL
LOWER
UPPER
CERES_SSF_Aqua-XTRK_Edition4A
30N
0
30S
150E
180
150W
120W
90W
60W
20 40 60 80 100 120 140 160 180 200
50 75 100 125 150 175 200 225 250 275 300 325 350 375 400