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

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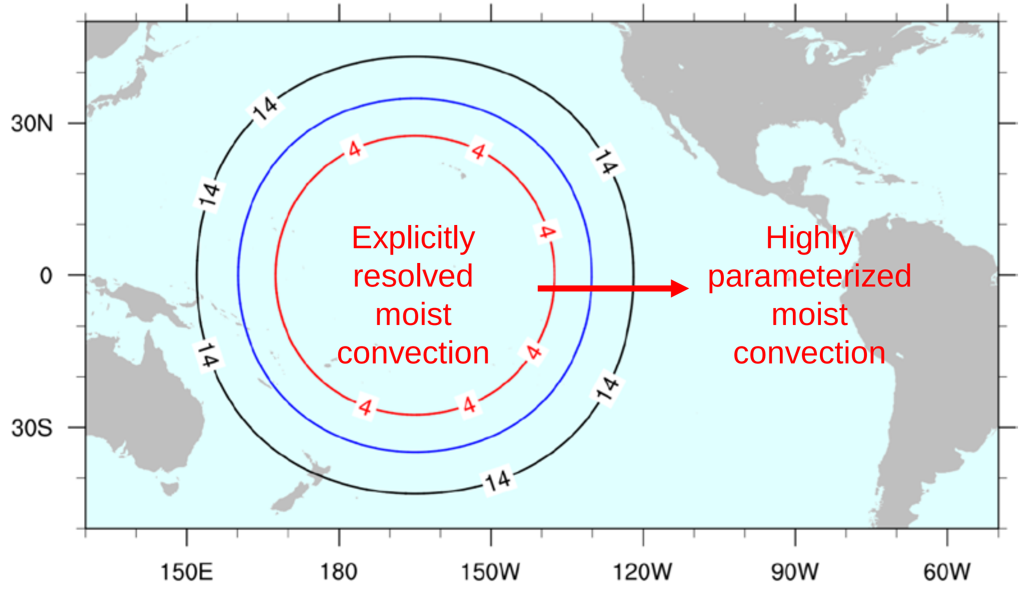
REMARKS AND MOTIVATIONS

1. Global convection-permitting scale climate simulations remain quite *expensive* to run: use of variable-resolution meshes in the Model for Prediction Across Scales (MPAS).
2. 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.
3. It is also important to understand the contribution of the parameterization of shallow convection in the refined and coarse areas of the mesh.
4. 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, …)

GEWEX CONVECTIVE-PERMITTING CLIMATE MODELING WORKSHOP II (4-6 September 2018), Boulder, Colorado.

EXAMPLE OF A VARIABLE-RESOLUTION MESH IN MPAS

15-3 km variable-resolution mesh over the Pacific Ocean



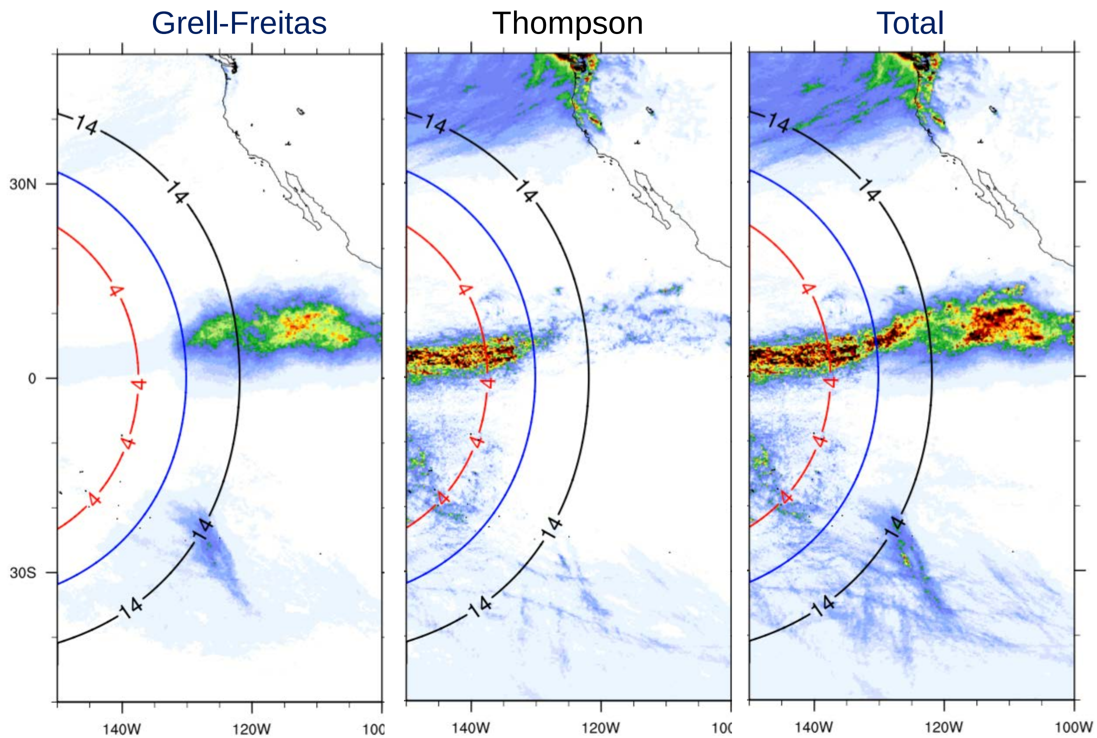
How do differences in the treatment of moist processes between the refined and coarse areas of the mesh affect precipitation, cloud condensates, cloud fraction, and radiation over the Tropical Pacific Ocean?

1. Variable-resolution meshes spanning from non-hydrostatic to hydrostatic scales as the ones built for the non- hydrostatic Model for Prediction Across Scales (MPAS) are ideal tools for regional climate modeling:
   - Computationally less expensive than global high-resolution meshes.
   - No need for nesting and nudging techniques at the edges of the high-resolution domain.
   - Allow two-way dynamics and physics interactions between the outer lower-resolution and inner higher-resolution meshes.
2. Variable-resolution meshes do require the use of scale insensitive physics parameterizations, particularly parameterized convection.

THE GRELL-FREITAS (GF) CONVECTION-PERMITTING SUITE IN MPAS

- 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.

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:

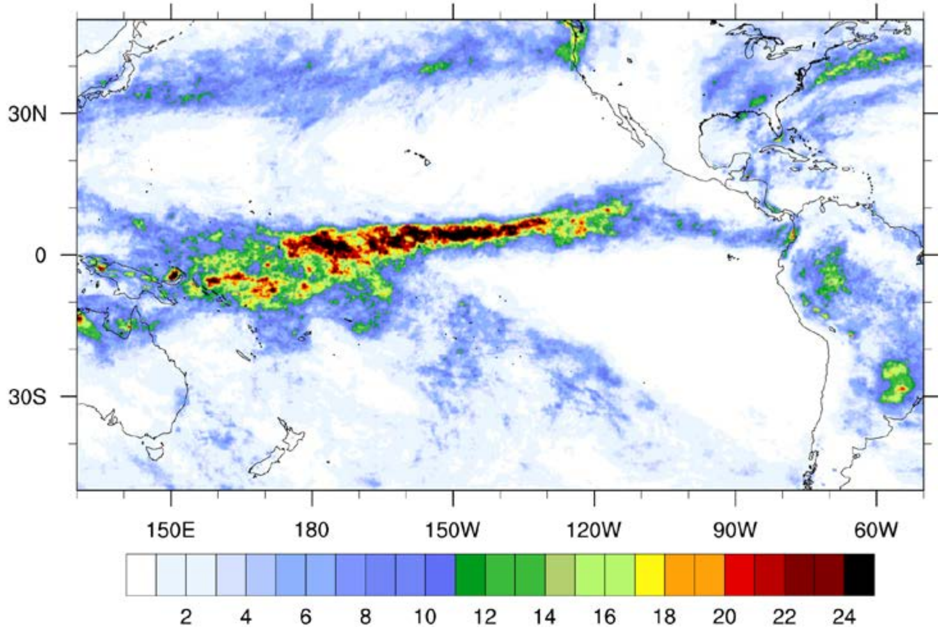
- Inside the refined mesh, grid-scale explicit microphysics processes (Thompson) dominate.
- Outside the refined mesh, parameterized convective processes (Grell-Freitas) dominate.

OTHER PARAMETERIZATIONS

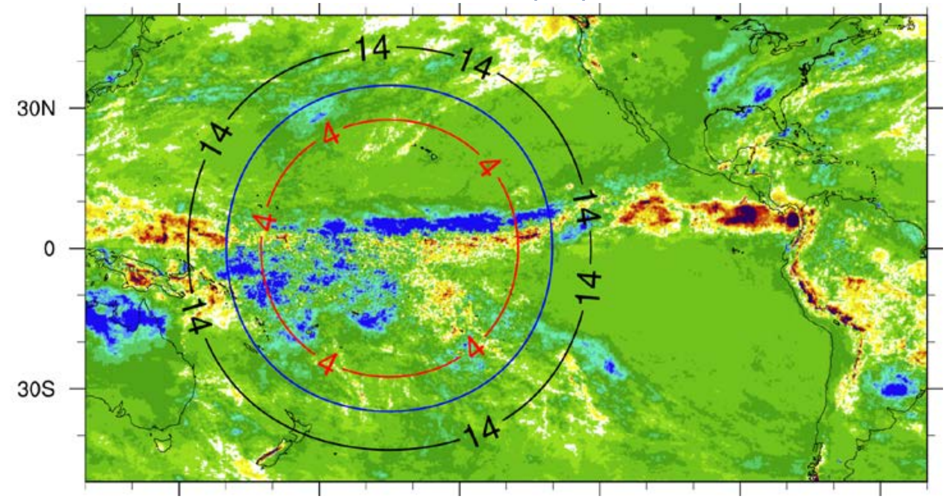
- Gravity wave drag over orography: GWDO (WRF 3.6.1).
- Long- and short-wave radiation: RRTMG (WRF 3.9.1), except for climatological aerosols.
- Horizontal cloud fraction: Function of relative humidity (WRF 3.9.1).
- PBL and surface layer: MYNN (WRF 3.9.1).
- Land model: NOAH (WRF 3.9.1).

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

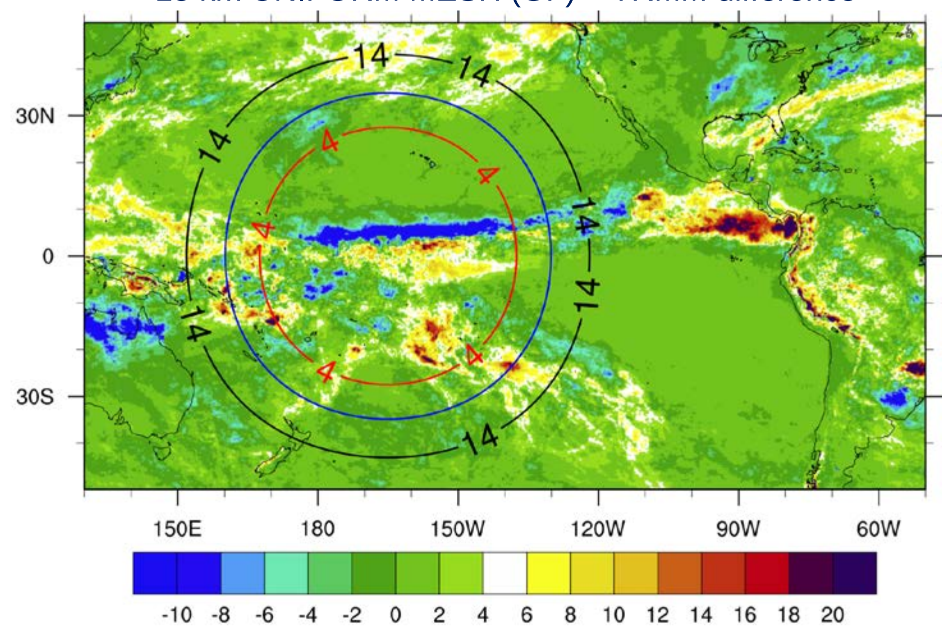
TRMM-3B42



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



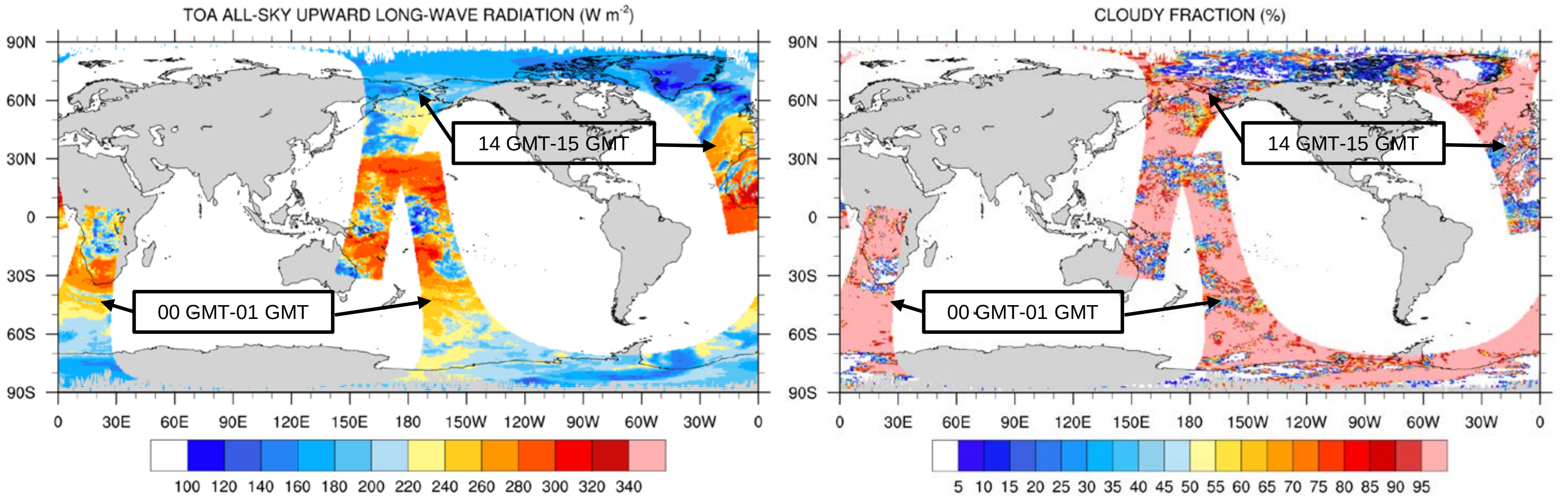
15 km UNIFORM MESH (GF) – TRMM difference



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.

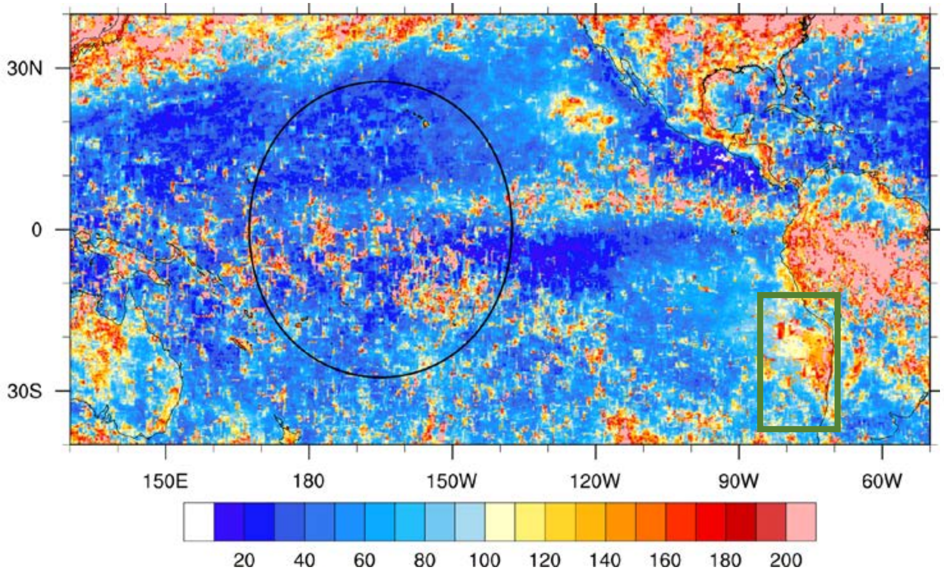
CERES_SSF_Aqua-XTRK_Edition4A SATELLITE DATA – 20151201



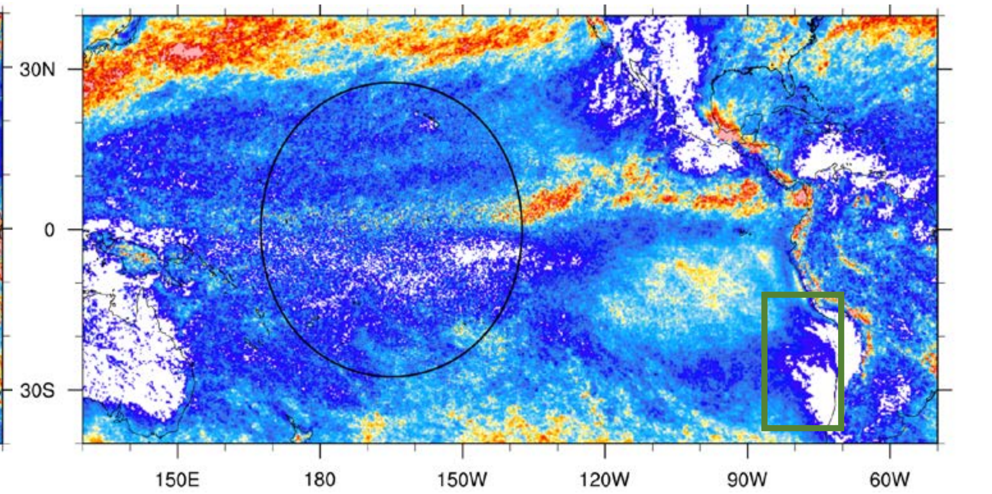
- Each CERES Single Scanner Footprint (20 km nadir resolution) includes TOA fluxes from CERES and spatially coincident cloud properties from MODIS.
- To compute MPAS monthly means, we regridded and masked hourly model outputs to simulate the actual satellite orbits.

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

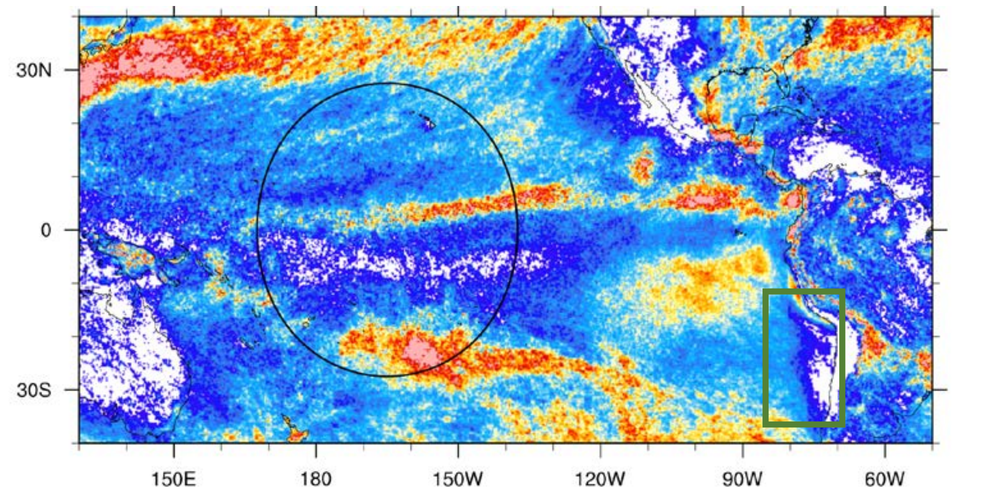
CERES_SSF_Aqua-XTRK_Edition4A



15-3 km VARIABLE MESH



15 km UNIFORM MESH



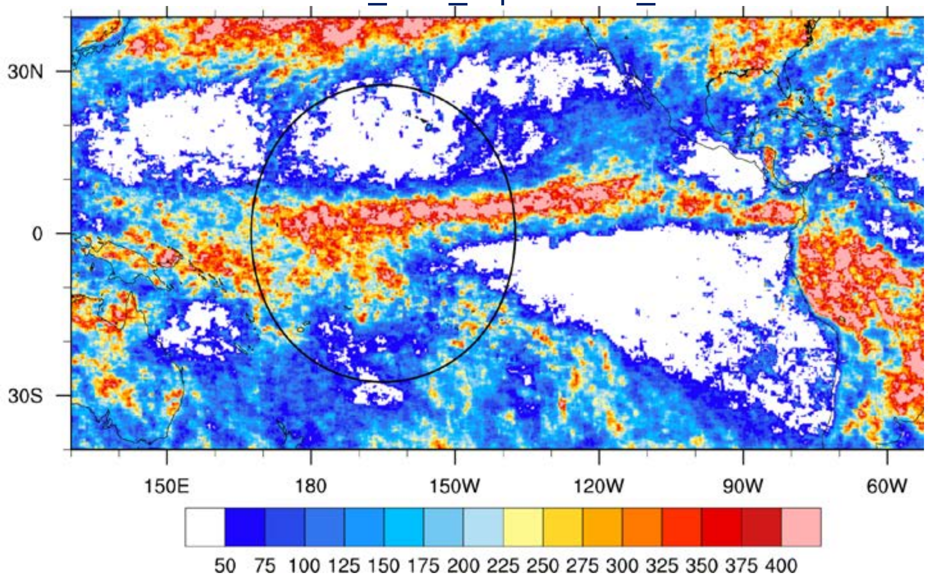
There is a sharp contrast in the LWP between the refined- and coarse-resolution of the mesh along the ITCZ:

- Maximum values of the LWP occur through detrainment of cloud liquid water from the GF scheme over the Eastern Pacific Ocean.
- Minimum values of the LWP over the refined mesh through cloud microphysics processes with the Thompson scheme.

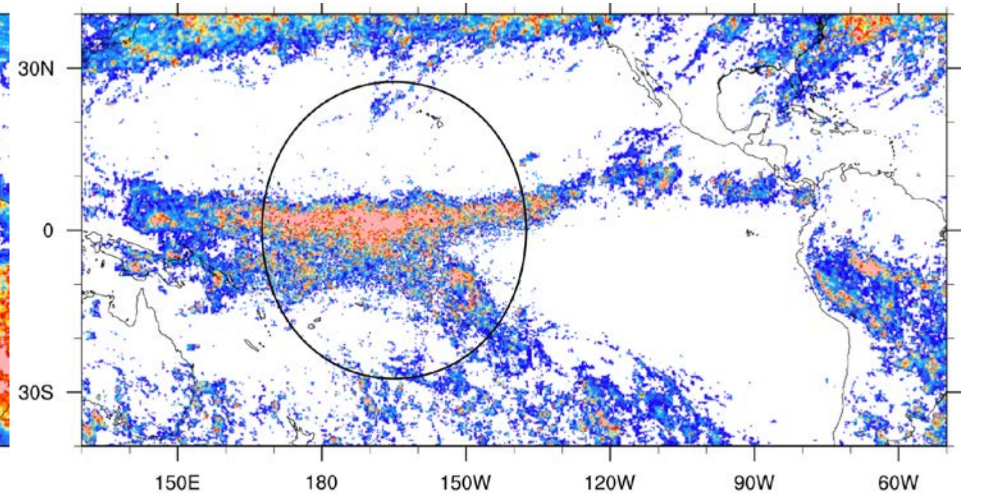
O : 4 km resolution isoline of the 15-3 km variable mesh.

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

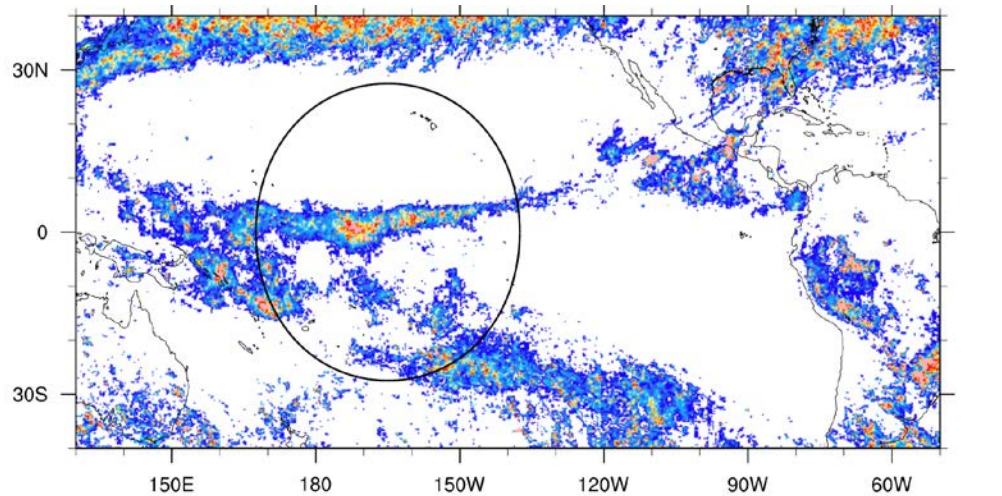
CERES_SSF_Aqua-XTRK_Edition4A



15-3 km VARIABLE MESH



15 km UNIFORM MESH



As for the LWP, there is a sharp contrast in the IWP between the refined- and coarse-resolution of the mesh along the ITCZ.

- Over the Eastern Pacific, decreased convection would lead to decreased convective precipitation and detrainment of cloud liquid water and ice.

O : 4 km resolution isoline of the 15-3 km variable mesh.

CONVECTIVE PARAMETERIZATIONS WITH THE CONVECTION PERMITTING SUITE

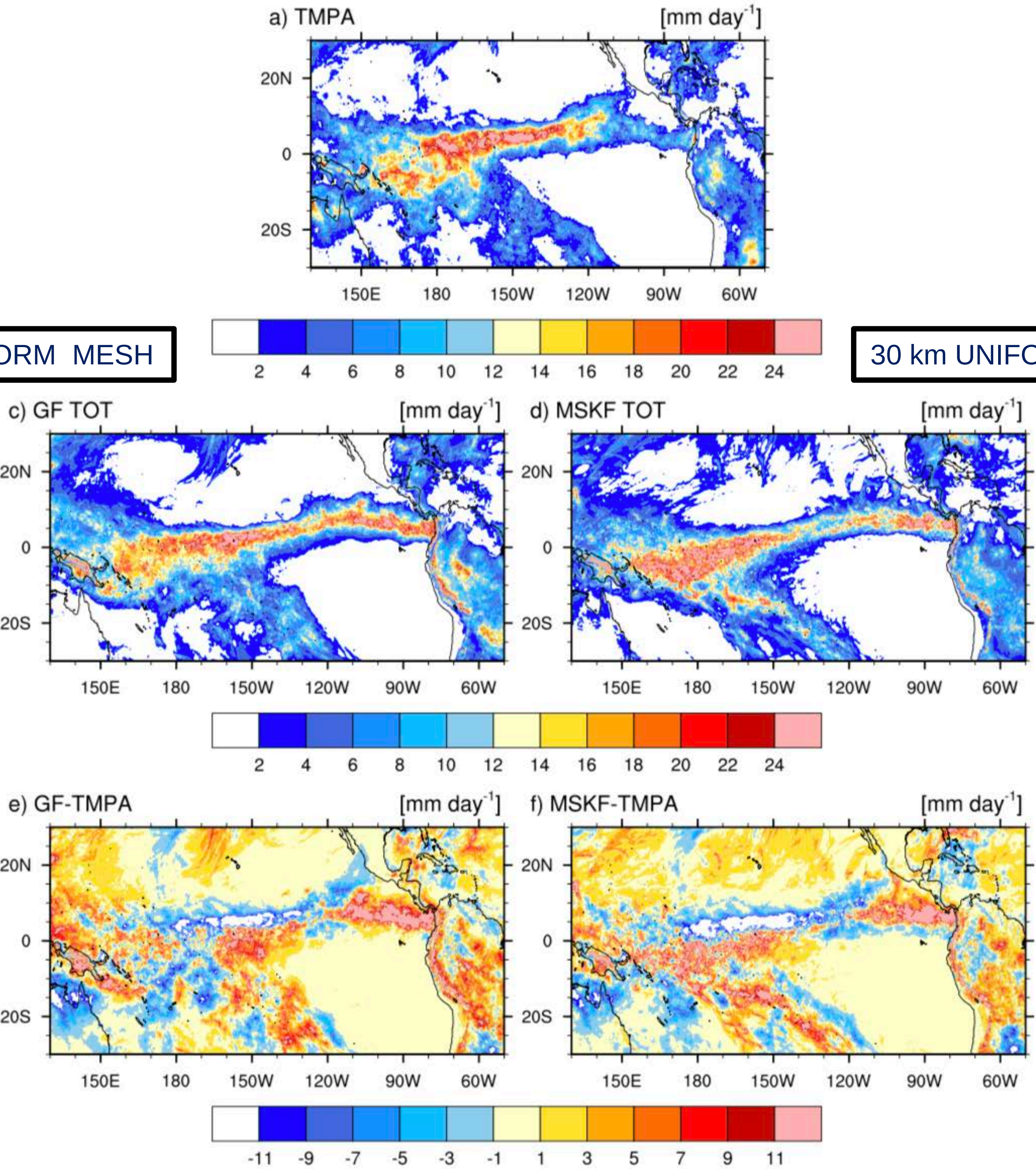
- **SCALE-AWARE PARAMETERIZATIONS OF CONVECTION**:
  - **GF**: from WRF 3.8.1, Grell and Freitas (2014), Fowler et al. (2016), scale insensitive, following Arakawa and Wu (2013).
  - **MSKF**: from WRF 3.9.1, Alapaty et al. (2014), scale insensitive through 1) adjustment time-scale; 2) ”Tokioka” parameter in the formulation of the entrainment.

- **DIFFERENCES BETWEEN GF AND MSKF:**
  - 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.
  - Treatment of non-precipitating shallow convection and its interactions with the grid-scale microphysics.

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

30 km UNIFORM MESH

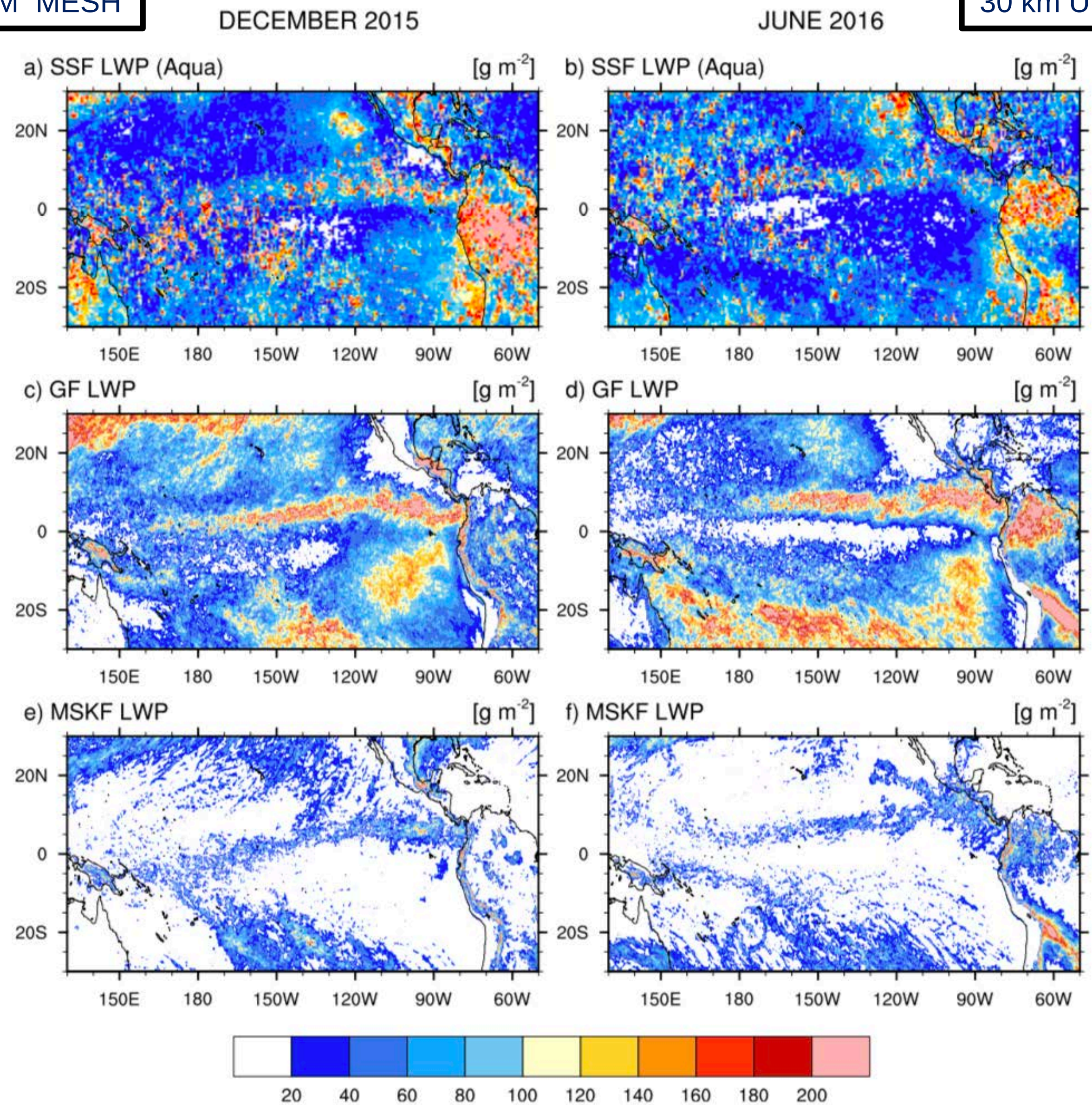
30 km UNIFORM MESH



CLOUD LIQUID WATER PATH (g m^{-2})

30 km UNIFORM MESH

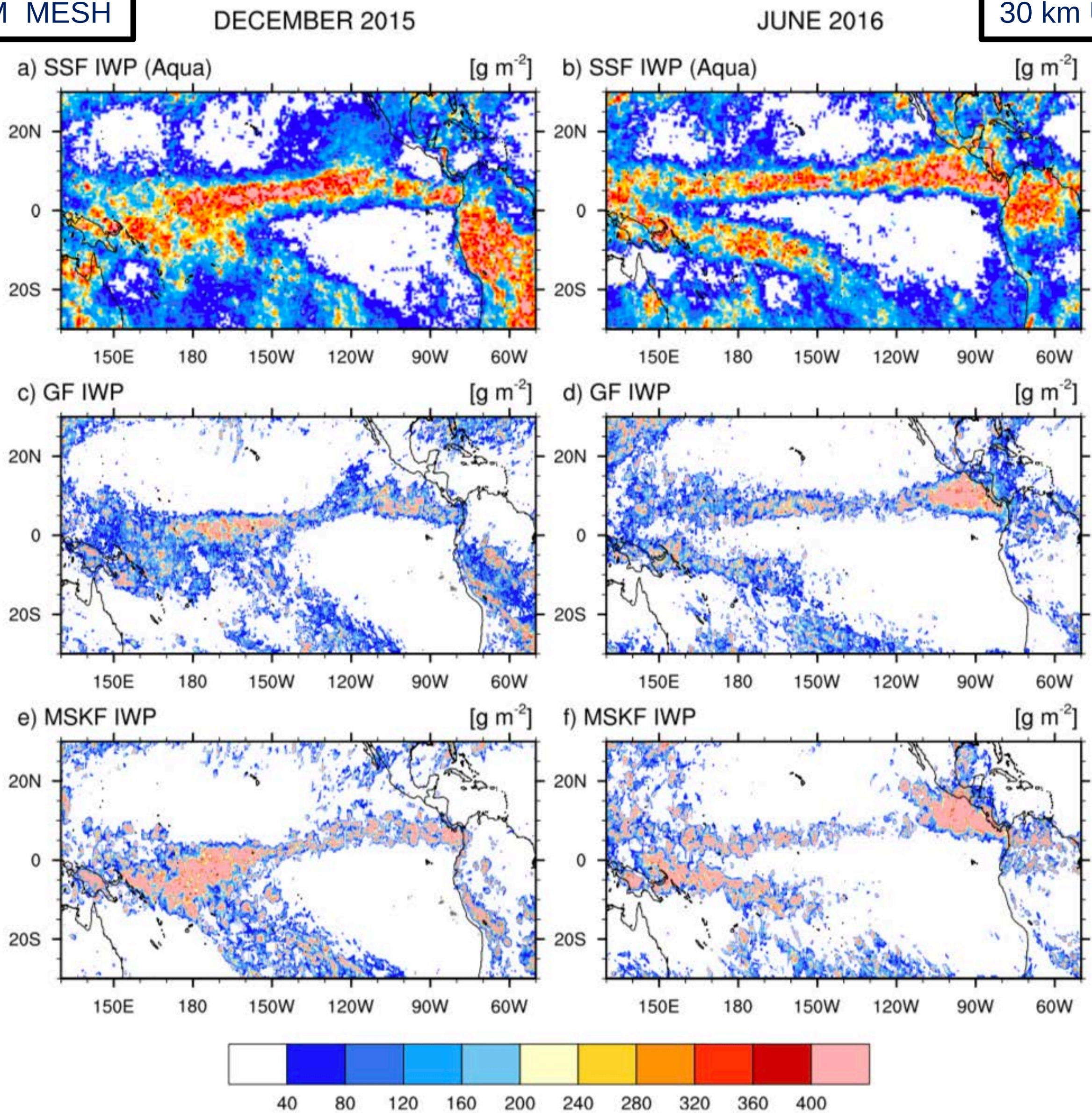
30 km UNIFORM MESH



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

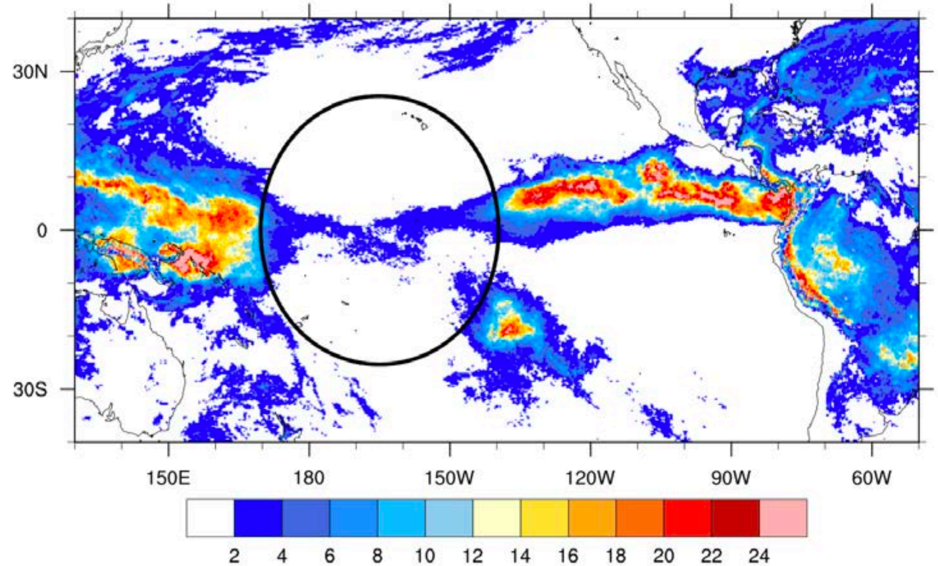
30 km UNIFORM MESH

30 km UNIFORM MESH

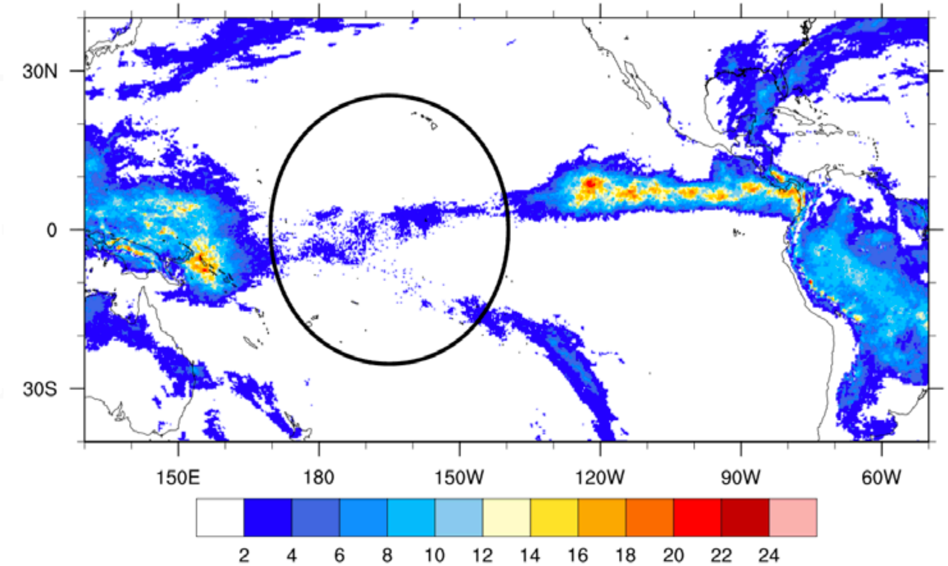


DECEMBER 2015 – CONVECTIVE PRECIPITATION RATE (mm day^{-1})

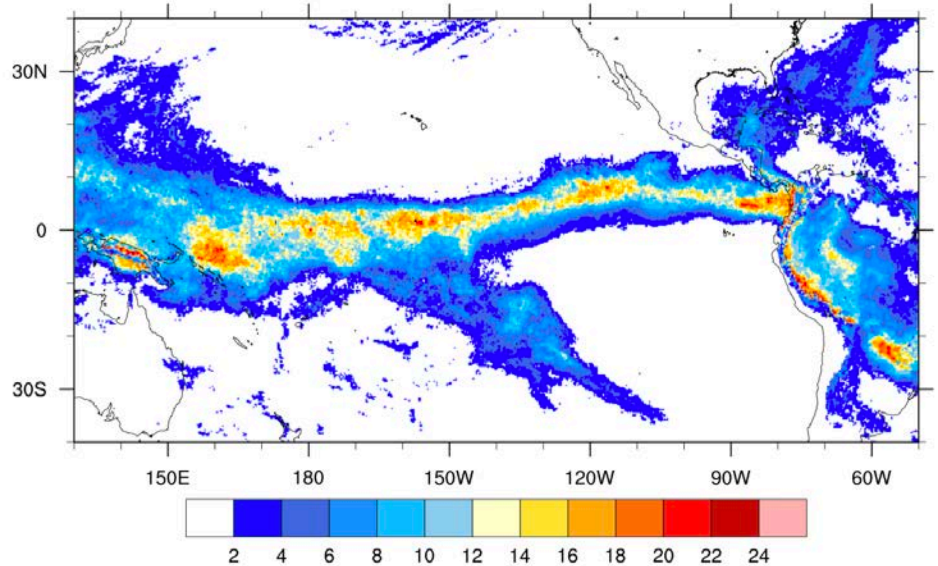
GF: 30-6 km VARIABLE MESH



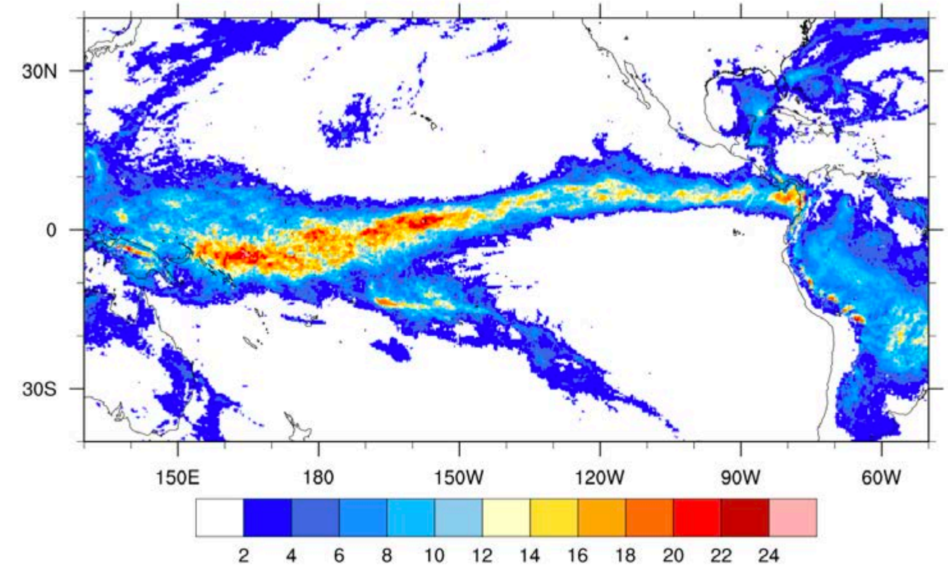
MSKF: 30-6 km VARIABLE MESH



GF: 30 km UNIFORM MESH



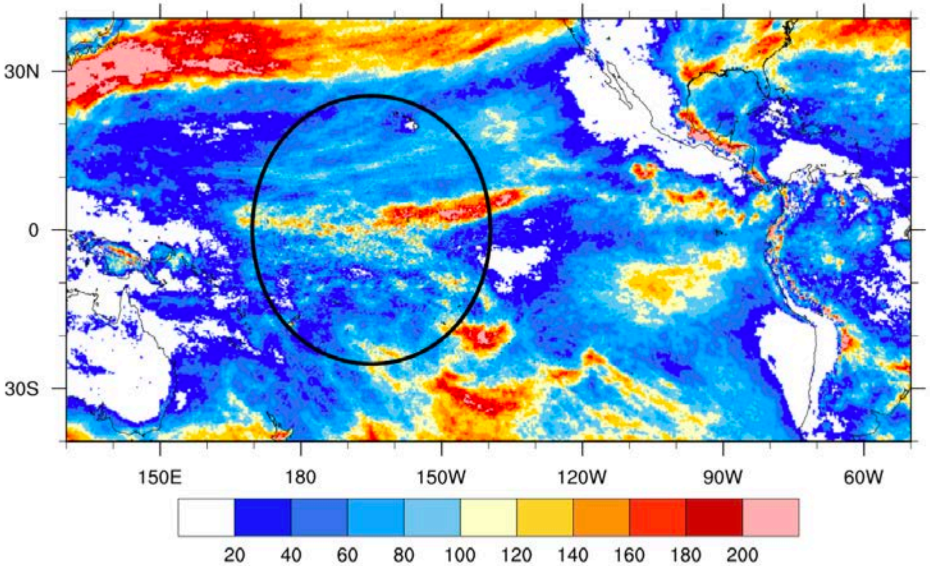
MSKF: 30 km UNIFORM MESH



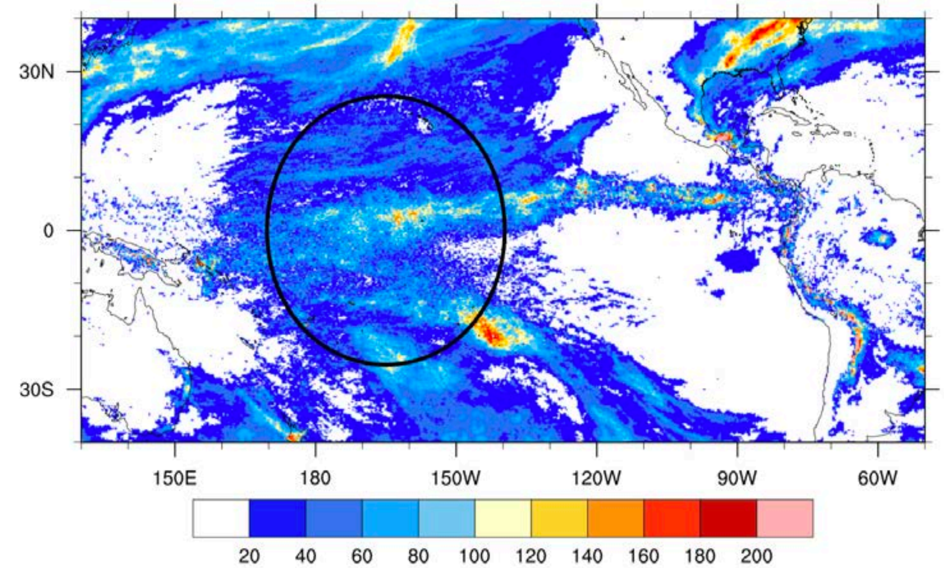
O : 7 km resolution isoline of the 30-6 km variable mesh.

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

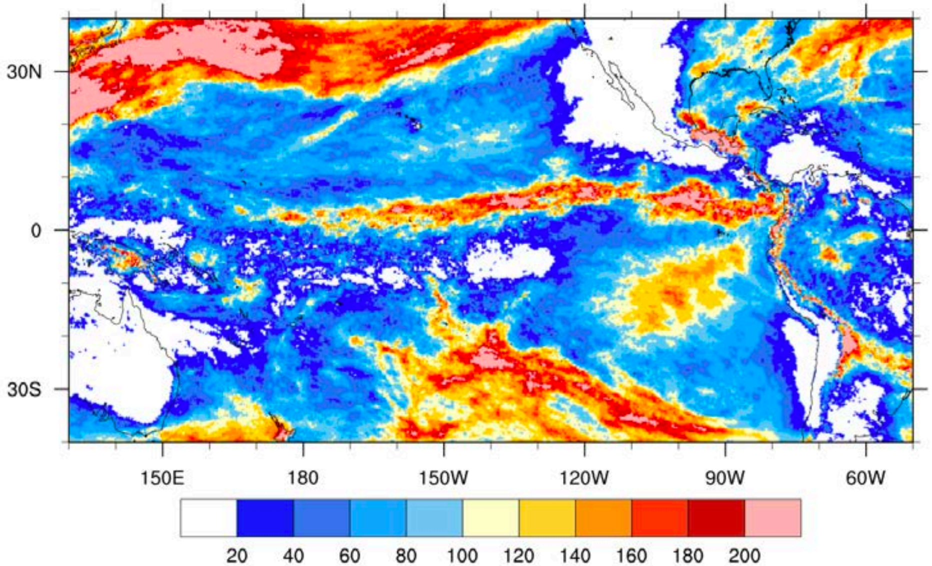
GF: 30-6 km VARIABLE MESH



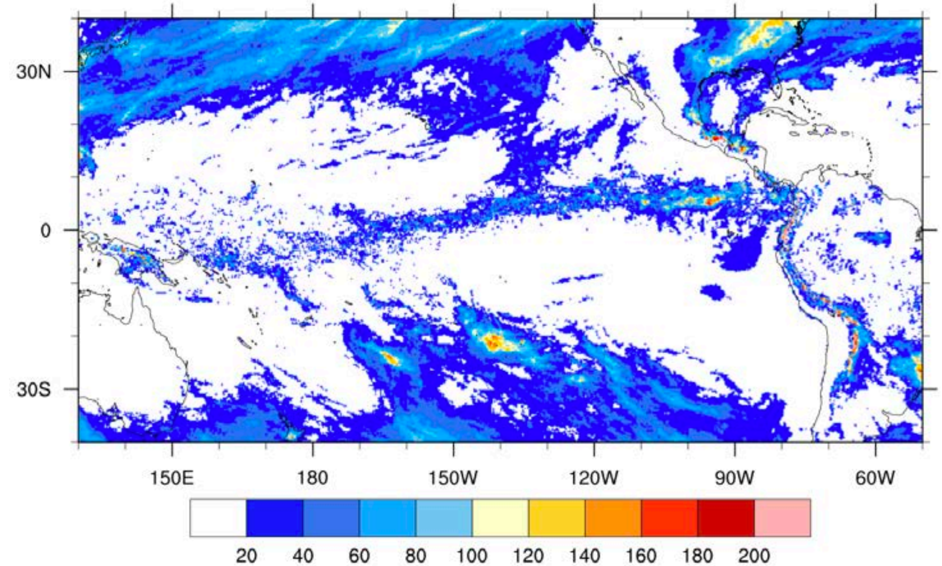
MSKF: 30-6 km VARIABLE MESH



MSKF: 30 km UNIFORM MESH



MSKF: 30 km UNIFORM MESH



O : 7 km resolution isoline of the 30-6 km variable mesh.

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.

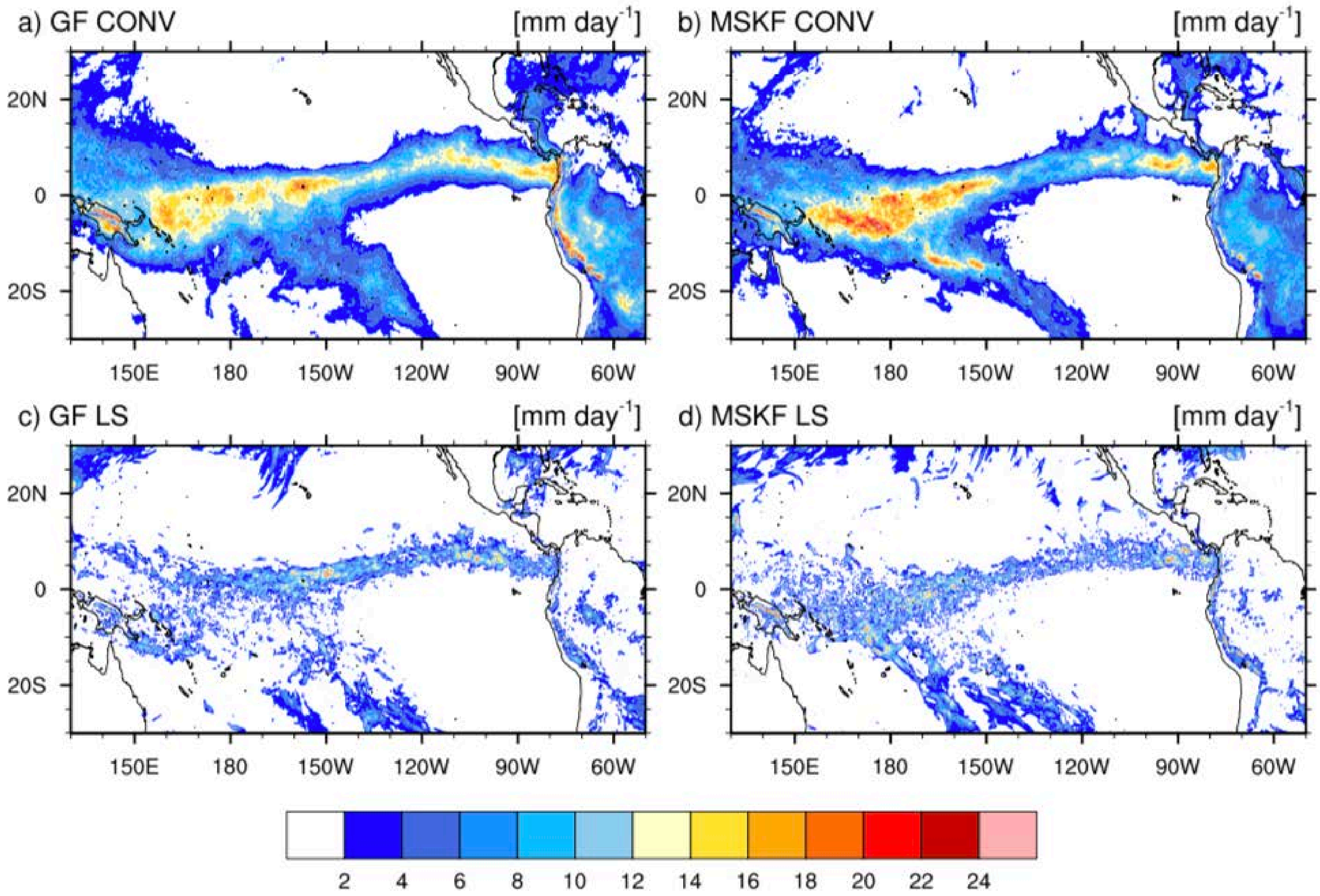
- Focus should be given to improve microphysics and precipitation processes in convection schemes.

- 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, and its impact in the coarse area of the mesh.

- In variable-resolution experiments, impact of the refined area of the mesh on the coarse area of the mesh on monthly-time scales.

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



DEC. 2015 – CLOUD LIQUID WATER PATH ($g\ m^{-2}$)

DEC. 2015 – CLOUD ICE PATH ($g\ m^{-2}$)

TOTAL

LOWER

UPPER