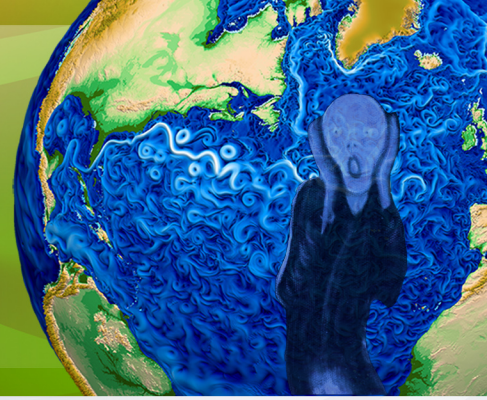

P3 Microphysics in the SCREAM project

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E3SM All-Hands, March 19-21, 2019

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What is P3 microphysics?

- P3 is a parameterization of microphysical processes in clouds, that represents the formation and sedimentation of condensed water. (P3, Morrison and Milbrandt, 2015 *J. of Atmos. Sciences*).
- The processes represented in P3 are an essential closure of cloud processes following the macrophysics scheme (SHOC in the case of SCREAM).
- P3 was designed for weather forecasting models that currently run at or near CRM resolution.
  - SCREAM leverages experience using P3 from the Weather Research and Forecasting (WRF) model community and will feed our experience back to them. **This has already happened.**
- Our version P3 of balances physical complexity with computational efficiency by simplifying away physical processes that are inconsequential for climate.
  - E.g. We have collapsed the number of ice categories in P3 down to one.

Accomplishments

- Integrated a simple base version of P3 into E3SM
  - Simplified P3-WRF optimized to focus computational effort on climate relevant processes
  - Assumed constant droplet concentration
  - No subgrid cloud variability (cloud-fraction is assumed to 0 or 1 at the grid-scale)
- Extended the base version of P3 to include fractional cloudiness
  - Normalize liquid, ice and rain mass/number mixing ratio by cloud fraction when calculating microphysical processes and determining sedimentation fall-speed
- Extended the base version of P3 to include aerosol activation of droplets and ice particles
- Performed SCM and climate simulation tests to ensure that simulations are physically reasonable
  - check_energy option turned on to ensure energy and water mass is conserved

Porting to E3SM and Feedback to P3-WRF

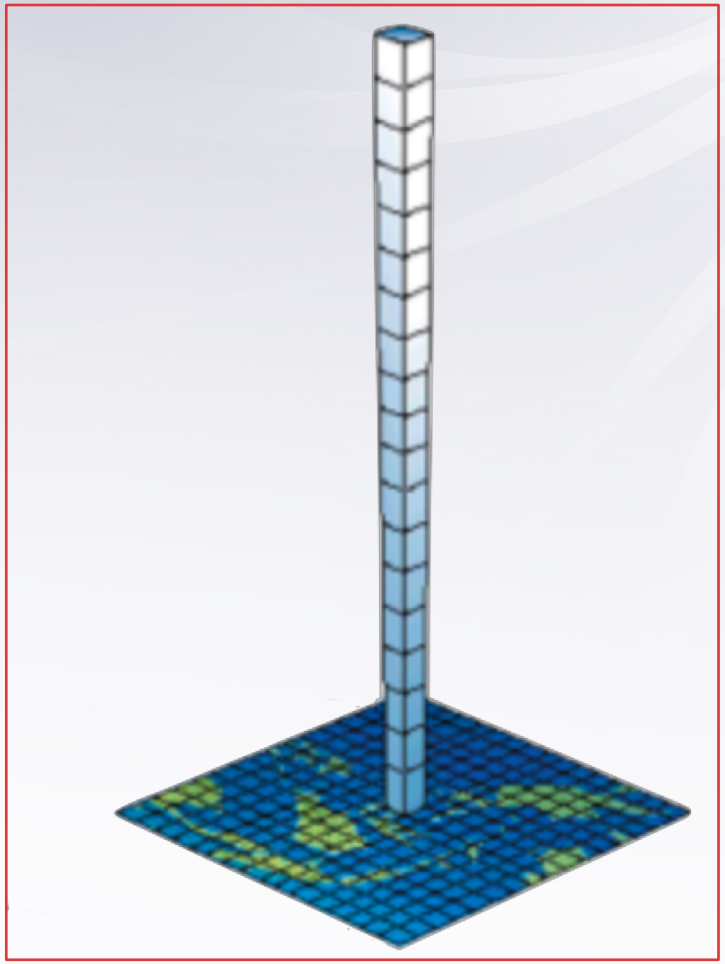
- Corrected an inconsistency in P3 between WRF and E3SM in the vertical coordinate system
  - Led to water and energy conservation violations
  - Corrected by changing the equations of sedimentation from being dz based to dp based
- Fixed a bug in interpolation of rain fall speed values a lookup table*
- Corrected an inconsistent update of potential temperature that used θ/T instead of the Exner function*
- Removed unused microphysics tendencies*
  - nchetc, nimul, nrhetc, qchetc, qrhetc, qrmul, qcmul

* fix reported and integrated in updates to community P3 models

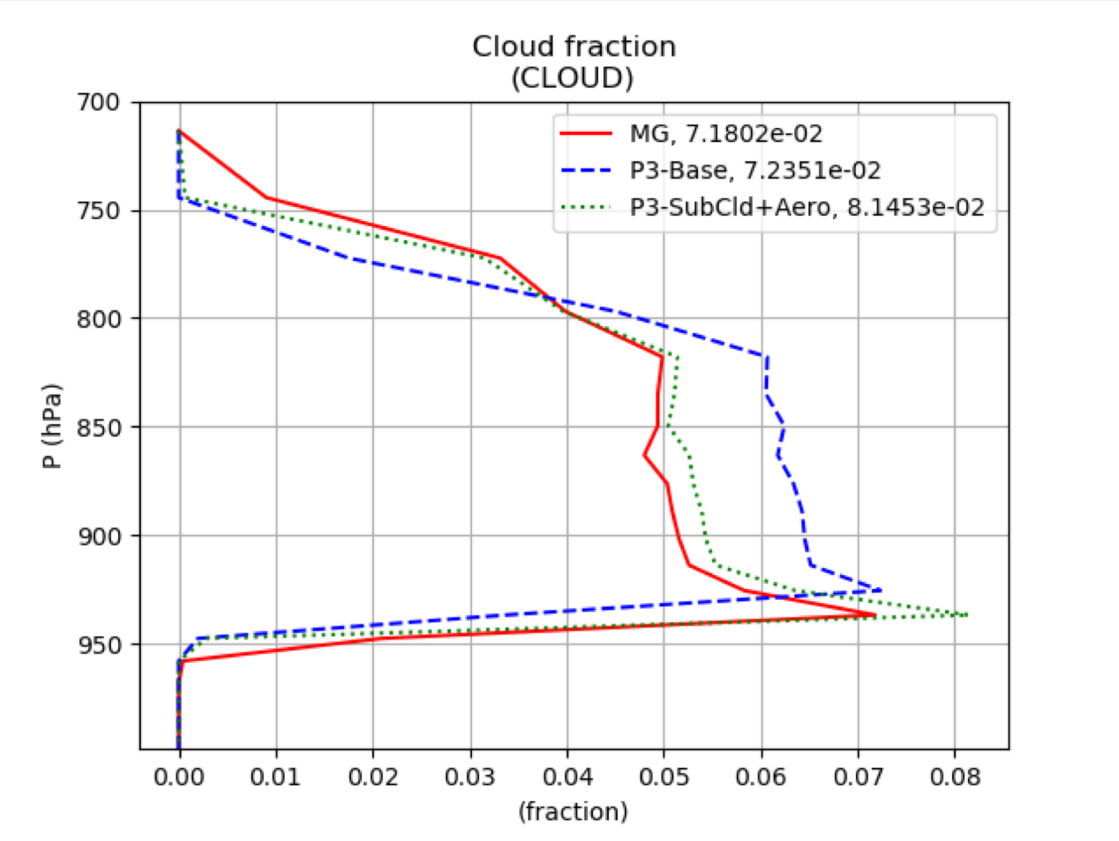
Single Column Simulations

Objective

- To determine the physical correctness of modifications to the parameterizations
  - Do modifications to the physics have the expected consequence?
- Simpler/faster to test in the single column rather than global context

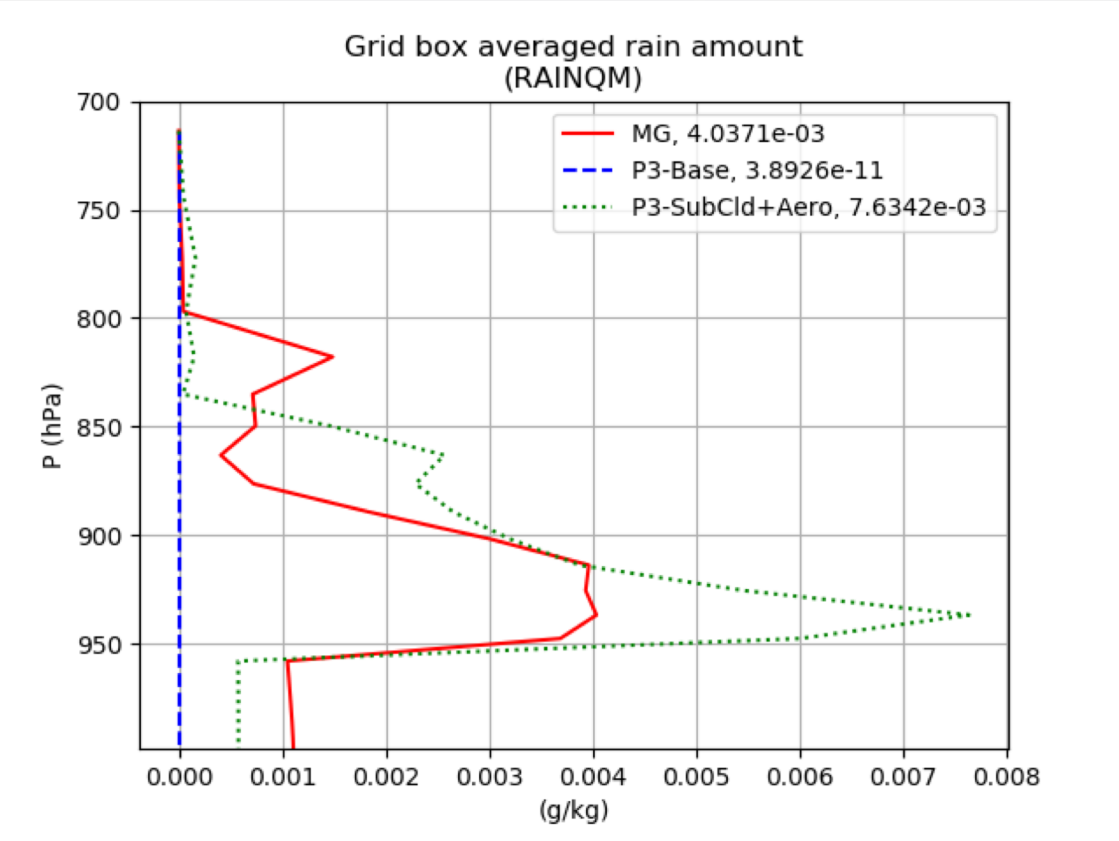


Precipitating Shallow Cumulus Clouds (RICO)



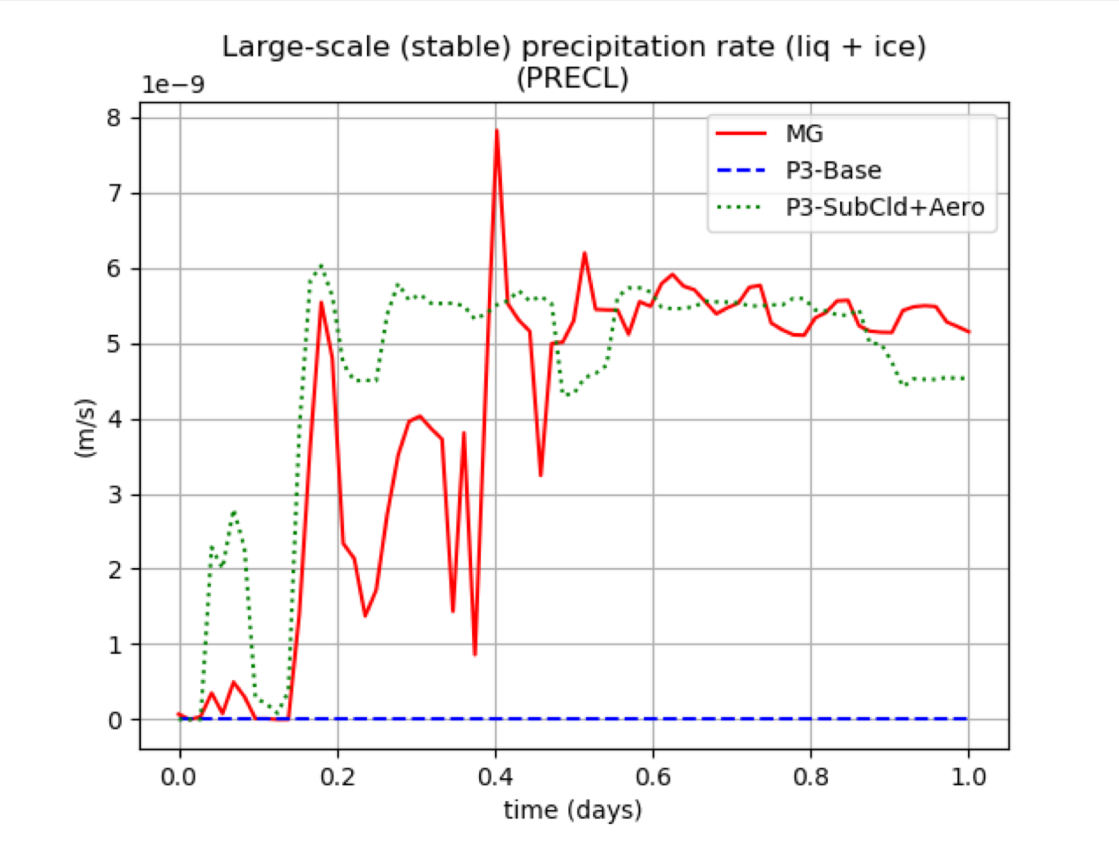
- Rain In Cumulus over the Ocean (RICO, Van Zanten et al., 2011)
- Including subgrid cloudiness and aerosol activation in P3 brings cloud fractions closer to those predicted by MG.
- Cloud-fraction is diagnosed based on RH, so the increased cloud fraction in P3-Base indicates higher moisture in the cloud layer.

Precipitating Shallow Cumulus Clouds (RICO)



- The higher moisture in P3-Base is a symptom of the scheme producing no precipitation (a sink on total-water content).
- The lack of precipitation in P3-Base is in turn a symptom of the built in assumption of no sub-cloud variability.
  - This is particularly acute in this case because of RICO's low cloud fractions.

Precipitating Shallow Cumulus Clouds (RICO)

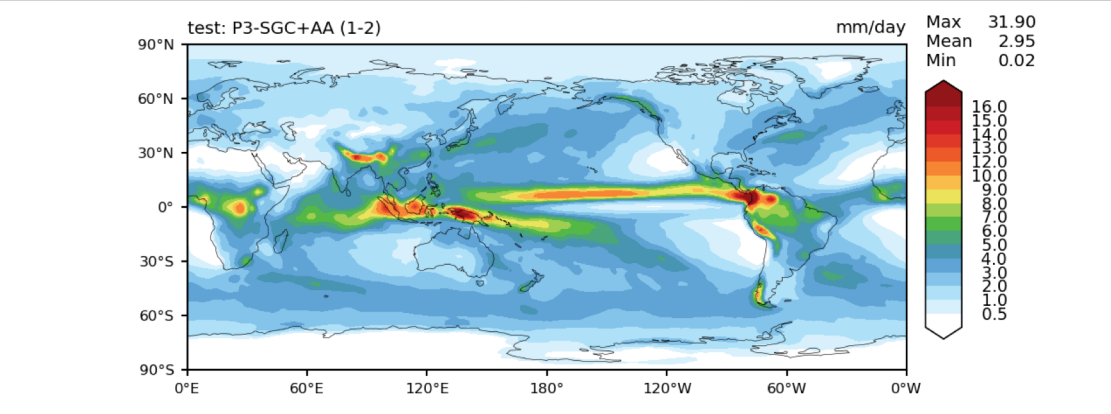


- The onset of precipitation predicted by P3-SubCld + Aerosol is similar to that predicted by the MG2 scheme.

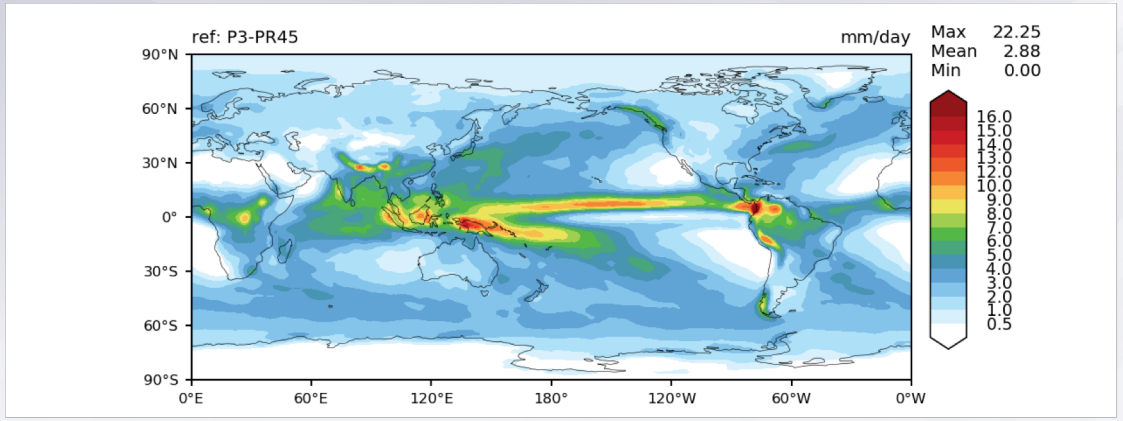
Climate Simulations

- Objective:
  - To determine if modifications to the model yield simulations that are stable and Earth like.
    - Simulations are carried out at 1-degree resolution.
    - P3 was designed for NWP models run at near or near CRM resolution. We have done **no model tuning**, so we expect potentially large biases in cloud radiative forcing.

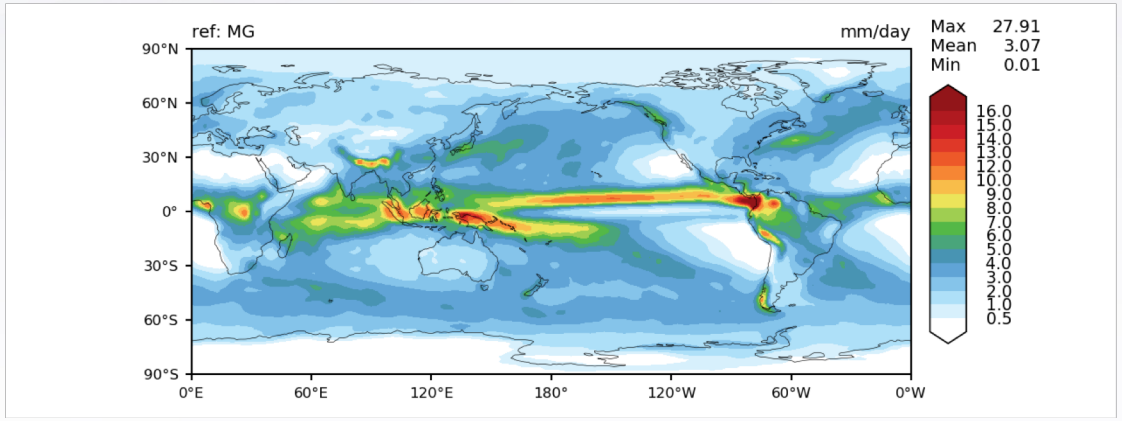
Global annual precipitation



P3 with sub-grid clouds and aerosol activation

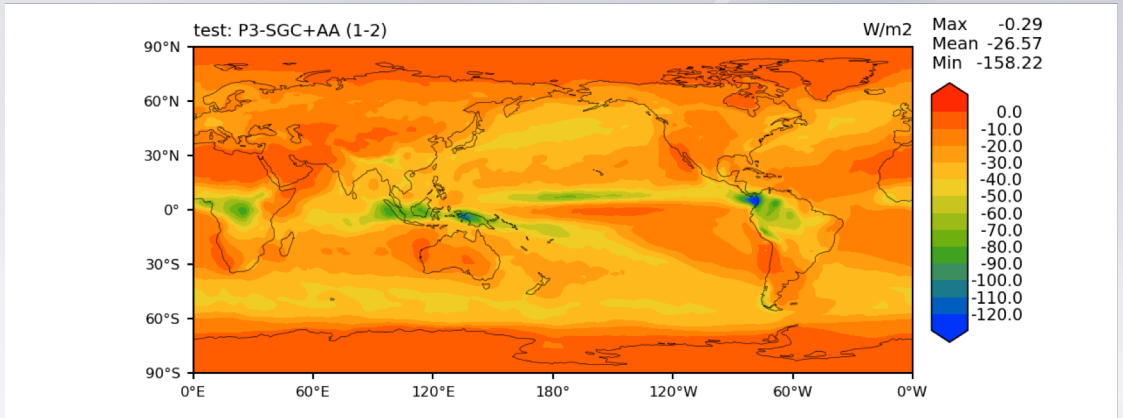


P3 baseline

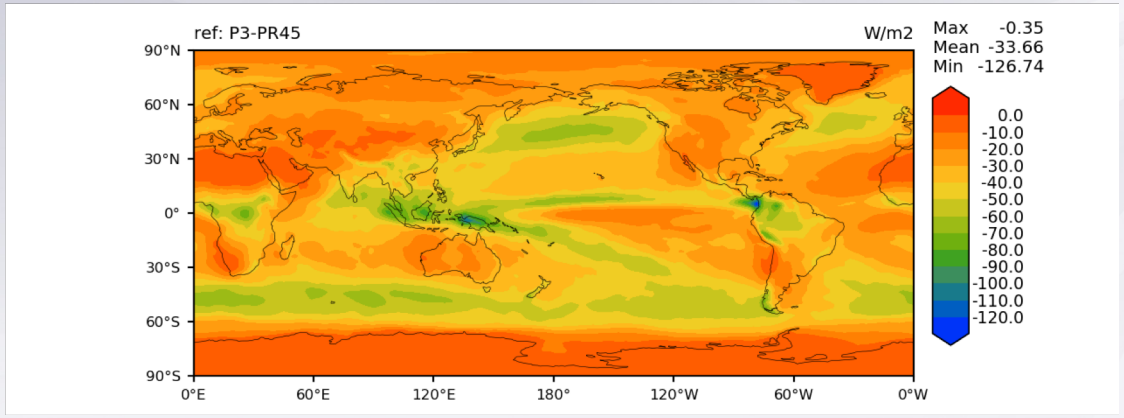


MG2 – for reference

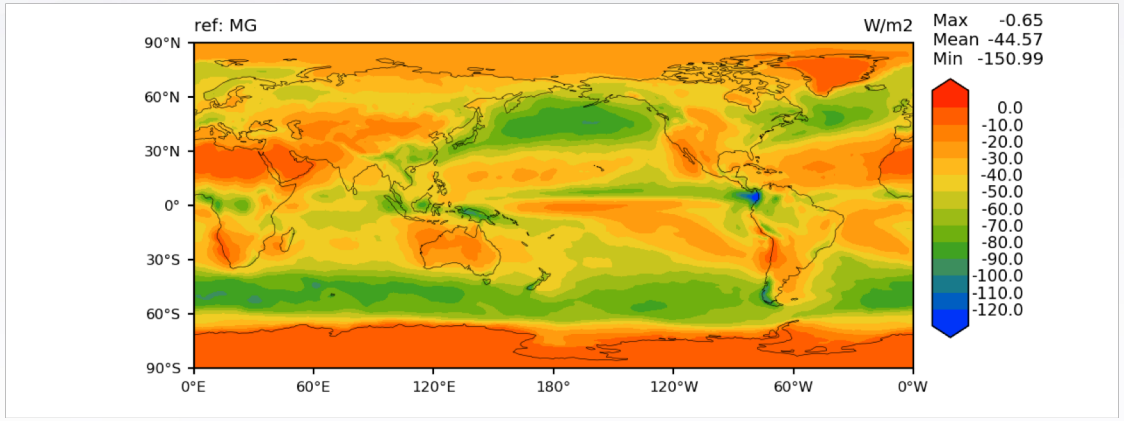
Global annual short wave cloud forcing



P3 with sub-grid clouds and aerosol activation



P3 baseline



MG2 – for reference

Next Steps

- Review saturation adjustment in P3-microphysics and make it consistent with CLUBB and SHOC
- Final clean-up of P3 codebase
  - Check for any lingering bugs or inconsistencies
- Combine P3 and SHOC and examine results
- Port P3 codebase to C++ SCREAM codebase

Extra Slides:

(RICO) Relative Humidity