Improvements and developments for HIWPP and the Grell Freitas (GF) convective parameterization

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Structure of talk

- Recent HIWPP developments and implementations into the Grell-Freitas (GF) convection parameterization and implementations of the GF scheme
- Ongoing work:
  - Aerosol-awareness and impact on numerical weather prediction (a connection to NGGPS)
  - Implementation in HWRF (a connection to NGGPS)

Grell-Freitas Convective Param

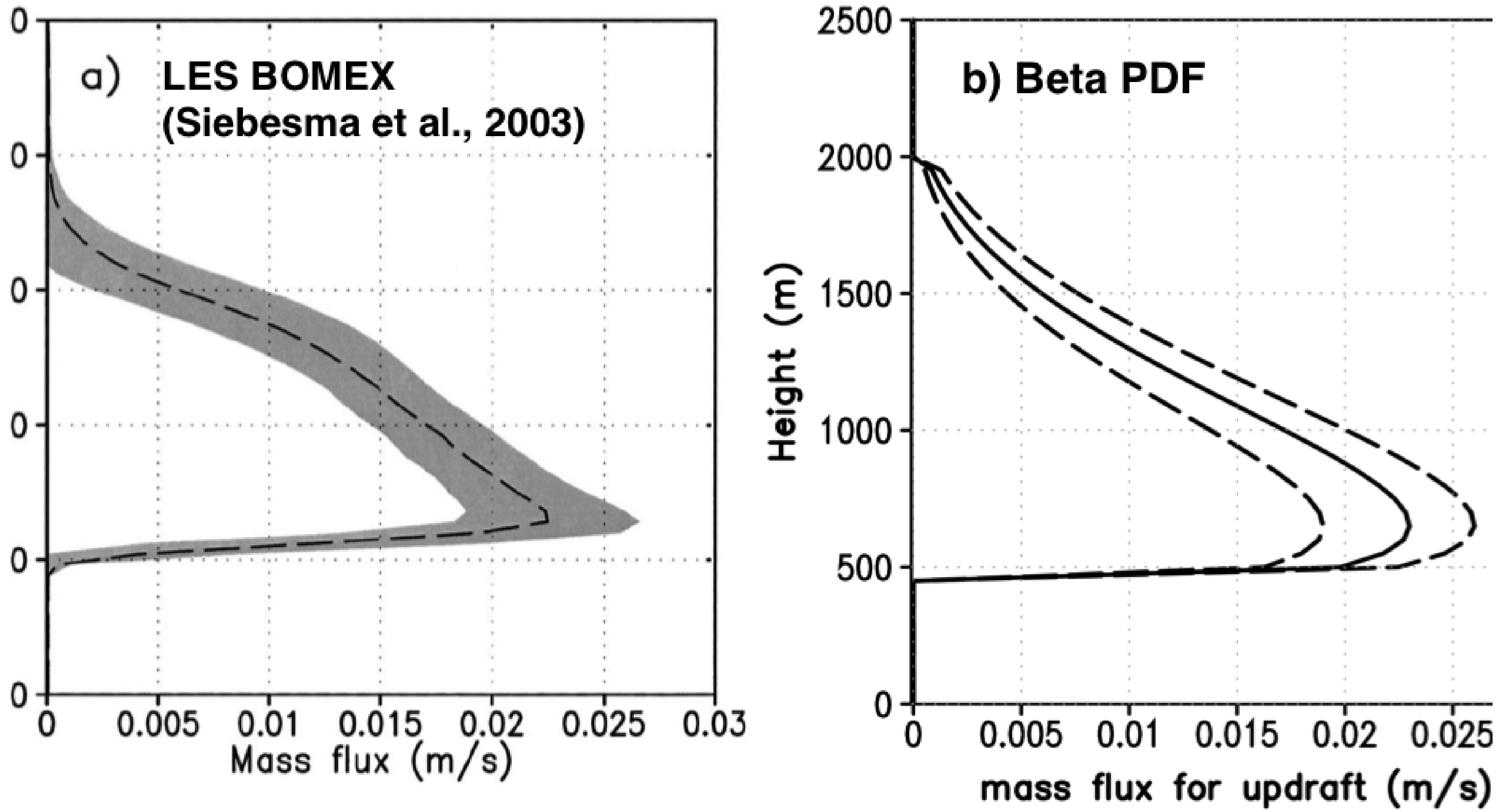
- **Scale-aware/Aerosol-aware (Grell and Freitas, 2014, ACP)**
  - Stochastic approach adapted from the Grell-Devenyi scheme
    - Originally many parameters could be perturbed
    - In 2014 version only 2 were kept (closures and capping inversion thresholds) – this has changed a lot in the most recent implementations
  - Scale awareness through Arakawa approach (2011)
  - Aerosol awareness is implemented with empirical assumptions based on a paper by Jiang and Feingold
  - Separate shallow scheme also exists with modifications by Joe Olson
  - Milestones: One publication **by Fowler et al (**scale awareness in MPAS) under review at MWR, one **by Freitas et al** will be submitted soon)

Recent new implementations into GF scheme

- Momentum transport (as in ECMWF and/or SAS)
- Additional closure for deep convection: Diurnal cycle effect (Bechtold)
- Changed cloud water detrainment treatment
- Additional closures for shallow convection (Boundary Layer Equilibrium (BLQE, Raymond 1995; W^*, Grant 2001, Heat Engine, Renno and Ingersoll, JAS 1996)
- PDF approach for normalized mass flux profiles was implemented
  - Originally to fit LES modeling for shallow convection
  - allows easy application of mass conserving stochastic perturbation of vertical heating and moistening profiles
  - Provides smooth vertical profiles
- Stochastic part can now be coupled to Stochastic Kinetic Energy Backscatter (SKEBS) approach (J. Berner)

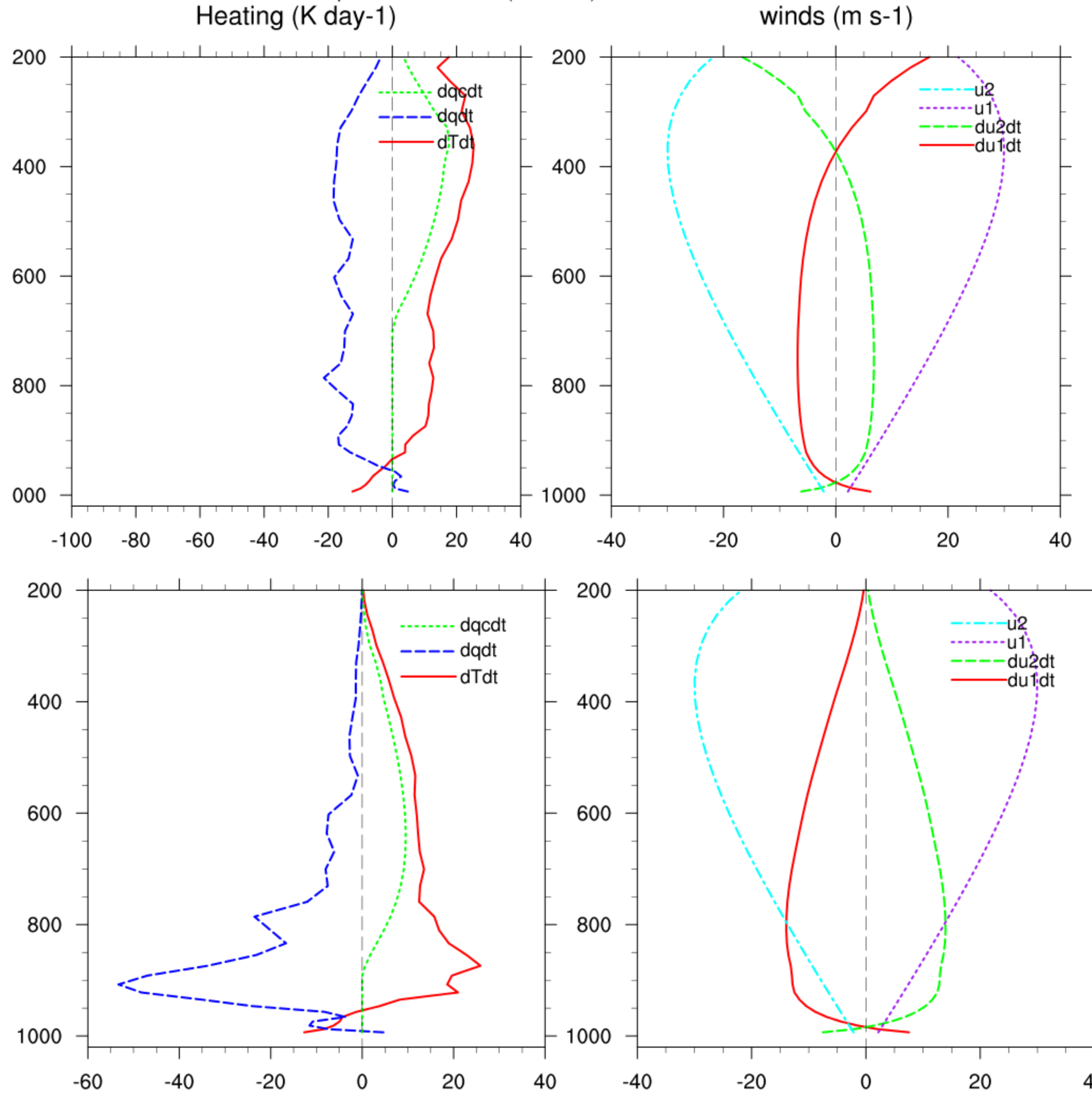
Evaluation within FIM, and will be done with HWRF and Rapid Refresh

The original reason for implementing PDF's for vertical mass flux: shallow convection



Changing the vertical mass flux PDF's

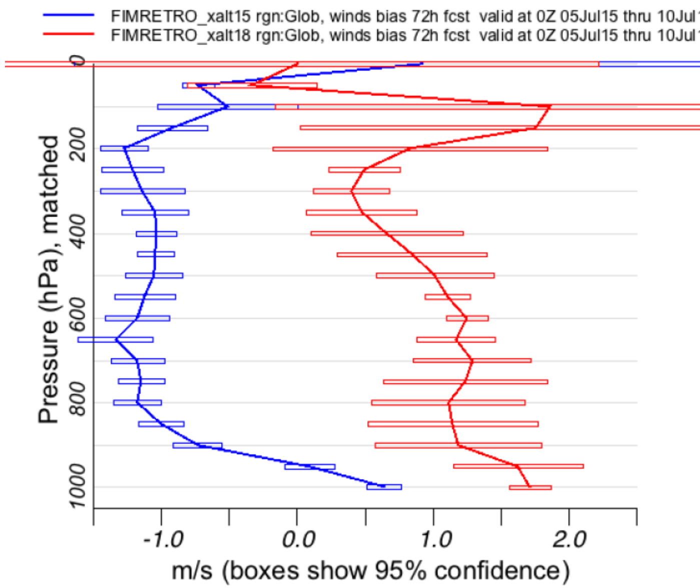
- Large changes in vertical redistribution of heat and moisture
- Mass conserving for stochastic approaches
- Large impact on HAC's

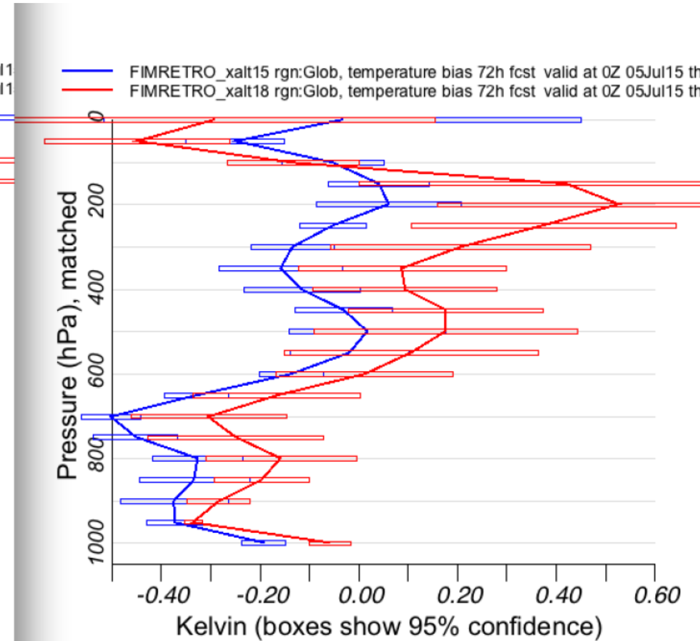


Impact of momentum transport and diurnal cycle implementation

Changing ***momentum transport*** constants:

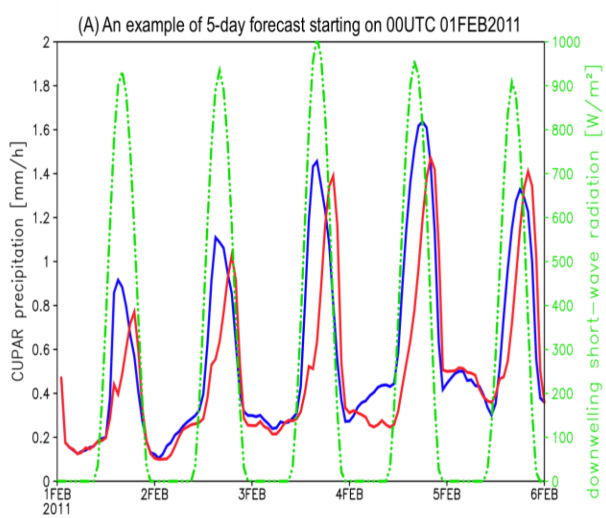
- large impact on comparison of global wind speed biases
- Improving wind bias has sifnificant impact on HAC’s but does not necessarily improve HAC’s

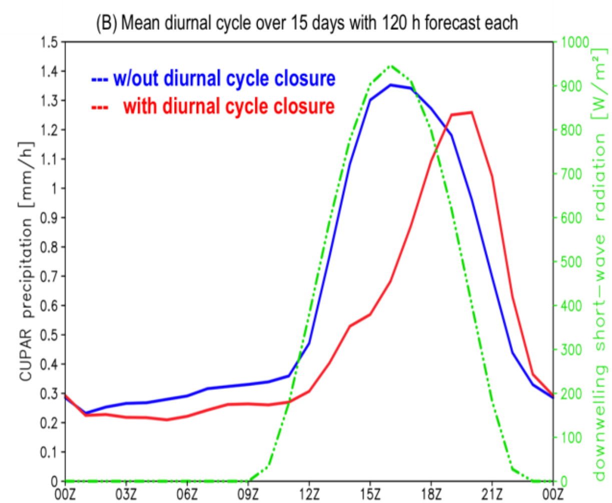




Diurnal Cycle implementation, 120 hour forecasts:

- precipitation averaged over Amazon basin is improved
- HAC’s little impacted





Recent new implementations of GF scheme

- Jian-Wen Bao has implemented it in GFS (through NUOPC physics coupler) – but not yet used
- HWRF experiments have started (NGGPS project)
- Some aspects have been implemented into **RR**
  - To be able to couple **stochastic part** with Stochastic Kinetic Energy Backscatter (SKEBS) approach (J. Berner)
  - Momentum transport in HWRF
  - Momentum transport, massflux PDF's, and cloudwater detrainment will be tested next in RR
  - Massflux PDF's will be tested next in RR and HWRF

Problem with HWRF: Valuable tests maybe too costly

Aerosol awareness

Change 1: Change constant autoconversion rate to aerosol (CCN) dependent Berry conversion

$$\left(\frac{\partial r_{rain}}{\partial t}\right)_{autoconversion} = \frac{(\rho r_c)^2}{60\left(5+\frac{0.0366\,CCN}{\rho r_c \mu}\right)}$$

Berry, 1968

Change 2: Modified evaporation of raindrops (Jiang and Feingold) based on empirical relationship

$$PE \sim (I_1)^{\alpha_s-1}(CCN)^{\zeta} = C_{pr}(I_1)^{\alpha_s-1}(CCN)^{\zeta}$$

Change 2 introduces a proportionality between precipitation efficiency (**PE**) and total normalized condensate (**I_1**), requiring determination of the proportionality constant **C_{pr}**

How do we get CCN?

1. Most sophisticated approach:
    - directly from complex model results (WRF-Chem)
2. Simpler approach:
    - from observed Aerosol Optical Thickness (AOT) at 550 nm (global or regional analysis), following Rosenfeld et al. (2008) and An

$$AOT = 0.0027\ CCN^{-0.643}$$

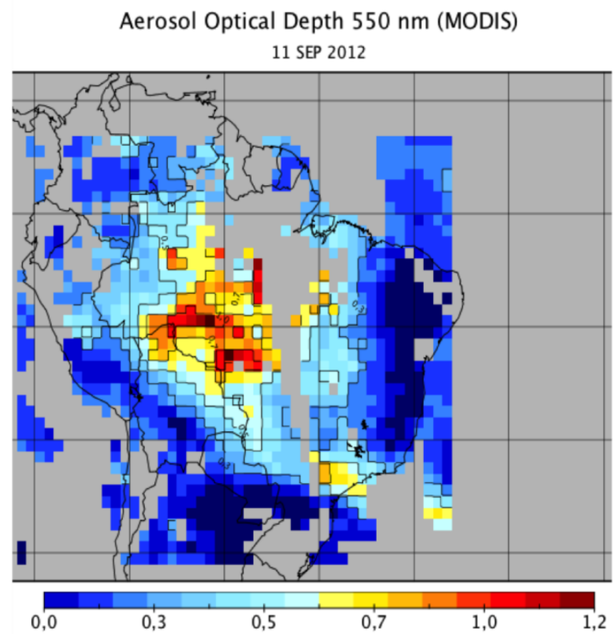
- Or anywhere in between – depending on complexity of model setup

Working Group for Numerical Experimentation (WGNE) exercise: Impacts of aerosols on weather prediction

Case 3- Persistent Smoke in Brazil - SEP 2012

Forecast experiments:

- September 5-15, 2012
- Twice daily, 00 UTC and 12 UTC
- 10 day forecasts for global models
- 3 day forecasts for regional (WRF-Chem) model
- Input and boundary conditions from ECMWF
- Chemistry from MACC



Three sets of runs for WRF and WRF-Chem, using same physics (20 runs each, 15km, 5km, 1.7km dx:

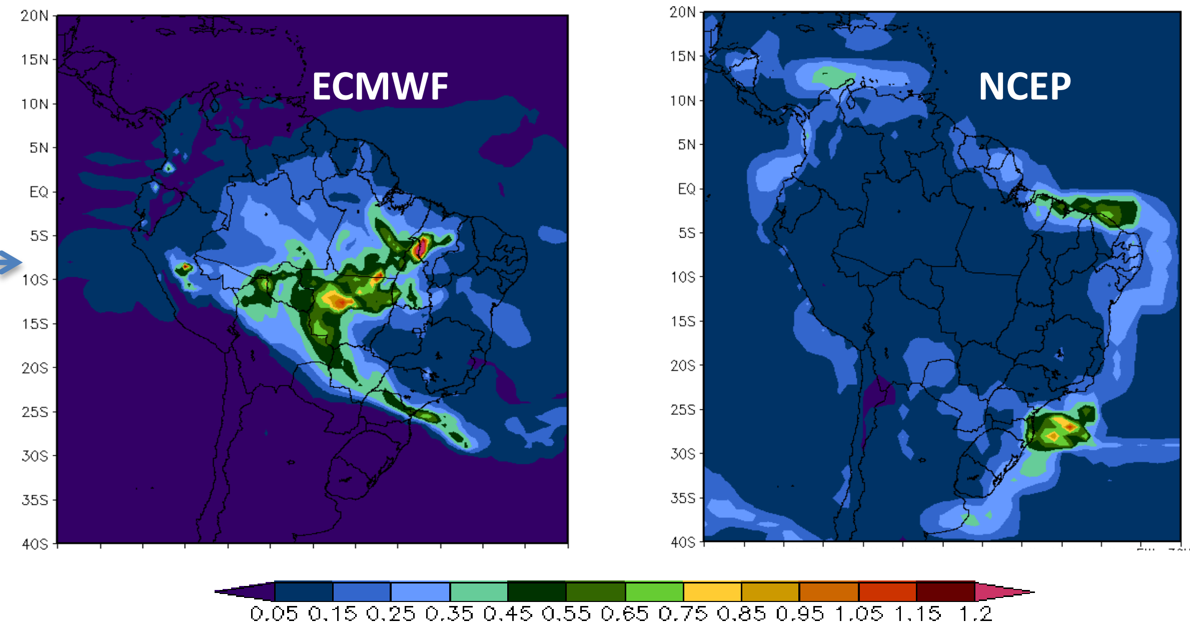
1. **WRF (no chemistry)**
2. **WRF-Chem (modal aerosols, gas-phase chemistry, full interaction with RRTMG radiation and Morrison microphysics**
3. **As in (2), but no fire emissions**

Some examples (ECMWF and JMA) from global models and the aerosol impact WGNE group

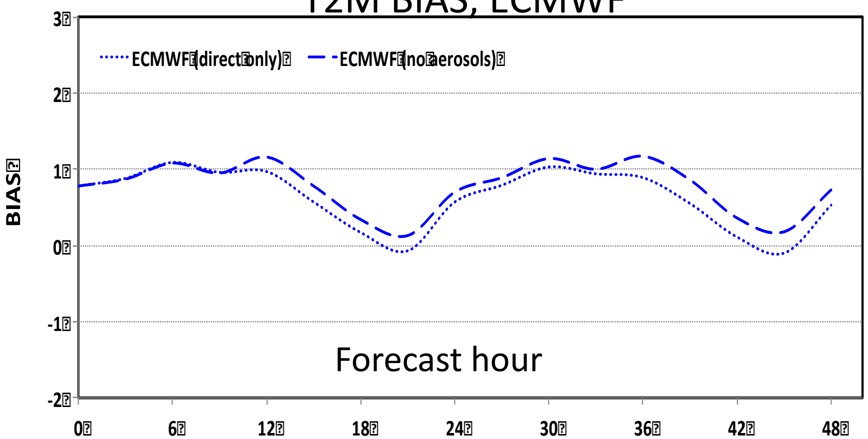
AOD at 550 nm
27 hr forecast for
15UTC 11SEP

Fires included

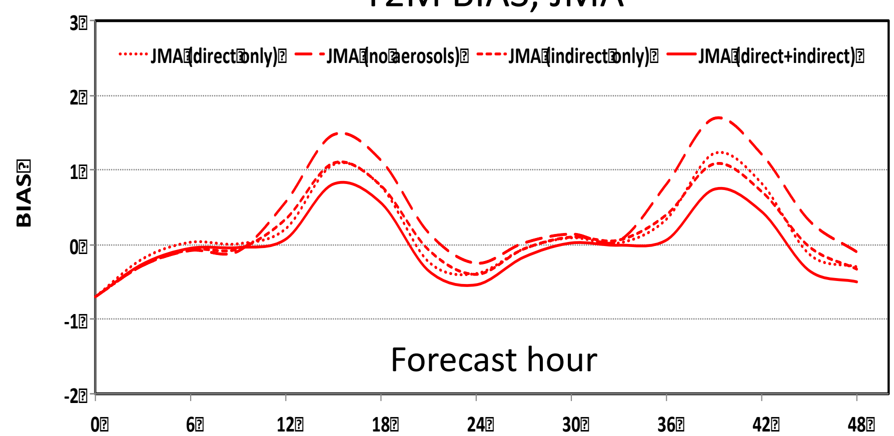
Climatology



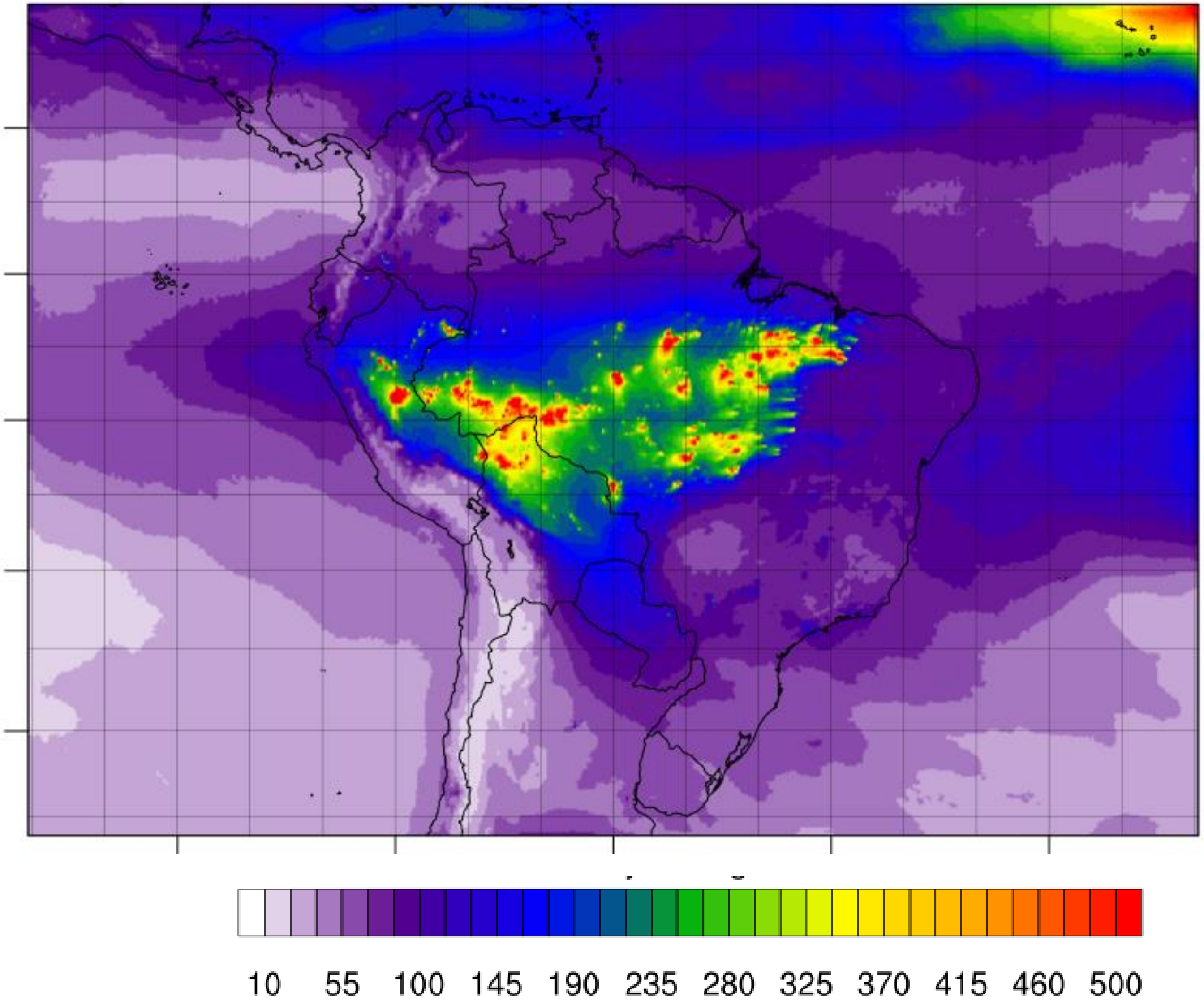
T2M BIAS, ECMWF



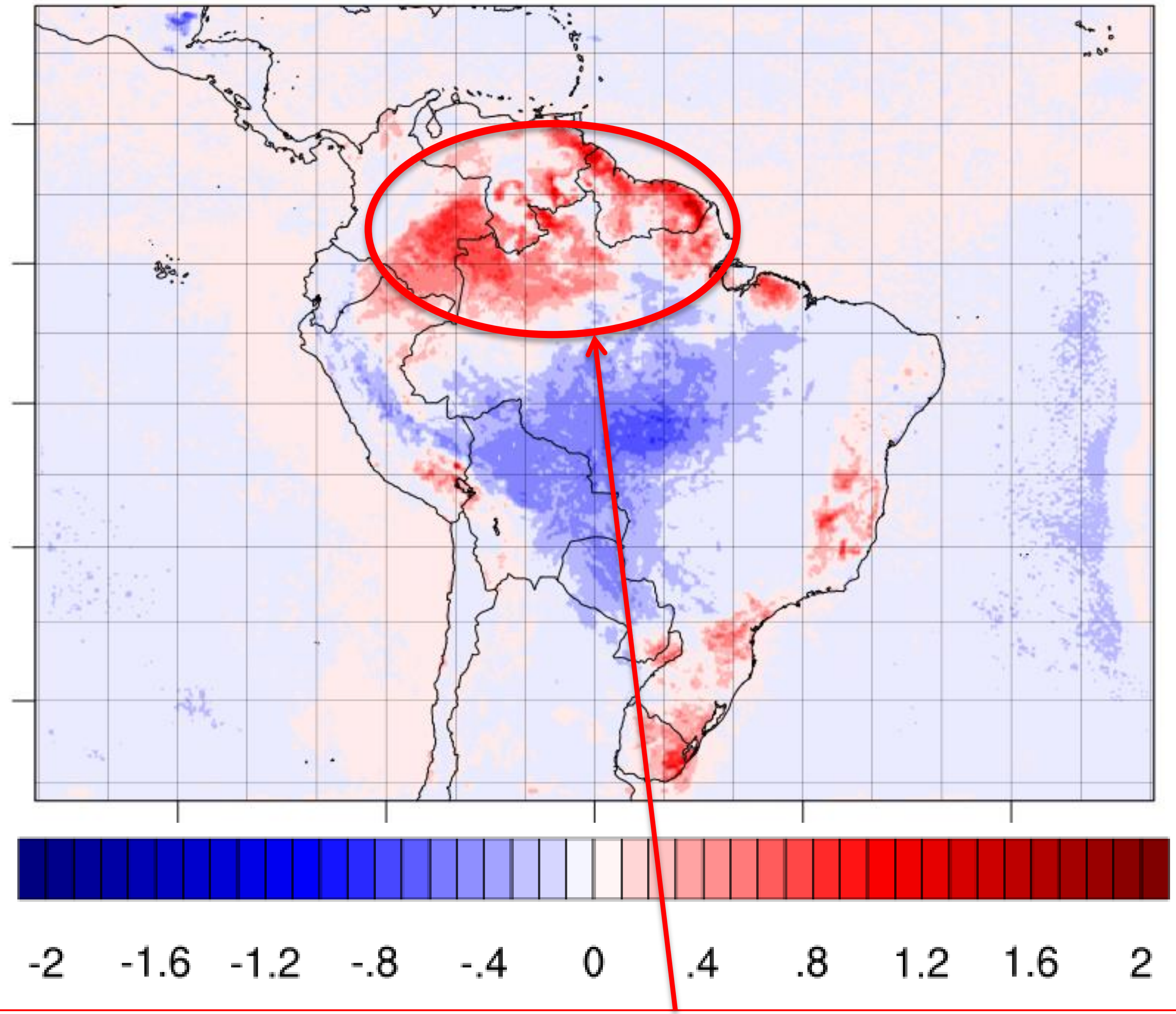
T2M BIAS, JMA



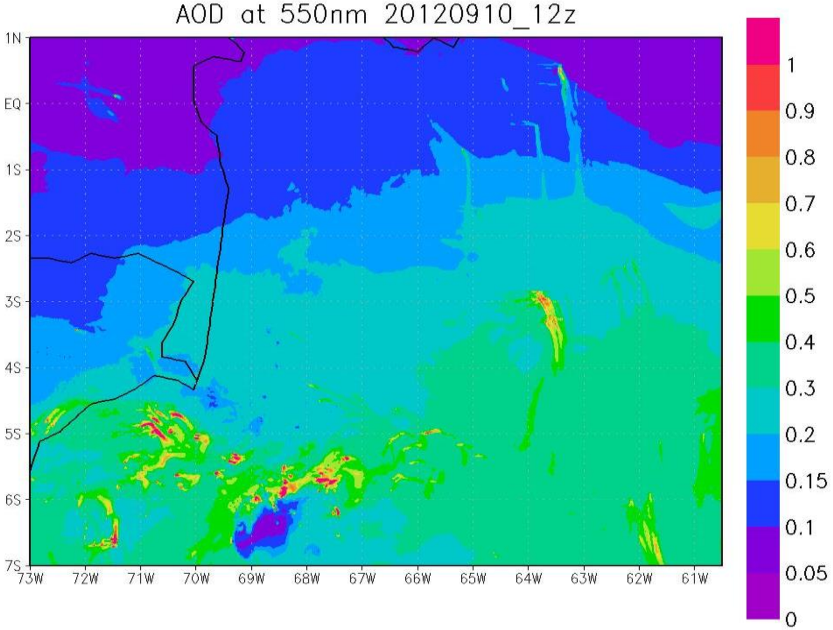
WRF-Chem runs, dx=15km, averaged total burden PM25 distribution (20 runs, each 72 hours), convection permitting simulations over NE Brazil and Columbia (1.7km dx)



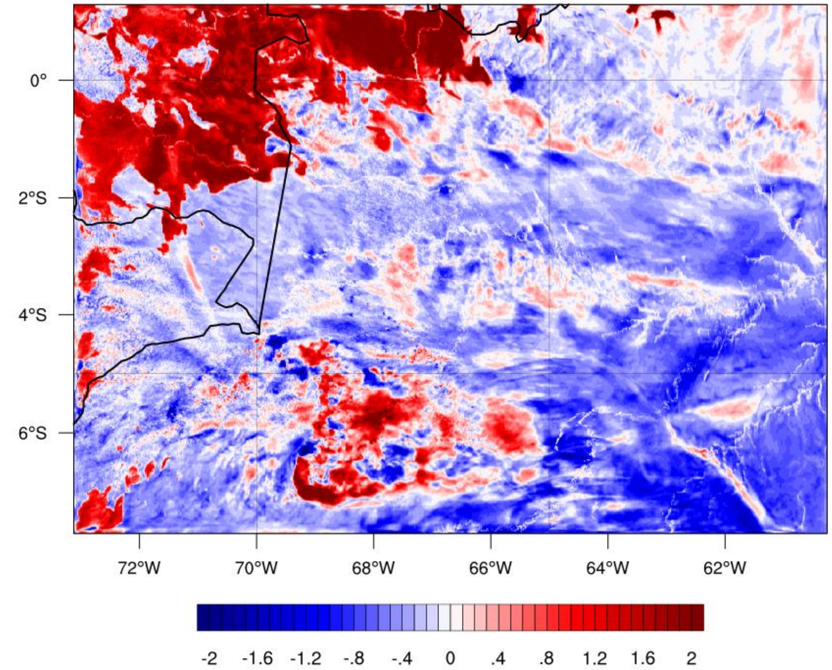
Average over 20 runs, 3 days, 12Z T2m differences, CHEM - MET

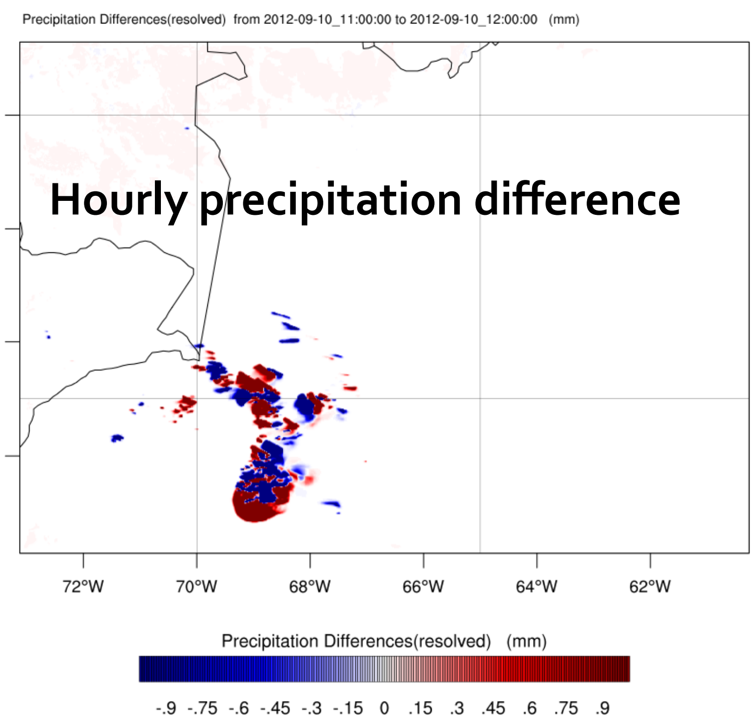


Low AOD: Most of this warming caused by not needing constant droplet number assumption in meteorology only run



T2M differences, Chem-Met, 12Z, Sep 10

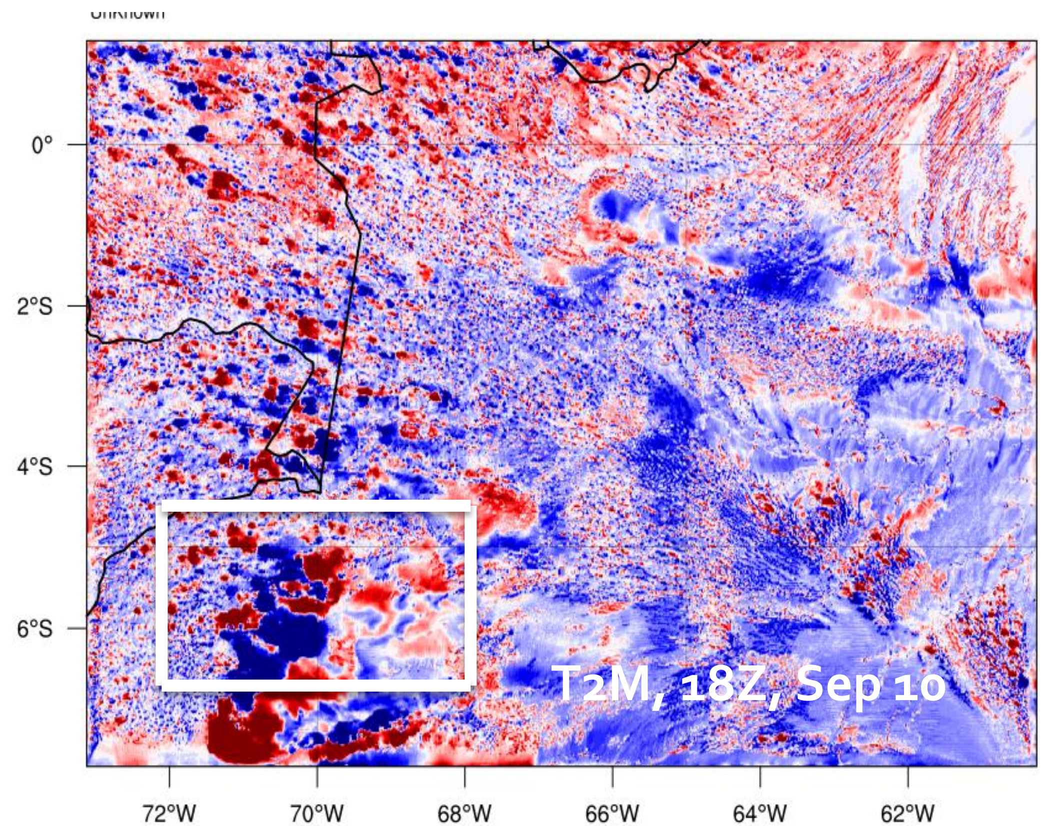


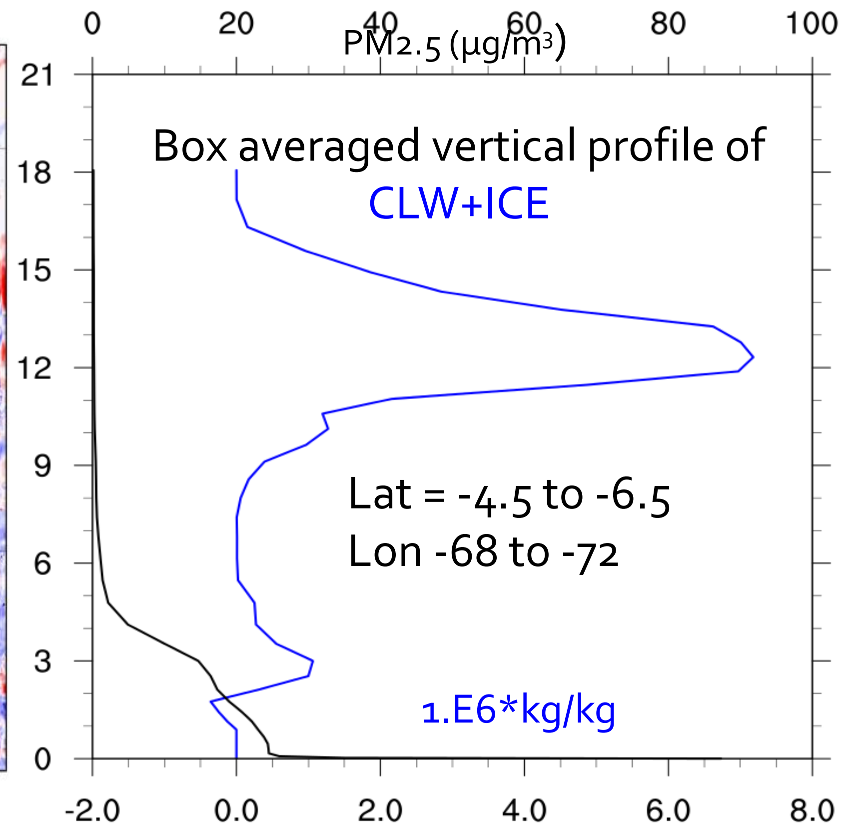


Convection Permitting Simulations, dx = 1.7 km

Low level clouds in NE corner do not exist in run with indirect effect included…

Averaging in areas with significant convection, dx= 1.7km

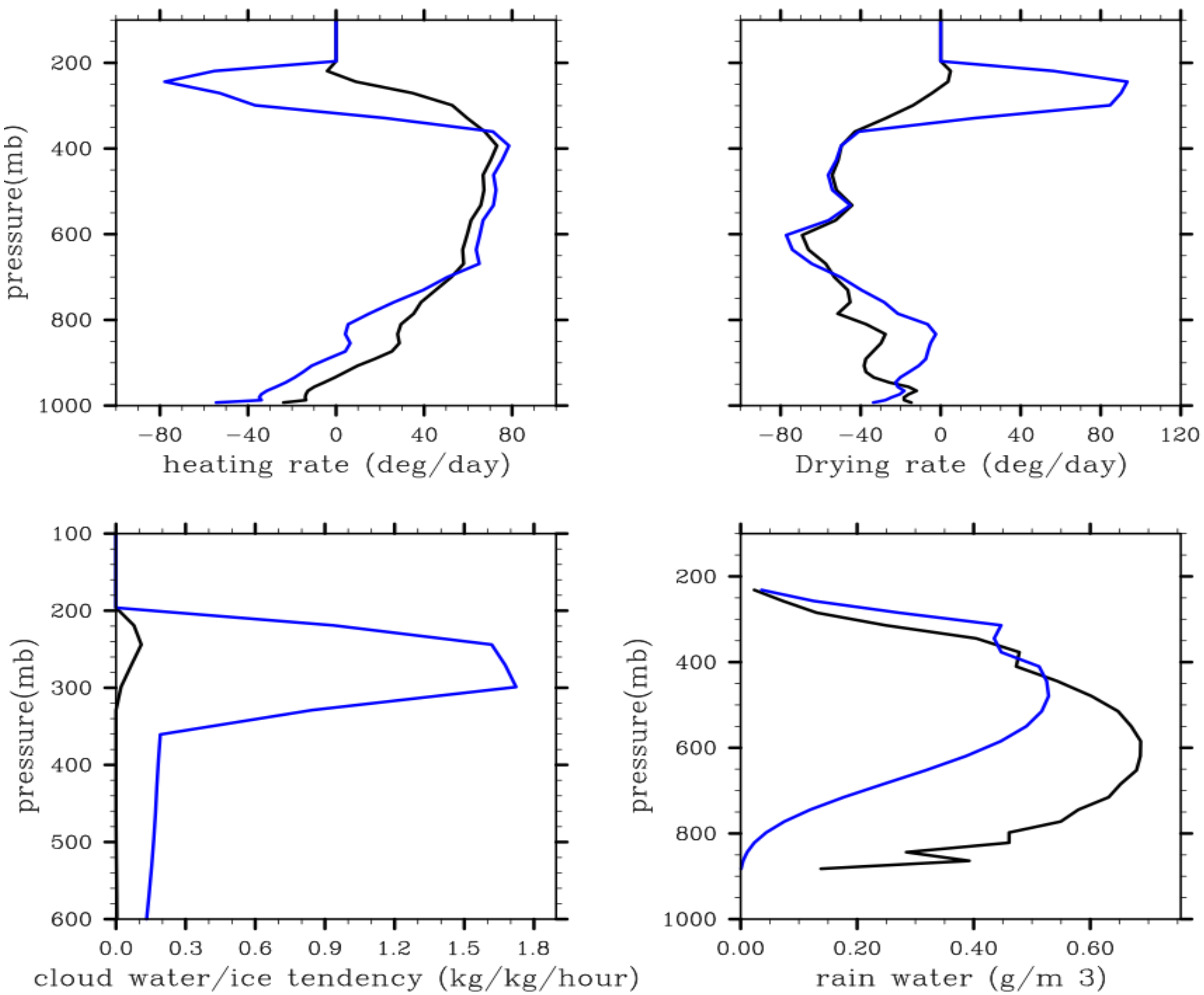




RNW appeared unpredictable: Convection has different strength

For high resolution run: CLW and ICE appear to have a signal

So what if you try this with aerosol-awareness turned on in the GF convective parameterization



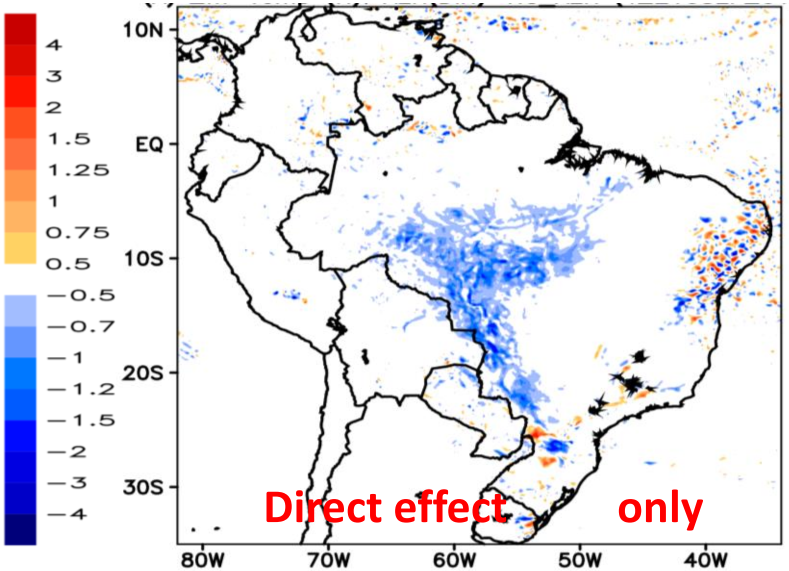
Polluted (AOD=1.)

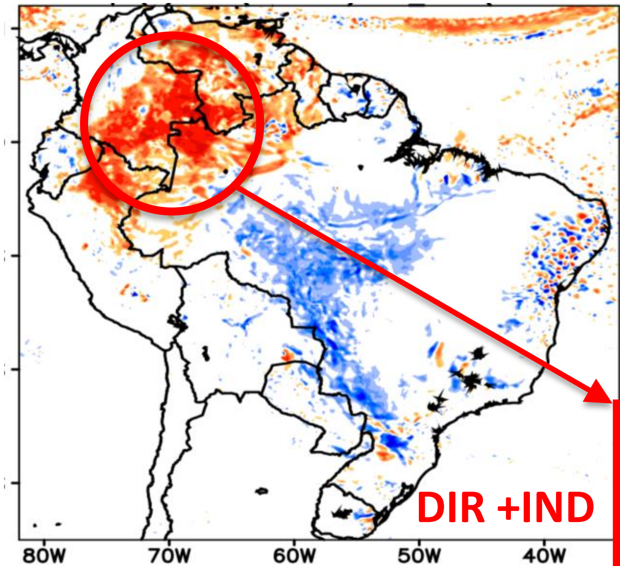
clean (AOD=.01)

Previous 1-d tests

- much more detrainment of cloud water and ice at cloud top
- less suspended hydrometeors, especially in lower part of parameterized clouds
- stronger downdrafts. Leading to less drying in and just above the boundary layer, but stronger cooling in lowest levels

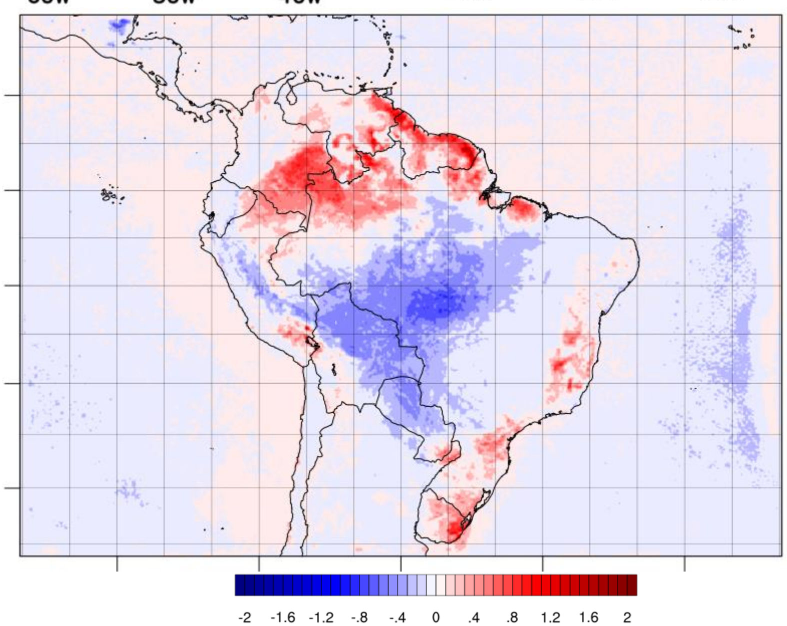
T2M difference fields, September 10, 1200UTC- mid-morning. Positive (red) is warmer compared to MET – simulation with convective parameterization





Using convective parameterization with and without aerosol awareness

Why should this be related to convective parameterization?



Full chemistry and physics, aerosol indirect explicitly included

Aerosol tests – initial conclusions

- Tropical environments may be the most likely to see an impact – **signal strength also very important (very low or very high AOD)**
- Strength of convection at this point, and with our model setup, may be difficult to correlate to aerosols
- Initial results for aerosol aware convective parameterization indicate more tests needed
  - Shallow convection
  - Need longer term statistics
  - Interpretation of 3d impact results will depend on environmental conditions
    - Because of the dependence of precipitation efficiency on wind shear and subcloud humidity in addition to CCN, impacts in middle latitudes may be much more mixed

Ongoing and future work

- Some final tuning adjustments for global predictions will take place over the next couple of month (we implemented mid level cloud, similar to what was done by ECMWF)
- Aerosol aware work will be combined with NGGPS FIM-Chem project, replacement for initial hire will be in place in March
- For aerosol awareness we will also test simpler chemistry modules and microphysics schemes with a focus on:
  - Thompson aerosol aware microphysics would be much less expensive approach and will be used operationally at NCEP on regional scales – initial version uses GOCART climatologies, plan is to supplement these with wildfire and dust emissions
  - GF scheme can run with observed AOD (no chemistry at all necessary)
- Experiments with stochasticism (Isidora Jankov, J. Berner, J.-W. Bao)

One example of comparison for WRF-Chem run differences with and without fire emissions (usually clean conditions), but full interactions allowed for both runs, 27hr forecast, 15z, Sep 12