Aerosol and scale aware convective parameterizations

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1. Gray scales: parameterizing convection when the dynamics is able to resolve some convective systems – but not all
2. Some examples of early and current ideas on what to do on gray-scales: A focus on the commonly used Arakawa approach
3. A new old approach
4. Aerosol awareness

Parameterizing convection when the dynamics is able to resolve some convective systems – but not all

Three approaches are possible

1. Convective parameterizations are being used without any modifications on gray-scales, because of “better” results
   - CON: With convective parameterization flow may become too viscous for model to explicitly simulate what may be resolvable
2. No convective parameterization is being used because of “better” results
   - CON: With no convective parameterization, convection may take too long to develop - Once it develops it may be too strong
3. Scale aware convective parameterizations are being used because of “better” results
   - In spite of some success stories, no perfect solution yet– serious flaws still exist

Some historic attempts to address these problems with modifications in parameterizations

1. UKMET office in 80's attempt to let the convective parameterization only do transport of mass – so no compensating subsidence – Met office technote, Golding 1990
2. Kuell and Bott (2007, QJRM) – as in (1) but claim success.
   – (1) and (2) can only be done in non-hydrostatic models, (2) at least existed in an experimental version of the operational model that was used by the German weather service
3. Super parameterization approach (Grabowski and Smolarkiewicz 1999 and/or Randall et al 2003,….) – using a 2d CRM inside the non cloud resolving model
4. Gerard et al (2009, MWR) – prognostic equations for σ and w_c
5. Applying the parameterization over a range of grid points - we did this in a version of the Grell scheme (G3, Grell and Freitas, 2014, ACP)
6. Arakawa et al 2011 by relaxing the σ requirement and defining a relaxed adjustment – now used in some way or the other in many different approaches

(1), (2) - in contrast to (6) –are based on the conceptual ideas. (5) appears to work for constant grid spacing, but requires communication across grid points and cannot easily and smoothly transition for irregular grids. (6) offers a smooth transition, is widely used

but is it really the way to go?

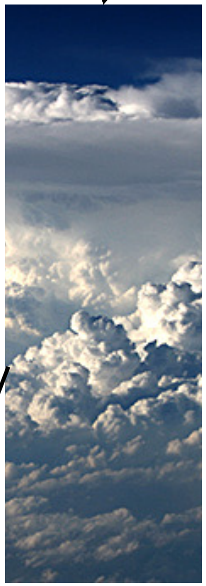
Scaling the tendencies, Arakawa's scale-aware approach as example

- A scale-aware parameterization is built on top of a conventional parameterization:
  - at low resolution, the conventional parameterization dominates,
  - at high resolution, the parameterization gives way to the microphysics scheme.

$$\overline{w'\phi'} = (1-\sigma)^2 \left(\overline{w\phi} - \bar{w}\bar{\phi}\right)_{adj}$$

$(1-\sigma)^2$ is simply a scaling factor!

Vertical eddy transport.



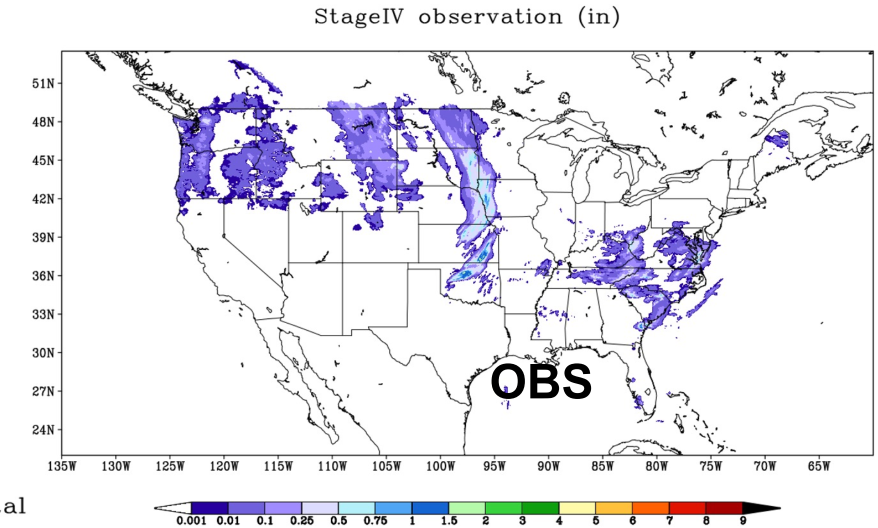
Grid box, where σ covers part of it

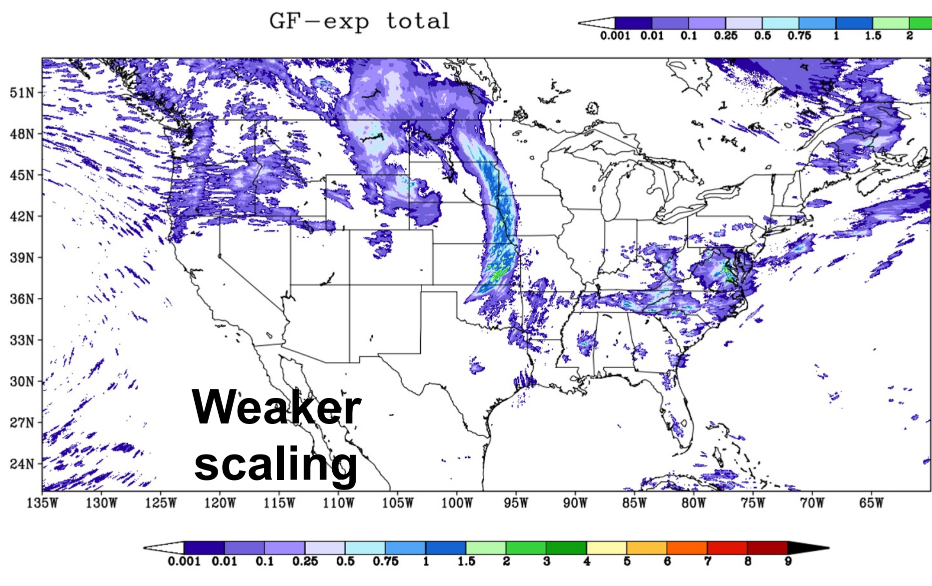
Eddy transport given by a conventional CP for a full adjustment

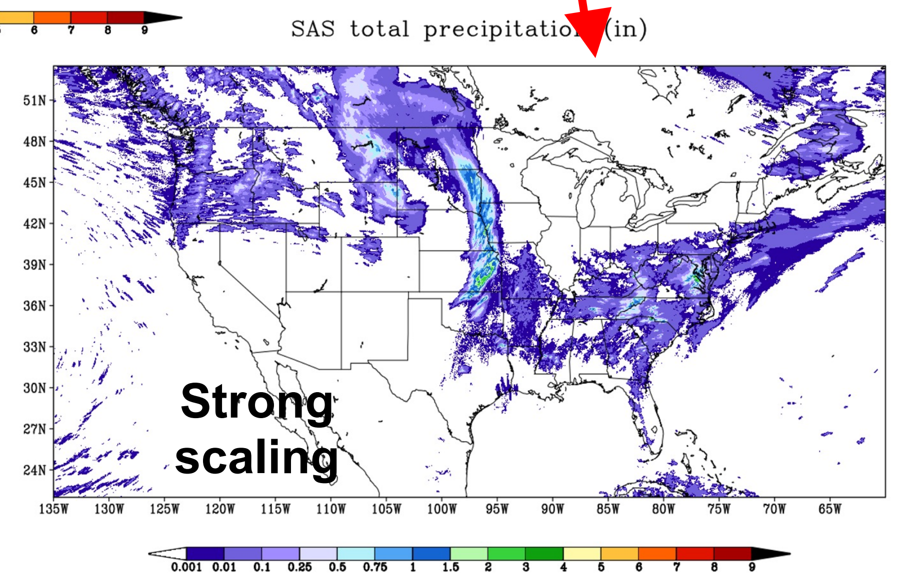
Why would convection have to be scaled? Instead of 1 inch rainfall, it would only rain 1mm? This can only work if resolved convection is already present! But even then: Convection has no influence on neighboring grid cells?

Scaling the tendencies will lead to very light precipitation (convective drizzle) – and to stronger overforecast of high threshold events. Cutting down on light precipitation will improve precipitation scores, but fail to forecast some very intense storms (important for short range storm scale forecasting)

3 hour total precip at hour 9 of RRFS forecast, May 6







A new old approach: 3d application

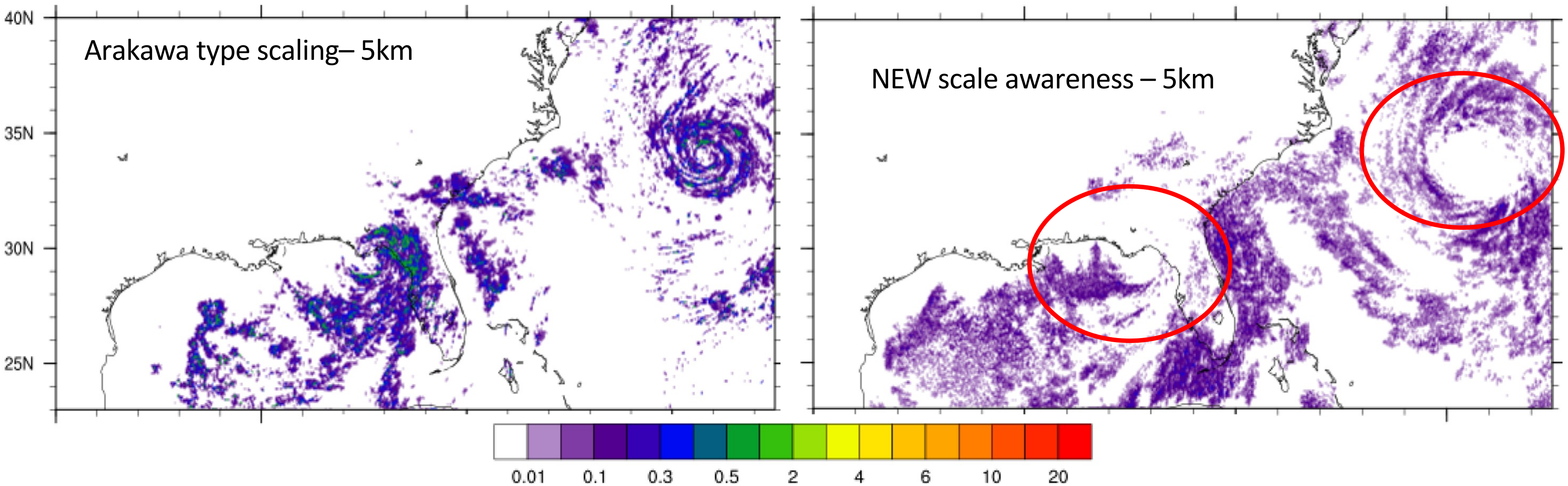
- Scaling approach method does not consider impacts on neighboring grid points
- Only should work when both explicit and parameterized physics are active,
- Most vulnerable for weakly forced environments (day time heating and/or tropics)

- New, physically more consistent scale aware approach was developed and implemented in MPAS, tested for hurricane simulations
    - Requires communication with neighboring grid points
    - Does not use any scaling
- MPAS was run using 12km, 7.5km, 5km, and 3km horizontal resolution out to 96 hours, Hurricanes Idalia and Franklin

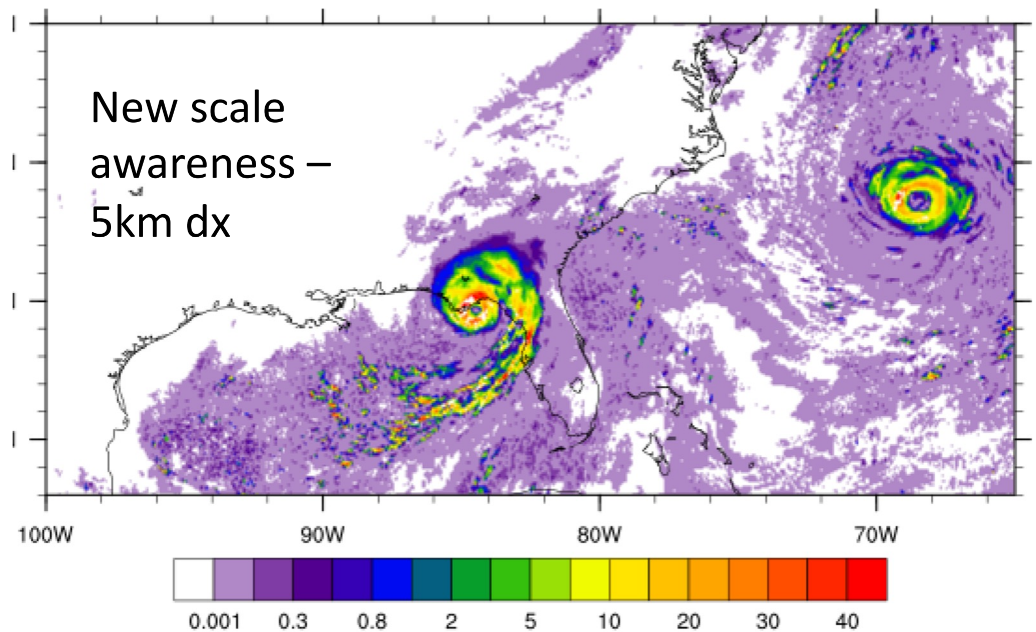
This work was done with Saulo Freitas (INPE/CPTEC) and Haiqin Li (NOAA/GSL and CU)

New Scale Aware Approach Idalia and Franklin experiments

Hourly parameterized precip at 5km dx, comparing old and new approaches



New approach smoothly turns itself over to explicit dynamics in areas where convection has best chances to be resolved by dynamics – rainbands, eyewalls,..



Currently receiving much attention at operational NWP centers: Aerosols

A Working Group for Numerical Experimentation (WGNE) was established to look at

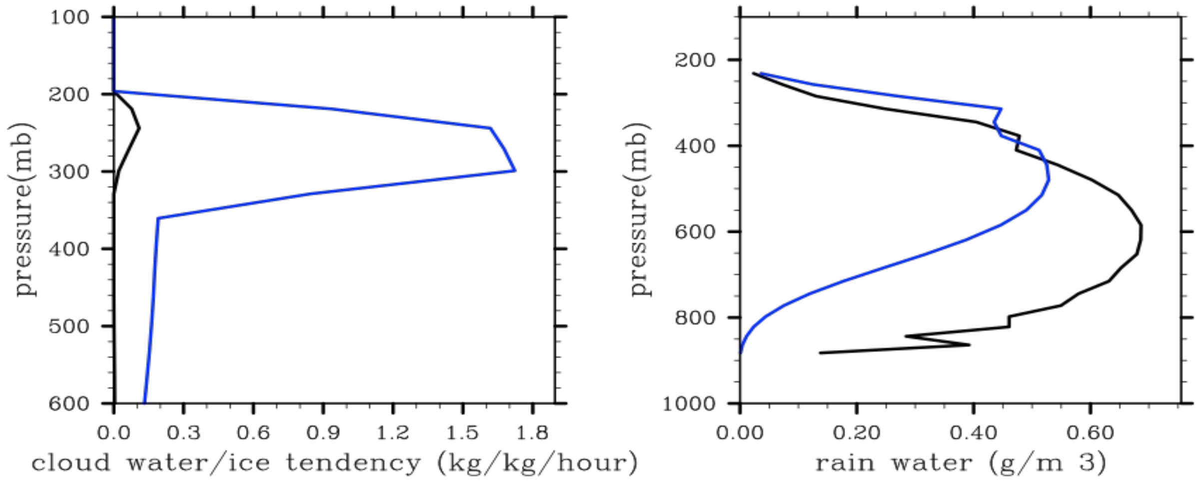
- Aerosol impacts on numerical weather prediction
- Interaction with radiation (direct and semi-direct effect),
- Interaction with clouds (indirect effect)
- Impact on data assimilation

Phase 2 was looking at the impacts of aerosols in more detail as well as their impact on sub-seasonal to seasonal predictions

Aerosol interactions in a convection parameterization: Two impacts included in GF and C3 parameterizations

Conversion of cloud water to rain water

Use CCN dependent conversion of cloud water to rain (Berry conversion, but others are easily possible)



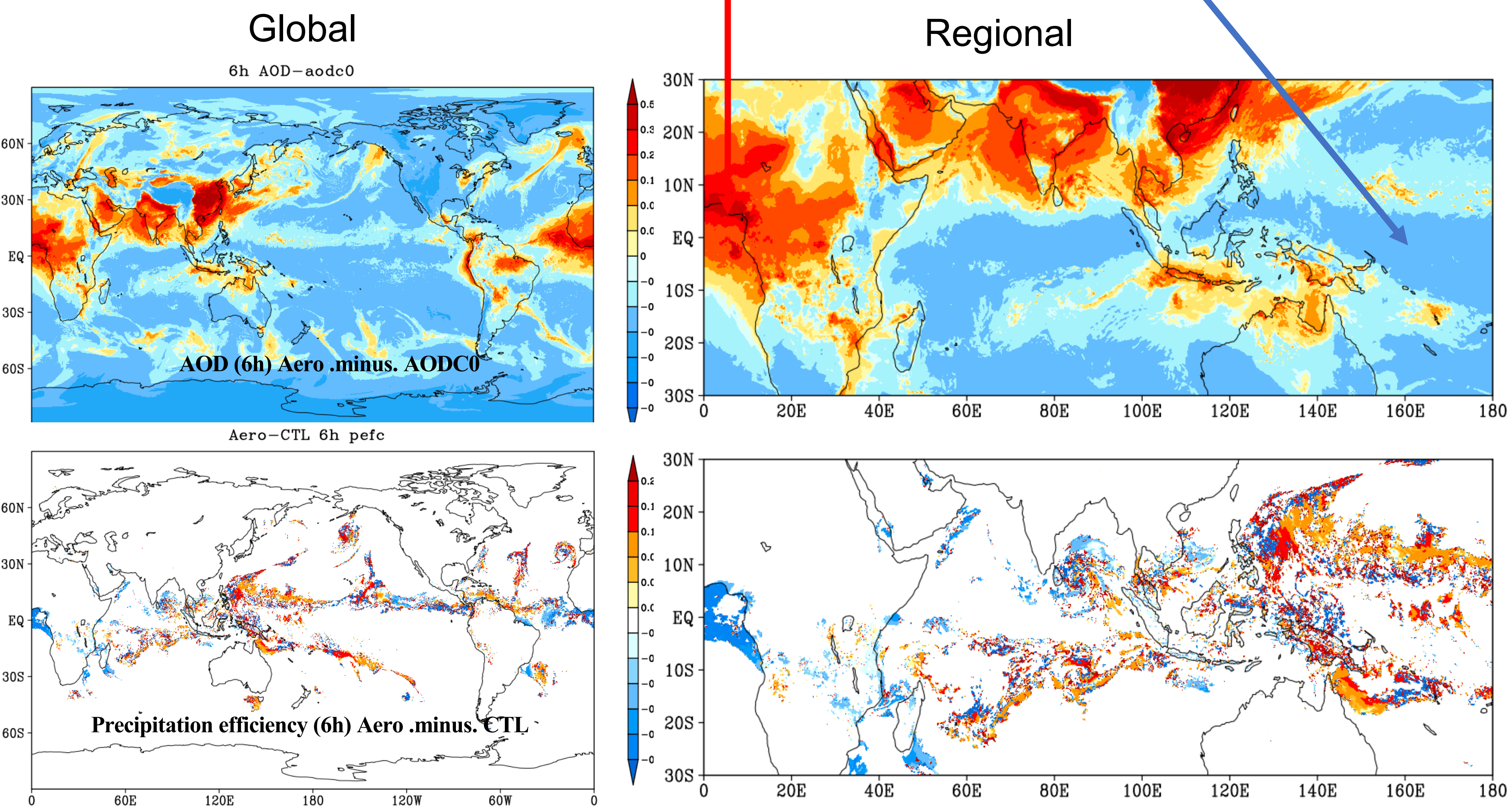
Precipitation efficiency

Introduces a proportionality between precipitation efficiency (PE) and total normalized condensate (I_1), and CCN

We use CCN as a measure of pollution, derived from AOD according to Rosenfeld et al. (2008) and Andreae et al. (2008)

UFS
UNIFIED FORECAST SYSTEM

One case in 3d UFS run: 6- hour forecast, comparing precipitation efficiencies where AOD is considered clean (AOD-AODC0 < 0.), and where it is polluted (AOD-AODC0 >>0.)



Thank you!   Questions?