A three-dimensional convective ensemble parameterization for a smooth transition to cloud resolving scales

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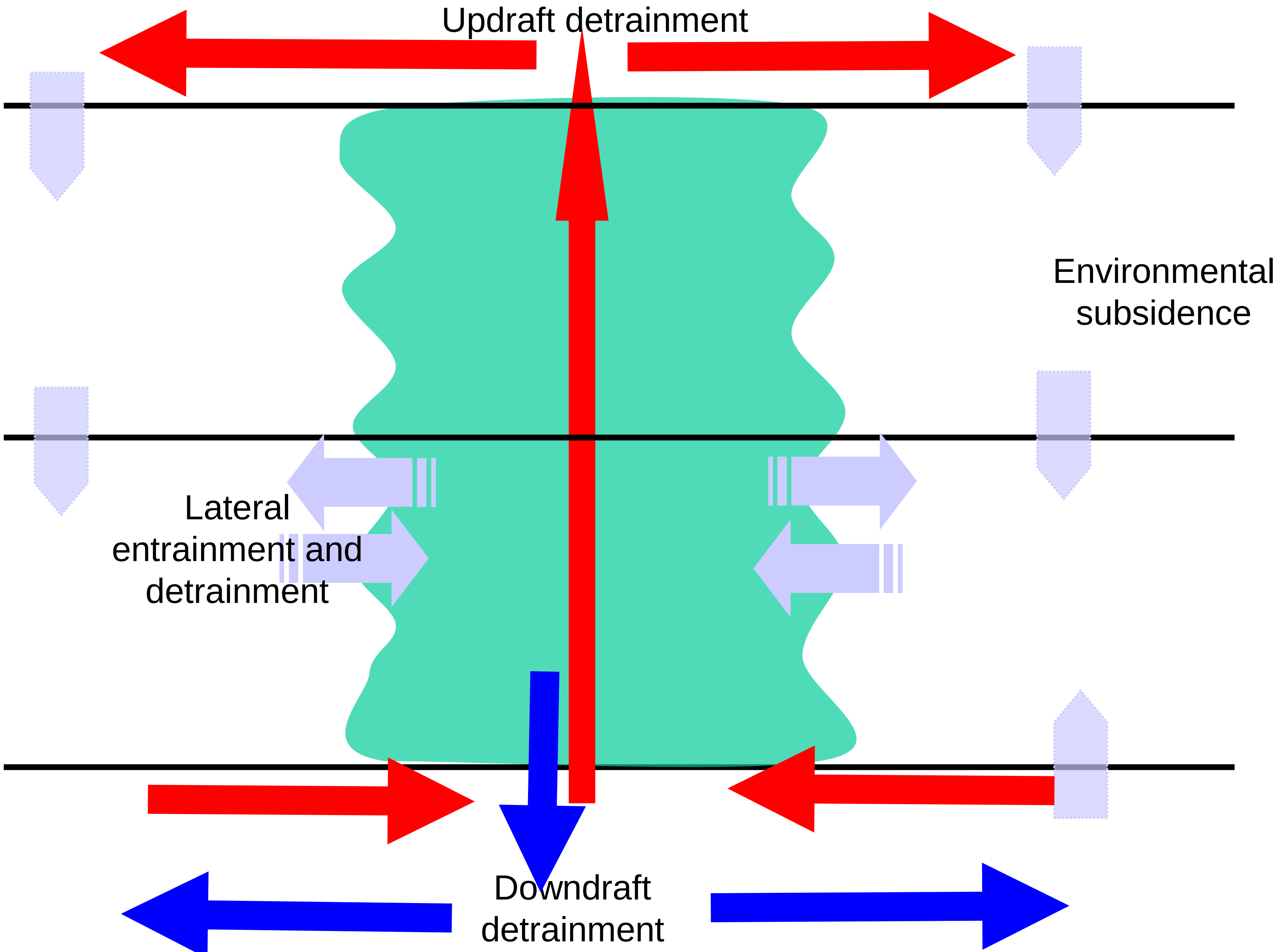
Structure of talk

1. Some aspects and improvements of capabilities of Grell-Devenyi (GD) convective parameterization
2. Spreading subsidence over neighboring grid points (the “G3” scheme)
3. Examples of some very different applications:
    - PDF’s for precipitation likelihood from one model run
    - Applying the scheme for EnKF data assimilation with many model runs

Typical "mass flux" scheme: One Grid Box



GD and G3 are ensemble schemes

Stochasticism in GD introduced through varying closure assumptions, feedback assumptions, or trigger functions used by various convective parameterizations

“Closures” within GD (assumptions that regulate the amount and location of parameterized convection

- Integrated vertical advection of moisture (Krishnamurthi)
- Low level vertical velocity (Brown or Frank and Cohen)
- Removal of instantaneous stability (like KF)
- Dependence on destabilization (old grell)
- Dependence on destabilization (as in SAS of GFS)

Triggers within GD and G3 used as an ensemble (important for location of convection):

How thin must the "cap" be before convection can poke through?

trigger ensemble for every closure

Possible perturbations of feedback assumptions

- Radius (size) of clouds, entrainment
- Detrainment from updraft (stability dependent)

Because of expense not used in basic scheme

- Wind shear dependent precipitation efficiency (dependence of downdraft strength on updraft strength)

Improvements of capabilities (GD to G3) : Change in “closures”

- Remove AS closure (SAS GFS)
- Add an ensemble to look at the min/max/average values of the other ensembles within the nearest neighbor grid points (could be nine or 25 grid points)
- Add a random number generator to arbitrarily pick some ensemble values out of the “pack”

<u>This constitutes the basic G3 scheme</u>

The not so basic G3 scheme

The G3 scheme has additional features that may be turned on or off:

- Horizontal and vertical smoothing of tendencies
- A three-dimensional application of the feedback to the model
- A stochastic approach to shallow convection
- Option for tracer transport and some aqueous phase chemistry and scavenging
- Direct coupling with atmospheric radiation (and photolysis) through outputting clw/ice mix ratios and cloud fraction

Why 3-d application?

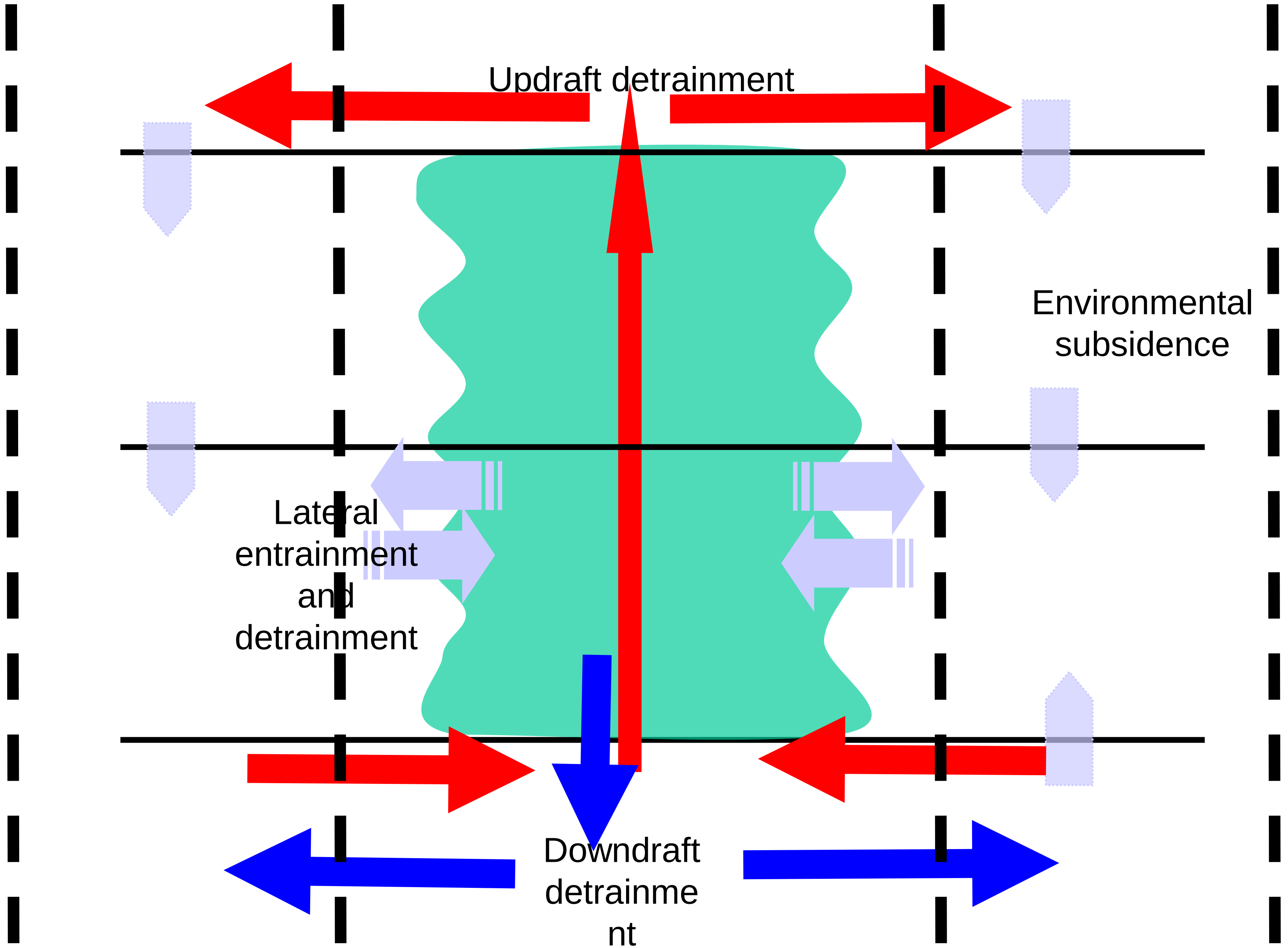
Gray scales: scale separation
Two main Problems

- Model may try to simulate the already parameterized process explicitly
- Parameterization may try to parameterize a process that the model may be able and **was supposed to simulate** explicitly
  - Subsidence dries too much! Flow will be too viscous for explicit convection!

Why 3-d application?

To allow for a smooth transition on “gray” scales, where more and more of the convection is resolved

G3: nine or more grid boxes

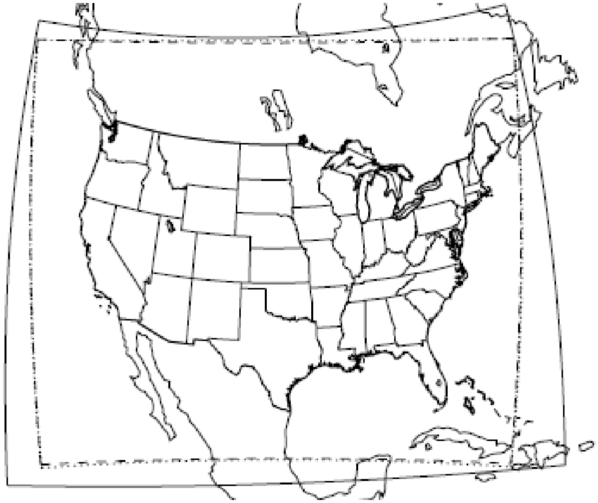


The number of grid points that is affected

- Inner most box only experiences lateral entrainment/detrainment
- Currently only neighboring grid points (9), in near future we will also test the neighbors of the neighbors (25 gridpoints)
- Also possible in near future: linear (smooth) transition of what part is spread in what box
- Mass conservation can easily be guaranteed

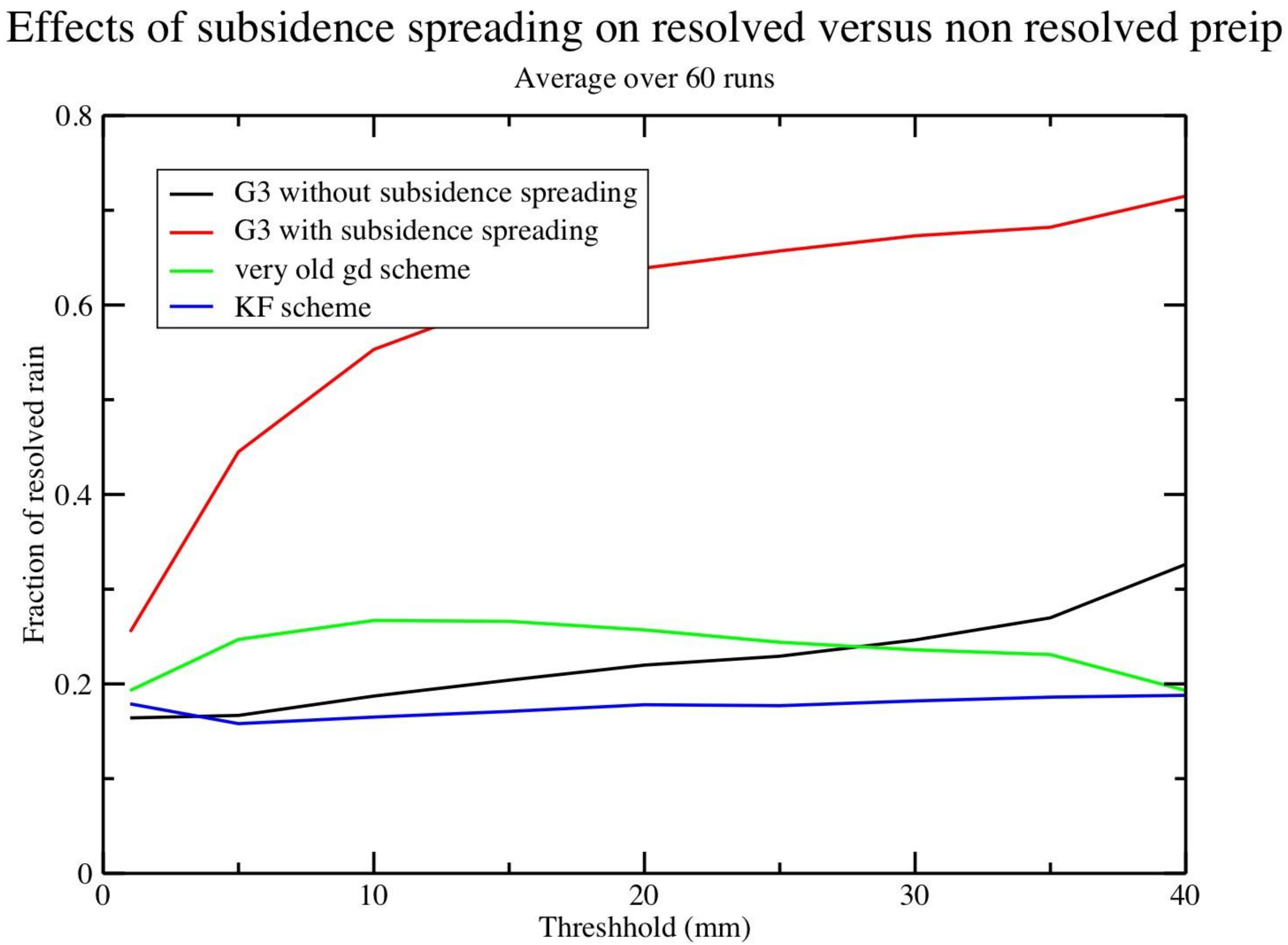
First, use “core comparison” test bed data set and test with ARW WRF

- Data set (1-month worth of 60 runs) was used to compute statistics and compare ARW and NMM cores within WRF
- CONUS grid with 12km resolution
- 24hr accumulated precipitation data based on rain gauge and radar analysis



Will be re-done at dx=3 km over shorter period

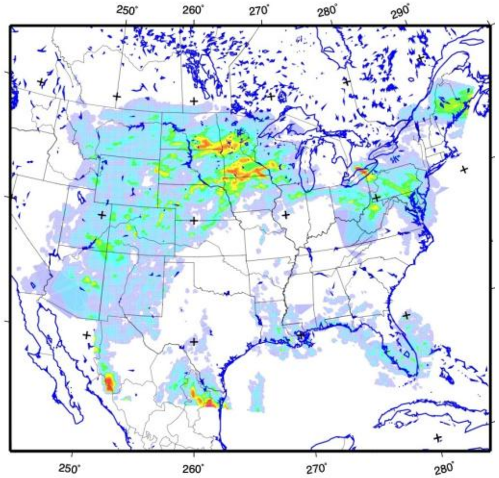
Fraction of modeled precipitation that is resolved over all runs!



As was intended: precipitation shifts from convective to explicit!

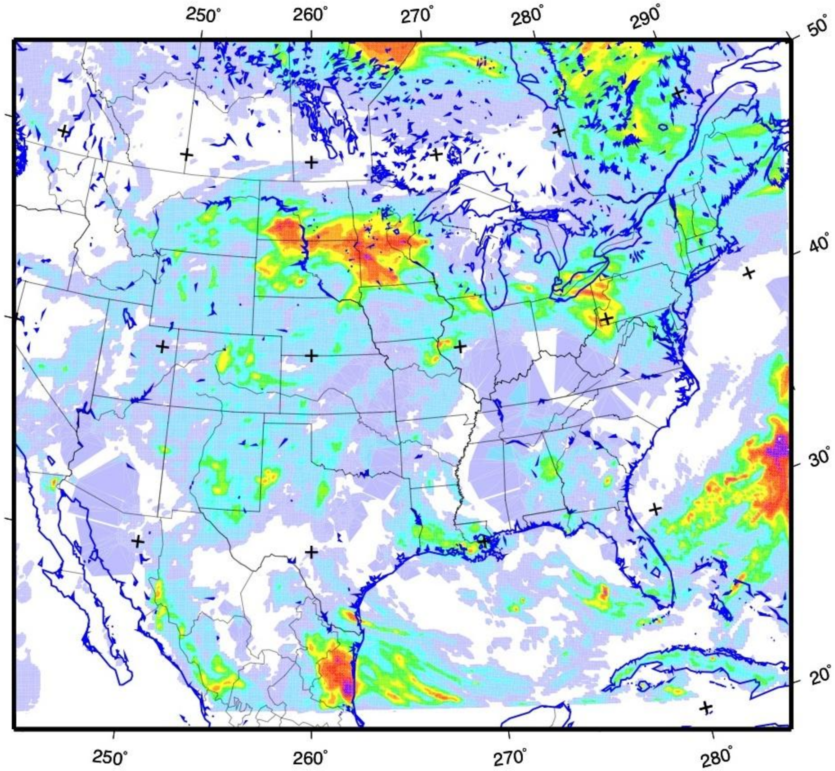
24hr accumulation at 07-26-00

Overall pattern not changed too much, less coverage, heavier precip at large thresholds

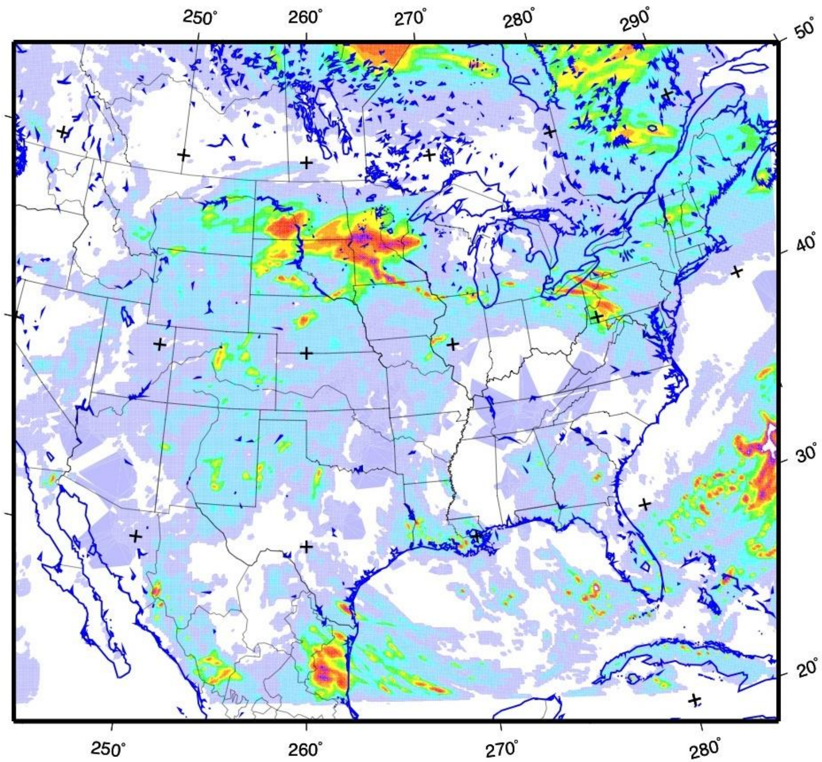


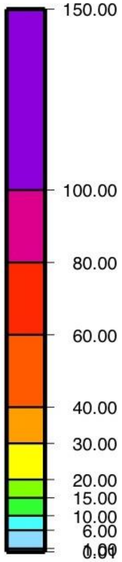
OBS

G3, no spreading

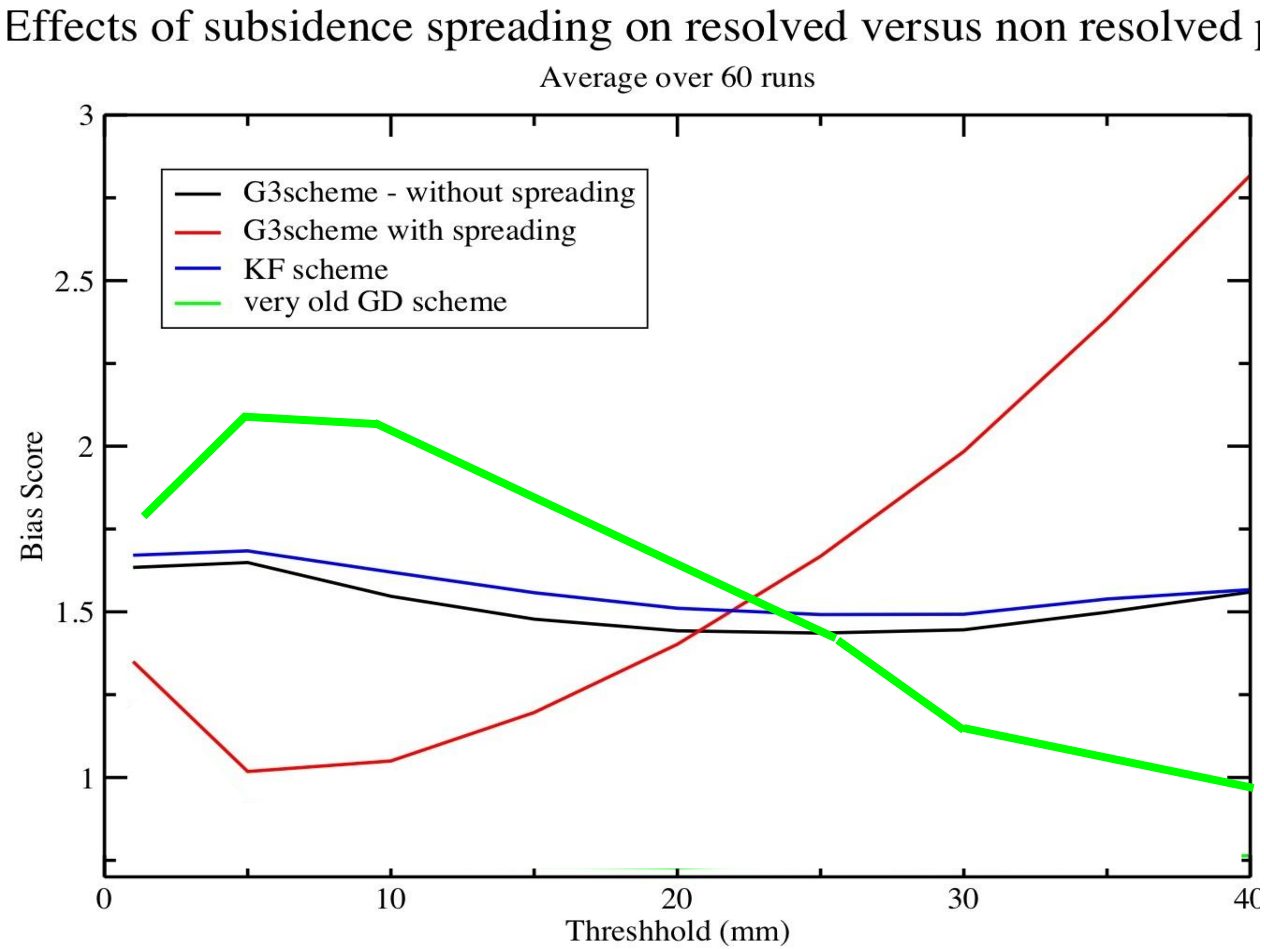


G3, with spreading





Bias scores over all runs!



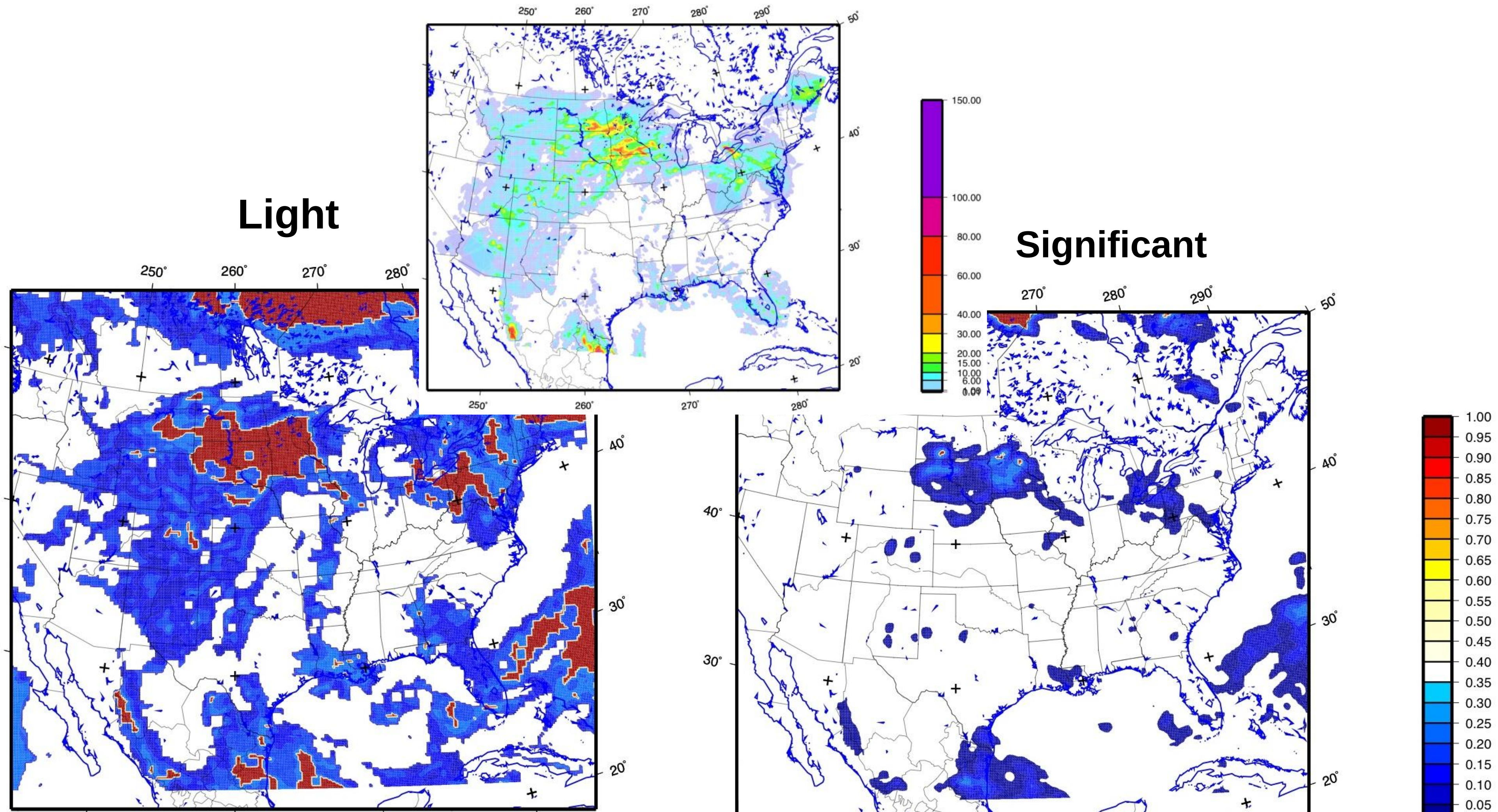
ETS scores were almost identical, with spreading slightly but insignificantly higher for low thresholds

Sone examples of PDF and weight applications

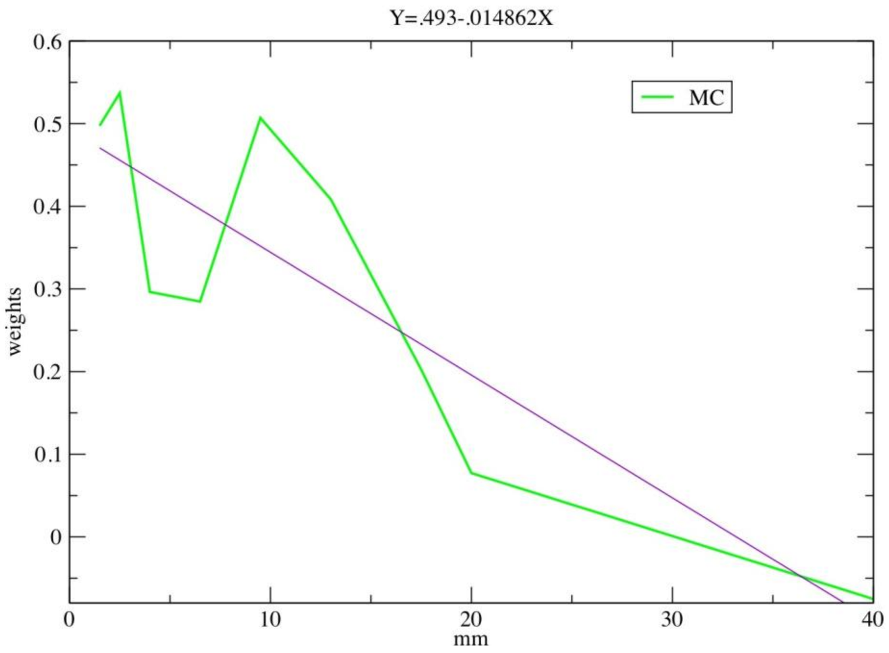
- PDF's are calculated on output (all ensemble precip rates)
- 3 examples of weights: Constant everywhere (w1), threshold dependent(w2), and threshold dependent only applied to output (w3, not during run)

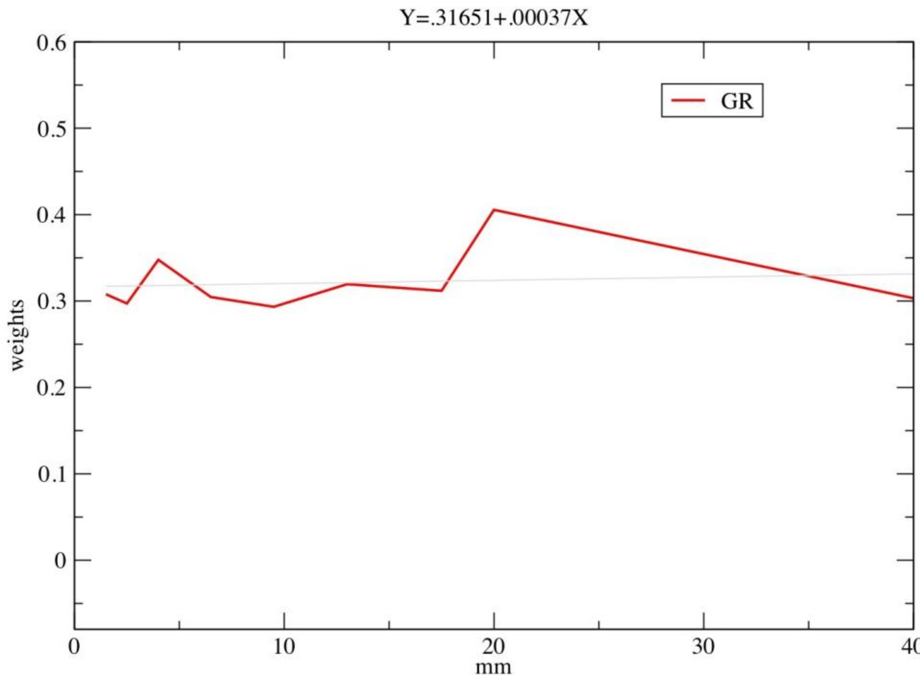
Probability density functions

Forecast probabilities for light (>1mm) and significant (>25mm) precipitation, 26-July 2005



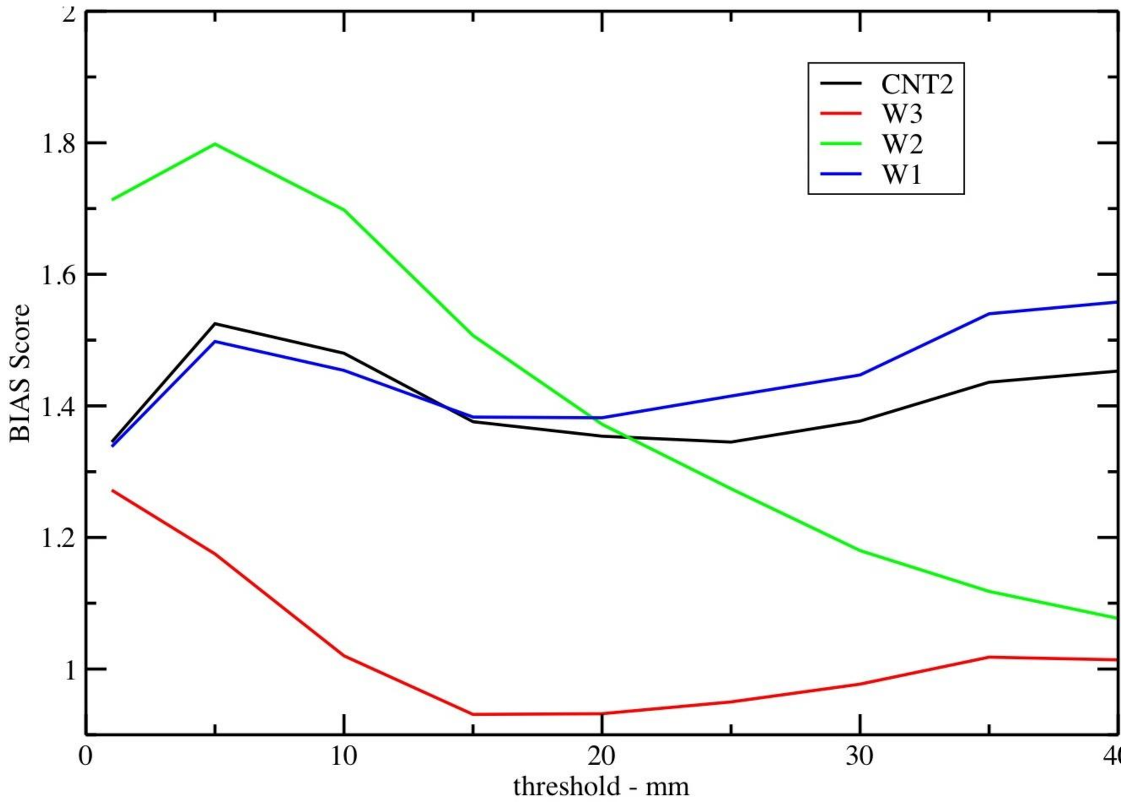
Threshold dependent weight calculation for 2 closures





30 runs – WRF (first two weeks)

Different Weight calculations and their verification scores



Bias Scores (last two weeks)

Also possible: use for EnKF data assimilation

Instead of using all perturbations within one model run, use only one or a few within one run (many runs to increase ensemble spread for EnKF)

Application within GFS

E. Grell and J-W Bao

ENSEMBLE MEMBERS	CLOSURE TYPE
1-8	Change of stability through effects other than convection (eg. Grell,1993)
9-16	Vertical motion dependent (eg. Brown, 1979, Frank and Cohen, 1987)
17-24	Integrated vertical advection of moisture (eg. Krishnamurti, 1983)
25-32	Instability removal within a specified time period (eg. Kain and Fritsch, 1992)
33-40	Change of stability as in members 1-8, but using climatological cloud work functions as in the GFS-SAS (Arakawa and Schubert, 1974)
41-48	Like members 1-8, but input T,q tendencies from PBL forcing only
49-56	Like members 33-40, but input T,q tendencies from PBL forcing only
57-64	Standard application of Grell-Devenyi scheme, uses mean mass flux from 16 members x 3 caps x 3 downdraft parameters at each time step

64 separate model runs !

Parameter Value Permutations

- Maximum thickness of capping inversion
- Detrainment rate in updraft (applied to unstable layers only)
- Vertical extent of downdraft detrainment

Implementation and Testing of the Method in NCEP's GFS Model

Model Framework

The NOAA/ESRL experimental ensemble Kalman Filter (EnKF) data assimilation system, based on the GFS model and developed by Whitaker et al. (2008).

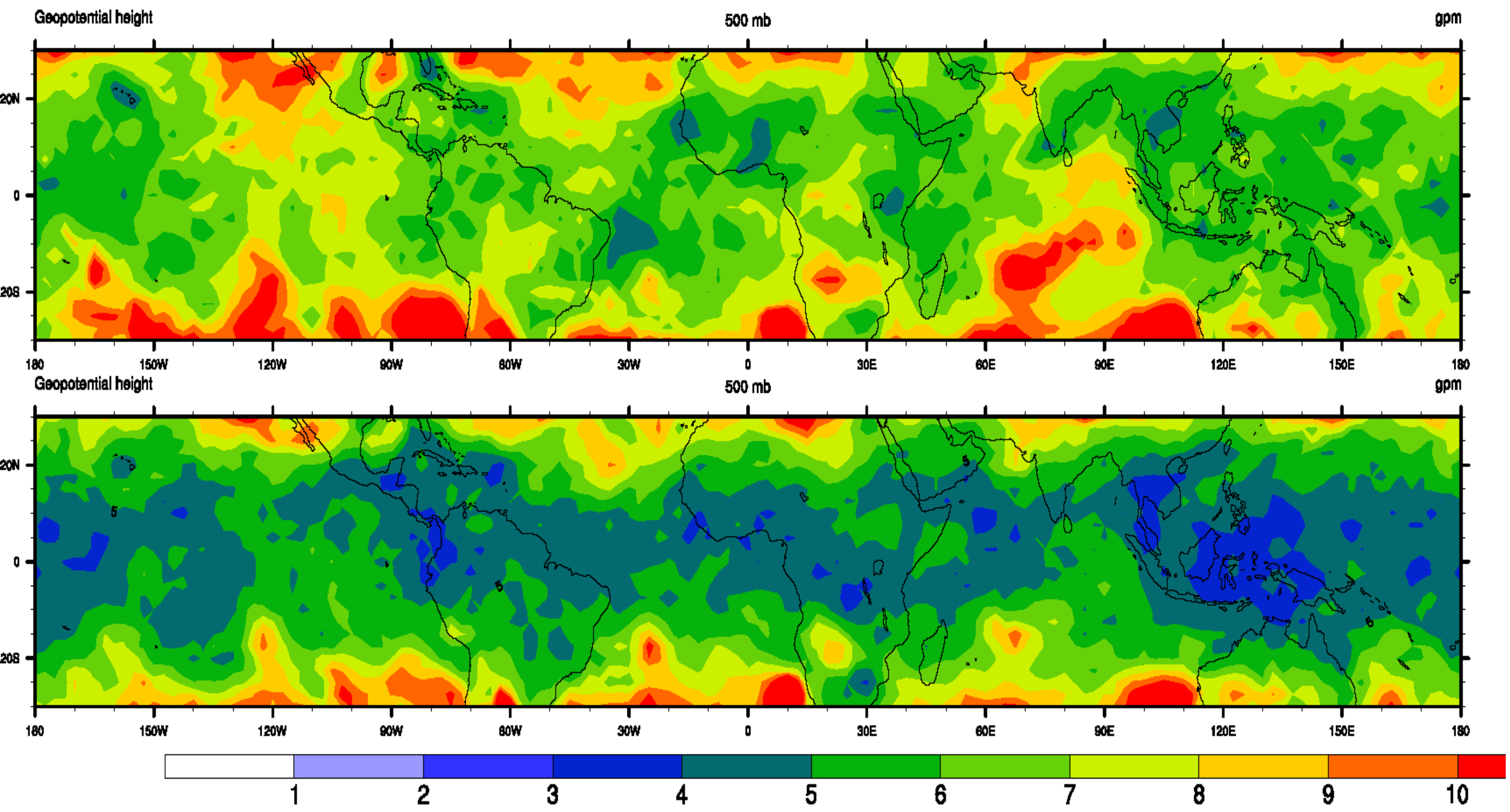
Experiment Design

The data assimilation system is run at the resolution of T190 for the period of one month (Dec 2007). A 64-member ensemble of 9-h forecasts are updated at 6 h with observations.

An Ensemble Kalman Filter (EnKF) (Whitaker and Hamill, 2002) is applied to generate an ensemble of analyses every 6h.

Some Results

Ensemble spread of the 500mb geopotential height for the ensemble generated by the stochastic GD scheme with EnKF (top) and by the EnKF only (bottom).

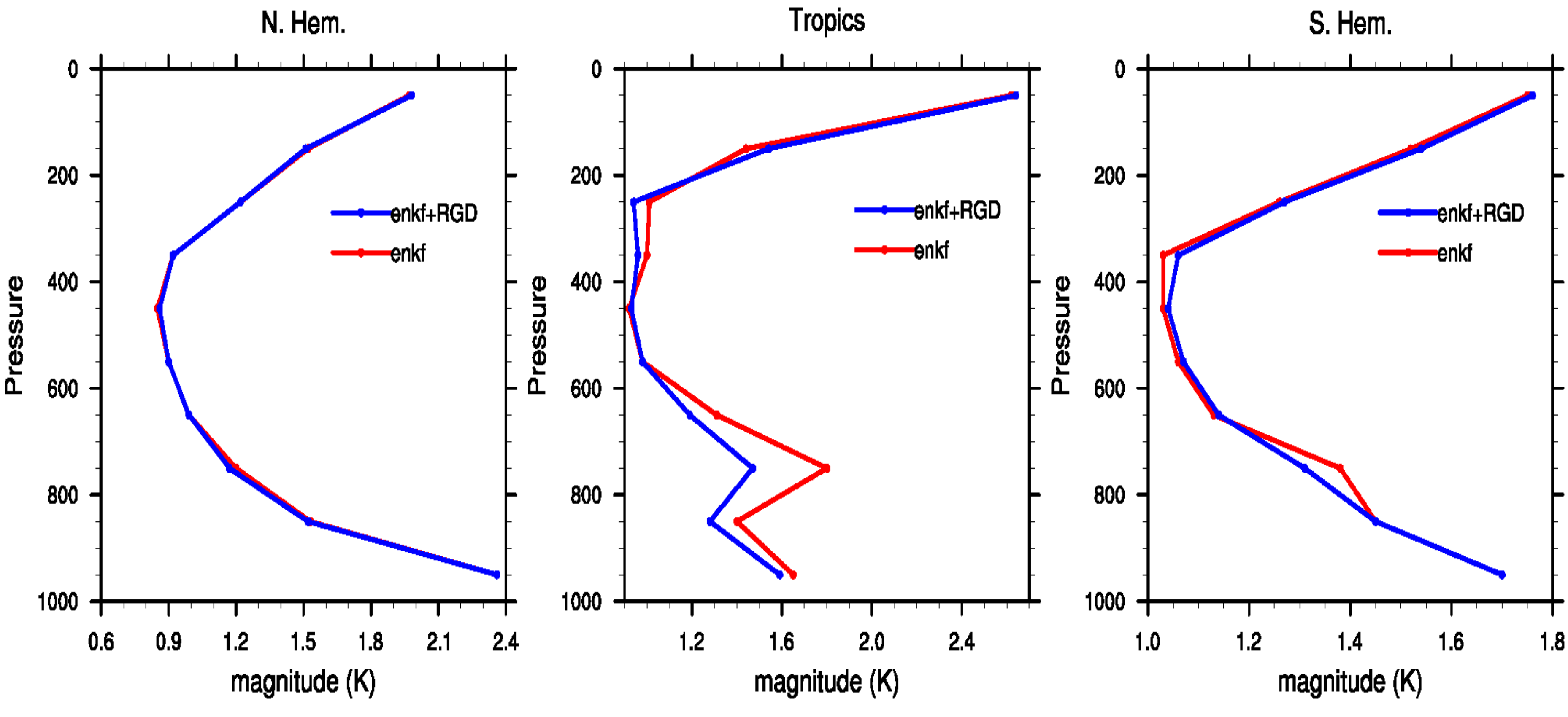


EnKF with GD

Regular EnKF

RMS error for GFS forecasts when using GD

6 day period (14-20 Dec 2007) with 6h cycling. Red lines are for the control ensemble generation; blue lines are for the ensemble generation using the stochastic convection scheme.



Summary and conclusions:

- G3 is improved compared to GD, ensembles are changed. Bias- and EQS-scores are improved.
  - Will run at NCEP in Rapid Refresh (but without spreading)
  - Can be used tocalculate PDF's, or use ensembles separate for EnKF data assimilation
- A 3-d version of the ensemble scheme is developed that spreads the subsidence effects over more than one grid cell
  - When spreading is turned on, the fraction of resolved precipitation increases drastically, especially for large thresholds
- Future and ongoing work:
  - Extend the range of spreading
  - High resolution (dx=3km or 4km) case of mesoscale convective systems (High Resolution Rapid Refresh, HRRR)
- Try the alternative approach of letting the resolved dynamics do all the subsidence

Thank you!