Radar Data Assimilation in the Canadian High Resolution Ensemble Kalman Filter System

Environment Canada   Environnement Canada

McGill

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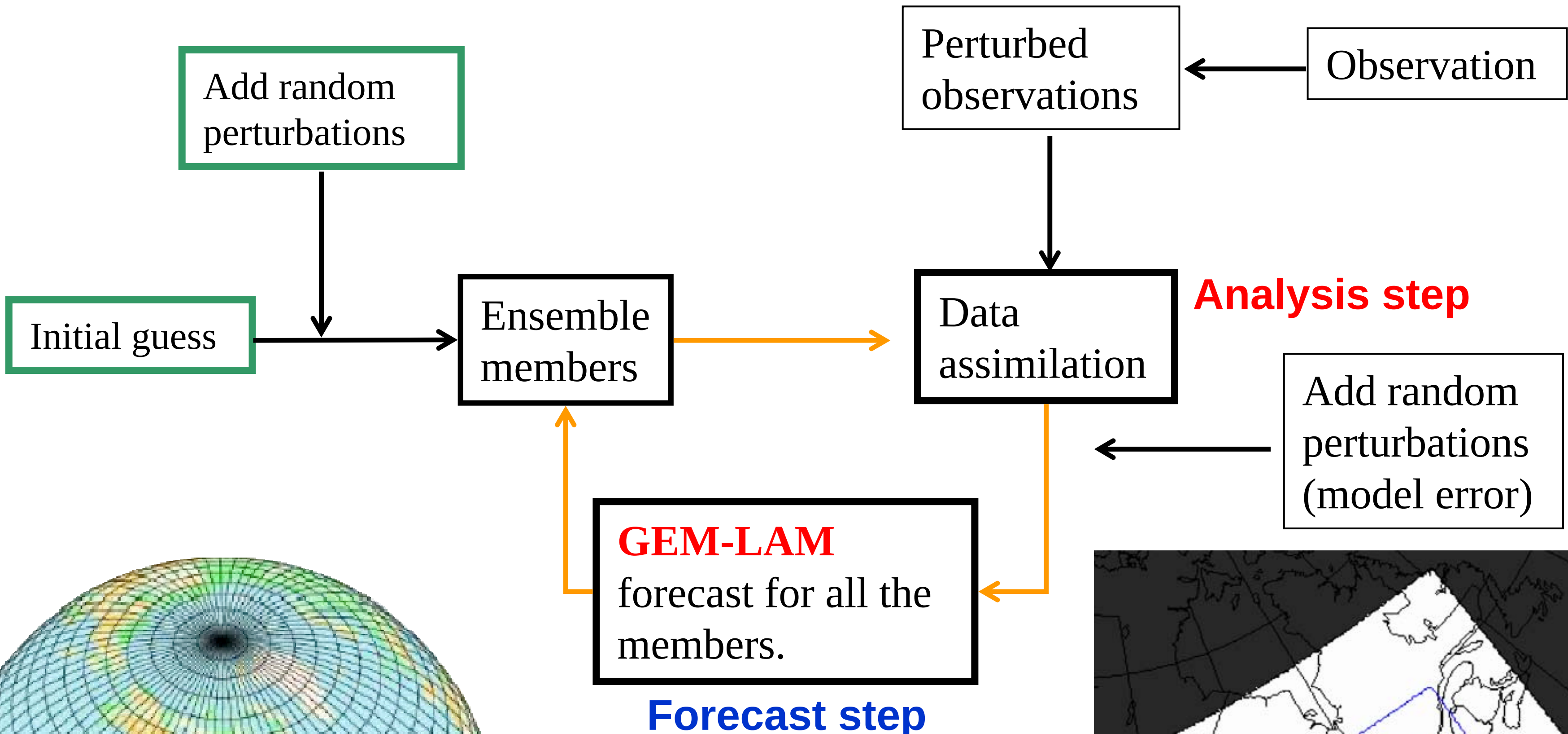
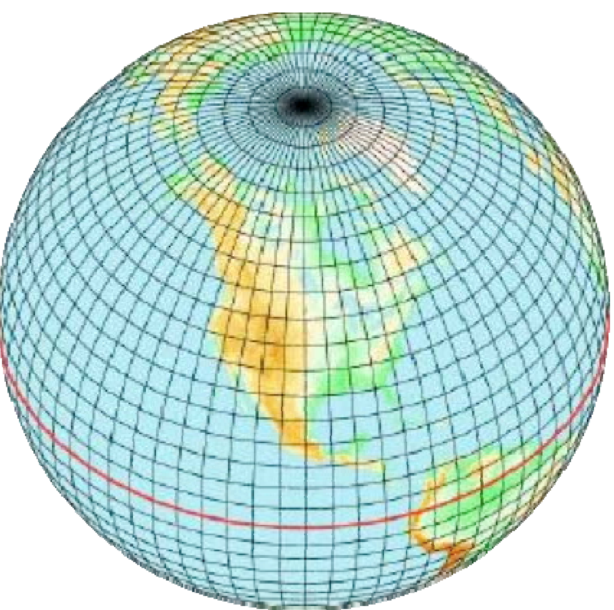
Outline

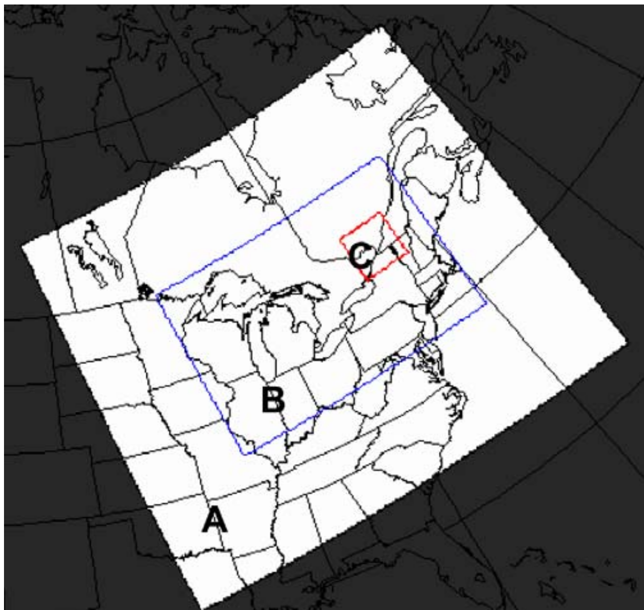
- **Introduction of the Canadian High Resolution Ensemble Kalman Filter (HREnKF) system**
- **Strategy of assimilating radar data and experiments designed**
- **Impact of assimilating radar data and verifications (two summer cases)**
- **Summary and future works**

High Resolution Ensemble Kalman Filter System
(HREnKF)





Global system (1998)
→ limited area



A: LAM15
B: LAM2p5
C: LAM1 300x300 (MTL region)

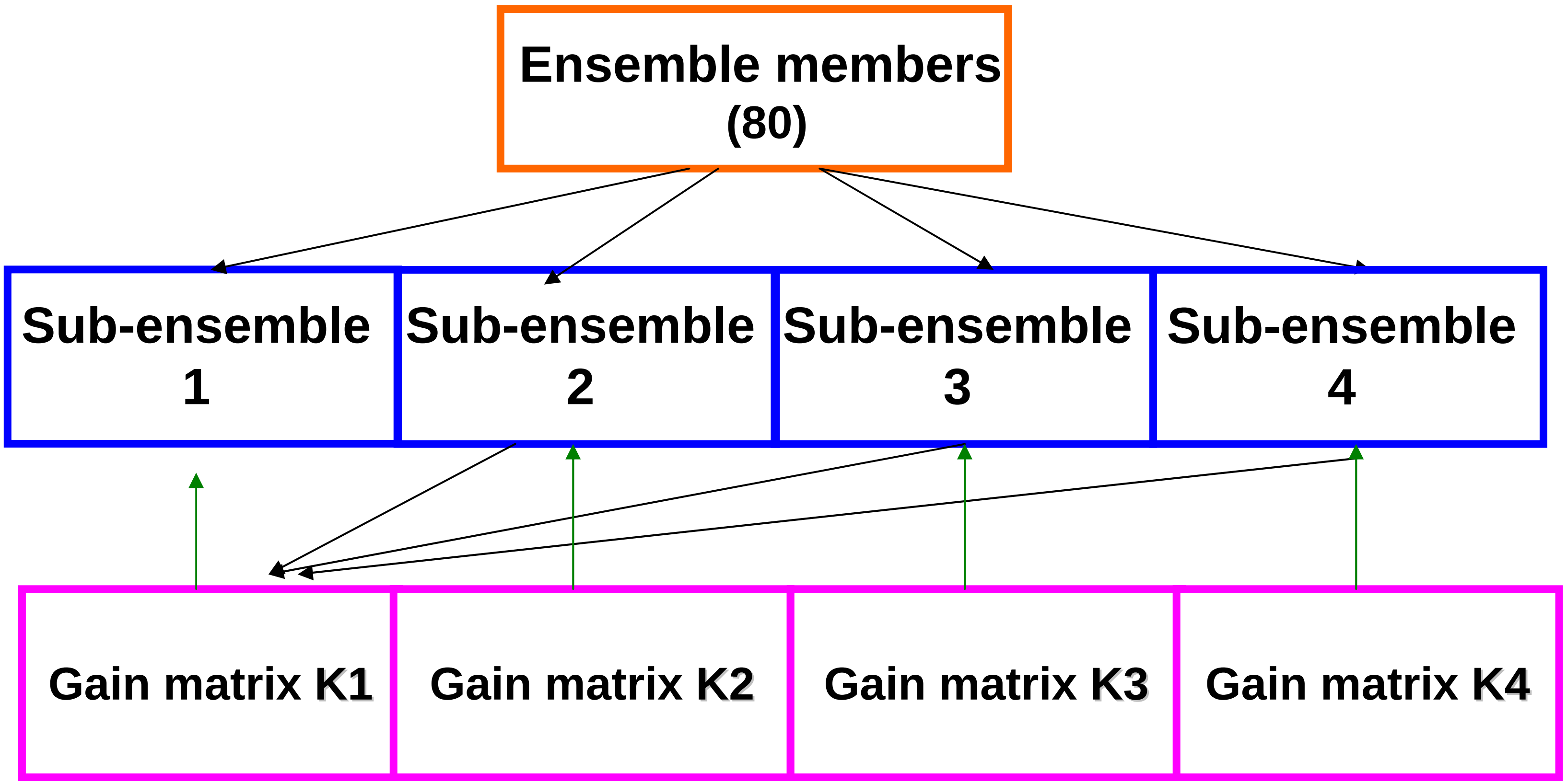
Features of the system

Sequential process to assimilate observations

Localization strategy

Partitioning the ensemble --- no inflation factor

(to deal with the underestimation of the error structure)

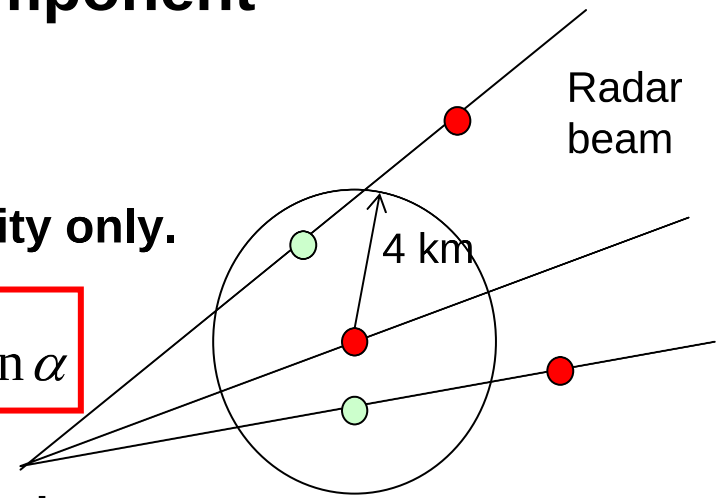


Assimilation of McGill Radar data in HREnKF

Assimilation of radial wind component

- **Doppler winds are assimilated.**
- **Reflectivity is used for terminal velocity only.**

$$V_r = (U \sin\varphi + V \cos\varphi)\cos\alpha + (W + V_T)\sin\alpha$$



- **Data thinning is performed in 3 dimensions.**

Depends on different cases

Radial wind (VR)	**Total number of observations**	**Percentage**
All data	10000~15000	100%
4 km Data thinning	3000~5000	~30%

1/3 of the observations have been assimilated in each case

Some features of the current set up:

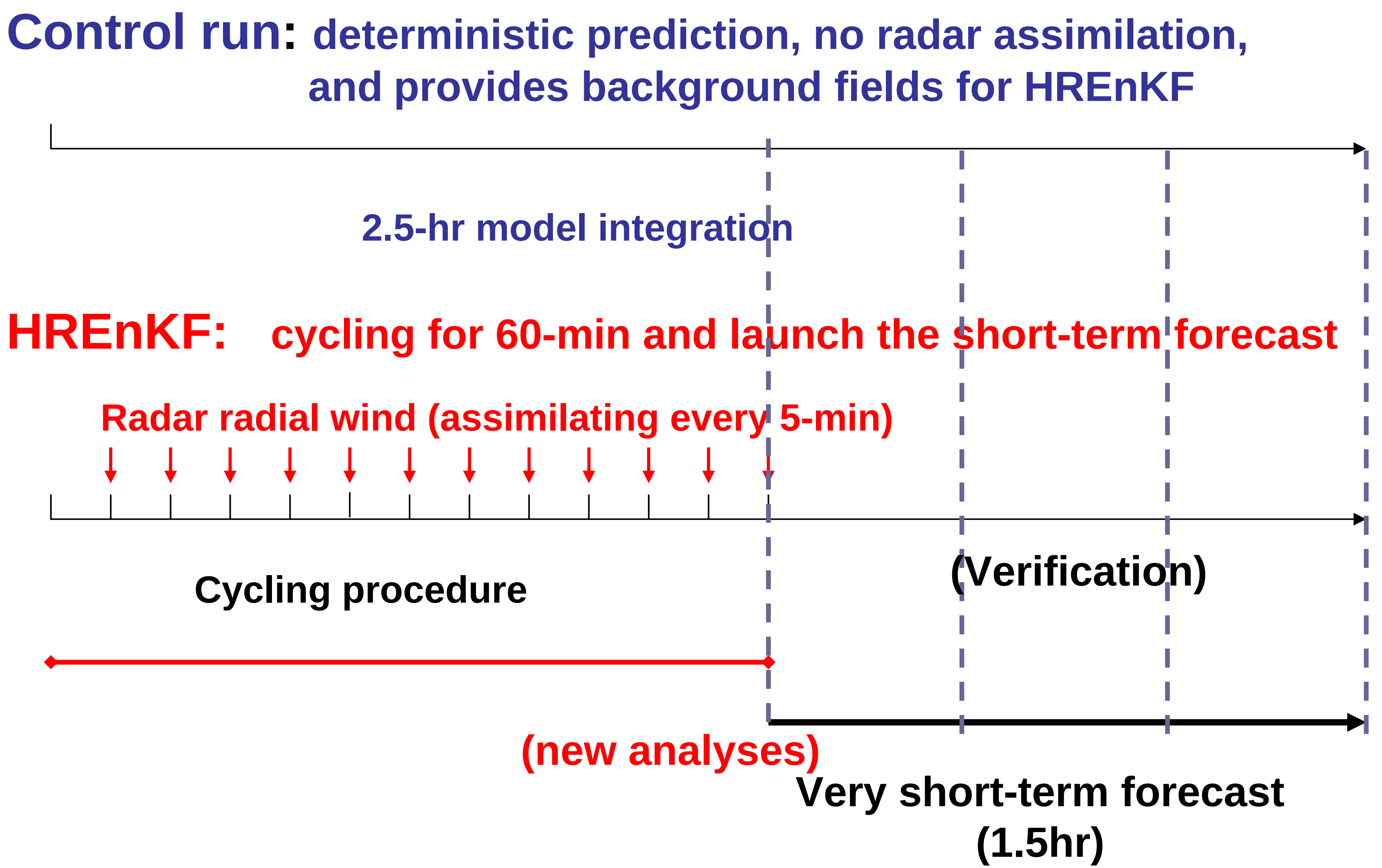
For the HREnKF

- Control variables: U, V, W, T, HU (specific humidity)
- Observations are perturbed according to its variance (no correlation).
- <u>Simplified</u> random perturbations to consider the model errors
- Localization: 10-km in horizontal; 2 * ln(Pressure levels) in vertical

For the GEM_LAM model at 1-km resolution

- Cycling hydrometeor variables
- Microphysical scheme: double moment scheme (Milbrandt and Yau, 2005)
- Fixed lateral boundary conditions for all ensemble members

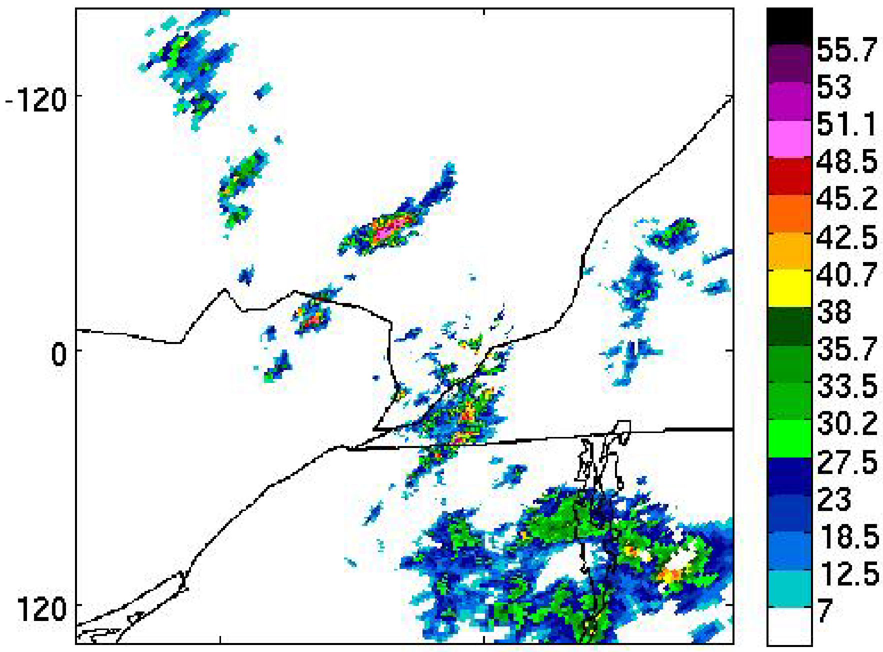
Standard procedure of the cycling procedure for all cases we examine



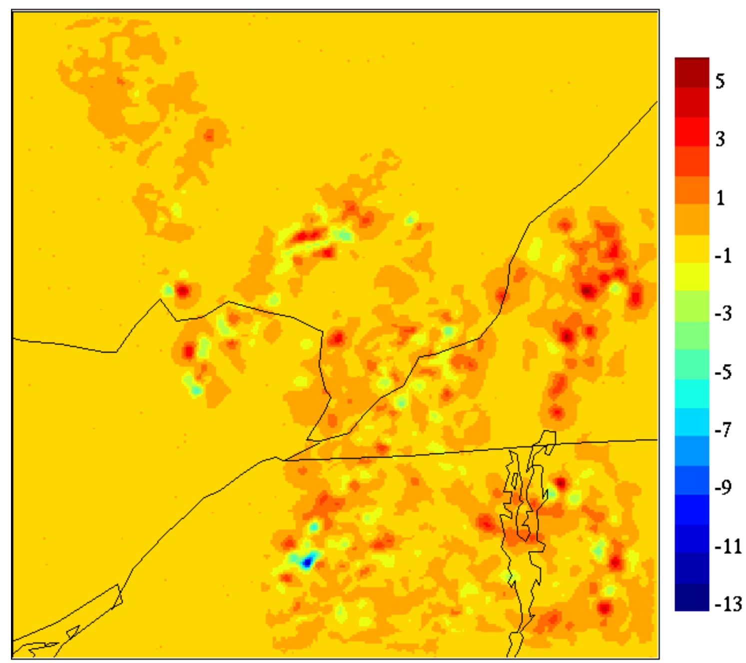
Impact of assimilating radial wind component

Is it able to propagate information to other control variables?

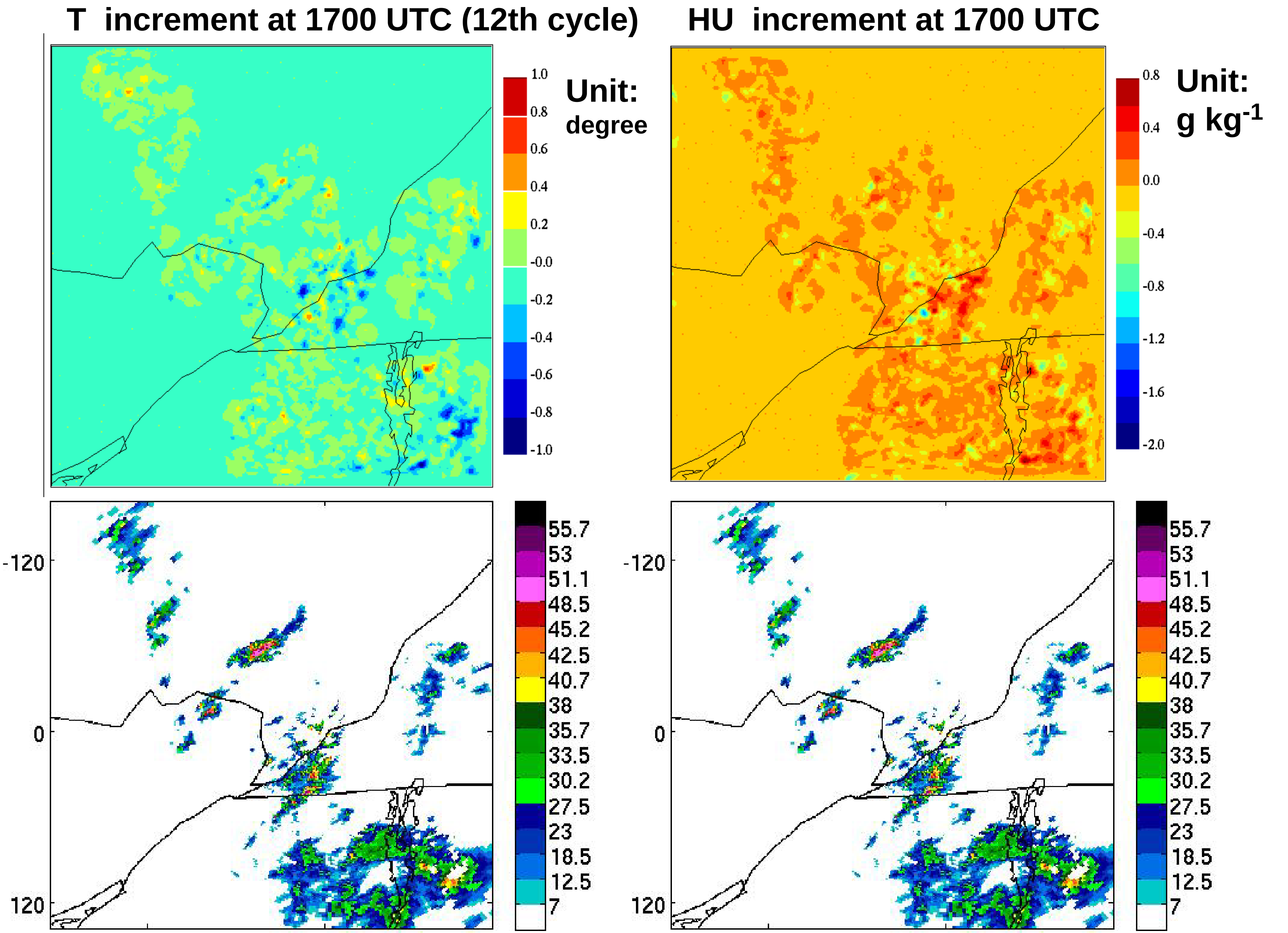
$$V_r = (U\sin\varphi + V\cos\varphi)\cos\alpha + (W + V_T)\sin\alpha$$



U increment at 1700 UTC (1-hr)



Unit: knots



T increment at 1700 UTC (12th cycle)
HU increment at 1700 UTC
Unit: degree
1.0
0.8
0.6
0.4
0.2
-0.0
-0.2
-0.4
-0.6
-0.8
-1.0
Unit: g kg-1
0.8
0.4
0.0
-0.4
-0.8
-1.2
-1.6
-2.0
-120
0
120
55.7
53
51.1
48.5
45.2
42.5
40.7
38
35.7
33.5
30.2
27.5
23
18.5
12.5
7

How do we examine the impact of assimilation radar observations ?

For real cases study, unfortunately, the truth is unknown. However, Radar observations provides part of the truth to examine:

- **Simulted radial wind v.s. observed radial wind :**

Bias and RMSE (Root Mean Square Error) of radial component of the wind in each elevation angel (all observations, no data thinning)

- **Precipitation**

Level 1: Qualitatively: (subjective examination)

Are we able to trigger the convections? (locations, intensities)
Is the system able to last as long as radar observed?
(locations, intensities, and patterns)

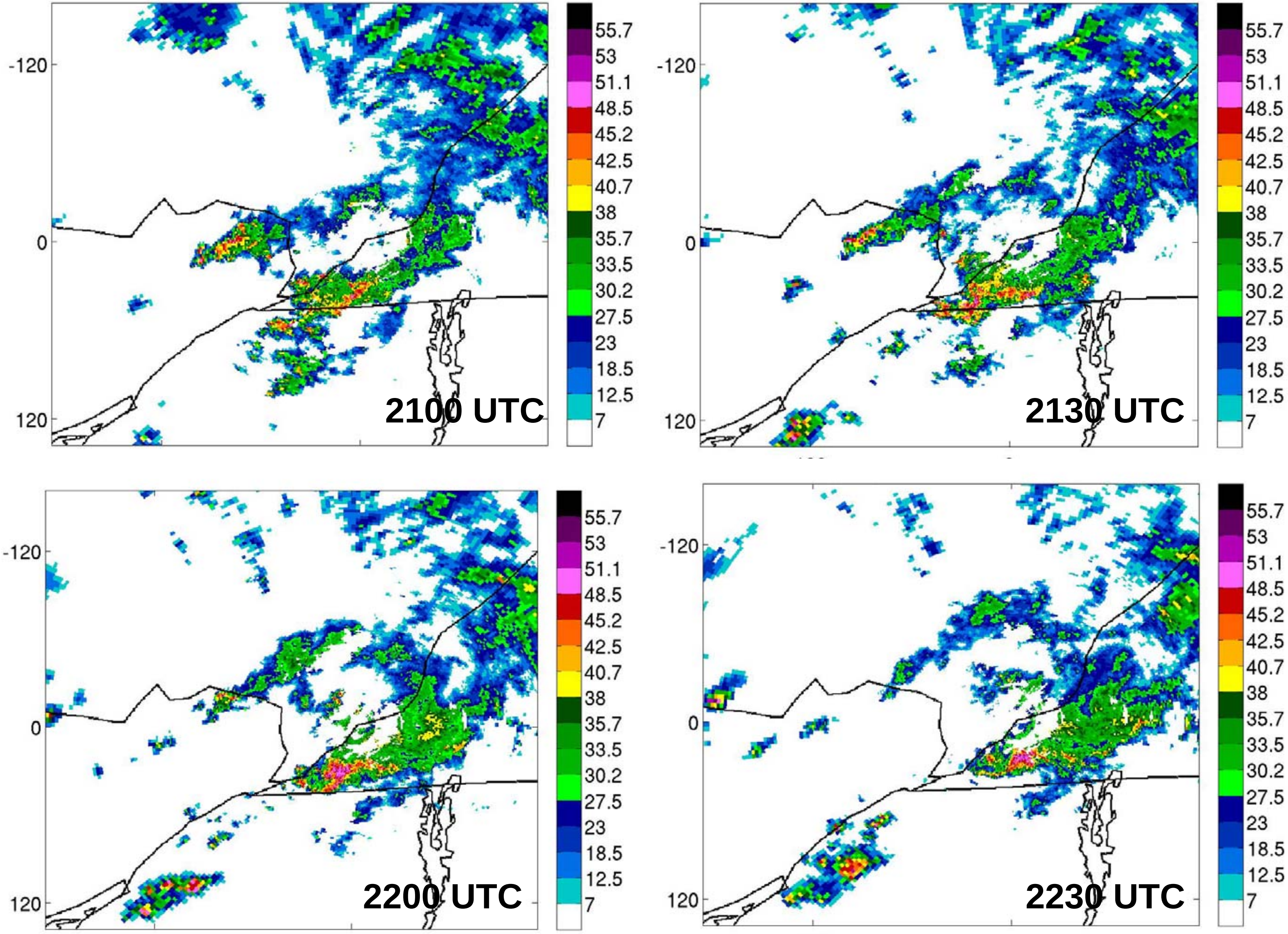
Level 2: Quantitatively : (Objective examination)

Traditional scores are not good to examine the precipitation at cloud-resolving scale.

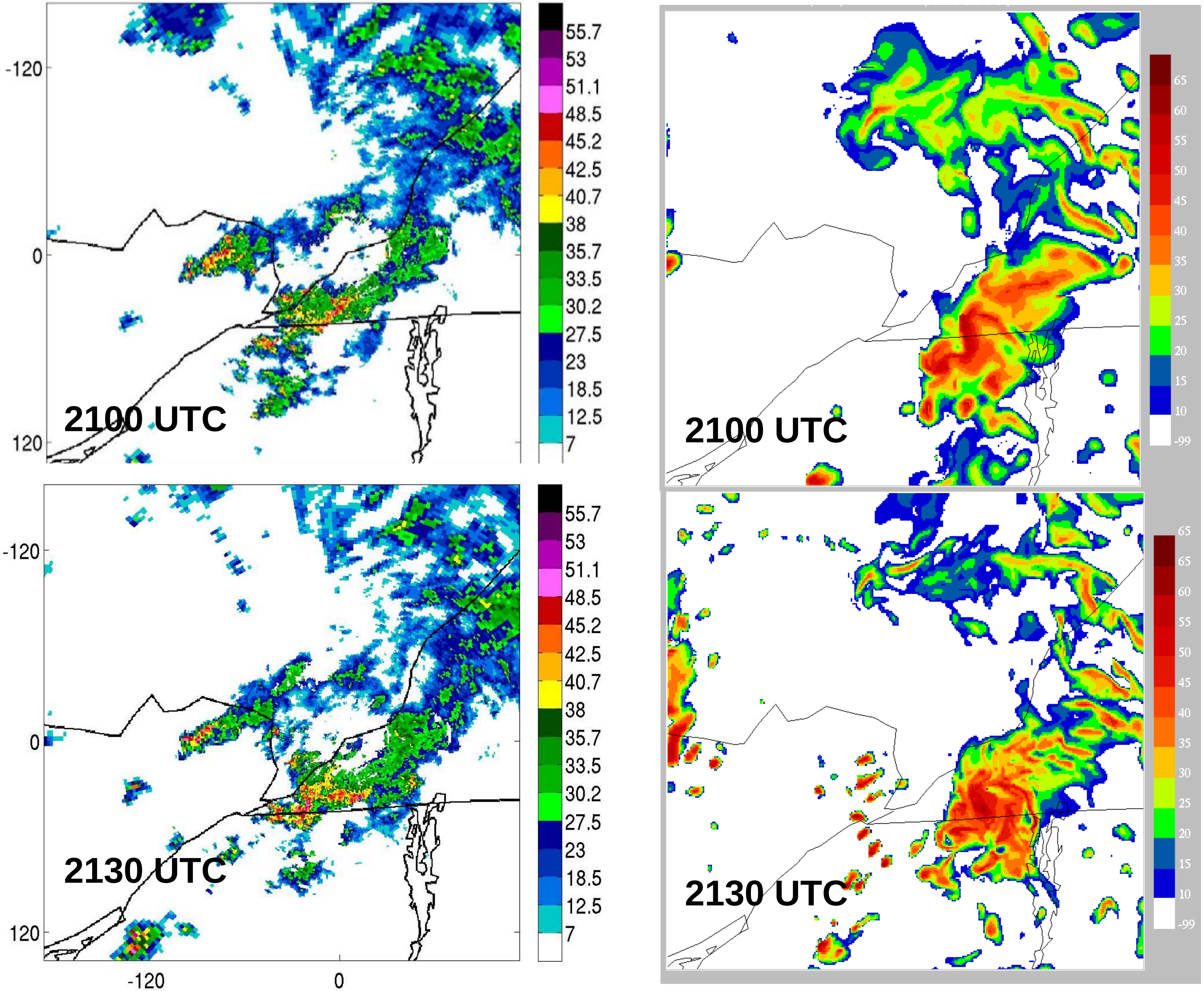
Summer cases	Features
June 12, 2011	Very localized convection happened over downtown Montreal area, and heavy rain last for couple hours.
June 23, 2011	Background field (precipitations) from deterministic prediction is not far from radar observation. In addition, there is phase errors for the convection in south-west.
July 21, 2010	Multiple cells and convections occurred over the analysis domain. Different stages of convections exist when the HREnKF started assimilating radar observaitons. In addition, very poor background field (precipitation) from deterministic forecast.
June 29, 2011	Squall line system passed by southern Quebec region. McGill radar observed very strong reflectivity for 3-hr.

Case study #1: June 23 2011

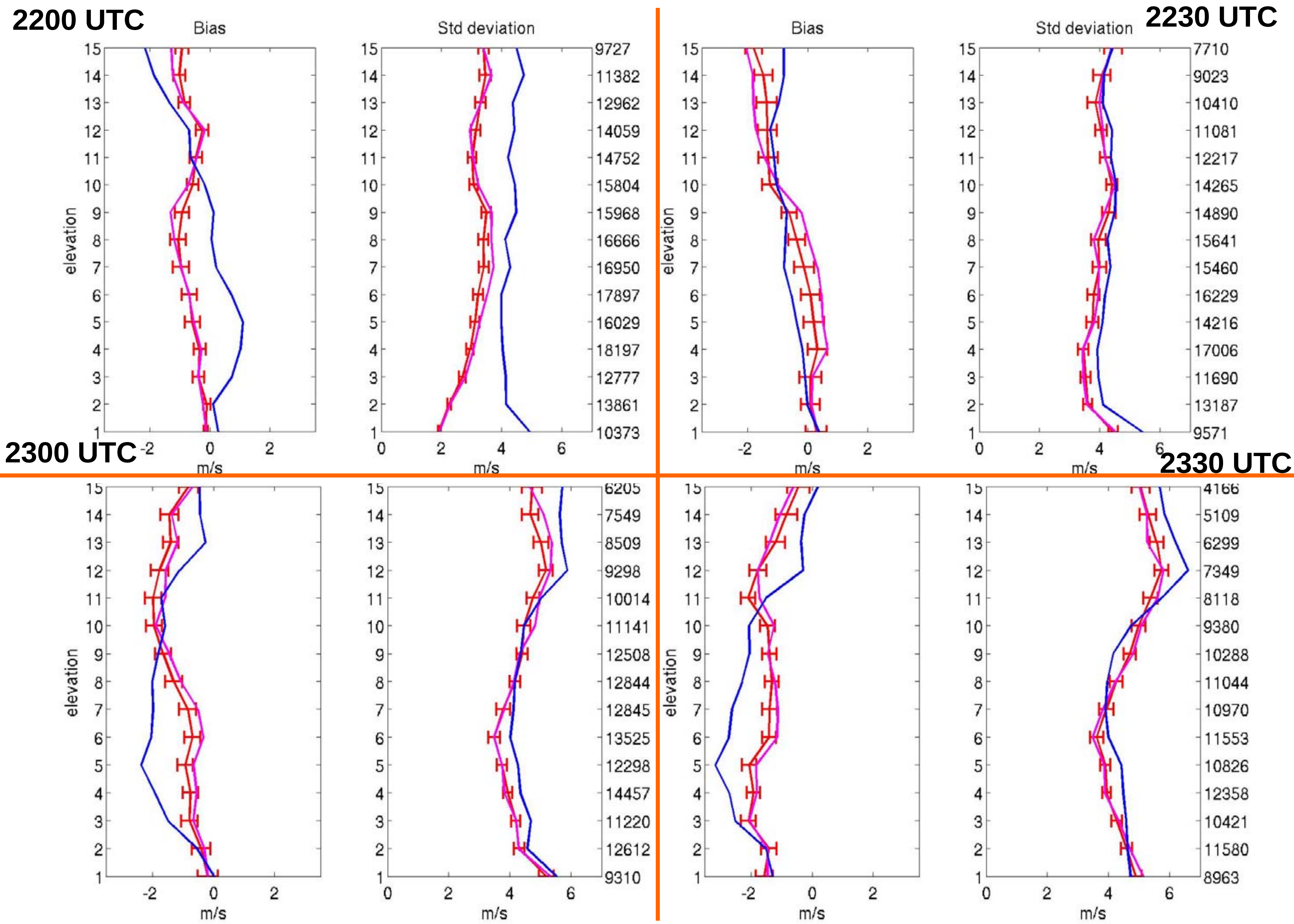
Background field is not far from radar observed, and some phase errors.



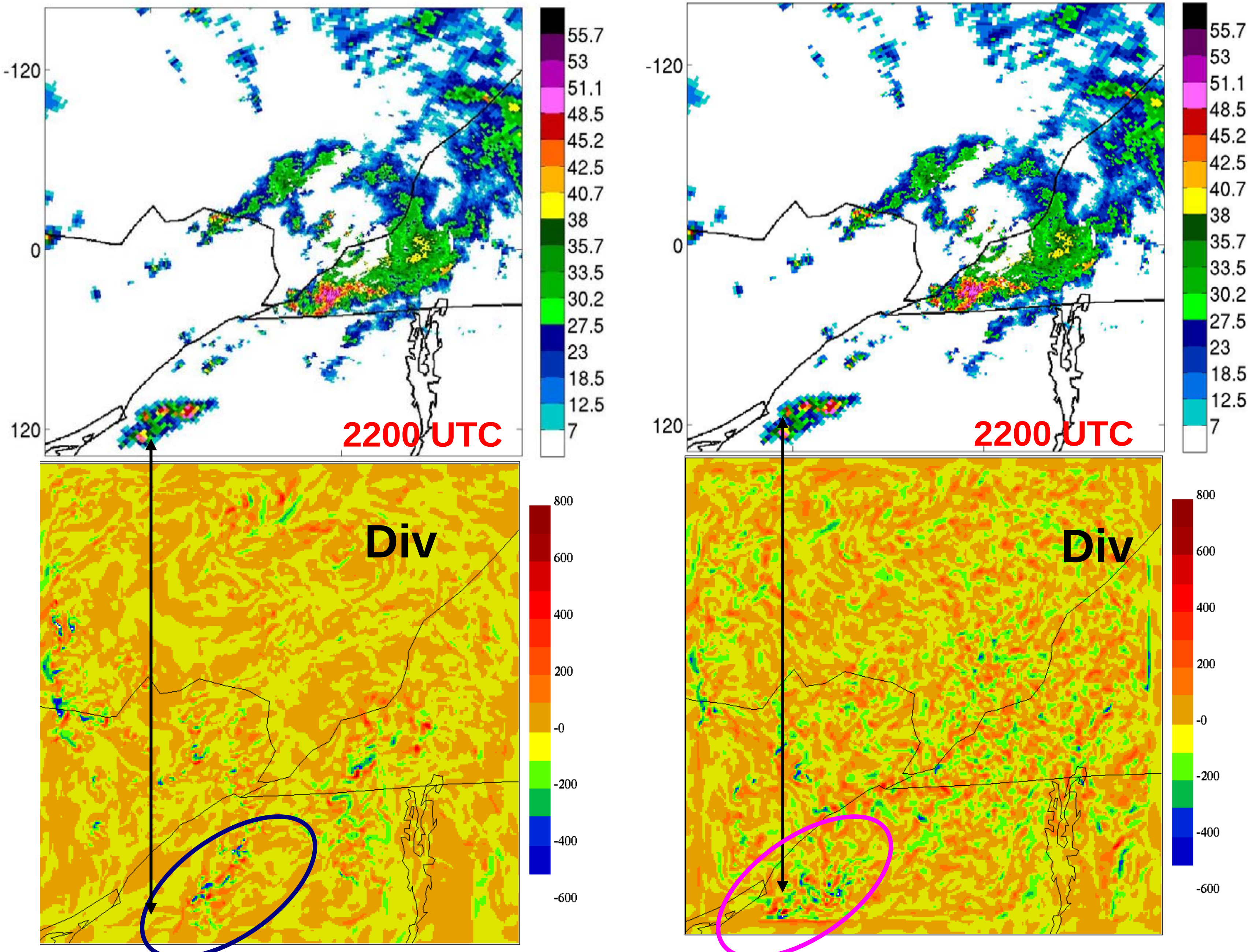
What kind of background field do we have in this case



Verification of radial wind

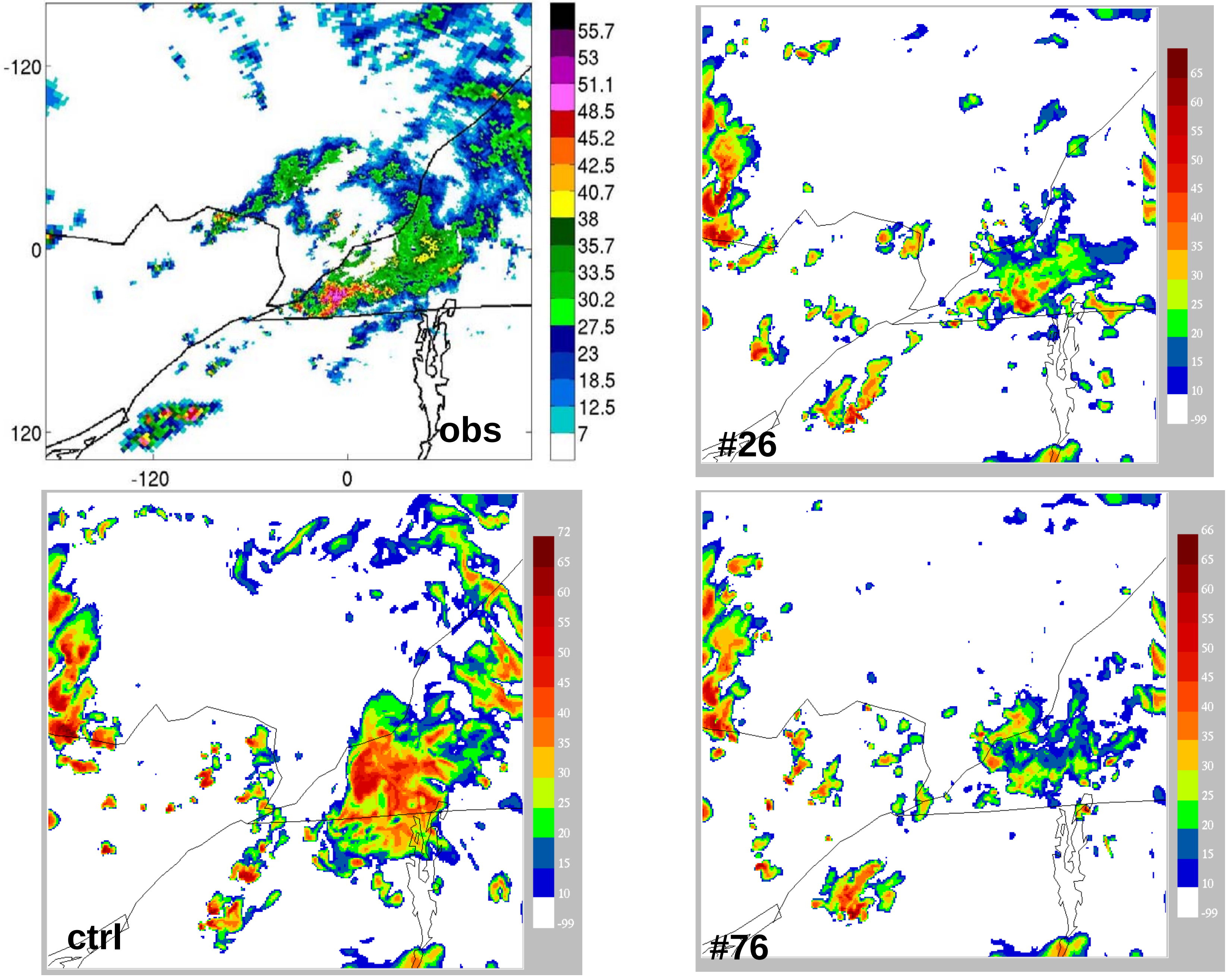


Phase correction (Postion correct)

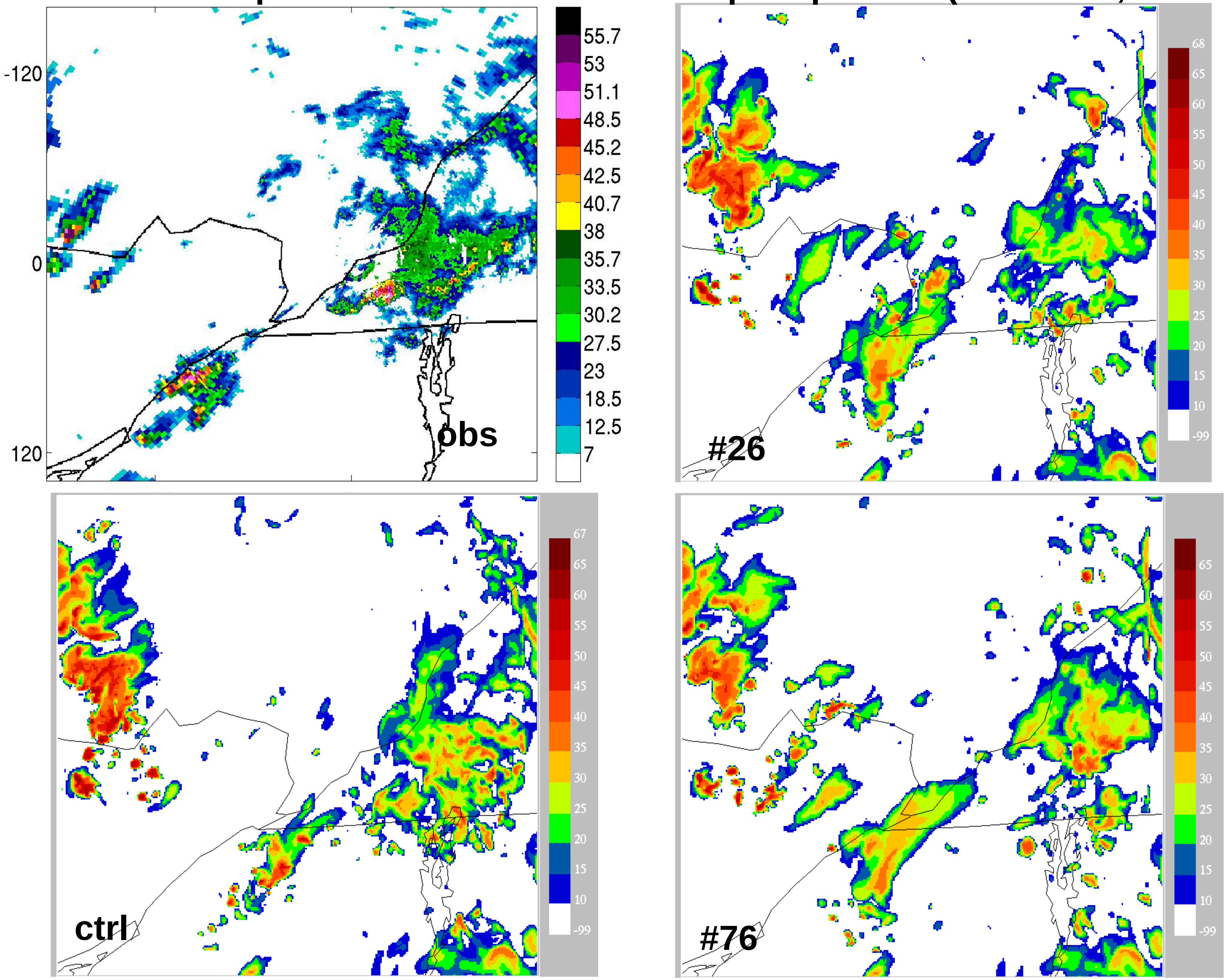


Control run (no assimilation)

What is the impact of precipitation at new analysis time (2200 UTC)

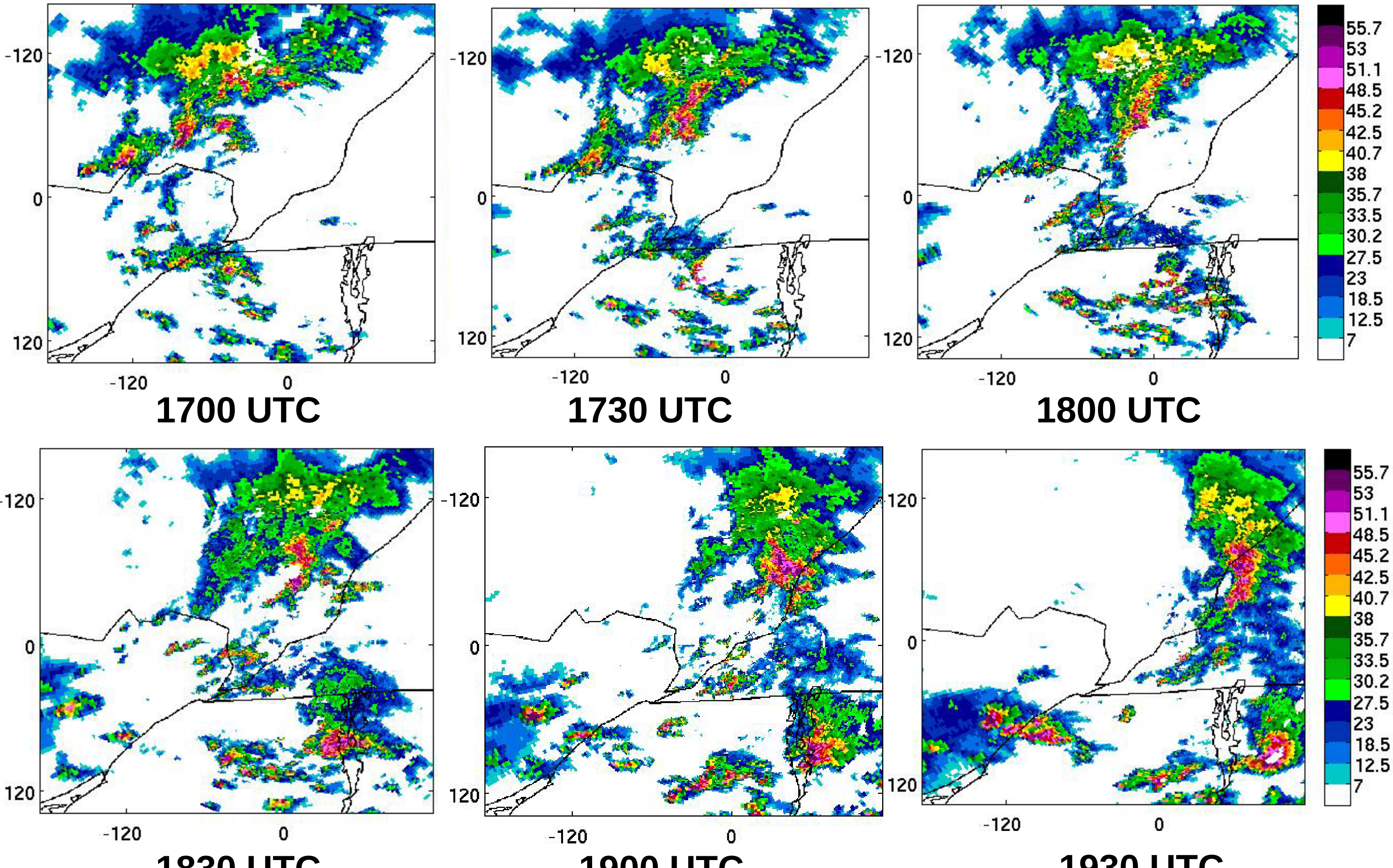


What is the impact of short-term forecasts precipitation (2300 UTC, 60-min)

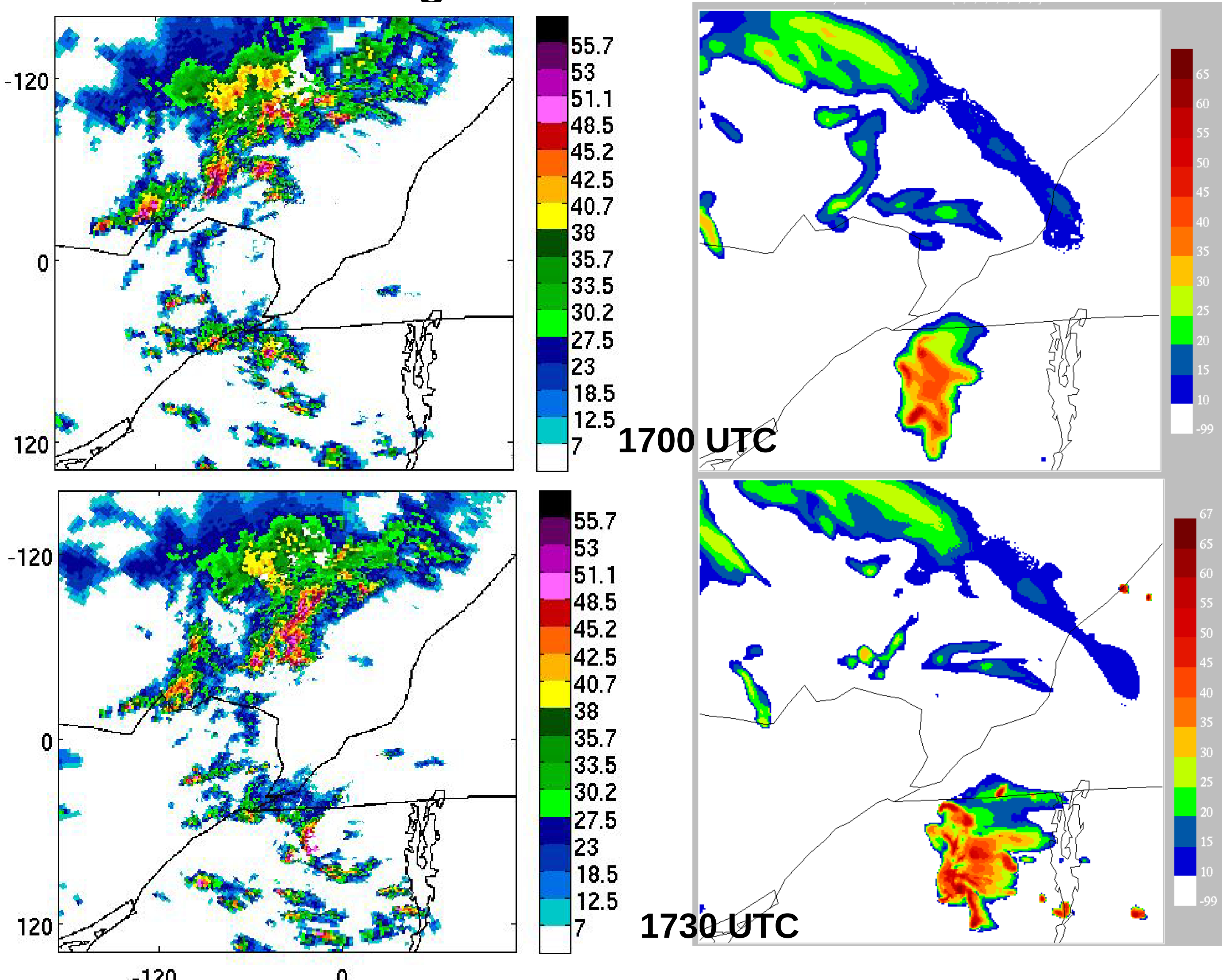


Case study #2: July 21 2010

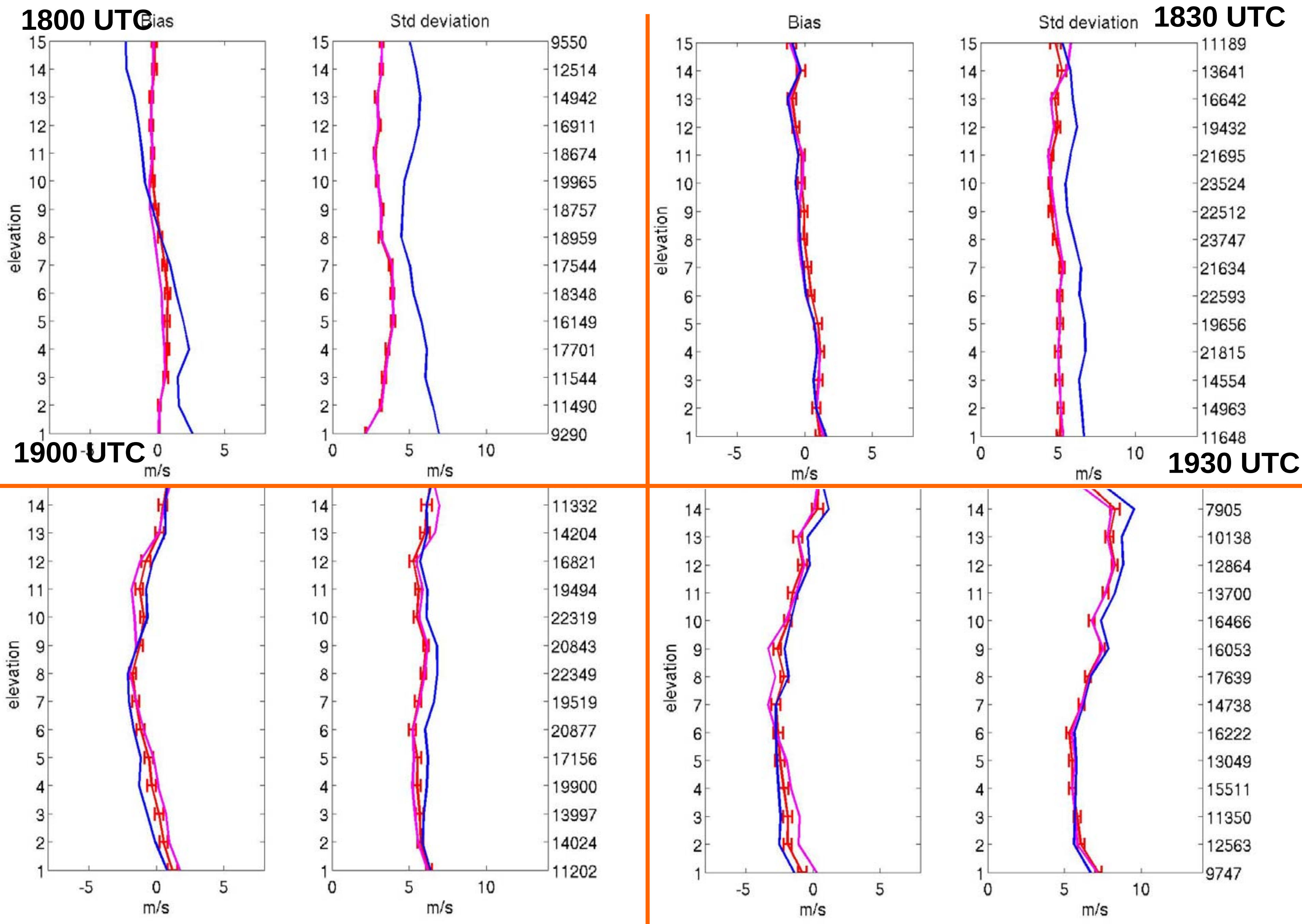
Multiple cells and convections, poor background field



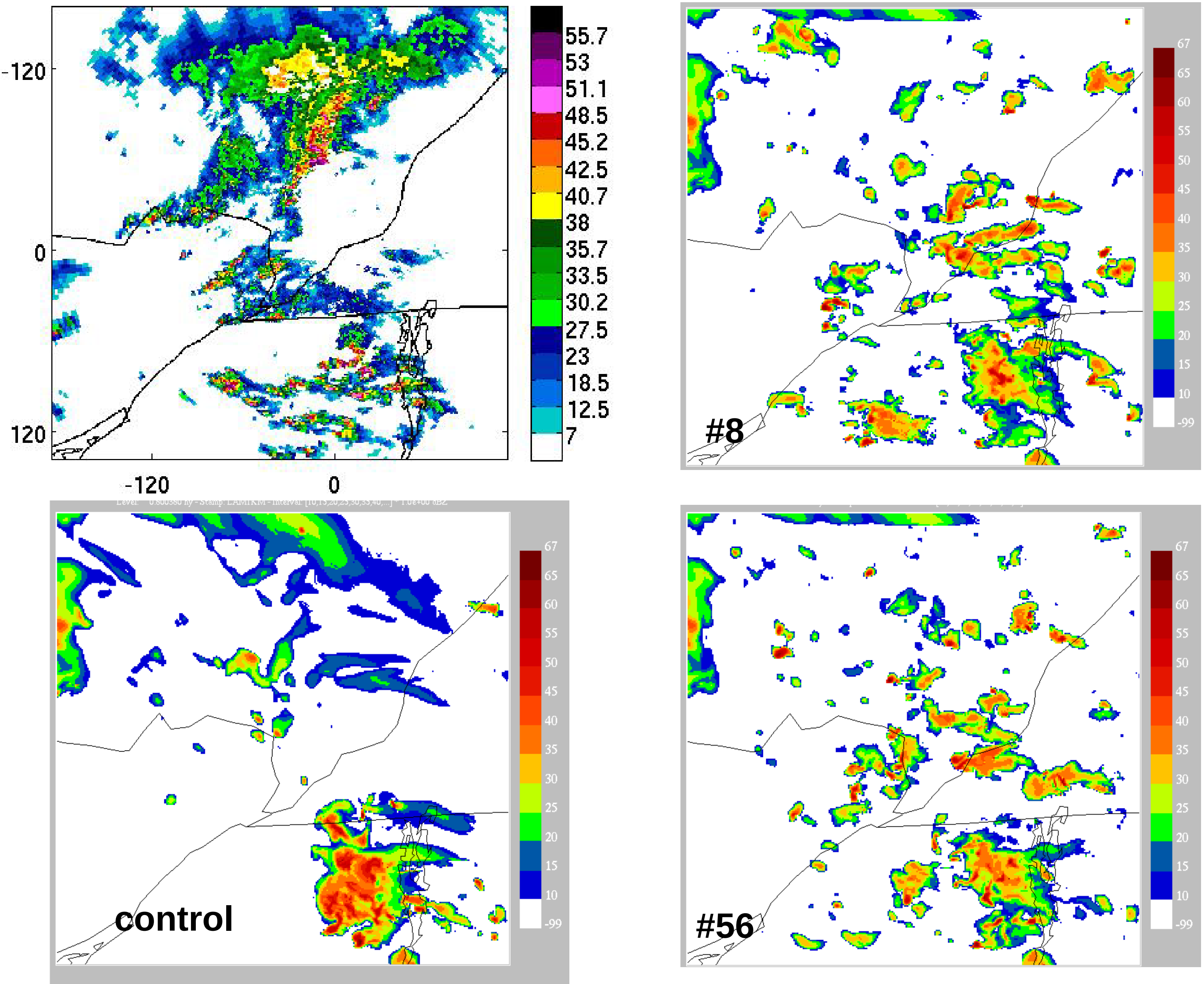
What kind of background field do we have in this case



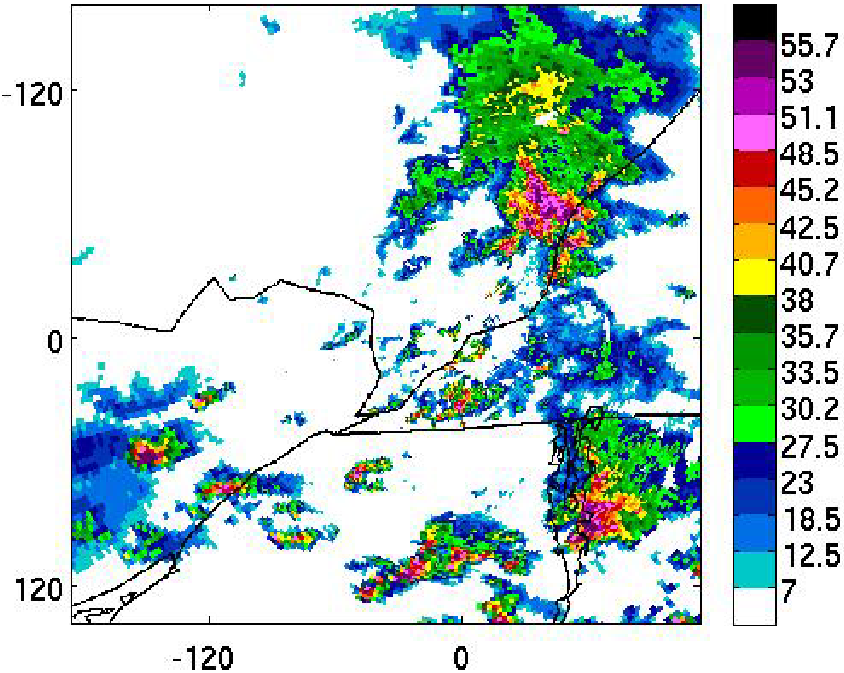
Verification of radial wind

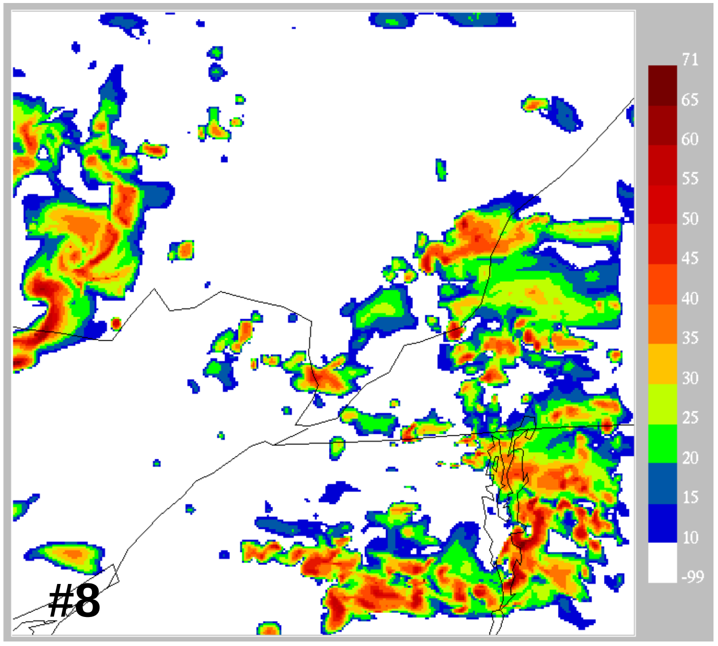


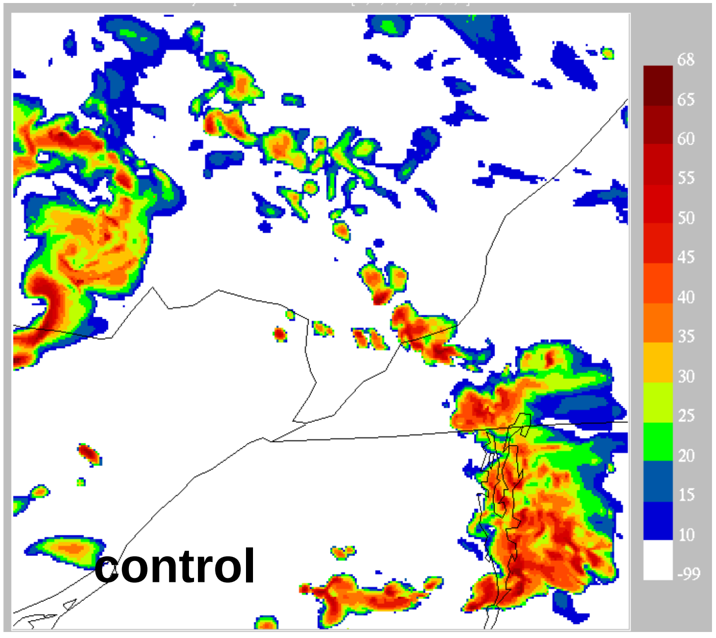
What is the impact of precipitation at new analysis time (1800 UTC)

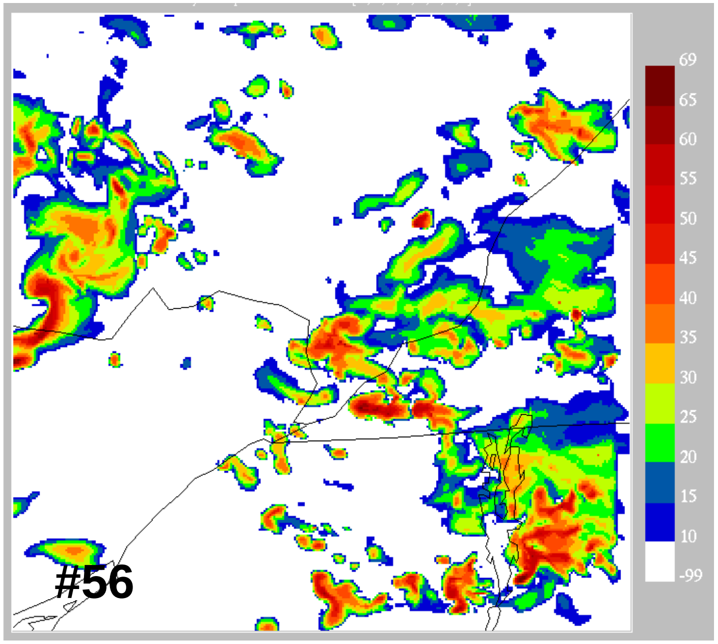


What is the impact of short-term forecasts precipitation (1900 UTC, 60-min)

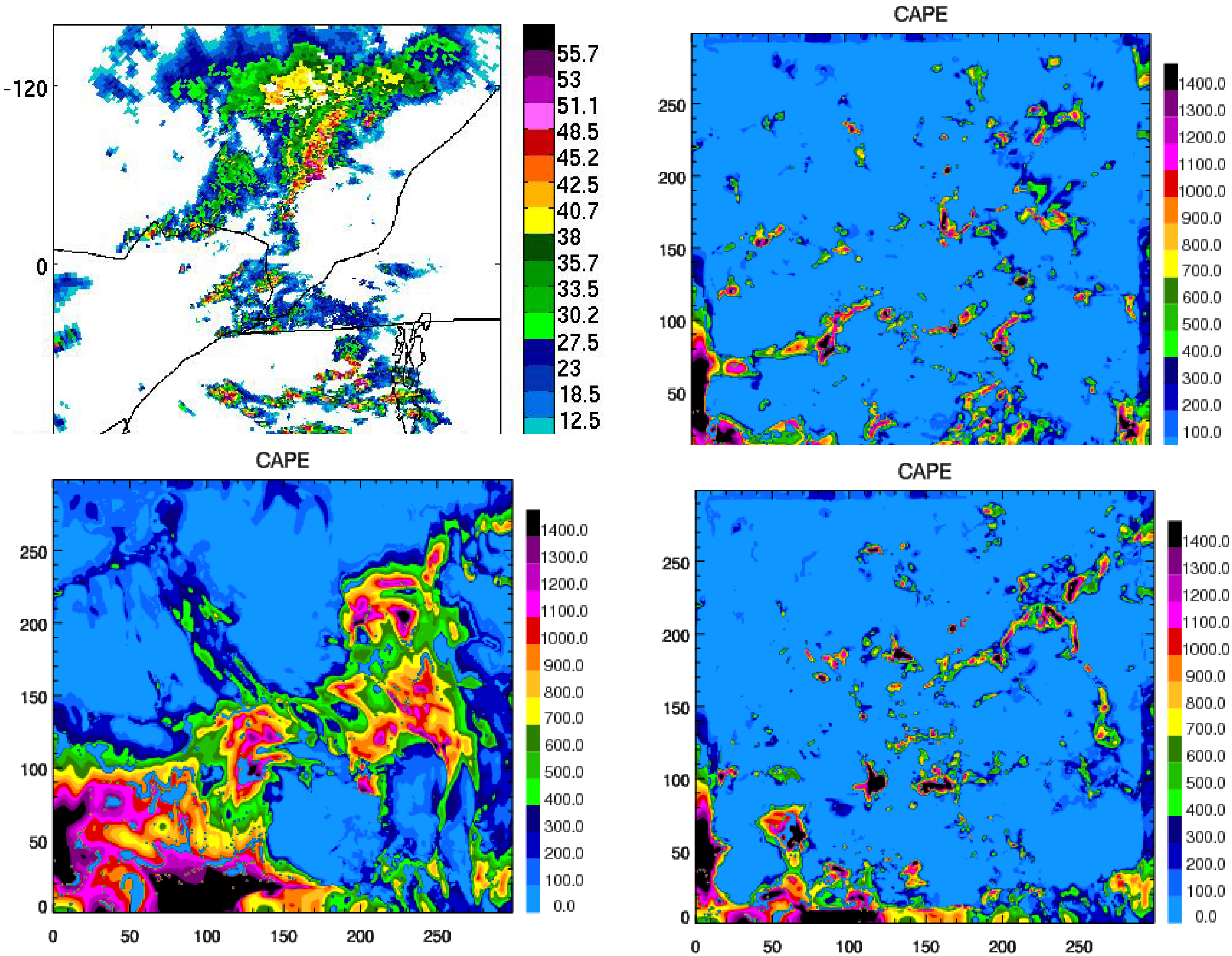








2-D CAPE value at 1800 UTC



5. Summary and Future works

- **By assimilating radar radial wind observations, it is able to modify other control variables (temperature and humidity fields).**

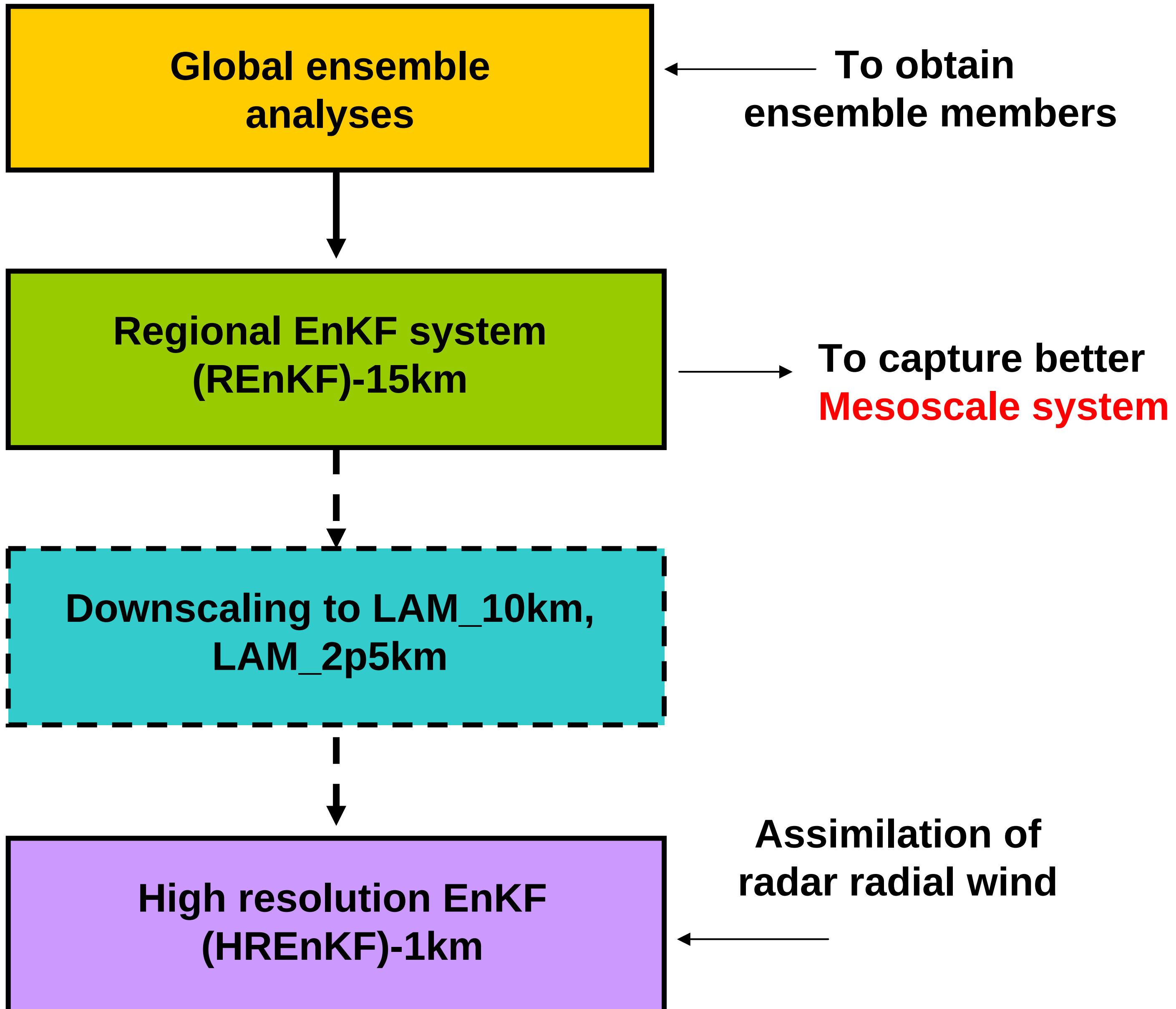
- **In general, the verification of the radial component shows that the improvement of short-term forecast is up to 1-hr. (Both bias and root-mean-square errors)**

- **The HREnKF system is able to trigger stronger convections, and short-term forecast can last for a while (case dependent) under conditions:**

  a) background field is not far from reality
  b) stronger signal is observed by radar
  (intense convections happened)

- **CAPE shows that by assimilating radial wind, the EnKF system pushs the new analyses toward right direction. However, is it enough? (When background is very bad, and when the it is weak precipitation)**

To increase the ensemble spread & obtain non-fixed lateral boundary conditions



- Use more complicated observation operator **(Frederic Fabry)**

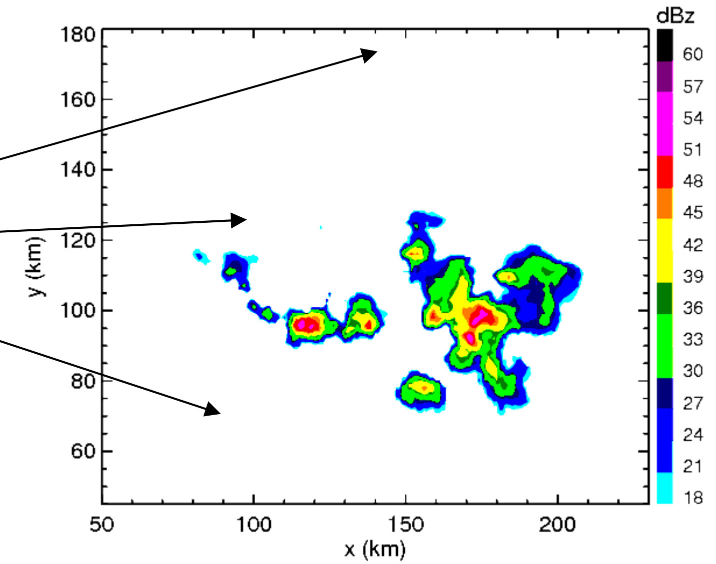
Consider: proper geometry, accurate propagation
Include: the sampling volume, signal and its processing

$$V_{r-bin} = \frac{\iiint\limits_{beam_i} V_r(r,\theta,\phi)\frac{Z_e(r,\theta,\phi)\exp(-2\tau)}{r^2}\left\{\sum_{i=1}^{N} G^2[(\theta-\theta_i)\cos(\phi'),\phi-\phi_i]\right\}d\theta\cos(\phi')d\phi\left[\sum_{j=1}^{M} W(r-r_j)\right]dr}{\iiint\limits_{beam_i} \frac{Z_e(r,\theta,\phi)\exp(-2\tau)}{r^2}\left\{\sum_{i=1}^{N} G^2[(\theta-\theta_i)\cos(\phi'),\phi-\phi_i]\right\}d\theta\cos(\phi')d\phi\left[\sum_{j=1}^{M} W(r-r_j)\right]dr}$$

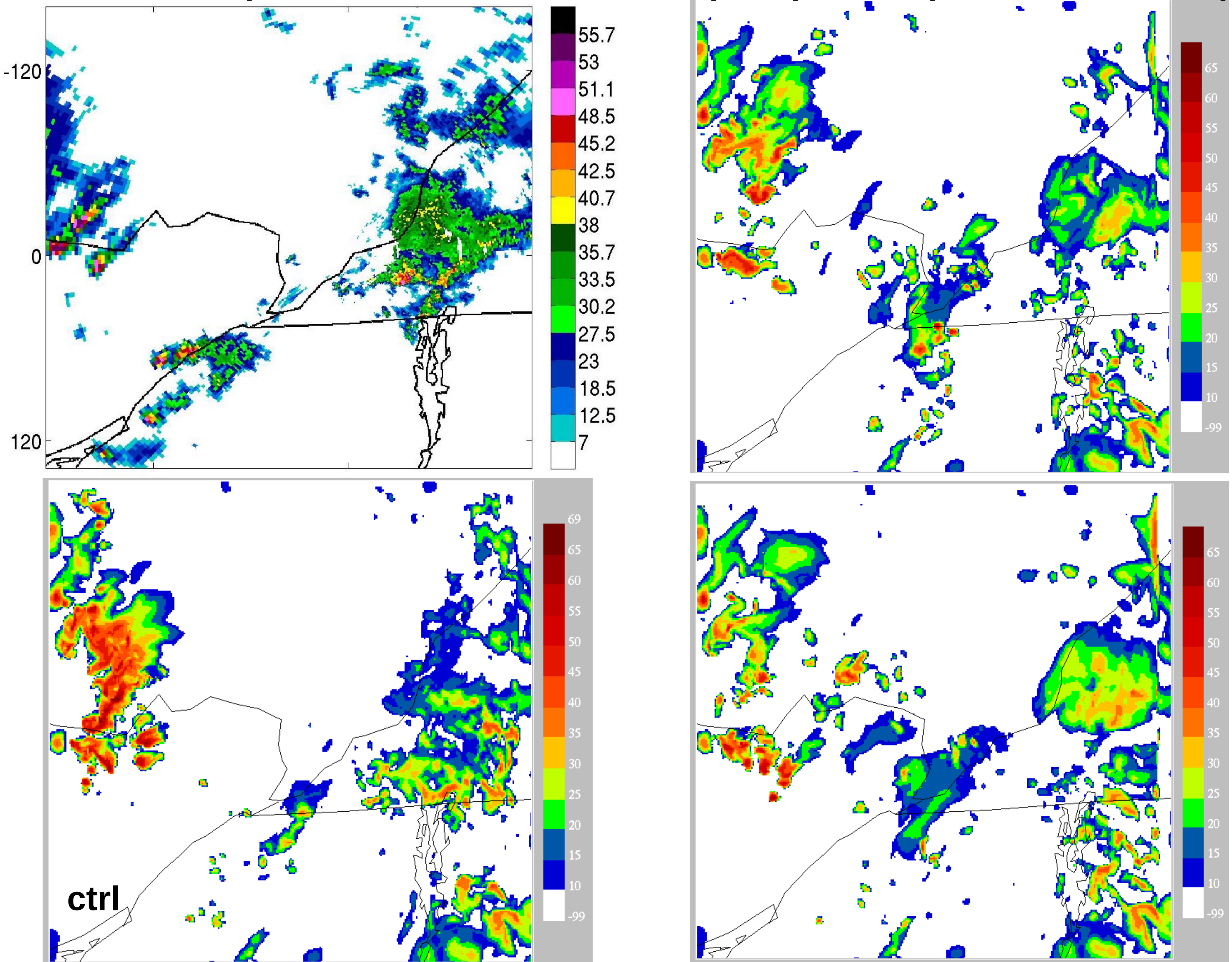
- Assimilate both radial wind and reflectivity observations

Refelctivity:
both precipitation and no-precipitation areas

Non-precipitating areas



What is the impact of short-term forecasts precipitation (2330 UTC, 90-min)



What is the impact of short-term forecasts precipitation (1930 UTC, 90-min)