Analysis of HARMONIE Forecasts Sensitivity to Initial Data using Simulated Radar Observations

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ALADIN / HIRLAM
24th Workshop /All Staff Meeting 2014

Bucarest 7-10 April

Presentation layout

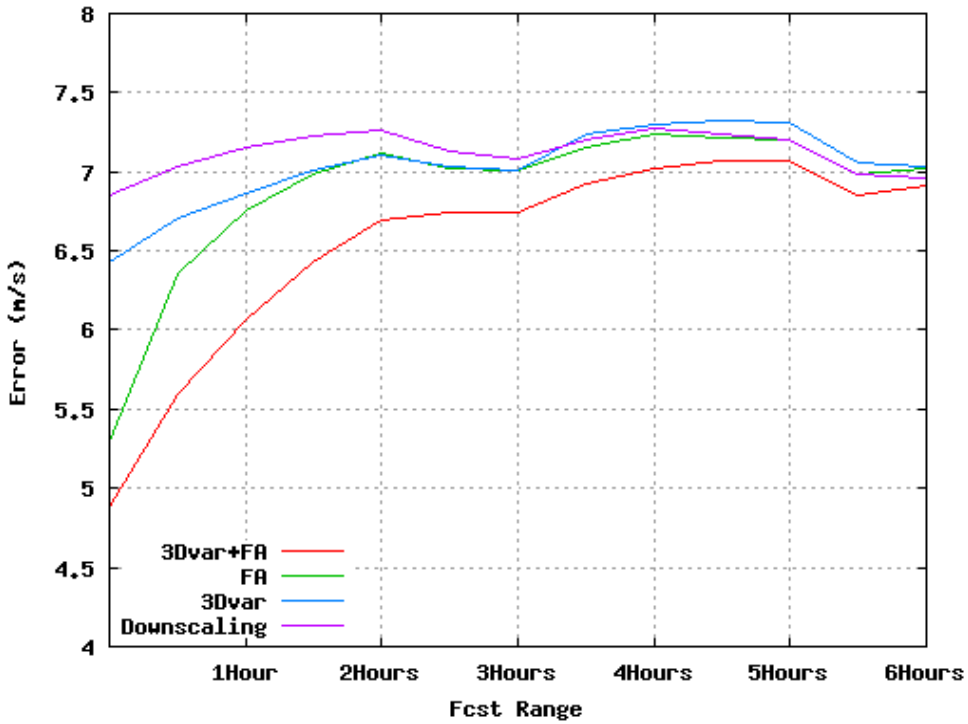
- Recall of last results of assimilation of DOW data with the FA method
- Presentation of the implementation of Z assimilation by FA
- Presentation of new validation of the method by experimentation with simulated obs
- Conclusions and outlook

Assimilation of Doppler Wind Radar Data in HARMONIE

- **Verification of forecasted radial wind using the own radar data:**

$$\text{Error} \equiv \langle (\text{Fcst} - \text{Radar})^2 \rangle^{1/2}_{\text{PPI=0.5}} + \langle (\text{Fcst} - \text{Radar})^2 \rangle^{1/2}_{\text{PPI=1.4}}$$

- **Results averaged over more than 150 cases:**



Assimilation of Doppler Wind Radar Data in HARMONIE

Encouraging results with the following three-step "hybrid FA+3DVar" scheme

a) Correction of position errors using Field Alignment

b) *Upscale and filter the FA corrections using the model error covariances*

c) 3DVar assimilation of radar data

Assimilation of Doppler Wind Radar Data in HARMONIE

Rationale behind step b)

- **Most of the model error is positional :** $\varepsilon_b = \left(\varepsilon_b\right)_{pos} + \left(\varepsilon_b\right)_{other} \sim \left(\varepsilon_b\right)_{pos}$

- **The FA correction is just a correction for this kind of error:**

$$\delta FA = -\left(\varepsilon_b\right)_{pos} + \varepsilon_{FA}$$

- **We upscale using a Minimum Variance Unbiased Linear estimate:**

$$\hat{\delta FA}_a = \sum_{\omega \in \Omega} W_{a\omega}\, \delta FA_\omega \qquad \textbf{with} \qquad \left\langle \varepsilon_b\, \varepsilon_{FA} \right\rangle = 0$$

- **Which can be approximated by the familiar model error covariances**

$$\vec{W}^T_{a\Omega} = \left\langle \delta FA_a\, \vec{\delta FA}^T_\Omega \right\rangle \left\langle \vec{\delta FA}_\Omega\, \vec{\delta FA}^T_\Omega \right\rangle^{-1} \sim$$

$$\left\langle \left(\vec{\varepsilon_b^T}\right)_\Omega \left(\varepsilon_b\right)_a \right\rangle \left(\left\langle \left(\vec{\varepsilon_b^T}\right)_\Omega \left(\vec{\varepsilon_b}\right)_\Omega \right\rangle + \begin{pmatrix} \sigma^2_{FA}(1) & 0 \\ 0 & \sigma^2_{FA}(\Omega) \end{pmatrix} \right)^{-1}$$

Assimilation of Doppler Wind Radar Data in HARMONIE

This solution is just the 3D-Var solution in its "incremental formulation"

$$2J(\delta\vec{FA}) = \delta\vec{FA}^{T} \left\langle \left(\varepsilon_b^{T}\right)_M \left(\vec{\varepsilon_b}\right)_M \right\rangle^{-1} \delta\vec{FA} +$$

$$(\delta\vec{FA}_\Omega - \delta\vec{FA})^{T} \begin{pmatrix} \sigma_{FA}^2(1) & 0 \\ 0 & \sigma_{FA}^2(\Omega) \end{pmatrix}^{-1} (\delta\vec{FA}_\Omega - \delta\vec{FA})$$

Therefore the implementation in the current system is done !

Assimilation of Reflectivity Radar Data in HARMONIE

- Reflectivity assimilation by FA implemented

- Position error correction for hydrometeors (rain, graupel, snow, clouds)

- Reflectivity is used also as a proxy for q, and T fields

- Z (mm**6/m**3) (not logZ (dBZ)) used as parameter because simpler expression for H

- Horizontal levels better than model levels for calculation of H. Specific treatment for orography

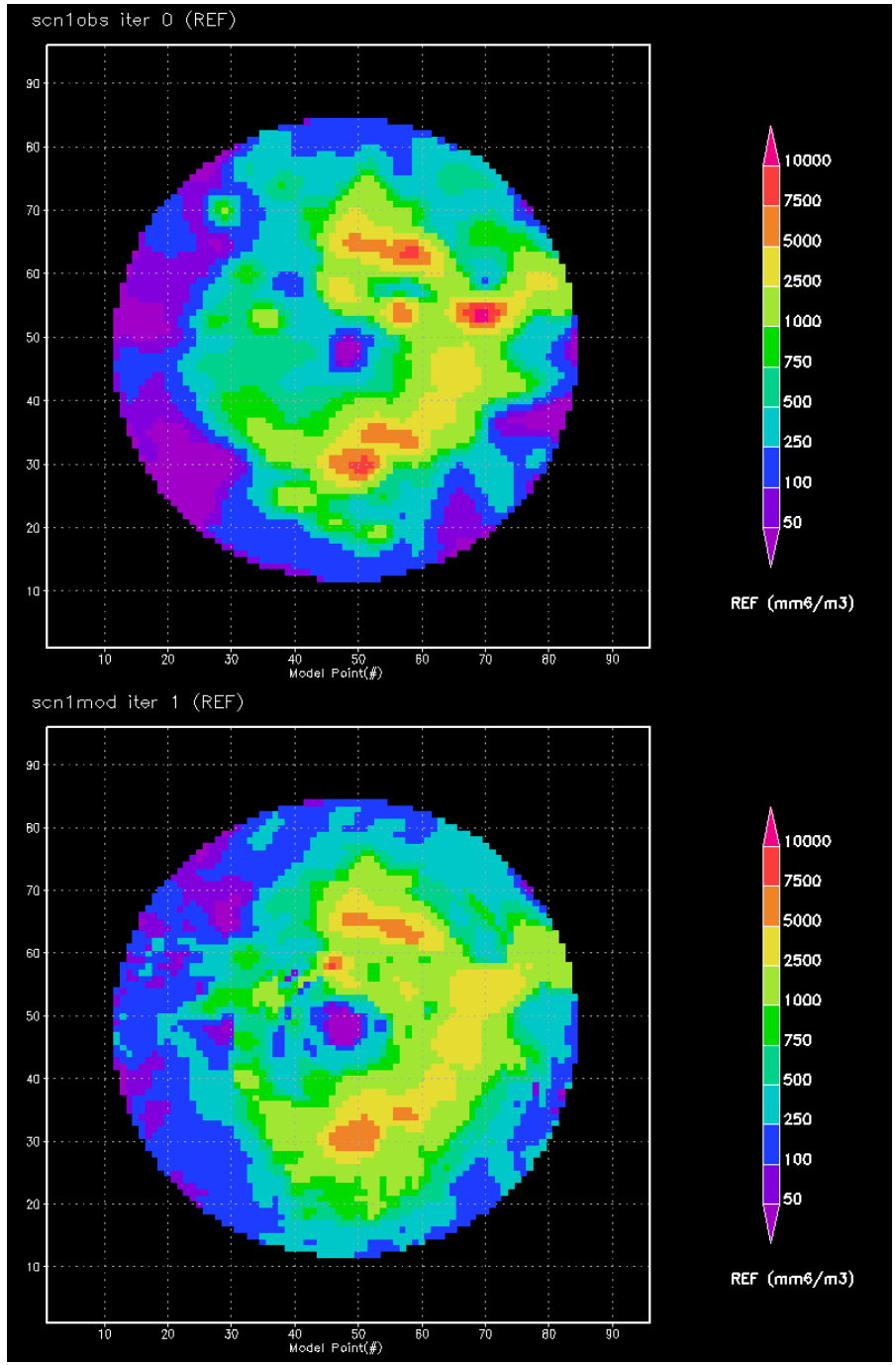
Assimilation of Z by FA

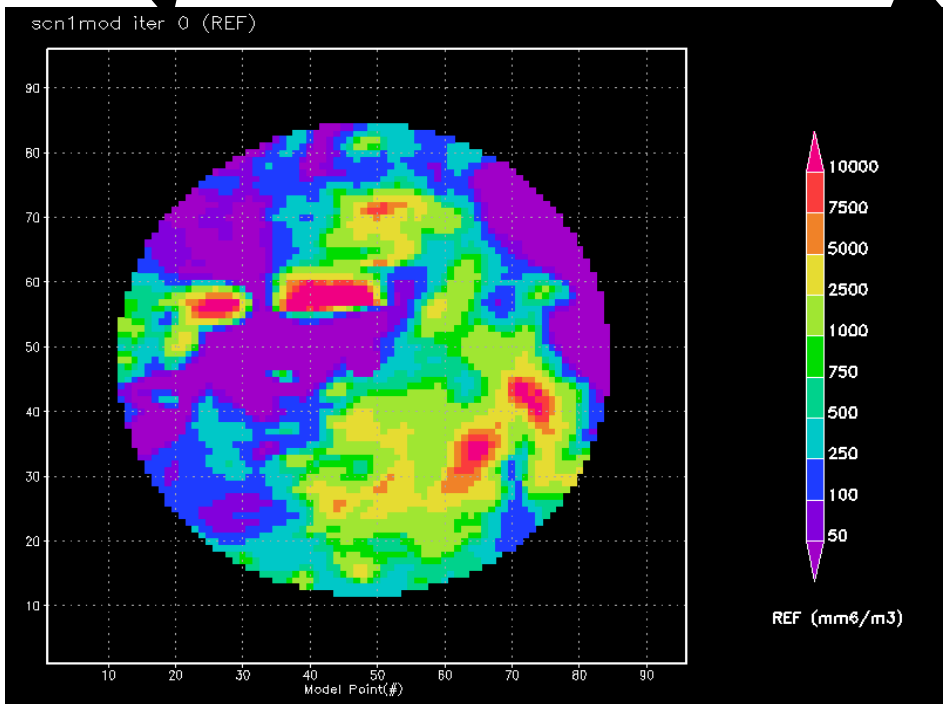
Results in PPI geometry

FG

OBS

corrected FG





Assimilation of Z by FA

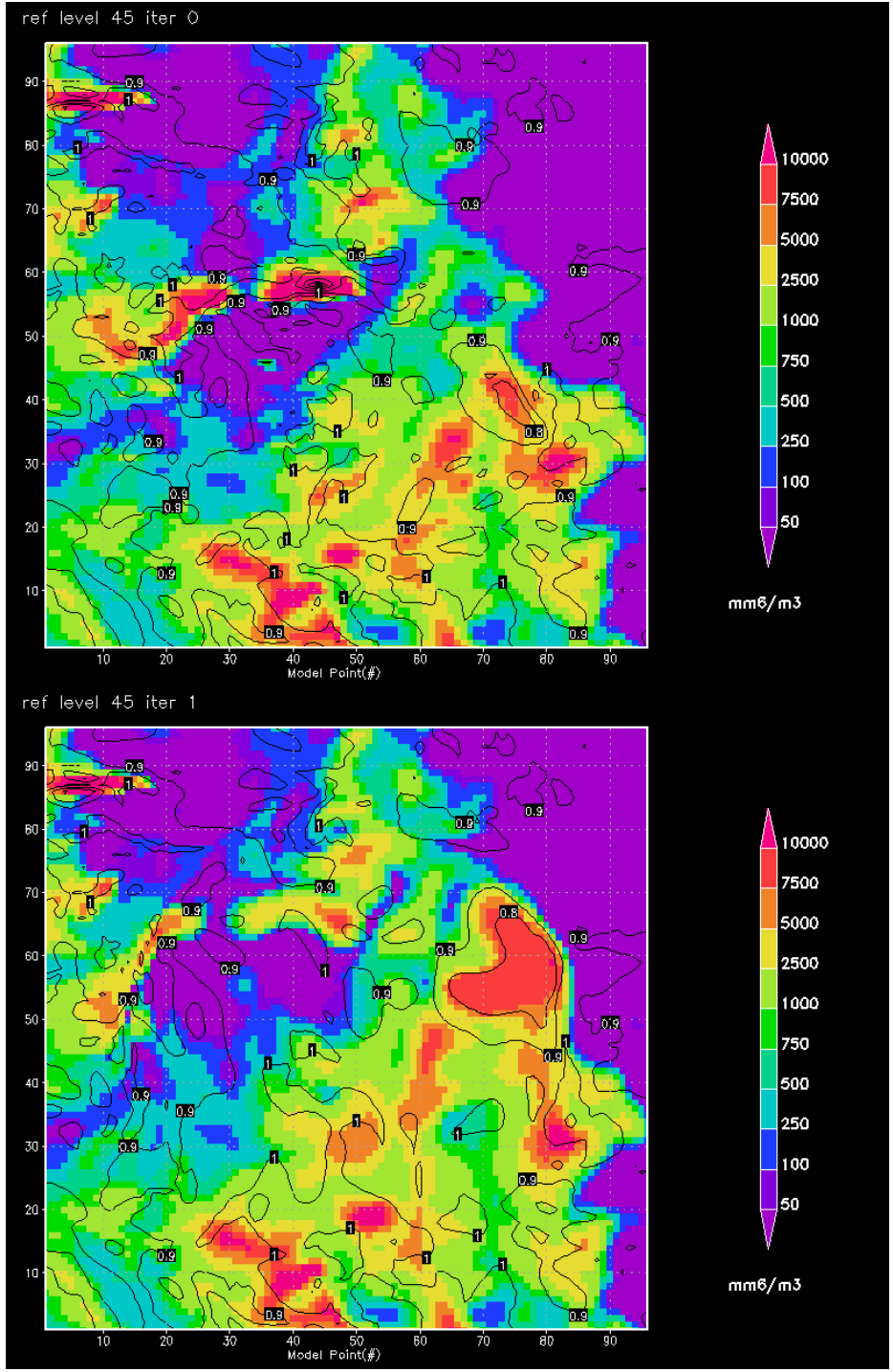
Results on Horizontal Levels Geometry

Reflectivity at H. Level 45.

Before

After

Black Contours show Relative Humidity



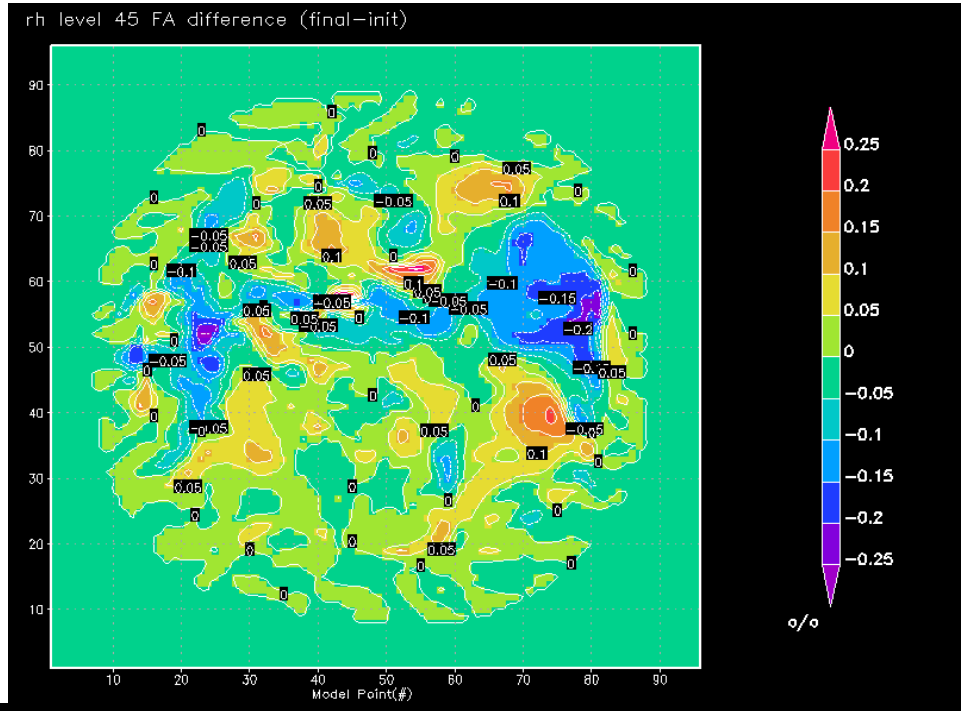
Assimilation of Z by FA

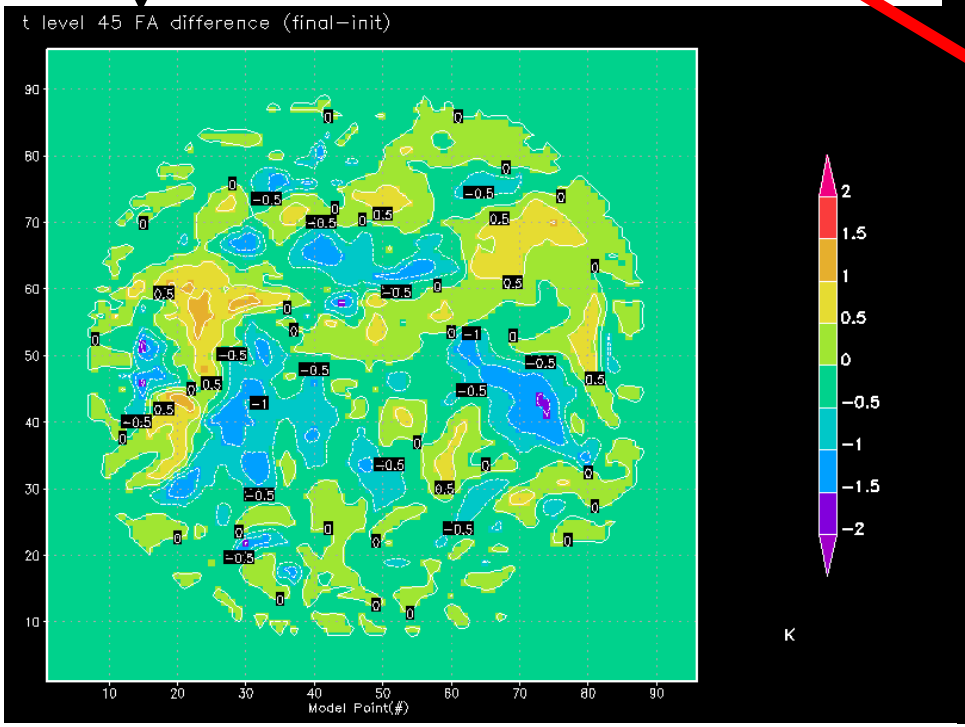
Results on Horizontal Levels Geometry

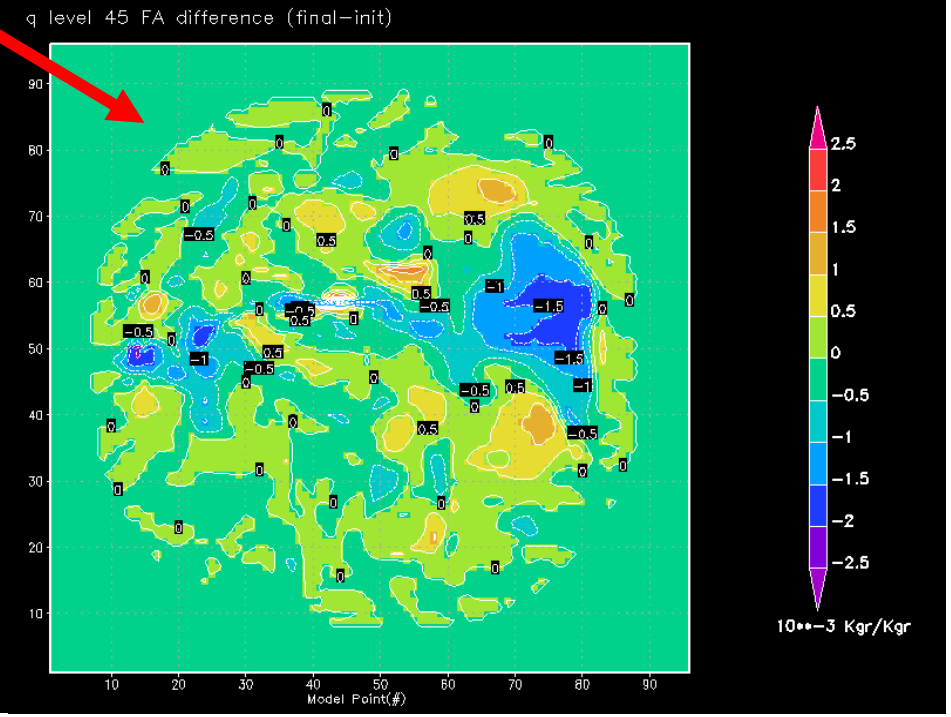
Relative Humidity Change on Horizontal Level 45

T

q







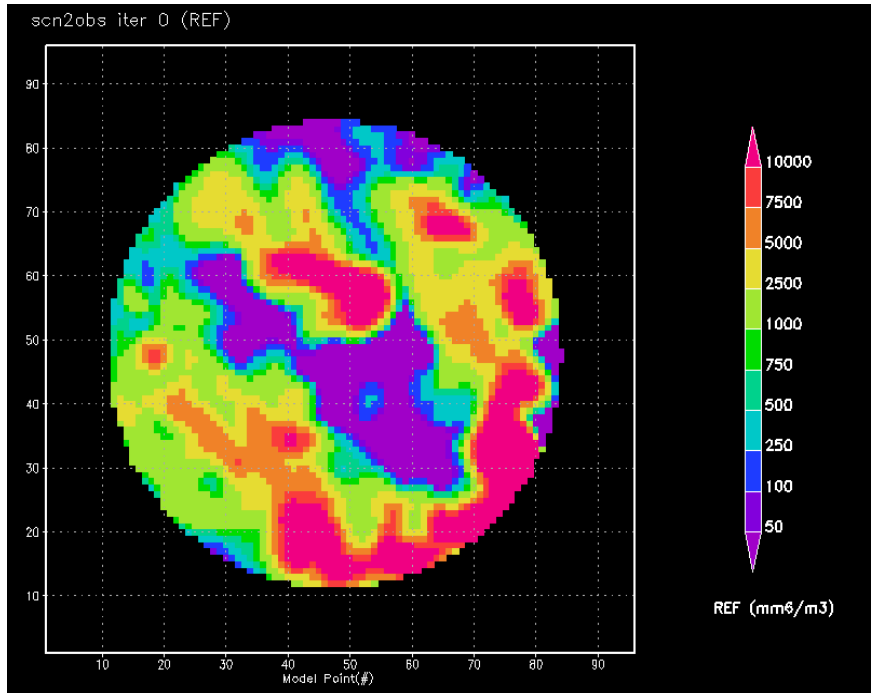
Assimilation of Z by FA

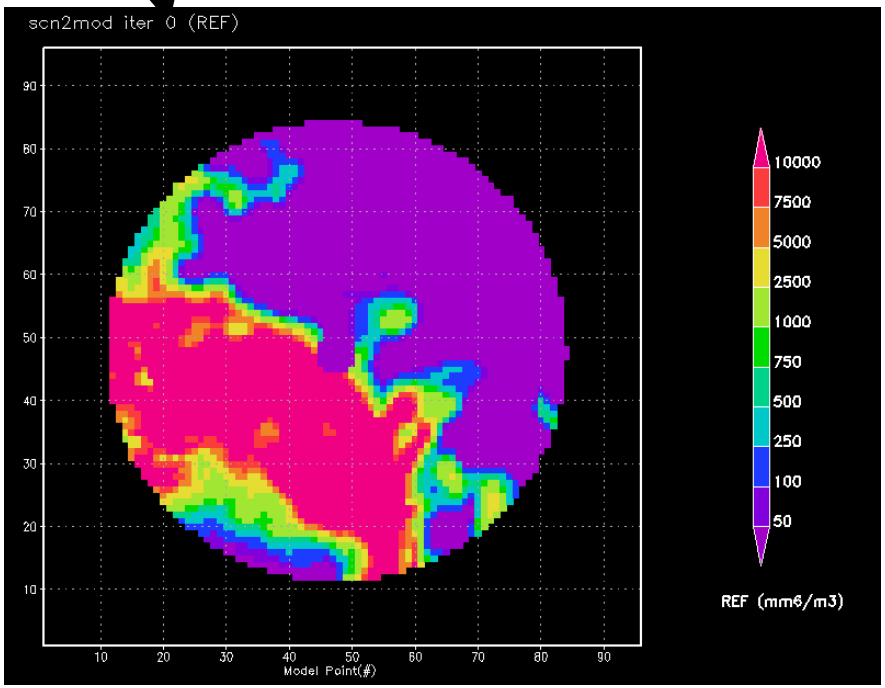
Results in PPI geometry

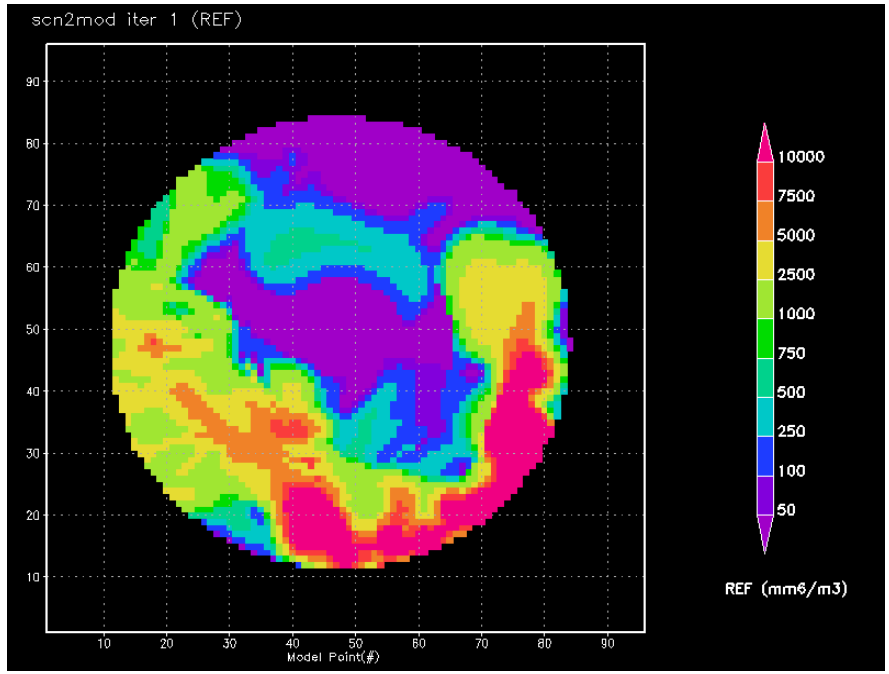
FG

OBS

corrected FG







Assimilation of Z by FA

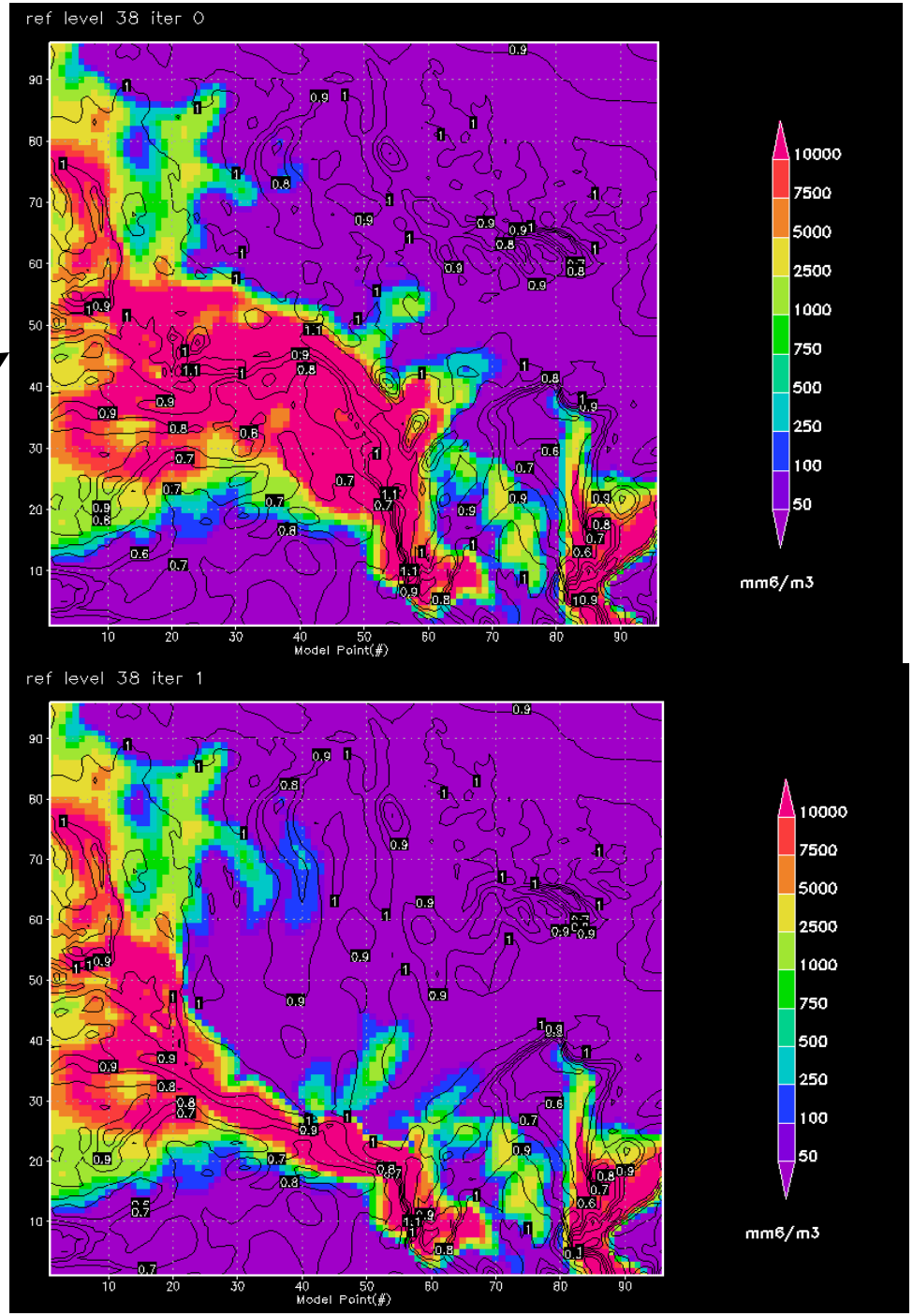
Results on Horizontal Levels Geometry

Reflectivity at H. Level 38.

Before

After

Black Contours show Relative Humidity



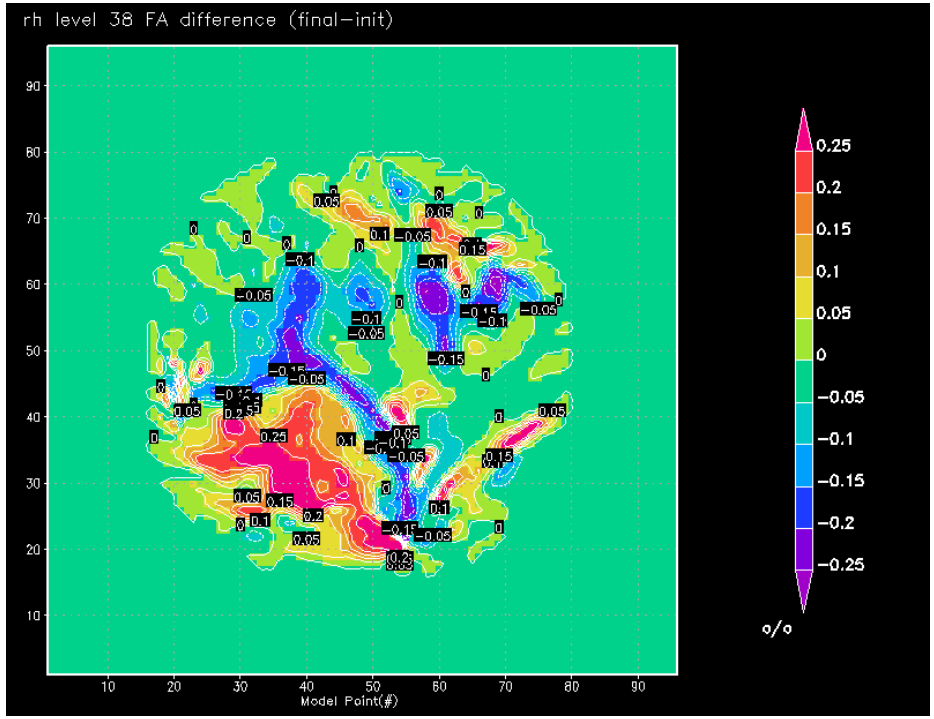
Assimilation of Z by FA

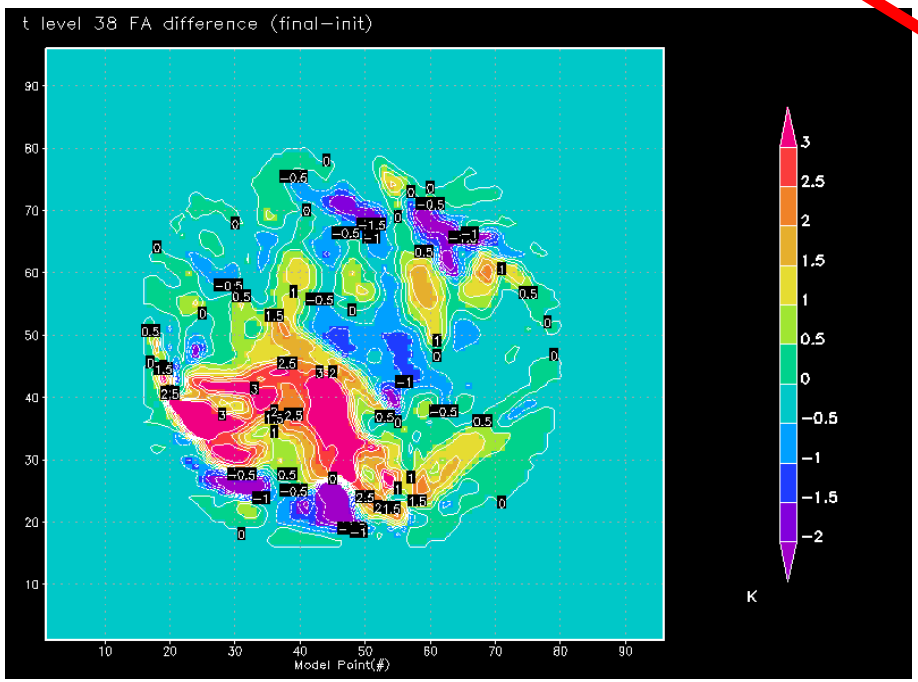
Results on Horizontal Levels Geometry

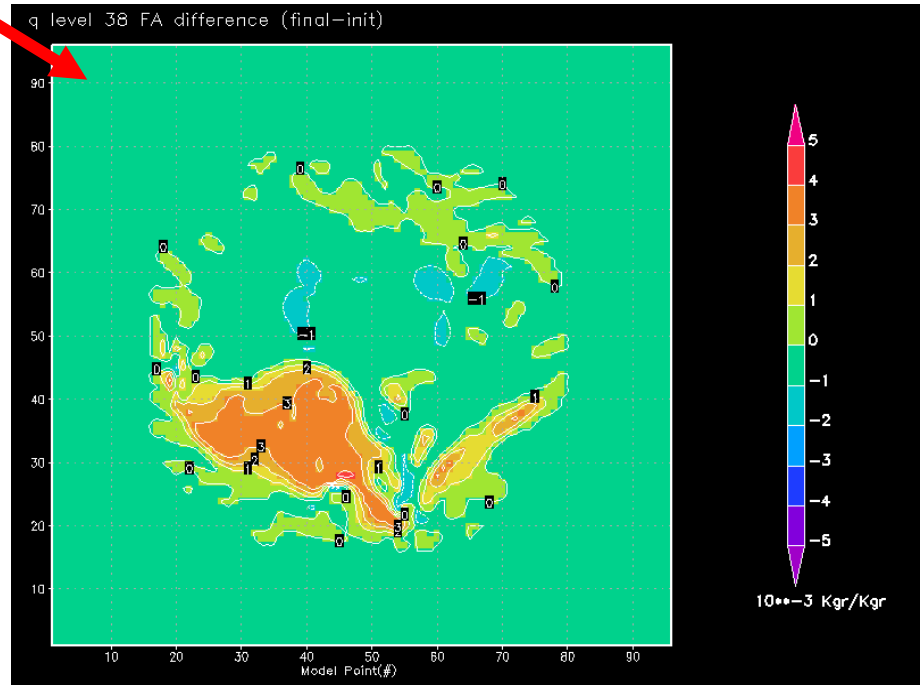
Relative Humidity Change on Horizontal Level 38

T

q







- Twin Experiments a convenient way of validating the radar assimilation developments

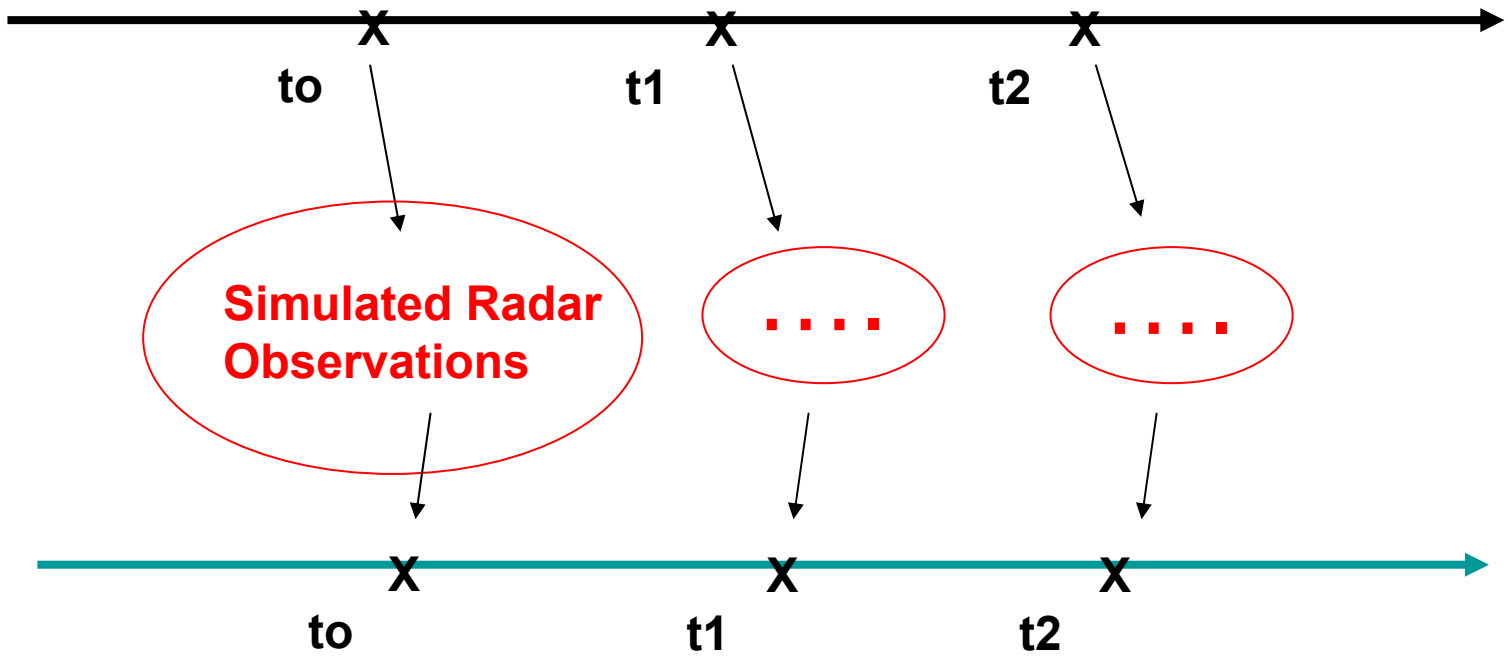
- Easy access to the validation reference at all scales

- “Perfect Model” scenario (realistic but false model dynamics)

- Easy gauging of model noise levels

- Freedom to test also hypothetical radar data acquisition schedules (ranges, elevations, number of PPIs,…)

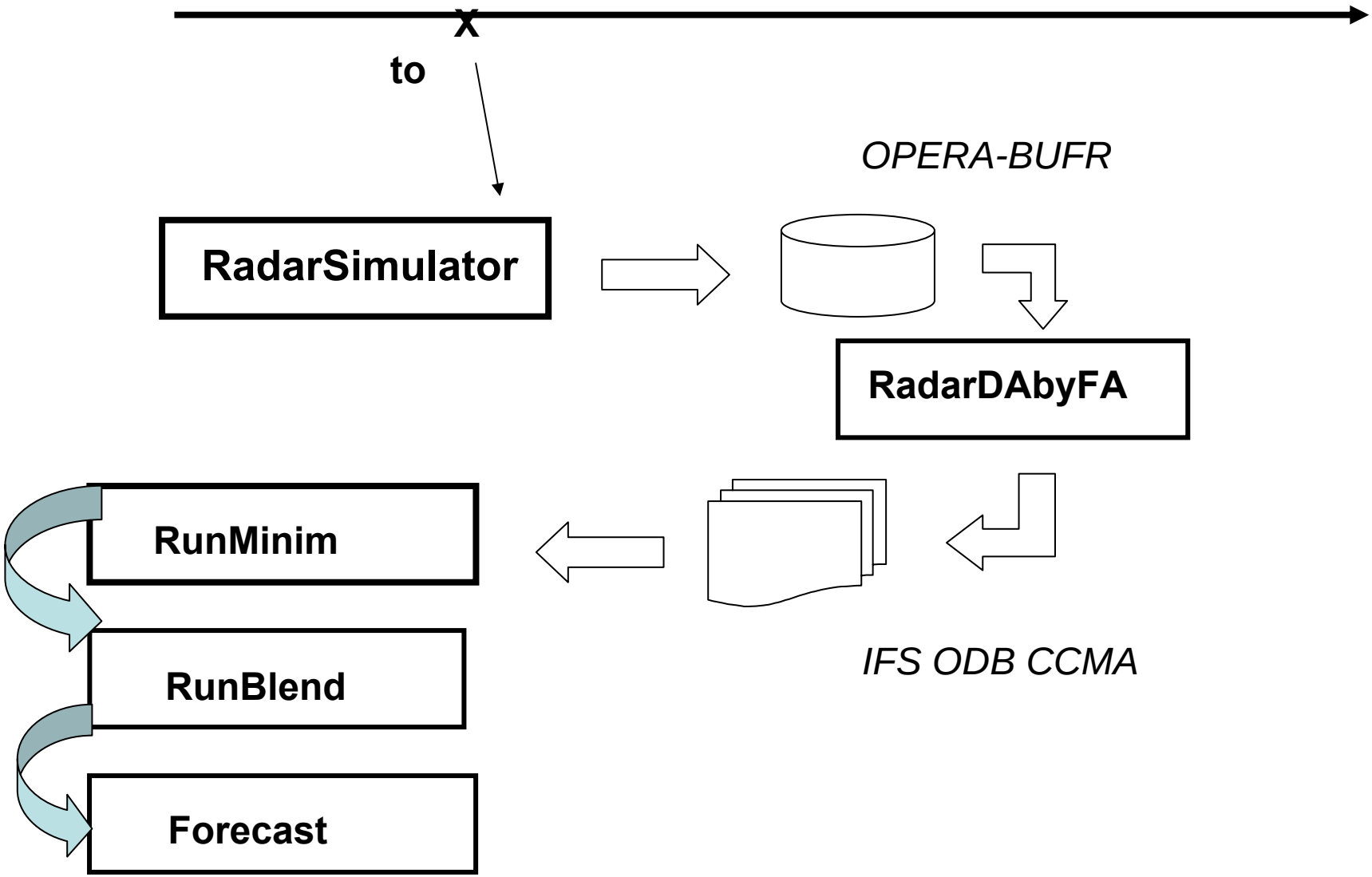
Twin0 (“nature”) : Init + LBC from enda#1



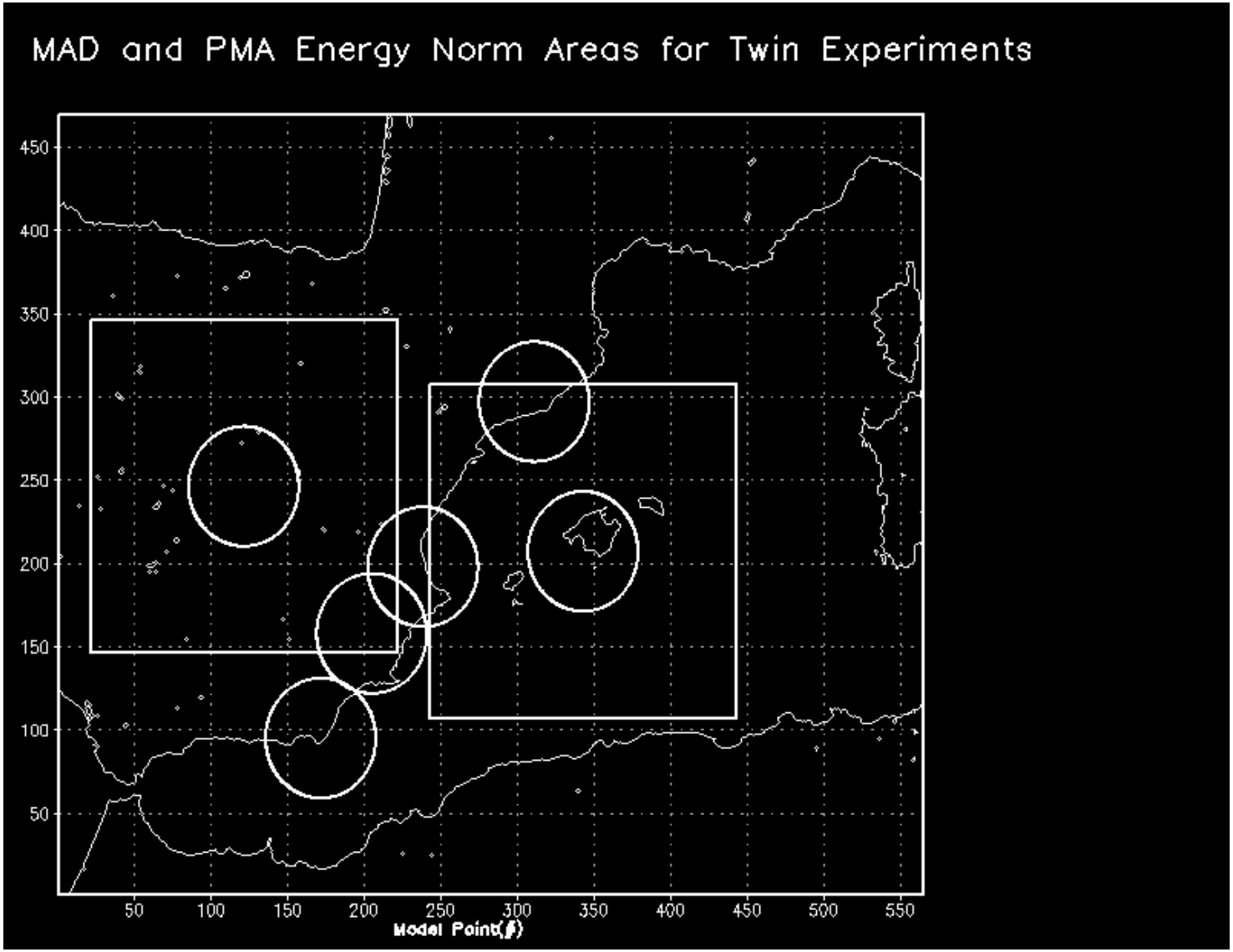
TwinN (“expN”) ….

Twin1 (“model”) : Init + LBC from enda#4

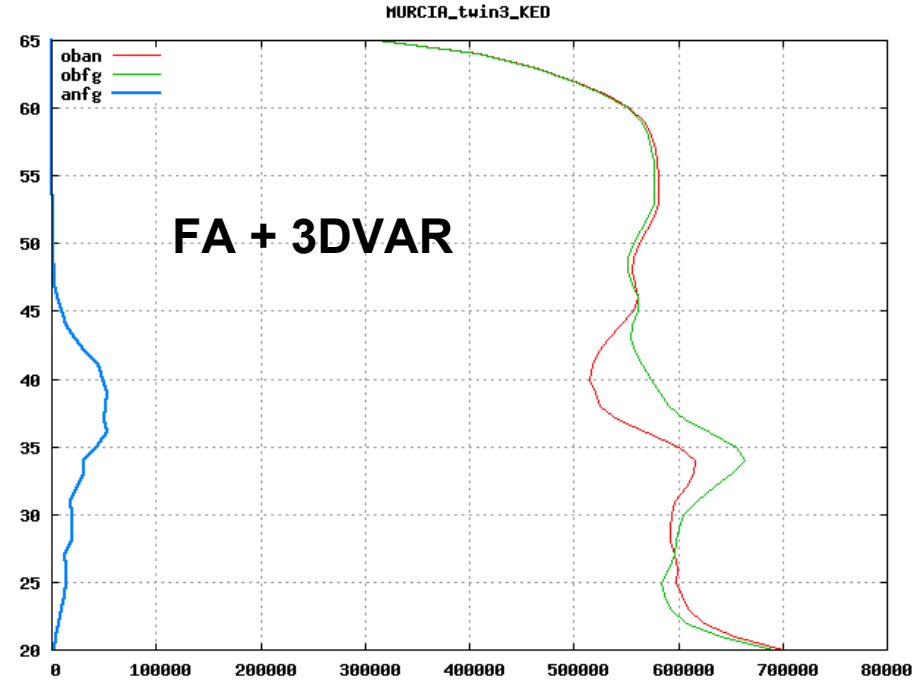
Twin0 (“nature”) : Init + LBC from enda#1

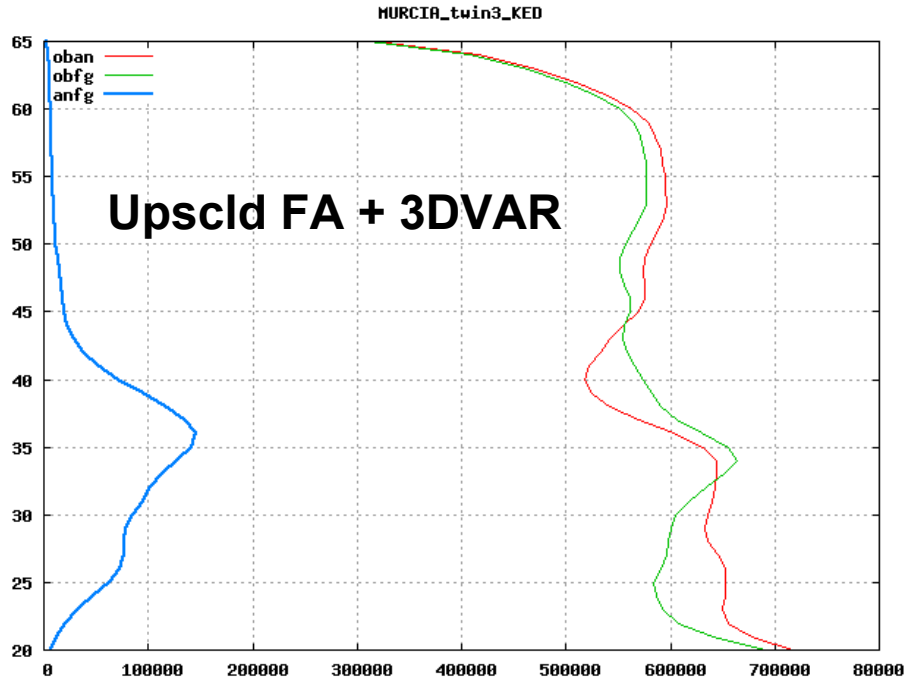


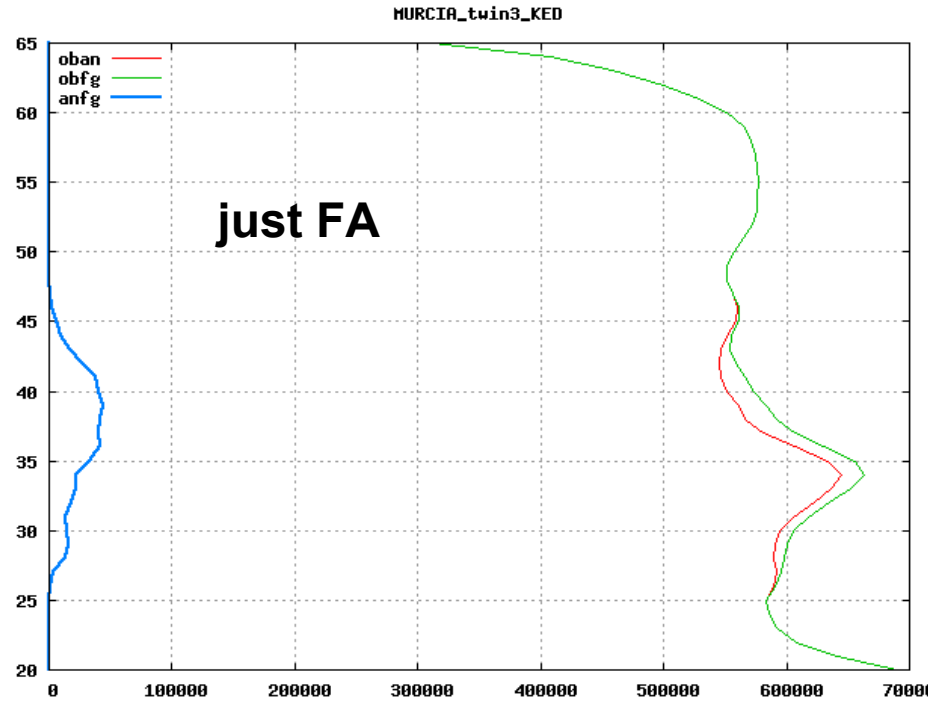
- Differences are calculated gridpointwise on big areas 200x200

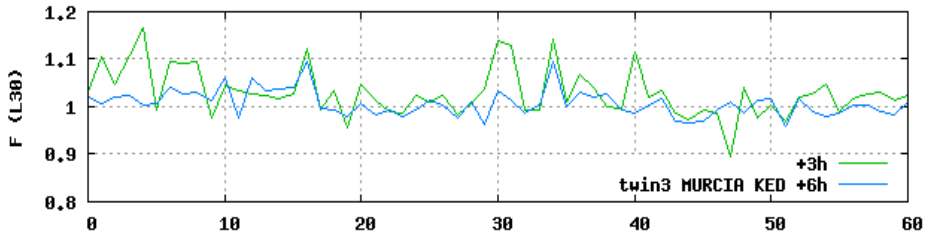


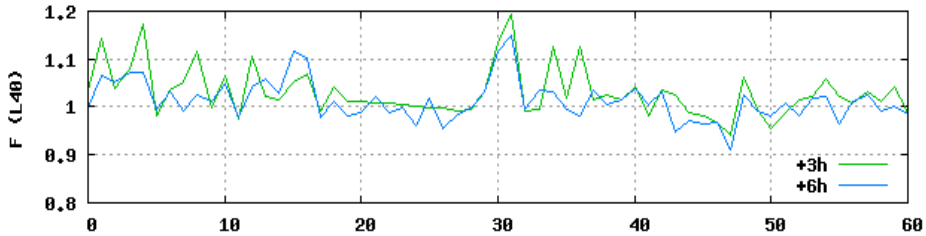
Trade-off between accuracy and (necessary) extrapolation (“balancing”)

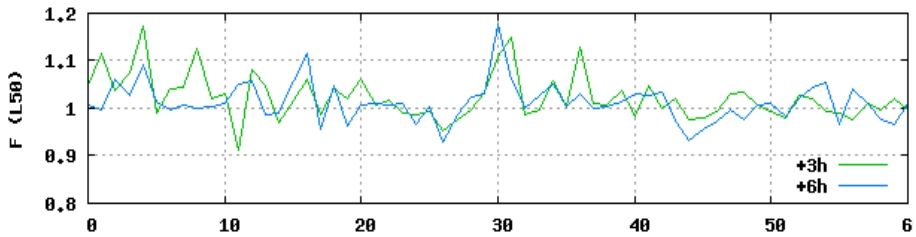






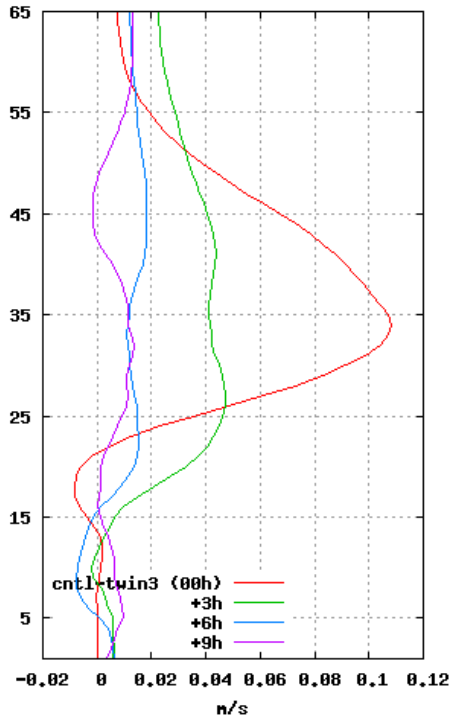


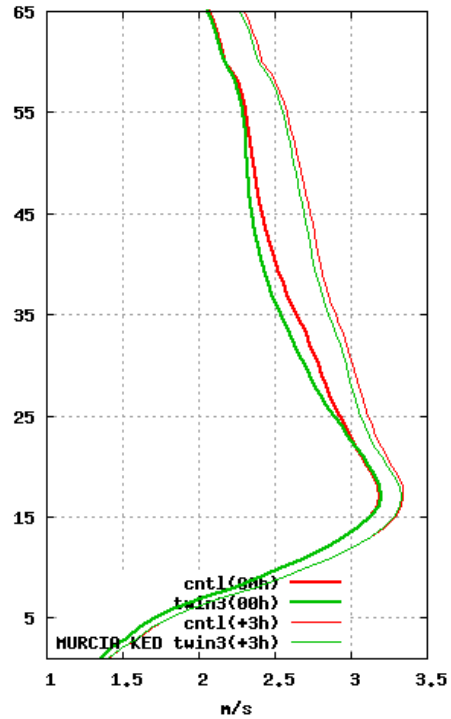


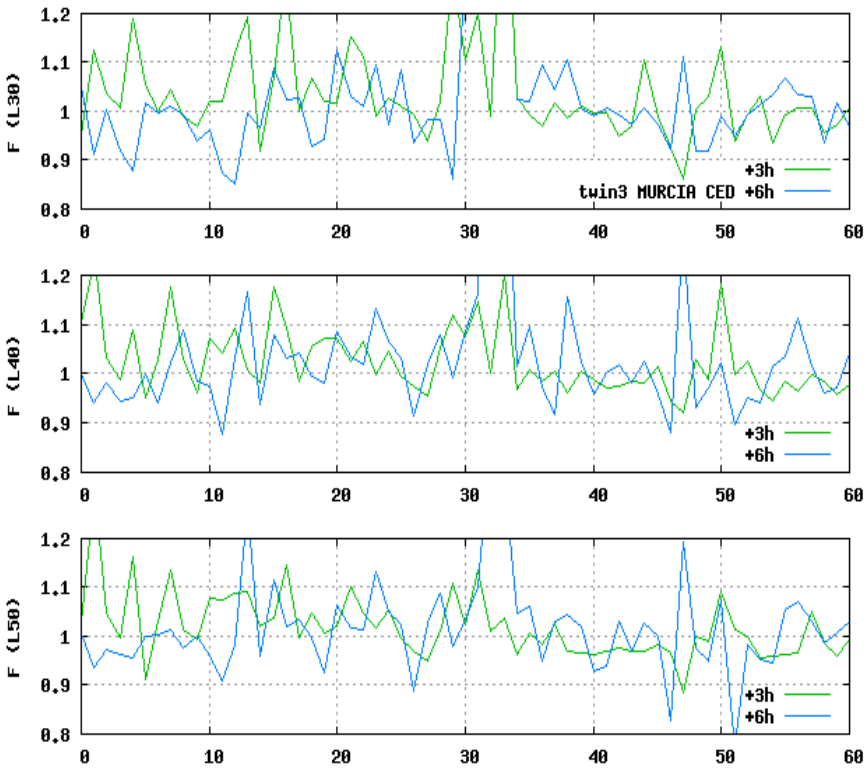


Results for WIND

61 cases, 2 PPI's, No cycling

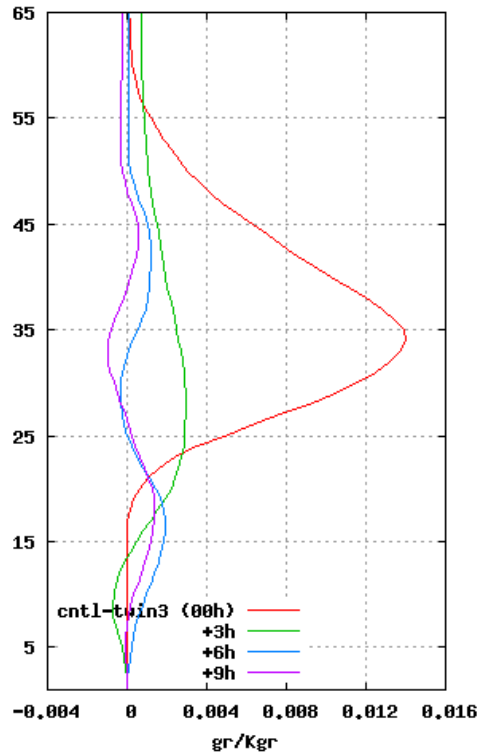


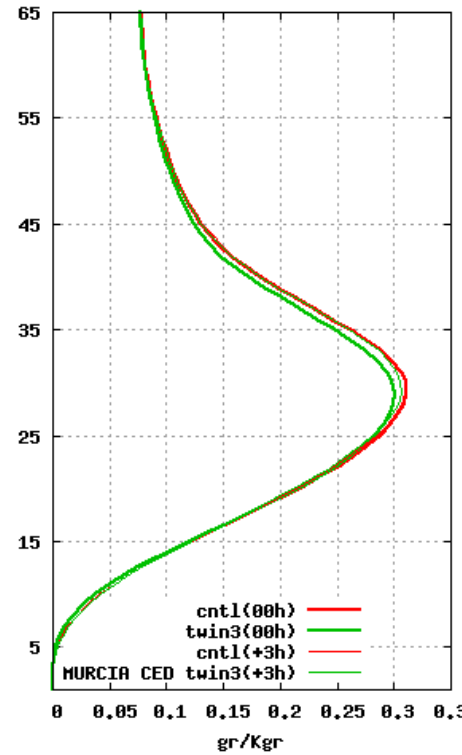


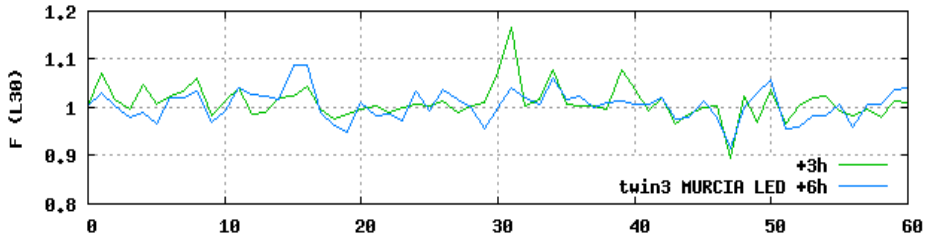


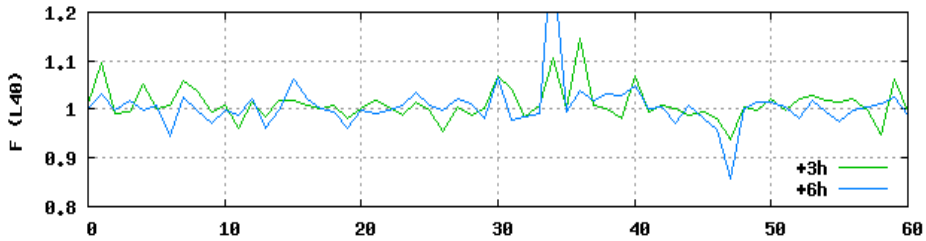
Results for CONDENSATE (rain+graupel+snow)

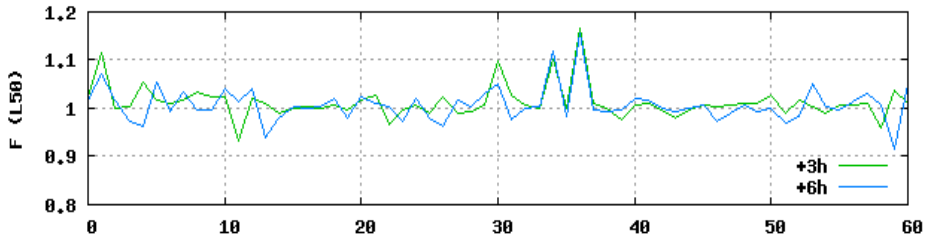
61 cases, 2 PPI's, No cycling





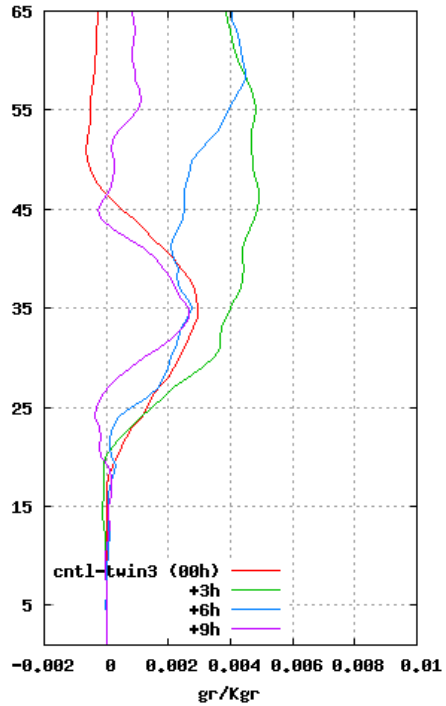


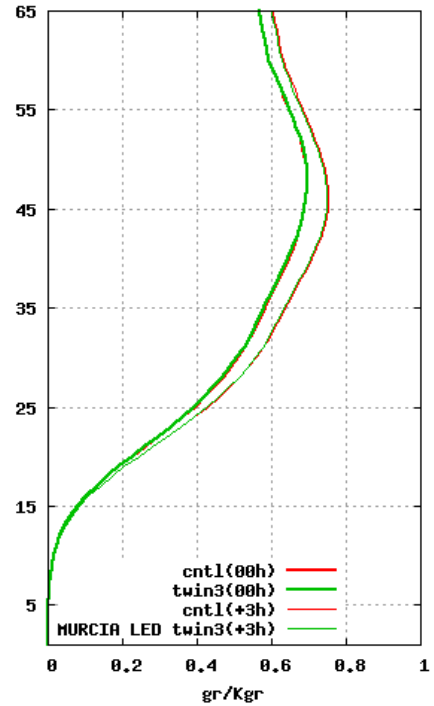


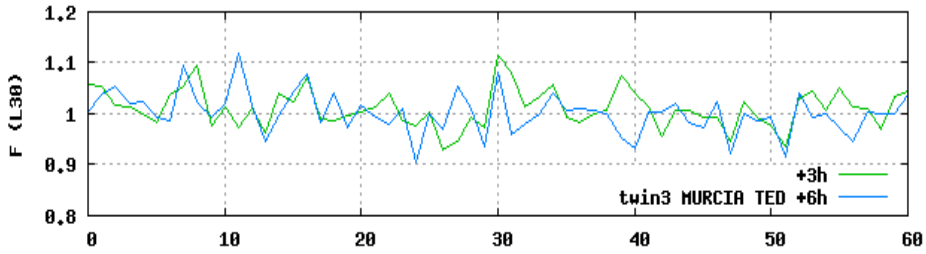


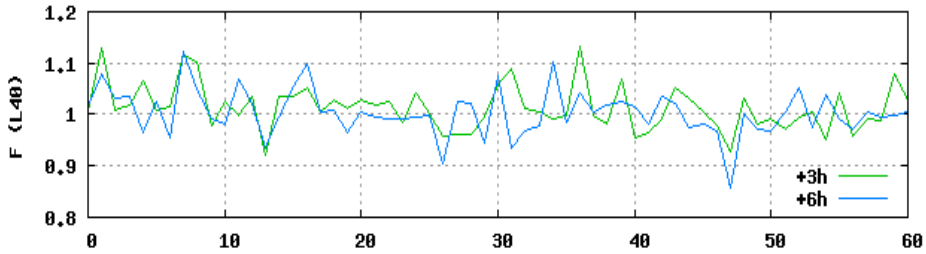
Results for SPECIFIC HUMIDITY

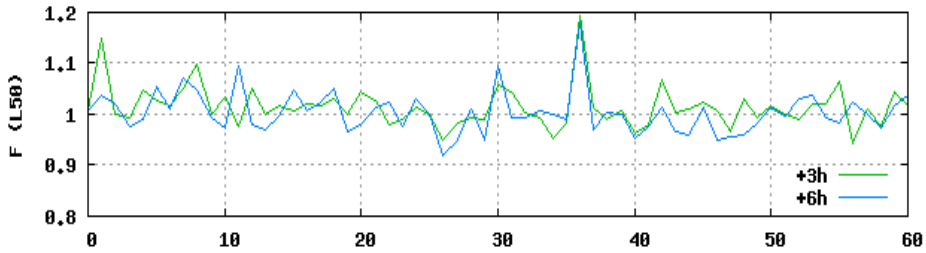
61 cases, 2 PPI's, No cycling





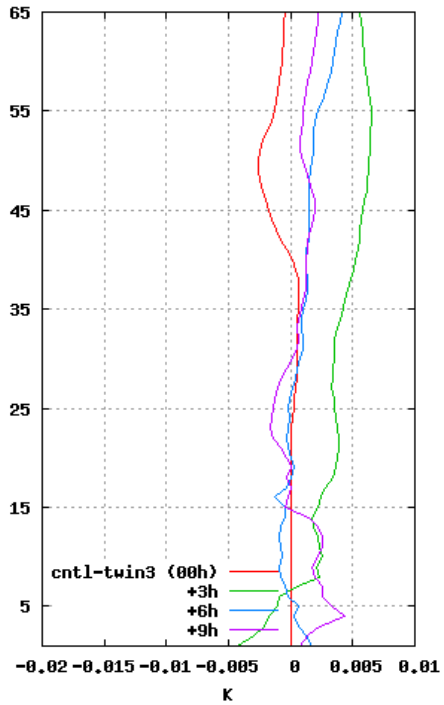


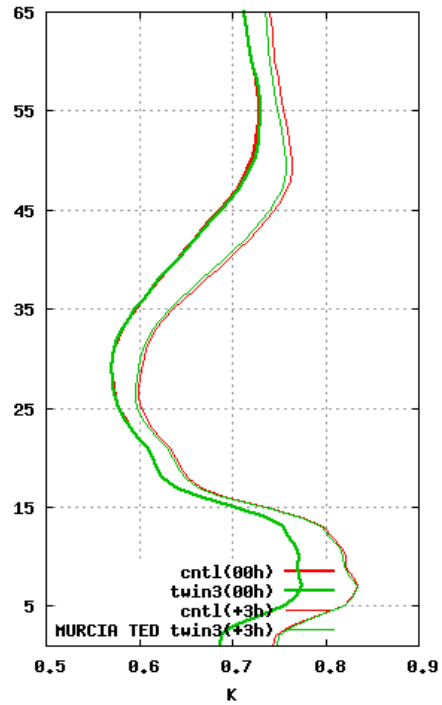




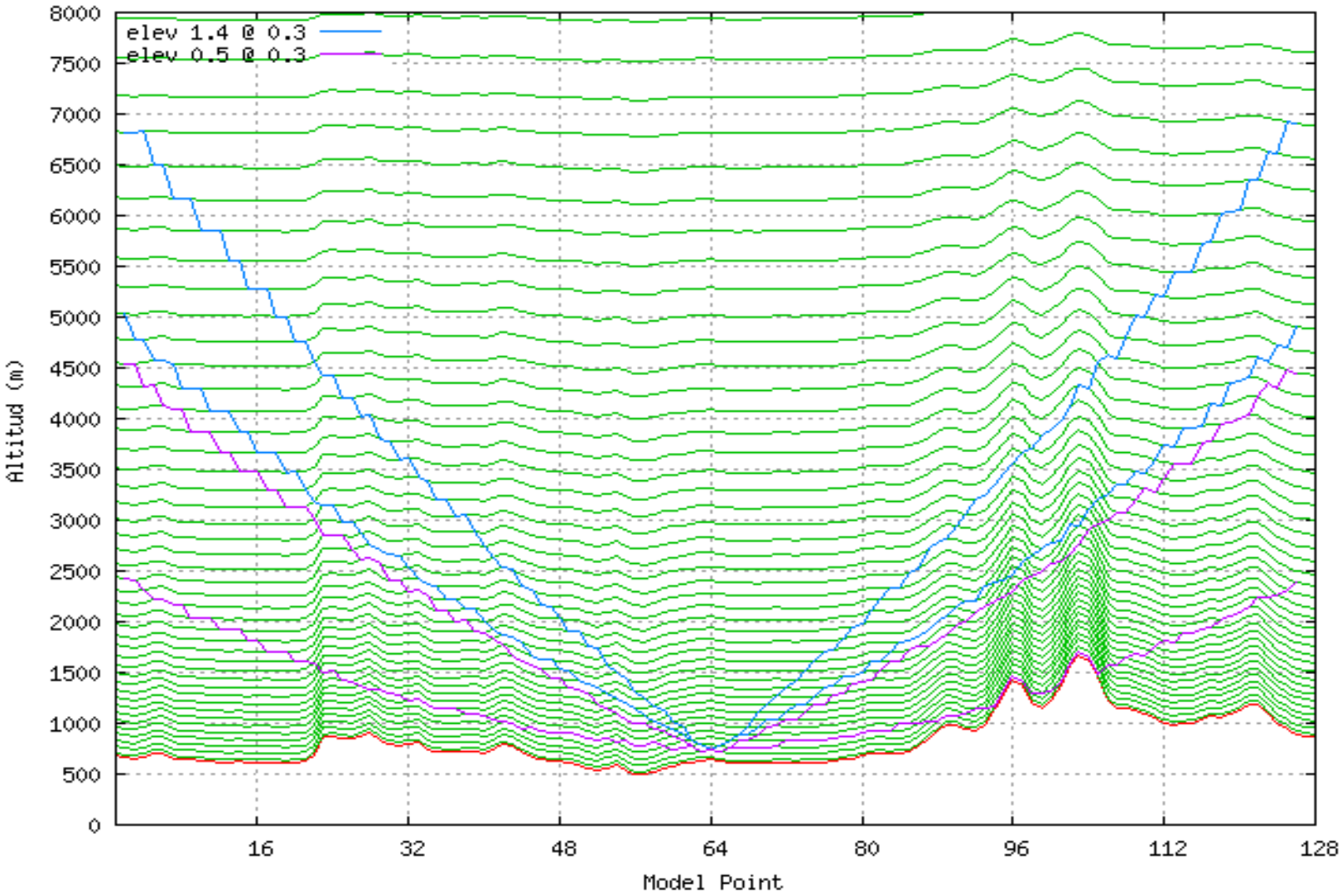
Results for TEMPERATURE

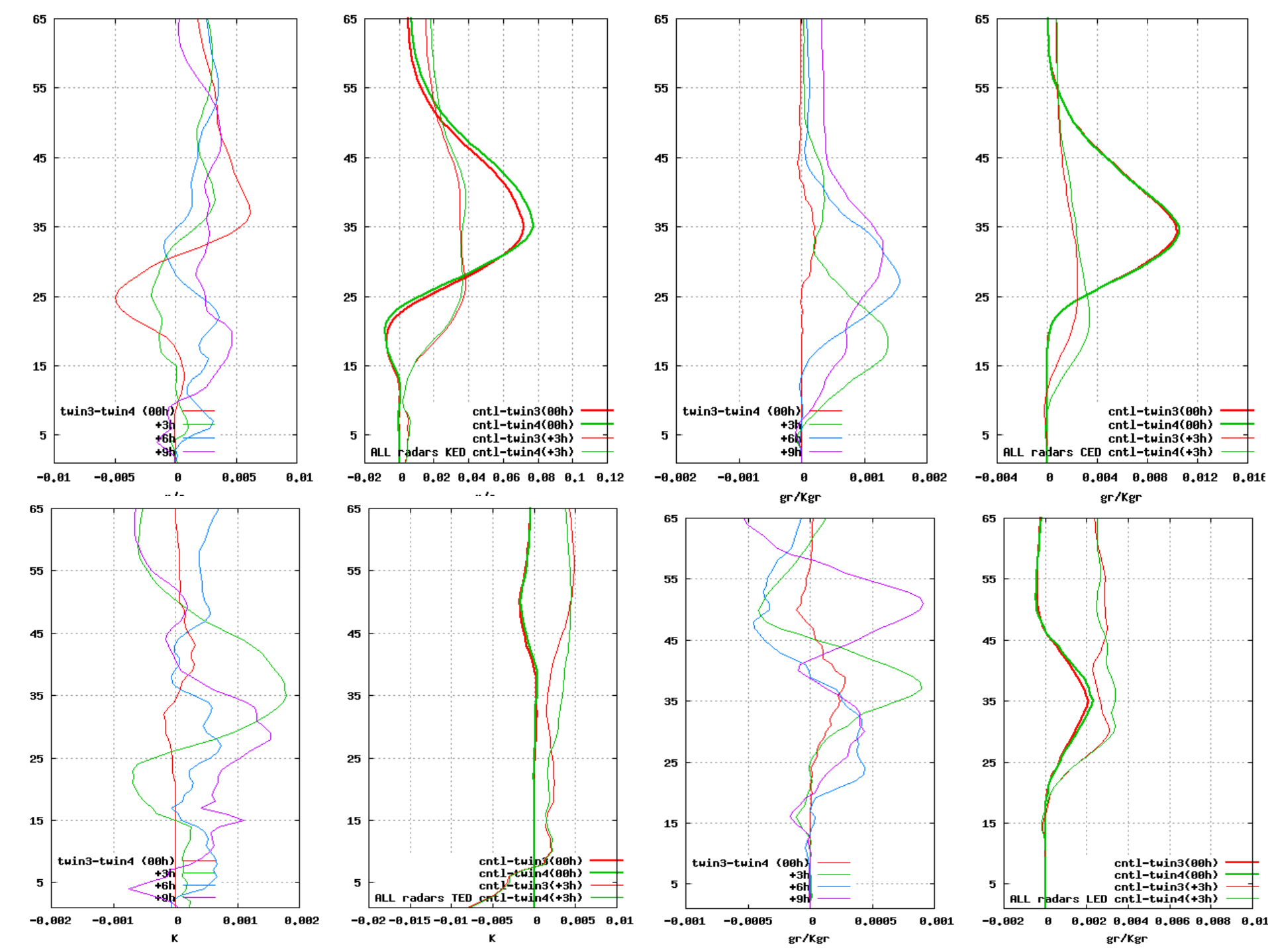
61 cases, 2 PPI's, No cycling





Experiment improving the sampling by addition of one more PPI




twin3-twin4 (00h)
+3h
+6h
+9h
cntl-twin3(00h)
cntl-twin4(00h)
cntl-twin3(+3h)
cntl-twin4(+3h)
ALL radars KED
ALL radars CED
ALL radars TED
ALL radars LED
gr/Kgr
K

CONCLUSIONS AND OUTLOOK

- The FA application for Z and DOW data is completed
- Experience on “how to use” the method and knowledge of its performance is now better
- Validation with simulated observations shows positive results consistently in the first hours of the forecast. More experimentation (cycling) is required
- More evaluations with real data (e.g., SOP-1, HYMEX) should be carried out
- The FA as a new “ingridient” in the search for convection scale DA must be seriously considered