Exploring UA-DA at Sub-Hourly Cycling Frequency with the HARMONIE-AROME System

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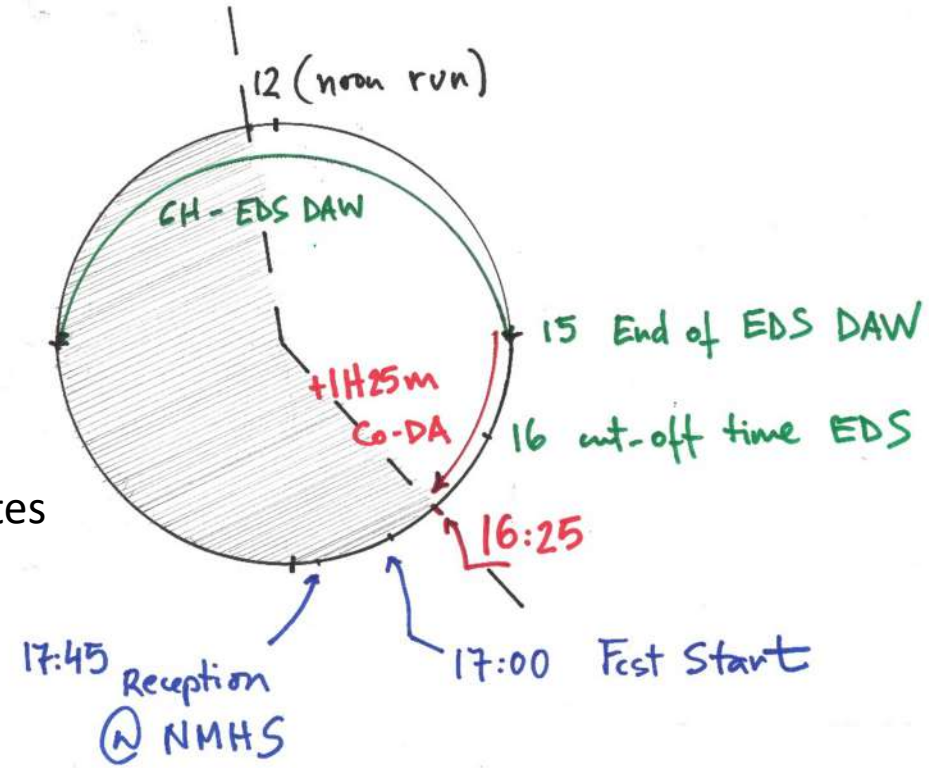
ECMWF Early Delivery System & Co - DA

Why ? Motivation for sub-hourly DA

- In hazardous rapidly developing weather situations which demand close tracking and monitoring

- In the context of VHR forecasting : smaller scales usually imply higher instability growing rates



How ? Two main options can be explored

SBH DA implemented under configuration 131 (variational analysis)

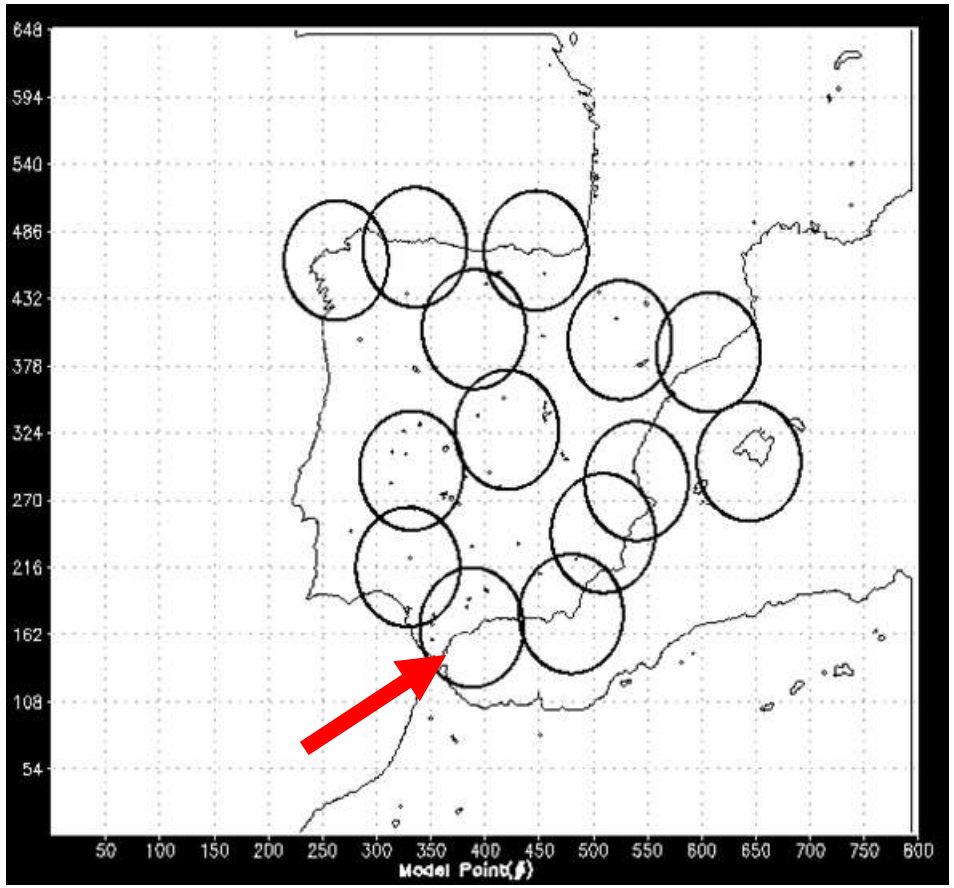
✓ Domain is IBERIAxxm_2.5 (2.5Km 800x648 L65)

✓ Heavy rain episode, in the area of Málaga weather radar, during the evening of 23th and early Morning 24th of March 2022

✓ Default B matrix for this domain in Cy43 (stab_structure_1_2012013118_248)

✓ Synthetic DOW observations. 4 scans with 120 km range, Elevations: 1.8, 1.6, 1.4, 1.2; one volumen every 10 minutes

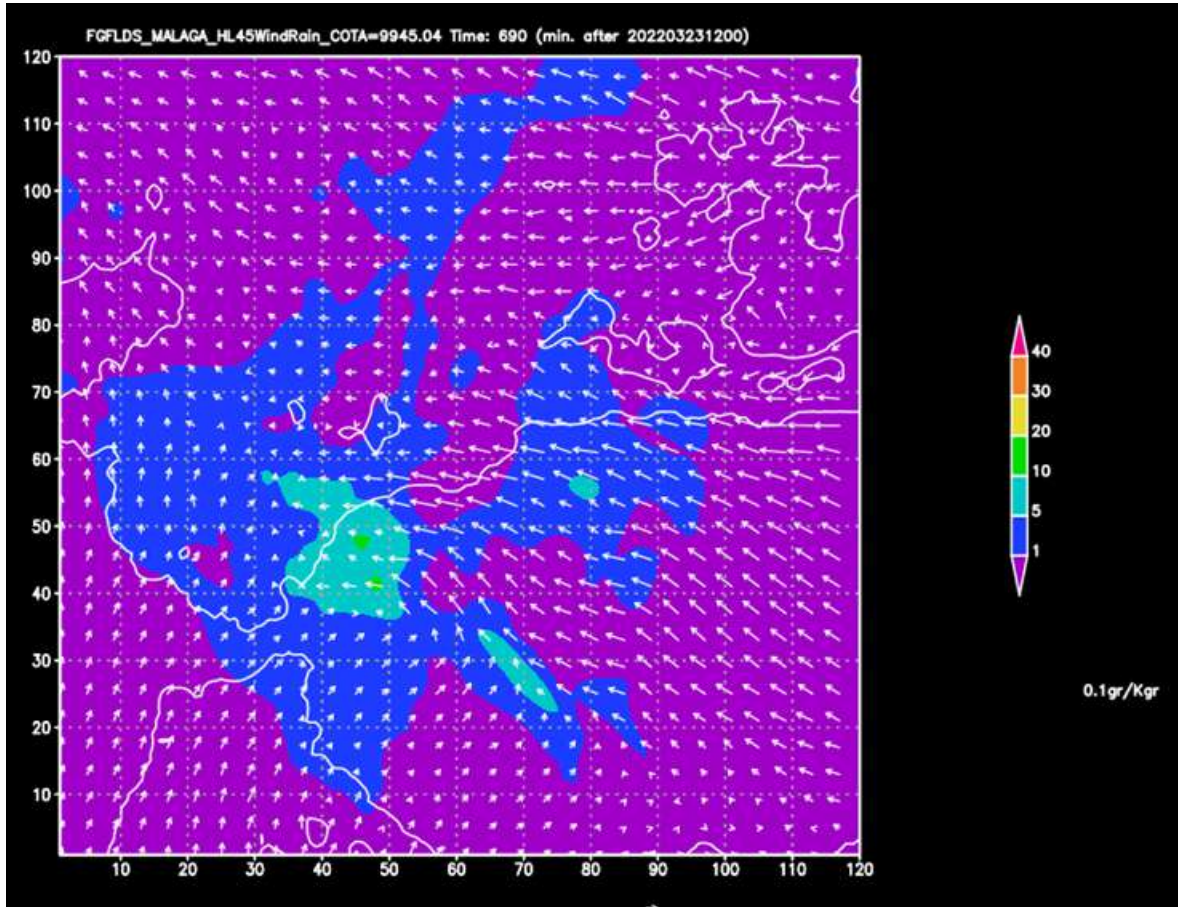
✓ Pseudo wind observations extracted by FA (Field-Alignment)



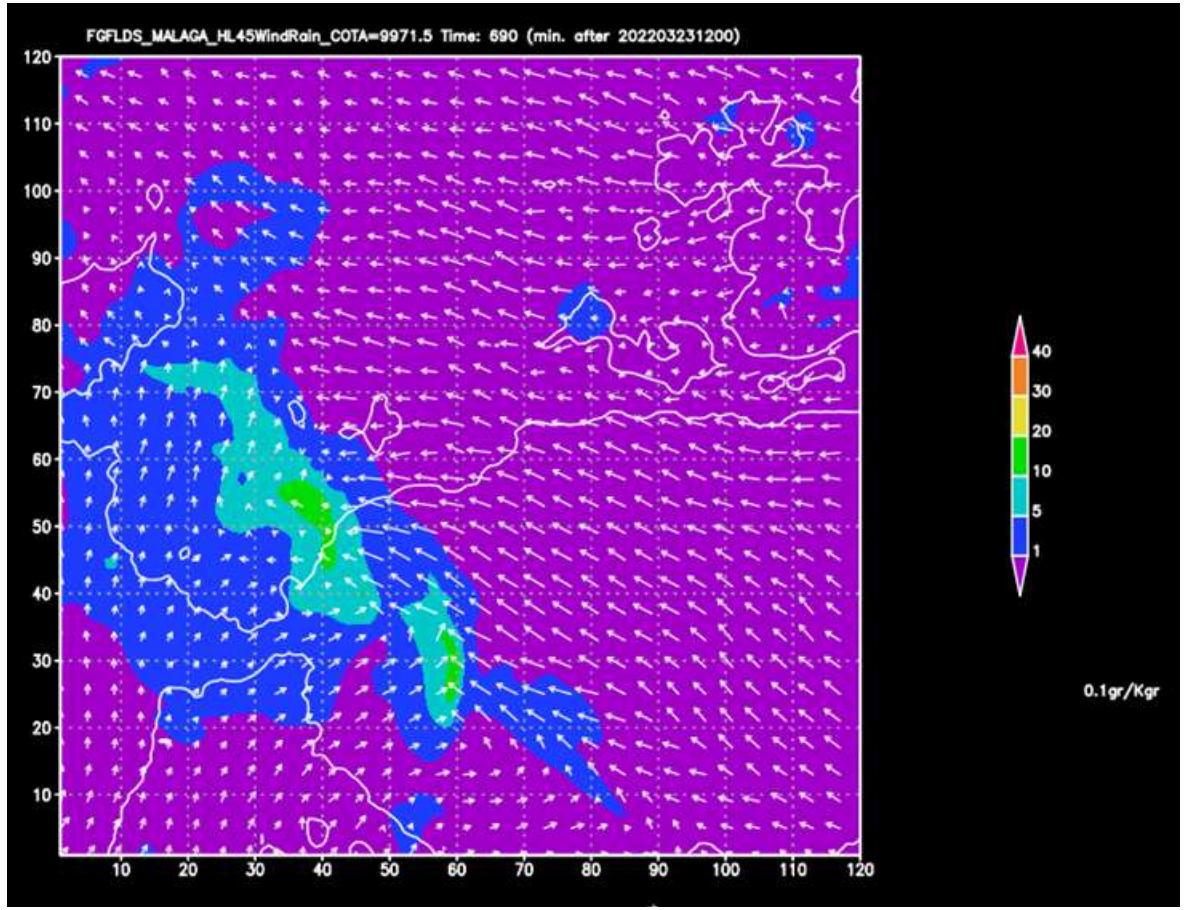
SBH DA implemented under configuration 1 (nudging)

✓ Issue not tackled in this work, but certainly of interest

Truth

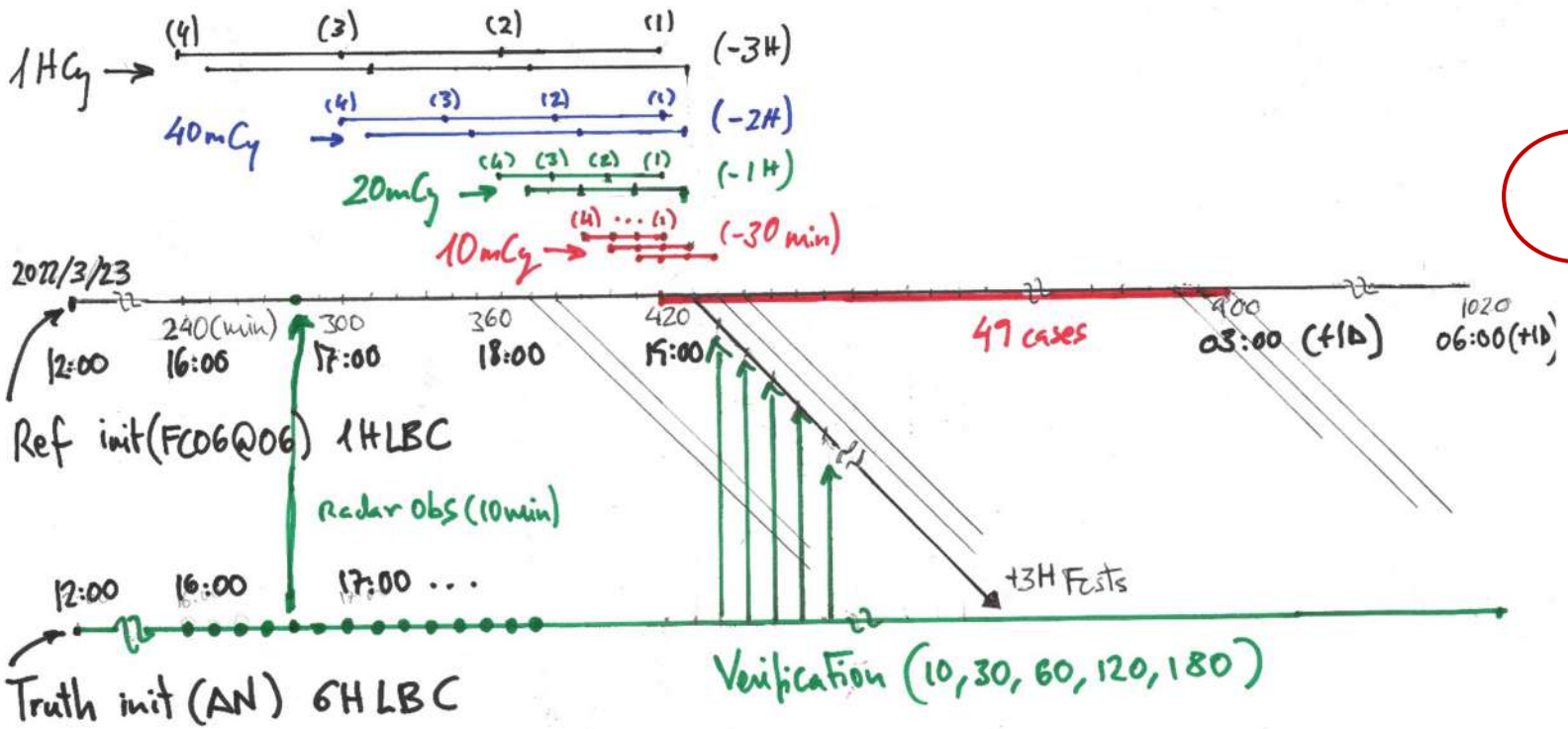


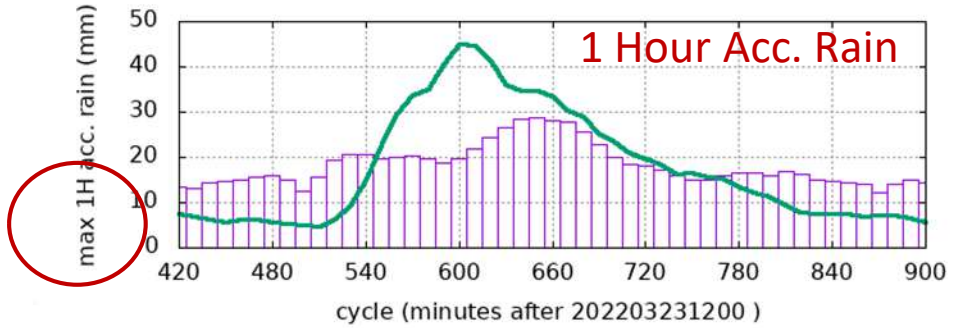
Null Exp (ref)

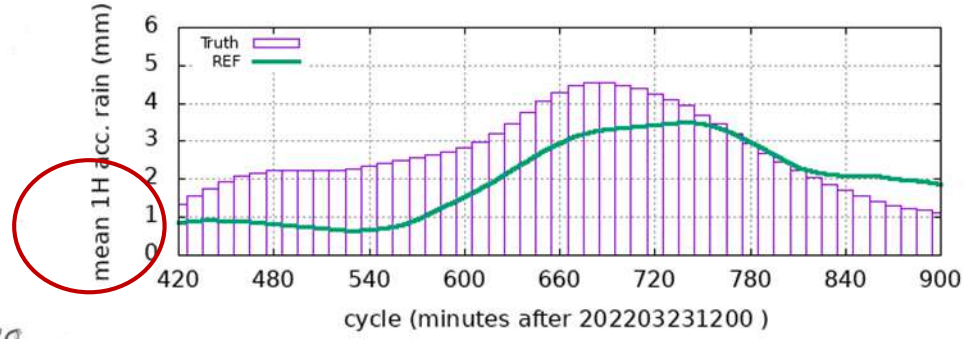


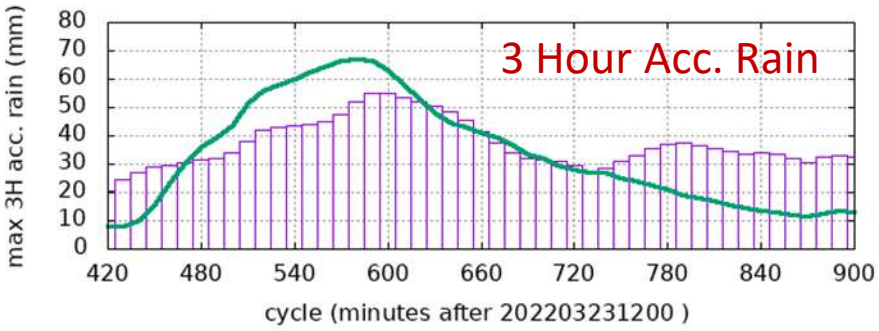
Experiment Set-Up

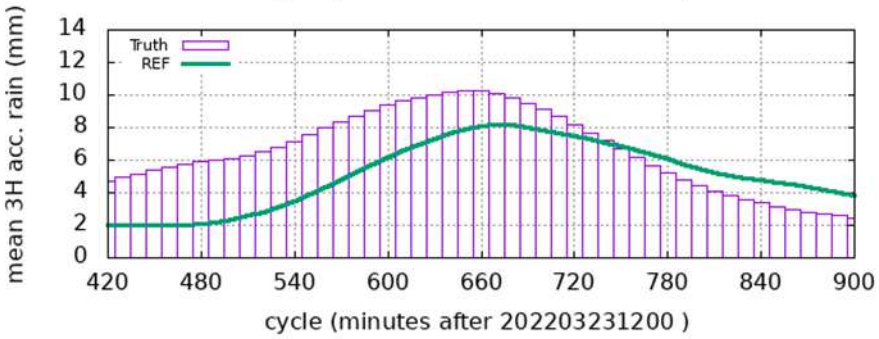
It is a “twin experiment”





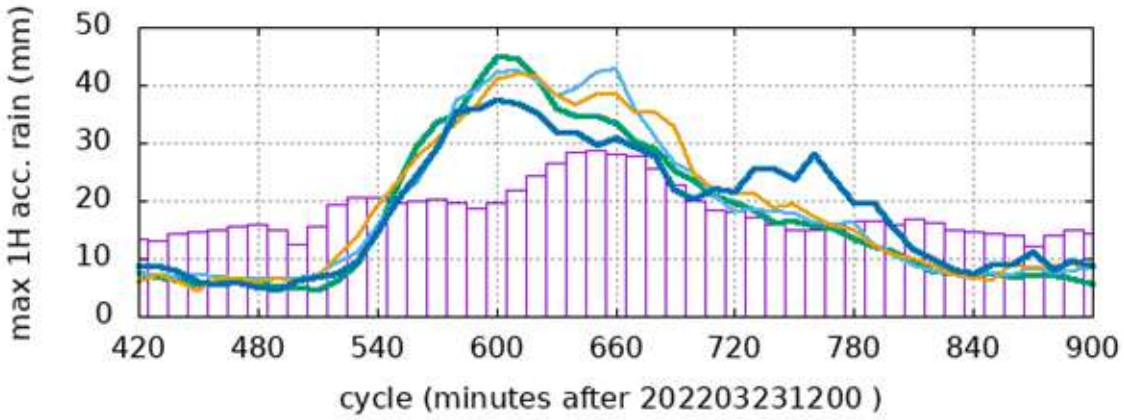


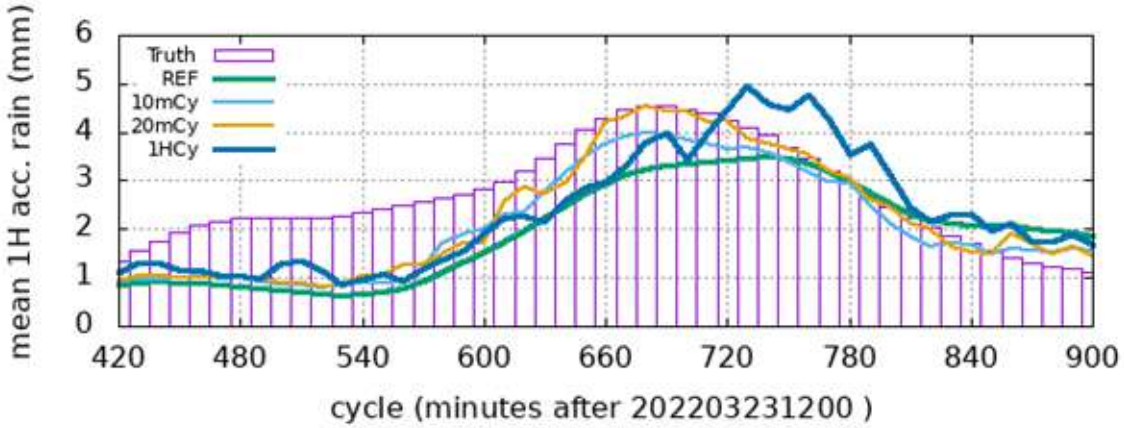




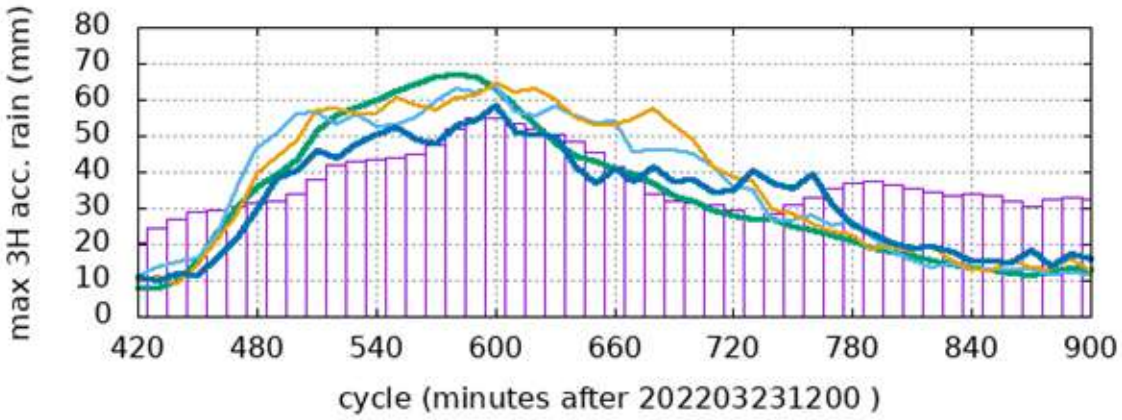
Experiment Results (1)

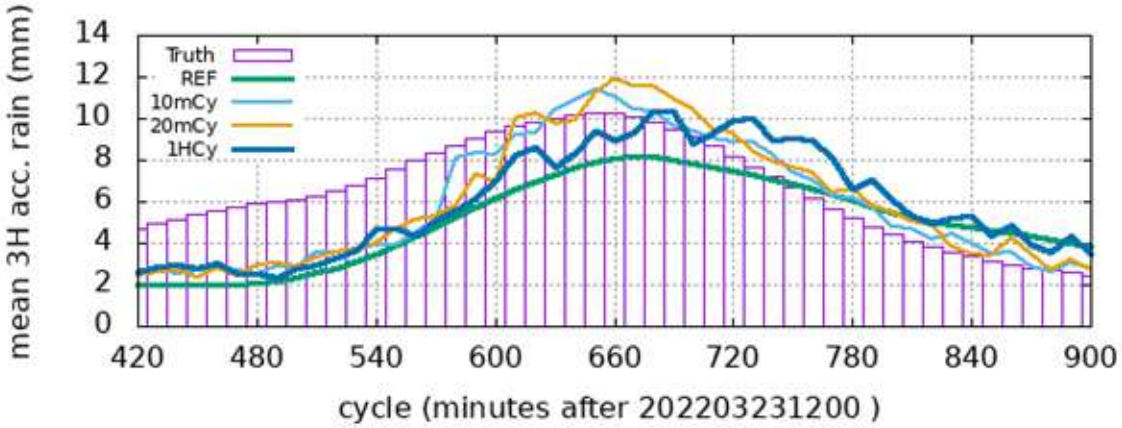
1 Hour Acc. Rain





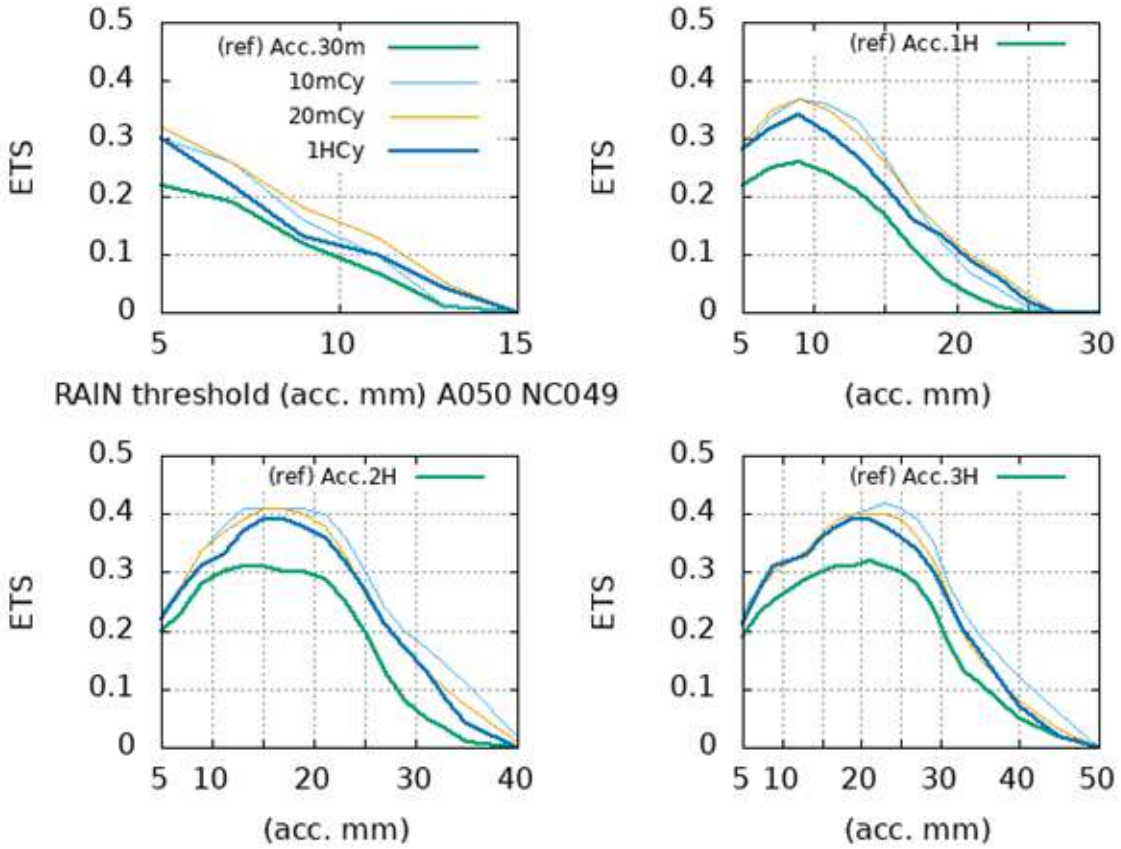
3 Hour Acc. Rain



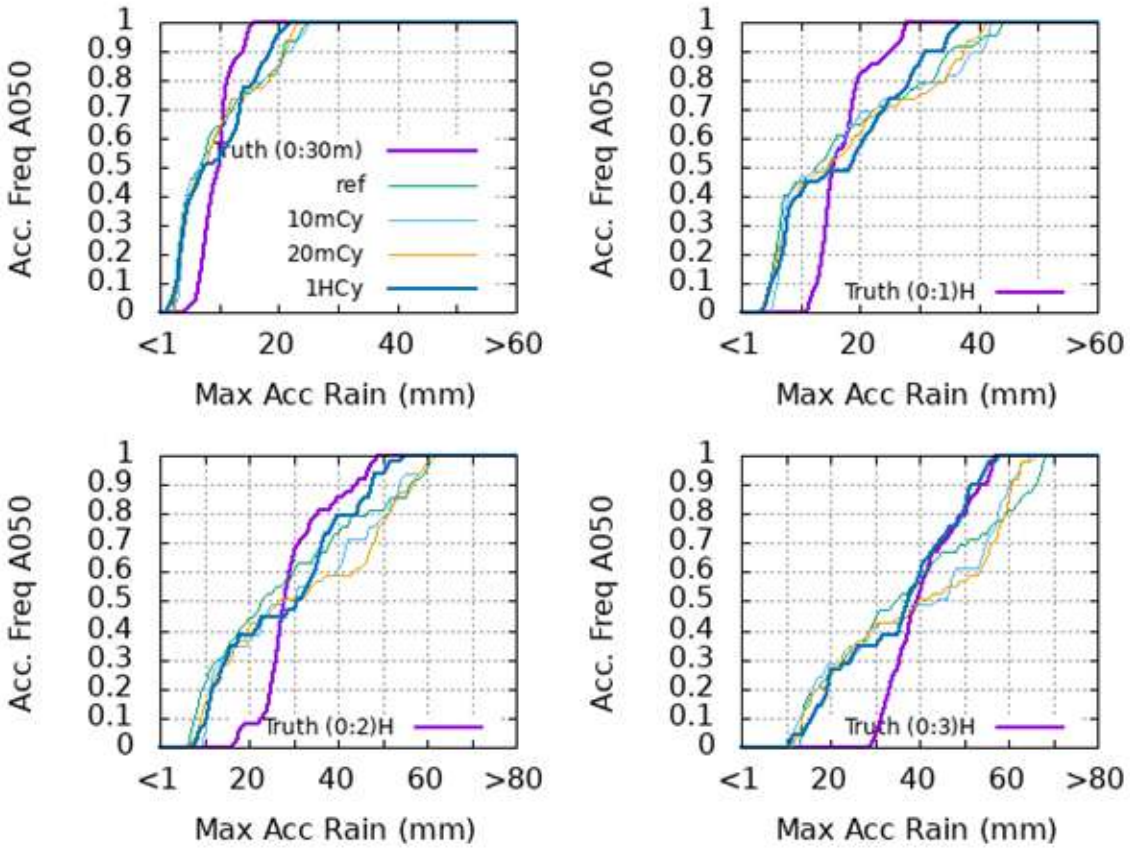


Experiment Results (2)

Equitable Threat Score for Acc. Rain (30min., 1H, 2H, 3H)

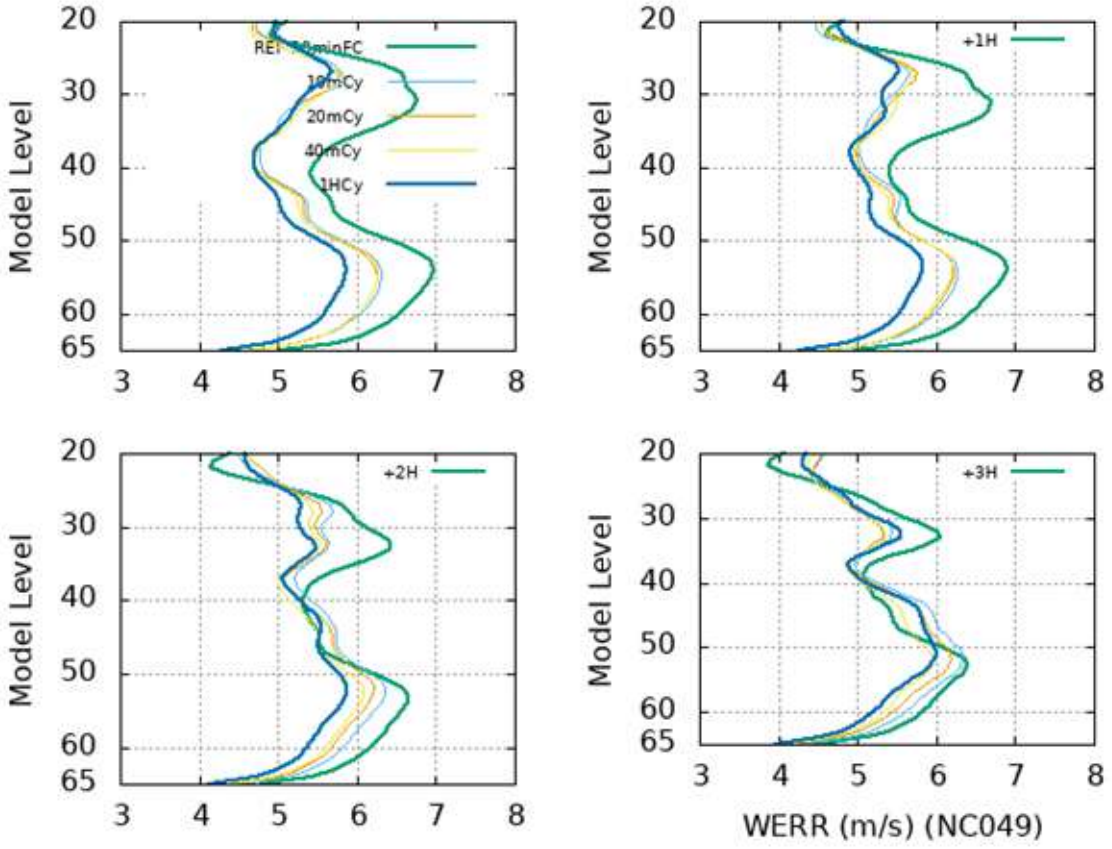


Histograms for Max Acc. Rain (30min, 1H, 2H, 3H)

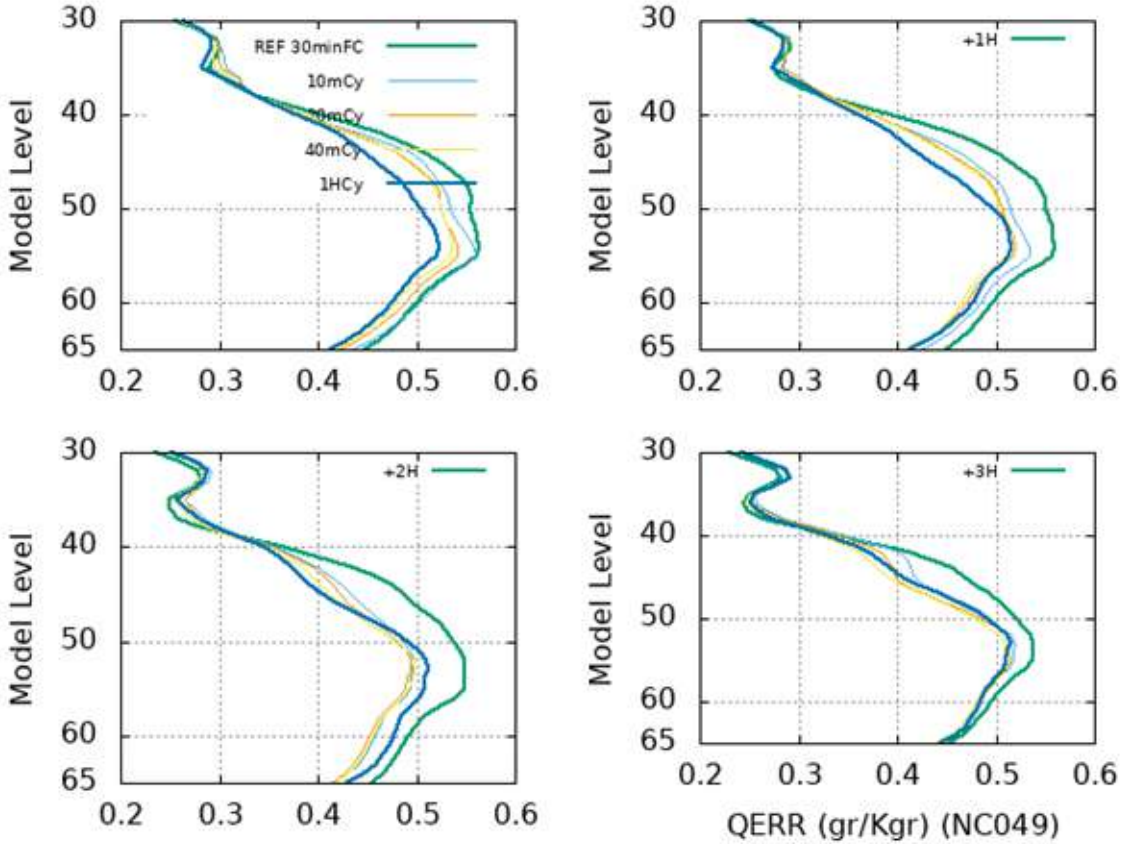


Experiment Results (3 and …)

Mean Wind **Error** Vertical Profiles (30min., 1H, 2H, 3H) Fcst

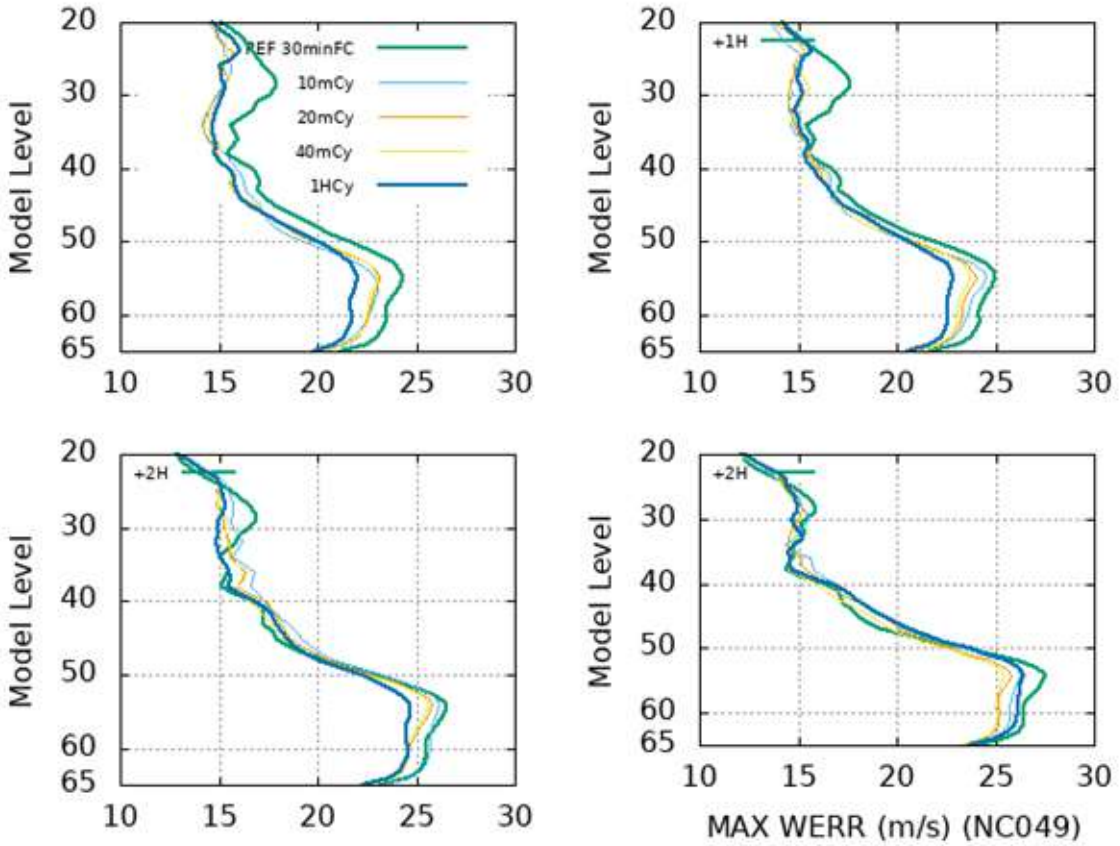


Mean Specific Humidity **Error**

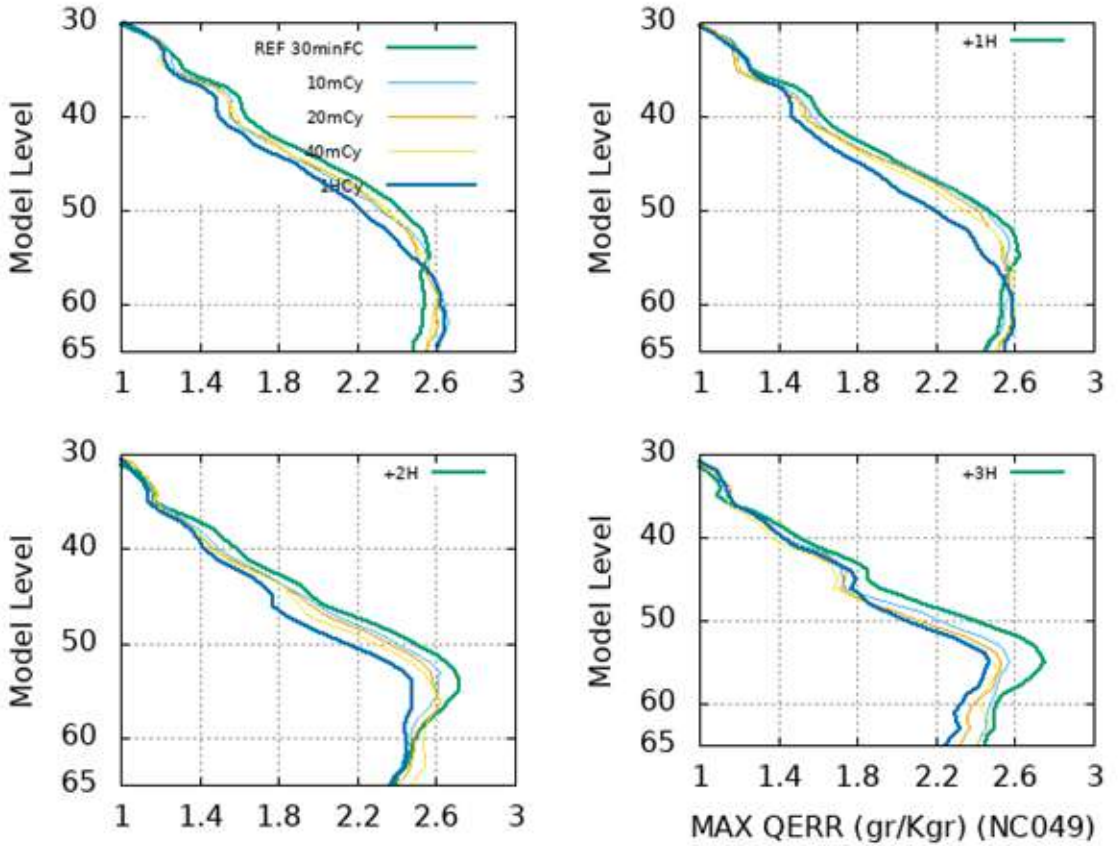


Experiment Results (4)

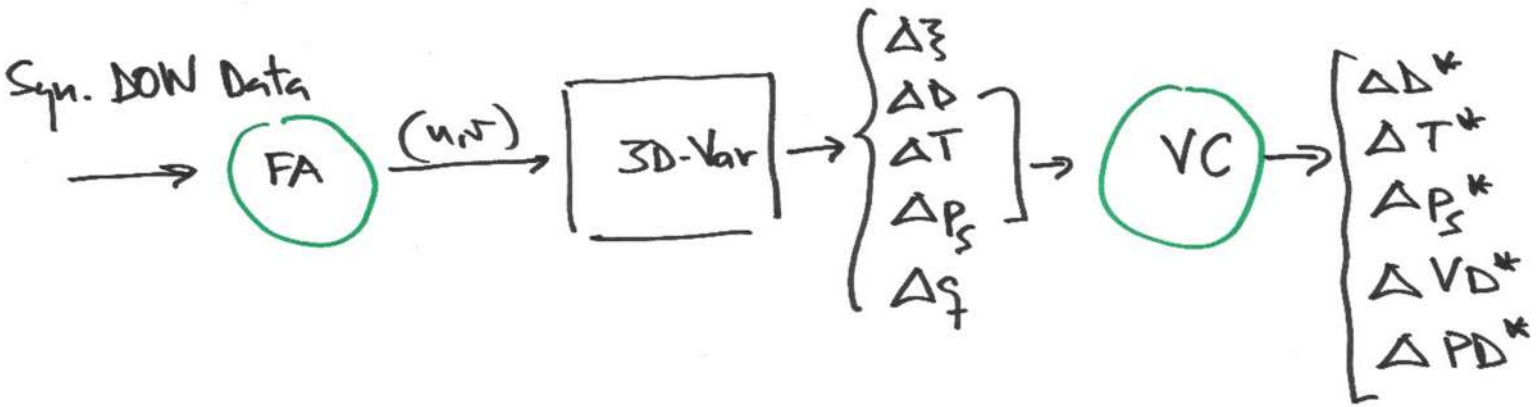
MAX Wind **Error** Vertical Profiles (30min., 1H, 2H, 3H) Fcst



MAX Specific Humidity **Error**



Impact from VC



Formulation of Balances for ALADIN-NH dynamics

$$2J(\Delta x) = \int_{o}^{\bar{\xi}} w\left(\Delta x - d\right)^2 + \left(M\ \Delta x\right)^2 = \int_{0}^{\bar{\xi}} w\left(\Delta x - d\right)^2 + C_1^2 + C_2^2 + C_3^2 + C_4^2$$

$$\Delta x^T = \left(\Delta gw\ ,\ \Delta D\ ,\ \Delta T\ ,\ \Delta \pi_s\right) \quad ; d^T = \left(gw_o - gw_b\ ,\ D_o - D_b\ ,\ T_o - T_b\ ,\ \pi_{s,o} - \pi_{s,b}\right) = \left(d_{gw}, d_D, d_T, d_{\pi_S}\right)$$

$$C_1 = \left(-\lambda + \partial\left(\partial + 1\right)\right)\Delta gw \equiv L\left[\Delta gw\right] \quad ; \qquad \Delta gw = \frac{\left(\Delta gw'\right)\Delta t}{RT^*} \quad ; \quad \lambda = \frac{1 + \gamma K^2\left(1 + \frac{R}{c_p}\omega_b^2\right)}{\gamma \omega_b^2}$$

$$C_2 = -K^2\left(1 + \gamma\ \partial\right)\Delta gw + \left(1 + \gamma\ K^2\right)\Delta D \quad ; \qquad \Delta D = \left(\Delta D'\right)\Delta t$$

$$C_3 = \Delta T + \frac{R}{c_v}\left(\Delta D - \partial \Delta gw\right) \quad ; \qquad \Delta T = \frac{\Delta T'}{T^*}$$

$$C_4 = \Delta \pi_s + N\left[\Delta D\right] \quad ; \qquad \Delta \pi_s = \frac{\Delta \pi_s'}{\pi_s^*}$$

When **J is made stationary** the following system of equations is obtained

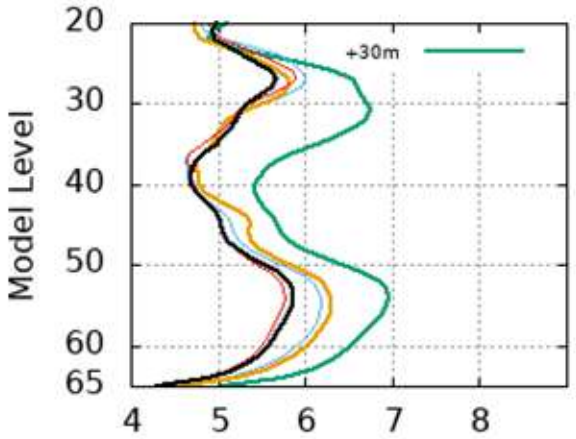
$$M^{+}M\,\Delta x + w\,\Delta x = w\,d; \quad w = \frac{w_o}{w_c};$$

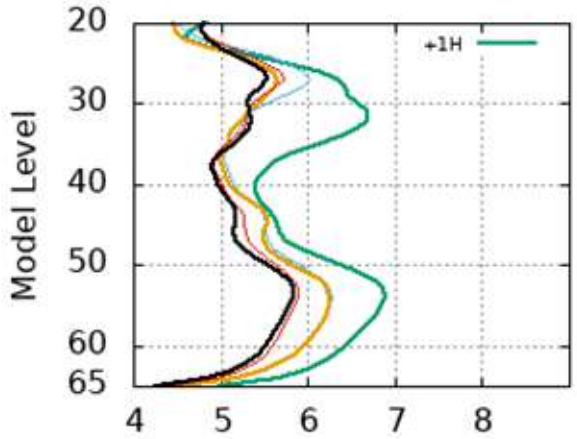
$$M = \begin{bmatrix} L & 0 & 0 & 0 \\ -K^2(1+\gamma\,\partial) & (1+K^2\,\gamma) & 0 & 0 \\ -\frac{R}{c_v}\partial & \frac{R}{c_v} & 1 & 0 \\ 0 & N[\ ] & 0 & 1 \end{bmatrix} \quad M^{+} = \begin{bmatrix} L^{+} & -K^2(1-\gamma\,\partial) & \frac{R}{c_v}\partial & 0 \\ 0 & (1+K^2\,\gamma) & \frac{R}{c_v} & N^{+}[\ ] \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

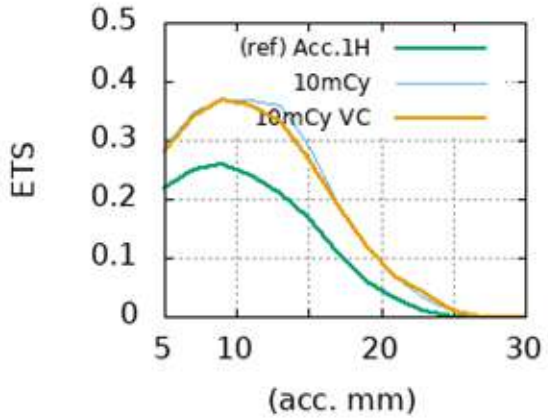
which turns out to be another elliptical boundary value problem (of 4 th order) on Δgw

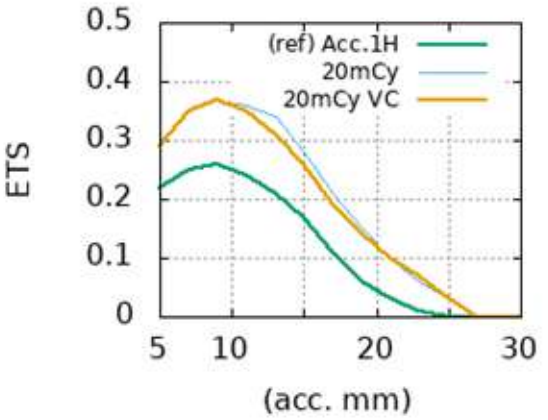
$$\Delta gw(0) = \Delta gw(\bar{\xi}) = \Delta\partial gw(0) = \Delta\partial gw(\bar{\xi}) = 0$$

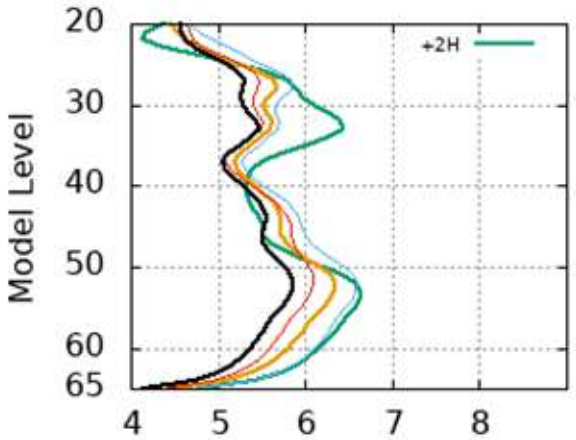
Impact from VC

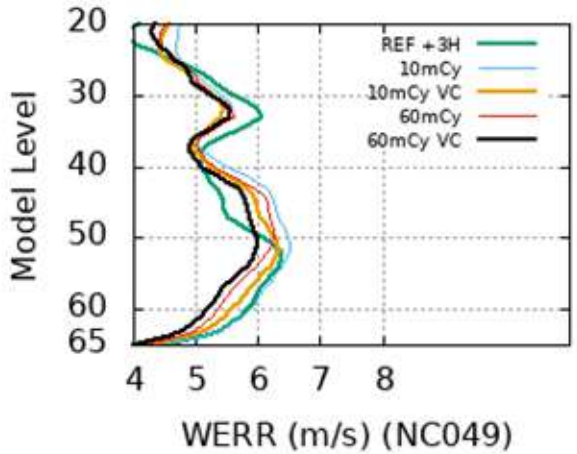


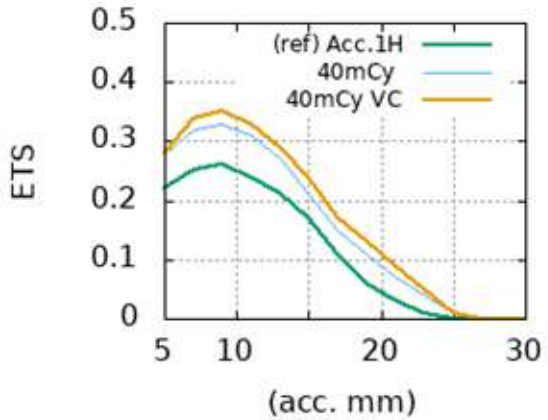


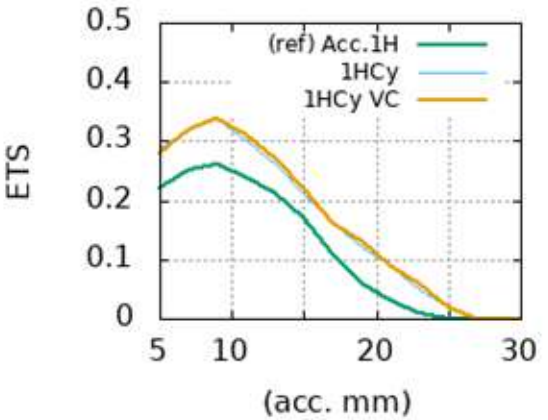


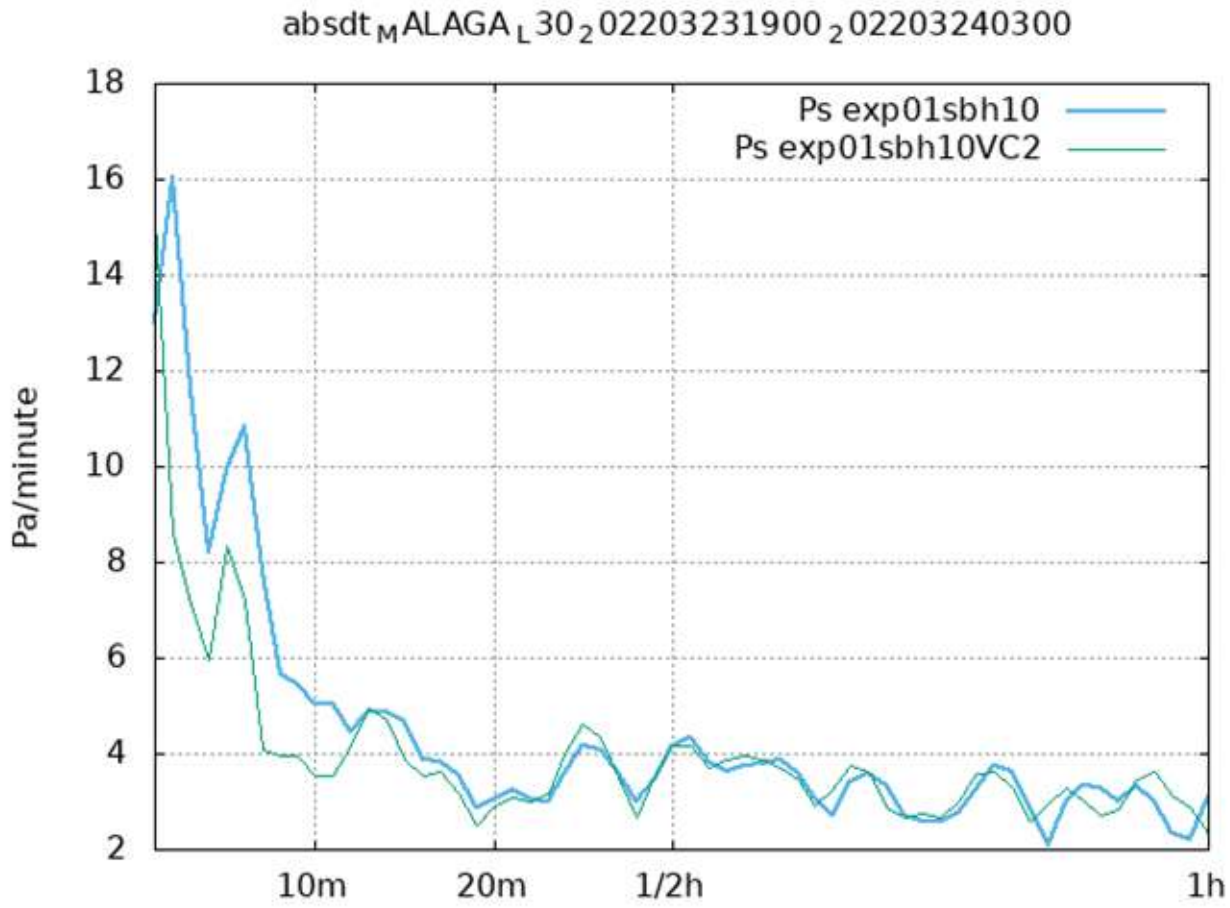


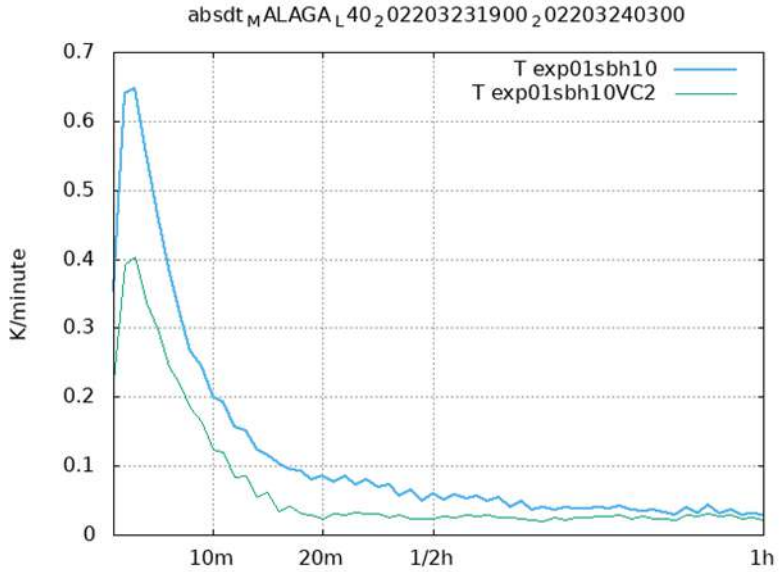


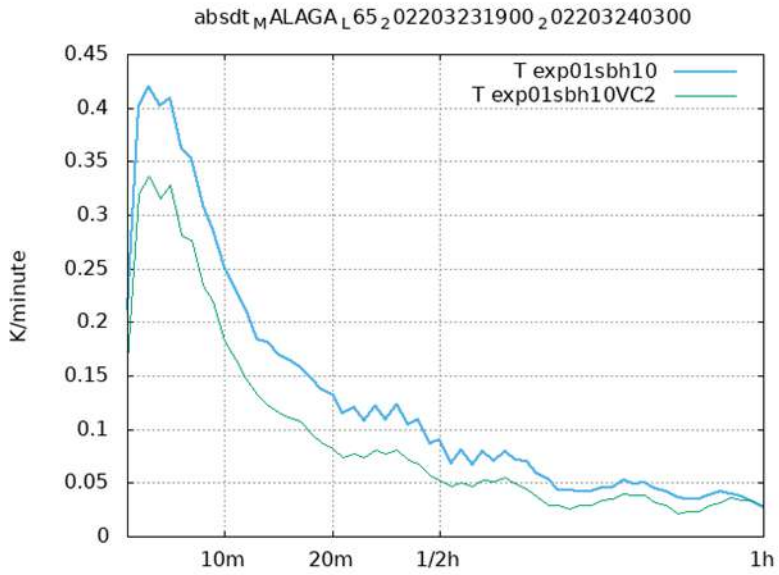




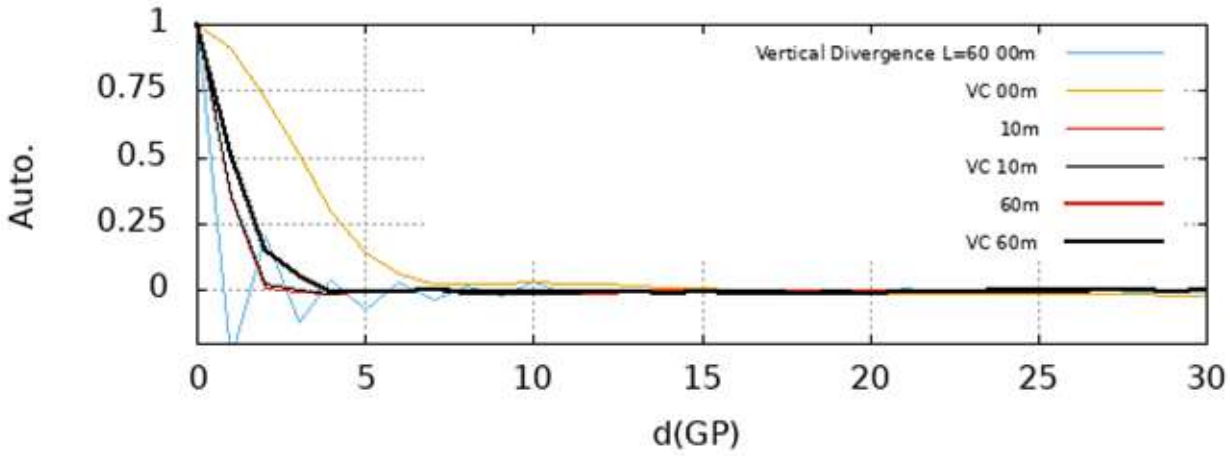


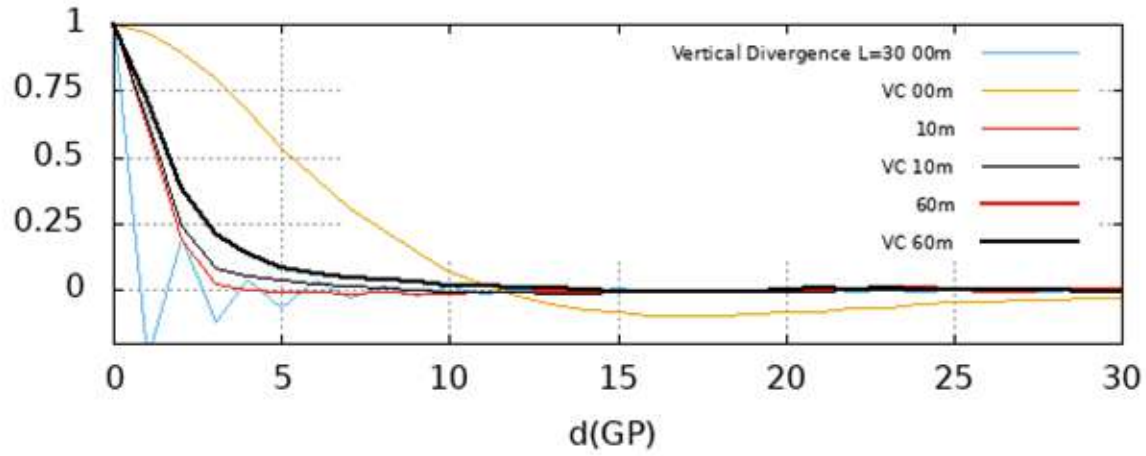

absdt_M ALAGA_L 30_2 02203231900_2 02203240300
Ps exp01sbh10
Ps exp01sbh10VC2
Pa/minute
18
16
14
12
10
8
6
4
2
10m
20m
1/2h
1h

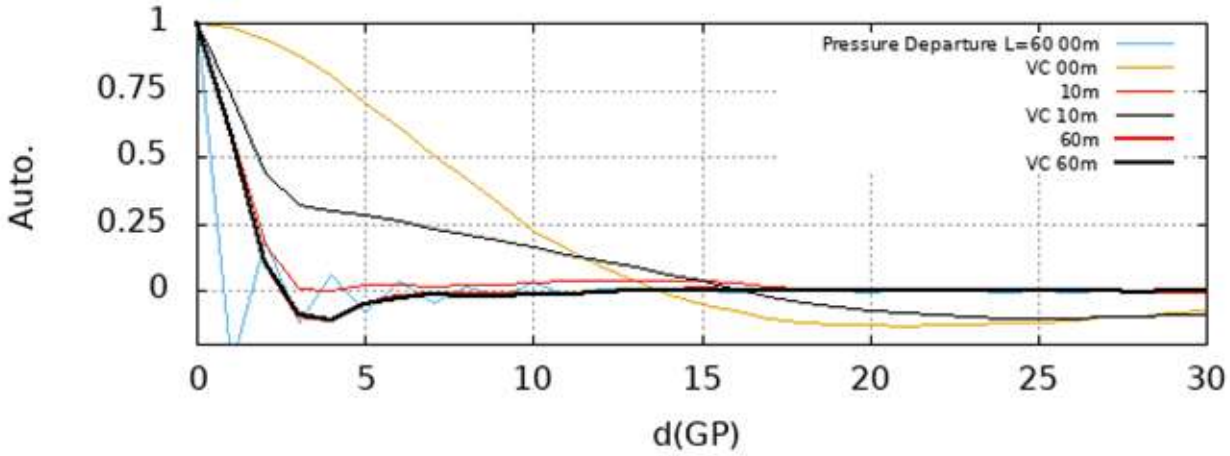

absdt_M ALAGA_L 40_2 02203231900_2 02203240300
T exp01sbh10
T exp01sbh10VC2
K/minute
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10m
20m
1/2h
1h

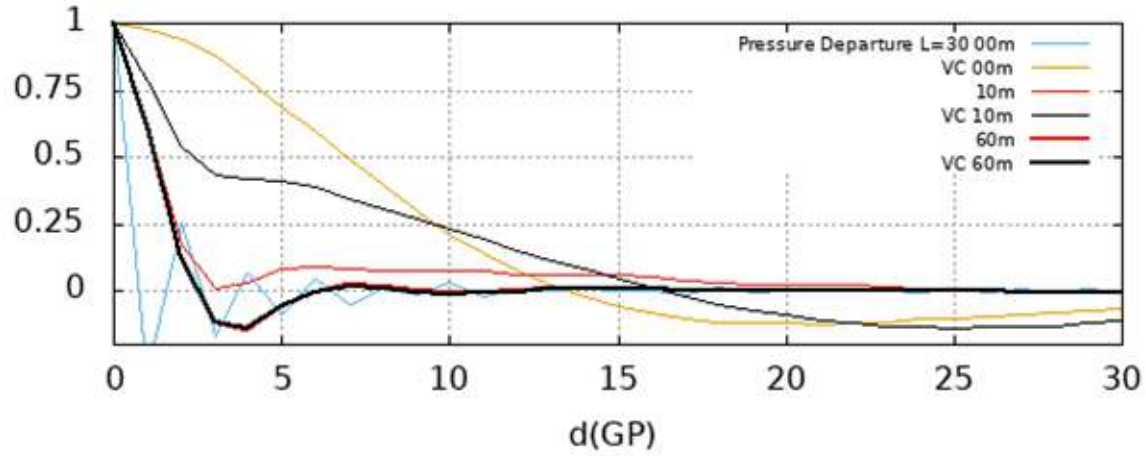

absdt_M ALAGA_L 65_2 02203231900_2 02203240300
T exp01sbh10
T exp01sbh10VC2
K/minute
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
10m
20m
1/2h
1h

Impact from VC, autocorrelation functions over the radar area for PD and VD. L60 (left), L30 (right)

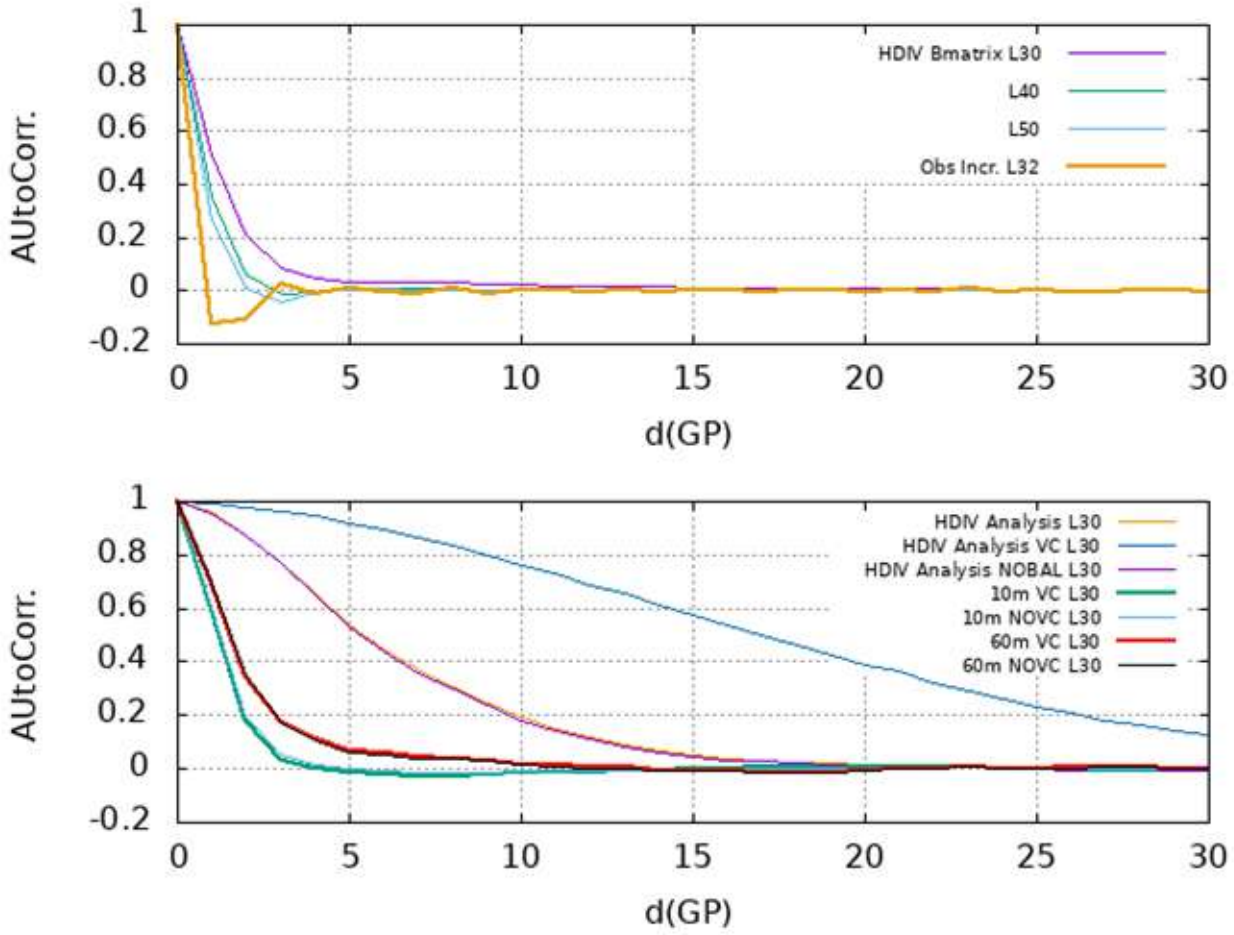








Balances and Initialization



The horizontal B structure functions employed in this work and Obs increments from radar data, display short horizontal correlation length scales (**upper plot**)

The analyses show distinctive large horizontal correlation length scales. When VC is applied, even larger (double Low Pass).

The situation does not change when the balances implemented in B are switched off

Conclusion:

- ✓ Vertical B correlation structure functions smooth a lot the horizontal increments
- ✓ These distinctive scale features in the analyses do not survive a long time in the forecasts

What has been achieved / learned from these experiments ?

- Sub-hourly technical implementation done for configuration 131
- These first sub-hourly tests show that there is no advantage over 1H cycling
- VC impact small. It improves sub-hourly results but still below the 1H cycling marks
- As central object in 3D-Var, the estimation of B should be examined closer
- Weak link between analysis and dynamics