Towards a NWC Application Based on HARMONIE-AROME

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Some considerations about NWP-NWC

- **LAM .vs. GLOBAL-NWP**. GLOBAL-NWP will always have it difficult to provide this kind of service. Strategic interest for LAM-NWP operators.

- **DA is at the core of a NWP-NWC system**. DA improved as the most practical way to tackle and give first benefits in forecasting atmos. phenomena with very short predictability time scales.

- DA developments in LAM-NWP and **DA legacy and directives from GLOBAL-NWP.** Time to break up ?

- Near future foreseable scenario**: important increase in atmos. data *flux*.** (e.g. crowd sourced data). Given that management and technical issues are sorted out: what to do with all these data ?

- **Ensemble generation for NWC**. DA a key element

- A big challenge in many respects. **Comprehensive re-organization of production** after requirements of adaptability and early delivery. (UWC opportunity situation ?)

Towards a NWC prototype on HARMONIE-AROME

Work during last months to integrate in v40 some interesting **NWC oriented developments**

(RWP 2019, WP DA-2 "Development of Flow-Dependent Algorithms",
WP DA-5 "Development of DA suited for NowCasting")

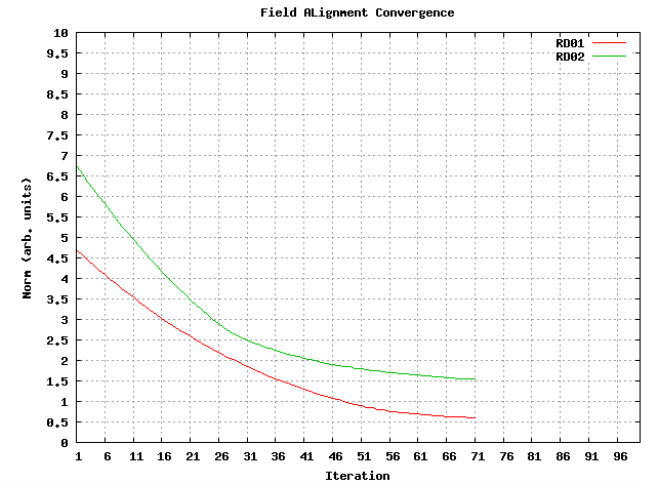
1. The Field-Alignment software running in configuration 131 (variational job).
   Also in configuration 2 (screening) ?

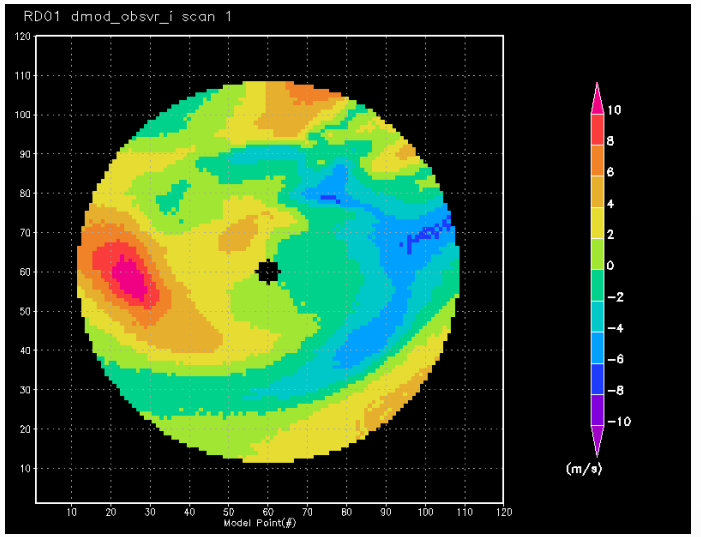
2. Variational Constraints to better balance, as dictated by SI dynamics, the initial conditions, also (to be) integrated in confg. 131

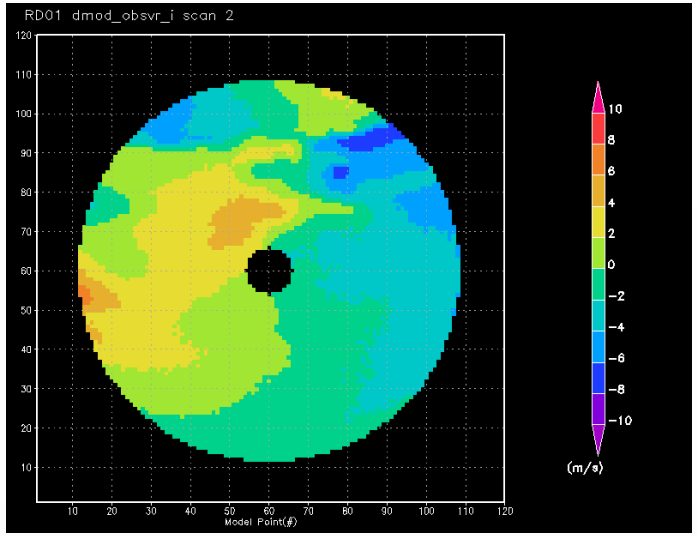
3. Introduction of Flow-dependency in covariances by means of Gaussian Integrals ?

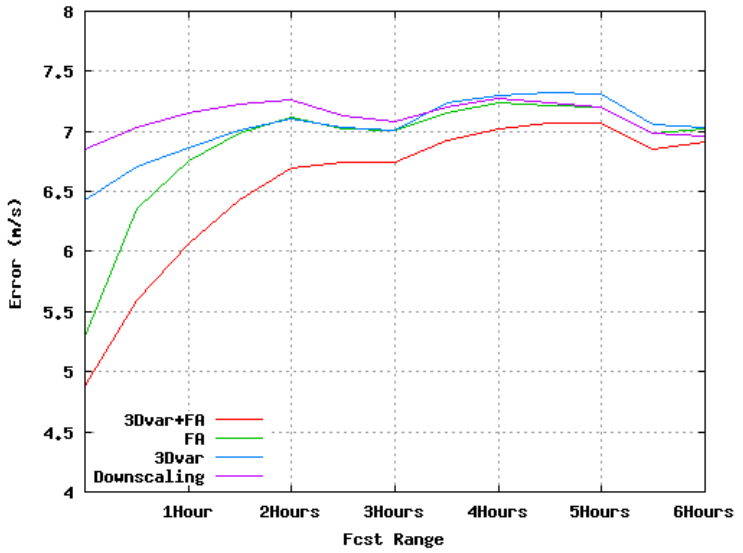
FIELD ALIGNMENT:

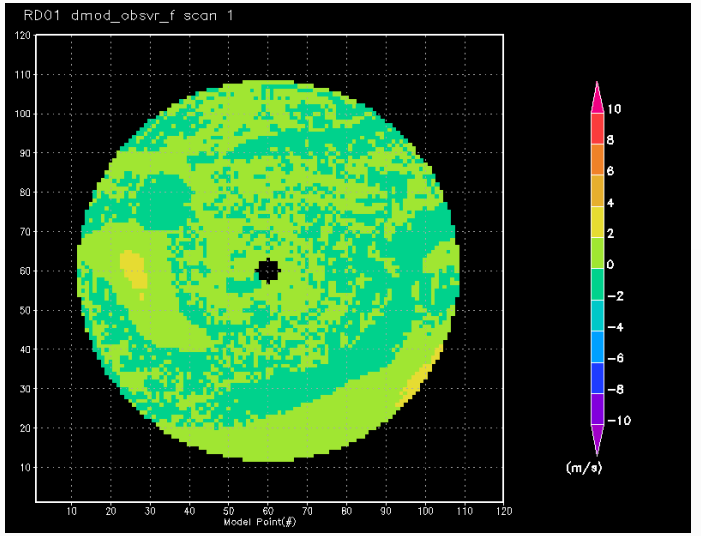
Ravela S., Emmanuel K. and McLaughlin D. (2007)

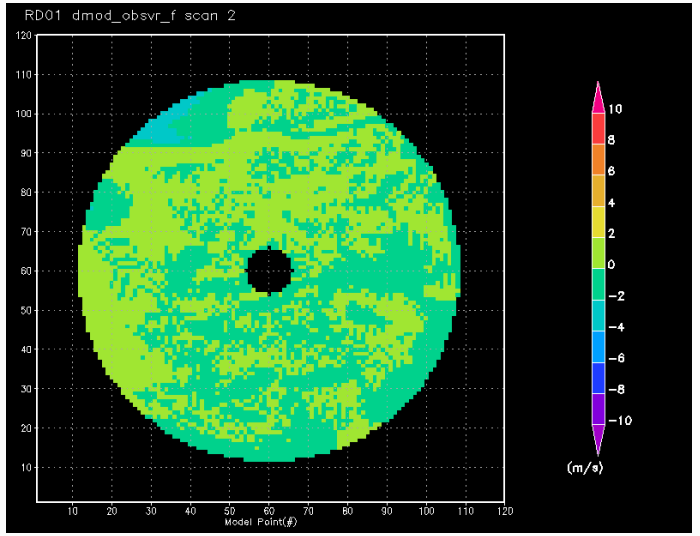






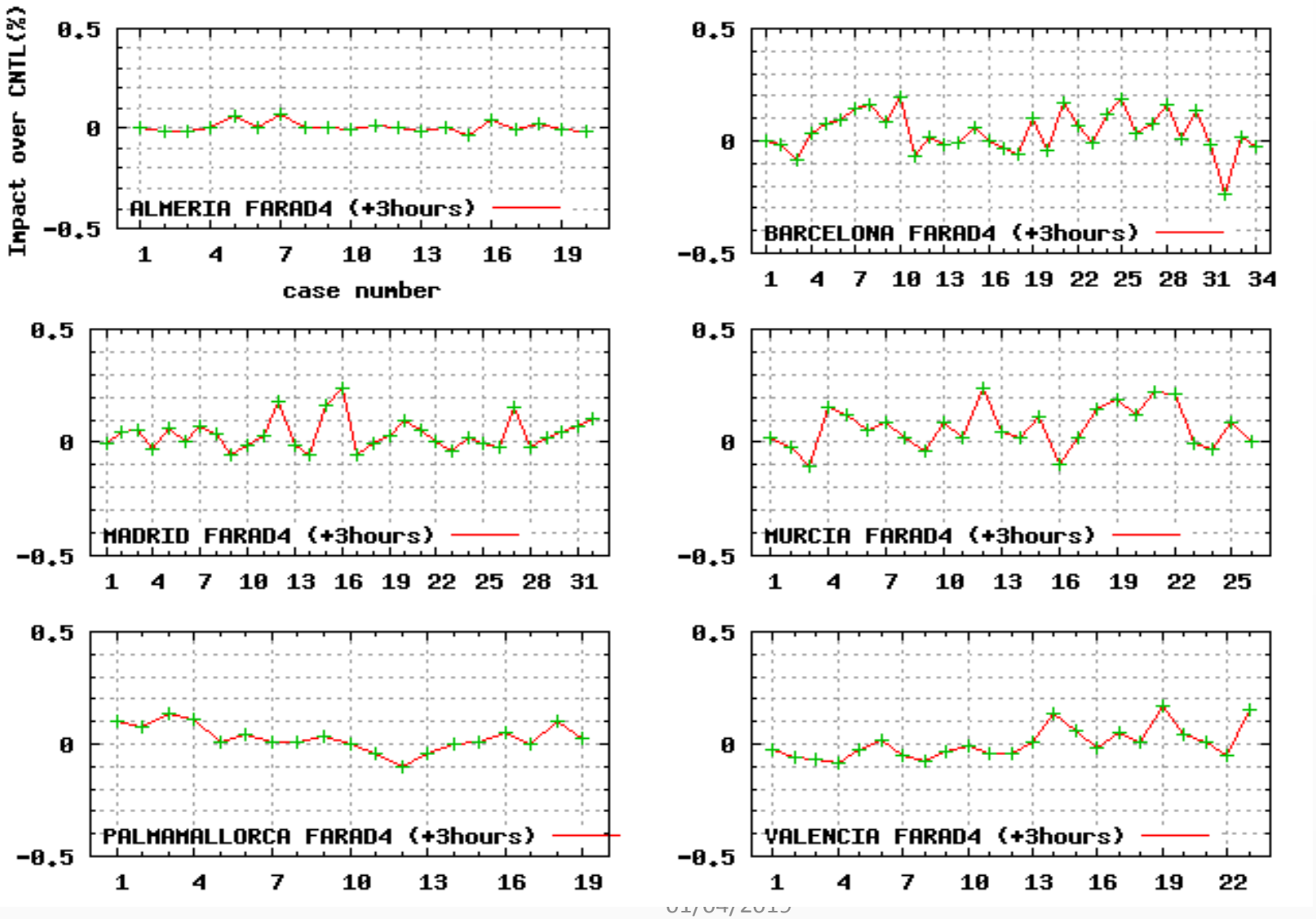






FIELD ALIGNMENT:

HYMEX –SOP1 (september-november 2012)



FIELD ALIGNMENT

Integration in v40

FA corrections are treated as full 2-D wind observations (*) , which are after added to CMA ODB for Minimization, together with the rest of observations that may be available. This has required some re-ordering of the obs setup for NCONF=131

CNT0

SU0YOMA

SU0YOMB

IF (LOBS. AND. (.NOT.LFA)) THEN
OBADAT
ENDIF

(NCONF == 1,2) CNT1

(NCONF == 131) CVA1

CVA1

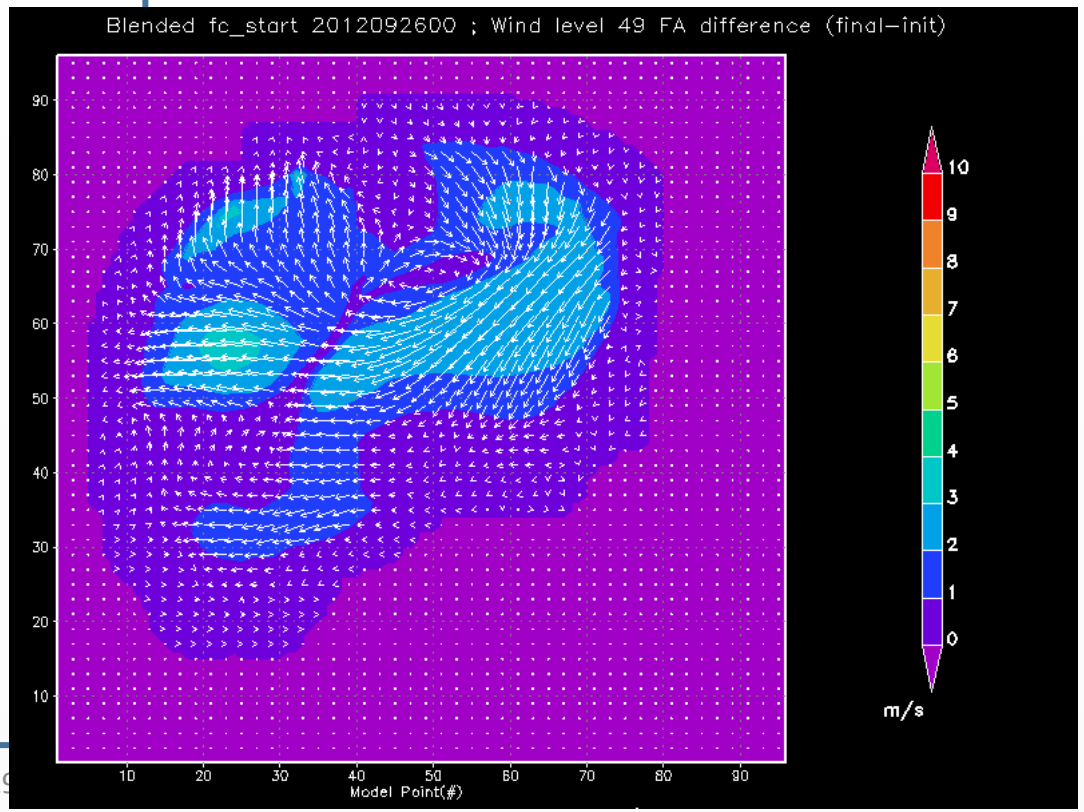
IF (LOBS. AND. (.NOT.LFA)) SUOBS

SU1YOM

IF (LFA .AND. LOBS) THEN
FA
OBADAT
SUOBS
ENDIF

CNT2
….
CVA2

(*)

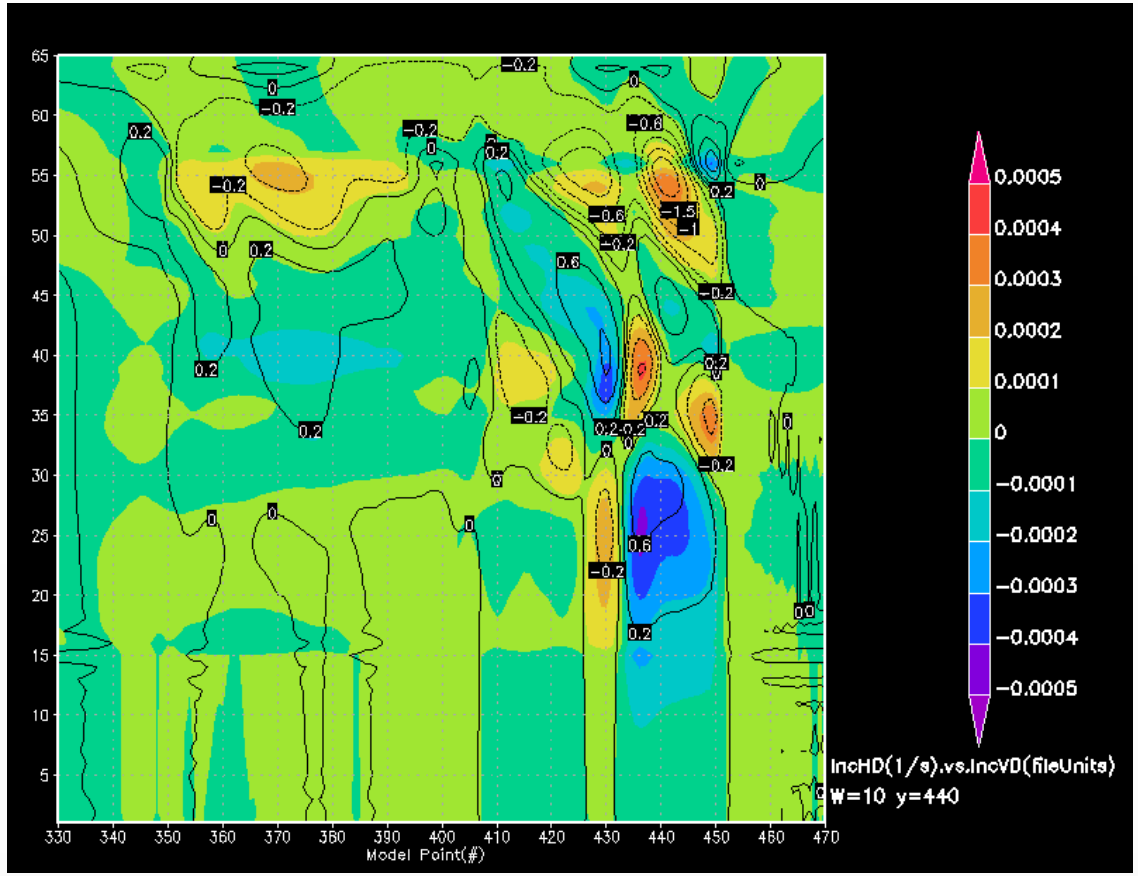


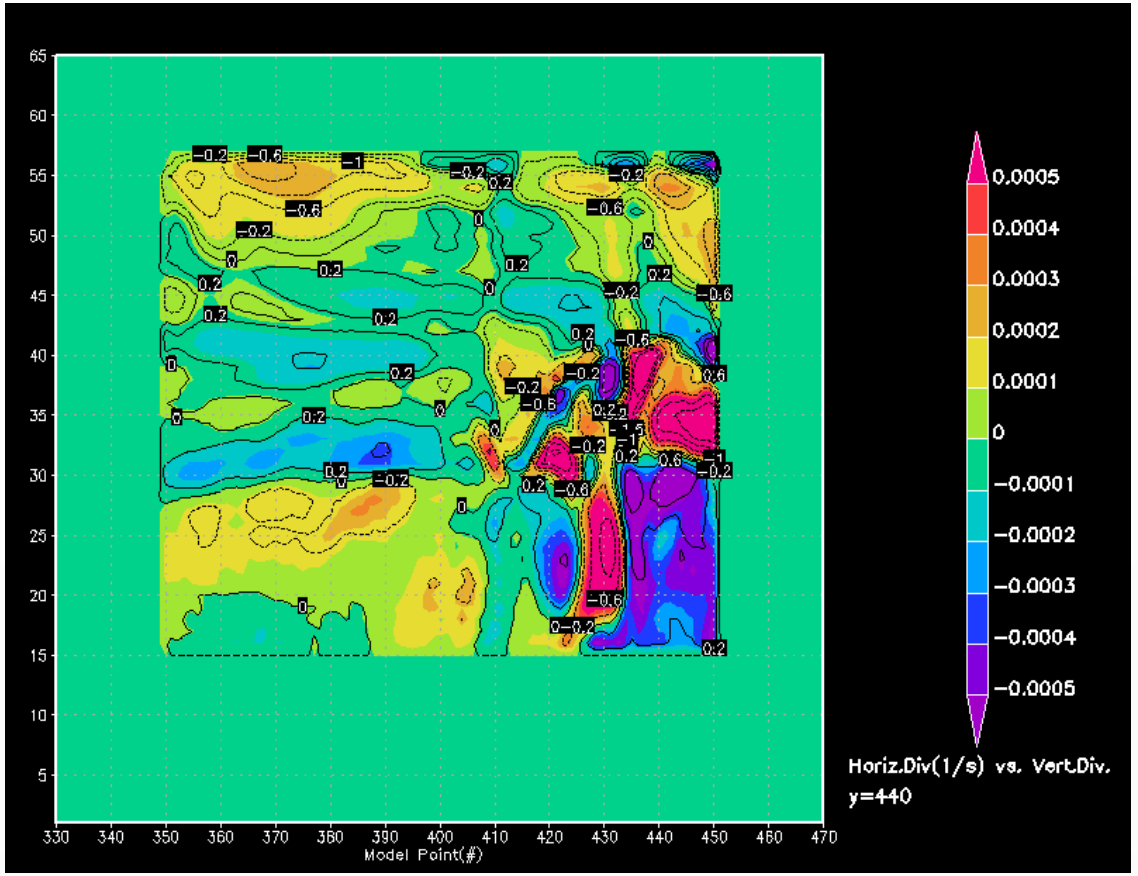
Variational Constraints (VC)

- Variational technique to balance the IC, as dictated by SI dynamics
- Numerical solution found with Green Functions. Interesting analogy between GF and covariance matrix
- Tested in several contexts, (with synthetic obs, on Field Alignment increments, on LETKF increments, and as substitute or complementary to 3D-Var statistical balances)
- Potential utilization as nudging scheme (not tested yet)

Variational Constraints (VC)

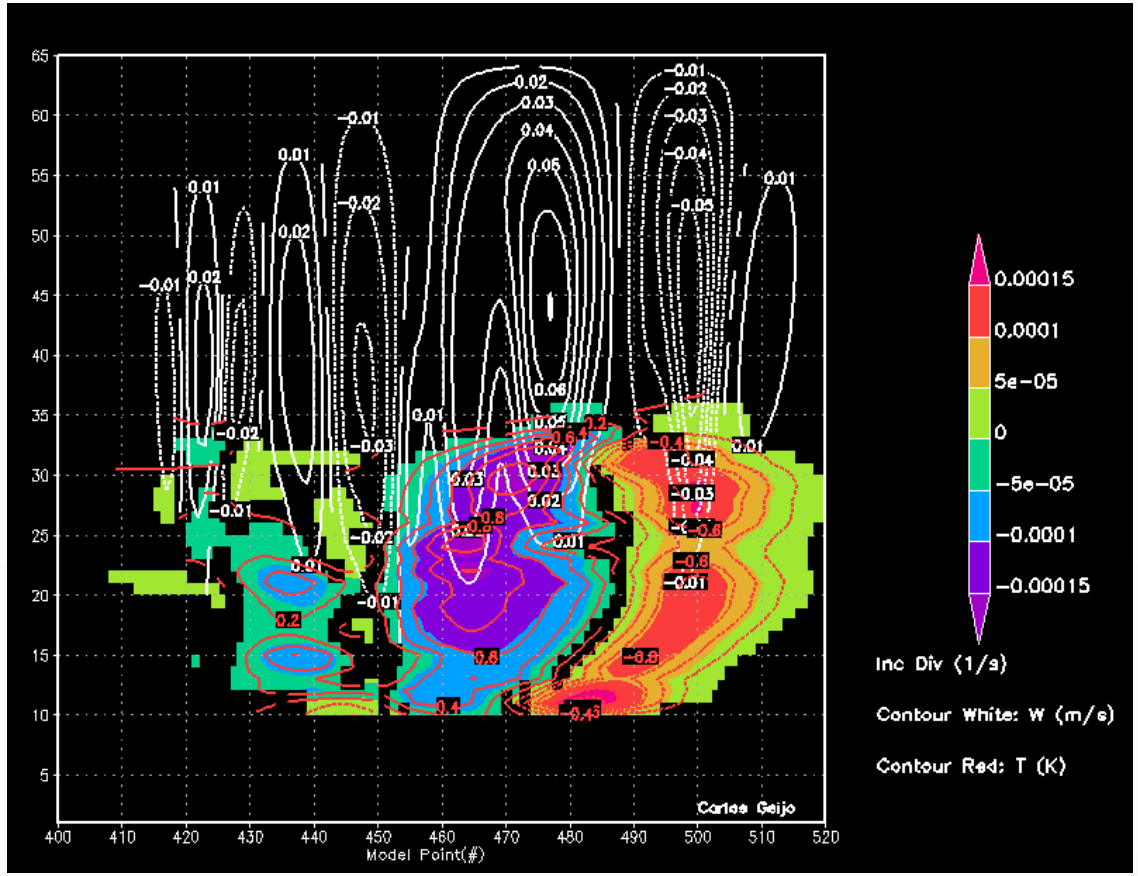
Test with Synthetic Observations

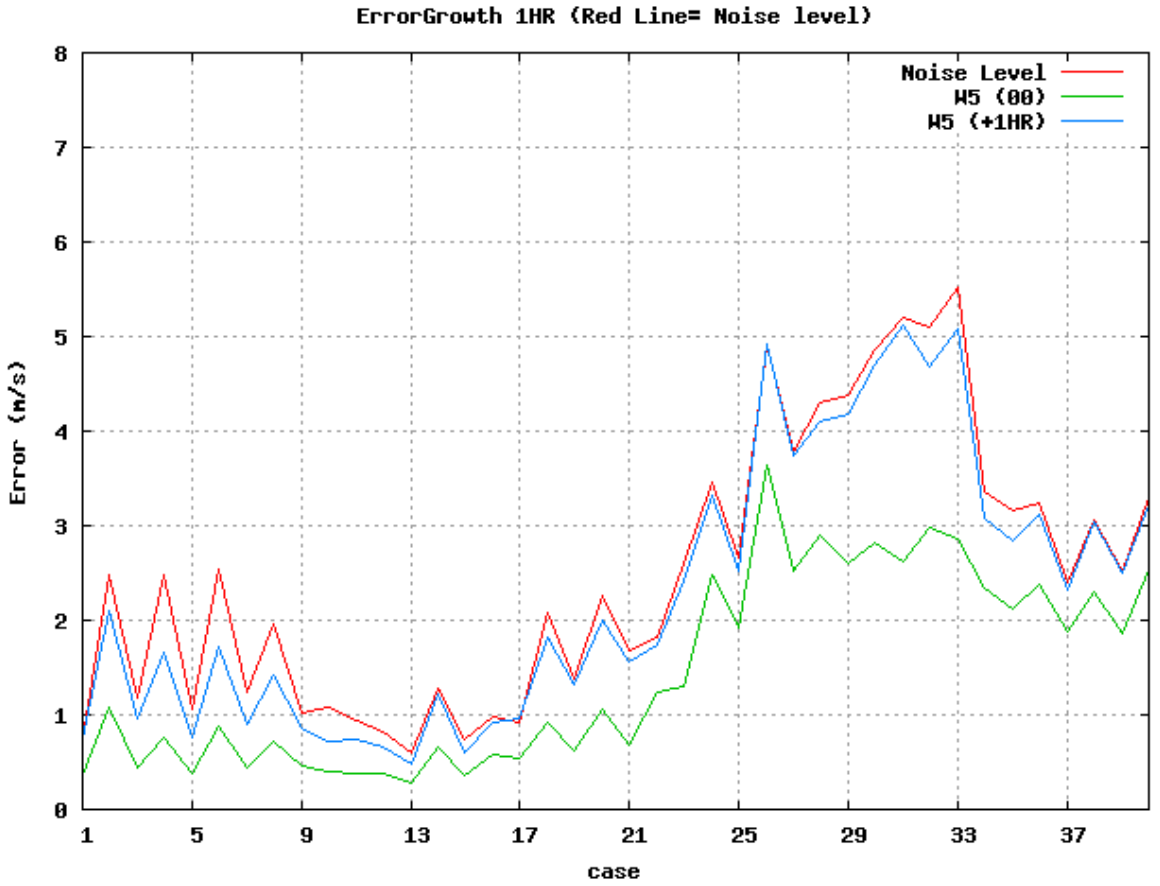




Variational Constraints (VC)

Test with Field-Alignment Increments

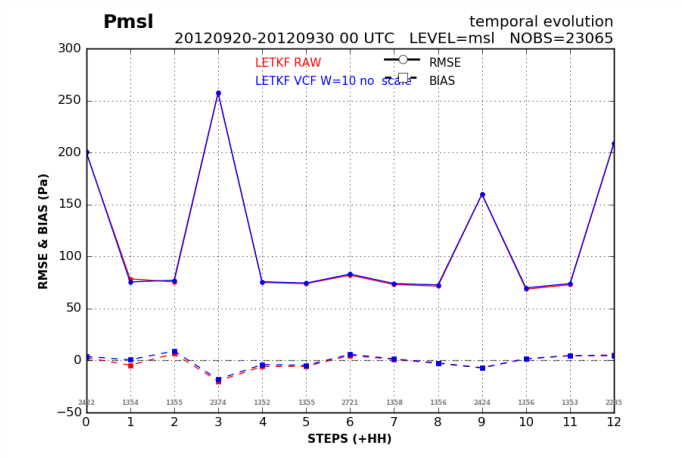


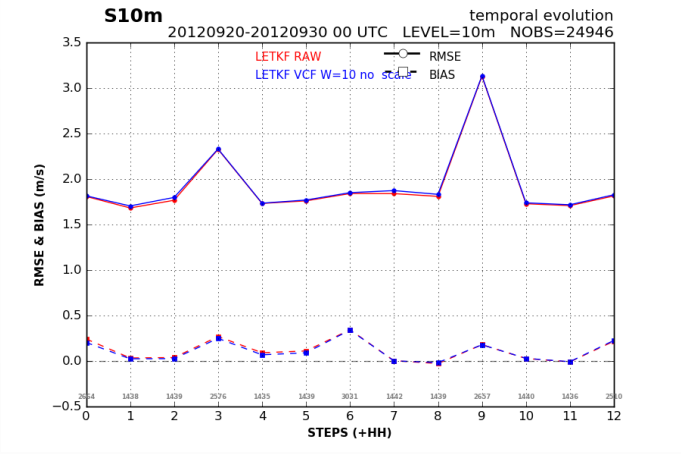


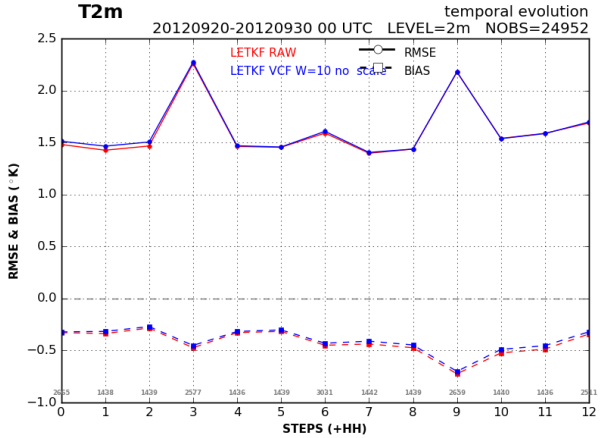
Variational Constraints (VC)

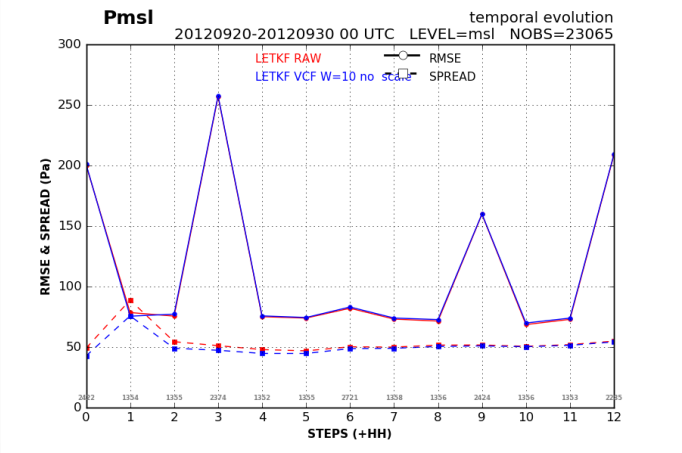
Test on LETKF increments

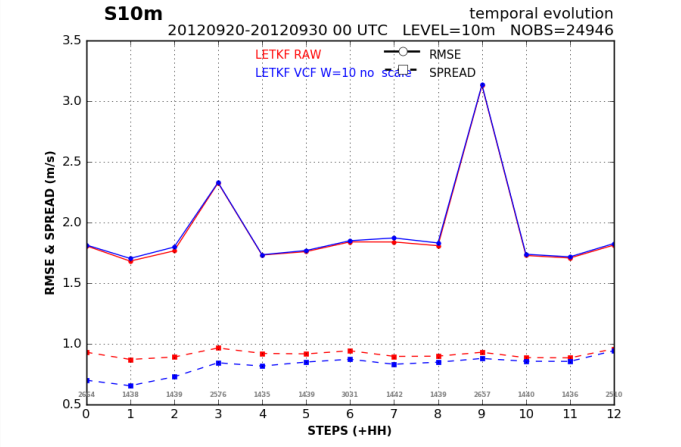
FG + VCFilt [LETKF_analysis – FG]

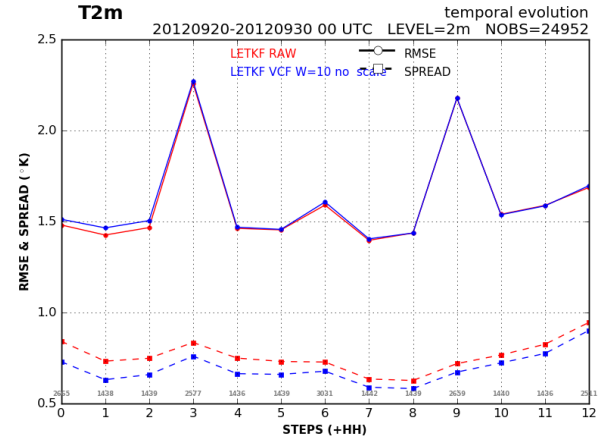






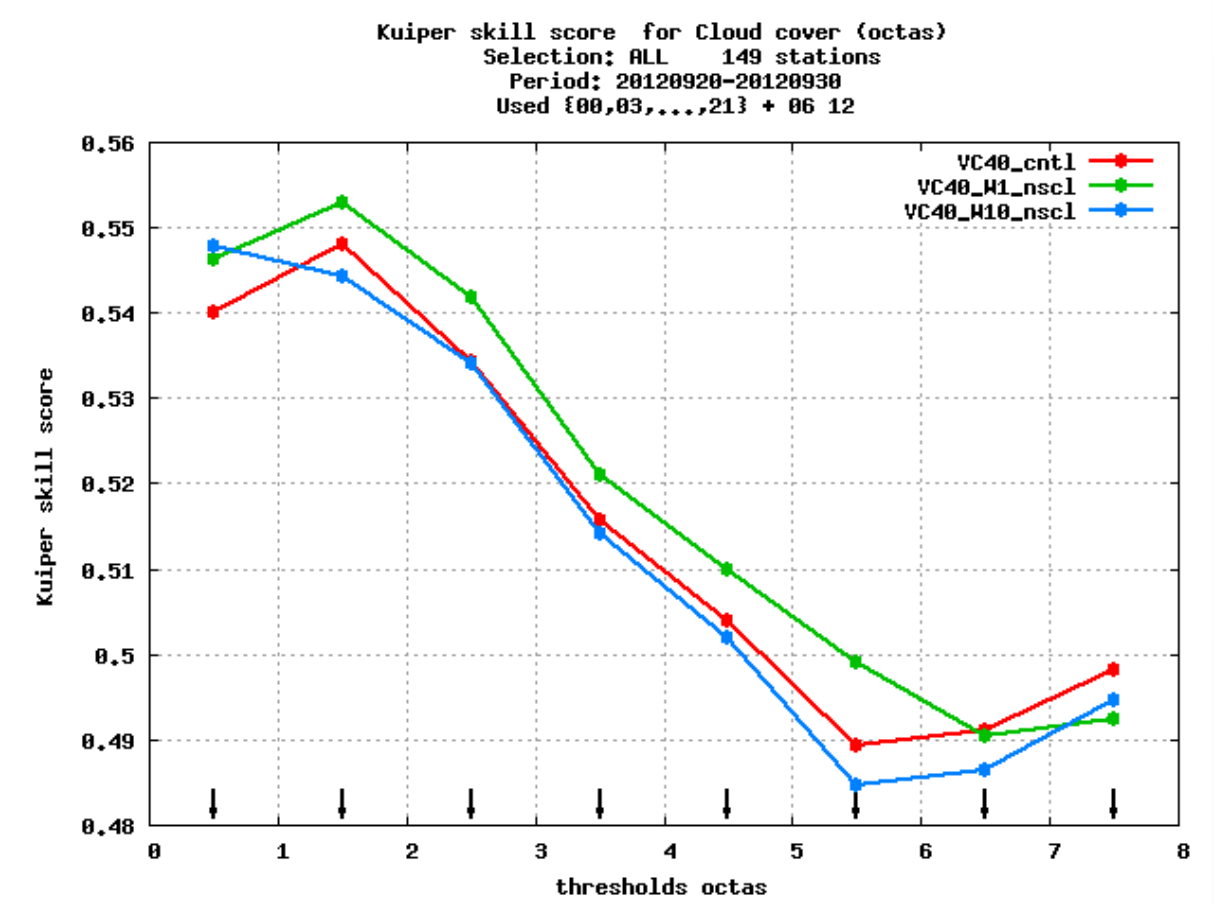


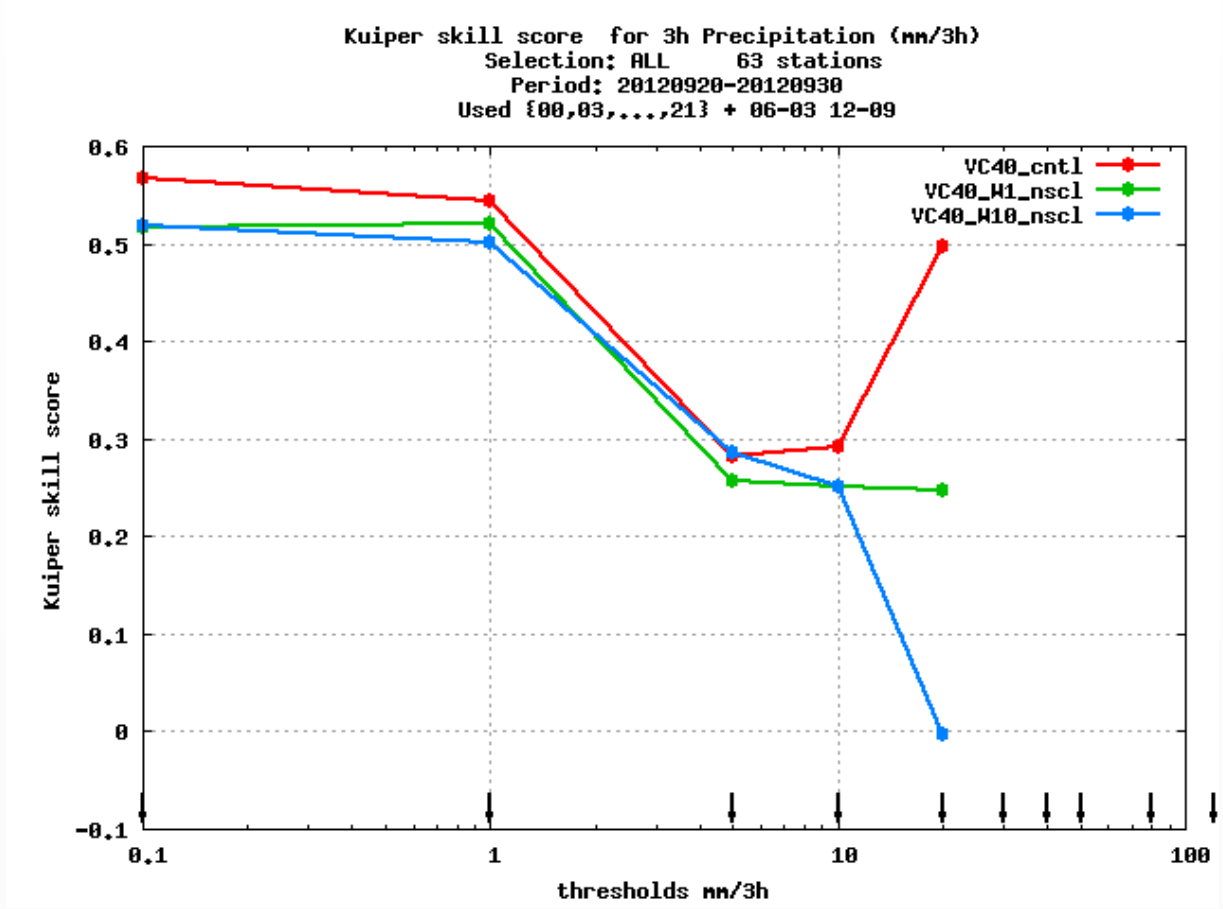




Variational Constraints (VC)

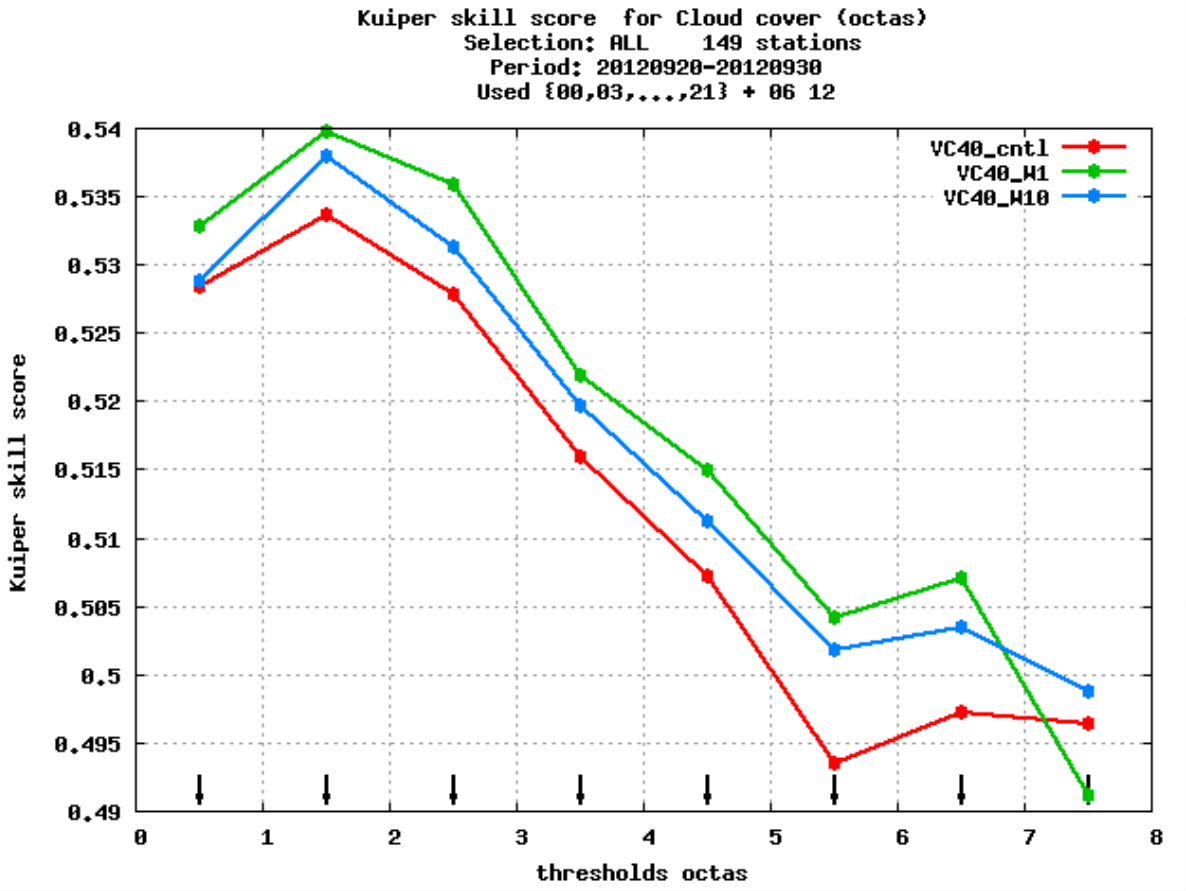
Test .vs. 3D-Var Stat. Bal FG + VCFilt [3D-VAR_analysis (uni.) – FG]

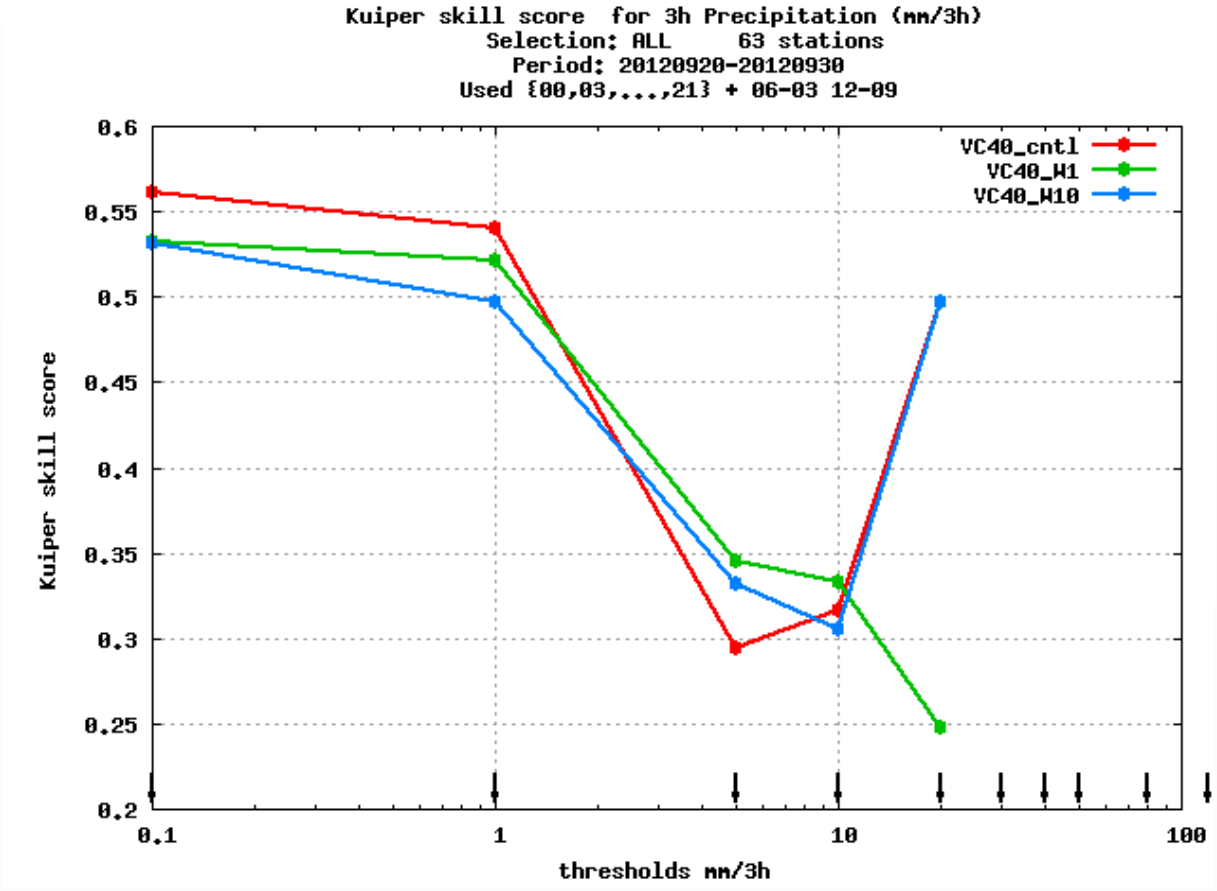




Variational Constraints (VC)

Test with 3D-VAR statbal FG + VCFilt [3D-VAR_analysis – FG]





Modelling Flow-Dependent covariances with Gaussian Integrals

- Consider the analyses increments as a Gaussian random field on a grid with a source. The pdf looks much like (a discrete version of) the kernel in random (or quantum) field theory (QFT)

$$P(\Delta) \sim \exp\left(-J_S(\Delta)\right) \quad ; \quad J_S(\Delta) = \frac{1}{2}\Delta^T G^{-1}\Delta - \Delta^T S$$

- In this framework, the classical 3D-VAR results read :

$$\left\langle \Delta_i \right\rangle_S = \left\langle \Delta_i \Delta_j \right\rangle_{S=0} S_j \quad = \quad G_{ij}\, S_j$$

$$\left\langle \Delta_i^2 \right\rangle_S - \left\langle \Delta_i \right\rangle_S^2 = \left\langle \Delta_i^2 \right\rangle_{S=0} \quad = \quad G_{ii}$$

Modelling Flow-Dependent covariances with Gaussian Integrals

- GF as a covariance matrix ⟹ think the covariance matrix as a GF ("propagator")

- As is common in QFT, introduce (non-random) external fields to calculate the effects of ambient or background fields on different probabilities

$$\left\langle \Delta_i \Delta_j \right\rangle_{S=0}\left[\vec{V}\right] \sim \int d\Delta_1 \cdots d\Delta_N \; \Delta_i \Delta_j \quad \exp\left(-\frac{1}{2}\Delta^T G^{-1}\Delta - \frac{\mu}{2} tr\left(\left[\vec{V}\cdot\vec{\nabla}\,\Delta\right]\left[\vec{V}\cdot\vec{\nabla}\,\Delta\right]^T \right)\right)$$

a) b)

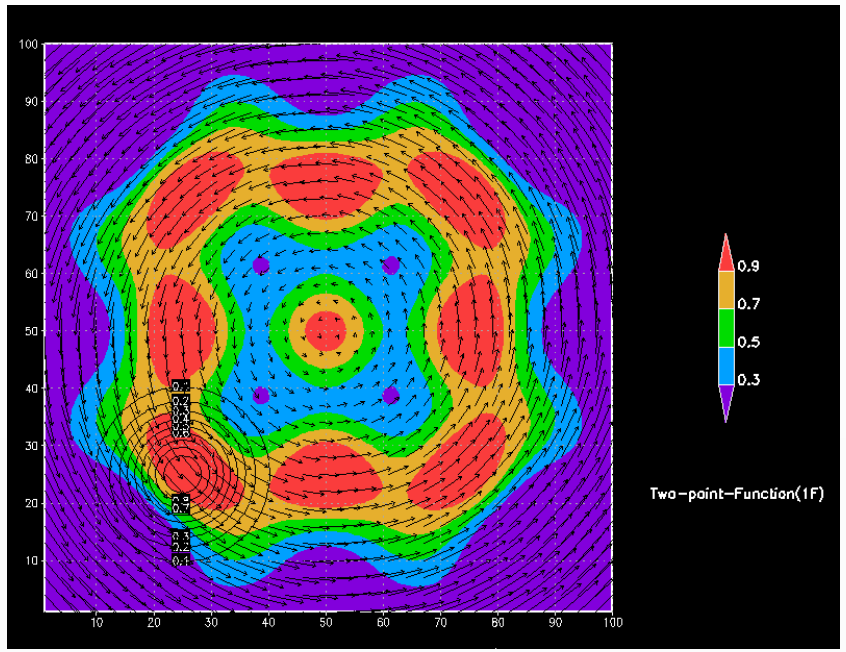
- Computations up to lower orders of μ can be done perturbatively

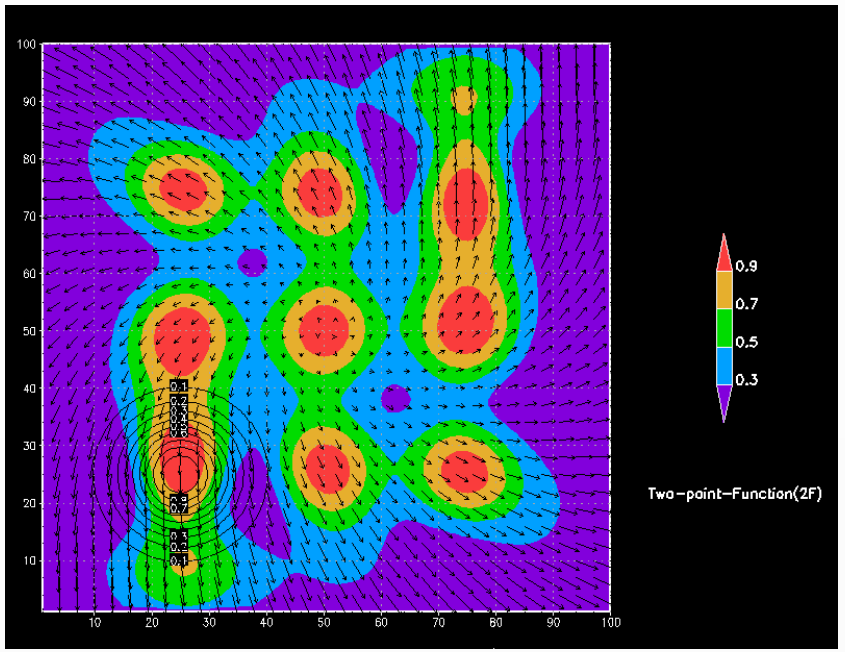
$$\left\langle \Delta_i \Delta_j \right\rangle_{S=0}\left[\vec{V}\right] \sim \int d\Delta_1 \cdots d\Delta_N \; \Delta_i \Delta_j \quad \exp\left(-\frac{1}{2}\Delta^T G^{-1}\Delta - \frac{\mu}{2}\left(\sum_p \left(\vec{V}\cdot\vec{\nabla}\Delta \right)_p^2 \right)\right) = \int d\Delta_1 \cdots d\Delta_N \exp\left(-\frac{1}{2}\Delta^T G^{-1}\Delta \right)\Delta_i \Delta_j \left[1 - \frac{\mu}{2}\sum_p \left(\vec{V}\cdot\vec{\nabla}\Delta \right)_p^2 + O(\mu^2) \right]$$

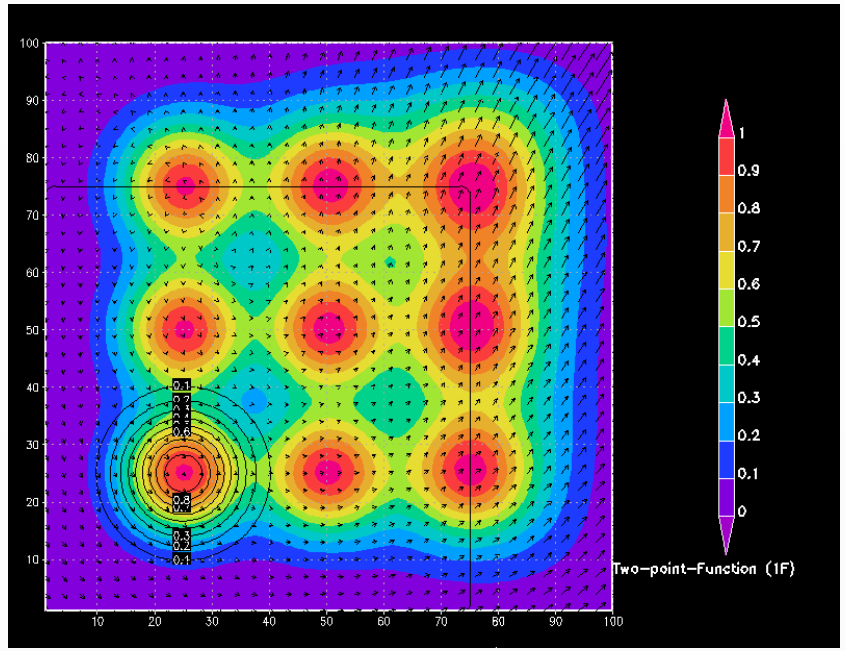
$$\left\langle \Delta_i \Delta_j \right\rangle_{S=0}\left[\vec{V}\right] \sim \left\langle \Delta_i \Delta_j \right\rangle_{S=0} - \frac{\mu}{2} \sum_p u_p^2 \left\langle \Delta_i \Delta_j \left(\partial_x \Delta \right)_p^2 \right\rangle_{S=0} + \ldots \qquad \left\langle \Delta_i \Delta_j \left(\frac{\Delta_{p+dx} - \Delta_{p-dx}}{dx} \right)_p^2 \right\rangle_{S=0} \Rightarrow \left\langle \Delta_a \Delta_b \Delta_c \Delta_d \right\rangle_{S=0} = G_{ab}G_{cd} + G_{ac}G_{bd} + G_{ad}G_{bd}$$

Modelling Flow-Dependent Co-variances with Gaussian Integrals

$$G_{i,j} = G(r_{ij}) = \exp(-(r_{ij}/10)^2)$$





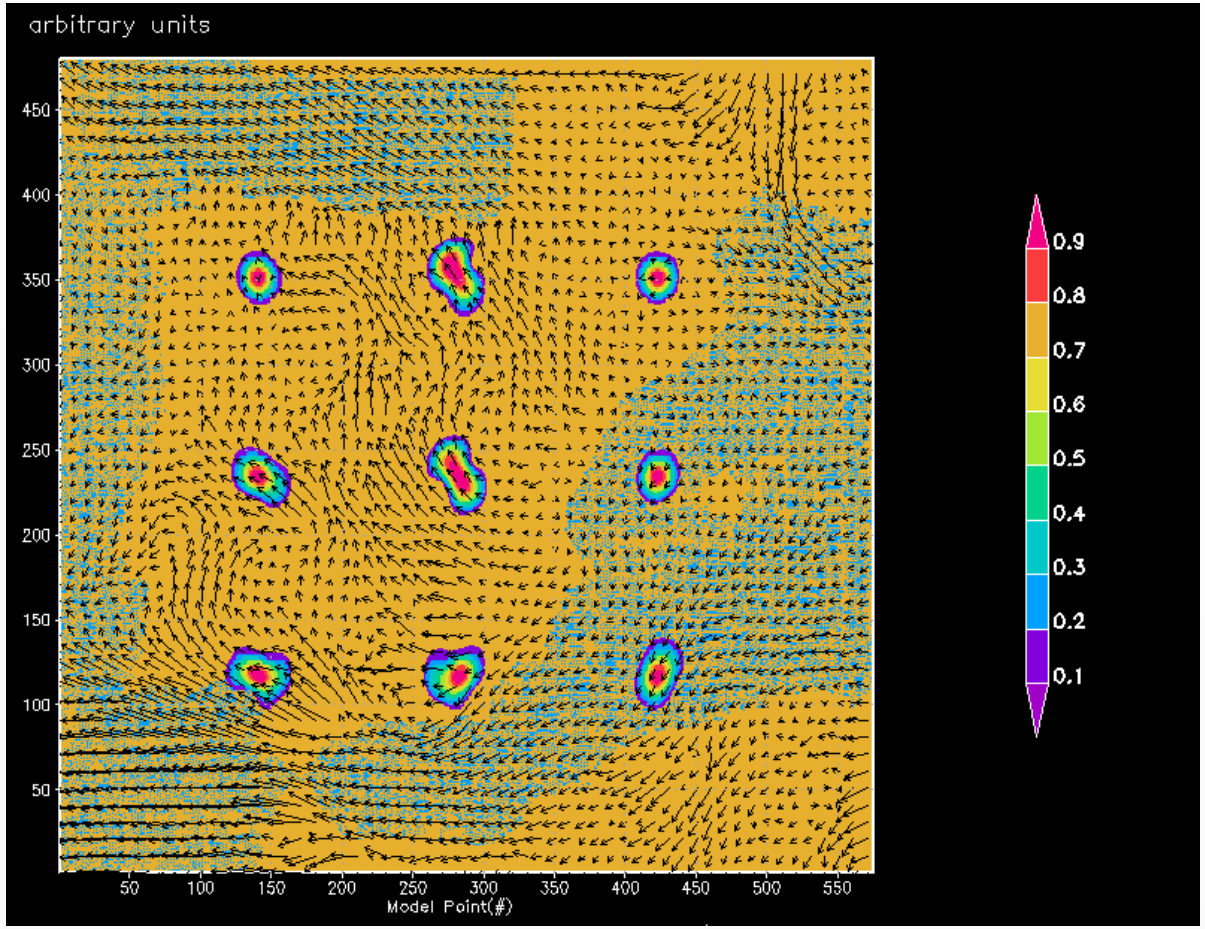


Modelling Flow-Dependent covariances with Gaussian Integrals

Correlations at model level 55
Modulated by the wind field

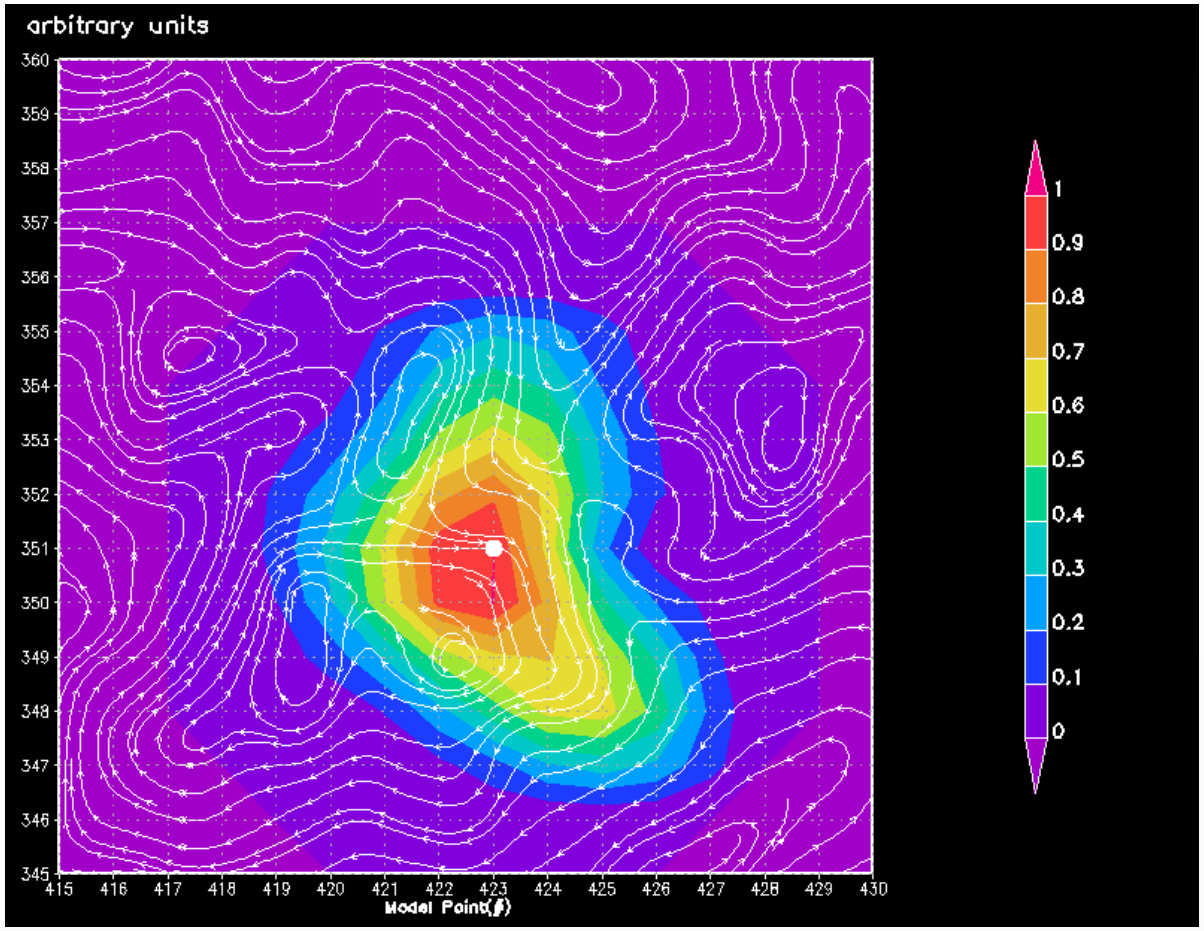
2D-test with 1 MPI-task and 32 OMP threads “–n1 –j1 –d32”

100 MPI-tasks -> 6000 obs/minute



Modelling Flow-Dependent covariances with Gaussian Integrals

Correlations at the surface
Modulated by orography



MUCHAS GRACIAS POR SU ATENCIÓN !