HYMEX TTM4a Atmospheric Data Assimilation (DA): A Unique Opportunity for DA-EPS Research

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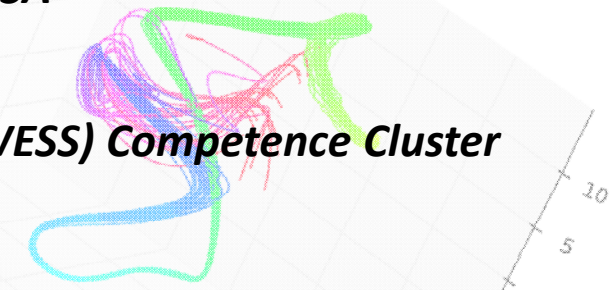


Based on:
- *TTM4a and TTM1 Science Documents*
- *WWRP Strategic Plan*
- *WWRP Working Group on Mesoscale Weather Forecasting Research (MWFR)*
- *EUMETNET SRNWP Workshop on DA and EPS*

The HyMeX DA-EPS Research Testbed

- **DEFINITION:** Well-defined research environment of different DA-EPSs operated by expert team (see e.g. D-PHASE)
- **SCIENTIFIC GOAL:** Develop general understanding of and guidance on improving DA-EPS for advanced process and predictability studies.
- Coordination includes driving EPS, domains and resolutions, observations and their error covariance matrices, model forward observation operators, etc.
- Stepwise approach: Case studies and/or operation periods (> 1 month)
- Analyses using the same verification data set

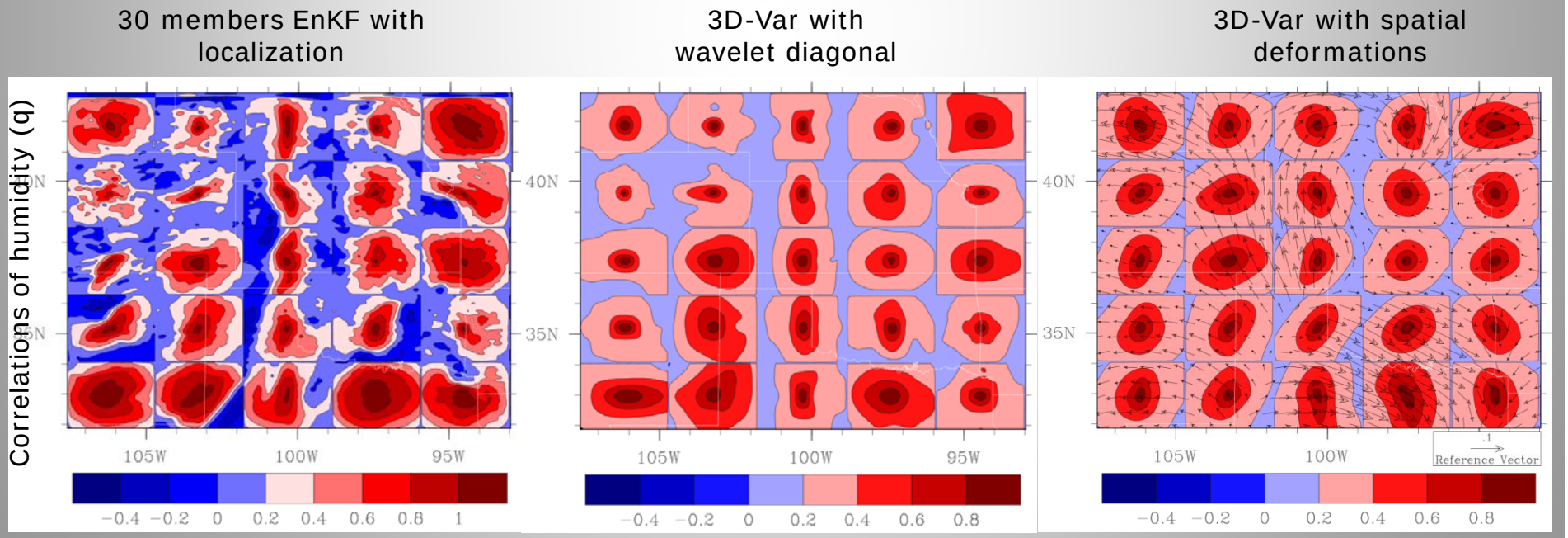
Science Issues Concerning DA

- Include hydrometeors into the control/analyzed variables
- Likewise with land-surface variables
- How to handle model errors (inflation, multi-physics, etc.)?
- What is the relative performance of variational and ensemble-based techniques as well as their variants?
- Hybrid combinations of VAR and EnKF?
- Construction of a flow dependent B-matrix for 3DVAR?
- Update of B-matrix of EnKF using covariance filtering and inflation?
- How to derive flow dependent localization length scales?
- How to handle model non-linearities and non-Gaussian error characteristics?

Background error modeling for convective-scale variational data assimilation [see Poster PO2.21]

Some recent developments in 3D-Var to incorporate flow-dependency and multivariate couplings linked with the physics of convection:

- ❑ **Flow-dependency with the use of AROME lagged ensemble data assimilation (P. Brousseau)**
- ❑ **Heterogeneous 3D-Var framework for computing separate statistics in precipitating and non-precipitating areas (T. Montmerle, Y. Michel)**
- ❑ **3D, multivariate covariances for hydrometeor variables (Y. Michel, T. Montmerle)**
- ❑ **New inhomogeneous correlation models: spatial deformations (Y. Michel)**

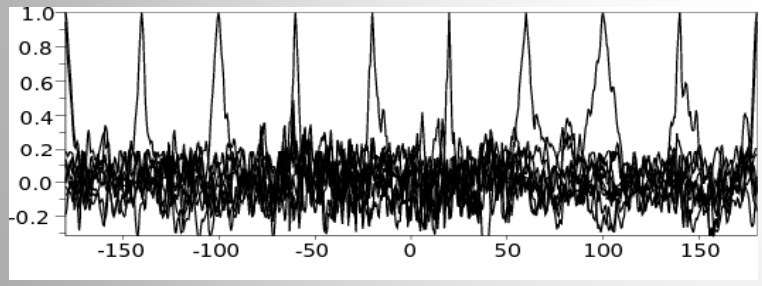


TTM4: Proposal for a large ensemble for studying covariance filtering

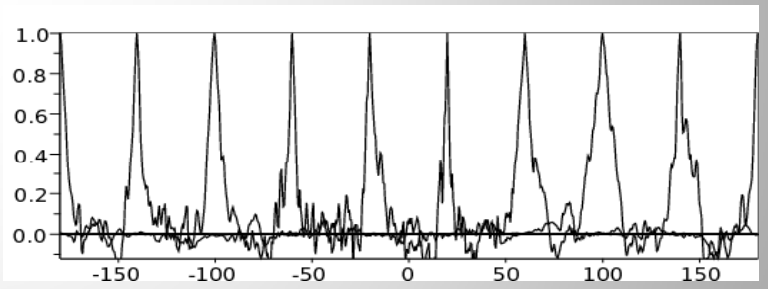
Background error models and EnKF localization both address covariance estimation in large dimensions with sampling noise and no truth.

It is proposed to run a large ensemble O(10^2-10^3) over a single EOP « golden case ».

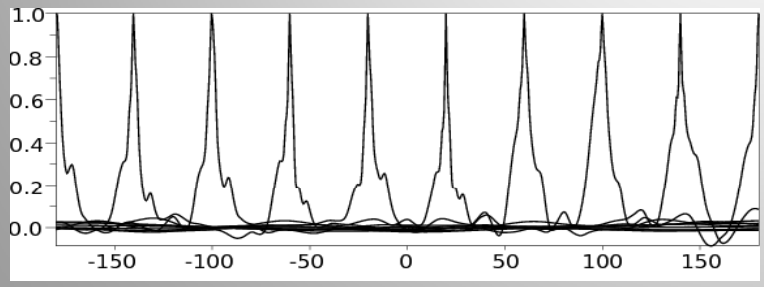
1. Filtering of variance maps in LAM (B. Ménétrier, CNRM-GAME)
2. Evaluation of background correlation model (Y. Michel, CNRM-GAME)
3. Study of coupled ocean/atmosphere covariances? (NRL?)



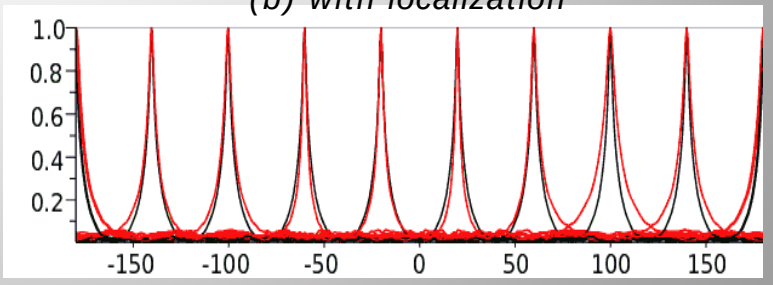
(a) 100 members raw correlations



(b) with localization



(c) Wavelet diagonal Correlations



(d) Spatial Deformations Correlations

Science Issues Concerning Obs.

- **Exploit full information content of active remote sensing:**
  - **GPS STD**
  - **water-vapor and temperature lidar (Wulfmeyer et al. MWR 2006)**
  - **radar Doppler wind, reflectivity, and polarization**
- **Information content in passive remote sensing systems:**
  - **use satellite radiances over the ocean and land**
  - **forward RTEs including error covariances considering nonlinear cloud and precipitation microphysics**
  - **data thinning**
  - **ground-based MWR and FTIR**
- **How to combine land-surface and atmospheric DA in a consistent way?**

Radar DA Issues, WRF Approach (Sun and Crook JAS 1998)

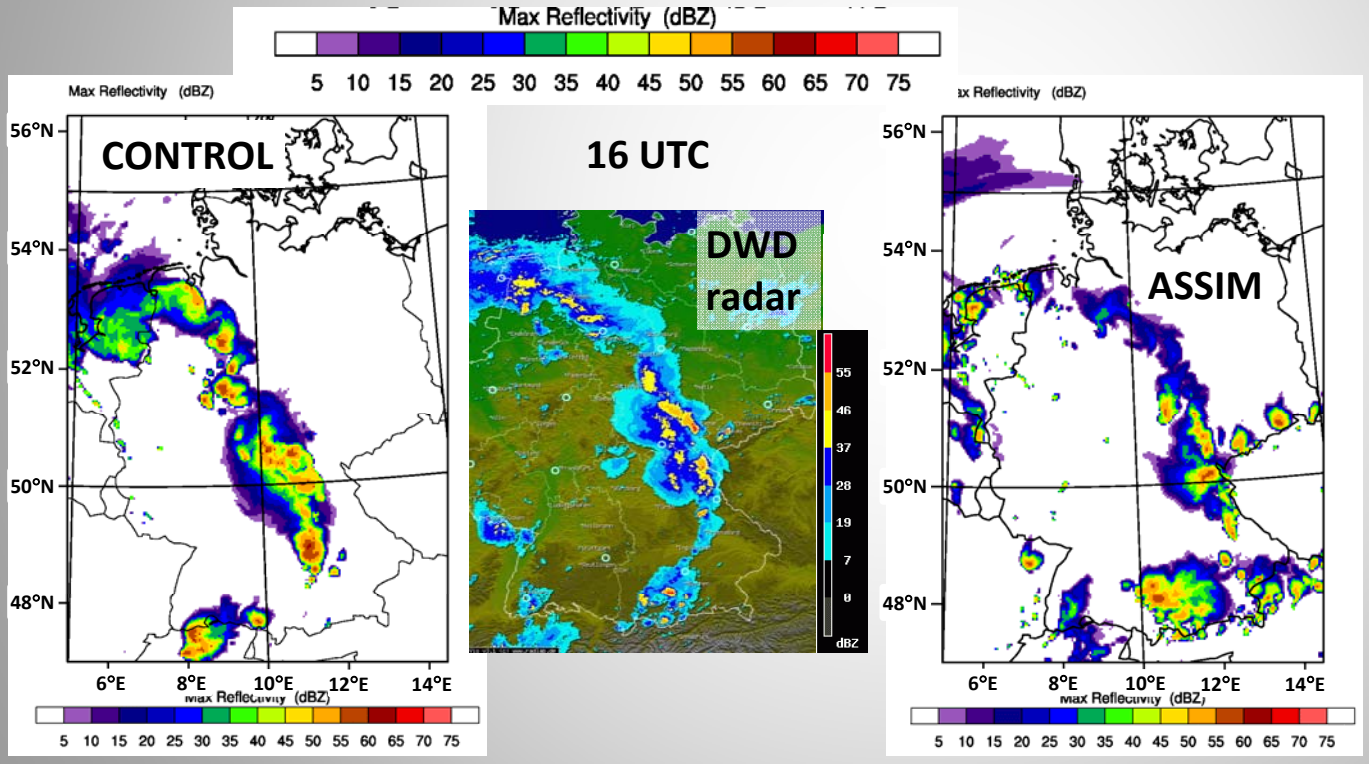
Doppler wind speed:

$$v_r = \frac{x - x_{radar}}{R} u + \frac{y - y_{radar}}{R} v + \frac{z - z_{radar}}{R} (w - v_T)$$

$$v_T = 5.4 \frac{m}{s} \left(\frac{p_0}{p} \right)^{0.4} q_{rain}^{0.125}$$

Reflectivity:

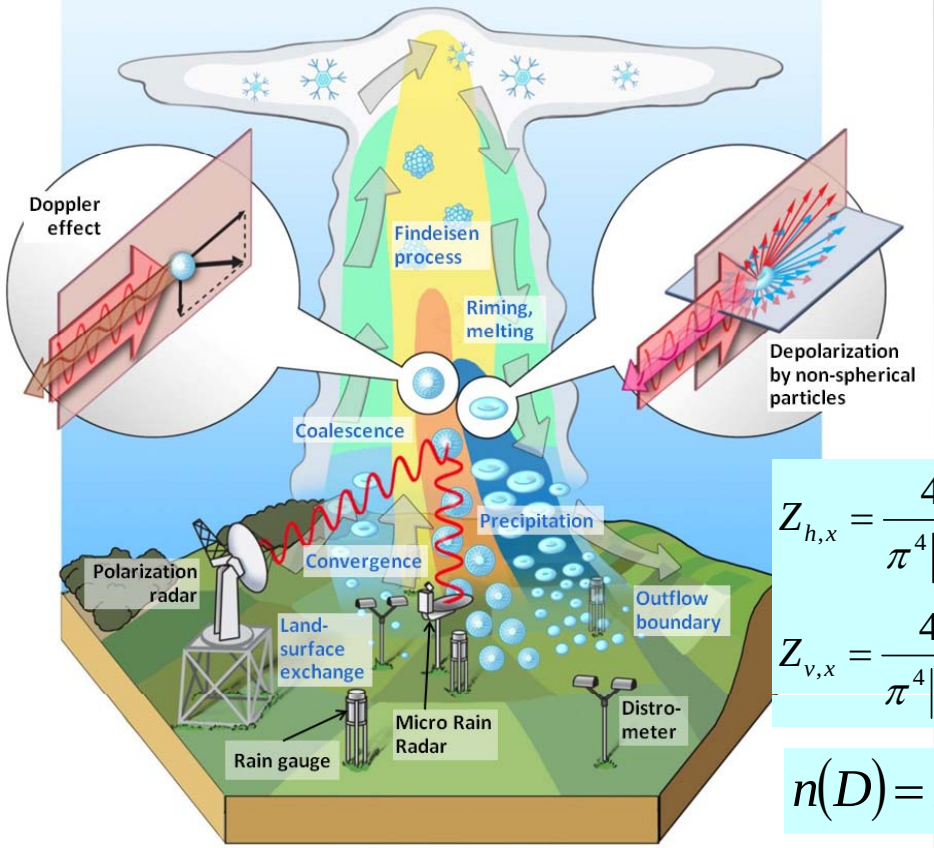
$$Z = 43.1\,\mathrm{dBZ} + 17.5 \log\left(\rho\, q_{rain} \frac{m^3}{kg} \right) \mathrm{dBZ}$$



First WRF 3DVAR RUC using DWD radar data and fixed Z(R). during COPS IOP 9c on July 20, 2007.

Key issue for improving QPE and QPF. For AROME radar DA see, e.g., Montmerle and Faccani MWR 2009, Caumont et al. Tellus 2010.

Proposal for Radar DA (Jung et al. MWR 2008)



Pol. radar provides information about:

- **Hydrometeor size distribution**
- **Hydrometeor type**
- **Spatial-temporal distribution**

However, the relation between radar signal and microphysics is complex:

$$Z_{h,x} = \frac{4\lambda^4}{\pi^4 |K_w|^2} \int n(D) \cdot \left(A |f_a|^2 + B |f_b|^2 + 2C |f_a| |f_b| \right) dD \quad \left(mm^6 m^{-3} \right)$$

$$Z_{v,x} = \frac{4\lambda^4}{\pi^4 |K_w|^2} \int n(D) \cdot \left(B |f_a|^2 + A |f_b|^2 + 2C |f_a| |f_b| \right) dD \quad \left(mm^6 m^{-3} \right)$$

$$n(D) = N_0 D^{\mu} e^{-\gamma D}$$

D: diameter, N_0: intercept parameter, γ: slope par., μ: spectra shape parameter

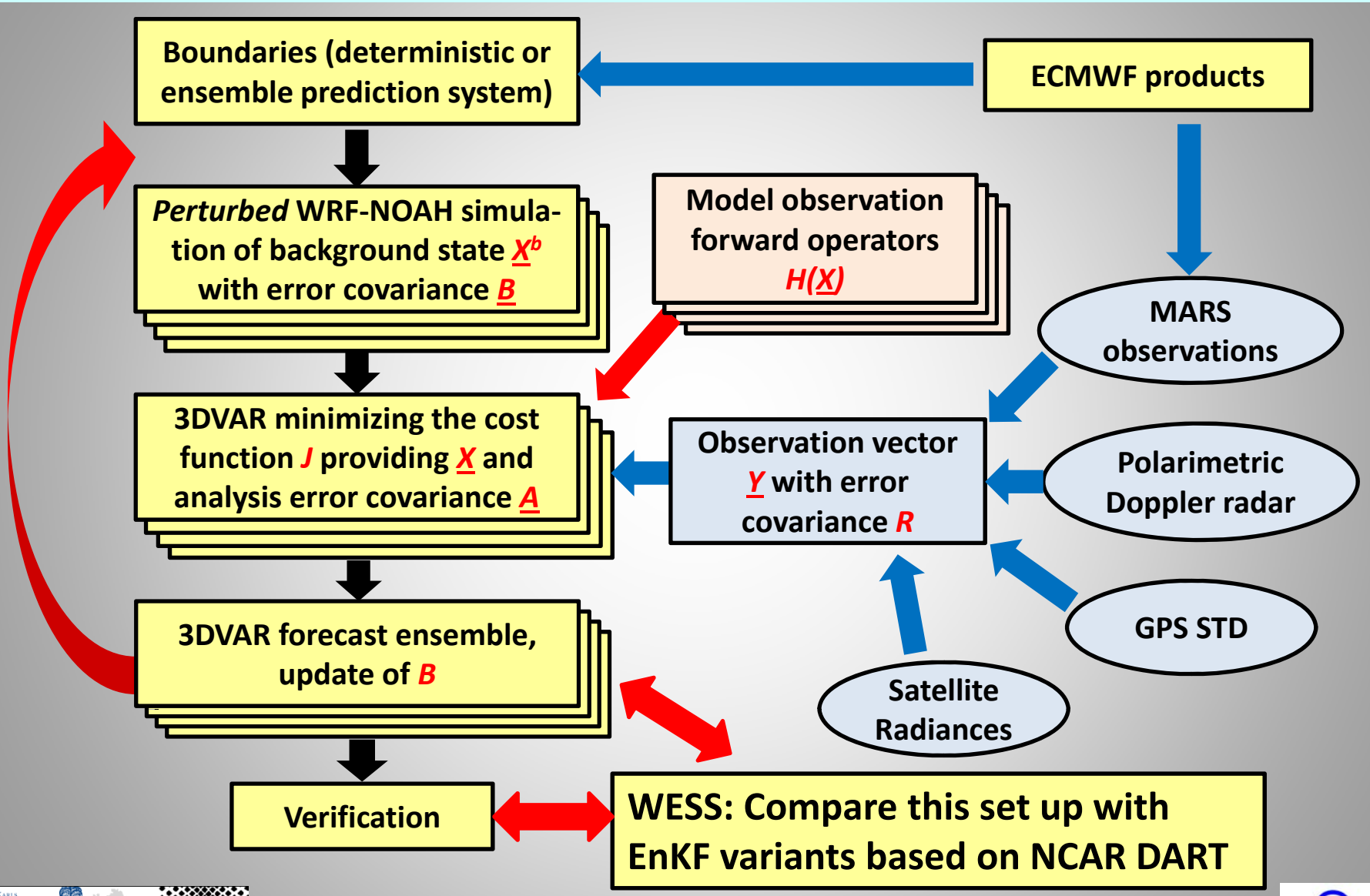
- A, B and C: Weighting functions depending on the mean canting angle and its standard deviation.
- „x“ can be either rain (r), rain-snow mixture (rs), rain-hail mixture (rh) or dry hail (dh)
- f_a and f_b: Backscattering amplitudes for polarization along the major (a) and minor (b) axes.
- This technique provide a detailed link between microphysics and observations.

Science Issues Concerning EPS

- How to derive surface IC?
- How to produce appropiate IC + LBC?
- Introduce scale-selective perturbations?
- How to derive a „good“ selection of relevant global/driving EPS members?
- Multi-model EPS versus multi-physics, and stochastic physics EPS?
- Should (and can) the EPS mimic the DA system?
- How to minimize model inbalance and/or spin up in this system?

Questions over questions …..

Science Issues Concerning EPS: IPM En3DVAR



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