Considerations for using hybrid ensemble-variational data assimilation in NASA-GMAO's next reanalysis system

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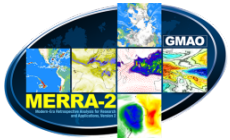


The NASA GMAO NWP and Reanalysis systems

MERRA-2 Modern-Era Retrospective analysis for Research and Applications, Version 2:

- Completed on Feb 2016, it provides data beginning in 1980 and runs a few weeks behind real time.
- Modern satellite database + Interactive analysis of aerosols +NASA's stratospheric ozone data.
- 3DVar with a grid of 72 levels and ~50km in the latitudinal direction.

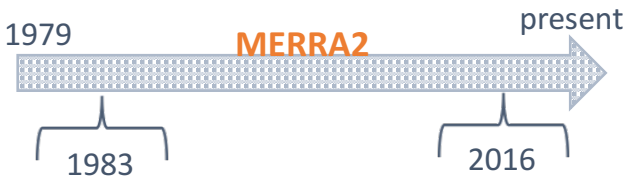
GEOS

- The NASA Global Modeling and Assimilation Office (GMAO) maintains a quasi-operational NWP system, recently upgraded in Jan, 2017.
- The upgrade included a transition from a Hybrid 3DVar to 4D-EnVar, along with an increase in the overall resolution of the system from (28km/50km/100km) to (12.5km/28km/50km).

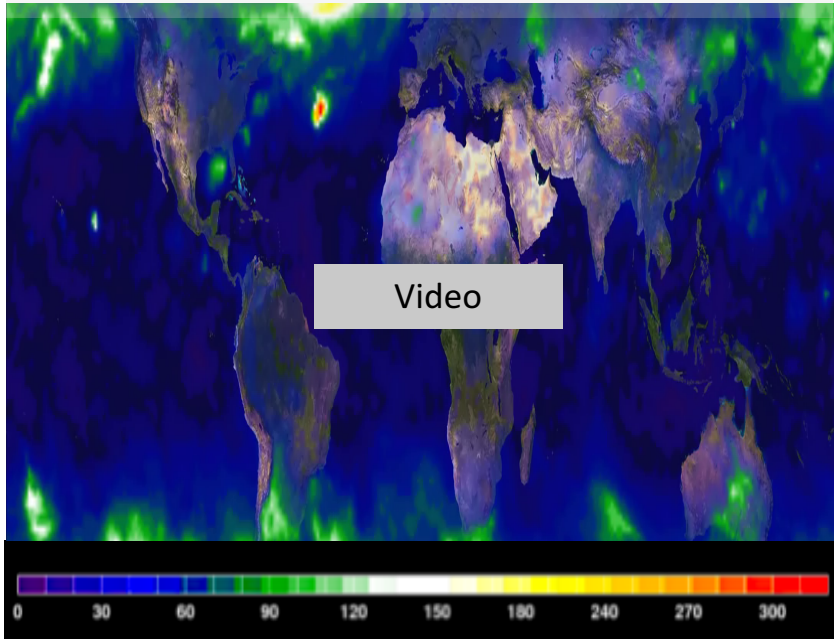
The NASA GMAO NWP and Reanalysis systems

Future Reanalysis

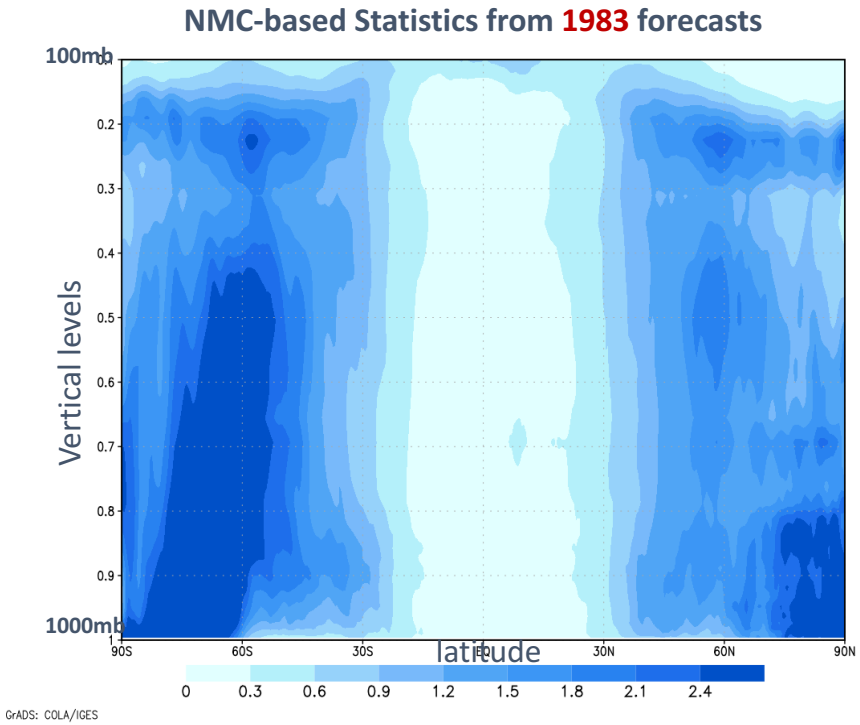
- Can we use some version of hybrid DA to improve the next reanalysis with flow dependent covariances?
- Can an ensemble help make the reanalysis system less sensitive to the observing system change?

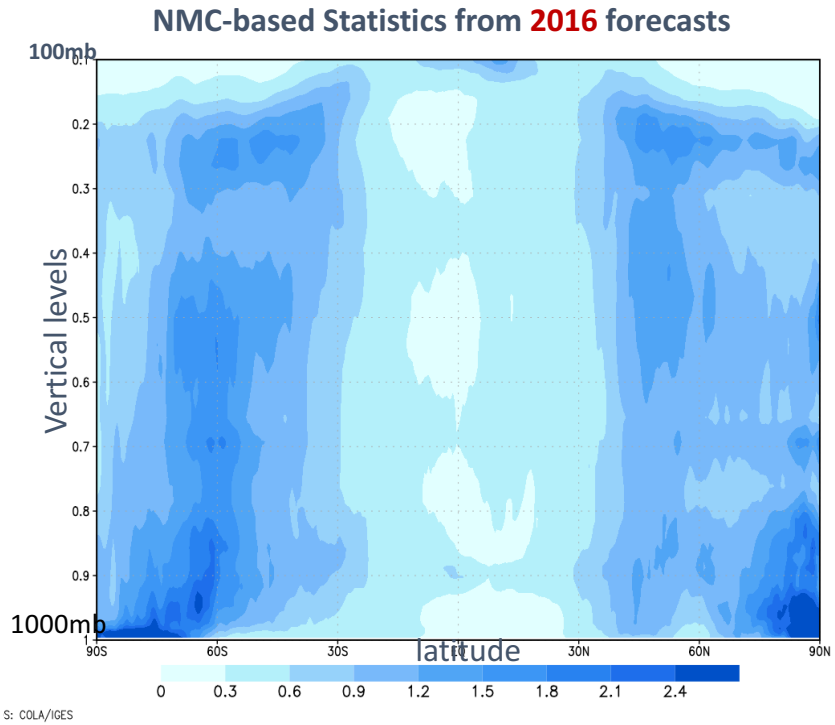


6h-Ensemble Spread of surface pressure
Operational hybrid system – Sep 2016



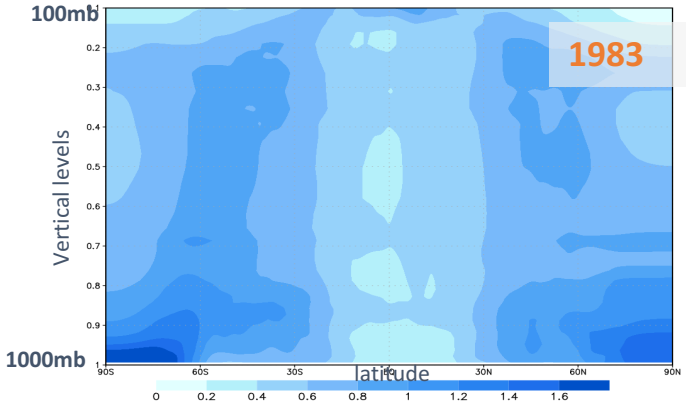
Total temperature variance (NMC method)

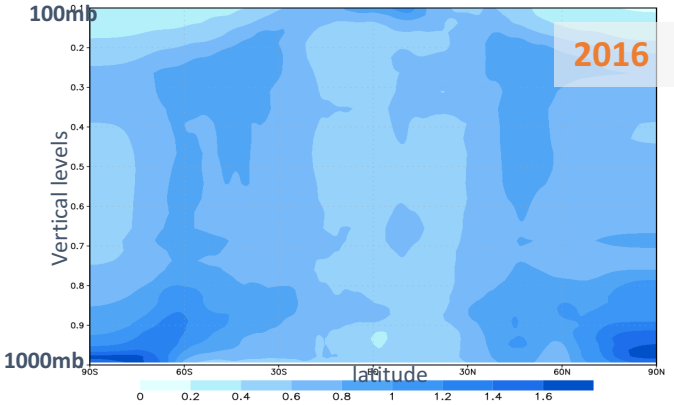




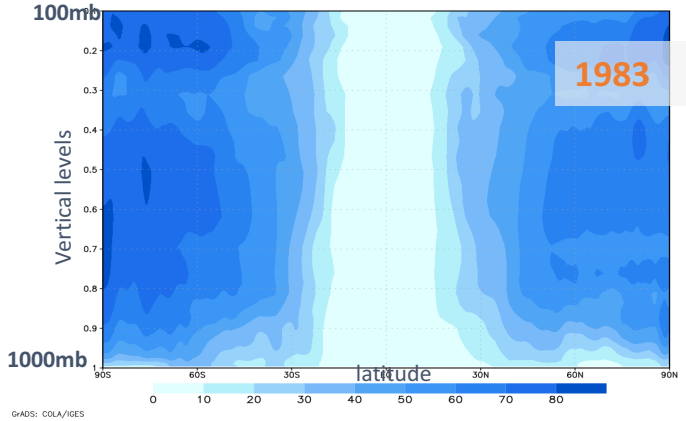
Balance contribution (NMC method)

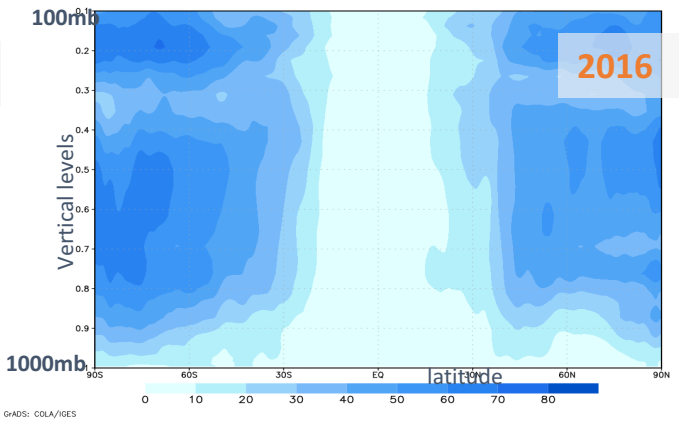
Unbalanced part of the temperature variance



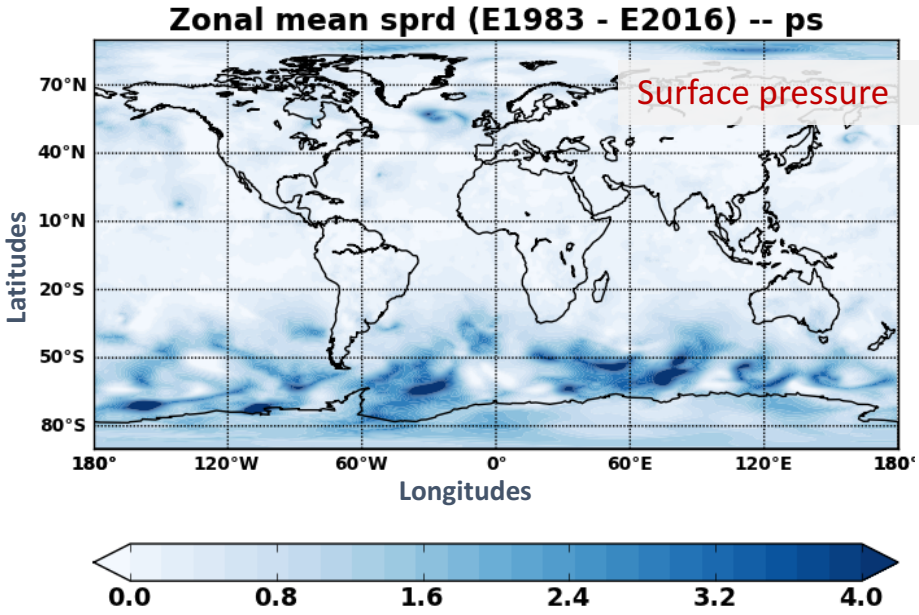


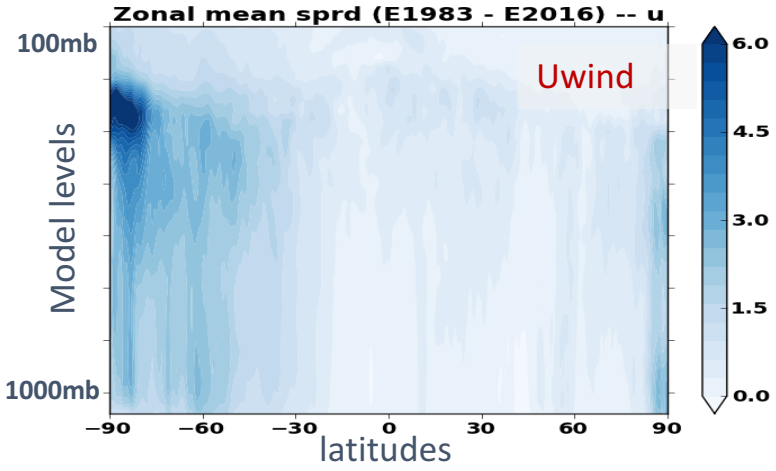
Percentage of total variance explained by the dynamical balance

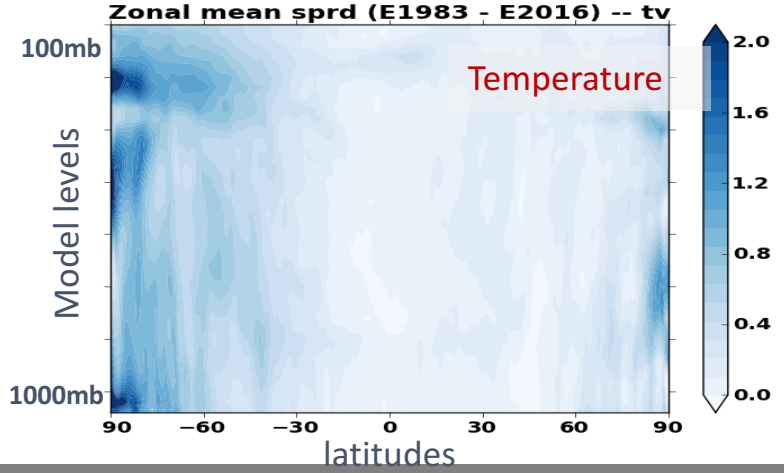




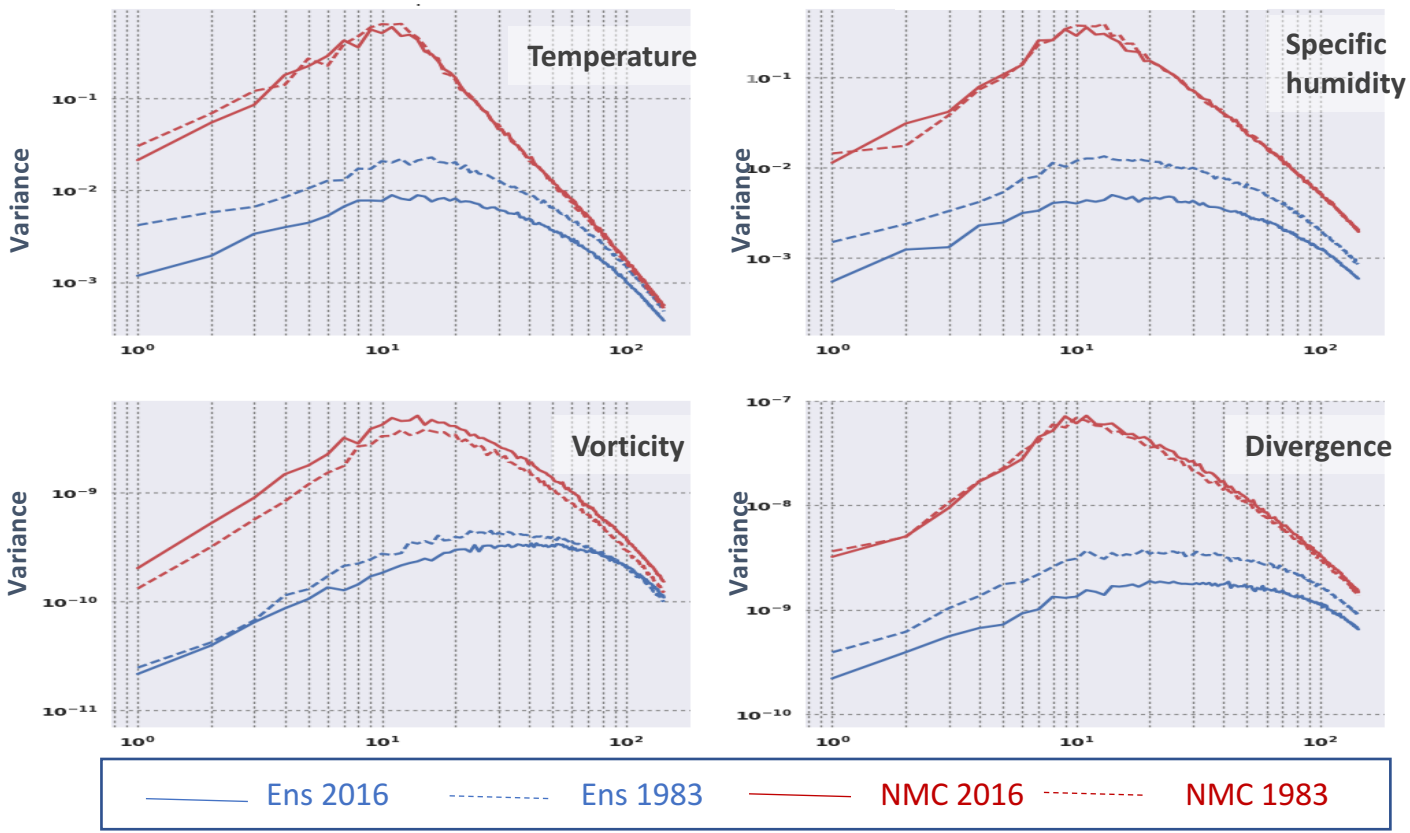
Ensemble Spread Difference





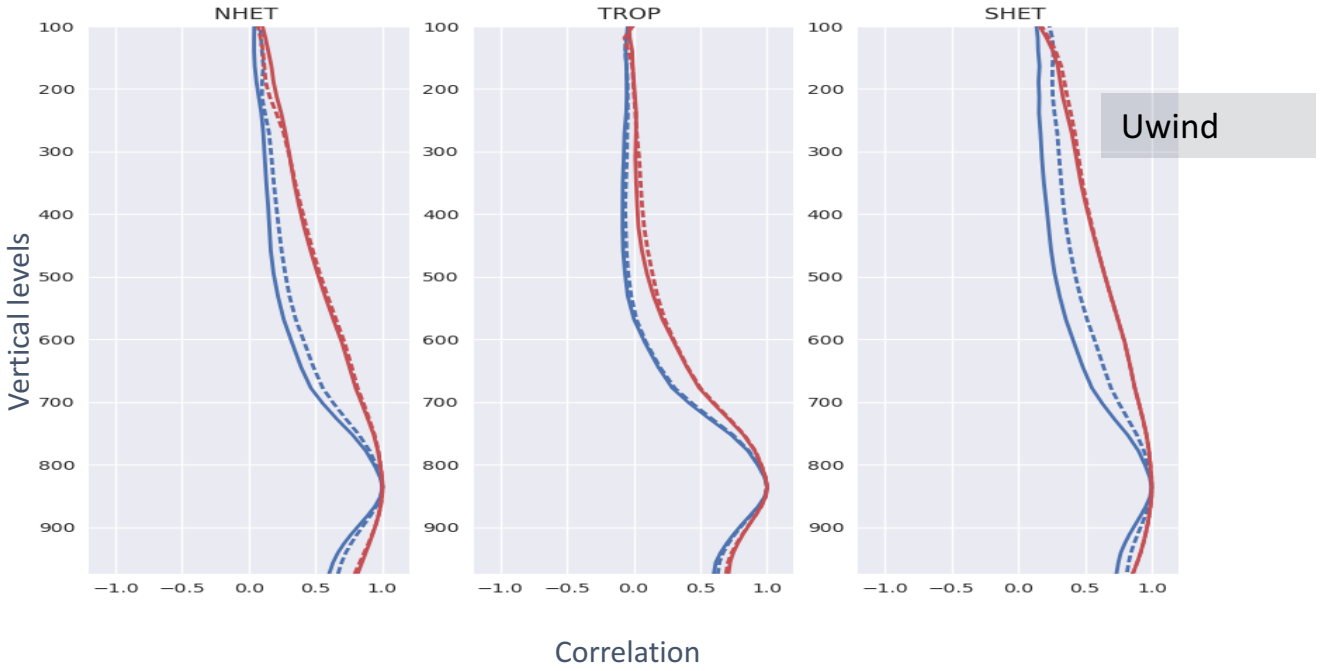


Spectral decomposition of total variance – level 850mb

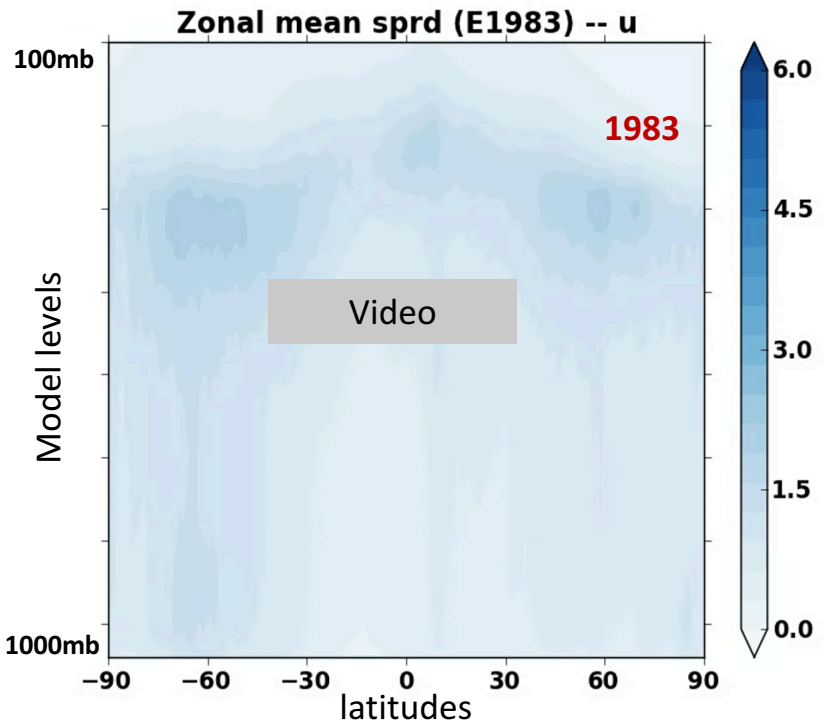


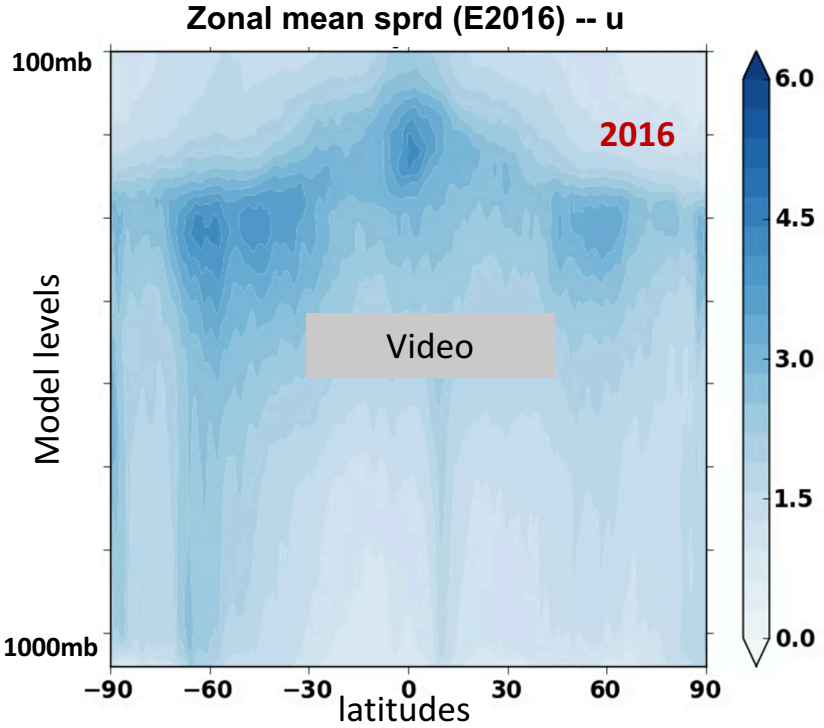
Vertical correlations
Level 850mb

ENS 1983
ENS 2016
NMC 1983
NMC 2016



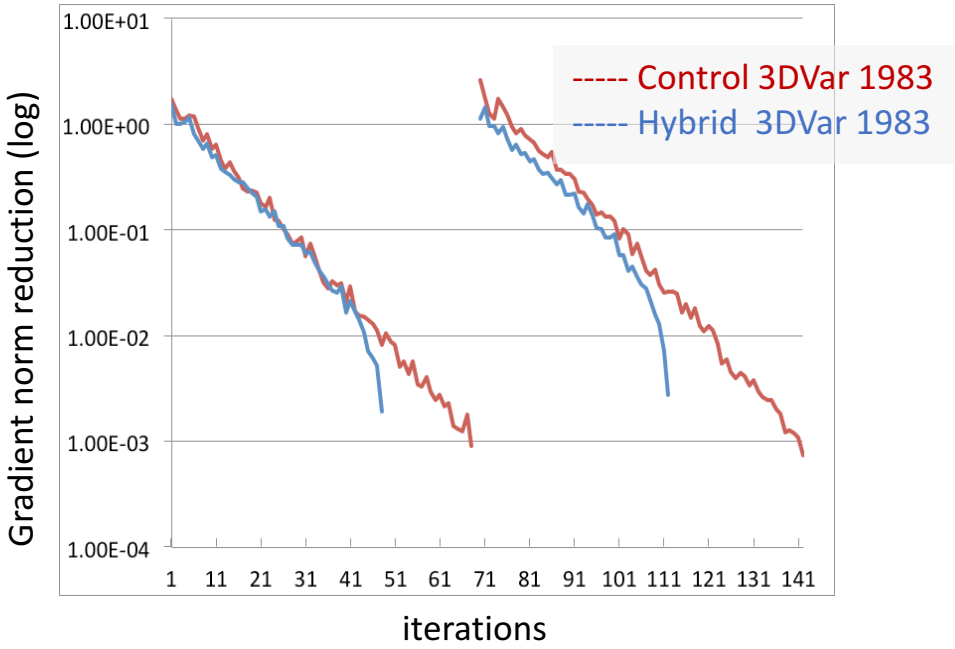
Challenges: Time series of ensemble spread



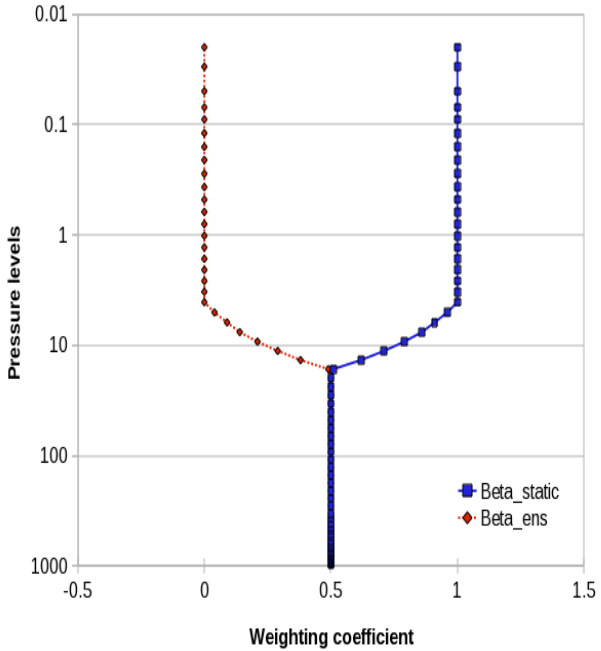


Challenges: Time series of ensemble spread

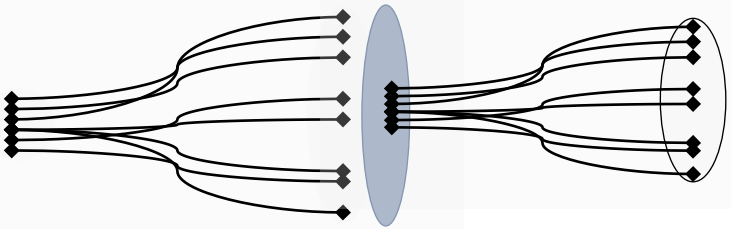
Convergence: BiCG breakdown cases



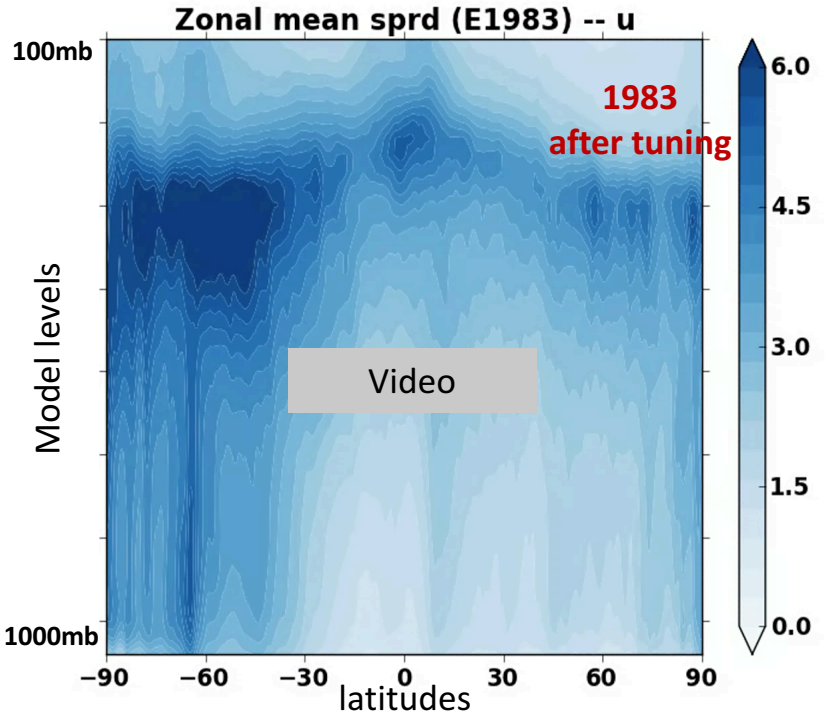
A deja-vu?



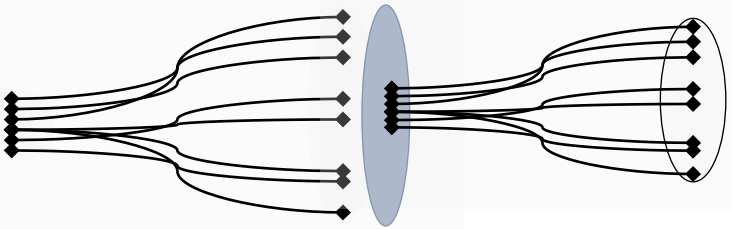
Challenges: Time series of ensemble spread



Sqrt EnKF analysis
relaxation to prior
additive inflation



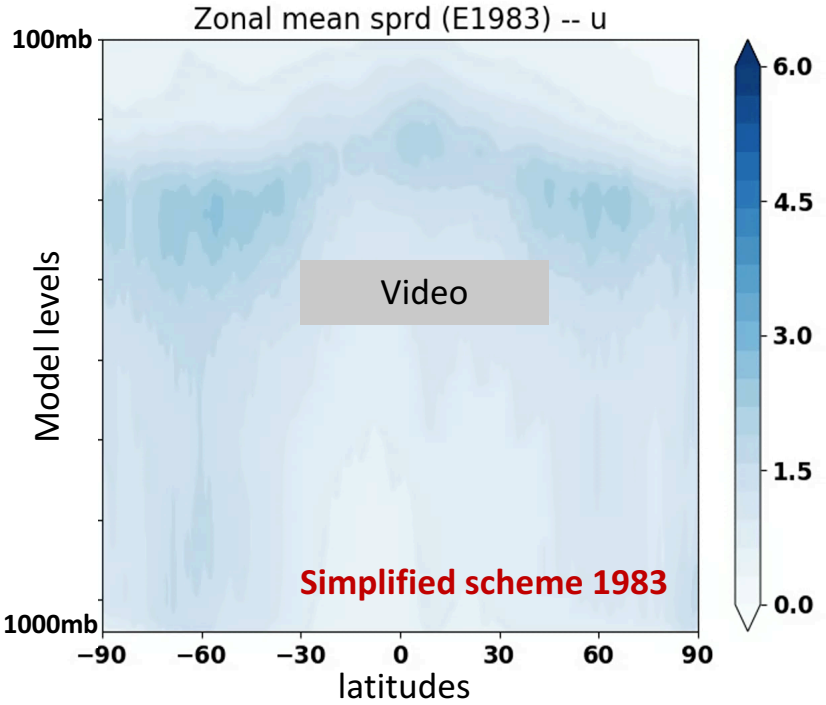
A simplified scheme (filter-free)



~~Sqrt EnKF analysis~~
~~relaxation to prior~~
additive inflation

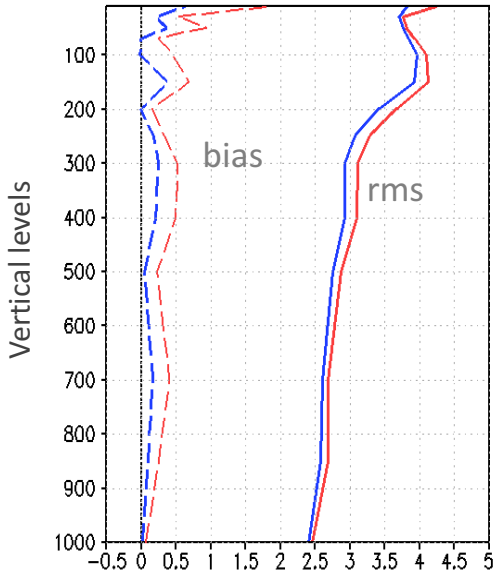
Simplified scheme: Only additive inflation

Ensemble of forecasts are initialized by perturbing the central analysis

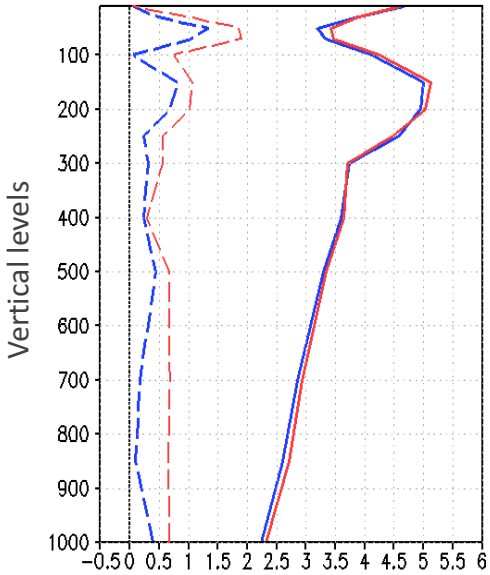


Observation minus background statistics – Uwind tropics

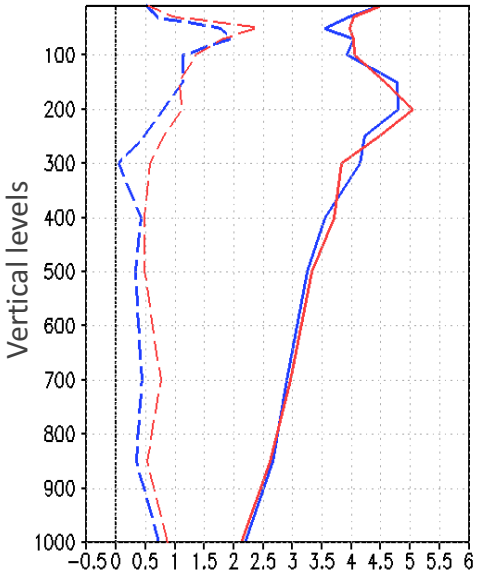
Hybrid 3DVar 2016



Hybrid 3DVar 1983

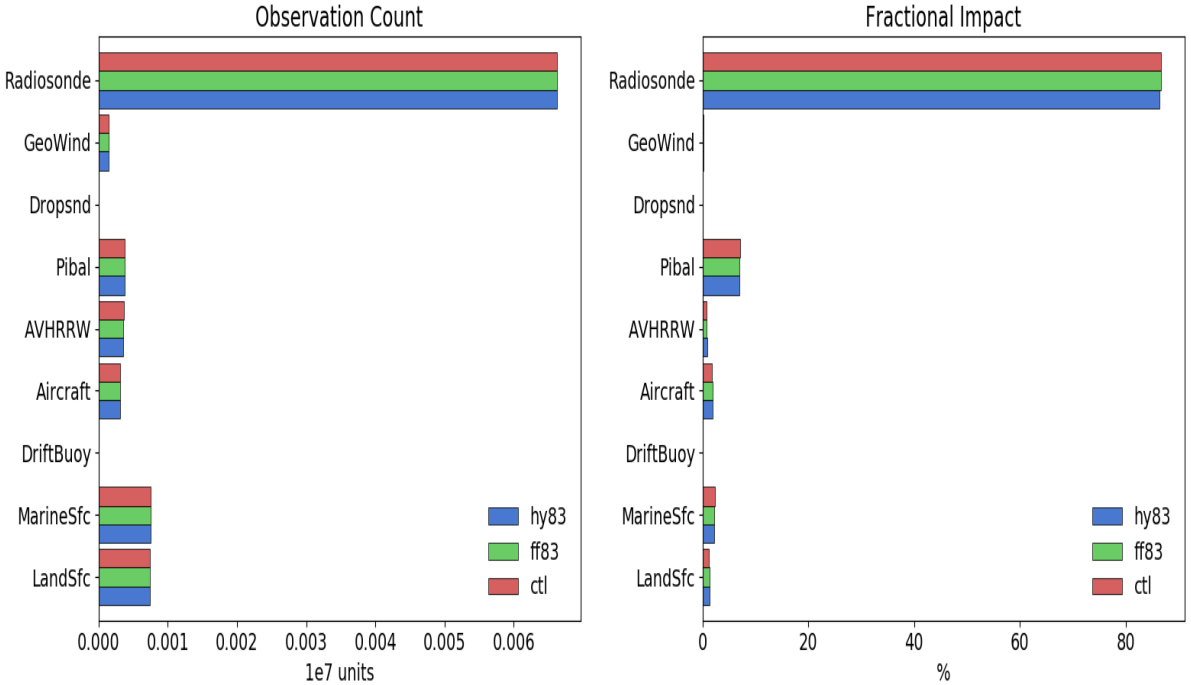


Hybrid 3DVar 1983 (Simplified scheme)



Hybrid 3DVar vs **Control 3DVar**

Observation impact



Control 3DVar

Hybrid 3DVar

Hybrid 3DVar (Simplified scheme)

Summary

- While the reanalysis concept relies on using a consistent (fixed) data assimilation technique, the use of ensembles in a hybrid reanalysis might be challenging if large differences in tuning are required for different time periods.
- Any tuning of the ensemble will have to consider the effect on transitional periods.
- Considering the long time run of the reanalysis, small additive unconstrained terms will end up causing undesirable instabilities.
- Use of stochastic physics based perturbations is expected to improve the behavior of the ensemble in the pre-satellite era. However, alone, these are not able to replace the additive inflation role in maintaining good ensemble spread in modern era.
- Results presented in this talk are preliminary and further aspects of the hybrid system are currently being examined.