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UERRA
Uncertainties in Ensembles of Regional ReAnalyses

http://www.uerra.eu/

UERRA Regional Reanalysis:
System Design

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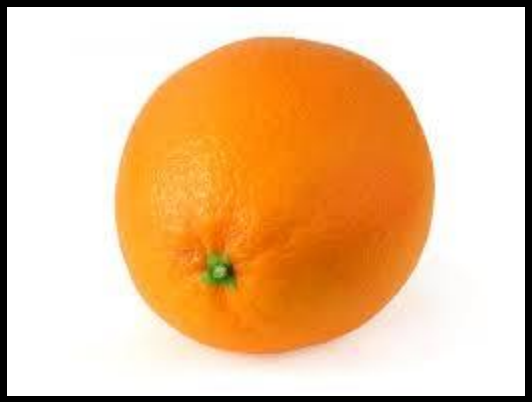
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Requirements

*Development and production of a satellite-era (**1978-present**) high resolution European **ensemble regional reanalysis** dataset, based on **ensemble-variational data assimilation**.*

UERRA D.O.W.

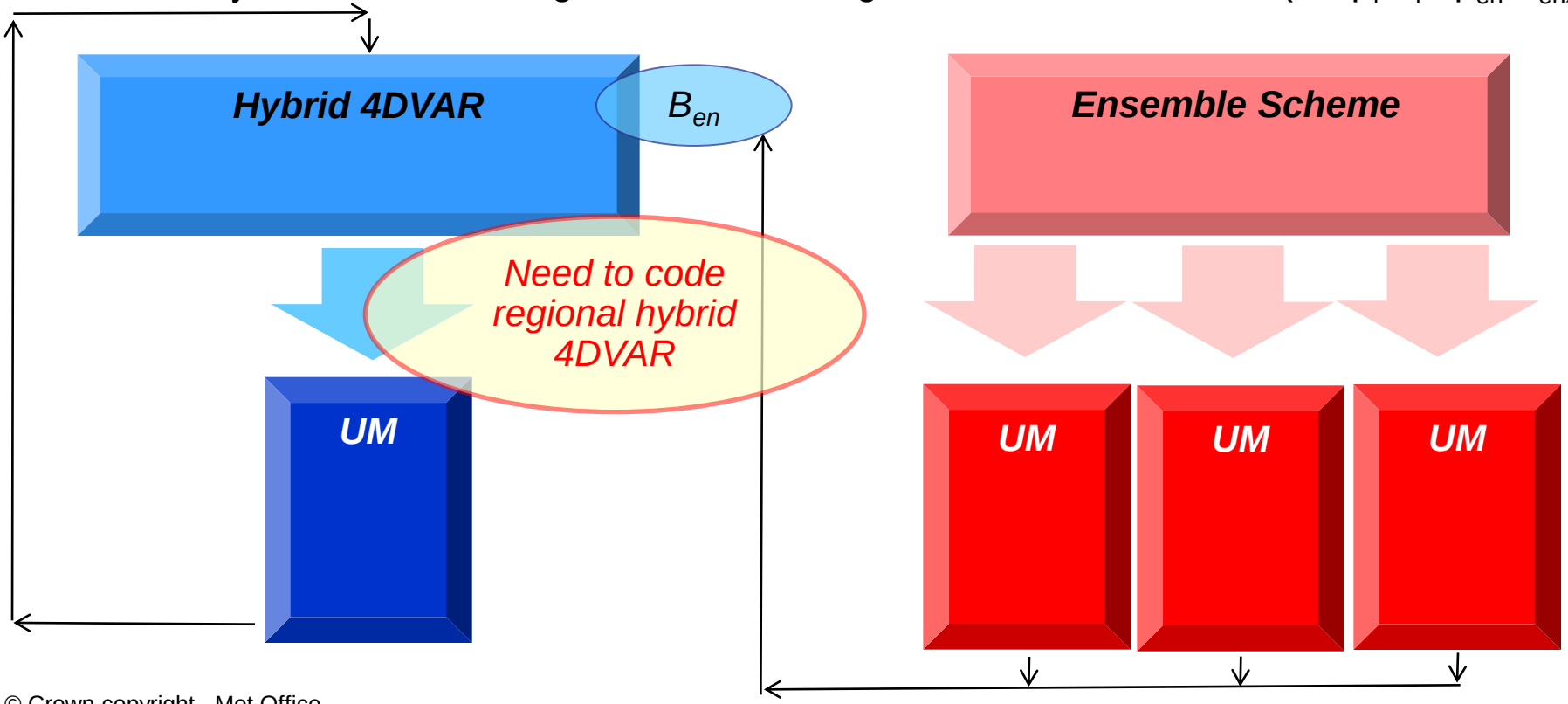
- EDA based deterministic reanalysis
  - 12km CORDEX-EU grid
- Ensemble of reanalyses
  - 20 members





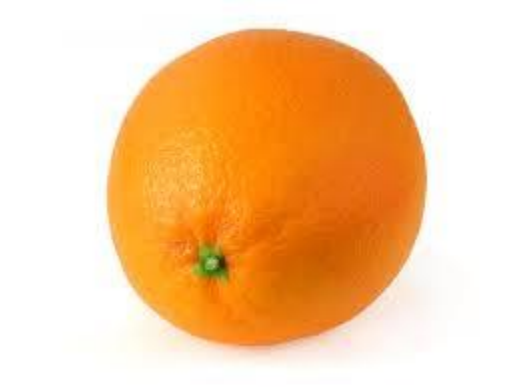
System Overview

- EURO4M - MO is a 12km European deterministic regional reanalysis
- 4DVAR assimilation scheme at 24km – fixed background error covariances ($B = B_f$)
- UERRA – MO will include a 12km European deterministic regional reanalysis
- EDA – "hybrid" 4DVAR – weighted sum of background error covariances ($B = \beta_f B_f + \beta_{en} B_{en}$)



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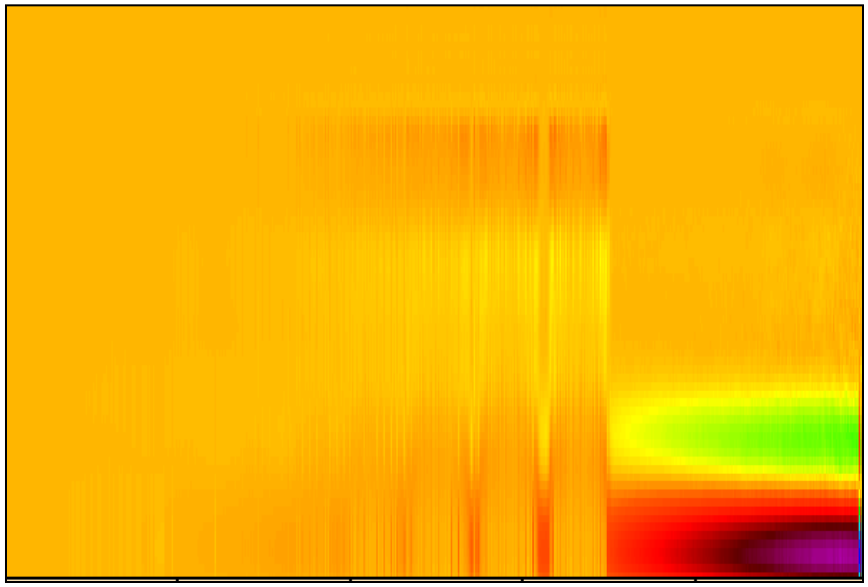
Deterministic System



Estimate state of atmosphere using obs & model

Background Error Cov

- "fixed" B_f will be updated on a regular basis
- B_f is a smooth idealised model with parameters tuned by training data
- B_{en} from ensemble – "Errors of the day"



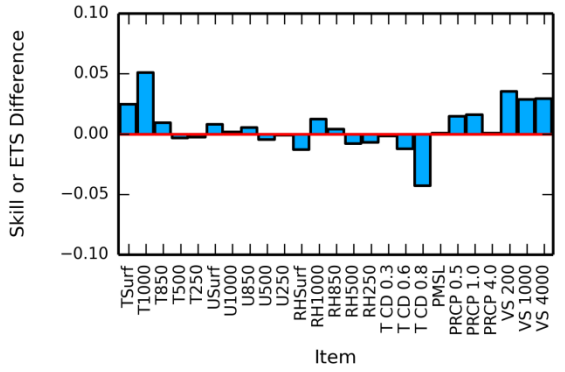
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Forecast Model: ENDGAME

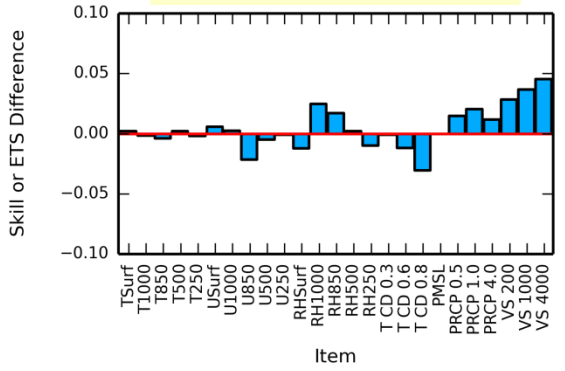
- New dynamical core
- Improved
  - coupling with parameterisations
  - handling of Rossby waves
  - stability
  - orographic effects
  - mass conservation

- Trials at 30km (2.5 x reanalysis grid)

Winter T+12



Summer T+12



- **Improved precip. & visibility**

of Regional ReAnalyses

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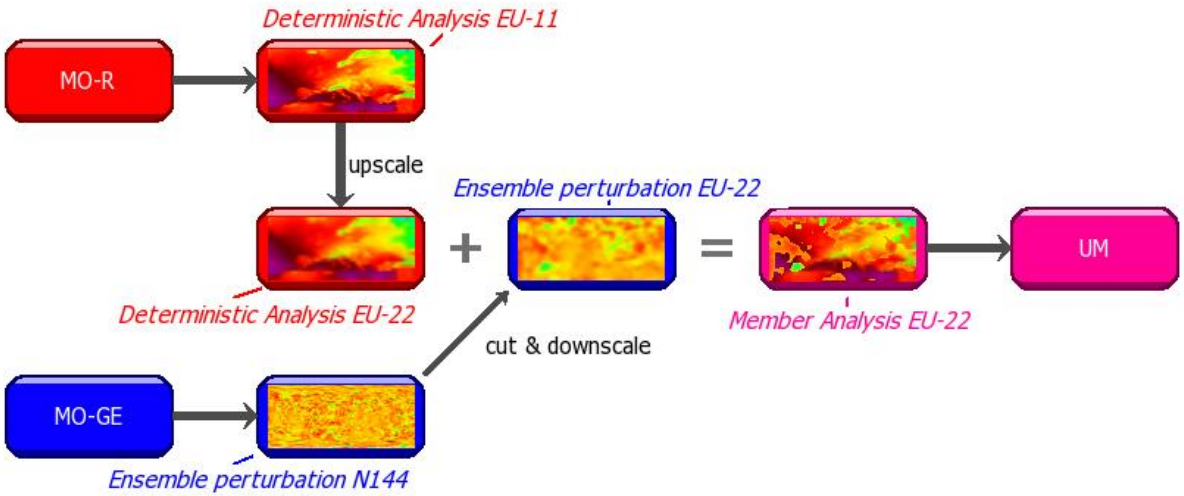
Ensemble System



Estimate uncertainty in det. system

Ensemble Candidate: ETKF

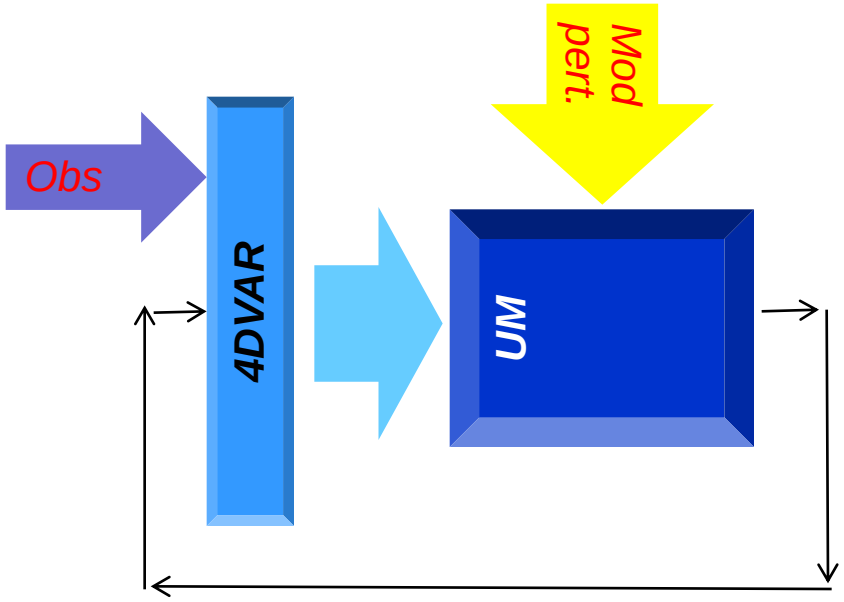
- Operational since 2005, ensemble (MOGREPS) is based on ETKF
- Requires inflation
- Known to be under-spread even after inflation
- Regional version **requires** global version
- Also requires two-way coupling with deterministic system



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Ensemble Candidate: En4DVAR

- Ensemble of deterministic system can be achieved by perturbing obs and model
- En4DVAR has been previously used to produce estimates of model error
- A similar system is used for operational EDA at ECMWF
- Closely follows det. system, i.e. Spread should be closer to det. uncertainty.
- Regional version **does not require** global version
- Also requires archive of deterministic analysis increments
- Each member runs a 4DVAR – much more expensive than ETKF



- En4DVAR is technically more flexible than ETKF

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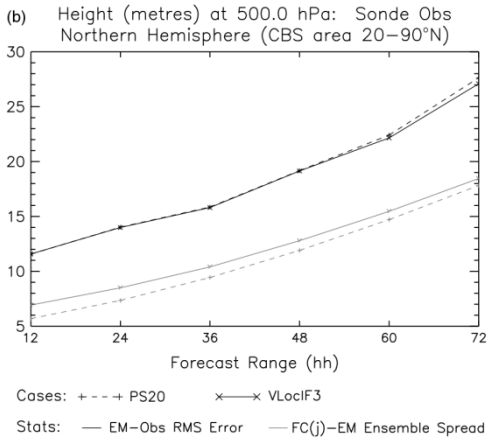
Candidate Comparison

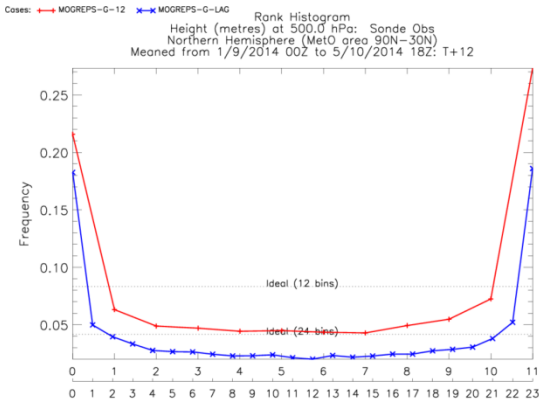
- NH 500hPa at T+6: **spread(En4DVAR) ≈ RMSE** **spread(ETKF) ≈ 0.5RMSE**

Spread Vs RMSE(mean)

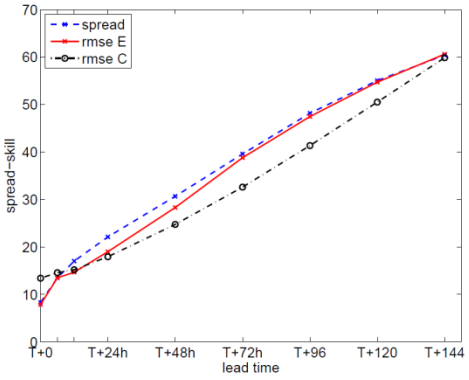
Rank Histogram

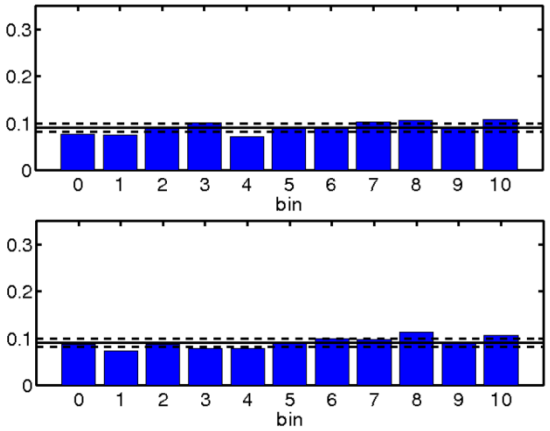
ETKF





En4DVAR

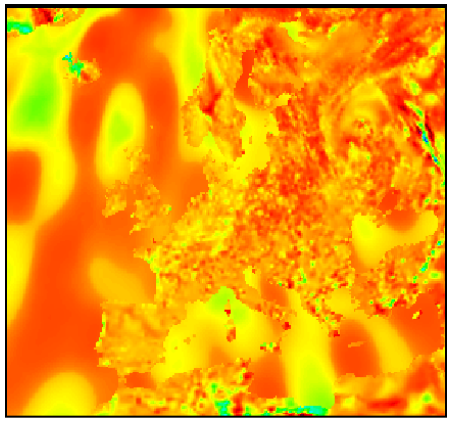
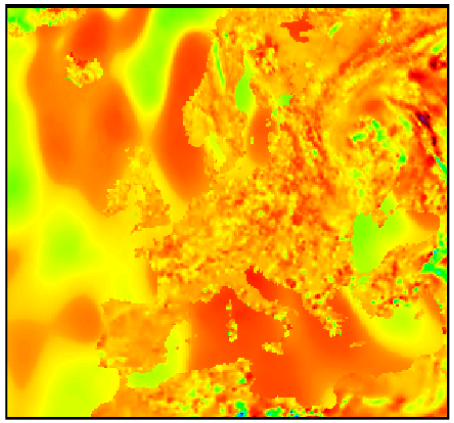
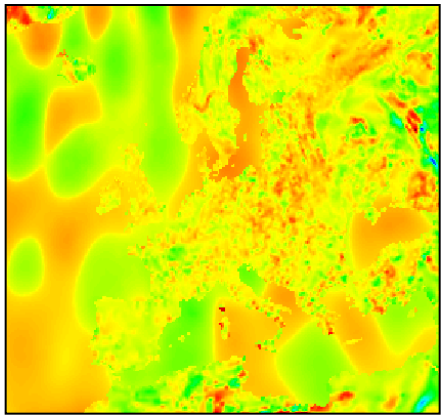




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En4DVAR

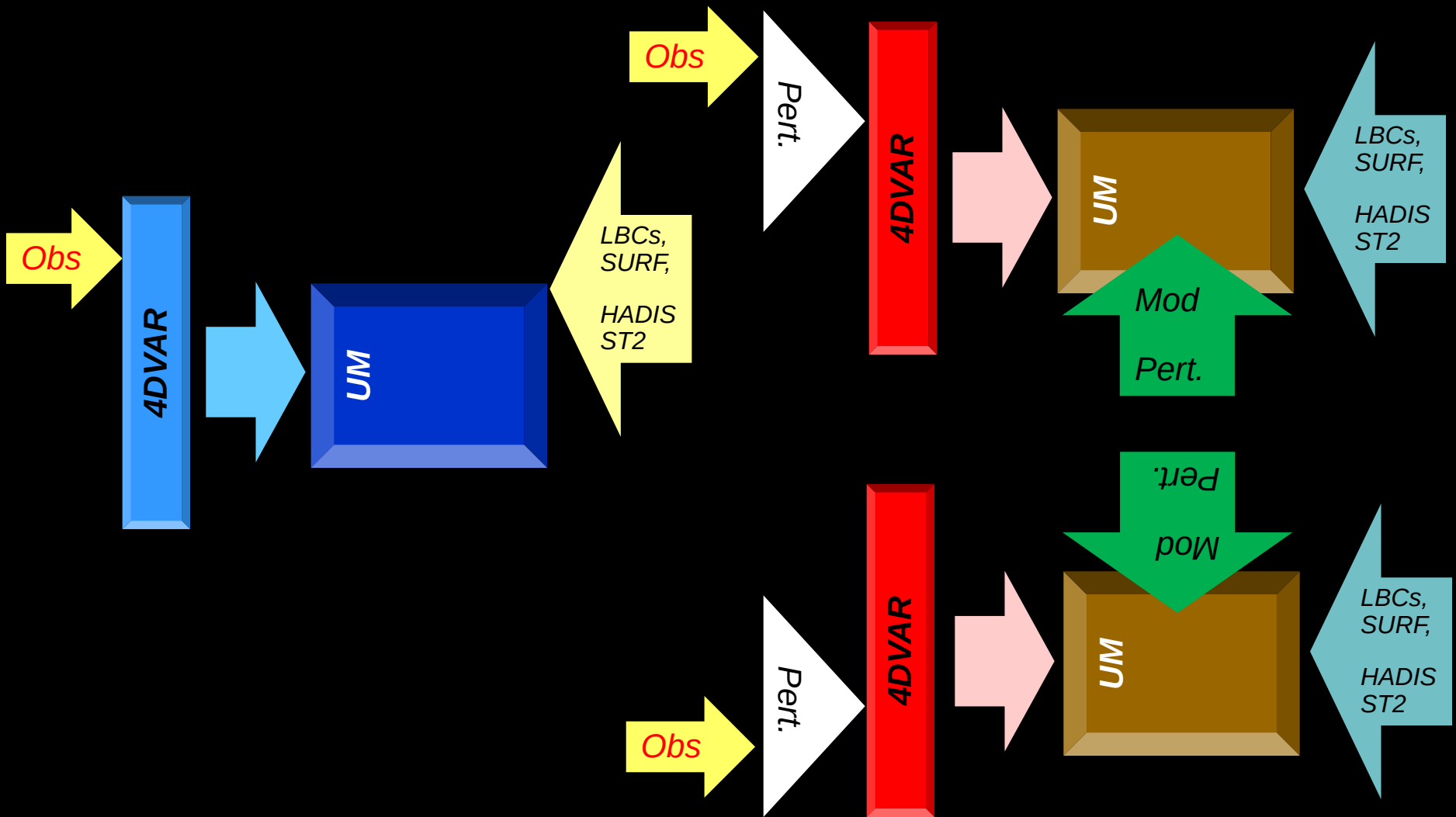
- Perturb...
  - **Observations** — **Random from error distribution**
  - **Model** — **Random archived analysis increment**
  - **External BCs** — **Ensemble datasets**

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Ensemble Members

- System is not complex - members are independent of each other & deterministic system



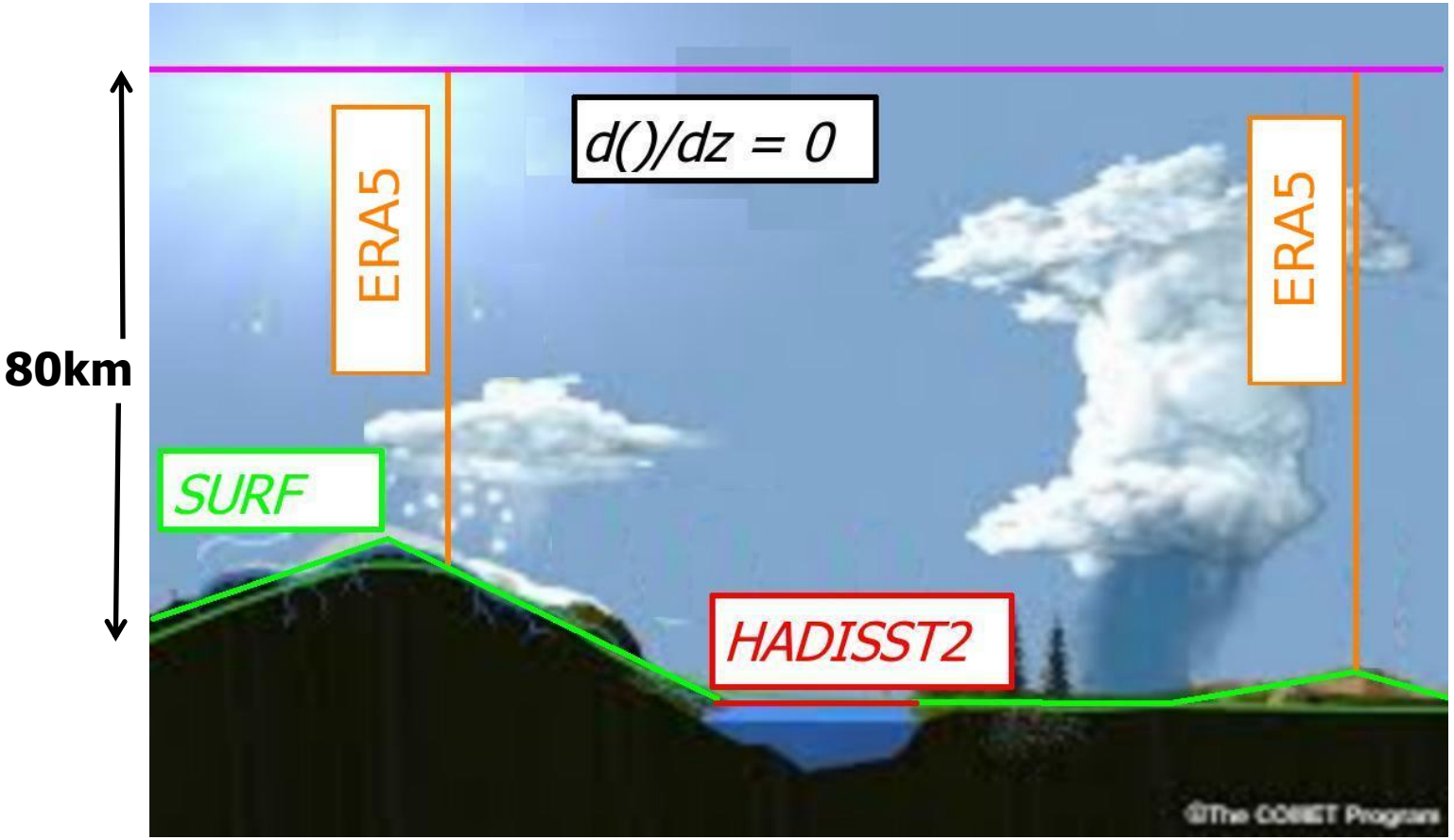
Cost

- En4DVAR ≈ 16 x Det.
- En4DVAR ≈ 2 x ETKF
- Reduce resolution
- Other efficiencies...



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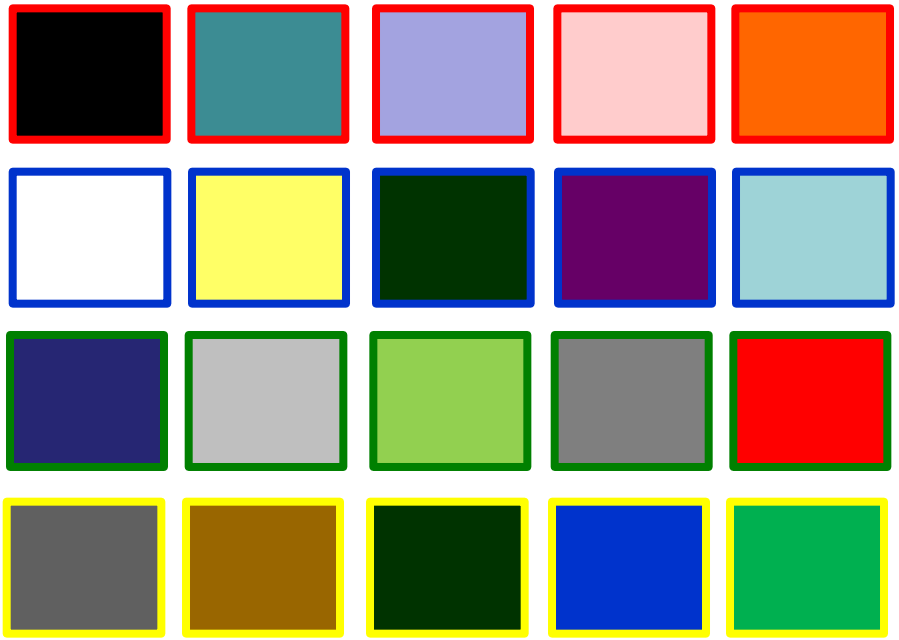
Boundaries



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Lateral Boundary Conditions

- Ensemble BCs from ERA-20C (max x10)
- Multiple members using the same BC – to include large scale and small scale uncertainty



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Summary

- Deterministic system will use hybrid 4DVAR (EDA)
- En4DVAR is expected to give a better estimate of uncertainty than ETKF
- En4DVAR is technically more flexible than ETKF
- En4DVAR may cost up to twice as much as ETKF, but costs can be reduced
- Ensemble includes representation of uncertainties in ...
  - Observations
  - LBCs
  - Surface (land/ocean)
  - Model

Thank you for listening...

...Questions?

Cost

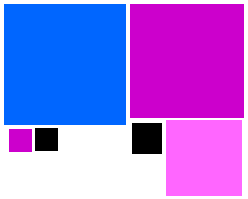
- Cost of deterministic system 90 PEdays/day
- Cost of ETKF estimated to be 600 PEdays/day
- Cost of full res. En4DVAR estimated to be 1400 PEdays/day
- Cost of 1/2 res. En4DVAR estimated to be 400 PEdays/day
- Further reduce cost via efficient use of ensembles

UM DA OPS

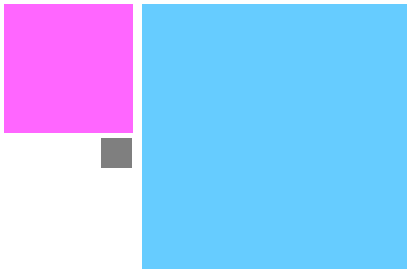
Det.



ETKF



En4DVAR full res.



En4DVAR 1/2 res.



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Forecast Model: Uncertainty

$$x_i^a = x_i^b + x_i^{'} \qquad x_i^{'} = x_i^a - x_i^b$$

$$x_i^b = M\left(x_{i-1}^a\right)$$

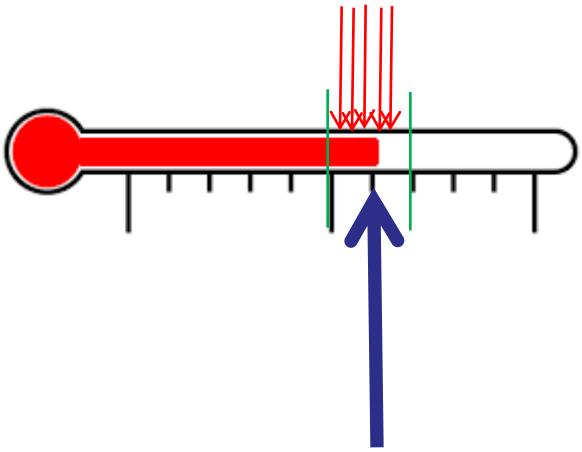
$$Q_i = x_i^* - M\left(x_{i-1}^*\right)$$

$$x_i^a - M\left(x_{i-1}^a\right) = x_i^a - x_i^b = x_i^{'}$$

$$\left\{x_j^{'}\right\} \approx \{Q_j\}$$

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Observations: Uncertainty

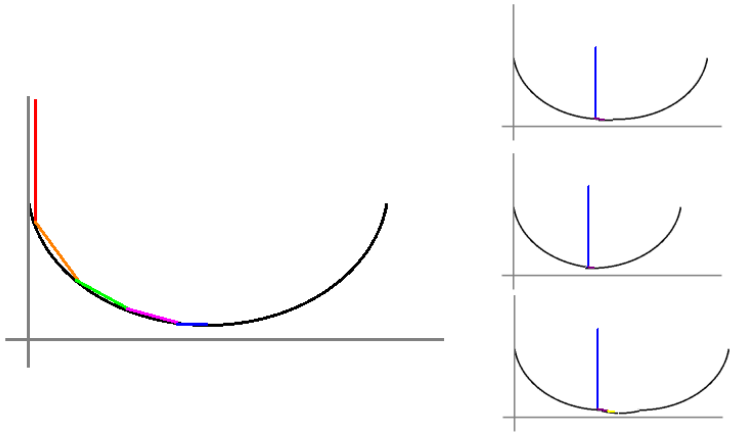


- Our assimilation scheme uses estimates of observation error ObsErr
- For a certain ensemble member, for each observation:
    - obtain a random number (usually [-0.5,0.5], Gaussian), Rand
    - ObsPert = ObsVal + Rand x ObsErr

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Efficient Ensemble Use

- Ensemble spread estimates uncertainty in ensemble mean
- Ensemble mean should be more accurate than deterministic system
- Ensemble mean may replace deterministic reanalysis
- Costs could also be reduced by using deterministic analysis as ensemble guess
- On each cycle a certain member may be more accurate than the mean or det. analysis...



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Observations

Met Office

UERRA Uncertainties in Ensembles of Regional ReAnalyses

ECMWF



Land Synop



Sondes



Ships & buoys

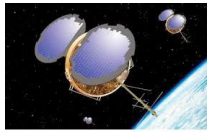


Aircraft



AIRS/TOVS/SSMIS/SEVIRIclear

Precip...



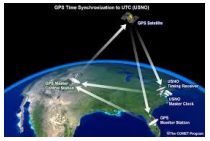
GPSRO

ECA&D

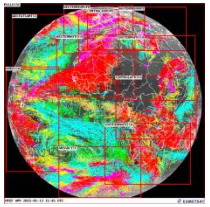
MetDB



Clouds (not avl.)



GroundGPS (not avl.)



AMVs (cant read)



Scatwinds (cant read)

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Satellite BC

- *VarBC*

$$bias = c^{scan} + \sum_{i=1}^{n} ci^{air} f(x_b)$$

Airmass-dependent bias correction of satellite radiances (based on Harris and Kelly, 2001)

VarBC will give smooth and automatic updating

(DingMin Li, Andrew Lorenc , Dale Barker)

- *Thanks to Richard Renshaw*