Ensemble Data Assimilation

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Analyses and forecasts become more accurate when:
- Observations, forecast model and/or data assimilation (DA) components improve.
- Forecast model carries information from past observations.
**Data Assimilation** is the process of combining prior knowledge of the state of the atmosphere (a previous model forecast) with new observations.

If we have equal confidence in prior forecast and new observation ($R = B$), analysis is half-way between (equal weight given to each).
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If we less confidence in prior forecast ($B > R$), analysis closer to observation. *The job of DA is to compute the weights that optimally blend the observations and the model forecast.*
What is the role of ensembles in DA?

The sample covariance estimated from an ensemble of first-guess forecasts is used to define the forecast uncertainty.

The Ensemble Kalman Filter (EnKF) algorithm integrates ensemble forecasts with DA.
PSD scientists developed EnKF software which became operational at NCEP in May 2012 as part of the 3D Ensemble-Var upgrade to the Global Forecast System (GFS).

Work is ongoing to improve the algorithms (4D EnVar upgrade coming Q1FY16), apply to new applications (e.g. hurricane forecasting, see H. Winterbottom poster).
Key factors limiting performance

**Sampling Error:** ensemble size $\ll$ model dimension. Need for *Covariance Localization*
Key factors limiting performance

**Model Error:** If every ensemble member run with the same model, uncertainty due to model formulation not accounted for. Need for **Stochastic Parameterization** (next talk)
Summary and Conclusions

- Ensembles allow a better characterization of forecast uncertainty – more information can be extracted from observations, improving analyses and forecasts.
  - Especially important when observations are sparse (20th Century Reanalysis)
- Improved treatments of sampling and model error are crucial for further progress.
- PSD research has directly benefited NOAA operations via partnership with NWS/NCEP.