Variational and Ensemble Techniques

- Equivalent in linear, Gaussian case.
  - Reasonable approximation in many (most?) applications of interest
- Different in nonlinear/non-Gaussian case but hard to reach general conclusions
- No realistic examples yet where one approach has distinct advantage
  - EnKF compared to operational systems
  - Convective scale, radar assimilation
  - (multimodal examples, variational QC)

Variational and Ensemble "Duality"

- Biggest remaining issues affect both approaches
  - Model error
  - Estimating forecast covariances
    - All estimates imperfect; need *quantitative* estimates of how imperfections influence analysis quality
    - "Cycling" covariance estimates … (hopefully) beneficial but also dangerous
  - Multiple spatial and temporal scales
  - If forecast model is crucial, how to use info from assimilation scheme to improve model? (nonlinearity crucial?)
- Now clear that EnKF-equivalent system could be built in existing variational frameworks.
  - Hybrid variational-ensemble schemes

Information from images

- "Tendency information," as in A. Lorenc's talk
  - Is the EnKF limited in its ability to use such information?

Social Aspects

- Ensemble filters lower the barrier to entry in DA
    - c.f. mesoscale models in mid 1980s
- Can only be good for the field

Multiple time and space scales

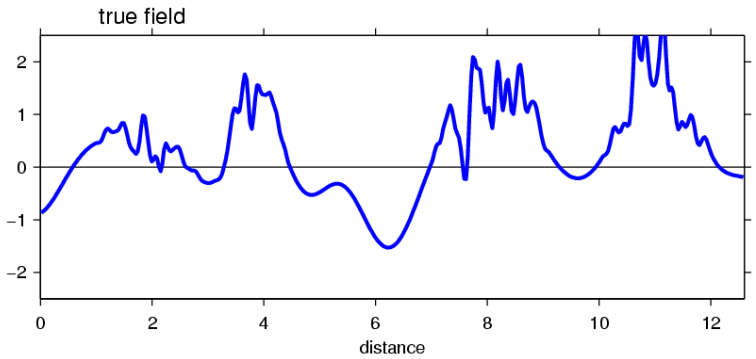
- How to choose localization scale in EnKF?
  - More “effective d.o.f” and thus more sampling error
  - Refinement (est. largest scales, then refine) vs. “upscale” influence of obs
- How to choose assimilation window in Var?
- How to model background covariances in Var?

Fundamental Issue

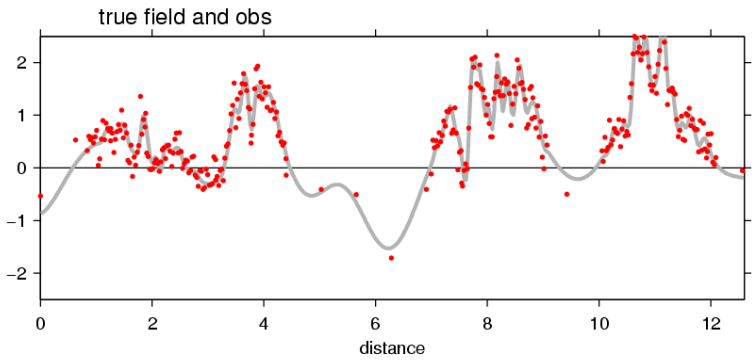
Line has both meso- and convective-scale structure

- intermittent: small-scales depend on larger scales

Consider assimilation for idealized, 1D random spatial field

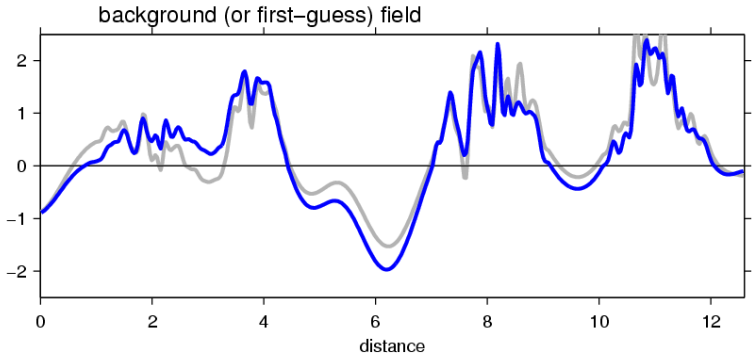


Idealized 1D example



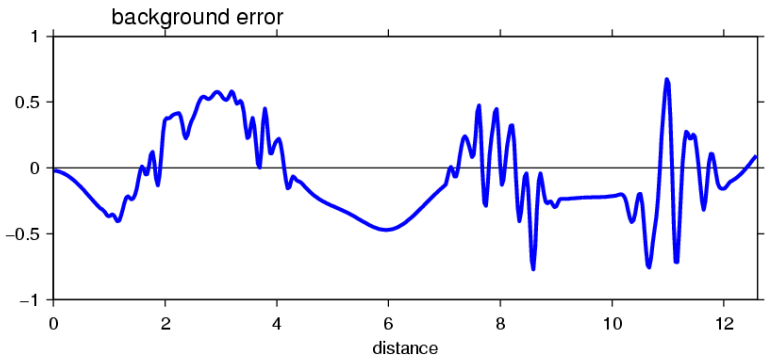
- simulate observations with random errors

Idealized 1D example

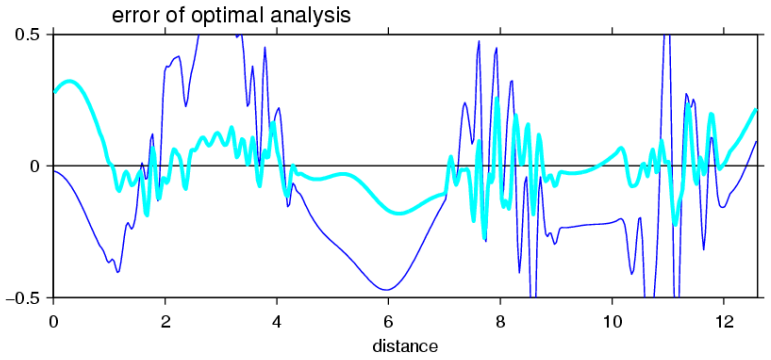


- error characteristics vary with large-scale field

Idealized 1D example

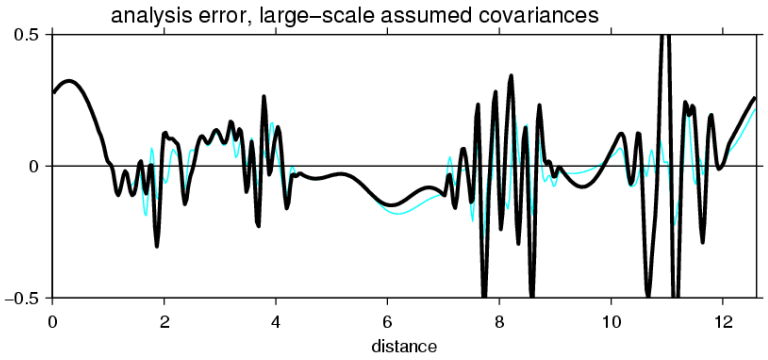


Idealized 1D example



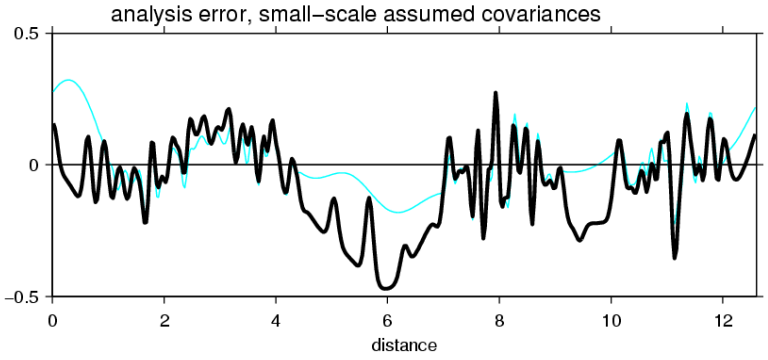
- optimal analysis uses correct covariances, which vary with location
- EnKF approximates optimal analysis well

Idealized 1D example



- sub-optimal assimilation, assuming errors have same correlation length everywhere
- assumed correlation length as in **large-scale** component of field

Idealized 1D example



- assumed correlation length as in **small-scale** component of field
- EnKF with analysis increments restricted to small neighborhood of

Summary

EnKF has practical attractions for "multi-scale" assimilation
- handles nests easily

Assimilation across meso- and convective scales
- localization of analysis increments is problematic in EnKF
- with sufficient obs, estimate mesoscale first, then refine
- ideally, estimate mesoscale given convective-scale observations

Assimilation with multiple scales fundamentally hard
- requires flexible, general covariance models
- How to choose length of 4DVar time window?