REGIONAL ENSEMBLES FOR USE IN DATA ASSIMILATION

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PREAMBLE

- Choice between variational vs. sequential DA
  - Ongoing debate, pros & cons
- Emerging consensus
  - Use variational method with ensemble covariance
    - Variational DA
      - Static plus ensemble covariance
    - Benefits of variational DA + ensemble covariance
  - ECMWF, UKMET, other centers
- NCEP chose to use GSI with hybrid covariance
  - Combination of static and ensemble-based covariance

REQUIREMENTS FOR ENSEMBLE

- Variance
  - Must match short-range forecast error variance
    - How to evaluate?
- Covariance
  - Must capture space of dynamically growing fcst errors
    - Small subspace of growing errors
      - Matter & can be captured
    - Very large subspace of neutral/decaying errors
      - Cannot be sampled well and hurts
    - How to evaluate?
- Consistency of regional ensemble with global ensemble
  - Lack of it hurts covariance

OPTIONS FOR ENSEMBLE GENERATION

- Interpolate global initial conditions to LAM resolution
  - Consistency with boundary conditions
  - Limited fine scale info in covariance of short-range fcsts
  - Variance on coarser scales as good as in global system
  - Temporal consistency – as in global ensemble
- Enkf DA
  - Variance – estimate independent of variational DA
  - Covariance – noise introduced as part of DA
    - Observational noise, inflation
  - Consistency with boundaries – not resolved?
  - Temporal consistency – the more data, the less consistency
  - Computational cost
  - Theoretically not appealing
    - Not clear why DA needs to run twice?

CYCLED PERTURBATIONS

- Concept
  - Create fine scale perturbations consistent with boundaries from global ensemble
- Methodology
  - Run regional short-range ensemble with
    - Boundary forcing from global ensemble
  - Cycle difference between global and regional forecasts
    - Difference between
      - Global perturbed forecast interpolated onto regional grid &
      - Regional perturbed forecast
  - Rescale ensemble variance to variance in global ensemble
    - Variance estimate from global Enkf can be used

CYCLED PERTURBATIONS - ATTRIBUTES

- Variance
  - Analysis / short-range error variance estimate needed
- Covariance
  - Dynamically conditioned
- Consistency with boundary conditions
  - Yes
- Temporal consistency in perturbed analyses
  - Yes
- Link with NCEP operational regional ensemble
  - Can be run either with global Enkf or ETR

FUNCTIONS/REQUIREMENTS FOR DA-ENSEMBLE HYBRID SYSTEM

DA

- Accurate estimate of the state of a system
- Estimate of error variance
  - GSI does not provide this

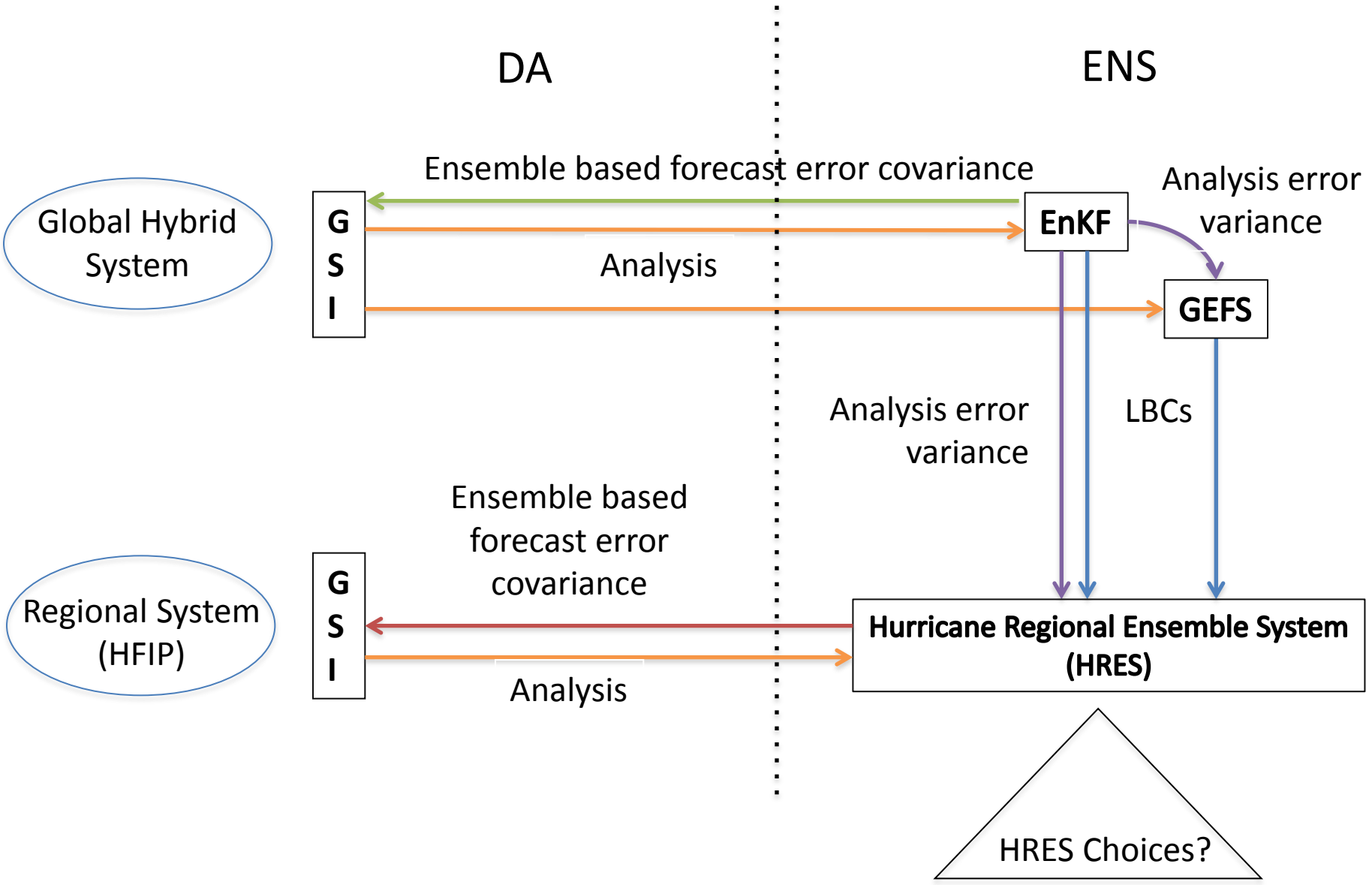
ENSEMBLE

- Dynamically conditioned forecast error covariance
- Forecast error variance reflecting background error variance

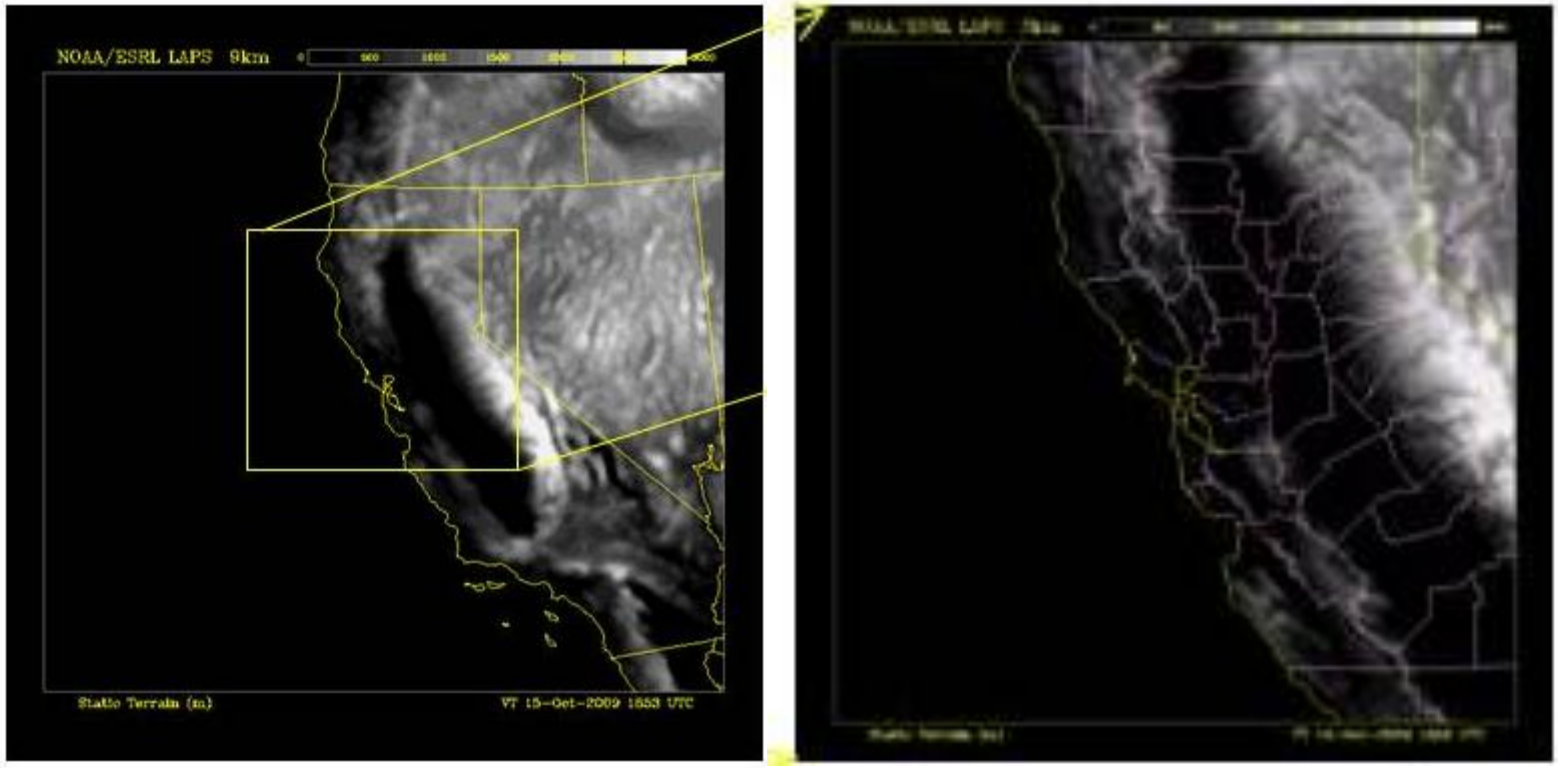
Regional DA & Ensemble systems fully consistent with global DA / Ens.

Temporally consistent series of perturbed initial conditions

COUPLED DATA ASSIMILATION & ENSEMBLE FCST SYSTEM

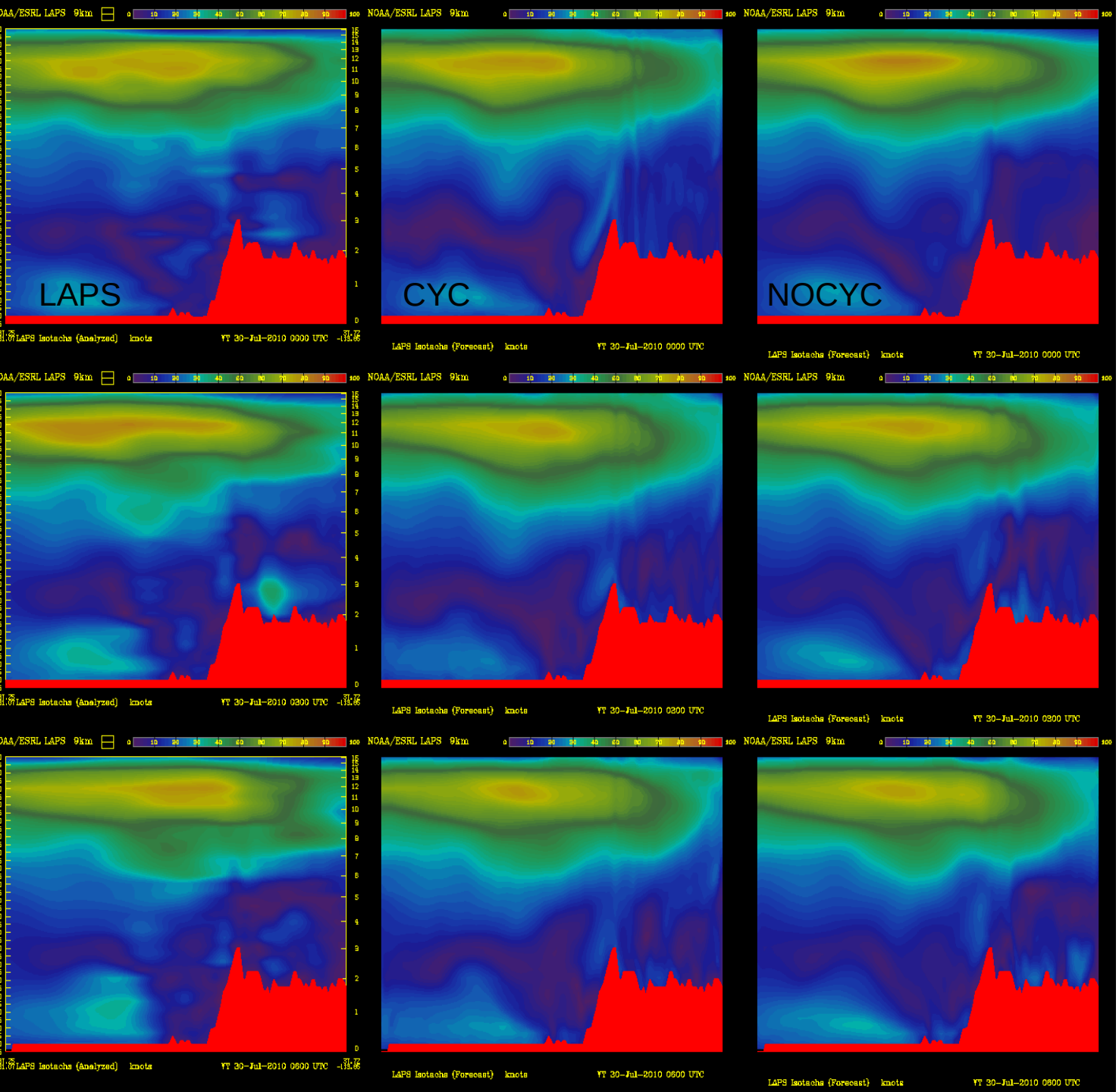


Preliminary IC perturbation test performed for HMT experiment 2009-2010



Nested domain:

- Outer/inner nest grid spacing 9 and 3 km, respectively.
- 6-h cycles, 120hr forecasts foe the outer nest and 12hr forecasts for the inner nest
- 9 members (listed in the following slide)
- Mixed models, physics & perturbed boundary conditions from NCEP Global Ensemble



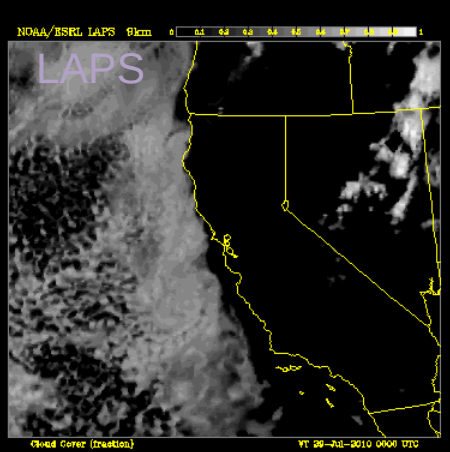
Wind Speed
July 30 2010 00UTC

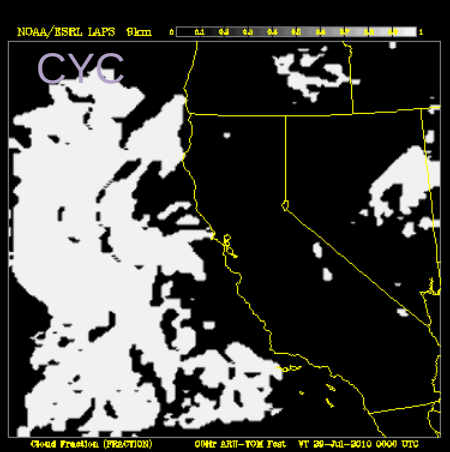
00hr

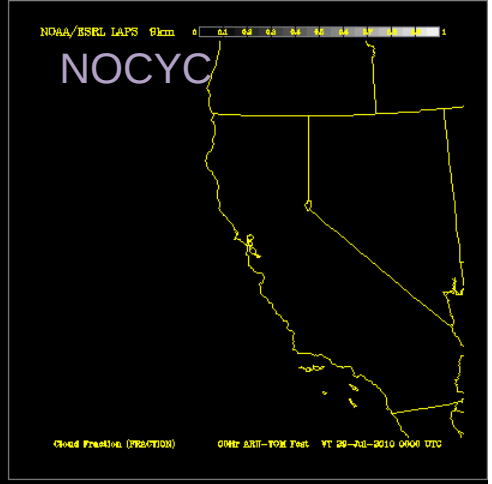
03hr

06hr

Cloud Coverage
July 30 2010 00UTC







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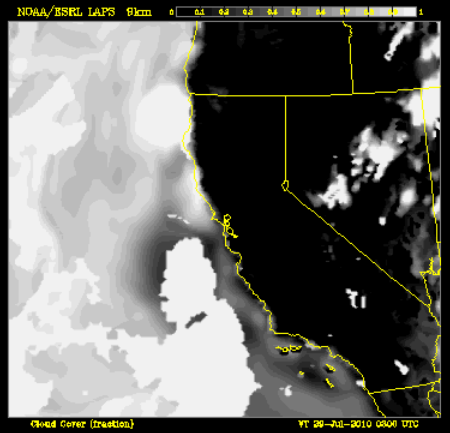

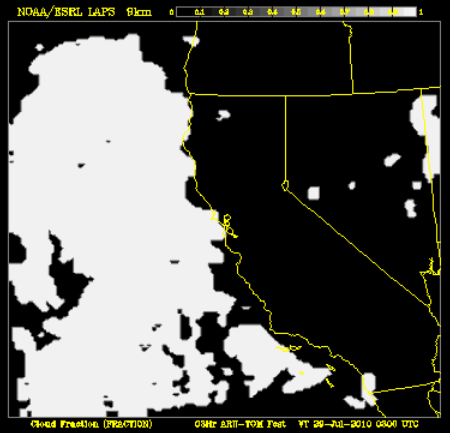

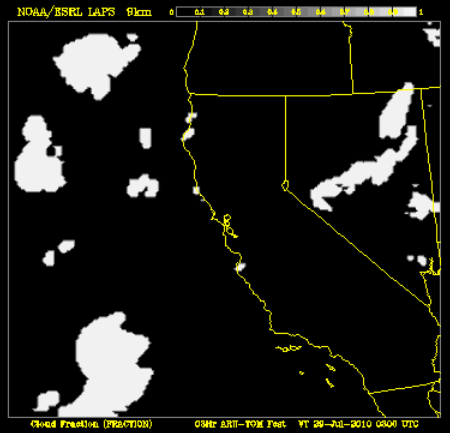

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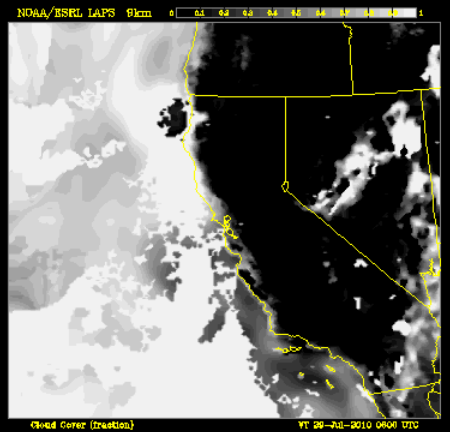

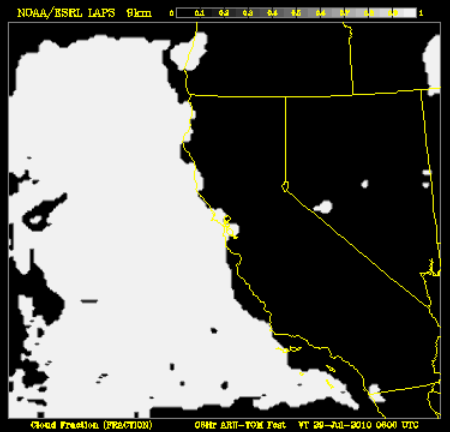

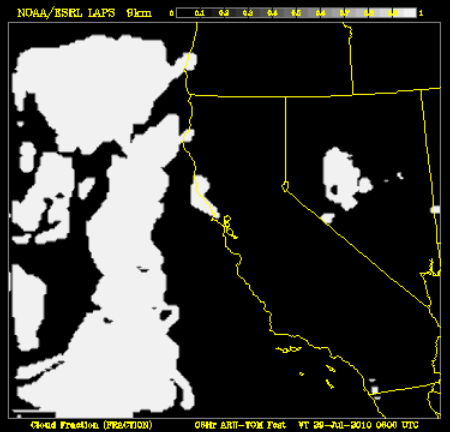

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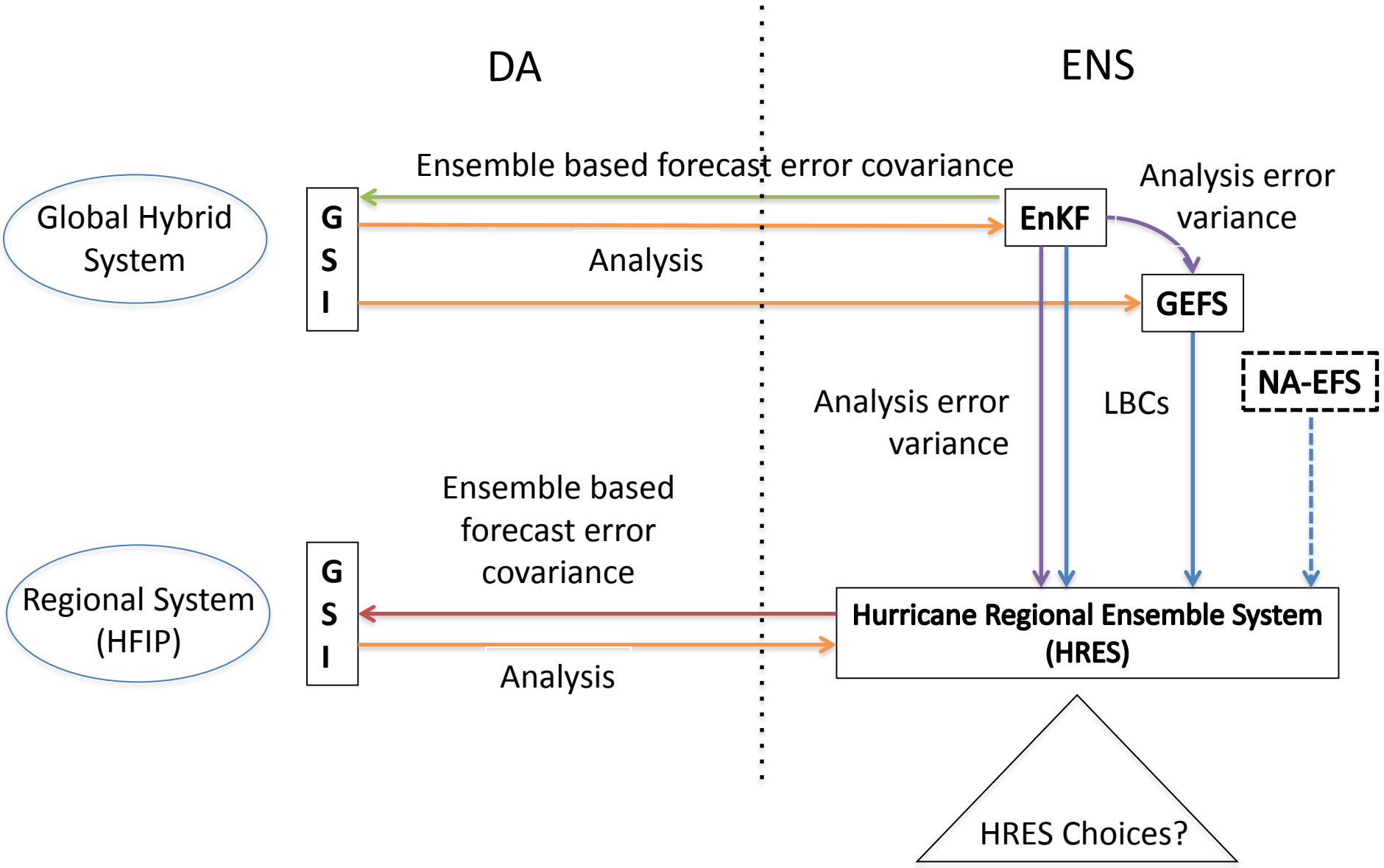
COUPLED DATA ASSIMILATION & ENSEMBLE FCST SYSTEM



BACKGROUND

HREF testing plan

- Consider testing use of 12-km NA ensemble
  - GSD – DTC – NCEP collaborative effort
  - Influence of improved forecast boundary conditions
- Test cycling initial perturbations for HREF
  - Compare with other initial perturbation methods
- Connect with hybrid GSI DA
  - Covariances derived from cycled HREF
  - Regional GSI used as center of ensemble at initial time

Current Status

- Ensemble simulation of Earl using global boundaries
  - To test various physics
- XML / HWRF workflow in collaboration with DTC
  - Test effects of forecast boundaries (GEFS vs. EnKF)
  - Access to latest HWRF version

OPERATIONAL REGIONAL ENSEMBLE SYSTEMS

- Overview
  - Different centers use different approaches to ICs and LBCs problem
  - Initial and LBC perturbations often use info from corresponding global EFS

- UK Met Office:
  - Global EFS uses regionalized version of Ensemble Transform Kalman Filter (Bishop et al. 2001).
  - Originally the global EFS was used to provide ICs and LBCs to the regional EFS by simple interpolation to higher resolution LAM grid
  - Regional ETKF used for a while
  - Based on the Bowler and Mylne 2009 study decision was reversed
    - Currently simple interpolation used

- Environment Canada:
  - Global EFS uses Ensemble Filter approach
  - Singular Vector approach tested
  - Simple interpolation currently in place
  - Ongoing development of regional Ensemble Filter?

- Central Institute for Meteorology and Geodynamics (Austria)
  - Cycled perturbations

PAST & CURRENT NCEP SYSTEMS

- Global Ensemble Forecast System (GEFS)
  - Breeding technique introduced – 1992
  - Ensemble Transform with Rescaling (ETR) – 2006
  - EnKF implementation planned for hybrid DA application – Spring 2012

- Short-Range Ensemble Forecast (SREF) system
  - Breeding implemented - 2000
  - ETR has not been implemented for the regional EFS
    - Global & regional systems not fully consistent
  - Different parts of ensemble use somewhat different perturbation techniques

HREF CHOICES – ENKF

- GSI is choice for DA
- EnKF can be used to generate ensemble
  - For generation of flow dependent covariance to be used in GSI
  - Running 2nd DA scheme to estimate error variances in GSI
    - Analysis error variance estimate is not for GSI (it is for EnKF)
  - Expensive
  - Perturbations may not be as dynamically consistent as with other options?
  - Regional EnKF may not be consistent with global ensemble?

HREF CHOICES – "CYCLING"

Dynamical downscaling or cycling of perturbations

- Simple
- Inexpensive
- Dynamically conditioned perturbations (by design)
- Regional system consistent with global (by design)
- Initial variance can be set according to best available estimate
  - Use analysis error estimates Global EnKF
- Initial & forecast boundary conditions from GEFS

Initial Perturbations "Cycling" using Global (GSI) Analysis and Global EnKF Forecasts