On the Need for Including Modularity/Flexibility in a Unified GSI Regional Hybrid

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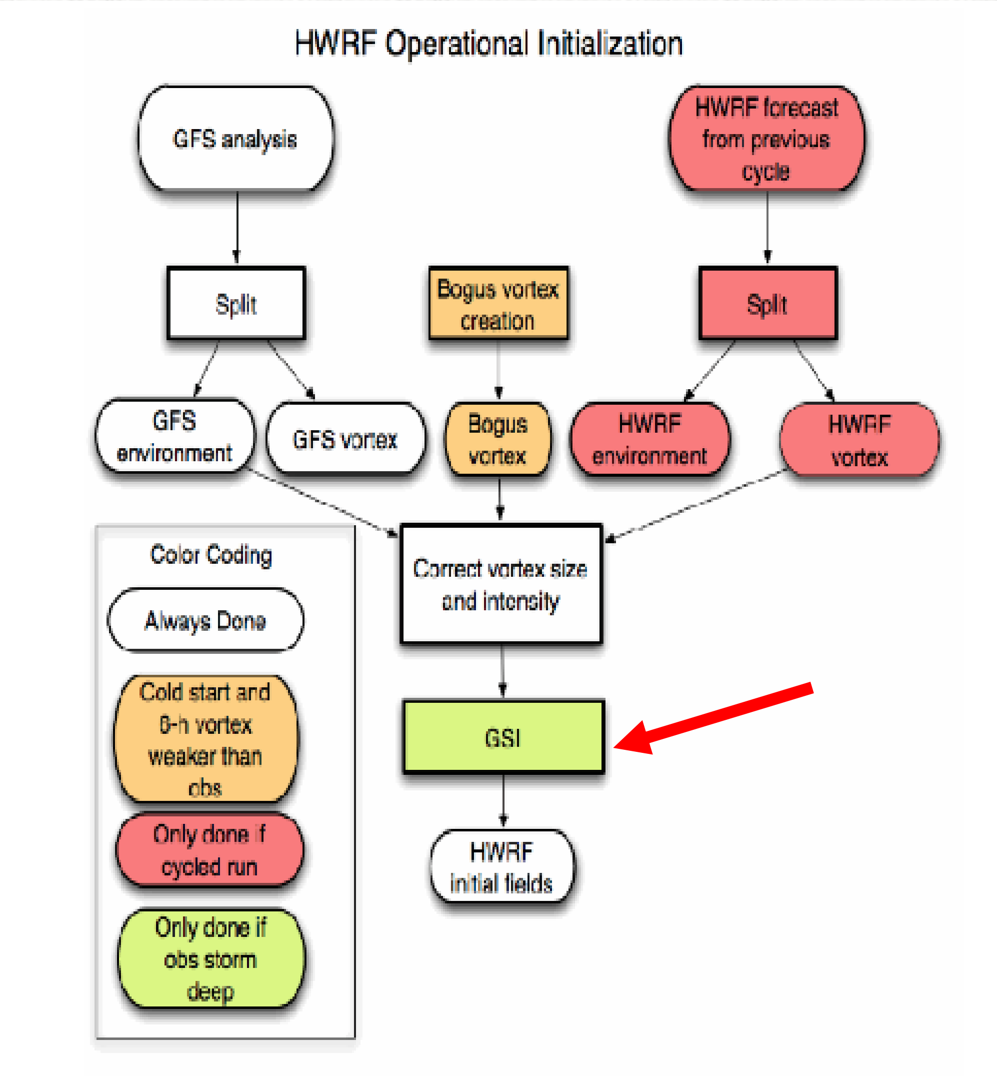
GSI in HFIP



- Excludes conventional data within 150 km of eye due to static/isotropic BE.
- Flow dependent BE is thought to be the solution.
- GSI regional hybrid is natural implementation strategy.
- QUESTION: Which ensemble perturbation strategy is optimal (i.e., produces the greatest forecast skill)?
- ANSWER: Unknown.

N E S L

GSI Regional Hybrid

1. GSI global hybrid developed by Dave Parish at NOAA/EMC in collaboration with Xuguang Wang from the University of Oklahoma.
2. NCAR/MMM modified the GSI global hybrid to apply it in a regional setting and incorporate the ETKF, LETKF, and EnKF.
3. Regional hybrid modifications were incorporated into the GSI trunk by Dave Parish and Daryl Kleist.

GSI Hybrid Cost Function

- Ensemble covariance is included in the 3DVAR cost function through augmentation of control variables.

$$J(\mathbf{x}_1^{'}, \boldsymbol{\alpha}) = \beta_1 J_1 + \beta_2 J_e + J_o$$

$$= \beta_1 \frac{1}{2} \mathbf{x}_1^{'T} \mathbf{B}^{-1} \mathbf{x}_1^{'} + \beta_2 \frac{1}{2} \boldsymbol{\alpha}^T \mathbf{C}^{-1} \boldsymbol{\alpha} + \frac{1}{2} \left(\mathbf{y}^{o'} - \mathbf{H}\mathbf{x}^{'}\right)^T \mathbf{R}^{-1} \left(\mathbf{y}^{o'} - \mathbf{H}\mathbf{x}^{'}\right)$$

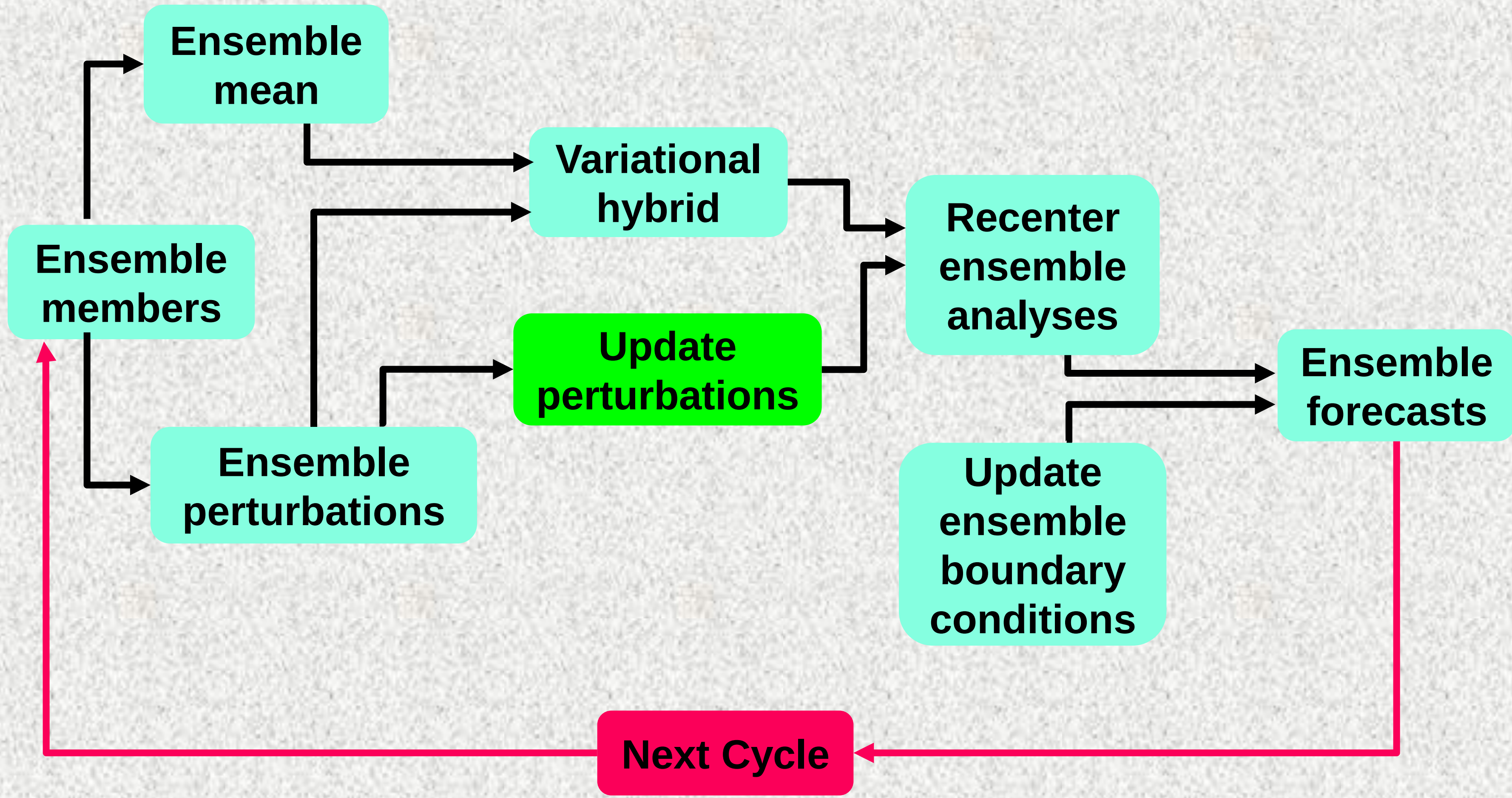
Extra term associated with extended control variable

$$\mathbf{x}^{'} = \mathbf{x}_1^{'} + \sum_{k=1}^{K} \left(\boldsymbol{\alpha}_k \circ \mathbf{x}_k^e\right)$$

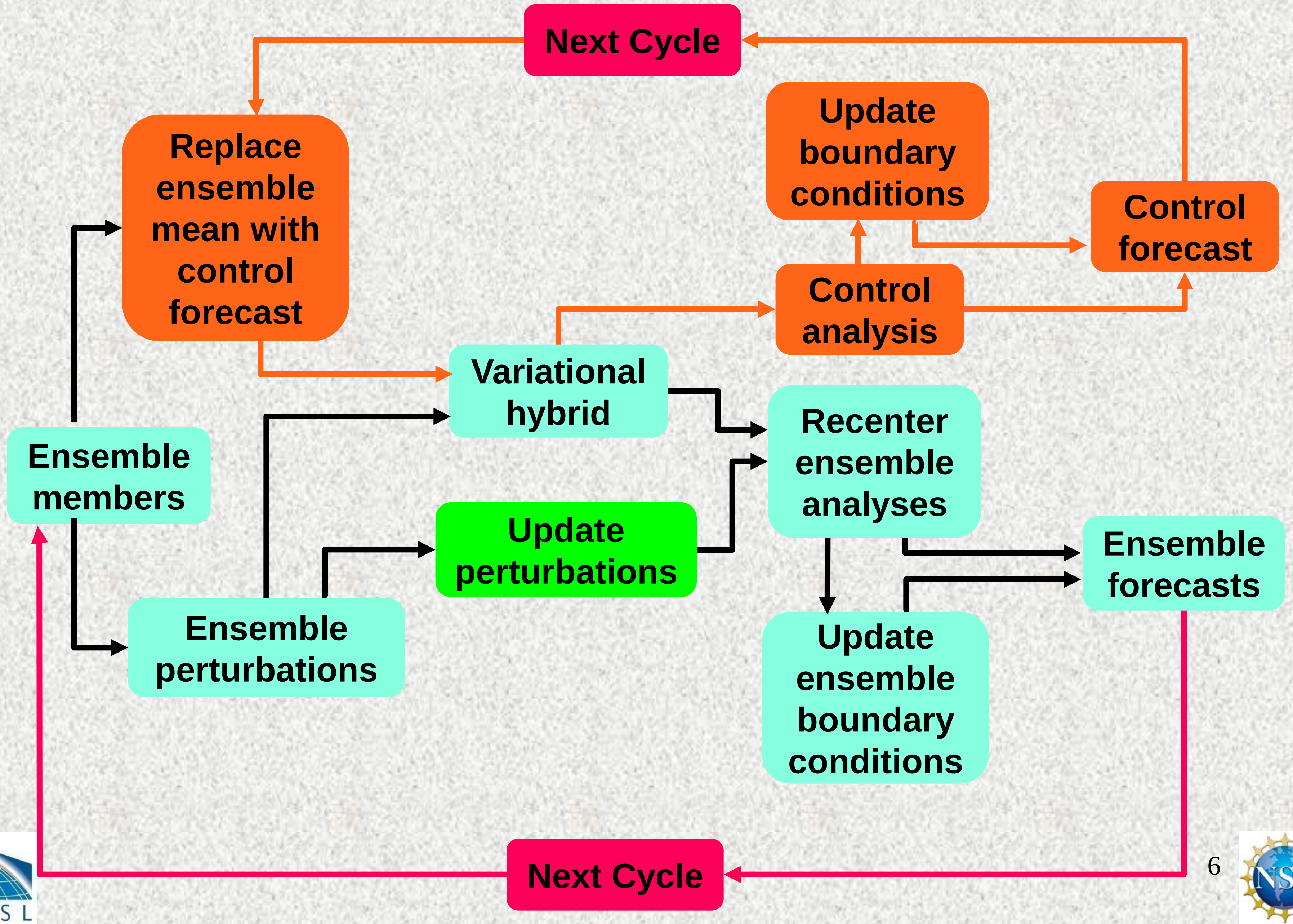
Extra increment associated with ensemble

$\mathbf{B}$ 3DVAR static covariance; $\mathbf{R}$ observation error covariance; K ensemble size;
$\mathbf{C}$ correlation matrix for ensemble covariance localization; $\mathbf{x}_k^e$ kth ensemble perturbation;
$\mathbf{x}_1^{'}$ 3DVAR increment; $\mathbf{x}^{'}$ total (hybrid) increment; $\mathbf{y}^{o'}$ innovation vector;
$\mathbf{H}$ linearized observation operator; β_1 weighting coefficient for static covariance;
β_2 weighting coefficient for ensemble covariance; $\boldsymbol{\alpha}$ extended control variable.

GSI Regional Hybrid Cycling



Regionalization of EMC Hybrid Cycling



Introduction to the MMM Regional Hybrid Testbed (MRHT)

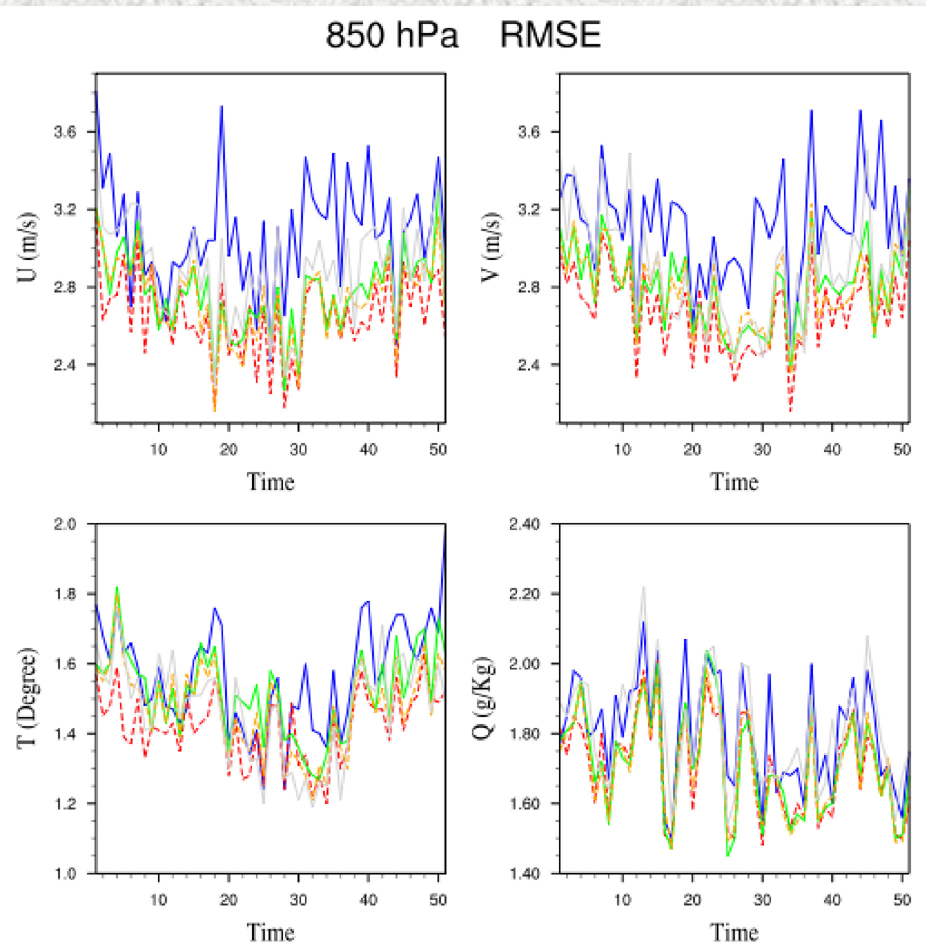
1. A community resource for developing/testing hybrid cycling strategies.
2. 80-member, low resolution (200km), CONUS domain, initial ensemble for the Hurricane Dean (Aug. 15 to Sep. 15, 2007) test case.
3. Observations in prep.bufr, ob.ascii, and obs.seq formats.
4. Hybrid cycling options for: GSI, WRFDA, ETKF (WG03, WG07, BW08, TRNK), LETKF, and DART-EnKF.
5. Modular and flexible so it easily incorporates new algorithms.

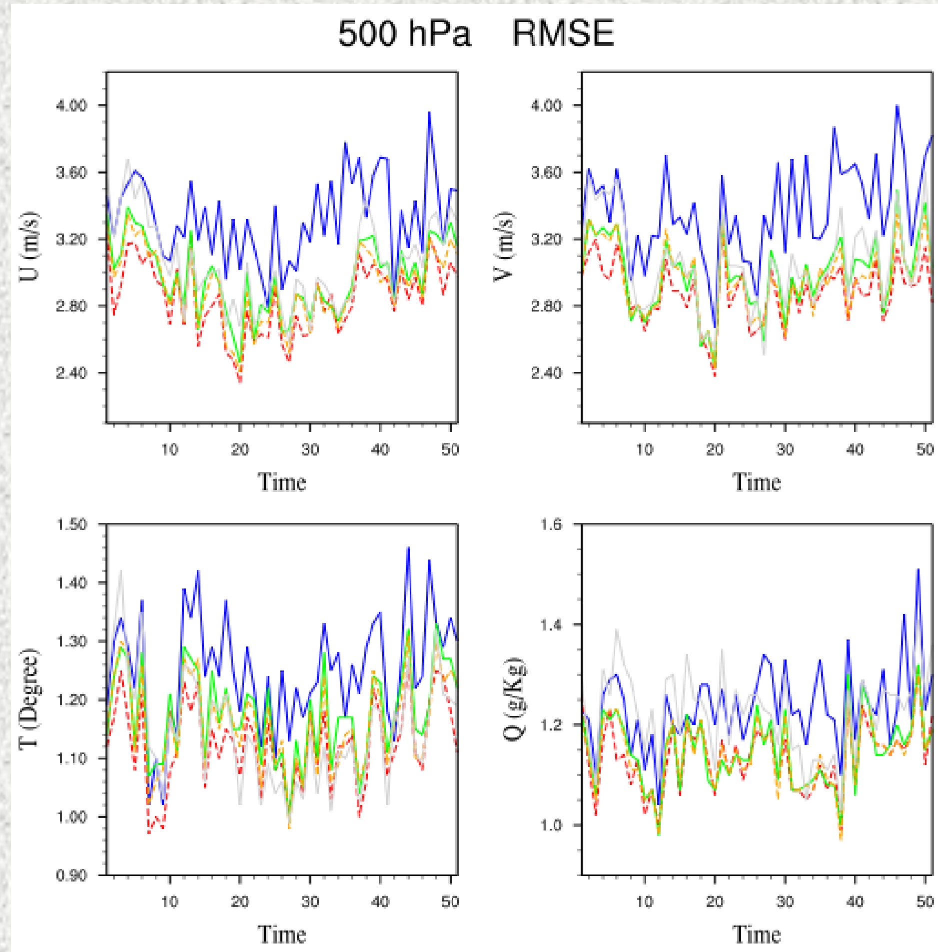
NESL

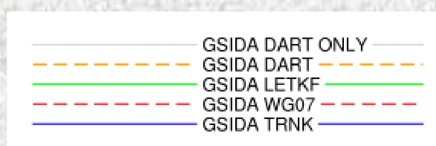
Motivational Experiment Setup

- 60-member ensemble.
- 12-hr cycling (Aug. 15 to Sep. 11, 2007)
- CONUS low resolution grid (200km)
- ETKF – Wang et al. (2007) inflation.
- LETKF – Loc = 3000 km, Inf = 1.036 Szunyogh et al. (2005).
- DART-EnKF – Prior_Inf = 2,0, Inf_damping = 0.9, Inf_sd_initial = Inf_sd_lower_bound = 0.6

ETKF/LETKF/DART-EnKF Hybrids (12-hr FCT RMSE)







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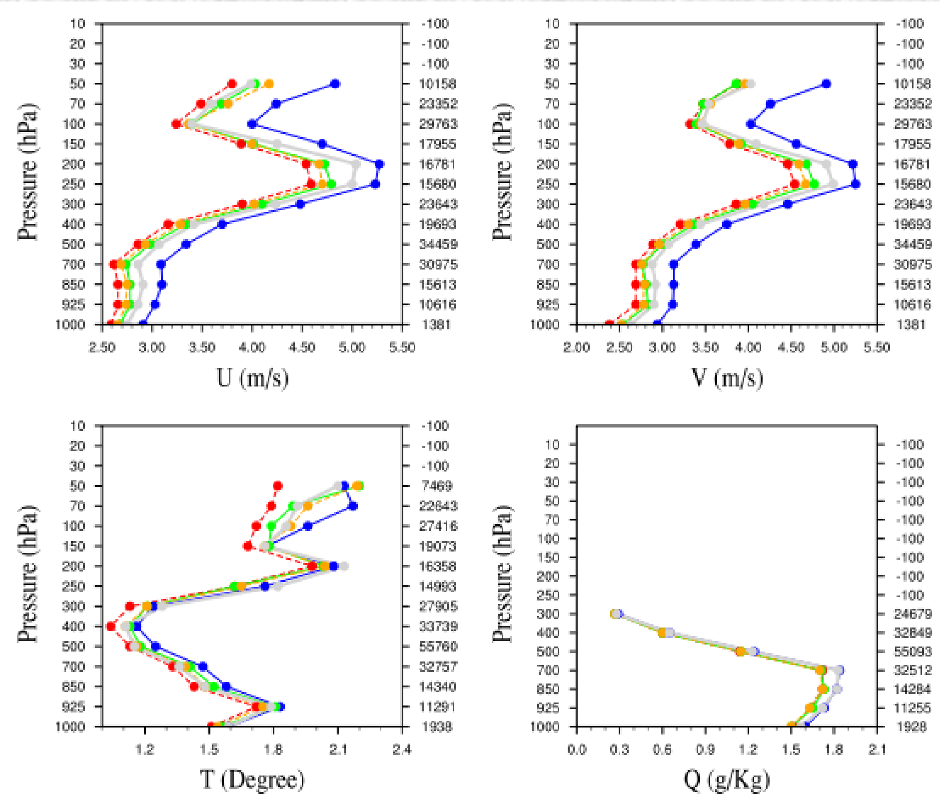
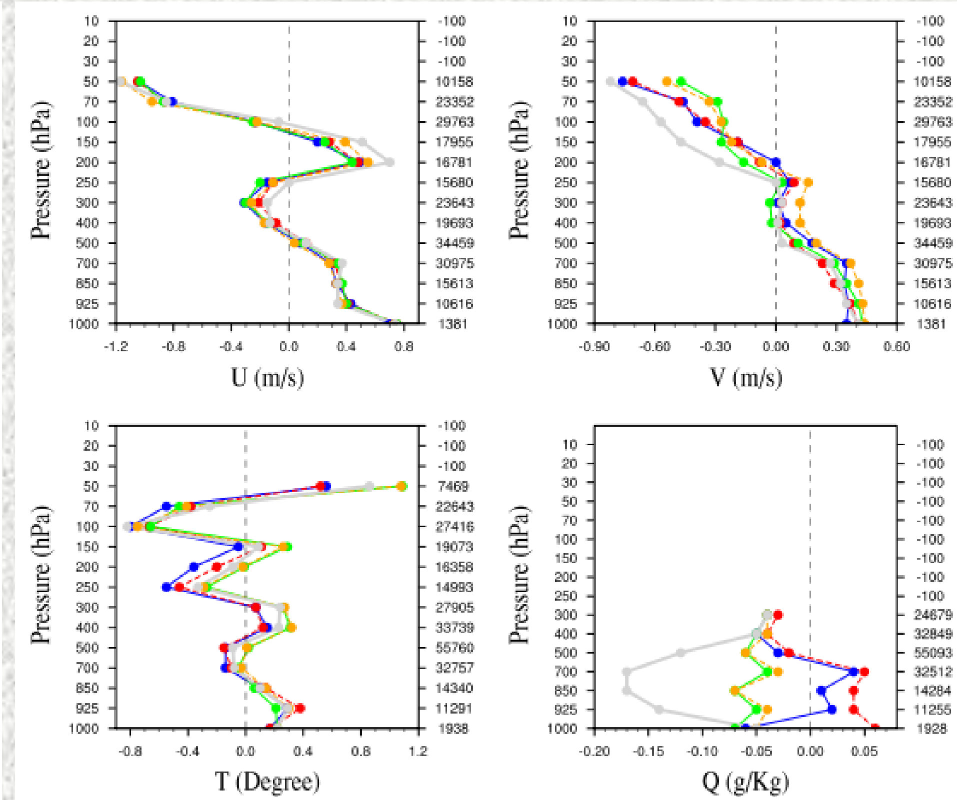
ETKF/LETKF/DART-EnKF Hybrids

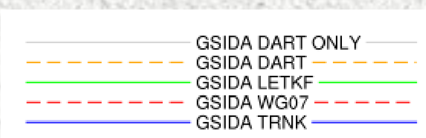
(Vertical Profiles of RMSE and Bias)

RMSE

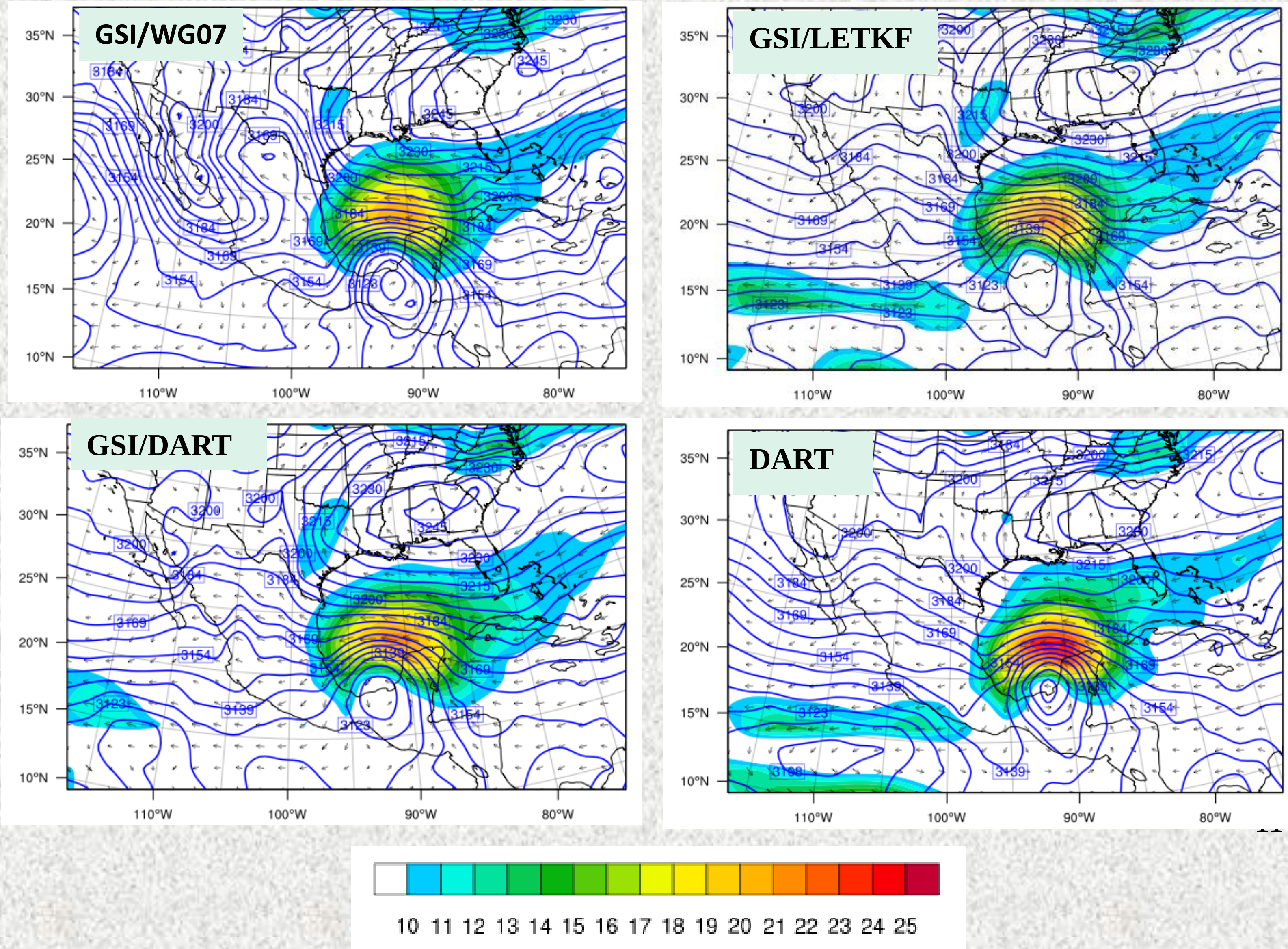


Bias





700 mb Height/Wind Speed Contours



MRHT Design Strategy

1. MHRT assumes the respective trunk directories, such as GSI, WRF, WRFDA etc. are installed and working properly.
2. MHRT directory structure is fixed and includes the following subdirectories:
   - “hybrid_code” – contains development code.
   - “hybrid_data” – contains all data (initial ensembles, perturbed boundary conditions, observations, etc.).
   - “hybrid_env_scripts” – scripts for linking the “hybrid_code” development directory to the respective trunk directories.

MRHT Design Strategy cont.

- “hybrid_run_scripts” – wrapper scripts for running the cycling algorithm.
- “hybrid_scripts” – driver scripts and step-specific driver scripts.

3. The top-level script is a wrapper script, which calls a driver script, which calls the step-specific driver scripts.
4. The wrapper script sets up environment variables that control the steps of cycling algorithm that are executed by the driver script.
5. Each step of the cycling algorithm has its own work directory.

MRHT Design Strategy cont.

5. Driver script prepares the step-specific work directory (linking prior output files as current input files, linking other necessary input files, and calling the step-specific driver script).
6. Step-specific driver script creates the step-specific namelist file and call the executable.
7. When incorporating a new procedure (like the Whitaker EnKF or HWRF):
   - The wrapper script gets new environmental variables for controlling the executable through the step-specific driver script.

MRHT Design Strategy cont.

- The driver script gets new environment variable switches and internal consistency tests.
- The driver script cycling flow tests are modified to incorporate the new algorithm.
- A new step-specific driver script is added to the "hybrid_scripts" subdirectory.

Parting Message

- Comparison of GSI/ETKF, GSI/LETKF, and GSI/EnKF hybrids shows that an ETKF or LETKF hybrids can perform as well or better than an EnKF hybrid.
- The MHRT design shows that by adopting a few organizational and scripting rules it is possible to include modularity/flexibility in a unified GSI regional hybrid.
- FUTURE GOALS: (i) work to incorporate flexibility in the unified GSI regional hybrid, (ii) apply GSI/ETKF, GSI/LETKF, and GSI/EnKF hybrids to study the assimilation of conventional data near the eye.

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