NPS

PRAESTANTIA PER SCIENTIAM

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MATERHORN-M

Predictability
8 Sept 2011, MATERHORN kickoff

Themes

1. Terrain-induced flow: predictable or not?
   - Strongly forced versus weakly forced backgrounds
   - Strongly forced versus weakly forced terrain-induced flow (perturbation flow)
   - Precursors to visibility restrictions

2. Observation impact
   - Observing strategies that have tangible impact on model predictions
   - Observation strategies likely different for strongly and weakly forced background/perturbation

3. Model error/inadequacy
   - Real barrier to improved predictions in some cases

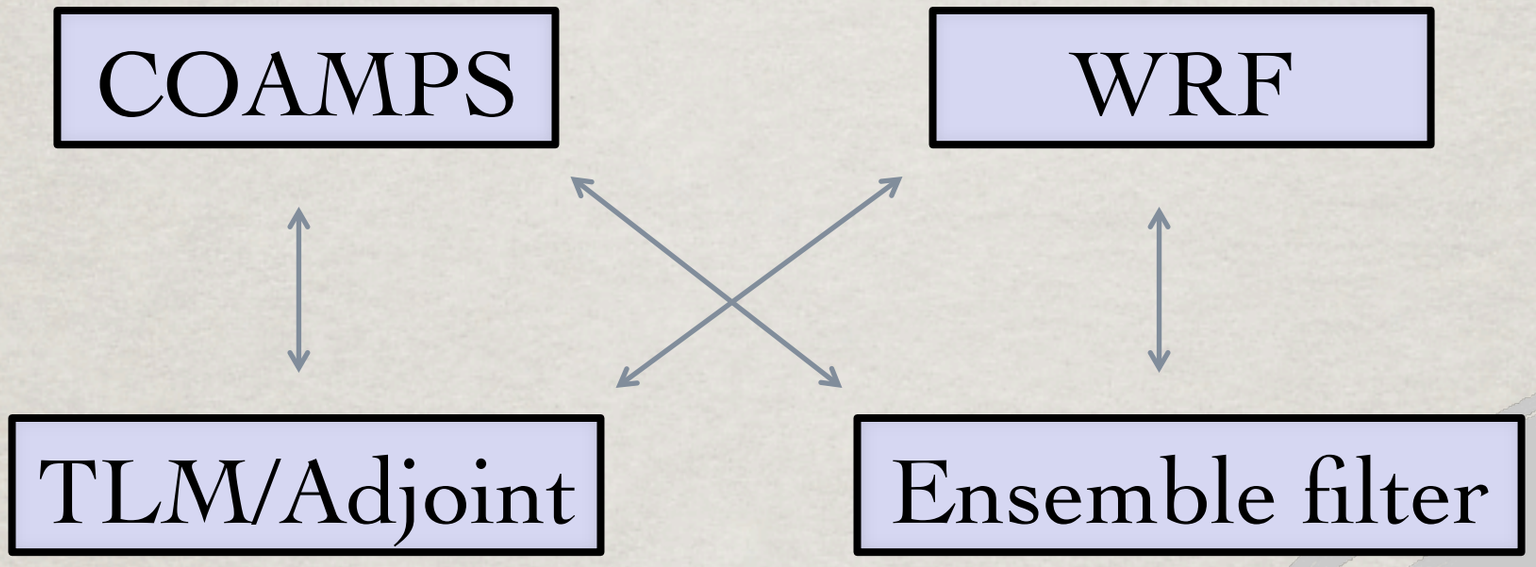
Experiment foci

1. Predictability of terrain-induced flows
   - Spatial predictability scales
   - Temporal predictability scales
2. Potential for error reduction
   - Reduced initial-condition uncertainty reduces forecast uncertainty; or
   - Already near limits of predictability
3. Propose and test observing strategies
   - Reduce forecast uncertainty
   - Nearer to predictability limits

Perfect or imperfect model

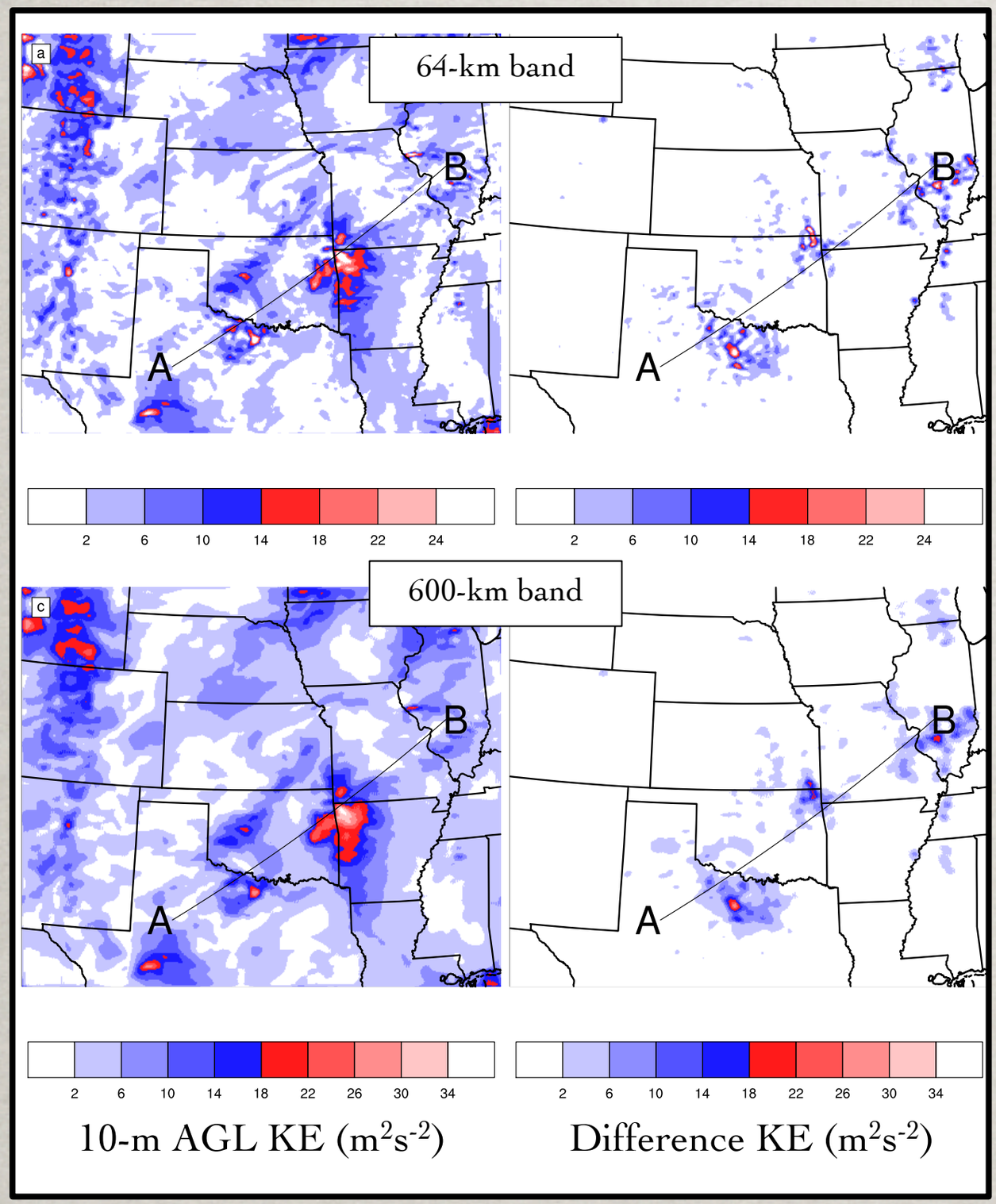
4. Characterize and quantify importance of model inadequacy
   - Difference between perfect-model/synthetic obs studies; and
   - Real-data cases following field programs
   - Systematic increments in data assimilation cycle

Tools



- COAMPS, Tangent linear model (TLM)/ Adjont, and ensemble-filter expertise at NRL
- WRF and ensemble-filter expertise at NPS
- Capability exchange, division of tasks TBD

Measuring predictability: classic methods



- Soil moisture perturbations applied at scales ≤ 64 km (16 Δ X).
- NWP model (WRF) simulations to quantify sensitivity.
- At 24-h, energy in the vector wind differences can equal or exceed energy in the wind itself.
- Interpret as a loss of predictability in a perfect-model context.
- Loss of predictability apparent at spatial scales an order of magnitude larger than the perturbation scale.

Predictability here is determined classically (Lorenz) with quadratic norms and identical twin experiments

Measuring predictability: sensitivities

- Sensitivity:

$$\frac{\partial J}{\partial \mathbf{x}_0} = \left[\mathbf{L}_{t,t_0}^{\mathbf{T}} \frac{\partial J}{\partial \mathbf{x}_t} \right]^{\mathbf{T}} \qquad \text{adjoint}$$

$$\frac{\partial J_e}{\partial \mathbf{x}_0} = \left[diag\left(\left\langle \delta\mathbf{x}_0 \delta\mathbf{x}_0^{\mathbf{T}} \right\rangle \right) \right]^{-1} \left\langle \delta\mathbf{x}_0 \delta\mathbf{x}_0^{\mathbf{T}} \right\rangle \frac{\partial J}{\partial \mathbf{x}_0} = \frac{\mathrm{cov}(\mathbf{J}, \mathbf{x}_0)}{\mathrm{var}(\mathbf{x}_0)} \qquad \text{ensemble}$$

J is response/cost function at time t

$\mathbf{x}$ is state vector

$\mathbf{L}$ is tangent-linear model

- Can be computed by an ensemble or with and adjoint
  - Small initial perturbations $\delta\mathbf{x}_0$
  - Linearity (statistical or dynamical)
- Sensitivity structures can be decomposed/analyzed
  - Spectrally
  - Some other bases
  - Composites and variability
- Easily extended to observation impact (Ancell and Hakim 2007)

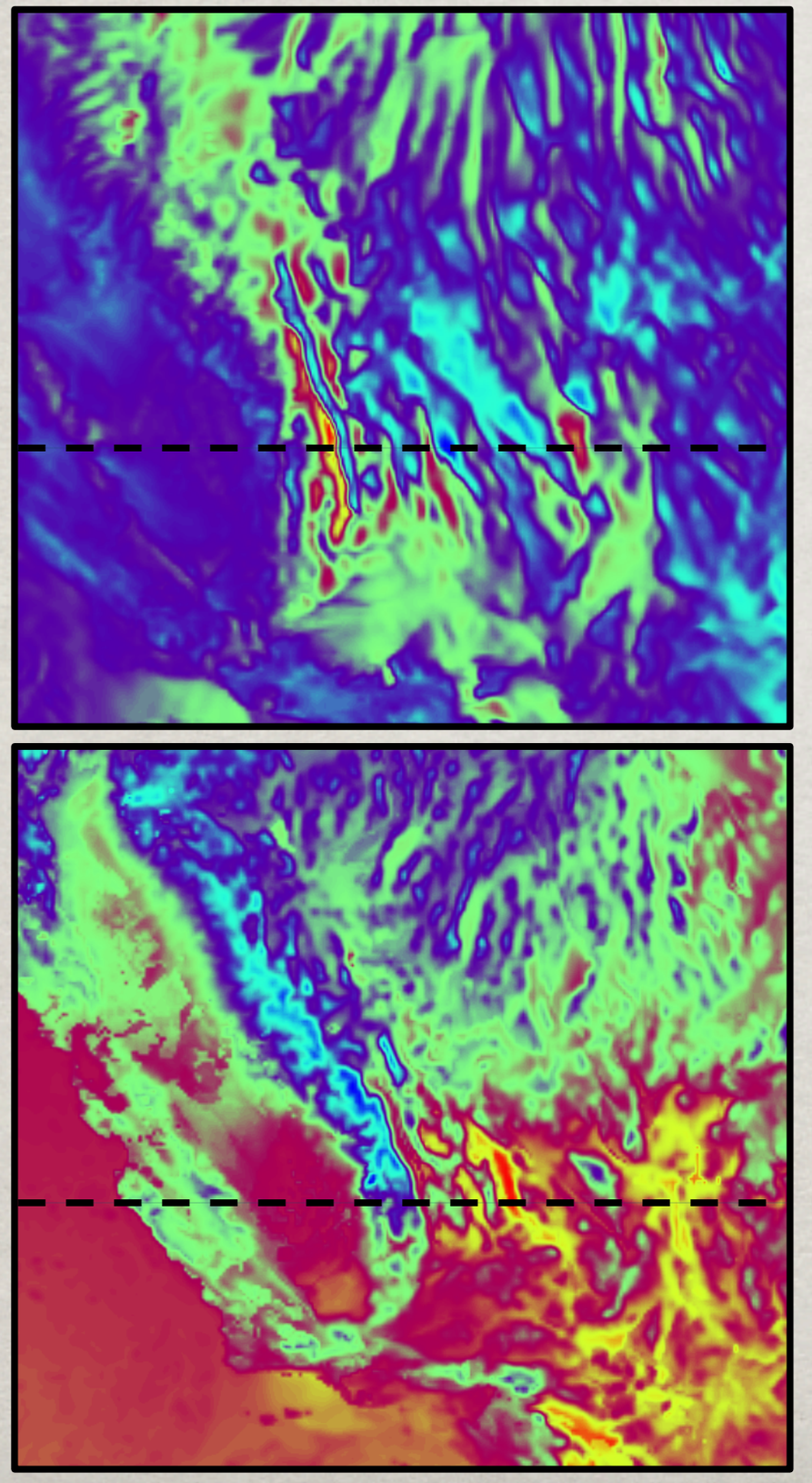
First year: modelingT-REX experiments

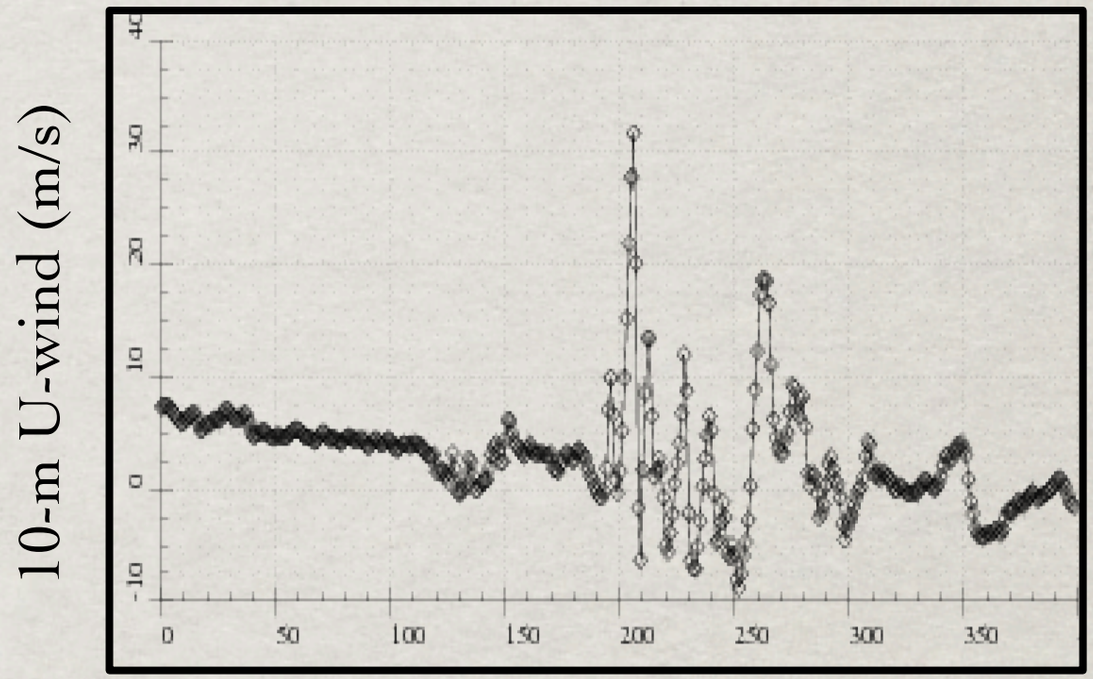
- 2006 IOP 6
  - 24-26 March: strong downslope
  - 27-28 March: mountain-valley thermal flows
- Perfect-model experiments
  - Proxy for the real atmosphere
  - Optimistic estimates of error growth
  - Good first step for scoping sensitivity and obs impact
- Ensemble data assimilation
  - Small and spatially consistent initial perturbations
  - Clean investigations of open issues in predictability and sensitivity

Ensemble sensitivity: open issues

- Sampling
  - Accuracy and uniqueness of solutions
  - Can't be eliminated, can be mitigated
  - Begin with convergence studies on ensemble size
- Break-down of linearity assumptions
  - Local linearity in cov(**J**,**x**) needed
  - Linear dynamics *not* needed
  - Will break down at some unknown forecast time
- Mesoscale predictions
  - More scale interactions may exacerbate sampling and linearity issues

WRF "truth" valid 12 UTC 25 March 2006





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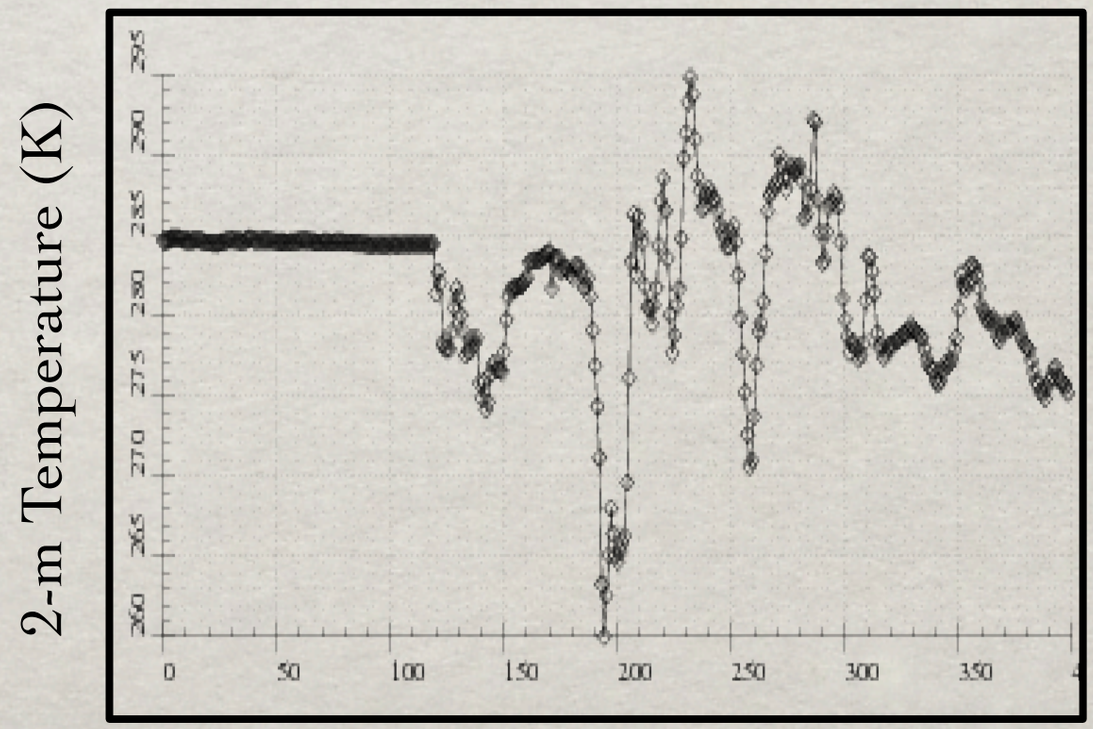

Personnel

- NPS: J. Hacker, K. Neilsen
- Postdoc (to be hired); advising shared with J. Doyle at NRL
- Contracted HPC support as needed (none so far).
- Students (unfunded): 1 USAF PhD, 1 USAF Masters, 1 USN Masters (possible)