Improving Source Data for Path Planning

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Content of presentation

Introduction to gliders

Figure: Glider in water

- Autonomous Underwater Vehicle (AUV)
- Changing its bouyancy it glides through water in a sawtooth pattern.
- Large cruising range, but slow ($v_{h,max} \sim 1\frac{km}{h}$)
- Heavily influenced by currents
- Measurement device for all sorts of ocean variables

Glider operation

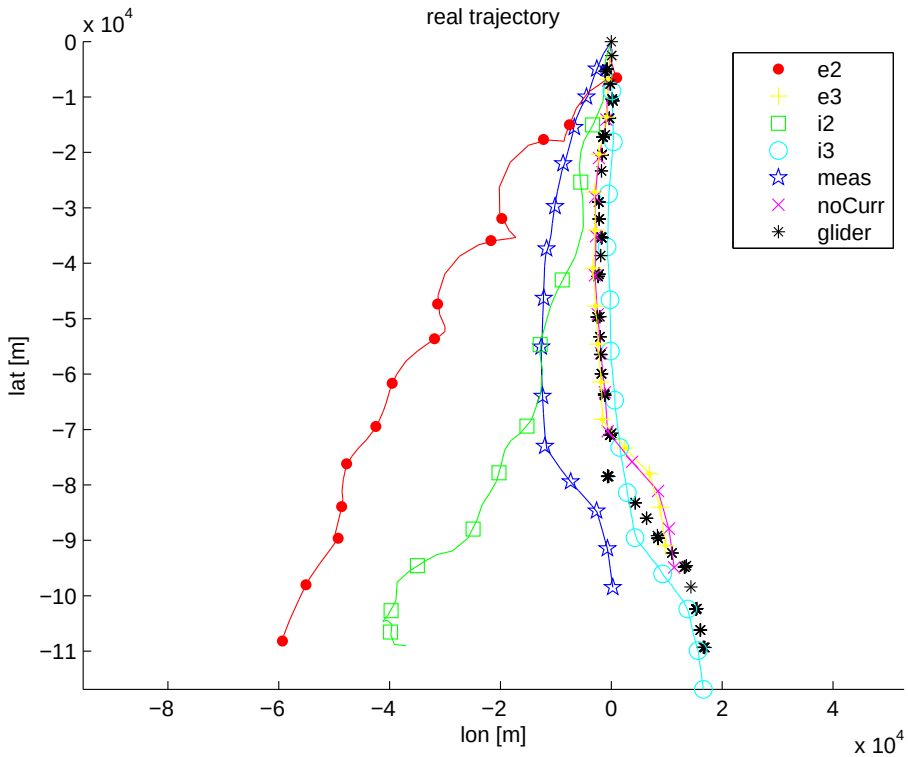
- Get recent ocean current forecast
- Use a simulator to pre-plan trajectory:
  - Modeling glider physics and set parameters (buoyancy, speed, gliding factor)
  - Define mission goals (diving depth, hold track or follow trajectory or feature)
- Optimization: Use different algorithms (suited for its purpose)
- Communicate resulting waypoints or heading angles to the glider

Improving operation

Where can problems appear?

- Glider Simulator: Basic simulator, numerical and physical model shortcomings
- Glider Parameter: Only estimation of velocity, gliding factor, heading errors
- Algorithms: some might not provide optimal paths
- Ocean model data: forecast differs from model to model

Glider Simulation Comparison



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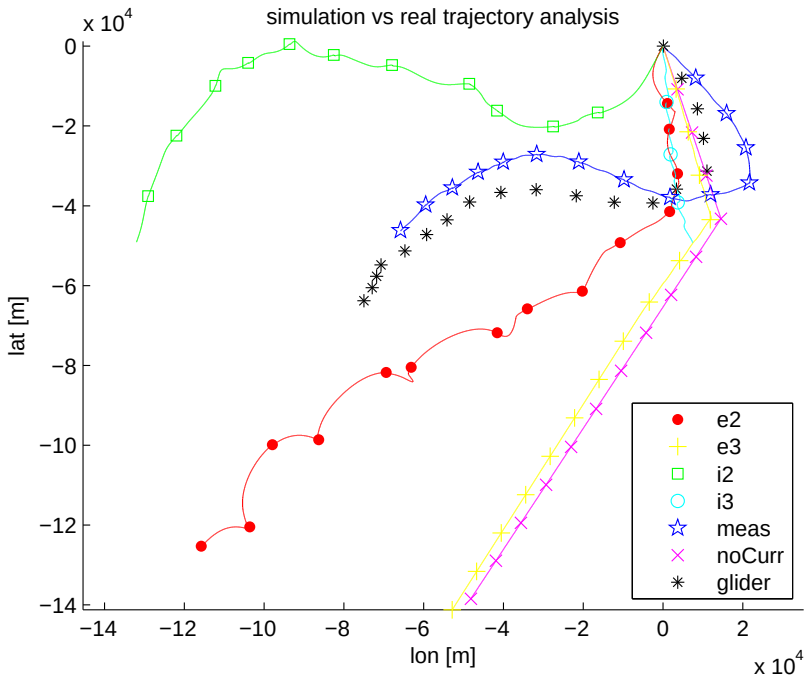


Improving operation

Where can problems appear?

- Glider Simulator: Basic simulator, numerical and physical model shortcomings
- Glider Parameter: Only estimation of velocity, gliding factor, heading errors
- Algorithms: some might not provide optimal paths
- **Ocean model data: forecast differs from model to model**

Model properties

- Various models for regions, different sources (ESEOO, IBI)
- Global vs ROM
- Difference in spatial resolution, temporal resolution
- Different time-scales, update-cycles
- Depth codification

Approach

- In-situ measurements of gliders
- Combine different models relying on the glider measurement data
- Ensemble with BMA (Bayes Model Averaging)
- Models are weighted to their actual recent and local performance

BMA Formula

For a variable y with the model forecasts $f_k, k = 1..K$ and its probability density function (PDF) $g(y|f_k)$ we obtain

$$p(y) = \sum_{k=1}^{K} w_k \cdot g(y|f_k) \tag{1}$$

- $g(y|f_k)$ is the conditional PDF for y for a fixed f_k that is supposed to be the best forecast in the ensemble.
- $w_k = p(f_k|y^T)$ is the posterior probability of forecast f_k being correct with given training data y^T
- w_k is determined with a log-likelihood function which needs to be maximized with the expectation maximization (EM) algorithm

BMA Ensemble

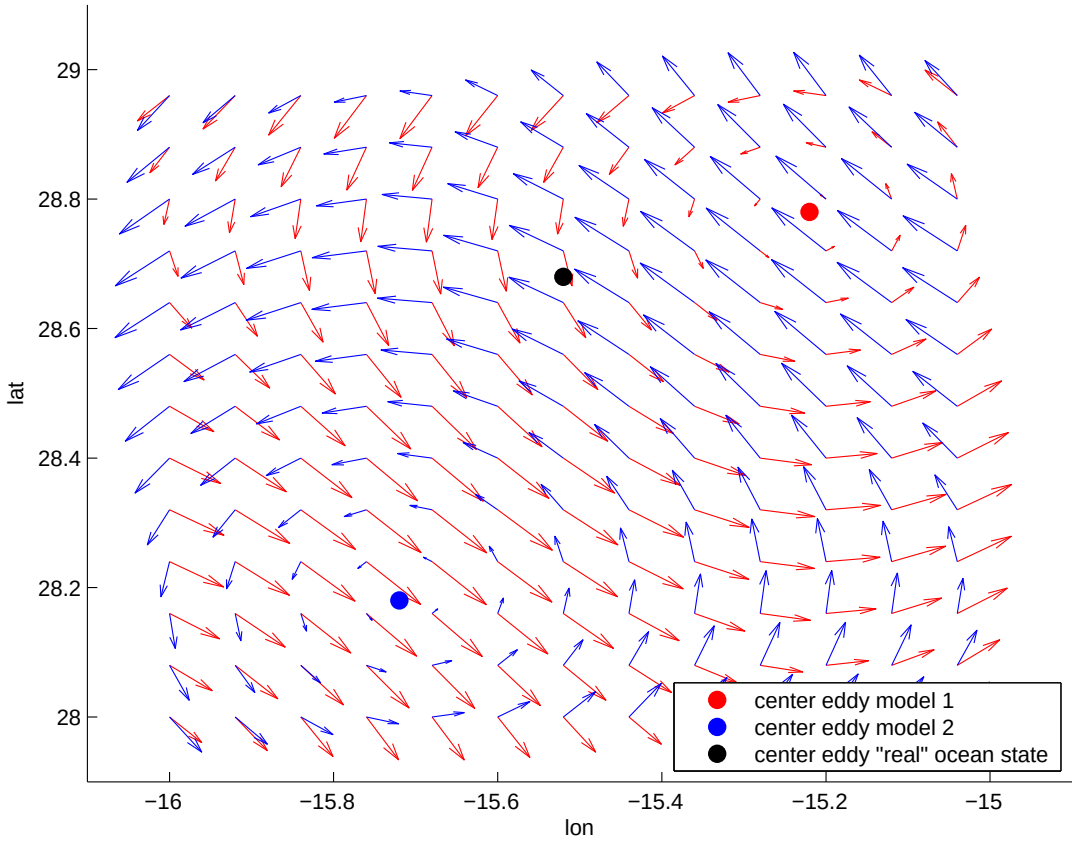
Expectation

$$E(y|f_1 \cdots f_k) = \sum_{k=1}^{K} w_k \cdot (a_k + b_k f_k)$$

Variance

$$Var = \sum_{k=1}^{K} w_k \left[(a_k + b_k f_k) - \sum_{i=i}^{K} w_i (a_i + b_i f_i) \right]^2 + \sum_{k=1}^{K} w_k \sigma_k^2$$

Eddy Simulation



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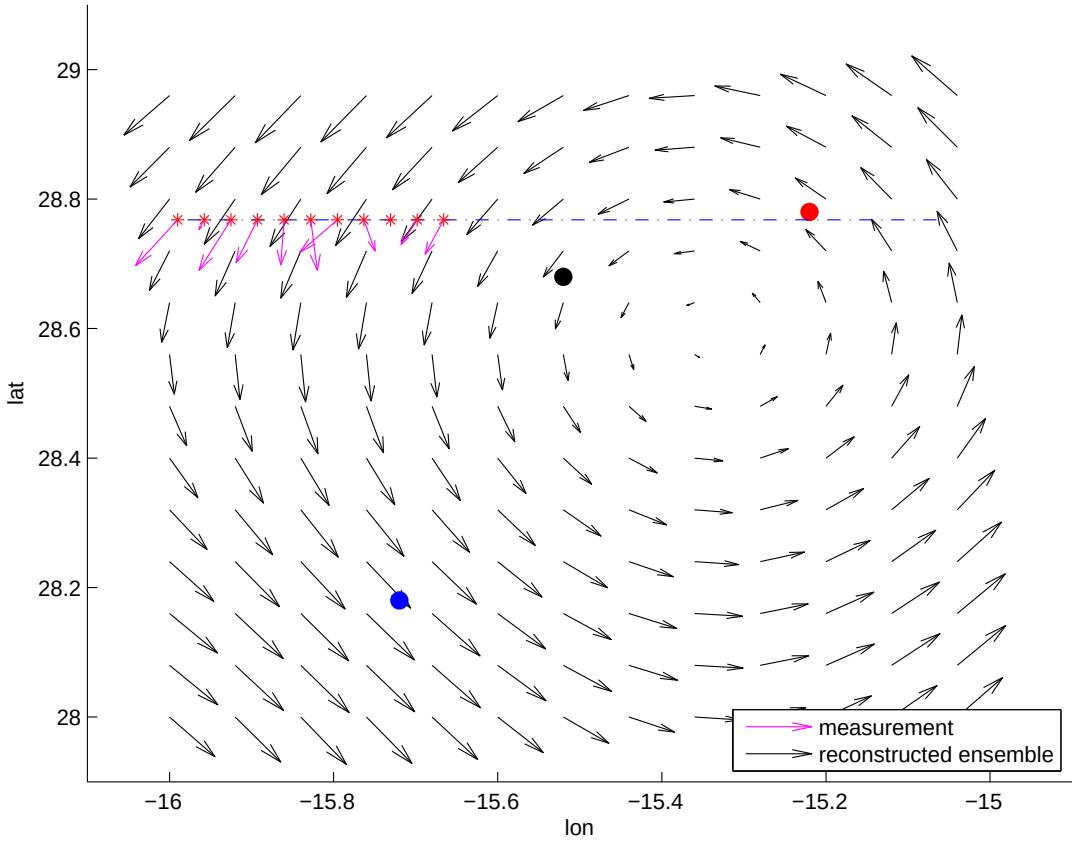

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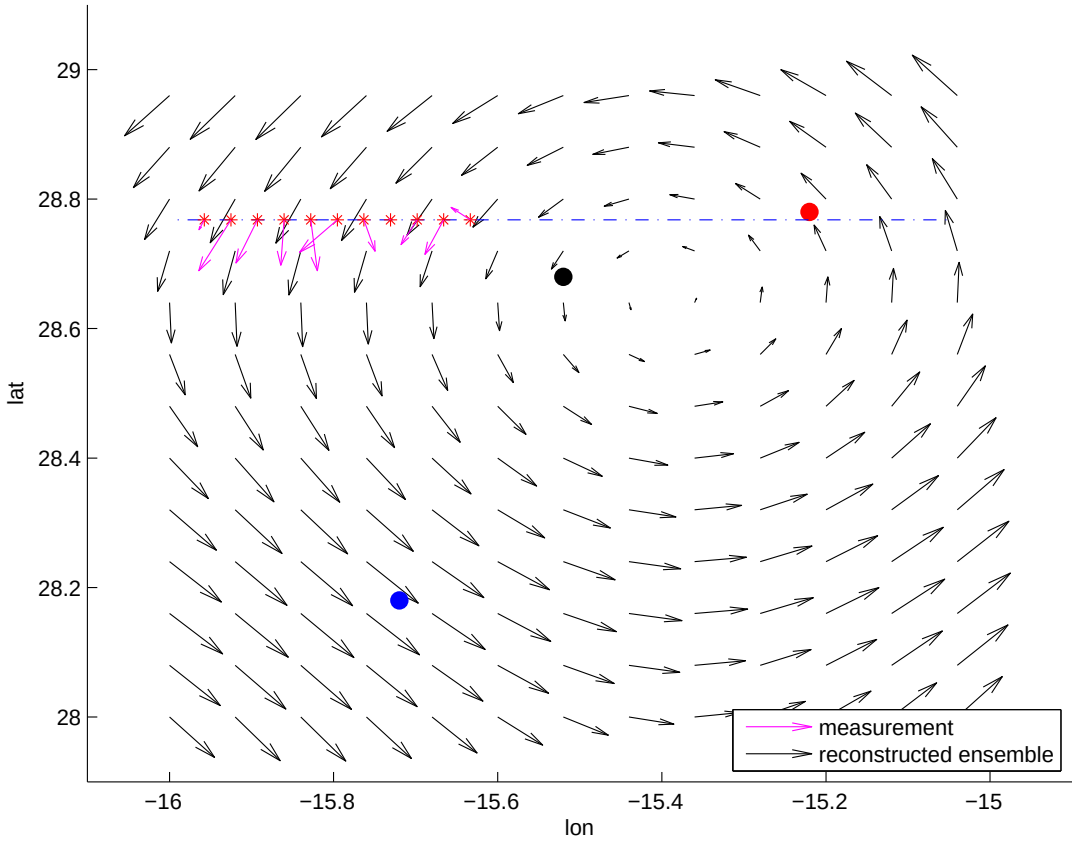

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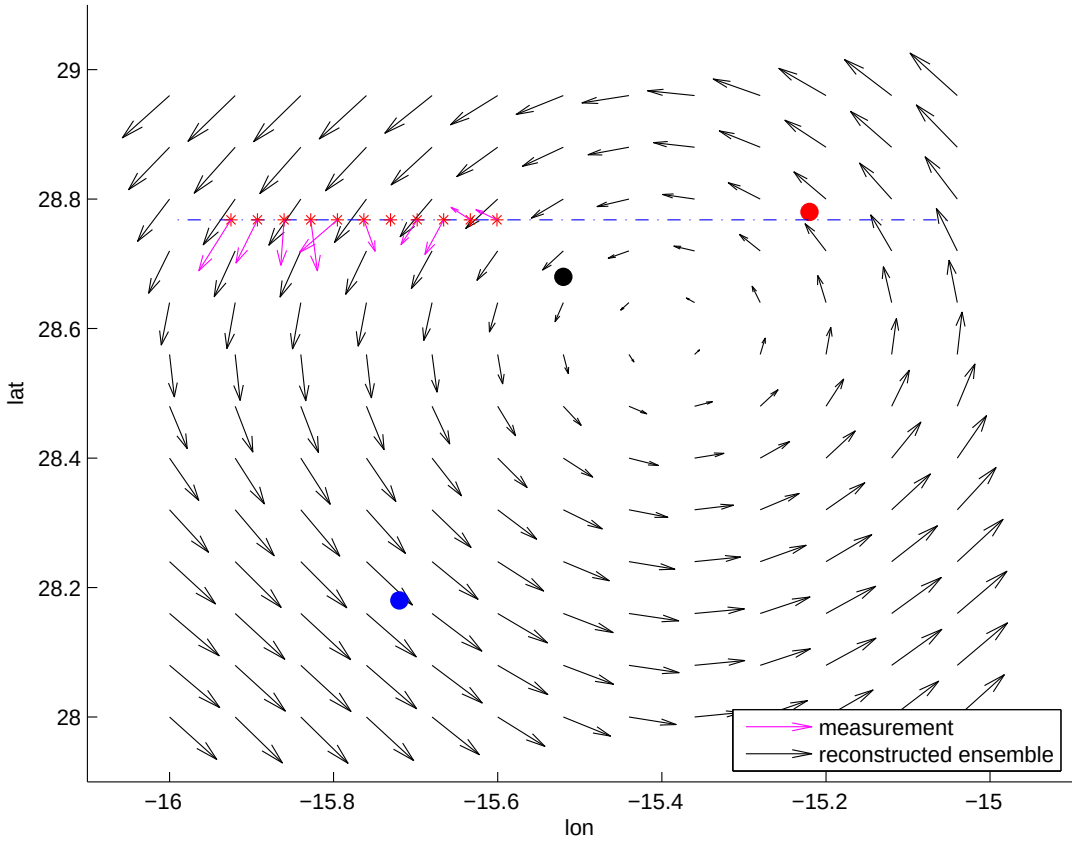

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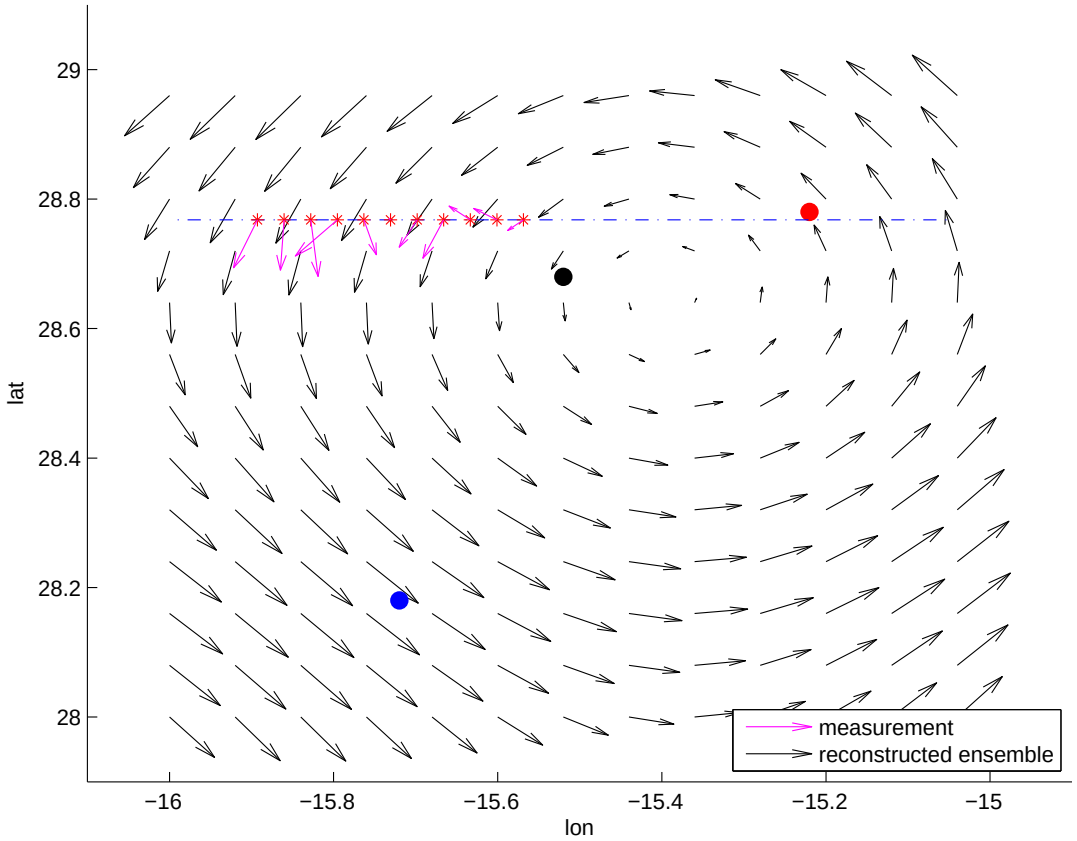

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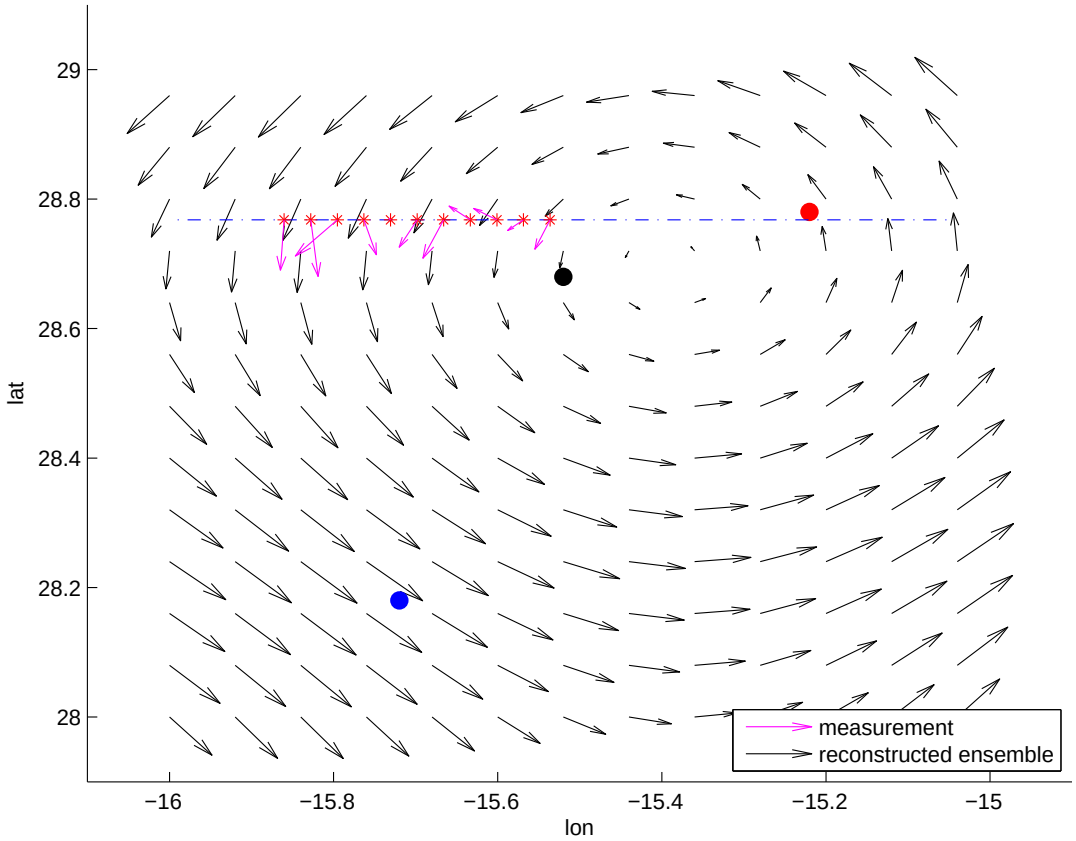

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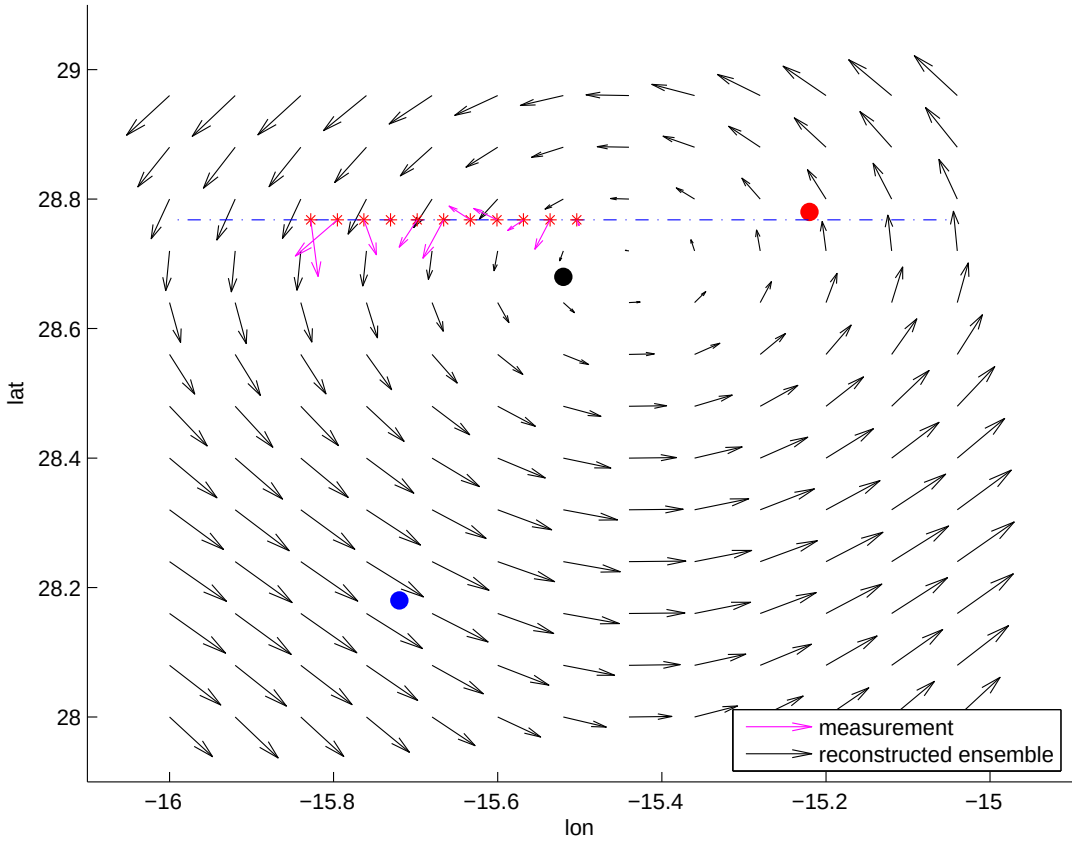

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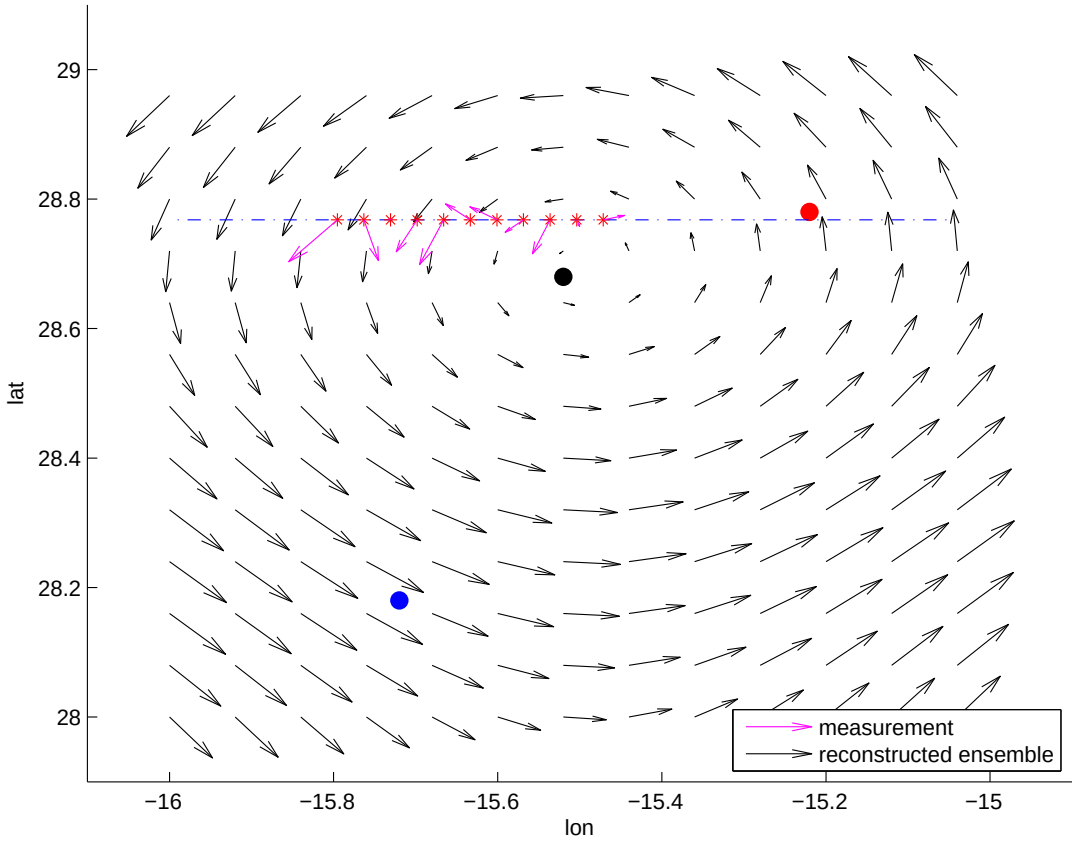

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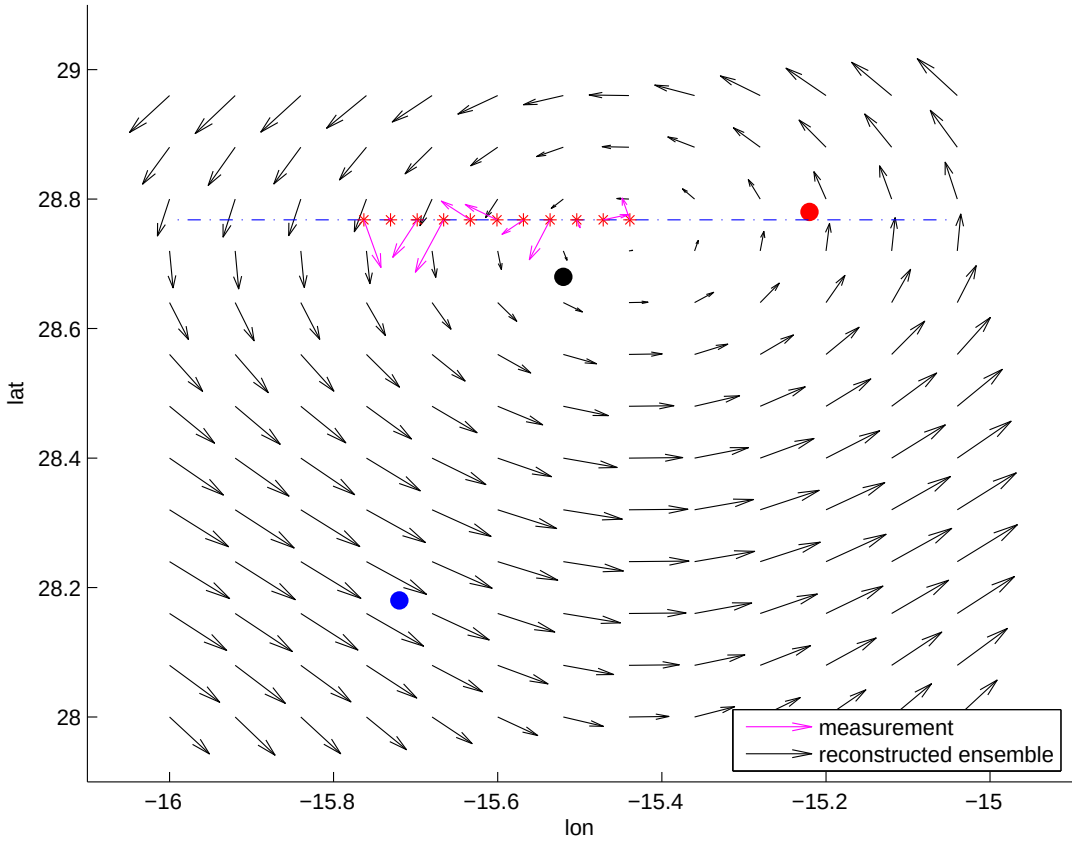

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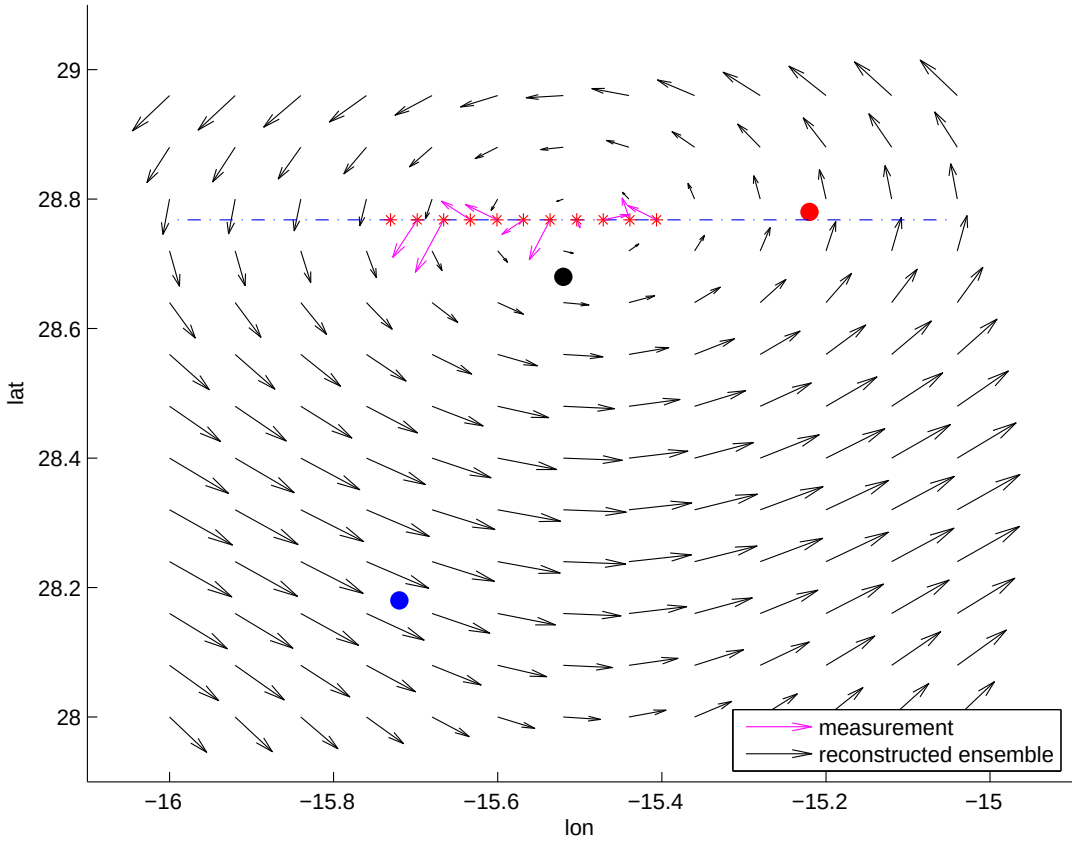

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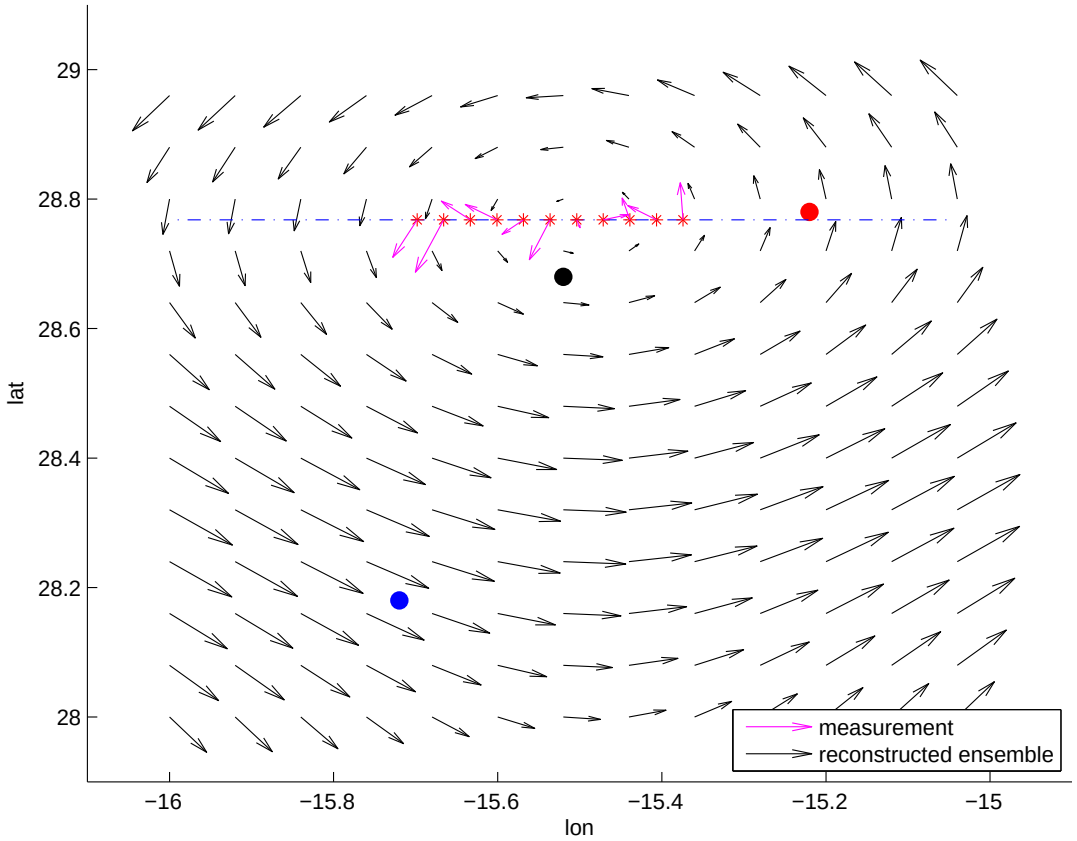

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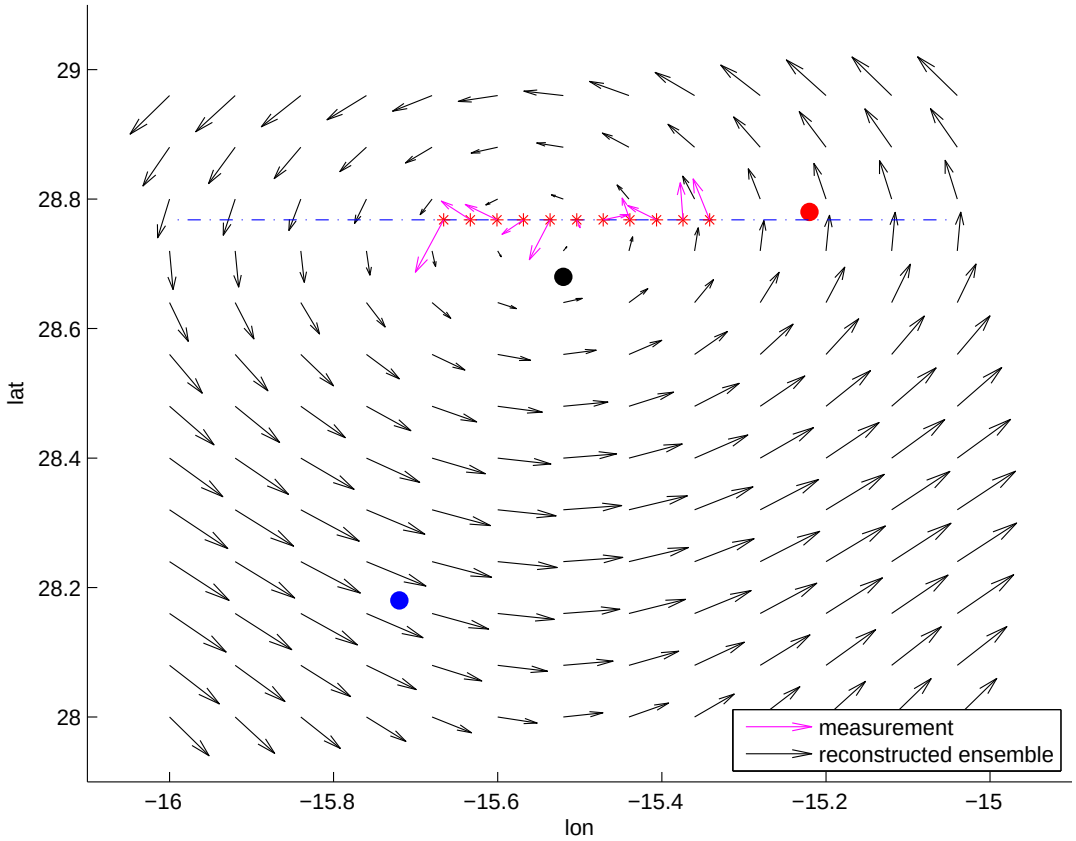

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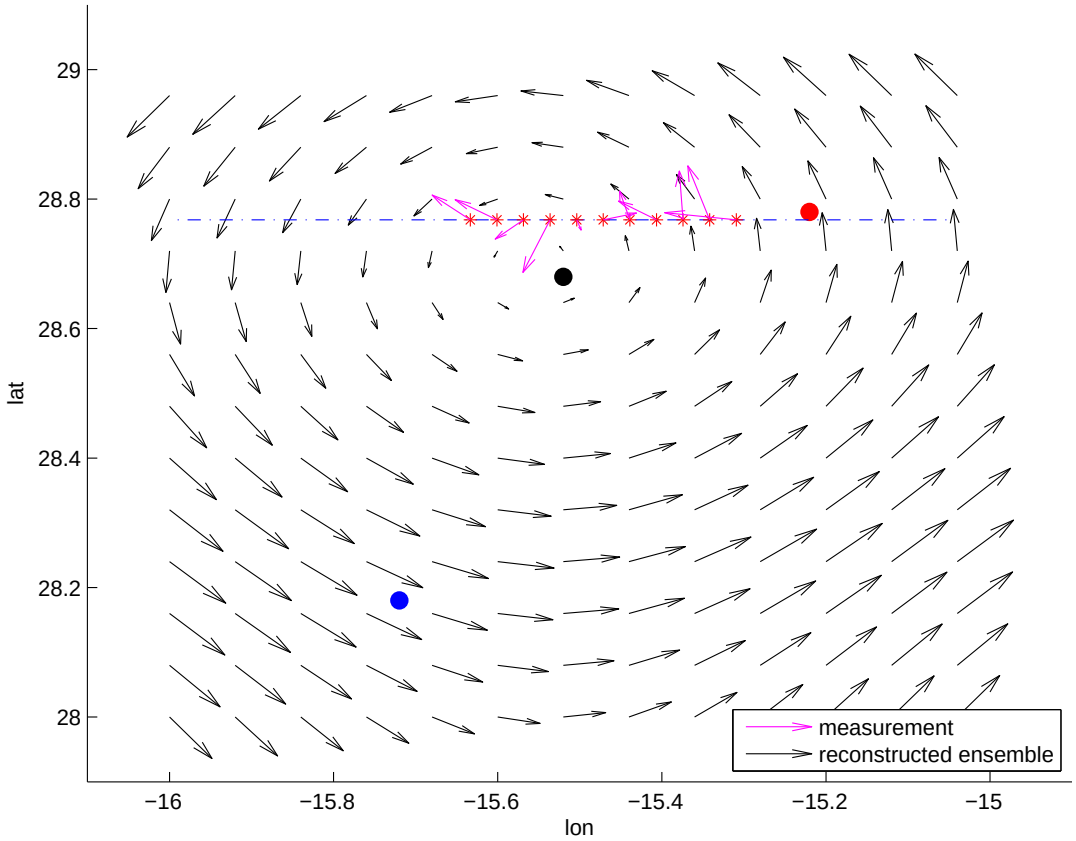

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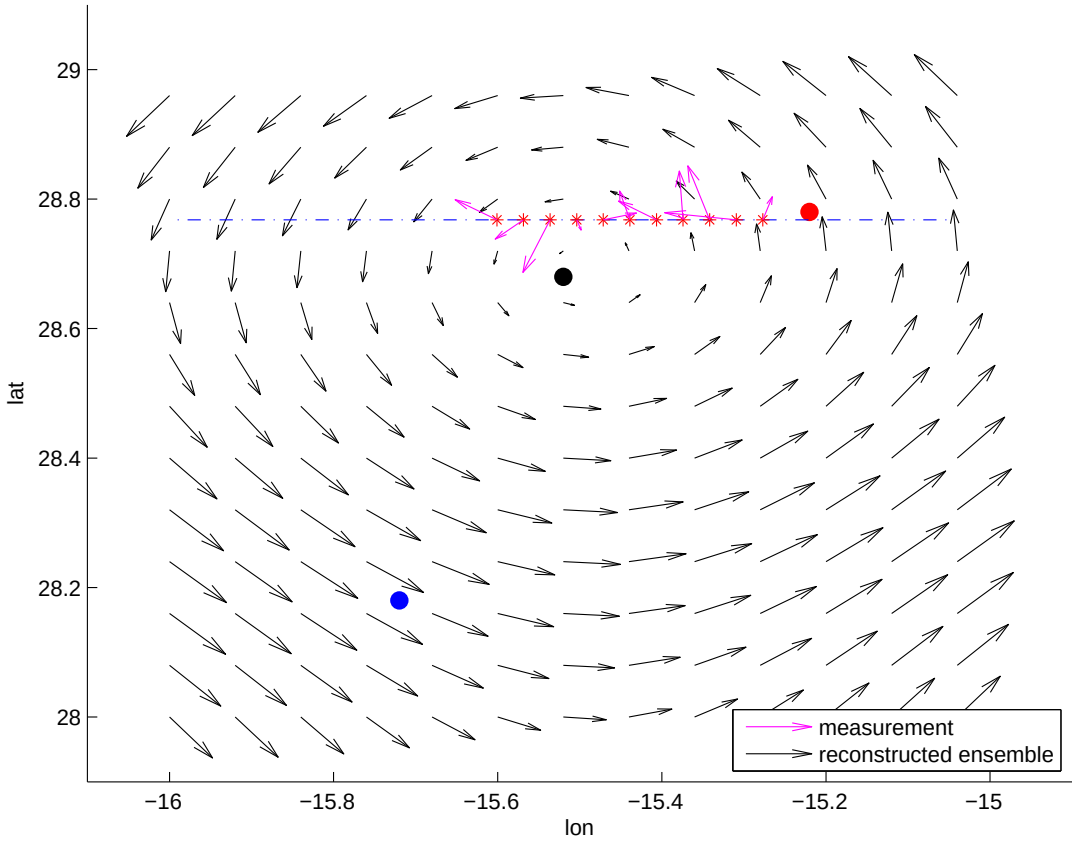

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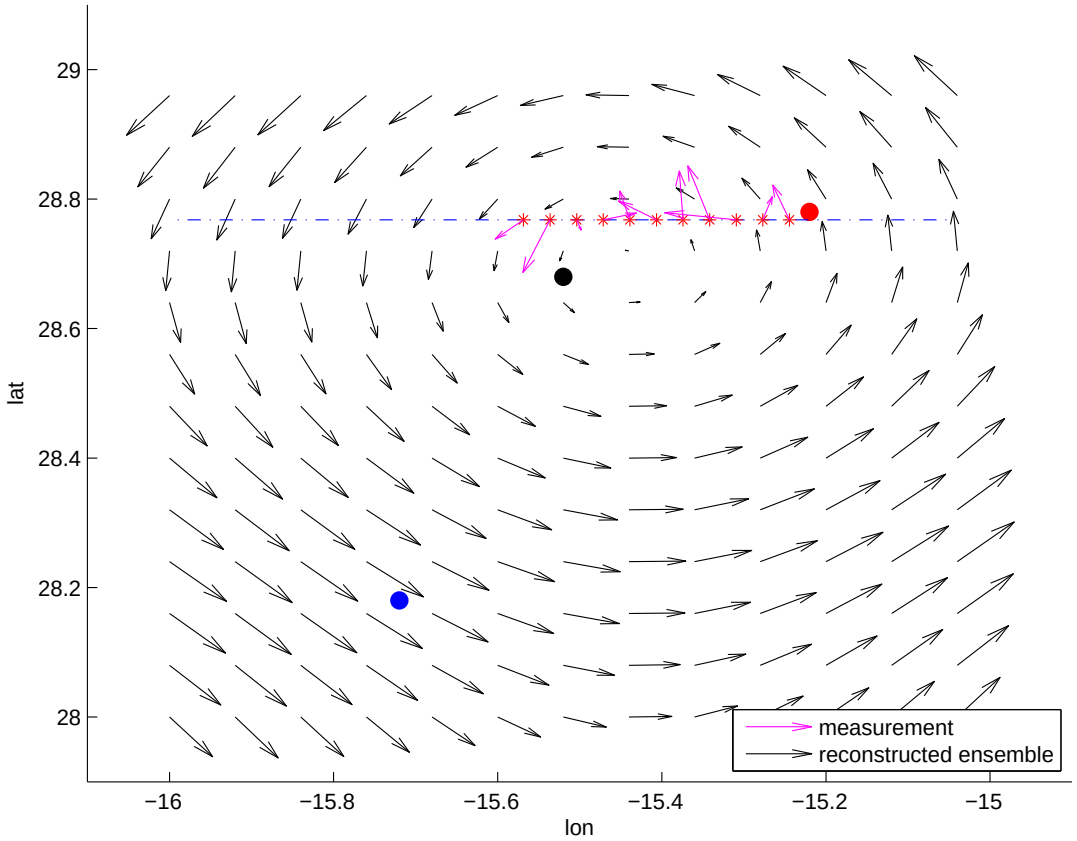

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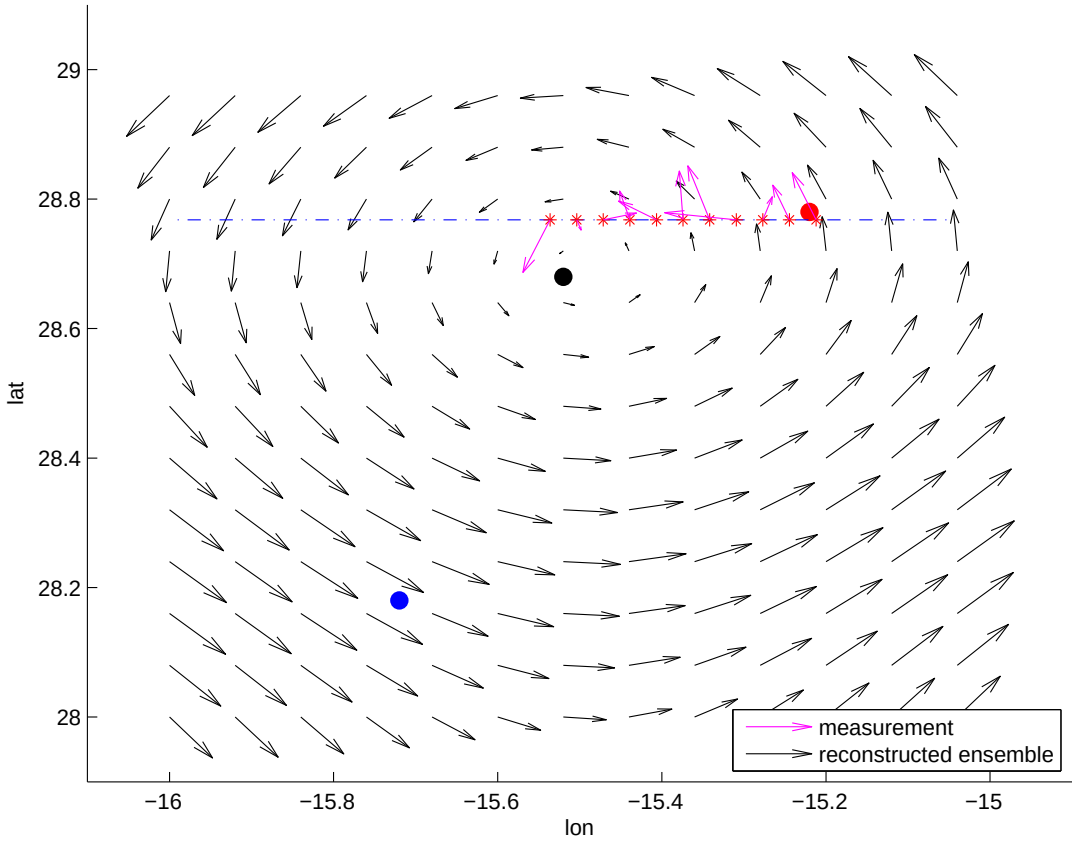
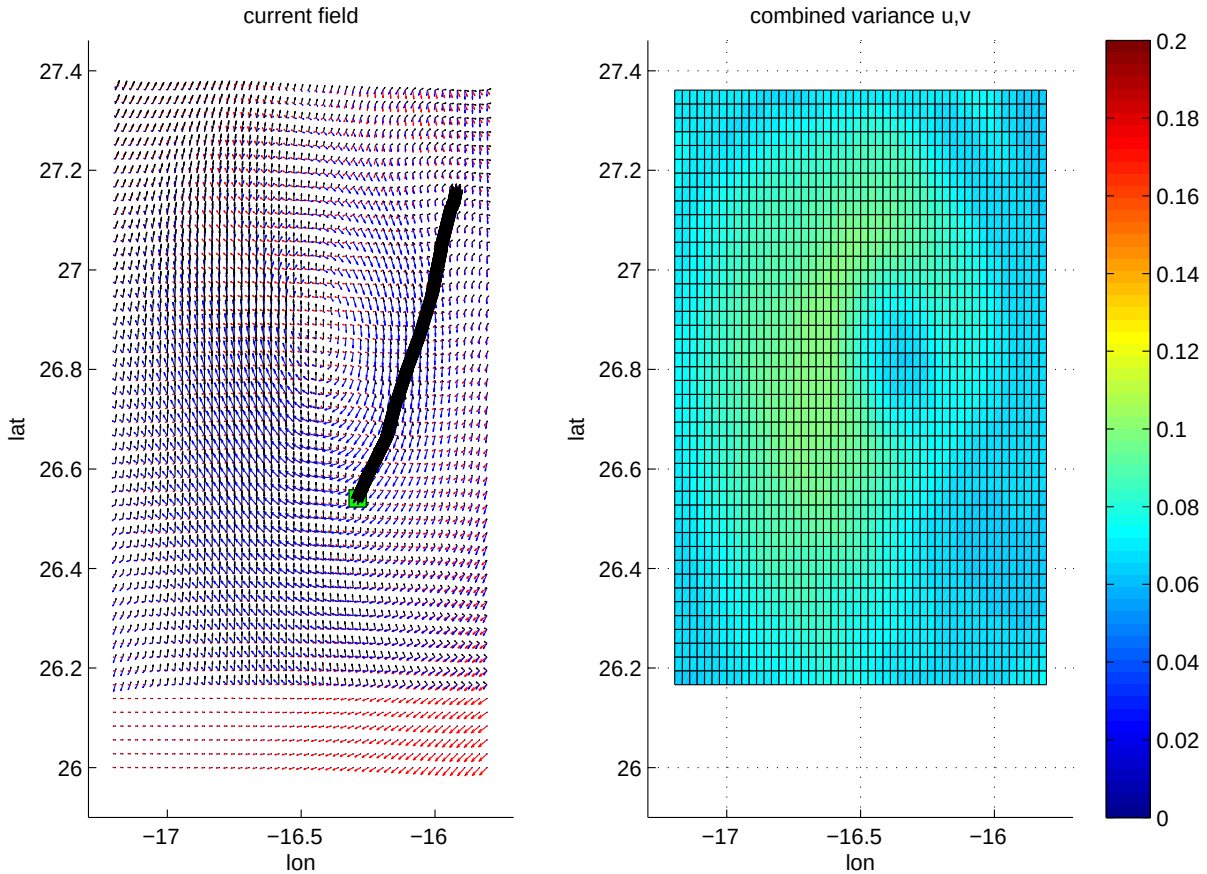


Real Mission Results



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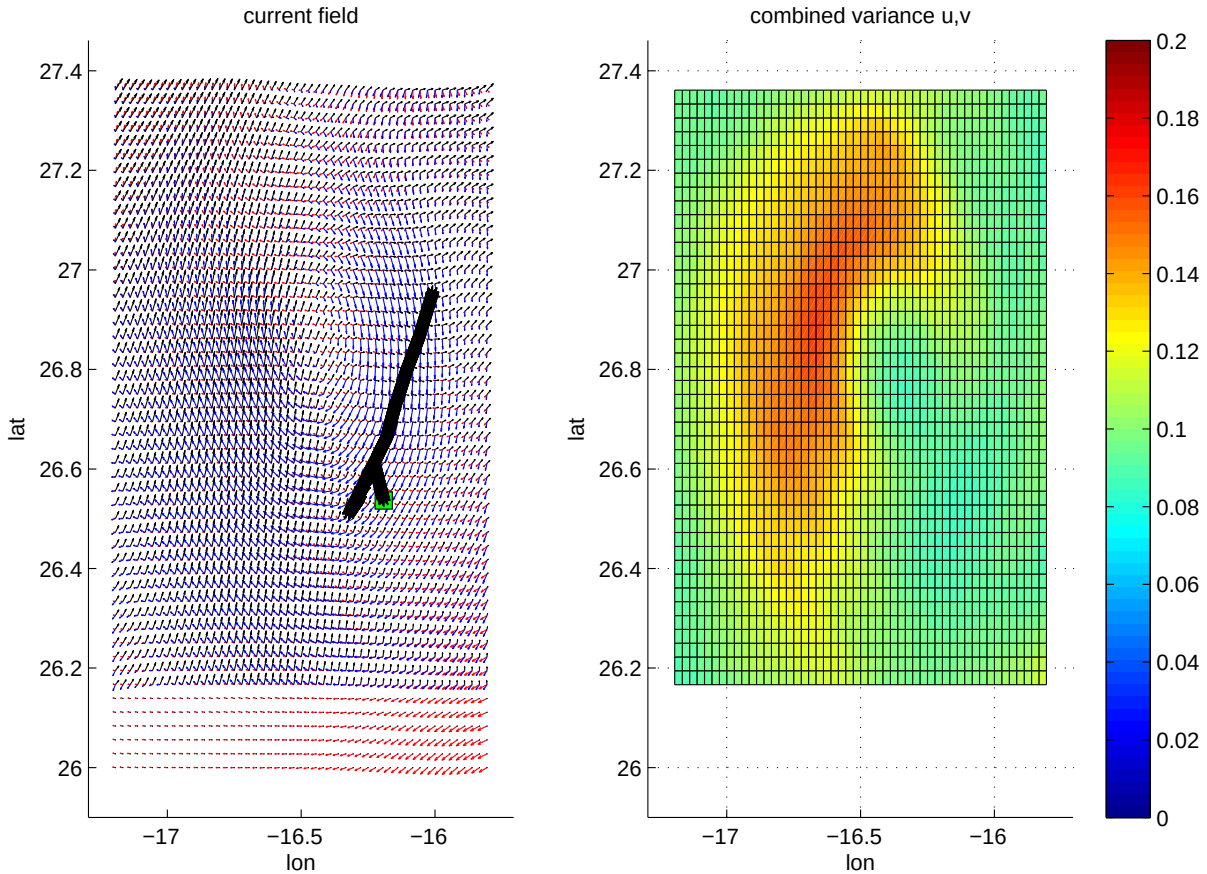

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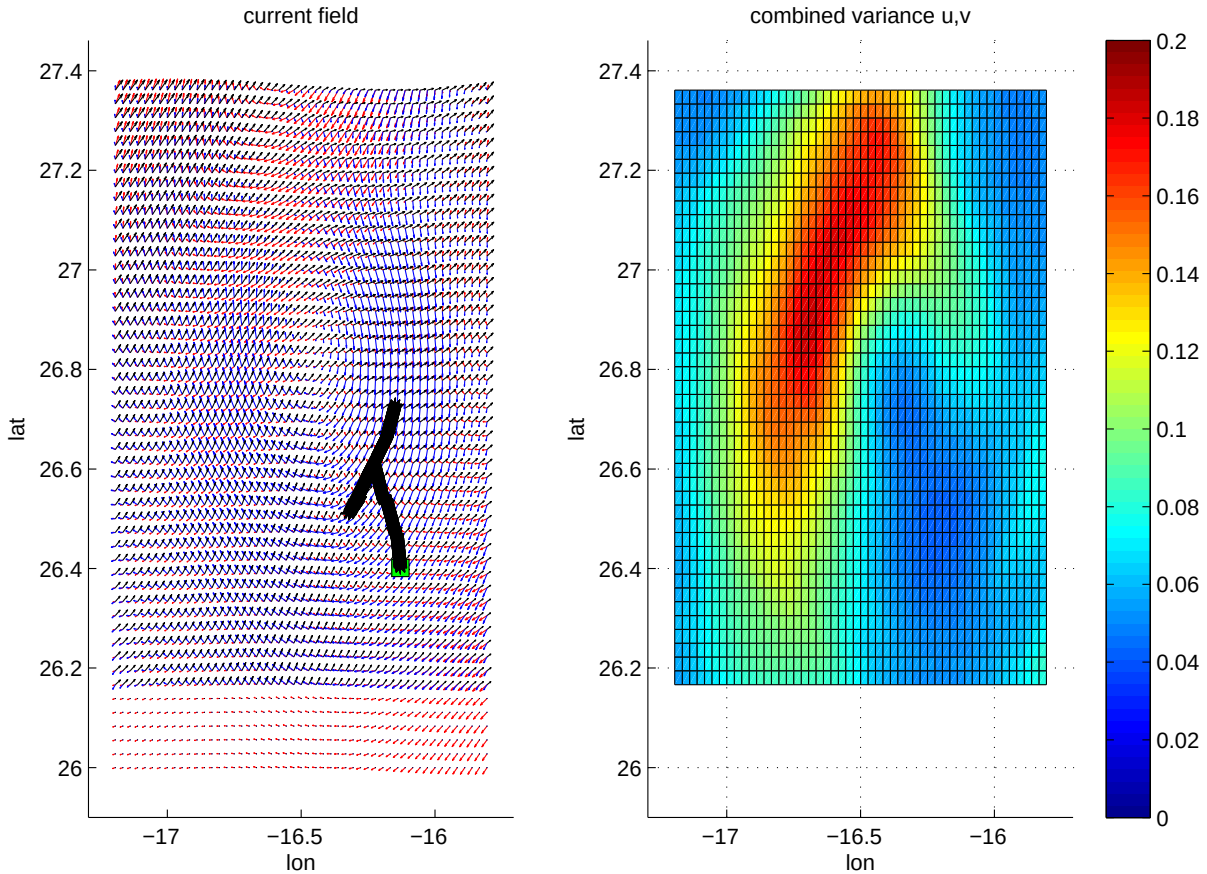

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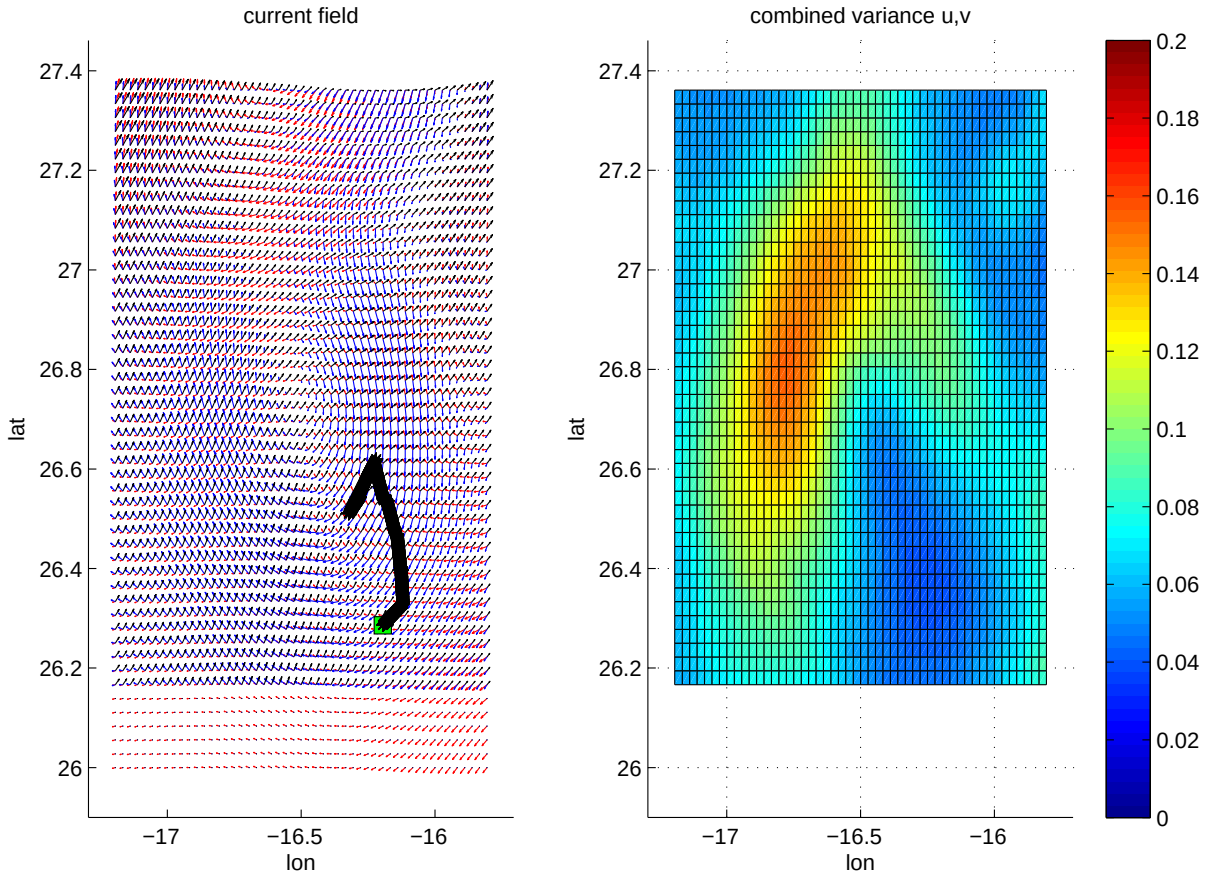

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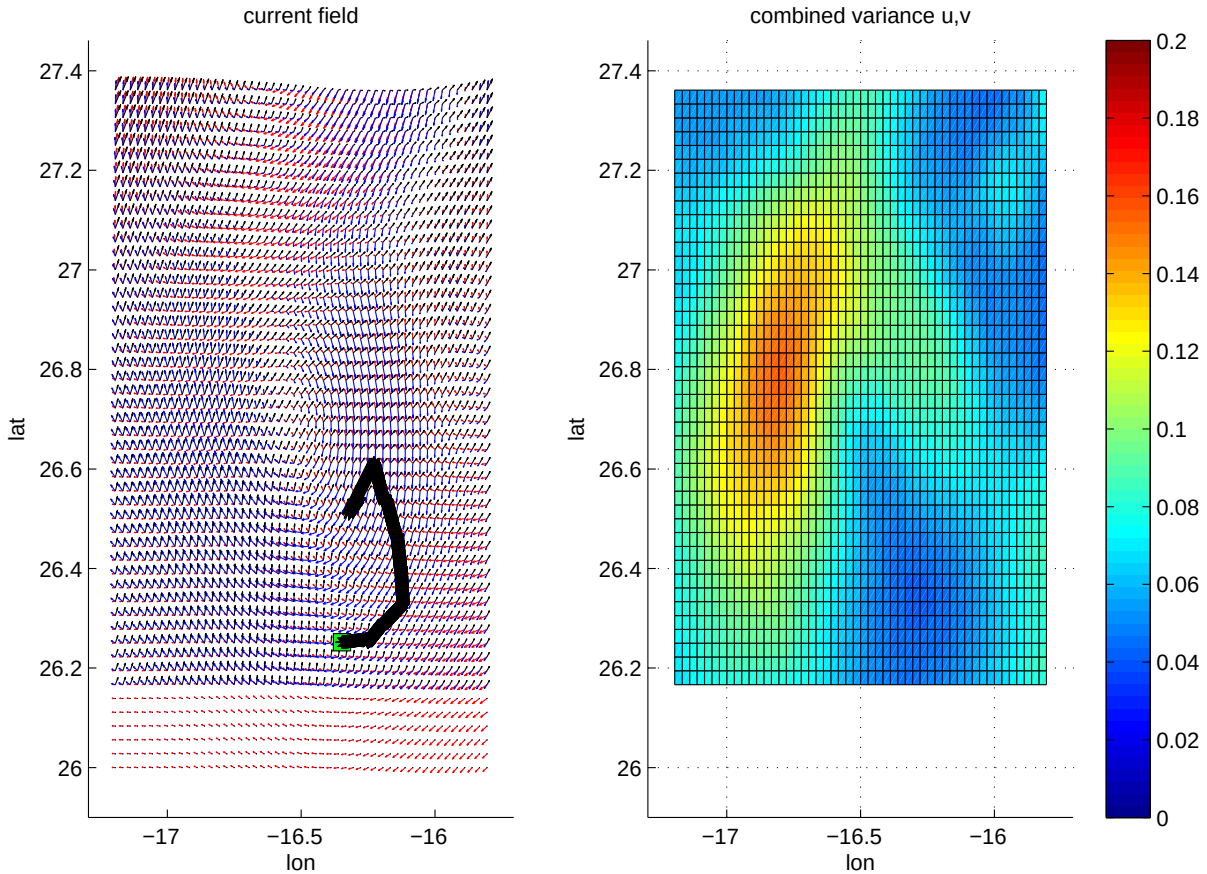

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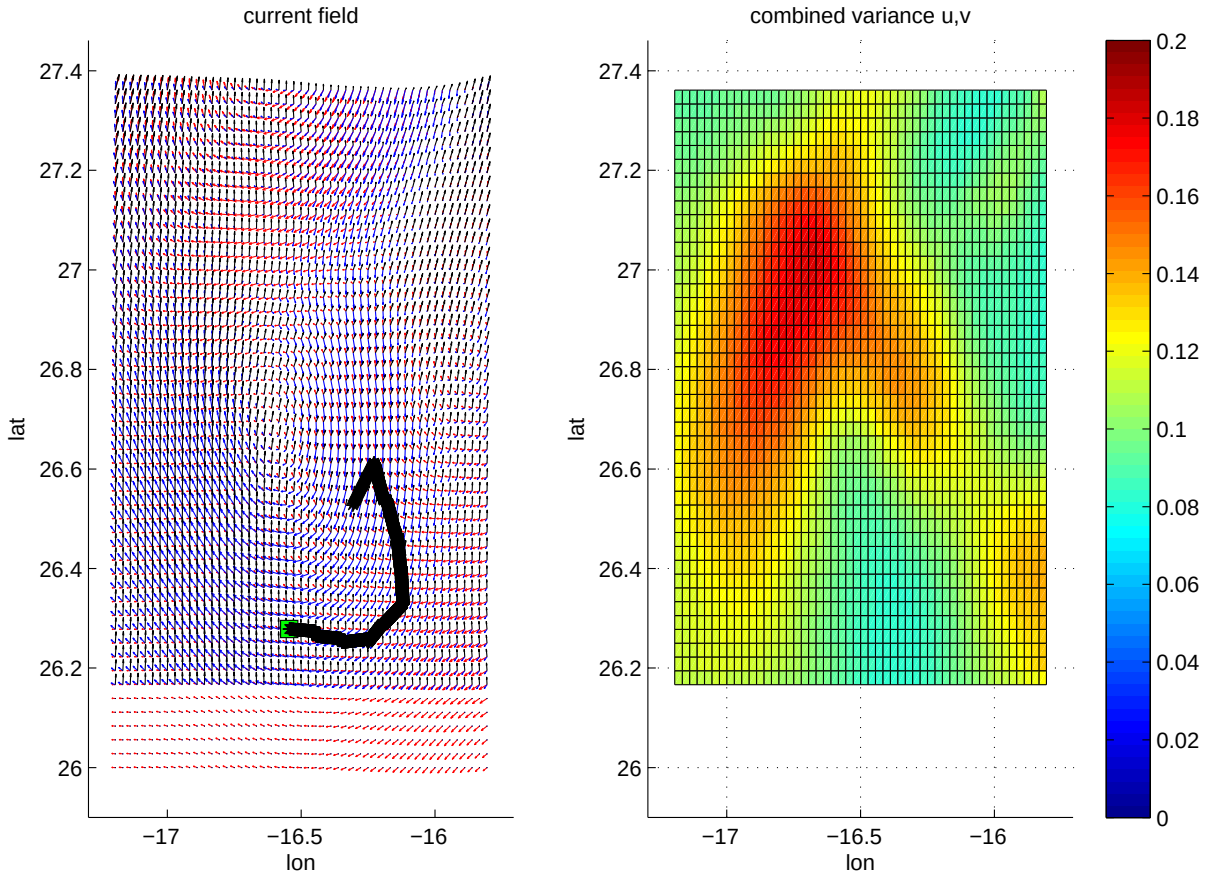

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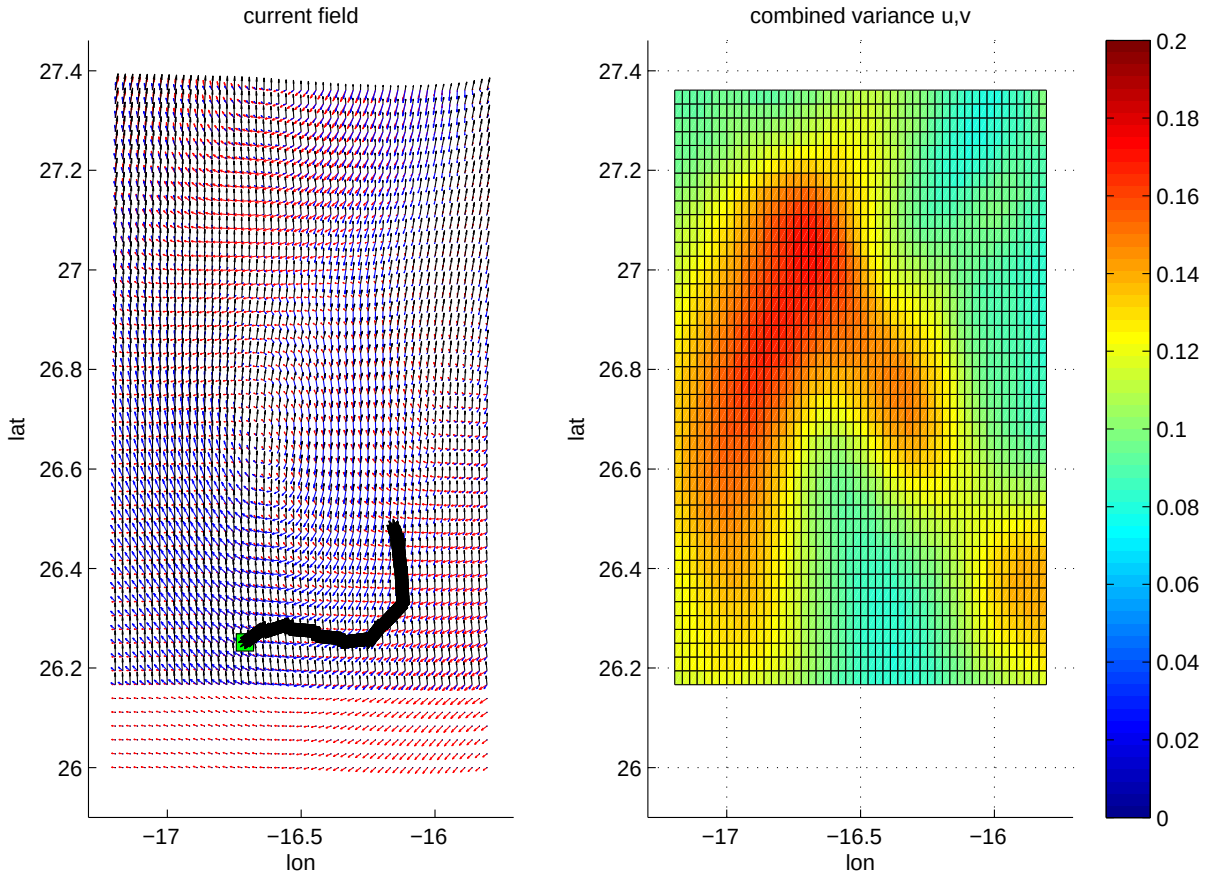

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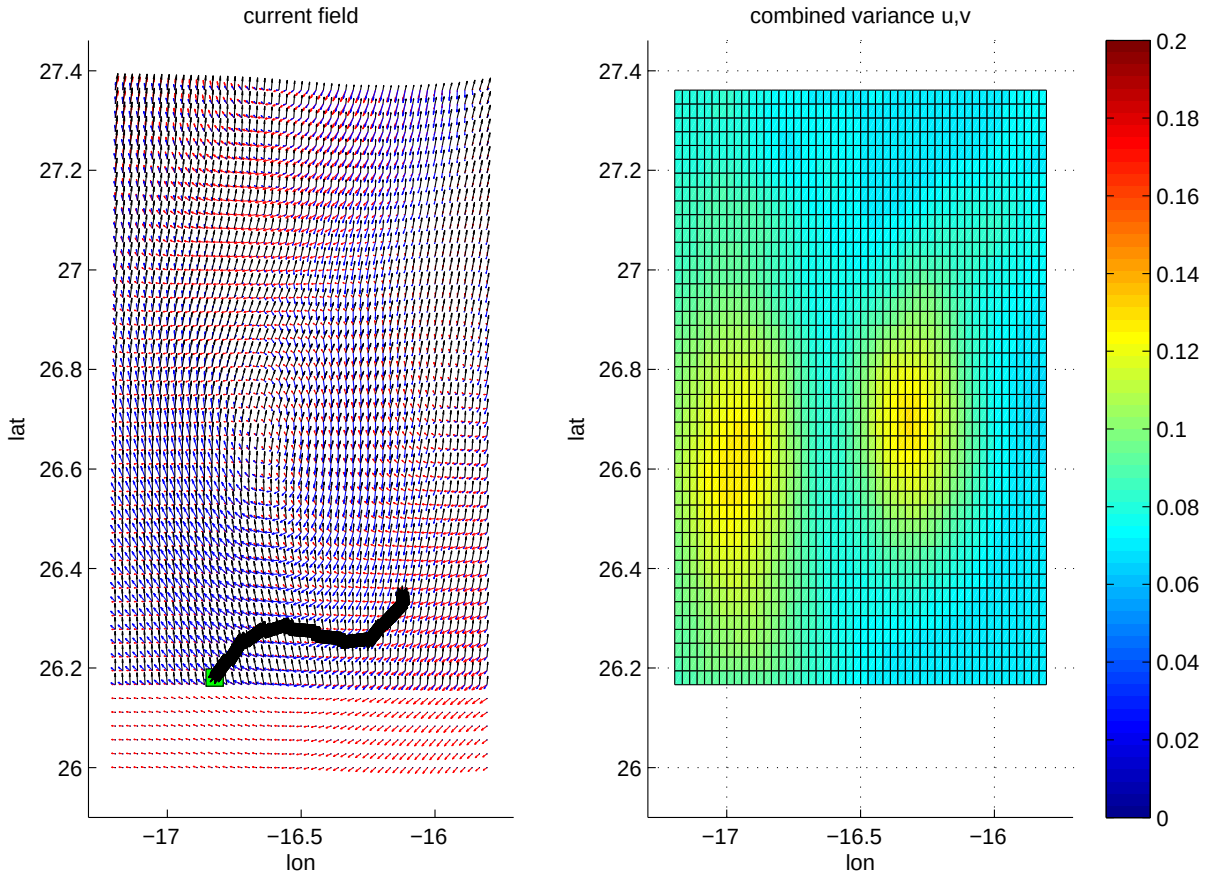

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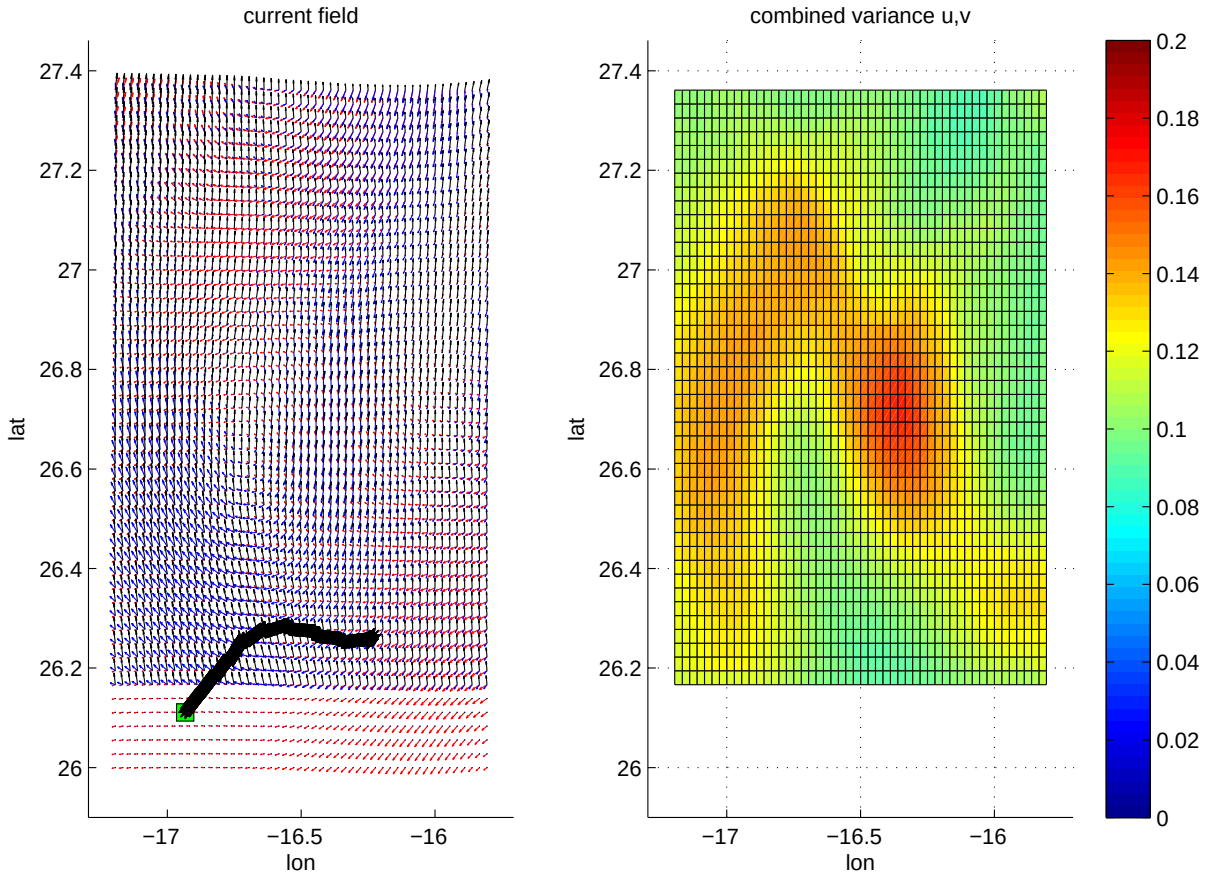

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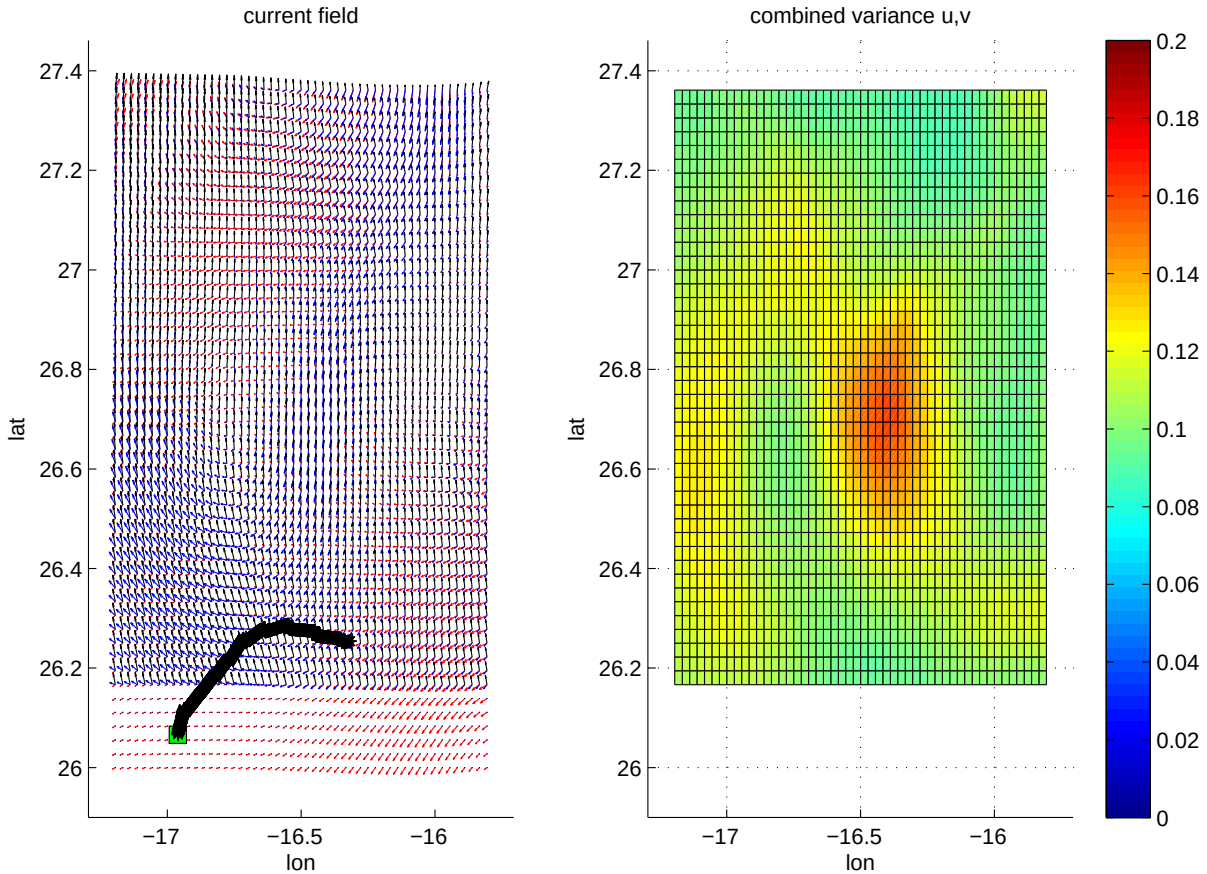

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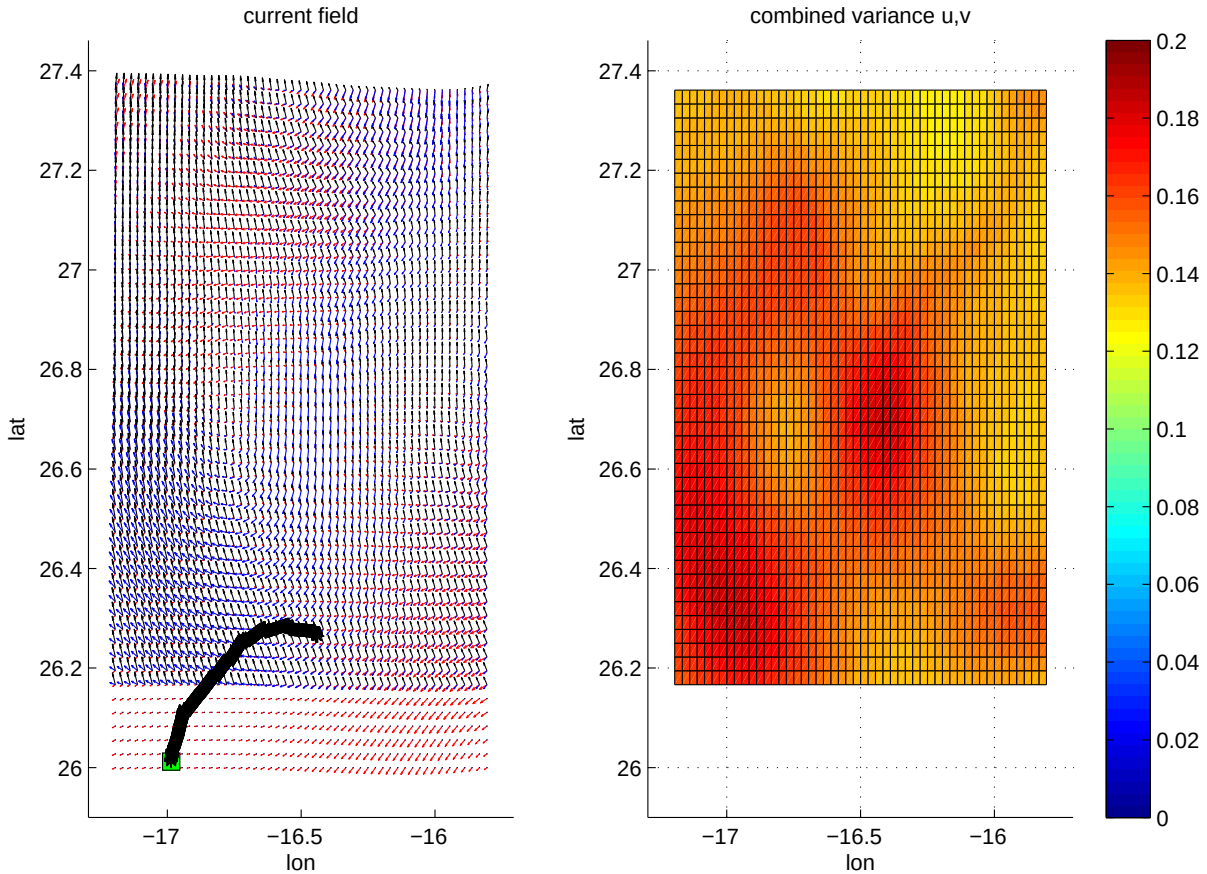
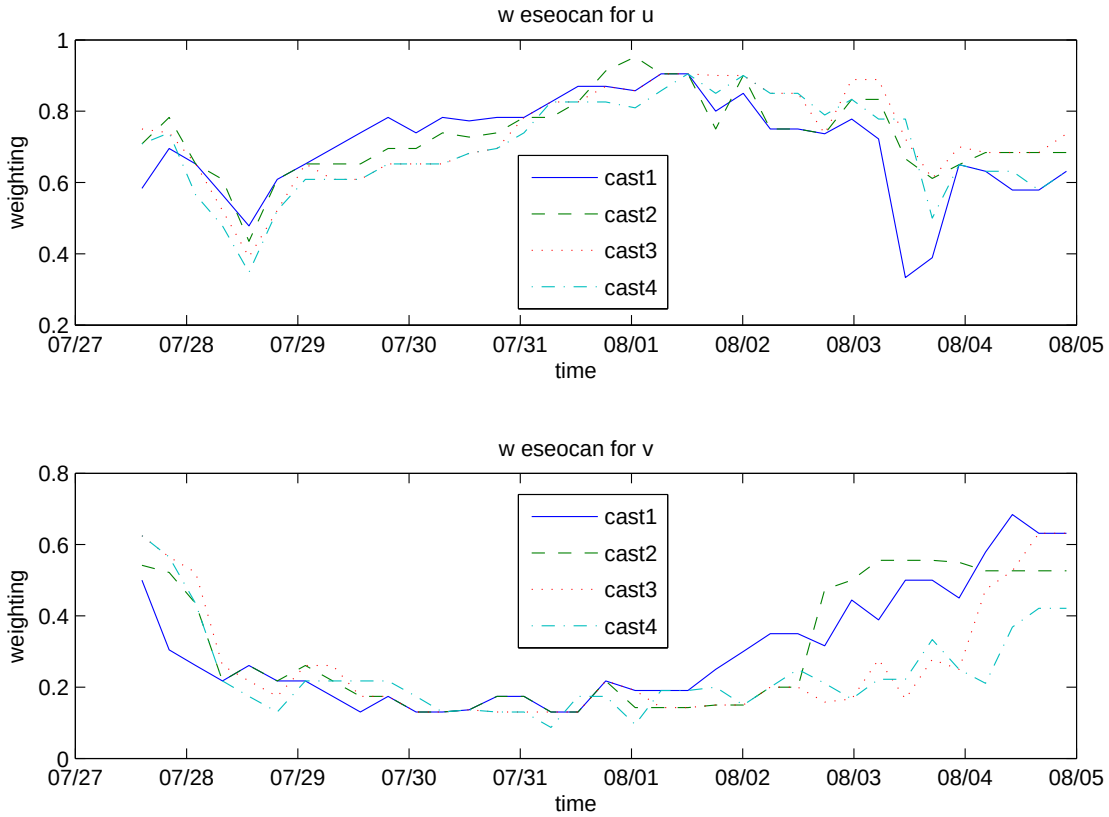


Different Forecast Ranges

- Models do not only have nowcast but different forecast ranges.
- Forecasts ranges are arranged in daily blocks (hindcast, nowcast, forecast1, etc.)
- Forecast blocks are compared to the glider measurement to their valid date
- BMA factors are calculated for different forecast modes

Weighting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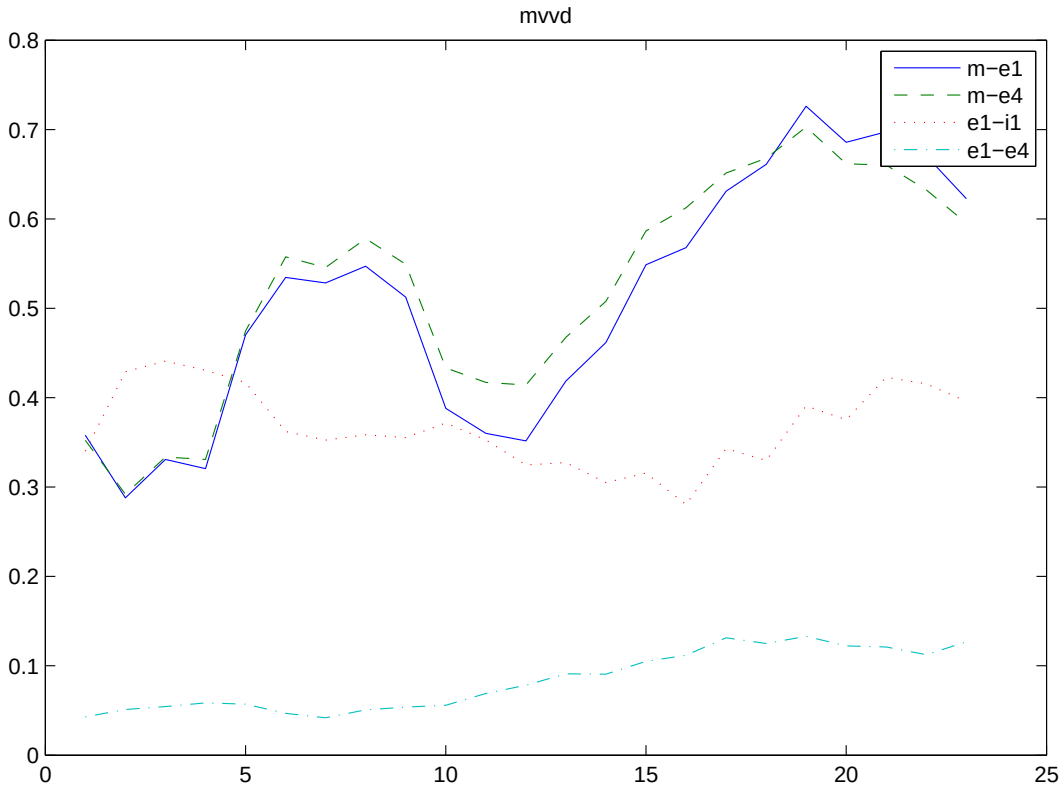
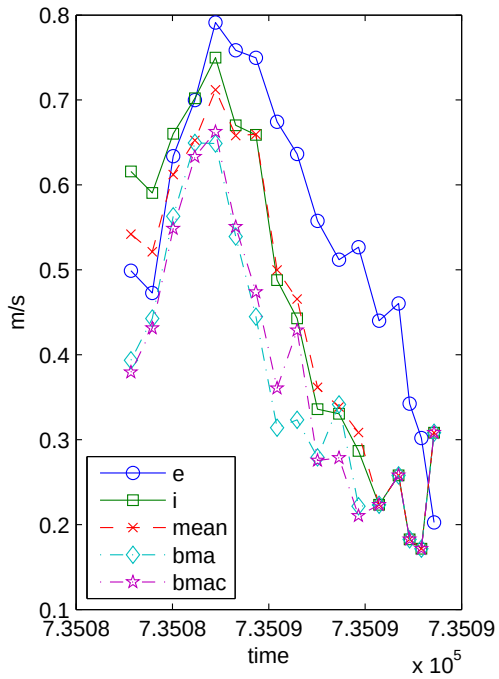
Glider-model errors



Errors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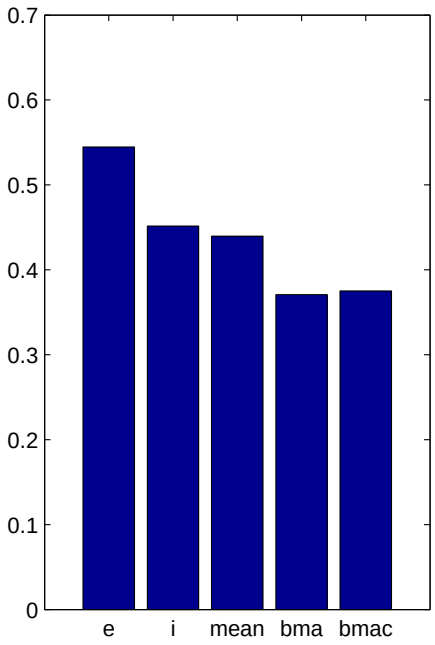
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Outlook

- Verify with more data
- Ensemble from more sources, various ocean variables
- Evaluate influence of time-scale

END