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Innovative Methods for Ionosphere-Thermosphere Discovery

General thoughts, specific examples

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A: Look to related fields for approaches/analyses

- Q: How do we develop new understanding of complex processes in the geospace system?

- Why? Challenges are
  - Nonlinear dynamics
  - Time-varying systems
  - Interacting ionized and neutral fluids.
- Example: searching for coherent structures for prediction of particle population advection
  - Environmental: rocket exhaust, meteor ablation, satellite debris contamination.
  - Communications, navigation: RF signal propagation affected by ionospheric structures.
  - IT structures map out to magnetospheric structures…

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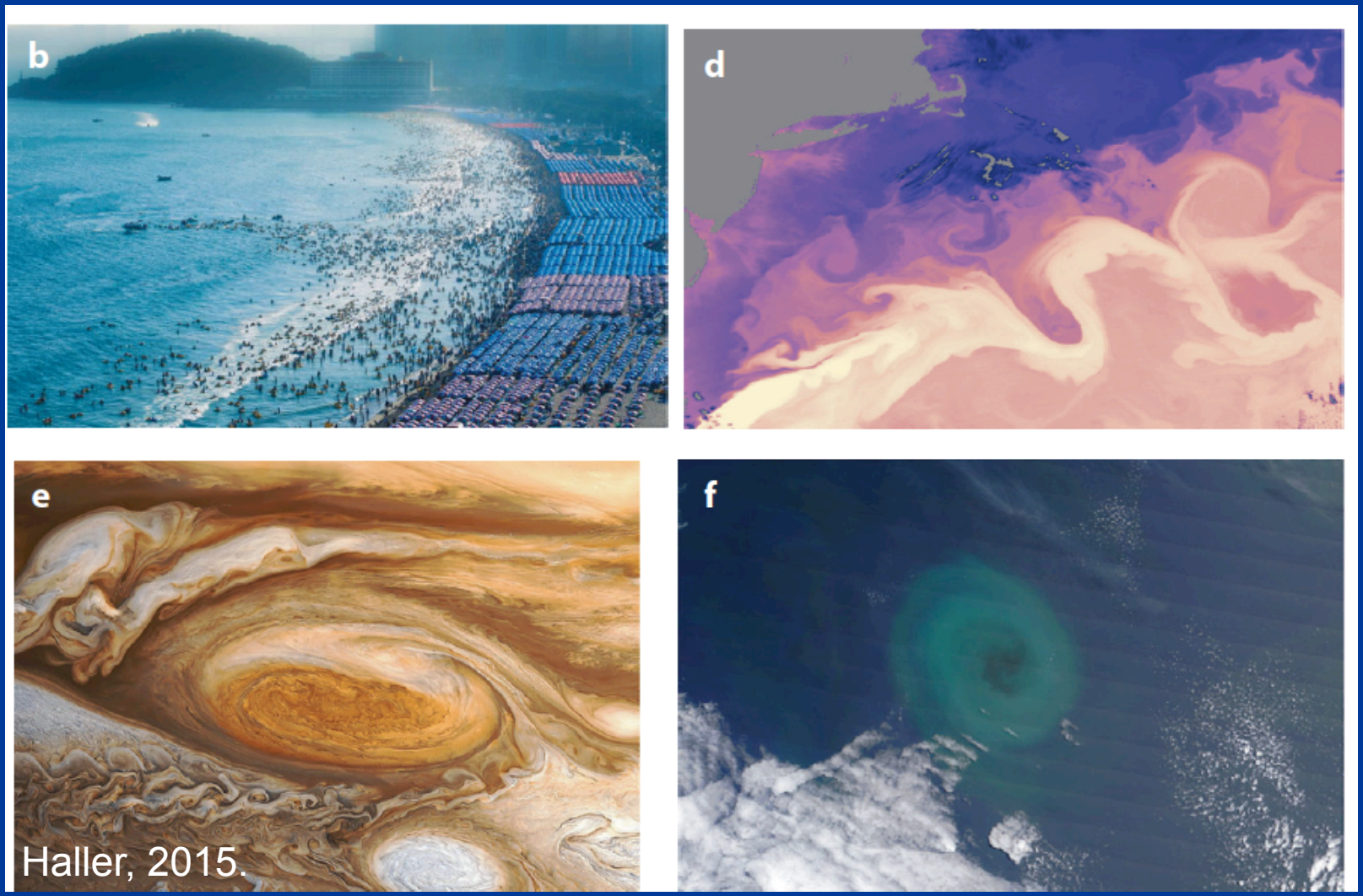
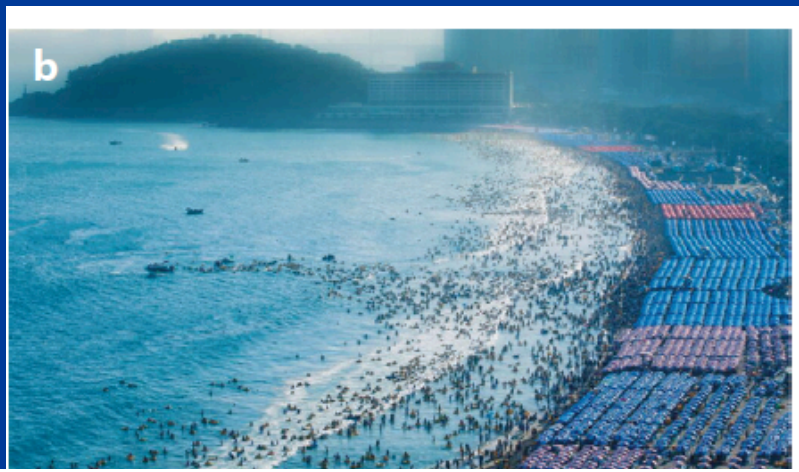
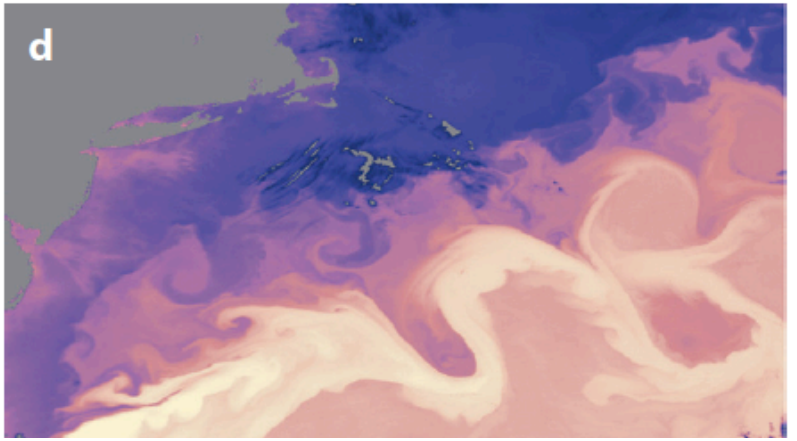
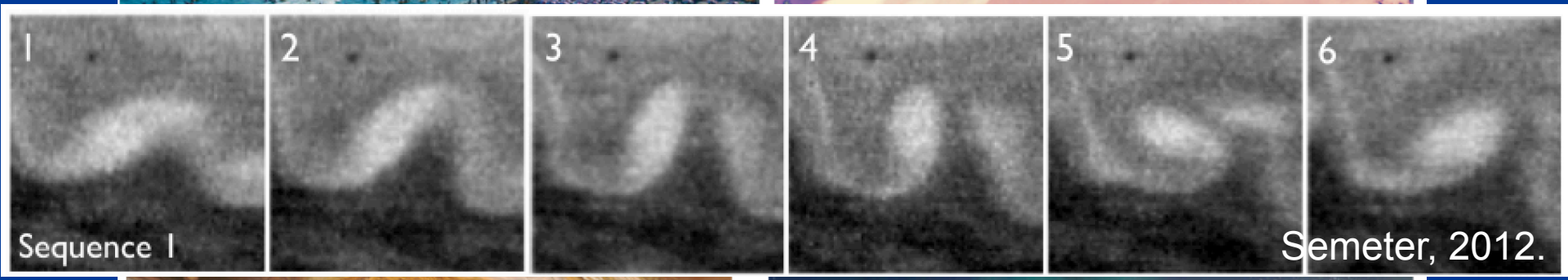
Example: Discovery Science in Flow Structuring

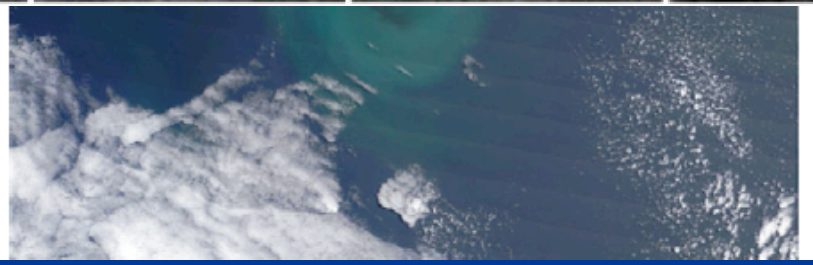


Example: Discovery Science in Flow Structuring







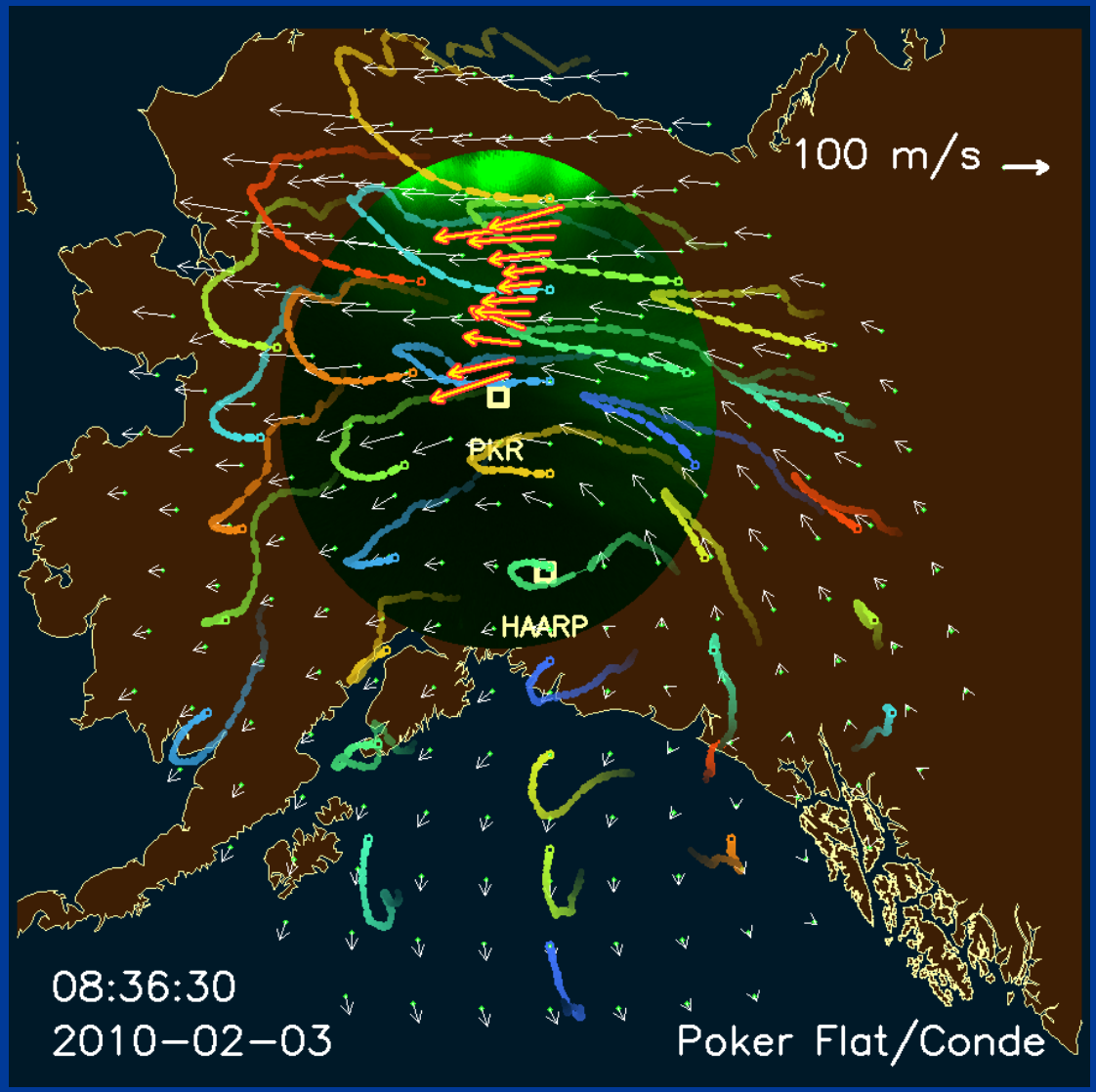


A: Data fusion brings specificity and fills in gaps

- Q: In what ways are new approaches, including the emerging fields of data fusion, data science, and machine learning, improving understanding of the geospace system?

- Why? Challenges are
  - Forecasting with uncertainty quantification
  - Actionable forecasts for space weather
- Example: At what scales do coherent structures form in the upper atmosphere?
  - Don't know yet: Need flow fields to observe them!

Example: Distributed sensing



Courtesy of M. Conde. [Anderson, Conde, and McHarg, 2012]

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A: Standardization and attention to user interface

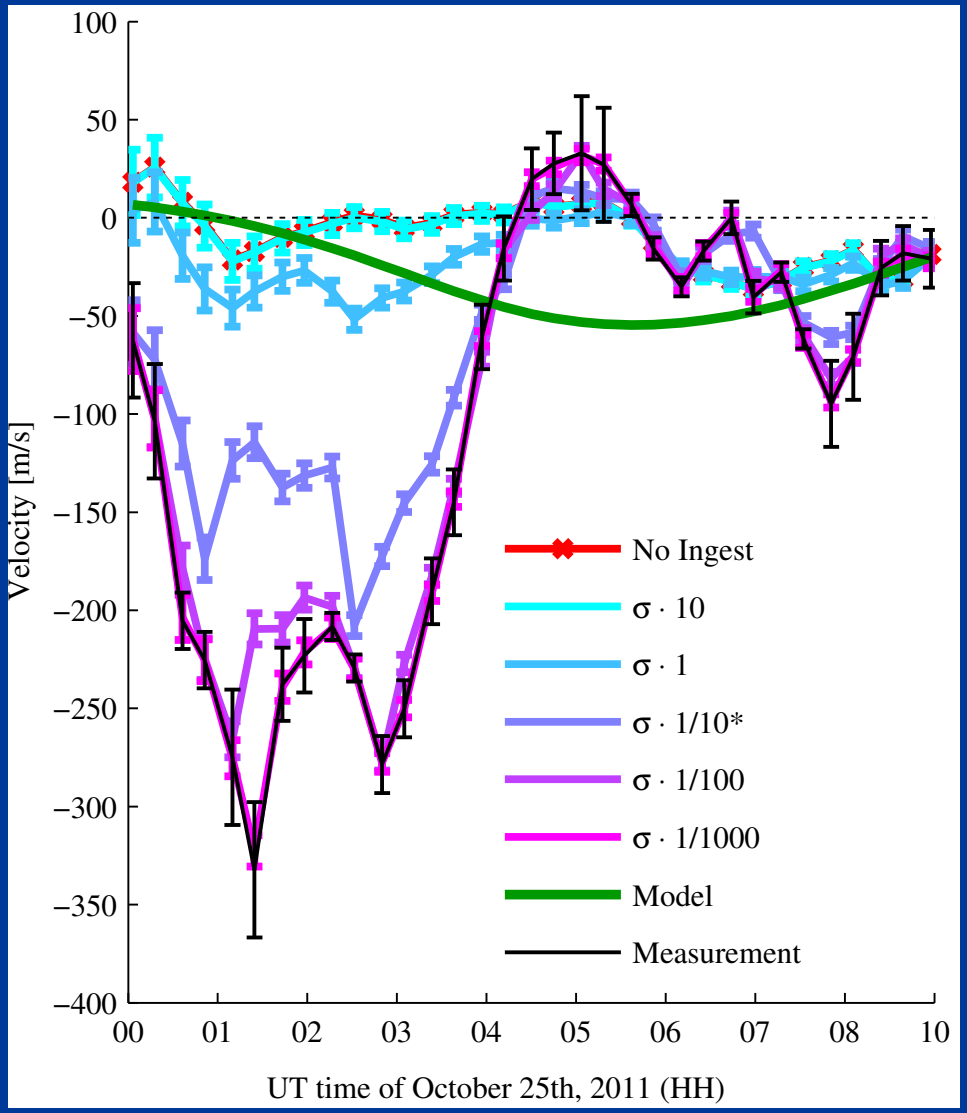
- Q: What allows a more efficient and widespread utilization of the geospace observational system?
- Why? Lowers the barriers to research entry
- Example: Global Navigation Satellite System (GNSS) networks
  - Single repository with map and standardized recording of site history gives ease of use.
  - Nothing draws a crowd like a crowd!
  - Receiver INdependent EXchange (RINEX) format
    - » Text file header specifies which observables are provided
    - » One RINEX script covers 1000s of receivers!

A: Error modeling (both of measurements and models)

- Q: What are the challenges of applied data-driven methods for the MIT system?

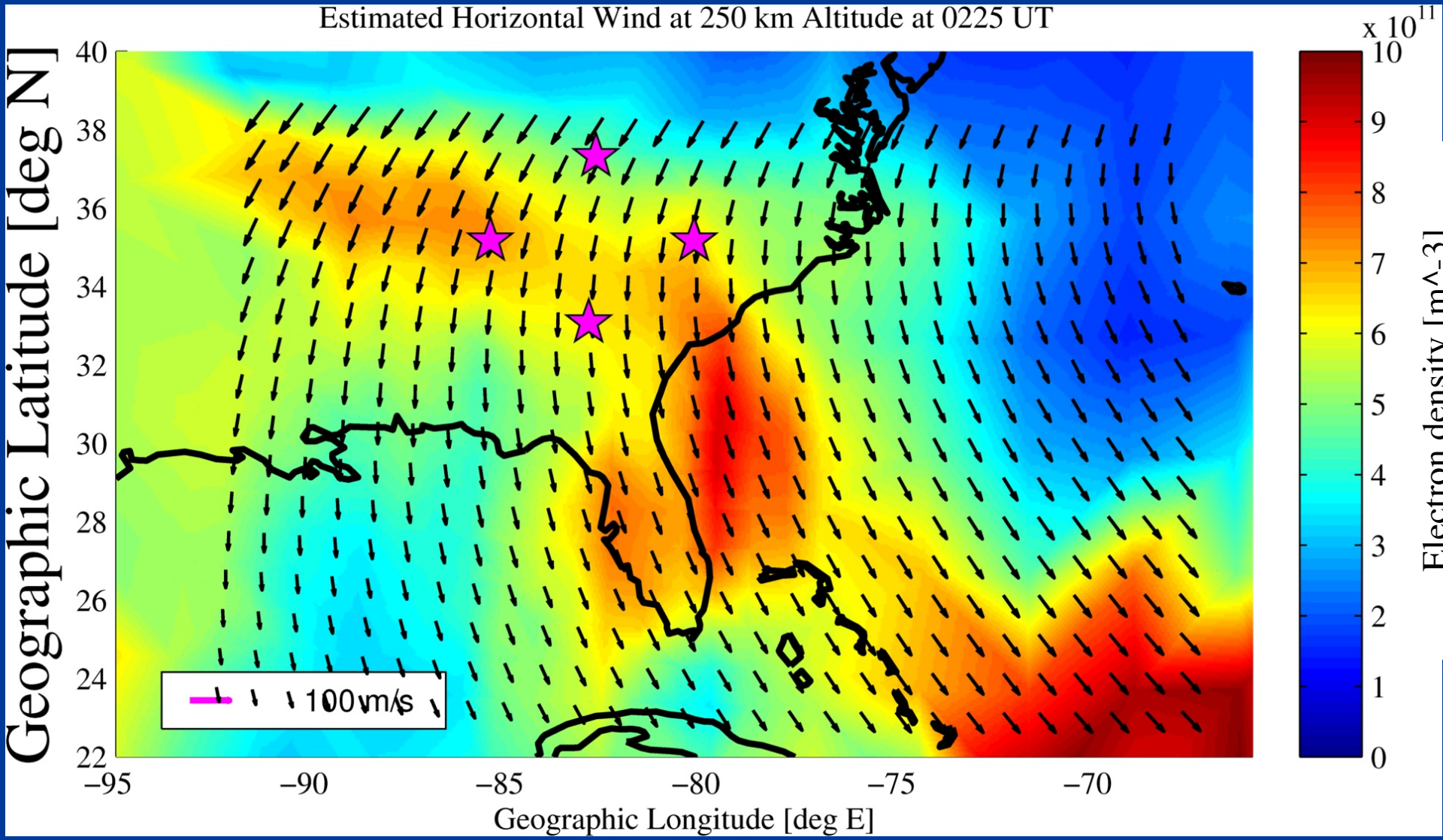
- Why?
  - Measurement error models are needed for accuracy and integrity ("trustability").
  - Model uncertainties – a broader problem for all fields
  - Significantly influence results of data assimilation when using optimized methods.
- Example: Kalman filtering of measurements and models depends on the covariances provided on a priori information (e.g., background models) and measurement updates

Example: GPS-based Ne and FPI neutral wind ingestion



Miladinovich et al., 2016.

Example: Data assimilation of FPI and GPS TEC



References

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