A semi-certain report about our certainly informative discussion about Uncertainty

The Lonely Hearts Club

a) Attributing Uncertainty

- Data denial experiments:
  - Systematically withhold datasets to examine effect on short-range ensemble sprea
  - Possibly use OSSE framework
  - Bias: which data most influence analysis increments?
- Retrievals: vary algorithmic parameters to determine impact on short-term spread
- Separate uncertainty in environment versus storm-scale: when does each dominate?
- Physics: sensitive parameters and components
  - Can simplify the model configurations for this purpose – e.g., single column models: large ensembles
  - Scale dependence of parameterization errors
- Numerics in models: evaluate different numerical schemes compared with, e.g., physics uncertainty

b) What is hindering the improvement of PRACTICAL Predictability: Storm scale?

- Need for more observations
  - PBL profiles; improved mixing and entrainment estimates
  - Water vapor: pre-convective state
  - Model biases (hinder assimilation): better use of obs to reduce model biases
- Limited reforecast datasets
  - Computational expense and data storage problems
  - Need to include null events (e.g. failed storm development, TC formation)
- Lack of physical understanding
- Difficulty of assimilating (some types of) observations
  - Dual-polarization radar variables
  - Cloudy radiances
  - High time resolution: What is maximum update frequency?

PBL = Planetary Boundary Layer

b) What is hindering the improvement of PRACTICAL Predictability: Mesoscale?

- Lack of More PBL observations, including wind profiles
- Difficulty of assimilating all-sky radiances accurately
- Land surface
  - Better soil moisture observations are needed -- modulates convective initiation
  - More accurate Bowen ratios/flux partitioning
  - Coupled data assimilation: how much will this help?
- Additional water vapor measurements through the mid troposphere
- Identification of boundaries in wind, moisture, and temperature to aid in convective initiation forecasts: we have limited observations

c) What are the key sources of uncertainty and how can they be minimized? (Storm scale)

- Storm (county) scale
  - Microphysics (once a system exists!)
    - How to determine uncertainty? See “Attributing Uncertainty”.
    - Verify how schemes work (dual-pol may help, but uses retrievals)
    - Improve ice nucleation through measurements of ice nucleii – but how?
  - PBL (pre-storm)
    - Leverage high-resolution satellite data (e.g., GOES-16) to drive model forecasts of convective initiation?
- Mesoscale
  - Gaps in observations: is there hope for observational targeting?
  - Cheap solutions: modify current obs strategies
    - Sounding timing
    - Change scan strategies to fill data gaps (almost no cost!)
    - Better climatology to perform model evaluation of the boundary layer

d),e) What additional tools, observations, and resources are needed to address the problems above?

- Additional Observations
  - Measurements in precipitation systems (convection)
      - Temperature
      - microphysics: presence of mixed phase
      - dynamics - measurements of w (or u,v and use continuity equation)
      - surface fluxes in high wind conditions (hurricane boundary layers – unmanned aircraft)
      - microphysics (+connection with in situ), important for model evaluation
      - water vapor (yes, water vapor in convection)
  - Measurements in the environment
    - Stability and shear profiles for convective initiation, gravity wave propagation, and storm maintenance
      - Lowest 5–6 km most important for storm mode
      - lidar, VAD, AMVs (above the surface) can all help
      - Clever modification of operational observing system strategies
    - GOES-16 multi-channel radiance measurements for T, q in lower-mid tropopshere
    - CCN and IN concentration measurements: not clear how to do this

d),e) What additional tools, observations, and resources are needed to address the problems above?

- What do we do with the data?
  - Data assimilation
    - Rapid cycling for frequent observations
    - Use high-frequency satellite and radar in combination to continue feeding model DA systems
    - Characterize observational errors and uncertainties
    - Develop more accurate forward operators
    - Use improved error covariance models for convective-scale data assimilation
    - Use advanced DA systems for identifying model biases
  - Better depict forecast uncertainty,: object-based methods like machine learning
    - Assess value of current strategies: paintball plots, spaghetti plots, etc.
    - Disentangle space/timing errors from other types of forecast error. Need tools to do this better.
    - Identify scenarios using image processing techniques

Take-home Points

- Focus on short time scales: greatest potential to reduce uncertainties (errors), furthest from predictability limit
- Do things that are “easy” and “cheap” first
  - Better use of existing data to reduce model biases
  - Clever changes to operational observing strategies
  - Use a hierarchy of methods to trace uncertainty through obs-DA-fcst system