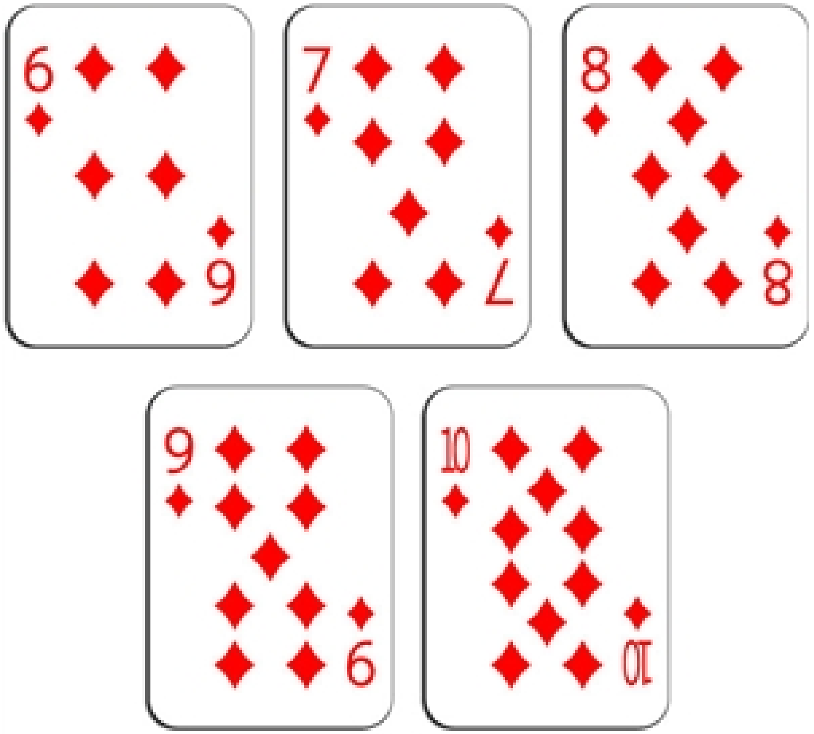
“The diamonds”

Good debate but also a lot of consensus..

“Judith… that actually makes sense!” – Glen



Our take on the morning discussions:

Model processes group:

- Microphysics uncertainties (but only acts in clouds), grid spacing, PBL physics and shallow cumulus in the gray zone
- Characterizing uncertainty in physics schemes: how to systematically test this?
- Challenge in that processes are often not directly observed

Our take on the morning discussions:

DA group:

- Model is major component/source of error.
- Need better communications with the other communities (e.g., observations and model development), stronger interactions with physics/model/observation/DA teams.
- Identifying and removing model bias (iterative work)
- Algorithm development, forward operators, correlated ob error, gaps in the observing system (BL, moisture, complex terrain, remote, unavailability of local observing networks e.g. radars from Europe), multi-scale DA, coupled DA
- For DA, ob error prevents convergence of the analysis on the obs – which is problematic

Our take on the morning discussions:

Measurements and retrievals group:

- In situ microphysical measurement challenges, limited means to observed particle size distributions and characteristics; challenges in airborne collection (e.g., probe tips)
- Applications of radar data (easy to get velocity and assimilated), can't reproduce the processes measured by dual pol (e.g., size sorting).
- Dual pol retrieval, e.g. Zdr column; Kdp for cooling rates
- Uncertainty quantification – need to know for DA

Predictability group:

- Broken down by time scales: 1 h (Regional; mostly remote obs, model error, spinup challenges and initial balance issues), next day (Regional; obs (upstream Pacific), systematic model error, reliability), several days (Global; coupled model systems, model error, physical process representation)

The questions:

How can radar retrievals, in situ measurements, DA systems and models with different scales used in an optimum way to reduce uncertainties in forecasts?

- DA is the glue for merging observations and models. Retrievals can be used to investigate model processes and used for verification of model forecasts. Background ensemble needs to be adequately rank sufficient, stochastic methods in the background ensemble may help.

- Ensemble spread issue: HREF has a wide pdf, lacking in formal ensembles – model error likely related to error growth problem common bias with little error growth in (dominated by systematic error), not clear how IC errors play a role. Structural errors in the model (not tied to parameterizations) are more difficult to find and address.

What is the best mechanism for establishing uncertainties in predicted variables?

- Ensemble predictions estimate the uncertainty – for a good ensemble the ensemble spread is a good predictor of forecast errors (e.g., large spread = large errors, and vice versa). Stochastic methods help address potential time accumulating errors by applying temporally consistent patterns in space to adjust the model physics end result.

- Could train some physical processes on LES simulations, but this is not as practical for microphysics because we don’t have good observations of the truth, including the processes involved, and requires a very accurate estimate of the state. Machine learning approaches hold promise, but as yet haven’t been well demonstrated to date.

- Verification of probabilistic predictions.

The questions:

What is hindering progress from being made on improving atmospheric predictability?

- Poor communication between observation, physics developers, model developers, and DA teams. ***Requires integrated teams across these expertise areas to work together collaboratively to drive model physics improvements.***

- Model error

- Analysis algorithms

- Gaps in observations

- Sources of error in initial conditions (large small scale errors, small large scale errors), which cannot be easily discriminated from forecast model spectra

The questions:

What is the key source of uncertainties, and how can they be reduced?

- Structural uncertainty (e.g., model solver, varied physics schemes)
  - Multi-model, multi-physics
  - Perhaps first quantify first before attempting to reduce
  - Perhaps address through model error diagnostic approaches
- Parameter uncertainty (uncertain specific parameter within a physics scheme process representation)
  - Apply SPP
- Inadequate observations to reduce initial condition uncertainty
  - More obs in data sparse regions, improved QC and observation certainty
- DA
  - Improve the analysis quality through improved methods

The questions:

What additional tools, models, obs, and resources are needed?

- Better utilization of cycled data assimilation diagnostics, time averaged physics tendencies to investigate systematic model bias
- Obs of the PBL and microphysics state, better coverage in the West of surface and radar, sharing more data sources locally and internationally, better QC and metadata.
- Funding support for physics suite analysis. DOE? NSF (not AGS)? Perhaps through big data initiatives.

More data sets? Yes

- Measurements in clouds (e.g., add sensors to commercial aircraft for microphysics, dynamic structures)
- Cloud chambers and lab studies, revisit physical processes, investigate scattering, riming, ice growth, etc…
- More in situ observations of winds, temperature, moisture especially above the ground
- Remote sensing of mid-tropospheric moisture, boundary layer winds, temperature (PBL focus)
- Long reforecast data sets from models

The questions:

New analysis?

- 3D RTMA – optimal analysis and uncertainty estimates to compare against forecasts
- DA methods for non-Gaussian distributions
- QPE uncertainty information

The questions:

Biggest priorities:

- Quantify structural uncertainty to enable systematic model error reduction
- Improve forecast reliability in short term forecasts (0-36 h)
- Improve multi-scale DA capabilities to better leverage convective-scale observations (e.g., radar and satellite observations)
- More observations to improve processes:
    - Observations in convective environments and within convection
    - Observations of the boundary layer
    - Land surface and water (lake, ocean) observations (e.g., fluxes)
- More observations to improve predictions:
    - More in situ observations of state above the surface
    - gap filling observations
    - mid-tropospheric moisture
    - international data sharing
    - Land and ocean surface observations (e.g., fluxes)
- Sufficient metadata with observations, particularly crowd-sourced data and mesonets
- Improved collaborative teams to address DA/observations/physical process/models in a joint effort
- Refined methods to verify probabilistic predictions, particularly for rare, high-impact events

The importance of collaboration!!!

Let's work together!

Get people with different expertise (DA, ensemble forecasting, observations, physics parameterizations) interested in a common problem… good things will happen!

- **Targeted workshops bringing people from different communities together (like this one!)**

- **Focused problems of interest (funding?)**