EnKF Data Assimilation and Breeding for the Martian Atmosphere

Steven J. Greybush, Eugenia Kalnay, Matthew J. Hoffman, John Wilson, Ross N. Hoffman, Kayo Ide, Takemasa Miyoshi
University of Maryland, College Park; Johns Hopkins University; GFDL; AER, Inc.

Research Goals
- Characterize the spatial distribution, temporal evolution, and physical mechanisms of instabilities in the Martian atmosphere.
- Create a Mars weather and climate reanalysis by assimilating spacecraft observations into a MGCM.

GFDL Mars Global Circulation Model (MGCM)
- Finite volume dynamical core
- Latitude-longitude grid
- 60x36 grid points (°x°29’) resolution
- 28 vertical levels
- Hybrid p / ω vertical coordinate
- Gaseous and condensed CO₂ cycle
- Tracers for dust and water vapor, with the option for dust radiative feedback

Breeding in the Martian Atmosphere
- In chaotic systems, two states that are initially similar grow along at least one unstable direction, or pattern.
- There is no stable pattern to predict, only that they will change.
- Breeding is a simple method for finding the shapes of these instabilities (errors).

Step 1: Create a nature run (control run) of the MGCM.
Step 2: Add an initial perturbation to the nature run.
Step 3: Allow the perturbed run to evolve in time using the MGCM.
Step 4: Scale the size of the difference between the runs back to the original value.

MGCM Breeding Experiment
- Rescaling Time Interval: 6 hours
- Rescaling Amplitude: 1 K
- Rescaling Norm: Temperature-Squared Norm, Scaled by Cosine Latitude
- Experiment Length: 1 Martian Year (668 Martian Days)
- Rescaling only occurs during periods of Bred vector growth beyond original amplitude.
- Bred vectors are kept “young” by adding random perturbation each rescaling interval whose magnitude is 5% of the original perturbation.
- Fixed dust scenario (opacity = 0.3)

Describing Instabilities: Bred Vector Energy Equations
- Begin from the equations of motion (momentum equation in sigma coordinates).
- The control run and perturbed run both satisfy these equations exactly.
- Derive a kinetic energy (KE) tendency equation for bred vectors (difference between control run and perturbed run).

Bias Correction and System Tuning
- Dust Variability and Assimilation
- TES Radiance Assimilation
- Comparison to the Oxford Reanalysis