**Data Assimilation and Parameter Estimation for the Global Ionosphere-Thermosphere Model using the Ensemble Adjustment Kalman Filter**

Alexey V. Morozov, Aaron J. Ridley, Dennis S. Bernstein - University of Michigan, Ann Arbor, MI
Nancy Collins, Timothy J. Hoar, Jeffrey L. Anderson - National Center for Atmospheric Research, Boulder, CO

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**Introduction**

- GITM underestimates mass density when compared with CHAMP measurements.
- One way to correct this is to use CHAMP measurements to estimate GITM parameters that would compensate for modeling error.

**Model**

Global Ionosphere-Thermosphere Model (GITM)
- is an upper atmosphere model,
- is a contractive system (i.e. strongly forced),
- does not assume a hydrostatic solution, and
- does not use a pressure-based coordinate system.

The last two features allow for more realistic physics in auroral region.

**GITM: Inputs and Outputs**

Inputs (parameters)
- solar flux index \( F_{10.7} \)
- neutral temperature \( T_u \)
- neutral pressure \( P_u \)
- pressure \( p \)
- neutral mass density \( N \)
- ion number density \( N_i \)

Outputs
- neutral velocity \( u \)
- ion velocity \( v \)
- ion temperature \( T_i \)
- neutral temperature \( T_u \)

**GITM: Vertical Equations**

- Vertical solver accounts for all the source terms.
- Vertical continuity, momentum, and temperature equations are

\[
\frac{\partial}{\partial z} \left( \frac{1}{\rho} \frac{\partial p}{\partial z} \right) = \frac{\rho_0 g}{\rho} - \nabla \cdot \mathbf{F} \quad \text{(1)}
\]

\[
g = \frac{\partial^2 q}{\partial z^2} + c_s^2 \partial^2 q + \frac{1}{2} \partial \left( \frac{\rho_0 g}{\rho} \right) \quad \text{(2)}
\]

- Localization

- The effect of assimilation can be restricted to a region to avoid updating uncorrelated states.

**Results: Simulated Data from Subsolar Point**

- This introduction example is a perfect model experiment, i.e. it takes measurements from a GITM truth simulation with \( F_{10.7} \) fixed at 130.
- EAKF assimilation window is 30 minutes, measurements are available every minute, horizontal cutoff of 30°, and vertical cutoff of 100km.
- 20 ensemble members are for 2 days prior to Dec 01 with \( \rho \) values coming from normal distribution \( ~N(10, 25) \).
- \( \rho \) is inflated using \( \rho_i = 7 \).

**Example: Estimating a Time-Varying Parameter**

- Consider the linear system

\[
x_k = 0.5x_{k-1} + u_{k-1}, \quad y_k = x_k + 2, \quad u_k = 1.0 \sin(0.5k), \quad x_0 = 0. \quad \text{(12)}
\]

**Conclusions and Future Work**

- EAKF was successfully used to estimate GITM states \( (N, N_i, P, T_u, u, \dot{u}) \) and a parameter \( F_{10.7} \) using CHAMP measurements.
- One proposed extension is estimating the full solar spectrum at the top of the atmosphere \( (T_u(z)) \).
- Another possible extension is using Total Electron Content (TEC) measurements to estimate heating efficiency \( \dot{u} \).