Data Assimilation of Neutral Wind Measurements to Estimate the Ionosphere-Thermosphere State

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Abstract and Objective

- Goal of this poster is to describe how the data assimilation tool called Estimating Model Parameters from Ionospheric Reverse Engineering (EMPIRE) can assimilate:
  - neutral wind measurements
  - electron density measurements and
  - physical models
- to optimally estimate the neutral wind state of the thermosphere-ionosphere system.
- This is the first time neutral wind measurements from Fabry-Perot interferometers (FPIs) are ingested into a Kalman Filtering data assimilation scheme.
- The results describe how neutral wind estimation is improved by approximately 39% and we provide an image of the stormtime neutral winds in a region where a plasma density enhancement formed at local nighttime.

Introduction

- Ionospheric Storm Structures
  Ionospheric storms cause the upper atmosphere’s states to dynamically change over a wide range of spatial and temporal scales. Particularly, the neutral wind is thought to be a significant driver for the redistribution of plasma into structures like the one shown below.

- Ion – Neutral Coupling
  The ion continuity equation (Kirchengast, 1996) is a governing equation that contains a formalization for the coupling between ionized and neutral gas within the ionospheric region.

\[
\frac{dn}{dt} = a_{\text{prod}} - a_{\text{loss}} - \vec{v} \cdot (N \vec{v}_i) - \vec{v} \cdot (N \vec{v}_e)
\]

\[
\vec{v}_i = \vec{v}_a + \frac{\vec{v}_i}{v_0} - D \frac{\partial N}{\partial z}
\]

- Linearization
  The ion continuity equation is linearized and the difference between measurements and models are estimated using a 3 dimensional Kalman filtering scheme that is implemented in EMPIRE.

\[
z = y - a
\]

Method

- Data Assimilation
  We use a 3 dimensional Kalman filter to optimally estimate each term in the ion continuity equation.

- Models
  \[a_0 = a_{\text{prod}} + a_{\text{loss}} + a_{\text{e}L} + a_{\text{e}I}\]

- Measurements
  \[\frac{dn}{dt} \text{ provided by Ionospheric Data Assimilation}\]

ID4D

- Assimilates total electron content (TEC) and electron density profiles measured by global navigation satellite systems and provides electron densities on a specified grid (Bust et al., 2007).

- IDA4D
  Assimilates to neutral wind measurements to the thermosphere

Results

1. Plasma-density-only neutral wind estimation
2. Full FPI ingestion for all measurement points
3. FPI ingestion at two of the measurement points

Conclusions and Future Work

- Ingestion of FPI red-line measurements provided improved neutral wind estimation by approximately 39% in the northward direction.
- These results show that EMPIRE estimates are mostly sensitive to the FPI measurements when the difference between model and measurements is significant.
- Next we are working on generalizing and expanding data ingestion to more FPI instruments.

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References


