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Latest research and future challenges for ionosphere-thermosphere data assimilation models

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The upper atmosphere presents a distinct challenge for data assimilation. It is a rapidly changing environment with complex statistical properties. Nonetheless there are a wide range of data assimilation models in development and use across the globe.

Data assimilation is the science of combining different sources of information to estimate possible states of a system as it evolves in time. In general data assimilation can determine an evolving probability density function, which specifies the range of possible states and the probabilities that they represent. Data assimilation has many names, depending on the field of application (e.g. state estimation, history matching, filtering, smoothing), and it is often combined with so-called inverse methods to extract maximum information from observations.

However the coupled ionosphere-thermosphere region is sparsely sampled by data, is strongly driven by solar inputs, and densities can vary by orders of magnitudes from day to night and in response to geomagnetic storms. Since there are a lack of satisfactory covariance models for the ionosphere-thermosphere this provides the impetus to examine the use of ensemble methods of data assimilation. These ensemble approaches, for example the ensemble Kalman filter, also provide the opportunity for producing probabilistic forecasts.

This tutorial will describe the various approaches to mathematical modelling of the ionosphere-thermosphere system, derive the data assimilation theory, how ensemble output can be used for probabilistic forecasts and how this can all be combined to provide actionable space weather products and services into Government and industry.

Whilst the examples in the tutorial will be based on the ionosphere-thermosphere, the techniques are applicable across a wide range of disciplines.