

# An ensemble data assimilation system with flexible parallelism, with applications to the ionosphere

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Distribution Statement A: Approved for public release. Distribution is unlimited



- DA system description
- Parallel scaling tests
- Ionosphere model and observations
- Forward operator implementation
- Ionospheric data assimilation initial results

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- Modular parallel data assimilation system written in modern Fortran
- DA solver parallelized independently from model
- Open source (MIT license)

https://github.com/LightDA-assim/lightda-core

## Functionality tests

 Ensemble Kalman filter implementation based on PDAF (Nerger 2005)

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 Basic functionality tested with a 1-D advection solver



### **Parallelization tests RESEARCH**

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Obs count	1,000
Ensemble size	15
State vector size	120,000,000
Batch size	10,000
Batch assignment	Random

### **Parallelization tests RESEARCH**

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Obs count	1,000
Ensemble size	15
State vector size	120,000,000
Batch size	10,000
Batch assignment	Uniform



- SAMI3 (SAMI3 is Another Model of the lonosphere) is an NRL-developed physics-based ionosphere model
- Solves time-dependent state equations for ion densities, velocities, and temperatures



traveling ionospheric disturbance (TID)

## Vertical TEC observations

 Madrigal world-wide GNSS database provides vertical total electron content (VTEC)

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 About 800-1000 observations within the SAMI3 domain every 5 minutes



Madrigal VTEC observations from January 7, 2015

## **Forward operator implementation**



- Predicting VTEC from a SAMI3 state requires computing a line integral through a non-uniform geomagnetic grid
- Done efficiently by performing a bisection search along each field line

## Test with synthetic observations



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- Synthetic observations created from a separate run of SAMI3
- Ensemble generated from random dates, F10.7, and Ap
- Ensemble standard deviation closely follows RMSE
- Model bias reduced to low level

## Test with real observations



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- Observations
- Ensemble generated using same method as before
- RMSE grows over time
- Model bias grows rapidly after assimilation



- Parallel performance of filter depends critically on distribution of the model state across MPI processes
  - Hypothesized to be driven by load balancing
- LightDA successfully assimilates synthetic VTEC observations into SAMI3, but fails to reduce error when assimilating real observations