# Assimilation of total electron content in a SAMI3 simulation

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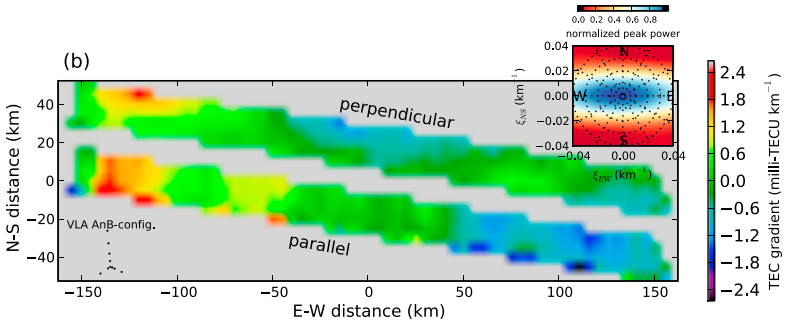
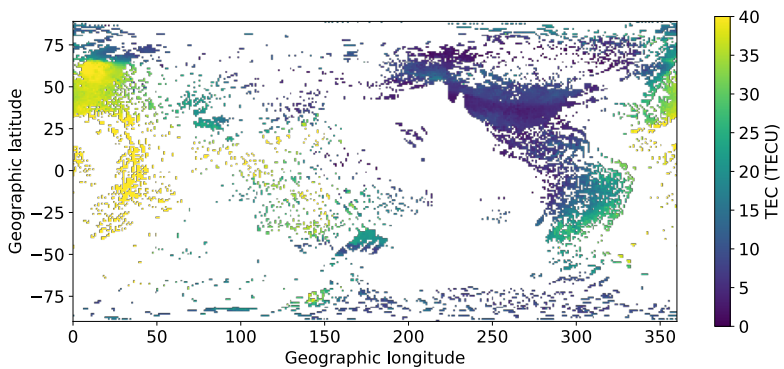
# Overview

- TEC datasets
- SAMI3 model description
- Data assimilation system description
- Forward operator implementation
- Data assimilation performance

# TEC datasets



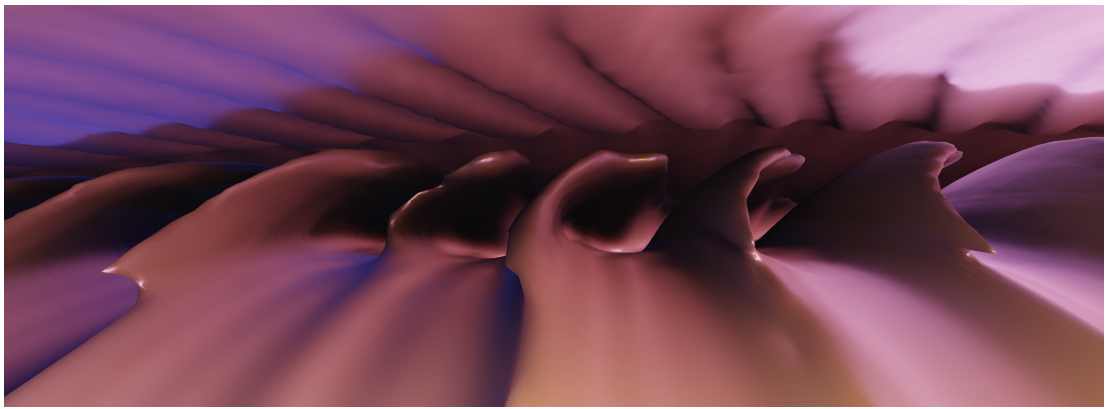

VLITE (Very Large Array Low-Band Ionospheric and Transient Experiment) drift-scan image (Helmboldt+2014)




GNSS TEC from Madrigal database

| | **VLITE** | **Madrigal GNSS** |
|---|---|---|
| | Helmboldt+2019 | Vierinen+2016 |
| Basis | 320-384 MHz radio obs. | Ground-based GNSS receivers |
| Coverage | ~100 km$^2$ | Global |
| Precision | ~0.01 TECU (diff.) | ~1-3 TECU (abs.) |

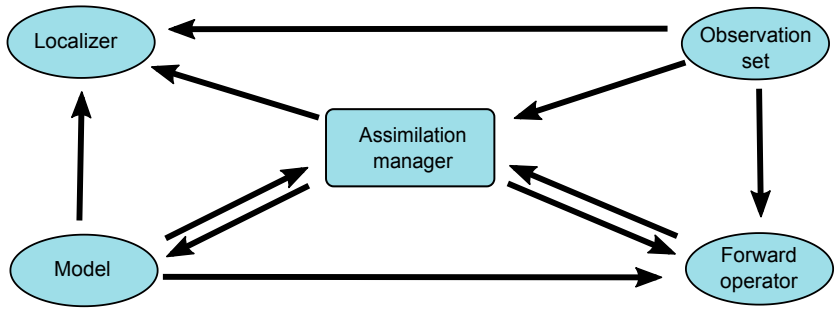
# SAMI3 ionosphere model



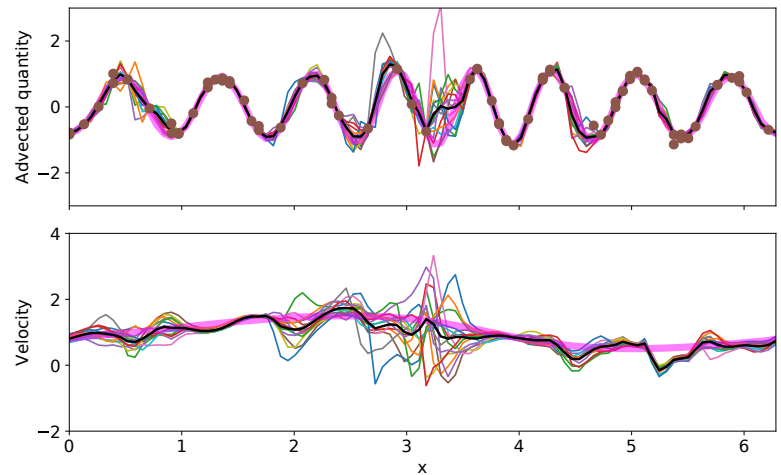
Isosurfaces of electron density in a SAMI3 simulation of a TID

- Developed at NRL by Huba+2000, Huba+Krall 2013
- Demonstrated to simulate TIDs arising from Perkins instability (Duly+2014)

# LightDA data assimilation system




LightDA architecture overview

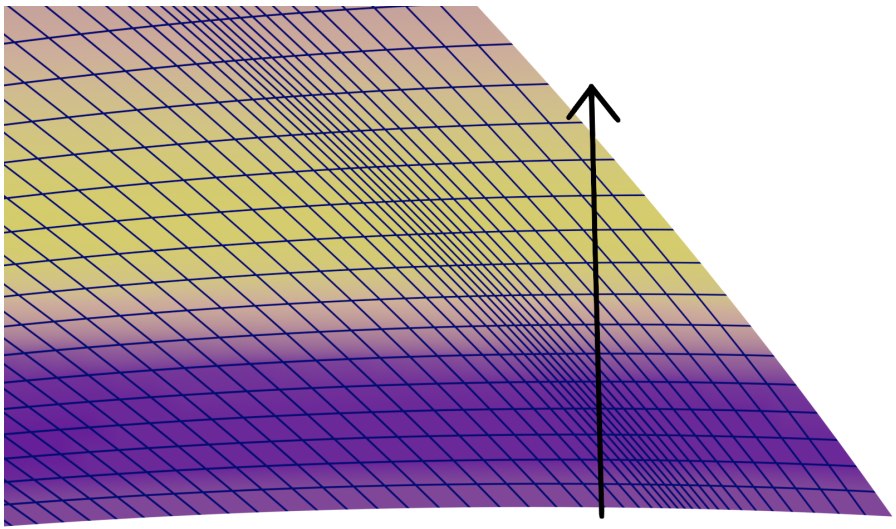



Output from a test using a 1-D advection solver

- Modular architecture; components can be added at runtime using shared libraries
- Parallelized using MPI
- Ensemble Kalman filter implementation based on PDAF (Nerger 2005)
- https://github.com/LightDA-assim/lightda-core

- Tested with several versions of GNU and Intel compilers

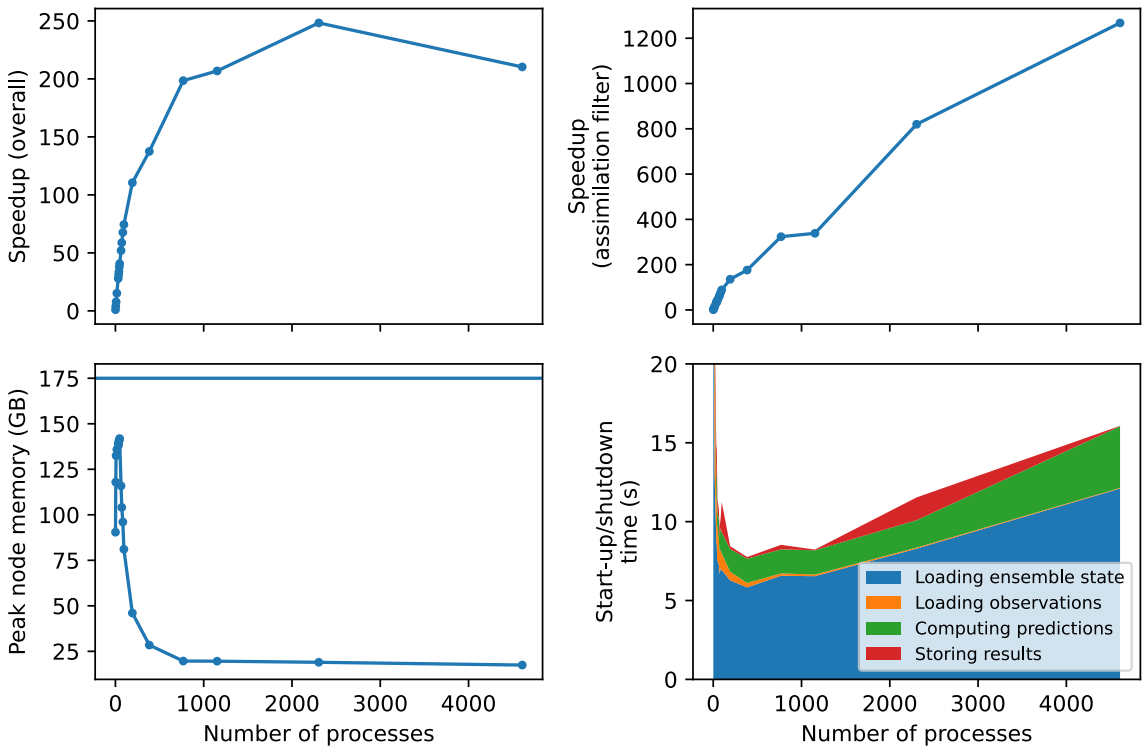
# LightDA+SAMI3 integration



TEC is computed using a line integral through the SAMI3 grid

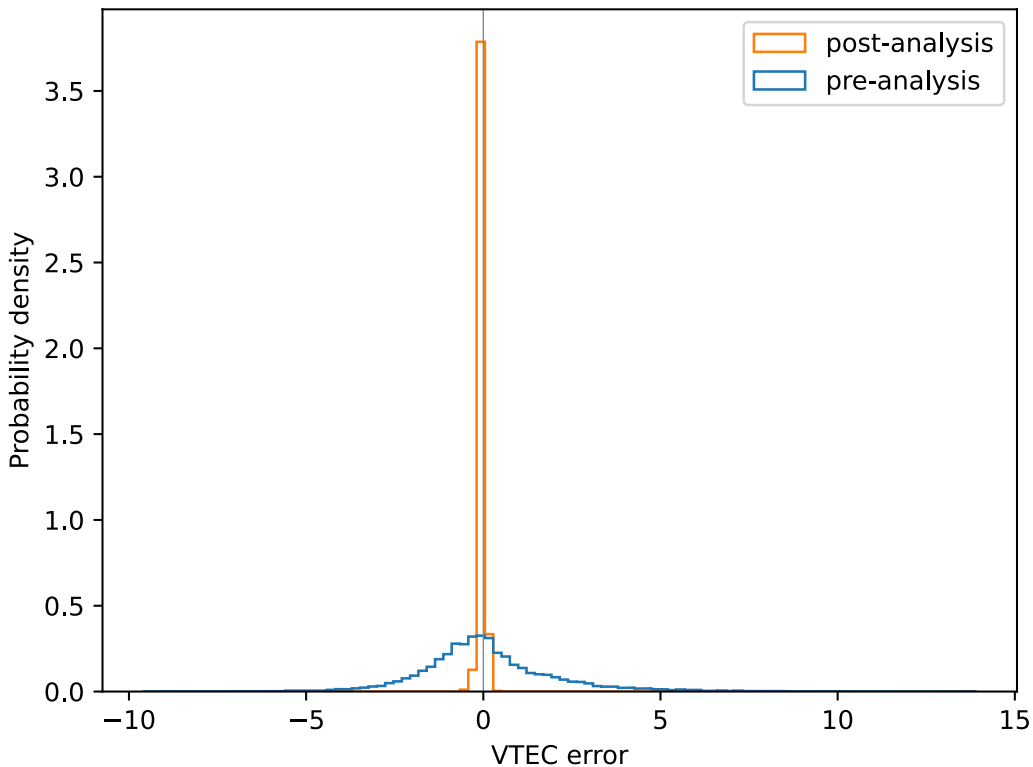
- Forward operator (computes TEC):
  - Integrates SAMI3 densities
  - The integral is computed efficiently using bisection searches, taking advantage of SAMI3's dipole-aligned grid
- Other components
  - Model interface (Read/write SAMI3 state)
  - Observation sets for TEC data
  - Localizer to compute localization weights

# LightDA+SAMI3 scaling performance



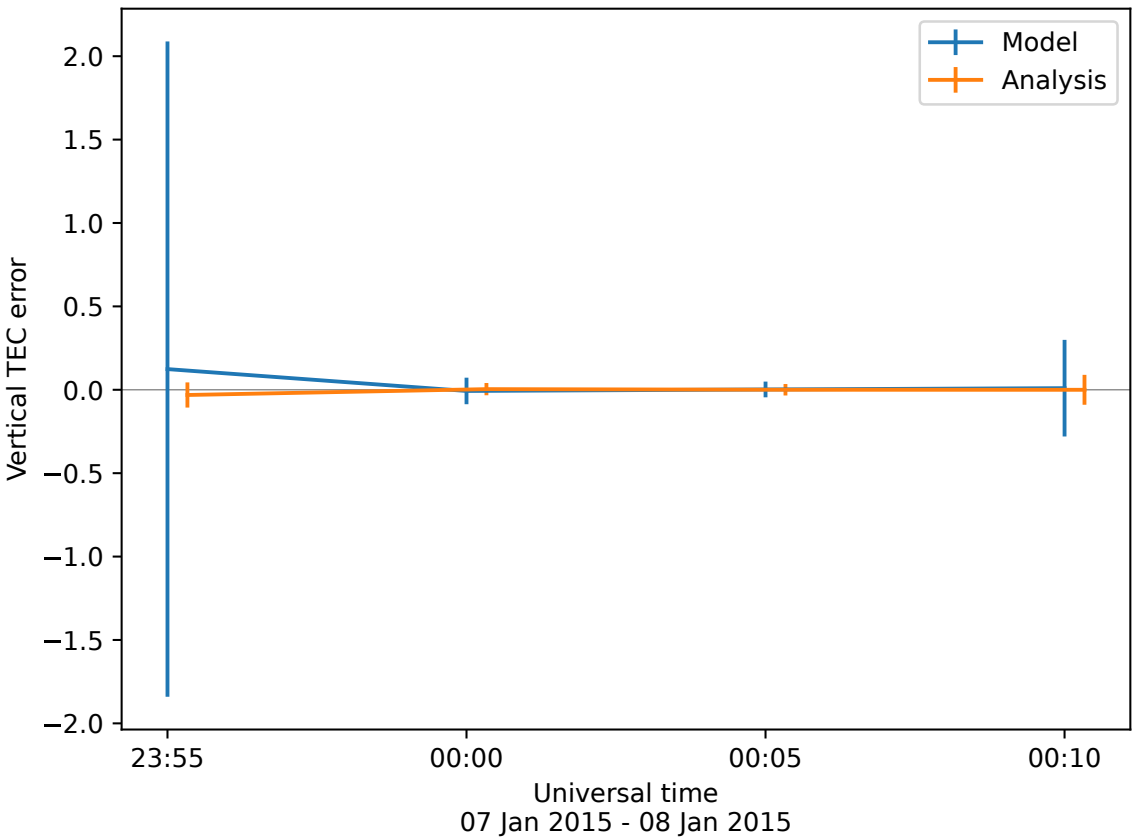

- 889 observations assimilated
- State size is ~2.2e8 elements
- Total time on 96 processes (2 nodes) is **53.8 s**
- Scalability be improved by further parallelizing model I/O or increasing number of observations

# Assimilation of synthetic observations




- Synthetic observations generated from a SAMI3 simulation
- 15-member SAMI3 ensemble with randomly perturbed initial states
- Assimilation converges the ensemble to a narrow distribution around the synthetic observations

# Assimilation of synthetic observations




- Convergence continues after assimilating additional data at later times

# Summary

- Developing a system for parallel assimilation of TEC into SAMI3
- Demonstrated for synthetic observations

**Next steps:**

- Demonstrate with real observations
- Improve forward operator to work with slant TEC
- Investigate effects of F10.7 and neutral wind on the system