

# TRIPL-DA: A New Opportunity at CCMC

Roy Calfas, T. Gaussiran, M. Pierce, D. Rainwater, W. Shutt



The University of Texas at Austin  
Applied Research Laboratories  
Austin, TX 78758



Jan 17, 2012

# Introduction

## Goal

Specify the ionosphere completely to support iono. science and space weather:

- Structure (bubbles, sporadic E, profile shapes, auroral ovals, ...)
- Dynamics (TIDs, connection with AGWs, ...)
- Response to solar input
- Response to magnetic storms
- Daily or shorter variations (weather)
- Connections to climate science

## Method

3DVAR data assimilation:

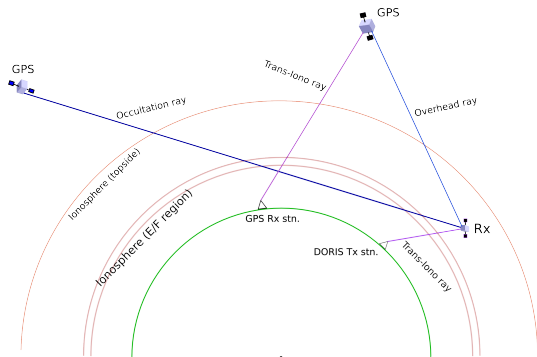
- Prior based on realistic physics (climo model, etc.)
- Arbitrary data sources possible
- Can get time evolution with Kalman filter
- True 3D specification
- Established technique in atmospheric weather modelling

▶ TRIPL-DA is ARL:UT's updated 3DVAR tool.

- ▶ Specifies only  $n_e$  (not other chemical species)
- ▶ Works in  $\log(n_e)$  space
  - Guarantees positive-definite specification
  - Easy to ingest multiple data types
- ▶ Ingests your favorite background model prior
- ▶ Global or regional grid
- ▶ User can specify arbitrary grid
  - Lat/Lon is independent of Alt, may be regular or irregular
  - Alt is specified explicitly
  - For every Alt layer the Lat/Lon grid is the same
- ▶ Grid can be as dense as you have CPUs to handle
  - $4^\circ \times 4^\circ$  global grid is routine
  - $\frac{1}{2}^\circ \times \frac{1}{2}^\circ$  regional grid is not too stressful
  - Vertical layers to geosynchronous altitude
  - Representativeness errors are smaller from finer resolution
- ▶ Sophisticated error and correlation handling
  - Ingested correlations can vary seasonally, daily, etc.
  - Instrument errors as specified by data provider
  - Representativeness errors calculated from grid and instrument collection details

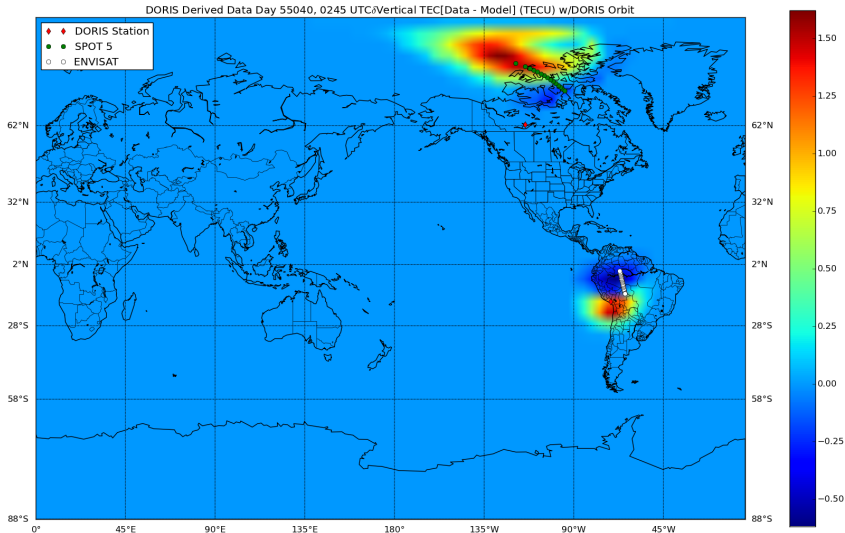
# Data Types Ingested

- **Electron density**
  - In-situ measurements
  - Ionosonde data ( $n_e(F_2), h(F_2)$ )
- **Ray TEC**
  - Ground-based GPS/GNSS rays
  - GPS/GNSS occultations
  - LEO beacons (C/NOFS, RadCal, Transit (dead), ...)
  - LEO DORIS rays - **NEW!** (cf. GEOScan proposal)
  - GPS/GNSS over-the-satellite rays



# Data Ingestion Example: DORIS LEO Data Results

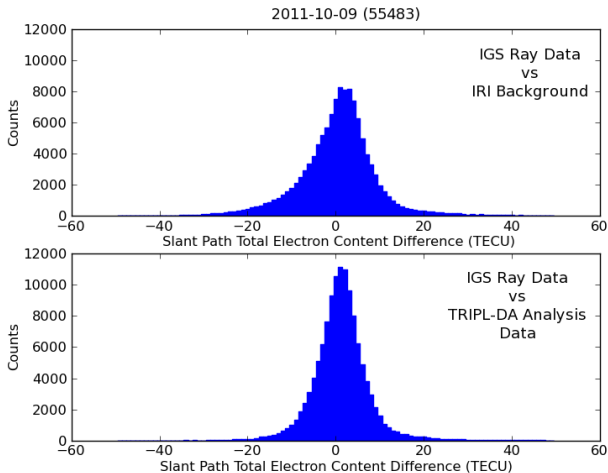
Example: DORIS data assimilated by TRIPL-DA:  
background model considerably modified



# Data Ingestion Example: GPS IGS Data Results

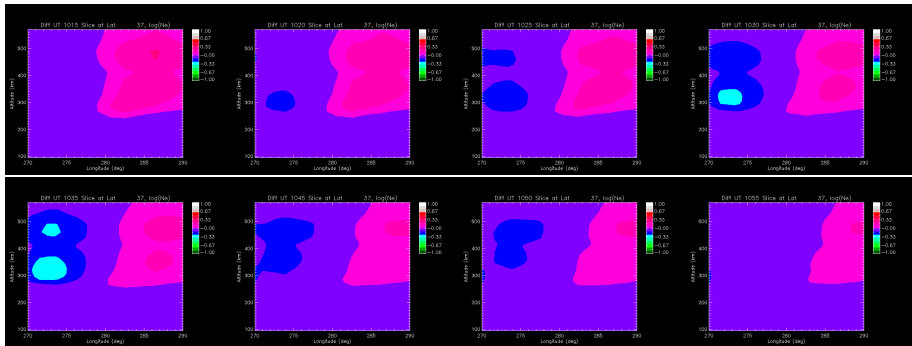
Trans-ionospheric ray data can markedly improve the bulk ionosphere specification.

- Deviations after ingestion are more Gaussian.
- Skew and shape are significantly corrected, leaving only Gaussian uncertainties from instrument & representativeness errors.



# Ionosphere Dynamics - Example 1

TID observed over Wallops Island, 09 Oct 2006 – slice at 37N (5 min timesteps)

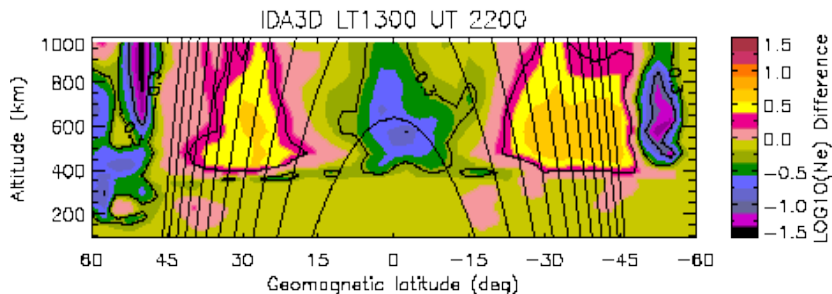


→ TRIPL-DA can capture small-scale dynamics on short time scales.

# Ionosphere Dynamics - Example 2

## Equatorial Fountain observation (Halloween Storm 2003)

→ TRIPL-DA can capture small-scale dynamics on short time scales.





We have a small, internally funded, grant to install and test TRIPL-DA at the CCMC

- Research team has logins and some testing has been done
- Contingent on funding:
  - Compile TRIPL-DA
  - Run test suite and compare results
  - Coordinate with CCMC staff to make TRIPL-DA available for ionospheric runs

We continue to research a number of ionospheric topics at ARL:UT

- Improving the background model ingested into TRIPL-DA
- Ionospheric data errors
  - Instrument thermal noise
  - Ionospheric spatial correlation using GNSS data

# Background Models Ingested

TRIPL-DA is very successful at generating accurate TEC maps.  
But let's consider the background models used more carefully...

- **USU GAIM-GM**

- Very coarse, so is interpolated to finer grid ( $\sim 4\frac{2}{3}^{\circ} \times 15^{\circ}$  @ equator as currently available)
- Limited in altitude (1400 km);
- Limited in latitude (simply IFM poleward of  $\pm 67\frac{2}{3}^{\circ}$ )

- **RIB-G**

- Frequently overestimates topside (by quite a bit)
- Not updated in many years

- **IRI**

- Under current development by COSPAR/URSI
- Limited in altitude (2000 km)
- Topside can be corrected

Model	Min. Alt. [km]	Max. Alt. [km]	Grid Size	Variances Present
GAIM	90	1400	$6^{\circ} \times 15^{\circ}$	yes; IFM poleward of $66\frac{2}{3}^{\circ}$
RIB-G	90	40000	user-specified	no
IRI	90	2000	user-specified	yes

► **Compelling need for a new ensemble model for completeness!**

# Ionospheric Data Errors

## Starting Point:

Most ionospheric data sources have poorly-characterized errors.

→ This will come as a surprise to some users.

Error sources include:

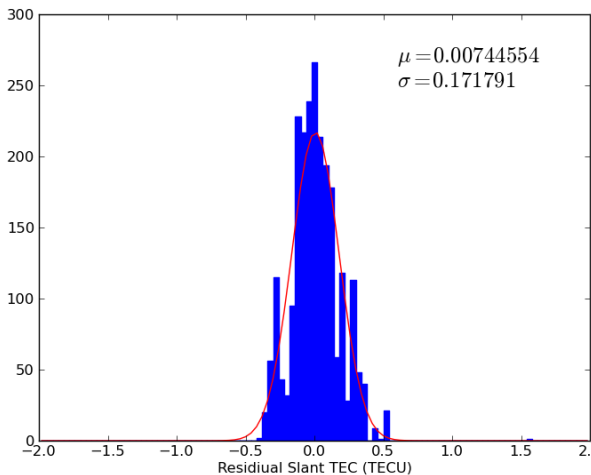
- Instrument (multiple sources; unique for each instrument type)
- Registration – how accurately an observation is stamped in space & time
- Representativeness – how well observational data matches the intended measurement
  - spatial coverage/extent
  - temporal coverage/extent
  - spatial/temporal mixing

Many (not all) users consider only instrument errors!

▶ Our current study uncovers misunderstood GPS instrument errors.

# GPS Instrument Errors: Thermal Noise

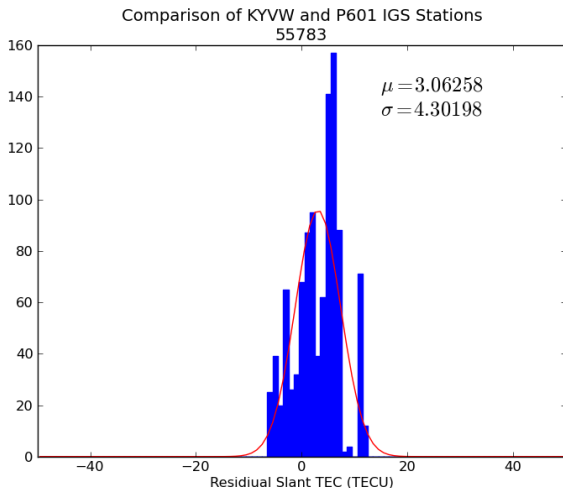
Method: 2 receivers, 1 antenna (common), relative diff. between two satellites, then relative diff. between two receivers: measures thermal noise



► Surprising 1-sigma error of 0.17 TECU

# GPS Instrument Error: Spatial Difference

Method: Residual slant TEC (relative rays) between two stations 10 km apart.



► This is MUCH larger than conventional wisdom.

# Summary

- ▶ TRIPL-DA is a significant evolution in ionosphere 3DVAR tools
  - New data types greatly broaden capability
  - Fine resolution enables study of detailed dynamics
  - Captures magnetosphere as well
  - Ensemble background model coming soon
- ▶ Capability to study detailed ionospheric dynamics demonstrated
  - TIDs observed in action
  - Equatorial fountain imaged temporally
- ▶ Ionospheric science is data-poor – need more sources!
  - Note that many potential data sources aren't good enough (too-large errors)
  - Current data sources are mostly regional and exclude oceans
  - ARL:UT - JHU/APL proposal to put DORIS Rx on Iridium-NEXT
- ▶ Ongoing study of iono. data source errors
  - GPS thermal noise is much larger than assumed
  - GPS ground data representativeness errors way underestimated
  - Future work will examine representativeness in more detail

# Contact Information

Thomas Gaussiran II, Director  
Space and Geophysics Laboratory  
[gauss@arlut.utexas.edu](mailto:gauss@arlut.utexas.edu)

Roy Calfas, Research Associate  
Space and Geophysics Laboratory  
[calfas@arlut.utexas.edu](mailto:calfas@arlut.utexas.edu)

<http://sgl.arlut.utexas.edu>