TRIPL-DA at the CCMC

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Introduction

Goal

Support iono. science and space weather at the CCMC:

- Response to solar input
- Response to magnetic storms
- Daily or shorter variations (weather)
- Connections to climate science

Method

3DVAR data assimilation:

- TRIPL-DA is *Data assimilation* not a model, no model constraints
- 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.

TRIPL-DA

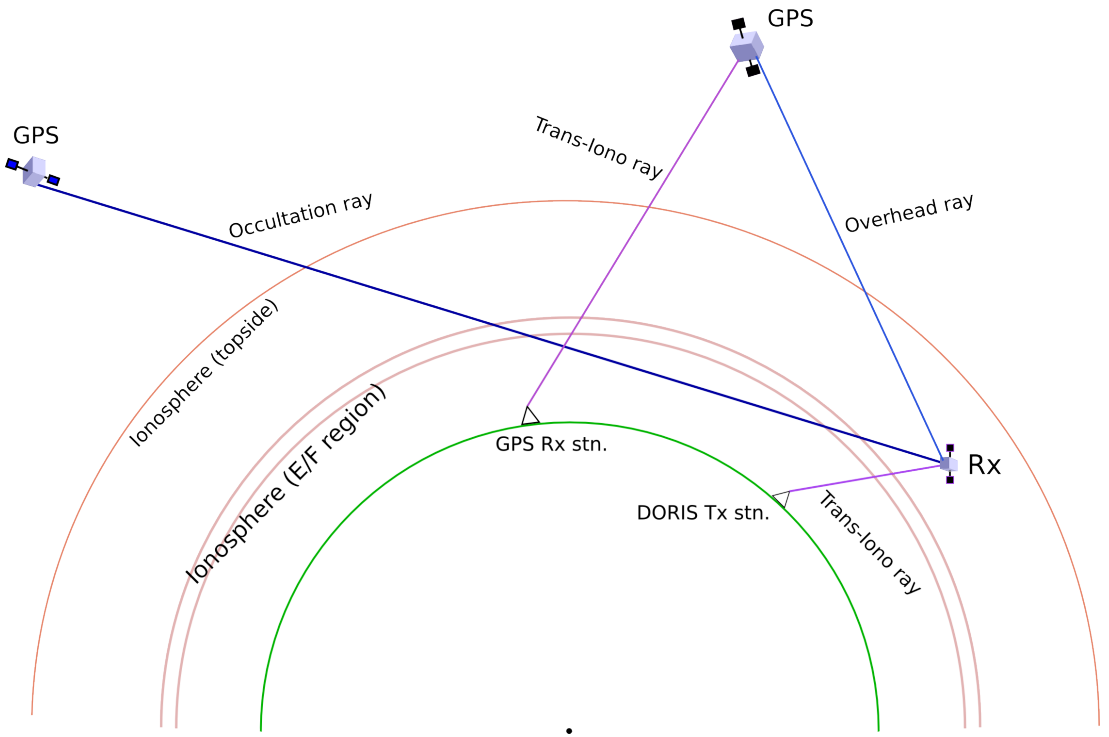
- Specifies only n_e (not other chemical species)
- Works in $\log(n_e)$ space
  - Guarantees positive-definite specification
  - Easy to ingest multiple data types
- Ingests a prior (background model)
- Global or regional grid
- User can specify arbitrary grid
  - Lat/Lon is independent of Alt, may 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

  $\rightarrow$ 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

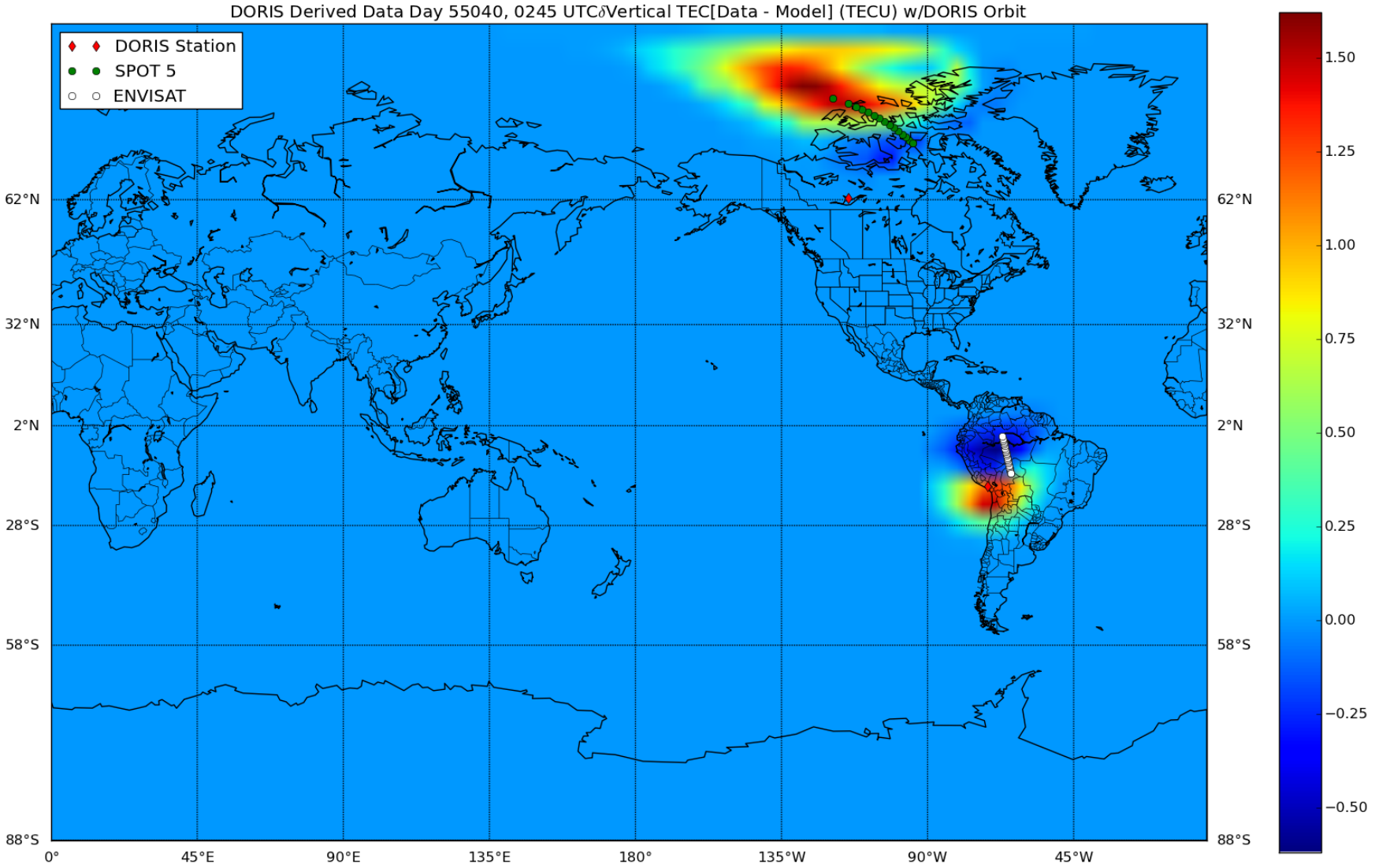
- Electron density
  - → In-situ measurements
  - → Ionosonde data ($n_e(F_2)$,$h(F_2)$)

- Ray TEC
  - → Ground-based GPS/GNSS rays
  - → GPS/GNSS occultations
  - → LEO beacons (C/NOFS, RadCal, Transit (dead), ...)
  - → LEO DORIS rays (ENVISAT, etc)
  - → GPS/GNSS over-the-satellite rays



Data Ingestion Example: DORIS LEO Data Results

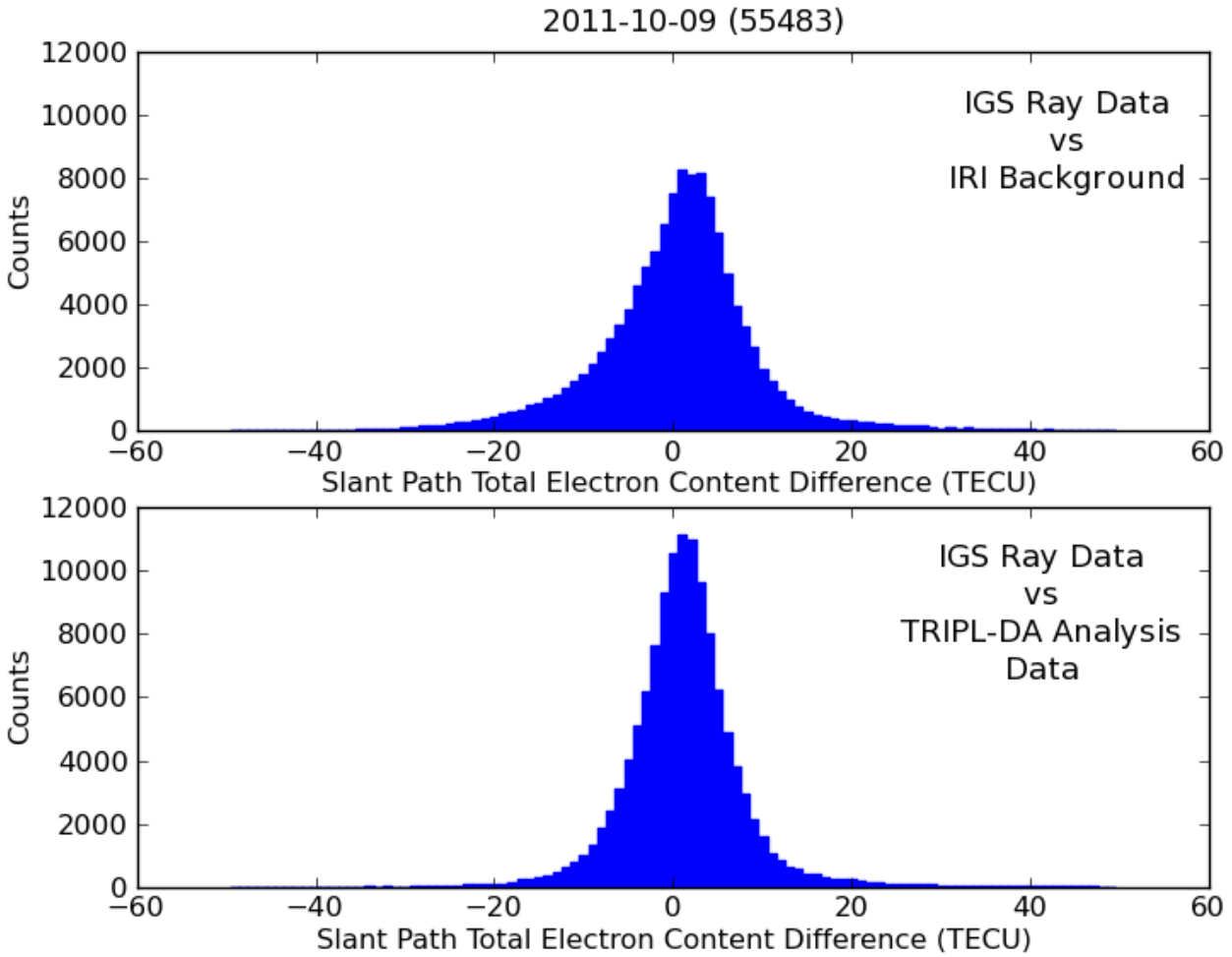
Example: DORIS data assimilated by TRIPL-DA:
background model considerably modified



Data Ingestion Example: GPS IGS Data Results

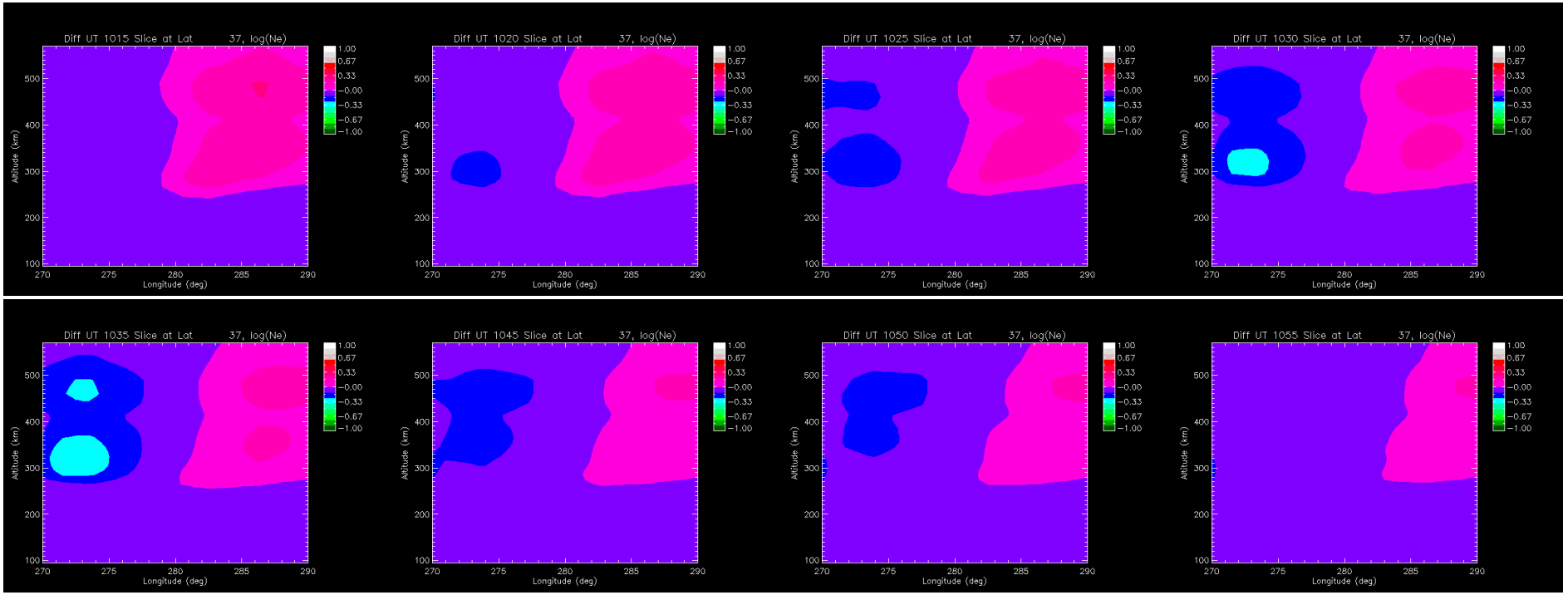
Trans-ionospheric ray data can markedly improve the bulk ionosphere specification.

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



Ionosphere Dynamics - Example

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



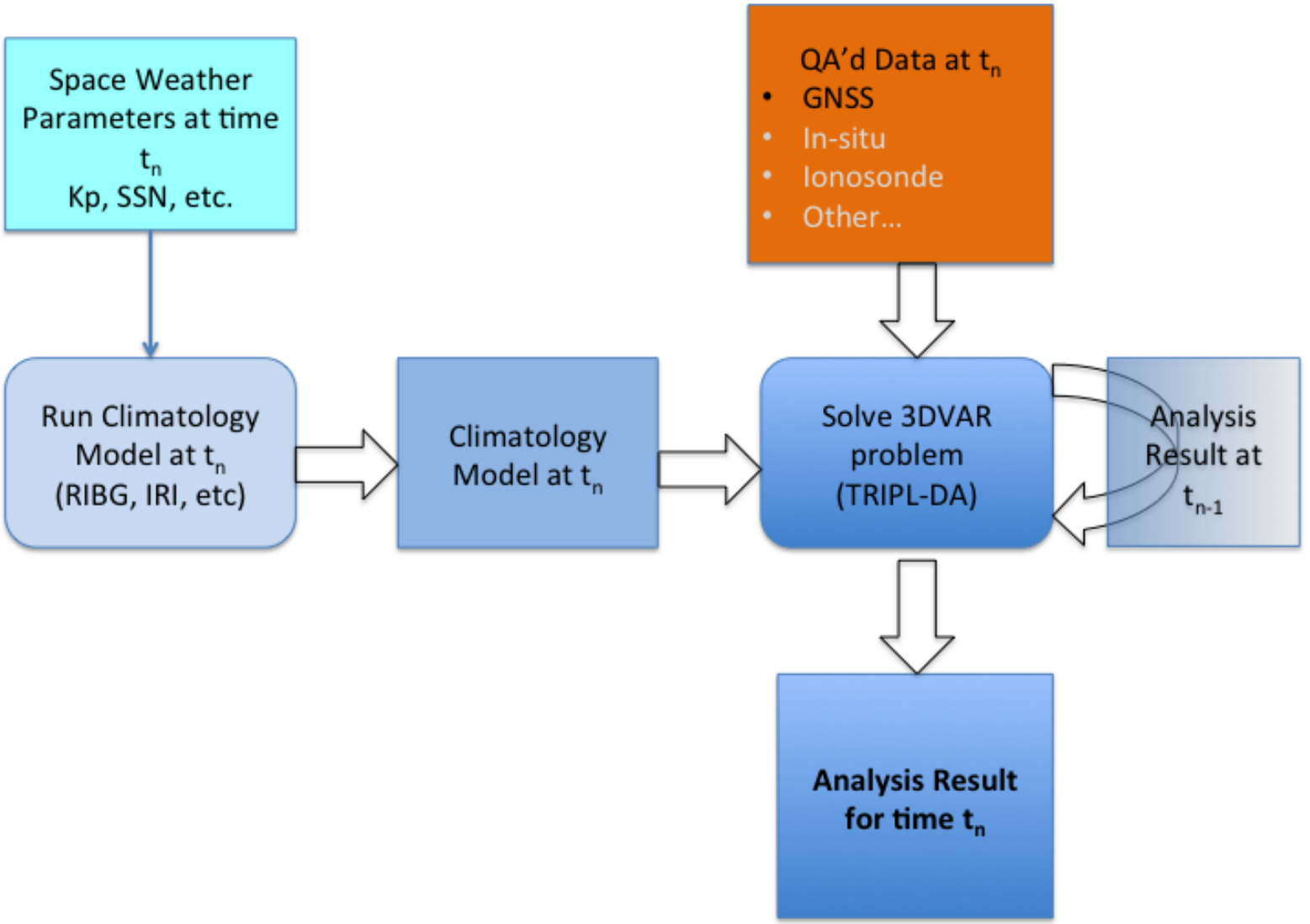
→ TRIPL-DA can capture small-scale dynamics on short time scales.

CCMC Implementation

- Emphasis on *data* not the model(s)
- Operate in Near Real Time
- Operate continuously
- First implementation based on GNSS data only
  - IGS rapid-update stations
  - File arrival times at GSFC impose a 24-38 min latency
  - Cumulative effect is an output valid for HHMM UTC at HHMM +1H UTC
- Upgrades to real time and other data sources as called for

CCMC Implementation

→ Simplified data flow



CCMC Implementation

- TRIPL-DA requirements:
  - Only tested on RHEL (v4, 5, or 6) x86_64
  - Requires Fortran 2003 compliant compiler (only Intel compiler suite has been tested)
  - Currently supports MPI and Shared-Memory schemes
- Output is netCDF
  - Compatible with v3 and v4 libraries
  - Contains grid parameters (Altitudes, Latitudes, Longitudes)
  - Includes the prior (IRI, RIBG, etc)
  - Contains the 3DVAR analysis data (N_e)
- Simple python (v2.7) analysis tools
  - Works on any *nix with python
  - Requires matplotlib, basemap, netCDF4