CDAAC Ionospheric Products

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COSMIC Ionospheric Measurements

GPS receiver: \{ Total Electron Content (TEC) to all GPS satellites in view \\
Ionospheric radio occultations (profiles) & scintillations \}

Tiny Ionospheric Photometer (TIP): Ultra-violet emission from ionosphere

Tri-Band Beacon (TBB): TEC & scintillations on satellite-to-ground links
Total Electron Content measurements:
- High-resolution (1 Hz) TEC to all GPS satellites in view at all times
- Can track up to 12 GPS satellites at the same time (9 aft + 4 fore)
- Useful for global ionospheric tomography and data assimilation
COSMIC Ionospheric Measurements

Ionospheric GPS occultation measurements:

- High-resolution (1 Hz) occultation TEC below orbit altitude
- Ionospheric electron density profiles from orbit altitude and down
- Ionospheric scintillations using the two limb antennas (50 Hz)
Tiny Ionospheric Photometer measurements:

- Emission (1356 Å) due to recombination of oxygen ions and electrons
- Nadir intensity along sub-satellite track – proportional to $\int N_e^2 dz$
- High quality data on night-side – uncertainty about day-side quality
Tri-Band Beacon measurements:

- Radio signals transmitted from COSMIC at 150, 400, and 1067 MHz
- TEC between the COSMIC satellites and chains of ground receivers
- Amplitude and phase scintillations on the satellite-to-ground links
Ionospheric Data from CHAMP, Oct 29 2003

![Graph showing ionospheric data from CHAMP on October 29, 2003. The graphs display variations in electron density and altitude over time, with markers indicating specific times such as 00:39 UT, 00:45 UT, 01:05 UT, and so on.]
Method of Deriving Orbit Electron Density

- Measurements available before occultation (dashed lines)

\[ \Delta \text{TEC} = \text{solid minus dashed} \]

\[ \Delta \text{TEC}(r) \approx 2\sqrt{2r_{\text{orb}}} N_e(r_{\text{orb}}) \sqrt{r_{\text{orb}} - r} \]

- Fit a straight line to \((\Delta \text{TEC})^2\) for the uppermost few km
Occultation Versus in-situ Electron Density

RMS = $1.3 \cdot 10^5$ cm$^{-3}$
Correlation = 0.95
Example of CHAMP - GPS data arc (PRN 03) on Oct 29, 2003.

- P2 - P1 (code)
- L1 - L2 (phase)
Example of CHAMP - GPS data arc (PRN 03) on Oct 29, 2003.

-> Cycle-slip detection and correction
Example of CHAMP - GPS data arc (PRN 03) on Oct 29, 2003.

\[ \rightarrow \text{Cycle-slip detection and correction} \]

- \( P2 - P1 \) (code)
- \( L1 - L2 \) (phase)
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- Cycle-slip detection and correction
- Quality Control
- Adjusting phases to codes
- Correcting for GPS Differential Code Bias
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- Correcting for CHAMP Differential Code Bias
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- → Cycle-slip detection and correction
- → Quality Control
- → Adjusting phases to codes
- → Correcting for GPS Differential Code Bias
- → Correcting for CHAMP Differential Code Bias
- → Converting to Total Electron Content
LEO Differential Code Bias estimation

- Weighted average of paired observations
- Model independent
- Assumption:
  \[ \text{TEC}_A \sin \theta_A = \text{TEC}_B \sin \theta_B \]
- Restrictions:
  Both \( \theta_A \) and \( \theta_B > 45^\circ \)
  Vertical TEC < 3 TECU

\[
\text{DCB}_{\text{leo}} = \frac{\sum (\sin \theta_B - \sin \theta_A)(\hat{\text{TEC}}_A \sin \theta_A - \hat{\text{TEC}}_B \sin \theta_B)}{\sum (\sin \theta_B - \sin \theta_A)^2}
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\]
Based on simple assumptions (e.g., azimuthal symmetry above LEO)

Single day estimates based on 24 hr average – next day prediction (for near real-time processing) based on smoothing over 50 days

For COSMIC there will be $6 \times 2$ DCBs to solve for
CHAMP Ionospheric Scintillation Map

S4, CHAMP, 2003.302–303

[Graph showing data with axes for Sun-fixed Latitude, Local Time, and a color scale for S4 Scintillation Index]
- Code to get TIP pointing location from attitude is completed
- Awaiting code from NRL for converting raw counts to radiances
Status and Plans for COSMIC

Total Electron Content measurements

**Plans:** Cycle-slip detection and correction, Quality control, and Differential Code Bias calibration

**Status:** Prototype working for CHAMP data – not yet integrated in CDAAC processing system

Ionospheric GPS occultation measurements

**Plans:** Reducing effects from horizontal gradients in profile retrievals using a model (e.g., GAIM)

**Status:** Profiles derived via Abel inversion ● Scintillation maps not yet integrated in CDAAC system

Tiny Ionospheric Photometer measurements

**Plans:** Providing radiances derived from raw data (counts) as well as pointing direction ● Combining TIP data and GPS occultation data for “in-plane” occultations (Naval Research Lab)

**Status:** TIP pointing location code is in place ● Anticipate to get radiance code from NRL soon

Tri-Band Beacon measurements

**Plans:** Plans regarding processing of TBB data are not in place ● One TBB receiver may be installed on the top of the roof at UCAR – CDAAC will process data from this one

**Status:** Ongoing work to install receiver chains in various countries all over the world (NRL)