# GNSS Data and the Real-Time International Reference Ionosphere

# IRI-RT


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*http://IRI.gsfc.nasa.gov*

# International Reference Ionosphere

- **IRI** is an empirical model based on a large volume of reliable data from ground and space observations.
- **IRI** describes monthly averages of electron and ion densities, temperatures, and many additional parameters
- **IRI** is an international project of COSPAR and URSI and is in the process of becoming an ISO standard
- **IRI** is similar to standards for other parts of the space environment: CIRA/MSIS, IGRF, etc,

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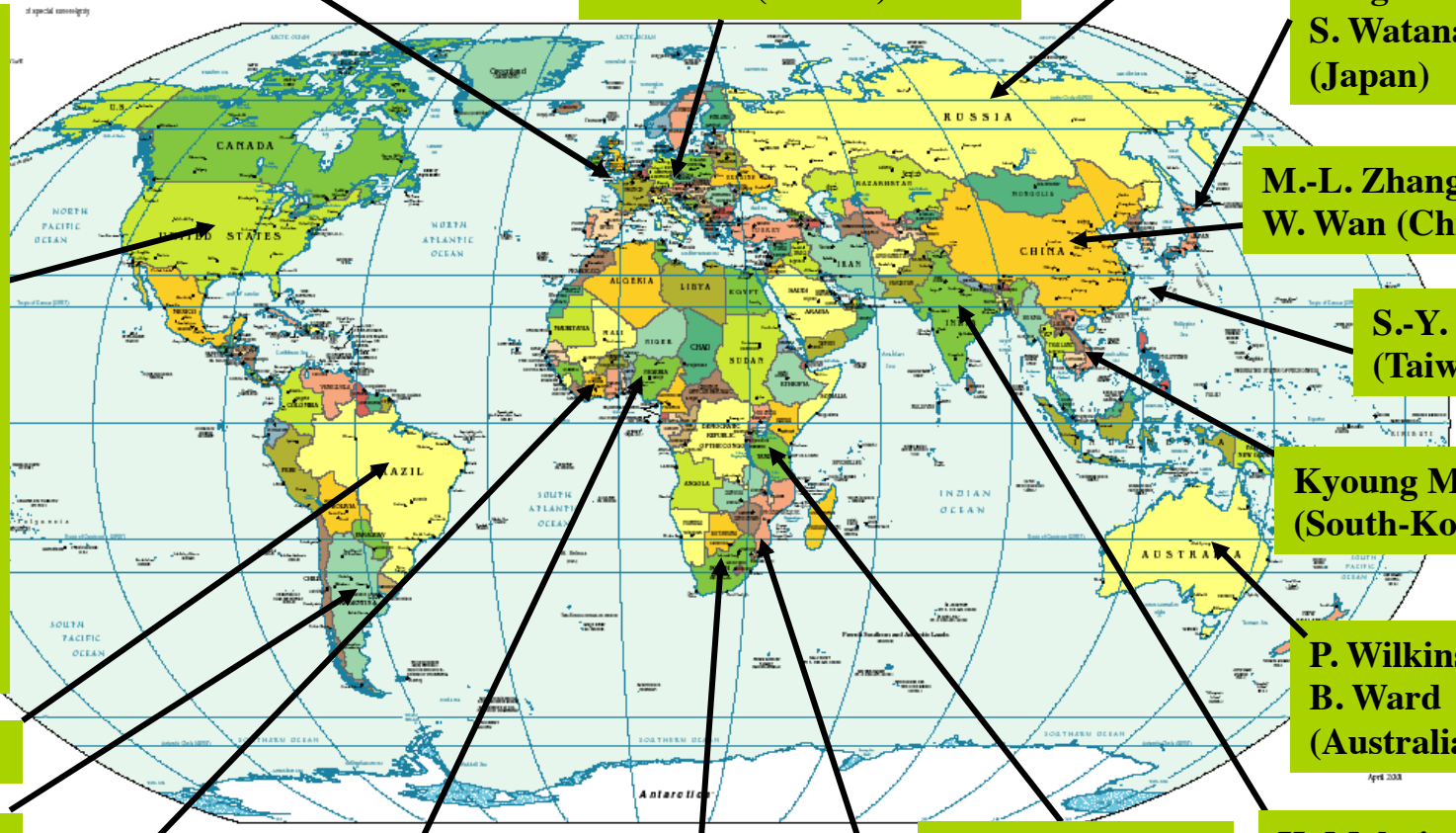


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(Uganda)

K. Mahajan
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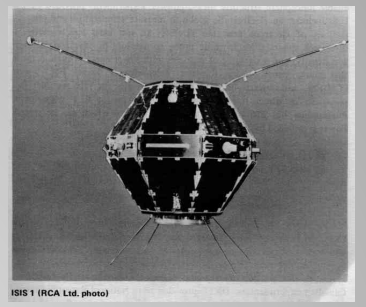
# IRI Working Group Members

## Data Sources

| *Instrument* | *Platform* | *Parameter* | *Comments* |
|---|---|---|---|
| Ionosondes | Worldwide Network | $N_e$ from E to F2 | Fifties to now |
| Incoherent Scatter Radar | Jicamarca, Arecibo, St. Santin, Millstone H., Malvern, | $N_e$ whole profile incl. E-Valley $T_e$, $T_i$ $N_i$, $v_i$ | Few radars, Many parameters |
| Topside Sounder | Alouette 1, 2 ISIS 1, 2 | $N_e$ topside profile | Newer data from Ohzora, ISS-b, IK-19 |
| Insitu | AE-C,-D,-E Aeros-A,-B IK-24, DE-2 | $N_e$, $T_e$, $T_i$, $N_i$, $v_i$ | many more: DMSP, TIMED |
| Rocket | Rocket Data Compilations | $N_e$ D-region, Ion comp. | sparse data set |

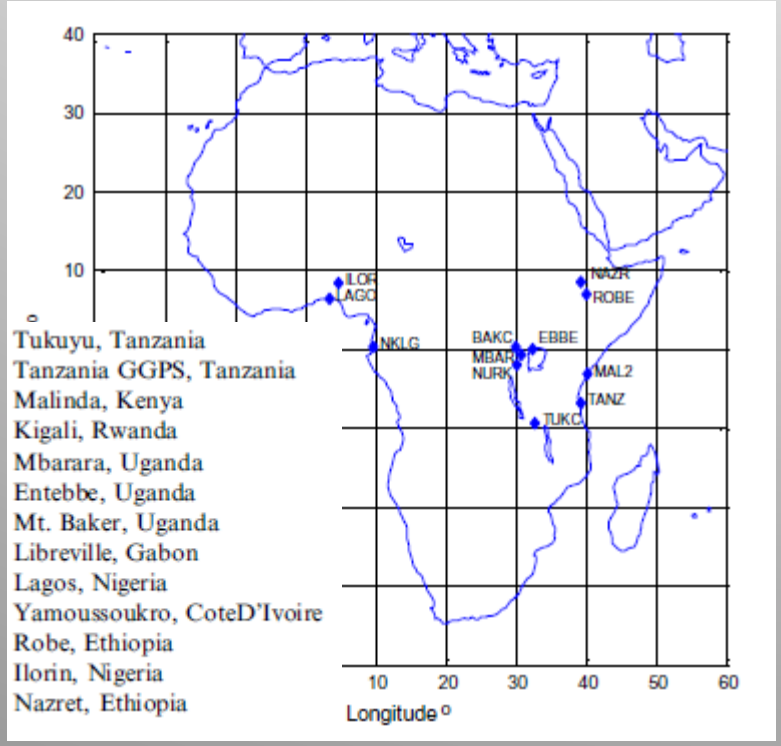



**Critical issue: Discrepancies between simultaneous measurements**

# IRI Workshop 2011

## Space Weather Center
## Hermanus, South Africa
## October 10-14, 2011

sansa
SOUTH AFRICAN NATIONAL SPACE AGENCY




**80 Participants from**
**20 countries, including**
**9 African countries**

**-Topside ionosphere**
**-Strom-time and real-time IRI**
**-F peak height and density,**
**-IRI in the African sector**
**-TEC and related parameters**
**-Inputs for IRI**
**-Lower ionosphere**
**-IRI Applications**
**-The ionosphere during the recent solar minimum**

New stations installed with help from the SCINDA (Scintillation Network Decision Aid) and Low-latitude Ionospheric Sensor Network (LISN) projects.

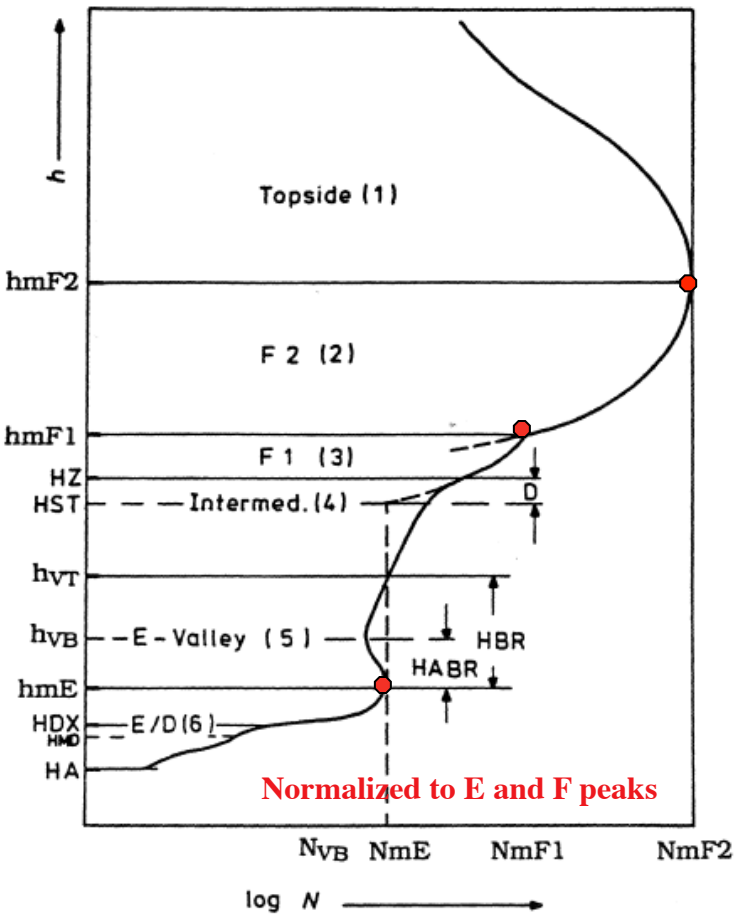
# Build-up of IRI electron density profile

## Mathematical functions:

**Global Variations:**
Spherical harmonics,
Interpolation
between regions

**Time Variations:**
Fourier,
Step-functions

**Height Variations:**
Epstein functions
Chapman function




**Global models for**
**foF2/NmF2 foF1/NmF1, foE/NmE, foD/NmD**
**[$N/m^3$=1.24E10 $(f/MHz)^2$],**
**hmF2/M(3000)F2, hmF1 , hmE, hmD**

http://IRI.gsfc.nasa.gov

# IRI Usage Statistics

## Percentage of papers using IRI

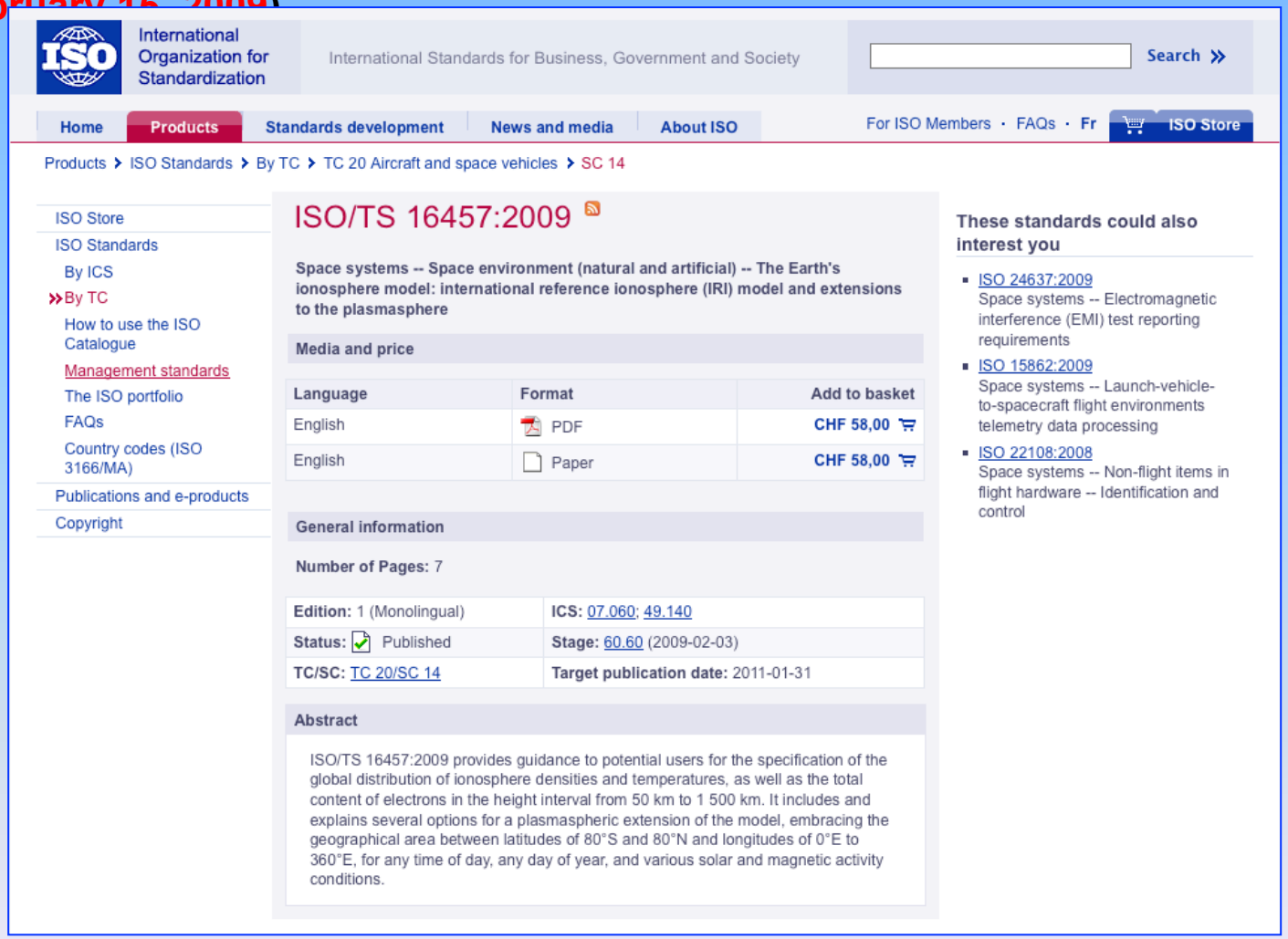
| | JGR | GRL | SW | RS |
|---|---|---|---|---|
| 2009 | 5.0% | 3.6% | 0.0% | 10.5% |
| 2010 | 5.6% | 4.7% | 5.6% | 11.8% |
| 2011 | 7.1% | 1.6% | 8.1% | 14.2% |

SW = Space Weather journal RS = Radio Science

| | |
|---|---|
| IRI ftp site downloads in 2011 | 4,015/month |
| IRIweb online accesses in 2011 | 29,384/month |

*http://IRI.gsfc.nasa.gov*

**ISO/TS 16457: 2009 ISO/TC 20/SC 14 Space systems -- Space environment (natural and artificial) -- The Earth's ionosphere model: international reference ionosphere (IRI) model and extensions to the plasmasphere (published February 15, 2009)**



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## ISO/TS 16457:2009

**Space systems -- Space environment (natural and artificial) -- The Earth's ionosphere model: international reference ionosphere (IRI) model and extensions to the plasmasphere**

**Media and price**

| Language | Format | Add to basket |
|---|---|---|
| English | PDF | CHF 58,00 |
| English | Paper | CHF 58,00 |

**General information**

**Number of Pages:** 7

| | |
|---|---|
| **Edition:** 1 (Monolingual) | **ICS:** 07.060; 49.140 |
| **Status:** Published | **Stage:** 60.60 (2009-02-03) |
| **TC/SC:** TC 20/SC 14 | **Target publication date:** 2011-01-31 |

**Abstract**

ISO/TS 16457:2009 provides guidance to potential users for the specification of the global distribution of ionosphere densities and temperatures, as well as the total content of electrons in the height interval from 50 km to 1 500 km. It includes and explains several options for a plasmaspheric extension of the model, embracing the geographical area between latitudes of 80°S and 80°N and longitudes of 0°E to 360°E, for any time of day, any day of year, and various solar and magnetic activity conditions.

**These standards could also interest you**

- ISO 24637:2009
  Space systems -- Electromagnetic interference (EMI) test reporting requirements
- ISO 15862:2009
  Space systems -- Launch-vehicle-to-spacecraft flight environments telemetry data processing
- ISO 22108:2008
  Space systems -- Non-flight items in flight hardware -- Identification and control

http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=51248

# Model evaluation performed by the CCMC:
## CEDAR Electrodynamics Thermosphere Ionosphere (ETI) Challenge

NmF2

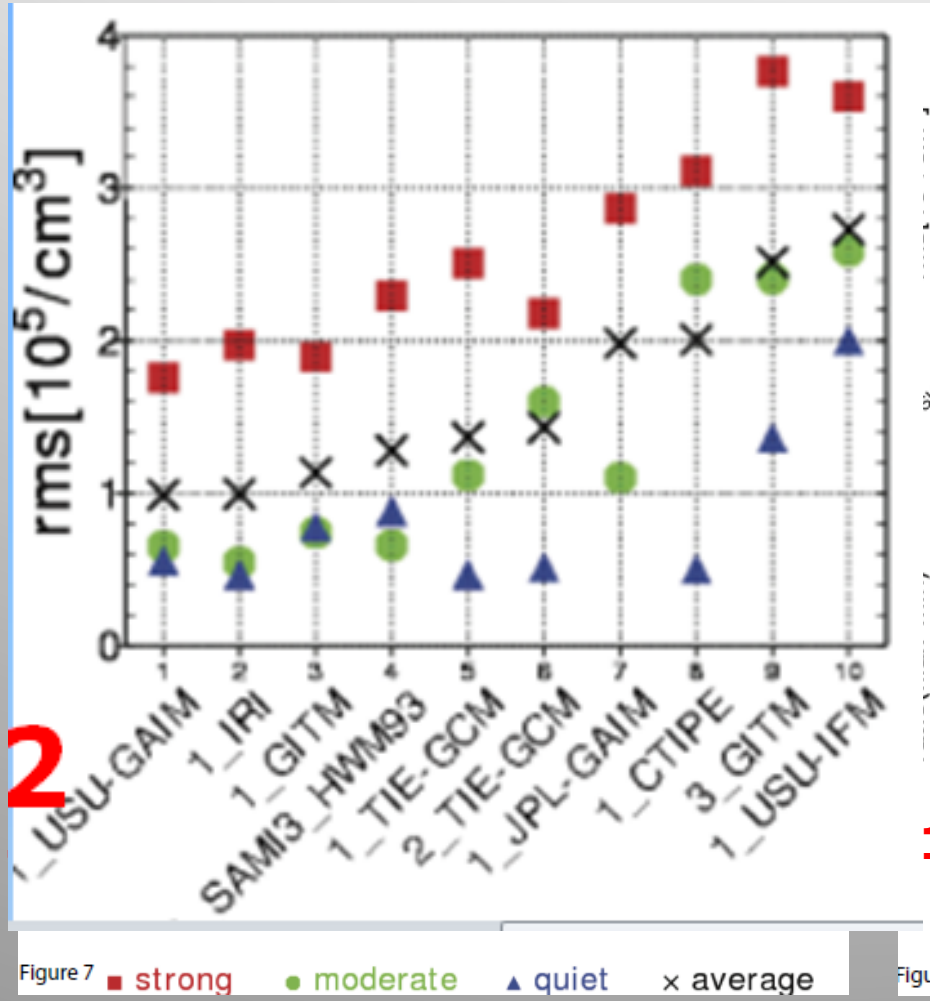



Figure 7 ■ strong ● moderate ▲ quiet × average

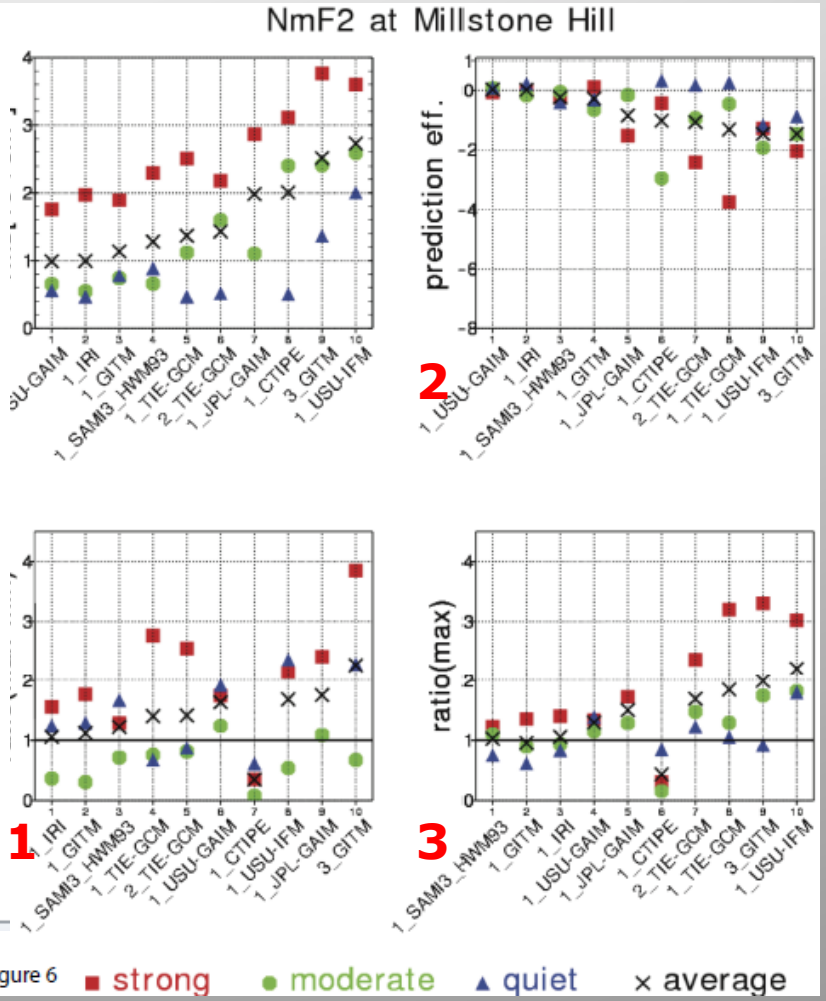
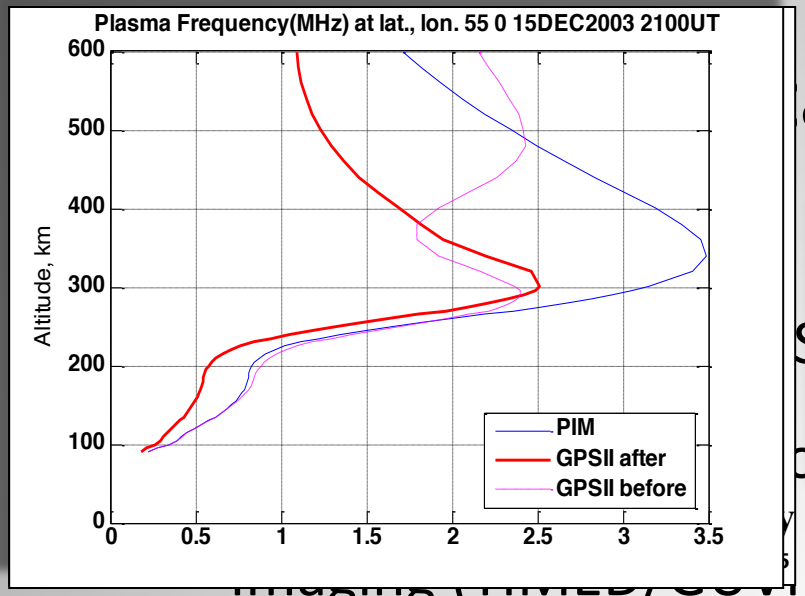



Figure 6 ■ strong ● moderate ▲ quiet × average

*Shim et al., AGU, December 2011, San Francisco*

# IRI-Real-Time

- GOAL: Transition from IRI climatological reference model to an ionospheric weather model
- METHOD: Combine IRI with ground and space data - Assimilation, Updating
- RESULT: Continuous data set of ionospheric weather for past years (post-processing) as well as a real-time characterization of the ionosphere for operational use
- ACTIVITIES: 2009 Colorado Springs Workshop; 2012 Prague IRI-RT meeting




The unrealistic split of the F2-layer is caused by Ne data from CHAMP passing at 370 km altitude

The pseudo-covariance matrix was modified to communicate to the GPSII code that it should try adjusting the height and plasma frequency of the F-layer.

(MHz)

, DMSP/SSUSI)

- In situ (C/NOFS, CHAMP, SWARM, DMSP)

# Data issues

- Data quality, discrepancies, and availability
- Effect of data sparse and data intense regions
- Impact of new data sources on trends

# Techniques

- Updating based on adjusting a solar index to measured data (ionosonde foF2 or GPS TEC)

- Assimilating measured parameters into the IRI background model using various techniques (Kalman filter, Ensemble Kalman filter, 3-D/4-D variational techniques, Gauss-Markov, etc.).

# IRI-RT Algorithms

- ADJUSTING WITH DATA:
  - Bilitza et al. (GMU) - Equivalent solar index (ESI) with ionosonde data
  - Komjathy et al. (JPL) - ESI with GPS VTEC
  - Hernandez-Pajares et al. (UPC) - ESI with GPS slant TEC
  - Nava and Radicella (ICTP) - Adjusting topside profile with GPS and NmF2 and hmF2 with ionosonde data
  - Zhang and L. Paxton (APL) - Auroral boundaries and NmE from GUVI and SSUSI

- ASSIMILATING DATA INTO BACKGROUND IRI:
  - Friedman et al. (NWRA) - GPSII - Tikhonov method with GPS data
  - Angling, Cannon et al. (QinetiQ) - EDAM - using GPS data
  - Schmidt et al. (DGFI) - Multi-dimensional B-spline (scaling) functions with GPS, COSMIC, and TOPEX/Jason
  - Pezzopane et al. (INGV) – ESI plus assimilation of bottomside profile
  - Huang, Galkin, Reinisch et al. (UML) - RTAM - Real-Time Assimilative Mapping with GIRO ionosonde data

# IRI-RT Examples

Australian Government
IPS Radio and Space Services

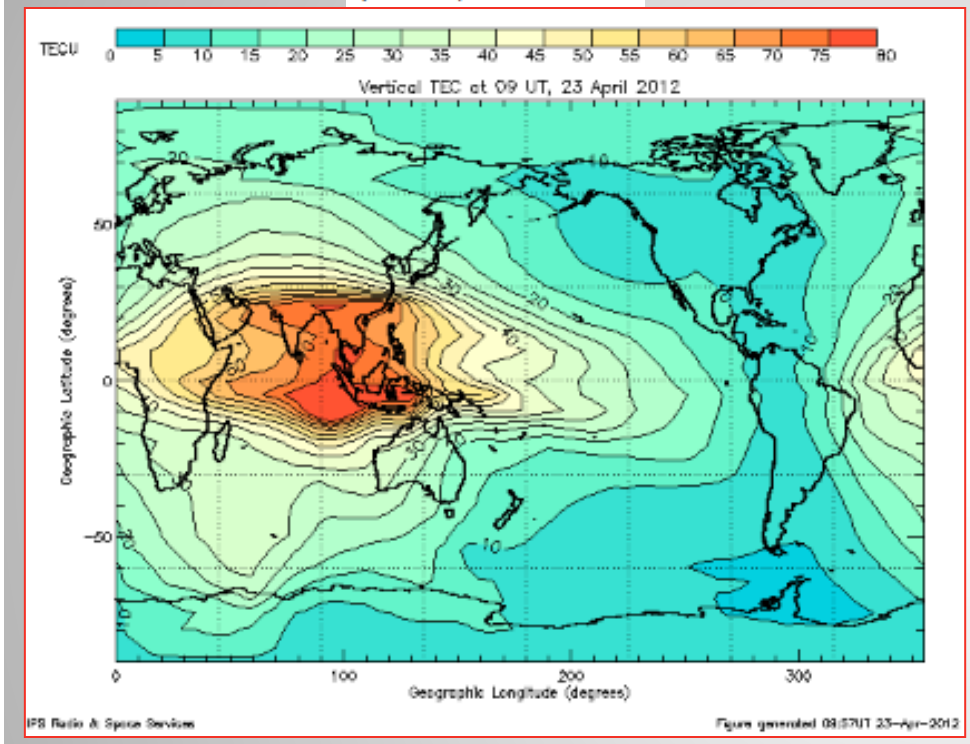
Bureau of Meteorology
Space Weather Branch

Space Weather | Satellite | Geophysical | Solar | HF Systems | Products and Services | Educational | World Data Centre

Total Electron Content

## TEC Regional Map

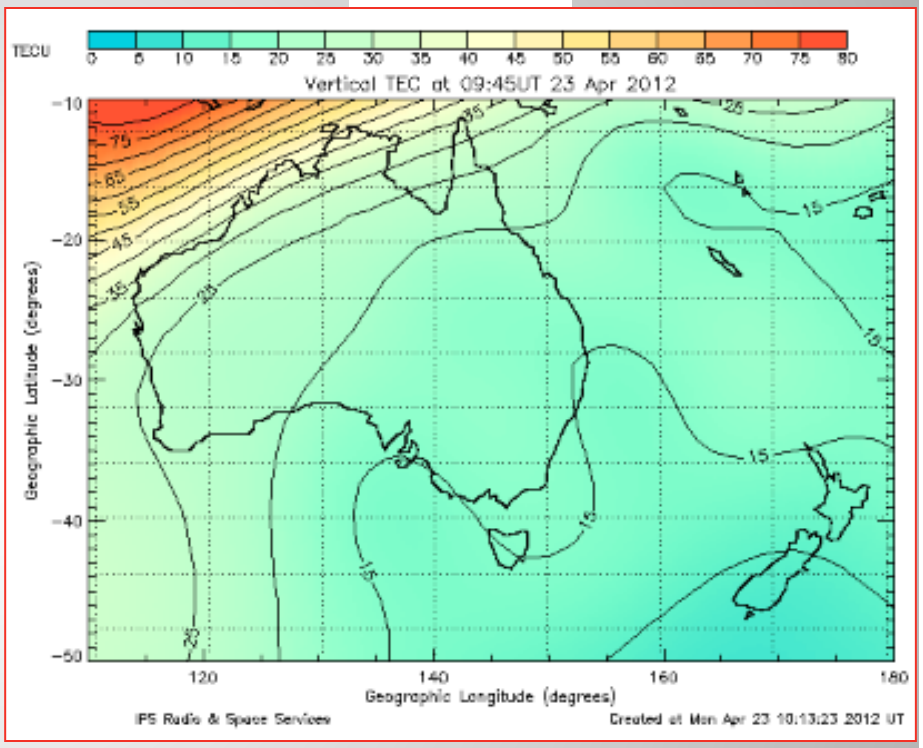
**Updates:** Every 60 minutes



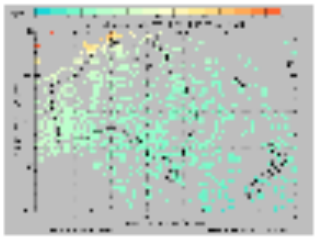

Total Electron Content

## TEC Global Map

**Updates:** Every 60 minutes



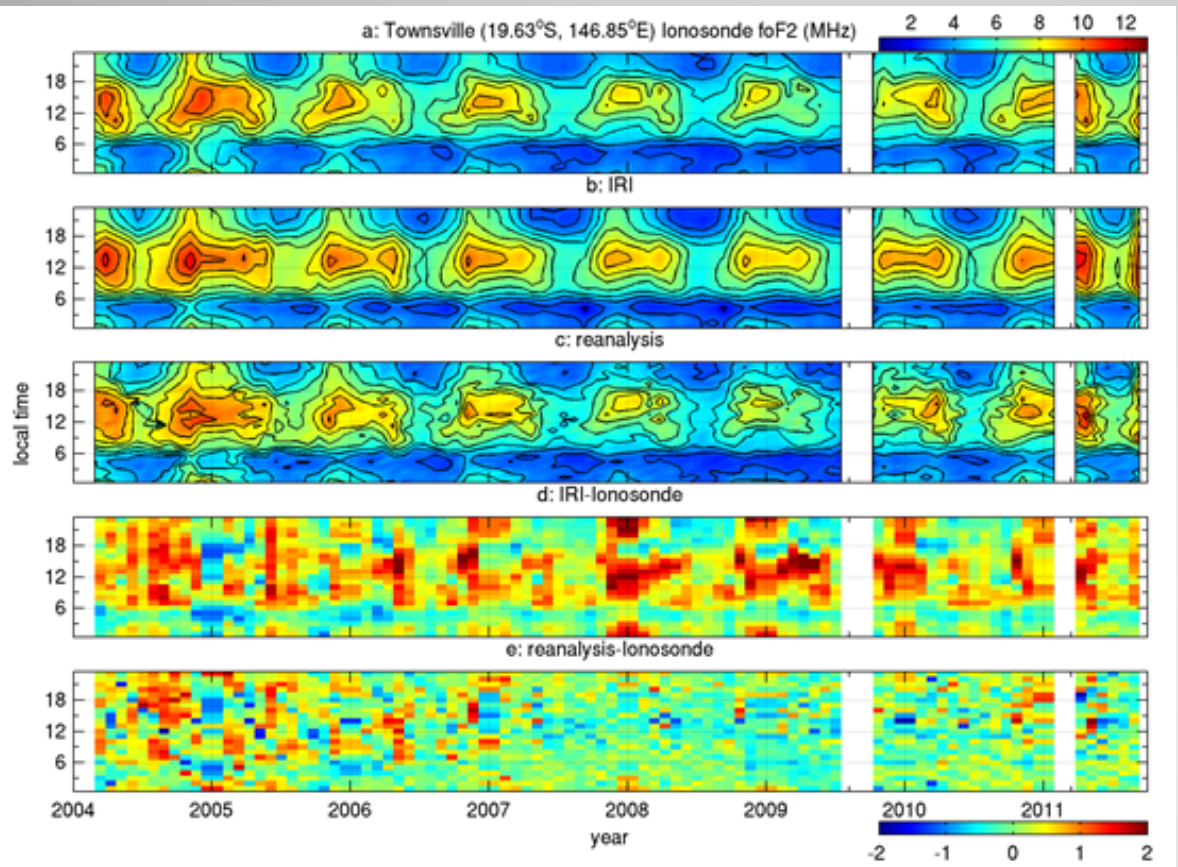

**Near real-time ionospheric total electron content (TEC) maps produced by combining GPS data and IPS ionosonde foF2 observations with the IRI-2007 ionospheric model**



Latest observations used. (click on thumbnail for full sized version)

*http://www.ips.gov.au/Satellite/2/1*

# Yue et al., submitted to JGR




**Monthly *foF2* (MHz)**

**(a) Ionosonde measurements**

**(b) IRI model**

**(c) IRI with data assimilation**

**(d) Difference between the ionosonde and IRI**

**(e) Difference between ionosonde and IRI with data assimilation**

Global 3-D ionospheric electron density during 2002-2011 based on assimilating TEC into the the International Reference Ionosphere (IRI) 2007 model using the Kalman filter technique. Data sources include TEC from GNSS, radio occultations by CHAMP, GRACE, COSMIC, SAC-C, Metop-A, and TerraSAR-X satellites, and Jason-1 and 2 altimeter TEC measurements.


**IRI-2013 Workshop**

**University of Warmia and Mazury, Olsztyn, Poland**

**24-28 June 2013**

***IRI and GNSS***

**MSO: A. Krankowski**