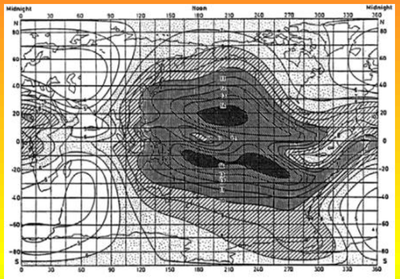
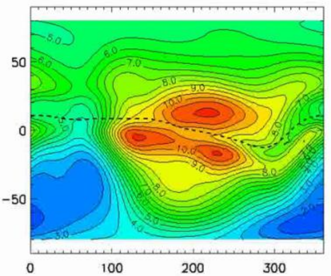
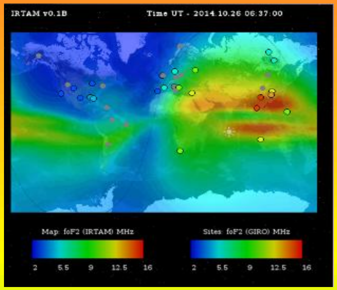
International Reference Ionosphere

Modelo Estándar de la Ionosfera

From Climatology to Real-Time







David Altadill: Observatori de L'Ebre (OE), CSIC – Universitat Ramon Llull, Roquetes, Spain

With support of

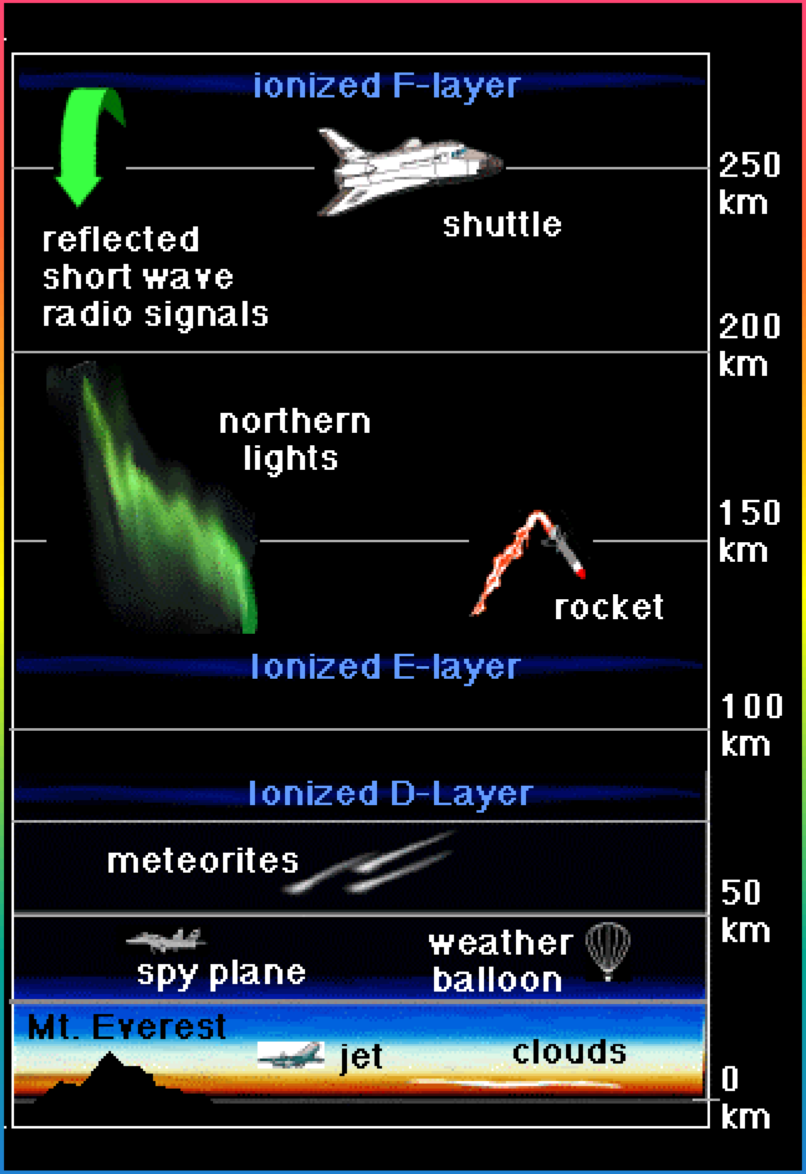
Dieter Bilitza: Space Weather Lab, George Mason University, Fairfax, Virginia, USA; and NASA/GSFC, Heliospheric Lab, Greenbelt, Maryland, USA

and

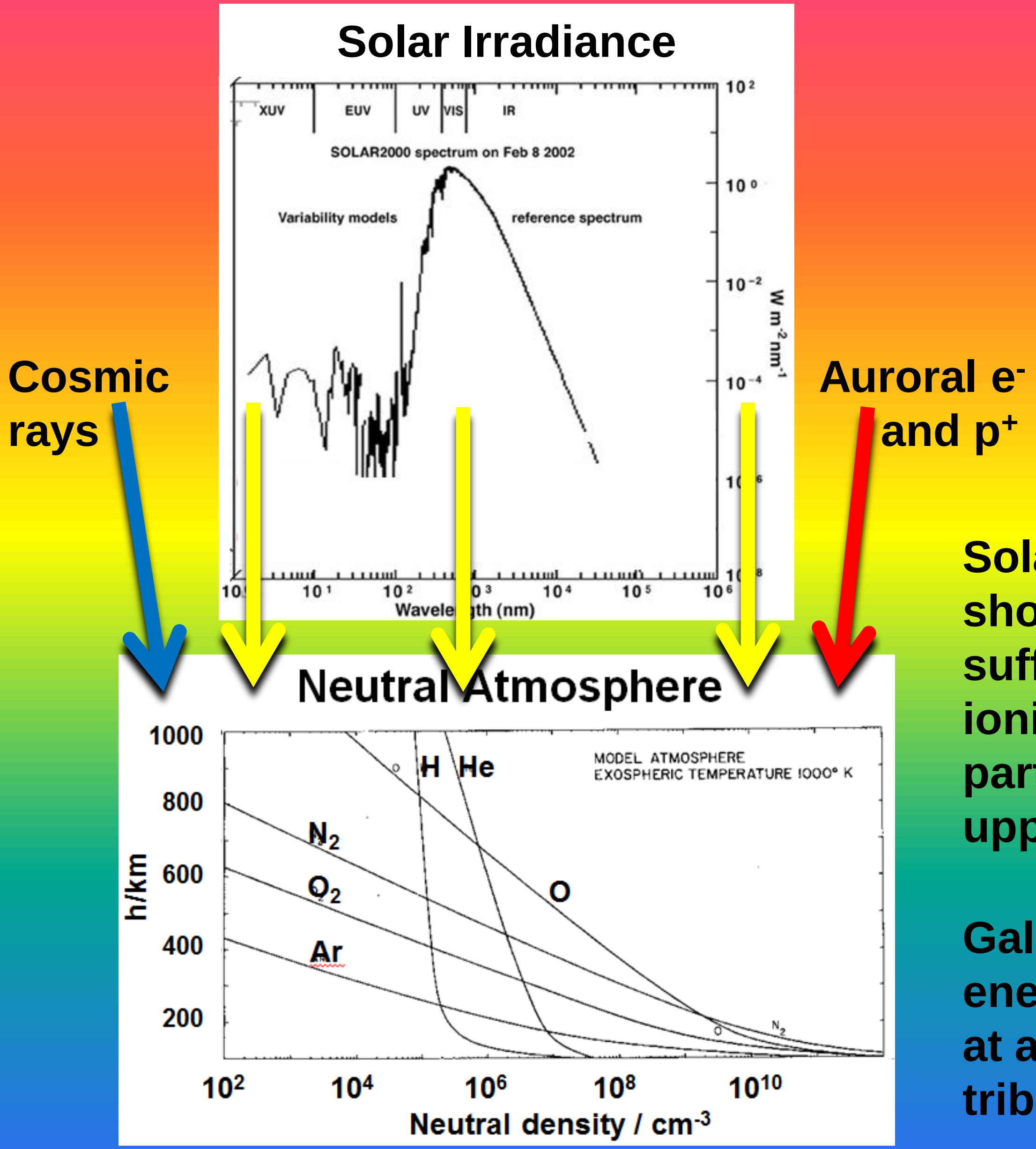
IRI Working Group

The ionosphere is a layer of plasma (electrons, ions) that surrounds the Earth in the altitude range from about 50 km to 1500 km.

The ionosphere makes up less than one percent of the upper atmosphere but it is very important because of its influence on the passage of radio waves. GPS, HF communications, and Earth observation from space are just a few of examples of the affected systems.



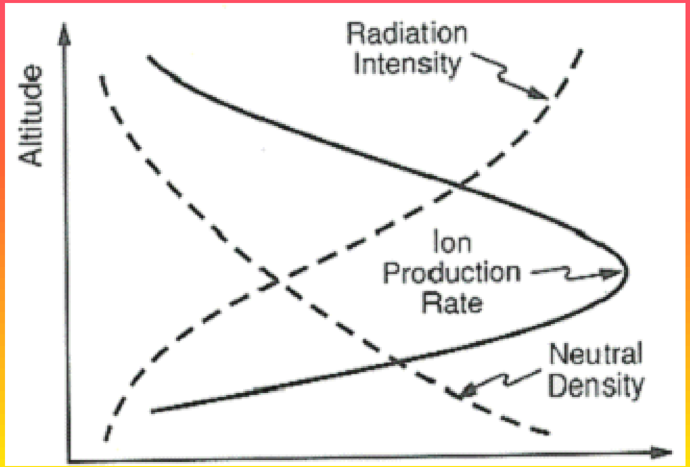
Theoretical background


Solar Irradiance

Cosmic rays

Auroral e^- and p^+

Neutral Atmosphere



Solar photons at wavelengths shorter than 102.6 nm have sufficient energy (>12 eV) to ionize the primary neutral particles (N_2, O and O_2) of Earth's upper atmosphere.

Galactic cosmic rays and energetic electrons and protons at auroral latitudes also contribute to the ionization process.

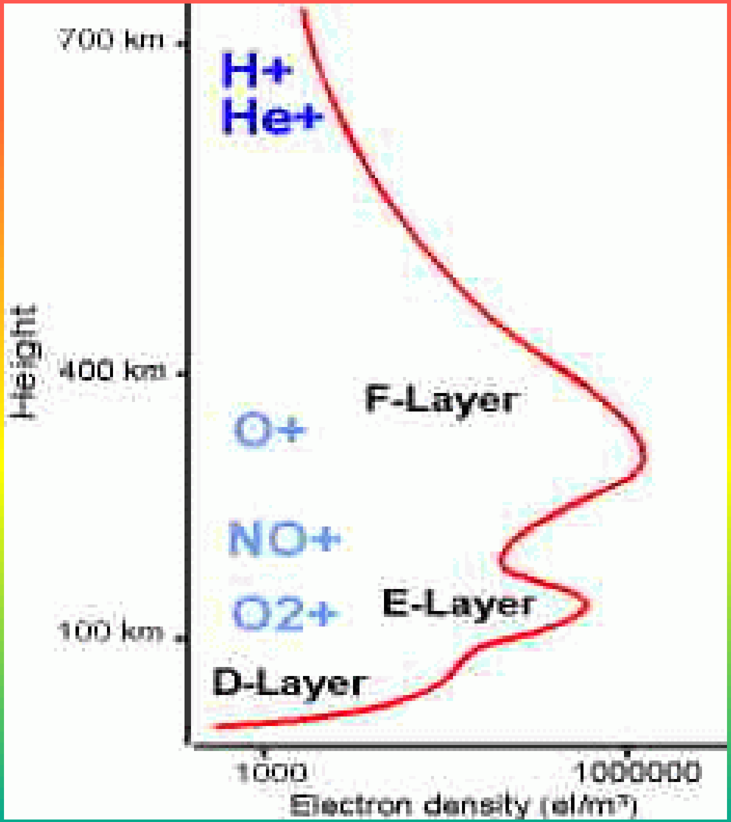
Ionospheric layers: D, E, F1, F2

Balance of production, loss and transport processes

Production – Ionization of O, N_2, O_2
Loss – Recombination
Transport – Diffusion and E and v_n induced drift along magnetic field lines

Solving Boltzman equations for the first three moments: density, temperature, and velocity

Altitude Range:	60 - 1500 km
Densities (e^-, A^+):	10^5 - 10^{12} m^{-3}
Temperatures:	300 - 4000 K
Ions below 500 km:	O^+, NO^+, $O2^+$
Ions above 500 km:	O^+, N^+, H^+, He^+
Charge neutrality:	$N_e = \sum n_i$



The Importance of Ionospheric Models

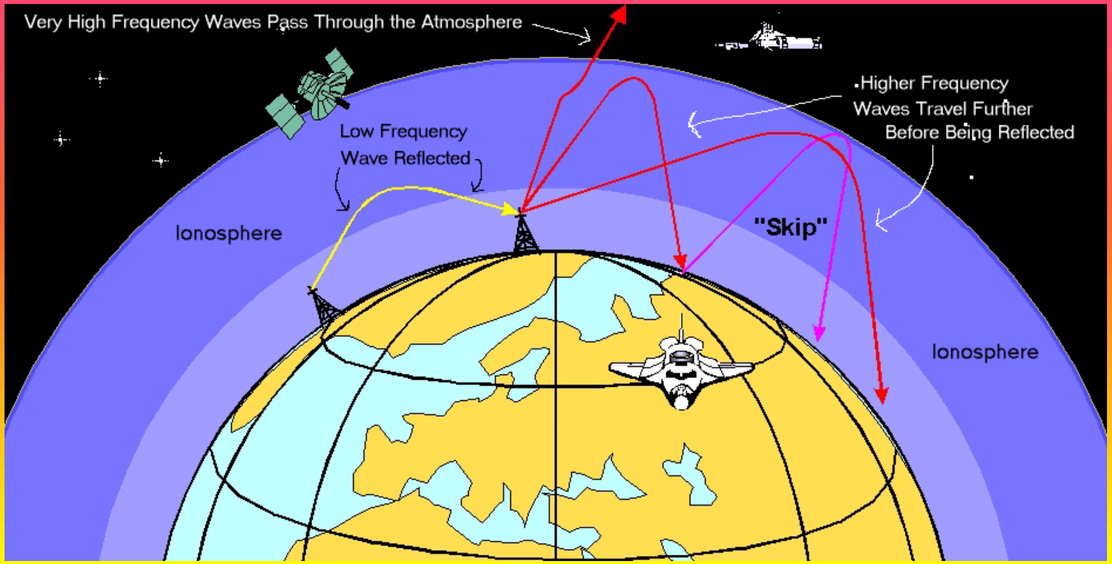
A few examples of commonly used systems that require ionospheric models:

- **HF communication**

- **Data analysis of Earth remote sensing data**

- **GPS related applications**

HF Propagation



Wave path through ionosphere depends on frequency and elevation angle.

Frequency squared is proportional to the electron density at the reflection point.

At large enough frequencies the wave traverses the ionosphere. without reflection but the ionosphere exerts a retarding effect that needs to be considered in signal processing

Frequency management for HF communication between two stations requires knowledge of ionospheric conditions.

Many developing countries use HF communications for vital civic and military operations.

Airplanes on polar routes depend on HF links for communication. Accurate predictions of PCA events (solar proton events) causing polar blackouts are essential.

Kelley et al, 2014 report on an incident during Operation Anaconda in Afghanistan where poor UHF Satellite Communications (SATCOM) very likely due to ionospheric disturbances resulted in a 'hot' helicopter landing under heavy fire.

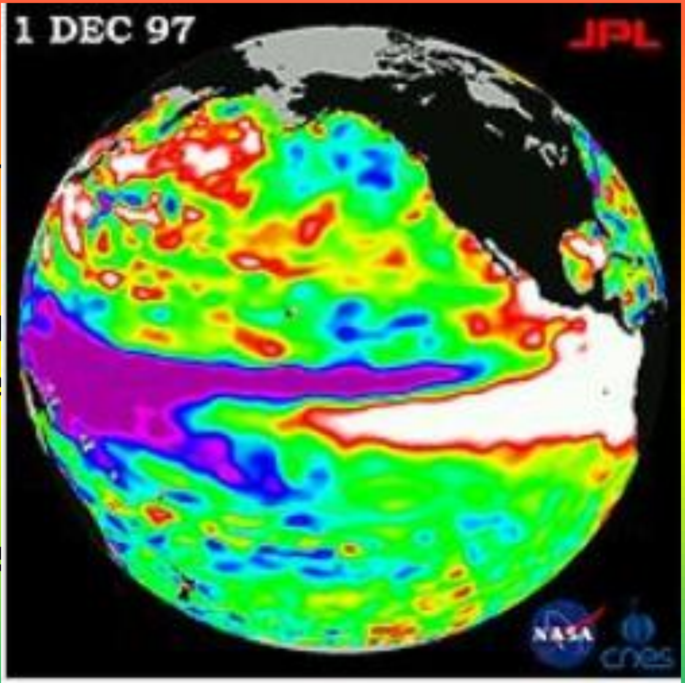
Ionospheric Correction for Earth Science Remote Sensing Data

Using ionospheric models to improve the acc altimeter data for El Nino/Climate studies: Pa 1997; Lillibridge, J. and R. Cheney, 1997]

Data analysis for future sea surface salinity m using IRI to eliminating the ionospheric influe [Abraham, S., and D. LeVine, 2004]

Processing of ERS-1 and ERS-2 data product Rep. C2–MUT–A–01–IF, 1996]

Work with Geosat Follow On (GFO) data [Navy 2000; Zhao et al., 2002.]



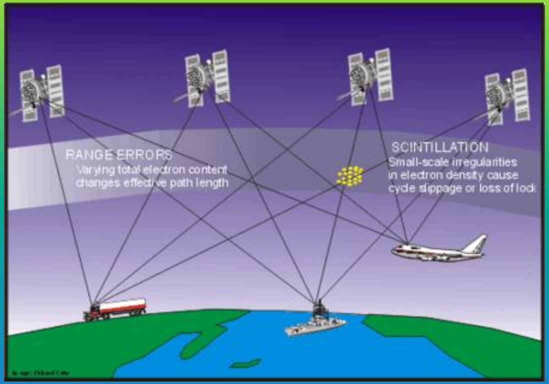
The 1997 El Niño observed by TOPEX/Poseidon. The white areas off the tropical coasts of South and North America indicate the pool of warm water[1]

Global Positioning Satellites (GPS)

GPS was developed by the US DoD as an all-weather space-based navigation system using satellite transmitters (30+) synchronized with onboard atomic clocks. Signal travels through ionosphere before reaching ground receivers. Other systems: Russian GLONASS, European Galileo, Chinese BeiDou, and indian IRNSS..

GPS related applications:
Railway control, highway traffic management, emergency response, commercial aviation, and marine navigation require high-precision positioning. Also car navigation, timing signal for cell phones….

Ionospheric impacts on GPS:
Range errors due to the refractive/retarding effect of the ionospheric plasma and loss of lock due to amplitude and phase fluctuations (scintillations) caused by ionospheric irregularities.



Ionospheric benefits from GPS:
With two frequencies the ionospheric contribution (TEC) can be deduced and GPS becomes an instrument for monitoring ionospheric TEC. Two issues remain: multipath and system hardware differential delays

Empirical models

Based on ground and/or space data

Use appropriate mathematical functions to represent the characteristic variation patterns seen in long data records;

Do not depend on our evolving understanding of the processes that shape the ionosphere environment

Empirical models are, in general, available to users in the form of a computer program, and can be readily adapted to a specific problem.

Theoretical models

Consider the production, loss, and transport of ionospheric electrons and ions, and obtain the electron density from the balance of these processes

Use a numerical (iterative) scheme to solve Boltzmann equations.

Theoretical models are primarily used in an investigative mode, to elucidate specific processes and their effects on the ionosphere

Theoretical models require considerable computer time, even on fast machines, and their complex computer code and logic make it difficult for people other than the model developers themselves to apply the model to a specific problem.

In actual fact, most ionospheric models are hybrids, using empirical as well as theoretical elements. An empirical model, for example, may use theoretical values to fill data gaps, whereas a theoretical model may use a data-based representation for specifying initial conditions or unmodelled input parameters (e.g., neutral densities and temperature, or high-latitude convection flows).

INTERNATIONAL REFERENCE IONOSPHERE (IRI)

IRI is a *joint project of COSPAR and URSI*.
COSPAR's (Committee on Space Research) prime interest is in a general description of the ionosphere as part of the terrestrial environment for the evaluation of environmental effects on spacecraft and experiments in space. URSI's (Union Radio-Scientifique Internationale; International Union of Radioscience) prime interest is in the electron density part of IRI for defining the background ionosphere for radiowave propagation studies and applications.

TERMS OF REFERENCE: The IRI Working Group was established to develop and improve a reference model for the most important plasma parameters in the Earth ionosphere. The model should be primarily based on *experimental evidence* using all available ground and space data sources and should not depend on the evolving theoretical understanding of ionospheric processes. But theoretical considerations can help to find the appropriate mathematical functions, to bridge data gaps and for internal consistency checks. As new data become available and as older data sources are fully evaluated and exploited, the model should be *revised* in accordance with these new results.

Where discrepancies exist between different data sources the IRI team should facilitate critical discussions to determine the *reliability of the different data bases* and to establish guidelines on which data should be used for ionospheric modeling.

International Reference Ionosphere (IRI)

IRI describes monthly averages of

- electron density
- electron temperature
- ion temperature
- ion composition (O^+, H^+, He^+, N^+, NO^+, O_2^+, Cluster ions)

IRI represents variations with

- altitude (50km – 1500 km)
- latitude, longitude (geographic or geomagnetic)
- date and time of day

External drivers:

- solar indices (F10.7, sunspot number)
- ionospheric index (IG)
- magnetic indices (ap and kp)

Additional output parameters:

- total ionospheric electron content (TEC)
- ion drift at equator
- occurrence probability for spread-F

International Reference Ionosphere (IRI)

IRI Working Group Members and Steering Committee 2014

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S. Watanabe (U. Hokkaido, Japan) *COSPAR Vice-Chairperson*
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2011

NRF HMO
National Research Foundation
Hermanus Magnetic Observatory

Improving IRI over the African Sector

Advances in Space Research Volume 52 Issue 10

2012

39th COSPAR
Mysore, India
July 14-22, 2012

Mysore, India

Global representation of ionospheric peak parameters for space weather applications

2013

UWM
UNIWERSYTET WARMIŃSKO-MAZURSKI

Olsztyn, Poland

IRI Improvements with GNSS Data

Advances in Space Research
Volume 55 Issue 8

2014

UMASS LOWELL

IRI Real-Time Task Force meeting, May 19, U Mass Lowell preceding the XIV International GIRO Forum

2014

COSPAR MOSCOW 2014
COSMOS
40th SCIENTIFIC ASSEMBLY
Russia, Moscow, 2-10 August 2014

Improved representation of the ionosphere in real-time and retrospective mode

31st URSI GA, Beijing, China, 16-23 Aug 2014

Ionosphere and Plasmasphere Density Profiles

2015

Gran Canaria, Spain

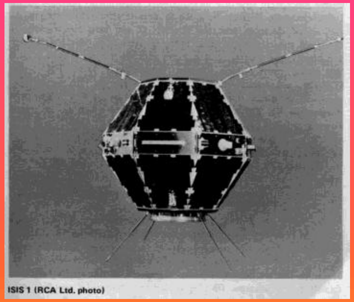
Assimilative Modelling and the Global Ionosonde Network
May 18-25, 2015

Bangkok, Thailand

COSPAR Capacity Building Workshop: Spread-F and scintillations
Nov 2-13, 2015

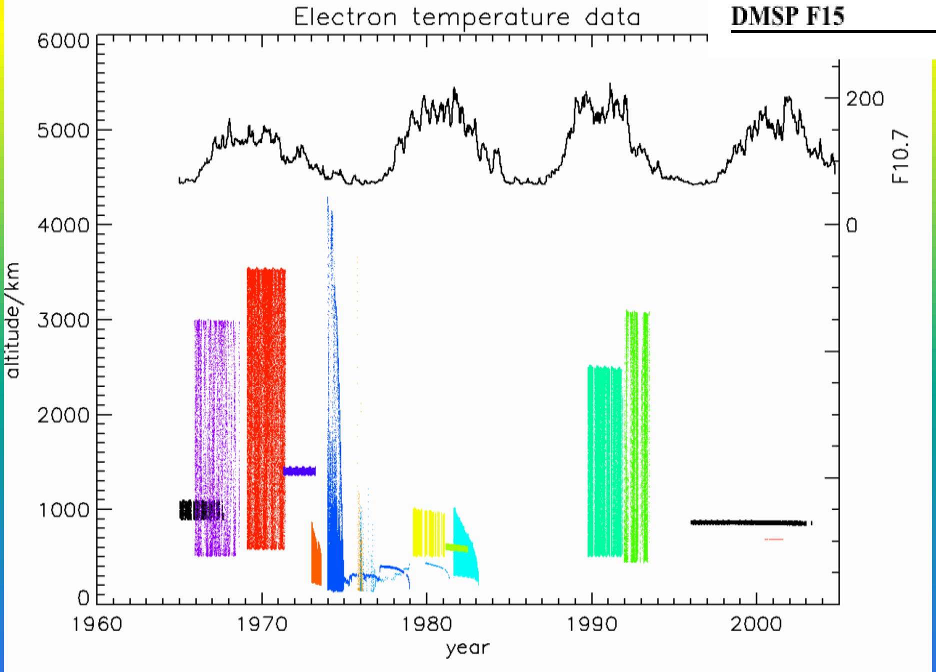
Data Sources

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



Data Base of Satellite Insitu Measurements

Satellite	Time period	Altitude [km]	Latitude [deg]	LT [h]
Explorer 22 (beb)	10. 1964 – 8. 1967	880 – 1110	–79 – 80	0 – 24
Explorer 31 (dmea)	11. 1965 – 8. 1968	500 – 3010	–79 – 79	0 – 24
ISIS 1	1. 1969 – 5. 1971	580 – 3550	–88 – 88	0 – 24
ISIS 2	4. 1971 – 3. 1973	1360 – 1460	–88 – 88	0 – 24
AEROS A	1. 1973 – 8. 1973	200 – 870	–83 – 83	3, 15 fixed
AE–C	12.1973 – 12. 1978	130 – 4300	–68 – 68	0 – 24
AE–D	10. 1975 – 1. 1976	140 – 3700	–90 – 90	0 – 24
AE–E	12. 1975 – 5. 1981	140 – 1250	–20 – 20	0 – 24
IK19	3. 1979 – 1. 1981	500 – 1020	–74 – 74	0 – 24
DE–2	8. 1981 – 2. 1983	200 – 1020	–90 – 90	0 – 24
Hinotori	2. 1981 – 6. 1982	560 – 640	–31 – 31	0 – 24
IK24	10. 1989 – 11. 1991	500 – 2530	–83 – 83	0 – 24
IK25	12. 1991 – 6. 1993	440 – 3110	–83 – 83	0 – 24
KOMPSAT	6. 2000 – 8. 2001	Appx. 685	-90 – 90	10.83, 22.83 fixed
DMSP F12	1. 1996 – 6. 2002	840 - 890	–90 – 90	9.5, 21.5 fixed
DMSP F13	3. 1995 – 12. 2003	840 - 880	–90 – 90	5.75,17.75 fixed
DMSP F14	1. 1997 – 12. 2003	840 - 880	–90 – 90	9.5, 21.5 fixed
DMSP F15	12.1999 – 12. 2003	830 - 880	–90 – 90	9.5, 21.5 fixed



Digisonde GIRO Network

Global Ionosphere Radio Observatory

Build-up of IRI electron density profile

Mathematical functions:

Global Variations:

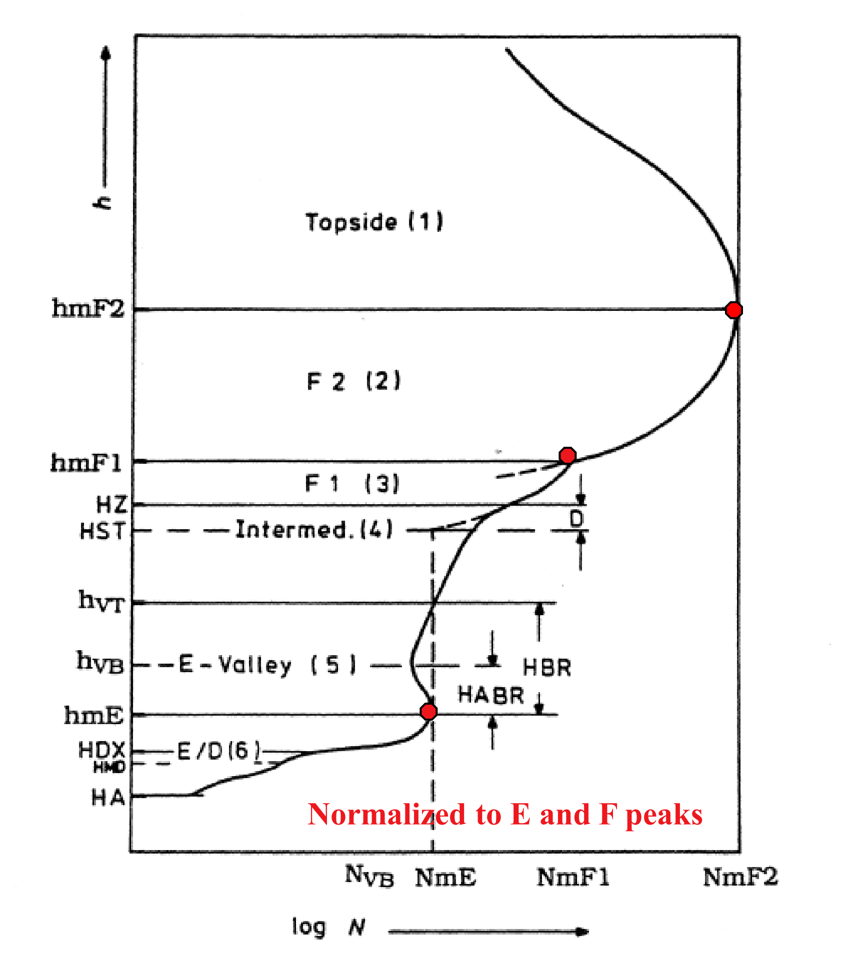
- Spherical harmonics,
- Interpolation between regions

Time Variations:

- Fourier,
- Step-functions

Height Variations:

- Epstein functions
- Chapman function

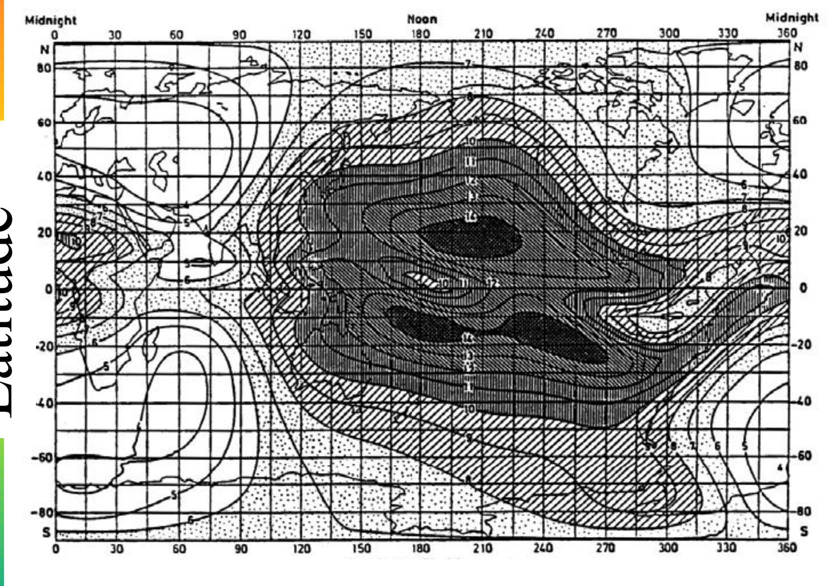


Global models for
foF2/NmF2 foF1/NmF1, foE/NmE, foD/NmD
[N/m^{-3}=1.24E10 $(f/MHz)^2$],
hmF2/M(3000)F2, hmF1 , hmE, hmD

Global models for the F2 peak density and height: *NmF2* and *hmF2*

Global models for F2 peak parameters

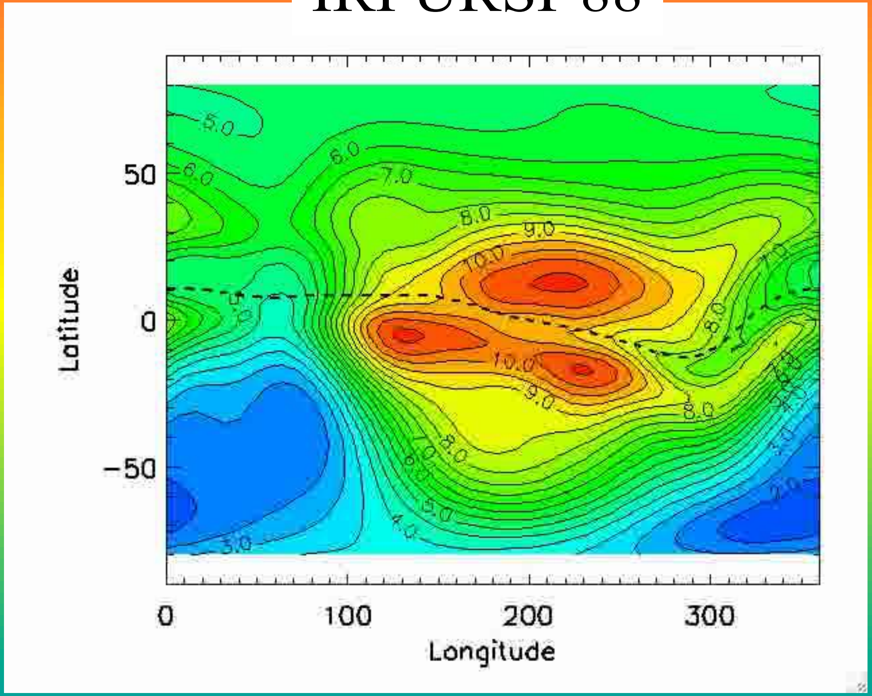
ISS-b data



Latitude

Longitude

IRI URSI-88



F2 peak height (*hmf2*) model in IRI

$$hmF2/\mathrm{km} = 1490 \,/\, \left(\boxed{M(3000)F2} + \Delta M \right) - 176$$

$$\Delta M = f_1 \bullet f_2 \,/\, \left(foF2 \,/\, foE - f_3 \right) + f_4$$

$$f_1 = 0.00232 \bullet R12 + 0.222$$

$$f_2 = 1 - R12 \,/\, 150 \bullet \exp\left(- \left(\Psi / 40^\circ \right)^2 \right)$$

$$f_3 = 1.2 - 0.0116 \bullet \exp\left(R12 \,/\, 41.84 \right)$$

$$f_4 = 0.096 \bullet \left(R12 - 25 \right) / 150$$

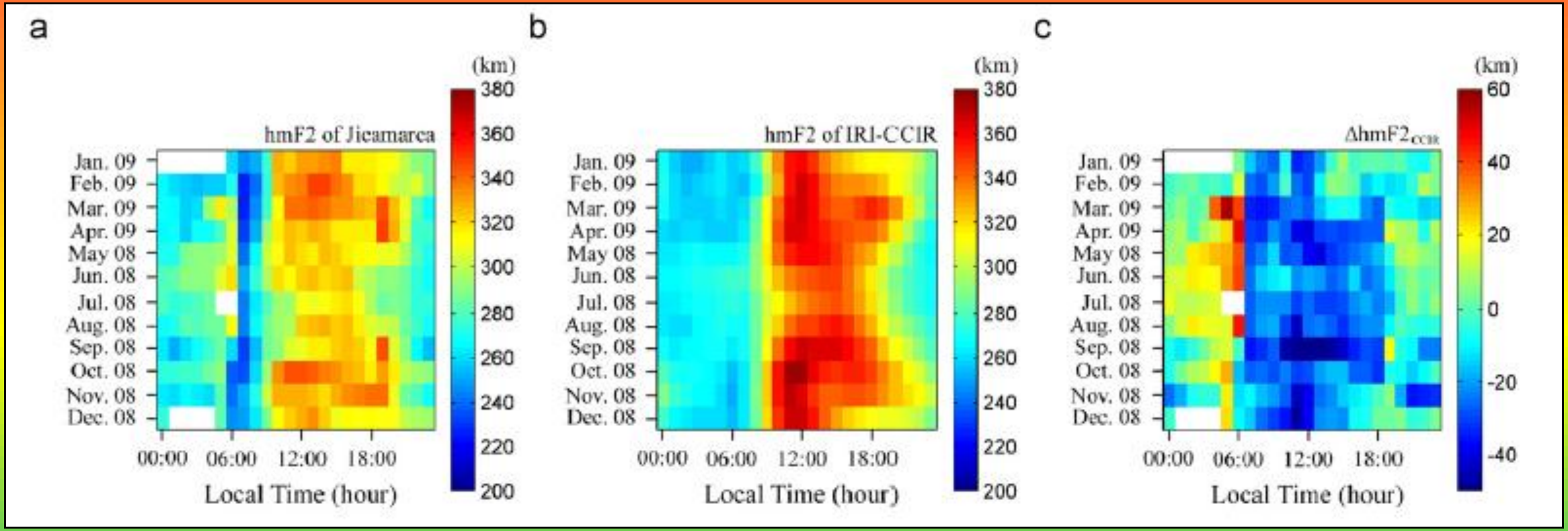
$R12$	12-month-running mean of solar sunspot number
Ψ	magnetic dip latitude
$foF2$	F2 peak plasma frequency
foE	E peak plasma frequency

$M(3000)F2$ = MUF/$foF2$ (routinely scaled from ionograms)

MUF	maximum usable frequency that refracted in the ionosphere, can be received at a distance of 3000 km.

Lee and Reinisch, JASTP 74, 217–223, 2012.

Diurnal and annual variation of hmF2 at Jicamarca during May 2008 to April 2009



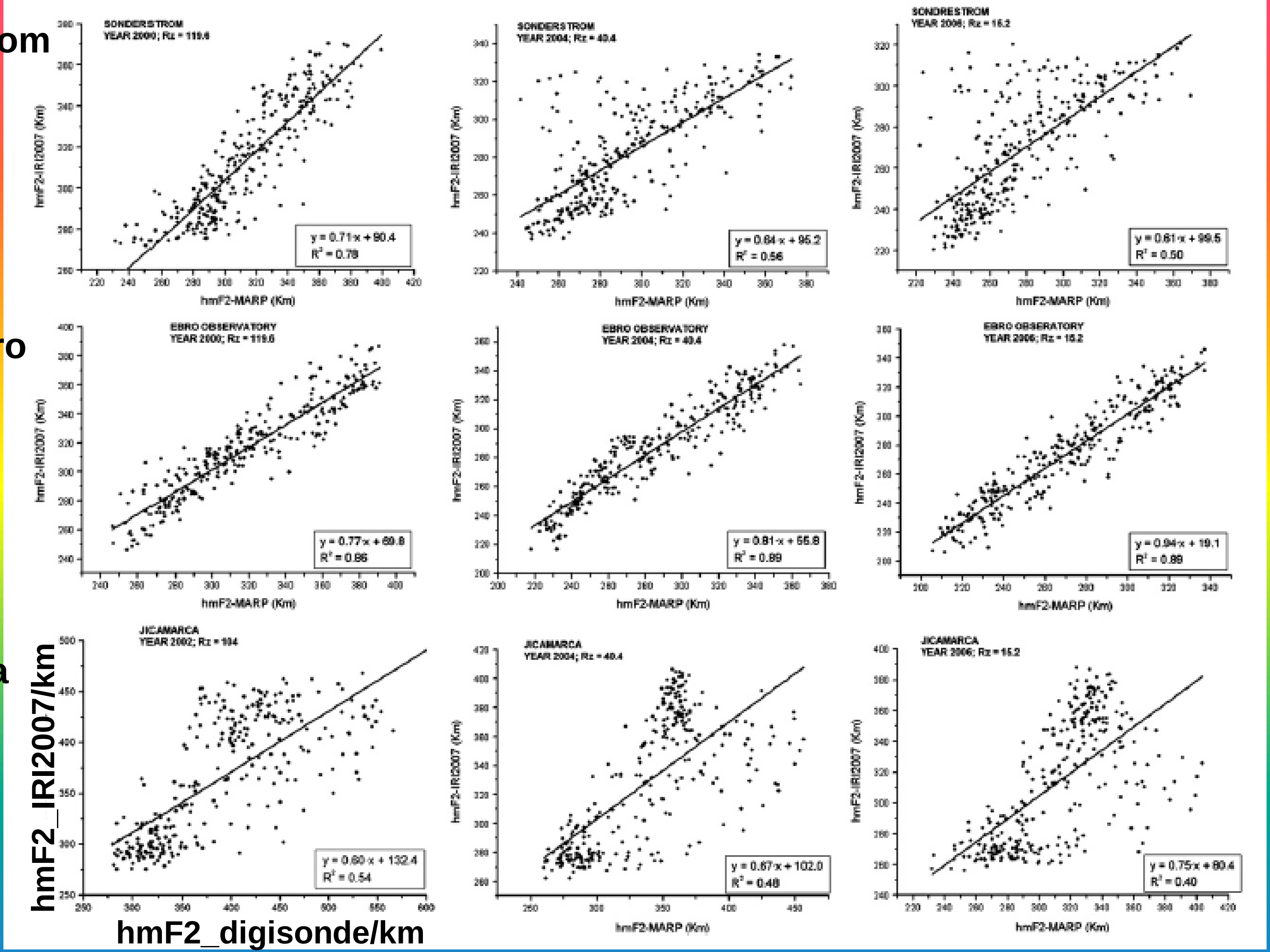
hmF2 (Digisonde) *hmF2* (IRI-2007) *ΔhmF2* Digisonde-IRI

2000, R=119 **2004, R=40** **2006, R=16**

Sondrestrom

Ebro

Jicamarca



hmF2_IRI2007/km

hmF2_digisonde/km

Magdaleno et al., JASTP, 2011

hmF2 Models

Gulyaeva et al., ASR, 2008

DATA: ~90,000 values extrapolated from ISIS 1, 2, IK-19, Cosmos-1809 TS Ne profiles
DEPENDs on local time, season, geomagnetic latitude/longitude, and solar radio flux

Hoque and Jakowski, AG, 2012

DATA: CHAMP, GRACE and COSMIC RO data & data from ~50 ionosondes (SPIDR, IPS)
DEPENDs on χ, LT, geomagnetic (dipole) latitude, season, F10.7 (13 coefficients)
IMPROVEs NeQuick/Dudeney from 16-18% to 12-13% (using data base)

Brunini et al., ASR, 2013

Using the Jones-Gallet formalism to represent the IRI hmF2 values directly instead of the currently used CCIR model for M(3000)F2 and hmF2-M(3000)F2 formula.

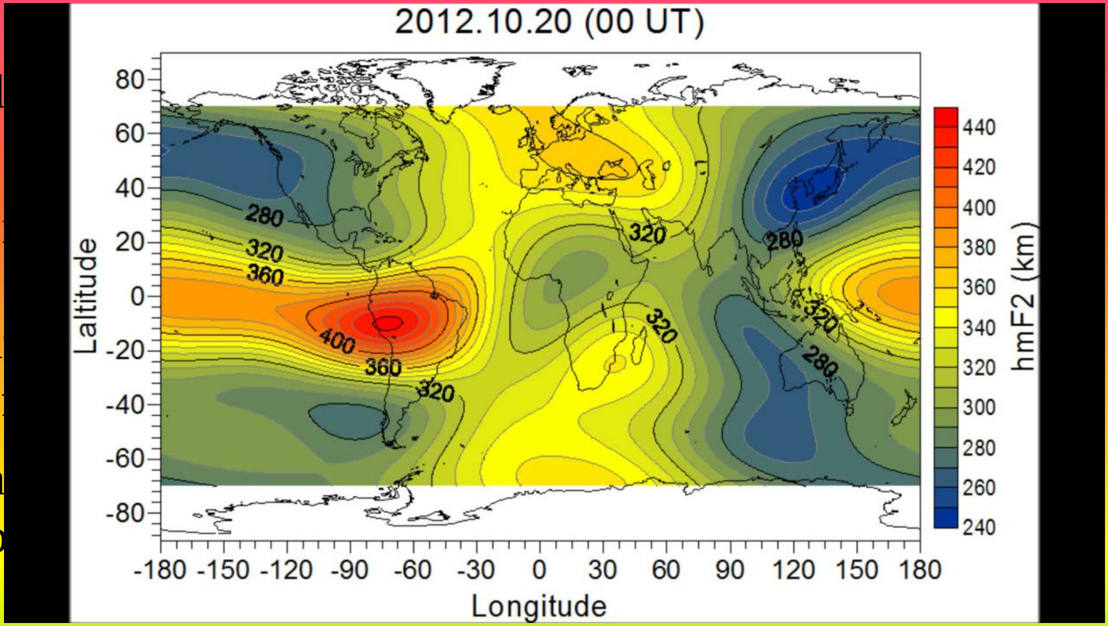
Altadill et al., ASR, 2013

DATA: **26 digisonde stations** for the time period **1998–2006**
Will be included in IRI

Shubin et al., JASTP, 2013

DATA: Radio Occultation from **CHAMP** (100,000), **GRACE** (70,000) and **COSMIC** (2,000,000) (only for low solar activity: F10.7A < 80).
Will be included in IRI

Altadill D., S. Magdaleno, J.M. Torta, E. Blanch, Global empirical models of the density peak height and of the equivalent scale height for quiet conditions, Adv. Space Res. 52, 1756–1769, 2013.

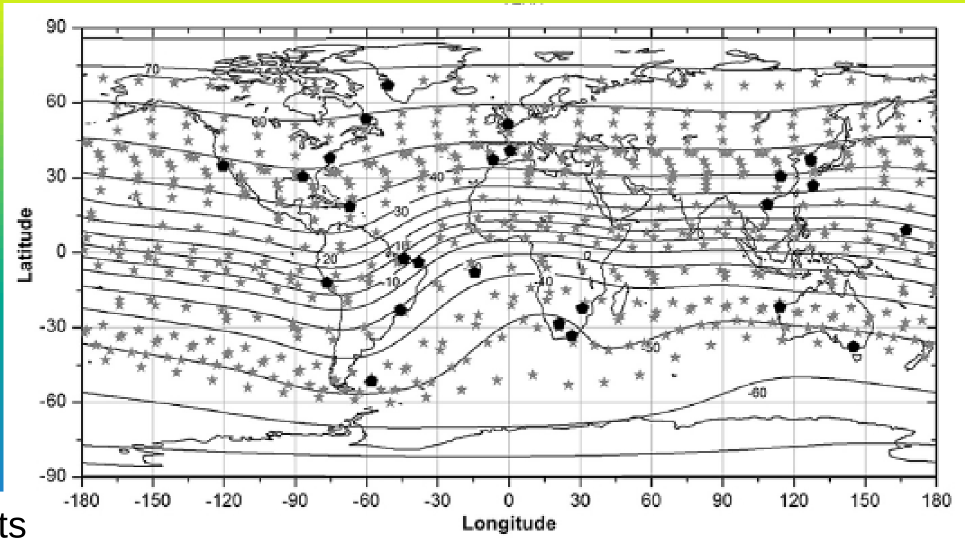


DATA: Monthly average electron d
time period 1998–2006.

FUNCTIONS: Quiet-time behavio
longitude/LT (order=4) and latitude
solar activity and the seasonal varia
of the coefficients. Total of 610 coe

IMPROVEMENT: New model im
average compared to IRI, and by up

FICTITIOUS STATIONS: Assuming that under quiet conditions the local time differences in hmF2 are equivalent to the longitudinal differences, 24 fictitious stations are evenly distributed along each station’s modip line (separated by 15 degrees longitude).



Original stations: black dots
Fictitious stations: grey stars

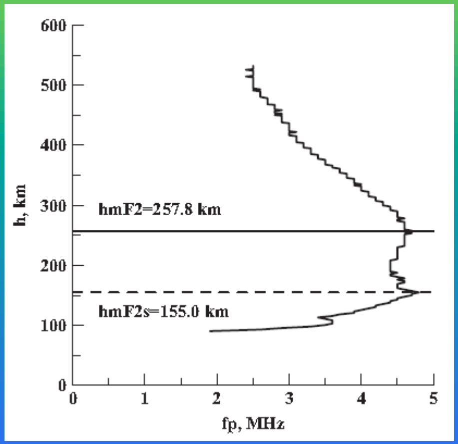
SMF2: Shubin, Karpachev, Tsybulya, Global model of the F2 layer peak height for low solar activity based on GPS radio-occultation data, JASTP, 2013.

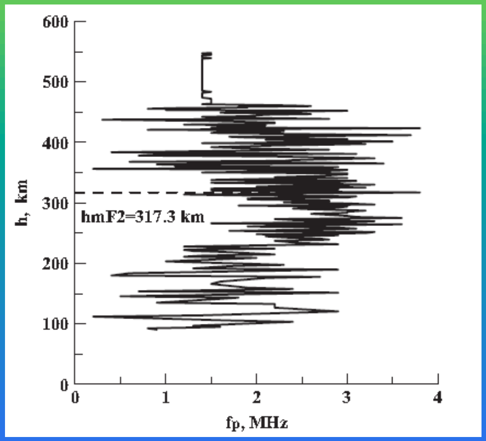
DATA BASE: GPS radio-occultation data from CHAMP (100,000 values), GRACE (70,000) and COSMIC (2,000,000) **for low solar activity** periods (F10.7A < 80). Ground-based ionospheric sounding data were used for comparison and validation.

FUNCTIONS: Spatial dependence of hmF2 is described with a Legendre-function expansion in latitude (order=12) and longitude (order=8) and temporal dependence (UT) with a Fourier expansion (order=3). Total of 149 coefficients

COMPARISON WITH IRI: RMSE of the radio-occultation and Digisonde data from the new model is 10–16 km (3-4%) for all seasons, while it is 13–29km (9-12%) for IRI-2012.

QUALITY CONTROL: ~10% of the COSMIC-RO hmF2 values were discarded because they were clearly outside the typical range or were difficult to obtain from strongly disturbed profiles.

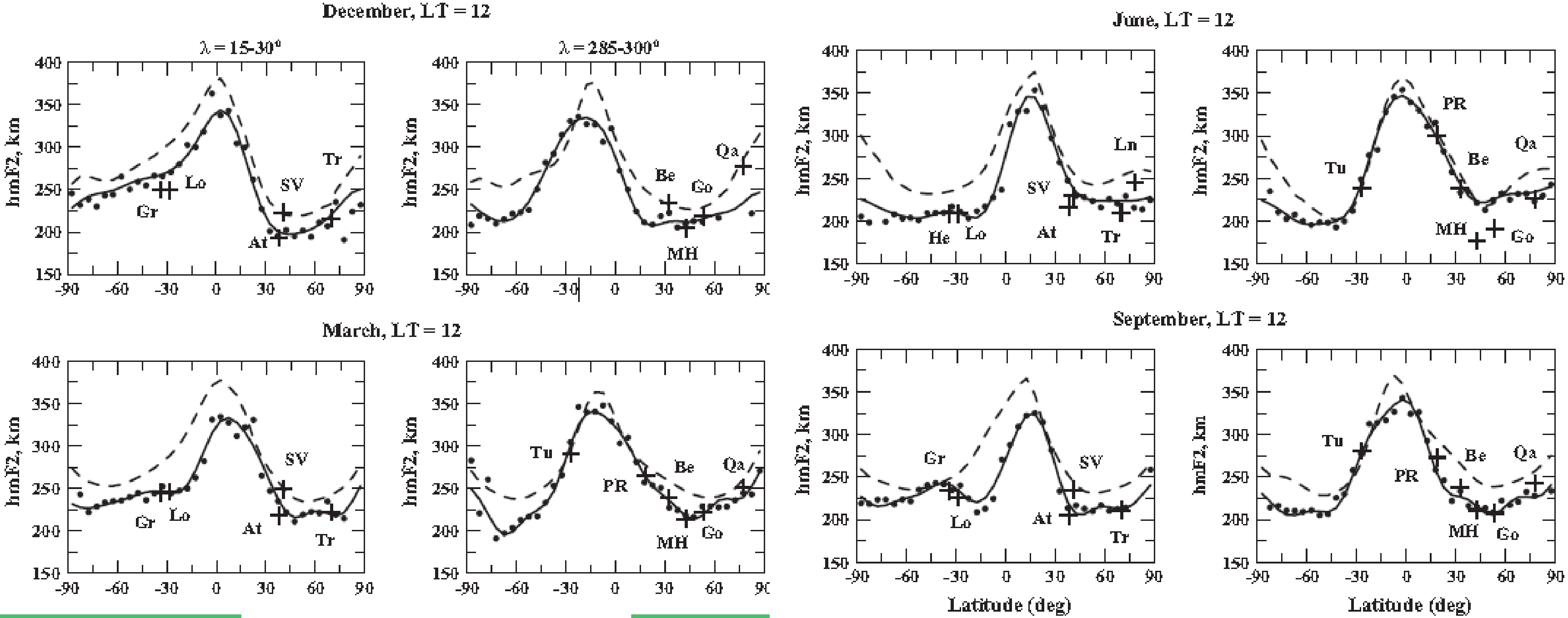




Latitudinal cross-sections of hmF2 at noon for the four seasons

European sector American sector European sector American sector

hmF2 / km



Latitude / degree

● Radio-occultation-derived hmF2 medians

— New model

– – – IRI-2012

\+ Digisonde-derived median values.

Storm effects on Nmf2 and hmF2

1) Solar CMEs and high-speed streams interact with the magnetosphere

2) Energy input results in Joule heating of the high latitude thermosphere which drives neutral wind surges and causes composition changes.

3) Ionization is also re-distributed by electro-dynamical processes which are caused by the penetration electric field and the disturbance dynamo which in turn are a result of the interaction between the interplanetary magnetic field (IMF) and the Earth’s magnetic field..

4) The combination of this two effects (2, 3) can result in ***NmF2*** depletions or enhancements. For summer mid-latitudes mostly negative storm effects are recorded while both positive and negative effects are seen in winter.

5) Negative effects are predominantly observed during nighttime while positive and negative effects are associated with daytime periods

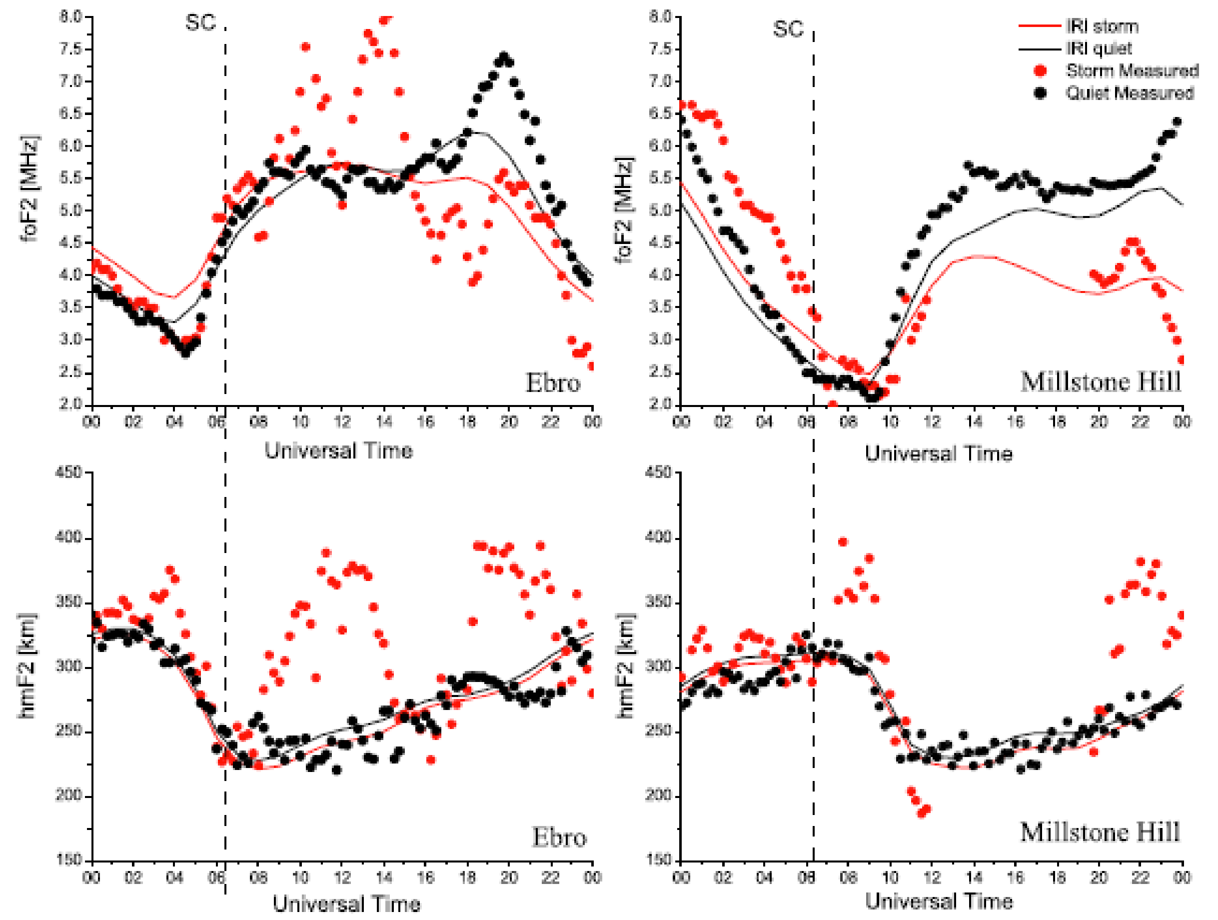
6) The peak height ***hmF2*** increases systematically few hours after storm onset.

Description of hmF2 storm effects

Ebro 24 August 2005 **Millstone Hill**

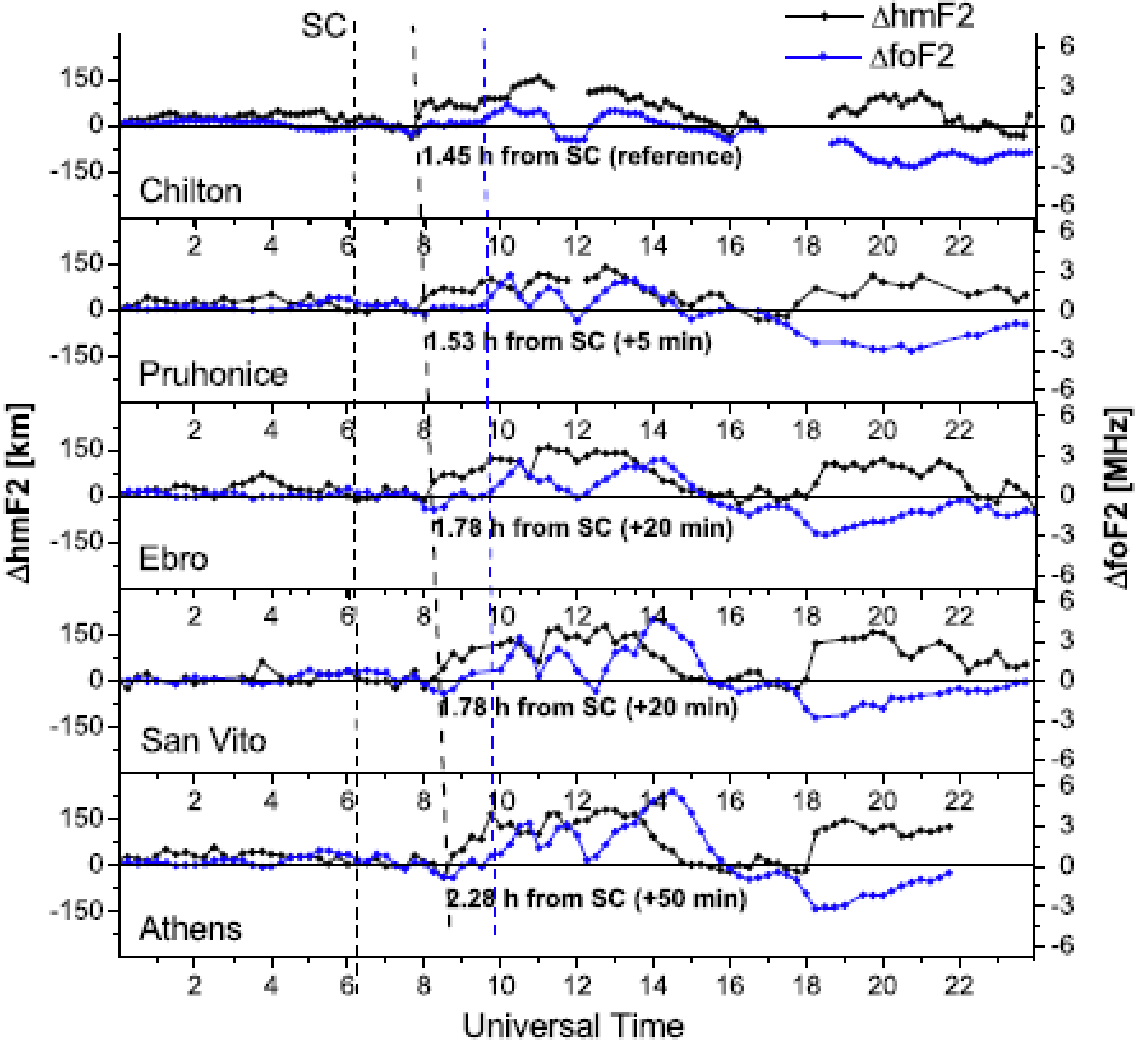
foF2

hmF2



Ionospheric uplifting is observed preceding both negative and positive foF2 storm effects

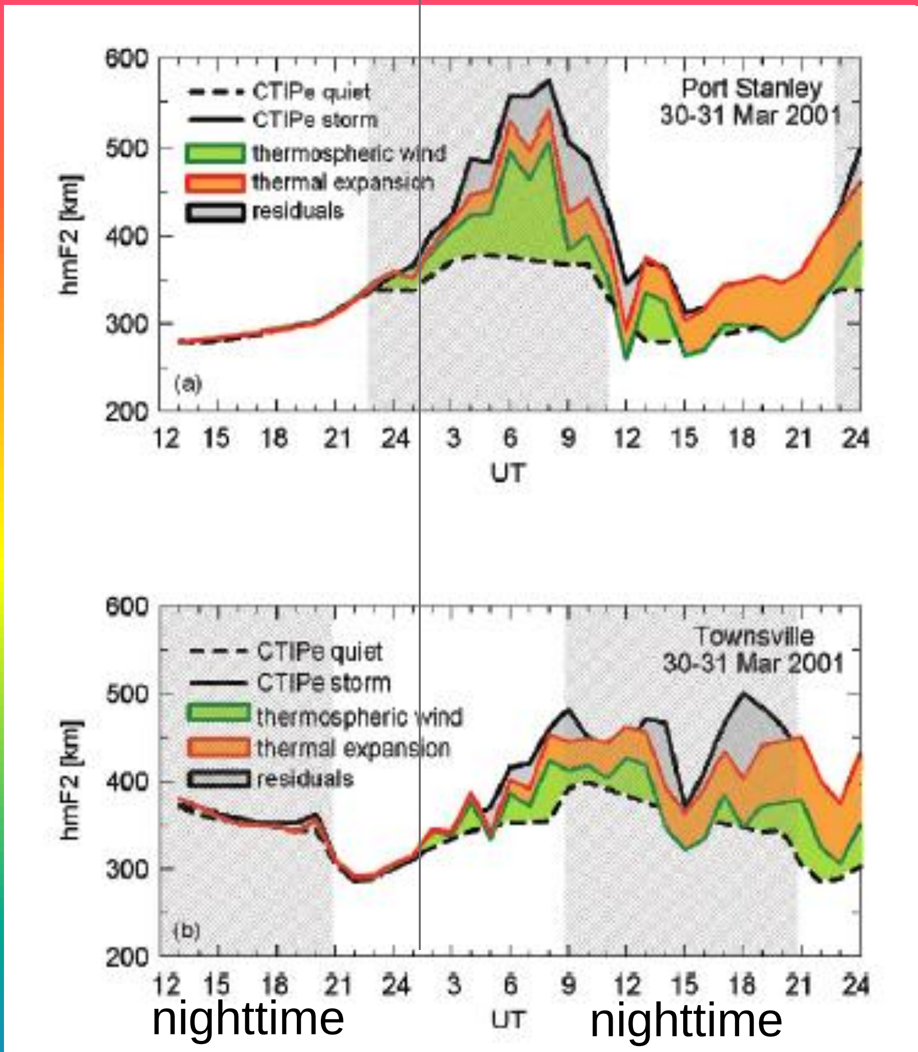
Paznukhov et al., JGR, 2009



- The increase in foF2 lags the increases in hmF2.
- Storm disturbance originating at high latitudes propagates equator-ward.

Paznukhov et al., JGR, 2009:

storm commencement on 31 March 2001 occurred approximately at 01 UT.



nighttime

nighttime

daytime

– – CTIPe *hmF*2 simulation results for quiet periods

— CTIPe *hmF*2 simulation results for storm periods

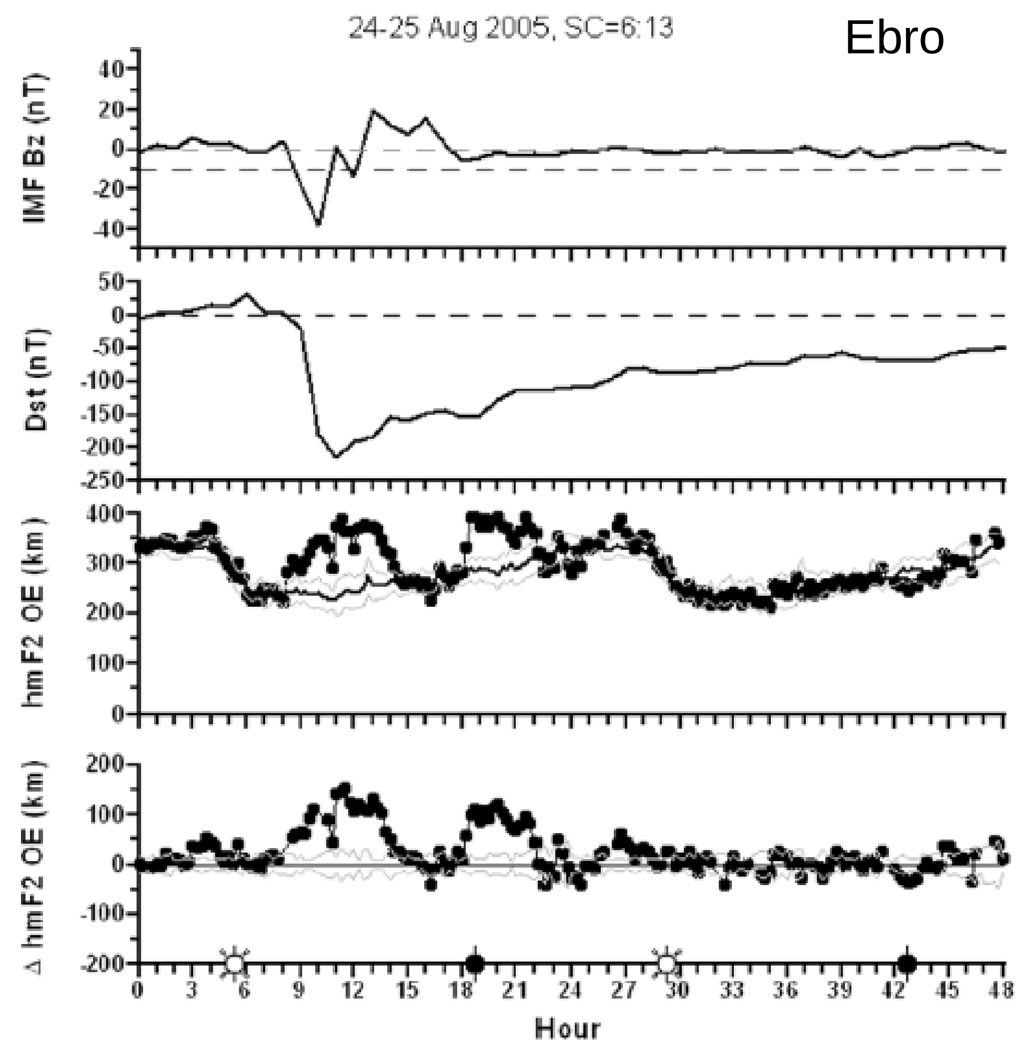
Green area: *hmF*2 changes due to the horizontal wind

Orange area: thermal expansion contribution in uplifting *hmF*2.

Gray area: residuals, due to uncertainties in the analysis and possible influence of electric fields at mid latitudes.

Fedrizzi et al., AGU Monograph, 2013

Description of hmF2 storm effects



IMF B_z

Dst

hmF2 measured (dotted line) quiet hmF2 pattern (black thick line)

ΔhmF2

Trigger mechanism:

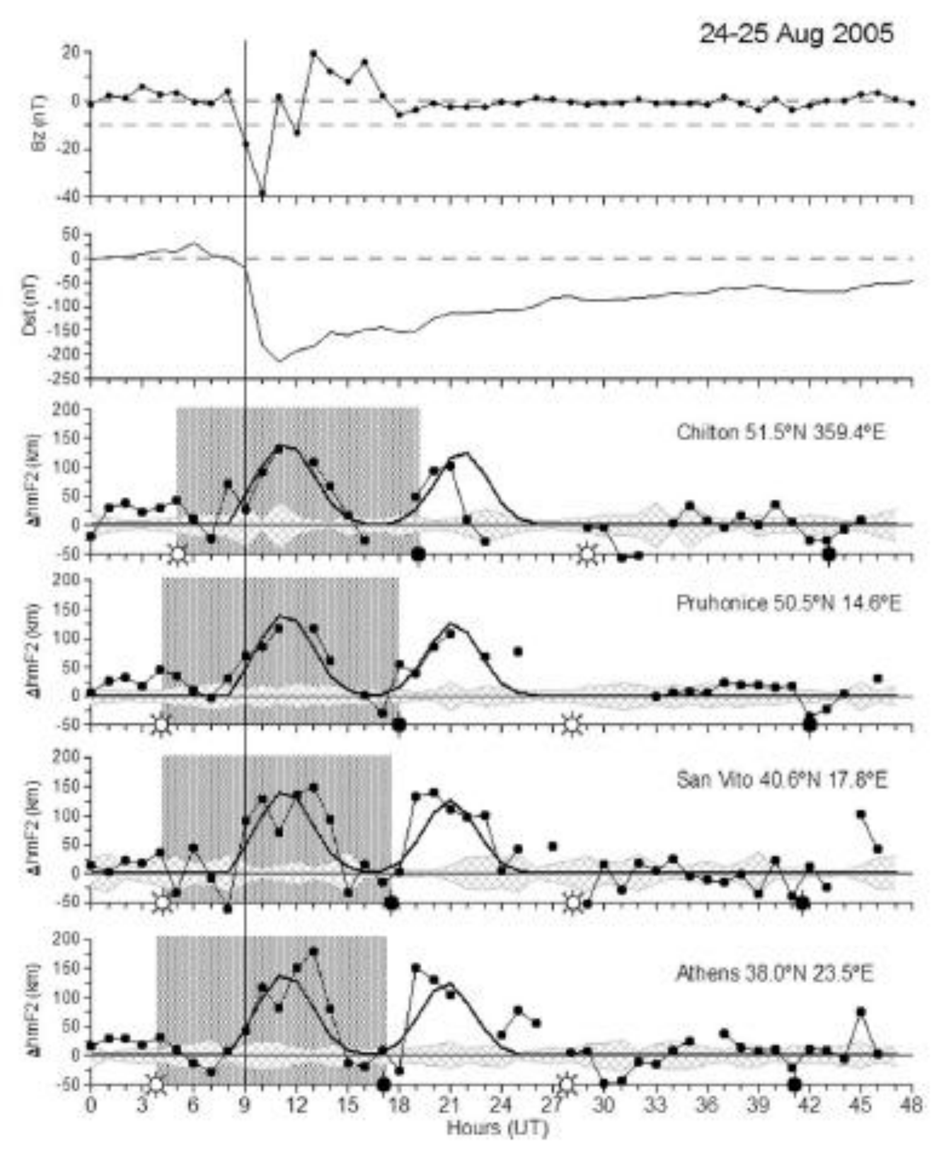
ΔBz > 20 nT within a time window of 3 hours

and

a drop of Bz to -10 nT

The thin gray lines indicate the standard deviation expected for a quiet day.

Blanch and Altadill, JGR, 2012

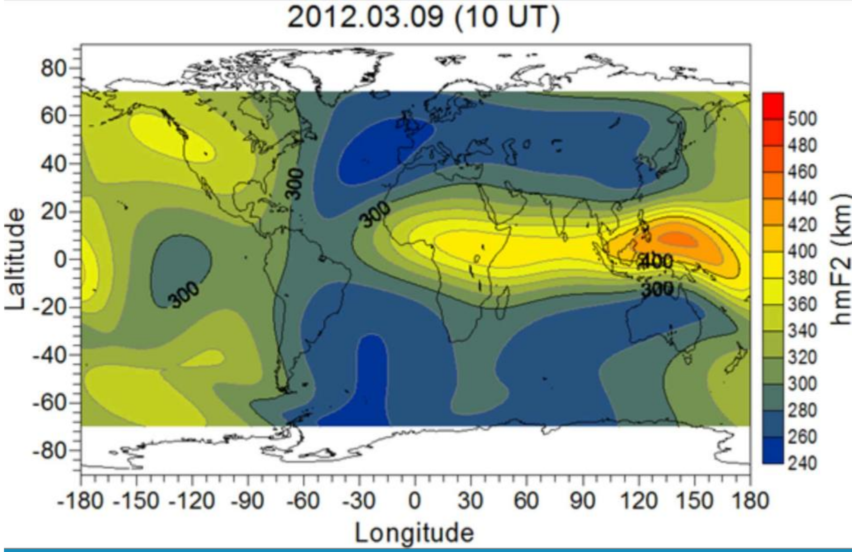


IMF B_z

Dst

●●● ΔhmF2 measured

—— ΔhmF2 model)



Blanch and Altadill, JGR, 2012

IRI-Real-Time

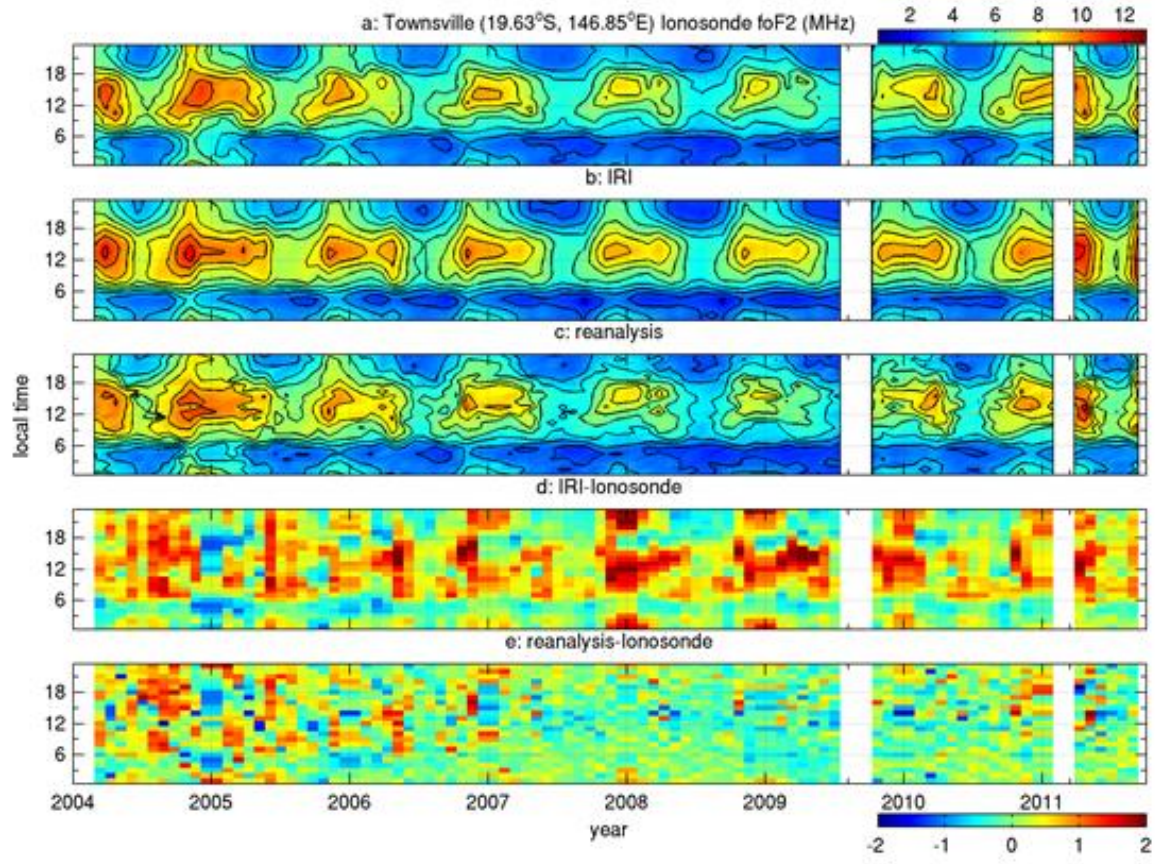
IRI
Real-Time

- ☐ GOAL: Transition from IRI climatological reference model to an ionospheric weather model
- ☐ METHOD: Combine IRI with ground and space data (ionosonde, GPS, COSMIC) – Assimilation, Updating
- ☐ RESULT: Continuous data set [illegible] 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; 2014 COSPAR IRI-RT Session 4.1

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 from GUVI and SSUSI
  - ○ Gulyaeva et al. (IZMIRAN) – Adjusting foF2 & hmF2 with GPS-TEC data
- ☐ 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
  - ○ Yue et al (UCAR) – Kalman filter technique with COSMIC radio occultation data (also GPS-TEC, and Jason-vTEC)
  - ○ Huang, Galkin, Reinisch et al. (UML) - RTAM – Real-Time Assimilative Mapping with GIRO ionosonde data employing a linear optimization of the CCIR coefficients every 15 minutes.

Yue et al., JGR, 2012



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.

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

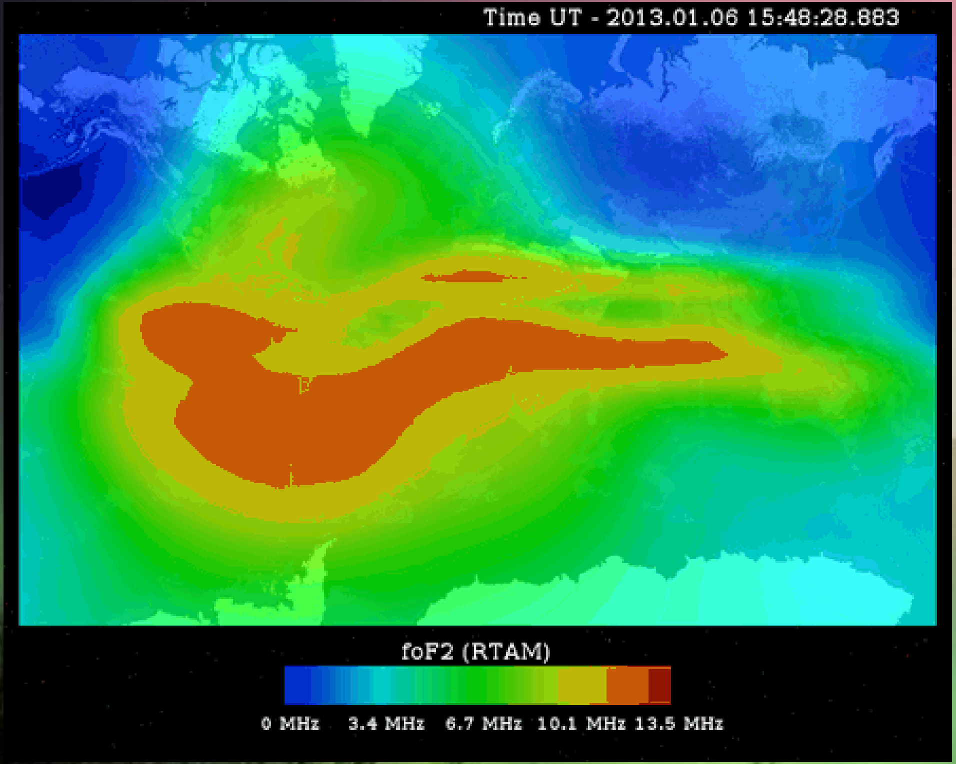
Real-Time Assimilative Mapping (RTAM) for IRI

Global Near-Real-Time F2-layer Critical Frequency

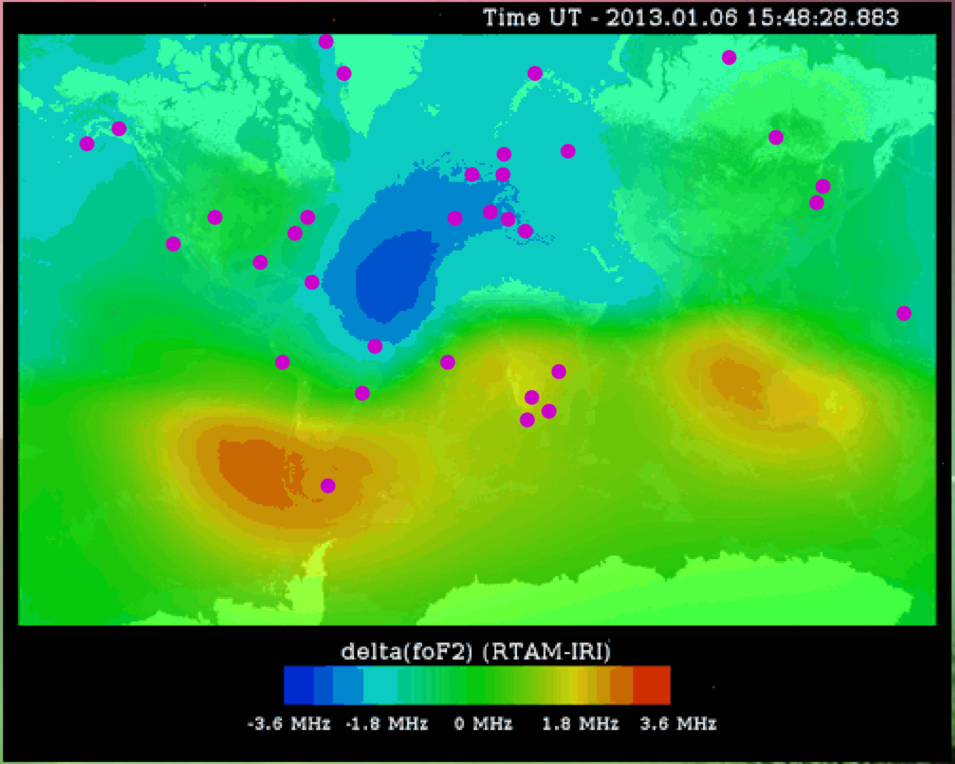
INTERNATIONAL REFERENCE IONOSPHERE

REAL TIME Assimilative Map RTAM

Latest 24-hour foF2



foF2: Weather minus Climate



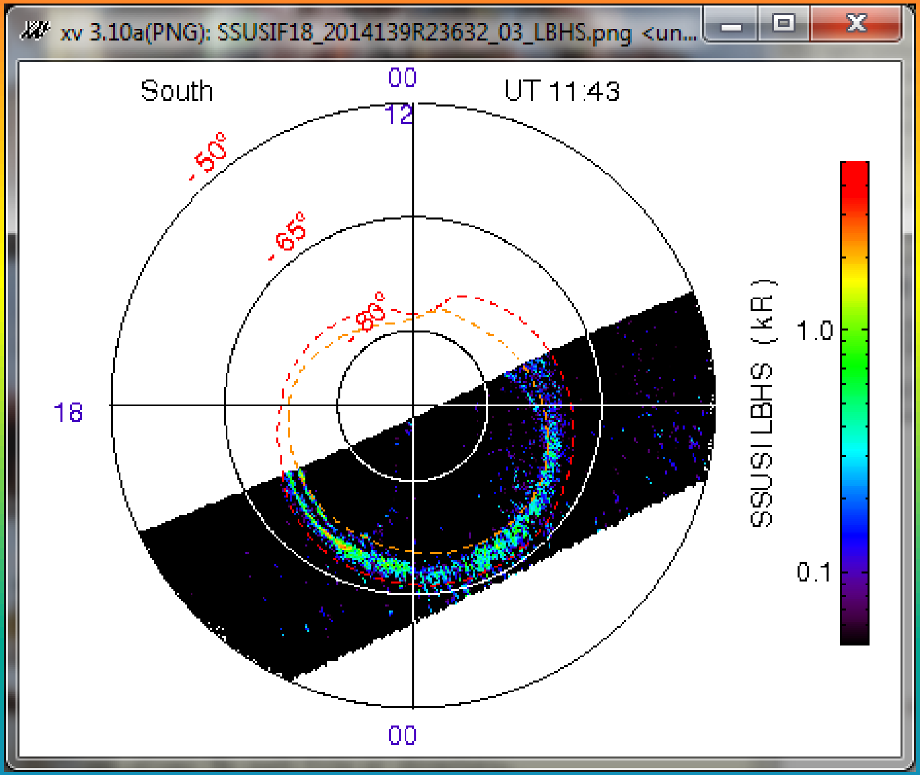
giro.uml.edu/RTAM

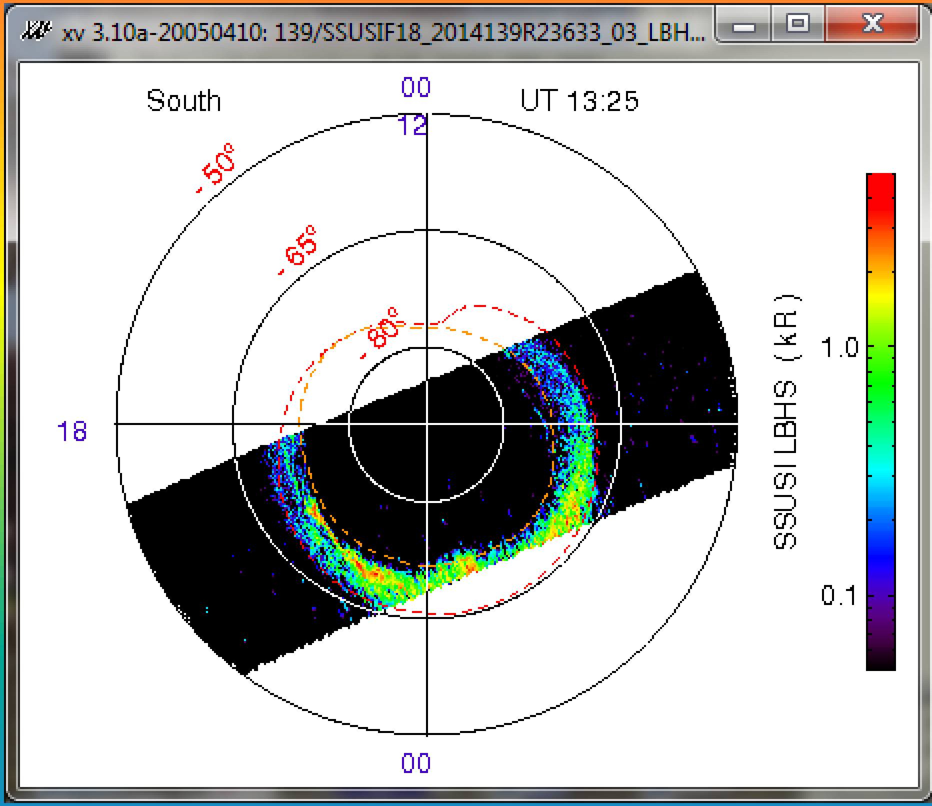
LDI LOWELL DIGISONDE INTERNATIONAL

UNIVERSITY OF MASSACHUSETTS LOWELL UMLCAR CENTER FOR ATMOSPHERIC RESEARCH

Near real-time SSUSI aurora data

SSUSI F18 (May 19, 2014), typically 2-3 hour delay from real time





Measures

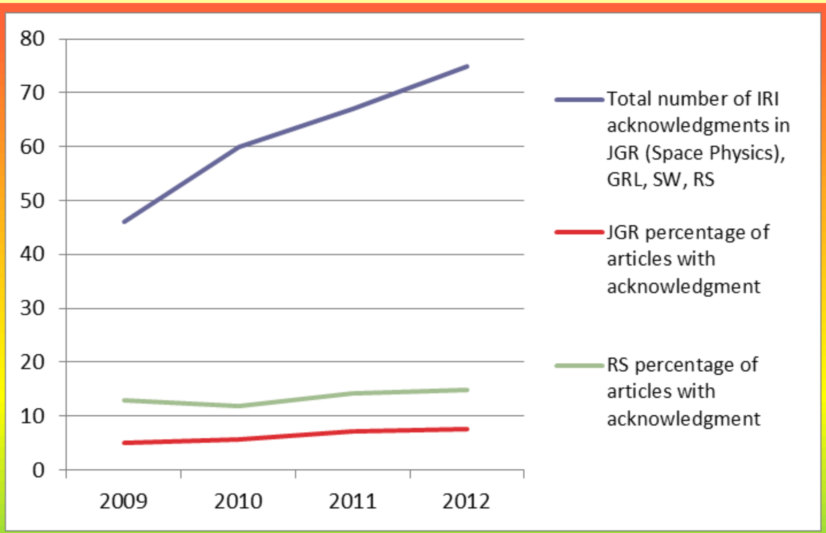
of

Success

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%
2012	8.0%	1.7%	9.5%	15.1%

JGR = Journal Geophysical Research –Space
GRL = Geophysical Research Letters
SW = Space Weather journal
RS = Radio Science



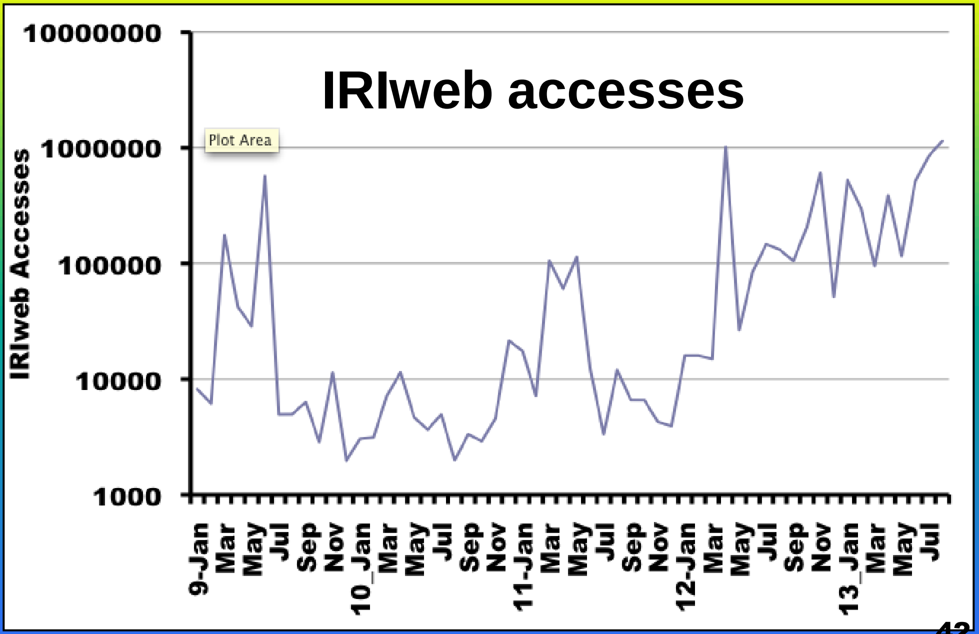
Citations in 23 different journals in 2009-2013:

Journal of Geophysical Research, Geophysical Research Letters, Space Weather, Radio Science, Journal of Atomospheric and Solar-Terrestrial Physics

Journal of Geodesy, Cosmic Research, Solar Physics Plasma Science and Technology, Applied Optics,

Computer Physics communications, GPS Solutions, Computers&Geosciences,

Chinese Journal of Aeronautica, Journal of Asian Earth Science



CEDAR Electrodynamics Thermosphere Ionosphere (ETI) Challenge

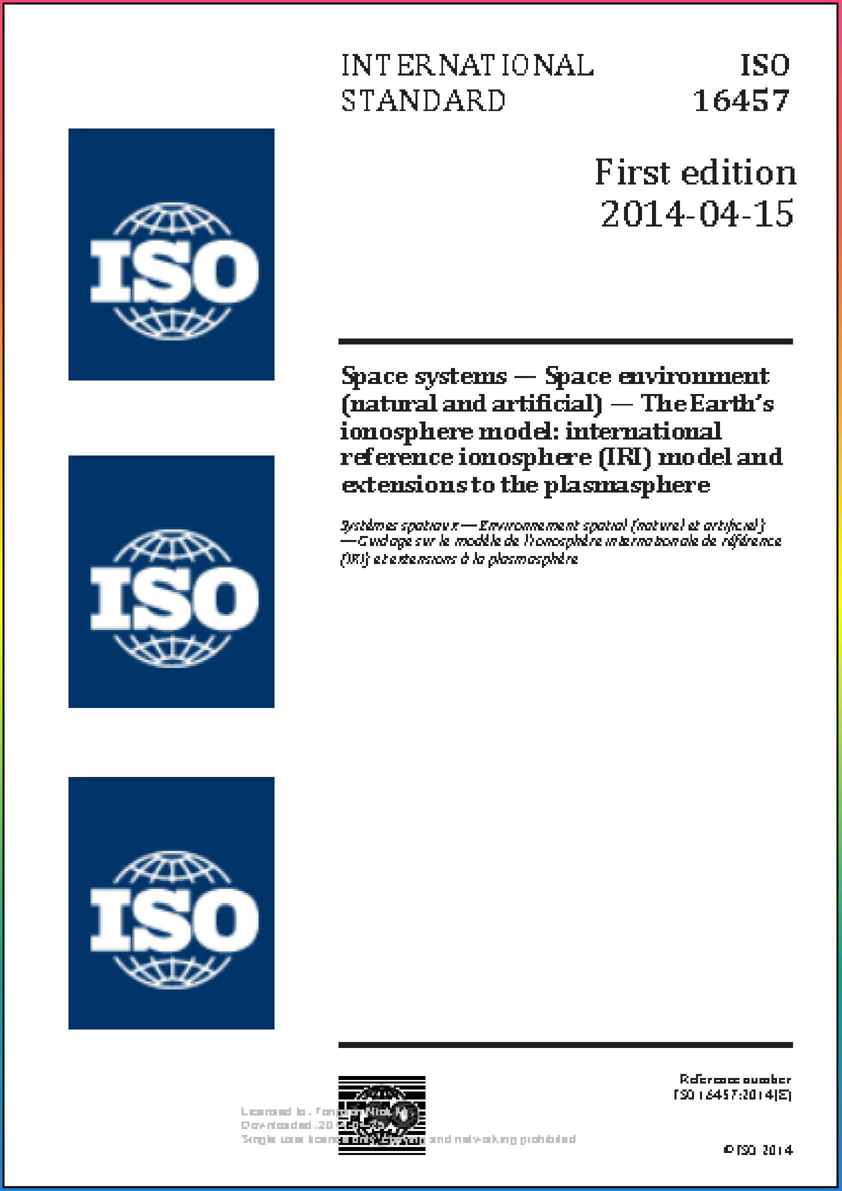
MODELS: IRI, SAMI3, USU-IFM, CTIPe, GITM, TIE-GCM, JPL-GAIM and USU-GAIM

PARAMETERS: ***NmF2*** and ***hmF2*** from ionosondes and COSMIC; ***vertical drift*** from Jicamarca ISR; ***Ne*** along CHAMP orbit

EVENTS: 2 strong, 4 moderate storm events 3 quiet periods

Shim et al., *Space Weather, 2011 and 2012*
Emery et al., *AGU Poster; ISEA talk; SWW talk*

IRI was the clear winner. If not first than second or third in all events and cases considered: RMS, eff=$RMS_{mod}/RMS_{ref}-1$, max_{mod}/max_{obs}, $(max-min)_{mod}/(max-min)_{obs}$



INTERNATIONAL STANDARD

ISO 16457

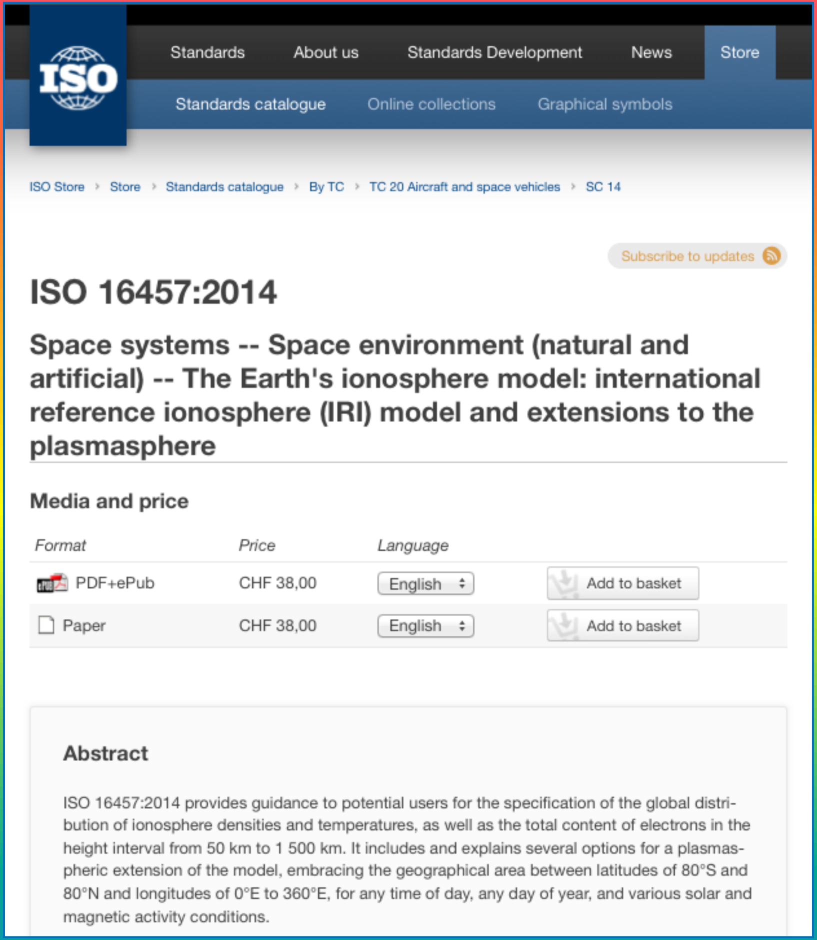
First edition
2014-04-15

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

Systèmes spatiaux — Environnement spatial (naturel et artificiel) — Guidage sur le modèle de l'ionosphère internationale de référence (IRI) et extensions à la plasmasphère

Reference number
ISO 16457:2014(E)

http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=61556



ISO 16457:2014

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

Format	*Price*	*Language*	
PDF+ePub	CHF 38,00	English	Add to basket
Paper	CHF 38,00	English	Add to basket

Abstract

ISO 16457:2014 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.

IRI homepage

http://IRImodel.org

CONCLUSIONES

Nuestros estudios el ámbito del modelo Internacional de Referencia Ionosférica han proporcionado una mejora en la predicción del comportamiento climatológico ionosférico. Además, se ha conseguido simular satisfactoriamente efectos (perturbaciones) causados por eventos severos de meteorología espacial sobre magnitudes ionosféricas clave y predecirlas con cierta antelación. Ello ha de ser un punto de partida para diseñar alertas a los usuarios del modelo para que adopten estrategias de mitigación a dichos efectos.

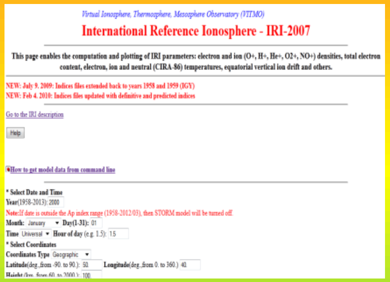
Como continuación del trabajo se pretende adaptar las funciones que determinan el modelo climatológico a las condiciones en un determinado momento, asimilando observaciones en tiempo casi real para obtener una predicción a corto plazo de la ionosfera más realista que la proporcionada por el modelo climatológico y en tiempo real. Además se debe continuar el estudio de las perturbaciones ionosféricas causadas por eventos de meteorología espacial y determinar y modelar el error o afectación que causan en sistemas tecnológicos basados en radiocomunicación y poder adoptar contramedidas adecuadas.

Additional slides

SOME APPLICATIONS

►STANDARD FOR ENGINEERING APPLICATIONS

► VISUALIZATION AND ONLINE TOOLS FOR SPACE ENVIRONMENT


Virtual Ionosphere, Thermosphere, Mesosphere Observatory (VITMO)

International Reference Ionosphere - IRI-2007

This page enables the computation and plotting of IRI parameters: electron and ion (O+, H+, He+, O2+, NO+) densities, total electron content, electron, ion and neutral (CIRA-86) temperatures, equatorial vertical ion drift and others.

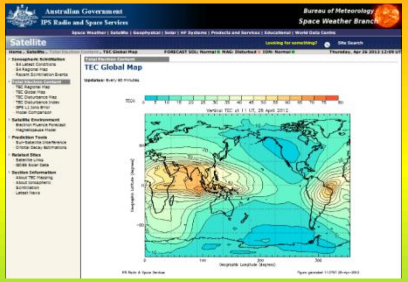
NEW: July 9. 2009: Indices files extended back to years 1958 and 1959 (IGY)
NEW: Feb 4. 2010: Indices files updated with definitive and predicted indices

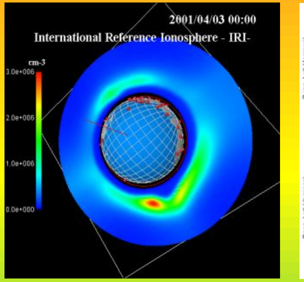
Go to the IRI description

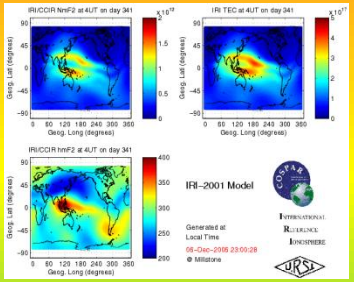
Help

How to get model data from command line

* Select Date and Time
Year(1958-2013): 2000
Note:If date is outside the Ap index range (1958-2012/03), then STORM model will be turned off.
Month: January Day(1-31): 01
Time Universal Hour of day (e.g. 1.5): 1.5
* Select Coordinates
Coordinates Type Geographic
Latitude(deg.,from -90. to 90.): 50. Longitude(deg.,from 0. to 360.) 40.
Height (km, from 60. to 2000.): 100.







► BACKGROUND IONOSPHERE FOR EVALUATING DATA RETRIEVAL TECHNIQUES (TOMOGRAPHY, RADIO OCCULATATION)

► IONOSPHERIC CORRECTIONS FOR EARTH OBSERVATIONS FROM SPACE

► IONOSPHERIC PARAMETERS FOR THEORETICAL MODELS

► HF COMMUNICATIONS (FREQUENCY MANAGEMENT, HAM RADIO)