Ionospheric sounding experiment IONO onboard CubeSat INSPIRE-SAT 7

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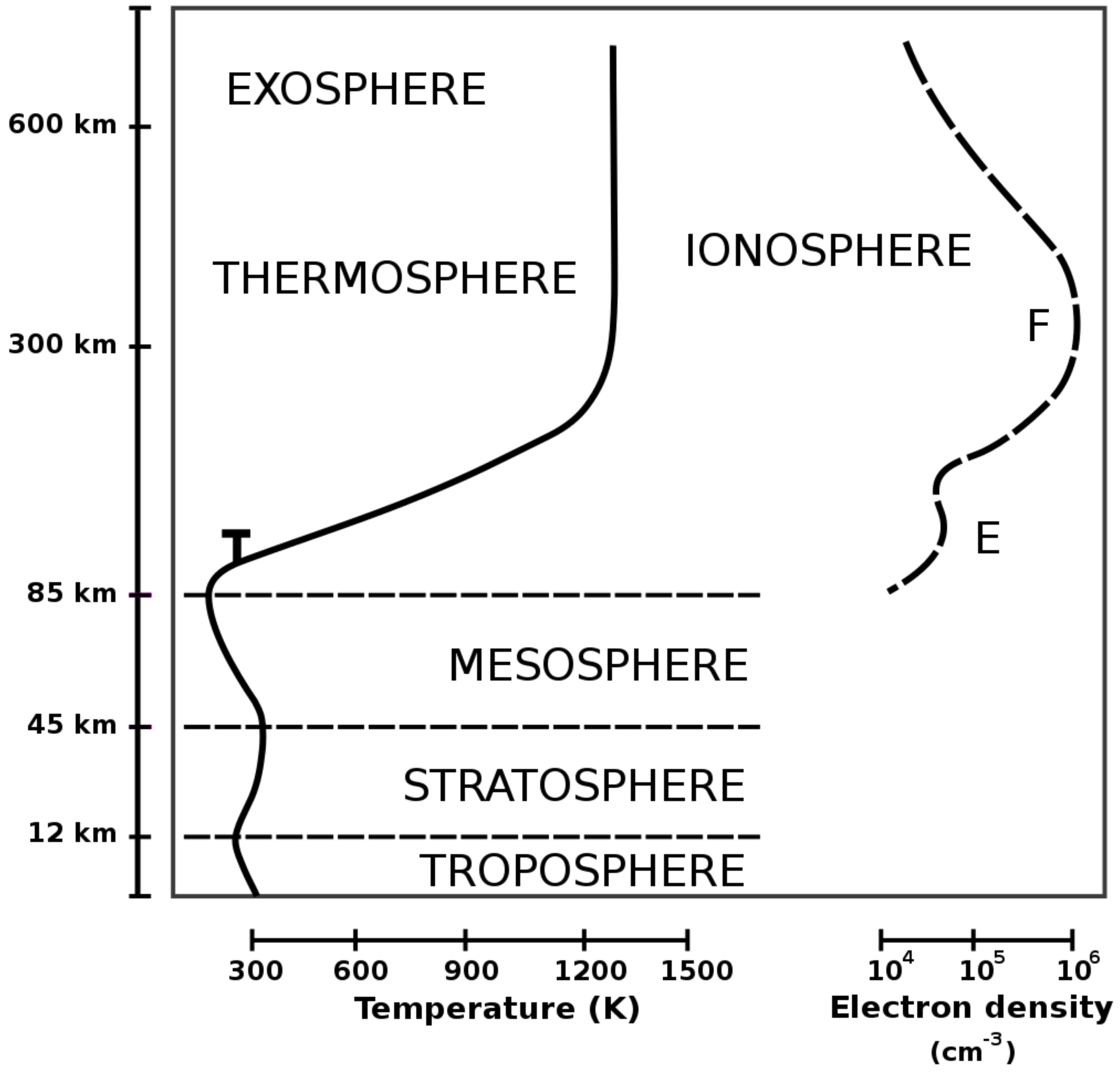
Ionosphere sounding

Motivations

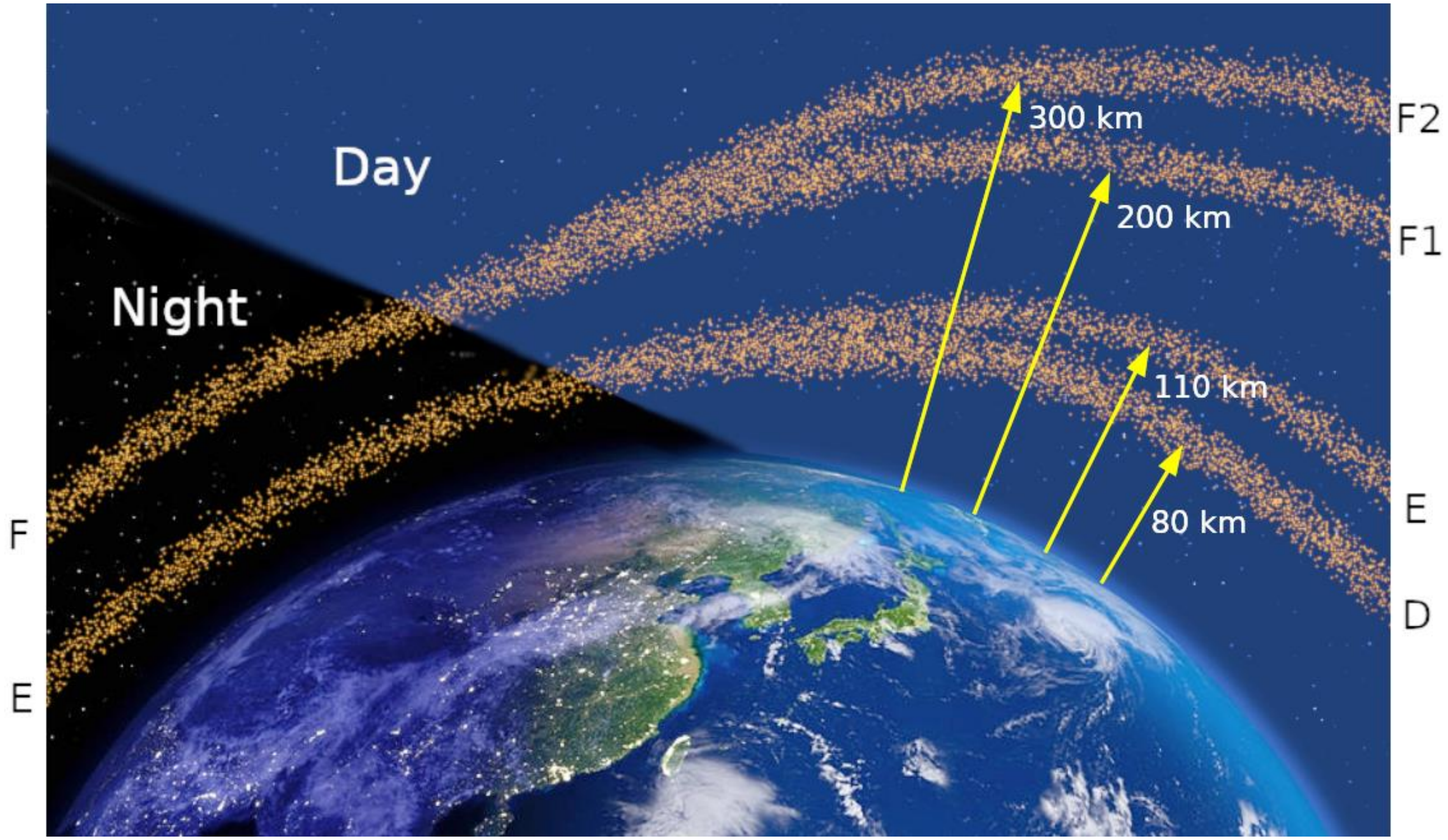
- The ionosphere (50 to 1000 km) receives UV and X radiations from the Sun and produces ions and electrons;
- The electronic density resulting from the ionization varies as a function of the local time, the season, the solar activity;
- The radio waves propagation is affected by the electron density and the emission elevation (refraction and reflection depending on the wavelength).



Ionosphere sounding

Applications

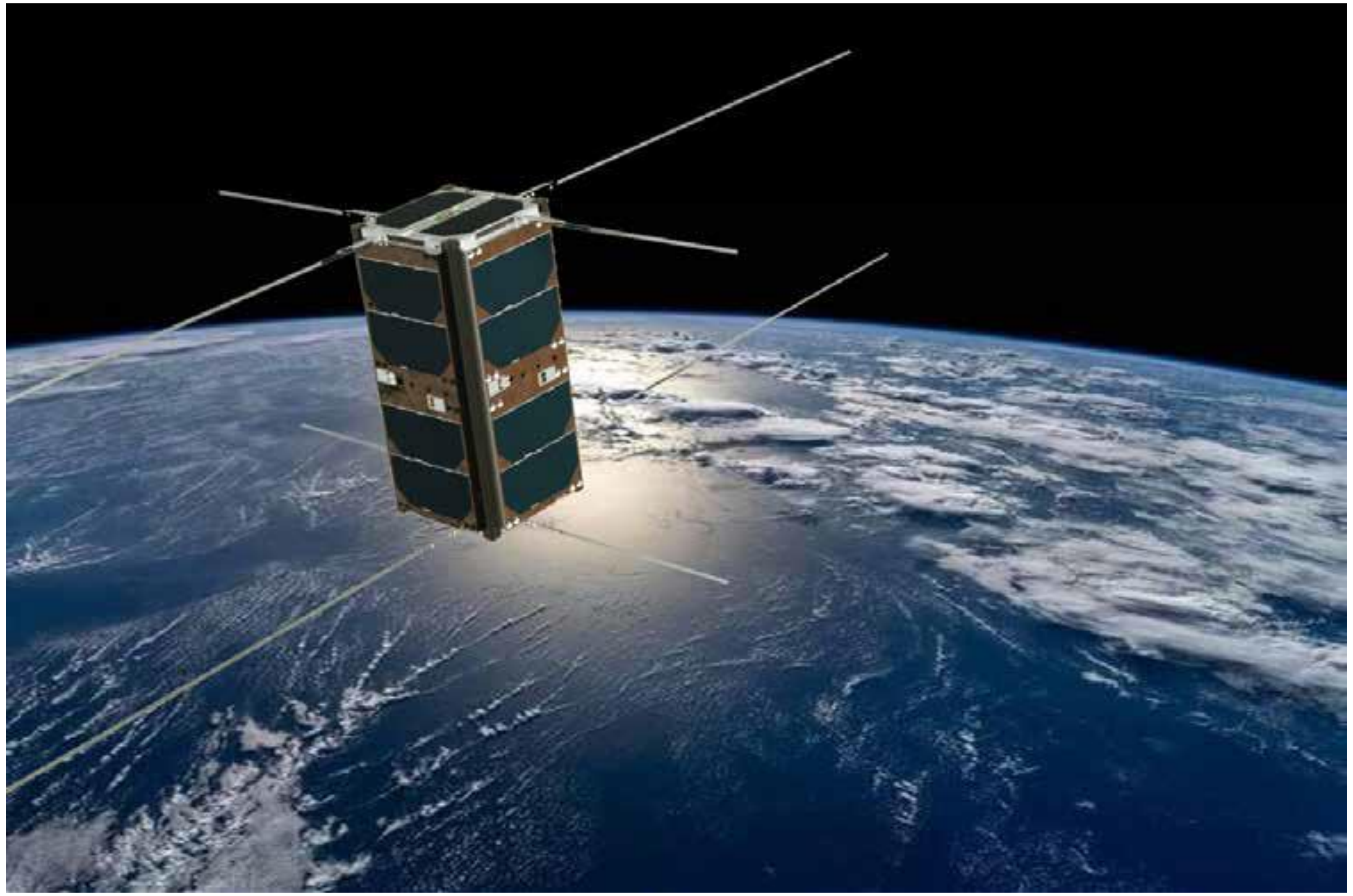
- Ionospheric modelling;
- HF wave propagation modelling;
- Disturbance characterization;
- Determination of radar horizon;
- Connection with the magnetospheric activity;
- Perturbation by atmospheric thunderstorms and seismic phenomena.



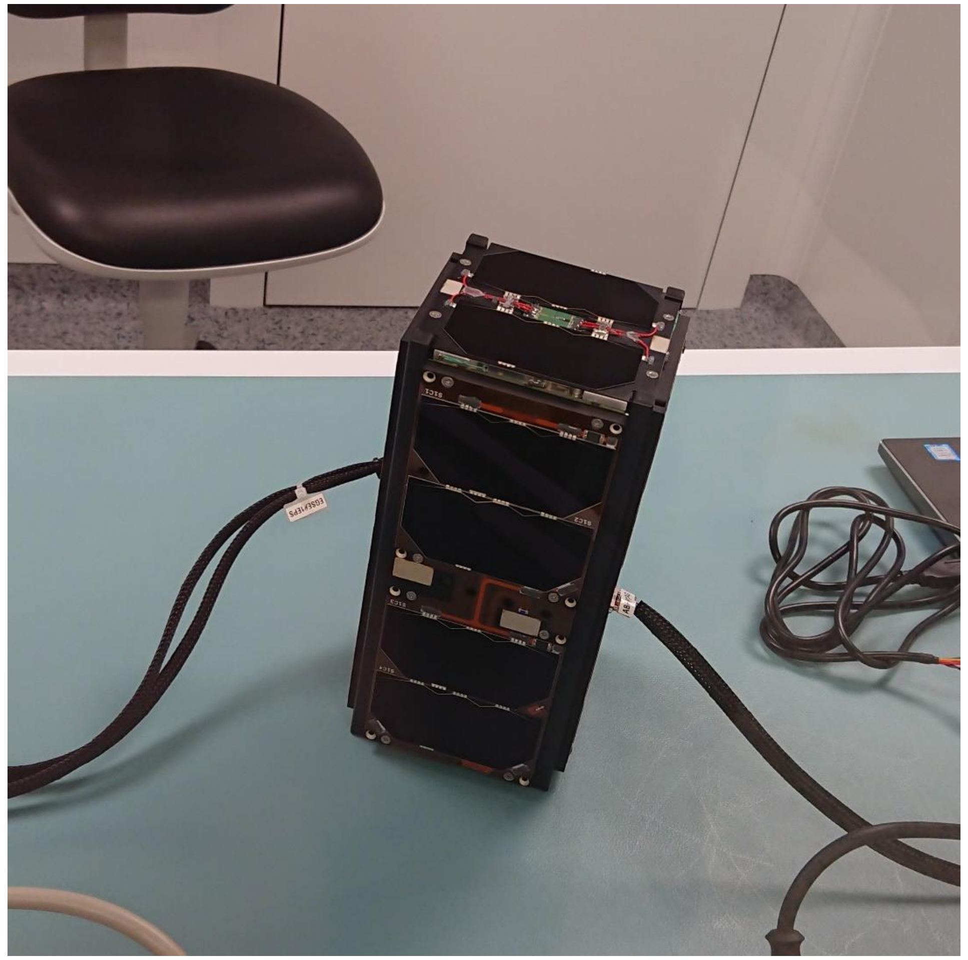
CubeSat INSPIRE-Sat 7

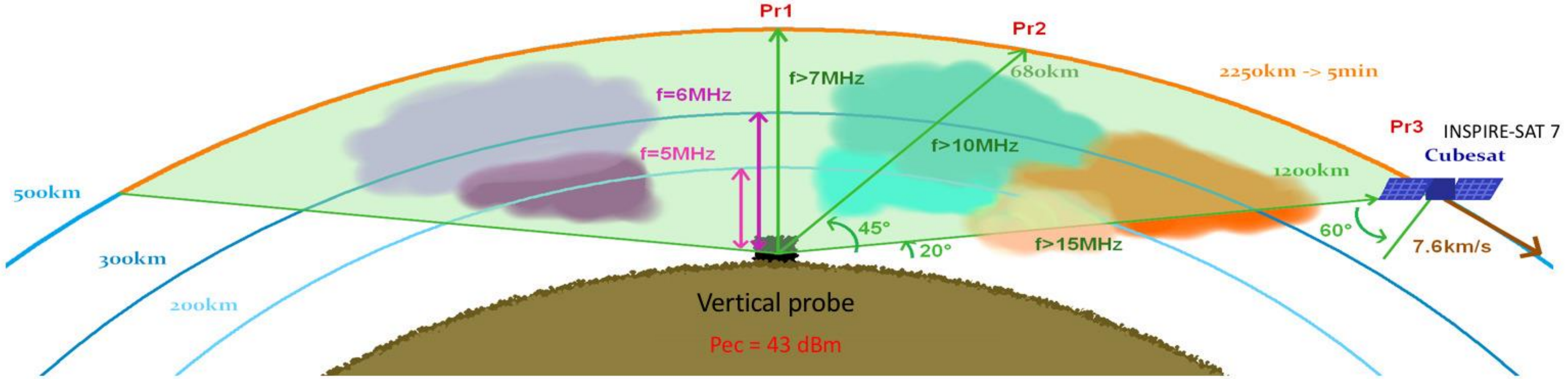
Scientific objectives

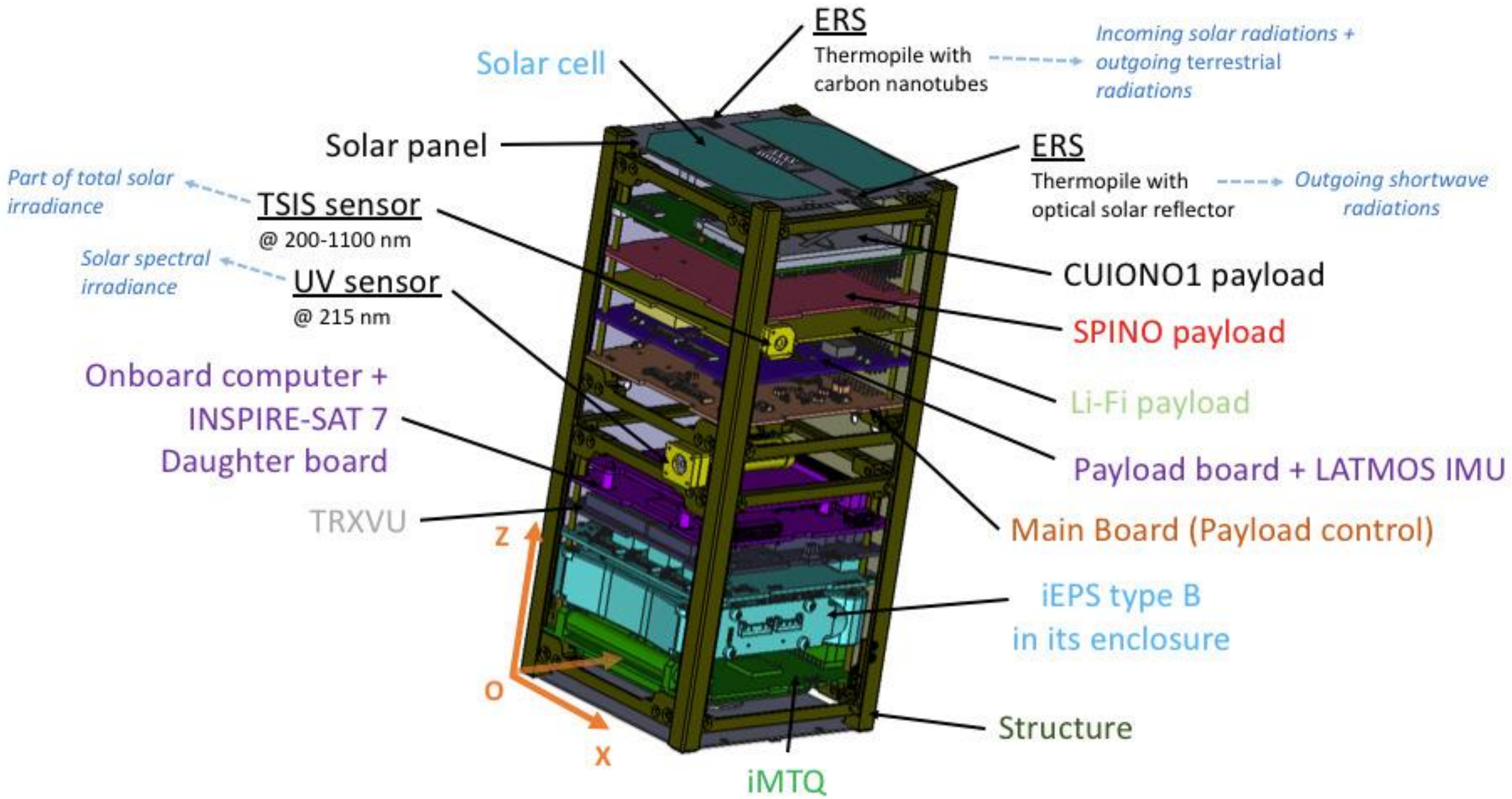
- Measuring the Earth's radiation budget at the top of the atmosphere and sounding the ionosphere;
- 2U CubeSat weighting ~3 kg;
- Power limit consumption 3 W;
- Sun-synchronous orbit at altitude 600 km with descending node at ~0930 LT;
- Launching in 2023;
- Will join UVSQ-Sat (1U CubeSat, launched on January 24th, 2021).



Ionospheric sounding experiment IONO







International Reference Ionosphere

IRI model history

Year	Event (referecne)	Description	Database
1968	COSPAR establishes IRI Working Group	K. Rawer, Chair; WG members predominantly from space community (satellite and rocket measurements)	
1969	URSI joins IRI project	New WG members from ground observation community	
1975	IRI-75: Set of Tables (Rawer et al., 1975)	Representative values for equat., low, mid latitudes	Ionosonde, ICS, AEROS
1978	IRI-79: URSI Special Rep.: (Rawer et al., 1978a)	Global coverage using CCIR maps for peak parameters,	Global ionosonde network
1981	IRI-79: WDC-A-STP Rep. (Rawer et al., 1981)	modified for foF1 and foE; using IG12 with foF2	
1986	IRI-86: floppy disk for PC (Bilitza, 1985, 1986)	- Improved Ne at low latitudes - Global Te, Ti models	AEROS-A,-B, AE-C,-D,-E, ISIS-1, -2, ICS data
1990	IRI-90: NSSDC Report (Bilitza, 1990)	- URSI maps for *foF2* - Improved NmE model	- More global ionosonde data - Incoherent scatter (ICS) data
1995	IRI-95: online (IRIWeb) (Bilitza, 1997)	Improvements at low latitudes	DE-2 data
1999	URSI Resolution	IRI recognized as the international standard for the ionosphere	
2001	IRI-2001 (Bilitza, 2001)	-2 new options for Ne D-region - new models for F1 and B0,B1 - STORM model - New model for Te - IGRF update	- Rocket compilations - Ionsonde network - Stormtime ionosonde data - Intercosmos 19, 24, 25 - Using latest coefficients
2007	IRI-2007 (Bilitza and Reinisch, 2008)	- 2 new options for Ne topside - new ion composition model - spread-F occurrence model - IGRF-10	- TS: Alouette 1,2, ISIS 1,2 - AE-C,-E, Intercosmos 24 - Brazilian ionosonde data - Using latest coefficients
2012	IRI-2012 (Bilitza et al., 2014)	- New model for B0 and B1 - Auroral boundaries model - Storm-time model auroral foE - Te solar activity dependence - FLIP ion composition model - NRLMSIS00, IGRF-11	- Worldwide digisonde data - TIMED/GUVI data - TIMED/SABER data - Satellite data base - FLIP normalized to IRI-Ne - Update to latest version
2014	ISO Certification	IRI certified as ISO standard for the ionosphere	
2016	IRI-2016 (Bilitza et al., 2017)	- 2 new models for hmF2 - Ion composition at low F10.7 - Real-Time IRI (IRTAM)	- Digisonde: Radio Occ. - C/NOFS data - Global Digisonde Network

IRI data sources

(a)

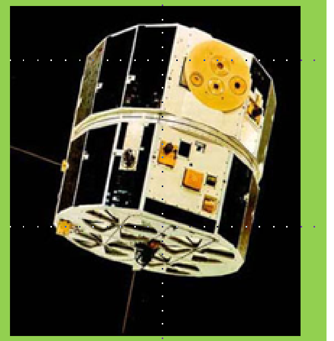
(b)

(c)

Data sources

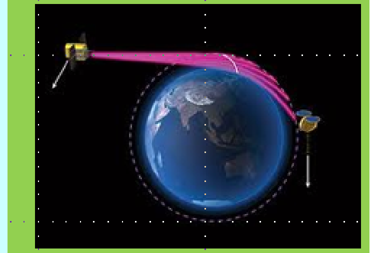
Instrument	*Platform*	*Parameter*	*Comments*
Ionosonde	Worldwide ~170 stations	N_e from E to F peak	From fifties to now
Incoherent scatter radar	Jicamarca, Arecibo, St. Santin Millst. Hill, Malvern	N_e whole profile incl. E-Valley T_e, T_i N_i, v_i	Few radars, World days *Comparisons:* EISCAT, Kharkiv
Topside sounder	Alouette 1, 2 ISIS 1, 2	N_e topside profile	Newer data from Ohzora, ISS-b, IK-19
In situ	AE, Aeros, IK, TIMED DE, C/NOFS	N_e T_e T_i N_i v_i	cont.: DMSP, Kompsat, Hinotori
Rocket	Rocket data compilations	D-region parameters	sparse data set
GNSS	GPS, Glonass Galileo,Navic Beidou	*TEC*	Global data; No profile information
LEO GPS (radio occultation)	COSMIC, CHAMP, others	N_e profile, *hmf2*	Data need quality control

(d)



(e)

(f)



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Bilitza, *Adv. Radio Sci.*, **16**, 1-11, 2018, https://doi.org/10.5194/ars-16-1-2018

Ionospheric dynamo region & variability

Diurnal ionospheric current

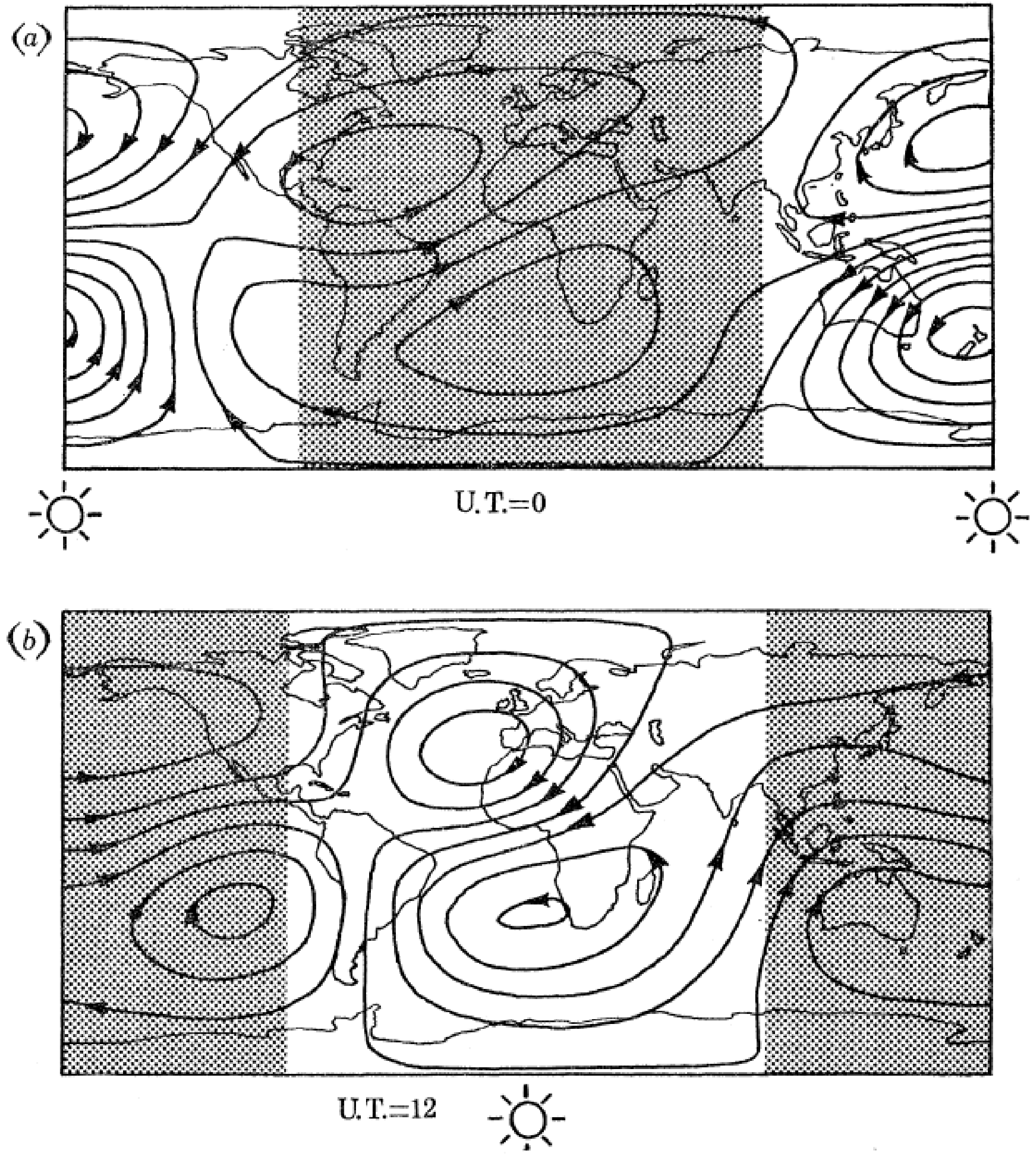


FIGURE A 2. Internal current function of S; contour interval 20 kA:
(a) U.T. = 0h. (b) U.T. = 12h.

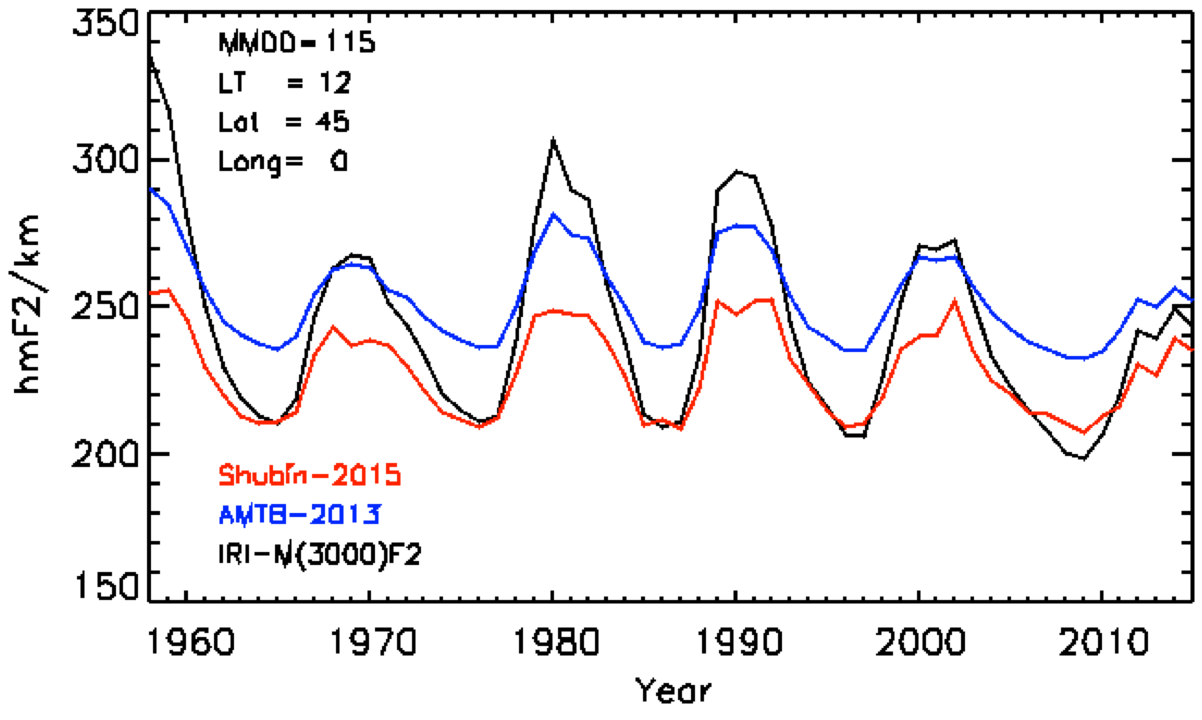
Worldwide Distribution of Geomagnetic Tides

Author(s): S. R. C. Malin

Source: *Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences*, Aug. 2, 1973, Vol. 274, No. 1243 (Aug. 2, 1973), pp. 551-594

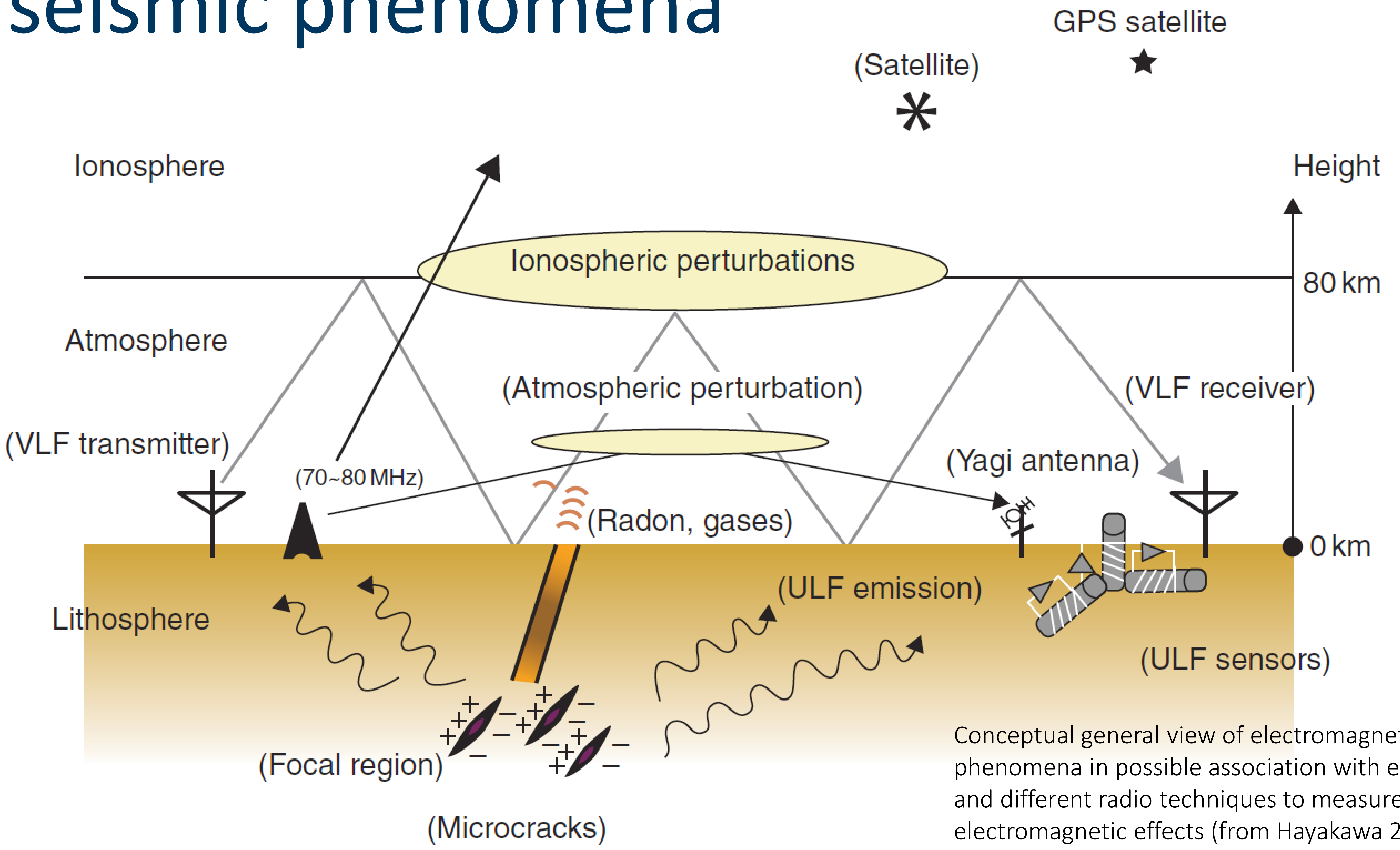
Published by: Royal Society

Stable URL: https://www.jstor.org/stable/74228



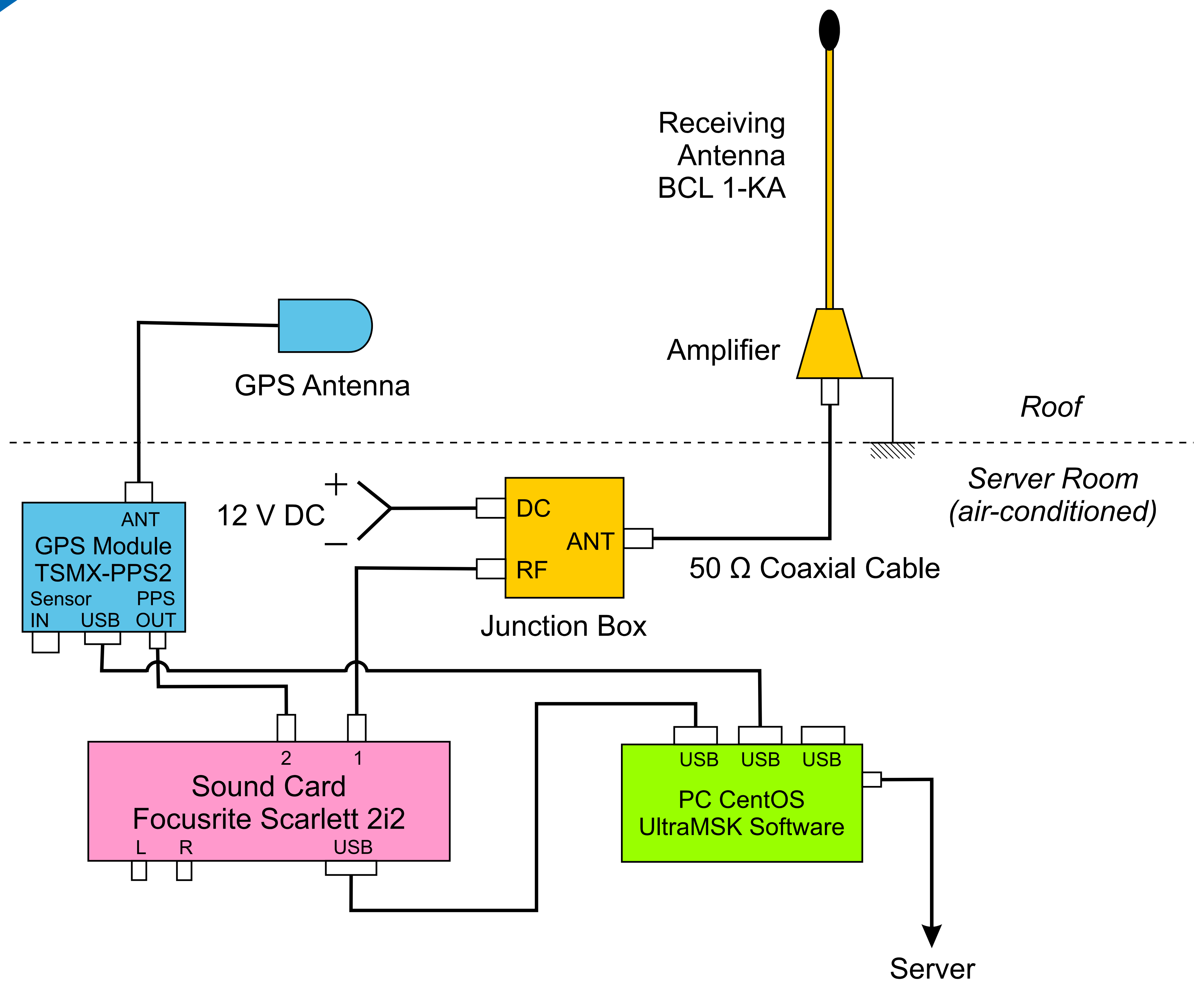
F-peak height in IRI model between 1958 and 2015. Bilitza, Adv. Radio Sci, 2018.

Perturbation by atmospheric thunderstorms and seismic phenomena



Conceptual general view of electromagnetic phenomena in possible association with earthquakes and different radio techniques to measure those electromagnetic effects (from Hayakawa 2015).

VLF/LF reception system



- Monopole antenna (92 cm, Procom BCL 1-KA, V polarization, 10 kHz – 100 MHz);
- Preamplifier;
- Junction box supplied by 12 V DC-current producing a RF-signal;
- Sound card (Focusrite Scarlet 2i2) digitizing the radio signal: sampling frequency 44.1 kHz – 192 kHz with 24-bit output coding;
- GPS receiver module with a PPS output (update rate 1 Hz) for precise synchronisation;
- PC running Linux CentOS with UltraMSK software;
- The system measures simultaneously the amplitude & phase of several transmitters (up to 20 channels).