Ionosphere

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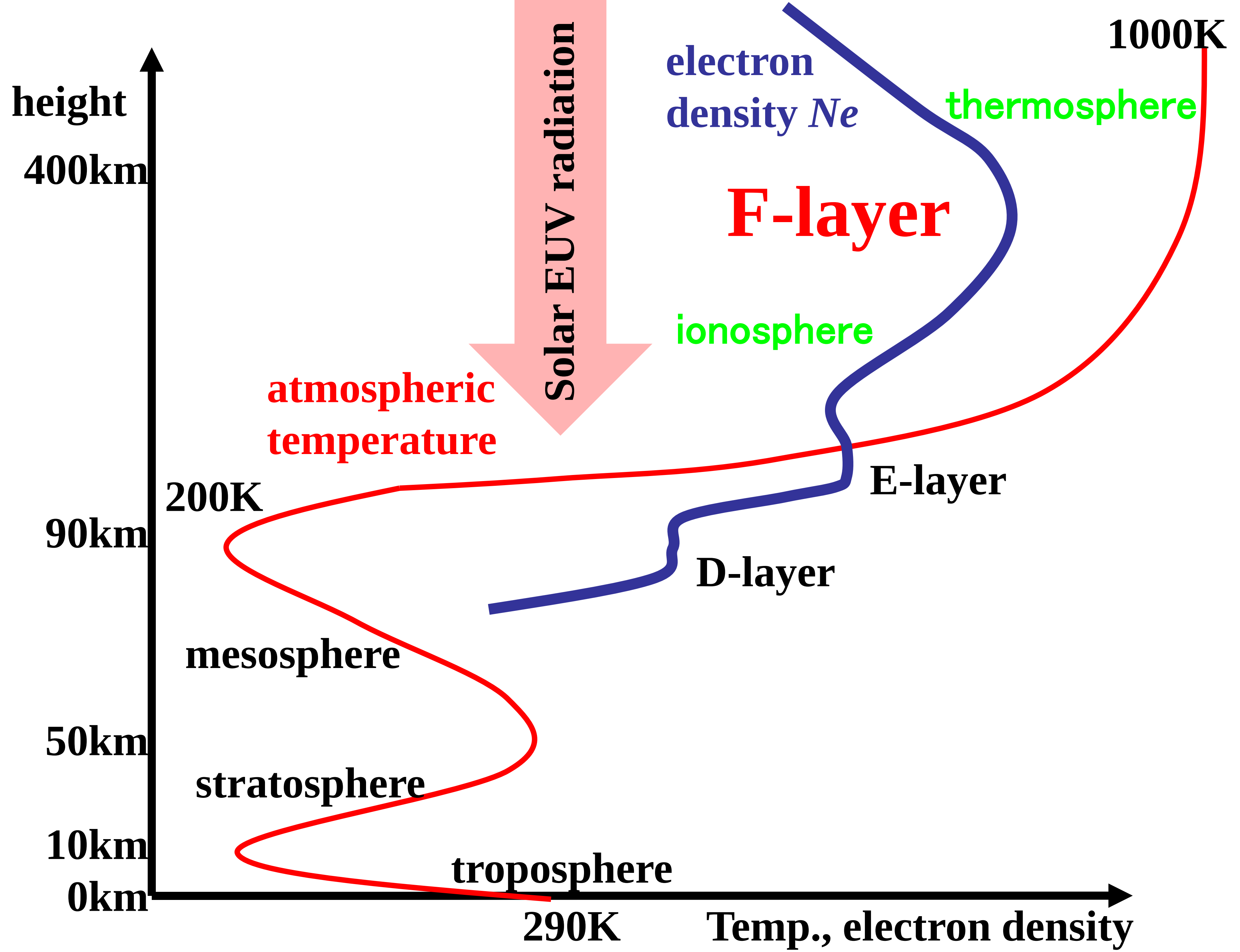
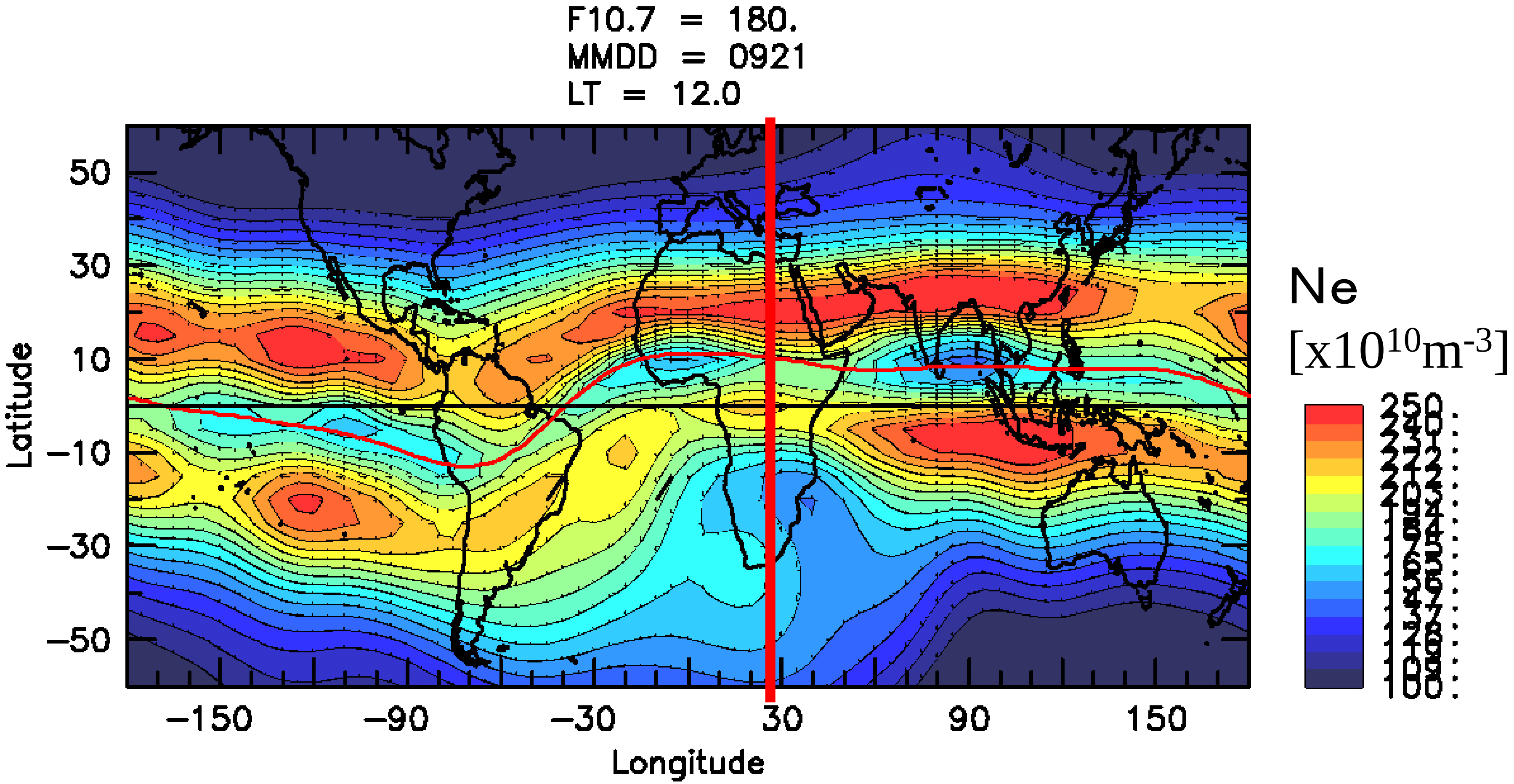
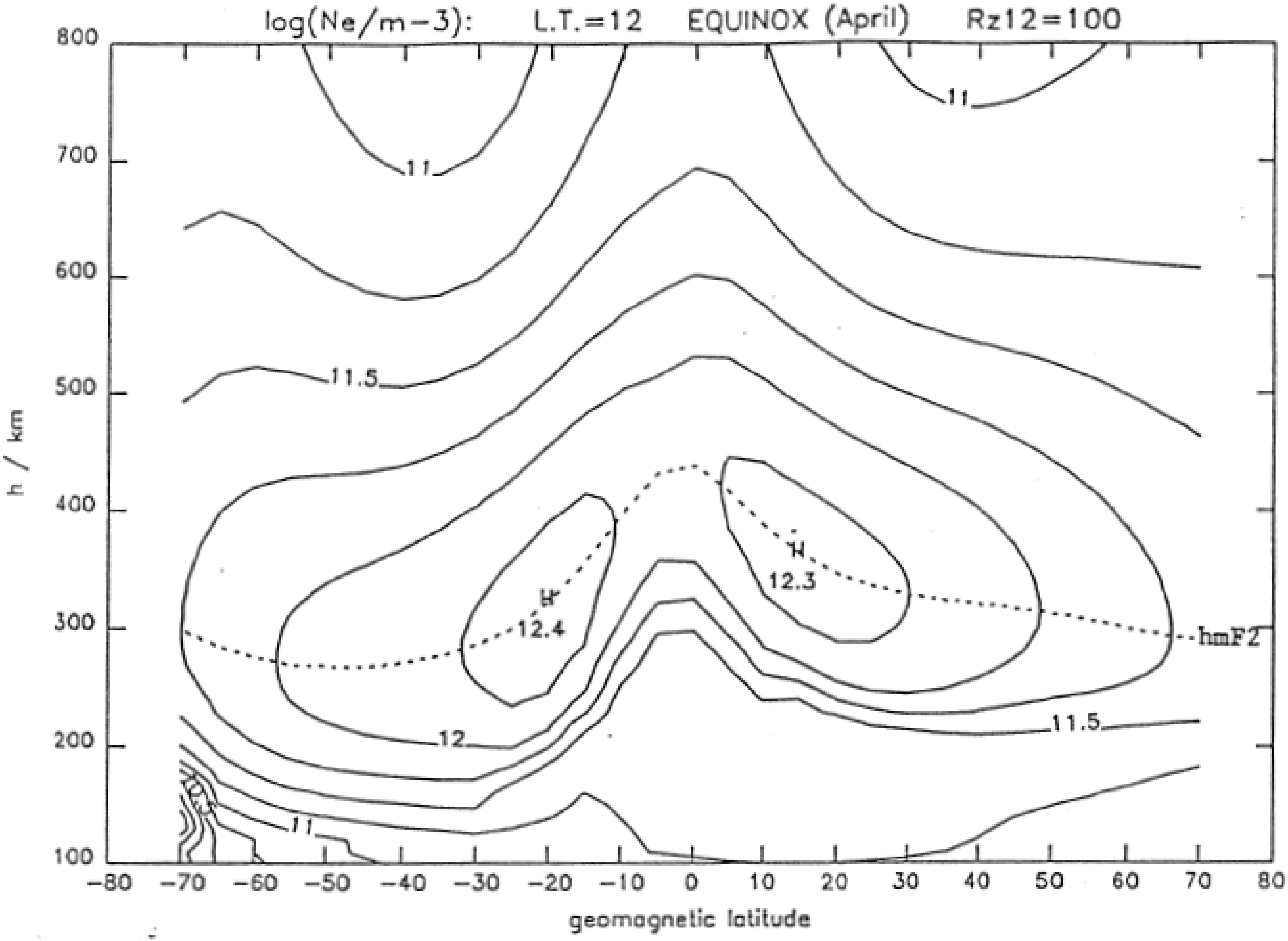
International Space Weather Initiative (ISWI) UN/NASA/JAXA Workshop,
Helwan, Egypt, November 6, 2010 (tutorial talk)

Contents


height
400km
90km
50km
10km
0km
Solar EUV radiation
electron
density Ne
thermosphere
1000K
F-layer
ionosphere
atmospheric
temperature
200K
E-layer
D-layer
mesosphere
stratosphere
troposphere
290K
Temp., electron density

IRI model
maximum electron density of the F_2-layer



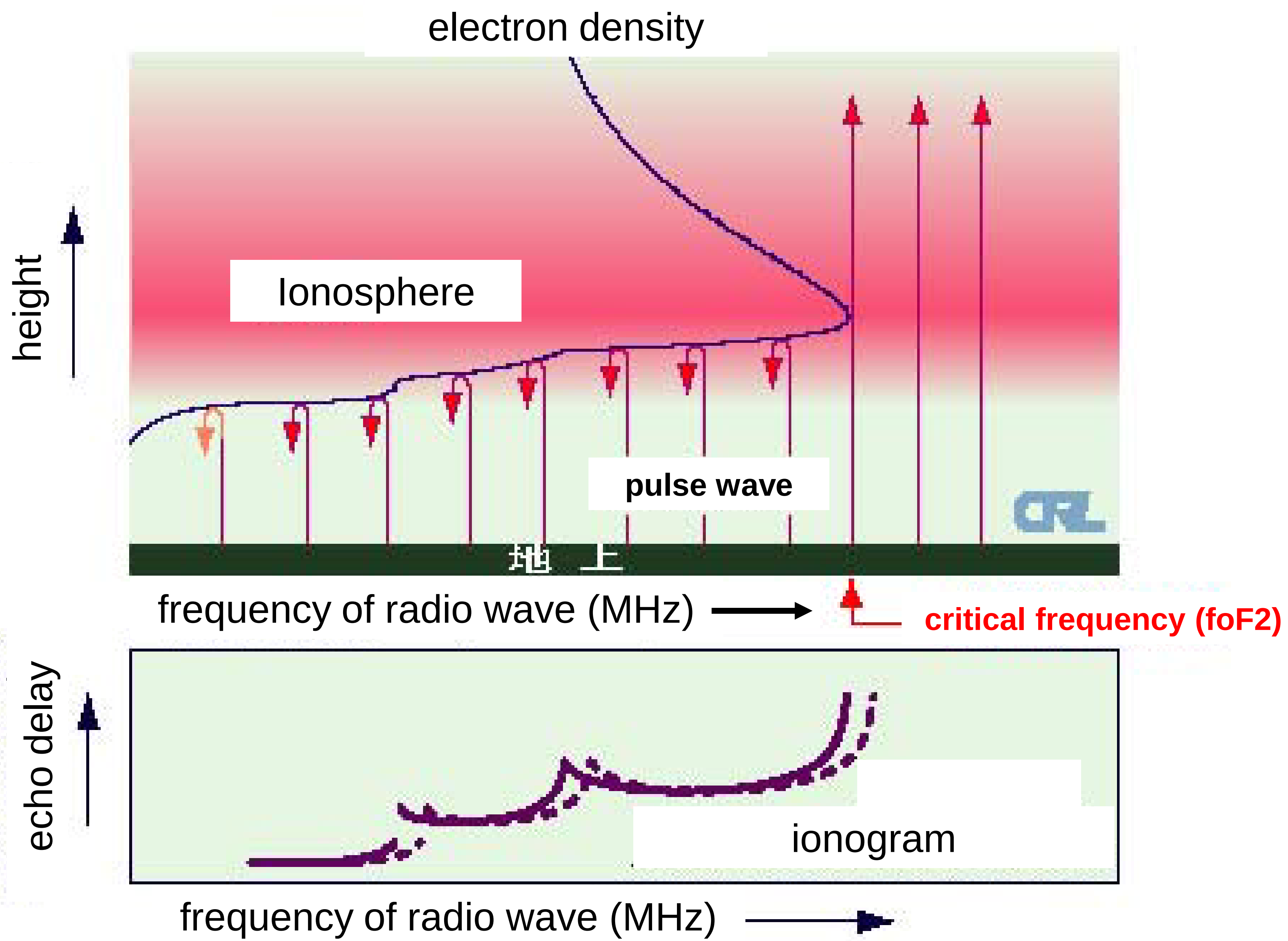


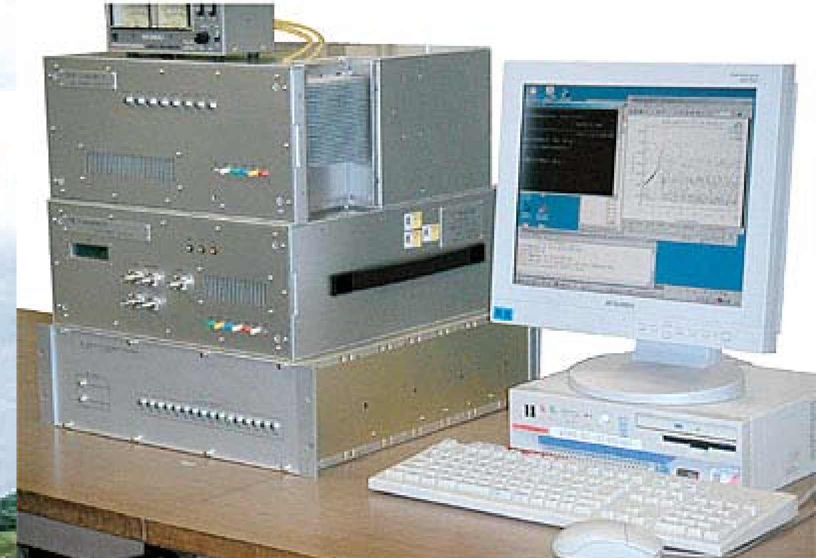
from IRI1990

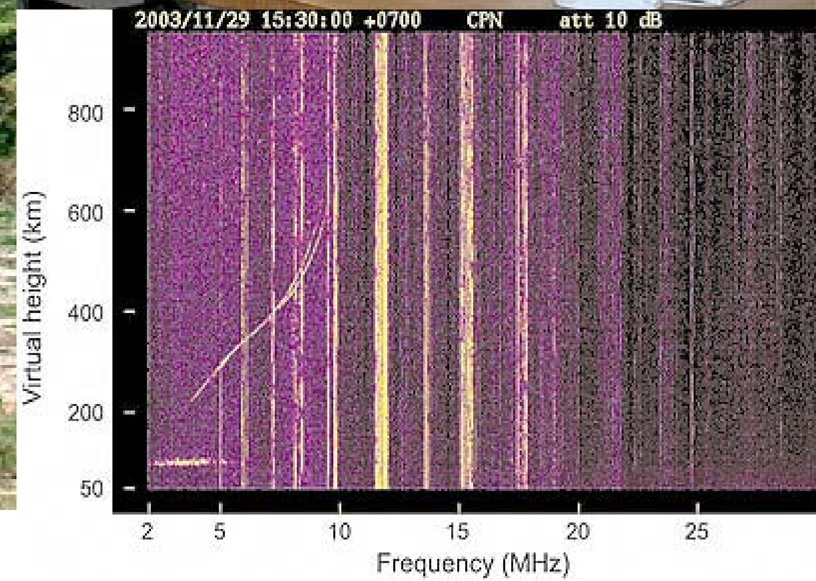
Contents

from NICT homepage

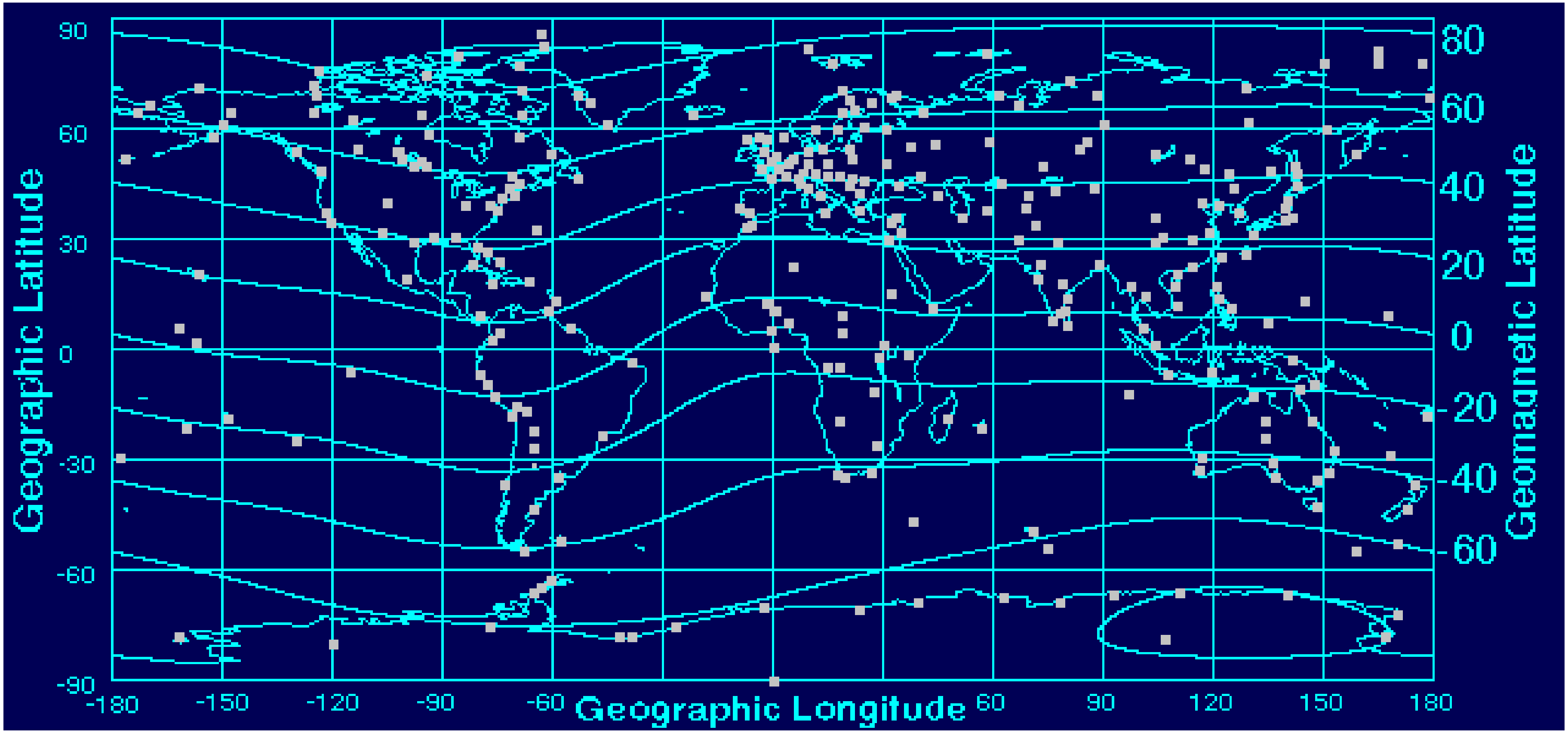
Ionosonde





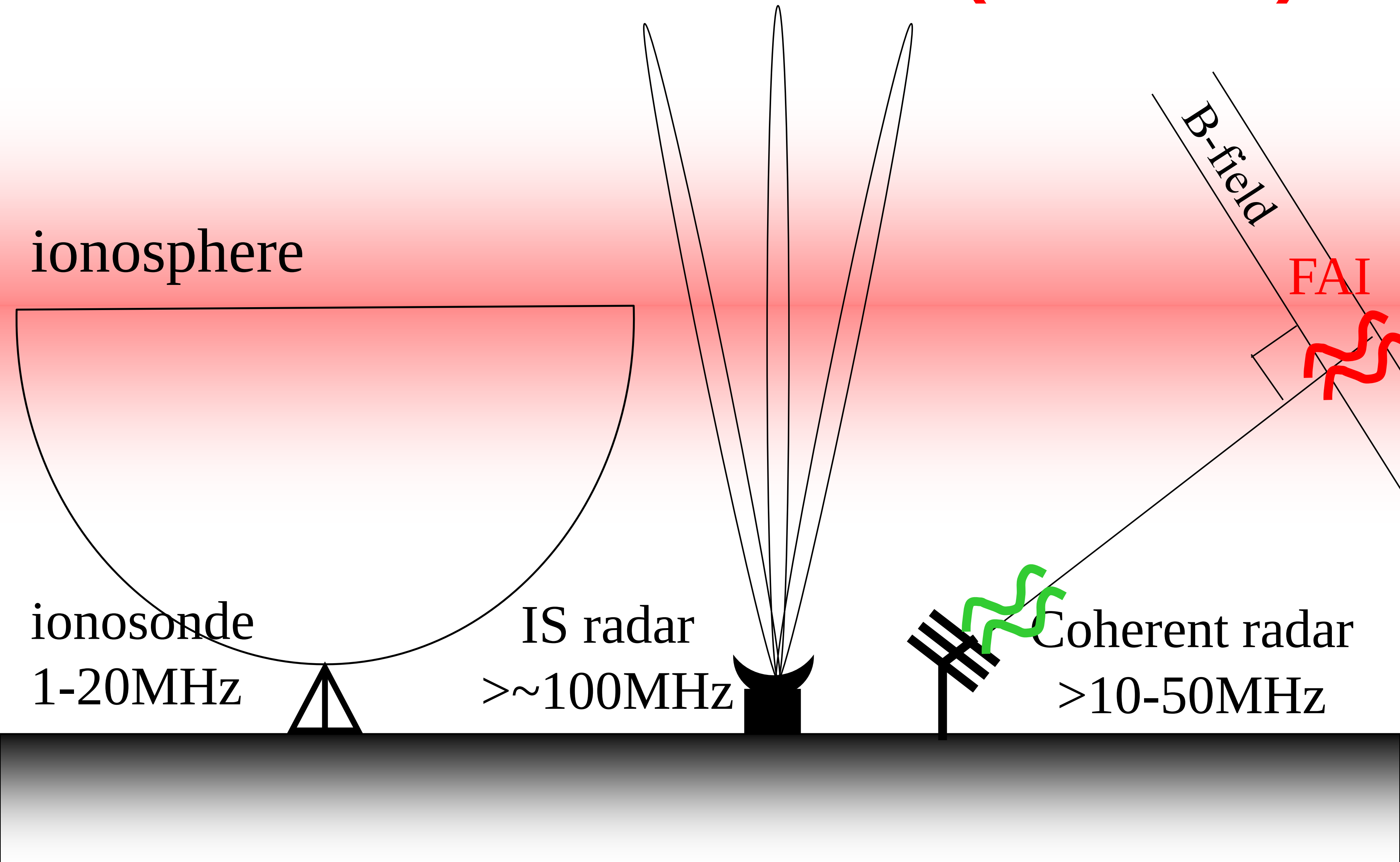


Ionosonde operated at Tailand by NICT, Japan

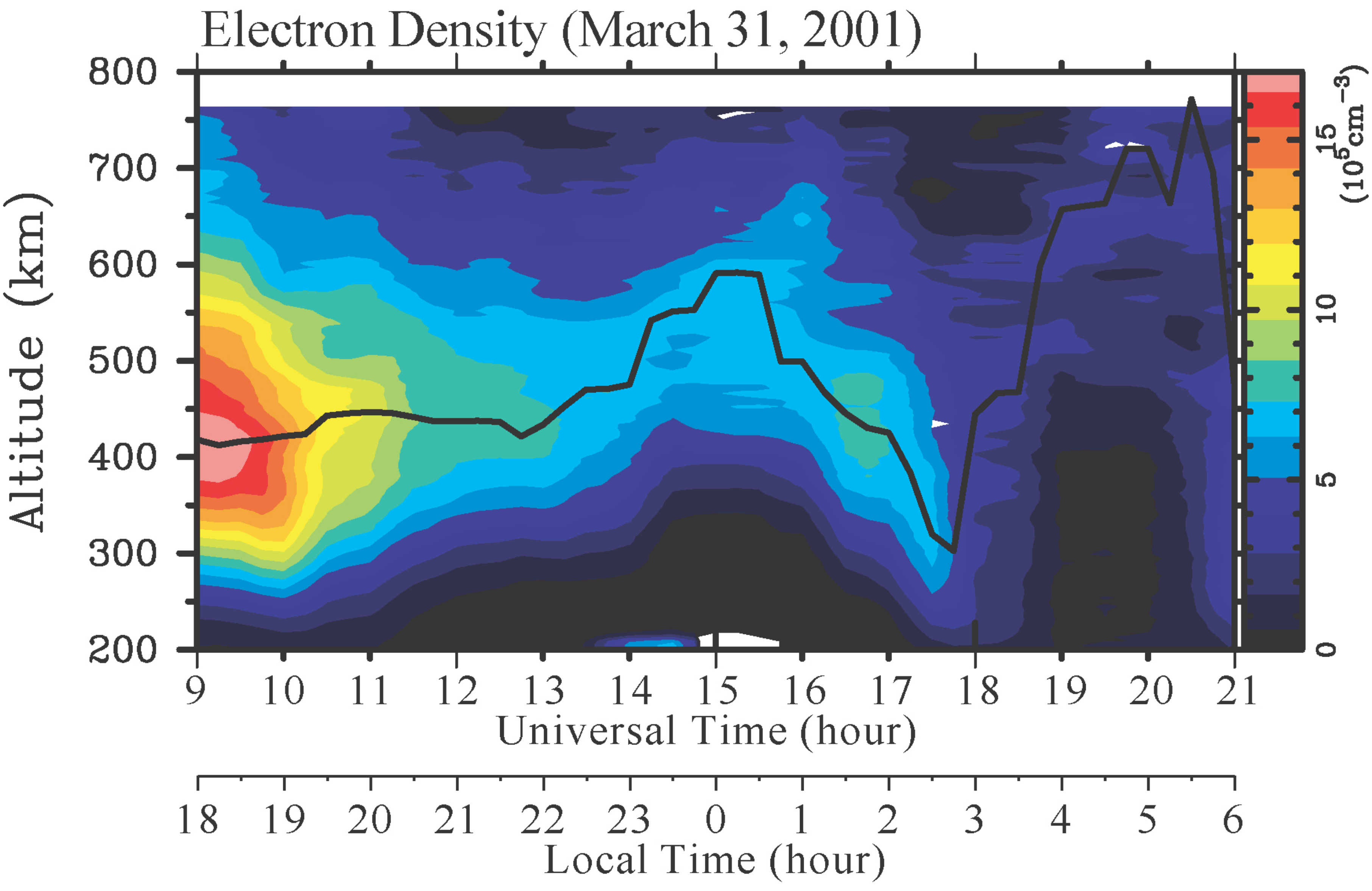


A world map with both Geographic Longitudes and Latitudes as well as corrected Geomagnetic Latitudes displays the catalog of all ionosonde stations and stations with digital data contained on the CD database. http://www.ngdc.noaa.gov/stp/CDROM/ionocd.html

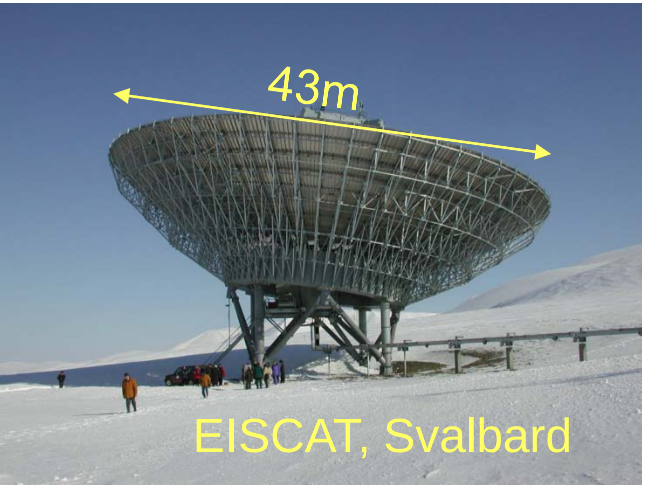
Coherent Scatter Radar
Incoherent Scatter Radar (IS radar)



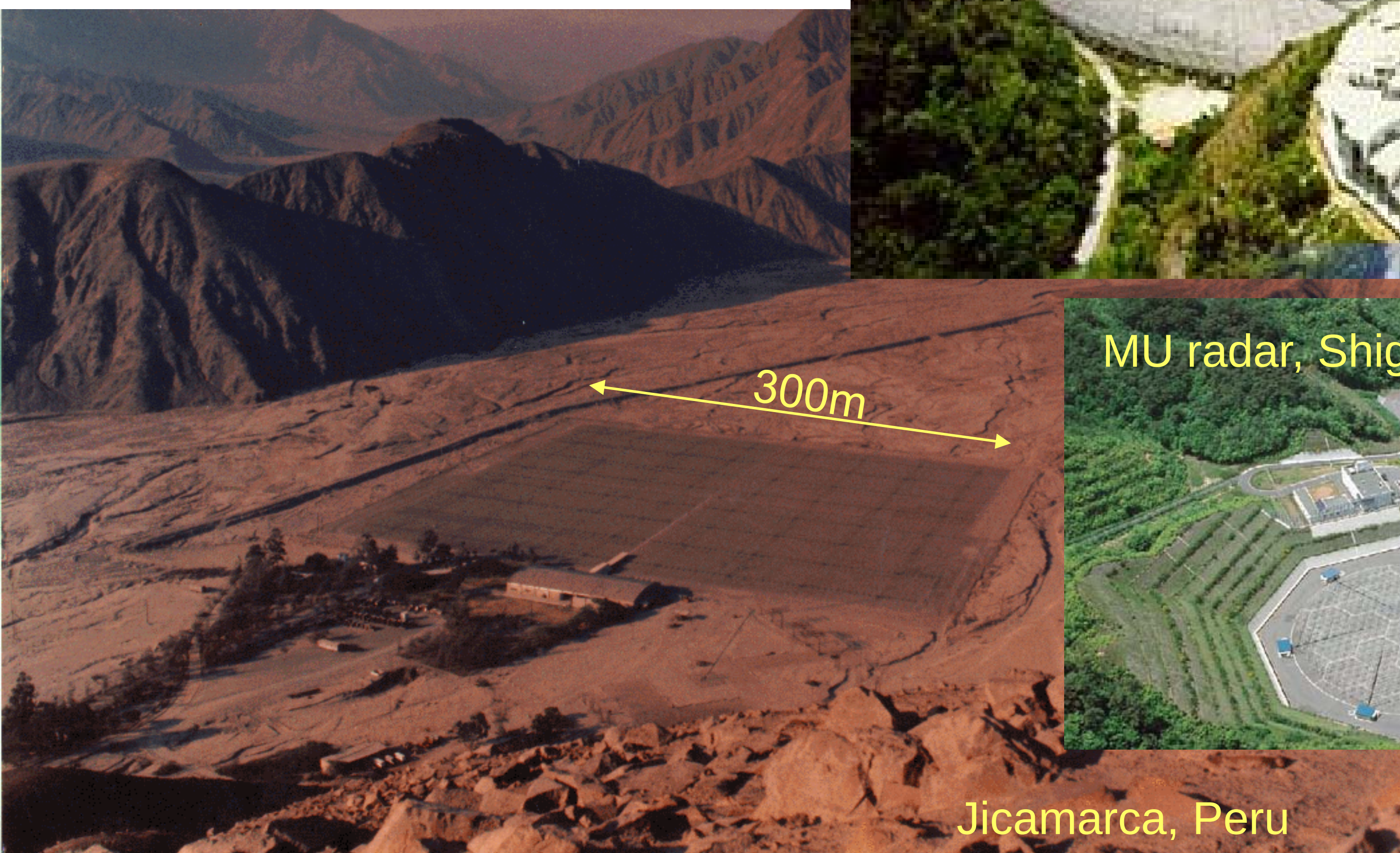
Electron Density Profile Measured by the MU Radar (IS radar)



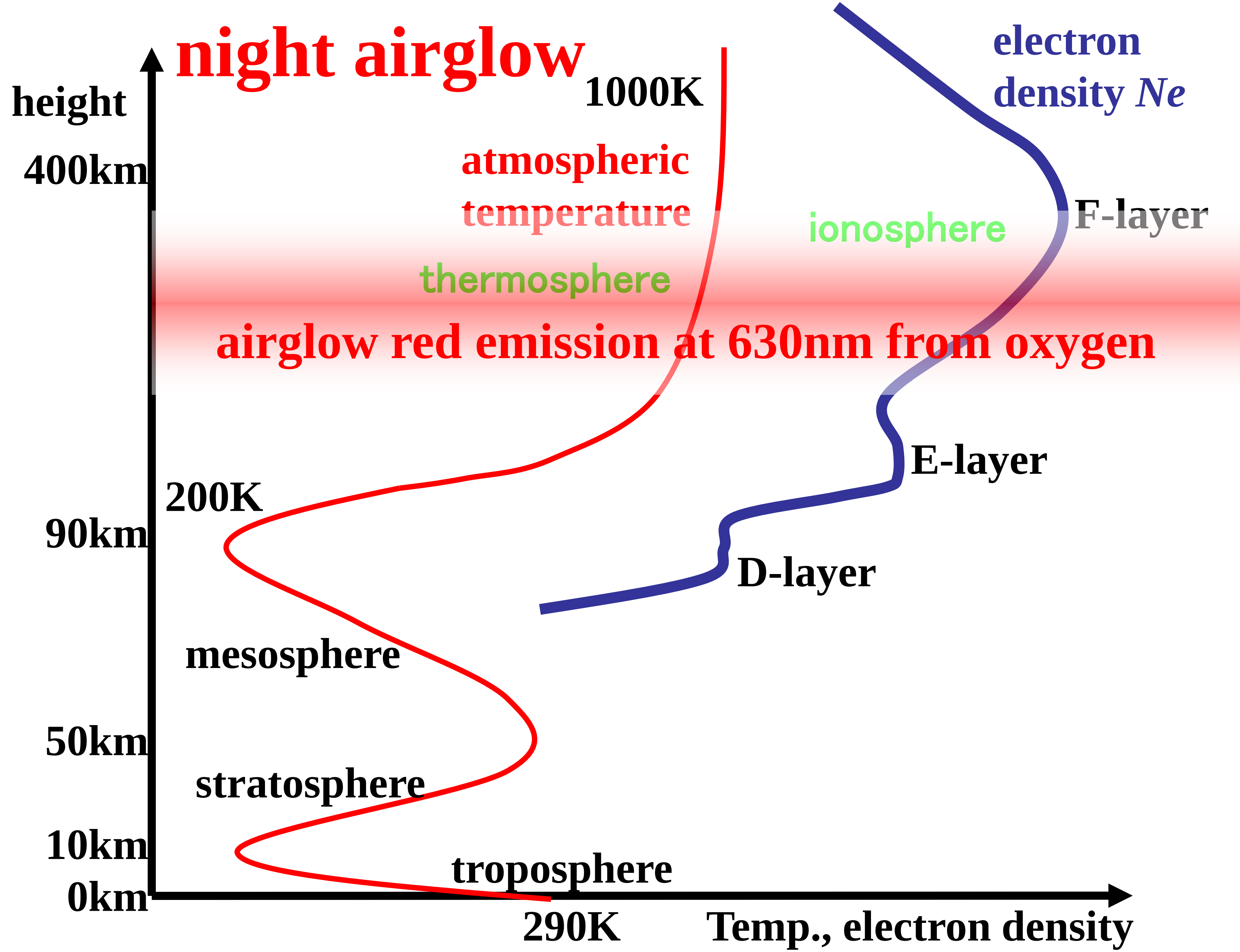
Shiokawa et al. [JGR, 2003]

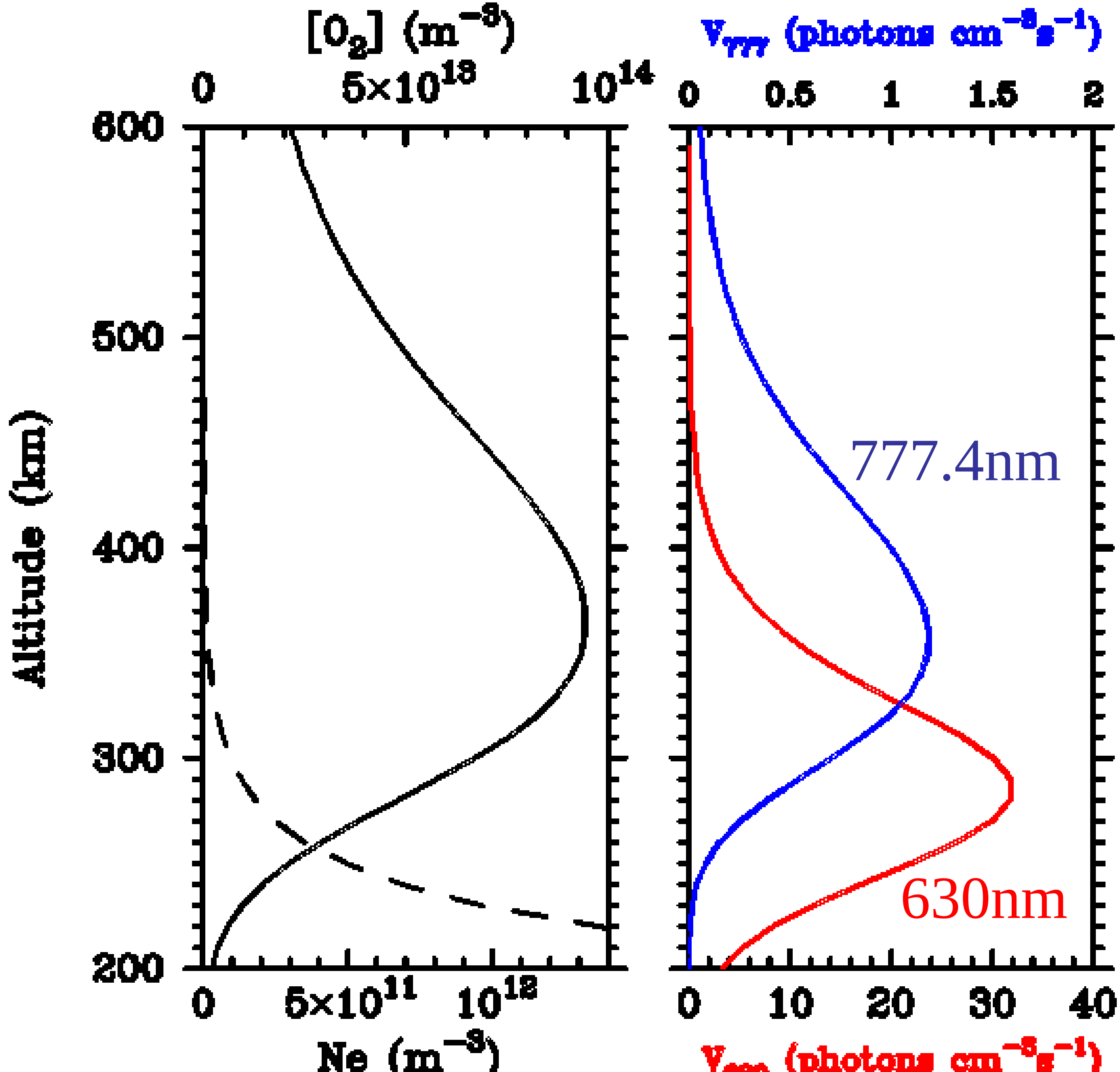

43m
EISCAT, Svalbard


Arecibo, Puerto Rico
300m
MI6.CO.UK


300m
Jicamarca, Peru


MU radar, Shigaraki, Japan

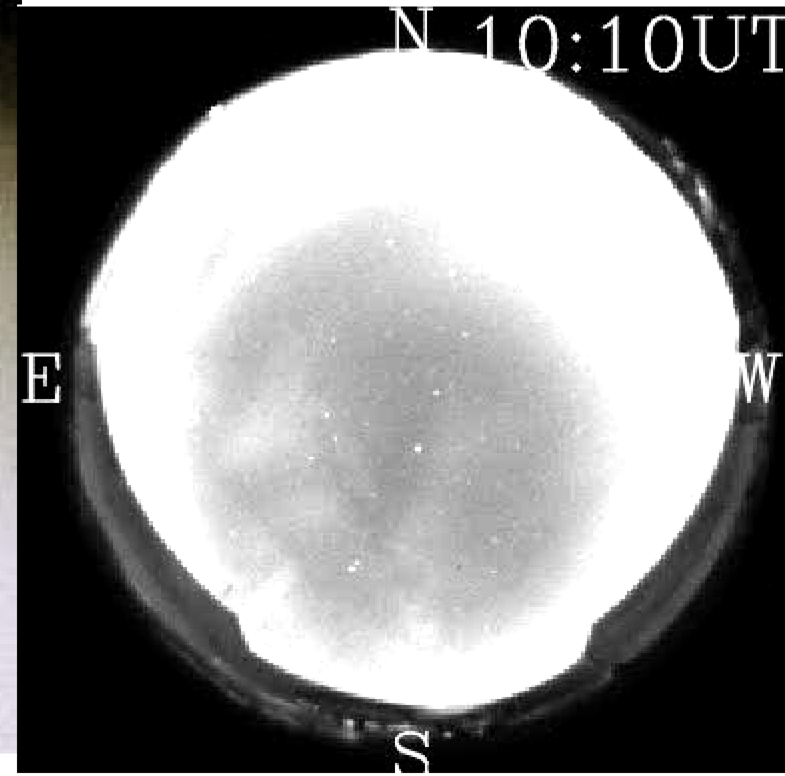

night airglow
height
400km
90km
50km
10km
0km
1000K
atmospheric
temperature
electron
density Ne
F-layer
ionosphere
thermosphere
airglow red emission at 630nm from oxygen
E-layer
200K
D-layer
mesosphere
stratosphere
troposphere
290K
Temp., electron density



Shiokawa et al. (JGR, 2003)

August 19, 2007
Paratunka, 630nm airglow

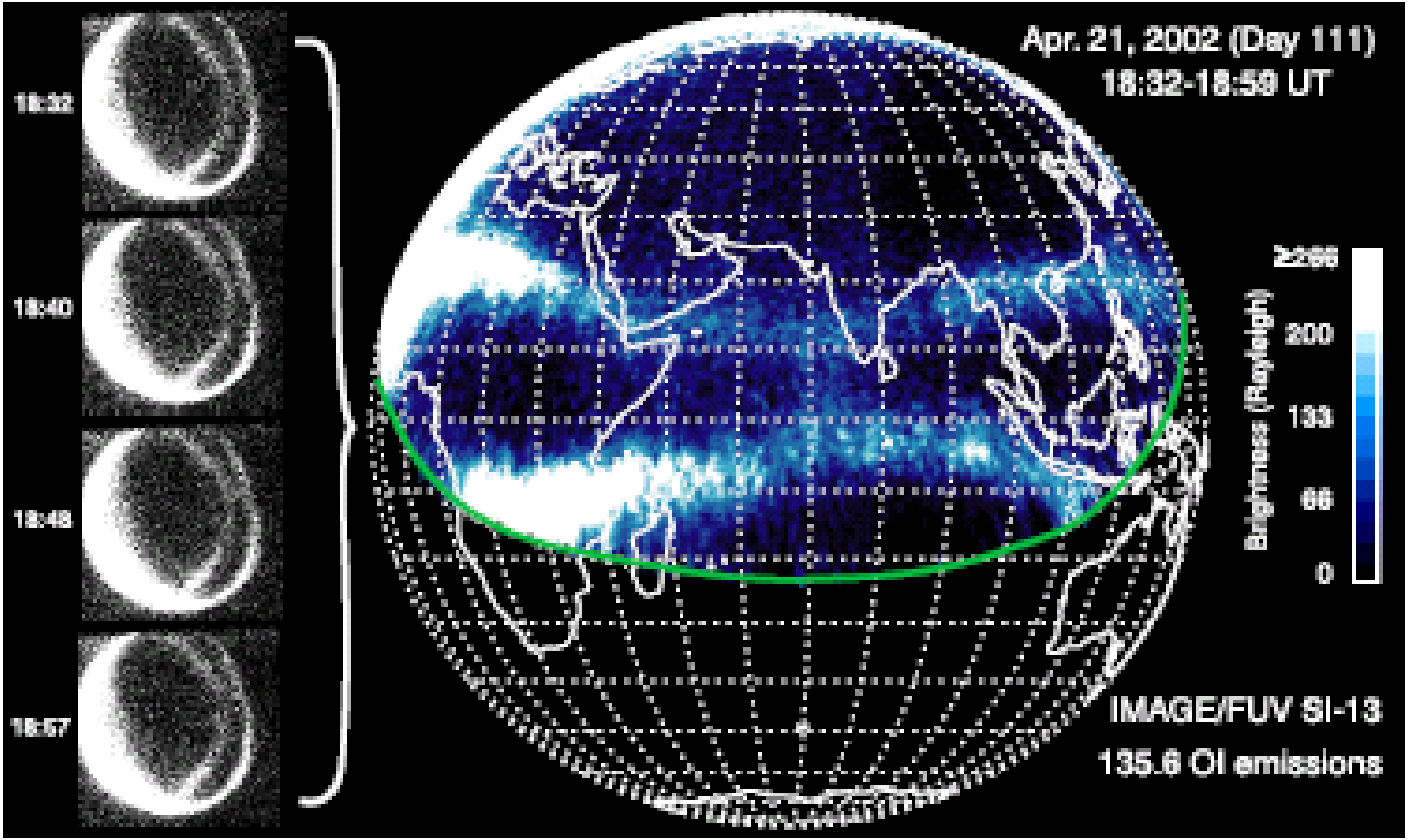
N



S

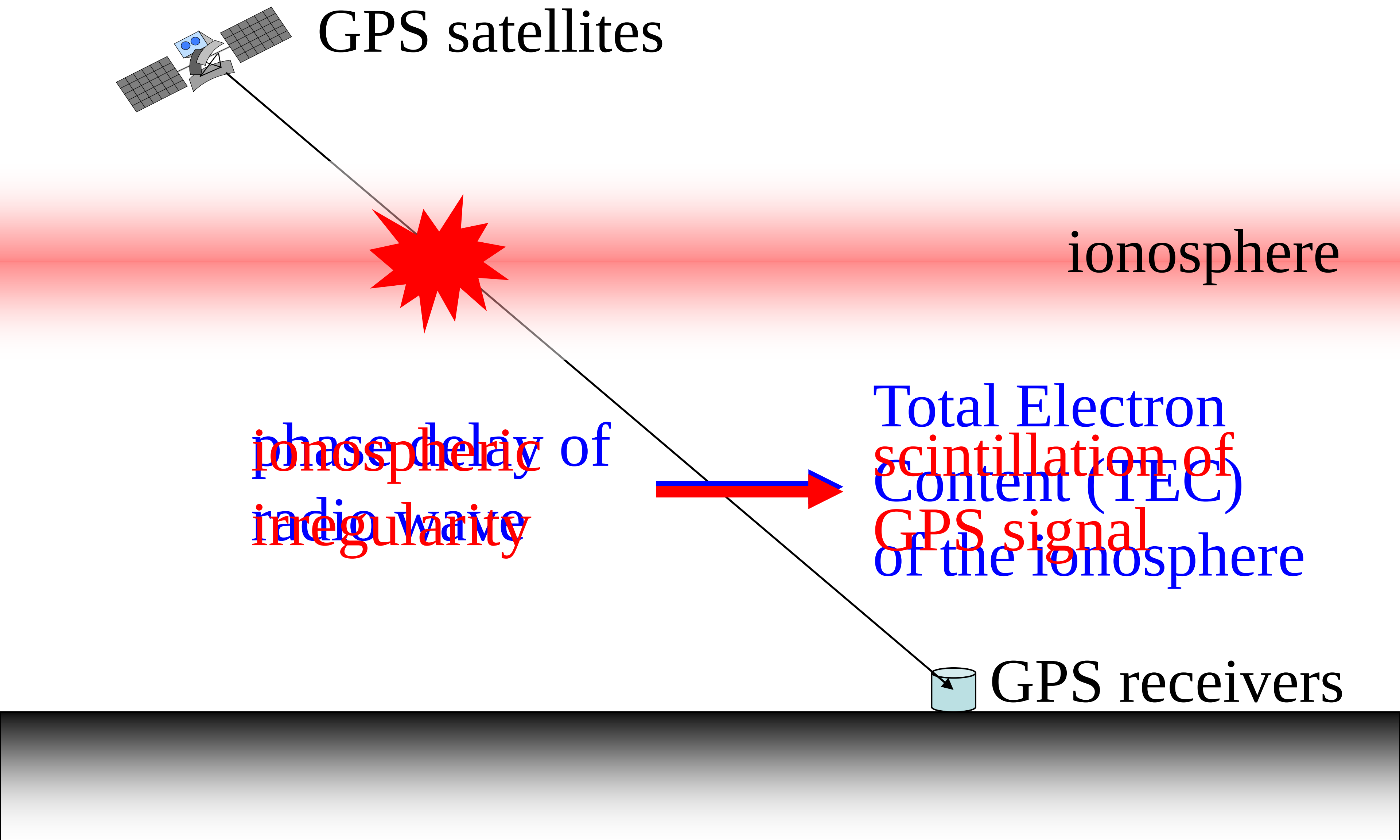
high-sensitive all-sky camera with cooled-CCD detector

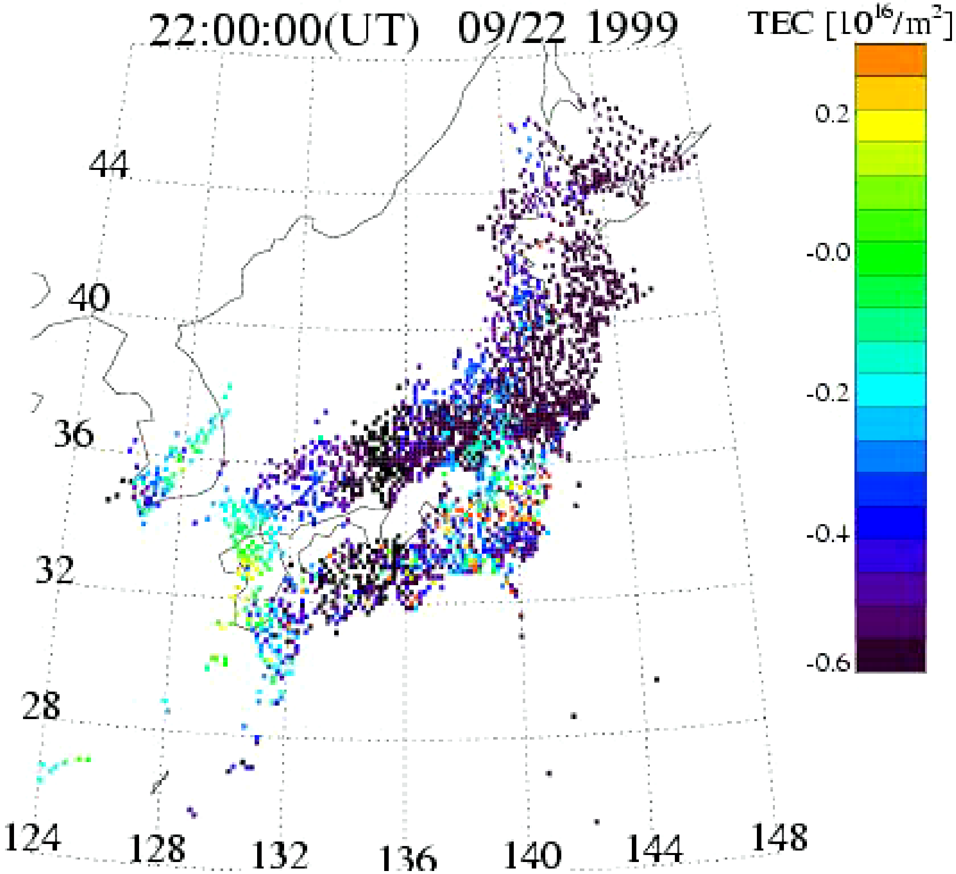
Far UltraViolet (FUV) airglow observed from space

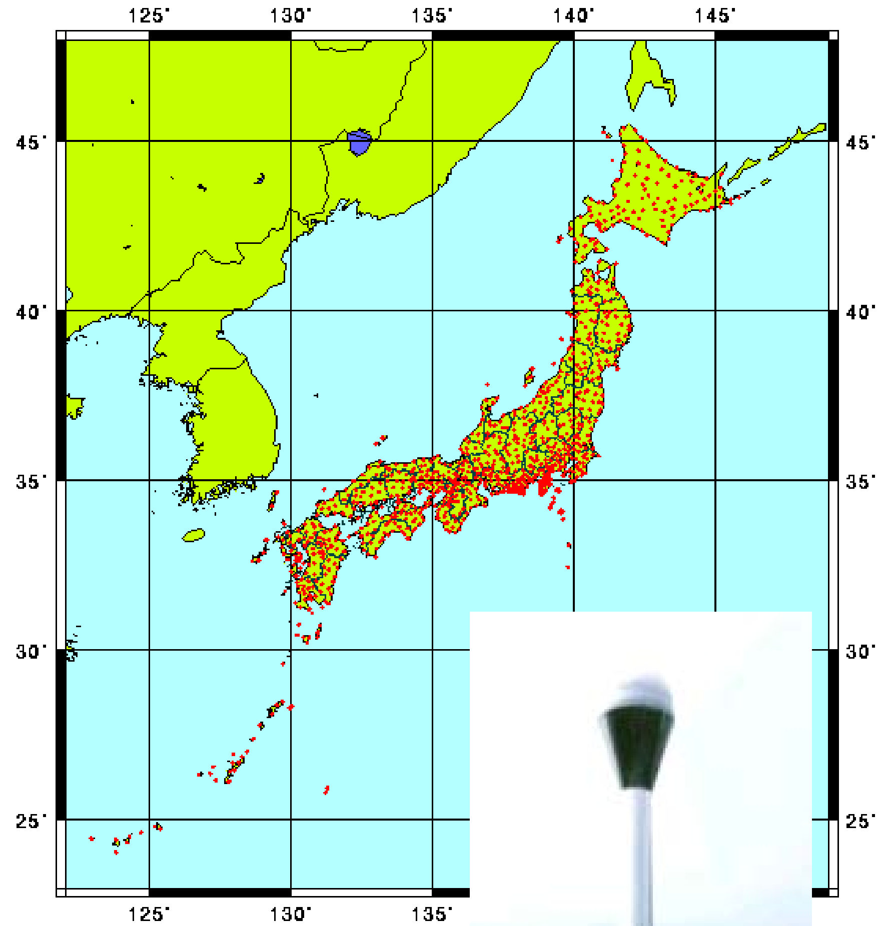


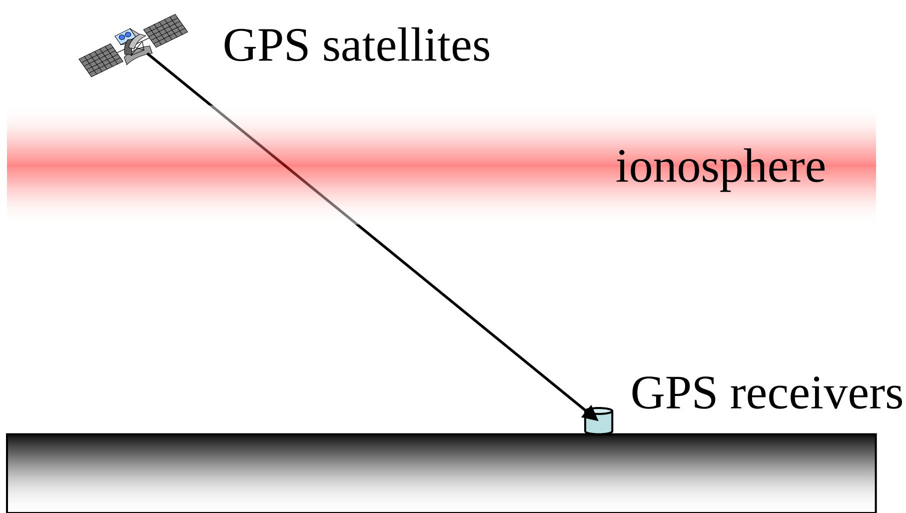
Immel et al. [GRL, 2006]

GPS receivers network

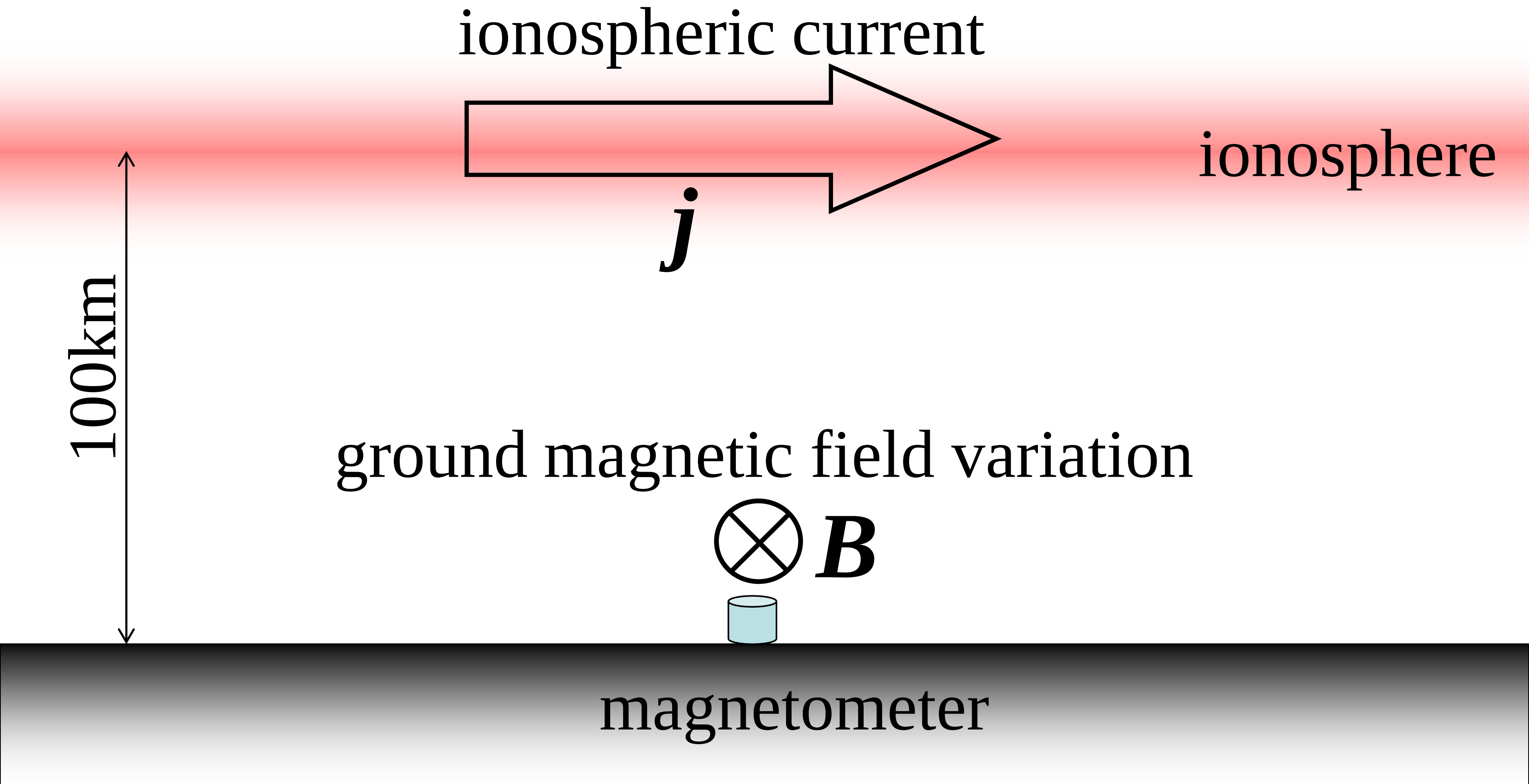



22:00:00(UT) 09/22 1999
TEC [10^16/m^2]
0.2
-0.0
-0.2
-0.4
-0.6
44
40
36
32
28
124
128
132
136
140
144
148


125˚
130˚
135˚
140˚
145˚
45˚
40˚
35˚
30˚
25˚

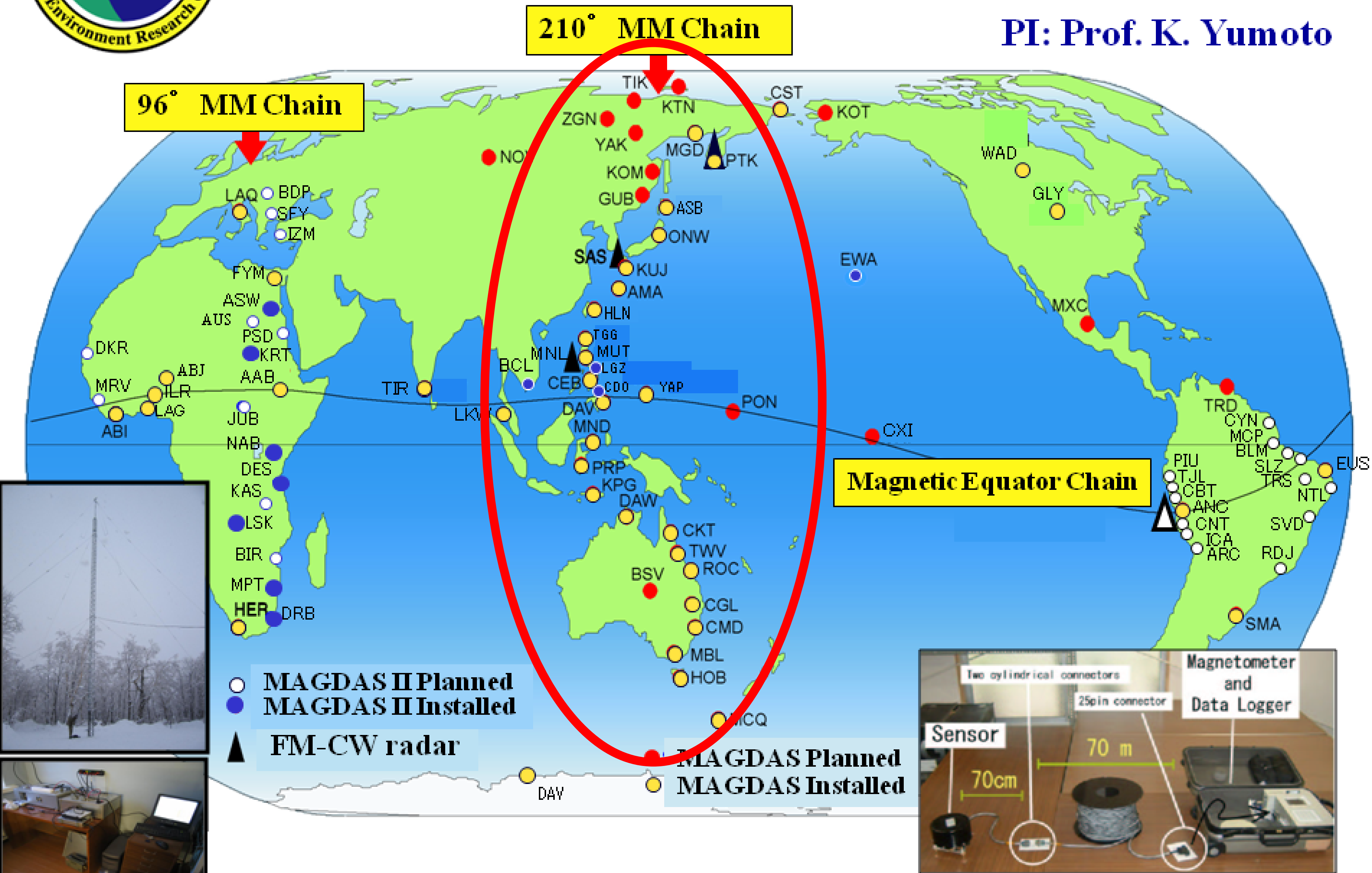

GPS satellites
ionosphere
GPS receivers

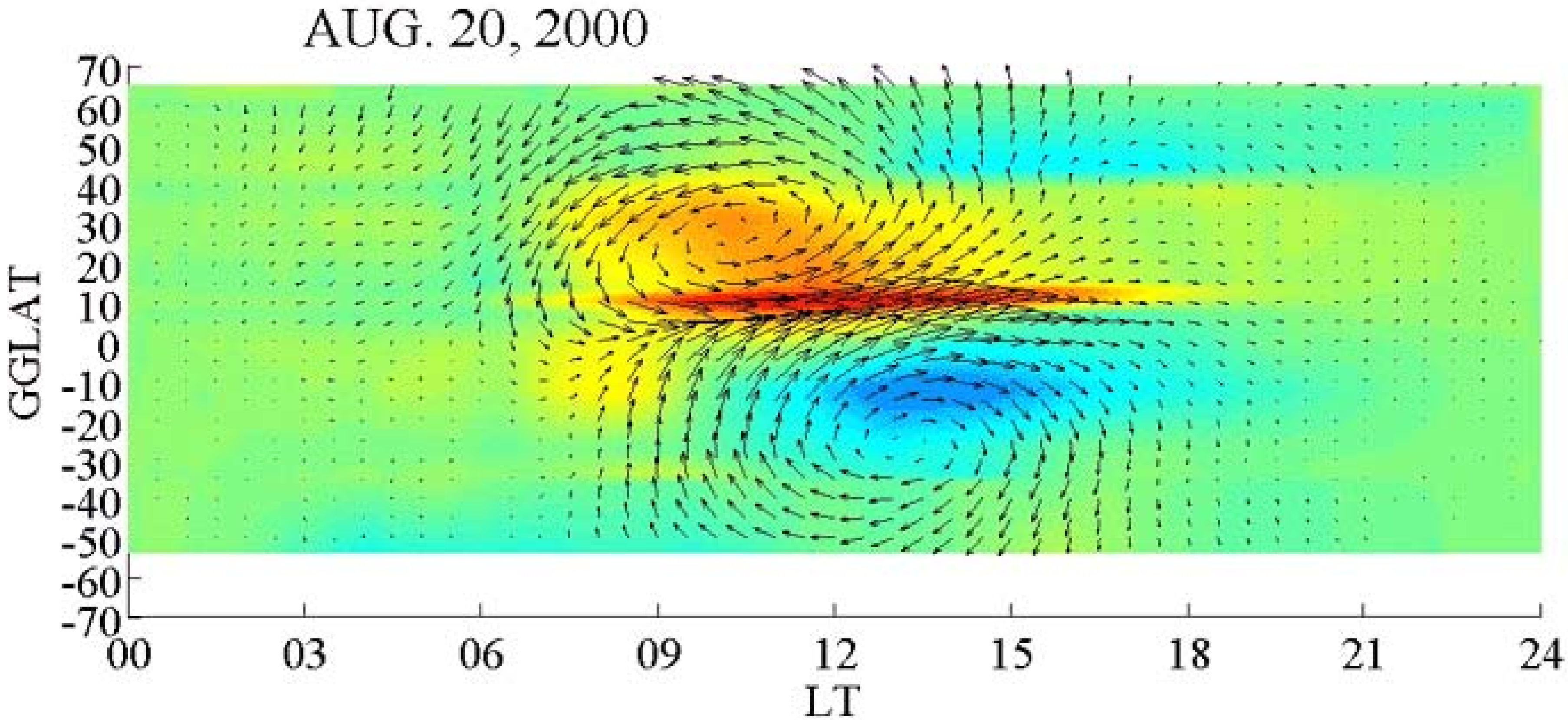
Magnetometer network



MAGDAS (MAGnetic Data Acquisition System) Network at SERC, Kyushu Univ.

PI: Prof. K. Yumoto





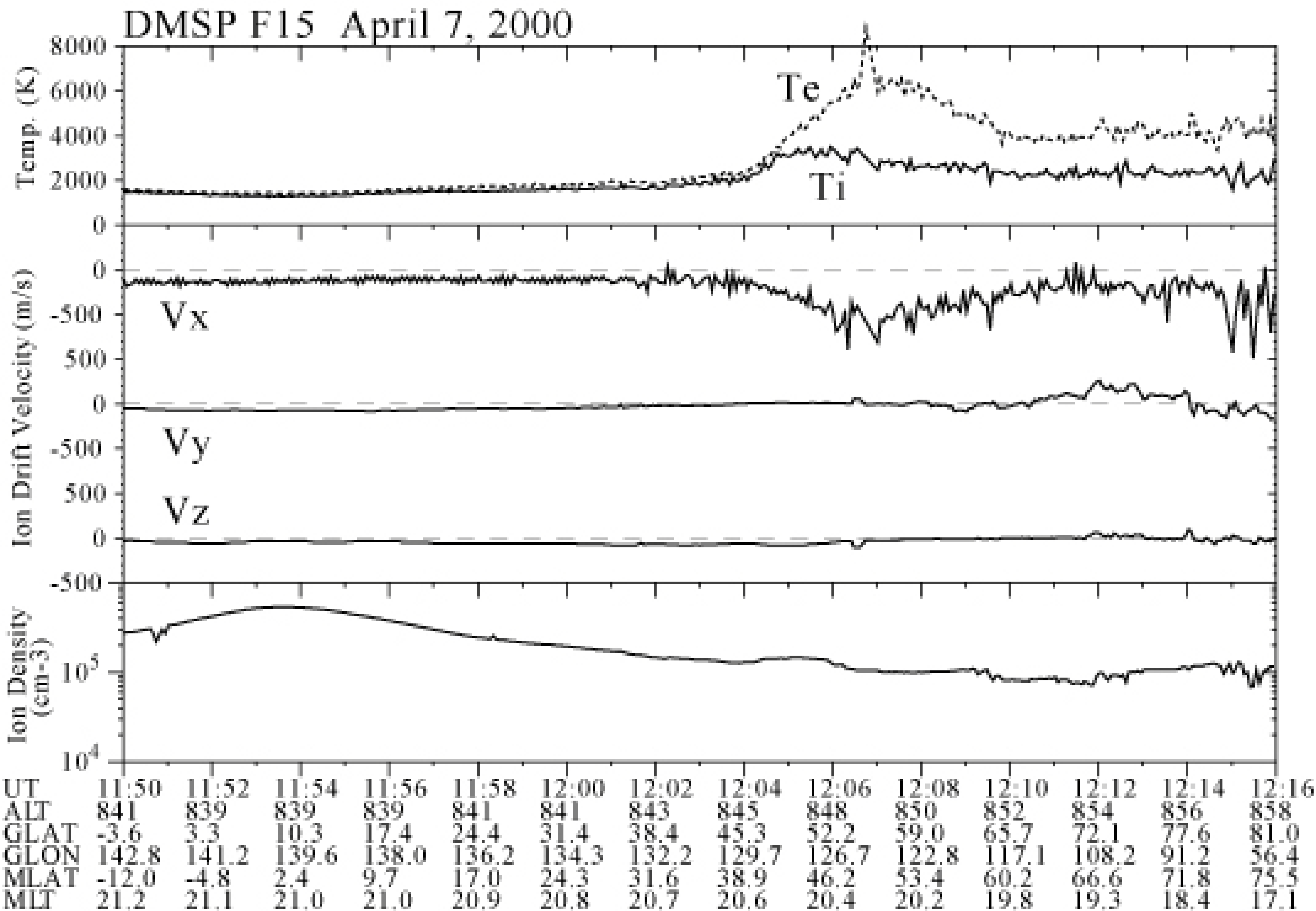
Courtesy: K. Yumoto

Direct measurement of ionospheric plasma by satellites at ionospheric altitudes

ionospheric satellites: DMSP, C/NOFS, CHAMP, FORMOSAT…

altitude: 400-1000 km

ionosphere



Shiokawa et al. [low-latitude aurora, JGR, 2005]

Contents

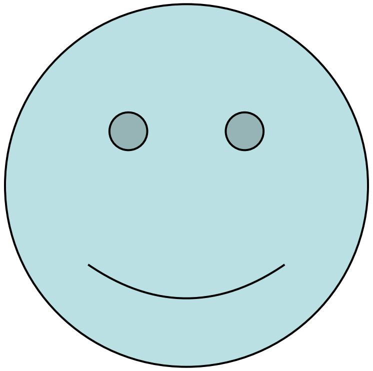
1. Introduction
2. Techniques to measure the ionosphere
   - ionosonde
   - coherent/incoherent scatter radar
   - airglow imager
   - GPS receiver network
   - magnetometer
   - satellites
3. Two major forces that cause dynamic variations of the ionosphere at midlatitudes
   - neutral wind vs electric field
4. Storm effect on the ionosphere
   - neutral wind effect, LSTIDs
   - electric field effect
   - composition change
5. Non-storm time variations
   - ionospheric instabilities (electric field)
     - plasma bubbles and MSTIDs
   - effect of the neutral waves
     - tides, equatorial waves, and acoustic waves by earthquake
6. Future problems

Dynamic variations of the ionosphere

two forces

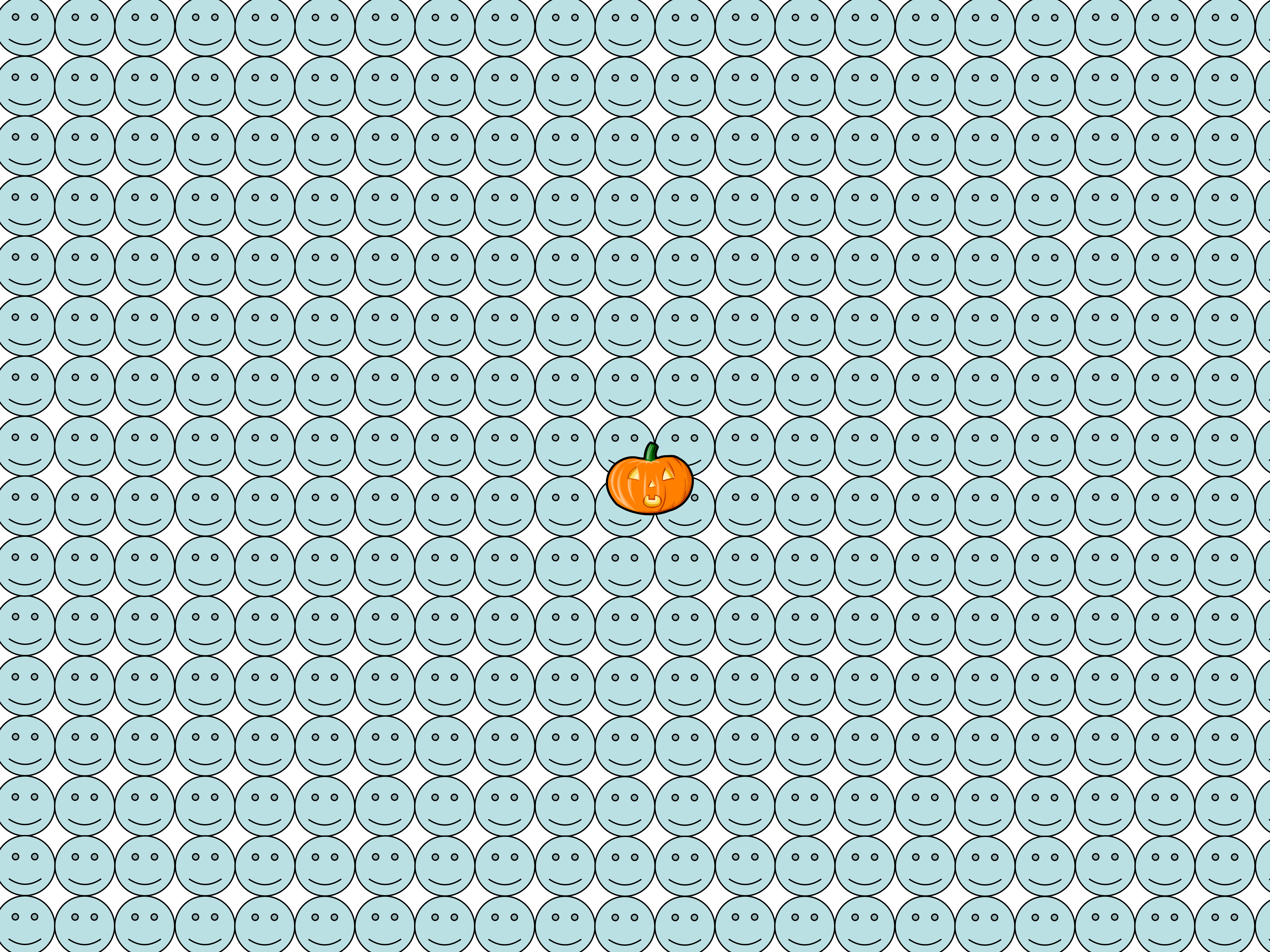
- north-south neutral wind
- east-west electric field

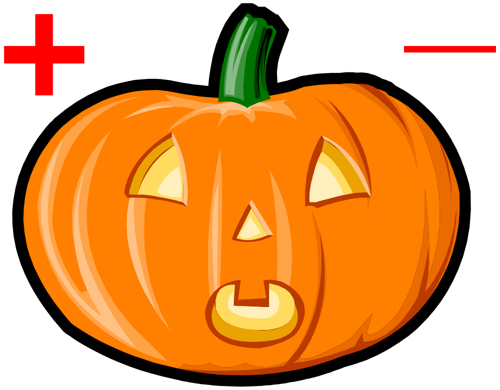
Ionosphere:
mixture of plasma and neutrals



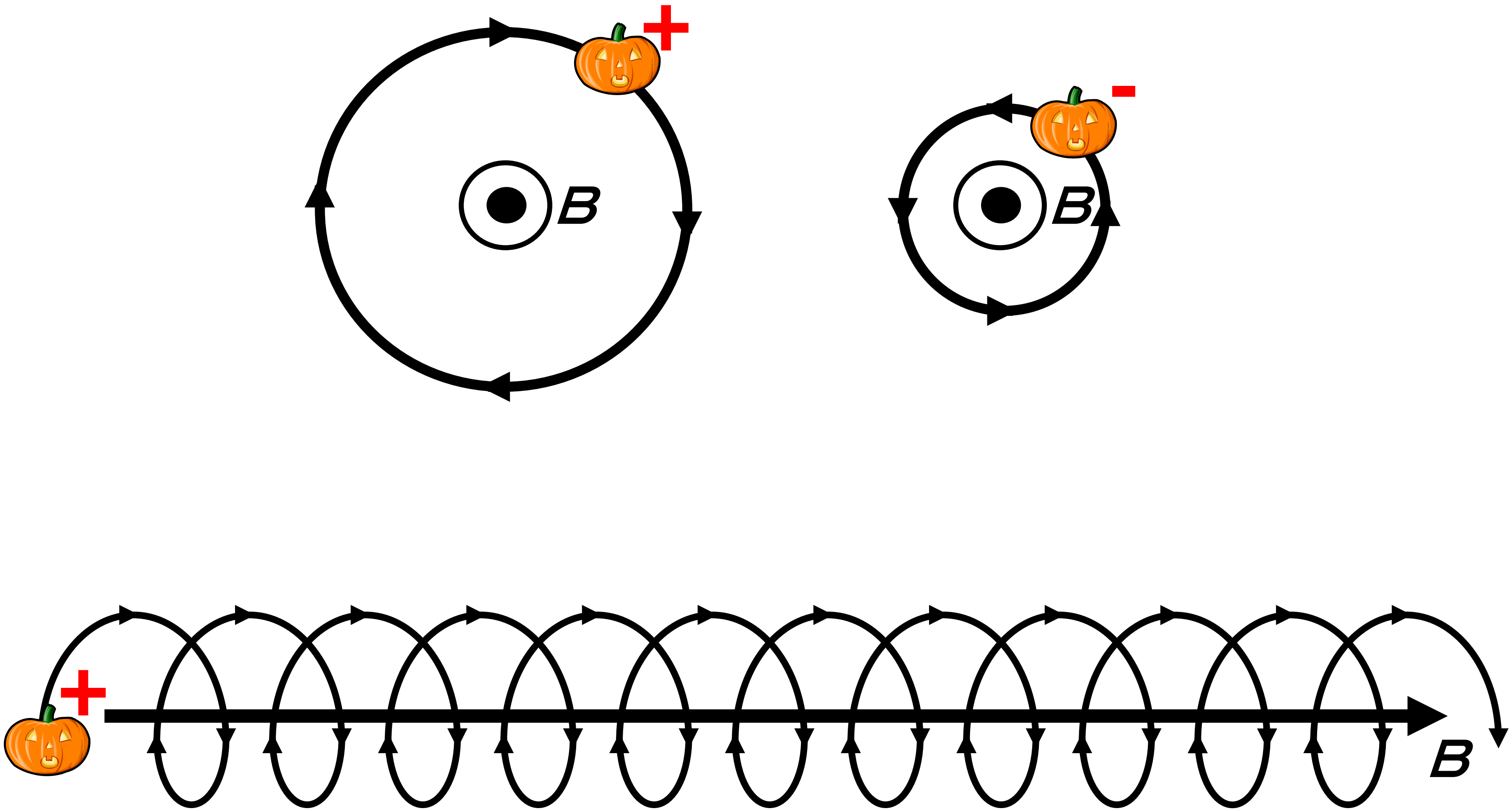
plasma **neutrals**

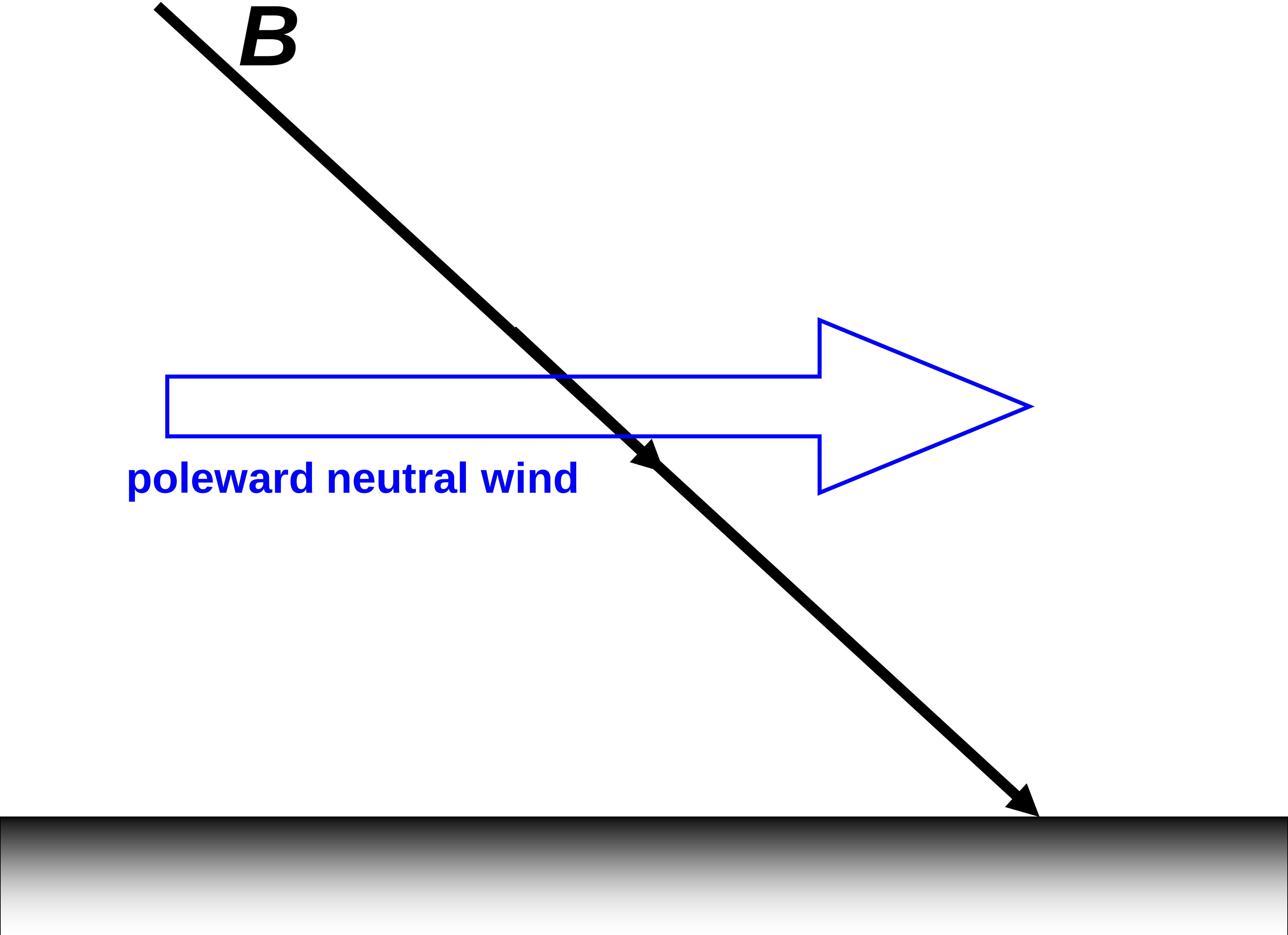
$10^6 /cm^3$ $10^9 /cm^3$

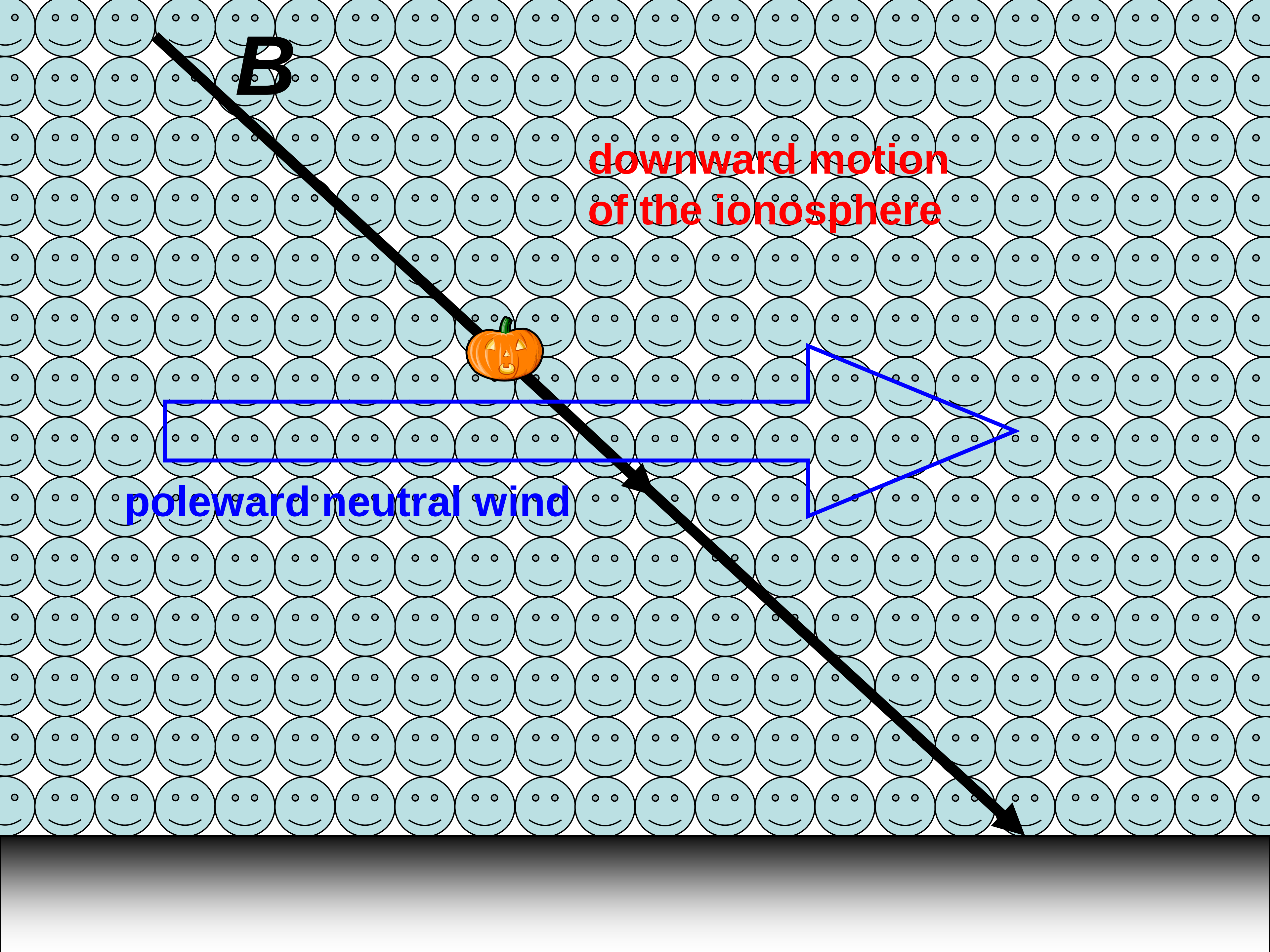


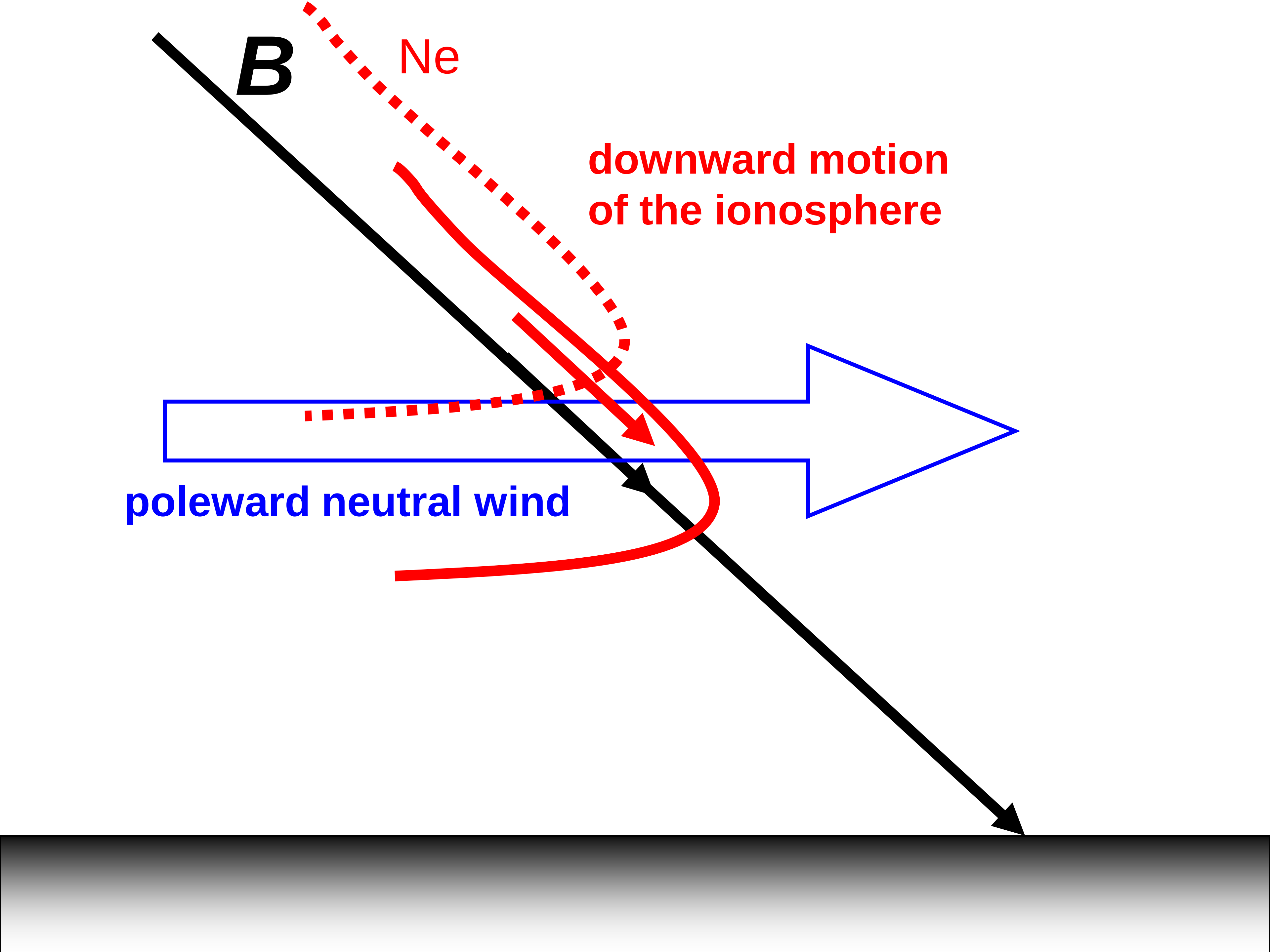


plasma

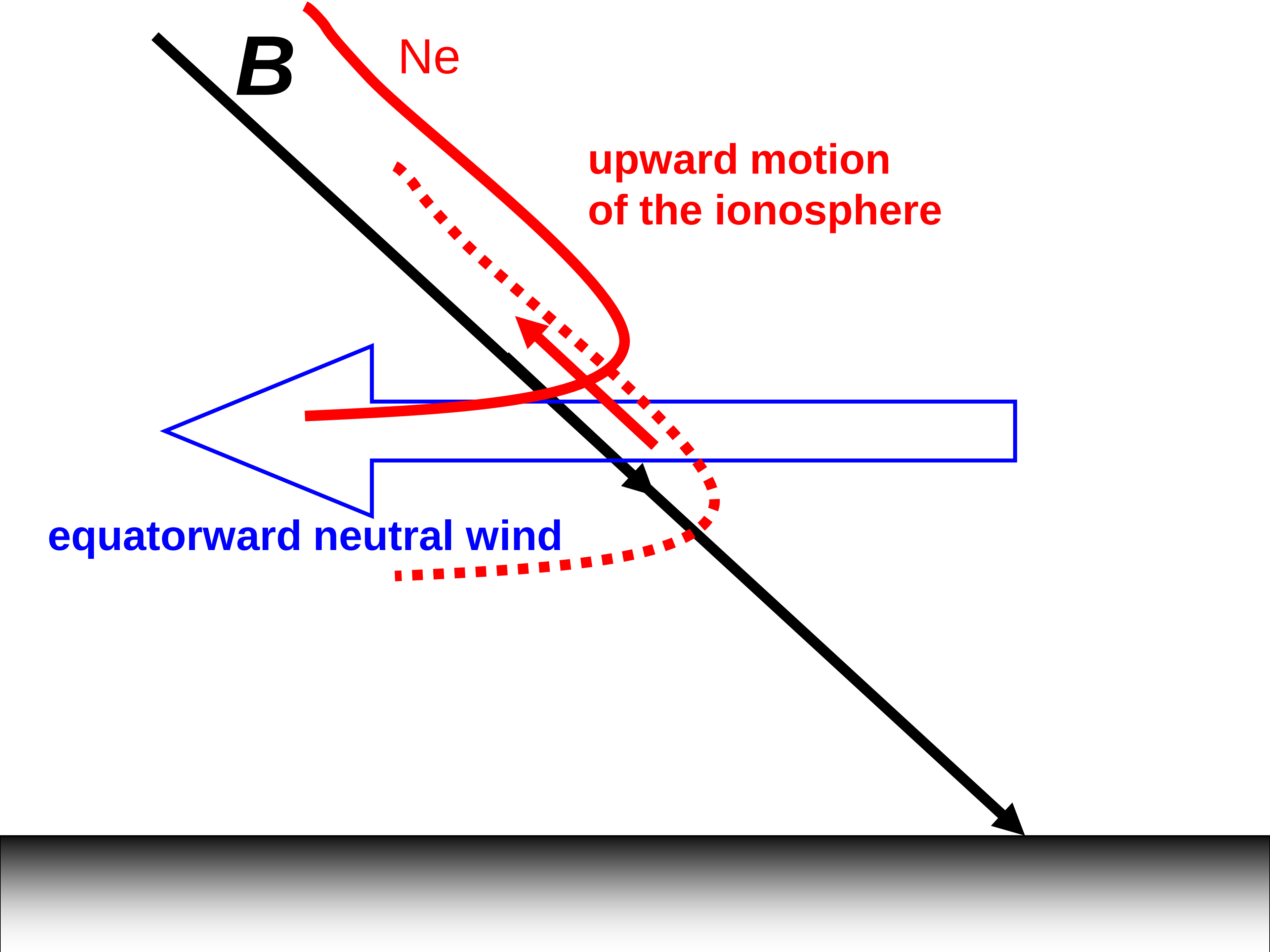

+
B
-
B
+
B


B
poleward neutral wind


B
downward motion
of the ionosphere
poleward neutral wind



B
Ne
downward motion
of the ionosphere
poleward neutral wind


B
Ne
upward motion
of the ionosphere
equatorward neutral wind

Dynamic variations of the ionosphere

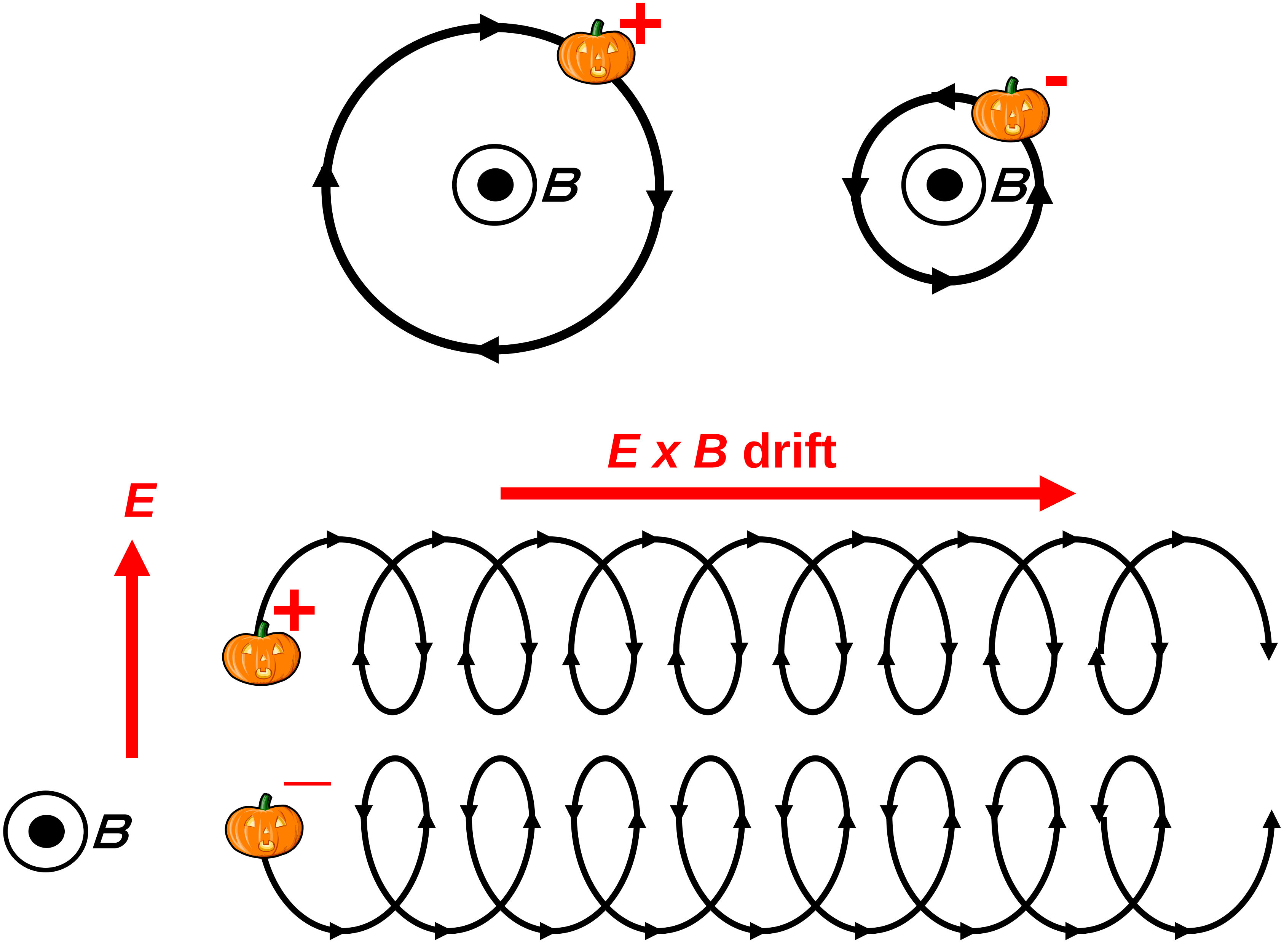
two forces

- north-south neutral wind
- east-west electric field

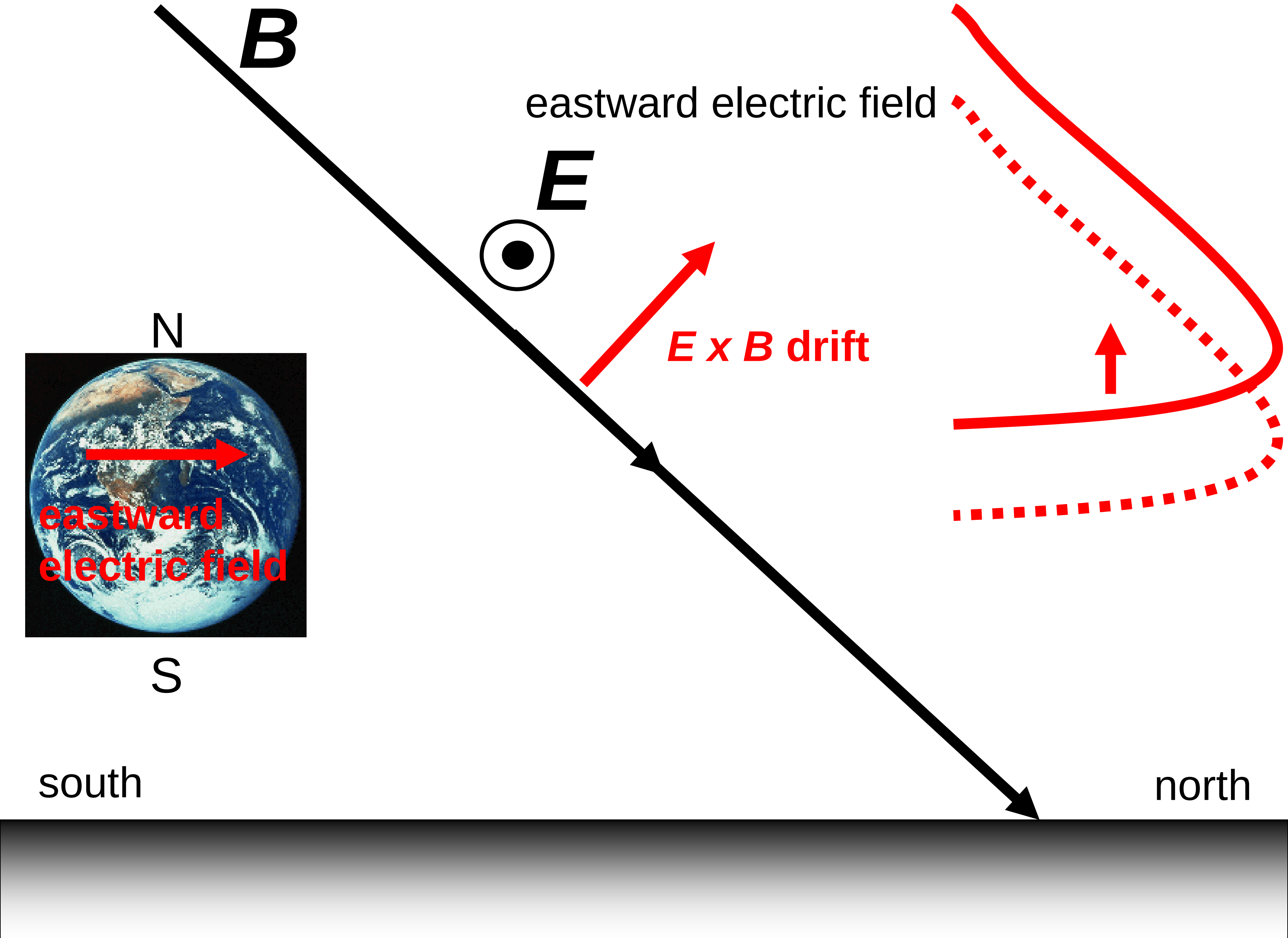
Dynamic variations of the ionosphere

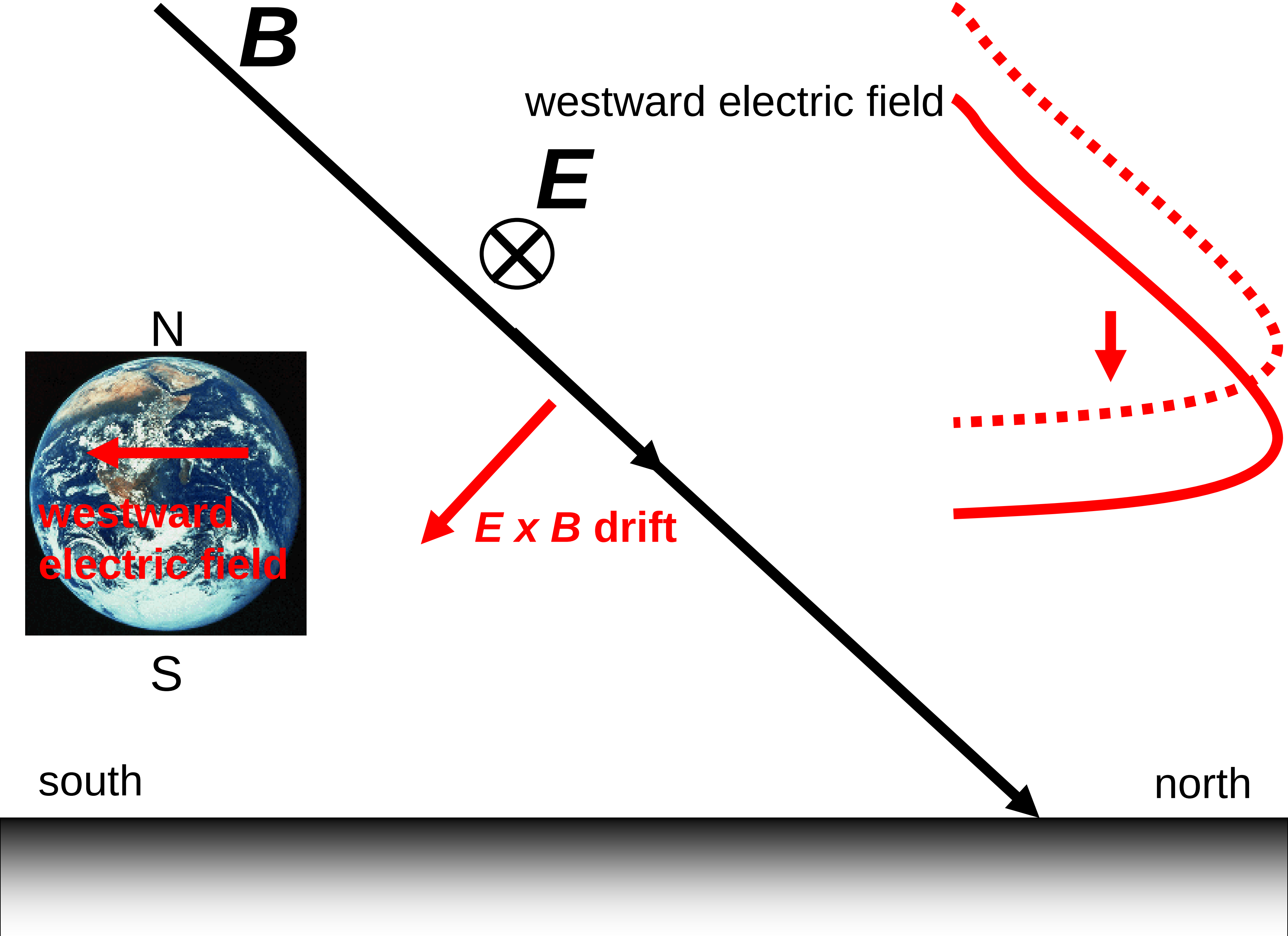
two forces

- north-south neutral wind
- east-west electric field



+
B
-
B
E x B drift
E
+
—
B


B
eastward electric field
E
E x B drift
N
eastward
electric field
S
south
north



B
westward electric field
E
N
westward
electric field
S
E x B drift
south
north

Dynamic variations of the ionosphere

north-south neutral wind

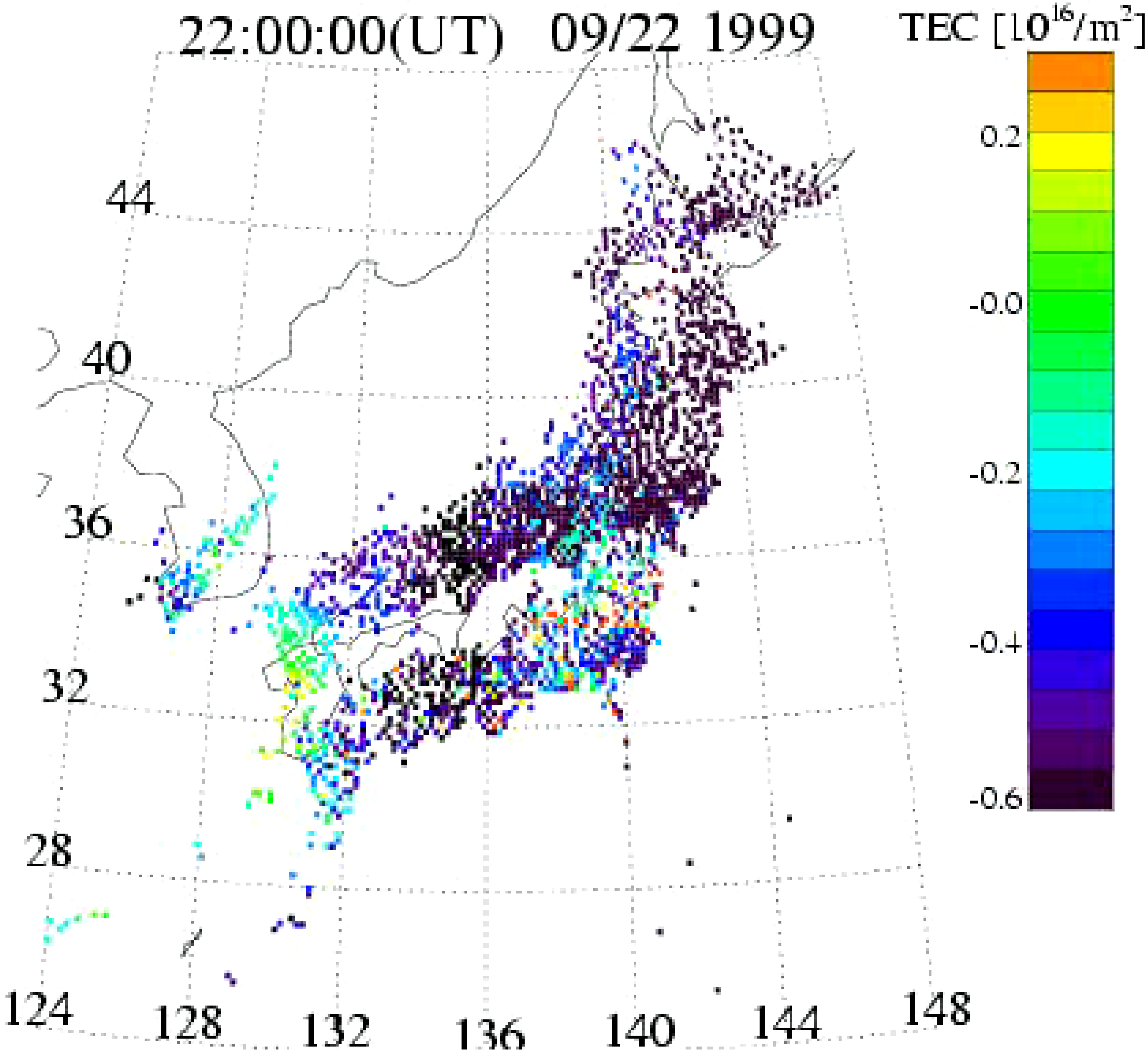
* slow (~hour)
* propagating latitudinally

east-west electric field

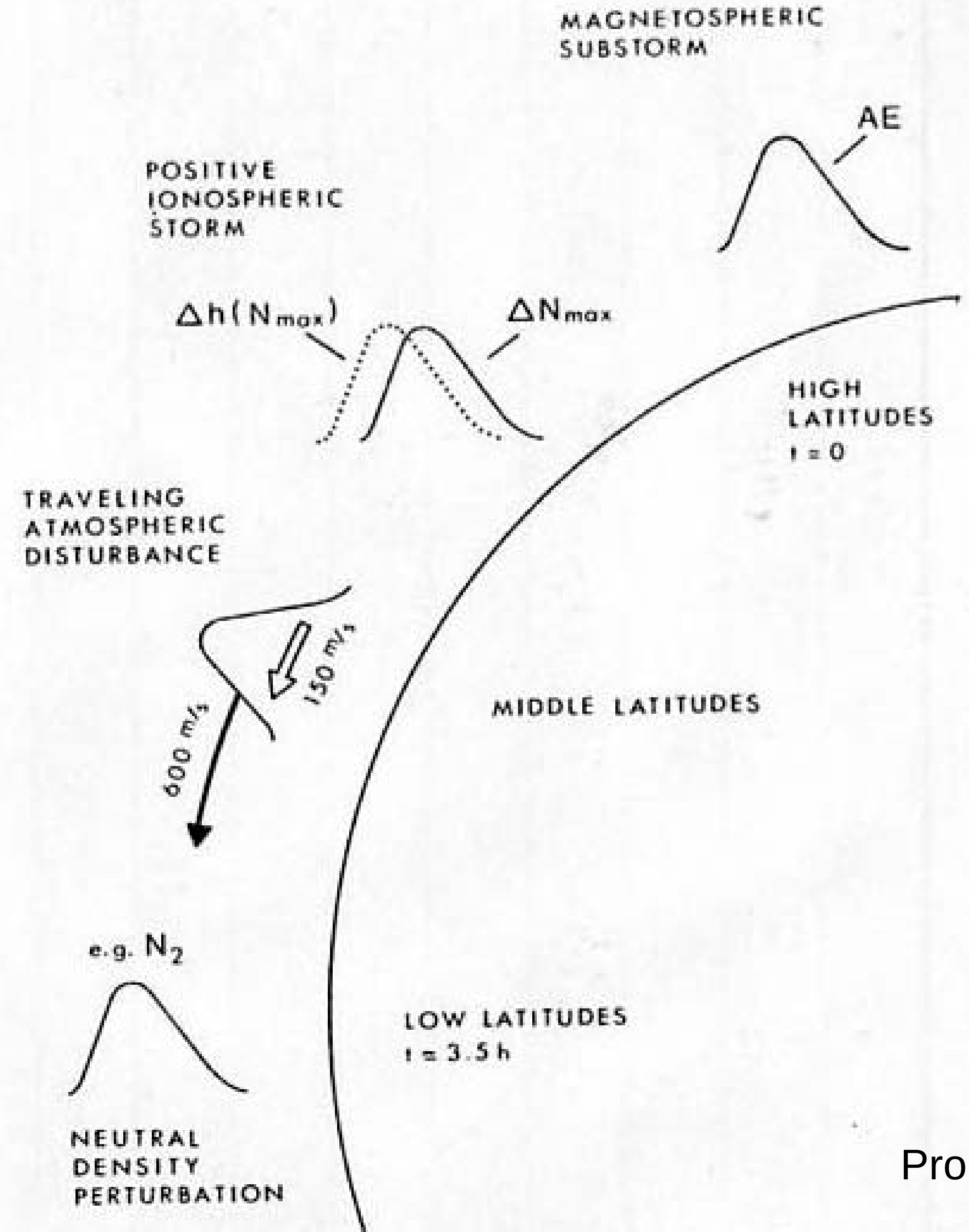
* fast (~min)
* simultaneous on global scale
* directly associated with geomagnetic disturbances

Contents

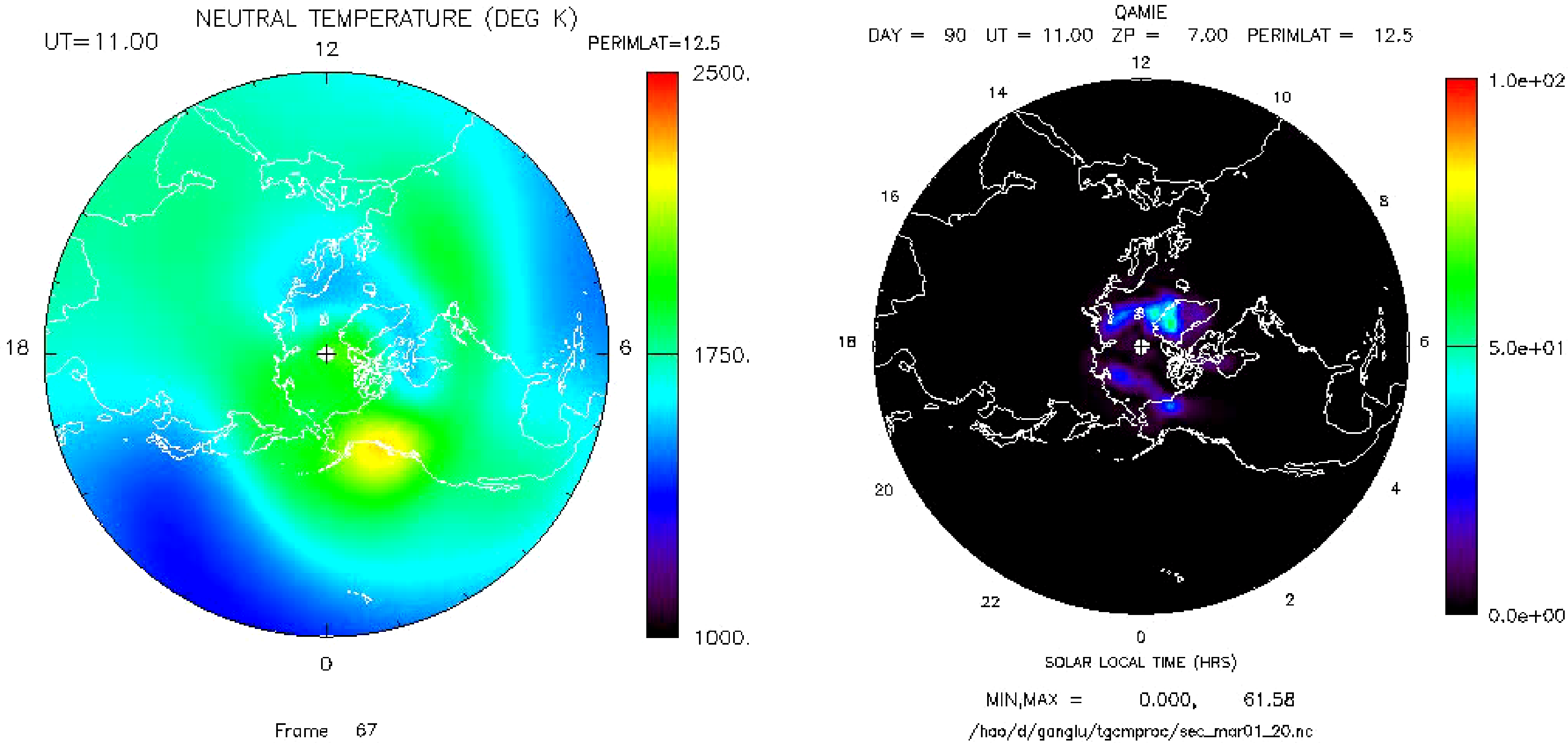
Large-Scale Traveling Ionospheric Disturbances (LSTIDs)



Tsugawa et al. [JGR, 2004]

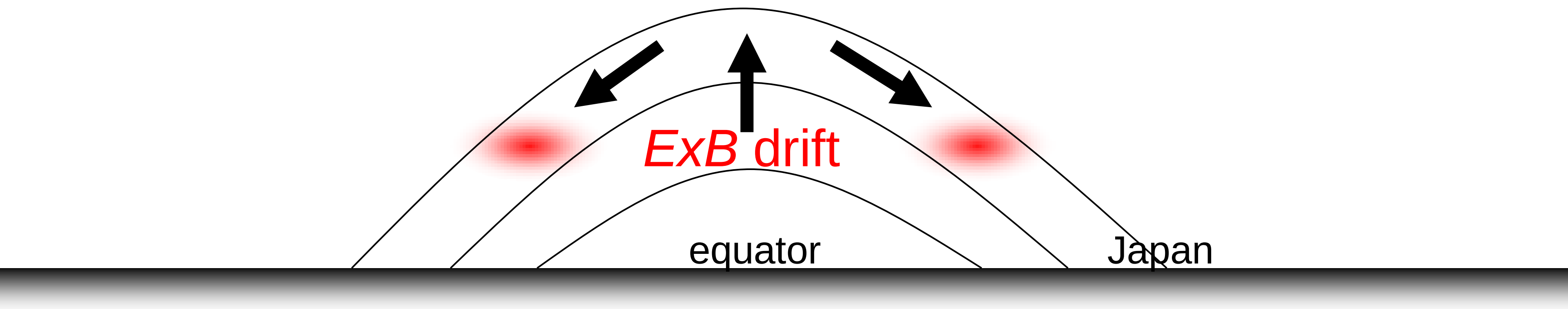


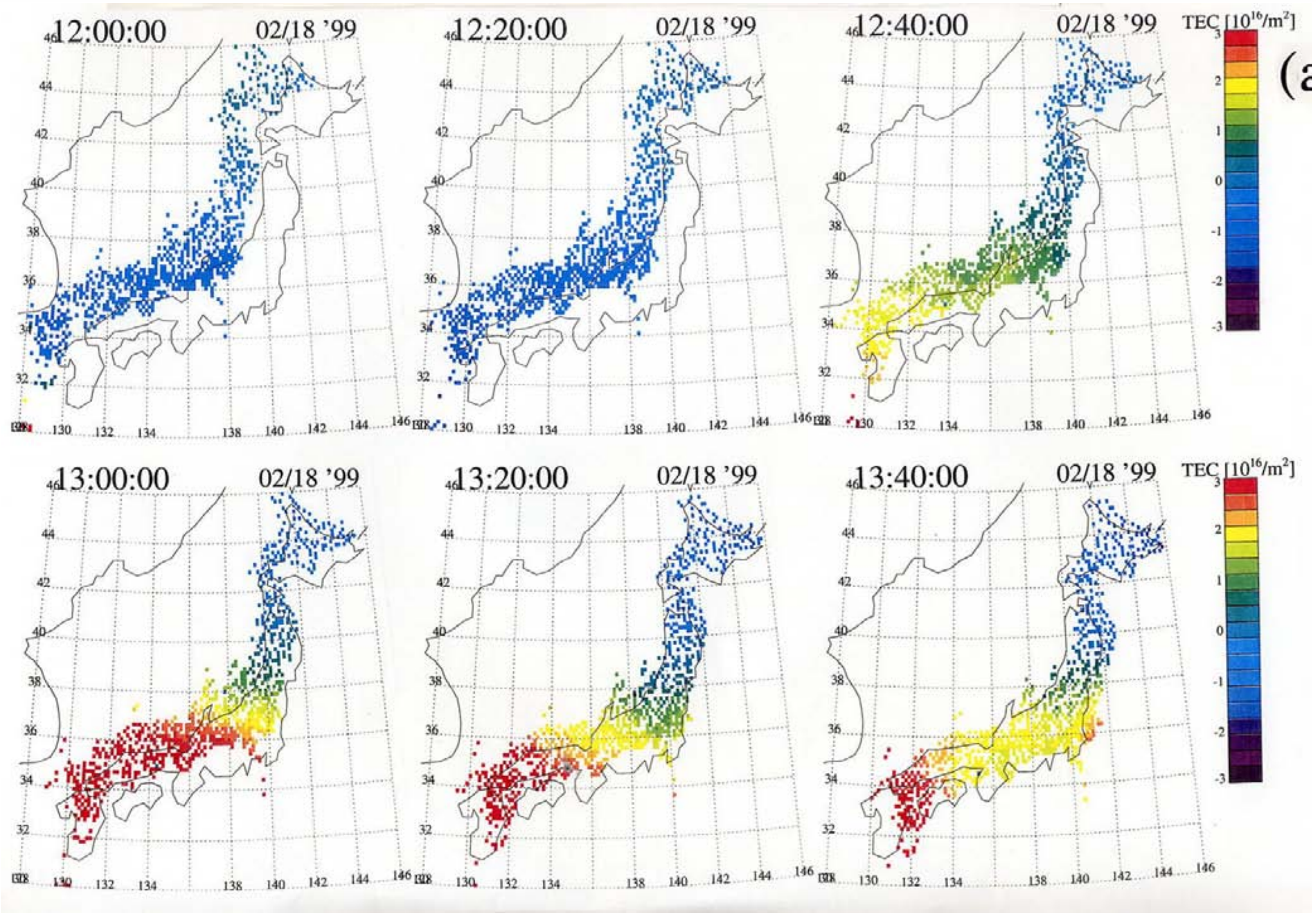
Prolss [JGR, 1993]



Shiokawa et al. [JGR, 2007]

Electron fountain effect associated with storm-time substorms

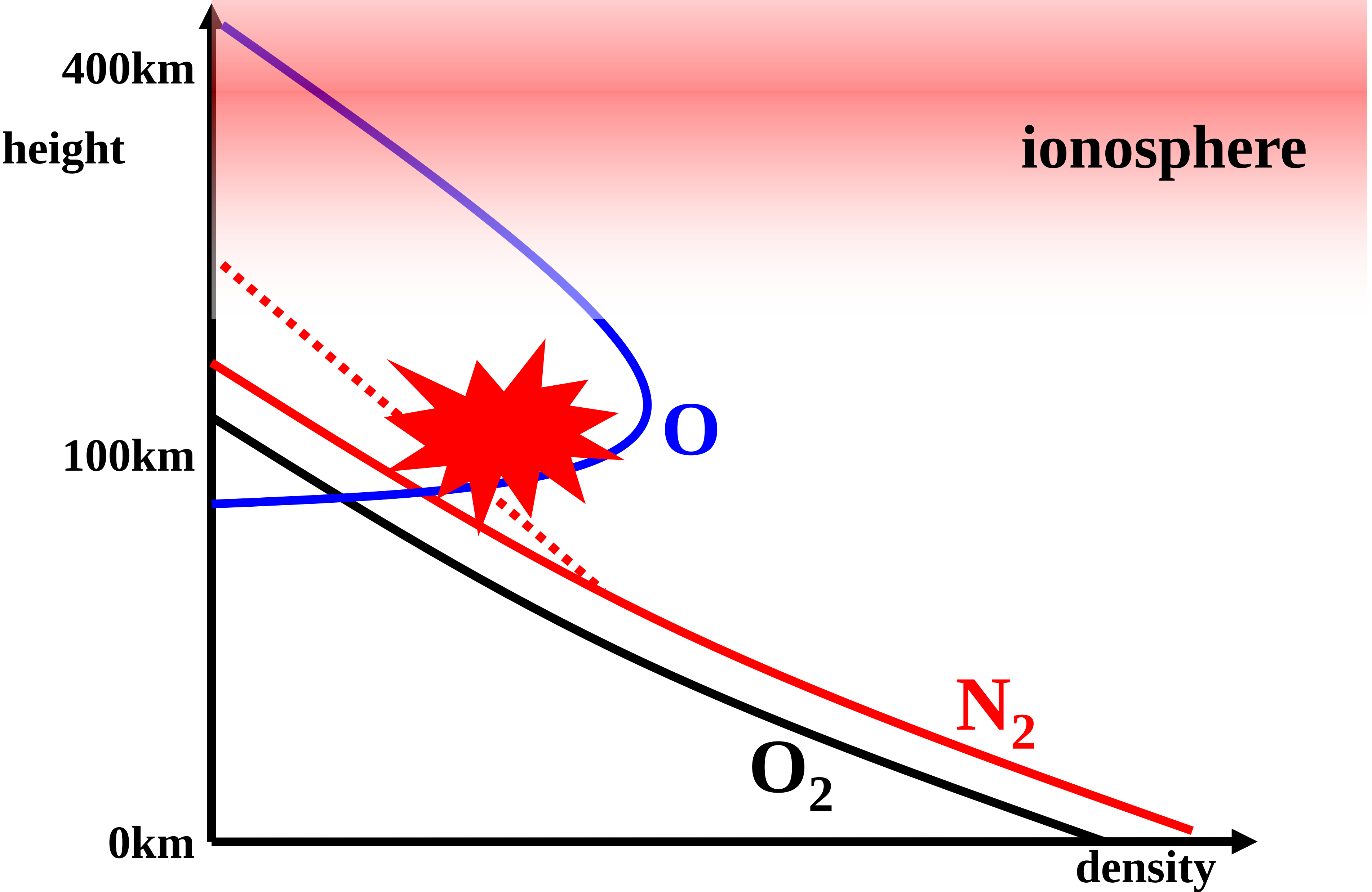


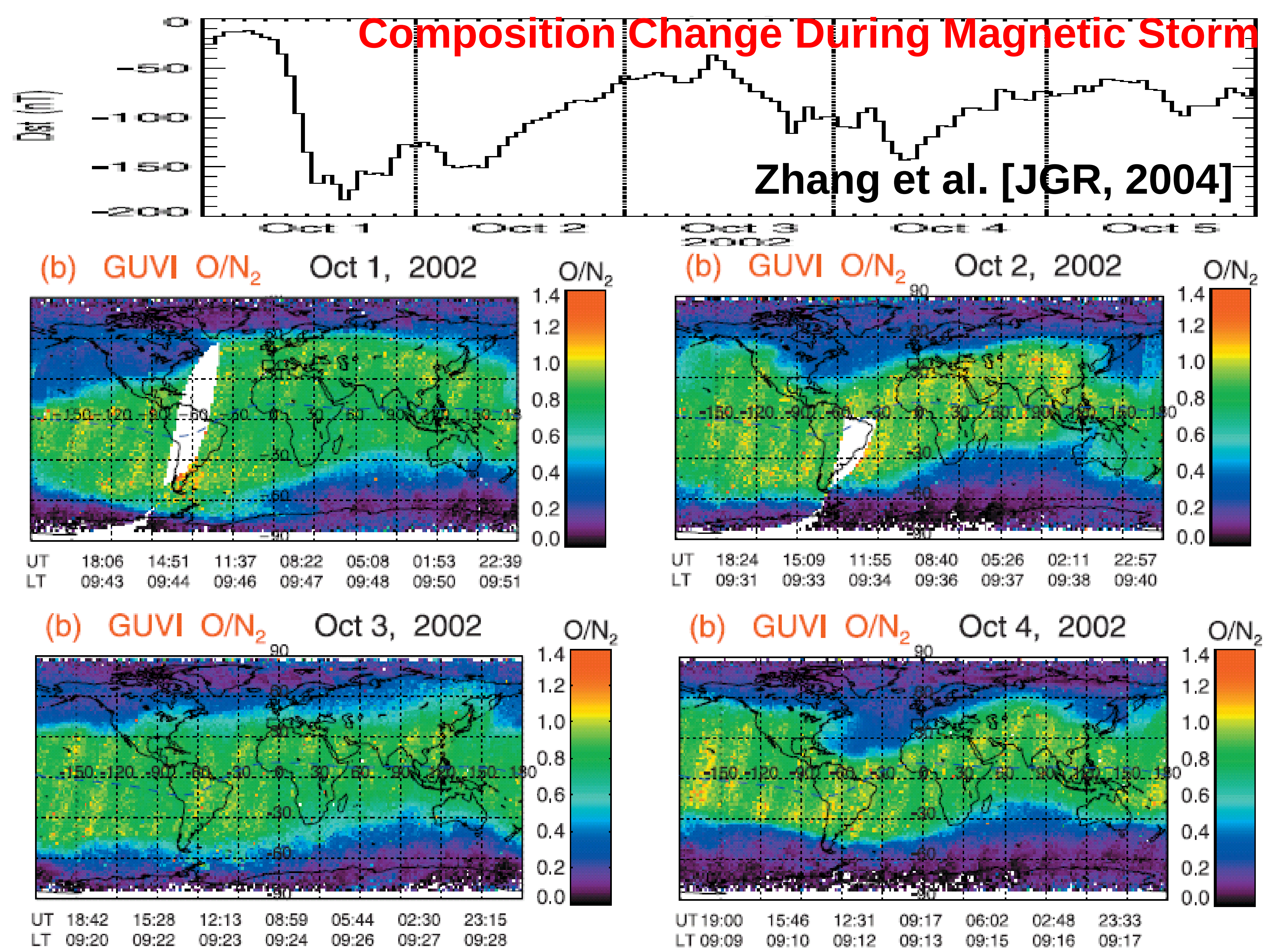


Shiokawa et al.
[JGR, 2000]

Composition Change During Magnetic Storm

decrease of O/N2 ratio → negative ionospheric storm





Composition Change During Magnetic Storm
Zhang et al. [JGR, 2004]
Dst (nT)
0
-50
-100
-150
-200
Oct 1
Oct 2
Oct 3
2002
Oct 4
Oct 5
(b) GUVI O/N$_2$ Oct 1, 2002
O/N$_2$
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
UT 18:06 14:51 11:37 08:22 05:08 01:53 22:39
LT 09:43 09:44 09:46 09:47 09:48 09:50 09:51
(b) GUVI O/N$_2$ Oct 2, 2002
UT 18:24 15:09 11:55 08:40 05:26 02:11 22:57
LT 09:31 09:33 09:34 09:36 09:37 09:38 09:40
(b) GUVI O/N$_2$ Oct 3, 2002
UT 18:42 15:28 12:13 08:59 05:44 02:30 23:15
LT 09:20 09:22 09:23 09:24 09:26 09:27 09:28
(b) GUVI O/N$_2$ Oct 4, 2002
UT 19:00 15:46 12:31 09:17 06:02 02:48 23:33
LT 09:09 09:10 09:12 09:13 09:15 09:16 09:17

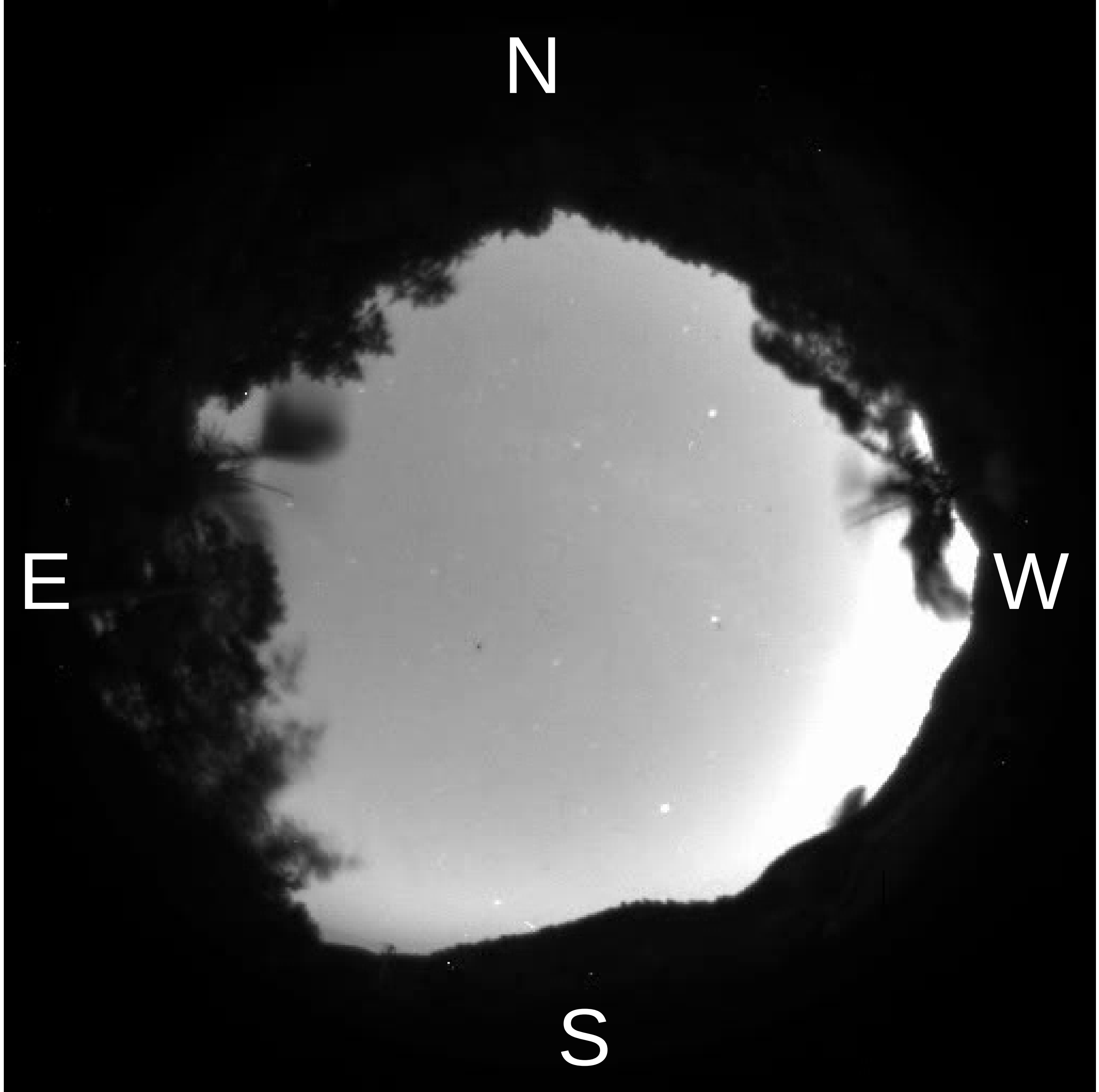
Contents

plasma bubble

Sata, Japan

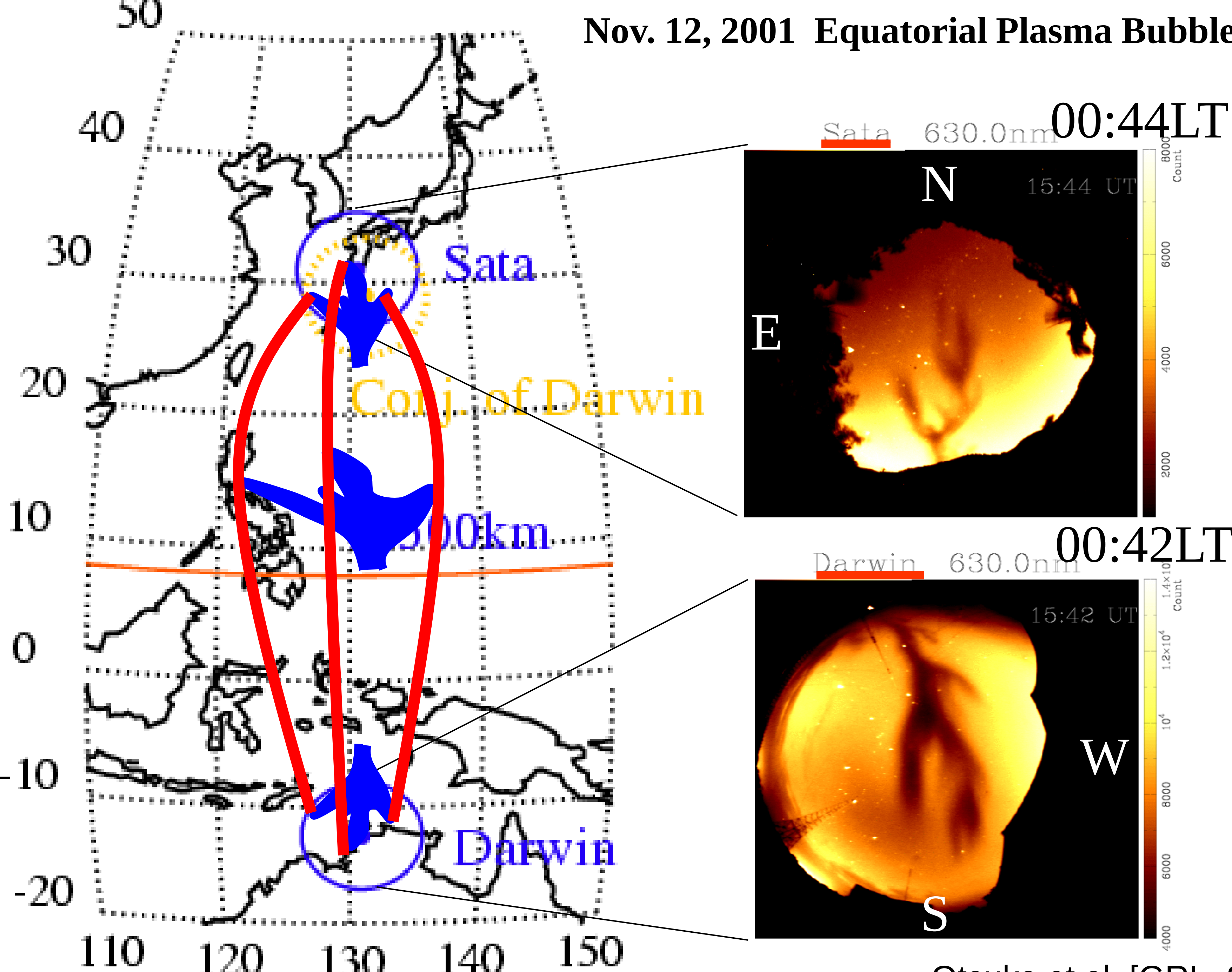
November 12, 2001

630nm



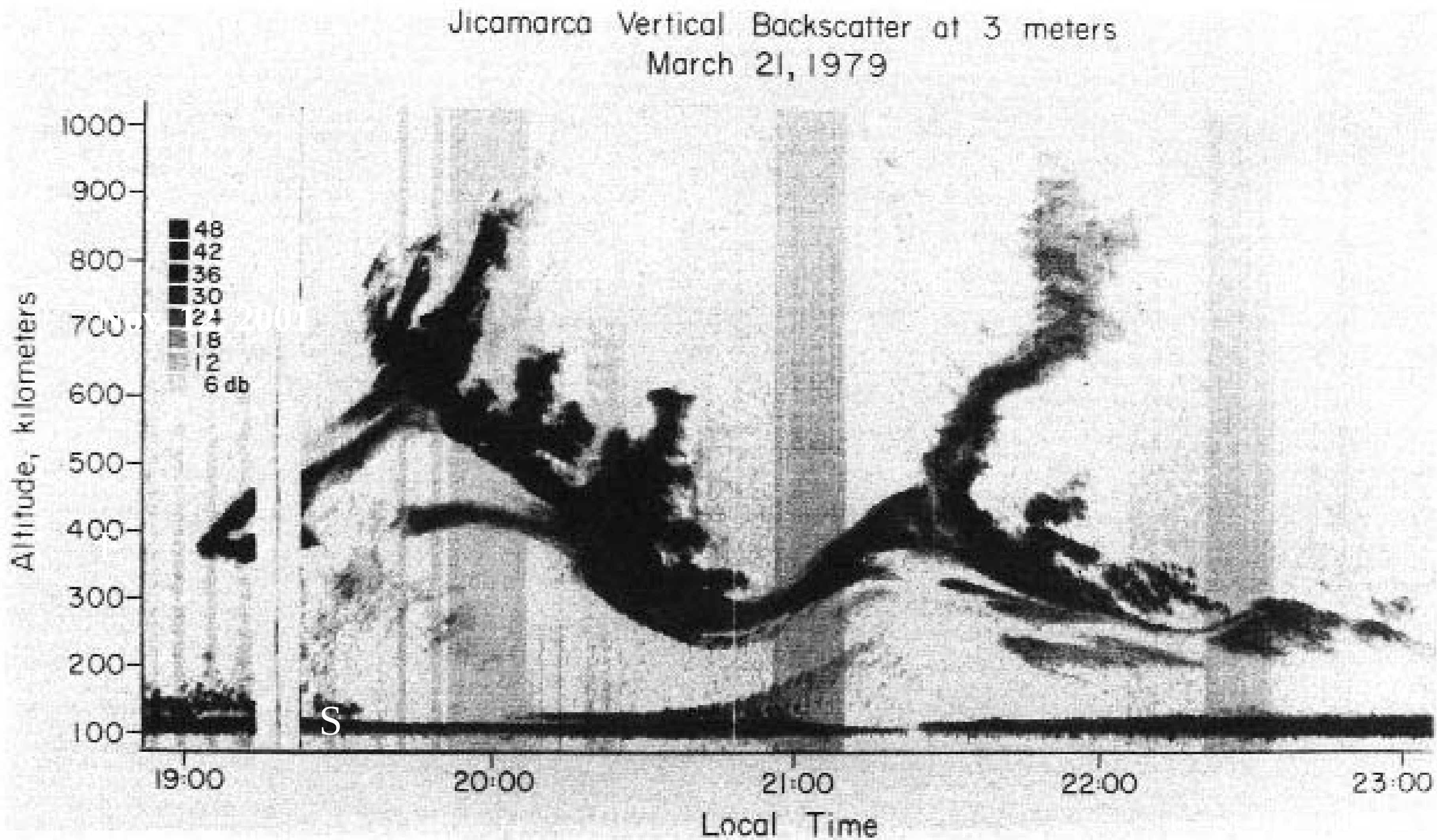
Otsuka et al. [GRL, 2002]

Nov. 12, 2001 Equatorial Plasma Bubble



Otsuka et al. [GRL, 2002]

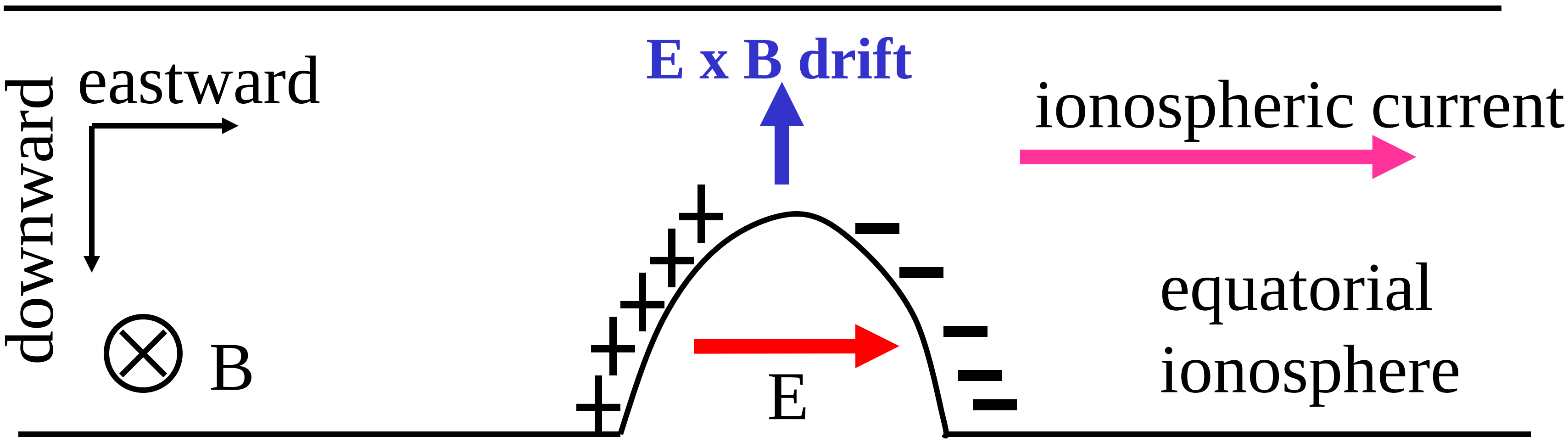
plasma bubble



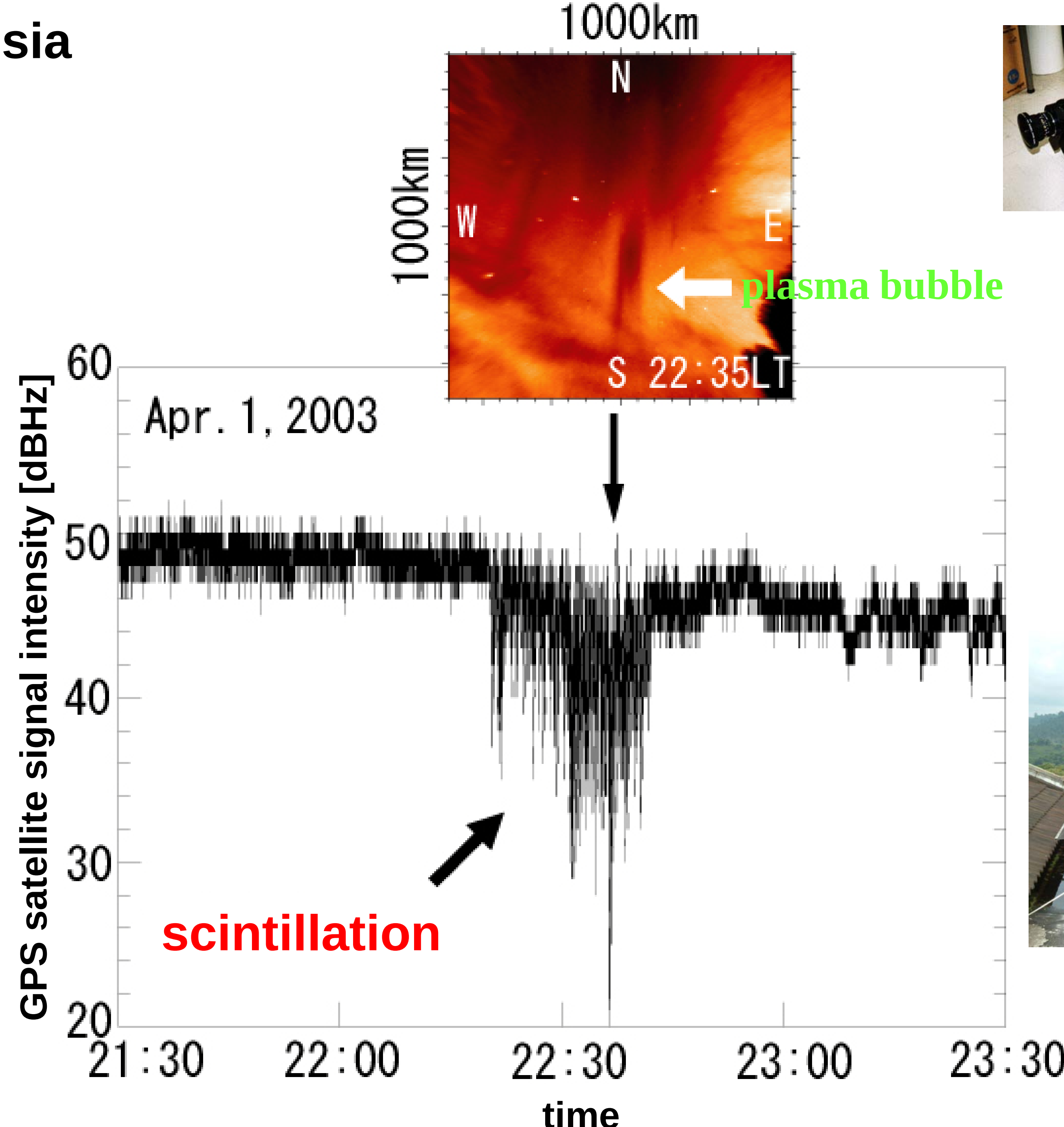
Kelley et al., Gravity wave initiation of equatorial spread F: A case study,

JGR, 86, 9087, 1981.

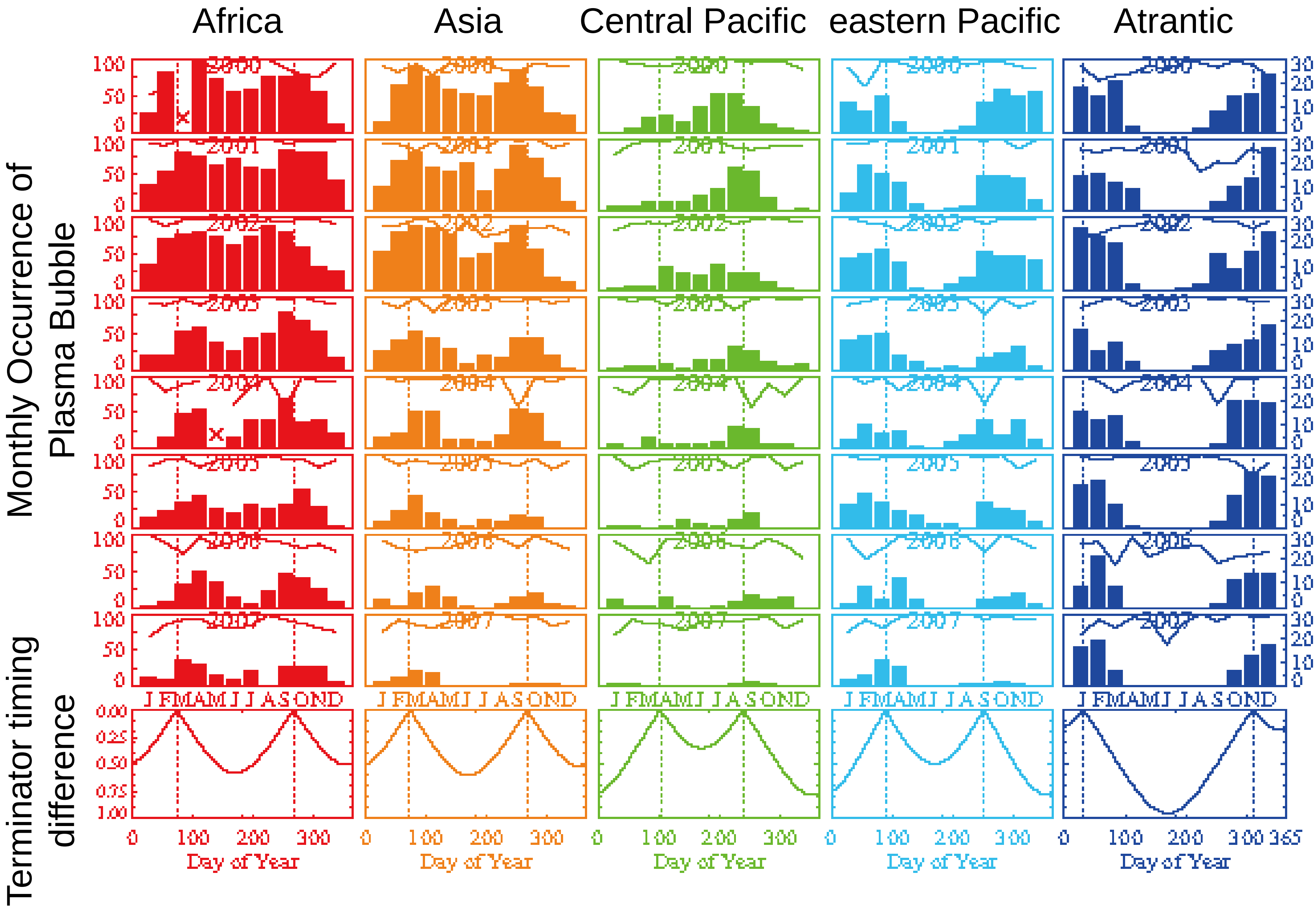
Generation of equatorial plasma bubble
= Rayleigh-Taylor Instability



Indonesia

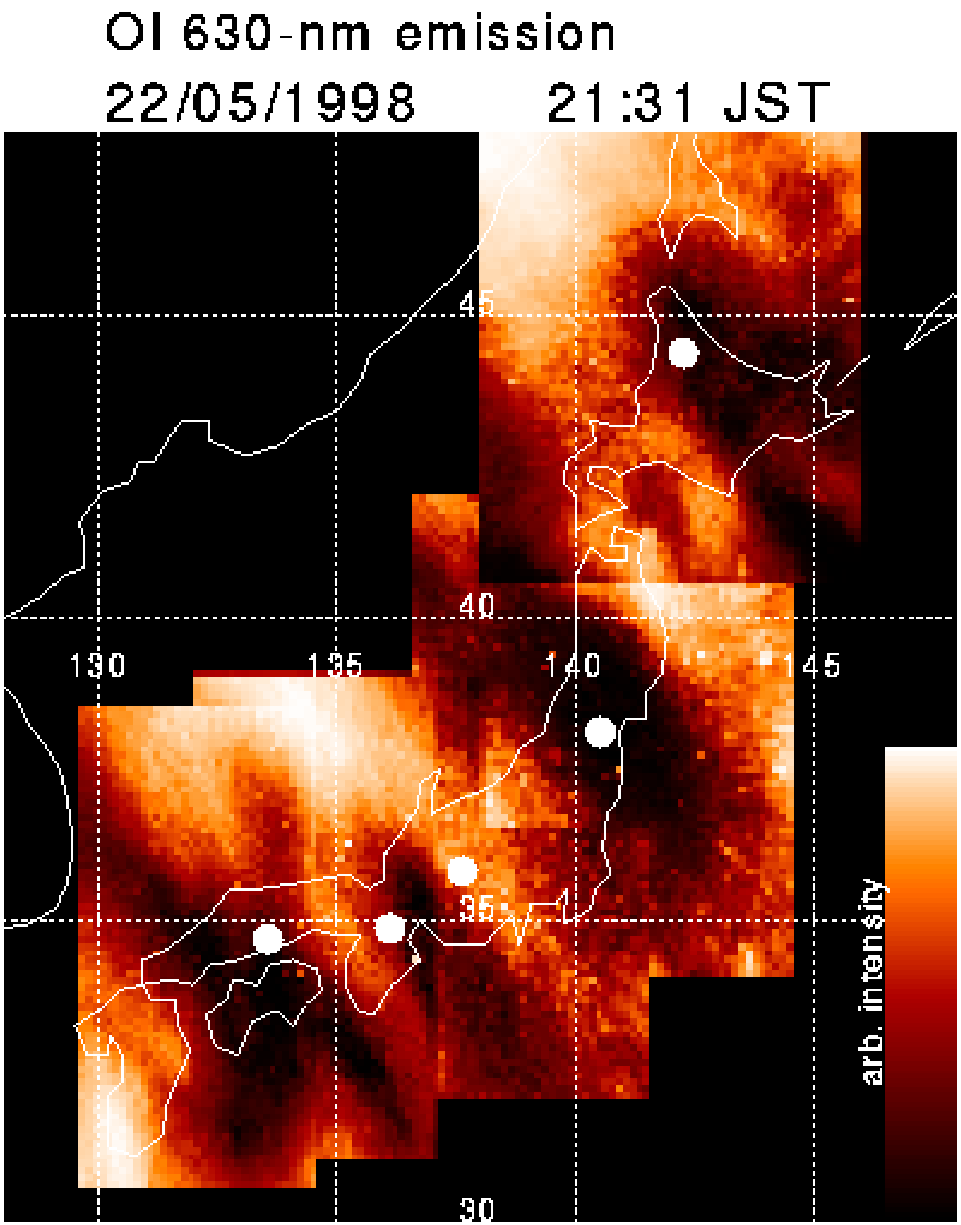


1000km
1000km
N
W
E
S 22:35LT
plasma bubble
Apr. 1, 2003
GPS satellite signal intensity [dBHz]
60
50
40
30
20
21:30
22:00
22:30
23:00
23:30
time
scintillation

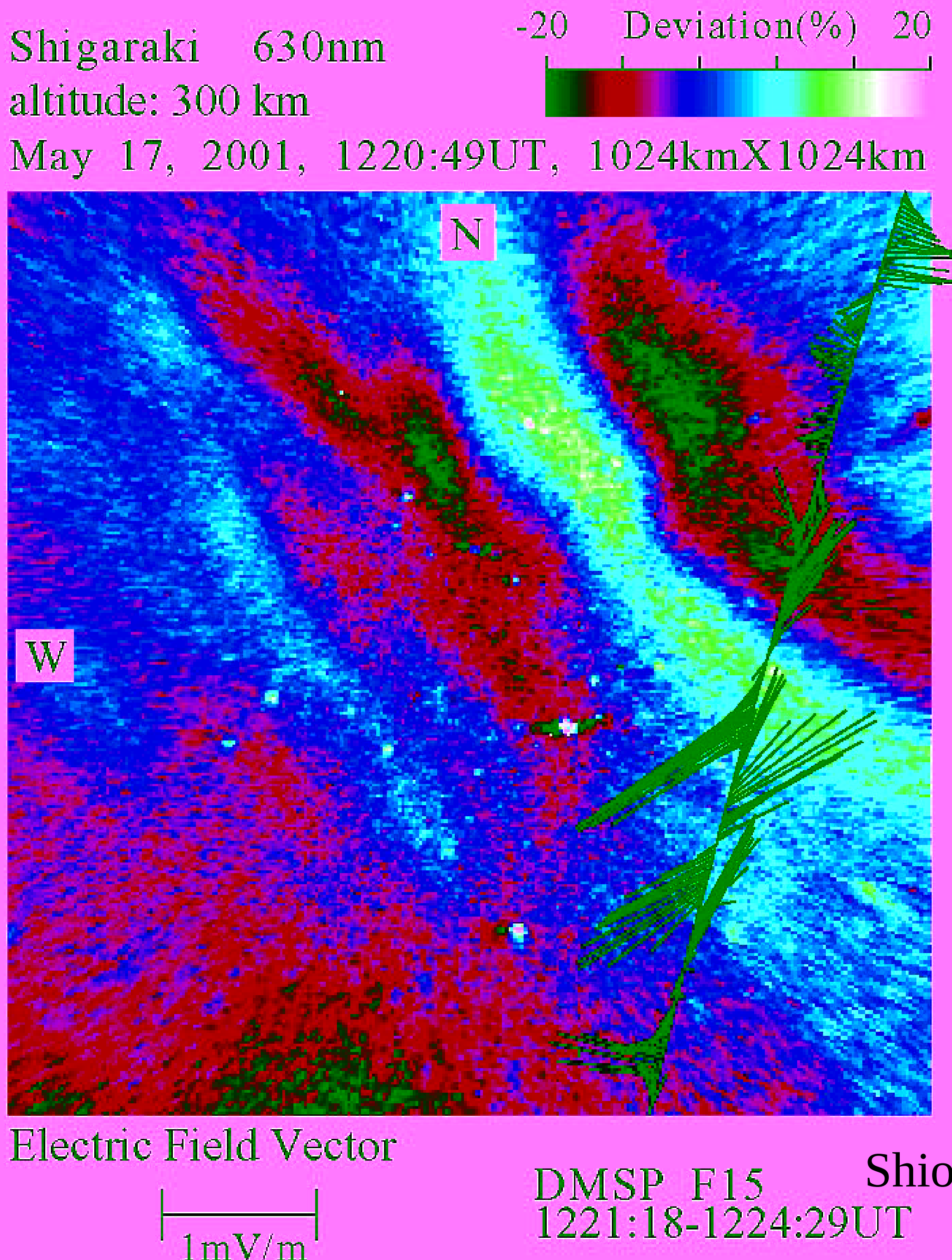


Nishioka et al. (JGR, 2008)

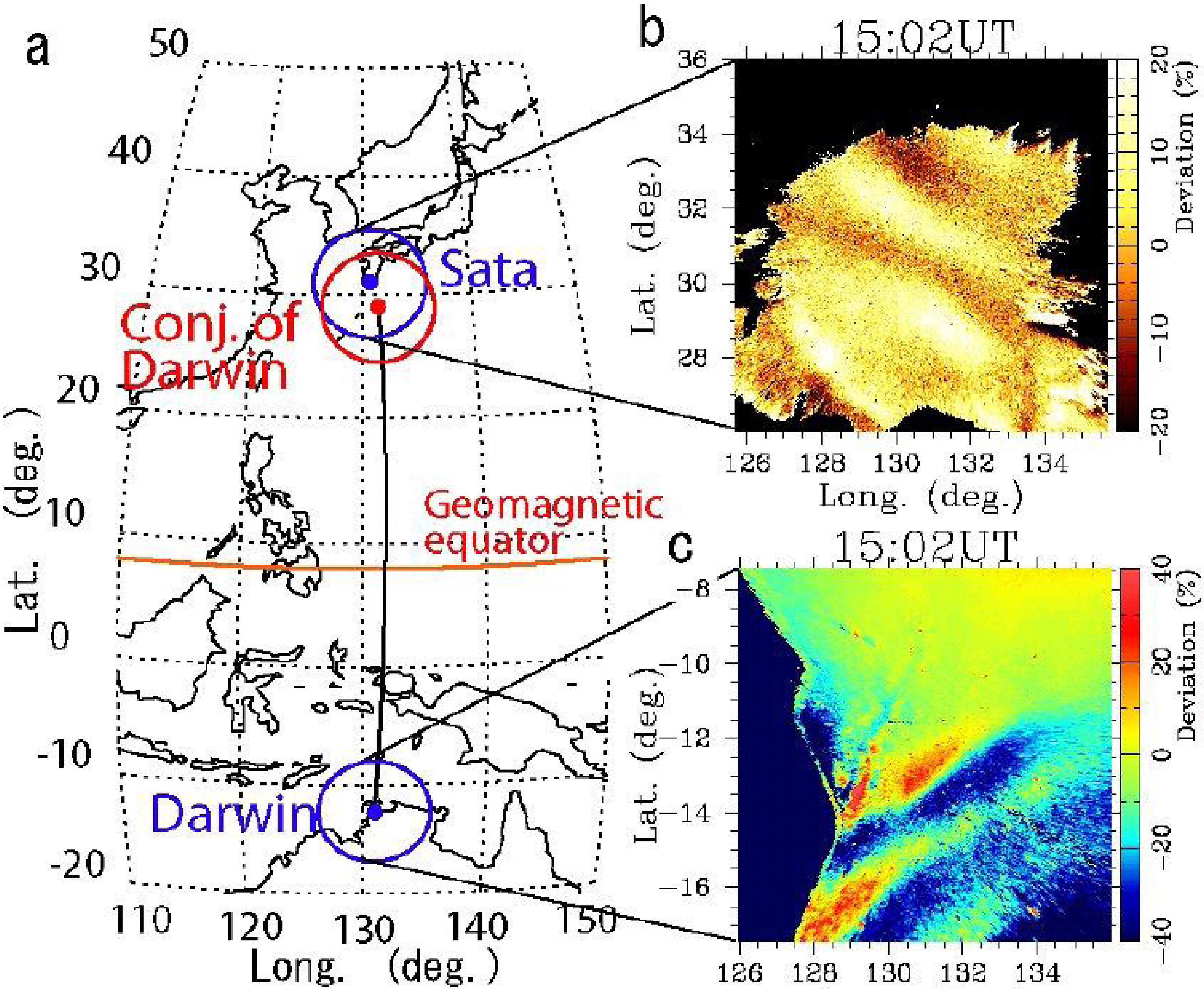
Medium-Scale Traveling Ionospheric Disturbances (MSTIDs)



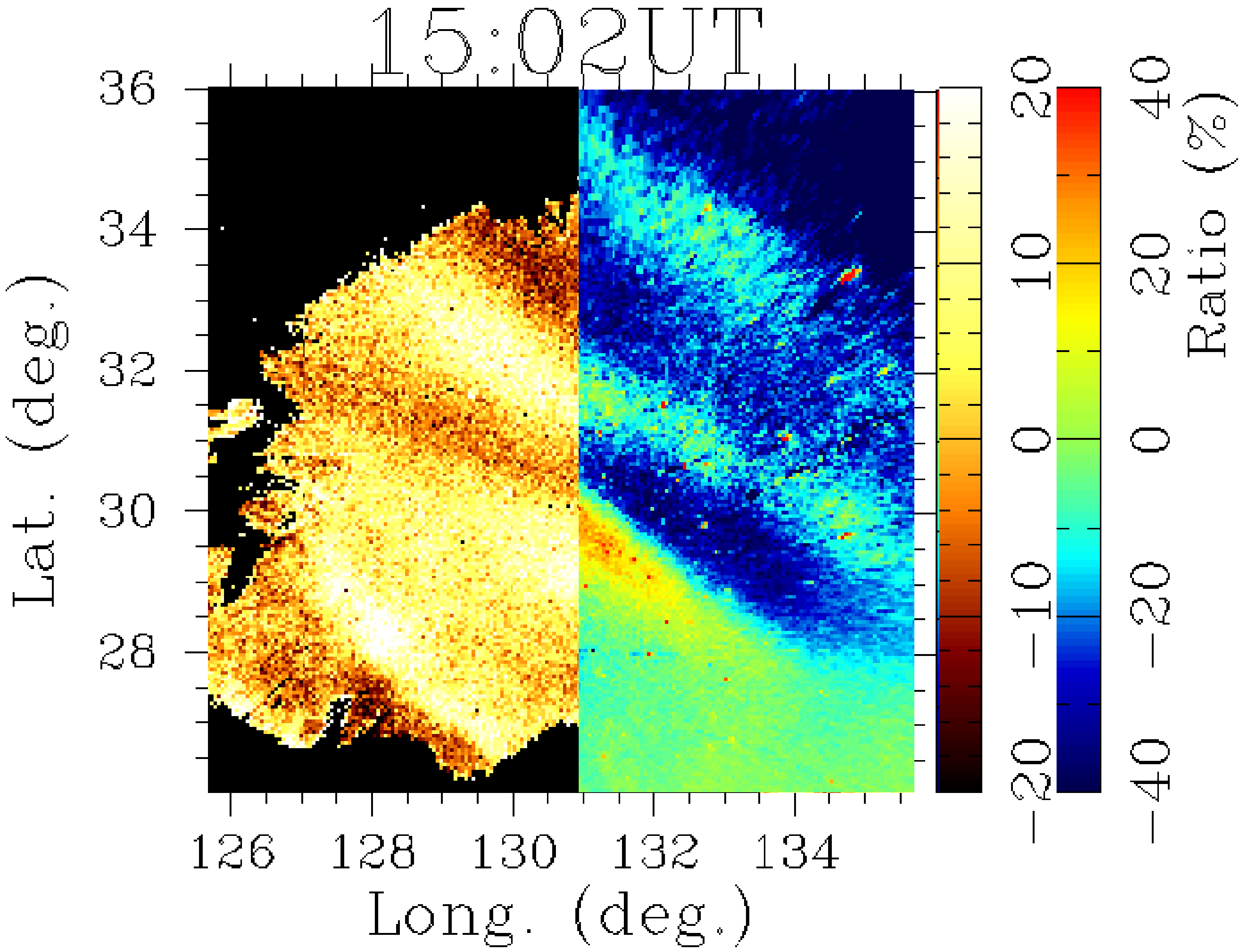
Saito et al.
[GRL, 2001]



Shiokawa et al. (JGR, 2003)



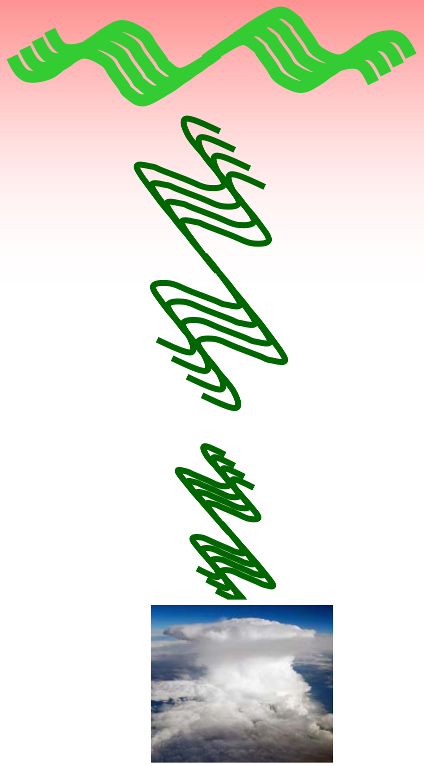
Otsuka et al. [GRL, 2004]



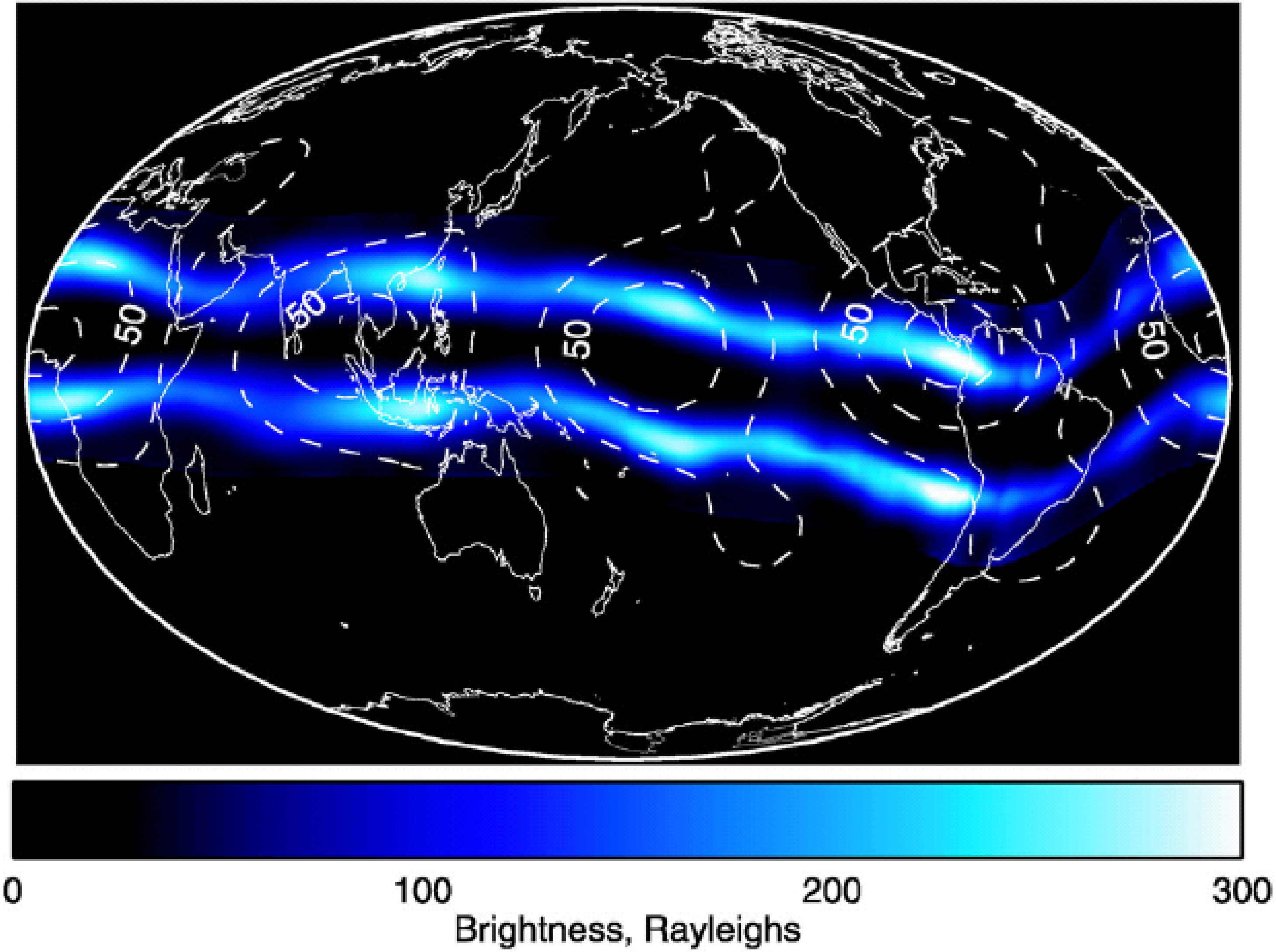
Otsuka et al. [GRL, 2004]

atmospheric waves from below

ionosphere



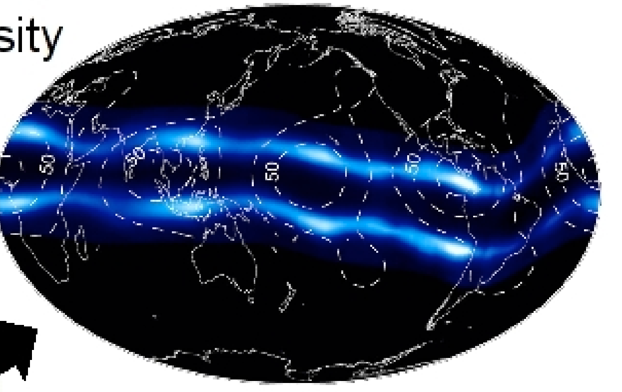
Wave-number 4 structure in the ionosphere



Immel et al. [GRL, 2006]

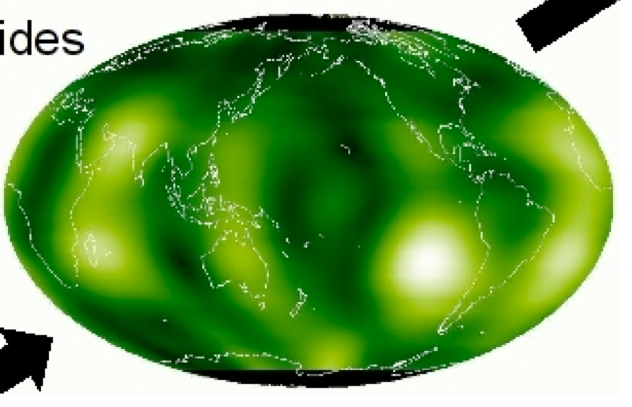
F-region plasma density
IMAGE satellite

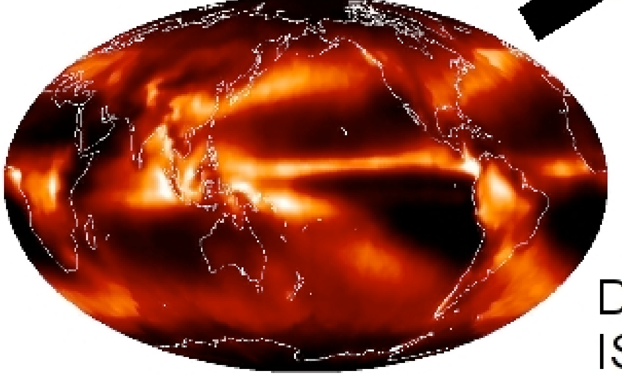
altitude: 400km



MLT zonal wind tides
TIMED satellite

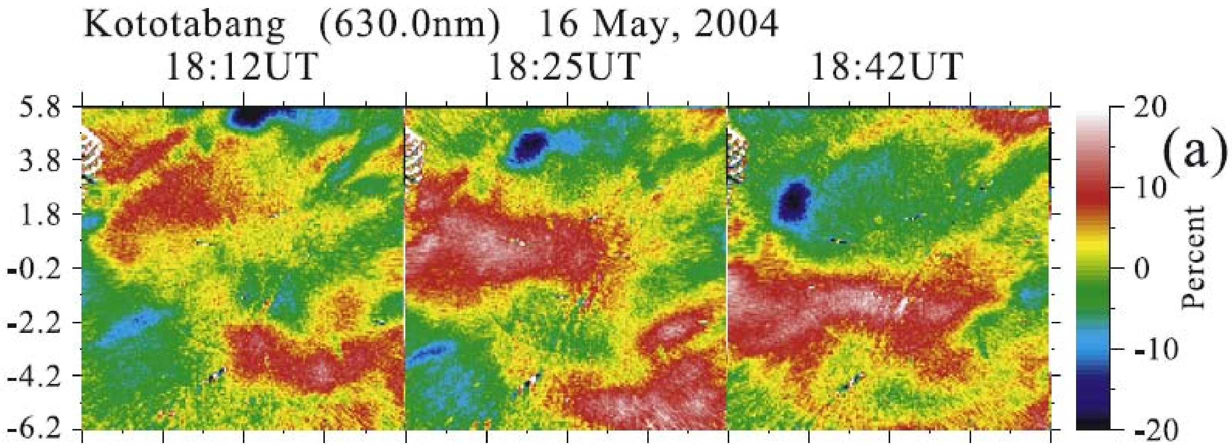
altitude: 100km

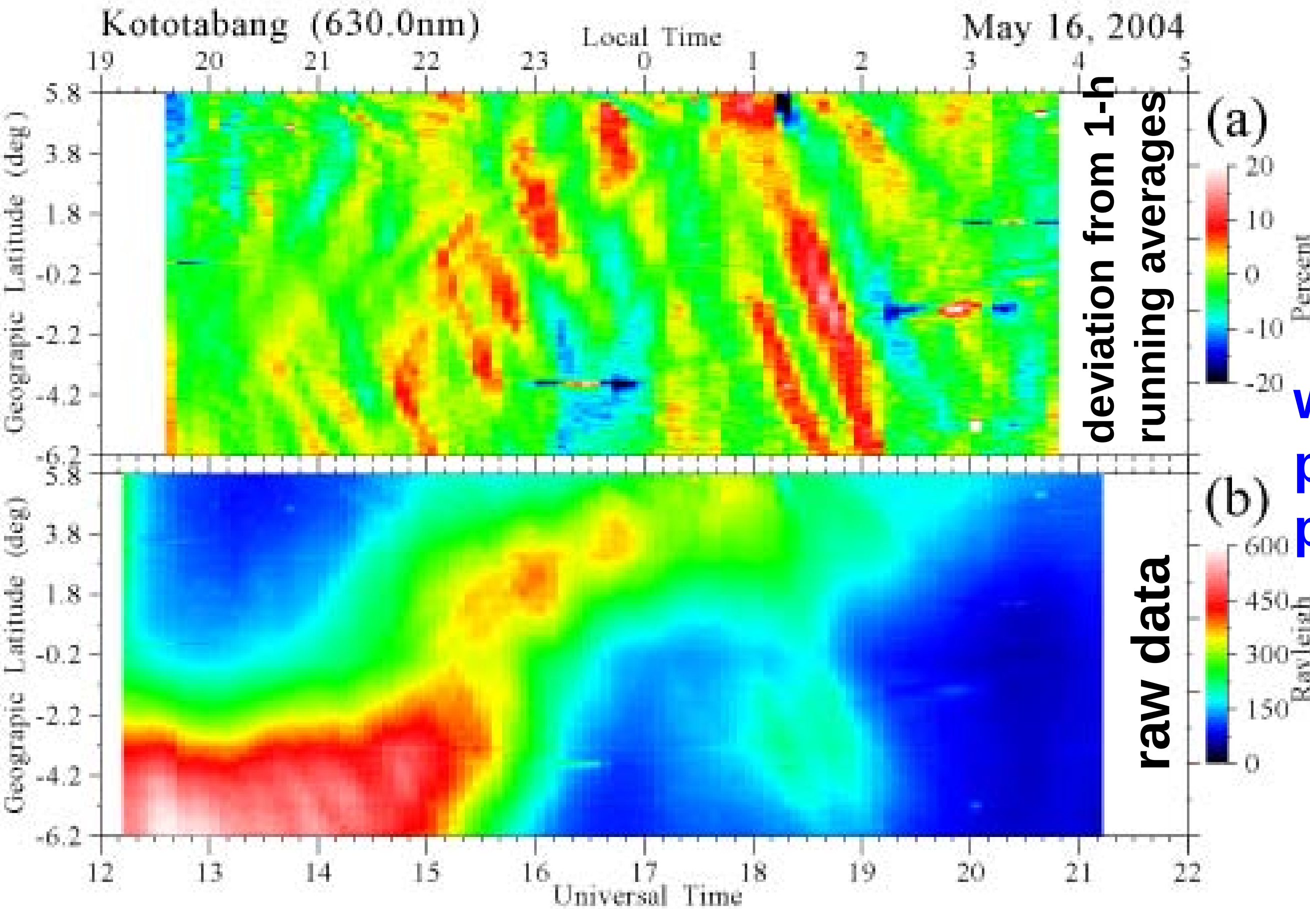




altitude: 10km

Daytime convective clouds
ISCCP climatology

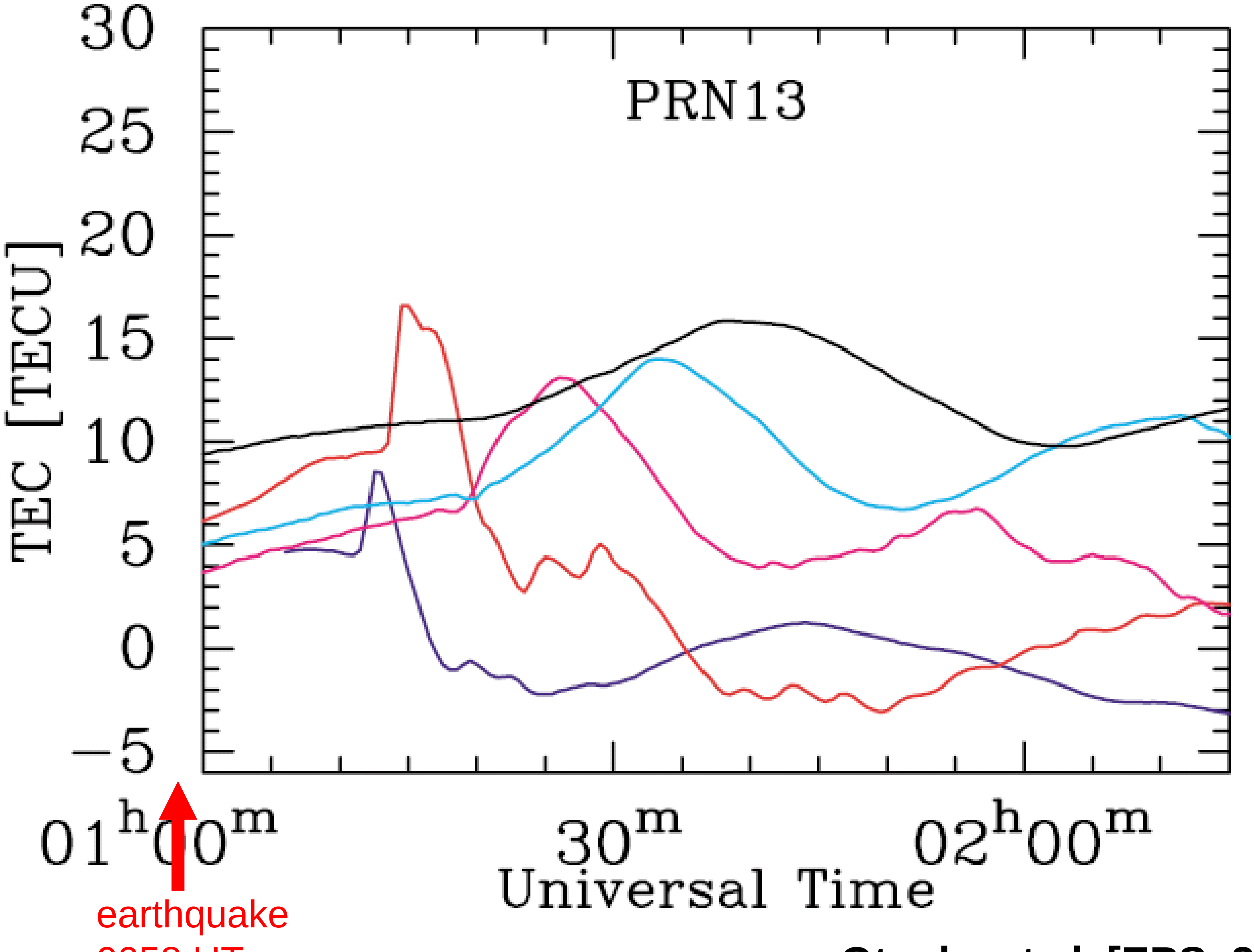




wavelength: ~700km
period: ~40min,
phase velocity: ~300m/s

Shiokawa et al.
(JGR, 2006)

Ionospheric disturbance after the Sumatra Earthquake (Dec.26, 2004)



Otsuka et al. [EPS, 2006]

Summary of unsolved questions

Neutral-plasma interaction is a persistent boundary field where a lot of unsolved but important questions exists

Atmospheric Waves from the Bottom

✗ How atmospheric waves penetrate into the ionosphere and initiate/modulate ionospheric instabilities?

bubble/large-scale wave interaction, day-to-day variability of bubbles, mid-latitude MSTID motion, interhemispheric coupling of MSTIDs/bubbles through field-aligned currents in the plasmasphere

Energy Input from the Magnetopshere

✗ How the high-latitude energy input changes the ionospheric dynamics and composition?

E-field/equatorward wind for plasma fountain, vertical wind near aurora, feedback to the plasma convection in the magnetosphere, composition change and transport

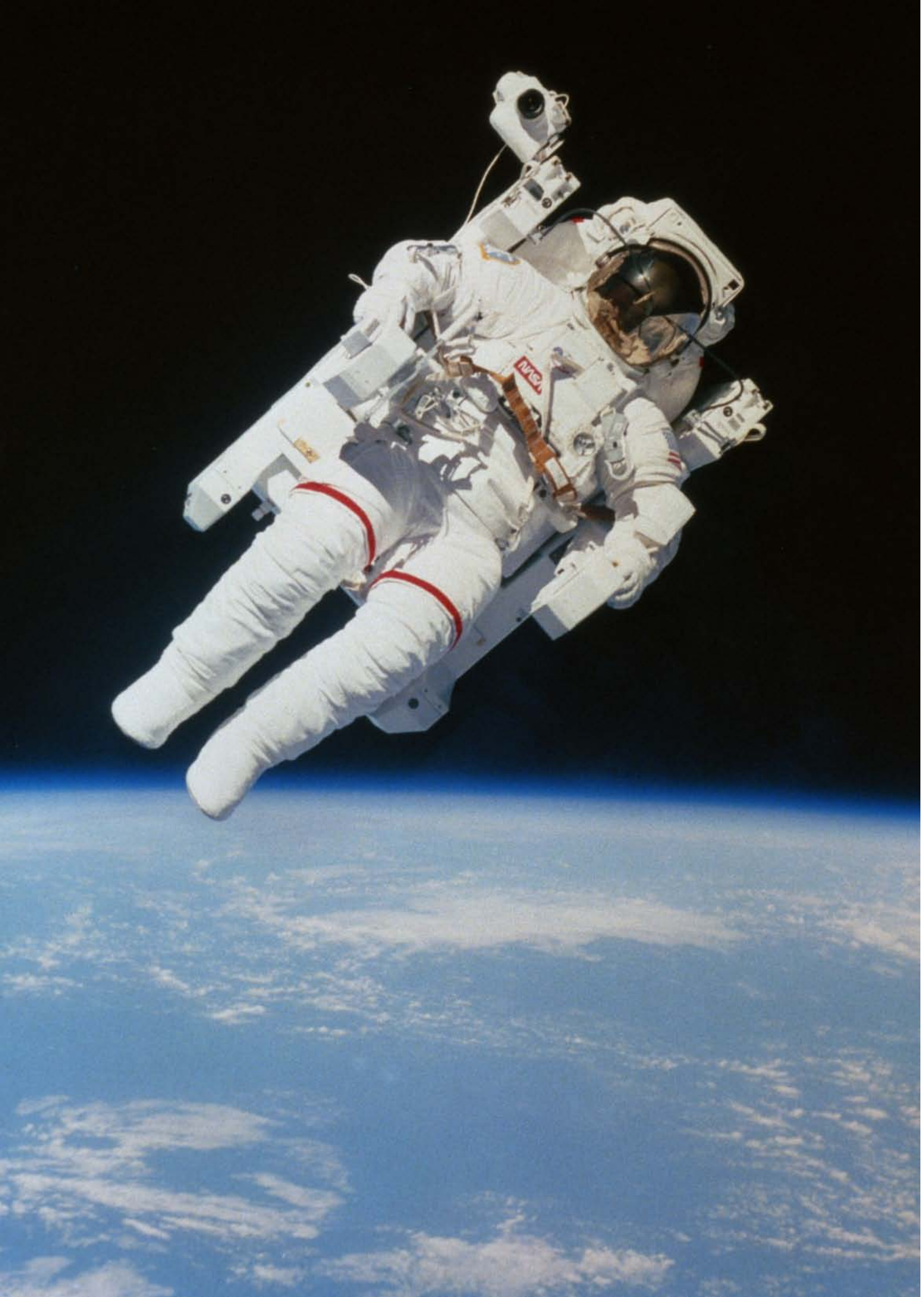
SCOSTEP CAWSES-II (2009-2013) Task Group 4:

What is the geospace response to variable inputs from the lower atmosphere?

Overall Objective:

TG4 will elucidate the dynamical coupling from the low and middle atmosphere to the geospace including the upper atmosphere, ionosphere, and magnetosphere, for various frequencies and scales, such as gravity waves, tides, and planetary waves, and for equatorial, middle, and high latitudes.

An essential part of TG4 is to encourage interaction between atmospheric and plasma scientists!



When human beings start to live in space, research on the ionosphere would become much closer to our daily life.

“Space Meteorology”