The use of DORIS as a tool to study the Earth ionosphere.

R. Warnant[1], L. Morel[2], S. Stankov[3],
J.-C. Jodogne[4], H. Nebdi[4], N. Jakowski[3]

[1]Royal Observatory of Belgium, Brussels, Belgium.
[2]Ecole Supérieure des Géomètres Topographes, Le Mans, France.
[3]German Aerospace Center, Neustrelitz, Germany.
[4]Royal Meteorological Institute of Belgium,Brussels, Belgium.

I - Space Geodesy and the ionosphere

The ionospheric refraction

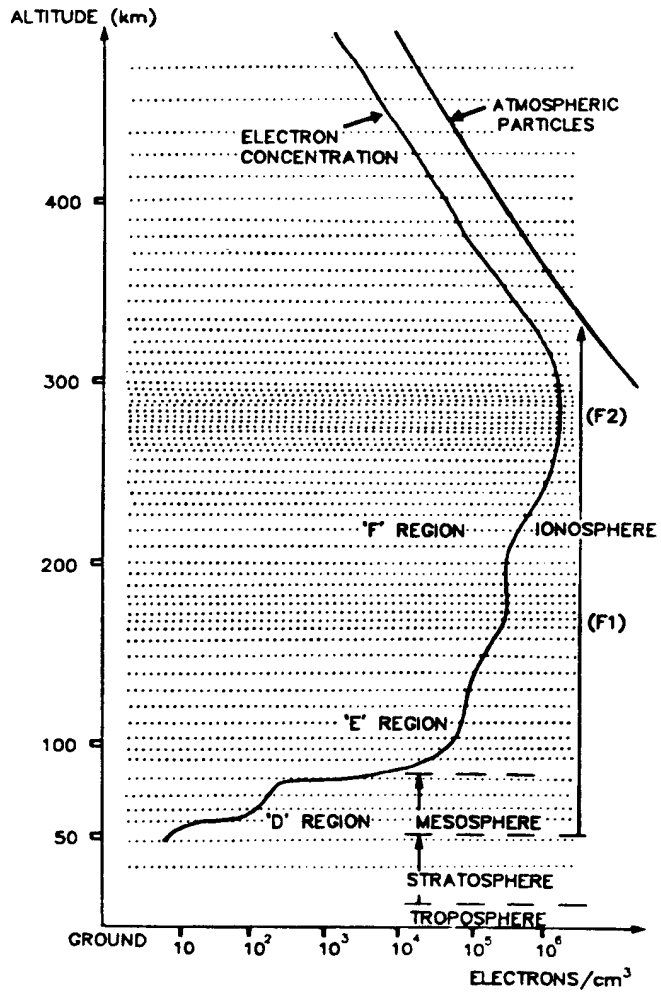
- Propagation of radio waves affected by the ionized atmosphere (i.e. free electrons) :

- the ionosphere (50–1000 km)

=> presence of a maximum

- the protonosphere (>1000 km)

=> not many measurements

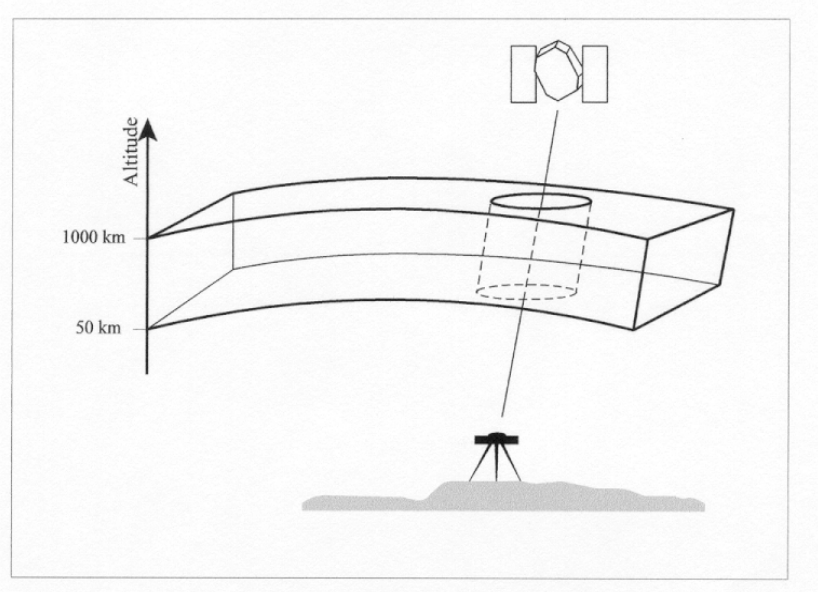


The Total Electron Content

- The ionospheric refraction depends on wave frequency and on the **Total Electron Content (TEC).**

- The TEC is the integral of the electron concentration.

- It is measured in TECU (1 TECU=10^{16} el/m^2).



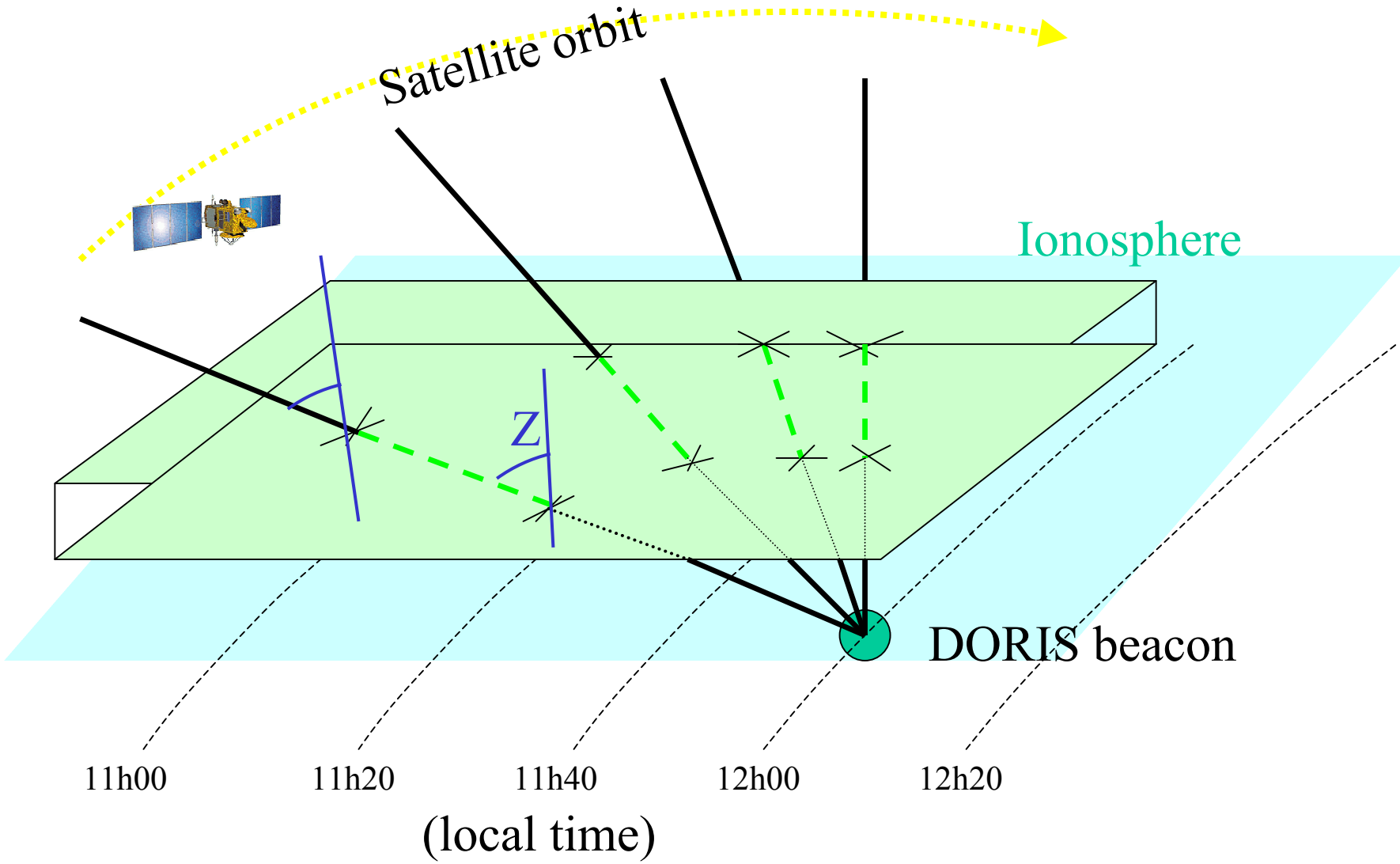
II - The use of Geodetic techniques for ionospheric studies

The principle

- The ionosphere is a dispersive medium for radio waves
- Dual frequency radio signals emitted by geodetic satellites can be combined in order to retrieve the TEC.
- Satellites used : Transit (1 000 km), GPS (20 200 km), GLONASS (19 200 km), DORIS (800 to 1 336 km)
- **The meaning of « TEC » depends on satellite altitude !**

- Satellites observed at different azimuths and elevations

  => ionosphere at different latitudes and longitudes

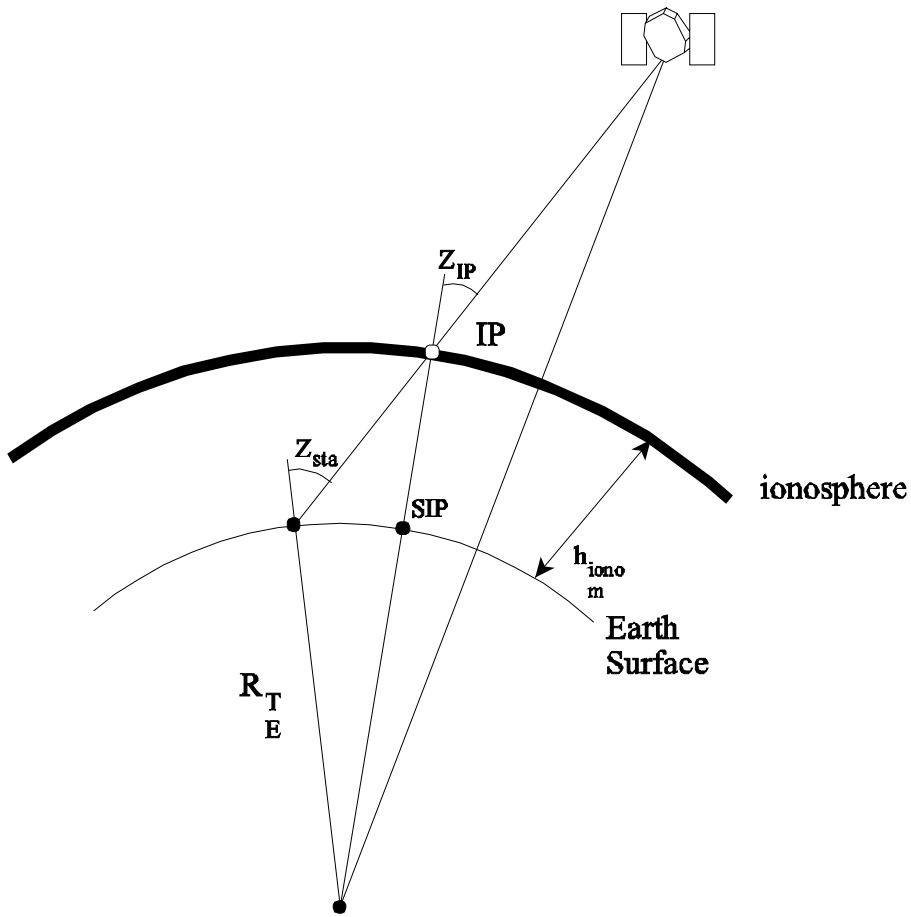


The ionospheric point

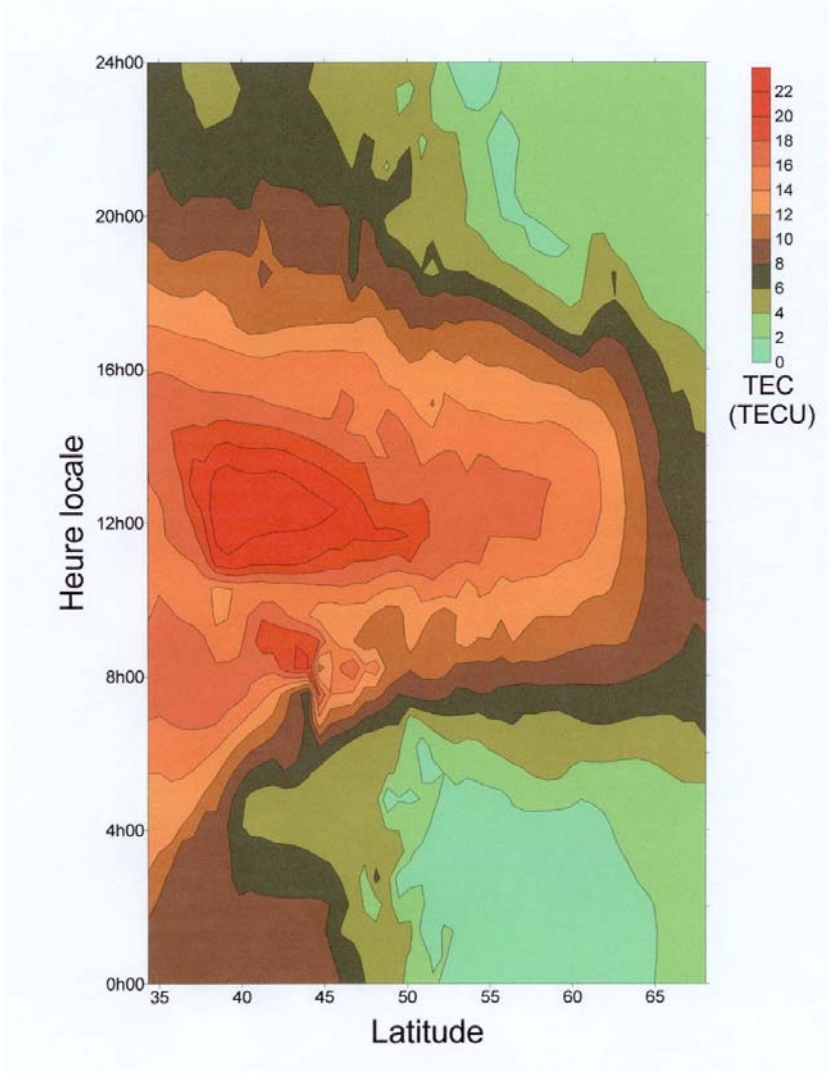
- Ionospheric point (IP)

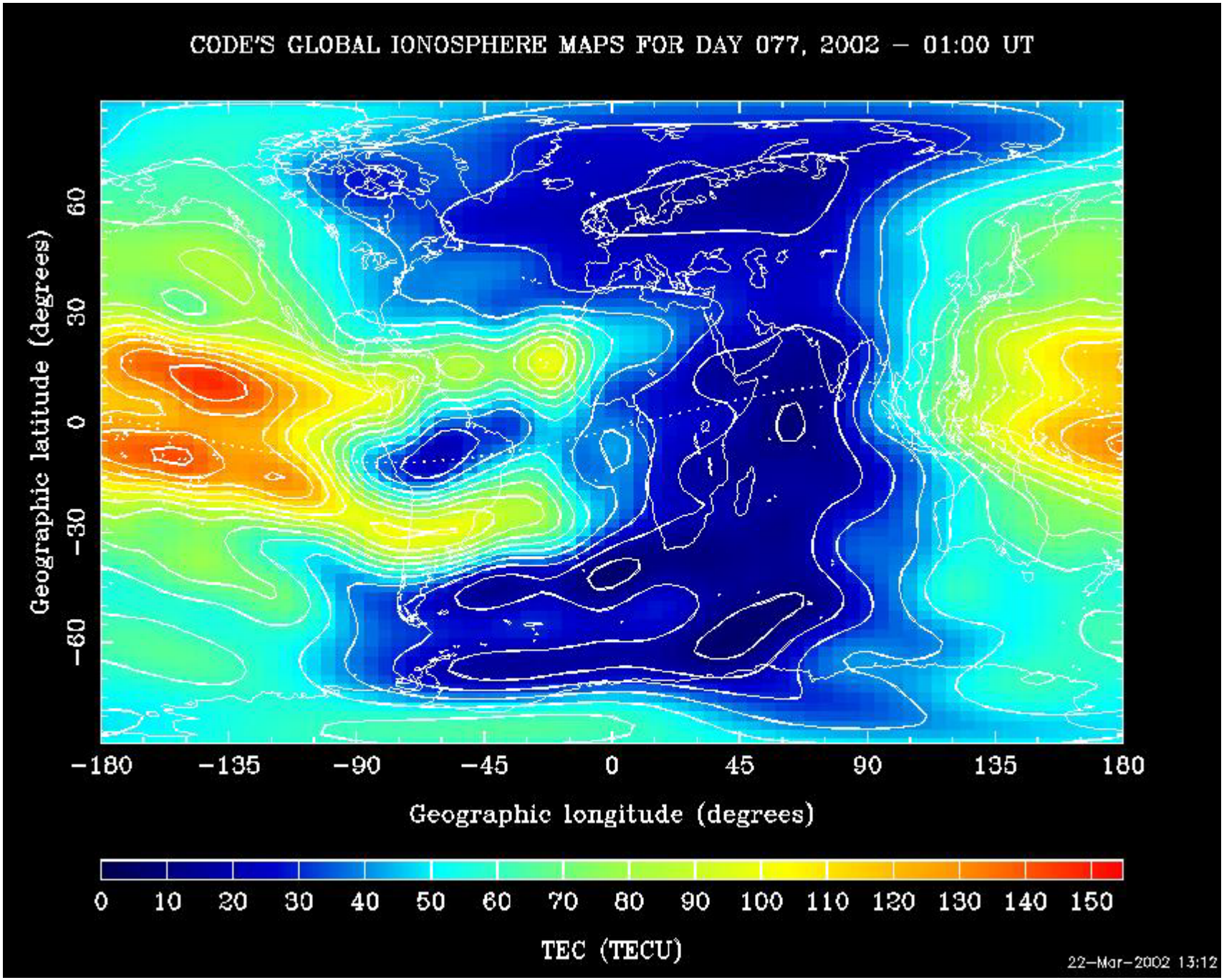
=> Orbit necessary

- Slant TEC ⇔ vertical TEC



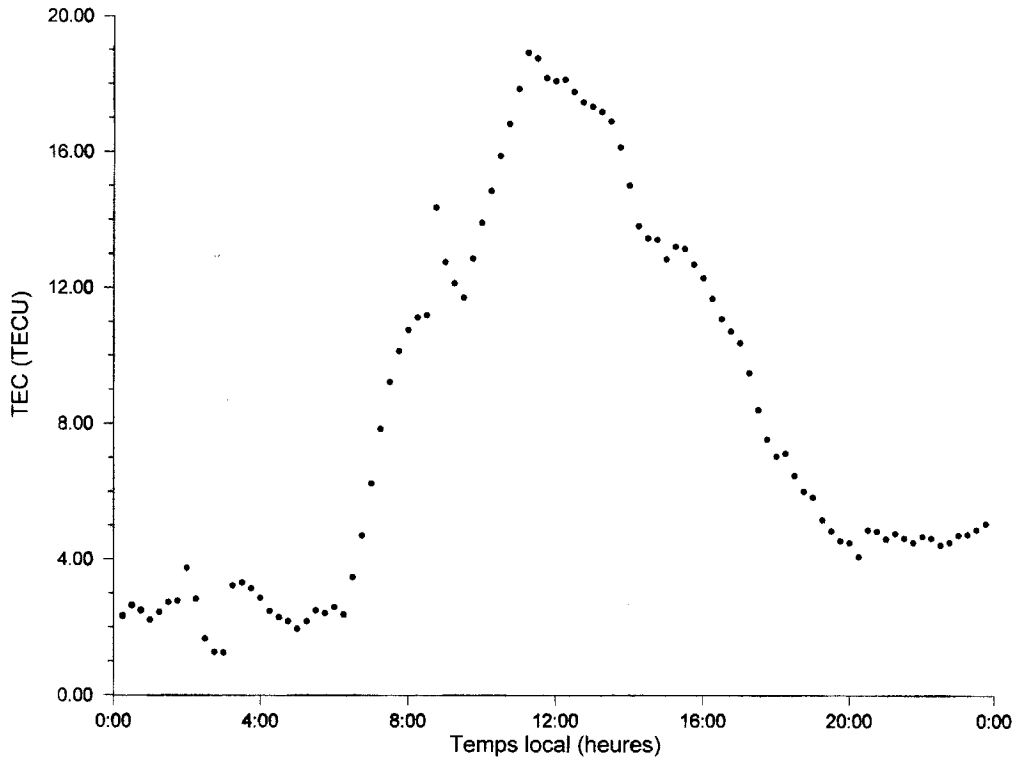
Global or regional maps



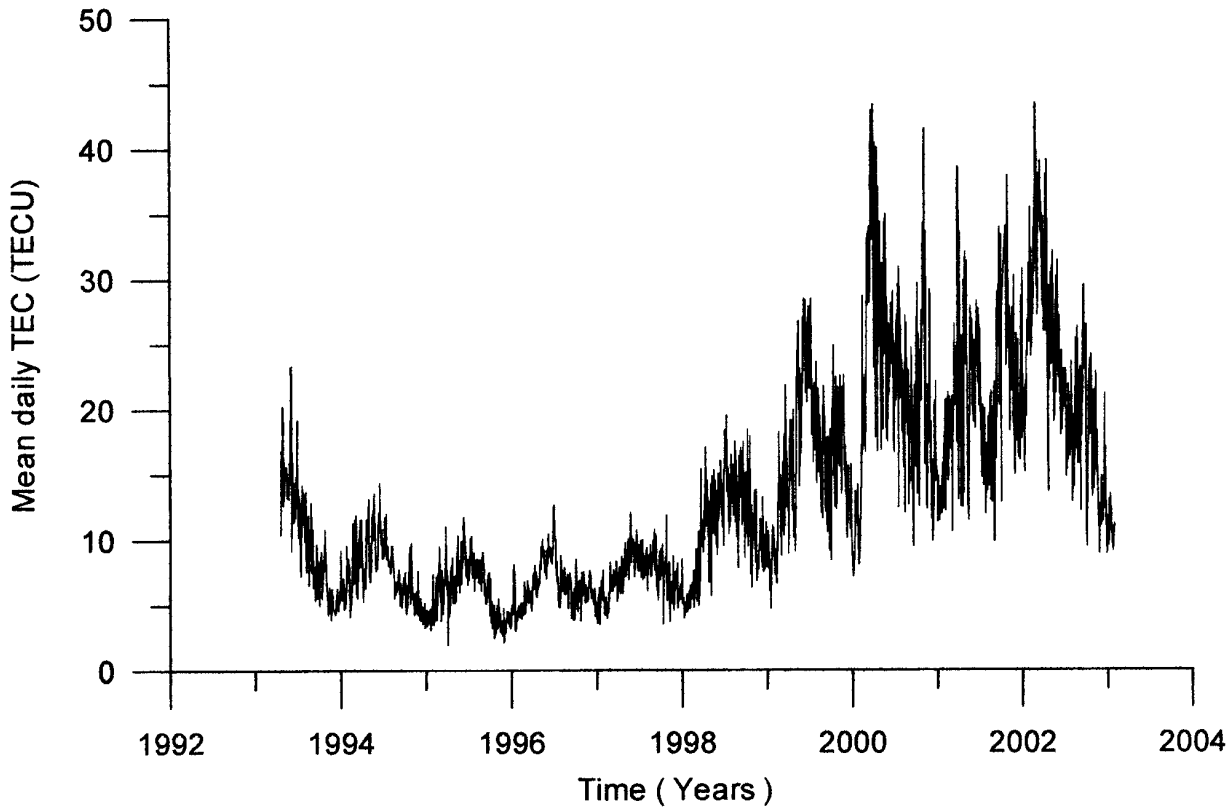

CODE'S GLOBAL IONOSPHERE MAPS FOR DAY 077, 2002 - 01:00 UT
Geographic latitude (degrees)
60
30
0
-30
-60
-180
-135
-90
-45
0
45
90
135
180
Geographic longitude (degrees)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TEC (TECU)
22-Mar-2002 13:12

Local studies

- TEC above the observing station



- Mean TEC at Brussels since April 1993



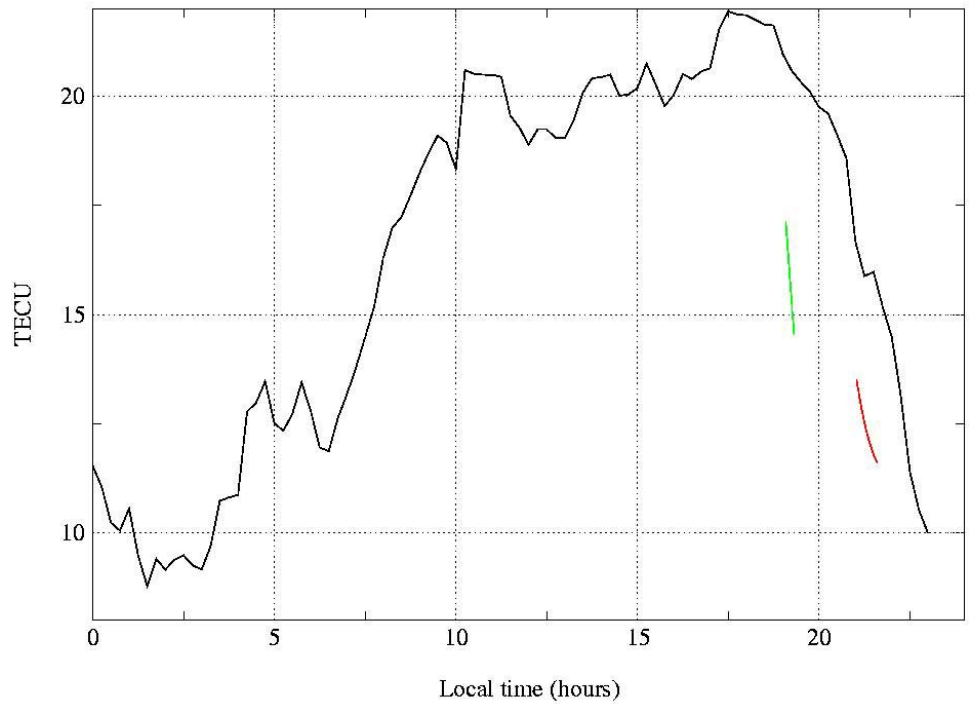
Collocation GPS + DORIS

- Due to the different altitudes, allows to study the electron content of the protonosphere

- $TEC_{protonosphere} = TEC_{GPS} - TEC_{DORIS}$

- Many collocations GPS – DORIS already existing !

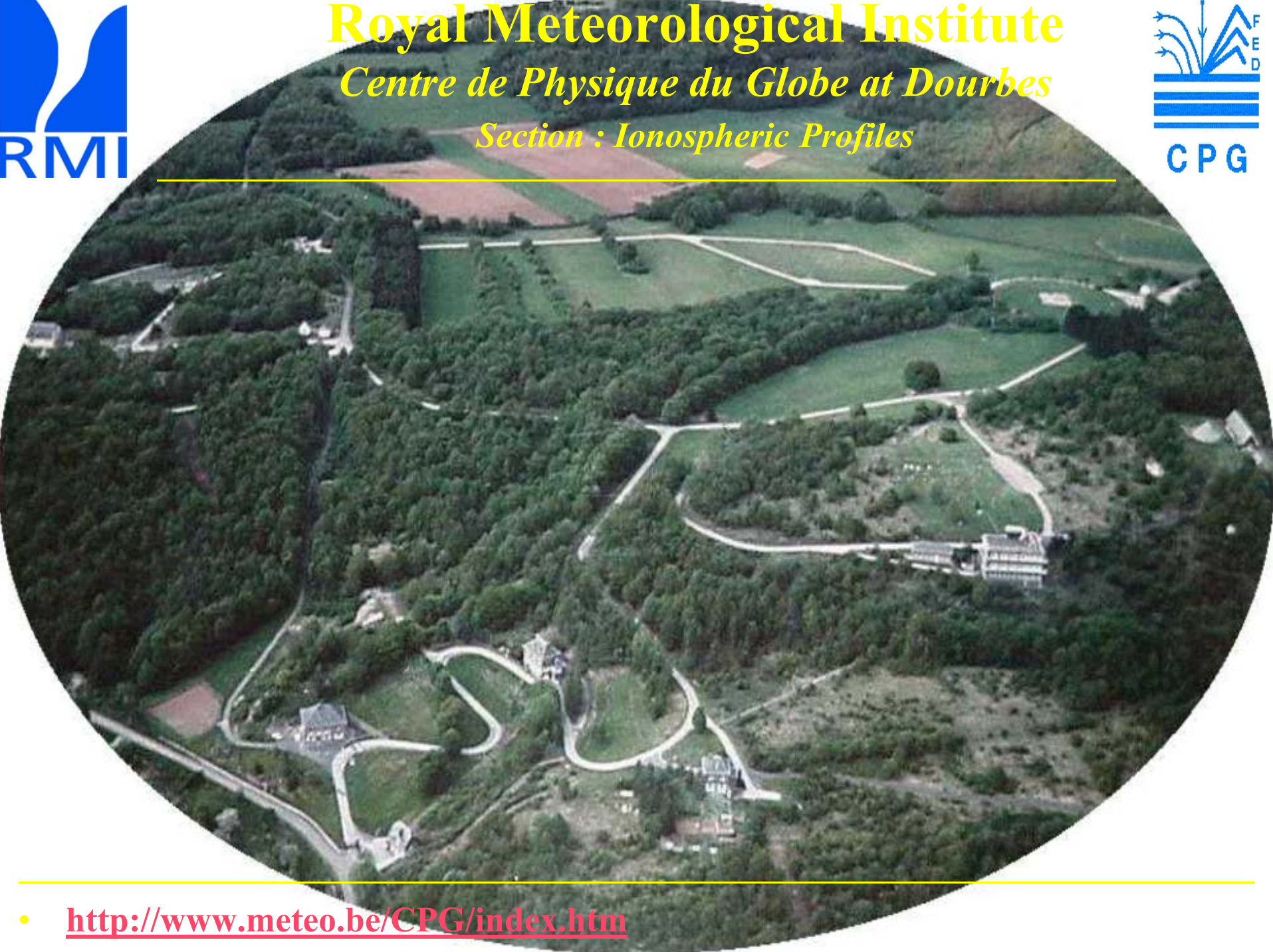
First result (Reykjavik)



Royal Meteorological Institute

Centre de Physique du Globe at Dourbes

Section : Ionospheric Profiles



- http://www.meteo.be/CPG/index.htm

Installation of a DORIS station at Dourbes

- At Dourbes, the following measurements are (already) available :

  - GPS data (ROB EUREF station)
  - geomagnetic data (RMI)
  - ionospheric sounding (RMI)

The electron concentration profile

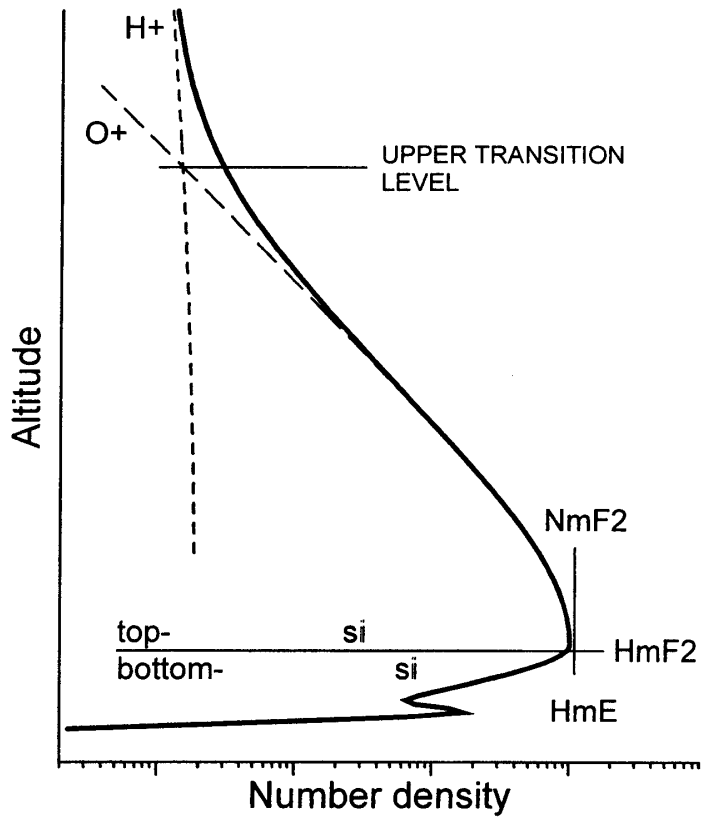
- Geodetic methods only give access to the integrated electron content
- Ionospherists are more interested in the electron concentration profile
- The bottom side profile (from bottom to maximum) can be measured using an ionosonde (as in Dourbes)
- At the present time, the existing models of the topside (IRI) still need to be improved.

Reconstruction of the electron concentration profile

- First experiments of reconstruction of the electron concentration profile have been successful (Dourbes)
- These experiments are based on the collocation between GPS and an ionosonde.
- The goal is to assess and improve the existing models of the topside ionosphere.
- Problem : the reconstruction technique needs information about the transition region O+ - H + (about 1000 km)

Solution : Collocation GPS + ionosonde + DORIS

- Bottomside given by ionosonde
- Topside modeled by a profiler (math. function)
- GPS gives a constraint on the integral
- DORIS would give a constraint on the transition region O^+ - H^+



The benefits for Geodesy and Navigation

- Nowadays, the ionospheric error remains the main limitation to the reliability of real-time applications of GPS
- The collaboration with the ionosphere community allows to promote the research about this effect
- Real-time monitoring of the ionospheric activity and forecasts of the TEC for real-time GPS applications, in particular for SPP.
- Forecasts of ionospheric storms (due to Space Weather conditions) giving rise to severe disturbances on GPS

The future

At Dourbes, in addition to the existing measurements :

- Make use of CHAMP radio-occultation data for the validation of the electron concentration reconstruction technique

- Make use of the Belgian DGPS reference network (70 stations over Belgium) to make a 3D reconstruction of the electron concentration

=> validation of ionosphere models

=> ionospheric correction for real-time GPS, effect of SW