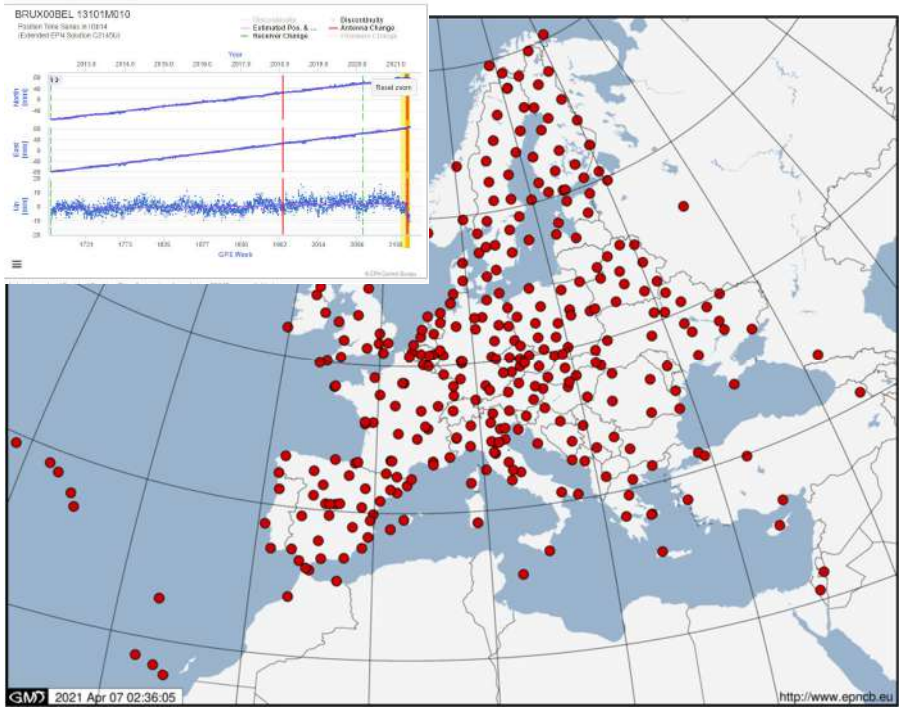
Access to Royal Observatory of Belgium node

WP7: Access to PITHIA-NRF facilities



Description of the infrastructure:

https://www.epncb.oma.be/

ROB hosts the Central Bureau of the EUREF Permanent GNSS Network (EPN) and performs the day-to-day management of the network (~360 stations).

The EUREF Permanent GNSS Network consists of a network of continuously operating GNSS (Global Navigation Satellite Systems, such as GPS, GLONASS, Galileo, Beidou, ...) reference stations.

Data centres providing access to the station data.

Analysis centres that analyze the GNSS data,

Product centres or coordinators that generate the EPN products

Central Bureau that is responsible for the daily monitoring and management of the EPN.

Use of this data base to retrieve ionospheric TEC using the ROB-IONO software

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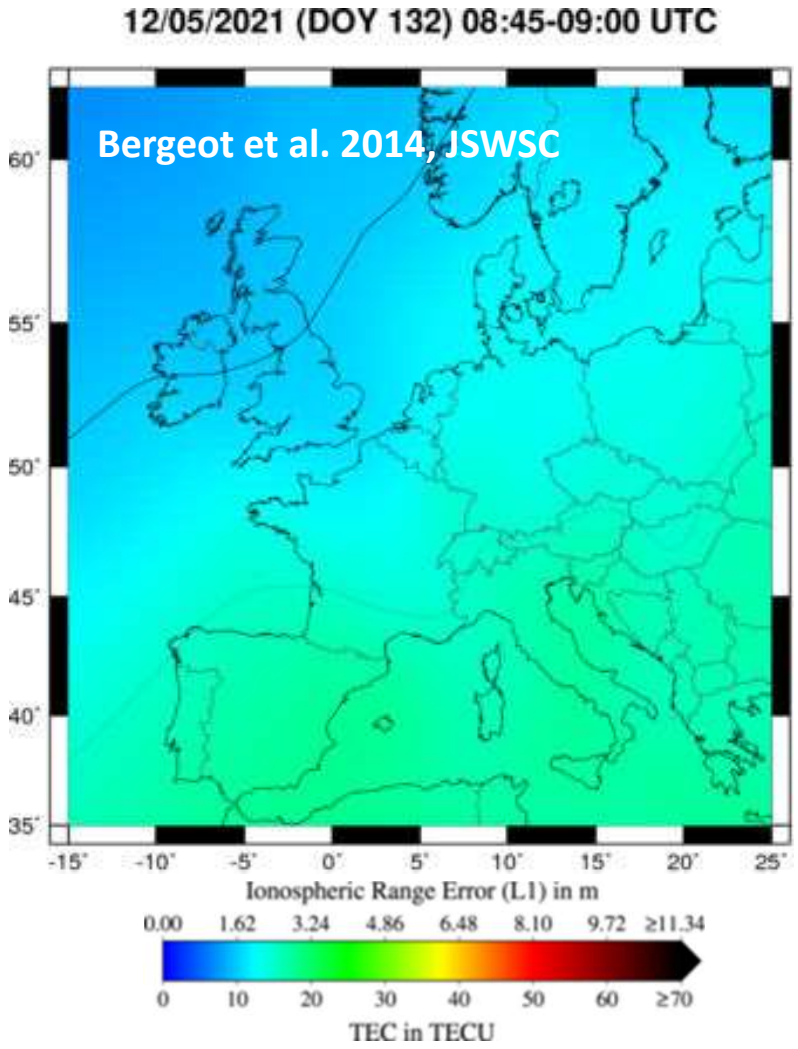

Products and models:

Since 2011, the ROB provides real-time ionospheric vTEC maps over Central Europe. Based on ~200 stations. The main products are 0.5°x0.5° grids of vTEC and vTEC variability available every 15 min with a latency of ~3 min. These maps can be consulted on a web interface (www.gnss.be) or downloaded in the IONEX format (ftp://gnss.oma.be). Post processing available since 1998.

Well adapted for disturbed periods.

Also provided the Differential Code Biases of the GNSS stations.

Less than 10Mb/day

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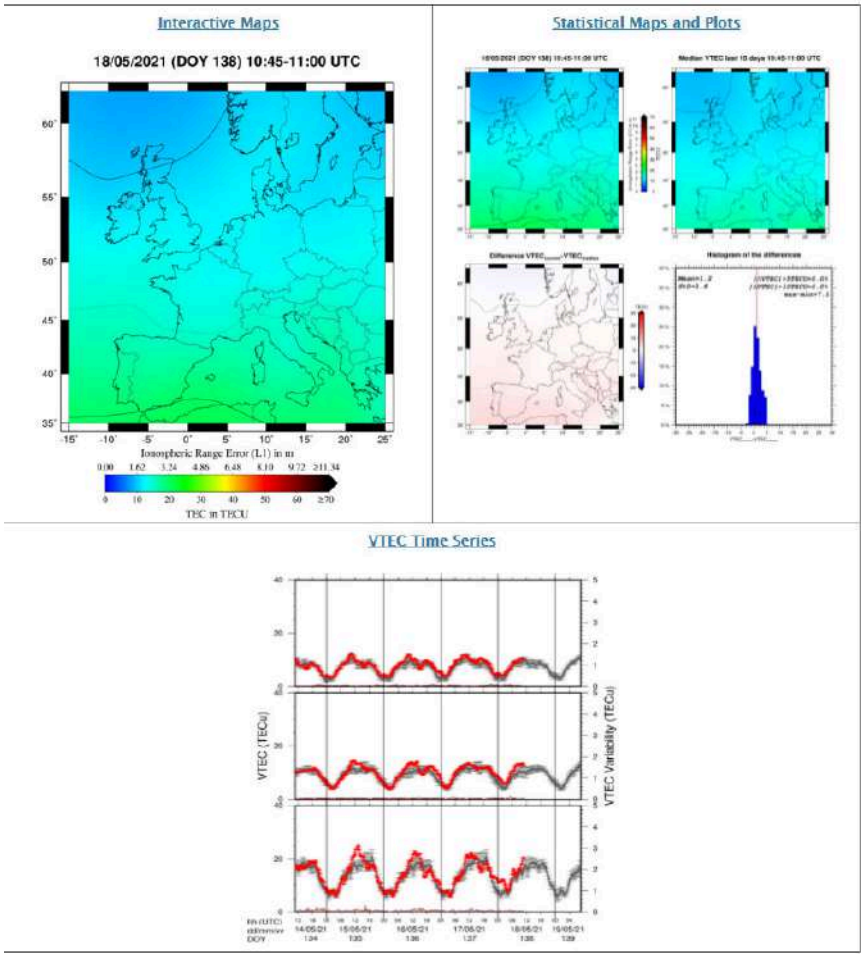

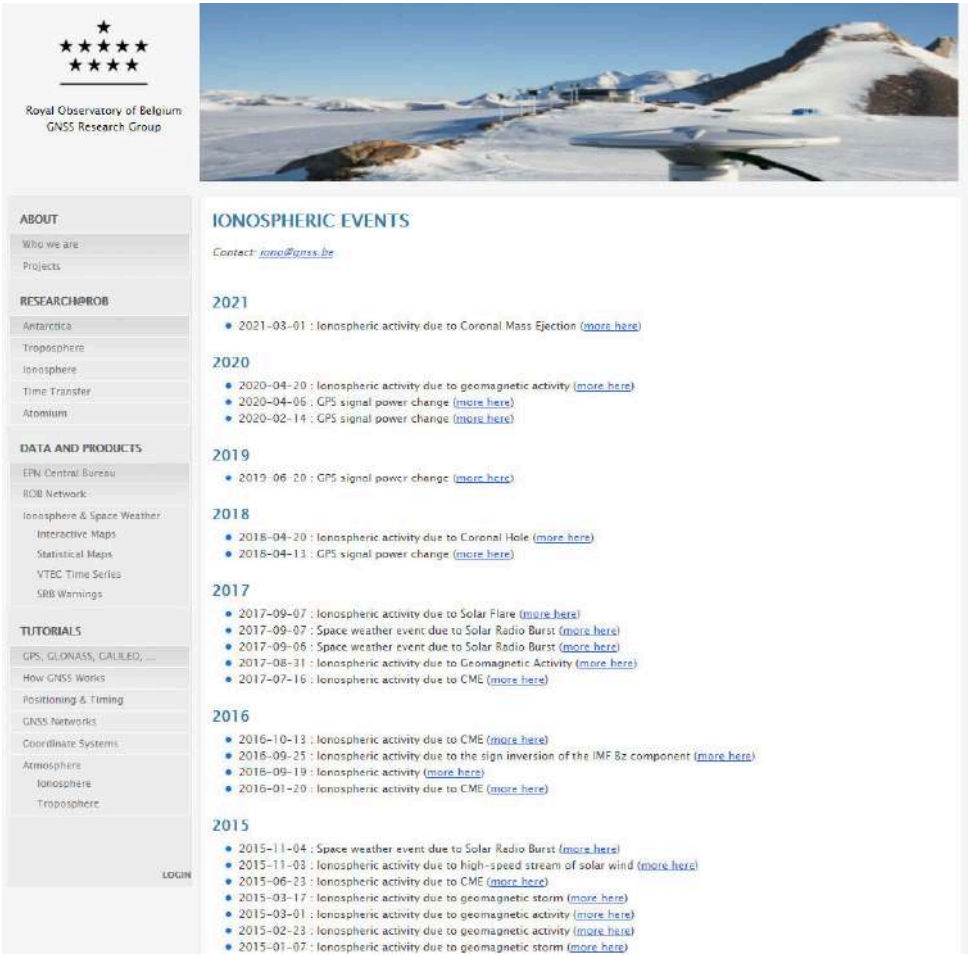

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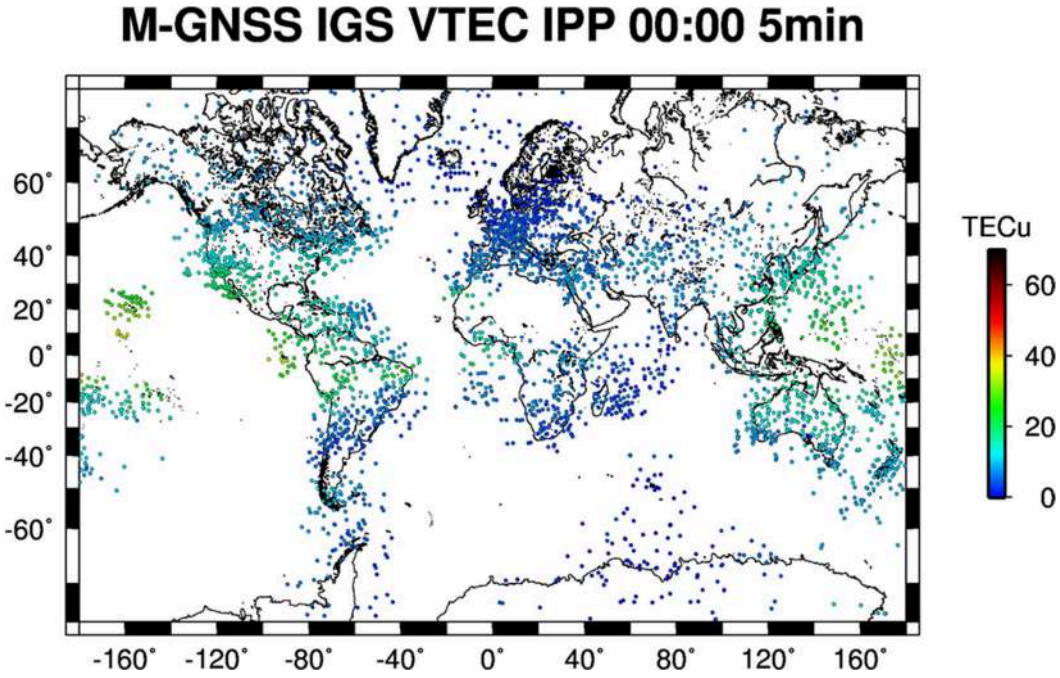
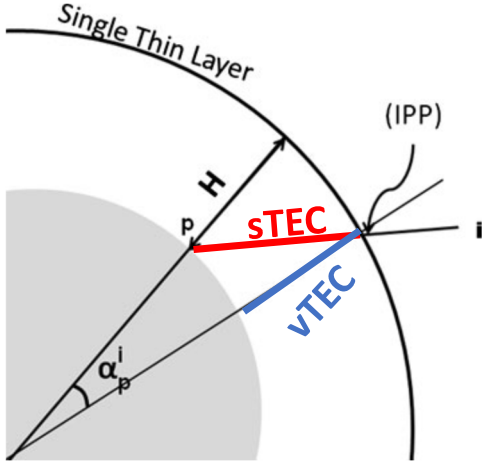


Products and models:

Since 2021, the ROB provide daily (less 1 day latency) vTEC estimation at Ionospheric Pierce Point from a selection of IGS stations (#220). The output consist in GNSS (GPS+GLONASS+GALILEO) sTEC and vTEC, as well as the DCBs for the different signal combinations every 30s.

More than 2Gb/day



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Main Challenges

- Go for multi-GNSS in NRT for EU maps
- Transfer all the ASCII files in a database in NRT (EU) or within 1 day/delay (GLOBAL)
- Go for full IGS station available (~500)
- On demand runs of ROB-IONO (e-science center ?) to retrieve the TEC information (slant and vertical) and DCBs for a submitted GNSS file (RINEX).
- Any needs for other planets ? (e.g. Mars)
- 2.5 years IT-engineer in the frame of PITHIA started in 2022

Contact persons : Jean-Marie Chevalier jmchev@oma.be
Nicolas Bergeot nicolas.bergeot@oma.be

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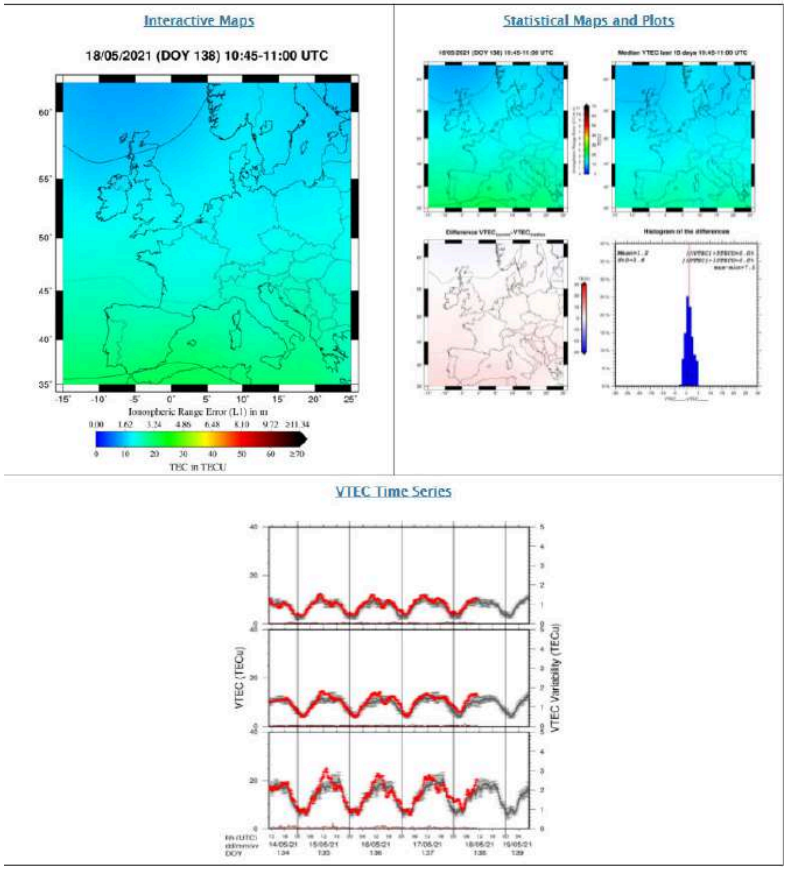
www.gnss.be



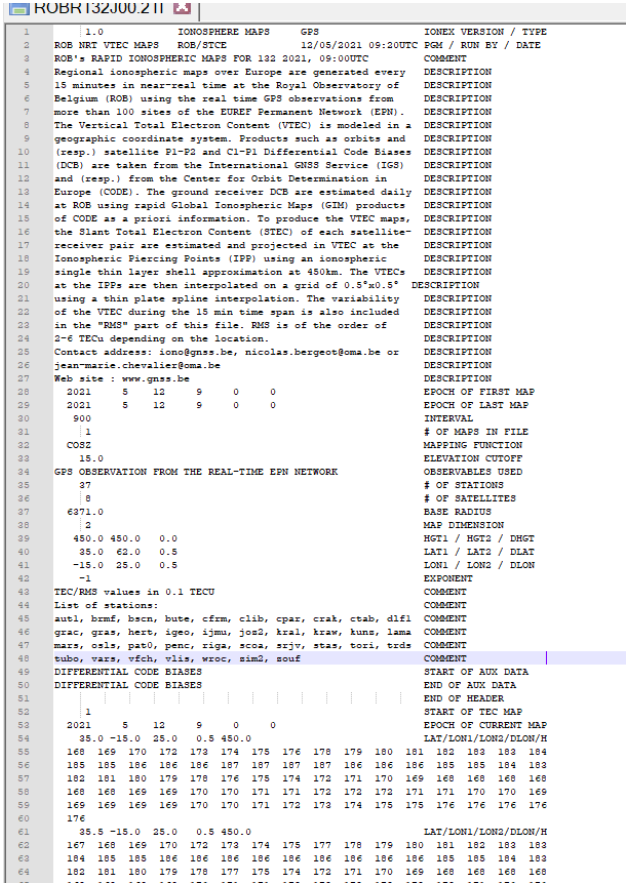
NRT CEU

Combination of TEC products

Regional for ROB-DLR-INGV Disturbed periods. Common campaigns with digisondes.

Global : for the biggest/greatest teams (DLR-INGV-UPC)

ftp://gnss.oma.be



ROBR132J00.21I

```
     1.0            IONOSPHERE MAPS     GPS                 IONEX VERSION / TYPE
ROB NRT VTEC MAPS   ROB/STCE            12/05/2021 09:20UTC PGM / RUN BY / DATE
ROB's RAPID IONOSPHERIC MAPS FOR 132 2021, 09:00UTC         COMMENT
Regional ionospheric maps over Europe are generated every   DESCRIPTION
15 minutes in near-real time at the Royal Observatory of    DESCRIPTION
Belgium (ROB) using the real time GPS observations from     DESCRIPTION
more than 100 sites of the EUREF Permanent Network (EPN).   DESCRIPTION
The Vertical Total Electron Content (VTEC) is modeled in a  DESCRIPTION
geographic coordinate system. Products such as orbits and   DESCRIPTION
(resp.) satellite P1-P2 and C1-P1 Differential Code Biases  DESCRIPTION
(DCB) are taken from the International GNSS Service (IGS)   DESCRIPTION
and (resp.) from the Center for Orbit Determination in      DESCRIPTION
Europe (CODE). The ground receiver DCB are estimated daily  DESCRIPTION
at ROB using rapid Global Ionospheric Maps (GIM) products   DESCRIPTION
of CODE as a priori information. To produce the VTEC maps,  DESCRIPTION
the Slant Total Electron Content (STEC) of each satellite-  DESCRIPTION
receiver pair are estimated and projected in VTEC at the    DESCRIPTION
Ionospheric Piercing Points (IPP) using an ionospheric      DESCRIPTION
single thin layer shell approximation at 450km. The VTECs   DESCRIPTION
at the IPPs are then interpolated on a grid of 0.5°x0.5°    DESCRIPTION
using a thin plate spline interpolation. The variability    DESCRIPTION
of the VTEC during the 15 min time span is also included    DESCRIPTION
in the "RMS" part of this file. RMS is of the order of      DESCRIPTION
2-6 TECu depending on the location.                         DESCRIPTION
Contact address: iono@gnss.be, nicolas.bergeot@oma.be or    DESCRIPTION
jean-marie.chevalier@oma.be                                 DESCRIPTION
Web site : www.gnss.be                                      DESCRIPTION
  2021     5    12     9     0     0                       EPOCH OF FIRST MAP
  2021     5    12     9     0     0                       EPOCH OF LAST MAP
   900                                                      INTERVAL
     1                                                      # OF MAPS IN FILE
  COSZ                                                      MAPPING FUNCTION
  15.0                                                      ELEVATION CUTOFF
GPS OBSERVATION FROM THE REAL-TIME EPN NETWORK              OBSERVABLES USED
    37                                                      # OF STATIONS
     8                                                      # OF SATELLITES
  6371.0                                                    BASE RADIUS
     2                                                      MAP DIMENSION
   450.0 450.0   0.0                                        HGT1 / HGT2 / DHGT
    35.0  62.0   0.5                                        LAT1 / LAT2 / DLAT
   -15.0  25.0   0.5                                        LON1 / LON2 / DLON
    -1                                                      EXPONENT
TEC/RMS values in 0.1 TECU                                  COMMENT
List of stations:                                           COMMENT
autl, brmf, bscn, bute, cfrm, clib, cpar, crak, ctab, dlf1  COMMENT
grac, gras, hert, igeo, ijmu, jos2, kral, kraw, kuns, lama  COMMENT
mars, osls, pat0, penc, riga, scoa, srjv, stas, tori, trds  COMMENT
tubo, vars, vfch, vlis, wroc, zim2, zouf                    COMMENT
DIFFERENTIAL CODE BIASES                                    START OF AUX DATA
DIFFERENTIAL CODE BIASES                                    END OF AUX DATA
                                                            END OF HEADER
     1                                                      START OF TEC MAP
  2021     5    12     9     0     0                       EPOCH OF CURRENT MAP
    35.0 -15.0  25.0   0.5 450.0                           LAT/LON1/LON2/DLON/H
   168  169  170  172  173  174  175  176  178  179  180  181  182  183  184  184
   185  185  186  186  186  187  187  187  187  186  186  186  185  185  184  183
   182  181  180  179  178  176  175  174  172  171  170  169  168  168  168  168
   168  168  169  169  170  170  171  171  172  172  172  171  171  170  170  169
   169  169  169  169  170  170  171  172  173  174  175  175  176  176  176  176
   176
    35.5 -15.0  25.0   0.5 450.0                           LAT/LON1/LON2/DLON/H
   167  168  169  170  172  173  174  175  177  178  179  180  181  182  183  183
   184  185  185  186  186  186  186  186  186  186  186  186  185  185  184  183
   182  181  180  179  178  177  175  174  172  171  170  169  168  168  168  168
```

NB1

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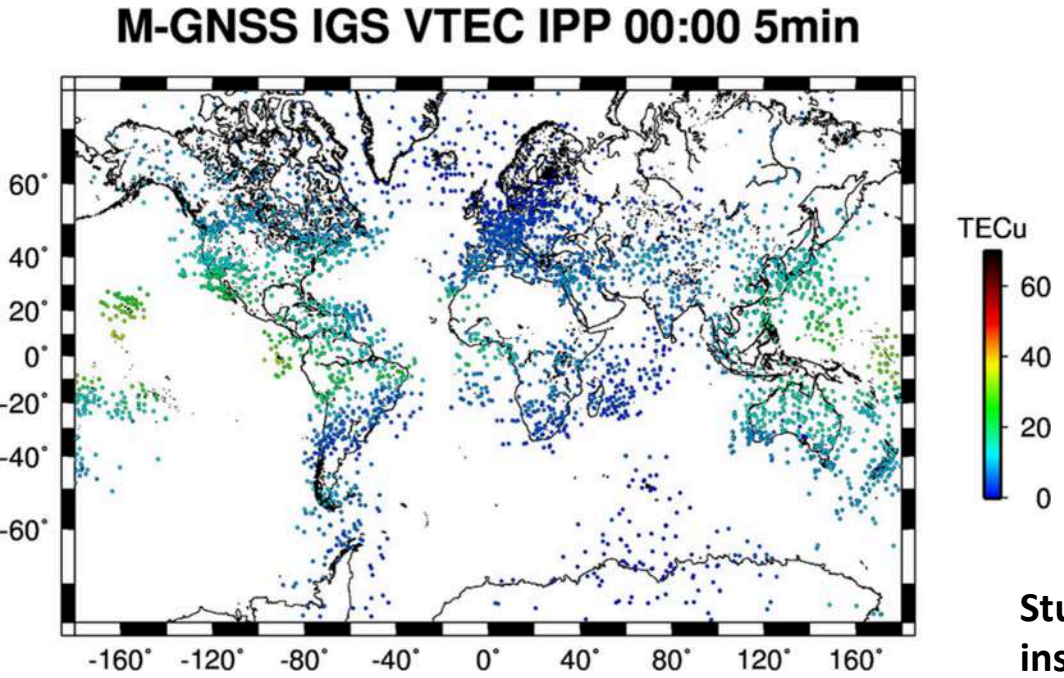
ROB Local serveur



POST GLOB

ROB Local serveur

Long	Lat	sTEC	vTEC	epoch	Sat	Station	Freq Comb	Elev	Azi	z'	DCB Sta	DCB Sat
°	°	TECu	TECu					°	°	°	ns	ns
-73.11	23.42	67.05	26.33	2024	E01	ABMF00GLP	C1C-C5Q-	10.07	305.54	66.88	3.51	-0.204
-73.05	23.43	67.03	26.35	2025	E01	ABMF00GLP	C1C-C5Q-	10.13	305.70	66.85	3.51	-0.204
-73.00	23.44	67.03	26.38	2026	E01	ABMF00GLP	C1C-C5Q-	10.20	305.86	66.83	3.51	-0.204
-72.94	23.45	67.01	26.40	2027	E01	ABMF00GLP	C1C-C5Q-	10.27	306.02	66.80	3.51	-0.204
-72.88	23.46	66.96	26.41	2028	E01	ABMF00GLP	C1C-C5Q-	10.33	306.17	66.77	3.51	-0.204
-72.72	23.49	66.95	26.50	2031	E01	ABMF00GLP	C1C-C5Q-	10.53	306.64	66.68	3.51	-0.204
-72.66	23.50	66.95	26.53	2032	E01	ABMF00GLP	C1C-C5Q-	10.60	306.80	66.66	3.51	-0.204
-72.61	23.51	66.92	26.55	2033	E01	ABMF00GLP	C1C-C5Q-	10.67	306.96	66.63	3.51	-0.204
-72.49	23.52	66.84	26.58	2035	E01	ABMF00GLP	C1C-C5Q-	10.80	307.27	66.57	3.51	-0.204
-72.44	23.53	66.73	26.57	2036	E01	ABMF00GLP	C1C-C5Q-	10.87	307.42	66.54	3.51	-0.204

Study of vTEC/sTCE for TIDs, gravity waves …. With other instrumentations.

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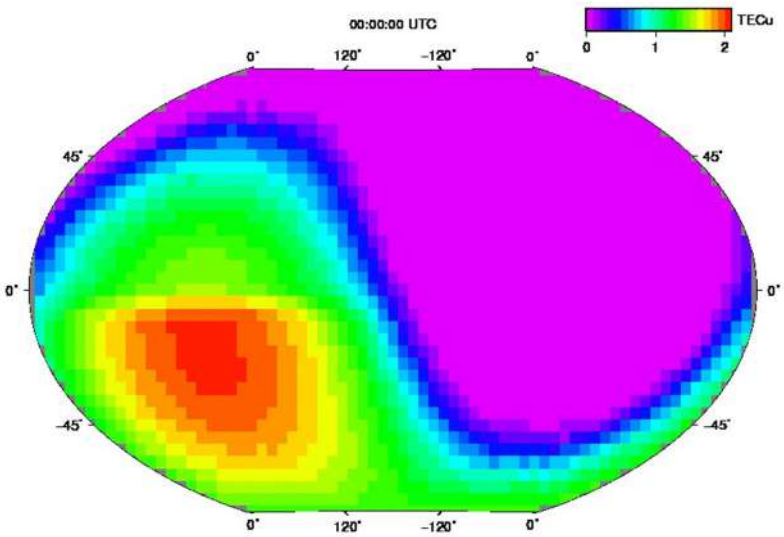
https://lara.oma.be/marsatmo/iono/momo.html

POST MARS

https://lara.oma.be/marsatmo/iono/momo.html



Bergeot et al. 2019, JSWSC

Comparison with IRAP output for Mars ionized atmosphere

```
subroutine momo(sza, lat, ls, sflux, tec)
    implicit none
C    Empirical Model of the Mars Ionospheric Total Electron Content
C    based on Mars Express MARSIS data
C
C    INPUT :
C       sza    Solar Zenith Angle (in decimal degrees)
C       lat    Latitude (in decimal degrees)
C       ls     Solar longitude (in decimal degrees)
C
C       sflux  F10.7P solar flux at Mars Level (in SFU).
C              available in the file Mars-sflux.dat
C              based on F10.7 Penticton radio telescope data (Tapping, 2013)
C                             and SPICE/NAIF software (Acton 1998; Acton et al. 2018) to retrieve the Sun-Mars distance.
C
C    OUTPUT :
C       tec    vertical Total Electron Content (in TECu with 1 TECu = 10^16 e^(-).m^(-2))
C
C    Nicolas Bergeot, Royal Observatory of Belgium
C    nicolas.bergeot@oma.be
C    https://lara.oma.be/marsatmo/iono/momo.html
C    Citation : Bergeot et al. 2019,
C             MoMo: a new empirical model of the Mars ionospheric total electron content based on Mars Express MARSIS data
C             J. Space Weather Space Clim.

    double precision, intent(in) :: sza, lat, ls, sflux
    double precision, intent(out):: tec

    double precision :: sza_rad,szaa
    double precision :: PI=DACOS(-1.D0)

C    Mars radius in km
    double precision :: R=3392.D0
C    Altitude of the ionospheric thin shell layer (km)
    double precision :: z=140.D0
C    Atmospheric scale height in km
    double precision :: H=15.D0

    double precision :: Xp, Y
    double precision :: dd
    double precision :: coskhi
    double precision :: a,b,c,d,f,g
    data a/1.0606963D0/, b/0.55643831D0/, c/1.0619896D0/
    data d/1.7245609D0/, f/0.5649823D0/, g/0.06651874D0/

    double precision :: ALPHA, BETA1, BETA2
    double precision, dimension(3) :: NH1, NH2, SH1, SH2
    data NH1/3.2847590432230 1D-2, 0.2624494420345833 1D0,
   &    1.5645912443740223 1D-2/
    data NH2/3.0040165820630 1D-2, 0.2950176962120725 2D0,
   &    1.4386102295657787 8D-2/
    data SH1/2.4735406051254 4D-2, 0.5521362982956148 4D0,
   &    9.6434489161730807 5D-3/
    data SH2/0.0357746382136027 D0  , -2.2163328499043899 5D-2,
   &    2.2872978550732725 5D-2/

C    Symmetry Sunset/Sunrise
...
    tec=ALPHA+(BETA1+BETA2*sflux)/sqrt(coskhi)
```