Ionospheric research and service based on near real time GNSS data

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Institute of Communication and Navigation

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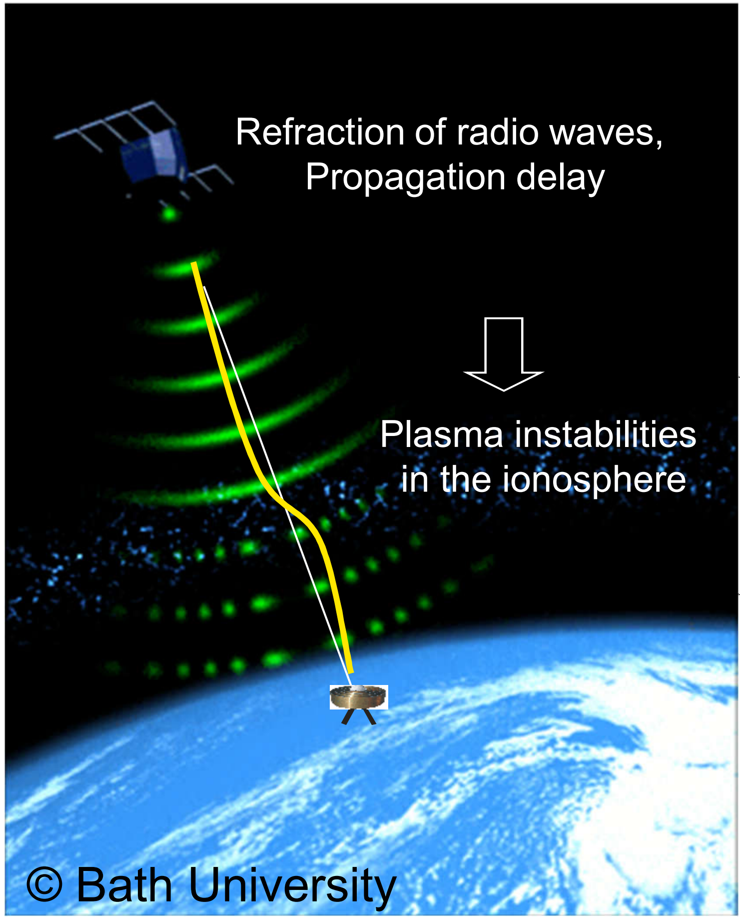
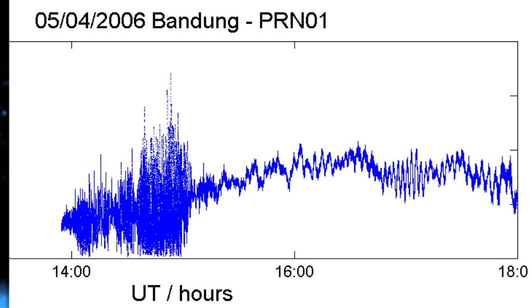
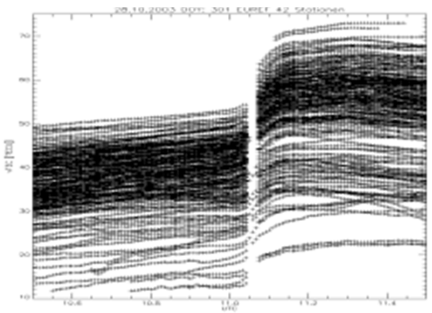
Impact of ionospheric effects are a challenge for navigation, communication and earth observation



The plasma of the ionosphere causes a delay of the radio signals

➔ ***Pretending an excess in distance between the satellite and the measurement site***





Plasma instability causes

- Signal strength fluctuations
- Defocussing of the signal

➔ ***Possible loss of the signal***

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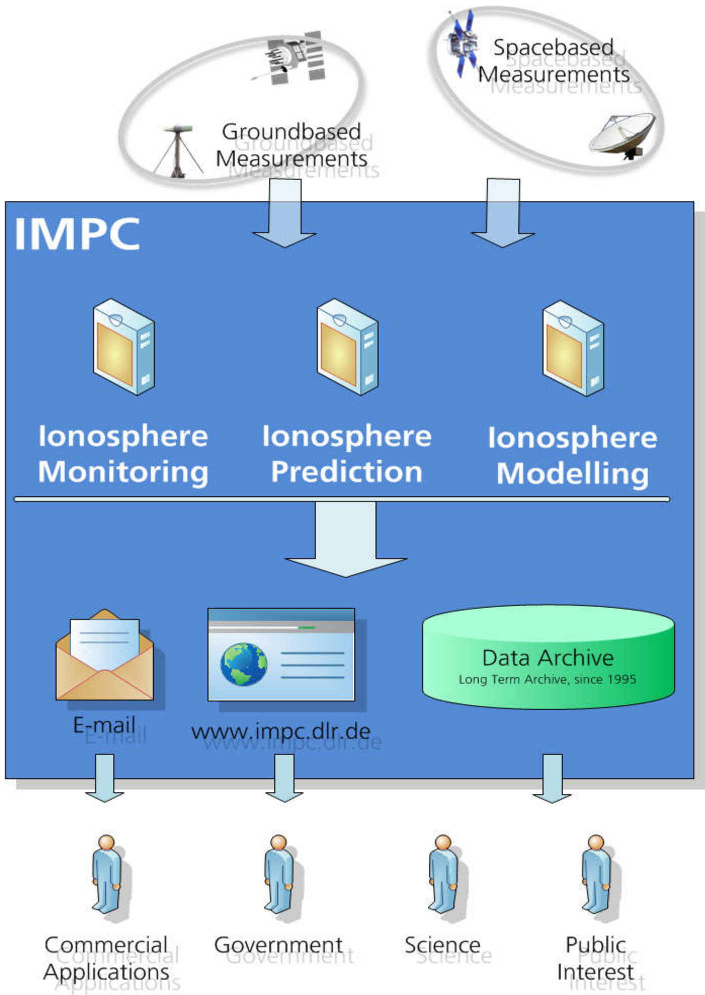
Ionospheric Monitoring and Prediction Center IMPC



The **Ionosphere Monitoring and Prediction Center (IMPC) of DLR contributes to the mitigation of ionospheric impacts** on technology with

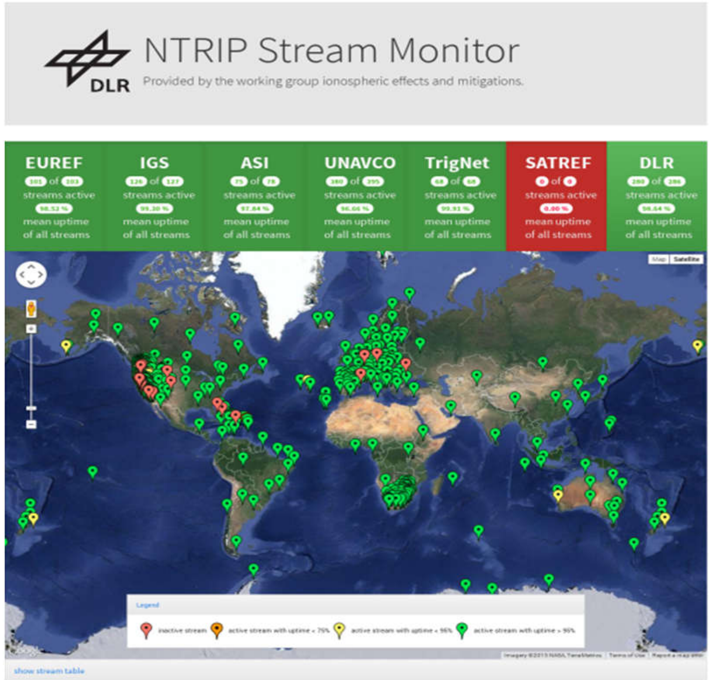
- Near real-time ionosphere monitoring
- Prediction of ionospheric conditions
- Modelling the ionosphere
- Information messages to users
- Data delivery services
- Education and public outreach

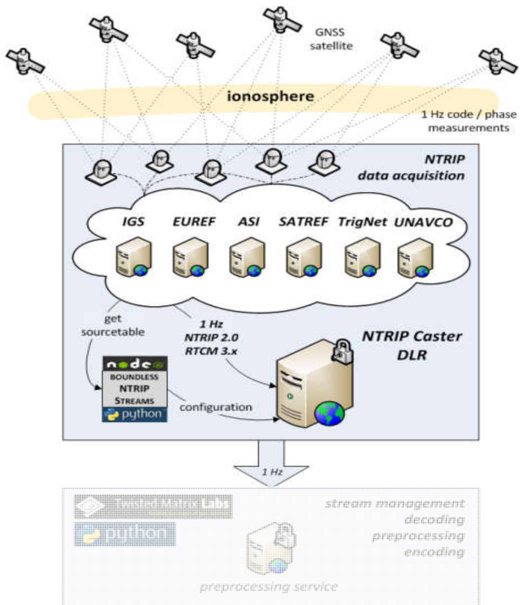
Information about the ionospheric state can afford significant contributions to avoid safety-critical situations (e.g. air transport) or high costs by useless expeditions (e.g. surveys of offshore resource development or precision positioning).

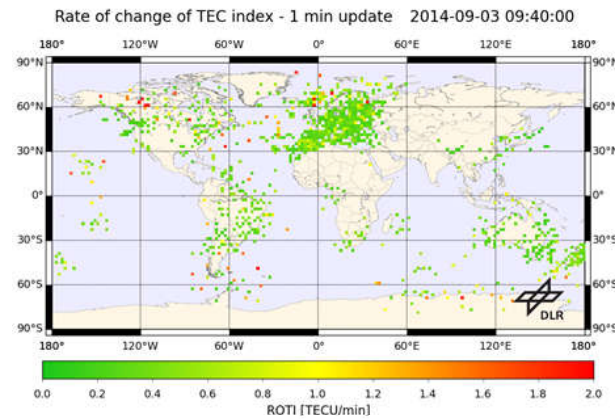
J. Berdermann, N. Jakowski, M.M. Hoque, N. Hlubek, K.D. Missling, M. Kriegel, C. Borries, V. Wilken, H. Barkmann, M. Tegler, Ionospheric Monitoring and Prediction Center (IMPC), Proceedings ION GNSS+, p. 14 – 21 (2014)

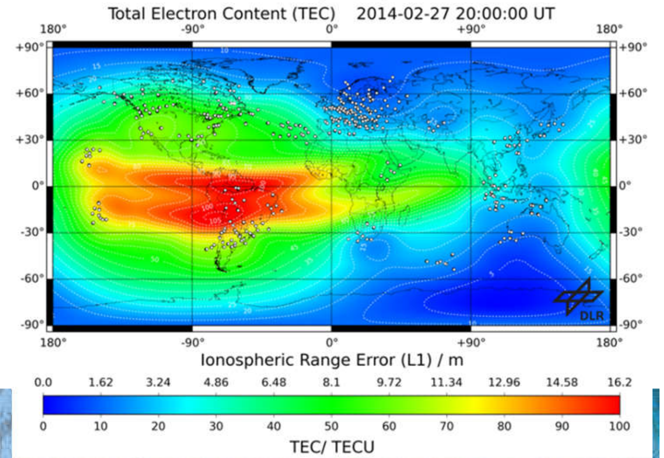
Technological ability for reception and distribution of GNSS ionosphere data streams

- Flexible software components have been developed in order to allow characterization of the actual state of the ionosphere
- The system automatically processes and distributes high rate GNSS data (1Hz) of several hundred GNSS receivers from GNSS-reference networks worldwide (IGS, EUREF, UNAVCO, ASI, TrigNet)









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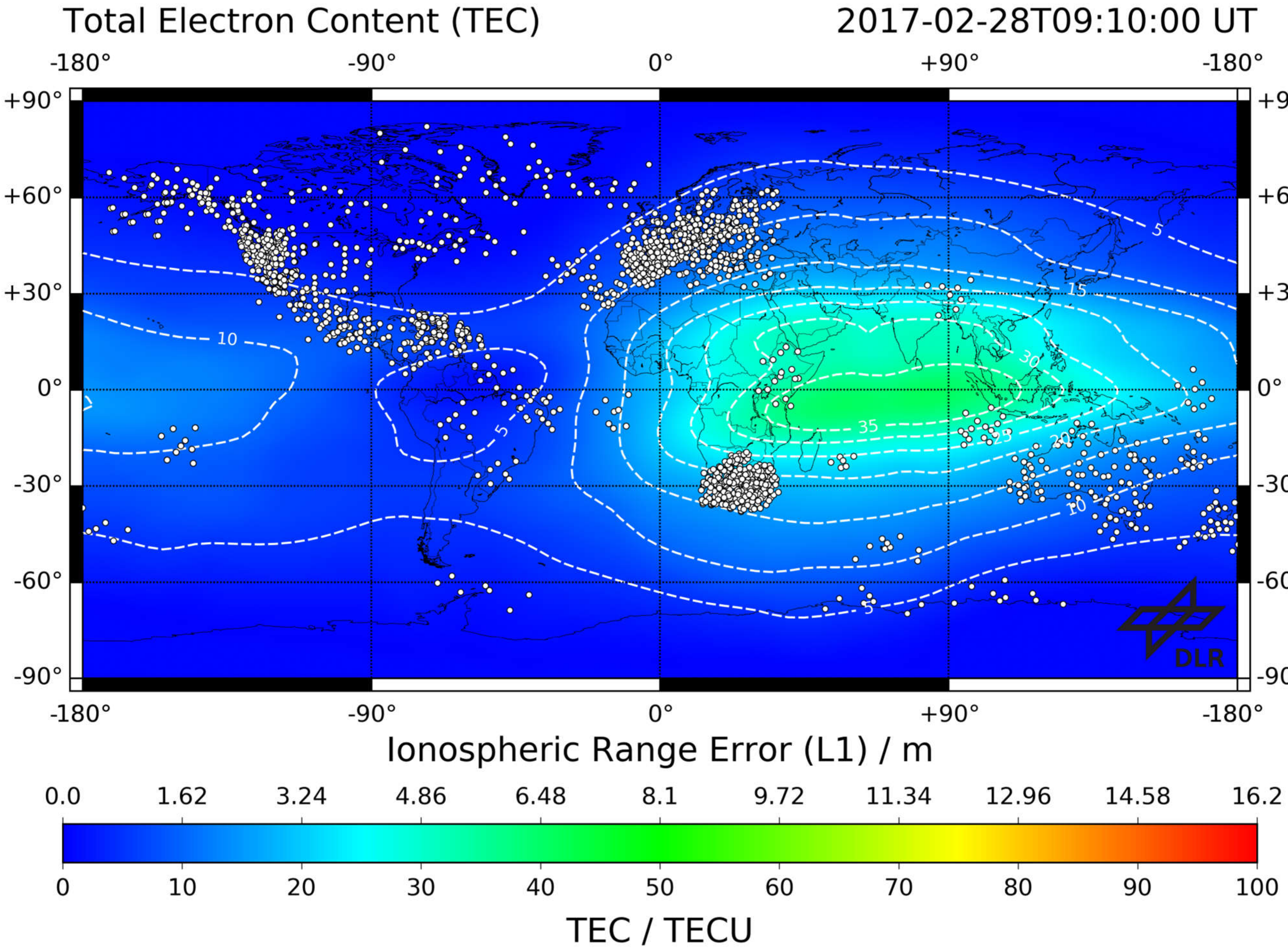
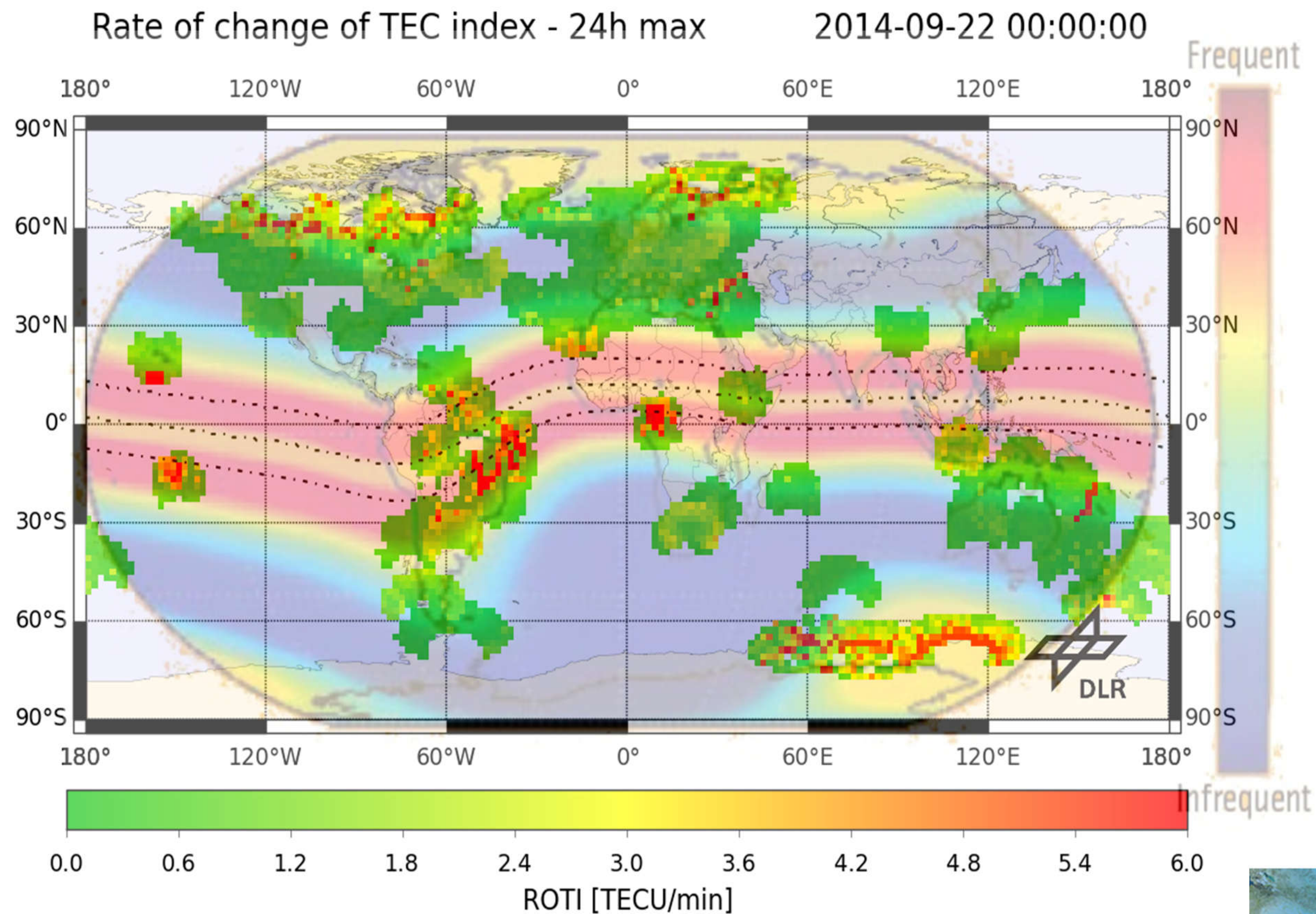
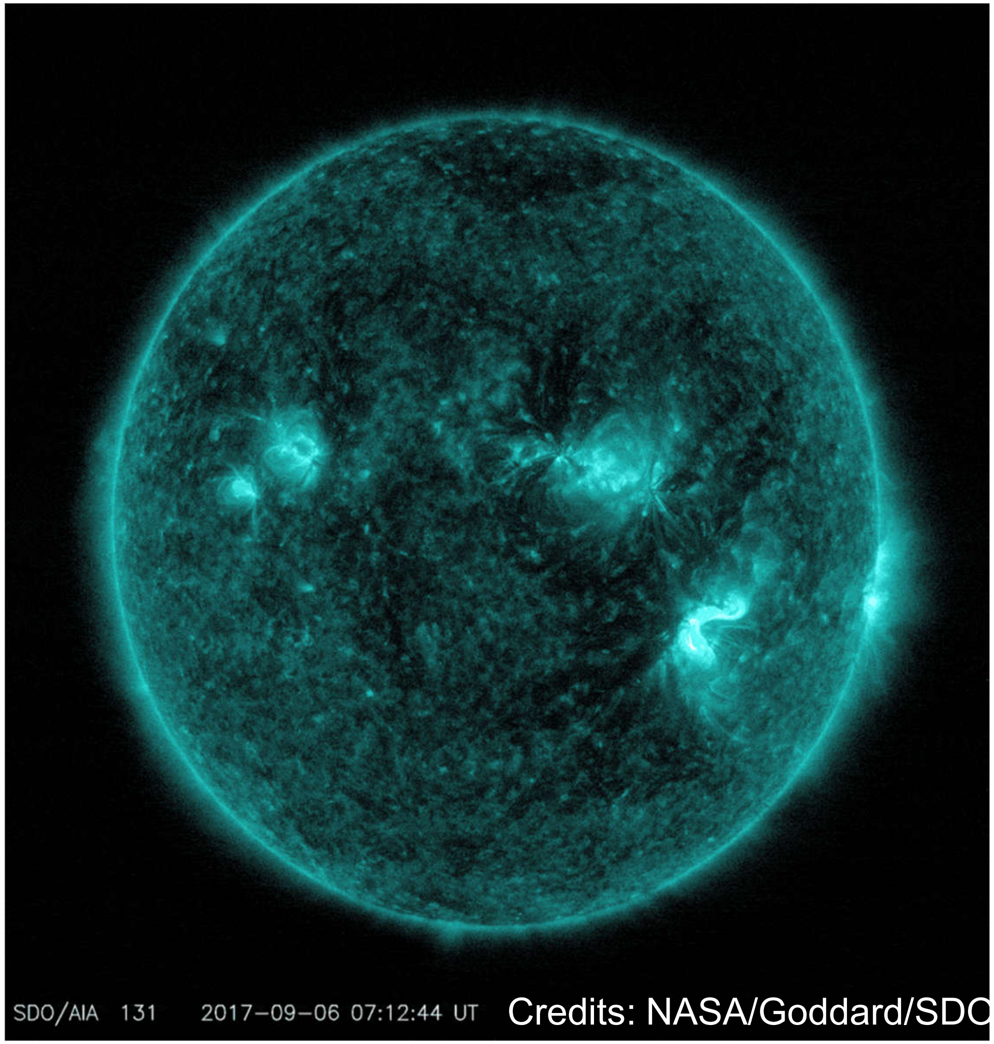

Total Electron Content (TEC)
2017-02-28T09:10:00 UT
-180° -90° 0° +90° -180°
+90° +60° +30° 0° -30° -60° -90°
5
10
15
20
25
30
35
DLR
Ionospheric Range Error (L1) / m
0.0 1.62 3.24 4.86 6.48 8.1 9.72 11.34 12.96 14.58 16.2
0 10 20 30 40 50 60 70 80 90 100
TEC / TECU

Global distribution of ionospheric irregularities



Space Weather Event 06/09/2017 (Solar Flare X9.3)

Ranking 14 (Last X Flare of this size 05/12/2006 X 9.0)



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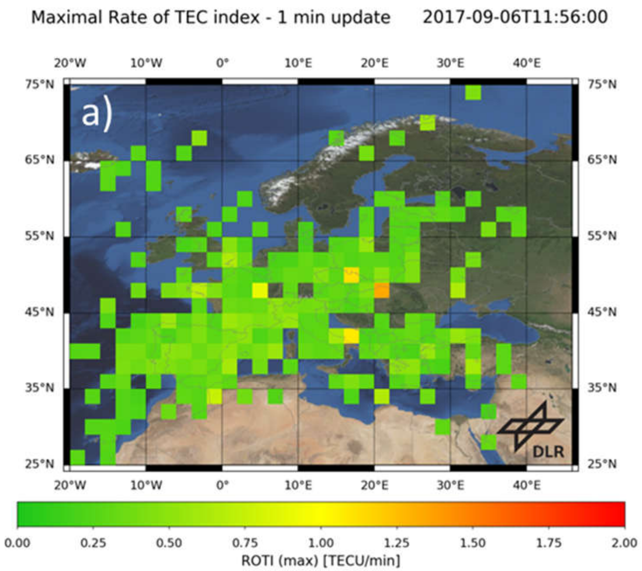
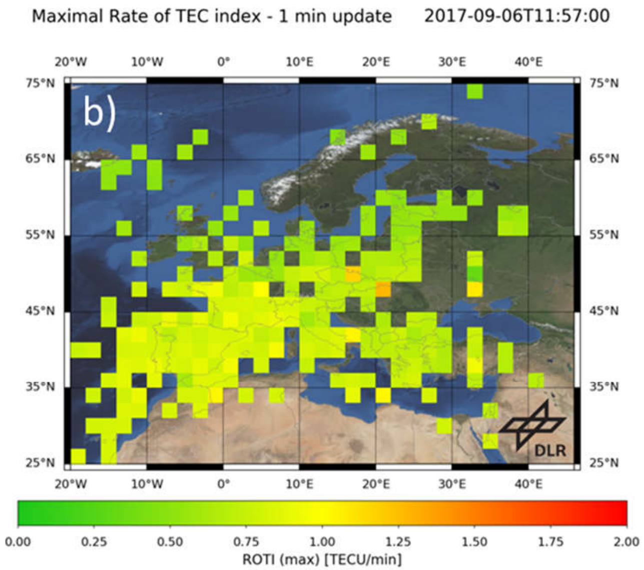
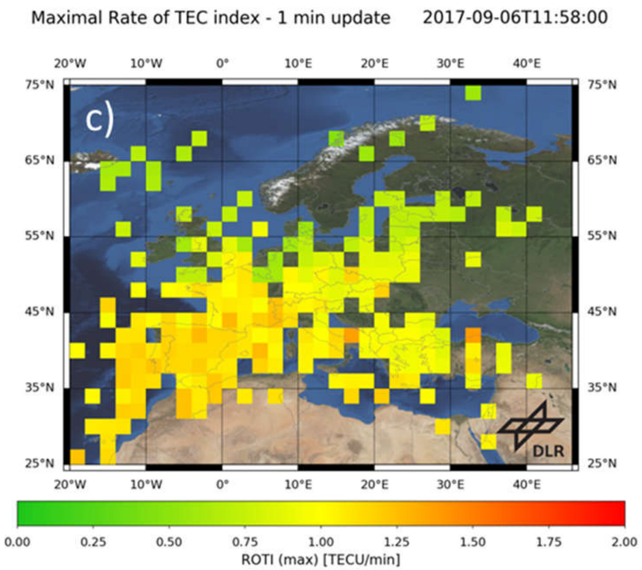
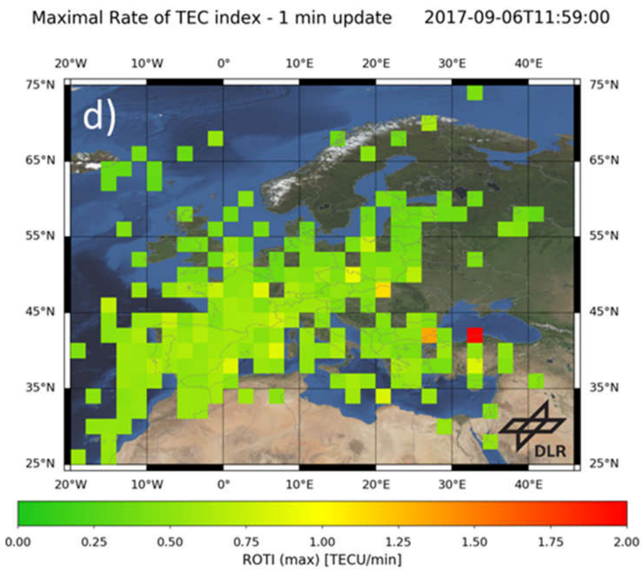
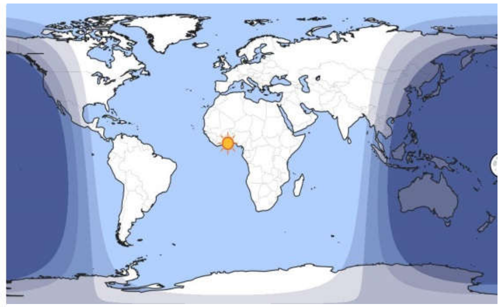
06/09/2017 (Solar Flare X9.3)



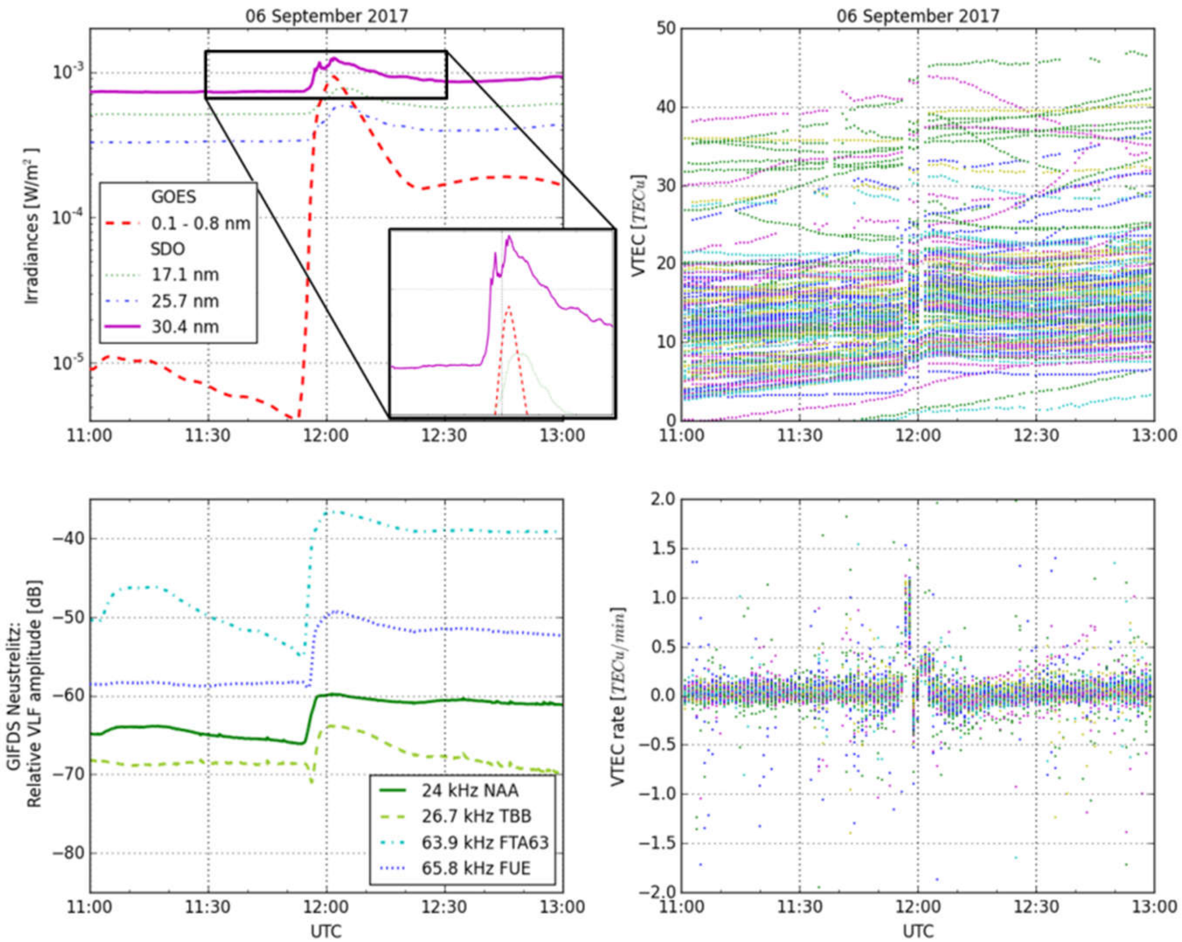






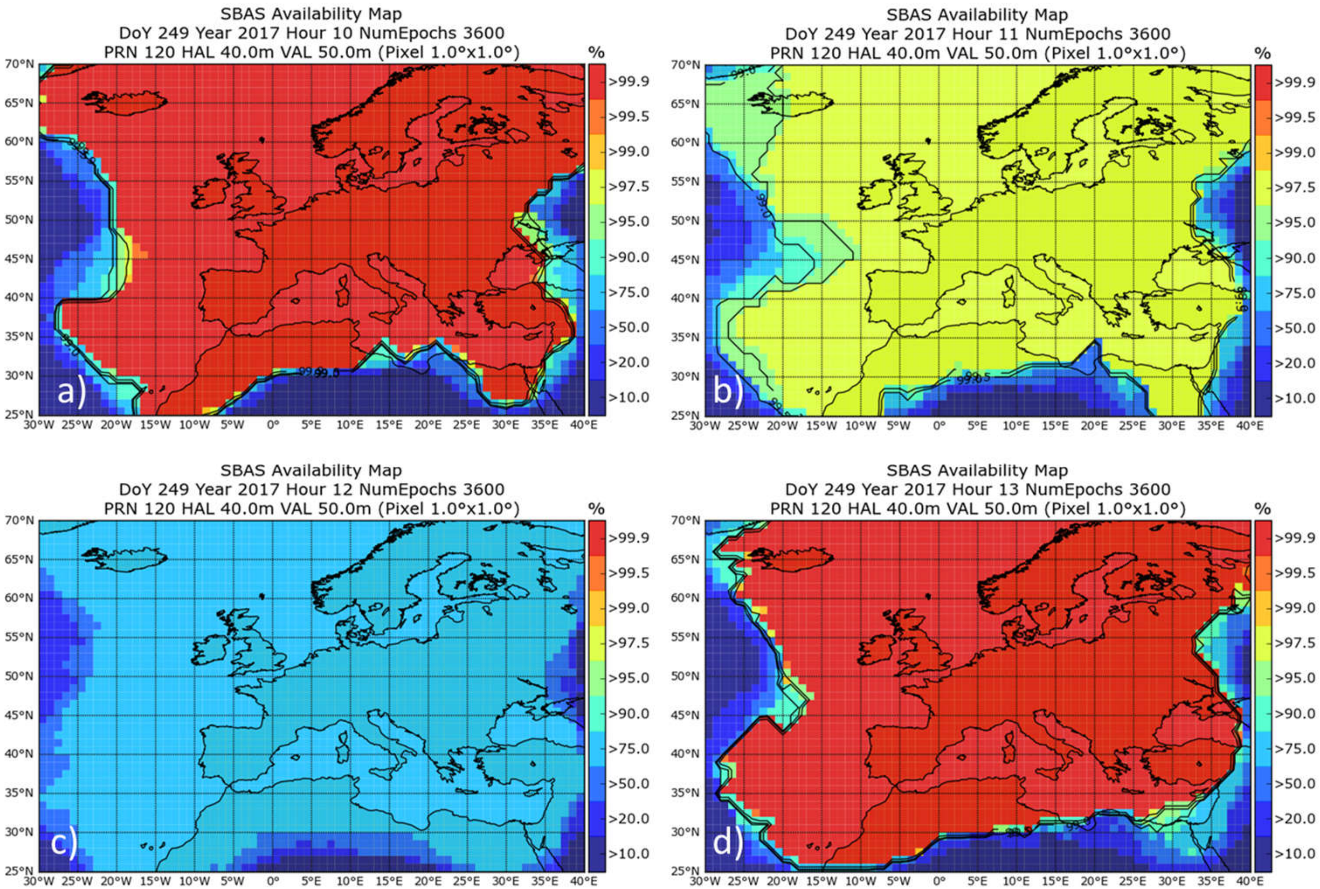


Implications for Navigation Services – Loss of Lock



Berdermann, J., Kriegel, M., Banys, D., Heymann, F., Hoque, M. M., Wilken, V., et al. (2018). Ionospheric response to the X9.3 Flare on 6 September 2017 and its implication for navigation services over Europe. Space Weather, 16. https://doi.org/10.1029/2018SW001933

Implications for Navigation Services - EGNOS



The plots are generated with the ESA/UPC GNSS-Lab Tool (gLAB) *Sanz et al.* [2012] and provided by ESA

Berdermann, J., Kriegel, M., Banys, D., Heymann, F., Hoque, M. M., Wilken, V., et al. (2018). Ionospheric response to the X9.3 Flare on 6 September 2017 and its implication for navigation services over Europe. Space Weather, 16. https://doi.org/10.1029/2018SW001933

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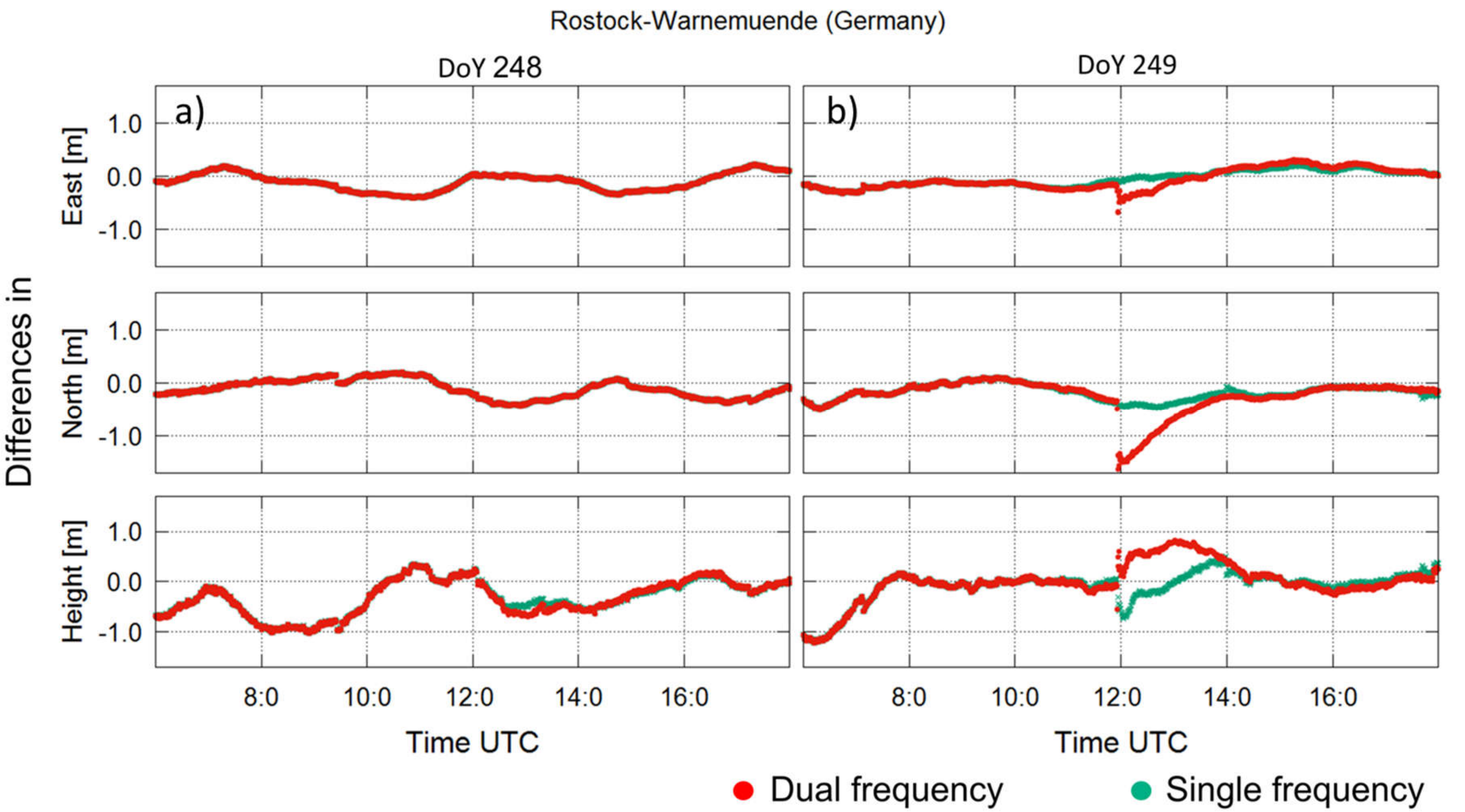
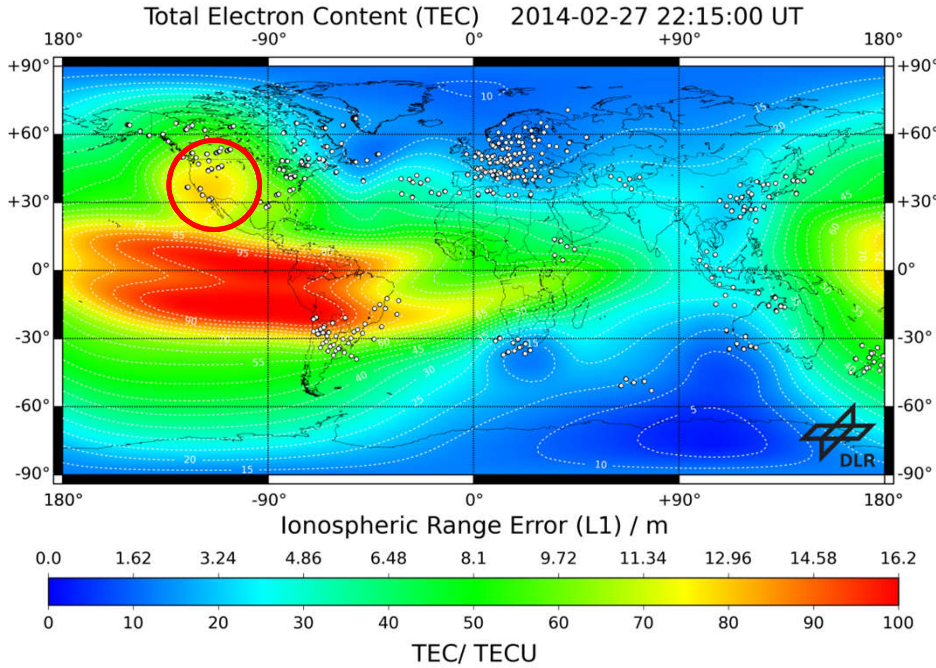
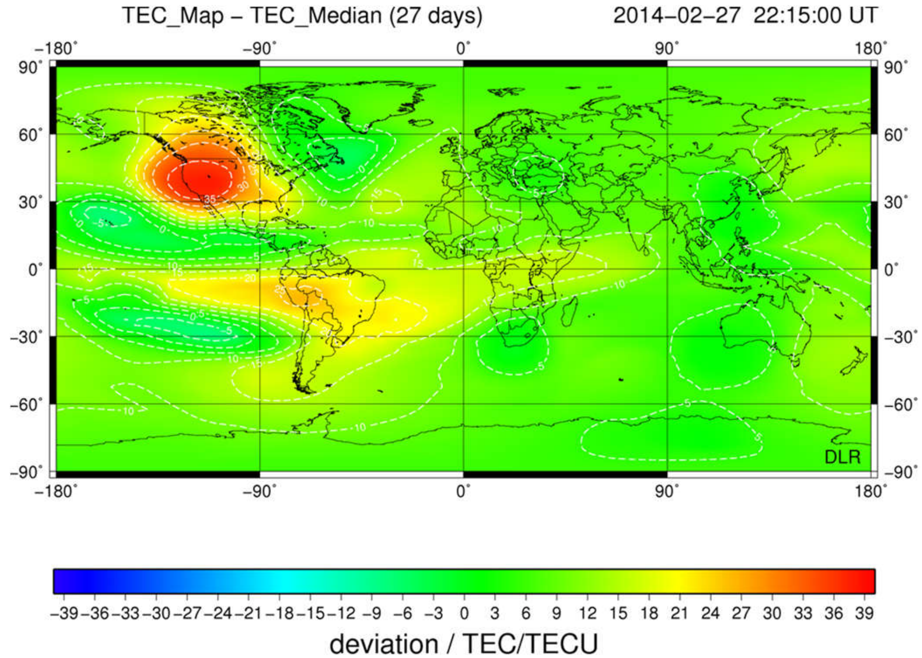
Implications for Navigation Services – Precise Point Positioning

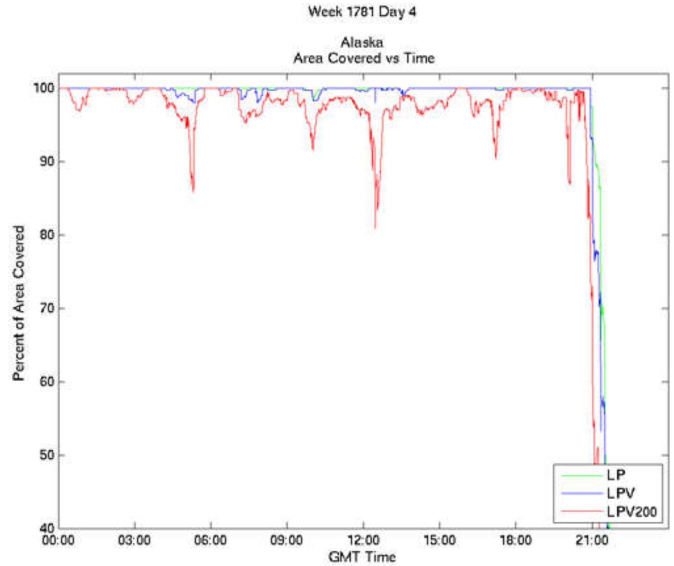


Berdermann, J., Kriegel, M., Banys, D., Heymann, F., Hoque, M. M., Wilken, V., et al. (2018). Ionospheric response to the X9.3 Flare on 6 September 2017 and its implication for navigation services over Europe. Space Weather, 16. https://doi.org/10.1029/2018SW001933

27/02/2014 (Ionospheric Storm)





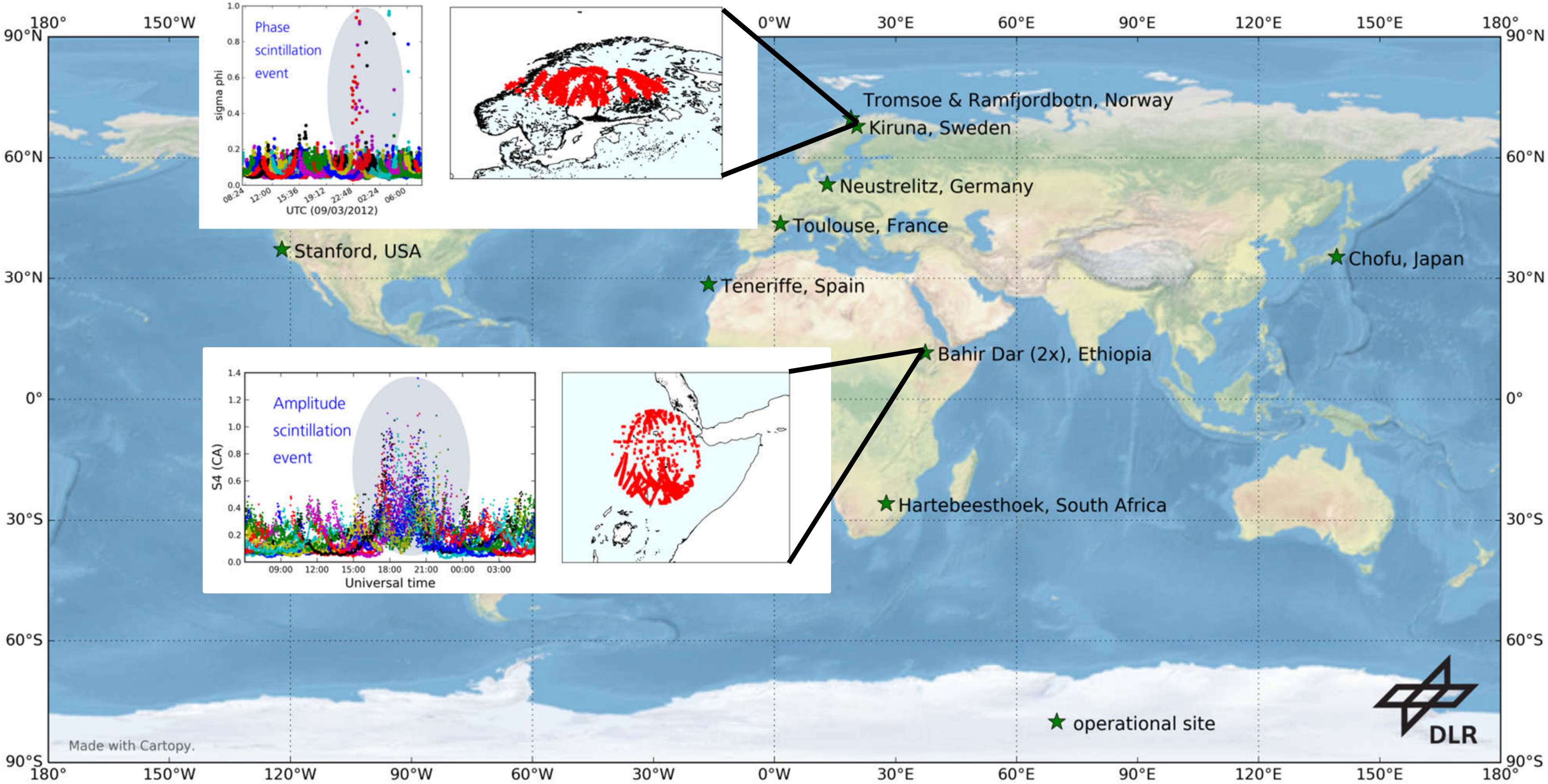


LPV availability of WAAS over Alaska on 27th February.

(LPV = **L**ocalizer **P**erformance with **V**ertical Guidance)

Experimentation and Verification Network (EV-NET)

DLR operates an high rate GNSS receiver network (50 Hz) for scintillation measurement from high latitudes (Kiruna /Sweden) down to equatorial regions (Bahir Dar/Ethiopia).



EVNet - Experimentation and Verification Network

Hardware

- Laptop (Linux/KVM based setup)
- Javad Delta 3 (20 / 50 Hz)
- Temex 10 MHz rubidium oscillator
- Choke ring antenna (e.g. Leica AR25)
- UPS, rack, network switch …

Software

- C++/ Python

Data

- scintillation indices (S_4, sigma phi)
- high rate multi freq. GNSS measurements (GPS, GLONASS, Galileo, Beidou, SBAS)

Bahir Dar 2nd station (Ethiopia)

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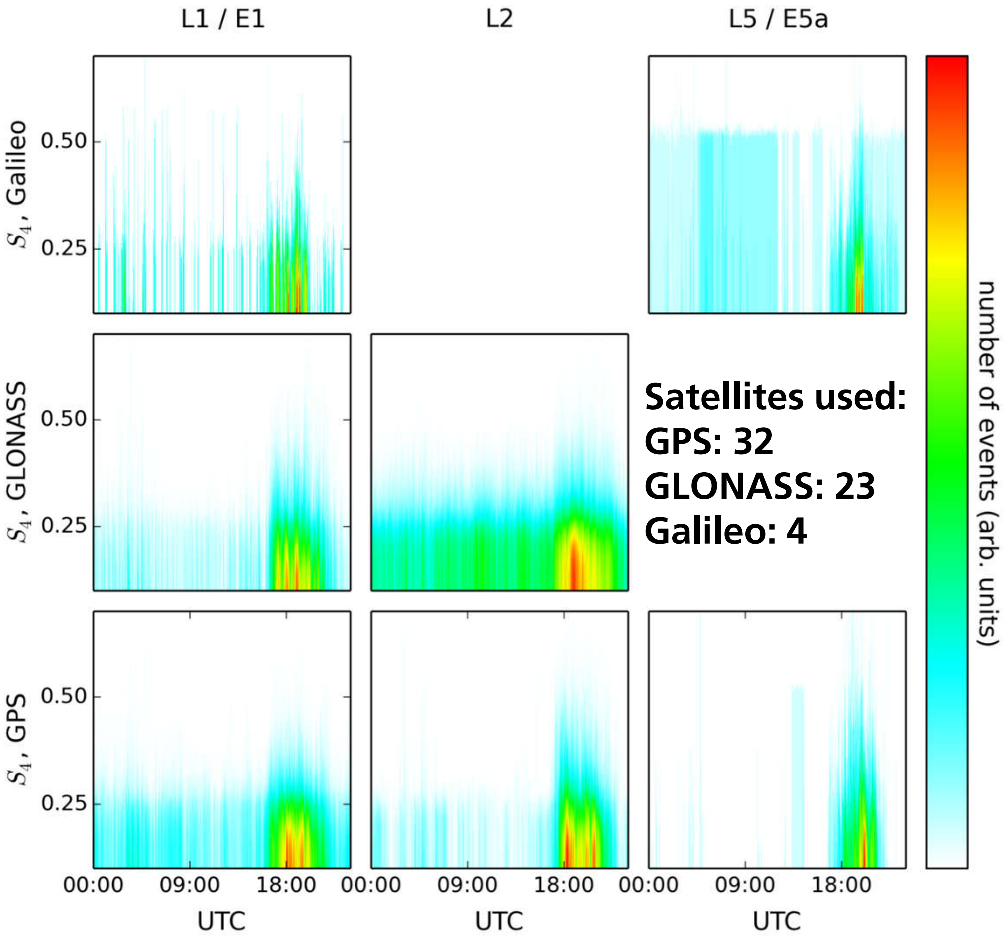
Experimentation and Verification Network (EV-NET)

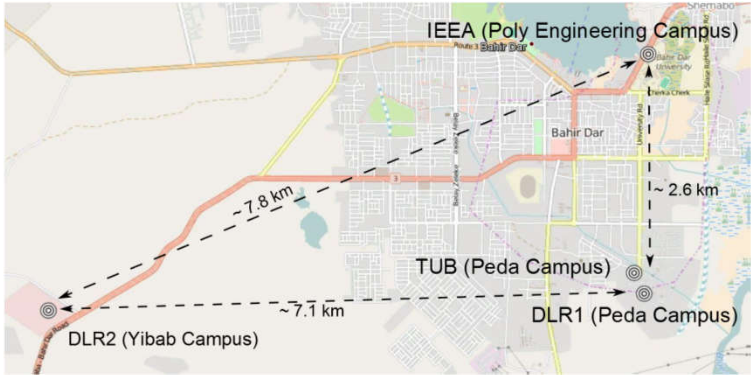
Bahir Dar/Ethiopia

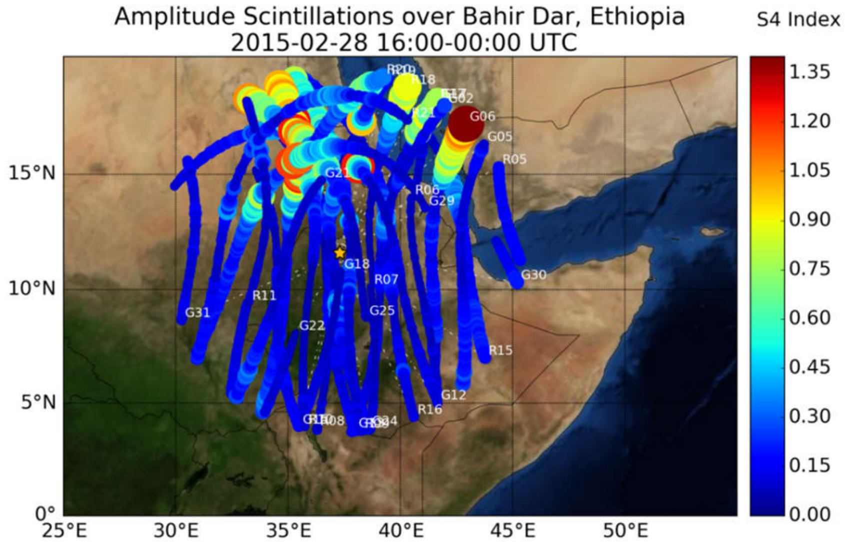
N. Hlubek, J. Berdermann, V. Wilken, S. Gewies, N. Jakowski, M. Wassaie, Baylie Damtie; Scintillations of the GPS, GLONASS, and Galileo signals at equatorial latitude, J. Space Weather Space Clim. 4 (2014) A22 DOI: 10.1051/swsc/2014020

Daily Scintillation Occurance



Satellites used:
GPS: 32
GLONASS: 23
Galileo: 4





Experimentation and Verification Network (EV-NET)

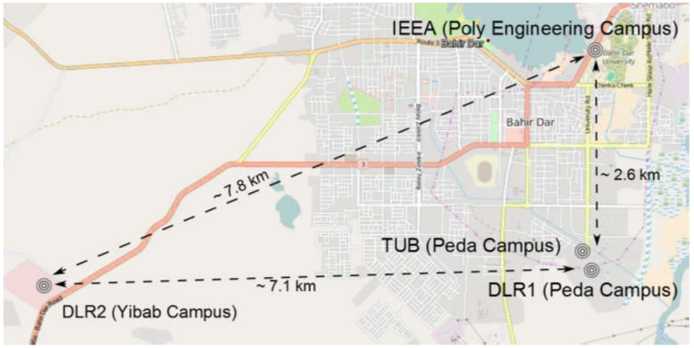
Bahir Dar/Ethiopia

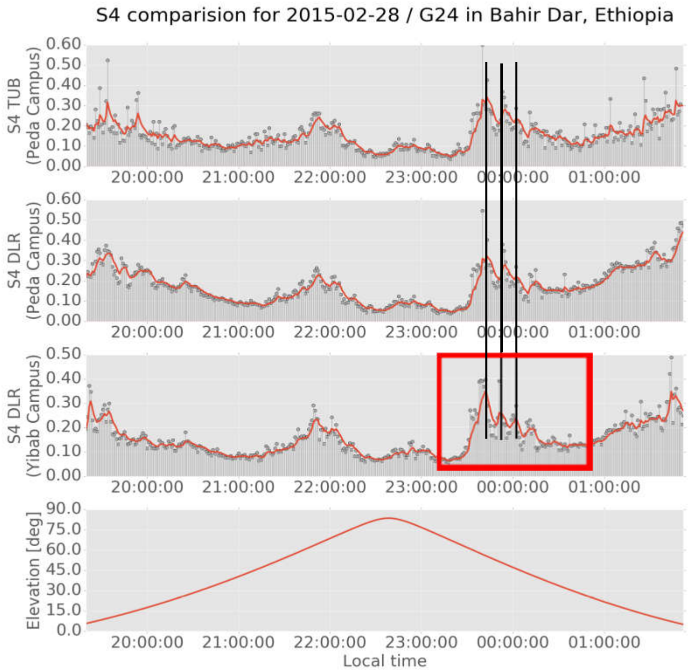
M. Kriegel, N. Jakowski, J. Berdermann, H. Sato, and M. W. Merhsa, Scintillation measurements at Bahir Dar during the high solar activity phase of solar cycle 24, (2017), Ann. Geophys., 35, 97–106

- Database of amplitude scintillation events measured with DLR's dual GNSS receiver setup (50 Hz):
- Similar scintillation signatures with different hard-/software setup at same campus
- Local network of scintillation receivers in Bahir Dar allows detecting plasma bubbles and their drift velocities

Table 4. Plasma irregularity characterization over Bahir Dar, Ethiopia.

Date	LT	PRN	Direction	Velocity	Size
28 Feb 2015	23:30	G24	eastward	$81\,\mathrm{m\,s^{-1}}$	292 km
28 Feb 2015	23:10	G29	eastward	$80\,\mathrm{m\,s^{-1}}$	144 km
28 Feb 2015	24:10	G29	westward	$102\,\mathrm{m\,s^{-1}}$	312 km
8 Apr 2015	23:00	G21	eastward	$80\,\mathrm{m\,s^{-1}}$	58 km
8 Apr 2015	23:00	G26	eastward	$84\,\mathrm{m\,s^{-1}}$	151 km
8 Apr 2015	23:30	G26	eastward	$78\,\mathrm{m\,s^{-1}}$	187 km





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Thank you!

Acknowledgments

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We thank all institutions that host EVNet equipment: Bahir Dar University, JAXA, Swedish Institute of Space Physics, Stanford University, University of Tromsø, Universidad de La Laguna, Hartebeesthoek Radio Astronomy Observatory, University of Toulouse, EISCAT Ramfordbotn.

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