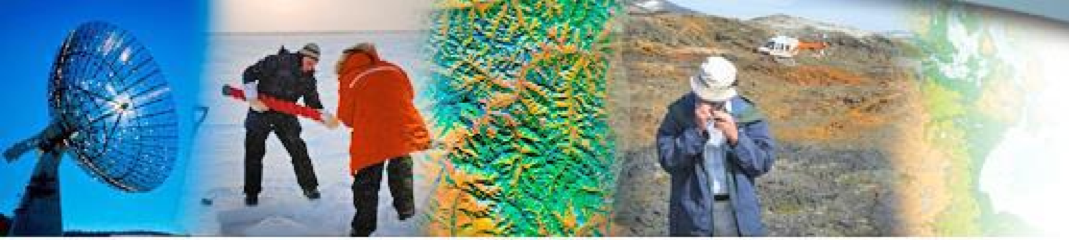

NATURAL RESOURCES CANADA - INVENTIVE BY NATURE

High rate GPS and GLONASS observations of RT-IGS network to monitor ionospheric irregularities and TEC mapping

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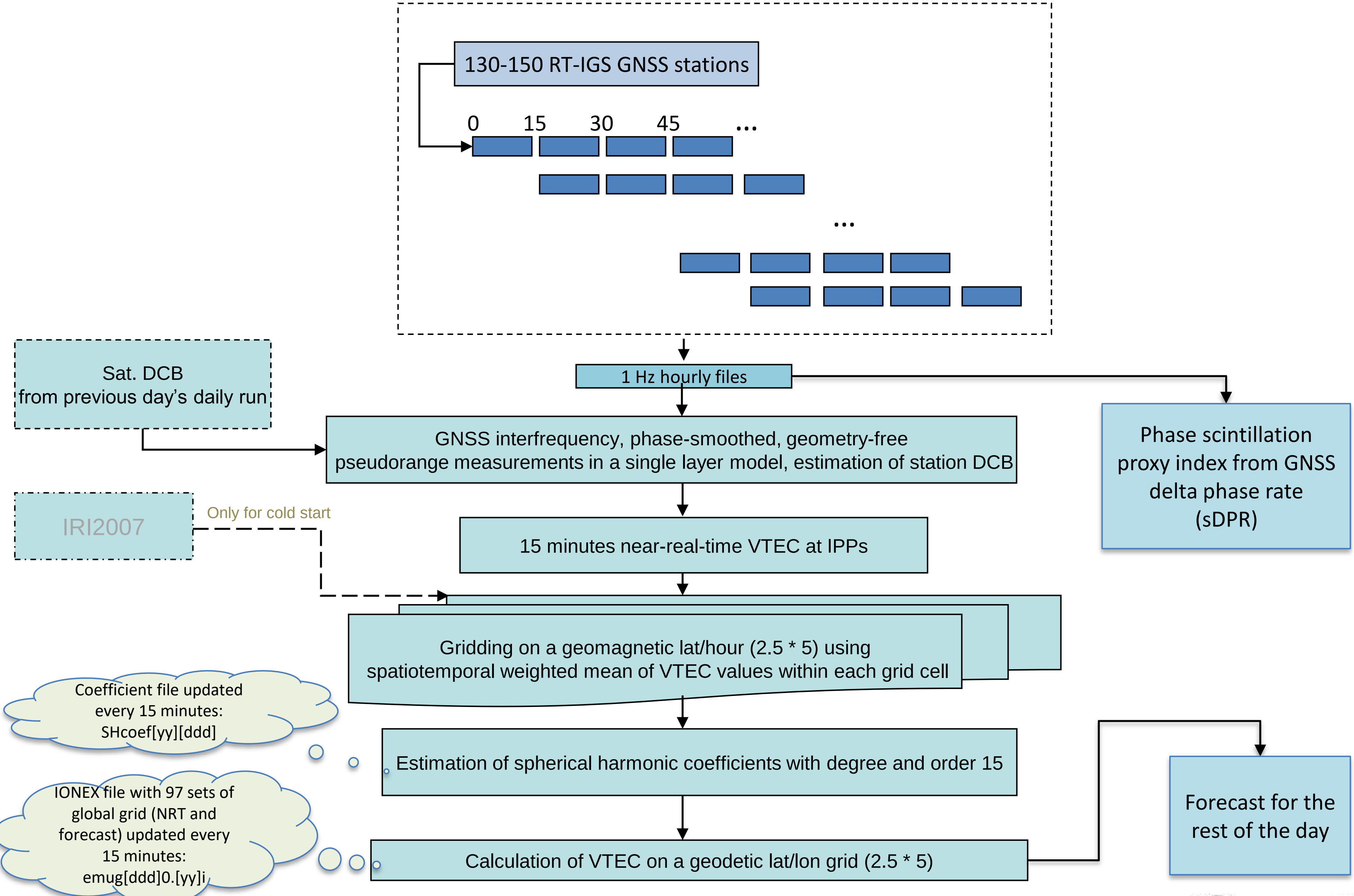
IGSWORKSHOP2017 PARIS
PATHWAYS TO IMPROVED PRECISION

Outline

- Ionospheric monitoring using RT-IGS network at NRCan
- Monitoring ionospheric irregularities using dual frequency GPS and GLONASS phase measurements
- Receiver and constellation dependent background phase noise
- NRT global TEC mapping and forecast
- Summary and conclusions

Ionospheric monitoring using RT-IGS network at NRCan



Monitoring ionospheric irregularities using dual frequency GPS and GLONASS phase measurements

At the Canadian Geodetic Survey of NRCan, 1 Hz phase measurements are used to derive indices over 30 sec intervals as follow:

$$sDPR = \frac{\sqrt{\left\langle \left(\frac{d(I_g(L_1, L_2))}{dt} \right)^2 \right\rangle - \left\langle \frac{d(I_g(L_1, L_2))}{dt} \right\rangle^2}}{m(e)}$$

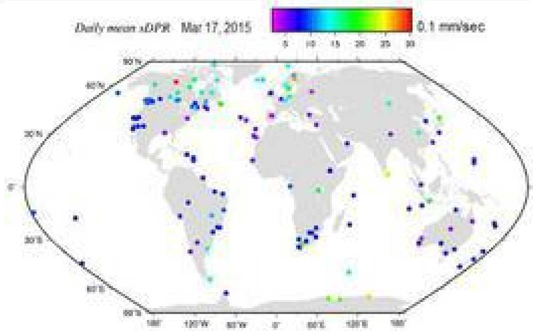
I_g: Geometry-free combination
$m(e)$: An elevation angle (e) dependent mapping function
GPS:
- L_1: L1C
- L_2: L2W

GLONASS:
- L_1: L1C
- L_2: L2P

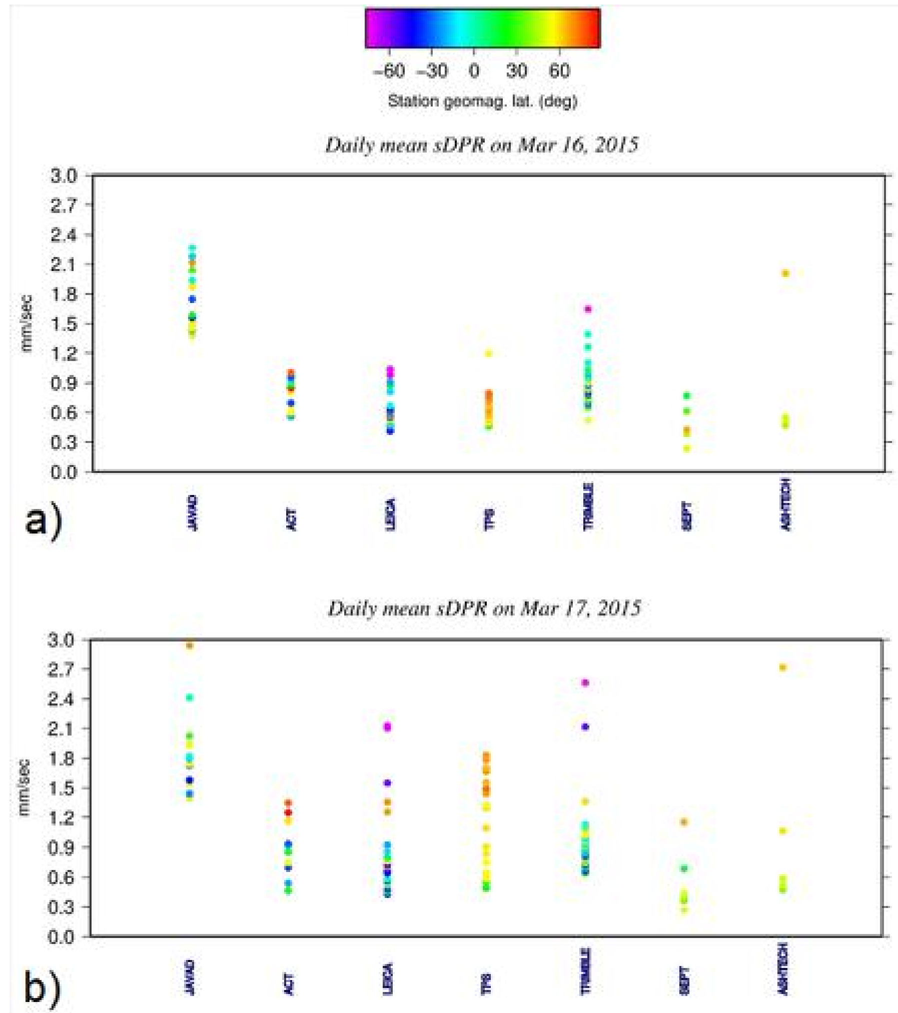
Experiments at collocated stations to study the impacts of:
- Constellation (GPS vs. GLONASS)
- Receiver type

Station and constellation specific de-trending of sDPR

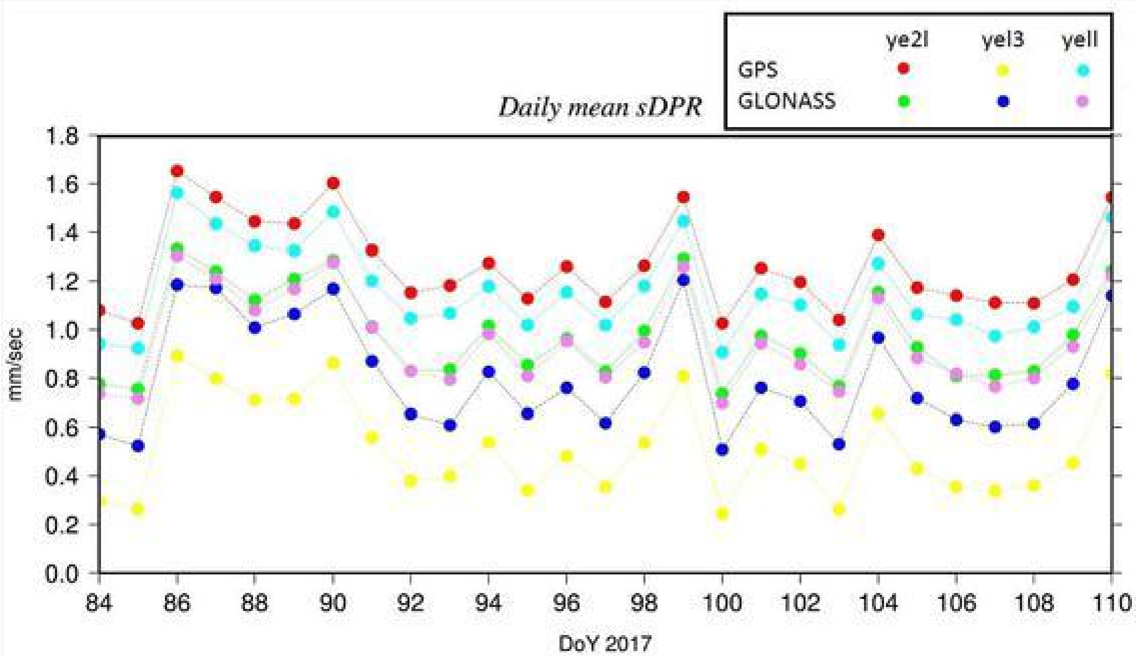
Real-time IGS network station specific background inter-frequency GPS phase rate noise by means of daily mean sDPR during March 16 (quiet day) and March 17 (stormy day), 2015



Representative name used in figures (a and b)	Receiver types	Number of receivers contributed in Mar 17, 2015
JAVAD	TRE_G3TH DELTA	15
ACT	AOA BENCHMARK ACT	11
	AOA SNR-12 ACT	1
LEICA	GRX1200GGPRO	15
	GRX1200+GNSS	2
	GRX1200	1
	GR25	4
	GR10	4
TPS	NET-G3A	21
	NETG3	1
	E-GGD	1
TRIMBLE	NETR5	6
	NETR8	5
	NETR9	25
	NETRS	26
SEPT	POLARX2	1
	POLARX4	5
	POLARX4TR	1
ASHTECH	UZ-12	1
	Z-X	1
	Z-XII3	2
	Z-XII3T	2

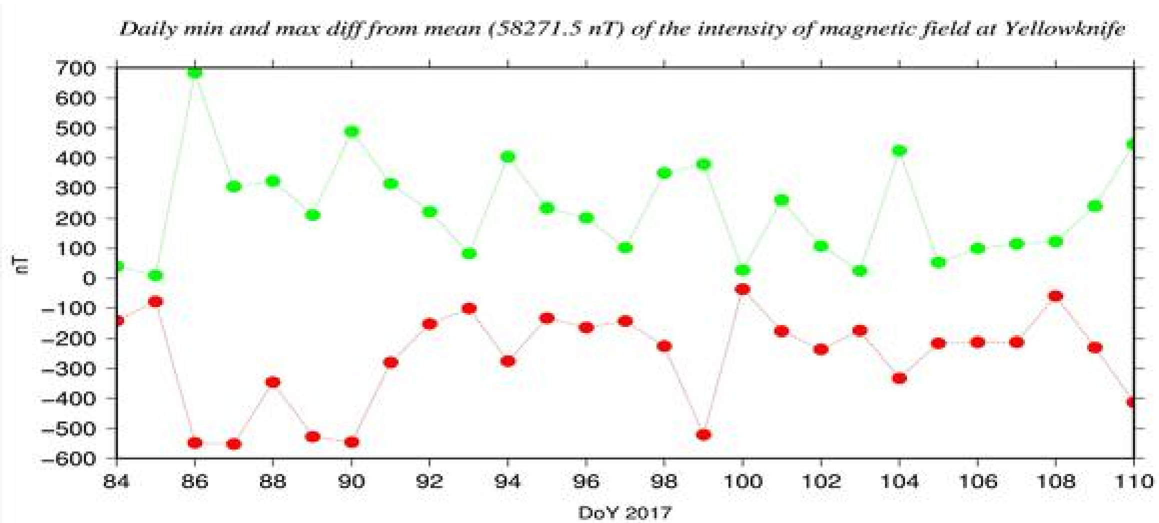


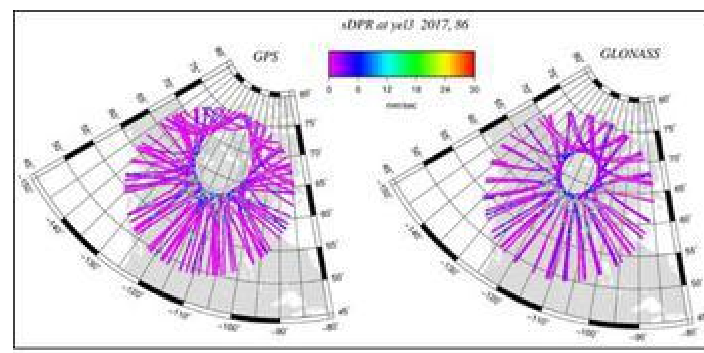
Receiver and constellation dependent background phase noise



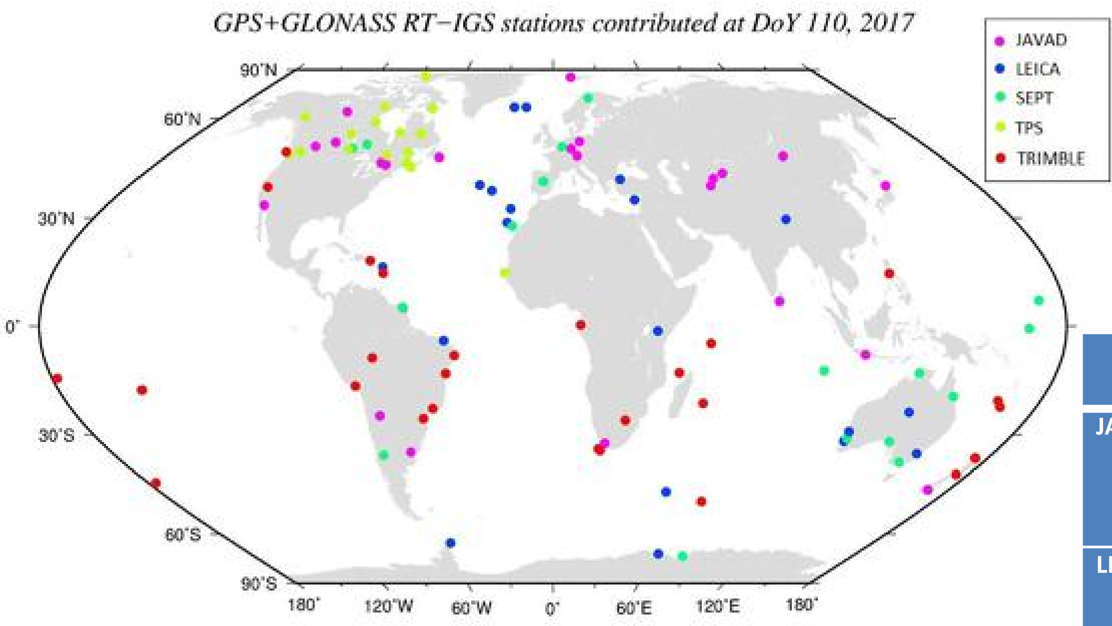
Co-located GNSS stations at Yellowknife, Canada (Lat: 62.481 Lon: -114.481)

Station	Receiver type	Antenna type
YE2L	JAVAD TRE_G3TH SIGMA	AOAD/M_T
YEL3	TPS NET-G3A	TWIVP6050_CONE
YELL	JAVAD TRE_3N DELTA	AOAD/M_T





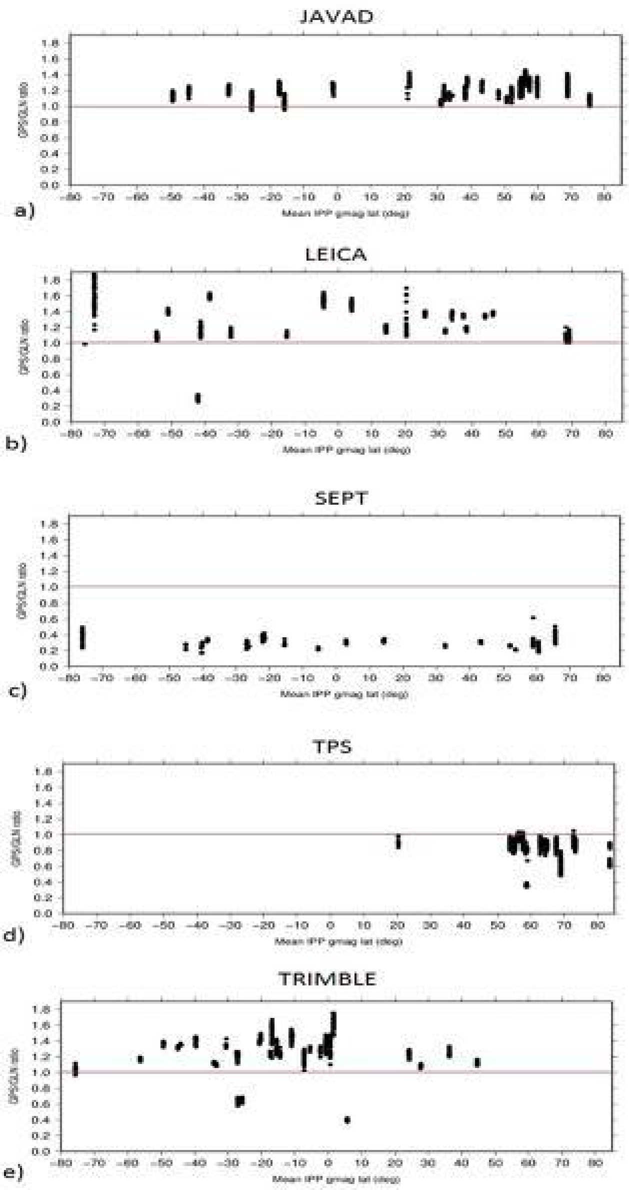
Receiver and constellation dependent background phase noise: RT-IGS stations

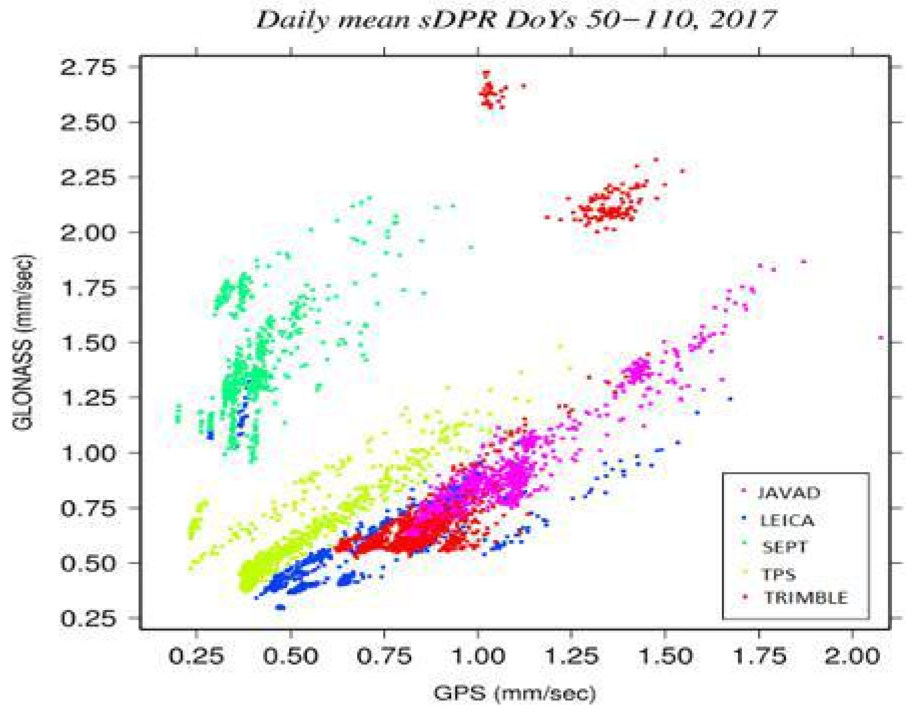


Receiver types contributed both
GPS and GLONASS in studies presented here

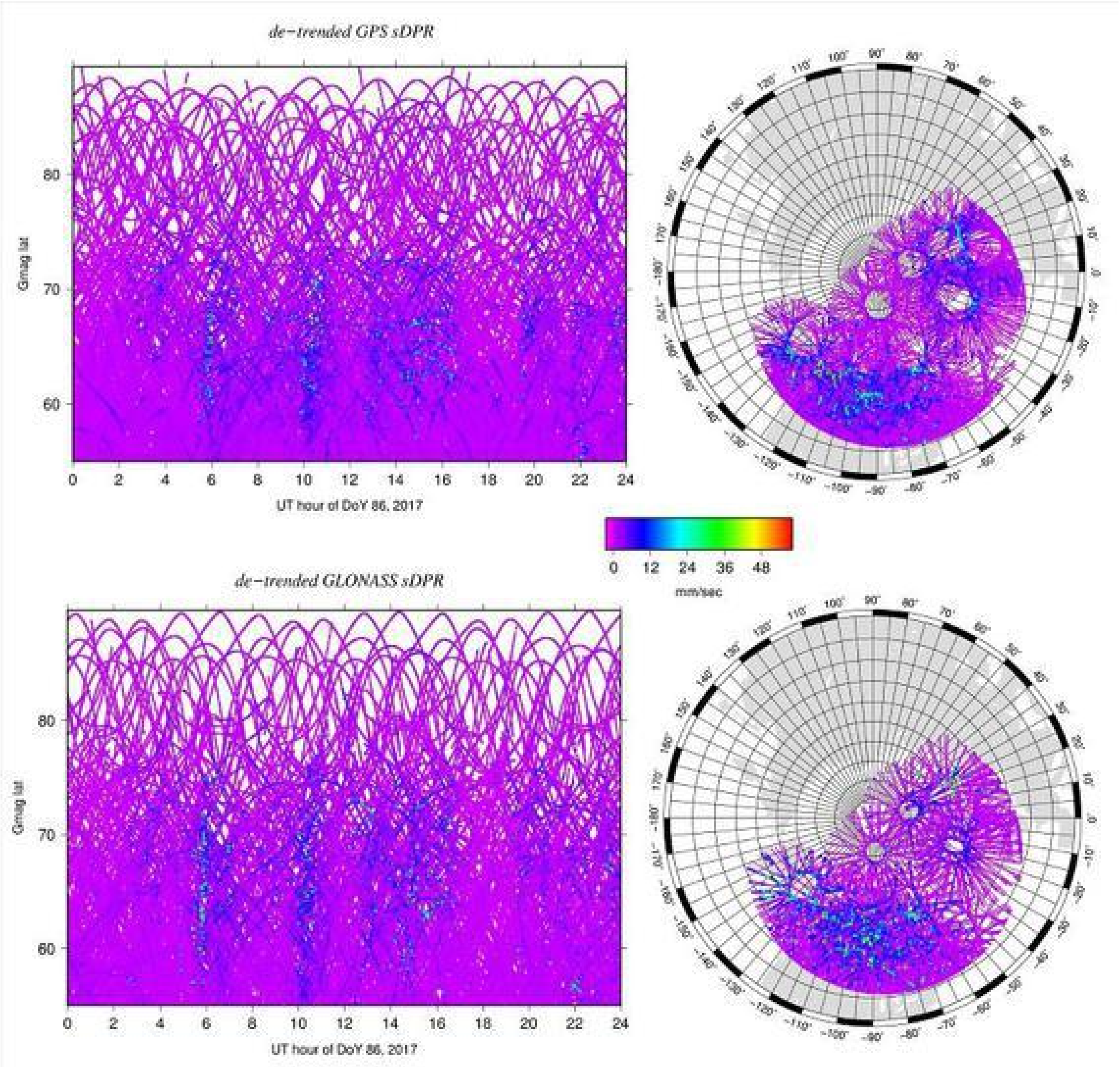
Representative name used in this presentation	Receiver types	Number of receivers
JAVAD	TRE_G3TH DELTA	20
	TRE_G3TH SIGMA	2
	TRE_3 DELTA	2
	TRE_3N DELTA	1
LEICA	GRX1200GGPRO	8
	GRX1200+GNSS	3
	GR25	9
	GR10	2
SEPT	POLARX4	8
	POLARX5	5
	POLARX4TR	6
	POLARXS	2
TPS	NET-G3A	24
TRIMBLE	NETR3	1
	NETR5	2
	NETR8	4
	NETR9	20

Receiver and constellation dependent background phase noise: RT-IGS stations

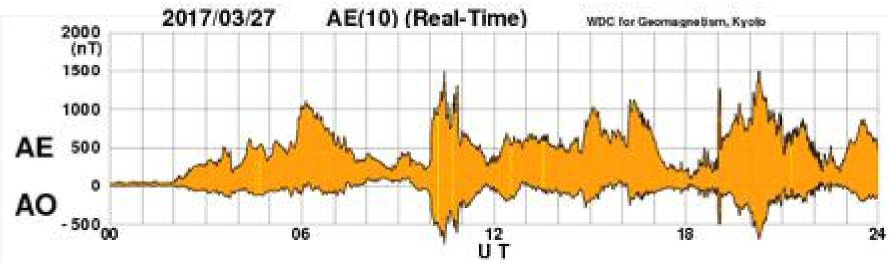




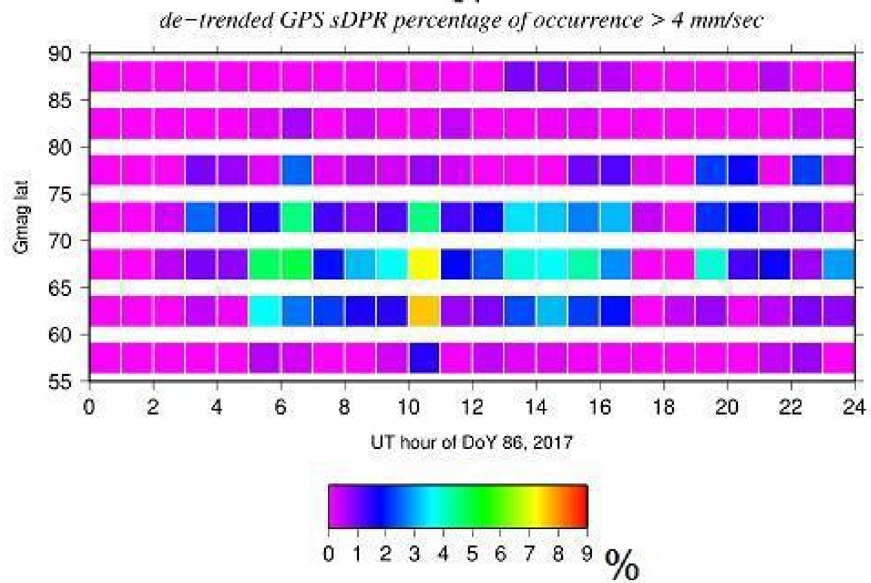
Detection of high latitude ionospheric irregularities using RT-IGS stations

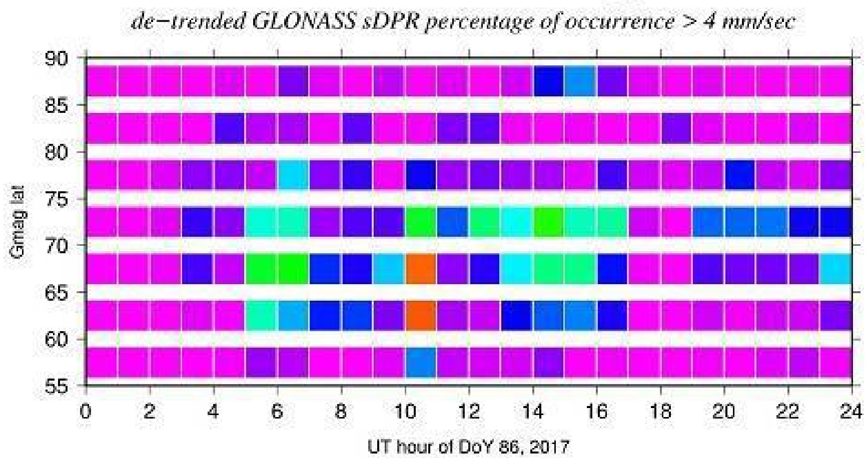


GPS and GLONASS IPPs from RT-IGS stations with gmag lat > 55 deg during March 27, 2017 (DoY 86), a day with moderate geomagnetic disturbances.



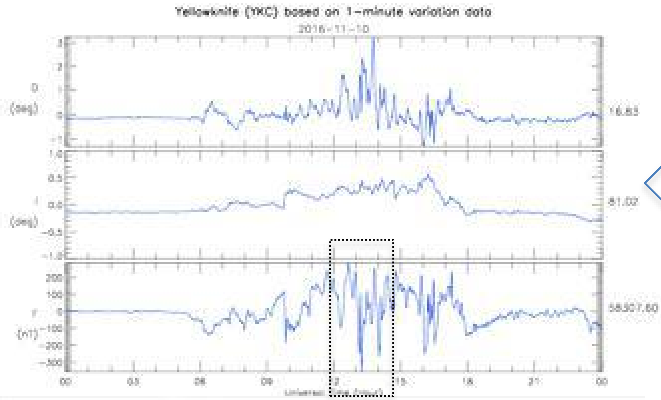
Auroral Electrojet Index



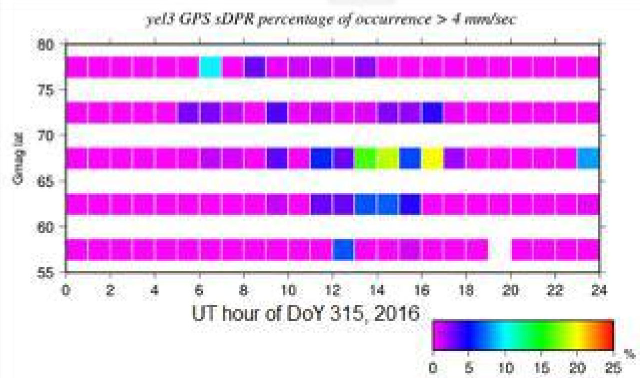


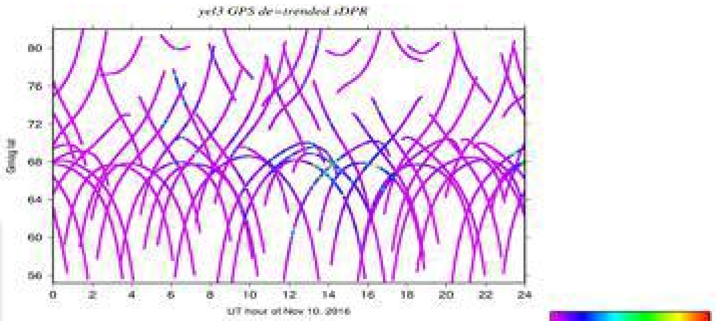
Percentage of occurrence of large (> 4 mm/sec) de-trended sDPR values in bins of 1 UT hour by 5 deg gmag lat; separately for GPS and GLONASS

GPS vs. GLONASS phase irregularities in response to geomagnetic field variations

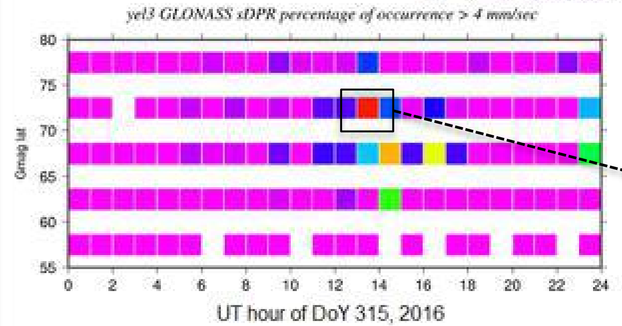


Geomagnetic field observations from a co-located magnetometer operated by NRCan at Yellowknife during Nov 10, 2016.

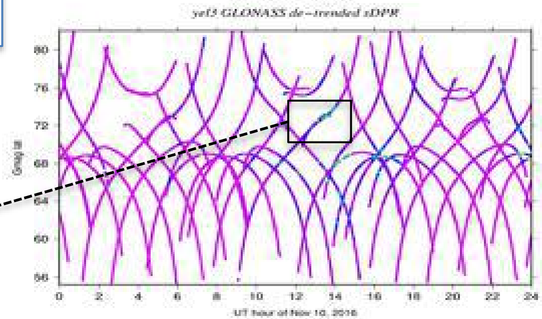




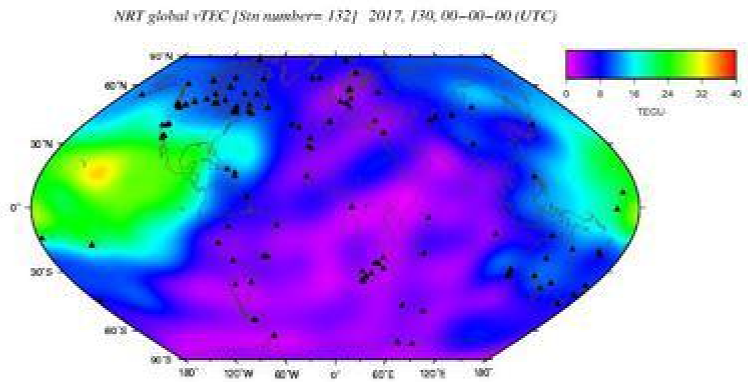
Percentage of occurrence of large (> 4 mm/sec) values in bins of 1 UT hour by 5 deg gmag lat



High latitude irregularities detected by GLONASS



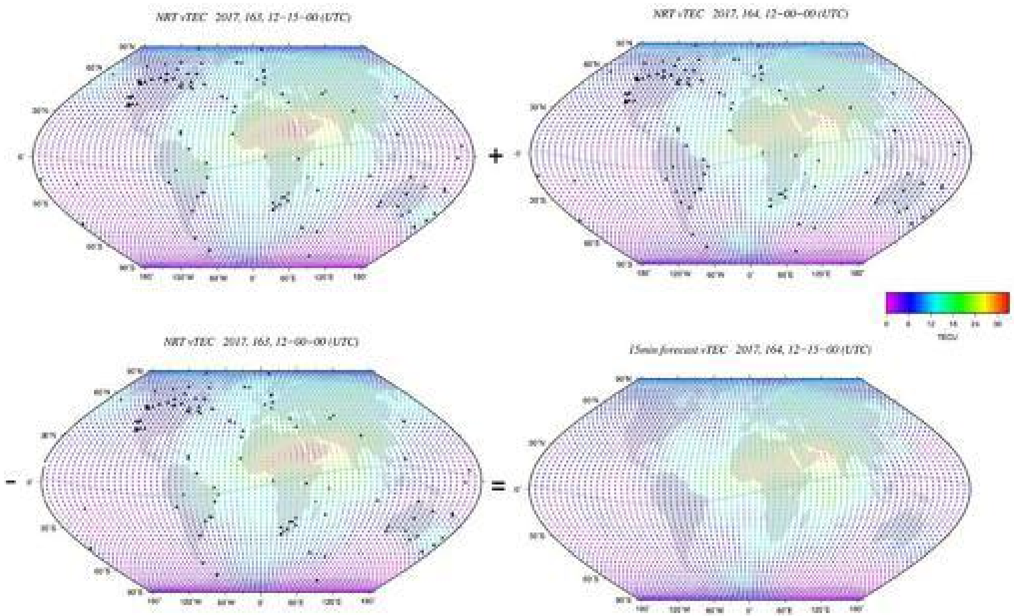
NRT global TEC mapping and forecast

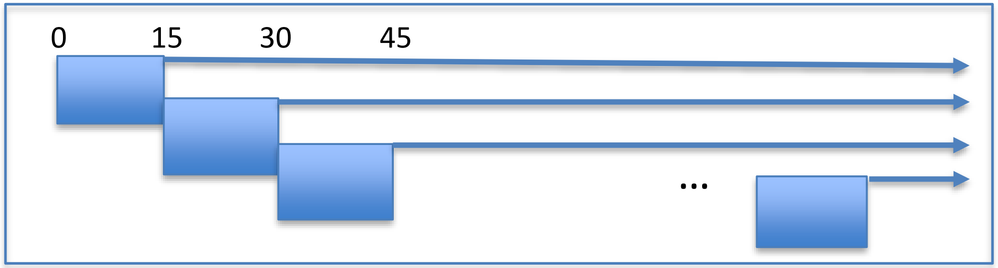


CGS near-real-time global TEC maps use high rate real-time IGS stations every 15 minutes. Forecast for up to 24 hours ahead…

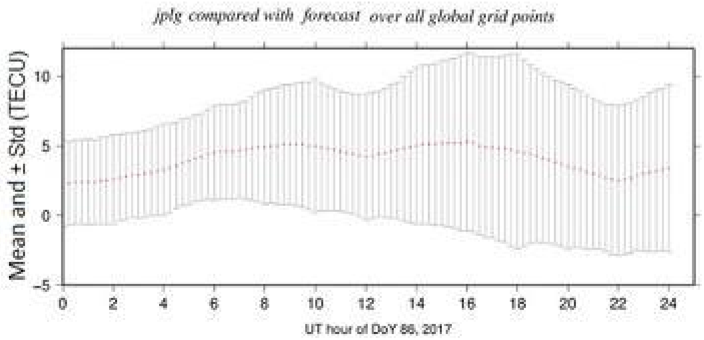
Grid forecast model:

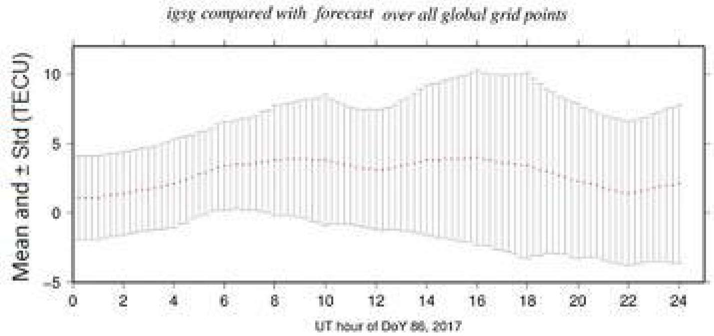
$$\hat{g}_d^{t_n} = g_{d-1}^{t_n} + \left[g_d^{t_m} - g_{d-1}^{t_m}\right]_{m=0,\dots,n-1}$$



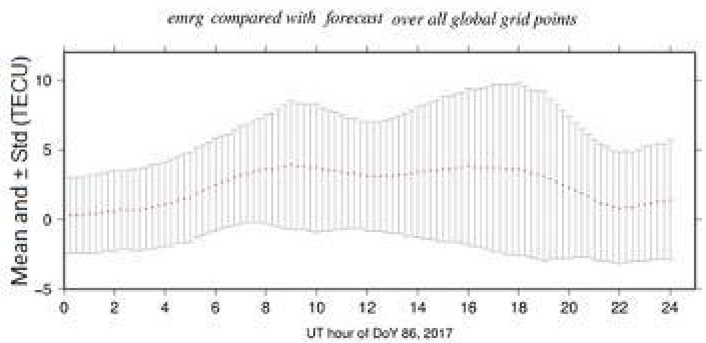


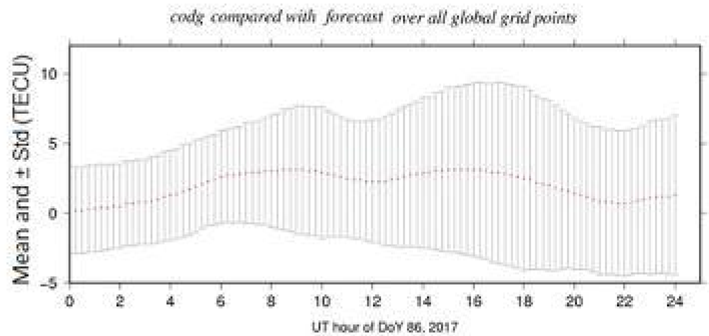
15 minutes to 24 hours TEC forecast: performance against IGSG and other ACs March 27, 2017

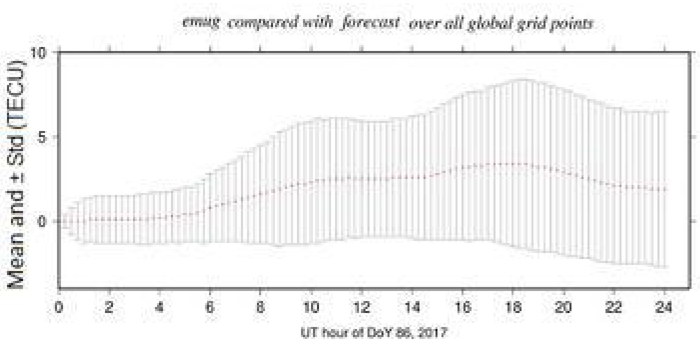


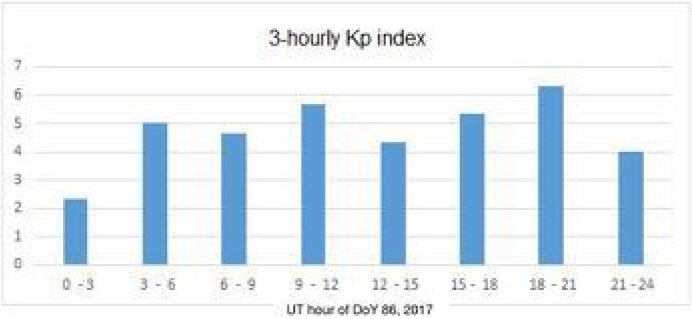


Red: global mean difference
Grey: ± global std of difference

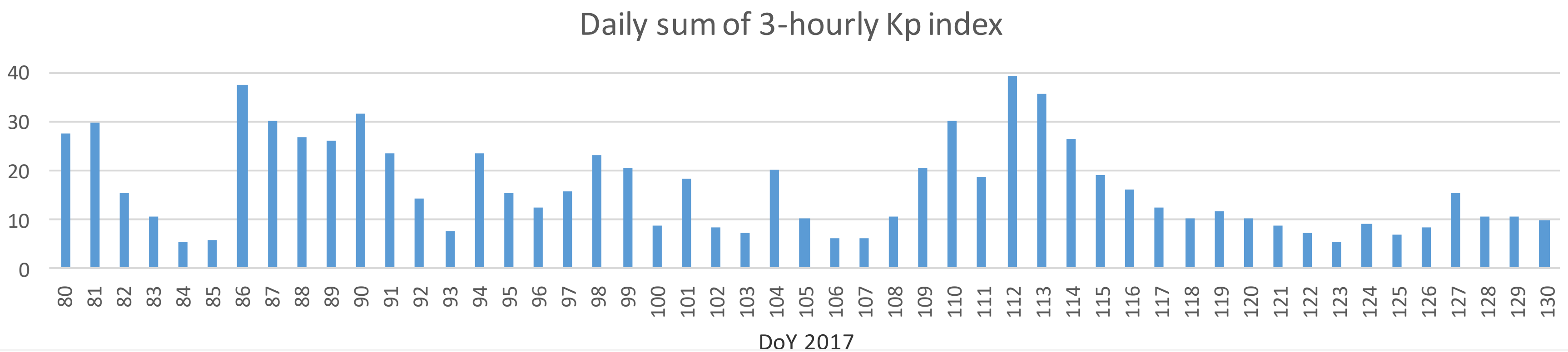


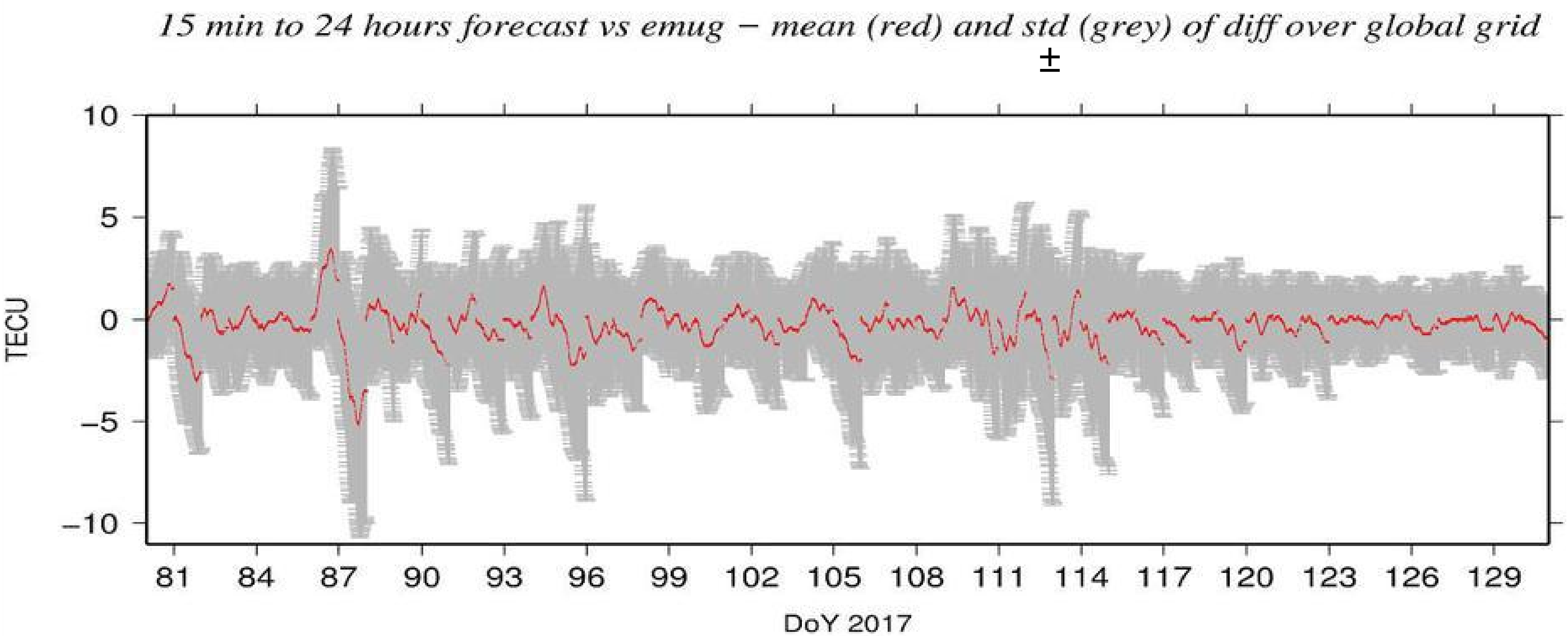




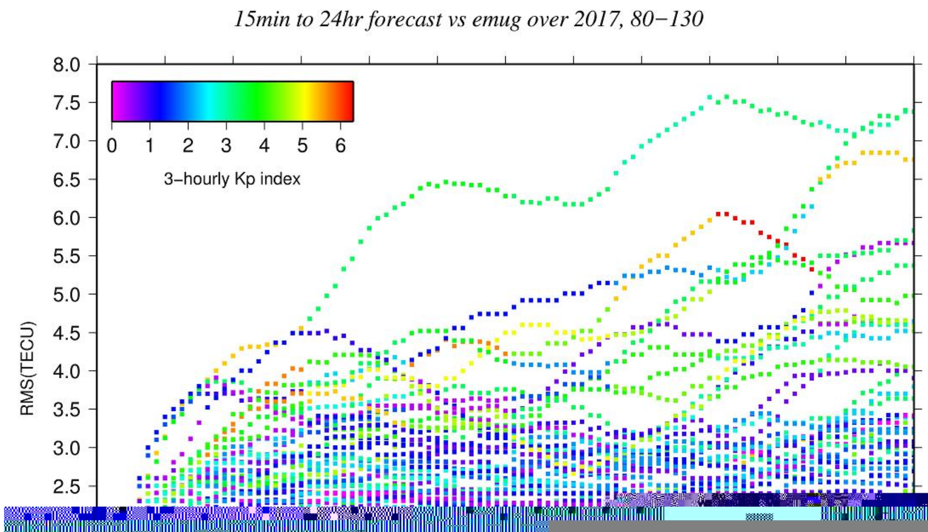


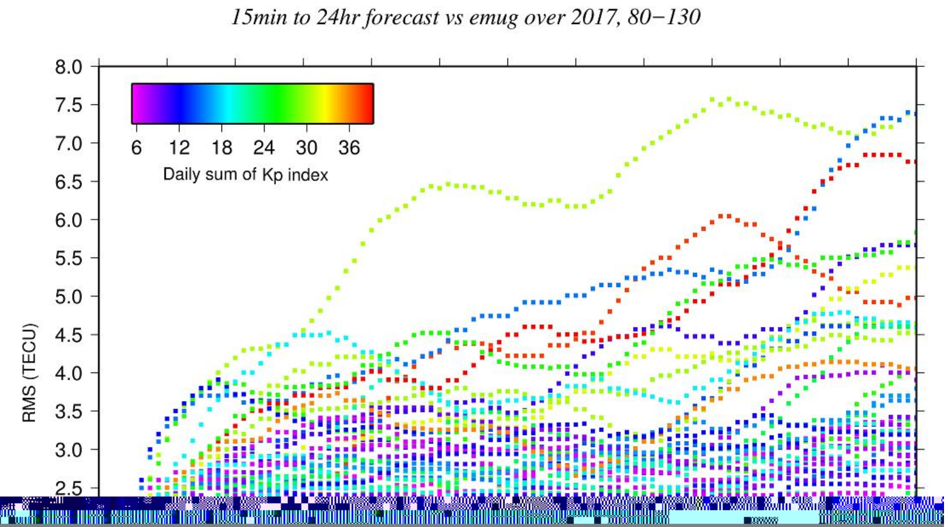
15 minutes to 24 hours TEC forecast: performance against emug (NRCan NRT TEC) March 21 – May 10, 2017



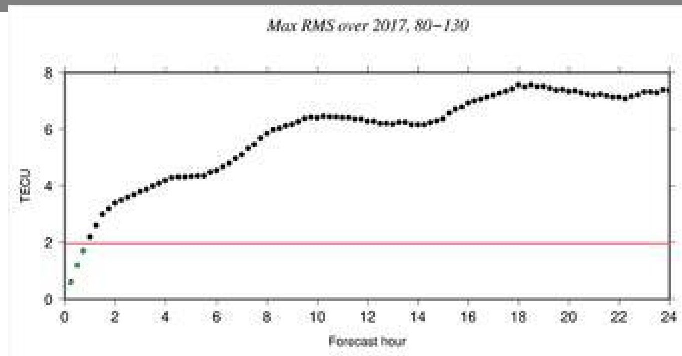


15 minutes to 24 hours TEC forecast: global RMS of difference from emug (NRCan NRT TEC) March 21 – May 10, 2017





During the studied period global RMS (NRT vs. forecast) was below 2 TECU for forecasts up to 45 minutes.



Summary and conclusions (1)

- At the Canadian Geodetic Survey of NRCan 1 Hz GPS and GLONASS observations from RT-IGS network are used for monitoring ionospheric irregularities and TEC mapping in near-real-time.

- Impact of receiver type and constellation (GPS and GLONASS) on GNSS-derived indices is quantified at stations of RT-IGS network. Inter constellation biases in GNSS derived indices are presented for different receiver categories operating within RT-IGS network using ratio of GPS to GLONASS daily mean sDPR. Even though such a ratio can be dependent on the spatial and temporal distribution of IPPs between two constellations, a clear receiver dependency among all regions and studied periods is observed.

- When GPS and GLONASS phase measurement are used together for detection of ionospheric irregularities, the station specific systematic bias between the two constellations needs to be evaluated and applied before interpretation of results.

Summary and conclusions (2)

- Overall, both GPS and GLONASS responded rather similarly to periods of ionospheric irregularities. Detection of irregularities with small spatiotemporal scales can benefit from multiple constellation due to increased coverage of measurements.
- NRCan's NRT TEC maps are generated from RT-IGS stations every 15 minutes and represented using spherical harmonics.
- A grid forecast method to generate global maps of 15 minute to 24 hours ahead is also implemented and evaluated.

Acknowledgments

- IGS and its contributing organizations.
- World Data Center for Geomagnetism, Kyoto.

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Thank you!

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