NeQuick Galileo

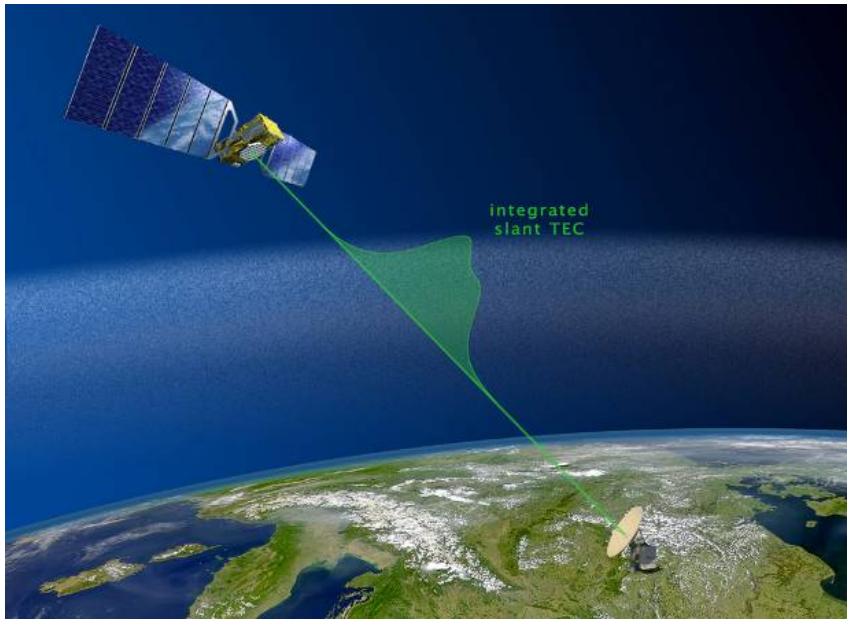
Galileo Ionospheric Correction Algorithm for Single-Frequency Users
- Performance Results -

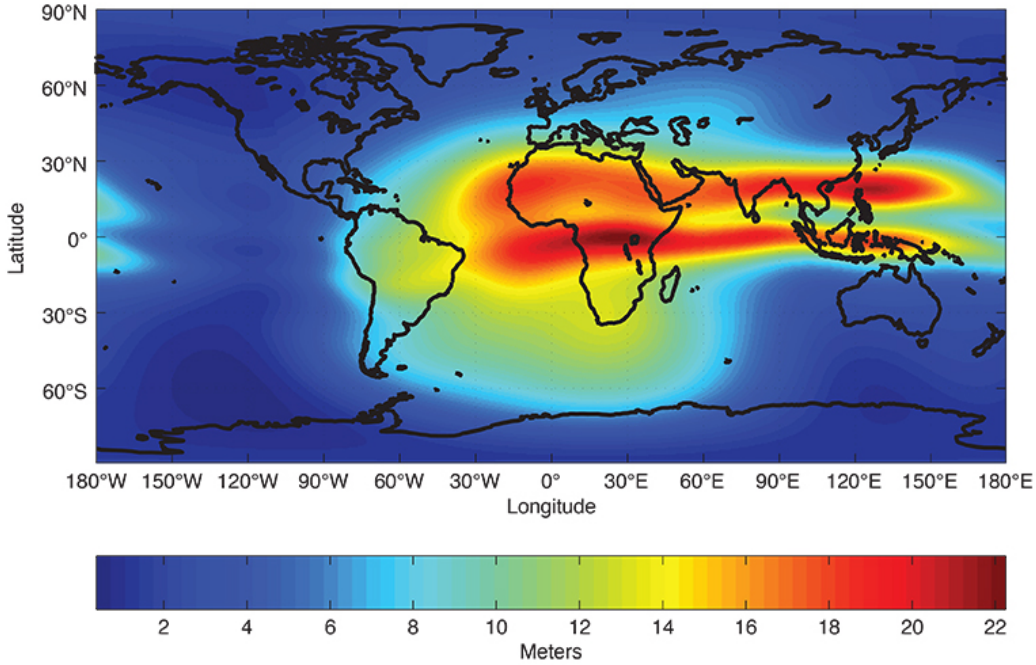
ICG-9, WG-B, Prague, 12/11/2014

esa
European Space Agency

GALILEO
EGNOS
Navigation solutions powered by Europe

NeQuick model





- Climatological (monthly mean) model of electron density
  - 3D (as opposed to single-layer ionospheric models SBAS, Klobuchar)
  - Driven by monthly-mean Solar Flux F10.7
- Recommended by ITU-R for propagation prediction
- Based on profiles of ionospheric layers
- Adapted in Galileo for nowcasting based on recent observations

Hochegger, G., B. Nava, S.M. Radicella and R. Leitinger (2000): A family of ionospheric models for different uses,Phys. Chem. Earth, 25 (4), 307-310.
Radicella, S.M. and R. Leitinger, "The evolution of the DGR approach to model electron density profiles", Adv. *Space Res.*, Vol. 27, Issue 1, pp. 35-40, 2001.

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Galileo ionospheric algorithm for single-frequency users

- Navigation message broadcast:
  - 3 Az (Effective ionisation level) coefficients.
- Based on an adaptation of the 3D empirical climatological electron density model NeQuick → ***NeQuick G***
  - From monthly-mean climatological modelling to real-time corrections.
  - Including a number of evolutions from NeQuick 1.
  - Galileo specific version of geomagnetic field model (modip file)
  - Adaptations due to software engineering process.

Parameter	Definition	Bits	Scale factor	Unit
a_{i0}	Effective Ionisation Level 1st order parameter	11	2^{-2}	sfu**
a_{i1}	Effective Ionisation Level 2nd order parameter	11*	2^{-8}	sfu**/degree
a_{i2}	Effective Ionisation Level 3rd order parameter	14*	2^{-15}	sfu**/degree^2
SF_1	Ionospheric Disturbance Flag for region 1	1	N/A	dimensionless
SF_2	Ionospheric Disturbance Flag for region 2	1	N/A	dimensionless
SF_3	Ionospheric Disturbance Flag for region 3	1	N/A	dimensionless
SF_4	Ionospheric Disturbance Flag for region 4	1	N/A	dimensionless
SF_5	Ionospheric Disturbance Flag for region 5	1	N/A	dimensionless
Total Ionospheric Correction Size		**41**		

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Correction algorithm end-to-end overview

SENSOR STATION

Observe slant TEC in Sensor Stations for 24 hours

↓

Optimise effective ionisation parameter for NeQuick to match observations

↓

SATELLITE

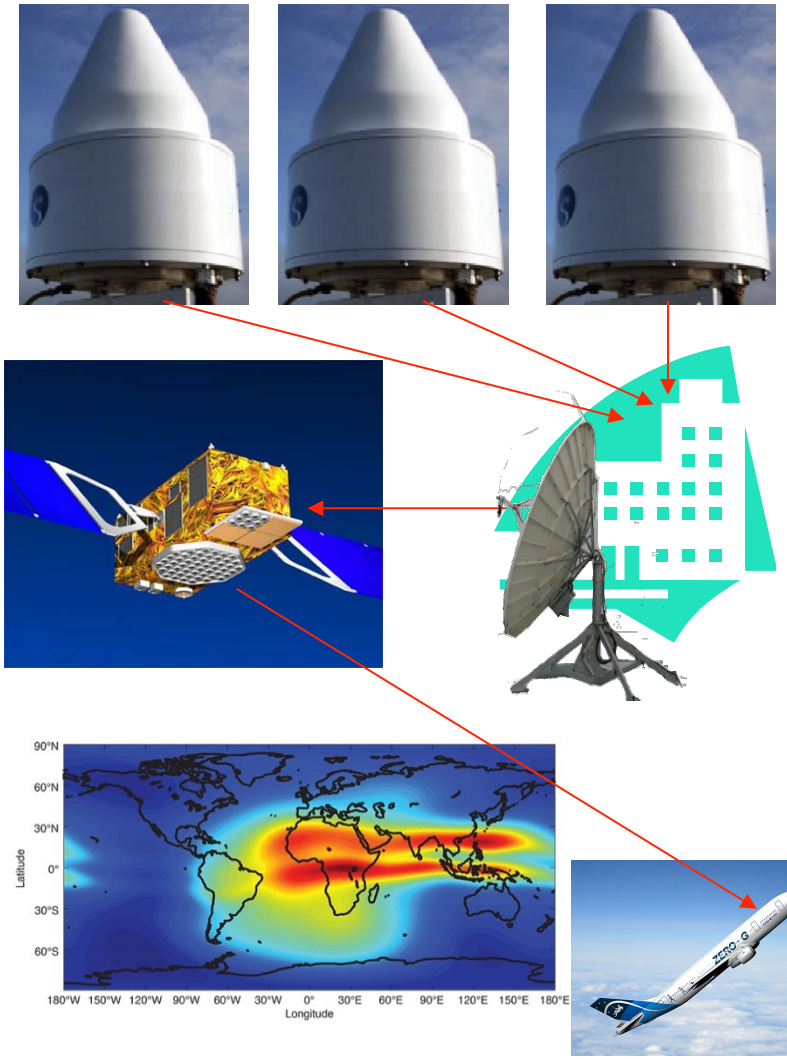
Broadcast effective ionisation parameter in Navigation message

$$Az = a_0 + a_1 \cdot \mu + a_2 \cdot \mu^2$$

↓

USER RECEIVER

Calculate slant TEC using NeQuick G with broadcast parameter. Correct for Ionospheric delay at frequency in question.



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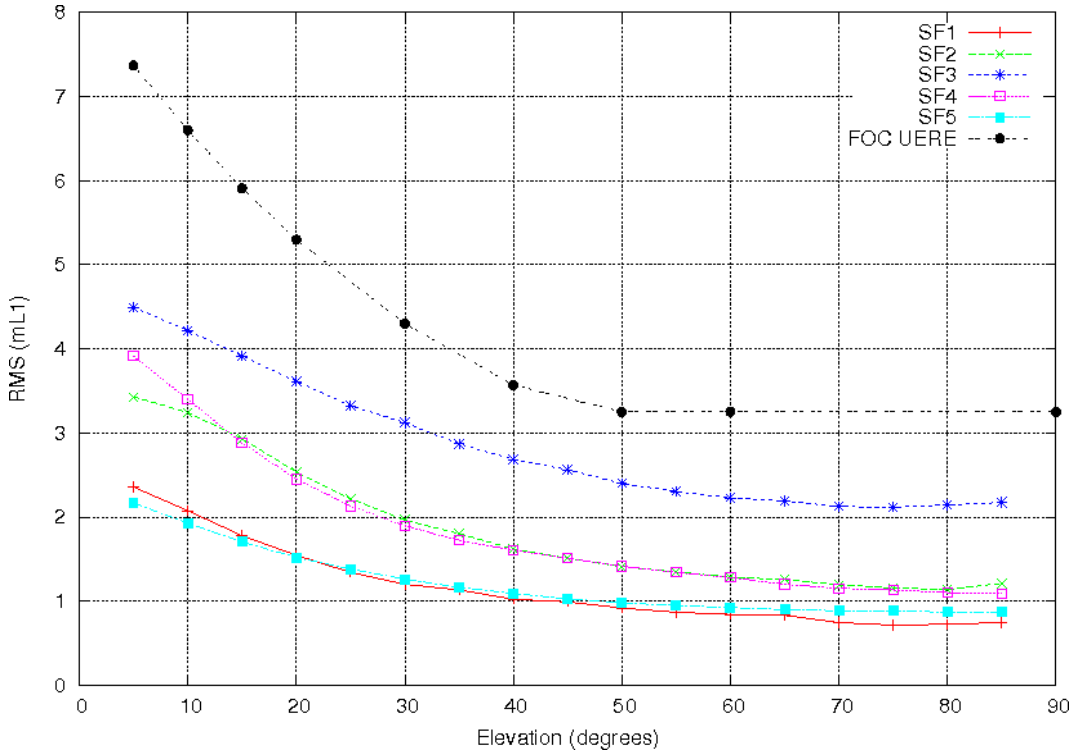
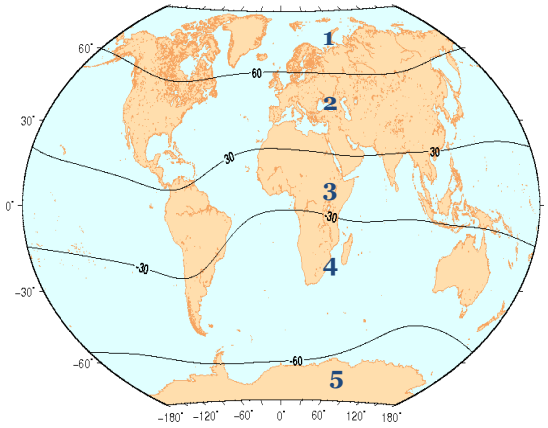
Actual Iono UERE residual contribution for Single Frequency Users per Region (SFi)

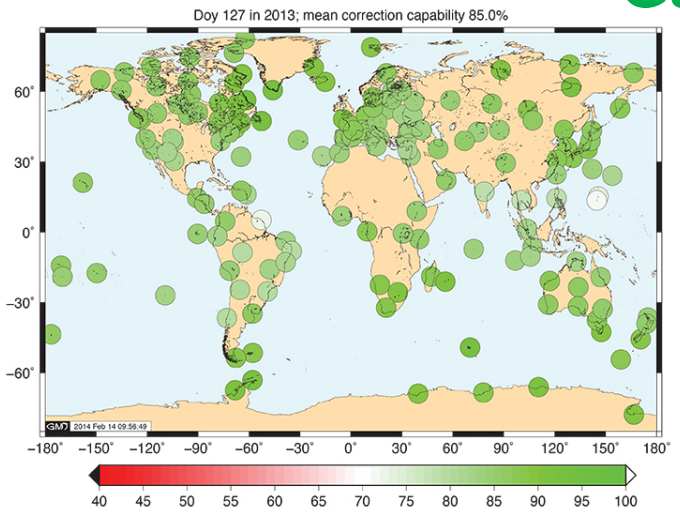
	Elevation angle (degrees)								
	5	10	15	20	30	40	50	60	90/85
Spec	*737.0*	*660.0*	*591.0*	*530.0*	*430.0*	*357.0*	*325.0*	*325.0*	*325.0*
SF1	235.8	207.5	178.0	154.6	120.1	102.2	91.7	84.4	74.5
SF2	343.0	324.5	293.1	253.7	196.4	161.9	141.0	128.7	121.3
SF3	449.5	421.8	391.6	361.5	312.2	268.5	240.1	222.9	217.4
SF4	391.6	339.9	288.2	245.1	189.7	160.7	141.6	128.1	109.0
SF5	216.7	192.7	170.6	152.1	126.2	109.0l	97.9	92.4	86.8





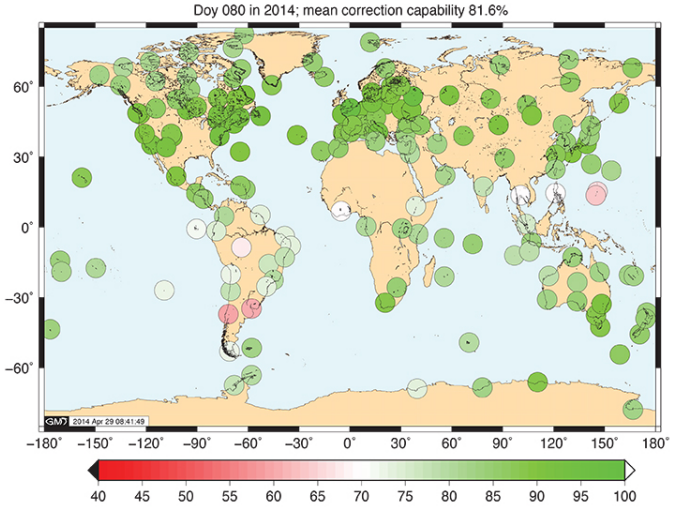
Ionospheric correction capability (%)

Galileo broadcast



85%

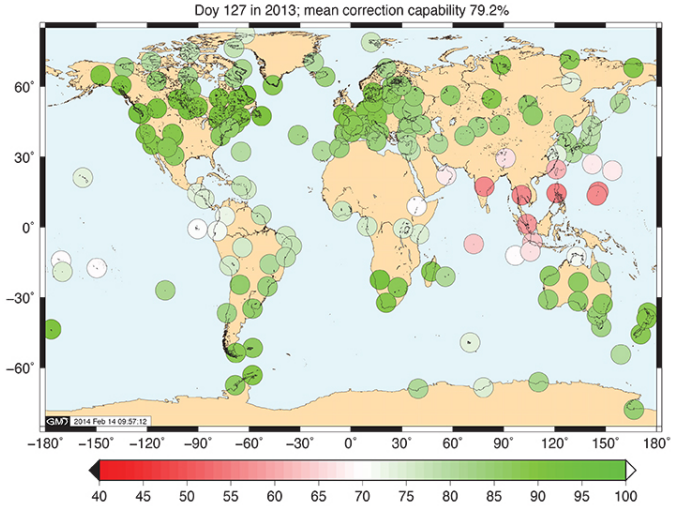
doy 127/2013



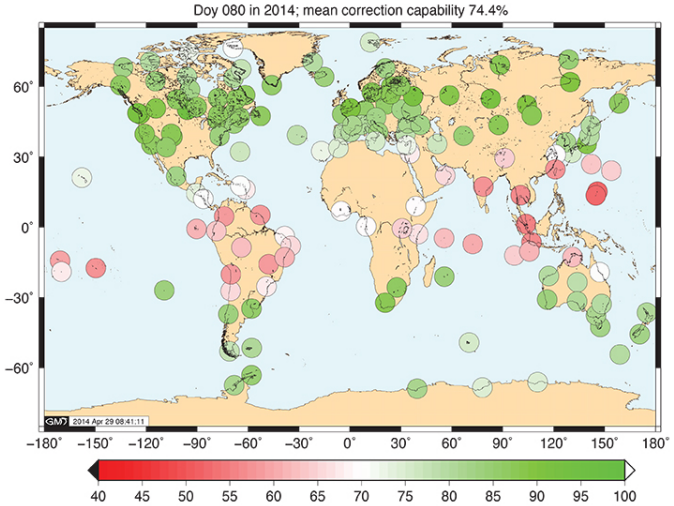
81.6 %

doy 080/2014

GPS broadcast



79.2 %



74.4 %

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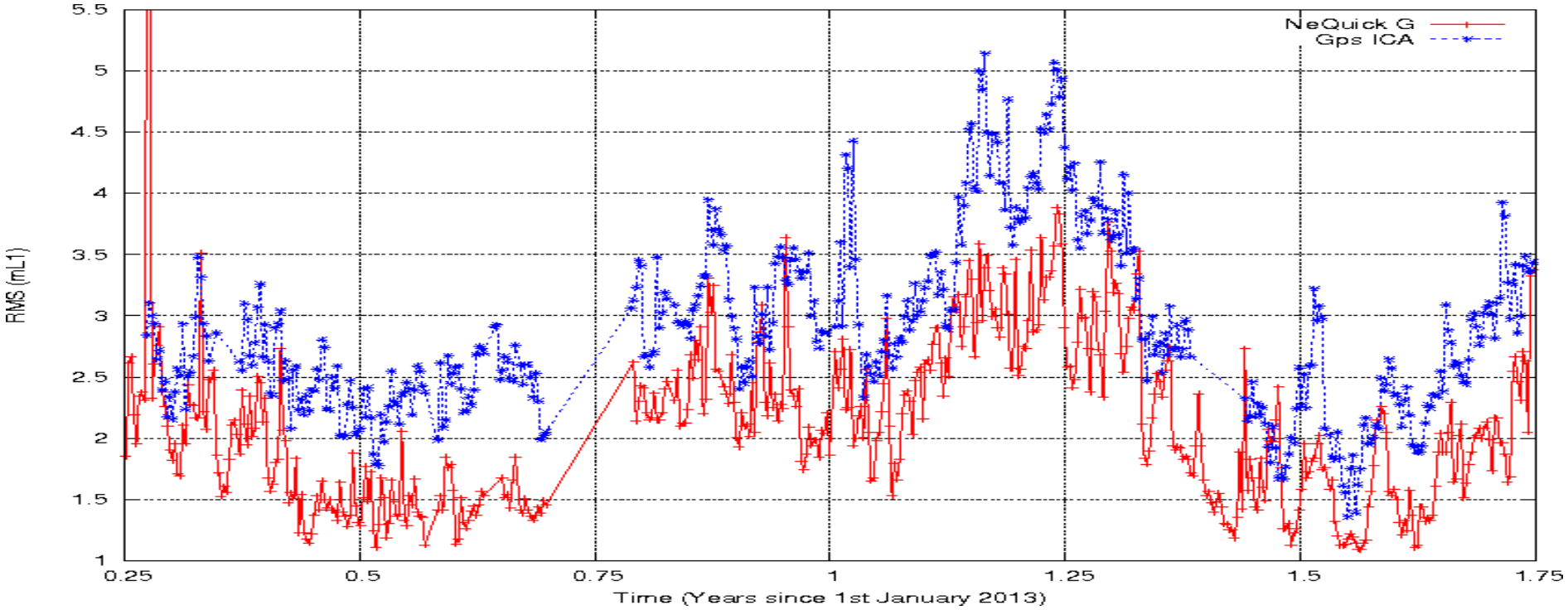
Residual RMS error (meters$_{L1}$) - daily evolution 2013-2014



- Broadcast NeQuick G performance very good despite the low (3-4) number of satellites used to drive the model

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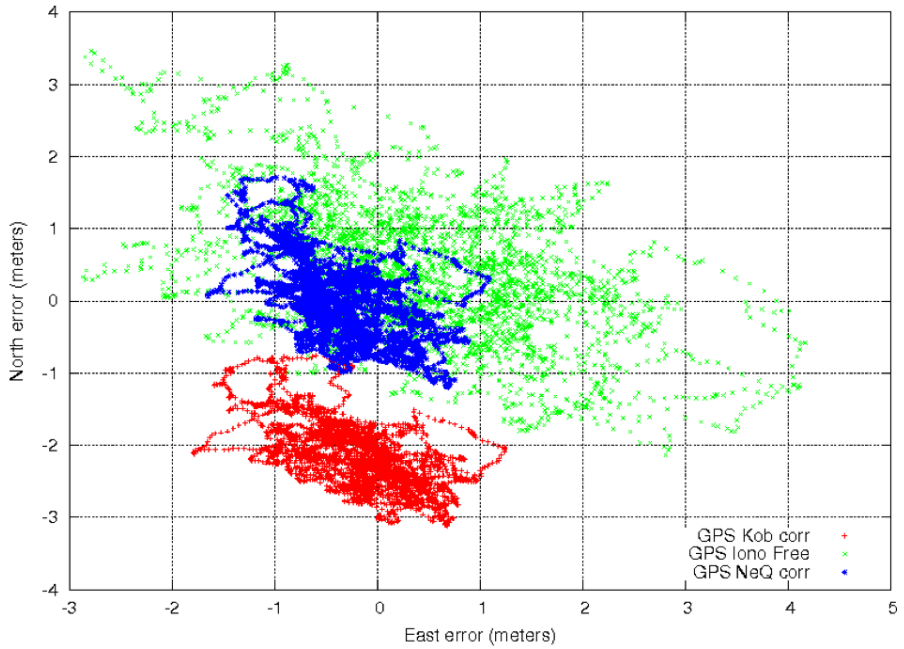
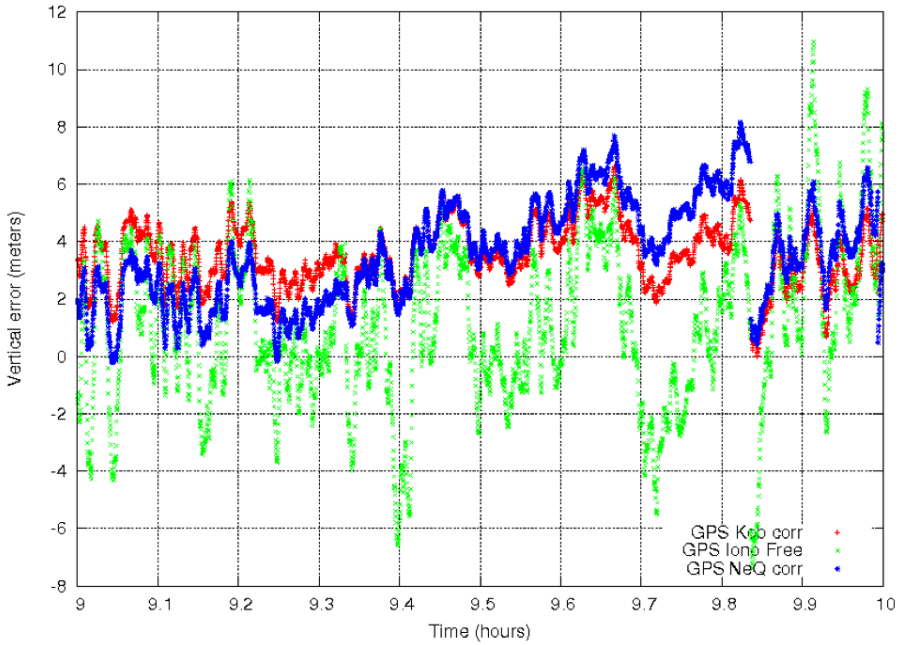
Positioning error (GPS – low-latitude)





Horiz. (left) and Vert. (right) GPS positioning error on L1 and single-frequency NeQuick G correction (blue), L1 and GPS ICA (red) and dual-frequency ionospheric-free (green) for low-latitude station Malindi (doy 172, 2013)

Specification document - Contents

- ★ Full step-by-step methodology and description
- ★ Complementary files
- ★ Input / Output validation files
- ★ Appendix with pseudo-code implementation