MODERNIZATION OF THE SWEPOS IONOSPHERIC MONITOR FOR THE NEXT SOLAR MAXIMUM

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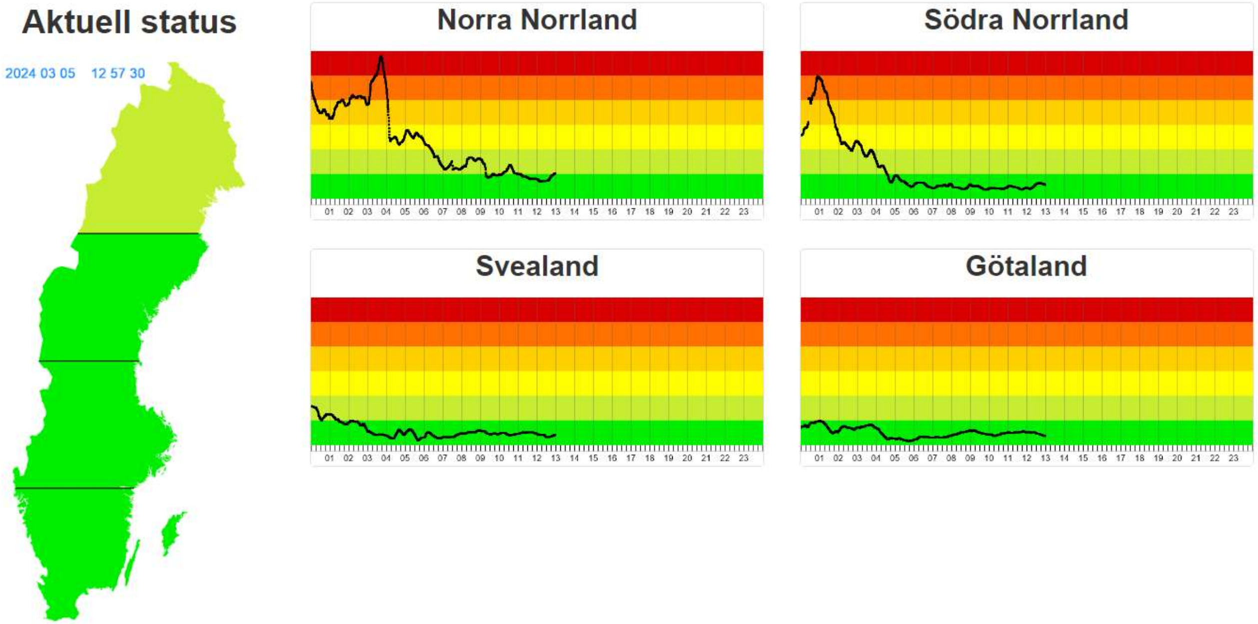
LANTMÄTERIET

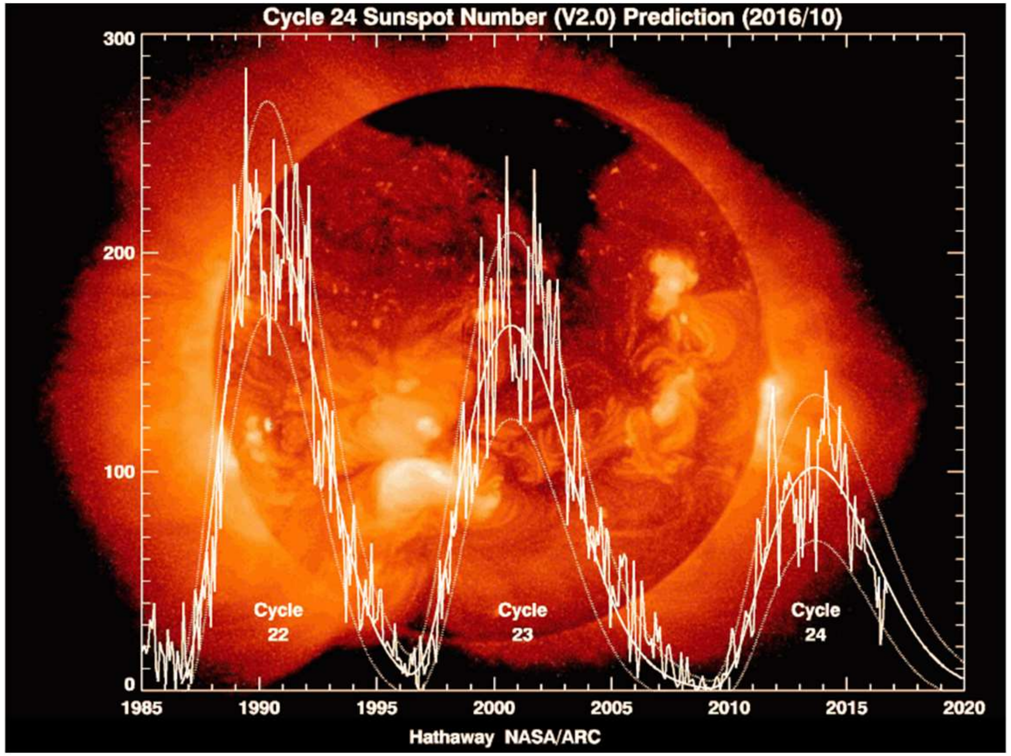
CURRENT MONITOR

- Purpose to aid users of the SWEPOS network-RTK service
- Was conceived in connection with the previous solar maximum (2012-2013)

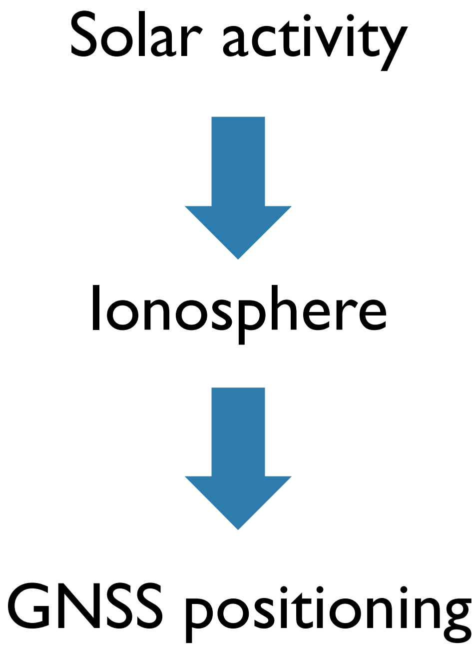


https://swepos.lantmateriet.se/services/iono.aspx

SOLAR ACTIVITY'S EFFECT ON GNSS POSITIONING



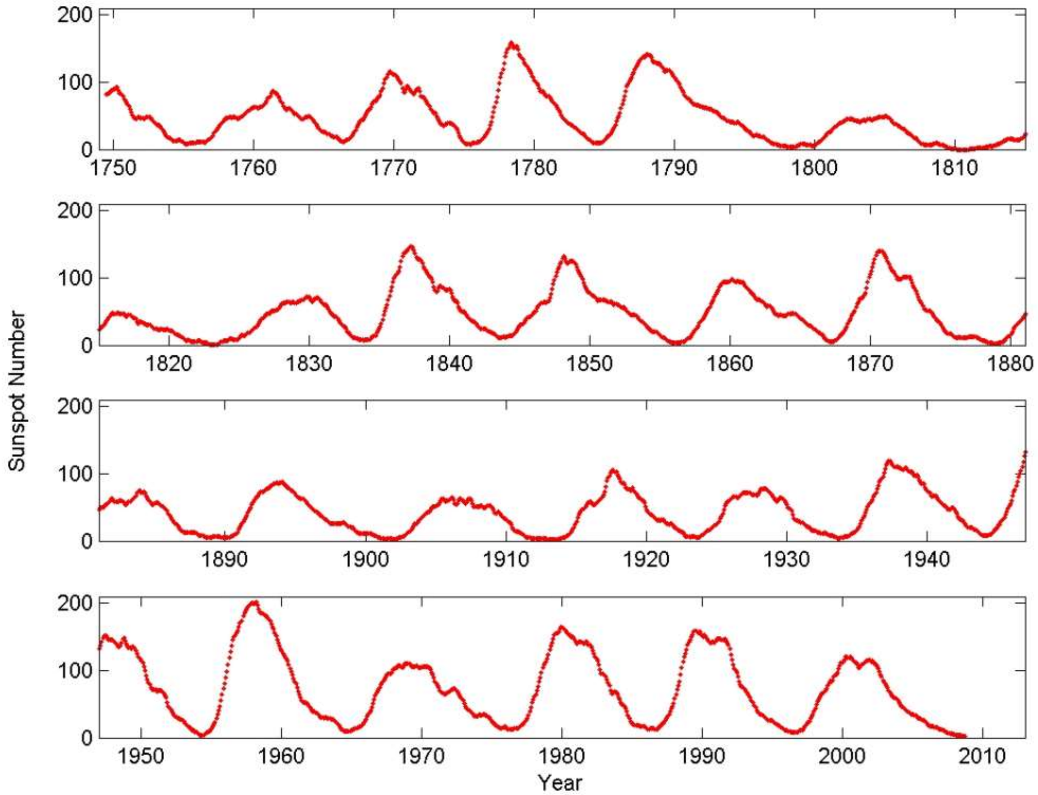
Source: http://solarscience.msfc.nasa.gov/predict.shtml



SOLAR ACTIVITY

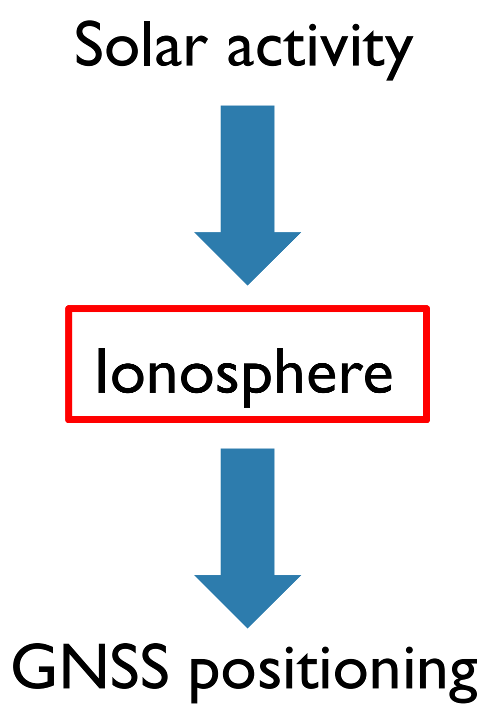
- The solar cycle has an average period of 11 years
- Solar activity is linked to the number of sunspots, with more UV radiation when there are many sunspots
- At solar maximum, the number of solar eruptions increases, leading to significantly increased radiation and coronal mass ejections

The Sunspot Cycle



THE IONOSPHERE

- Region in the atmosphere with large concentrations of electrically charged particles (ionized gas molecules and free electrons).
- Upper part of the atmosphere 50km – 1000km
- The presence of electrically charged particles in the ionosphere is an effect of ionizing UV and X-ray radiation from the sun
- The concentrations thus vary with the intensity of the sun's radiation
  - For example, lower concentrations at night and at higher latitudes
  - Solar eruptions at high solar activity



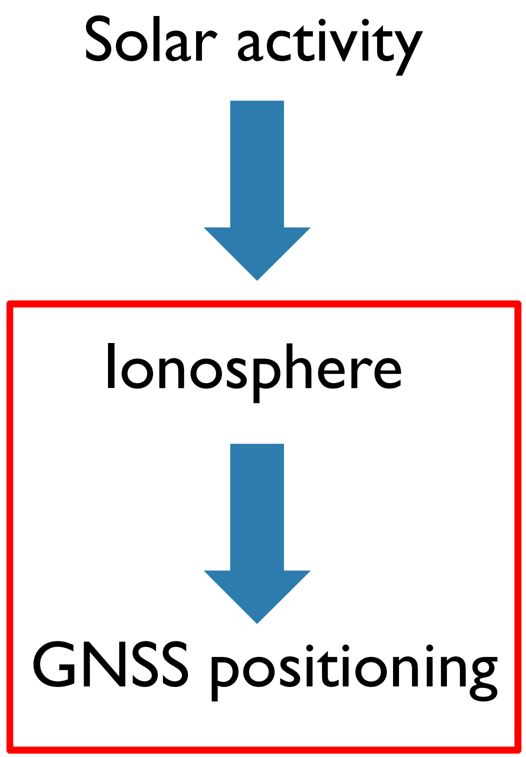
IMPACT ON GNSS

Effect:

- Ionized gas molecules and free electrons delay (or advance) the GNSS signal
- Dispersive (frequency-dependent) error source
- Impact size: Up to tens of meters

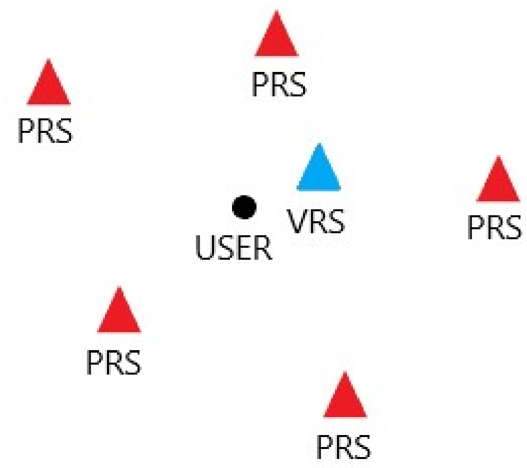
Handling:

- Ionospheric model (deterministic or determined from measurement)
- Linear combination of GNSS observables
- GNSS observations from nearby reference station



EFFECT ON NETWORK-RTK

- Network RTK relies on interpolation of atmospheric errors from known values at physical reference stations
- Expected interpolation error is connected with the spatial variability of the atmosphere (in this case the ionospheric part)
- Spatial variability will therefore provide meaningful information about expected positioning performance of Network-RTK



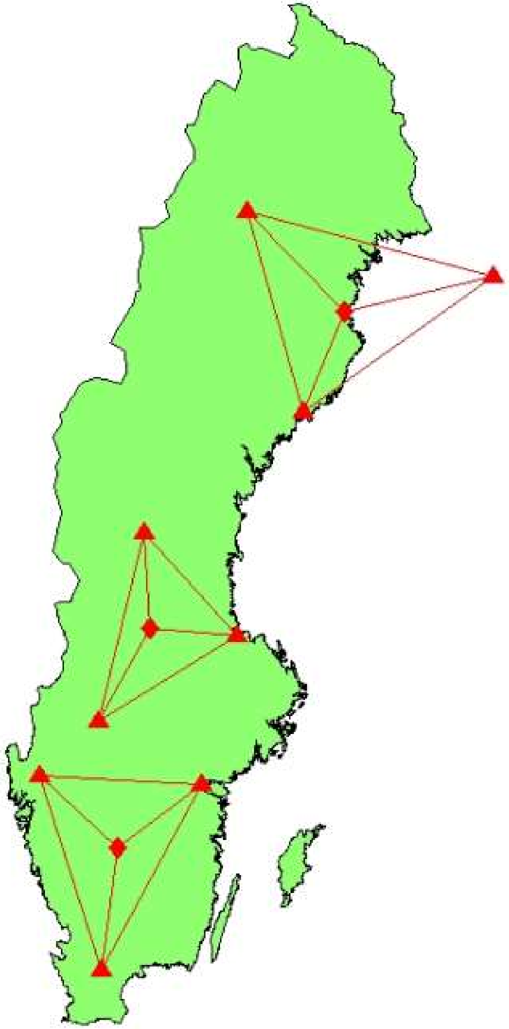
THE CLOSE II STUDY

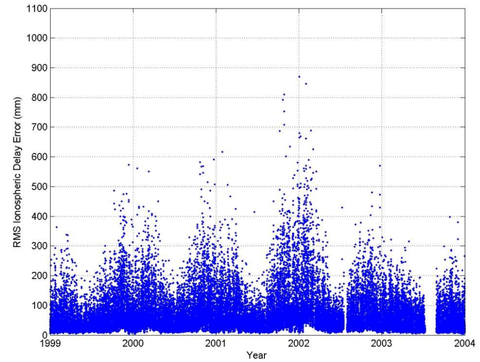
- This study was conducted in a collaboration between Lantmäteriet, RISE, and Chalmers University of Technology before the solar maximum of 2012-2013 (cycle 24)
- In this study spatial variability and how it affects precise GNSS positioning was investigated

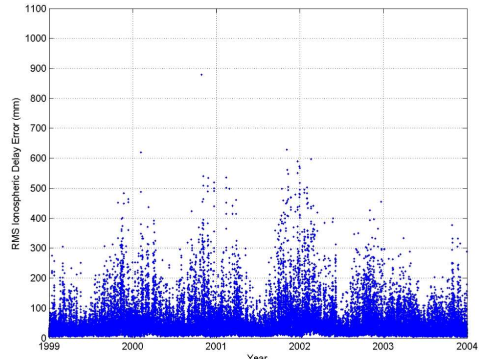
CLOSE II

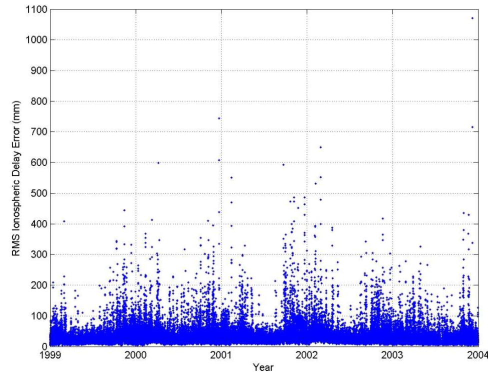
Variability was examined by determining interpolation errors for three "triangles" of reference stations

	RMS	50%	90%	95%	99%	99.9%
Variability Total	17.1	7.5	24.9	35.6	63.5	112.8
Variability north	19.3	9.5	30.2	40.3	65.3	105.8
Variability mid	19.1	8.1	27.6	39.6	72.6	130.2
Variability south	12.2	6.0	16.1	22.6	45.5	88.8

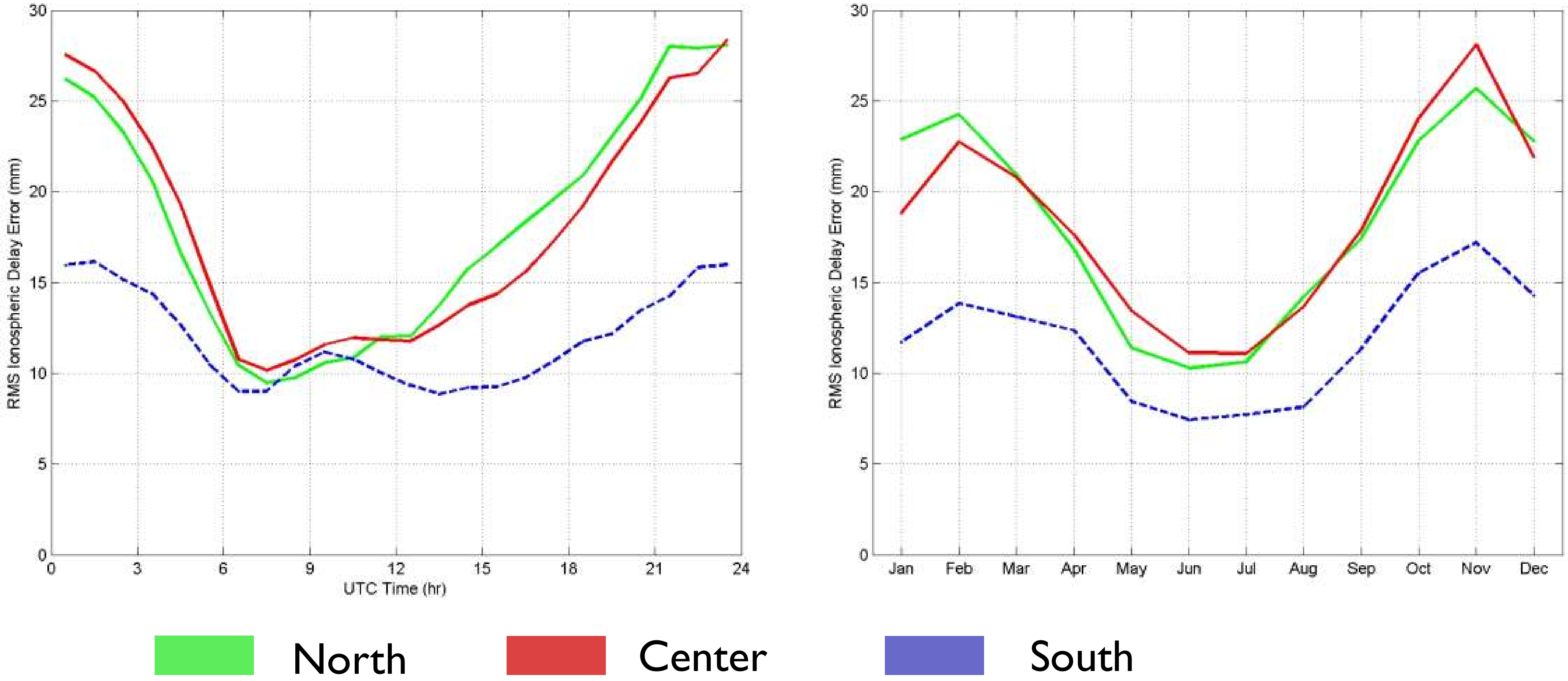




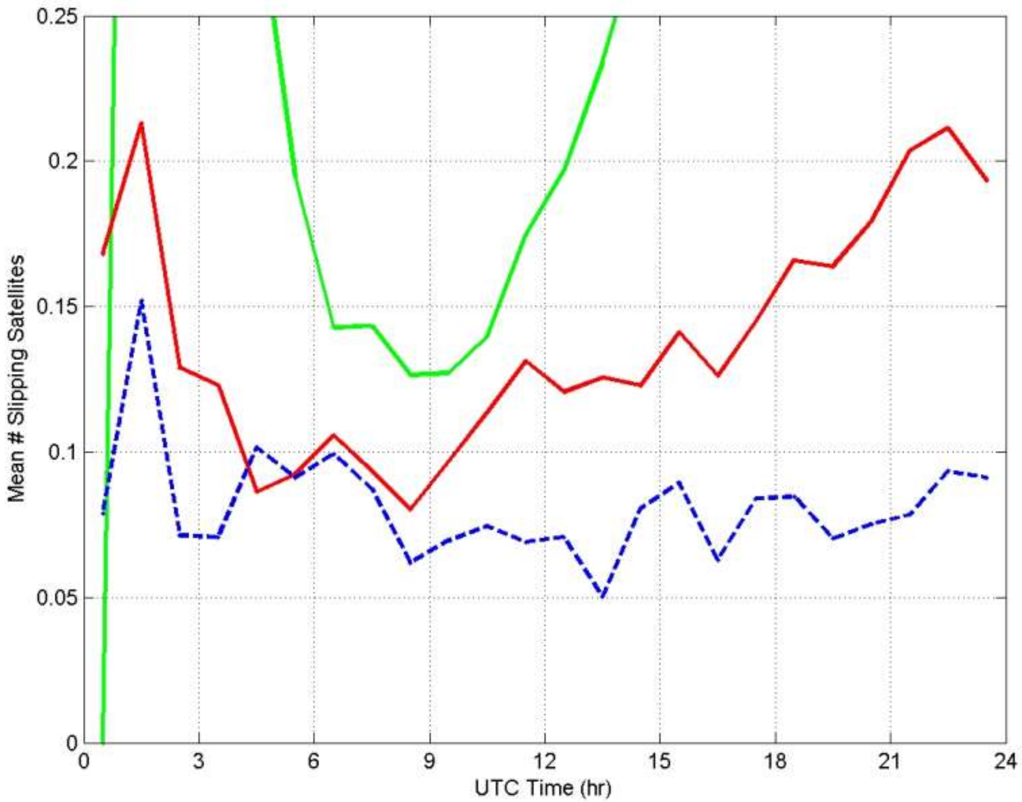


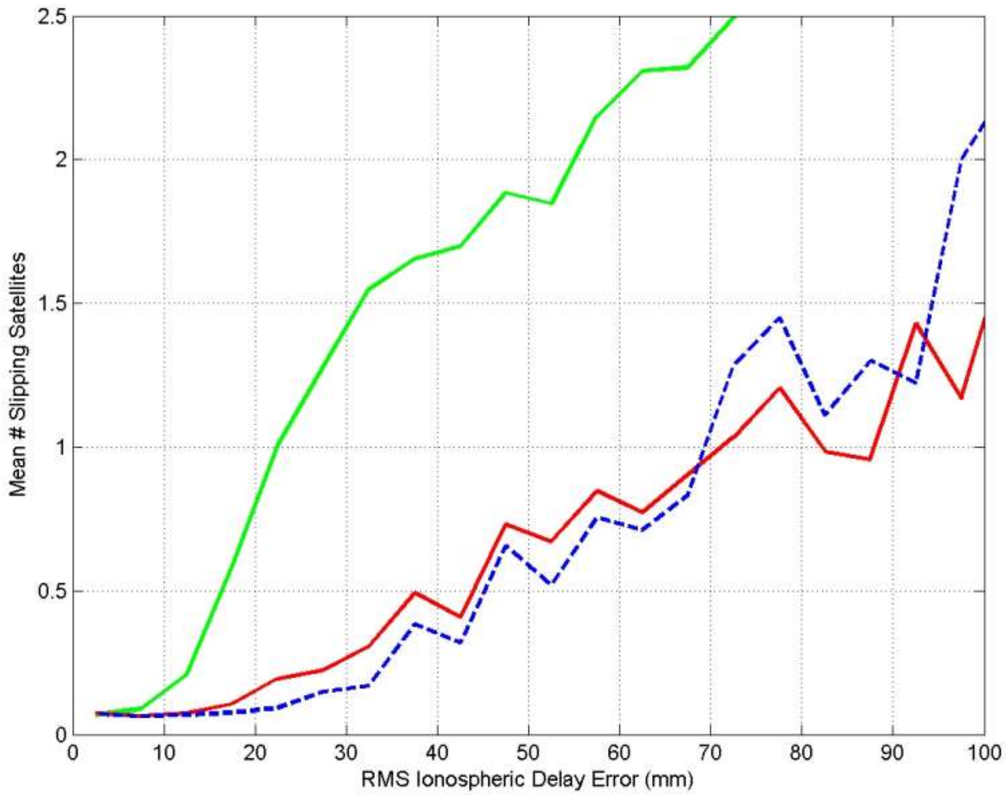


CLOSE II - DIURNAL AND SEASONAL DEPENDENCY OF THE INTERPOLATION ERROR



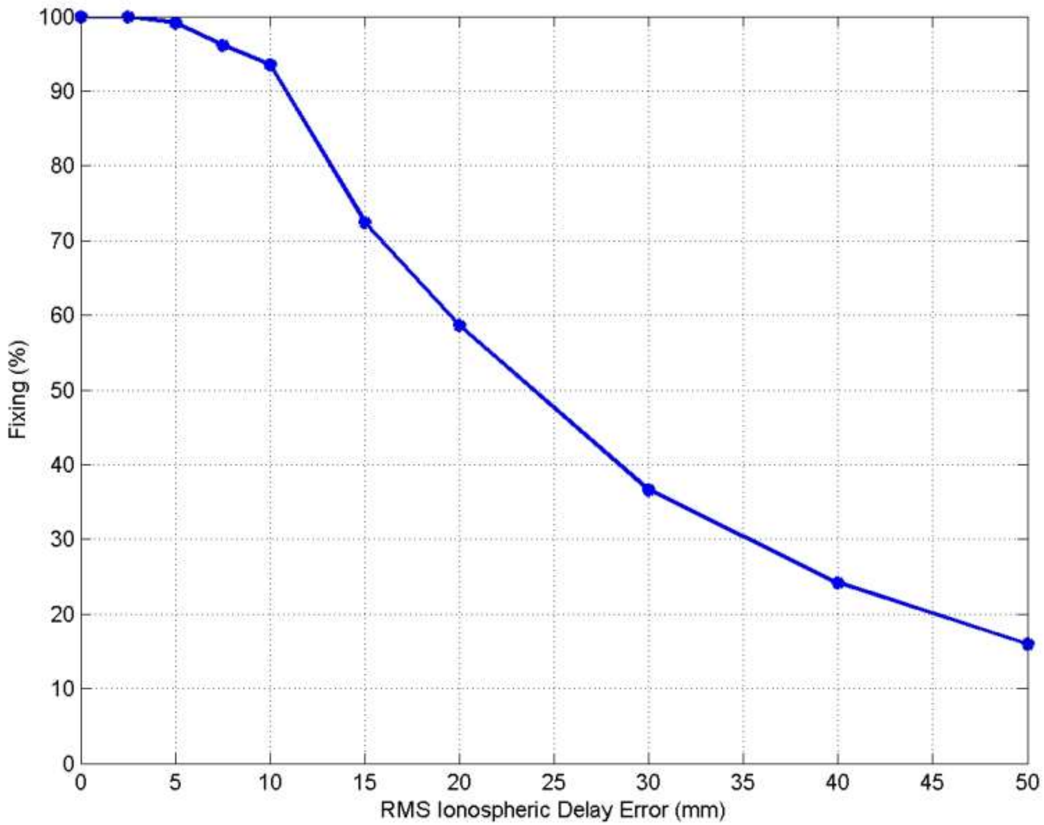
IMPACT OF VARIABILITY ON GNSS MEASUREMENT

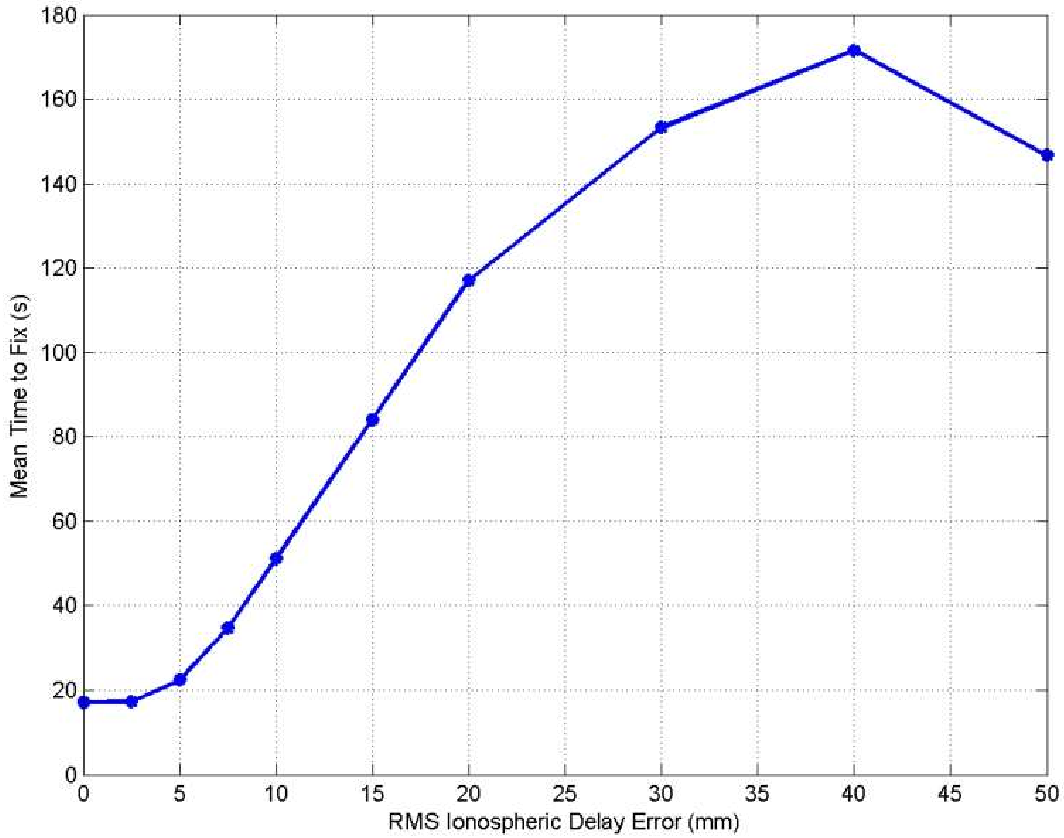




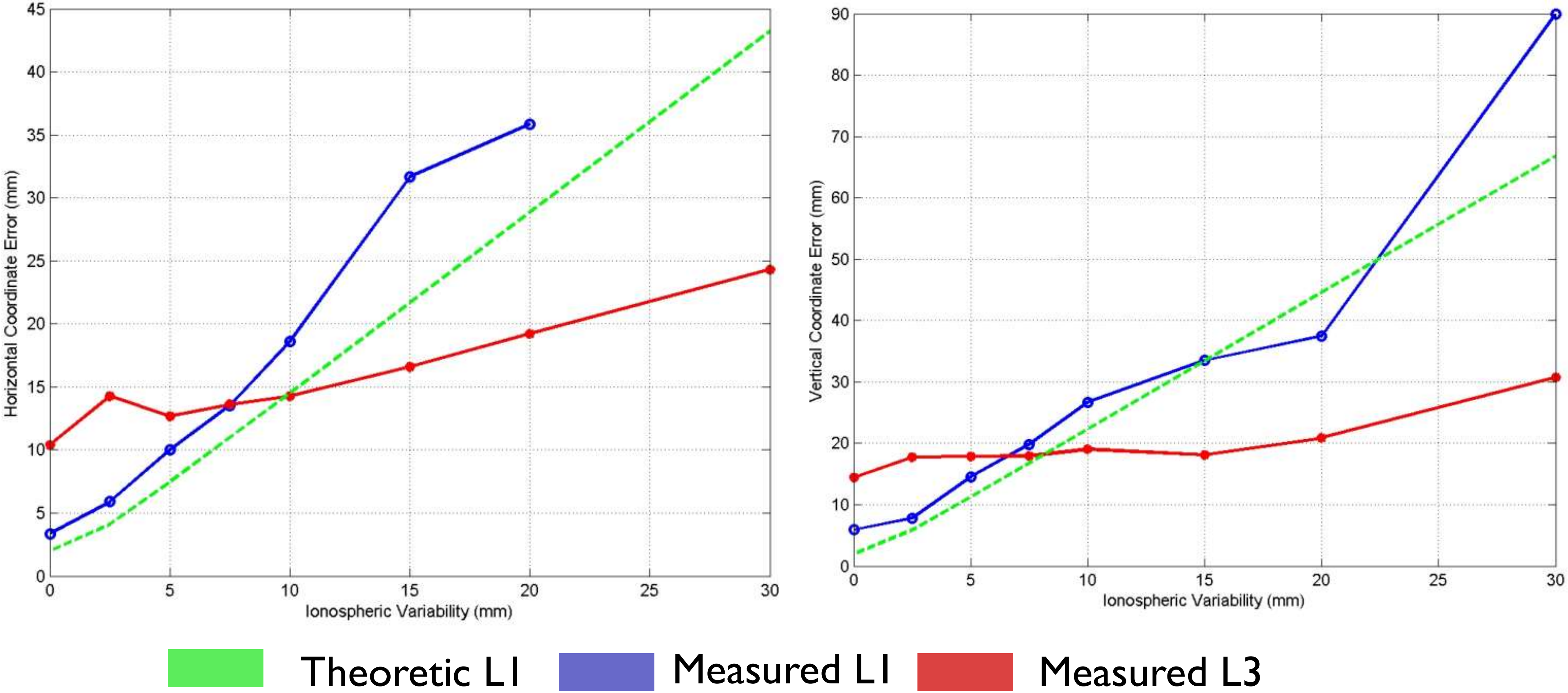
North Center South

SOLVING PHASE AMBIGUITY UNDER VARIOUS IONOSPHERIC CONDITIONS



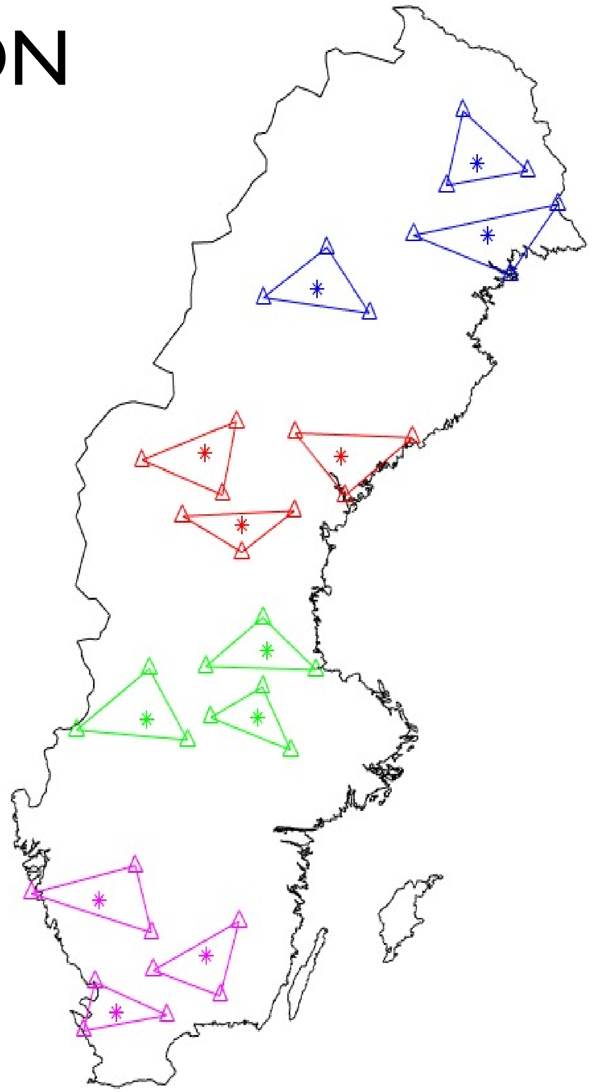


L1 VS. L3 FOR MANAGING IONOSPHERIC VARIABILITY



IONOSPHERE MONITOR - CALCULATION

- Redundancy with 3 triangles per region
- The last hour of 30-second observations from each station is used for calculation
- From these, the L4 combination is calculated to eliminate the geometry-dependent terms
- The standard deviations of the differences between 'actual' and interpolated L4 are used to determine variability



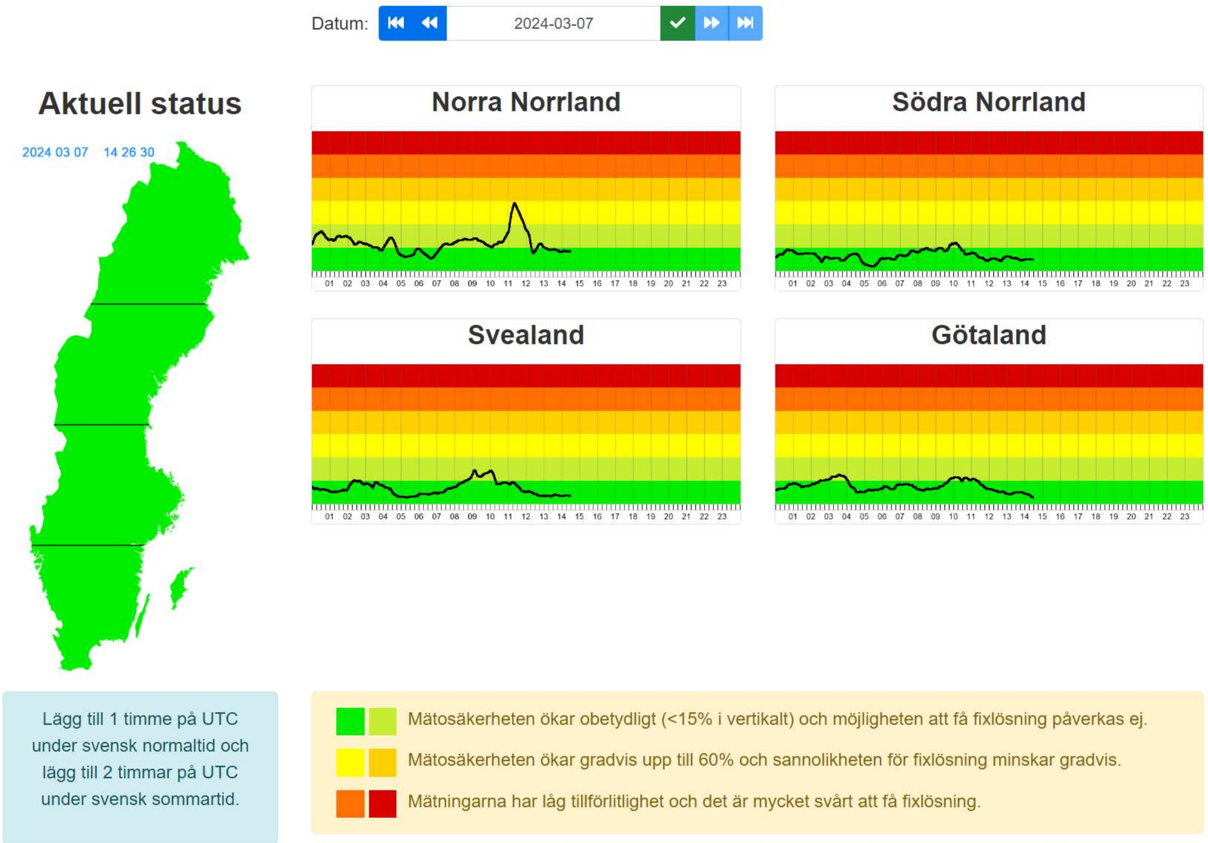
IONOSPHERE MONITOR - TIME SERIES 2013-2024

Credit: Topi Rikkinen

IMPROVED IONOSPHERE MONITOR

- Variability calculated with the same method
- Handle all 4 global constellations
- Better 'resolution' for the map
- Variability per satellite
- Built on top of an API
- First stage finished later this year

Current monitor



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