Kartverket

Characterization of ionospheric disturbances and their relation to GNSS positioning errors at high latitudes

Knut Stanley Jacobsen and Michael Dähnn (Norwegian Mapping Authority)

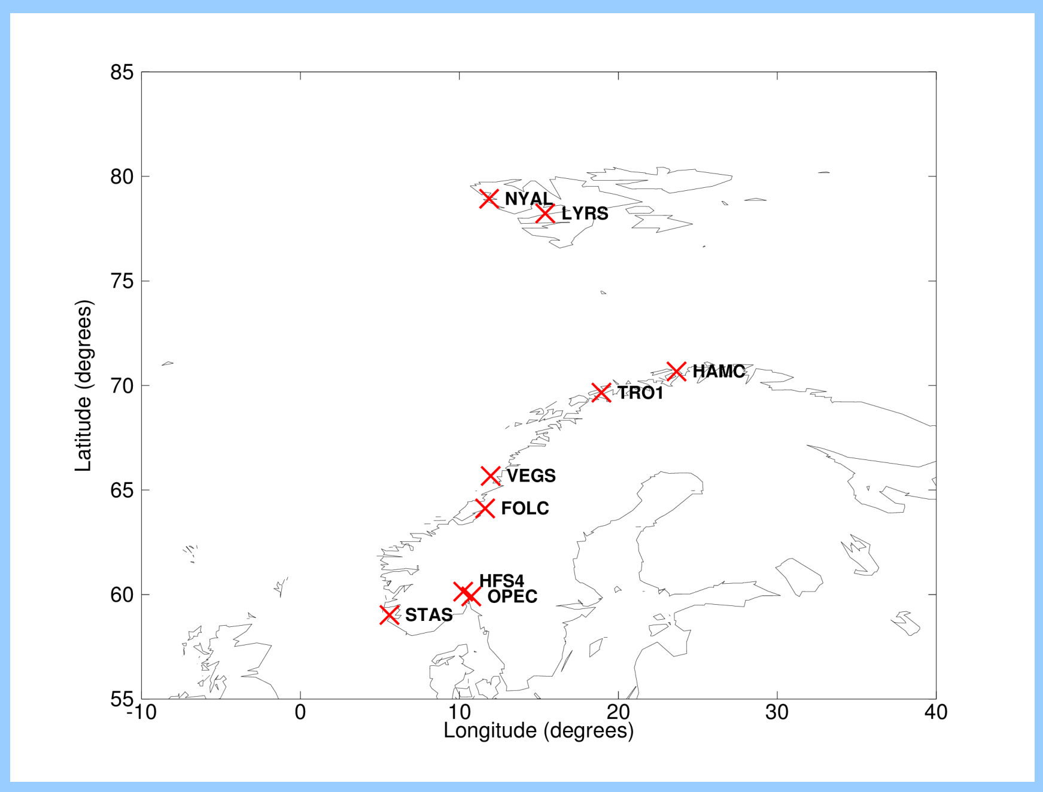
This poster shows some results from the paper which is available here: **http://dx.doi.org/10.1051/swsc/2014024** (Open Access)

Location and strength of ionospheric disturbances

During strong ionospheric activity, the ionosphere is the dominant error source for GNSS signals.
The occurrence of scintillation at high latitudes is related to the auroral oval, cusp, and polar-cap patches, through the formation of small-scale plasma structures due to particle precipitation or plasma instabilities.

In this study, ionospheric disturbances are measured by the ROTI. It characterizes small-scale and/or rapid variations of TEC, and is strongly related to scintillation. Its main advantage over scintillation indices is that it is calculated based on measurements from standard dual-frequency GNSS receivers sampling at 1 Hz, which have been and still are far more common than scintillation receivers.

ROTI values have been computed every 5 minutes for the year 2012, for all GPS satellites observed by 10 receivers at latitudes from 59 to 79 degrees North.



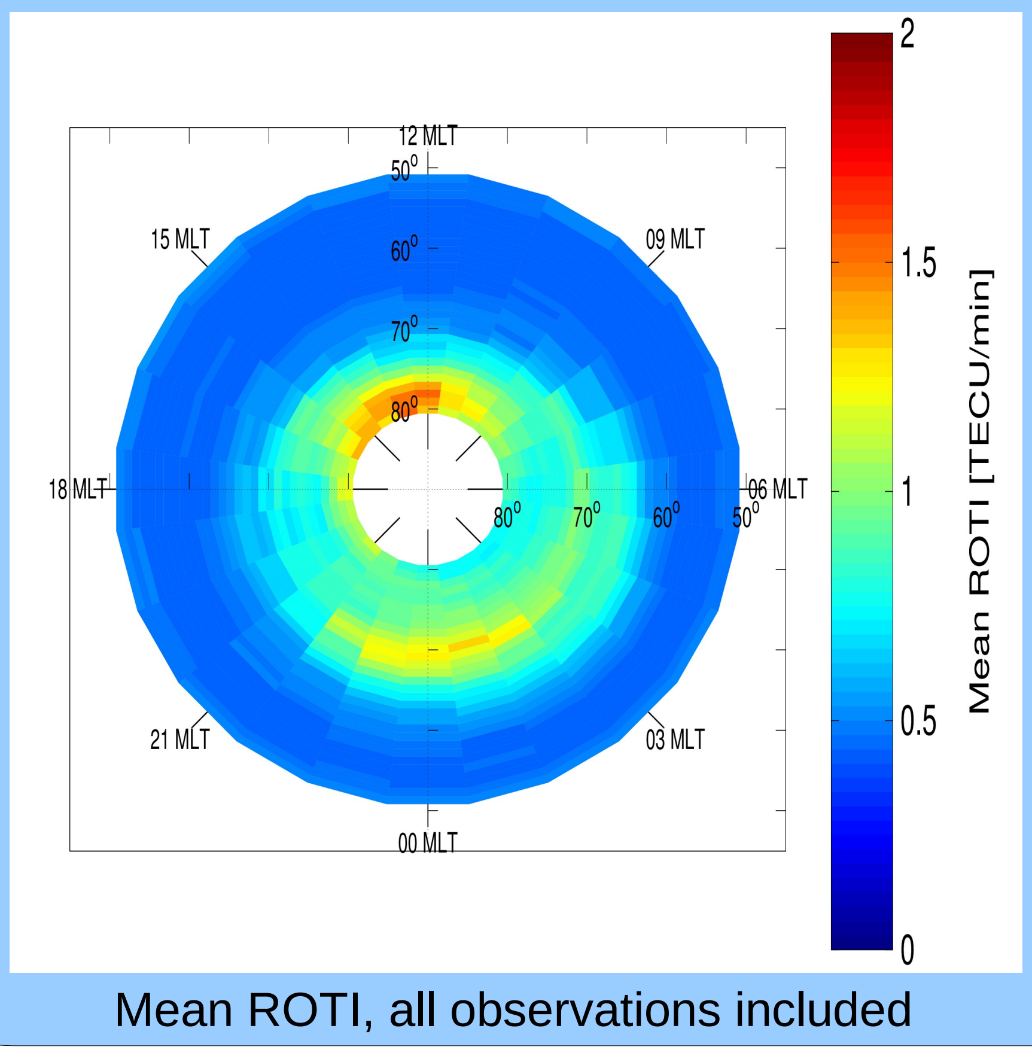
Locations of the receivers used for the study

Enhanced ROTI occurrence plotted in geomagnetic coordinates:

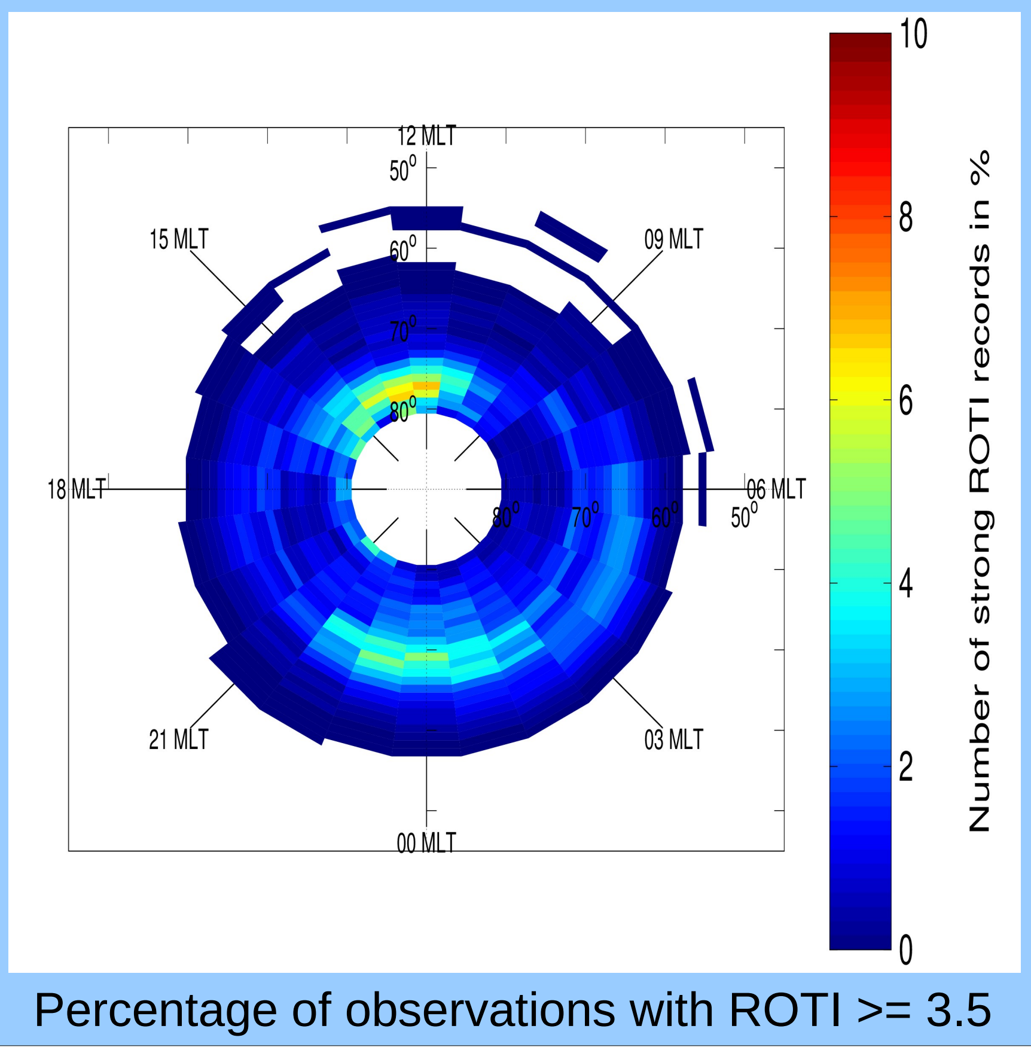
Enhanced ROTI values occurs mainly in the cusp and nightside auroral oval regions.

Large ROTI values are more common in the cusp, but very large ROTI values are more common in the nightside auroral oval.

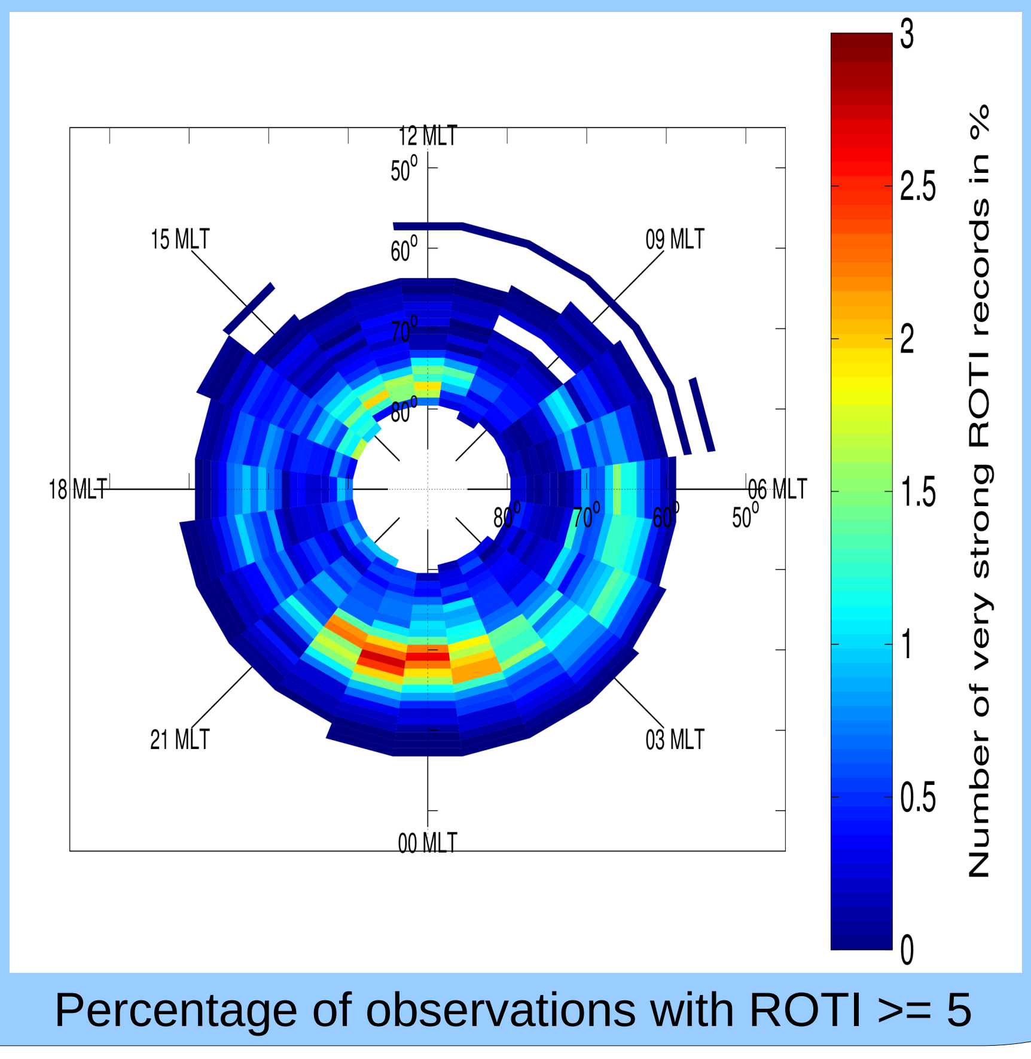
(NB: An elevation cutoff of 30 degrees was applied to the data used for these plots, to exclude low elevation effects.)



Mean ROTI, all observations included



Percentage of observations with ROTI >= 3.5



Percentage of observations with ROTI >= 5

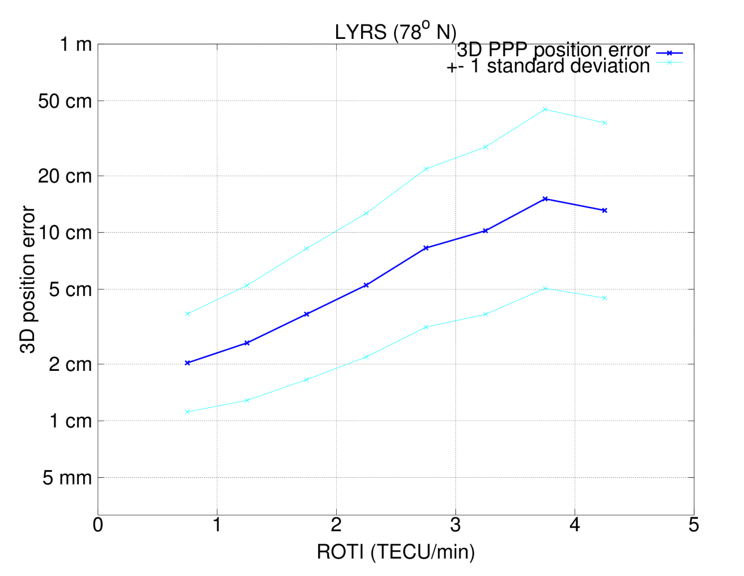
ROTI vs. PPP 3D error

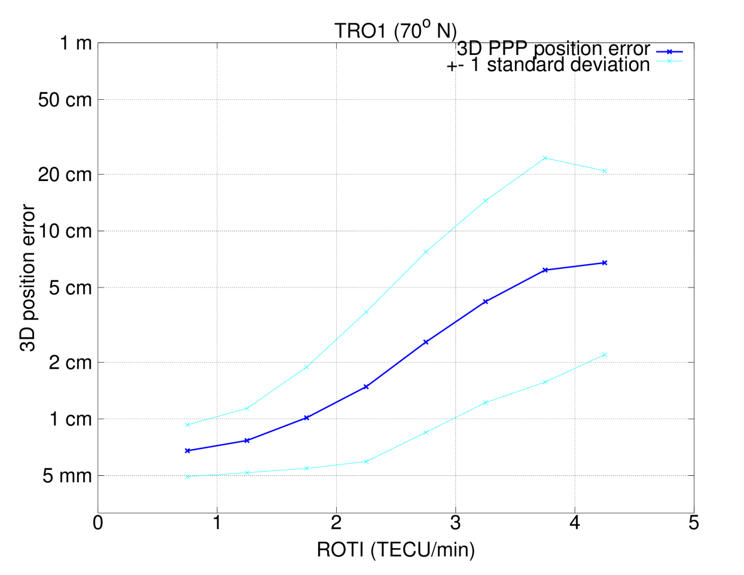
To investigate the relation to positioning errors, receiver coordinates were computed using the GIPSY software, for the same receivers and time resolution.

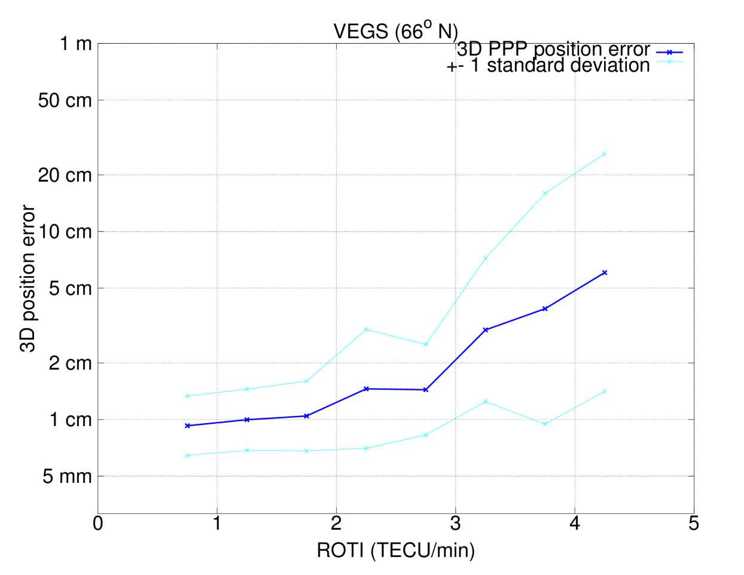
The long-term trend was removed from the PPP solutions by subtracting a linear fit to the coordinate time series for the entire year, for each receiver. The 3D position error was then defined as the offset of the detrended coordinate from its median value.
For each receiver and each hour we calculated the mean of all ROTI values observed by that receiver.
We binned the 3D position errors by the hourly ROTI value in intervals of 0.5 TECU/min and computed the mean and standard deviation of the 3D position errors within each bin. Results for 4 receivers are shown on the right. (The rest are in the paper.)

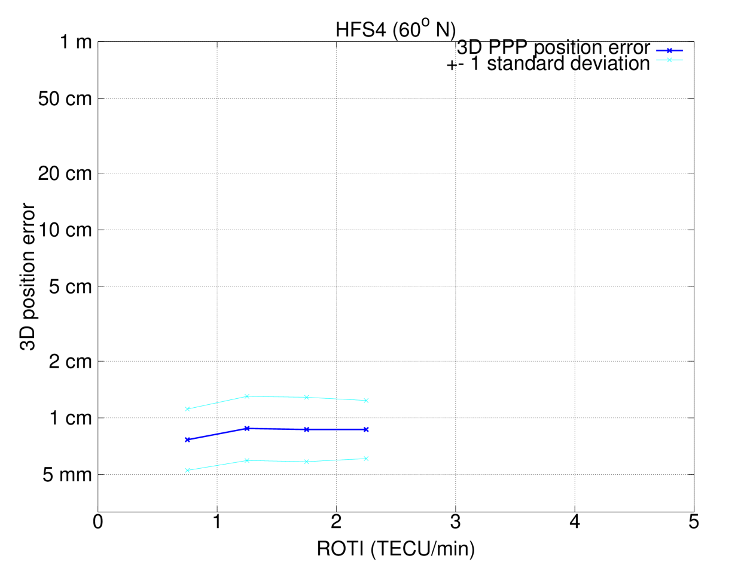
We found that there is a strong positive correlation between Precise Point Positioning (PPP) error and ROTI for receivers that are affected by space weather.

The 3D position error increases exponentially with increasing ROTI.

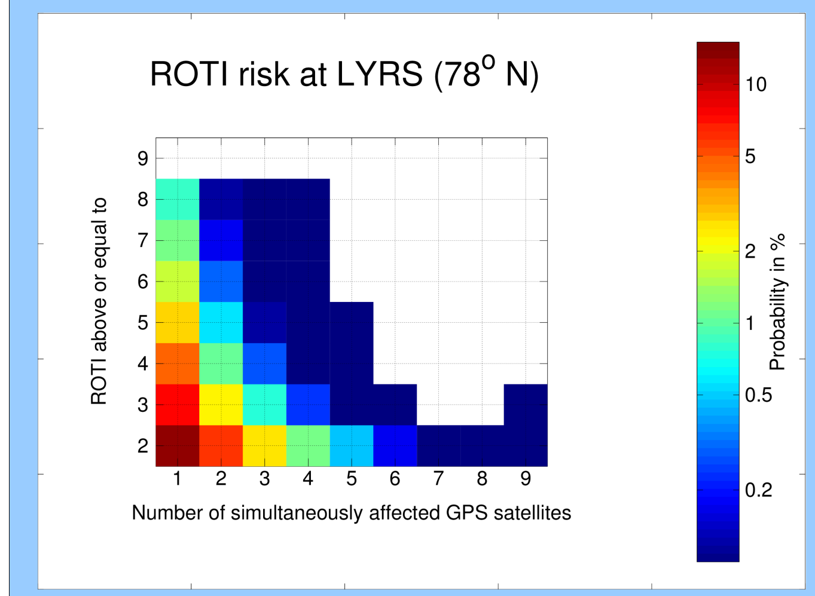


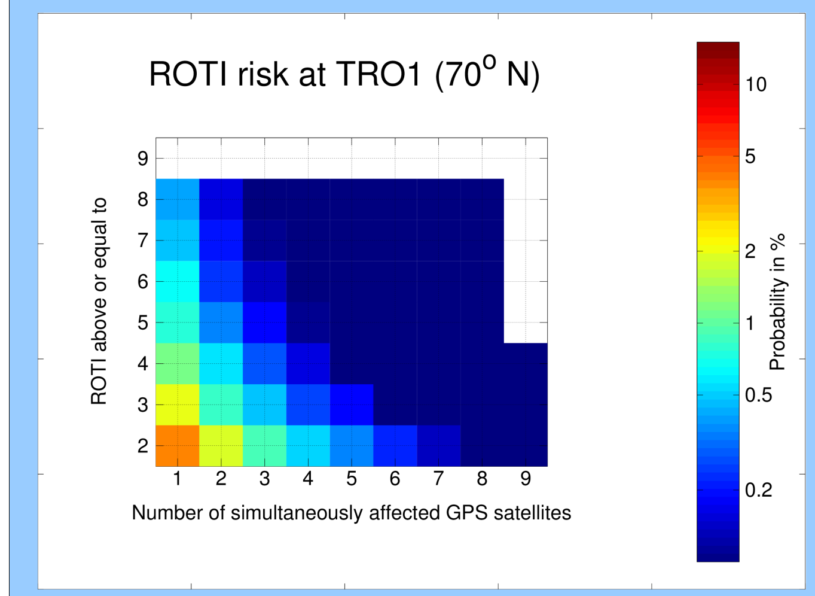


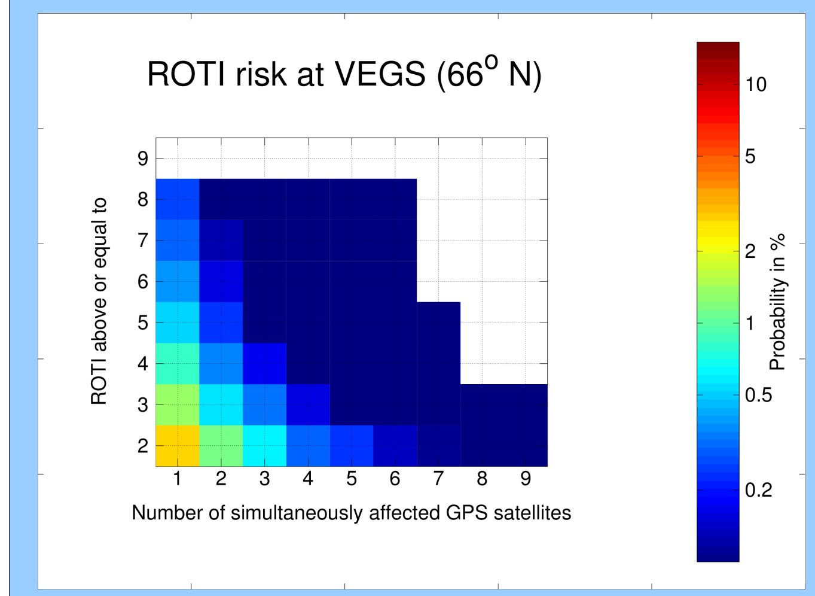


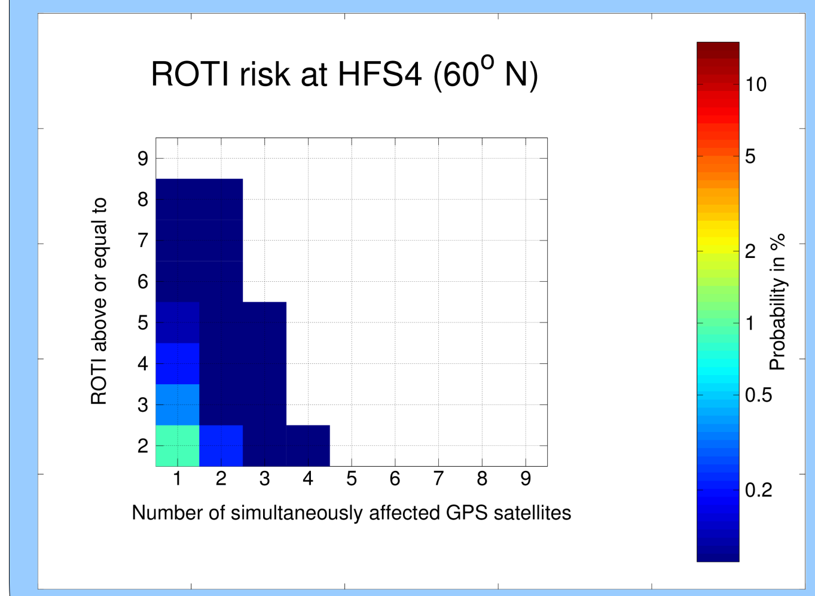


Disturbance Risk









For most uses of GNSS, it is relevant to assess the risk of having several satellites disturbed simultaneously.

The tables on the left show the probability to have certain levels of ROTI simultaneously affecting several satellites observed by the same receiver. For each entry (colored square) in the figures, the probability was calculated simply as the percentage of ROTI measurement epochs (5 min resolution) in which the ROTI values simultaneously exceeded the defined level for the given number of satellites.
As an example of how to read the tables, in the top figure the probability of simultaneously having two satellites at a ROTI value of at least 3 TECU/min is around 2%.

Generally, both the magnitude of ROTI, and the number of satellites affected, were higher for receivers at higher latitudes. For the northernmost receivers, which are located at Svalbard, the maximum number of simultaneously affected satellites at high ROTI levels was somewhat less than that for receivers in the middle of Norway. This is caused by less satellites being visible at such a high latitude.

Whether these risks are significant or not, depends on the kind of system that uses the data, and what thresholds are set for that system.