Statistics of ionospheric disturbances and their correlation with GNSS positioning errors at high latitudes

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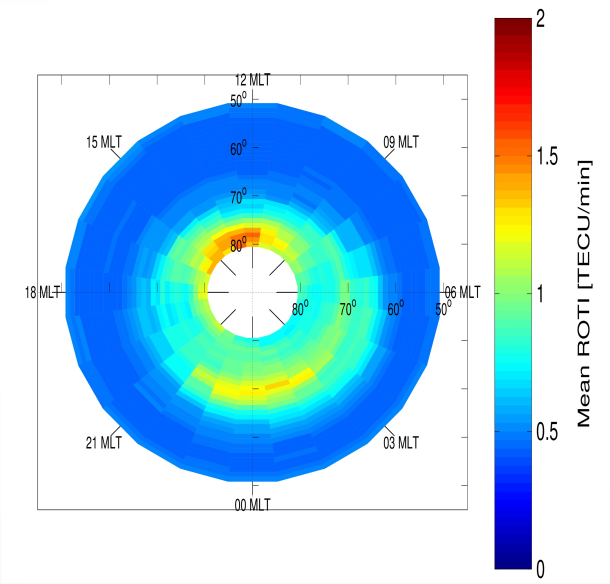
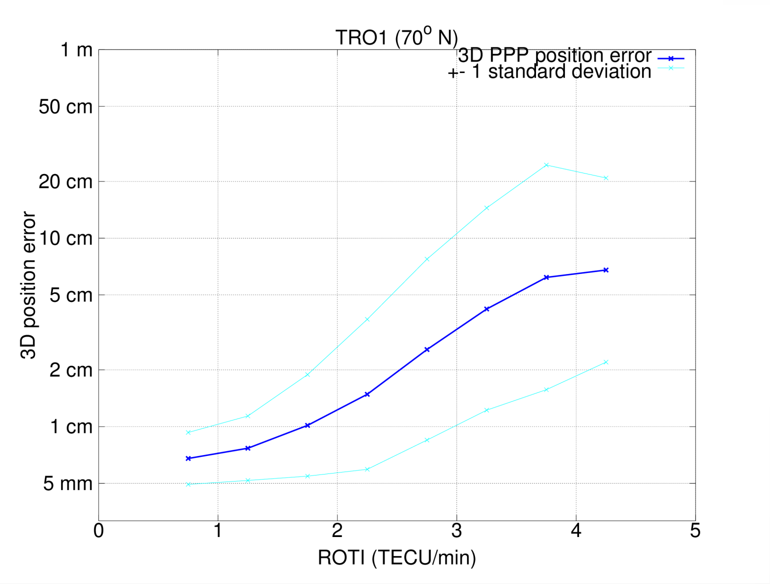
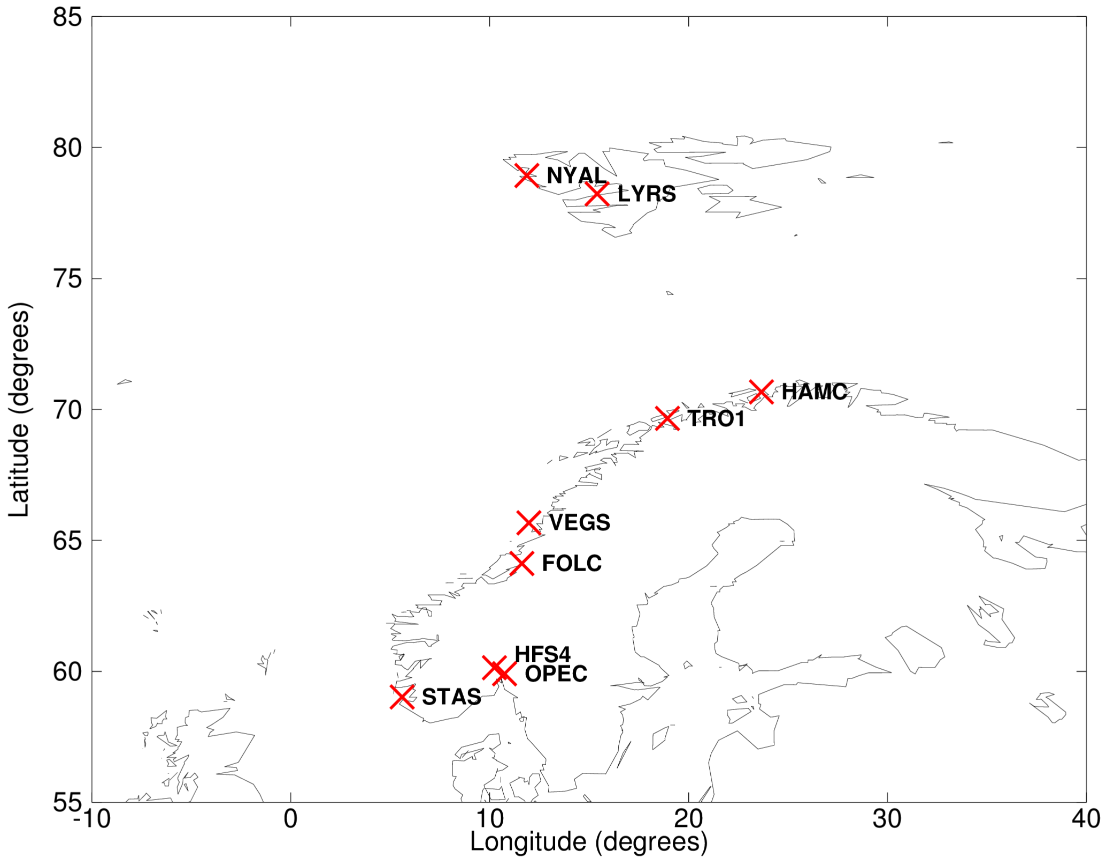




Data source



- 9 GNSS receivers, 1 Hz sample rate
- Time period: 2012 (the entire year)

Calculations

Every 5 minutes, for each satellite observed by each receiver, we calculated:

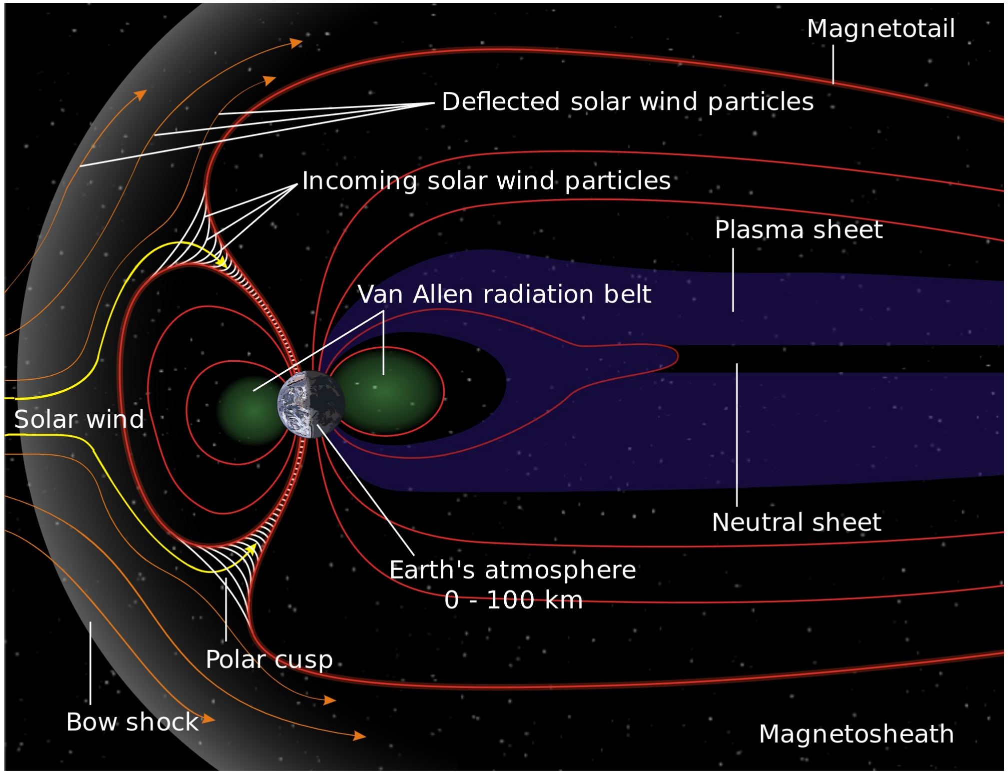
- ROTI (A measure of ionospheric disturbance level)
  - Standard deviation of Rate-of-TEC
- 3D position
  - Calculated using GIPSY

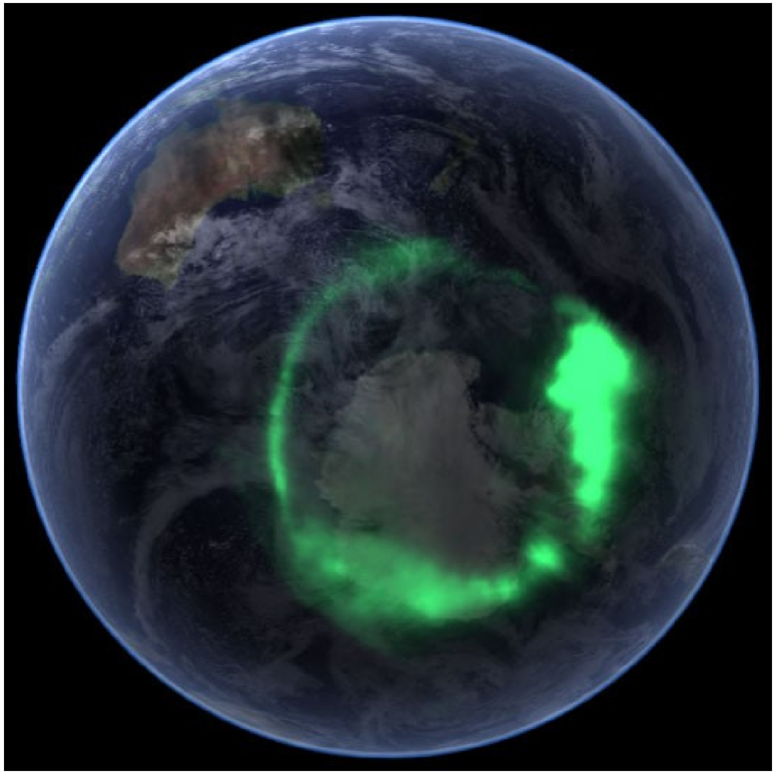
The 3D position error was calculated by taking the difference between the instantaneous values of the coordinate time series and its median value, after removing the linear trend from the coordinate time series by subtracting it's linear fit for the year.

Geomagnetic coordinates were calculated for all measurement points, using AACGM.

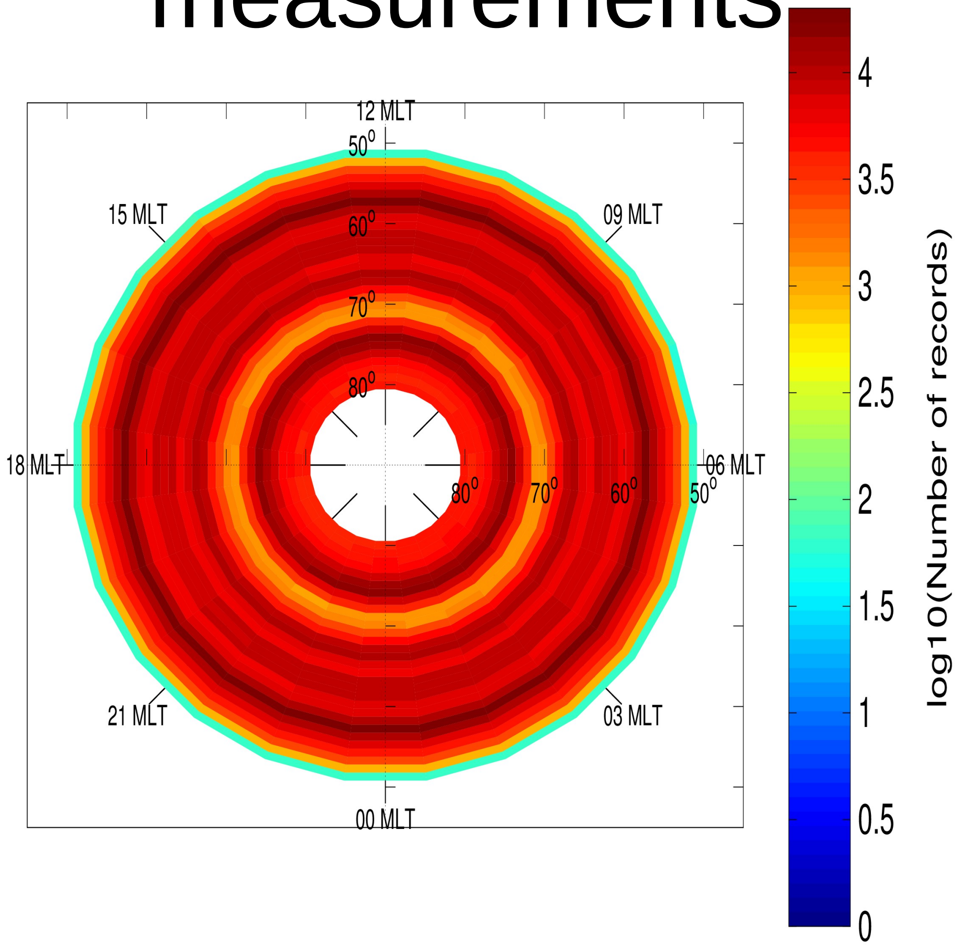
Relevant space weather regions at high latitudes

- The Auroral Oval
- The Polar Cusp





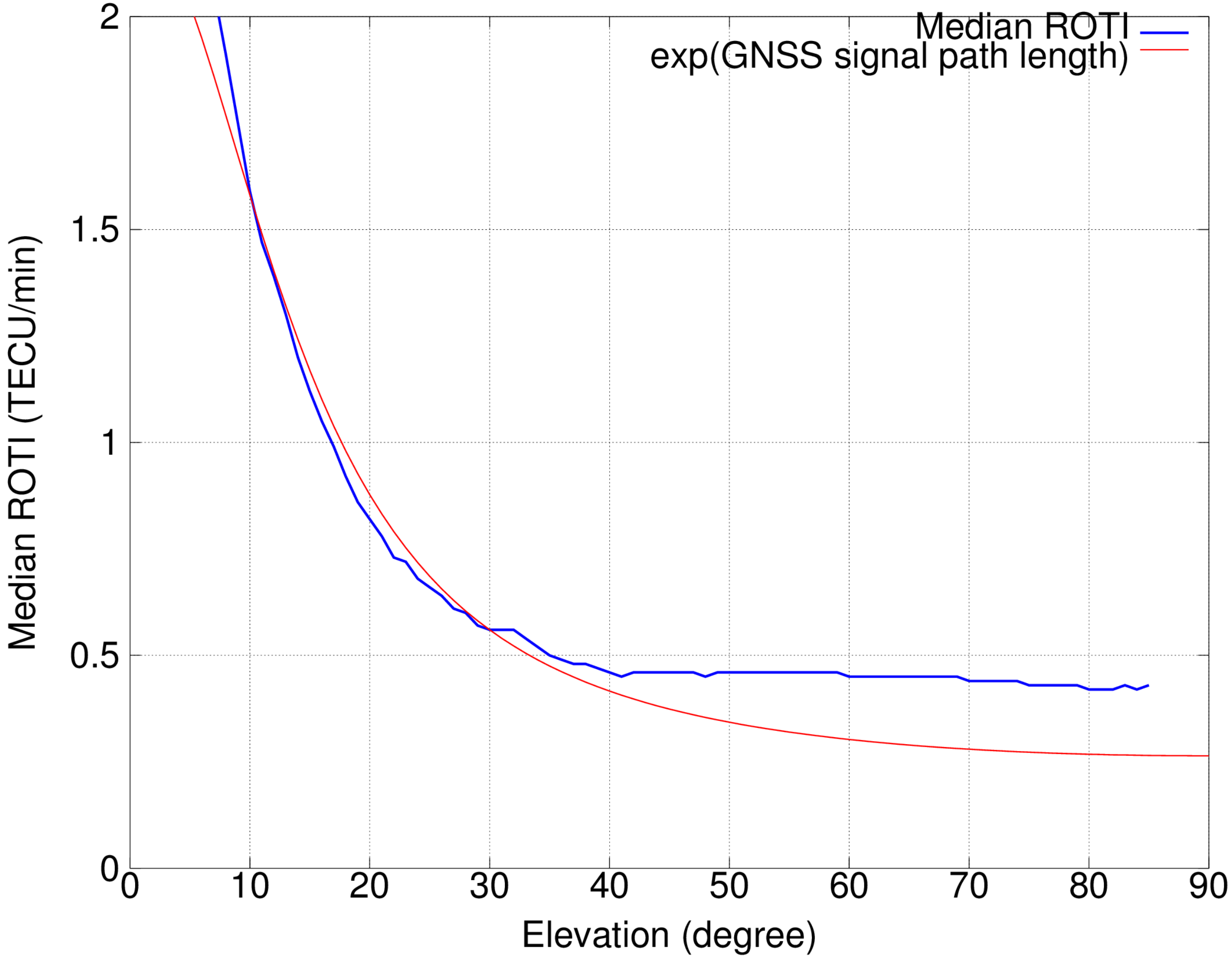
Amount and distribution of measurements



- 10.3 million satellite measurement points
- 0.94 million receiver coordinates

Result 1 – ROTI vs Elevation

- At elevations below 30 degrees, the value of ROTI depends strongly on elevation. The value of ROTI increases exponentially with the length of the signal path through the atmosphere.
- At elevations above 40, other effects dominate over the elevation dependence.



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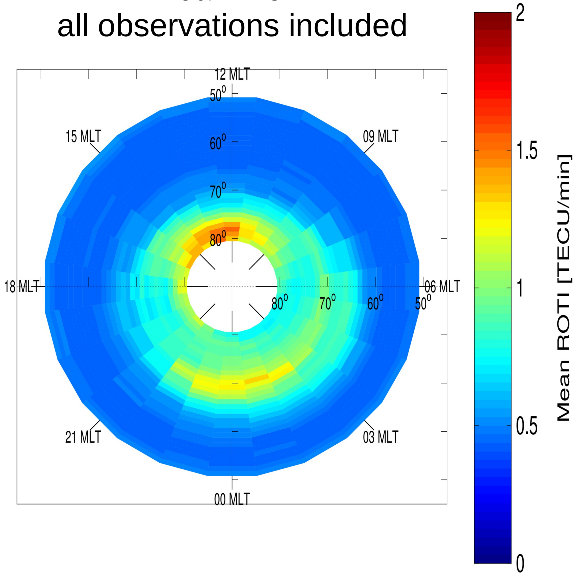
Result 2 – ROTI occurrence statistics

(In geomagnetic coordinates)

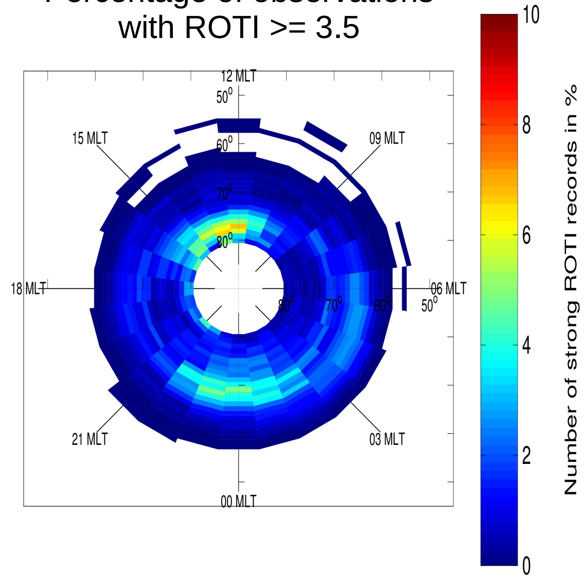
Elevated ROTI values occur mainly in the cusp region and in the nightside auroral oval.

Enhanced ROTI values most commonly occur in the cusp region, but when they occur in the nightside auroral oval, they are higher.

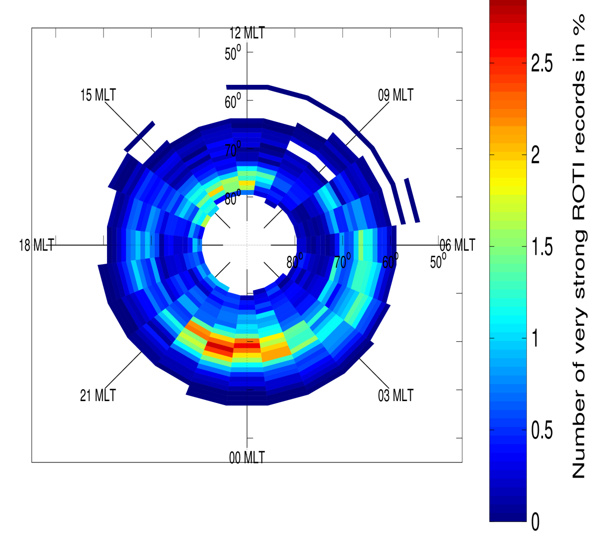
Mean ROTI
all observations included



Percentage of observations
with ROTI >= 3.5



Percentage of observations
with ROTI >= 5



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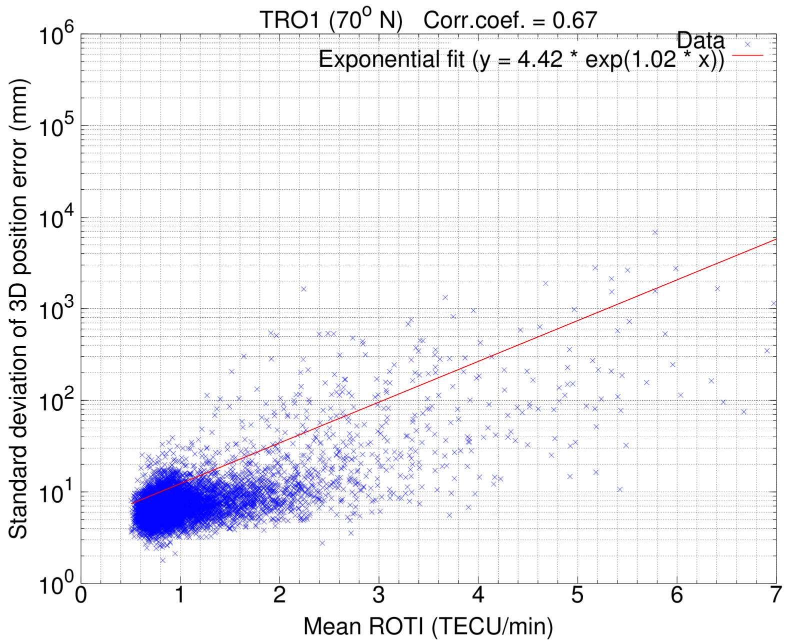
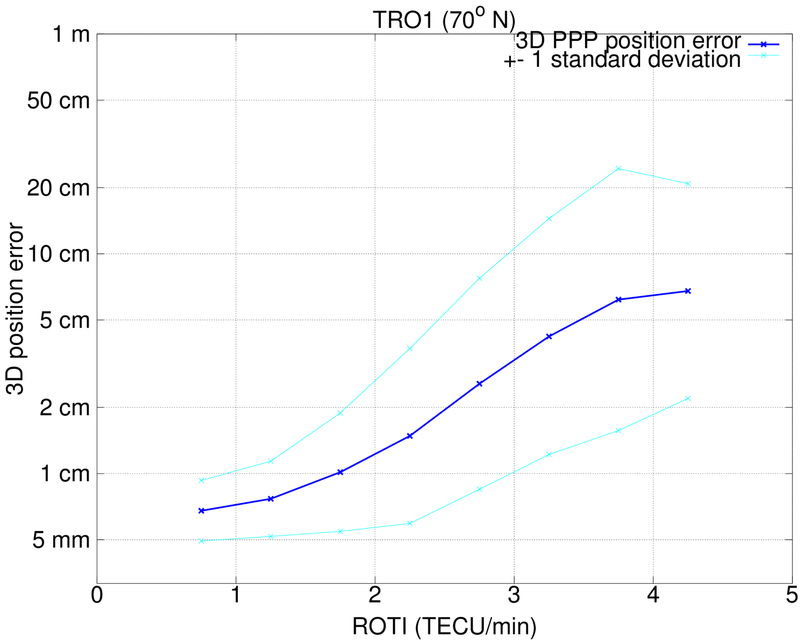
Calculations

Characterizing the connection between ROTI and position error





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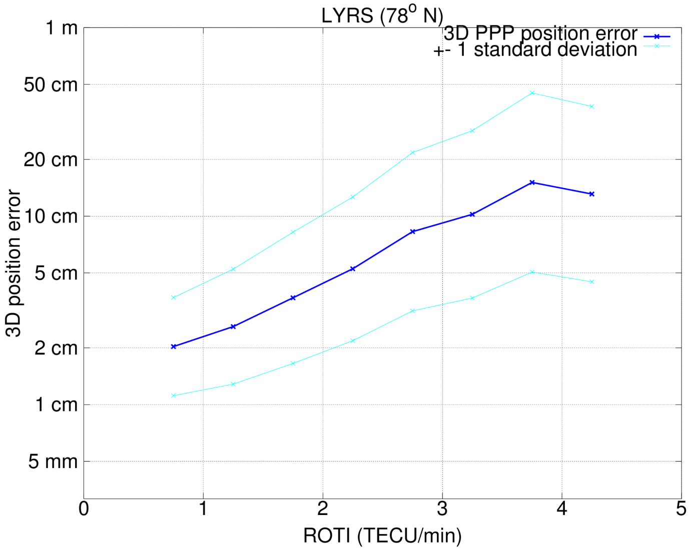
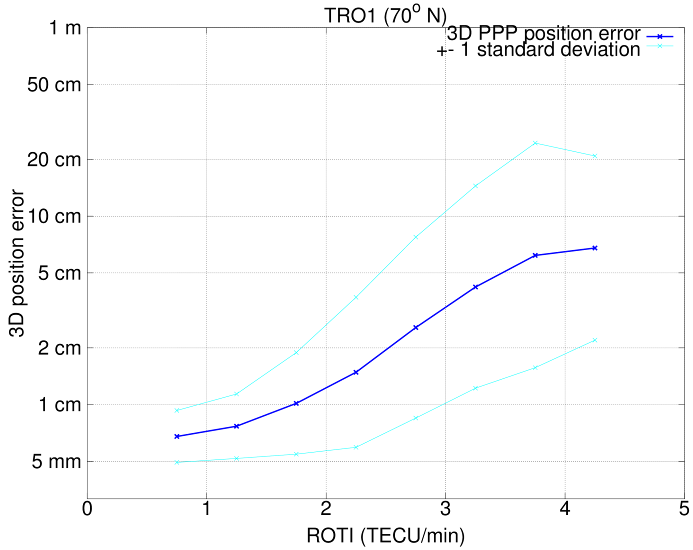
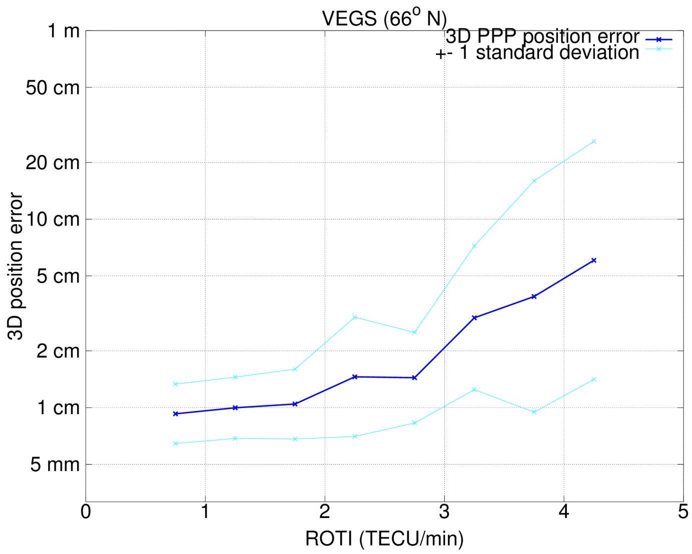
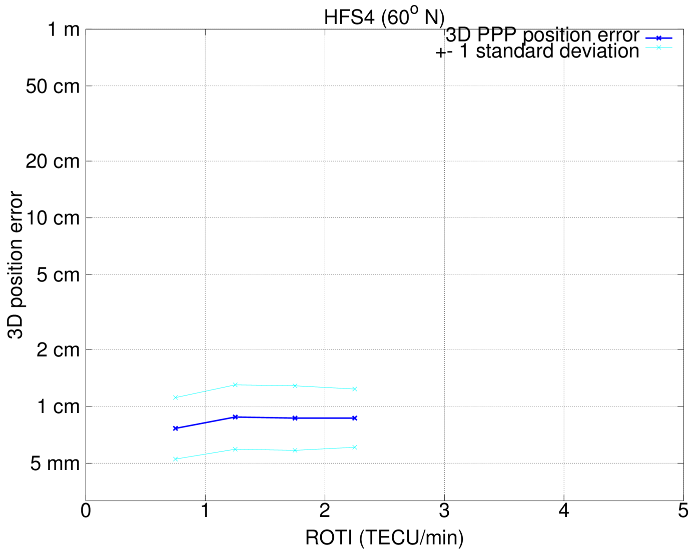
Result 3 – The connection between ROTI and position error









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Result 3 – The connection between ROTI and position error

ID	Latitude	Corr. coeff.	b
NYAL	78.93	0.46	1.67
NYA1	78.93	0.39	0.75
LYRS	78.23	0.47	0.99
HAMC	70.67	0.66	0.88
TRO1	69.66	0.67	1.02
VEGS	65.67	0.49	0.9
FOLC	64.12	0.41	0.83
HFS4	60.14	0.09	0.13
OPEC	59.91	0.14	0.24
STAS	59.02	0.16	0.31

$$PosErr_{3D,\ 1h} = a * e^{(b * ROTI_{Avg,\ 1h})}$$

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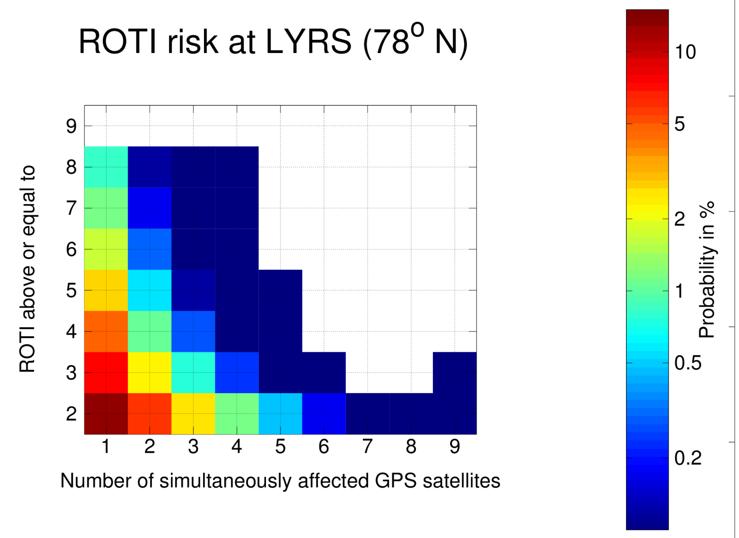
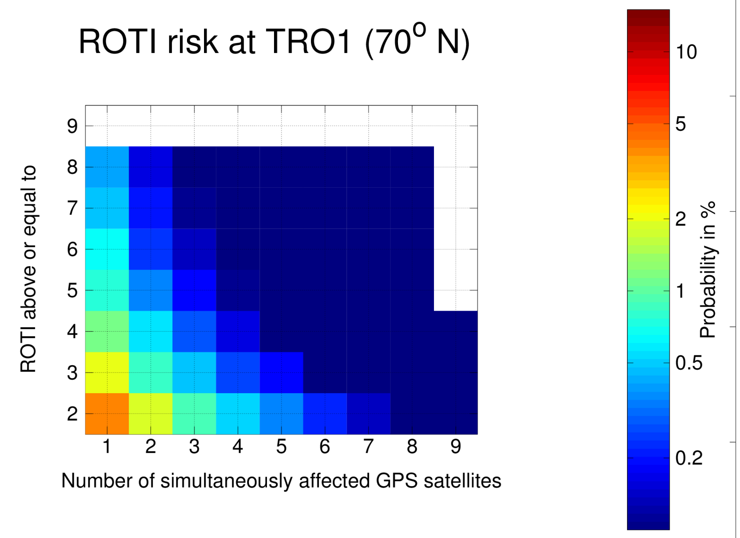
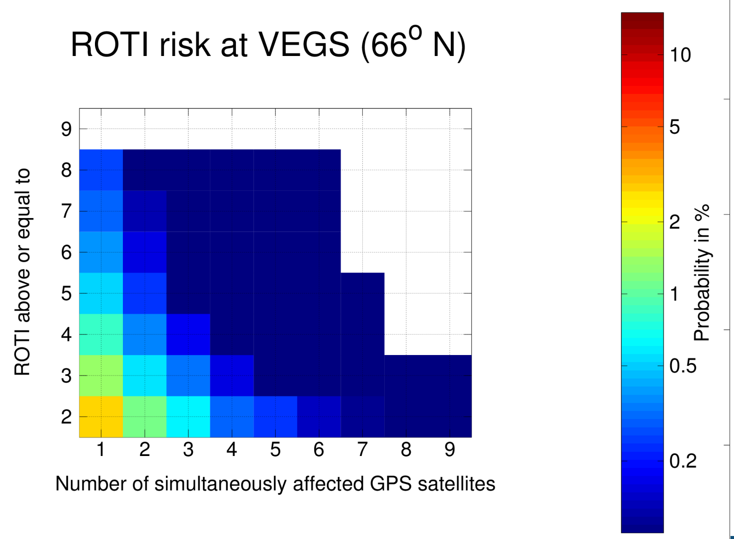
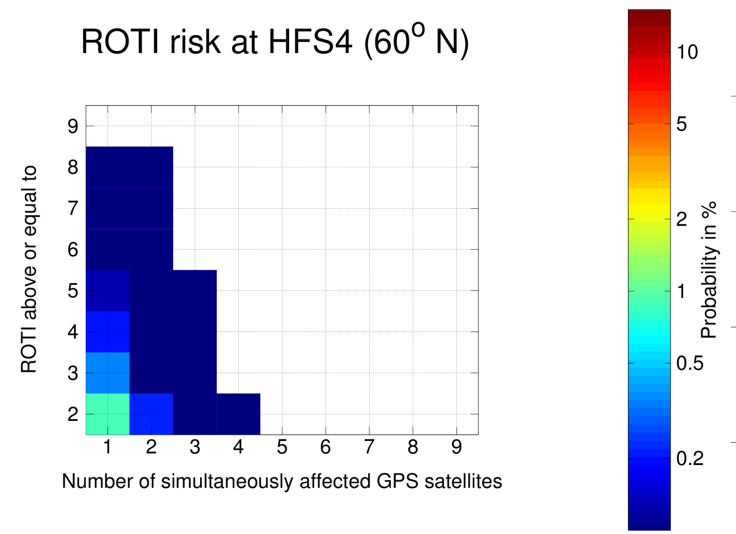
Result 4 – Risk of simultaneous disturbance









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Conclusions

- PPP position error is strongly correlated with ROTI.
- PPP position error increases exponentially with ROTI.
- At elevations below 30 degrees, the length of the signal path through the atmosphere is the dominating factor for the average ROTI value.
- Elevated ROTI values occur mainly in the cusp region and in the nightside auroral oval.
- Enhanced ROTI values most commonly occur in the cusp region, but when they occur in the nightside auroral oval, they are higher.
- The risk of having multiple satellites simultaneously disturbed is greater at higher latitudes.