Empirical modelling of the ROTI at high latitudes for L band ionospheric channel studies.

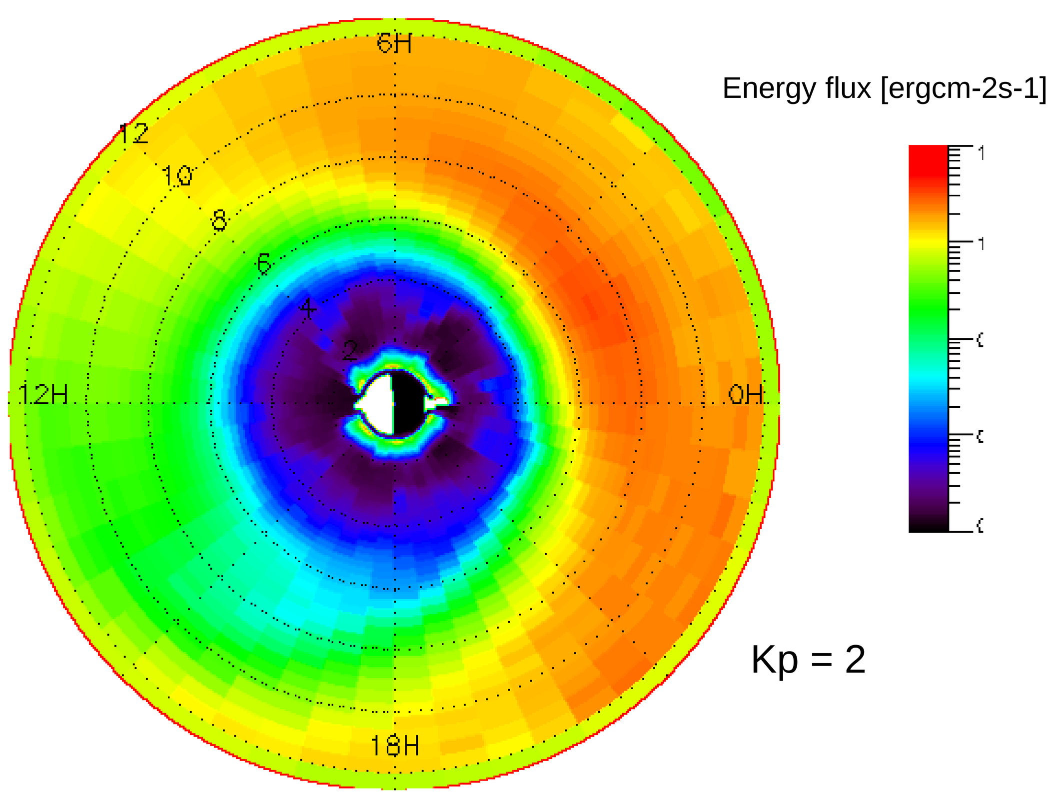
D. Boscher, V. Fabbro, J. Lemorton, R. Fleury, F. Carvalho

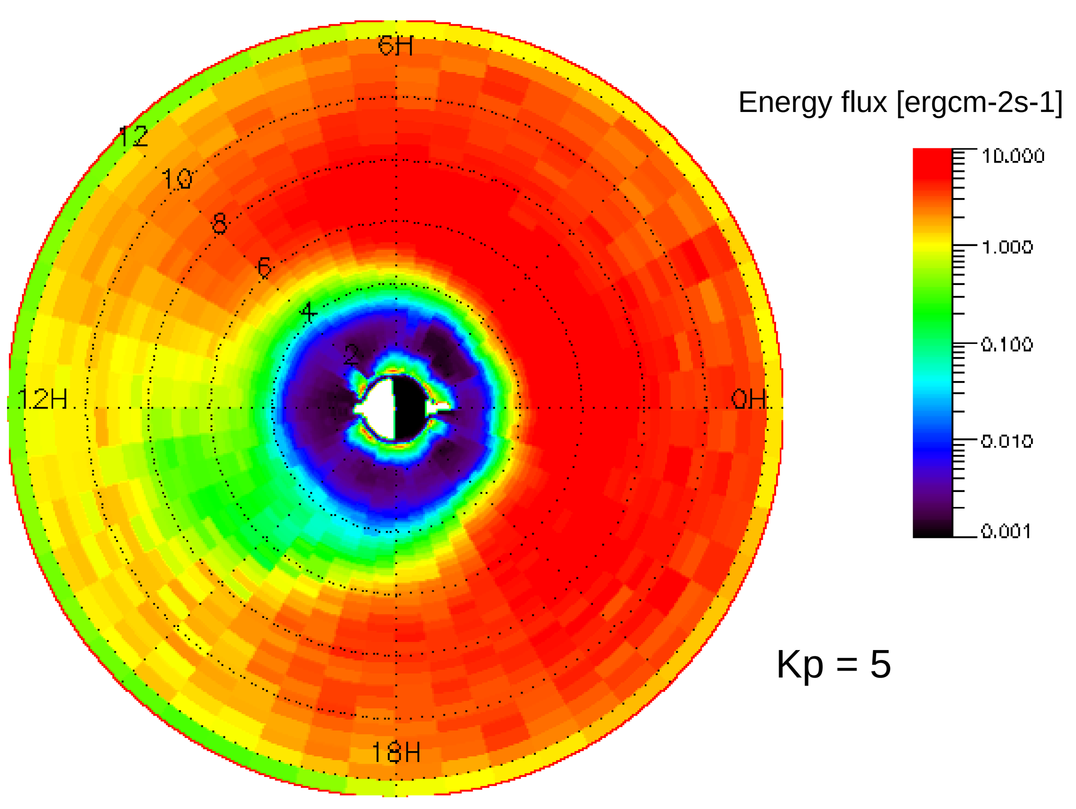
Abstract: GNSS position errors due to ionosphere are partially linked to scintillations. This study focuses on scintillation activity observed under high latitude regions.. Three ISM (Ionospheric Scintillation Monitor) have been running measurements at 50Hz since end of 2012 in Norway in the frame of a collaboration between CNES and NSC/NMA for the ionosphere scintillations modelling. As the period of ISM data collection is not long enough for a valuable modelling, we first attempt to model the ROTI, the index of TEC rate of change which is among the observables affected by ionosphere disturbances, using data collected over many years (since around 1994) from the NMA GNSS network stations. In this study we have integrated electron flux obtained on the NOAA POES satellites to get a good statistics of the electron flux. Taking advantage of the 5 current POES satellites (POES 15 to 19) scanning at the same time several local times, and the fact that the first spacecraft has spent more than one solar cycle in orbit, the obtained statistics is very good, as for example more than 60,000 points with 8s resolution were obtained at extreme magnetic activity (for magnetic index Kp>8+). Averages of the electron energy flux in a McIlwain parameter L versus magnetic local time maps were obtained and correlated to the ROTI measurements made at two latitude distant GNSS stations: Tromsoe and Trondheim. Therefore a model of ROTI was developed with as input parameters the station location and the time in day, the magnetic activity Kp, and the viewing direction (elevation and azimuth). This model can be used, associated with a Kp prediction, to forecast the ROTI, anywhere in the Scandinavian Norway. Intermediate analysis made to obtain it will be presented as well. Possible improvements will also be discussed

Use of the NOAA POES data (5 satellites POES 15,16, 17, 18, 19 from 1998): TED flux (0.16, 0.84, 2.6, 1.98keV) and MEPED flux (>30, >100, 300keV) from the 0° detector; calculation of the electron energy flux

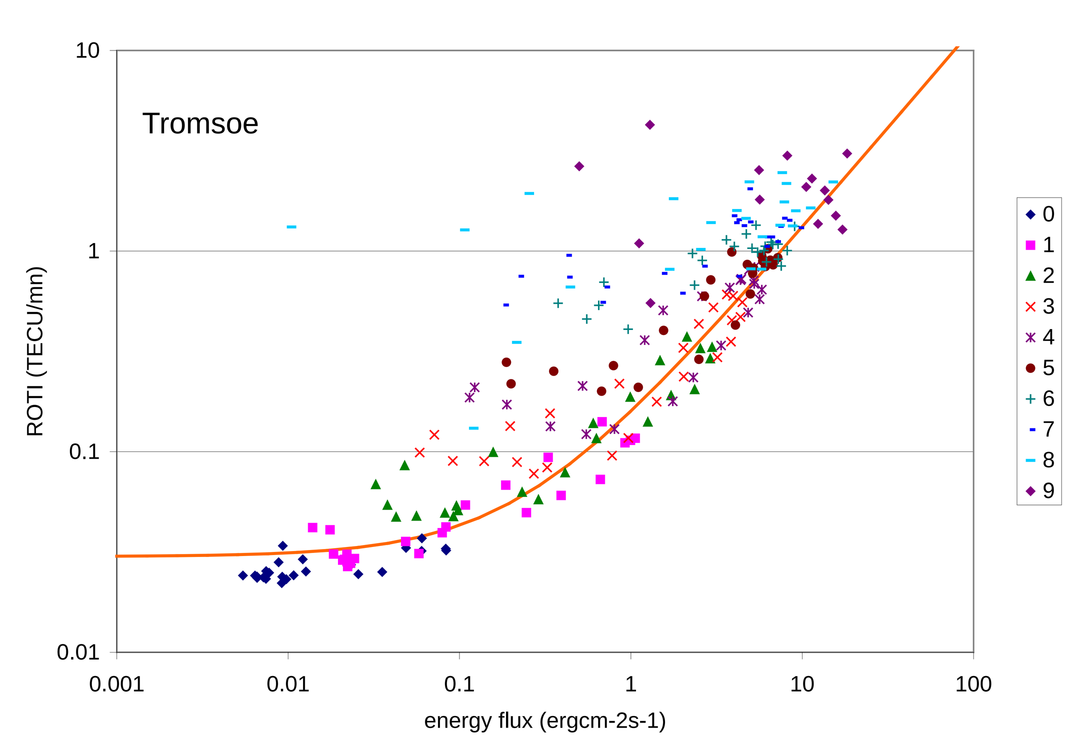
$$H = 4\pi \int_0^\infty vEfp^2 dp = 4\pi \int_0^\infty j(E) E dE$$

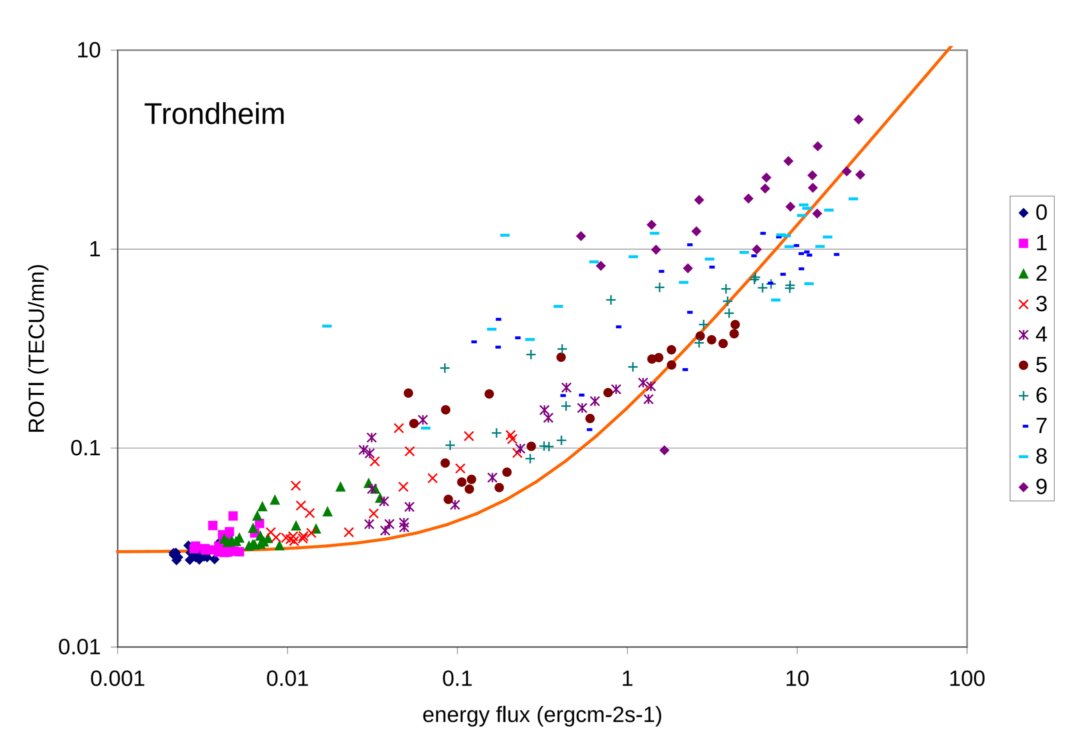
Binned with McIlwain L (60 logarithmic values from L=1 to L=12) and MLT (48 values) and classified according to the magnetic index Kp (10 values from Kp=0 to Kp=9)



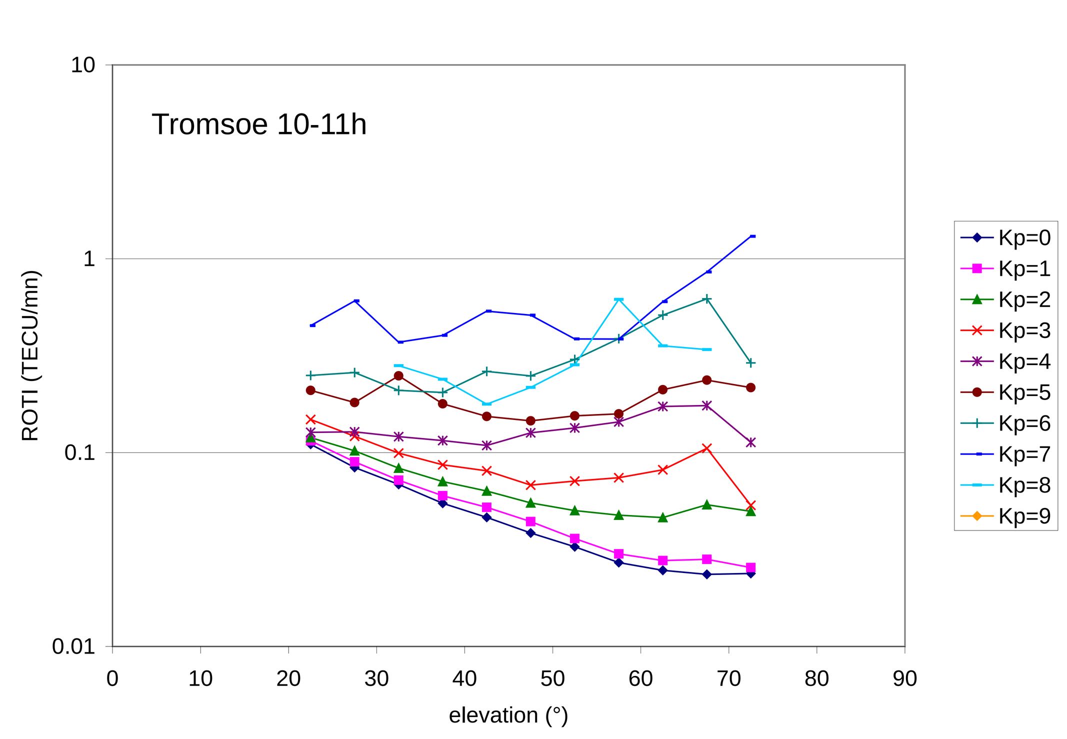


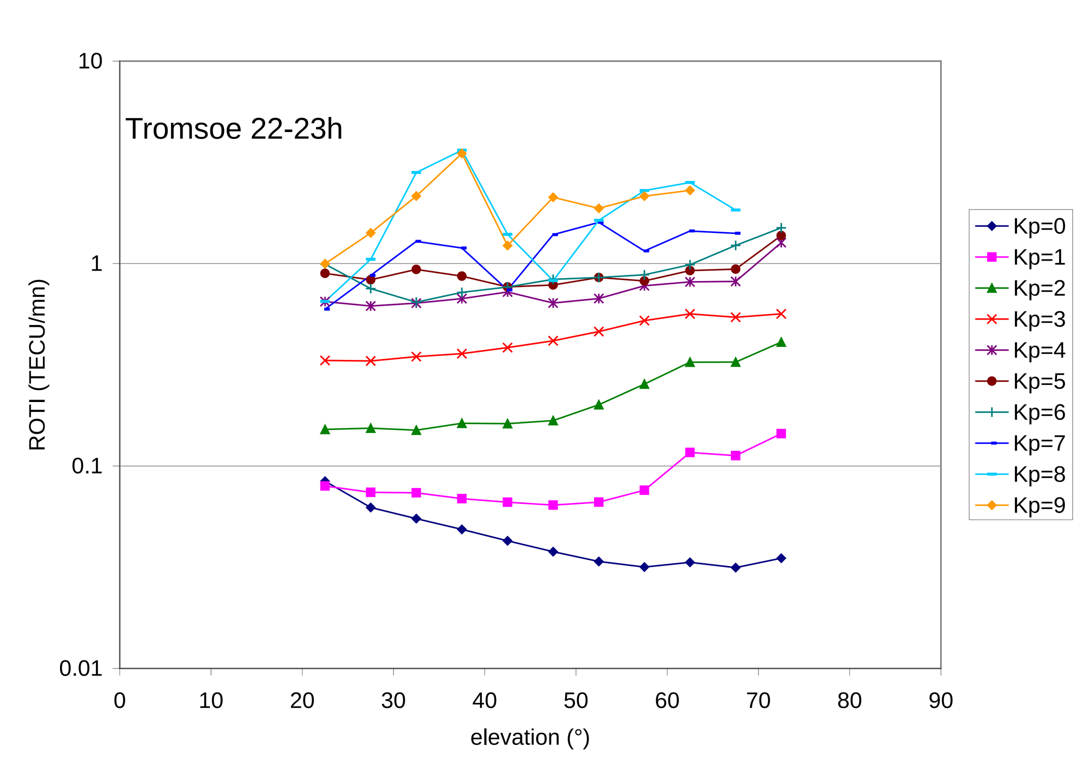
Correlation between ROTI and energy flux for high elevation (>60°) measurements
Correlation as high as 0.95 were obtained between energy flux and ROTI (average of ROTI for fixed hour-fixed Kp).
Simple law was derived:
ROTI = 0.03+0.1294 energy_flux





Influence of the elevation
South azimuth (to eliminate problems with LT mixing)
→Different day-night
→Different low-high magnetic activity

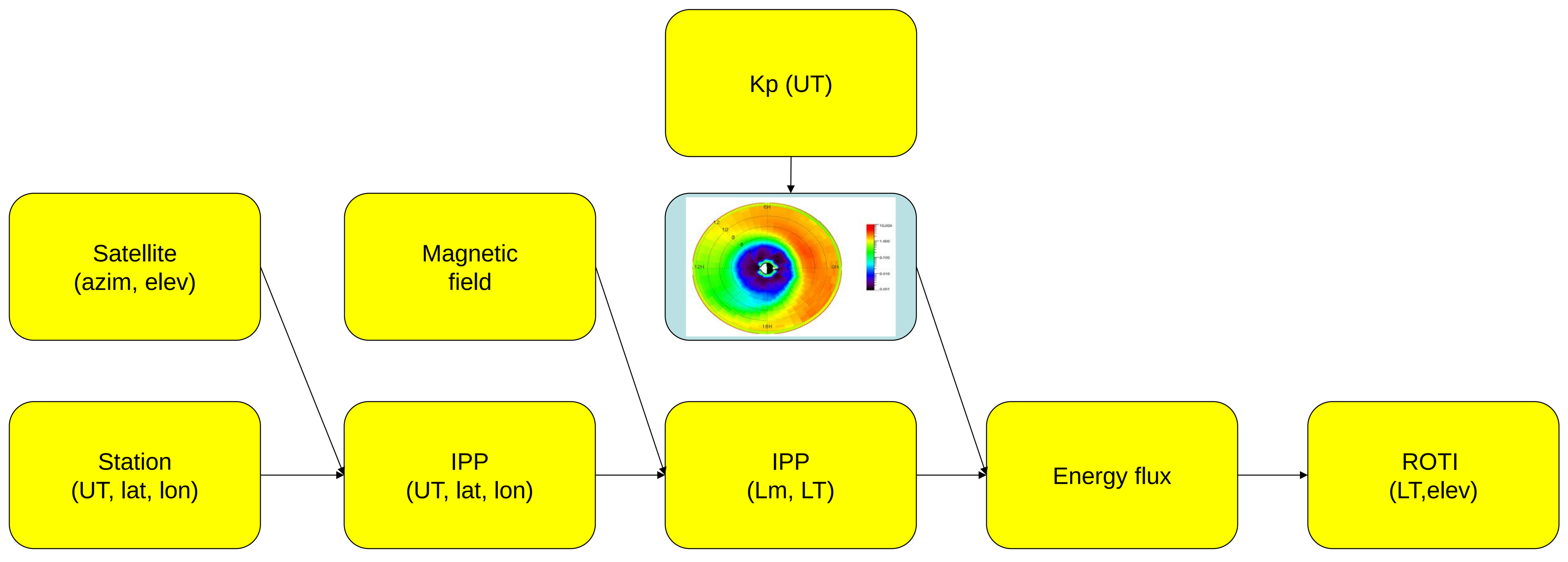




A first model was derived, which can be used for determining the ROTI, knowing the magnetic index Kp (it can be used for prediction, using predicted Kp values)

$$ROTI[TECU/mn] = \frac{0.025 + 0.05\sin(lt[h]+5)}{\sin(elev[°])^{1.5+0.5\sin(lt[h]+17)}} + 0.1294 energyflux[erg/cm2/s] 1.0082^{elev[°]-65.2}$$

* *Energyflux = f(L,LT,Kp)*



Conclusion:
This model can be used to assess GNSS position errors depending of the number and the location of the viewable GPS satellites.

Possible improvements:
- Decrease the time resolution of Kp
- use solar wind parameters
- Better understand the links

Acknowledgements: This work has been performed in the framework of a collaboration between CNES and NSC/NMA. The authors thank the Norwegian Mapping Authority for providing the GNSS data measurements performed over more than one decade at several Norwegian stations.