



Ionospheric Scintillation Effects on GPS Measurements

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Ionospheric Scintillation Effects on GPS Measurements

EPSRC

Engineering and Physical Sciences
Research Council

- EPSRC funded project
 - Study effects of ionospheric scintillation and of North/South TEC gradients in Northern Europe and mid-latitudes (UK) by
 - Investigating impact on GPS applications
 - Assessing impact on GPS accuracy, integrity and availability
- 3 years duration
- IESSG with collaborators:
 - Thales Geosolutions Group Ltd
 - Trinity House Lighthouse Service
 - University of Calgary



Work Packages

WP1 Establishment of a scintillation observing GPS network

Using an array of GPS scintillation monitors
Co-located with dual-frequency receivers

WP2 Develop data processing and archiving strategies

WP3 Assess impact on EGNOS

WP4 Assess impact on Maritime DGPS

WP5 Assess impact on different receiver technologies

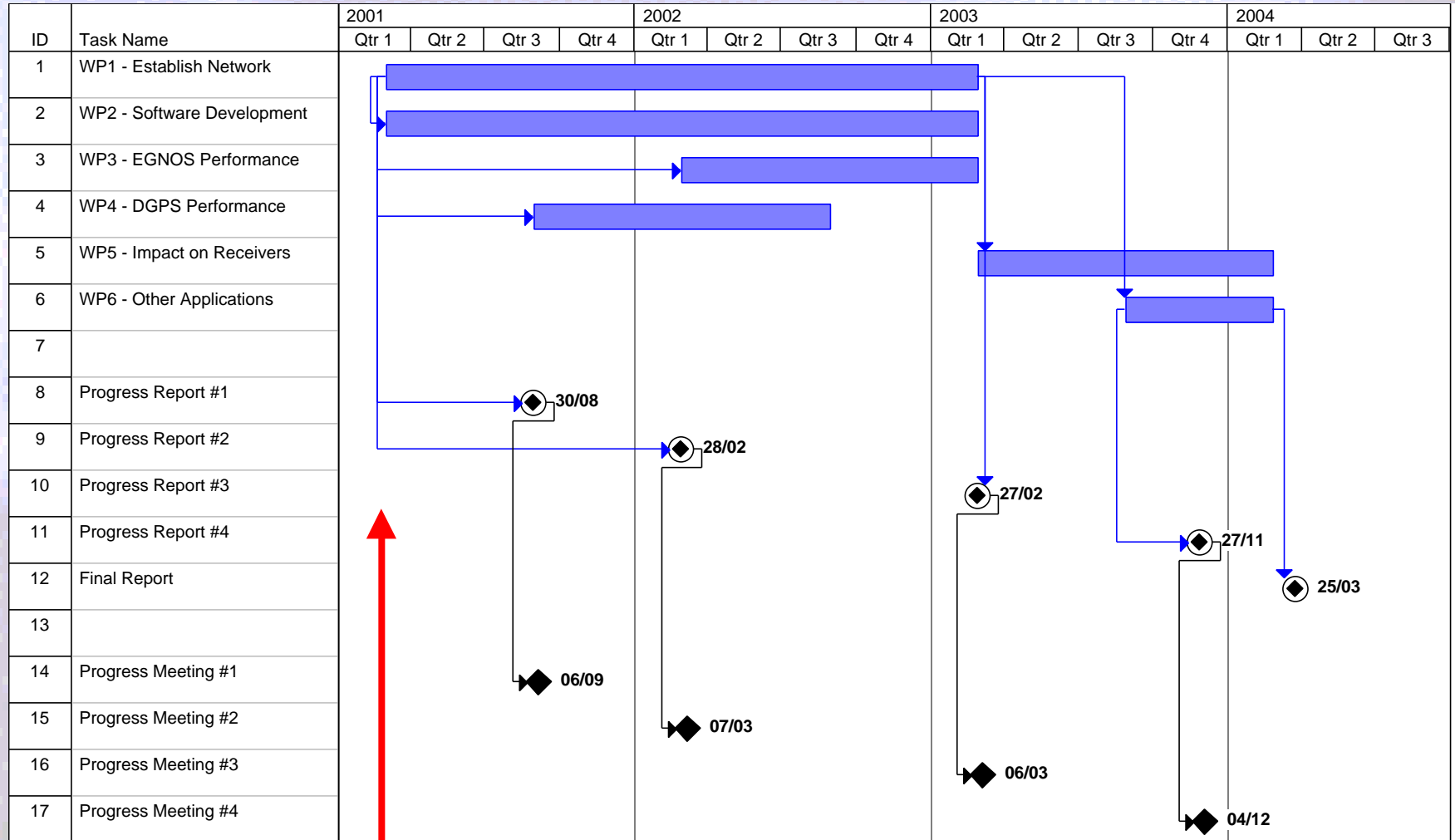
WP6 Application to other satellite systems

Also: Form data base for future (next solar maximum)

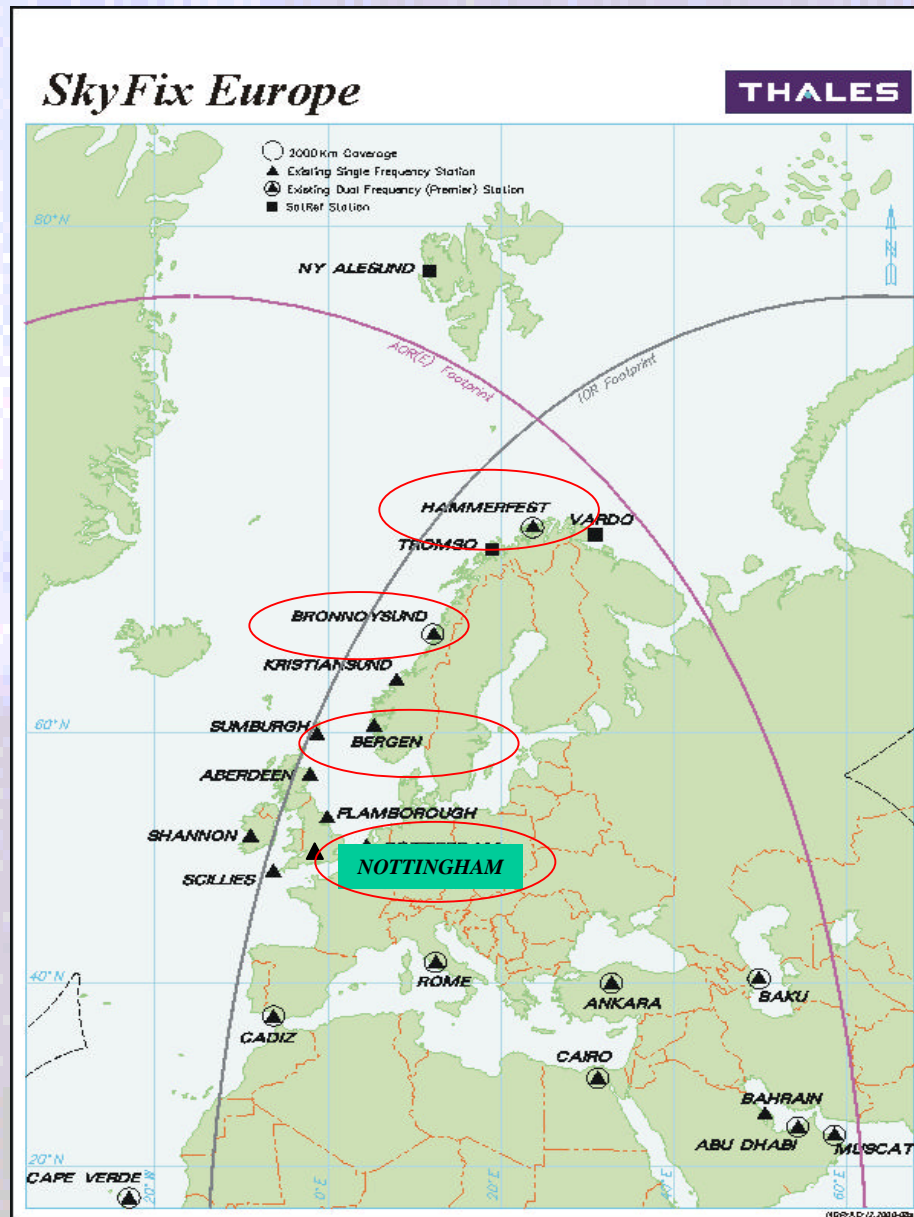
Develop warning & mitigation mechanisms ?



Time Scale



01 March 2001



The Monitoring Network

- Thales SkyFix Europe Network
- North South Distribution (red ellipses)
- GPS Iono Scintillation Monitors
- Co-located with 2-freq receivers



Ionospheric Scintillation Monitor

- GPS Silicon Valley GSV 4004
- Dual Frequency 12 channel NovAtel OEM4 card
- Stable ovenized crystal oscillator
- Wide bandwidth to insure that all spectral components of amplitude and phase scintillation are measured (50 Hz raw data)
- Logs and Outputs Statistics of Phase and Amplitude Scintillation (60 seconds data)



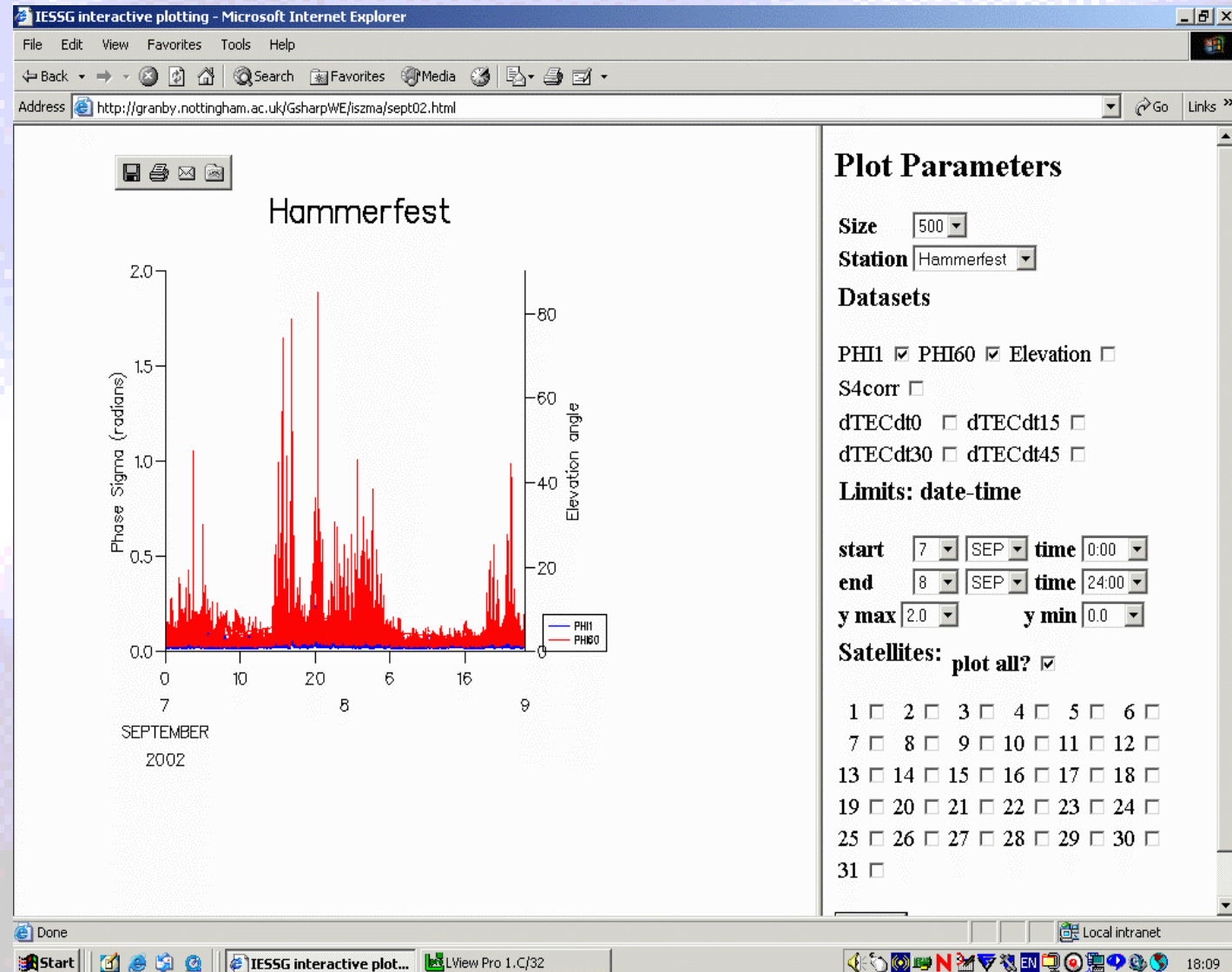
- Also outputs TEC and dTEC

The monitor can also track one SBAS satellite (e.g. EGNOS or WAAS)



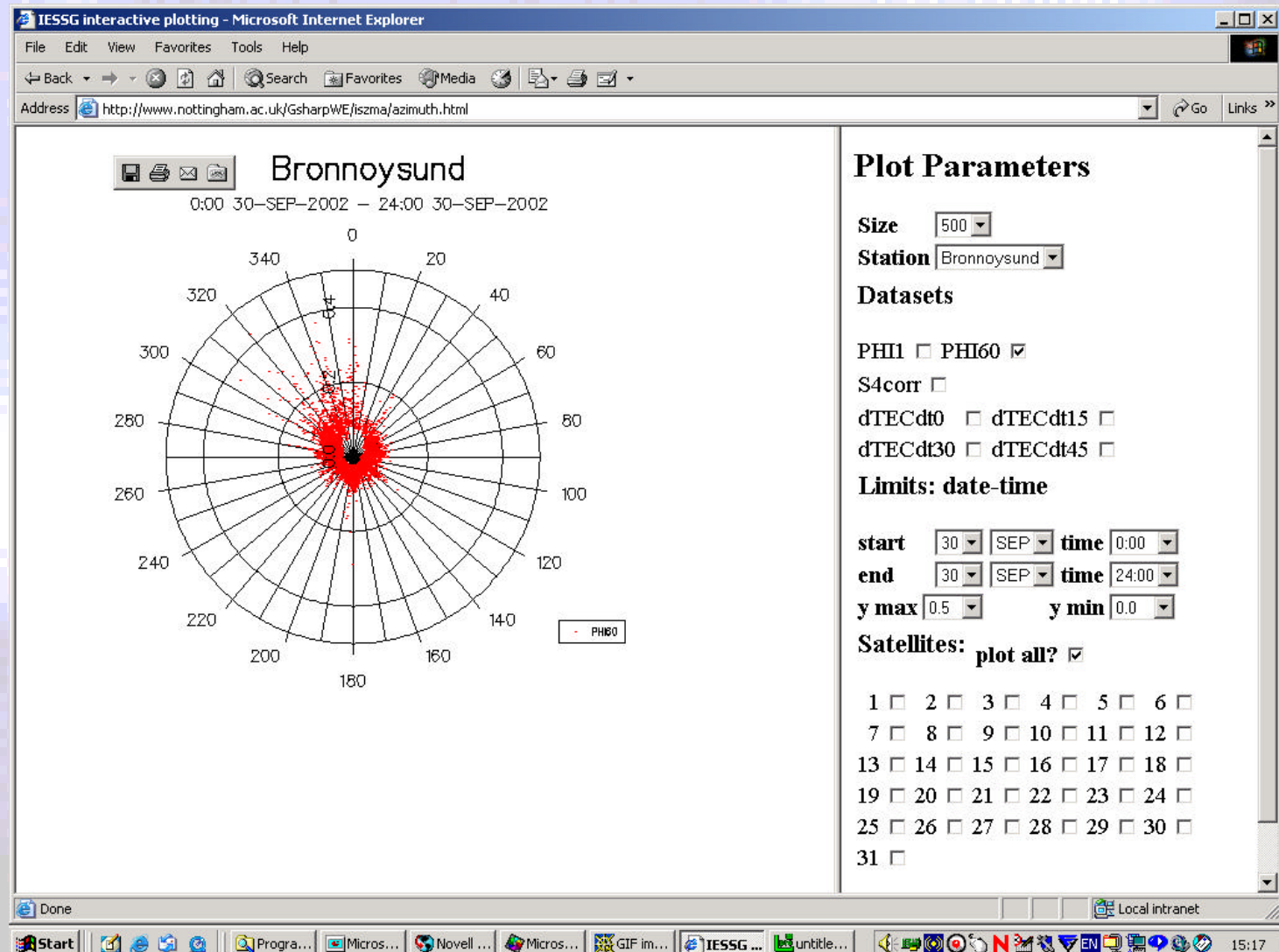


Experimental IESSG Interactive Scintillation Plots Web Interface



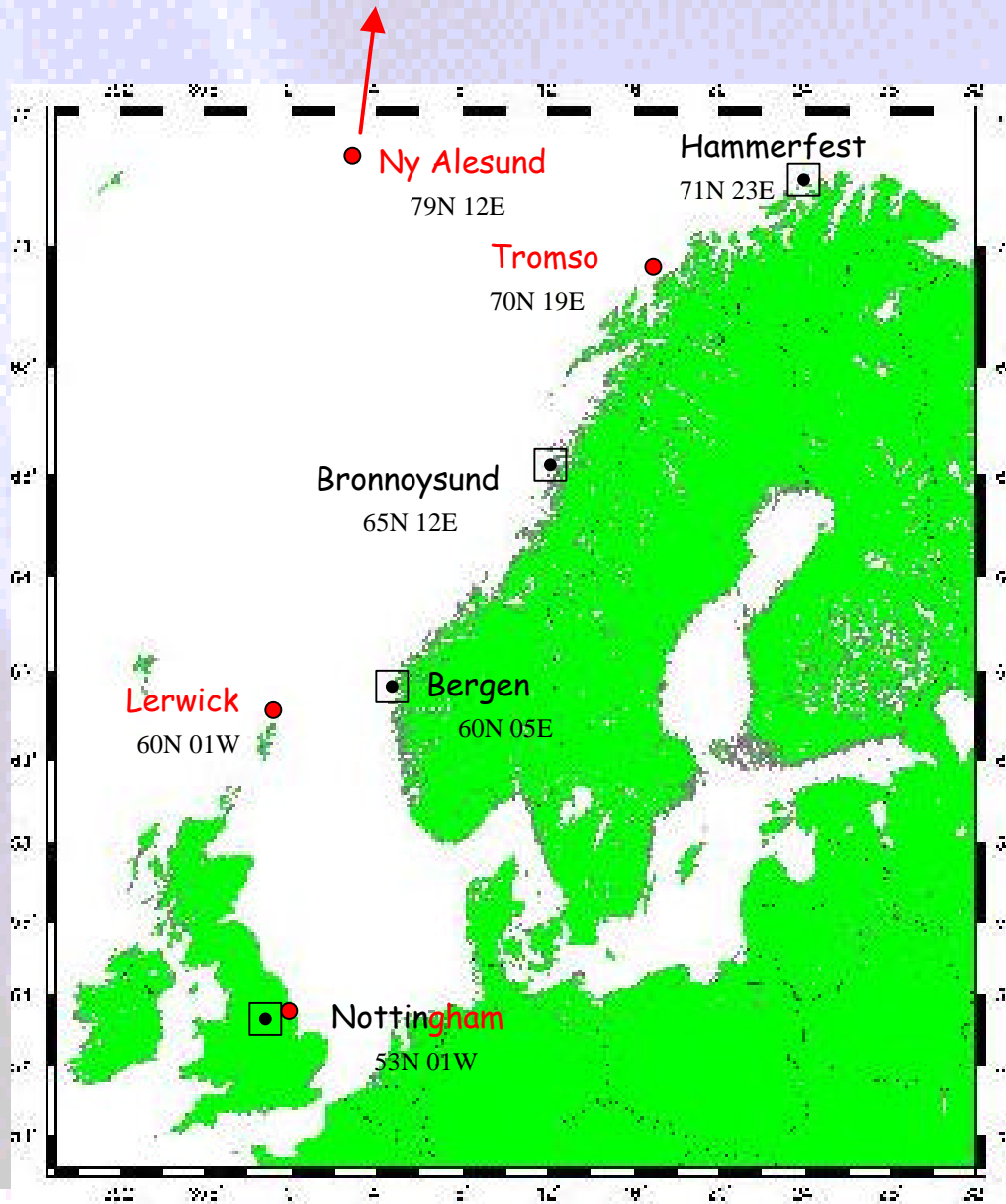


Experimental IESSG Interactive Scintillation Plots Web Interface





Stations with Dual-frequency/Scintillation Data



● Station with dual frequency Data

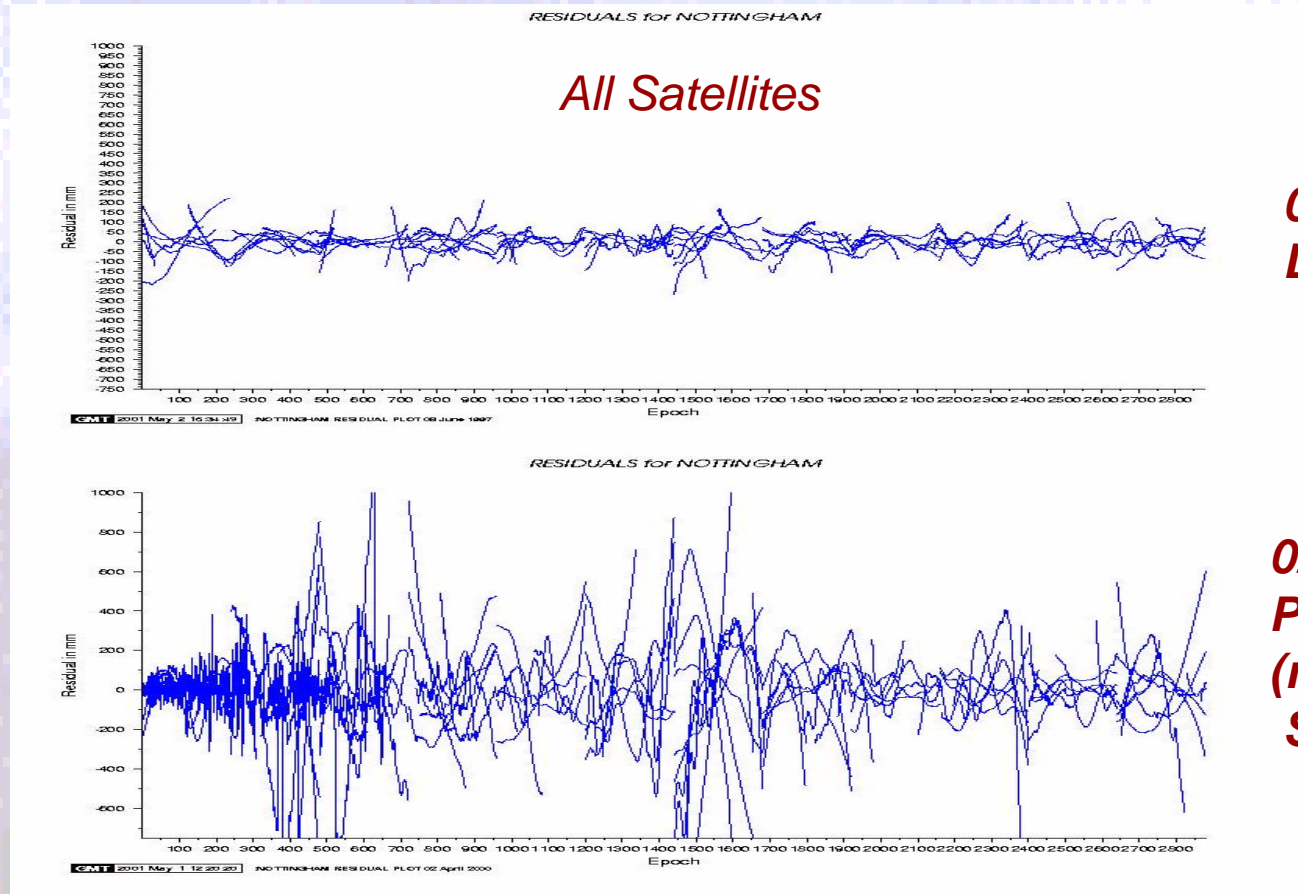
◻ Station with Scintillation Data
(current monitoring network,
part of Thales SkyFix Network)



Dual-Frequency Model Residuals

Bernese software

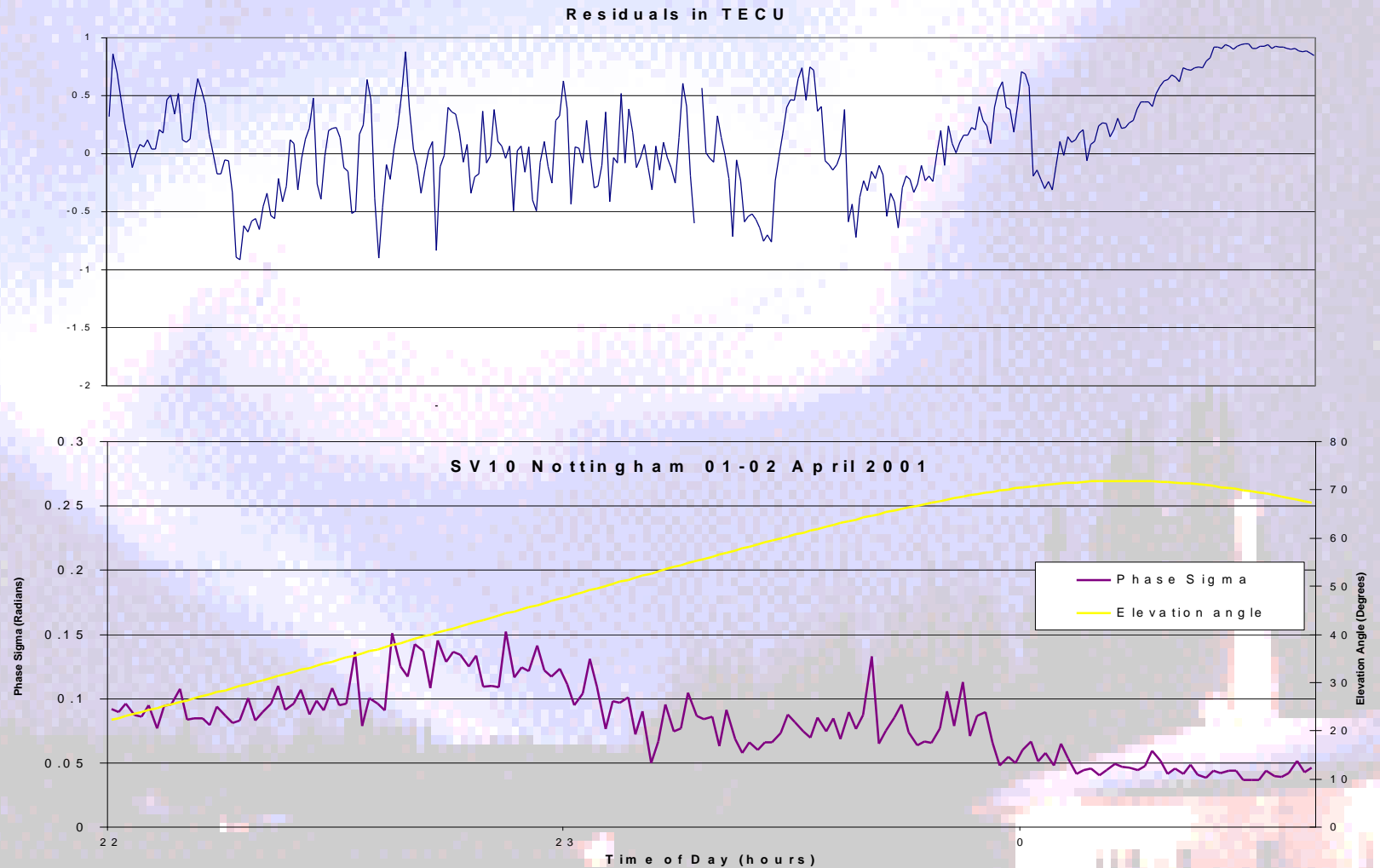
24 Hrs, 30 sec dual-freq data from Nottingham





Correlation of TEC residuals with Phase Scintillation (Iono Storm Apr 2001)

Phase Scintillation Data for PRN 10, starting at 22:00 UT on 01 Apr 2001

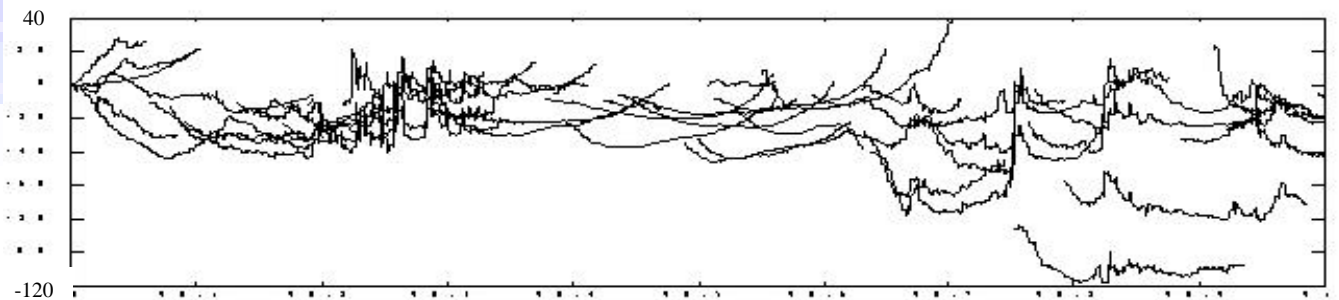




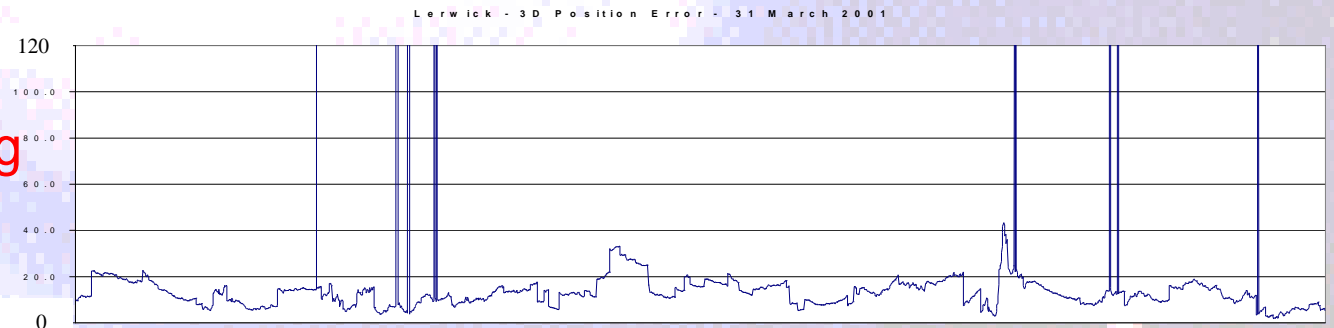
Correlation of TEC Variations, GPS Positioning Errors and Hourly Standard Deviation of Geomagnetic Field

Lerwick 31 March 2001

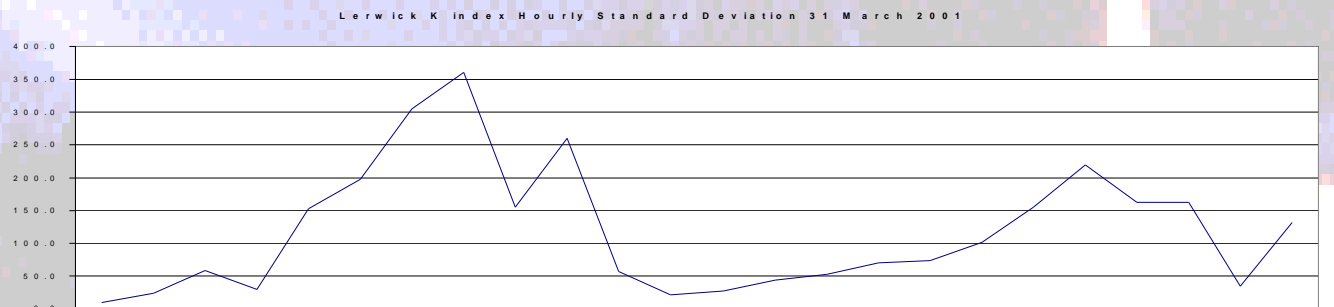
TEC Variations
at Lerwick



GPS 3D Positioning
Errors at Lerwick



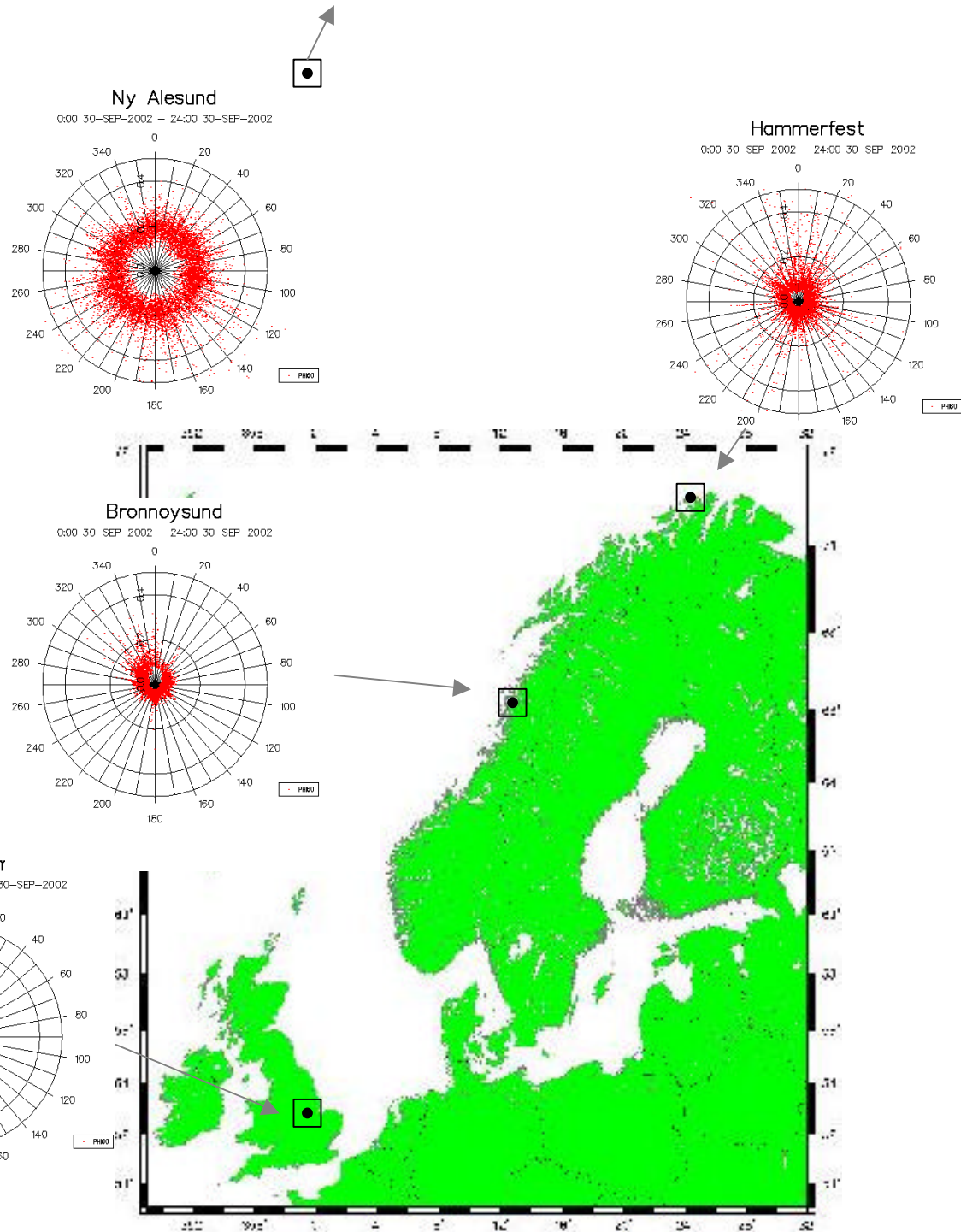
Hourly
Stdev of Geomag
Field from Lerwick





Spatial Analysis of Phase Scintillation

07 September 2002





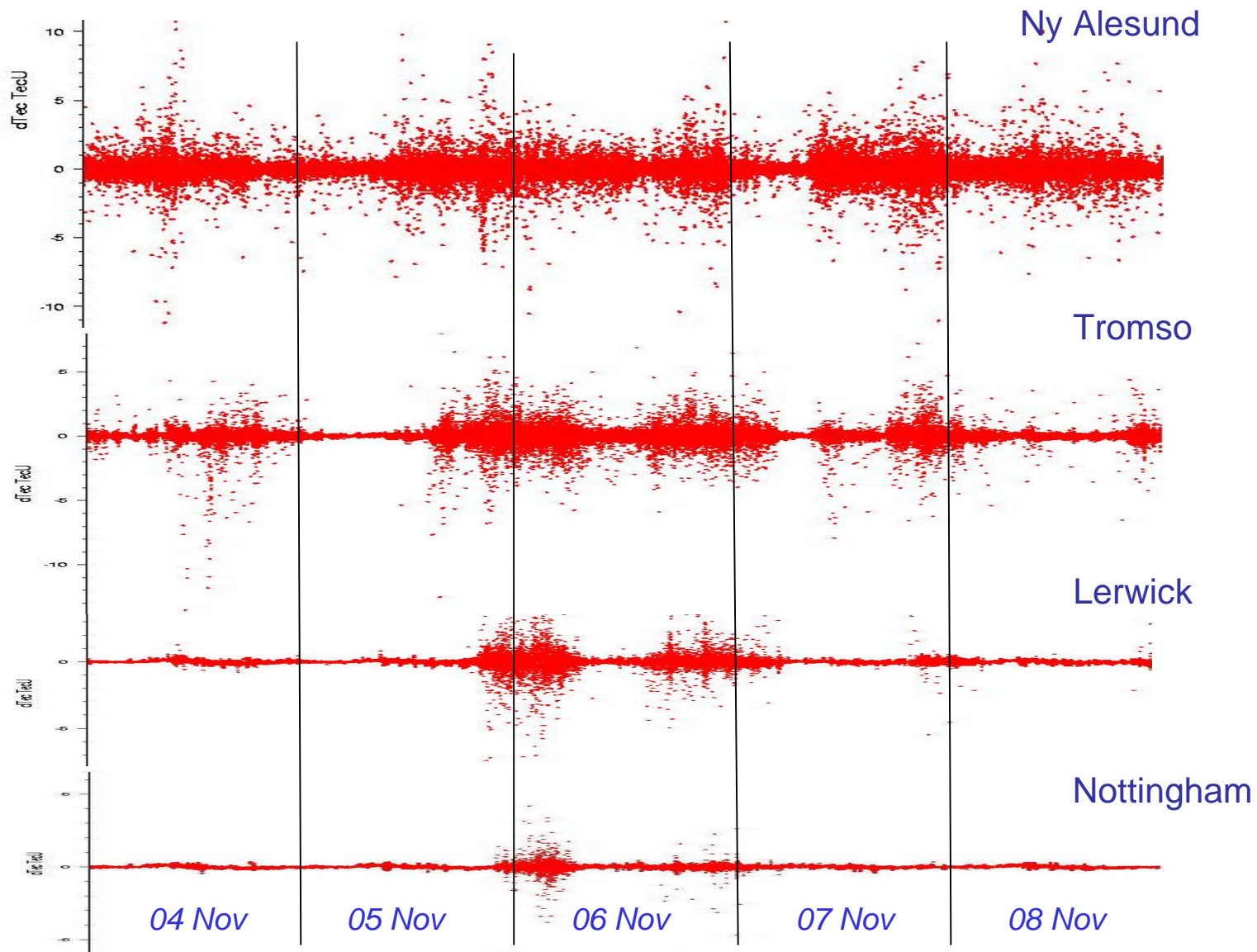
North-South Gradient in TEC Change Iono Storm Nov 2001

Lat 79° N
Long 12° E

Lat 70° N
Long 19° E

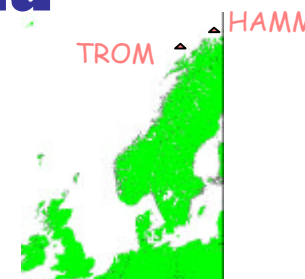
Lat 60° N
Long 01° W

Lat 53° N
Long 01° W

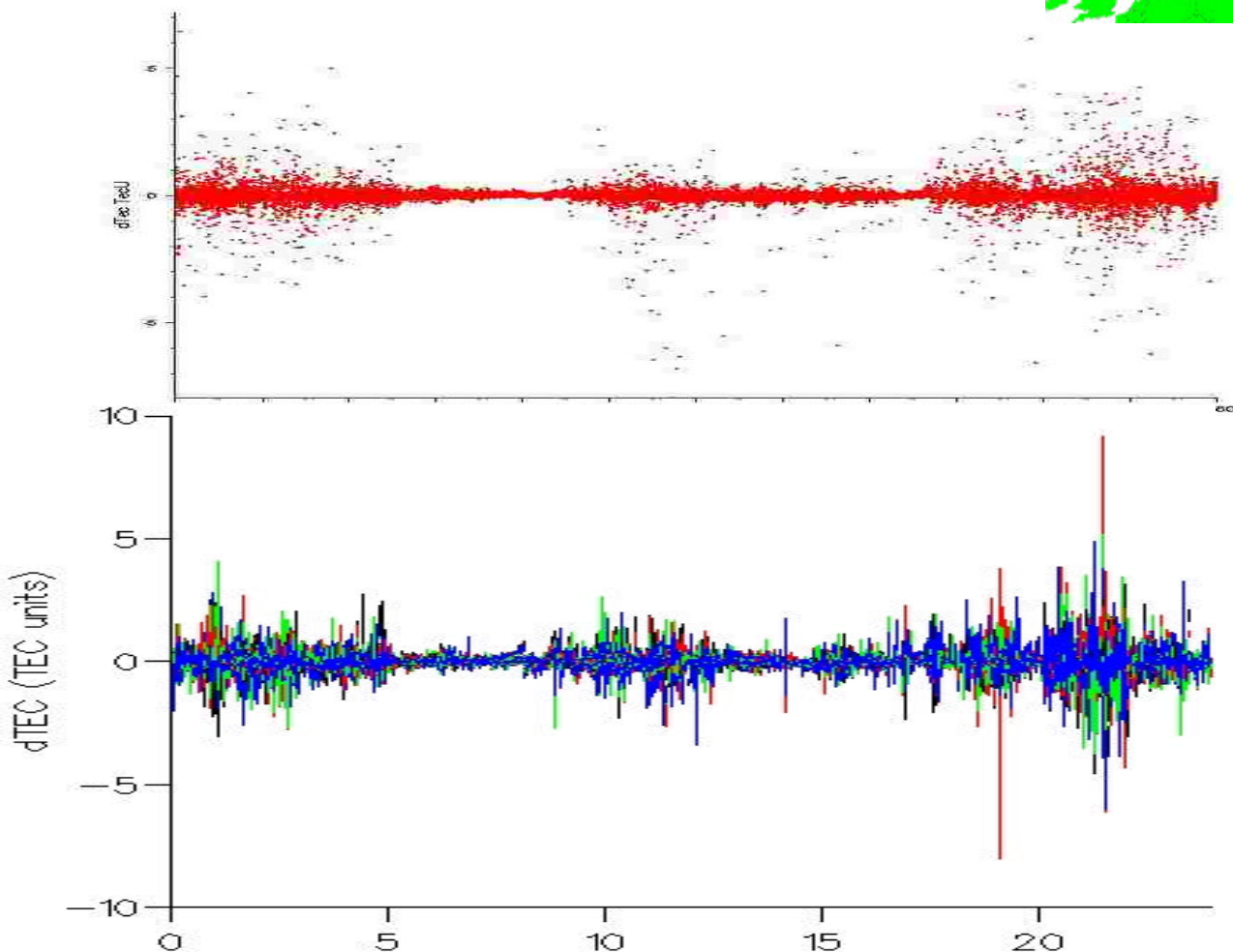




TEC Change Observed at Tromso and Hammerfest on 7 November 2001



Tromso -
IGS 2-freq data
processed
with Bernese



Hammerfest -
output data from
GSV4004



Lerwick Nov 01 - Correlation of TEC Variations, GPS Residuals, Phase Scintillation (Bergen) and Hourly Standard Deviation of Geomagnetic Field

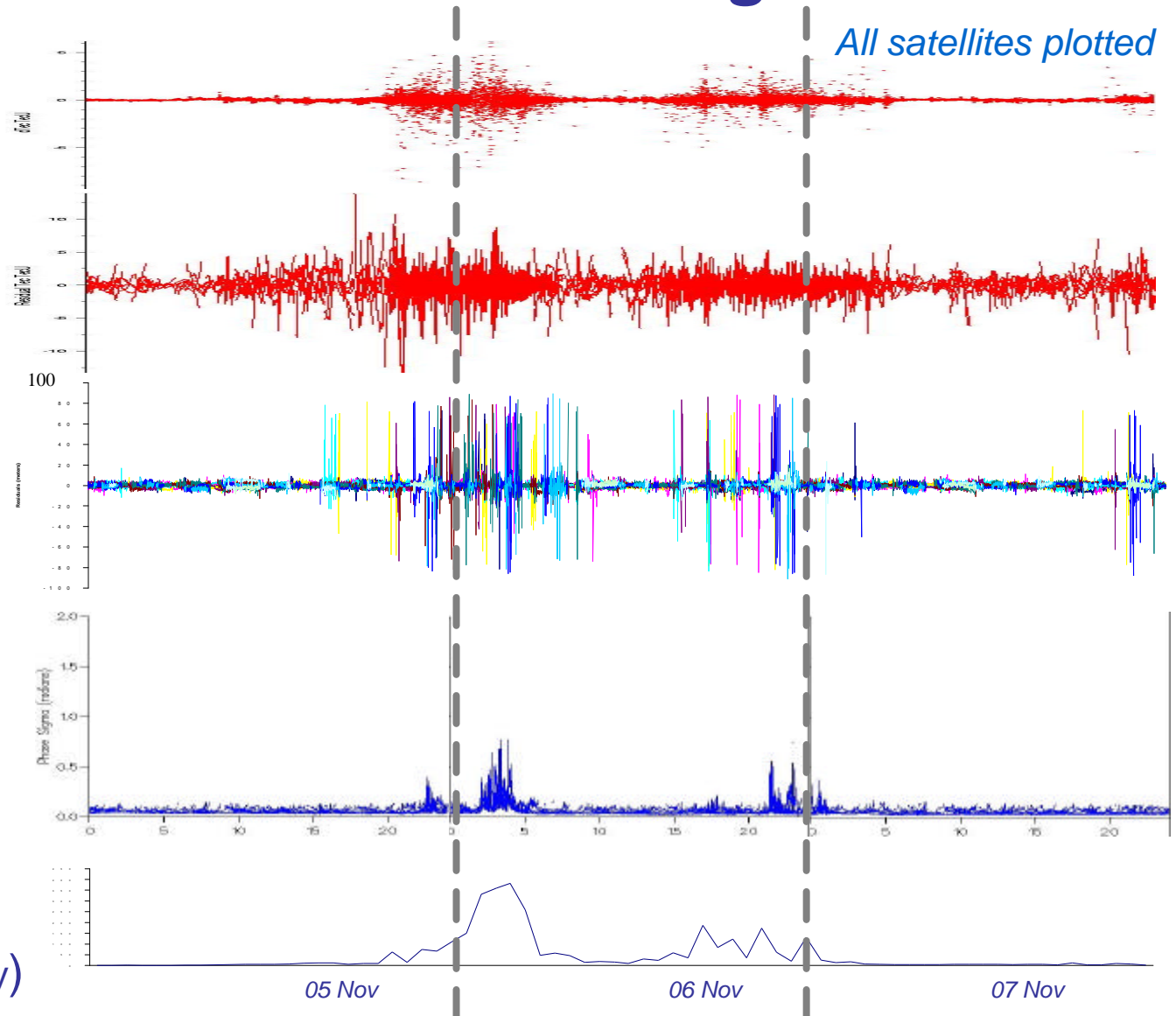
TEC change per 30 seconds

Dual Frequency residuals

GPS 3D position Residuals

Phase Scintillation (at Bergen)

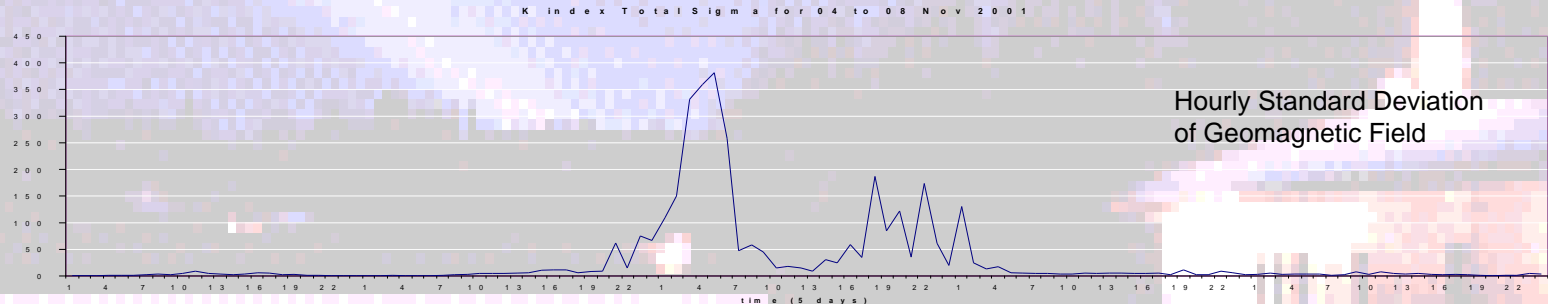
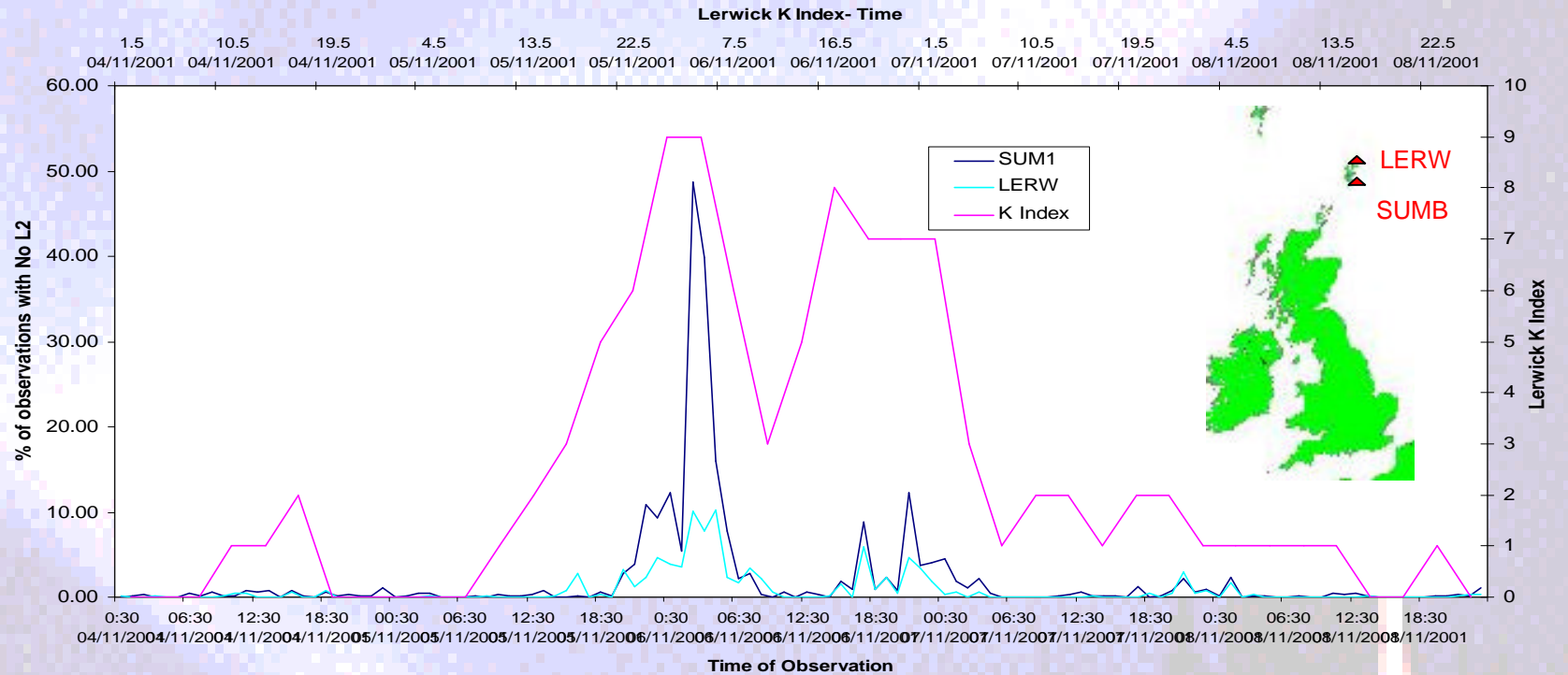
Hourly Standard Deviation of geomagnetic field (Lerwick Observatory)





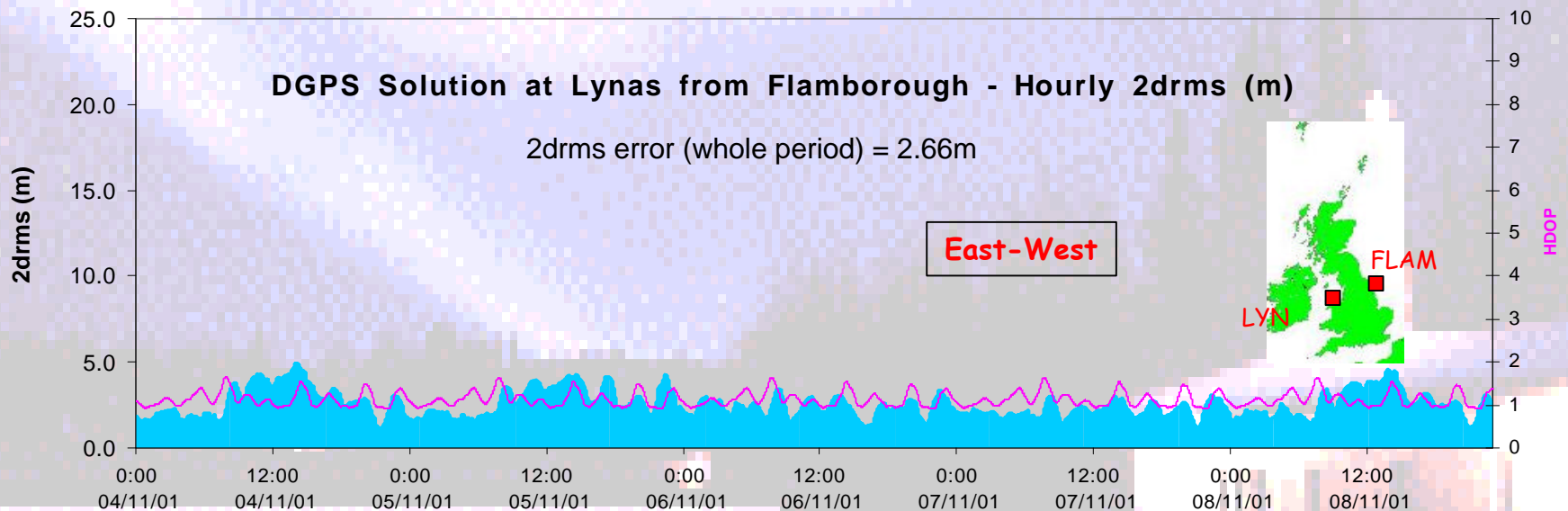
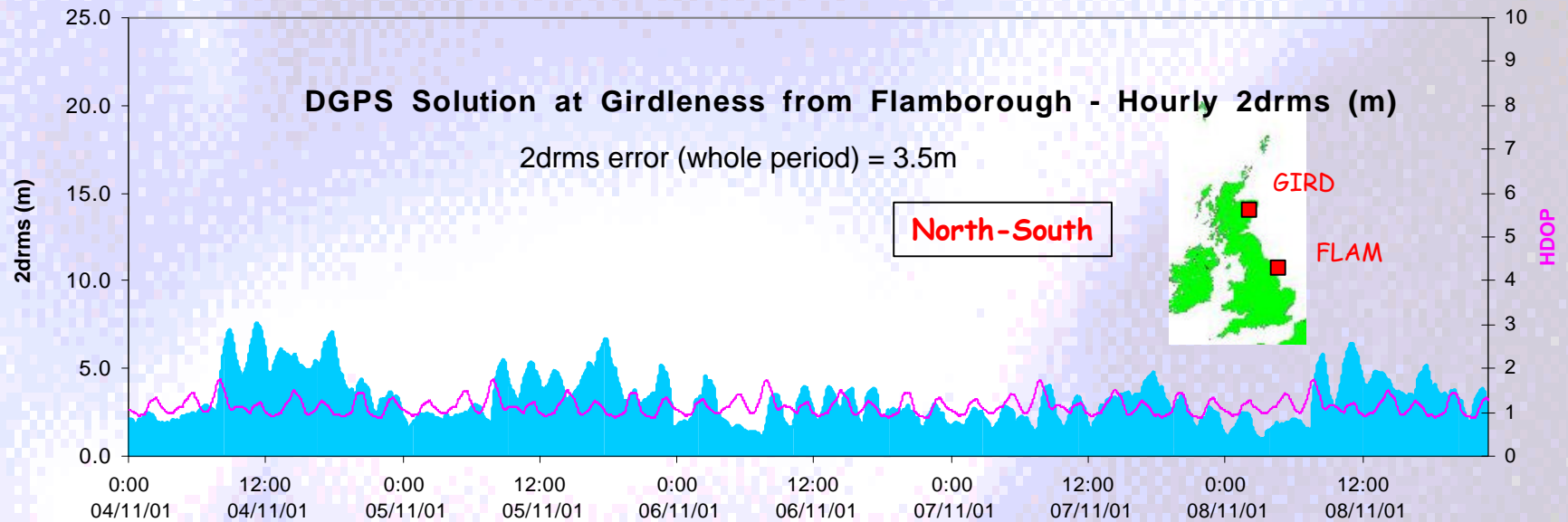
L2 Data Loss for Different Receivers at Lerwick and Sumburgh, 4 to 8 Nov 01

4th - 8th November 2001 - Sumburgh Head (TRIMBLE SSI) LERWICK (ASHTECH ZX11)



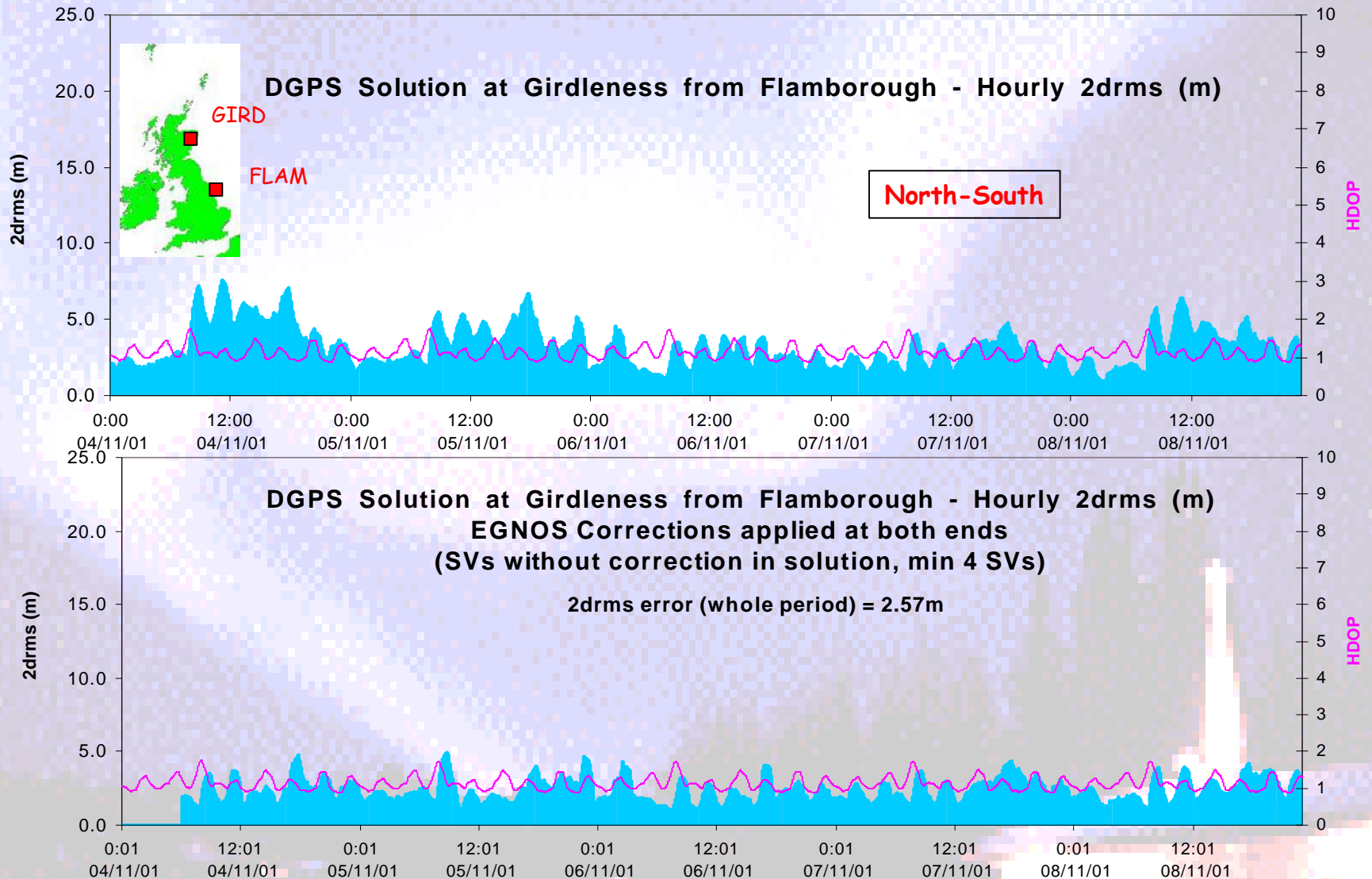


North-South vs East-West Baseline DGPS (4 to 8 Nov 01)



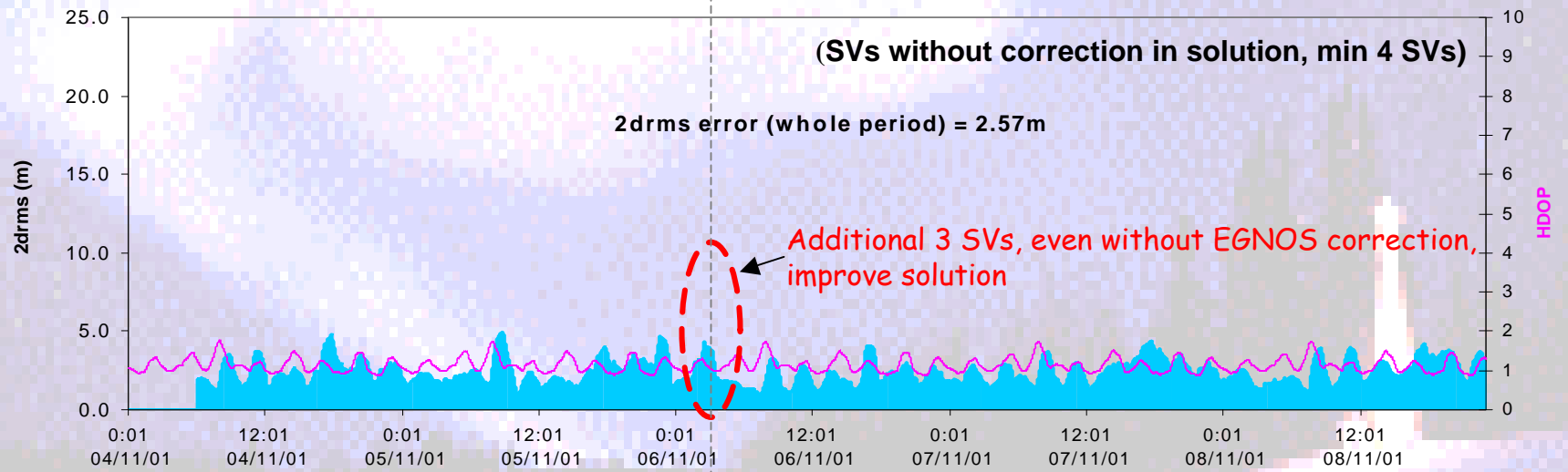
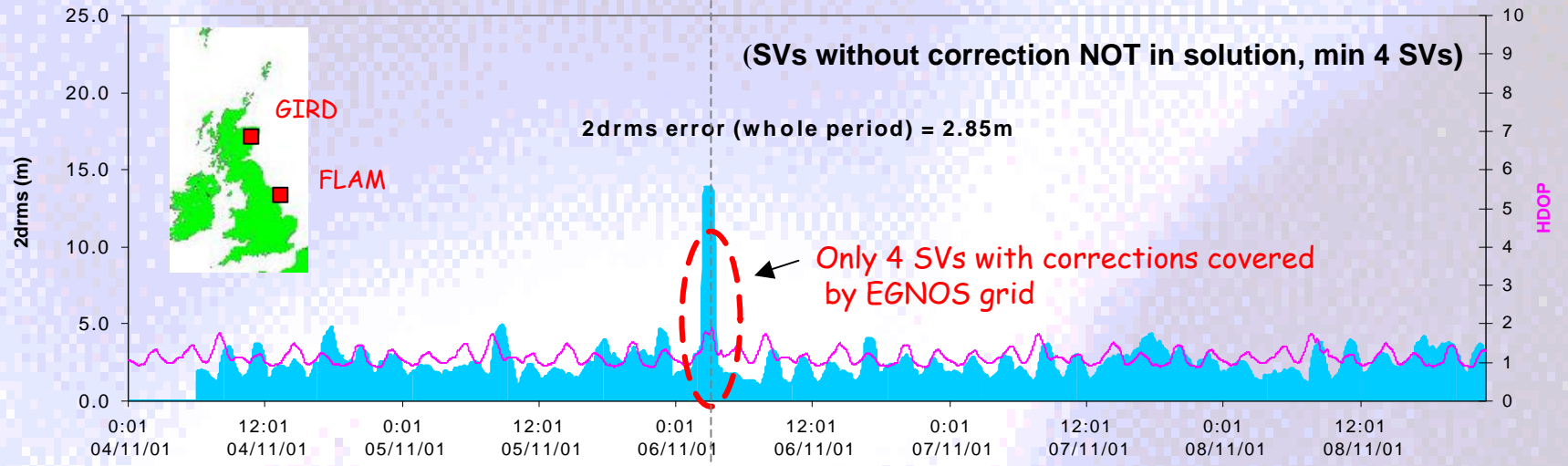


Improvement with the EGNOS Corrections on a North/South Baseline (4 to 8 Nov 01)

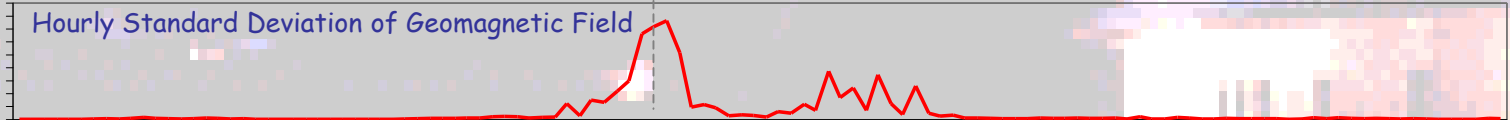




However



Hourly Standard Deviation of Geomagnetic Field





Possible Development of Warning Mechanisms

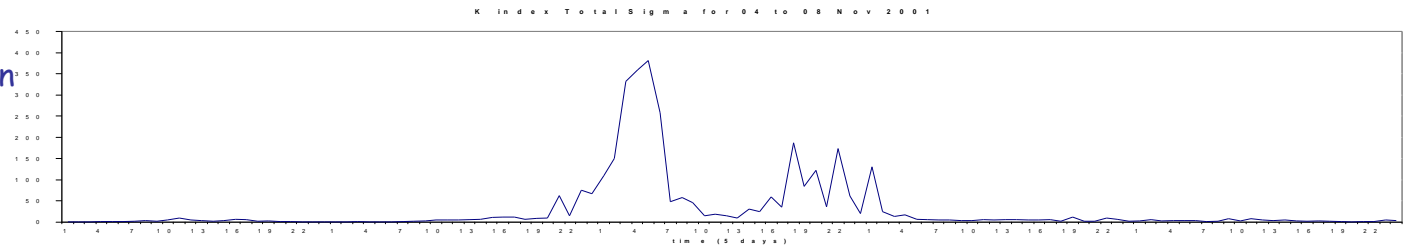
Prediction of Scintillation Levels with WBMOD (Wide Band Model)

- Based on climatological models of global distribution of ionospheric irregularities + propagation theory
- Developed by NorthWest Research Associates Inc.
- Inputs: location, day of the year, local time, SSN, Kp
- Relevant outputs: S4 and Phase RMS (SPHI)
- Predictions based on the L1 GPS frequency

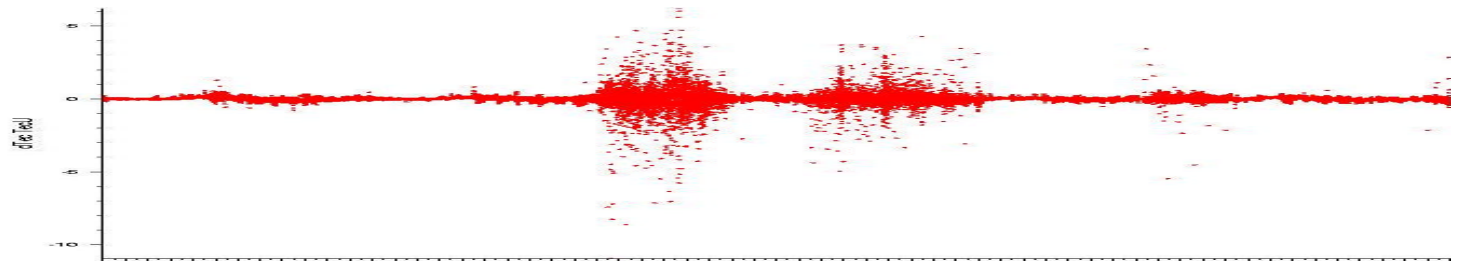


Correlation of TEC Changes with hourly standard deviation of Geomagnetic Field, WBMOD prediction and Data Loss, Lerwick, 4 to 8 November 2001

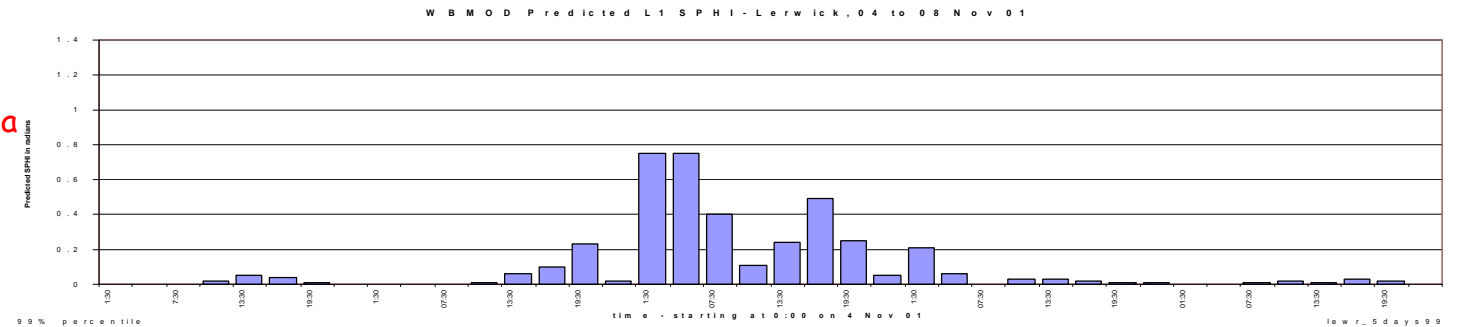
Hourly Standard Deviation of Geomagnetic Field



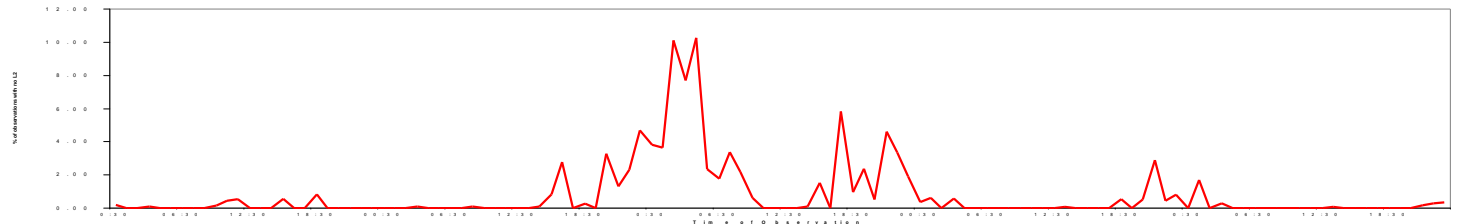
TEC changes



Predicted Phase Sigma (99% percentile)



Percentage of L2 loss on a semicodeless GPS receiver





Correlation of WBMOD phase and amplitude scintillation predictions with DGPS and EGNOS user 2drms - Trondheim, 4 to 8 Nov 2001

