Near real-time input to an HF propagation model for nowcasting of HF communications with aircraft on polar routes

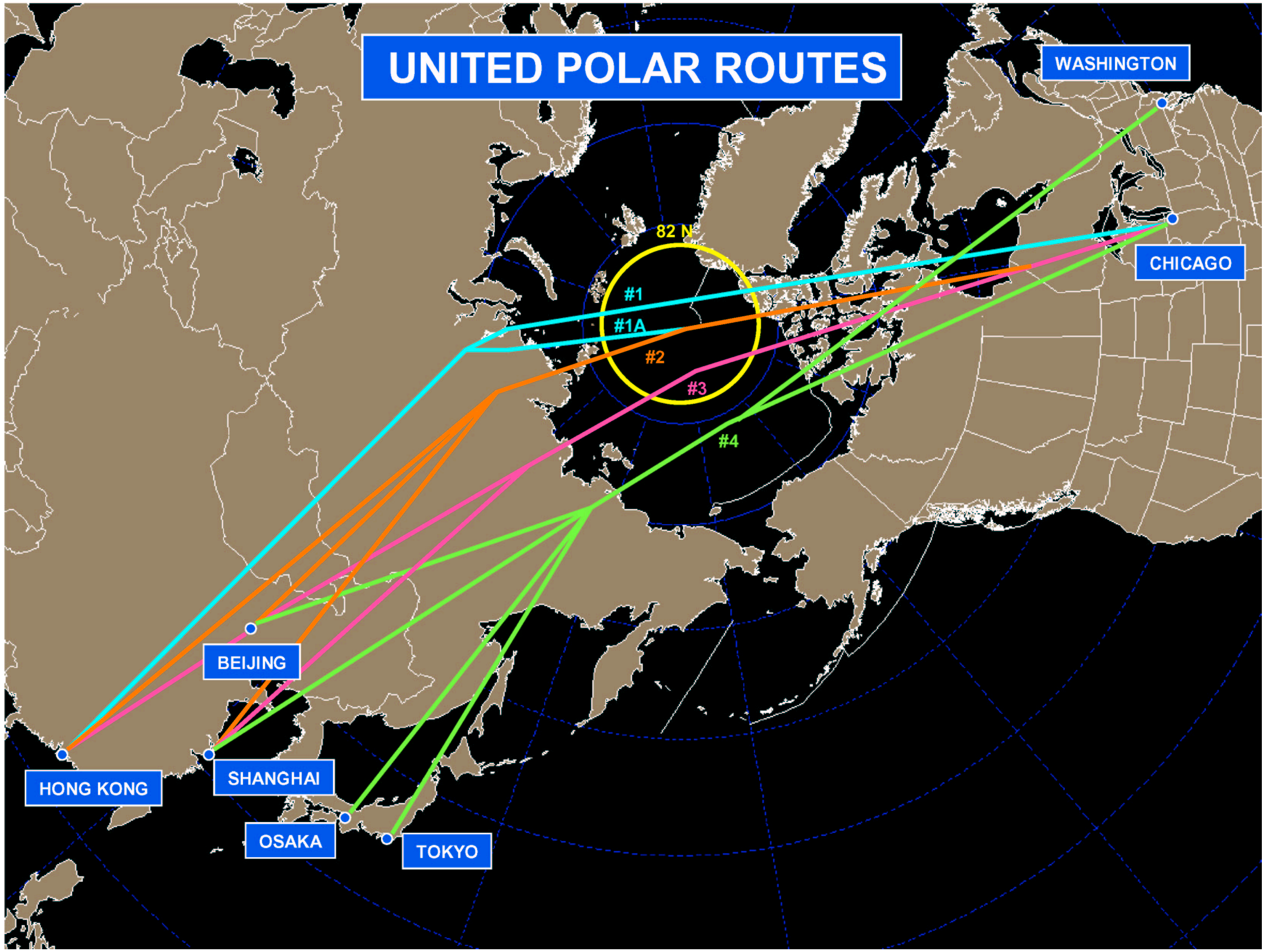
E.M. Warrington, A.J. Stocker, D.R. Siddle, J. Hallam

N.Y. Zaalov

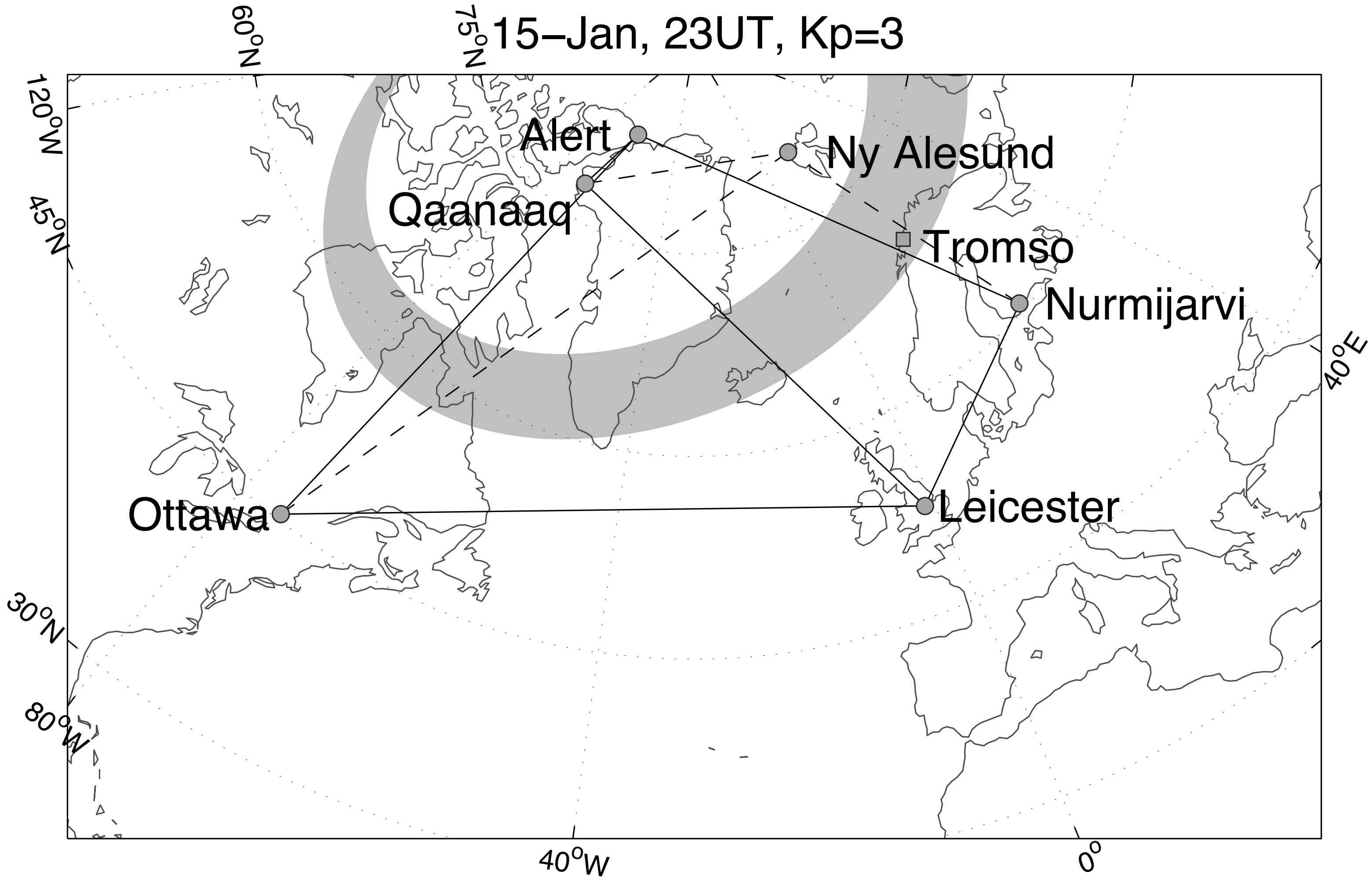
F. Honary, N. Rogers

D.H. Boteler, and D.W. Danskin

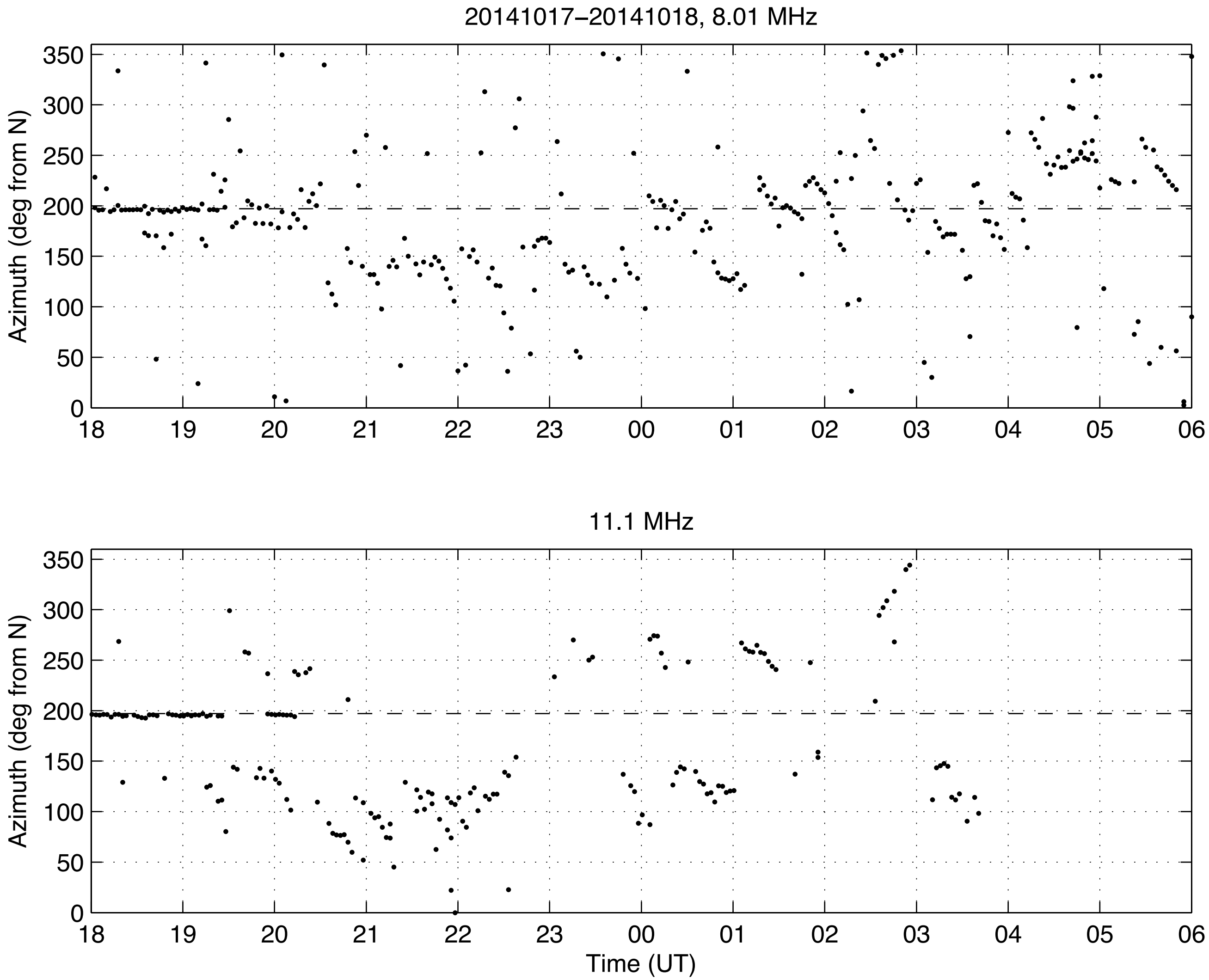
Airlines are increasingly using trans-polar routes as these provide more direct travel between some destinations.



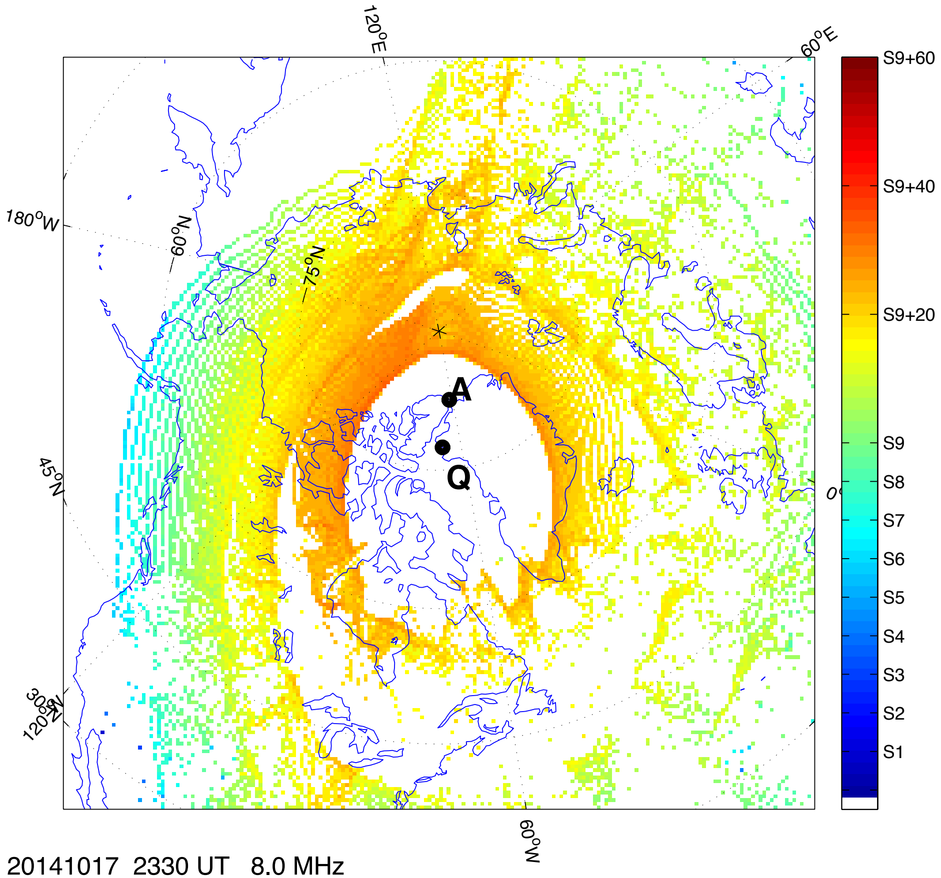
Map of HF stations



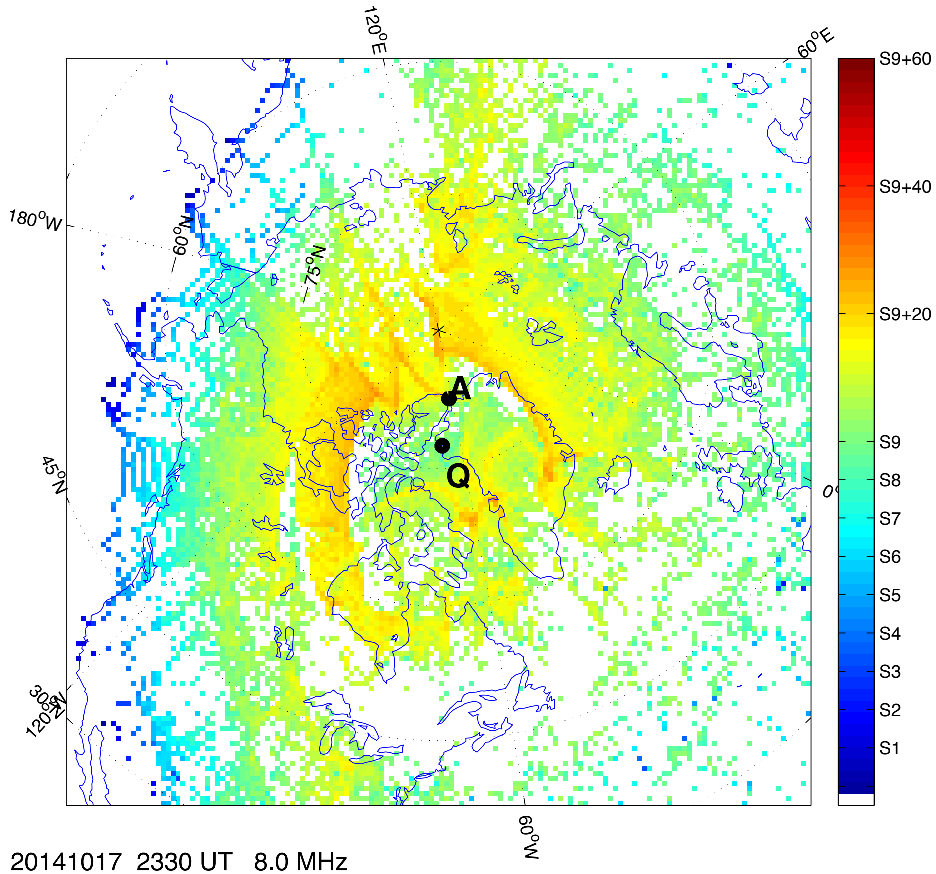
Example measurements in the polar cap



Example simulation output



20141017 2330 UT 8.0 MHz



20141017 2330 UT 8.0 MHz

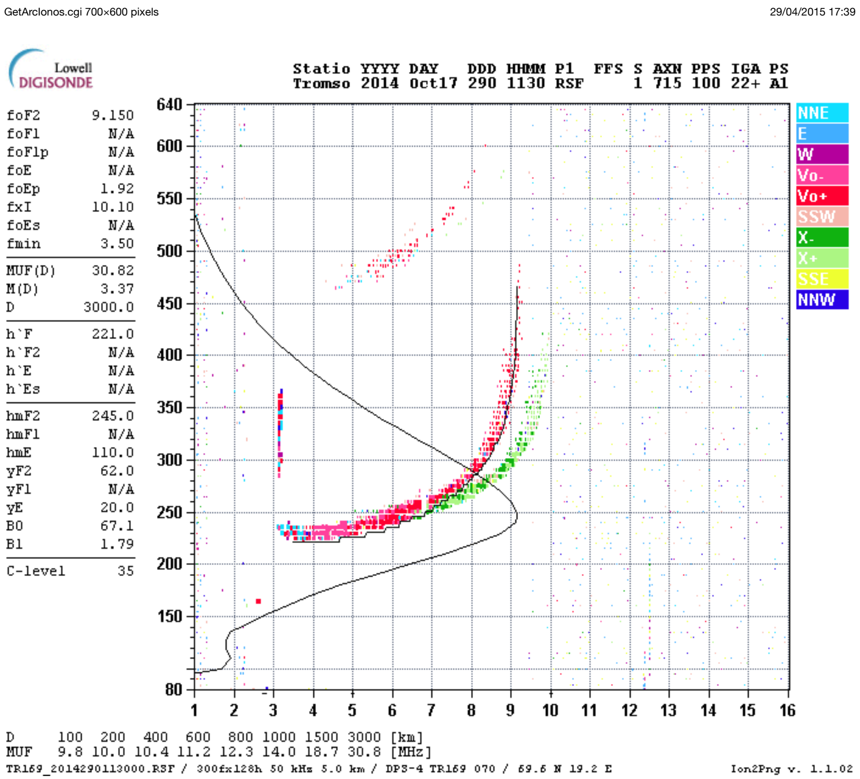
Current state of the model

- Manually intensive
- The background ionosphere derived from ionosonde measurements (from simulation time ±12 hours)
- Intensity, number, and initial location of patches are randomised based on estimates of these parameters from the literature (and ensemble statistics generated)
- D-region absorption model based on DRAP values

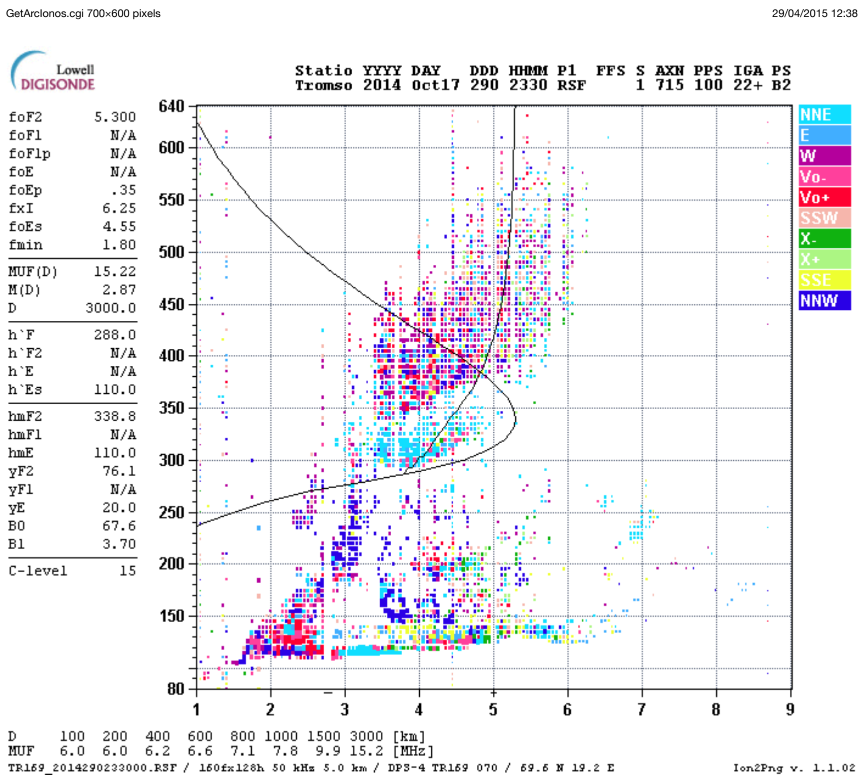
Assimilation of real-time inputs to the model – 1

- Background ionosphere
  - Structure based on IRI
  - Relatively few ionosondes in polar cap and can be difficult to interpret and derive values

Example ionograms (Tromsø, 17 October 2014)



1130 UT

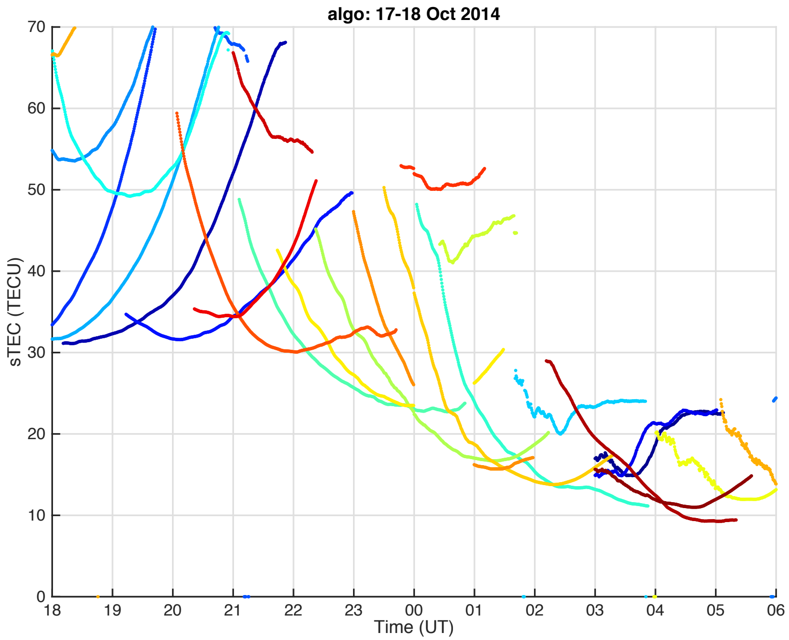


2330 UT

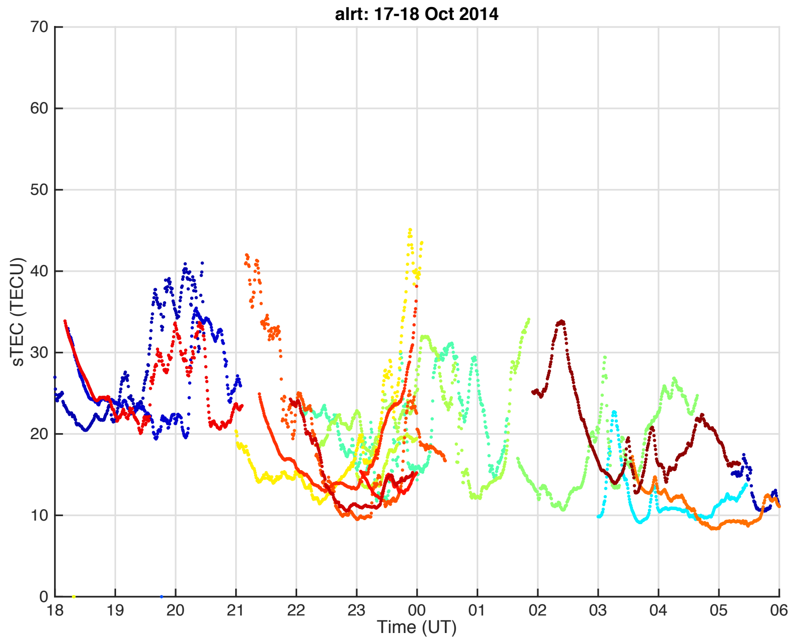
Assimilation of real-time inputs to the model – 1

- Background ionosphere
  - Structure based on IRI
  - Relatively few ionosondes in polar cap and can be difficult to interpret and derive values
  - So, adjust IRI to fit to TEC observations derived from GPS measurements

Example TEC measurements (17–18 October 2014)



Algonquin (mid-latitude)



Alert (polar cap)

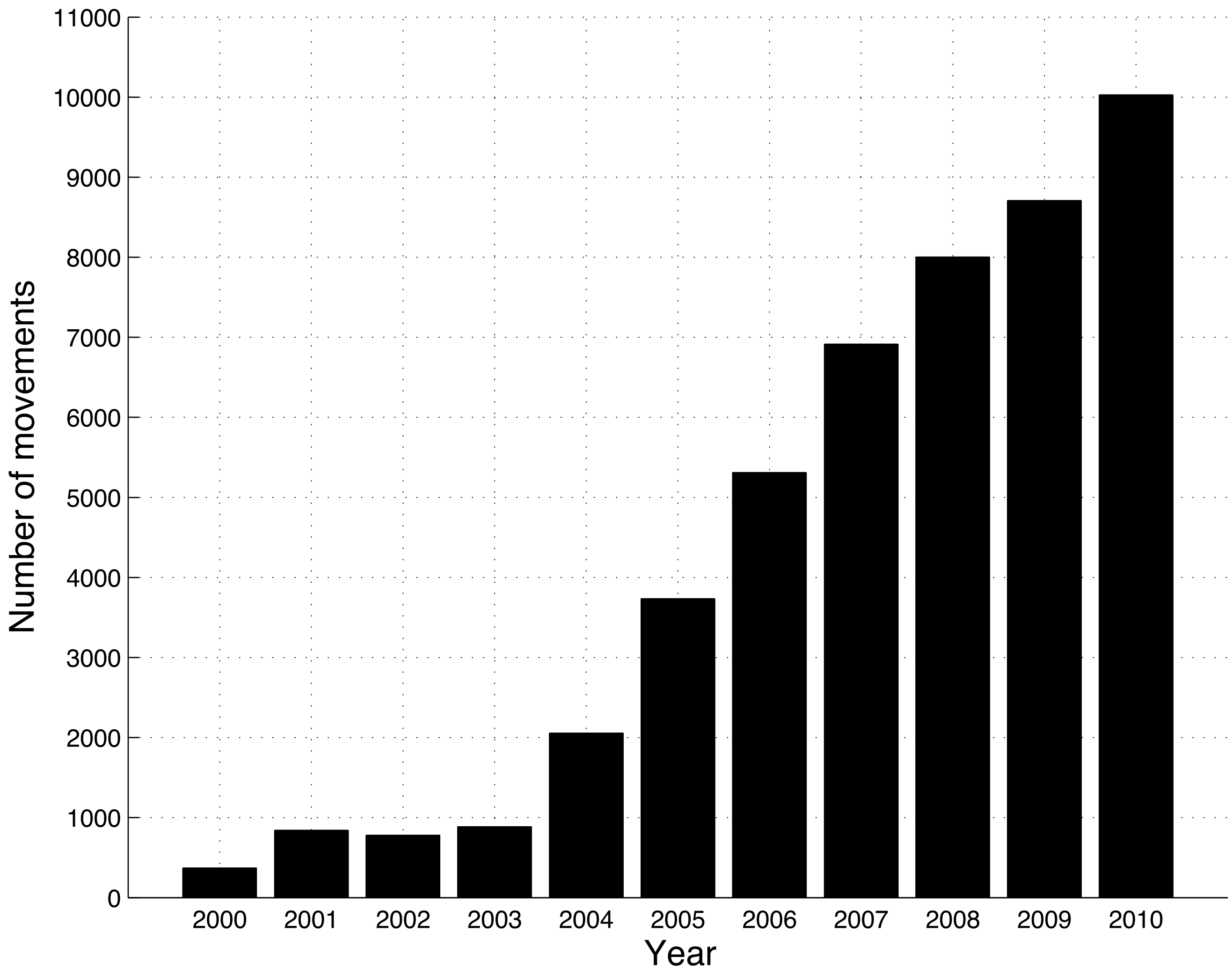
Assimilation of real-time inputs to the model – 2

- Patches
  - Intensity can be estimated from TEC data
  - Minimum number can be estimated from TEC data
  - Position of these can be estimated from TEC data
  - Cannot be certain that all patches are observed
- D-region absorption
  - Based on PCA models
  - Optimised using real-time riometer measurements

Concluding remarks

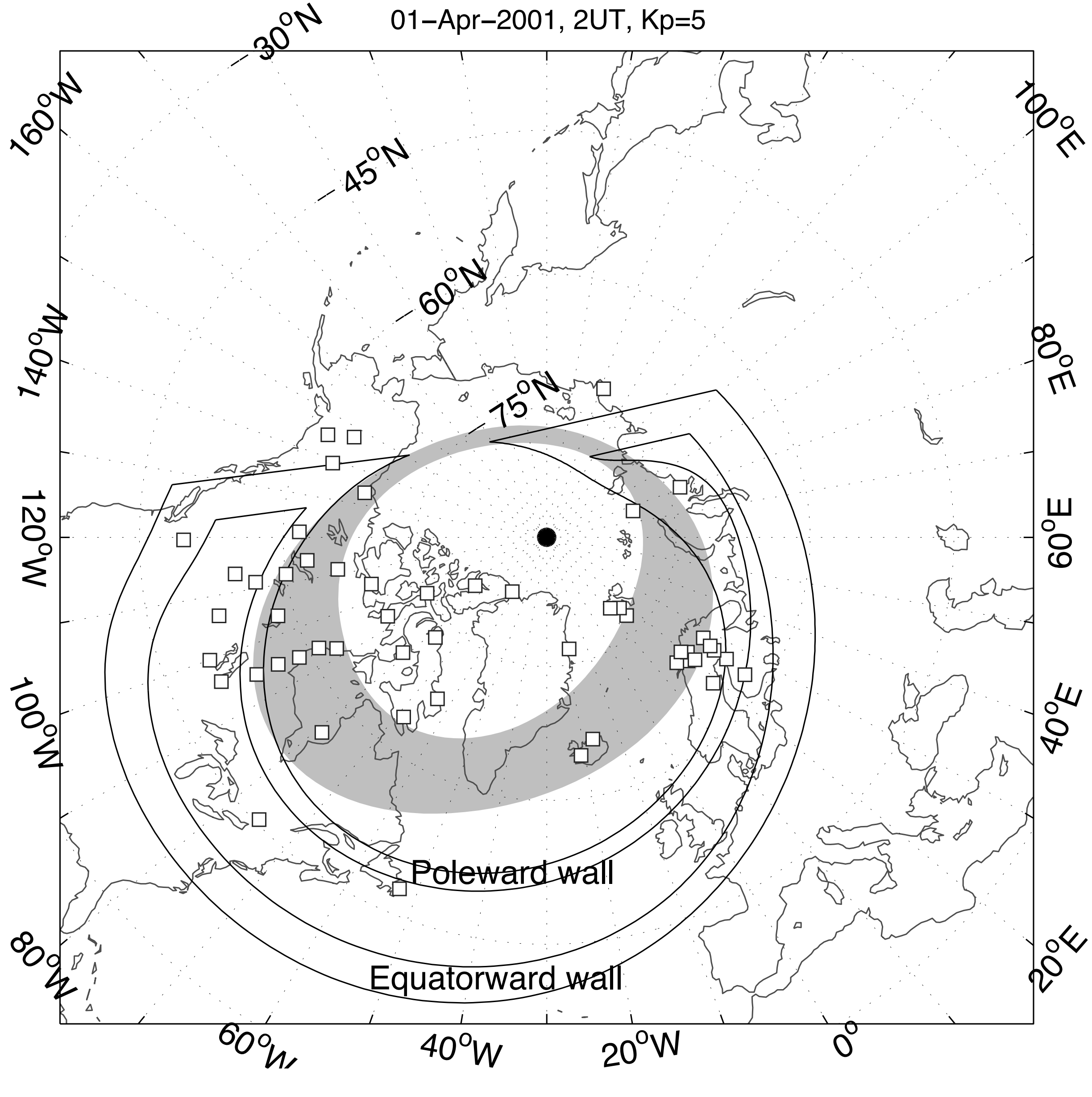
- Good fit to observations for coverage maps produced using historical data
- Are currently updating model to assimilate data from real-time sources – some challenges remain
- Aim is to be able to:
    - forecast HF propagation conditions up to 12 hours ahead
    - provide this information for airline despatchers

Cross-polar flights, 2000-2010

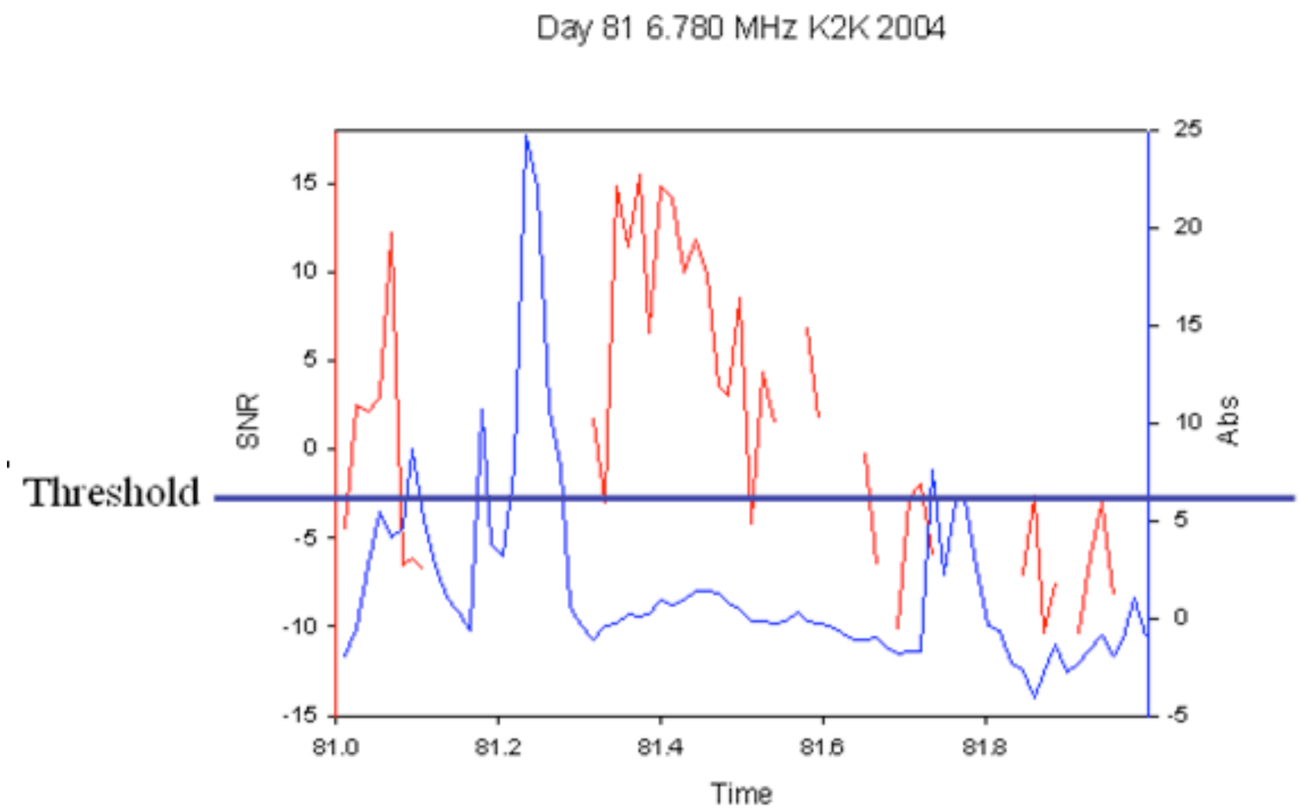


Absorption

Riometer sites



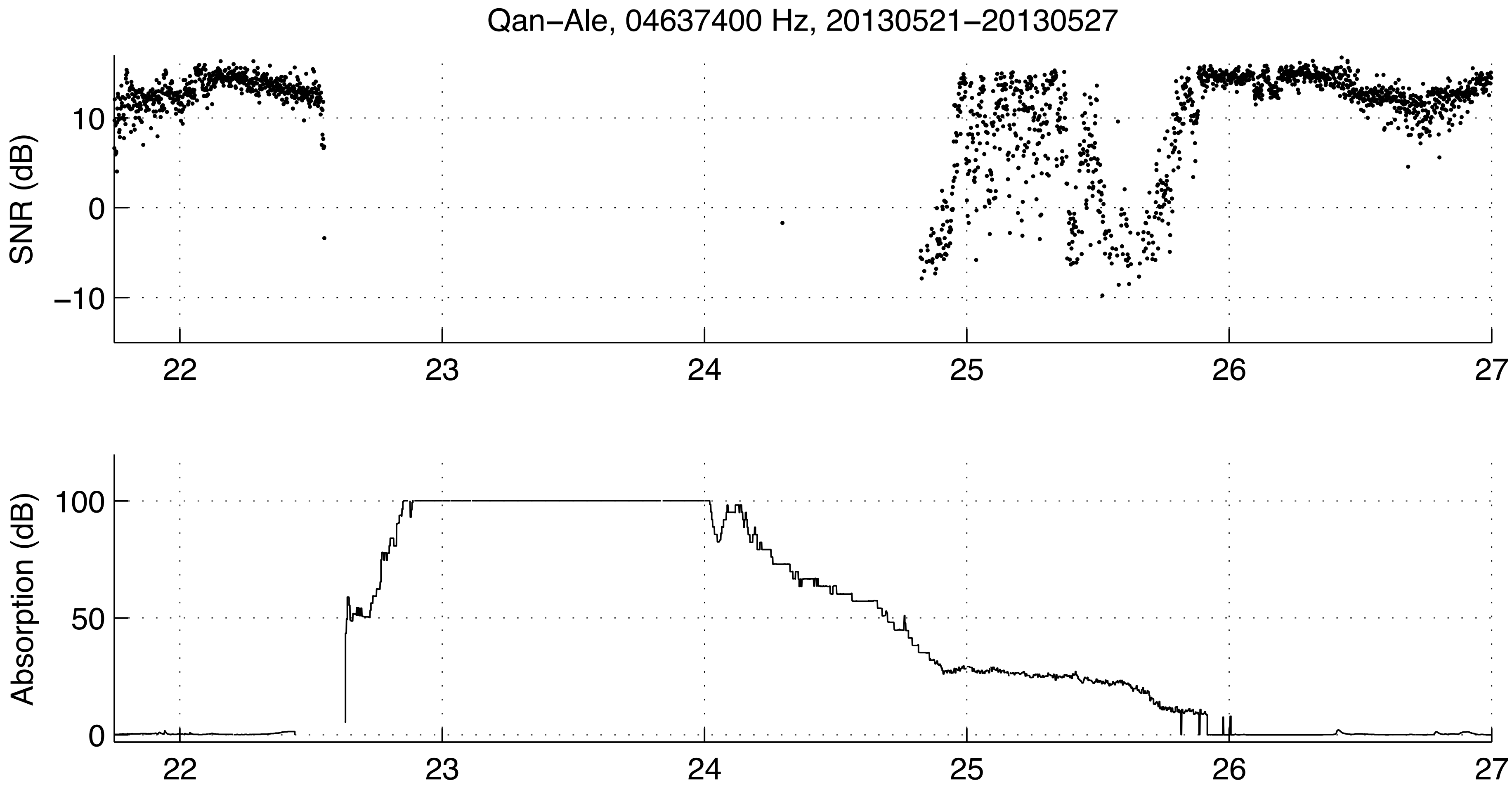
Absorption – HF and riometer measurements



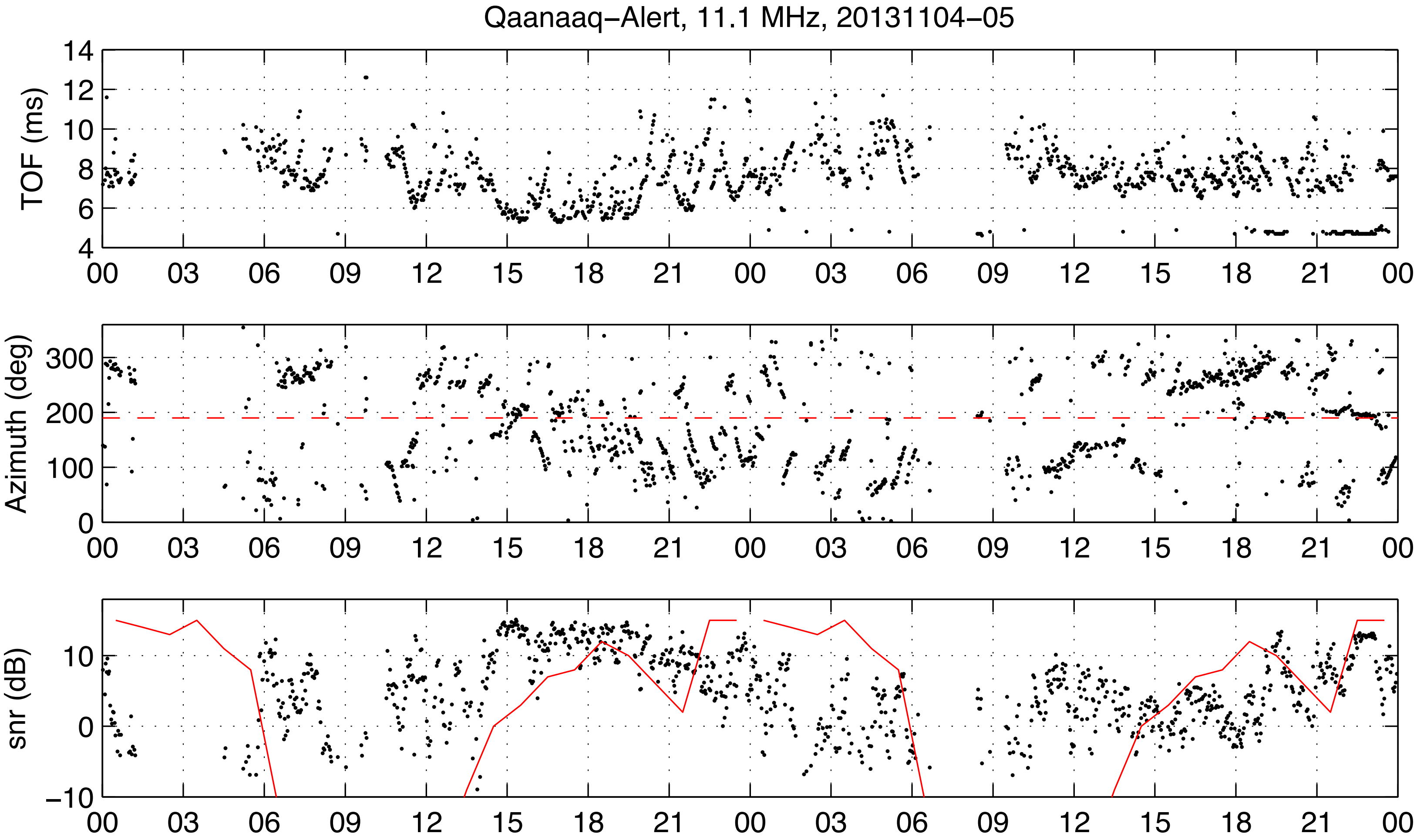
Signal-to-noise ratio on link between Kirkenes and Kiruna (440 km)

Riometer absorption scaled to 6.780 MHz.

Absorption – HF measurements and D-RAP predictions



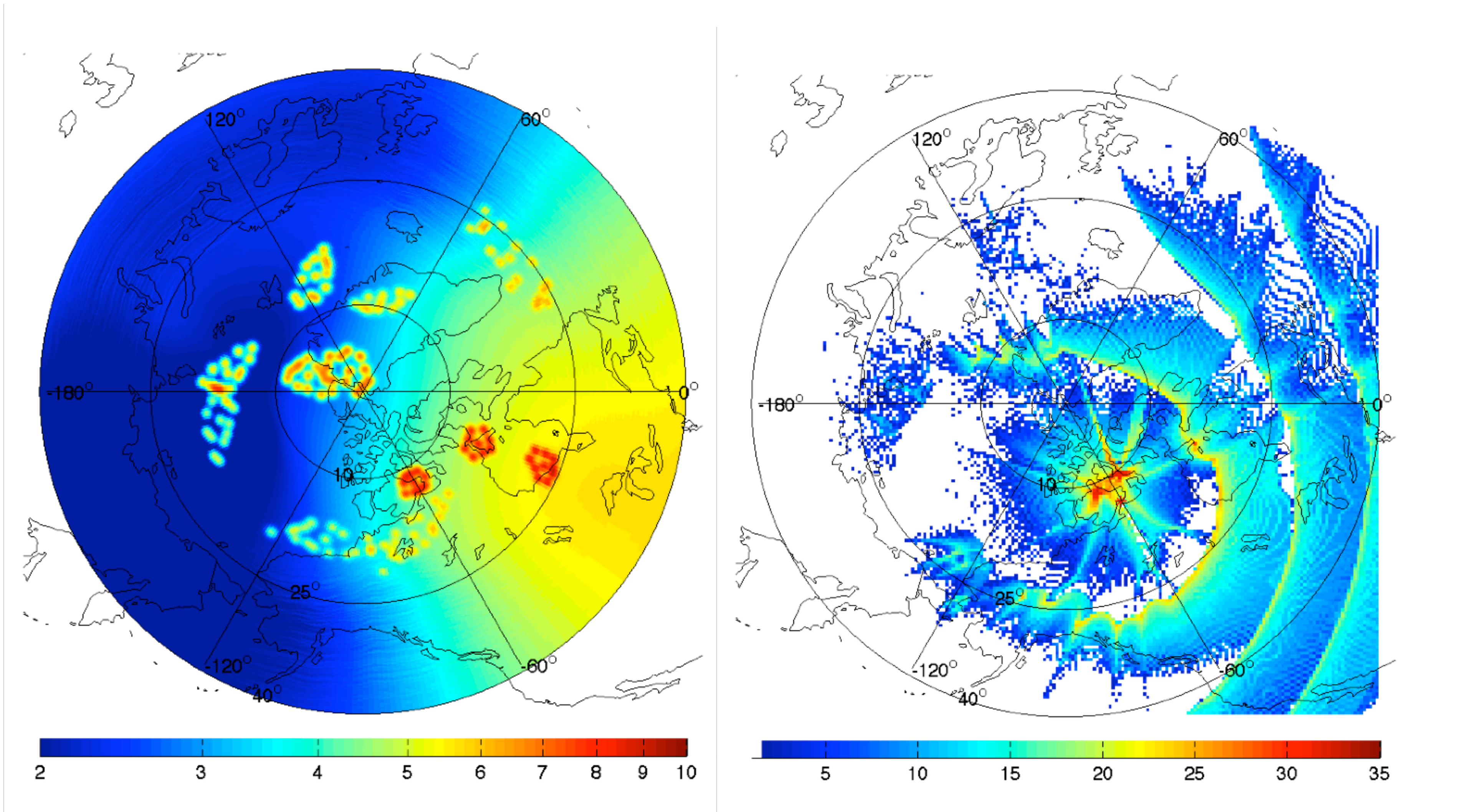
Example HF observations



Area coverage simulations

- Ray tracing model with realistic high latitude ionosphere
- To date, the simulations have been undertaken in relation to HF-DF, i.e. have been of the direction of arrival and time of flight of signals received over a fixed link.
- It is possible to undertake a very large number of ray traces to estimate the coverage area of a transmitter.

Currently incorporating absorption models and real-time inputs



F-region critical frequency (left) and area coverage of 12 MHz signal transmitted from Cambridge Bay (right) at 18 UT

Signalling effects

- Multipath spread: Multiple propagation paths from transmitter to receiver.
  - signal fading and reduced data rates in digital systems.

- Doppler spread: Ionospheric movements can lead to signals arriving with a range of Doppler shifts
  - reduced signal quality and data rates.

Observations as a function of solar activity (2001, and March 2009–July 2012)