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SolarMetrics

Space weather effects on airline HF radio communications in the high latitude regions

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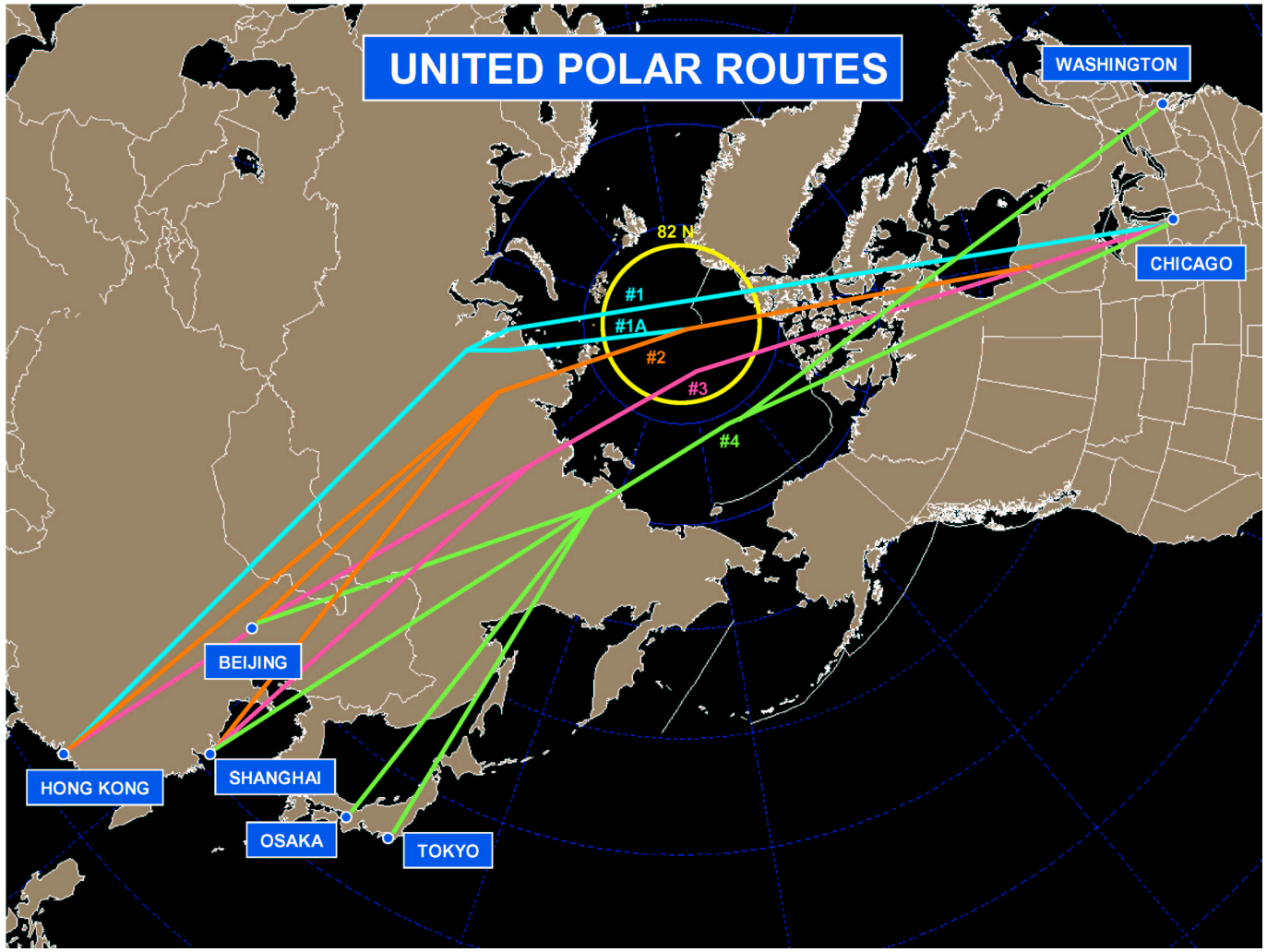
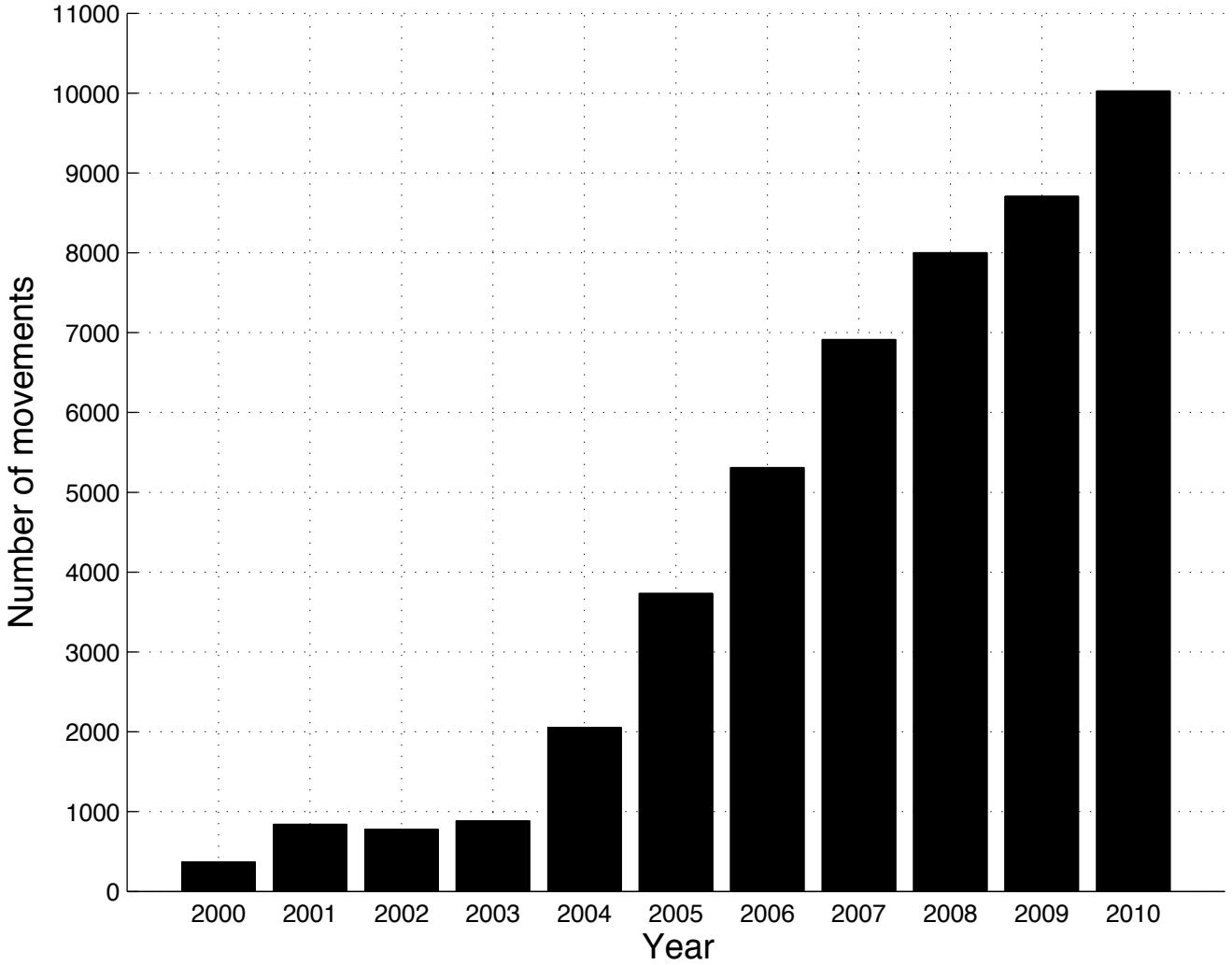
Airlines are increasingly using trans-polar routes as these provide more direct travel between some destinations.



Cross-polar flights, 2000-2010

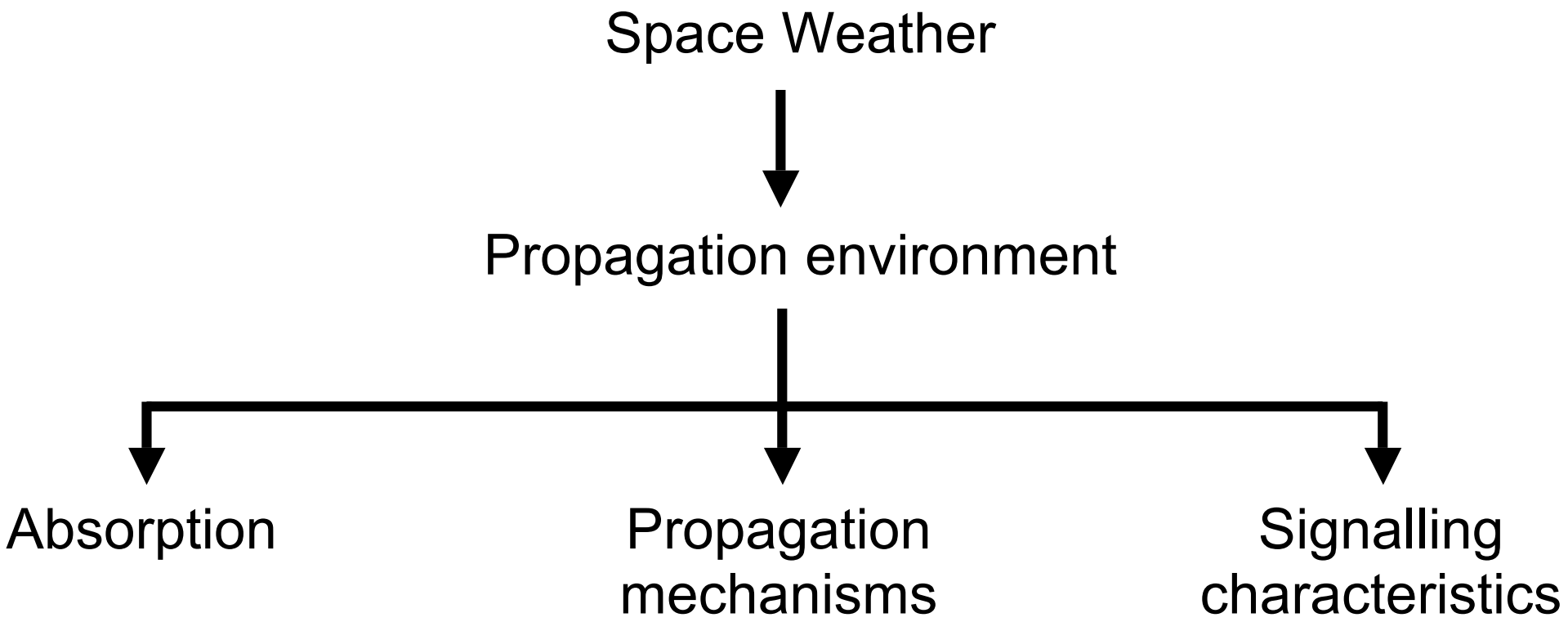


- For safe operations, commercial aircraft have to be able to communicate with air traffic control centres at all times.
- This communication is possible by VHF links whilst within range of the widespread network of ground stations and by HF links in remote areas.
- At times when HF communication fails, or is anticipated to fail, the aircraft are routed over more southerly paths with a consequent increase in flight time, fuel usage, and costs (e.g. direct costs of ~$40k; indirect costs ~$100k).

Space weather impact on air traffic control

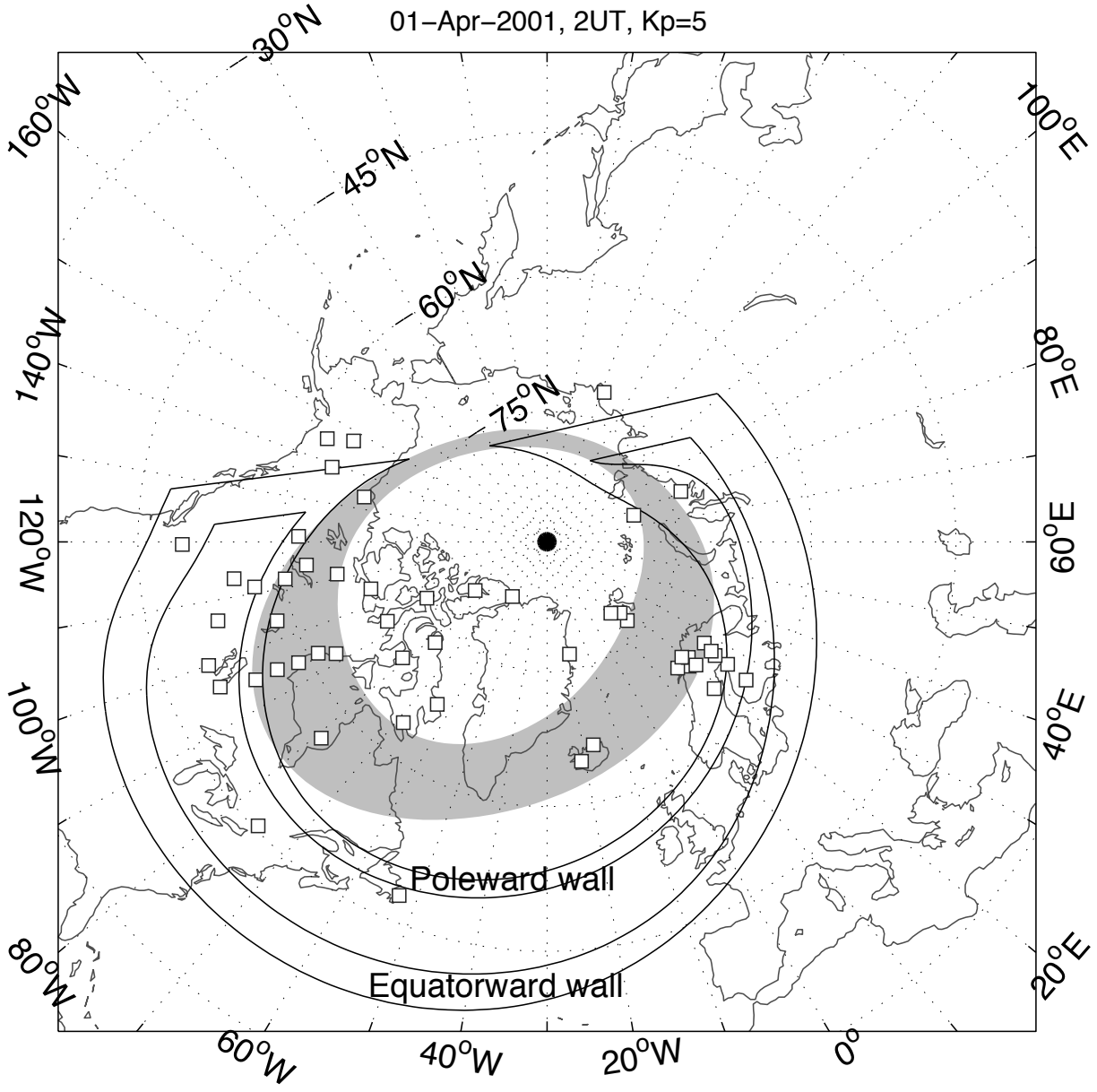
- At high latitudes, disturbances in the ionosphere can severely disrupt the ability of aircraft to stay in contact with air traffic control.
- Current HF forecasts are regarded by the airlines as inadequate for their needs.

A £1m project funded by the EPSRC and supported in-kind by NRC Canada to address this issue by improving the forecast methodology for HF communications in the polar regions.

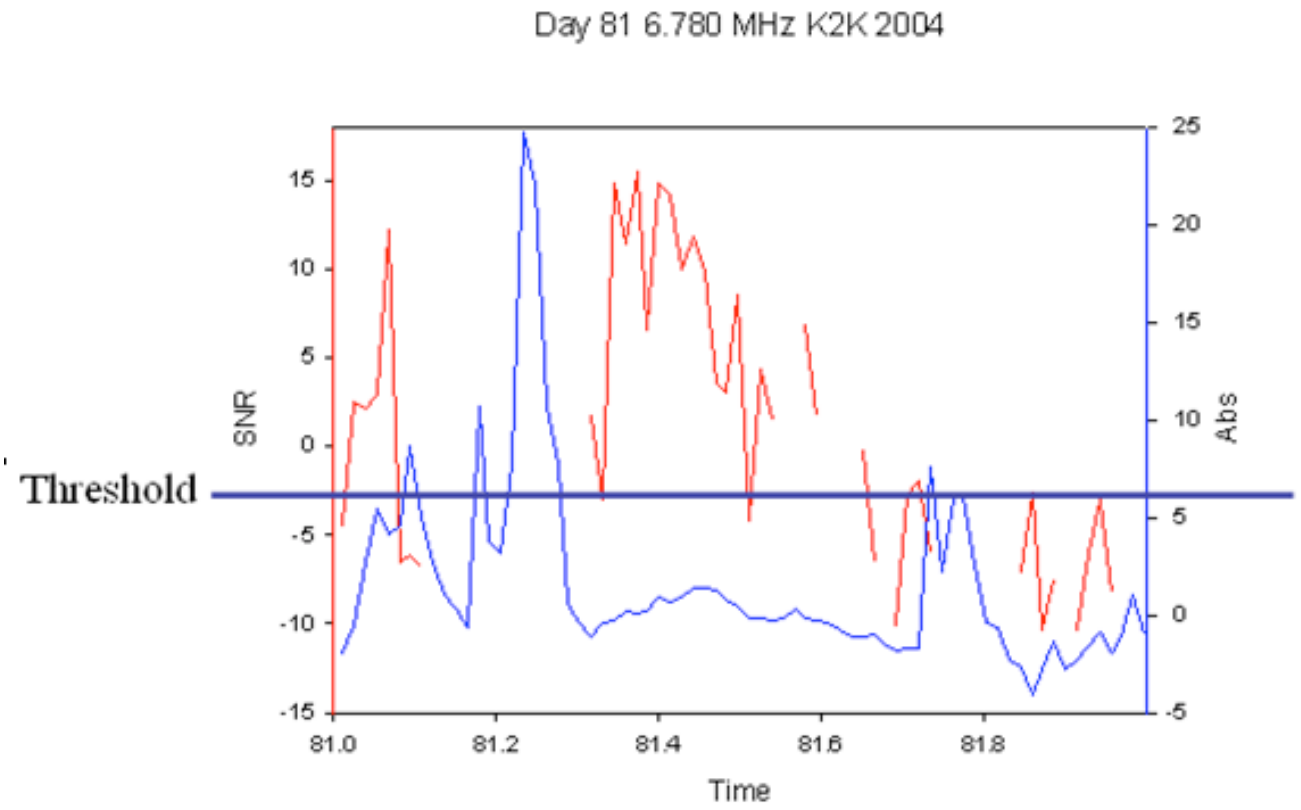

Space Weather
Propagation environment
Absorption
Propagation mechanisms
Signalling characteristics

Absorption (see poster by Rogers et al.)

Riometer sites



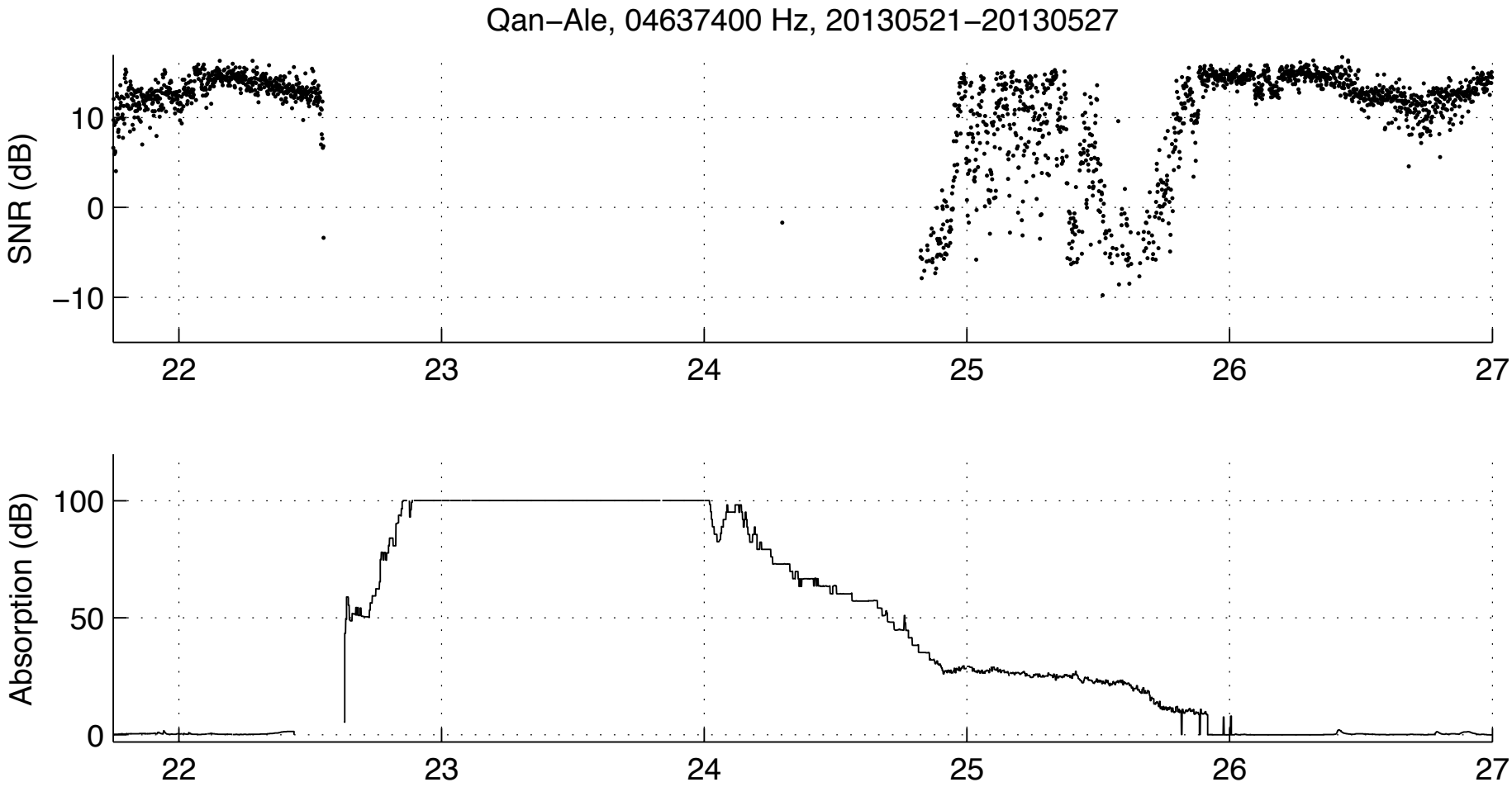
Absorption – HF and riometer measurements



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

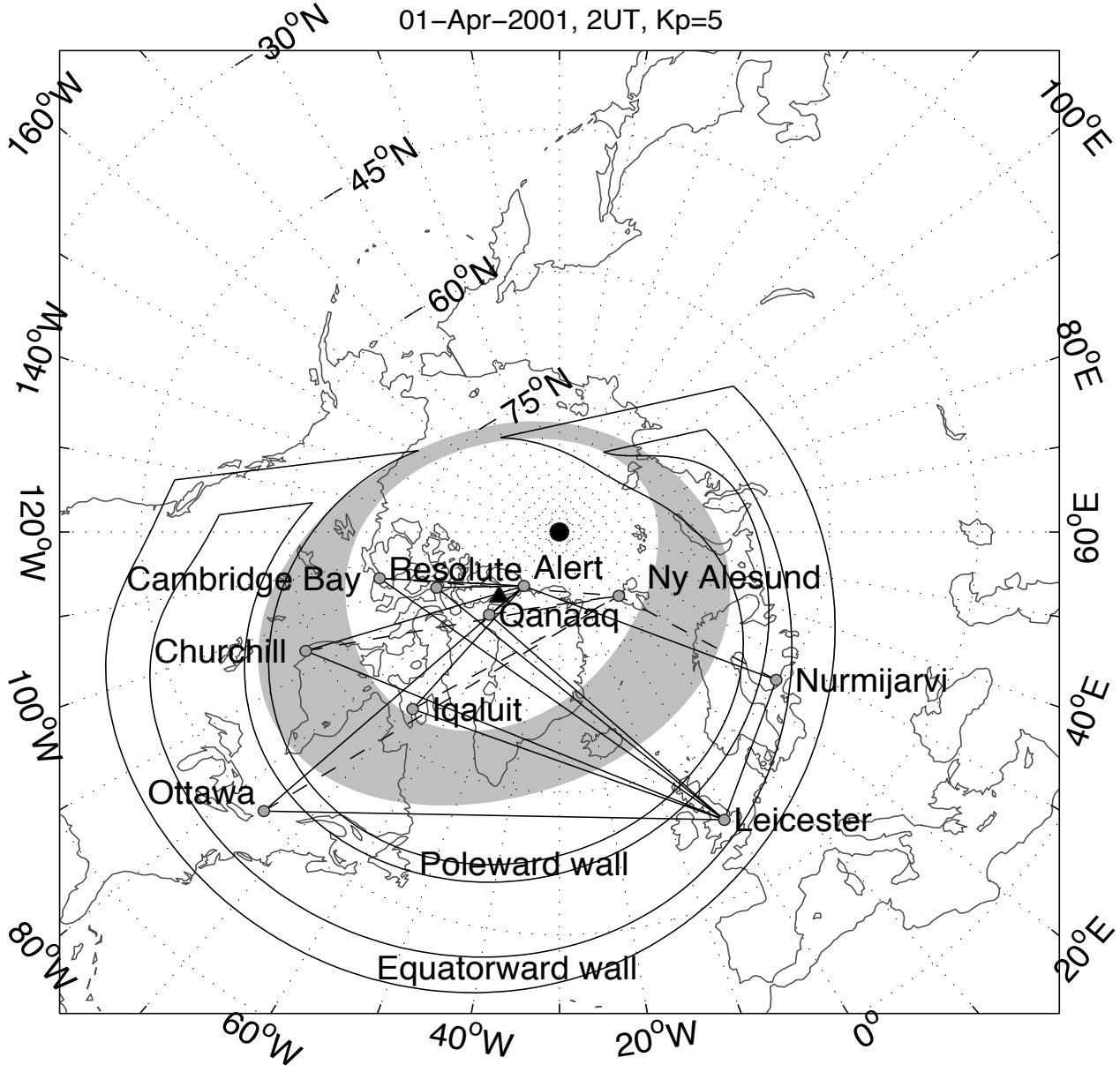


Propagation mechanisms

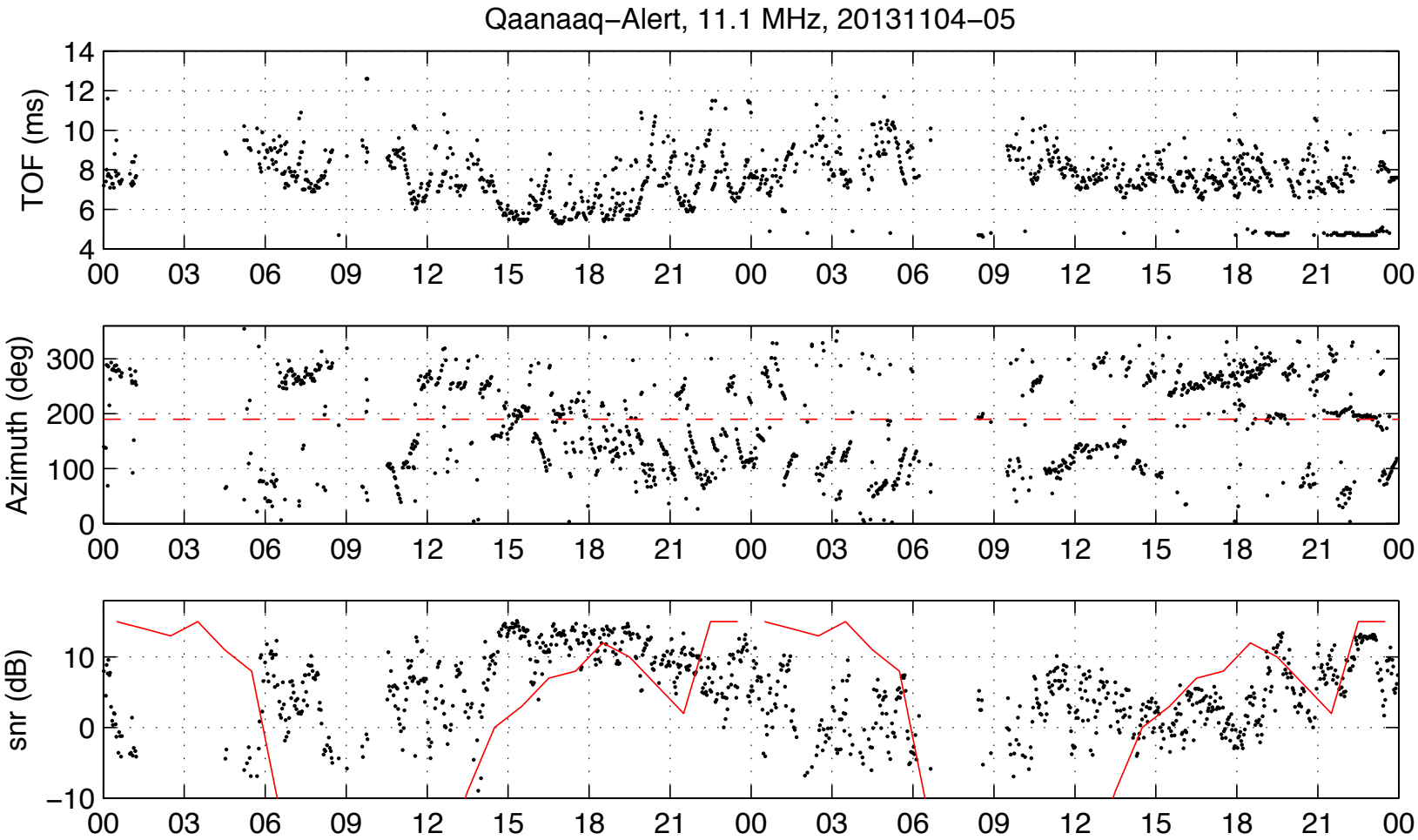
An extensive network of HF links

Measurements of:

- SNR
- Time of flight
- Direction
- Signalling



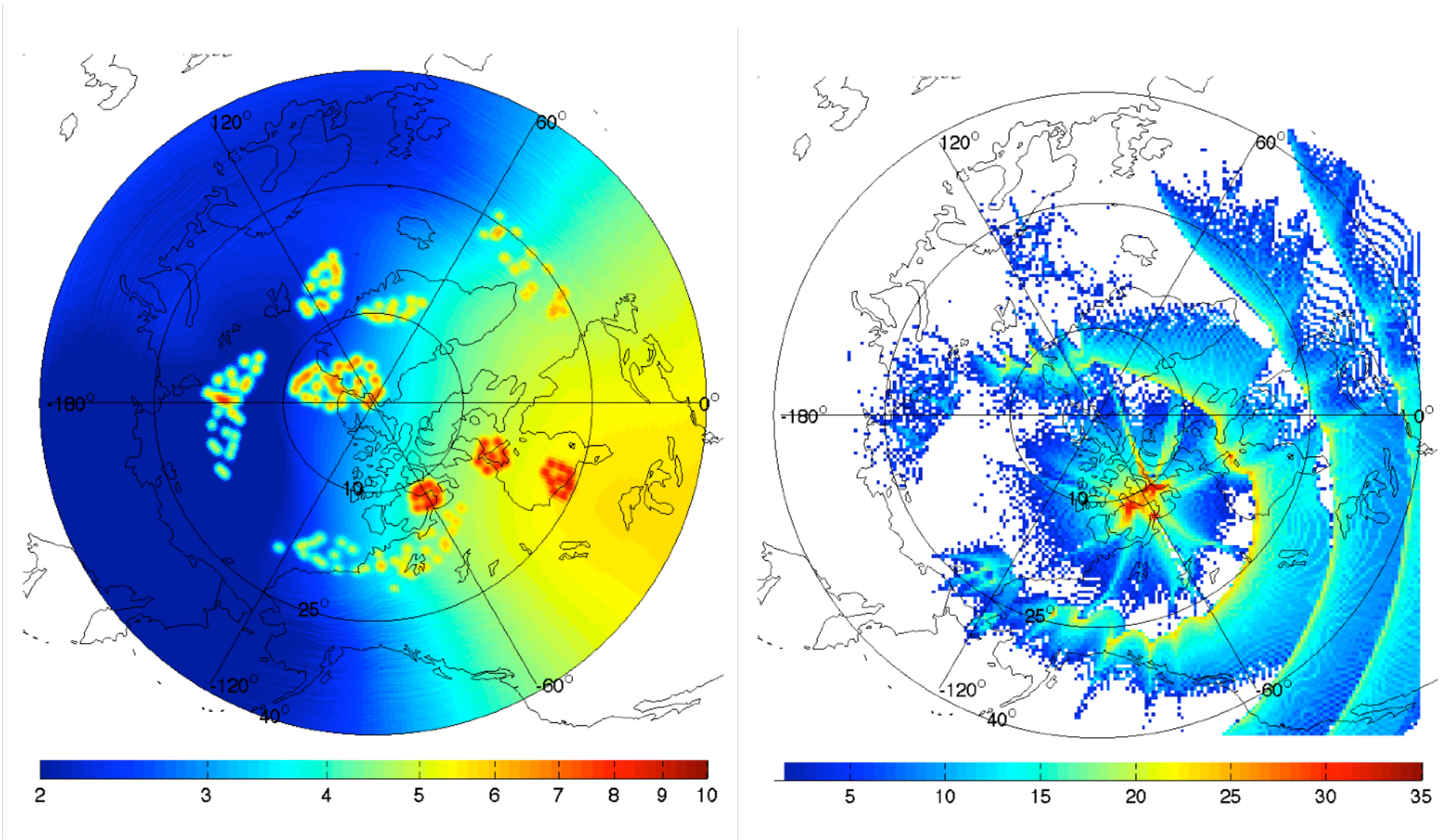
Example HF observations



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



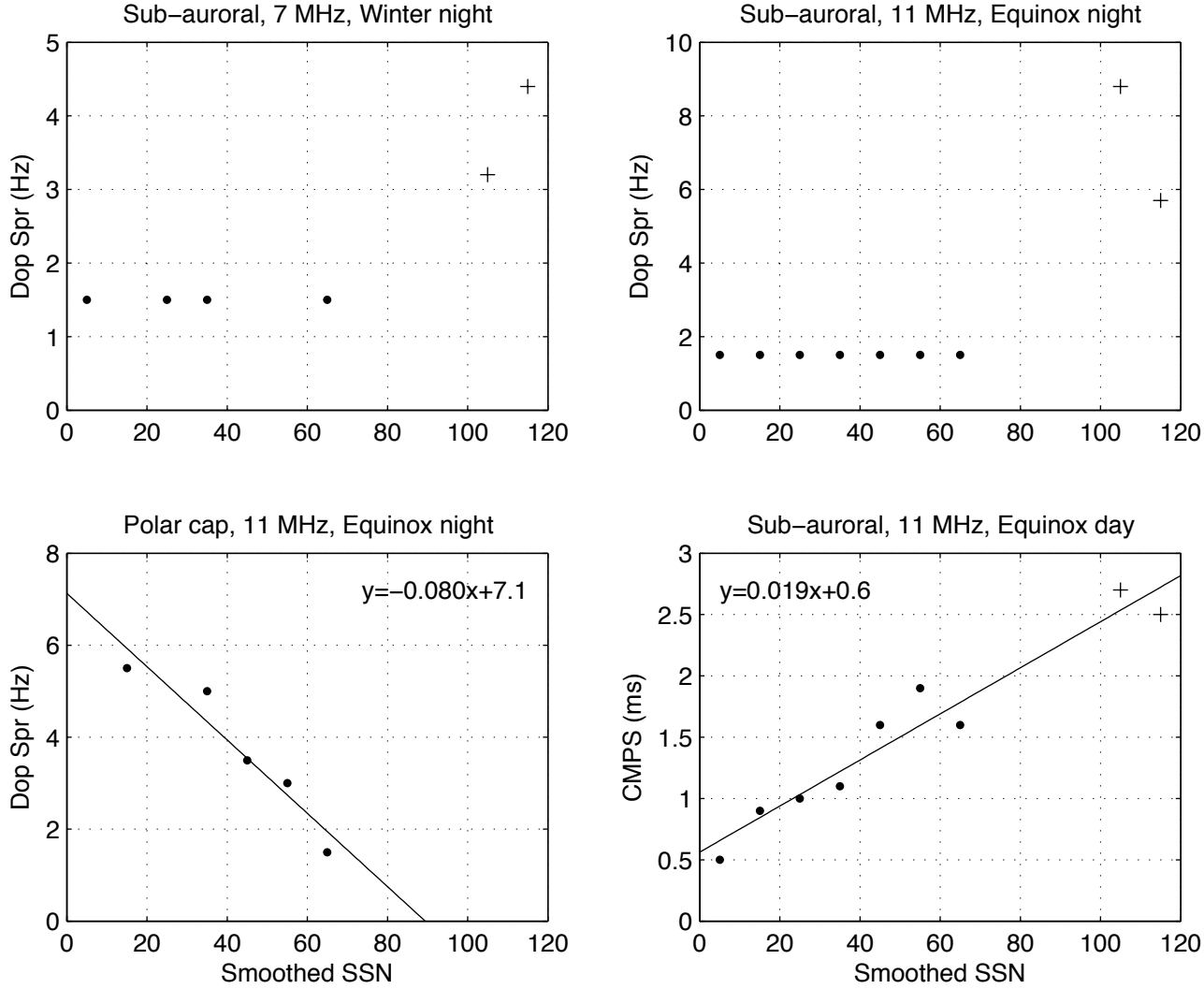
F-region critical frequency (left) and area coverage of 12 MHz signal transmitted from Cambridge Bay (right) at 18 UT

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)



CONCLUDING REMARKS

A new project to improve the forecast methodology for HF radio comms for trans-polar airline routing has begun.

- Extensive measurement campaign (absorption, propagation, and signalling characteristics are being measured)
- Simulations are likely to be able to provide statistical forecasts (i.e. probabilities of successful communications)

In addition to the financial impact, the potential to decrease fuel usage by operating trans-polar routes is highly relevant to current concerns over global warming.

Forecasts and nowcasts are issued

++++++++++++++++Impact on Air Traffic++++++++++++++++++

+++San Francisco Communications Center 19-10-2003+++

Reported solar activity having moderate-to-severe impact on all HF groups for over two hours.

An unknown number of ATC message deliveries to aircraft delayed.

Advisory was issued notifying customers of the possibility of disrupted HF communications.

The airlines act on them:

A major airline rerouted six polar flights to non-polar routes requiring fuel stops in Japan and/or Anchorage

Numerous other US flights rerouted or restricted

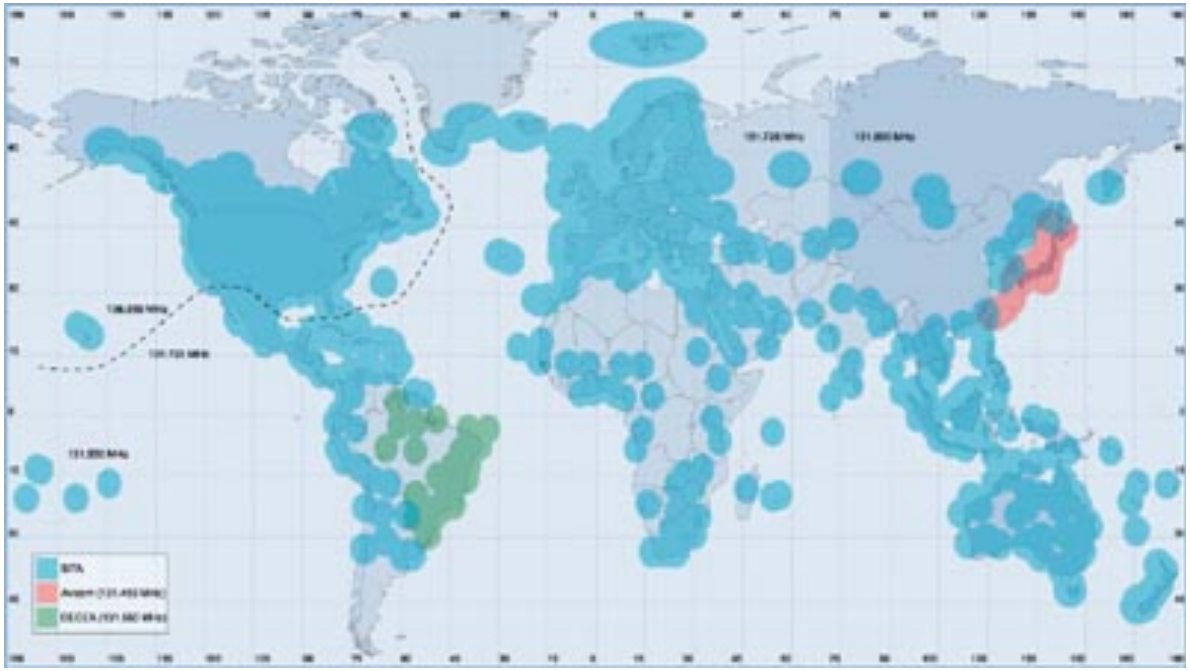
British controllers kept trans-Atlantic jets on more southerly routes than usual to avoid the communication problems

British Airways pilots deviated from the airline's flight plans and flew at lower altitudes amid concerns over health risks to passengers and crew from radiation

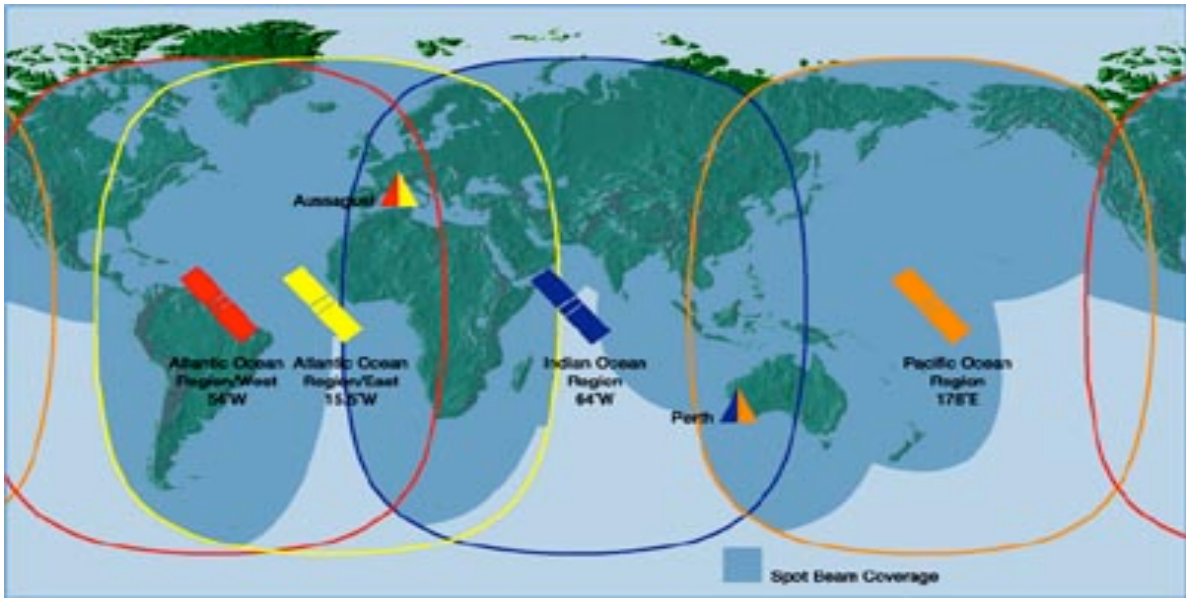
Sunday Times, 9 November 2003

Clearly important to be as accurate as possible, and not to be over-conservative.

Why is HF needed?

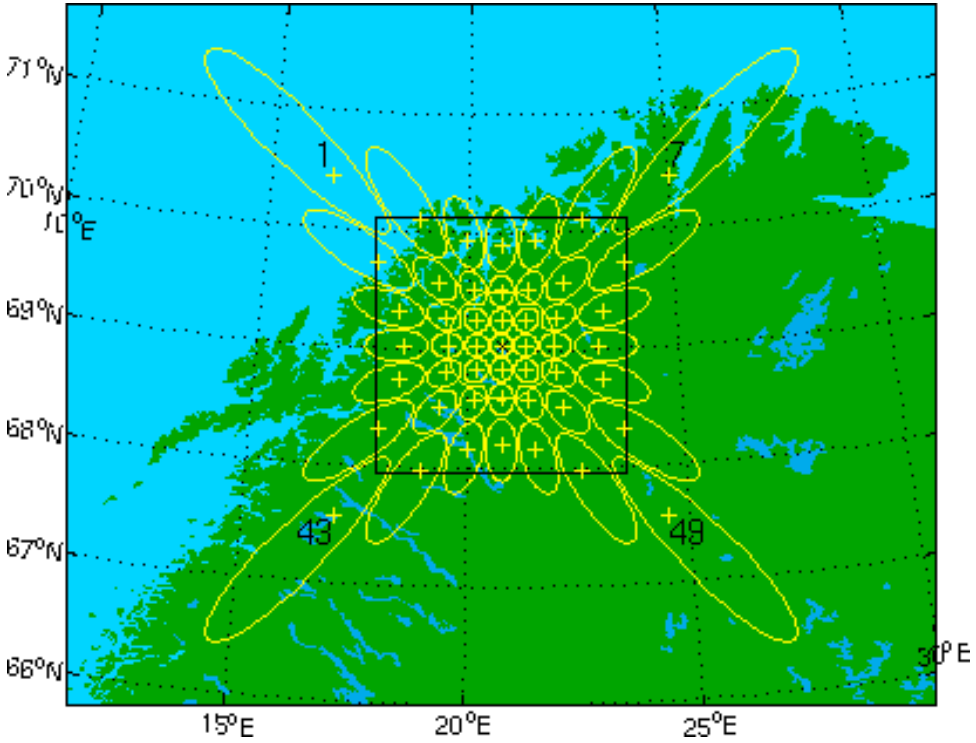


VHF coverage very limited in the high latitude regions

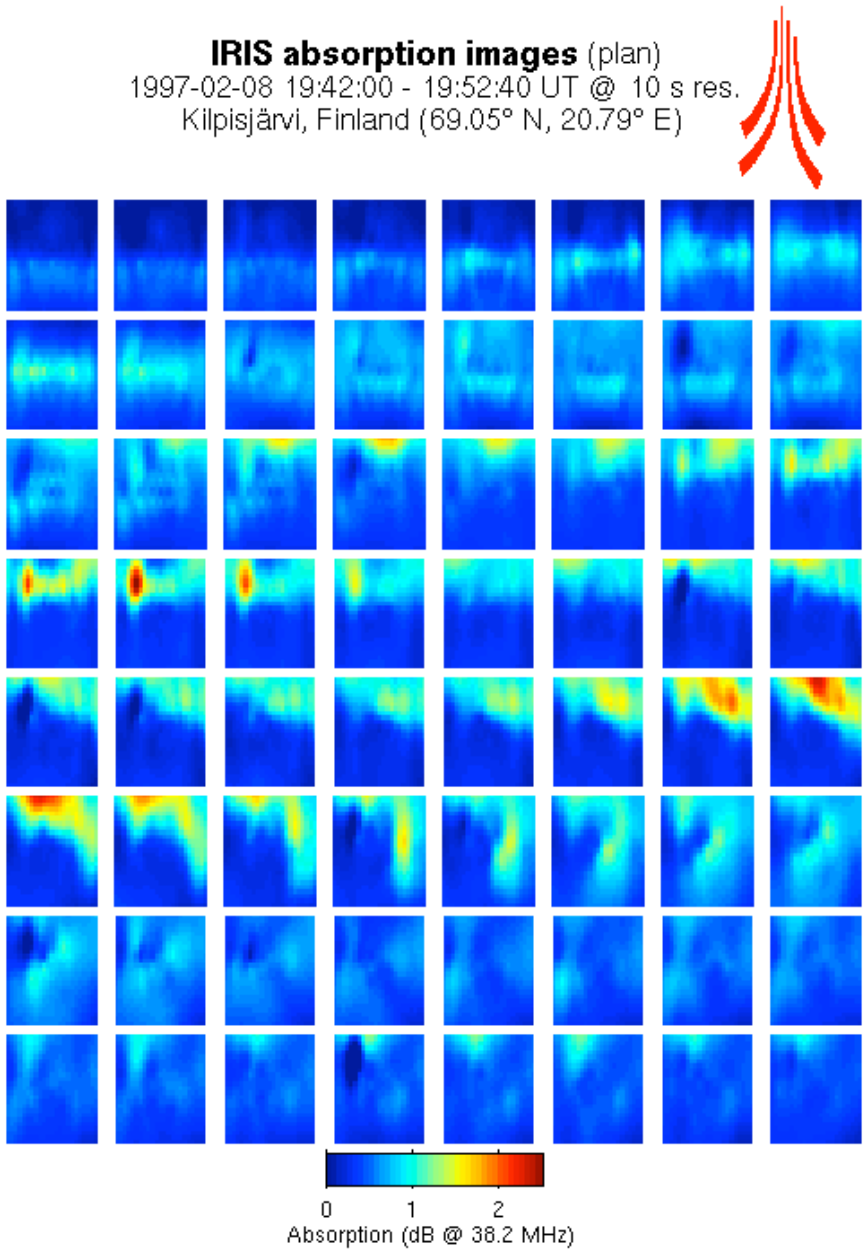


No geostationary satellite coverage near the poles

IRIS = **I**maging **R**iometer for **I**onospheric **S**tudies



Beam projection when mapped to 90km (normal measurement height).

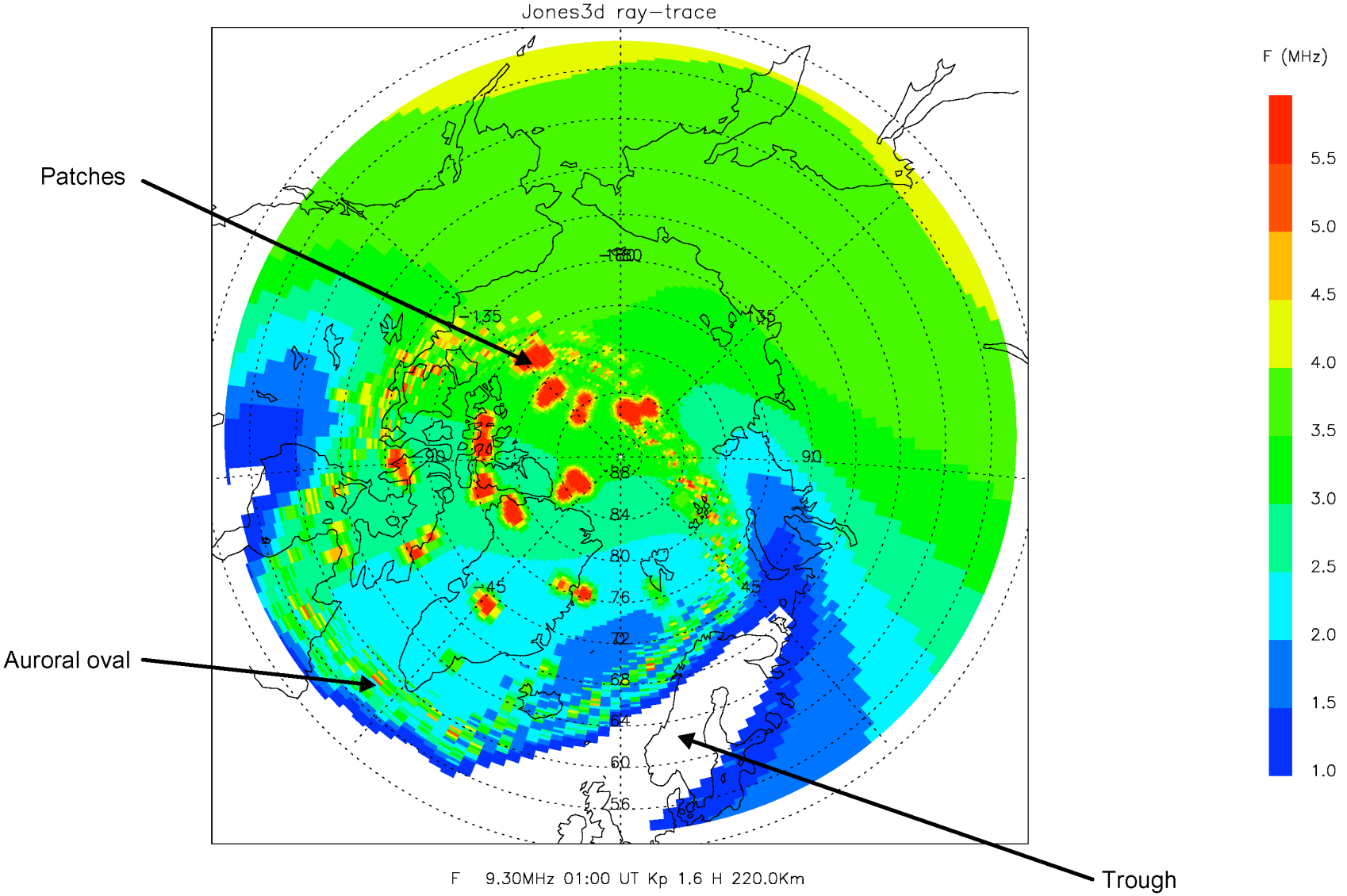

IRIS absorption images (plan)
1997-02-08 19:42:00 - 19:52:40 UT @ 10 s res.
Kilpisjärvi, Finland (69.05° N, 20.79° E)
0
1
2
Absorption (dB @ 38.2 MHz)

Description of Model

A comprehensive computational model of the high-latitude ionosphere has been developed which includes models of:

a) the background ionosphere,
b) electron density enhancements associated with patches and arcs in the polar cap area, coupled with a reasonable approximation of the convection flow patterns,
c) electron density irregularities in auroral oval region, and
d) the electron density distribution inside the mid-latitude trough.

Need to refine the model to be driven by real time data (where possible) and add absorption models.


Jones3d ray–trace
Patches
Auroral oval
Trough
F (MHz)
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
F 9.30MHz 01:00 UT Kp 1.6 H 220.0Km