

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

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Map of HF stations



Example measurements in the polar cap



Example simulation output



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)

GetArclonos cai 700×600 pixels

Lowell

DIGISONDE

29/04/2015 17:39

GetArclonos.cgi 700×600 pixels

Lowell Statio YYYY DAY DDD HHMM P1 FFS S AXN PPS IGA PS Tromso 2014 Oct17 290 1130 RSF 1 715 100 22+ A1 DIGISONDE 640 9.150 foF2 foFl N/A 600 -N/A foFlp w foE N/A foEp 1.92 Vo+ 550 fxI 10.10 10 foEs N/A fmin 3.50 500 · MUF(D) 30.82 M(D) 3.37 NNW 450 D 3000.0 h`F 221.0 M/A h`F2 400 h`Ε N/A N/A h`Es 350 hmF2 245.0 ý hmFl N/A hmE 110.0 300 yF2 62.0 yF1 N/A γE 20.0 250 БO 67.1 B1 1.79 200 35 C-level 150 -80 10 11 12 13 2 3 5 6 7 8 9 14 15 16 - 1 - 4 D



640 foF2 5.300 foFl N/A 600 · foFlp N/A w foE N/A Vn. foEp .35 Vo+ 550 · fxI 6.25 1.23 foEs 4.55 fmin 1.80 500 -MUF(D) 15.22 M(D) 2.87 NNW 450 · D 3000.0 h`F 288.0 h`F2 N/A 400 h`E N/A h`Es 110.0 350 hmF2 338.8 hmFl N/A hmE 110.0 300 yF2 76.1 yF1 N/A -34 γE 20.0 250 БO 67.6 B1 3.70 200 · C-level 15 150 80 5 100 200 400 600 800 1000 1500 3000 [km]

Statio YYYY DAY DDD HHMM P1 FFS S AXN PPS IGA PS Tromso 2014 Oct17 290 2330 RSF 1 715 100 22+ B2

MUF 6.0 6.0 6.2 6.6 7.1 7.8 9.9 15.2 [MHz] TR169_2014290233000.R3F / 160fx128h 50 kHz 5.0 km / DP3-4 TR169 070 / 69.6 W 19.2 E

Ion2Png v. 1.1.02

29/04/2015 12:38

1130 UT



8

Assimilation of real-time inputs to the model – 1

- Background ionosphere
 - $_{\odot}\,\text{Structure}$ 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
 - \circ 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 realtime sources – some challenges remain
- Aim is to be able to:

o forecast HF propagation conditions up to 12 hours ahead
 o provide this information for airline despatchers

Cross-polar flights, 2000-2010







Absorption – HF and riometer measurements



Day 81 6.780 MHz K2K 2004

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.

o signal fading and reduced data rates in digital systems.

 Doppler spread: lonospheric 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)

