Toward a development of NICT radio propagation simulator

Kornyanat Watthanasangmechai, Takashi Maruyama,
Tsutomu Nagatsuma*, Mamoru Ishii,
and Takuya Tsugawa (NICT)

Literature review

➢ A number of researches on ionospheric effect on a radio propagation were done in mid-latitude.

- o Propagation of large amplitude ionospheric disturbances with Velocity dispersion observed by the SuperDARN Hokkaido radar after the 2011 off the Pacific coast of Tohoku Earthquake (Nishitani et al., 2011; EPS letter).

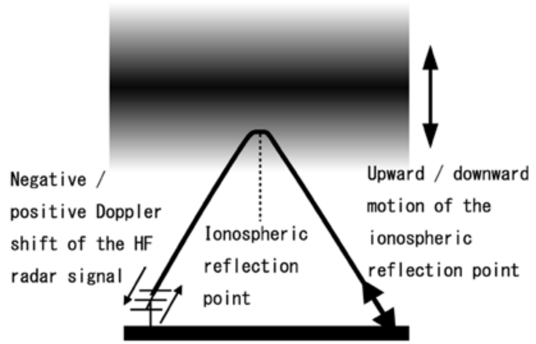


Fig. 2. Working geometry of the HF radar observing the effect of the upward/downward motion of the ionospheric reflection point (modified from Hayashi *et al.*, 2010).

[Nishitani et al., 2011; EPS letter]

- o SuperDARN radar HF propagation and absorption response to the substorm expansion phase (Gauld et al., 2002; AnnGeo).

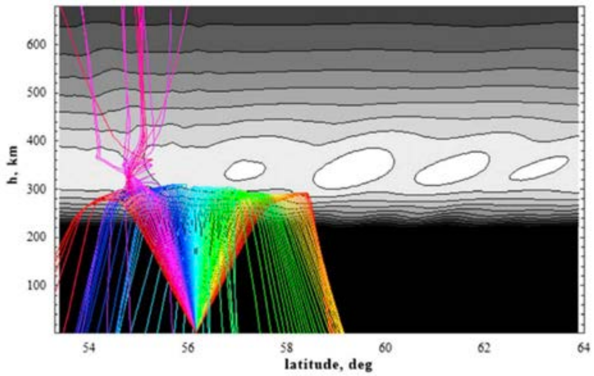


Figure 5. The ray structure for the pump wave (O-mode, f_{PW} = 4.785 MHz) and electron density distribution shown in Figure 4. Initial angles of the rays are coded with colors.

[Andreeva et al., 2016; Radio Sci.]

- o Radiotomography and HF ray tracing of the artificially disturbed ionosphere above the Sura heating facility (Andreeva et al., 2016; Radio Sci.)

➢ Radio propagation simulator can clarify the wave structure propagating trough or reflected from the ionospheric disturbances.

Literature review

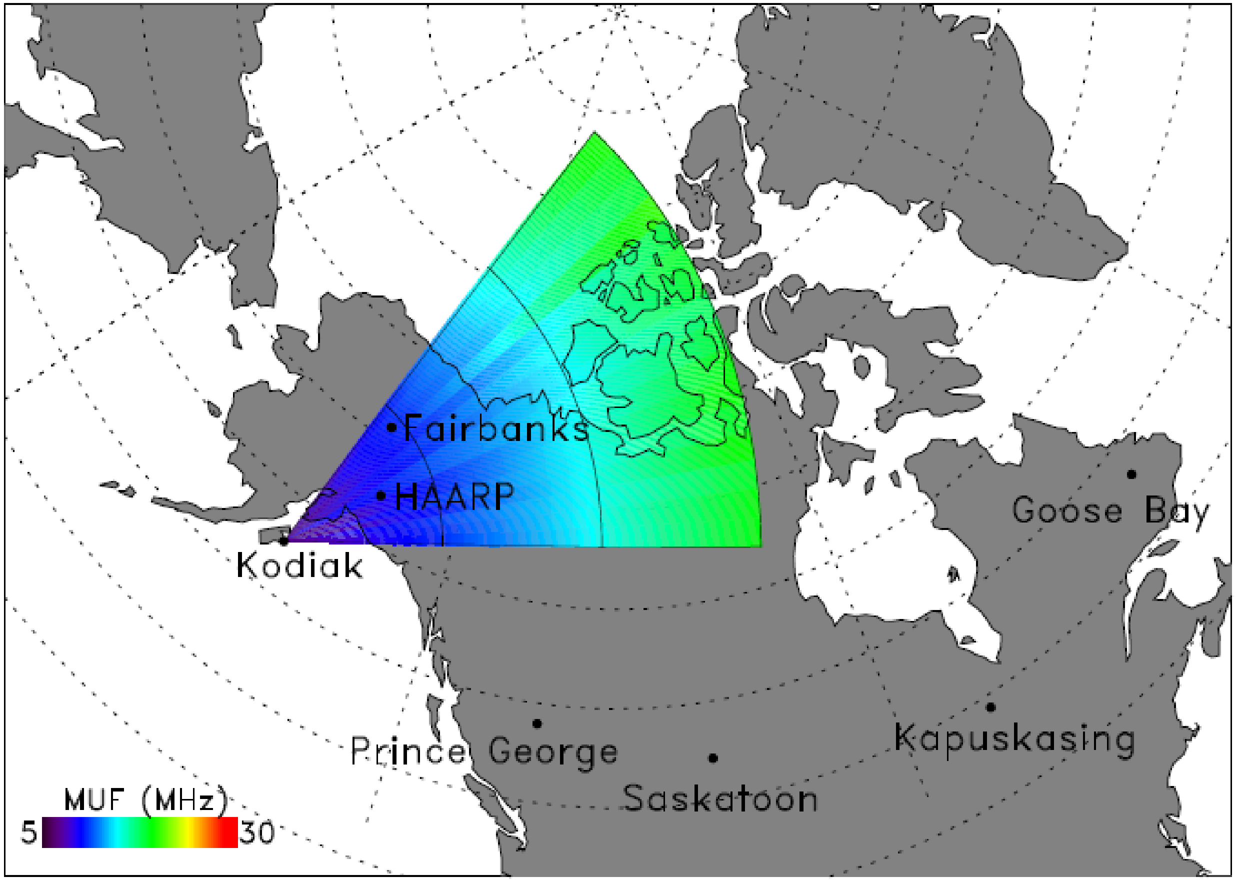
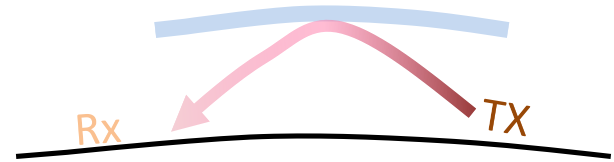


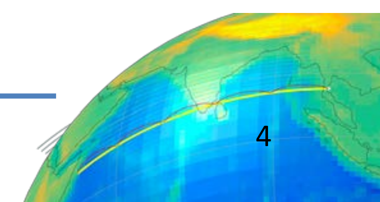
Fig. 2. Maximum usable frequency as a function of ground range over the Kodiak SuperDARN radar field-of-view obtained using ground-scatter data recorded on 23 June 2001 from 22:39–22:55 UT. For any point in the field-of-view, the color scale indicates the best-fit value of MUF for HF communications between that location and the Kodiak radar site.

[Hughes et al., 2002]

Introduction



- NICT has recently been developing a radio propagation simulator based on ray tracing method.
- The main targeting frequencies are in the HF band.
- Because radio waves in HF band can be reflected back to the Earth by the ionosphere layer, ionospheric variation and its irregularities directly play an important role on availability, integrity, and reliability of the HF sky-wave communication.
- This paper reports an integration of ionospheric knowledge on the simulator, and its preliminary result.
- Future plan regarding to the simulator will be introduced.



Methodology

Conceptual diagram

Observational data

Electron density data (3D tomography)

E_s layer & spread-*F* (ionosonde)

Model data

Altitudinal profile from model (IRI/ GAIA/ NeQuick)

N×N matrix calculation

↑

Point-to-point calculation

↑

Ray-tracing

Radio propagation simulator

- Confined TEC
- User-defined frequency
- Plasma bubble effect simulator

- **3D ray tracing algorithm**
- **Differential equations with Hamiltonian formalism.**
- **Simulator is written in GNU Fortran.**
- **Output is written in MATLAB.**

Short wave

Point-to-point
- Path length
- Propagation delay
- Refractive index

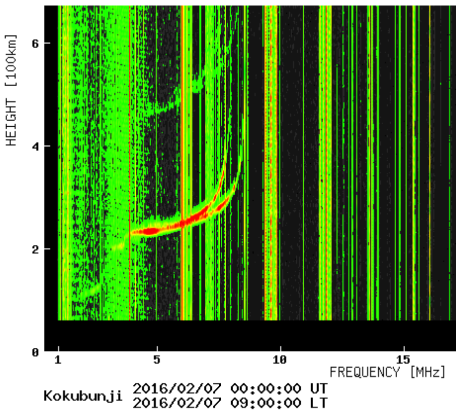
Coverage area map

Target: **1. To evaluate the ionospheric effect on shortwave communications.**
2. To clarify the location of plasma bubble in low latitudes.

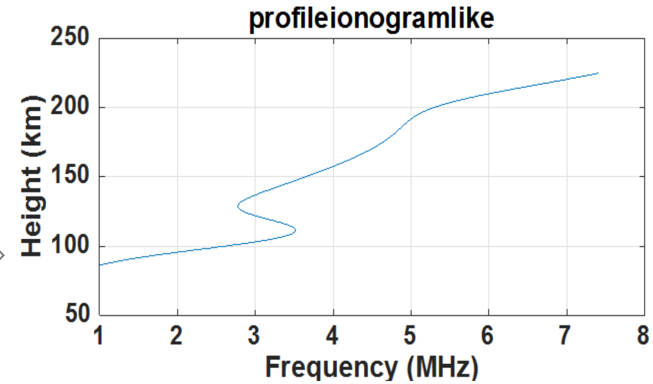
Preliminary results

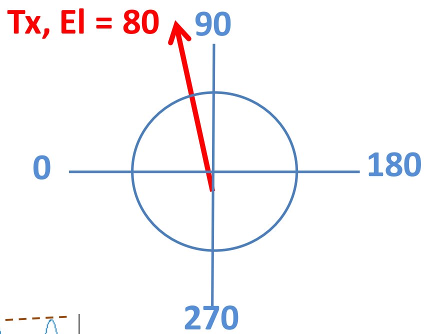
Tx: Elevation angle = 80

Ionospheric background



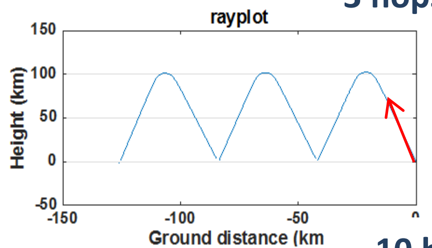
Reconstruct profile



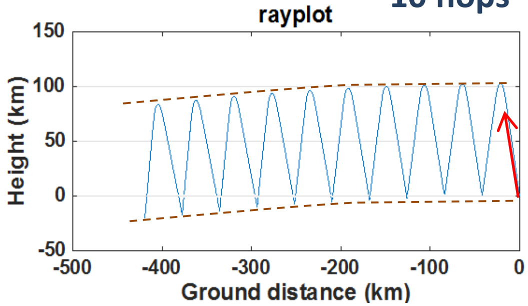


- 3MHz

3 hops

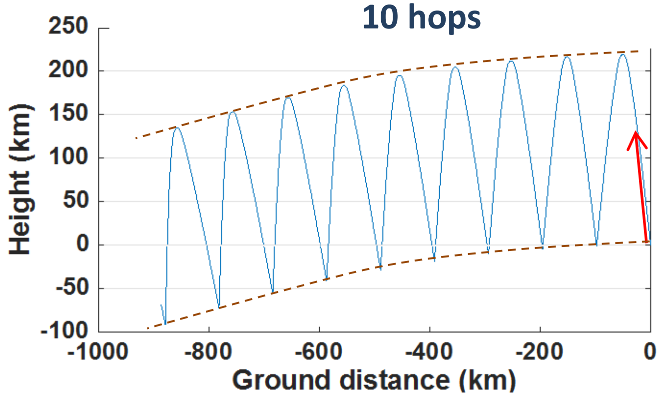


10 hops

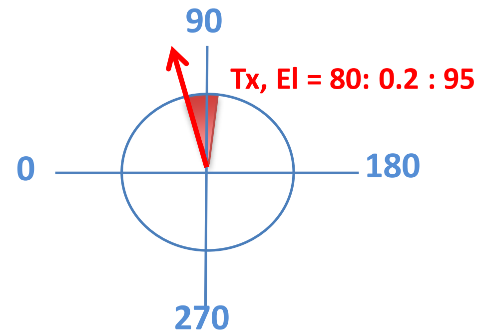


- 7MHz

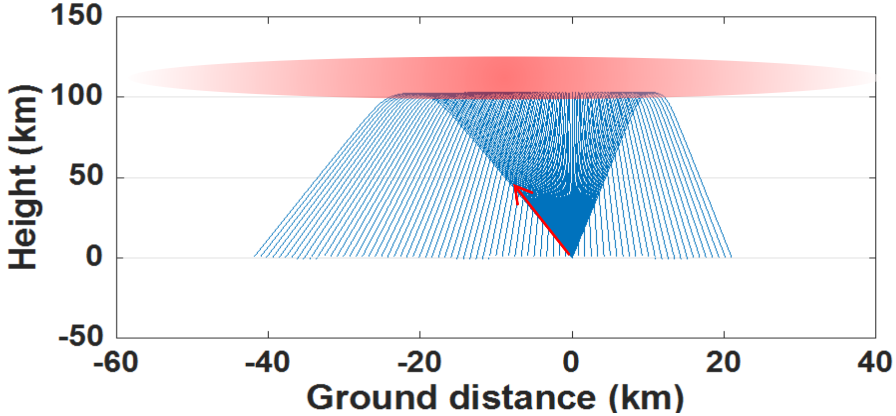
10 hops

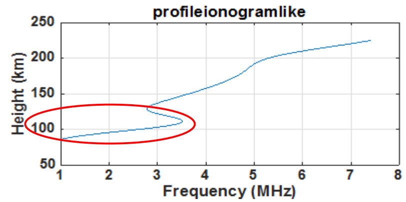


3 MHz, Elevation angle = 80 : 0.2 : 95

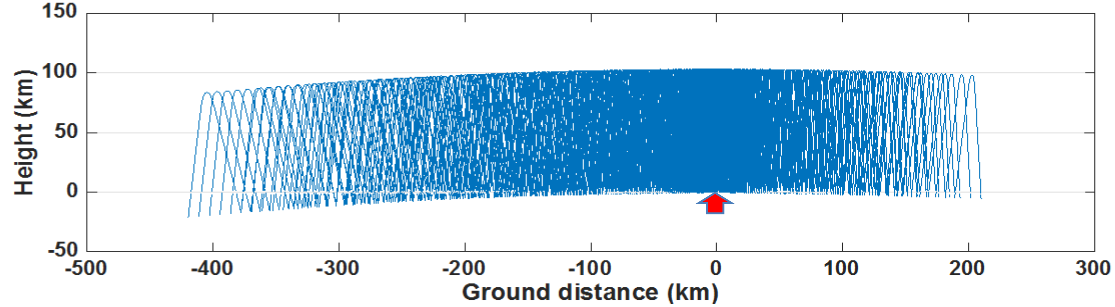


1 hop, with E layer

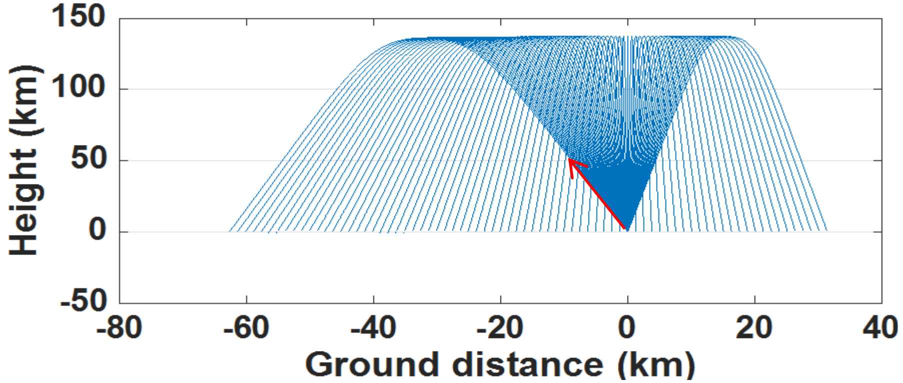


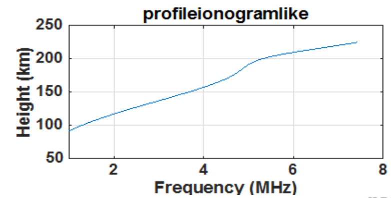


10 hops, with E layer

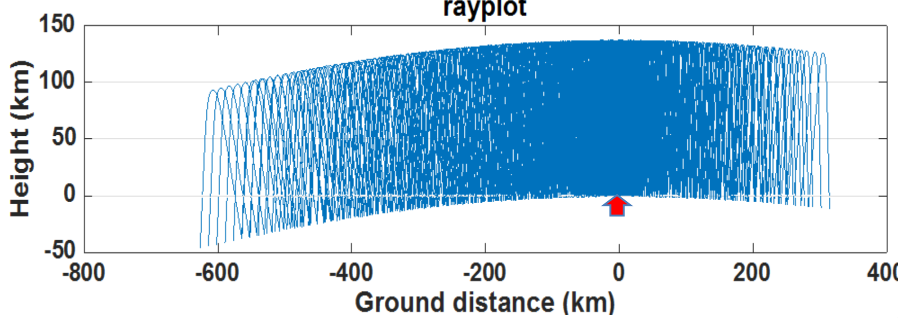


1 hop, without E layer



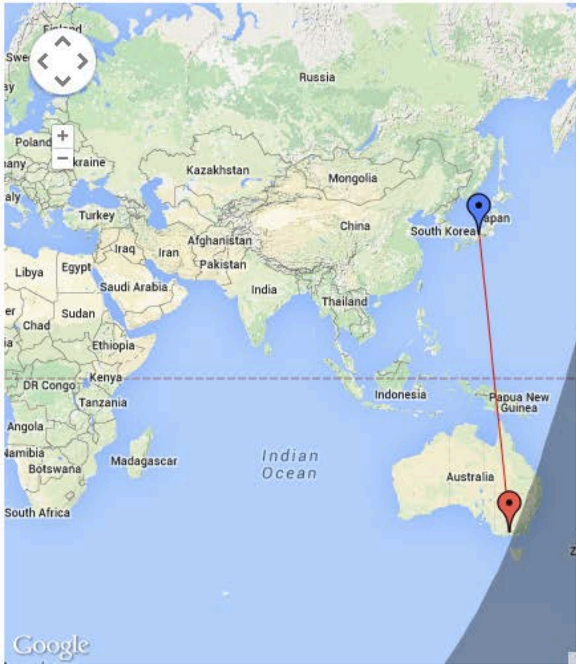


10 hops, without E layer



Next step: Full wave simulation, VOACAP-like user interface

Example of point-to-point circuit reliability



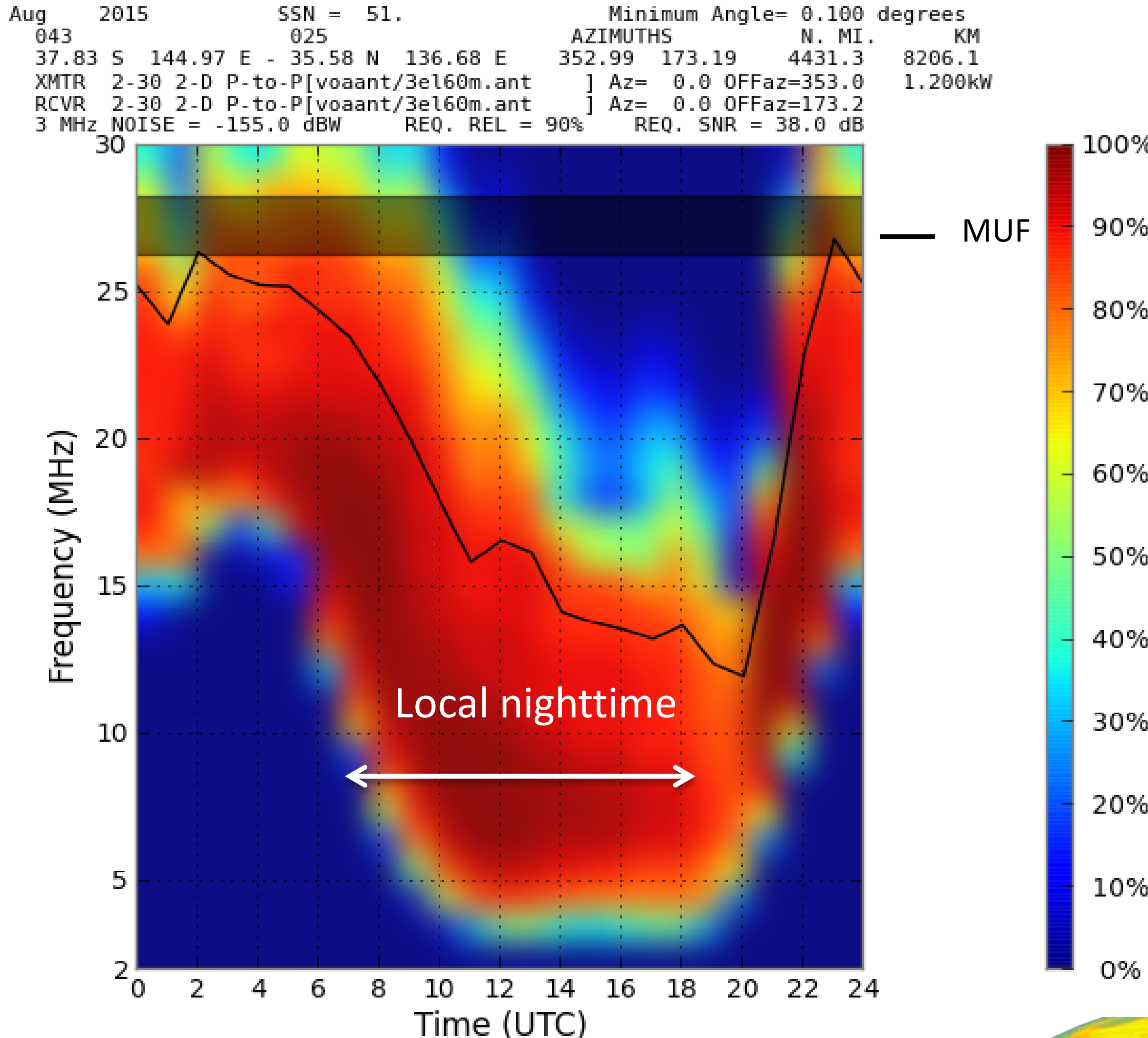
TX to RX: 8217 km, 5106 mi, 35 °

Date
Year: 2015 Month: August
SSN: This month
Remember these values

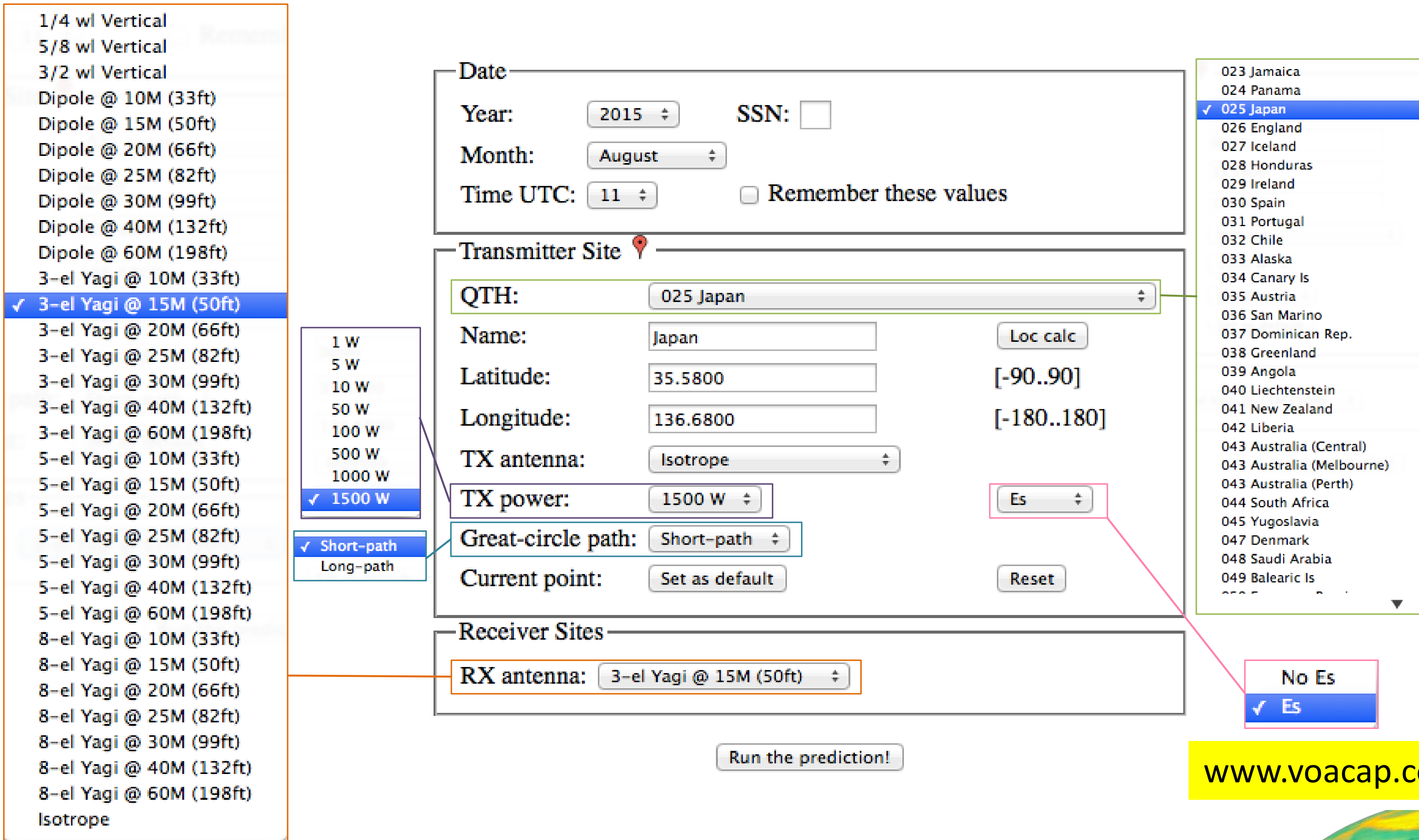
Note: VOACAP 11M Online knows about the correct SSN values. Therefore DO NOT set any value to SSN, unless you want to experiment.

After you have entered a value in any of the fields, press the TAB key instead of ENTER.

www.voacap.com

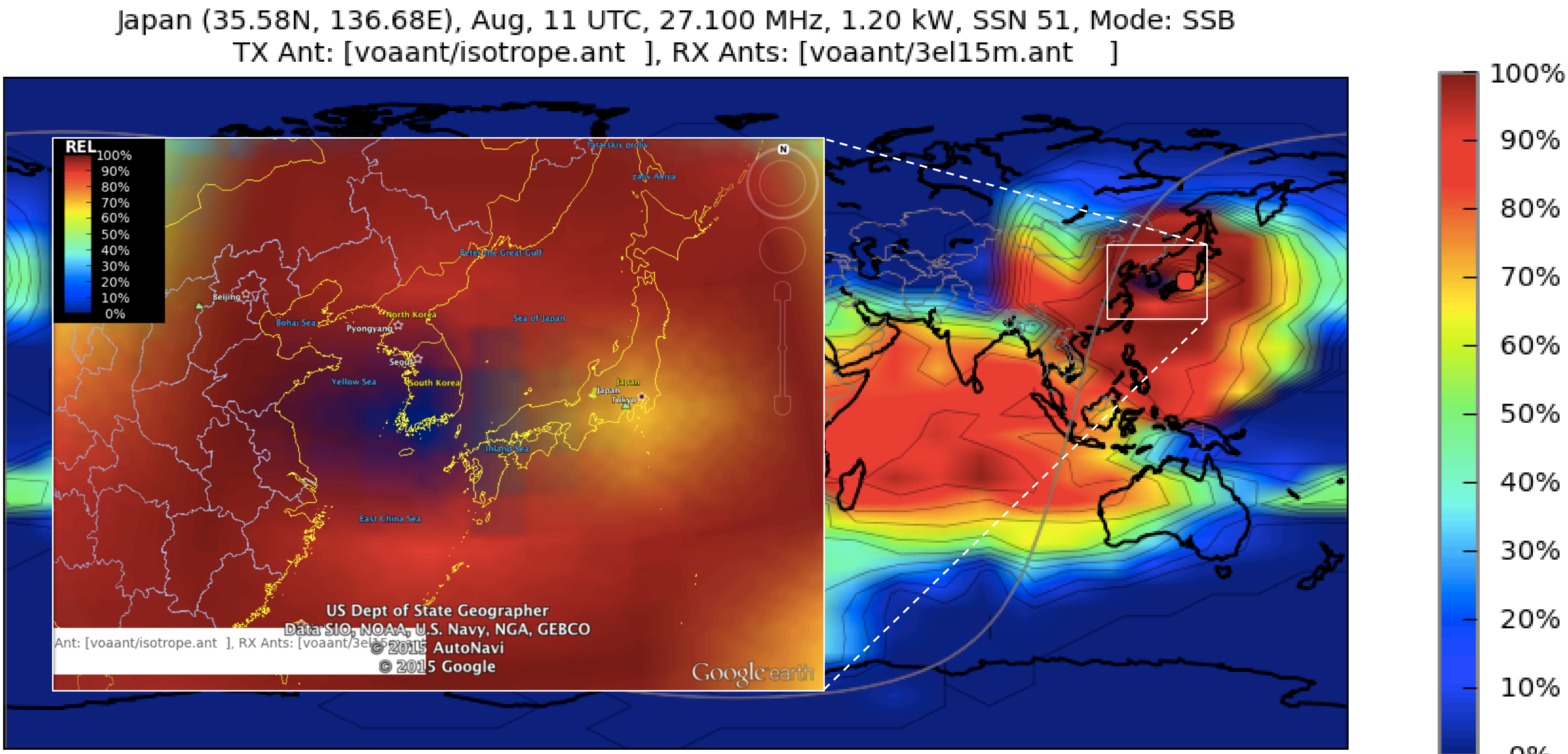


Example of coverage area map input



www.voacap.com

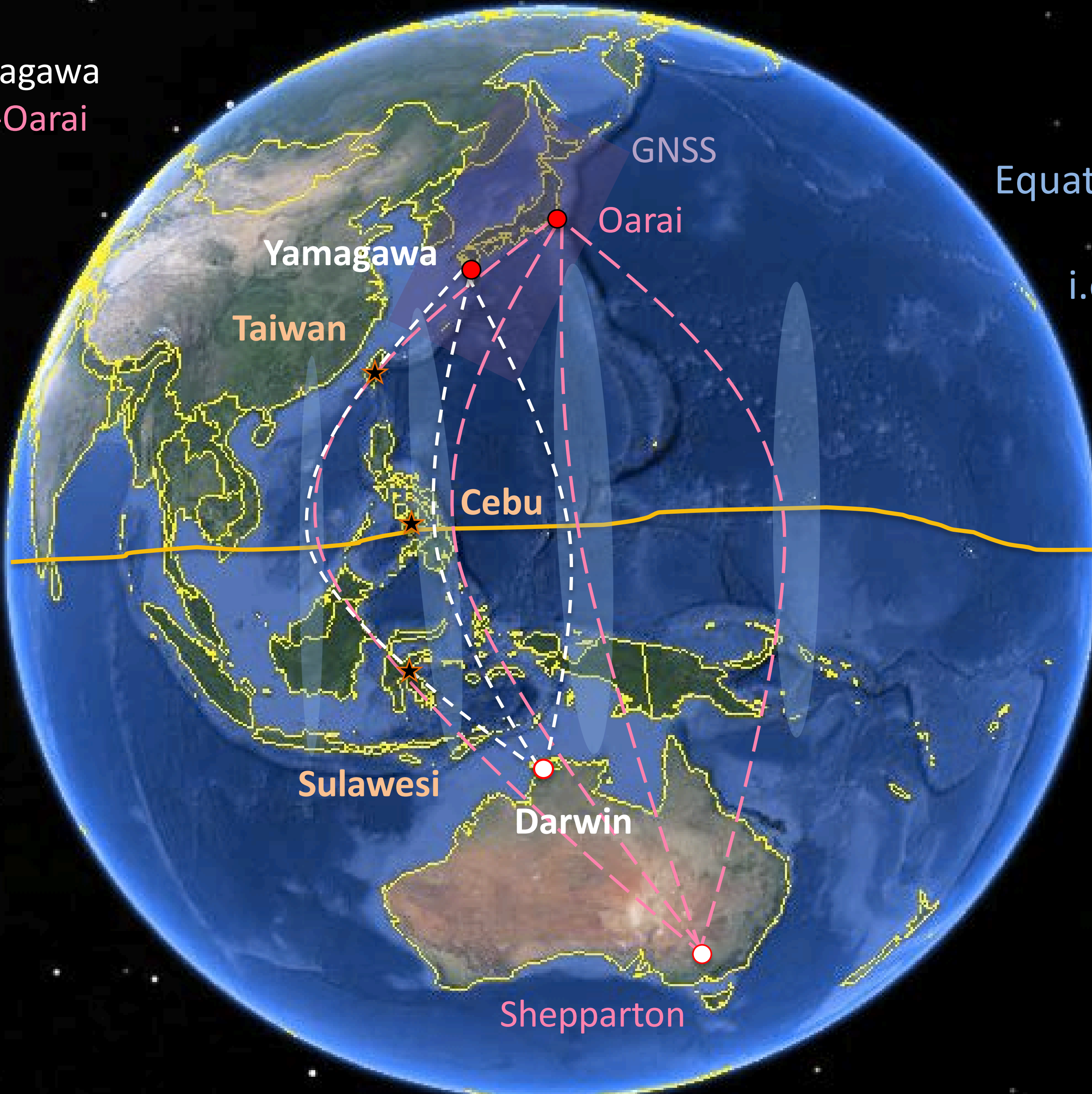
Example coverage area map for short wave



www.voacap.com

Future plan: To clarify the ray path of the trans equatorial propagation (TEP) in order to monitor the plasma bubble that is propagating to a Japanese meridian

TEP
- o Darwin-Yamagawa
- o Shepparton-Oarai



Equatorial ionospheric Disturbances, i.e. plasma bubble

Dip Equator

Interpretation of HF-TEP arrival angle for plasma bubble

IDEA #1

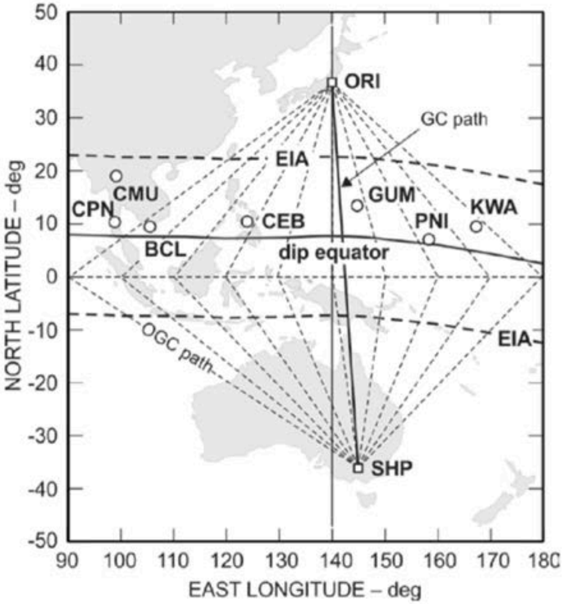


Illustration of how TEP propagation with single side-reflection at the geographic equator (assumed by Maruyama and Kawamura [2006]) might be distributed.

[Courtesy of R. T. Tsunoda]

IDEA #2

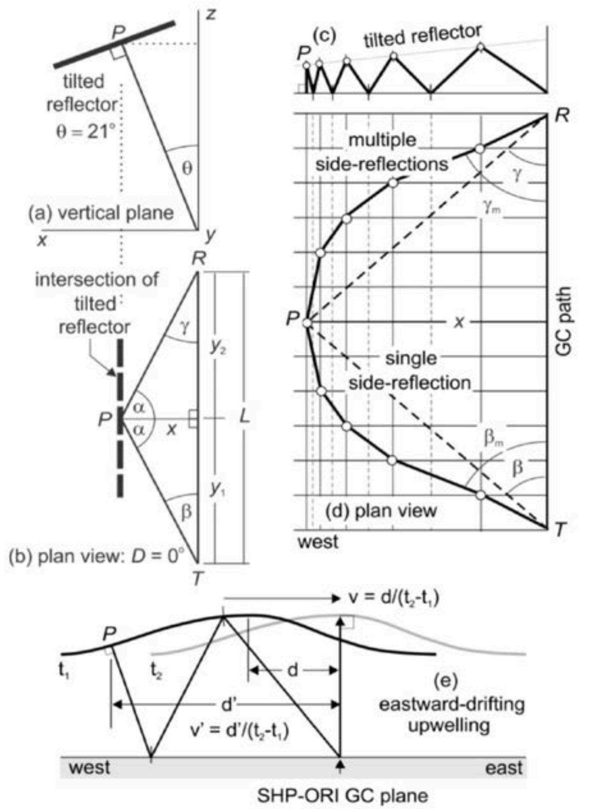
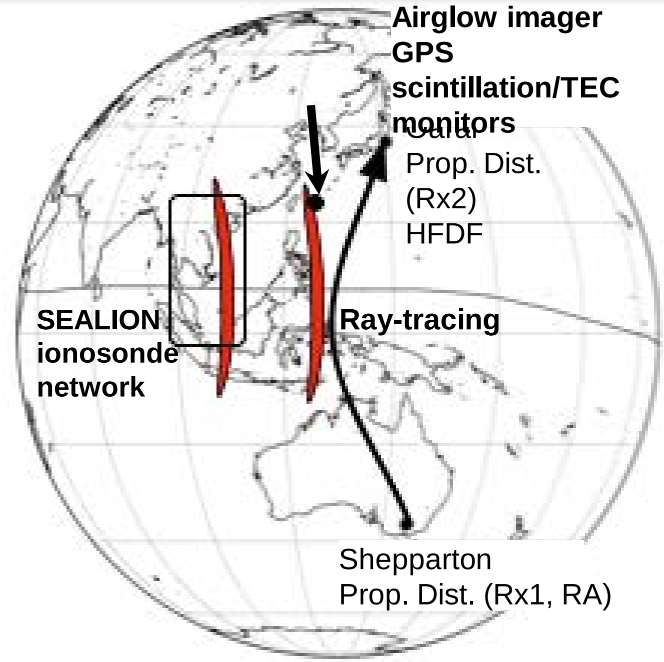


Illustration of how TEP propagation with multiple side-reflection because of tilted reflector and eastward-drifting upwelling. (Proposed by R. T. Tsunoda and submitted to JGR.)

[Courtesy of R.T. Tsunoda]



[Courtesy of S. Saito]

Ray tracing is prominent way to prove whether idea#1 or idea#2 is more suitable for the real-world plasma bubble monitoring. To be done soon.

Summary

- A radio propagation simulator based on ray tracing method is under developing by NICT.
- The user interface of the simulator will be design based on user needs. (Collaborating with Hazard map work task of PSTEP.)
- NICT is now monitoring plasma bubble that would propagate to a Japanese meridian by SEALION and HF-TEP.
- Together with ray tracing, HF-TEP arrival angle and propagation distance measurements are promising for better monitoring of plasma bubbles. (Future work)