IRI-2011 ray paths simulation for mid-latitude SuperDARN station in Poland

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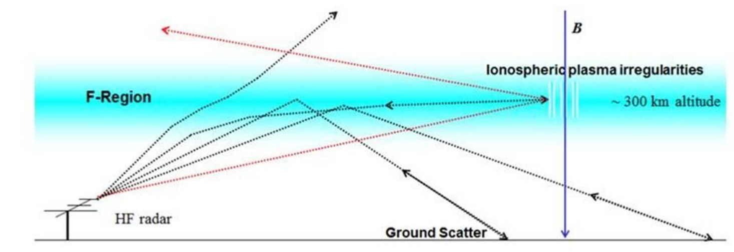
Outline

1. SuperDARN introduction and latest achievements
2. Polish station as a member of SuperDARN chain
3. Comparison of data from SuperDARN station with simulation based on IRI 2011 model
4. Estimation of possible backscatter region for planned Polish radar with the use of IRI 2011 model
5. Discussion on the best boresite

What is SuperDARN



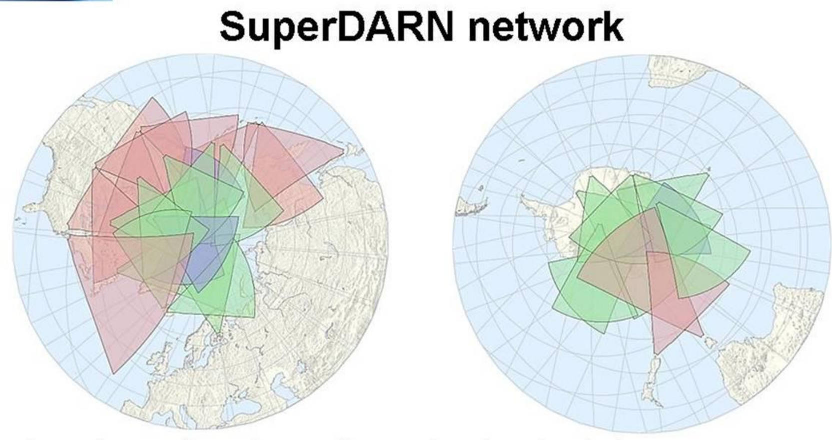
- HF rays are refracted in the ionosphere due to gradients in medium density.
- Signal can be backscattered (in radar direction):
  - from ionospheric irregularities when wave vector is orthogonal with the ambient magnetic field (aspect condition) -> **ionospheric scatter**
  - from the ground -> **ground scatter**

Source :
J. M. Ruohoniemi et al. (2012), „Remote Sensing of the Ionosphere and Earth's Surface with HF Radar"

SuperDARN applications

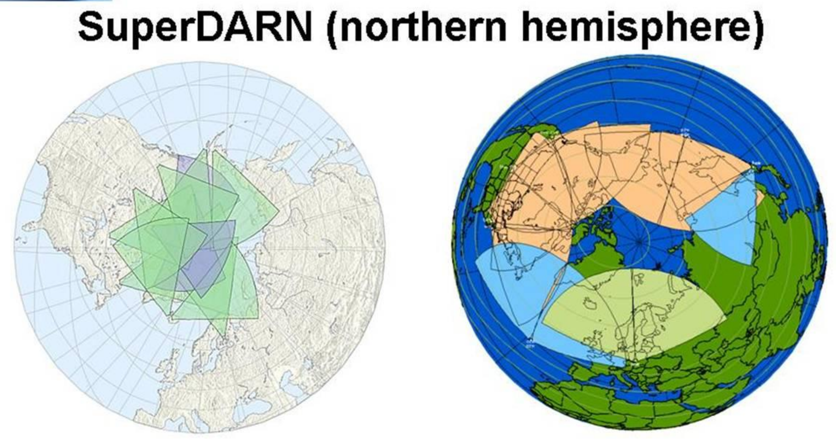
1. Tracking of ionospheric plasma drifts — electric field, atmosphere-ionosphere-magnetosphere interaction
2. Observations of large-scale winds, waves and structures in the atmosphere
3. Measurements of roughness at the Earth's surface including ocean waves and ice cover

SuperDARN network



Currently operating radars, northern and southern hemisphere
Legend: polar, high latitude, mid-latitude
Source:
http://superdarn.jhuapl.edu/

SuperDARN (northern hemisphere)



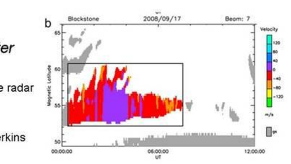
polar and high latitude radars — mid-latitude radars (operating and planned)

Source:
http://superdarn.jhuapl.edu/

Courtesy of prof. S. Shepherd
Dartmouth College

Mid-latitude SuperDARN observations

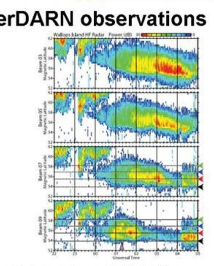
Sub Auroral Ionospheric Scatter (SAIS)
Observed at Blackstone radar (Virginia – USA)
Caused probably by Perkins instability



Source:
A. J. Ribeiro et al. (2012), „A survey of plasma irregularities as seen by the midlatitude Blackstone SuperDARN radar"

Mid-latitude SuperDARN observations

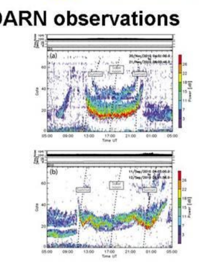
DUsk Scatter Event (DUSE)
Observed at Wallops Island radar (Virginia – USA)
Caused by Gradient and Temperature Drift Instabilities



Source:
R. A. Greenwald (2006), „Identification of the temperature gradient instability as the source of decameter-scale ionospheric irregularities on plasmapause field lines"

Mid-latitude SuperDARN observations

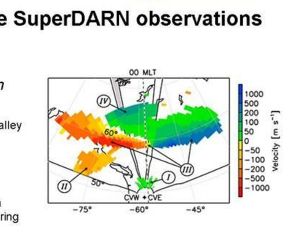
Midlatitude Evening Anomaly
Observed at Blackstone radar (Virginia – USA)



Source:
S. de Larquier et al. (2011), „First observations of the midlatitude evening anomaly using Super Dual Auroral Radar Network (SuperDARN) radars"

Mid-latitude SuperDARN observations

Sub Auroral Polarization Stream (SAPS)
Observed at Christmas Valley radar pair (Oregon – USA)
Caused by field-aligned currents driven by plasma pressure gradients in the ring current

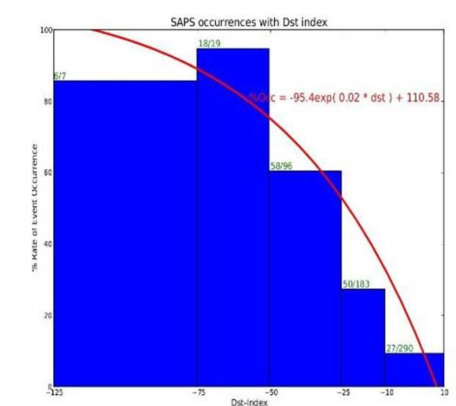


Source:
L. B. N. Clausen et al. (2012), „Large-scale observations of a subauroral polarization stream by midlatitude SuperDARN radars: Instantaneous longitudinal velocity variations"

Mid-latitude SuperDARN observations

Sub Auroral Polarization Stream (SAPS)

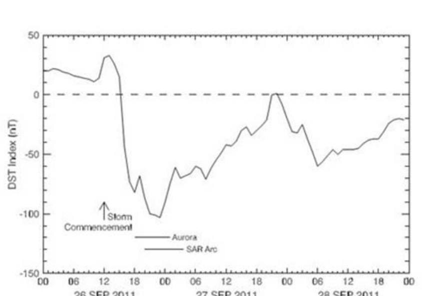
- Very frequent phenomena, about 160 events between 01.2011 ÷ 08.2012
- Observed during varying geomagnetic conditions



Source :
B. S. R. Kunduri et al. (2013), „Statistical characterization of sub-auroral polarization stream using large scale observations by mid-latitude SuperDARN radars"

Simulation vs real data

Characteristics of the geomagnetic storm of 26-28 Sep 2011

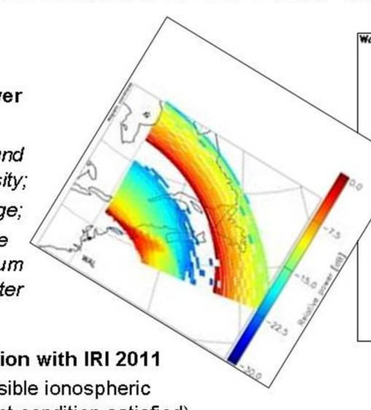


Magnetically disturbed period: *26-28 Sep 2011*

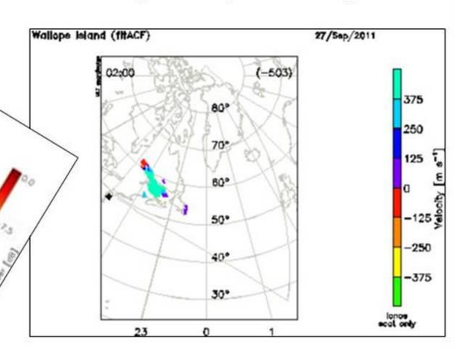
Source:
J. Baumgardner et al. (2013), „Imaging space weather over Europe"

Simulation vs real data http://vt.superdarn.org/

Relative power
~ N^2/R^3
N – background electron density;
R – slant range;
Power relative to the maximum value of scatter type



Simulation with IRI 2011
Power of possible ionospheric scatter (aspect condition satisfied) for Wallops Island radar

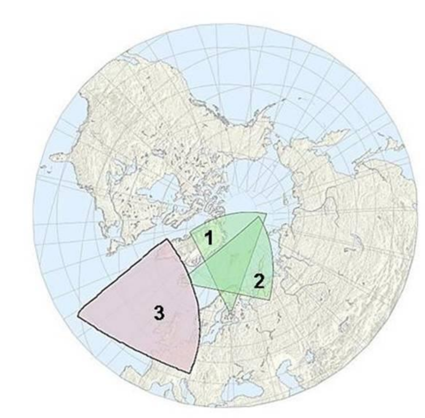


Real data
Doppler velocities (right) of received ionospheric backscatter

27.09.2011 02 UT
At this moment SAR arc was observed over Europe along 55° MLAT, and equatorward boundary of diffuse oval at ~58° MLAT

European region radars

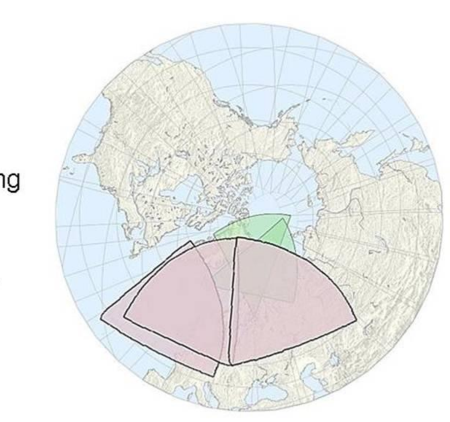
1. Hankasalmi, (Finland) high latitude
2. Stokkseyrii, (Iceland) high latitude
3. Graciosa, Azores (Portugal) mid-latitude (under construction)



Source:
http://superdarn.jhuapl.edu/

Why SuperDARN in Poland?

- Still lacking of mid-latitude radars in the region
- Filling the gap between existing mid-latitude stations
- Overlapping with field of view of Graciosa radar (possibility of 2D Doppler velocity measurements)

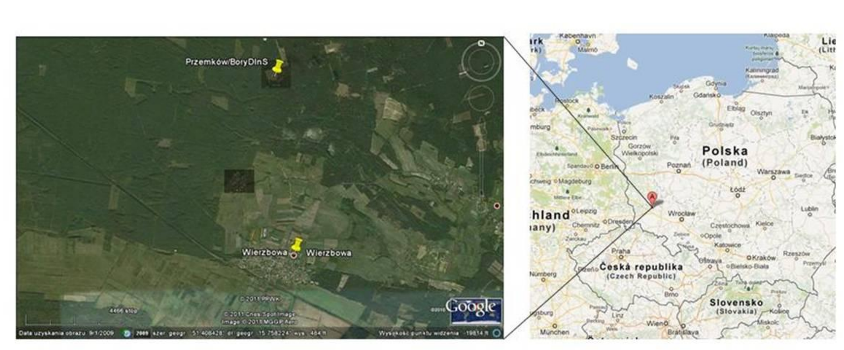


Source:
http://superdarn.jhuapl.edu/

Possible applications of Polish SuperDARN

- Monitoring of ionosphere for European Galileo system
- Monitoring of local ionosphere for Polish LOFAR stations
- Better space weather service for Poland
- Input to ESA Space Situational Awareness system

Proposed location



near Wierzbowa, 51°23'N 15°46'
Site is good for -40°boresite
(„clean" 15 km ahead)

Source :
Google Earth

Simulation

Purpose

estimation of radar capabilities (backscatter regions) depending on:

- season
- local time
- solar cycle phase
- radar frequency

Tool

Virginia Tech ray-tracing software (courtesy of S. de Larquier):

- 2D ray path calculation (*Coleman [1998]*)
- Runge-Kutta Cash-Karp numerical integration
- non-collisional transverse Appleton-Hartree formula for computation of refractive indices

Simulation

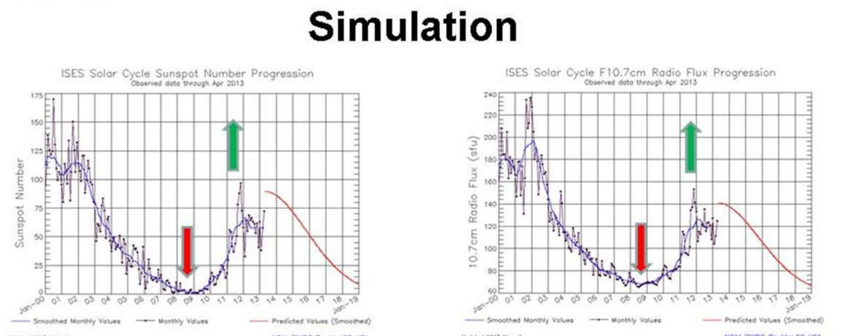
Simulation period

- minimum solar activity (2008, summer/winter, day/night)
- proxy for weak maximum solar activity (2011, summer/winter, day/night)

Simulation parameters

- boresite: -40° (horizontal angle, negative anti-clockwise from geomagnetic north)
- transmitter frequency: 9MHz, 16MHz
- elevation: 5° ÷ 50°, every 0.1°

Simulation



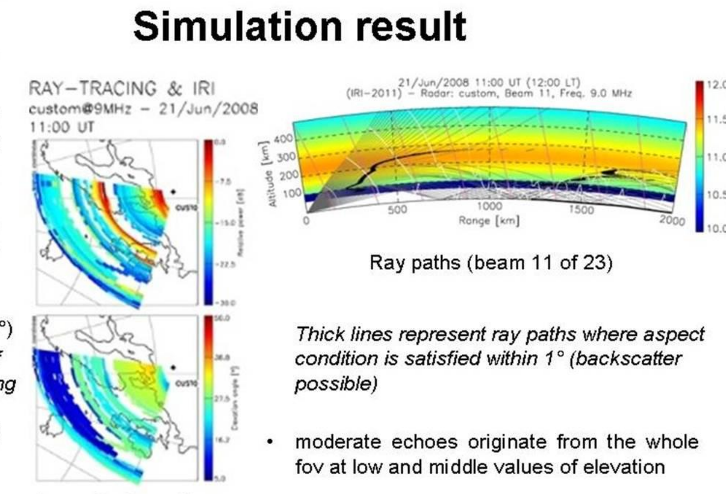
- Solar cycle sunspot number
- Solar cycle F10.7cm radio flux

Source:
http://www.swpc.noaa.gov/SolarCycle

Simulation result

Relative power
~ N^2/R^3
N – background electron density;
R – slant range;
Power relative to the maximum value of scatter type

Elevation (5÷50°)
Average take-off angle in scattering volume where condition aspect is satisfied



Ray paths (beam 11 of 23)

Thick lines represent ray paths where aspect condition is satisfied within 1° (backscatter possible)

- moderate echoes originate from the whole fov at low and middle values of elevation

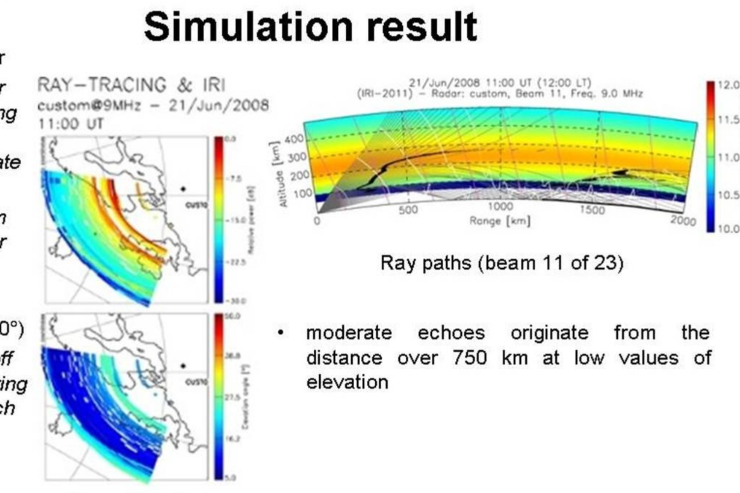
Ionospheric scatter

21.06.2008 12:00 LT, frequency 9MHz

Simulation result

Relative power
~ to the number of rays scattering within a given 45 km range gate
Power relative to the maximum value of scatter type

Elevation (5÷50°)
Average take-off angle in scattering volume for which ray is bended to the ground and reflected



Ray paths (beam 11 of 23)

- moderate echoes originate from the distance over 750 km at low values of elevation

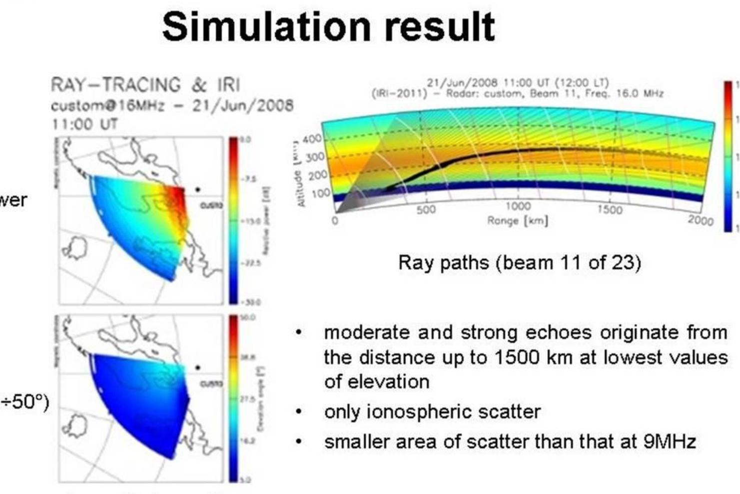
Ground scatter

21.06.2008 12:00 LT, frequency 9MHz

Simulation result

Relative power

Elevation (5÷50°)



Ray paths (beam 11 of 23)

- moderate and strong echoes originate from the distance up to 1500 km at lowest values of elevation
- only ionospheric scatter
- smaller area of scatter than that at 9MHz

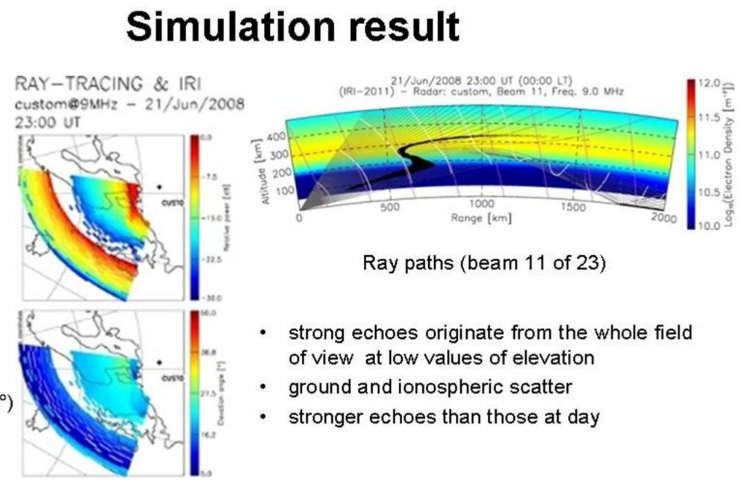
Ionospheric scatter

21.06.2008 12:00 LT, frequency 16MHz

Simulation result

Relative power

Elevation (5÷50°)



Ray paths (beam 11 of 23)

- strong echoes originate from the whole field of view at low values of elevation
- ground and ionospheric scatter
- stronger echoes than those at day

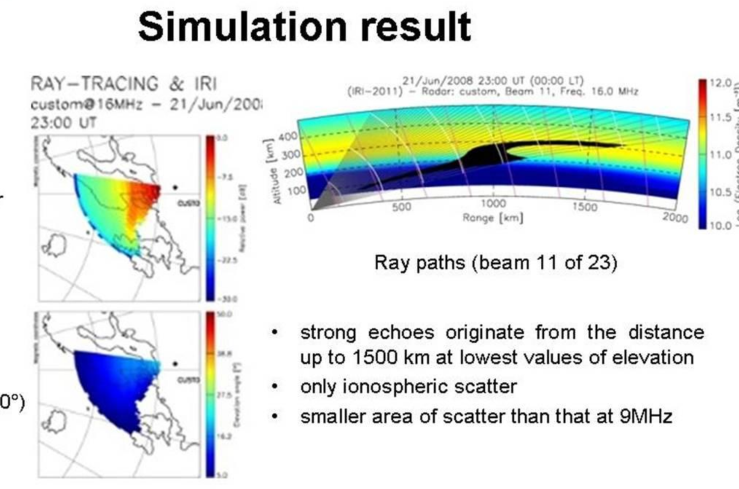
Ionospheric scatter

21.06.2008 00:00 LT, frequency 9MHz

Simulation result

Relative power

Elevation (5÷50°)



Ray paths (beam 11 of 23)

- strong echoes originate from the distance up to 1500 km at lowest values of elevation
- only ionospheric scatter
- smaller area of scatter than that at 9MHz

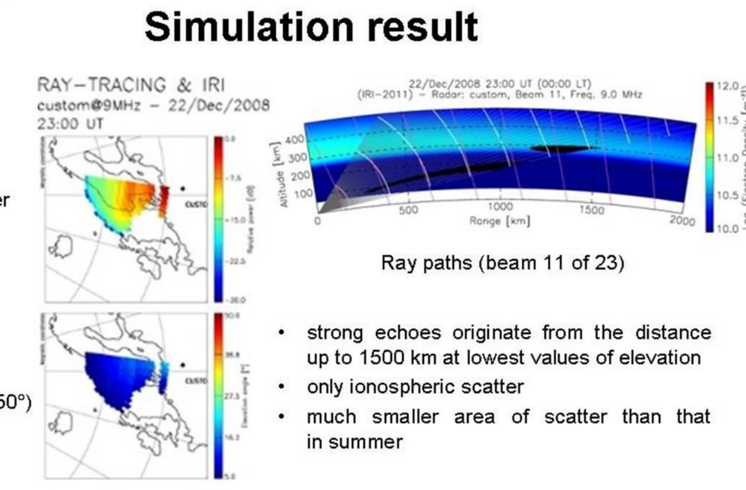
Ionospheric scatter

21.06.2008 00:00 LT, frequency 16MHz

Simulation result

Relative power

Elevation (5÷50°)



Ray paths (beam 11 of 23)

- strong echoes originate from the distance up to 1500 km at lowest values of elevation
- only ionospheric scatter
- much smaller area of scatter than that in summer

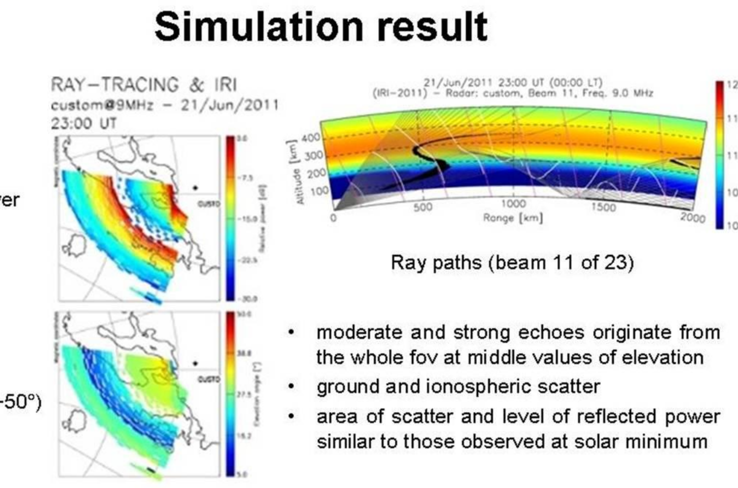
Ionospheric scatter

22.12.2008 00:00 LT, frequency 9MHz

Simulation result

Relative power

Elevation (5÷50°)



Ray paths (beam 11 of 23)

- moderate and strong echoes originate from the whole fov at middle values of elevation
- ground and ionospheric scatter
- area of scatter and level of reflected power similar to those observed at solar minimum

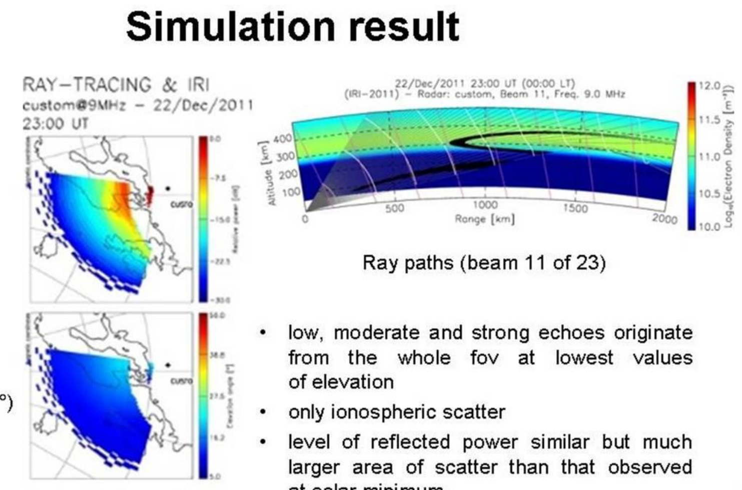
Ionospheric scatter

21.06.2011 00:00 LT, frequency 9MHz

Simulation result

Relative power

Elevation (5÷50°)



Ray paths (beam 11 of 23)

- low, moderate and strong echoes originate from the whole fov at lowest values of elevation
- only ionospheric scatter
- level of reflected power similar but much larger area of scatter than that observed at solar minimum

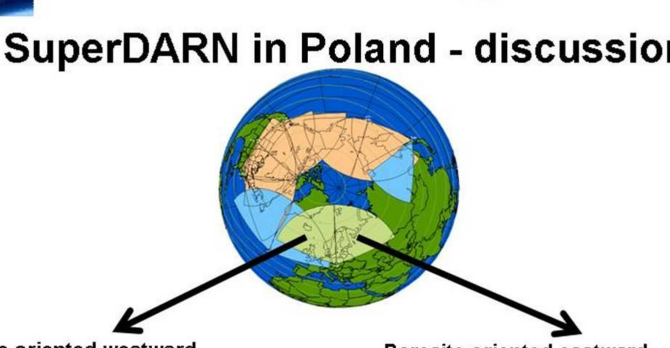
Ionospheric scatter

22.12.2011 00:00 LT, frequency 9MHz

Simulation result - summary

1. Estimation of possible backscatter echo areas with use of ray tracing software based on IRI 2011 model was done
2. According to simulations, coverage highly depends on time of the day, season and selection of operational frequency
3. According to simulations, coverage slightly depends on solar cycle
4. STORM model of the ionosphere should be also used for comparison in the future

SuperDARN in Poland - discussion



Boresite oriented westward
☺Overlapping with FOV of Graciosa radar (possibility of 2D Doppler velocity measurements)
☹Graciosa radar covers nearly the whole mid-latitude european region; polish station will be „redundant" ?

Boresite oriented eastward
☺radar would be oriented toward areas still uncovered by SuperDARN chain
☹possible formal obstacles – FOV would cover areas of non-EU countries
☹ searching for another place is needed

Maybe another location…

Wierzbowa

Hylaty region in Bieszczady is considered as a most southern region in Poland

Source :
Google Maps