Proposed Satellite Service for Storm Warning and Ice-Edge Detection

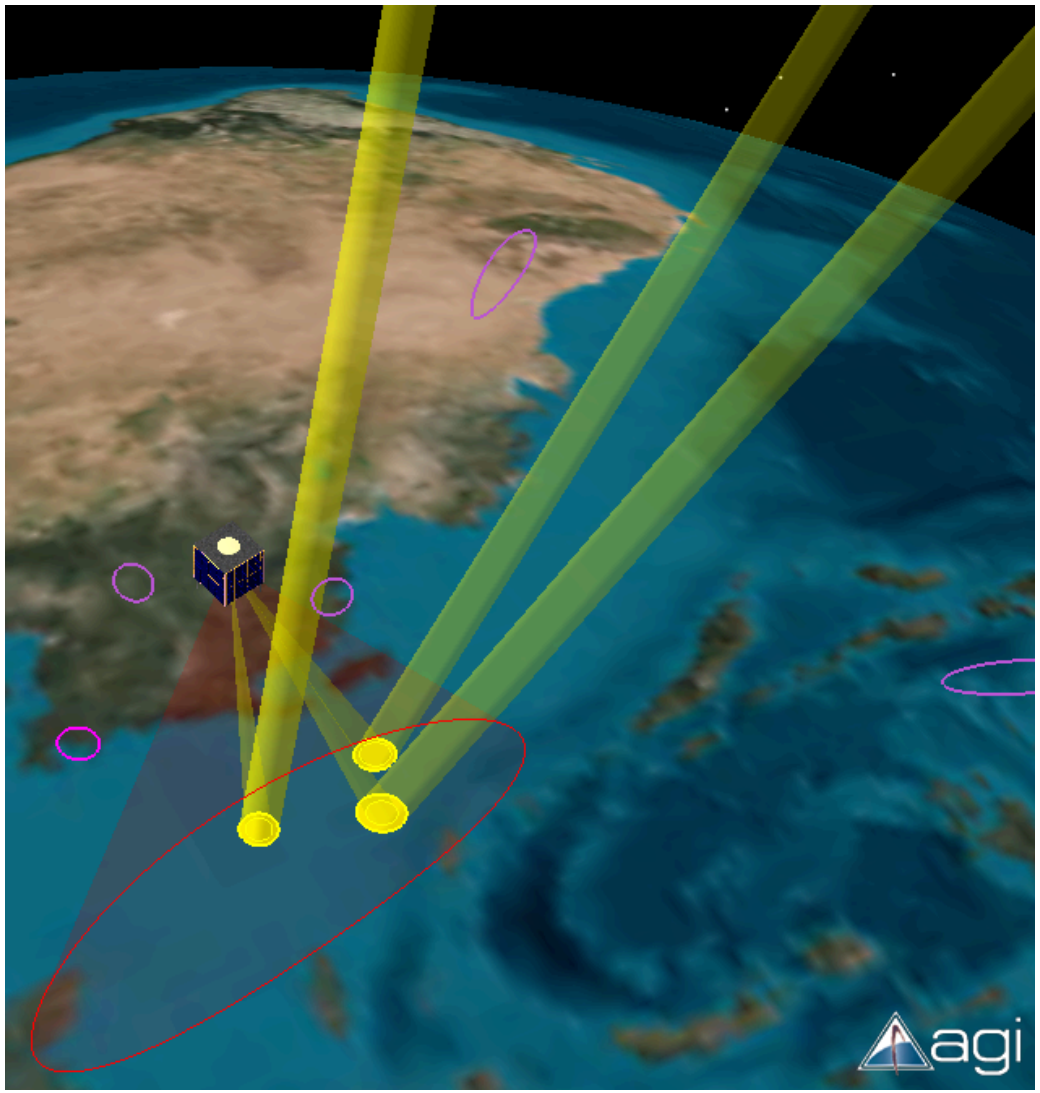
Martin Unwin [2]
Philip J. Jales [1]
Craig Underwood [1]

(1) Surrey Satellite Technology Ltd.
(2) Surrey Space Centre

NAV08/ILA37, Westminster, London

October 2008

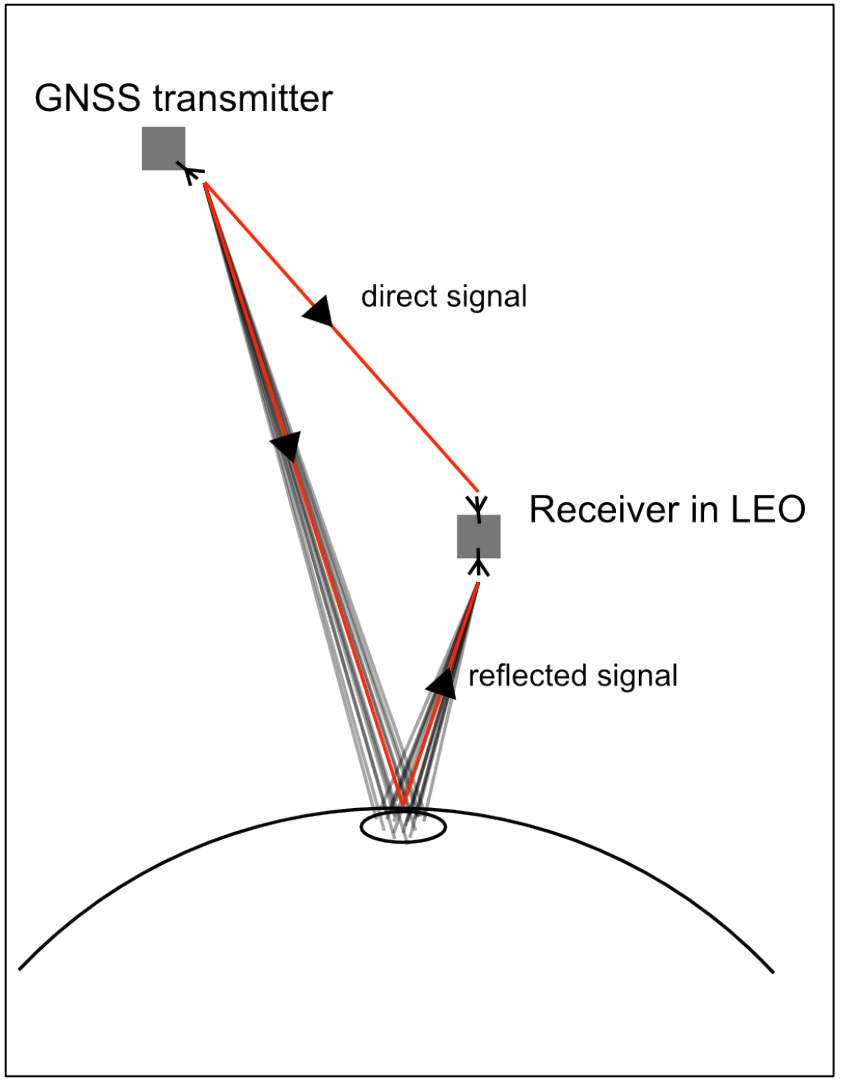
Contents



- GNSS Reflectometry introduction
- UK-DMC GPS Reflectometry Experiment
  - Results over Ice & Sea
- Potential Future Service
  - Ice Edge
  - Ocean Roughness

GNSS Reflectometry

- Satellites in low Earth orbit (LEO) can pick up GNSS signals reflected off the ocean
- Bistatic arrangement
  - No transmitter on GNSS-R satellite
- Reflections contain information about surface
- Potential applications:
  - Ocean roughness
  - Ice monitoring
  - Soil moisture, biomass sensing
  - Flood detection
  - Sea height
  - ...

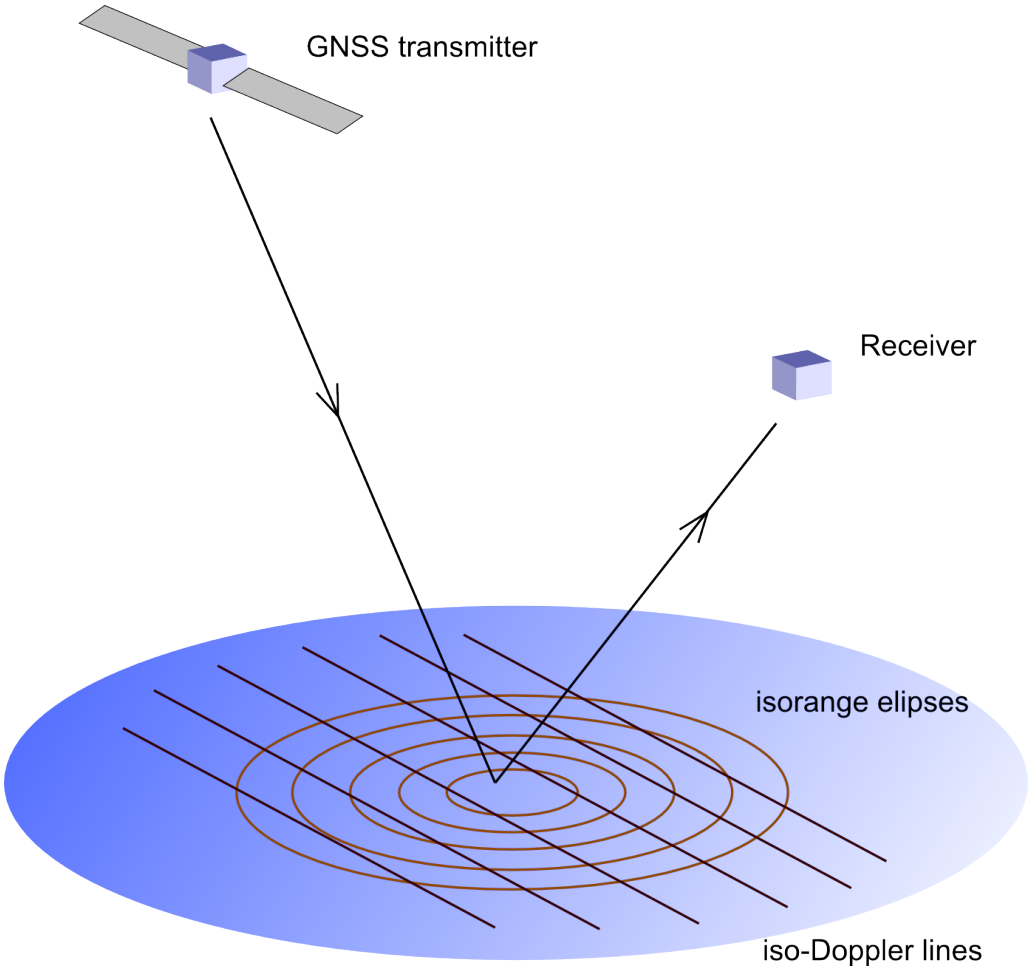


Ocean GNSS Reflections

- Signal affected by
  - Earth's rough surface => spreads the signal path-delay and Doppler frequency

The signal delay & distortion contain information about the surface

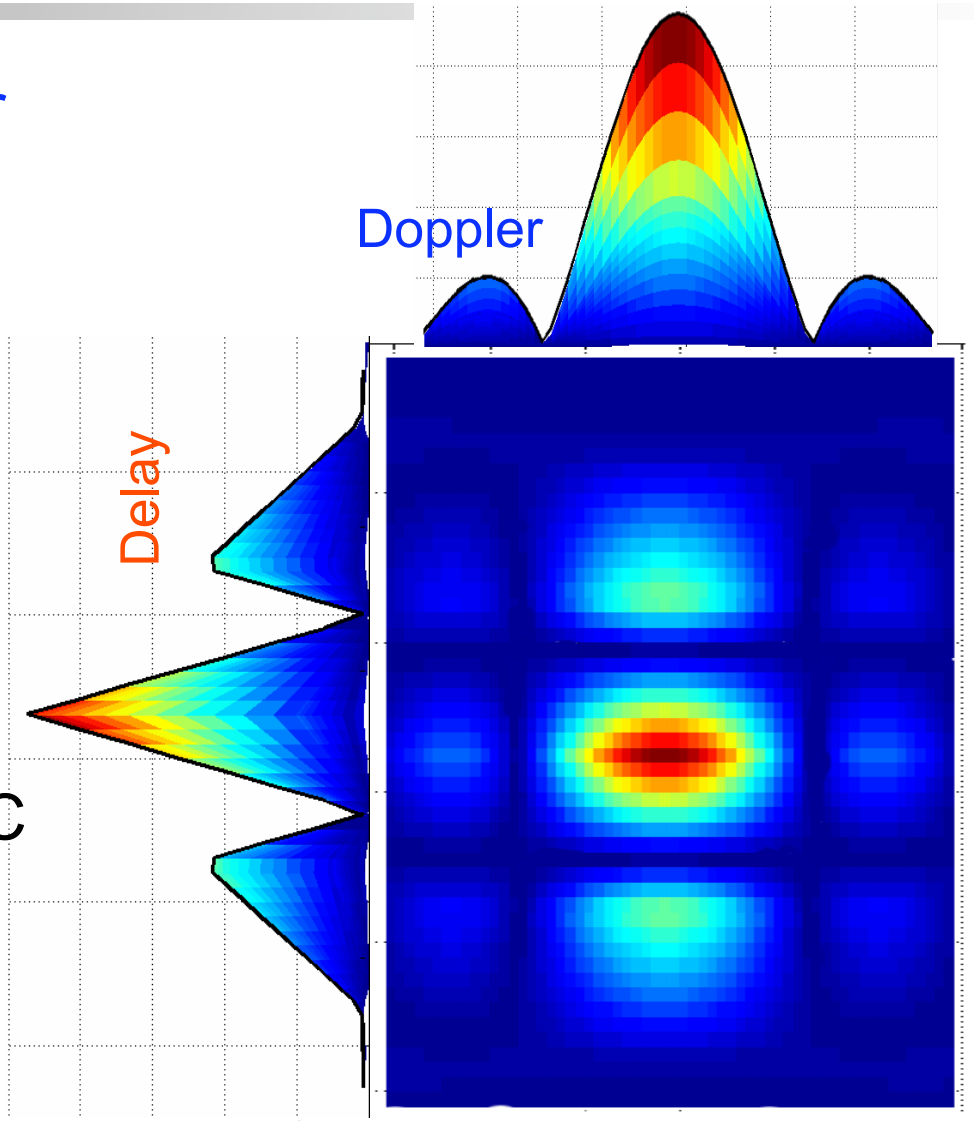
- Delay: surface height
  - Need dual frequency to measure
- Distortion: Recover wind / waves
  - Models being developed
  - Single freq.



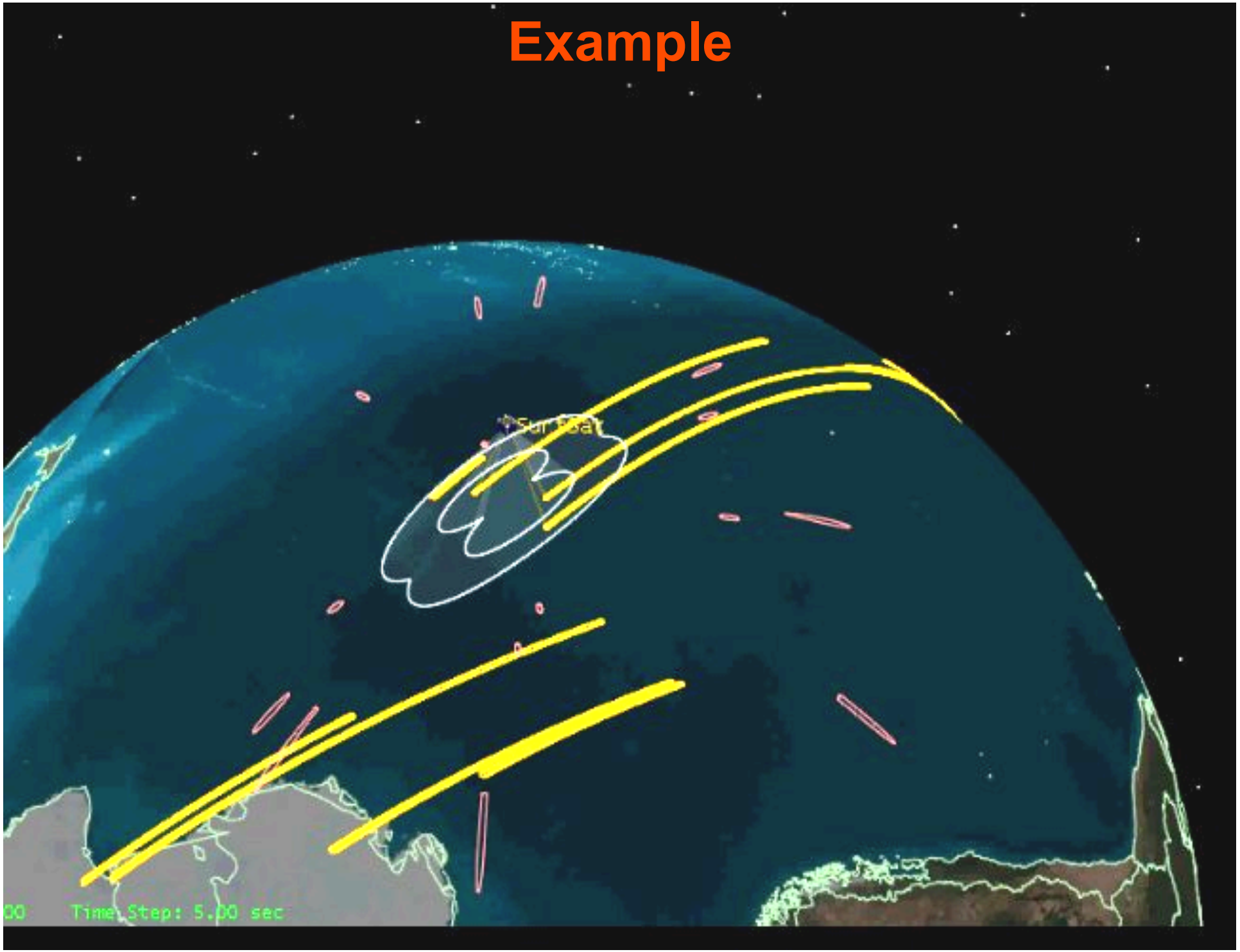
Taking Measurements: Delay Doppler Map

- Generate Code and Carrier replica
- Signal reception when aligned with Doppler frequency and code delay
  - Stepping through these, produces 2D map, similar to radar
- Weak signal - Integration
- Delay-Doppler map of BOC (1,1) direct signal

(Galileo L1B & L1C – simulated)

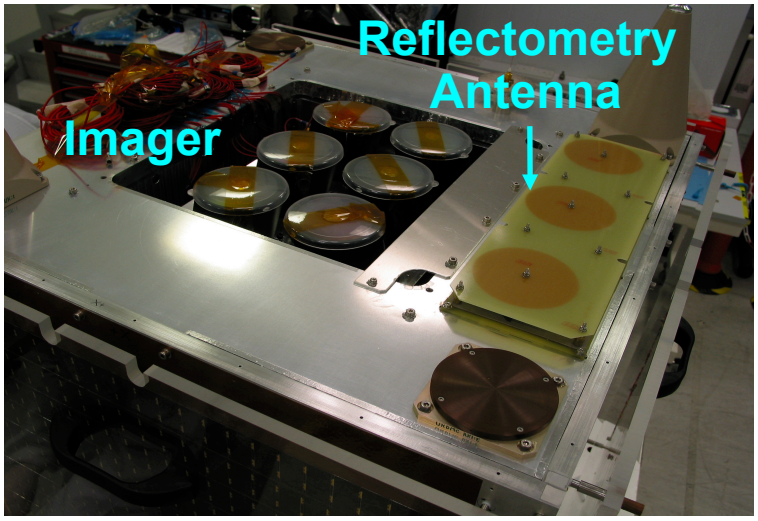


Example



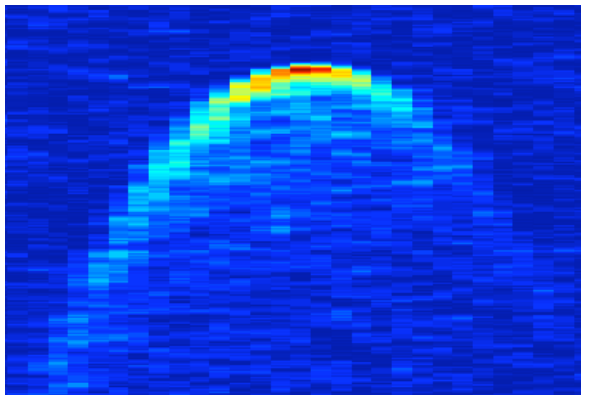
GPS-Reflectometry in-orbit Experiment

- UK-DMC 100 kg satellite, 2003
  - First dedicated GNSS reflectometry experiment
- GPS-R experiment
  - Modified space GPS receiver
  - Medium-gain antenna ~12dBi
  - Data recorder collects 20s of raw data
  - Processed on ground
  - So far scheduled 80 collections
  - Recovered signals showed link to sea state
- Planning towards future operational instrument



Applications:
GNSS Reflections off Ocean

GNSS Reflections off Ocean



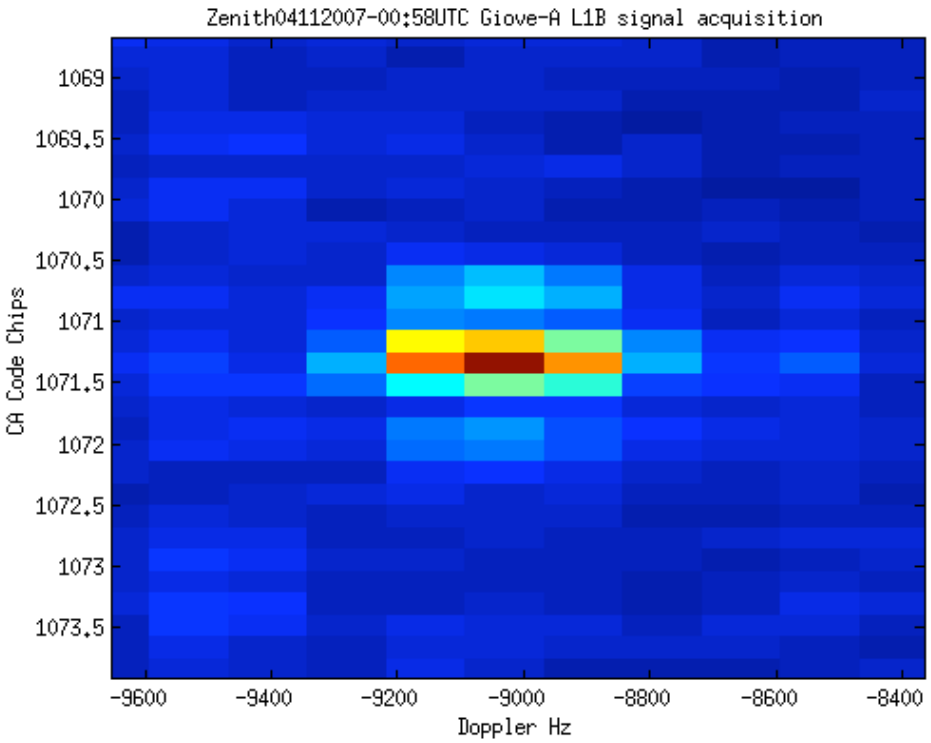
- Summary of status
  - Selected for ESA mission
    - SMOSops
  - Collections
  - Modelling methods
  - Output related to mean square slope
- Application
  - Rapid production of ocean roughness
  - Storm warning

Ocean reflection using Galileo

First collection of Galileo signal reflection, November 2007

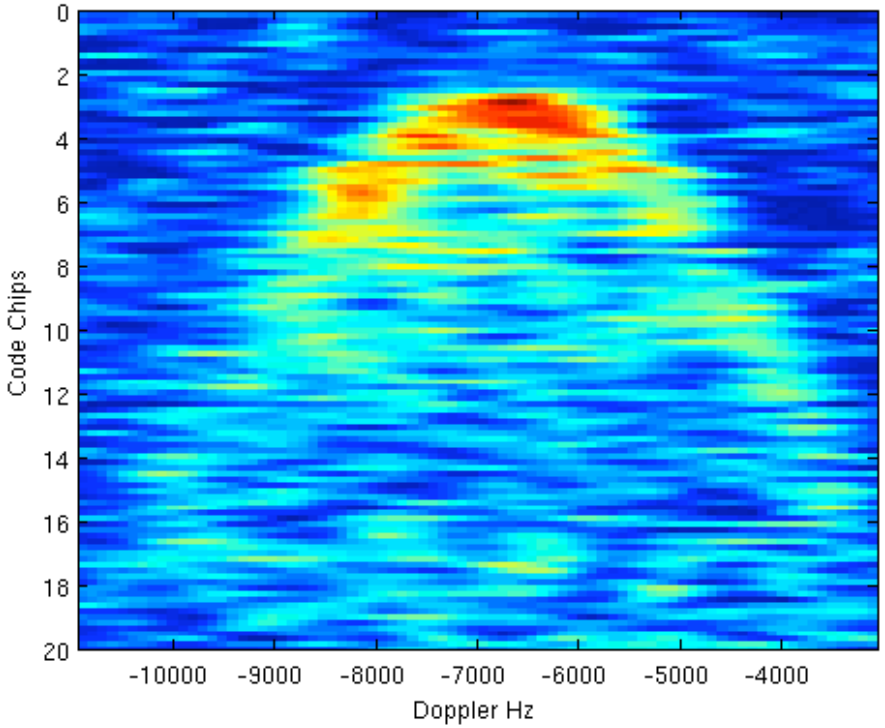
Direct signal

acquired and tracked



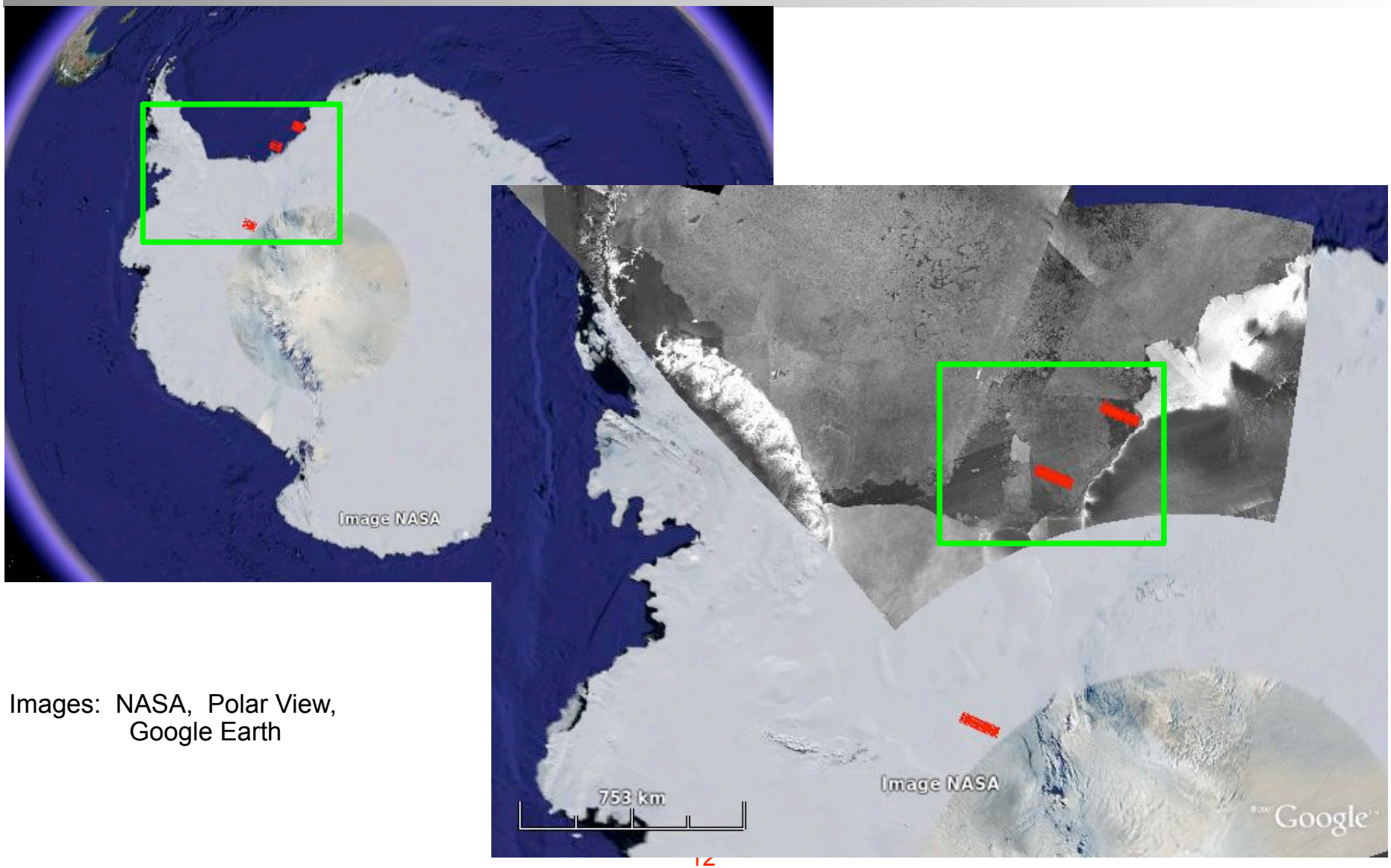
Ocean reflected signal

Coherent addition of L1B and L1C signals



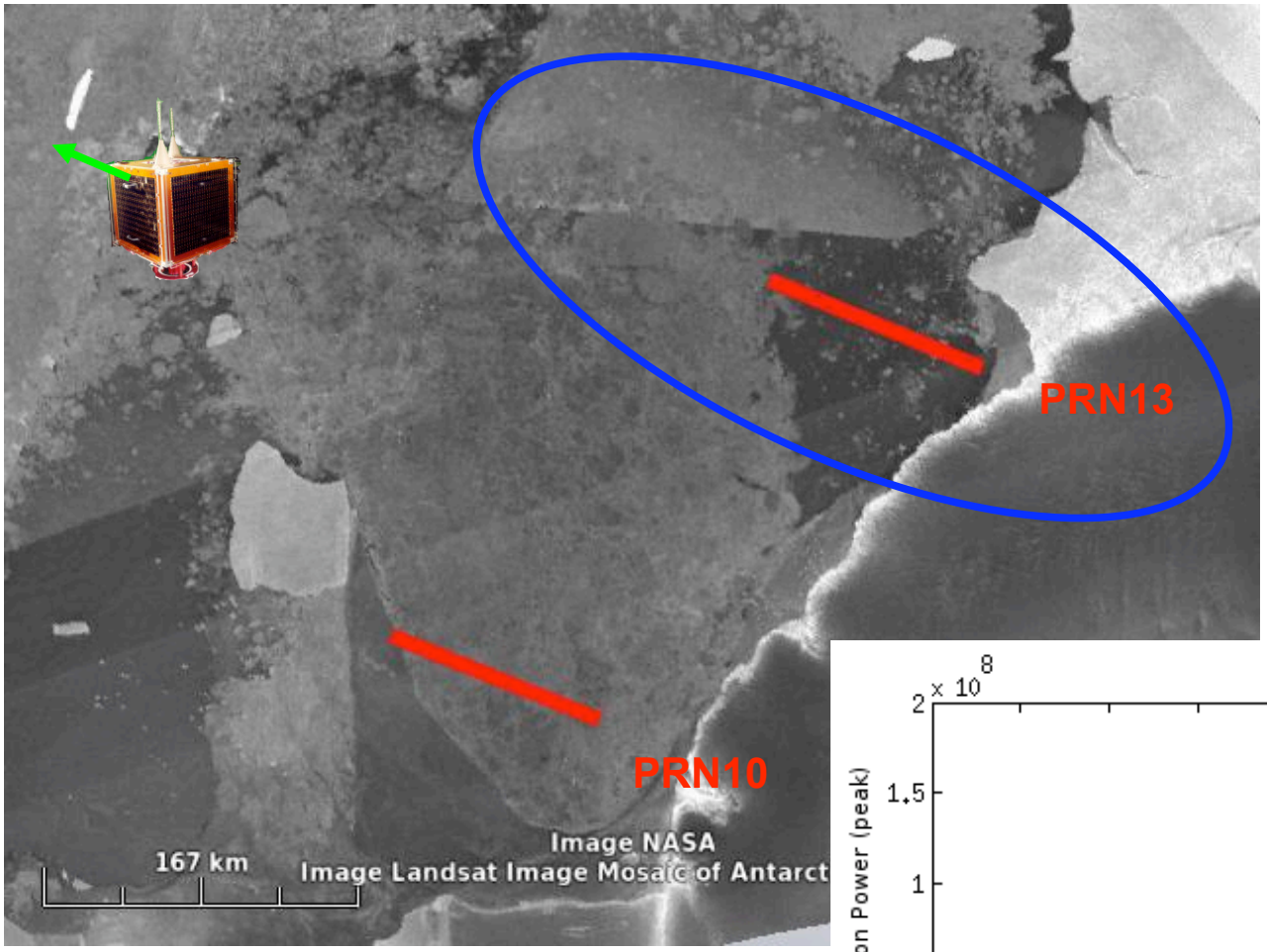
Exploring Applications: GPS Reflections off Ice

GPS Reflectometry over Antarctic Ice
January 2008



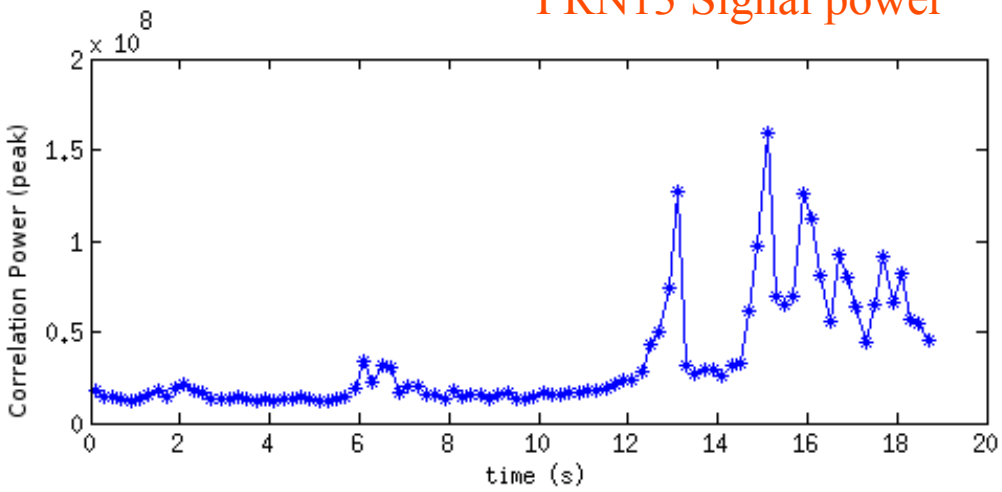
Images: NASA, Polar View, Google Earth

GPS Reflectometry over Antarctic Ice



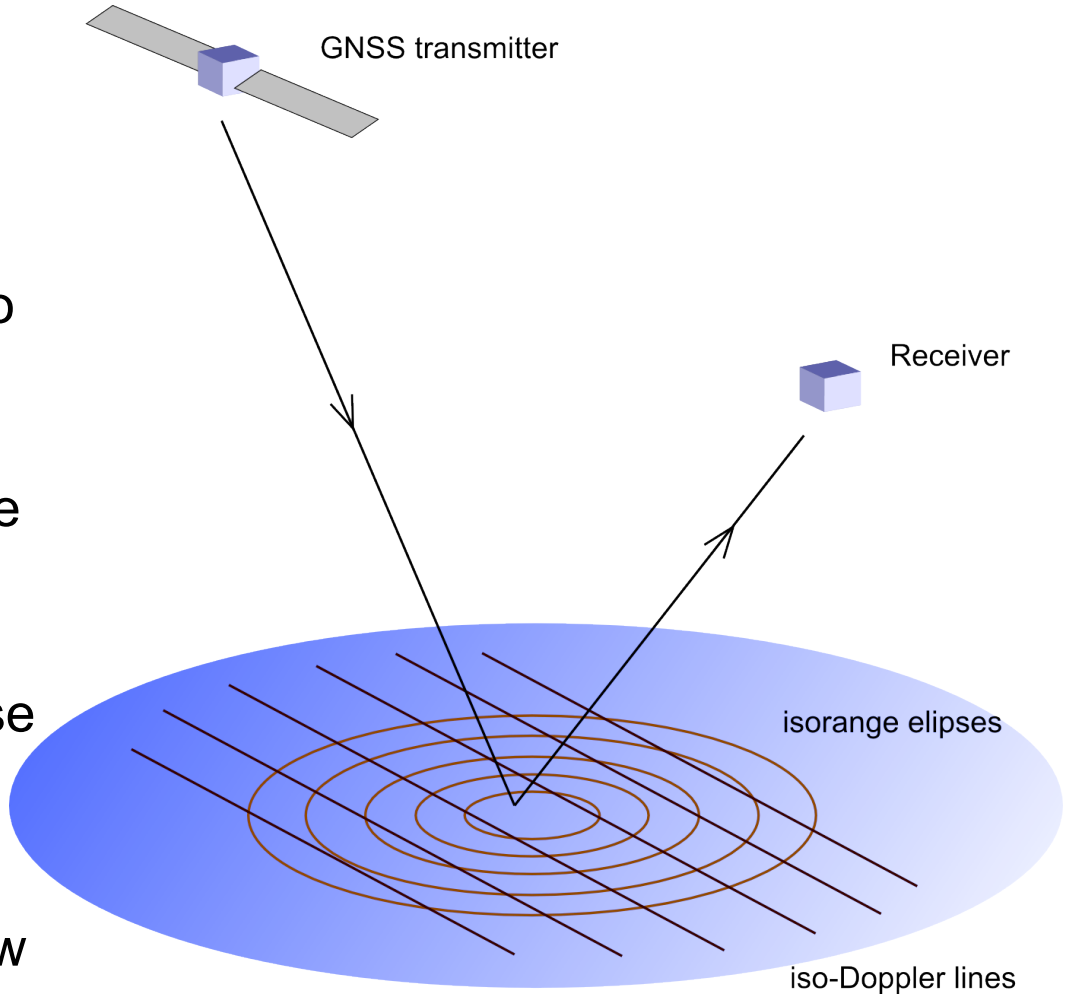
Envisat ASAR 3 day mosaic, Polar View

PRN13 Signal power

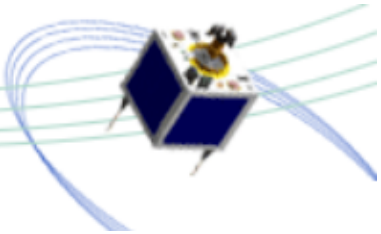


Sensing polar ice

- Polar ice data products:
  - Ice edge info
    - Resolution 20km due to code selection
    - But data suggests two orders better is possible (~400 metres)
    - New wideband frequencies will increase resolution
  - Ice height mapping
    - L-band penetrates snow for mapping of the ice surface



Current State-of-Art



- Existing Services
  - Radiometers
    - DOD SSMI – 20 km rsln, daily
      - To be replaced by NPOES
    - NASA AMSIR – 10 km rsln, daily
  - Envisat GM SAR Data
    - – 2 days (when active)
- Niche for service
  - Higher resolution, more measurements
    - Potential of 400 metre or better with new signals
    - Coverage increases with number of satellites

Service Provision:
Storm Warning & Ice Edge

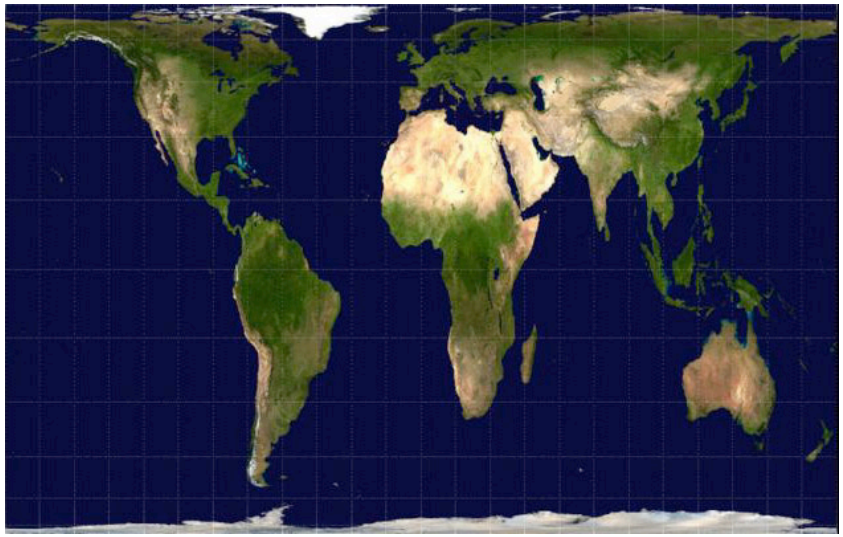
Satellite and Instrument Design

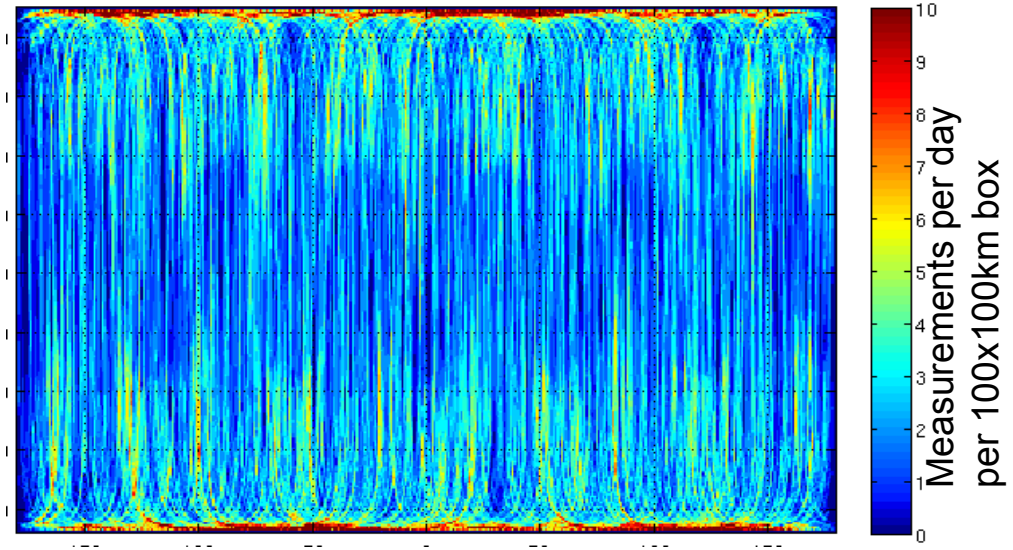
- Instrument is 2 kg < 10 Watts
- Antenna is 12 x 30 cm
  - Reduction may be possible
- Data rate low
- Dedicated satellite could be very small
  - Multiple satellites on each launch

  or
- Instrument of opportunity (LEO)
  - DMC satellites – 5 satellites coordinated by SSTL
  - Orbcomm – SSTL is preparing to deliver 19 GPS receivers for Orbcomm-2
  - Iridium has 66 satellites – offering to carry remote sensing instrumentation (780 km, 86.4 deg, 6 planes)

Coverage

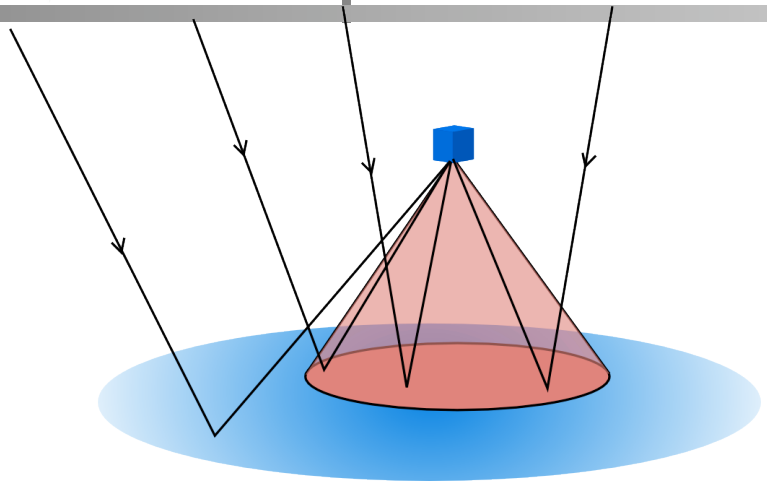
- Coverage requirements differ from sea to ice
- Over Sea:
  - Stationarity (spatial correlation) varies with latitude.
  - Preliminary assumption: 100km, 2 hour requirement
- Over ice:
  - Lower temporal requirement, but higher spatial requirement
  - Weekly update – covered to x km resolution?





Simulation: instrument on 12 Iridium satellites; GPS constellation; Receive +/-40 degrees from Nadir

Coverage



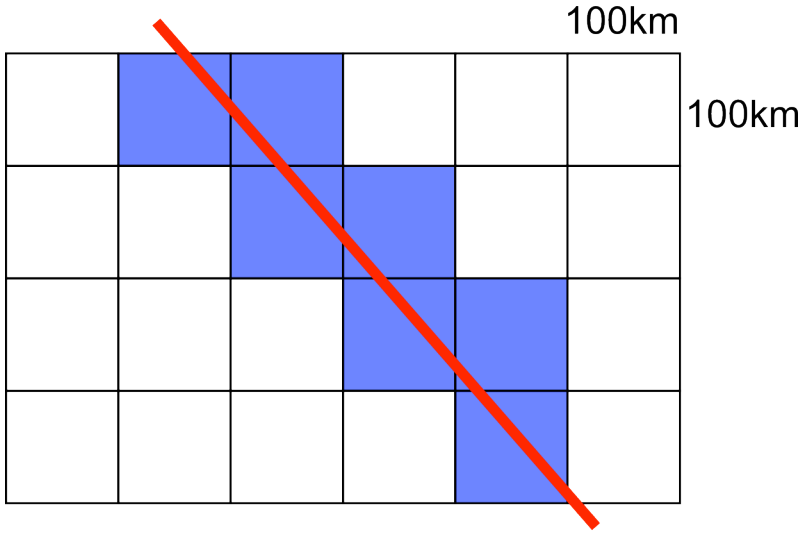
Simulation of coverage

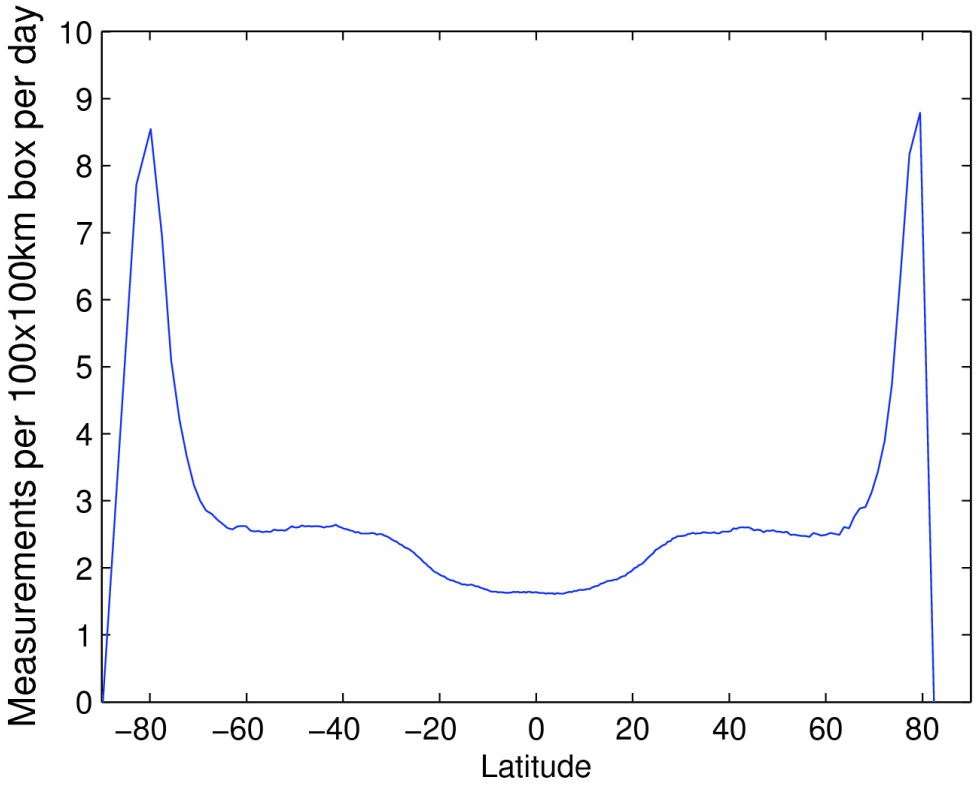
e.g. instrument on 12 Iridium comm sats

GPS constellation 31 satellites

Receiver antenna +/-40 degrees from Nadir

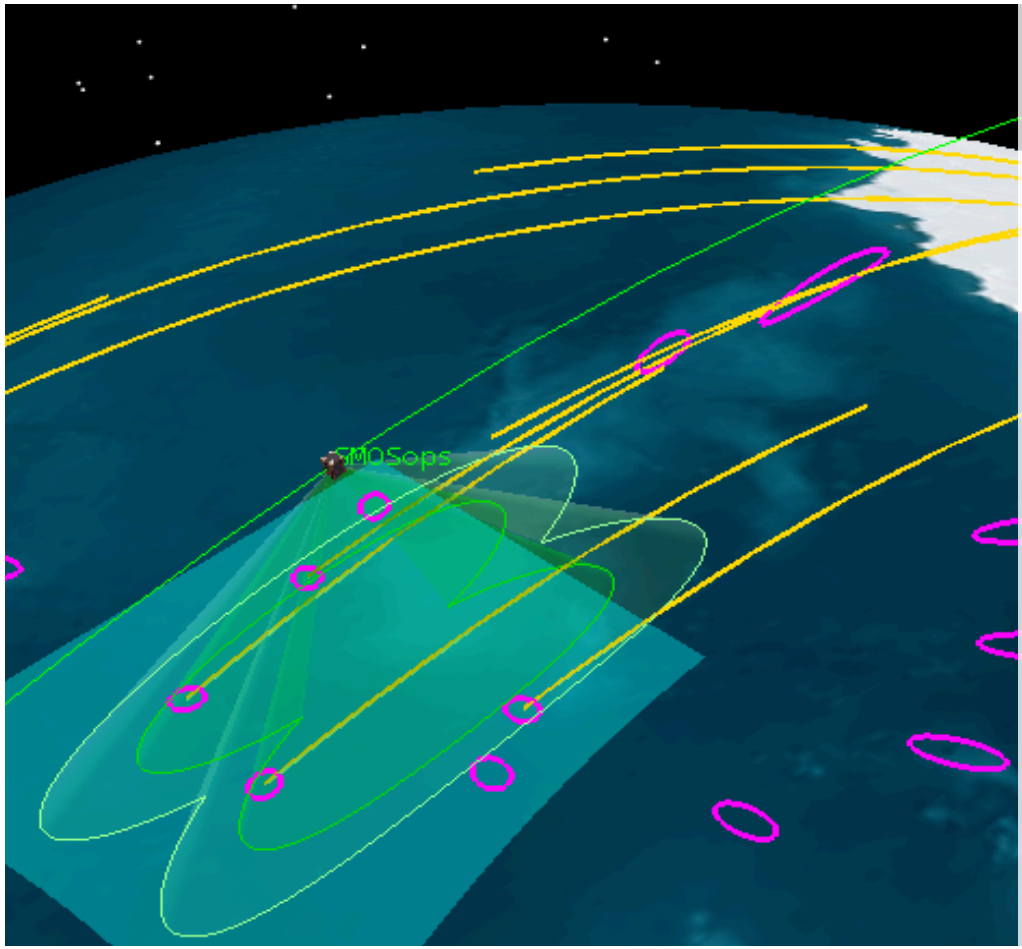
Coverage calculation:





Future Challenges

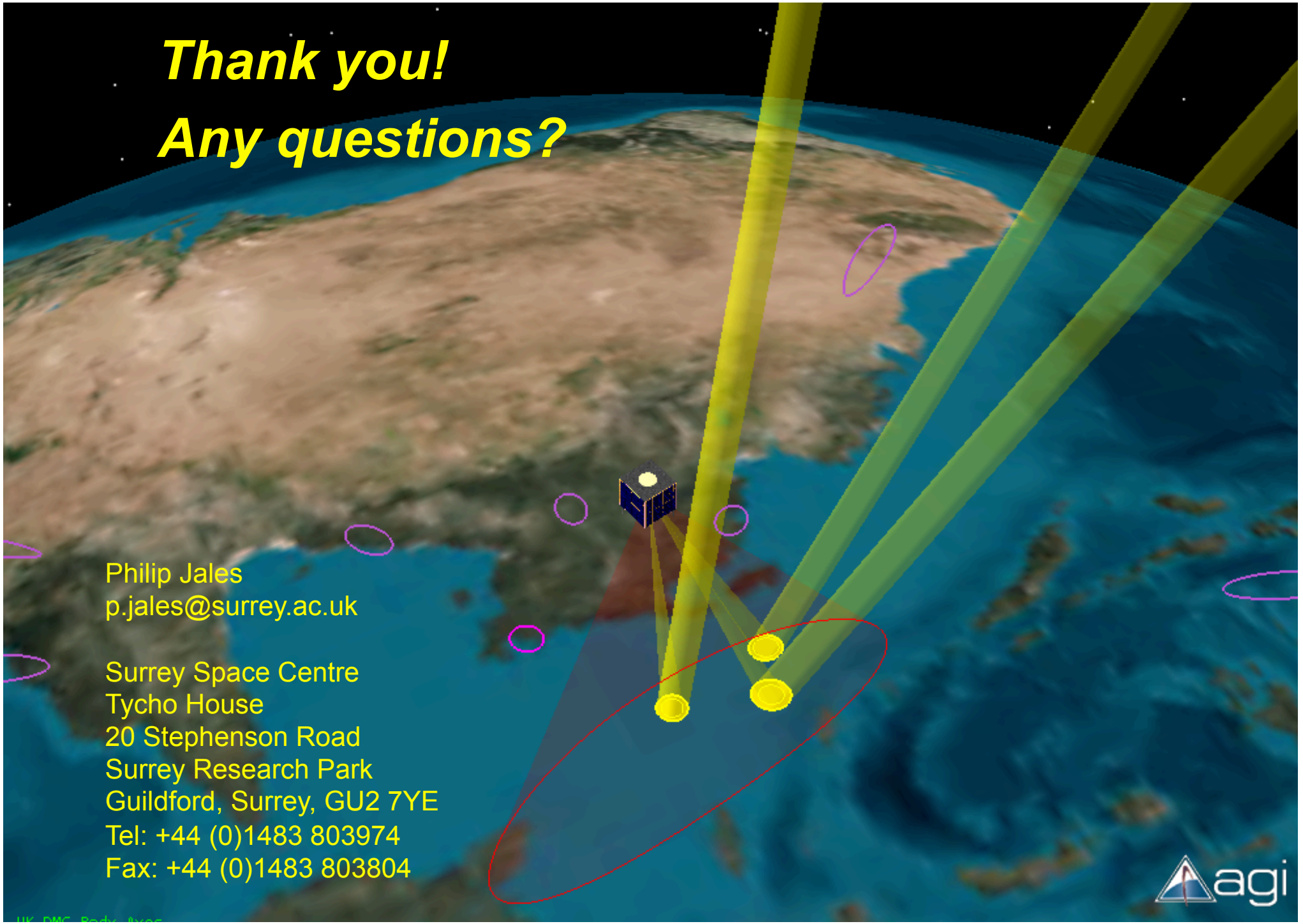
System Challenges



- Modelling and inversion
  - Measurement potential, accuracy characterisation
  - Calibration / Validation
- Gaps in measurements using just GPS
  - More coverage from also using Galileo, GLONASS, COMPASS & SBAS systems
- Data dissemination means
- Demonstrator mission required

Conclusions

- GNSS Reflectometry technique offers potential for a new marine and ice measurement service
- Challenge: demonstrate performance
  - Ocean roughness
  - Ice edge resolution
- Challenge: to distribute data as a service
  - User needs and requirements to be collated
- Instrument development underway and demonstration on forthcoming satellite


Thank you!
Any questions?
Philip Jales
p.jales@surrey.ac.uk
Surrey Space Centre
Tycho House
20 Stephenson Road
Surrey Research Park
Guildford, Surrey, GU2 7YE
Tel: +44 (0)1483 803974
Fax: +44 (0)1483 803804
agi