A blackbox view of incoherent scatter radar

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2021 ISR Summer School

Outline

Blackbox ISR Video 1

- The nature of ISR measurements
- Brief discussion of ISR blackbox
- Where are there existing ISRs?
- Existing ISRs treated as blackbox
  - Exercise with simulator -

Blackbox ISR Video 2

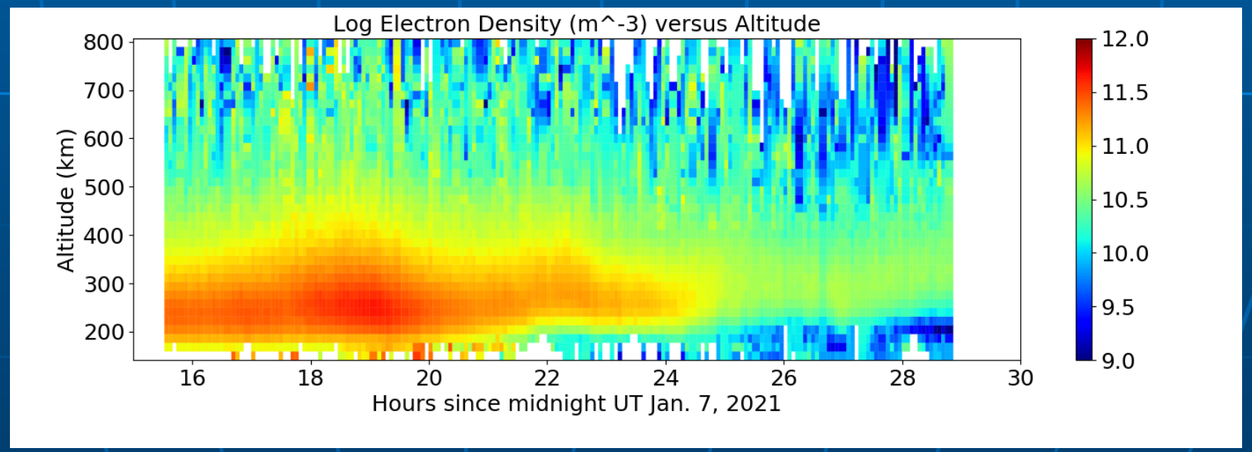
- New ISRs treated as a black box
  - Exercise with simulator - new ISRs Simulate creating a new ISR

The nature of ISR measurements

Each measurement has a range resolution

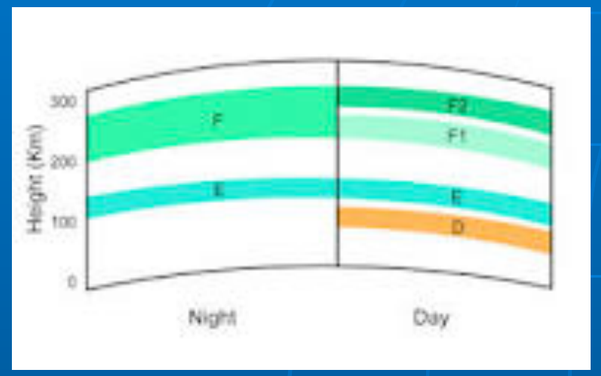
The beam width at a given altitude and the range resolution give the spatial resolution

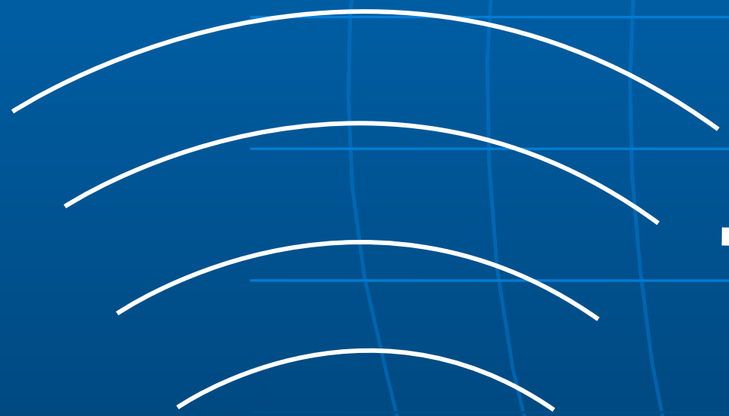
All ranges are measured at the same time; but multiple pulses need: time resolution

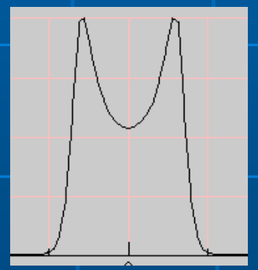


Typical ISR plot

Blackbox ISR Outputs







Parameters

- Electron density
- Electron temperature
- One (or more) ion temperatures
- One (or more) ion velocities

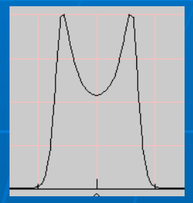
Quality of measurement

- Error bar on each parameter
- Spatial resolution
- Time resolution
- Spatial coverage

Treat ISR as a blackbox

- What are the science outputs?
- What knobs can you turn at the input?
  - For an existing ISR
  - If you got to build a new ISR
- Try it yourself with two jupyter notebook tools
  - Existing and new ISR simulators

Error bars 101: The nature of ISR measurements

 is a probability distribution, not a signal...

Imaging trying to determine if a coin is fair in a dark room...

Both the number of tries and the chance of mistaking head and tails needs to be taken into account...

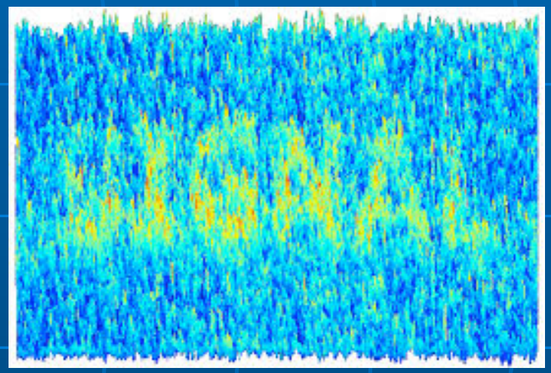
Nature of ISR measurements

What determines the error bar on a measurement?

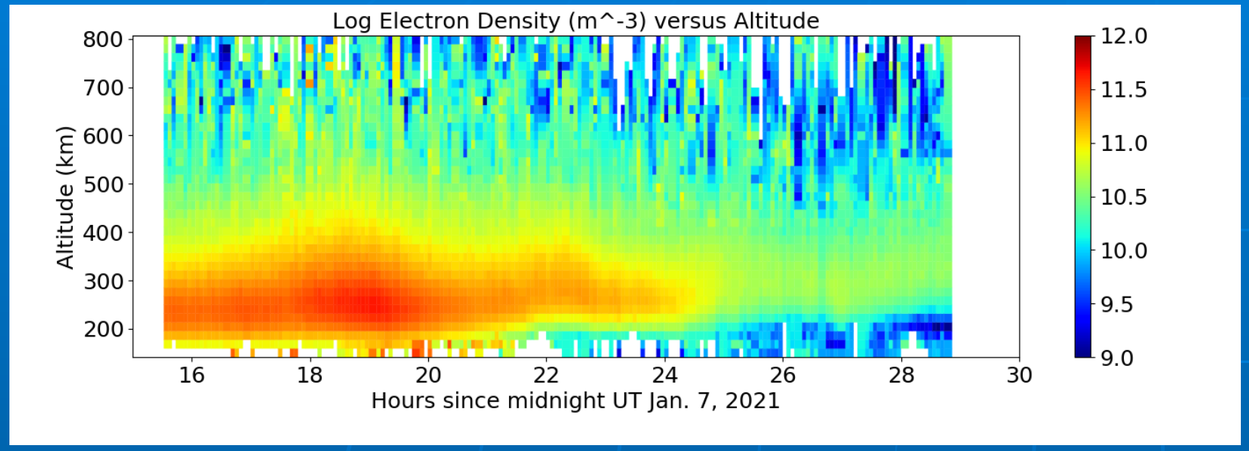
The number of measurements

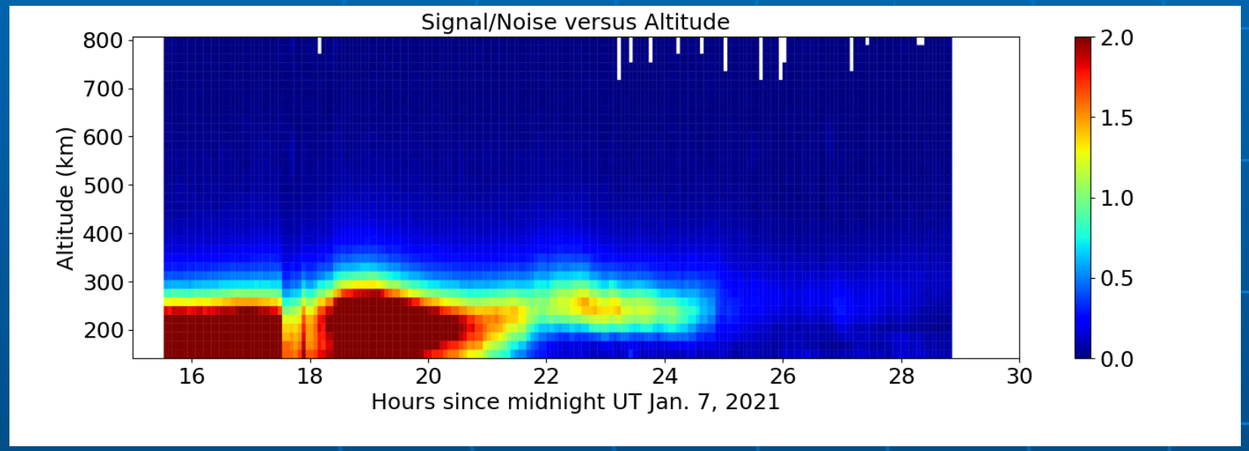
and

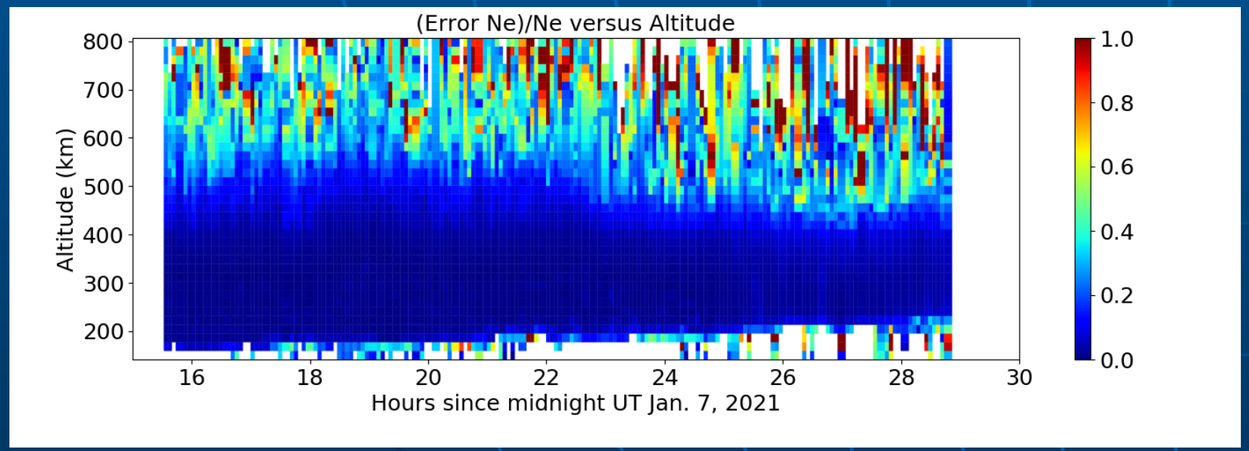
The measurement S/N

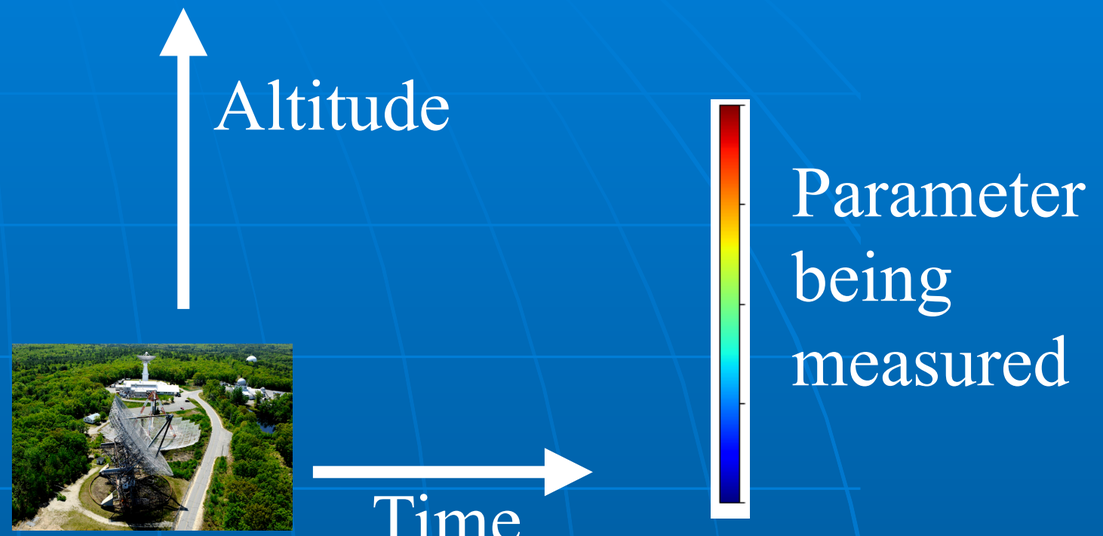


- Flipping a coin in a bright room only one time tells you little (good S/N - small count)
- Flipping a coin a million times in a completely dark room tells you little (poor S/N, large count)









Where would you think good data is using signal/noise?

Where would you think good is using error bars?

<u>Error bars</u> combine S/N with integration time

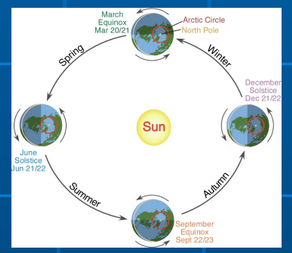
ISR blackbox inputs

What can an ISR user typically control with an existing ISR?

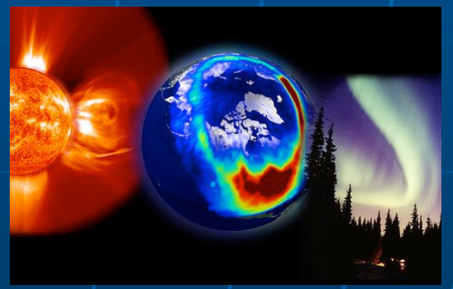
Pointing direction pattern

Integration period (sets count statistics)

Radar mode (pulse length and coding, interpulse period)



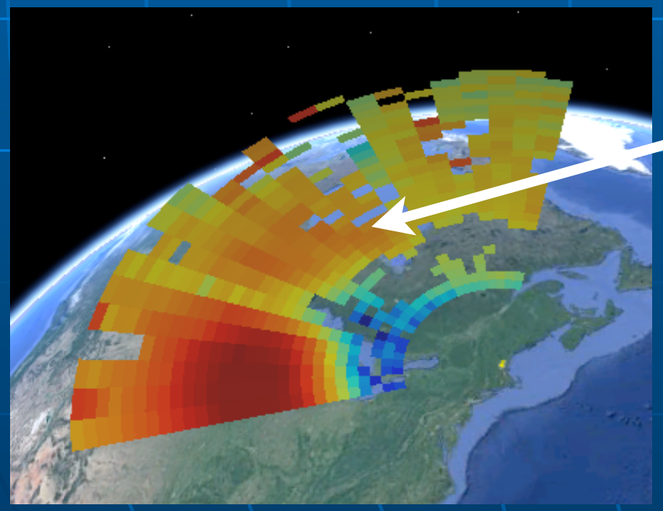
Time of year and solar activity during measurement



Pointing direction (monostatic)

Single direction gives best time resolution

Multiple directions in local area gives vector velocities

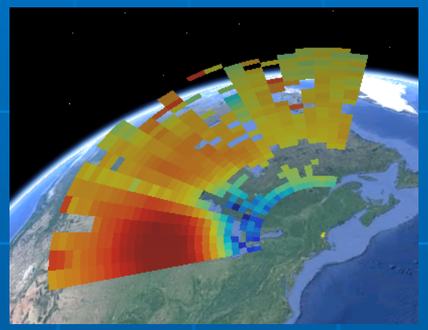


Measurements can be combined into scans

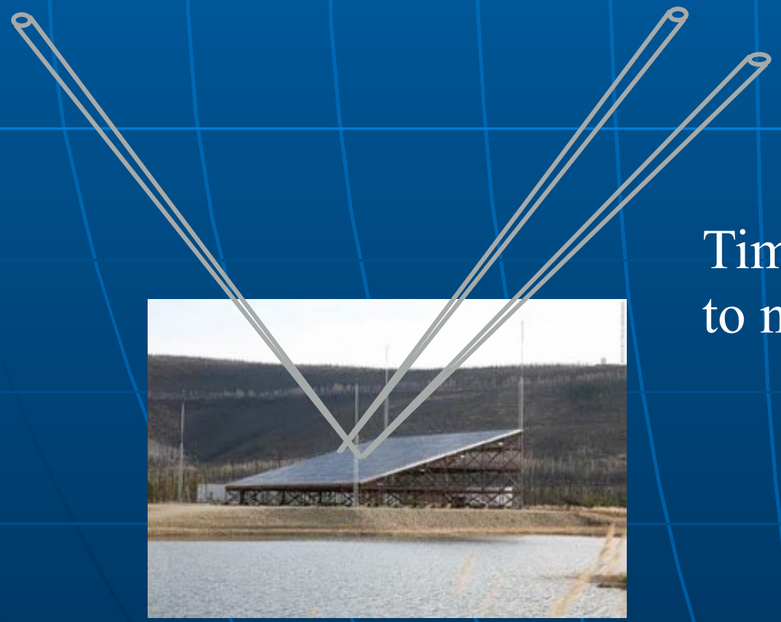
Tradeoff: number of pointing directions versus time resolution

Integration period

For dish antenna with multiple positions, integration periods must be selected beforehand.



For phased array antenna or single position dish antenna, can be chosen after the experiment is run.



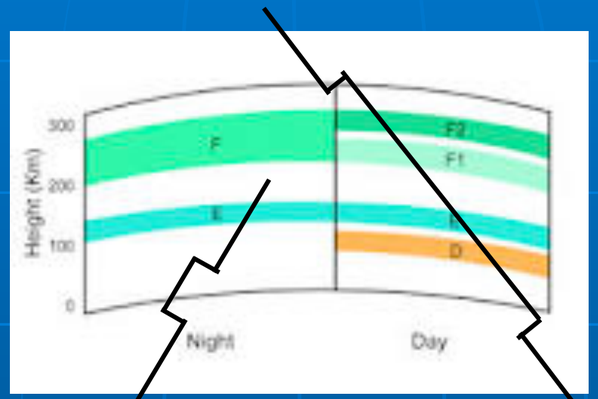
Time resolution is inversely related to number of beams.

ISR modes - single pulse

Parameters to set:

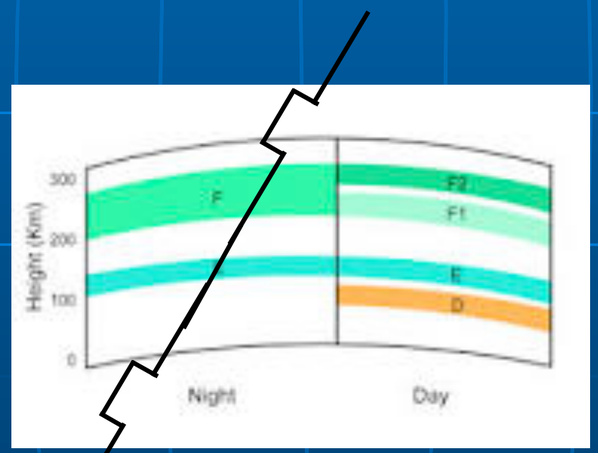
Pulse length

Shorter uncoded pulses:
Better spatial resolution,
worse S/N



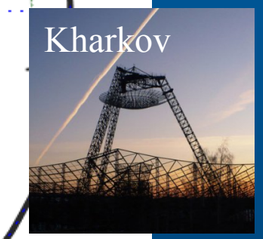
Longer uncoded pulses:
Worse spatial resolution,
better S/N

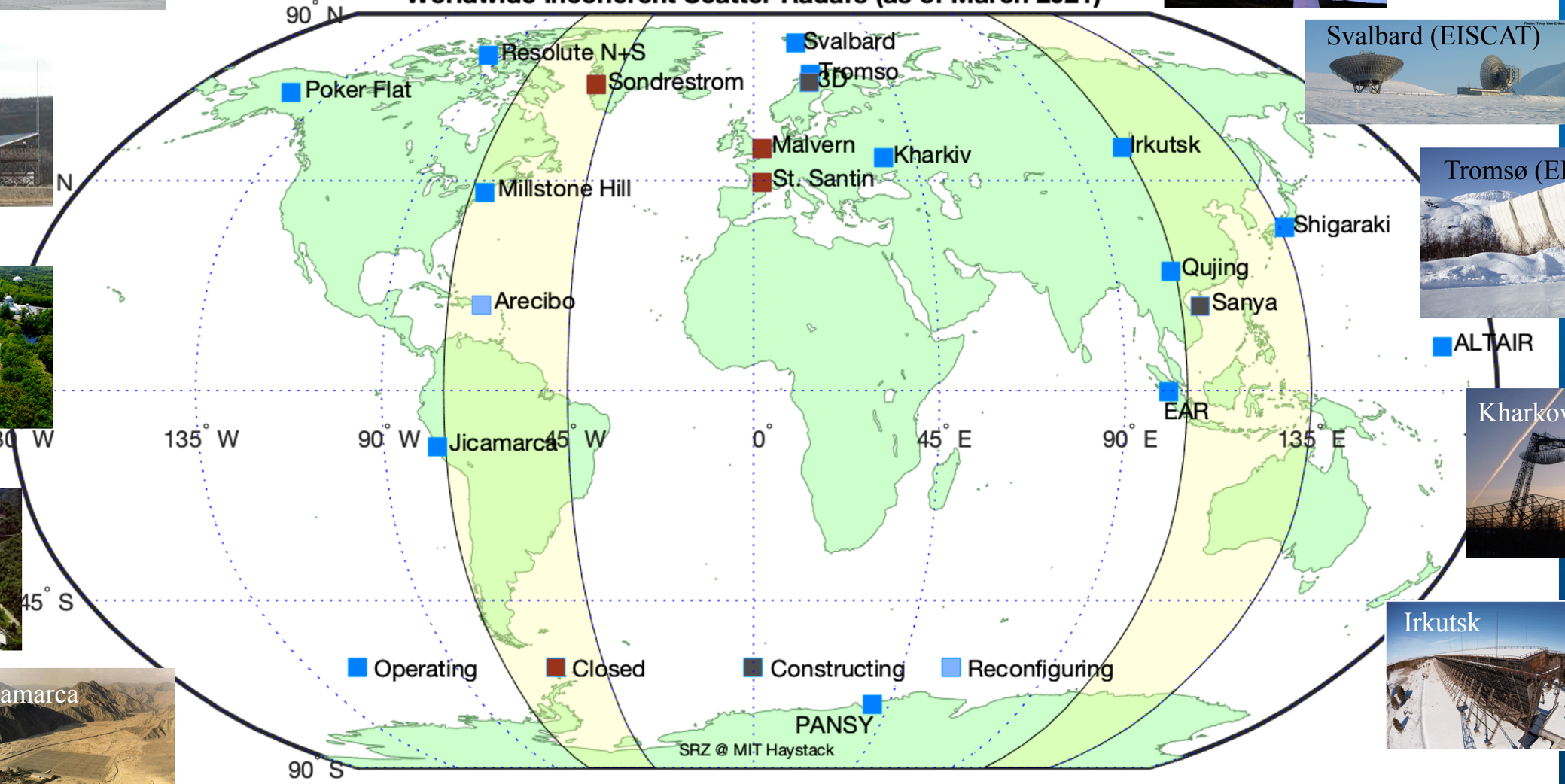
Interpulse period



Shorter time increases counts/sec, limited by duty cycle of transmitter and need to have previous pulse not returning signal

Where in the world are/were/will there be ISRs?





Where to get ISR data

- Active ISRs fully in Madrigal
  - Poker Flat (Alaska), RISR North and RISR South (northern Canada)
  - Millstone Hill (Massachusetts), Jicamarca (Peru)
  - Eiscat (Svalbard, mainland ISRs)
  - Arecibo (Puerto Rico) - future uncertain
- Active ISRs partially in Madrigal
  - Kharkov (Ukraine), Irkutsk (Russia), Qujing (China)
- Historical ISRs in Madrigal
  - Sondrestrom (Greenland), Malvern (UK), St. Santin (France)
- Radars that run occasionally in ISR mode
  - Altair (Kwajalein), Shigaraki MU (Japan) - some in Madrigal
  - EAR (Indonesia), PANSY (Antartica)
- ISR Radars under construction
  - Eiscat 3D (Scandinavia), Sanya (China)

Existing ISR simulator exercise

Additional inputs

https://tinyurl.com/2021ISR

Blackbox ISR exercises

ISR blackbox inputs for a new radar

What design decisions affect a new monostatic ISR?

- Radar frequency
- Aperture (m^2)
- Peak power
- Location
- Steering method and range

New ISR simulator exercise

Ionosphere generated by IRI model (quiet day)

Full code available (~650 lines of python)

All equations to be covered in rest of this course

https://tinyurl.com/2021ISR

Blackbox ISR exercises