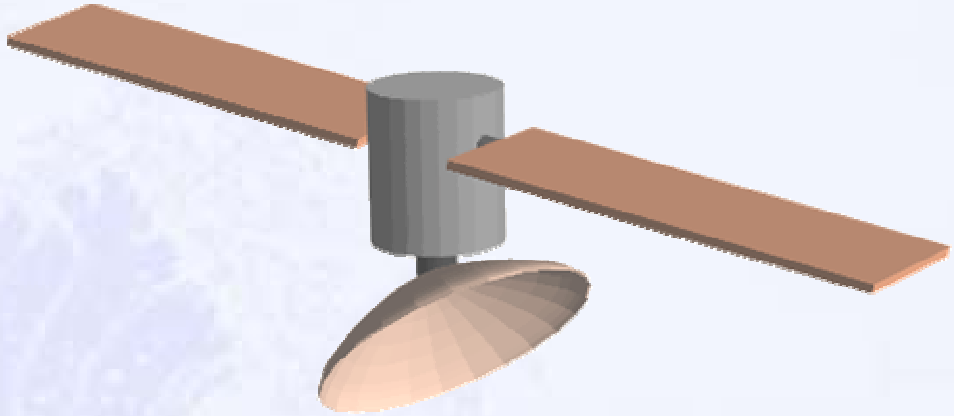
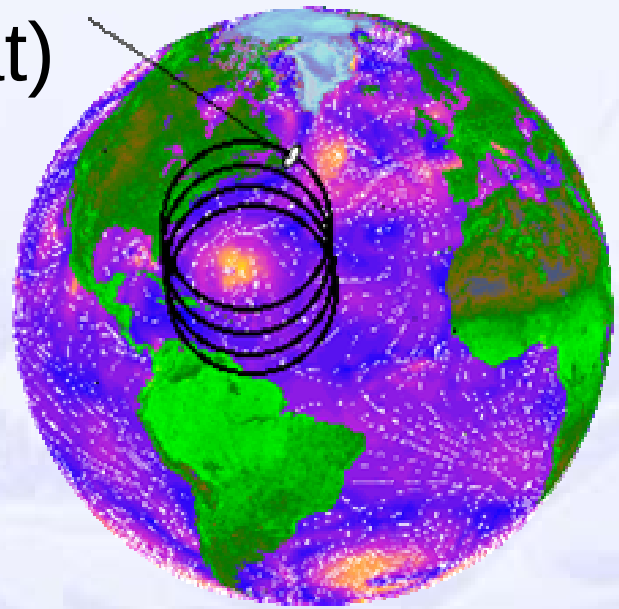


MEO Scatterometer (MEOScat) Mission Concept



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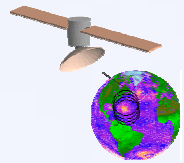
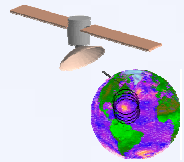
MEOScat Study Objectives

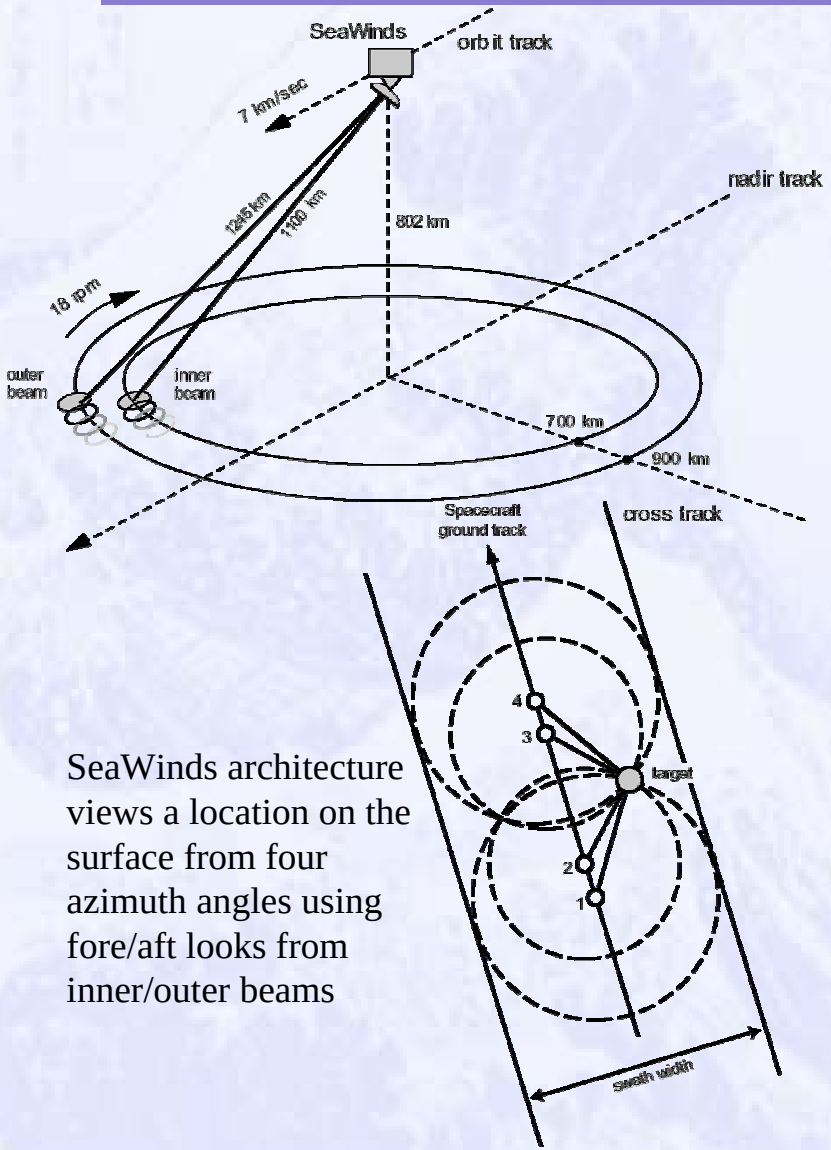


- Develop wind scatterometer mission concept with significantly improved coverage
  - Single satellite revisit time comparable to multiple LEO platforms
  - Contiguous, successive swaths with no gaps
- Improved performance
  - Higher spatial resolution
  - Improved wind accuracy

➢ Potential challenges:
  - Optimum orbit selection
  - Larger antenna
  - Radiation environment

Scatterometer Measurement

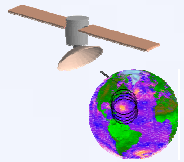




SeaWinds architecture views a location on the surface from four azimuth angles using fore/aft looks from inner/outer beams

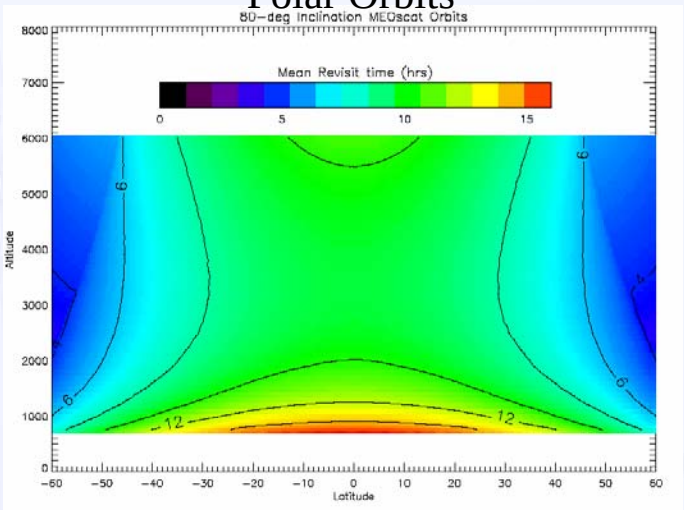
- Wind scatterometers are radars (5-14 GHz) which infer sea surface wind speed and direction from measurements of radar backscatter cross-section (σ_0).
- Scatterometer systems have been successfully flown at LEO (i.e., SeaWinds at 800 km)
- To retrieve wind, scatterometer must:
  - Measure the same point on surface from different azimuth angles within a short (minutes) period of time.
  - Measure surface at incidence angles between 20-60 degrees.
- These constraints limit scatterometer altitudes to MEO and LEO “swath based” measurements; not well suited for GEO

Single S/C Orbit Analysis (1 of 2)

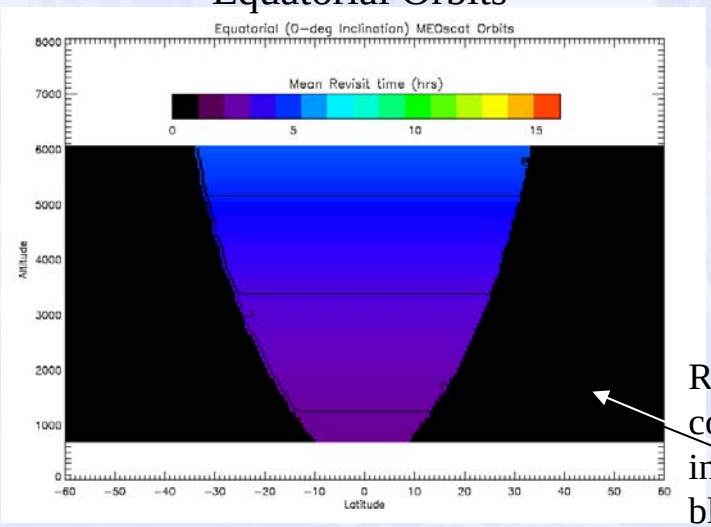


- Revisit characteristics for a range of orbits examined:
  - Single satellite, circular orbit
  - Swath width fixed by maximum incidence angle of 60º.
  - Altitudes from 800 km to 20000 km.
  - Inclinations from 0º to 90º.
- Average and maximum revisit time for each point on Earth up to +/- 60º latitude calculated.

Polar Orbits

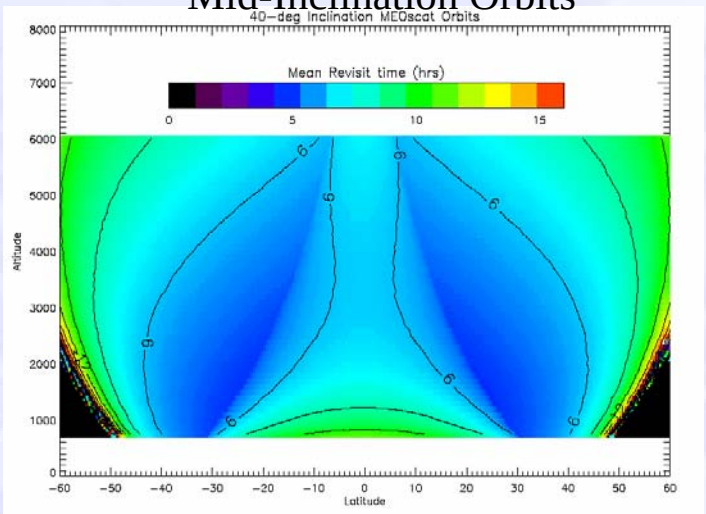


Equatorial Orbits

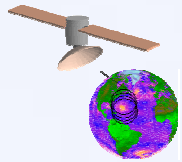


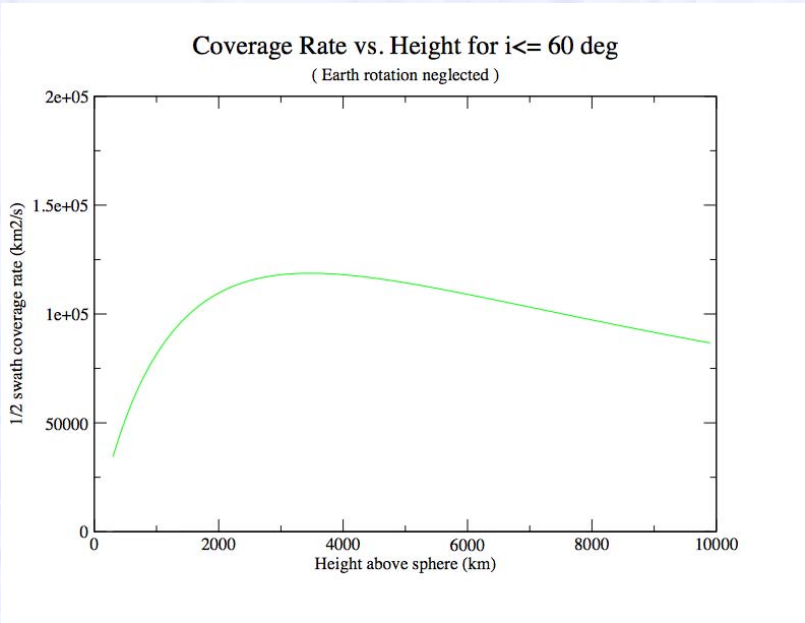
Regions not covered indicated by black

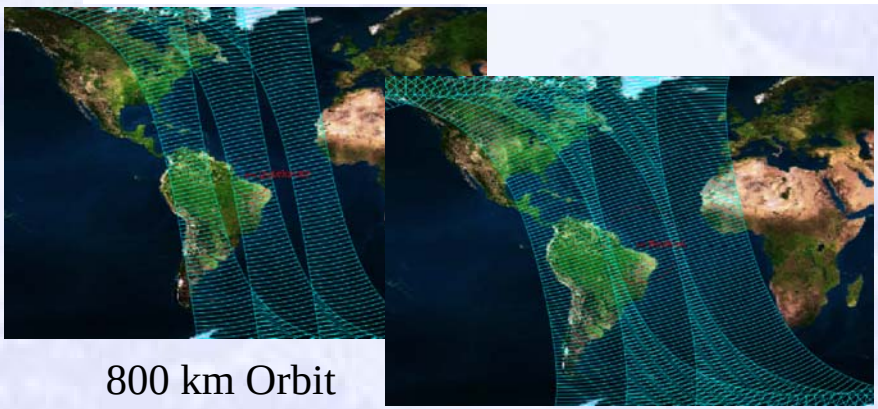
Mid-Inclination Orbits



Single S/C Orbit Analysis (2 of 2)







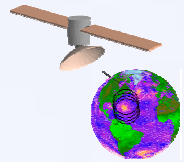
800 km Orbit (SeaWinds)

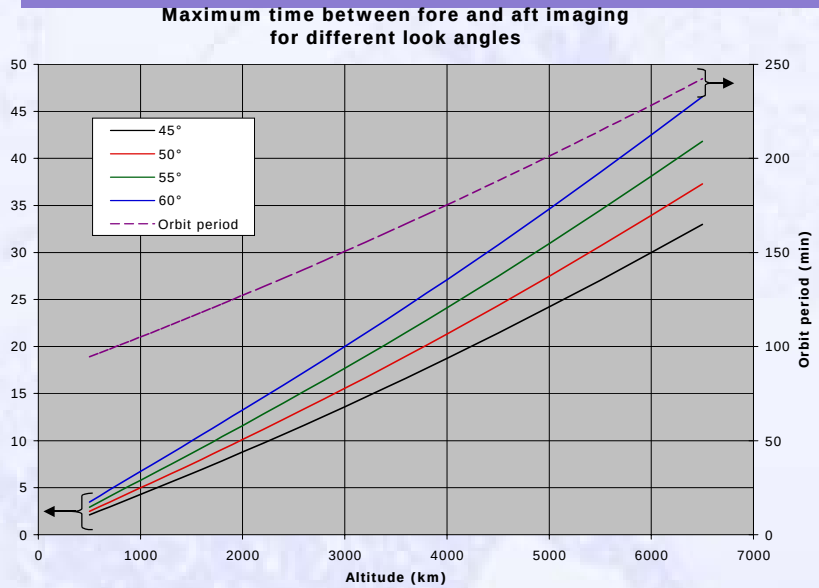
1500 km Orbit

- Equatorial Orbits:
  - Excellent revisit time (near orbit period).
  - Systematically excludes higher latitudes.
- Polar orbits:
  - Global coverage.
  - Revisit performance improves rapidly up to about 1500 km, then levels out.
    - Area coverage rate improves rapidly up to about 1500 km, levels out to a peak at 3000 km.
    - 1500 km near point where successive swaths overlap.
- Middle Inclination Orbits
  - Excellent average revisit statistics at mid-latitudes, but revisits come in “bursts.”
  - No coverage in near-polar regions.

➢ “Best” single S/C solution seem to be 1500 km polar (or sun synchronous) orbit.
  - ➢ Single S/C does work of two LEO’s
  - ➢ Global coverage

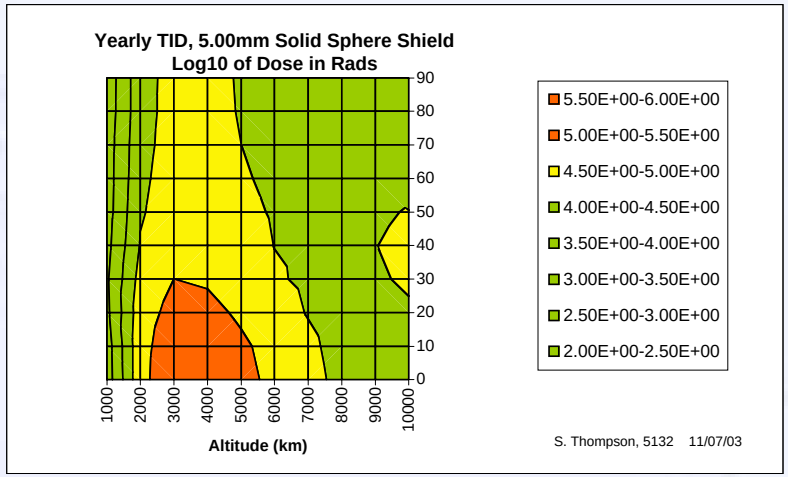
Additional Orbit Considerations





Measurement Duration

- Assuming 10 m/s feature advection, measurement duration limits "best resolution to…
  - 3 km res at 800 km altitude
  - 6 km res at 1500 km altitude
  - 12 km res at 3000 km altitude
  - 25 km res at 6000 km altitude

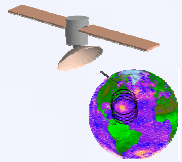


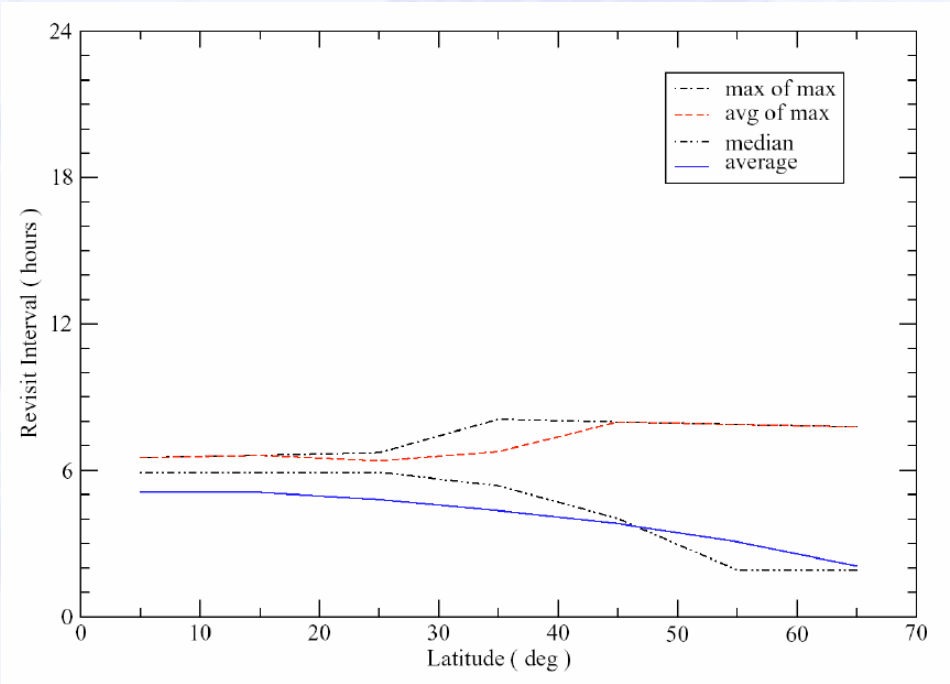
Radiation

- Worst-case total incident dose (TID) radiation through 5 mm Al environment calculated for range of altitudes and inclinations.
- Qualitative radiation zone designations:
  - "Green" < 32 kRads, straightforward with available parts and shielding.
  - "Yellow" < 100 kRads, part selection and shielding moderately difficult.
  - "Red" > 100 kRads, ability to find parts more difficult.

➔ 1500 km orbit near optimum for revisit, coverage, measurement duration and radiation.

MEO Constellations

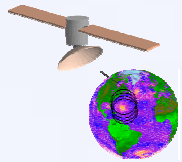




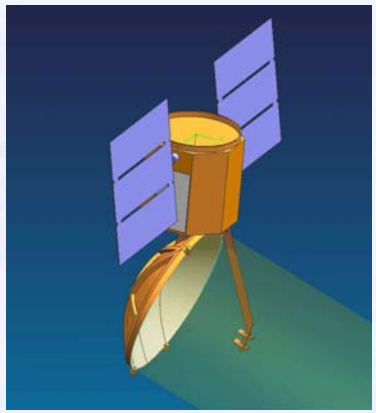
Mean and max revisit statistics as a function of latitude for a 2 S/C 1500 km constellation

- Although single S/C revisit time is substantially improved at MEO over LEO orbits, goal falls short of operationally desired 6 hour revisit.
- Single S/C revisit time at 1500 km:
  - 10 hrs mean at equator (compared to 15 hrs for LEO)
  - 12 hour max at equator (compared to 24 hrs for LEO)
- Constellation is required to meet 6 hr goal
  - 2 S/C constellation at MEO at 1500 km
  - 3 S/C constellation at LEO at 800 km

Antenna Technology

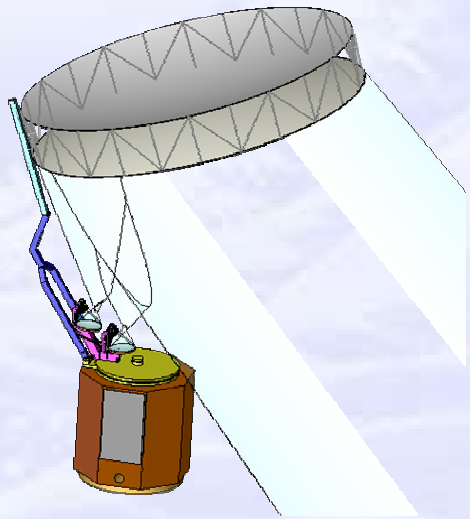


- For scatterometer missions, rotating reflector antenna is best solution:
  - Wide scan easily achieved
  - Radiometrically stable
  - Easily accommodates multiple channels (active and passive)
- Increased antenna size required at higher altitude for spatial resolution
  - Linear increase for real aperture
  - Synthetic aperture techniques more efficient for higher resolutions and higher altitudes
- Two antenna technologies considered for MEOScat:
  - Rigid, 2 meter reflector achieves same resolution as SeaWinds (25 km real-aperture) at 1500 km altitude
  - Deployable mesh, 4.5 meter antenna can achieve 10 km real-aperture resolution or 2-5 km synthetic-aperture resolution at 1500 km altitude

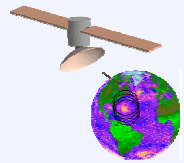


2 meter, rigid spun antenna for standard resolution (25 km) from MEO. High heritage technology.

4.5 meter, spun deployable mesh antenna for high resolution (2-10 km) from MEO. Use of *spinning* mesh antenna is new technique, but extensive analysis has established feasibility.

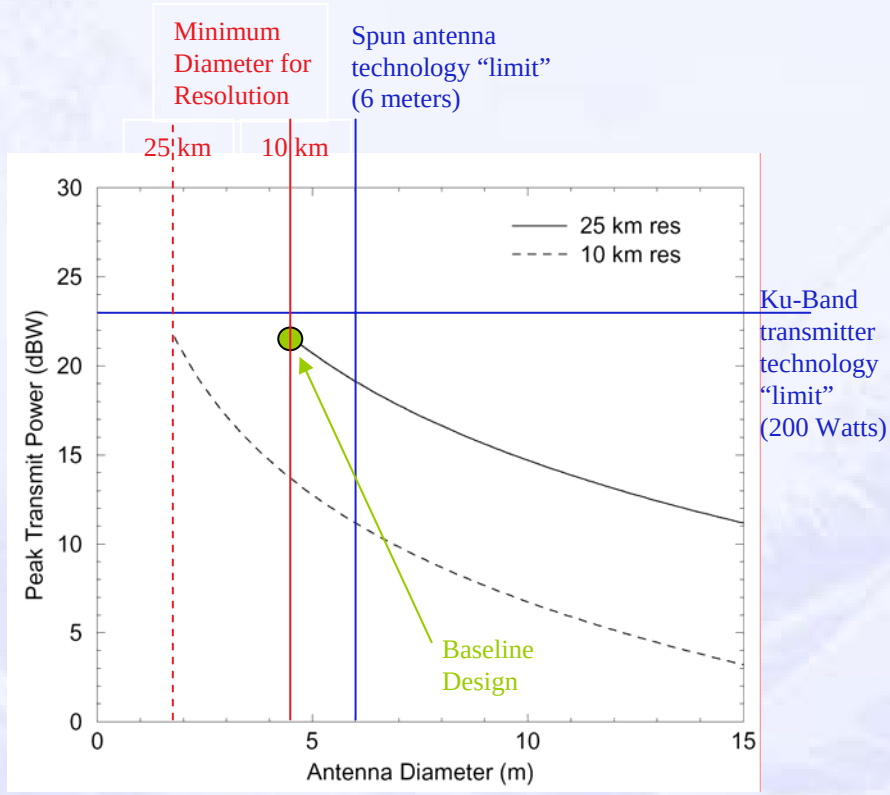


Transmitter Technology

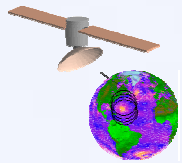


- Higher orbits lead to longer slant range to surface, which trends towards lower SNR.
- Possible need for more capable, higher power transmitters.
- For real aperture antennas, however, the necessary growth in diameter to maintain resolution also increases gain.

➢ Antenna diameter increase with altitude almost exactly compensates for slant range effect (for real aperture), allowing current 120 W Ku-Band transmitter technology to be applied at MEO.



Conclusions



- Optimal single satellite scatterometer system not so “far out” after all:
  - Altitude of 1500 km (barely MEO!) near peak of revisit performance, does job of two LEO birds.
  - Radiation environment still relatively benign.
  - Current antenna and transmitter technology can be employed.
- Constellation of two MEO S/C required to meet regular 6 hour revisit time ultimately desired by operational users.
- Results applicable to other “swath based” remote sensing systems.