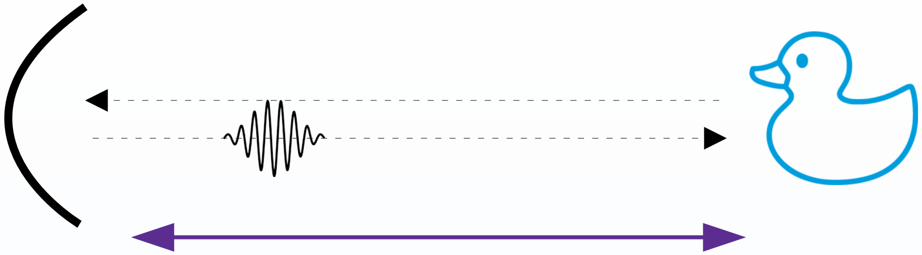
EGM703 – Advanced Active and Passive Remote Sensing

Week 3, Part 3: Principles of Radar

Radar: the basic idea

- **Ra**dio **D**etection **a**nd **R**anging
- Active microwave remote sensing
- Send a signal, measure return
  - Travel time
  - Signal strength (amplitude)
  - Polarization
  - Phase
  - Frequency
- Power received (P_r) depends on:
  - Power transmitted, P_t
  - Antenna gain, G
  - Distance to target (range), R
  - Target’s radar cross-section, σ



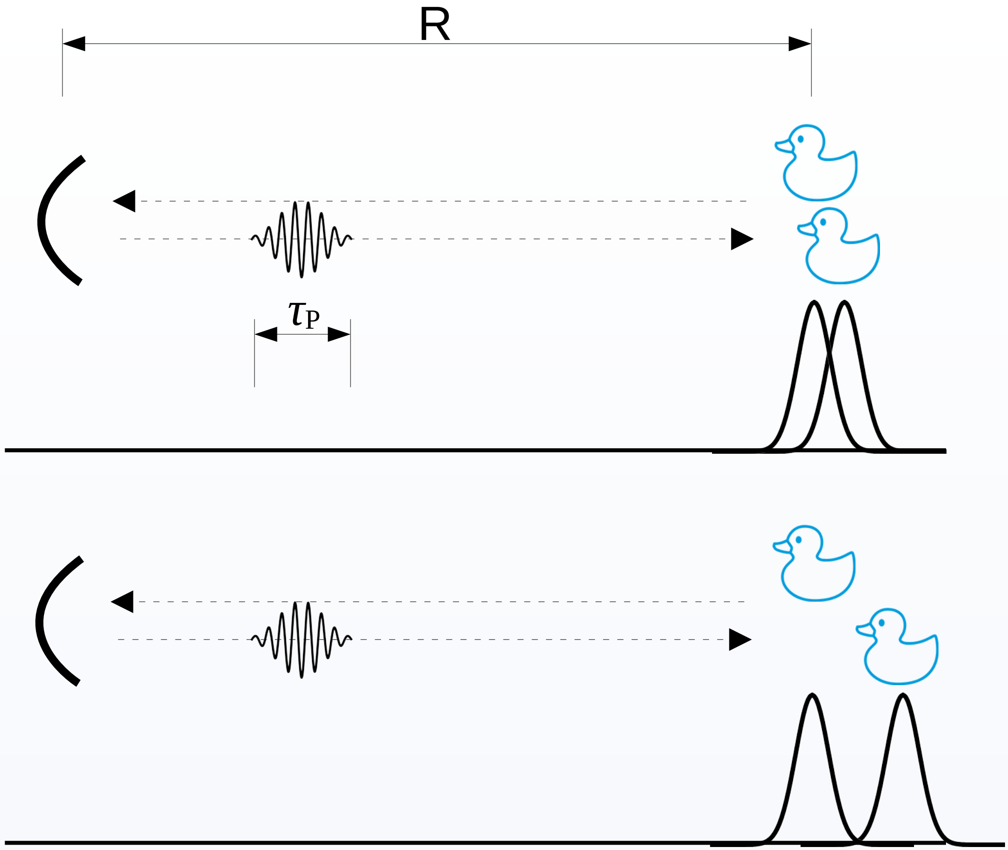
$$R = \frac{c \cdot \Delta t}{2}$$

$$P_r = P_t \frac{G^2 \lambda^2}{(4\pi)^3 R^4} \sigma$$

the radar equation

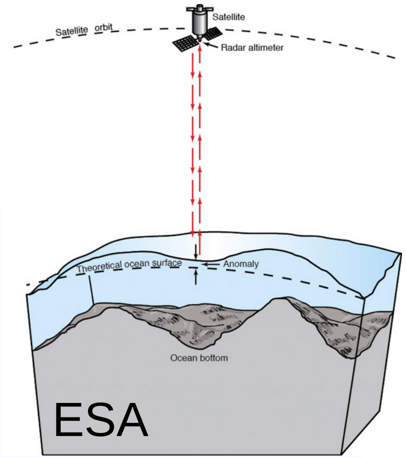
Range resolution

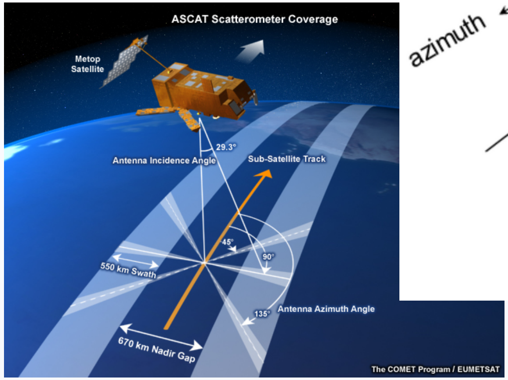
- Range: the distance between the sensor and the target
- Range resolution (ρ_R): the ability to distinguish between two targets
  - Depends mostly on signal bandwidth, τ_P
  - Formula: $\rho_R = \dfrac{\tau_P c}{2}$

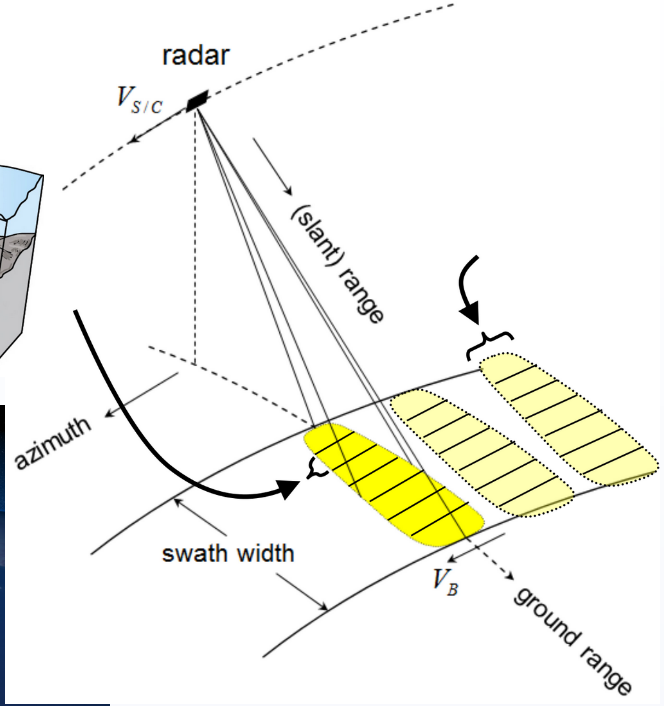


Types of radar systems

- Differentiate between radar systems based on measurement type
- Non-imaging radar
  - Radar altimeters (distance)
  - Scatterometers (σ)
- Imaging radar
  - Side-looking airborne radar (SLAR)
  - Synthetic Aperture Radar (SAR)

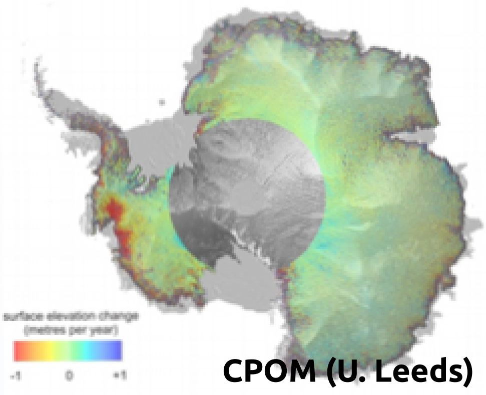


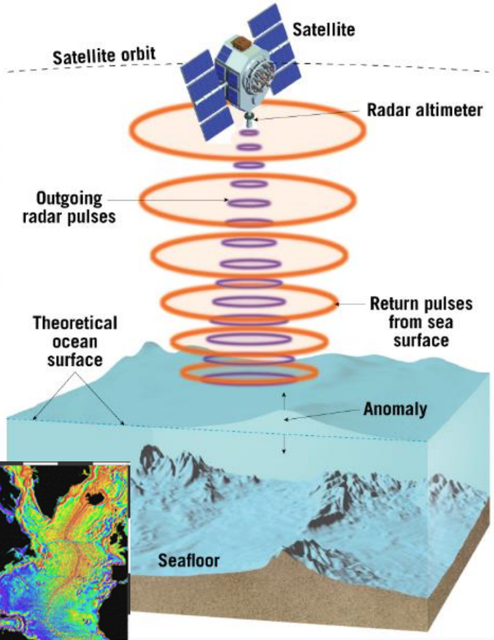


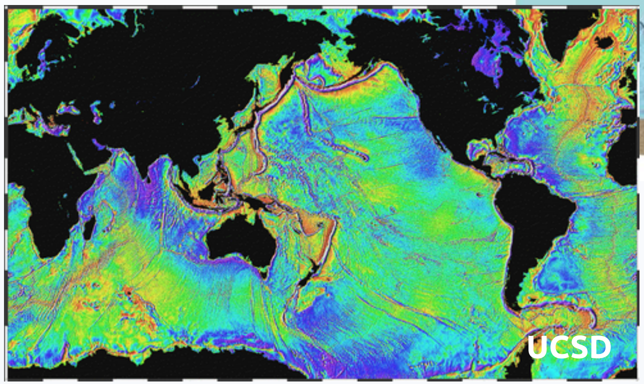


Radar Altimeters

- Used to measure distance between satellite and surface
- Can achieve high accuracy (< 3 cm)
- Large footprint limits application to “flat” surfaces
  - Ocean
  - Ice Sheets

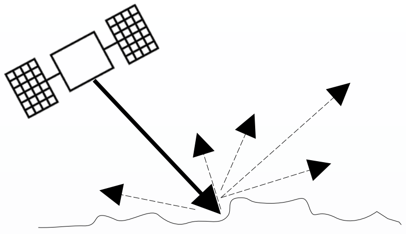


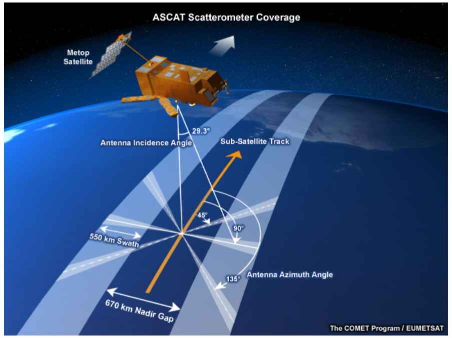


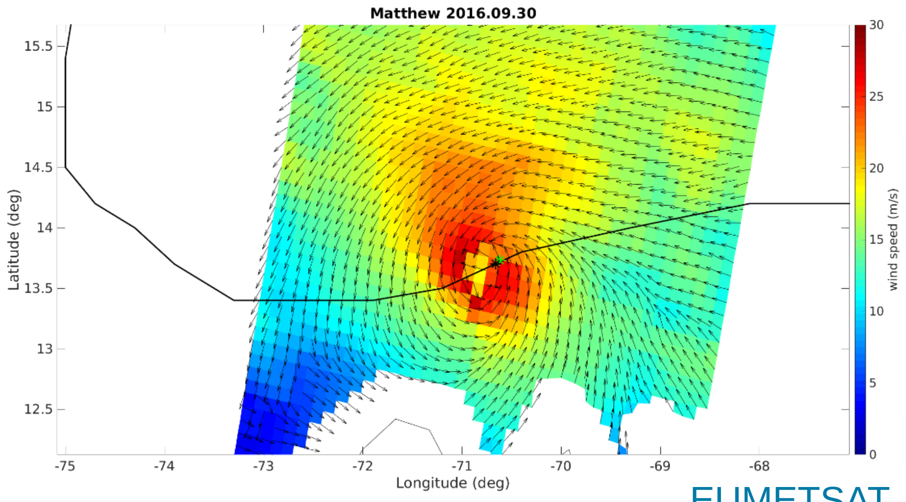


(Radar) Scatterometers

- Detect signal scattered by Earth's surface
  - Measure radar cross-section, σ^0
- Main application: measuring surface wind speed
  - σ^0 depends on ocean roughness, viewing angle
  - Ocean roughness depends on near-surface wind speed
  - Different viewing angles → different backscatter → wind direction
- Example: Hurricane Matthew, 2016







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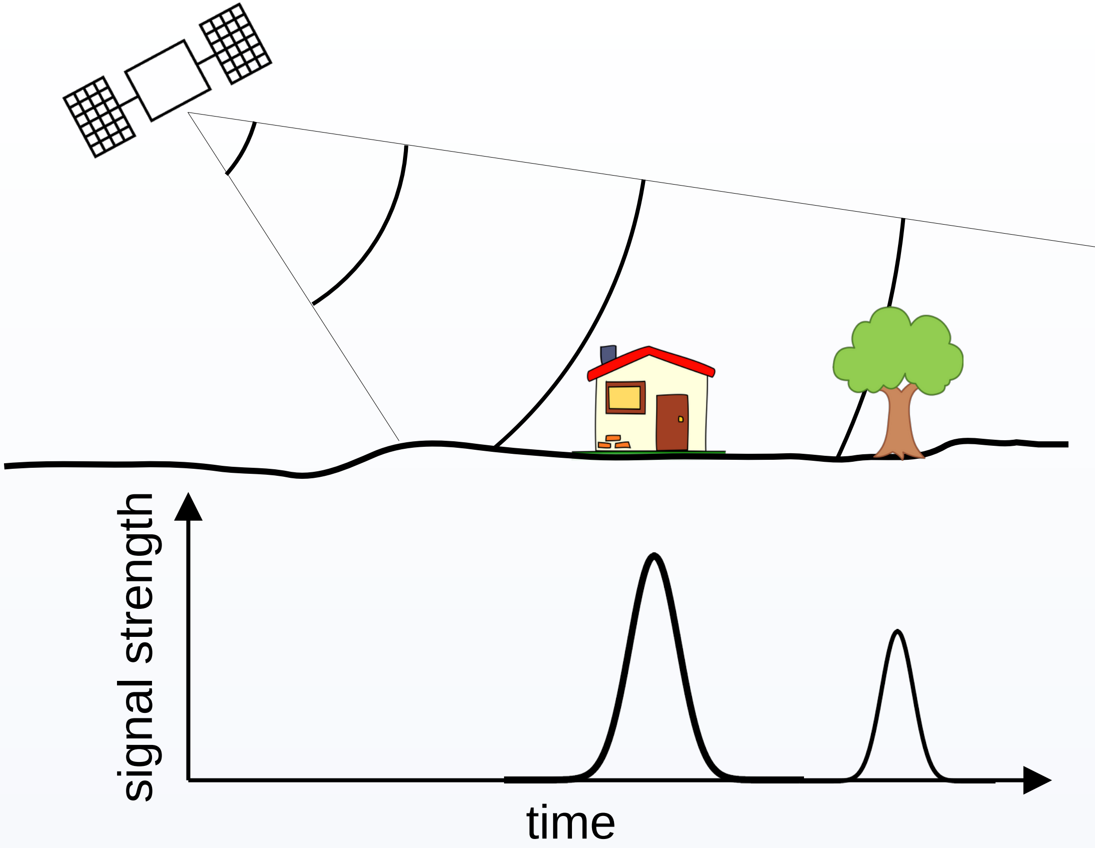
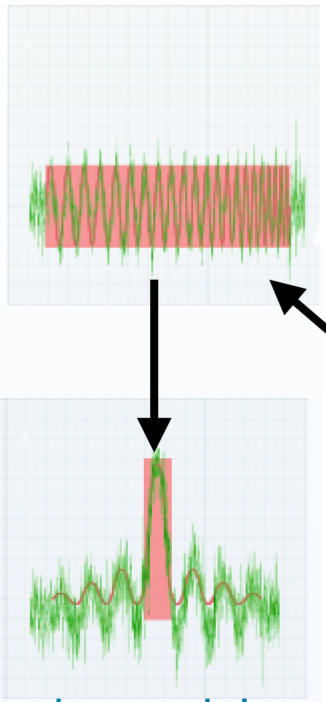
Imaging radars

- Side-looking radar
- Signal from objects further away (in slant range) is recorded later
  - Can translate to ground distance to sensor/antenna path
- As antenna moves along flight direction (azimuth), continues recording
- Enables us to build a 2D image of signals

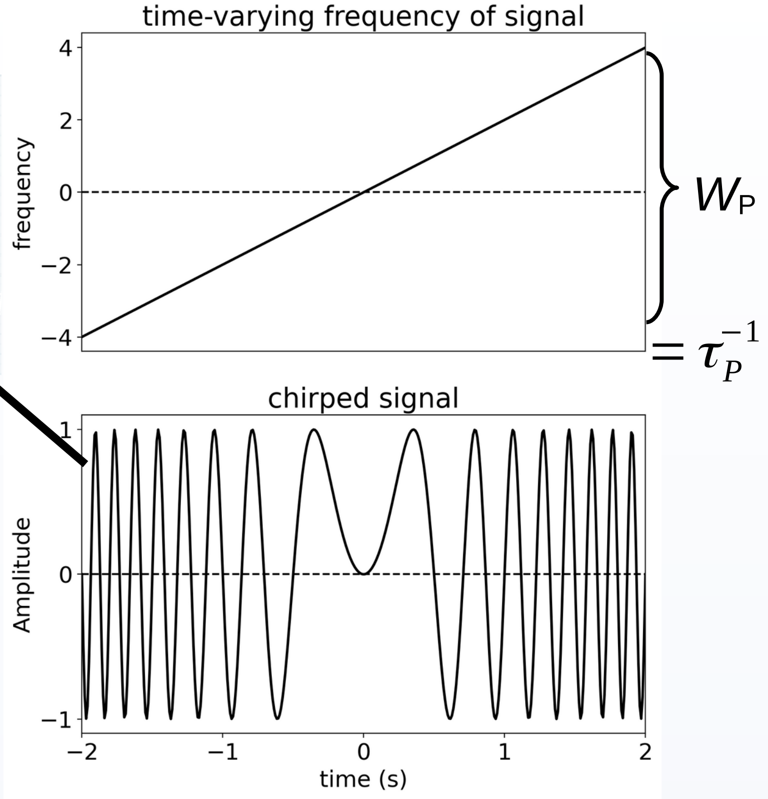


Range compression

- The problem: transmitting a short, powerful pulse is hard.
- Solution: make it unique!
  - Transmit a signal with frequency-coded signal (chirp)
- Range compression: correlate received signal with chirp
  - Helps with problem of overlapping signals
- Range resolution: $\rho_R \approx \dfrac{c}{2W_P}$

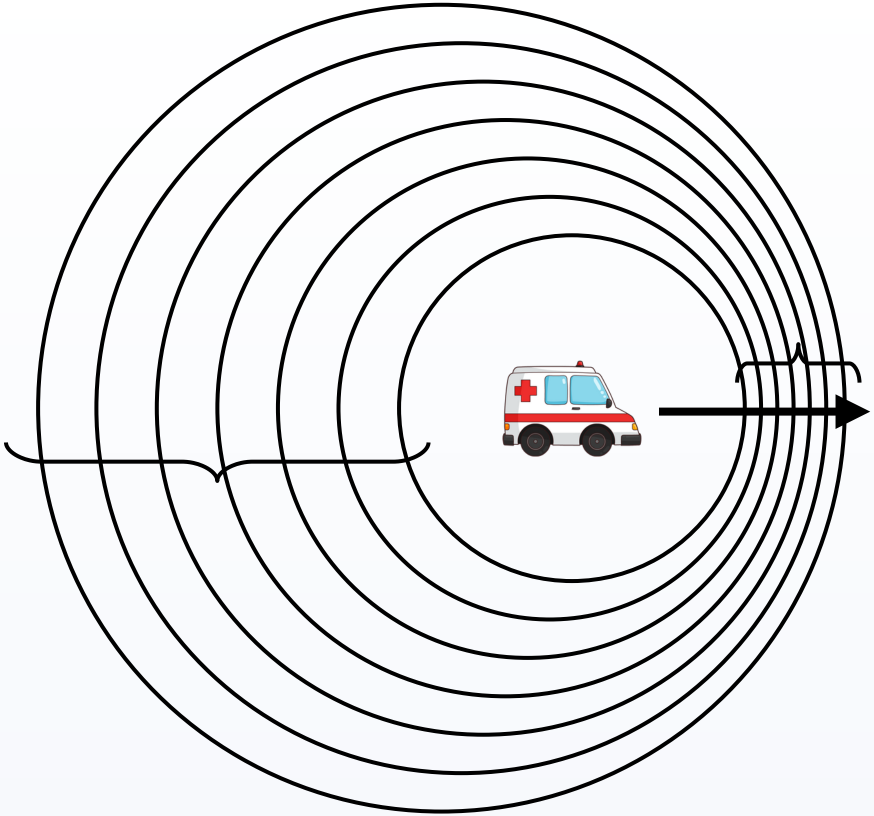


radartutorial.eu



The Doppler effect

- Moving source causes a shift in frequency
  - Toward observer: increases
  - Away from observer: decreases
- By measuring shift in frequency, can calculate relative velocity
- Alternatively, if we know relative velocity (e.g., satellite), can calculate frequency shift



Summary

- Radar is active remote sensing: send out signal, measure return
- Signal returned depends on properties of target
- Radar systems have two main flavors: imaging/non-imaging
- With some neat signal processing, can improve (range) resolution of system

Additional resources

- Lillesand, Kiefer & Chipman – Chapter 6
- Campbell & Wynne – Chapter 7
- radartutorial.eu
- Tutorial on Satellite Derived Wind Products [EUMeTrain]
- Why we need radar satellites [ESA]
- Altimetry Explained [ESA]