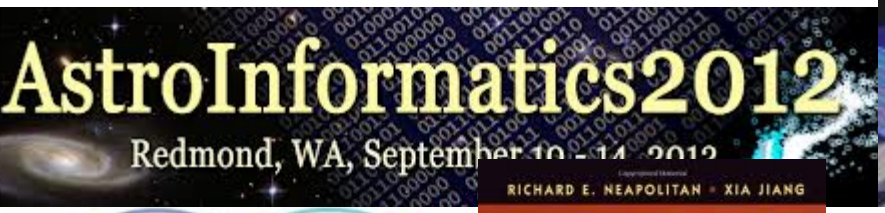
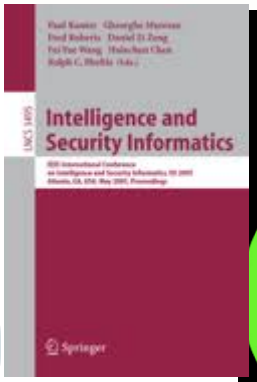
X-Informatics: Radar Informatics (with application to glaciology)

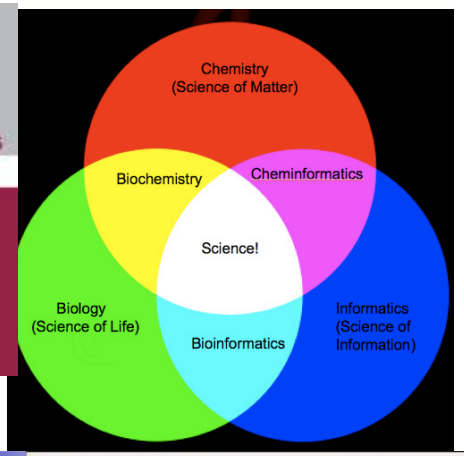
Jerome E. Mitchell
School of Informatics and Computing
Indiana University Bloomington

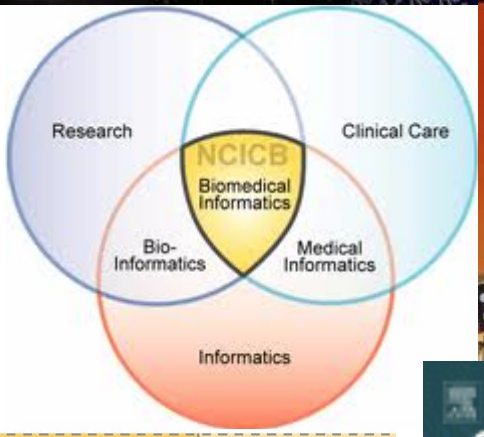
INDIANA UNIVERSITY

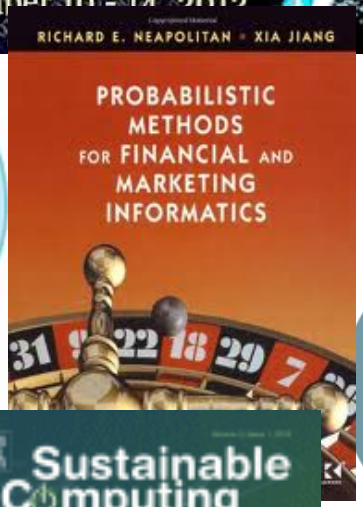
Lesson 1

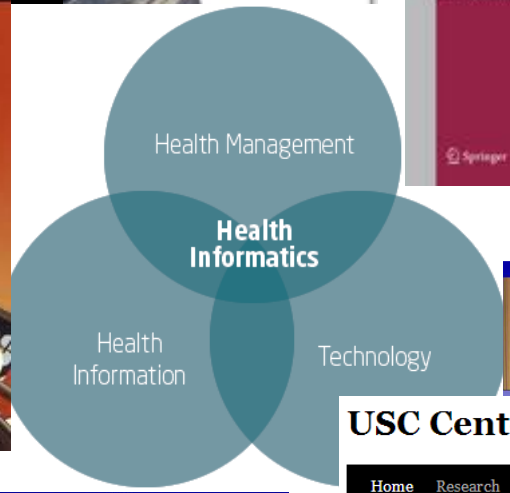


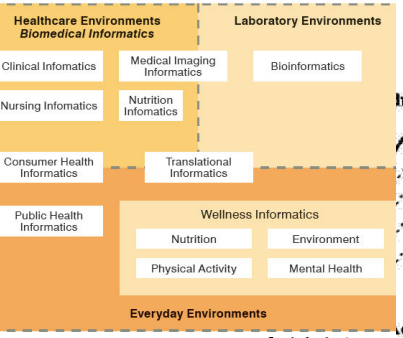


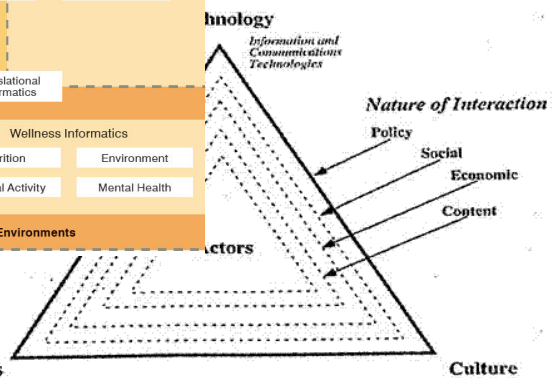




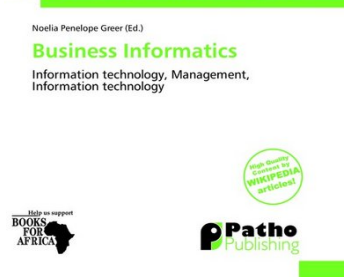








Social Informatics

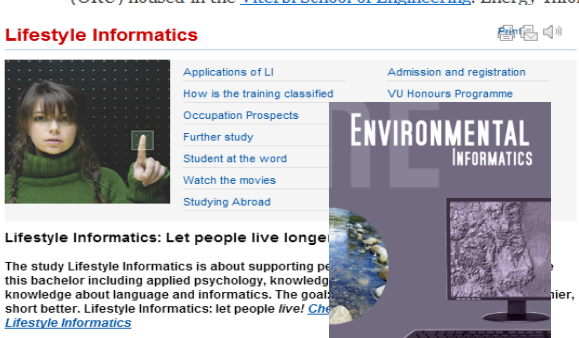


USC Center For Energy Informatics

Home | Research | Publications | Smart Grid | Smart Oil Field | News | People

About the Center

Welcome to the Center For Energy Informatics (CEI) at USC, an Organized Research Unit (ORU) housed in the Viterbi School of Engineering. Energy Informatics is the application of



Big Data Ecosystem in One Sentence

Use Clouds running Data Analytics Collaboratively
processing Big Data to solve problems in
X-Informatics (or e-X)

X = Astronomy, Biology, Biomedicine, Business, Chemistry, Climate, Crisis, Earth Science, Energy, Environment, Finance, Health, Intelligence, Lifestyle, Marketing, Medicine, Pathology, Policy, Radar, Security, Sensor, Social, Sustainability, Wealth and Wellness with more fields (physics) defined implicitly

Spans Industry and Science (research)

Education: Data Science see recent New York Times articles

http://datascience101.wordpress.com/2013/04/13/new-york-times-data-science-articles/

MOTIVATION

- CHANGING (DISAPPEARING OUTLET GLACIERS)
- DATA ANALYTICS INVOLVES IMAGE PROCESSING AFTER DETAILED PROCESSING OF RADAR DATA
- EXAMPLE OF LARGE (PETABYTE TODAY) GEOLOCATED DATASET

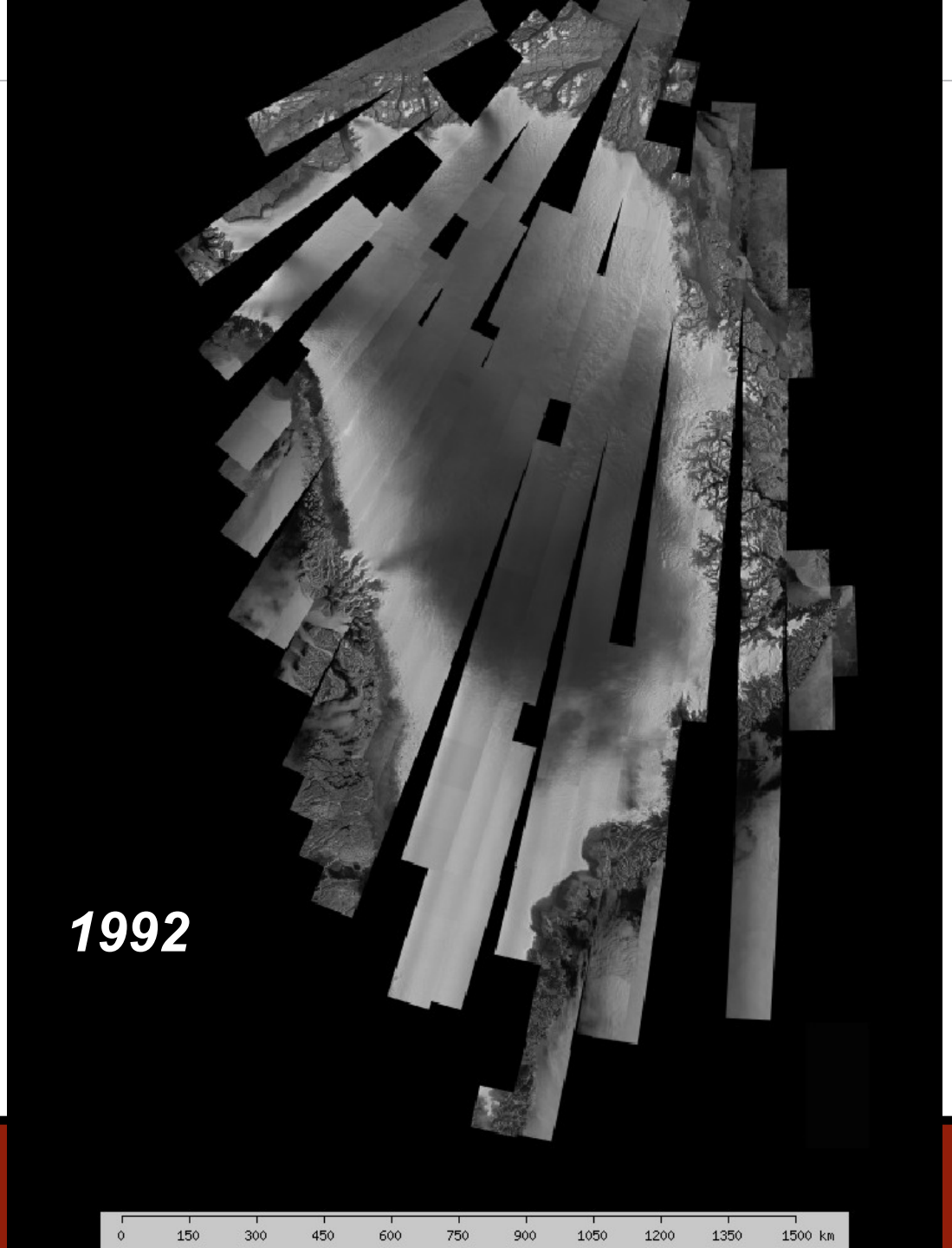


IMAGE CREDIT:
IAN Joughin/Mark Fahnestock

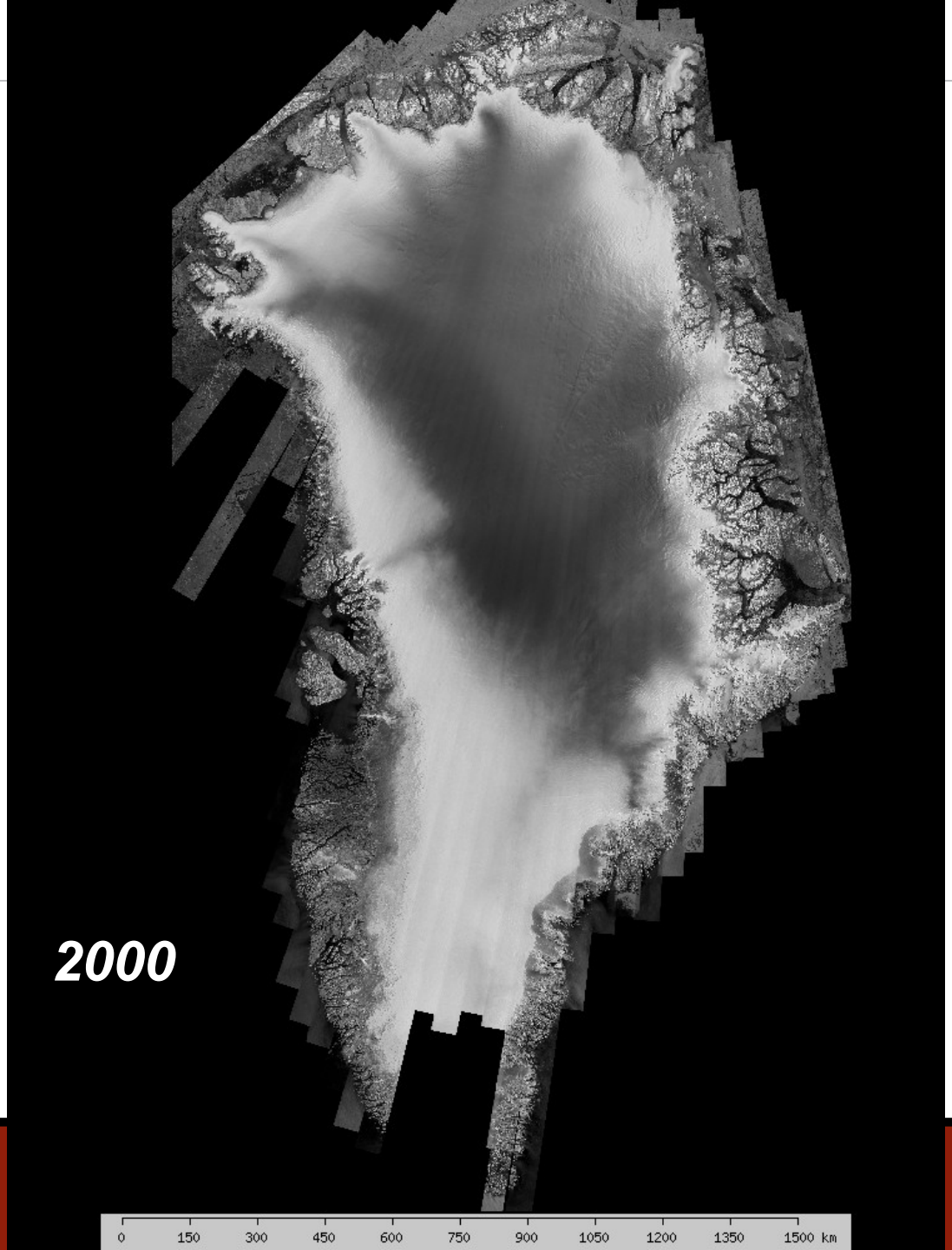


IMAGE CREDIT:
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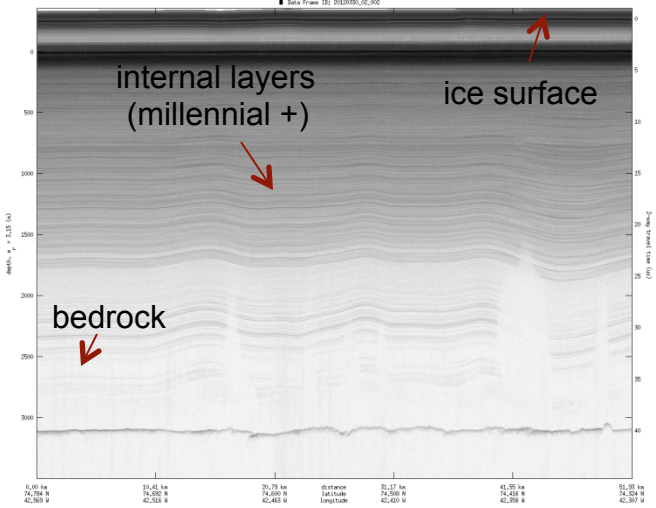
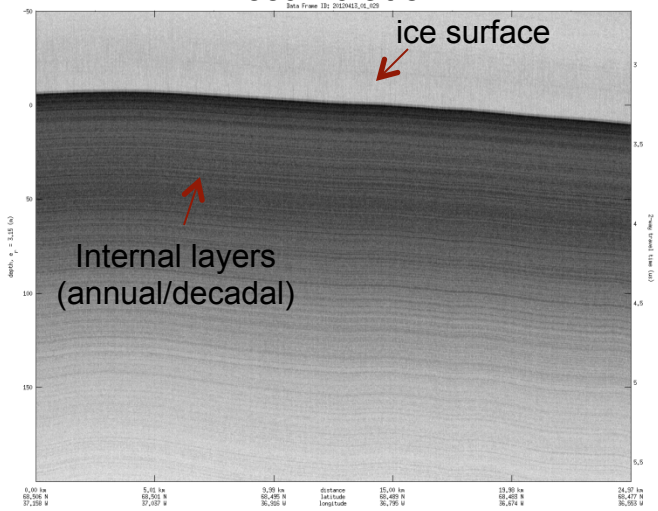
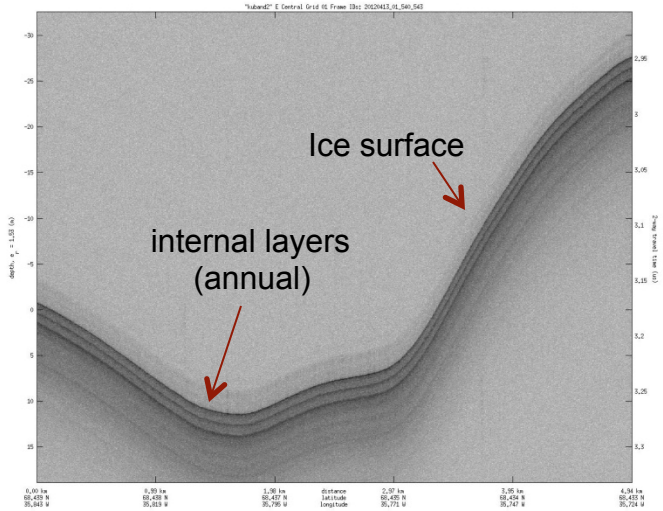
Depth Sounder



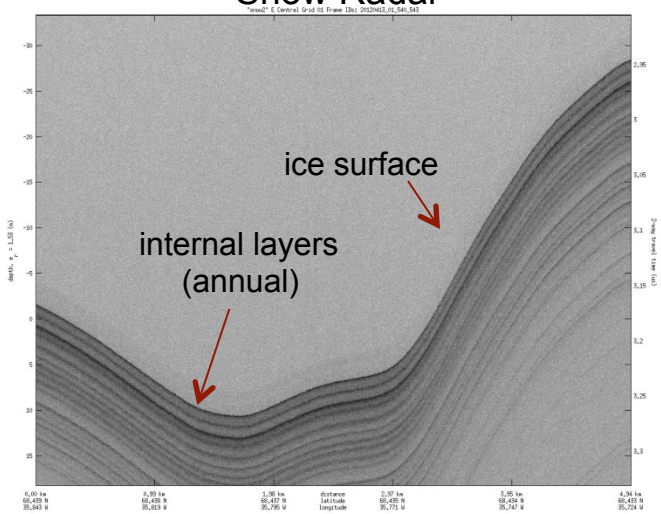
Accumulation



Ku-Band Altimeter



Snow Radar



IMAGES CREDIT:
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Outline

- Background – Remote Sensing
- Background – Global Climate Change
- Ice Sheet Science
- Radar Overview
  - Radar Basics
- Radar Informatics

Lesson 2

X-Informatics: Radar Informatics (with application to glaciology)

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Overview of Remote Sensing

What is Remote Sensing?

- Remote Sensing is the art and science of
  - Acquiring
  - Processing
  - Interpreting
- Images and related data obtained from ground-based, air or space-borne instruments, which record the interaction between a target and electromagnetic radiation

Remote Sensing Process

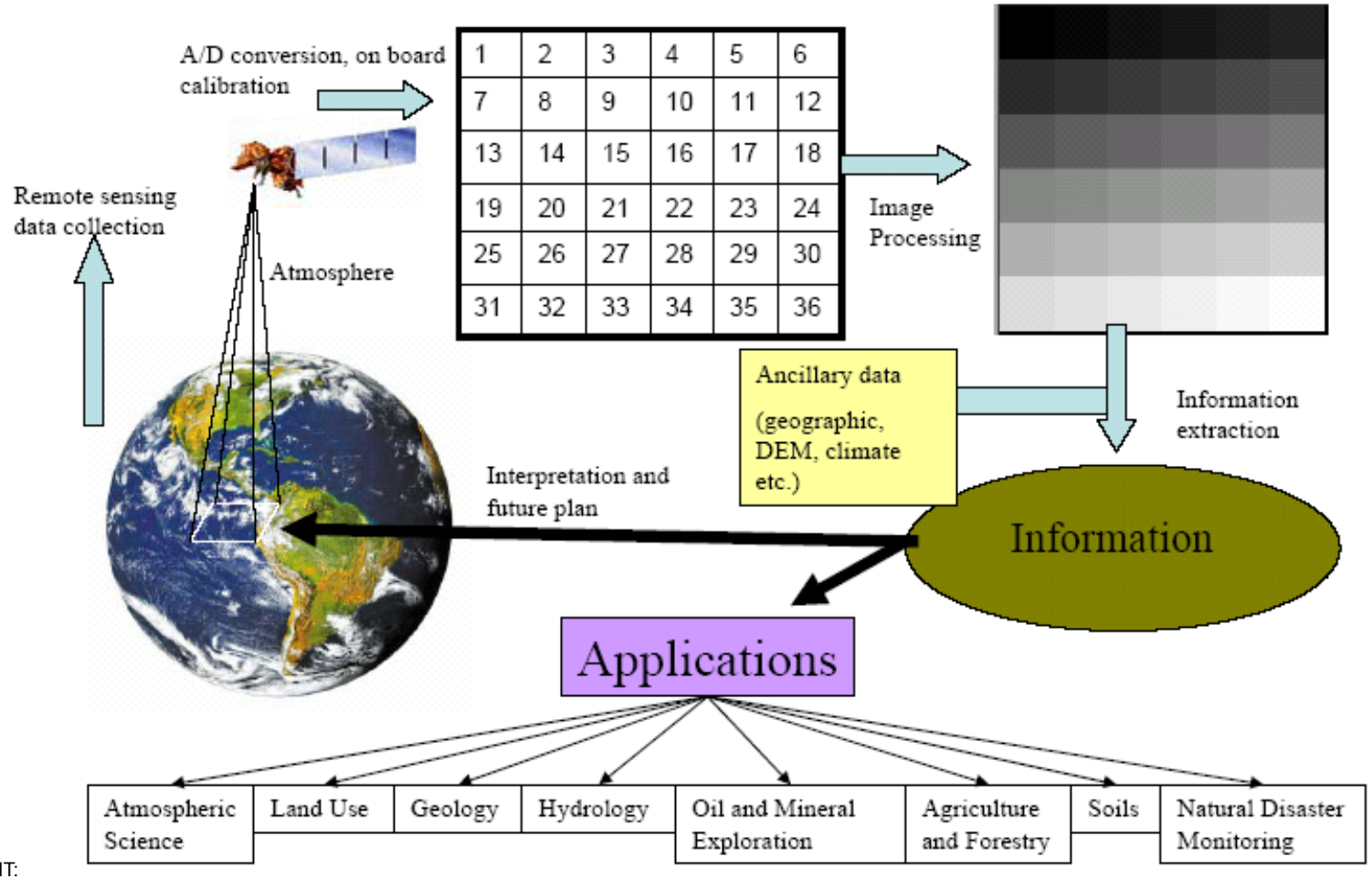
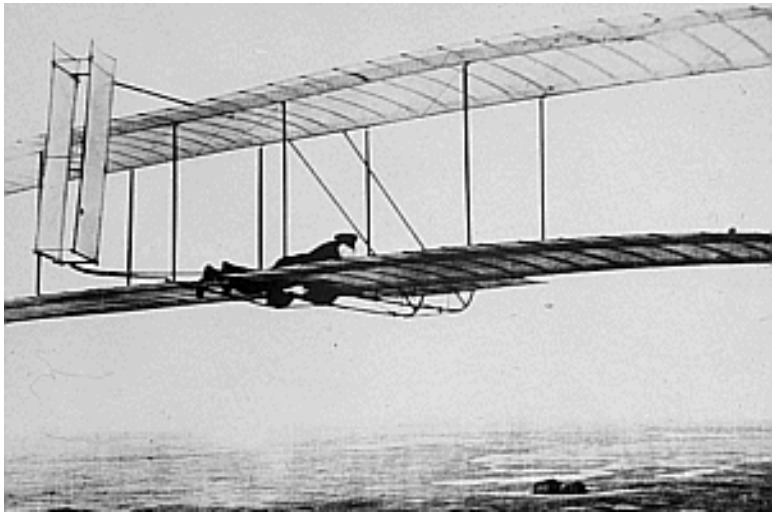


IMAGE CREDIT:
Tribal Earth Science and Technology Education Program

History of Remote Sensing

IMAGE CREDIT:
Tribal Earth Science and
Technology Education Program

1908 - First photos from an airplane



First flight, Wright Bros., Dec. 1903

1914-1918 - World War I

IMAGE CREDIT:
Tribal Earth Science and
Technology Education Program

History of Remote Sensing

IMAGE CREDIT:
Tribal Earth Science and
Technology Education Program

1903 - The Bavarian Pigeon Corps

IMAGE CREDIT:
Tribal Earth Science and
Technology Education Program

1909 - Dresden International Photographic Exhibition

What is Remote Sensing?

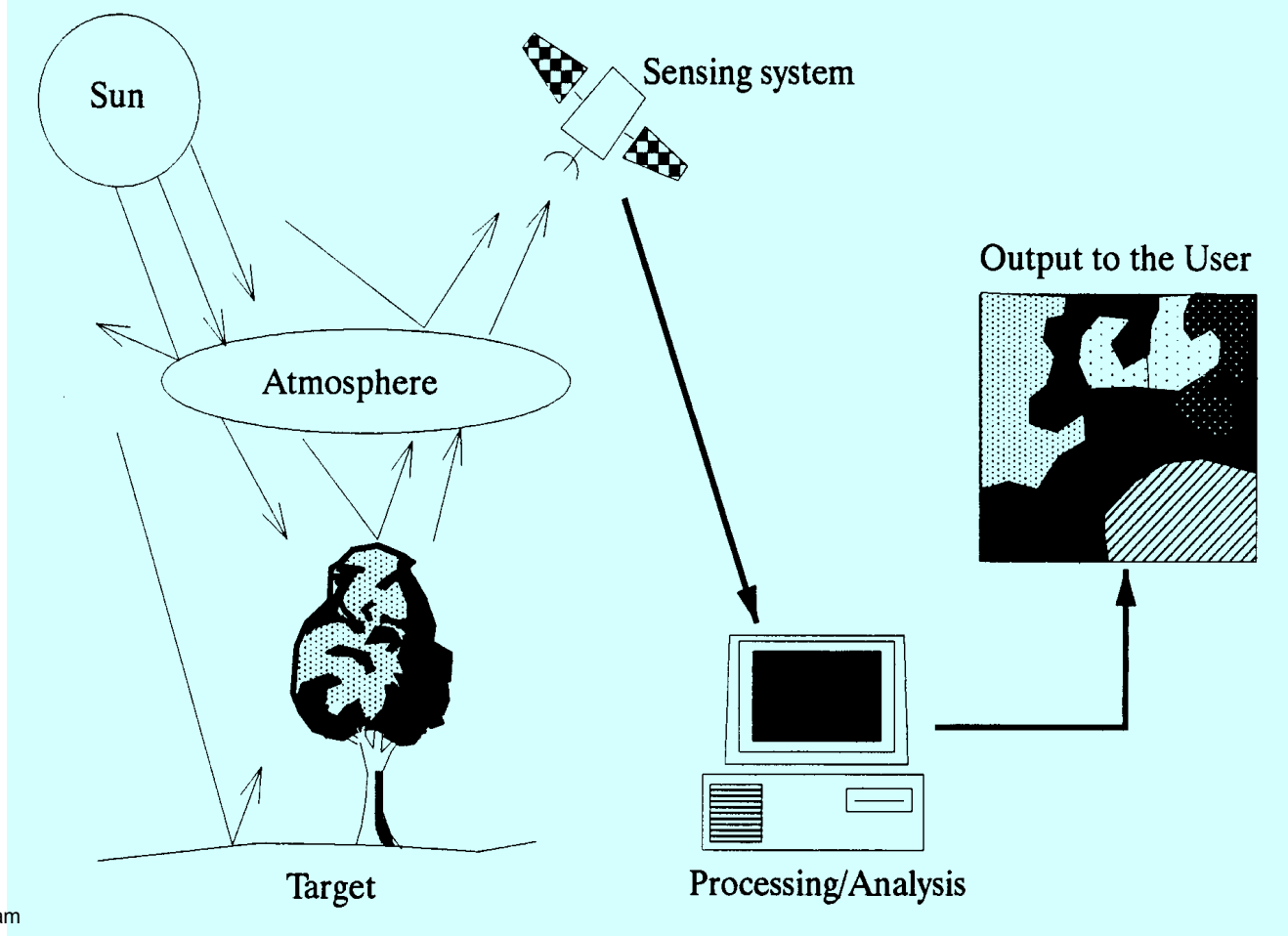


IMAGE CREDIT:
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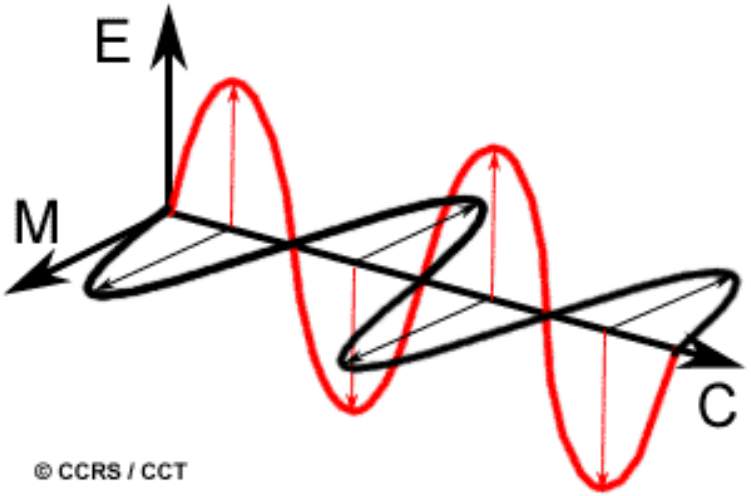
Technology Education Program

Types of Remote Sensing

- **Passive**: uses natural energy, either reflected sunlight (solar energy) or emitted thermal or microwave radiation.
- **Active**: sensor creates its own energy
  - Transmitted toward Earth or other targets
  - Interacts with atmosphere and/or surface
  - Reflects back towards sensor (backscatter)
  - Advantages: all weather and all times

Electromagnetic Radiation

- Remember, the first requirement for remote sensing is to have an energy source to illuminate the target
  - unless the sensed energy is being emitted by the target
- This energy is in the form of electromagnetic radiation.



Electromagnetic radiation consists of an electrical field (E) which varies in magnitude in a direction perpendicular to the direction in which the radiation is traveling, and a magnetic field (M) oriented at right angles to the electrical field. Both these fields travel at the speed of light (c).

THE ELECTROMAGNETIC SPECTRUM

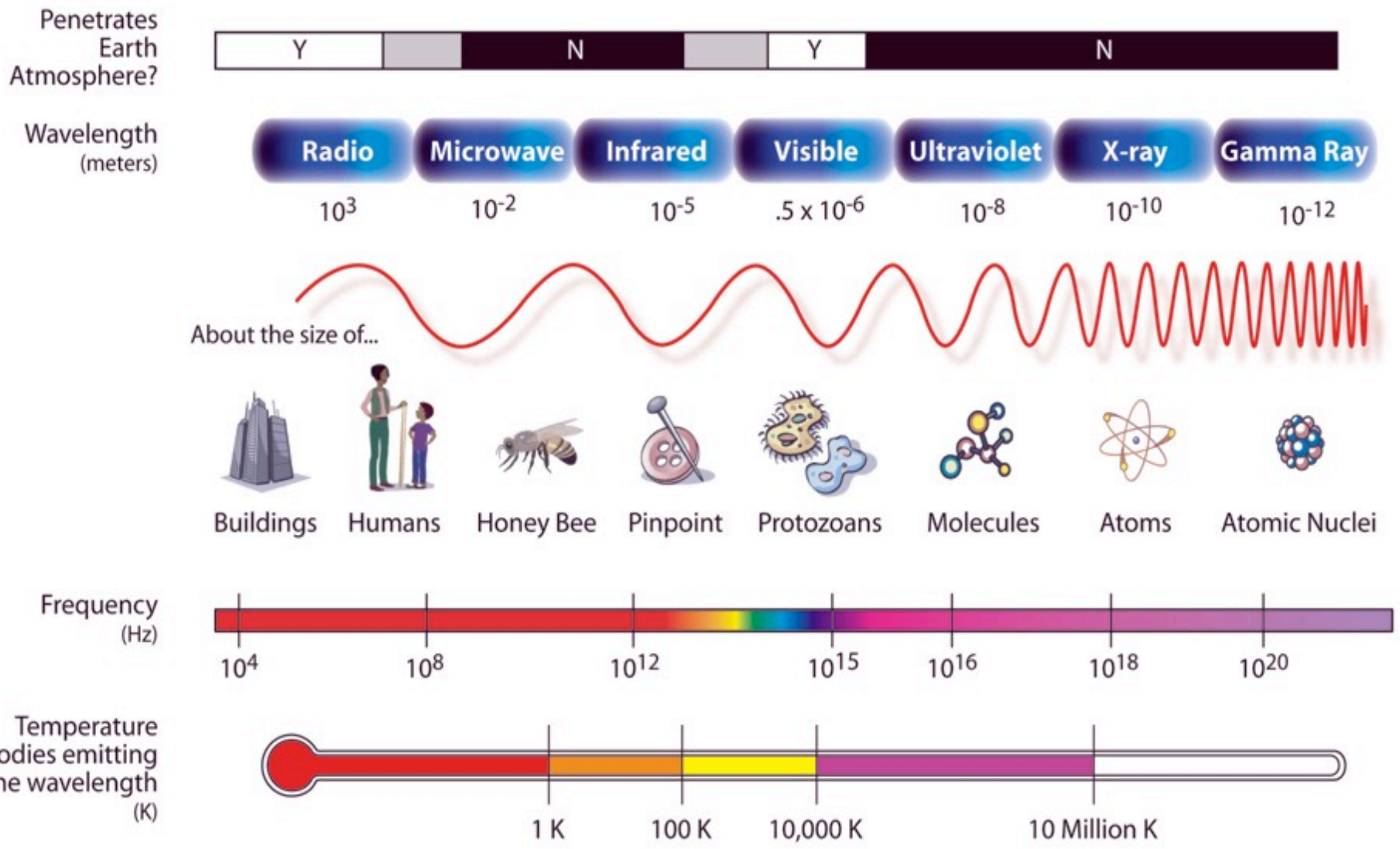


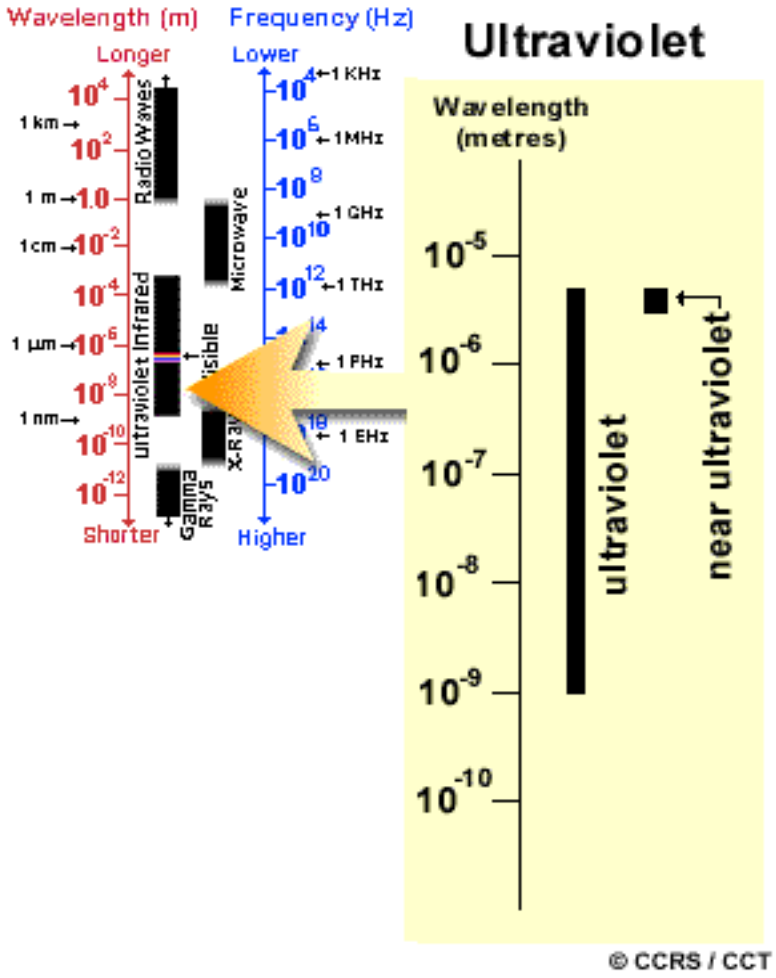
IMAGE CREDIT:
Tribal Earth Science and Technology Education Program

The Electromagnetic Spectrum

Ultraviolet radiation (UV):

The shortest wavelengths, which are practical for remote sensing. This radiation is just beyond the violet portion of the visible wavelengths.

Some Earth surface materials, primarily rocks and minerals, emit visible light when illuminated by UV radiation

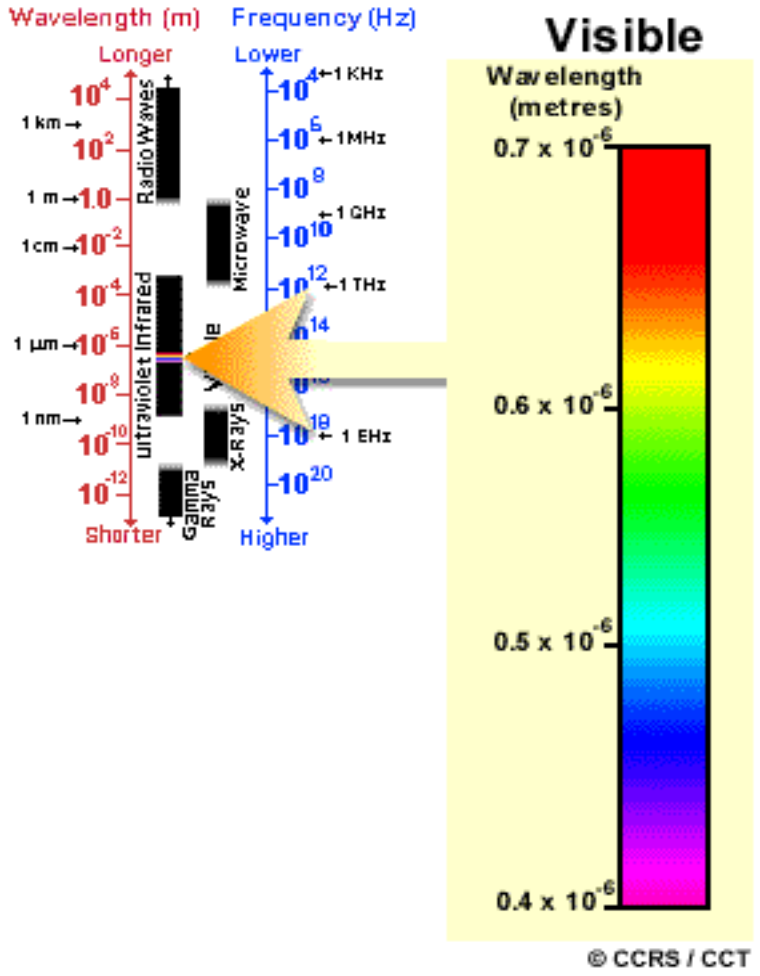


The Electromagnetic Spectrum

Visible radiation:

The light which our eyes - our own "remote sensors" - can detect is part of the visible spectrum. The visible portion of the electromagnetic spectrum is smaller compared to the spectrum.

Visible waves have great utility for remote sensing of vegetation and for the identification of different objects by their visible colors.

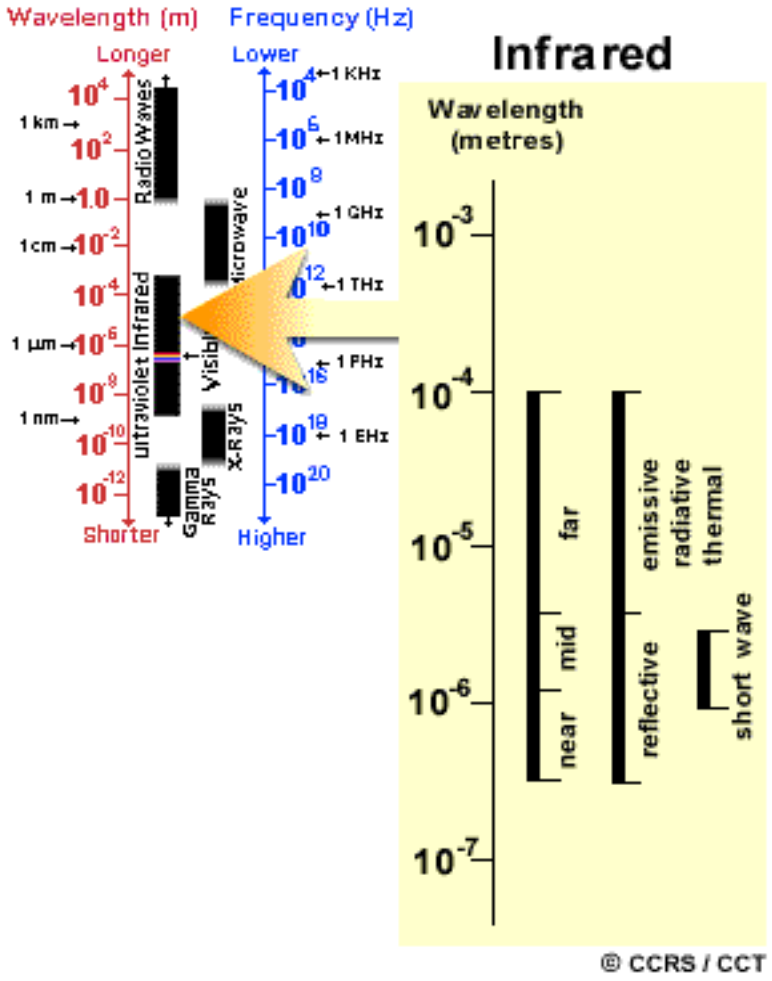


The Electromagnetic Spectrum

Infrared Radiation (IR):

The infrared (IR) region is more than 100 times as wide as the visible portion! The infrared region can be divided into two categories based on their radiation properties - the reflected IR, and the emitted or thermal IR.

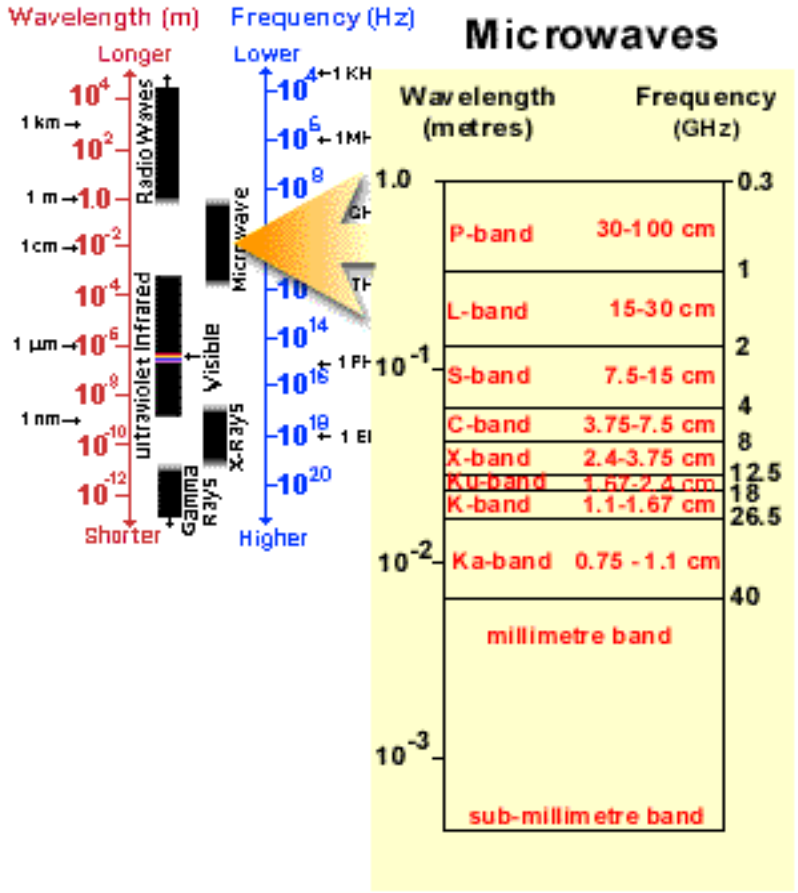
Scientists use the near-IR to determine the health of vegetation and to monitor forest fires.



The Electromagnetic Spectrum

Microwave Radiation

These are the longest wavelengths used for remote sensing. The shorter wavelengths have properties similar to the thermal infrared region while the longer wavelengths approach the wavelengths used for radio broadcasts



Lesson 3

X-Informatics: Radar Informatics (with application to glaciology)

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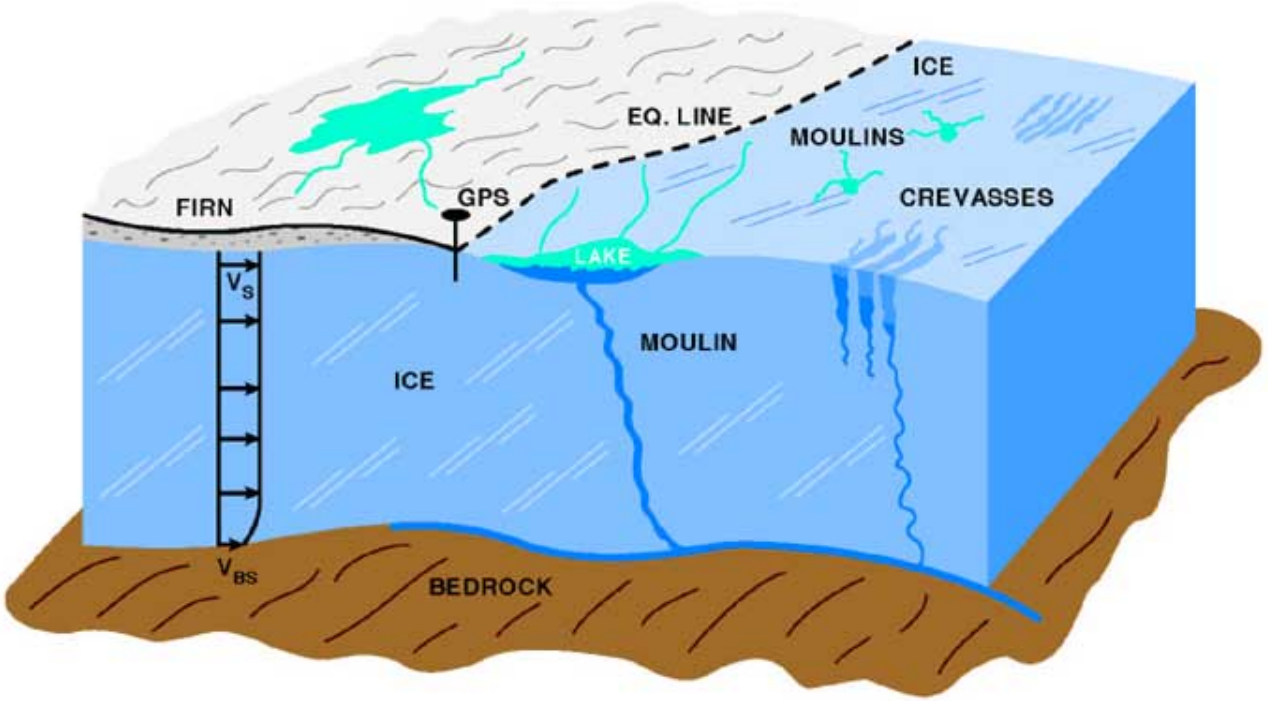
Overview of Ice Sheet Science



- Ice melt flows to bedrock through crevasses and moulins
- Water between bedrock and ice sheet acts as lubricant
- Allows ice sheet to move faster toward the coastline

Lesson 4

X-Informatics: Radar Informatics (with application to glaciology)

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Overview of Global Climate Change

Jellyfish creature the answer to global warming? www.Scienceblog.com

SPIEGEL ONLINE

Global warming causing new evolutionary patterns nzherald.co.nz

Seattle mayors' meeting a cozy climate for business The Seattle Times

EXAGGERATED SCIENCE

How Global Warming Research is Creating a Climate of Fear

The New York Times ON THE WEB

WHAT HAVE YOU HEARD?

Global warming could burn insurers
Activists call on industry to act

seattlepi.com

Seattle reports milestone in cutting emissions The Seattle Times

In a Shift, White House Cites Global Warming as a Problem

Rise in wild fires a result of climate change

CNN INTERNATIONAL .com

Is Global Warming Fueling Katrina?

TIME

Research Links Global Warming to Wildfires

STT SCI-TECH TODAY Technology, Discovery & Innovation

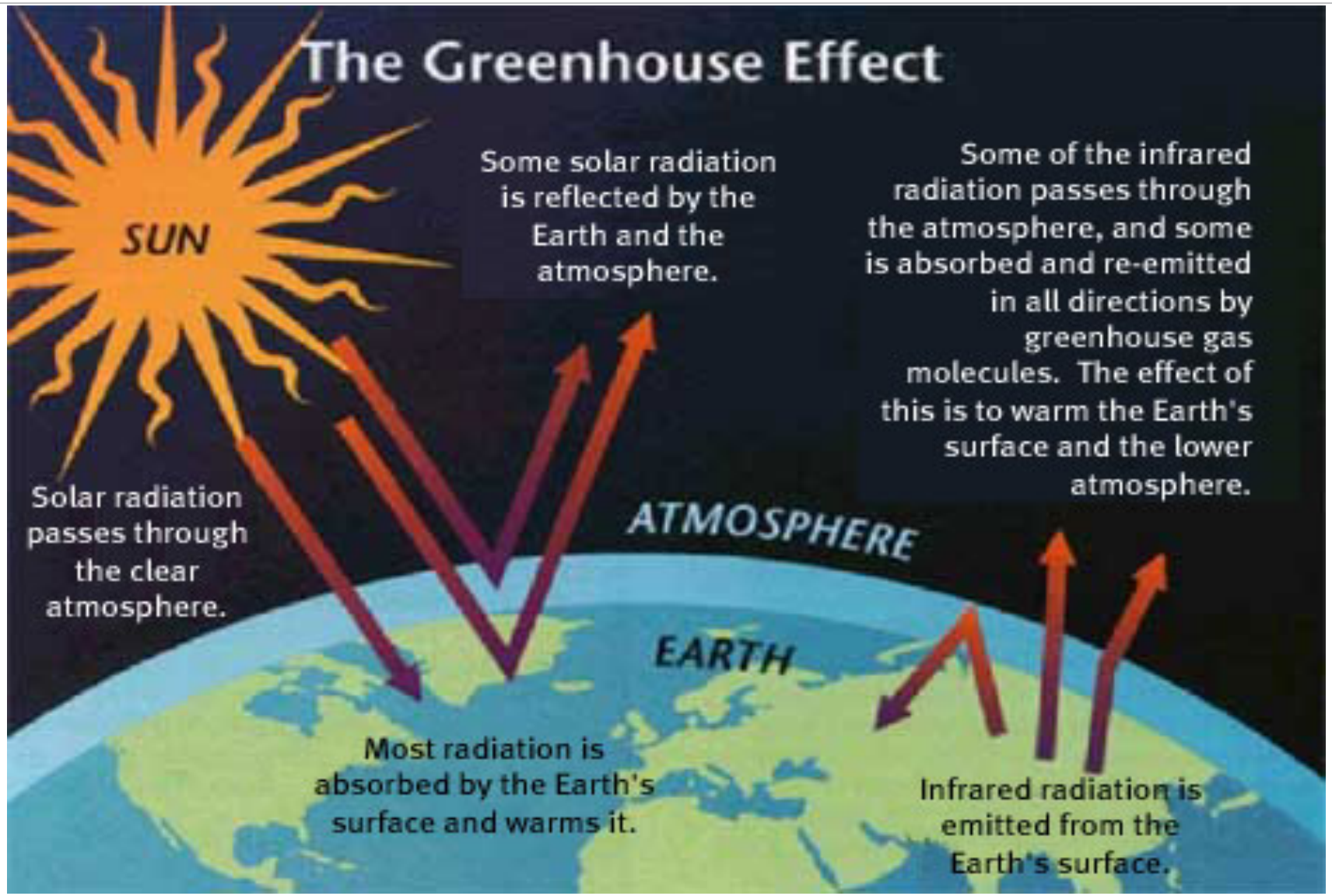


IMAGE CREDIT: SEAI

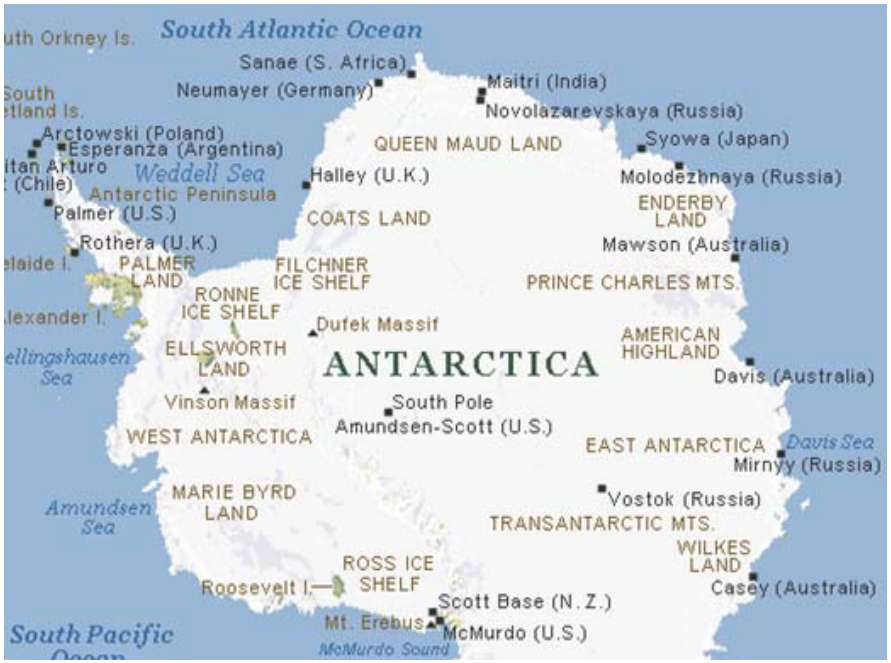
Background

- Sea-level rise resulting from the changing global climate is expected to directly impact many millions of people living in low-lying coastal regions.

- Accelerated discharge from polar outlet glaciers is unpredictable and represents a significant threat.

- Predictive models of ice sheet behavior require knowledge of the bed conditions, specifically basal topography and whether the bed is frozen or wet

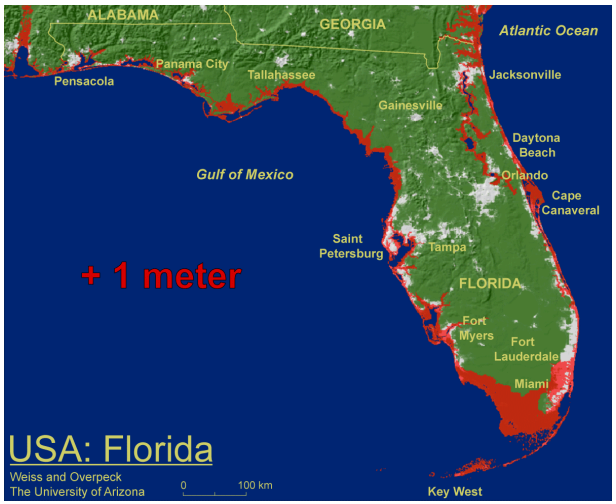
Ice Sheet and Sea Level



Greenland: 1.8 x 10^6 km^2 area (enough water to raise sea level about 7 meters)

Antarctica: 1.3 x 10^7 km^2 area (enough water to raise sea level about 60 meters)


ALABAMA
GEORGIA
Atlantic Ocean
Panama City
Pensacola
Tallahassee
Jacksonville
Gainesville
Daytona Beach
Gulf of Mexico
Orlando
Cape Canaveral
Saint Petersburg
Tampa
Present
FLORIDA
Fort Myers
Fort Lauderdale
Miami
USA: Florida
Weiss and Overpeck
The University of Arizona
0
100 km
Key West


ALABAMA
GEORGIA
Atlantic Ocean
Panama City
Pensacola
Tallahassee
Jacksonville
Gainesville
Daytona Beach
Gulf of Mexico
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Cape Canaveral
Saint Petersburg
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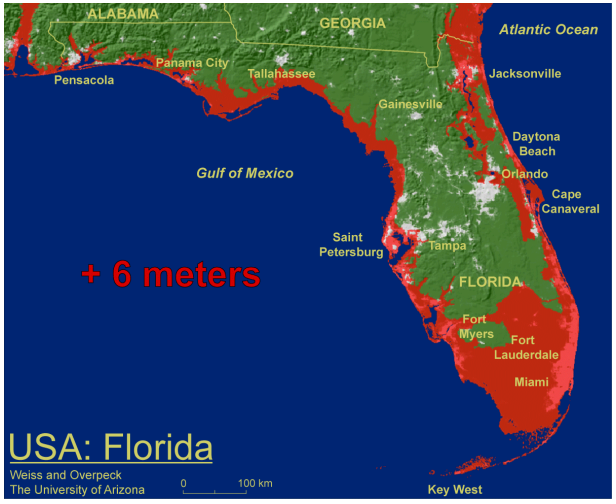
+ 1 meter
FLORIDA
Fort Myers
Fort Lauderdale
Miami
USA: Florida
Weiss and Overpeck
The University of Arizona
0
100 km
Key West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Daytona Beach
Gulf of Mexico
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Cape Canaveral
Saint Petersburg
Tampa
+ 6 meters
FLORIDA
Fort Myers
Fort Lauderdale
Miami
USA: Florida
Weiss and Overpeck
The University of Arizona
0
100 km
Key West


ARKANSAS
Shreveport
Monroe
Jackson
LOUISIANA
Alexandria
MISSISSIPPI
TEXAS
Hattiesburg
Baton Rouge
Hammond
Beaumont
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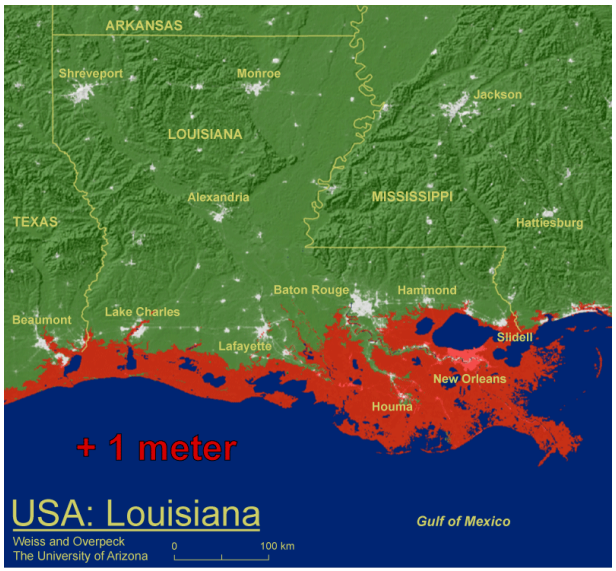
ARKANSAS
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Monroe
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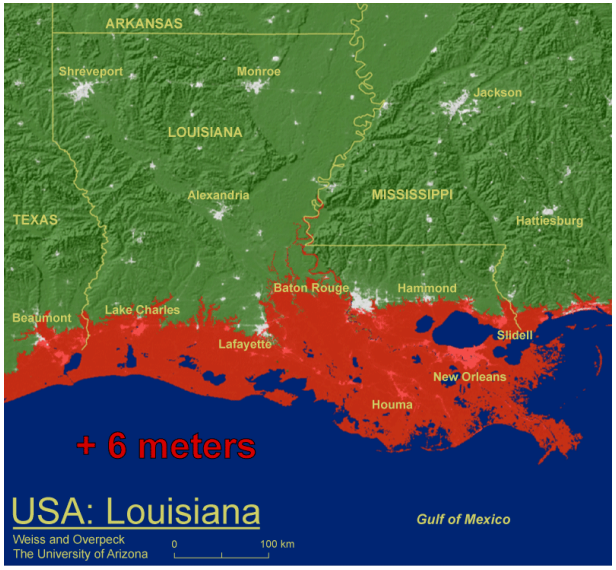
MISSISSIPPI
TEXAS
Hattiesburg
Baton Rouge
Hammond
Beaumont
Lake Charles
Lafayette
Slidell
New Orleans
Houma
+ 1 meter
USA: Louisiana
Weiss and Overpeck
The University of Arizona
0
100 km
Gulf of Mexico


ARKANSAS
Shreveport
Monroe
Jackson
LOUISIANA
Alexandria
MISSISSIPPI
TEXAS
Hattiesburg
Baton Rouge
Hammond
Beaumont
Lake Charles
Lafayette
Slidell
New Orleans
Houma
+ 6 meters
USA: Louisiana
Weiss and Overpeck
The University of Arizona
0
100 km
Gulf of Mexico

Lesson 5

X-Informatics: Radar Informatics (with application to glaciology)

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Overview of Radar

(non equation perspective)

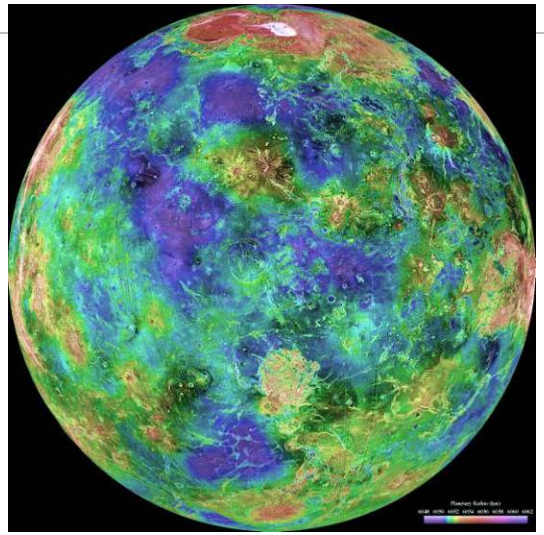
Overview of RADAR

- RADAR– Radio Detection And Ranging
- Developed in the early 1900s (pre-World War II)
  - 1904 Europeans demonstrated use for detecting ships in fog
  - 1922 U.S. Navy Research Laboratory (NRL) detected wooden ship Potomac River
  - 1930 NRL engineers detected an aircraft with simple radar system
- World War II accelerated radar's development
- RADAR's has deep military roots

Overview of RADAR

- **Various Classes of Operation**
  - Pulsed vs. continuous wave (CW)
- **Measurement capabilities**
  - Position (range and direction), Radial velocity (Doppler)
  - Target characteristics

Overview of RADAR



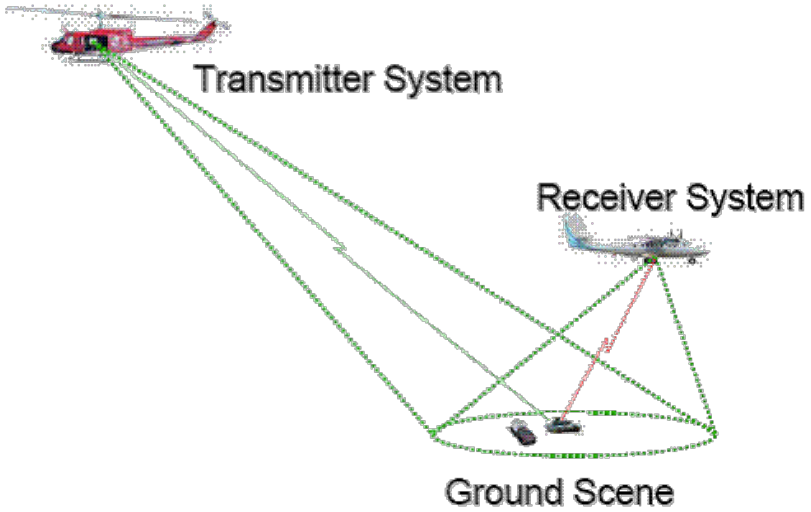
- **Active Sensor**
  - Provides its own illumination
  - Operates in day and night
  - Largely immune to smoke, haze, fog, rain, snow, …
  - Involves both a transmitter and a receiver
- **Configurations**

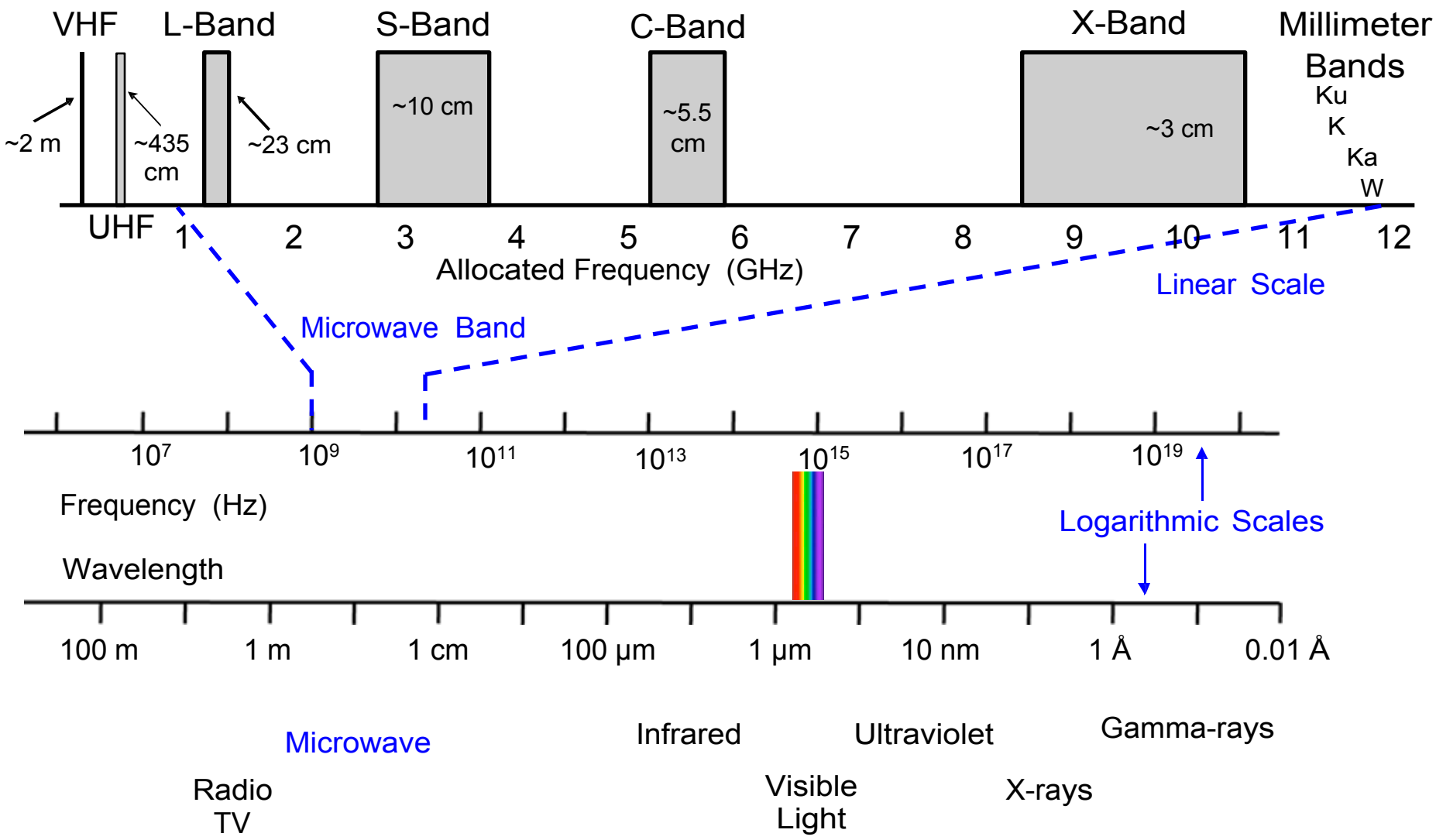
  Monostatic

  Bistatic

  Multistatic

  Passive




VHF
L-Band
S-Band
C-Band
X-Band
Millimeter Bands
Ku
K
Ka
W
~2 m
~435 cm
~23 cm
~10 cm
~5.5 cm
~3 cm
UHF
1
2
3
4
5
6
7
8
9
10
11
12
Allocated Frequency (GHz)
Linear Scale
Microwave Band
10^7
10^9
10^11
10^13
10^15
10^17
10^19
Frequency (Hz)
Logarithmic Scales
Wavelength
100 m
1 m
1 cm
100 µm
1 µm
10 nm
1 Å
0.01 Å
Microwave
Infrared
Ultraviolet
Gamma-rays
Radio
TV
Visible Light
X-rays

Active Remote Sensing

- Active Microwave (RADAR)
- LIDAR
- SONAR

Types of RADARs

- NonImaging RADAR
  - Doppler RADAR system
    - Determine the speed by measuring frequency shift between transmitted and return microwave signal
- Imaging RADAR
  - High spatial resolution
  - Consists of a transmitter, a receiver one or more antennas, GPS, computers

How RADARs Work – The Short Answer

- An electromagnetic wave is transmitted by the radar
- Some of the energy is scattered when it hits a distance
- A small portion of the scattered energy is collected by the radar antenna

Lesson 6

X-Informatics: Radar Informatics (with application to glaciology)

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RADAR Informatics

RADARs on a Variety of Platforms

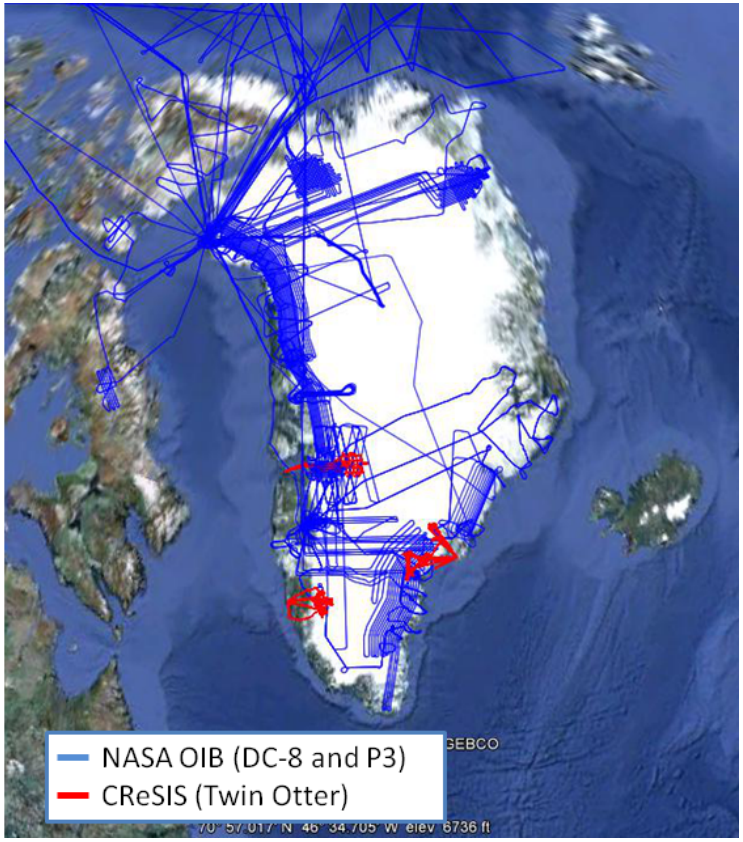
NASA DC-8

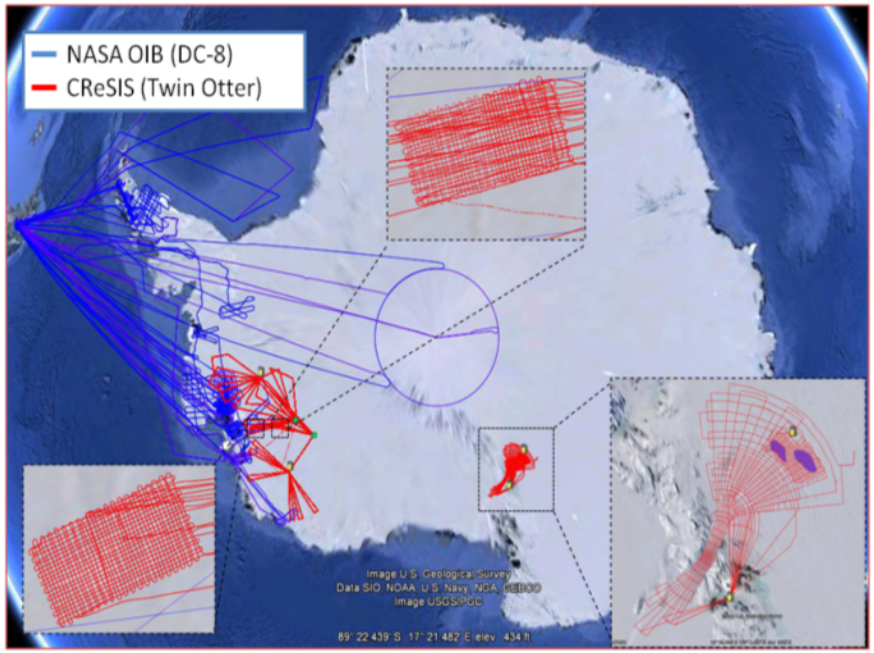
NASA P-3

Twin-Otter

UAV's

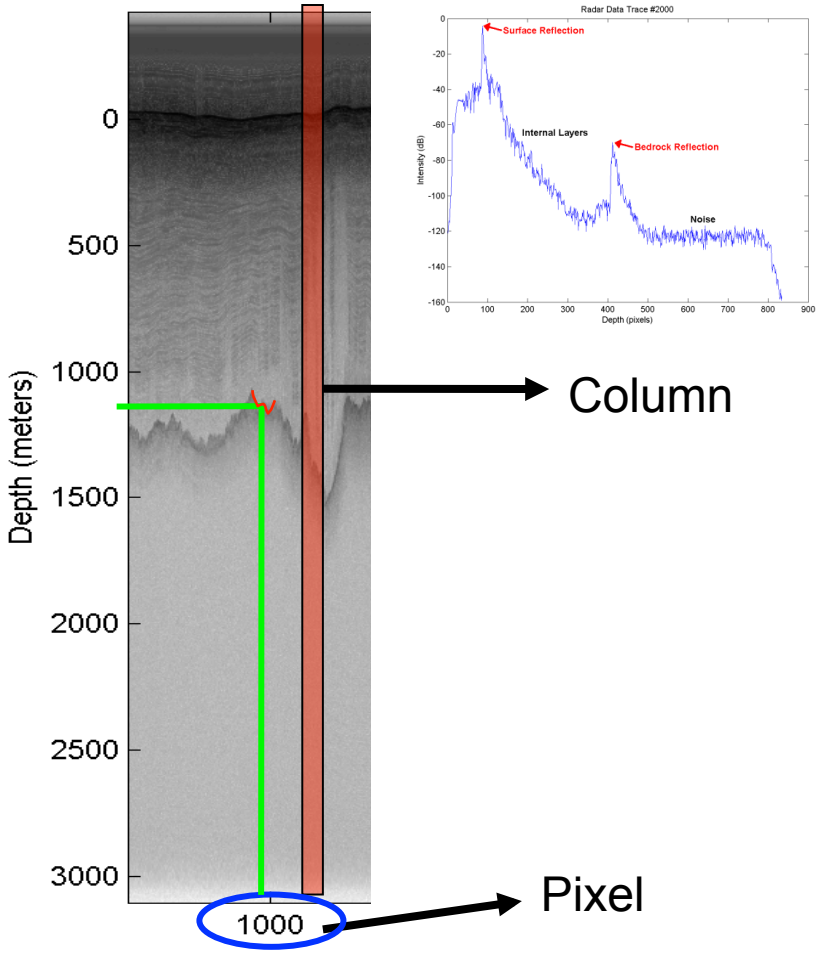
Survey Regions





RADAR Imagery

- A radar trace consist of signals, representing energy due to time.
- In an image, a trace is an entire column of pixels, each pixel represents a depth.
- Each row corresponds to a depth and time for a measurement, as the depth increases further down.



Layer Identification

- The Problem
- Understanding Layers in the radar images:

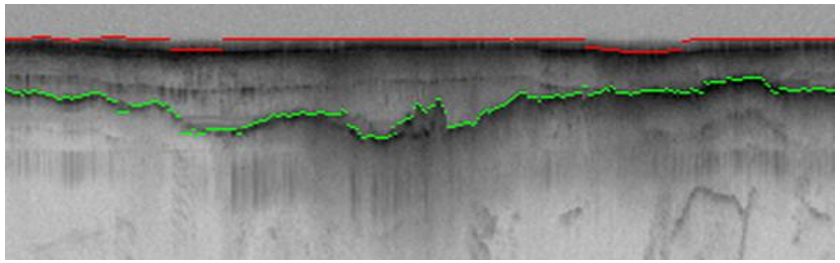
  helps compute the ice thickness and accumulation rate maps

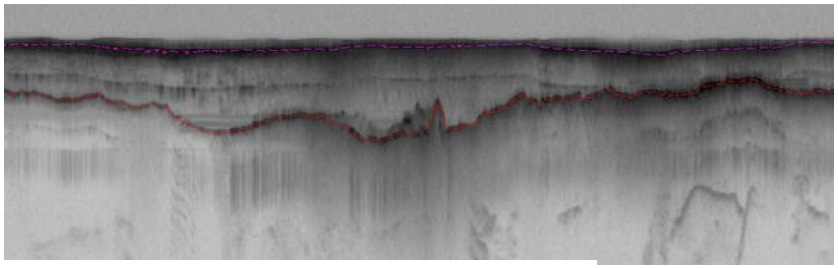
  help studies relating to the ice sheets, their volume, and how they contribute to climate change.
- Develop an automated tool for tracing Layers in radar imagery

Challenges in Processing RADAR Imagery

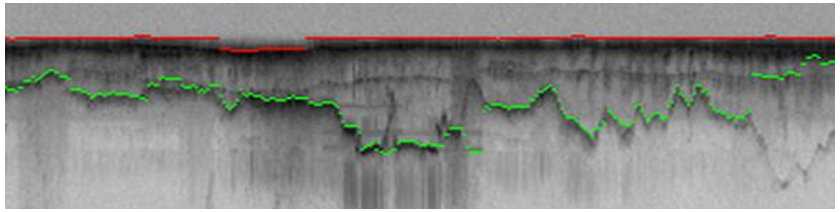
- Bedrock/Surface Layers
  - Two Layers (but, false positives)
  - Low magnitude, faint, or non-existent bedrock reflections
  - Strong surface reflections can be repeated in an image causing surface multiples
- Near Surface Internal Layers
  - Multiple Layers (a couple dozen)
  - Fuse into existing Layers
  - Dis/Reappear

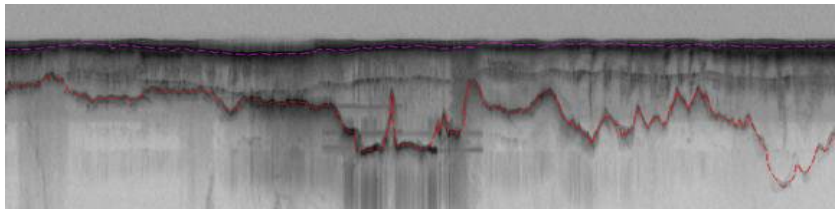
Bedrock (Hidden Markov Model)

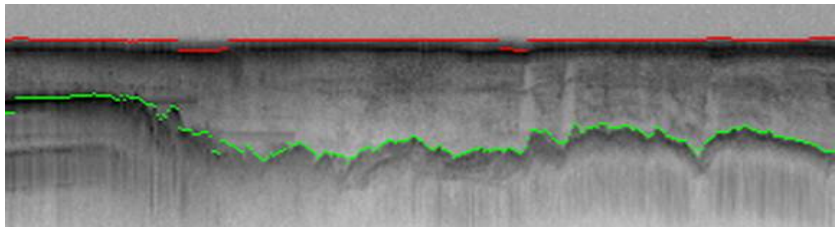


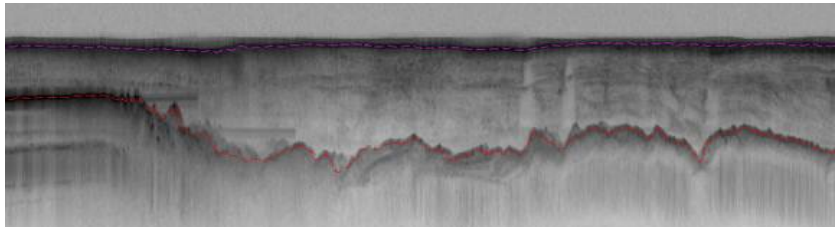


P. Felzenszwalb, O. Veksler, Tiered Scene Labeling with Dynamic Programming, IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2010



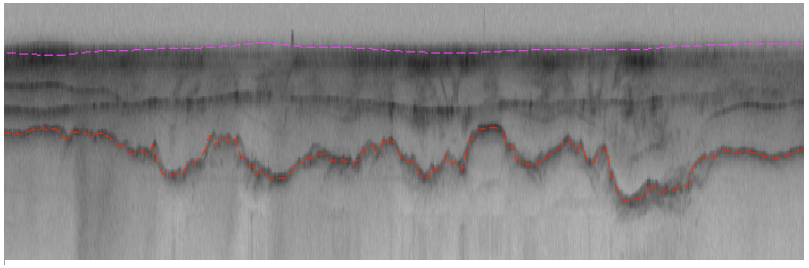


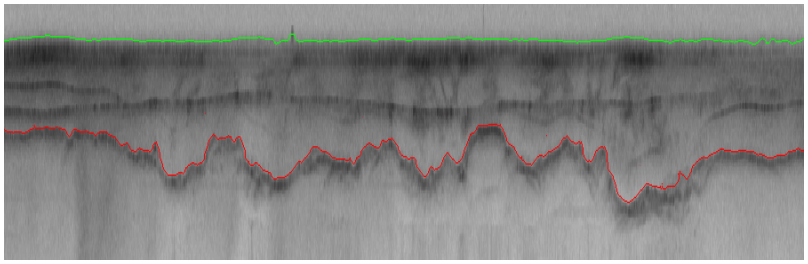




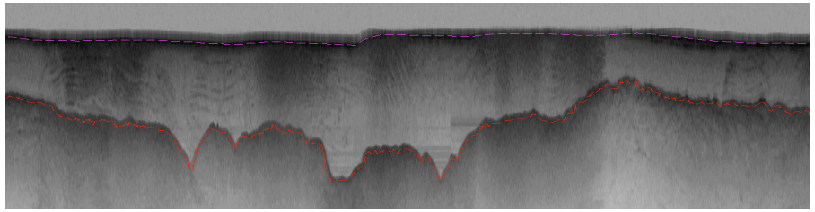
Crandall, Fox, Paden, International Conference on Pattern Recognition (ICPR), 2012.

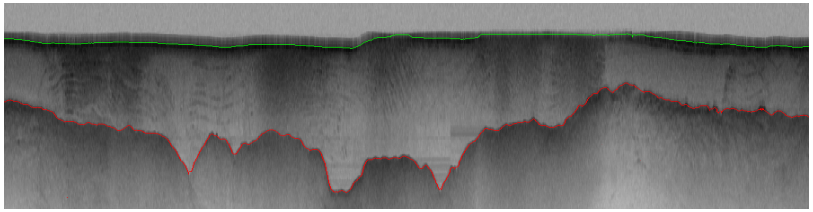
Bedrock (Level Sets)

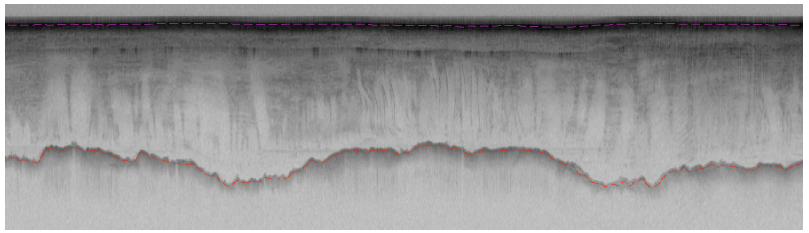


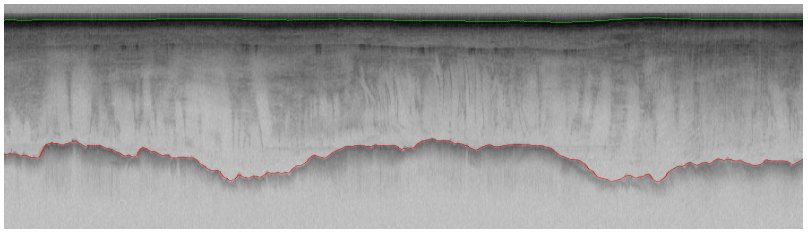


S. Osher and J. A. Sethian, “Fronts propagating with curvature-dependent speed: algorithms based on hamilton-jacobi formulations," Journal of computational physics 79 (1), pp. 12-49, 1988.



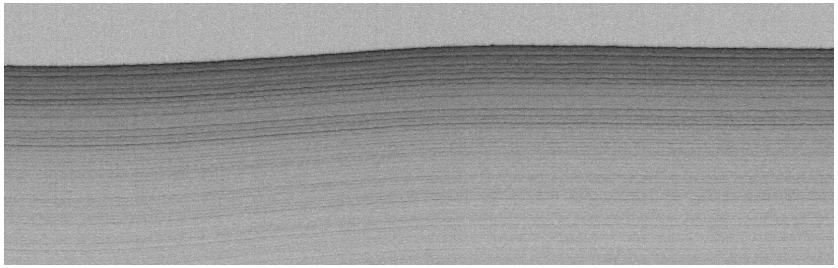


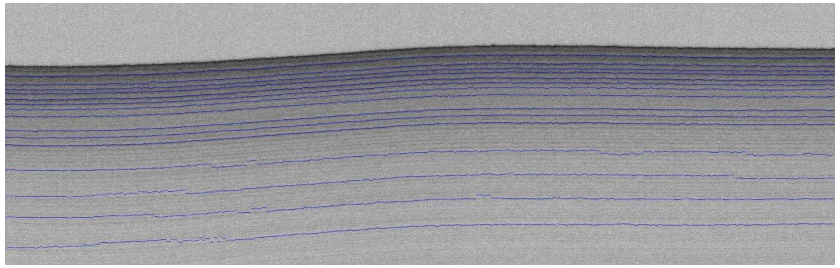




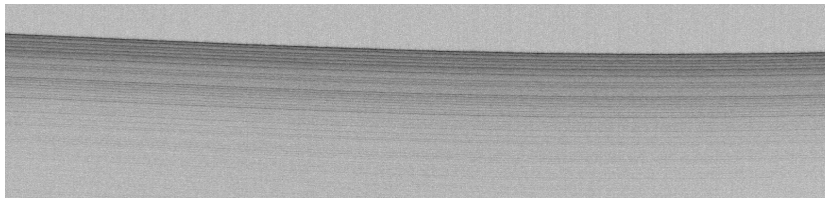
Mitchell, Crandall, Fox, Rahnemoonfar, and Paden, SPIE Remote Sensing, 2013

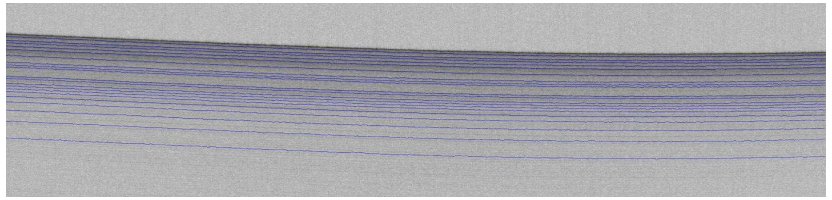
Near Surface Internal Layers

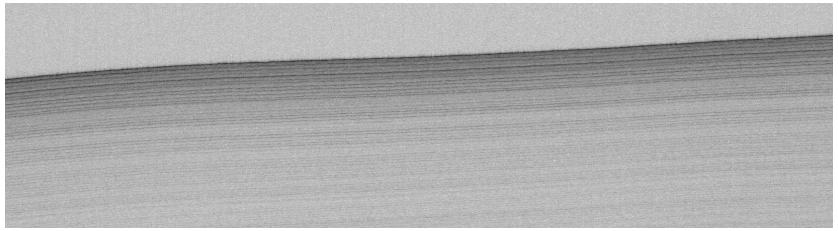


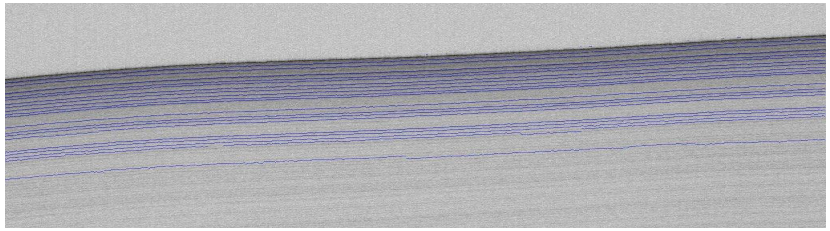


M. Kass, A. Witkin, and D. Terzopoulos, “Snakes: Active contour models,” International Journal of Computer Vision , vol. 1, no. 4, pp. 321–331, 1988.









Mitchell, Crandall, Fox, and Paden, International Geoscience and Remote Sensing (IGARSS), 2013