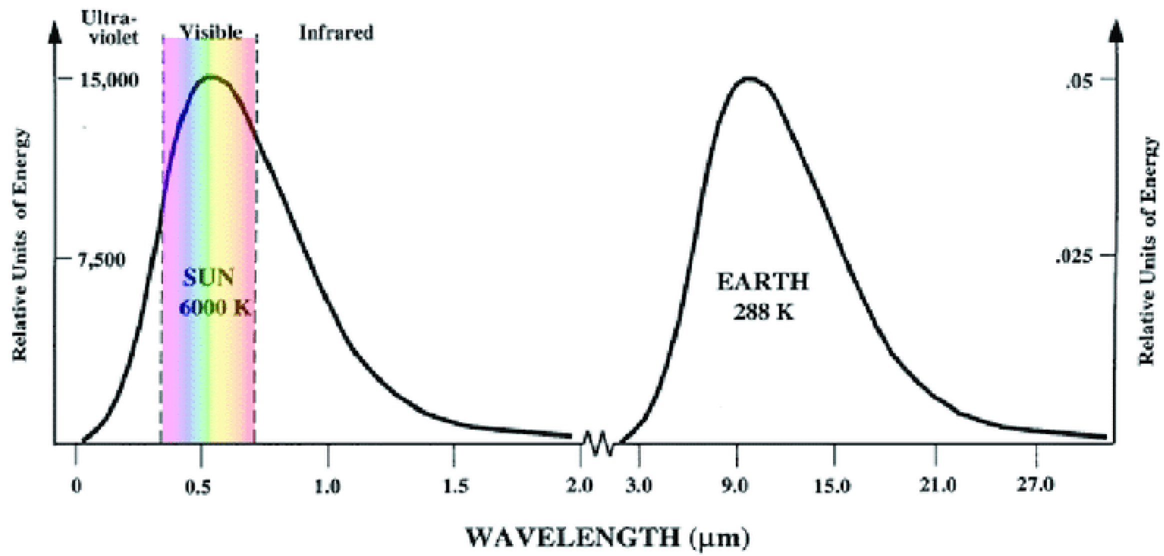
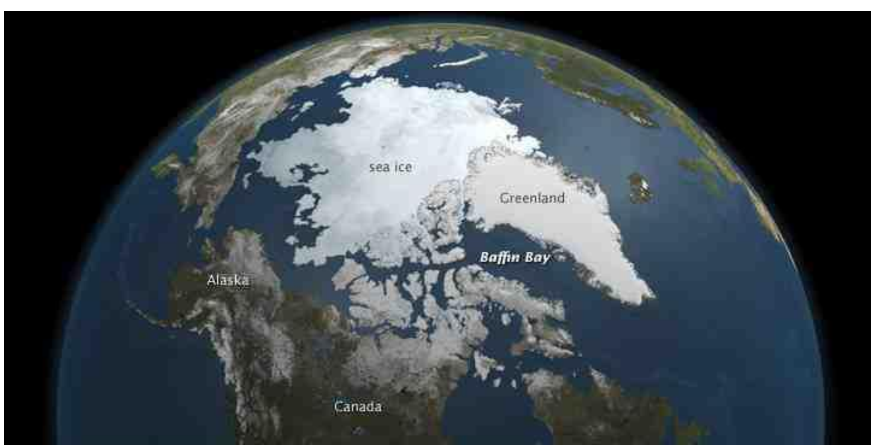
Microwave Sensing: 1mm to 1 metre (mostly 1cm-30cm)

These wavelengths beyond the infra-red can 'see through' clouds and light rain, but there is a low amount - emitted from Earth

… and why we use these wavelengths for communications.

It is used to monitor oceans, snow, sea ice cover and atmospheric ozone





Energy emitted by the earth
There is limited natural energy in microwave wavelengths
… so pixels needs to be large

Passive microwave sensing is a continuation of recording thermal energy into the microwave wavelengths. The signal is a **brightness temperature** but there is less terrestrial energy to sense, so a large pixel, ca. 10-25km is needed for radiometric resolution.

Radiance = temperature x emissivity

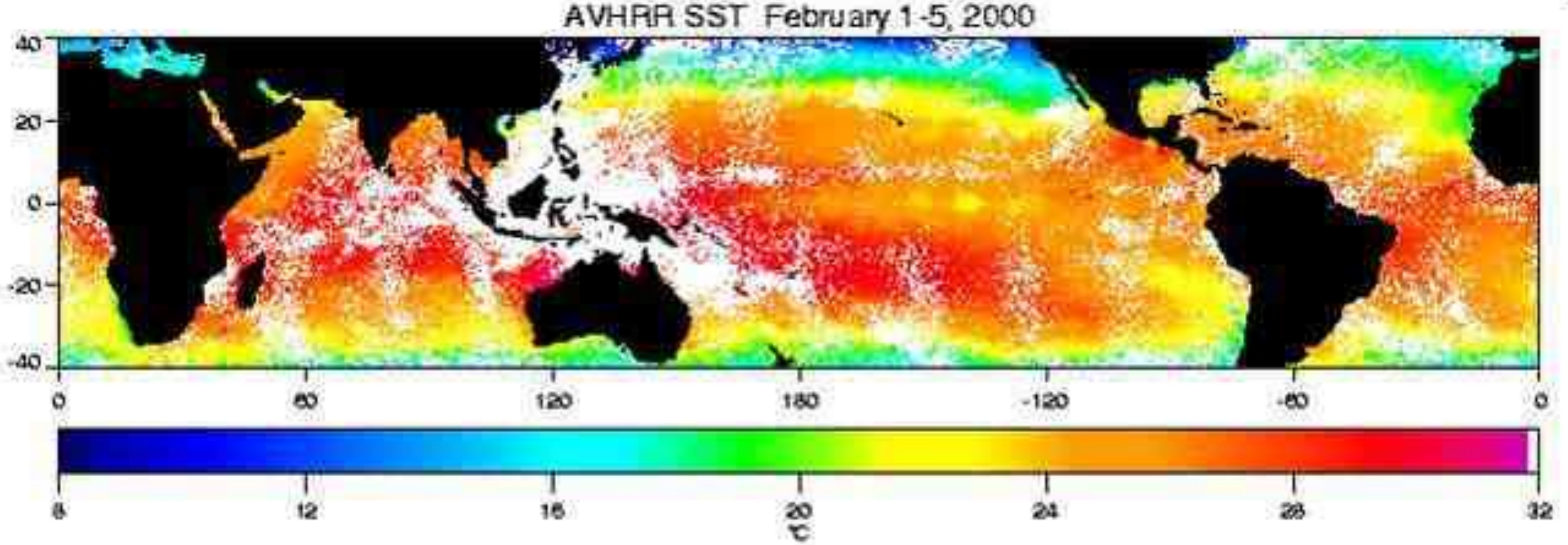
Remote sensing at microwave wavelengths is effective because …

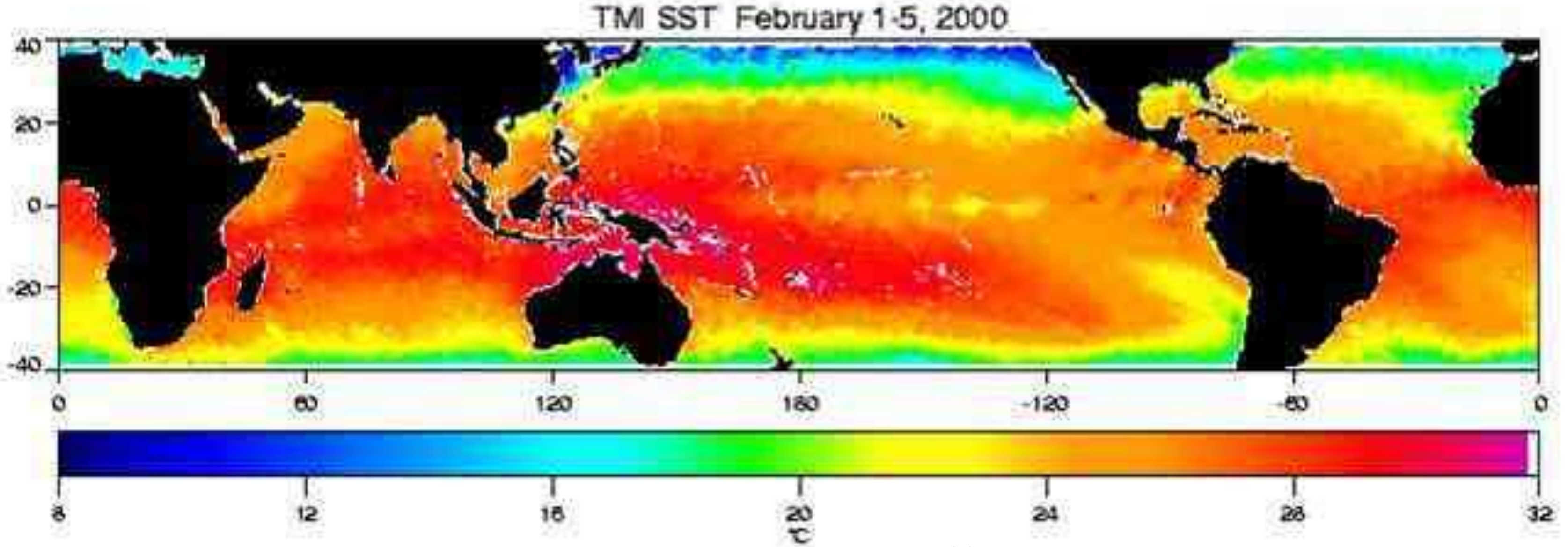
insignificant atmospheric attenuation for microwave windows

= **unaffected by clouds**

- **Microwave sensors: SMMR TMI-TRMM AMSR SSM/I ESMR**

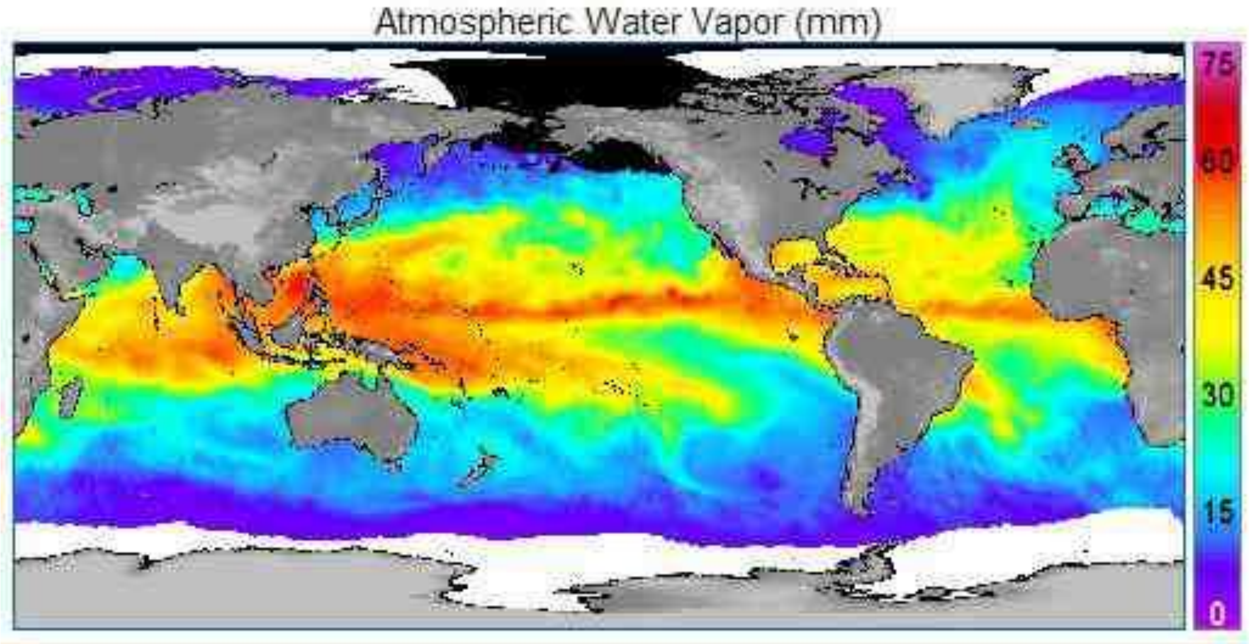
Sea Surface Temperature a. Thermal IR, b. Microwave passive

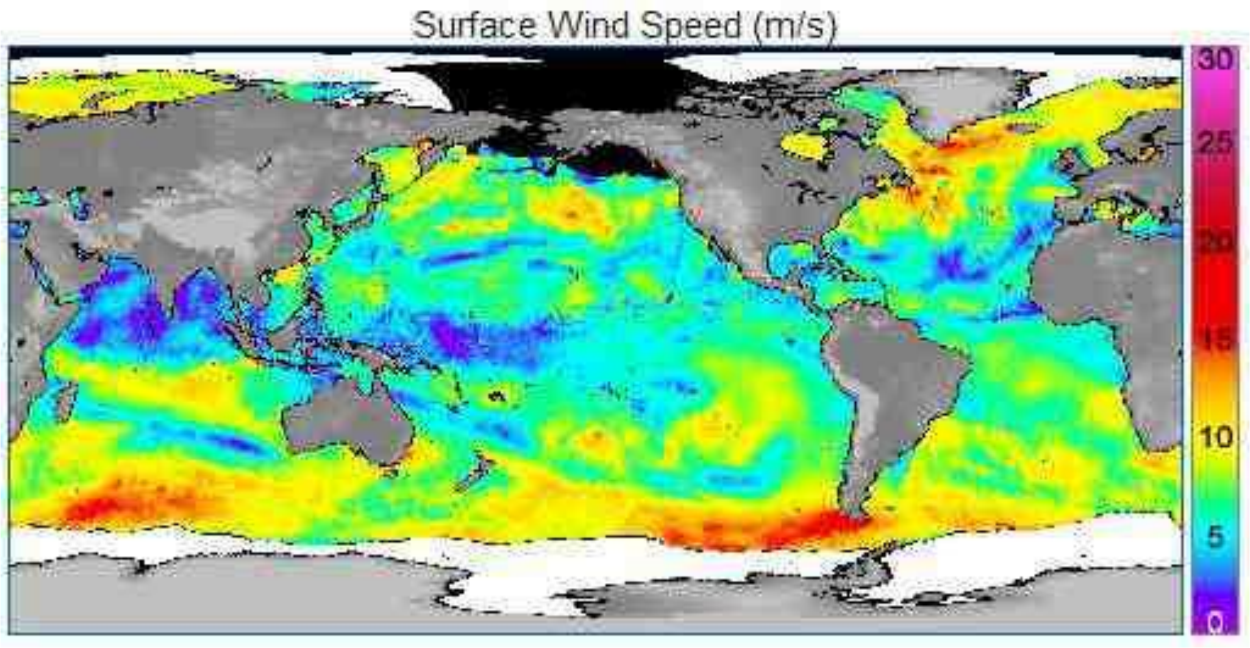




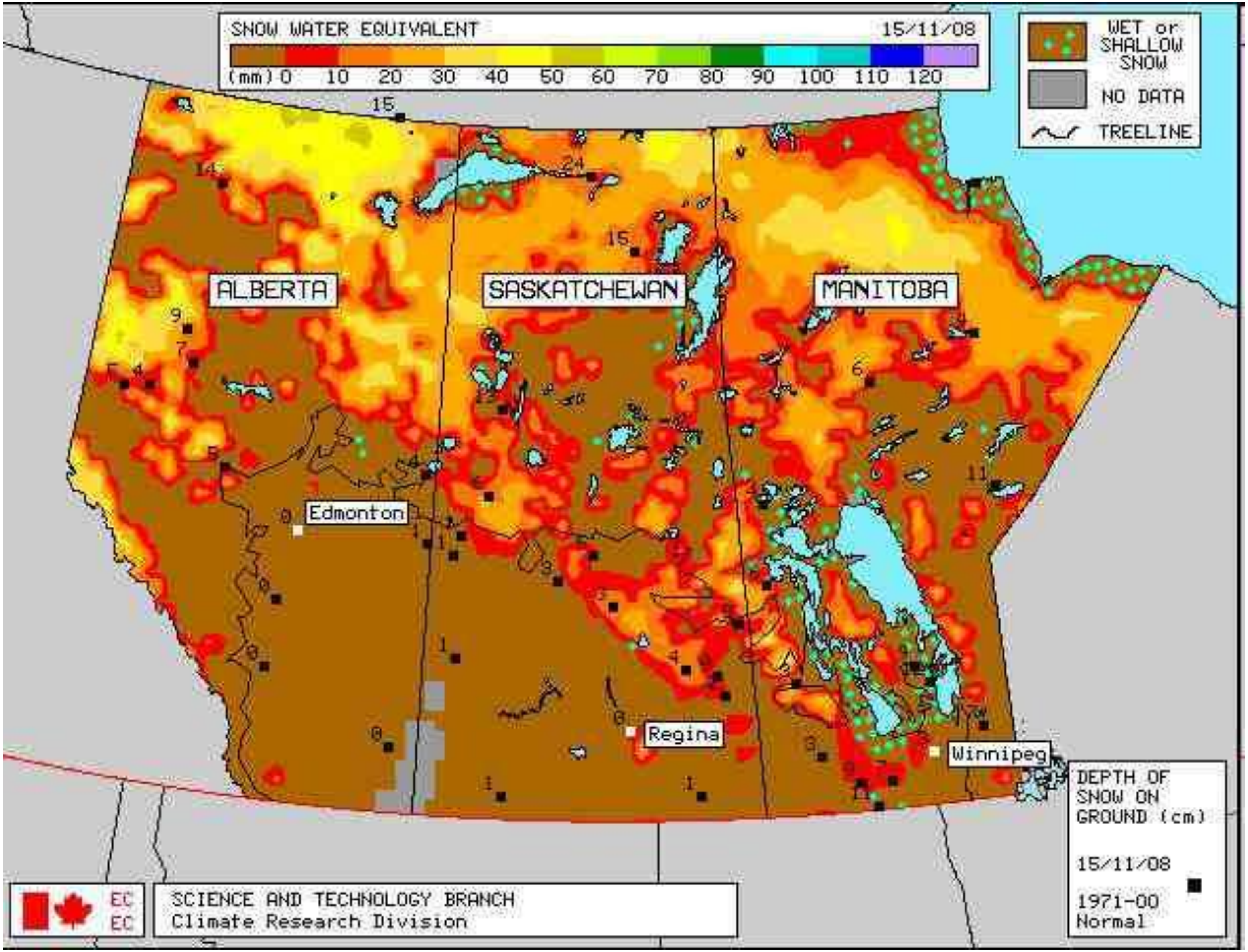
Thermal IR: higher resolution and accuracy; affected by clouds

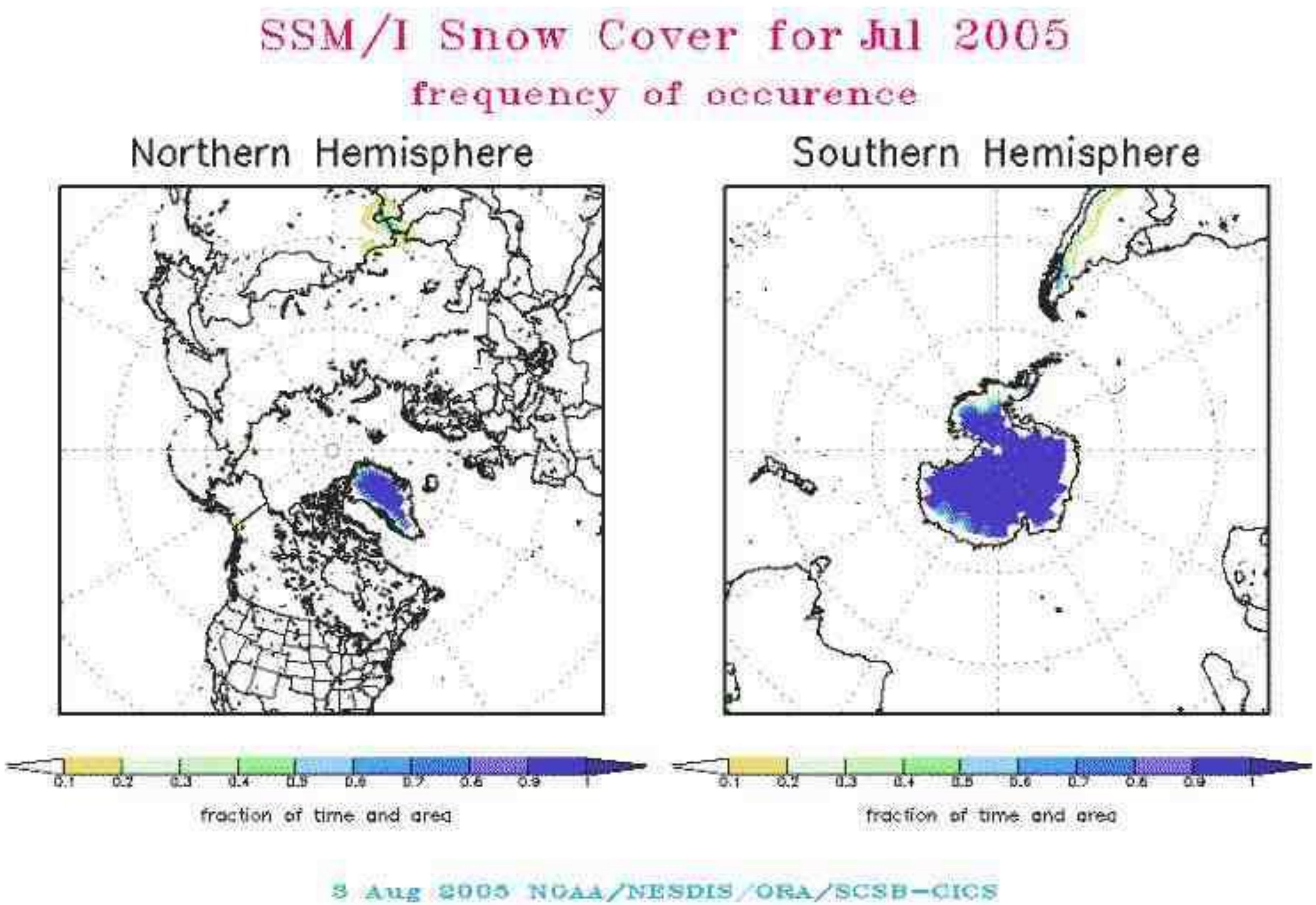
Microwave: unaffected by clouds, sensitive to precipitation and surface roughness http://www.ssmi.com/ssmi/ssmi_data_weekly.html





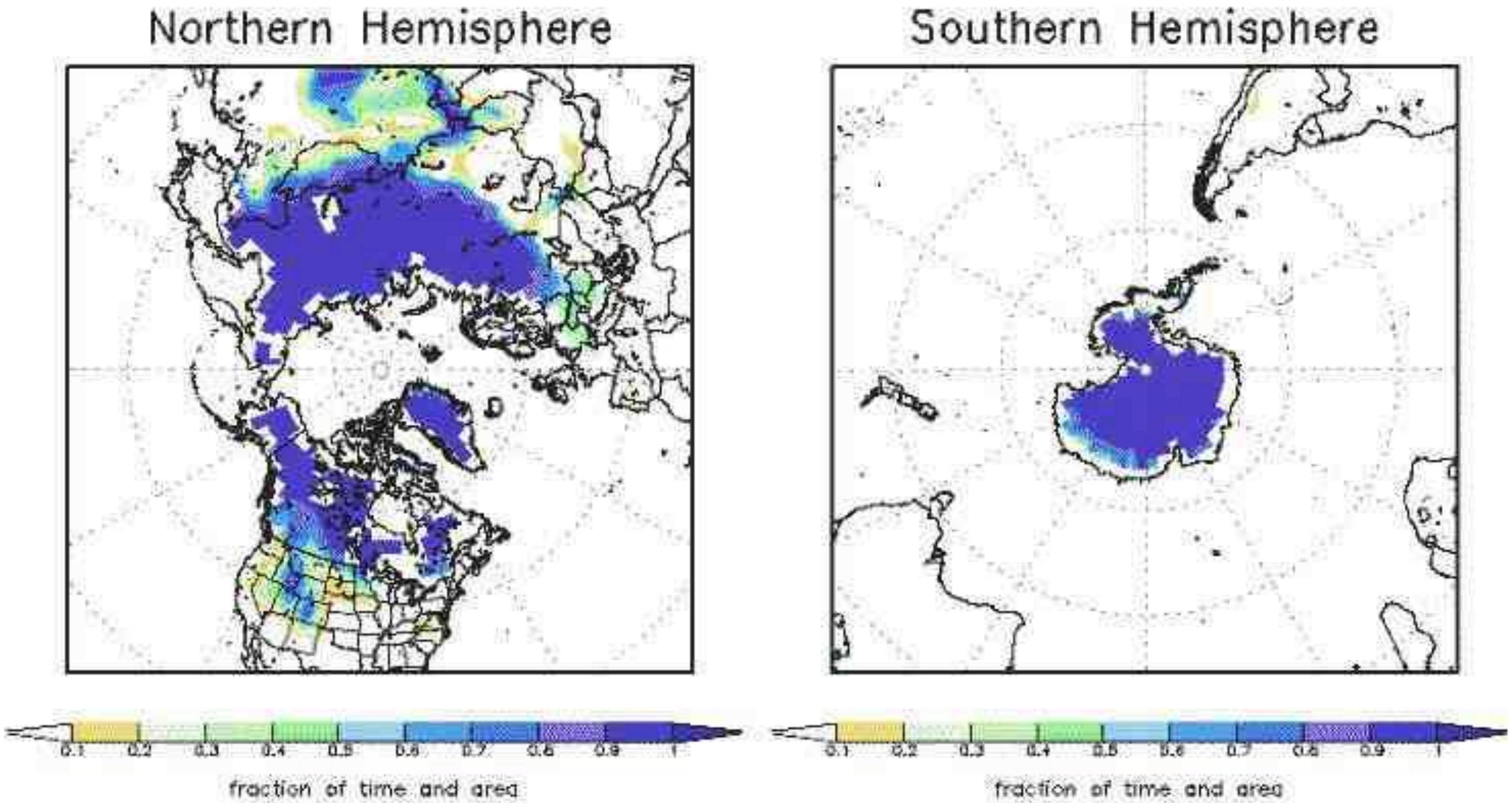
Snow Water Equivalent Map for Canadian Prairies: AMSR-E




SSM/I Snow Cover for Jul 2005
frequency of occurence
Northern Hemisphere
Southern Hemisphere
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
fraction of time and area
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
fraction of time and area
3 Aug 2005 NOAA/NESDIS/ORA/SCSB-CICS

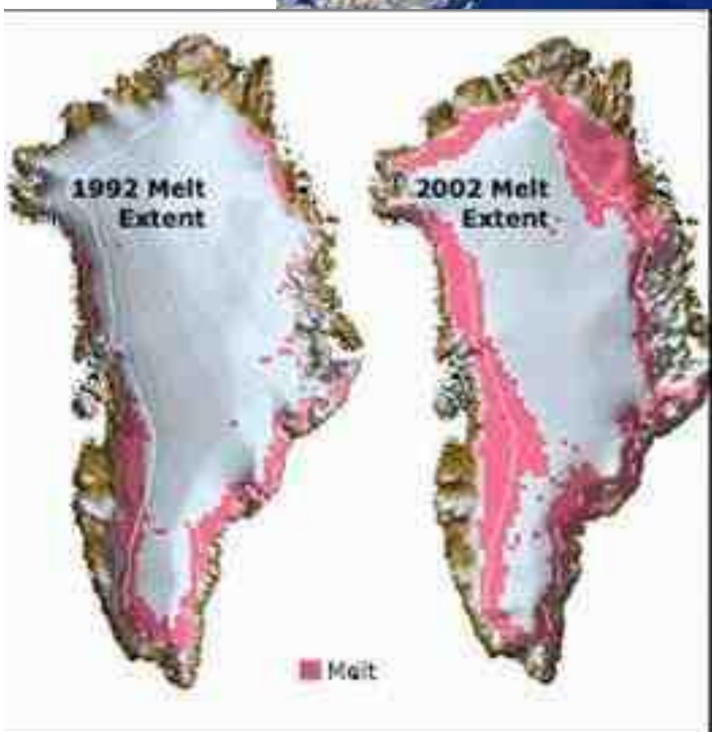
SSM/I Snow Cover for Mar 2005

frequency of occurence

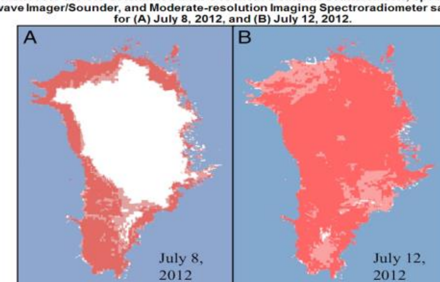


4 Apr 2005 NOAA/NESDIS/ORA/SCSB−CICS

Changes in snowmelt, Greenland

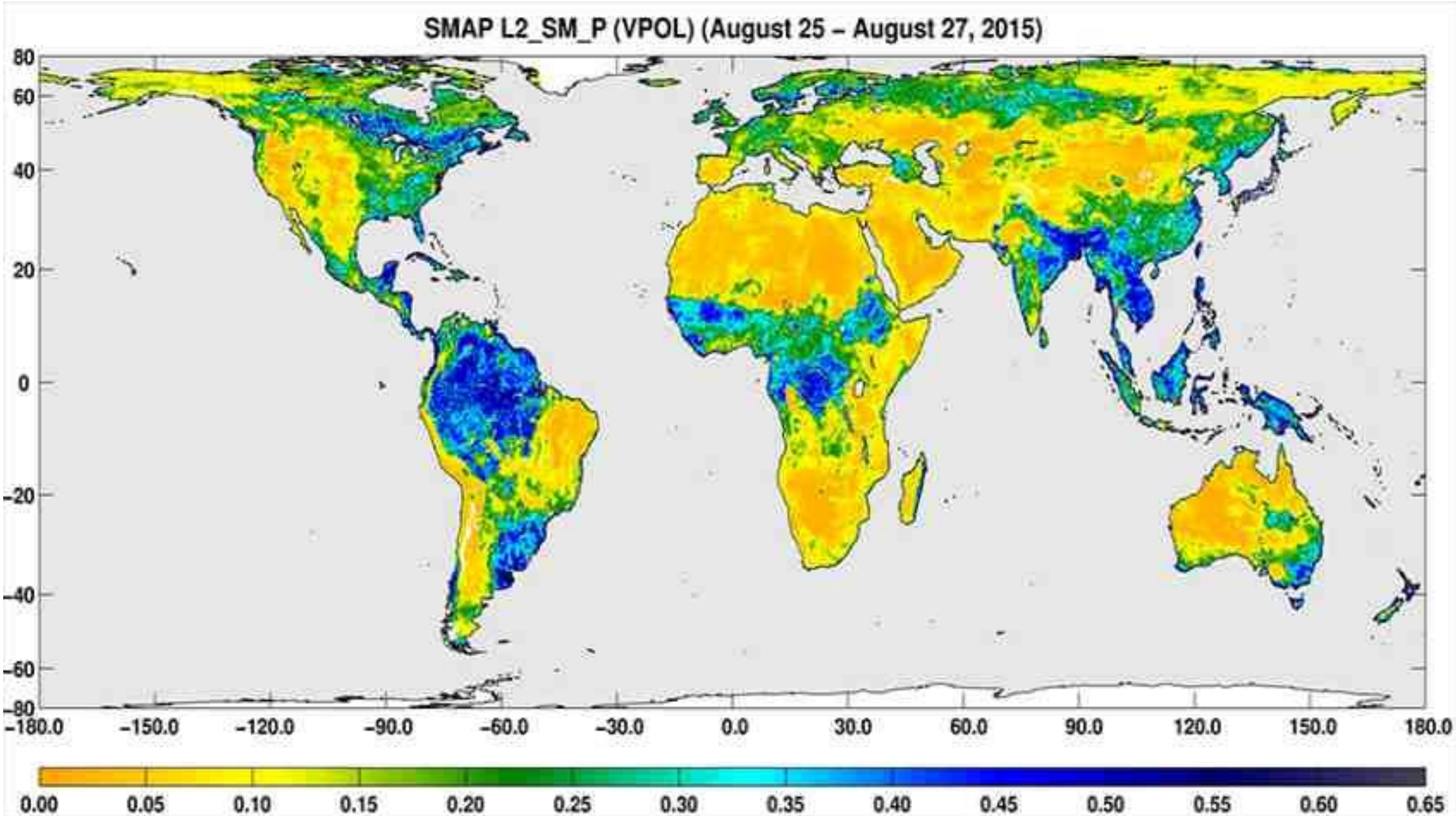


Melt extent over the GIS determined from Oceansat-2 satellite scatterometer, Special Sensor Microwave Imager/Sounder, and Moderate-resolution Imaging Spectroradiometer satellite data for (A) July 8, 2012, and (B) July 12, 2012.



Keegan K M et al. PNAS 2014;111:7964-7967

2012



A three-day composite global map of surface soil moisture as retrieved from SMAP's radiometer instrument between Aug. 25-27, 2015. Wetter areas are blue and drier areas are yellow. Resolution 9km merged with 1-3km RADAR. *Image Credit: NASA:* Soil Moisture Active Passive (*SMAP*) 2015-present

1.4 Types of Remote Sensing

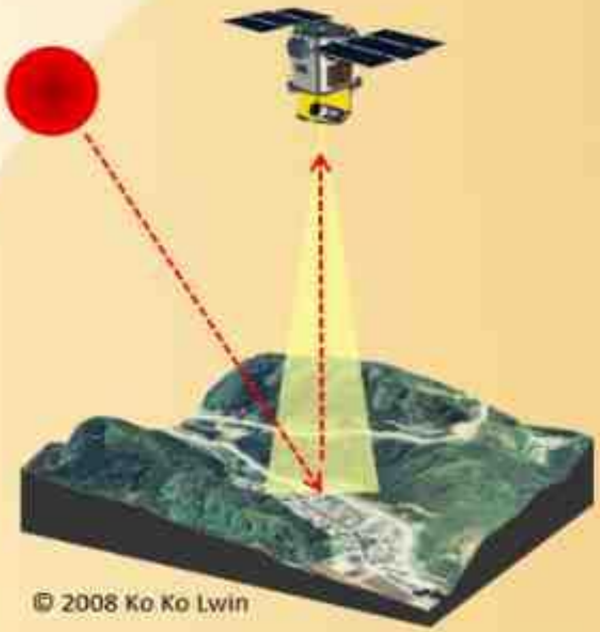
Passive Remote Sensing and Active Remote Sensing

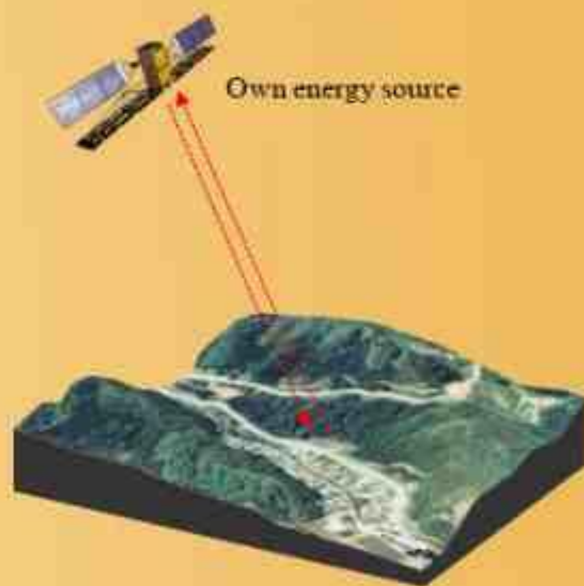
Passive Remote Sensing

Remote sensing of energy naturally reflected or radiated from the terrain.

Active Remote Sensing

Remote sensing methods that provide their own source of electromagnetic radiation to illuminate the terrain. Radar is one example.

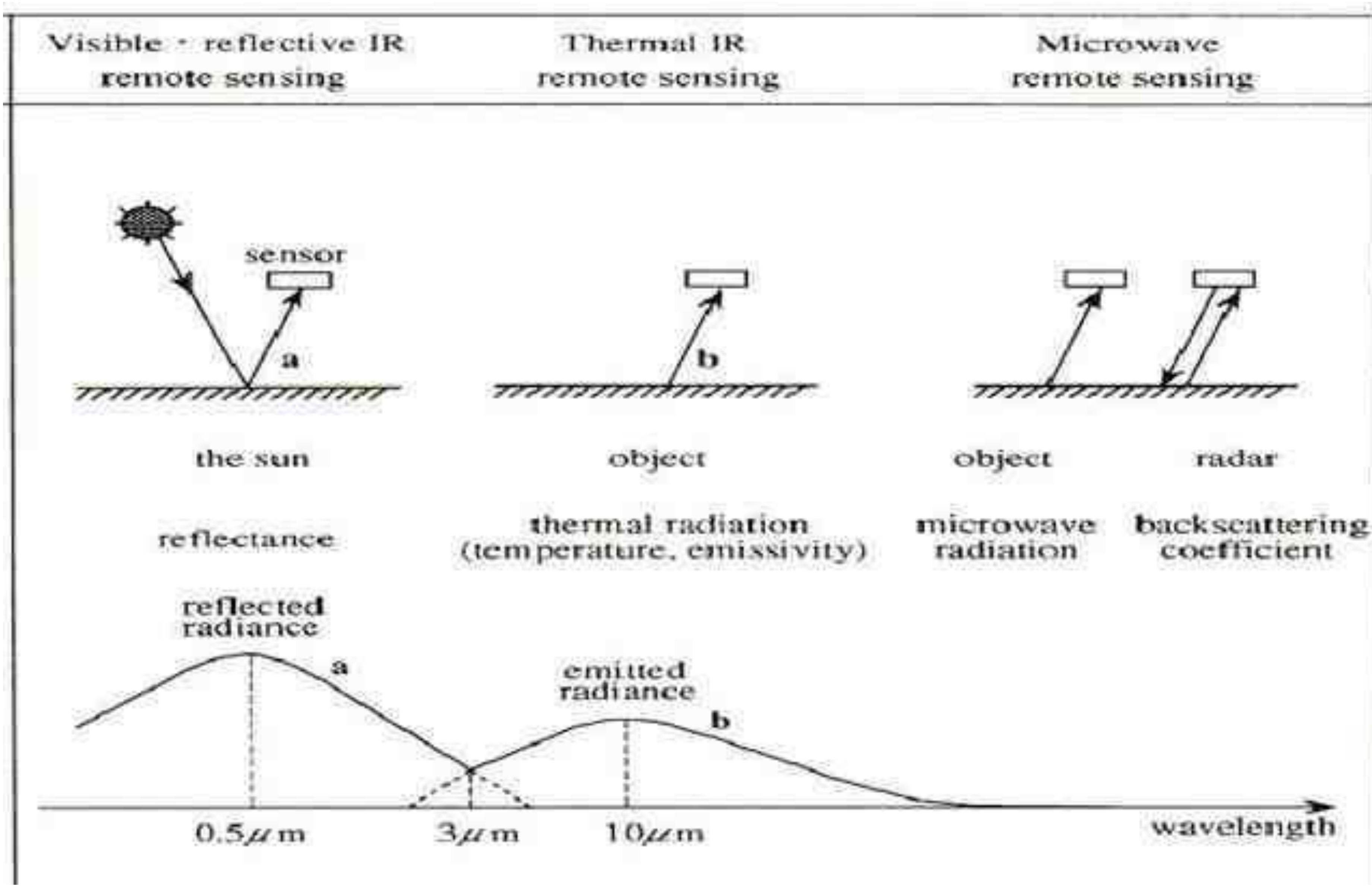




As **passive** microwave sensors deal with very low resolution, more applications in these wavelengths use **active** sensors

RADAR is the most commonly used space-based *active* sensing system.

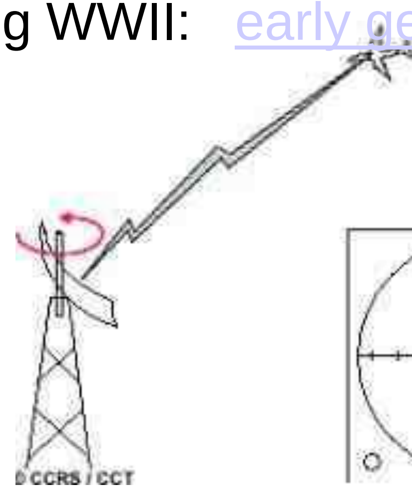
It is an acronym for ***RAdio Detection And Ranging***.

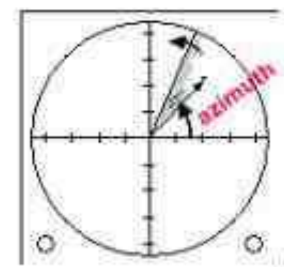


Radar systems were first implemented in the 1930s to detect ships on water and to measure their proximity, and later airplanes.

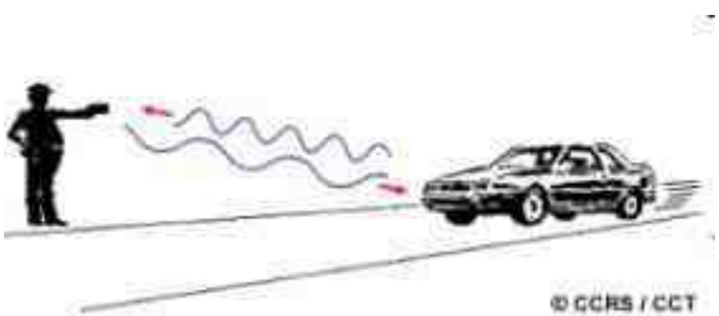
Imaging radar systems have been in use since the 1950s.

The original technology was developed during WWII: early german radar.





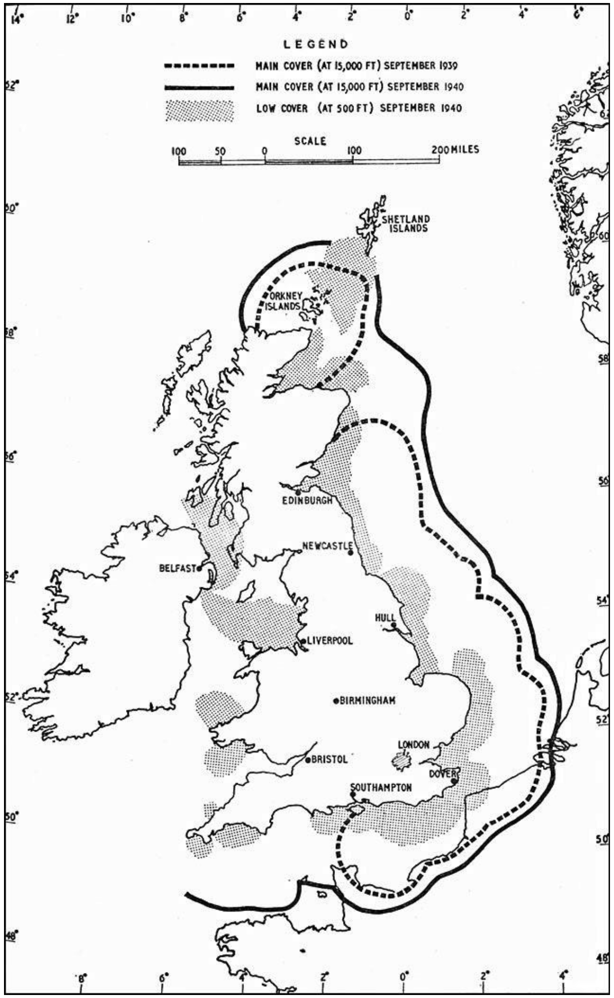
Non-imaging radar



Plan position indicators (PPI) produce a type of image. These radars use a circular display screen to indicate objects surrounding the rotating antenna. They are commonly used for weather monitoring, air traffic control and navigational systems.

Invention/development of RADAR: Robert Watson-Watt (1935)

Use of transmitting Radio waves to detect enemy aircraft in World War II



In 1956, he moved to Canada where Watson-Watt reportedly was pulled over for speeding by a radar gun - toting policeman (his own invention).

Massachusetts-based Raytheon in 1947 named the original microwave the **“Radarange”** because it cooked food using the same radio-wave-producing magnetron tubes that the company manufactured for use in military radar.

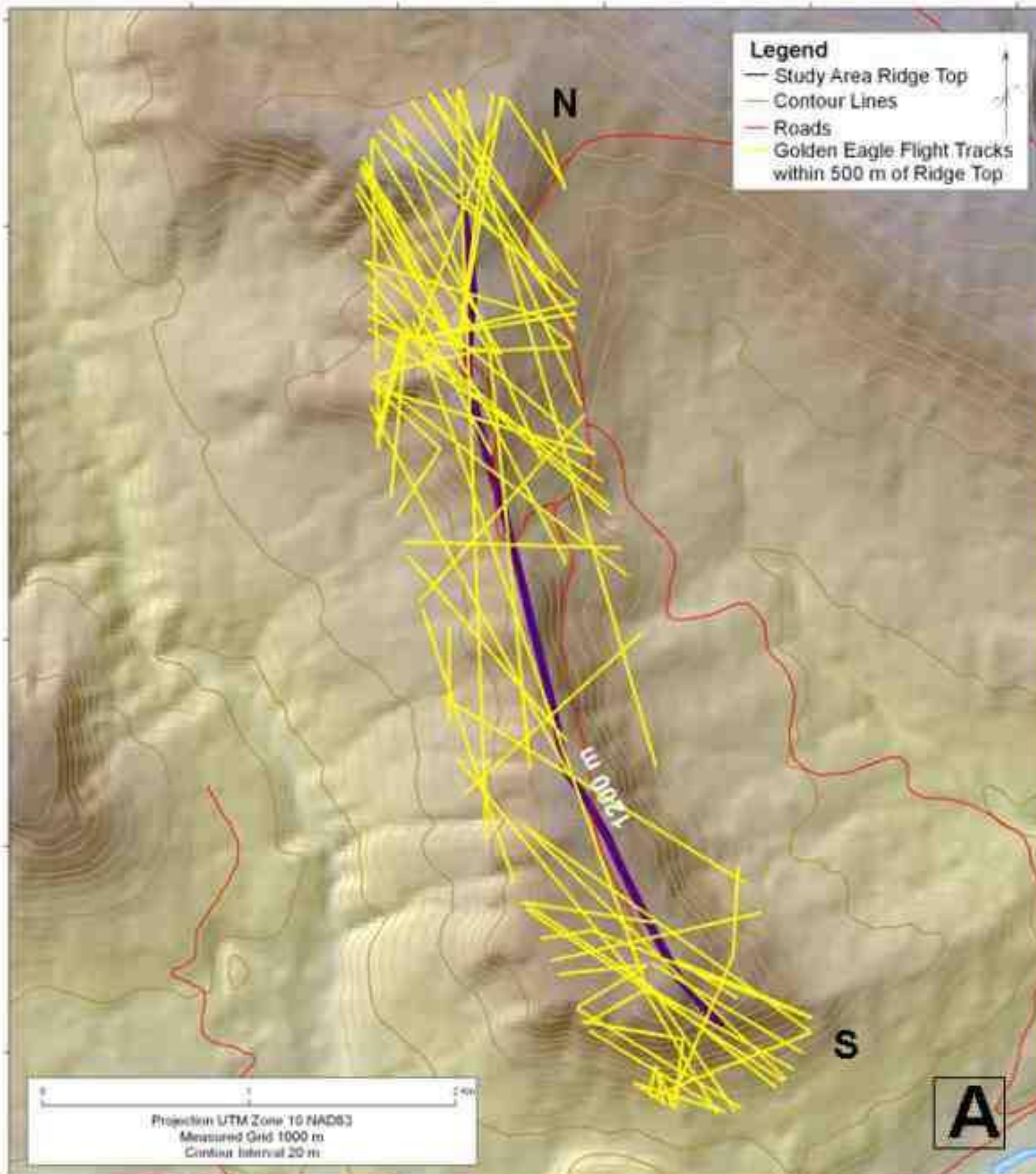
Raytheon credits the discovery of microwave cooking to an engineer named Percy L. Spencer. One day in 1945, Spencer was walking through a radar test room with a chocolate bar in his pocket, and the candy began to melt.

UNBC bird study using RADAR – near Chetwynd

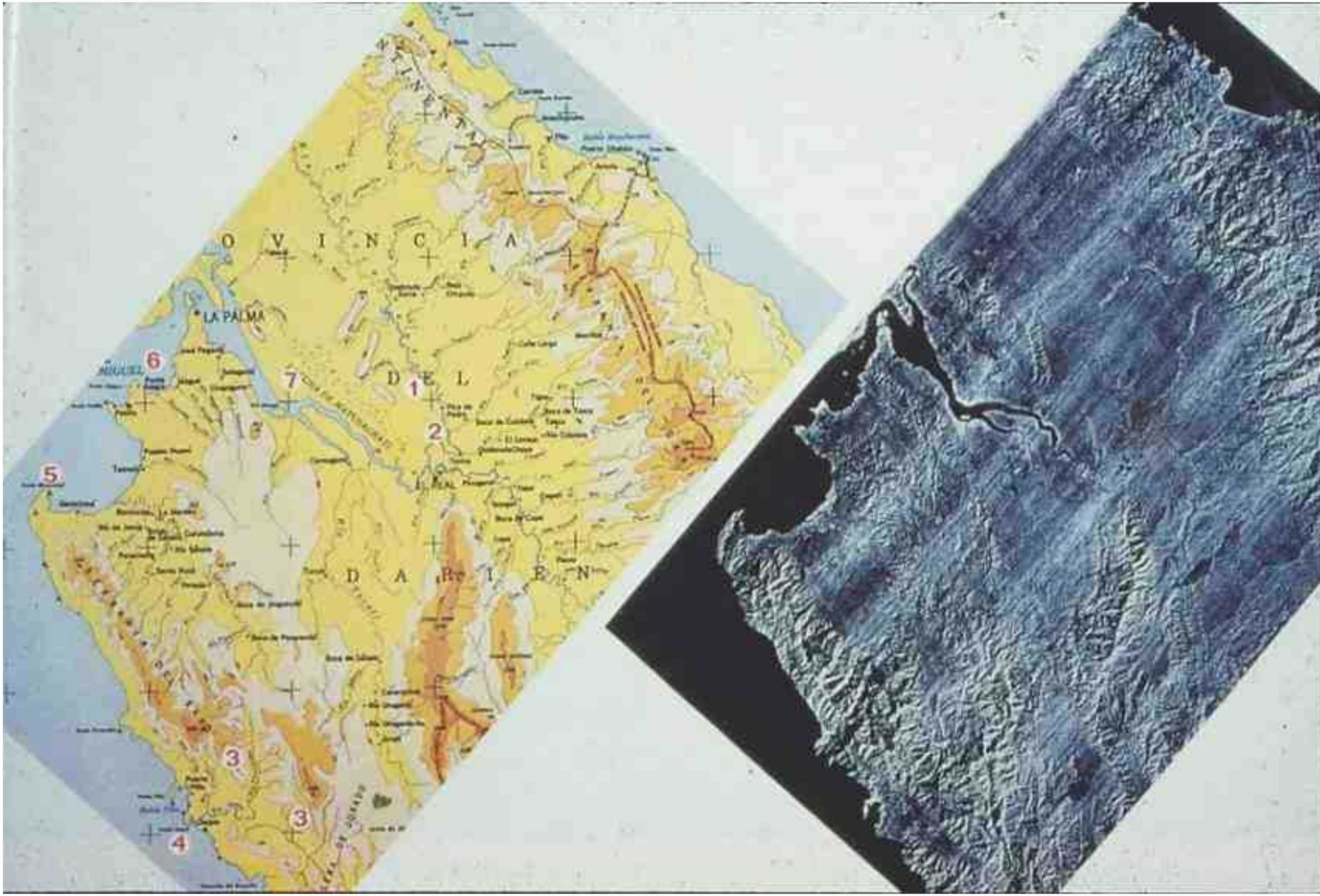
(Dr. Ken Otter)

Dokie Ridge

Site of wind turbines

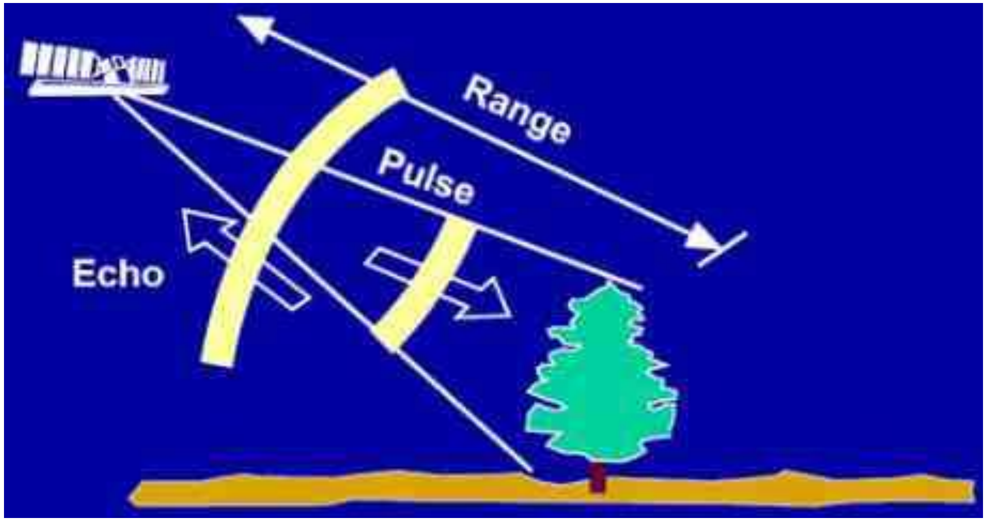


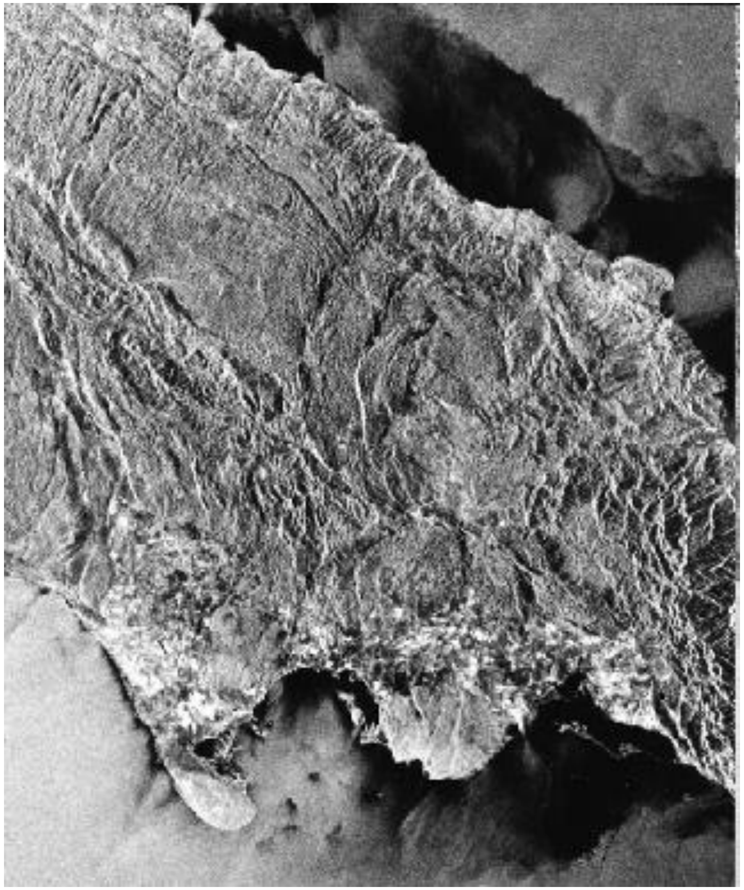
Most early imaging RADAR was airborne, e.g. Calgary Intera technologies: Panama



Tropical areas are often cloud-covered and poorly mapped without RADAR

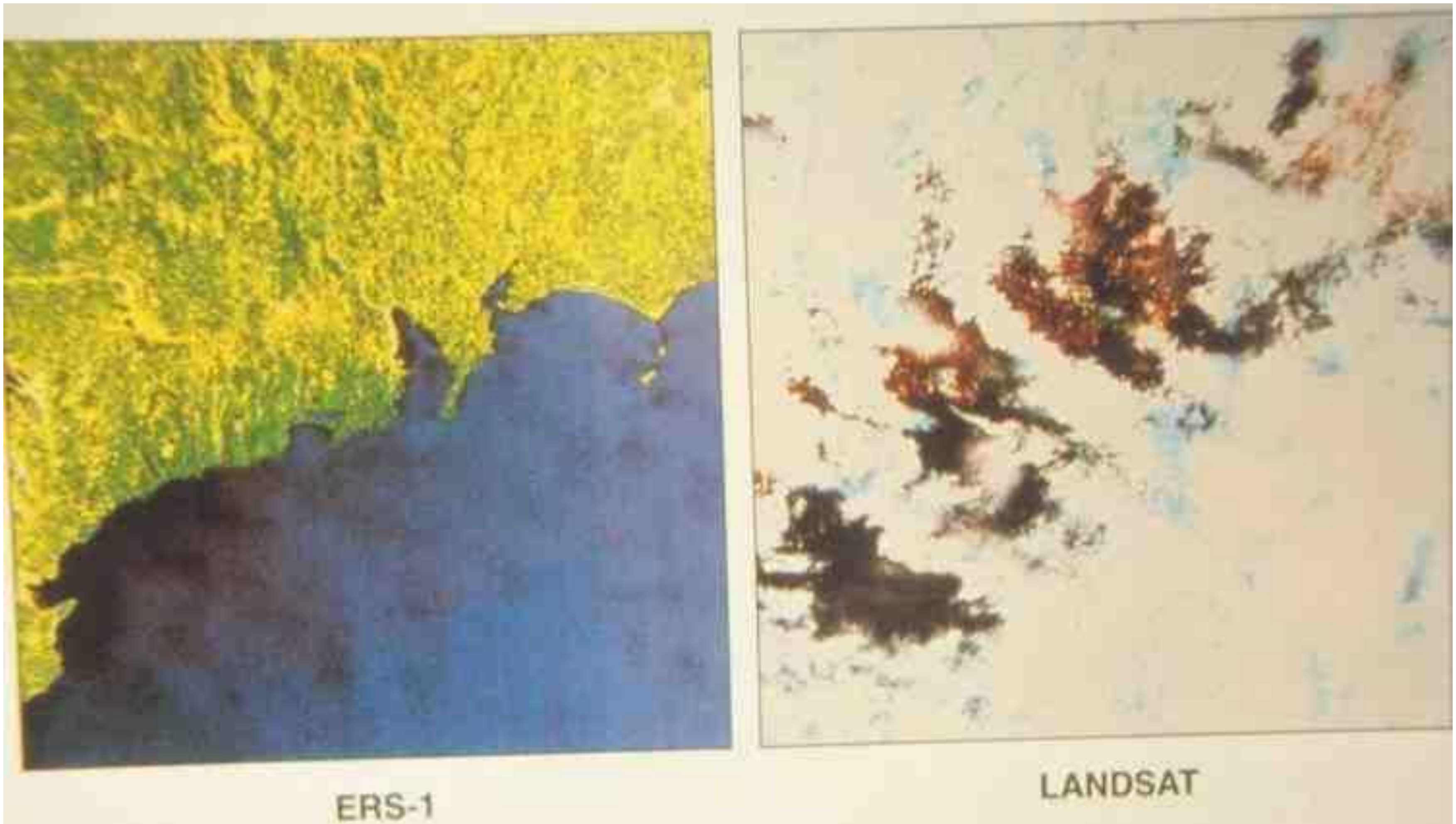
The RADAR device transmits energy, a portion of which is returned to the sensor. The time taken gives the distance (location) of the target, the strength of the return describes its characteristics.





Satellite imaging radar started with SEASAT, launched in 1978.

As it is not affected by darkness or weather, it is especially useful in **arctic regions for mapping ice**; and tropical areas, which are consistently **cloud covered** as well as other areas often cloud covered, both temperate and tropical.



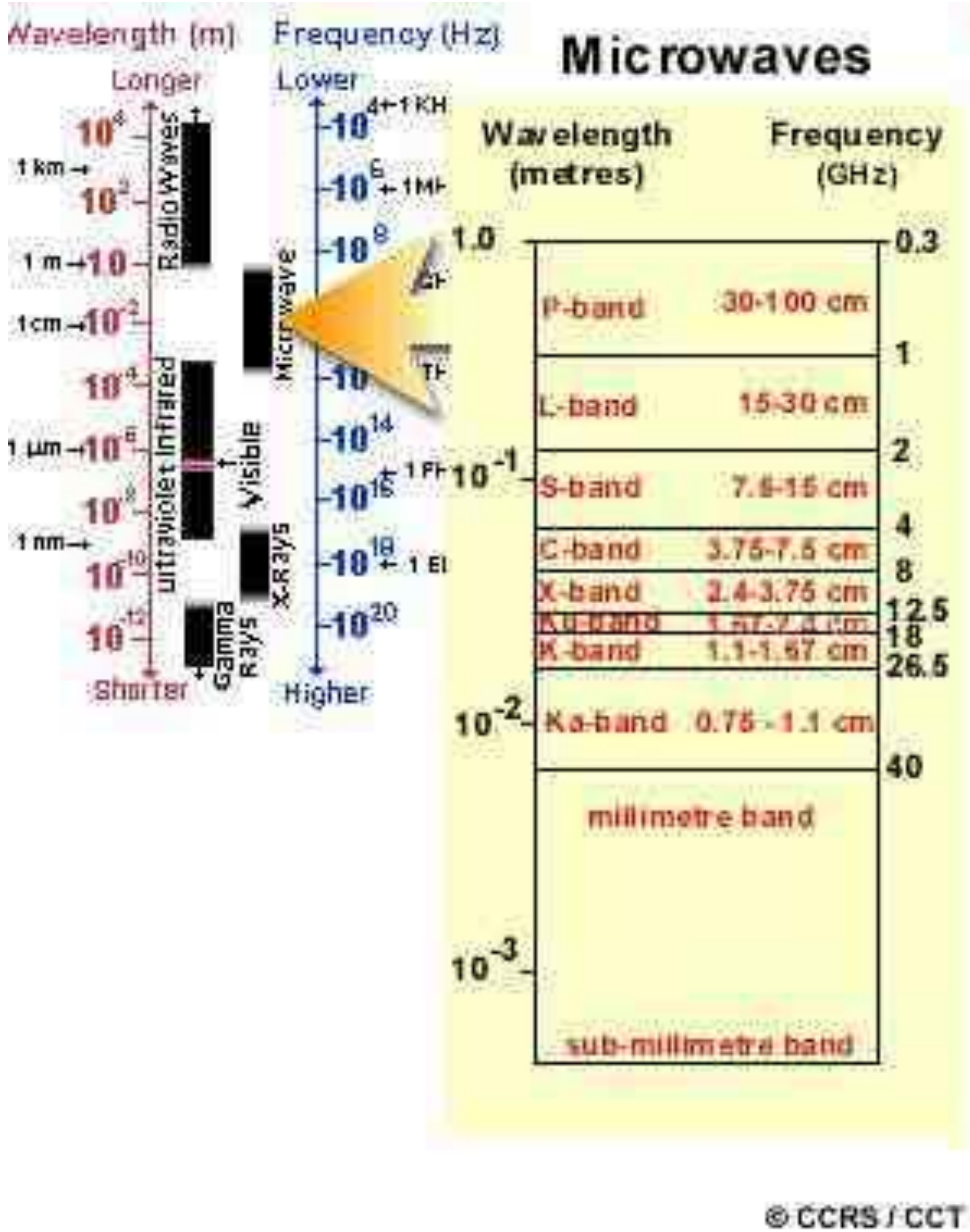
Ireland, 1991: Radar and Visible image

In RADAR microwave, it as usual to refer to bands by frequency in Gigahertz **(waves/second)** **as in wavelength**

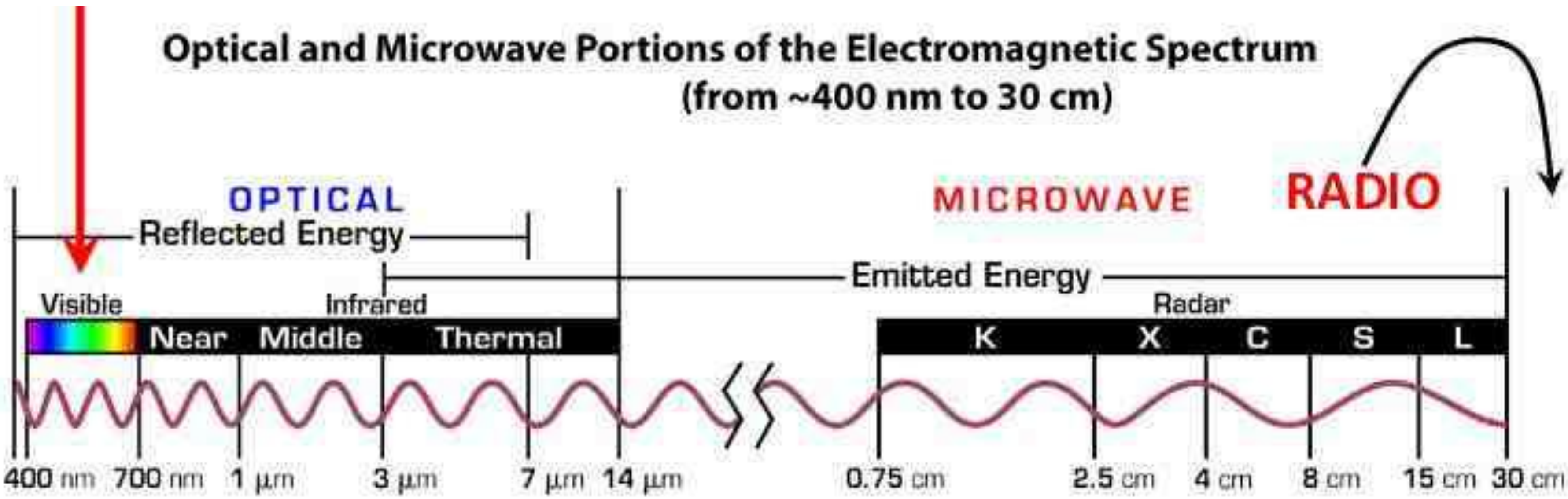
Frequency is inversely proportional to wavelengths

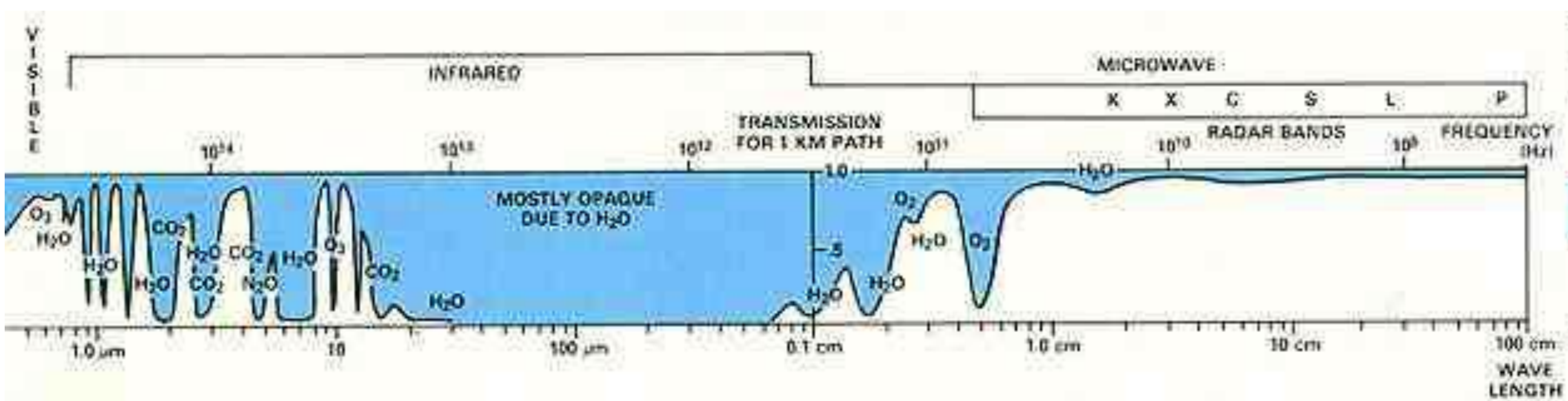
e.g. 1cm - 10cm =
30 - 3 GHz

P = penetration
L= Longwave
S= shortwave
C=compromise
X= Cross(hairs) **as in WWII**
K = Kurtz (short in german)



Optical and Microwave Portions of the Electromagnetic Spectrum
(from ~400 nm to 30 cm)





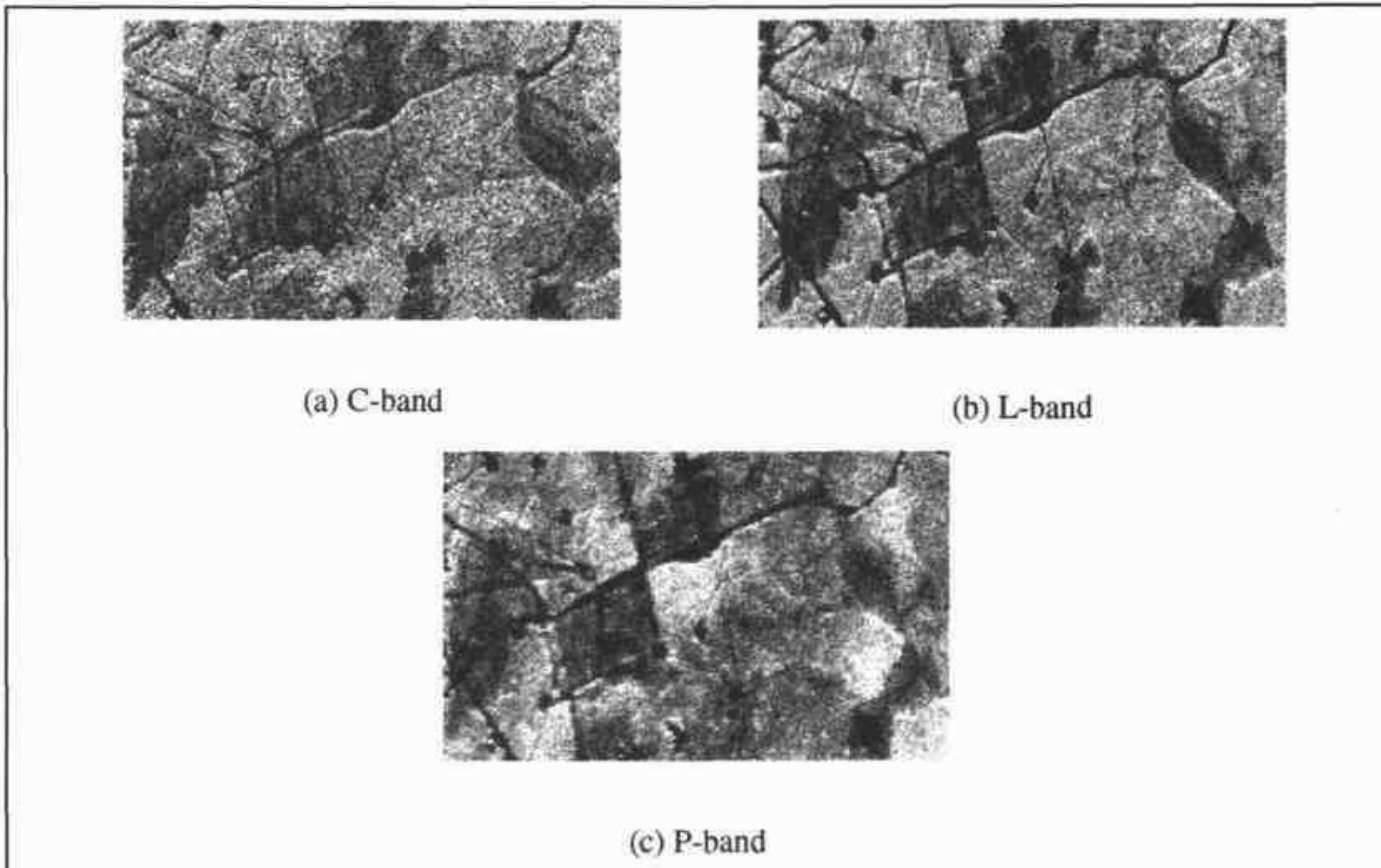


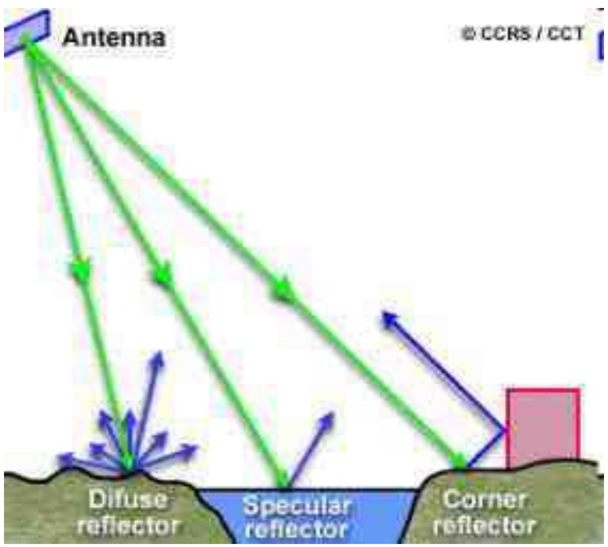
Fig. 3. Comparison between HH-polarized *SAR* images acquired with the *JPL-AIRSAR* in three bands (C, L and P), on the same harvested area near Whitecourt, Alberta, in May 1991.

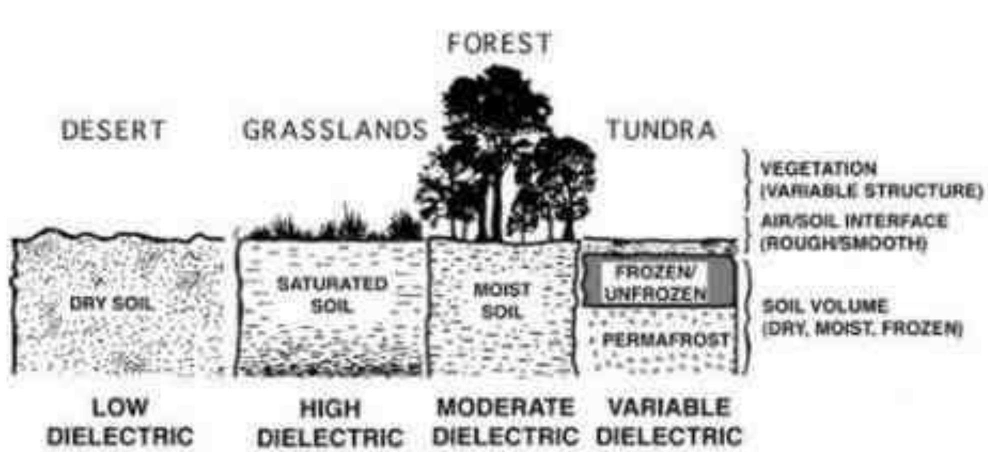
multiband – CPL (multifrequency) image of San Francisco

Radar image interpretation: Digital Numbers

The response to radar energy by the target depends on three factors:

- **Surface structure and roughness**
- **Moisture content: electrical properties (dielectric constant)**
- **Radar - surface geometry relationship**

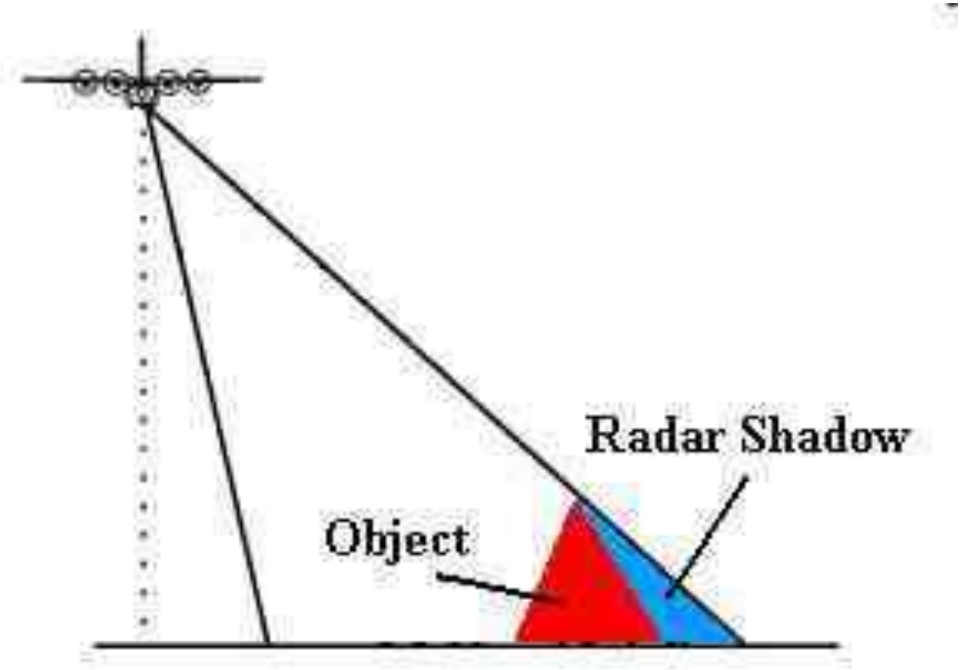




http://www.geog.ucsb.edu/~jeff/115a/remote_sensing/radar/radarroughness.jpg

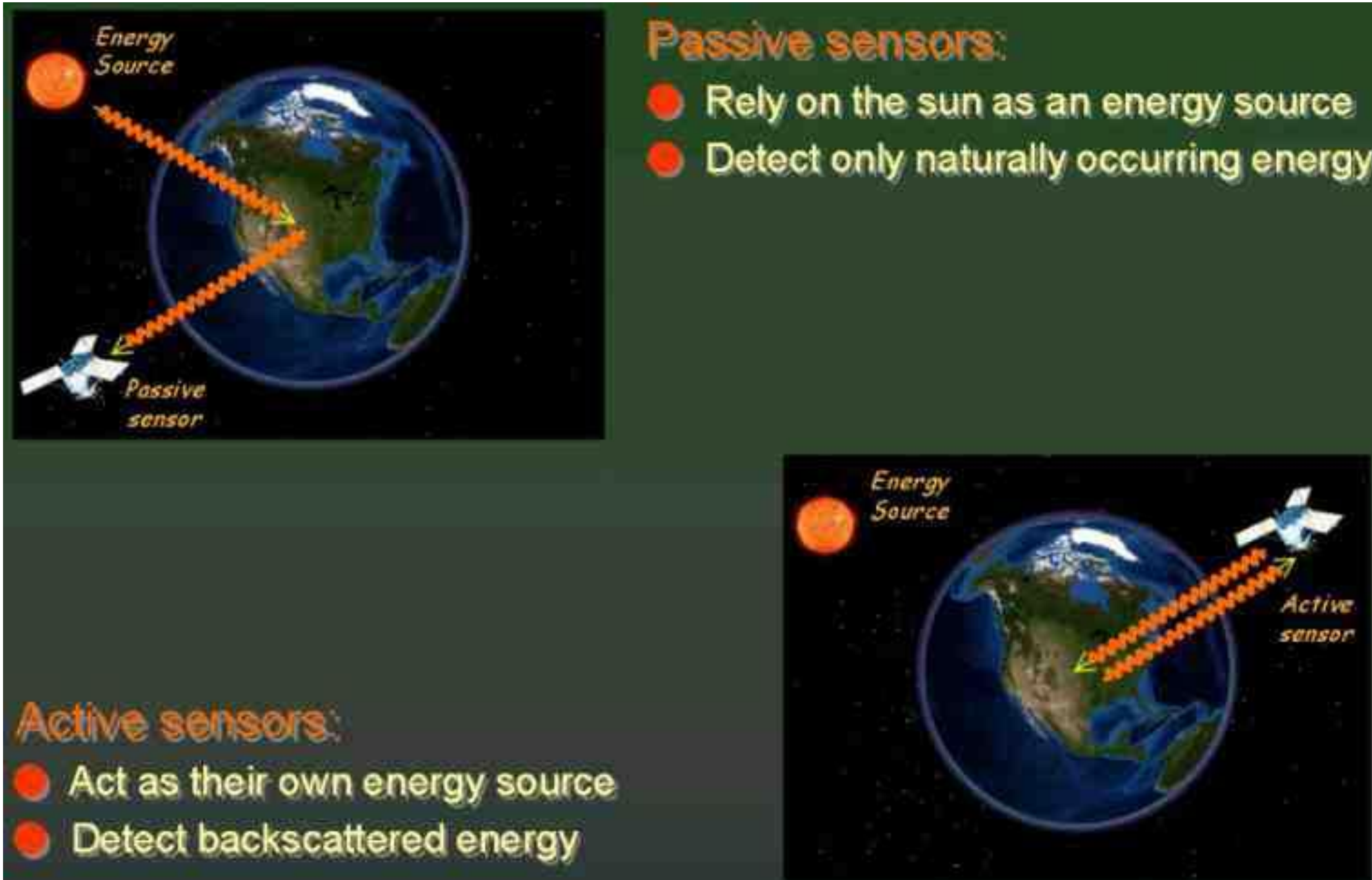
Radar - surface geometry relationship: shadows

Most imaging RADAR is ‘side-looking’



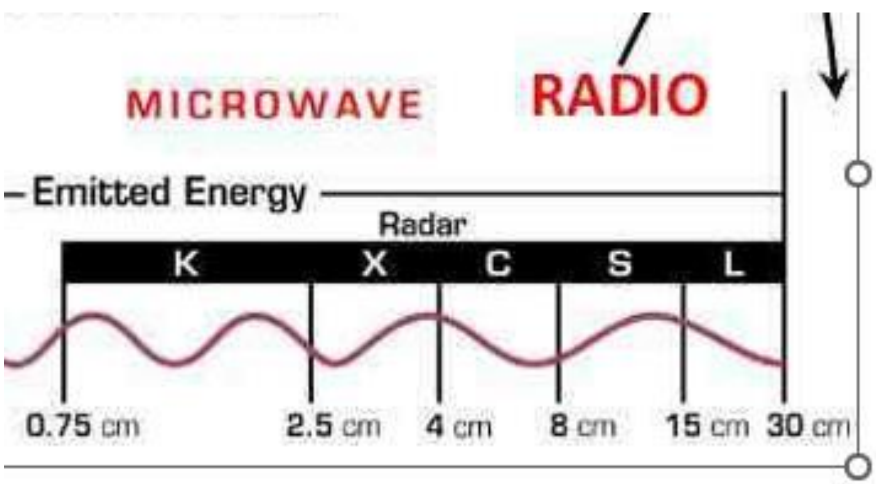
http://hosting.soonet.ca/eliris/remotesensing/bl130lec13.html

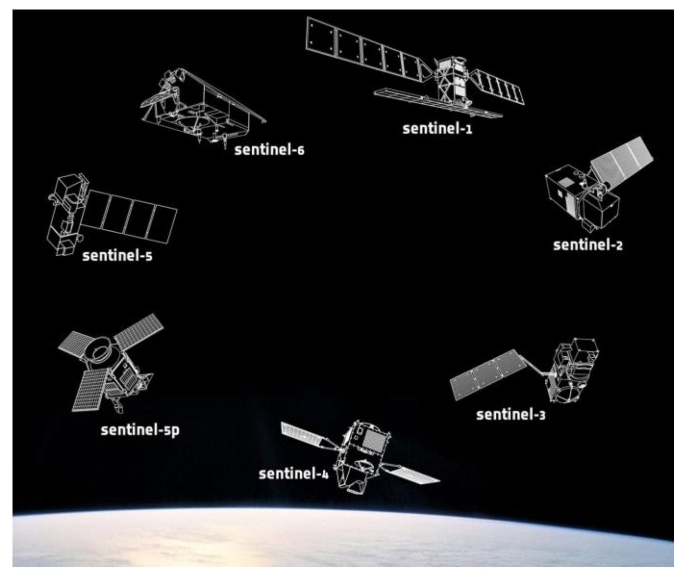
So far, we have mostly looked at 'passive' remote sensing systems. As **passive** microwave sensors deal with very low resolution, more commonly applications in these wavelengths use **active** sensors:



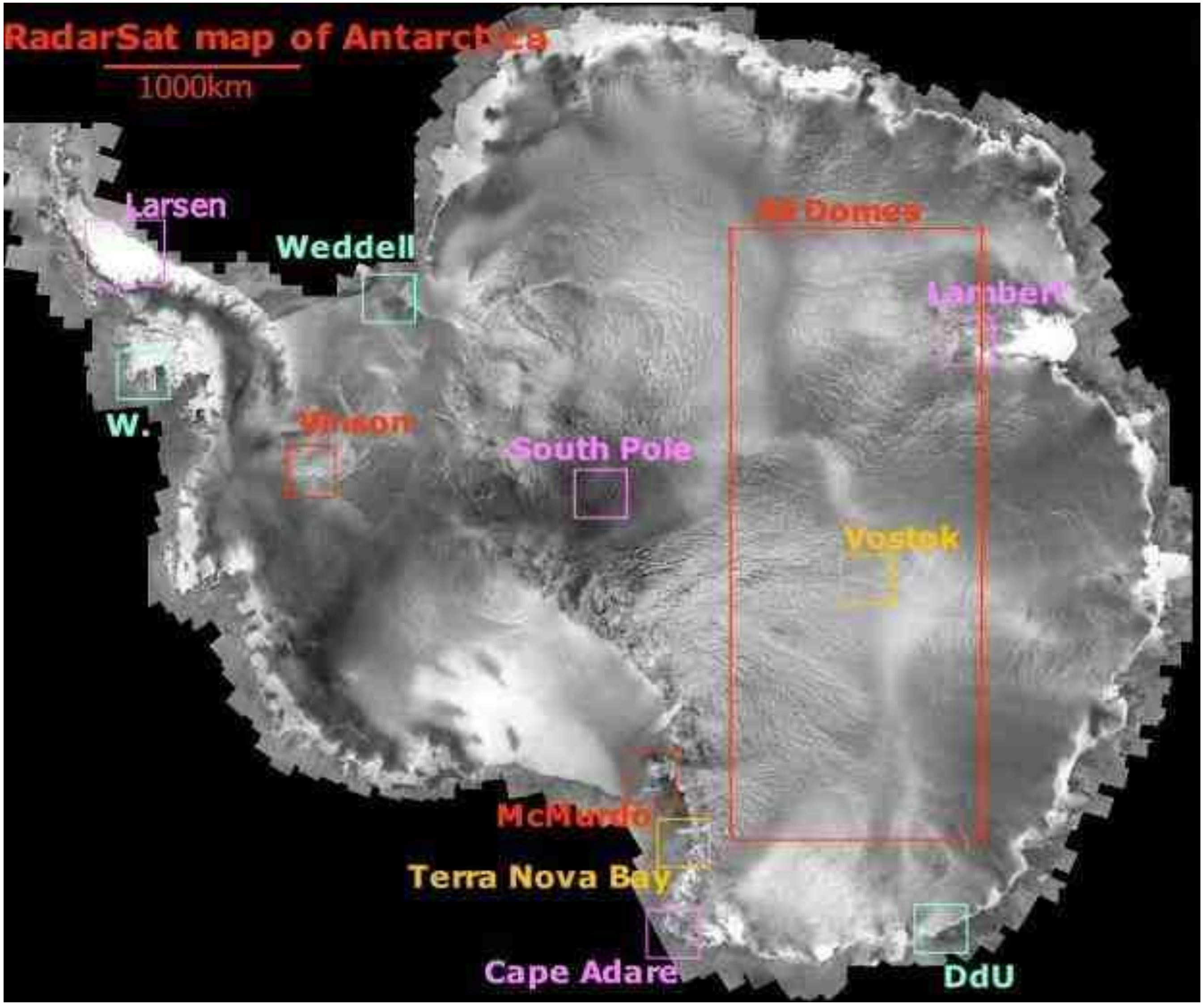
Some early RADAR satellite systems (Date launched, Wavelength, Resolution)

SEASAT (USA)	1978	L	25m
SIR- A,B,C (USA) JPL	1981	L	40m (Shuttle Imaging Radar)
ERS (EUROPE)	1991, 1995	C	30m
JERS (JAPAN)	1992	L	25m
RADARSAT (CANADA)	1995	C	10-100m CCRS - Radar
ENVISAT (EUROPE)	2002		multiple
RADARSAT 2 (Canada)	**2007**	**C**	**3-100m**
Sentinel-1 (ESA) A/B	**2014 / 2016**	**C**	**10m (Free)**

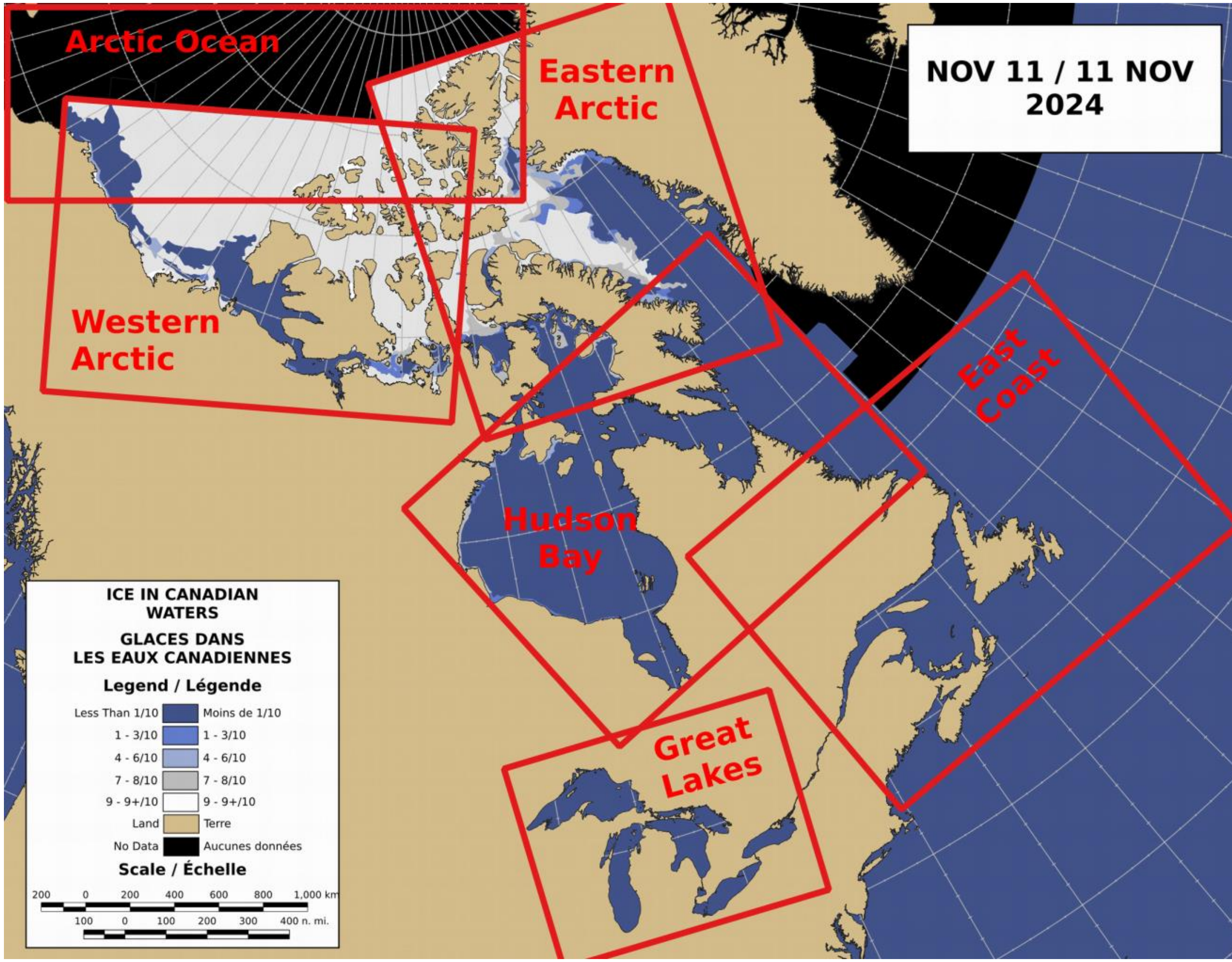


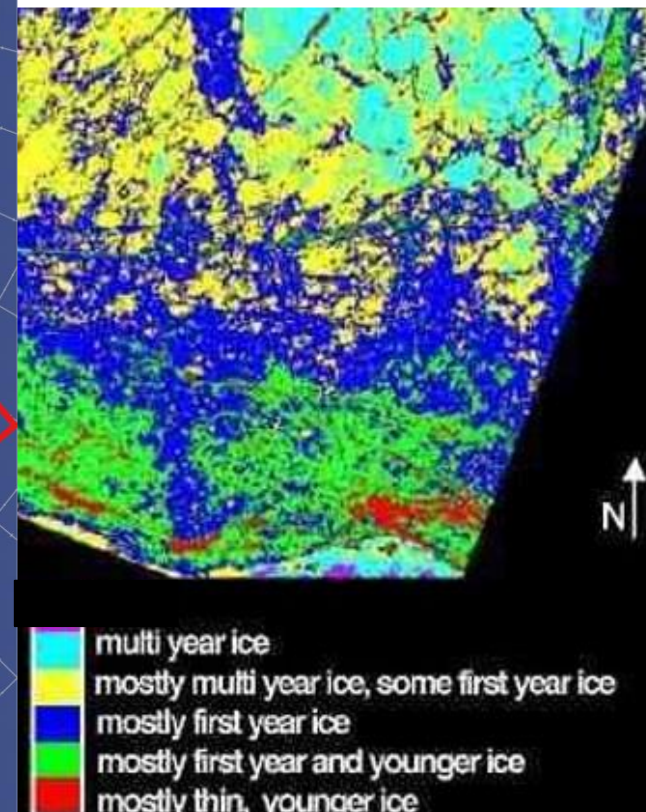


Canada produces the first complete image of Antarctica – we rock !
RADARSAT launched by NASA in 1995 in exchange for complete map image



https://www.asc-csa.gc.ca/eng/satellites/radarsat1/antarctic.asp https://www.canada.ca/en/environment-climate-change/services/ice-forecasts-observations/latest-conditions.html





https://natural-resources.canada.ca/maps-tools-and-publications/satellite-imagery-elevation-data-and-air-photos/educational-resources/tutorial-radar-polarimetry/sea-ice-applications/9571

RADARSAT – Canadian Space Agency (CSA)

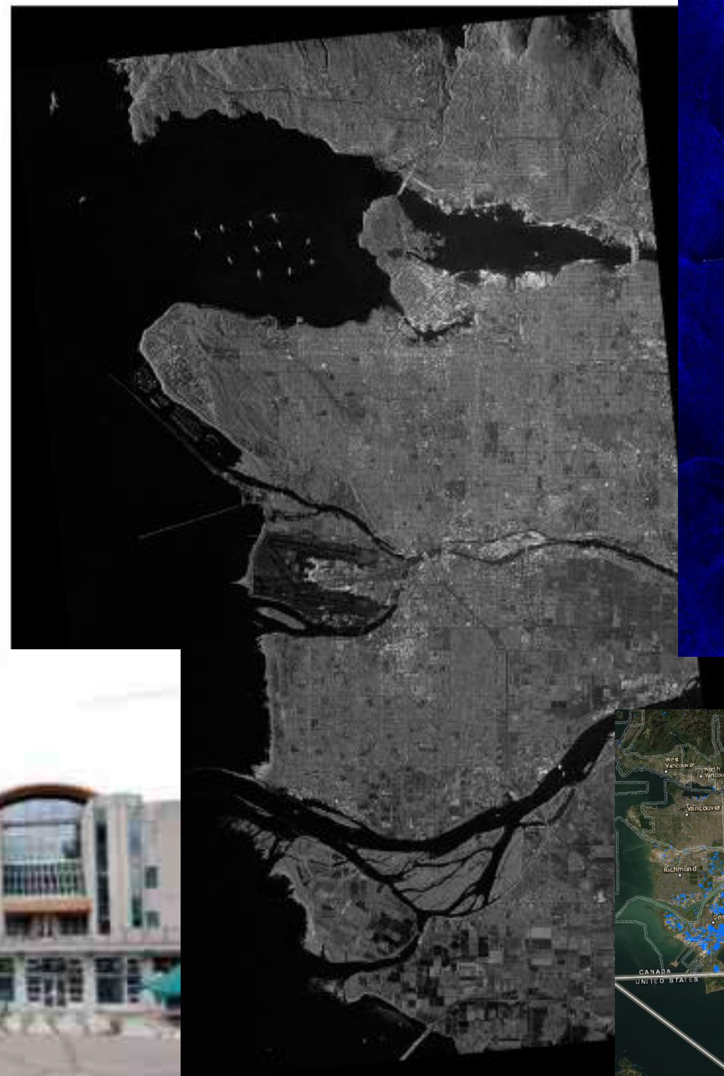
RADARSAT1: 1995-2013, RADARSAT2: 2007 ->

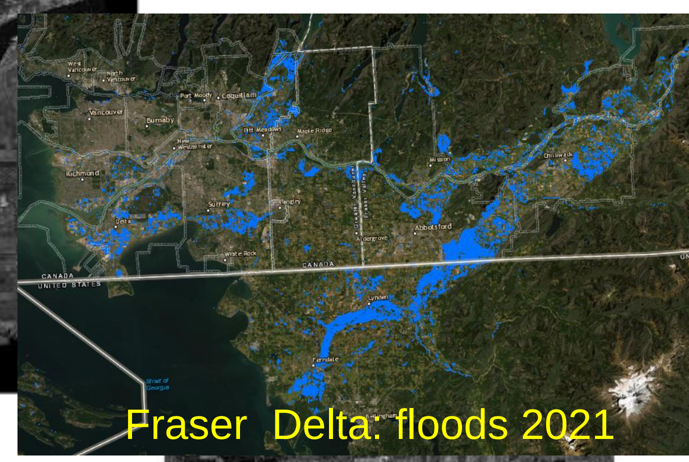
Bright = texture

Low = low dielectric constant (low texture)

Highest – corner reflectors

John S. MacDonald
Co-founder MacDonald-Dettwiler Associates /
UNBC Chancellor, 2008-15



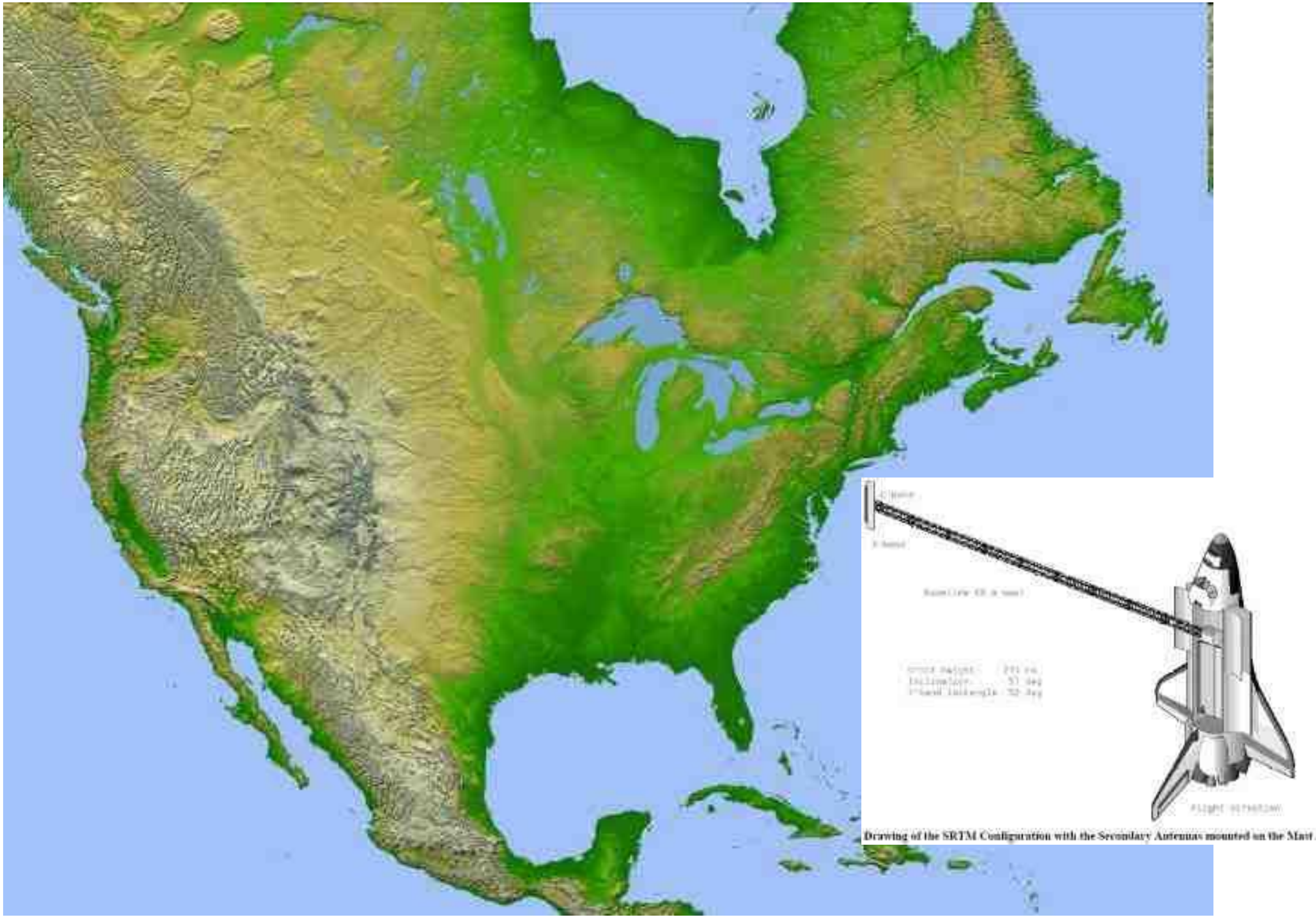


Oceanography – oil spills

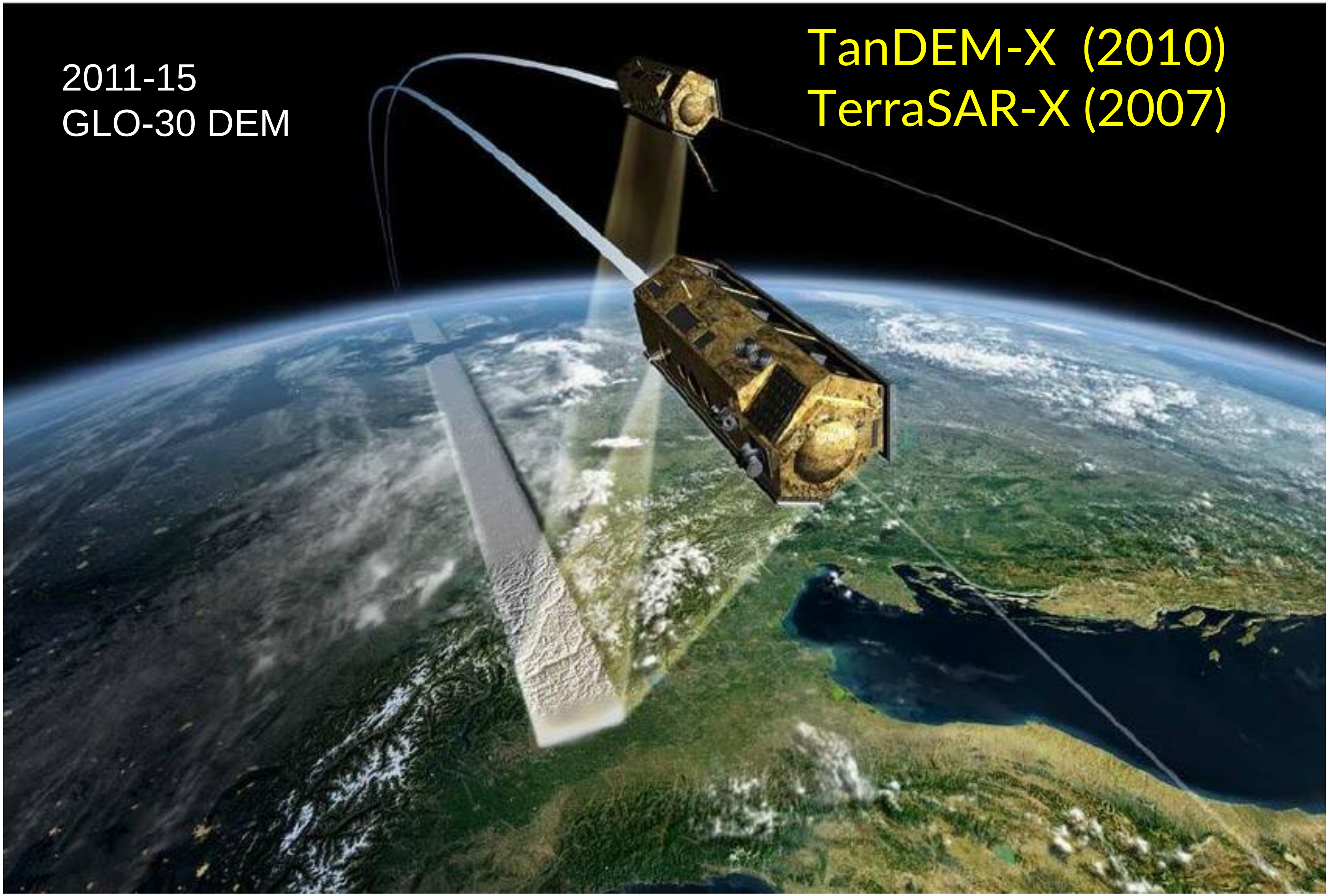
http://earth.esa.int/ew/oil_slicks/wales_gb_96/

http://www.mms.gov/tarprojectcategories/remote.htm

DEMs from RADAR e.g. Shuttle Radar Topographic Mission, 2000



The first ‘near-global’ high-res DEM (30-90m) – C / X bands used to create Google Earth

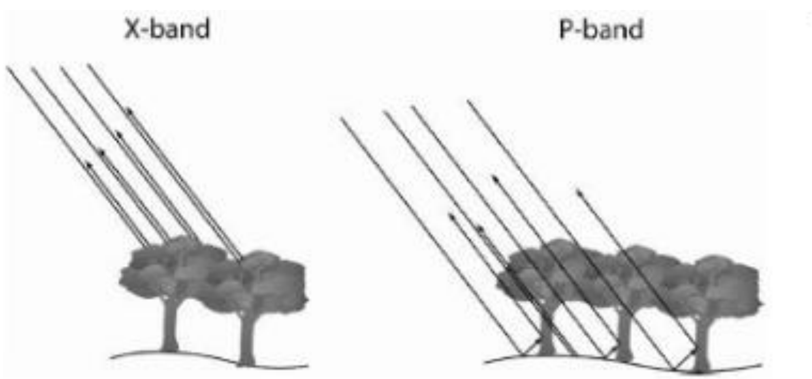


https://spacedata.copernicus.eu/collections/copernicus-digital-elevation-model

https://dataspace.copernicus.eu/explore-data/data-collections/copernicus-contributing-missions/collections-description/COP-DEM

SIR-A in November, 1981. The color scene is a Landsat subimage of the Selma Sand Sheet in the Sahara Desert within northwestern Sudan.

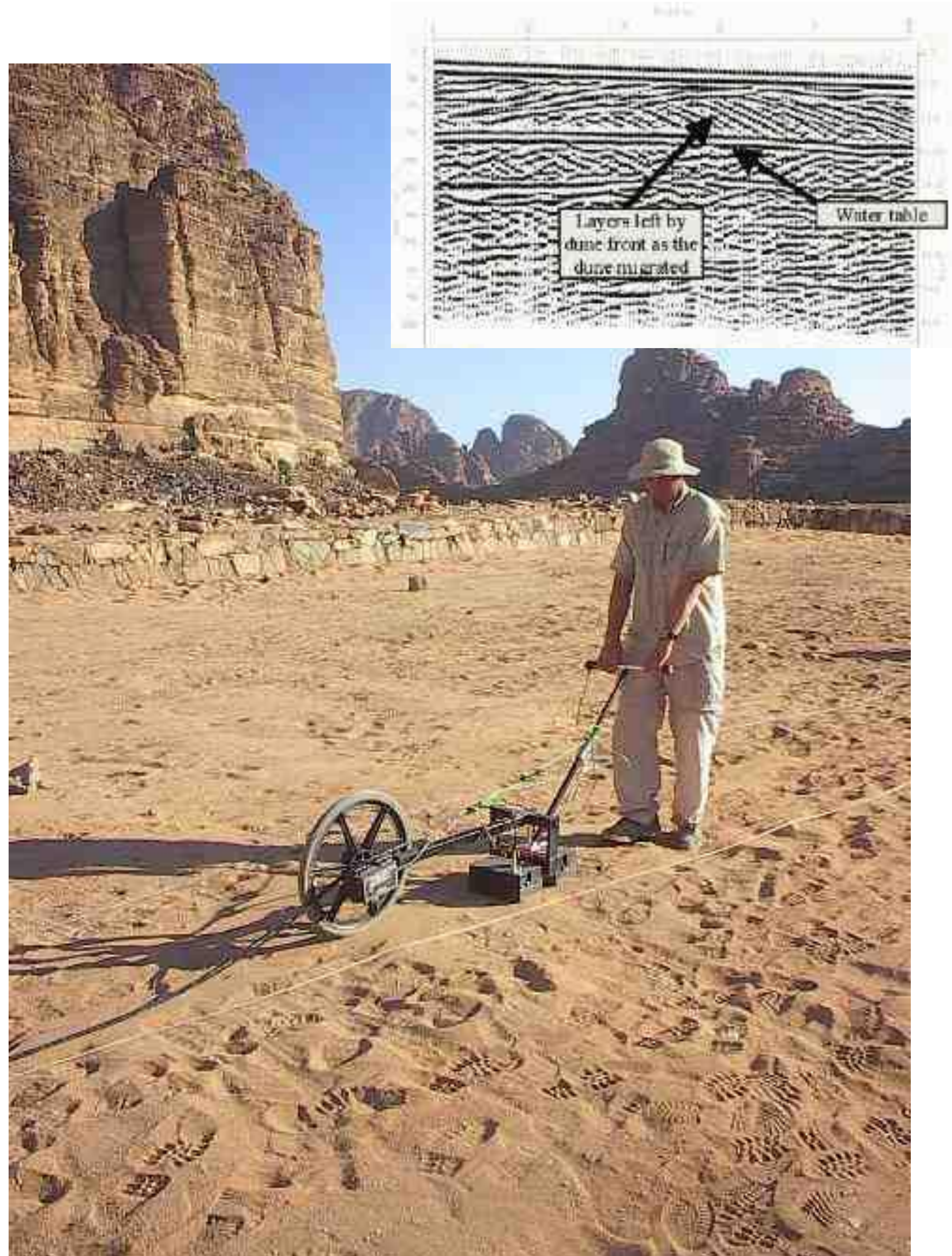
Because dry sand has a low dielectric constant, very long P ('previous') radar waves penetrate these small particles by several metres



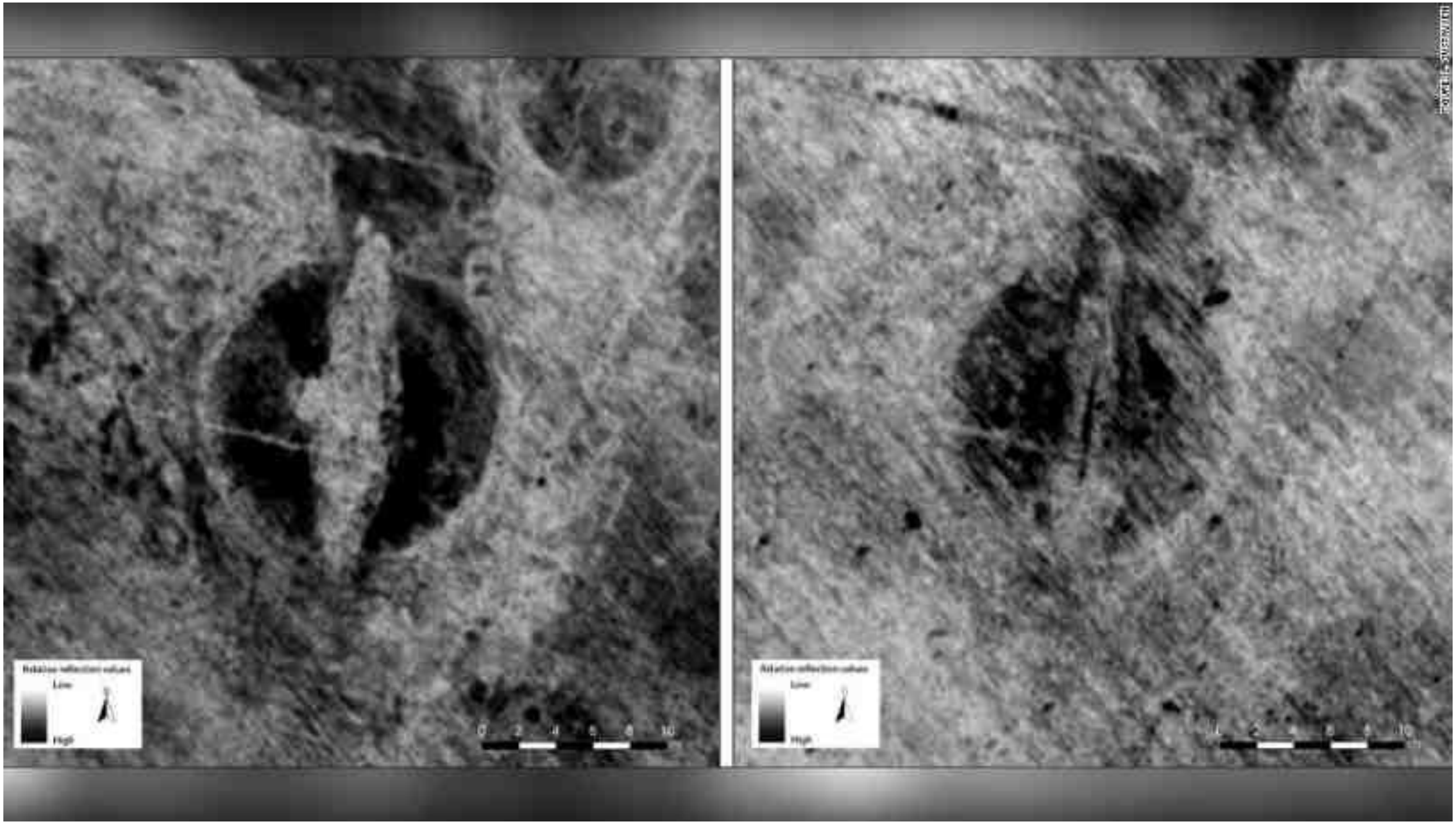
Ground penetrating radar (GPR) is a tool for analysing underground objects (such as graves), gravel and sand layers, and other underground features e.g. buried tombs and archaeological structures

… is this then still remote sensing ?

Also possible from aircraft / drones – surface penetration not as good



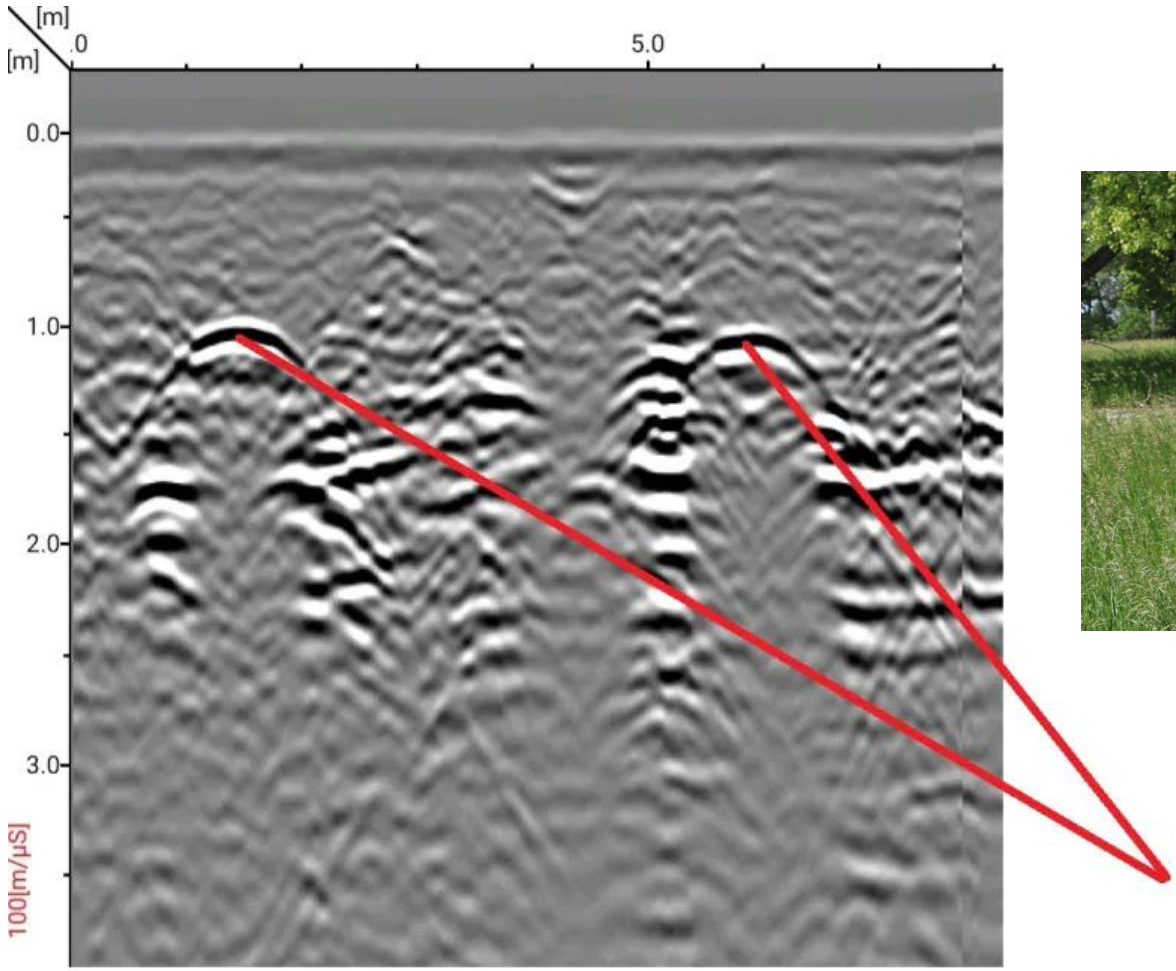
Nov 11, 2020: GPR discovers buried Viking ship
Late Nordic Iron Age, 550 to 1050



https://www.sciencetimes.com/articles/28180/20201112/viking-ship-discovered-norway-using-ground-penetrating-radar.htm

Ground Penetrating Radar (GPR) discovers unmarked graves in residential schools: Canada 2021-22

https://www.cbc.ca/news/canada/ground-radar-technology-residential-school-remains-1.6049776



Reflections from known graves (coffins)