The use of remote sensing in climate change research

SO503: Honors Research Methods
Dept. Oceanography, United States Naval Academy
03/30/11
Learning Objectives:

- Some basic concepts of remote sensing:
  - Resolutions, satellite orbits, types of systems

- Why remote sensing and climate science?
  - Earth system science & remote sensing

- Example: satellites, sensors & products
  - Satellite: NASA’s flagship Earth Observing System, Terra
  - Sensor: MODIS
  - Products: MODIS snow, IMS snow & ice

- Climate change case study:
  - Sea ice under changing climate
Who here has ever done remote sensing?

Source > Sensor > Processor > Interpretation

PASSES OVER A DISTANCE therefore “remote”
Things get a little more complicated when we increase the scale!


http://asterweb.jpl.nasa.gov/
**Remote Sensing** is the measurement or acquisition of some property of an object or phenomenon, by a recording device that is not in physical contact with the object or phenomenon under study (formal definition of the ASPRS)

- Information about an object or area
- Instrument (Sensor)
- Distance (How far is remote?)
- Remote sensing is both a science and an art
Satellite remote sensing: monitoring radiation from space

- Satellites observe flux of radiation entering and leaving TOA.

From Professor J. Clint, University of Wisconsin
http://sprott.physics.wisc.edu/sprott.htm
Satellite remote sensing: monitoring radiation from space

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- Generally inserted in 1 of 2 orbital configurations

Polar-orbiting, sun-synchronous satellites

Geosynchronous satellites
Satellite remote sensing: monitoring radiation from space

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Polar-orbiting, sun-synchronous satellites

Geosynchronous satellites
Geosynchronous/Geostationary versus Polar-Orbiting

True relative distances from Earth to Geostationary orbits and polar orbiting satellites

Geostationary Satellite
35,800 km altitude

mean distance to moon = 384,400 km

17.4°

earth radius = 6,370 km

typical shuttle orbit = 225 - 260 km

Hubble Space Telescope = 600 km

110.8°
Polar Orbiting Satellite
850 km altitude
Remote Sensing Systems

- **Passive sensors** record naturally occurring electromagnetic radiation that is reflected or emitted from the surface.

- **Active sensors** bathe terrain in man-made electromagnetic energy and then record the amount of radiant flux scattered back toward the sensor system.

MONTHLY ANTARCTIC SEA ICE CONCENTRATION FROM SSM/I JUNE 2009.
Source: NSIDC

COMPOSITE OF 3 SSM/I SENSORS SHOWING WATER VAPOR OVER OCEANS, AUG 12 2005.
Remote Sensing Systems

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References:

- ICESat
- RADARSAT
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*ICESat*. Radarsat Geology Handbook. Richmond, B.C.
4 major resolutions associated with each remote sensing system:

- Spatial resolution
- Temporal resolution
- Spectral resolution
- Radiometric resolution

These resolutions should be understood by the scientists (users) in order to extract meaningful biophysical or hybrid information from remotely sensed imagery.
Jensen 2007:
Remote Sensing of the Environment
Why is remote sensing so applicable to the study of Climate Change?

*Earth System Science* is interdisciplinary scientific endeavor, treating Earth as a complex but integral system.

http://serc.carleton.edu/images/eslabs/climate/earth_system.jpg
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Global data from multiple sensors on NASA’s Terra satellite.

http://earthobservatory.nasa.gov/IOTD/view.php?id=485
NASA’s Earth Observing Program:
Spacecraft/instruments in orbit currently
Remote Sensing & Climate Change: example satellites & sensor

NASA’s **Terra & Aqua** satellite:
- Terra: launched on 18th Dec 1999.

Both have MODIS sensor:
**Moderate Resolution Imaging Spectroradiometer**

- 1-2 days to complete earth view
- 36 spectral bands
- Resolution: 1000-250 meters

http://earthobservatory.nasa.gov/IOTD/view.php?id=485
Remote Sensing:
satellites, sensors ➔ products

**MODIS** snow product

- Fully automated snow detection algorithm
- Can you see any potential problems?
Development of Northern Hemisphere Snow Earth System Data Records

As part of NASA’s Making Earth Science Data Records for Use in Research Environments (MEaSUREs)
MEaSUREs Snow Team

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Project Goals

- Assess compliance of current NH snow cover products over land, sea ice and the Greenland ice sheet with NRC Climate Data Record (Earth System Data Record (ESDR)) characteristics

- Develop ESDRs of NH snow conditions for individual and integrated products

- Make the ESDRs available to the user community via the project website, deliver ESDRs to national data centers, and encourage their use.
MODIS Cloud Gap Filling

From Dorothy Hall, Goddard Space Flight Center. NASA MEaSUREs Project
A different type of remote sensing product:

Interactive Multi-sensor Snow and Ice Mapping System (IMS)
Remote Sensing & Climate Change: example products

**Interactive Multi-sensor Snow and Ice Mapping System (IMS):**

- NOAA operational product of daily Northern Hemisphere snow and ice fields
- Trained analysts use multiple satellite products to interactively create, save and distribute snow and ice fields
- Used to further a longer NH snow extent dataset, spanning 44 years!
Remote Sensing & Climate Change: example products

IMS snow and sea ice extent charts:
- Analysts use multiple products to composite into one map
MODIS CGF and Daily IMS

Red = 4.21808  Yellow = 1.59482 (x10^6 km^2)
Remote sensing and snow cover extent change

- In January, anomalous SCE over eastern U.S., eastern Europe and western China.
- In February, SCE remained above average at $47.4 \times 10^6$ km$^2$
- Snow cover and sea ice extent are strongly linked to negative AO phase
What about sea ice?
Remote sensing of Arctic Sea Ice:

Sea ice detection with passive microwave sensors:

- **ESMR**
  - 1972-1977
- **SMMR**
  - 1978-1987
- **SSM/I, SSMIS**
  - 1987-present
- **AMSR-E**
  - 2002-present

- Sea ice extent varies through the year.
- In recent years however........

Mar = 4 x $10^6$ km$^2$
Sep = 19 x $10^6$ km$^2$

Data derived from Sea Ice Index data set, NSIDC.
Remote sensing of Arctic Sea Ice:

September monthly sea ice, 1979 - 2008

Data derived from Sea Ice Index data set (http://nsidc.org/data/virtual_globes/). Credit: National Snow and Ice Data Center
How much Sea Ice Loss?

*Let's consider September monthly average extent...*

1980: 7.85 million sq km

2005: 5.57 million sq km

2007: 4.28 million sq km

Image by D. Perovich, U.S. Army Cold Regions Res. Eng. Lab
Ice age maps for spring 1989 and 2009 showing large changes in age coverage

From J. Maslanik, C. Fowler, Univ. Colorado. NASA MEaSUREs Project.
What will “ice-free” summers in the Arctic mean?

- “Ice-free” will not really be the case. Small floes and remnant ice remaining.
- Wildlife
- Native cultures

Photo by Mike Webber, U.S. Fish & Wildlife Service

Lower right photo by Craig George
What will “ice-free” summers in the Arctic mean?

- “Ice-free” will not really be the case. Small floes and remnant ice remaining.
- Northwest Passage navigable.
- In 1906 Roald Amundsen successfully navigated the Northwest passage in 3 years!
- 2007, the same feat was achieved in a 57-foot sailboat in about 6 weeks.
“Ice Free” Arctic: National Sovereignty Issues

- Territorial claims in the Arctic Ocean have not been formalized
- Issues of U.N. Law of the Sea Treaty
- Open coastlines need to be defended
- More people in Arctic waters means more risk – rescue operations

- Research to determine extensions of coastal shelf regions to claim additional territory
- Russia plants flag on ocean bottom at North Pole, Aug. 2007
- Canada establishes new military bases
Quick concept check:
Remote sensing application
Quick concept check..... Remote sensing application

Place each proposed study appropriately based on temporal versus spatial resolution necessary.
Quick concept check..... Remote sensing application

Determine area changes in forest/other land-cover classes between 1975 and 1989, Rio Grande do Sul, southern Brazil

Investigate the influence of Sea Surface Temperature on the path and strength of Hurricane Katrina, Gulf coast Aug 25-31, 2005

Detect the spatial extent and rate of coral bleaching occurring throughout Australia’s great coral reefs
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