Geography 403
Lecture 10
Weather and Climate Applications of Remote Sensing

Needs: Lect_403_10.ppt, satellite pass-arounds (images 5-12), GOES-E image viewer

Key Terms and Concepts
Macro- and Meso-scale Features that can be observed from Cloud Patterns
Atmospheric "Soundings"
Radiation Budget/Energy Balance
Radiatively Active Atmospheric Constituents
Investigating the Role of the Ocean in Climate
Investigations of the Cryosphere (Ice)
Meteorological Satellites

A. Introduction
1. Remote sensing probably is the most significant breakthrough for monitoring the Earth's weather and climate, ever!
2. Images can provide quick information around the world
    a. WMO has been one of the more effective U.N. organizations
3. Many uses still quite "primitive", just visual appraisals
4. Mostly analyzing movement of weather systems in the atmosphere rather than stationary classifications

B. Macroscale--primarily panchromatic visible and thermal IR, radar
PP1 (use satellite pass-arounds as examples)
PP2-5 1. Clouds--different types have a characteristic pattern and brightness temperature
    a. These are associated with level and composition
    b. Once cloud types are known, other elements can be inferred
2. Circulation patterns--gross movement of storm systems from geostationary orbits
3. Fronts, troughs, and ridges
PP6-13 a. Cold front--band of clouds
    b. Low pressure system—"comma" cloud
    c. Warm front--more difficult to locate
    d. Trough or ridge line, curved pattern or small "swirls"
PP14-20 4. Example--MLC of 11/12/93 (use GIFs and satellite TIR image to show relationships between weather variables and image, also look at other examples)
PP21 5. Jet stream--bands or streaks of cirrus clouds form a sharp break in the area of a jet stream ridge
    a. Wind direction, shear, turbulence, and temperature gradient can be determined
6. Low pressure system development
    a. Hourly data available to help quickly determine areas of formation--detection of fast developing situations

b. Internet applications for rapid viewing and analysis (view example sites, such as NWS-Sullivan)

7. Tropical cyclones (National Hurricane Center, https://www.nhc.noaa.gov/)

PP22-23 a. Detection and tracking--an early and important use

PP24 b. Cloud patterns have been studied for a long time, and classification based on surface data has led to the T-scale, which can be used to relate observed cloud patterns to expected max. wind speeds and central pressure

c. Danger can be minimized by tracking and early warnings

d. Direct measurement of wind speeds with modern radar

8. Winds and clouds

a. Winds can be determined from cloud motions in geostationary images, if level is known

b. TIR imagery--calibrated B-B temp. of cloud tops, plus knowledge of atmospheric temperature structure can allow calculation of cloud top height

c. Thunderstorm tracking--height of cloud top and size of anvil top relate to storm strength

d. Temperature-heights can also be used for simple cloud ID and interpretation

PP25 9. Atmospheric Sounding--determination of vertical temperature and moisture
PP26 profile--considerations for different TIR bands (Green Bay Example)

a. Available Energy--atmospheric window (transparency of atmosphere) is greatest at around 15 µm, falling off in both directions

b. Temperature sensitivity--depends on temperature of material, with shorter wavelengths more sensitive to warmer materials

c. Cloud transmission--low for 15 µm, improves with increasing wavelength

d. Can develop weighting functions for various wavelengths, (based on transparency of atmosphere and composition) so that energy (and therefore temperature) can be assigned to a particular level

e. Smaller the wavelength interval, the more precise the weighting function, but trade off is less band energy

f. Non-uniqueness problem--weighting functions may peak at one level, but have contributions from all (which must be minimized)

g. Same type of procedure can be used for moisture, in fact moisture is an “interference factor” in the temperature sounding

h. System operational on latest TIROS satellites

i. Comparisons good with radiosondes, but "trust" needed

j. Presents the rare problem of too much data, must chose locations to measure

10. Precipitation estimates

a. Geostationary satellites are used to estimate precipitation based on cloud area and stage of development with TIR images

b. Success with hurricane rainfall totals prediction

C. Mesoscale--high resolution recent data have made possible examinations of smaller size
PP27 features and processes (show loop from Lab exercise)

1. Fog and stratus distribution and dissipation

PP28 a. Can relate brightness of fog to thickness, and thereby estimate time to dissipation--difficult if not impossible from surface

2. Lake effect storms

PP29 a. Extent and development of winter snowfall in "snow belts"

b. Downwind effects can be clearly observed

3. Squall line and thunderstorm growth

a. Timeliness of severe weather detection

b. Precipitation and "hook echo" on PPI

c. Speed and direction of wind on modern Doppler systems

d. Passive R.S.--storms may emit very long wave energy, basis of “tornado detectors”

e. Sonics--may be able to "hear" hail formation 1 hour in advance

PP30 4. Differential heating--land-sea breezes and convection monitoring

PP31 5. Urban heat island studies-Fresno example

6. Mountain effects--"wave" clouds and effects on downwind areas

7. Air pollution monitoring by "haze" content

a. LANDSAT--make upward laser observation of aerosol content coincident with satellite measurement, try to develop a grayness-pollution index (many practical problems)

D. Radiation Budget--Energy Balance

PP32 1. Solar input--solar constant measurements from satellite (two best)--need to monitor and answer the question "Is the solar amount changing?" and assess implications for Earth's climate

2. Energy balance of the Earth as a whole

Net radiation = $(1 - \alpha)$ Solar - Long wave

a. Satellites can measure these values for the whole globe (Is the earth gaining or losing energy?)

b. Limitations due to changes in surface angle of reflection

c. Provides info for top of atmosphere, but can be integrated with surface instruments to estimate surface energy balance

PP33 d. Example product

E. Radiatively active atmospheric constituents

PP34-37 1. Monitoring of water vapor, CO_2 , ozone, and particulate which affect flow of radiation

2. Cloud heights and particulate levels can be monitored with lasers

3. Use radiative transfer equations, plus knowledge of absorption spectrums to estimate heights and amounts of various components

F. Investigating the Ocean’s role in Climate

PP38-40 1. Monitoring of sea-surface temperature, which has been shown to be involved with El Niño variability, and events like the cold winters of the late 1970s

2. Would like to know heat storage of oceans, but can't measure directly--can be related to SST over time
    a. Clouds can hinder measurements--use visible band to remove
    b. Too much “noise” may mask climatic signal
PP41 c. Differences between bathythermographs and remote sensed SST
3. Wind speed--radar observes scatter of 1 cm radar energy from
PP42 surface of the sea, which is a function of wind speed (related to waves on surface)
4. Rainfall over the Oceans (a great unknown!)
    a. Measure total water in atmosphere over oceans, and then make assumptions of rainfall rate
    b. Use a 19 Gigahertz (1.6 cm) radar sensor to measure rain size

G. Investigations of the Cryosphere (Ice)
PP43-44 1. A dynamic part of Earth-Ocean interface
2. May be a major factor in climate change
3. Measure sea, lake, and river ice in visible band for seasonal extent of ice cover and its variation
4. Measure mid-latitude snow cover and its yearly variation
    (See: http://www.nohrsc.noaa.gov/index.htm)
5. Ice cap measurements (Greenland) can give information on size and changes in shape that may be hard to get from surface
6. Measurements can be made of snow pack in the mountains (Colorado Rockies and California Sierra Nevada)
    a. Relates to runoff, flood damage, and potential drinking water supply

H. Investigations of the Hydrosphere
PP45 1. Soil moisture relations to runoff, floods, global climate modeling, heat balance, and desertification
2. Many possible uses of passive microwave because of its ability to detect different levels of soil moisture
3. Desertification, deforestation, and urbanization
    a. Mapping of changes to relate local dynamics to global energy balance

I. Meteorological Satellites
PP46 1. Polar orbiting and low earth orbit
    a. TIROS (Tel. & IR Obs. Sat.) 1st April 1960, found hurricane several days after launch
    b. ESSA (Late 60s-HRR)
    c. ITOS (early 70s-VHRR, first profiling experiments)
    d.TIROS-N NOAA (late 70s-AVHRR, operational temperature profilers, locate ship emergency beacons for search and rescue, ozone measurements, monitor earth energy budget)
    e. NIMBUS-used primarily for research of new systems

2. Geostationary satellites (see GOES-E Image viewer, https://www.star.nesdis.noaa.gov/GOES/GOES16_CONUS.php
    a. ATS-entire western hemisphere every 20 minutes in 1966, primarily experimental
    b. GOES-1974 to present, designed to have two-satellite coverage of U.S.
3. Future of GOES, NOAA, and LANDSAT
4. EOS system, MODIS (Terra and Aqua), ASTER