Lecture 3.

Fundamentals of aerosols and clouds. Part 2. Observations.

1. Means of observations.

2. Aerosol observational capabilities

3. Cloud observational capabilities.

4. Precipitation observational capabilities.

Required reading:

Chapter 5 in *Aerosol Pollution Impact on Precipitation: A Scientific Review*.
WMO/IUGG INTERNATIONAL AEROSOL PRECIPITATION SCIENCE ASSESSMENT GROUP (IAPSAG) REPORT.

Chapter 2. Remote Sensing and *In Situ* Measurements of Aerosol Properties, Burdens, and Radiative Forcing *in* Atmospheric Aerosol Properties and Climate Impacts, U.S. Climate Change Science Program Synthesis and Assessment Product 2.3, 2009.

1. Means of observations:

- ✓ Laboratory measurements (especially, aerosols and clouds)
- ✓ Ground-based observations (long-term monitoring or short-duration measurements)
- ✓ Field campaigns (often include combination of ground-based, ship-based, air-borne and space-borne observations)
- ✓ Space-borne observations (individual satellite sensor or synergy of multi-satellite, multi-sensor data)

Each type of observations has strengths and specific limitations

Differences in space/time coverage

2. Aerosol observational capabilities.

Laboratory measurements:

aerosol formation and evolution processes

Ground-based monitoring:

longest records from visibility measurements conducted at meteorological stations

Ground-based networks:

air quality sites (PM10, PM2.5)

sites with in-situ and/or remote sensing instrumentation

*Example*s:

NOAA Global Monitoring Division - GMD sites

NASA Aerosol Robotic network - AERONET

Ground-based lidar networks

Field campaigns: targeted at selected regions of interest

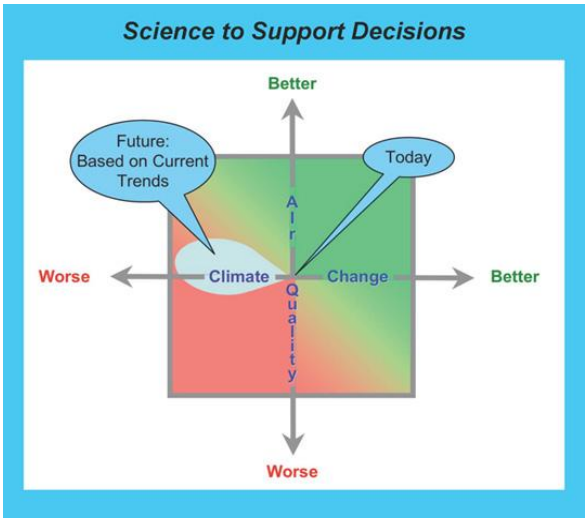
short-duration (~ few weeks)

Examples:

Carbonaceous Aerosols and Radiative Effects Study (CARES) (2010, California)

http://campaign.arm.gov/cares/

CalNex2010- Research at the Nexus of Air Quality and Climate Change
http://www.esrl.noaa.gov/csd/calnex/



CalNex White Paper - http://www.esrl.noaa.gov/csd/calnex/whitepaper.pdf

Satellites:

common products – aerosol optical depth, aerosol index, fine/coarse mode, and type

Satellite instrument	Time Period	AOD	Size or Shape[1]	Absorption[2]	Vertical Profile	Global Coverage
Historic / Current						
AVHRR	Since 1981	√	√			Ocean only
TOMS	1979-2001	√		√		√
POLDER	Since 1997	√	√			√
MODIS	Since 2000	√	√			√
MISR	Since 2000	√	√	√		√
OMI	Since 2004	√		√		√
GLAS	Since 2003[3]		√		√	
CALIOP	Since 2006		√		√	
Scheduled to Launch						
VIIRS (on NPP/NPOESS)	2009-	√				√
OMPS (on NPP)	2009-	√		√		√
APS (on Glory)	2009-	√	√	√		
HSRL (on EarthCARE)	2013-				√	

Table 3.1 Summary of satellite aerosol measurements

3. Cloud observational capabilities.

Laboratory measurements:

Ice and water drop formation and evolution processes

Ground-based observations (monitoring) of clouds: type and fraction

Cloud classification is based on the form and height of clouds.

- ✓ Clouds are classified into a system that uses Latin words to describe the appearance of clouds as seen by **an observer on the ground**. The four principal components of this classification system are cumulus (means heap or pile), stratus (layer), cirrus (means a lock of hair) and nimbus (rain). These four words and a word *altum* (means height) are used either separately or in combination to define 10 clouds types, which are organized into three corresponding to the base of clouds above the local height (see Table 2.1, Lecture 2)

Type	Height	Height of cloud base			Precipitation
		Polar regions	Temperate regions	Tropical regions	
Cumulus Cumulonimbus Stratus	Low	Below 2km	Below 2km	Below 2km	Light showers are possible Always reported when showers /thunderstorms/hail occurs Near costs/hills
Nimbostratus Altostratus Altocumulus	Middle	2-4 km	2-7 km	2-8 km	Normally continuous Often continuous Occasionally
Cirrus Cirrostratus Cirrocumulus	High	3-8 km	5-13 km	6-18 km	No

Ground-based networks:

In situ measurements and remote sensing

Examples:

ARM sites http://www.arm.gov/sites

Field campaigns:

Rain in Cumulus over the Ocean (RICO) http://www.eol.ucar.edu/projects/rico/

VAMOS Ocean-Cloud-Atmosphere-Land Study (VOCALS)

http://www.eol.ucar.edu/projects/vocals/

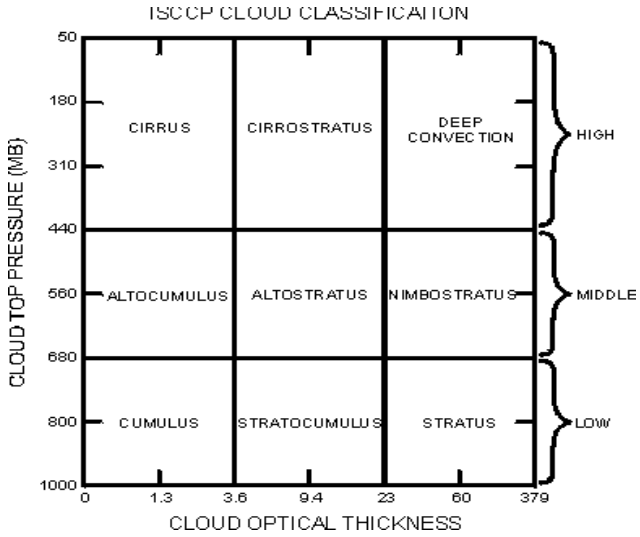
Space-based observations (satellites):

Common satellite cloud products: coverage, cloud top, cloud drop effective radius, LWC, cloud optical depth, cloud thermodynamical phase, and layering.

Cloud classification used in satellite remote sensing is based on retrieved cloud top pressure and cloud optical depth.

Example: The International Satellite Cloud Climatology Project (ISCCP)

http://isccp.giss.nasa.gov/



For details seehttp://isccp.giss.nasa.gov/climanal7.html

Satellite vs. ground-based observations of clouds

Type of observation	Advantages	Disadvantages
Ground-based	• direct observations • history (long records) • can often distinguish between cloud types • other complimentary measurements • cost/automatic/frequent observations • provide validation to satellite observations	• non-uniform coverage • human error • multi-layer cloud impacts
Satellite	• global coverage • system consistency • easier to model (radiative transfer codes) • sensitive to vertical structure with potential for vertical resolution	• short lifetime of an individual satellite • difficulty of inter-calibrating instruments on different satellites • problems in distinguishing multi-layered clouds, lower clouds and fog • high cost

4. Precipitation observation capabilities.

- ✓ Ground-based: rain gauges and snow gauges (snow is measured as water equivalent). An extensive network of meteorological stations with long-term records.
- ✓ Ground-based: radar (relates radar backscattering to rain drop size distributions)
- ✓ Satellites:

  Examples: TRMM – Tropical Rainfall Measuring System (sampling footprint between 35°N and 35°S) http://trmm.gsfc.nasa.gov/

  CloudSat http://cloudsat.atmos.colostate.edu/

  Global Precipitation Climatology Project (GPCP) product - based on the synergy of multi-satellite, multi-sensor data