Lecture 3.

Observations of aerosol and clouds

1. Means of observations.
2. Aerosol observational capabilities
3. Cloud observational capabilities.

Required reading**:** Chs. 3 and 4 from Heintzenberg&Charlson (2009)

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
- ✓ 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, etc.

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

*Exampl*es:

NOAA Global Monitoring Division - GMD sites

NASA Aerosol Robotic network - AERONET

Ground-based lidar networks

Field campaigns: targeted at selected regions of interest

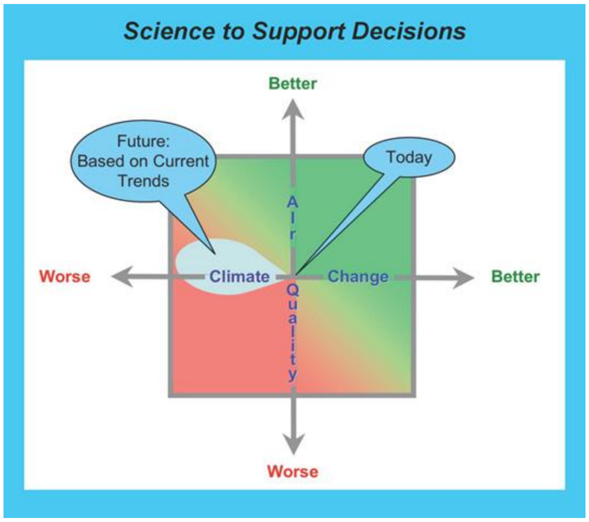
short-duration (~ few weeks)

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

<u>Satellites:</u> Common satellite-retrieved products: aerosol optical depth, aerosol index, fine/coarse mode, and type.

Table 3.1 Summary of satellite aerosol measurements (From Ch2. Of U.S. Climate Change Science Report)

Category	Properties	Sensor/platform	Parameters	Spatial coverage	Temporal coverage
Column-integrated	Loading	AVHRR/NOAA-series	optical depth	~daily coverage of global ocean	1981-present
		TOMS/Nimbus, ADEOS1, EP		~daily coverage of global land and ocean	1979-2001
		POLDER-1, -2, PARASOL			1997-present
		MODIS/Terra, Aqua			2000-present (Terra) 2002-present (Aqua)
		MISR/Terra		~weekly coverage of global land and ocean, including bright desert and nadir sun-glint	2000-present
		OMI/Aura		~daily coverage of global land and ocean	2005-present
	Size, shape	AVHRR/NOAA-series	Ångström exponent	global ocean	1981-present
		POLDER-1, -2, PARASOL	fine-mode fraction, Ångström exponent, non-spherical fraction	global land+ocean	1997-present
		MODIS/Terra, Aqua	fine-mode fraction	global land+ocean (better quality over ocean)	2000-present (Terra) 2002-present (Aqua)
			Ångström exponent		
			effective radius	global ocean	
			asymmetry factor		
		MISR/Terra	Ångström exponent, small, medium, large fractions, non-spherical fraction	global land+ocean	2000-present
	Absorption	TOMS/Nimbus, ADEOS1, EP	absorbing aerosol index, single-scattering albedo, absorbing optical depth	global land+ocean	1979-2001
		OMI/Aura			2005-present
		MISR/Terra	single-scattering albedo (2-4 bins)		2000-present
Vertical-resolved	Loading, size, and shape	GLAS/ICESat	extinction/backscatter	global land+ocean, 16-day repeating cycle, single-nadir measurement	2003-present (~3months/year)
		CALIOP/CALIPSO	extinction/backscatter, color ratio, depolarization ratio		2006-present

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 Lecture 2)

Type	Height	Height of cloud base Polar regions	 Temperate regions	 Tropical regions	Precipitation
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/

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