Lecture 15.

Course Review: remote sensing science, applications, and techniques for studying the atmosphere and oceans

Clouds:

Cloud amount/coverage (cloud mask)

Visible+ IR => Lecture 10-11 and Lab 8

Principles: *based on a combination of thresholds for solar reflectivity and brightness temperature (in the IR)*

Active (CALIPSO, CloudSat) => Lab 10

Cloud liquid water content (column integrated)

Microwave => Lecture 8 and Lab 6

Cloud type

ISCCP classification => Lecture 10

Cloud particle size distribution and optical depth

MODIS retrieval technique => Lecture 10 and Lab 8

Cloud thermodynamic phase

MODIS retrieval technique => Lecture 10

Cloud–top pressure

O_2 absorption technique" and "CO_2 slicing technique = > (see textbook)

Cloud height and cloud detection

Lidars/Radars => Lectures 12-13 and Lab 10

Aerosols:

Aerosol optical depth/particle size distribution/Angstrom exponent

Sunphotometers (AERONET) => Lecture 4 and Lab 3

Principles: *based on measurements of direct solar radiation that permit to retrieve the aerosol optical depth*

Visible-near IR satellite remote sensing (MODIS, MISR, AVHRR, SeaWiFS) => Lecture 6 and Lab 5

Principles: *based on measurements of reflected solar radiation and look-up tables for pre-defined aerosol models (size distribution and refractive index)*

Vertical profile of backscattering and optical depth (lidars) =>

Lecture 13 and Lab 10

Ozone and trace gases (NO_2, SO_2, BrO, OClO):

Ozone profile

Sounding => Lecture 9

Other gases => see Table below

Table 15.1 Summary (incomplete) of satellite instruments, coverage of their measurements, **gases** measured and the satellite platform. The list is not intended to be complete, but merely to illustrate the currently available instrumentation.

Name	Target Species	Satellite Platform	Orbit
ATMOS, Atmospheric Trace Molecule Spectroscopy	O_3, NO_x, N_2O_5 ClO NO_2, HCl, HF, CH_4, CFCs, *etc.* (upper troposphere)	Space Shuttle Spacelab-3 (1985), ATLAS-1,2 and 3 (1992,1993, 1994)	inclined
BUV, Backscatter Ultraviolet Ozone Experiment	O_3 (profiles)	Nimbus-4 (1970-1974)	Polar
GOME, Global Ozone Monitoring Experiment	O_3, NO_2, H_2O BrO, OClO, SO_2, HCHO, clouds, aerosol	ESA-ERS-2 (1995-present), METOP-1 - METOP-3 (2005/6 2010/11, 2015/16)	Polar, Sun Sync.
GOMOS, Global Ozone Monitoring by Occultation of Stars	O_3, NO_2, upper troposphere	ESA ENVISAT (2001 -)	Polar, Sun Sync.
IASI, Imaging Atmospheric Sounding Instrument	O_3, CO, CH_4, N_2O, SO_2	METOP-1 (2005/6)	Polar, Sun Sync.
IMG, Interferometric Monitor for Greenhouse Gases	O_3, N_2O, H_2O, CH_4, CO and CO_2	ADEOS (1996-97), ADEOS-II (2001)	Polar, Sun Sync.
MERIS, Medium Resolution Imaging Spectrometer for Passive Atmospheric Sounding	H_2O, clouds and aerosol	ESA-ENVISAT (2000)	Polar, Sun Sync.
MIPAS, Michelson Inferometer for Passive Atmospheric Sounding	O_3, NO_x, N_2O_5 $ClONO_2$, CH_4, CFCs, *etc.*; temperature (upper troposphere)	ESA ENVISAT (2000)	Polar, Sun Sync.
MOPITT, Measurement of Pollution in the Troposphere	Total column of CO; CH_4 + CO profiles	NASA AM-1 (1999)	
ODUS, Ozone Dynamics Ultraviolet Spectrometer	SO_2, NO_2, BrO, OClO	GCOM-A1 Prog, Japan (2005)	inclined
OMI, Ozone Monitoring Instrument	O_3, SO_2, NO_2,	NASA-EOS-CHEM (2004)	Polar, Sun Sync.
SAGE I-II Stratospheric Aerosol and Gas Experiment	O_3, NO_2, (H2O), aerosols (upper troposphere)	NASA- Atmospheric Explorer Mission (1979-81), Earth Radiation Budget Sat. (1984 - pres.)	inclined
SAGE III, Stratospheric Aerosol and Gas Experiment III	O_3, OClO, BrO, NO_2, NO_3 aerosols	Meteor 3M (2001); International Space Station (2003?)	inclined
SBUV, Solar Backscatter Ultraviolet Ozone Experiment	O_3 profiles	Nimbus-7 (1979-90)	polar

SCIAMACHY, Scanning Imaging Absorption Spectrometer for Atmospheric Cartography	O_2, O_3, O_4, NO, NO_2, N_2O, BrO, OClO H_2CO, H_2O, SO_2, HCHO, CO, CO_2, CH_4, clouds, aerosols, p, T, col. and profiles	ESA-ENVISAT (2001)	Polar, Sun Sync.
TES, Tropospheric Emission Spectrometer	Various incl. HNO_3, O_3, NO, H_2O (col. and profiles)	NASA-EOS-CHEM (2004)	
TOMS, Total Ozone Monitoring Spectrometer	O_3	Nimbus 7 (1979-92) ADEOS (1996-97) Earth Probe (1996-) Meteor (1992-94)	polar
OMI, Ozone Monitoring Instrument	O_3, NO_2, SO_2, BrO, OClO	Aura (July 2004-present)	polar

Gases profile:
Lidars => Lecture 13

<u>Water vapor</u>:
Integrated column (total precipitable water) from microwave => Lecture 8 and Lab 6
Profile from IR sounding => Lecture 9
Profile from microwave sounding => Lecture 9
Profile from Raman lidar, DIAL => Lecture 12

<u>Precipitation</u>

Visible/IR techniques => Lecture 10-11
<u>Principles</u>: indirect method that relates properties of clouds to precipitation

Microwave techniques => Lecture 10-11
<u>Principles</u>: direct method that relates the optical depth associated with the emitting rain drops and brightness temperature measured by a passive microwave radiometer.

Radar => Lecture 12 and Lab 9
<u>Principles</u>: measured backscattering from rain drops is related to the Z factor (size distribution) and then to precipitation via Z-R relationship

<u>Atmospheric temperature (profile)</u>

IR (or microwave) sounding techniques => Lecture 9 and Lab 7
<u>Principles</u>: multi-spectral remote sensing in the 15 μm CO2 absorbing band (in microwave in the O2 absorbing region)

<u>Sea Surface Temperature</u>

IR split-window technique => Lecture 9
Microwave techniques => Lecture 9

Ocean color mapping

Solar remote sensing (MODIS, SeaWiFS) = > Lecture 5

Sea ice

Passive microwave = > Lecture 2 and Lab 1
Active microwave (radars) => (see textbook)