Lecture 17.

Course Summary: remote sensing applications, principles and techniques for studying the atmosphere and oceans

Clouds:

Cloud amount/coverage (cloud mask)

Visible+ IR => Lecture 13 and Lab 5

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

Active (CALIPSO, CloudSat) => Lab 11

Cloud liquid water content (column integrated)

Microwave => Lecture 11 and Lab 7

Cloud type

ISCCP classification => Lecture 13

Cloud particle size distribution and optical depth

MODIS retrieval technique => Lecture 13 and Lab 9

CloudSat => Lab 11

Cloud thermodynamic phase

MODIS retrieval technique => Lecture 13

Cloud–top pressure

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

Cloud height and cloud detection

Lidars/Radars => Lectures 14-15 and Lab 11

Aerosols:

Aerosol detection

TOMS/OMI Aerosol Index (UV remote sensing) => Lecture 10

Aerosol optical depth/ particle size distribution/Angstrom exponent

Sunphotometers (AERONET) => Lecture 6 and Labs 3, 6

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 8 and Lab 6

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 15

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

Ozone amount

UV downlooking spectrometer (TOMS) => Lecture 10

Differential Optical Absorption Spectroscopy (DOAS) => Lecture 10

Dobson's method = >Lecture 10

Ozone profile

Sounding => Lectures 10 and 12

Other gases => see Table 17.1 below and Lecture 4, Table 4.6

Table 17.1 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 [modified from Burrows 2000]

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	O_3, OClO, BrO, NO_2, NO_3	Meteor 3M (2001);	inclined

and Gas Experiment III	aerosols	International Space Station (2003?)	
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

Water vapor*:*

Integrated column (total precipitable water) from microwave => Lecture 11 and Lab 7

Profile from IR sounding => Lecture 12

Profile from microwave sounding => Lecture 12

Profile from Raman lidar, DIAL => Lecture 15

Precipitation

Visible/IR techniques => Lecture 13

Principles: indirect method that relates properties of clouds to precipitation

Microwave techniques => Lecture 13

Principles: direct method that relates the optical depth associated with the emitting rain drops and brightness temperature measured by a passive microwave radiometer.

Radar => Lecture 14 and Lab 10

Principles: measured backscattering from rain drops is related to the Z factor (size distribution) and then to precipitation via Z-R relationship

Sea Surface Temperature

IR split-window technique => Lecture 12 and Lab 8

Microwave techniques => Lecture 12 and Lab 8

Atmospheric temperature (profile)

IR (or microwave) sounding techniques => Lecture 12 and Lab 8

Principles: multi-spectral remote sensing in the 15 μm CO2 absorbing band (in microwave in the O2 absorbing region)

Ocean color mapping

Solar remote sensing (MODIS, SeaWiFS) = > Lecture 7 and Lab 5

Sea ice

Passive microwave = > Lecture 3 and Lab 1

Active microwave => (see textbook)