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 (NO₂, SO₂, BrO, OCIO):**

*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.

<table>
<thead>
<tr>
<th>Name</th>
<th>Target Species</th>
<th>Satellite Platform</th>
<th>Orbit</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATMOS, Atmospheric Trace Molecule Spectroscopy</td>
<td>O₃, NOₓ, N₂O₅, ClO NO₃, HCl, HF, CH₄, CFCs, etc. (upper troposphere)</td>
<td>Space Shuttle Spacelab-3 (1985), ATLAS-1,2 and 3 (1992,1993, 1994)</td>
<td>inclined</td>
</tr>
<tr>
<td>GOMOS, Global Ozone Monitoring by Occultation of Stars</td>
<td>O₃, NO₂, upper troposphere</td>
<td>ESA ENVISAT (2001 -)</td>
<td>Polar, Sun Sync.</td>
</tr>
<tr>
<td>MIPAS, Michelson Inferometer for Passive Atmospheric Sounding</td>
<td>O₃, NOₓ, N₂O₅, ClONO₂, CH₄, CFCs, etc.; temperature (upper troposphere)</td>
<td>ESA ENVISAT (2000)</td>
<td>Polar, Sun Sync.</td>
</tr>
<tr>
<td>MOPITT, Measurement of Pollution in the Troposphere</td>
<td>Total column of CO; CH₄ + CO profiles</td>
<td>NASA AM-1 (1999)</td>
<td></td>
</tr>
<tr>
<td>Oacus, Ozone Dynamics Ultraviolet Spectrometer</td>
<td>SO₂, NO₂, BrO, OCIO</td>
<td>GCOM-A1 Prog, Japan (2005)</td>
<td>inclined</td>
</tr>
<tr>
<td>SAGE III, Stratospheric Aerosol and Gas Experiment III</td>
<td>O₃, OCIO, BrO, NO₂, NO₃ aerosols</td>
<td>Meteor 3M (2001); International Space Station (2003?)</td>
<td>inclined</td>
</tr>
<tr>
<td>SBUV, Solar Backscatter Ultraviolet Ozone Experiment</td>
<td>O₃ profiles</td>
<td>Nimbus-7 (1979-90)</td>
<td>Polar</td>
</tr>
<tr>
<td>Instrument</td>
<td>Species</td>
<td>Source</td>
<td>Equator, polar, Sun Sync.</td>
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<tr>
<td><strong>SCIAMACHY</strong>, Scanning Imaging</td>
<td>O₂, O₃, O₄, NO, NO₂, N₂O, BrO, OCIO, H₂CO, H₂O, SO₂, HCHO, CO, CO₂, CH₄, clouds, aerosols, p, T, col. and profiles</td>
<td>ESA-ENVISAT (2001)</td>
<td></td>
</tr>
<tr>
<td><strong>OMI</strong>, Ozone Monitoring</td>
<td>O₃, NO₂, SO₂, BrO, OCIO</td>
<td>Aura (July 2004-present)</td>
<td>polar</td>
</tr>
</tbody>
</table>

**Gases profile:**
Lidars => Lecture 13

**Water vapor:**
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

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

Microwave techniques => Lecture 10-11
*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 12 and Lab 9
*Principles: measured backscattering from rain drops is related to the Z factor (size distribution) and then to precipitation via Z-R relationship*

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

**Sea Surface Temperature**
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)