Condensation

- Dew and frost
- Fog
- Clouds

Condensation Nuclei

- Dew condenses on vegetation and other objects close to the ground
- In the atmosphere, water condenses on condensation nuclei [p 127/133/109]
  - typically 1 per mm$^3$
  - nuclei > 0.1 μm are good for forming clouds
  - main source of nuclei is near ground; greatest concentration in lower atmosphere, near cities
  - nuclei stay airborne for days
  - large nuclei 0.2 to 1 μm [table 6.1]
  - oily and waxy nuclei are hydrophobic

Size of Nuclei & Drops (after table 6.1/5.1)

<table>
<thead>
<tr>
<th>Type of particle</th>
<th>Approx. radius (μm)</th>
<th>No. of particles cm$^{-3}$ (range)</th>
<th>Typical no. of particles cm$^{-3}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small (Aitken) condensation nuclei</td>
<td>&lt;0.2</td>
<td>1000 → 10,000</td>
<td>1000</td>
</tr>
<tr>
<td>Large condensation nuclei</td>
<td>0.2 → 1.0</td>
<td>1 → 1000</td>
<td>100</td>
</tr>
<tr>
<td>Giant condensation nuclei</td>
<td>&gt;1.0</td>
<td>&lt;1 → 10</td>
<td>1</td>
</tr>
<tr>
<td>Fog &amp; cloud droplets</td>
<td>&gt;10</td>
<td>10 → 1000</td>
<td>300</td>
</tr>
</tbody>
</table>

Radiation & Valley Fog

- Ground fog
  - cooling below dew point of air in contact with ground by radiation, often on still, clear nights
- Valley fog:
  - cooler air has drained downhill into the valley and then condensation has taken place

Forming Fog

- Fog forms on condensation nuclei
- Fog is made more likely by evaporation from ground water
- Fog droplets greater than 25 μm in diameter fall faster than 50 mm s$^{-1}$ in still air
Advection Fog

- This is formed by moist air being blown over a cool surface (such as cool water) which cools the air to dew point [p 131/134/112]
  - Advection fog is often blown inland from the sea during the summer months
  - In hotter climates it provides essential moisture for coastal plant and animal life
- Headland fog is encouraged by the cooling of rising air coming over the headland from the sea [p 131/137/114]

Clouds

- International names and symbols for clouds, based on appearance and height [Luke Howard, 1802]
  - High clouds: Cirrus (Ci), Cirrostratus (Cs), Cirrocumulus (Cc)
  - Middle clouds: Altostratus (As), Altocumulus (Ac)
  - Low clouds: Stratus (St), Stratocumulus (Sc), Nimbostratus (Ns)
  - Vertically developed: Cumulus (Cu), Cumulonimbus (Cb)
- Some of the following illustrations are the historic B&W pictures by our local George Aubourne Clark

Cloud Types

- Above 5000 m in our latitudes
- Thin, detached, "mares' tails", white, ice-crystal clouds, fair weather; may have hooked ends

Cirrus (Ci)

- Small globular masses showing convection cells sometimes rippling lines

Cirrocumulus (Cc)
Cirrostratus (Cs)
- thin veil of high cloud, often presaging worsening weather; sun visible through it

Altostratus (As)
- grey sheet of cloud, at least 2 km high, with well defined base; sun weakly visible through it; typically occurs before rainy weather

Altocumulus (Ac)
- lower, thicker and often more extensive than Cc; water droplet clouds; "sheep's fleeces" [p. 144/120]

Stratus (St)
- low layer of dark grey cloud

Nimbostratus (Ns)
- low rain clouds, poor visibility beneath; GAC's picture shows fractus or broken cloud

Cumulus (Cu)
- cloud formed in upwelling convection currents; like floating cotton wool; variety of forms; fair weather cumulus humilis
19 Mid-day cumulus (Cu)

- Build-up of cumulus over the Argyllshire coast, seen from the Sound of Mull

Photo: JSR

20 Cumulus (Cu), from the air

Photo: JSR

21 Cumulonimbus (Cb)

- A giant cumulus cloud with its top often reaching the tropopause and flattening; bringer of rain showers and thunderstorms

Photo: JSR

22 Cumulonimbus (Cb) at hand

- See notes for the accompanying story

Photo: JSR

23 Other Clouds

- In the textbook you will find pictures of lenticular clouds, banner clouds, mammatus clouds, nacreous clouds, noctilucent clouds and other forms

Photo: JSR

24 Digression on Luke Howard

- Howard (1772 – 1864) was an amateur meteorologist with a lifelong interest in clouds
- Published his cloud naming scheme in 1803
  - widely considered appropriate and formed the basis of international cloud names established in 1896
  - use of Latin names aided international acceptance
  - some historical pictures follow
Luke Howard's drawings

Cirrus & Cumulus

Cirro-cumulus & Stratus

Scene from Howard

Strato-cumulus

Nimbus

Composite illustration

Cirrus, Cirro-cumulus and Nimbus

Cirro-stratus, Cumulus and Strato-cumulus

From Beauties of the Heavens ~1840
Vortex clouds seen by Landsat

Area 170 × 170 km

Near the Cloud Base

The Cobbler →
Loch Lomond ↓

What Kind of Clouds?

Hongkong →
Lake District ↓

Dawn cumulus over the winter sea at Findon →
Summer cumulus over Coll
Sky Conditions

Satellite Observations

Geostationary Satellites

Geostationary met coverage
Polar Orbiting Satellites

- Look almost straight down at any point on Earth
  - successive images are displaced
  - visible images see the tops of clouds (in daytime)
  - IR images coded white from cold, high cloud; gray from lower cloud
  - NOAA series most often illustrated (images from Dundee University)
- multi-spectral example:

Polar Satellite Orbits

- Typical scan area received by Dundee centre
- Orbit inclined at ~98.8° to equator
- NOAA ‘weather’ satellites orbit about 800 - 900 km above the Earth
- Period is ~102 minutes, giving ~14.11 revolutions per 24 hours
- Orbital plane slowly rotates during the year to keep it synchronous with the Sun

Visible light image

- Scotland during exam preparation time
  - ~ midday
  - 05/05/2008

Satellite Images - 1

- Hurricane Hugo

Satellite Images - 2

- Visible and water vapour (rhs) images from Modis
- IR images of clouds are grey-scale coded for temperature, with white being coldest and dark-grey warmest
**Satellite Images - 3**
- Enhanced image from geostationary satellite

**Satellite Images - 4**
Composite Mollwiede projection

**Satellite Images - 5**
Composite with colour-coded temperatures

**Satellite Images - 6**
Antarctica, composite image

**Satellite Images - 7**
Snow over Scotland and higher ground to the south

Courtesy: DSRS 03-Dec-2008
Satellite Images - 8
UK covered in snow, Jan 7th 2010
Courtesy DSRS

Satellite Images - 9
25th Jan 1998 from Belgian Met Office

Satellite Images - 10
Sea surface temperatures:
http://www.npm.ac.uk/rsg/projects/mceis/zx/7days/AVHRR/sstp/1205107200
Chlorophyll concentrations:
http://www.npm.ac.uk/rsg/projects/mceis/zx/7days/MODIS

Satellite Images - 11
Average North Sea temperatures in June from NOAA data 90 - 93