Condensation

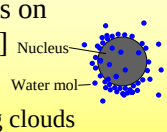
- Dew and frost

- 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)

Type of particle	Approx radius (μm)	No. of particles cm^{-3} (range)	Typical no. of particles cm^{-3}
Small (Aitken) condensation nuclei	<0.2	1000 → 10,000	1000
Large condensation nuclei	0.2 → 1.0	1 → 1000	100
Giant condensation nuclei	>1.0	<1 → 10	1
Fog & cloud droplets	>10	10 → 1000	300

Staying up all Night

- Tiny particles can stay afloat for days
  - air resistance to falling increases with the speed of fall
  - for tiny particles, air resistance equals their weight at very small speeds
    - they then stop accelerating toward the ground
- Weight ∝ $size^3$, air resistance ∝ $size^2$
  - reduce size to 1/10th, resistance/weight increases by 10

$$\frac{\text{air resistance}}{\text{weight}} \propto \frac{1}{\text{size}}$$

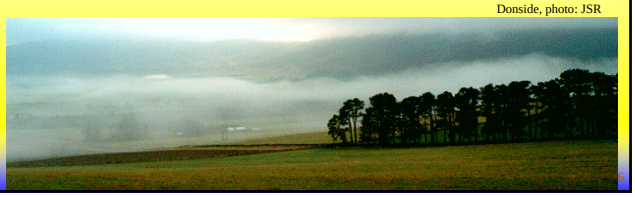
Radiation & Valley Fog

- 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

Donside, photo: JSR



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

Courtesy: http://www.md5summer.org/Postcards/images/Postcard39.jpg

- **Headland fog** is encouraged by the cooling of rising air coming over the headland from the sea [p 131/137/114]

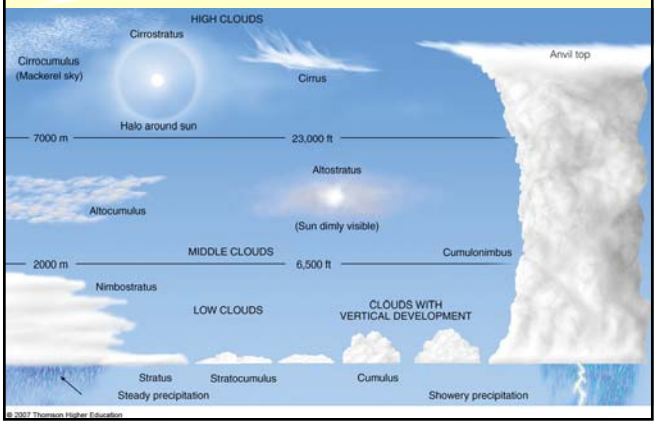
Clouds

See fig. 6.20/5.23, next slide

International **names** and **symbols** for clouds, based on *appearance* and *height* [*Luke Howard*, 1802]

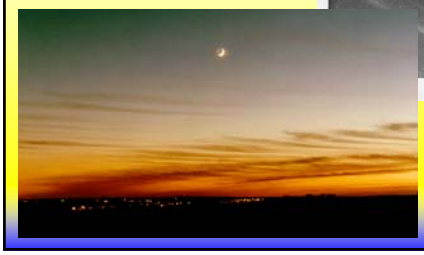
- High clouds: **Cirrus** (**Ci**); **Cirrostratus** (**Cs**); **Cirrocumulus** (**Cc**)
- Middle clouds: **Altostratus** (**As**); **Altocumulus** (**Ac**)
- Low clouds: **Stratus** (**St**); **Stratocumulus** (**Sc**); **Nimbostratus** (**Ns**)
- Vertically developed: **Cumulus** (**Cu**); **Cumulonimbus** (**Cb**)
- Some of the following illustrations are the historic B&W pictures by our local George Aubourne Clark

Cloud Types



Cirrus (Ci)

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



← Findon

Photo: JSR

Cirrus (Ci)

Photo: JSR

Salen ↑

Tennerife →

Photo: JSR

Cirrocumulus (Cc)

- small globular masses showing convection cells sometimes rippling lines

Photo: JSR

↑ Findon

Photo: JSR

Cirrostratus (Cs)

- thin veil of high cloud, often presaging worsening weather; sun visible through it

↑ Findon

Photo: JSR

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

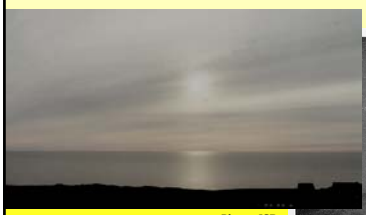
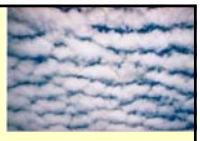


Photo: JSR

↑ Findon

Altocumulus (Ac)



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

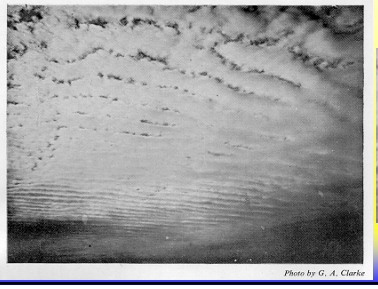


Photo: JSR

Stratus (St)

- low layer of dark grey cloud

Photo: JSR

↑ Mull

← Findon

Photo: JSR

Nimbostratus (Ns)

- low rain clouds, poor visibility beneath; GAC's picture shows *fractus* or broken cloud

↓ Findon

Photo: JSR

Cumulus (Cu)

- cloud formed in upwelling convection currents; like floating cotton wool; variety of forms; fair weather *cumulus humilis*

← Cevennes

Photo: AJR

↓ Findon

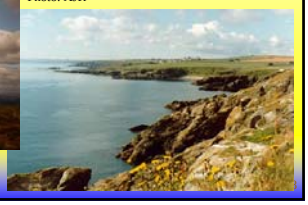


Photo: JSR

Mid-day cumulus (Cu)

Photo: JSR

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

Cumulus (Cu), from the air

Photo: JSR

Photo: JSR

Cumulonimbus (Cb)

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

Cumulonimbus (Cb) at hand

- See notes for the accompanying story

← Off the port bow

Photos: JSR

Astern ↓

Other Clouds

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

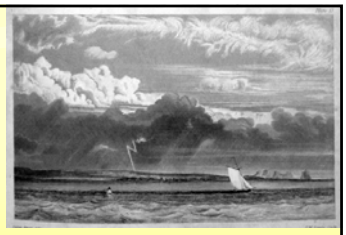
Photo: JSR

Contrail clouds Arisaig ↑

← Nacreous clouds Findon

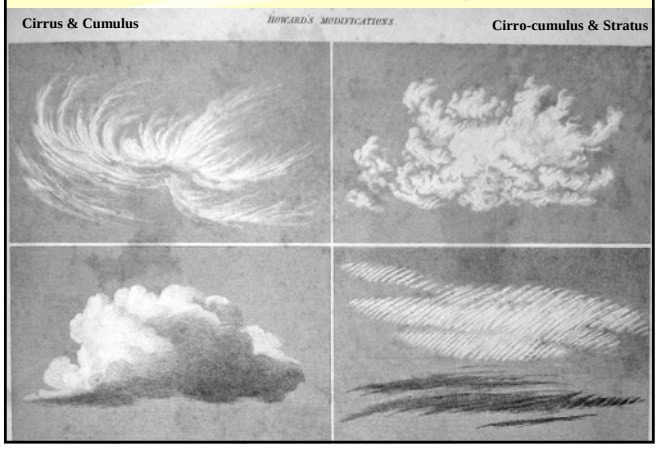
Photo: JSR

Digression on Luke Howard

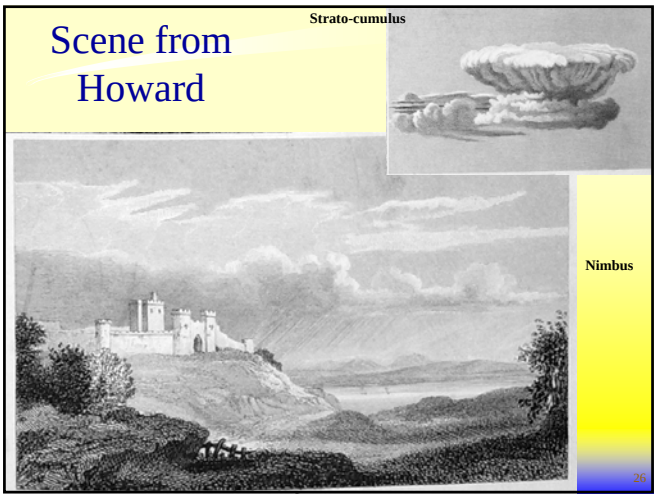


- Howard (1772 – 1864) was an amateur meteorologist with a lifelong interest in clouds
- Published his cloud naming scheme in 1803
  - widely considered appropriate and formed the basis of international cloud names established in 1896
  - use of Latin names aided international acceptance
  - some historical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

Luke Howard's drawings



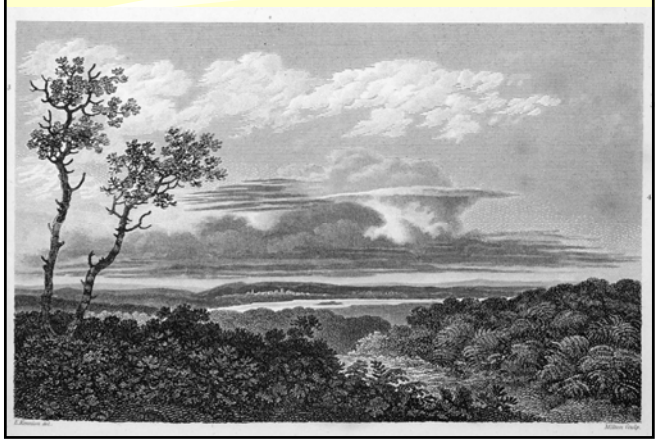
Scene from Howard



Composite illustration

Cirrus, Cirro-cumulus and Nimbus

Cirro-stratus, Cumulus and Strato-cumulus



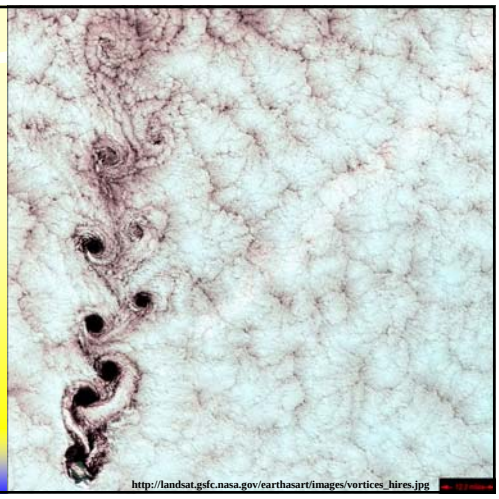
From Beauties of the Heavens ~1840

From Beauties of the Heavens ~1840

From Beauties of the Heavens ~1840

Vortex clouds seen by Landsat

- Off Alexander Selkirk Island, South Pacific
  - Area 170 × 170 km



Near the Cloud Base

The Cobbler →

Loch Lomond ↓

Photos: MER

What Kind of Clouds?

Hongkong →

Lake District ↓

Photos: MER

Photo: JSR

← Summer cumulus over Coll

Dawn cumulus over the winter sea at Findon →

Photo: JSR

Nimbus at Findon →

Photo: JSR

Winter nimbostratus at Findon ↓

Photo: JSR

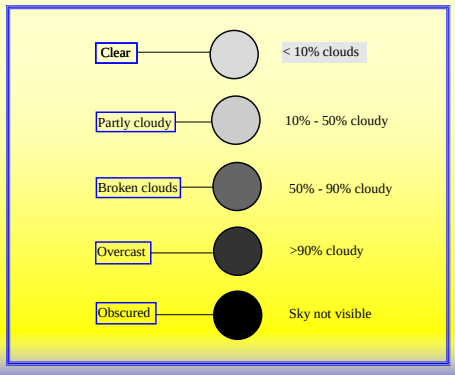
Stratocumulus and front ↑ near Ardnamurchan point

Photo: JSR

Cumulus in Michigan

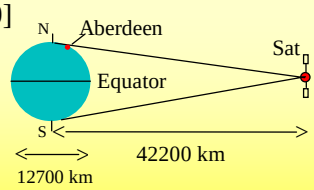
Photo: JSR

Sky Conditions



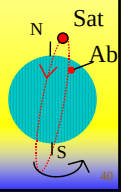
Satellite Observations

- **Geostationary satellites** orbit above the equator [p 151/156/130]
  - view of Aberdeen is very oblique (~74° to vertical)
  - minimum of 3 sats to cover most of globe



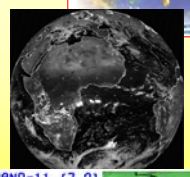
- **Polar orbiting satellites** have orbits fixed in space; the Earth revolves beneath
  - orbits don't go exactly over poles

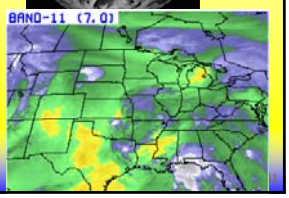
Polar orbiting



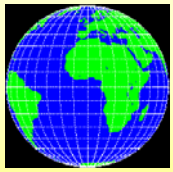
Geostationary Satellites

- Fixed view of Earth
  - each frame ~5000×5000 *pixels*
  - successive frames make a time-lapse film
  - images in visible light, and several IR bands to pick up H_2O (7 μm band), CO_2 and the H_2O window in the (10.5 - 12.5 μm band)
  - GOES series (US) [p 151/157/131] GOES 8 images here:- METEOSAT (Europe)

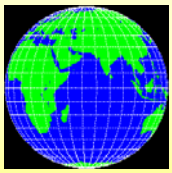




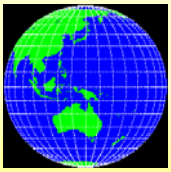
Geostationary met coverage



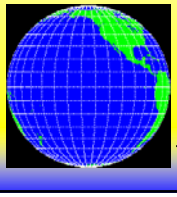
Meteosat ↑



IODC ↑



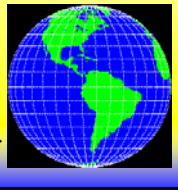
GMS ↑



Areas covered courtesy http://www.sat.dundee.ac.uk/coverage.html

← GOES W

GOES E →

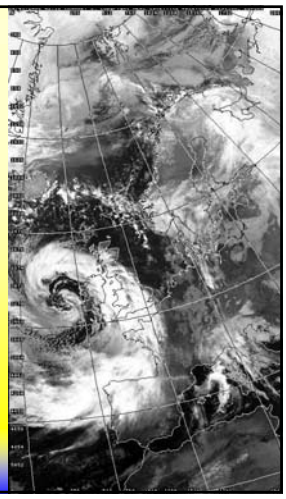


Polar Orbiting Satellites

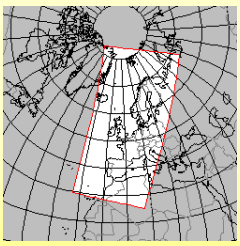
- Look almost straight down at any point on Earth
  - successive images are displaced
  - visible images see the tops of clouds (in daytime)
  - IR images coded white from cold, high cloud; gray from lower cloud
  - NOAA series most often illustrated (images from Dundee University)
  - multi-spectral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

Details of this satellite pass

Satellite	NOAA 18
Direction	Southbound
Equator crossing angle	181.720 degrees West
Orbit number	14449
Identification	000/00A (deprecated)
Number of lines in pass	5693
Average altitude	856.000 km
Time of first line	2008-03-10 02:10:43.331
Time of last line	2008-03-10 02:26:31.998
Duration	15.85071 minutes (theoretical)
Equator crossing time	2008-03-10 01:43:30.014
Horizon time	2008-03-10 02:10:34.600
Overhead time	2008-03-10 02:18:33.528
Delay	27.08452 minutes from equator
Format	HRPT-Packed
Number of bad lines	21
CD identification	108 03 17 02
Attitude yaw roll pitch	0.0000 -0.142 -0.080 0.000



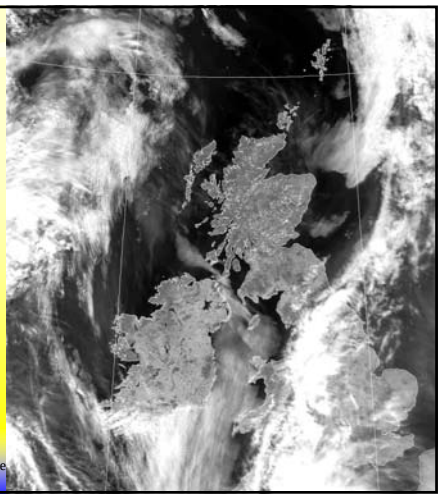
Polar Satellite Orbits



- Typical scan area received by Dundee centre →
- Orbit inclined at ~98.8º 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

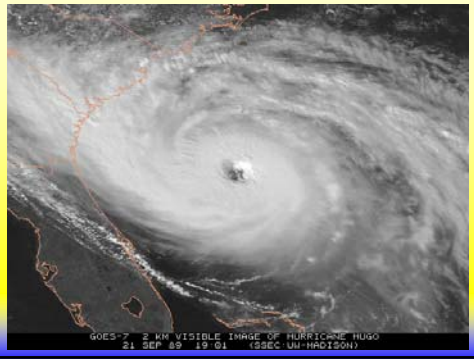
- Scotland during exam preparation time
  - ~ midday 05/05/2008



Courtesy: Dundee Satellite Receiving Station

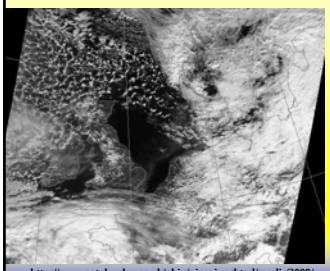
Satellite Images - 1

- Hurricane Hugo

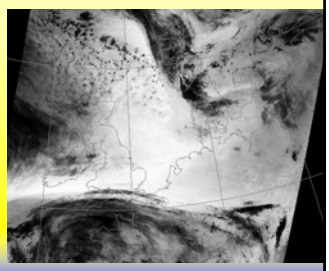


Satellite Images - 2

- 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



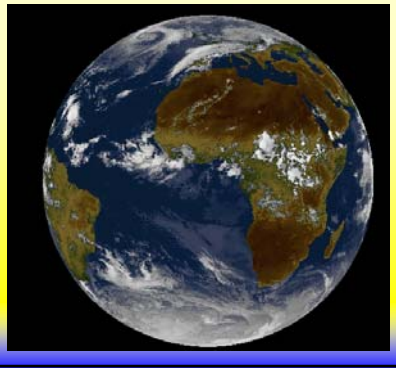
http://www.sat.dundee.ac.uk/abin/piccyjpeghtml/modis/2008/2/27/1102/ch1.jpg



http://www.sat.dundee.ac.uk/abin/piccyjpeghtml/modis/2008/2/27/1102/ch28.jpg

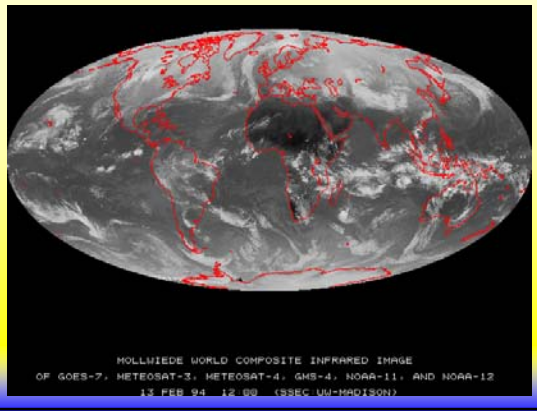
Satellite Images - 3

- Enhanced image from geostationary satellite



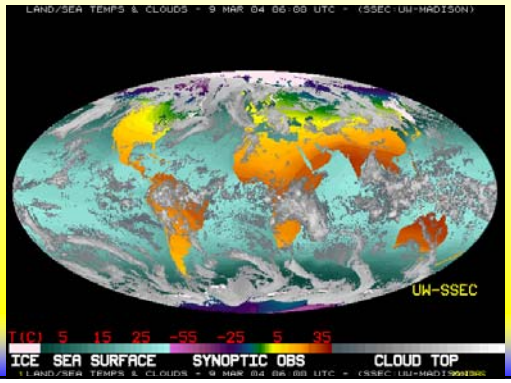
Satellite Images - 4

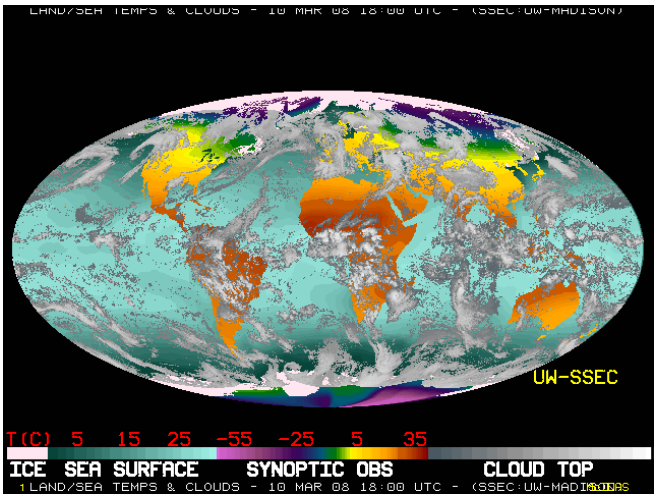
Composite Mollwiede projection



Satellite Images - 5

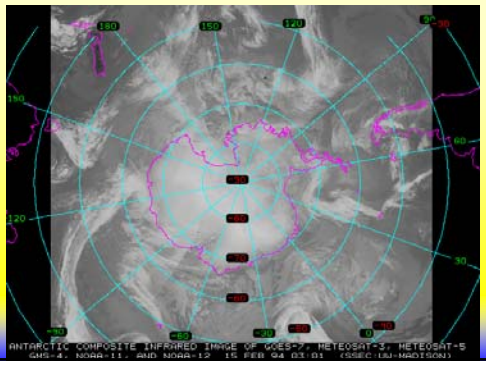
Composite with colour-coded temperatures





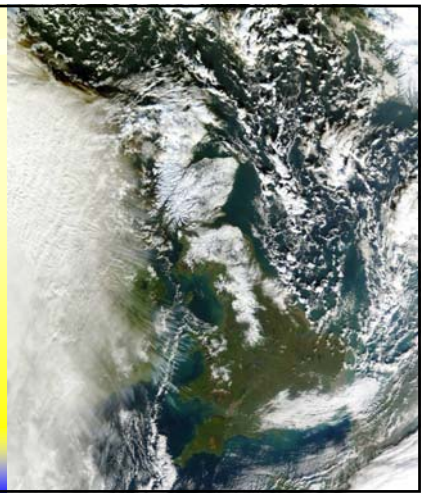
Satellite Images - 6

Antarctica, composite image



Satellite Images - 7

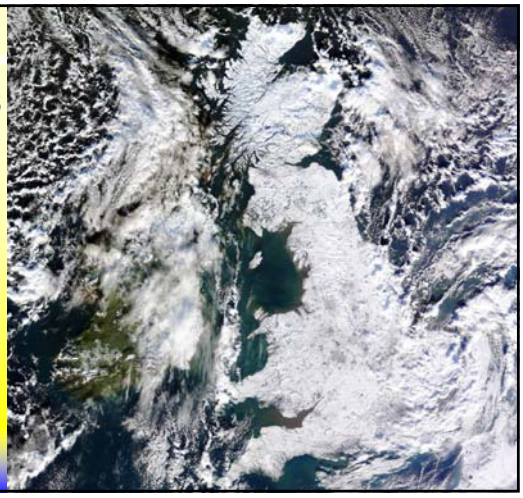
Snow over Scotland and higher ground to the south



Courtesy: DSRS 03-Dec-2008

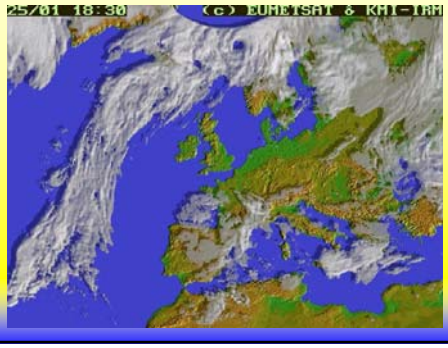
Satellite Images - 8

UK covered in snow, Jan 7th 2010 Courtesy DSRS

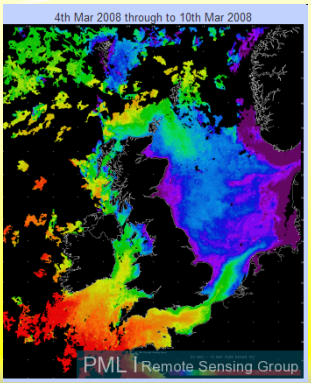


Satellite Images - 9

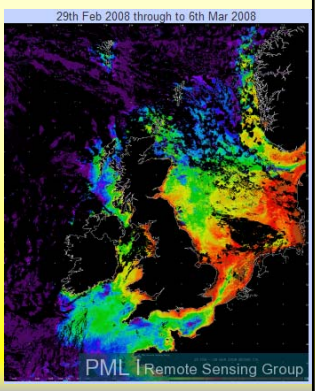
- 25th Jan 1998 from Belgian Met Office



Satellite images - 10



Sea surface temperatures:
http://www.npm.ac.uk/rsg/projects/mceis/zx/7days/AVHRR/



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