NERC SCIENCE OF THE ENVIRONMENT

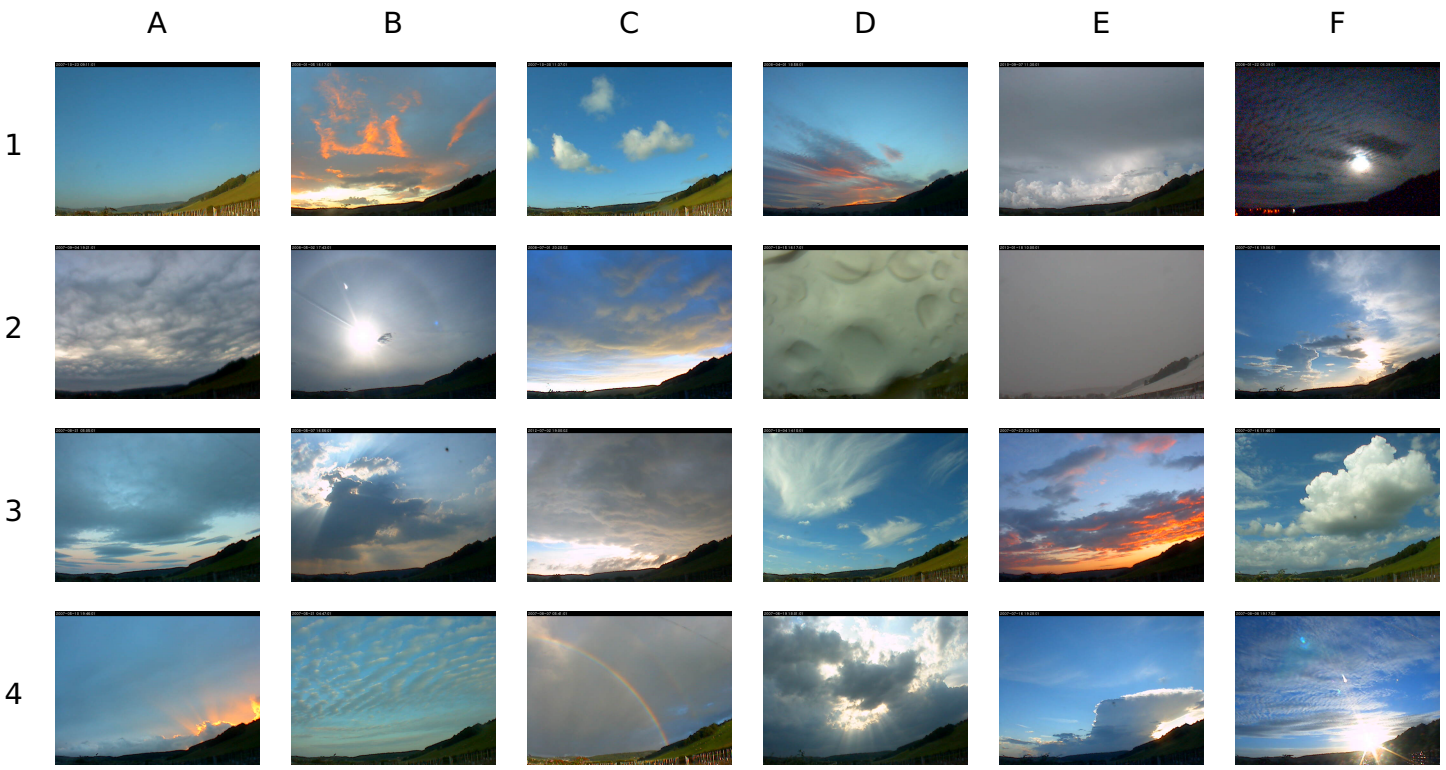
The NERC MST Radar Facility at Aberystwyth
http://mst.nerc.ac.uk

"Atmospheric Science"

An educational poster (final page), together with brief explanatory notes, illustrating some of the many ways in which atmospheric conditions can vary. The images were taken by the Sky Camera at the NERC MST Radar Facility at Aberystwyth (UK).

created by David A. Hooper
December 22, 2015.

Copies of this work are available from: http://cedadocs.badc.rl.ac.uk/1259/.



1 Permissions

The individual images are made available through the Centre for Environmental Data Analysis (CEDA) - http://catalogue.ceda.ac.uk/uuid/5a18810018d9be419a0c37bd276d04fe - under an Open Government License:
http://www.nationalarchives.gov.uk/doc/open-government-licence/.

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

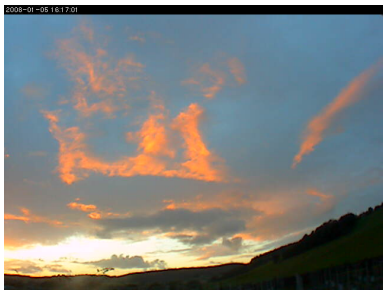
RAL Space

2 Brief Description Of Images

The NERC MST Radar Facility at Aberystwyth is an atmospheric science research station. Its Sky Camera captures an image of atmospheric conditions every minute. The main purpose of the poster on the final page of this document is to illustrate the wide variety of these conditions. Nevertheless, brief descriptions of each image are included in this section and explanatory notes are given in the following section. Technical terms are indicated by *italics*.

Images are labelled by row (1 to 4) and by column (A to F) as shown on the front page. The dates and times when they were taken (in Greenwich Mean Time) are shown in [YYYY-MM-DD HH:MM] format.

Row 1, Column A - [2007/10/23 09:11] - Clear blue sky.



Row 1, Column B - [2008/01/05 16:17] - The irregular base of *Cumulus* clouds lit orange by the setting Sun.

Row 1, Column C - [2007/10/30 11:37] - *Fair-Weather Cumulus* clouds.

Row 1, Column D - [2008/04/01 18:58] - *Stratus* clouds lit orange by the setting Sun.

Row 1, Column E - [2010/09/07 11:30] - *Towering Cumulus* clouds.

Row 1, Column F - [2008/01/22 06:39] - *Billow clouds* lit by the Moon.

Row 2, Column A - [2007/09/04 19:21] - The irregular base of *Stratocumulus* clouds.

Row 2, Column B - [2008/05/02 17:43] - a *22°* *Halo* in a *Cirrostratus* cloud layer and an aircraft *contrail* across the Sun.

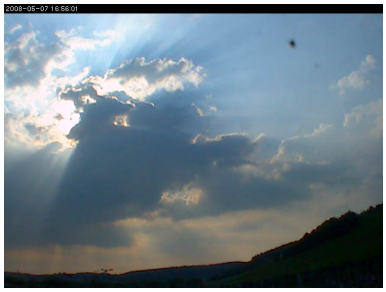
Row 2, Column C - [2008/07/01 20:20] - The irregular base of *Cumulus* clouds lit by the setting Sun.

Row 2, Column D - [2007/10/15 16:17] - Rain drops (on the lens of the camera).

Row 2, Column E - [2013/01/18 10:00] - Snow.

Row 2, Column F - [2007/07/16 19:06] - *Towering Cumulus* clouds. This cloud is the same one shown in image 4E, but captured an hour earlier.

Row 3, Column A - [2007/08/21 05:05] - *Lenticular* clouds (close to the horizon).



Row 3, Column B - [2008/05/07 16:56] - *Crepuscular Rays*.

Row 3, Column C - [2012/07/02 19:00] - The irregular base of *Cumulus* clouds lit by the setting Sun.

Row 3, Column D - [2007/10/04 14:10] - *Cirrus* clouds, i.e. high-altitude clouds composed of ice crystals.

Row 3, Column E - [2007/07/23 20:24] - Clouds lit orange by the setting Sun.

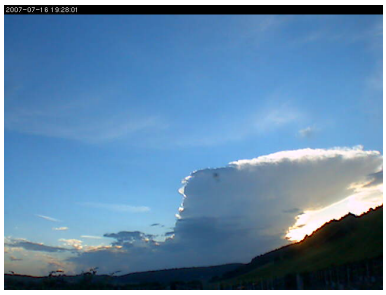
Row 3, Column F - [2007/07/16 11:46] - *Cumulus* clouds.

Row 4, Column A - [2007/05/10 19:46] - *Crepuscular Rays*.

Row 4, Column B - [2007/05/21 04:47] - *Billow Clouds*.

Row 4, Column C - [2007/08/07 05:41] - A *Double Rainbow*.

Row 4, Column D - [2007/06/19 18:01] - *Crepuscular Rays*.



Row 4, Column E - [2007/07/16 19:28] - An “Anvil” on a *Towering Cumulus* cloud. This cloud is the same one shown in image 2F, but captured an hour later.

Row 4, Column F - [2007/08/08 19:17] - *Billow Clouds* showing evidence of both *Kelvin-Helmholtz Instabilities* and *mountain wave* activity.

3 Explanatory Notes

The *density* of air (a measure of its “thickness”) mostly decreases with increasing altitude above the ground. This makes the atmosphere *(convectively) stable*, which means that it suppresses vertical movements. Consequently, clouds that exist in *(convectively) stable* regions of the atmosphere don’t have much vertical structure. They have a layered appearance and are known as *Stratus*

clouds - see images 1D, 1F, 2A, 2B, 3A, 3D, 3E, 4B, and 4F.

When the *(convectively) stable* atmosphere is subjected to a vertical disturbance - such as being forced to rise where the wind encounters a hill or mountain - it will vibrate like a plucked string. The resulting *atmospheric waves* are similar to the waves seen on the surface of water. *Lenticular* (meaning "lens-shaped") clouds form in the rising portions of *mountain waves* - see image 3A. Their position remains fixed relative to the landscape, whereas other clouds drift downstream with the wind. Bands of long, thin clouds are referred to as *Billow Clouds*. Although clouds of this form can be associated with *mountain waves* (formed over ridges rather than isolated hills/mountains), the ones shown in images 1F and 4B are probably caused by *Kelvin-Helmholtz Instabilities*. These are wave patterns that arise spontaneously where the wind speed changes sharply with altitude.

If the air at one altitude becomes warmer than at the altitude above, it becomes less-dense and rises in a process known as *convection*. This is common in the lowest layers of the atmosphere as a result of sunlight heating the ground (which heats the air above). As the air rises, it expands and cools, which reduces its ability to hold water in gas form. If the air rises high enough for its temperature to drop below the *dew point*, the *water vapour* will condense into liquid water droplets and be seen as clouds. The process of condensation releases *latent heat*, which helps the *convection* to rise even higher. These *Cumulus* clouds are therefore characterised by their vertical structure - see images 1C, 1E, 2F, 3F, and 4E.

The vertical extent of a *Cumulus* cloud depends on the vertical structure of both temperature and *water vapour* concentration. Shallow *Fair-Weather Cumulus* clouds form when not much *water vapour* is available - see image 1C. They are sometimes short-lived (evaporating after only a few tens of minutes), but at other times they can grow into deeper clouds. They usually have to grow into deep *Towering Cumulus* clouds before they can produce rain - see image 1E and 2F. The water typically exists in the form of ice crystals at the top of these clouds, but usually melts before it reaches the ground. A horizontal layer spreading out from the top of a *Towering Cumulus* cloud is known as an *Anvil* - see image 4E. It indicates that the cloud has encountered *temperature inversion*, which is a sharp increase in atmospheric temperature with increasing altitude. This is highly *(convectively) stable* and acts as a "lid", which suppresses further vertical movement. The cloud is forced to spread out sideways along the direction of the upper level wind.

Apparently-white sunlight is composed of a *spectrum* of colours. The individual colours are revealed in the form of a *Rainbow* where the sunlight encounters raindrops - see image 4C. The *22° Halo* is the equivalent where sunlight encounters a diffuse cloud of ice crystals - see image 2B. The blue of a clear sky and the reds/oranges of sunset are also a consequence of the *spectrum* of sunlight.

Shafts of light and shadow are often seen around clouds when the Sun is at a low elevation above the horizon - see images 3B, 4A, and 4D. These are called *Crepuscular Rays* (although the term "crepuscular" actually implies twilight).

4 How to attribute/credit this work

The recommended way to attribute a web-based resource is by "Title" (i.e. the name of the material), by "Author" (i.e. who owns/created the material), by "Source" (i.e. where it can be found), and by "License" (i.e. how it may be used). See https://wiki.creativecommons.org/wiki/Best_practices_for_attribution for more details. The relevant details for this work are:

Title	Atmospheric Science
Author	David A. Hooper
Source	http://cedadocs.badc.rl.ac.uk/1259/
License	https://creativecommons.org/licenses/by/4.0/

5 Acknowledgements

I am grateful to Joseph Prentice, Emily Mackintosh, Daniel Khosla, Kathryn Stone, Kieran Cook, Natasha Bierrum, and Amelia Gilio. They contributed to a systematic log of Sky Camera events whilst on work experience placements at the STFC Rutherford Appleton Laboratory - http://www.stfc.ac.uk/workexperience. Most of the images used in this document were identified from that log. I am also grateful to Charlotte Pascoe (who supervised one of the work experience students, to Caroline Callard (who motivated the creation of the original poster for the RAL Space exhibit at the Harwell Open Day in July 2015), to Kate Winfield (for feedback on the image descriptions and explanatory notes in this document), and to Graham Parton (for help with publishing this work).

The NERC MST Radar Facility at Aberystwyth - http://mst.nerc.ac.uk - is funded by the Natural Environment Research Council (NERC) - http://www.nerc.ac.uk/ - through the National Centre for Atmospheric Science (NCAS) - https://www.ncas.ac.uk. It is managed by STFC RAL Space - http://www.ralspace.stfc.ac.uk/.

6 Poster

The poster on the next page was designed to be printed at A0 size. It reproduces well when printed at A4 size, although some of the fine details will not be visible.

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

NERC SCIENCE OF THE ENVIRONMENT

The NERC MST Radar Facility at Aberystwyth
http://mst.nerc.ac.uk

RAL Space

Atmospheric Science

These images were taken by the Sky Camera at the NERC MST Radar Facility at Aberystwyth. They illustrate some of the many ways in which atmospheric conditions can vary.