



Cloud Structures

Observing the Earth from space reveals its cloudy envelope. The main colours are the oceanic blue and the different shades of white and grey of clouds.

Having a closer look one will notice that the clouds are neither uniform nor chaotic; they are grouped into formations and structures, and these occur in specific places around the globe. The work presented here describes some cloud formations over the ocean and includes examples of the most frequently found cloud structures.

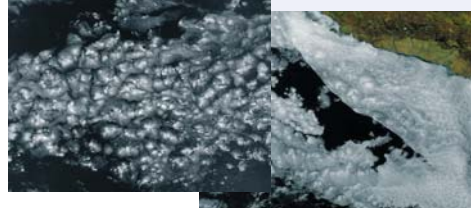
Cloud structures are a visual expression of a process taking place in the atmosphere. The appearance of a cloud structure often remains invariant during the year and does not depend on its geographical location, but sometimes on orographic features. This allows a characterisation of the cloud structures on the base of appropriate criteria and to systematically investigate their occurrence. In this work a cloud structure is defined as a compact cloud formation of a distinct spatial form, with the dimensions of more than 10-20 km and reflecting a certain state of the atmosphere and the underlying surface.

The image data have been taken by MERIS onboard ENVISAT between 2002 and 2007. This imaging spectrometer measures the backscattered sunlight in 15 spectral bands. These measurements enable a realistic RGB presentation of the cloud structures and permit the calculation of cloud physical parameters such as the cloud optical thickness and cloud top height. The image processing was performed using the BEAM software package.

Convective Cells

Close Cells

*Clouds and eclipses stain both moon and sun,
 And loathsome canker lives in sweetest bud.
 Shakespeare, Sonnet XXXV*

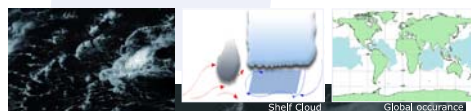


Closed cells are formed by convective surface winds over the ocean. They are oval structures and large numbers of these cells are packed closely in large cloud fields. These can extend over more than a million square kilometres.

Outflow Boundary

A Shelf Cloud

*Bright as a cloudless summer sun,
 With stately port he moves...
 Robert Burns, 'A Noble Earl's Picture'*

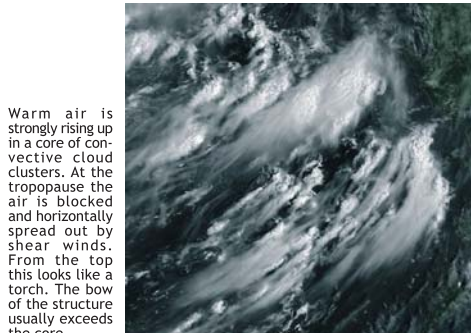


The mixing of warm and cold air behind a thunder storm cloud leads to this structure which appears as a narrow circle, an arc or even a sickle shaped when observed from space.

Convective Cloud Cluster

A Cloud Torch

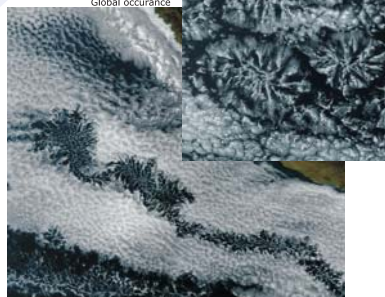
*They rise upon clouds, and sport in the wind...
 William Blake, 'The Chimney-Sweeper'*



Warm air is strongly rising up in a core of convective cloud clusters. At the tropopause the air is blocked and horizontally spread out by shear winds. From the top this looks like a torch. The bow of the structure usually exceeds the core.

Actinoform

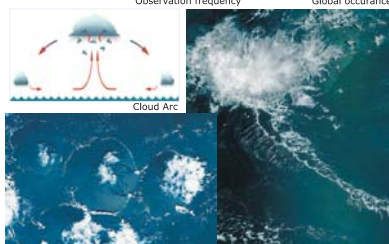
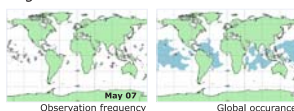
*Sun, wind, and cloud shall fail not from the face of it,
 Stinging, ringing spindrift, nor the fulmar flying free...
 Rudyard Kipling, 'The Last Chantey'*



The actinoform cloud structure appears where large fields of open and closed convective cells occur. It is a circular or oval structure with radial filaments of clouds. It appears also as a long band, so called train, assembled by a large number of single cells.

Cloud Arc

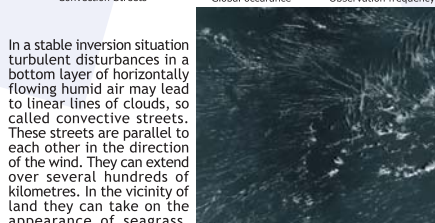
*The little white clouds are racing over the sky,
 And the fields are strewn with the gold of the flower...
 Oscar Wilde, 'Magdalen Walks'*



Convection over the ocean leads to an (alto)stratus cloud in the centre of a convective system. At the boundary colder air masses sink and a circle of (strato)cumulus clouds occur at a lower altitude. Horizontal winds lead to deformations and displacements of this circle.

Convection Streets

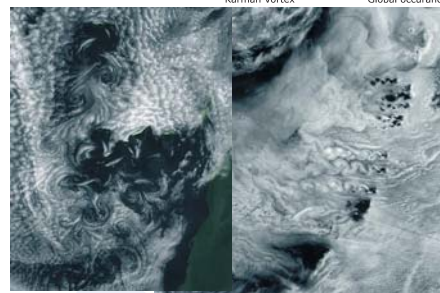
*In this kingdom by the sea,
 A wind blew out of a cloud by night...
 Edgar Allan Poe, 'Annabel Lee'*



In a stable inversion situation turbulent disturbances in a bottom layer of horizontally flowing humid air may lead to linear lines of clouds, so called convective streets. These streets are parallel to each other in the direction of the wind. They can extend over several hundreds of kilometres. In the vicinity of land they can take on the appearance of seagrass.

Karman Vortex

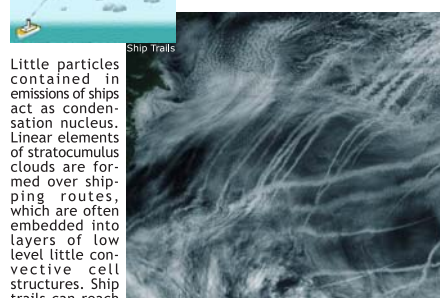
*Through transparent cloud and vapor,
 And amid celestial splendors
 On the Evening Star alighted...
 Henry W. Longfellow, 'The Song Of Hiawatha'*



Turbulent mixture of the air after passing a barrier, such as an island, forms well organised large scale spirals, so called eddies, within a layer of closed cells of stratocumulus and stratus clouds. Each eddy rotates counter clockwise on the left side of the barrier and clockwise on the right side.

Ship Trails

*Robed in flames and amber light,
 The clouds in thousand liveries dight...
 John Milton, 'L'Allegro'*



Little particles contained in emissions of ships act as condensation nucleus. Linear elements of stratocumulus clouds are formed over shipping routes, which are often embedded into layers of low level little convective cell structures. Ship trails can reach up to 1000 km length.

Extratropical Cyclone

*Thou art wrapt as with a shroud,
 Thou art gather'd in a cloud...
 George Gordon Byron, 'Manfred'*



Extratropical cyclones are high spiral structures with dimensions of several thousands of kilometres. They occur at latitudes greater than 30° where warm and cold air masses meet. The Coriolis force sets the structure in clockwise rotation on the Northern and counterclockwise on the southern hemisphere.