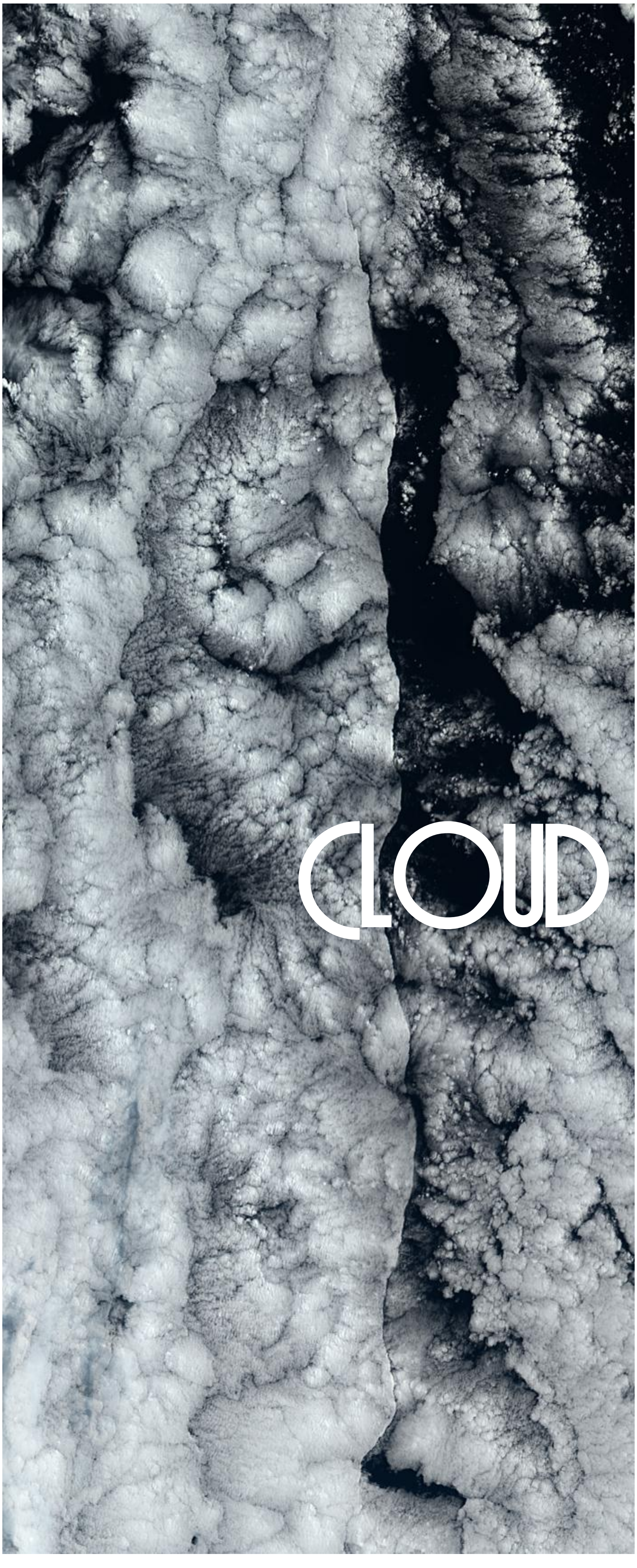
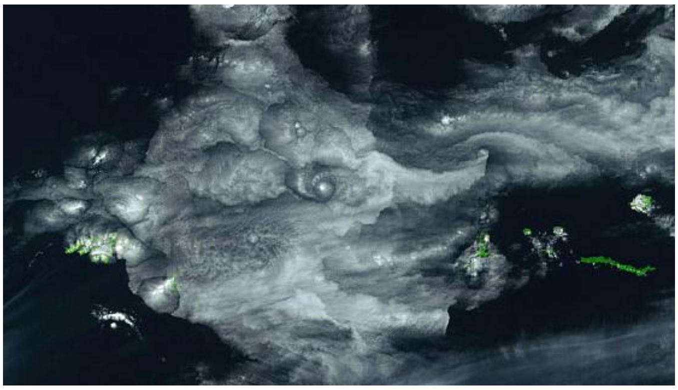
M. Paperin



Cloud Structures

- short version -



Hamlet
   Do you see yonder cloud that's almost in shape of a camel?
Polonius
   By the mass, and 'tis like a camel indeed.
Hamlet
   Methinks it is like a weasel.
Polonius
   It is backed like a weasel.
Hamlet
   Or like a whale.
Polonius
   Very like a whale.

William Shakespeare: Hamlet, Prince of Denmark: ACT III. Scene II

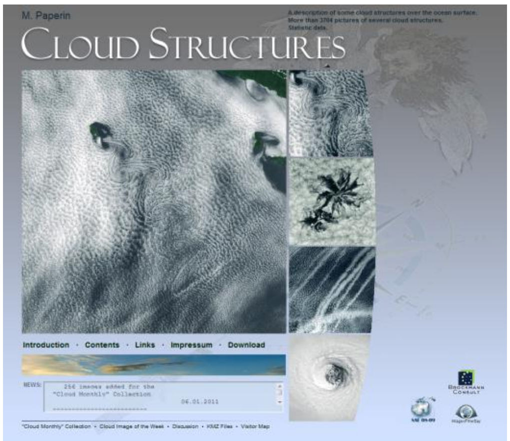
In 2002 ESA launched the ENVISAT satellite equipped with many devices including MERIS (medium-spectral resolution, imaging spectrometer). While making visual archive for this sensor I have happened to witness tens of thousands of circuits since then. Observing the cloudy cover regularly I noticed that in large areas clouds form structures, of which appearance and properties may depend on geographic and seasonal elements. The cloudy envelope of the planet is a ranked rather than a chaotic accumulation of clouds as far as it concerns their forms. These forms either repeat themselves or differ but in any event they reflect definite process taking place in the atmosphere. All this could allow to try to unify them on the base of appropriate criteria and thus to speak about the cloud structures and systemize them.
That was how the idea occurred to me to try to somehow systemize what I‘d seen.

The Cloud Structures project was started in 2006 is a dynamic one, meaning that there appear additional examples of the structures that have already been revealed as well as even new structures and phenomena.
Because cloud structures correlate with atmospheric processes they help to study the latter, whether already known or new. Thus the efforts to compile a catalogue of cloud structures are also aimed at arousing scientists’ interest in still incomprehensible phenomena and providing researchers with examples to facilitate finding explanations.
It could be convinced that the picture of the cloudy cover along with a set of cloud structures defines the Earth to the same extent as the planet is defined by its size, atmospheric parameters (thickness and chemical composition) and underlying surface. And undoubtedly, to study cloud structures may be important not only for scientific purposes but also from the point of view of aesthetics.

This work is to describe some cloud formations over the ocean as well as present examples of some of the most frequently found cloud structures. The work includes the analysis of the notion "a cloud structure" (also known as "a cloud pattern"). To present the most of structures the following data will be offered:

- Statistic data
- Global Occurrence
- The physical explanation for a structure emergent
- Pictures of corresponding structure for the time period (mostly) 2006-2010

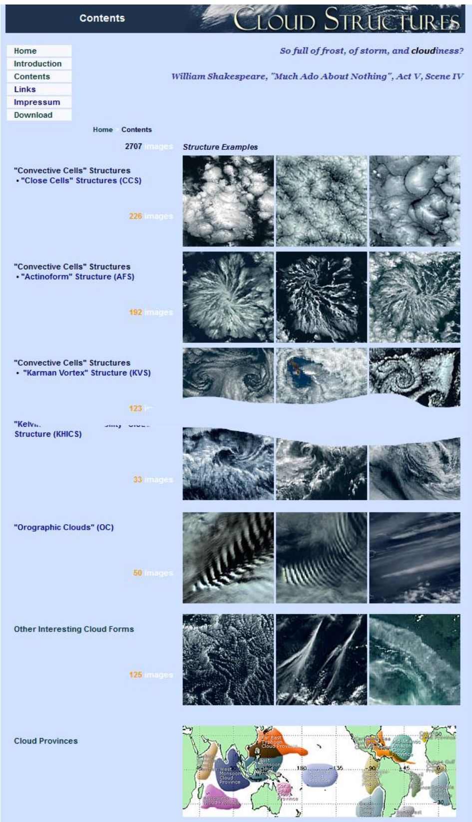
The Software BEAM VISAT developed by the Brockmann Consult, Germany, was used as the basic tool.

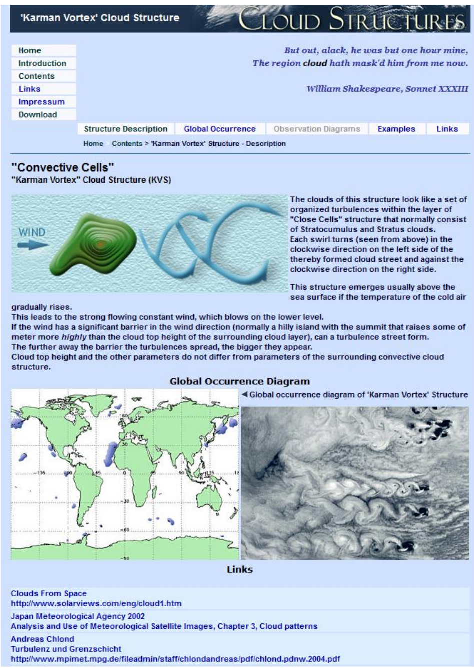


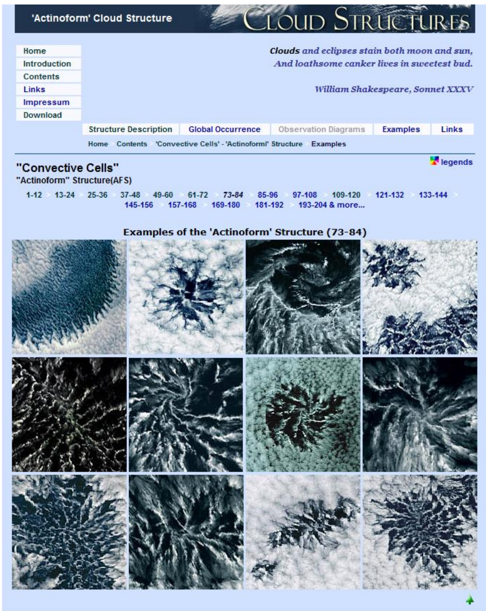
Screenshot of the title "Cloud Structure" page

"Cloud Structures" website is hosted at the Brockman Consult, Germany:
http://www.brockmann-consult.de/CloudStructures/.
It consists in whole of the introduction, where the sources are identified and the methods and tools are described, and a collection of the cloud structures and phenomena.
Each structure, of which there are currently more than 20, contains its description of the structure, possible physical explanation of the emergence, statistical data and several tens often even hundreds of examples.
A cloud provinces were defined as a limited territory over the world ocean (and sometimes over parts of the coast). It is characterized by a cloud picture which is specific for it and probably depends on the season. Currently 18 of them are defined.
Since 2008 the new interesting pictures were grouped monthly. This may, among others, show the variability of the Earth unique portraits within the seasons and possibly the change from year to year.
In the "Discussion" section a few watched phenomena I found interesting or could not explain clearly were presented. In the "Download" section some posters and flyers are available for download and also a short PDF - version about some cloud structures is offered. The page will be continuously supplemented.
I’d like to express my gratitude to my chief Dr. Carsten Brockmann, who made it possible for me to be engaged in this project.

Michael Paperin, 2012







Screenshots of some "Cloud Structues" pages.

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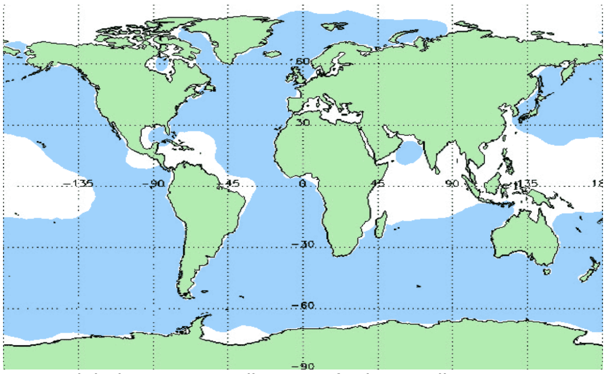
The study of cloud structures not only allows a deeper understanding of the processes occurring in the atmosphere of our planet, but also get great aesthetic pleasure from their contemplation.

Close Convective Cells

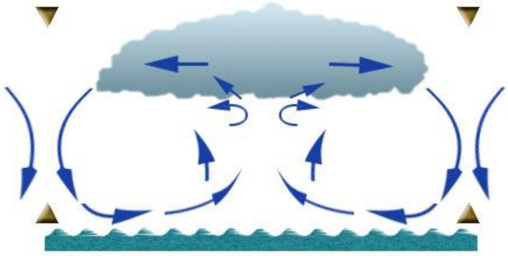
They are normally polygonal, round or oval and often stay close to each other and form large fields up to more than a million square kilometres in size. The area extent of an individual cell unit is from several kilometres to one hundred or even more kilometres. The Cloud top height is normally from several hundred meters up to 1.5÷2.5km, rarely up to 3÷3.5km.



Global occurrence diagram of 'Close Cell' Structures

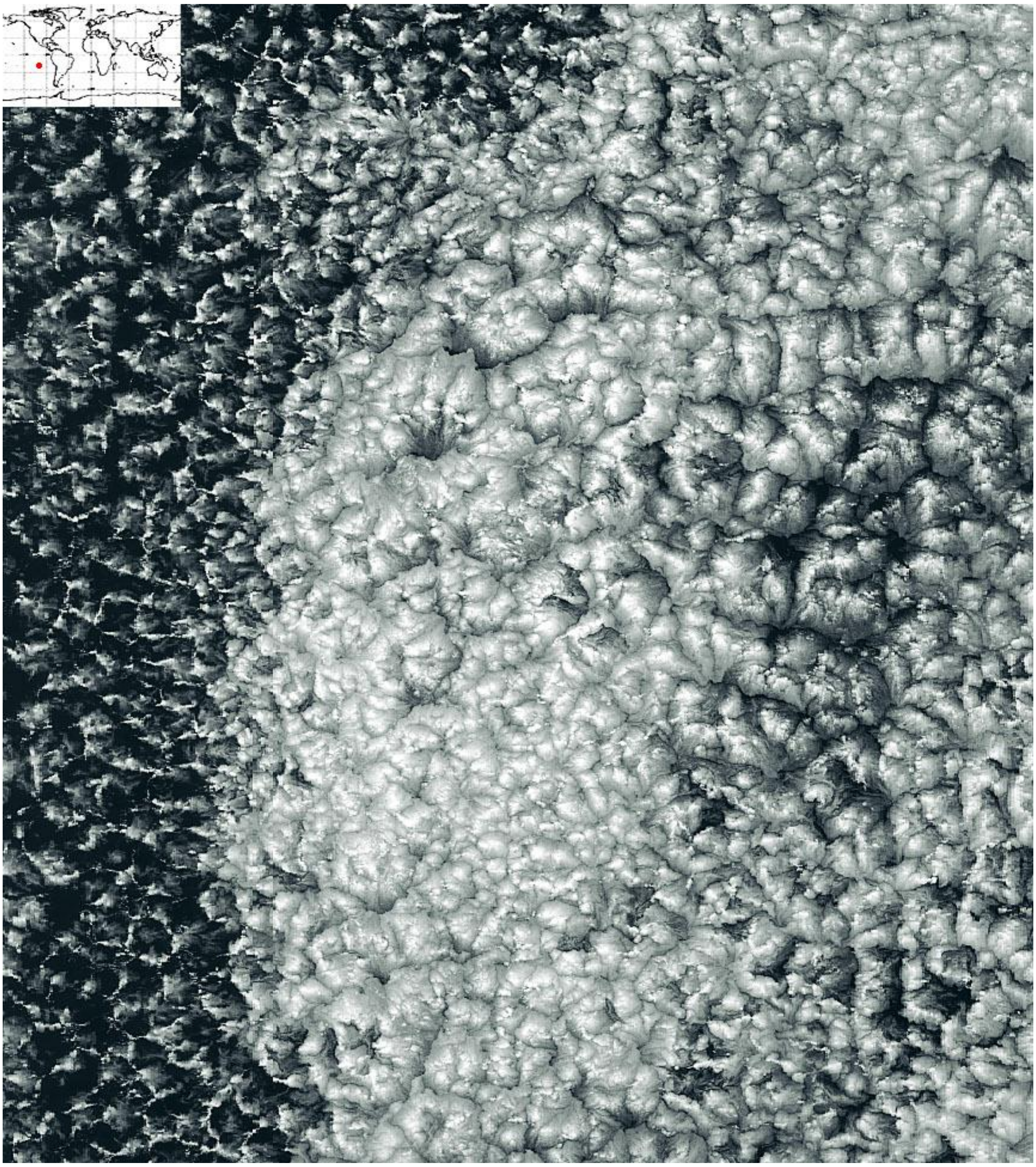
The 'Close Cell' Cloud Structure may shape:

above areas situated in middle latitudes where the temperature difference between the sea surface and the troposphere is little, at the edge of cyclones vortices in middle latitudes, above polar seas. Various physical phenomena can emerge and be seen on the cloudiness of this structure type, besides other types of structures may use the said structure as the foundation for their evolution.

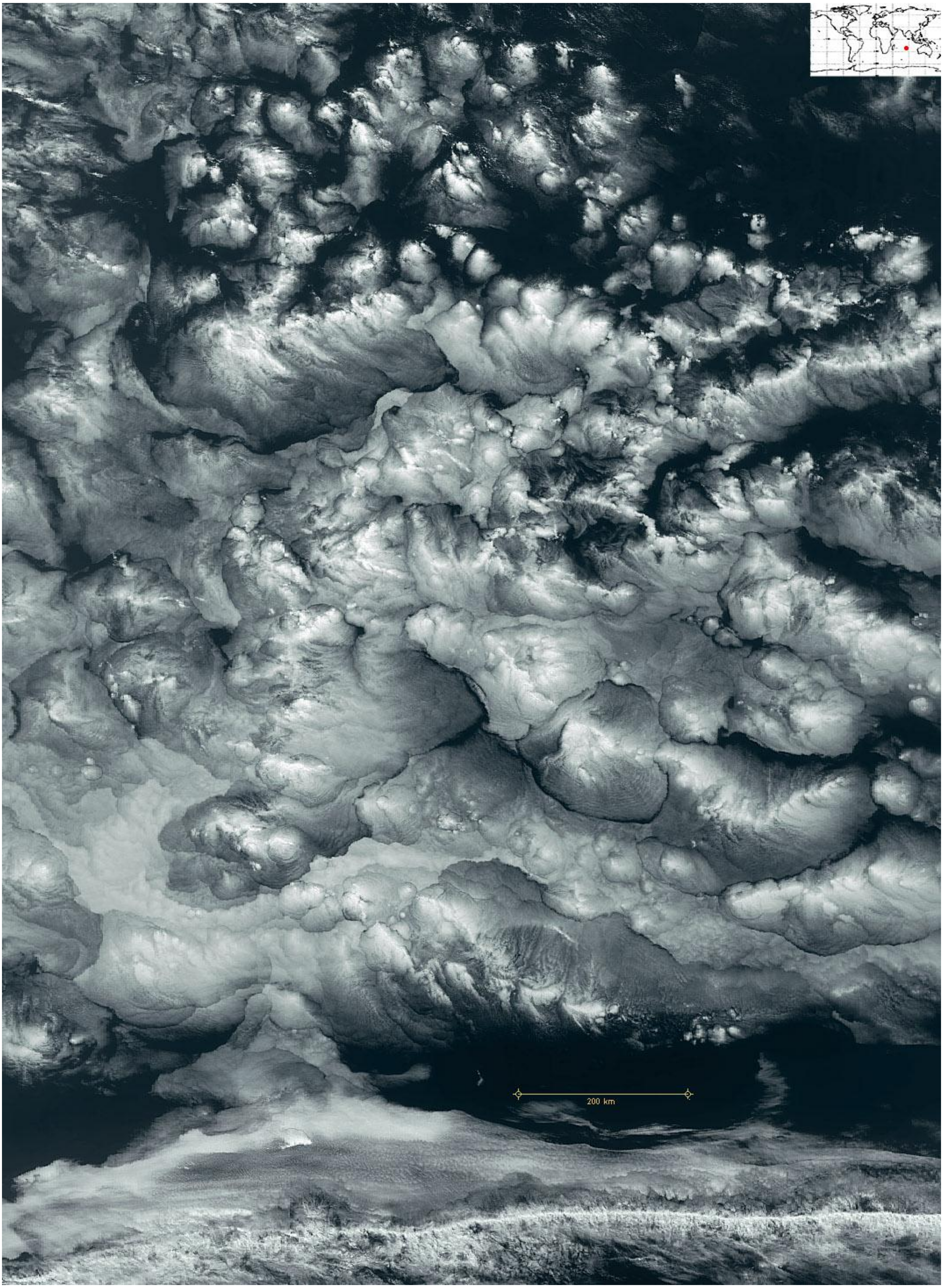


The Closed cells consist of convective clouds and their circulation is vertical. These cells appear frequently in the atmospheric layer in rough hexagonal rows, and consist of Stratocumulus and Stratus clouds. The sides of the cloud tops are kept down by the inversion layer.

Closed cells appear when the temperature difference between the sea surface and the troposphere is minor. They may shape when the inflow of cool air is weak. Besides, they can convert from Opened cells in the event that the flowing cool air subsides. In this case the future form of cells (opened or closed) depends on the intensity of the inflow of the cool air. However this process is very chaotic and it is very difficult to predict the result of convention. Sometimes the conditions of the atmosphere change, which gives rise to curious forms of clouds.



2009.09.08 Orbit: 39344
Close convective cells over the east Pacific close to the coast of the South Peru.
The spreading of the field in the North-South direction reaches 2200km.

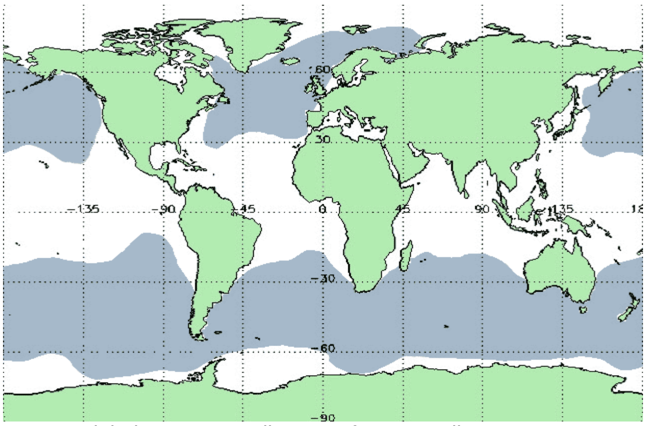


2009.09.13 Orbit: 39408

Close convective cells over the Indian ocean in the west of Australia. The largest of cells reaches almost 200 km. The ridges and valleys can be observed. They were caused by sinking down the cold air currents. They cause the cloud-free belts between the cells . The concentric waves reflect the processes of growth of the cells.

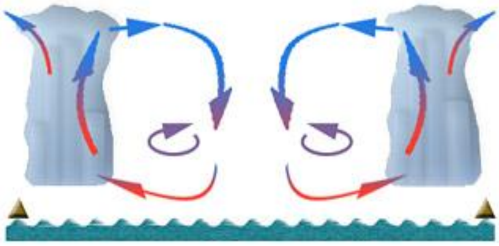
Open convective cells.

An open cell consists of convective clouds, which top reaches only the lower layers of the troposphere. Within the cell vertical circulation takes place: the streams of the air go up in the zone close to its vertical borders (the cell sides) and then go down in an "empty place" (in the middle of the cell where there are almost no clouds).



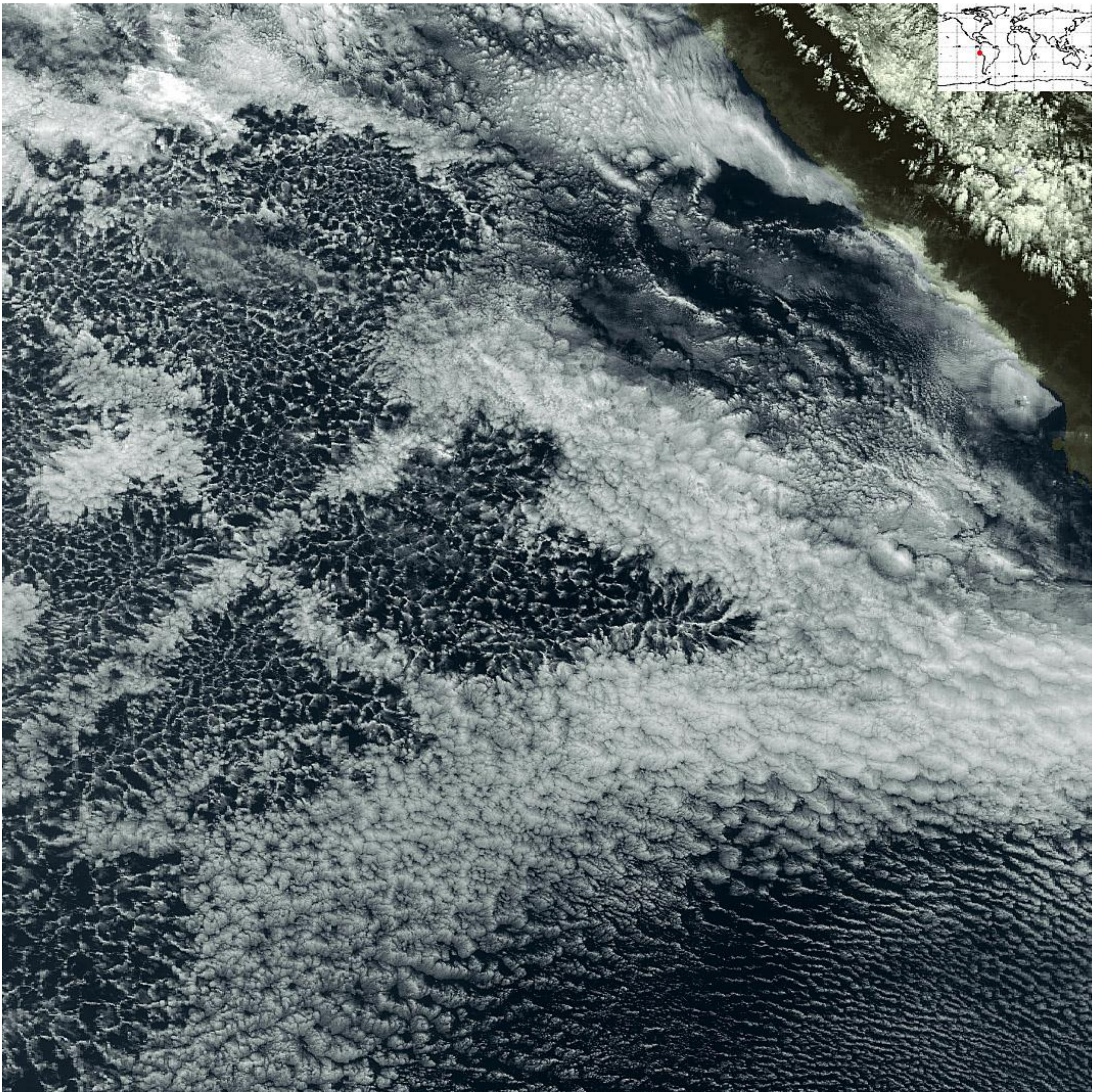
Global occurrence diagram of 'Open Cell' Structures

Seen from above, an open cell ideally looks like a hexagon with the sides formed by rising clouds.



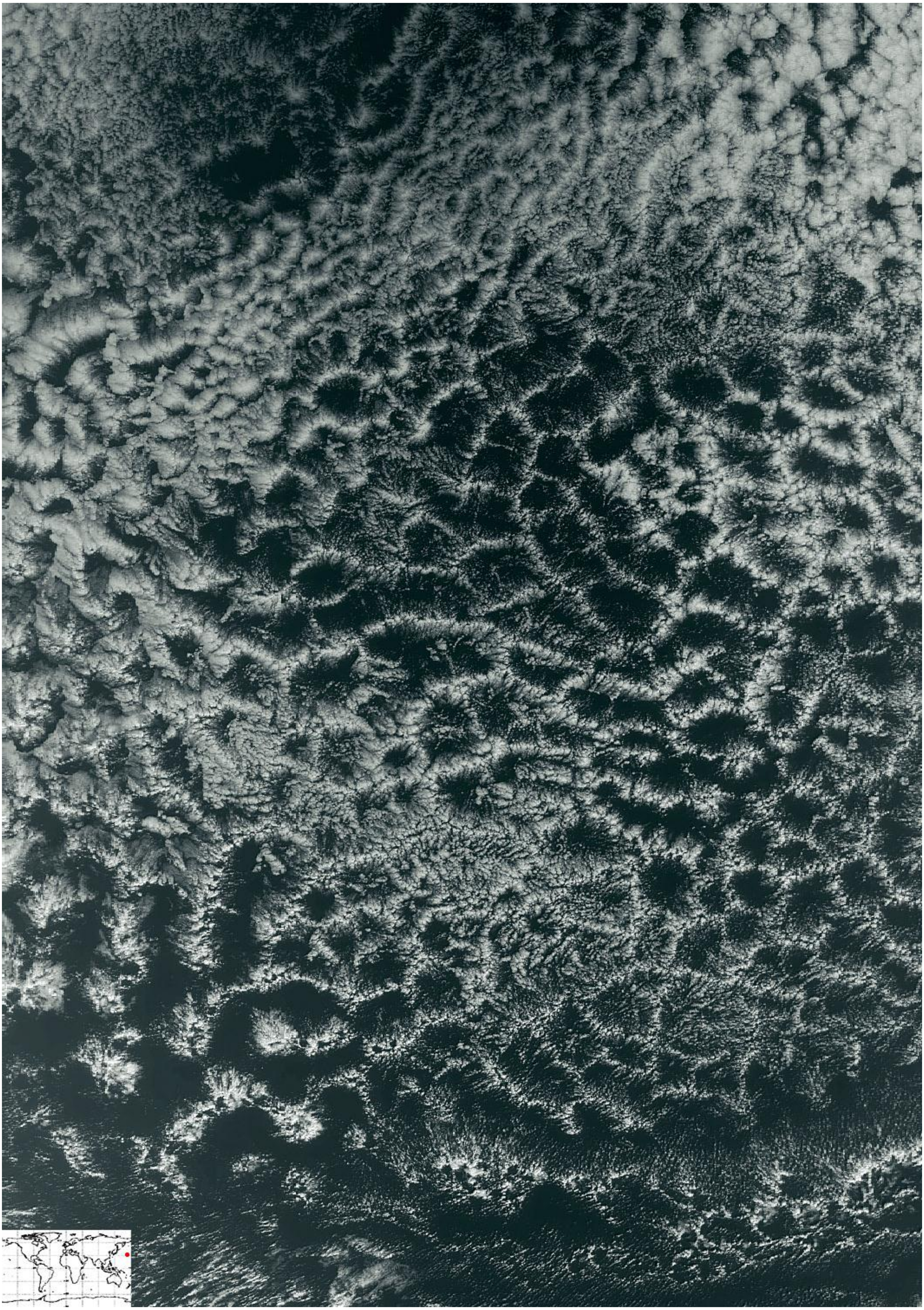
The size of a cell is up to 70 km (not rarely up to 100 km). The cloud top height of an open cell is 1.5-2.5 km, (sometimes up to 3 km).

Space pictures often enable to see open and close cells sharing one and the same cloud field.



2009.07.09 Orbit: 38470

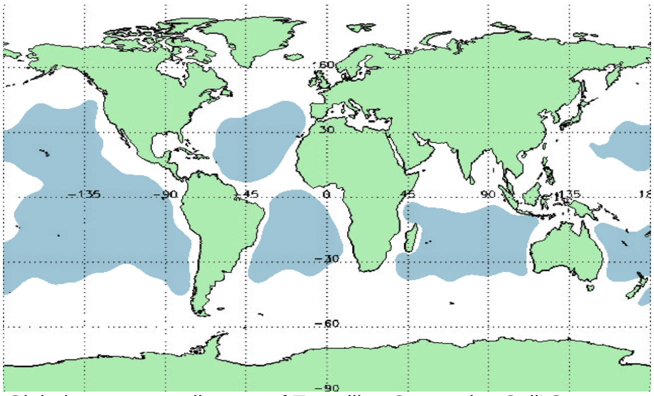
Open und close convective cells cloud structures over the east Pacific close to the Peru coast.



2008.12.21 Orbit: 35612
Open convective cloud cells over the west Pacific.

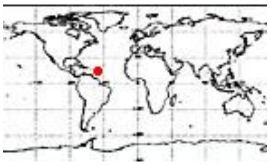
Travelling Convective Cells *.

The clouds of this structure emerge probably from “Close Cell” cloud structure.
If the assumption is correct, these cloud form demonstrate certain stability, while they depart from with the wind Close Cells field. It is not clear, whether there are only the clouds back of convective cells, or the whole convective cells travels also. In any case some metamorphoses, which happen with clouds, are to be observed.
The large (up to 300 km) separate (if they are emerged from the CCS) cells, which are outlasted the dissolution process, are usually covered with the ravines. It could be accepted that they developed from the cold air flows, which flow downward from the summit of the cloud form. Cold dry air drives the water vapour out to lower warmer layers, so that the ravines become finally deep enough and the clouds among them disappear completely. The remnants in form of mountain combs “live” still longer, after that they will smaller and finally dissolve.

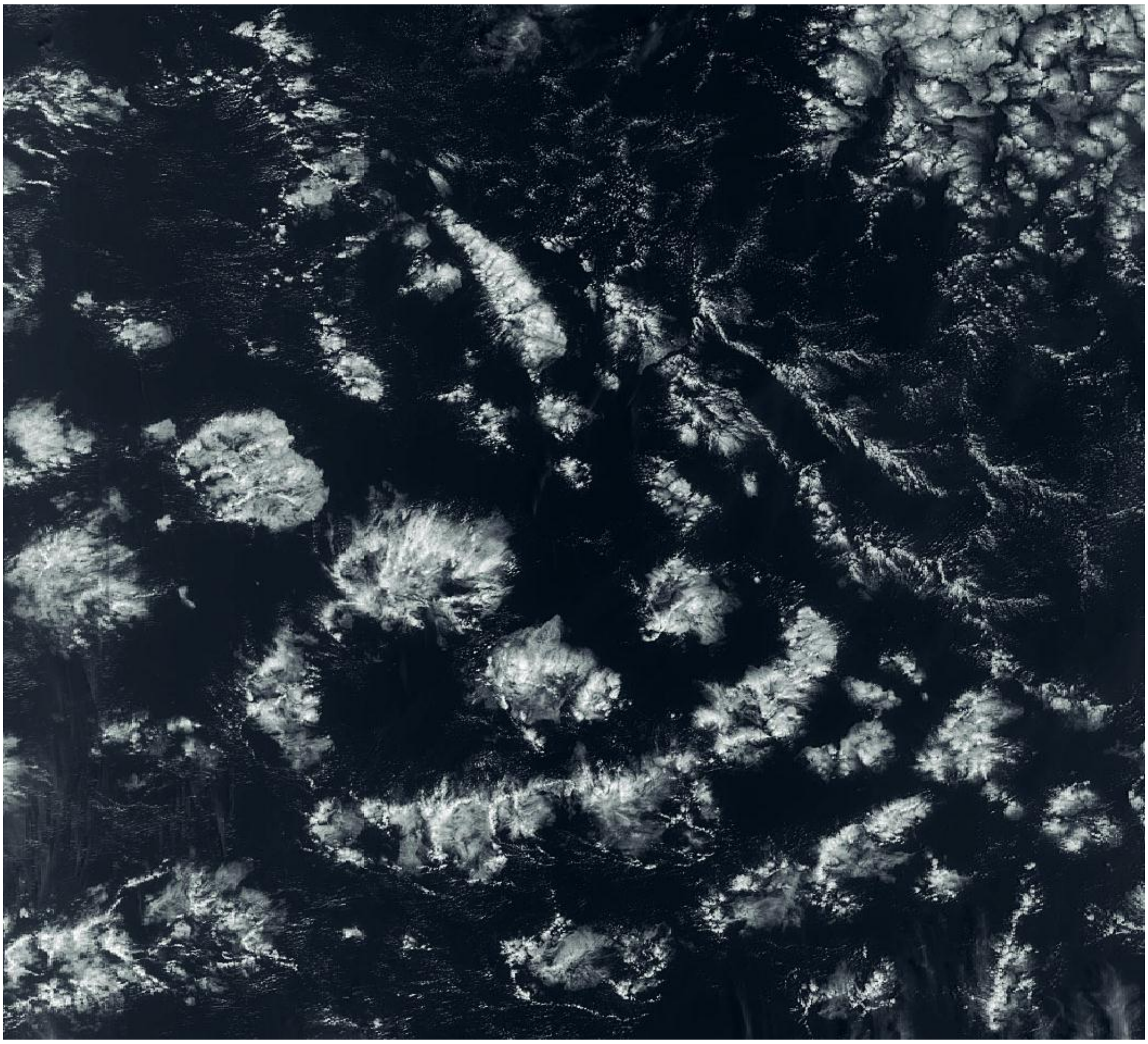


Global occurrence diagram of Travelling Convective Cell' Structures

Elements of this structure are seasonally observed as single, but also in groups. Sometimes they go more than thousands of kilometres away from their sources.
They are observed over the warm latitudes.
In east Pacific in a strip of ±40° above equator,
In west Pacific above [+15°, +40°] and [- 15°, - 40°],
In Atlantic above [+5°, +40°] and [+2°, -40°],
In Indian ocean above [- 2°, -40°].
Sometimes it is nevertheless very difficult to say, where they came from, which field of “Close Cell” cloud could be the source for it. This refers to the fact that some travel cells can have another origin than “Close Cell” cloud structure.
In this sense the “Mid-Atlantic Amazon Cloud Province” [in a rectangle with coordinates top-left (+30°, -55°) ÷ down-right (+5°, -40°)] is particularly interesting. There the “travel cells” are seasonally observed as the knots of a regular net. They are relatively small (starting from 30 km), have a star-like shape and dissolve fast. It is not clear, where they are come from. The “travel convective cells” form also the season-conditioned “Coral Sea Cloud Province”.



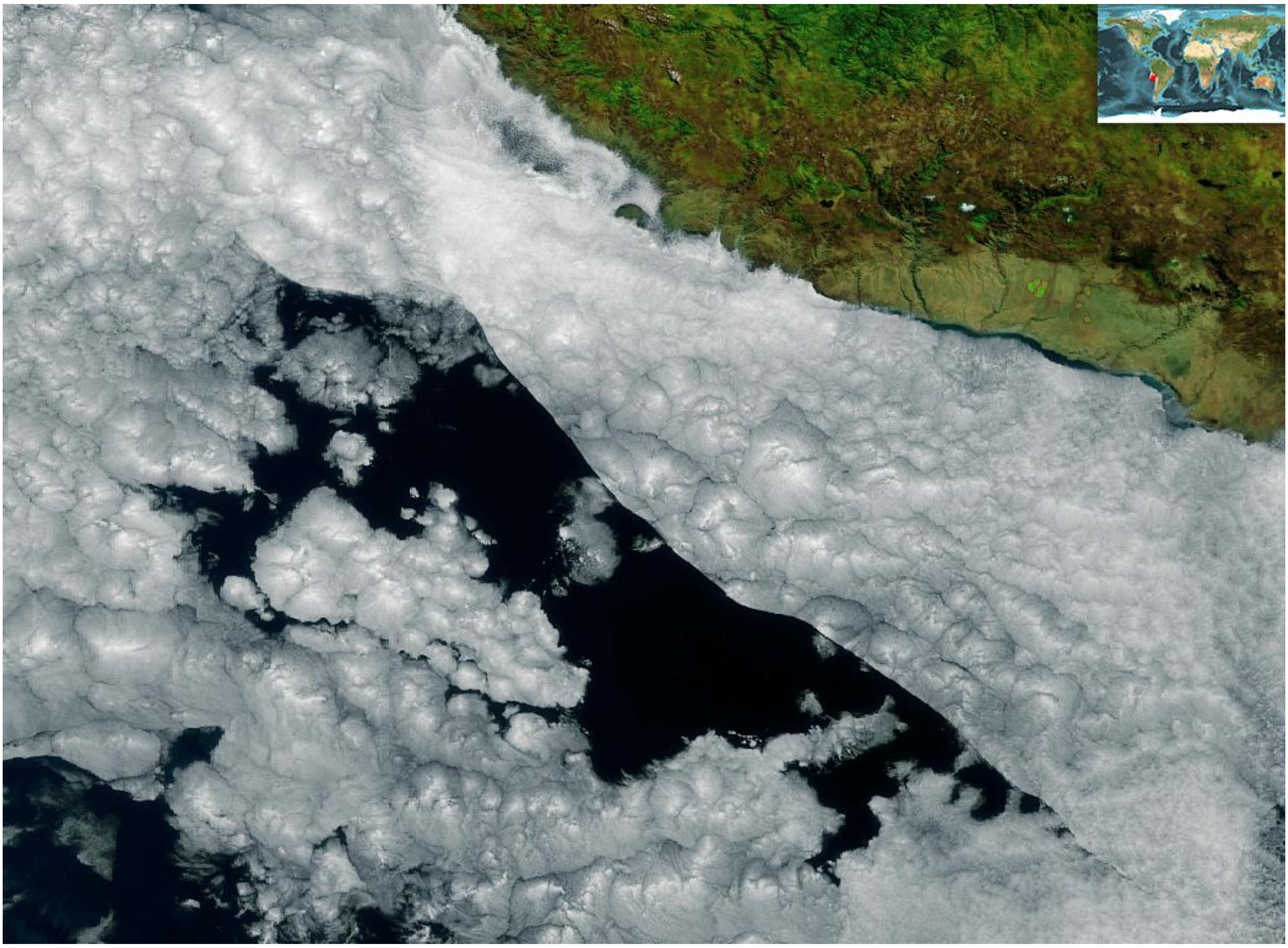
[* my own tentative denotation]



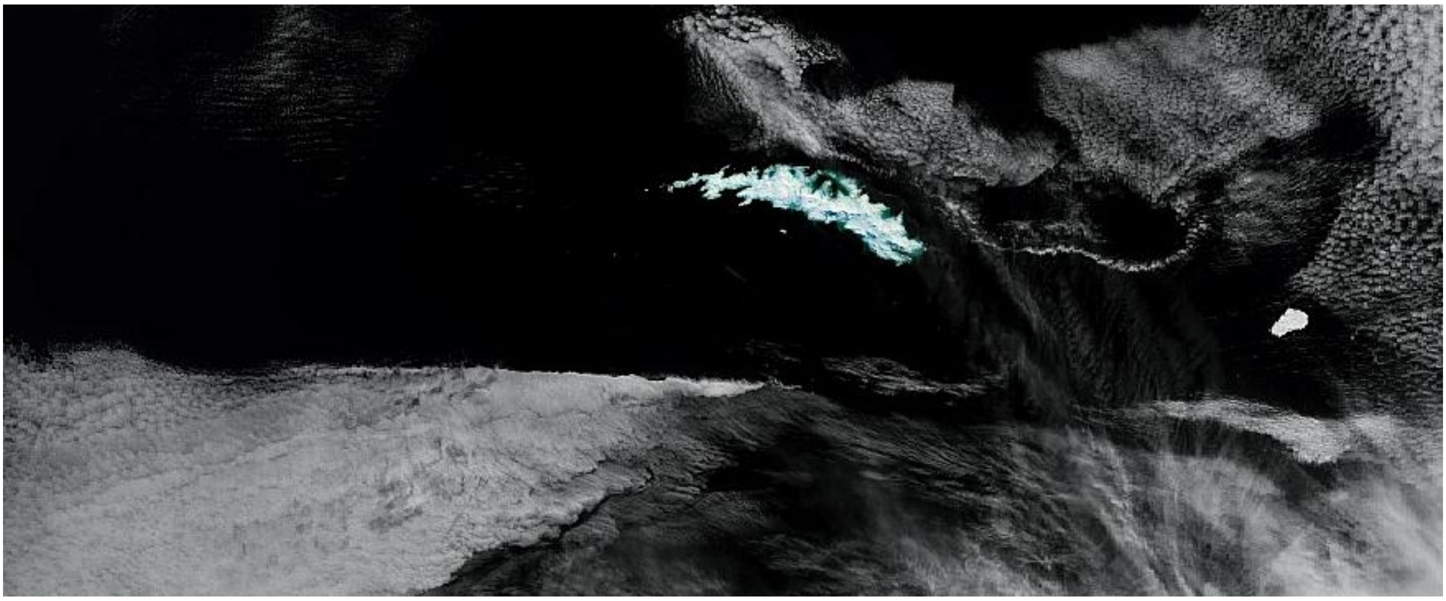
2009.02.16
Orbit: 36422
Travelling convective Cells over the "Mid-Atlantic Amazon Cloud Province"

Convective Cells - "Cutting" Phenomenon *.
This phenomenon looks (seen from above) like a sharp border between the field of convective close cells and usually cloudless sky. The border is more often a straight line, sometimes a bend-like one. As a result large close cells are often cut off like a solid substance in the middle. It can be supposed that the phenomenon is caused by the movement of the inversion layer. The straight-line or curved front of cold inversion layers will be printed downward and prevents the existence of the cloud cells. Cold air flows downward. The mentioned downward pressure can be affected by a high-pressure area or by a low frequencies oscillation in inversion layer.

[* my own tentative denotation]

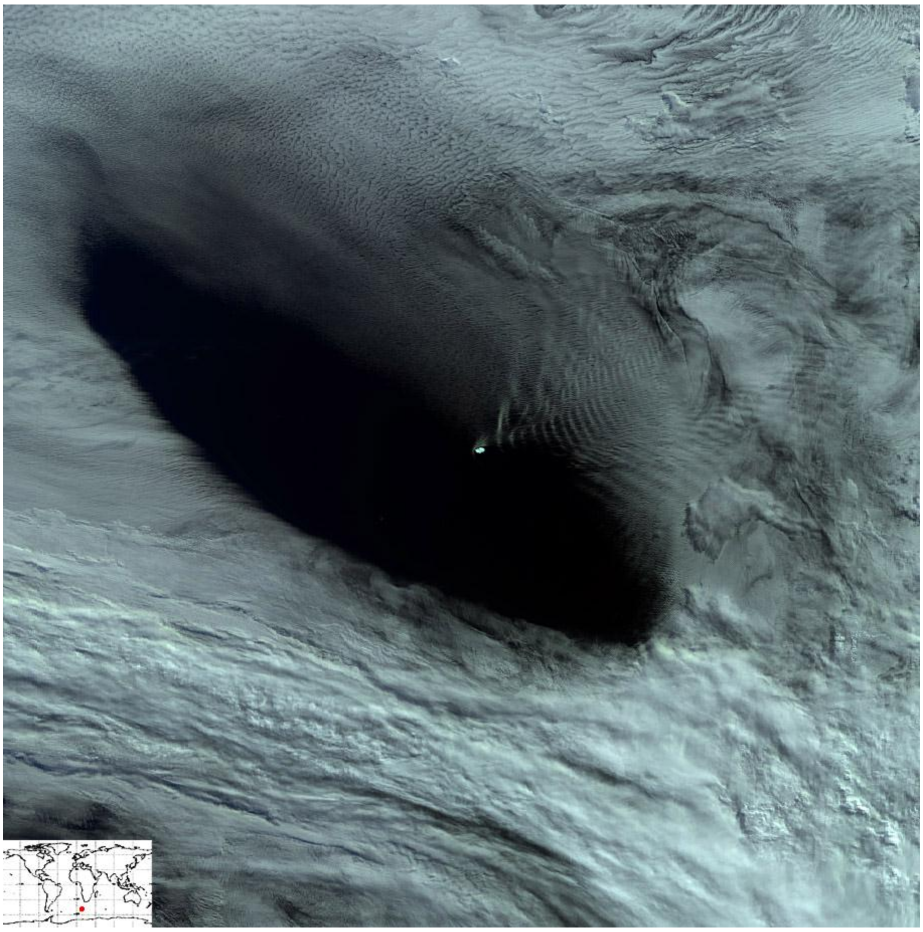


2006.07.24 Orbit: 22996
"Cutting" Phenomenon over Pacific close to the South Peru Coast



2005.10.01 Orbit: 18757
"Cutting" Phenomenon over the South Atlantic in the Southwest of the South Georgia island

"Convective Cells" - "Black Holel" Phenomenon *



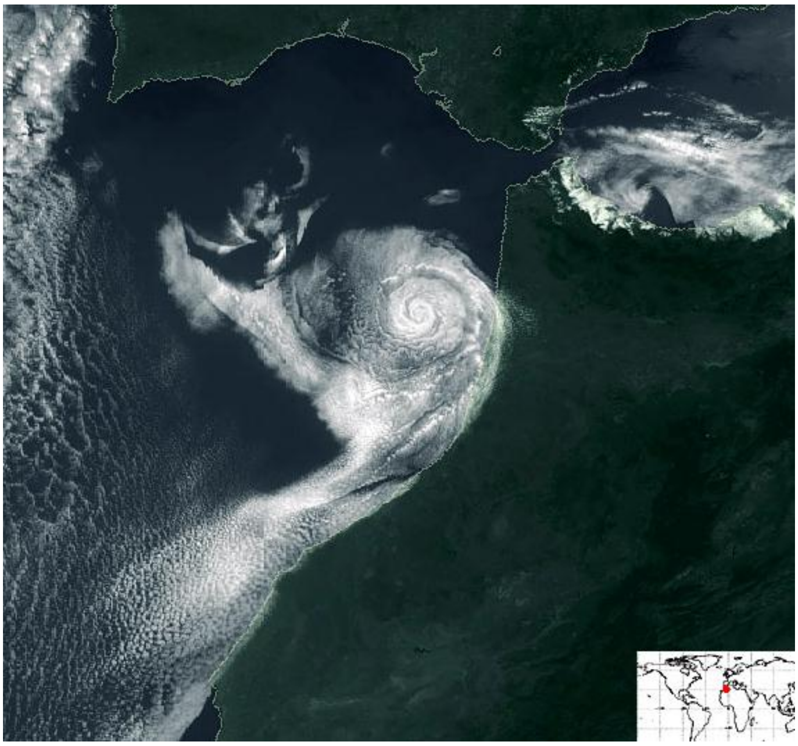
The absence of cloudiness within Convective Close Cells structures may be explained by anticyclone developments (which is proved by the near surface wind direction around the "black hole").
Such phenomenon may occur in the area above masses of cold water where cold dry air rushes out from the upper layers of the atmosphere, driving away the cloud cells in its way.
The holes are usually round or oval, but their shape is often irregular, "lacerated". This phenomenon mainly emerges within low small-cells convective cells structures in the circumpolar regions above water surface, mostly above the waters situated close to the Antarctic. The edges of black holes usually make up small closed convective cells, nearly dissolved in the air. The holes may be several dozens of kilometres in size or much larger - up to several hundreds of km. Cloud black holes do not emerge often in the atmosphere.

[* my own tentative denotation]

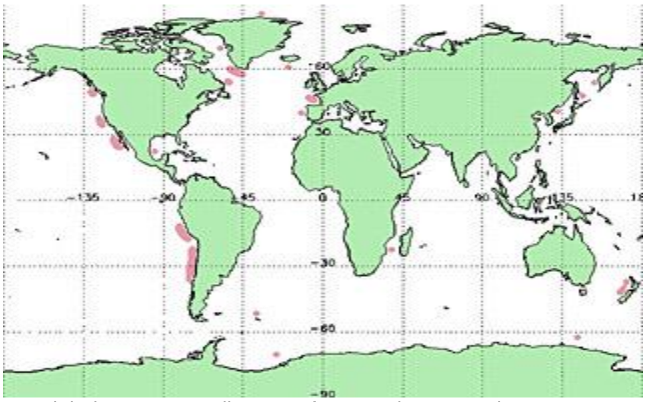
2008.02.22 Orbit: 31266
A "cloud black hole" phenomenon around Bouvet Island.

"Convective Cells" - "Coast Vortex" Phenomenon *

The phenomenon, which was tentatively called "coast vortex", can be observed in the form of medium sized (20-150km) low cloud eddies over the water in the frontier "sea-country". During the observations of "coast vortex" phenomena it was noticed that over the neighbouring country is nearly always clear. This could refer to high pressure area. It is (in cases of "coast vortex") not rare that the neighbouring country has rather mountainous coast area.



2007.06.24 Orbit: 27789
A "coast vortex" phenomenon close to the northwest of the Morocco coast, Gibraltar



Global occurrence diagram of "Coastal Vortex" Phenomenon

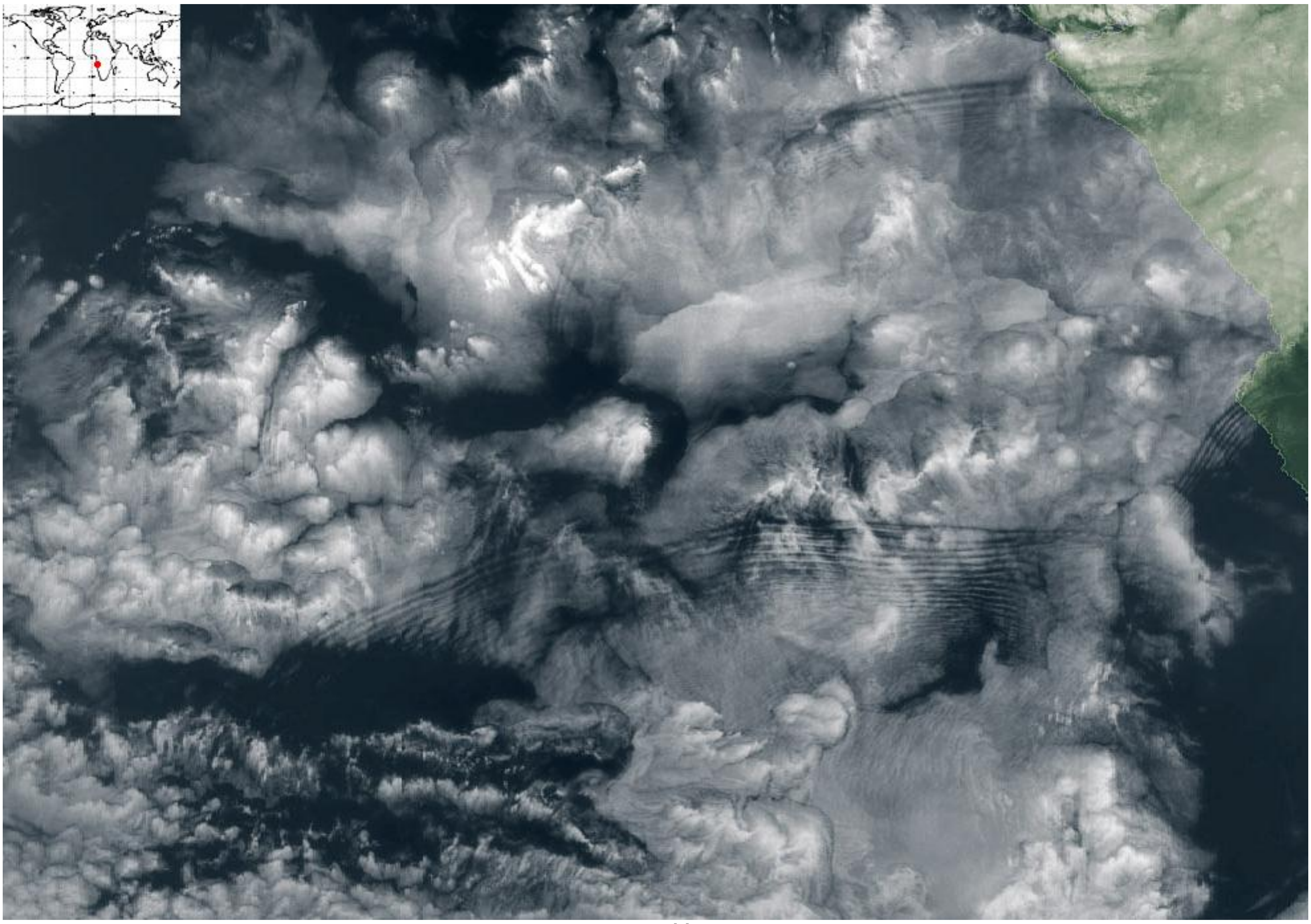
The cause of the emergence "coast vortex" phenomena could be the following. In a high pressure area above a land (not rare - above a high land) the mass of dry air sinks toward the earth's surface and flow finally apart. There are hardly large convective cloud cells above the neighbouring sea area. If in this area the winds in the land direction occur, they force to move the clouds in same direction. However it is obstructed by conditions dominant over the country. The eddy can appear by air friction. It could be the other reason: cold land air masses heat up over the water and rise. The wind over the water affects the upward rise. The Coriolis Effect veers the clouds into appropriate direction.
The phenomenon is to be observed rarely and only in certain places with mostly more highly coastal area. Sometimes it occurs above large bays, where developing eddies flows the coastal line around.

[* my own tentative denotation]

"Convective Cells" - "Wave over" Phenomenon *

The wavelike convective close cells structures were tentatively defined as "Wave over" structures.
The "gravity waves" can appear when the relatively stable and stratified air masses are disturbed by a vertical trigger from the overlying (or underlying) environment. The inversion layer (sudden increase of the temperature with the height), which lies a little bit higher than convective close cells field, and is affected by gravity waves, has an effect on the underlying calm layer of convective clouds in such a way that those reflect the wave picture.
The wave front shows often arc-like or nearly straight-line structures. Thees structures are not seen frequently.
They can be observed mostly over Southeast Atlantic close to the West Africa coast, around the sound coast of South America, over North Atlantic and Northwest of Indian Ocean.

[* my own tentative denotation]

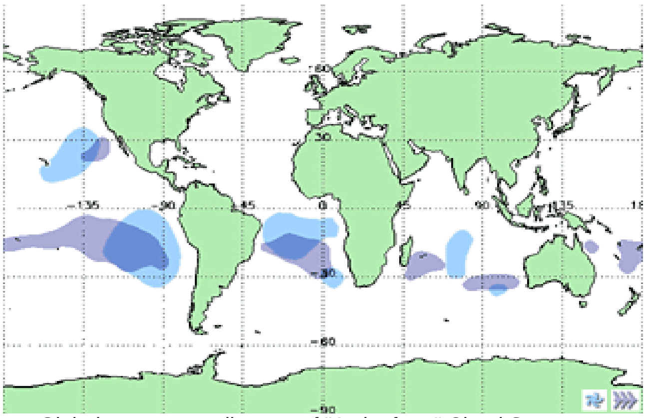


2007.09.02 Orbit: 28790
"Wave over" phenomenon over the east of Atlantic ocean close to the coast of Angola

"Actinoform" Cloud Structure *

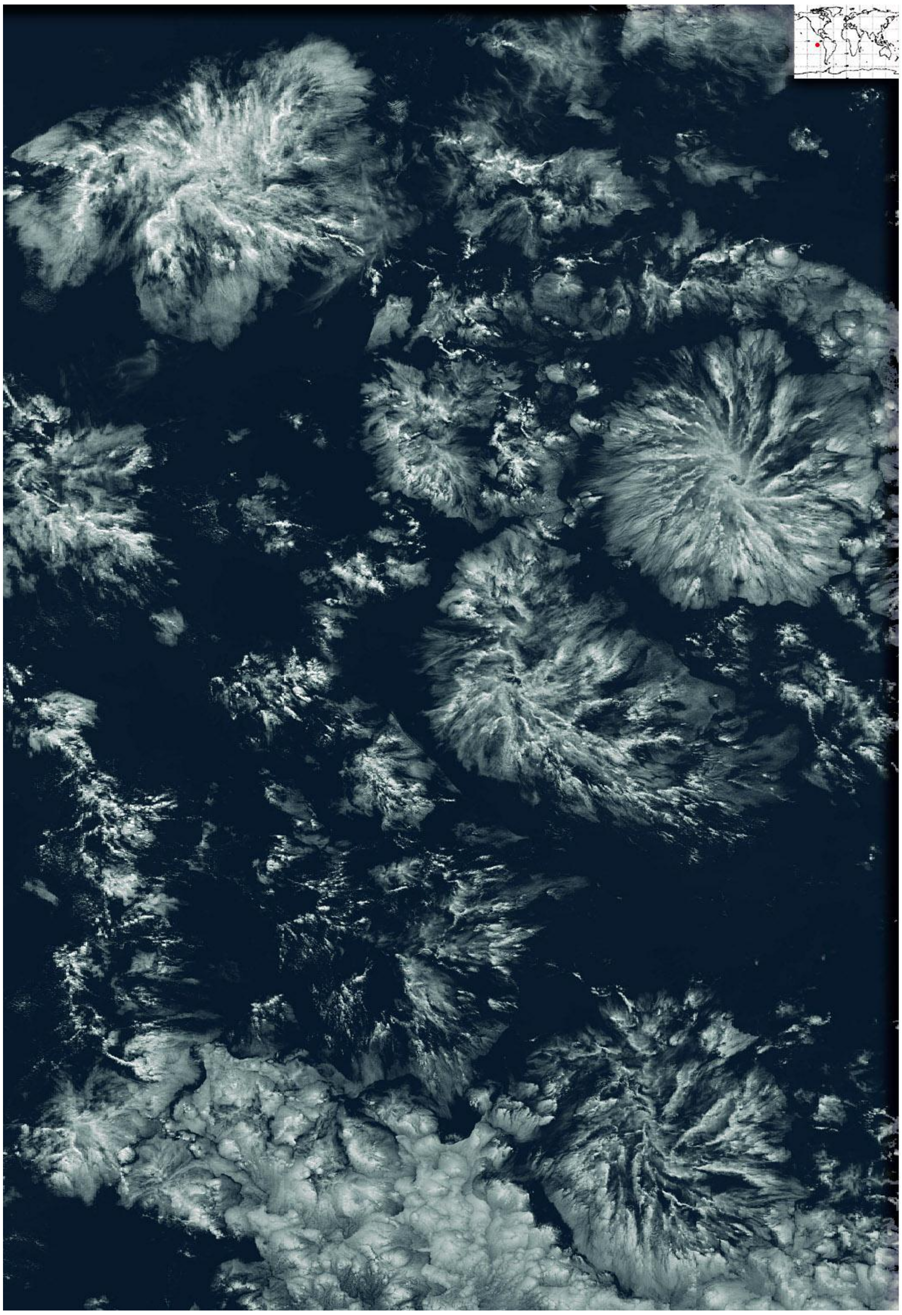
The Actinoform Structure (named after the greece actinos, a beam) may have two forms:

- round or oval cloud formation where there appear to be radial symmetry and sometimes even helical motion. These formations, when seen from high above, resemble veins of a leafe. In this case the dimension of the structure is from 80 to 400 km (seldom more).
- long (up to thousands of kilometers) bands that consist of "accrete" cells. When seen from above this structure looks like a huge centipede with well-marked spine and multiple ribs. In this event the width of the band is 70-120 km, and the length is from several hundreds to 1-1.5 thousand (or even more) km.

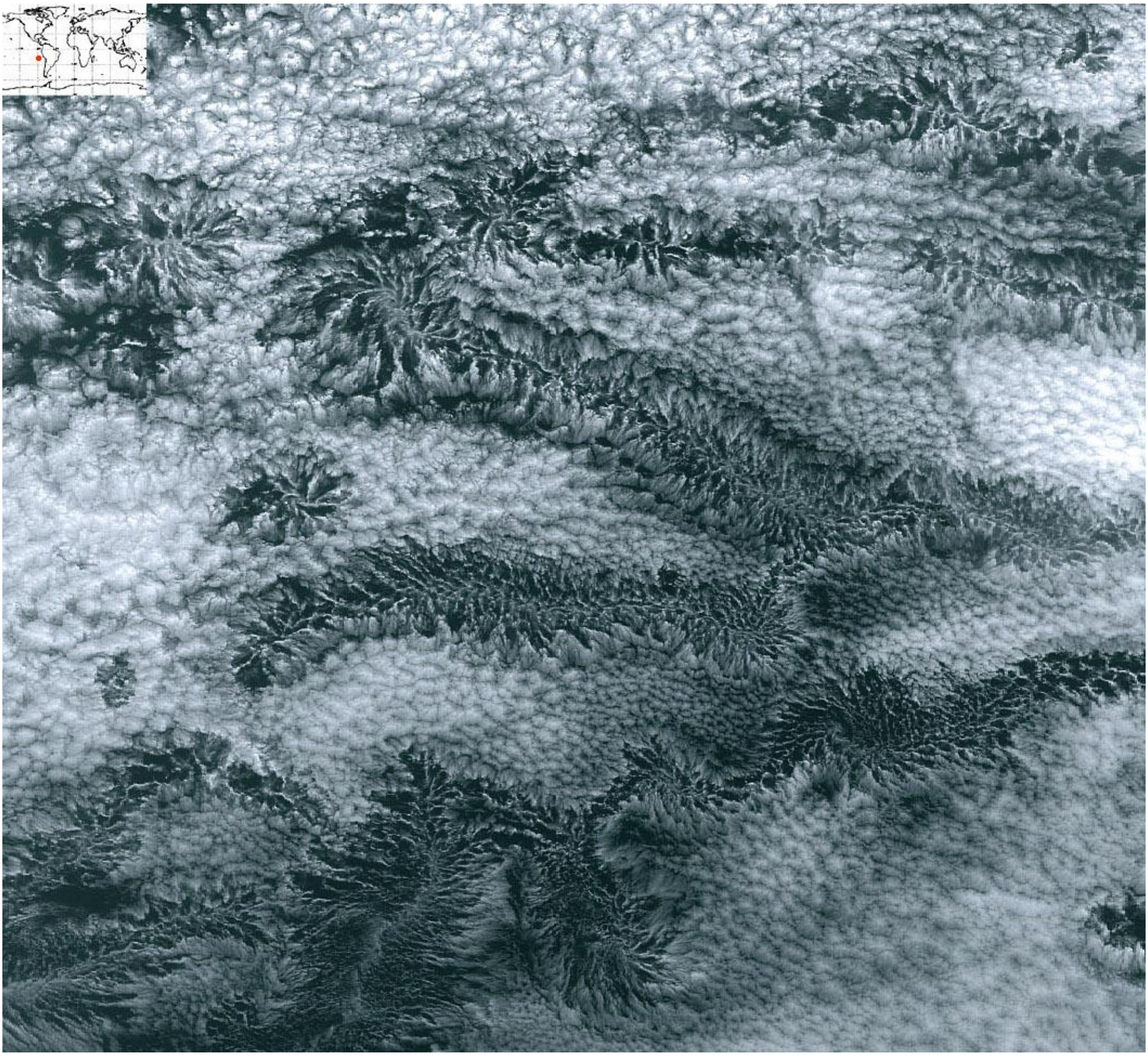

Global occurrence diagram of "Actinoform" Cloud Structures

The cloud top height is from 0.6 - to 2 km, seldom to 2.5.
It is interesting to note that according to the measurements the cloud top height in the centre of round structures (as well as the "spine" of the band structures) is always 300-700 m lower than the cloud top height of the clouds located in the periphery of the structures.
Actinoform Structures are not seen frequently, though they can be seen quite often. They can be observed where there are large fields of open and close convective cells: mostly over East Pacific not far from the Peruvian cost, as well as not far from the Atlantic coast of Brazil and above the Indian Ocean close to the coast of Western Australia.

[*common name]



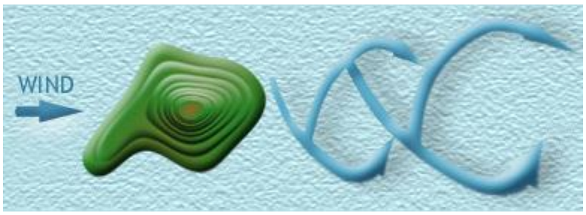
2005.06.27 Orbit: 17386
Round "Actinoforms" Cloud Structures over the east Pacific in the south of Equator.



2007.07.17 Orbit:28121
"Actinoforms" Cloud Structures over the east Pacific.

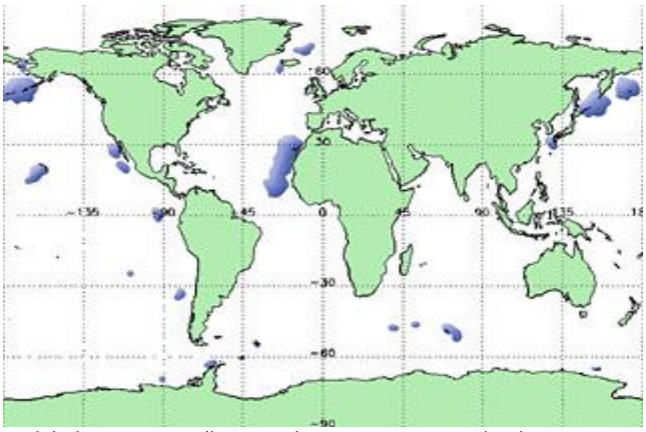
"Karman Vortex" Cloud Structure

The clouds of this structure look like a set of organized turbulences within the layer of "Close Cells" structure. This phenomenon is well-known as Karman vortex or Karman turbulences.

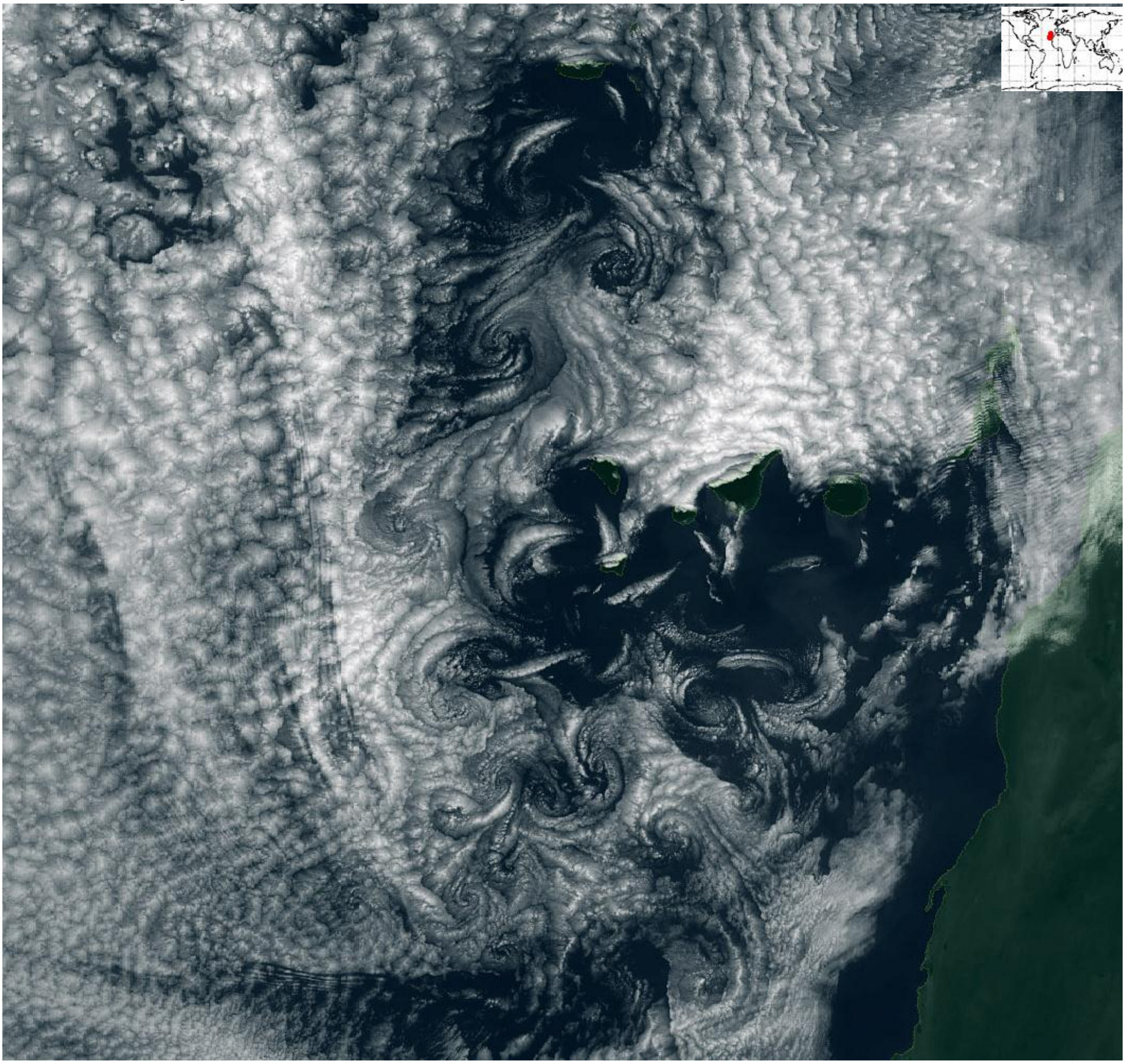


Each swirl turns (seen from above) in the clockwise direction on the left side of the thereby formed cloud street and against the clockwise direction on the right side. This structure emerges usually above the sea surface if the temperature of the cold air gradually rises. This leads to the strong flowing constant wind, which blows on the lower level. If the wind has a significant barrier in the wind direction (normally a hilly island with the summit that raises some of meter more highly than the cloud top height of the surrounding cloud layer), can a turbulence street form. The further away the barrier the turbulences spread, the bigger they appear.

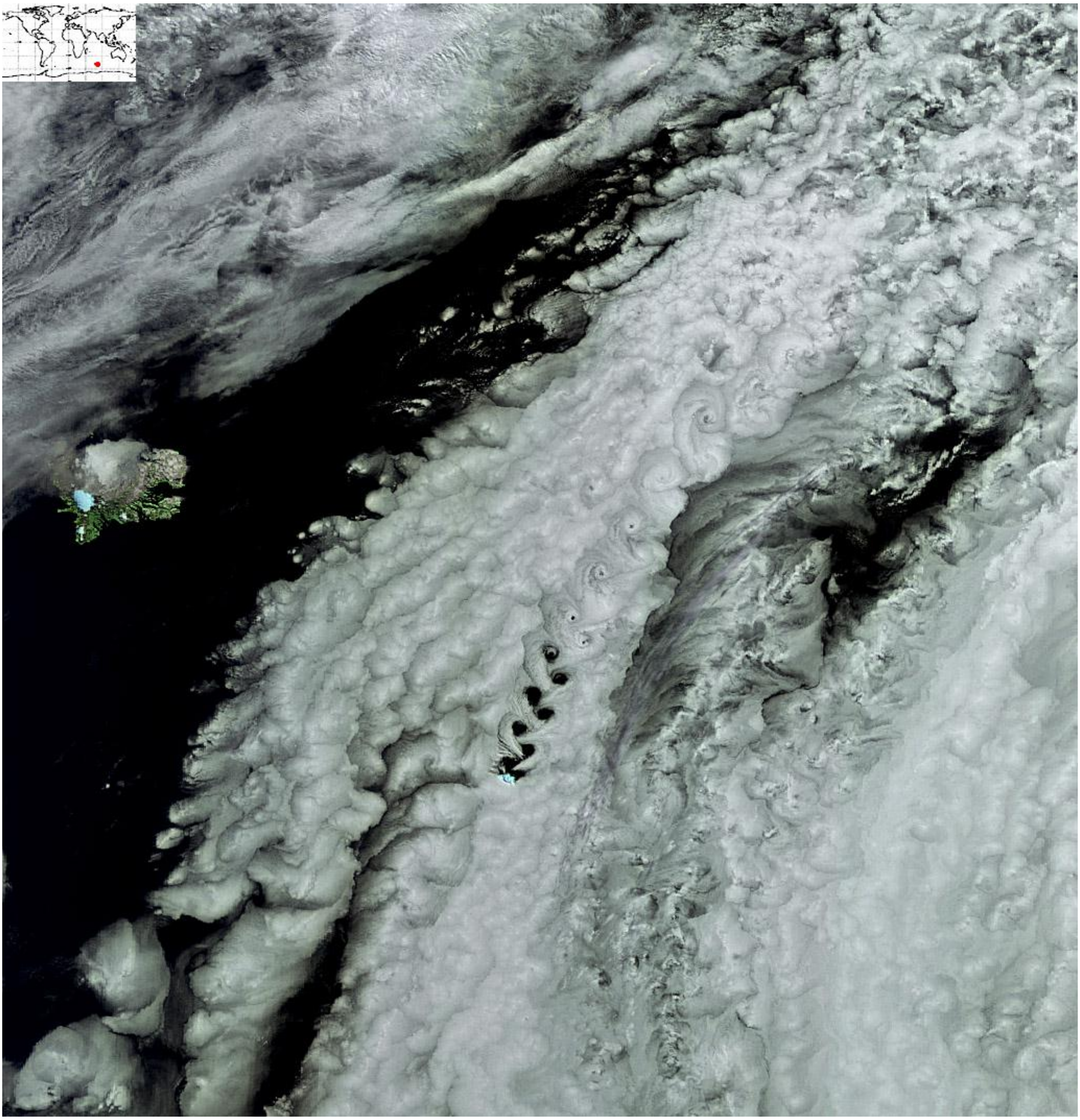
During the observation period this structure was seen only in few places: at most above Canarias, Cabo Verde islands and over Aleutian and Kuril islands, in addition, above Cheju, Guadalupe, Jan Mayen, Alexander Selkirk, Heard and some other islands.



Global occurrence diagram of "Karman Vortex" Cloud Structures

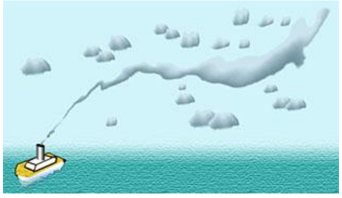


2006.07.14 Orbit: 22851
"Karman Vortex" over Canarias.

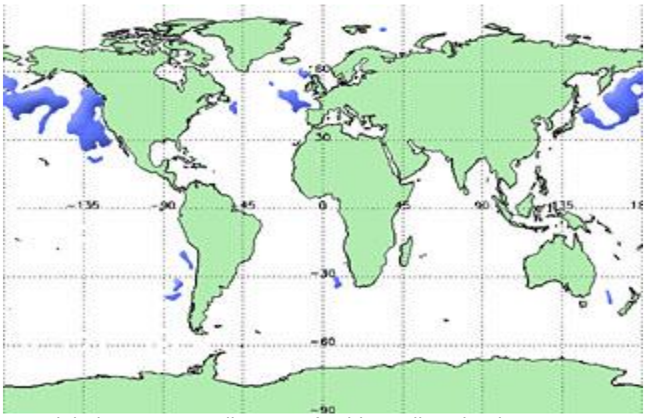


2009.02.02 Orbit: 36216
"Karman Vortex" caused of the Heard Island

"Ship Trails" Cloud Structure

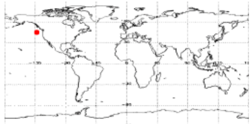


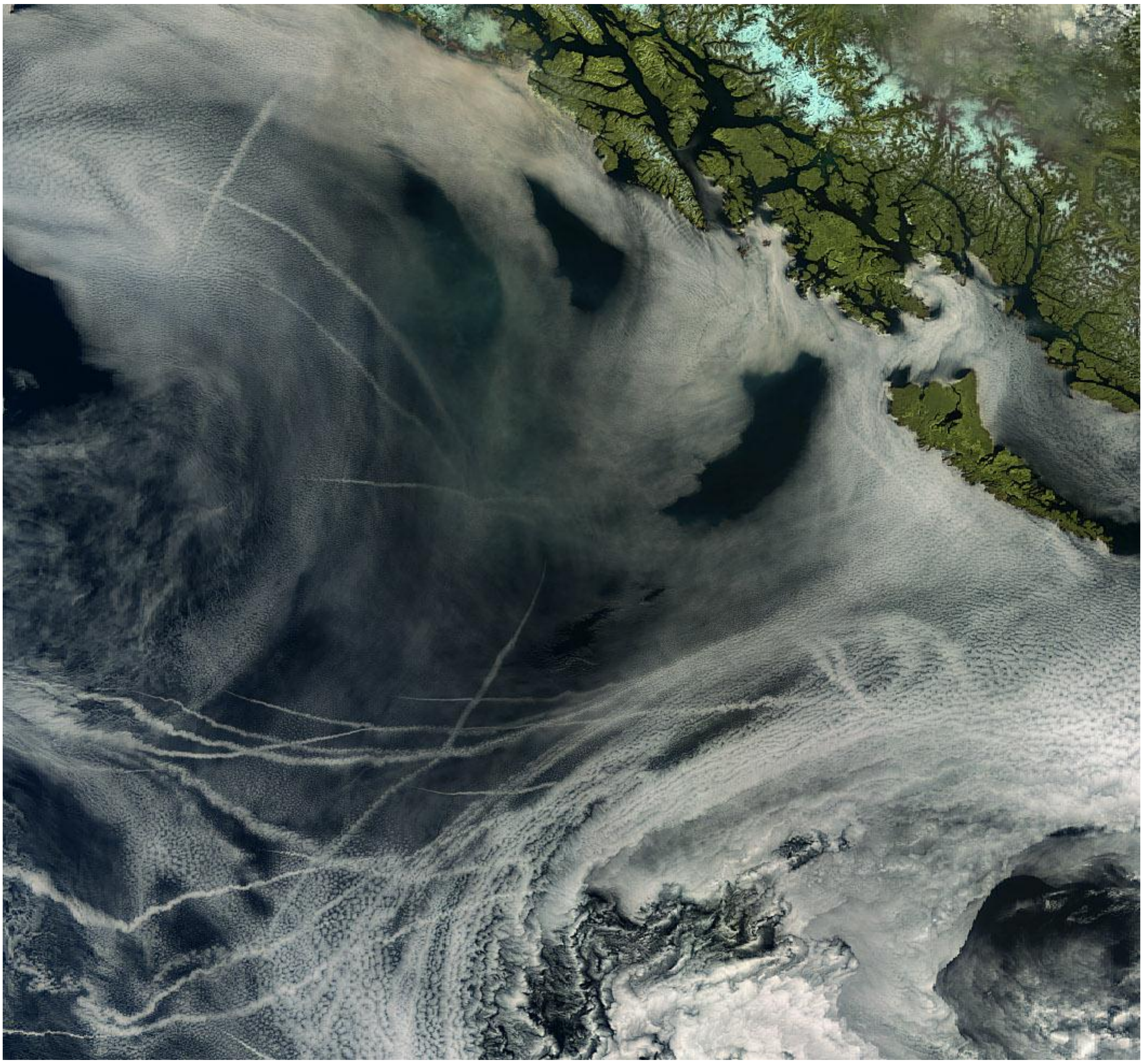
Clouds of this structure, embedded in a layer of small and low convective close cells structure, can be observed above a sea areas. Cloud top height does not exceed the height of 1-2km. The dimension of such cloud lines reaches as much as 30 km width (sometimes up to 50 km) and up to 1000 km (and more) length.
In the image of visible range it has the higher brightness than the surrounding low clouds, however it can not be recognized in the infrared picture, because the cloud top height are low. However within the infrared range they can be only badly recognized, because the cloud top height is low and accordingly warm.
It is supposed that this structure has an artificial origin, because it is connected with the navigation of vessels. The moving ships give off the fine particles (also called aerosols) and warm exhaust steam.



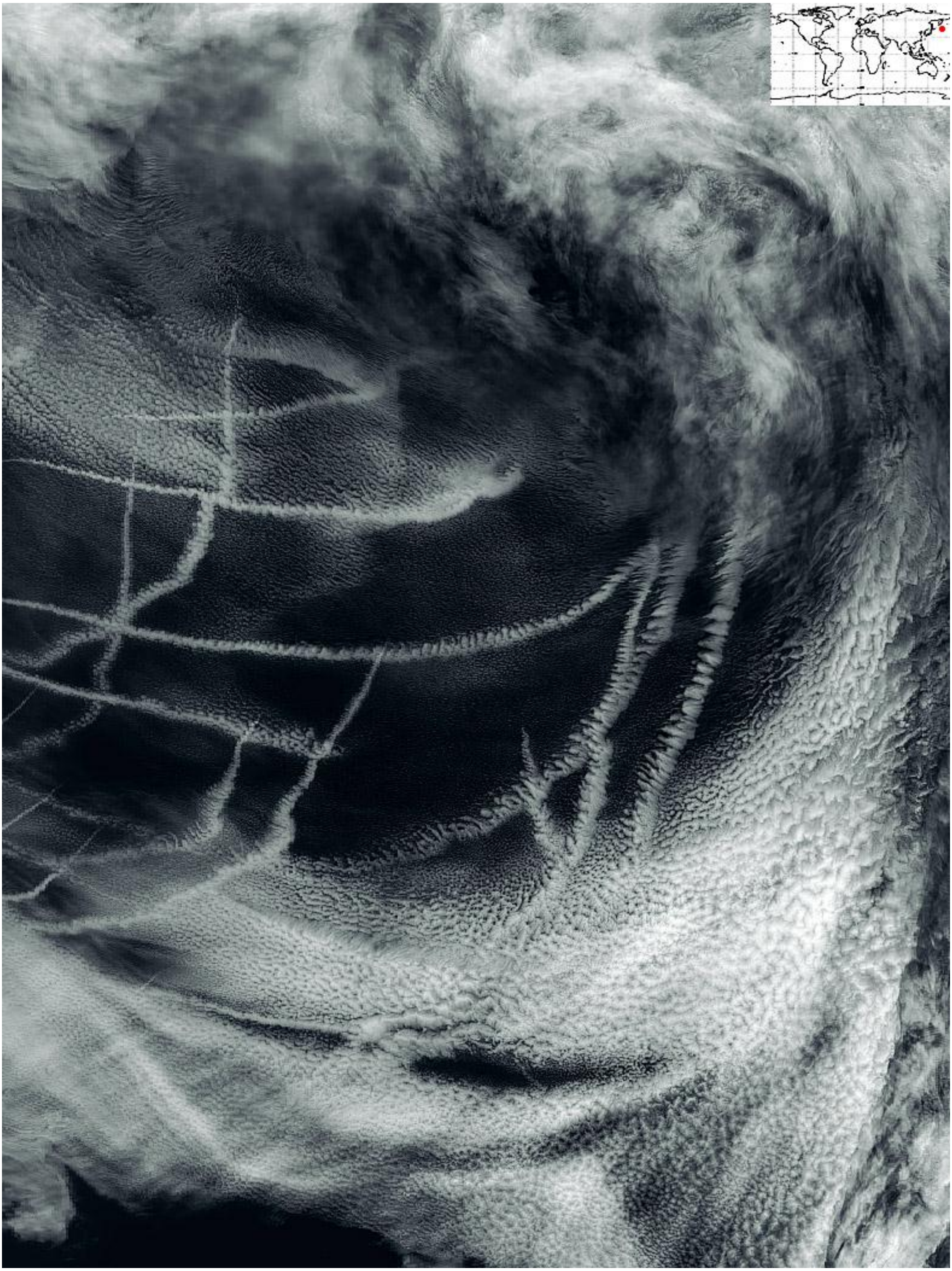
Global occurrence diagram of "Ship Trails" Cloud Structures

In a cool and humid atmospheric layer, which is connected with a high-pressure system, these particles become a condensation nucleus of clouds, absorb the humidity and produce the bright clouds. Those consist of the small droplets. The small droplets reflect more lights (within the visible range) than large droplets, therefore the clouds of "Ship trails" structure have the higher brightness than the surrounding convective cells clouds.
The "Ship trails" cloud structure can be observed mostly over North Pacific (close to the west coast of the USA, Aleuts, Kamchatka and northeast coast of Japan) as well as over North Atlantic (west coast of Europe, east coast of Newfoundland), rarely - not far from the Peruvian and Chile coast, coast of Namibia, Tasman Sea.



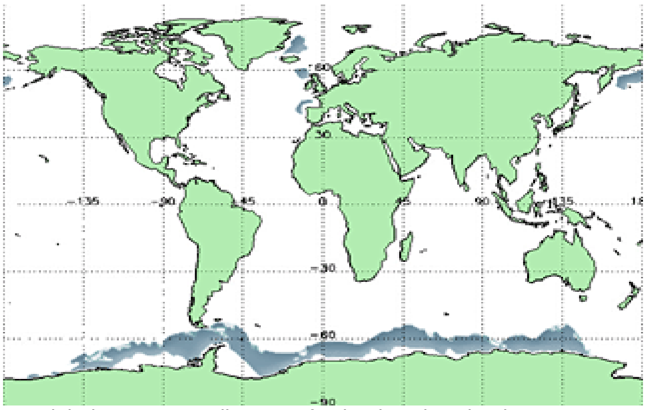


2009.07.09 Orbit: 38473
Ship Trails" over the north Pacific.



2009.06.26 Orbit: 38289
Ship Trails" over the north Pacific.

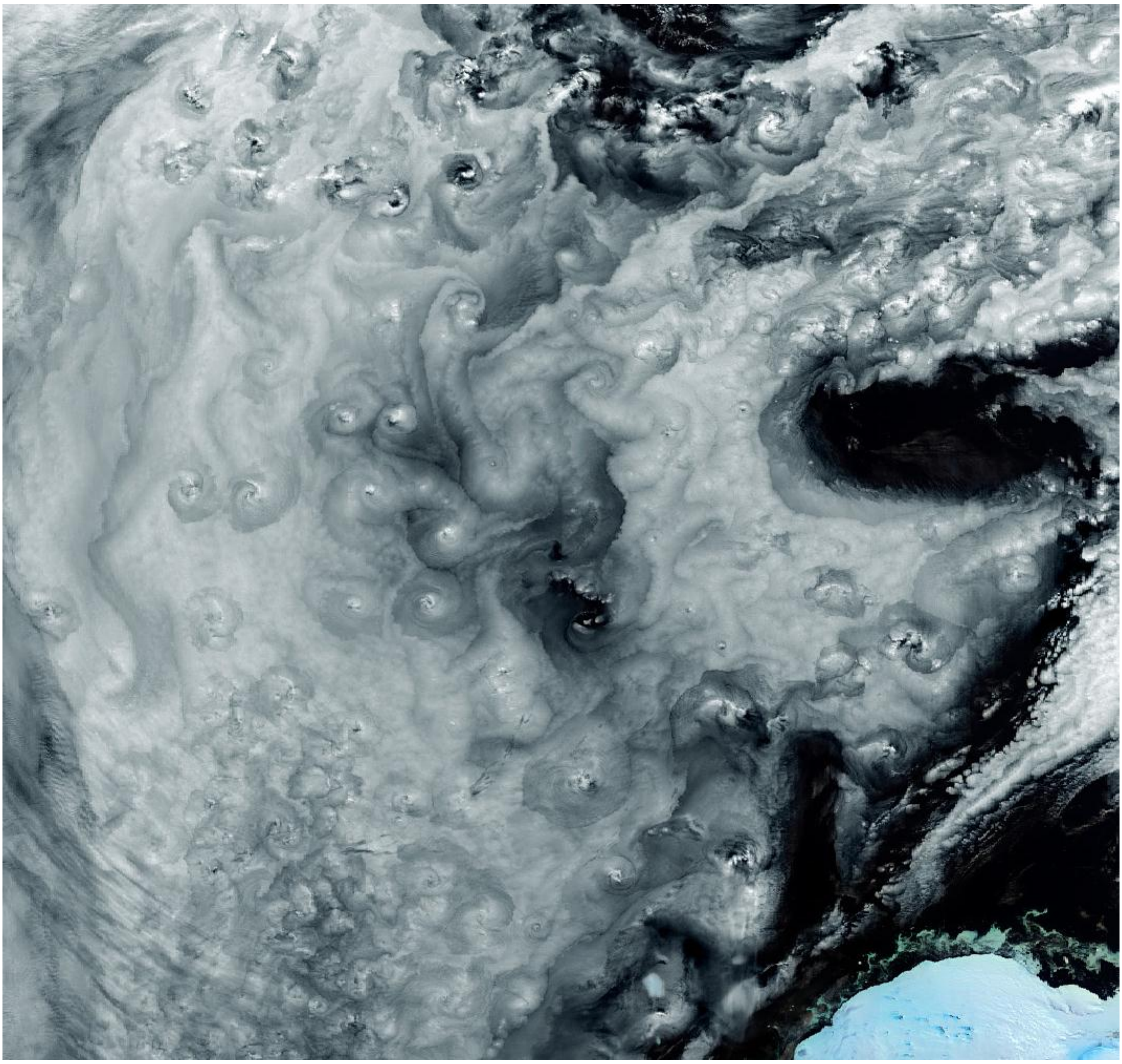
"Cloud Curls" Structure *



Global occurrence diagram of "Cloud Curls" Cloud Structures

Cloud Structures tentatively called Cloud Curls occur rather seldom and mainly above cold waters, most often above the circumpolar waters situated close to the Antarctic.
Cloud Curls usually appear in groups. The size of each curl varies from 40 to 80 km, rarely from 20-30 km to 120-140 km. Quite often the Cloud Curls top is a little bit lower than the surrounding cloud field top, and the curls themselves have an outer border which is well marked and clearly seen. An interesting peculiarity of this structure is that the top of the curls' center is often lower than the top of their bulk (forming some kind of a funnel-like relief) and has a greater albedo.
The nature of the rise of such a structure is not clear. It is possible to assume that the discrepancy in the temperature of the sea surface beneath the cloud cover may stipulate for the initiation of local winds. These winds interacting with the prevailing mesoscale wind and experiencing the Coriolis effect (the cloud curls twist in one and the same direction depending on the hemisphere, and there are no swirls less than 15-20 km in size), which becomes stronger as the cloud approaches the Poles, may form swirls. The cold air is drawn out from upper atmosphere layers into these swirls, cooling them. As the result the swirls go down compared with the surrounding cloud field. Cold heavy air that amasses in the center of the funnel cools the remaining clouds, besides the reduction of pressure leads to the rise of the ice-point, so that ice crystals appear (which is accompanied by the increase of their albedo), and pushes them more downward.

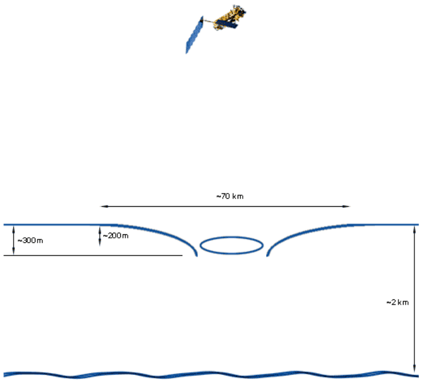
[* my own tentative denotation]



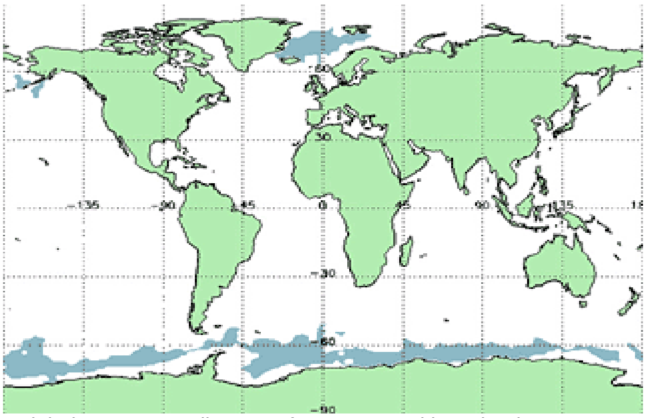
2006.02.01 Orbit: 20514
These structures are often observed above Antarctic circumpolar current close to the Enderby Land.

"Dragon-Looking Cloud" Structure

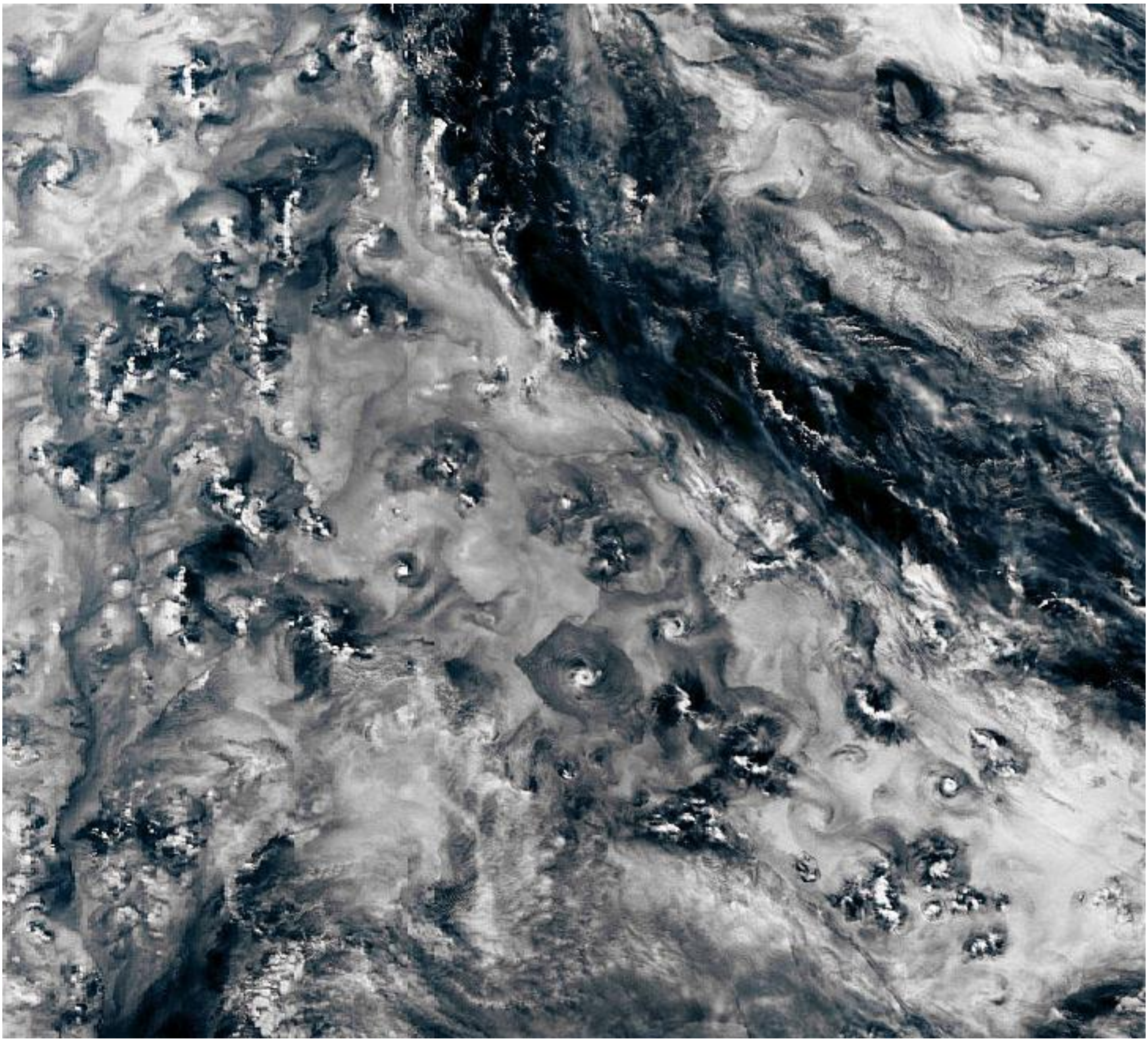
The "Dragon Eye" structure was so called because I discovered this name on the NASA Visible Earth web page (http://visibleearth.nasa.gov/view.php?id=57703).



It would be natural to suppose that the warm streams of air go upward, "breaching" a layer of stratocumulus clouds, where ice crystals fluffy cloud with great albedo further (increasing in the height) appear. At the same time the cold dry air moves downward, surrounding the warm "column" along its perimeter and breaching the layer of stratocumulus clouds from above, driving away clouds. However the MERIS Level 2 data show that the upper board of the clouds (the so called 'eye"), is not located over the upper boarder of the surrounding cloud field. Such structures are down-directed funnels and the clouds located in the centre, underneath of the upper board and have great albedo.

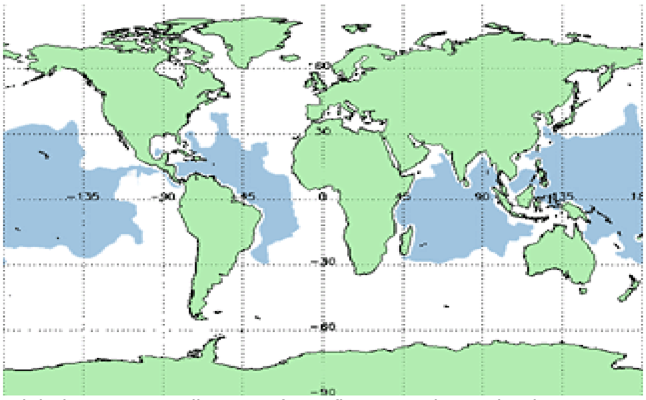


Global occurrence diagram of "Dragon-Looking Cloud" Structures



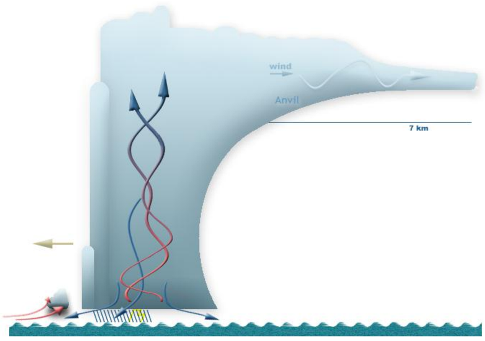
2005.01.05 Orbit: 14904
"Dragon-looking cloud" structures over the South ocean close to the Tange Promontory Peninsula

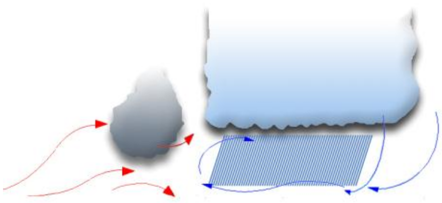
"Outflow Boundary" Structure



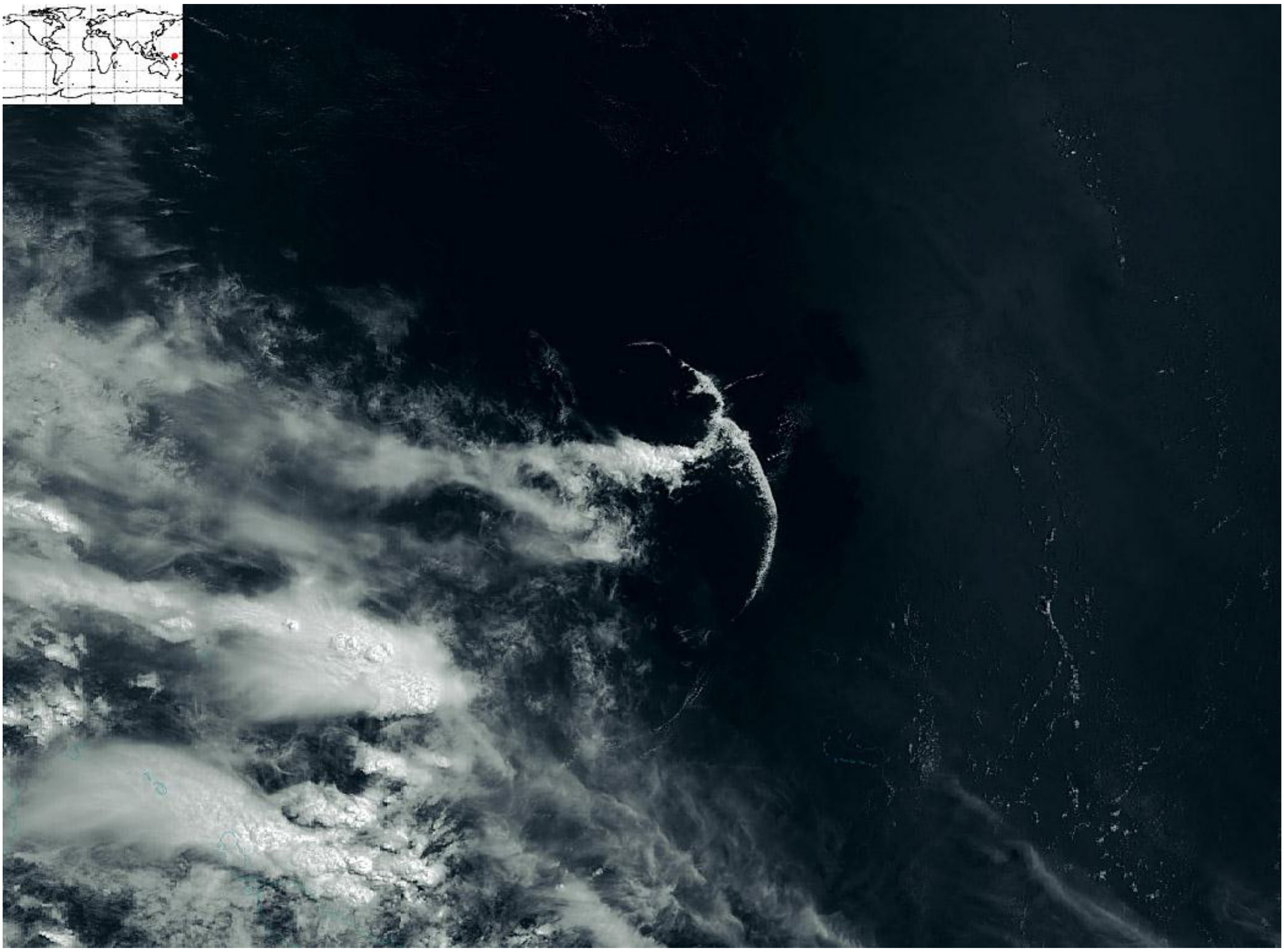
Global occurrence diagram of "Outflow Boundary" Cloud Structures

Warm air rises up at the border of warm-humid and cold air masses flowing one to the other. Therefore it is cooled down, which leads to the condensation.
So formed clouds are often seen from a satellite as a narrow circle, an arc, a ring segment or a sickle.
Cloud top height: 1-2 km.
A part of the regarded cloud structures is connected with large more-cellular thunderclouds.
Outflow boundary develops if a cold front that is connected with the low pressure area or large thunderstorm cell (general: Mesoscale Convective system) penetrates wedge-like into the offshore warm sector.
If in a convective cloud system rainfall (or even hail) begins, the against-flowing warm upwind is cooled down and turns over downward, which leads to the accumulation of cool air in the near-surface volume.

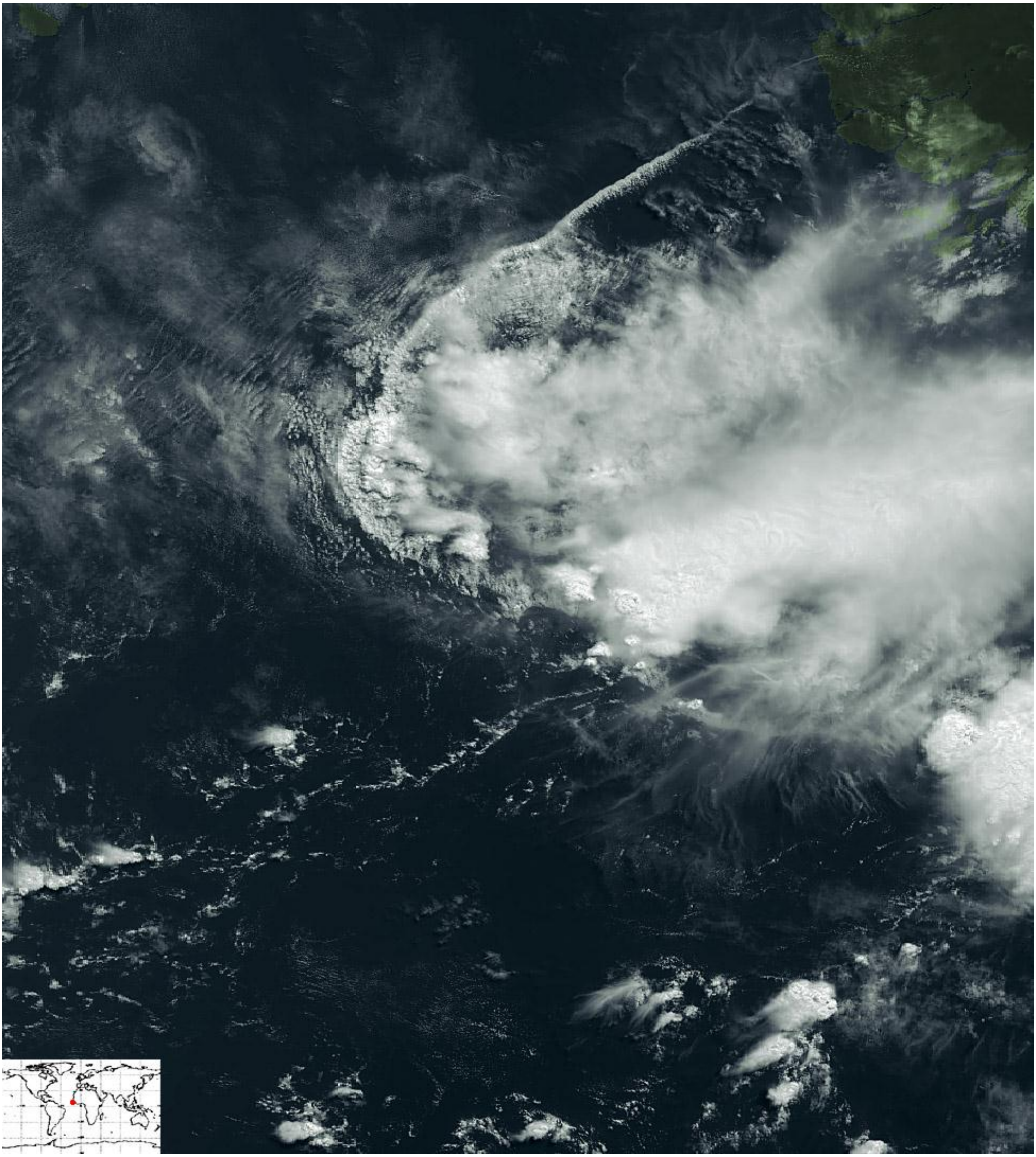




This layer of cool air moves in front and together with the convective system (e.g. thunderstorm cell cluster) and raises there warm-humid air, which flowed towards the thundercloud, whereby the typical "arcus clouds" emerge. They can be recognized on the satellite images more frequently as a "shelf clouds".
The further the clouds far away from the front of the "outflow boundary" structure are (however within the structure), the more largely their cloud top height is: from 1 km to 3.5 km; sometimes more.
The "Outflow Boundary" cloud structure is normally observed within a zone ±30° by the equator.



2009.03.20 Orbit: 36886
"Outflow Boundary" Structure over the west of Pacific in the northeast of the Salomon Islands



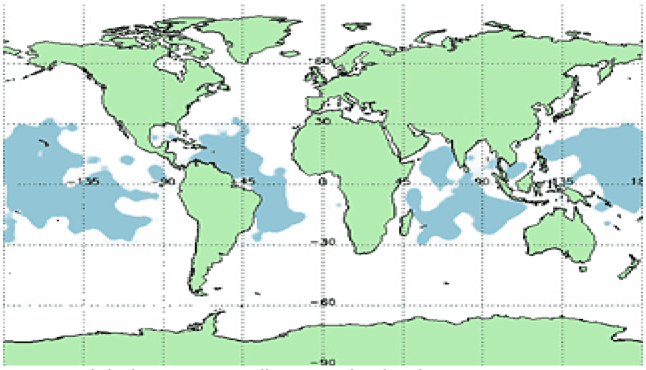
2008.06.07 Orbit: 32785
"Outflow Boundary" Structure over the east of Atlantic in the southwest of Guinea Coast.

"Cloud Arc" Structure *

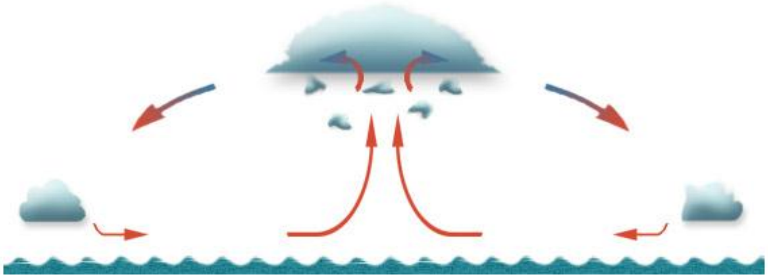
The structure looks from above with optimal conditions (there is hardly cross-wind) circular or oval. There is more highly lying cloud mass in the centre of the very narrow circle belts of cumulus and stratocumulus. The luff side very often disappears (or is squeezed along the wind direction) and the cloud form of the centre shifts to the lee side. It can be also structures observed, where there are no clouds insides; then only empty circles is seen.

The size of this structure is from 15 km (the smaller one was not noticed because of the resolution of satellite images) up to 250 km and more.

The Cloud top height of the circular belts is 1.5-2.5 km; the Cloud top height the interior clouds is 3-3,5 (sometimes to 4,5) km. The structure emerges normally within +-30° latitude: above central and west Pacific, above west Atlantic, above Indian ocean usually in the south of equator.



Global occurrence diagram of "Cloud Arc" Structures



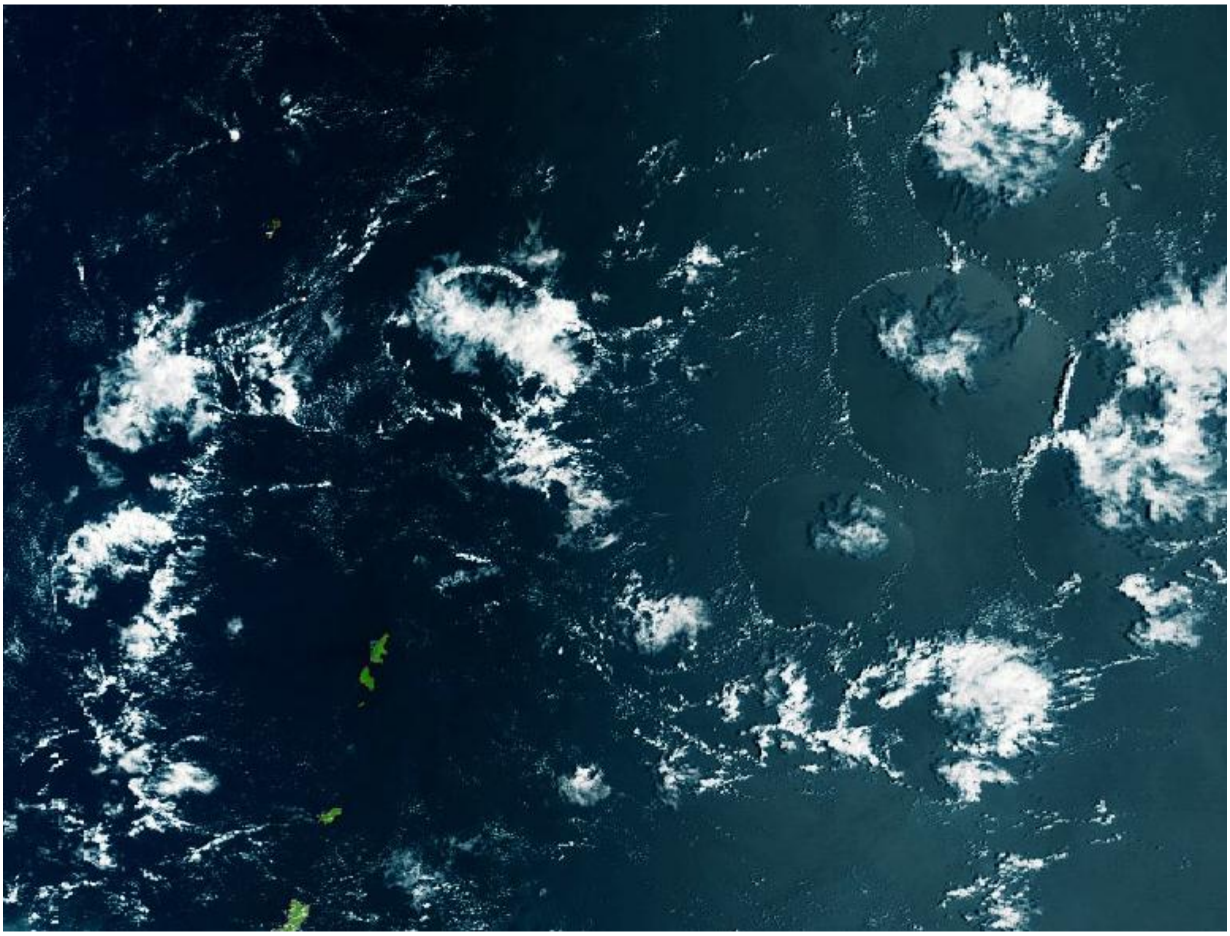
While air rises to inversion layer, it spreads horizontal in all directions, until it finally cools and sinks down back to the sea surface. This process pushes all existing small cumulus clouds away of the central region of convection. In addition if air sinks, it warms and prevents the forming of other small clouds. Therefore the area within the circle is kept cloudless. The horizontal flow of sinking air becomes rather weaker on the circle border. It will be influenced of central rising flow. Air moves towards the centre now, where it can rise again.

It is interesting to observe the form of the sea surface under the "Cloud Arc" structure.

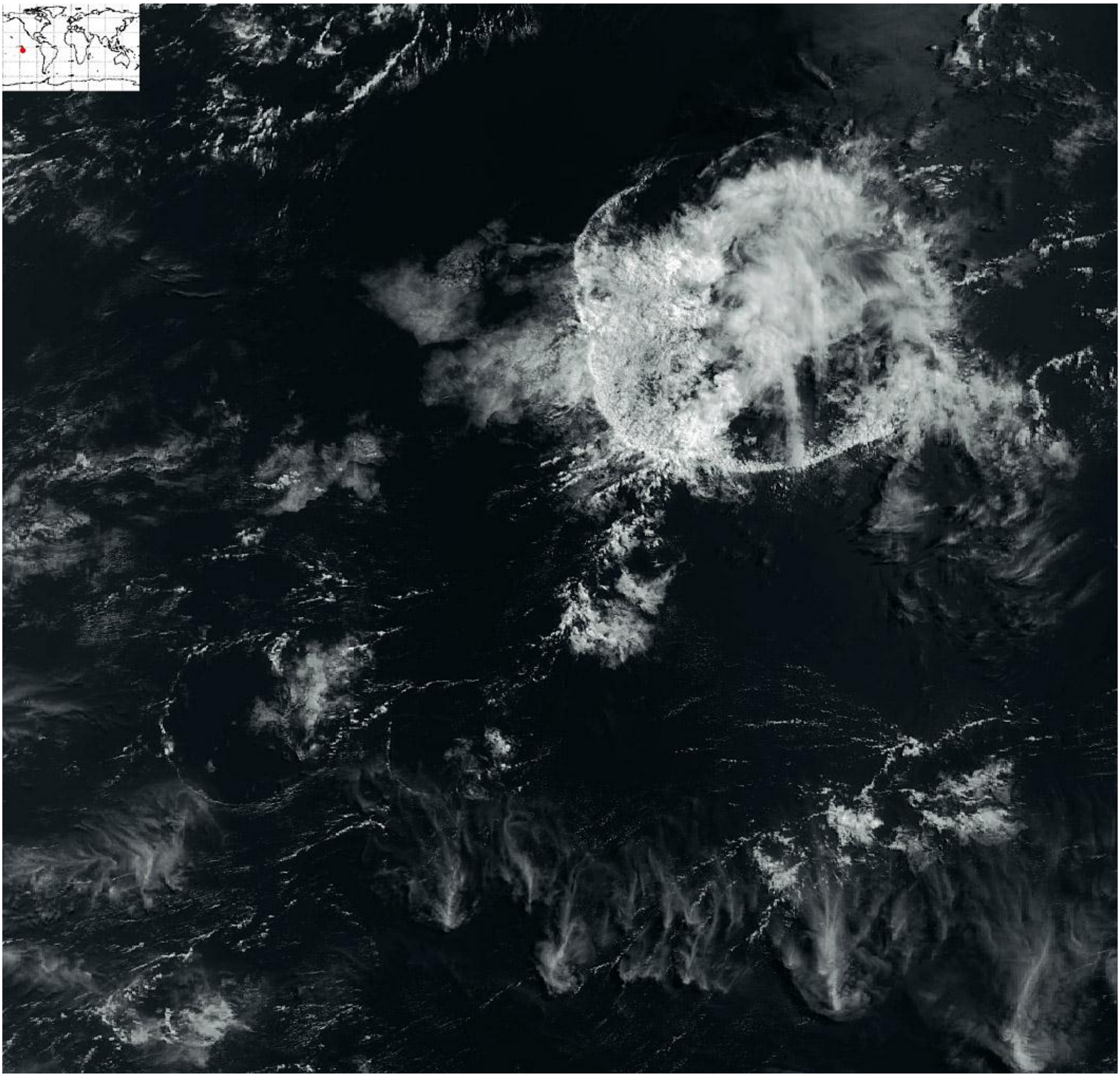
If this structure lies in a sun glint area for the satellite point of view, the brighter lighting of the sea surface from the sun side is seen, so it looks that the water surface which is under the structure would raise a little.

The phenomenon could be explained as follows. The deeply flowing wind is stronger near to the centre of "Cloud Arc" cell. It produces the waves, which reflect the sun light less. From the other side the water surface could be really sucked upward with the air, which rises in the centre of the cell. The sea surfase rises by a very small amount so, that it can be noticed.

[* I found this name ca. 6 years ago in the internet as an image description, but I can not remember the link]

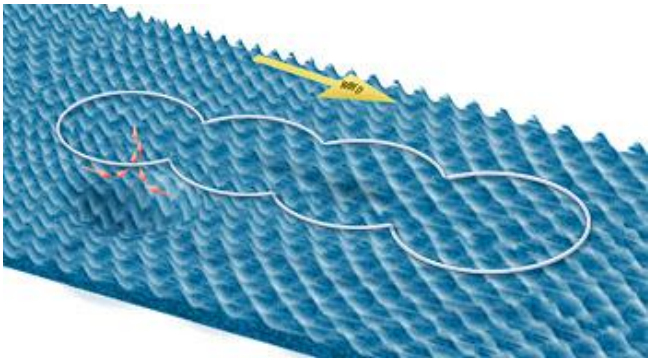


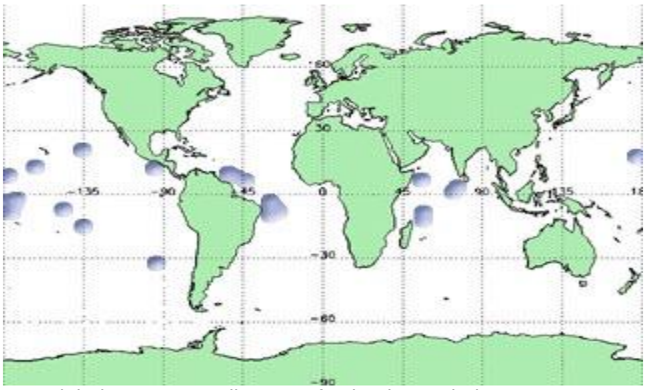
2006.03.14 Orbit: 21098
"Cloud Arc" Structures over the Pacific close to the Northern Mariana Islands



2008.03.31 Orbit: 31816
"Cloud Arc" Structures over the east Pacific

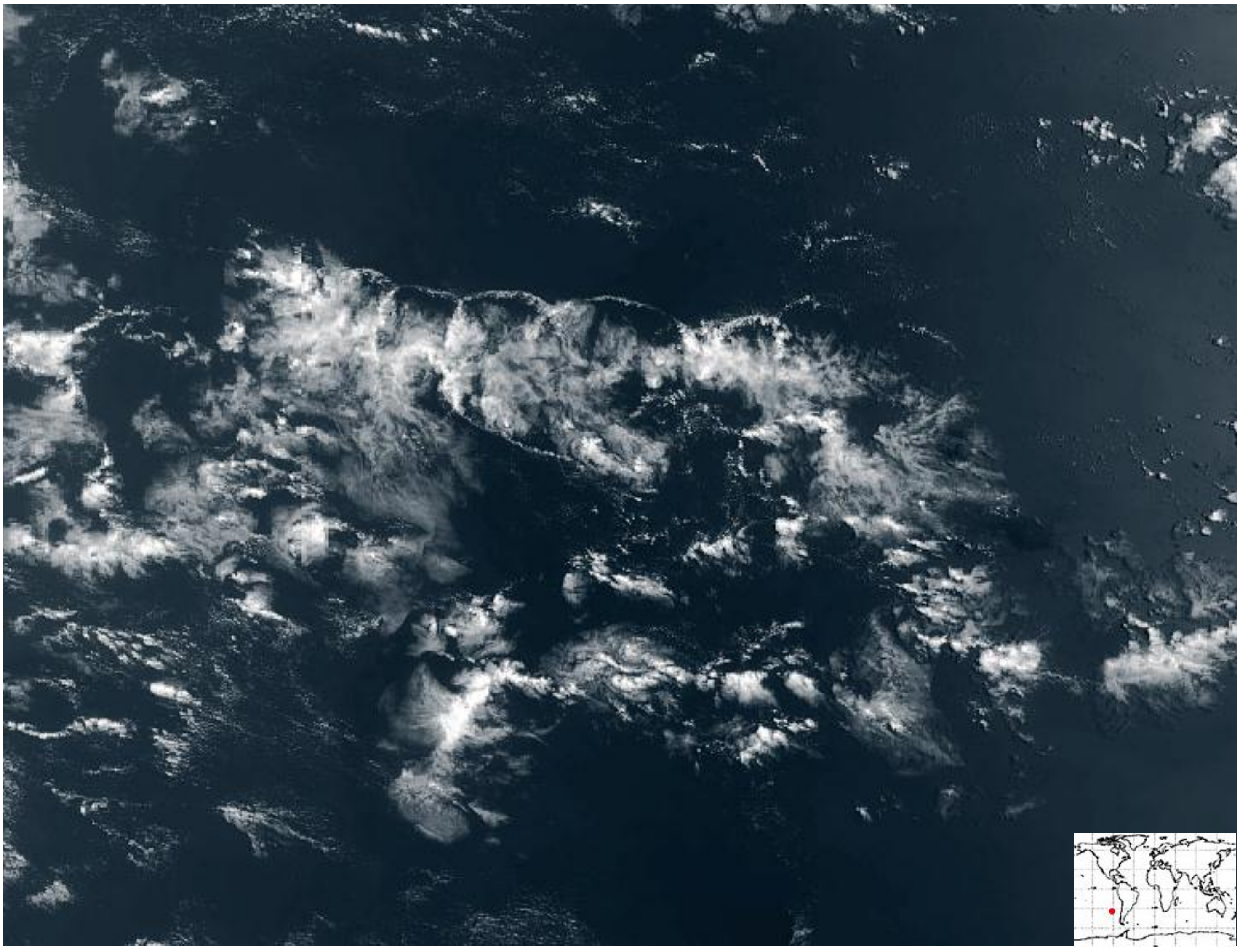
"Cloud Arc Chain" Structure





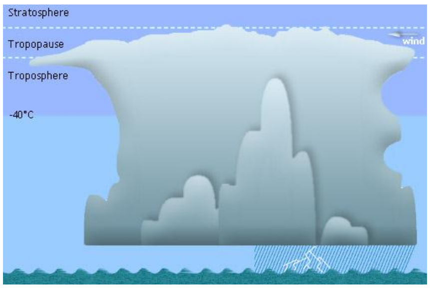
Global occurrence diagram of "Cloud Arc Chain" Structures

The neighbouring circles of the "cloud arc" structures can lie on a straight line and follow each other. Then they merge often in such a way that boundary lines disappear. This picture differs from that, where a static group of coexisted "cloud arc" structures is observed.
The explanation of this phenomenon could be the following.
A local place on the water surface becomes warmer than its environment. Air over this place will be also warmer and rises up. The water vapour is transported upward with warm air and as a result a "cloud arc" structure can emerge. However the size of the "heating source area" is smaller than the size of the whole "cloud arc" structures. This "heating source area" could affect as a kind of Hotspot on air masses passing over it.
After the emergence of one "cloud arc" structure it will be shifted by the wind, which flows in upper layer, and the place for the emergence of new "cloud arc" structure will be free. It will be also shifted in wind direction, etc. The shape of entire chain picture will depend on the wind velocity.



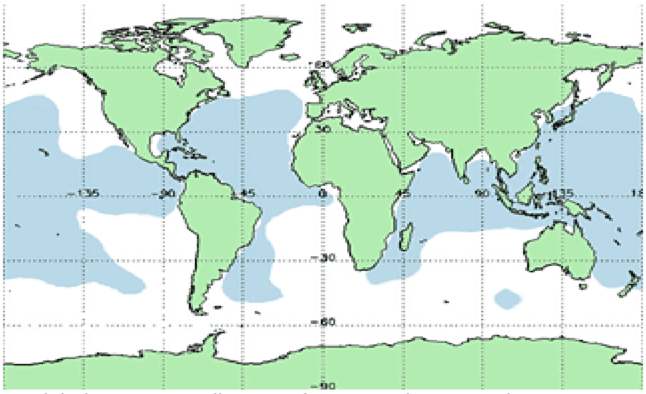
2007.01.10 Orbit: 25430
"Cloud Arc" Structures over the southeast Pacific not far from the Chile Coast

"Mesoscale Convective" System



The "Mesoscale Convective system" consists of high cloud forms, to whose mostly belong cumulonimbus clouds. Its size is from 20-40km (for the single thunderstorm) up to several hundreds (up to ca. 200-400km), even thousand kilometres and extents its surface up to half million square kilometres. The cloud top height reaches 13-15 km, sometimes up to 16km.

If warm air rises above the cooler one, it begins to cool down and the water vapour condenses as water droplets. This condensation causes the heating of surrounding air and thus the continuation of its rising. The water vapour cools in the height and forms more water droplets and also the ice crystals, which begin to fall. This downward movement competes with the upward one.

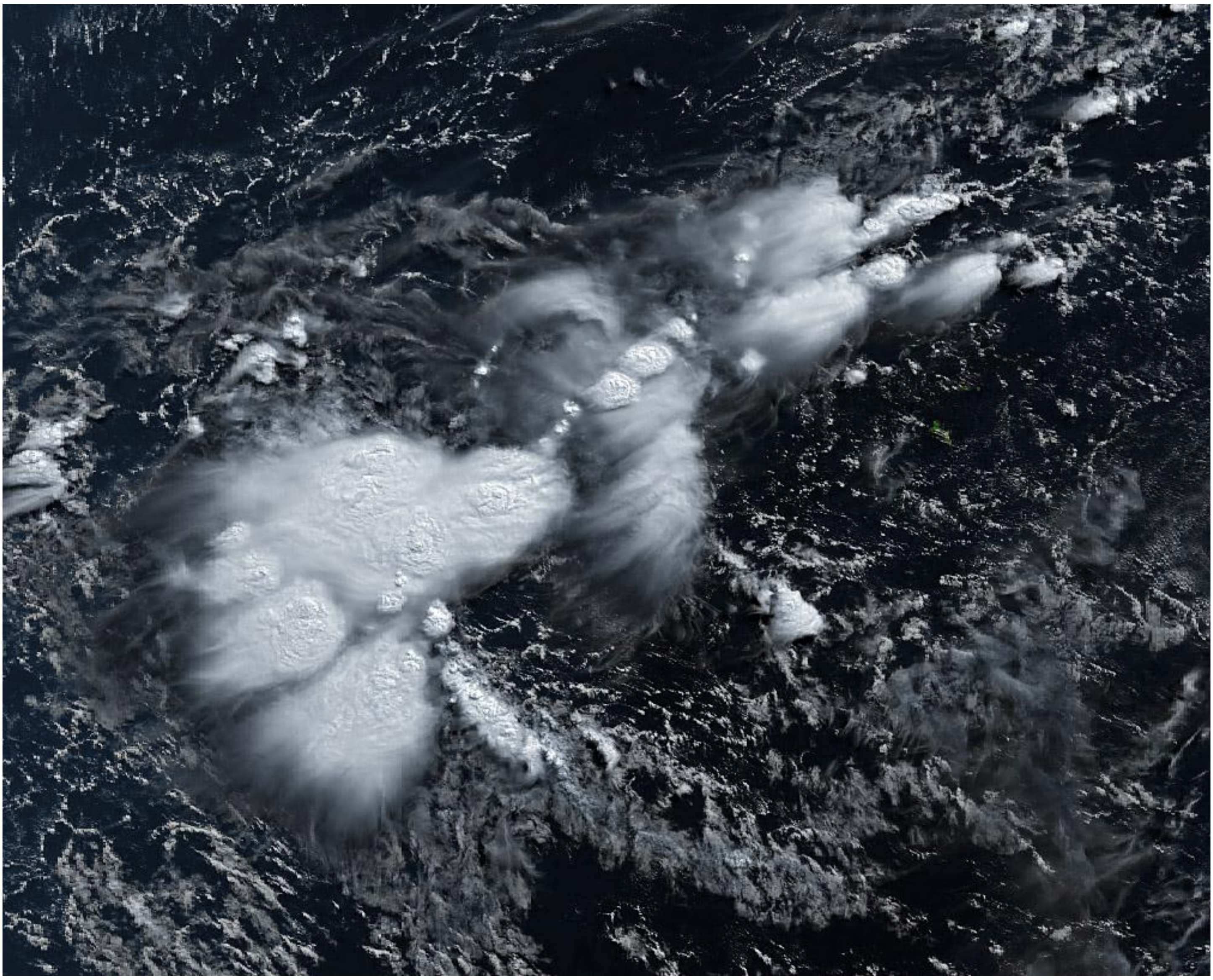

Global occurrence diagram of "Mesoscale Convective" System

The Mesoscale Convective system can be emerged: above the Tropics, in the latitude band from -15° to +15° von Equator, above the northern part of the Indian ocean, close to the eastern coastal regions from North America and Asia in the latitude of 40°-45° N, more rarely close to the eastern coastal regions of South America, Madagascar and Australia, above Samoa - Cook Island area

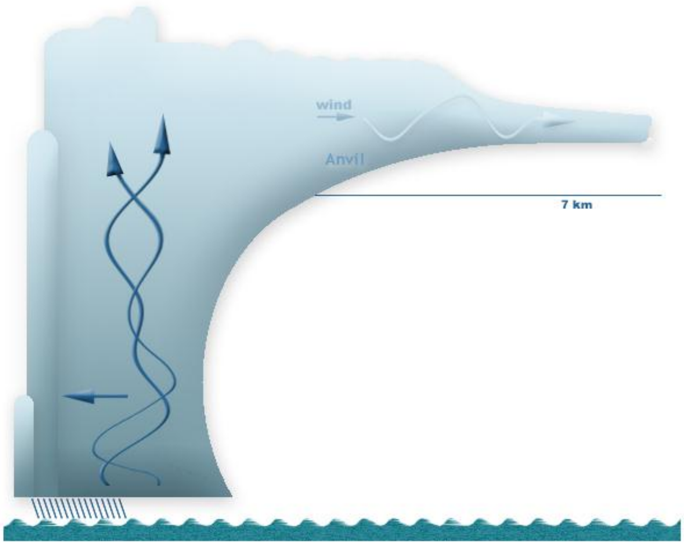
The structures of this type will observed also over the land between the latitudes of 40°N and 40°S.

The Mesoscale Convective system is connected with the low pressure areas and its clouds cause heavy rainfalls, thunderstorms and hail.

It is interesting to observe the rough surface structure of the top of clouds, where sometimes are the concentric waves to see. The wave periods are more or less equal and lie in the interval of 2-6 km. Perhaps the waves emerge if the rising air masses affect to the inversion layer.



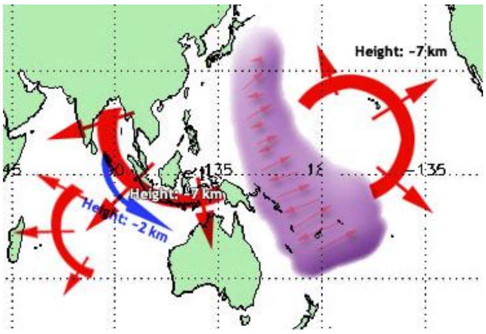
2005.05.30 Orbit: 16979
The "Mesoscale Convective" Clouds over Seychell Islans



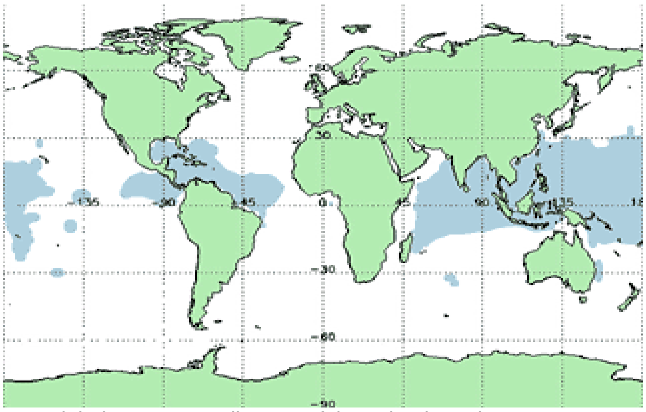
"Cloud Torch" Structure *

This structure was called (* my own tentative denotation) in such a way, because it looks from above always as a torch. It contains the convective clouds as a "nucleus", which rise upward intensively with warm air.

In the height of 7-8 km and more at the edge of the tropopause the anvil clouds will be blown by the wind (often in opposite direction than "nucleus" flows). This 'bow' can be much longer than the "nucleus". The further air departs from raised flow, the more it cools down, becomes heavier and sinks into warmer layers, where its humidity dissolves. That is the result that the environment is relative drying. The "nucleus" consists normally from several convective cells, so called Convective Cloud Cluster.



Such structures emerge mostly above the ocean, not far from low pressure close to warm fronts. It reaches the height of 12-15 km and more. Its albedo is 0.9-1. The "bow" can reach some hundred kilometres. It normally located on the height of 7-11 km, has a lower albedo and consists of cirrus, cumulonimbus, cirrostratus and altostratus clouds.



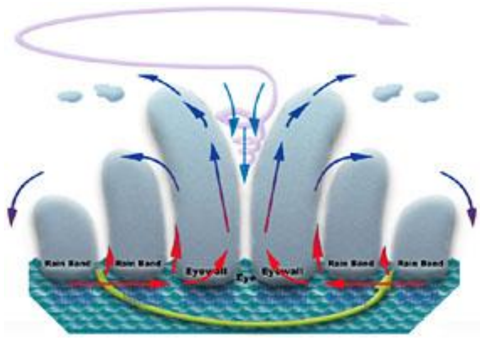
Global occurrence diagram of the "Cloud Torch" Structures

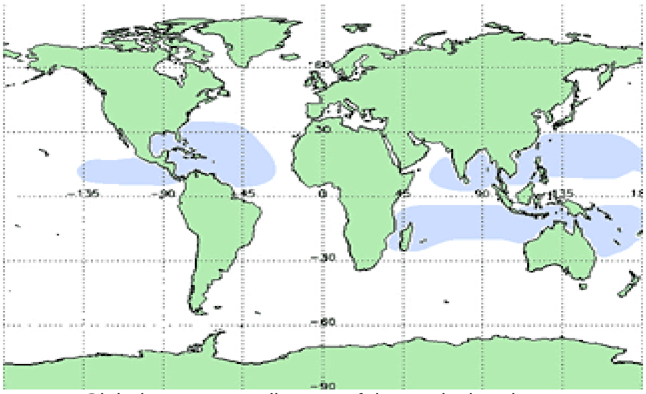
This structure can be often seen mostly above the western part of Pacific, north, northeast part of the Indian Ocean and around the Central America coast. In addition, it can be discovered in centre of the Pacific and close to the east coast of Madagascar. But it never spreads over +30° and only rarely -15° latitude. This structure brings tempests.

2007.08.21 Orbit: 28616
"Cloud torch" Structures over the Indian ocean over the south of Arabian Sea

Tropical Cyclone

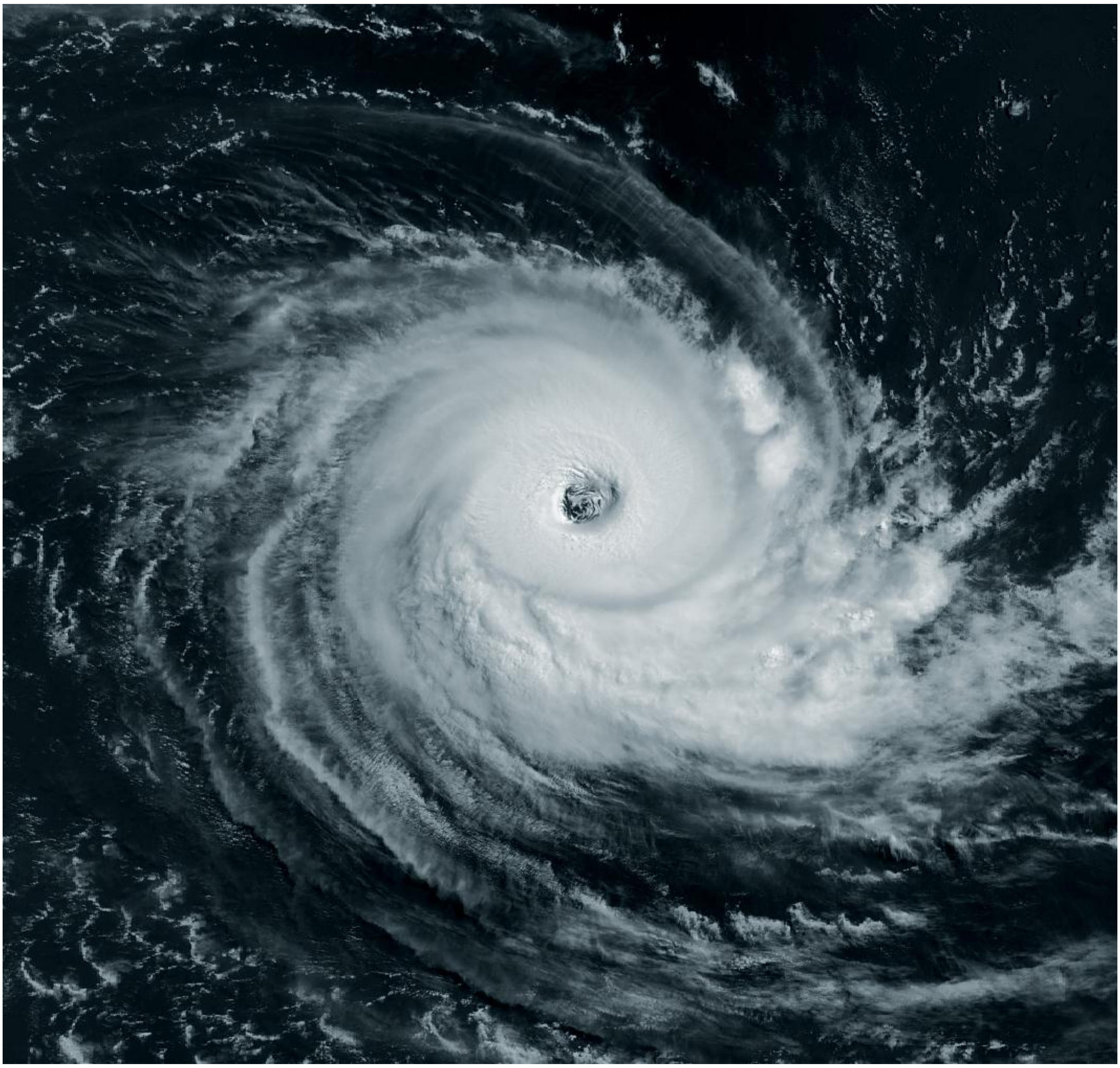
Tropical cyclones (are also well-known as Hurricanes or Typhoons) are regarded as a subtype of the "Mesoscale Convective System".
They differ from the other cloud vortex forms by having other emerge, development and structure.





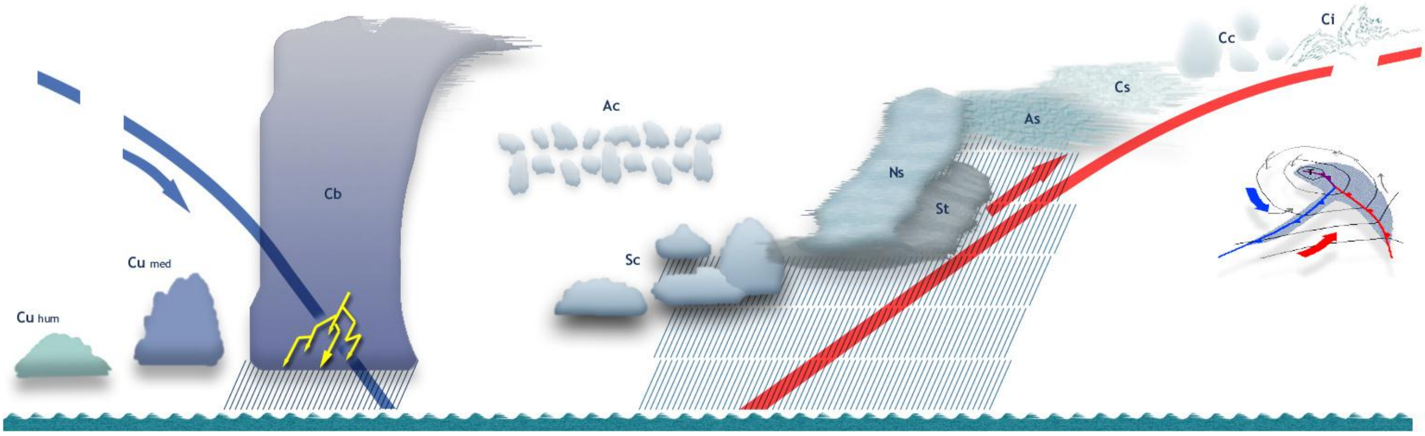
Global occurrence diagram of the tropical cyclones

They are frontless low pressure systems with organized convection, heavy thunderstorms and a closed surface-wind circulation around the low pressure centre. The sizes of the cyclone are from 500-700 km to 1200, rare 1500km. Its cloud top height reaches 12-15, to 16 km.
Most tropical cyclones emerge above the sea surface within a zone, which lies between the southern and the northern latitudes of 30°, if the water temperature is min 26.5 °C up to a depth of 40 m.
In order to cause a rotating cyclonic motion, the Coriolis Effect must be effectively enough and it happens only starting from 5° northern and from -5° southern latitude. Therefore the tropical cyclones are not observed above the equator area.
Air masses move towards the centre (convergence) in deeper layers of a cyclone. After rising in approx. 12 - 15 km height they flow again apart (height divergence). This leads to the development of the strong clouds. The spiral-like air rising is additionally increased by the heat radiation that is accompanied with the condensation of water weapon.



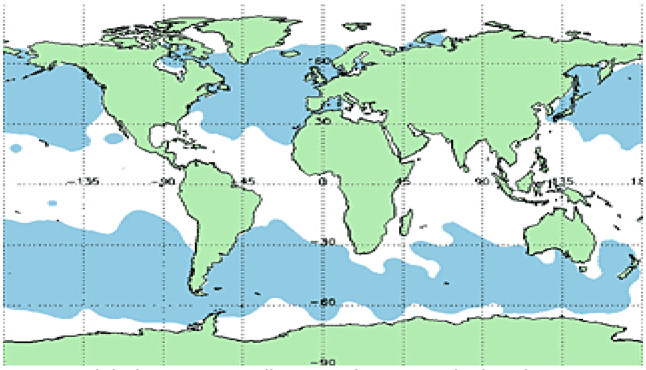
2006.02.28 Orbit: 20900
The center of the Indian ocean, the tropical cyclone 'CARINA'; (MAX Sustained Winds 130 KT, Gusts 160 KT)

Extratropical Cyclone



The extra tropical cyclones look in Northern Hemisphere as a comma. In Southern Hemisphere the picture is reflected. The size of the extra tropical cyclones reach several thousands of kilometres. Cloud top height is up to 9 km. They bring rainy weather.

The warm air, which flows in the high layer from the Tropics toward the poles, is eastward diverted in Northern Hemisphere, due to the Coriolis Effect. This causes there western prevailing winds. The near-surface back-flowing cool polar air is diverted in western direction. This opposite turbulent winds form in the middle latitudes low pressure vortex,

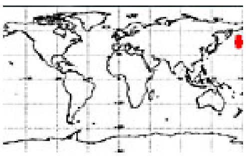


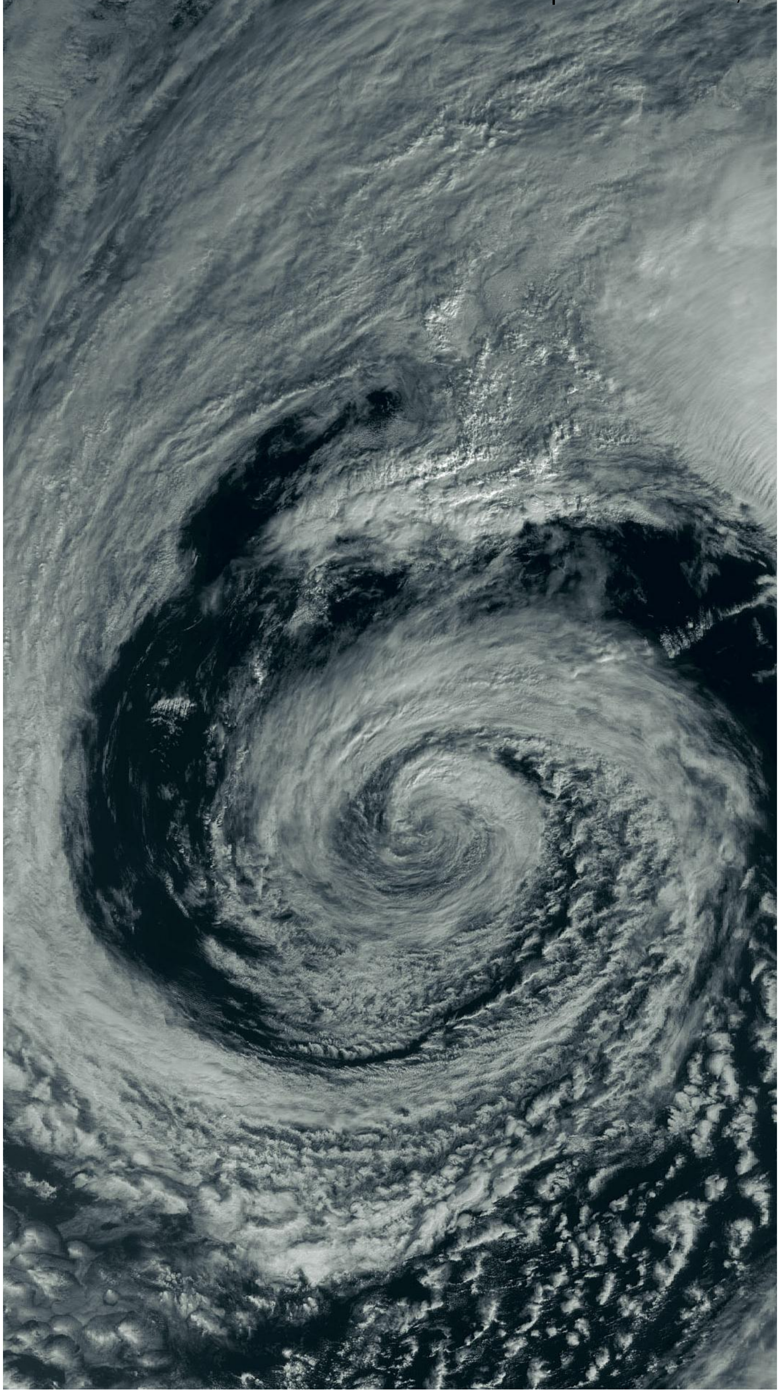
Global occurrence diagram of extra tropical cyclones

which in Northern Hemisphere moves eastward and has a vertical axis, so that winds have nearly the same direction at the ground and in the height.

This cloud structure contains a number of different types of the other cloud structures. Among them are convective cells structures necessarily. The cirrus clouds are forerunners of a cyclonic warm front coming soon. They seal to large and deeper stratus and cirrostratus clouds. From the cirrostratus, due to advection, develop altostratus clouds, after which nimbostratus clouds follow. In the following cold front the upward displaced warm air cools down, thus convective cumulus clouds develop.

The extra tropical cyclones are described detailed in literature and internet.

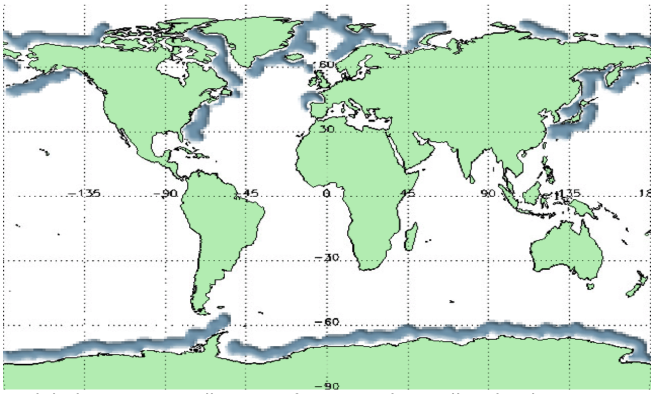




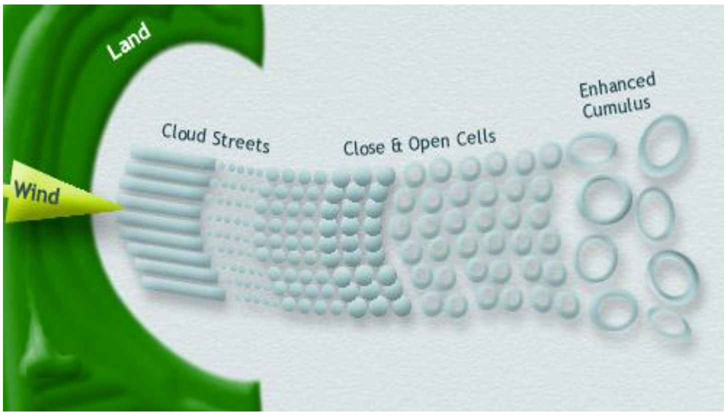
2007.09.17 Orbit: 29013
Extra tropical cyclone over the north of Pacific in the south of the Bering Sea

Convection Cells Streets

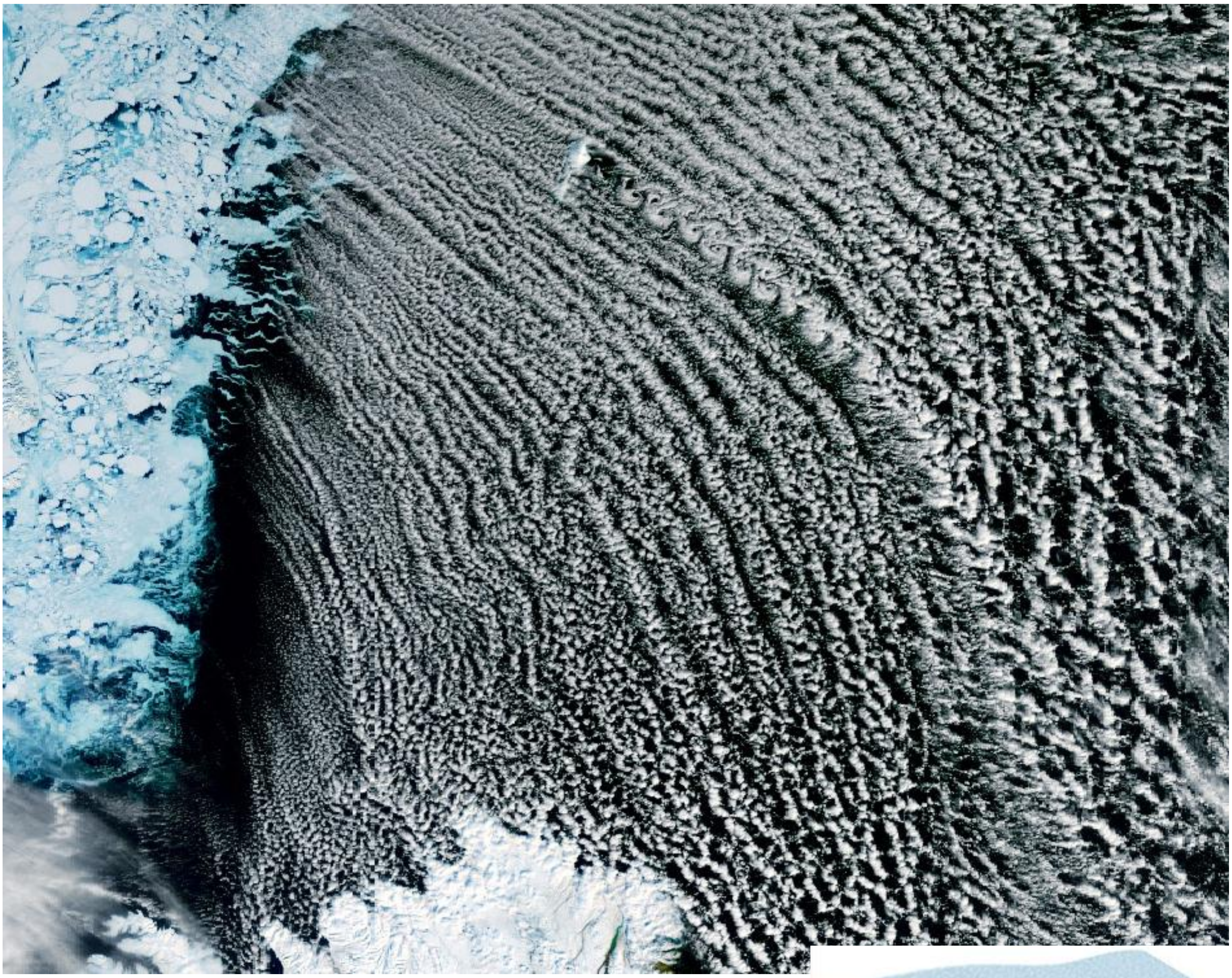
The organization of the clouds in "streets" can be explained by the existence of the horizontal role turbulences in the boundary layer. The clouds are formed in the upper layer of this roll system. If outbreaks of the continental cold dry air spread above a neighbouring relatively warm ocean, the cloud streets can be seen. This takes place frequently behind a



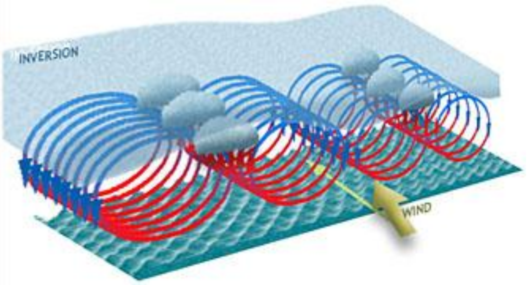
Global occurrence diagram of "Convective Cells" cloud structures



cold front. If the cool air leaves the land or ice surface, its properties changes by vertical transfer of the heat and humidity of the underlying water surface. An inversion layer is formed and its basis rises with the distance from the coast. The transformation of air mass leads finally to the formation of the clouds, that, under certain circumstances, the shape of the cloud streets assumes, and develops approximately parallel to the wind direction.
Further the streets develop to the three-dimensional opened cells.
Near the upper-trough the convection is enhanced and Enhanced Cumulus becomes to form. These structures can be often observed in spring and winter above polar waters, in addition, above cold water of middle latitudes.

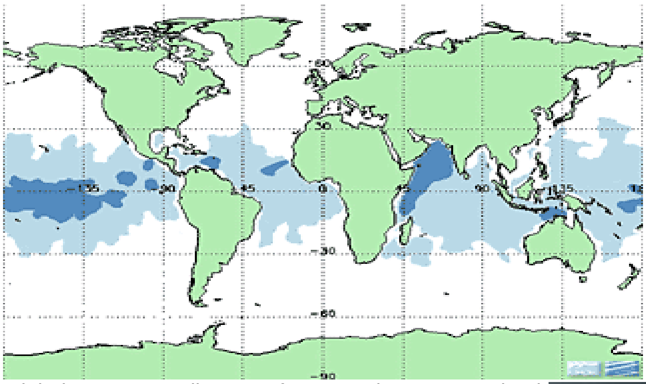


2005.04.07 Orbit: 16224
Convection cells streets over the north Atlantic, close to the coast of Greenland.
The Karman vortex cloud structure emerges at the back of the mountains of the island Jan Mayen.



"Convection Streets" Cloud Structure

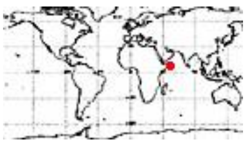
If in the ground flowing humid air, which is covered with approx. 1.5-2 km high lying inversion layer, turbulent movements appear, then the cloud streets can form into this air. They are called “convective streets”, because they are parallel to each other and to the wind direction. They are only 1-3 km wide, but they can reach the length up to several hundred kilometres.
The emergence of “cloud streets” happened often if the higher air sinks, like e.g. possibly at the high pressure of area (anticyclone) or during the nocturnal ground fog. The circulations are formed under a sinking inversion layer, as one follow of moderate and strong wind flowing in almost constant direction. If the wind speed increases from the ground to the inversion layer up to 10 m/s and the air humidity is sufficient for the condensation, then cumulus (and stratocumulus) clouds can develop in rising and therefore cooled down air of the circulations and move along the resulting convergence lines.



Global occurrence diagram of "Convective Streets" cloud structures

The circulating air masses have the form of little flattened cylinders, whose adjustment deviates from the wind direction. The horizontal distance between the streets corresponds in ideal case to the triple height of inversion layer (in reality 3N-times, [N = 1,2,3]). Should the inversion layer be not a very stable, the stronger convective clouds form along the lines and the street can branch out on corresponding places, so that it looks from above as a sea-grass. It can be some more thickly (up to 5-7 km) and longer (to 1000 km and more).
The “cloud streets” are observed normally in masses, particularly in the centre of the Pacific in Kiritimati (Christmas Island) area (so-called "Kiritimati Cloud Province") and in/around Arab sea.

In addition, they can be seen above the north path of the Indian Ocean, in/around Gulf of Bengal and above the west part of Pacific. Generally, they appear within ±30° band from Equator, in most cases even within ±15°.
The cloud line can appear also as an individual line. Then it marks a convergence zone, where warm air rises upward.
There are cloud street structures, which have the same emergence, but form in middle latitude under strong cold flowing wind above relatively warm water. They develop as blowing out close & open cells. They are not considered here, but with “the Convective Cells Structures” part.



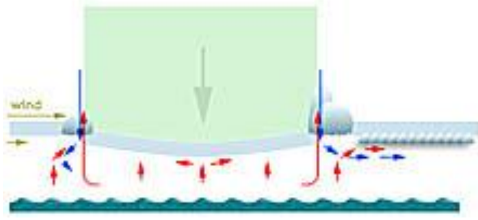
2007.09.10 Orbit: 28903 Convective Streets" cloud structures over the Arabian Sea close to the Somalia Coast

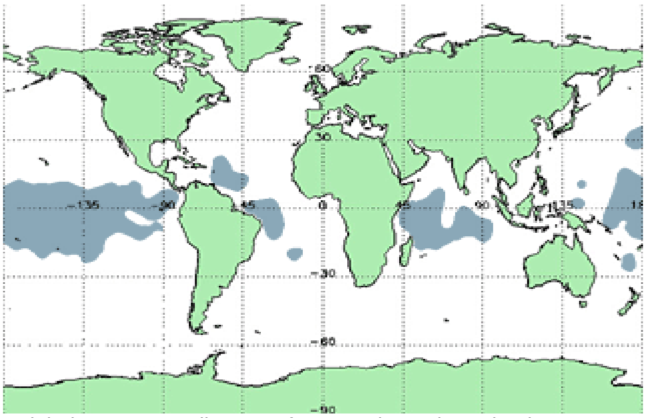
"Peacock Feather" Cloud Structure *

The clouds of this structure often look from above like the parts of peacock’s feather or also like cacti of the kind “Opuntia ovata”. These are round, oval or arc-like cloud forms or cloud series (with the cloud top height up to 3, rarely 3.5km), connected with each other and mixing with cloud lines often in the form of sea-grass (cloud top height 1.5-2km).

Most frequently they are to be observed above equator into so called “Kiritimati Cloud Province”. Strictly speaking, this structure characterizes the province.

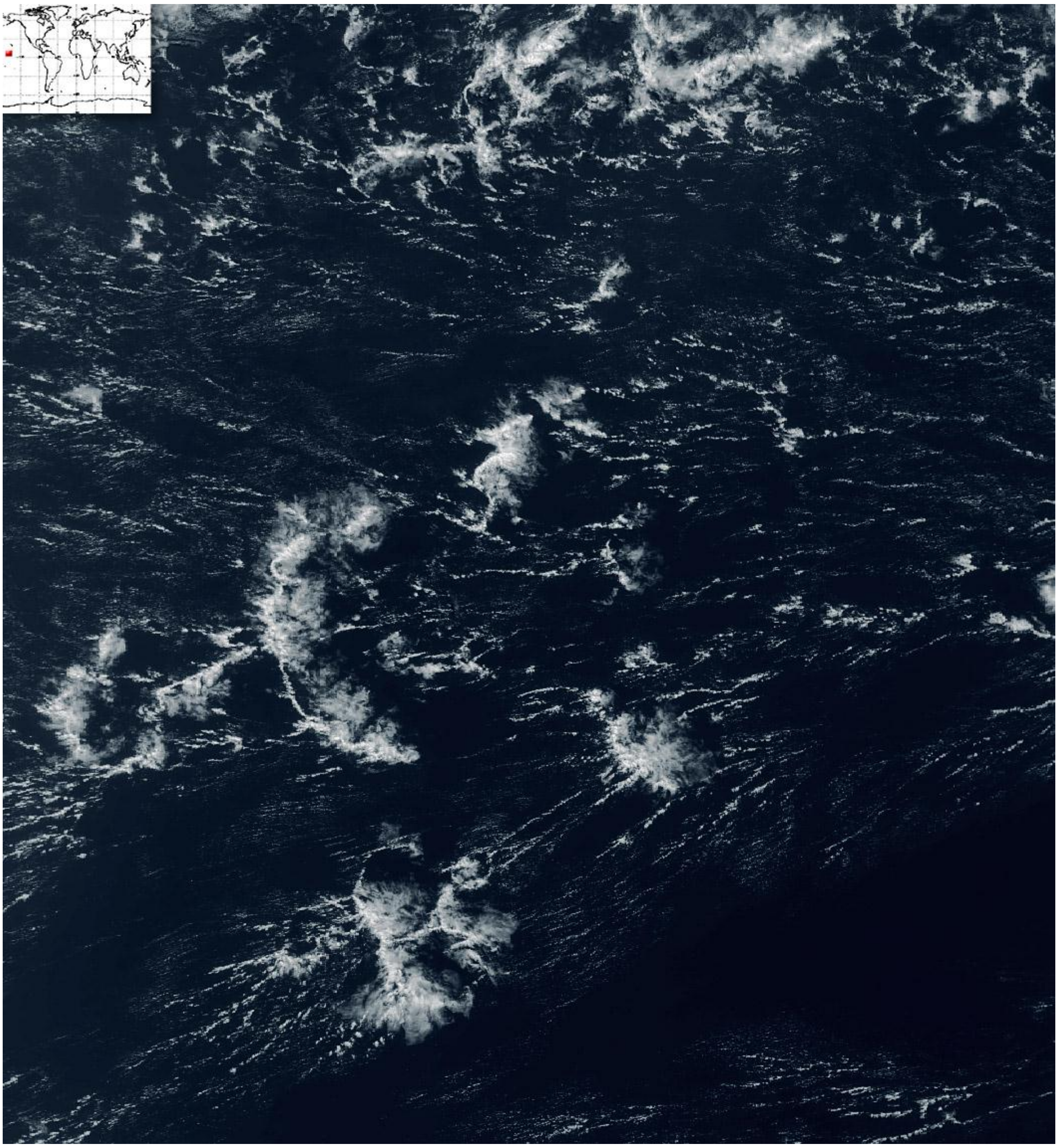
The reason for the emergence of this structure is not completely clear. The explanation could be the following. A highly lying local high pressure area with relatively cold air can occur above the low lying inversion layer. The air flows from the sea surface, rises upward at the edge of this area, break through the inversion layer and cools down. The clouds emerge. The cold air flows from the high pressure area in the opposite direction. If it contacts with warm air, it promotes still stronger cloud emergence and creates conditions for the emergence of “cloud streets”.



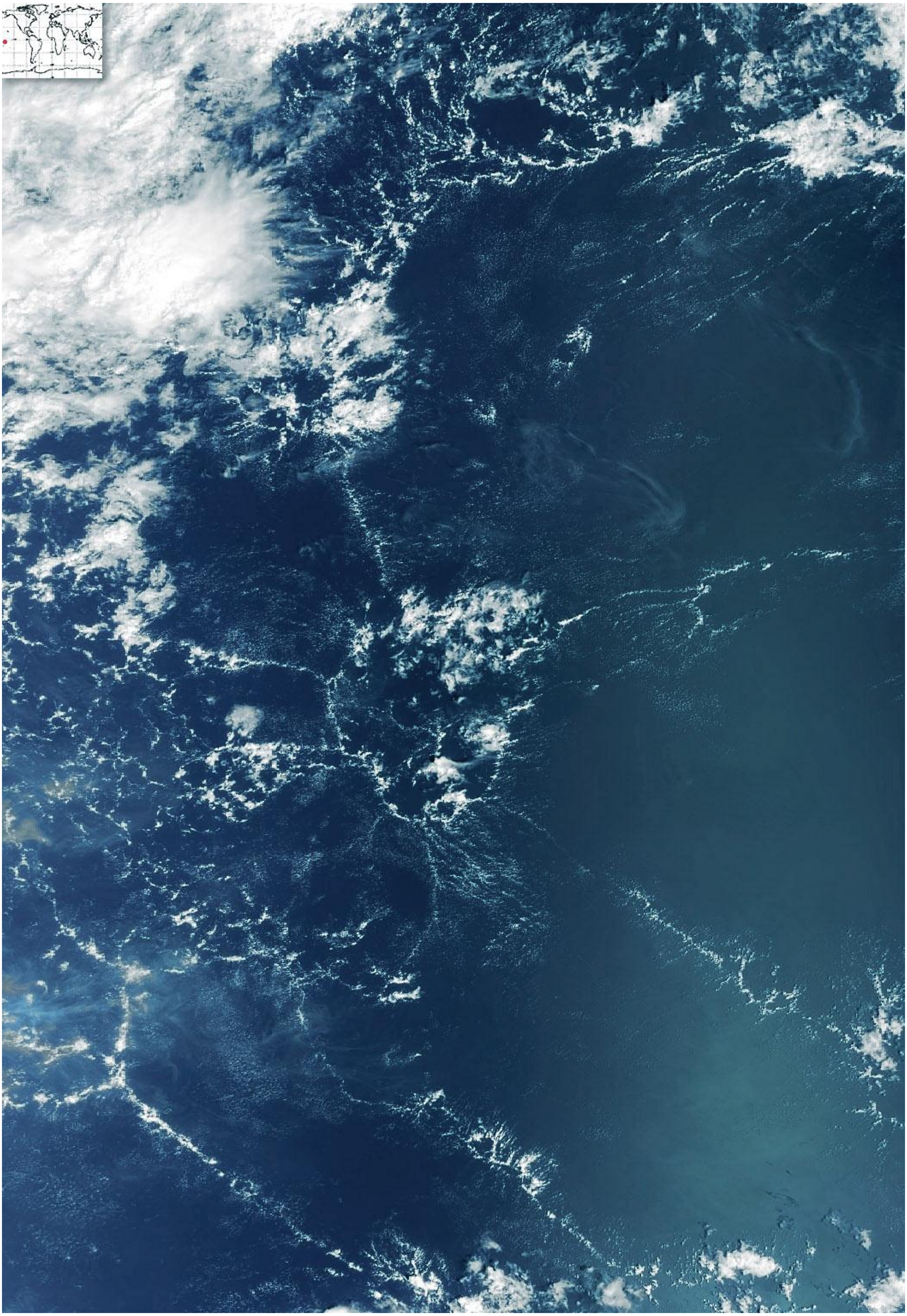


Global occurrence diagram of "Peacock Feather" cloud structures

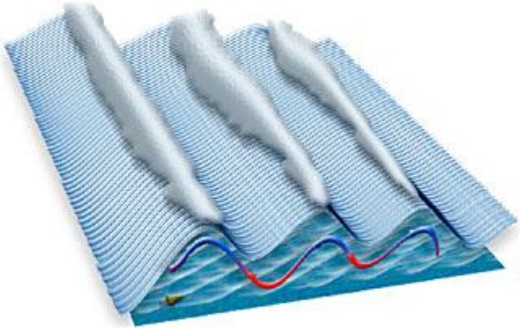
The structure was observed: everywhere over equatorial Pacific, also over Atlantic near to east Brazilian coast and over Antilles, over the Indian Ocean it can be seen close to the east African coast and Madagascar. [* my own tentative denotation]



2006.06.21 Orbit: 22527
"Peacock Feather" cloud structure over the central Pacific.



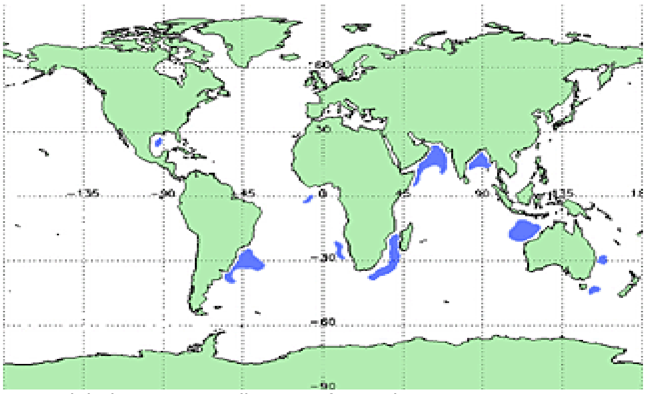
20061202_24875
Unique "Peacock Feather" cloud structure over the central Pacific.



"Gravity Waves" Cloud Structure.

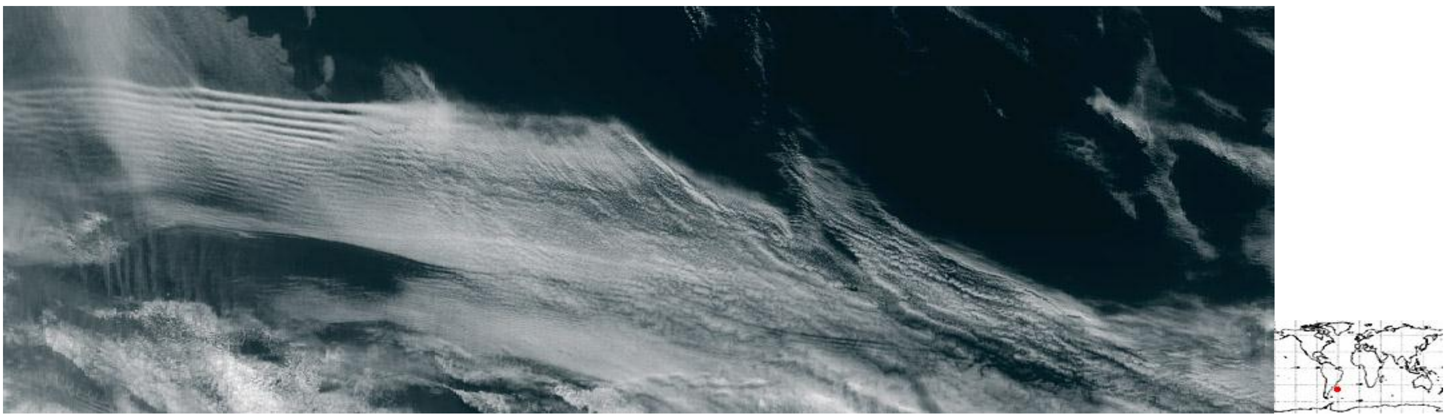
The gravity wave clouds above the water surface are not often observed. They can have many hundreds kilometres long, but rarely more than 5-15 strips. They are formed in a layer, which does not normally locate over 2 km, rarely over 3 km, above certain geographical regions.

A reason for the wave sample over the water surface is a formation of the clouds in a steady thin air layer, in which the air temperature does not change very much with the height. The physical parameters of this layer do not differ from those that lie over and possible under it, and for the certain time the air of neighbour layers does not mix. The possible air disturbance in the layer can cause the waves, along the border between this and framing layers. If air in the layer is humid enough, clouds emerge in the place, where air rises up and cools. These clouds float above the comb of the internal wave at the border to upper layer. If air falls down to the wave trough, then clouds evaporate. At most these structures were regularly observed within ±30° latitude over the ocean waters near coasts of South Atlantic, close to east coast of the South America, over the Indian ocean (South of the Mozambique channel, close to northwest coast of Australia).



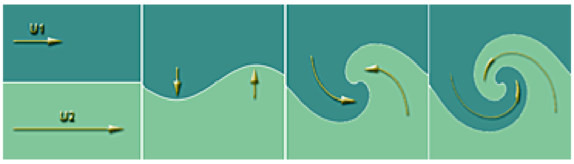
Global occurrence diagram of "Gravity Waves" structures

2007.07.24 Orbit: 28216, "Gravity waves" cloud structure over the southwest of the Indian ocean

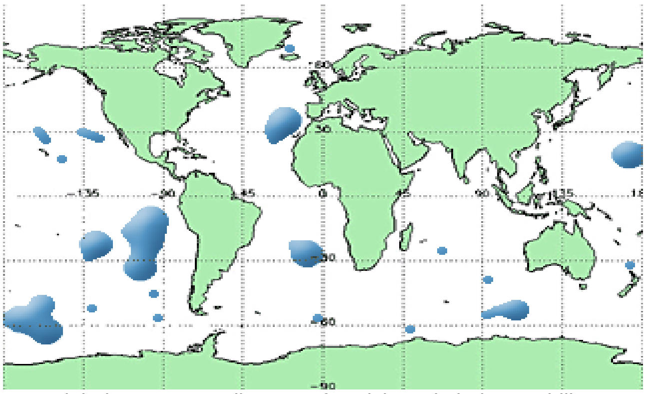


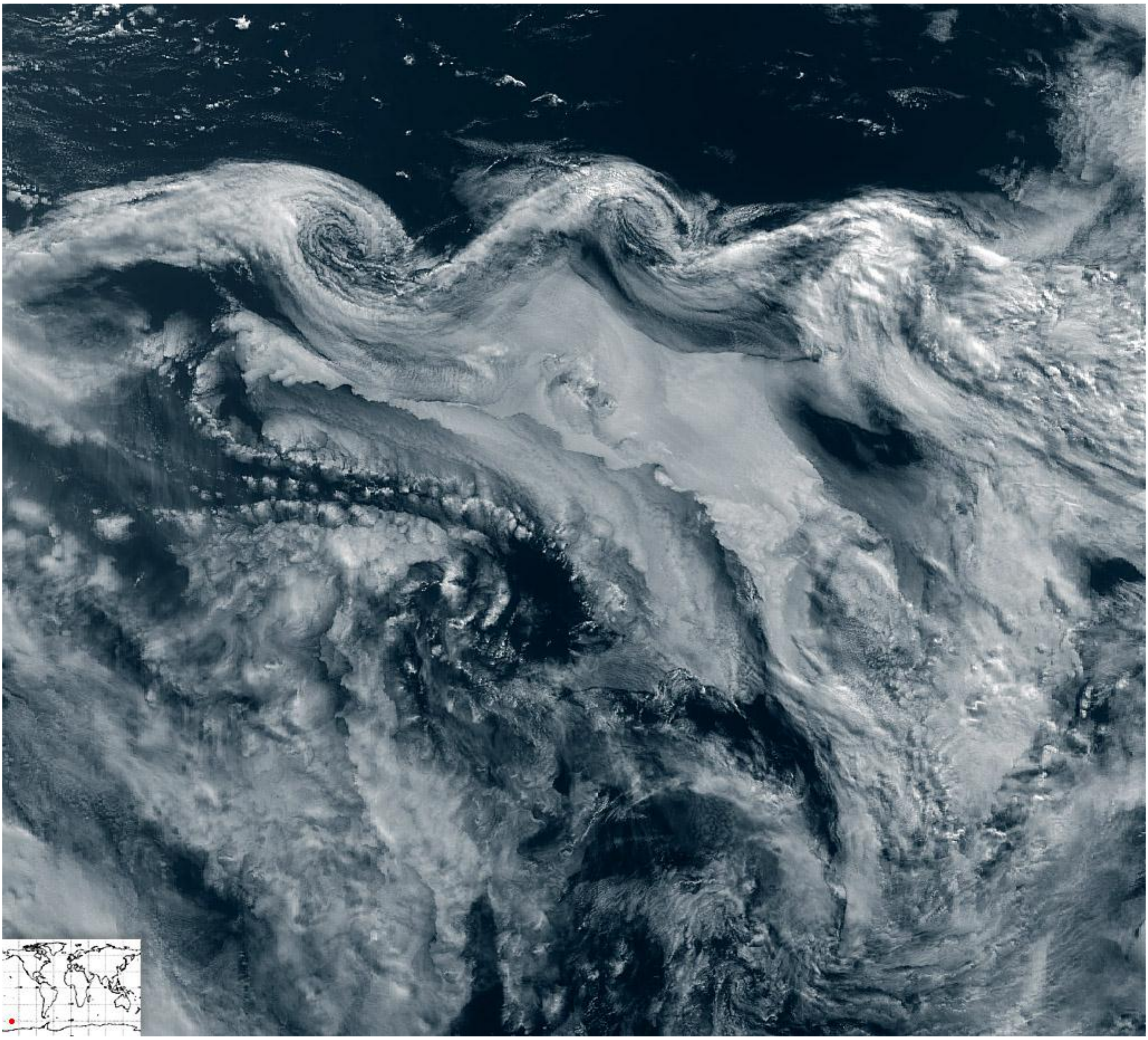
2006.09.15 Orbit: 23753, "Gravity waves" cloud structure over the southwest of the Atlantic ocean

'Kelvin-Helmholtz Instability' Cloud Structure.



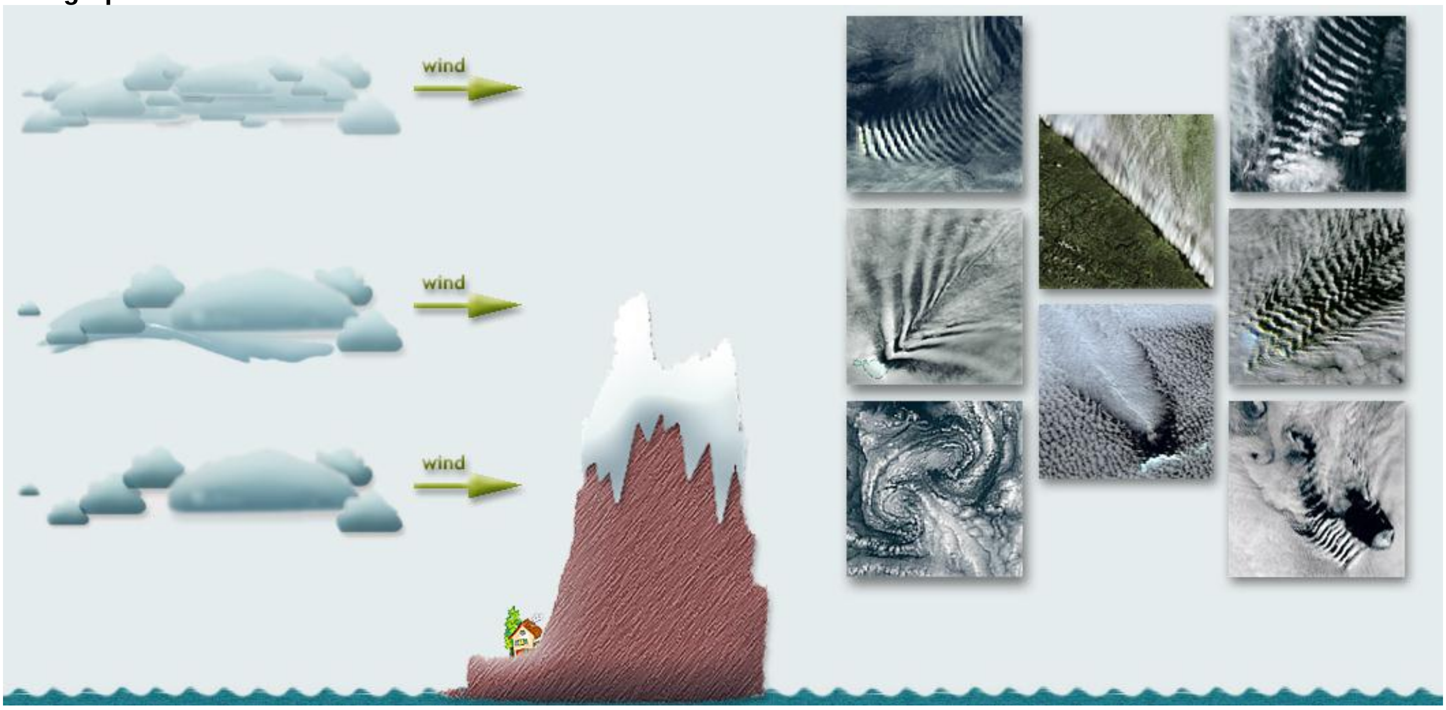
The Kelvin-Helmholtz instability results from a turbulence of two air layers lying close to each other, which move with different speed and/or direction.
It can be assumed that due to the friction force between two air masses, which move with different speed, one (or several) irregularity in the form of penetration of a layer in the other one develops. The penetration can be observed in the form of wave or hill.
Because of the continuous of the air flow, an air element, which is close to some air barrier, moves around it faster than another one, which is more far from the border of air masses.
According to Bernoulli's Principle the pressure beside an air layer with the higher wind velocity is smaller than in the environment. Consequently there is a force, which pulls the barrier shape (wave comb or hill summit) in the direction of the faster air flow. Close to a wave trough (or a “valley”), air flows more slowly than in the environment, and therefore the ambient pressure is locally higher. This area will be pressed in the opposite direction.
The Kelvin-Helmholtz instability is rarely observed in large air masses.
At most they can be observed over the Southern Hemisphere, where the extra-tropical cyclones have obviously more place and larger speed in comparing to environment.


Global occurrence diagram of "Kelvin-Helmholz Instability"

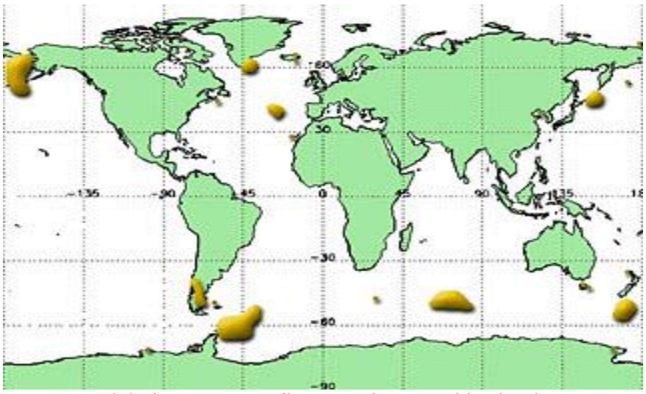


20070223_26062
"Kelvin-Helmholtz instability" cloud structure over the South Pacific

"Orographic Clouds"



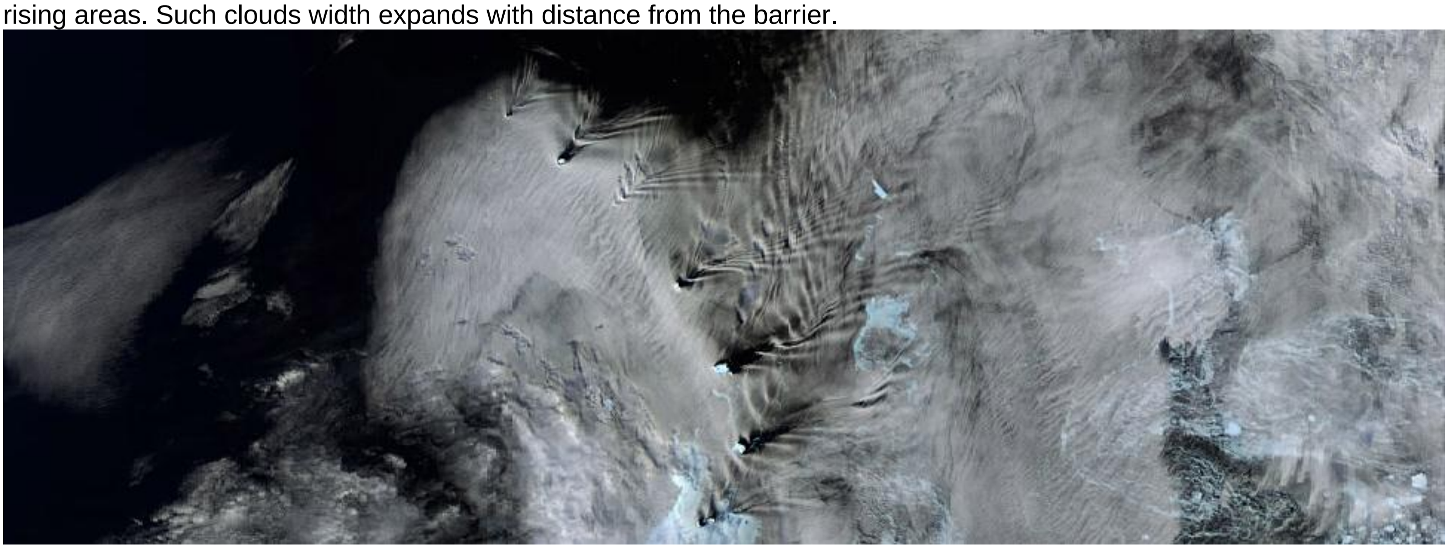
Orographic clouds develop in response to the forced lifting of air by the earth's topography (mountains for example). Air passing over a mountain oscillates up and down as it moves downstream. If the air lifts upward and cools through expansion as it rises to its saturation temperature during this process, the water vapour within condenses and becomes visible as a cloud.



Global occurrence diagram of orographic clouds

Upon reaching the mountain top, the air is heavier than the environment and will sink down the other side, warming as it descends. Once the air returns to its original height, it has the same buoyancy as the surrounding air. However, the air does not stop immediately because it still has momentum carrying it downward. With continued descent, the air becomes warmer than the surroundings and begins to accelerate back upward towards its original height. It is during the upper-most ascent phase of this cycle that clouds develop. In regions where air is descending, skies are clear. The lifting of moist air can result in the generation of clouds, while lifting drier air may not produce any clouds at all. The oscillations continue as the air moves further downstream from the mountains but are eventually dampened out by mixing and friction.

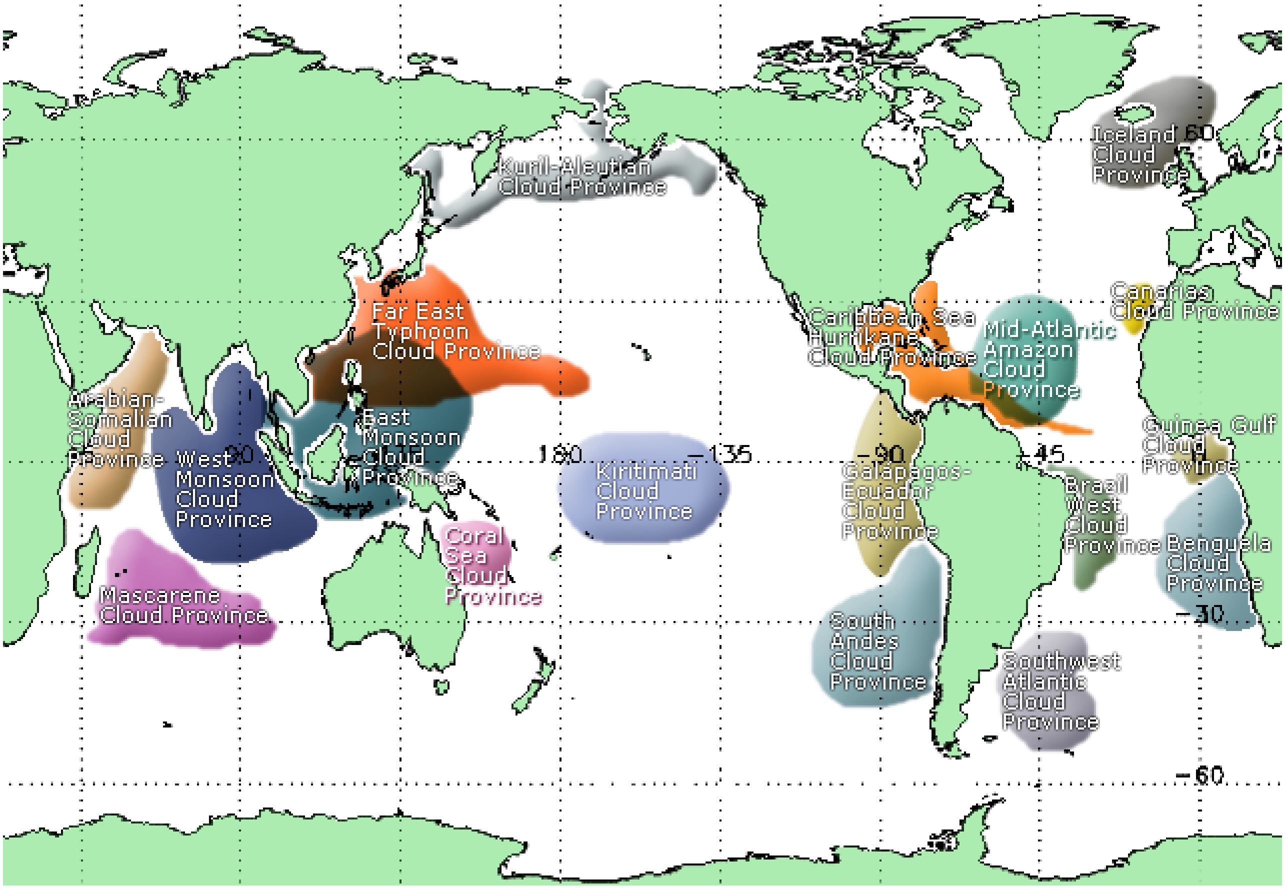
Which cloud type is caused behind the barrier depends on the wind speed and on the wind layer height. If the winds layer lies significantly lower than the height of the barrier, the "Karman Vortex 'Cloud Structure, or slipstream (cloudless area) can be developed behind this barrier. When the wind layer lies within the area of the height of the barrier, the so-called V-shaped clouds (with an Kelvin's Limit Angle of 19°28') or banner clouds can grow behind this barrier. Wenn the wind blows in the moist air layer, that lies higher than the barrier, then the strip-like cloud structures can be developed in the air rising areas. Such clouds width expands with distance from the barrier.



2008.12.20 Orbot: 35590
Orographic clouds at the back of the South Sandwich Islands

Cloud Provinces *(CP)*

A cloud province may be defined as a limited territory over the world ocean (and sometimes over parts of the coast).
It is characterized by a cloud picture which is specific for it and probably depends on the season.
A cloud picture may be represented by one or several interacting cloud structures.
Some cloud provinces have similar cloud pictures, and some have unique ones, typycal only for them.



- *Kiritimati Cloud Province*
  The province is situated above the centre the Pacific close to Kiritimati Island. It contains almost exclusively "Peacock Feather Looking" (with seasonally-dependent intensity) and "Convection Streets". It is shaped by constant east wind and water temperatures.
- *Galápagos-Ecuador Cloud Province*
  The province spreads from Pacific coast of Central America to ca. 20°S latitude. It is bordered from the east side by the coast of Colombia, Ecuador and north Peru and from the west side to ca. 105°W longitude. The season-dependent cloud picture consists of the clouds (from north to south) of " Mesoscale Convective" system, "Convection Streets" and prolonged"Close Convective Cells ". It is shaped by Humboldt Current, by the wind around Pariñas Point and also highland coast.
- *Coral Sear Cloud Province*
  The province is situated over Coral Sea, close to northeast Australian coast. In this area wind and sea current come from southeast. The clouds, mainly "Travelling Convective Cells", emerge season-conditionally (particularly in there spring time) within the area between New Zealand and Fiji and move in northwest direction to Australia, where over Great Dividing Range dissolve.
- *East Monsoon Cloud Province*
  The province is situated over Pacific east of Indochina and it is bordered from the east side by the ca. 150° E longitude (western Micronesia), from the north side by Taiwan Island, from the south side - by Lesser Sunda Islands. The seasonally cloud picture mostly consists of "Cloud Torch" and "Outflow Boundary" and depends on monsoon wind.
- *West Monsoon Cloud Province*
  The province is in the west of Indochina Peninsula over Andaman Sea, Gulf of Bengal and centre of Indian ocean to ca. 70°E longitude (over the east of Arabian Sea); it is bordered from the north side by the Asia coast and from the south one - by 15°-18°S latitude. The cloud picture mostly consists of "Cloud Torch" and "Outflow Boundary" and seasonally depends on monsoon wind.
- *Arabian-Somalian Cloud Province*
  The province is very interesting. It is situated over western and central parts of the Arabian Sea and over the western part of the Indian Ocean between Africa coast and Seychelles. The "Convective Close Cells" are season-conditionally (in the summer months) observed here (not particularly expecting, but possibly caused by the relatively cold water). In the late summer and autumn, the very impression "Convection Streets" are here observed, which is caused by monsoon fringe.
- *Mascarene Cloud Province*
  It contains nearly the whole year the clouds of "Travelling Convective Cells" (and some different one). It is situated over Mascaren islands and is bordered from the east side by 100°E, and from 15°S to 35°S latitude - from the north and south side accordingly. Here normally blows the eastern wind. The sea current comes also from the east.

- *Kuril-Aleutian Cloud Province*
  The province is situated over the north part of Pacific: Sea of Okhotsk, Kuril Island, Aleut Island, Gulf of Alaska and Bering Sea. The strong meridional cold wind blows there in the late spring, and it cause clouds of “Karman Vortex”. The “Ship Trails” and “Convective Cells Streets” Phenomenon can be also observed there.
- *Far East Typhoon Cloud Province*
  In the province typhoons are observed in the late summer and in the autumn.
- *Caribbean Sea Hurricane Cloud Province*
  In the province hurricanes are observed in the late summer and in the autumn.
- *Canarias Cloud Province*
  The province is situated over Madeira Islands, Canarias Island and spreads 200-300 km more in the south direction. The wind, which blows here from the north, often causes “Karman Vortex”.
- *Guinea Gulf Cloud Province*
  The province is situated over the Gulf of Guinea. The season-dependent cloud picture reminds here of another one, which is to be observed in northern part of Galápagos Ecuador CP: the clouds of “Mesoscale Convective” System and “Convection Streets”, which is caused by warm sea surface temperature and by northern, from the African coast flowing wind.
- *Benguela Cloud Province*
  The province is situated over south Atlantic, close to the southwest of the African coast. It is bordered from the west side by 15°W longitude. The cold Benguella current and the warm wind from the continent causes here one of the largest atmosphere field of “Convective Cells” CS (at most “Close Cells”). The “Cutting” Phenomenon, the “Wave over” Phenomenon and “Actinoform” can be observed here. At the southern edge of this province the “Open Cells” are often to be seen. The province resembles the South Andes.
- *South Andes Cloud Province*
  The province is situated over south Pacific, close to south Peruvian coast and Chilean coast. It is bordered from the west side by 110°W longitude, by the south - by 45°-50°S latitude. The cold Humboldt sea current, the height mountainous coast and the wind from Andes cause here the world largest accumulation of clouds of “Convective Close Cells”. The large fields of “Actinoform” could be season-dependently observed here. From the south of this province the clouds of “Convective Open Cells” come very often. The province is a source of “Travelling Convective Cells”. It resembles the Benguela CP.
- *Mid-Atlantic Amazon Cloud Province*
  The province is situated over the centre of Atlantic, in the rectangle [30°N-10°N], [60°W-40°W]. It is appropriate in the east of Caribbean Sea and in the north of the north coast of Brazil. The season-dependent (in the spring) cloud picture has here a singular mega structure of “Travelling Convective Cells”, which lay more or less in regular knots of a net and are in last decay phase.
- *Brazil West Cloud Province*
  The province is situated over Atlantic in the east of the east coast of Brazil. The cloud picture is here represented by a singular mixture of “Travelling Convective Cells”, of “Actinoform” and not rare of “Cloud Arc”.
- *Southwest Atlantic Cloud Province*
  The province is situated over south Atlantic close to Argentine coast. From the east side it is boarded by 30°W longitude. The “Extra tropical Cyclone” and “Gravity Waves“are often to be observed here.
- *Iceland Cloud Province*
  The province is situated over Iceland in the north Atlantic. It is the source of “Extra tropical Cyclone”, which strongly affects the European climate.