



Fig. 12-1. *Altocumulus stratiformis undulatus*,
07 Jan 2025, Boynton Beach, FL.



Fig. 12-2. Cellular Altocumulus 27 Oct 2017 (top). Fig. 12-3 Banded Altocumulus (undulatus), 19 Nov 2018 (bottom). Both over Cheyenne, WY. Jan Curtis.

Wonders of the Atmosphere

Chapter 12: Patterned Cloud Sheets

Started 13Apr 2025

12.1 Properties of Patterned Cloud Sheets

Think back to a glorious sunrise or sunset when an intricately patterned cloud layer, riveted ruby red, gilded with gold fringes, and perfected with patches of purple, were all set in a spectral sky. Recall also gossamer cloud ripples that distilled the sunlight into brilliant glowing kaleidoscopic opalescence, with iridescent fringes or circular coronas, the subject of Chapter 14.

Can you remember the humble cloud genera that made these visual feasts possible?

They are almost invariably the patterned layer clouds, altocumulus and cirrocumulus in the troposphere and nacreous in the stratosphere. They are the clouds of honeycomb cells or rippled waves (Fig. 12-1), or orderly bands criss-crossing the sky in woven shredded-wheat patterns of ranks and rows (Fig. 12-2 and Fig. 12-3). Sometimes the patterned cloud sheet contains all these and more, as in Fig. 12-4, 1st place winner in the 2021 Weatherwise Magazine Photo Contest. Its extra feature is the field of oval holes or lacunae at upper right. Little wonder its official classification is, *cirrocumulus translucidus undulatus radiatus lacunosus*!

One more species of patterned cloud sheets is lenticularis, the flying saucer or lens (lenticil) shaped clouds that hover motionless around mountain peaks and ridges. It forms the subject of Chapter 13.

The patterns of the elements in thin cloud sheets are molded by the patterns of the airflow. Honeycomb cells are due to gentle, overturning cellular convective motions confined to a humid layer that is either heated at its base or cooled at its top. The honeycomb



Fig. 12-4. Cirrocumulus translucidus undulatus radiatus lacunosus, 31 Jan 2021 over Cheyenne, WY. Jan Curtis.

cells form when there is little or no vertical wind shear. As wind shear increases, the flow marshalls the cells into waves, ranks and

rows. Obstacles to the flow such as mountain-topped islands create downwind wakes and vortices in the (mainly stratocumulus) patterned cloud fields so large they are best seen from Space.

Patterned sheets of stratocumulus, altocumulus, cirrocumulus, and the rare nacreous and noctilucent clouds of twilight have such similar form they probably should constitute a single genus. However, they have been classified as distinct cloud genera, distinguished mainly by the heights of their bases. Stratocumulus bases are generally less than 2 km above the surface, altocumulus bases between about 2 and 6 km and cirrocumulus bases are usually above about 5 km. Nacreous or Mother of Pearl clouds (named for their astounding iridescence) reside in the Stratosphere, between about 15 and 25 km. Noctilucent clouds reside in the Mesosphere, between about 75 and 85 km.



Fig. 12-5. Thin Ac band with transverse waves over Cliffside Park, NJ. SDG.

Largely as a result of the height of the sheet, the three tropospheric cloud genera are also distinguished by the apparent size of the elements. A good rule of thumb is to use your thumb. Hold your outstretched hand above your head. Stratocumulus cells or ripples are wider than your thumb (span an angle $> 5^\circ$), Cirrocumulus cells or

ripples are narrower than your pinky nail ($< 1^\circ$). Altocumulus elements are between (1° to 5° wide).

The patterned cloud sheets are often geometrically and optically thin, of order 100 m, as in the sidelit cloud line of Fig. 12-5. Optical thickness of the sheets generally decreases with height as temperature and vapor capacity of the air decrease. Stratocumulus, lowest and warmest, generally has the greatest optical thickness of the patterned cloud sheets. Cirrocumulus, highest and coldest, is usually the thinnest and most delicate of the structured cloud sheets. Quite often cirrocumulus cloud sheets have fine ripples and are gossamer thin, conditions ideal for coronas and iridescence.

Much of the differences in form of the three genera result from differences in their origin. Cellular stratocumulus clouds, especially over the subtropical oceans, form when the gently subsiding air near the surface of the great subtropical anticyclones is cooled by contact with the cold waters. Vertical wind shear is often too small to align the cells. Islands do by diverting the brisk winds.

Cirrocumulus and altocumulus often derive from droplets and ice crystals ejected from storm tops by outflowing winds, often with significant vertical wind shear. As they move out away from the storms that ejected them, they may evaporate. However, at some distance downwind, especially after a night of cooling, they may recondense as broken cloud sheets. These high cloud sheets often appear fully developed the moment the rising Sun illuminates them. They often evaporate when the Sun heats the layers during the day, only to reappear yet again as the air cools when the Sun sinks, just in time to embellish the evening fire-sky spectacle.

12.2 Fire Skies

“The Sun was setting - Suddenly the sky became a bloody red...the flaming clouds ... hung like blood and a sword over the blue-black fjord and city....I felt a loud, unending scream

piercing nature....I painted this picture, painted the clouds as real blood.” Edvard Munch.



Fig. 12-6. Deep red stage: Altocumulus 50 minutes before dawn. Cheyenne, WY 29 Oct 2018. Jan Curtis.



Fig. 12-7. Red stage: Altocumulus 38 minutes before dawn, tinted orange near the horizon by the yellow sky. Cheyenne, WY 05 Oct 2018. Jan Curtis.

Awestruck and briefly paralyzed by a striking twilight sunset scene (likely produced by tropospheric lenticular clouds or stratospheric mother of pearl clouds), Edvard Munch was inspired to paint his iconic work, *The Scream*. Though few people may experience such overwrought anxiety when viewing flaming twilight fire skies, we can't help being inspired and awestruck by the color and light show.



Fig. 12-8. Orange stage: Altocumulus about 10 minutes before sunrise on 24 Feb 2023. Jan Curtis.



Fig. 12-9. Orange and yellow stage: Telephoto view of Altocumulus 10 minutes before dawn on 24 Nov 2017. Jan Curtis.

The colors and drama of clear sky twilights, beautiful as they are, can be greatly embellished by clouds. This we have already shown, mainly with cumulonimbus clouds and their appendages in §4.2, and it is true of all cloud genera that allow sunlight or skylight through at



Fig. 12-10. Panoramic view of multicolored, ‘swirling’ altocumulus 10 minutes before dawn, 24 Nov 2017, Cheyenne, WY. Jan Curtis.

twilight. The multicolored cirrus sunset of 15 Nov 2022 with green sky highlights (Fig. 4-2) is one of many examples.

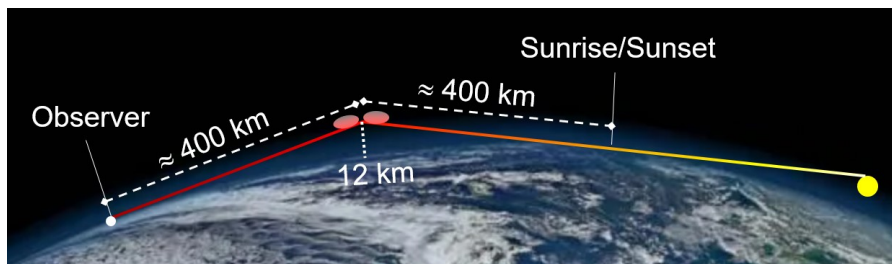


Fig. 12-11. Maximum distance into twilight sunlit clouds 12 km high can be seen. SDG.

Even so, many of the greatest twilight sky shows are reserved for the wavy or dappled sheets of altocumulus and cirrocumulus. Why not stratocumulus? Height matters for twilight colors on the spherical Earth. The higher the cloud, the further into twilight the cloud can still be sunlit and the deeper red it can be, while the deeper blue the twilight sky aloft can be. Let’s look first and explain later.

Twilight skies form a color continuum but are prolonged enough to be divided into two stages: the red stage of deep twilight and the orange stage near sunrise and sunset. A full 50 minutes before sunrise on 29 Oct 2018 deep red clouds appeared in a deep blue sky toward the eastern horizon of Cheyenne, WY (Fig. 12-6). Three weeks before that, on 05 Oct 2018, and 38 minutes before sunrise,

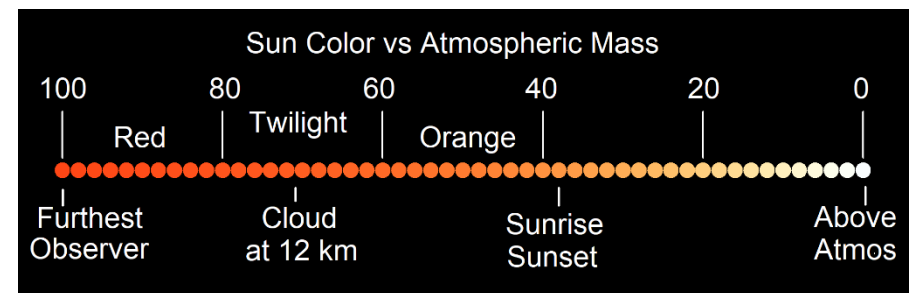


Fig. 12-12. Sun (or illuminated cloud) color vs atmospheric mass. SDG.

the altocumulus cloud sheet still gleamed red in the deep blue sky above, but orange-red near the horizon, where it was tinted by the bright yellow strip of sky just above the horizon line (Fig. 12-7).

These red twilight clouds with their deep blue skies aloft contrast with the orange twilight altocumulus and paler blue skies, sometimes tinged with a distinctive strip of green, that rule within about 10 minutes of sunrise or sunset, as in Fig. 12-8. Other colors emerge as skylight and sunlight combine to contribute to the light that clouds reflect or transmit. In Fig. 12-9 and the panoramic Fig. 12-10, both 10 minutes before sunrise on 24 Nov 2017, blazing yellow horizon skylight appears below the orange sunlit altocumulus. At the same time, the rose-speckled cloud on the right side of the photo gets its color from the mixture of blue skylight aloft plus orange sunlight.

Clouds can be sunlit deep into twilight because of the Earth's curvature. A cloud at 12 km and normal atmospheric refraction will remain sunlit until it is ≈ 400 km into twilight. An observer can be up to an additional ≈ 400 km for a total of ≈ 800 km or 7.2° deep into twilight (Fig. 12-11). At the equator, where the Sun goes straight down or up on the equinoxes, that translates to 29 minutes. In the mid or high latitudes, where the Sun goes down at a slant, clouds in the upper troposphere can be sunlit an hour or more before sunrise or after sunset.

Why are deep twilight clouds so red? Add it all up and the reflected

or transmitted sunlight on the cloud that reaches the observer had to pass through up to the equivalent of 100 atmospheric masses. Recall (§2.4 and Fig. 2-13) that the greater the total atmospheric mass sunlight must pass through the smaller the fraction of short waves that penetrates. Orange clouds prevail a short distance into twilight while red clouds prevail deep into twilight (Fig. 12-12). Of course, the light is feeble because even the deepest red light passing through 100 atmospheric masses has been reduced by over 96%.

The sky aloft in the deep twilight photos of Fig. 12-7 and Fig 12-8 is deep blue because ozone absorbs much orange light when sunbeams pass obliquely through the stratosphere (recall §2.8). When the Sun is straight overhead and the atmospheric ozone content is near its mean depth of 300 Dobson Units (3 mm when compressed to sea level pressure), 5% of the orange light is absorbed (but less than 1% of the blue light). During twilight, sunbeams lighting the sky aloft have taken such an oblique path through the ozone laden stratosphere that almost all the orange light has been absorbed – hence the deep blue scattered skylight.

Because of their greater height, nacreous, and especially noctilucent clouds can be seen even deeper into twilight. Noctilucent clouds



Fig. 12-13. Noctilucent clouds over southern Alberta, Canada 27 Jun 2021. ©Alan Dyer.

often appear wavy because of shear produced in the enormous wind speeds of the Mesosphere up to 650 km/hr. They are rarely seen as far south as Cheyenne, WY, where they were captured 57 minutes before sunrise on 20 June 2021 in Fig. 12-13. Few people other than Vincent Van Gogh (ala his *Starry Night*) get up so early.

On the twilight side of sunrise and sunset the sunlit sides of towering cumulonimbus clouds exhibit a continuous color gradation much like that of Fig. 7-6 from near white at top to near red near the base as the effective atmospheric mass the sunlight must penetrate to reach the cloud increases. For cloud layers at discrete heights the color differences are discrete, as on 22 Oct 2022, where the altocumulus cells are pronounced pink and deep orange while the patch of higher cirrocumulus is a pale orange much closer to white (Fig. 12-14).



Fig. 12-14. Cloud color vs height over Vail, AZ 22 Oct 2022 . Jan Curtis.



Fig. 12-15. Twilight cloud with underlit mamma, 38 minutes before sunrise, 23 Dec 2019. Jan Curtis.

A distinctive aspect of twilight cloud sheets is that they are underlit because the Sun is below the horizon. Features of cloud bases that are shaded or even masked during the day suddenly light up during twilight and add drama. In Fig. 12-15 pouches of mamma hanging below the body of a sheet of altocumulus were lit a lurid, blood red by the sunlight of deep twilight. As we will see in Chapter 13, some of the most dramatic twilight underlighting, and certainly the weirdest, occurs with mountain wave clouds.

12.3 Honeycomb Cloud Cells

Cellular convection is one of the simple motions of patterned cloud sheets. It is mostly a gentle form of convection as opposed to the more vigorous and even violent penetrative convection of cumulus



Fig. 12-16. Closed Cell Altocumulus, Keene, NY. SDG.

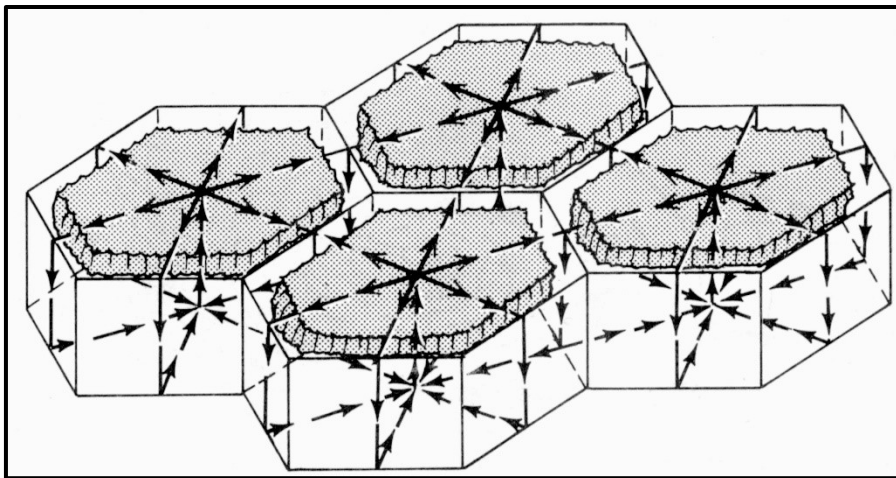


Fig. 12-17. Air motions for closed cellular clouds. SDG.

and cumulonimbus. When vertical wind shear is weak, cloud sheets often consist of tightly packed cells with a honeycomb appearance,



Fig. 12-18. Open Cell Cirrocumulus, 31 Jan 2021, Cheyenne, WY. Jan Curtis.

ideally as hexagons. This is caused by gentle, cellular convective motions in which the layer becomes slightly unstable (due to heating from below or cooling at the top) and fractures into a series of distinct circulation cells.

There are two classes of cloud cells, closed cells (Fig. 12-16 and Fig. 12-17) and open cells (Fig. 12-18). Closed cells have rising, cloudy air in the center of each cell, and clear alleys of sinking air, illustrated in Fig. 12-17. Closed cells tend to form when the top of the layer cools by radiation. The sinking motion is more intense and narrower than the rising motion. (Note: Some closed cells are donut-shaped with larger clearings at triple junctions.) If the humid layer is slowly rising, even the alleys will be cloud-filled, resulting in a mottled overcast, as in Fig. 12-19. Large areas of closed stratocumulus cells hover over the cold waters west of each continent in subtropical latitudes, as off the coast of California, Chile, or Namibia, as in the bottom frame of Fig. 12-20, centered at 23.8 South Latitude and 0.5 West Longitude on 04 Jan 2024.



Fig. 12-19. Closed Cell Altocumulus with banding and cloud-filled alleys, 08 Apr 2009, Coulterville, CA. SDG.

Open cells have narrow, cloud fringes of rapidly rising air, and broad clear centers with gently sinking air. They tend to form when a humid layer of air is heated from below. Open cells that form over warm ocean waters resemble diamond studded bracelets because they consist of interlaced rings of penetrative cumulus or cumulonimbus, as in the top frame of Fig. 12-20, centered at 57.8 South Latitude and 72.2 West Longitude. Such open cells are so large they can only be recognized from space.

12.4 Shear Wave Clouds and Cloud Streets

Tiny (Rayleigh-Bénard) convection cells can form at the top of a cup of hot cocoa that is cooling. If you stir the cocoa gently the cells will stretch into bands. In the atmosphere, wind shear can align the honeycomb cells into long bands or cloud streets parallel to the wind or swirl them into vortices. Cloud streets often form when cold, dry polar air acquires heat and moisture as it pours over warmer ocean waters and act as wind vanes. Since shear can also marshall clouds in

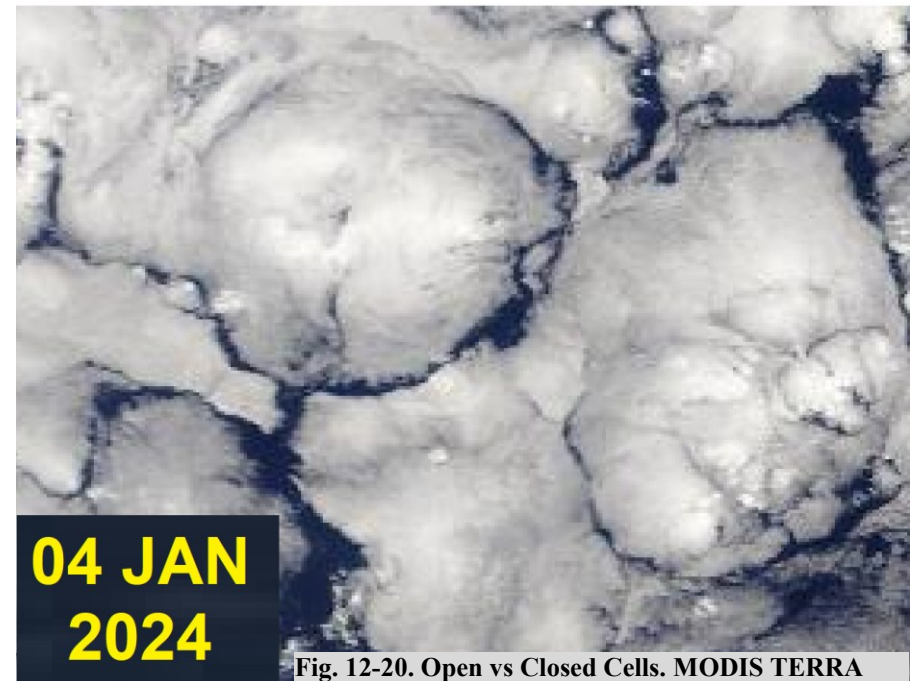
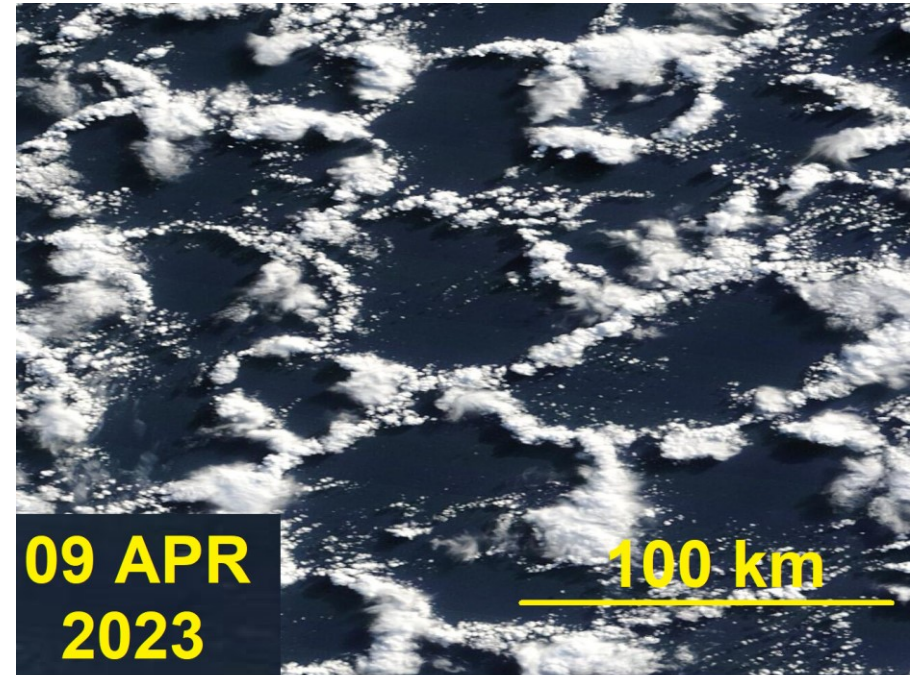


Fig. 12-20. Open vs Closed Cells. MODIS TERRA



Fig. 12-21. Train of a dozen Kelvin-Helmholtz wave clouds riding on an inversion, 30 minutes before Sunrise east of Cheyenne, WY 03 Jan 2020. Jan Curtis.

wave crests perpendicular to the wind, a cloud matrix can include any or all of these forms simultaneously. When two trains of wave clouds cross the cloud pattern is called a mackerel sky because it resembles fish scales.

the right humidity, cloud bands fill the crests where the air rises above its condensation level and clearings occupy the troughs, where air sinks below the condensation level.

Many waves develop as the result of an instability first diagnosed by Lord Kelvin and Hermann von Helmholtz. When wind blows over water that may appear glass smooth, any miniscule irregularity or disturbance will ripple the airflow. The wind accelerates where it is 'squeezed' to pass over a hump. As it speeds, pressure is reduced by Bernoulli's principle. If the wind is fast enough, i. e., if its kinetic energy is larger than the potential energy needed to lift the denser water then the lower pressure will lift the 'lump' further. At the same time, the wind spreads and slows, so pressure increases over any depression, deepening it. The result is amplifying waves.

Kelvin-Helmholtz (K-H) waves form in the atmosphere when wind speed changes abruptly at the interface of inversions in which a warm layer with faster winds overlays a cold layer. If the difference of wind speed between the two layers is large enough, Kelvin-Helmholtz waves will form, grow, and break in the air like plunging ocean waves break as they approach a beach, but in slow motion. And, if a line of cloud exists just below the inversion it will trace the motions of the growing K-H waves illustrated in Fig. 6-25. Fig. 10-10, Fig. 12-21 and Fig. 12-22 are among the examples of K-H wave clouds seen in graceful development perhaps several times in a cloud watcher's lifetime. Why are they so rare when breaking waves are



Fig. 12-22. Kelvin-Helmholtz wave clouds over the Czech Republic. ©Lukas Gallo.

The vertical wind shear that bends cirrus streamers or whips up huge ocean waves produces waves in the air with crests perpendicular to the shear. In dry air the waves are invisible, but if an air layer has just



Fig. 12-23. Cirrocumulus waves over Granada, Spain. SDG.



Fig. 12-24. Altocumulus waves over San Mateo, CA, 17 May 2014. SDG.

common on a beach? The conjunction of factors (without a beach) needed to produce K-H waves and make them visible as clouds plus



Fig. 12-25. Stratocumulus waves, 25 Dec 2022, Boynton Beach, FL.SDG.

their brief lifespan of several minutes all contribute to making them rare creatures, which adds a special note to their geometrical beauty.

Recall (Fig. 6-26) that curling K-H waves also appear for a few brief moments when rogue thermals, usually in cumulus cloud streets, poke up above the parent cloud into large wind shear. The vorticity of the thermals adds to the ambient shear to produce the waves, which quickly break and disappear. These rogues mostly occur as one or perhaps two waves rather than as a wave train.

Far more often, vertical wind shear ripples patterned cloud sheets into trains of small-amplitude waves that do not grow and break. The same is true for ocean waves out at sea, which do not break unless strong winds rip their tops off mercilessly. Examples of clouds that render simple wave trains in the air visible include Fig. 12-23, a delicate, evanescent case of rippling in cirrocumulus above the Alhambra in Grenada, Spain (where the wave crest barely reaches the condensation level, altocumulus rolls over San Mateo, CA (Fig.

12-24) and stratocumulus waves in the overcast at Boynton Beach, FL (Fig. 12-25).



Fig. 12-26. Stratocumulus ripples extending for over 1000 km across Little Sandy Desert of west Australia, 10 Sep 2020. NASA Suomi



Fig. 12-27. Propagating gravity waves over the Gulf of Mexico on the Ides of March 2008. MODIS TERRA and AQUA (4 hours later)



Fig. 12-28. Morning Glory Cloud, Burketown, Australia 11 Aug 2009. ©Mick Petroff.

From Space, cloud waves can be seen extending over hundreds of km. Dramatic examples include the 1000+ km long band of stratocumulus cloud waves over Western Australia's Little Sandy Desert, produced in a very thin humid layer with large vertical wind shear 1500 m above sea level that was capped by an inversion (Fig. 12-26).

Perhaps more striking was the sinusoidal train of gravity waves captured by the MODIS satellites in the act of crossing the Gulf of Mexico on 15 Mar 2008 (Fig. 12-27). The cause was a rapid increase of NW winds impinging on a humid veneer at 400 m above sea level capped by a pronounced inversion. The wave train that spread out resembles a train of water waves produced when a board is shoved forward. The clouds (and their motions) resemble arcus roll clouds advancing away from a thunderstorm downdraft

The most famous stratocumulus roll or rope cloud is the Morning Glory, which forms over the Gulf of Carpentaria, Australia in a similar manner, in association with the sea breeze. One of the classical photos was taken from a plane on 11 Aug 2009 by Mick Petroff (Fig. 12-28). Sailplane pilots converge on Burketown around October, when it is most likely to soar the updraft ahead of the advancing clouds.



Fig. 12-29. Longitudinal Stratocumulus bands 1500 m above Boynton Beach, FL, 28 Jan 2020. SDG.

Cloud streets or bands that may be confused with waves form parallel to the wind, as the result of helical motions illustrated in Fig. 6-27. Fig. 12-29 is an example of stratocumulus cloud streets with mostly smooth edges aligned parallel to the west wind.

12.5 Ranks and Rows

Most of the time patterned cloud sheets contain messy mixtures of cells, waves, streets, ranks, and rows. (The artist, J. M. W. Turner

loved these complex cloud sheets.) For example, while the dominant wave pattern of cloud-filled crests and clear troughs that cross the shearing west wind at 6600 m in Fig. 12-1 is oriented N-S, bands that extend E-W are also visible. The pattern of crossing waves and bands is more pronounced in Fig. 12-3, where distinctive lacunae form in some of the clear checkerboard troughs of sinking air. And Fig. 12-30, with cells, gaps, and ripples in long bands, is so complex it can be interpreted as Pac-Man seeking his heart.



Fig. 12-30. Pac-Man altocumulus seeking his heart. 07 Mar 2010, Killington, VT. SDG.

The simplicity of the motion of patterned cloud sheets stands in stark contrast to the complexity of their form. Yet, time lapse videos show that the fine-scale cells and ripples undergo very little dynamical change during the few minutes the sheets take to traverse the sky. Examples abound, including videos of the late afternoon cell-lined bands of altocumulus of 31 Dec 2023 over Cheyenne (Fig. 12-31).

https://www.flickr.com/photos/cloud_spirit/53433605237/in/album-72157673924732027/lightbox/

and the mackerel sky of 14 Mar 2016

https://www.flickr.com/photos/cloud_spirit/25774629235/in/album-72157662969788496

where all the cloud elements remain almost frozen in form as the sheet traverses the sky.



Fig. 12-31. Altocumulus bands 31 Dec 2023, Cheyenne, WY. Jan Curtis.

Visible changes of the clouds result more from larger scale fields of rising and sinking air, where blotches of patterned clouds appear or disappear in fixed form. It dramatizes the very slow speed of the small-scale churning motions of the cells and ripples.

Dynamic waves do appear in the time-lapse video of 12 March 2016, where two patterned cloud sheets at different heights move in opposite directions.

https://www.flickr.com/photos/cloud_spirit/25443517670/in/album-72157662969788496/

The higher sheet, a frozen field of cellular altocumulus moves away from the camera. The lower sheet is riddled with cloud fragments that move with the wind toward the camera. The fragments grow as they catch up to the slower-moving wave crests marked by the cloud lines and shrink or even evaporate as they exit the cloud waves and pass through the wave troughs.

All in all, the cells, waves, ranks and rows of the patterned cloud sheets produce some of the most spectacularly beautiful skies..

12.6 Cloud Wakes and Vortices

Obstacles in the flow can add a final twist to patterned cloud sheets. When moving patterned cloud sheets encounter mountainous islands the airflow and resulting cloud patterns are distorted in at least two distinct ways, best seen from space because the patterns tend to extend several hundred km downwind from the islands.

A: Kelvin Wake Wave Clouds

First are the Kelvin wake waves, whose classical cases form in the wake of moving boats and ducks, as in Fig. 12-32. Water piles up in front and a series of waves spreads out at a 17° angle on each side of the track of the vessel. (Ships are now designed with torpedo-shaped protrusions in their bows below water line to reduce the bow waves and their hydrodynamic drag.)

In the atmosphere, islands with isolated, often volcanic peaks serve as the moving boat or duck when fast winds pass by. An inversion capping the cloud top is the ideal scenario to produce waves in the air with appreciable vertical motions. The wake clouds show to greatest advantage when the cloud layer is thin enough so that it evaporates in the wave troughs and thickens noticeably in the crests.



Fig. 12-32. Kelvin wake waves made by a swimming duck. Note bow wave crest in front of the duck. ©Daderot.

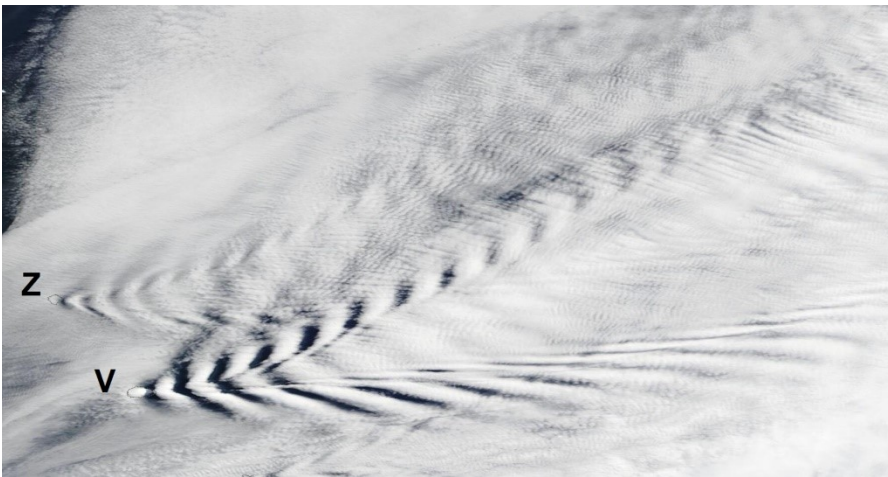


Fig. 12-33. Kelvin wake waves of Zavodovski (Z) and Visokoi (V, with bow wave) Islands, 10 Feb 2017. NASA TERRA Image.

The remote South Sandwich Islands, a chain of 11 major volcanic islands that runs N-S serve as ideal barriers to the relentless, often gale speed, westerly winds of the ‘Screaming 50’s’. The meteorological setting is often optimal for Kelvin wake waves, with low-level clouds capped by stable layers or inversions somewhat

above the height of the peaks. In some cases, each of the islands, like ships in an armada, produces its own wake.

On 10 Feb 2017, one of countless cases, a cloud layer less than 100 m thick at 1 km, the height of the peak on Visokoi Island, proved the perfect setting for a long train of Kelvin Wake Clouds (Fig. 12-33). The split pattern of wake clouds in both Fig. 12-32 and Fig. 12-33, separated by calm central wedges, occurs when the duck or wind is faster than the wave speed (Froude Number > 1). Zavodovski Island did not produce as marked a wake wave pattern because its highest peak is only 550 m. Fine scale ripples, whose cause is uncertain because there was little vertical wind shear, can be seen dappled across much of the disrupted cloud field.

B: Wake Vortex Clouds

The graceful cloud vortices that form in the flow downwind from peninsulas, capes, or islands are produced by primarily horizontal motions that occur with brisk but slower winds and lower Froude Numbers (typically ≈ 0.4) than for the Kelvin wake wave clouds, which are primarily the result of vertical motions. On rare occasion, an island can generate wake waves and vortices simultaneously, as with Robinson Crusoe Island on 02 Feb 2019 (Fig. 12-34).

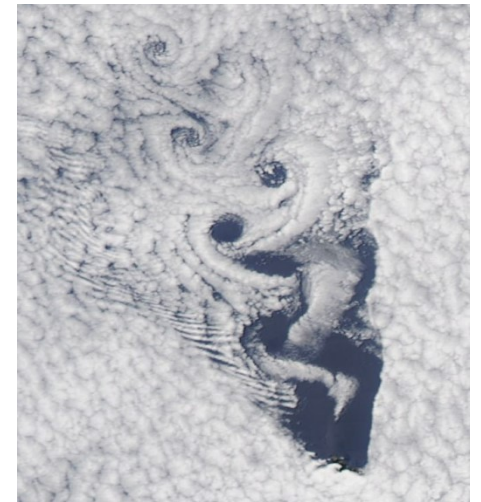


Fig. 12-34. Kelvin wake waves and von Karman vortices downwind (N) of Robinson Crusoe Island, 02 Feb 2019. NASA MODIS AQUA.

Peninsulas or capes that jut into the flow produce single vortices in their wake. A pronounced mesoscale cyclonic vortex developed off the coast of Portugal on 16 Jul 2017 as the NNE winds rounded Cape Finisterre of Galicia, Spain. The vortex in turn distorted the stratocumulus cloud field. Fig. 12-35 shows two images of the large



Fig. 12-35. A cyclonic vortex swirls the stratocumulus cloud field in the wake of Cape Finisterre 17 May 2017 and wraps up during the four hours between NASA MODIS TERRA and AQUA images.

cloud vortex and how it wrapped up in the four hours between the morning TERRA image and afternoon AQUA image.

Islands immersed in a moving cloud field split the airflow. As the wind skirts around the island it is ‘squeezed’ laterally and accelerates. The resulting horizontal shear often generates a regular pattern of von Kármán vortices that spin in opposite directions and are shed alternately on opposite sides of the island. Each vortex wraps up as it moves downwind and its trajectory is affected by the velocity field of its neighbors.

Since the motions of the von Kármán vortices are largely horizontal, their main effect is to align clouds rather than to create or destroy them. The result might be considered a beautification of a patterned

cloud sheet that is beautiful to begin with. Examples abound downwind of many islands (e. g., Guadalupe, the Canary Islands, the Juan Fernández Islands, and the South Sandwich Islands when wind speed abates), with one of the paradigm cases occurring downwind from Guadalupe Island off the western coast of Mexico on 24 May 2017 (Fig. 12-36). The von Kármán vortices aligned the cloud cells so perfectly that the distorted wind field can be traced easily even without the help of videos. Of course, videos always add vibrancy.

<https://www.youtube.com/watch?v=SawKLWT1bDA>

As the spirals wrap up, they may develop large clear ‘eyes’ mainly by encircling areas of clear air in the wake of the island. A paradigm case of clear vortex ‘eyes’ occurred in the wake of Heard Island



Fig. 12-36. Vortices in the stratocumulus cloud field trace von Kármán vortices downwind of Guadalupe Island, 24 May 2017. NASA Landsat Image.
(with its 2945 m peak) in the South Indian Ocean on 03 May 2016 (Fig. 12-37) with motions and scale shown in Fig. 12-38.

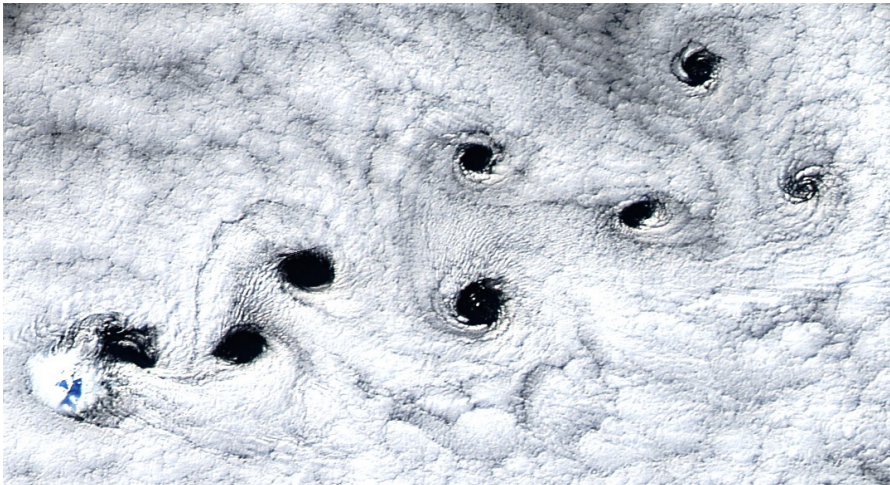


Fig. 12-37. Vortices with clear cores in lee of Heard Island, 03 May 2016. NASA MODIS AQUA .

Von Kármán vortices occur in many places, and not always on Earth. For example, they occur around the Great Red Spot and in other bands of Jupiter's atmosphere as well as in the atmospheres of all the gas giant planets.

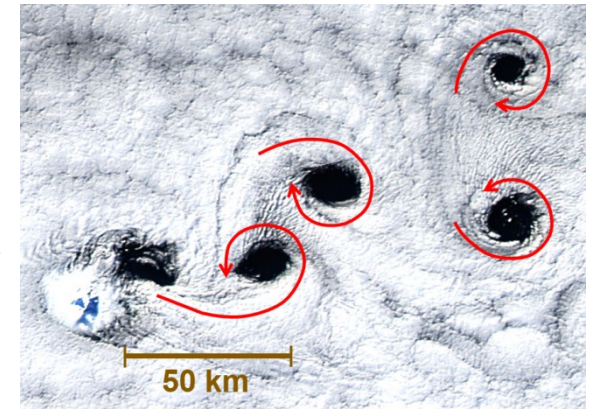


Fig. 12-38. Motions and scale for Fig. 12-37.

12.7 Patterned Cloud Sheet Gallery



Fig. 12-39. Rippled altocumulus cells over Vail, AZ 06 Dec 2022. Jan Curtis.



Fig. 12-40 Stratocumulus undulatus from the air. SDG.



Fig. 12-42 Stratocumulus undulatus over CCNY. SDG.



Fig. 12-41 Stratocumulus undulatus from the air. SDG.



Fig. 12-43 Stratocumulus undulatus over CCNY. SDG.



Fig. 12-44 Altocumulus San Mateo, CA Jun 2015. SDG.



Fig. 12-46 Altocumulus over Mt. Lafayette, NH Jul 1999. SDG.



Fig. 12-45 Hole punch altocumulus Fort Lauderdale, FL. SDG.



Fig. 12-47 Altocumulus over Chicago, 13 Jul 2009. SDG.



Fig. 12-48 Altocumulus Big Bend National Park, TX 02 Mar 2012. SDG



Fig. 12-49 Altocumulus vertebratus Boynton Beach, FL 12 Dec 2014. SDG.



Fig. 12-51 Altocumulus duplicatus Boynton Beach, FL 12 Dec 2014. SDG.



Fig. 12-50 Altocumulus waves and cells Boynton Beach, FL 06 Jan 2018. SDG.



Fig. 12-52 Altocumulus Bands at angle Boynton Beach, FL 01 Feb 2015. SDG.



Fig. 12-53 Cirroumulus undulatus Sapphire, NC 20 Oct 2018. SDG.



Fig. 12-55 Cirrocumulus (9.5 km) above altocumulus (5.5 km) Boynton Beach, FL 14 Jan 2010. SDG.



Fig. 12-54 Cirrocumulus San Mateo, CA, 09 Nov 2016. SDG.



Fig. 12-56 Cirrocumulus and Altocumulus Boynton Beach, FL 28 Nov 2023.. SDG.