Satellite Imagery Interpretation

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Satellite imagery is a useful source of analysis for the oceanic regions in the southern hemisphere, particularly in data sparse areas. The following is a compilation from various sources to help the beginning user interpret images from polar orbiting satellites. This guide is not all encompassing but should provide enough information of the basics to enhance the interpretation. An attempt will be made to recognize surface flow, cloud patterns and for locating 1000-500 mb troughs and ridges. It is accepted that the vertical motion field associated with cloud patterns can be described in particular combinations of 1000-500 thickness and surface isobaric patterns.
Polar satellite imagery software commercially available provides imagery in the Visible (VIS) and Infrared (IR) wavelengths. Solar radiation occurs at wavelengths between 0.2 and 3&#x3BC;m, known as short waves. The atmosphere absorbs a very small amount of this energy while the earth the majority. The earth, as well as dense cloud, re-radiates this energy at wavelengths between 3-100 &#x3BC;m, termed long waves, which falls entirely within the infrared region of which maximum intensity is around 11 &#x3BC;m. Operationally, satellite visible imagery detects reflected wavelengths between 0.4-1.1 &#x3BC;m; IR wavelengths between 10-12 &#x3BC;m and water vapor emissions of 6-7 &#x3BC;m. In the black and white display of VIS images, the brightness depends on the albedo, or reflection, of the underlying surface. In general it may be said that the thicker the cloud the brighter the response, and for the same thickness liquid water clouds will appear brighter than ice clouds. Thin clouds do not show up very brightly in VIS imagery. IR imagery indicates the temperature of radiating surfaces. In black and white, warm areas are shown as dark tones and cold areas in light tones. Clouds appear whiter than the earths surface because of their lower temperature. Because cloud top temperature decreases with height, IR images show good contrast between clouds at different levels (unlike VIS imagery), thus is useful in estimating cloud type and height. IR imagery is inferior to VIS in providing information about cloud texture because it&#x2019;s based upon emitted and not scattered radiation. Also low cloud and fog can rarely be observed in IR at night because they are too similar in temperature.
CLOUD INTERPRETATION
It is not always easy to recognize clouds and, in complicated weather scenarios, their genera may even be a combination of the recognized types of which there are ten: Cirrus, Cirrostratus, Cirrocumulus, Altocumulus, Altostratus, Nimbostratus, Stratocumulus, Stratus , Cumulus and Cumulonimbus. Many of these have a number of species. Together, the type and species determine how the cloud was formed. As such, they are pointers to the type of weather occurring as they form and disperse. Often the simple distinction by the surface observer is drawn between convective and stratiform clouds where convective cloud tends to be deeper and gives the appearance of a &#x2018;boiling&#x2019; fluid, whereas stratiform cloud is shallow, layered and more quiescent. As a rule air does not cross sharp cloud boundaries at the level of the cloud. Ragged edges denote that air is flowing into or out of the cloud. Mid level instability of convective cloud is sometimes marked by a form of Altocumulus clouds shaped like the turrets of a castle, known as castellanus. The views from polar orbiting satellites is far different from surface observations and the following cloud types have been chosen for review:
Cumulus humilis. These are small cumulus cells and the smallest may not be resolved by satellite. The presence of shallow cumuli will increase the brightness in visible images compared to a cloud free area. In IR the cloud tops are relatively warm but cooler than the underlying surface, so shallow cumulus may appear lighter than cloud free area.
Cumulus congestus. The larger cloud elements and increase in cloud top height produce a brighter visible image. In the IR they appear light grey. Most cumulus is not normally detected in the WV image.
Cumulonimbus. Cb&#x2019;s may appear as isolated, nearly circular cells when there is little wind shear with height. When shear is large, a cluster of Cb&#x2019;s will produce a large cirrus shield. Cb&#x2019;s appear in the VIS as a very white cloud with a uniformly bright top. When a large wind shear exists the Cb will have a distinct edge on the windward side and the cirrus anvil with a fibrous indistinct edge on the leeward. In the IR Cb&#x2019;s are generally bright white with well defined boundaries.
Stratus. In VIS the tone of the cloud varies from white to gray depending on the density. Stratus is difficult to detect in IR. The individual cloud elements of Stratocumulus are similar in appearance to small and medium cumulus, namely irregularly shaped globules of cloud. The overall view is of an extensive sheet or cloud elements aligned in bands parallel to the wind. In IR Sc is seen as medium to dark grey.
Nimbostratus, Altostratus and Altocumulus. In VIS, thick altostratus and nimbostratus appear as very bright cloud with a fairly uniform surface organized into bands or extensive sheets. In the IR these clouds are white. Altocumulus is often indistinguishable from altostratus in VIS and may not be seen in IR.
Cirriform Cloud. These are composed of ice particles. Cirrus fibratus is often formed into long narrow bands up to about 50nm wide and up to several hundred nm long. It&#x2019;s a thin tenuous cloud and often transparent enough to allow the underlying terrain and lower cloud to be visible. In VIS the cloud is light grey and in IR it&#x2019;s normally light grey to white. Cirrus spissatus is often found in a band 50-100 nm wide and up to several hundred nm long. In VIS the elements can be globular or elongated and white to grey. In the IR it&#x2019;s white in the center and often grey near the edge with very fine detail radial &#x2018;streamers&#x2019; perpendicular to the band. Cirrostratus in VIS may appear as white long bands or as an extensive sheet. The cloud surface is remarkably smooth and uniform. The tone between white and grey marks the IR.
MESOSCALE CLOUD PATTERNS AND FORMS
Open Cells. Open cells are cloud formations of quasi hexagonal shape with a cloudless space inside and a ring of convective clouds at the edges. The cloud ring consists of several dozen cloud elements merging into one another.
Closed Cells. These are hexagonal in shape bounded at their edges by a cloudless space. They consist of Stratocumulus clouds and have horizontal sizes from 5 to 50 nm.
Wave clouds. Can be caused by terrain barriers with the cloud appearing as a pattern of bands usually perpendicular to the wind. The bands are separated by clear spaces of the same size. The patterns are usually Stratocumulus and Altocumulus.
Mesoscale vortices. These are cloud formations consisting of one or more alternating spirals with varying amounts of cloudiness. They are often seen downstream of small islands or peninsulas and are caused by horizontal wind shear.
Cloud lines.A cloud line is a line of convective cloud elements stretching in the direction of the wind at cloud level. These are seen as parallel lines of cloud, curved or straight.
SUB-SYNOPTIC SCALE CLOUD PATTERNS
Vortices in Stratus and Stratocumulus. Vortices occurring in extensive fields of stratocumulus and stratus commonly occur over oceans. They represent weak cyclonic circulation in the lower atmosphere beneath an inversion. The curved appearance of these clouds are apparent.
Vortices in Cumulus and Cumulonimbus. These are usually small and create spirals. The diameters of these vortices range from 100 to 250 nm. They can be found in the rear of a depression, where convection is well developed and are observed over the tropical oceans. They are formed as a result of mid-tropospheric vortices building downward. These vortices can form well apart from low level depressions. In the tropics as the mid level vortice builds down it will organize altocumulus into a weak vortex like pattern, but unless the circulation builds downward to &#x2018;tap&#x2019; the warm moist air, releasing its latent instability, no marked spiral structure or resulting cirrus shield will develop. Never the less, even with weak patterns, squally surface weather may occur.
Squall lines. These can be seen ahead of a cold front. They consist of a thin line of cumulus and cumulonimbus in front and parallel to a frontal band.
Cumulonimbus clusters. A cluster consists of numerous Cb cells whose tops are seen as bright patches from which cirrus streamers emanate at the 200 mb level. Sometimes &#x2018;lumpy&#x2019; parts are seen and are the locations where updrafts &#x2018;overshoot&#x2019; above the cirrus canopy, indicative of the active precipitating regions of the clusters.. Each overshooting top represents an individual thunderstrorm updraft. They appear similar in both VIS and IR. Clusters are thus associated with intense convective storms. Merging clusters are termed mesoscale convective systems (MCS).
SYNOPTIC SCALE CLOUD PATTERNS
Comma Shaped Cloud Formations. This pattern is generated with fields of Cumulus clouds associated with maxima of cyclonic vorticity. The appearance is of curved lines or bands of clouds organized about a center.
Cold Fronts. A cold front is clearly recognizable in satellite imagery. It lies along the outer segment of the spiral band which forms the vortex or comma head. As a rule the width of cold frontal cloud band decreases away from the vortex center.
Active cold fronts appear as continuous, well developed cloud bands, bright in both VIS and IR. These frontal cloud bands are associated with strong baroclinic zones that have considerable thermal advection and strong vertical shear. They consist of nimbo-stratus and cumulonimbus clouds. Bands in which nimbostratus predominate are usually wider than bands consisting mainly of cumulonimbus.
Inactive cold fronts usually appear as narrow, fragmented and discontinuous cloud bands over water. Inactive cold fronts are associated with weak baroclinic zones, weak cold air advection and slight vertical shear. They are bright in VIS, but grey in IR.
Warm Fronts. The identification of warm fronts is quite difficult. The classic northern hemisphere feature is a zone of banded structure that can be 150-250 nm wide and up to several hundred nm long. In the southern hemisphere very long cloud zones are rarely seen. When the occlusion process begins, the cloud band contracts until all that is visible is a slight projection of cloud at the occlusion point. This is all tha remains of the warm front that was previously present. The cloud zone of a warm front has anti-cyclonic curvature, bulging toward the cold air. The cloud of a warm front is usually uniform nimbostratus and in warm climates, masses of Cb. Warm fronts which are weak or non-existent near the ground produce bands of cirrus clearly seen in satellite imagery.
Occluded Fronts. The occluded front is placed along the cloud spiral from the point of the cold fronts maximum width toward the center of the spiral. Usually this point lies poleward of the vortex center. On VIS the occluded front is bright. On IR the brightness decreases along the band towards the center of the spiral where the clouds are lower. The position of the occlusion point can sometimes be determined from a small projection of warm frontal clouds off the main cloud band. If the cloud band has a well defined inner boundary the occluded front is drawn to the rear of the cloud spiral. If the inner band is not sharp then the front is drawn in the middle of the band.
Stationary Fronts. The cloud band of a stationary front has virtually no cyclonic or anti-cyclonic curvature. On VIS and IR the boundaries of the band are more amorphous and the band itself is irregular often with gaps. A quasi-stationary front can be active or inactive. The active stationary front tends to have the upper level flow parallel or nearly parallel to the frontal zone, A wide cloud band is characteristic, and surface waves can develop on such bands. Inactive stationary fronts are usually found in lower latitudes. These fronts generally appear as fragmented east-west cloud bands. The subsidence from a subtropical High leads to the dissipation of clouds within the frontal zone, therefore, few low and middle clouds appear in the band. The line of the surface front usually coincides with the central part of the cloud band when the upper level flow is parallel to the cloud band. If wave development is occurring then the front should be shifted from the center of the cloud band to the warm side.
Pre-frontal and post frontal squall lines. The prefrontal cloud line is situated in the warm air, parallel to the cold front and often separated by a relatively cloudless zone 25-50 nm wide. The most intensive parts of the squall line are bright in both IR and VIS. The clouds of the post frontal squall line look, on VIS and IR, like broken spirals. These bands consist of cumulonimbus and cumuliform cloud.
ANALYSIS AND ASSOCIATIONS
Distributions of thermal gradients, locations of thermal troughs and ridges, 1000-500 mb thickness patterns, and surface isobars can usually be inferred from the arrangement of small scale cloud features, such as convective cell shape, striations and alignments in major cloud bands. A well developed cloud pattern, for example, is taken as evidence that a significant departure from the climatalogical normal thickness pattern exists. The following interpretation principles can be used.
Solid, bright areas and bands of thick cloud always correspond to warm tongues and indicate thickness values above normal. In other words, warm advection.
Areas of open cell convection cloud always correspond to cold troughs and indicate thickness values below normal. In other words, cold advection
Areas of closed cell convection and low level stratiform cloud indicate thickness values close to normal. In other words, weak thermal advection.
The area of convective cells is usually one of the most distinctive features in analysis. Normally &#x2018;open cells&#x2019;, with varying degrees of distortion from the classic &#x2018;polygon&#x2019; shape, to blown out ellipses and elliptical chains, are most prominent near the middle of the convective field, These can build up into clusters of enhanced cumulus (called PVA masses) in the eastern sector due to general uplifting in areas of cyclonic vorticity advection. On the western side of the convective area the open cells merge or graduate into &#x2018;closed cells&#x2019; and the sharpness of the transition between open and closed cells is an aid to position the jet and the shape of surface isobars. Open cells appear when the temperature difference between the sea surface and surrounding air is large. Thus open cells develop in a warm air flow, or cold air flow, relative to the ocean. They can be used as an index to estimate the strength of cold air flowing into the rear of a developing Low. As open cells tend to appear in cyclonic flow it&#x2019;s because cold advection is usually intense and the temperature difference is large between sea and air. Compared with open cells, closed cells appear when the temperature difference is small between sea and air. Closed cells can replace open cells when cold air flow is abating.
Ahead of the convective area is the Frontal Cloud Band consisting of multi-layered middle to high level cloud which results from organized vertical motion. The important characteristic of this band are its width, solidity and the sharpness of the rear edge.
The controlling element of the cyclonic system is revealed by the organization of the frontal vortex or comma cloud at the southern end of the frontal band. The amount of vertical structure and the extent of solid, upper-level cloud are indicators of the stage of development of the system. In practice, actual cloud patterns are often more complex or less clearly organized. The pattern can take on classical forms of development; from the initial wave stage (baroclinic leaf)- which is merely a widening or an anti-cyclonic bulge in a frontal cloud band, to the familiar cloud spirals of the occluded and decay stages of the system. Or the system may develop into a &#x2018;cut-off&#x2019; low. Additionally, a secondary depression can develop in the post frontal cold air with its own life cycle, or move to join the original front as an &#x2018;instant occlusion&#x2019;.
LOCATING DEPRESSION PATTERNS
Cloud formations produced by cyclonic disturbances represent the combined effect of active condensation from upward vertical motion and horizontal advection of cloud.
Wave stage.The emergence of a wave at a front is indicated by a widening of a segment of the frontal cloud band up to several hundred nm in length. Also called a baroclinic leaf, the band develops an anti-cyclonic bulge toward the cold air. The clouds over the surface position at this stage show no evidence of a vortex pattern. The cloud band is bright in both VIS and IR and usually has a smooth edge on the cold side and a ragged edge on the warm side. The 500 mb vorticity center is situated on the cold side of the leaf and near the &#x2018;bulge&#x2019;.
Young depression stage. As the wave develops, the curvature of the bulge becomes more pronounced. The center of low pressure is near the apex of the cloud band where the clouds are thickest. It is placed towards the center of the band near where the curvature of the frontal band changes from concave to convex. This stage is very short.
Developing depression stage. In its central part, the early cloud bulge resembles the head of an octopus and soon develops into a spiral form with the cold and warm fronts fusing into the spiral. Shortly thereafter, in the rear of the depression, a well defined relatively cloudless area appears, in which lines of cumuliform clouds develop. At this stage the cloud band associated with the cold front becomes dominant.
Occluding stage. As the depression begins to occlude a definite spiral is seen and a cloudless dry slot begins to form behind the front. The main difference between this and the previous stage is that the cloud band associated with the warm front decays almost completely, leaving only a small projection. The cloud system of the occluded front and the cold front form a single cloud spiral. This structure may remain unchanged for a considerable time&#x2026; up to three days.
Occluded stage. The main feature of cloud cover in an occluded cyclone is that the vortex cloud system becomes isolated from the cloud bands associated with the main front. The presence of a cloud vortex consisting of several cloud spirals and surrounded by a cloudless or relatively cloudless space, is the main indication of an occluded depression. This stage may persist for several days.
Dissipation stage. The cloud spirals start to decay and eventually will disappear as the vortex fills.
Cut-off lows. Well developed cut-off lows also produce spiral vortex patterns. Low latitude cut-offs that develop at the base of existing upper level troughs (the apex is &#x2018;pinched&#x2019; off) produce a cloud pattern similar with frontal vortex development. Instead of moving poleward as in the case of true wave development, the cloud system with the cut off either remains stationary or tracks towards the equator. It thus becomes separated from the westerlies and lies north of them.
THE SURFACE FLOW PATTERN BEHIND A COLD FRONT
Four criteria can be used to analyze the flow pattern to the rear of major frontal cloud bands.
Open cellular cloud existing right up to the rear edge of a sharp-edged frontal cloud band indicates cyclonic flow south of west immediately behind the front-and the more developed are the convective cells the more southerly is the flow.
A clear area between the frontal cloud band and the open cellular cloud indicates a flow north of west, without marked cyclonic curvature. The surface isobaric trough is positioned at the eastern extremity of the convective cells
The appearance of open cells, occurring immediately to the rear of the frontal cloud band but being much more developed well to the west (PVA masses), is characterized by positioning the post-frontal surface trough over the enhanced convection by a change in the orientation of the isobars from southwest to south.
Winds back rapidly behind frontal bands where the cloud field consists of closed cells (Stratocumulus). The flow pattern in this area is anticyclonic and is usually found further along the frontal band.
Two rules are invoked for pressure analysis in the vicinity of the &#x2018;occluded&#x2019; part of the frontal band which sweeps back into the mature vortex.
The occluded part of the frontal cloud band is analyzed as a line of pressure minimum with the lowest pressures always located near the most pronounced spiraling.
Strong pressure rises occur behind the bent back occluded cloud band, particularly if clear areas or low stratiform cloud occur immediately to the west.
THE 1000-500 MB THICKNESS FIELD
The main cloud patterns which can be used as analysis indicators are summarized as follows:
The extent and orientation of the thickness trough is well defined by the extent and orientation of the convective area.
The vertical shear between the top and bottom of the convective layer as indicated by the shape of the cells, approximates very closely to the direction and magnitude of the shear in the 1000-500 mb layer.
The width, solidity and orientation of the frontal cloud band provides a guide to the extent and orientation of the thickness ridge.
A sharp edge on the cold side of the frontal cloud band indicates strong 1000-500 mb shears aligned very closely along the direction of the edge.
The primary vortex cloud is usually located at an inflexion point between the thickness trough and the thickness ridge.
THERMAL TROUGHS
The visual appearance of convective cloud found within the thermal trough area (the &#x2018;cold tongue&#x2019;) can be summarized as follows.
Open cloud cells. Circular or &#x2018;doughnut-shaped&#x2019; cells form as cold air is heated over the warmer ocean, in conditions of light vertical shear. The &#x2018;doughnut&#x2019; is made up of numerous individual Cumulus. Downdrafts reaching the surface produce cloud free areas and the appearance of open rings. The diameter of the cells is related to the depth of the cold air. Large diameters are indicative of very deep cold air and occur along the axis of the thickness trough. Cells of smaller diameter are the sign of shallower convection and small thickness anomalies. Wall size or the thickness of the cloud ring is a guide to the intensity of the convective process. The coldest air has the thickest walls. Movement is cyclonic and if the cells remain &#x2018;doughnut shaped&#x2019; their speed is usually less than 10 kts. And if the &#x2018;donut&#x2019; becomes elongated the speed is 10-20 kts.
Blown out ellipses. &#x2018;Horse-shoe&#x2019; shaped cells indicate a great amount of vertical shear. The direction of the shear, and usually the wind is in the direction from the open &#x2018;U&#x2019; to the &#x2018;bend&#x2019;. Movement is cyclonic with speeds from 21-30 kts.
Compressed doughnut. This was previously a circular doughnut open cell that has been compressed so that no open space exists. It appears elongated and indicates wind in the elongation direction with speeds greater than 30 kts.
Elliptical chains. These are continuous bands of &#x2018;blown-out ellipses&#x2019; joined together in a chain like structure parallel to the surface wind. Movement is cyclonic. They can turn into cloud streets if they lose their cellular pattern. Precipitation is not normally associated with cloud streets, but it is possible from deeper cloud and would be in the form of light to moderate showers.
Linear rolls. Narrow bands of cloud interpreted as strong vertical shear directed along the line of the cells. They are most frequently found near the boundary between the open cells and the closed cells and can be considered a transition zone.
PVA masses. Fused clusters of large cumulus and cumulonimbus formed by the imposition of upper vorticity advection ahead of the trough axis.
Closed cells. These are stratocumulus cells, indicating the tendency for subsidence where the unstable layer is capped by a stable layer, causing the cumulus to flatten out into stratocumulus. Thus it is the Sc that is seen rather than the Cu producing it. Movement is anticyclonic. They appear bright in VIS and grey in IR.
THERMAL RIDGES
The frontal cloud band is the indicator. Fronts (zones of baroclinicity) appear in VIS and IR as cloud bands. It consists of multi-layered middle-level cloud and cirrus, of a width, texture and orientation closely related to the thickness gradient in, and warm advection ahead of, the frontal zone. Four factors are:
The width of the band. Is the band broad or narrow?
The solidity of the cloud. Is it ragged cumuliform or solid stratiform?
The nature of the preceding cloud. Is it cold convective, streaks of cirrus or low stratus?
Generally, broad bands indicate broad thickness ridges and narrow bands indicate a narrow thickness ridge. Broken or fibrous cloud indicates little departure from normal thickness while solid, bright bands indicate a definite thickness ridge. The pre-frontal cloud ahead of the band constitutes a guide as to the manner in which the thickness isopleths spread out from the ridge. If cold air convection cells occur immediately ahead of the frontal cloud then the thickness ridge is contained well within the frontal cloud mass. If non-convective cloud precedes the frontal cloud the thickness ridge tends to be forward of the band. A sharp rear edge to the cloud band indicates strong 1000-500 mb shear and the sharper the edge the more closely is the shear parallel to the edge as is the wind direction.
LOCATING THE THICKNESS RIDGE AXIS
Where the frontal band is broad (250 nm or more) the ridge axis lies along the axis of the cloud band. Cirrus streamers from the forward edge of the cloud band are a guide to the shape of the thickness isopleths turning anti-cyclonically with the upper flow.
Where the frontal band is narrow (less than 250 nm) then attention to the cloud ahead of the band must be taken to locate the ridge axis.
If the narrow band is immediately preceded by cellular convection then the thermal ridge axis lies along the axis of the cloud band. The width of the band corresponds very closely with the width of the ridge.
When a cloud band is preceded by ragged, unorganized cloud the ridge axis is located along the leading edge of the frontal band. If streaks of cirrus or &#x2018;cloud fingers&#x2019; are evident the axis should be placed along the line where these emanate from the cloud band. In cases of narrow bands the cirrus streamers should be ignored as they are often the result from &#x2018;stretching deformation&#x2019; in the upper level flow rather than vertical shear.
When the cloud band is preceded by clear areas, or sheets of low stratus, the ridge axis should be positioned out ahead of the leading edge of the band.
THERMAL CENTERS
Thickness troughs typically take the form of cyclonic curving &#x2018;tongues&#x2019; of cold air. It is usual to find a point along the axis of the trough where the cold air has its greatest development which is the &#x2018;cold pool center&#x2019;. The location of the center of the cold tongue is revealed in the satellite image by the following:
The center of curvature as indicated by the visual &#x2018;impression&#x2019; of the curved cloud pattern.
The point at which the open cells have the most circular appearance and the largest size.
PVA masses which form immediately ahead of the center.
CLOUD VORTICES
The comma part of the disturbance can incorporate either a cold tongue flowing cyclonically into the vortex and/or a warm tongue curving cyclonically into the vortex from the frontal band.
JET MAX
The approximate location of the jet max can be determined by:
Unorganized clusters of enhanced cumulus ahead of the trough axis usually indicates the jet max is located well upstream in the western flank of the thickness trough
Distinct and organized PVA masses with a tendency for strong vertical structure or the solidity of the &#x2018;comma&#x2019; formation indicate the jet max is located in the apex of the trough, with the thickness lines spreading out on either flank.
With no PVA masses and well developed open cells in evidence right up to the rear of the frontal band, the jet max is located in the eastern flank of the trough and parallel to the edge of the frontal cloud band.
The boundary between open and closed cells will give an indication of the position of the jet stream.
COMPATIBILITY OF SURFACE FLOW AND THICKNESS PATTERNS
It&#x2019;s important that thickness pattern and surface isobaric analysis be not only consistent but they must correlate. There are four guiding principles that maintain compatibility between surface flow and thickness structure.
The amplitudes of 1000-500 mb thickness troughs and ridges are always approximately the same as amplitudes of the surface isobaric troughs and ridges.
The axes of the 1000-500 mb thickness troughs and ridges are always aligned approximately along the direction of the surface wind flow.
Thickness lines and surface wind flow are practically parallel over stratocumulus, and are at a large angle over open convective cells and solid upper level cloud.
Thickness gradients are very slack over clear areas and areas of low stratiform cloud.
THE SUB-TROPICAL JET STREAM
A continuous band of upper level cloud (usually 1000 nm long or more) originating in the tropics often extends into the subtropics, pole ward of 7 to 15 degrees latitude. The jet is associated with an upper level baroclinic zone and is generally not reflected in the 1000-500 mb thickness field. The cirrus plume associated with the jet usually has some anti-cyclonic curvature, but at low latitudes may be straight on a polar stereographic projection. Moisture and clouds move pole wards in response to the amplification of a low latitude trough in the westerlies, or the digging of a mid-latitude trough into the sub-tropics. Often this cirrus plume has transverse bands, oriented across, or perpendicular to, the direction of the upper wind flow. The bands are usually on the equator ward side of the Jet, are wide, thick and are bright in VIS. The bands are a result of strong horizontal wind shear. The equatorward edges of each band may trail off due to slower wind speeds north of the jet core. The trails point to where the wind is coming from. This is an area of moderate to severe upper level turbulence. Also evident may be a scallop pattern of cloud along the band on the polar side. These give the appearance of a ragged or lumpy edge. Often Cirrus streaks are observed. These are oriented nearly parallel to the wind at cloud level and indicate the direction of upper wind flow.
LOCATING THE JET: Cirrus is a result of vertical and horizontal shear motions. Cirrus predominates on the equatorward side of the wind max as it creates anti-cyclonic shear. The poleward boundary of the cirrus is usually sharp in appearance. A jet that is cyclonically curved will have an effect on lower cloud. On the right side, looking downwind, low temperatures and unstable air create open cell cumulus ,and on the left or warmer side stratiform or closed cell cumulus are found. A cirrus band is commonly seen on the eastern side of an upper level trough extending downwind to the upper ridge. Much of the cirrus dissipates when the jet curvature changes from anti-cyclonic to cyclonic.
LOCATING SURFACE HIGH PRESSURE CELLS AND THE RIDGE AXIS
Over the oceans surface high pressure centers cannot be reliably located from cloud imagery. High pressure areas can be clear of cloud or cloud covered, with closed cellular Sc in areas of cold advection on the east side, and low stratiform clouds on the west side where warm air is being advected over cooler sea surfaces. The usual analysis procedure it to locate the high pressure center over the area of closed cells at the point where the closed cells are smallest. The following may offer further useful guidelines:
In cold air over warm land or sea. Over land the center of the High is in the middle of the cloudless area behind a cold front. Over ocean areas cumuliform cloud in the form of open convective cells delineates the area of the High center.
In warm air over sea. If the temperature difference between air and sea is small, the anti-cyclonic area in IR is relatively cloudless with a minimal amount of cloud in the High center or ridge line. If a high level warm High develops over a cold surface extensive areas of stratus or closed cells is evident. If closed cells then the High center is where the cells are smallest.
Ridge lines ahead of a frontal cloud band can be evidenced by &#x2018;cloud fingers&#x2019; coming off the frontal band. The ridge is drawn at the end of the fingers then roughly running parallel to the frontal cloud band.
When two Lows are in close proximity a sharp surface ridge is found between them. It is located close to the western Low and very close to the solid cloud band of the cold front to it&#x2019;s west, and the cumuliform cloud just to it&#x2019;s east which forms in the colder air behind the second Low. Also, the ridge axis is placed approximately parallel to the boundary between the closed and open cumuliform cells, and several degrees of latitude on the closed cellular side.
Sub-tropical ridges on the Highs western quadrant are found at the boundary between the tradewind cumulus and the stratiform cloud formed when the air flows southward over colder water. Ridges forming to the east may sometimes, but not always, be located by stratiform cloud to the south of the ridge axis and tradewind cumulus north of the axis.
Locating upper Highs. Closed upper Highs are best found when a distinct WV boundary forms as a dark circular area. Surrounding this band whiter shading indicates cloud or moisture flowing anti-cyclonically. IR imagery would show this as a grey circular area nearly surrounded by a ring of whiter cloud.
BLOCKING REGIMES.
Deformation zones associated with mid-level blocking can be detected by satellite imagery quite successfully. The middle level clouds form a ragged &#x201C;fountain&#x201D; or &#x201C;flower&#x201D; pattern laid on its side facing westward. The &#x201C;stem&#x201D; of clouds,occurring in the flow (generally easterly) is located between the cyclonic and anti-cyclonic centers. Some of the clouds curve cyclonically around the Low to the north, and other cloud moves anti-cyclonically around the adjacent ridge to the south. Identification of this deformation pattern can be crucial to the recognition of the existence, persistence and location of blocking regimes in the southwestern Pacific which are often poorly depicted on upper air analysis.
SYNOPTIC ANALYSIS IN THE TROPICS
In the tropics, direct analysis of the wind field plays an important role in daily synoptic analysis. Clouds over the tropics, viewed from satellites, reveal many features of the flow. Firstly, the distribution of widespread cloud systems has definite relationships to major trough and ridge positions and makes possible estimates of the general flow. Secondly, wind estimates for both upper and lower tropospheric levels can be obtained from an analysis of Cumulus and Cirrus cloud formations. These estimates are based either on the interpretation of a single picture or on actual measurements of cloud motion from a series of pictures. The inhibiting effects of cool water on Cumulus formation are readily seen. For example, the abrupt southern edge of the ITC cloud band in the eastern pacific parallels the northern edge of the cold Humboldt current. No deep convection occurs over the cold waters in any season. The effects of local sea breeze circulations in concentrating clouds along the coastlines are apparent in the tropics. The concentration of clouds over tropical islands is clearly evident. Convective-type clouds over land areas in the tropics are the result of diurnal heating. Clouds also can form over long tropical atolls that run parallel to the trades due to friction and horizontal shear causing convection. Cirrus plumes from big buildups indicate the direction of upper flow usually around 200mb. The main Cb flow is mainly guided by winds at 700mb. There are specific features of planetary scale flow which control cloud distributions. Near the equator the Equatorial Trough (current term is the NETWC or Near Equatorial Trade Wind Convergence) is a breeding ground for storms. In the trades, the upper tropospheric (300-200 mb) mid-oceanic troughs are responsible for surface disturbances with potential for development. On any given day, the tropics and sub-tropics contain many weak disturbances which have an effect on local weather. In satellite imagery these disturbances appear as areas of Cumulonimbus with considerable amounts of Altostratus and Cirrus present. Weak disturbances can be transient. They can develop within 24 hours and dissipate just as rapidly. For a weak tropical disturbance to be considered significant with regard to potential development, its cloud system must be 100 nm in diameter and it must persist longer than 24 hours. There are several indications which show whether a disturbance will intensify.
The area of strong convection becomes larger or convection increases in strength. This is reflected by an increase in the area of Cirrus from one day to the next.
A vertical pattern develops in the clouds.
Indications of weak shear. Short cirrus streamers in a diverging pattern indicate this. Only a concern in the tropical cyclone season.
Also strong vertical shear. Strong upper flow vents mass to sustain cloud clusters as the clusters are moved along by the trades.
The Tropical Upper Level Tropospheric Troughs (TUTTS) which occur in the summer are evident at 200 mb. In the mean their axis lies 5 to 10 degrees equatorward of the sub-tropical ridge line. A first approximation of the trough position, evidenced by upper level vortices, is in the form of curved Cumulus lines and estimates of upper level wind direction based on Cirrus plumes. If the circulation reaches the surface, it becomes an integral part of the upper vortex. Neither forms independently, nor does the surface disturbance move away from the vortex. Even if the upper system moves eastward, the surface trough or vortex will move upstream against the surface trades. The TUTT can also exist as a shear line with no detectible vortices and is evidenced as a line of convective surface disturbances associated with upper level flow.
Burst band disturbances occur as a surge of air moves across the equator into the northern hemisphere, where it engages the Intertropical Cloud band or ITCZ. The flow curves anti-cyclonically after it crosses the equator and forms a small anti-cyclone which moves westward. As it does so, a cloud band develops in advance, is a weather producer, and is called a burst band. The formation can cause heavy rain, lasts for one or two days, then disintegrates into small fragments or isolated cloud clusters.
Tropical Cloud Incursion.
Amplification of upper level troughs in mid-latitudes may initiate an extensive southward incursion of cloud and moisture from the tropics. The cloud band produced lies just ahead and parallel to the Northwest upper flow and thus progresses to the southeast. Discrete cloud clusters can be embedded in the band as a result of an upper jet max. Often these disturbances are not reflected on surface analysis charts.
Tropical storms will not be addressed in this compilation.
This summary is intended as a basic guide for polar satellite imagery interpretation. It is aimed as a refresher for operational forecasters and practical users such as commercial fishermen and cruising yachtsmen. The later should ideally have at least a beginning course of university meteorology. The data is a compilation from the following sources:
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Any errors, omissions, or misinterpretations in this paper are solely mine. David Sapiane, 21 August 2008