

APPLICATION OF SATELLITE IMAGERY IN OPERATIONAL FORECASTING FOR AVIATION

TADESSE SOBOKA
NATIONAL METEOROLOGICAL SERVICE AGENCY
ADDIS ABEBA, ETHIOPIA

ABSTRACT

Imagery from satellites observations do provide to me a mechanism for describing weather features, such as cloud, precipitation patterns and pressure systems. It is possible to make useful inference about the fields of wind flow. The relationship in weather and cloud are associated with the areas of convergence and updrafts while clear skies associated with divergence and sinking of air.

Local studies of the relation between convergence, divergence and weather by using analyzed wind of local observation, ECMWF products and satellite data made forecasters active in Ethiopia. Local influence is also considered with continuity through the study of the climatology of Ethiopia

There are three seasons in Ethiopia

Wet Season: (June-September) During the wet season Northern Hemisphere Summer the I.T.C.Z. move north and the Tropical maritime air originate from the Indian Ocean and Equatorial maritime air from South Atlantic Ocean. These air masses have high moisture content and converge over the central high lands. That convergence line is extended northeastward from south west (Congo air boundary) and the area over this region is unstable air and produces extensive cloudiness and severe thunderstorms. Depending on the intensification of Mascarene high and St. Helena high, extensive cloudiness, severe thunder storms associated with icing, turbulence, lightning, thunder and under most severe cases tornadoes are expected.

Dry Season: (October- February). The Sub-Tropical cells of high pressure over Arabian Peninsula and Sahara desert are the source regions for air masses during the dry season. Strong northeasterly and northwesterly winds are common. It is dry warm air masses and haze is significant weather and visibility is reduced to less than 5km over most areas of northern half of the country. The satellite picture, the surface isobaric and low level stream analysis, the upper wind analysis and tropical easterly jet play a big role in our daily local weather forecast during all seasons.

Small Rainy Season: (Mid-February to May). During the small rains a trough line extend southward from extra tropical lows located over the Mediterranean Sea to our area and the Inter tropical convergence zone approach from south to north ward to Ethiopia. Due to these systems the winds for the lower 12,00ft is from the Indian Ocean south easterly and southerly, which is favorable for the formation of clouds over the high lands. The southern half of the country is under the influence of both systems and significant weather to aviation is a day-to-day Phenomenon in the area. Both the I.T.C.Z and the

through a line from the extra tropical lows are easily detected by the satellite picture and it makes easier for the continuity of the systems to forecast.

The satellite picture is our major data to analyze charts, to locate position of the systems and to see weather significant to aviation such as thunderstorm, dust storm and fog. The topography of the country is favorable for the formation of significant weather to aviation. Surface and upper air observation are very scarce, so the satellite picture is the only one, which covers the whole country. We use satellite imagery for continuity of weather systems, to predict the weather and to provide more reliable information for en-route and TAFOR. Our observation stations are very scarce, but the satellite image covers the gaps in between.

Introduction and background

Ethiopia is a tropical country located quite near the equator between 3 and 15 degree North latitude and 33 and 48 degree east longitude. Altitude within Ethiopia varies from 116 meters below mean sea level Dallol and 4620 meter above mean sea level on the top of Ras Dejen. This reality subjects the country to variety of weather.

Imagery from satellite observations do provide mechanism for describing weather features, such as cloud, precipitation pattern and pressure systems. It is possible to make useful inference about the fields of wind flow. The relationship in weather and cloud are associated with the area of convergence and updrafts while clear skies associated with divergence and sinking of air. Satellite imagery products made forecasters active in Ethiopia

The weather has a direct impact on the flight operation. Improving the collection of data, satellite picture, surface and upper air from different sources both from domestic and international is essential to issue the accurate weather forecast to the flight. One of the systems to issue good forecast is learning from international communities on such a conference. In view of the impact of weather on Ethiopian aviation, National Meteorological Agency (NMA) is continuing efforts to improve forecasting accuracy, but still there is a lot to do.

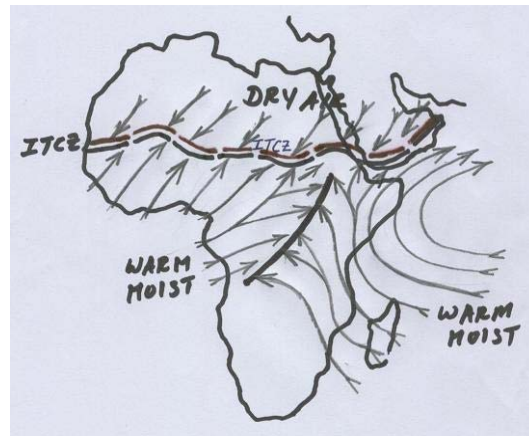
Presentation

There are three seasons in Ethiopia

1. The Long rainy season: June _September

The major components of the long rainy period on which the pattern of weather activity strongly depend upon are the position and intensity of the Mascarene high and the orientation of its ridge axis, St. Helena high, the Low Level (Somali Jet) flow across the equator, the Tropical Easterly Jet, the Congo air boundary and the ITCZ position. During this season it reaches its maximum position.

The major air masses during this season are the southeasterly warm moist which originate from south Indian Ocean and south westerly from south Atlantic. Weather elements significant to aviation in this season are low clouds and poor visibility, mist fog, precipitation, thunderstorm, icing, turbulence and extensive cloudiness with low ceiling.



WIND FLOW AND ITCZ POSITION IN WET SEASON

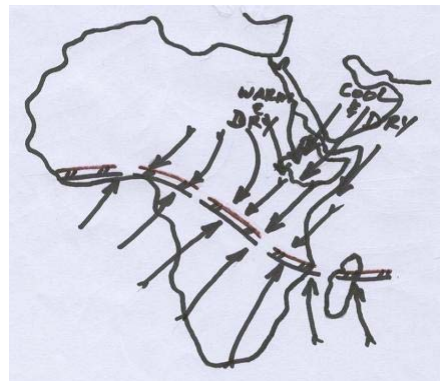
2. The short rainy period: Mid February _ May

The main rain producing systems are the interaction between the tropical and extra tropical lows over the eastern Mediterranean Sea; the ITCZ movement from south to north, the other major system is the formation of high over the Arab sea.

During the short rain period, the southern half of the country and northeastern high lands are under the influence of short rainy period. Both in long and short rainy season significant weather to aviation are commonly observed over the high lands of Ethiopia.

3. The Dry Season: October _ February

Most of the country is under the influence of dry northwesterly flow from the high over the Sahara and dry and cool northeasterly flow from the high over the Arabian Peninsula. When the Siberian Anticyclone intensifies and centered over lower latitude of central Asia, its ridge extends along the Arabian Peninsula to the Horn of Africa. Then the dry and cool periods dominate over most of the country. The cloud distribution over the country is very low except southern regions and the high land regions are characterized by cold nights, sunny with strong winds during the day.



NORTH EASTERLY AND NORTH WESTERLY WINDS IN DRY SEASON

Dominant Synoptic Systems

The Northern Hemisphere anticyclone intense and a ridge from the Azores high extend eastward along the Sahara to northeast Africa. During the dry season Siberian anticyclone intensifies and its ridge extend along the Arabian Peninsula to the Horn of Africa. When the ridge has a continental axis dry and cool air dominates the northeast and central regions at some high land stations then temperature below zero is recorded. The upper air easterlies weaken and westerly start to penetrate in to the region.

When the Mascarene and St. Helene anticyclone intensification is seen from the analysis maritime axis wind flow along the east coast of the continent towards the Horn of Africa is seen. On the analysis of surface chart when the pressure value at the center of the high over the Mascarene and St. Helene high is respectively above 1025hpa and 1024hpa, Monsoon lows over Arab land, India and heat low over Sudan is deepening with central pressure values less than 1000hpa, the tropical Easterly Jet equal to or greater than 60 knot then very high moisture penetrates to the country, as a result dense clouds covering wide area and heavy thunder storm clouds develop over high grounds and heavy rain or rain showers or heavy thunderstorm with shower accompanied with strong gusty winds result and also reduce the surface visibility to less than normal. Duration of the storm and precipitation over the aerodrome depend on the coverage of the clouds and on numbers of the storm cells behind, most of the time from one cell of a storm I am expecting less than 40 minutes duration of precipitation over head.

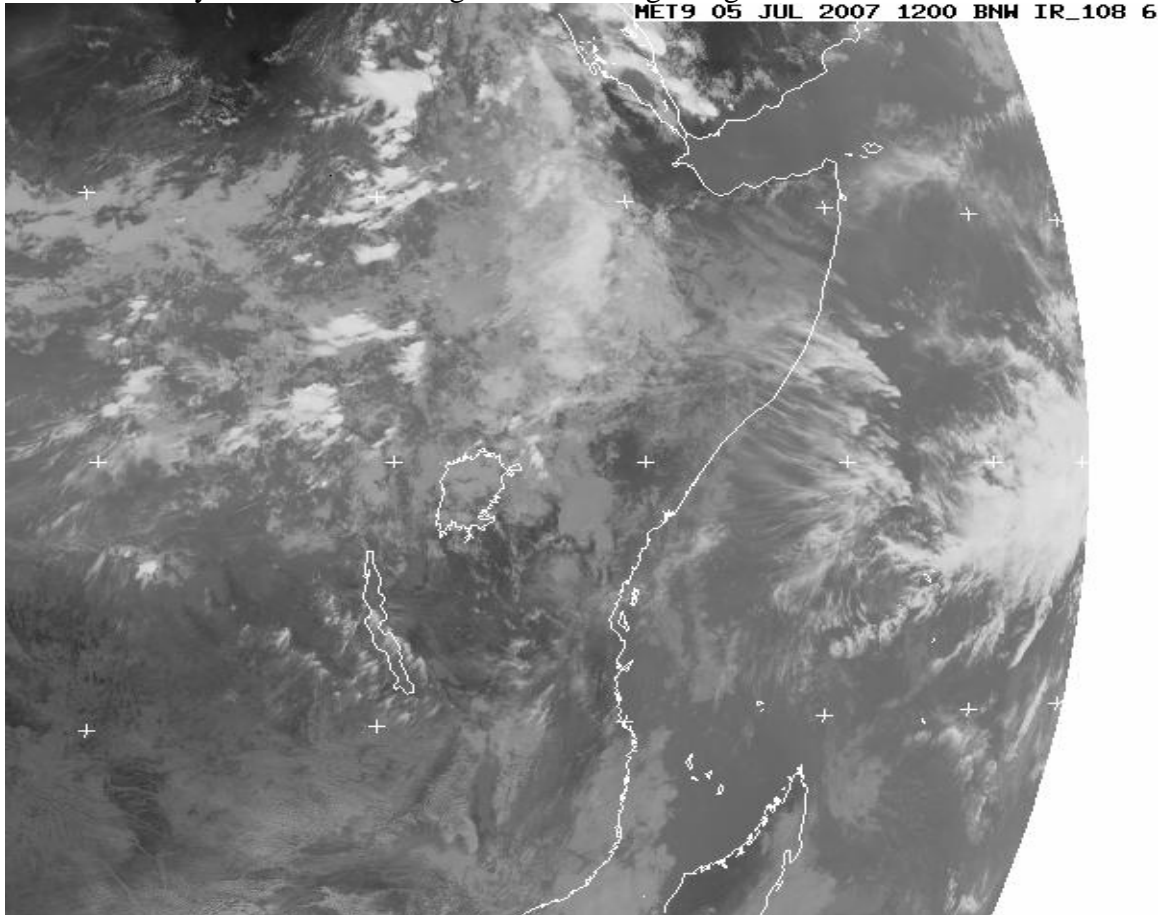
Forecasting dust, haze and poor visibility

During the dry season the high over Sahara and Arabian high intensify and cover much of the Sahara region and the Arabian Peninsula. When these highs are stronger than the normal conditions the winds are strong and the general wind flow at the surface and low level is from northwesterly and northeasterly which are from dry air masses. These winds brings dust particles and reduce the surface horizontal visibility and flight visibility to less than normal from surface up to 10,000ft. over northern half of the country. On the other hand during the small rains (February to April) the extra tropical lows develop over the Mediterranean Sea and a trough extend southward to the high lands of Ethiopia from these lows. When the position of the trough is over the high land the general flow over northwestern regions of the country is strong northwesterly wind, which is from the arid region of Sudan. Its source region is Sahara anticyclone then visibility is very low result problem to aviation. Some times dust is associated with thunderstorm which is known as Haboob generate and reduce the surface horizontal and vertical visibility to less than 1km for a long hours which is a big problem to aviation. EUMETSAT picture (visible) detect this phenomena and by monitoring the continuity of the picture we forecast the effects of it on visibility

Low Clouds and Poor visibility

A large increase in cloudiness and different weather elements associated with moisture increase in intensity from April to September with northward movement of the Inter Tropical Convergence Zone (ITCZ). Most areas with cloud amount greater than 6oktas over the highlands is recorded. . Stratified cloud maxima in the morning, mist and fog forming during the night thickening to stratus by sunrise as surface temperature increase and breaking up in mid- morning. Cumuliform clouds maxima in the afternoon. The EUMETSAT satellite imagery is evidence and shows all high lands covered by low and convective clouds (stratocumulus, cumulus and cumulonimbus) in the afternoon and Cumulonimbus cloud extending hundreds of km.

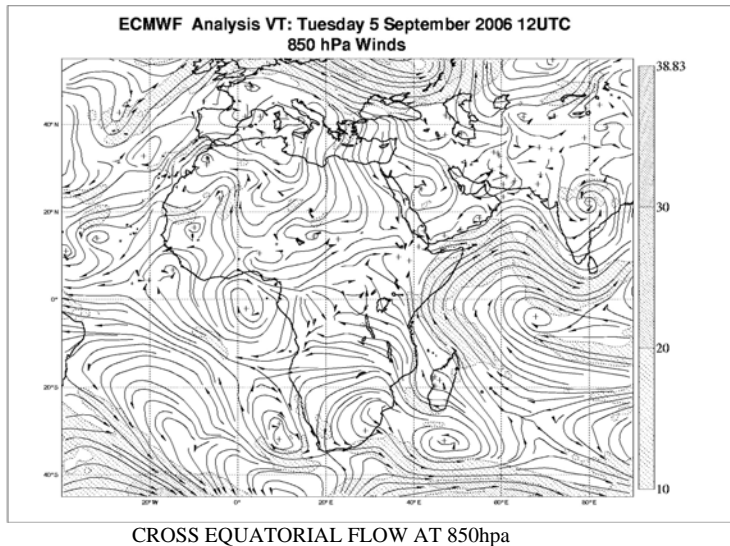
Ethiopian topography is favorable for the formation of low clouds and fog, especially in wet (kiremt) season and the high lands is covered with low clouds most of the time. For aviation purposes low cloud and poor visibility due to mist, fog and low ceiling clouds is common in the months (JJAS) especially during the night and morning. These low clouds and fog are clearly shown up in visible image. Affected areas are the Southwestern regions, Northwestern, Eastern highlands and Central regions. Most affected area is the south western region for example Jimma and Gore air port where surface horizontal visibility less than 1km at the aerodromes almost every day due to mist and fog from late night to mid morning (0300 to 0900 local time). At Bole international air port the chance of low visibility due to mist and fog in the morning is high.



Systems, which are favorable for low cloud and fog formation in Ethiopia, are:

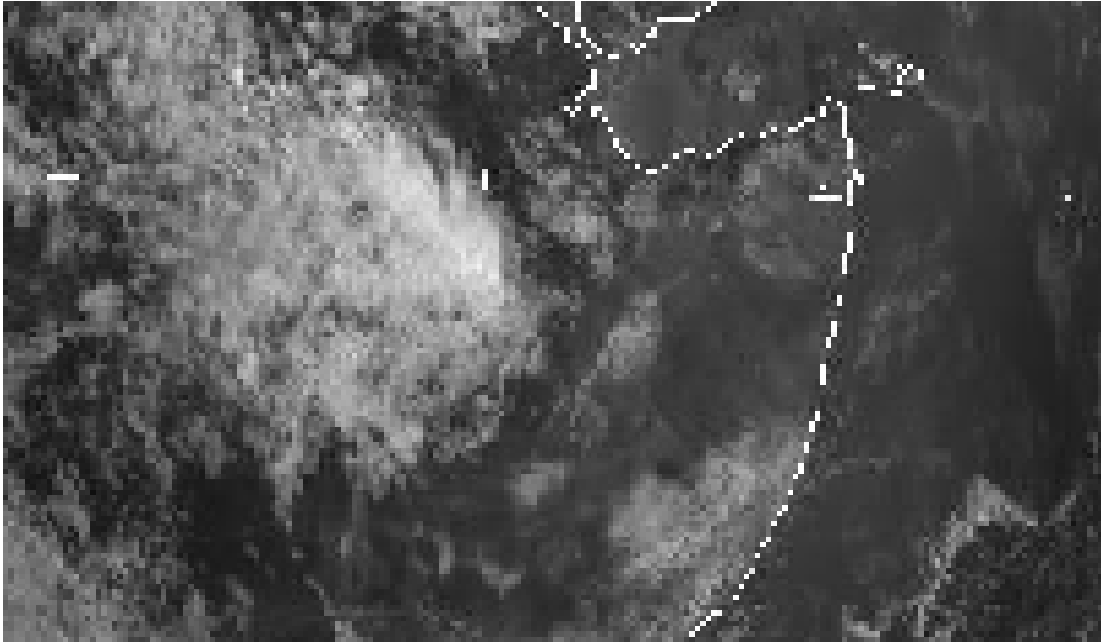
- Intensification of Southern Hemisphere high over the Indian and Atlantic oceans.
- Penetration of moist air from southern Indian Ocean.
- Strength of Congo air boundary.
- The deepening of heat lows along the ITCZ.
- Strength of cross-equatorial wind flow (low level Somali Jet) at 850hpa.

The above conditions are also favorable for the formation of dense clouds and heavy to moderate rain.



Conditions to forecast poor visibility

- Satellite picture is good evidence to forecast low clouds and poor visibility.
- Surface inversion (surface to 4000ft).
- Surface temperature and dew point temperature spread less than 2degrees.
- Light surface wind less than 5knot
- Clear night.
- Rain at the station 10hrs before.
- Humidity more than 85%



15 AUGUST 0600z IMAGE GORE AIR PORT VISIBILITY <1km in FOG (SW ETHIOPIA)

Thunderstorm Icing and Turbulence forecasting

The storms developing over western half of the country is more intense and more severe than the storms developing over the eastern high lands, because the range of mountains extends from south to north, the Congo air boundary where the two moist air converge from south Indian Ocean and south Atlantic ocean is in the place and the Inter Tropical Convergence Zone is more significant over western side than over eastern side of the country. The severity of thunderstorm decreases from west to east, especially the north western regions near lake Tana and mount Ras Dejen is where severe thunderstorms in some severe cases tornadoes develop over these region. There are also some killer storms in these areas associated with strong gusty winds, heavy thunderstorm with showers, flooding, hail, thunder and lightning with August month having the largest amount of any month. Icing is also common above the freezing level (15,000FT) some aircrafts are forced to land at Bahar Dar air port near lake Tana, because they encountered icing, while south eastern and southern Ethiopia observe few to scattered low clouds (st, sc and cu) Turbulence is common any where in the convective clouds and along the convergence line. This seasonal hazardous weather to aviation is verified mainly by south to north movement of ITCZ, intensification of the Southern Hemisphere Sub-Tropical highs, Tropical Easterly Jet and the topography of the country.

Cloud animation, I use to see the development, movement of the storms, the direction, the speed and the growing or the dissipation of the storm and then to forecast for short period. Satellite picture is one of the best and reliable data for our service. 24 hrs forecast from the European Center for Medium range Forecast, local wind analysis, low level (850hpa), mid level (500hpa) and high level (200hpa) analysis is additionally used for short period forecast.

Satellite picture aids in surface analyses

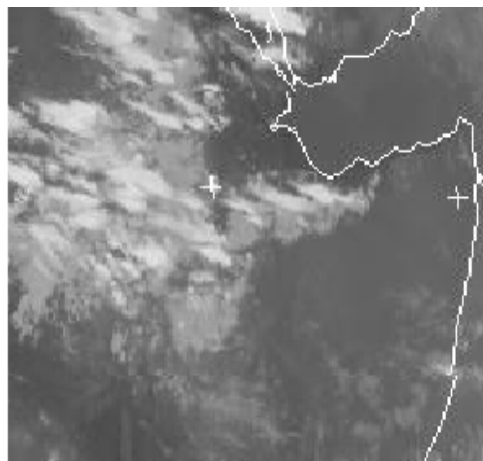
Every day we analyze local surface chart. Our synoptic data are very scarce and it is very hard to do the analysis without the use of satellite data. Based on the evidence of EUMETSAT IR and VIS image and data from few synoptic stations, the cloud pattern suggests drawing low, high-pressure area and a trough line. The development, movement and decay of cloud and pressure systems can be monitored by continuity of images.

Issuing En- route and Aerodrome Forecast from satellite image and other products

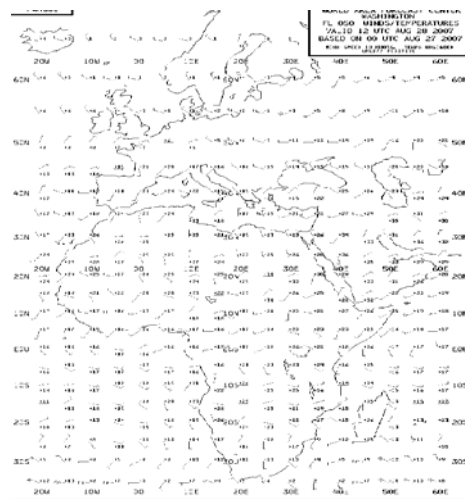
In Ethiopia synoptic observation data are sparse and at many domestic destinations no synoptic observation is taken. The only data, which is the best, useful and reliable for both en-route and aerodrome forecast, is imagery. When I use satellite imagery carefully no complains from the users. Satellite image is available day and night so for operational flight the development, movement, and decay of each cloud cell can be monitored and a short period forecast can then be provided by extrapolation. In this case satellite image, ECMWF and WAFC's products assist for issuing Aerodrome and en- route forecast.

The satellite imagery, ECMWF and WAFC products increase the confidence of issuing and briefing the pilots the weather condition for the aerodromes and en route.

Satellite imagery is used to estimate the cloud amount, type and base, WAFC 850hpa for surface wind for stations found between 4000 to 6000ft MSL. And WAFC's 700hpa and others for flight level temperature and win



IMAGERY USED TO ESTIMATE CLOUD AMOUNT



WAFCs 850 FOR SURFACE WIND

Conclusions

There are, however limits to the data, which can be obtained from, ground and upper air observation. In particular ground observations are often confined to the proximity of main roads, big cities or other lines of communication and upper air observation is only done at national center. The communication between synoptic stations with the aeronautical met office is not satisfactory.

Application of meteorological satellite has increasingly become useful in our service as they have the capability of providing comprehensive regional and global data coverage continually day and night and cover all inaccessible remote areas. Based on EUMETSAT satellite image coverage, movement and type of cloud, weather briefing and preparation

of flight documentation for en-route weather for domestic and international flights is simplified. In our met office service satellite imageries can contribute to a more complete, reliable, accurate and more timely data for pilots and surface analysis if the interpretation is done correctly.

References:

Forecasting Guide to Tropical Meteorology,. By D.Atkinson USAF
Weather for Air Crews, AF Manual 51-12 and AF105-5
Ethiopia Weather Kashaun