On the combined use of satellite imageries and dynamical fields for characterization of weather systems over East Africa

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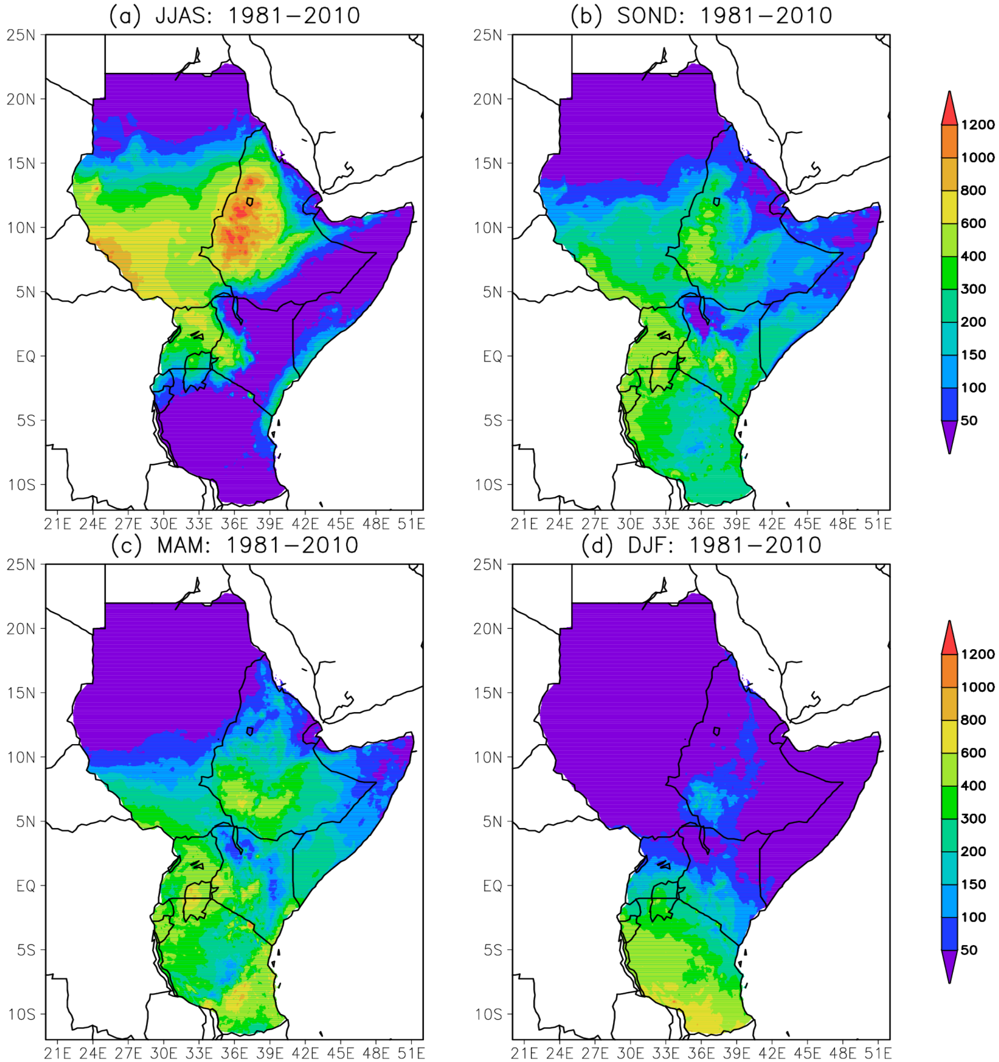
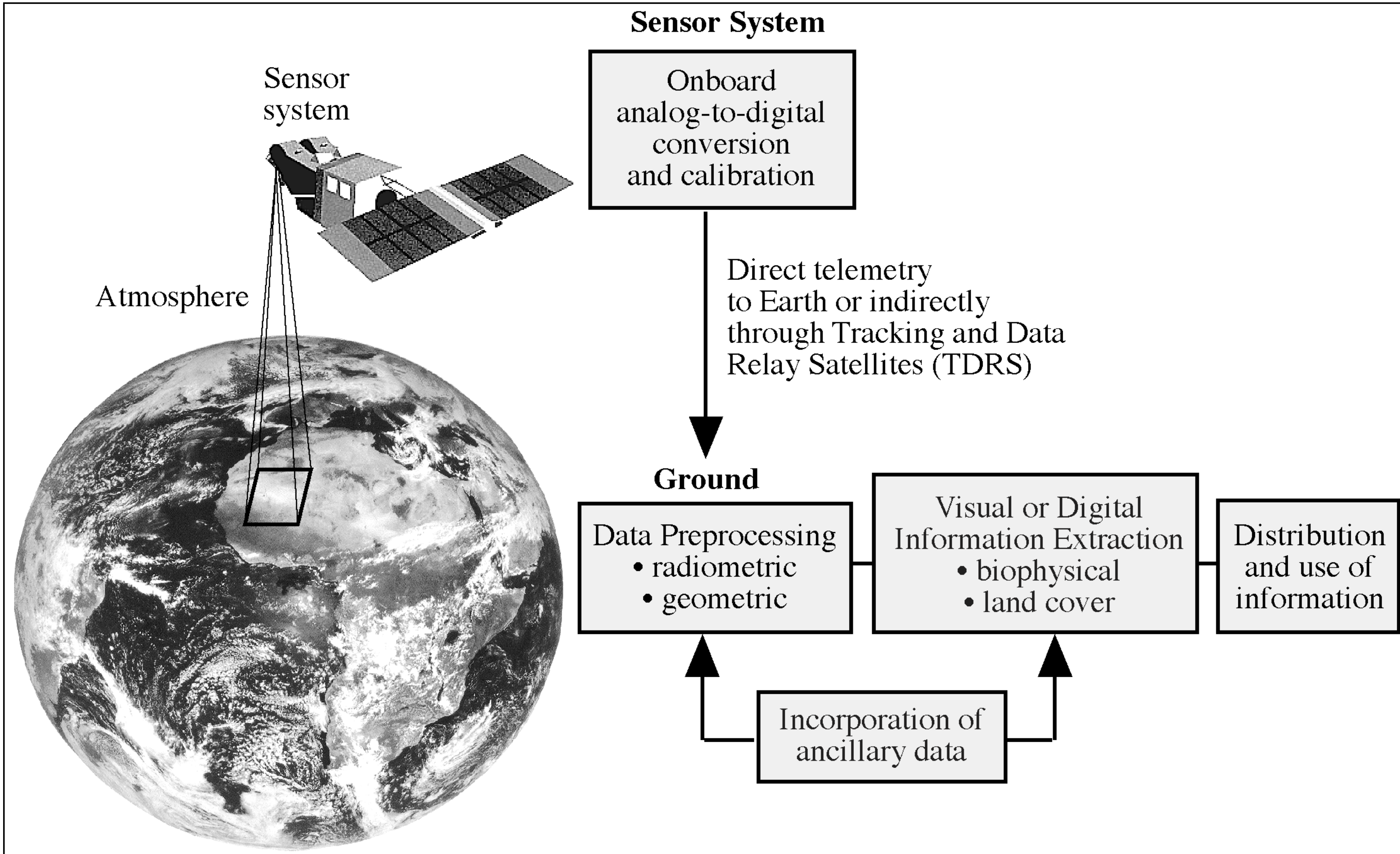
Introduction:East Africa



- **Receives rainfall year round**
- **Northern half in JJAS and southern extreme-DJF**
- **Bimodal rainfall across the equatorial region due to ITCZ migration with season**

Introduction:Sensor System



Introduction: History of application of satellite remote sensing

- **Began with TIROS1, launched in April 1960**

- **Simple TV system on board to map clouds**

- **Satellites are now a vital an integral part of our weather forecasting system.**

Introduction: Satellite remote sensing

- **Now both polar orbiting and geostationary satellites are used**

- **Polar orbiters operate in a similar way to other remote sensing satellites (Landsat, SPOT etc.)**

- **Geostationary satellites continually view the same portion of the Earth.**

Introduction: Satellite remote sensing

Geostationary Satellites

- **Orbit above the equator at 35,800 Km and complete one orbit every 24hrs.**
- **Remain over the same point on the surface of the Earth.**
- **Continually view the same portion of the Earth.**
- **A network provides coverage of the entire globe**

Introduction: Satellite remote sensing

Major Applications

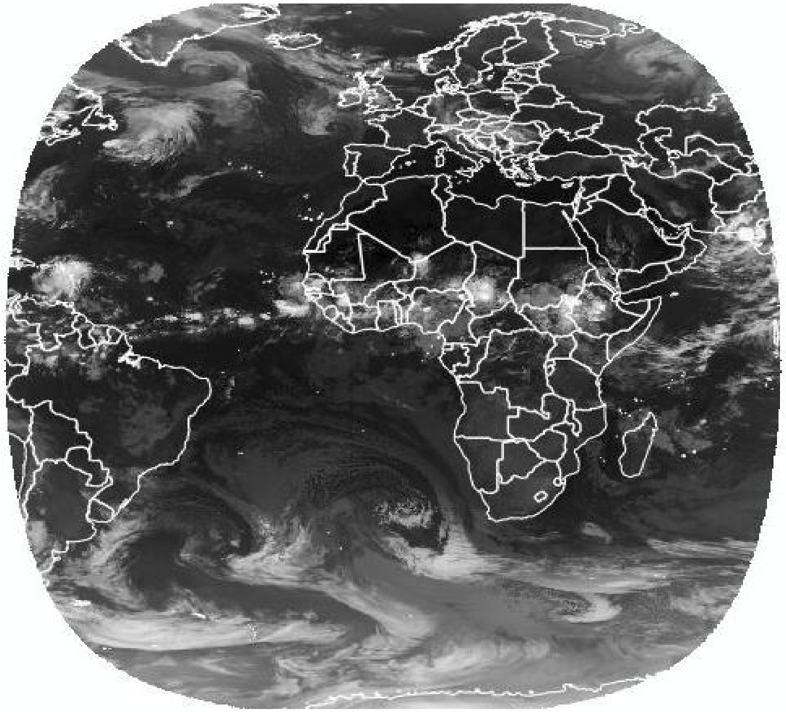
- **Solar radiation exposure**
  - **Uses a model based on an advanced estimate of cloud cover**
- **Cloud and Water Vapour Motion vectors**
  - **Tracks identifiable cloud features**
- **Entered into weather forecasting models**

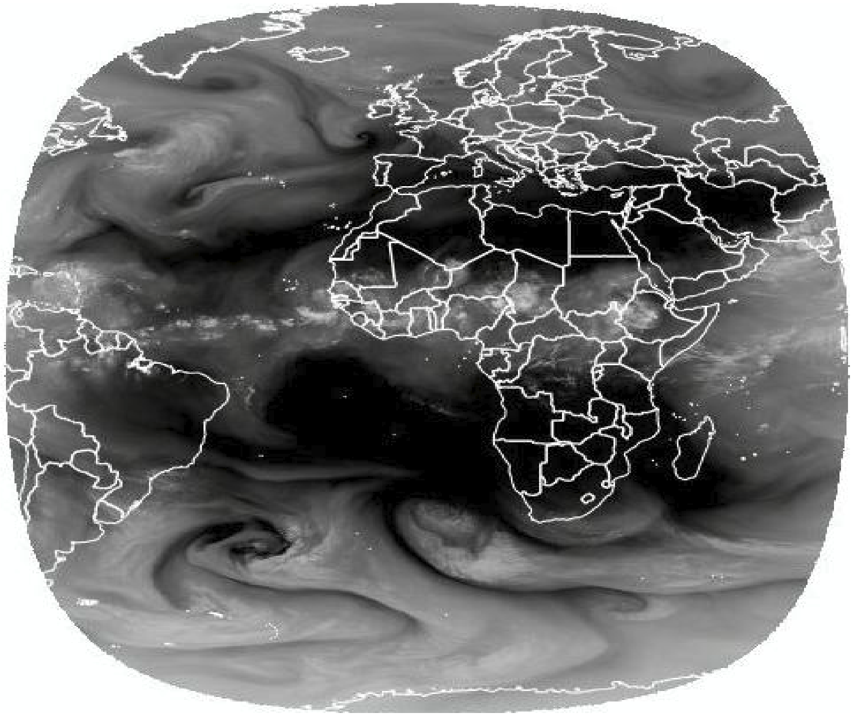
Introduction: Instrument Observing Characteristics

Observations depend on

- telescope characteristics (resolving power, diffraction)
- detector characteristics (signal to noise)
- communications bandwidth (bit depth)
- spectral intervals (window, absorption band)
- time of day (daylight visible)
- atmospheric state (T, Q, clouds)
- earth surface (Ts, vegetation cover)

METEOSAT SG (MSG):Image from different bands





- **Left: IR channel (10.8) Right: Water Vapour MSG (6.2)**

METEOSAT MSG: Channels (bands)

Channel 01: VIS 0.6 μ

Channel 02: VIS 0.8 μ

Channel 03: NIR 1.6 μ

Channel 04: MIR 3.9 μ

- Channel 05 WV 6.2 μ
- Channel 06: WV 7.3 μ

Channel 07: IR 8.7 μ

Channel 08: IR 9.7 μ („Ozon")

Channel 09: IR 10.8 μ

Channel 10: IR 12.0 μ

Channel 11: IR 13.4 μ „CO_2")

Channel 12: HRV (High Resolution Visible)

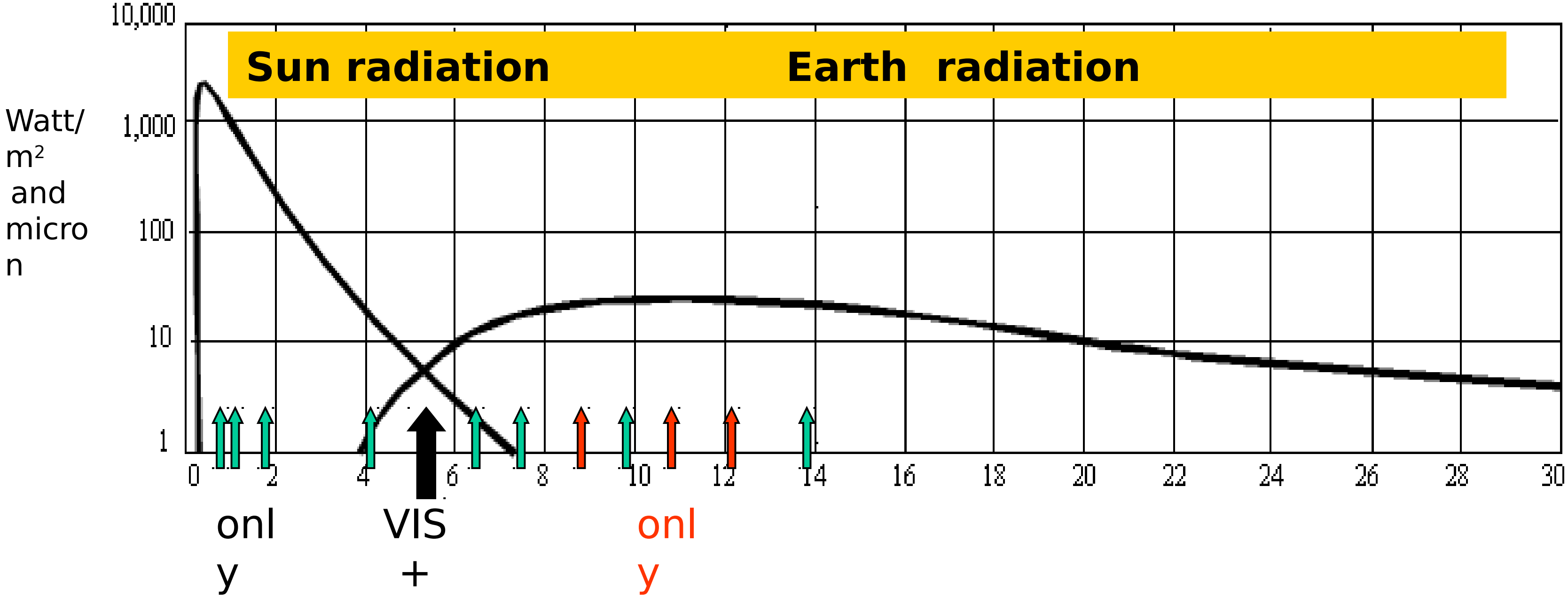
METEOSAT MSG: Channels (bands)-contd.

For wave length < 5 µm solar radiation is dominant

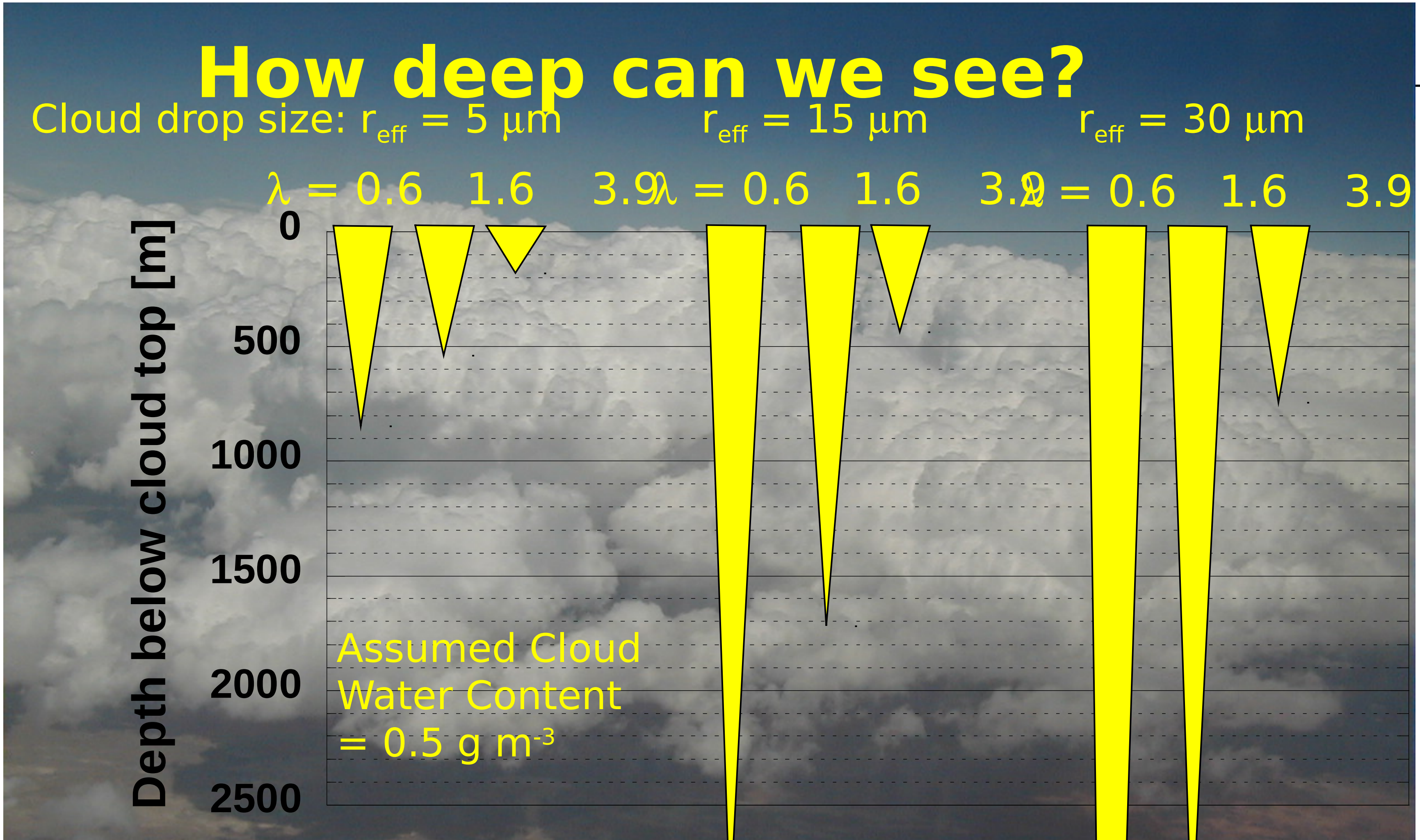
For wave length > 5 µm radiation of earth is dominant

- Ch01, 02, 03, 12: only sun radiation

- Ch04: both: radiation from sun and earth
- Ch 05, 06, 07, 08, 09, 10, 11: only thermal earth radiation

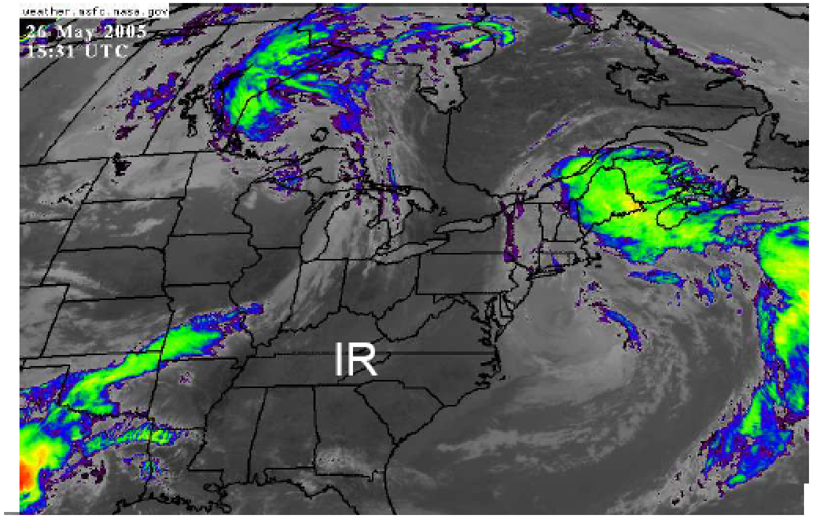


METEOSAT MSG: Channels (bands)-contd.



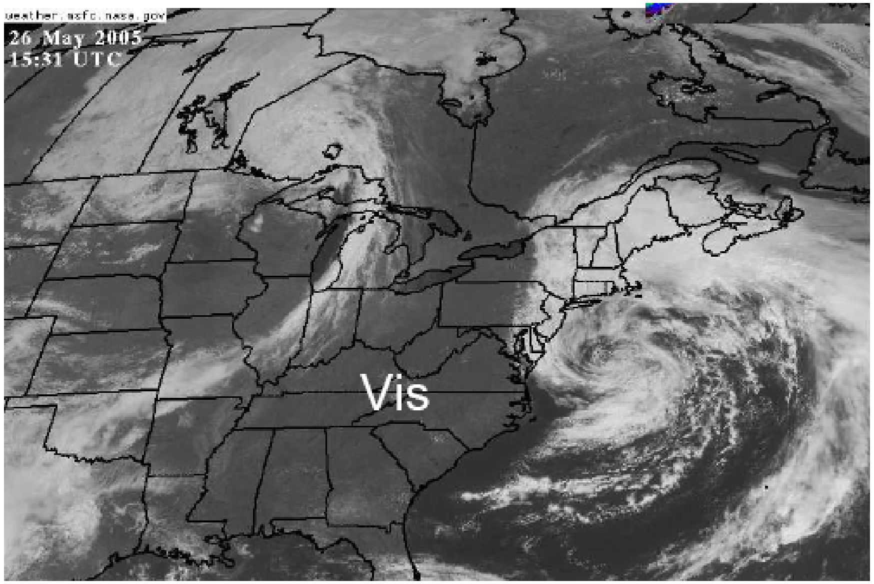
- ***3.9 µm measures mainly near cloud top***
- ***1.6 µm penetrates into larger cloud depth***
- ***0.6 µm often affected by surface, especially in clouds with large drops or ice particles***

Satellite image/signal-Interpretation: Contamination



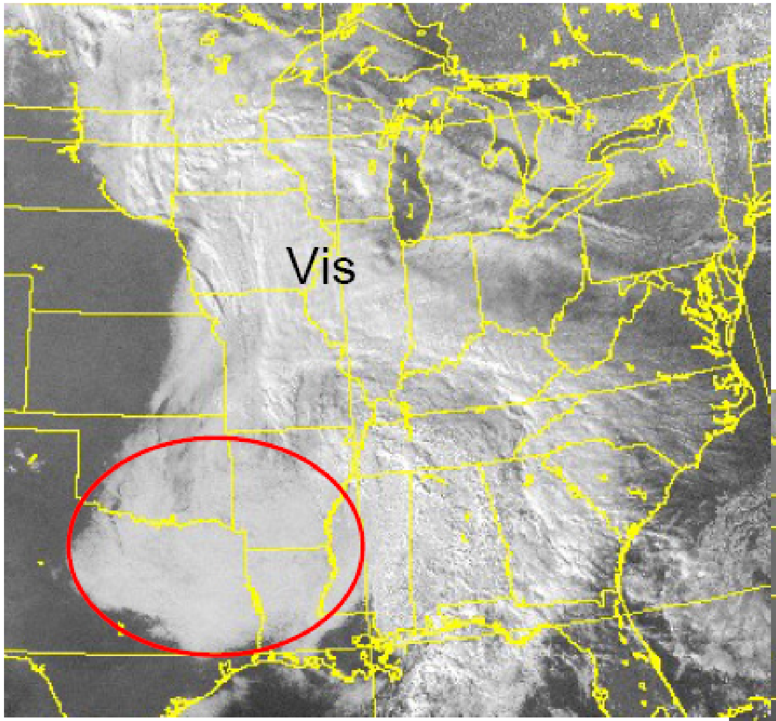
Note how thin, highly reflective cirrus clouds in the visible image appear warmer (lower) in the IR image.

This is also a problem in microwave imagery.



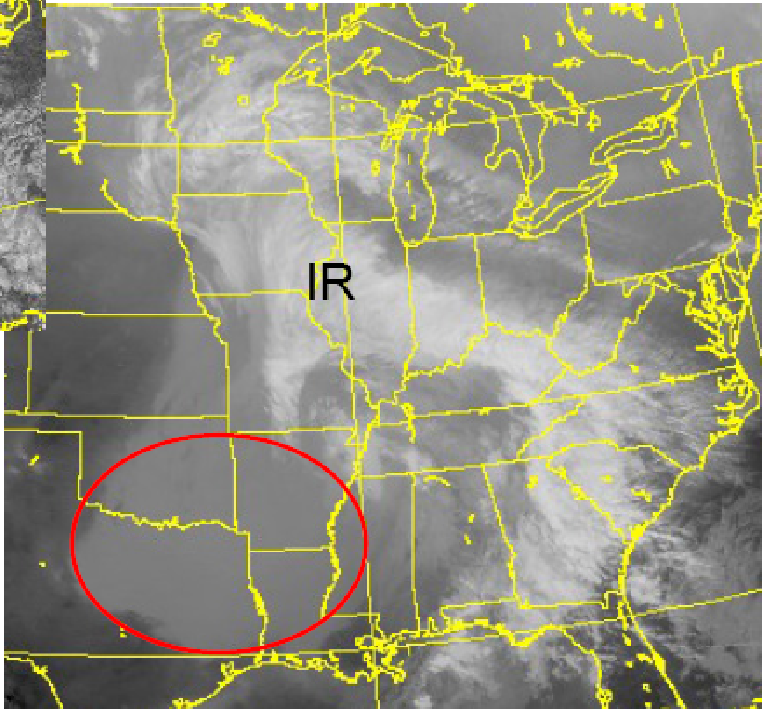
When emission from low objects combines with emission from a high object, making the high object appear warmer.

Satellite image/signal-Interpretation: Attenuation



Attenuation

When scattering or absorption makes a low object appear more reflective or colder.



Note how the stratus in the oval in the visible image could be mistaken for cold cloud unless we compare it to IR image.

Satellite image/signal-Interpretation: Clouds

1) High Clouds – composed of small ice crystals.

a) Cirrus – thin hooks, strands, and filaments or dense tufts and sproutings.

i) Visible imagery – thin cirrus is difficult to detect due to visual contamination. Dense cirrus shows as patches, streaks, and bands, casting shadows on lower clouds or terrain.

(1) Brightness – normally a darker or translucent appearance, often obscuring definitions of lower features. A light gray compared to thicker clouds.

(2) Texture – fibrous with banding perpendicular to winds.

ii) IR imagery

(1) Brightness – usually dense patches are very bright but thin cirrus is subject to considerable contamination and appears much warmer (darker gray) than the actual temperature.

Satellite image/signal-Interpretation: Clouds

(2) Texture – subject to variation due to contamination.

b) Cirrostratus – High/thin to dense continuous veil of stable ice crystals covering an extensive area. Commonly found on equatorial side of jet streaks.

i) Visible imagery – generally appears white, thick, smooth, and organized when associated with cyclones. Casts shadows on surfaces below.

ii) IR imagery – appears as uniformly cold (white), often the coldest, cloud layer (except when cumulonimbus clouds are present) with small variations in gray shades. Thin cirrostratus has considerable contamination problems.

c) Anvil Cirrus (detached from cumulonimbus clouds) – dense remains of thunderstorms, usually irregularly shaped, aligned parallel to the upper level winds. Vary in shape and especially in size from 5 to 500 km. Tends to become thin and dissipate rapidly.

Satellite image/signal-Interpretation: Clouds

i) Visible imagery – bright white but diffuse. Thick anvils may cast shadows on lower
surfaces whereas thin anvils are often translucent to lower features.

ii) IR imagery – bright white patches, usually coldest (whitest) cloud, except when
active thunderstorms are present.

d) Cirrocumulus – cumuliform ice crystal clouds formed by upward vertical motions in the
upper troposphere. May precede rapidly developing cyclone.

i) Visible imagery – thin patches of clouds, gray to white, usually in advance of a
cyclone. Individual elements often below the resolution of geostationary sensors.

ii) IR imagery – similar to cirrostratus, white to gray clouds subject to contamination.

Satellite image/signal-Interpretation: Clouds

2) Middle Clouds – composed of supercooled water droplets and graupel (soft hail).

a) Altocumulus – indicates vertical motion and moisture in the mid-troposphere. Usually accompanies large, organized synoptic scale cyclones, minor upper tropospheric waves, and tropical waves. For well-developed systems, sometimes masked by extensive cirrus.

i) Visible imagery – Bright white, textured, or lumpy, and very difficult to distinguish from stratocumulus.

(1) Wave clouds appear as parallel bands.

(2) Altocumulus castellanus (ACCAS) appear as a diffuse, ragged band of small blobs. In summer ACCAS may be found near air mass boundaries preceding thunderstorm development.

ii) IR imagery – Colder (lighter gray) than stratocumulus but warmer (darker gray) than high clouds. Must be compared to other clouds in the area.

Satellite image/signal-Interpretation: Clouds

(1) Wave clouds frequently appear warmer and lower (darker gray) than actual due to contamination. Individual waves may be below resolution of geostationary sensors.

(2) ACCAS often appear with frontal systems. Rather large temperature variations may be observed.

b) Altostratus/Nimbostratus – stratiform cloud in mid levels. Normally found in extensive sheets with cyclones.

i) Visible imagery – Bright white, extensive sheet. May be difficult to distinguish from low or high stratiform clouds. Often textured, unlike cirrostratus, but uniform. May cast shadows, unlike stratus.

ii) IR imagery – nearly uniform gray shade indicating the middle temperature ranges. Usually distinguishable by comparison with other cloud layers, warmer (grayer) than cirrus, colder (brighter) than stratus.

Satellite image/signal-Interpretation: Clouds

3) Low Clouds − composed of water droplets. Wintertime conditions and vertical growth may allow glaciation.

a) Cumulus − similar to detached cauliflower-like clouds with sharp outlines. Often, a region of unorganized cumulus ("popcorn") forms over landmasses during fair weather. Cumulus clusters whose edges are clearly visible are referred to as "open cell" cumuli.

i) Visible imagery − scattered individual elements are often below the resolution of geostationary sensors and appear as gray areas due to contamination. Large individual elements and groups of broken cumulus appear as bright white blobs of clouds.

ii) IR imagery − only large areas show due to contamination, appearing as dark gray blobs.

b) Towering Cumulus − cumulus of moderate or strong vertical extent.
i) Visible imagery − similar to cumulus but elements are larger, so are more likely to be distinguishable as bright white blobs.
ii) IR imagery − similar to cumulus, but appearing as lighter gray blobs

Satellite image/signal- Interpretation: Clouds

c) Cumulonimbus – cumulus of strong vertical development with or without cirrus anvils. Vary greatly in size and shape depending on storm intensity and environment. If upper level winds are weak, mature thunderstorms are circular cirrus clouds often with cirrus plumes (filaments) streaming out nearly symmetrically in all directions with occasionally lumpy, penetrating tops (indicated by shadows on visible imagery). Stronger winds aloft blow the cirrus anvil downstream and create a diffuse downwind boundary with a sharp, smooth upwind boundary. In region of vigorous thunderstorms, cirrus anvils may merge into cirrus canopies. The active cells are indicated on visible imagery by their lumpy penetrating tops. Much of the cirrus in the ITCZ is actually decaying cirrus anvils.

i) Visible imagery – bright white cellular shape covered with diffuse thin cirrus and often a lumpy penetrating top.

ii) IR imagery – bright white, smooth cellular shape. Enhancement techniques help identify the maximum cloud tops by relating cloud top temperatures to height.

Satellite image/signal-Interpretation: Clouds

d) Stratocumulus − formed by the spreading of cumulus or convective development of stratus.

Large regions are found over cold ocean currents such as the California current off the West Coast (convective development of coastal fog and stratus) and in the lee of cold fronts (spreading of cumulus). Stratocumulus clouds form along the low level flow. Widely scattered and smaller patches of stratocumulus (trade wind cumulus) are found throughout the tropics. These scattered patches look like polygonal plates and range in diameter from 100−500 km and have limited vertical development.

i) Visible imagery − light gray to white, appearing in cloud lines or sheets composed of parallel rolls. Textures are noticeable.

ii) IR imagery − Dark gray, often difficult to distinguish from the surface due to contamination. Cellular or textured nature often not observed.

Satellite image/signal-Interpretation: Clouds

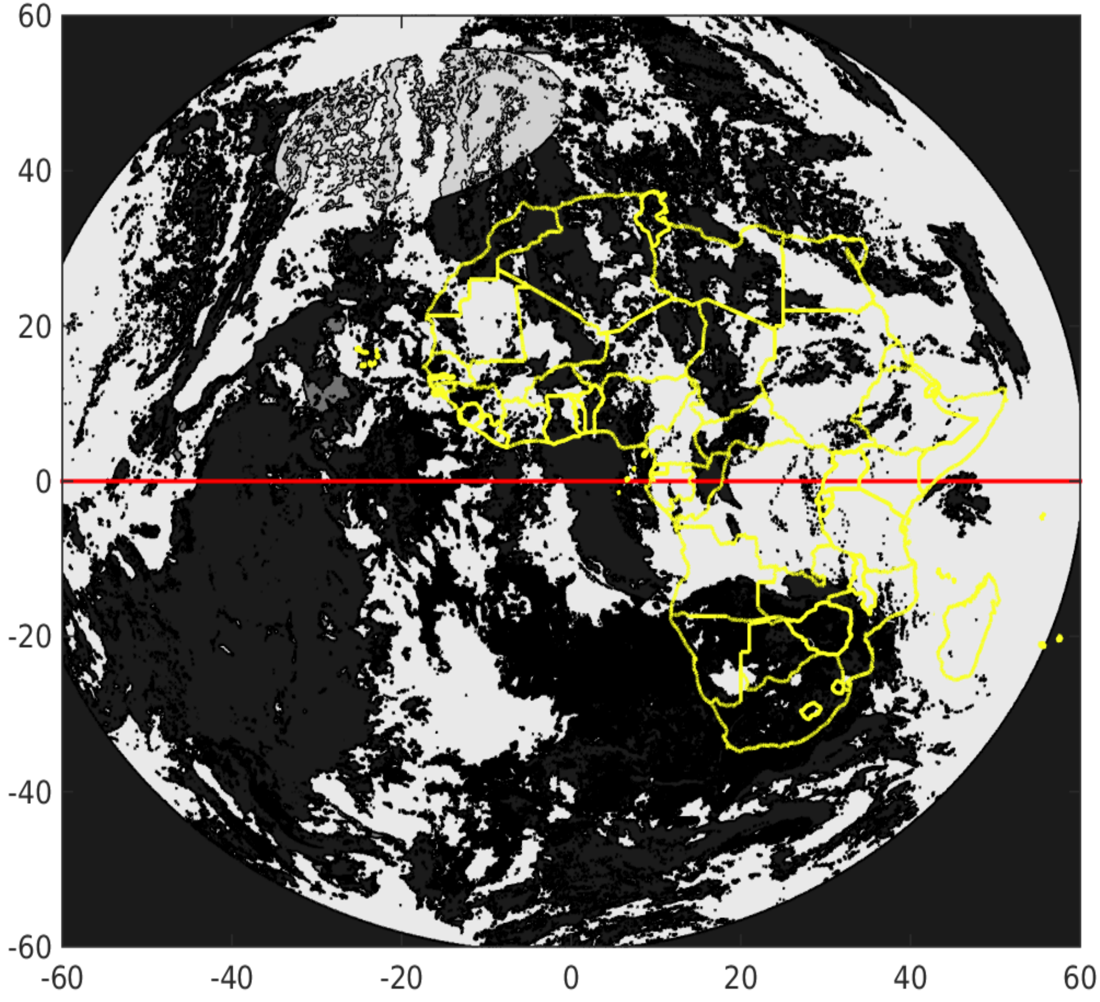
e) Stratus and Fog – caused by various means.

Large areas of stratus are found over cold ocean currents, as warm subsiding air underneath anticyclones meets the cold water below.

i) Visible imagery – white to gray, uniform, smooth sheet, except when terrain features penetrate above the stratus tops. Coastal and valley stratus often outlines the surrounding terrain.

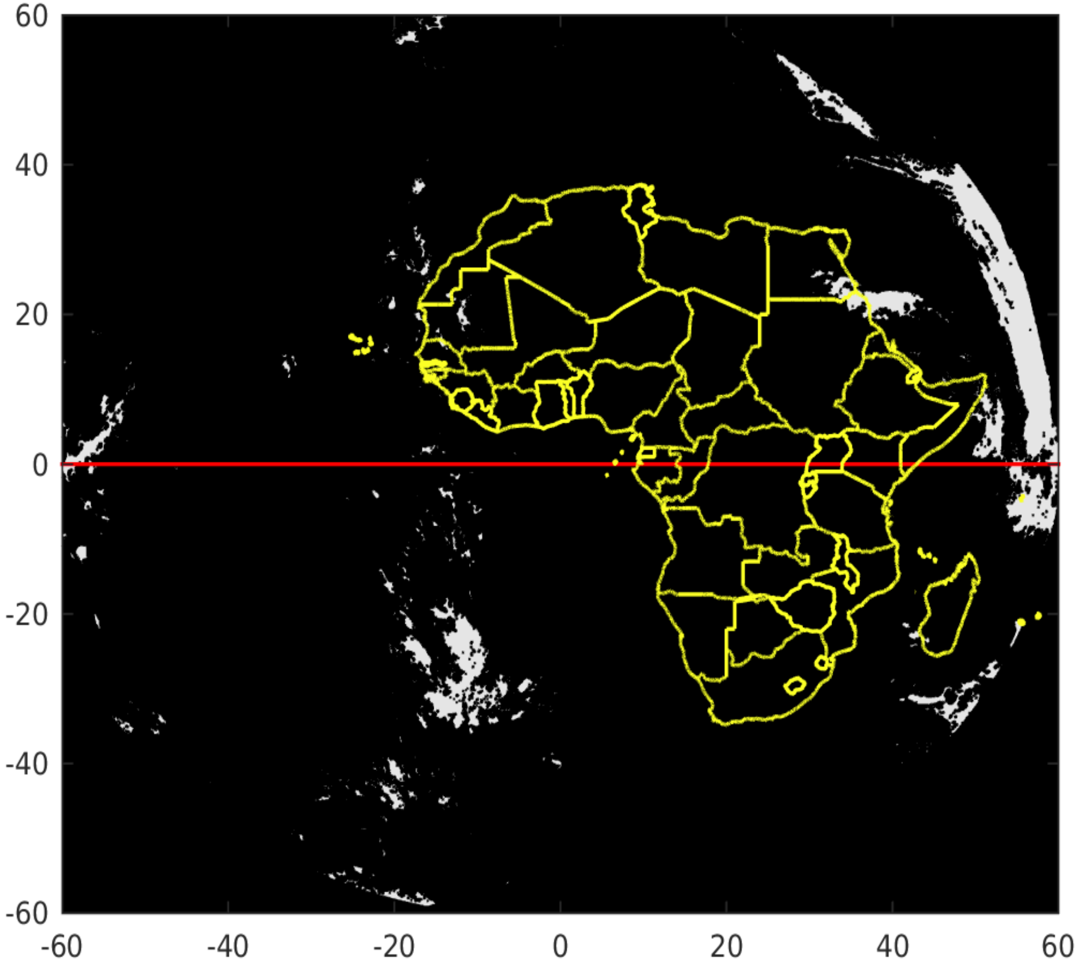
ii) IR imagery – nearly invisible due to lack of contrast between the surface and cloud top temperatures. Occasionally, stratus forming beneath a radiation inversion will appear warmer (darker) than the surface, and is called “black” stratus.

MSG Cloud imagery products: challenges and opportunity



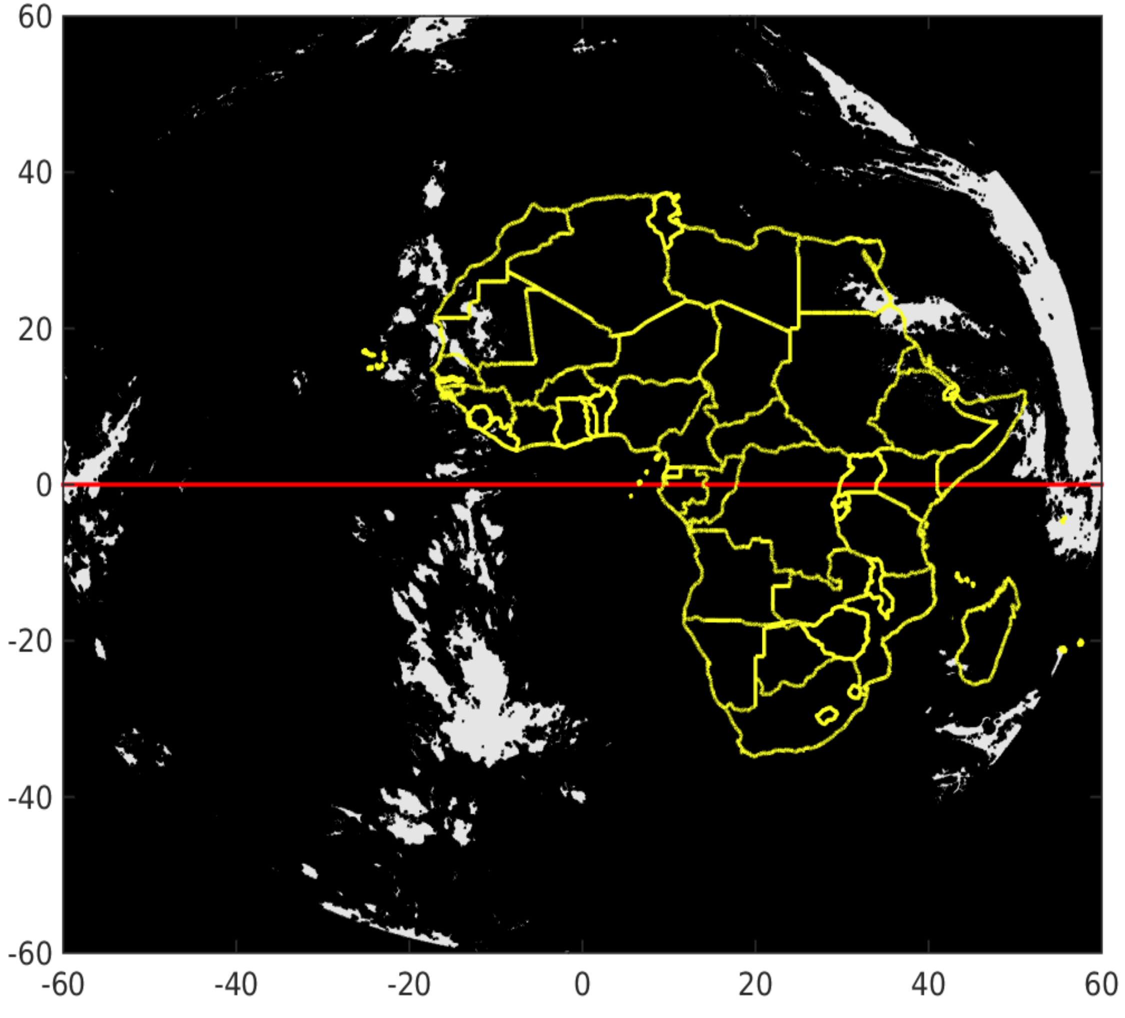
- **all clouds**
- **This is difficult to characterise using dynamical fields**

MSG Cloud imagery: challenges and opportunity



- **cirrus clouds**

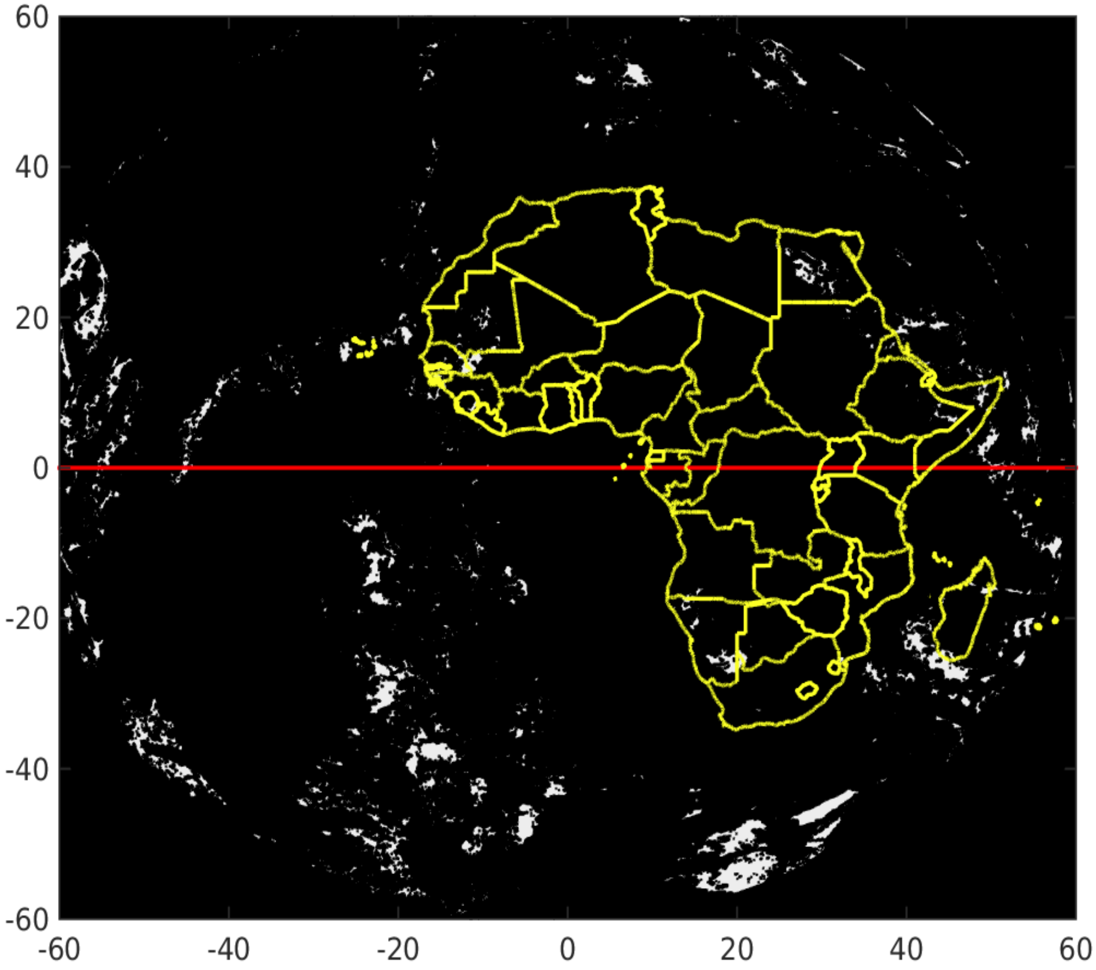
MSG Cloud imagery: challenges and opportunity



high level clouds

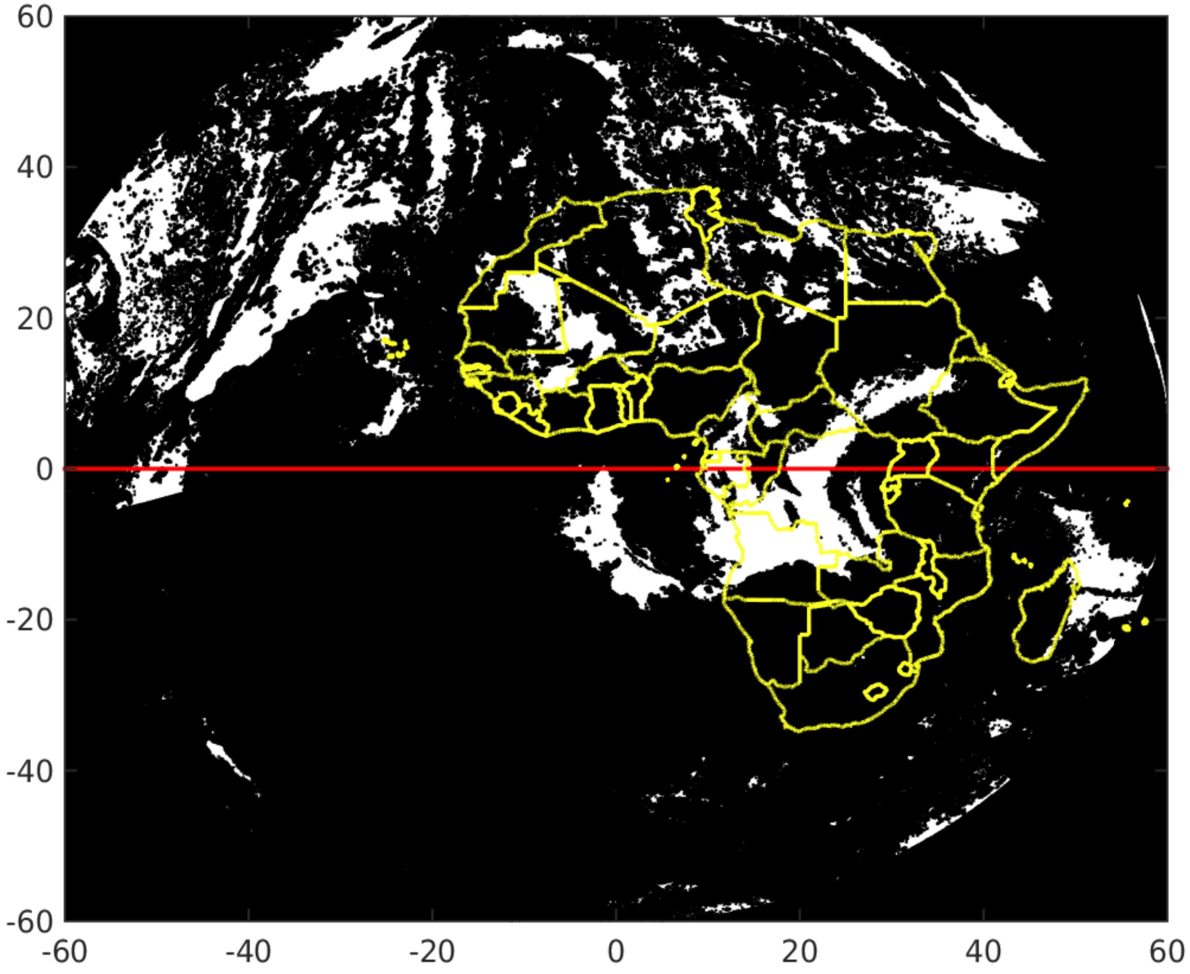
including **cirrus clouds**

MSG Cloud imagery: challenges and opportunity



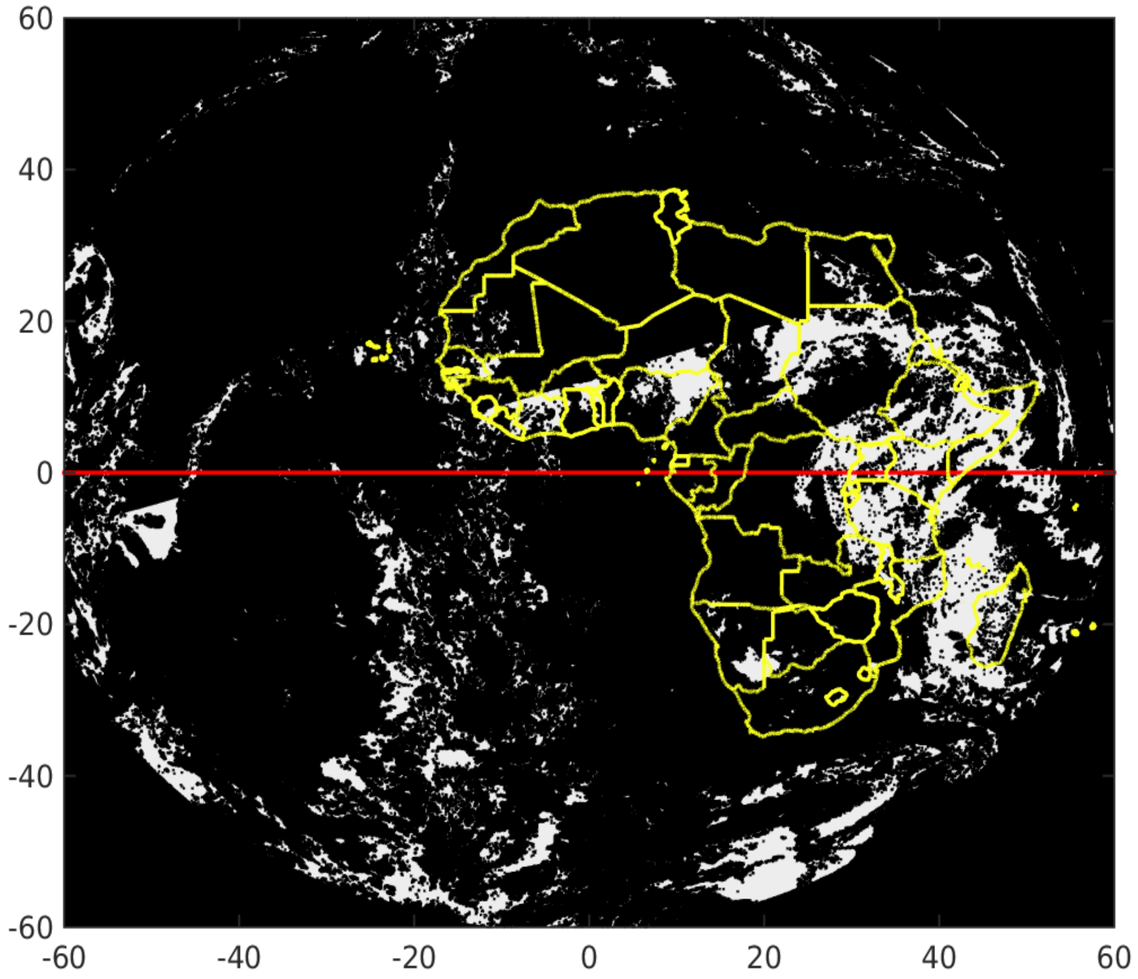
- **Only mid level clouds**

MSG Cloud imagery: challenges and opportunity



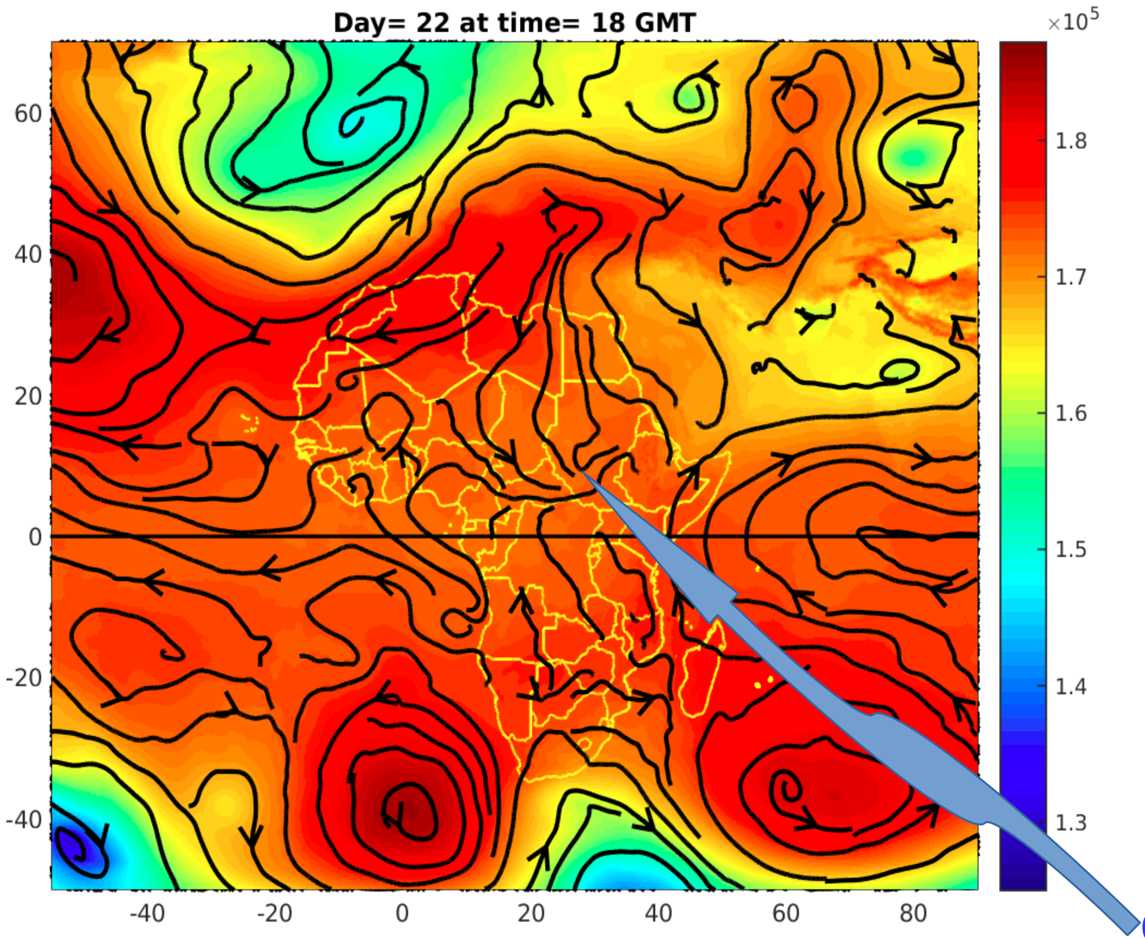
- Only low level clouds

MSG Cloud imagery: challenges and opportunity



- Filtered for cirrus/stratus clouds as well as cirrcus
- This can be used to understand observed weather using dynamical fields: PV, winds

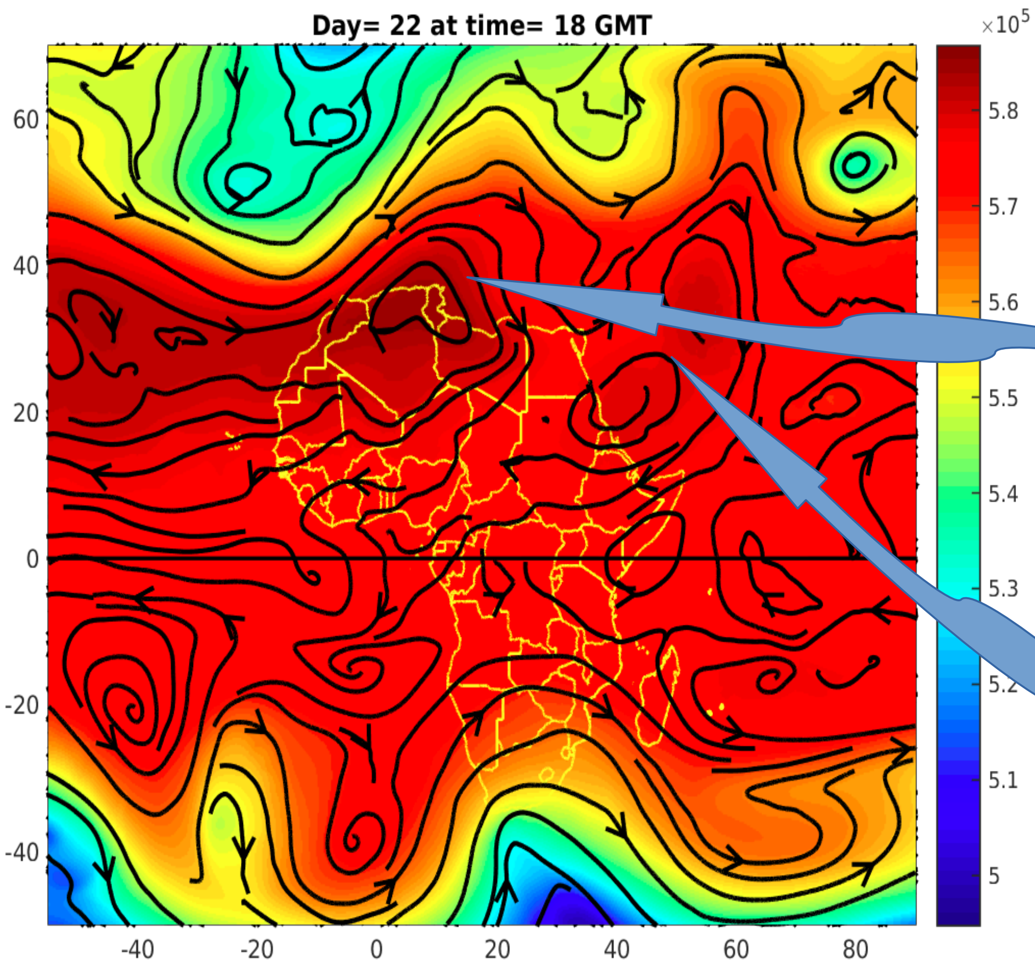
Characterization of weather systems over East Africa: Dynamic fields and imagery



- Geopotential height at 850 hPa level. Overlayed: wind field
- Southeasterly flow on the eastern flank of Mascarene high pressure curves towards north and east after cross the equator.

Convergence zone (ITCZ): SE &NW

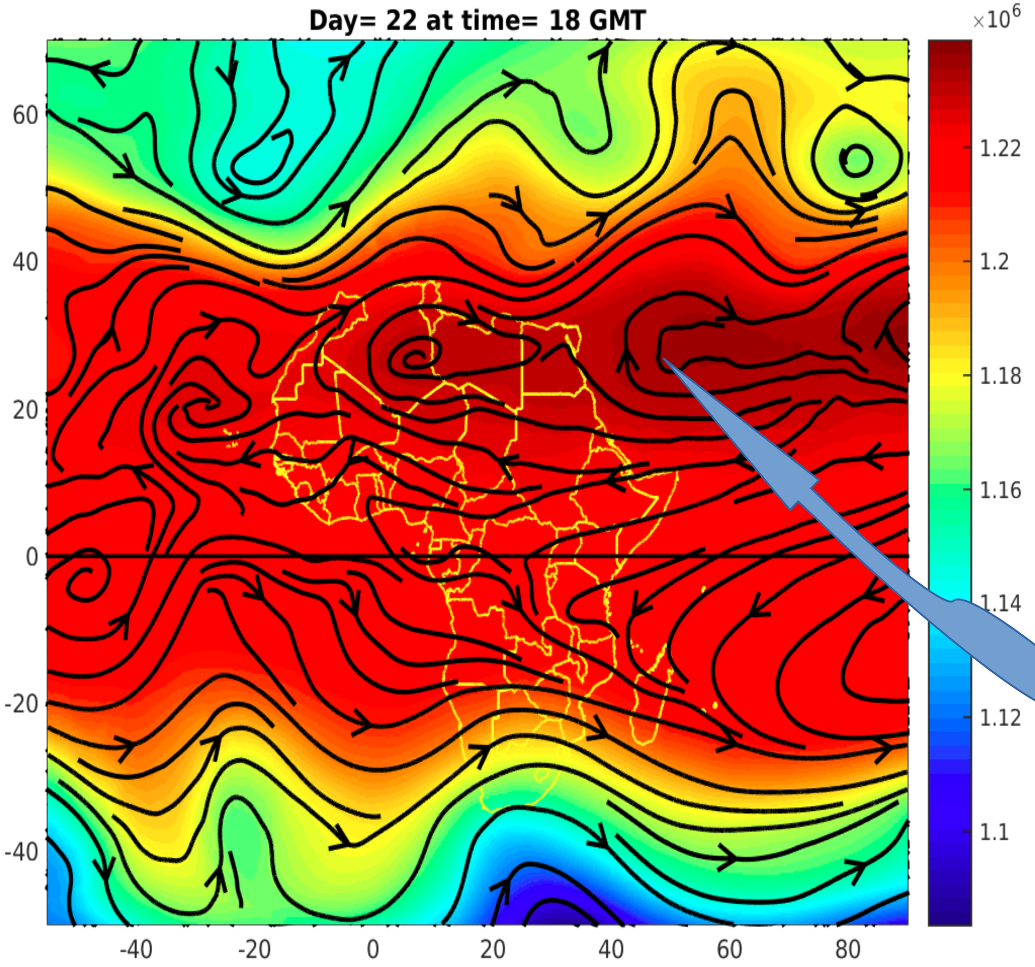
Characterization of weather systems over East Africa: Dynamic fields and imagery



Visible subtropical high pressure zone formation at 500 hPa level

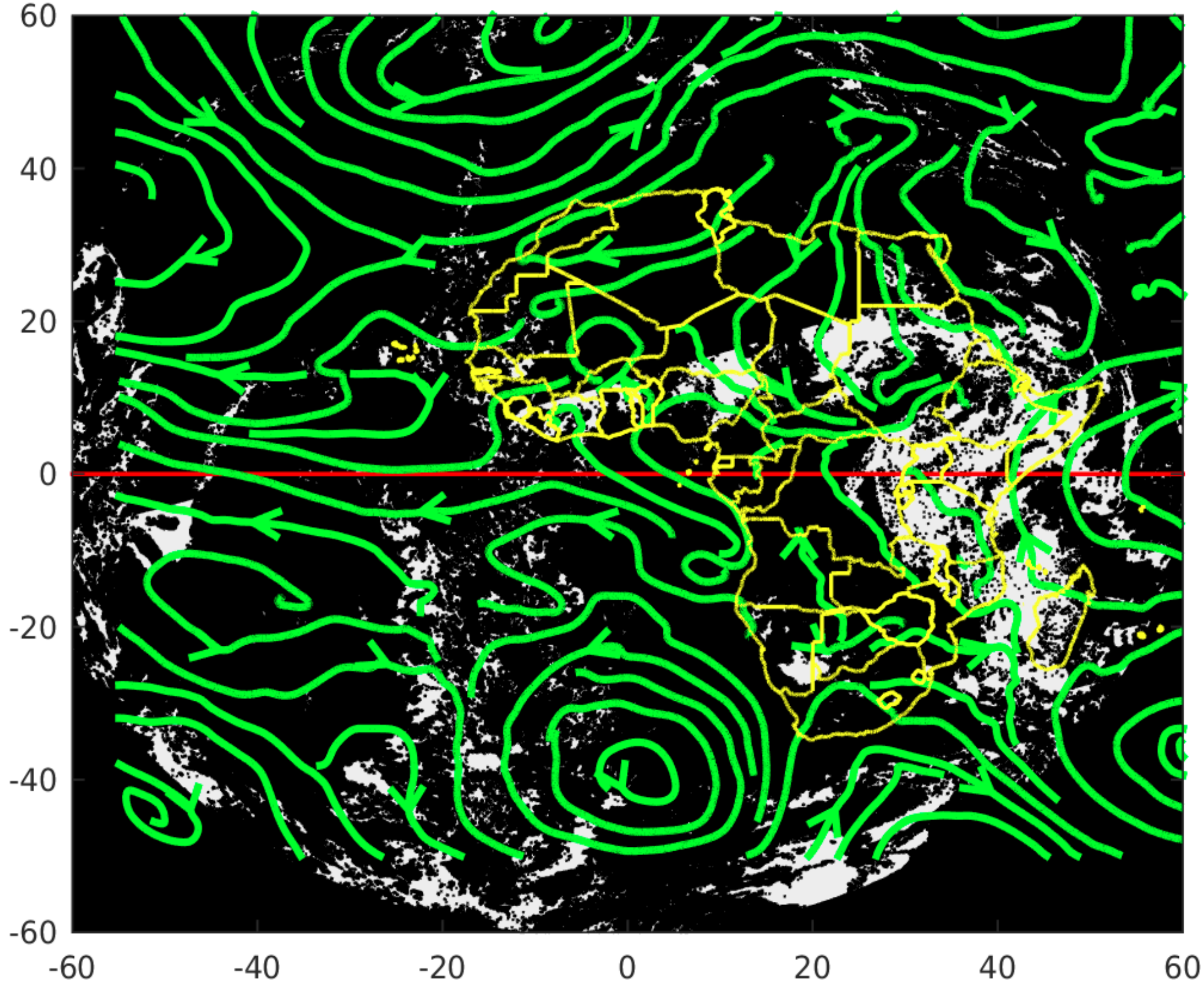
High pressure forms over NE East Afrca extending NE ward across Arabian Peninsula at 500 hPa

Characterization of weather systems over East Africa: Dynamic fields and imagery



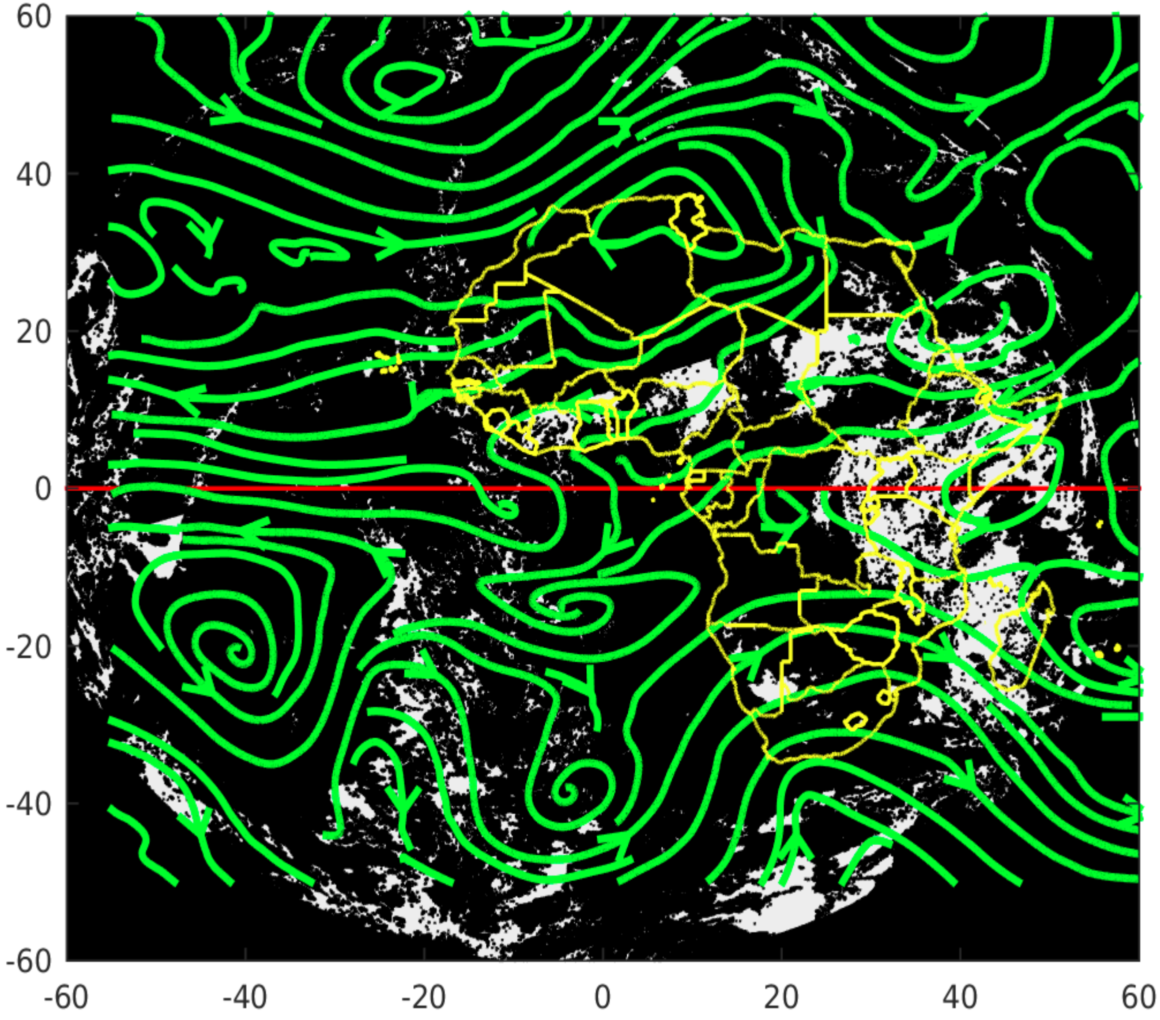
- High pressure slightly moved southward at 200 hPa
- Strong upper level divergence over low level convergence at 850 hPa.
- Strong wind i.e. subtropical westerly jet and tropical easterly get over East Africa

Characterization of weather systems over East Africa: 850 hPa



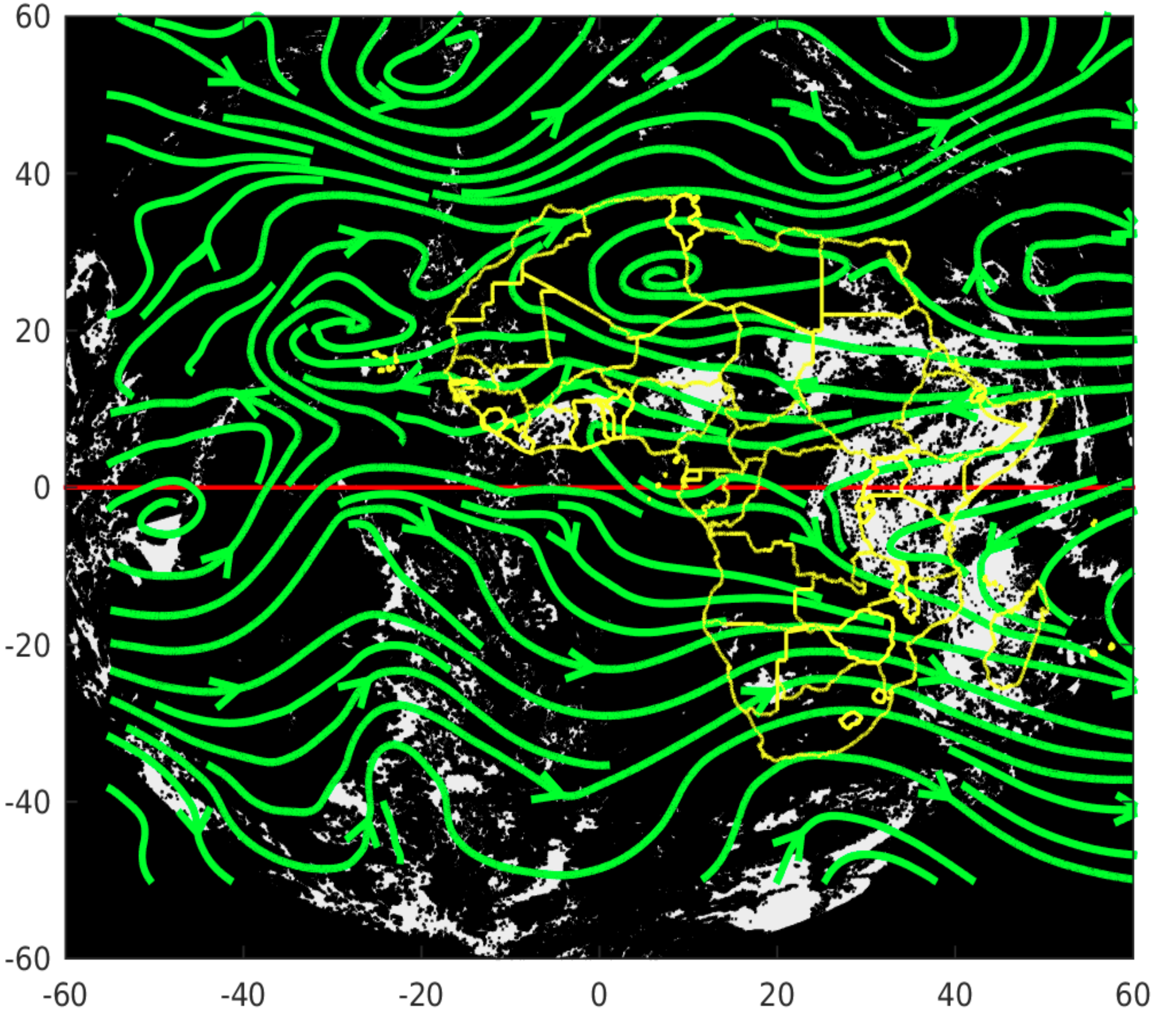
- High pressure at 850 hPa is associated with clear sky
- ITCZ zone with cloud cover.
- cirrus and fog/stratus clouds are excluded to have a clear association of clouds and atmospheric circulation

Characterization of weather systems over East Africa: 500 hPa



- Subtropical High pressure Zone begins to emerge 500 hPa
- At 500 hPa level is still vertical assent along the cloud bands-ITCZ

Characterization of weather systems over East Africa: 200 hPa



- Subtropical High pressure Zone is clearly evident at 200 hPa with cloud bands on its south side