# Satellite basics

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Most slides taken from EUMETSAT training events, Jochen Kerkmann

# CONTENT

# 1. Introduction

- The Global Humanitarian Forum states:
  - "Developing countries, which are most likely to suffer the brunt of climate change impacts, have the least number of ground-level weather data observation systems, the critical basis for efficient delivery of weather information.
  - Despite covering a fifth of the world's total land area, Africa has the least developed land-based weather observation system of all continents, and one that is in a deteriorating state.
  - Many existing weather stations do not operate properly, or do not operate at all.
  - WMO estimates that in an ideal scenario, 10 000 weather stations should be operating in Africa. Currently, there are only around 744 stations operational, less than a quarter of which provide observations that meet WMO requirements for standard and frequency of data."

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Global Humanitarian Forum (2008). *Weather information for all initiatives 2008-12* available at http://info.publicintelligence.net/WIFA_Project_Outline_Executive_Summary.pdf.

# Severe Weather Forecasting Demonstration Projects (WMO CBS SWFDP)

- Fourth meeting of the CBS-SWFDP Steering Group in Geneva, February 2012:
  - **Challenge for the SWFDP: "the need for very short-range forecasting tools, to address especially the rapid onset of localized severe thunderstorms which can produce heavy precipitation and strong wind, given the absence of adequate real-time observational networks, especially weather radar coverage."**
  - The usefulness of EUMETSAT **satellite based instability products**, such as the Global Instability Index, for nowcasting purposes was recognized
  - Also agreed that **real time satellite rainfall estimates** have proven particularly useful in regions where rain gauges and radar coverage is sparse.
- Surface-based measurement systems in DC and LDC are still needed to accurately measure, monitor as well as aid in validation of other (satellite and model based) methodologies.

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# 2. SATELLITE ORBITS

## GEO

- Located along the equatorial plane.
- About 36000 km above the earth
- Has Geo-synchronous orbit
- Period of 1436 minutes
- Good coverage from remote areas
- Has wide field of view ~ 50 degrees
- Has low resolution
- Provides continuous data ~ 15-30 min.
- Not very suitable for vertical soundings

## LEO

- Near polar orbiting
- 800 -900 km above the earth
- Has Sun-synchronous orbit
- Period of 101 minutes
- Excellent coverage at the poles
- Has relatively narrow field of view
- Has high resolution
- Passes vary with latitude
- Very suitable for vertical soundings

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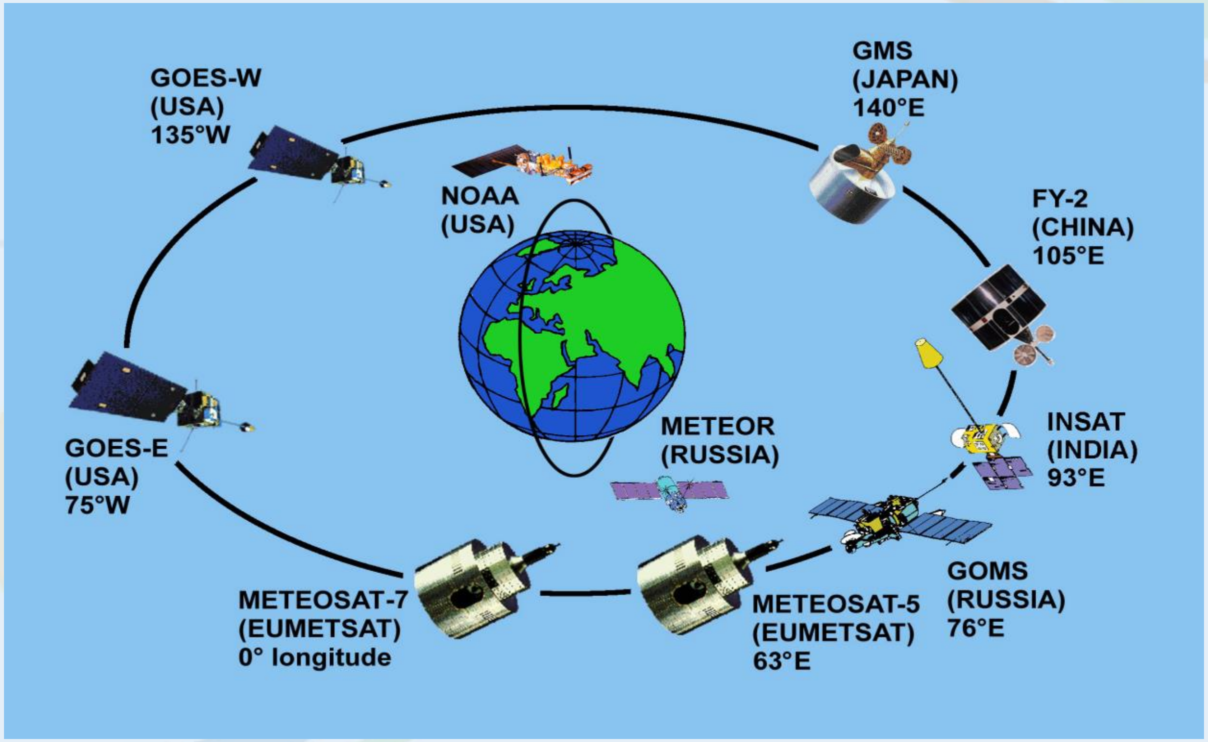
# 2. SATELLITE ORBITS (cont)

**GEO satellites**

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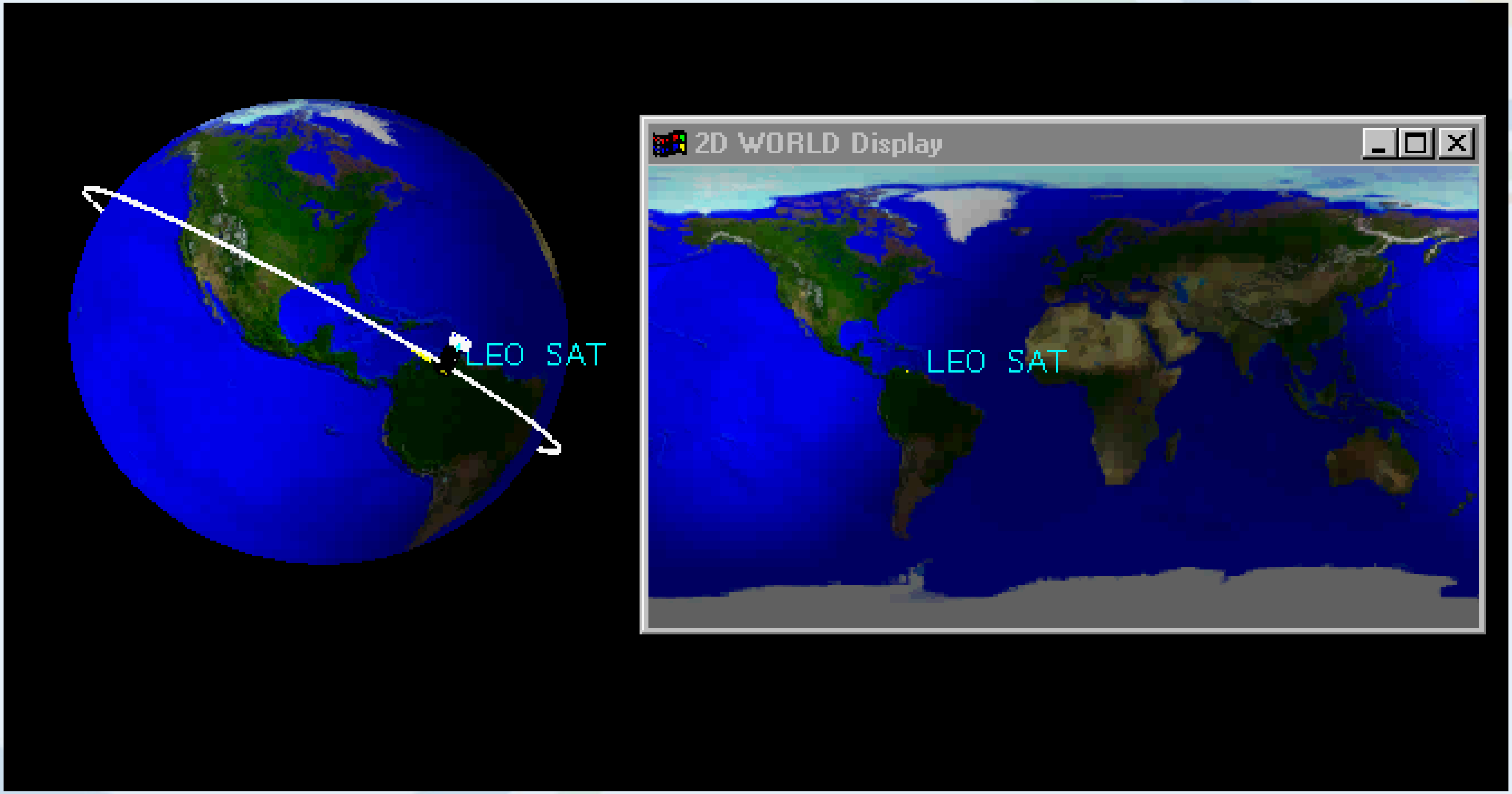
# 2. SATELLITE ORBITS (cont)

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# 3. METEOROLOGICAL SATELLITES

- Many types of satellites have been launched for various purposes.
- For monitoring the environment, there are three types namely the:
  - Meteorological (weather) satellites
  - Earth Resource satellites (ERS)
  - Research and Development satellites (R&D).

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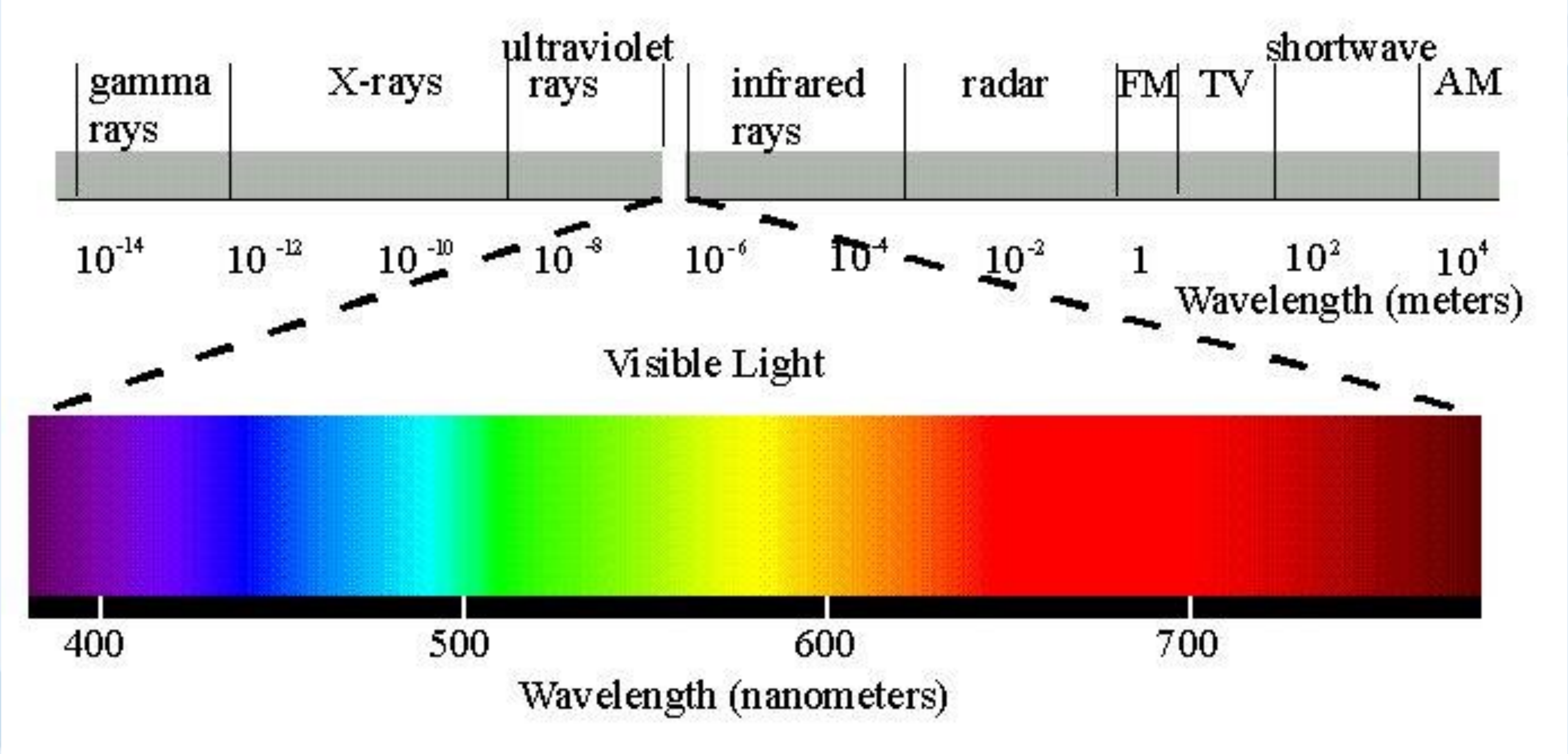
# 4. THE EM SPECTRUM AND RESOLUTION

- The Electromagnetic (EM) spectrum is defined as a spectrum of all types of EM radiation in which each type of <u>radiation is ordered according to its wavelength</u>

# Electromagnetic Spectrum



# 4. THE EM SPECTRUM (cont)

- In the visible portion features are observed by virtue of *reflected solar energy*
- In the infrared portion, sensing of *emitted energy* predominates
- Remote sensing data acquisition of *surface features* is limited to the *non-blocked* spectral regions of the EM referred to as *atmospheric windows*
- Atmospheric windows define wavelength ranges in which the atmosphere is particularly *transmissive* of energy

# The seven MSG window channels

| Window | Band (um) | Airmass | Band (um) |
|---|---|---|---|
| VIS 0.6 | 0.56 - 0.71 | WV 6.2 | 5.35 - 7.15 |
| VIS 0.8 | 0.74 - 0.88 | WV 7.3 | 6.85 - 7.85 |
| NIR 1.6 | 1.50 - 1.78 | IR 9.7 | 9.38 - 9.94 |
| MIR 3.9 | 3.40 - 4.20 | IR 13.4 | 12.40 - 14.40 |
| IR 8.7 | 8.30 - 9.10 | | |
| IR 10.8 | 9.80 - 11.80 | High Res VIS | |
| IR 12.0 | 11.00 - 13.00 | HRV | 0.4 - 1.1 |

3 km data sampling intervals, except HRV (1 km)
Images each 15 minutes (5 minutes Met-8 rapid scan)

# 4. THE EM SPECTRUM (cont)

- The atmospheric constituents like gases, aerosols and water vapour are selective *absorbers* of radiation depending on their wavelength, pressure and temperature
- In a clear atmosphere gas molecules such as carbon dioxide absorb radiation in selective wavebands creating a complicated pattern of atmospheric absorption bands
- An absorption band is defined as a range of wavelengths in the EM spectrum within which *radiation is absorbed by a substance*

# 4. THE EM SPECTRUM (cont)

- NON-ATMOSPHERIC WINDOWS
  - Around 4.3 $\mu$m, carbon-dioxide
  - Around 6.7 $\mu$m, water vapour
  - Around 9.7 $\mu$m, ozone
  - Around 15 $\mu$m, carbon-dioxide
  - Around 5 mm, oxygen

- Depending on what we need to know, one uses window/non-window channels for different purposes
- So much for very basic background information…
- Let us look at more practical examples of how to use satellite images…

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# MSG SEVIRI CHANNELS

| Channel | Main Cloud Physical Properties (for Cb clouds, NADIR viewing) |
| --- | --- |
| 01 (VIS 0.6) | optical thickness, amount of cloud water and ice |
| 02 (VIS 0.8) | optical thickness, amount of cloud water and ice |
| 03 (NIR 1.6) | optical thickness, particle size & shape, phase |
| 04 (IR 3.9) | Day-time: top temperature, particle size & shape, phase<br>Night-time: top temperature (very noisy below -50°C) |
| 05 (WV 6.2) | top temperature, WV content in stratosphere |
| 06 (WV7.3) | top temperature, WV content in stratosphere |
| 07 (IR 8.7) | top temperature |
| 08 (IR9.7) | top temperature |
| 09 (IR 10.8) | top temperature |
| 10 (IR 12.0) | top temperature |
| 11 (IR13.4) | top temperature |
| 12 (HRV) | optical thickness, amount of cloud water and ice |

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# 5. Satellite image interpretation

- 5.1 VIS
- 5.2 IR
- 5.3 WV
- 5.4 NIR

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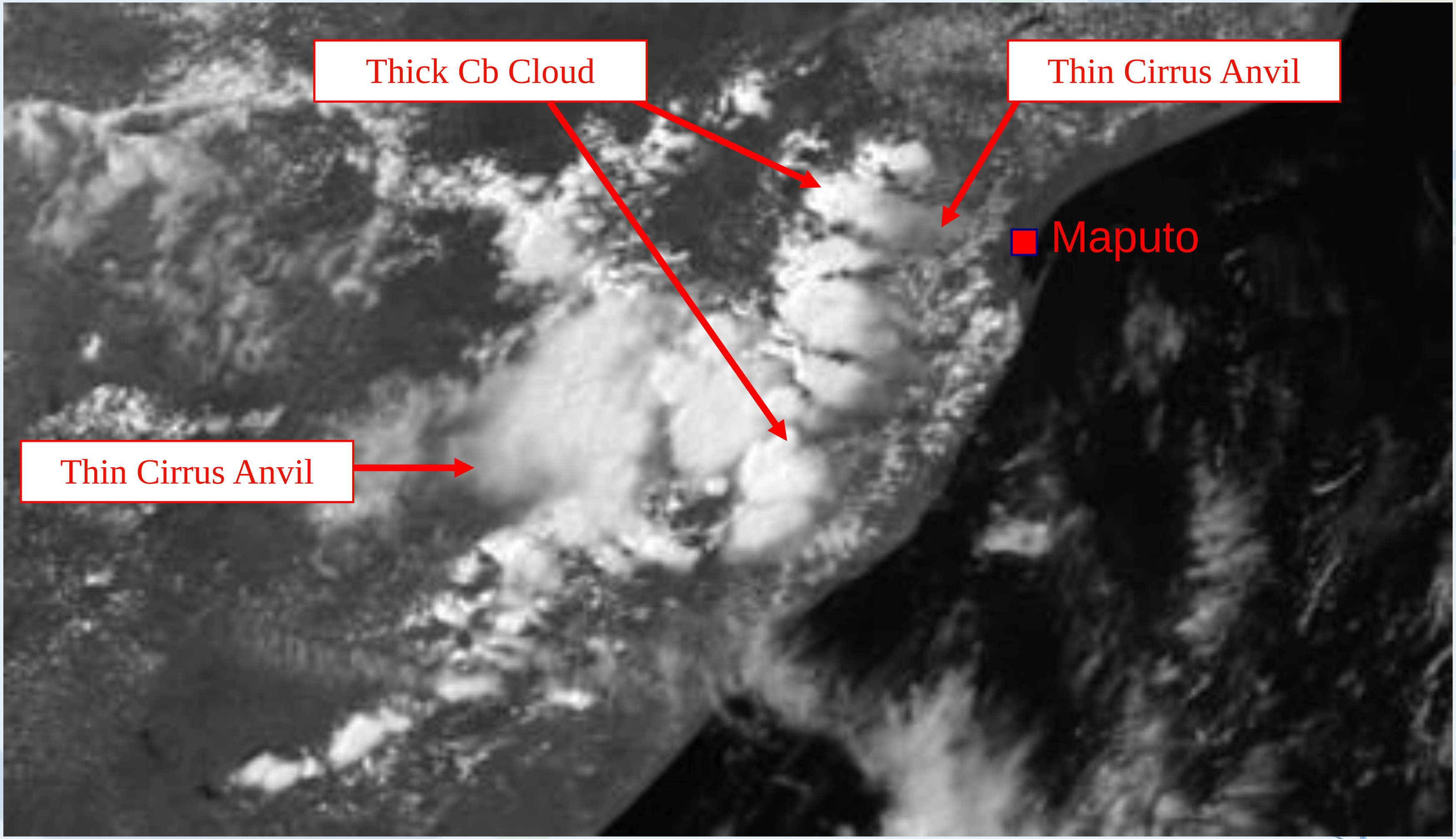
# 5.1 VIS IMAGES

- Low clouds are less bright since they do not have large amount of ice. Their droplets contain more water that absorbs VIS rather than reflect
- High clouds consist of more ice crystals than water and are very bright
- Clouds physical properties of high albedo are:
  - large depth,
  - high cloud water (ice) content,
  - small average cloud-droplet size
- Cloud physical properties of low albedo are:
  - shallow depth,
  - low cloud water (ice) content,
  - large average cloud-droplet size
- VIS imagery shows *shadows* and helps to identify cloud structure when sun is at an angle.

# Channel 02 (VIS0.8): Optical Thickness




MSG-1, 6 November 2004, 12:00 UTC, Channel 02 (VIS0.8)
Range: 0 % (black) to 100 % (white), Gamma = 1.0

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# 5.2 IR IMAGES

- IR imagery indicates the Temperature of the radiating surface.
- Low cloud and fog can not be observed at night since their temperature is similar or near to that of surface.
- During the day such low clouds are detectable with VIS.
- Special properties of 3.9 micron radiation help in detecting low clouds at night

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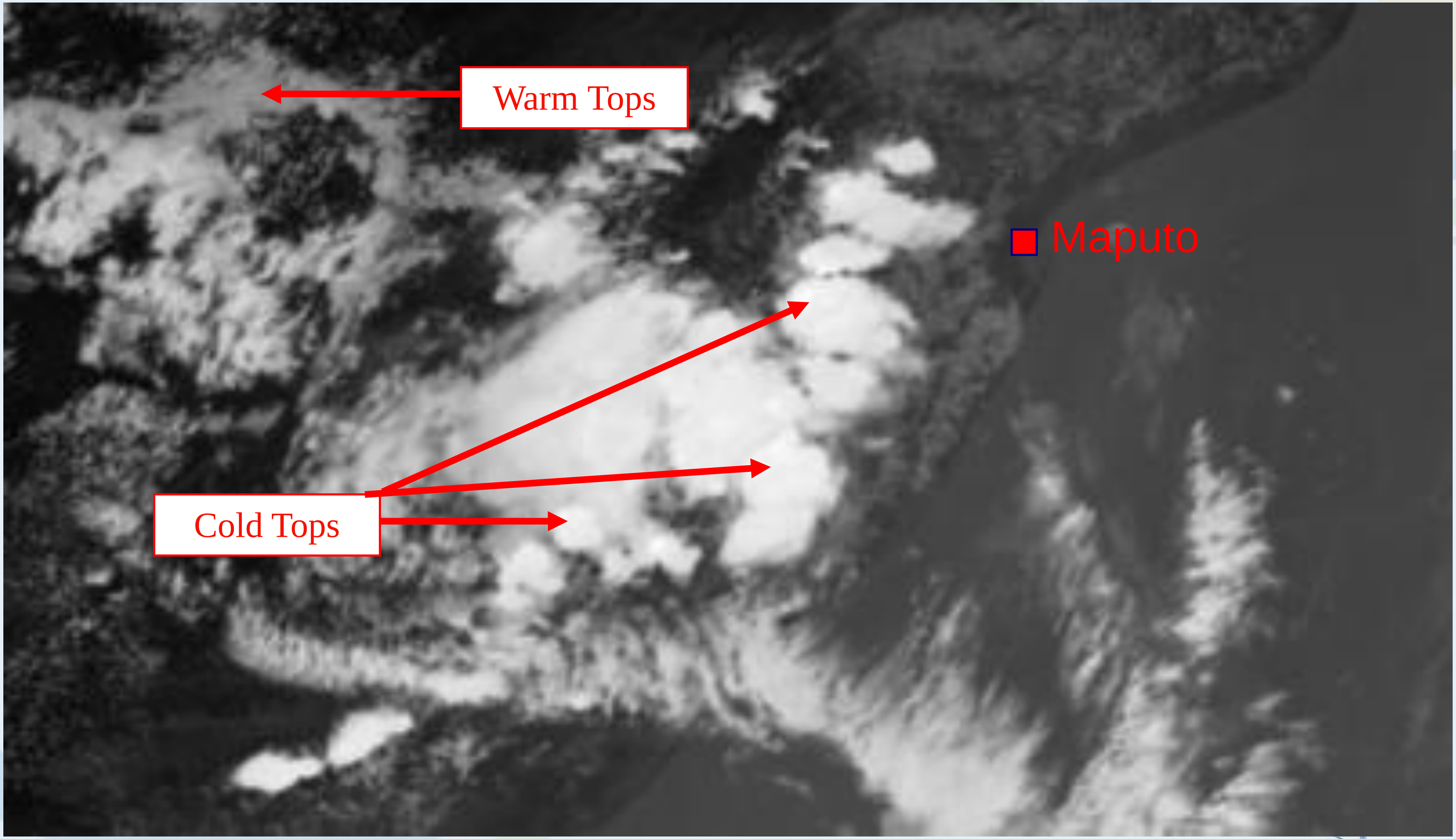
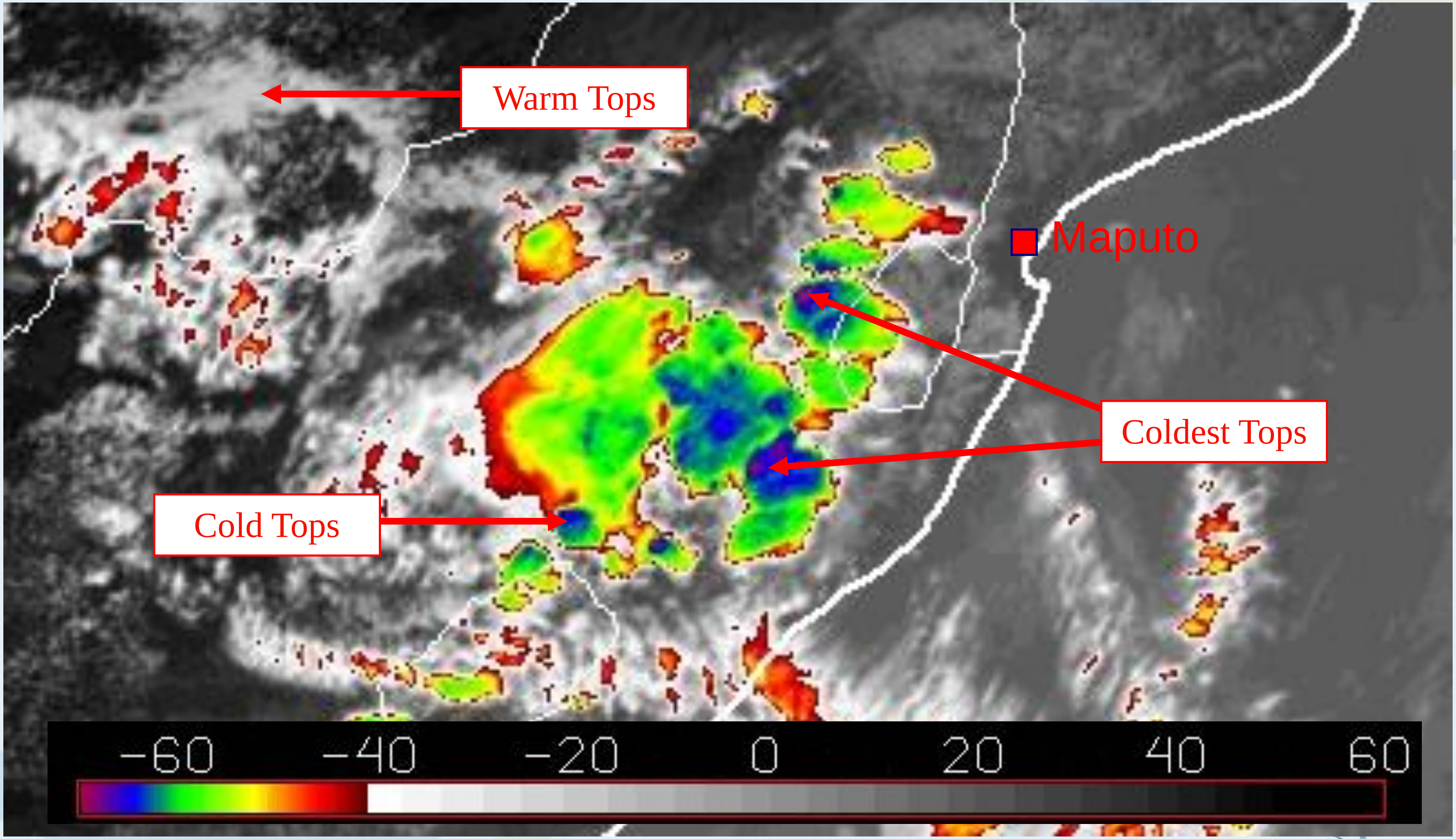
# Channel 09 (IR10.8): Top Temperature




MSG-1, 6 November 2004, 12:00 UTC, Channel 09i (IR10.8i)
Range: +50°C (black) to -70°C (white), Gamma = 1.0

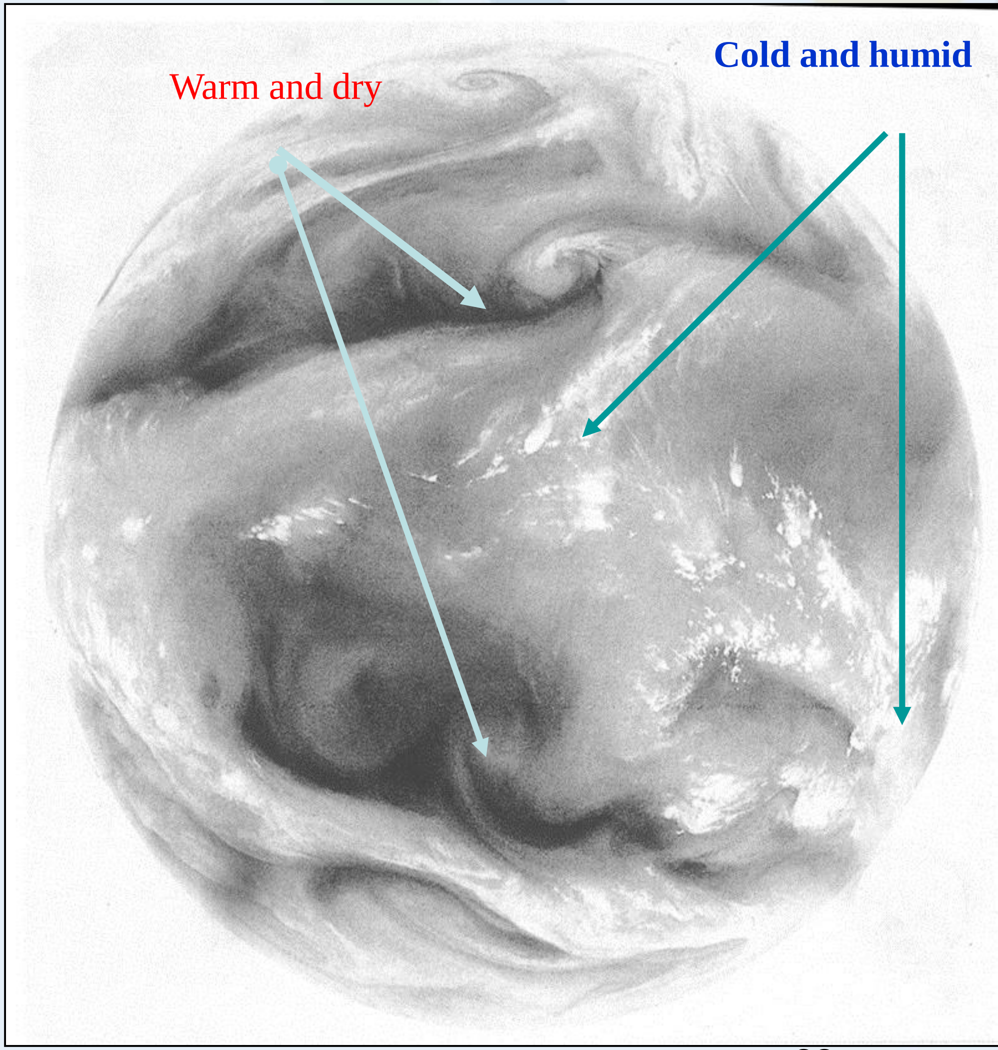
# Channel 09 (IR10.8): Top Temperature



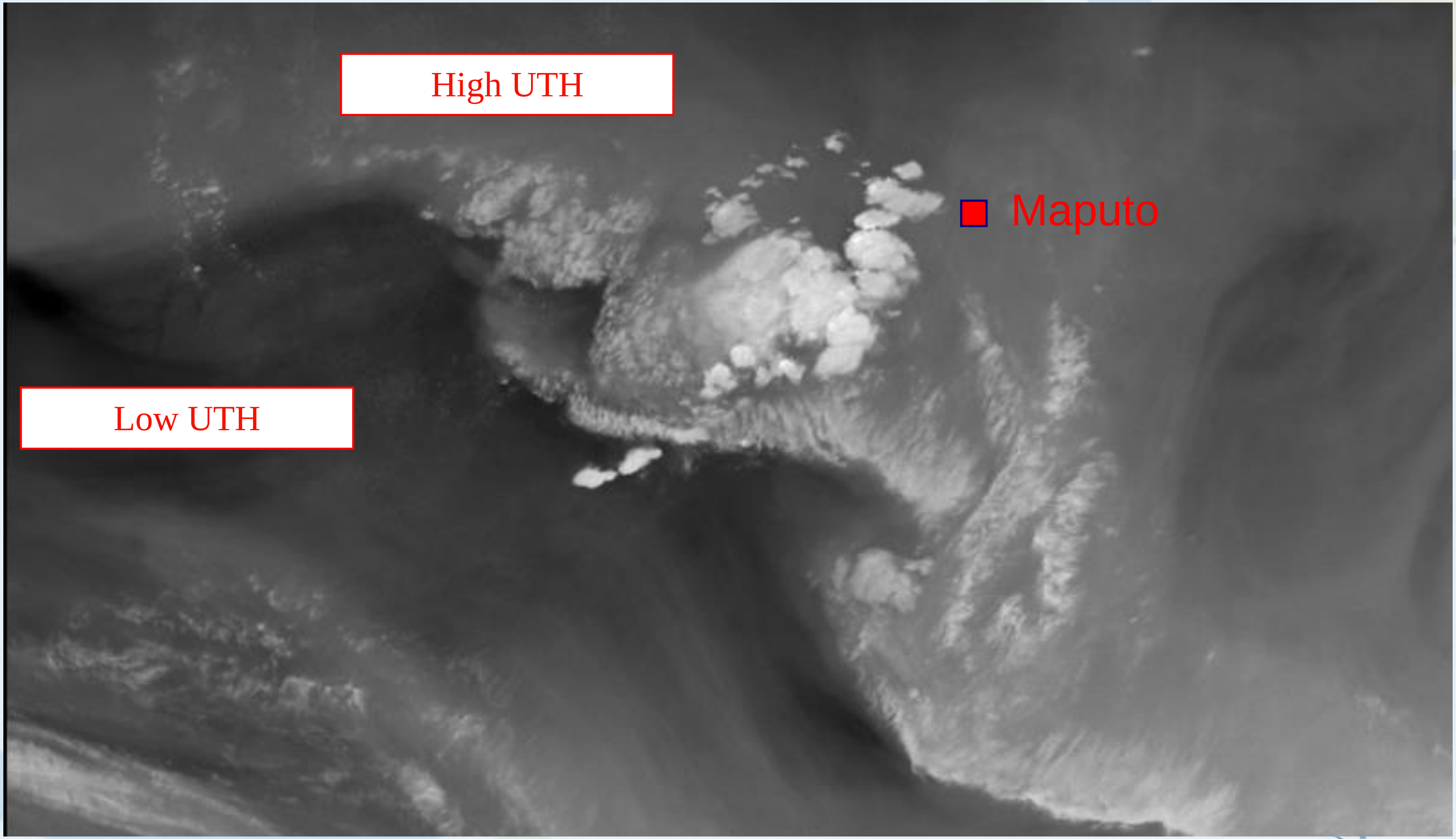

MSG-1, 6 November 2004, 12:00 UTC, Channel 09 (IR10.8)

# 5.3 WV IMAGES (cont)

- Regions with high upper trop. Humidity appear white or light(cold) and regions with low humidity appears warm(dark)
- For moist atmosphere most WV radiation comes from middle layers.
- Very little moisture from lower layers is detected on the WV radiation.
- It is good tracer of atmospheric motions



# Channel 05 (WV6.2): Upper Level Moisture




MSG-1, 6 November 2004, 12:00 UTC, Channel 05i (WV6.2i)
Range: -20°C (black) to -70°C (white), Gamma = 1.0

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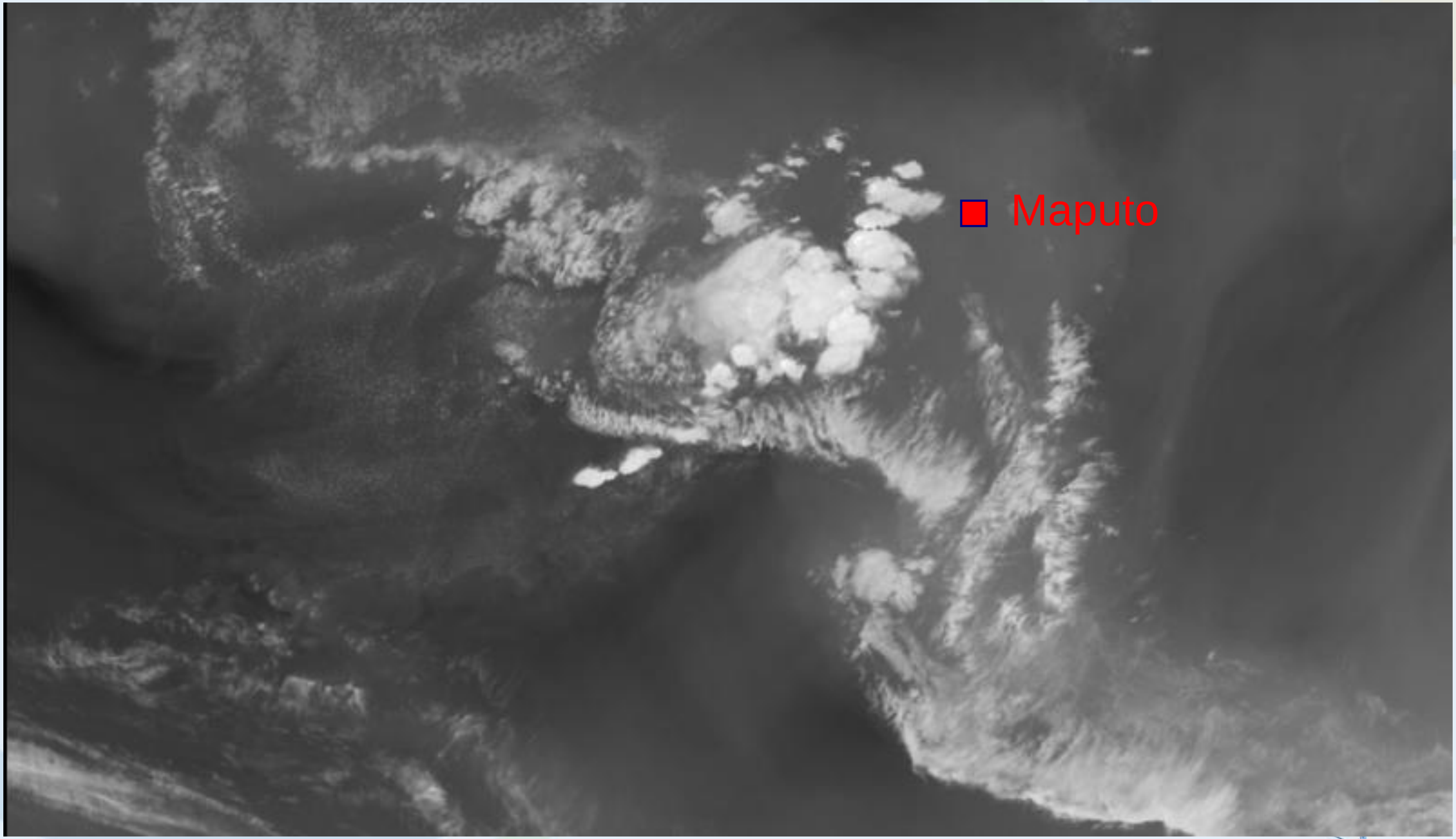
# Channel 06 (WV7.3): Mid Level Moisture




MSG-1, 6 November 2004, 12:00 UTC, Channel 06i (WV7.3i)
Range: +10°C (black) to -70°C (white), Gamma = 1.0

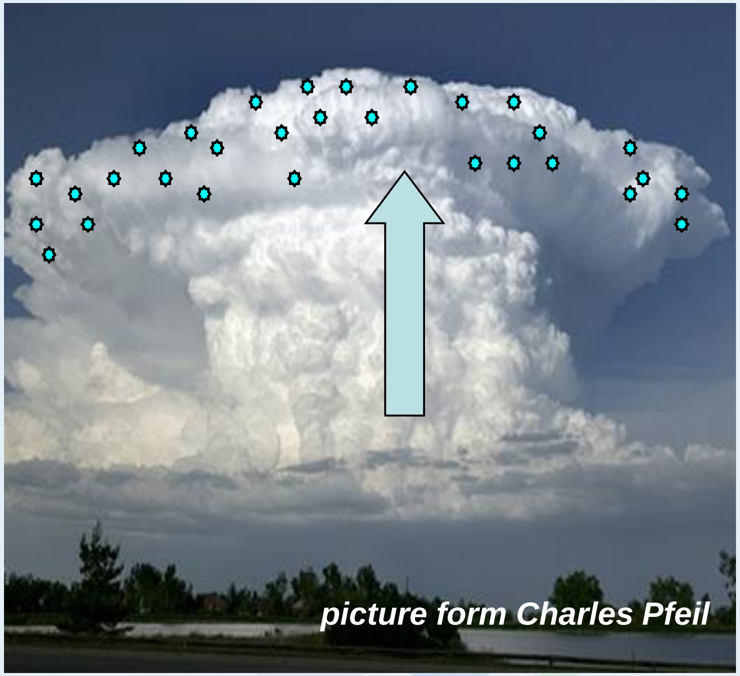
# MSG Channel Differences Useful to Monitor Convection

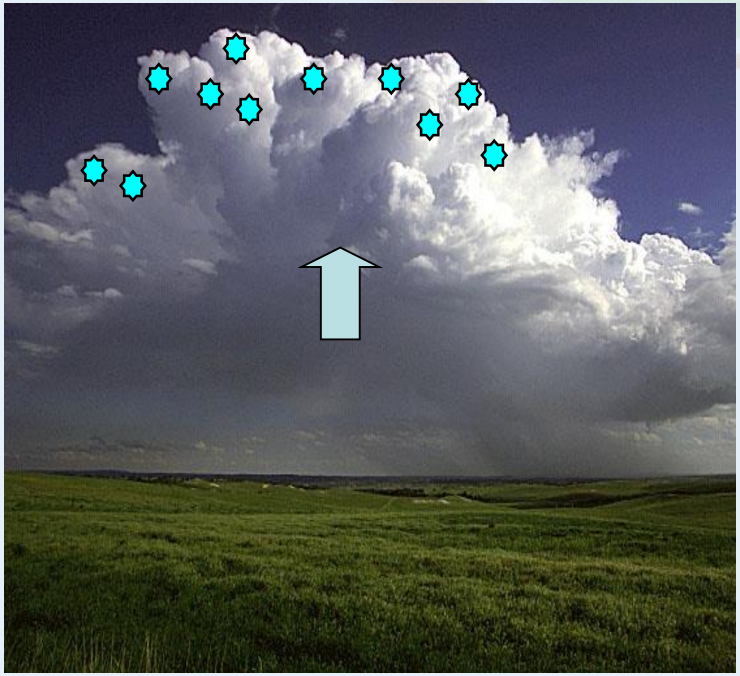
| Channel Diff. | Application |
| --- | --- |
| IR8.7 - IR10.8 | Day/Night: optical thickness, phase |
| IR10.8 - IR12.0 | Day/Night: optical thickness |
| NIR1.6 - VIS0.6 | Day: phase (ice index), particle size |
| IR3.9 - IR10.8 | Day: particle size<br>Night: particle size (only for warm clouds) |
| WV6.2 - IR10.8 | Day/Night: overshooting tops |

# Why is it important to know whether we see small/large ice particles and whether clouds are thin/thick?

- Thick clouds can be Cb
- Ice inside clouds can become hail on the ground
- Strong updrafts produce small ice particles which can indicate severe convection

# Small / Large Ice Particles in Cb Clouds



strong updraft
➔ small ice particles

weak updraft
➔ large ice particles

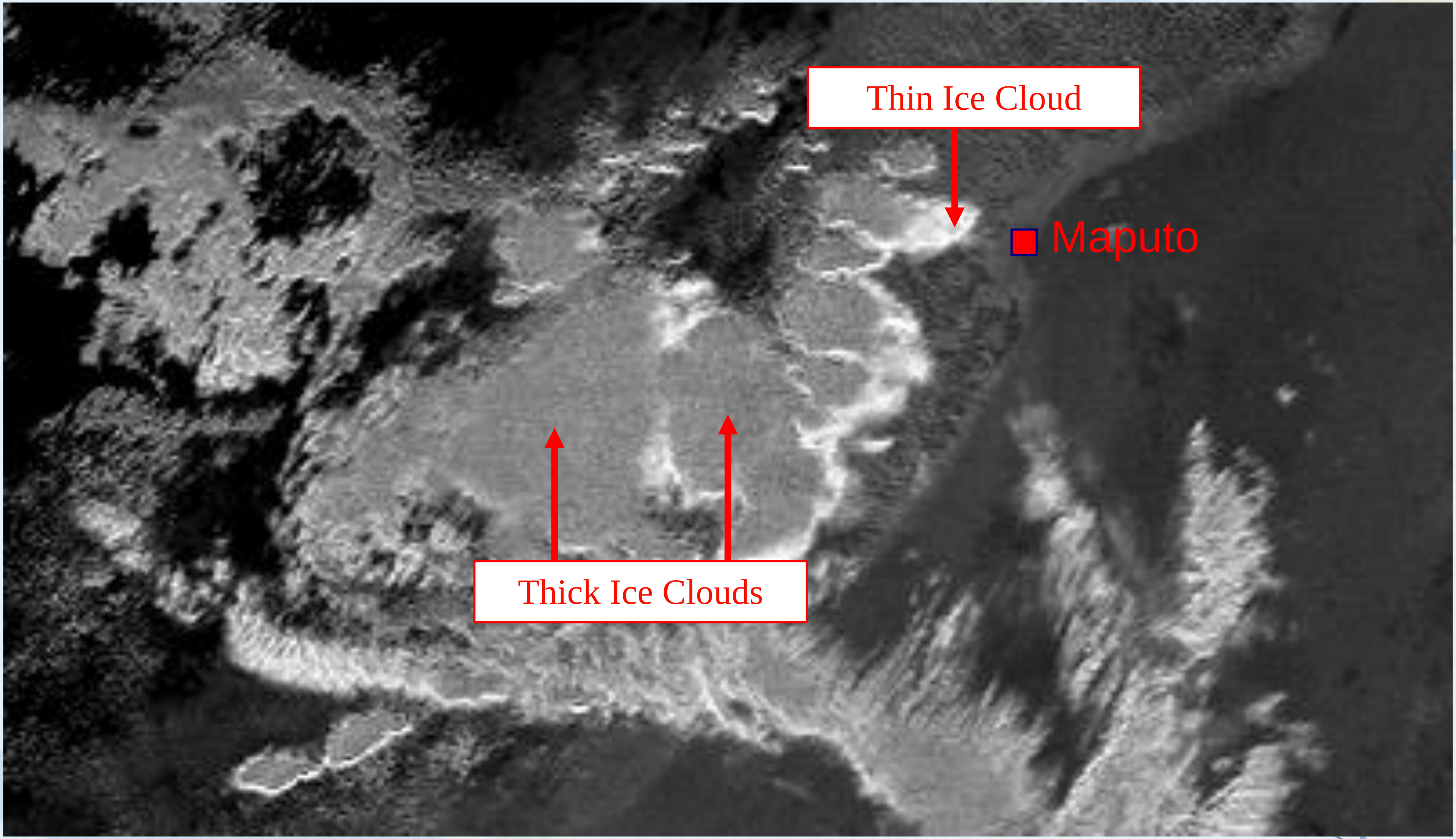
# Channel differences

1. Channel 7-9

IR8.7 – IR10.8

Locate thin ice cloud and thick ice cloud

# Difference IR8.7 - IR10.8: Optical Thickness & Phase




MSG-1, 6 November 2004, 12:00 UTC, Difference IR8.7 - IR10.8
Range: -5 K (black) to +5 K (white), Gamma = 1.0

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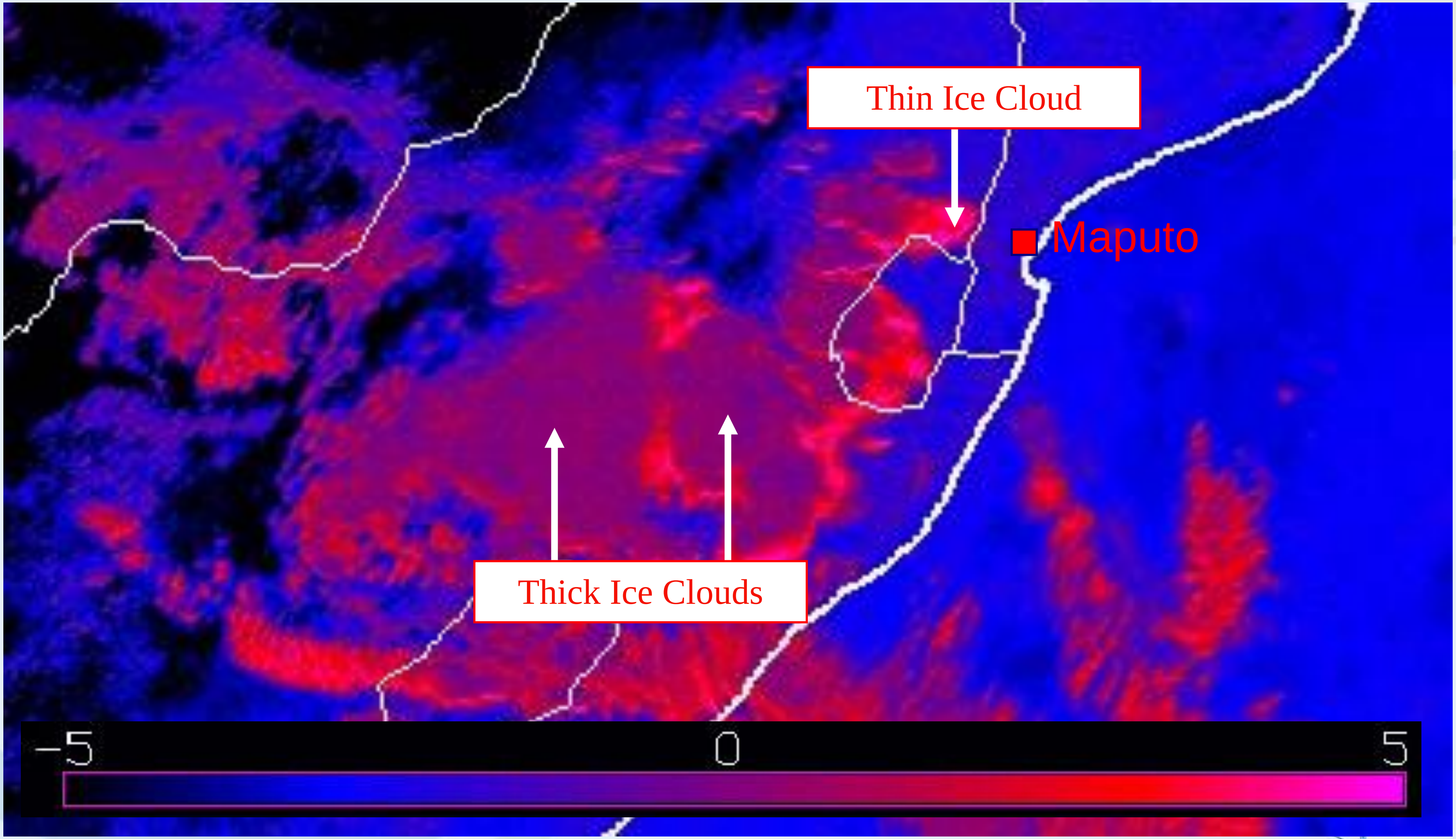
# Channel differences

1. Channel 7-9

IR8.7 – IR10.8 Colour enhanced

Locate thin ice cloud and thick ice cloud

# Difference IR8.7 - IR10.8: Optical Thickness & Phase




MSG-1, 6 November 2004, 12:00 UTC, Difference IR8.7 - IR10.8

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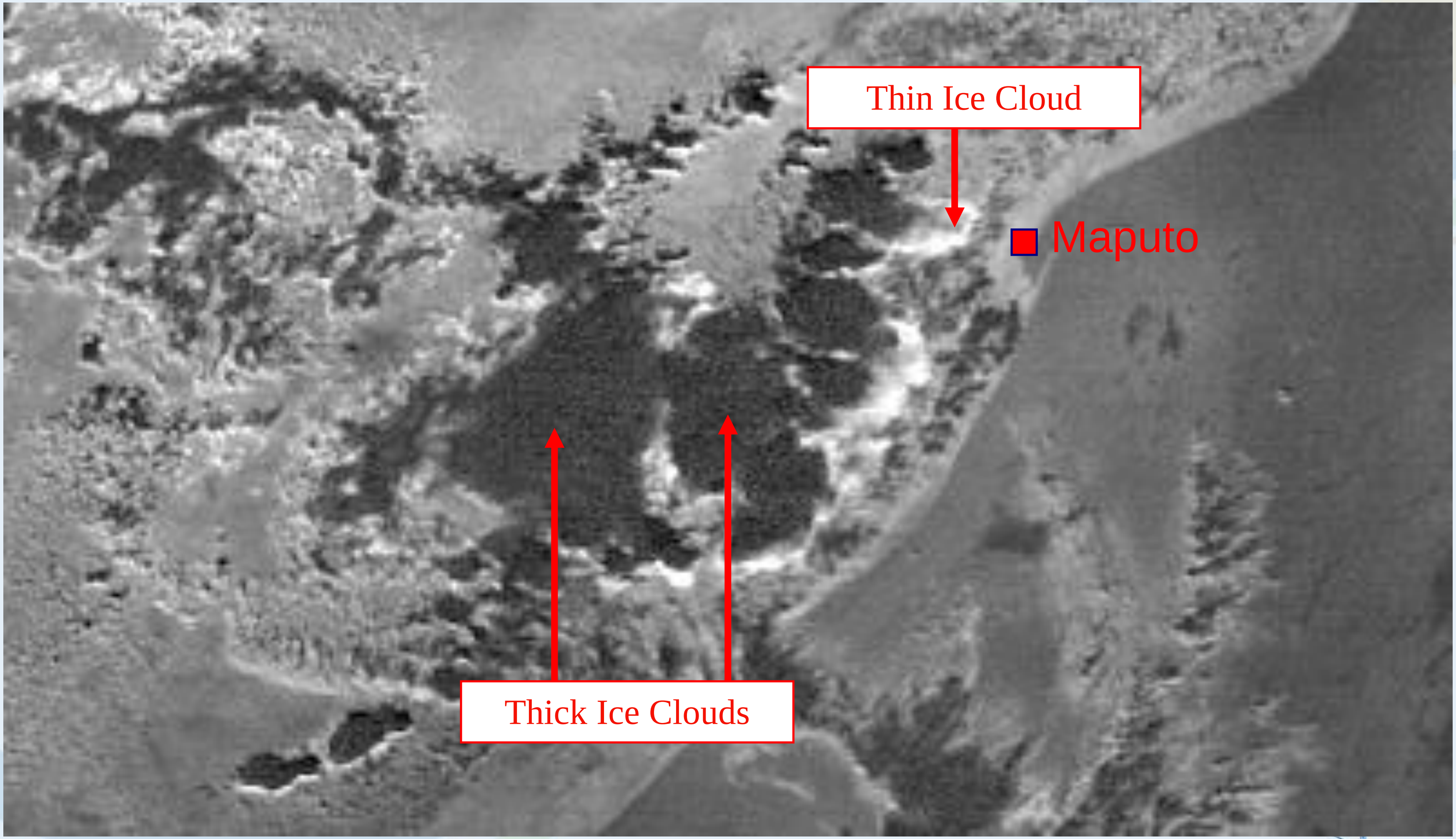
# Channel differences

2. Channel 9-10

IR10.8 – IR12.0

Locate thin ice cloud and thick ice cloud

# Difference IR10.8 - IR12.0: Optical Thickness




MSG-1, 6 November 2004, 12:00 UTC, Difference IR10.8 - IR12.0
Range: -2 K (black) to +8 K (white), Gamma = 1.0

# Channel differences

3. Channel 3-1

NIR1.6 – VIS0.6

Locate particle size and cloud phase

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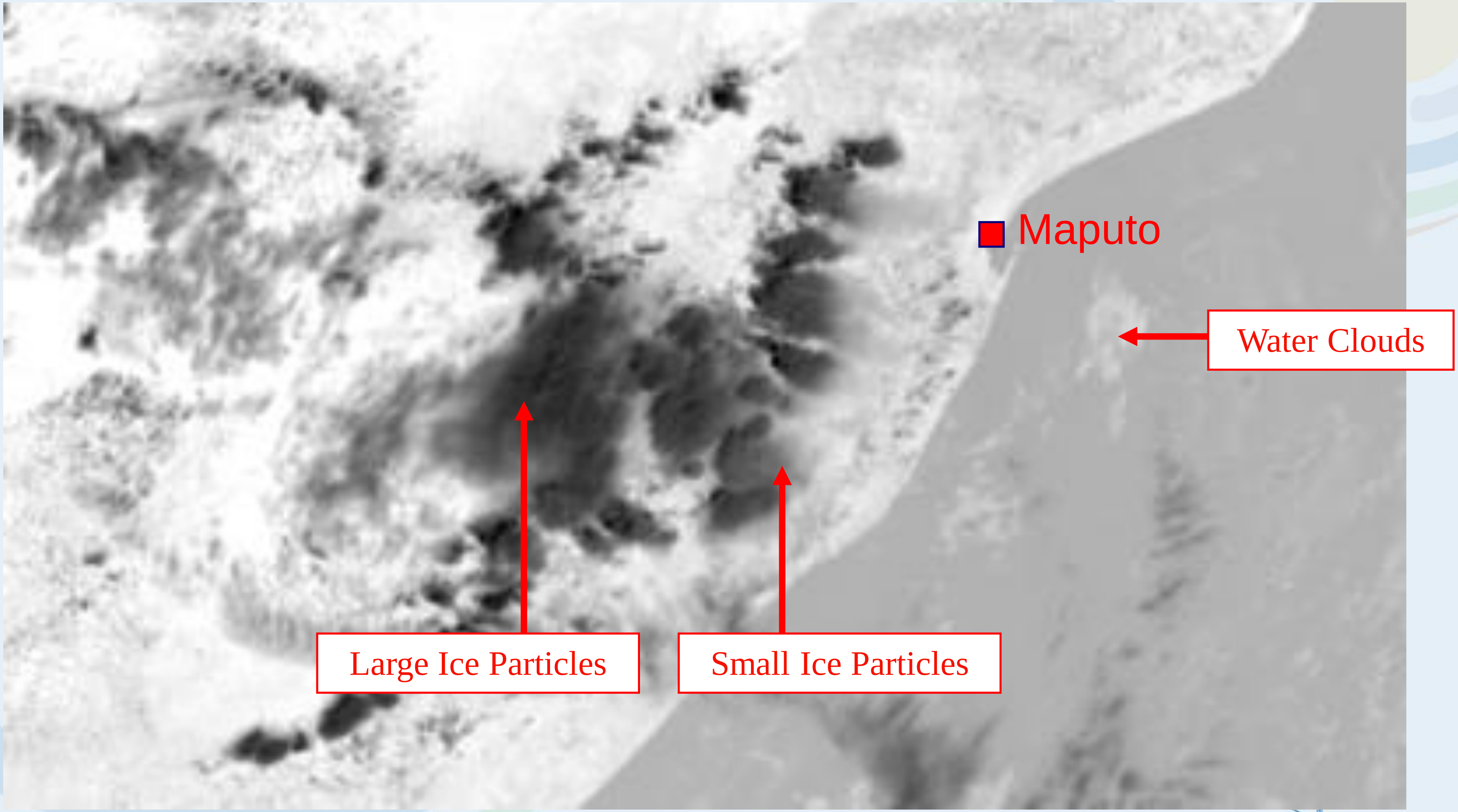
# Difference NIR1.6 - VIS0.6: Particle Size & Phase




MSG-1, 6 November 2004, 12:00 UTC, Difference NIR1.6 - VIS0.6
Range: -75 % (black) to +25 % (white), Gamma = 1.0

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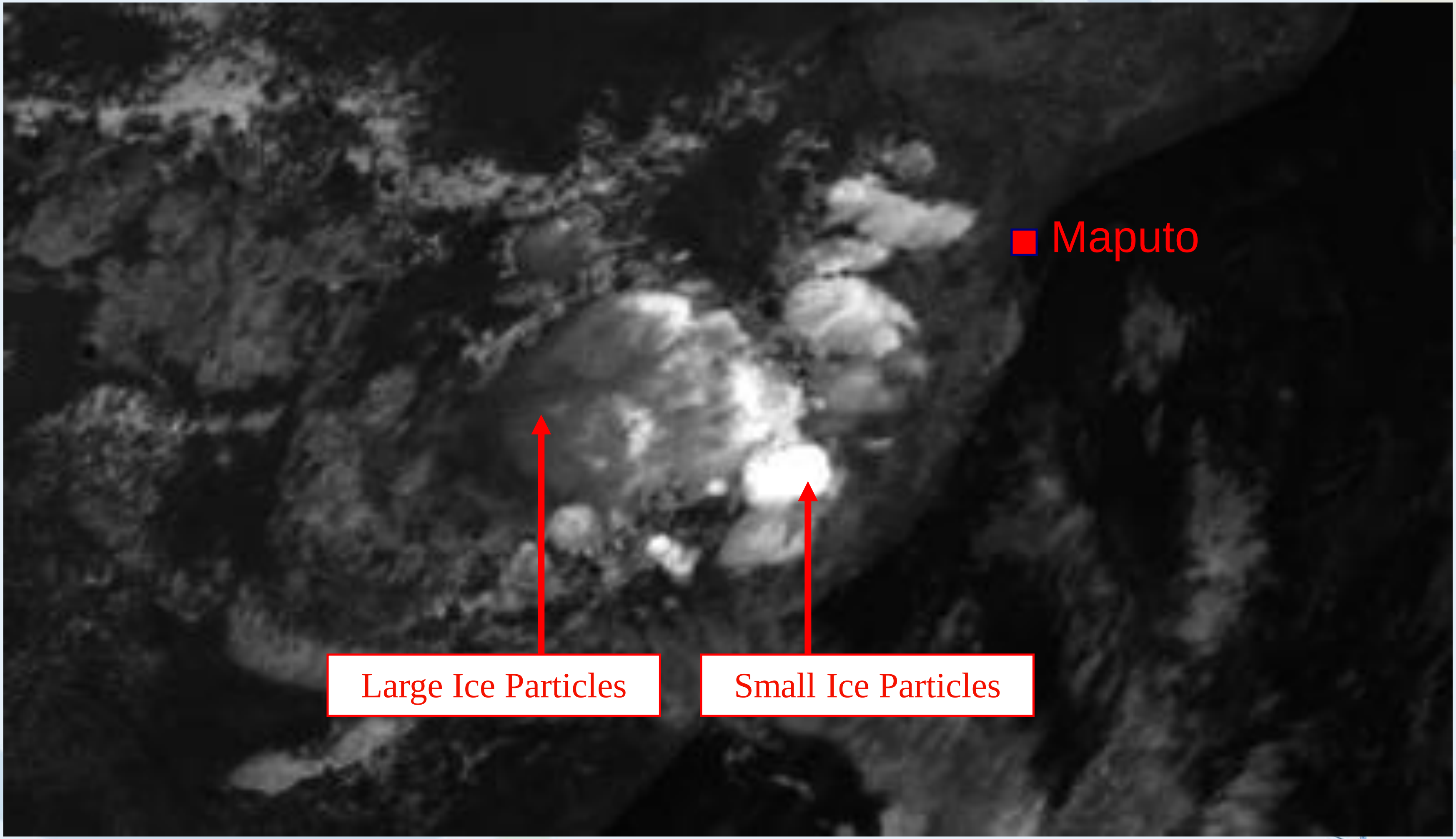
# Channel differences

4. Channel 4-9

NIR3.9 – IR 10.8

Locate small and large particles in clouds

# Difference IR3.9 - IR10.8: Particle Size & Phase




MSG-1, 6 November 2004, 12:00 UTC, Difference IR3.9 - IR10.8
Range: -5 K (black) to +70 K (white), Gamma = 0.5

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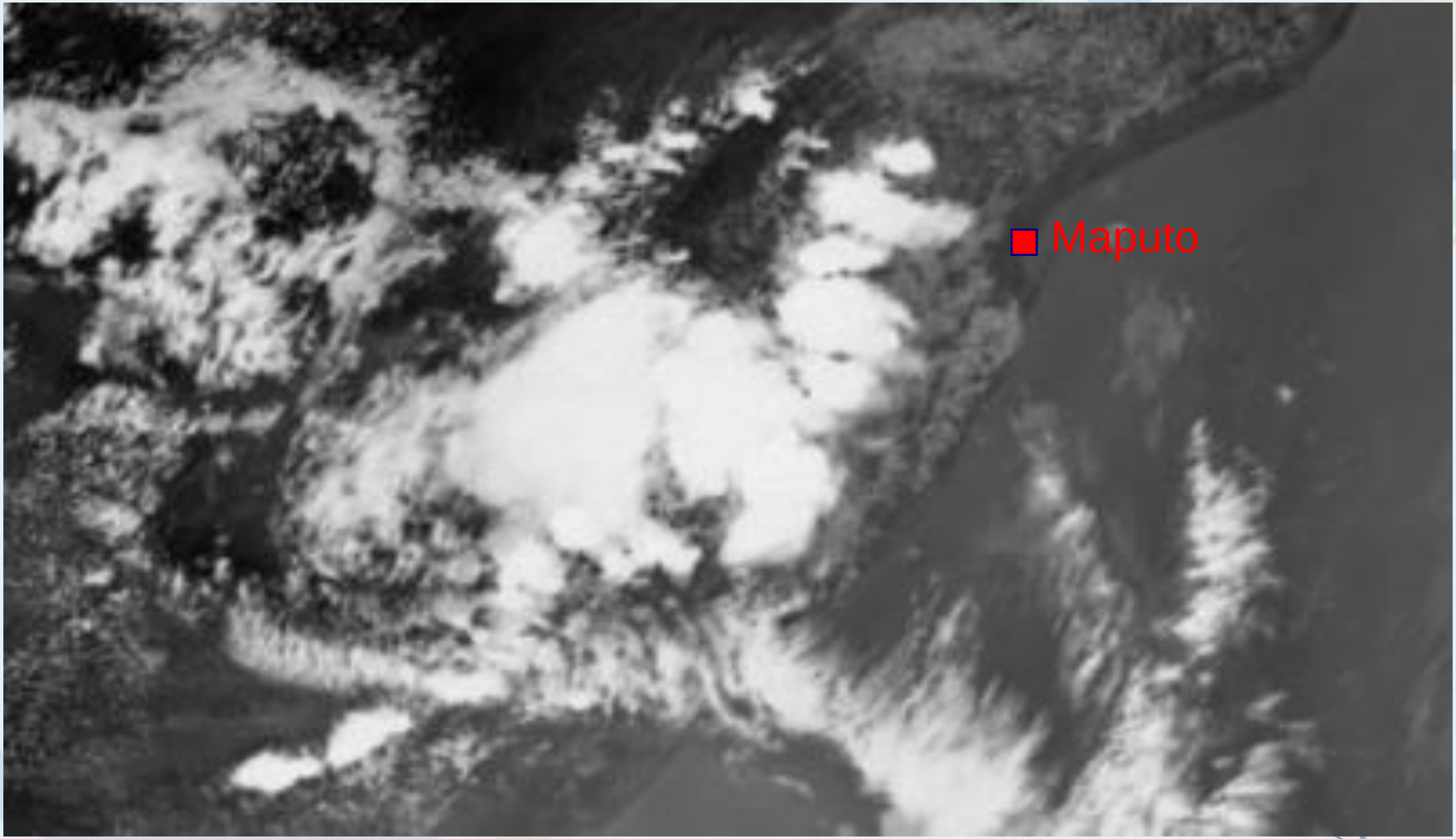
# Channel differences

5. Channel 5-9

WV6.2 – IR 10.8

Locate overshooting tops

# Difference WV6.2 - IR10.8: Overshooting Tops




MSG-1, 6 November 2004, 12:00 UTC, Difference WV6.2 - IR10.8
Range: -85 K (black) to +5 K (white), Gamma = 1.0

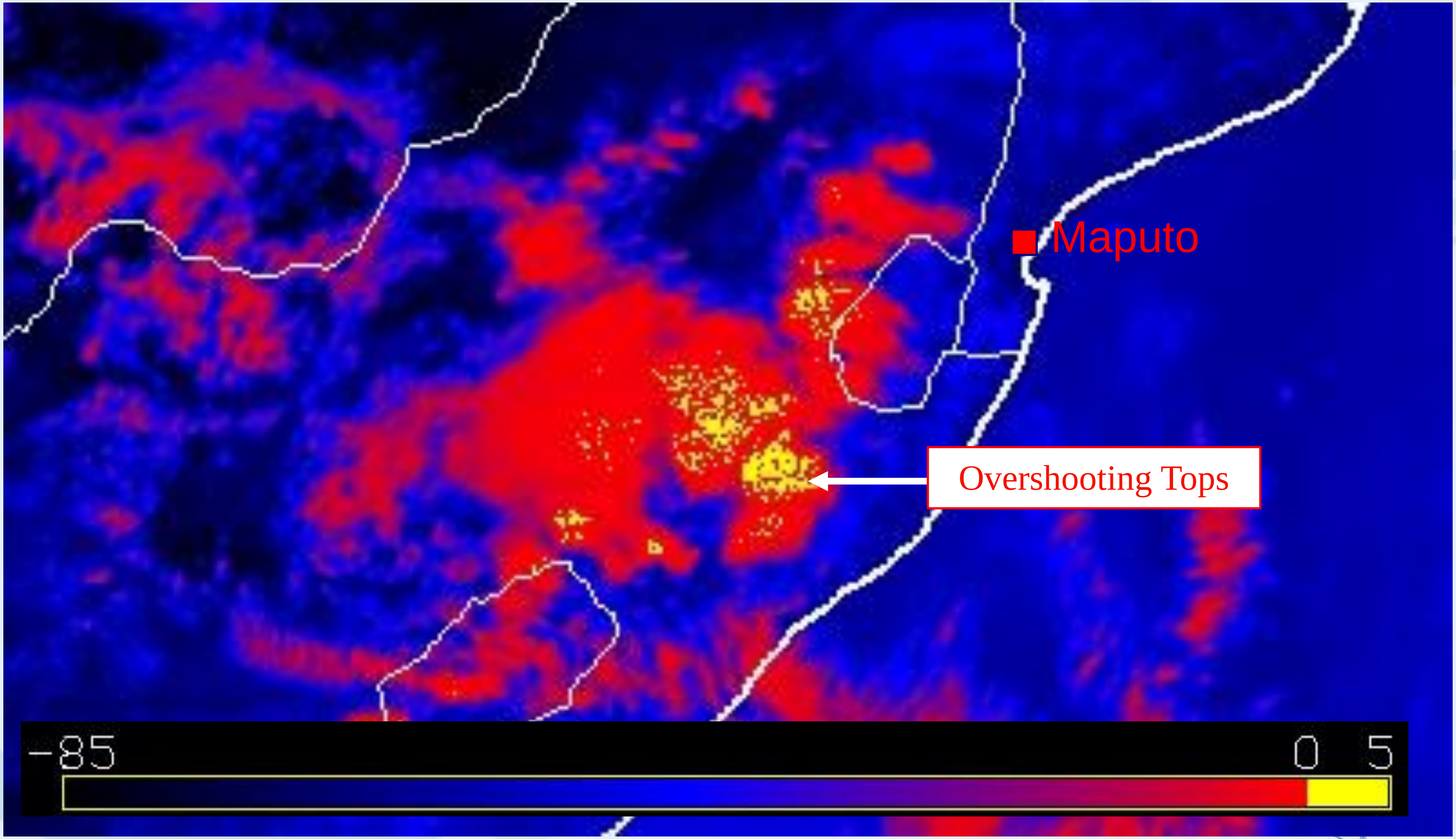
# Channel differences

5. Channel 5-9

WV6.2 – IR 10.8 Colour enhanced

Locate overshooting tops

# Difference WV6.2 - IR10.8: Overshooting Tops




MSG-1, 6 November 2004, 12:00 UTC, Difference WV6.2 - IR10.8

# 6. Summary

- VIS good for day time usage
- HRV to see fine-scale details
- IR108 good for vertical extent of clouds (Cloud top temp)
- WV6.2: shows high level moisture
- WV7.3 shows mid-level moisture (early convection)
- Channel differences used for particle size and phase

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# 7. Conclusion

- Where radar systems are in place - best option for nowcasting systems, complemented by NWP and satellite information.
- Without the luxury of expensive radar systems and/or software display systems - use NWP, satellite data sources and internet based systems for display.
- Ground based data sources (such as gauge networks and radar systems) – remain crucial/ideal not only for observation but for verification of effectiveness of other data sources.