EUMETSAT

Monitoring weather and climate from space

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Outline

1) History of meteorological satellites

2) Satellite orbits & elements

3) EUMETSAT's current satellites

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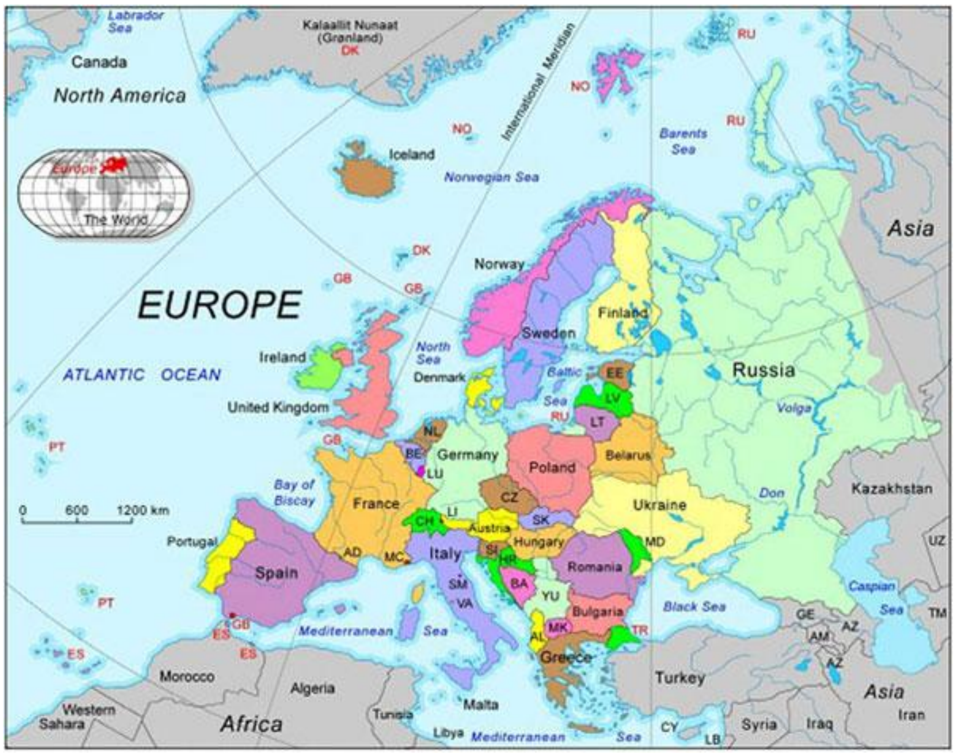
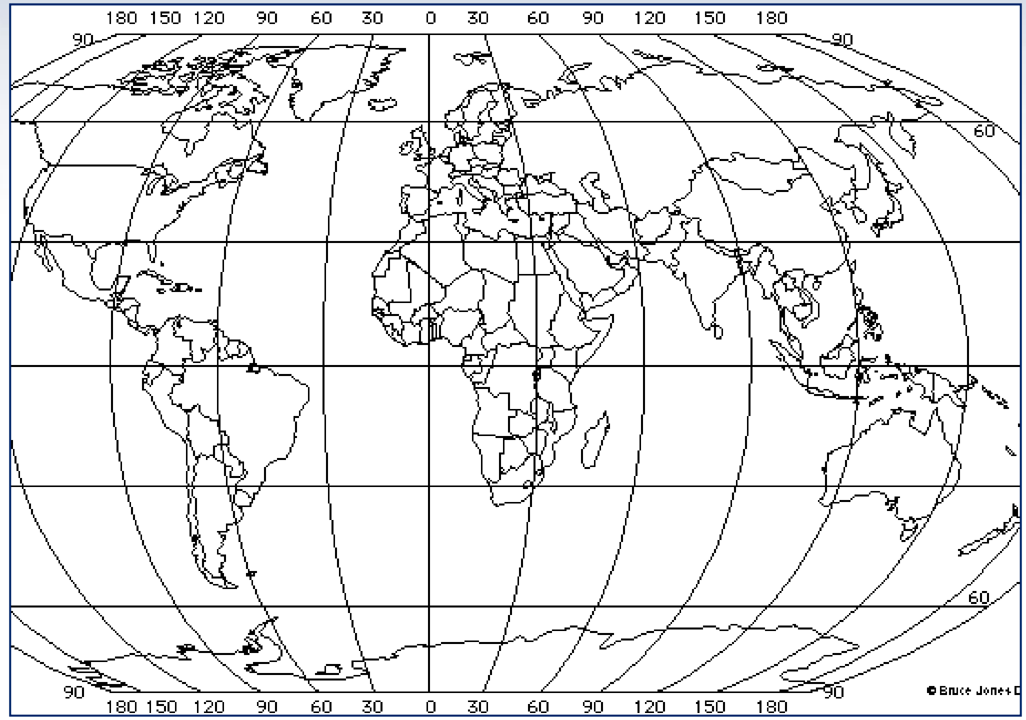
Where are you ?





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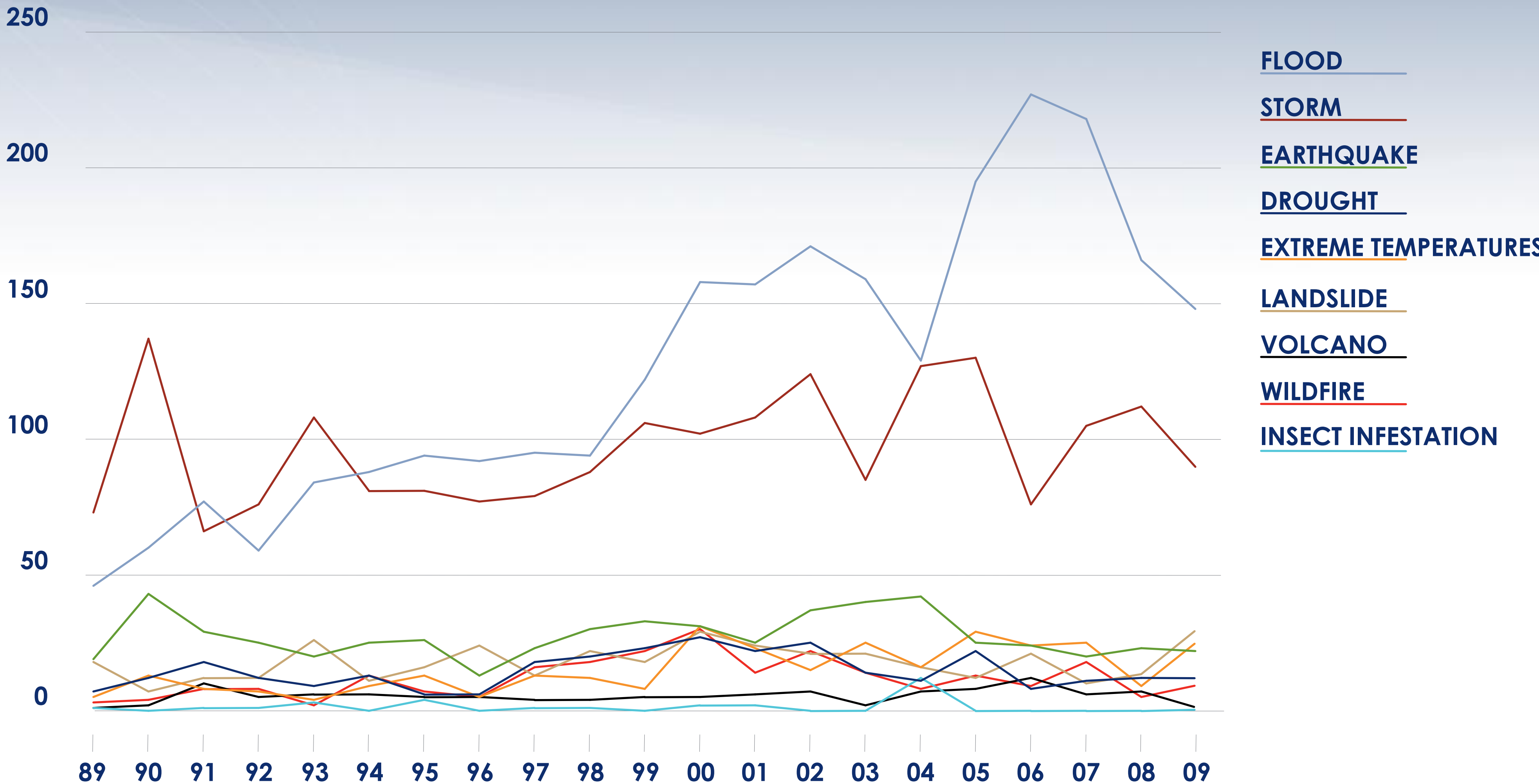
Motivation: number of weather disasters increases



Source: EM-DAT: The OFDA/CRED International Disaster Database

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History of meteorological satellites

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1946: Rockets and Cameras

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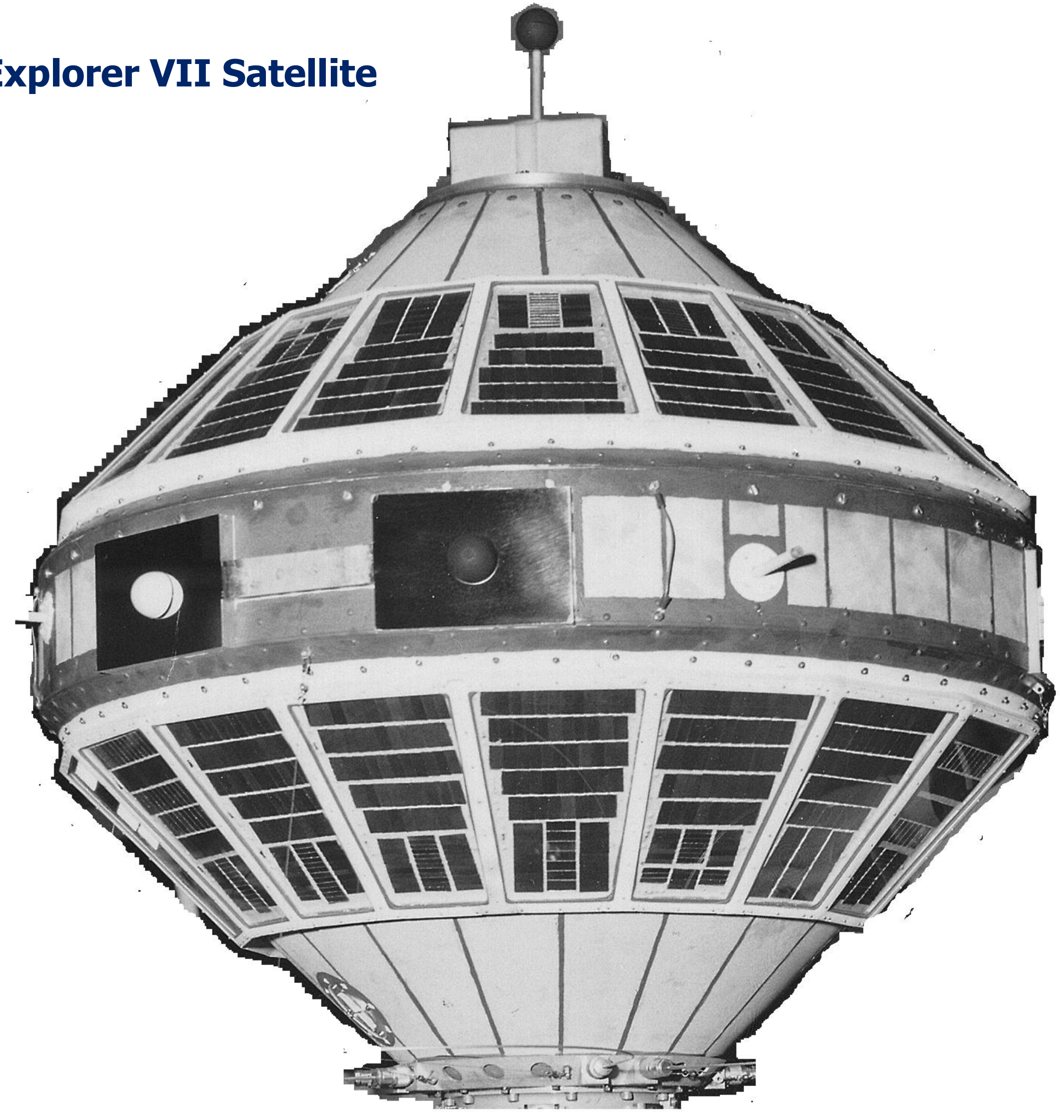
1957: Russia launches Sputnik-1

1957 - Russia launches Sputnik-1, this was unexpected and encouraged the US government to make space exploration a priority.

1959: The first meteorological satellite

Explorer VII Satellite



The <u>first successful meteorological experiment</u> conducted from a satellite, was launched on Explorer VII on <u>13 October 1959</u>. Explorer VII carried an early version of a radiometer designed to measure Earth's heat balance from a satellite. The architects of the radiometer were the University of Wisconsin's Verner E. Suomi and Robert J. Parent.

First weather satellite TIROS-1

- TIROS-1, first pure weather satellite
- 1964: Nimbus-1, Nimbus weather satellite program begins
- ATS (Applications Technology Satellite), 1966, first geostationary weather satellite
- Afterwards many TIROS, NIMBUS, ESSA, NOAA, GOES, Meteosat etc.

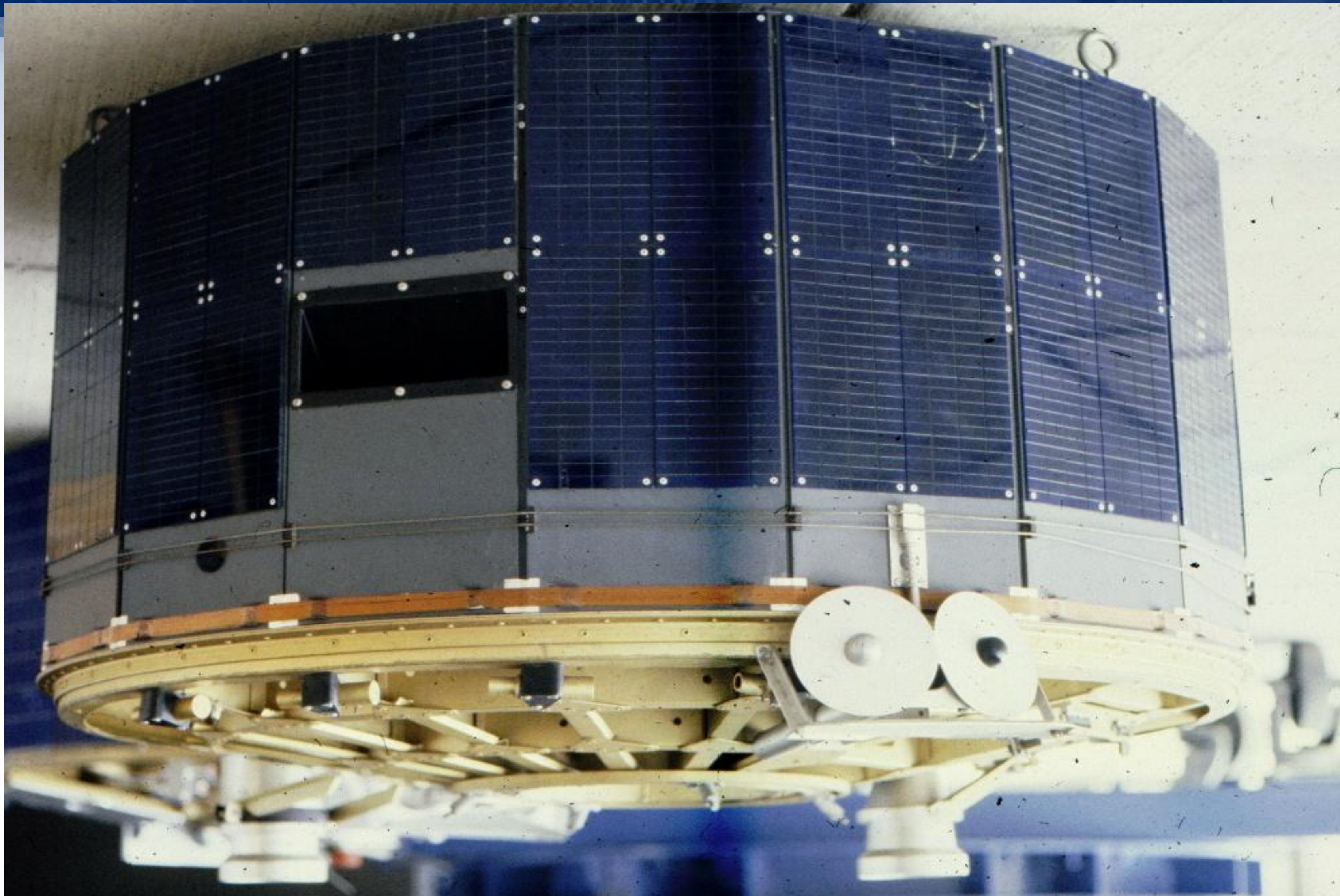
When was the first real weather satellite launched ?

1960: first weather satellite TIROS-1

- TIROS-1, 1 April 1960, first pure weather satellite
- 1964: Nimbus-1, Nimbus weather satellite program begins
- ATS (Applications Technology Satellite), 1966, first geostationary weather satellite
- Afterwards many TIROS, NIMBUS, ESSA, NOAA, GOES, Meteosat etc.

When was the first real weather satellite launched ?

TIROS Satellite Model with Suomi Radiometers



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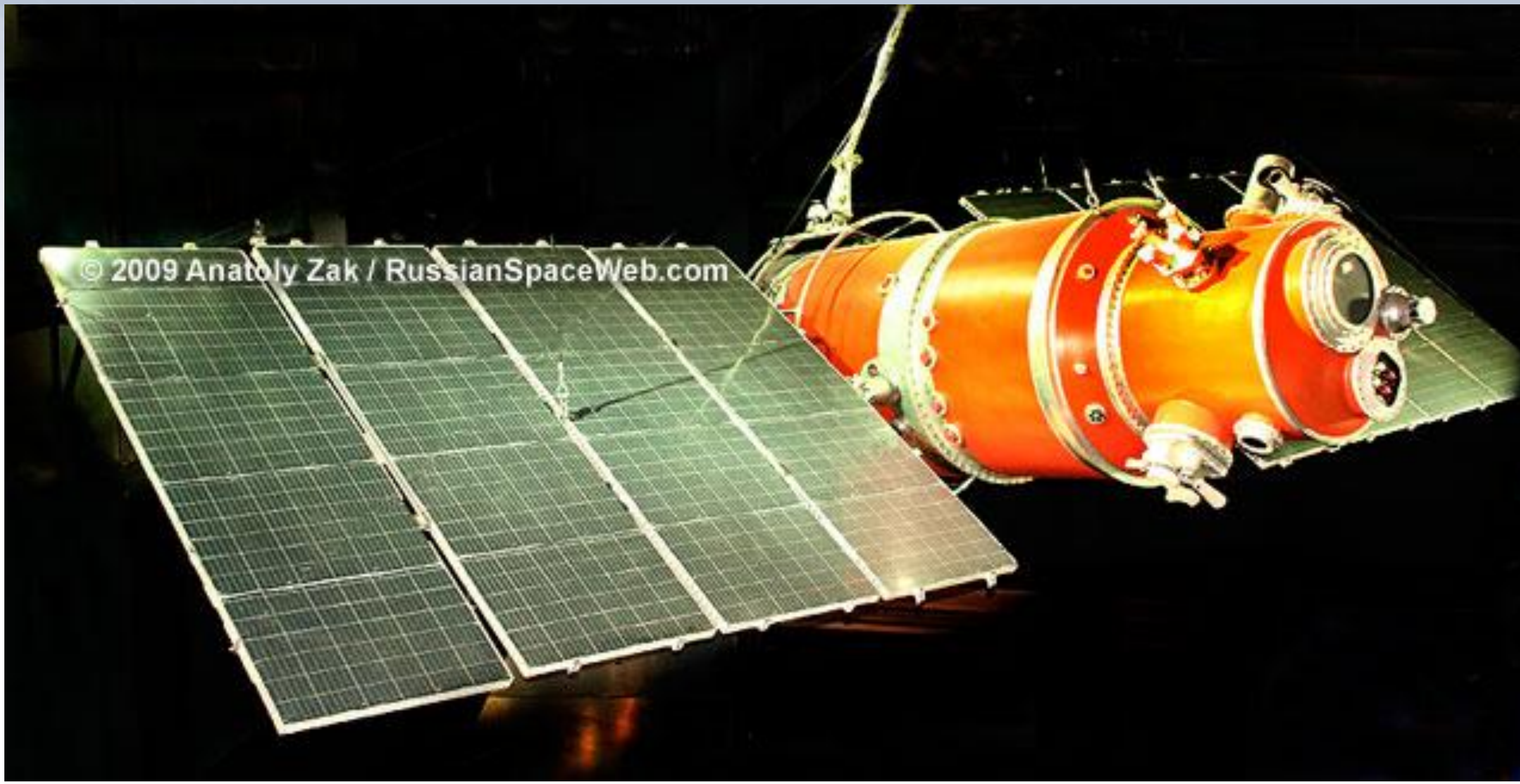
Polar Satellites 1965

First complete view of the world's weather (TIROS-9) Jan 1965
and first satellite in a sun-synchronous orbit !

1969: first Russian weather satellite



The Soviet Meteor series of meteorological satellites were introduced in 1969, preceded by three years of flight testing of experimental satellites

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2009: GOES-14 LAUNCH

Which was the first GEO satellite with a WV channel ?

- **Launched on June 27, 2009 aboard a Delta-IV rocket from Space Launch Complex (SLC) 37B at Cape Canaveral Air Force Station, Florida.**

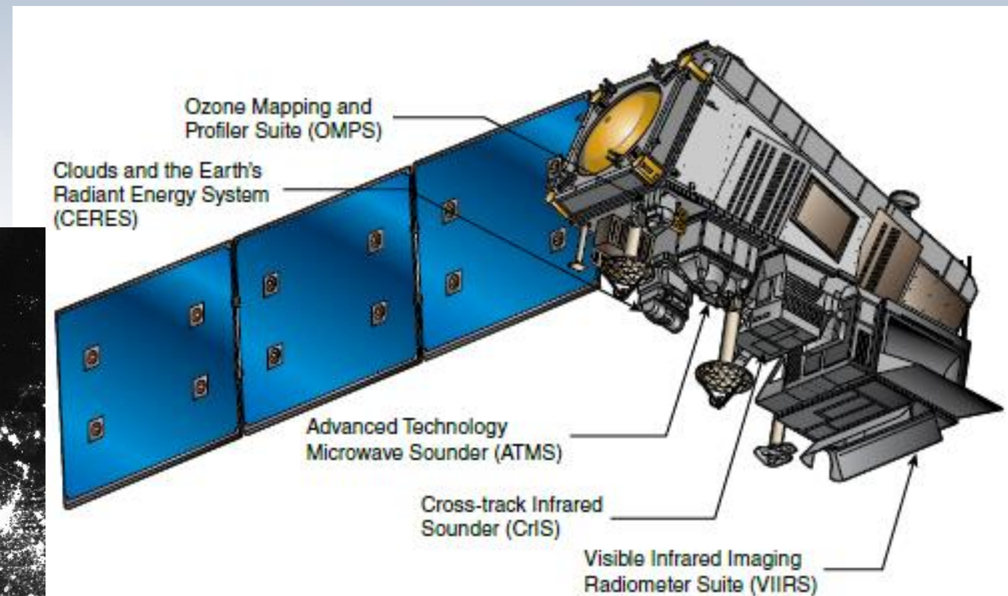
17 U.S. Geostationary weather/environmental satellites launched	
SMS	GOES
1974-75	1975 to Present
2	15

1950 **1970** **1990** **2010** **2030**

ATS 1-3
SMS-1/2
GOES A-H
GOES I-M
GOES NOP
GOES R-U

2011: Suomi NPP Satellite Launch
NPP = National Polar-orbiting Partnership

VIIRS DNB Image (from M. Setvak)



- **new instruments, on a new satellite bus, using a new ground data network**
- **replacement for the NOAA Polar Operational Environmental Satellites**

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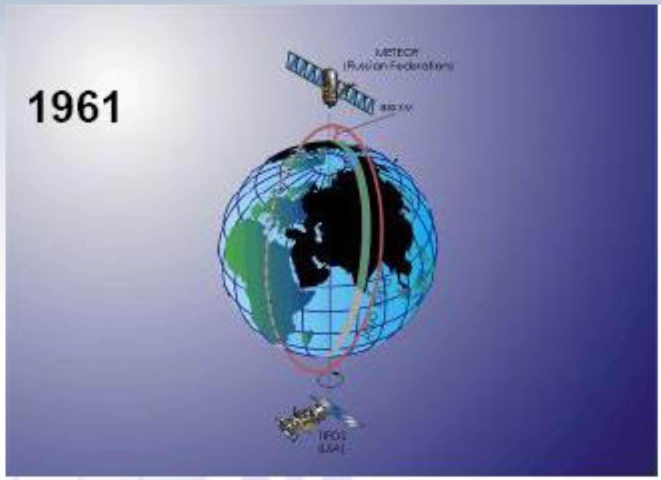
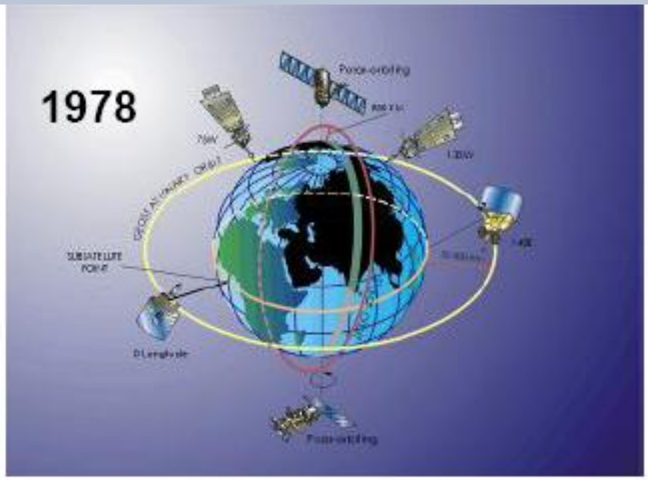
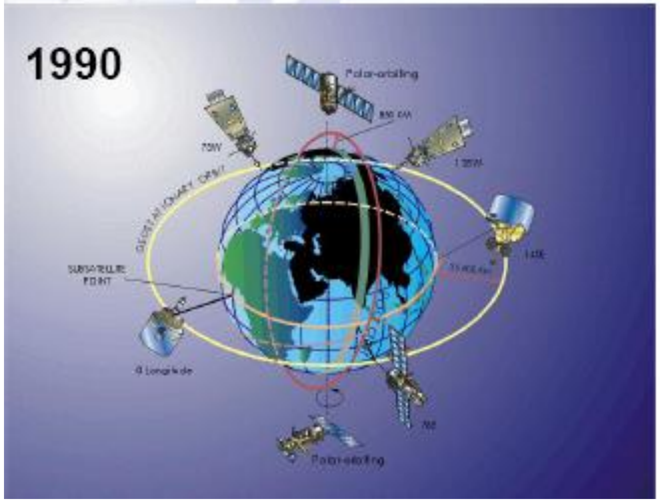
Space-based global observing system: 1961-2009







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History of EUMETSAT (ESA) satellites

Meteosat First Generation (first GEO satellite with WV channel)

Meteosat-1:
Meteosat-2: 1981
Meteosat-3: 1988
Meteosat-4: 1989
Meteosat-5: 1991
Meteosat-6: 1993

Meteosat-7: 1997, operational at 57.5E in support of the Indian Ocean Data Coverage Service

When was Meteosat-1 launched ?

History of EUMETSAT satellites

MSG, Metop and Jason

Meteosat-8 (MSG-1):	2002
Meteosat-9 (MSG-2):	2005
Metop-A (Metop-1):	2006
Jason-2:	2008
Meteosat-10 (MSG-3):	2012
Metop-B (Metop-2):	2012

Sentinel-3:	2014
Jason-3:	2015
Meteosat-11 (MSG-4):	2015

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Which other important (meteorological) satellites do you know ?

ERS-1: 1991, ERS-2: 1995

Terra: 1999, Aqua: 2002

ENVISAT: 2002

...

Satellite orbits & elements

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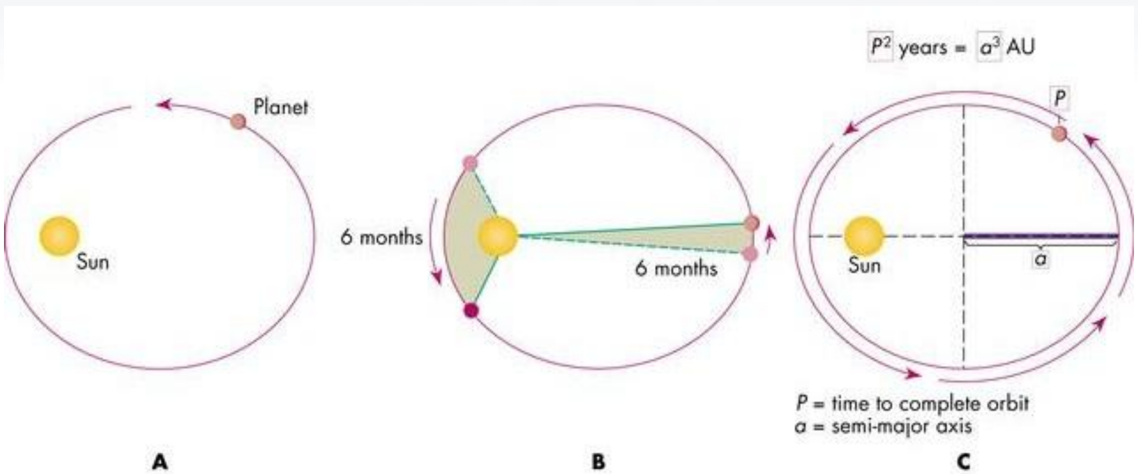
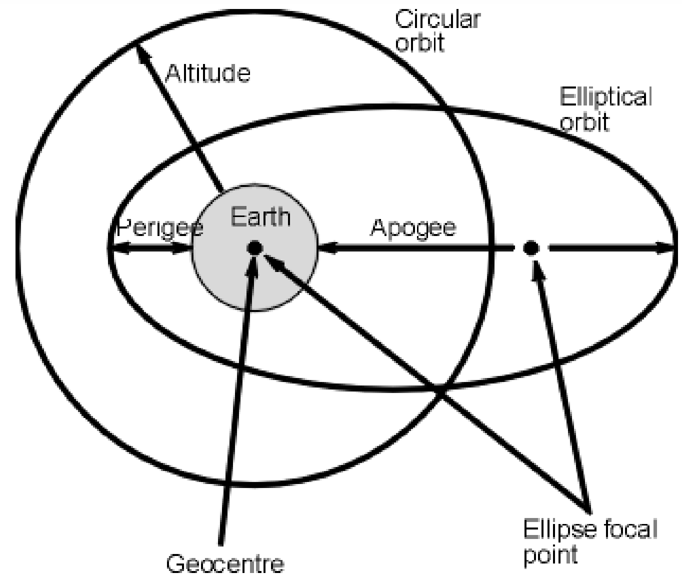
Satellite orbits

Satellite orbits may be classified by their altitude, inclination and eccentricity



Keppler's Laws



Altitude

- High Earth Orbit (>35,786 km)
- **Geosynchronous Orbit : GEO (35,786 km)**
- Medium Earth Orbit (2,000 to 35,786 km)
- **Low Earth Orbit : LEO (< 2,000 km)**

- The higher the satellite the longer the period of its orbit
- For circular orbit: tangential velocity v = sqrt(Gm_E/r), so v depends only on the altitude of the orbit (not on the satellite's mass)

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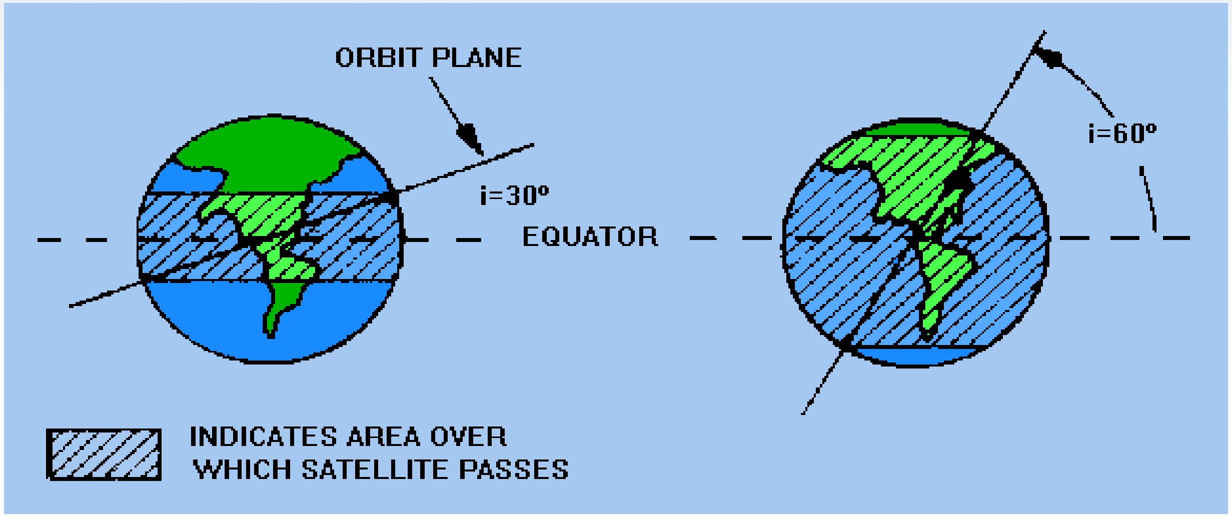
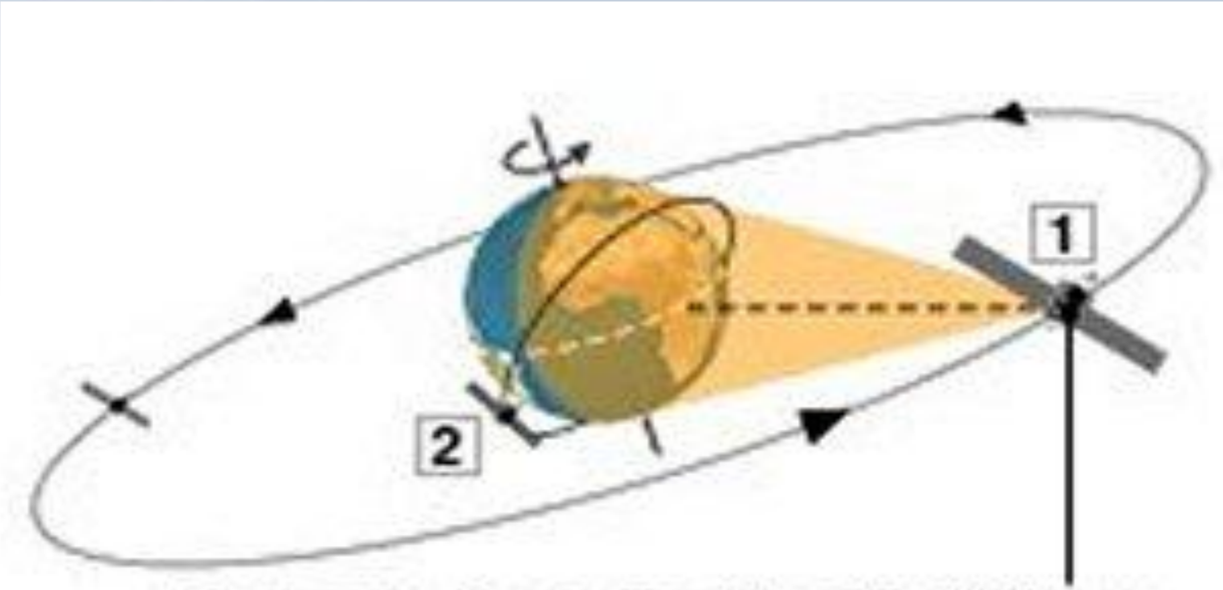
Inclination



- Inclination 0 degrees : On equator
- Inclination 90 degrees: Directly over pole
- Inclination < 90 degrees prograde orbit
- Inclination > 90 degrees retrograde orbit

Image source: http://www.tpub.com/neets/book17/76.htm

Geostationary Orbit : GEO



- Inclination 0 degrees : On equator
- Speed: 1 rotation/24 hrs
- Distance to surface ~ 35,786 km

Image source: http://www.daviddarling.info/images/geostationary_orbit.jpg

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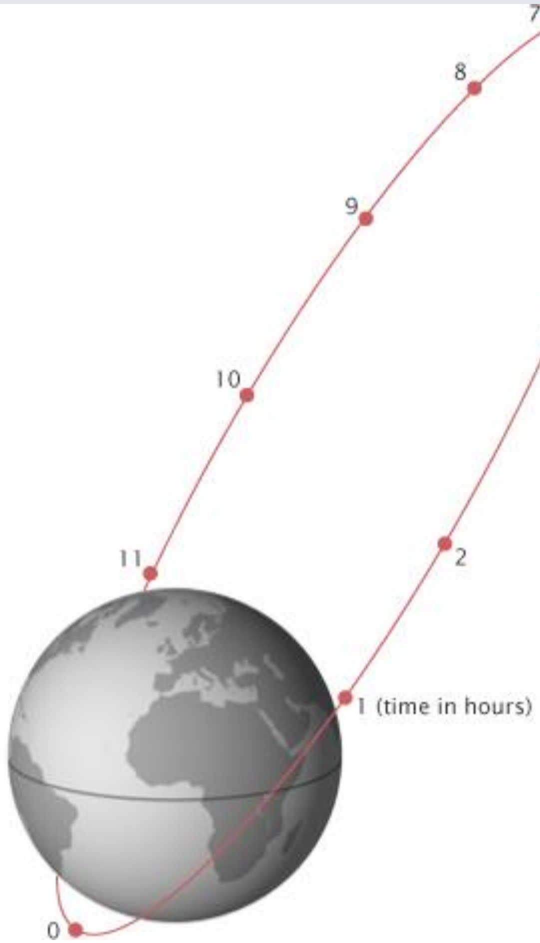
Medium Earth Orbit

Two medium Earth orbits are notable:
the semi-synchronous orbit (GPS satellites) and the Molniya orbit



The Molniya orbit combines high inclination (63.4°) with high eccentricity (0.722) to maximize viewing time over high latitudes

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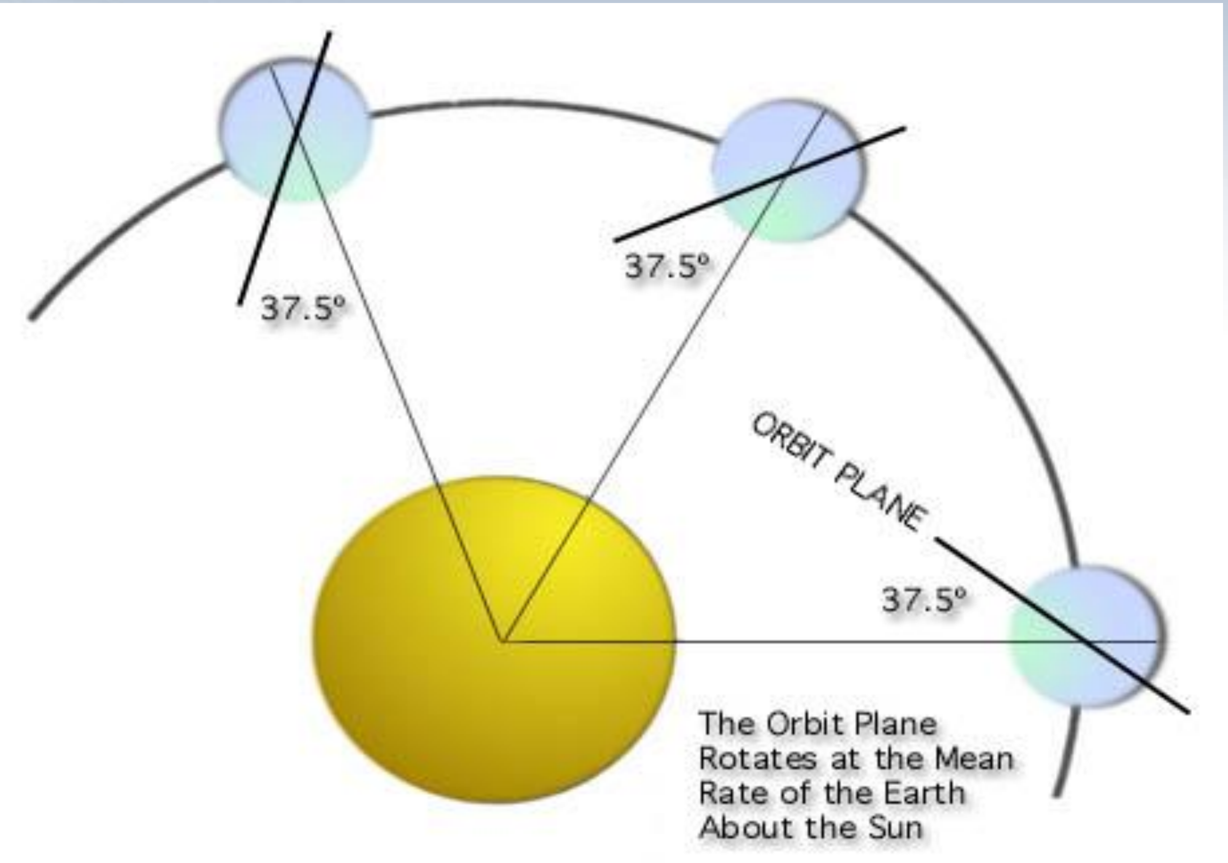
Sun-synchronous Orbit (Low Earth Orbit)

- A Sun-synchronous orbit is a geocentric orbit which combines altitude and inclination in such a way that a satellite on that orbit ascends or descends over any given Earth latitude at the same local mean solar time.
- The surface illumination angle will be nearly the same every time. This consistent lighting is a useful characteristic for satellites that image the Earth's surface in visible or infrared wavelengths.

Sun-synchronous Orbit (Low Earth Orbit)

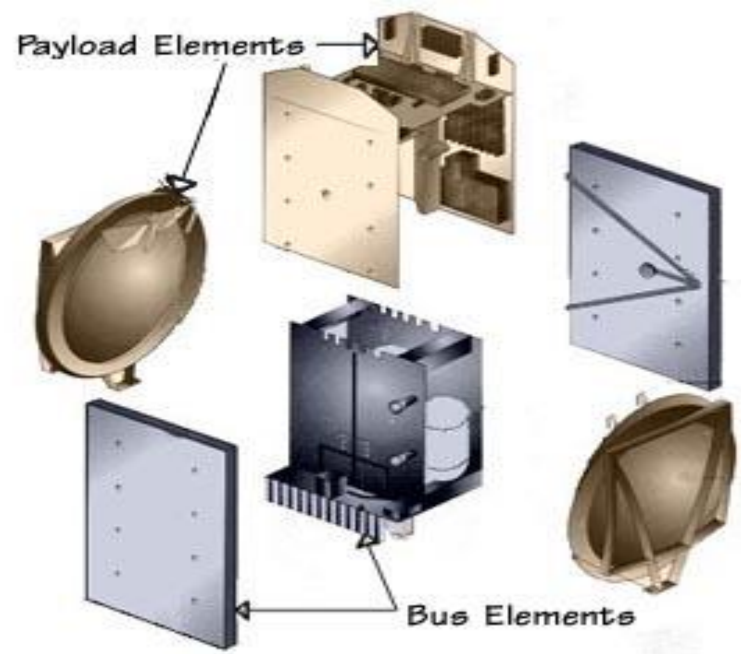


- Inclination slightly retrograde
- Speed: One rotation per 90-100 minutes
- Distance to surface ~ 600-800 km

Image source: http://spaceyuga.com/files/2010/04/orbital_plane.jpg

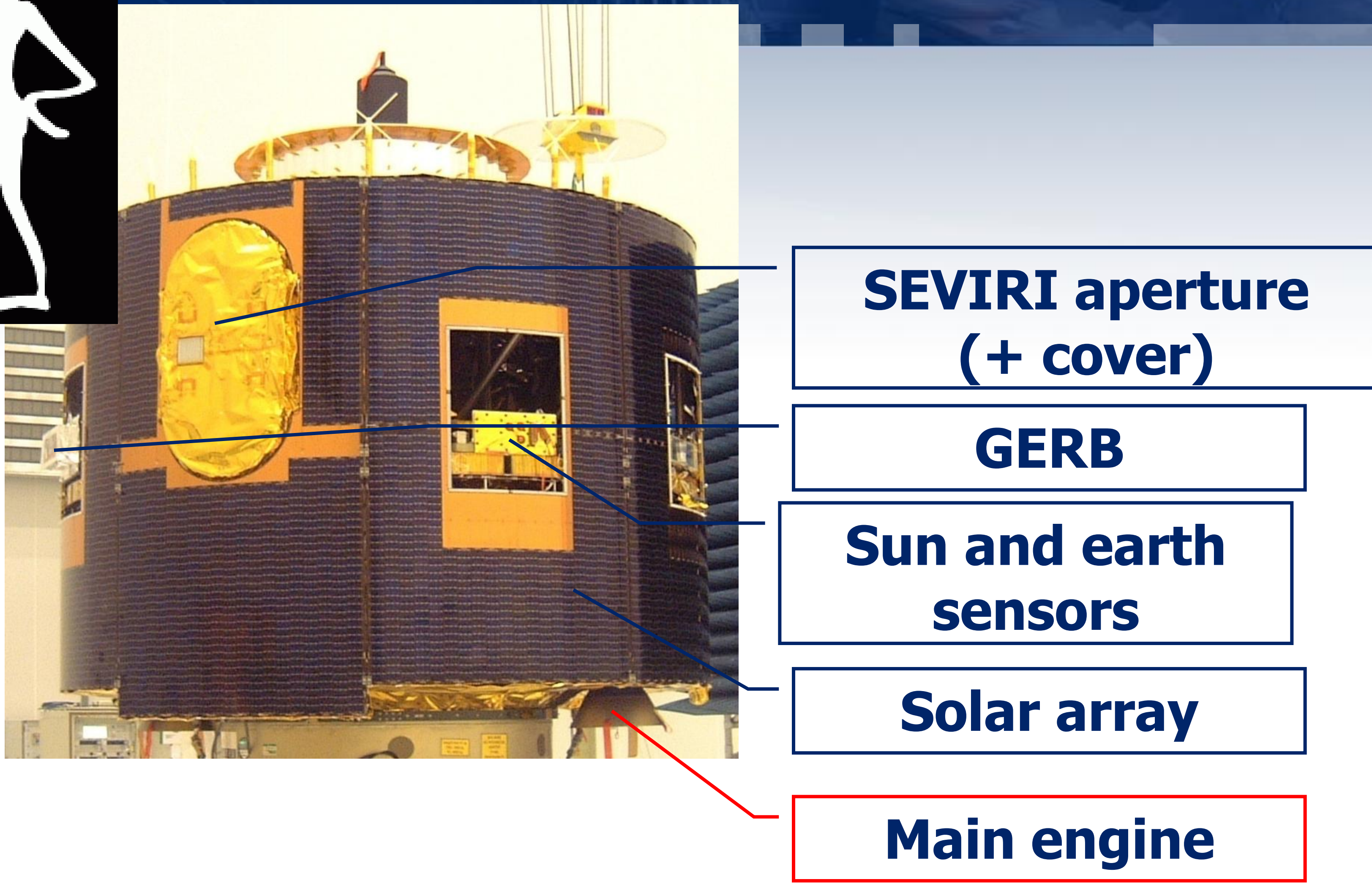
Satellite Elements

The **payload** is all the equipment that a satellite needs to do its job. This can include antennas, cameras, radar, and electronics. The payload is different for every satellite. For example, the payload for a weather satellite includes cameras to take pictures of cloud formations, while the payload for a communications satellite includes large antennas to transmit TV or telephone signals to Earth.



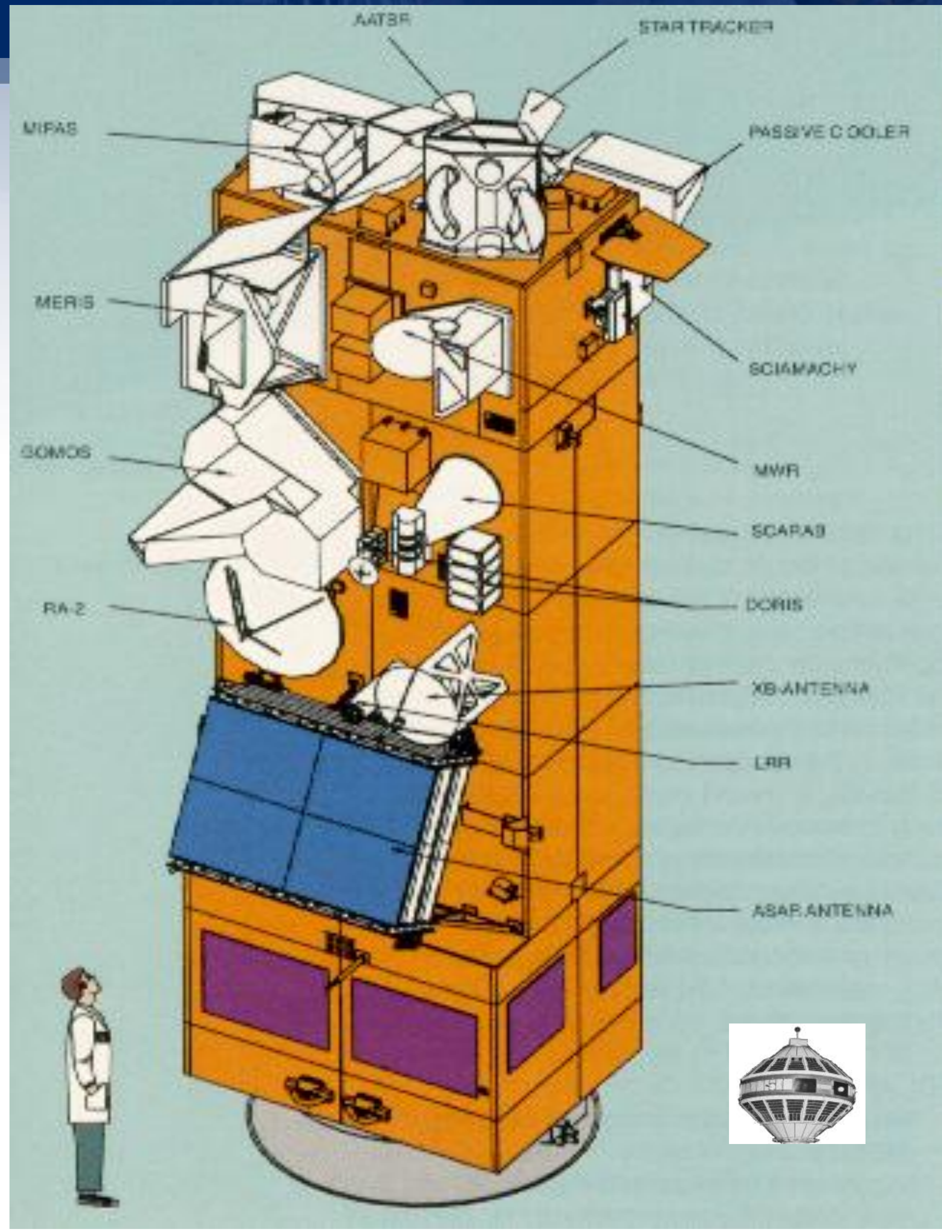
The **bus** is the part of the satellite that carries the payload and all its equipment into space. It holds all the satellite's parts together and provides electrical power,computers, and propulsion to the spacecraft. The bus also contains equipment that allows the satellite to communicate with Earth.

MSG Elements



Where is the antenna to transmit the instrument data ?

Explorer VII vs ESA's ENVISAT



EUMETSAT's current satellites

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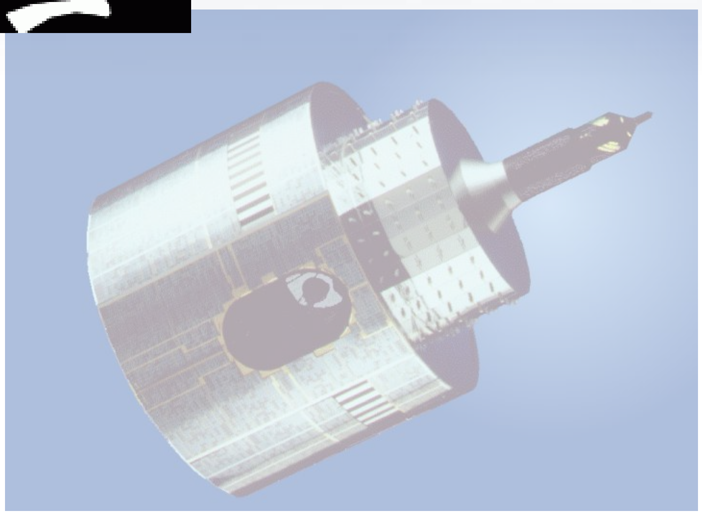
Geostationary satellites

Meteosat First Generation (MFG) (Meteosat-7)



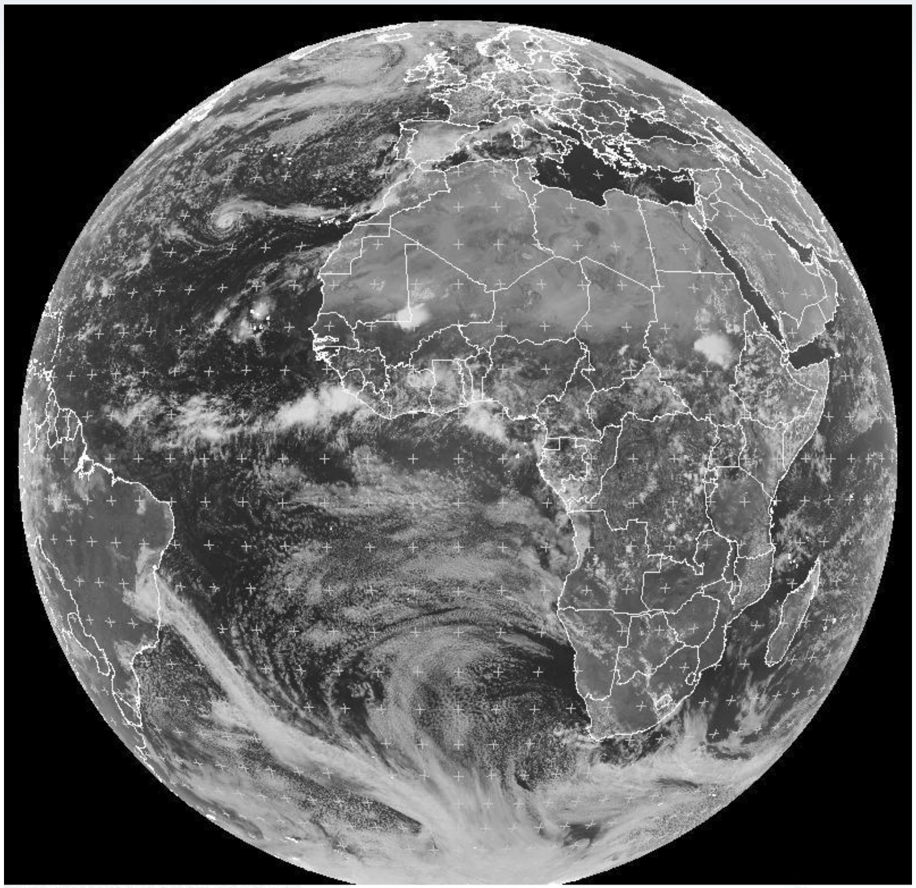
- Positioned over the Indian Ocean (57.5°E)
- 3 Spectral Channels (VIS, WV, IR)
- Images every 30 Minutes
- Lifetime 1997-2016

Which is the sampling (resolution) of the MFG channels ?

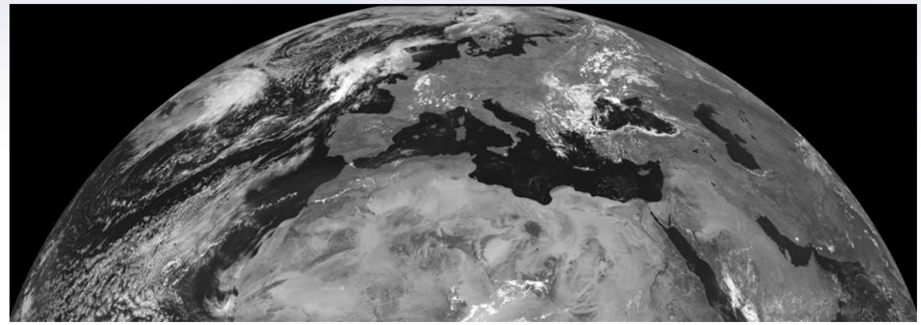
Geostationary satellites

Meteosat Second Generation (MSG) (Meteosat-8, Meteosat-9, Meteosat-10)

- 12 spectral bands, 3 km horizontal sampling, HRV channel 1 km



MET9 VIS006 2012-09-27 12:00 UTC EUMETSAT



- Meteosat-9
- Positioned over 9.5°E
- Images every 5 minutes (Rapid Scan Service)

- Meteosat-8
- Positioned over 3.5°E
- Backup satellite

- Meteosat-10
- Positioned over 0°E
- Images every 15 minutes

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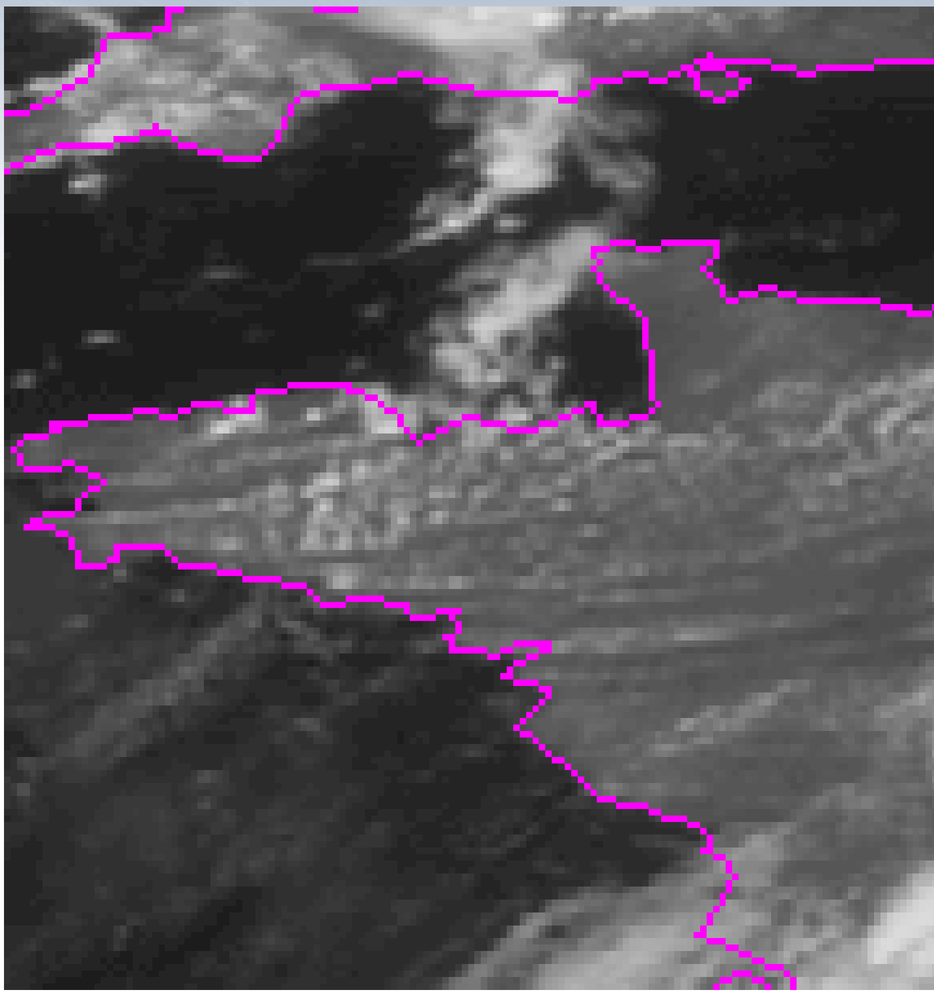
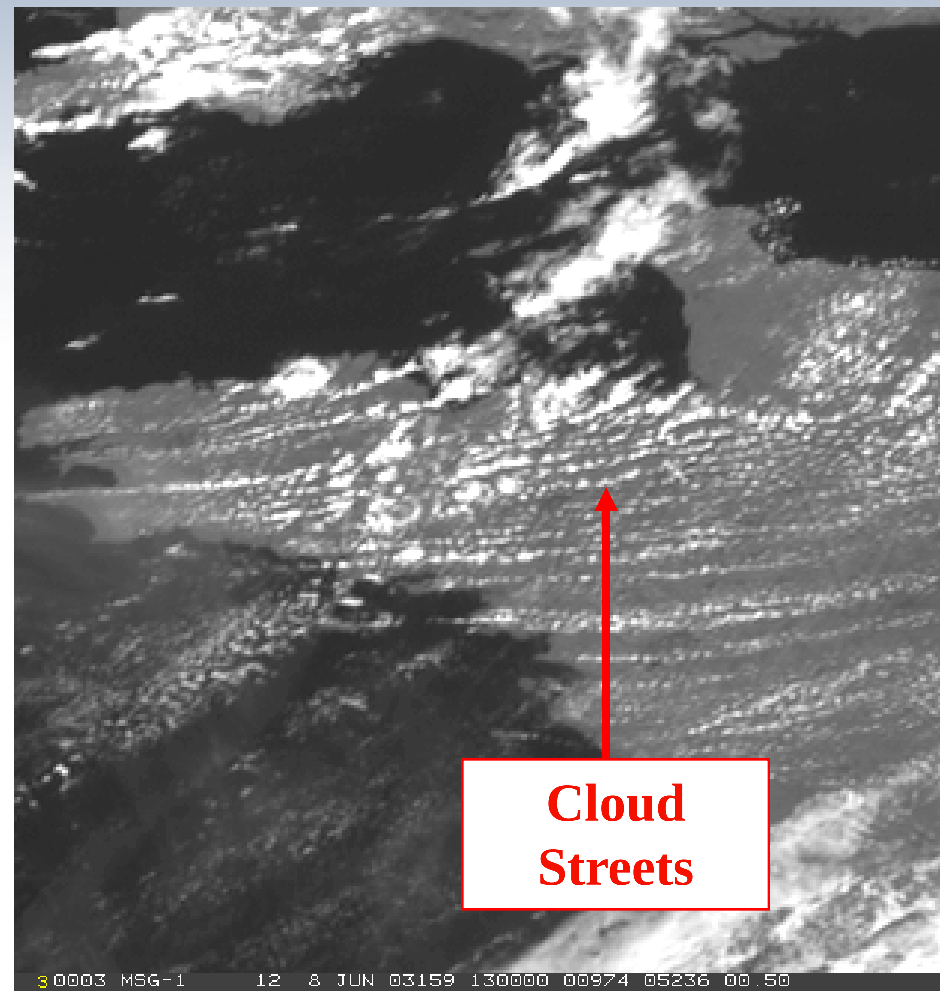
MSG Improvements: HRV (1 km sampling)



MFG VIS Channel



MSG Channel 12 (HRV)

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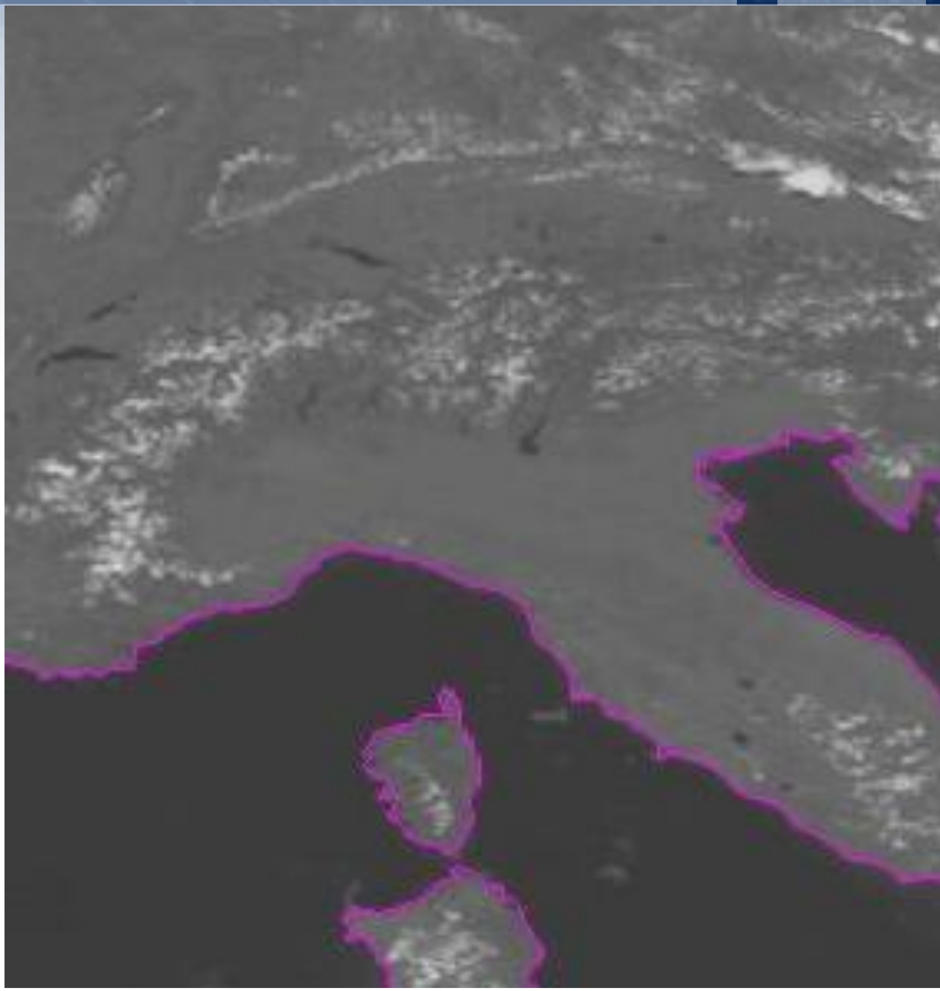
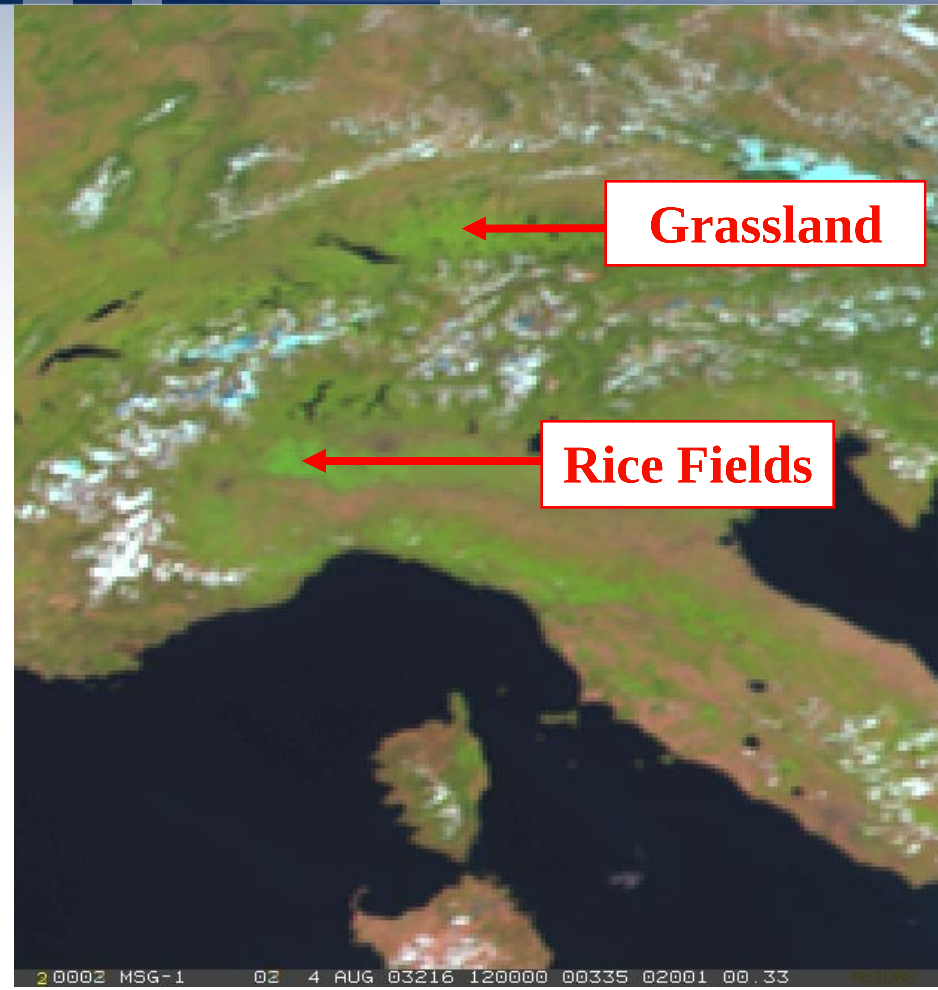
MSG Improvements: Vegetation



MFG VIS Channel



MSG Natural Colours RGB

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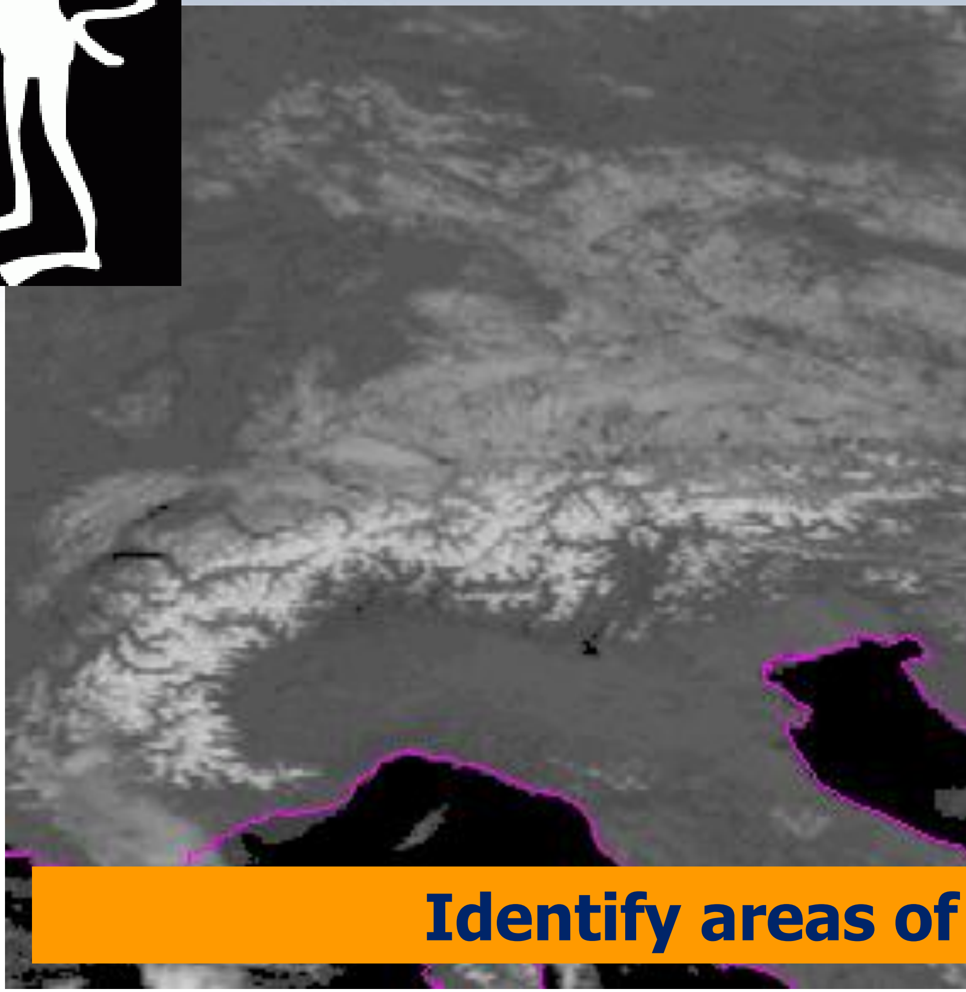
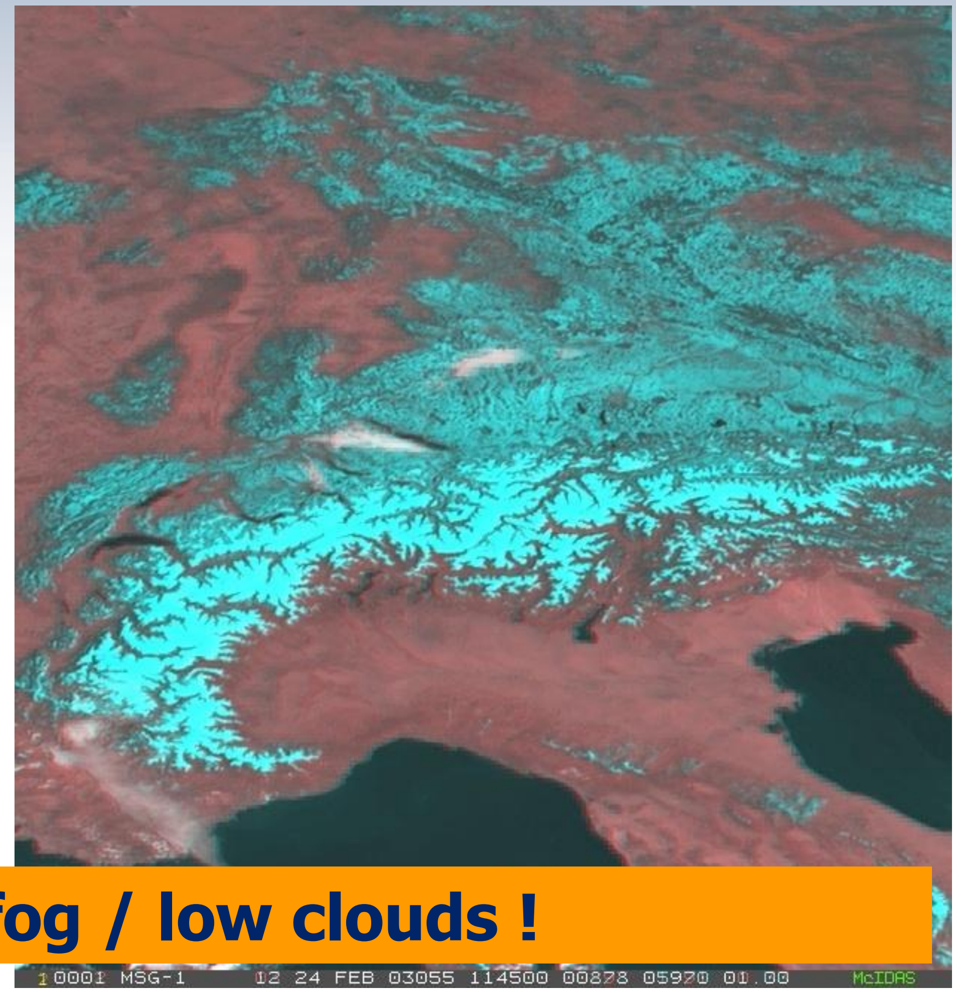
MSG Improvements: Snow





Identify areas of fog / low clouds !

MFG VIS Channel

MSG RGB NIR1.6, HRV, HRV

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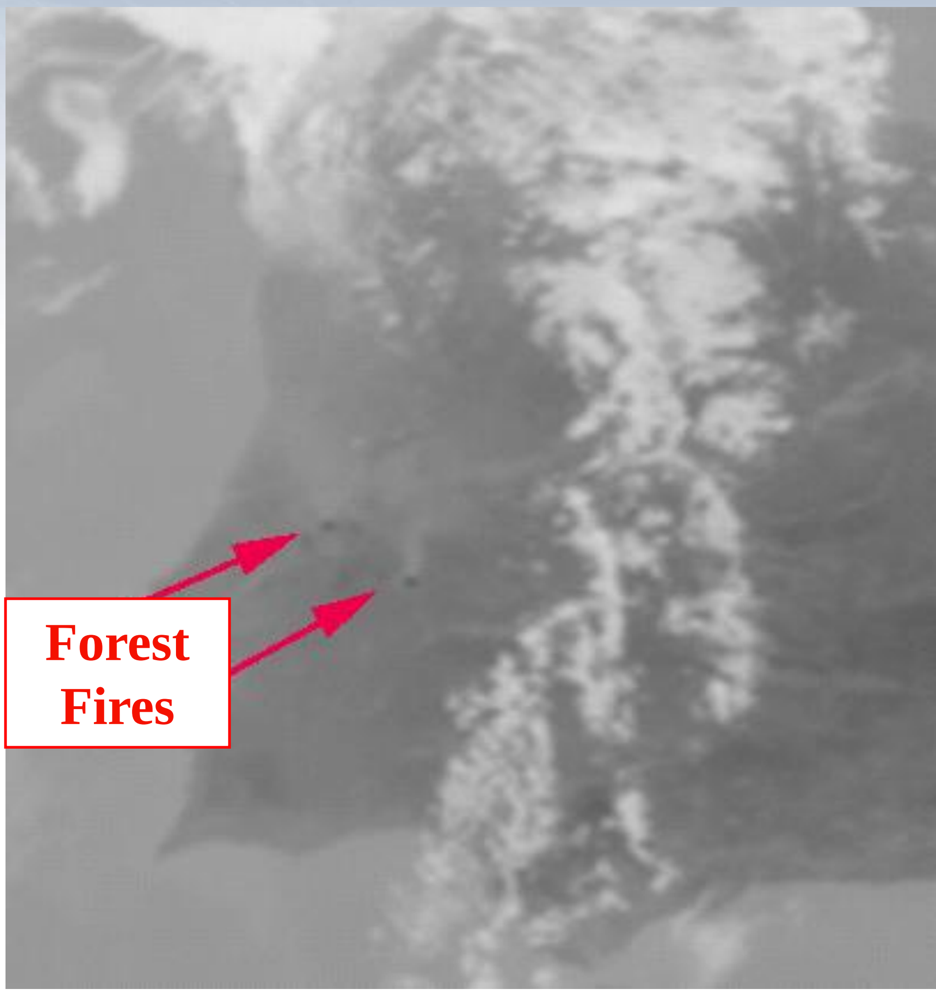
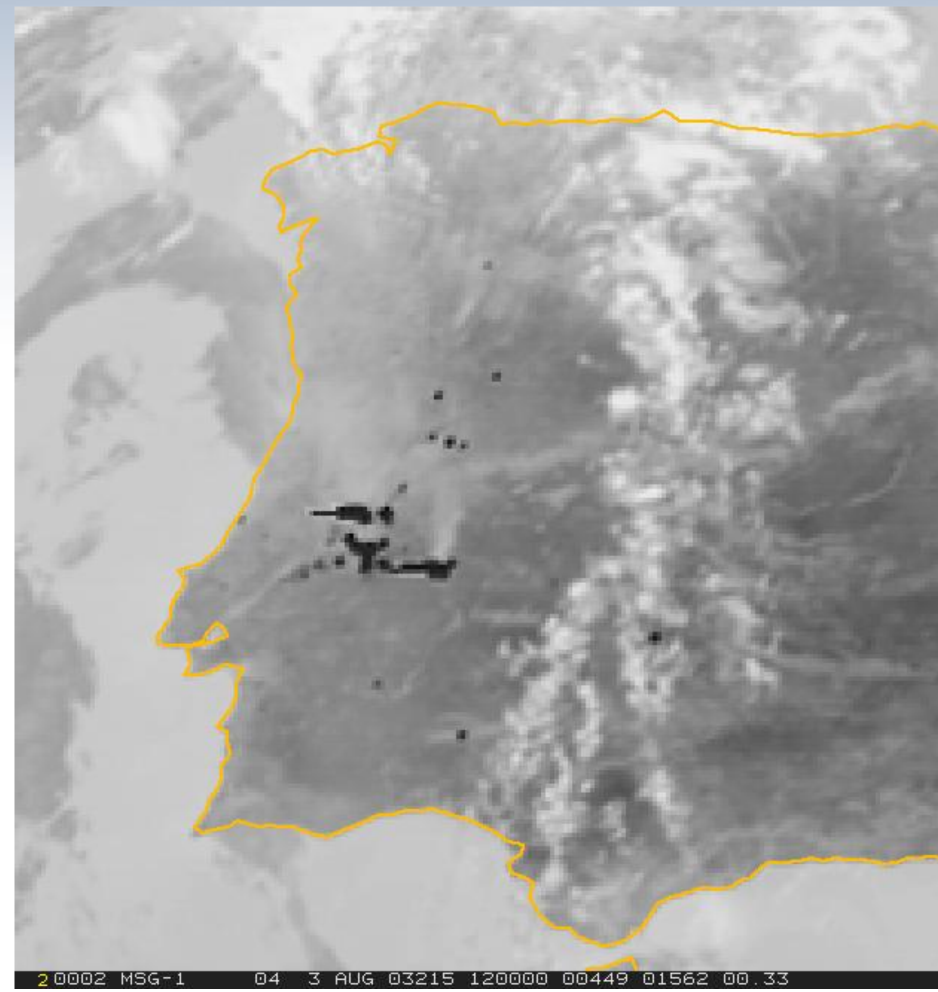
MSG Improvements: Fires



MFG IR Channel



MSG Channel IR3.9

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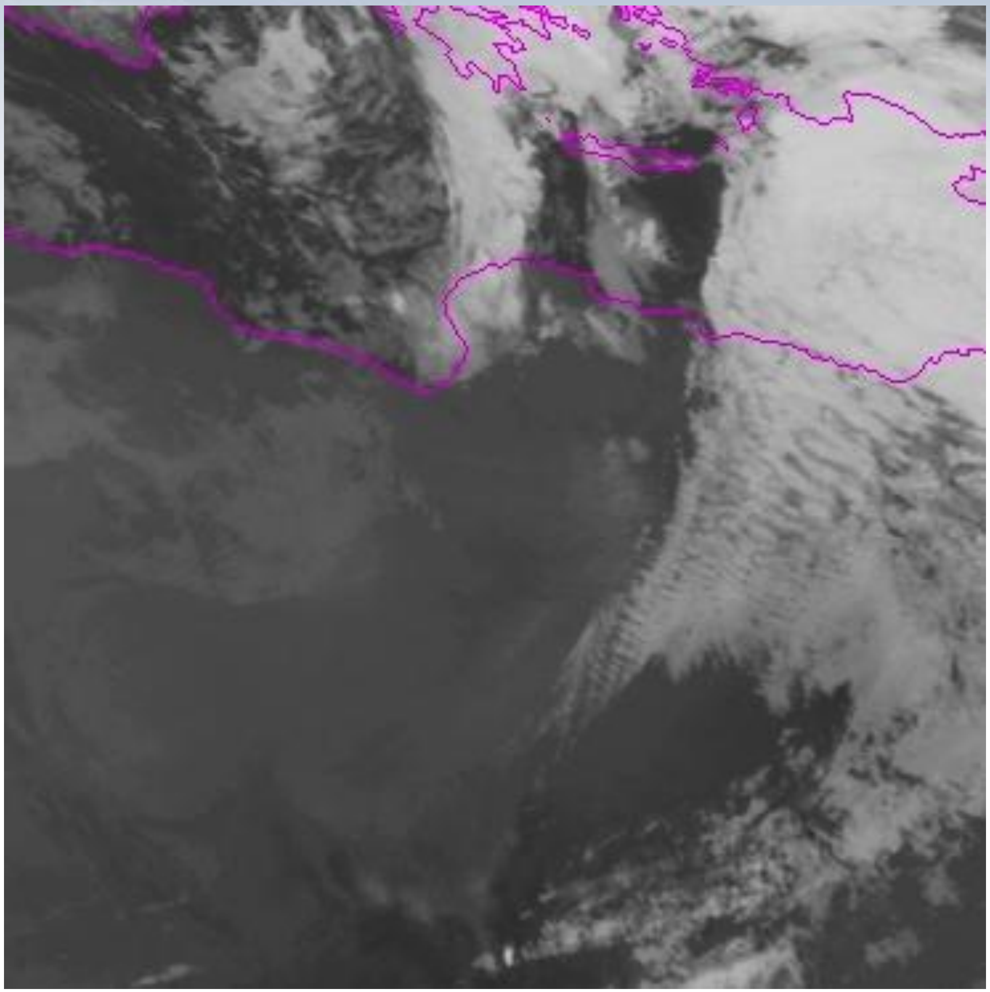
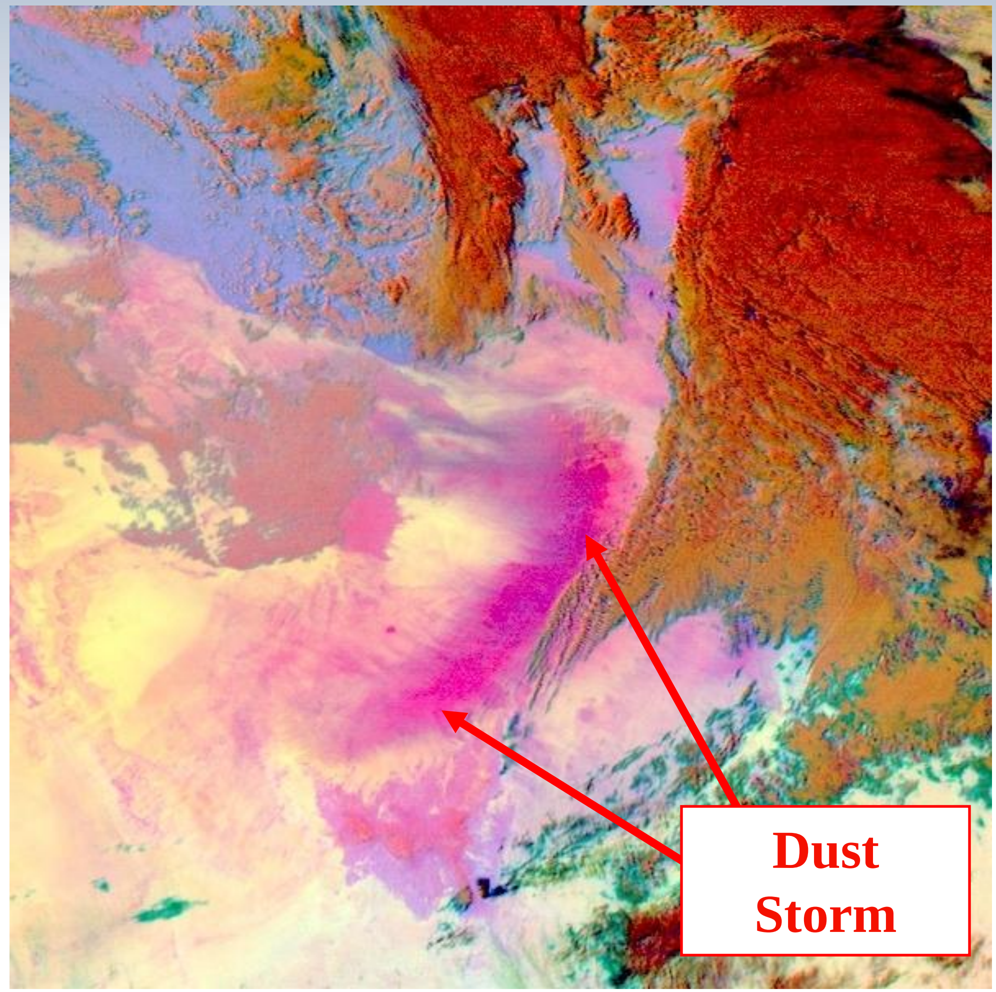
MSG Improvements: Aerosols (Dust, Ash, Smoke)



MFG IR Channel



MSG Dust RGB

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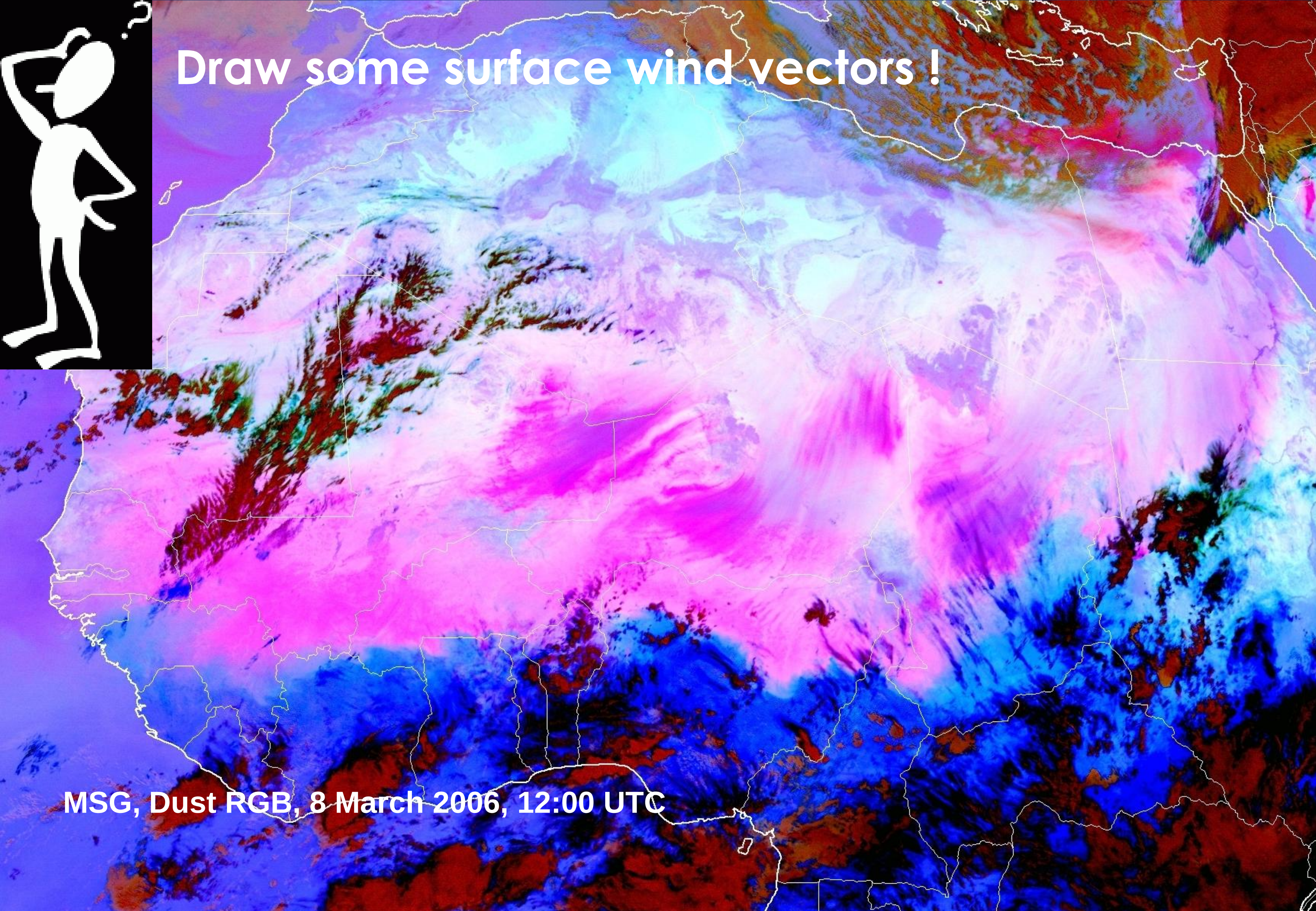
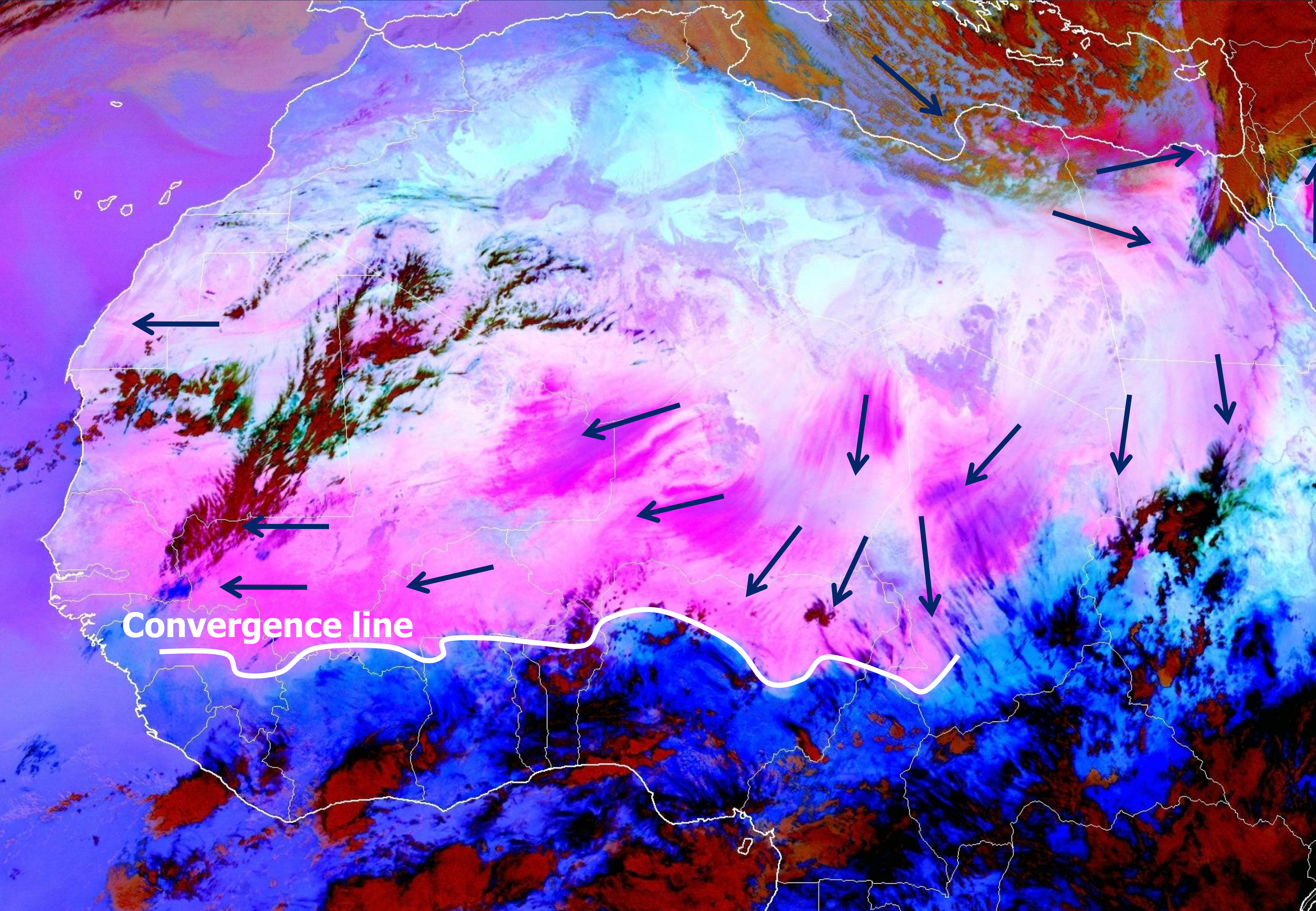
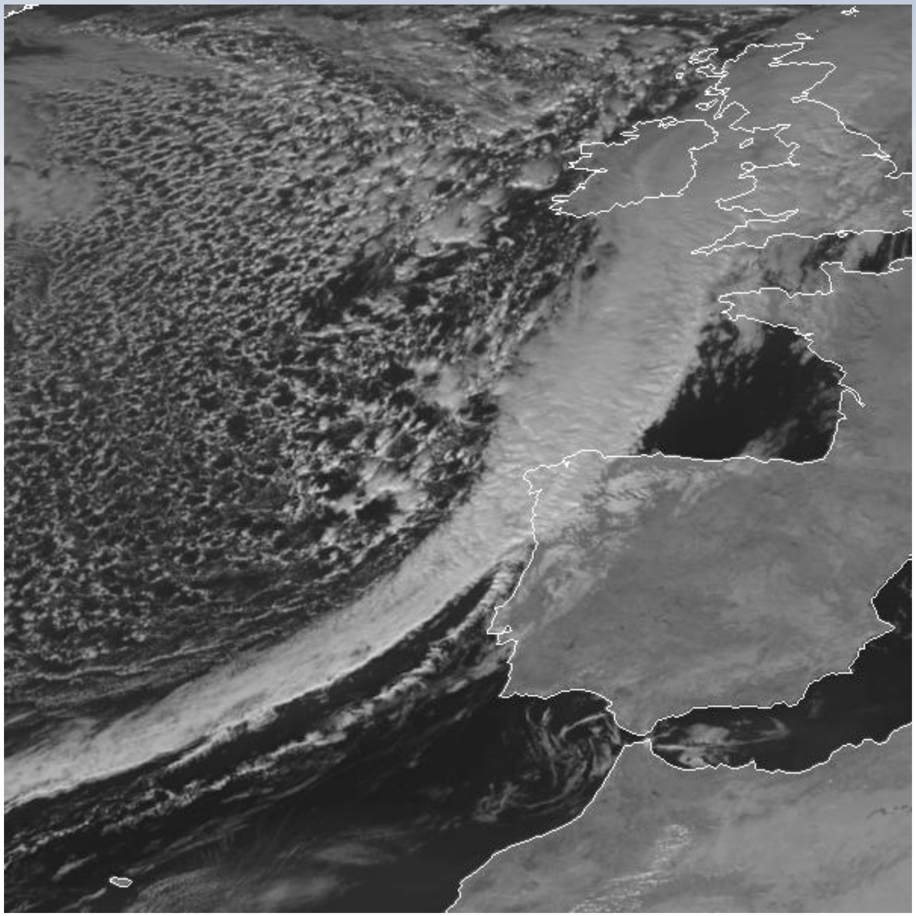
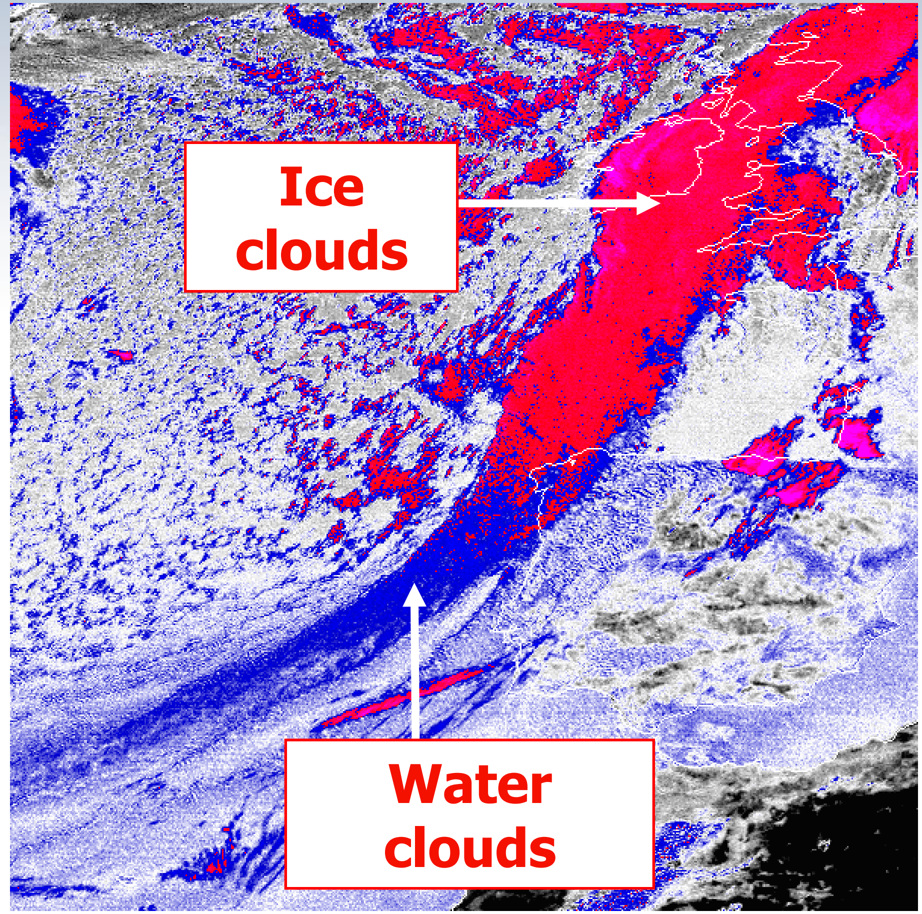

Draw some surface wind vectors !
MSG, Dust RGB, 8 March 2006, 12:00 UTC


Convergence line

MSG Improvements: Cloud Phase



MSG VIS0.8 Channel



MSG BTD IR8.7 – IR10.8

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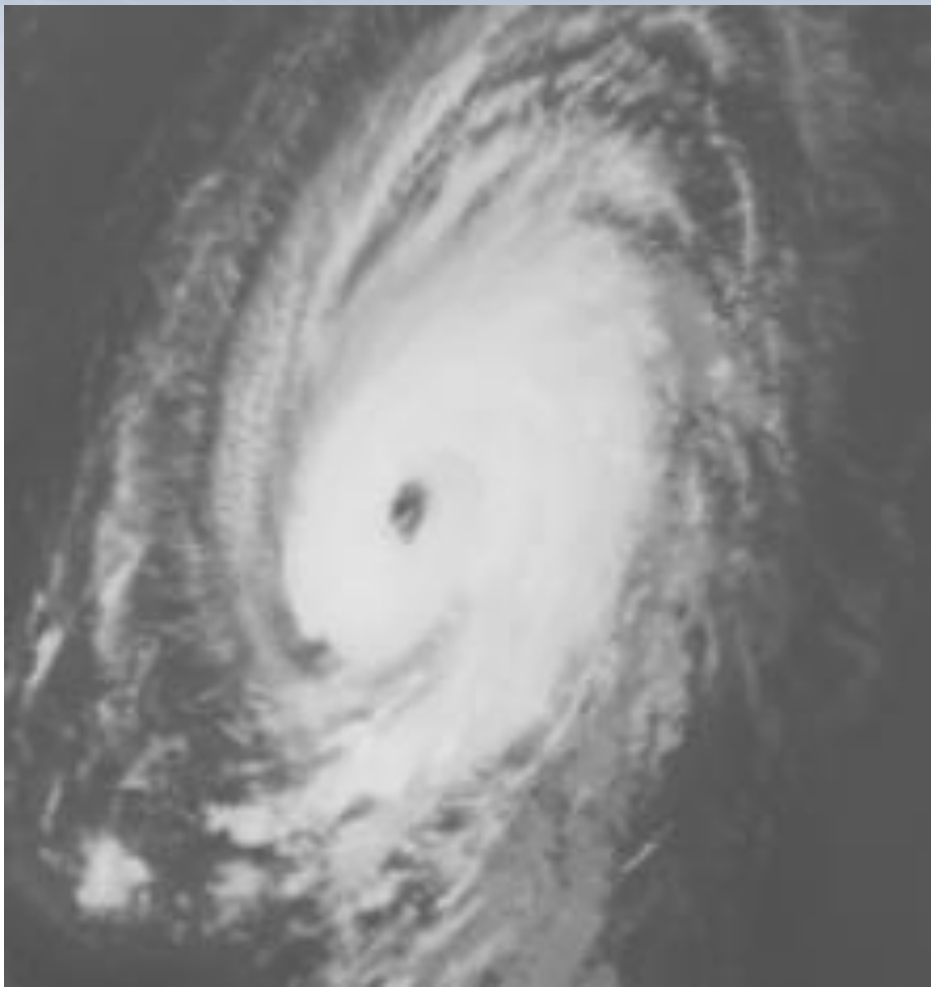
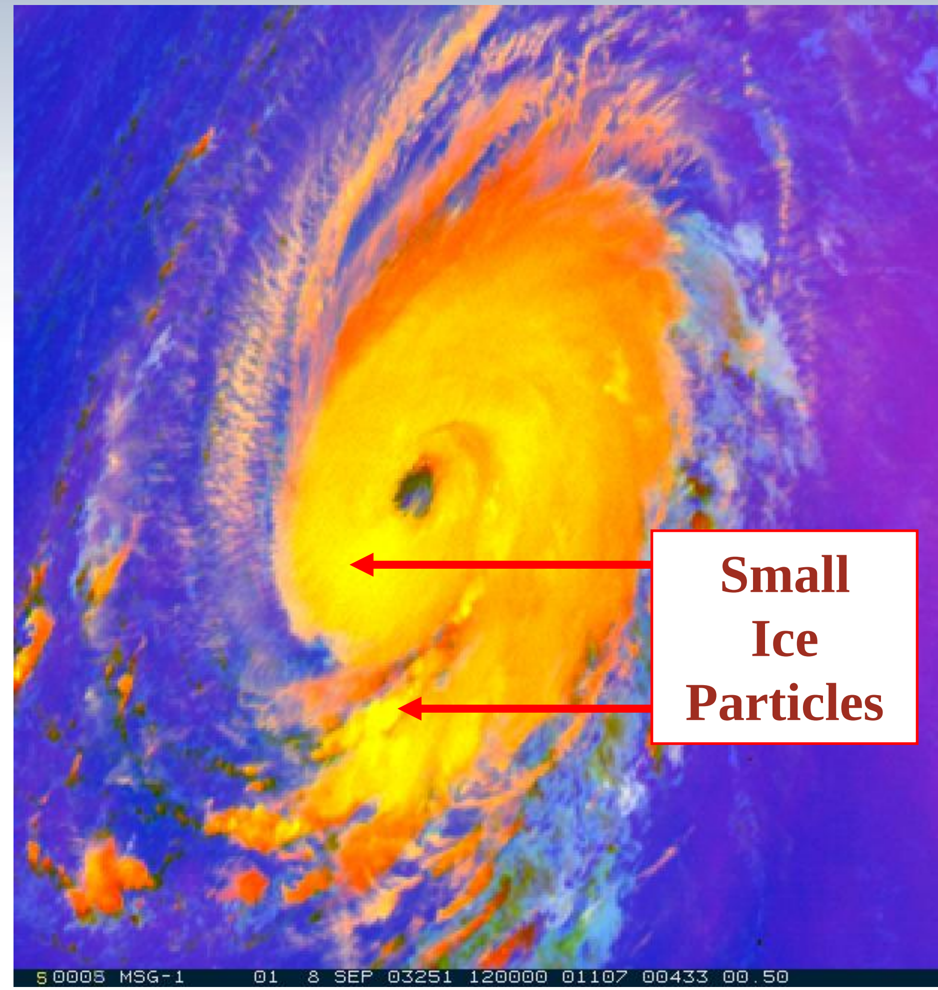
MSG Improvements: Cloud Particle Size



MFG IR Channel



MSG Convection RGB

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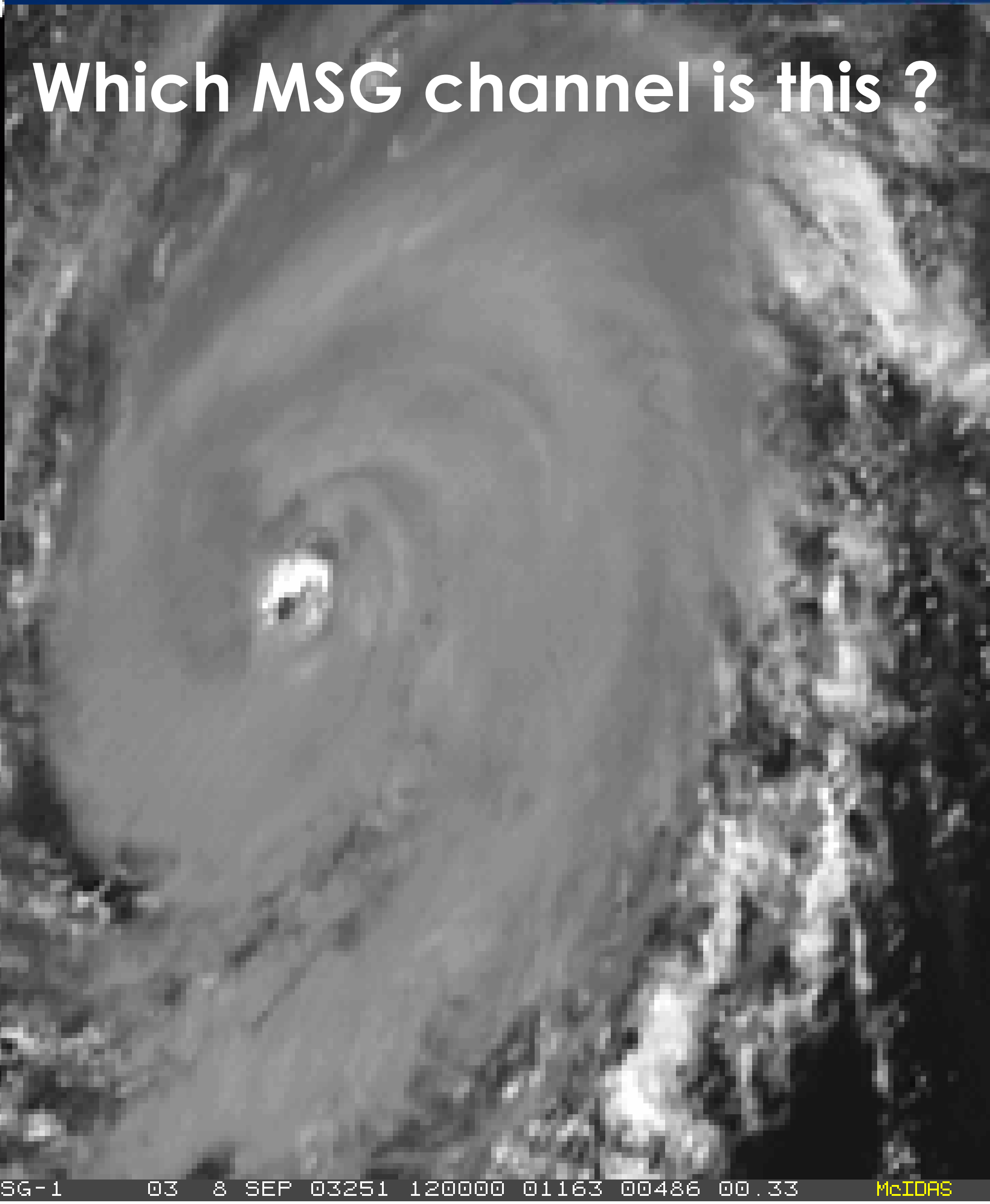
Which MSG channel is this ?



- VIS0.6 ☐
- NIR0.8 ☐
- NIR1.6 ☐
- IR10.8 ☐

MSG
8 September 2003
12:00 UTC

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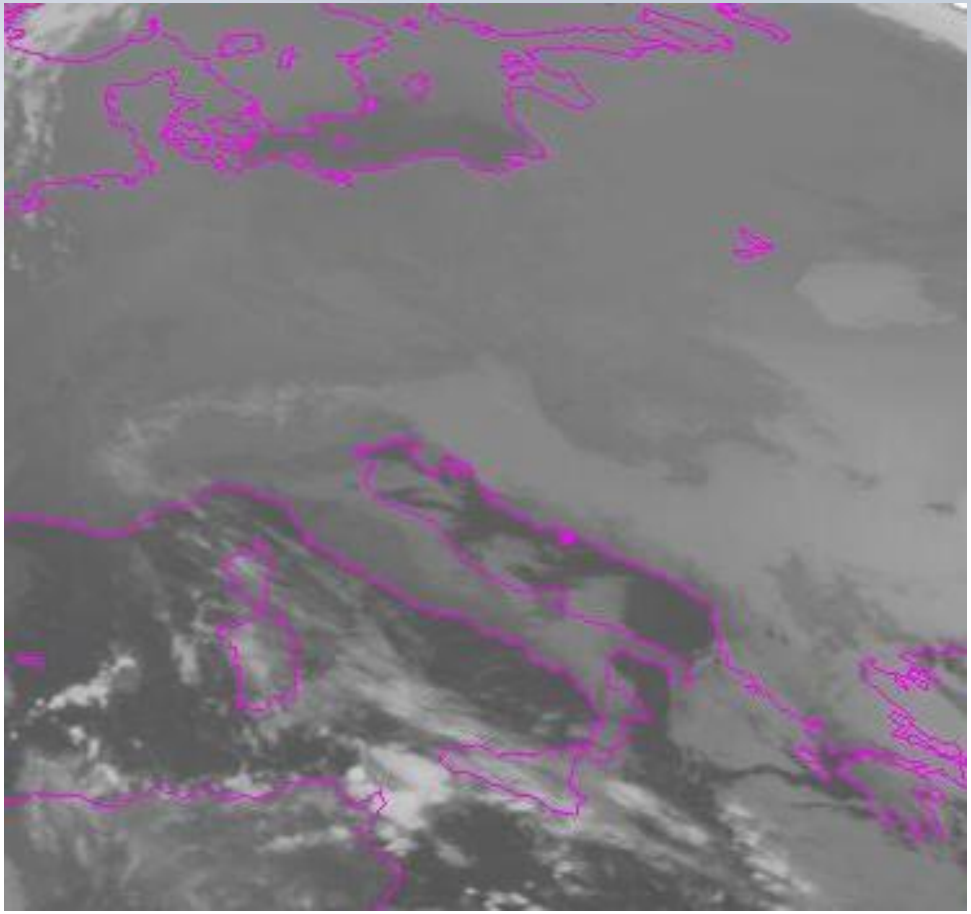
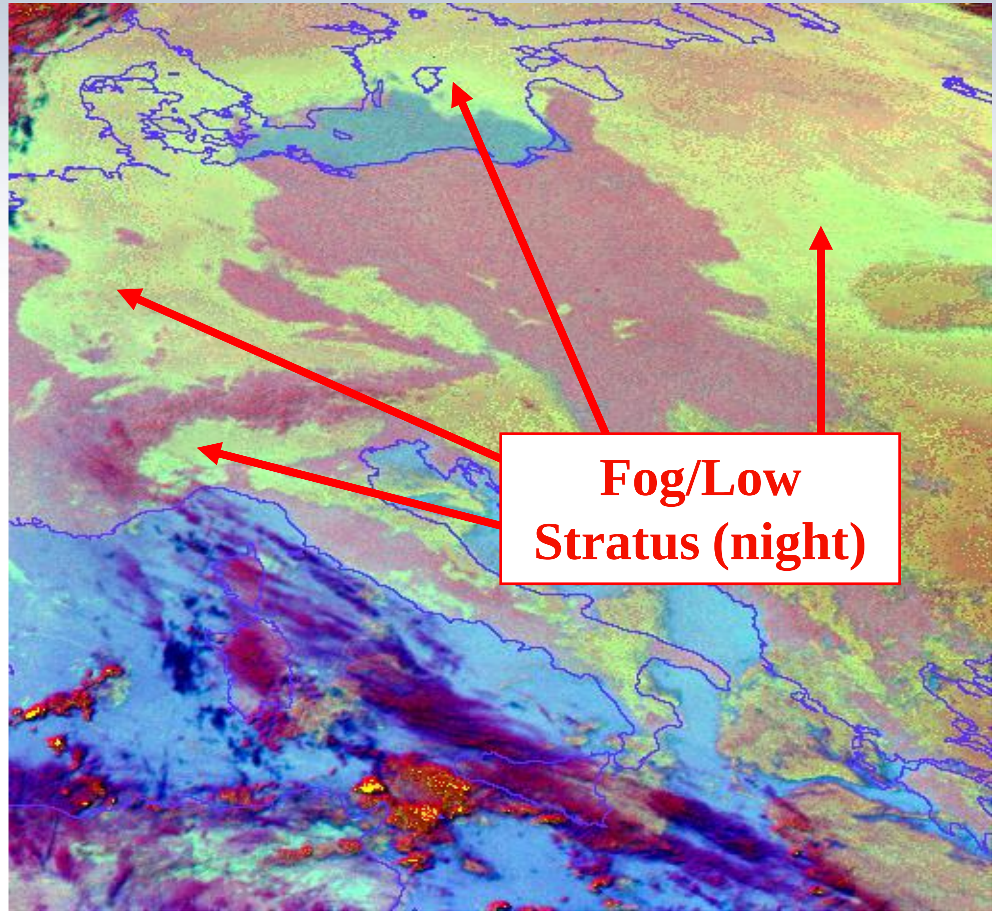
MSG Improvements: Clouds at Night



MFG IR Channel



MSG Night Micro RGB

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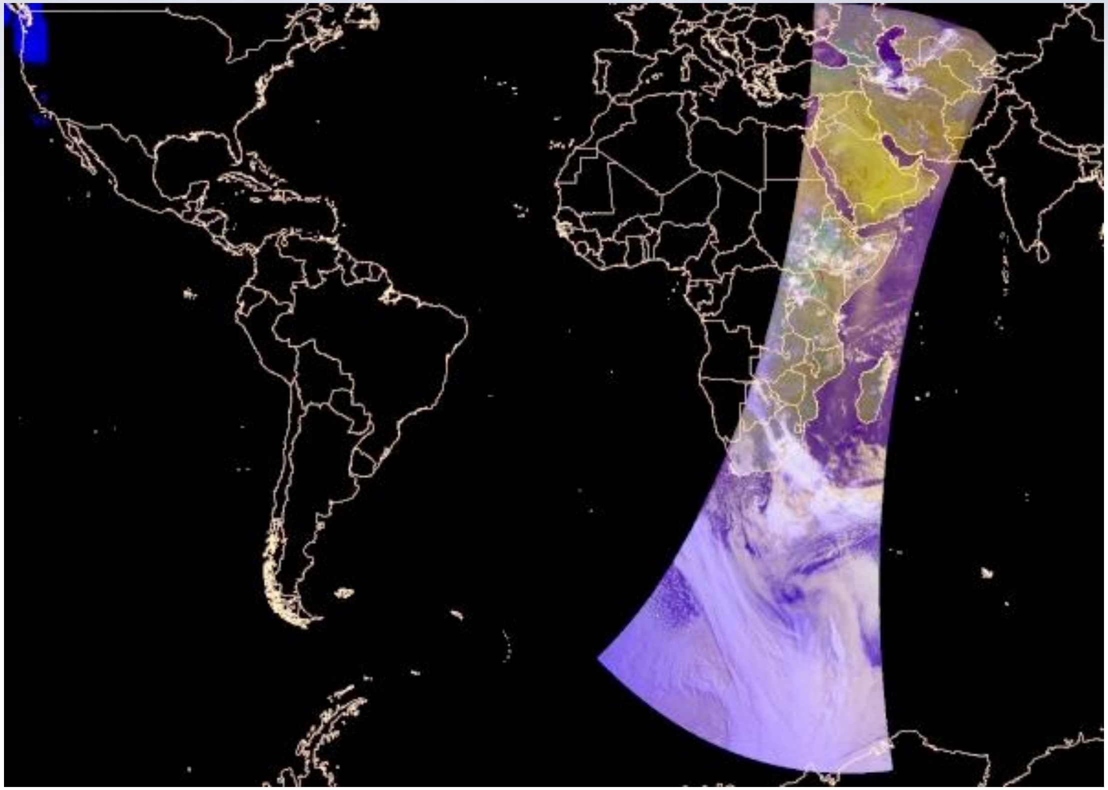
Polar-orbiting satellites

EUMETSAT Polar System (EPS)



Metop-A (in operation since 2007)
Metop-B (in operation since 2013)

- carry imaging and sounding instruments
- direct broadcasting and data collection capabilities

Partners: NOAA

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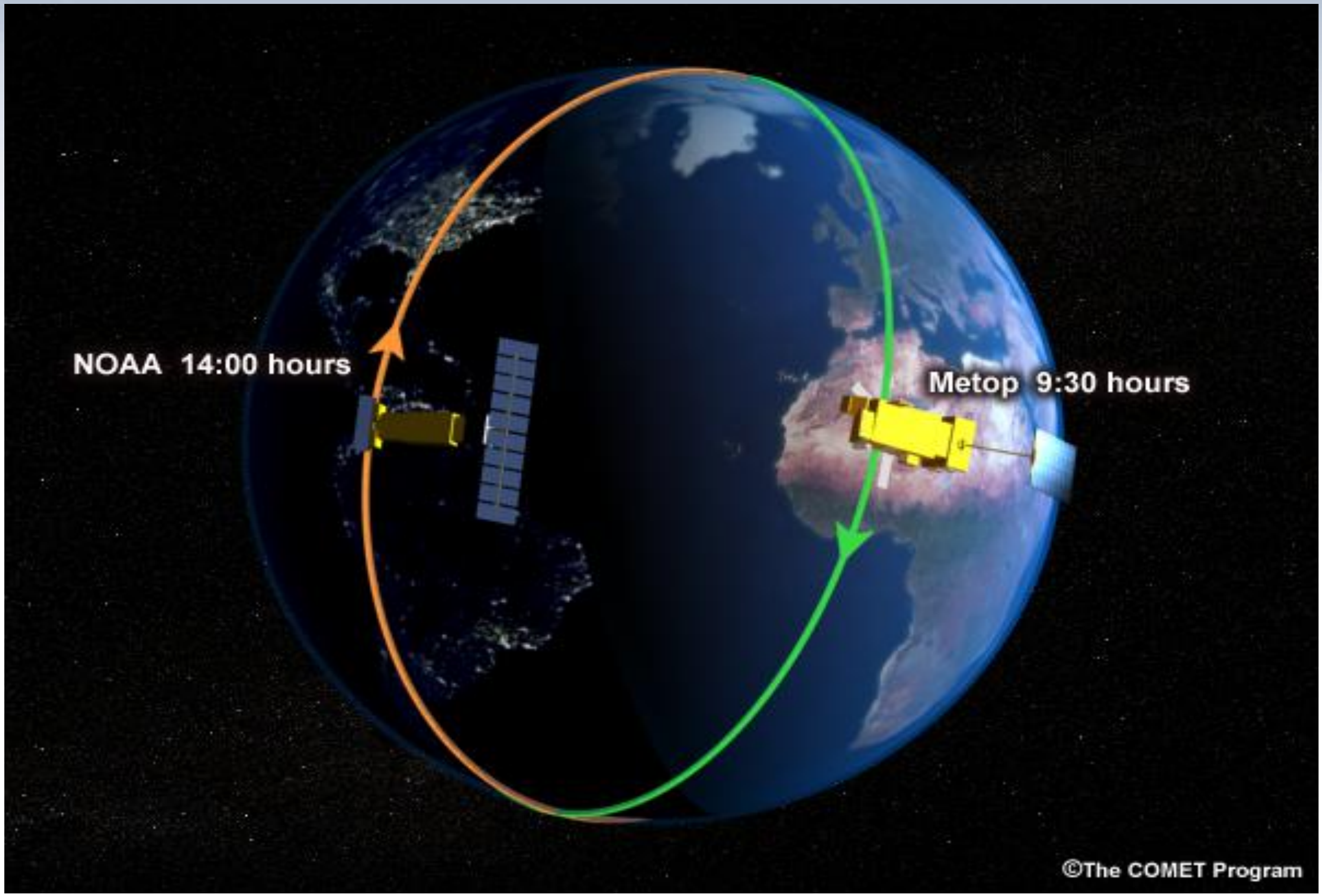
Metop Orbit



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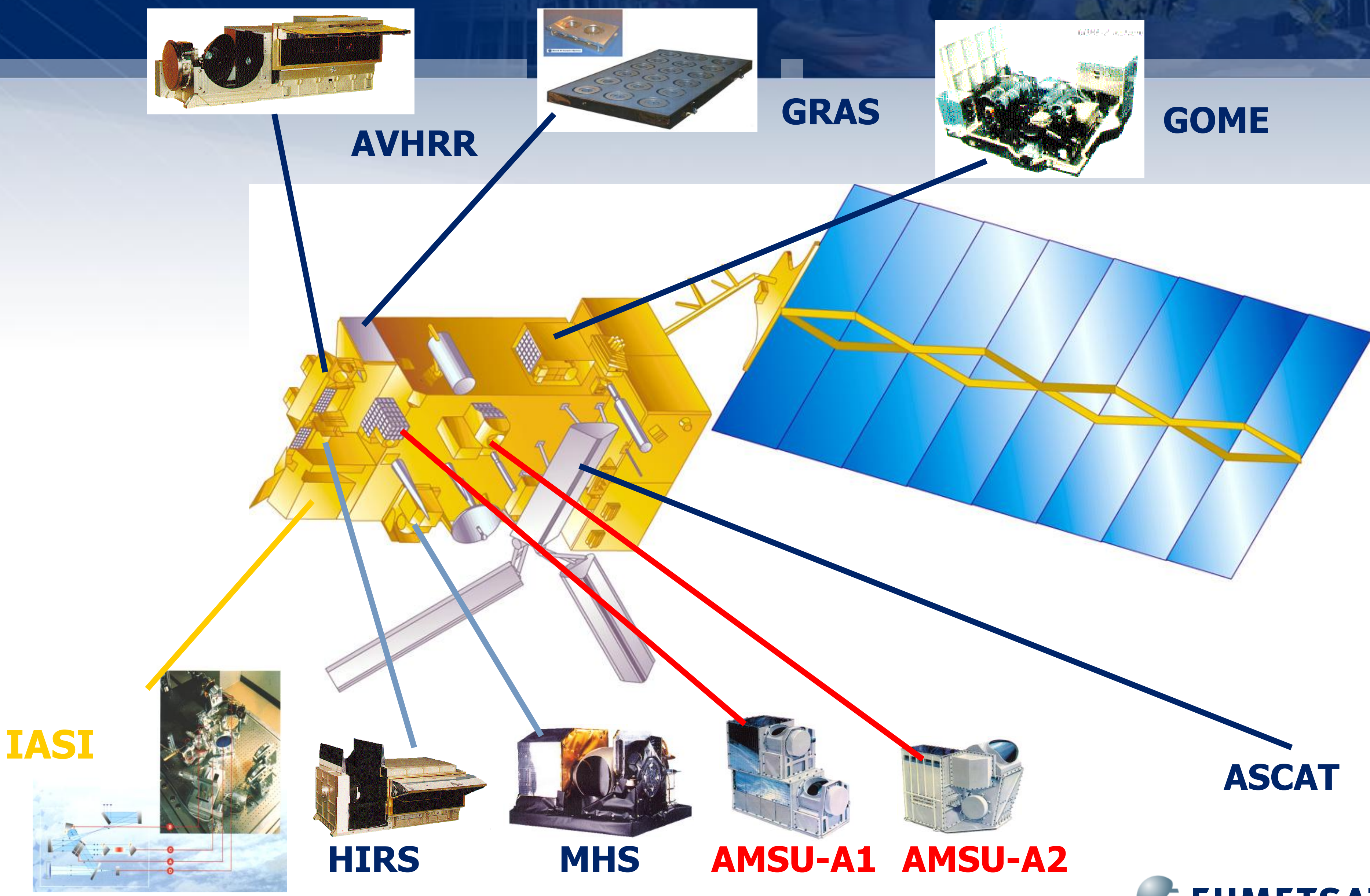
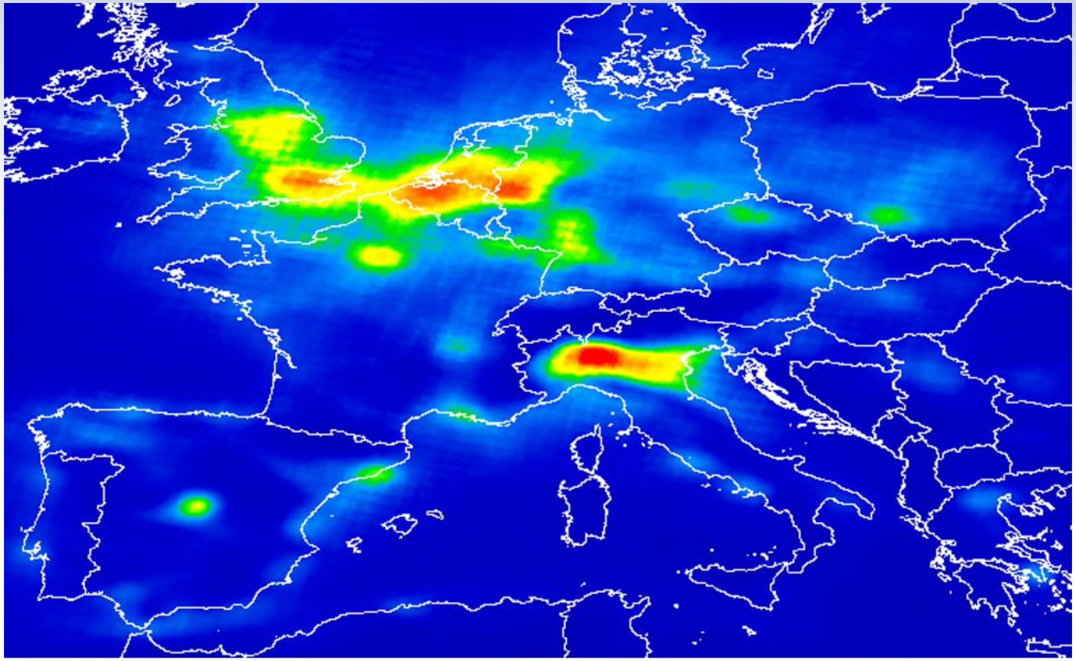
Metop instrument payload



Metop Improvements: trace gases – atmospheric pollution (e.g. NO2)



Tropospheric NO_2 over Europe (from GOME-2)

Source: DLR / Ozone SAF

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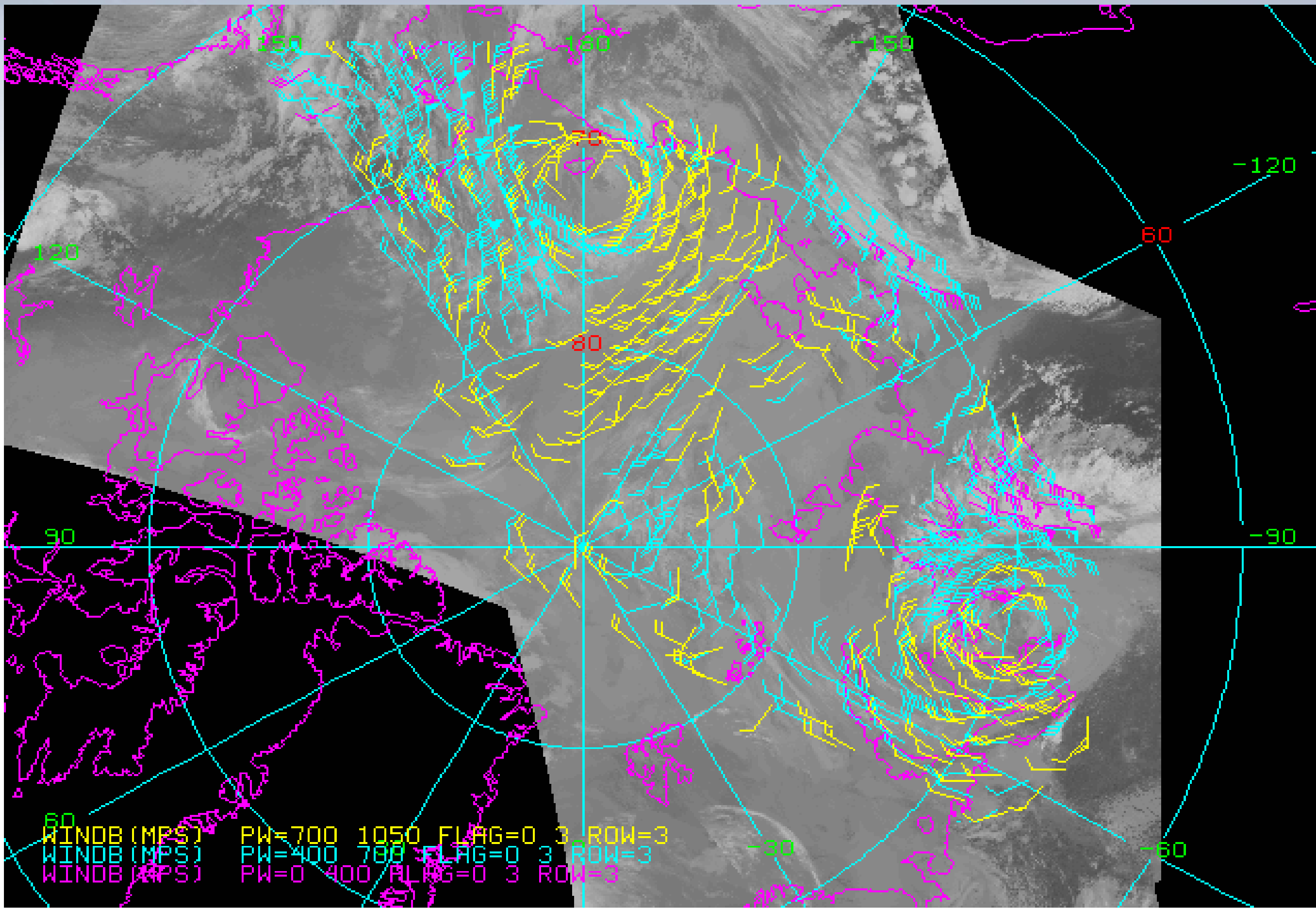
Metop Improvements: winds above polar regions



AVHRR
Winds from
4 June 2008
06:38 – 06:58 UTC

Ackermann, 2008

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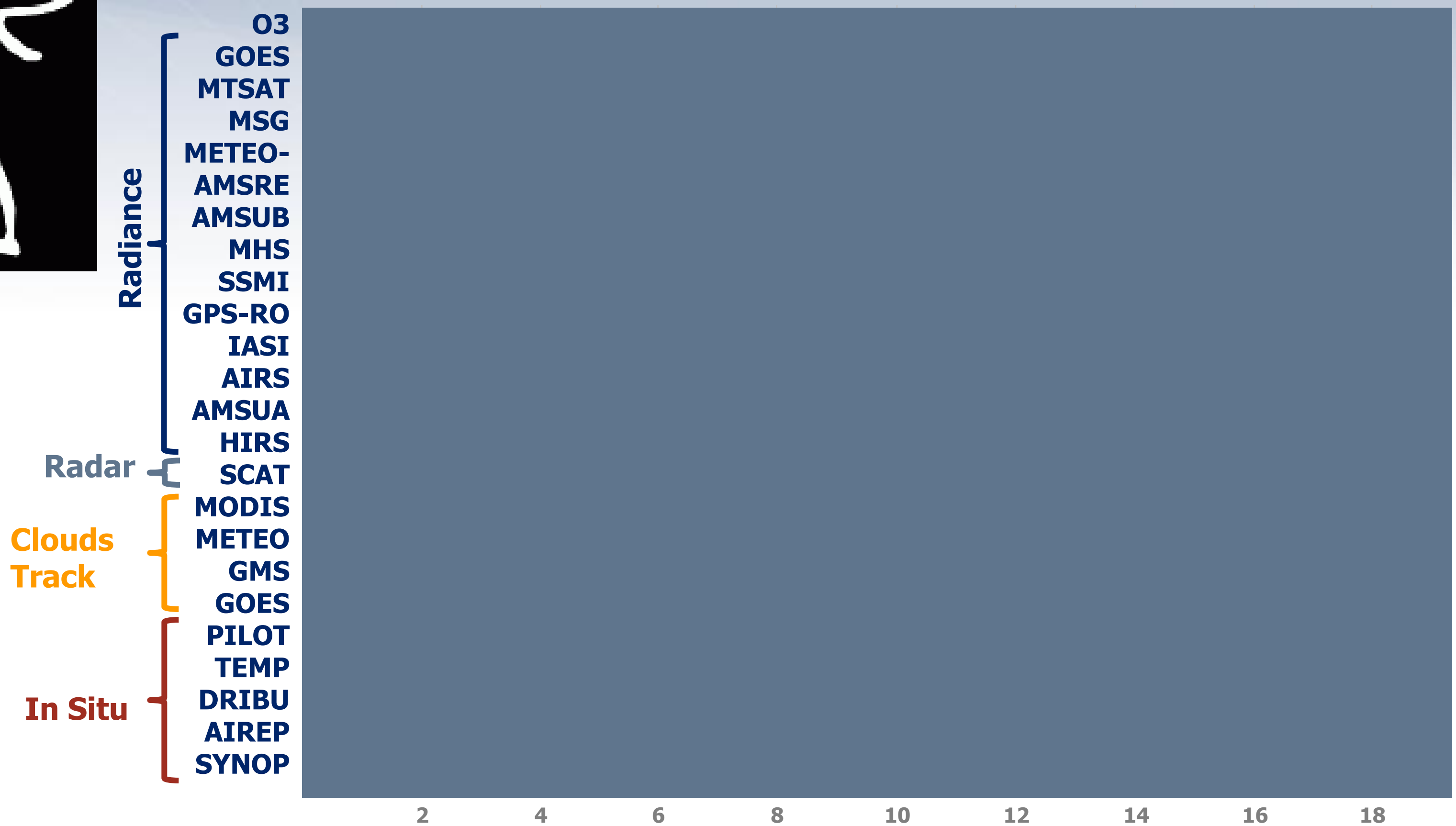
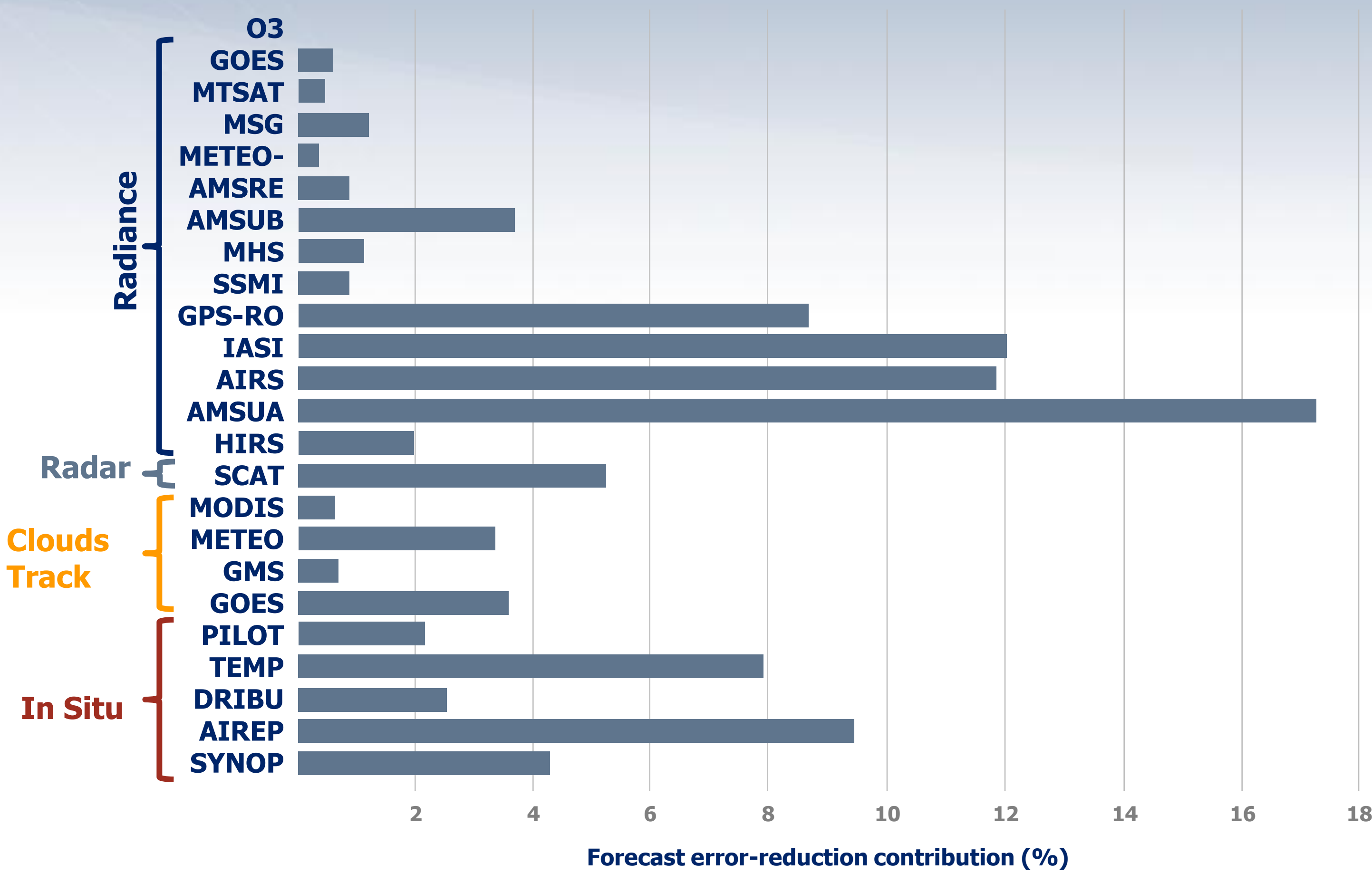
Instrument contribution to Numerical Weather Prediction error-reduction



Forecast sensitivity to observations
24-hour forecast error-reduction contribution (%) of the components (types) of the observing system during September – December 2008.
(Source: ECMWF)

Which instruments have the largest contributions ?

Instrument contribution to Numerical Weather Prediction error-reduction



Forecast sensitivity to observations
24-hour forecast error-reduction contribution (%) of the components (types) of the observing system during September – December 2008.
(Source: ECMWF)

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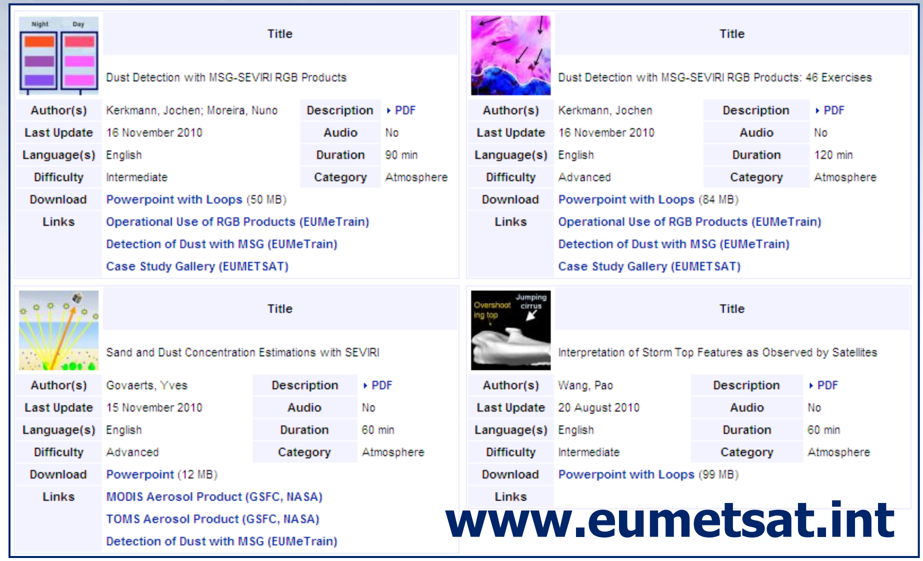
Have a look at the online training libraries



	Title		
	Dust Detection with MSG-SEVIRI RGB Products		
Author(s)	Kerkmann, Jochen; Moreira, Nuno	Description	PDF
Last Update	16 November 2010	Audio	No
Language(s)	English	Duration	90 min
Difficulty	Intermediate	Category	Atmosphere
Download	Powerpoint with Loops (50 MB)		
Links	Operational Use of RGB Products (EUMeTrain) Detection of Dust with MSG (EUMeTrain) Case Study Gallery (EUMETSAT)		

	Title		
	Dust Detection with MSG-SEVIRI RGB Products: 46 Exercises		
Author(s)	Kerkmann, Jochen	Description	PDF
Last Update	16 November 2010	Audio	No
Language(s)	English	Duration	120 min
Difficulty	Advanced	Category	Atmosphere
Download	Powerpoint with Loops (84 MB)		
Links	Operational Use of RGB Products (EUMeTrain) Detection of Dust with MSG (EUMeTrain) Case Study Gallery (EUMETSAT)		

	Title		
	Sand and Dust Concentration Estimations with SEVIRI		
Author(s)	Govaerts, Yves	Description	PDF
Last Update	15 November 2010	Audio	No
Language(s)	English	Duration	60 min
Difficulty	Advanced	Category	Atmosphere
Download	Powerpoint (12 MB)		
Links	MODIS Aerosol Product (GSFC, NASA) TOMS Aerosol Product (GSFC, NASA) Detection of Dust with MSG (EUMeTrain)		

	Title		
	Interpretation of Storm Top Features as Observed by Satellites		
Author(s)	Wang, Pao	Description	PDF
Last Update	20 August 2010	Audio	No
Language(s)	English	Duration	60 min
Difficulty	Intermediate	Category	Atmosphere
Download	Powerpoint with Loops (99 MB)		
Links			

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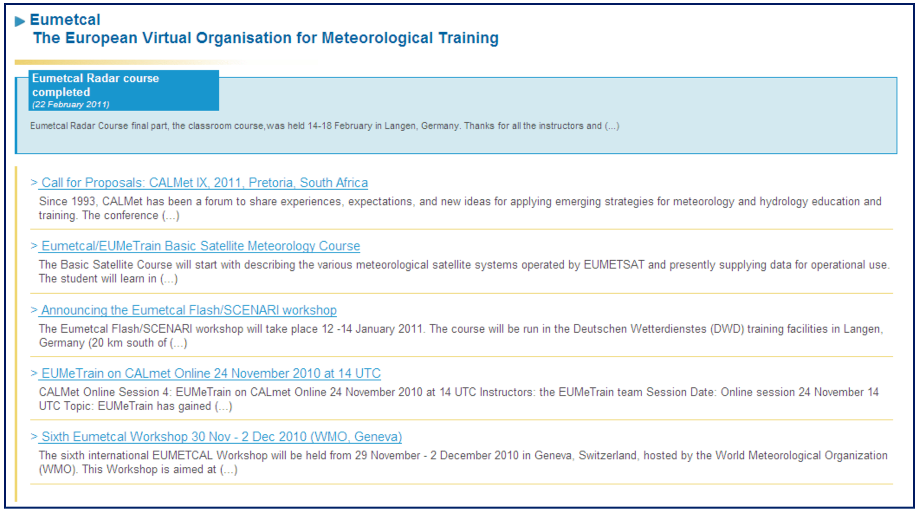

Eumetcal
The European Virtual Organisation for Meteorological Training

Eumetcal Radar course completed
(22 February 2011)
Eumetcal Radar Course final part, the classroom course,was held 14-18 February in Langen, Germany. Thanks for all the instructors and (...)

> Call for Proposals: CALMet IX, 2011, Pretoria, South Africa
Since 1993, CALMet has been a forum to share experiences, expectations, and new ideas for applying emerging strategies for meteorology and hydrology education and training. The conference (...)

> Eumetcal/EUMeTrain Basic Satellite Meteorology Course
The Basic Satellite Course will start with describing the various meteorological satellite systems operated by EUMETSAT and presently supplying data for operational use. The student will learn in (...)

> Announcing the Eumetcal Flash/SCENARI workshop
The Eumetcal Flash/SCENARI workshop will take place 12 -14 January 2011. The course will be run in the Deutschen Wetterdienstes (DWD) training facilities in Langen, Germany (20 km south of (...)

> EUMeTrain on CALmet Online 24 November 2010 at 14 UTC
CALMet Online Session 4: EUMeTrain on CALmet Online 24 November 2010 at 14 UTC Instructors: the EUMeTrain team Session Date: Online session 24 November 14 UTC Topic: EUMeTrain has gained (...)

> Sixth Eumetcal Workshop 30 Nov - 2 Dec 2010 (WMO, Geneva)
The sixth international EUMETCAL Workshop will be held from 29 November - 2 December 2010 in Geneva, Switzerland, hosted by the World Meteorological Organization (WMO). This Workshop is aimed at (...)

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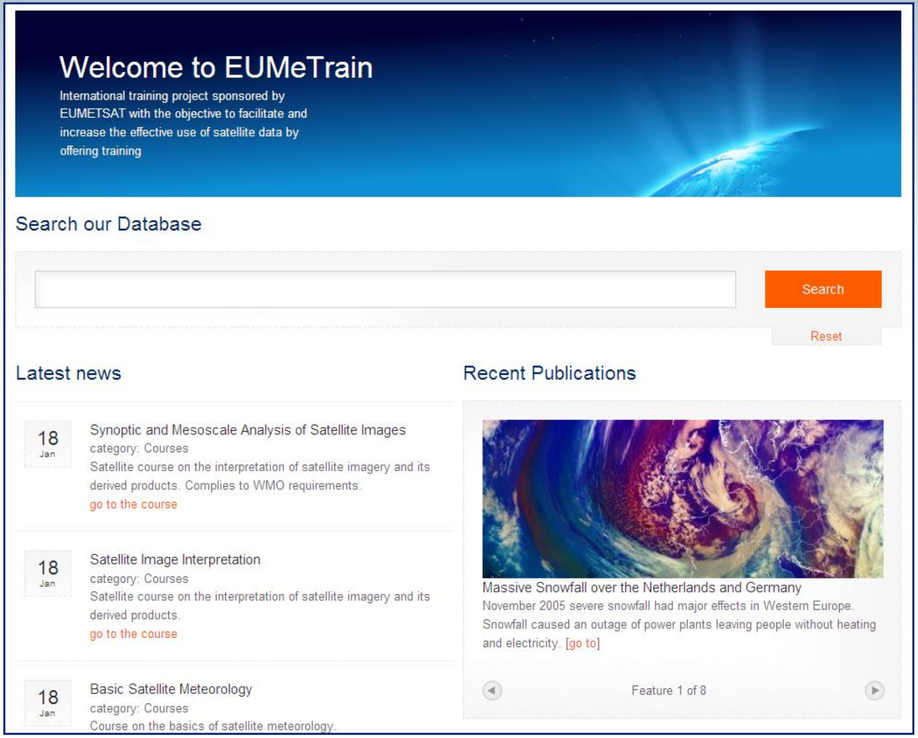

Welcome to EUMeTrain
International training project sponsored by EUMETSAT with the objective to facilitate and increase the effective use of satellite data by offering training

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Latest news

18 Jan — Synoptic and Mesoscale Analysis of Satellite Images
category: Courses
Satellite course on the interpretation of satellite imagery and its derived products. Complies to WMO requirements.
go to the course

18 Jan — Satellite Image Interpretation
category: Courses
Satellite course on the interpretation of satellite imagery and its derived products.
go to the course

18 Jan — Basic Satellite Meteorology
category: Courses
Course on the basics of satellite meteorology.

Recent Publications

Massive Snowfall over the Netherlands and Germany
November 2005 severe snowfall had major effects in Western Europe. Snowfall caused an outage of power plants leaving people without heating and electricity. [go to]
Feature 1 of 8

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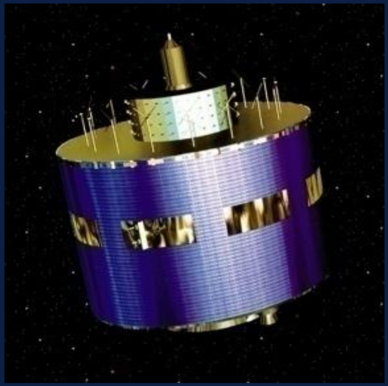
THANK YOU !

EUMETSAT

Extra slides (from Martin Setvak)

EUMETSAT



Meteosat Second Generation (MSG) SEVIRI bands

Spinning Enhanced Visible and Infrared Imager

- Band 01 VIS 0.6 — 0.56 - 0.71 µm
- Band 02 VIS 0.8 — 0.74 - 0.88 µm
- Band 03 NIR 1.6 — 1.50 - 1.78 µm
- Band 04 IR 3.9 — 3.48 - 4.36 µm
- Band 05 WV 6.2 — 5.35 - 7.15 µm
- Band 06 WV 7.3 — 6.85 - 7.85 µm
- Band 07 IR 8.7 — 8.30 - 9.10 µm
- Band 08 IR 9.7 — 9.38 - 9.94 µm
- Band 09 IR 10.8 — 9.80 - 11.80 µm
- Band 10 IR 12.0 — 11.00 - 13.00 µm
- Band 11 IR 13.4 — 12.40 - 14.40 µm
- Band 12 HRV — 0.4 - 1.1 µm

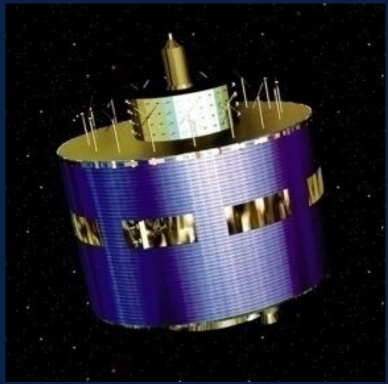
Reflected (backscattered) solar radiance

Thermal emission

Reflected (backscattered) solar radiance

Meteosat Second Generation (MSG) SEVIRI bands

Spinning Enhanced Visible and Infrared Imager



Pixel size (at nadir): 3 km (bands 1 – 11), and 1 km (HRV)

Operational sampling every 15 minutes, full globe (except for HRV, and 5-min rapid scan – geographical subsets only).

- **Band 01 VIS 0.6** — **0.56 - 0.71 µm**
- **Band 02 VIS 0.8** — **0.74 - 0.88 µm**
- **Band 03 NIR 1.6** — **1.50 - 1.78 µm**
- **Band 04 IR 3.9** — **3.48 - 4.36 µm**
- **Band 05 WV 6.2** — **5.35 - 7.15 µm**
- **Band 06 WV 7.3** — **6.85 - 7.85 µm**
- **Band 07 IR 8.7** — **8.30 - 9.10 µm**
- **Band 08 IR 9.7** — **9.38 - 9.94 µm**
- **Band 09 IR 10.8** — **9.80 - 11.80 µm**
- **Band 10 IR 12.0** — **11.00 - 13.00 µm**
- **Band 11 IR 13.4** — **12.40 - 14.40 µm**
- **Band 12 HRV** — **0.4 - 1.1 µm**

Visible and near-IR bands

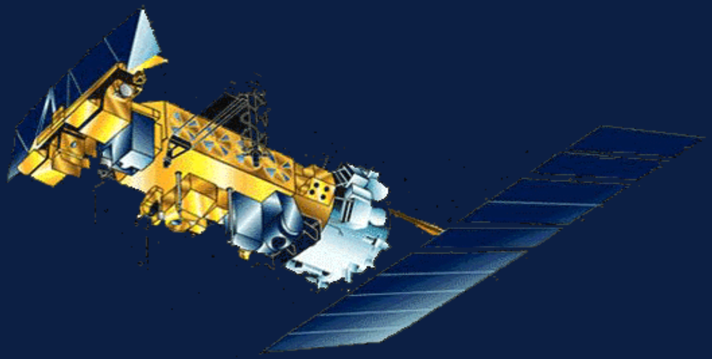
Microphysical bands

Absorption bands

IR window bands

AVHRR

Advanced Very High Resolution Radiometer



NOAA POES (NOAA 15 - NOAA 19) satellites
EUMETSAT Metop satellites

Pixel size (nadir resolution): 1100 m; swath width ~ 3000 km

channel 1	0.58 - 0.7 µm	VIS	VIS 0.6
channel 2	0.7 - 1.0 µm	NIR	VIS 0.8
channel 3A	1.58 - 1.64 µm	NIR	NIR 1.6
channel 3B	3.5 - 4.0 µm	NIR	IR 3.9
channel 4	10.2 - 11.5 µm	IR	IR 10.8
channel 5	11.4 - 12.5 µm	IR	IR 12.0

Reflected** (backscattered) **solar radiance

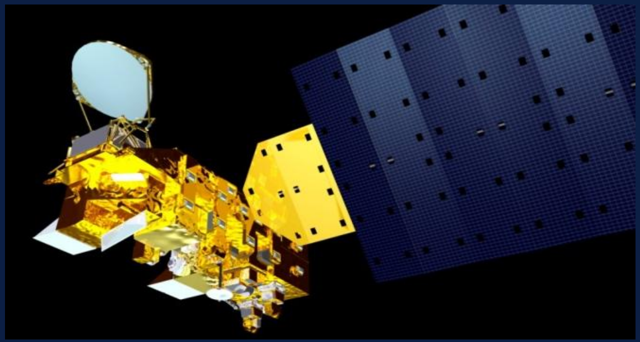
Thermal emission

- used since 1978 (TIROS-N), presently 3rd generation ... AVHRR/3

MODIS

Moderate Resolution Imaging Spectrometer

NASA EOS satellites Terra (1999) and Aqua (2002)



Reflected (backscattered) solar bands

Band	Bandwidth	Central Wavelength	Pixel Size
1	0.620 - 0.670 µm	0.6455 µm	250 m
2	0.841 - 0.876 µm	0.8565 µm	250 m
3	0.459 - 0.479 µm	0.4656 µm	500 m
4	0.545 - 0.565 µm	0.5536 µm	500 m
5	1.230 - 1.250 µm	1.2416 µm	500 m
6	1.628 - 1.652 µm	1.6291 µm	500 m
7	2.105 - 2.155 µm	2.1141 µm	500 m
8	0.405 - 0.420 µm	0.4113 µm	1000 m
9	0.438 - 0.448 µm	0.4420 µm	1000 m
10	0.483 - 0.493 µm	0.4869 µm	1000 m
11	0.526 - 0.536 µm	0.5296 µm	1000 m
12	0.546 - 0.556 µm	0.5468 µm	1000 m
13	0.662 - 0.672 µm	0.6655 µm	1000 m
14	0.673 - 0.683 µm	0.6768 µm	1000 m
15	0.743 - 0.753 µm	0.7464 µm	1000 m
16	0.862 - 0.877 µm	0.8662 µm	1000 m
17	0.890 - 0.920 µm	0.9040 µm	1000 m
18	0.931 - 0.941 µm	0.9355 µm	1000 m
19	0.915 - 0.965 µm	0.9352 µm	1000 m

Solar (20-26) and emission (20-25) bands

Band	Bandwidth	Central Wavelength	Pixel Size
20	3.660 - 3.840	3.785 µm	1000 m
21	3.930 - 3.989	3.960 µm	1000 m
22	3.930 - 3.989	3.960 µm	1000 m
23	4.020 - 4.080	4.056 µm	1000 m
24	4.433 - 4.498	4.472 µm	1000 m
25	4.482 - 4.549	4.545 µm	1000 m
26	1.360 - 1.390	1.383 µm	1000 m
27	6.535 - 6.895	6.752 µm	1000 m
28	7.175 - 7.475	7.334 µm	1000 m
29	8.400 - 8.700	8.518 µm	1000 m
30	9.580 - 9.880	9.737 µm	1000 m
31	10.780 - 11.280	11.017 µm	1000 m
32	11.770 - 12.270	12.032 µm	1000 m
33	13.185 - 13.485	13.359 µm	1000 m
34	13.485 - 13.785	13.675 µm	1000 m
35	13.785 - 14.085	13.907 µm	1000 m
36	14.085 - 14.385	14.192 µm	1000 m

Thermal emission only bands (27-36)

MODIS

Moderate Resolution Imaging Spectrometer

Pixel size (nadir resolution): 250 m, 500 m and 1000 m; swath width 2330 km

Corresponding MSG SEVIRI bands

Band	Bandwidth	Central Wavelength	Pixel Size	MSG SEVIRI
1	0.620 - 0.670 µm	0.6455 µm	250 m	VIS 0.6
2	0.841 - 0.876 µm	0.8565 µm	250 m	VIS 0.8
3	0.459 - 0.479 µm	0.4656 µm	500 m	
4	0.545 - 0.565 µm	0.5536 µm	500 m	
5	1.230 - 1.250 µm	1.2416 µm	500 m	
6	1.628 - 1.652 µm	1.6291 µm	500 m	NIR 1.6
7	2.105 - 2.155 µm	2.1141 µm	500 m	
8	0.405 - 0.420 µm	0.4113 µm	1000 m	
9	0.438 - 0.448 µm	0.4420 µm	1000 m	
10	0.483 - 0.493 µm	0.4869 µm	1000 m	
11	0.526 - 0.536 µm	0.5296 µm	1000 m	
12	0.546 - 0.556 µm	0.5468 µm	1000 m	
13	0.662 - 0.672 µm	0.6655 µm	1000 m	VIS 0.6
14	0.673 - 0.683 µm	0.6768 µm	1000 m	
15	0.743 - 0.753 µm	0.7464 µm	1000 m	
16	0.862 - 0.877 µm	0.8662 µm	1000 m	VIS 0.8
17	0.890 - 0.920 µm	0.9040 µm	1000 m	
18	0.931 - 0.941 µm	0.9355 µm	1000 m	
19	0.915 - 0.965 µm	0.9352 µm	1000 m	

Band	Bandwidth	Central Wavelength	Pixel Size	MSG SEVIRI
20	3.660 - 3.840	3.785 µm	1000 m	
21	3.930 - 3.989	3.960 µm	1000 m	
22	3.930 - 3.989	3.960 µm	1000 m	IR 3.9
23	4.020 - 4.080	4.056 µm	1000 m	
24	4.433 - 4.498	4.472 µm	1000 m	
25	4.482 - 4.549	4.545 µm	1000 m	
26	1.360 - 1.390	1.383 µm	1000 m	
27	6.535 - 6.895	6.752 µm	1000 m	WV 6.2
28	7.175 - 7.475	7.334 µm	1000 m	WV 7.3
29	8.400 - 8.700	8.518 µm	1000 m	IR 8.7
30	9.580 - 9.880	9.737 µm	1000 m	IR 9.7
31	10.780 - 11.280	11.017 µm	1000 m	IR 10.8
32	11.770 - 12.270	12.032 µm	1000 m	IR 12.0
33	13.185 - 13.485	13.359 µm	1000 m	
34	13.485 - 13.785	13.675 µm	1000 m	IR 13.4
35	13.785 - 14.085	13.907 µm	1000 m	
36	14.085 - 14.385	14.192 µm	1000 m	

VIIRS *(Visible Infrared Imaging Radiometer Suite)*

		Band No.	Wave-length (µm)	Horiz Sample Interval (km Downtrack x Crosstrack) Nadir	End of Scan	Driving EDRs	Radi-ance Range	Ltyp or Ttyp	Signal to Noise Ratio (dimensionless) or NEΔT (Kelvins) Required	Predicted	Margin
VIS/NIR FPA	Silicon PIN Diodes	M1	0.412	0.742 x 0.259	1.60 x 1.58	Ocean Color	Low	44.9	352	483	37%
						Aerosols	High	155	316	827	162%
		M2	0.445	0.742 x 0.259	1.60 x 1.58	Ocean Color	Low	40	380	501	32%
						Aerosols	High	146	409	774	89%
		M3	0.488	0.742 x 0.259	1.60 x 1.58	Ocean Color	Low	32	416	573	38%
						Aerosols	High	123	414	747	80%
		M4	0.555	0.742 x 0.259	1.60 x 1.58	Ocean Color	Low	21	362	482	33%
						Aerosols	High	90	315	586	86%
		I1	0.640	0.371 x 0.387	0.80 x 0.789	Imagery	Single	22	119	135	13%
		M5	0.672	0.742 x 0.259	1.60 x 1.58	Ocean Color	Low	10	242	306	26%
						Aerosols	High	68	360	450	25%
		M6	0.746	0.742 x 0.776	1.60 x 1.58	Atmospheric Corr'n	Single	9.6	199	279	40%
		I2	0.865	0.371 x 0.387	0.80 x 0.789	NDVI	Single	25	150	212	41%
		M7	0.865	0.742 x 0.259	1.60 x 1.58	Ocean Color	Low	6.4	215	467	117%
						Aerosols	High	33.4	340	467	37%
CCD		DNB	0.7	0.742 x 0.742	0.742 x 0.742	Imagery	Var.	6.70E-05	6	6.2	3%
S/MWIR	PV HgCdTe (HCT)	M8	1.24	0.742 x 0.776	1.60 x 1.58	Cloud Particle Size	Single	5.4	74	109	47%
		M9	1.378	0.742 x 0.776	1.60 x 1.58	Cirrus/Cloud Cover	Single	6	83	156	88%
		I3	1.61	0.371 x 0.387	0.80 x 0.789	Binary Snow Map	Single	7.3	6.0	71	1084%
		M10	1.61	0.742 x 0.776	1.60 x 1.58	Snow Fraction	Single	7.3	342	461	35%
		M11	2.25	0.742 x 0.776	1.60 x 1.58	Clouds	Single	0.12	10	14	44%
		I4	3.74	0.371 x 0.387	0.80 x 0.789	Imagery Clouds	Single	270 K	2.500	0.236	68%
		M12	3.70	0.742 x 0.776	1.60 x 1.58	SST	Single	270 K	0.396	1.039	141%
		M13	4.05	0.742 x 0.259	1.60 x 1.58	SST	Low	300 K	0.107	0.051	111%
						Fires	High	380 K	0.423	0.353	20%
LWIR	PV HCT	M14	8.55	0.742 x 0.776	1.60 x 1.58	Cloud Top Properties	Single	270 K	0.091	0.057	60%
		M15	10.763	0.742 x 0.776	1.60 x 1.58	SST	Single	300 K	0.070	0.034	105%
		I5	11.450	0.371 x 0.387	0.80 x 0.789	Cloud Imagery	Single	210 K	1.500	1.004	49%
		M16	12.013	0.742 x 0.776	1.60 x 1.58	SST	Single	300 K	0.072	0.059	23%

Swath width: 3000 km (± 56° from nadir)