THE EUMETSAT SATELLITE PROGRAMMES

AN OVERVIEW FROM NOW TO THE FUTURE

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EUMETSAT

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from EUMETSAT and its partners

Current EUMETSAT satellite fleet – Extrapolated end 2016

METOP -A and -B
(LOW-EARTH, SUN – SYNCHRONOUS ORBIT)

EUMETSAT POLAR SYSTEM/INITIAL JOINT POLAR SYSTEM

Sentinel -3a
(LOW-EARTH, SUN-SYNCHRONOUS ORBIT)

Copernicus Global Marine and Land Environment Mission
Operated by EUMETSAT

JASON-2, -3
(LOW-EARTH, 63° INCL. NON SYNCHRONOUS ORBIT)

OCEAN SURFACE TOPOGRAPHY MISSION

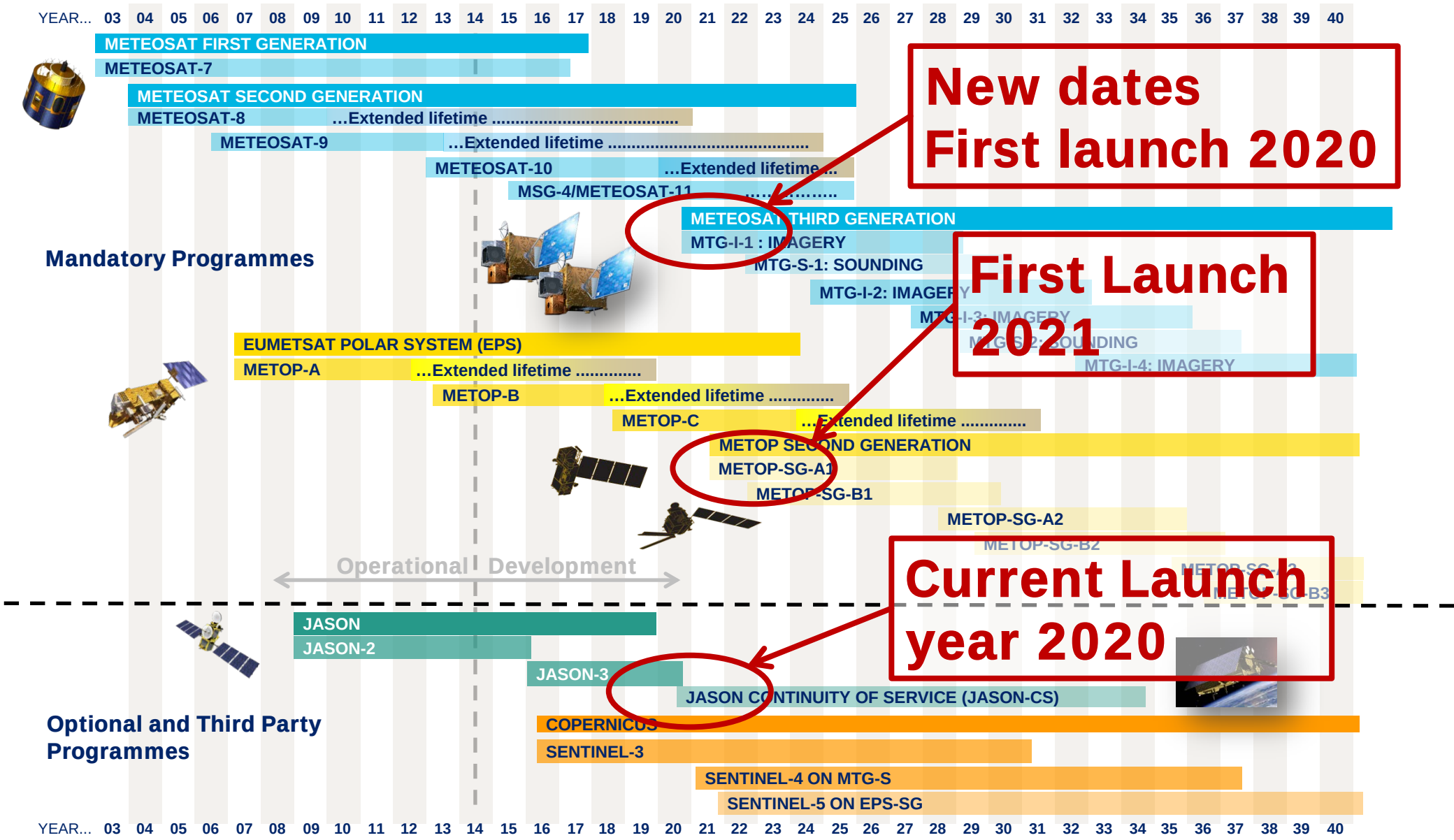
METEOSAT SECOND GENERATION -9, -10, -11
(GEOSTATIONARY ORBIT)

TWO-SATELLITE SYSTEM:
- METEOSAT-11: IN-ORBIT BACKUP
- METEOSAT-10: FULL DISK IMAGERY MISSION AT 0° (15 MN)
- METEOSAT-9: RAPID SCAN SERVICE OVER EUROPE AT 9.5°E (5 MN)

METEOSAT -8 (2nd GENERATION)
(GEOSTATIONARY ORBIT)

INDIAN OCEAN DATA COVERAGE MISSION
AT 40° E (TBD June 2016)

EUMETSAT programmes overview



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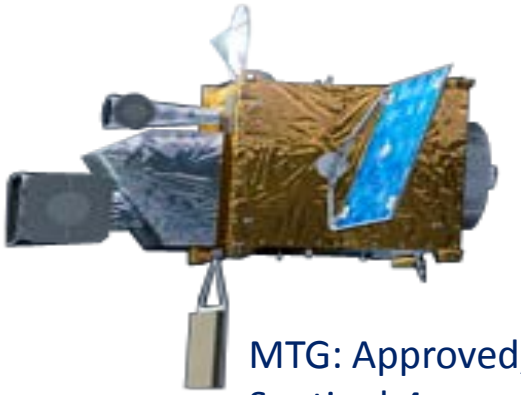
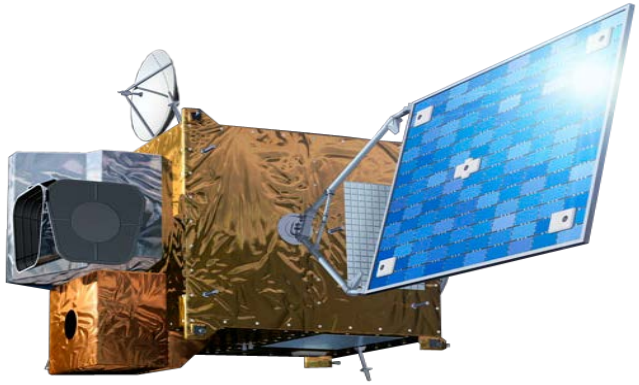
Future programmes shape the 2020 – 2040 timeframe





MTG: Approved, under development
Sentinel-4 approved (funded by Copernicus)

Jason-CS/Sentinel-6:
Approved, under development

EPS-SG: Approved, under development
Sentinel-5 approved (funded by Copernicus)

MTG Programme – Space Segment

Twin satellite concept – based on 3-axis platforms:

4 geostationary imaging satellites **(MTG-I)**

2 geostationary sounding satellites **(MTG-S)**

Established through a cooperation between:

esa

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MTG-I: - Flexible Combined Imager (FCI)
- Lightning Imager Instrument (LI)

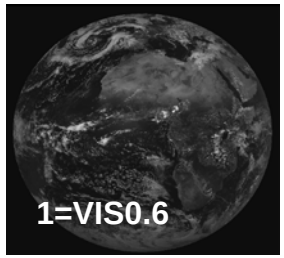
20 years of operational service

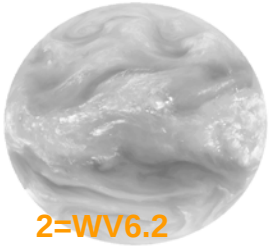
MTG-S: - Infrared Sounder (IRS)
- Ultra-violet, Visible and Near-infrared Sounder (UVN)

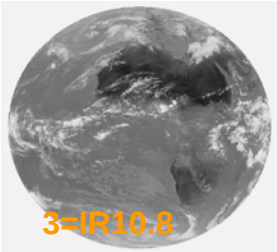
15.5 years of operational service

From MVIRI on MTP...

Meteosat-7 is the last
Located over
- **Indian Ocean**
- **until end of 2016**







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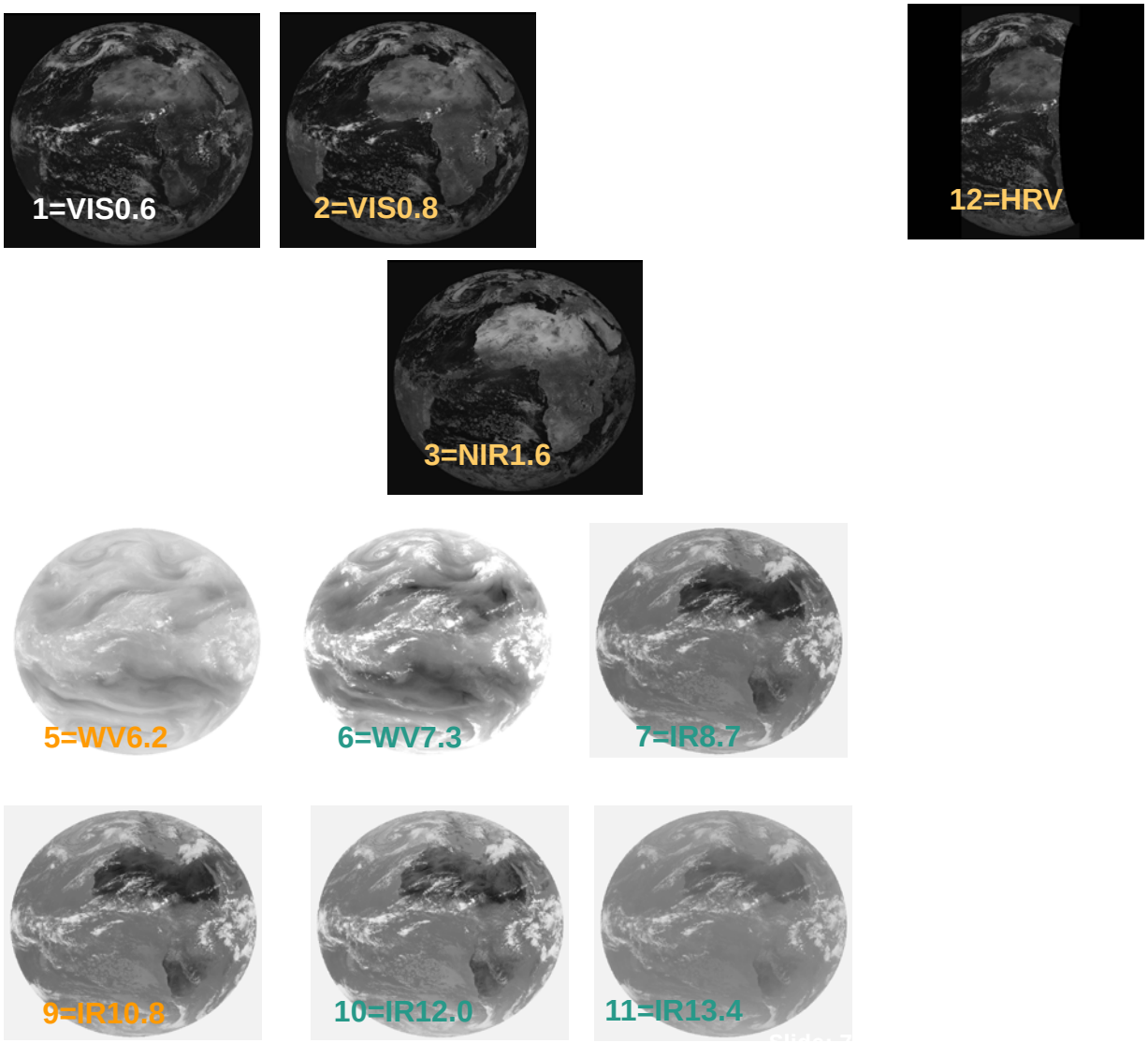
From MVIRI on MTP to SEVIRI on MSG...



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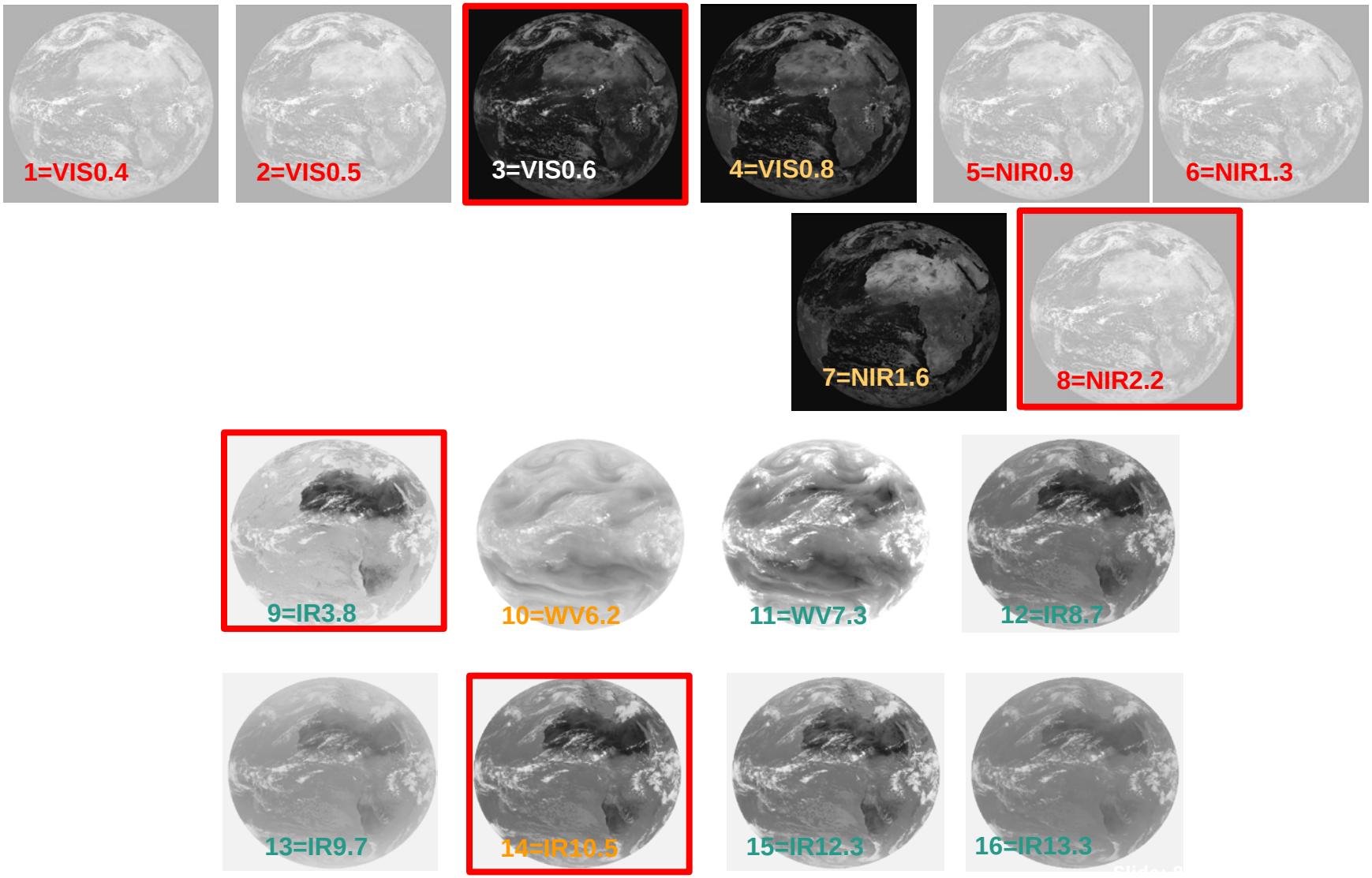
From MVIRI on MTP to SEVIRI on MSG to MTG FCI



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38 years of observations and counting ....

	Meteosat 1st Generation			Meteosat 2nd Generation			Meteosat 3rd Generation		
'Core' channels	Central wavelength (µm)	Width (FWHM) (µm)	Spatial Sampling (km)	Central wavelength (µm)	Width (FWHM) (µm)	Spatial Sampling (km)	Central wavelength (µm)	Width (FWHM) (µm)	Spatial Sampling (km)
FC-VIS 0.4							0.444	0.06	1.0
FC-VIS 0.5							0.510	0.05	1.0
FC-VIS 0.6	0.7	0.35	2.5	0.635	0.08	3.0	0.645	0.08	0.5
FC-VIS 0.8				0.81	0.07	3.0	0.86	0.07	1.0
FC-NIR 0.9							0.96	0.06	1.0
FC-NIR 1.3							1.375	0.03	1.0
FC-NIR 1.6				1.64	0.14	3.0	1.61	0.06	1.0
FC-NIR 2.2							2.26	0.05	0.5
FC-IR 3.8*				3.9	0.44	3.0	3.8	0.40	1.0
FC-IR 6.2	6.1	1.3	5.0	6.2	1.0	3.0	6.2	1.00	2.0
FC-IR 7.3				7.35	0.5	3.0	7.35	0.50	2.0
FC-IR 8.7*				8.7	0.4	3.0	8.7	0.40	2.0
FC-IR 9.7				9.66	0.3	3.0	9.66	0.30	2.0
FC-IR 10.8	11.5	1.9	5.0	10.8	1.0	3.0	10.5	0.7	1.0
FC-IR 12.0				12.0	1.0	3.0	12.3	0.5	2.0
FC-IR 13.3				13.4	1.0	3.0	13.3	0.60	2.0
Repeat Cycle :	30 min			15 min			10 min		

P. Griffith / HARRIS :

FPM	FPA	Resolution (km)	AHI Band #	Nominal Wavelength (µm)		
				ABI	AHI	AMI
VNIR	A047	1	1	0.47	0.47	0.47
	A086	1	2	0.86	0.51	0.51
	A064	0.5	3	0.64	0.64	0.64
	A161	1	4	1.61	0.86	0.86
	A138	2	5	1.38	1.61	1.38
	A225	2	6	2.25	2.26	1.61
MWIR	A390	2	7	3.9	3.9	3.9
	A618	2	8	6.185	6.185	6.185
	A695	2	9	6.95	6.95	6.95
	A734	2	10	7.34	7.34	7.34
	A850	2	11	8.5	8.5	8.5
LWIR	A961	2	12	9.61	9.61	9.61
	A1035	2	13	10.35	10.35	10.35
	A1120	2	14	11.2	11.2	11.2
	A1230	2	15	12.3	12.3	12.3
	A1330	2	16	13.3	13.3	13.3

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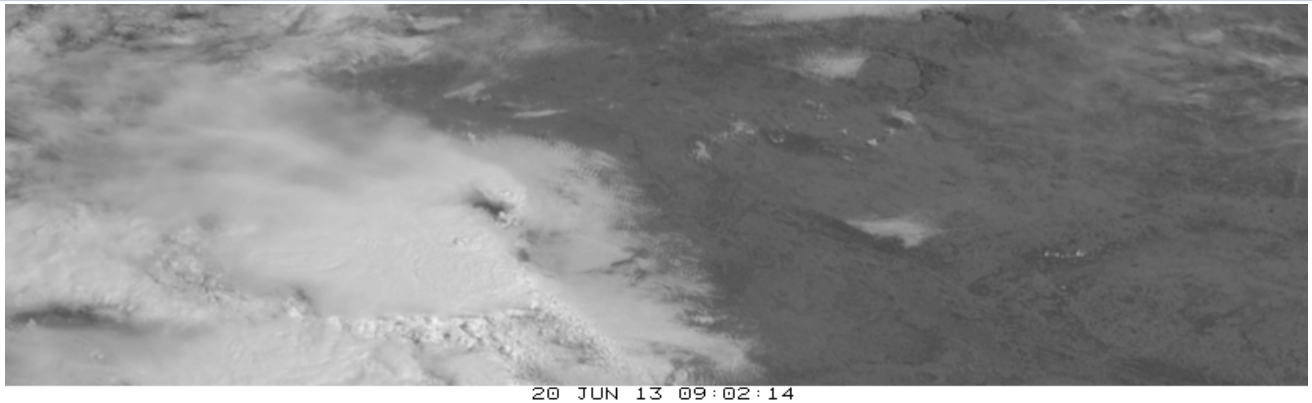
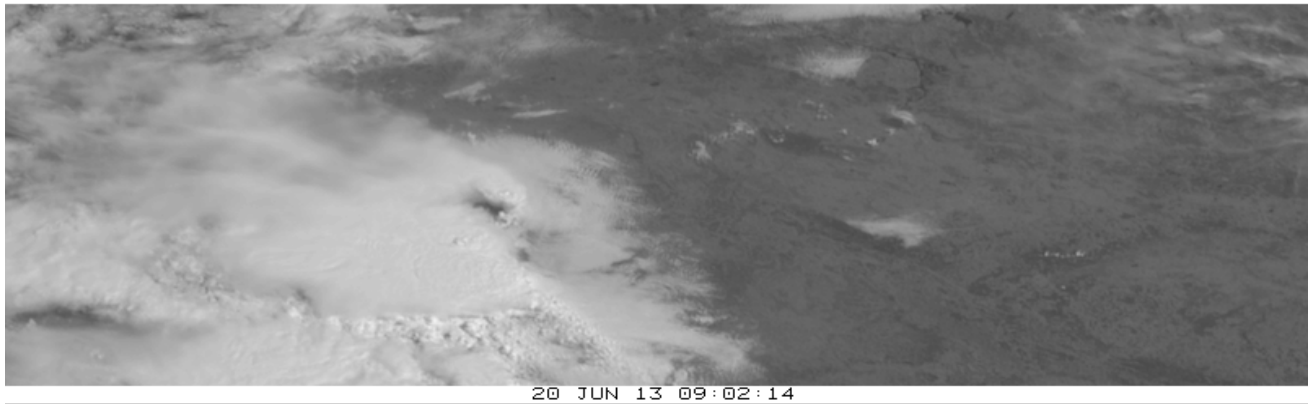
Met-8 super-rapid scans 2.5 min experiment

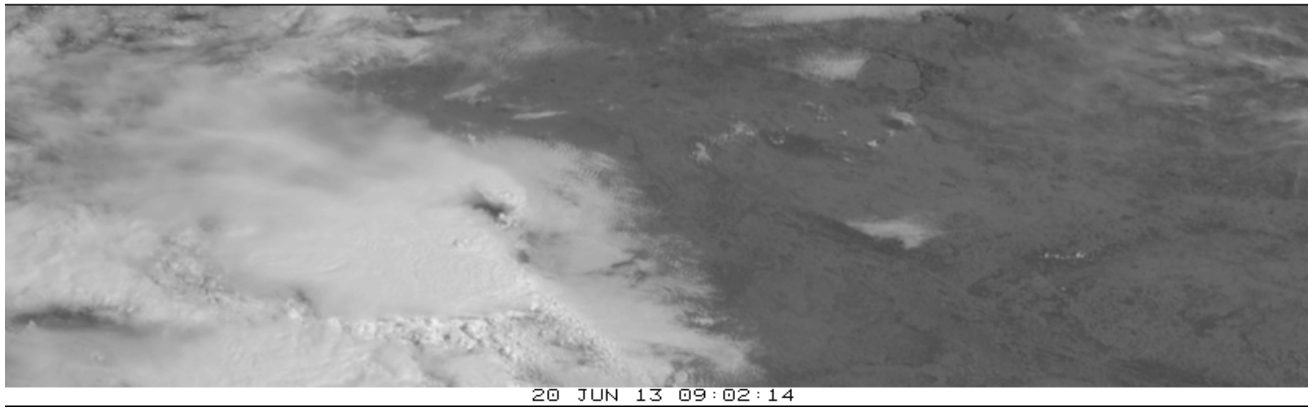
2.5 minutes Repeat Cycle



5 minutes Repeat Cycle



15 minutes Repeat Cycle



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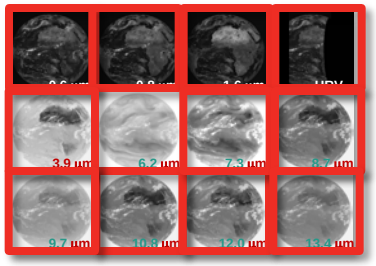
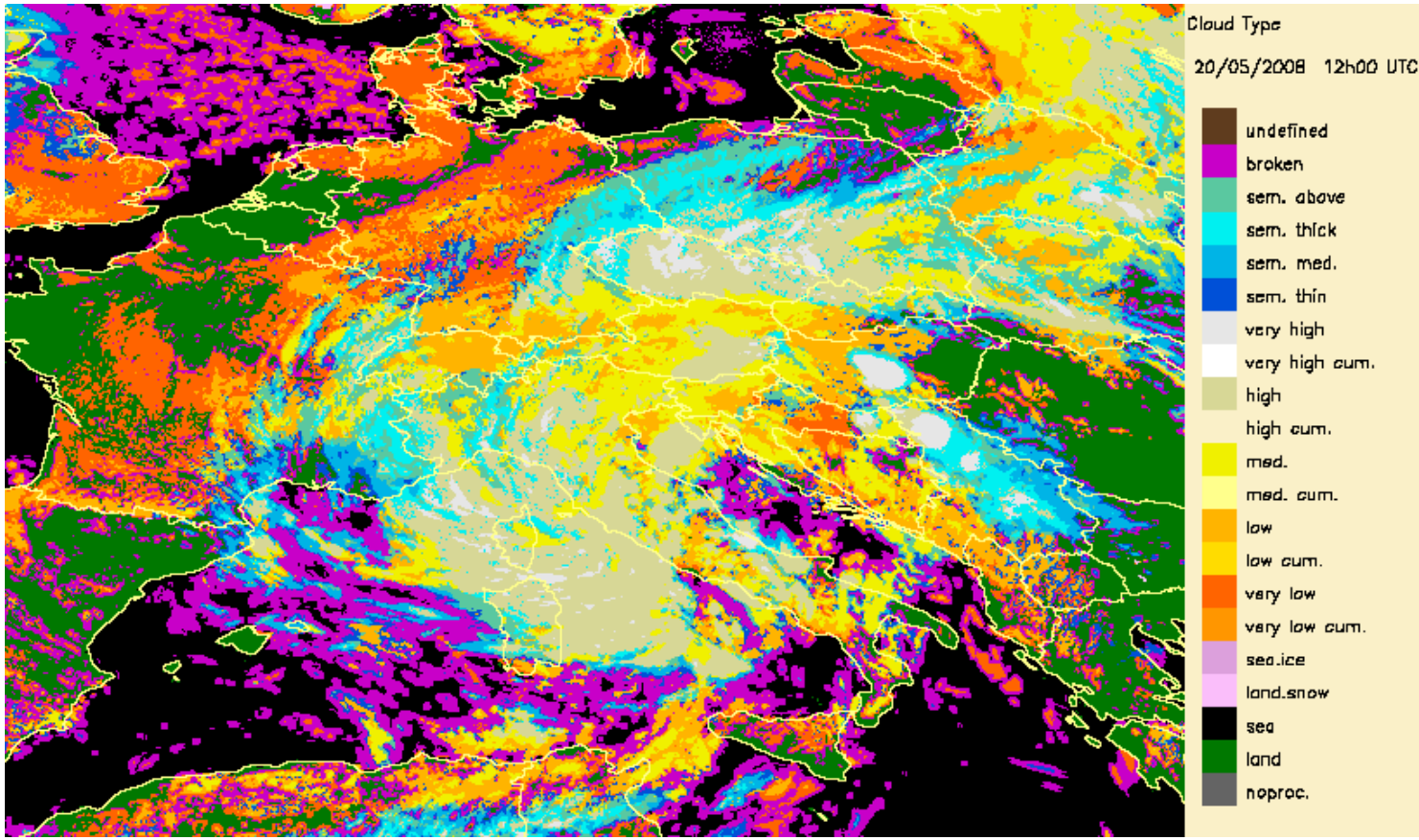
Cloud Analysis Improves

Channel **values** and **differences** are '**firmed up**' using thresholds plus supporting information such as **forecast** fields and **physical** properties. This enables **decisions** to be made on scene contents.





NWC SAF

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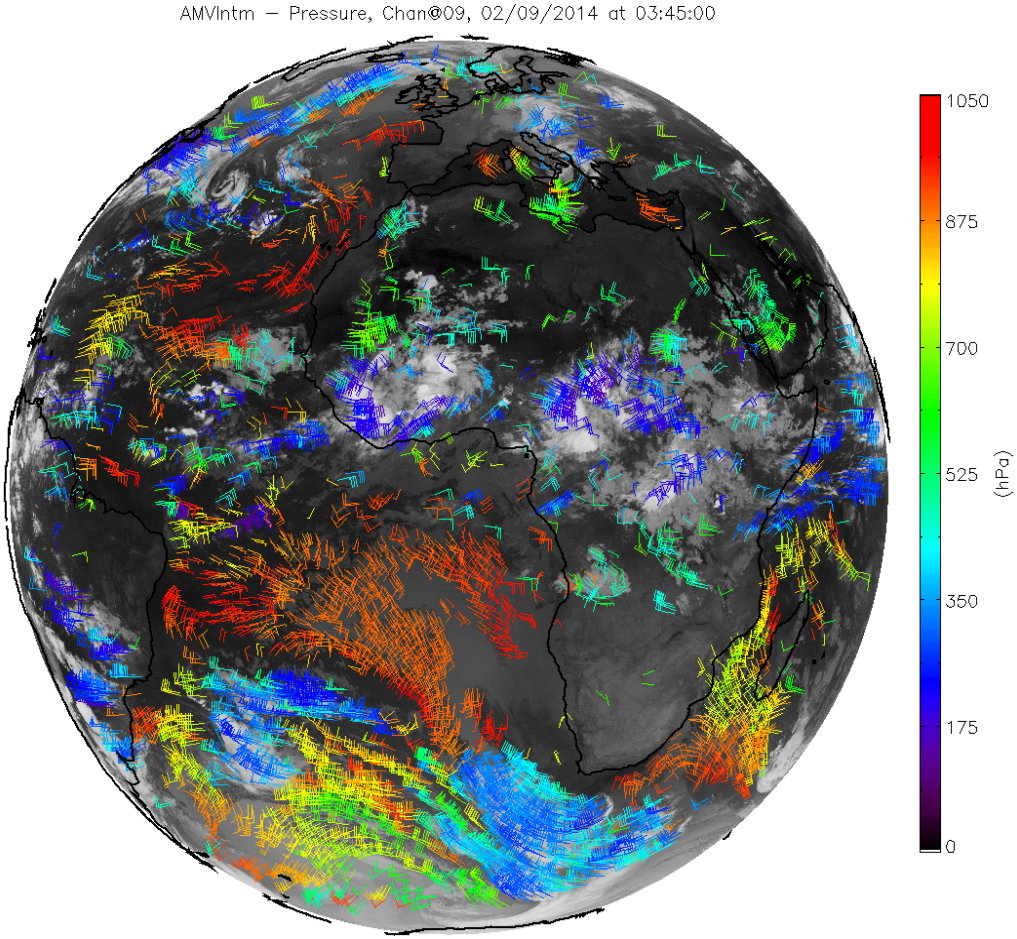
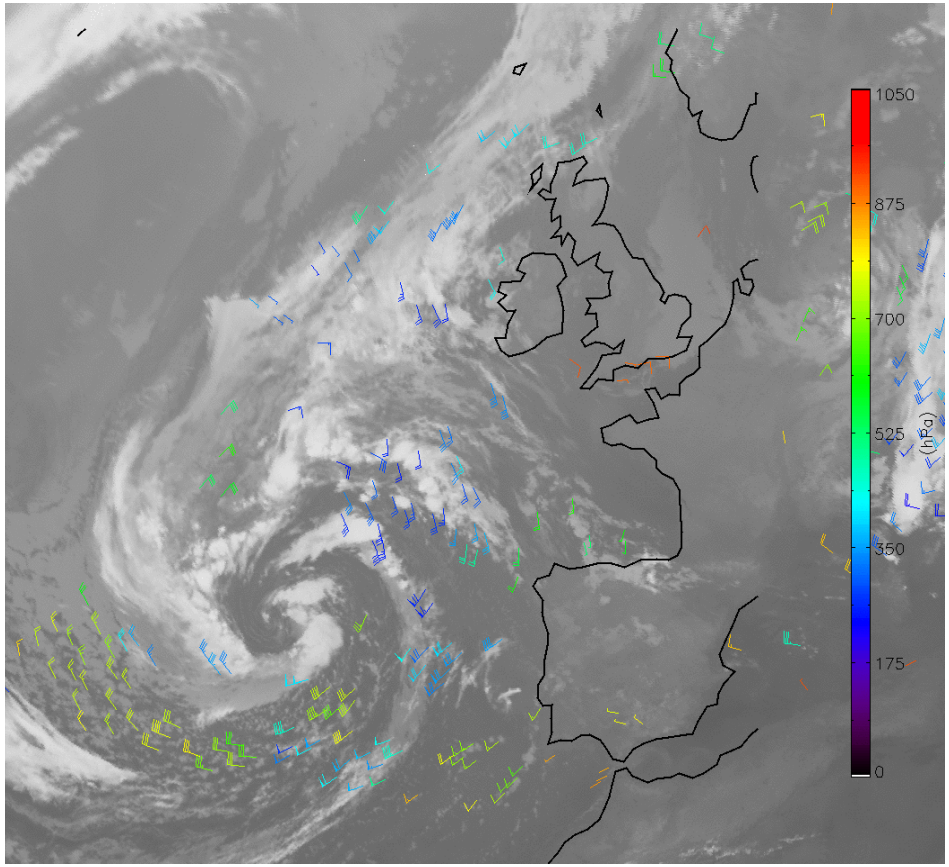
Continuation of AMVs Guaranteed!

FES, 02/09/2014, 20:45 – 03/09/2014, 19:45



RSS, 11/09/2014, 6:30 – 12/09/2014, 5:30



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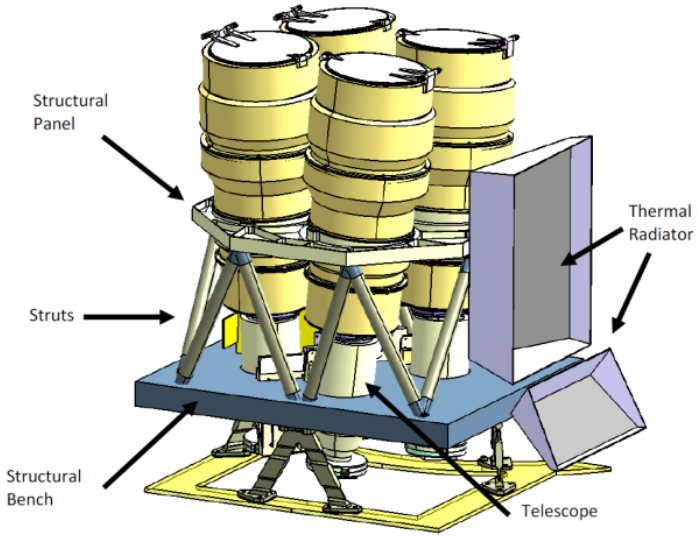
The LI Instrument

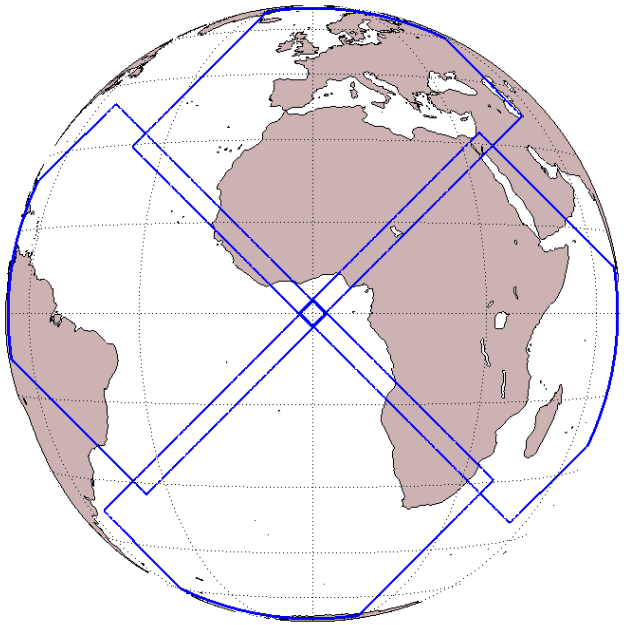


LI Main characteristics:

- Measurements at 777.4 nm
- Coverage close to “visible disc”
- Continuous measurements of (lightning) triggered events
- Spatial resolution ~ 4.5 km at SSP
- Integration time per frame 1 ms
- Background subtraction & event detection in on-board electronics

The baseline for the LI is a 4-Optical Chain solution:

- 4 identical optical channels with CMOS back-thinned backside illuminated detectors
- 1170 x 1000 pixels per camera



End-users (Level 2) will not see the “detector structure”

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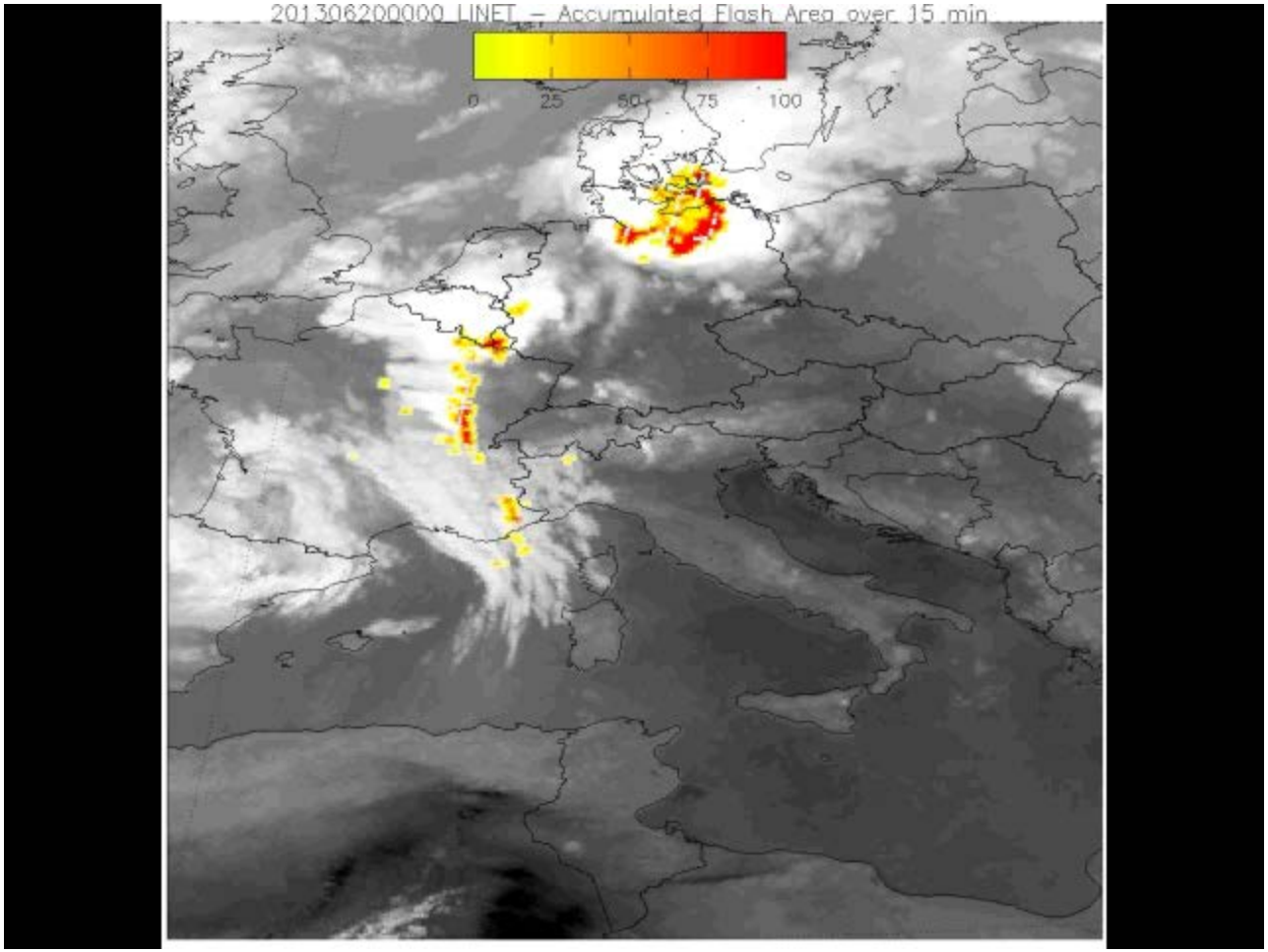
Observing lightning
Reference processor product example

"Accumulated flash area" product, integrated over 15 minutes and updated every 30 seconds
Date: 20 June 2013.



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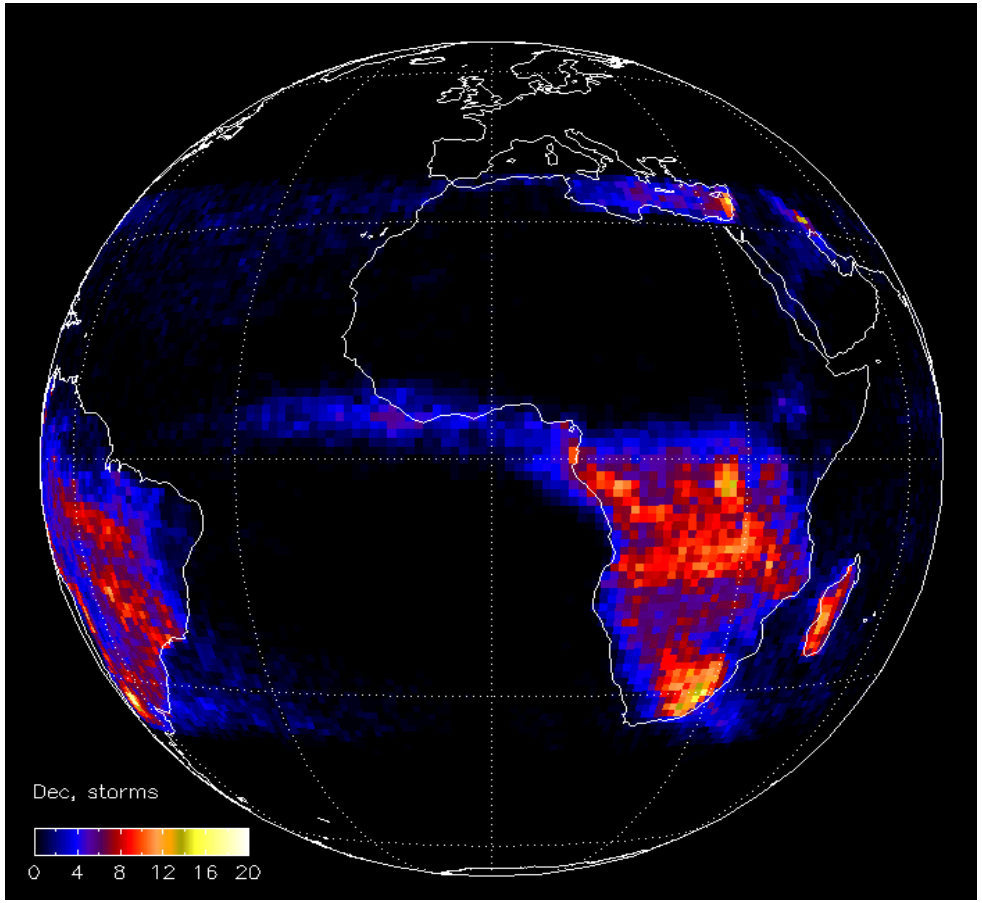
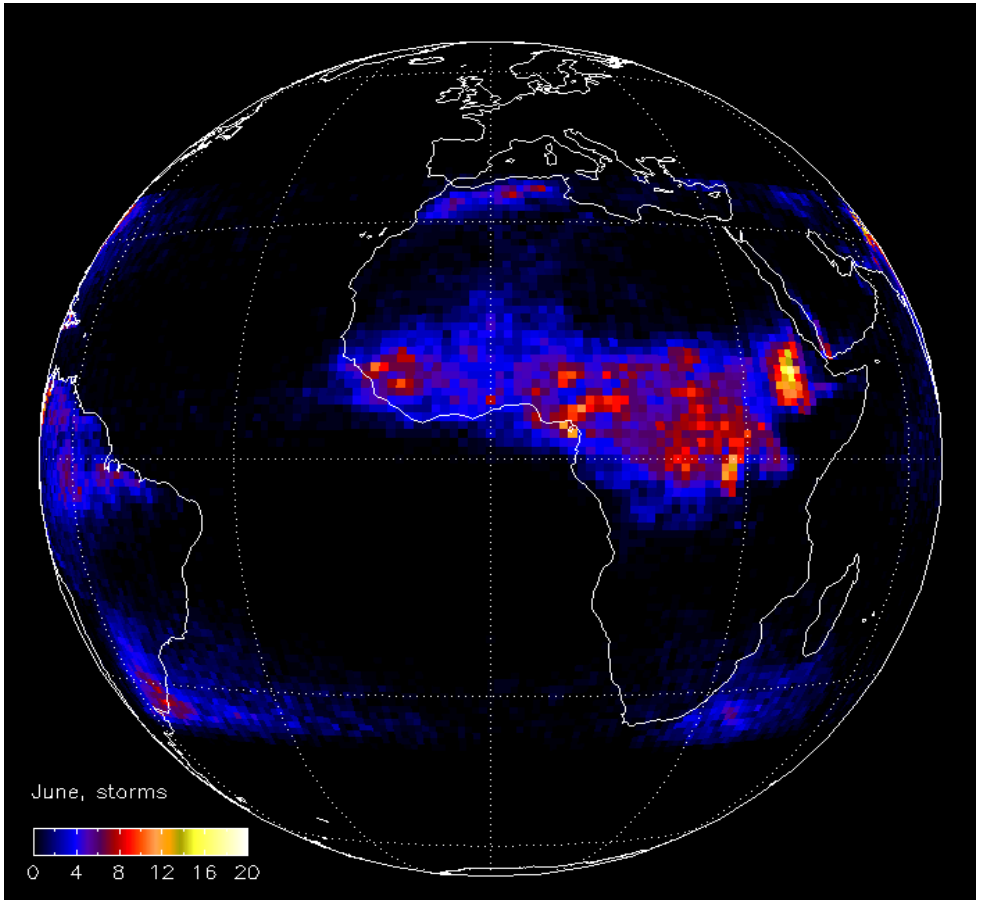
LIS Lightning Storm Climatology 1998-2006



LIS - December



LIS - June

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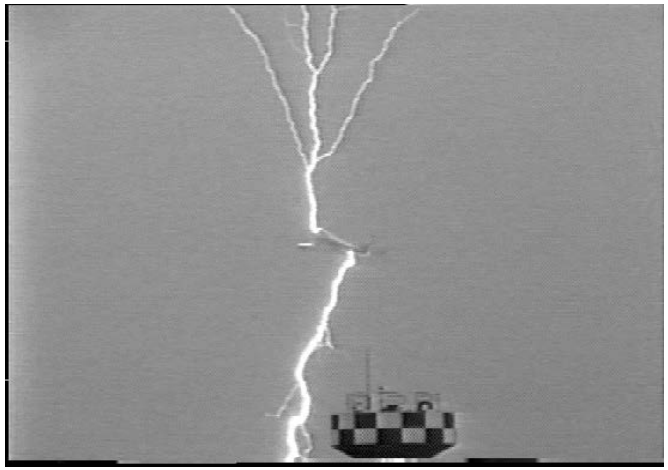
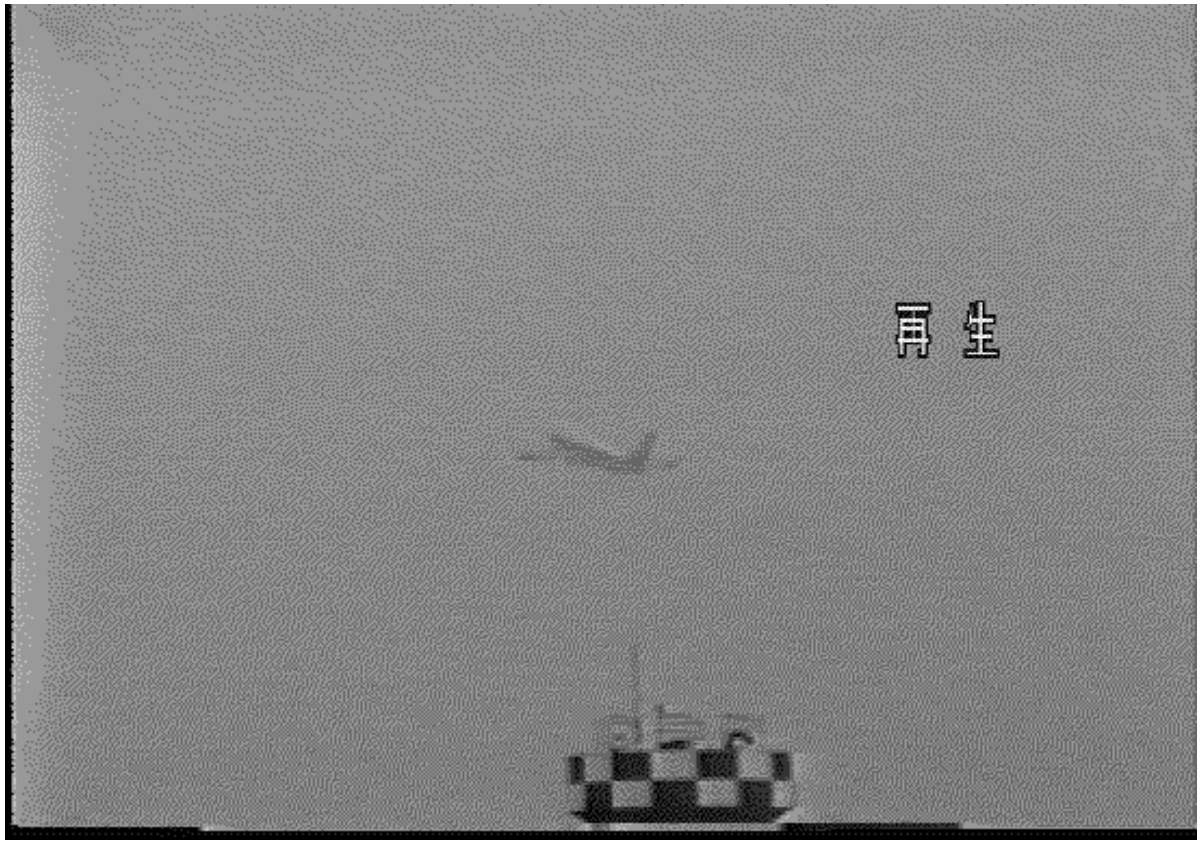
The LI – Role of Lightning – Why do we care?

- Improved knowledge of the state of electrification of thunderstorms (weak electrification within the extended anvils) will improve aviation guidance in the vicinity of airports and en route.

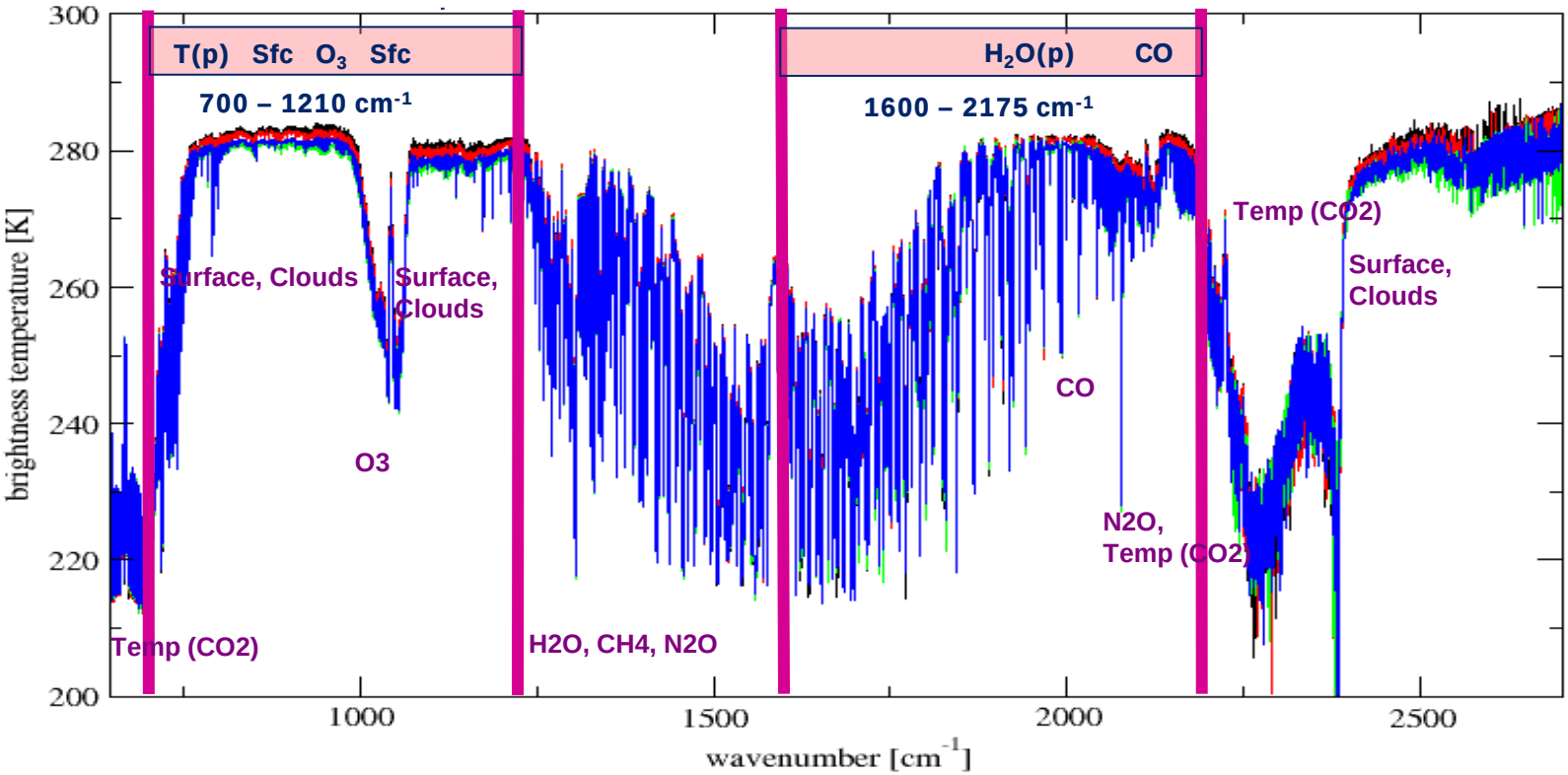




Source: Kawasaki, Univ. Osaka

MTG Mission: InfraRed Sounder (IRS)

- MTG-IRS will deliver unprecedented information on horizontal and vertical gradients of moisture, wind and temperature from the geostationary orbit:
  - Full Disk Sounding;
  - spatial resolution of 4 km,
  - hyperspectral soundings at 0.625 cm-1 spectral sampling in two bands:
    - Long-Wave-IR (LWIR: 700 – 1210 cm-1 ~820 spectral samples)
    - Mid-Wave-IR (MWIR: 1600 – 2175 cm-1 ~920 spectral samples)



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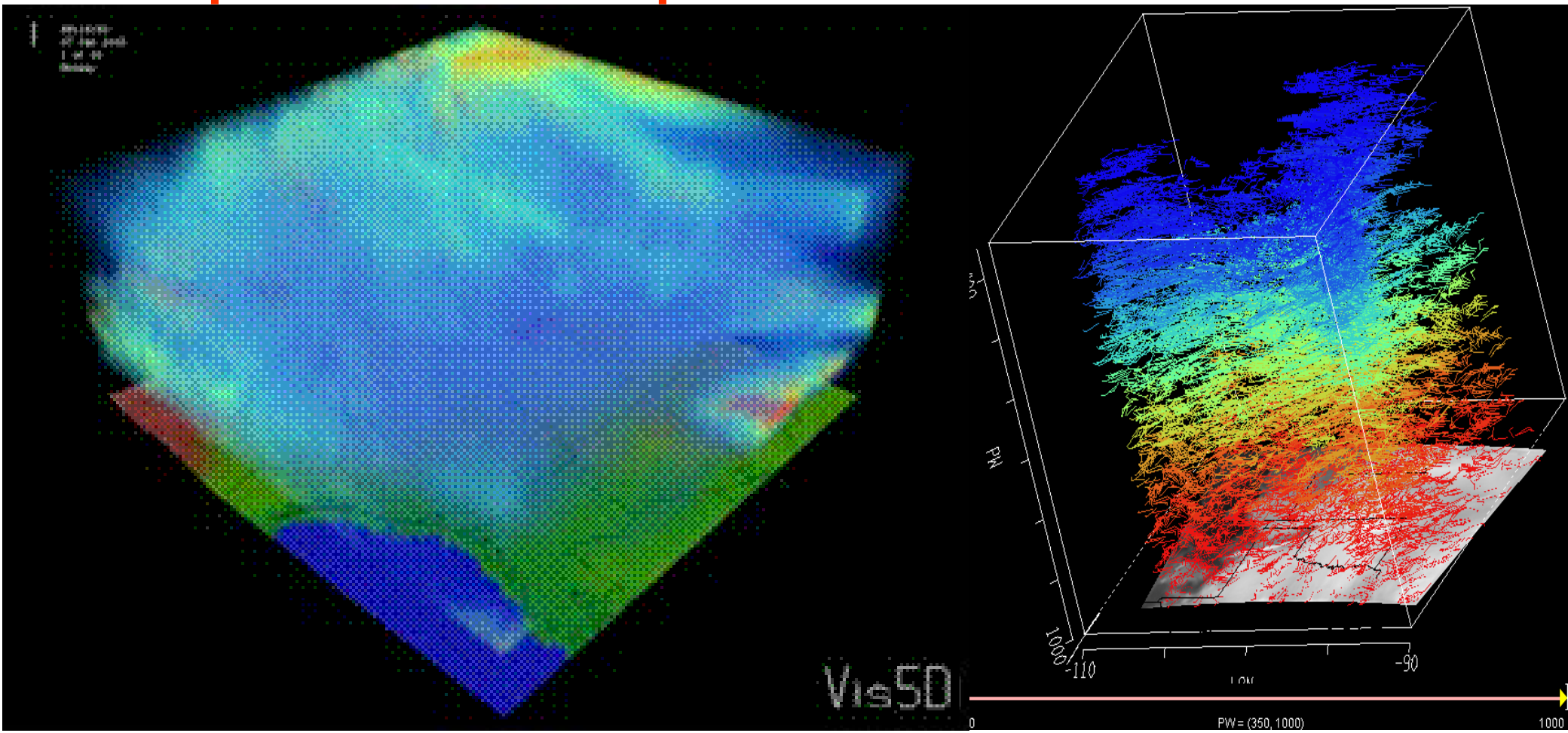
MTG-IRS observations

time sequence of water vapour structures **simulated AMVs**



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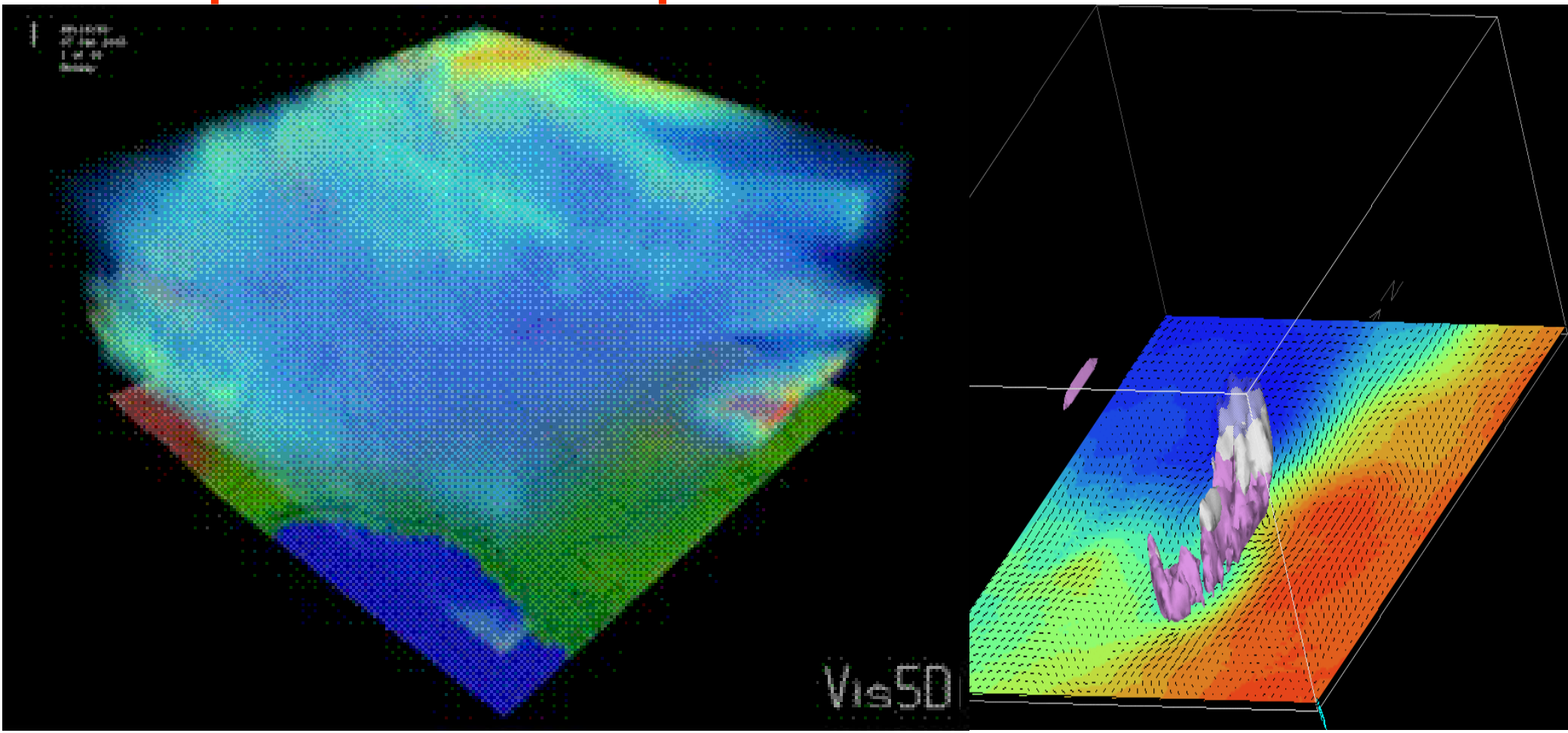
MTG-IRS and short range NWP

time sequence of water vapour structures **model convection**



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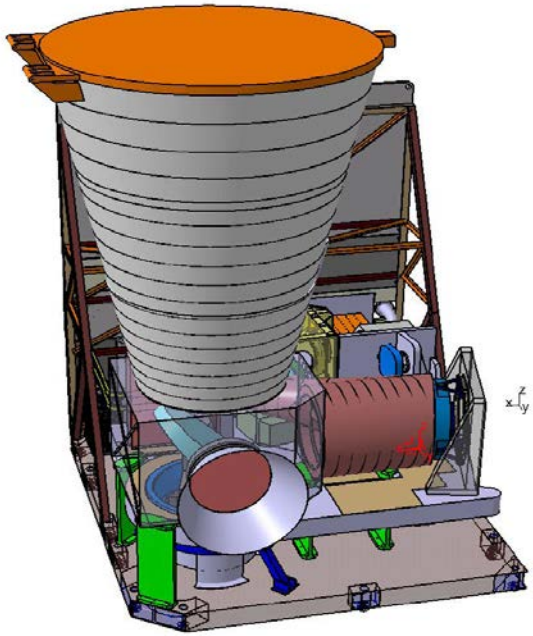
MTG-IRS Instrument Characteristics

- The InfraRed Sounder (IRS) is based on
  - an imaging interferometer with a hyperspectral resolution of 0.625 cm^{-1},
  - 2 detector arrays with each 160 x 160 detectors,
  - taking measurements in two bands: the Long-Wave InfraRed (LWIR, 700–1210 cm^{-1} or 14.3–8.3 µm) with 800 spectral channels and the Mid-Wave InfraRed (MWIR, 1600–2175 cm^{-1} or 6.25–4.6 µm) with 900 spectral channels,
  - with a spatial resolution of 4 km,
  - with a basic repeat cycle of 60 min.



Volume: 1.4 x 1.6 x 2.2 m^3
Mass: 400 kg
Power: 750 W

The IRS will provide e.g. highly resolved vertical structures of humidity, temperature (+ boundary layer temperature profile), ozone, and wind.....

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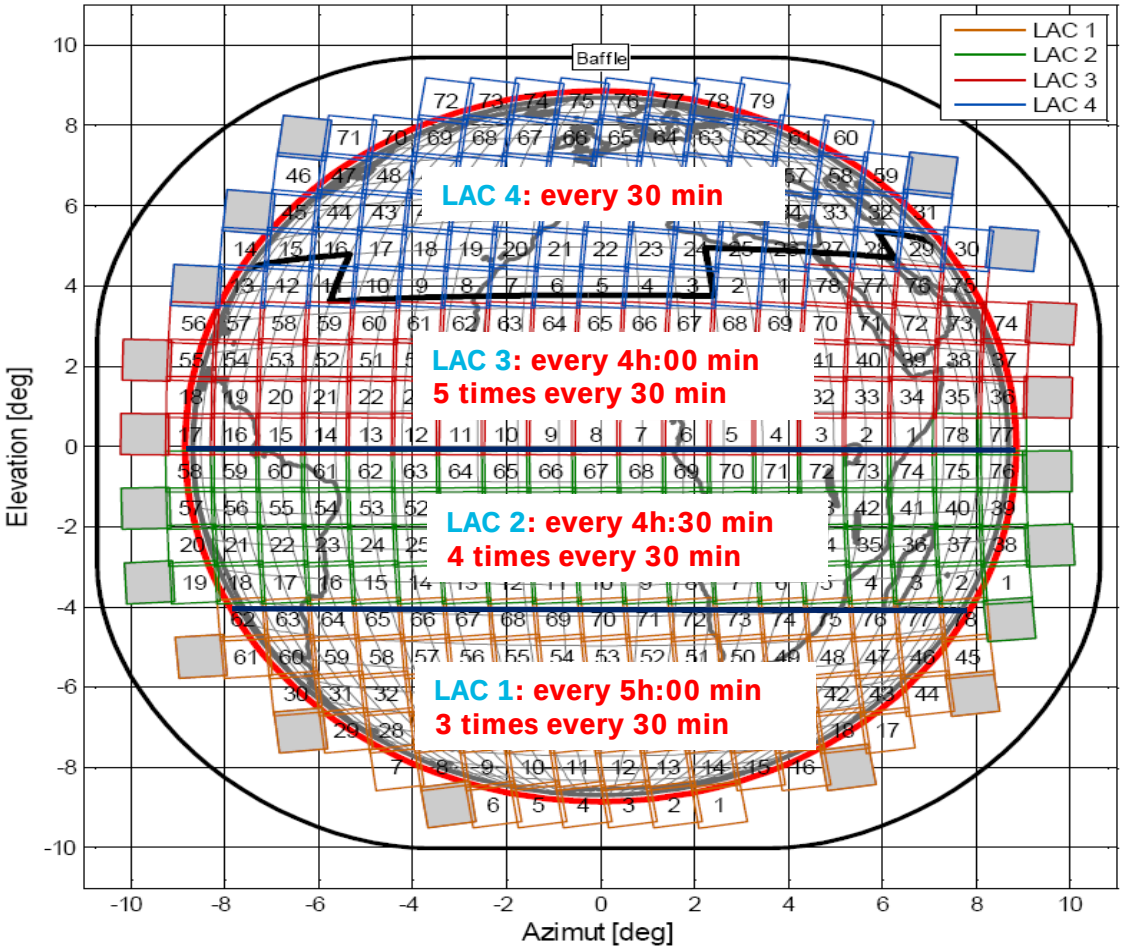
MTG-IRS Concept: Every 30 Minutes Europe

~ 300 stares for Full Disc Coverage

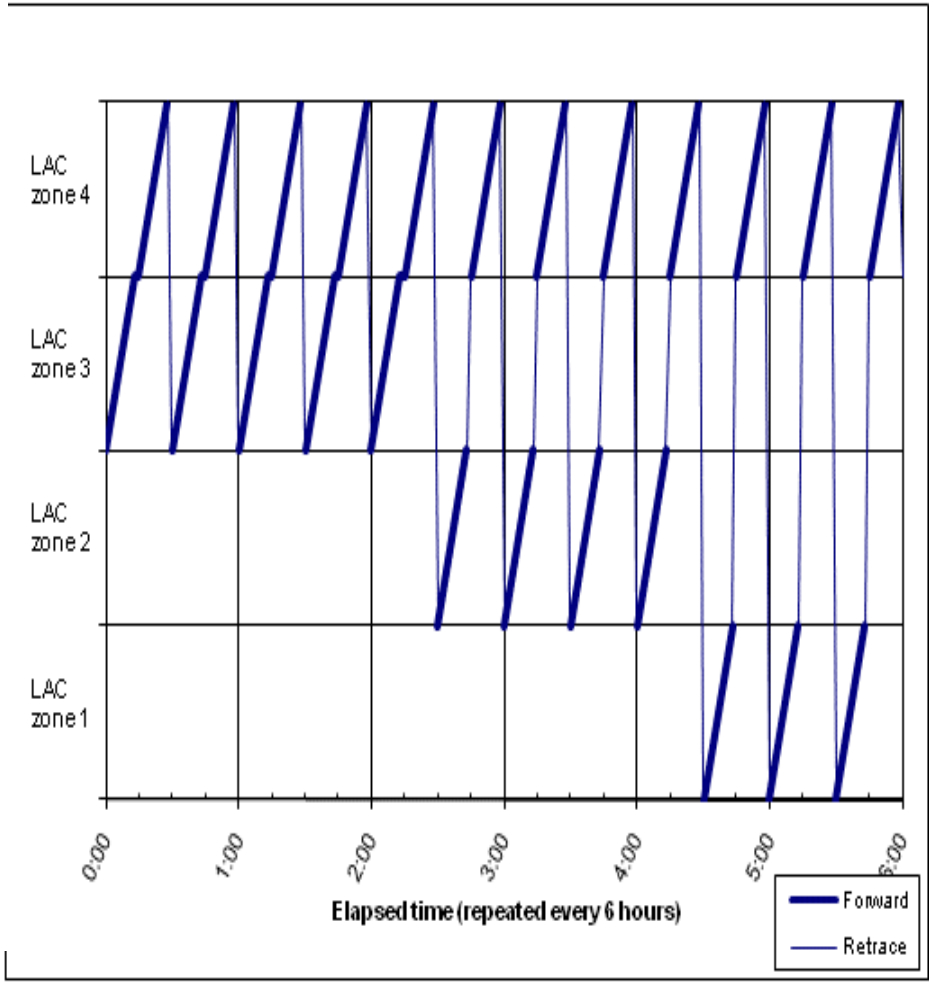
78 LAC1 + 78 LAC2 + 78 LAC3 + 79 LAC4 = 313 Dwells



~ 75 stares Local Area Coverage (LAC)

LAC-1/2/3/4 repeat cycle: 15 min including 2-3 min for calibration

MTG-IRS Operations Scenario



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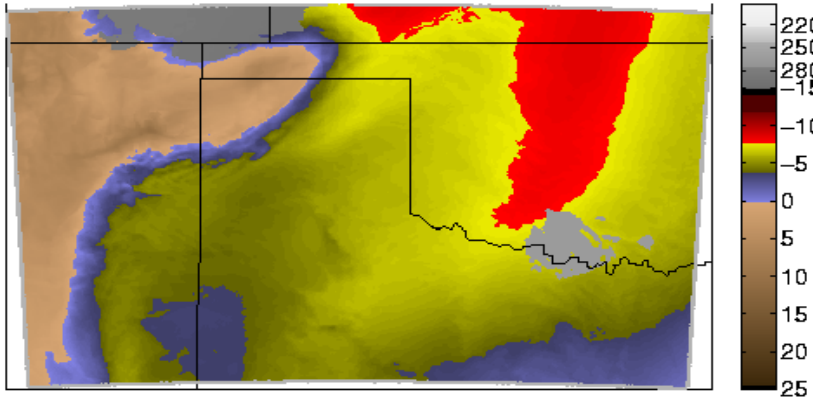
Simulating the Geo-IRS perspective

University of Wisconsin-Madison Space Science and Engineering Center
Cooperative Institute for Meteorological Satellite Studies

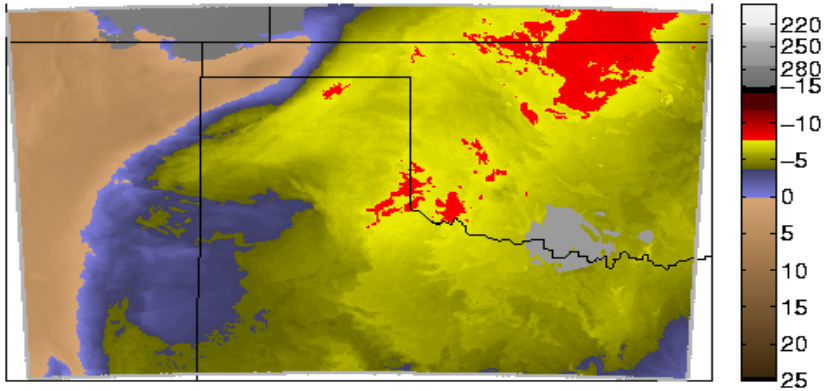
True

06–12–2002, 1200 UTC
Lifted Index [°C]



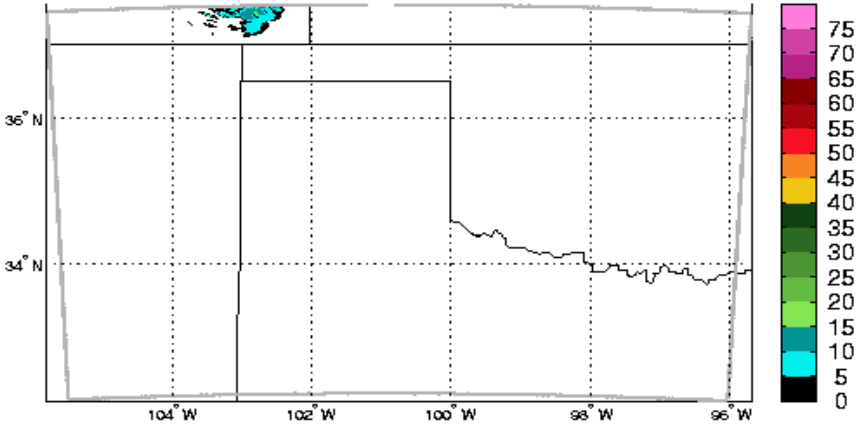
GIFTS/HES/IRS

06–12–2002, 1200 UTC
Lifted Index [°C]



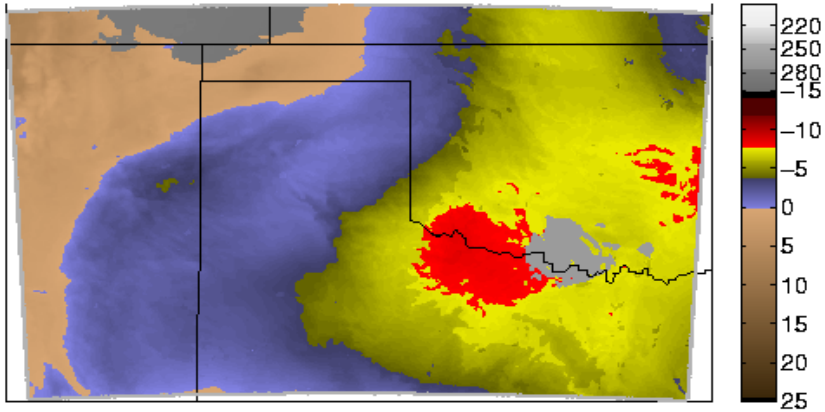
Red = extreme instability

06–12–2002, 1200 UTC
Radar reflectivity [DBZ]



UW/CIMSS

06–12–2002, 1200 UTC
Lifted Index [°C]



UW/CIMSS

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Summary User Priorities on MTG Missions

Absorbed Shortwave Radiation	Cloud Top Phase	All Sky Radiances
Active Fire Detection / Monitoring	Cloud Top Pressure	Rainfall Potential and Probability
Aerosol/Dust Detection	Cloud Top Temperature	Rainfall Rate/ Multisensor QPE
Aerosol Optical Thickness	Cloud Type	Reflected Solar Radiative Flux TOA
Aerosol Particle Size	CO Concentration	Scene Analysis
All Sky Radiances	Convection Initiation	Sea & Lake Ice/Age
Aircraft Icing Threat	Atmospheric Motion Vectors	Sea & Lake Ice/Concentration
Air Mass Analysis	Downward Longwave Irradiance	Sea & Lake Ice/ Displacement and Direction
Atmospheric Moisture Profile	Downward Shortwave Irradiance	Sea & Lake Ice/Extent and Characterization
Atmospheric Temperature Profile	Emitted Longwave Radiative Flux TOA	Sea Surface Temperature
Capping Inversion Information	Enhanced Overshooting Top Detection	Snow Cover
Clear Sky Masks	Fire Radiative Power	CO Concentration
Clear Sky Radiances	Fire Radiative Energy	Surface Albedo
Clear Sky Reflectance Map	Flood/Standing Water	Surface Emissivity
Climate Data Set	Global Instability Indices	Total Precipitable Water
Cloud Coverage	High Resolution Precipitation Index	Total Water Content
Cloud Ice Water Path	Humidity Products (upper/midlevel rel. Hu)	Turbulence
Cloud Imagery	Ice Covered Land	Upward Longwave Radiation at Surface
Cloud Layers / Heights and Thickness	Land Surface (Skin) Temperature	Vegetation Fraction LAI
Cloud Liquid Water	Lightning Detection	Vegetation Index
Cloud Mask	Low Cloud and Fog	Visibility
Cloud Optical Depth	Moisture Flux	Volcanic Ash
Cloud Particle Size Distribution	Ozone Layers	Wind Divergence
Cloud Top Height	Ozone Total	

MTG Flexible Combined Imager	MTG Infrared Sounder	MTG Lightning Imager

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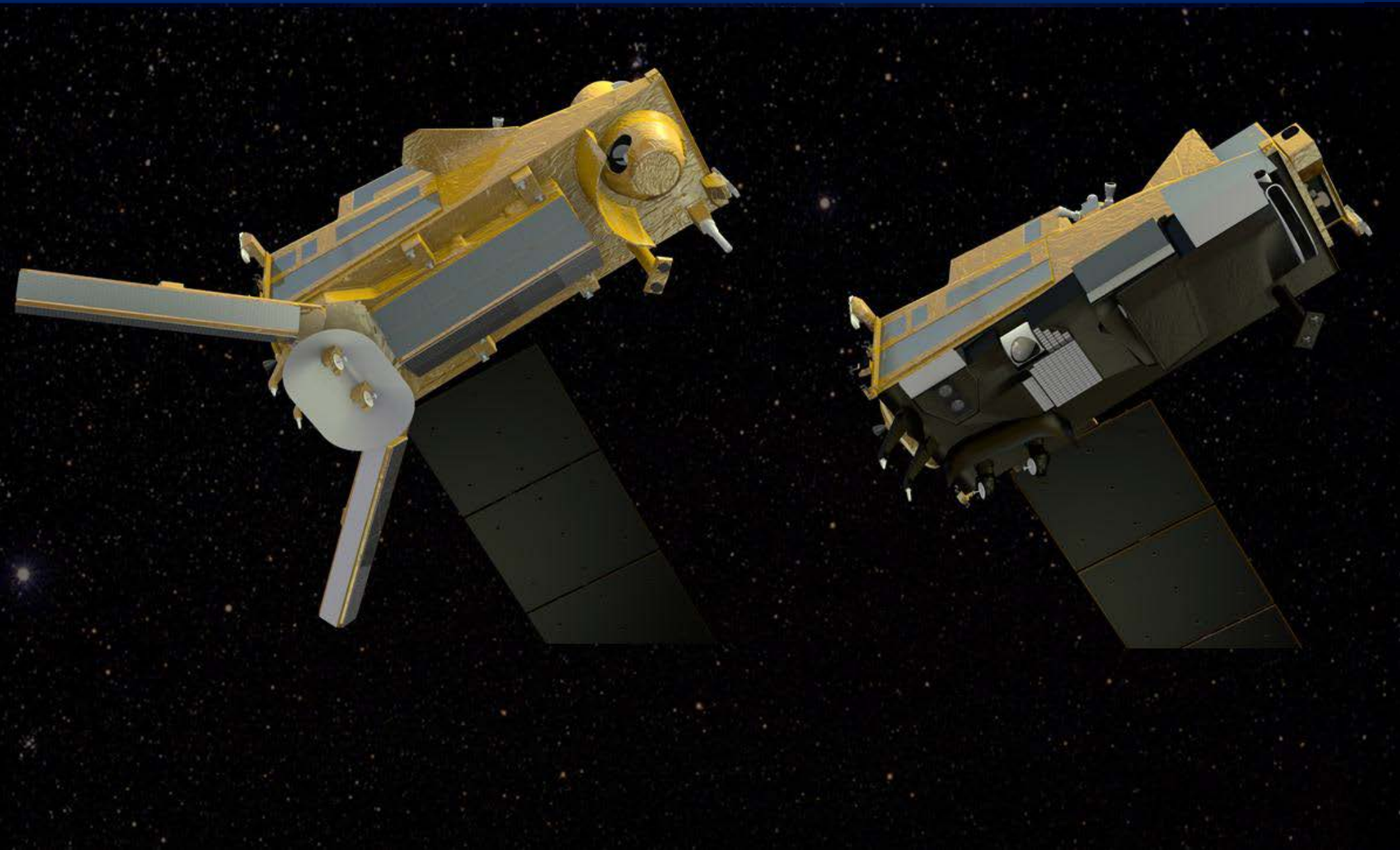
IRS NRT Demonstration service planned for Europe

- Aims to involve potential operational users of MTG-IRS Level 2 products in the development of the level 2 processor.
- The results of this evaluation will be used to identify limitations of the envisaged products and where possible to start mitigation actions in light of the experience with the proxy data.
- The near real time demonstration project is expected to start before 3Q 2016, and will run for 6 months.
- It will be based on level 2 products from IASI (on Metop-A and B) and CrIS (on NPP-1)
-
- Besides vertical profiles for temperature and humidity and their uncertainty, and the surface temperature and its uncertainty, also the so-called scaled projected states (and the associated Observation Operator) of these two variables will be made available.

EPS Second Generation: A twin satellite system



EPS Second Generation

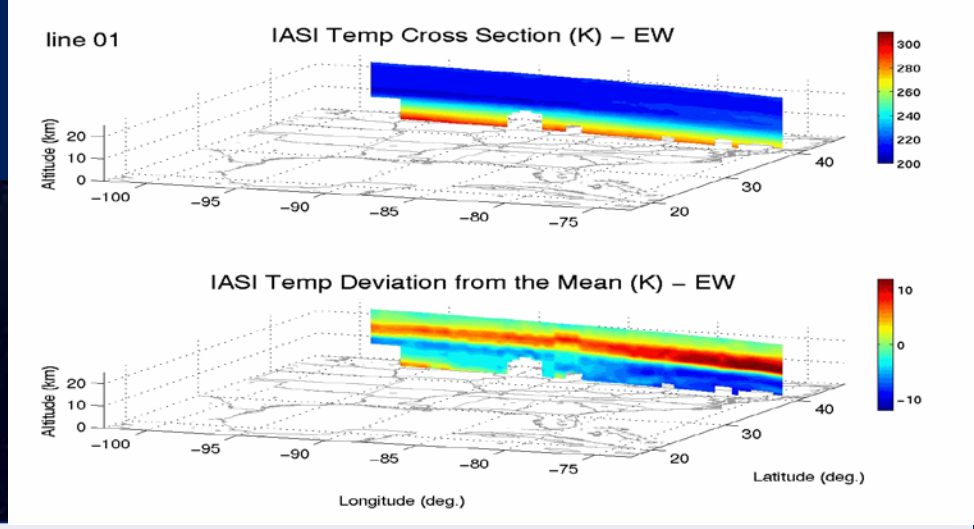
- Continuation and enhancement of service from mid morning polar orbit in 2021 – 2040
- Twin satellite in-orbit configuration:
  - Metop-SG A: optical imagery and sounding mission
    - Flies the Copernicus Sentinel-5 instrument
  - Metop-SG B: microwave imaging mission
- Two series of 3 successive satellites for 21 years of operations
- Orbit @ 09:30 LTDN (Same as Metop)
- Phasing of Sat-a and Sat-b 180°

	Satellite a	**Satellite b**
Payload	METImage, IASI-NG, MWS, 3MI, S-5, RO	SCA, MWI, ICI, ARGOS-4, RO
Launch mass	3661 kg	3339 kg
Power	2.3 kW	2.0 kW
P/L data rate	54 Mb/s	6.3 Mb/s

Observation Missions

Mission	Instrument	Applications Benefitting
Hyper-spectral Infrared Sounding	IASI-NG	NWP, NWC, Air Quality, CM
Visible/Infra-red Imaging	METimage	NWC, NWP, CM, Hydrology, Oceanography
Microwave Sounding	MWS	NWP, NWC, CM
Radio Occultation Sounding	RO	NWP, CM
Nadir viewing UV/VIS/NIR/SWIR Sounding	Sentinel 5	Ozone-UV, Air Quality, CM, Composition-Climate interactions
Multi-viewing, -channel, -polarisation Imaging	3MI	Air Quality, CM, NWC
Scatterometry	SCA	NWP, NWC, Oceanography, Hydrology
Microwave Imaging	MWI	NWP, NWC, Hydrology, CM, Oceanography
Ice Cloud Imaging	ICI	NWP, NWC, Hydrology, CM

Hyper-spectral infrared sounding: IASI – NG



- **Objectives**
  - Temperature/humidity profile at high vertical resolution
  - Clouds, trace gases (O_3, CO, CH_4, CO_2,...)
  - Sea/land/ice surface temperature
  - Aerosols, Volcanic Ash

- **Implementation**
  - Development of Fourier Transform
  - Spectrometer IASI-NG by CNES

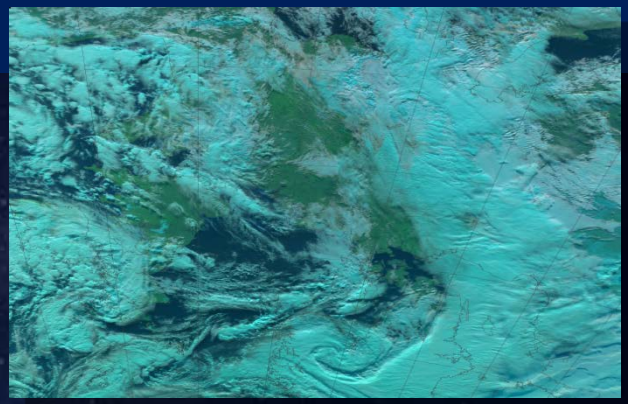
- **Key performances**
  - spectral range: 645 – 2760 cm-1
  - spectral resolution: 0.25 cm-1
  - radiometric calibration: 0.25 K
  - stability: 0.1 K
  - Radiometric noise: 0.045 – 1.1 K
  - pixel size: 12 km
  - spatial sampling: 25 km
  - cross-track scan

Breakthrough

- **Doubling of radiometric and spectral resolution of IASI for the benefit of weather forecast and atmospheric composition**
  - 75% more information in temperature profiling, particularly PBL
  - 30 % more information in water vapour profiling
  - Quantification of trace gases which are currently only detected
  - Vertical resolution of trace gases instead of columnar amounts only

Optical imaging

METimage



- **Objectives**
  - Hi-res cloud products, incl. microphysics
  - Aerosols
  - Polar AMVs
  - Vegetation, snow, fire
  - Sea/ice/land surface temperature
  - Support to sounding missions
- **Implementation**
  - Development of *METimage* by DLR
- **Key performances**
  - 20 channels: 0.443 – 13.345 µm
  - absolute calibration: 5% (short-wave)
    - 0.5 K (long-wave)
  - radiometric sensitivity:
    - SNR 60 – 500 (short-wave)
    - 0.05 – 0.2 K (long-wave)
  - spatial sampling: 500 m
  - cross-track scan

Breakthrough

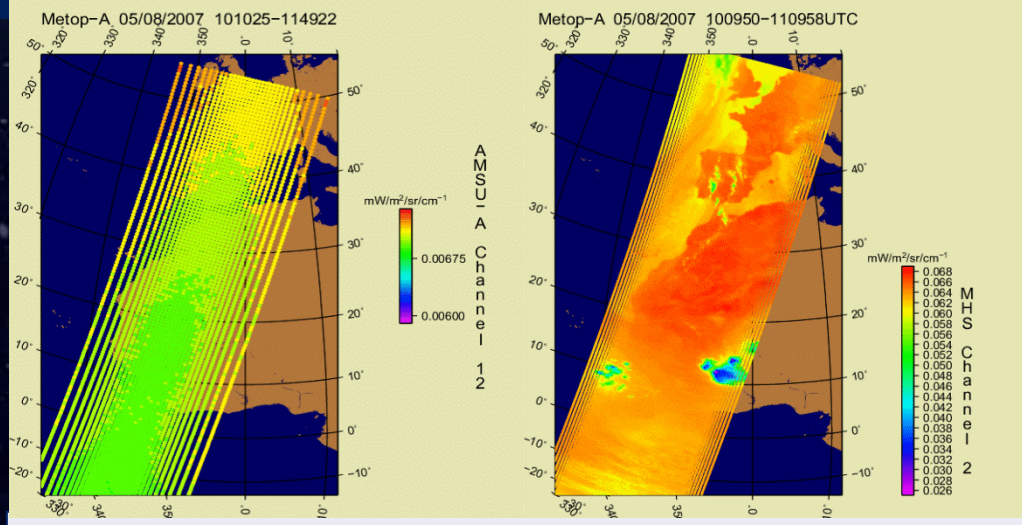
- **Far more spectral channels than AVHRR for the benefit of measuring more variables**
- **Higher spatial resolution (500 m):**
  - more complete coverage through greater likelihood to measure surface variables in partly cloud conditions
- **Better radiometric resolution for more accurate quantification of many variables**

Microwave Sounding

- **Objectives**
  - Temperature/humidity profiles in clear and cloudy air
  - Cloud liquid water total column
  - Imagery: precipitation

- **Implementation**
  - ESA development

- **Key performances**
  - 24 channels: 23.8 – 229 GHz
  - absolute calibration: 0.5 K
  - radiometric noise: 0.2 – 1.6 K
  - footprint size: 17 – 40 km
  - cross-track scan



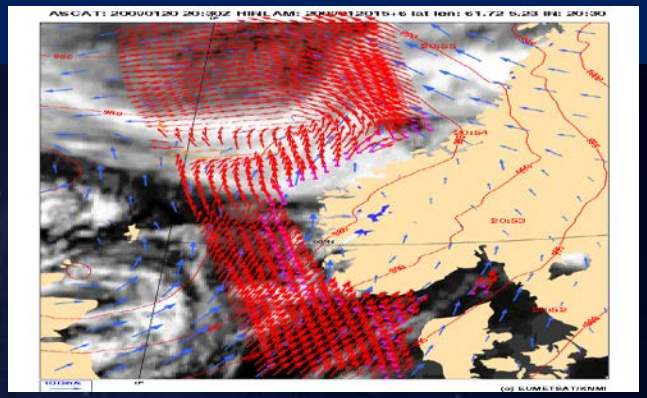
Breakthrough

- **Addition of a quasi-window channel at 229 GHz (recommended by ITSC-11)**
  - Cirrus cloud information giving a better humidity retrieval performance

- **Addition of sounding channels**
  - **+ 2 channels at 53-54 GHz**
  - **+ 3 channels at 183.31 GHz**

  - More information on temperature and water vapour profiles

Scatterometry



- **Objectives**
  - ocean surface wind vectors
  - soil moisture
  - snow equivalent water
  - sea-ice type
- **Implementation**
  - ESA development
- **Key performances**
  - C-band carrier frequency
  - VV + VH polarisation
  - measurement range: 4 – 40 m/s
  - Radiometric resolution: 3%
  - spatial resolution: 25 km
  - dual swath: 550 km each

Breakthrough

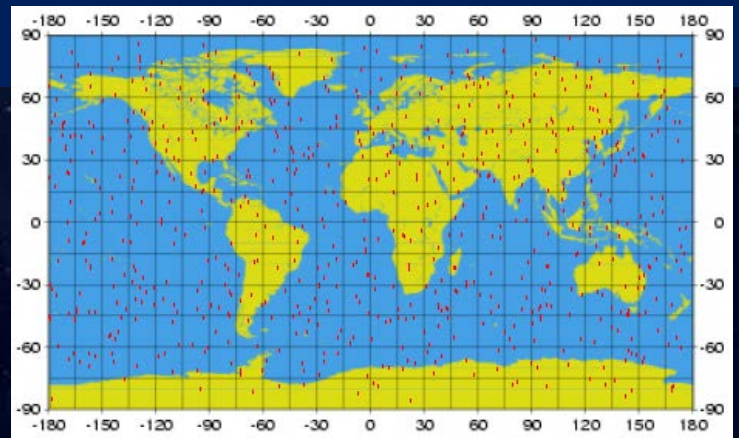
- **Increase of spatial resolution to 25 km**
  - Better approach of coast lines
- **Increase of swath width to >1100 km**
  - Enhanced coverage
- **Addition of VH polarisation**
  - Covers higher wind speeds without saturation, will benefit observation of tropical and extra-tropical storms

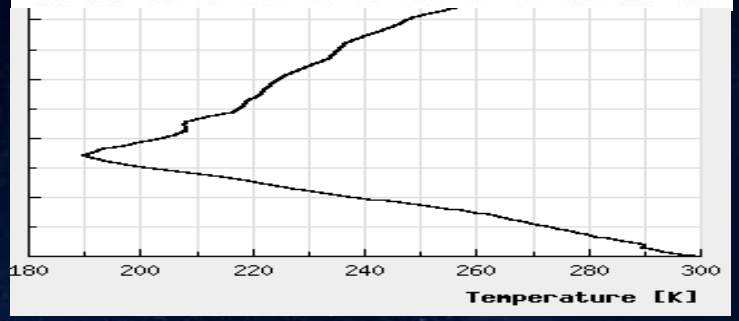
Radio-Occultation

- **Objectives**
- Refractivity profiles at high vert. resolution
- Temperature / humidity profiles
- PBL top and tropopause height
- Ionospheric electron content

- **Implementation**
- ESA development

- **Key performances**
- tracking of GPS and Galileo satellites
- optional: GLONASS and COMPASS
- RO on two satellites: > 2600 occultations per day
- bending angle accuracy: 0.5 µrad or 0.2%





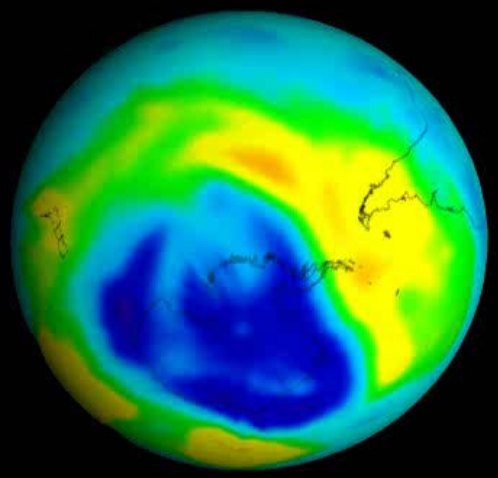
Breakthrough

- **Tracking of GPS and Galileo satellites to double the number of occultation measurements**

- **Equipment of both Metop-SG satellites with RO in case of a dual satellite configuration**

UVNS Nadir Viewing
UV/VIS/NIR/SWIR sounding

- **Objectives**
- Ozone profile and column
- Columns of CO_2,SO_2, NO_2, H_2O, CO, CH_4,
- Aerosol optical depth
- Columns of BrO, HCHO, OCHCHO
- Volcanic Plumes
- **Implementation**
  - GMES Sentinel-5 to be embarked
  - on Metop-SG, ESA development
- **Key performances**
- spectral range: 0.27 – 2.385 µm
  - spectral resolution: 0.25 – 1 nm
- radiometric calibration: 1 – 2%
- SNR: 120 - 1500
- spatial sampling: 7 km
- Cross-track scan



Breakthrough

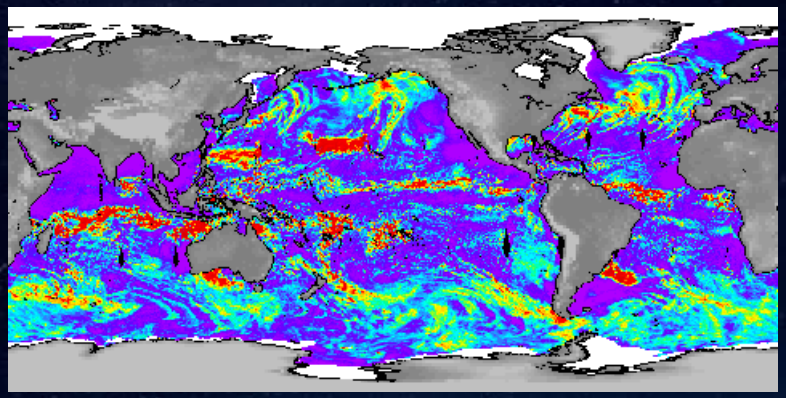
- **Drastically increased spatial sampling (7 km)**
  - for the benefit of air quality monitoring
- **Extended spectral range into the near and shortwave infrared regions**
  - to measure aerosols as well as methane and carbon monoxide in the PBL

Microwave Imaging

- **Objectives of a new mission**
- precipitation and cloud products
- water vapour profiles and imagery
- sea-ice, snow, sea surface wind

- **Implementation**
  - ESA development

- **Key performances**
- 18 channels: 18.7 – 183 GHz
- dual polarisation (V, H) up to 89 GHz
- V polarisation at higher frequencies
- radiometric accuracy: 1 K
- radiometric sensitivity: 0.6 – 1.2 K
- Footprint size: 10 – 50 km
- spatial sampling: 7 km
- conical scan



Breakthrough: 18 channels

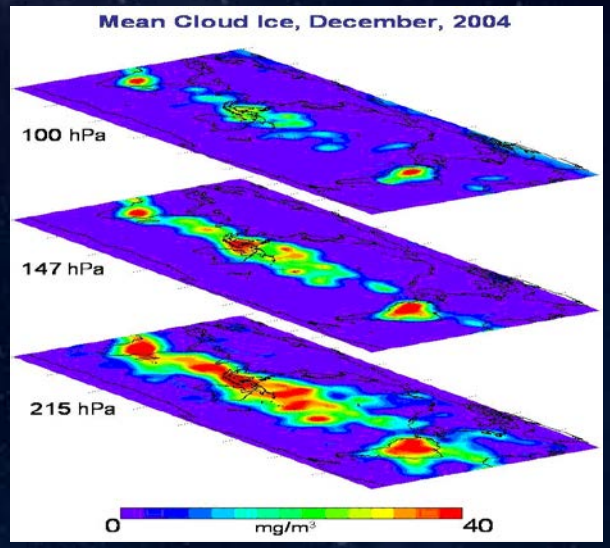
- **Continuity of key microwave imager channels for weather forecast**
- **Inclusion of dedicated sounding channels (118.75 GHz)**
  - Enhanced precipitation measurements through inclusion of dedicated sounding channels
- **Extended suite of 183.31 GHz channels**
  - water-vapour and cloud profiling

Ice Cloud Imaging

- **Objectives of a new mission**
- Cloud products, in particular ice clouds
- Snowfall detection and quantification
- Water-vapour profiles and imagery

- **Implementation**
  - ESA development

- **Key performances**
- 11 channels: 183 – 664 GHz
- single polarisation (V) for all channels
- dual polarisation (V, H) at 243 and 664 GHz
- radiometric accuracy: 1 – 1.5 K
- radiometric sensitivity: 0.6 – 1.9 K
- Footprint size: 15 km
- spatial sampling: 7.5 km
- conical scan

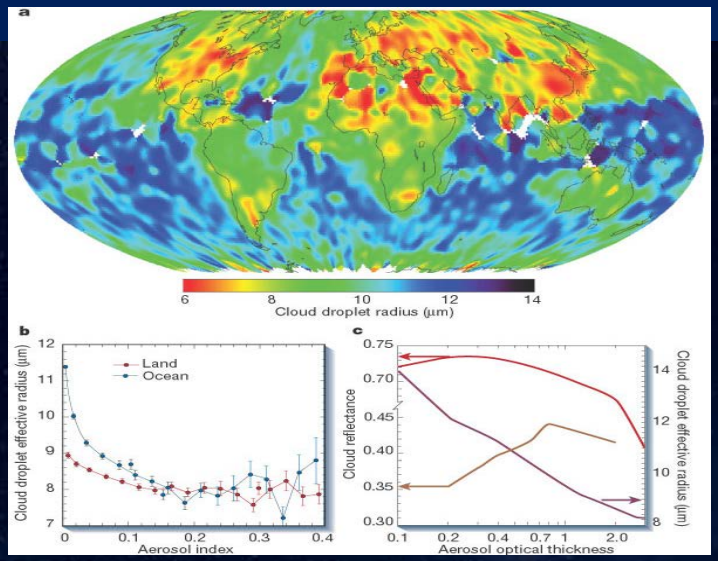


Breakthrough: 11 channels

- **Establishes operational ice-cloud imaging mission**
- **Support of weather forecast, hydrology, and climate monitoring**

Multi-viewing multi-channel multi-polarisation Imaging

- **Objectives of a new mission**
- Aerosol – optical thickness, particle size, type, height, absorption
- Volcanic Ash
- Cloud phase, height, optical depth
- Surface albedo



Kaufman et al. (2002)

- **Implementation**
  - ESA development

- **Key performances**
- 12 channels: 0.41 – 2.13 µm
- 3 polarisations: 0°, 60°, -60°
- 14 views
- radiometric bias: 3%
- SNR: 200
- spatial sampling: 4 km
- push-broom scan (2200 km swath)

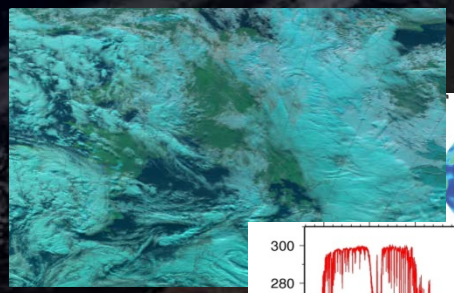
Breakthrough:

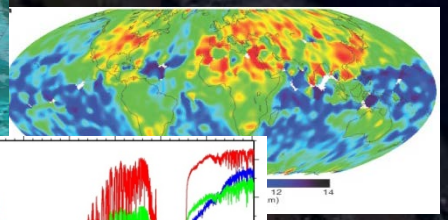
- **Enhanced spatial sampling (4 km)**
  - Improves separation of cloudy areas
- **12 spectral channels (9 polarised), extending into the UV and SWIR**
  - Better aerosol characterisation
- **Higher angular resolution (14 views)**
  - Better phase function characterisation

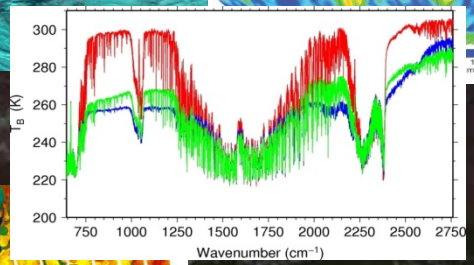
EPS Second Generation
Synergy of observation missions

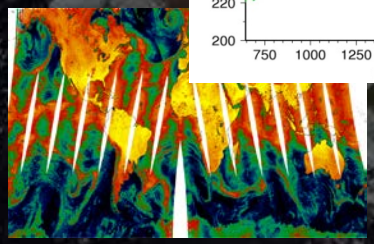
Observation missions are highly complementary

- Co-registration of measurements will allow to optimise the information extraction
- Synergy to be considered in payload distribution of a dual satellite configuration







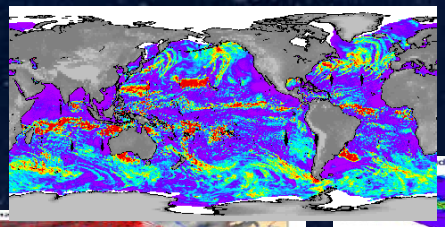


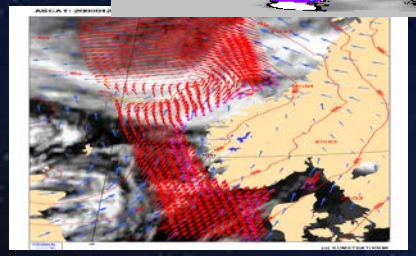
Essential co-registrations

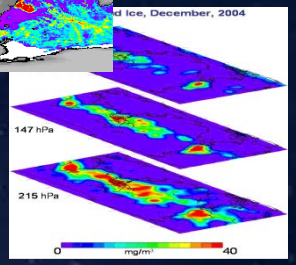
- IAS – VII – UVNS
- MWI - ICI

Desired co-registrations

- IAS – MWS
- VII – 3MI
- IAS – UVNS – 3MI
- MWI – SCA – VII







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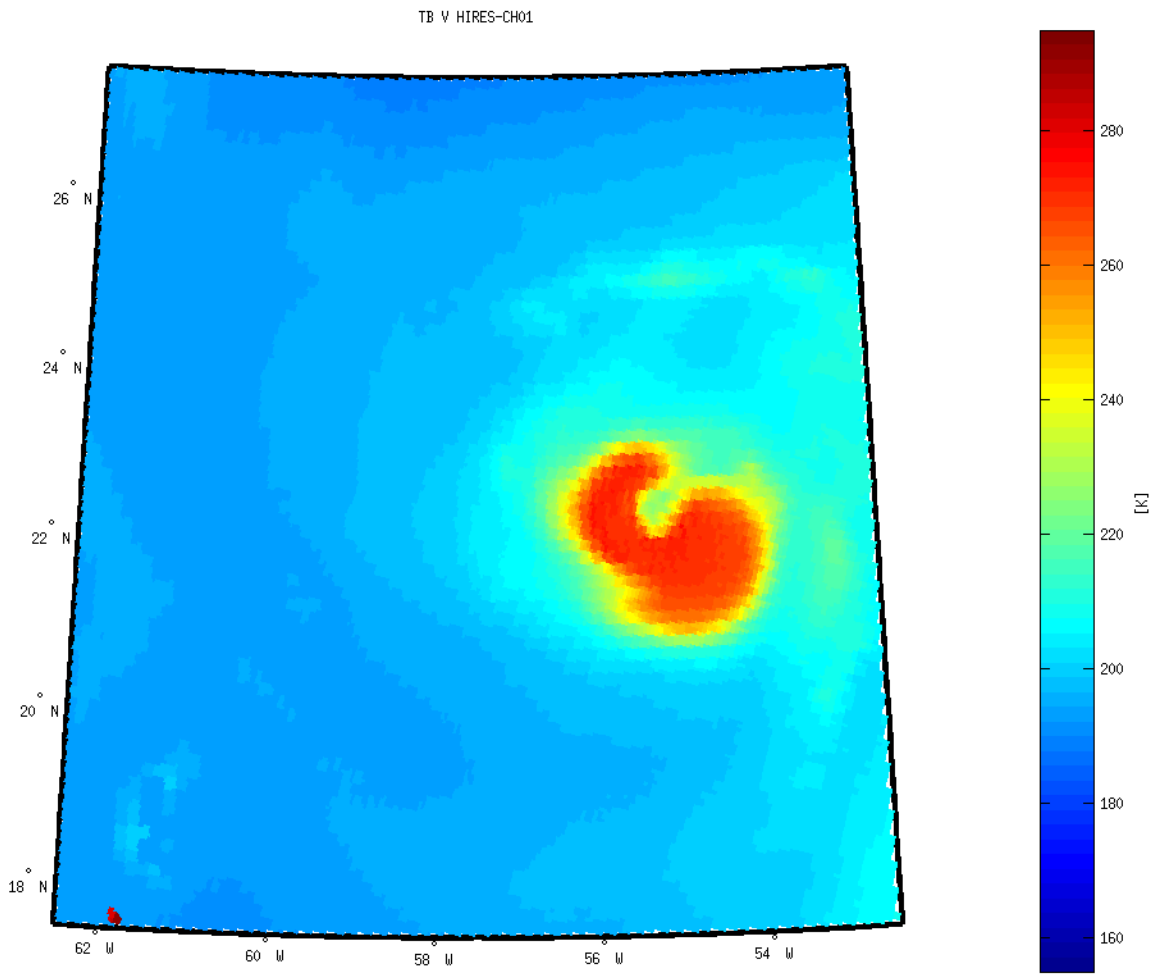
Test Data: MWI-1 HiRes



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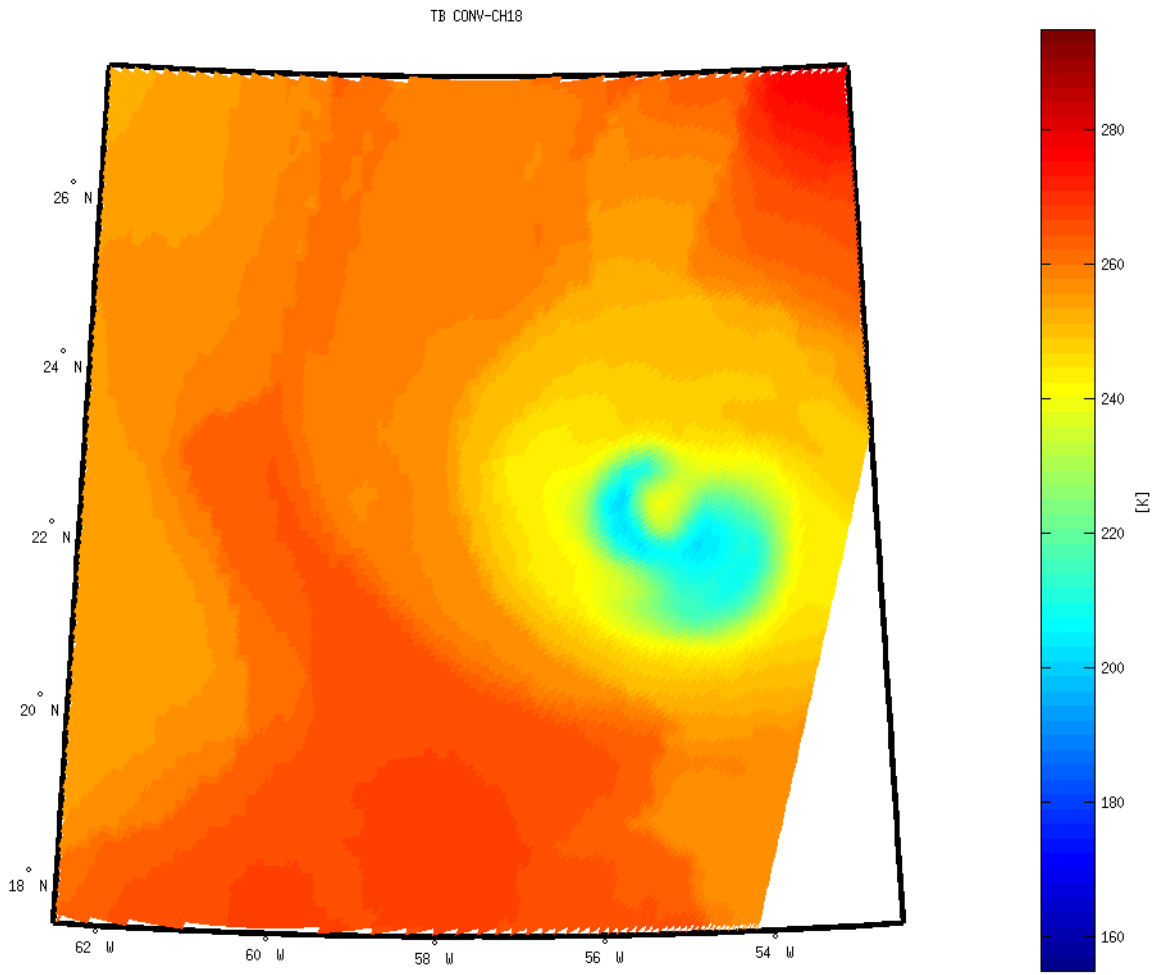
Test Data: MWI Channels 1 - 18

Channel	Frequency (GHz)
MWI-1	18.7
MWI-2	23.8
MWI-3	31.4
MWI-4	50.3
MWI-5	52.610
MWI-6	53.24
MWI-7	53.750
MWI-8	89.0
MWI-9	118.7503±3.20
MWI-10	118.7503±2.10
MWI-11	118.7503±1.4
MWI-12	118.7503±1.2
MWI-13	165.5±0.75
MWI-14	183.31±7.0
MWI-15	183.31±6.1
MWI-16	183.31±4.9
MWI-17	183.31±3.4
MWI-18	183.31±2.0



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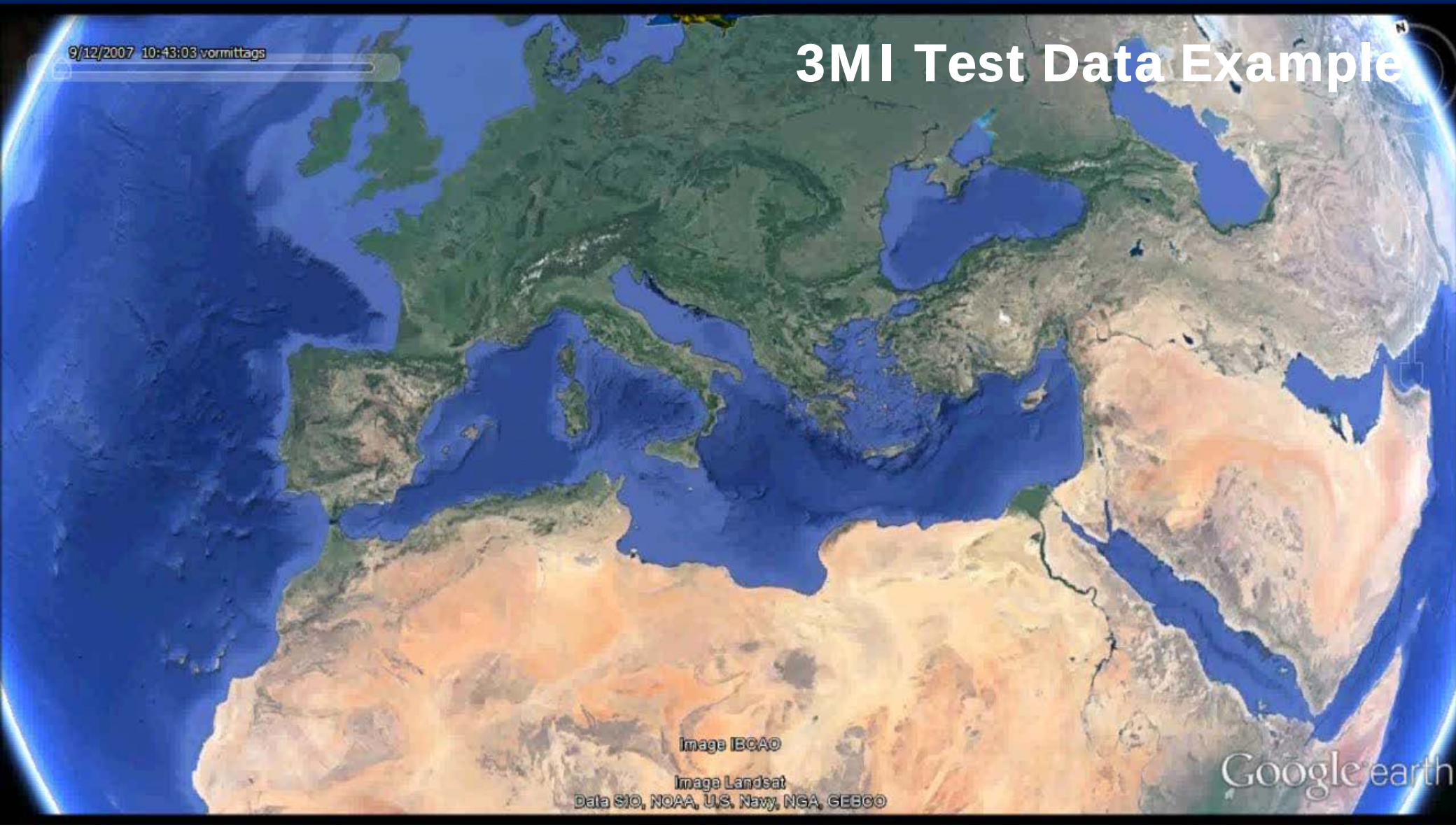
Thank You – Any Questions



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