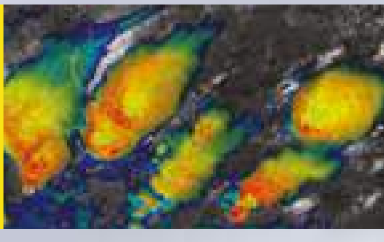
METEOSAT THIRD GENERATION

THE CASE FOR PREPARING NATIONAL USERS



MONITORING WEATHER AND CLIMATE FROM SPACE

EUMETSAT

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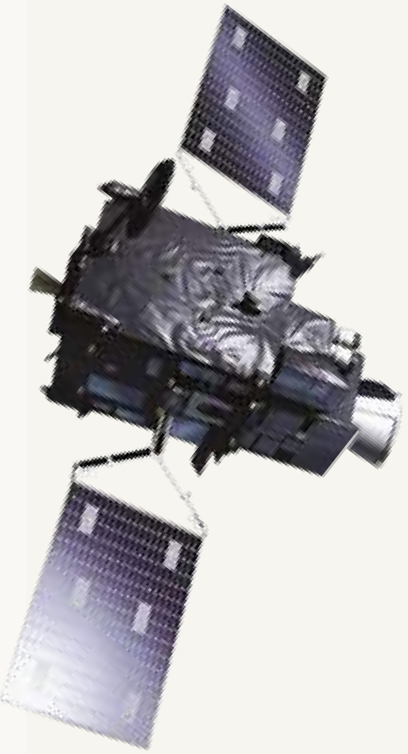
A WORD FROM THE DIRECTOR-GENERAL OF EUMETSAT



The impact of severe storm events on economies in Europe has significantly increased over the past decade compared to earlier decades, as shown in loss statistics maintained by the re-insurance sector. Hail, high winds, extreme rainfall and related flash floods pose hazards to the lives and property of European citizens. The ability of National Meteorological and Hydrological Services (NMHS) to forecast severe storms with lead times of several minutes up to a few hours ahead provides a vital 'last line of defence' for vulnerable economic sectors such as transport, tourism, and for the first responders in emergency services.

In preparing for the upcoming Meteosat Third Generation satellites (MTG), European NMHS are adding a powerful capability to their forecasting services: 4-dimensional observations of the key ingredients in severe weather that will provide new insight into convective processes, especially the formation and development of potentially dangerous storms. A '4D Weather Cube' such as this is composed of atmospheric soundings of temperature and humidity, derived wind information, lightning observations and imagery. All of these data will be collocated and available from a geostationary orbit at high temporal and spatial resolution.

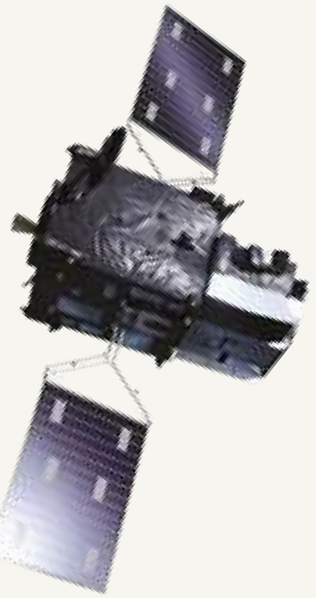
MTG will constitute a massive leap forward with respect to the existing Meteosat Second Generation satellites that have been serving Member State NMHS reliably since the early 2000s: MTG data will provide continuity of observations from geostationary orbit and enable innovation in weather forecasting at the most critical timescales. It does so by providing vital and unique observations that better inform the forecast scenario in the critical half an hour or hour ahead. MTG data will also continue the ongoing Meteosat climate data record, starting in 1981 and extending it well into the 2040s.

In the run-up to the launch of the first MTG Imager satellite, currently scheduled in Q4 2021, Member States are invited to evaluate their respective elements of meteorological data reception, processing and visualisation infrastructure and related human resources in light of massively increased data volumes, the novelty of data especially from the Lightning Imager (LI) and the InfraRed Sounder (IRS), and new data formats and means of data delivery. Additional investments in national infrastructure may be required to ensure user readiness when MTG data become available.

In support of the preparation by Member State NMHS to MTG, I am enclosing the package 'MTG: The Case for Preparing National Users', intended to inform NMHS decision-makers and national administrations. The package highlights the main improvements to weather and related environmental services expected from the MTG mission, and provides technical details relevant for procurement purposes as an annex. Along the same lines, I encourage all Member States to participate actively in the MTG User Preparation Project (MTGUP), which fosters information exchange and support among Member States.

I wish you every success in preparing for MTG!

Alain Ratier
Director-General



1 METEOSAT THIRD GENERATION (MTG): A GREAT LEAP AHEAD

Meteosat Third Generation (MTG) is a highly innovative geostationary satellite system for Europe and Africa to support meteorological and related environmental services, especially for improving forecasts from several minutes up to a few hours ('nowcasts').

Forecasts such as these are the 'last line of defence' in weather forecasting, vital to protect the life and property of citizens in the case of severe storm events, and for complementing the skill of numerical weather prediction models. MTG will also provide important, novel data to further enhance numerical weather prediction, air quality monitoring, and other applications. As the successor of the current Meteosat Second Generation (MSG), MTG has the capability to fulfil the geostationary satellite data requirements of Member States, needed to continue supporting and improving applications and services at national meteorological centres. The first MTG data are planned to be available in 2022.

The MTG programme, adopted by Member States of EUMETSAT in 2011, derives directly from the EUMETSAT Convention. Furthermore, EUMETSAT Member States are committed to the MTG mission for two main reasons:

VALUING CONTINUITY

Transitioning to MTG allows Member States to safeguard their investment in weather-related services and skills that build on data from the current Meteosat Second Generation (MSG) satellites. While providing higher resolution in space and time, the spectral channels of the MTG imagery mission include the heritage of MSG. MTG allows for the continuation of the Meteosat-based climate data record, going back to 1981, into the 2040s. In addition, new opportunities arise from additional spectral imager channels, e.g. for creating 'true colour' imagery, or for better detecting and understanding clouds. Using MTG data, Member States can preserve and enhance the value of their existing MSG-related applications and services.

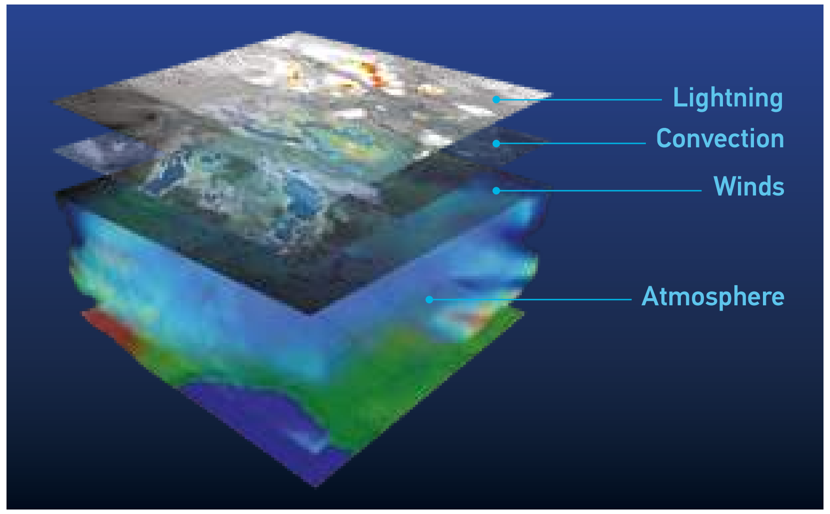


Figure 1: Artist's illustration of the '4D Weather Cube', enabled by Meteosat Third Generation instruments which probe the atmosphere in three dimensions and with high repeat cycle, for the first time over Europe. Forecasters will be able to simultaneously track meteorological phenomena, such as convection, winds and lightning activity, and, thus, more accurately detect and forecast rapidly developing high-impact weather, like thunderstorms.

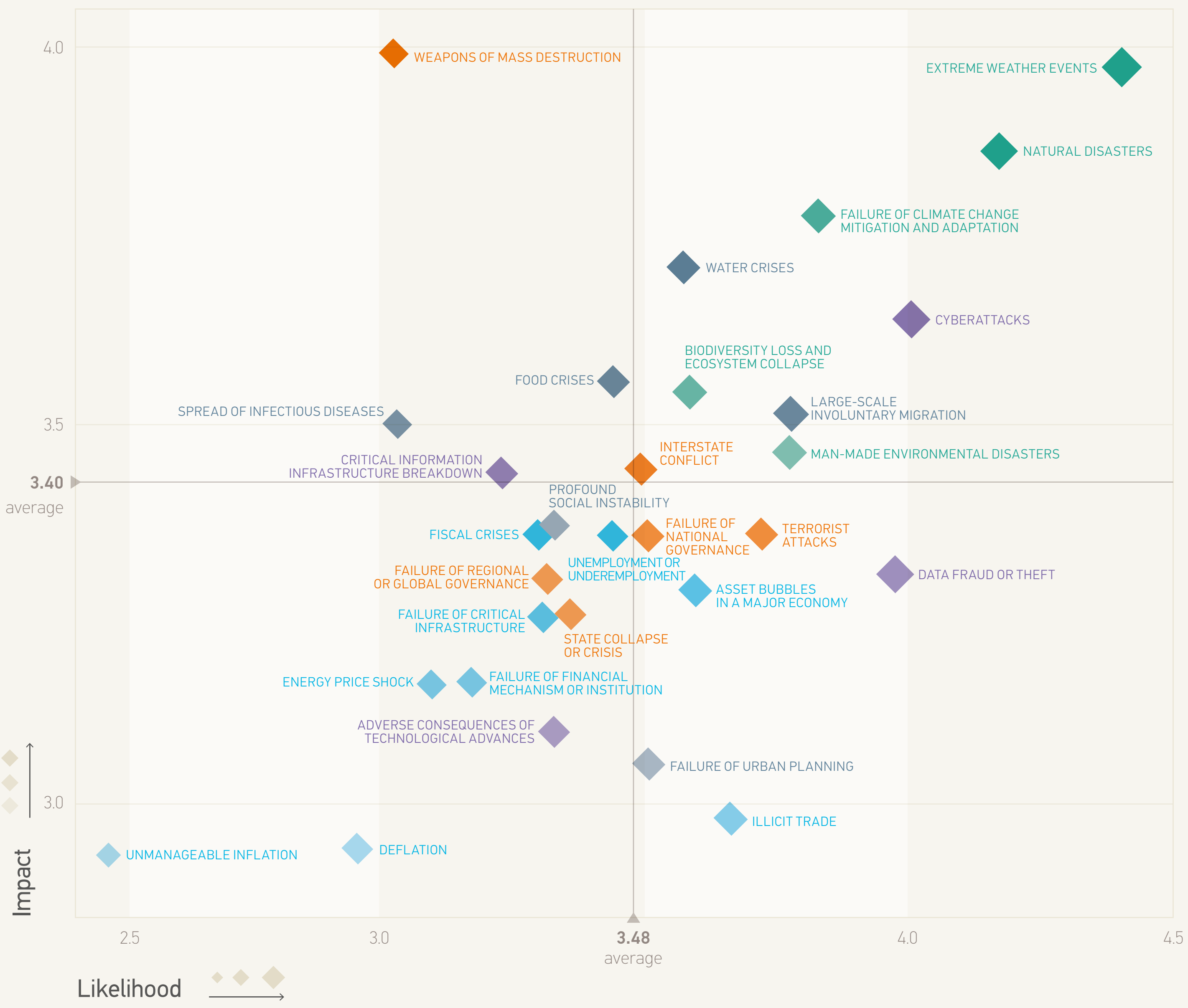
ENABLING INNOVATION

The lightning and infrared sounding missions of MTG offer novel data types to European users with high innovation potential. Unprecedented information on the dynamic features of atmospheric moisture and temperature will be available every 30 minutes over Europe at high vertical and horizontal resolution from the operational geostationary infrared-sounding mission. By adding collocated spectral imagery and lightning data to the '4D Weather Cube', national services are expecting a breakthrough in gaining precious prediction lead time through early detection of rapidly-developing high-impact weather events, such as severe storms. Among other uses, lightning data will provide air traffic management with information on electrically active storms. Air quality monitoring over Europe will be enhanced, such as the measuring of nitrogen dioxide, ozone and fine particles. Member States are investing in the scientific development of new methods and tools to exploit the innovation potential of these data.

2 TACKLING MAJOR WEATHER-RELATED ECONOMIC RISKS

Among 30 global risks identified by the World Economic Forum in its 2018 Global Risks Perception Survey, extreme weather events and natural disasters are ranked as the top two global risks in terms of likelihood, and number two and three in terms of impact on economies; the risk of failure to mitigate climate change and adapt to climate change impacts come shortly after.

Figure 2: Global Risks Landscape 2018 (World Economic Forum, 2018)[1]



> *"Traditionally, the overall benefits accrued from investment made in the meteorological and hydrological infrastructures were estimated to be, in several countries, in [the] order of 10:1."*
>
> **M. Jarraud**
> Former Secretary-General of WMO (World Bank, 2013[2])

In the national institutional landscape, National Meteorological and Hydrological Services (NMHS) are key providers of information for reducing the major economic risks associated with extreme weather and natural disasters. The return on investment in national weather service has an estimated benefit-cost ratio of at least 2:1, and often 5-10:1 or more.

Using nowcasting techniques, weather prediction models, satellite and other observational data, NMHS monitor and predict weather-related extremes, and provide authoritative advisories and warnings to the public.

Severe convective storms are some of the most dangerous weather-related events in Europe. Hazards associated with severe storms include flash floods, hail, heavy rain, gale-force wind gusts, and lightning. Over the period 2007-2017, the losses from convective storms in Western Europe amounted to around €35 billion[4].

Satellite data make a substantial contribution to improving weather and related services, i.e. in saving lives and property. Satellite data are important for nowcasting services, especially in areas with sparse coverage of ground-based observing systems, such as over sea. The rapid repeat cycle of geostationary data from MTG forming the '4D Weather Cube' is particularly vital for nowcasting and very short-range forecasting severe weather events up to a few hours. Furthermore, satellite data are the dominant observational data source for assimilation into global numerical weather prediction (NWP) models, which are at the core of weather forecasting services. Data from the current EUMETSAT Metop and future MTG Sounder and EPS Second Generation satellites are key in this regard.

In addition, MTG will enable a range of improvements to the use of satellite data in fire and fog monitoring, and open new applications such as satellite-based air quality monitoring at high temporal frequency.

> *"[For] a range of specific met/hydro services in developed and developing countries, for individuals, households, and a variety of economic sectors, benefit-cost ratios range from 2:1, to 36:1, and are often between 5 and 10:1."*
>
> **Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services (WMO, 2015[3])**

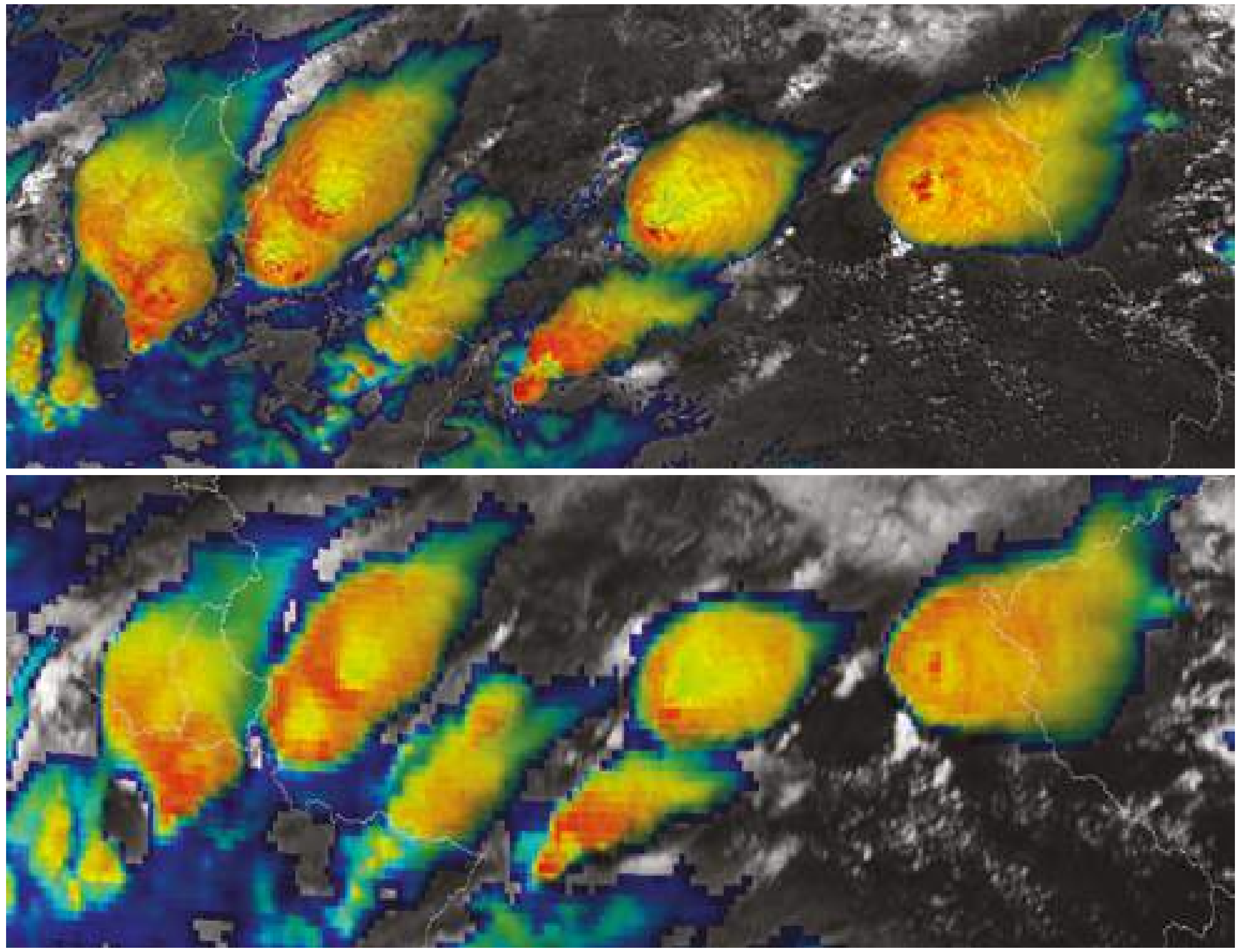
EUMETSAT

3 APPLICATION SCENARIOS FOR MTG DATA

MONITORING AND NOWCASTING SEVERE CONVECTIVE STORMS

Monitoring, tracking and short-term prediction ('nowcasting') of potentially severe storms will benefit greatly from the Flexible Combined Imager (FCI) on board MTG. In this example, satellite imagery[5] shows a series of convective storms over Central Europe. Areas of lowest cloud top temperature and the most active convection appear in dark red. The MTG FCI instrument will provide imagery at a higher spatial resolution (1 km spatial sampling distance, upper panel) than is available currently from Meteosat Second Generation channels (3 km spatial sampling distance, lower panel). This, together with double sampling frequency (every 2.5 minutes compared to 5 minutes currently) enables forecasters to better see cloud top details, thus, more accurately assess storm intensity and make short-term predictions several minutes ahead.

Figure 3: Convective storm clouds over Central Europe, as seen from current Meteosat imagery (lower panel) and with imagery simulating the higher-resolution future MTG imaging mission (upper panel), enabling a better view of cloud top details and, thus, more accurate assessments of storm intensity



DETECTING CONVECTIVE INITIATION, A PRECURSOR OF POTENTIALLY SEVERE STORMS

This example[6] from the current American Geostationary Operational Environmental Satellite (GOES)-East Advanced Baseline Imager (ABI) over Kansas, USA, illustrates the capability of the future MTG imager to provide early detection of a surface boundary - a severe storm precursor. Valuable situational awareness and potential nowcasting lead time can be gained from such imagery. Looking at the difference between two ABI infrared channels (10.3 µm and 12.3 µm), the right-hand panel shows low-level water vapour, one of the ingredients for severe storms: the region displayed in red-orange extending from the centre to the lower right of the scene indicates deeper low-level water vapour along a boundary. Boundaries often serve as a focal point for convective initiation and sometimes storm formation later in the day[7]. At the same time, the visible channel (left-hand panel, 0.6 µm channel) shows clear skies and no formation of clouds, which are a common precursor for convective development. The boundary was evident about 2.5 hours before the clouds formed, therefore, giving the operational meteorologist additional lead time and, therefore, the ability to provide earlier warnings. The below panel shows the same scene 3.5 hours later, with a fully developed convective system producing severe wind and large hailstones.

Figure 4: Detection of low-level moisture over Kansas, USA (right panel, in orange-red colours, extending from below the centre to the bottom of the scene), a precursor for potentially severe storms, while conventional imagery and ground-based radar detect no signal (left panel)

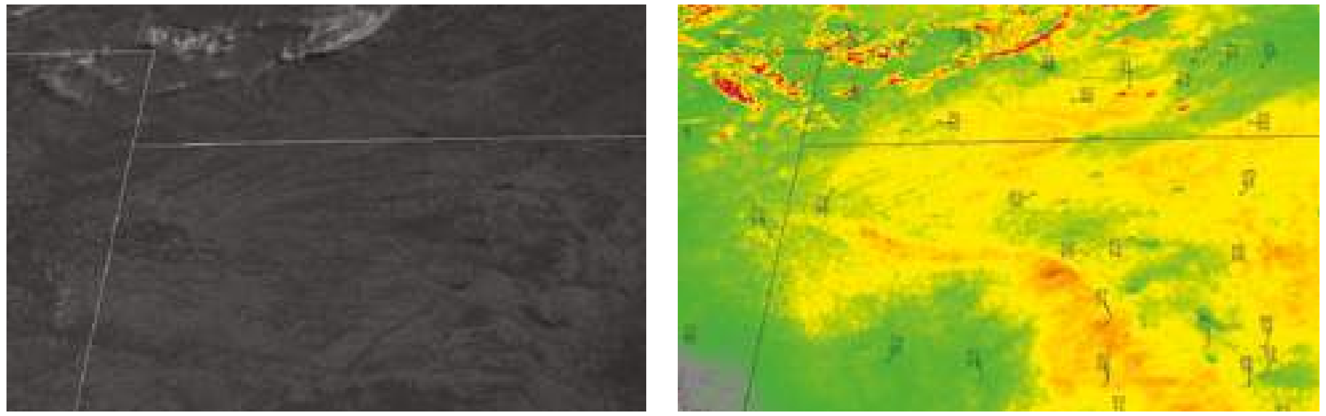
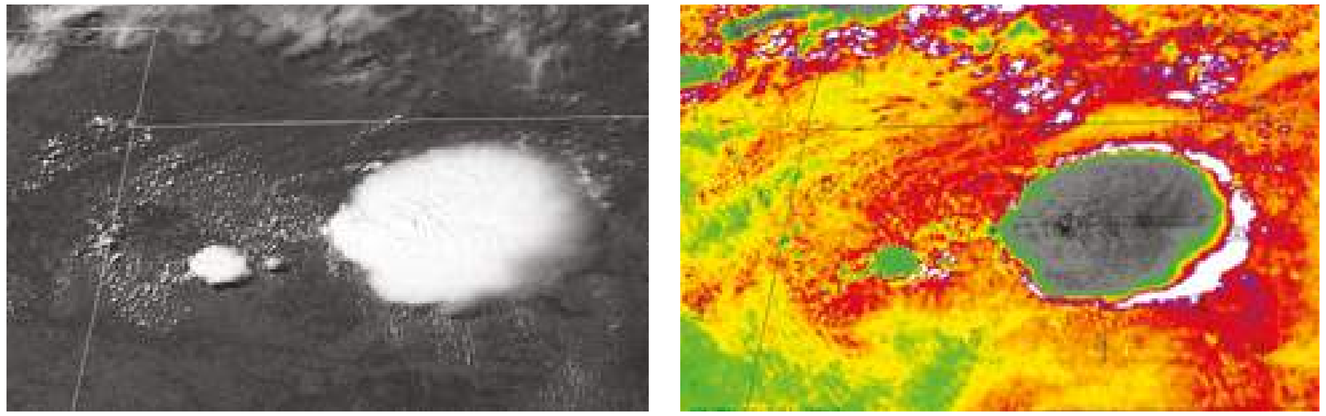


Figure 5: Three and a half hours later, a fully developed hail storm in the same area as shown in Fig. 4



3 APPLICATION SCENARIOS FOR MTG DATA

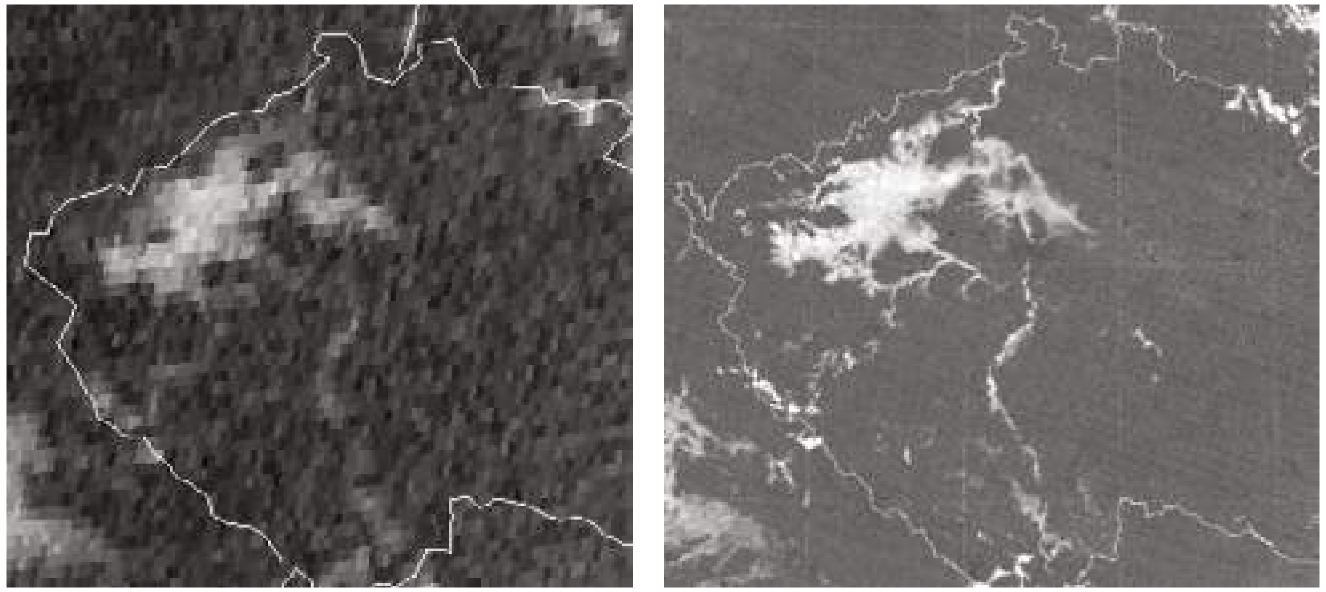
FOG DETECTION FOR TRANSPORT SAFETY

Fog detection benefits greatly from satellite imagery at higher spatial and temporal resolution. MTG imagery will be of higher resolution than from MSG: while 11 of 12 spectral channels of the MSG Spinning Enhanced Visible and Infrared Imager (SEVIRI) are available at 3 km horizontal spatial sampling distance and only one channel at 1 km sampling distance, FCI hosts eight bands at 1 km and eight bands at 2 km sampling distance. These are all available for scanning the full Earth disc every 10 minutes. Moreover, FCI has two bands at 0.5 km and two other bands at 1 km sampling distance for rapidly scanning Europe and adjacent areas every 2.5 minutes.

This example shows thin fog spreading above central Bohemia (Czech Republic)[8]. The product focuses on low clouds detection, based on the difference between two infrared channels (3.8 µm and 11.5 µm), showing fog and low stratus clouds as white and cloud-free terrain in dark grey. The below panel demonstrates the sharper delineation of fog-covered areas, mostly narrow river valleys, in simulated FCI imagery compared to current, lower-resolution MSG SEVIRI imagery.

Fog monitoring is very important for airport operations and air traffic control. Using imagery from the MTG FCI-like GOES ABI, the US National Weather Service has experienced a reduction of lead times for warnings over San Francisco airport, thanks to 5-minute repeat cycle mesoscale rapid scan ABI imagery available at 0.5 km sampling distance and with short timeliness (~2 minutes). Incoming or dissipating fog can, thus, be better monitored than with the old GOES imager (providing 1 km imagery every 15 minutes), alerts issued or lifted at shorter latency, leading to cost savings by airlines.

Figure 6: Detection of early-morning fog over Czech Republic based on current Meteosat imagery (left panel), and with proxy data simulating future MTG imagery (right panel) allowing more precise monitoring of fog location



LIGHTNING MONITORING FOR STORM TRACKING OVER OCEANS

Severe convective storms are usually accompanied by large jumps in lightning activity. The MTG Lightning Imager will, for the first time over Europe and Africa, provide continuous observation of total lightning activity from space, including cloud-to-cloud and cloud-to-ground flashes. This adds particular value to detecting and monitoring convective storms in otherwise data-sparse areas, such as over the ocean and over parts of Africa. This example[9] shows lightning data from the American GOES Geostationary Lightning Mapper (GLM) over a convective line in the Gulf of Mexico. The GOES GLM serves as a precursor for the MTG Lightning Imager. Using satellite-based lightning data, weather forecasters have additional information to more precisely monitor convective development, identify gaps in storms, and observe long flashes behind the convective line, all in an area which is outside the coverage of ground-based weather radars and most lightning detection networks. This is beneficial for issuing weather alerts and for providing information to weather-sensitive economic sectors, such as aviation.

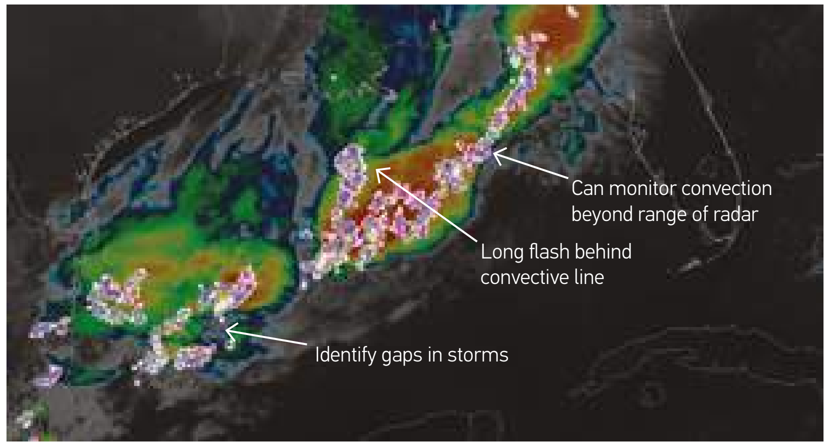


Figure 7: Lightning activity monitored from space (in white-blue-magenta colours) along a convective storm line (yellow-orange-red shades in background infrared imagery) over the Gulf of Mexico

AIR QUALITY MONITORING

Air quality monitoring and management is an important part of environmental regulation. The monitoring of air pollutants such as nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone, formaldehyde, and fine particles is of increasing societal importance. The Copernicus Sentinel-4 Ultraviolet, Visible and Near-infrared Sounder (UVN) instrument will provide hourly information on tropospheric NO_2, and many other air quality parameters over Europe, at a sampling distance of 8 km. NO_2 is a key atmospheric pollutant caused by combustion processes (vehicles, industry, households) and is a major concern in many cities and industrial areas. UVN data will be used within the Copernicus Atmosphere Monitoring Service (CAMS) and by many other users. MTG imagery and IRS soundings are also expected to contribute to air quality monitoring.

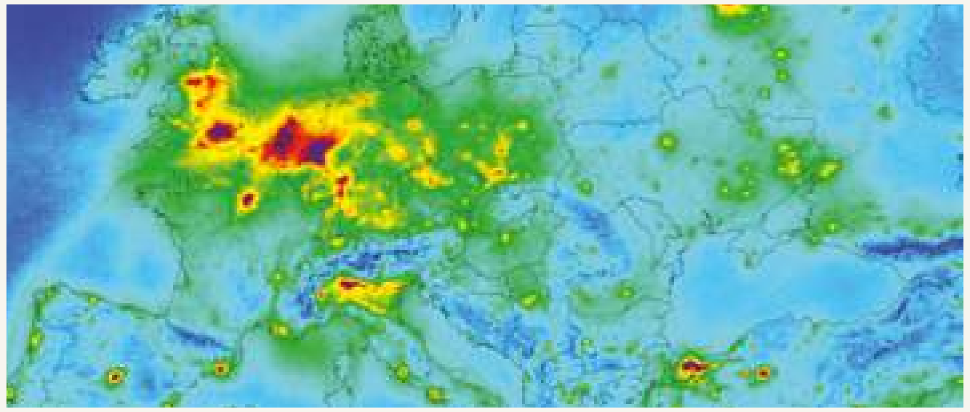


Figure 8: Seasonal average NO_2 tropospheric column map at horizontal resolution of 2 km; TROPOMI instrument on Sentinel-5P © ESA/KNMI, Henk Eskes

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3 APPLICATION SCENARIOS FOR MTG DATA

FIRE DETECTION AND MONITORING

The fire events in Portugal and Greece during the European heat wave in 2018 cost lives, devastated property and burned vegetation. Fire detection and monitoring using MTG FCI-type geostationary imagery has become an important new application area, as experience in using the American GOES and the Japanese Himawari-8 imagers shows: data at 0.5-1 km sampling distance and rapid repeat cycle (2.5-10 minutes with MTG FCI) provide a powerful tool for detecting and fighting fires, detecting smoke, and mapping fire-burned areas. The American forest service has used the fire detection capability of GOES to improve tactical planning in its operations.

The example below from the 2018 Portugal fires showcases the future capability of MTG FCI (right-hand panel) to more accurately monitor the location of fires compared to current Meteosat imagery (left-hand panel)[10]. FCI also has a new infrared channel (at 2.2 μm) for improved fire detection compared to MSG.

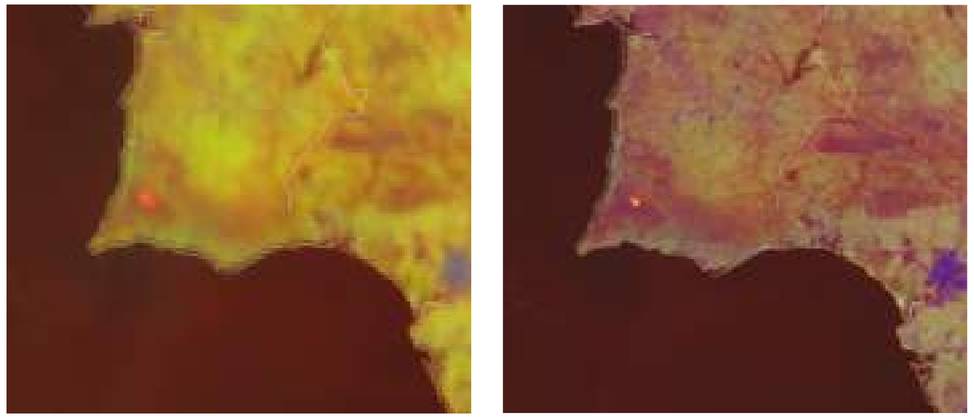


Figure 9: August 2018 fires over Portugal mapped with current Meteosat imagery (left panel), and with proxy data simulating imagery from future MTG (right panel)

The second example showing wildfires in Botswana demonstrates the advantage that FCI will have over current MSG SEVIRI imagery in locating fires and in estimating their intensity[11].

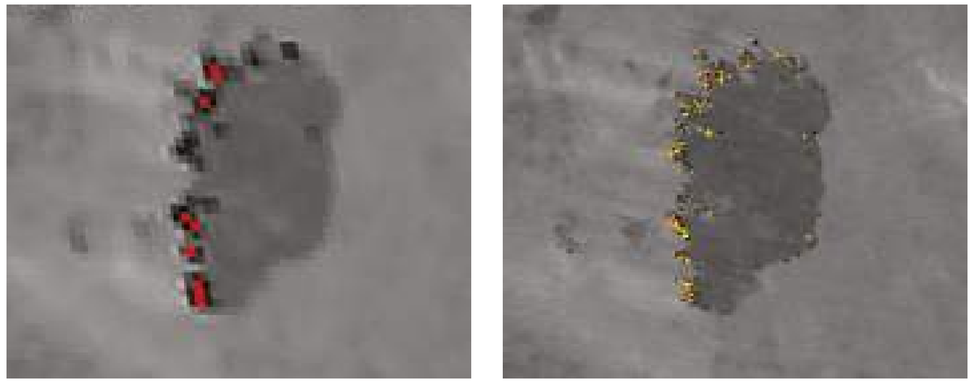
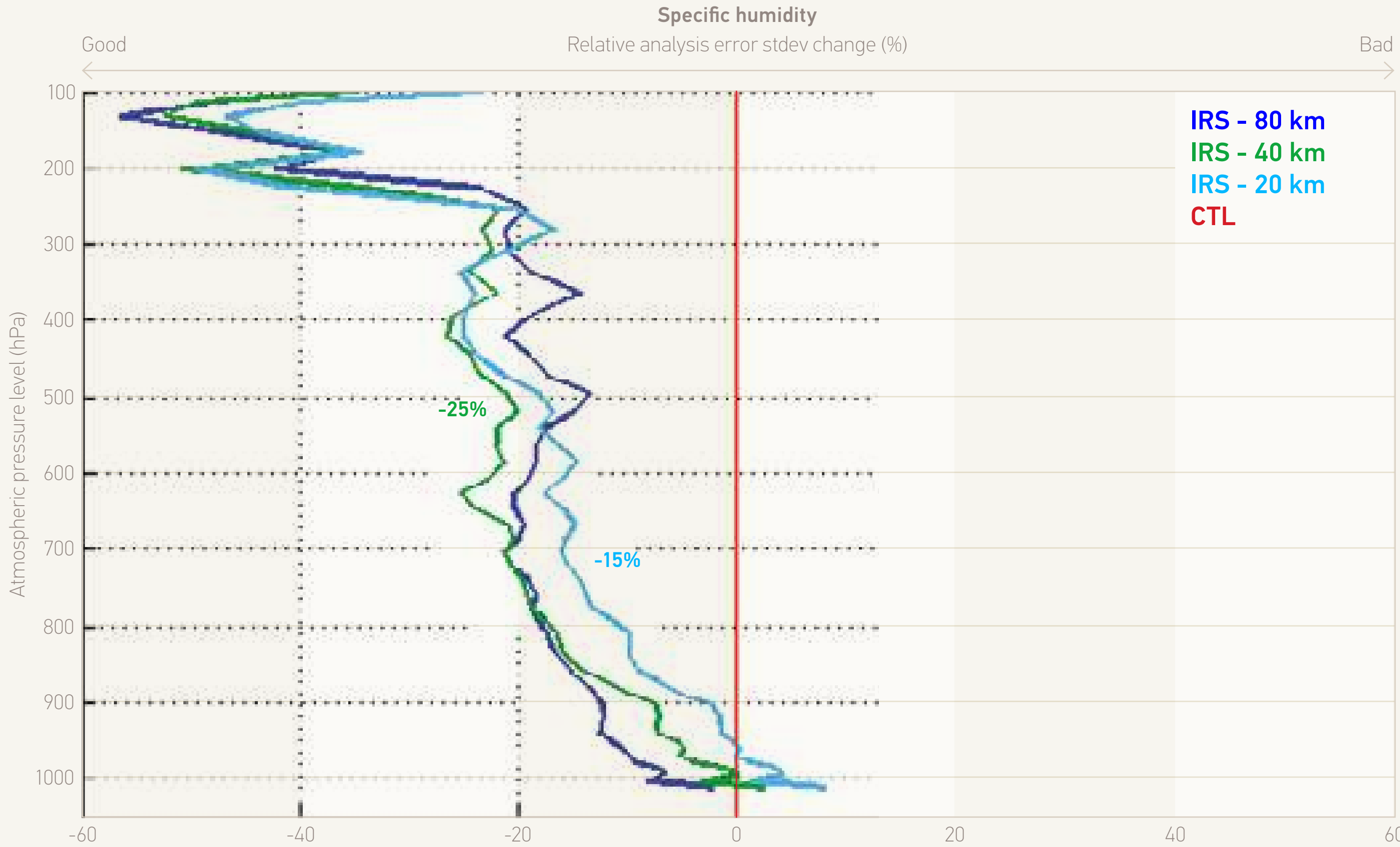


Figure 10: Bushfire line in Botswana as seen in imagery from current Meteosat (left panel) compared to future MTG imagery simulated by proxy data (right panel). MTG imagery will enable more precise detection of fire location and better fire intensity estimates.

ENHANCING NUMERICAL WEATHER PREDICTION

The MTG InfraRed Sounder (IRS) data will be the first of its kind over Europe: probing atmospheric temperature and moisture every 30 minutes is expected to lead to enhancements in nowcasting and very short-range numerical weather prediction (up to a few hours ahead), as well as in techniques blending the two methods. The impact of IRS soundings in mesoscale NWP models is being tested using simulations[12]. Figure 11 shows the result of an observing system simulation experiment, assessing the impact of 25 simulated water vapour channels of IRS in the AROME regional weather model of Météo-France. It highlights the ability of the model to predict the atmospheric humidity profile against a control run (red line), for three degrees of 'thinning' the IRS dataset. The positive impact is significant for lead times of up to 18 hours. IRS data are expected to help advance the ability of the model to correctly represent moisture-related processes, such as convective development.

Figure 11: Simulated MTG infrared sounding data have a demonstrated positive impact on regional weather modelling, by reducing the error of forecasting specific humidity and other meteorological parameters



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4 GETTING READY – A NATIONAL PERSPECTIVE

Member States are expecting a significant return on investment from using MTG data: improved nowcasting of severe weather events, a step change in air quality monitoring, an enhancement to numerical weather prediction and an extension of climate data records.

"The MTG mission has massive potential to improve our weather and climate services. We intend to leverage MTG data to improve our situational awareness, to enhance our numerical weather prediction capability and to extend into the future our ability to monitor changes to our environment."

Simon Keogh
Met Office, UK

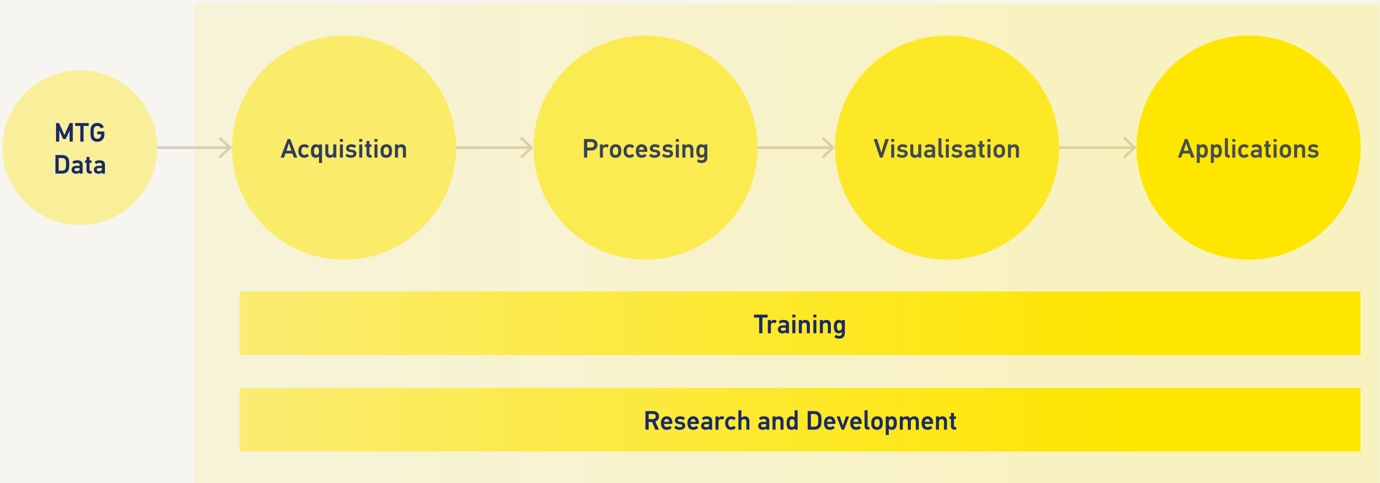
"We expect from MTG data an improvement to our nowcasting and severe weather warnings, better rainfall estimates in complex terrain, and better detection of fire events along the Adriatic coast."

Nataša Strelec Mahović
DHMZ, Croatia

To fully realise these improvements, Member States need to verify to what extent their national technical infrastructure and resources (Figure 12) are able to:

- access the increased data rates and volumes;
- handle the novel data streams and their format in data processing and visualisation systems;
- adapt local software, algorithms and products to MTG data;
- ingest MTG data and products into applications.

Figure 12: MTG-related data value chain, to guide the adequacy assessment of national infrastructure, and related investments



Several NMHS have started user preparedness projects to address these issues. User preparedness projects help identify national priorities, define necessary scientific and technical developments, and are a means to secure national resources. The return on investment in national weather services has a benefit-cost-ratio of at least 2:1, and often 5-10:1 or more[3]. WMO recommends initiating user preparedness projects at least three years before a satellite launch[13].

In terms of human and infrastructure resources, Member States are advised to:

- raise awareness among forecasters and other national users of the advent of new-generation data and their potential;
- assess whether the workforce in the NMHS has the necessary skills to handle and interpret MTG data, and identify training needs;
- assess the national infrastructure requirements to manage the data flow and utilise the data in operational services.

"The Netherlands have significant economical interests related to transportation by air, water, and land. Transport capacity planning will benefit from improved observations and forecasts enabled by MTG, next to the enhanced safety by better and more timely warnings in a densely populated area."

Paul de Valk
KNMI, The Netherlands

Member States share information and experience within the MTG User Preparation Project (MTGUP), facilitated by the EUMETSAT Secretariat. When formulating a user preparedness project for MTG, Member States should also consider the preparation for other satellite mission data planned for the 2020s, such as from the polar-orbiting EPS Second Generation or the Copernicus Sentinel satellites.

Figure 13: MTG User Preparation Project (MTGUP): First User Workshop, November 2017; MTGUP fosters collaboration and sharing of knowledge across European NMHS as they prepare for MTG

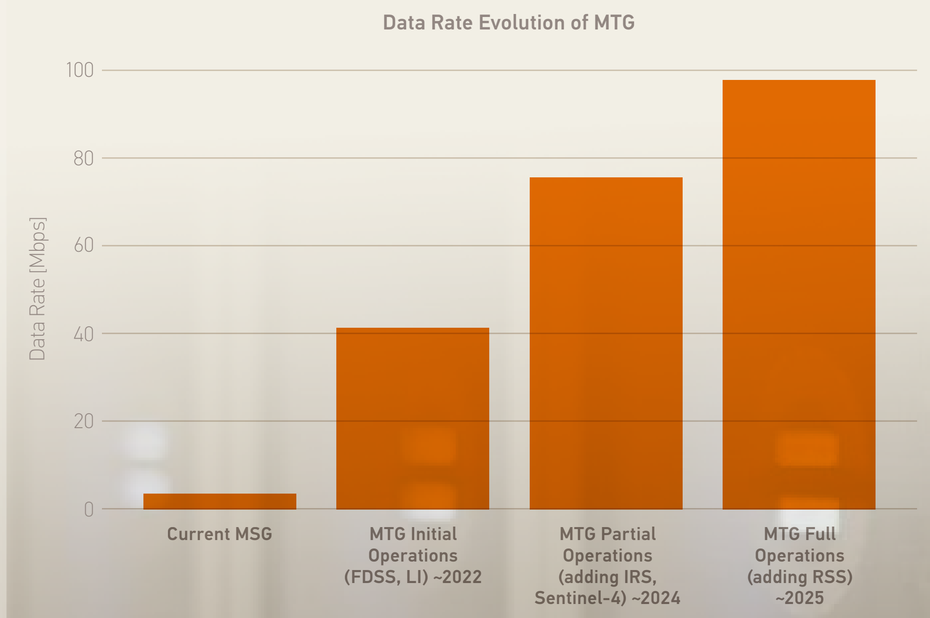
5 DATA ACCESS AND PROCESSING

Users of the current EUMETCast Europe service will need to upgrade their reception and processing systems to cope with the data rates available as of 2022, after launch and commissioning of the first MTG satellite (MTG-I1).

The MTG era will see satellite data rates growing at least tenfold, compared to current MSG services. Therefore, users need to assess how fit for purpose their data acquisition and processing systems are, to ensure continuity of data services and to access new data streams. As a result, users may need to invest in upgrades to their systems. In relation to this data evolution, the EUMETCast Europe service is undergoing a capacity upgrade in the 2021-2024 timeframe. Users of the current EUMETCast Europe service will need to upgrade their reception and processing systems to cope with the data rates available as of 2022, after launch and commissioning of the first MTG satellite (MTG-I1). Additional data access options, based on terrestrial networks, are currently being explored and tested by EUMETSAT.

MTG data will be delivered in the NetCDF-4 baseline format. Selected products will be made available in the World Meteorological Organization (WMO) BUFR and GRIB formats, and other formats where required to continue an existing service.

Figure 14: Evolution of data rates from current MSG to the full MTG operations



6 TECHNICAL ANNEX

6.1 THE MTG MISSION

The Meteosat Third Generation (MTG) programme encompasses the following observation missions, for the benefit of enhanced weather and related environmental services:

SPECTRAL IMAGERY MISSION, ACHIEVED THROUGH THE FLEXIBLE COMBINED IMAGER (FCI),
Providing 16 channels in the visible and infrared spectrum with a spatial sampling distance in the range of 1-2 km (also called Full Disc High Spectral resolution Imagery (FDHSI)); and/or four channels with a spatial sampling distance in the range 0.5-1 km (also called High spatial Resolution Fast Imagery (HRFI)). The FCI scans the Earth disc in 10 minutes in support of the Full Disc Scanning Service (FDSS), or a quarter of the disc (i.e. Europe) in 2.5 minutes in support of the Rapid Scanning Service (RSS).

LIGHTNING IMAGERY MISSION, ACHIEVED THROUGH THE LIGHTNING IMAGER (LI) INSTRUMENT,
Detecting lightning discharges taking place in clouds or between cloud and ground continuously over almost the full Earth disc, with a spatial sampling distance of 4.5 km at nadir.

INFRARED SOUNDING MISSION, ACHIEVED THROUGH THE INFRARED SOUNDER (IRS) INSTRUMENT,
A first over Europe, providing hyperspectral sounding information from geostationary orbit in two bands, a Long Wave InfraRed (LWIR: 700-1210 cm^{-1}) and Mid Wave InfraRed (MWIR: 1600-2175 cm^{-1}) band with a spatial sampling distance of around 4 km, every 30 minutes over Europe. The Earth disc is split in four zones of equal size (called Local Area Coverage - LAC), and numbered LAC 1 to LAC 4, from south to north. The scan pattern repeat sequence revisits each LAC zone in a manner adapted to the need of the end users.

COPERNICUS SENTINEL-4 SOUNDING MISSION
The MTG programme comprises the accommodation of the Copernicus Sentinel-4 sounding mission, achieved through the Ultraviolet, Visible and Near-infrared Sounder (UVN) instrument, covering Europe every hour and taking measurements in three spectral bands (UV: 305–400 nm; VIS: 400–500 nm, NIR: 750–775 nm) with a spatial sampling distance of around 8 km.

MTG-I

MTG-S

PAYLOAD

MTG-I
1 FCI *(Flexible Combined Imager)*
2 LI *(Lightning Imager)*
3 DCS *(Data Collection and Retransmission Service)*
GEOSAR *(Geostationary Search and Rescue Relay)*

MTG-S
4 IRS *(Hyperspectral InfraRed Sounder)*
5 COPERNICUS SENTINEL-4 UVN *(Ultra-violet, Visible and Near-Infrared Sounder)*

Copernicus Europe's eyes on Earth

EUMETSAT

6 TECHNICAL ANNEX

APPLICATIONS BENEFITTING FROM THE MTG SPECTRAL IMAGER INCLUDE:

- detection of rapid atmospheric processes such as severe storms;
- monitoring of clouds, dust outbreaks, aerosols, fires, land surface changes and a range of other phenomena.

APPLICATIONS BENEFITTING FROM THE MTG INFRARED SOUNDER INCLUDE:

- three-dimensional information on humidity, temperature, and wind, to support monitoring and forecasting of convective storms;
- enhanced air quality monitoring, through estimates of daily variation of trace gases such as ozone and carbon monoxide.

APPLICATIONS BENEFITTING FROM THE MTG LIGHTNING IMAGER INCLUDE:

- improved monitoring and forecasting of severe storms;
- enhanced lightning-related safety for air traffic routing and control.

APPLICATIONS BENEFITTING FROM THE COPERNICUS SENTINEL-4 SOUNDING MISSION ON MTG INCLUDE:

- enhanced air quality monitoring on an hourly basis over Europe;
- estimates of the daily variation of trace gases such as ozone, nitrogen dioxide, sulphur dioxide, formaldehyde, and aerosols.

6.2 TRANSITIONING FROM MSG TO MTG

The MTG system comprises two types of three-axis stabilised satellites: MTG-I ('Imaging') and MTG-S ('Sounding'). When fully deployed, the system will include two MTG-I satellites operating in tandem, one scanning Europe and Africa every 10 minutes, and the other scanning only Europe every 2.5 minutes, and one MTG-S satellite. The other main component of the MTG system is a comprehensive ground segment used to control the satellites, acquire and process the data and deliver the extracted products to users worldwide. The following table provides the transition schedule from the current Meteosat Second Generation services based on Meteosat-10 and -11, to MTG starting in 2021 (schedules can be subject to change).

PLANNED SATELLITE PAYLOADS WITHIN THE MTG PROGRAMME

Satellite	Instrument payload
MTG-I1	Imaging (FCI, LI)
MTG-S1	Sounding (IRS, UVN)
MTG-I2	Imaging (FCI, LI)
MTG-I3	Imaging (FCI, LI)
MTG-S2	Sounding (IRS, UVN)
MTG-I4	Imaging (FCI, LI)

TRANSITION SCHEDULE

(Status: April 2019)

Year	Launch & Commissioning	0° services	Rapid Scanning Service
2021	**MTG-I1**	Meteosat-11 (parallel) MTG-I1	Meteosat-10
2022		Meteosat-11 (parallel) MTG-I1	Meteosat-10
2023	**MTG-S1**	Meteosat-10 (parallel) MTG-I1 MTG-S1	Meteosat-11
2024		MTG-I1 MTG-S1 Meteosat-10 (parallel)	Meteosat-11
2025	**MTG-I2**	MTG-I2 MTG-S1	MTG-I1 Meteosat-11 (parallel)
2026		MTG-I2 MTG-S1	MTG-I1

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6.3 DATA AND PRODUCTS FROM MTG SERVICES

MTG data are delivered in the NetCDF-4 baseline format. Selected products will be made available in the WMO BUFR and GRIB formats, plus other formats where required to continue an existing service. The following tables contain the planned MTG data and products (Level 1, Level 2).

MTG LEVEL-1 DATA[14]

	FCI	LI	IRS	UVN
Disseminated in near-real time	**Compressed using CharLS algorithm:** 16 imager channels (Full Disc Scanning Service), 4 imager channels at high spatial resolution (Rapid Scanning Service)	None	Principal component scores	None
Available from data archive	**Uncompressed:** 16 imager channels (Full Disc Scanning Service), 4 imager channels at high spatial resolution (Rapid Scanning Service)	Lightning Triggered Events	Full spectral channels, Principal component scores	Daytime Earth radiances and solar irradiances in NIR and UV/VIS bands

MTG LEVEL-2 GEOPHYSICAL PRODUCTS[14]

	FCI	LI	IRS	UVN
Disseminated in near-real time, and available from data archive	Atmospheric Motion Vectors All Sky Radiance Clear/Cloud/Dust /Ashes Flag Clear Sky Reflectance Cloud Analysis Fire Detection Global Instability Indices Cloud Drop Effective Radius Outgoing Longwave Irradiance at Top of Atmosphere Ozone Total Column Volcanic Ash	Accumulated Flash Area Accumulated Flash Radiance Accumulated Flashes Lightning Flashes Lightning Groups	Temperature profile Humidity profile Instability indices Ozone profile Surface temperature (land and sea) Surface emissivity (land) Cloud products (detection, fraction, top pressure)	Ozone Total Column Ozone Tropospheric Column Nitrogen Dioxide Total Column Nitrogen Dioxide Tropospheric Column Sulphur Dioxide Formaldehyde Glyoxal Aerosol Index Aerosol Layer Height

6.4 EVOLUTION OF DATA ACCESS AND DISSEMINATION

Users of the current EUMETCast Europe service will need to upgrade their reception and processing systems to cope with the data rates available as of 2022, after launch and commissioning of the first MTG satellite (MTG-I1).

The MTG era will see satellite data rates growing at least tenfold compared to current MSG services – to be acquired, processed and distributed to users by the MTG system ground segment; on their part, users need to assess whether their data acquiring and processing systems are capable of accessing and handling MTG data, to ensure smooth access to the new data streams and continuity of data services.

The prime user access to EUMETSAT data for time-critical applications such as weather forecasting and warning is through the EUMETCast-Satellite DVB-S2 reception technology (similar to satellite TV). In the MTG era, for fulfilment of official duties of NMHS for safety-critical nowcasting and high-impact forecasting, EUMETSAT continues to rely on this technology to support its 4000+ user base in the footprint of the EUMETCast Europe service. Additional near-real-time and other data dissemination options, such as using terrestrial networks, are currently being explored.

Multicast technology and dissemination logic of the EUMETCast service remain the same in the MTG era. EUMETCast users should be able to seamlessly transition to high rate acquisition of high volumes of MTG data and products, provided they upgrade their reception and processing systems to cope with the data rates available as of 2022, after launch and commissioning of the first MTG satellite (MTG-I1).

On top of this step change induced by MTG, the 2020s will see the addition of data from other missions operated by EUMETSAT, such as the polar-orbiting EUMETSAT Polar System Second Generation (EPS-SG) and the Copernicus Sentinel missions operated by EUMETSAT on behalf of the European Commission. This leads to further increases in total data volumes and rates of EUMETSAT data services. Users of these services are advised to take these changes into account when designing their future data access and processing infrastructure.

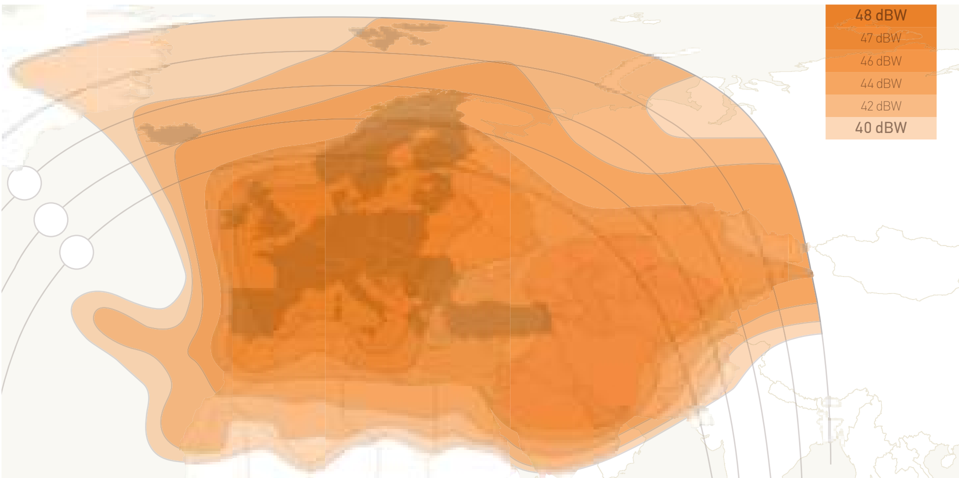

Figure 15: EUMETCast Europe footprint

EUMETSAT

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MTG DATA RATE AND FRACTION PER PRODUCT

Figure 16: Evolution of MTG data rates and fraction of data rate used per MTG product class

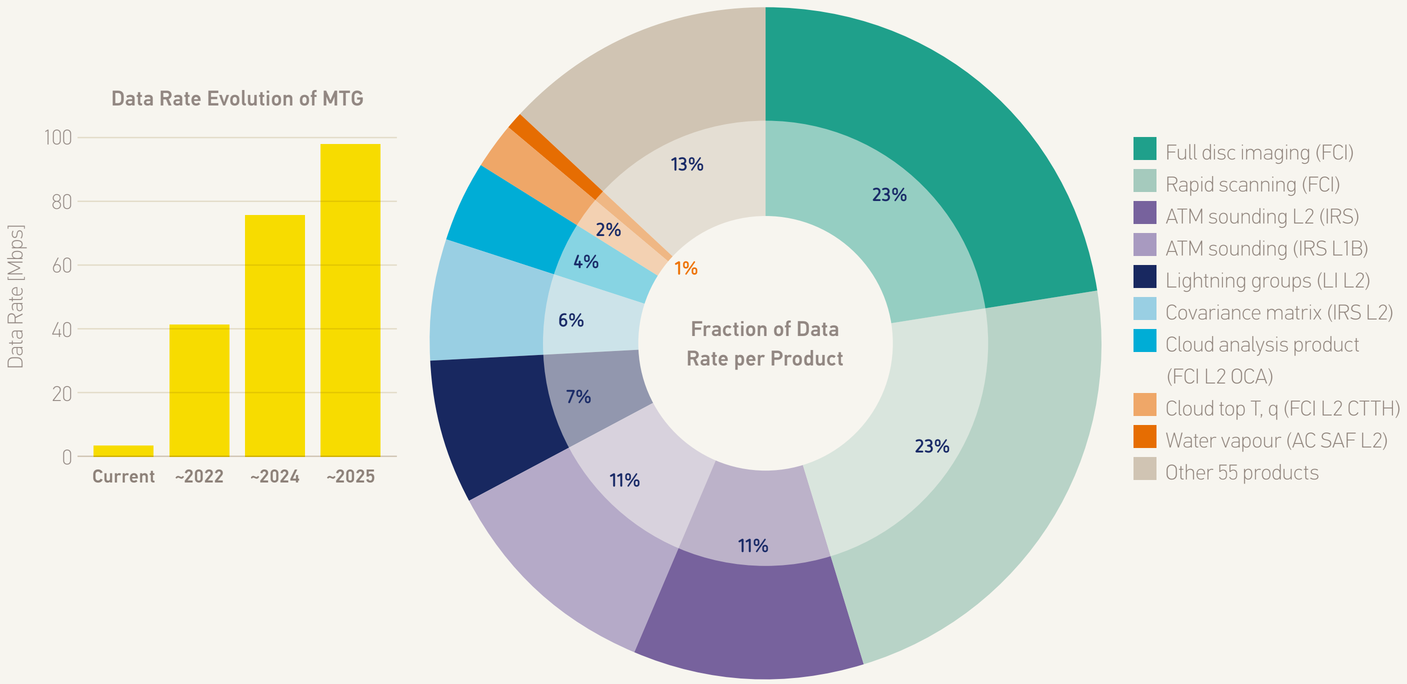
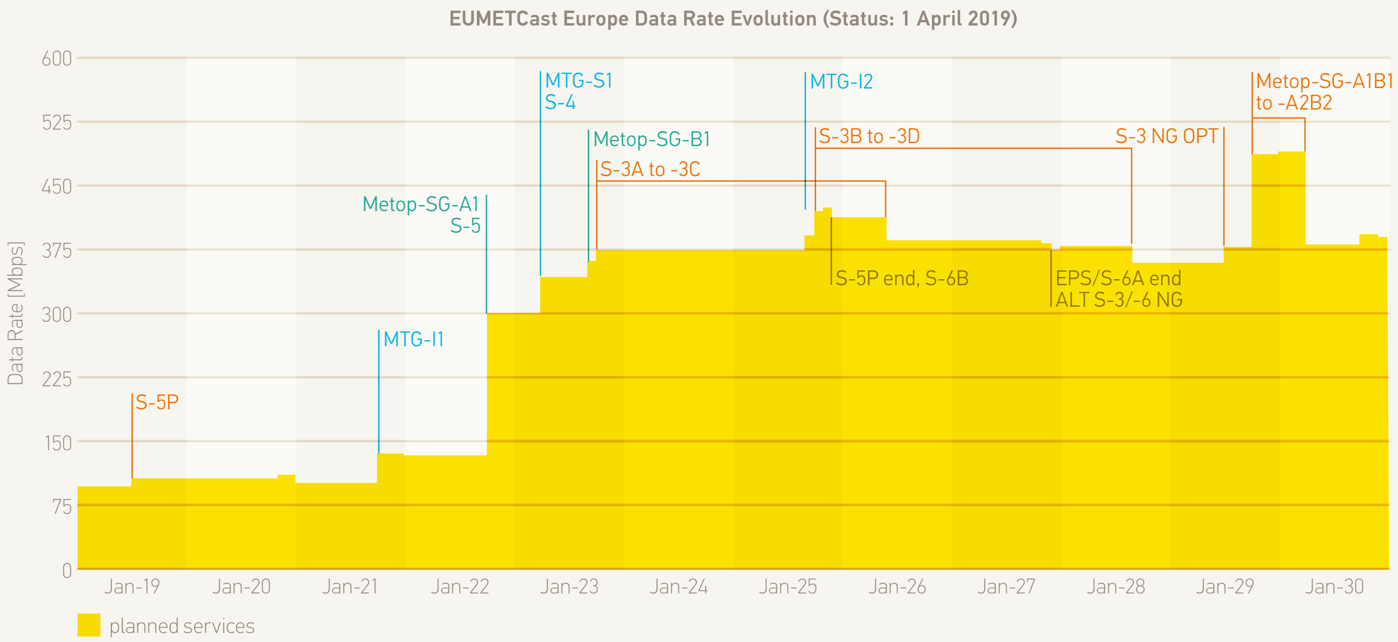


Figure 17: EUMETCast Europe data rate evolution. The full operational MTG capability is planned to be reached by 2026.



TECHNICAL IMPLICATIONS FOR EUMETCAST EUROPE USERS

EUMETCast Europe users have a range of choices to prepare for MTG: at least one separate antenna is required for each DVB Satellite (prime and backup), large enough for the high volume service. One additional spare/backup antenna is recommended for professional users, to ensure uninterrupted service in case of antenna maintenance. Depending on the distance between the prime and backup satellite, dual feed systems can be used to cover both. For each transponder, generally one DVB receiver is needed. Some multi-input DVB receivers support simultaneous reception of multiple transponders.

Regarding the low-noise block downconverter (LNB):

- Downlink frequency band is in the Ku-band
- Each transponder works on a single Ku sub-band
  - frequency band - can be high or low
  - polarisation - can be horizontal or vertical;
- A Quattro LNB is recommended for each antenna, in connection with multi-switches: such a configuration can support all Ku sub-bands simultaneously, i.e. is ready to support reception of any number of transponders from the same satellite

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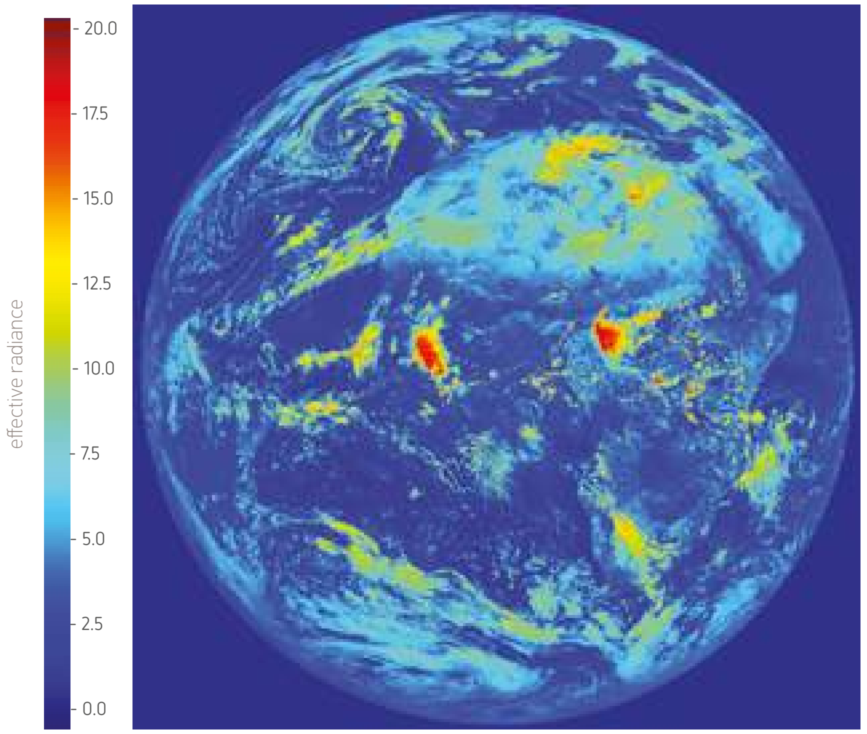
6.5 GETTING READY FOR MTG: USER FAMILIARISATION DATA

To ensure user readiness, it is extremely important that users have access to data that will, in a best possible way, resemble the data that will be available from the future instruments.

User familiarisation (test) data should have the best possible maturity in data content and in format specifications attached to different data. This is valid both for the pre-launch development period and during post-launch commissioning activities.

User test data can take different form, for instance having more or less scientific values, formats and sizes. However, different test data can be associated with different user preparation processes, from tailoring of data acquisition systems to visualisation and utilisation of the satellite data in an operational environment.

Figure 18: Example of simulated FCI L1c user familiarisation data (VIS 0.6 µm channel, 10 April 2017). To reduce data volumes in near-real-time services such as EUMETCast, the NetCDF-4 near-real-time FCI Level 1c data will only be available in compressed form using the CharLS algorithm.



EUMETSAT distinguishes between:

- synthetic data - no scientific value, but realistic sizes and formats. Used for user dataflow testing;
- simulated data - data used to test data processing and visualisation tools. These data are simulated by forward Radiative Transfer Model (RTM) calculations, based on NWP model output; generally do not contain realistic spatial structure and temporal variability;
- proxy data - data with valid scientific content, to be used in early training on instrument capabilities and application areas, for example in test beds. These are real datasets from relevant existing precursor instruments, e.g. 2.5 minute data from Meteosat-10 serving as proxy for MTG-FCI. These data do not need to be presented in the baselined format;
- pre-operational data - real satellite data generated as part of the commissioning activities, but before full validation has been completed (no warranty on specified data quality). For the training and dissemination scenarios, these data will be used in the same manner as proxy data.

In 2019, the following simulated data were made available by EUMETSAT:

- FCI Level 1c data for format familiarisation;
- IRS Level 1b data for format familiarisation;
- LI Level 2 data for user familiarisation.

To support user preparation efforts, EUMETSAT plans the release of further user familiarisation datasets with increasing scientific value.

6.6 HOW EUMETSAT CAN HELP

USER SUPPORT

The EUMETSAT User Service Helpdesk can answer your questions regarding MTG. Contact our team at ops@eumetsat.int

TRAINING

Building on years of experience in training operational meteorologists, the EUMETSAT training programme has started to focus on MTG applications. There will be a range of opportunities for Member States and staff of NMHS to engage.

https://twitter.com/eumetsat_users

or contact ops@eumetsat.int.

MTG USER PREPARATION PROJECT (MTGUP)

EUMETSAT is facilitating the preparation by Member States through the MTG User Preparation Project (MTGUP). It brings together expert representatives from all Member States, fostering cross-institutional exchange of experience and collaboration. The project also helps Member State experts liaise with technical staff in the Secretariat on questions of:

- science support;
- user information and communication;
- user familiarisation (test) data and format support;
- user training;
- data access support.

7 SOURCES

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3. WMO, 2015: Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services, WMO-No 1153.

4. MunichRe, 2019: NatCatService – Natural catastrophe statistics online, https://www.munichre.com/en/reinsurance/business/non-life/natcatservice/index.html.

5. M. Setvak; 11 June 2018, 11.37 UTC; SEVIRI data in lower panel, and upper panel with FCI imagery simulated over Central Europe based on data from the VIIRS instrument on the NOAA Suomi-NPP satellite; combining 0.865 µm imagery (background) and 11.45 µm (convective storms) to a 'sandwich' product.

6. Lindsey et al., 2018 : Using the GOES-16 Split Window Difference to Detect a Boundary prior to Cloud Formation, Bull. Am. Met. Soc. August 2018, http://doi.org/10.1175/BAMS-D-17-0141.1 ; GOES-16 imagery, 15 June 2017, 15.32 UTC.

7. Purdom, J.F.W., 1976: Some uses of high-resolution GOES imagery in the mesoscale forecasting of convection and its behaviour. Mon. Wea. Rev., 104, 1474-1483, https://doi.org/10.1175/1520-0493 (1976)104<1474:SUOHRG>2.0.CO;2.

8. M. Setvak, J. Kerkmann; 16 Nov 2018, 01.37 UTC; simulated FCI imagery at 2 km spatial resolution based on data from the VIIRS instrument on the NOAA Suomi-NPP satellite (right panel), and SEVIRI imagery at approximately 5 km spatial resolution over Czech Republic (3 km spatial resolution at sub-satellite point, left panel).

9. G. Stano; 4 May 2017, 13.07 UTC; 1-minute GLM lightning group density; ABI 11.2 µm imagery (preliminary, non-operational data).

10. Right-hand panel: MODIS RGB imagery as proxy for FCI at 1 km spatial sampling distance; left-hand panel: RGB from MSG SEVIRI at 3 km spatial sampling distance; Portugal, Algarve, 5 August 2018.

11. Right-hand panel: MODIS 3.9 µm channel at 1 km sampling distance simulating FCI imagery, and showing more detailed fire locations and a range of fire brightness temperatures (yellow-orange-red colours); left-hand panel: MSG SEVIRI 3.9 µm channel at 3 km sampling distance, with brightness temperature saturating at 344 K (red pixels); Botswana, 29 August 2008.

12. Guedj et al., 2014: An Observing System Simulation Experiment to evaluate the future benefits of MTG-IRS data in a fine-scale weather forecast model. EUMETSAT Fellowship Report, 2014.

13. WMO, 2017: Guidelines on Best Practices for Achieving User Readiness for New Meteorological Satellites, WMO-No. 1187.

14. [EURD] for FCI, LI, IRS; [S4HQ] for UVN; products planned by the EUMETSAT Satellite Application Facility (SAF) are not shown. More details on the MTG data and products baseline, algorithm theoretical basis documents, product guides, and forthcoming MTG applications and user guides are being published on the EUMETSAT MTG webpages.

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MEMBER STATES

EUMETSAT also has established cooperation agreements with organisations involved in meteorological satellite activities, including the National Meteorological Services of Canada, China, India, Japan, Russia, South Korea and USA

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