# On the Role of NWP Impact Studies to Support the Evolution and Development of Current and Future Satellite Programmes

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# Salient points and issues (1)

- Informed decisions on future operational meteorological satellites and related services must be based on careful analyses
- Important constraints to be observed: i) the continuity and robustness services and ii) the evolution of services based on new requirements
- An established way to demonstrate usefulness/benefit of a specific observing system is through impact studies with an NWP system

- Need for OSSEs remains for new instruments (was addressed in my talk in 2008 with an example for the hyper-spectral sounder (IRS) on MTG with OSSE by Hans Huang)

# Salient points and issues (2)

- This presentation suggests to enhance within the framework of WMO the provision of information that:
- ➢ shows and regularly updates the impact of current (satellite) observing systems on NWP impact; important details (metric used and what that means etc.) should be included. Generally speaking, one should include guidance on how to read the impact results.
- ➢ provides a robust basis to demonstrate the need and benefit of new satellite programmes and new instruments (the need for this has inter alia arisen during the ongoing approval process toward EPS (Metop) Second Generation)

# Salient points and issues (3)

- Regular updating of the above is needed; is every four years sufficient (as done at this workshop ?)

- Even without a major change to the existing GOS the relative impact of individual components can change significantly:

  i. because of the better use of the data

  ii. because of model improvements in general (requiring more accurate data)

# Salient points and issues (4)
## Some general points important to planning

- The spaced-based GOS should be resilient to sudden failures of individual instruments (and reasonably resilient to a loss of a satellite)
- Ideally the space-based GOS should be based on a prudent joint planning from the beginning at the international level (this is presumably too ambitious and left for the future ☺ )
- Current cooperation within CGMS regarding the responsibility for different polar orbits by meteorological satellite operators is a very laudable achievement; i.e. early morning proposed to CMA, EUMETSAT at 9:30h and NOAA at 13:30h.

# Recalling the status of EUMETSAT development/future programmes:

- Meteosat Third Generation (MTG): here the development of  the use and the demonstration of the benefit of new instruments will be essential

  (=> example discussed: hyperspectral sounder IRS)

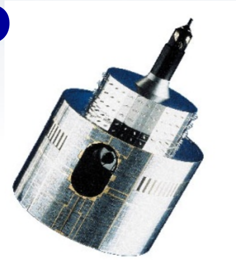
- EPS-Second Generation (next Metop series): This is not approved yet, demonstration of the benefit has been a major effort (=> performed with support from European Weather Services, e.g. UK Met Office)

# Meteosat Third Generation (MTG)

Evolution of the European Geostationary meteorological programmes:

1977 2002 2018 **MTG**

**MOP**



**1** observation mission:

-MVIRI: 3 channels

-**Spinning** satellite

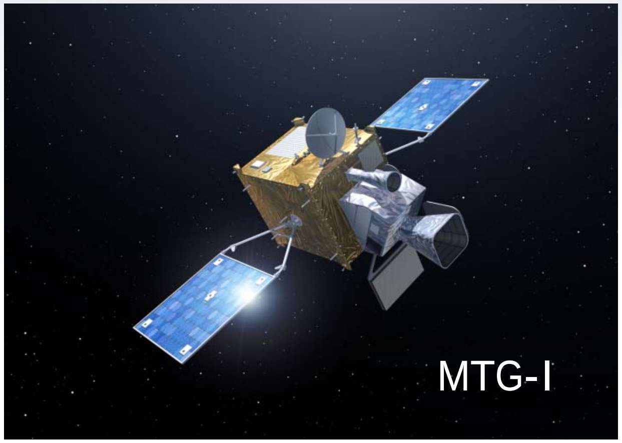
**MSG**

**2** observation missions:

- SEVIRI: 12 channels

- GERB

- **Spinning** satellite




**5 observation missions**

**2 satellite types**

**MTG-I (Imager)**

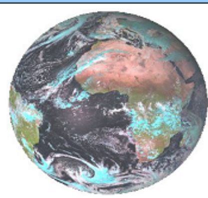
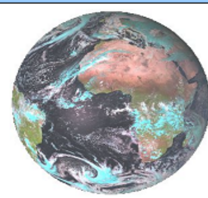
**MTG-S (IR Sounder)**

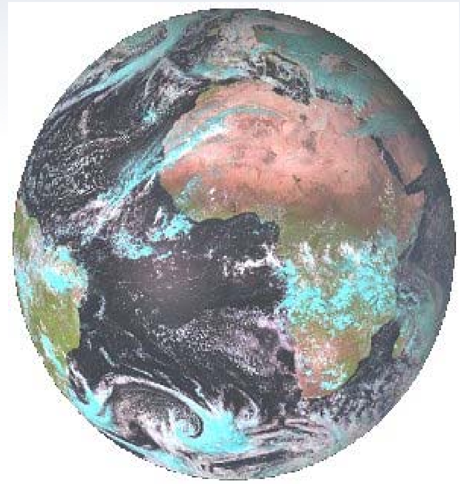
**Common <u>3-axis stabilised</u> platform**

# MTG FCI Imagery Mission:
# Better imagery products, such as clouds and AMVs

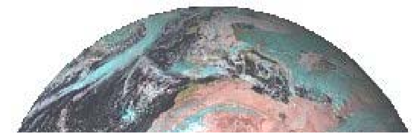
## FROM MSG TO MTG: HRFI & FDHSI IMAGERY MISSIONS

Improvements in number of channels (2 => 5 visible and 9 => 11 IR), spatial & spectral resolution, full disk acquisition time

| Characteristics | MSG performance | MTG performance |
|---|---|---|
| Full-disk Image cycle | <br>15 mn | <br>10 mn |
| Spectral Channels | HRV<br>VIS 0.6<br>VIS 0.8<br>NIR 1.6<br>IR 3.8<br>IR 6.2 (WV)<br>IR 7.3 (WV)<br>IR 8.7<br>IR 9.7 ($O_3$)<br>IR 10.8<br>IR 12.0<br>IR 13.4 ($CO_2$) | VIS 0.4<br>VIS 0.5<br>VIS 0.6<br>VIS 0.8<br>VIS 0.9<br>NIR 1.3<br>NIR 1.6<br>NIR 2.2<br>IR 3.8<br>IR 6.3 (WV)<br>IR 7.3 (WV)<br>IR 8.7<br>IR 9.7 ($O_3$)<br>IR 10.5<br>IR 12.3<br>IR 13.3 ($CO_2$) |
| Sampling Distance | 1 km (HRV)<br>3 km (others) | 0.5 – 1.0 km (VIS-NIR)<br>1.0 – 2.0 km (IR) |
| Telescope Diameter | 500 mm | 300 mm |
| Scan Principle | N/S scan mirror<br>E/W spinned satellite | N/S and E/W single scan mirror<br>3-axis stabilized satellite |



**FULL DISK**
16 channels every 10 mn



**LOCAL AREA COVERAGE**
FD/n coverage (in N/S direction)
16 channels every 10/n mn
Can be placed anywhere in FD

**Future advanced imagers on:**

**Himawari-8 (AHI),**

**GOES-R (ABI),**

**FY-4 ,**

**MTG (FCI)**

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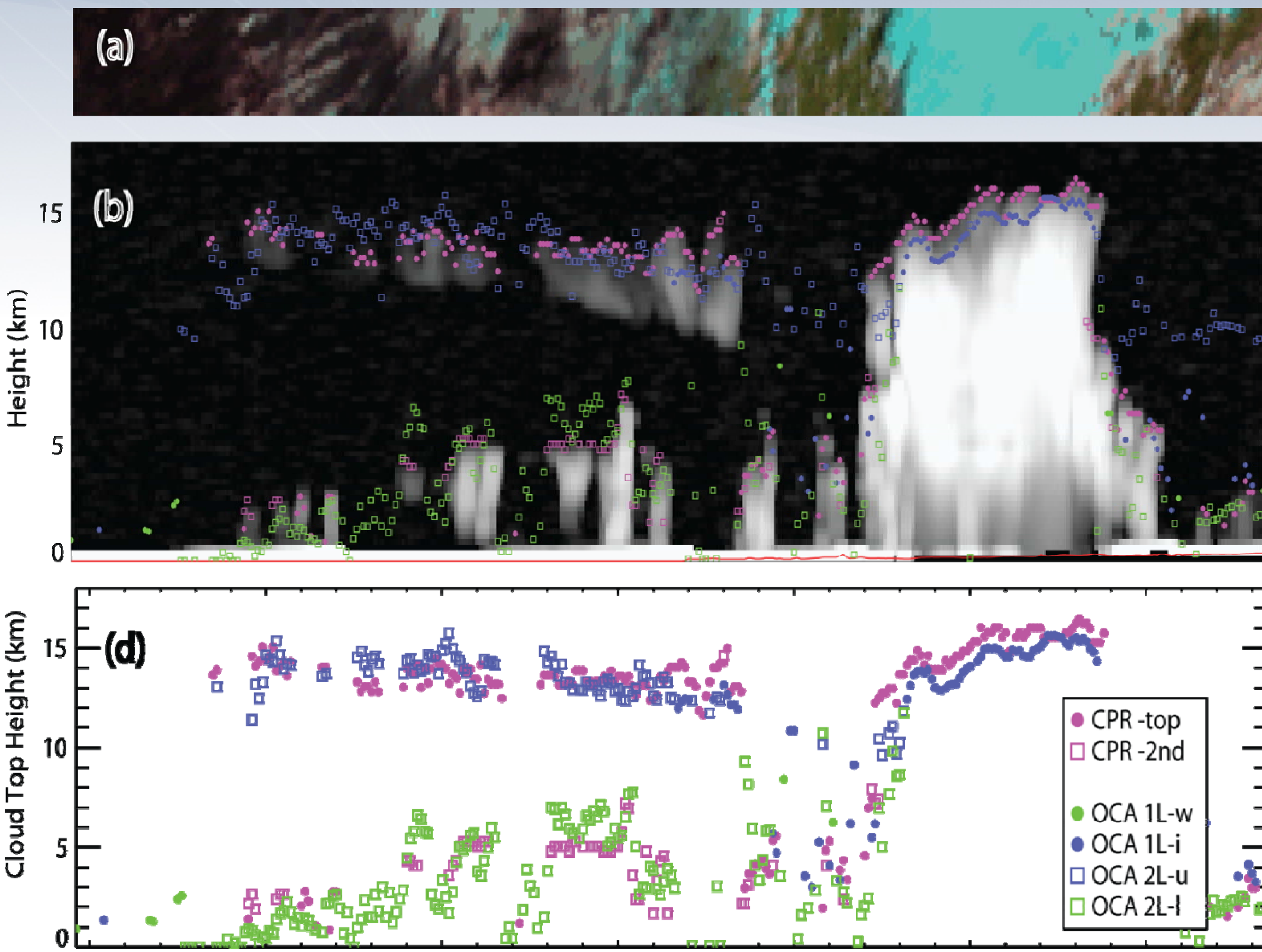
# Retrieval of two cloud layers from MSG SEVIRI
# => will be pursued for MTG, GOES-R and Himawari-8

**(P. Watts et al., 2011)**




**Comparison of cloud top retrieval between:**

**optimum estimation method using SEVIRI**

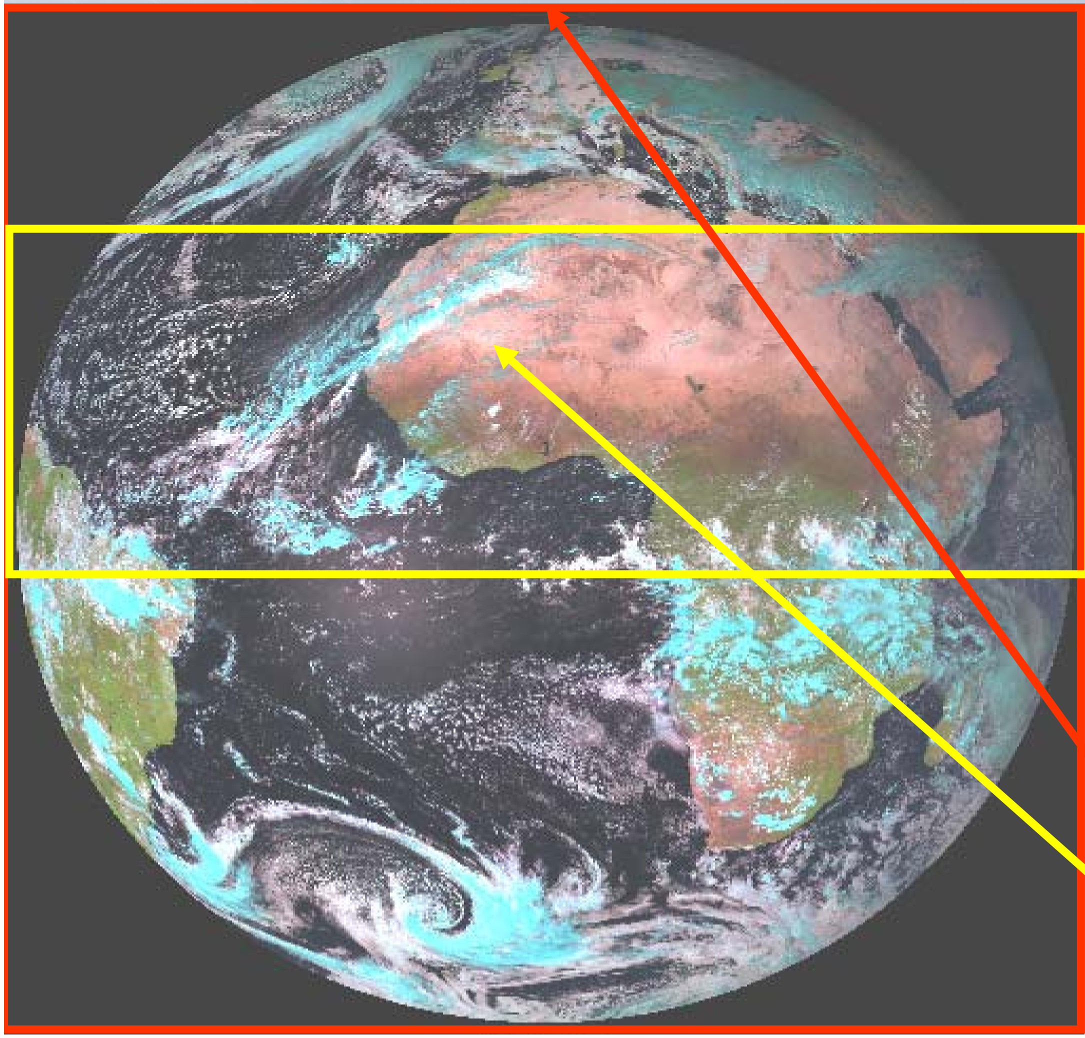
**And cloud radar on Cloudsat**

**=> Very good agreement for single layers**

**⇒ Also good agreement for two cloud layers**

**Only the thermal IR channels of SEVIRI (except 9.7 µm) have been used**

# MTG IR Sounding Mission



| Mission Band | Frequency range $cm^{-1}$ | | Main Contribution |
|---|---|---|---|
| IRS-1 | 700 | 770 | $CO_2$ |
| IRS-2 | 770 | 980 | Surface, Clouds |
| IRS-3 | 980 | 1070 | $O_3$ |
| IRS-4 | 1070 | 1210 | Surface, Clouds |
| IRS-6 | 1600 | 2000 | $H_2O$, |
| IRS-7 | 2000 | 2175 | CO, |

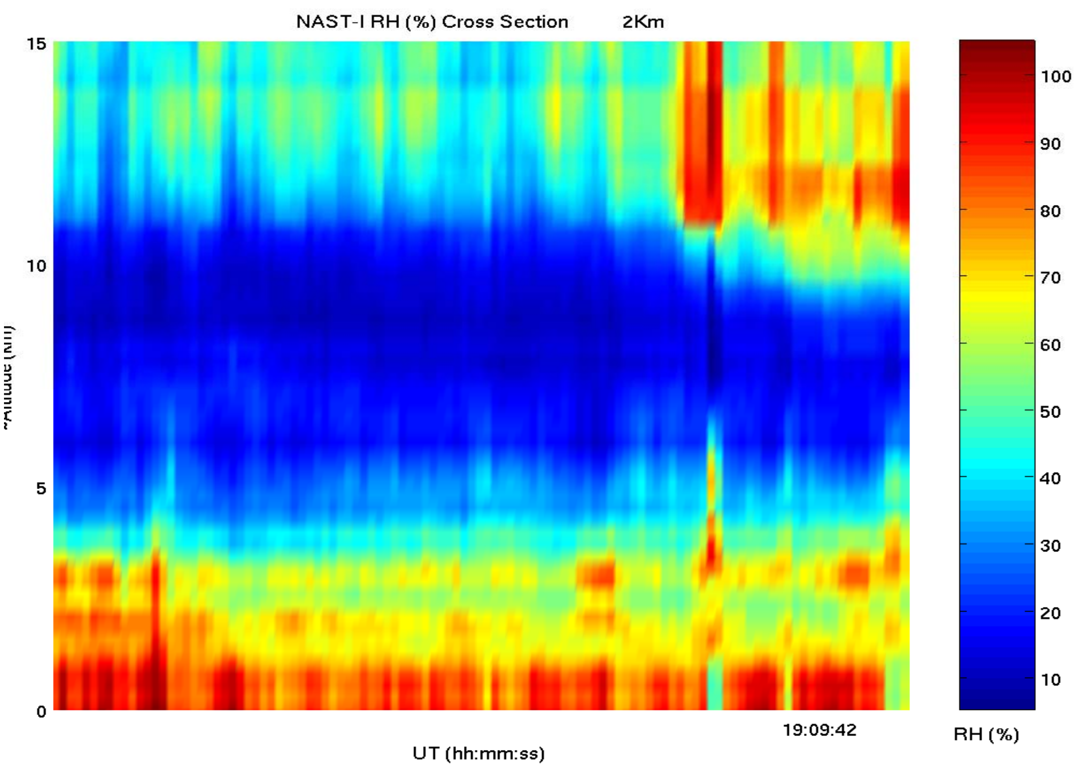
**1800 channels**

**Spec.res. 0,62 1/cm**

| | Coverage | Repeat cycle |
|---|---|---|
| Full Disk Coverage | 18°x18° | 60 min |
| Local Area Cov. | 18°x6° | 10 min |

# MTG IR Sounding Mission

**Hyperspectral IR sounding with focus on time evolution of vertically resolved water vapour structures**




## Priorities IRS Mission

- Four-dimensional variation of water vapour
- More frequent information on Temperature and Humidity profiles for NWP (on convective scales and larger)
- Monitoring of instability / early warning of convective intensity
- Cloud microphysical structure
- support chemical weather and air quality applications

| | Coverage | Repeat cycle |
|---|---|---|
| Full Disk Coverage | 18°x18° | 30 min |
| Local Area Cov. | 18°x6° | 10 min |



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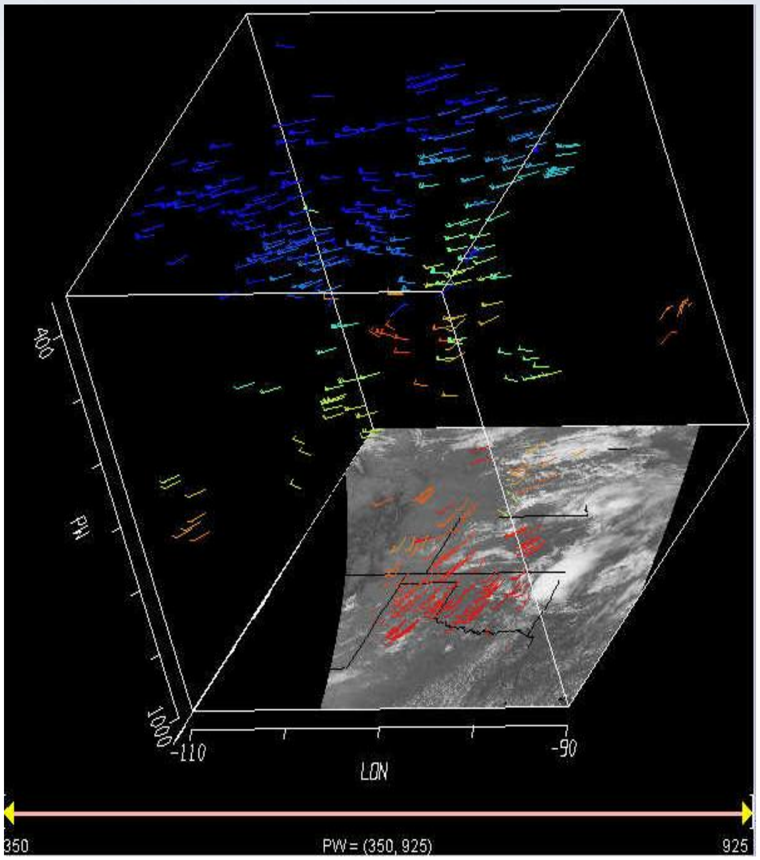
# Greatly Improved Atmospheric Motion Vectors with hyperspectral sounder

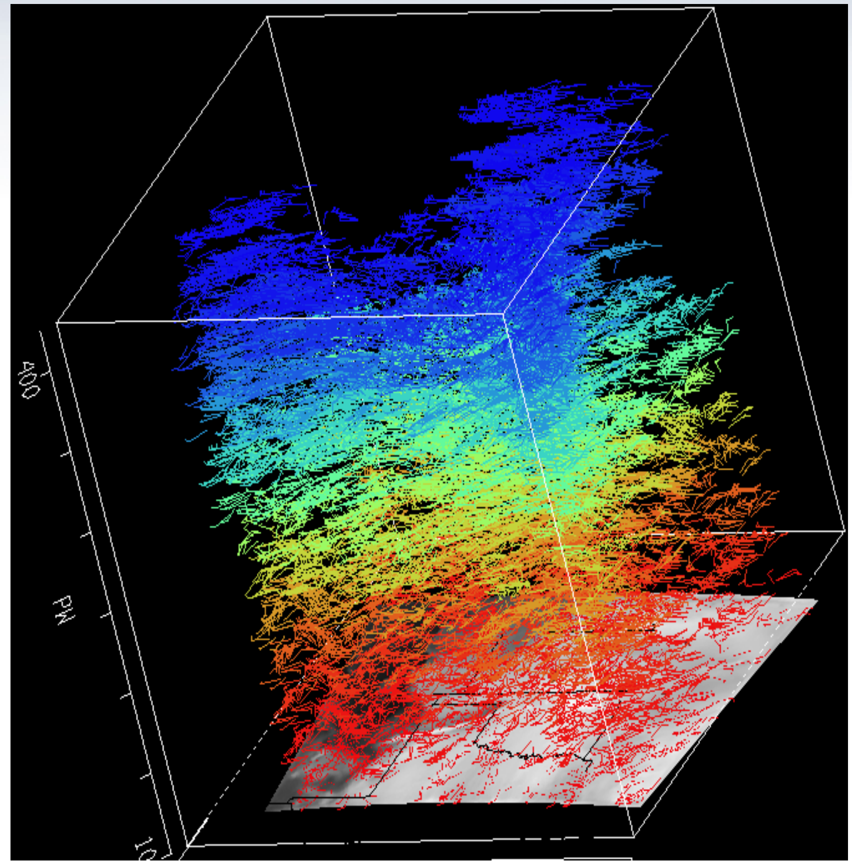
*(Figure courtesy of C. Velden)*

***NOTE: There are science issues to be resolved and primarily related to spatial and temporal scales (representativeness)***

## Current GOES




## High-spectral



# Benefits expected from the infra-red sounder (IRS) on Meteosat Third Generation

*Report from a working group (J. Eyre, V. Casse, S. English and J. Pailleux) some 4+ years back:*

- MTG-IRS is an infra-red sounder of high spectral resolution which will provide information on atmospheric temperature, **humidity** and wind **at high horizontal, vertical and temporal resolution**
- MTG-IRS data **will contribute both through assimilation into convective-scale, regional and global NWP models** and through nowcasting products. They will be particularly important for observing the **advection and convergence of low-level moisture associated with some types of severe weather** in Europe
- => this is being pursued, inter alia, by EUM Research Fellows

# EPS-SG Two Satellite Configuration

Sat A Payload: **MetImage, IASI-NG, MWS, 3MI, S5/UVNS, RO, ARGOS**

Dry mass: 2,500 kg

Launch mass: 2,900 kg

Power: < 2 kW

Solar array: 13 $m^2$

Launcher: Soyuz class

Sat B Payload: **SCA, MWI-P, RO, ARGOS**

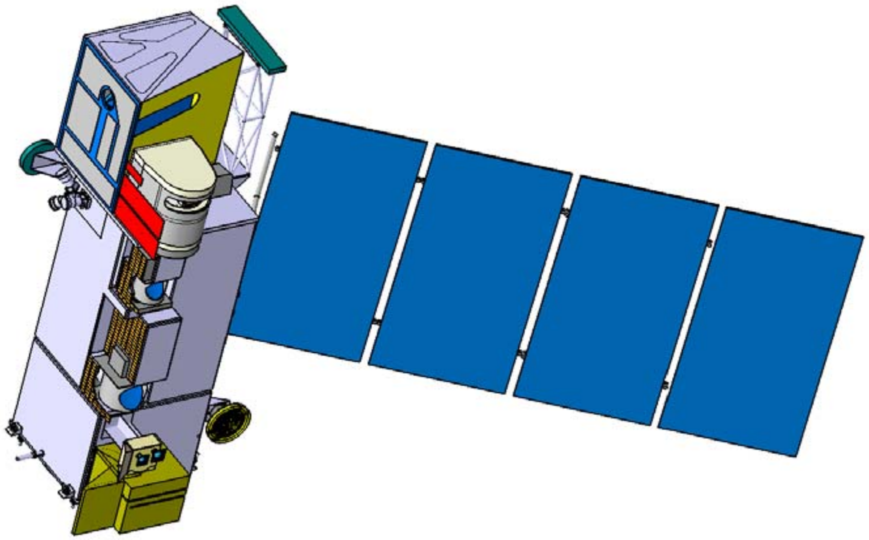
Dry mass: 2,000 kg

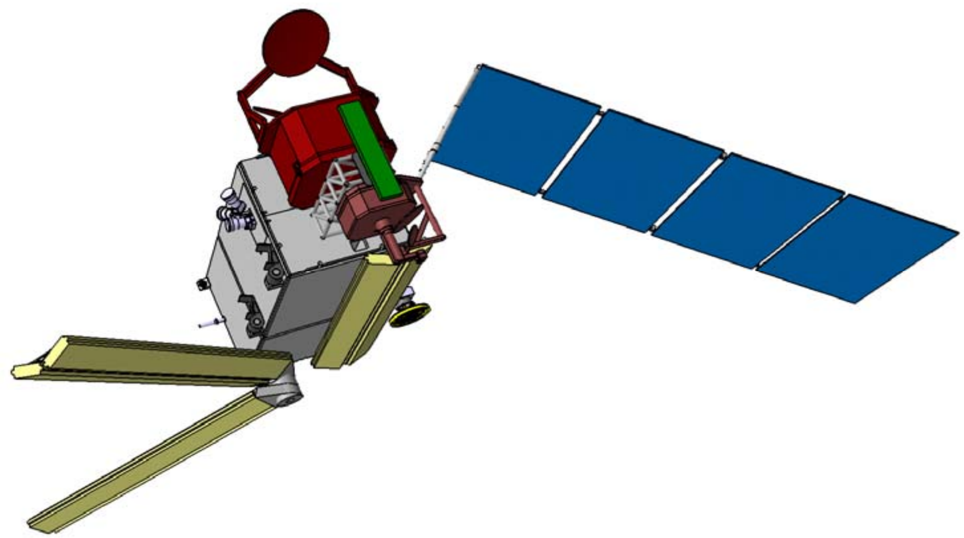
Launch mass: 2,300 kg

Power: 1.5 kW

Solar array: 12 $m^2$

Launcher: Soyuz





# Proposed Payload Complement for Council 75

| Satellite-A Missions | Instrument (and Provider) | Predecessor on Metop |
|---|---|---|
| Infrared Atmospheric Sounding (IAS) | IASI-NG (CNES) | IASI (CNES) |
| Microwave Sounding (MWS) | MWS (ESA) | AMSU-A (NOAA)<br>MHS (EUM) |
| Visible-infrared Imaging (VII) | METImage (DLR) | AVHRR (NOAA) |
| Radio Occultation (RO) | RO (ESA) | GRAS (ESA) |
| UV/VIS/NIR/SWIR Sounding (UVNS) | Sentinel-5 (GMES, ESA) | GOME-2 (ESA) |
| Multi-viewing, -channel, -polarisation Imaging (3MI) | 3MI (ESA) | -/- |

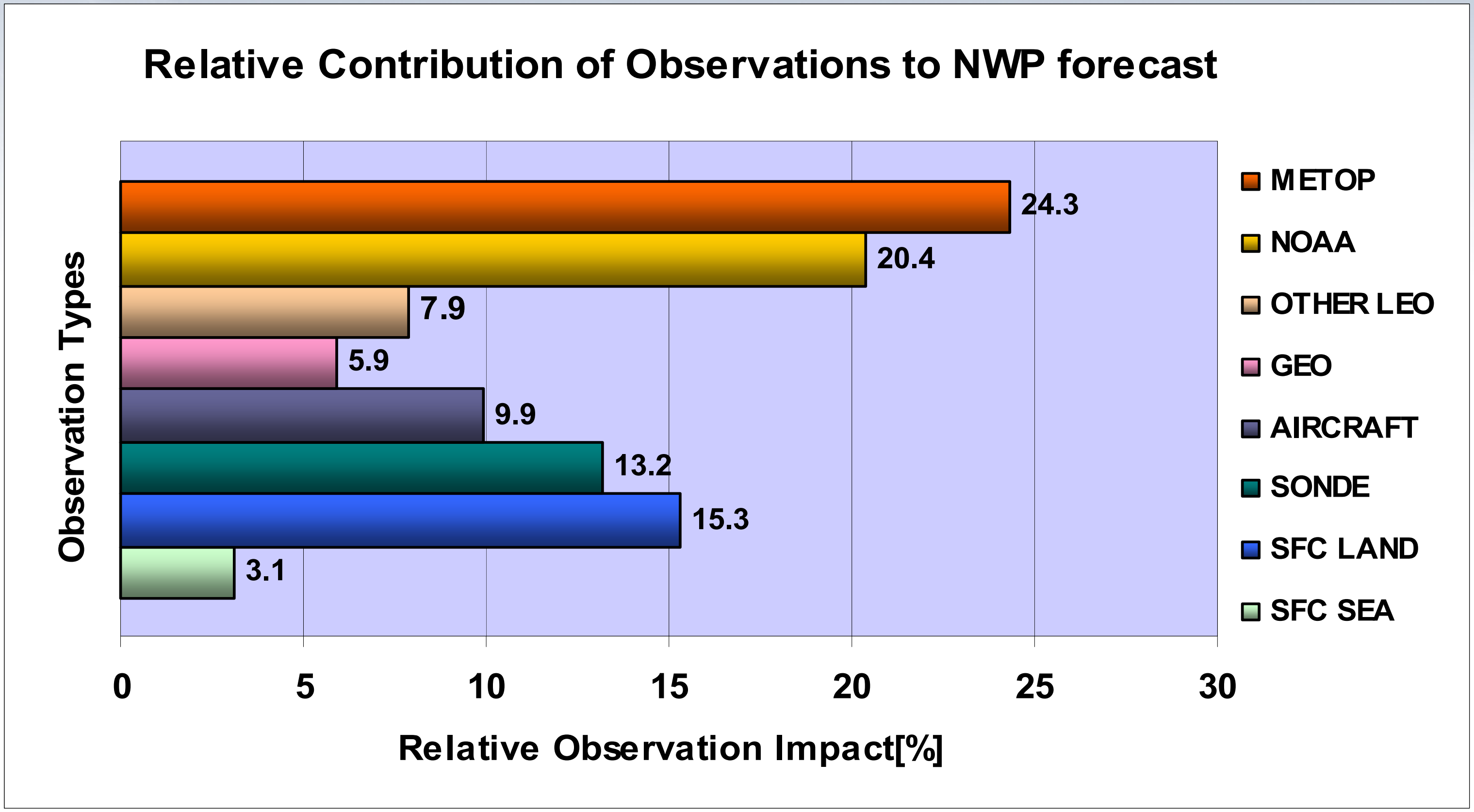
| Satellite-B Missions | Instrument (and Provider) | Predecessor on Metop |
|---|---|---|
| Scatterometer (SCA) | SCA (ESA) | ASCAT |
| Radio Occultation (RO) | RO #2 (ESA) | GRAS (ESA) |
| Microwave Imaging for Precipitation (MWI) | MWI (ESA) | -/- |
| *Other equipment* | | |
| Advanced Data Collection System (ADCS) | Argos-4 (CNES) | A-DCS |

# EPS versus EPS-SG: Mission evolution

| Instrument | Metop | EPS-SG |
|---|---|---|
| **IASI / IASI-NG** | **645 to 2760 $cm^{-1}$<br>NEΔT 0.1 - 0.6 K (<2400 $cm^{-1}$)<br>Δν = 0.35 - 0.5 $cm^{-1}$<br>pixel size 12 km** | **645 - 2760 $cm^{-1}$<br>NEΔT ≤ 0.5 NEΔT(IASI)<br>Δν ≤ 0.5 Δν(IASI)<br>pixel size 12 km** |
| **AHVRR / METimage** | **6 channels:<br>0.58 – 12.5 µm** | **≥ 20 channels: 0.41 – 14.2 µm<br>spatial sampling 500 m,<br>3 solar channels sampled at 250 m** |
| **AMSU-MHS / MWS** | **15 + 5 channels:<br>23 - 190 GHz** | **24 channels:<br>23.8 – 229 GHz** |
| **ASCAT / SCA** | **spatial resolution 50 km<br>dynamic range 4 - 25 m/s** | **spatial resolution 25 km<br>dynamic range 4 - 25 m/s** |
| **GRAS / RO** | **GPS tracked<br>650 occultations / day** | **GPS and Galileo tracked<br>breakthrough @ 2600 occultations / day** |
| **GOME-2 / Sentinel-5 UVNS** | **0.29 – 0.74 µm<br>80x40 $km^2$ resolution** | **9 bands: 0.27 – 2.385 µm<br>7 km sampling** |

# Impact of Metop Data to NWP forecast

## (UK Met Office, 24 h forecast, J. Eyre et al., 2011)




**Source: UK Met Office**

# Reasons behind improvements in NWP due to satellite data

*(from Uccellini, 2007)*

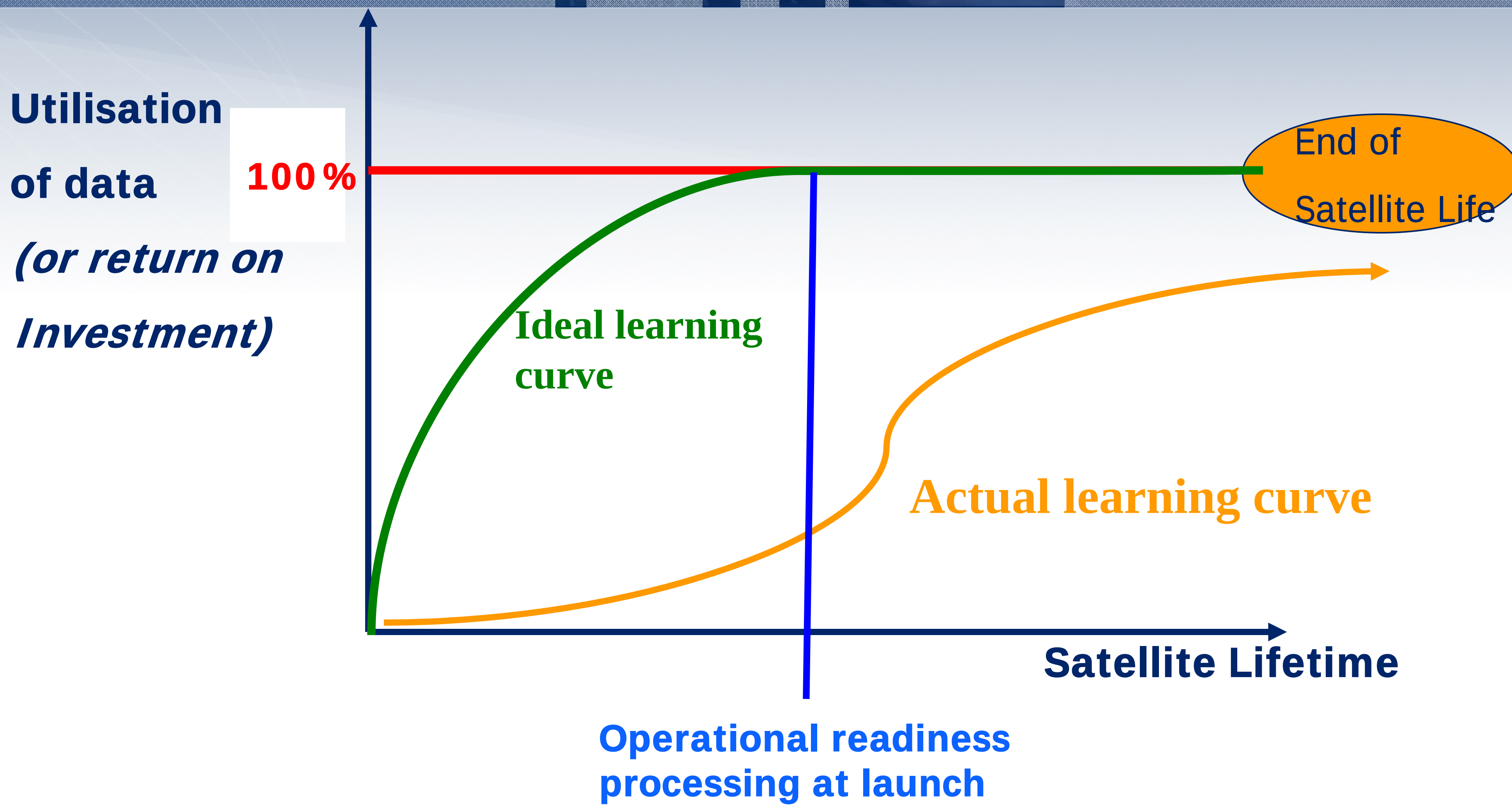
Improvement is due to a balance among:

- Observations
- Data Assimilation & Model technology
- Computing resources

An estimated 30 - 40% comes from improvements due to the observations (principally global LEO satellite data) and 60 - 70% from advances in data assimilation and modeling techniques and better computing resources

=> This suggests that R&D for advanced utilisation of future missions should commence early, i.e. well before launch. This activity should be clearly separated from the development of an operational ground segment

# Adequate investment in R&D on utilisation of data will increase the return on investment



# Conclusions and Suggestions (see also beginning)

- Impact studies (data denial or forecast error contributions) are a good tool to demonstrate the robustness of the GOS and to provide guidance on priorities for improved use of current data and of future missions
- WMO could enhance processes that:
  - maintain an up-to-date knowledge on impact of satellite data on NWP including guidance on interpretation (update cycle of this is tbd)
  - provide guidance for development work toward improved use of current data (that could also help to leverage dedicated funding)
  - provide guidance on future satellite missions (that does exist to large extent and is agreed => vision for the global GOS)
- *Longer term future:* WMO could trigger a concerted effort in support of the planning and coordination of a future space-based GOS from the very beginning

# Global Operational Satellite Observation System