UPDATE ON EUMETSAT’S PROGRAMMES & CALIBRATION ACTIVITIES

EUMETSAT

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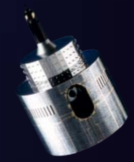


Outline

- EUMETSAT Objectives
- EUMETSAT Programmes
  - Present
  - Future
- Calibration Activities
  - Vicarious Calibration
  - Inter-Calibration (through GSICS)
  - Other

EUMETSAT's Objectives and Vision

EUMETSAT STRATEGY

A GLOBAL OPERATIONAL SATELLITE AGENCY AT THE HEART OF EUROPE

EUMETSAT's objectives:

1. To establish, maintain and exploit European systems of operational meteorological satellites
2. To contribute to the operational monitoring of the climate & the detection of global climatic changes
3. Furthermore, other environment monitoring issues are considered when interactions with the atmosphere or the ocean are involved

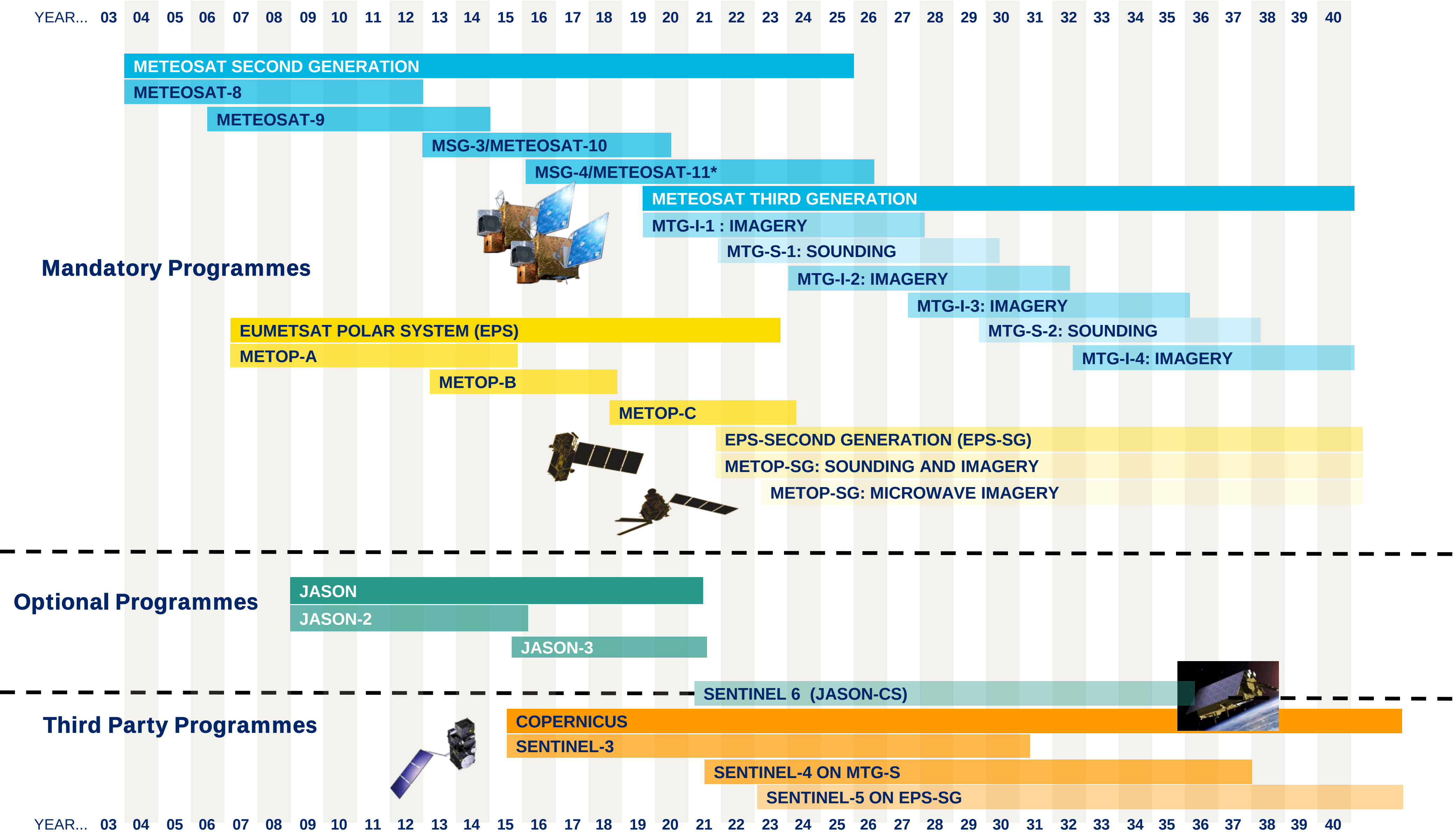
EUMETSAT's vision:

- Be the leading user-governed operational agency for European Earth Observation satellite programmes that are consistent with the objectives of the EUMETSAT Convention and,
- Be a trusted global partner for the provision of satellite data from GEO and LEO orbits.

EUMETSAT’s strategy – Eight objectives

1. Deliver satellite programmes which meet the needs of EUMETSAT Member States;
2. Provide services based on cost-effective ground and space segment infrastructures which respond to evolving user requirements;
3. Meet additional needs of EUMETSAT Member States for global space-based observations through international cooperation;
4. Secure new opportunities in areas that are complementary to EUMETSAT’s programmes and meet Member States’ requirements;
5. Extend the user base for EUMETSAT data, products and service in EUMETSAT Member/ Cooperating States and for WMO Members;
6. Be an active partner in European and Global initiatives of relevance to space-based weather, climate and environmental monitoring;
7. Deliver continuously improved management processes;
8. Recruit and maintain a core resource of talented and engaged people with relevant skills.

EUMETSAT commitment to long term continuity...



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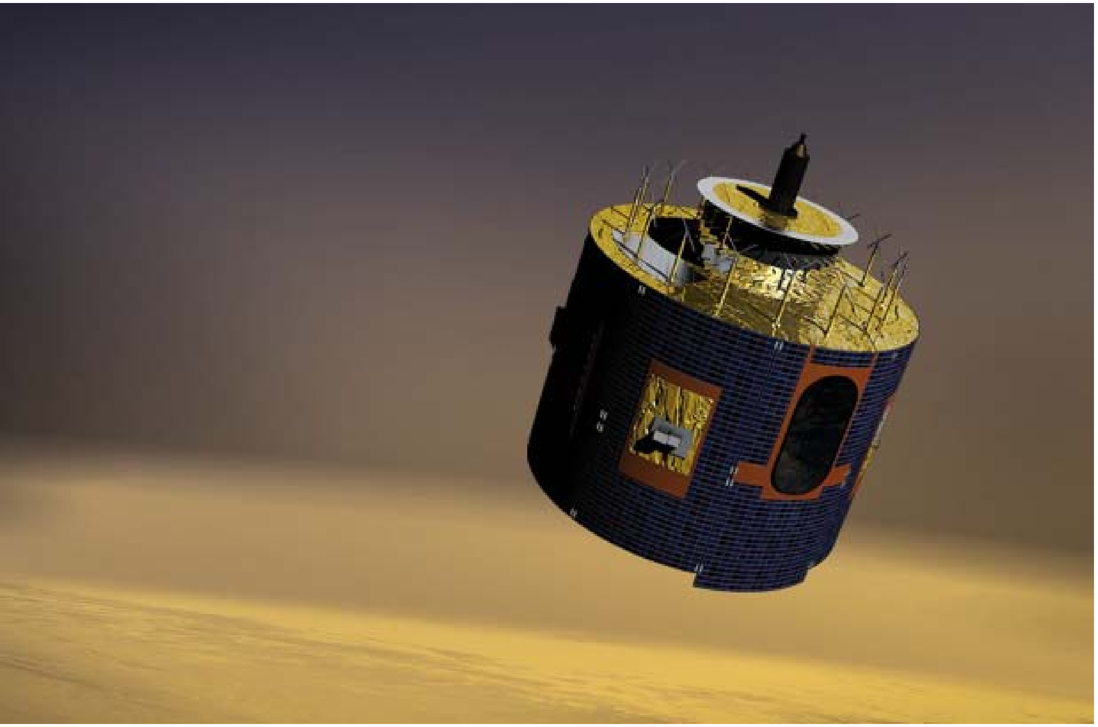
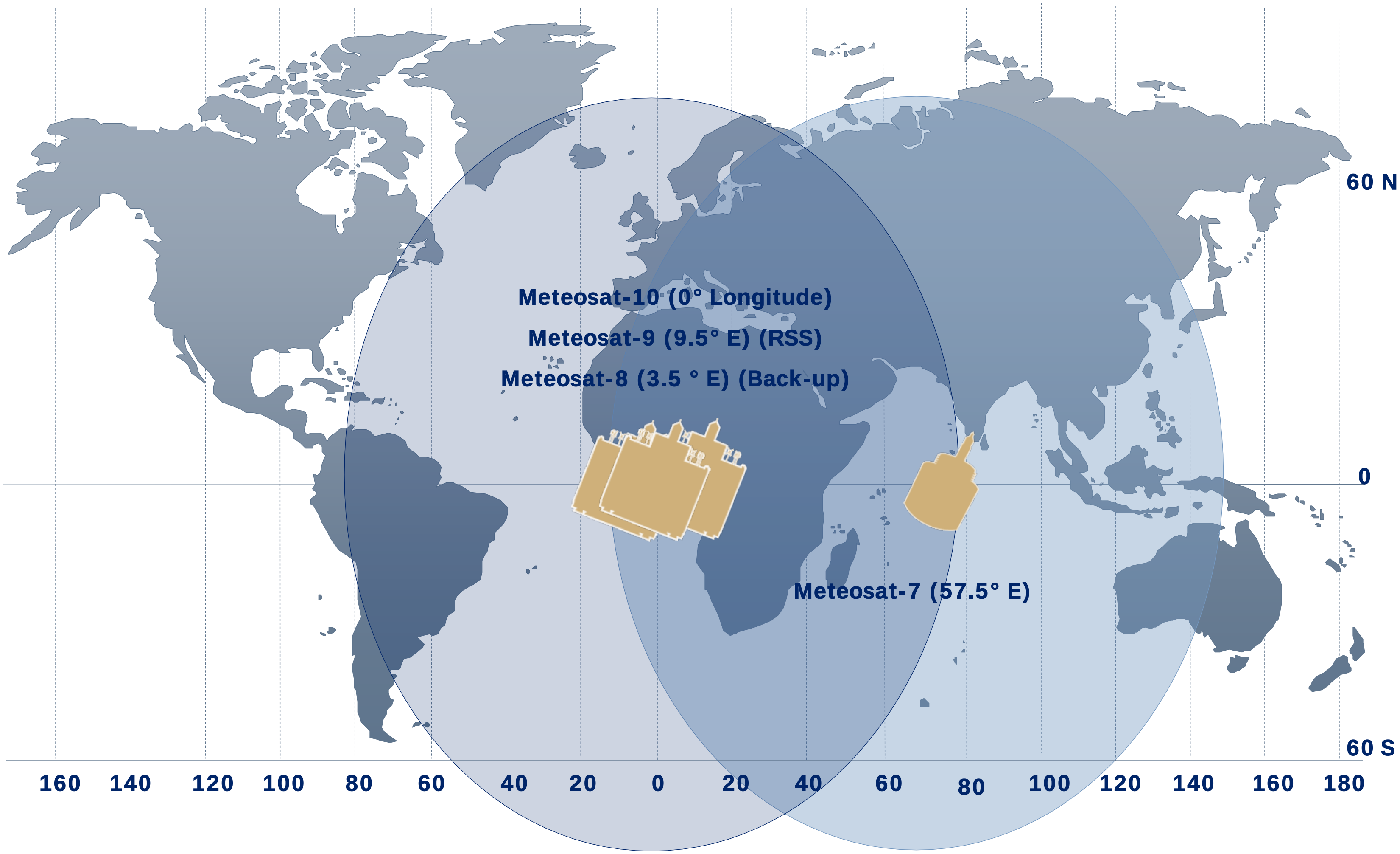
Geostationary satellites

Meteosat Second Generation (MSG)



- 4 geostationary weather satellites, operations at least until 2018 (MTG)
- Full disk imagery: Imaging European weather, every 15 minutes with 12 spectral bands (currently Meteosat-10)
- Rapid Scan Service (RSS) every 5 minutes (currently Meteosat-9): detection of rapid, local development of convective systems
- Data collection for environmental monitoring

EUMETSAT's geostationary satellite coverage



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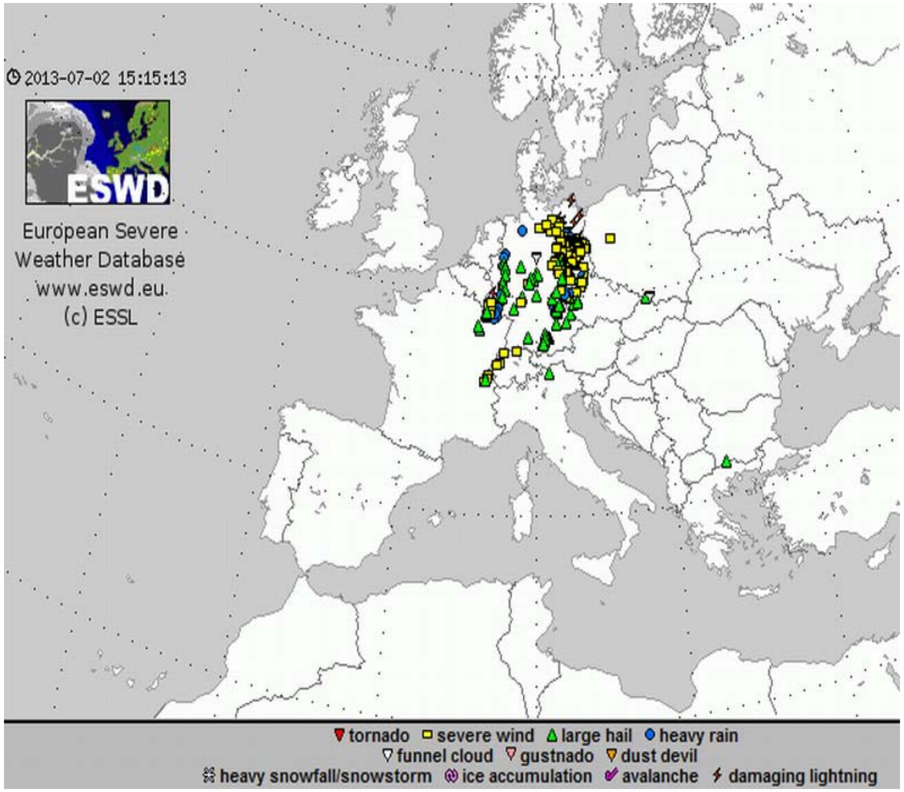
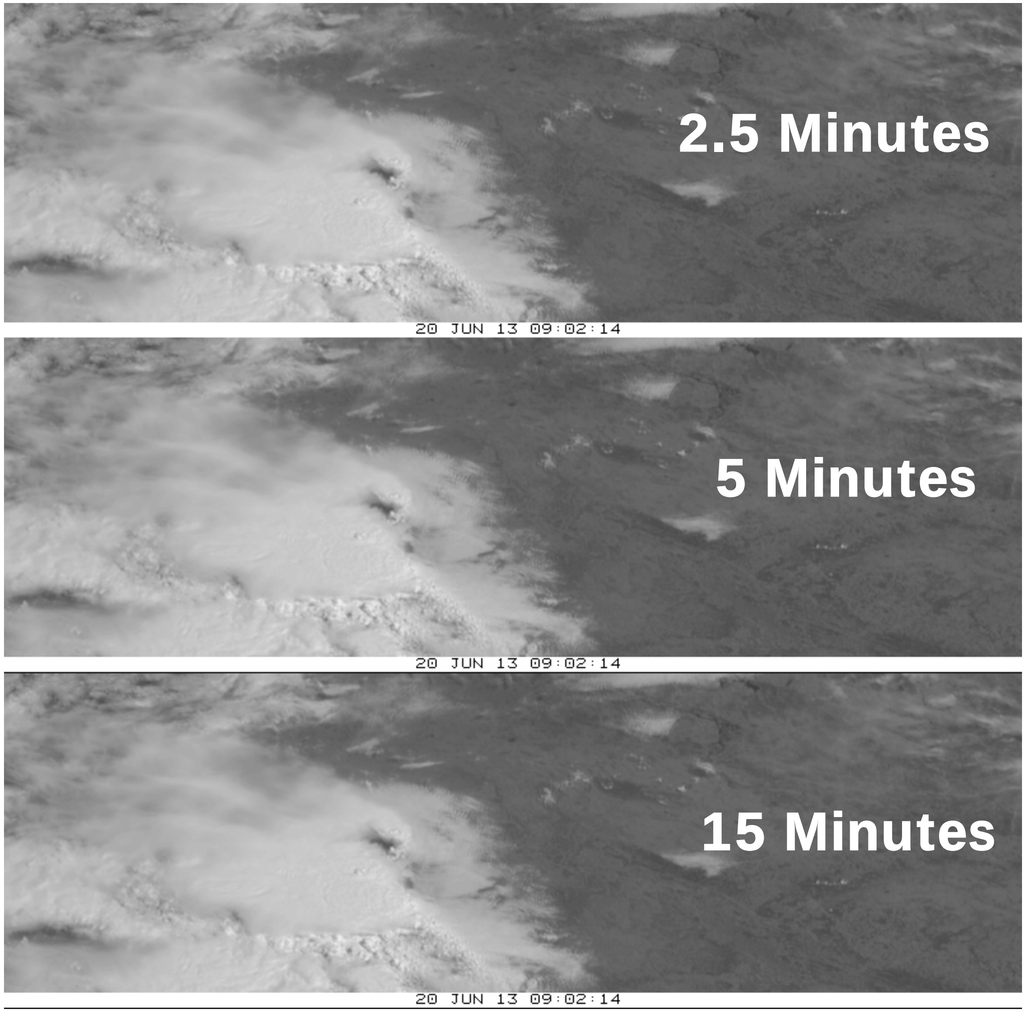
Meteosat-8 12-hour "super rapid scan" experiments
(shown: 20 June 2013)

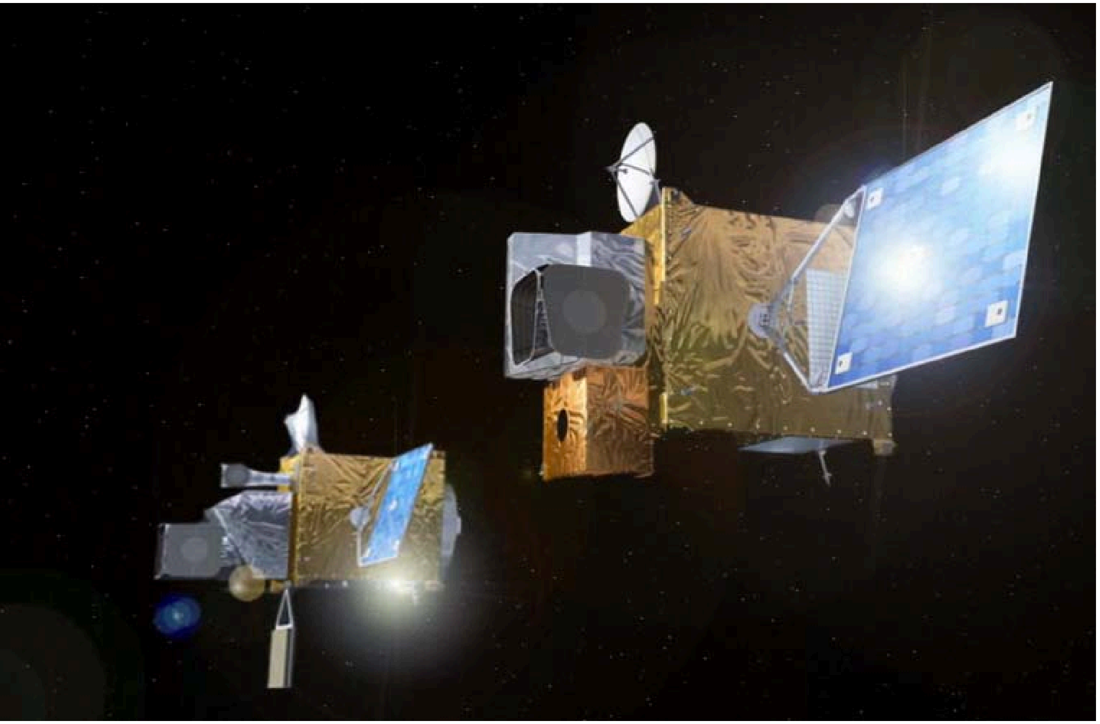
- **Four days: 17 May, 17, 20 June, 29 July**
- **Enables research on convection and preparation for Meteosat Third Generation**





Future Geostationary satellites : MTG-I and MTG-S

Meteosat Third Generation (MTG)



- 4 MTG-I imaging and
- 2 MTG-S sounding satellites
  – both 3-axis stabilised

- Start of operations in 2018 and 2019,
  - for 15-20 years

- Imaging mission
  - Imaging Full Disc/European weather
    - every 10/2.5 minutes
    - with 16 spectral bands
  - new Lightning Imager

- Sounding mission (IR and UV)
  - Hyperspectral infrared sounder (IRS)
    - high-resolution soundings of
    - water vapour, temperature, O3 in 4D
  - Ultra-violet, Visible and NIR Sounder (UVN):
    - atmospheric chemistry and air quality monitoring
    - Copernicus Sentinel 4 Instrument

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MTG Programme Status

- **MTG-I Satellite:**
  - **schedule is stable with FAR (Flight Acceptance Review) in July 2018.**
  - **PDR of the LI is on-going.**

- **MTG-S Satellite**
  - **Most probable date for the MTG-S FAR is January 2021**
  - **Closure of the MTG-S PDR : October 2013**
  - **Closure of the S-4 PDR : November 2013**

Current Polar-orbiting satellites: EUMETSAT Polar System

Dual operation of Metop-A and Metop-B

Metop-A launched in 2006: 21:30 Asc
Metop-B launched in 2012: +48 min

Metop-B prime satellite since April 2013

Metop-C launch planned for 2018

Part of Initial Joint Polar System shared with NOAA

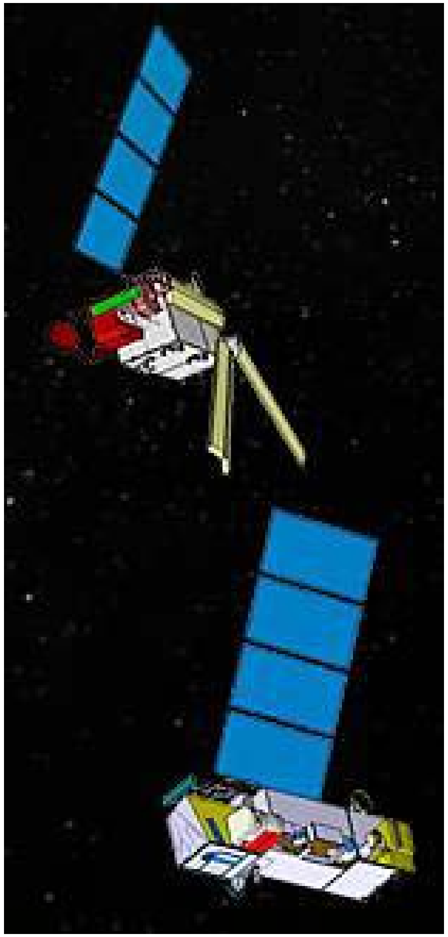
Missions and Payload
- Imagery (VIS, IR), sounding (IR, MW, UV, GPS occultation), radar (ASCAT)
- direct broadcasting and data collection capabilities

Applications
- Numerical Weather Prediction and Nowcasting at high latitudes
- Marine meteorology and oceanography
- Air quality, atmospheric chemistry

EPS-SG (Second Generation) Payload

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) 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 (Copernicus, 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 (ESA)	GRAS (ESA)
Microwave Imaging for Precipitation (MWI)	MWI (ESA)	-/-
Ice Cloud Imager (ICI)	ICI (ESA)	-/-
Advanced Data Collection System (ADCS)	Argos-4 (CNES)	A-DCS



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EPS-Second Generation (next generation of Metop satellites)

- Metop-SG Programme was approved by ESA Council
  - Approval of contract proposals for phases B2/C/D expected in April 2014
  - Phase B2 to be kicked off in July 2014

- EPS-SG End User Requirements Document was approved by Council as baseline for Phase B
  - Nine observation missions to be implemented with a two-satellite system serving 21 years of operation, first launch foreseen in 2021

- EPS-SG full programme approval expected in 2014
  - Cooperation with NOAA on JPS, signed in 2013
  - ESA as main development agency for the space segment
  - Provision of IASI-NG (Next Generation) by CNES
  - Provision of future imager METimage by DLR

Monitoring the oceans and climate in partnership

High precision altimetry

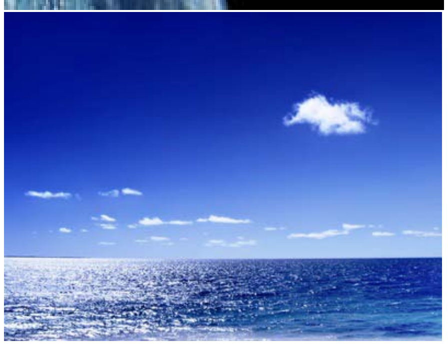
Partners:

Jason-2
- launched in June 2008
- EUMETSAT's first optional programme (new convention)
- Applications: marine meteorology, operational oceanography, seasonal prediction and climate monitoring

Jason-3
- under development, to provide continuity with Jason-2
- launch scheduled in April 2014

Jason-CS
- future programme under discussion with ESA, EC, NOAA in the context of Copernicus
- to provide continuity after Jason-3

Monitoring the oceans within Copernicus: Sentinel 3



EUMETSAT will operate the Sentinel-3 satellite for the European Copernicus programme

- Further response to the operational needs of the European
- marine (and climate) community,

Data provision with near-real-time and off-line products includes:

- sea-surface topography (radar altimetry);
- sea-surface temperature (advanced visible/thermal radiometer)
- ocean-surface colour (visible spectrometer).

***ultimately under ESA responsibility**

Calibration Activities at EUMETSAT

- On-board calibration monitoring
  - Gain, noise, stats, ...
- Vicarious Calibration using Pseudo Invariant Targets
  - Deserts }
  - Rayleigh scattering } MSG, MFG, MTG-FCI
  - Deep Convective Clouds - MSG, MFG, MTG-FCI
  - Moon - MSG, MFG, MTG-FCI
- Inter-calibration – through GSICS
  - Pseudo Invariant Targets - As above wrt MODIS
  - Collocated Observations - IR: MSG, MFG, HIRS, MTG
- Support for Climate Services
  - Reprocessing & Recalibration based on above
  - Generation of Fundamental Climate Data Records

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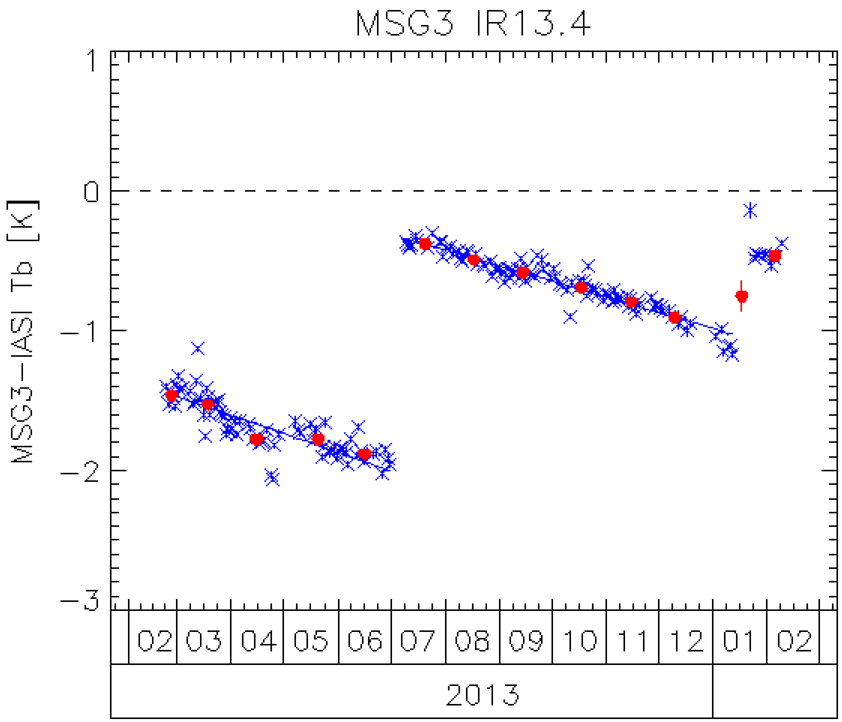
Inter-Calibration

- Inter-Calibration Corrections
  - Developed within GSICS
- GEO-LEO IR
  - Collocated observation (SNO)
  - Meteosat/SEVIRI-Metop/IASI
  - Pre-Operational
  - Including Uncertainty Analysis
  - Bias Monitoring
  - Used to support commissioning
  - Analysis of ice contamination
  - Developing Delta Correction to migrate references
- GEO-LEO VIS
  - Pseudo-Invariant Targets
  - In Development
  - for Meteosat/SEVIRI– Aqua/MODIS:
    - Deep Convective Cloud
    - Lunar



Example of EUMETSAT's Bias Monitoring of Meteosat-9 for GSICS

Time series of standard bias in infrared channels of Meteosat-10/SEVIRI relative to Metop-B/IASI, expressed in brightness temperature [K].

- These comparisons used to generate inter-calibration corrections.
- Allow monitoring of instrument anomalies.
- The trend lines show steady degradation of the 13.4 μm channel's calibration and sudden recoveries, following the spacecraft decontamination procedures.
- Validated model of how the ice contamination.
- Other channels (not shown) have small, stable biases.

Lunar calibration – EUMETSAT achievements

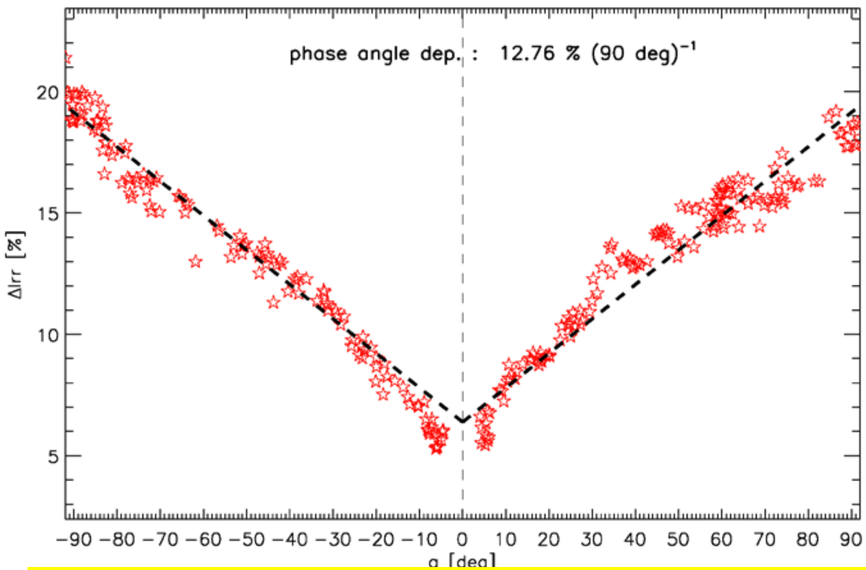
- **Developed automatic lunar imagery extraction tool**
- **Extensive and unique archive of lunar images acquired by Meteosat-7, -8, -9 and -10**
  - **(for SEVIRI only, about 1030 images at low resolution and about 170 for HRVIS).**
- **EUMETSAT implementation of USGS ROLO model**
  - **(fully validated and tested with USGS)**

➔ **Enhanced monitoring and inter-calibration capabilities for reflective solar bands.**

- **Through collaboration with USGS and CNES**
  - **phase angle dependence was identified**
  - **Issue for GEO imagers**

  (no choice on illumination)
  - **should be corrected**

Example SEVIRI Imagettes Extracted for Lunar Calibration



ΔIrradiance vs. g for the MSG2/NIR1.6 channel

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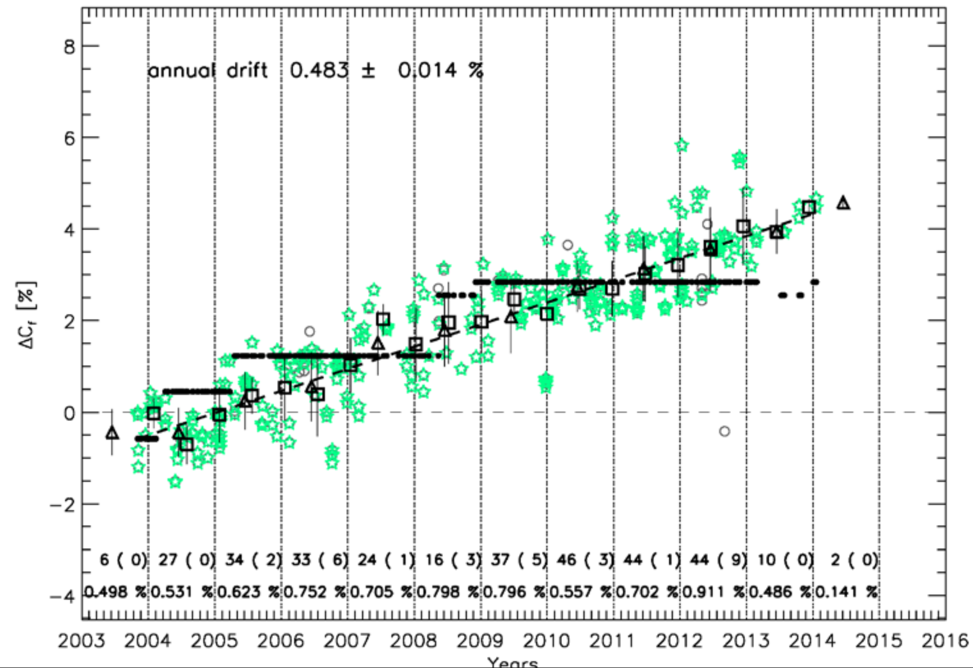
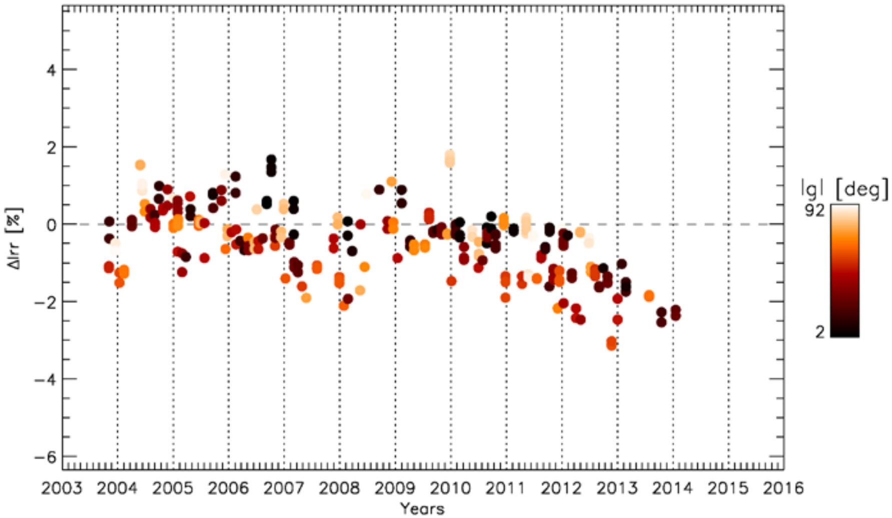
Lunar calibration – EUMETSAT achievements

- **Bias in irradiance = monitoring of the combined system instrument/calibration**
- **Gain on ROLO scale = monitoring of the instrument drift**

➔Combining analysis = powerful monitoring tool

BUT phase angle dependence should be characterized and removed





	VIS0.6	*VIS0.8*	*NIR1.6*	*HRVIS*
Meteosat-8	**0.483 ± 0.014**	**0.444 ± 0.013**	**-0.013 ± 0.018**	**0.493 ± 0.059**
	(0.3583 ± 0.228)	(0.3673 ± 0.193)	(0.031 ± 0.180)	(0.398 ± 0.222)
Meteosat-9	**0.475 ± 0.022**	**0.468 ± 0.020**	**0.033 ± 0.025**	**0.550 ± 0.062**
	(0.359 ± 0.255)	(0.467 ± 0.249)	(-0.051 ± 0.220)	(0.510 ± 0.285)
Meteosat-10	**-0.841 ± 0.293**	**-0.665 ± 0.203**	**-0.365 ± 0.634**	**N.A.**
	(-0.590 ± 2.756)	(-0.318 ± 2.990)	(0.128 ± 2.222)	(-0.653 ± 2.752)

Annual Average Rate of Calibration Gain Drift

Bold = Moon results. In small italic = SSCC drift from all available runs.

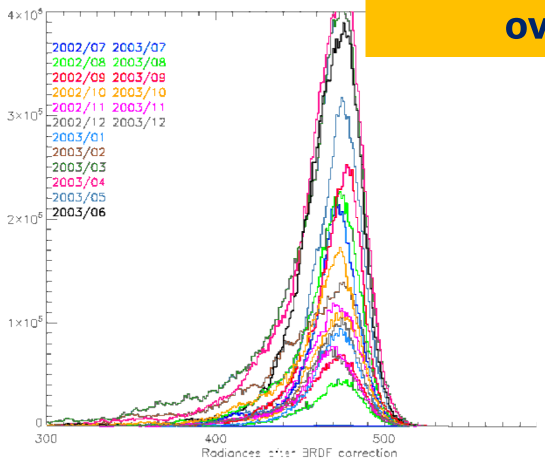
All SEVIRI within specifications for long-term drift

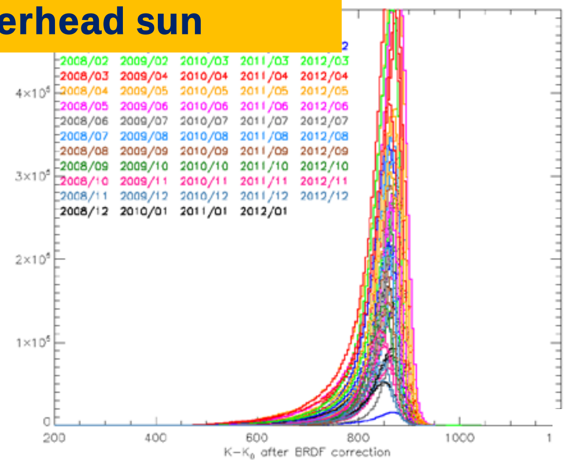
GSICS - Inter-calibration with MODIS – DCC

Implementation of the GSICS ATBD

https://gsics.nesdis.noaa.gov/pub/Development/AtbdCentral/GSICS_ATBD_DCC_NASA_2011_09.pdf

After BRDF correction to overhead sun





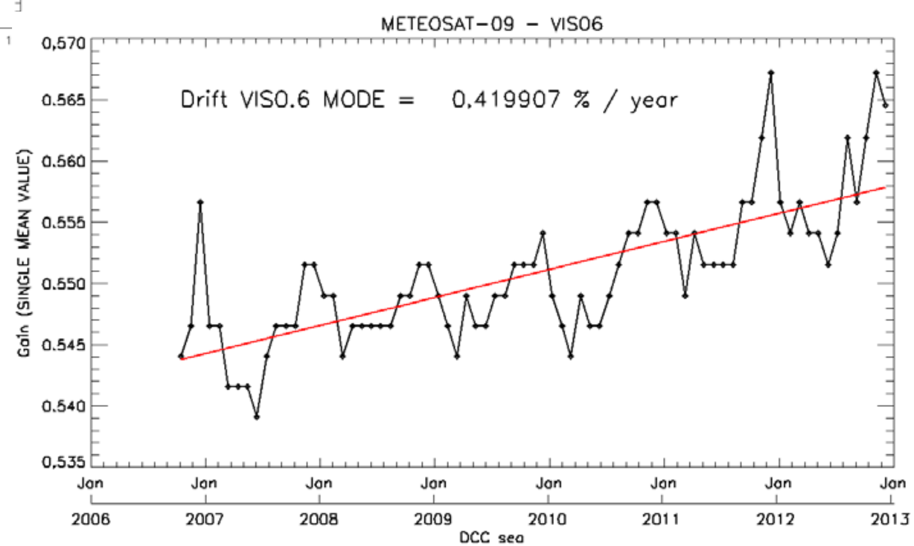
Monthly PDFs of DCC reference radiances (MODIS Aqua)

Monthly PDFs of DCC target counts (geostationary satellites [Meteosat])

$$Gain_{Met9} = \frac{Aqua^{Equiv.Nadir}_{Radiance} \cdot SBAF_{MET9/Aqua}}{K^{Equiv.Nadir}_{Met9} - K_0}$$

- **Deep Convective Clouds**
  - **inter-calibration transfer targets**
- **No need for simultaneous observations (DCC stability over time)**
- **Inter-calibration between all GEOs possible due to DCC global distribution (common calibration reference)**

Example of gain derived for Meteosat-9 VIS0.6



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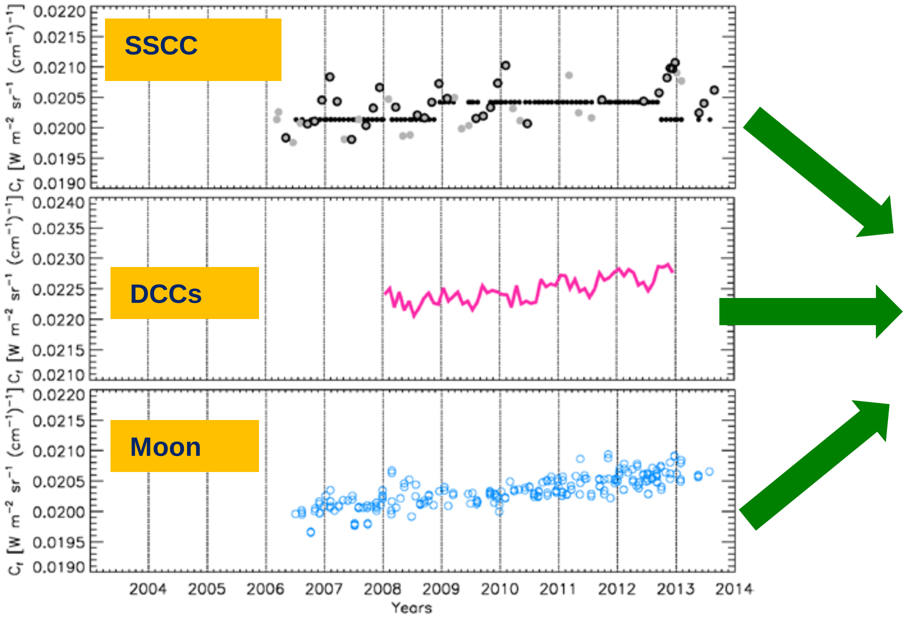
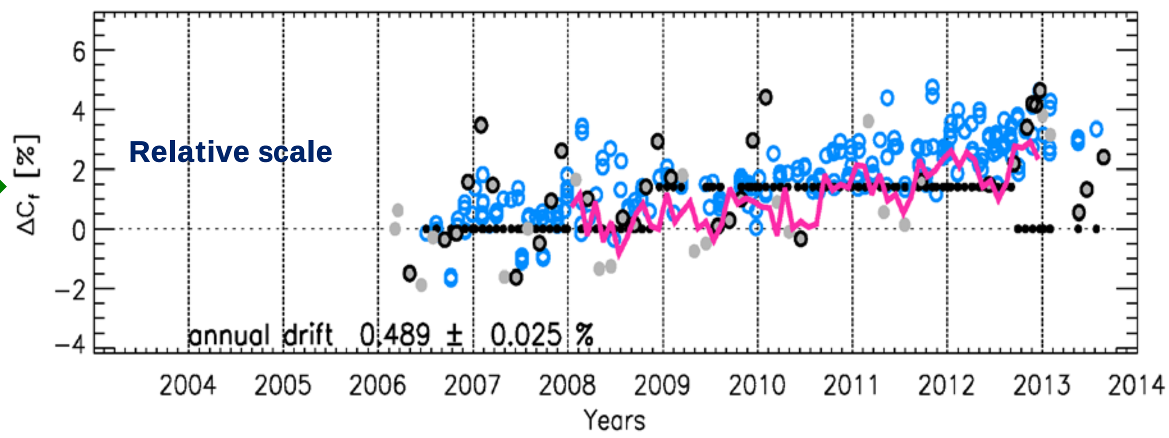
Combining results





Example of the VIS06 band on MSG2/SEVIRI.
Grey/black big dots: SSCC gains.
Black small dots: gains as available in Level 1.5 image headers (derived from SSCC).
Blue dots: lunar calibration.
Magenta: DCC gains

Development of Multi-Mission Integrated Calibration Monitoring System

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Summary

- **Calibration is key to ensuring EUMETSAT achieves its objectives:**
    1. To establish, maintain and exploit European systems of operational meteorological satellites
    2. To contribute to the operational monitoring of the climate & the detection of global climatic changes
    3. Furthermore, other environment monitoring issues are considered when interactions with the atmosphere or the ocean are involved

- **EUMETSAT continues to develop new calibration capabilities**
    - **For real-time operations**
    - **and in support of climate reanalysis**
    - **In international cooperation, including**
        - **Global Space-based Inter-Calibration System**
        - **WGCV**

Thank you