Sustained Climate Monitoring for Climate Services: EUMETSAT's Perspective

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Why Climate Services?

- Climate variability and change are having profound effects on society;
- Mitigation and adaptation planning needs sustainable climate services including fit for purpose climate data products;
- Society deserves full and open access to the data and methods used to produce climate products.

EUMETSAT Mandate

- The primary objective is to establish, maintain and exploit European systems of operational meteorological satellites, taking into account as far as possible the recommendations of the WMO;

MSG-3 launch on 5 July 2012.

- A further objective is to contribute to the operational monitoring of the climate and the detection of global climatic changes.

What we do …

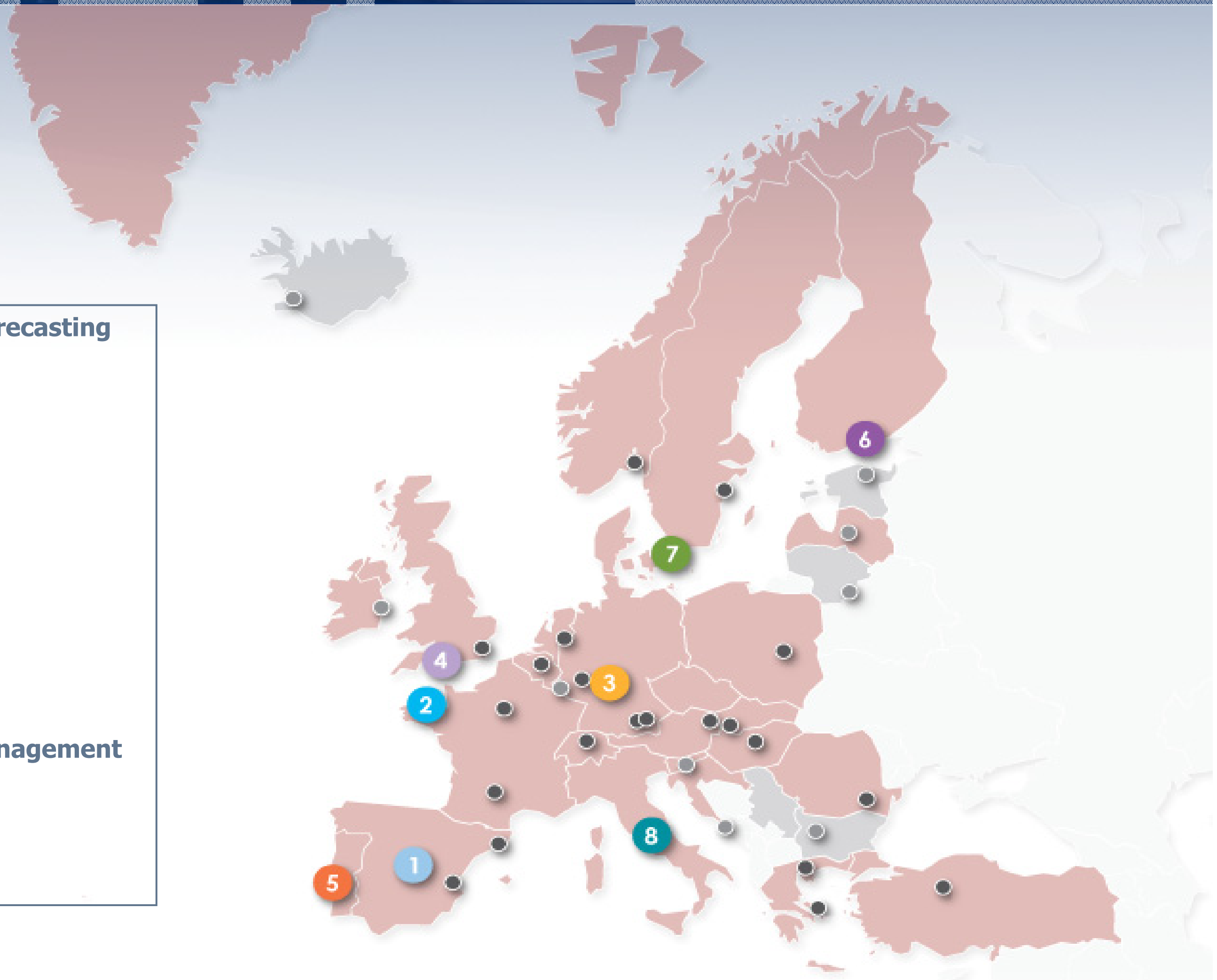
USER REQUIREMENTS
European National Meteorological Services
Private Enterprises, Value-Added Services, End-Users
Science Institutions (in particular important for climate)
Operating Agency
Interface with users and overall system design and development. Responsible for procurement of ground segment and launch services.
EUMETSAT
esa
Satellite development and procurement agency
European Space Industry
DELIVERY (Data and specific products)

Satellite Application Facilities (SAFs) in Europe

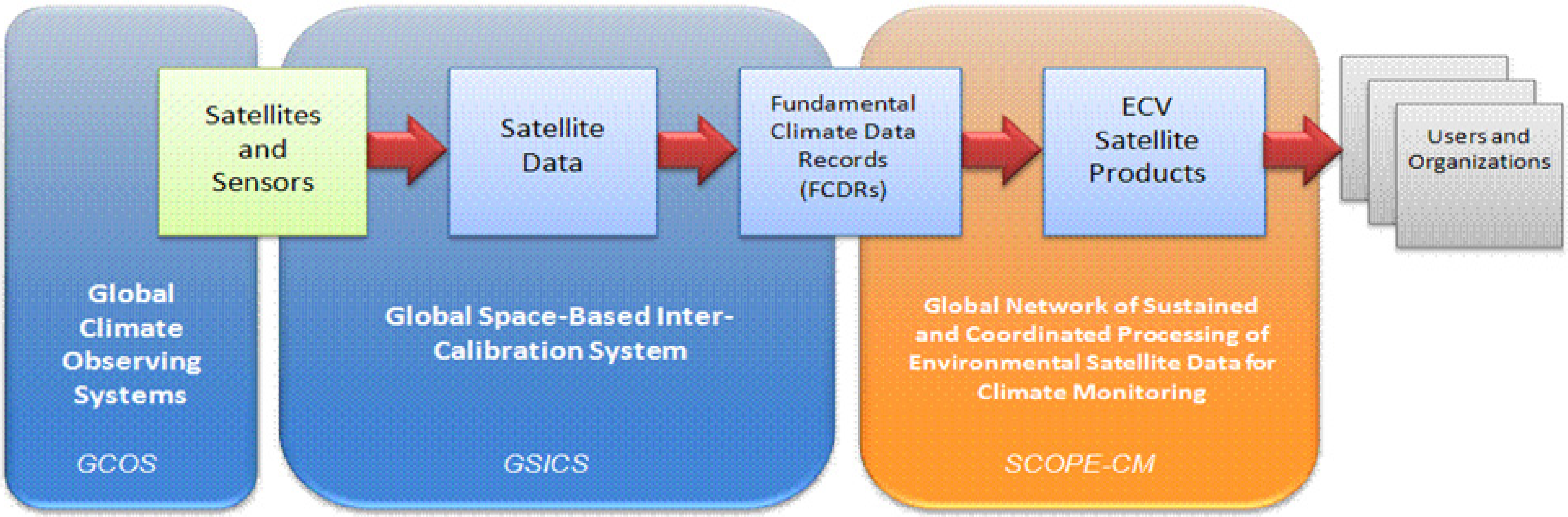
Member State	Cooperating State

1. Support to Nowcasting and Very Short Range Forecasting
2. Ocean and Sea Ice
3. Climate Monitoring
4. Numerical Weather Prediction
5. Land Surface Analysis
6. Ozone and Atmospheric Chemistry Monitoring
7. GRAS Meteorology
8. Support to Operational Hydrology and Water Management

- SAF Consortium Member
- Additional Met Service Users

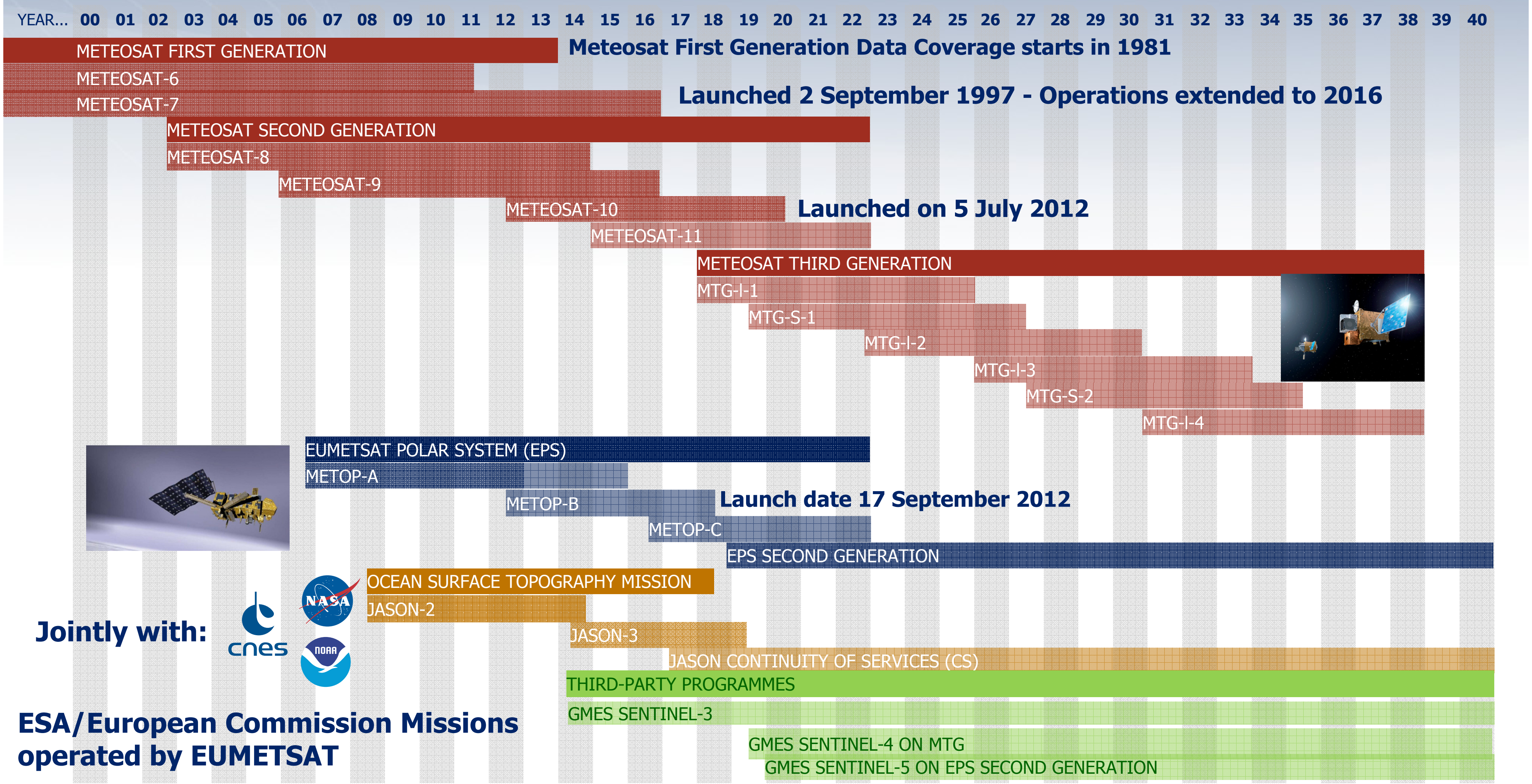


Conceptual View of End-to-End Provision of ECV CDRs



The architecture for space-based climate monitoring contributing to the Global Framework for Climate Services in the context of WMO considers the whole chain from observations to decision making.

EUMETSAT Space Segment



Data Records (Produced 2011 - 2013)

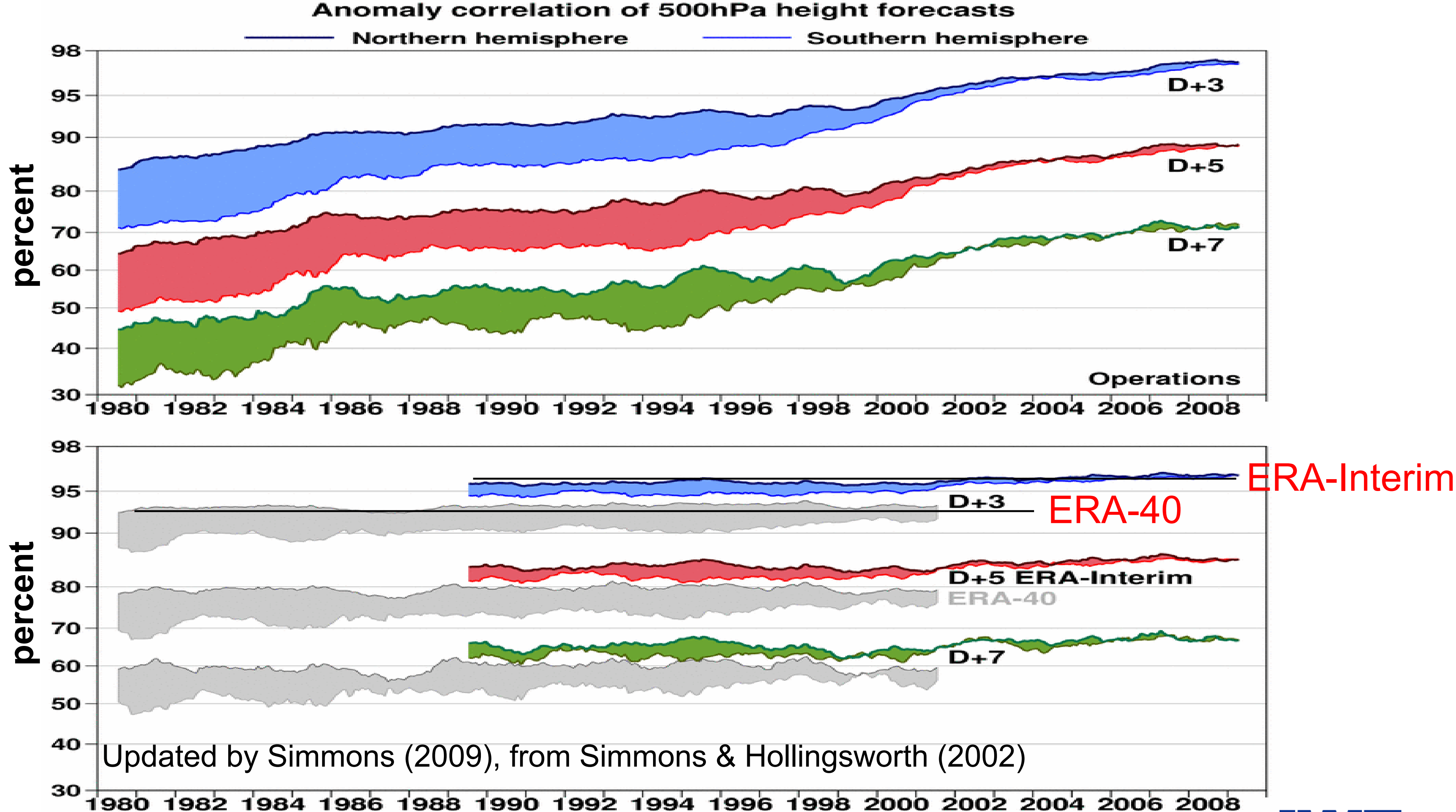
Activity Name	Int . project	Delivery Date	Record start	Record end	Output in GB	Users	Nr. of Users
MSG L15 Image	SCOPE-CM	Sep-11	01/01/2004	04/05/2009	**32000**	Reanalysis Centre (ECMWF), CM-SAF, LSA-SAF, OSI-SAF, ESA CCI	**10**
GOME-2 Level 1	UNEP Ozone Ass.	Q2/2012	01/01/2007	31/12/2011	**16000**	O3M-SAF, ESA CCI, Research Institutes	**10**
MFG 7 Geostationary Surface Albedo	SCOPE-CM	Q3/2012	01/12/2006	31/12/2011	**61**	Climate Modelling (MPI-M)	**5**
MFG 3 Geostationary Surface Albedo	SCOPE-CM	Q3/2012	01/08/1991	31/12/1995	**39**	Climate Modelling (MPI-M)	**5**
MSG AMV-CSR-ASR	ERA-CLIM, SCOPE-CM	Q4/2012	01/01/2004	31/12/2012	**3700**	**Reanalysis Centre (ECMWF)**	**5**
AVHRR Polar Winds	ERA-CLIM	Q4/2012	01/11/2006	31/12/2012	**137**	**Reanalysis Centre (ECMWF)**	**5**
COSMIC Level 1	ERA-CLIM	Q1/2013	01/04/2006	31/12/2012	**24600**	**Reanalysis Centre (ECMWF)**, ROM-SAF	**5**
GRAS Level 1	ERA-CLIM	Q1/2013	01/11/2006	31/12/2012	**5750**	**Reanalysis Centre (ECMWF)**, ROM-SAF	**5**
ASCAT Level 1	ERA-CLIM	2013	01/01/2007	31/12/2012	**27500**	**Reanalysis Centre (ECMWF)**, OSI-SAF, ESA-CCI	**10**
MFG Re-Calibration - 1	ERA-CLIM	2013	01/08/1982	31/12/2012	**4700**	**Reanalysis Centre (ECMWF)**, CM-SAF	**10**
IASI Level 1c	-	2013	01/04/2007	31/12/2012	**60170**	**Reanalysis Centre (ECMWF),** CM-SAF	**10**
CHAMP Level 1	ERA-CLIM	Q2/2013	01/09/2011	30/09/2008	**2100**	**Reanalysis Centre (ECMWF),** ROM-SAF	**5**
GRACE Level1	ERA-CLIM	Q2/2013	01/01/2005	31/12/2012	**2400**	**Reanalysis Centre (ECMWF)**, ROM-SAF	**5**
MFG AMV-CSR	ERA-CLIM, SCOPE-CM	Q4/2013	01/01/1982	31/12/2012	**3630**	**Reanalysis Centre (ECMWF)**	**5**
ERA-CLIM-OZONE	ERA-CLIM	Q4/2013	01/01/2007	31/12/2012	**150**	**Reanalysis Centre (ECMWF),** ESA CCI	**10**

*

Total estimated Output volume of min. 130 TB *). Multiplying the data set volumes with the expected no. users, the expected special total delivery volume is ca. 1100 TB *)[1] – a factor 3 more than the annual delivery volume of the Archive (387 TB) in 2011.

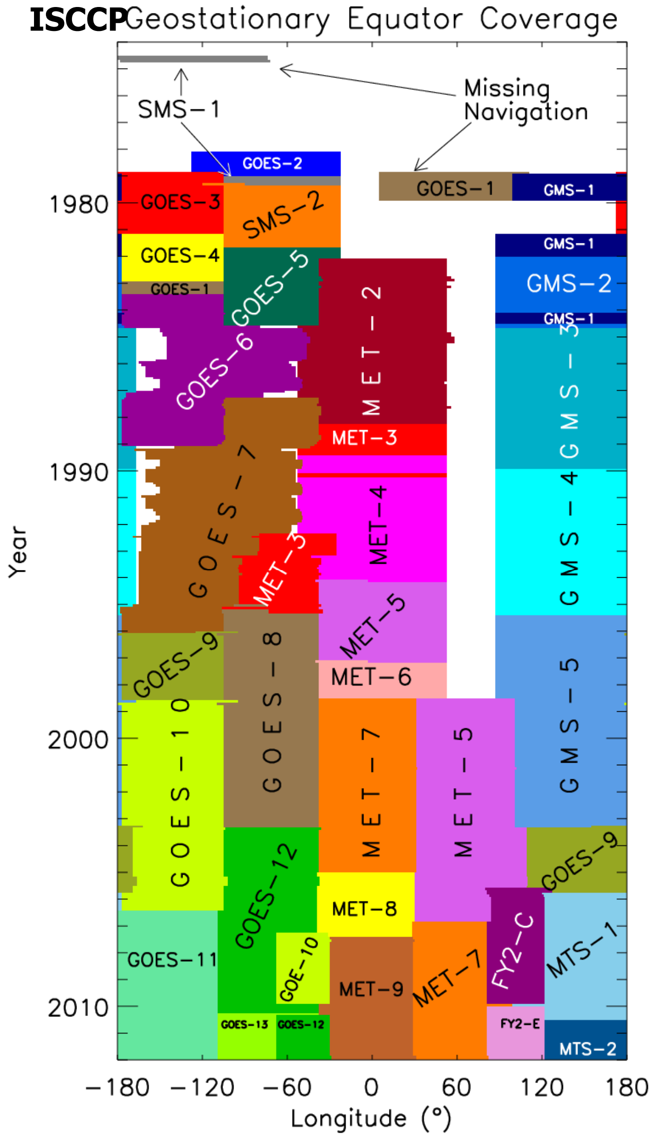
[1]Compression may bring the number down to 720 TB at the computing cost for decompression.

Raising the bar:
NWP operations improve product quality over time
Reanalysis datasets are more consistent in time



Updated by Simmons (2009), from Simmons & Hollingsworth (2002)

FCDR Creation - Scale of the Challenge



- International community has embarked on the creation of FCDRs for archived data (EUMETSAT, NOAA-CDR program and similar programs);
- It is essential for fulfilling GCOS ECV requirements;
- Inter-calibration of the sensors to allow seamless products is a weakness in existing data records, e.g., GEWEX data projects;
- The creation of FCDRs has a large science component calling for collaborations of space agencies and scientists **<- WCRP involvement**;
- **GSICS and SCOPE-CM are the right frameworks to make progress and achieve GCOS goals.**

Figure: Courtesy of Ken Knapp, NOAA-NCDC

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Inter-Satellite Calibration To a Reference

Difference between Meteosat and collocated IASI observation is utilised to correct systematic errors.

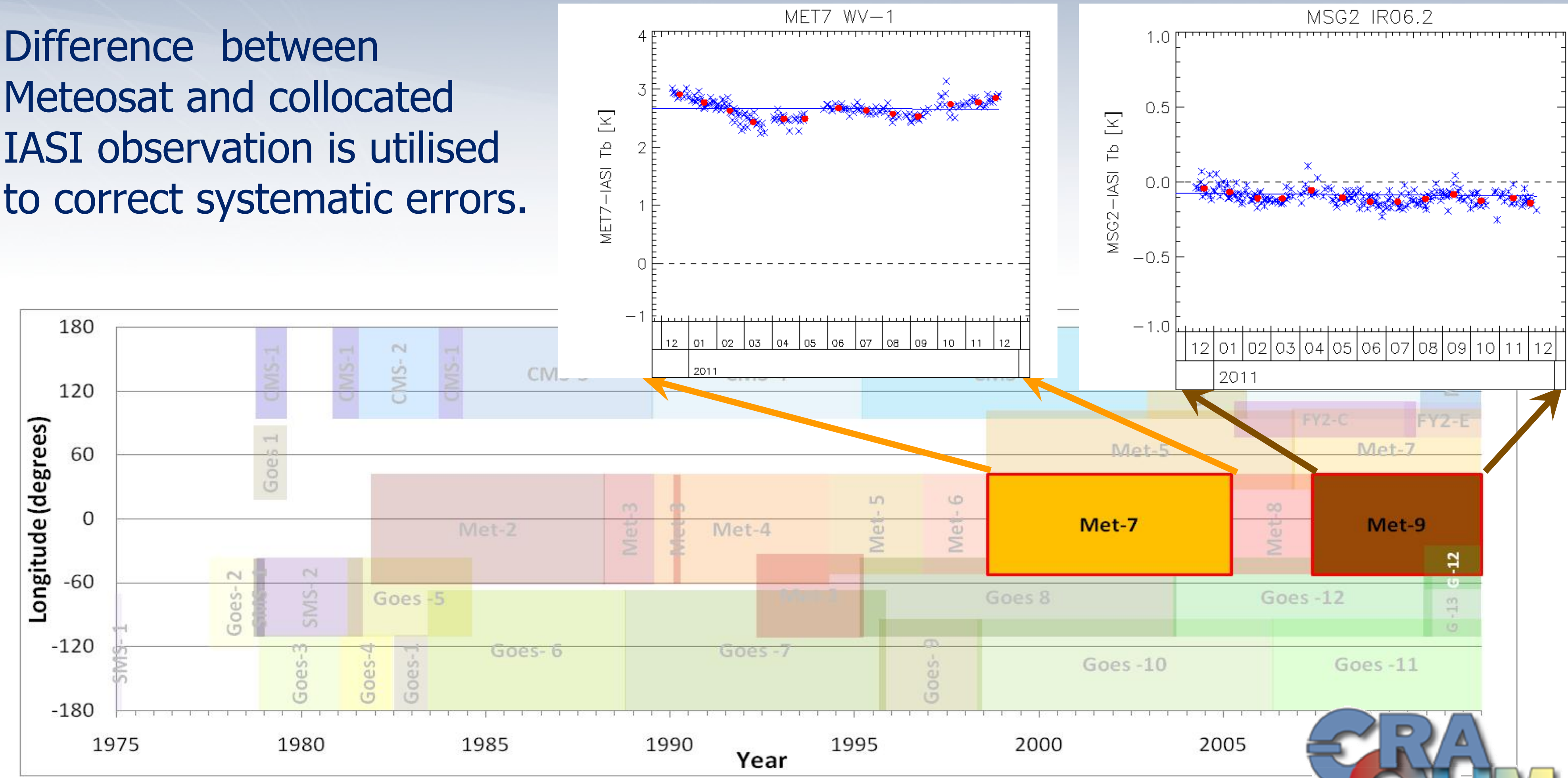


Fig: *Satellites used for the ISCCP climate data record. (Courtesy of Ken Knapp, NOAA-NCDC)*

EUMETSAT

Monitoring Change of Surface Albedo with Meteosat

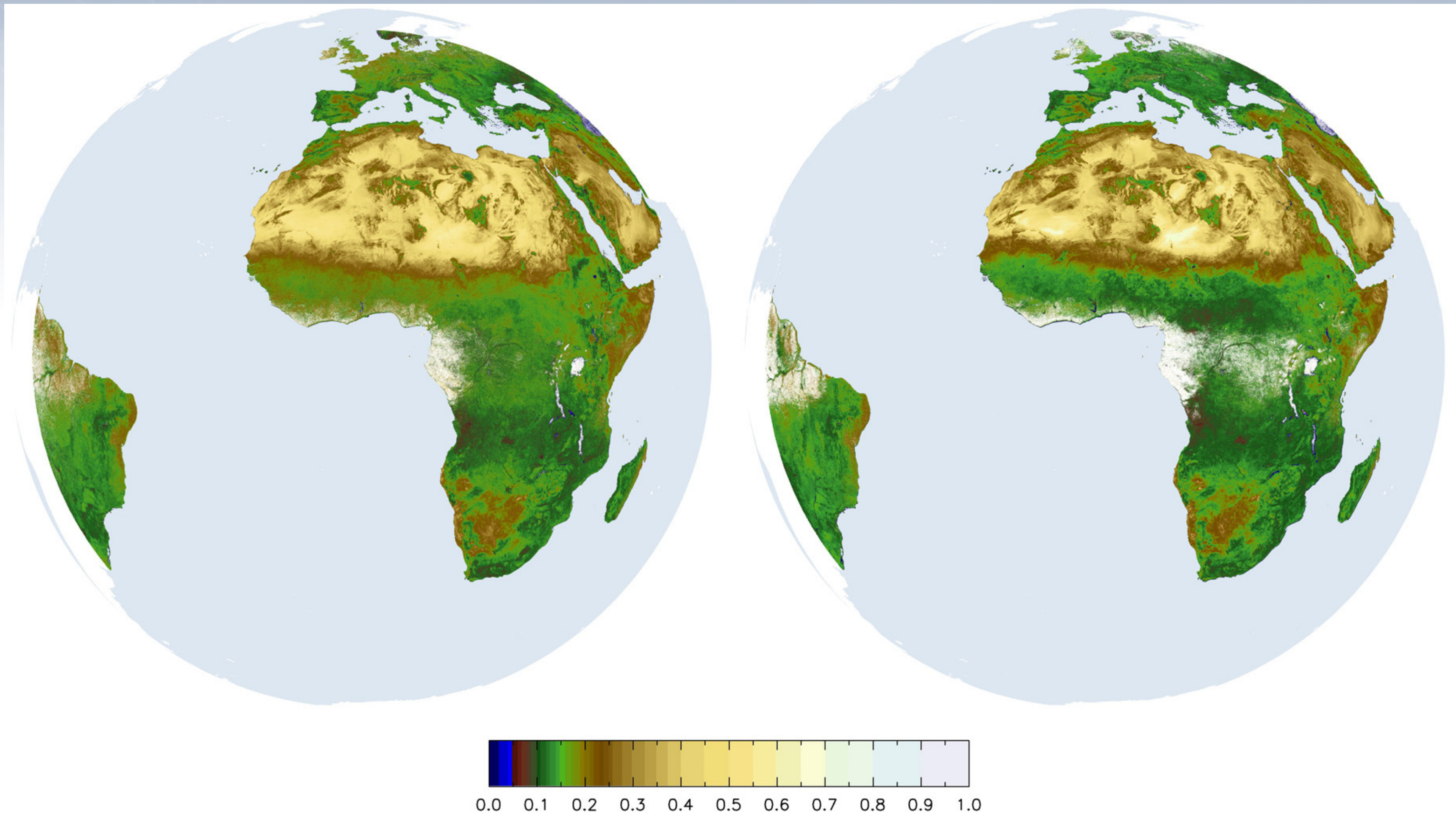
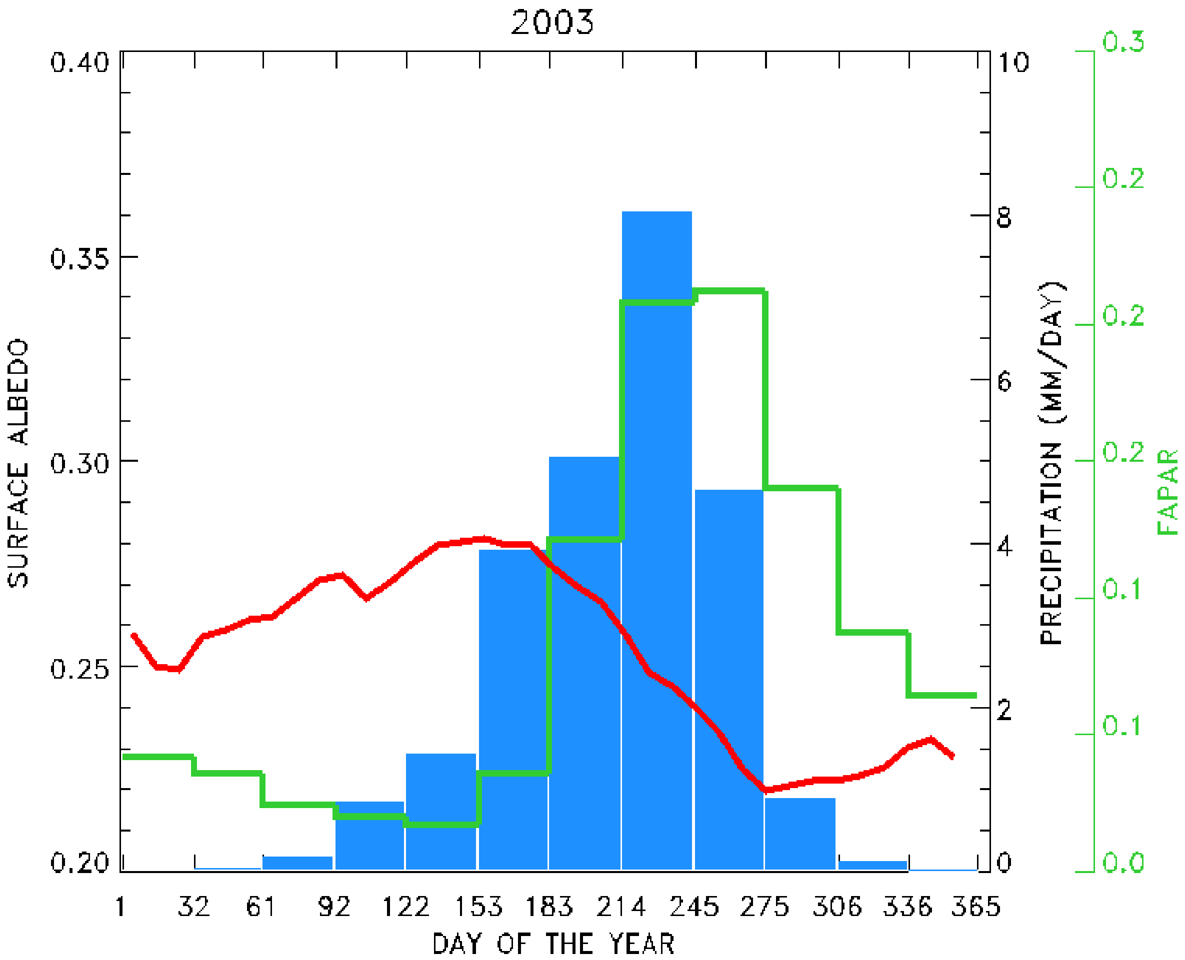
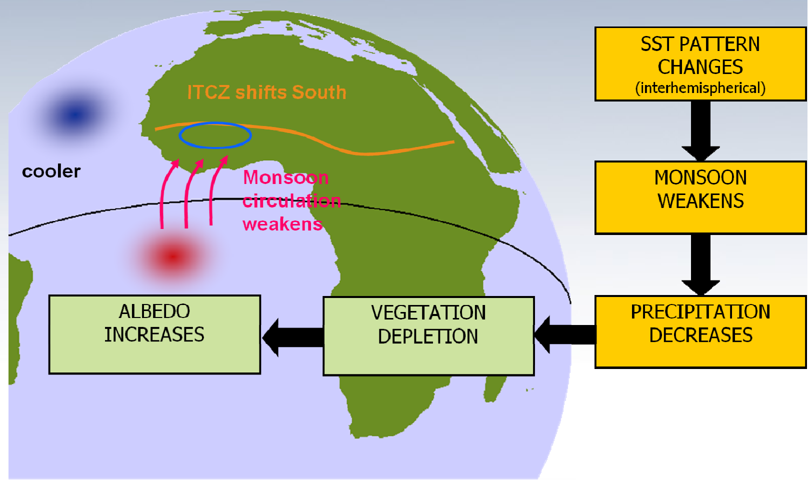


Fig. 4. Mean broadband surface albedo derived from Meteosat observations for the August–October (ASO) period for year 1984 (left) and 2003 (right). Unprocessed data are shown in white to the exception of oceans which are shown in light blue. Products available from www.eumetsat.int.

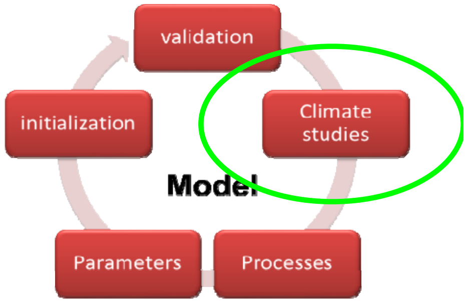
An Application of Meteosat Surface Albedo: Albedo Response to Precipitation Change





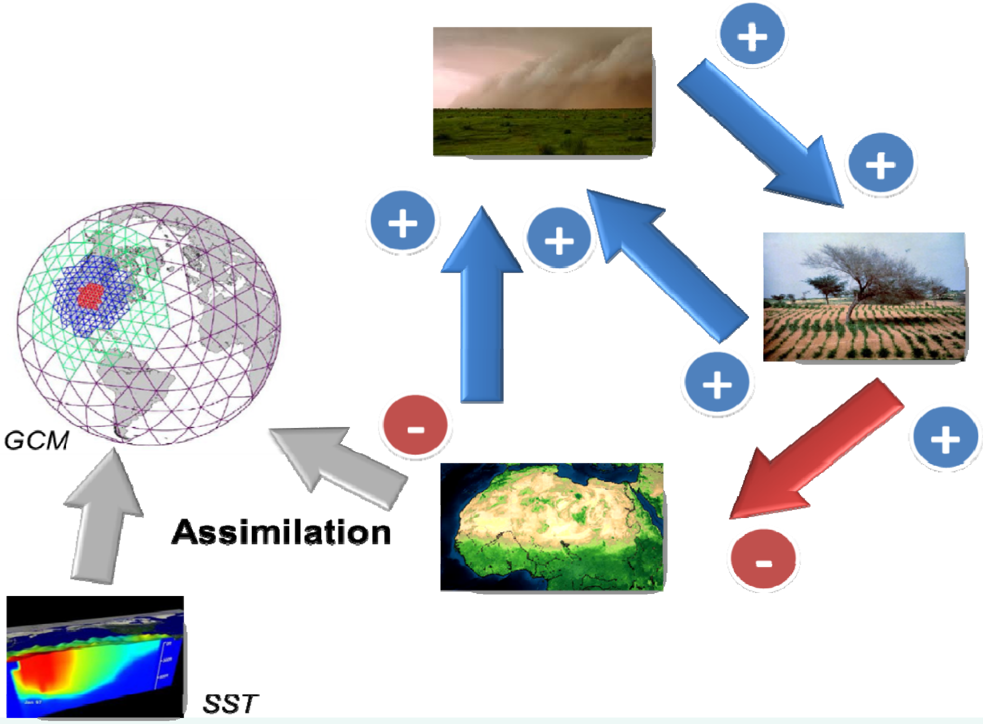
- Seasonal cycle (2003, spatial average over 8.5ºW–8.5ºE and 12.5º–15.5ºN) of monthly mean precipitation in mm/d (blue) from the Global Precipitation Climatology Project, Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) (green) derived from SeaWiFS and surface albedo (red) derived from Meteosat 7 data.
- The delay between the onset of precipitation and growing vegetation is ~ 1 month.
- The inverse proportional effect between vegetation growth and corresponding albedo change is indicating high consistency of observations.

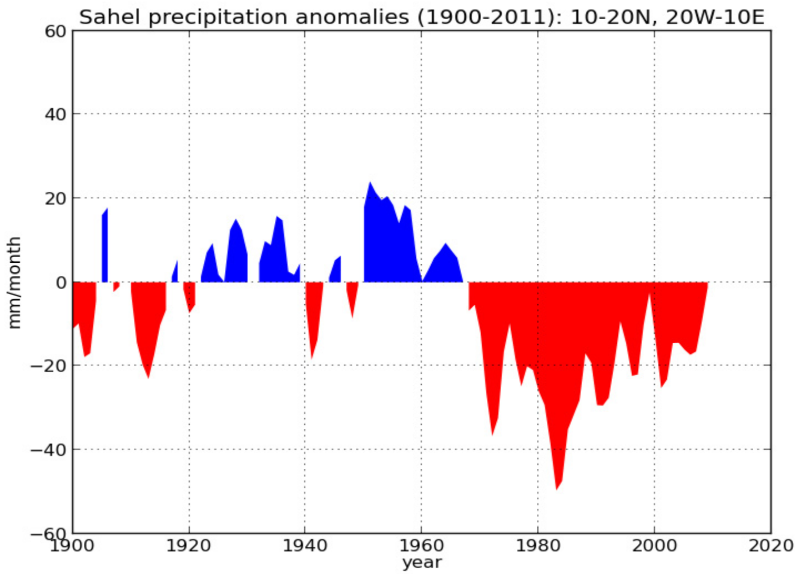
From observations to information



New opportunities in climate modelling using long-term satellite observations

Example Sahel drought: how does the land surface affect droughts?

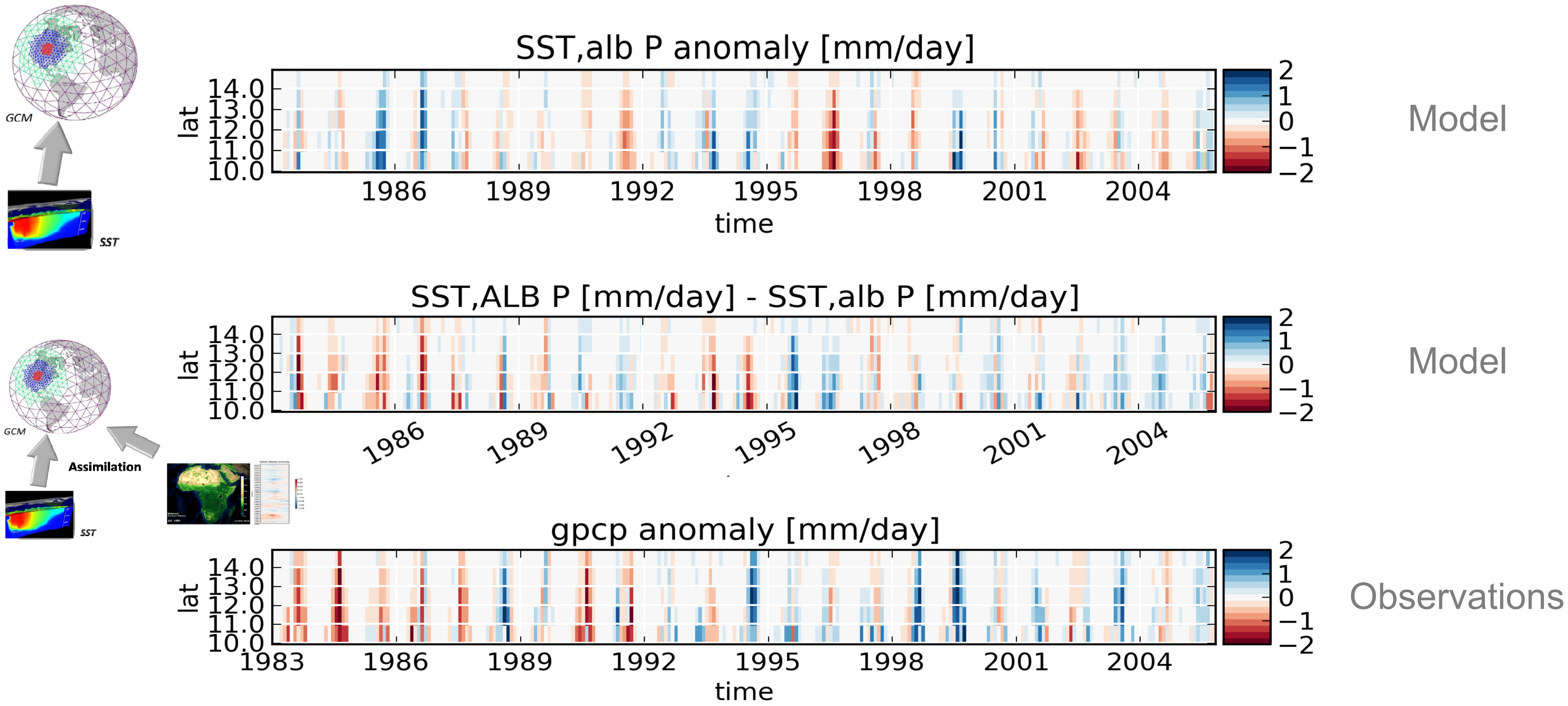




Courtesy of Alexander Loew, MPI-M, Hamburg, Germany

Assimilation of EUMETSAT albedo observations in ECHAM

... results in more realistic precipitation variability

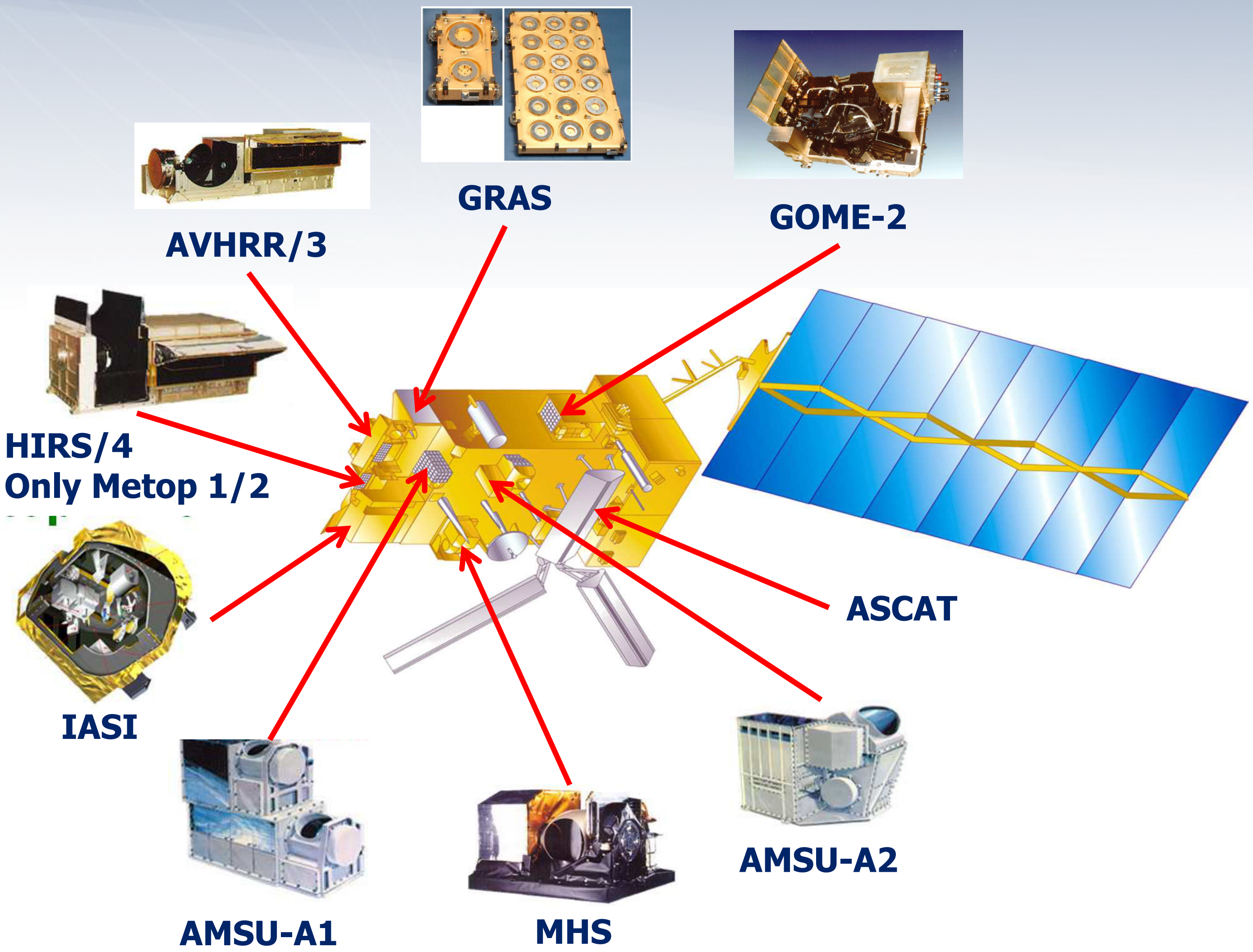


Max-Planck-Institut für Meteorologie

Courtesy of Alexander Loew, MPI-M, Hamburg, Germany

Hagemann & Loew, 2012, JAMES

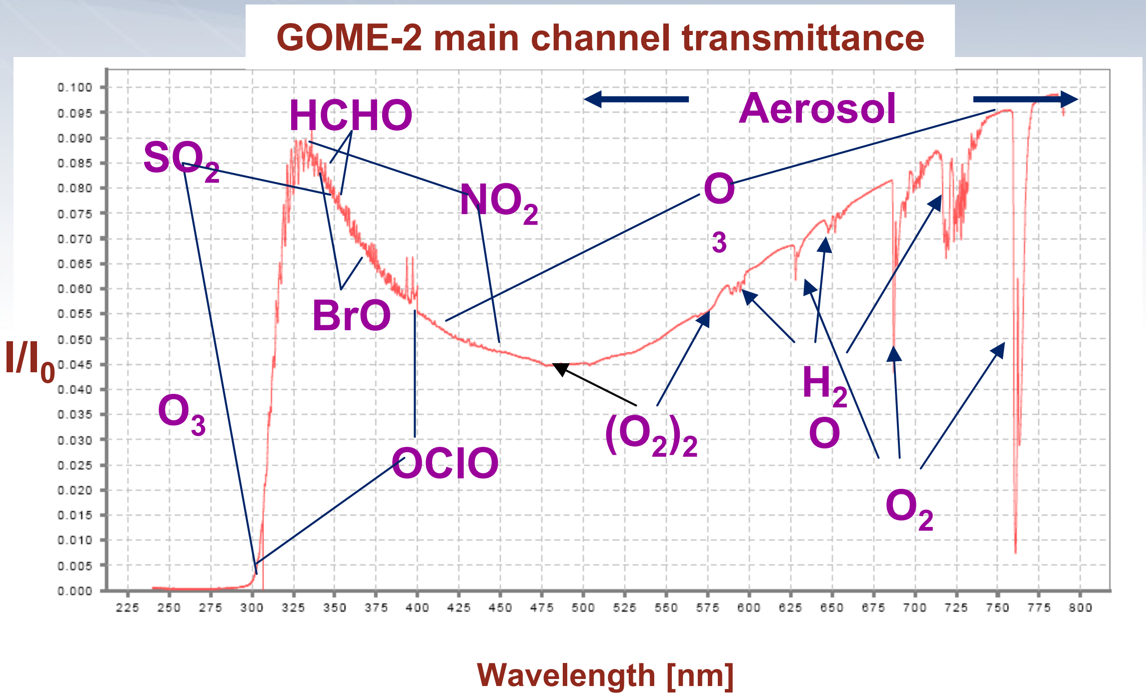
Metop Instruments Contribute to Climate Monitoring

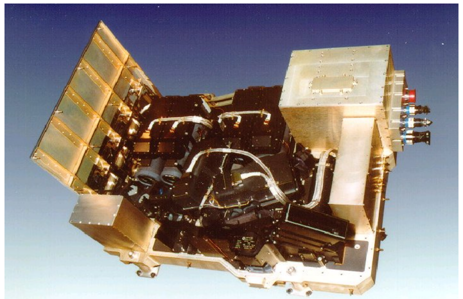


- Atmospheric Sounding (temperature, moisture, trace gases):
  - IR/MW imaging sounders: HIRS-4/IASI, AMSU-A/MHS
  - UV/VIS imaging sounder : GOME-2
  - Limb viewing radio occultation sounder: GRAS
- Global VIS/IR Imagery: AVHRR/3
- 2-D wind field at the ocean surface: ASCAT
- Data Location and Collection: ARGOS terminal
- Global and Local Data Access: solid state recorder HRPT/LRPT
- Search & Rescue Terminal

The GOME-2 instrument on Metop

Measuring atmospheric composition





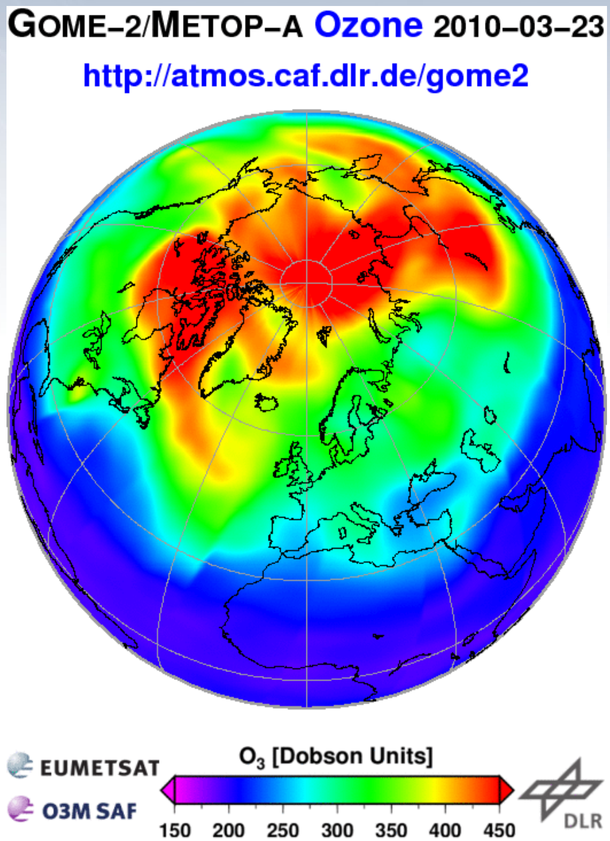
Orbit file sizes

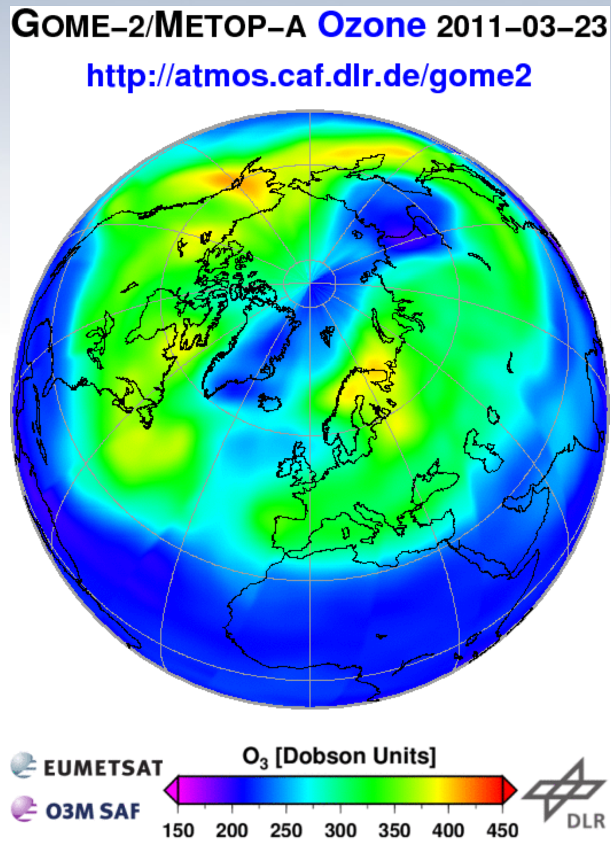
GOME-2 L1B ~ 1GB
IASI L1C ~ 2GB

GOME-2:

- series of 3 instruments on Metop (Metop A launched in 10/2006)
- sun-synchronous orbit, 09:30
- 412 orbits (29 days) repeat cycle
- Global coverage 1.5 days
- 240 nm to 800 nm
- 0.25 to 0. 5 nm spectral resolution (FWHM)
- 4 channels with 4098 energy measurements of polarisation corrected radiances (40 x 80 km^2)
- 2 channels with 512 energy measurements of linear polarised light in perpendicular direction (S/P) (40 x 10 km^2)

Example: Ozone Monitoring



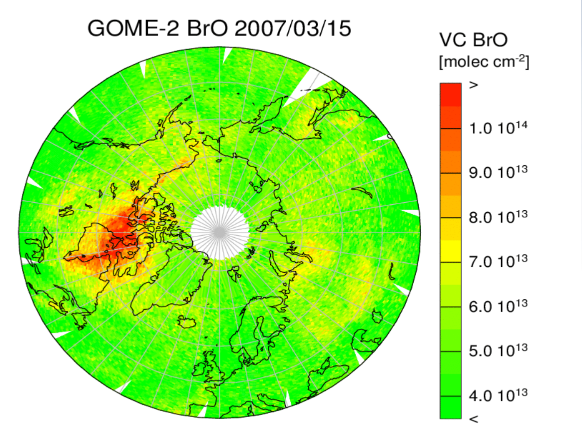


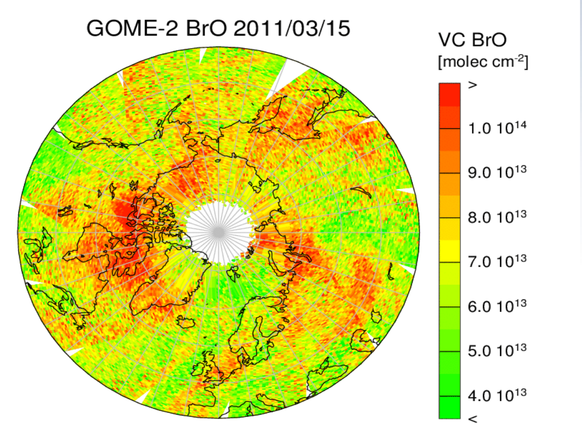
Total Ozone Column over the Arctic, observed with GOME-2 on Metop-A
Source: Ozone SAF, DLR, 2011

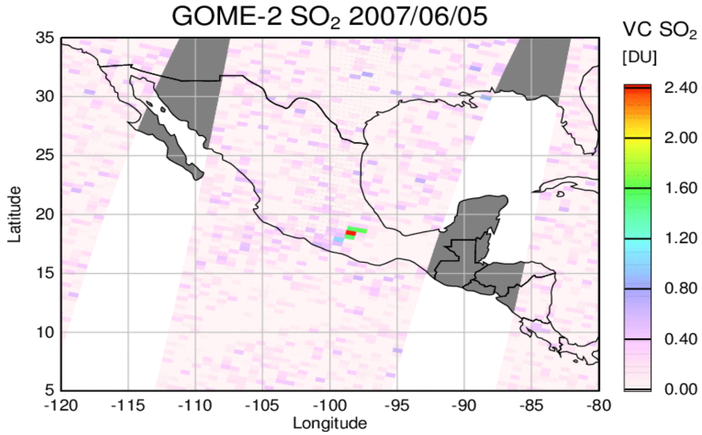
Motivation of GOME-2 Reprocessing

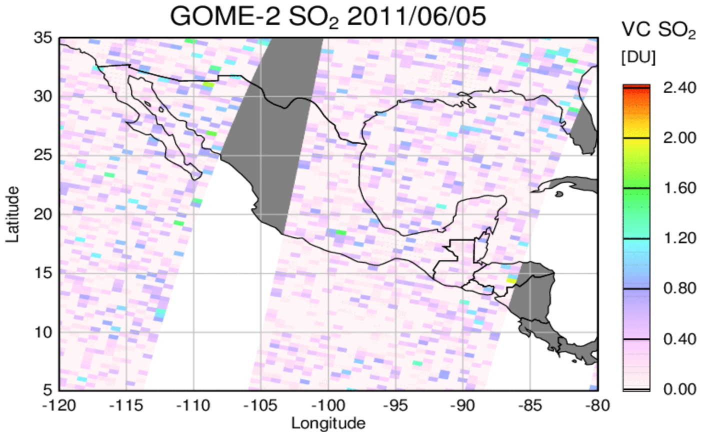
At beginning of mission

After 4 years of operation





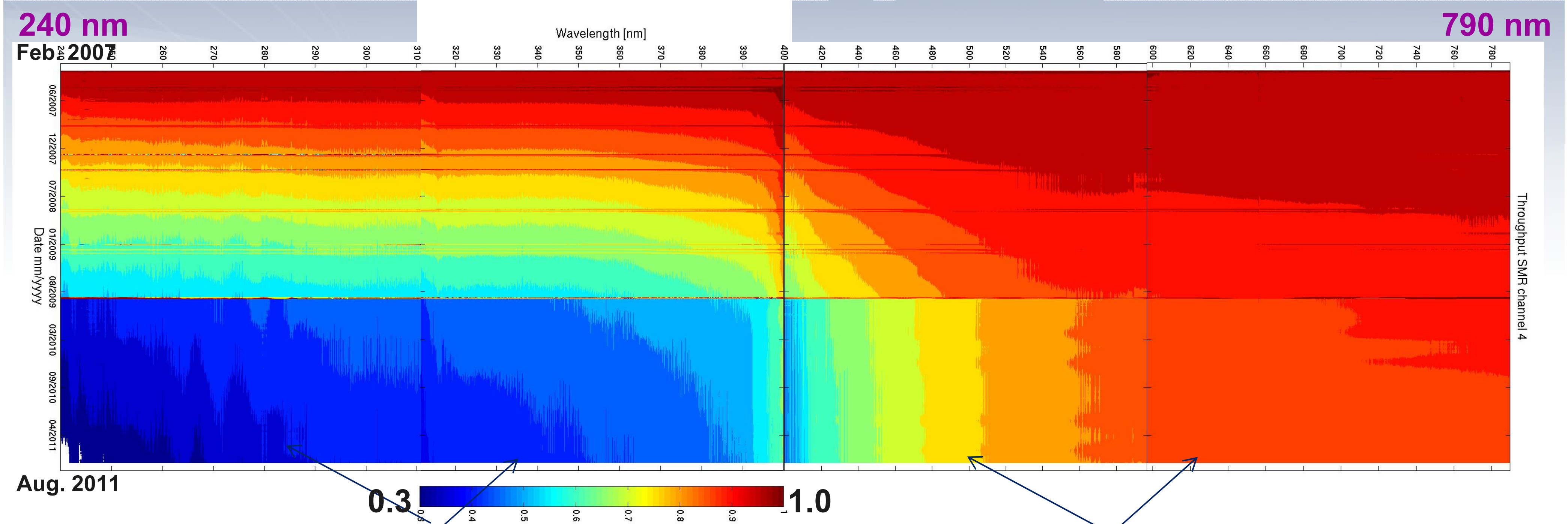




Figures courtesy of A. Richter, University of Bremen

GOME-2 Long-term Throughput Changes

Solar Mean Reference (SMR) spectrum



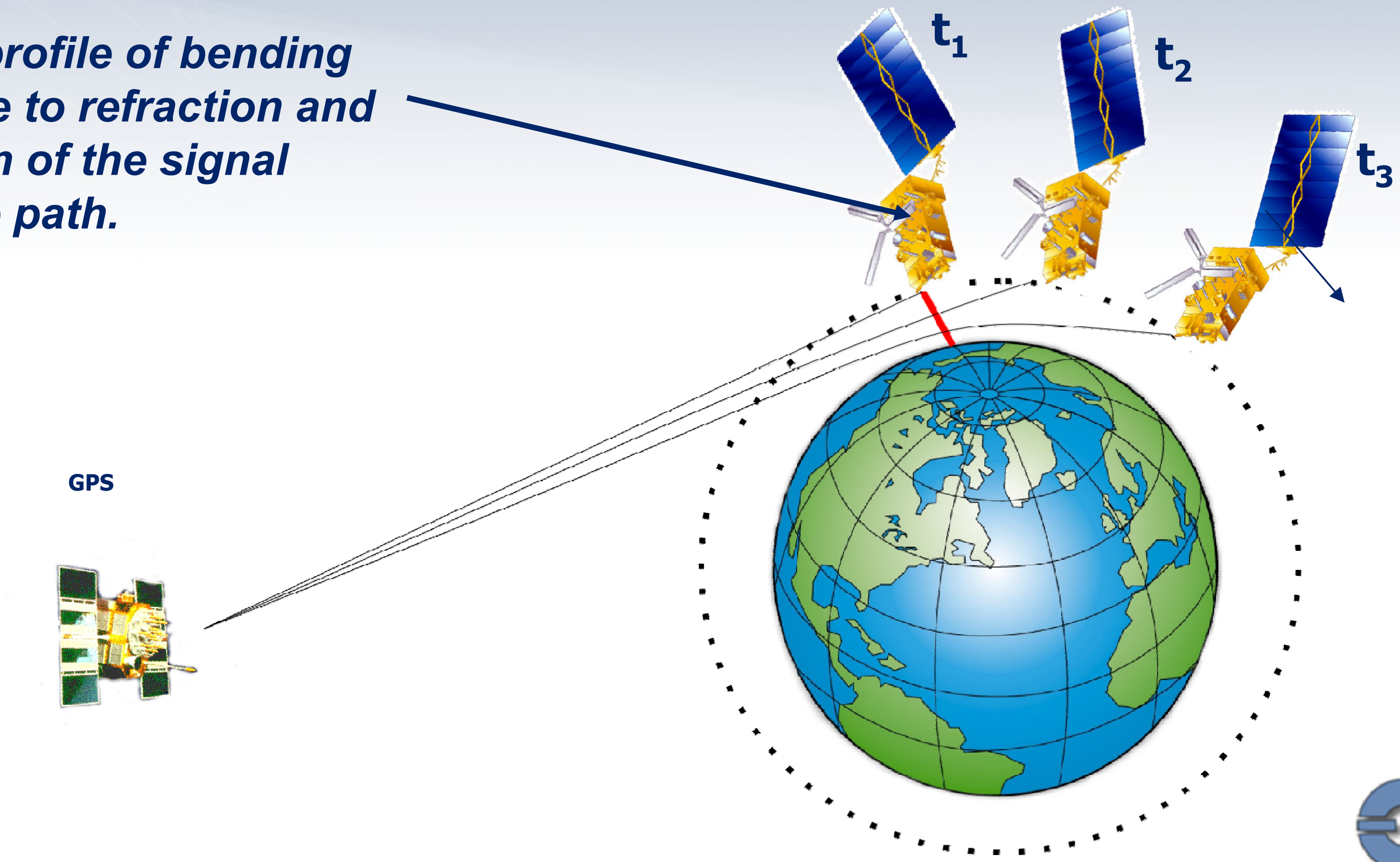
Slow onset of degradation observed after 2nd throughput test in channel 1 and 2.

Instrument is stable now in channel 3 and 4.

Reprocessed signals R2 PPF 5.2 until August 2011 relative to February 2007

Atmospheric Profiling by Radio Occultation (RO)

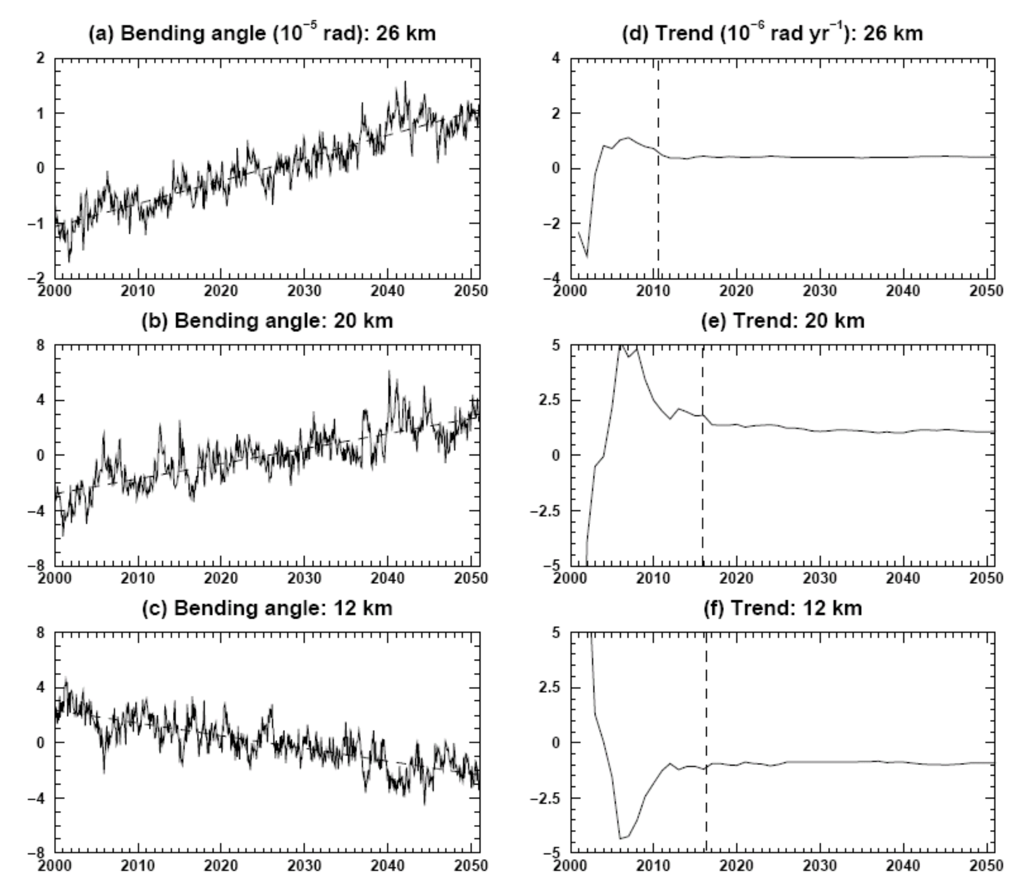
Vertical profile of bending angle due to refraction and extinction of the signal along the path.



ERA CLIM

EUMETSAT

Monitoring 21st Century Climate Using GPS Radio Occultation
(Ringer and Healy, 2008)



- Time series of the monthly mean bending angle at equator at impact heights of 12, 20 and 26 km, respectively

- Trend is discernable (temperature change)
- Detection times with 95% confidence:
  - at 12 km: 14.6 - 18.2 years
  - at 20 km: 13.6 - 18.7 years
  - at 26 km: 9.7 - 11.7 years

EUMETSAT Current and Future Programme for Operational Oceanography

Mandatory Programs

EPS – until 2022

EPS-SG
2018 -2035

Meteosat First Generation
(until 2016)

MSG (until 2020)

MTG (2018-2038)

- Monthly and Seasonal Forecasting
- Ocean Weather Prediction
- NWP Nowcasting
- Wave Forecasting
- Long Term Climate
- Coastal Inland

Optional Programs

Jason-2
Jason-3
Jason -CS
GMES Sentinel 3

Plus access to and use of third party mission data.

OSI SAF – Ocean and Sea Ice

CM SAF – Climate Monitoring

Operational Products :

- Sea Surface Temperature (SST)
- Sea Surface Heights (SSH)
- Ocean Surface Vector Winds (OVW)
- Sea Ice Concentration
- Ocean Surface Fluxes (Radiation)
- Ocean Colour (OC) with GMES S3

Climate Data Records:

- SSM/I FCDR (CM-SAF)
- Sea Ice Concentration (OSI-SAF)
- Ocean Surface Wind Speed (CM-SAF)
- Ocean Surface Fluxes (Latent Heat, Precipitation and Radiation) (CM-SAF)

Recommendation: Build on Existing Operational Weather Satellites for Climate Services

- Use the operational "weather" satellite systems for climate – their usefulness has been proven and they are pursued by WMO and others;
- There is a need for improvements, and research space agencies can address that best:
  - Improve calibration and characterisation of future instruments and establish reference system (GSICS);
  - Continue specific missions not directly relevant to weather and NWP (e.g. Earth Radiation Budget);
  - Close gaps in Essential Climate Variable (ECV) observations;
  - New research-type observations are needed for process studies in order to better understand how the climate system works;
- Improve (re-)processing capabilities for climate data and analysis (utilise existing international activities such as SCOPE-CM, CGMS, CEOS, GMES, GEO, etc.).

Conclusions

- Operational and research satellites contribute to many essential climate observations. Operational satellites provide the sustained component!
- Continuity for climate observations needs assured as part of operational weather satellite programmes such as Meteosat and Metop, i.e., the continuation of operational satellite programmes is a conditio sine qua non.
- It is prudent to build climate observations and services upon existing elements of the operational space-based GOS (Global Observing System).
- However: Additional resources/activities are needed to establish an adequate and sustained climate observing/monitoring system from space.