UNESCO-Brazil, Foz de Iguacu, 19 July 2016

Global Monitoring with LoRes EO-Imagery
Time Series Analysis with SPIRITS software

vito
vision on technology

Vlaamse Instelling voor Technologisch Onderzoek
Flemish Institute for Technological Research
Herman Eerens

1. **VITO's Remote Sensing Centre (TAP)**
2. EU-MARS: Global Agricultural Monitoring
3. FAO-ASIS: Global Drought Monitoring
4. SPIRITS: Introduction & Overview
5. SPIRITS: Some practical exercises

EUROPEAN UNION

BELGIUM

EU-JRC

European Union Joint Research Centre

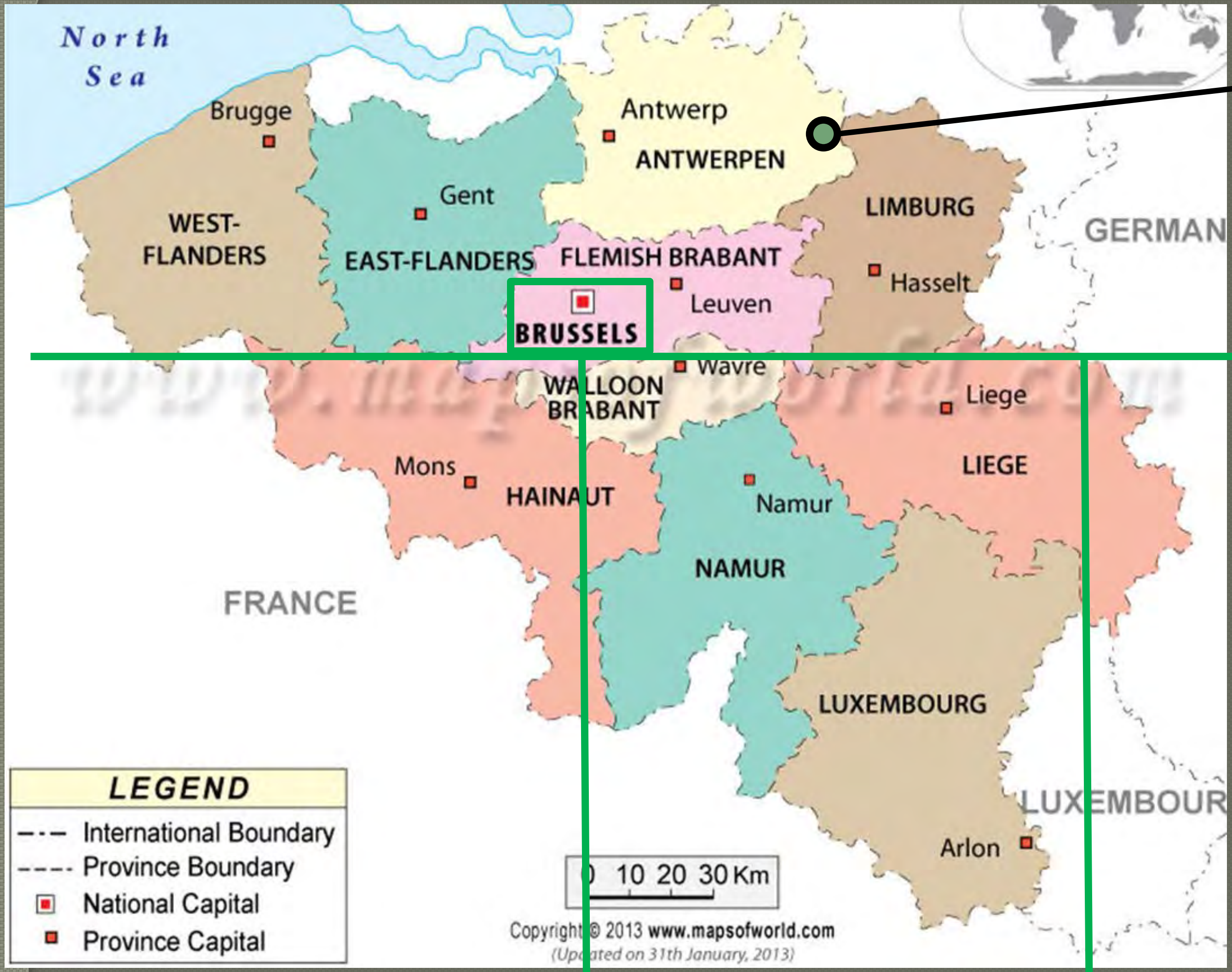
Ispra - ITALY

UN-FAO

Food and Agriculture Organisation

Rome - ITALY

BELGIUM



VITO

FLANDRES

(Dutch 55%)

WALLONIA

(French 35%)

BELGIUM

Area: 30 000 km²

Population: 11 M

BRUSSELS

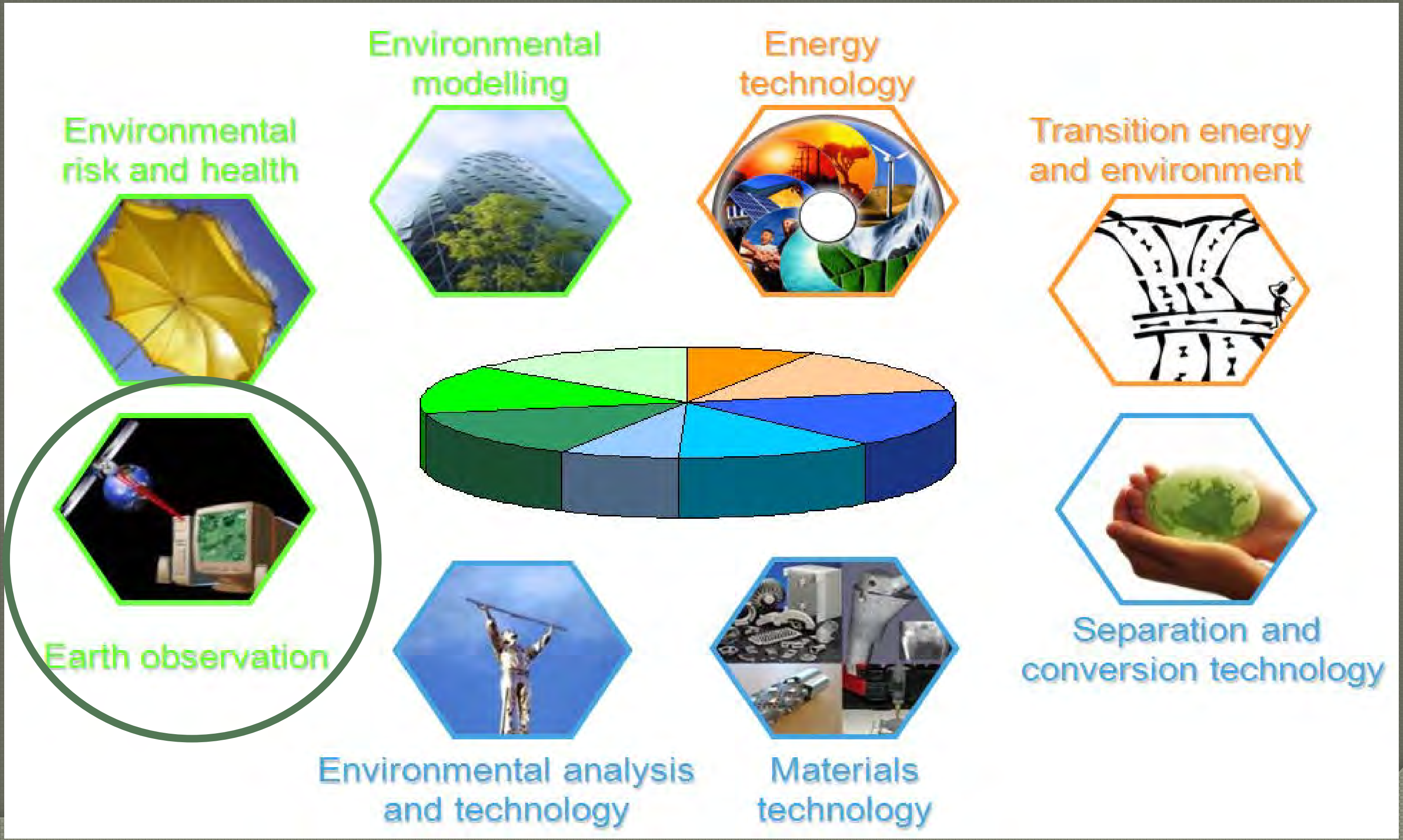
(200 languages 10%)

EAST

(German)

VITO = Research Institute of Government of FLANDRES Region

- *800 staff members*
- *8 "Centres of Expertise"*
- *Headquarters in MOL (+ 4 other distributed sites)*
- *Budget 2014: 150 M€ (30% subsidies from government)*



VITO-TAP = Centre for Remote Sensing

- *80 staff members*
- *Budget 2014: 15 M€ (15% subsidies from government)*

VITO-TAP: Three Major Domains

TECHNOLOGY

- *New sensors & platforms*
- *Flight organisation*

GEODATA

- *CTIV= Centre de Traitement d'Images VEGETATION)*
- *Pre-processing of raw images (Low → High Resolution)*
- *Data archiving*
- *Data dissemination*

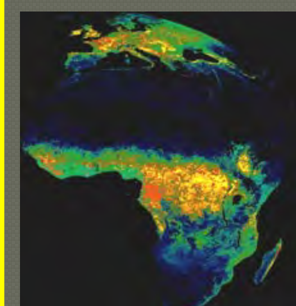
APPLICATIONS

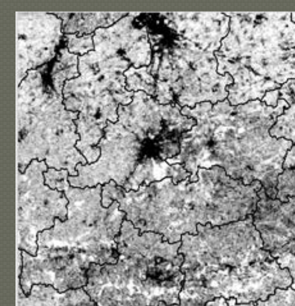
- *Extraction of dedicated image information ≈ objectives*
- *Client-oriented projects (agri-environment)*
- *Capacity building & training*

+ SOFTWARE DEVELOPMENT at all LEVELS

EO-Data & Scale of Applications

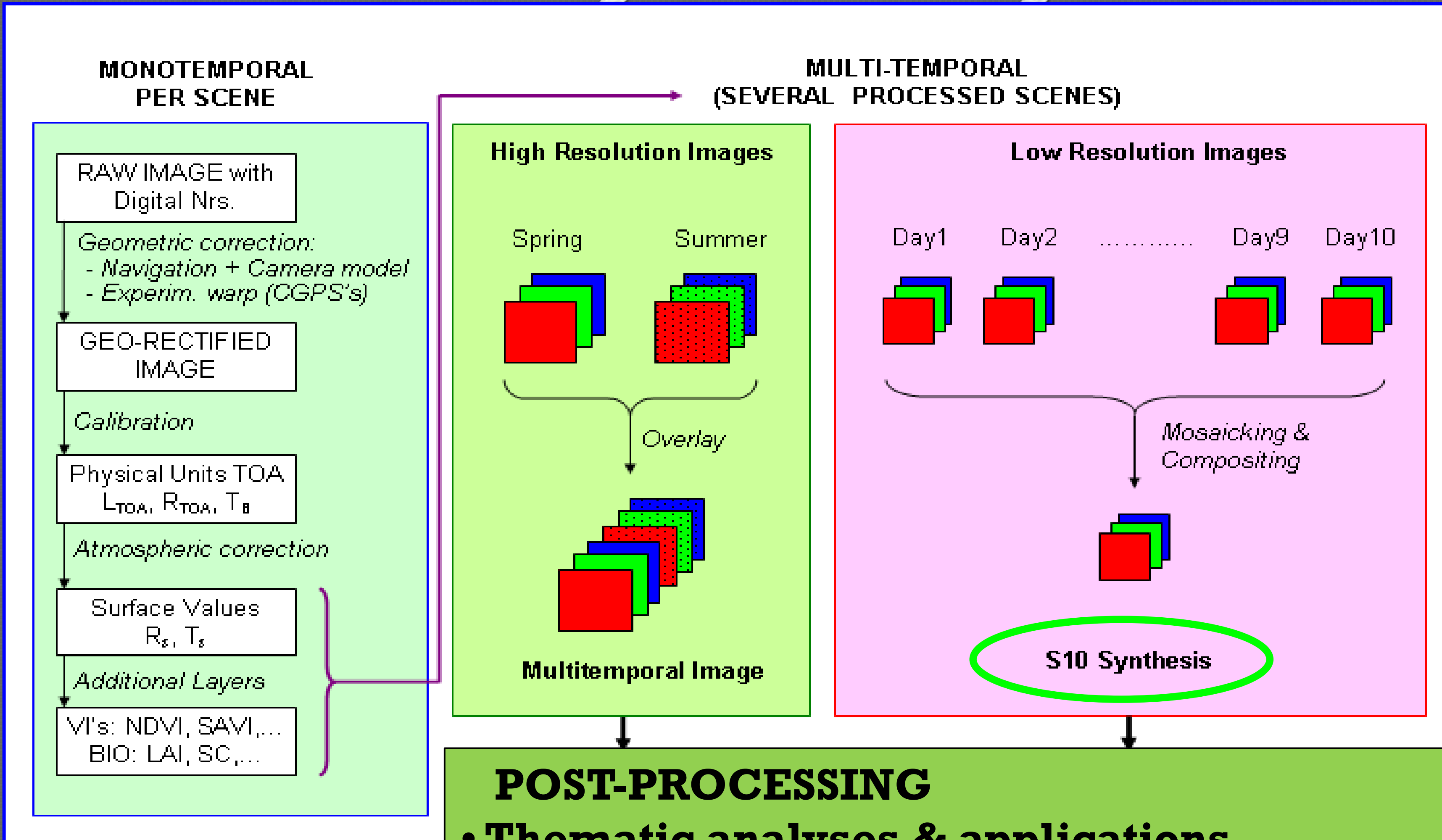
RESOL.	VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH
Pixel size	±5 km	±1 km	250-500m	20-30m	1-5m
Frequency	±hour	±1 day	±2 days	2-3 weeks	on demand
Image size	Earth Disk	2000-4000km	1000-2000km	60-300km	10-20km
Examples	Geostation-aries: MSG…	SPOT-VGT, NOAA-AVHRR	MODIS PROBA-V	Landsat-TM Awiffs, DMC	IKONOS, Quickbird





Scales: Global←Continental←National←Regional ←Field

Image Processing: Pre ↔ Post



POST-PROCESSING

- **Thematic analyses & applications**
- **Monitoring of vegetations/forests/crops**
- **LU-mapping and area estimation**
- **Carbon sequestration & Yield forecasting**

Pre-processing: Global SPOT-VGT since 1998

VITO-CTIV=Centre de Traitement d'images SPOT-VEGETATION

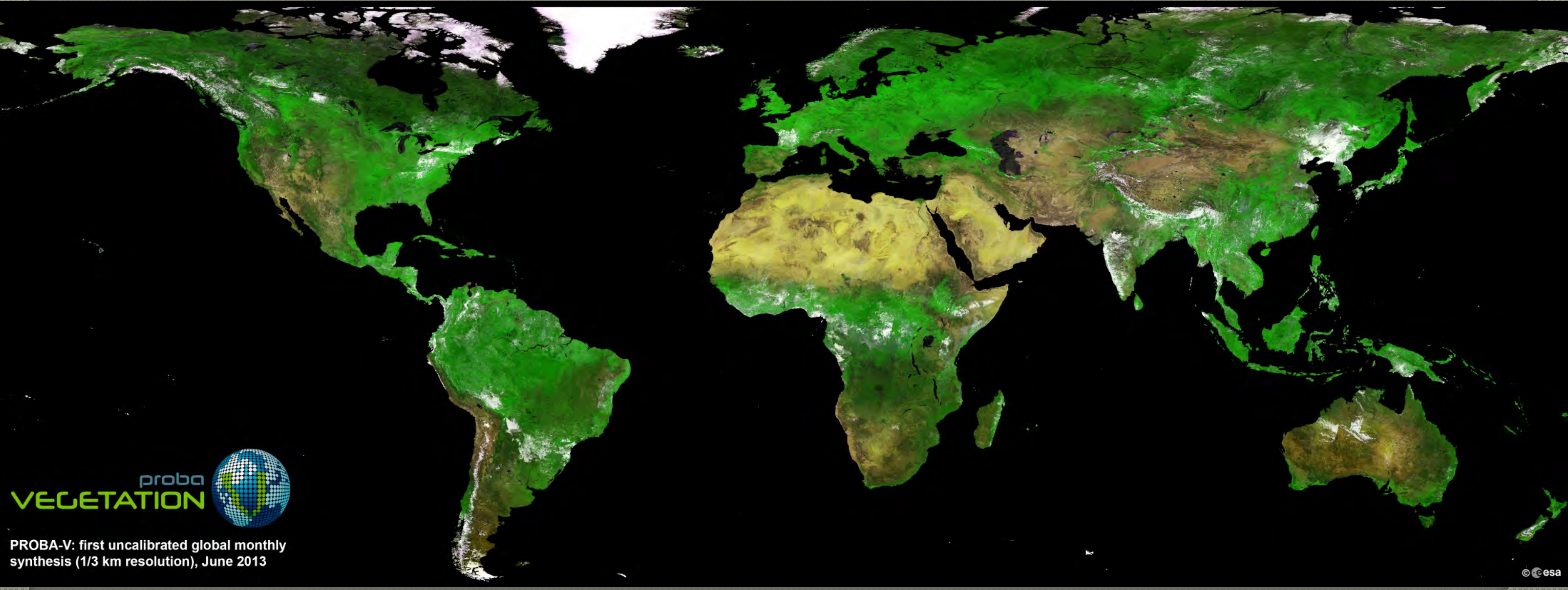
Global S10 of SPOT-VGT:

- Every 10 days (dekad) a new image
- Global, at 1 km resolution
- April 1998 → May 2014 (> 15 years)
- High accuracy
- Wide user community
- Many applications

VITO-TAP: New platforms & sensors

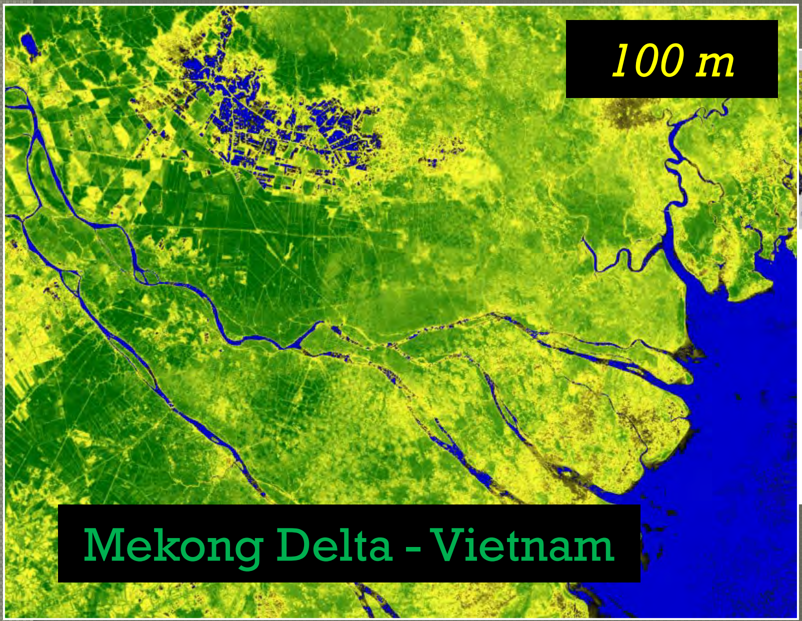
PROBA-V = Follow-up of SPOT-VEGETATION

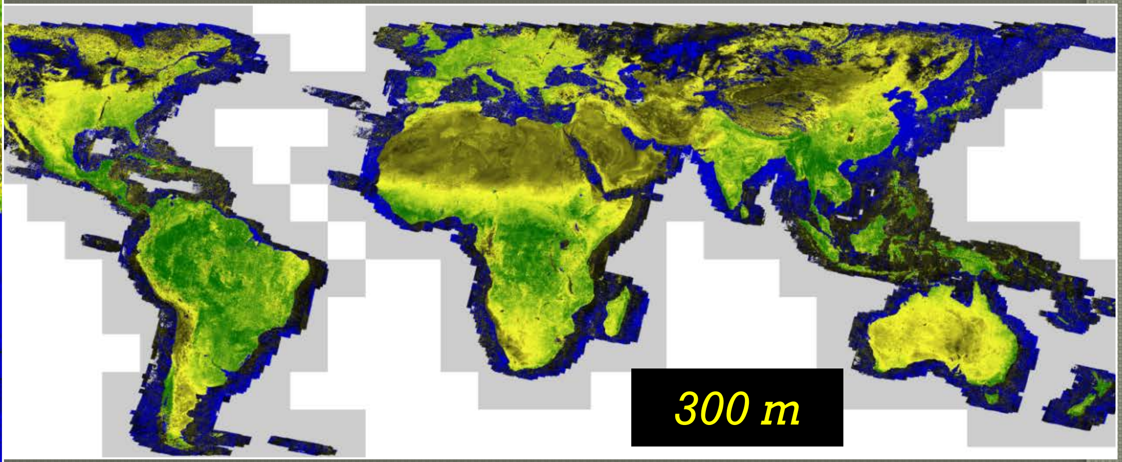
- Low budget, sponsored by ESA & BELspo
- Developed by Belgian companies, maintained by VITO
- Operational since November 2013
- Same features (spatial, spectral) & products as SPOT-VGT
- But three resolutions: 1km, 333m, 100m



PROBA-V: first uncalibrated global monthly synthesis (1/3 km resolution), June 2013

PROBA-V as follow-up of SPOT-VGT



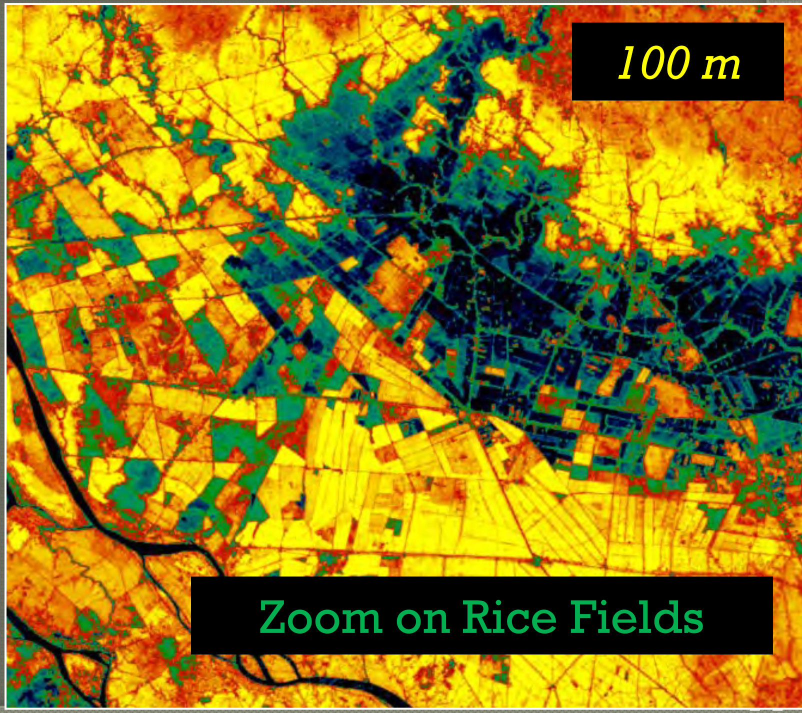


Spatial and spectral similarity with VGT

1km → Continuation of SPOT-VGT

300m → Continuation of MODIS/MERIS

100m → Global monthly NDVI-composites
→ NDVI December 2013 (55 GB)
→ **Global & dynamic crop mapping!**



Copernicus Initial Operations

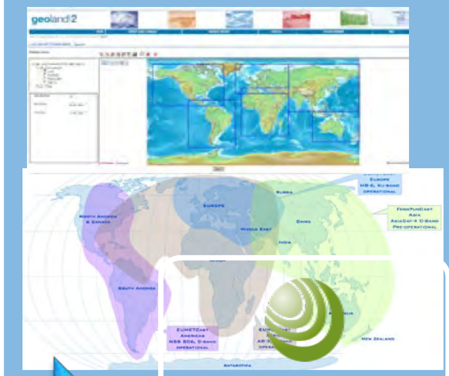
Global Land Service

- Timely production of 14 Global, Biophysical parameters (Vegetation, Radiation, Water)
- Many European partners.
- Data processing, dissemination & archiving by VITO.

Satellite data Input

Processing and Archiving

Product Dissemination



GEONETCast

Delivering Environmental Data to Users Worldwide

VITO-TAP: New platforms & sensors

Aerial photography for Flanders

- Flights & data acquisition
- Mobile mapping
- Storage & analysis (changes)

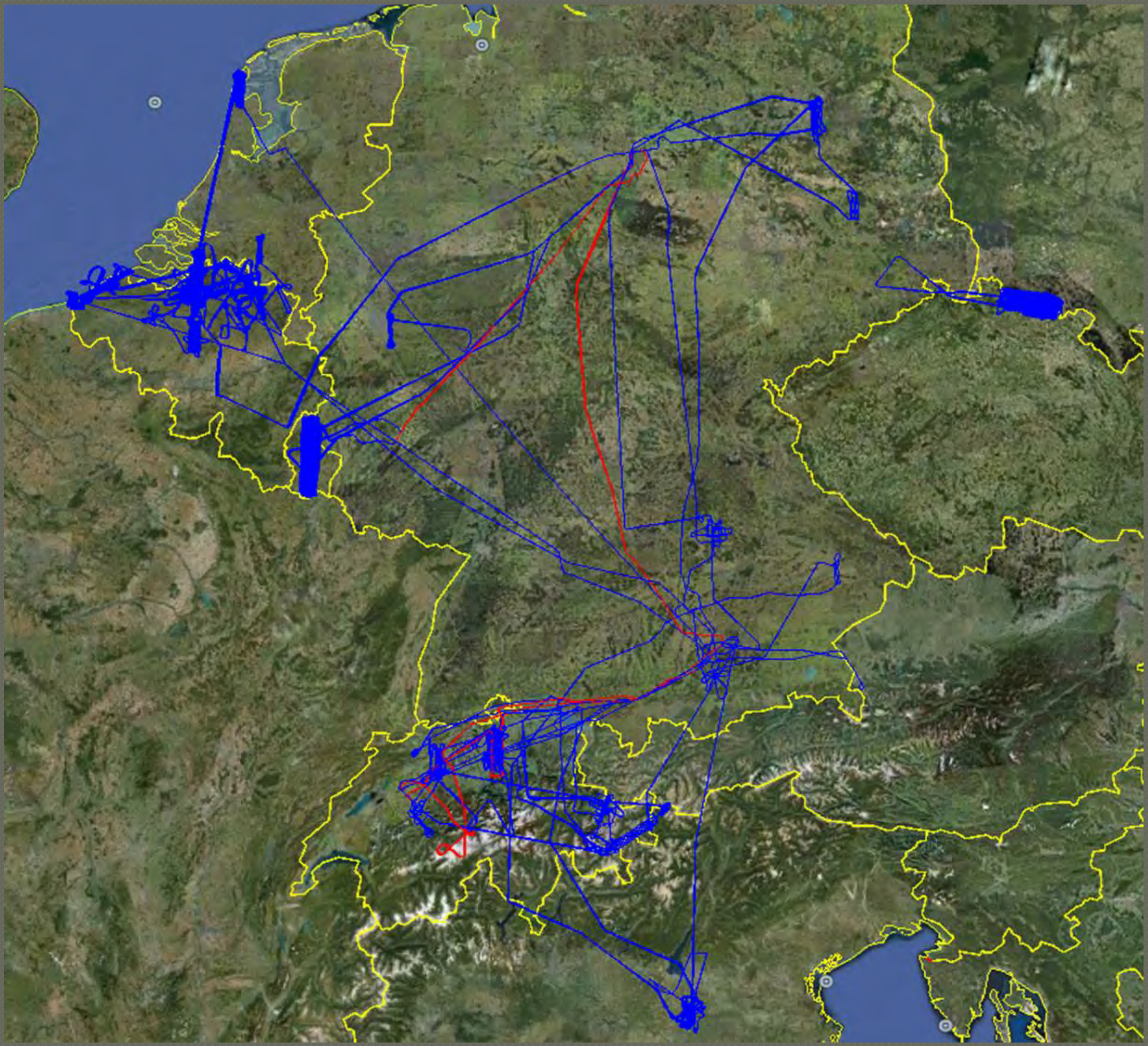
Hyperspectral domain:

- Camera development (APEX, MEDUSA)
- Flights & data acquisition
- Storage, analysis & distribution

Unmanned Aerial Systems (UAS, drones)

- Full system development
- Flights & data acquisition
- Legal issues
- Storage & analysis (field-level)

Airborne Campaigns @ VITO



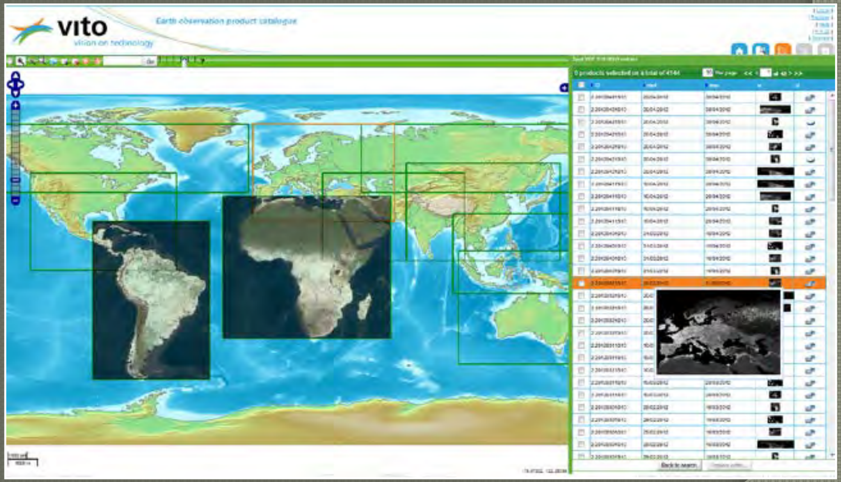
VITO-TAP: New platforms & sensors

On-going development of PROBA-V2 (alias “GLOBAL-V”)

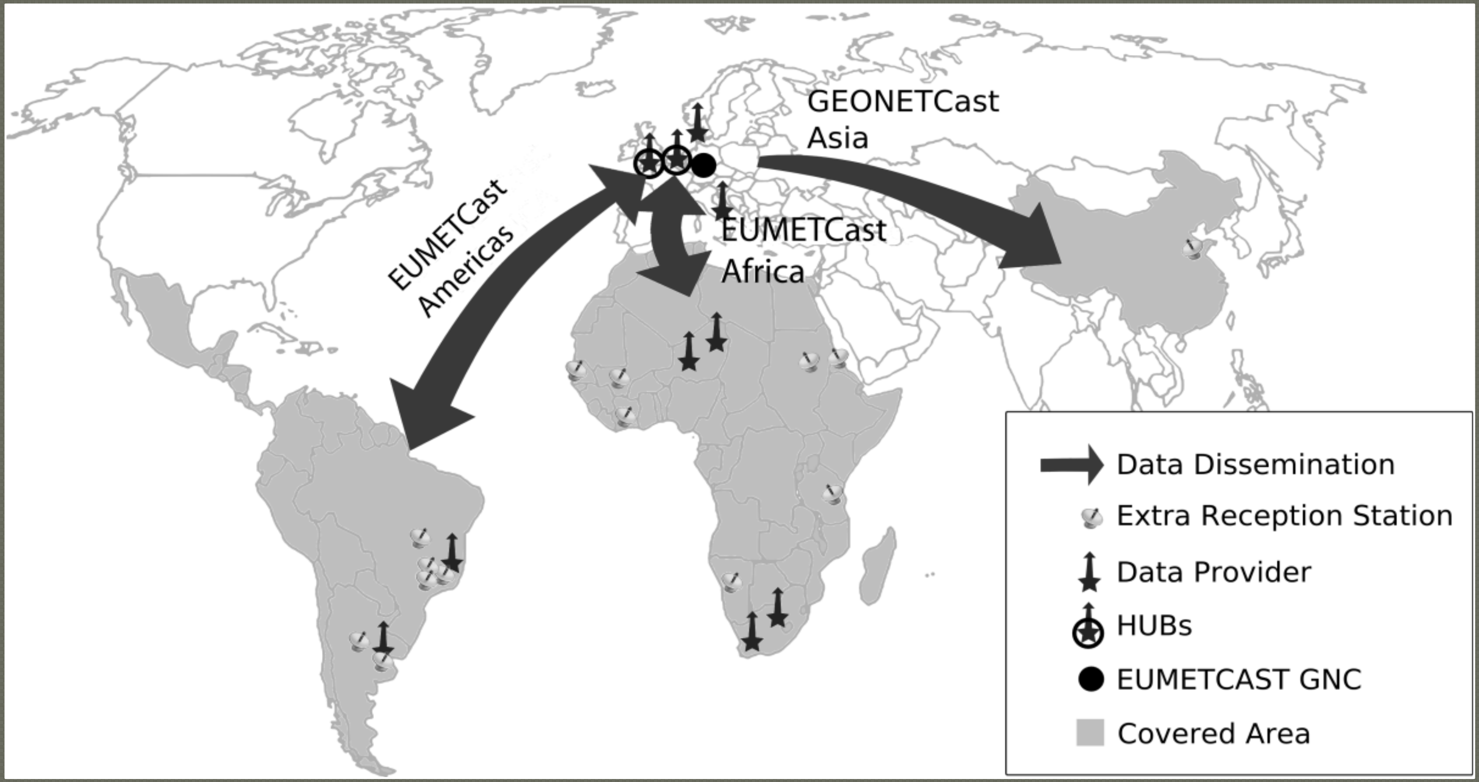
- Sino-Belgian co-operation (RADI, VITO)
- Focus on 100m, daily, global
- Vis/NIR (VITO) + TIR (China)

Conclusions:

- Developments by TECHNOLOGY
- Daily operation by GEODATA (CTIV)
- Additionally:
    - Data centre with PB capacities (1 PB = 1000 TB)
    - Data distribution portals
    - Processing on demand (POD)
- All data available for APPLICATIONS



Data ingestion & distribution via GEONETCAST



VITO-TAP: Three Major Domains

TECHNOLOGY

- *New sensors & platforms*
- *Flight organisation*

GEODATA

- *CTIV= Centre de Traitement d'Images VEGETATION)*
- *Pre-processing of raw images (Low → High Resolution)*
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APPLICATIONS

- *Extraction of dedicated image information ≈ objectives*
- *Client-oriented projects (agri-environment)*
- *Capacity building & training*

+ SOFTWARE DEVELOPMENT at all LEVELS

APPLICATIONS: General overview

Focus of this presentation:

- Low Resolution (250m to 5km) but High Frequency
- Spatial Domain: Regions, Continents, Globe
- Two major examples: JRC-MARS and FAO-ASIS
- *See later for more details!*

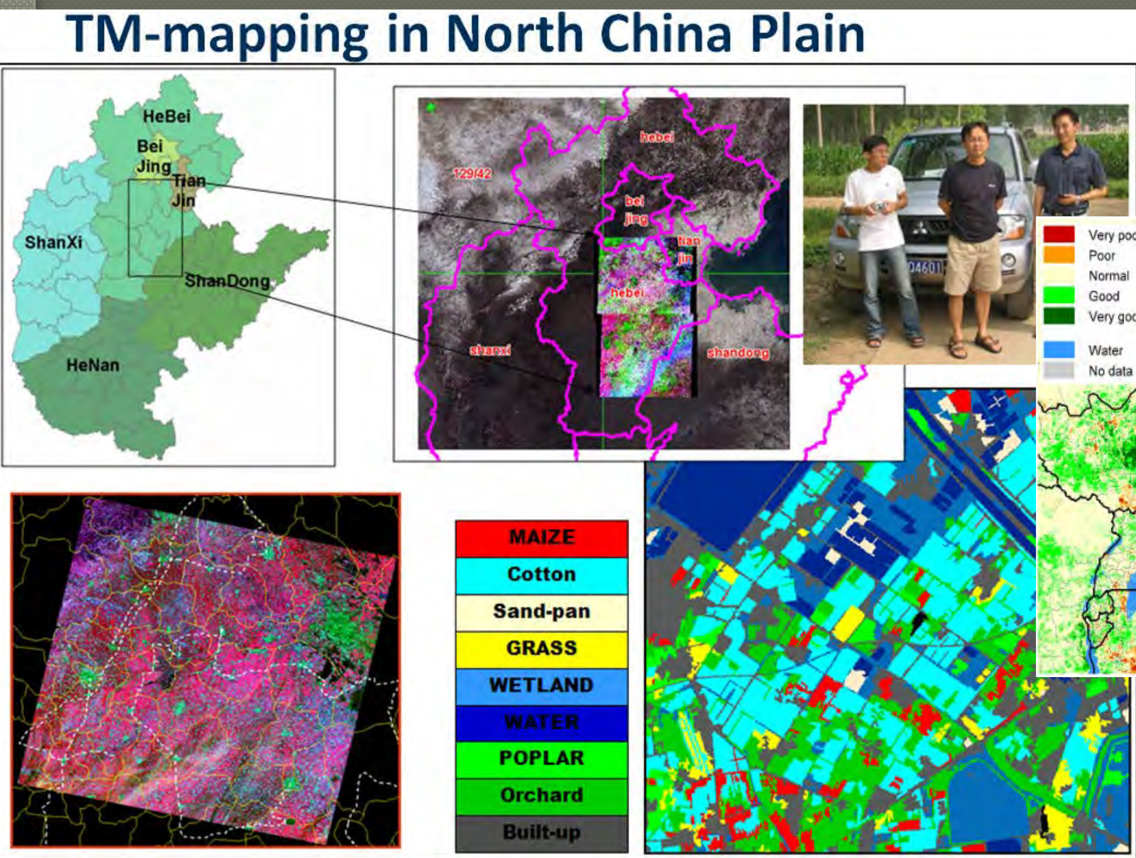
Other related activities mentioned for completeness:

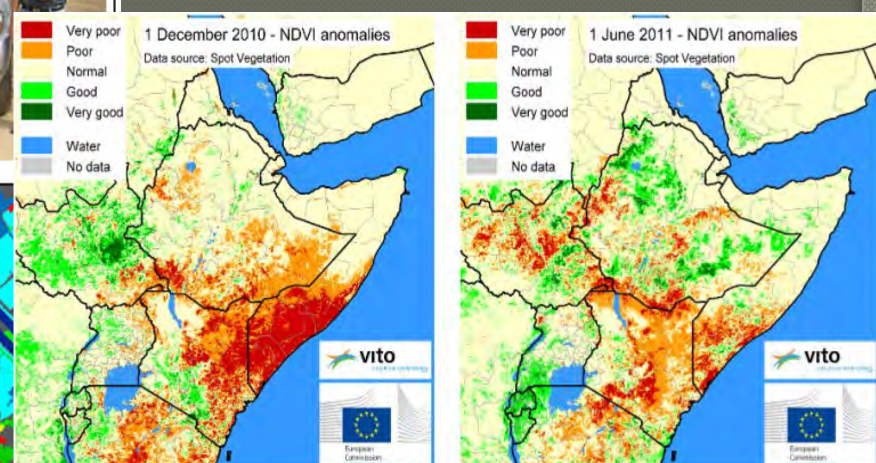
- Local applications
- Software development
- Capacity building
- Activities in High Resolution domain

APPLICATIONS: Low Resolution

Local Activities in many Countries

- Africa: Kenya, Senegal, Niger, Mozambique, Morocco, …
- Asia: China, Vietnam,…
- Europe: Belgium, Netherlands, France, Ukraine, Russia, …

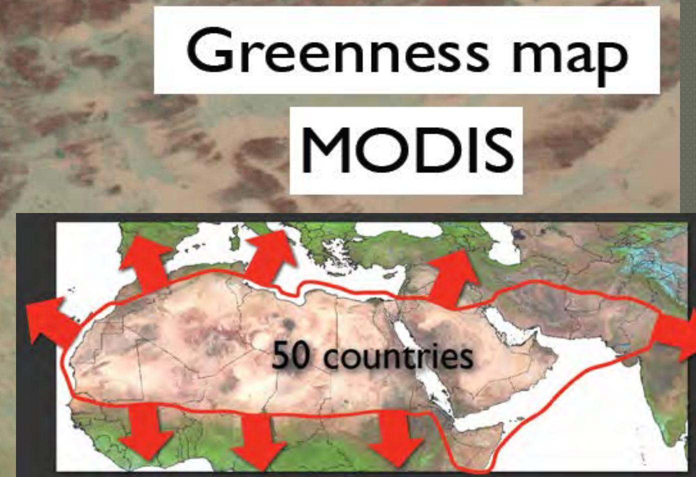




APPLICATIONS: Low Resolution

Local Activities in many Countries…

southern Mauritania invasion (early summer 2004)

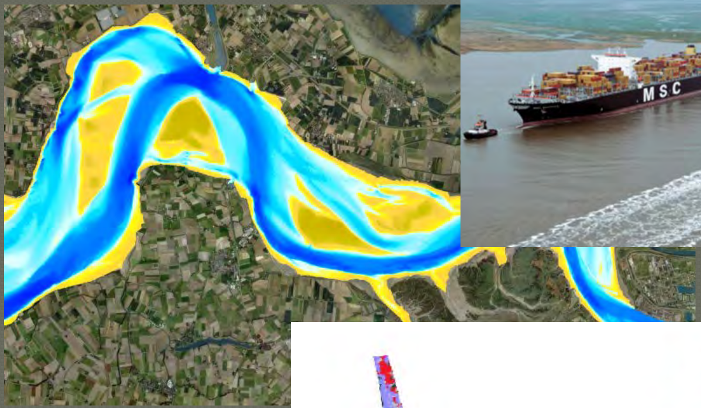


- **Desert Locust prefer green vegetation**
- **Satellite products to identify greening areas**
- **Support FAO and regional analysts**

APPLICATIONS: High Resolution (Local)

Water quality: Estimation of...

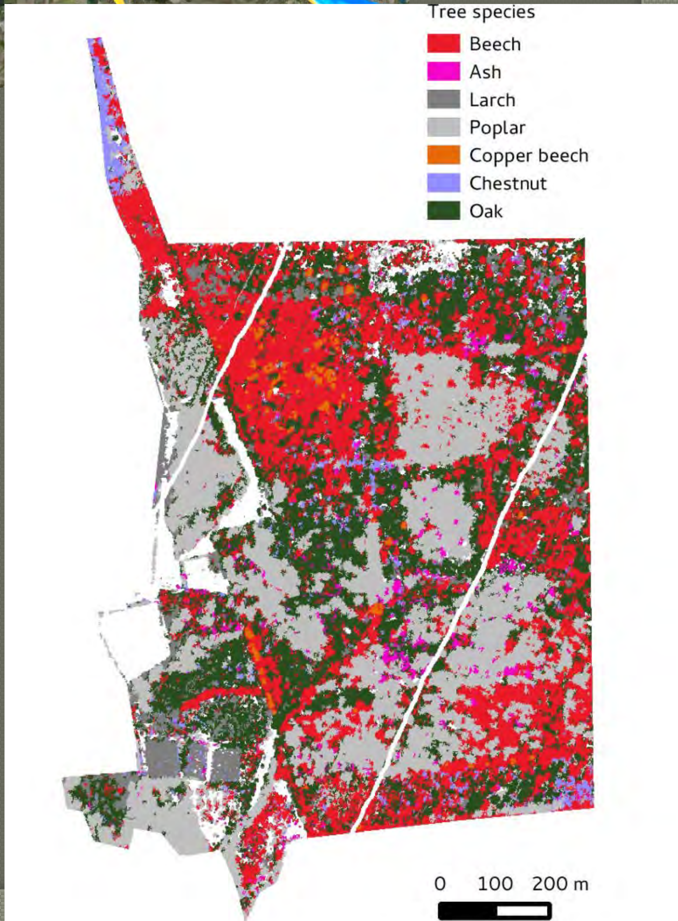
- Suspended particulates
- Chlorophyll
- Dissolved organic matter



Coastal management

Nature conservation

- Habitat mapping
- Forest inventories
- Biodiversity



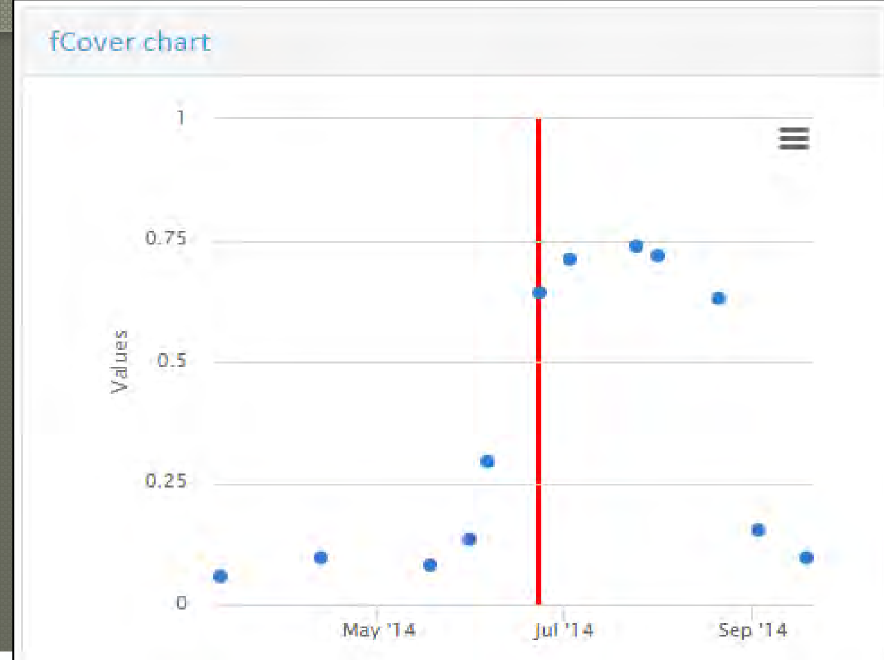
Agriculture

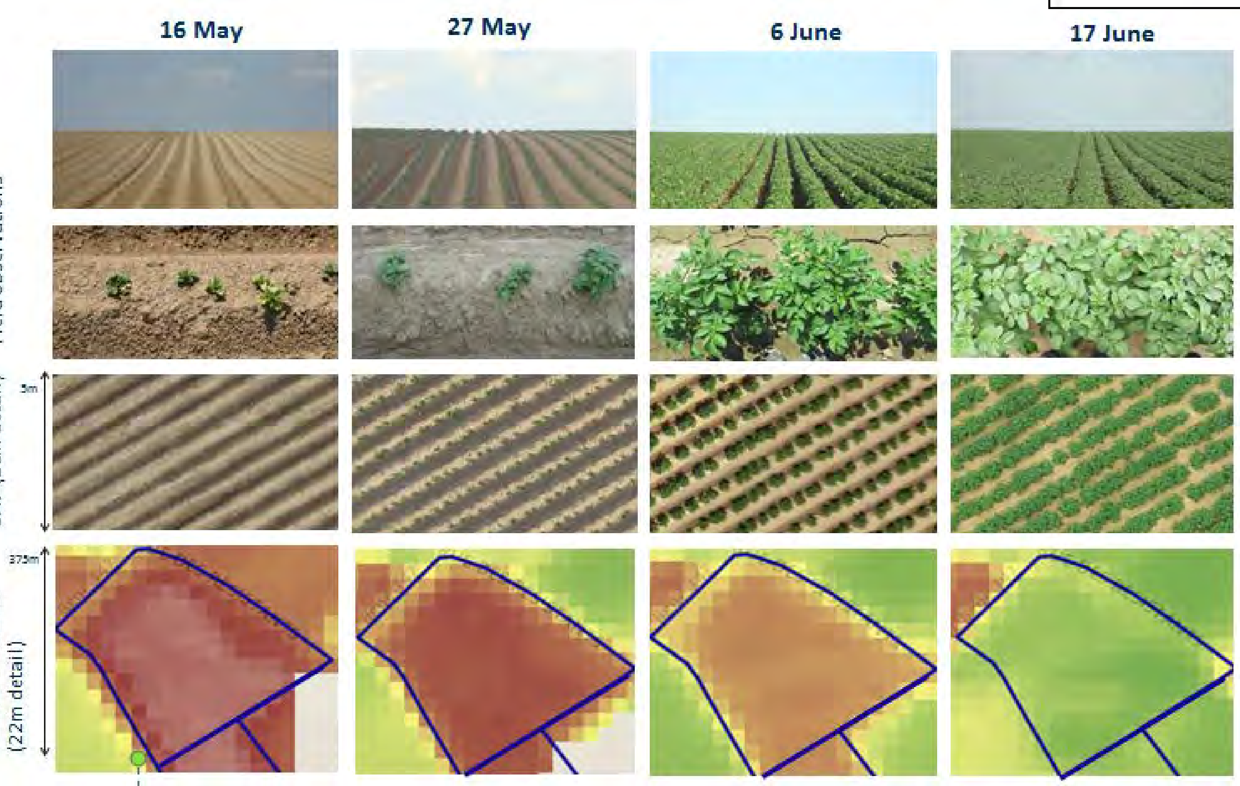
- Monitoring at field level
- Precision farming
- Disease management
- Estimation of damages (hail,...)

APPLICATIONS:
High Resolution (Local)

Crop monitoring at field level:

- Coverage %
- Time series of DMC-Deimos
- Validated with UAV images





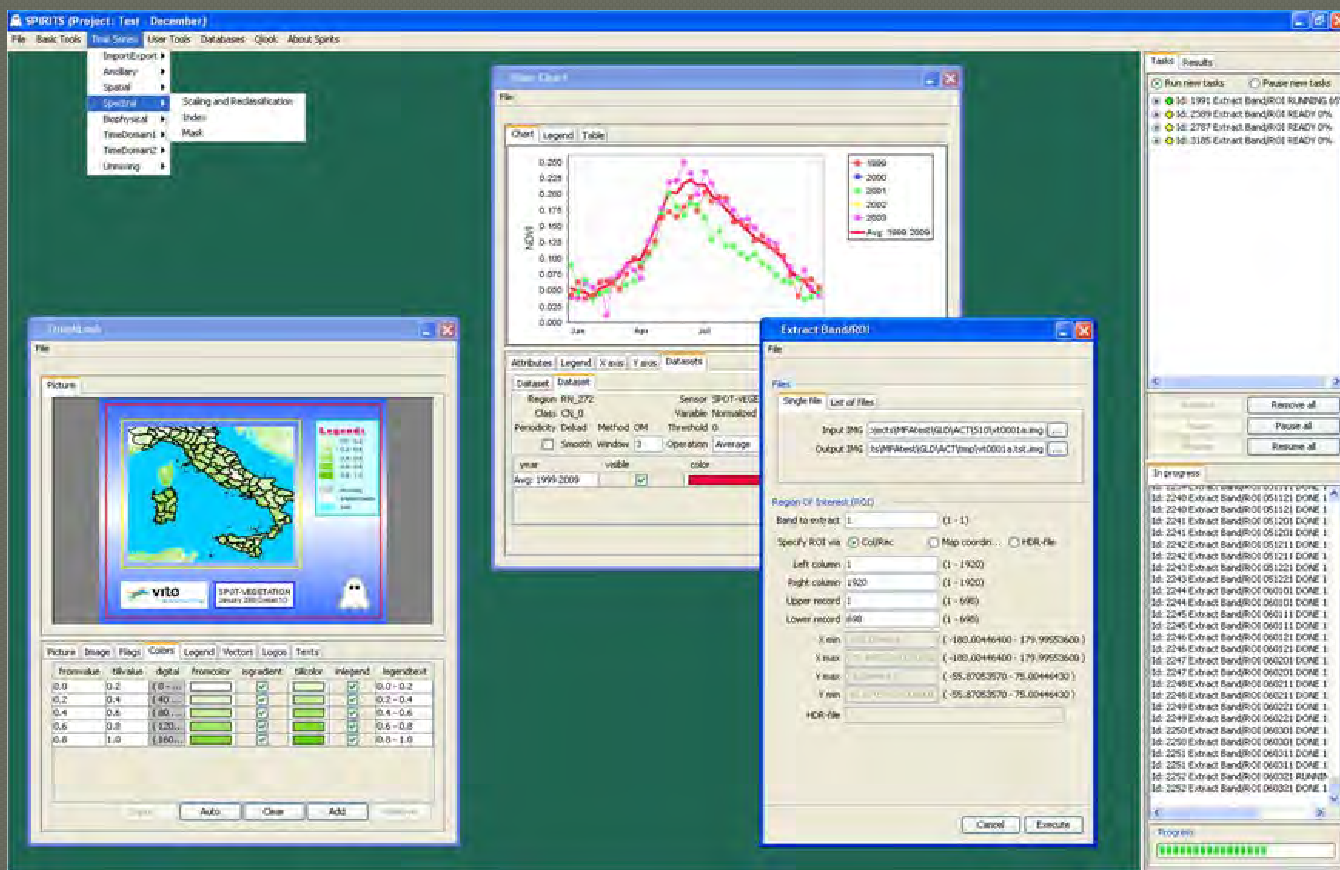
Field observations

UAV (2cm)

DMC (22m)

Software development:

- VGTextract: Adaptation/reformat of SPOT-VGT syntheses
- MSG ToolBox: Pre-processing of MSG data from LandSAF
- GLIMPSE & SPIRITS: Generic processing of time series



Others:

- Capacity building & Training sessions
- Websites & WIKIs
- Dedicated data portals

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MARS = Monitoring Agricultural ResourceS

Definition:

- EU-initiative, started in 1989
- Objectives:
  - Standardise AGRO-statistics amongst (alweys new) EU-states
  - Introduce new techniques (RS, GIS, GPS,…)
- Formerly called "Monitoring Agriculture with Remote Sensing"
- Many sub-actions:
  - Crop yield estimation per administrative region
  - Crop area estimation → area/point frame samplings
  - Control of farmer declarations for area-based primes

Focus here: Crop monitoring per administrative region

- **Final objective (per region/crop): Production = Area x Mean Yield**
- **Areas are fixed (too difficult to monitor changes on global scale)**
- **Estimate Mean Yield per region/crop**
- **Productions needed for all political decisions**

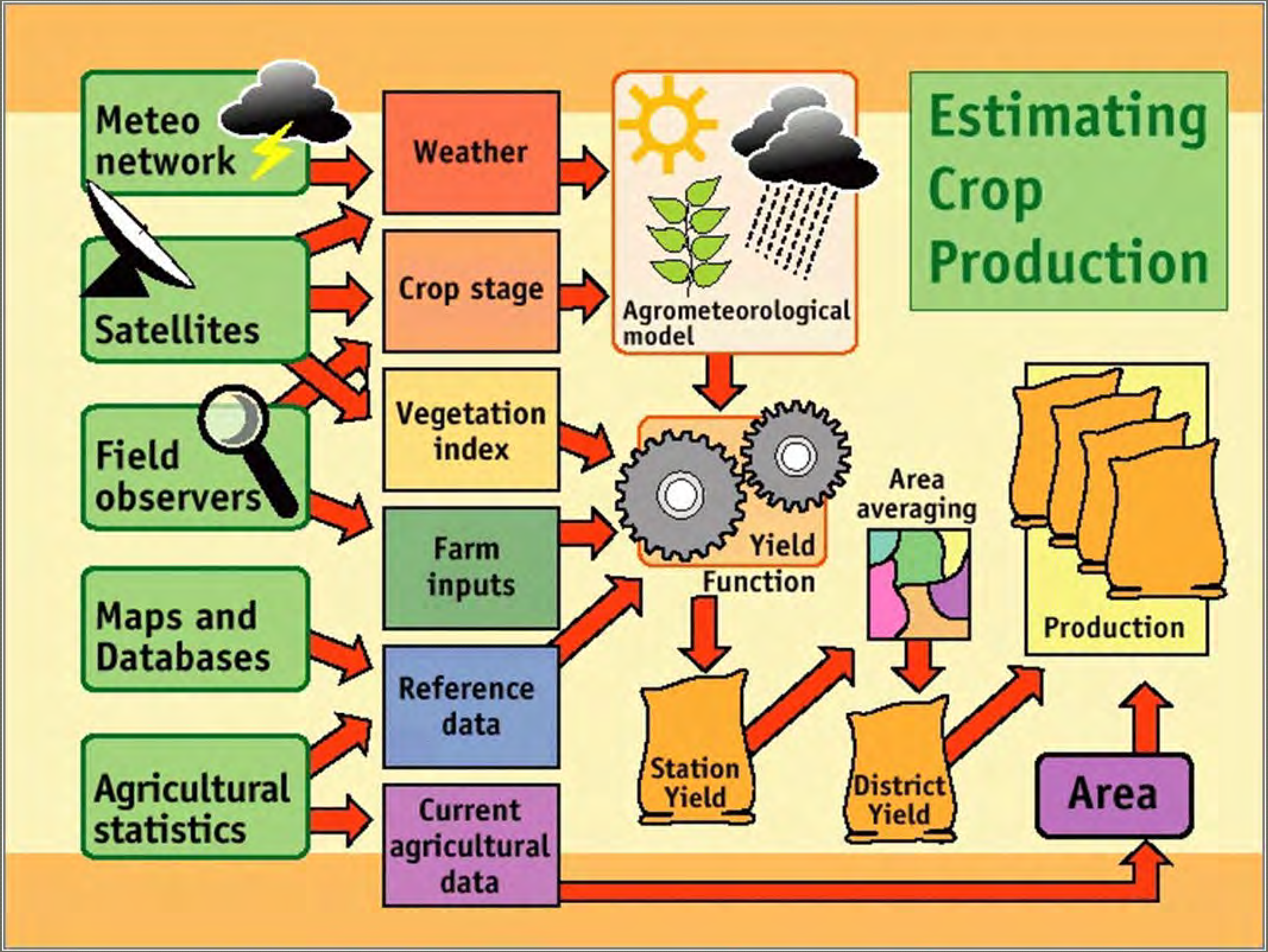
  ≈ import/export, humanitarian aid, …

MARS = Monitoring Agricultural ResourceS

Overview: Regional crop yield estimation

1. General approach
2. Input data: S10-composites from RS and ancillary info
3. Basic improvements: Flagging, smoothing, …
4. Derived, final information
5. Conclusions

MARS: General approach of EC-JRC



Courtesy: René Gommes (FAO)

MARS: General approach of EC-JRC

JRC MARSOP contracts (since 2000)

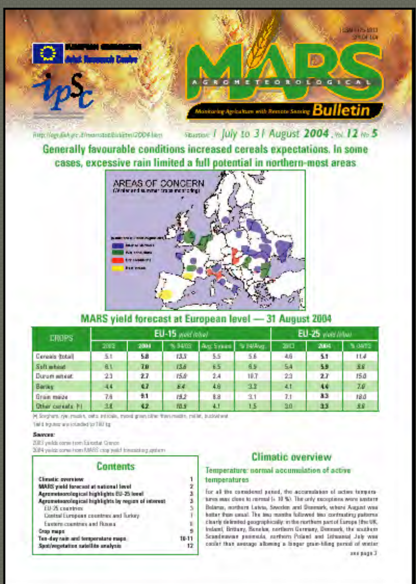
METEOCONSULT
Daily MeteoData

ALTERRA
CGMS-Results

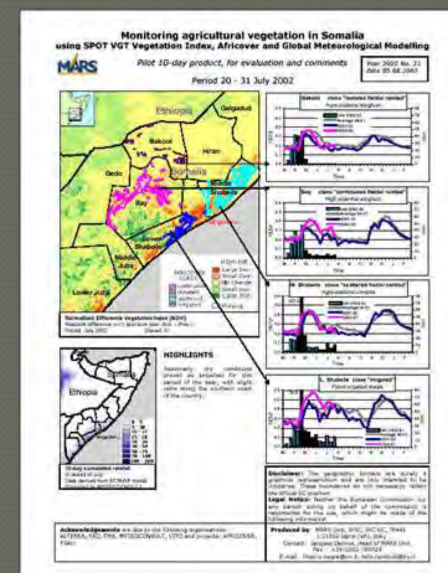
VITO
RS-Products

JRC-IES-MARS (Monitoring Agricultural ResourceS)

Agri4Cast ***FoodSec***



Website & DB-Viewers
http://www.marsop.info



DG-AGRI ***Scientific users*** ***DG-AIDCO/RELEX***

MARS: General approach of EC-JRC

page | discussion | view source | history

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site

- WikiMCYFS Main Page
- Weather Monitoring
- Remote Sensing
- Crop Simulation
- Yield Forecasting
- Software Tools
- History of the system
- FAQ
- Links
- Current events
- MARS Publications
- References
- Recent changes
- Sitemap

toolbox

- What links here
- Related changes
- Special pages
- Printable version
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Remote Sensing

Introduction

The remote sensing component of the MCYFS basically involves four actions:

- Data collection: Systematic acquisition of the raw imagery of a number of earth observation (EO) satellites, typically with low resolution but high repetitivity.
- Pre-processing: Correction of the raw scenes for radiometric, atmospheric and geometric effects, and composition of all the corrected tracks to 10-daily (dekadal) synthesis images (S10).
- Post-processing: Extraction from the pre-processed S10-syntheses of value-added products useful for vegetation and crop monitoring.
- Analysis: Use of this information in the final analyses and decision processes concerning crop monitoring.

Over the years, the systematic ingestion and processing of all the EO-data gave rise to a number of "time series" of images, with continental coverage and dekadal frequency. In the MCYFS, the series are systematically extended and every dekad a new set of products is added in near-real time (NRT). The MCYFS uses the image series in three different ways:

- Qualitative analysis: The mere display of the imagery immediately gives an overview of the general state of the vegetation in a certain area and period. This information is often useful to confirm, adjust or refute the decisions based on the growth modelling approach.
- Image-derived indicators can be included in the statistical yield forecasting process.

http://marswiki.jrc.ec.europa.eu/agri4castwiki/index.php/Remote_Sensing#Introduction

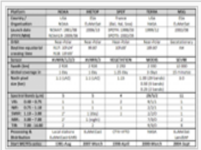
- Sensors: An overview of the sensors used and the processing steps from raw data to final products.
- Products and algoritms: A description of all sensor-independent algorithms and procedures.
- Technical information: A technical desciption of the output products.

A short introduction of these topics is provided below.

Sensors

In line with the objectives of JRC-MARS, the remote sensing data must cover Europe and have to be updated at least every ten days to allow the monitoring of the relatively fast crop growth dynamics. In the MCYFS, all remote sensing products focus on this ten-daily or dekadal step. Currently, only two types of EO-systems can fulfil these requirements:

- Near-polar orbiting satellites equipped with panoptic wide-swath sensors, such as NOAA/METOP-AVHRR, SPOT-VEGETATION and TERRA-MODIS. These systems provide daily global coverage, at a course resolution of about 1 km (250m for MODIS).
- Geostationary satellites, which are fixed above a certain point on the equator, at a distance of about 36 000 km. MSG (Meteosat Second Generation) hangs above the point with zero longitude and systematically scans the exposed part of the earth surface, mainly Africa and Europe. The image frequency is high (15-30 minutes) but due to the distance, the spatial resolution is very low (3 km sub-nadir).



The 5 EO-Systems used by the MARS project

In practice the MCYFS exploits the data of the five different EO systems, listed in the table below.

The processing of the EO-data is organised in two parts, namely the pre- and the post-processing.

The pre-processing involves all steps between acquisition of the raw registrations (often called "segments") and the delivery of fully corrected composite images, with a daily (S1) or most often 10-daily (S10) time step. In great lines, this involves the following operations:

- Geometric corrections: definition of each pixel's geolocation and remapping of the entire segment image to a common projection.
- Radiometric corrections: calibration and atmospheric correction to obtain surface reflectances (visible channels), brightness temperatures (thermal bands).
- Masking: detection of bad observations (clouds, cloud shadows, snow/ice and observation errors) and labelling of the involved pixels in a dedicated image, the "status mask".
- Compositing: combining all image segments within a pre-defined period to create a synthesis image according to a compositing rule (e.g. maximum value) and by excluding the bad observations.

The pre-processing software is run on LINUX machines. The concatenation of individual modules into operational "chains" is realised by the commercial software AppWorx. The post-processing ingests the S1/S10 composites, delivered by the pre-processing, and creates a number of more specific, value-added products in the form of Images, Quicklooks and databases of regional unmixed means (see products and algorithms). The post-processing is performed on Windows PC's with the GLIMPSE software (Global Image Processing Software), and it ends with the delivery of the final products to JRC.

The processing of the data is discussed per sensor in the links below.

More information

- NOAA-AVHRR
- METOP-AVHRR
- SPOT-VEGETATION
- TERRA-MODIS
- MSG-SEVIRI

Overview: Regional crop yield estimation

1. General approach
2. Input data: S10-composites from RS and ancillary info
3. Basic improvements: Flagging, smoothing, …
4. Derived, final information
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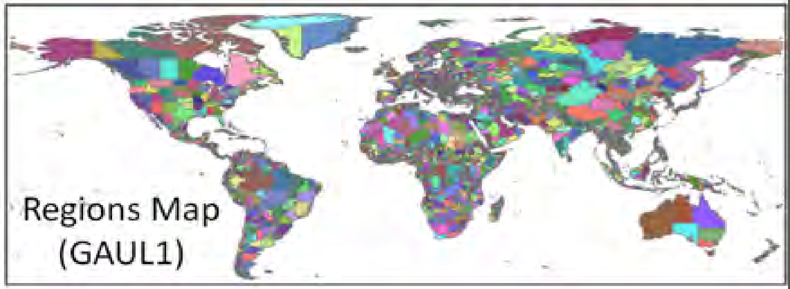
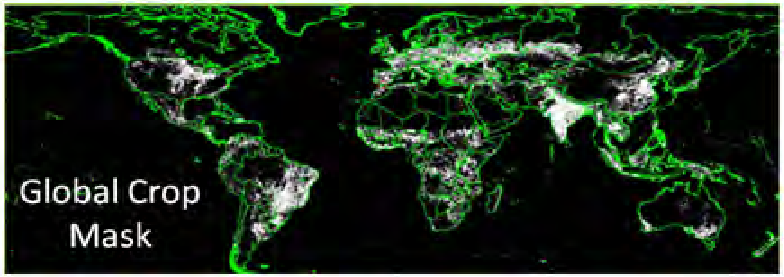
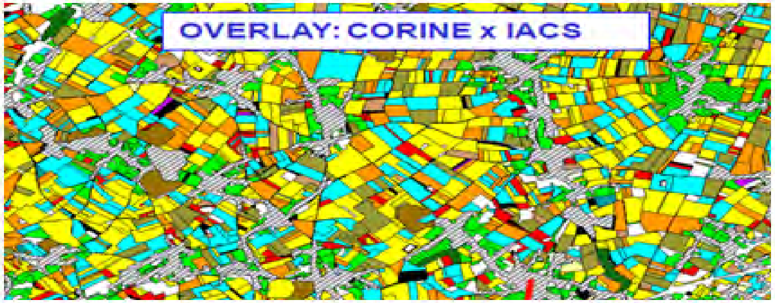
MARS: Ancillary Input Data

Ancillary Data Sets

1. Administrative regions
2. LU-maps
   - GLC2000, GlobCover
   - Crop masks for specific regions
   - IACS parcel maps
3. DB with official crop statistics
   - Areas and yields
   - Per region x crop x year
4. Meteodata - 1.AgroMet
   - Daily, all variables
   - Global at 0.25° from ECMWF
   - Europe at 25km from 4000 stations
   - Belgium at 10km from all stations
5. Meteodata – 2.AeroMet (CVB)
   - For Atmo-correction (SMAC)
   - Water vapour ...







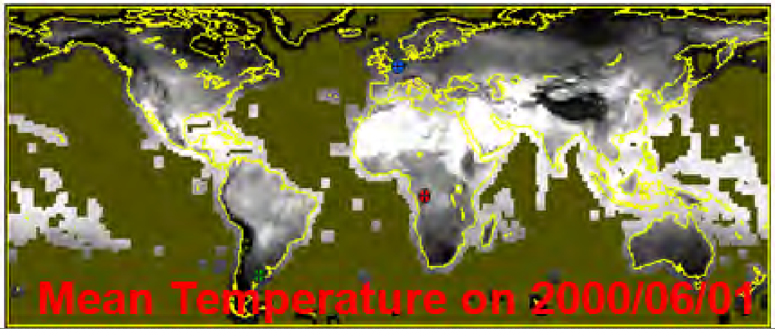
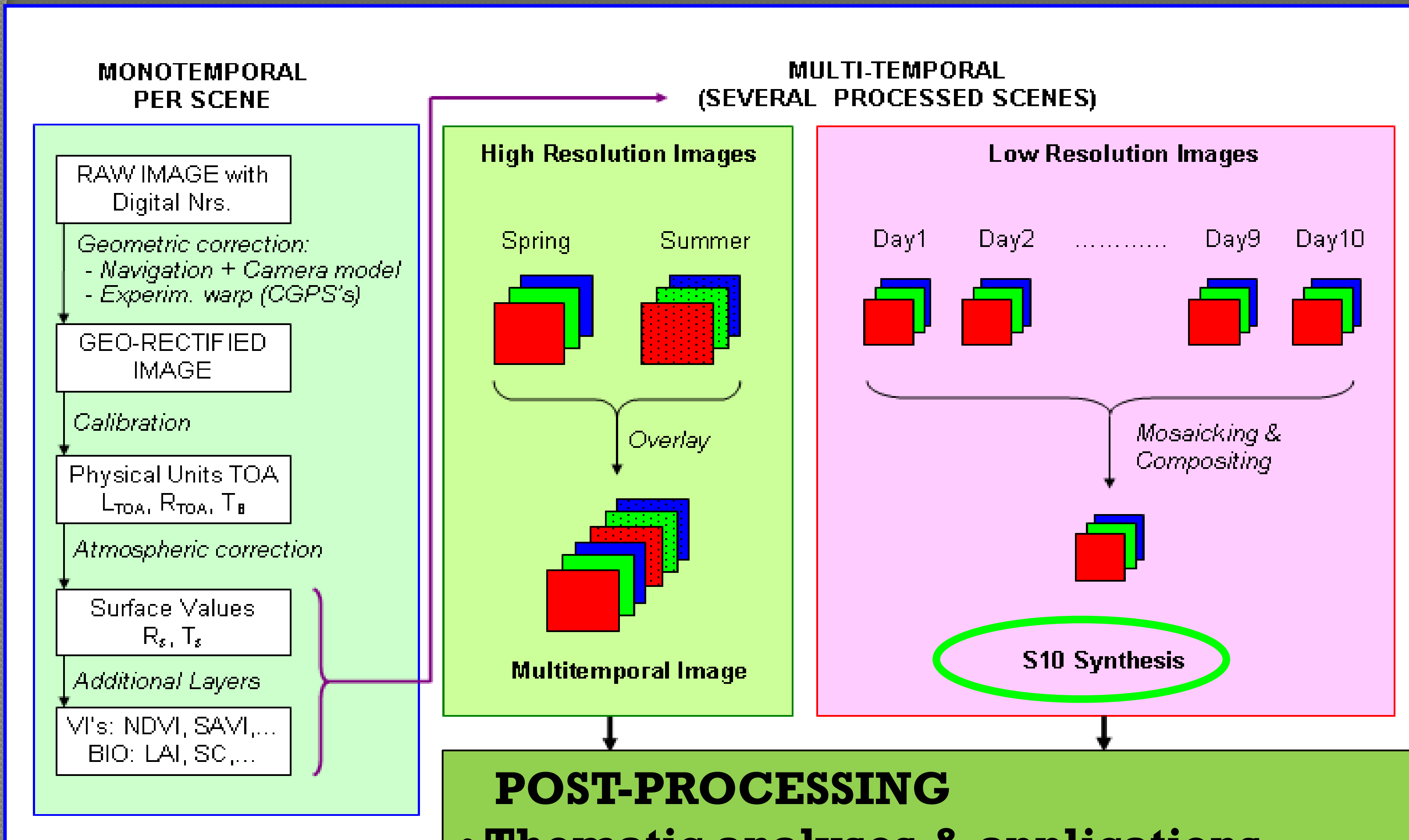


Image Processing: Pre ↔ Post

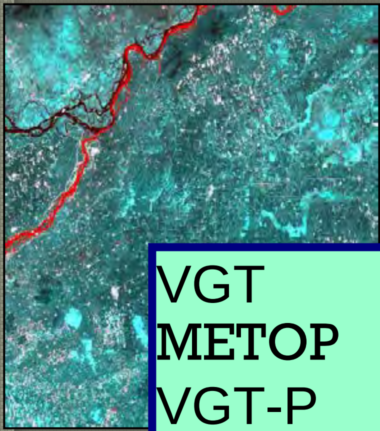


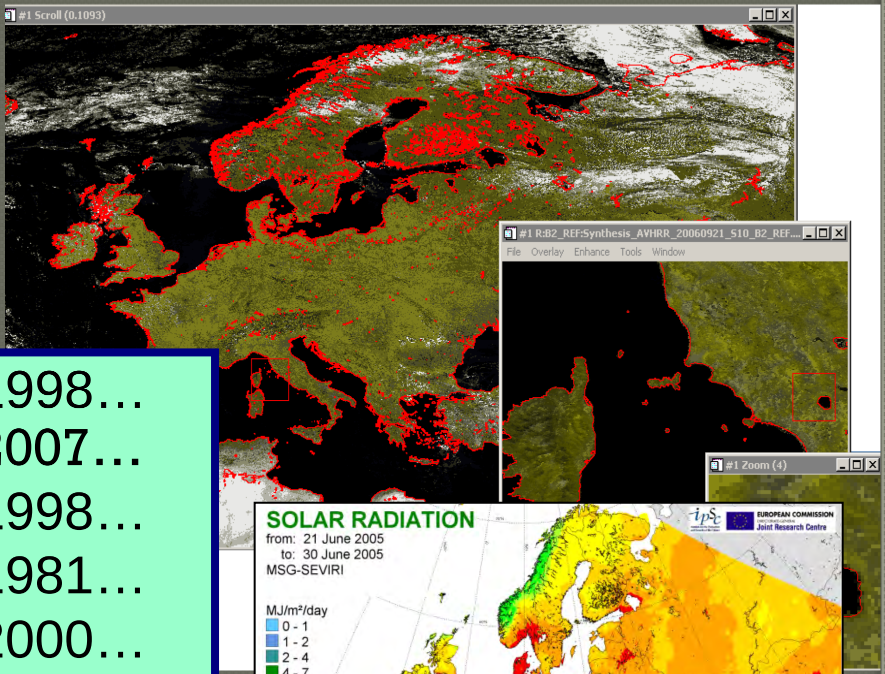
POST-PROCESSING

- **Thematic analyses & applications**
- **Monitoring of vegetations/forests/crops**
- **LU-mapping and area estimation**
- **Carbon sequestration & Yield forecasting**

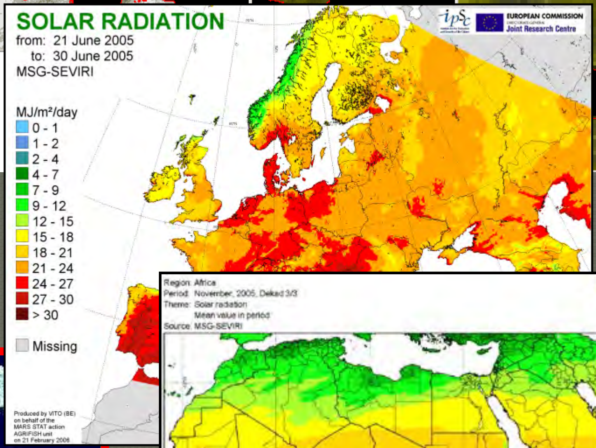
Pre-Processing: Sensors & Archives of S10

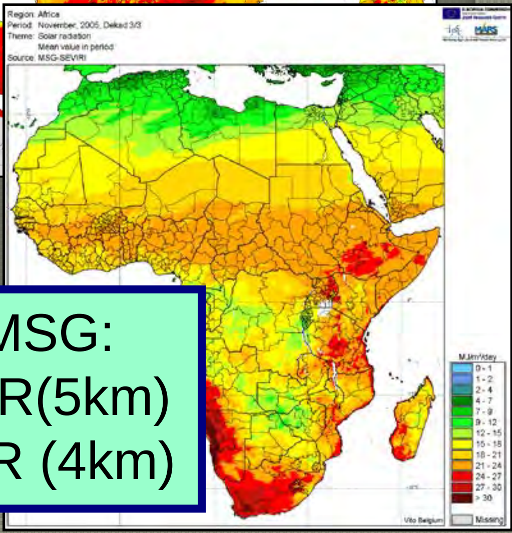
HiRes IMGs (10-50m - Local)

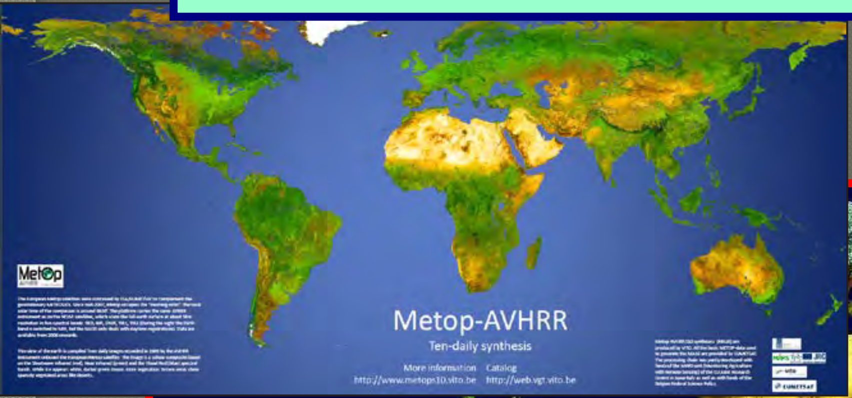




VGT	GLO	1 km	1998…
METOP	**GLO**	**1 km**	**2007…**
VGT-P	EUR	1 km	1998…
NOAA	EUR	1 km	1981…
MODIS	EUR/IGAD	250m	2000…







MSG:
EUR(5km)
AFR (4km)

Pre-processing: Global SPOT-VGT since 1998

VITO-CTIV=Centre de Traitement d'images SPOT-VEGETATION

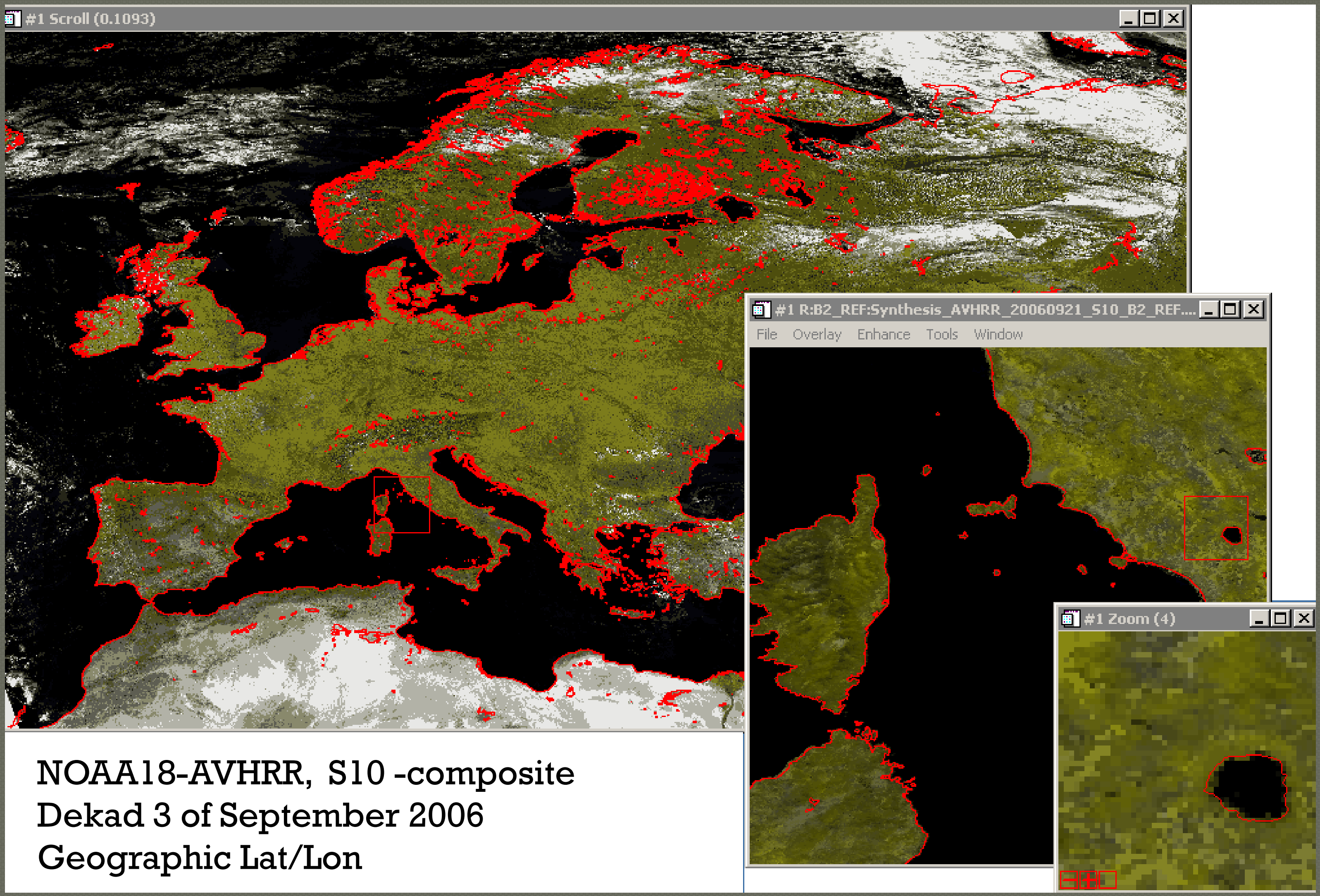
Global S10 of SPOT-VGT:

- Every 10 days (dekad) a new image
- Global, at 1 km resolution
- Since 1998 (now more than 15 years)

- High accuracy
- Wide user community
- Many applications

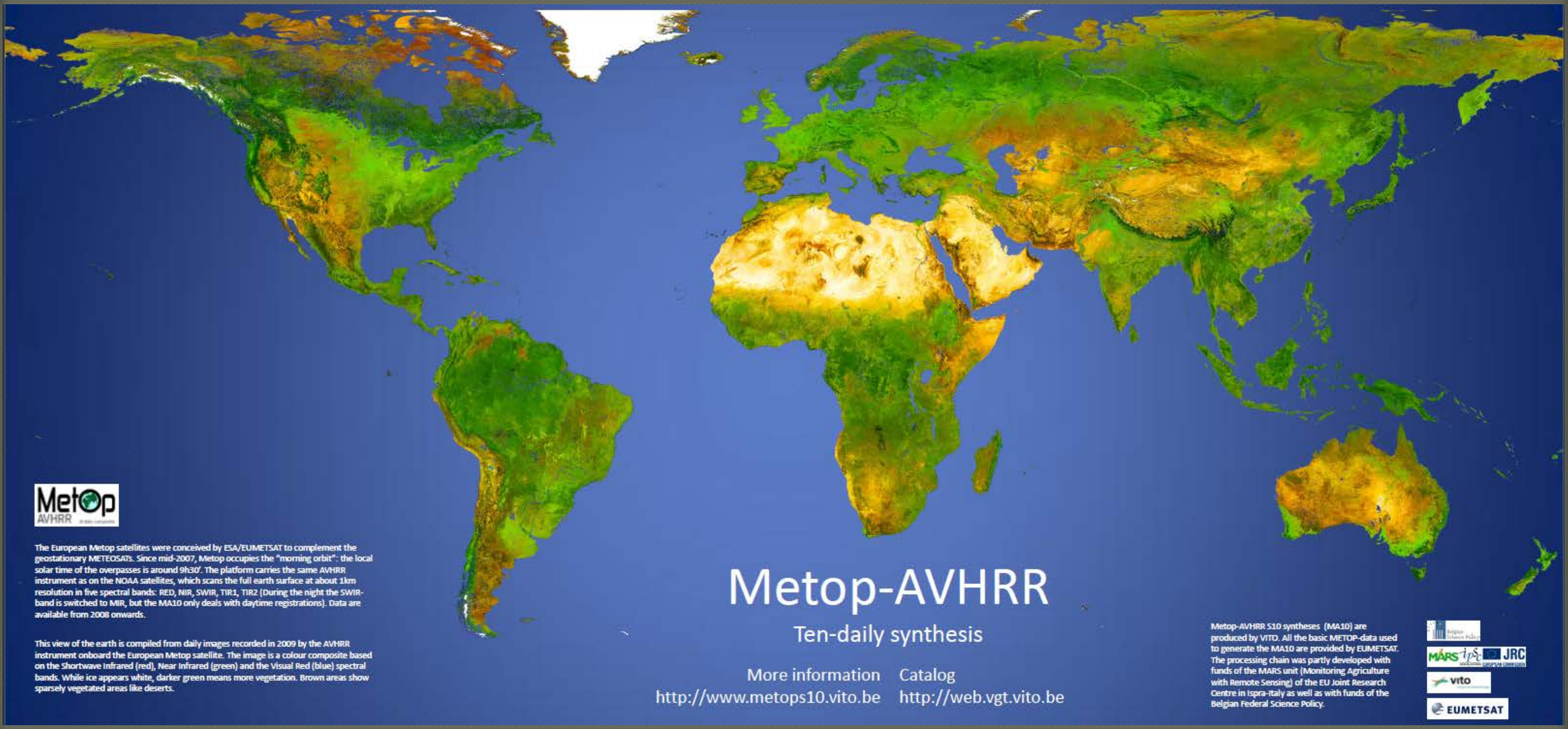
Pre-Processing: European NOAA-AVHRR since 1981

All European data since 1981 at 1 km
Processing by VITO for JRC-MARS



NOAA18-AVHRR, S10 -composite
Dekad 3 of September 2006
Geographic Lat/Lon

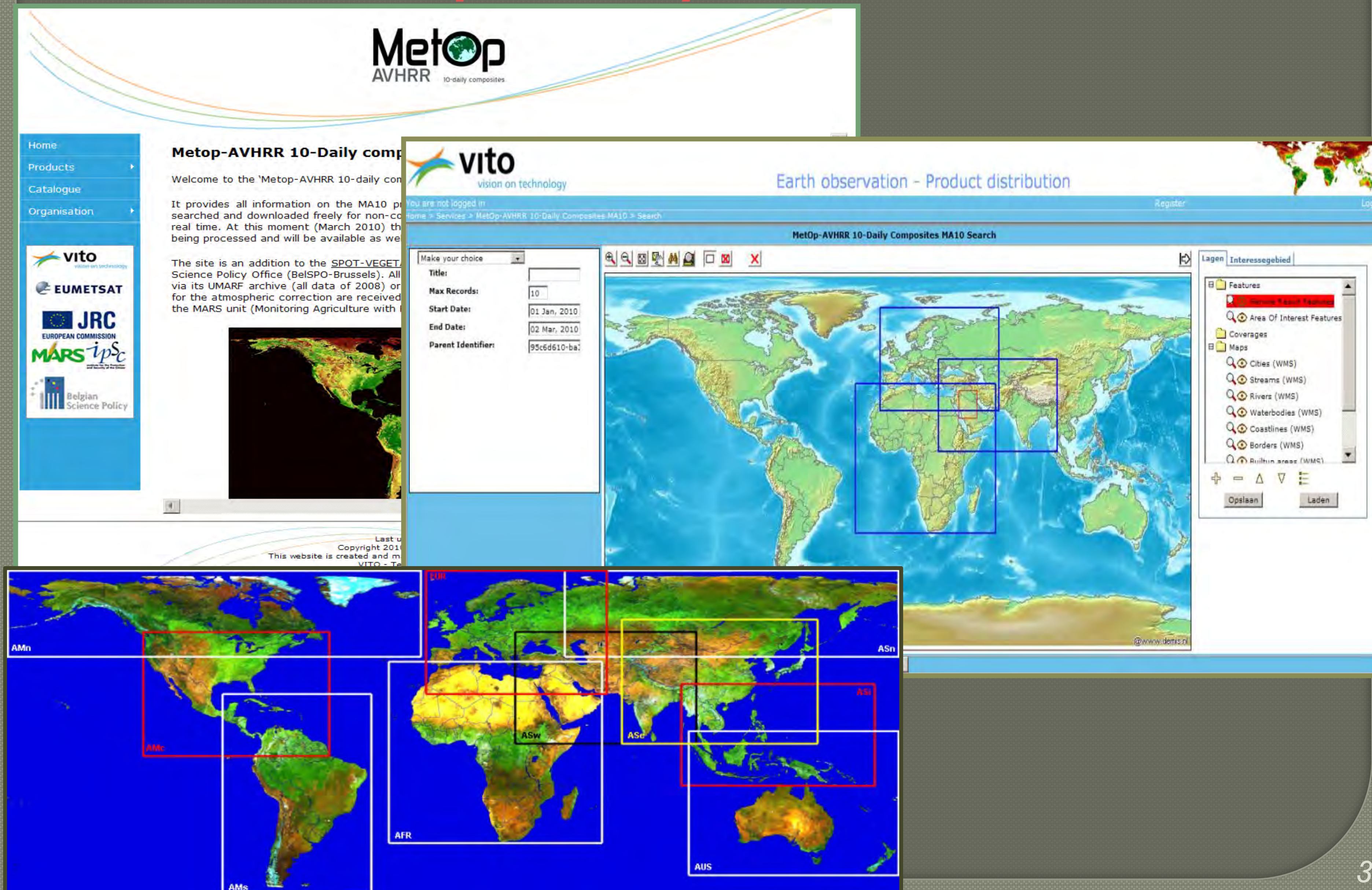
METOP-AVHRR: Global S10 from VITO



- Series of 10-daily composites from March 2007 → Present
- New dekads added in NRT.
- Layers: reflectances, BT, sun/view angles, NDVI, LST, quality information
- Funded by Belgian Science Policy Office (BELSPO)

METOP-AVHRR: Free downloads of S10

Website & Data Portal: http://www.metopS10.vito.be



METOP-AVHRR: Global S10 from VITO

Each S10-Composite comprises 16 image layers.

The lower table gives the SM interpretation.

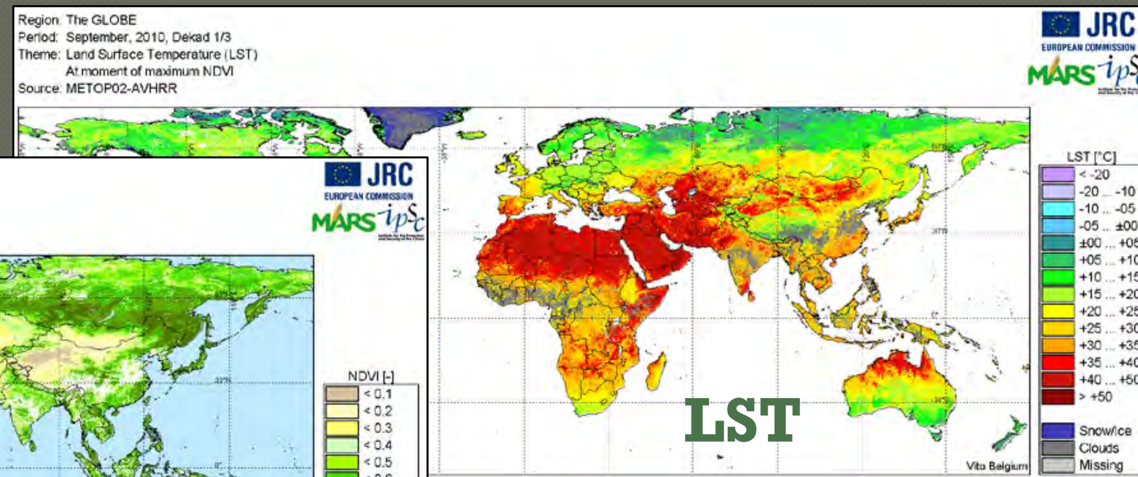
DT=1 for BYTE, 2 for SHORT INTEGER.

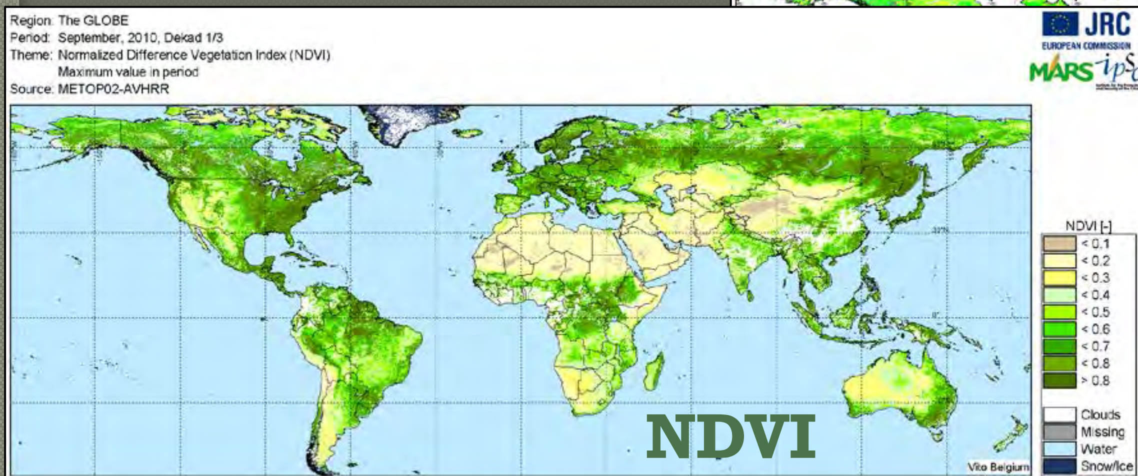
IMAGE		Physical Values Y			Scaling	Digital Values V	
vvv	**DT**	**CONTENT**	**UNIT**	$Y_{lo} \rightarrow Y_{hi}$	$Y = V_{int} + V_{slo} * V$	$V_{lo} \rightarrow V_{hi}$	V_{flag}
B1_REF	1	$R_{s,RED}$	%	0 → 62.50	Y=0.250*V	0 → 250	255
B2_REF	1	$R_{s,NIR}$	%	0 → 83.33	Y=0.333*V	0 → 250	255
B3A_REF	1	$R_{s,SWIR}$	%	0 → 62.50	Y=0.250*V	0 → 250	255
B4_BT	2	BT-Band 4	K	0 → 3276.7	Y=0.100*V	0 → 32767	-1
B5_BT	2	BT-Band 5	K	0 → 3276.7	Y=0.100*V	0 → 32767	-1
NDVI	**1**	**NDVI**	**-**	**-0.08 → 0.92**	**Y=-0.08 + 0.004*V**	**0 → 250**	**255**
LST	**1**	**Land surface temp.**	**°C**	**-50 → 75**	**Y=-50 + 0.5*V**	**0 → 250**	**255**
SZA	1	Sun Zenith Angle	degrees	0 → 125	Y=0.500*V	0 → 250	255
VZA	1	View Zenith Angle	degrees	0 → 125	Y=0.500*V	0 → 250	255
SAA	1	Sun Azimuth Angle	degrees	0 → 360	Y=1.500*V	0 → 240	255
VAA	1	View Azimuth Angle	degrees	0 → 360	Y=1.500*V	0 → 240	255
TVO	1	Nr. of Valid obs.	-	1 → 255	Y=V	1 → 255	0
TCO	1	Nr. of Clear obs.	-	1 → 255	Y=V	1 → 255	0
DAY	1	Day in Dekad	-	1 → 11	Y=V	1 → 11	0
ID	2	Segment_ID	-	1 → 32767	Y=V	1 → 32767	0
SM	1	Status Map	-	*bit-interpretation (see table below)*		1 → 255	0

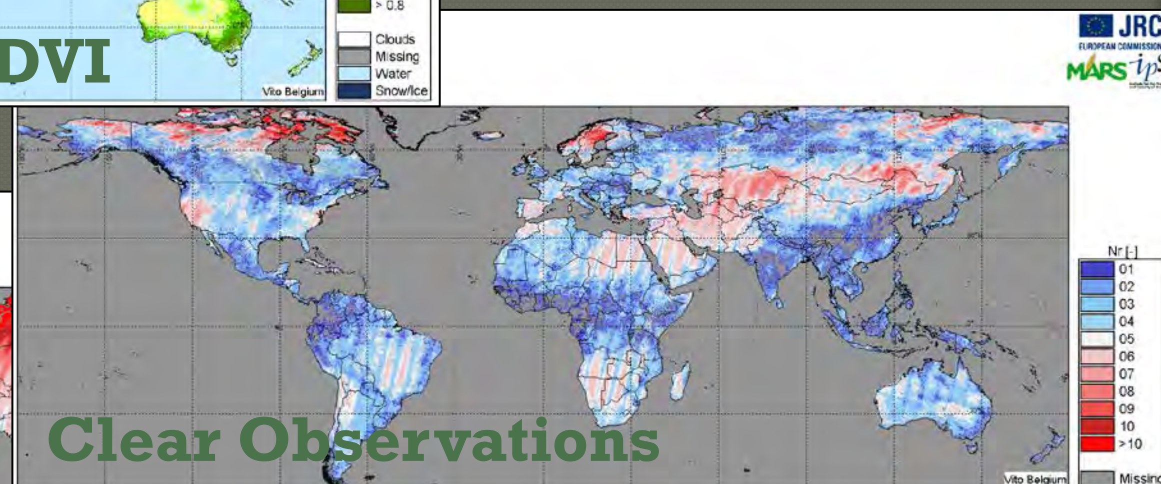
Decimal	128	64	32	16	8	4	2	1
Bit-Value	**Bit7**	**Bit6**	**Bit5**	**Bit4**	**Bit3**	**Bit2**	**Bit1**	**Bit0**
1	Land	ValidObs	never	never	Good	Cloud or shadow	Cloud	Snow
0	Sea	NoValidObs	always	always	Acceptable	none of these	Cloudfree	NoSnow

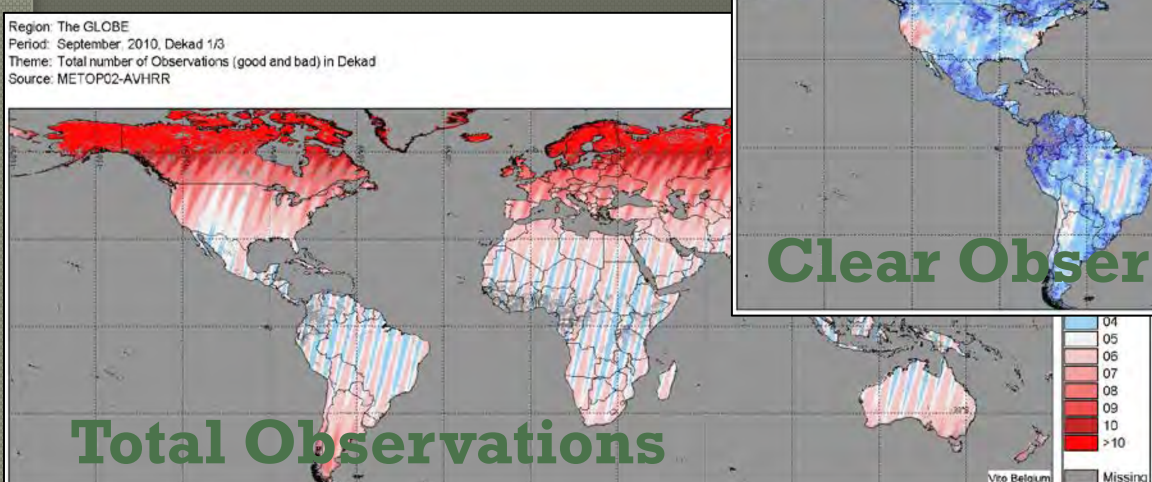
METOP-AVHRR: examples of global products

September 2010
Dekad 1



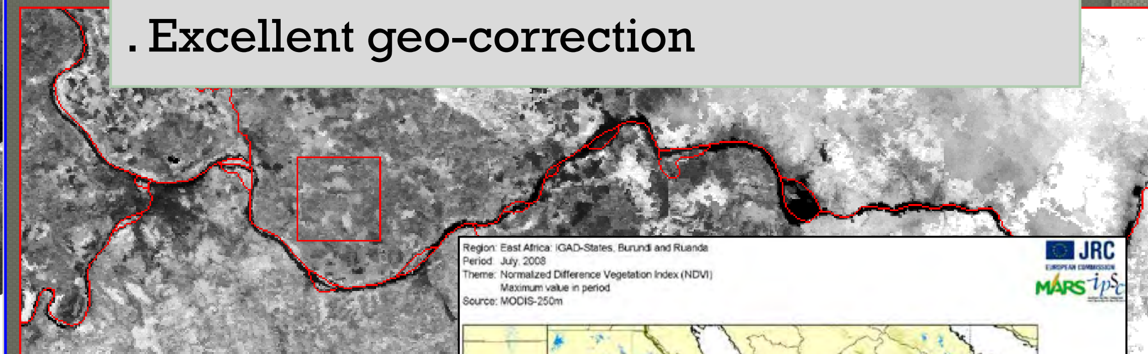


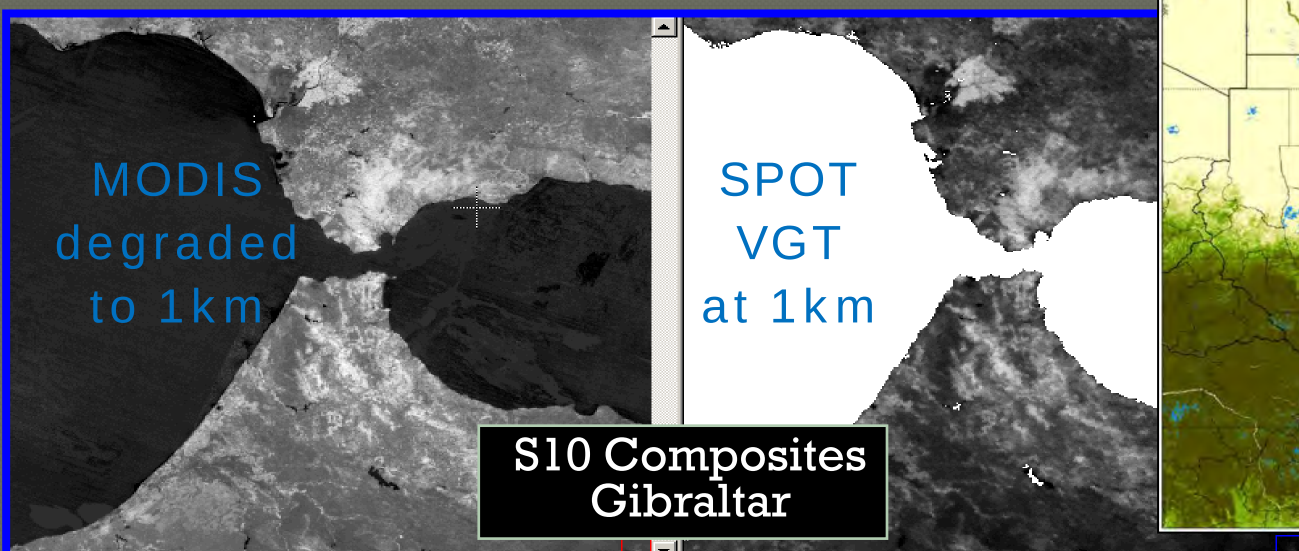


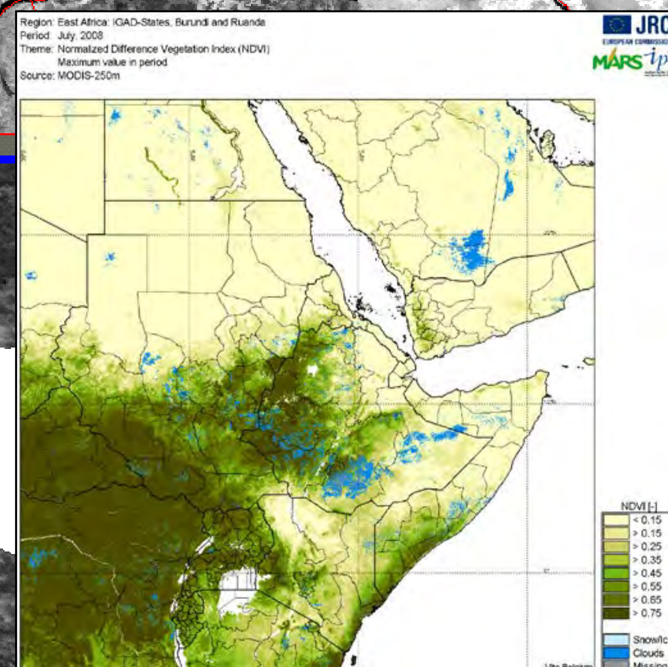


Pre-processing: TERRA-MODIS 250m since 2000

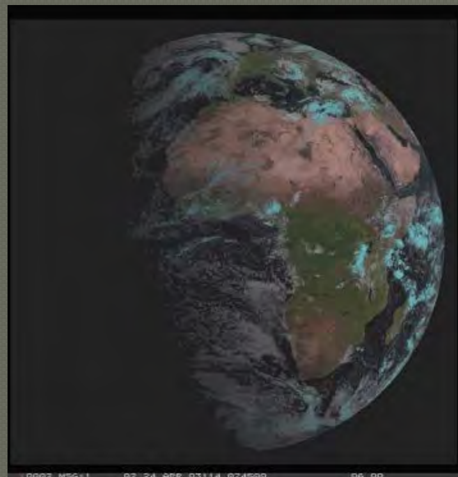
- . MODIS 250m (RED+NIR → fAPAR)
- . Pre-processing from L1 (LP-DAAC)
- . Europe & IGAD (Horn of Africa)
- . Excellent geo-correction







Adaptation of MSG-Products of LSA-SAF



Network of SAFs
(Space Application Facility)
co-ordinated by EUMETSAT

METEOSAT
Registration

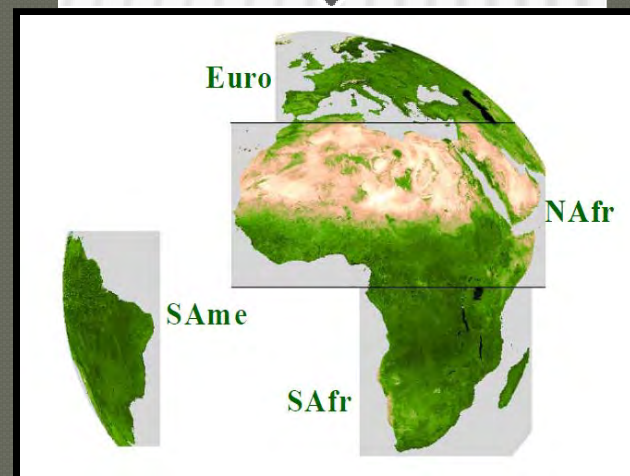
↓

EUMETSAT
Pre-processing

↓

LAND SAF
Derived products

↓



↓

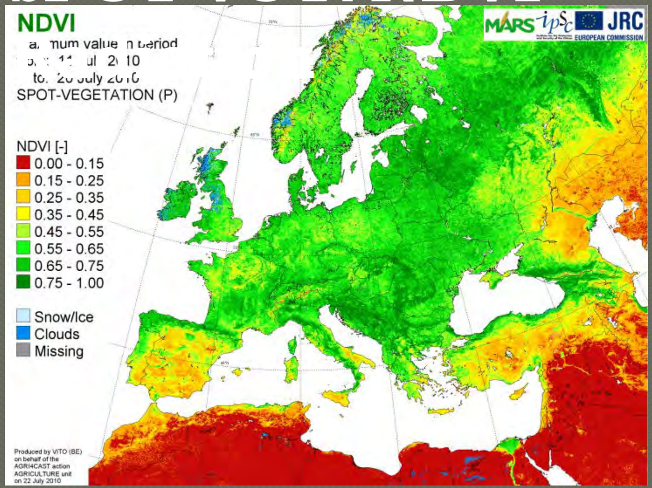
VITO
Adaptations

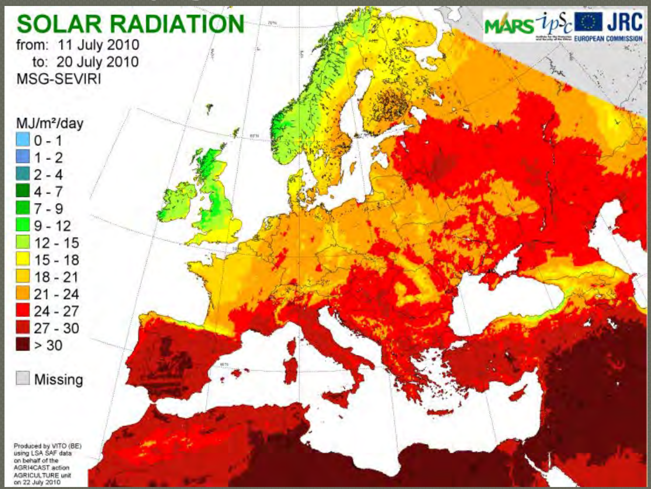
MSG spatial adaptations: Remap & Join

inputs

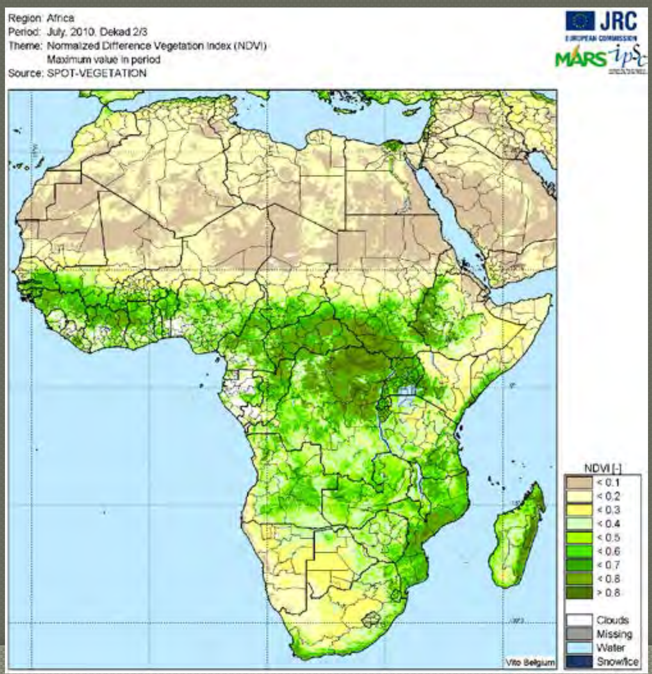
SPOT-VGT: NDVI

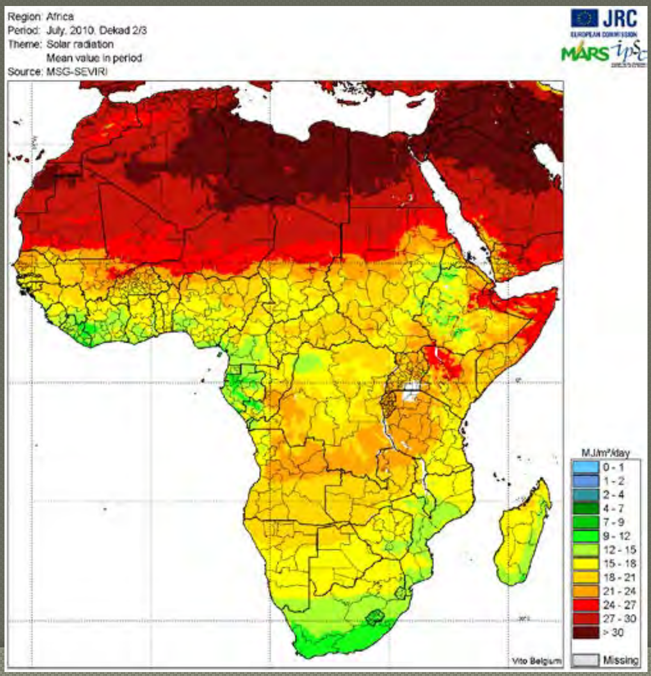
MSG:





EUROPE
Inspire-LAEA
5 km

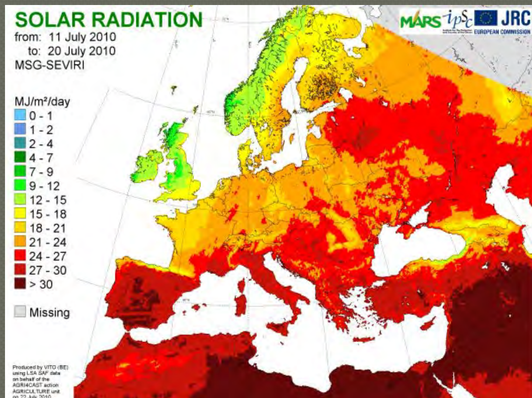


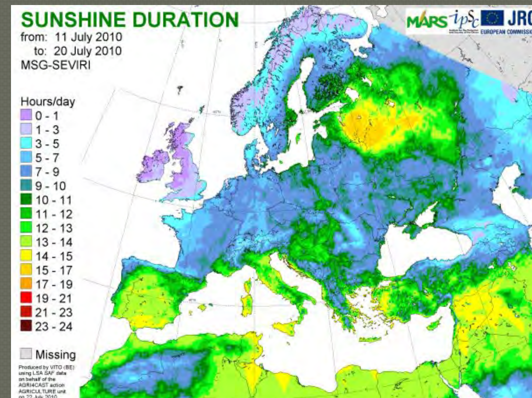


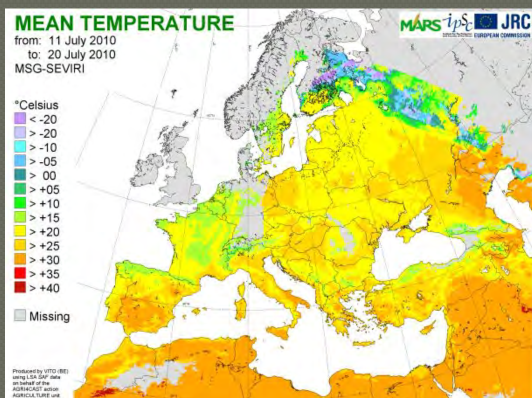
Spatial compatibility with products from other sensors

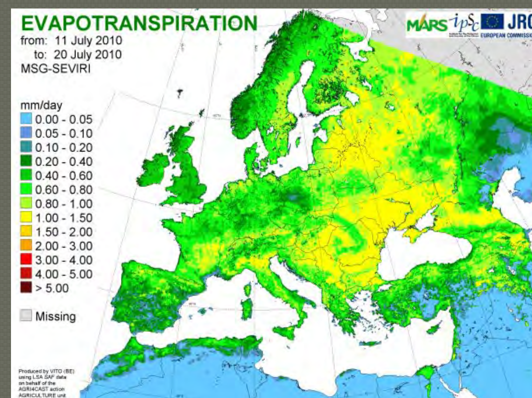
AFRICA
LonLat
4 km

MSG thematic adaptations

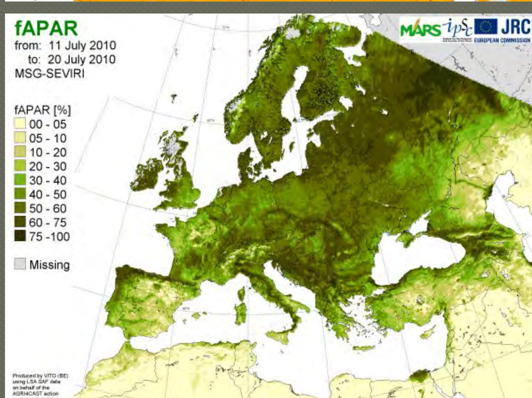


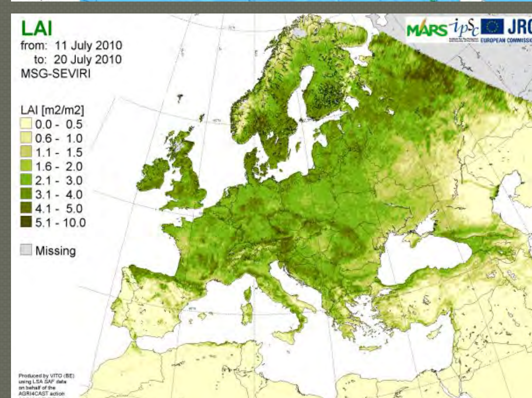


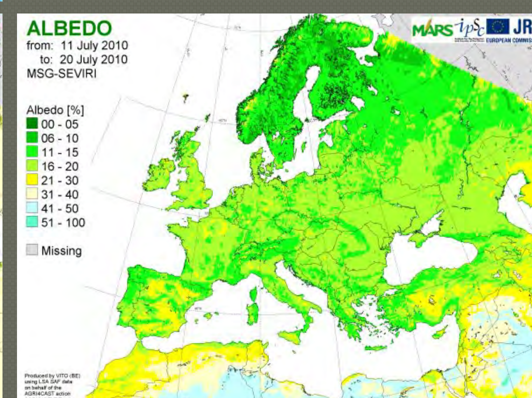




Europe (S1/S10):
- ex: end July 2010
- Not shown:
    - Snow cover
    - Tmin, Tmax
- Not entirely filled
- Especially T
- Excellent VEGA

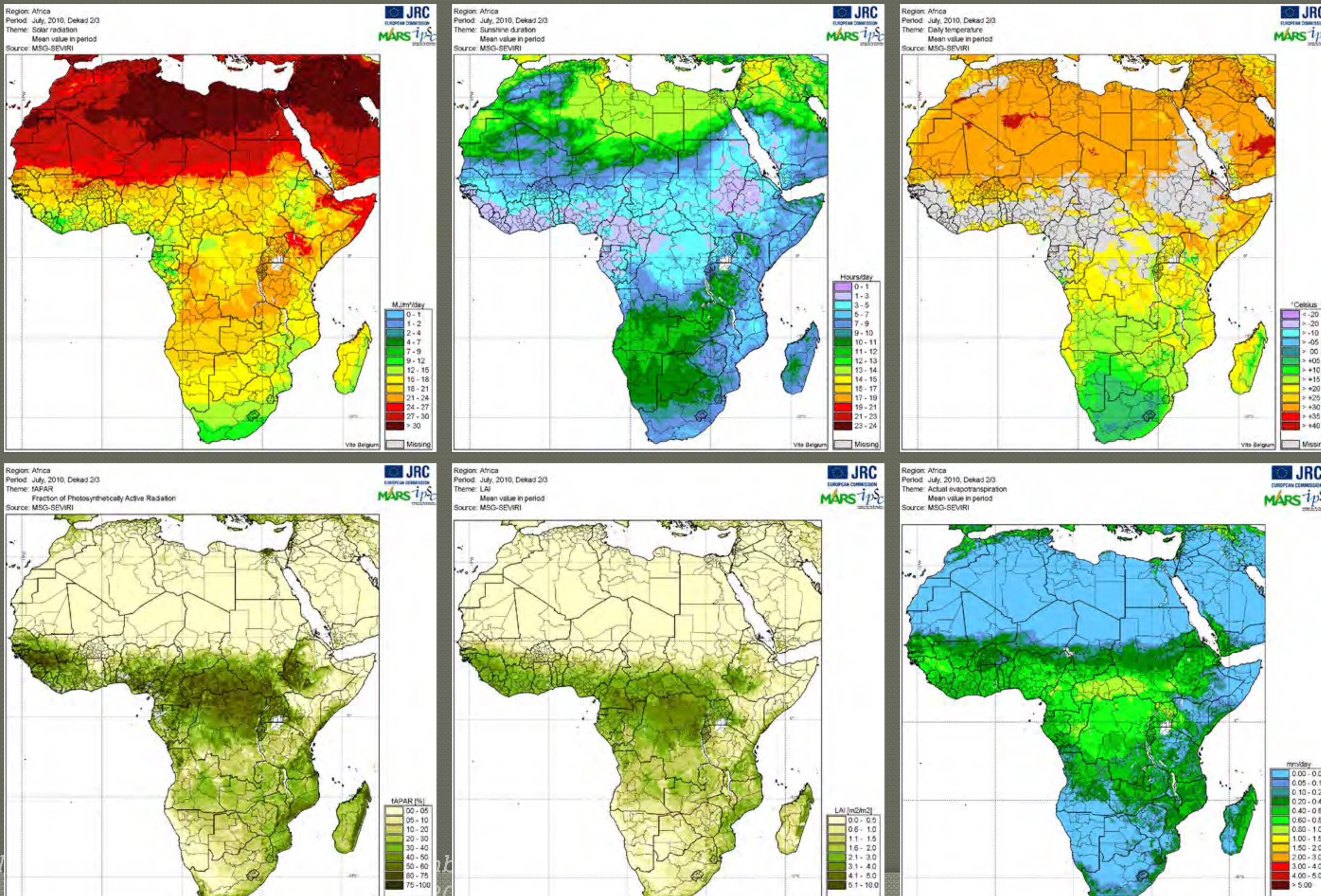




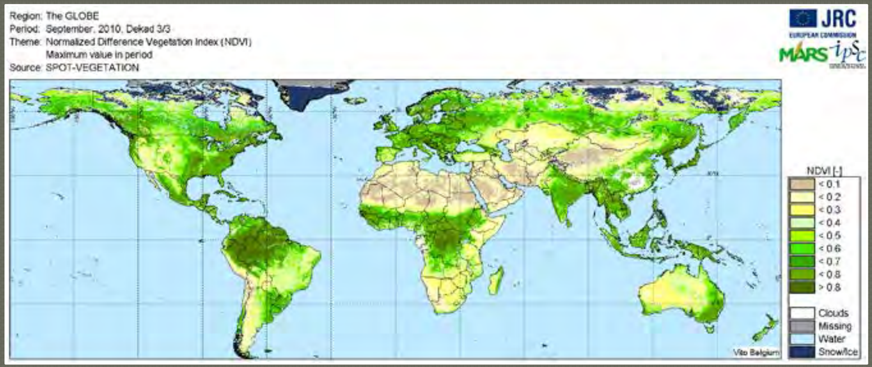


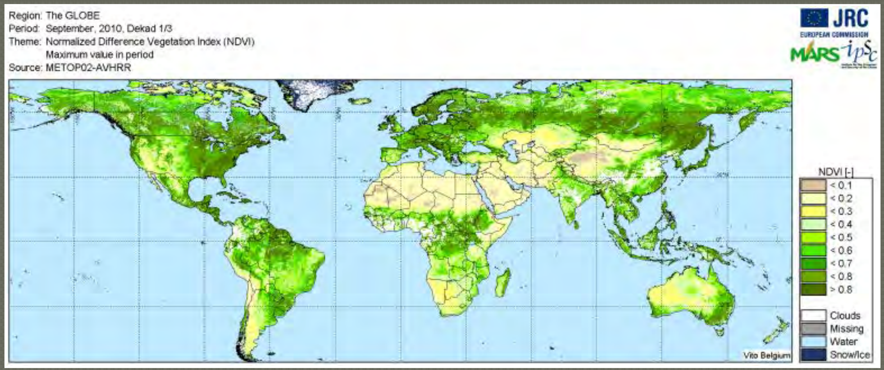
MSG thematic adaptations

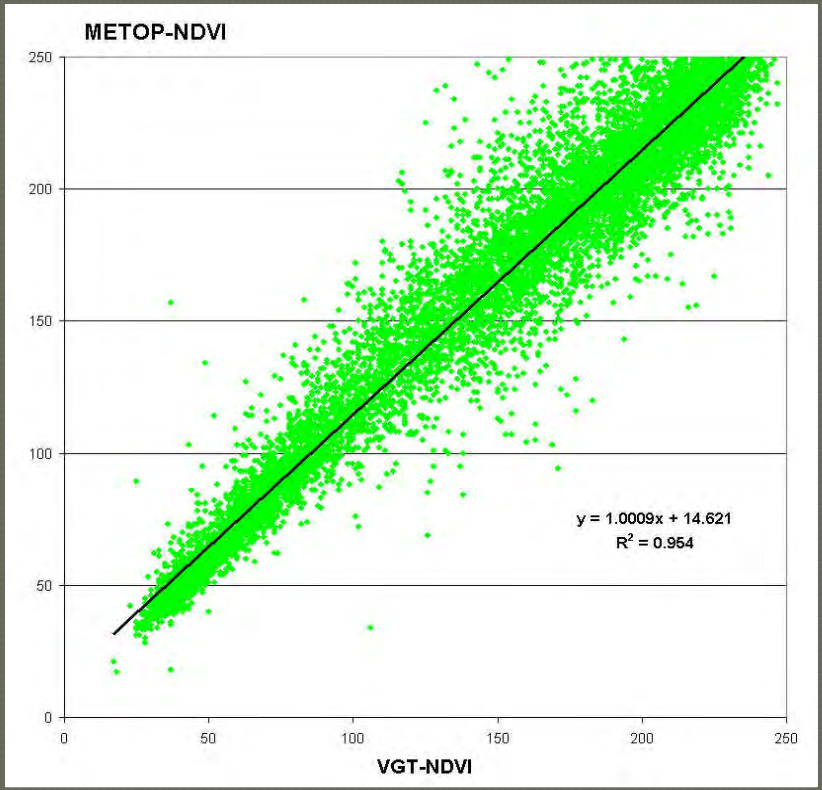
Africa: same products, better filled



Consistency between EO-sensors







Method

- Samples from paired S10-observations
- From 12 global S10 of year 2009/2010
- **Both of same registration day!**
- **Both absolutely cloudfree!**
- **R^2 = 95%, Slope = 1.0**
- No improvement "per land cover class"

Residuals due to:

- METOP 1h earlier than VGT
- Different geometries
- Different spectral response
- Etc.

METOP is directly available alternative for SPOT-VGT!

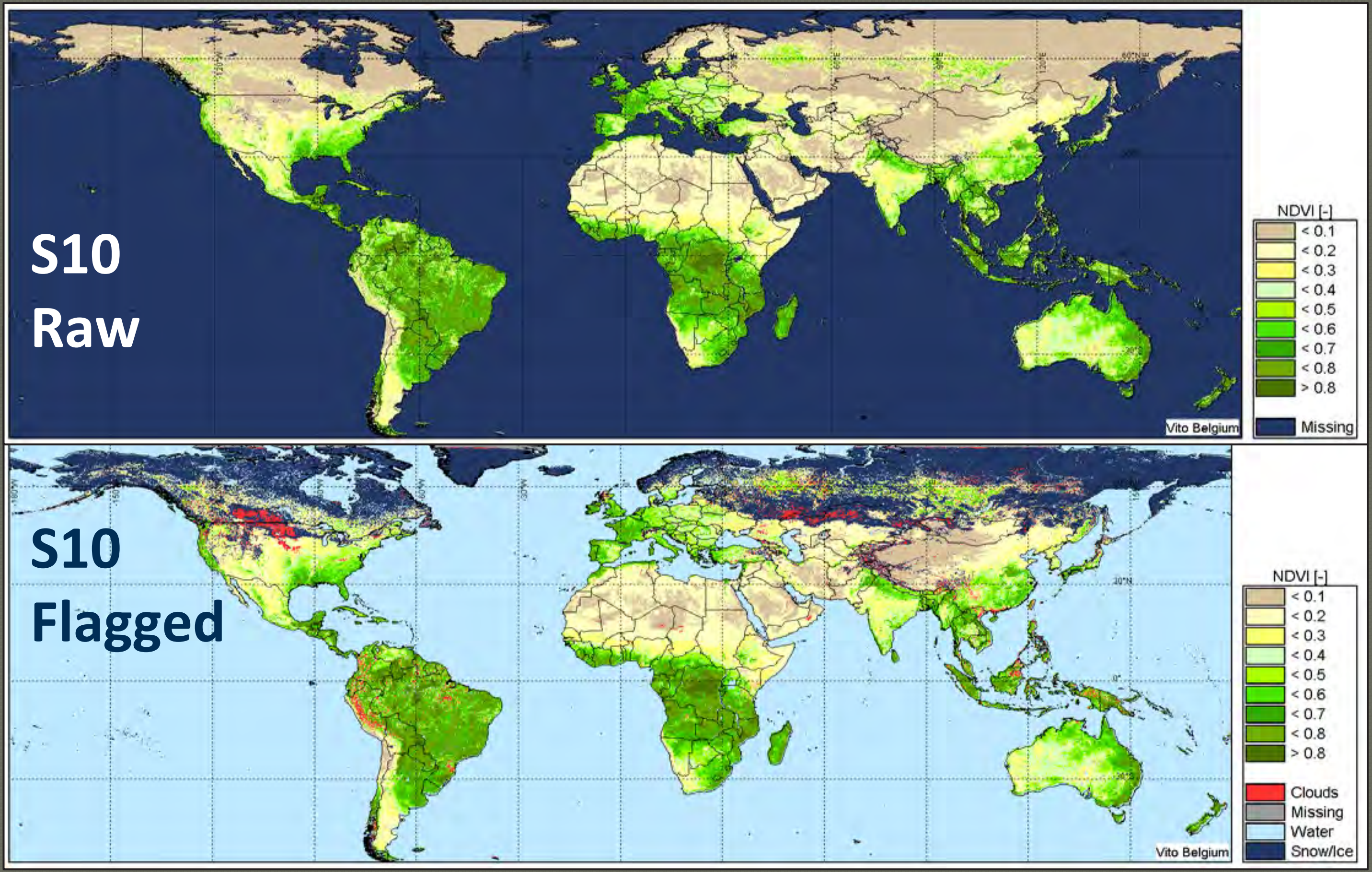
Overview: Regional crop yield estimation

1. General approach
2. Input data: S10-composites from RS and ancillary info
3. Basic improvements of S10: Flagging, smoothing, …
   - **Flagging**
   - **Smoothing & Gap filling**
   - **Addition of fAPAR and DMP**
4. Derived, final information
5. Conclusions

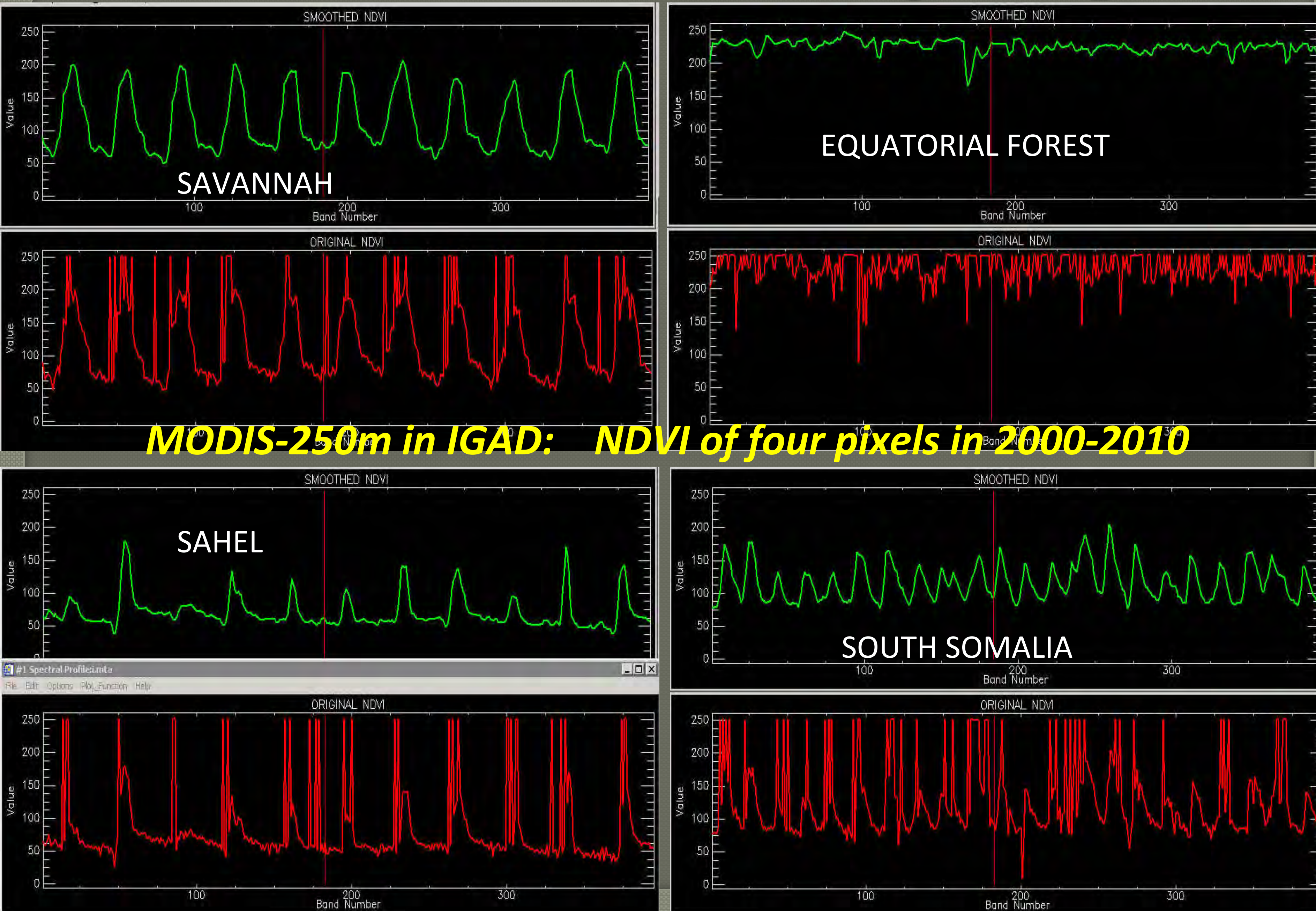
MARS:Basic Improvements

Make flagged S10: From…

- EO-IMG
- Associated Status Mask
- External Land/Sea Mask



MARS: Smoothing of VI-profiles

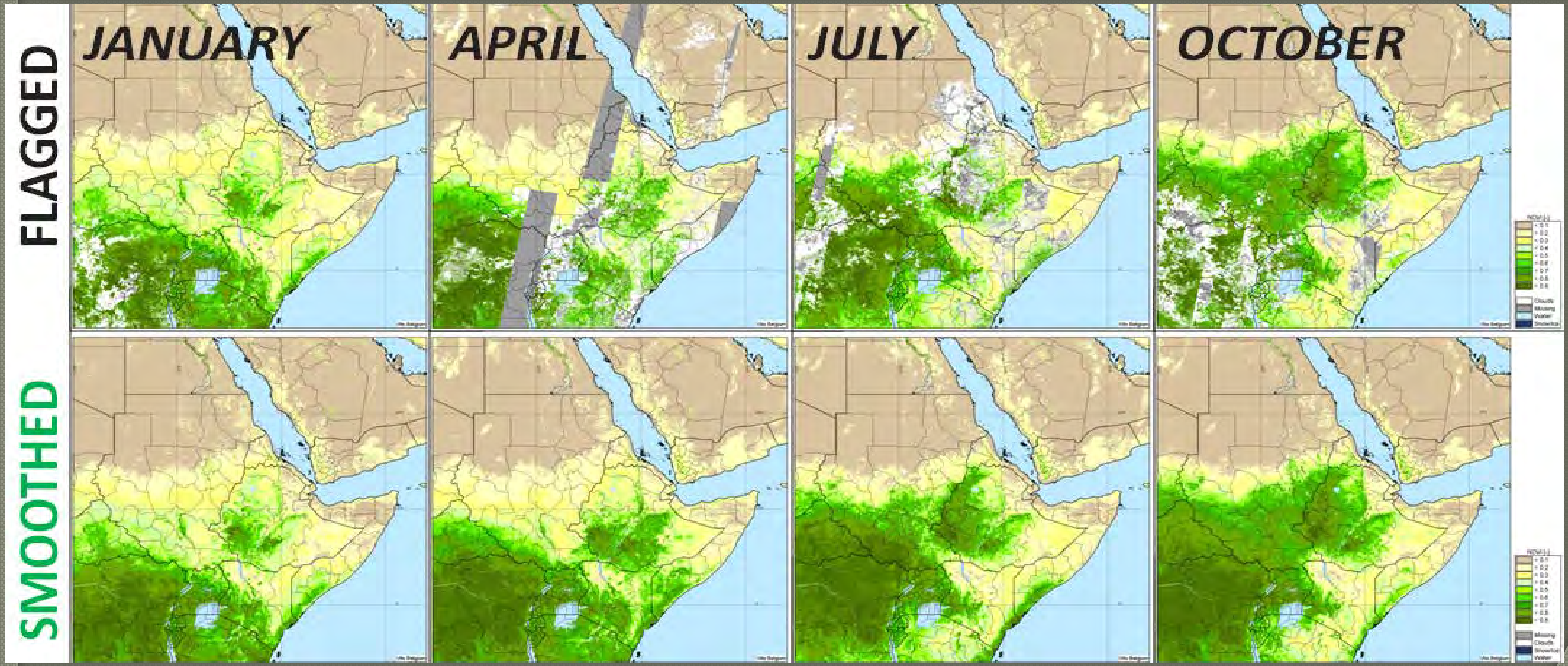


MARS: Smoothing & Gap Filling

MODIS-250m over the Horn of Africa:

Original and smoothed NDVI for four dekads in 2010

Clouds and missing values replaced by appropriate values.



MARS: Addition of fAPAR & DMP

fAPAR = Fraction of Absorbed PAR (400-700nm) [%]

Reflectances (RED, NIR,…)

Sun Zenith/Azimuth Angles

View Zenith/Azimuth Angles

Neural Network

Cyclopes (INRA-France)

fAPAR

DMP = Dry Matter Productiivity [kgDM/ha/day]

fAPAR

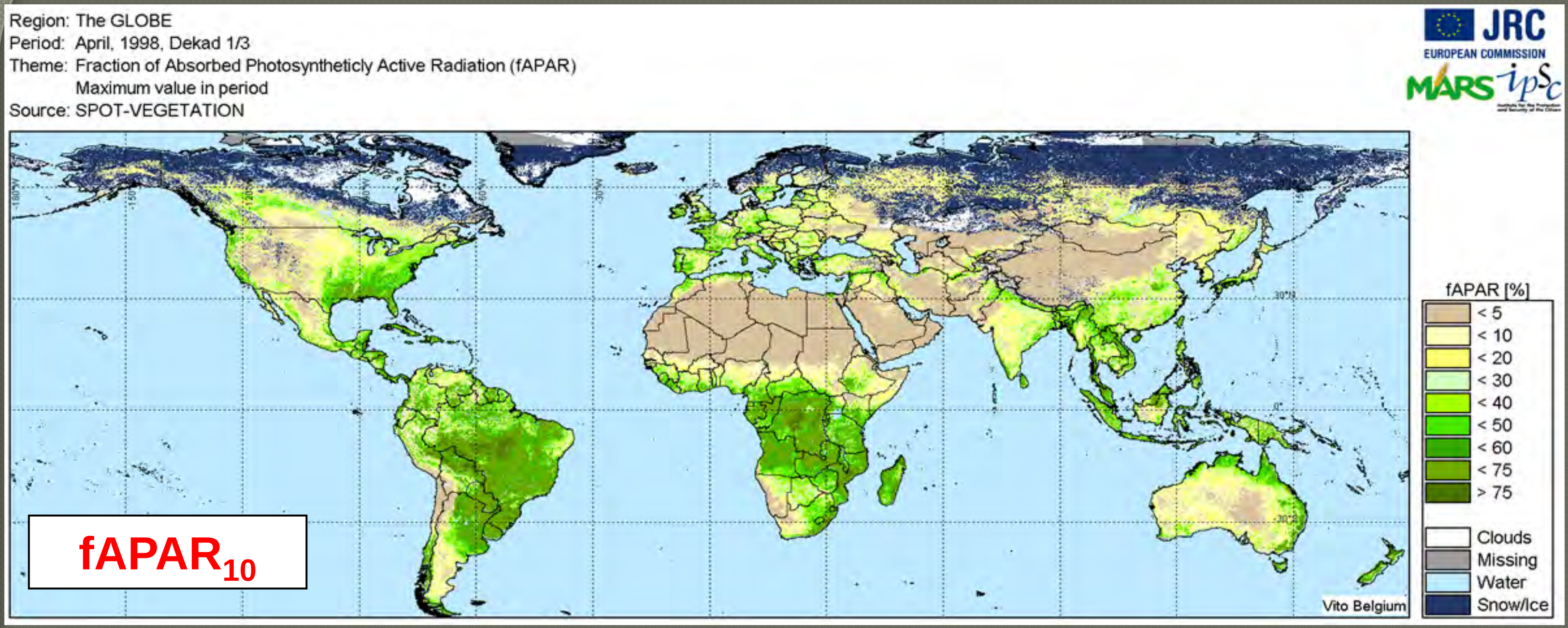
Solar radiation

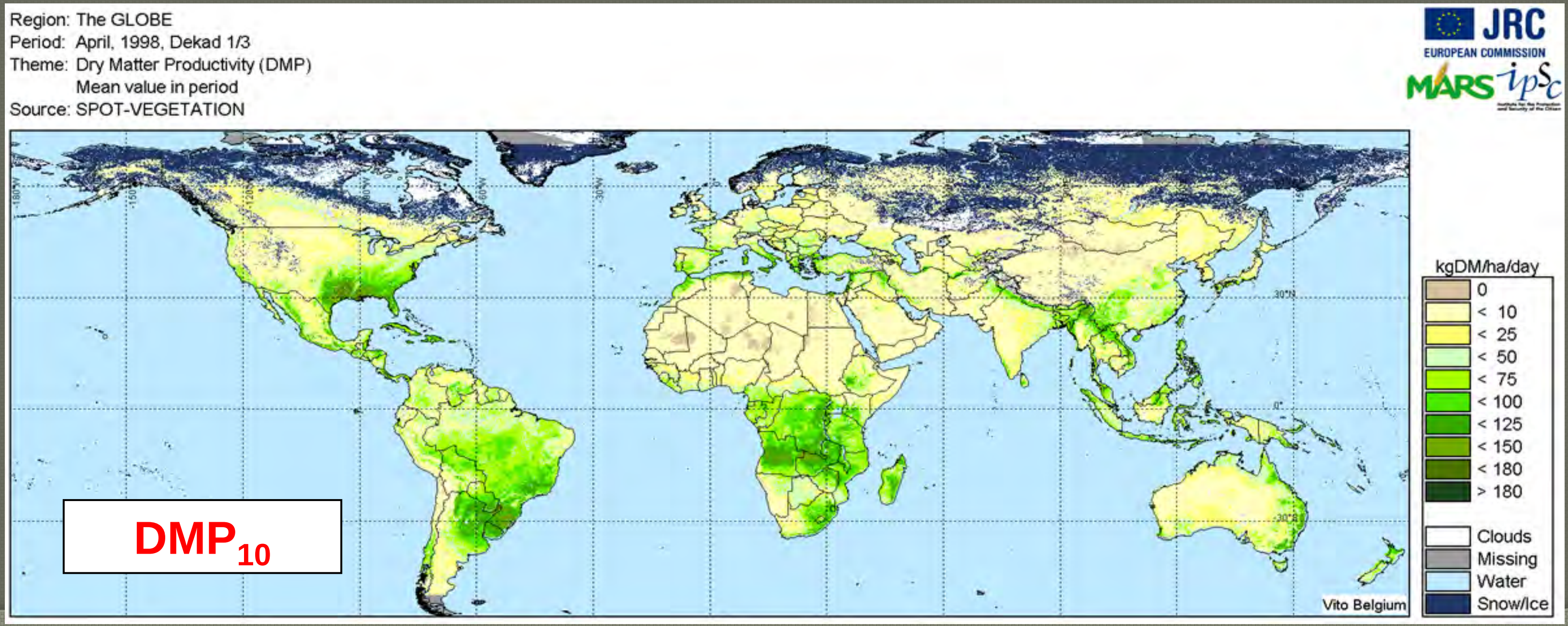
Tmin/Tmax

Monteith-Model

DMP

MARS: Addition of fAPAR & DMP





MARS = Monitoring Agricultural ResourceS

Overview: Regional crop yield estimation

1. General approach
2. Input data: S10-composites from RS and ancillary info
3. Basic improvements: Flagging, smoothing, …
4. Derived, final information:
   - Long-Term Statistics & Anomalies
   - Phenological information
   - Clustering
   - RUM-Databases
   - Regional yield assessment
5. Conclusions

MARS: Long-term Statistics & Anomalies

period	1	2	…	p	…	N_p
year = 1	X(1,1)	X(1,2)	…	…	…	X(1, N_p)
…	…					…
y	…			**X(y,p)**		…
…	…					…
N_y	X(N_y,1)	X(N_y,2)	…	…	…	X(N_y, N_p)

Actual IMGs:

X=NDVI,DMP,…

Np=36 dekads

12 months

Period	1	2	…	p	…	N_p
Mean	$\mu_x(1)$	$\mu_x(2)$	…	$\boldsymbol{\mu_x(p)}$	…	$\mu_x(N_p)$
Minimum	$Min_x(1)$	$Min_x(2)$		$\boldsymbol{Min_x(p)}$		$Min_x(N_p)$
Maximum	$Max_x(1)$	$Max_x(2)$		$\boldsymbol{Max_x(p)}$		$Max_x(N_p)$
St. Dev.	$\sigma_x(1)$	$\sigma_x(2)$		$\boldsymbol{\sigma_x(p)}$		$\sigma_x(N_p)$
N_{good}	$N_x(1)$	$N_x(2)$	…	$\boldsymbol{N_x(p)}$	…	$N_x(N_p)$

Historical Year:
Long-Term Statistics
(+ *Deciles*)

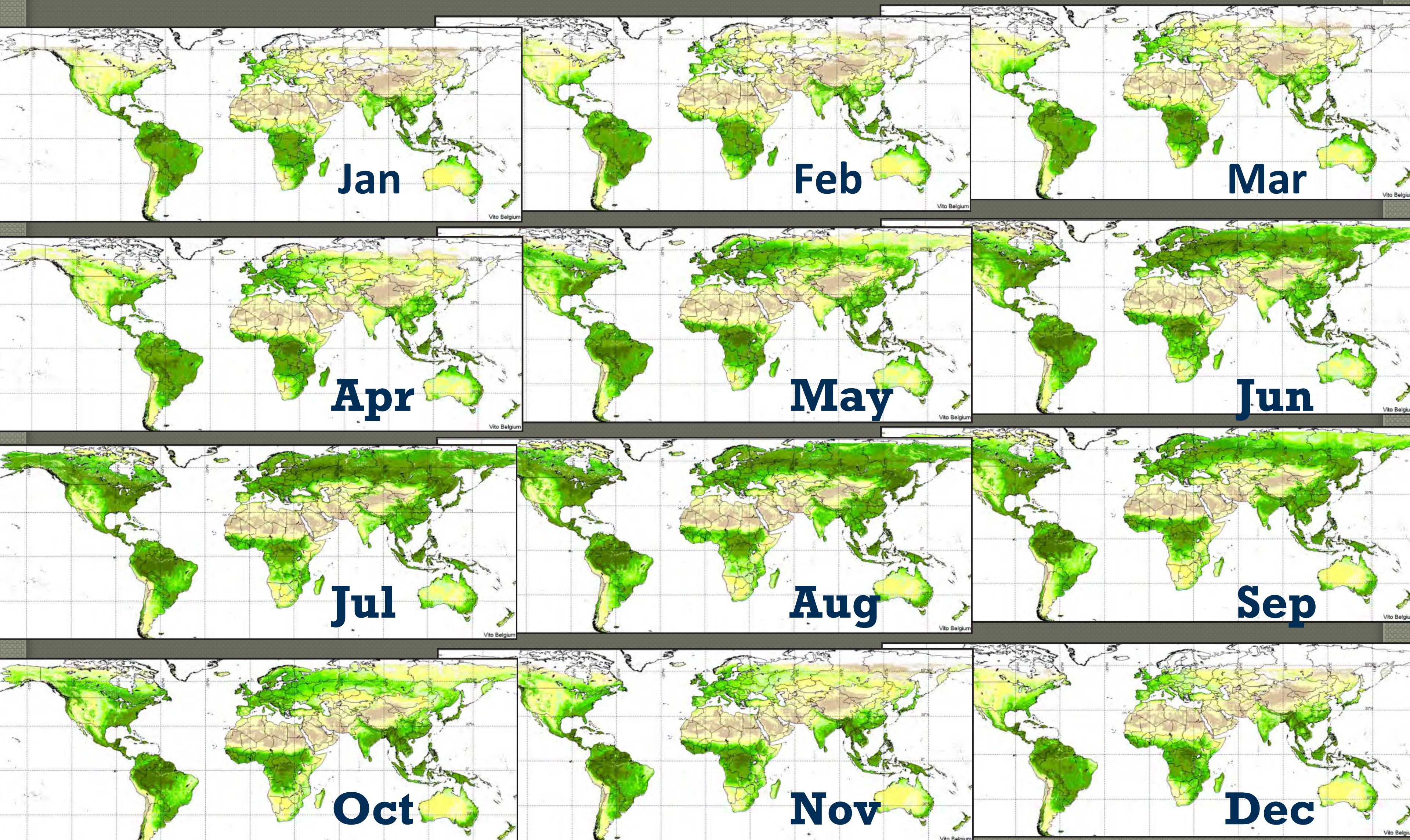
period	1	2	…	p	…	N_p
year = 1	$A_X(1,1)$	$A_X(1,2)$	…	…	…	$A_X(1, N_p)$
…	…					…
y	…			$\boldsymbol{A_X(y,p)}$		…
…	…					…
N_y	$A_X(N_y,1)$	$A_X(N_y,2)$	…	…	…	$A_X(N_y, N_p)$

DIFh:

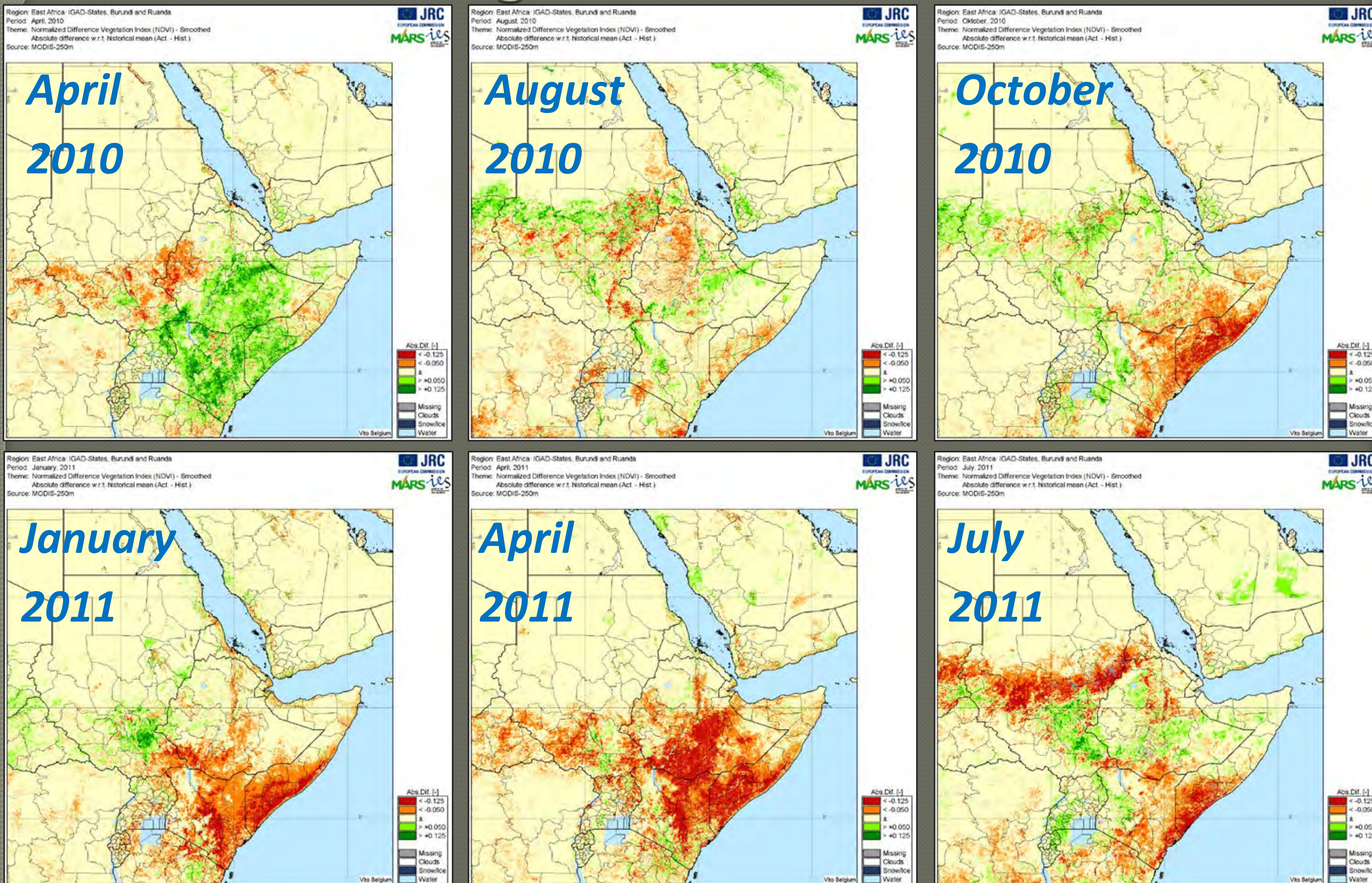
Anomaly IMGs
Difference wrt.
Historical Year

MARS: Long-term Statistics & Anomalies

LTA of 15 Year SPOT-VGT monthly NDVI



MARS: Long-term Statistics & Anomalies



Smoothed, monthly MODIS-NDVI: Absolute Difference to LTA

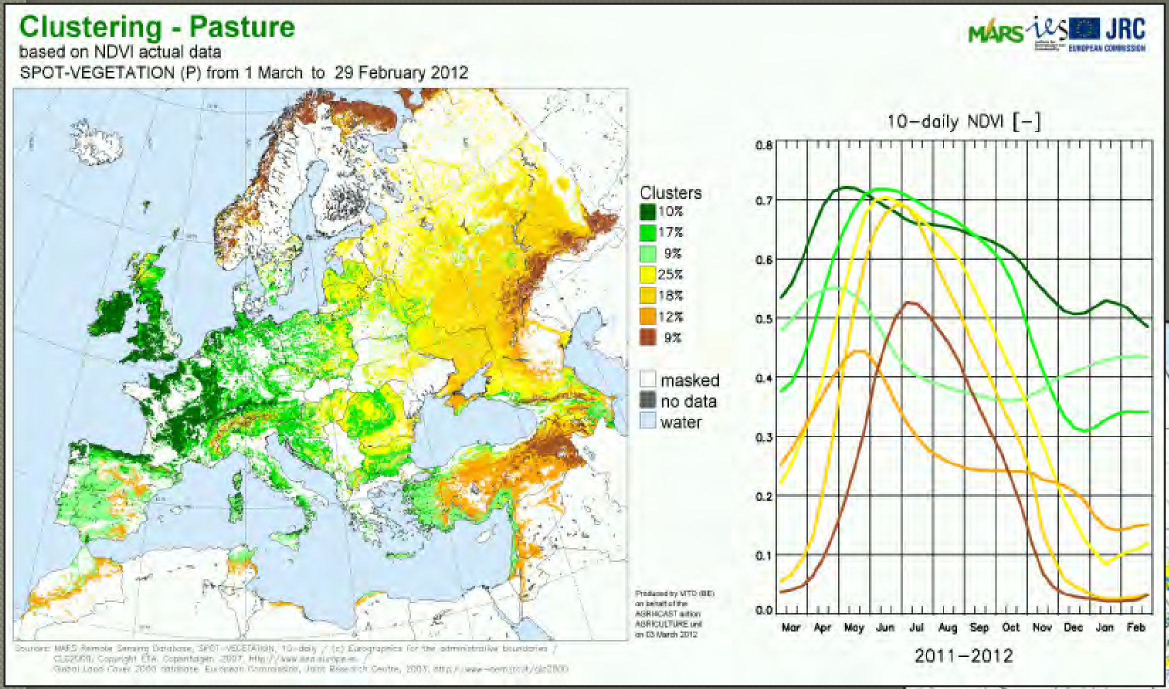
→ Severe drought in IGAD visible since October 2010

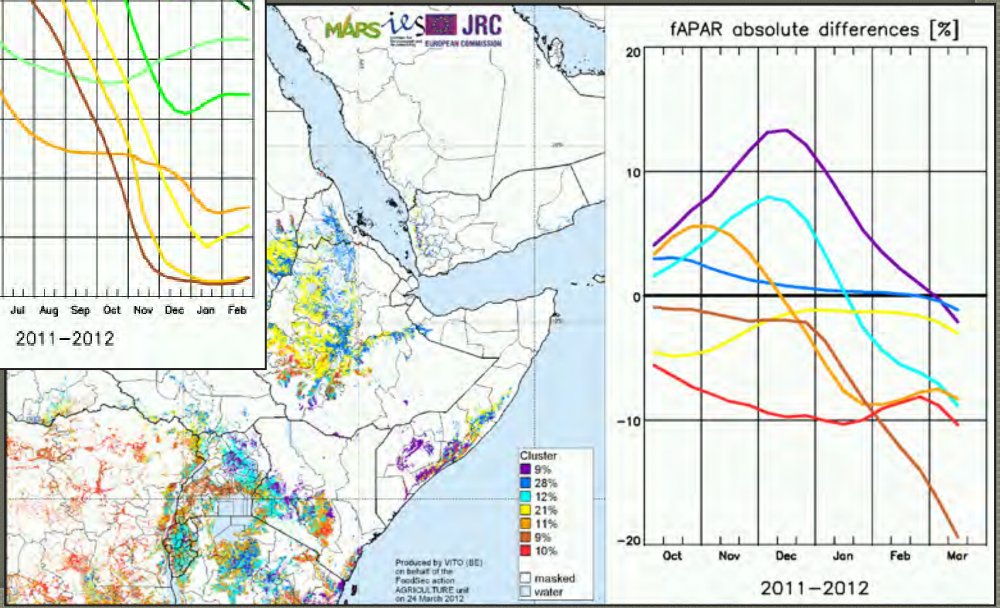
MARS: Cluster maps

Statistical, non-supervised clustering of the data in a Time Series

- Calibration (training): Enhanced ISOclus algorithm
- Application: Minimum distance classifier
- MARS: Every dekad repeated for several TS (sensors/ROIs/periods)

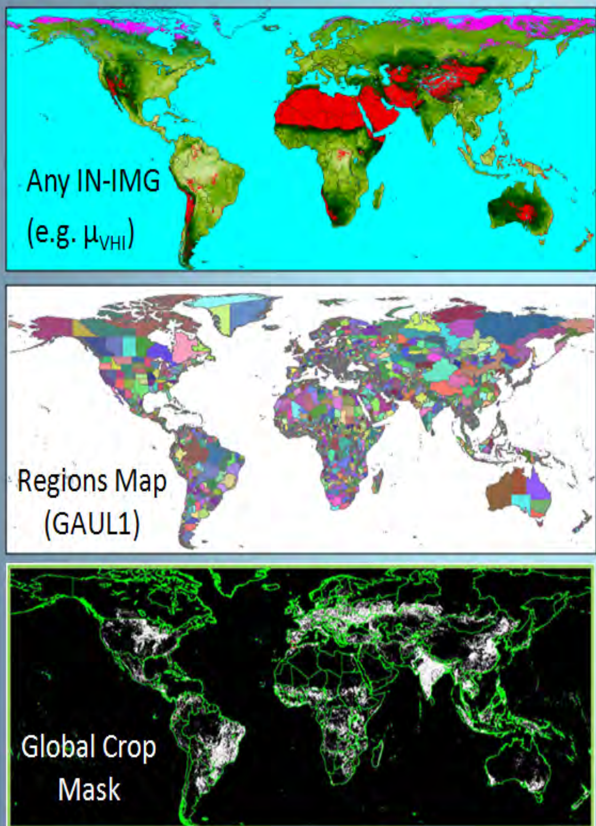
  ⇒ Map of homogeneous regions with similar behaviour





MARS: Regional Unmixed Means (RUM)

Principle



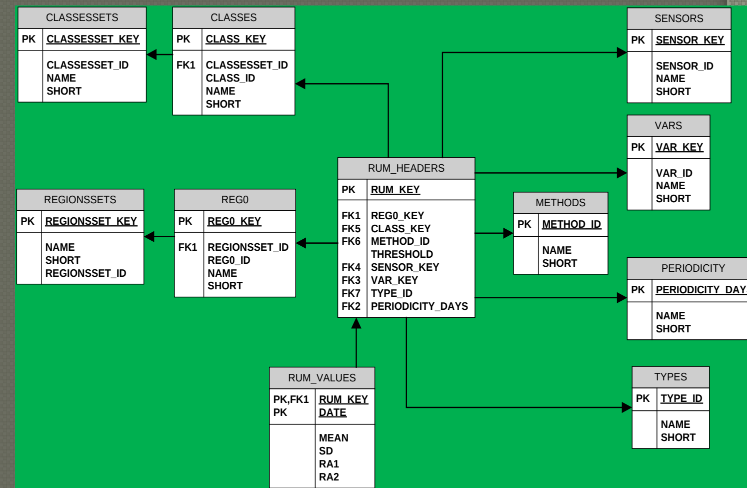
RUM-FILE:

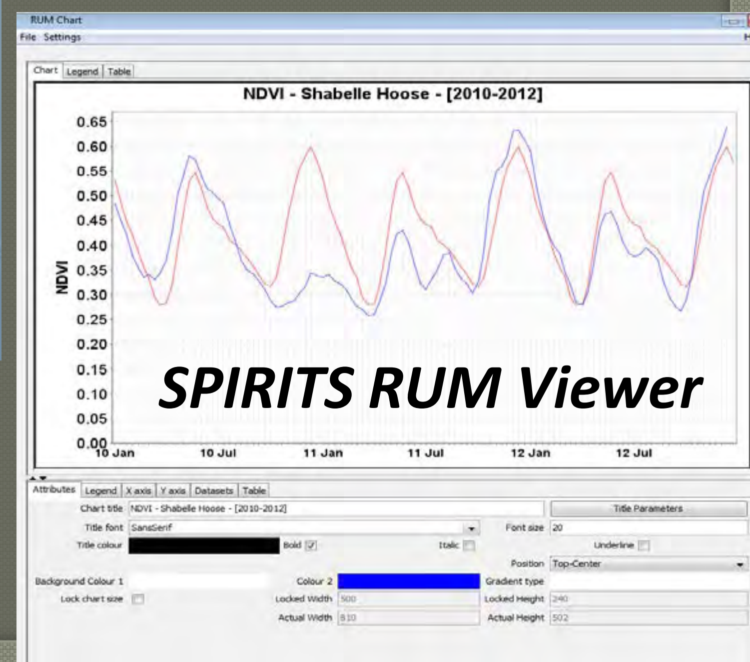
- *ASCII-TXT*
- *Comma-separated values*
- *Each line contains MEAN value of IN-IMG-values of crop pixels in a given GAUL1-region*
- *Additional items: date, sensor-ID, variable-ID,…*

Works for IN-IMGs with:

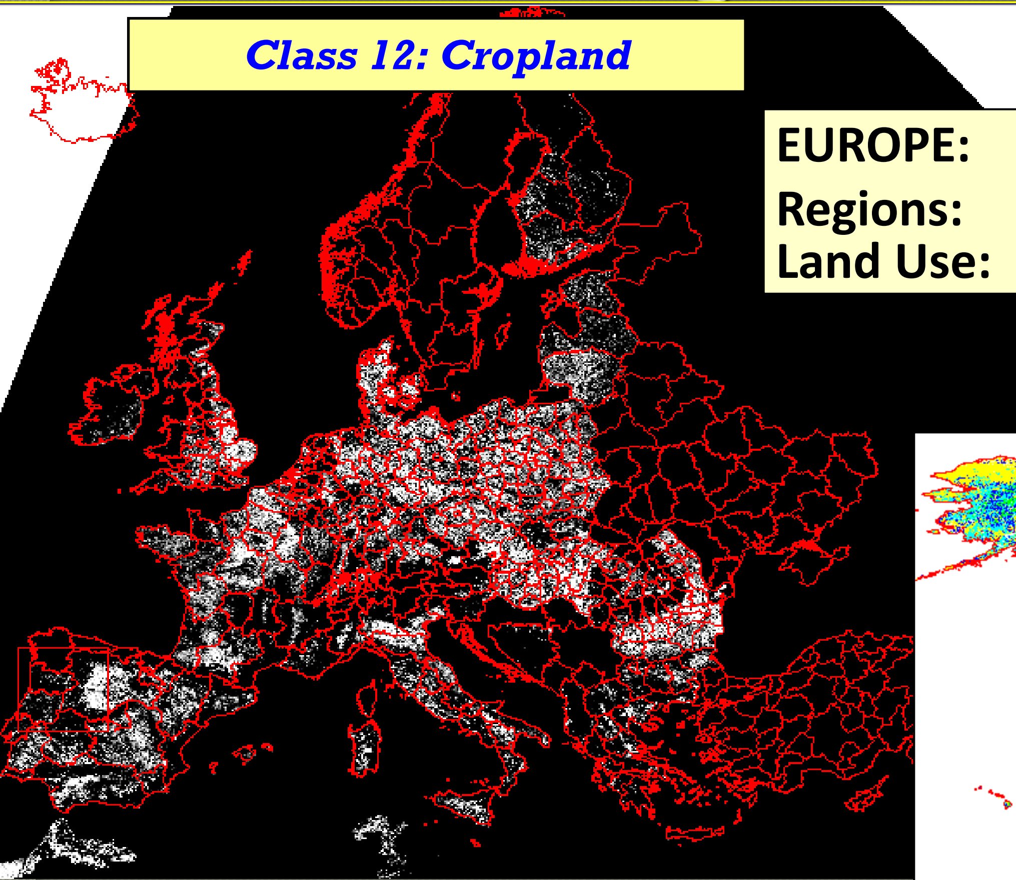
- *ordinal variables (NDVI,…)*
- *categorical variables ("events")*
  → Regional frequencies (ASI)

SPIRITS RUM-Database



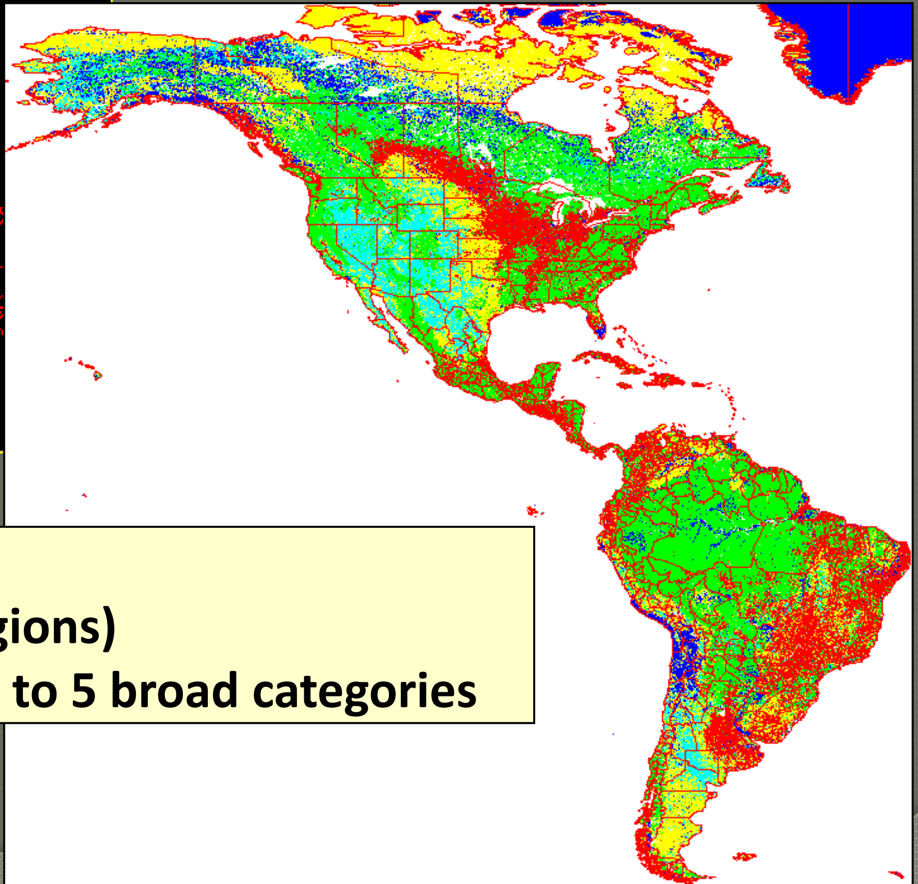


MARS: Regional Unmixed Means (RUM)



EUROPE:

Regions:	NUTS2 (600 regions)
Land Use:	AFI's from CLC2000 (2000)



GLOBAL:

Regions:	FAO-GAUL1 (2688 regions)
Land Use:	GLC2000, re-grouped to 5 broad categories

MARS: Regional Yield forecasting

Principle: $Y = f(X_1, X_2, X_3,\ldots)$

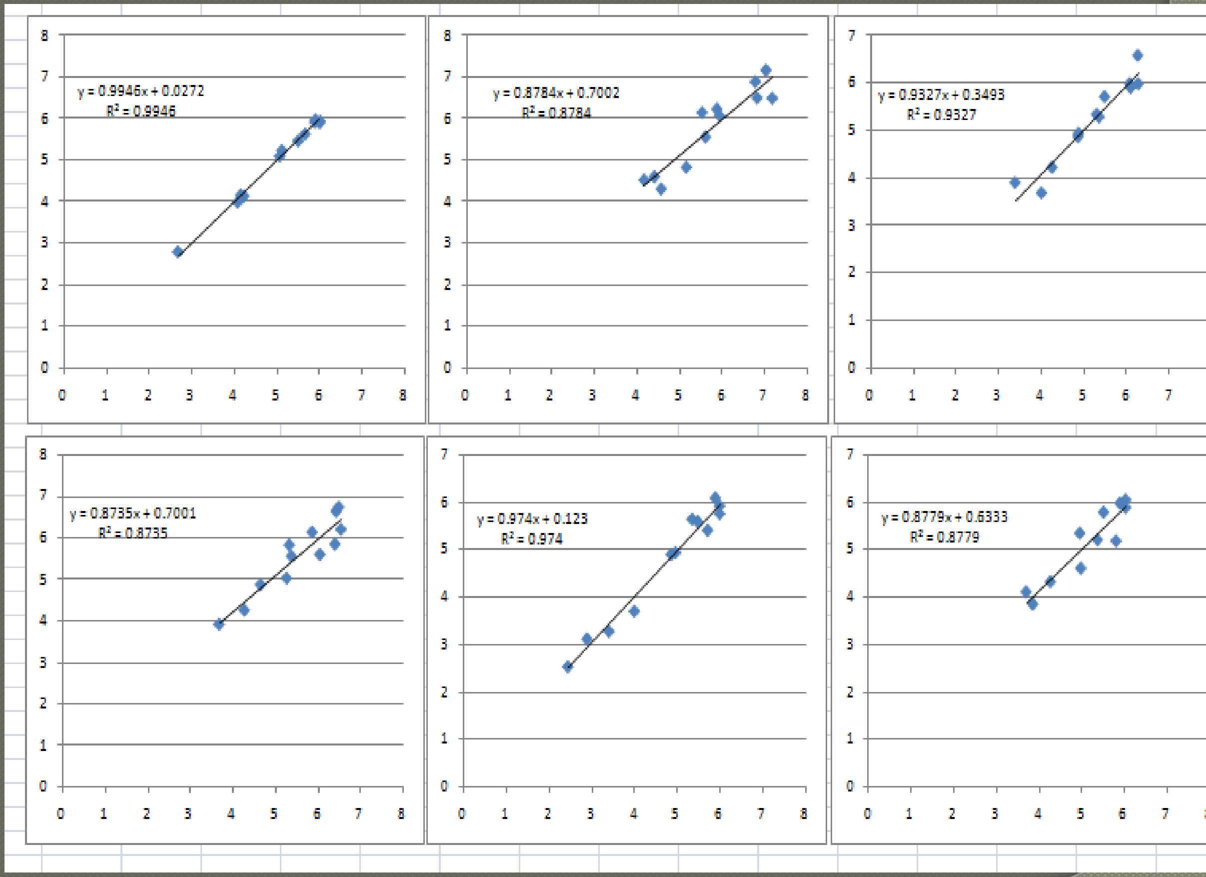
- Y = Official yield of given crop in given administrative region
- X_n= RUM-values of RS-indicators [+ covariables from meteo, model-simulations,…]
- f = Multiple regression model, Jack-knife calibrated, on data of previous years

Applied on X_n-data of current year $\Rightarrow$ Yield Forecasting

Example from DRAGON-project North China Plain:

Winter Wheat in 6 districts
X_1=DMP summed over season
X_2=Idem for Temp., Rain
X_3=Chemical fertilizer input

R^2: 85% $\rightarrow$ 99%
RMSE: 0.29 $\rightarrow$ 0.06 Ton/ha



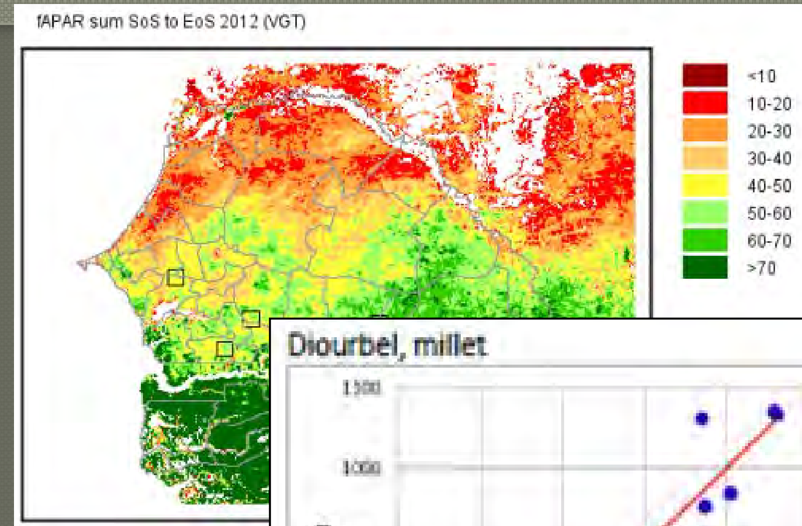
MARS: Agri-Insurances

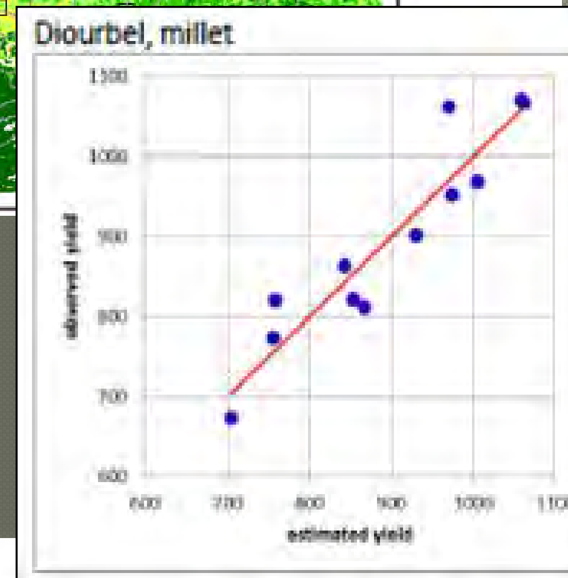
RS-based Index Insurance for IFAD-WFP in SENEGAL:

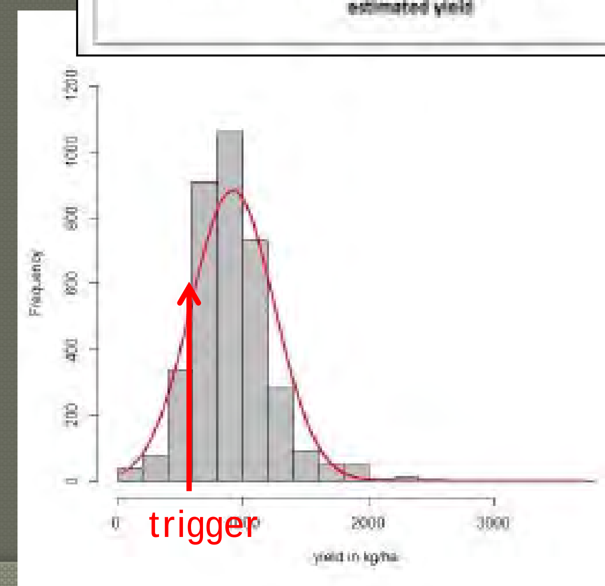
- Index: Mean fAPAR over season
- Good correlation with yield
- Use relation to define "Trigger":

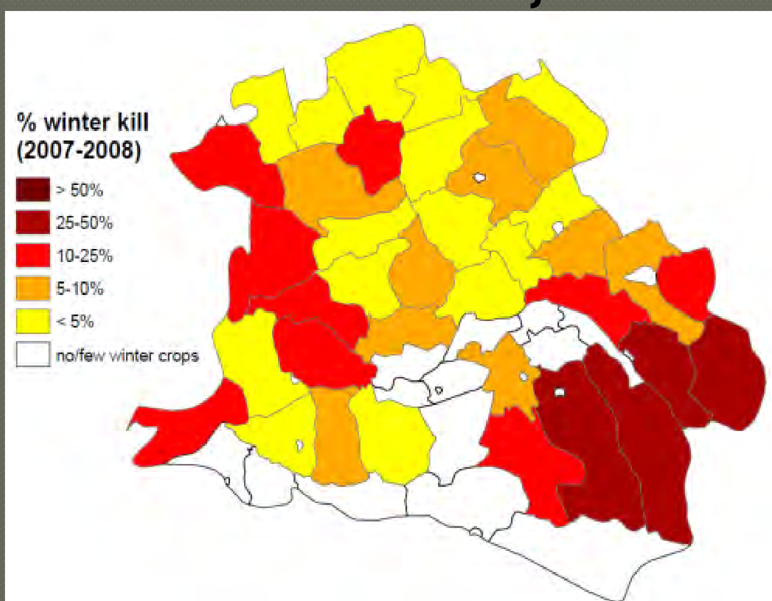
  If Index of current year < Trigger ⇒ Farmers paid

Also for Ukraine, Morocco,… (SwissRe)









Overview: Regional crop yield estimation

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2. Input data: S10-composites from RS and ancillary info
3. Basic improvements: Flagging, smoothing, …
4. Derived, final information:
5. Conclusions

MARS: Conclusions

Per Region/Crop/Year: P [Ton]=Area [ha] x Yield [Ton/ha]

MERITS:

- Drivers: – Static info: Crop areas, soil maps, …
  – Dynamic: RS-images, meteo-data, official yields
  – Science: Growth model, statistical calibration
- Satisfactory for EU-politics (import/export, human. Aid,…)
- Timely information: Much earlier than “official statistics”

DRAWBACKS:

- Areas assumed “fixed” over years.
- Dynamic mapping needed: – Crops vs. Non-Cropland
  – Better: specific per crop
- EO-systems needed with High Resolution & Frequency

  e.g. Proba-V at 100m, Sentinel2 at 10m

UNESCO-Brazil, Foz de Iguacu, 19 July 2016

Global Monitoring with LoRes EO-Imagery
Time Series Analysis with SPIRITS software

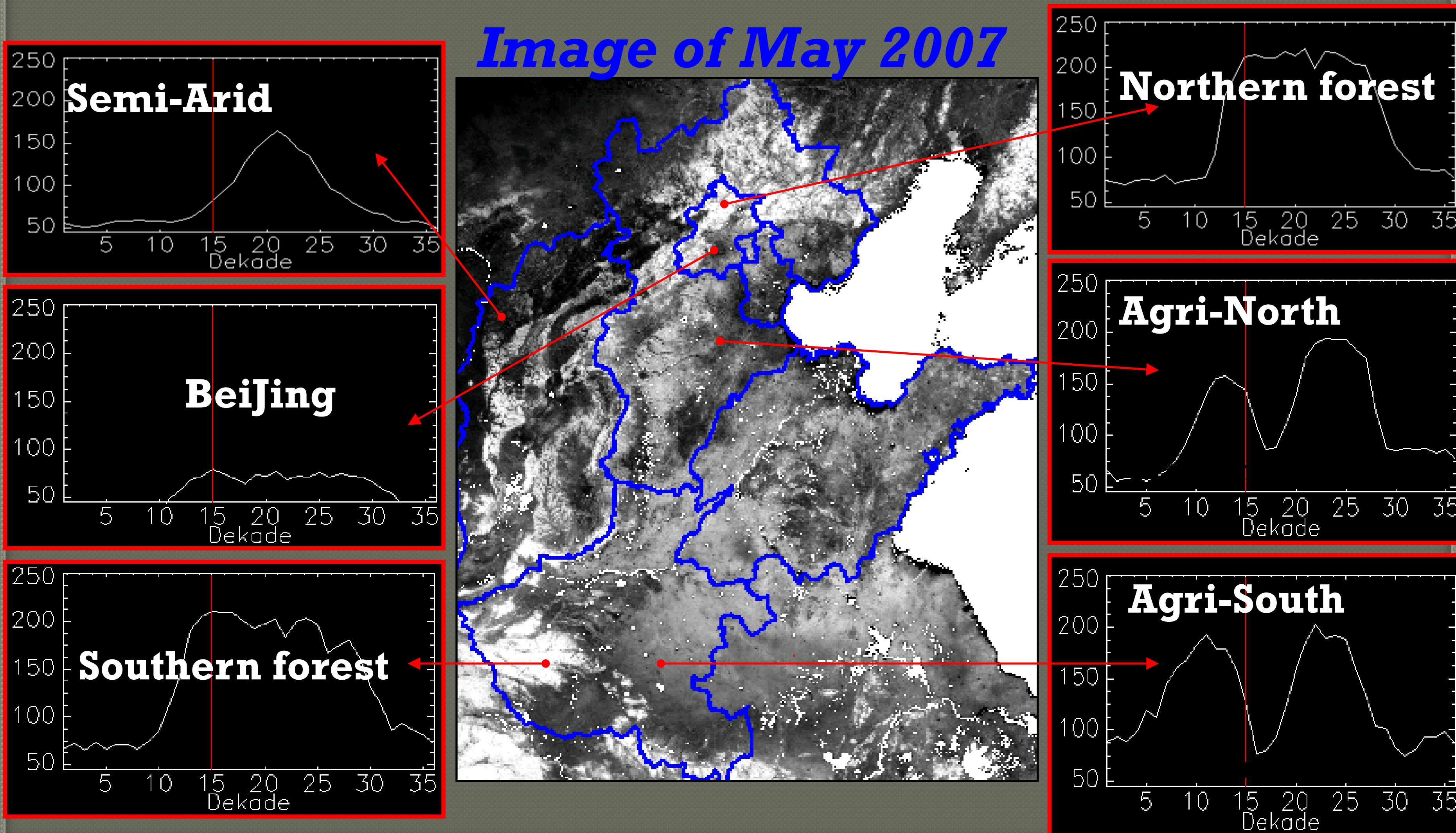
vito
vision on technology

Vlaamse Instelling voor Technologisch Onderzoek
Flemish Institute for Technological Research
Herman Eerens

1. VITO's Remote Sensing Centre (TAP)
2. EU-MARS: Global Agricultural Monitoring
3. **FAO-ASIS: Global Drought Monitoring**
4. SPIRITS: Introduction & Overview
5. SPIRITS: Some practical exercises

Basic Inputs: Time series of S10-composites

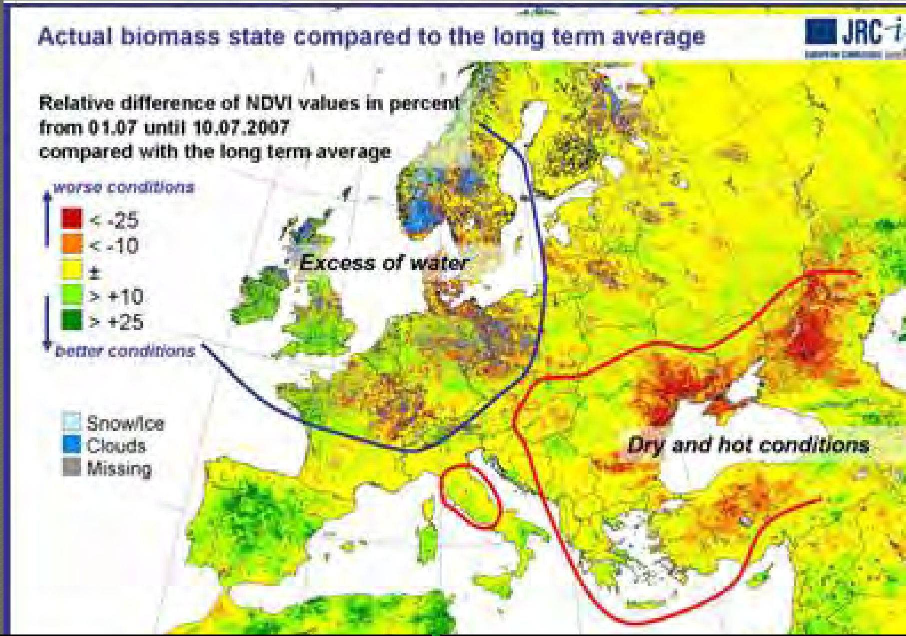
North China Plain, NDVI, year 2007

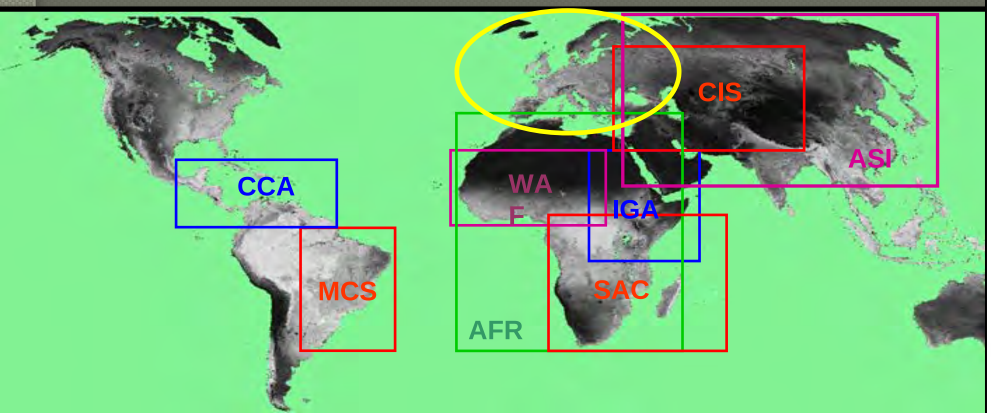


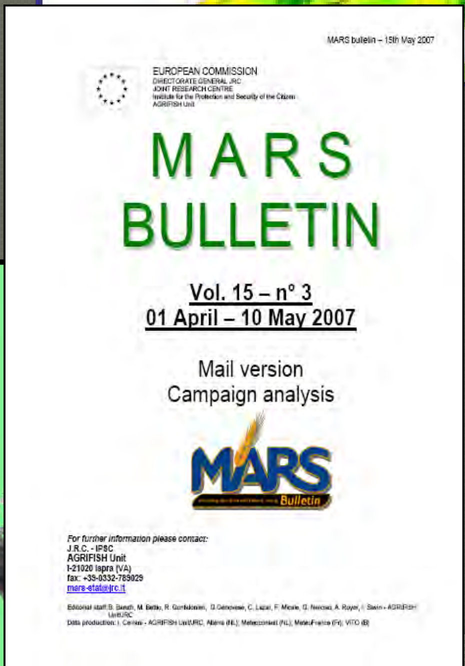
APPLICATIONS: Low Resolution

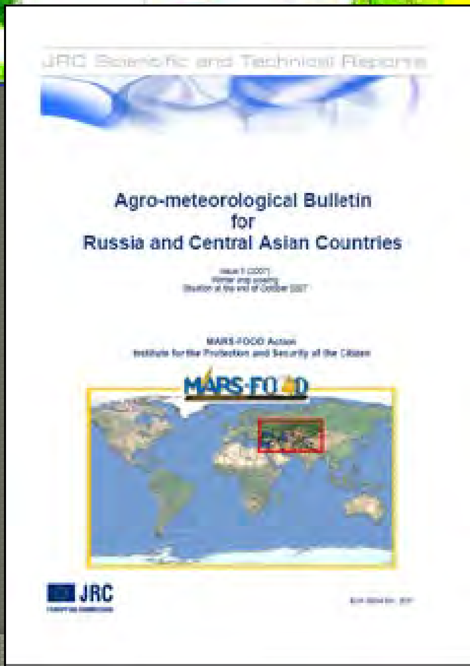
JRC-MARS (since 2000)

- NRT-delivery of RS-Information on crop state and yields
- Consortium:
  - Alterra (NL): Modelling
  - MeteoGroup (NL): Meteodata
  - VITO: RS-data
- JRC: Compilation & Bulletins for…
  - DG-AGRI: Import/export
  - DG-AIDCO: Food security

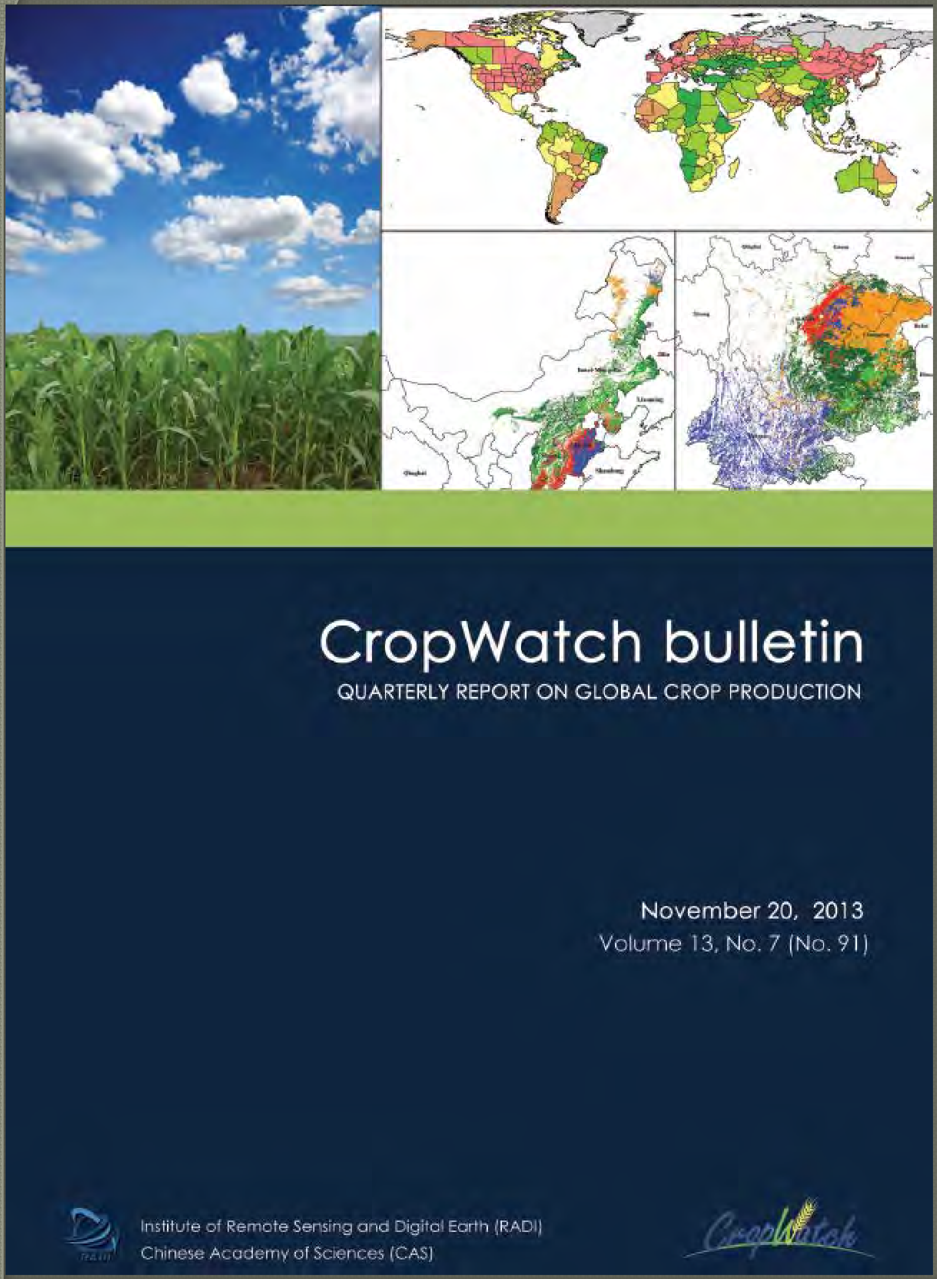








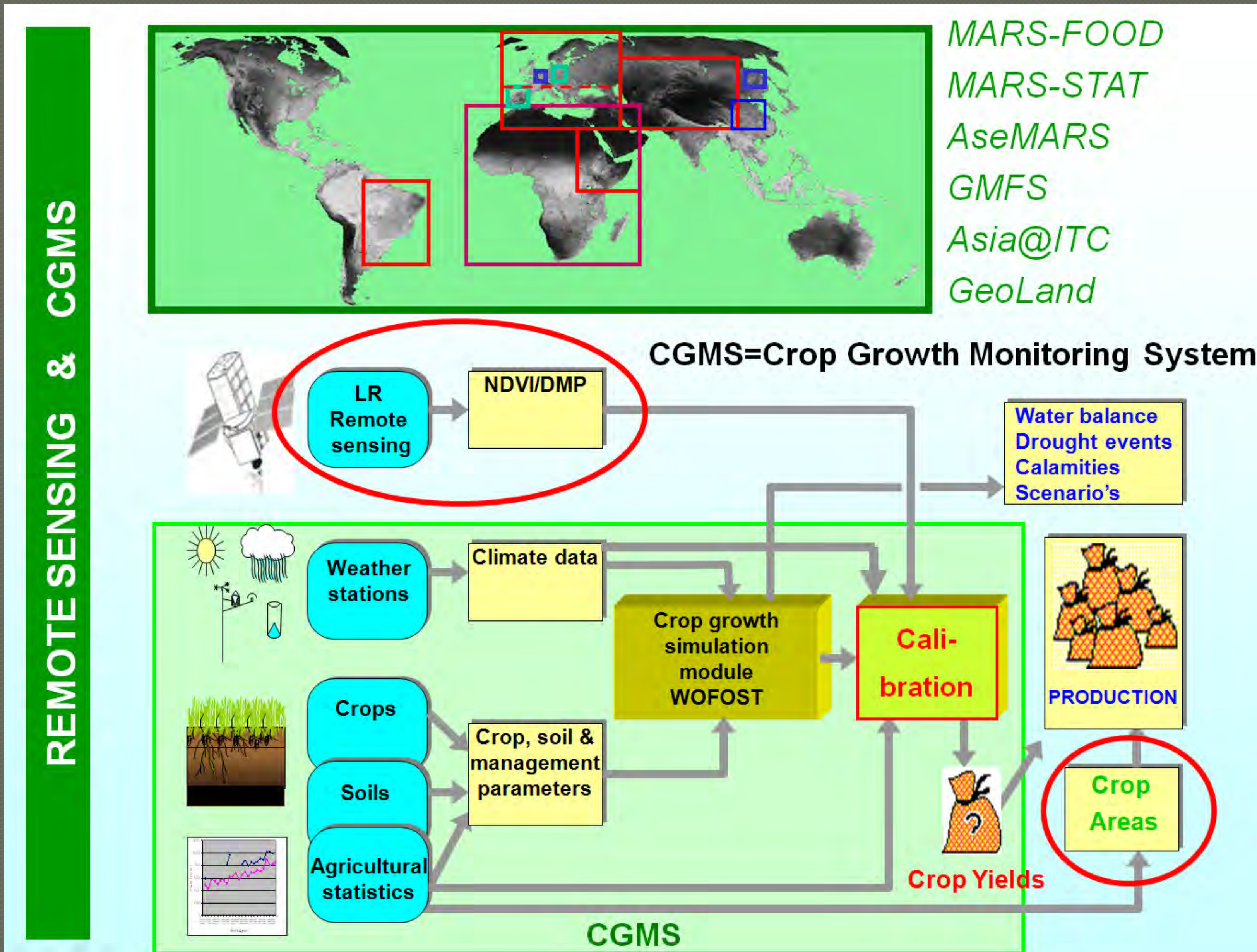
CROPWATCH: The Chinese approach



CropWatch Bulletins:

- Created and distributed by RADI
- Start year:
  - 1998 for China
  - 2013 for the Globe
- Similar to MARS but so far no:
  - crop growth simulations
  - statistical calibration against historical yields

MARS: General approach of EC-JRC



MARS: Addition of DMP

MONTEITH-Approach: $\text{DMP} = R \cdot 0.48 \cdot \text{fAPAR} \cdot \varepsilon\,(T_{min}/T_{max})$

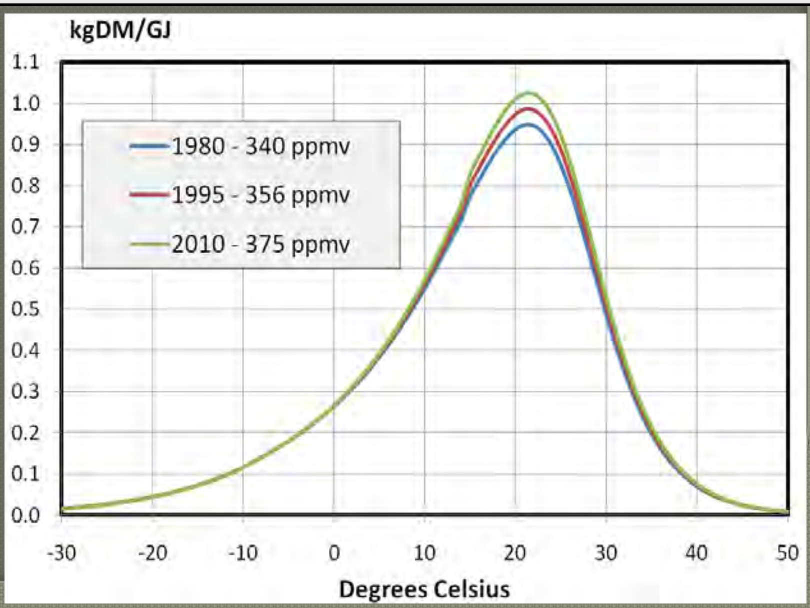
Symbol	Meaning	Units	Source
DMP	Dry Matter Productivity	kgDM/ha/day	
R	Incoming solar radiation (0.2–3.0µm)	J/ha/day	Meteo
0.48	Fraction of PAR (0.4–0.7µm) in R	–	
fAPAR	PAR–fraction absorbed by Vegetation	–	Remote Sensing
T_{min}/T_{max}	Daily min/max temperature	°C	Meteo
ε	Efficiency ≈ Autotrophic respiration: – conversion of absorbed PAR–Energy to carbohydrates – maintenance respiration	kgDM/J	

$\text{DMP} = \text{DMP}_{max} \cdot \text{fAPAR}$

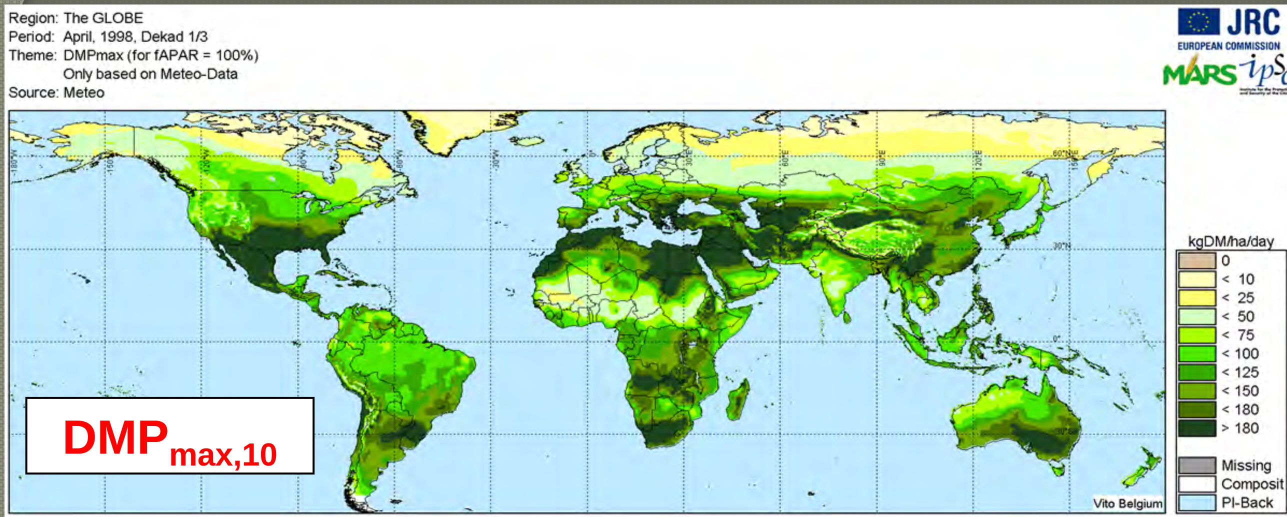
$\text{DMP}_{max} = R \cdot 0.48 \cdot \varepsilon$

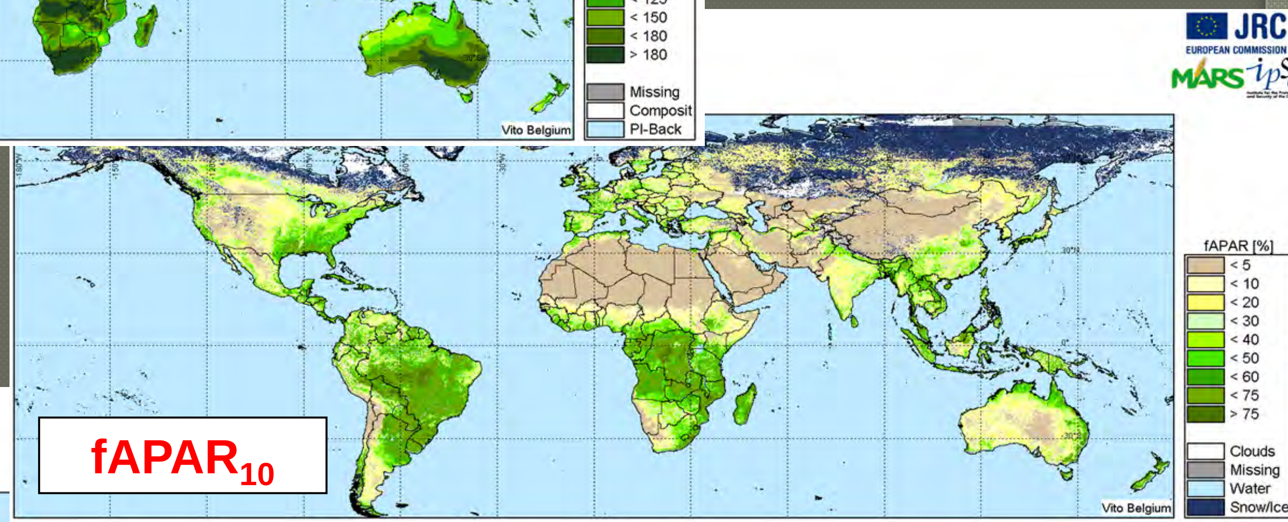
- based on meteodata
- for fAPAR=0

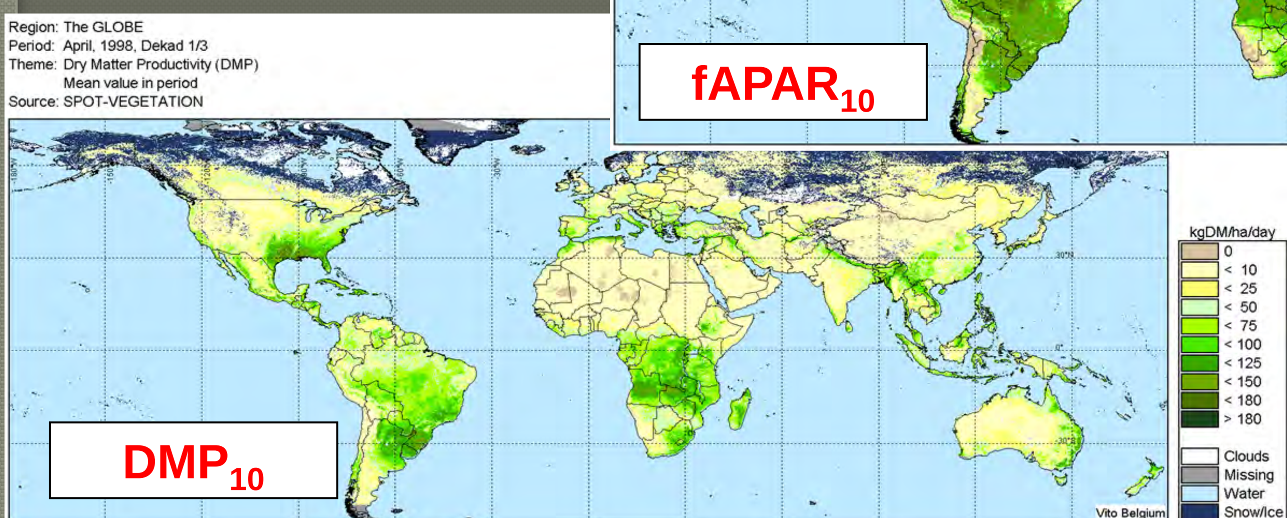
Dependency of DMP_{max} on Temperature and CO2



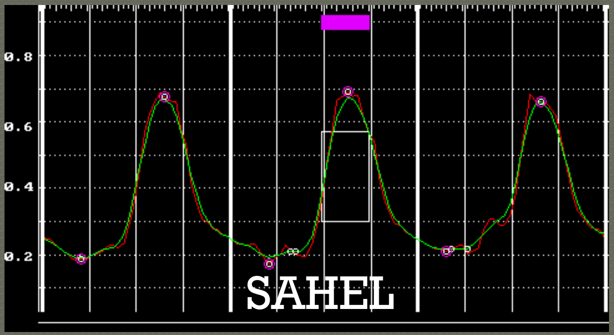
MARS: Addition of DMP

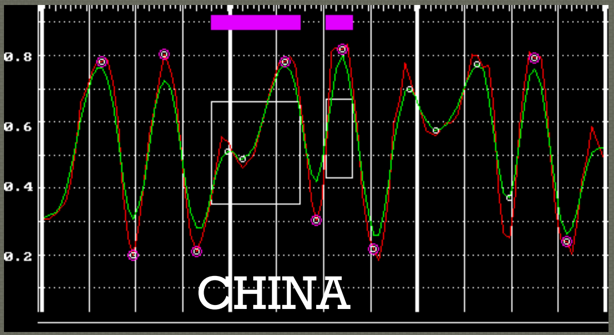






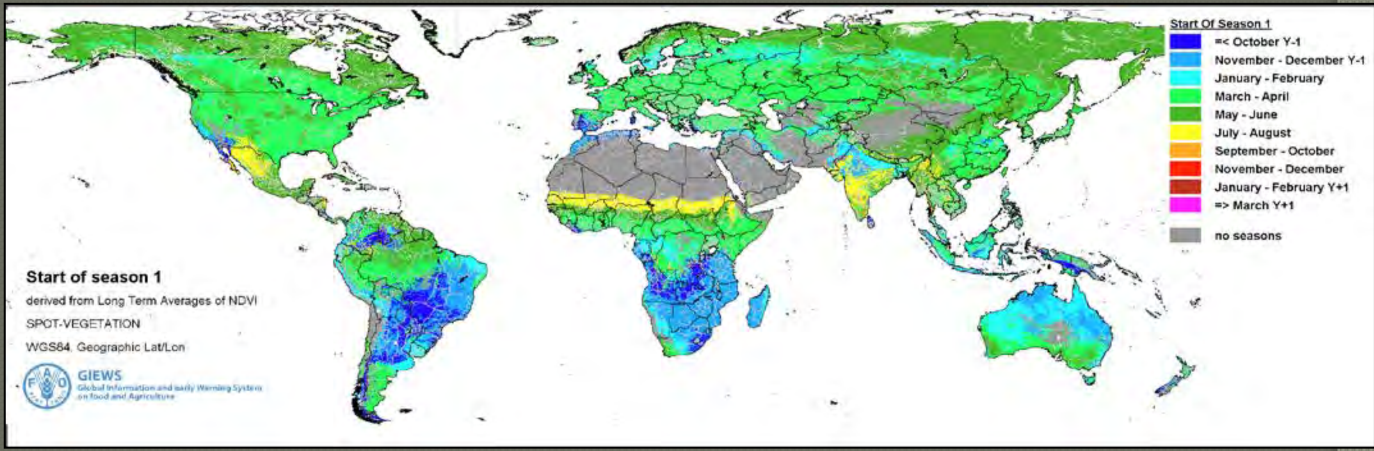
MARS: Phenological stages (SOS/EOS)

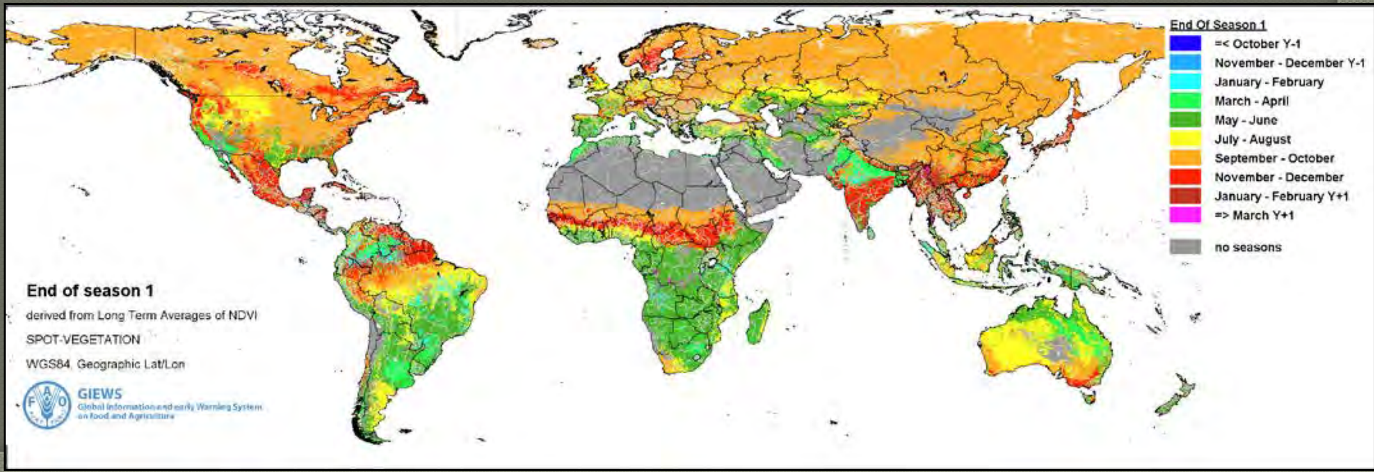




Inspect multi-annual VI-profiles per pixel

IMGs with Dates of Start and End of 1 or 2 Seasons in Central Year





Example for NDVI-LTA of SPOT-VGT