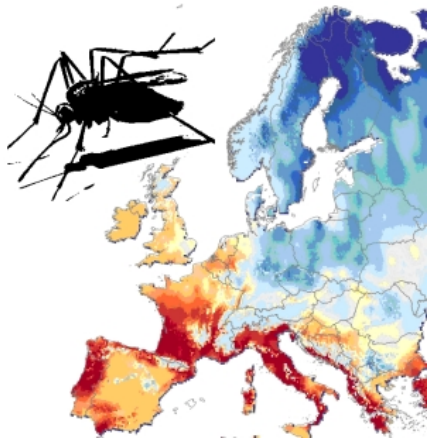
Space & Epidemiology
The VECMAP project



Integrated Applications Promotion

European Space Agency

M. Kruijff

Integrated Applications Promotion

Integrated Application Promotion (IAP) aims to:

- Incubate sustainable services that benefit society
  - addressing global / novel challenges
  - listening to needs of users
  - partnering with stakeholders
- Increase societal demand for satellite services
  - integration of multiple space assets yields new opportunities
  - assessment of added value

Some IAP Themes

- Agriculture
- Development
- Energy
- Fisheries
- Health
- Transport
- Safety

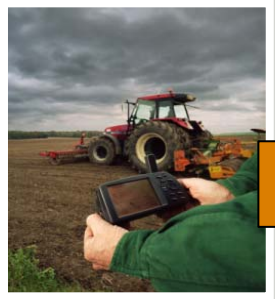
IAP Program Structure

User

Service

IAP Program Structure

- **Awareness Activities**
  - **Understand, foster and organize user demand for service solutions**



User

Awareness

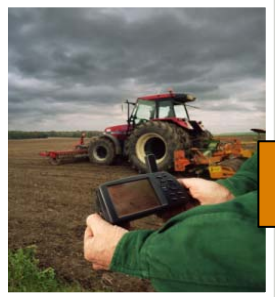
3 months

Service

Integrated Applications Promotion

IAP Program Structure

- **Awareness Activities**
  - Understand, foster and organize user demand for service solutions
- **Feasibility Studies**
  - Assess technical and economical viability of these services



User

Awareness

3 months

Feasibility

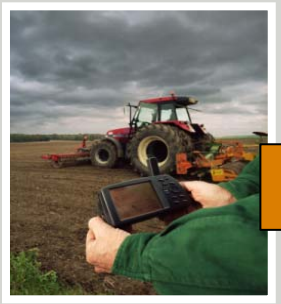
12 months

Service

Integrated Applications Promotion

IAP Program Structure

- **Awareness Activities**
  - Understand, foster and organize user demand for service solutions
- **Feasibility Studies**
  - Assess technical and economical viability of these services
- **Demonstration Projects**
  - Implement pre-operational services
  - 50% co-funding by stakeholders



User

Awareness

3 months

Feasibility

12 months

Demonstration

2-3 years

Service

Typical IAP activities in Health / Epidemiology

- Field data collection
- Vector and disease risk mapping
- Early warning & emergency response
- Telemedicine
- Integration / centralized data & analysis

Space for Health

IAP Projects	Earth Observation	Navigation	SatCom	Human Space Flight techn.
HEWS (pre-IAP)			■	
SAFE (pre-IAP)		■	■	
Water quality monitoring in Egypt	■		■	
AMAZON		■	■	
PREDICT – Senegal	■	■	■	
Portable Telemedicine Workstation		■	■	
eHealth in Subsaharan Africa			■	■
VECMAP	■	■		

The VECMAP project

Disease vector mapping

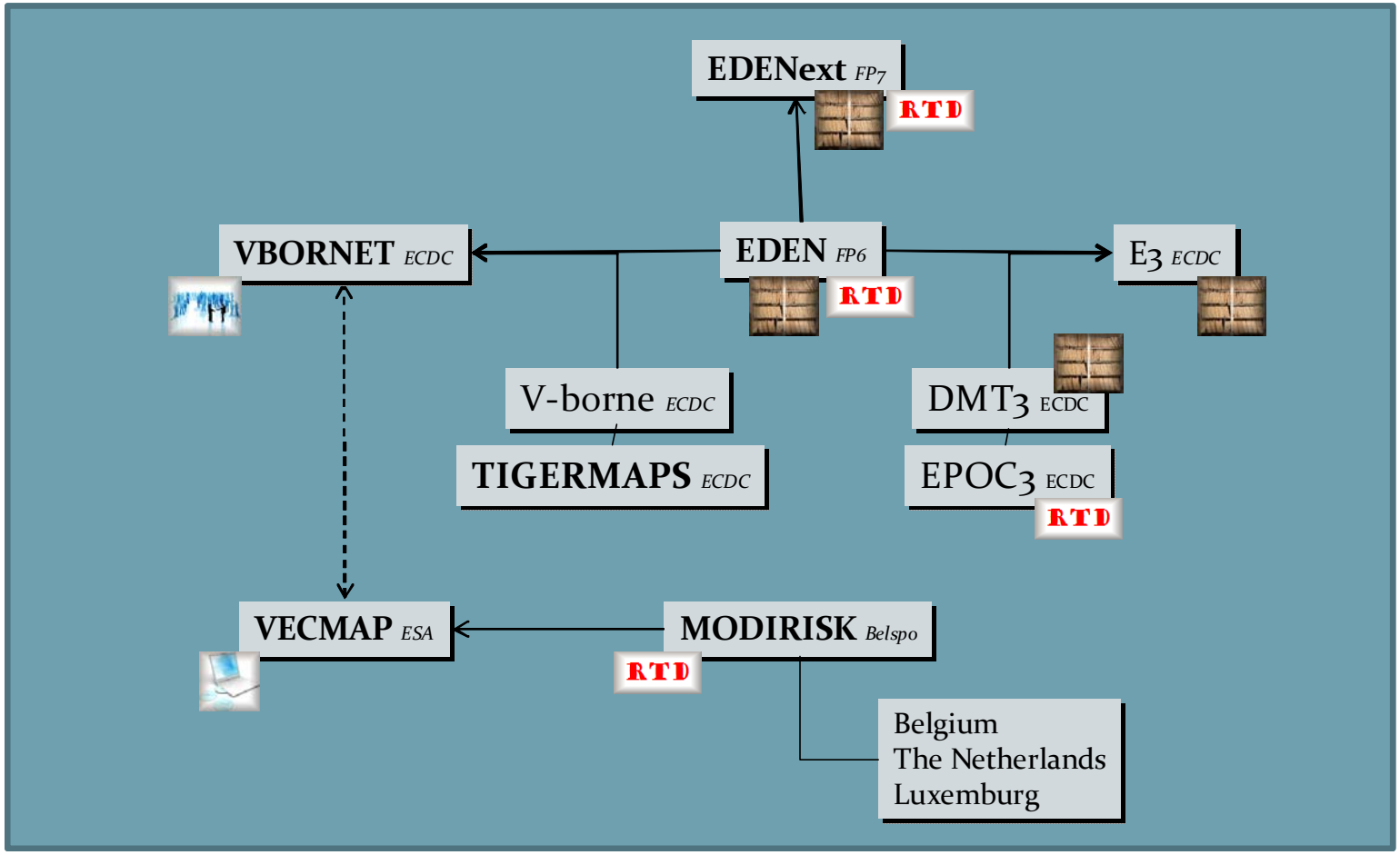
- Outbreaks of Chikungunya
  - Reunion 2005-2006
  - Ravenna (Italy) 2007
- Global introductions of disease vectors
  - International trade (e.g. eggs in tyres)
  - Tourism
  - Global warming
- Need for surveillance, early warning systems & control
  - Vectors survive only in particular ecosystems
  - Need for spatial prediction maps

Asian Tiger Mosquito

***A. Albopictus*, vector for:**

- West-Nile
- Dengue
- Chikungunya
- Yellow fever
- St. Louis Encephalitis

Project origin and context

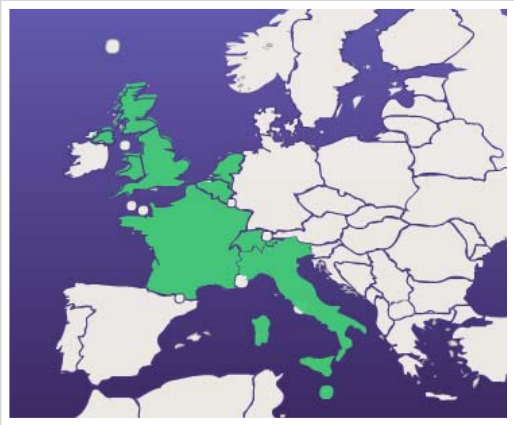


Users & their needs

1. **Academic users**
   - Reduce field work, more focus on analysis of data
   - More standardized results

Academic Users

- PhD students
- ITM (B)
- UZH (CH)
- CEH (UK)

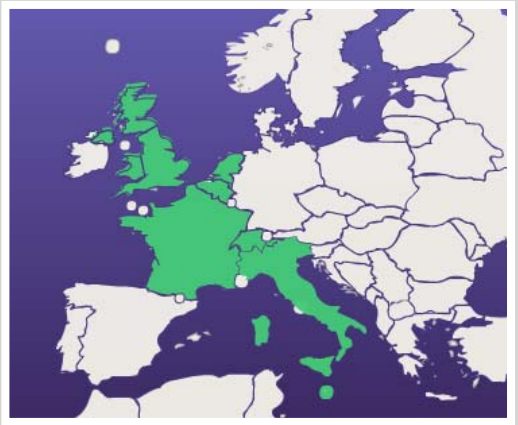


Users & their needs

1. **Academic users**
2. **Public Health (decision makers)**
   - Early warning vector presence
   - Critical species
   - Where are they now
   - Where will they be in future
   - National coverage

Public Health

- RIVM (NL)
- IPH (B)
- PH Malta
- PH French Polynesia



Users & their needs

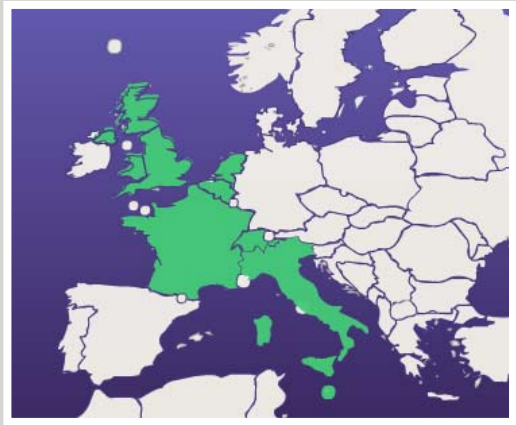
1. Academic users
2. Public Health (decision makers)
3. Control agencies
   - Critical & nuisant species
   - Where are they (mosquitoes, larvae, eggs), high resolution
   - When will eggs hatch & population peak
   - Cover a greater area with the same budget
   - Use less pesticides

Control agencies

-EID Mediterranee (F)

-CAA (I)

-CMV (NL)



The use case

- **Cross-sectional baseline study**

Cross-sectional baseline study

–Extensive in-situ sampling (CO_2 traps)

–Randomly selected locations

–Taking into account land use distribution & seasonal effects

–Register location & conditions

–Collect field reports

The use case

- **Cross-sectional baseline study**
- **Laboratory analysis**

Laboratory analysis

- Species count
- Male / female
- LIMS reports

The use case

- Cross-sectional baseline study
- Laboratory analysis
- Spatial modeling

Spatial modeling

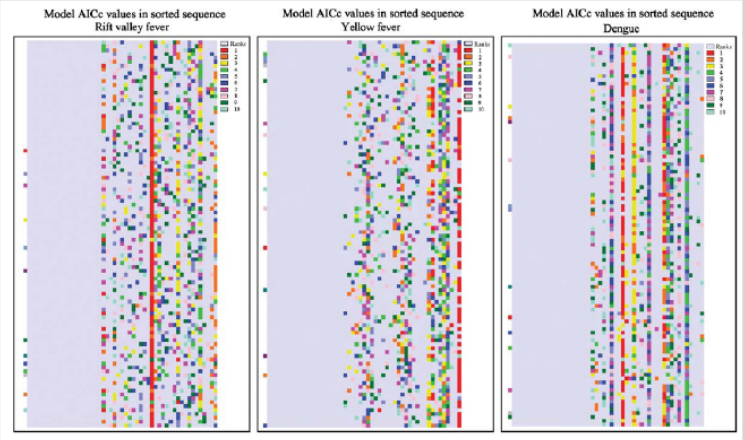
–Collect & resample spatial data (elevation, vegetation, temperature, demographics etc.)

–Fourier analysis (seasonal effects)

–Bootstrap in-situ datasets

–E.g. non-linear discriminant analysis

–Identify correlations with physical parameters



The use case

- Cross-sectional baseline study
- Laboratory analysis
- Spatial modeling
- Risk maps

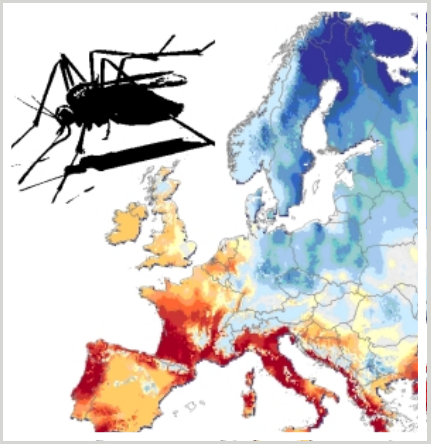
Risk maps

–Suitability of environment

–For each stage of vector life cycle

–Available at 1 km and 30 m resolution

–Raster functions for trend and impact analysis



The use case

- Cross-sectional baseline study
- Laboratory analysis
- Spatial modeling
- Risk maps
- Longitudinal study

Longitudinal study

–Continued sampling in high-probability locations

–Register local conditions

–Collect field reports

Data of Interest for Vector Mapping

Data of Interest for Vector Mapping

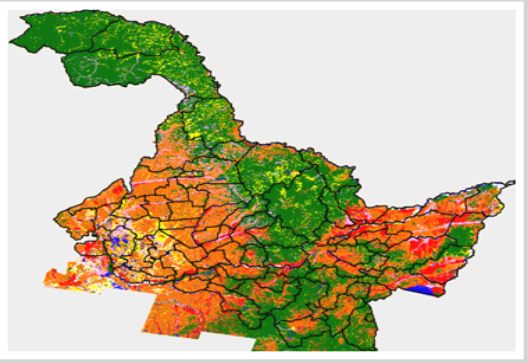
- **Static data**

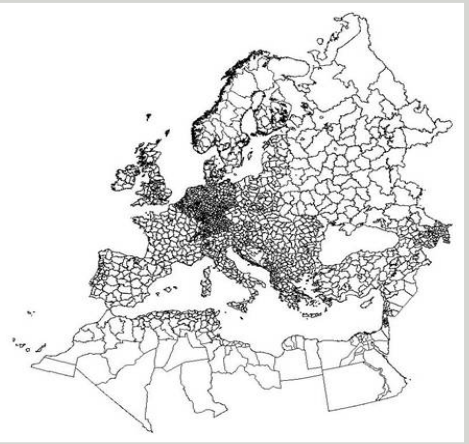
Static data

–Digital Terrain Maps (GTOPO30)

–Land use maps (GLC2000, Corine)

–Administrative regions (NUTS 1,2,3)



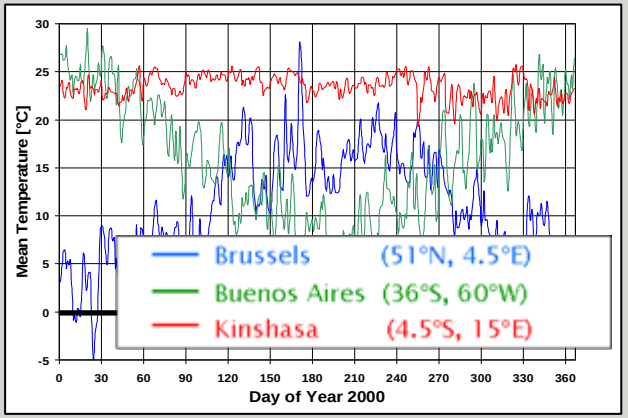


Data of Interest for Vector Mapping

- **Static data**
- **Meteo data from ground stations**

Meteo data from ground stations

- Daily AGROMET-data (Tmin, Tmax, Rad, Pluvio)
- Atmospheric data, water vapour etc.



Data of Interest for Vector Mapping

- Static data
- Meteo data from ground stations
- Satellite band combi's

Satellite band combi's

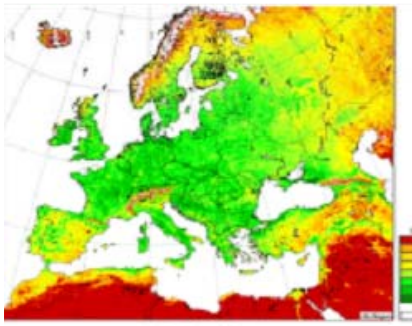
–Proxy's from spectral band ratio's

–Normalised Difference Vegetation Index

–SAVI, NDWI

–Visual and Infrared

–Envisat, Terra/Aqua, Spot



NDVI

Data of Interest for Vector Mapping

- Static data
- Meteo data from ground stations
- Satellite band combi's
- Satellite model-based data

Satellite model-based data

–fAPAR Fraction of Absorbed Photosynthetically Active Radiation

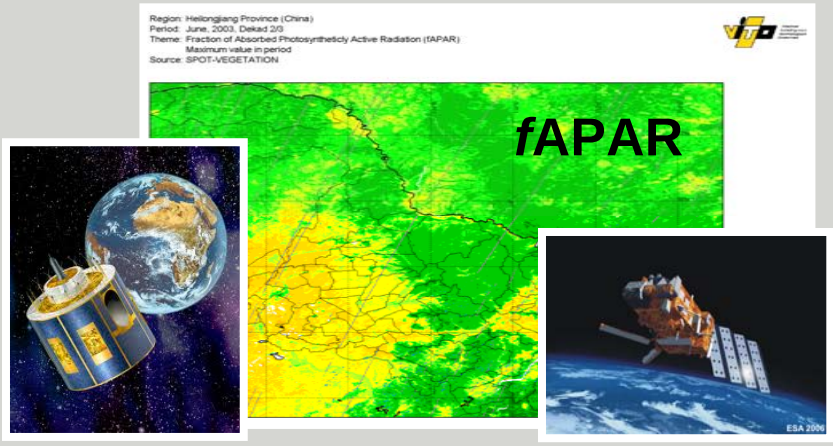
–Dry Matter Productivity (DMP)

–Leaf Area Index (LAI)

–Evapotranspiration, Precipitation: VIR/TIR, MSG

–Land Surface Temperature (LST): TIR

Terra/Aqua, NOAA/METOP



Data of Interest for Vector Mapping

- Static data
- Meteo data from ground stations
- Satellite band combi's
- Satellite model-based data
- Satellite navigation data

Satellite navigation data

–Currently: GPS, 15 m

–Since 2008, EGNOS Augmentation: 5 m + integrity

–From 2013: Galileo: integrity + guarantee

–Galileo + GPS: increased availability (urban)

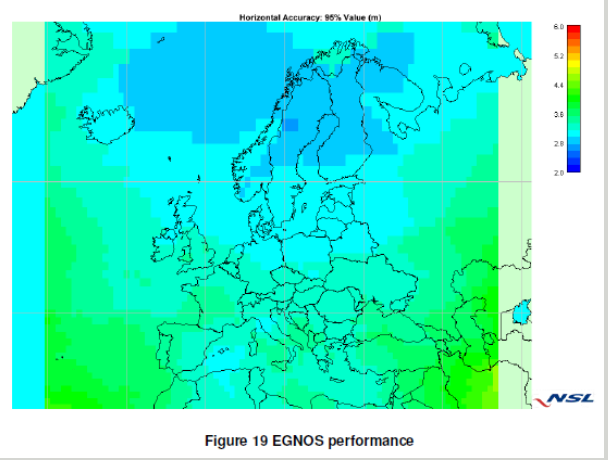


Figure 19 EGNOS performance

The VECMAP project

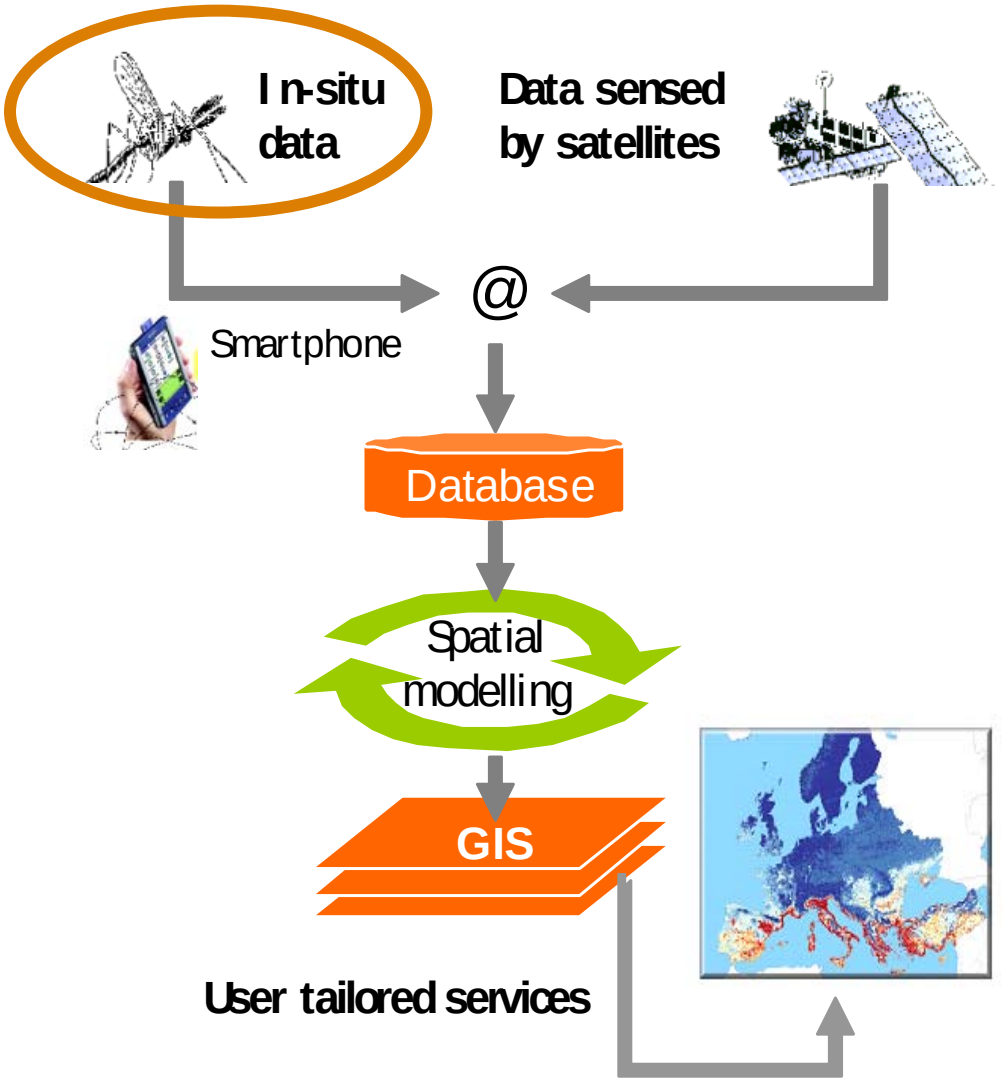
Consortium

- Avia-GIS (B)
  - Team leader & service provider
- ERGO (UK)
  - Geospatial modelling based on in-situ and Earth Observation data
- MEDES (F)
  - In-situ measurements and field reporting
- EARS (NL) and VITO (B)
  - Analysis of Earth Observation data
- RIVM (NL)
  - Key public health user

VECMAP team at EID user in Montpellier

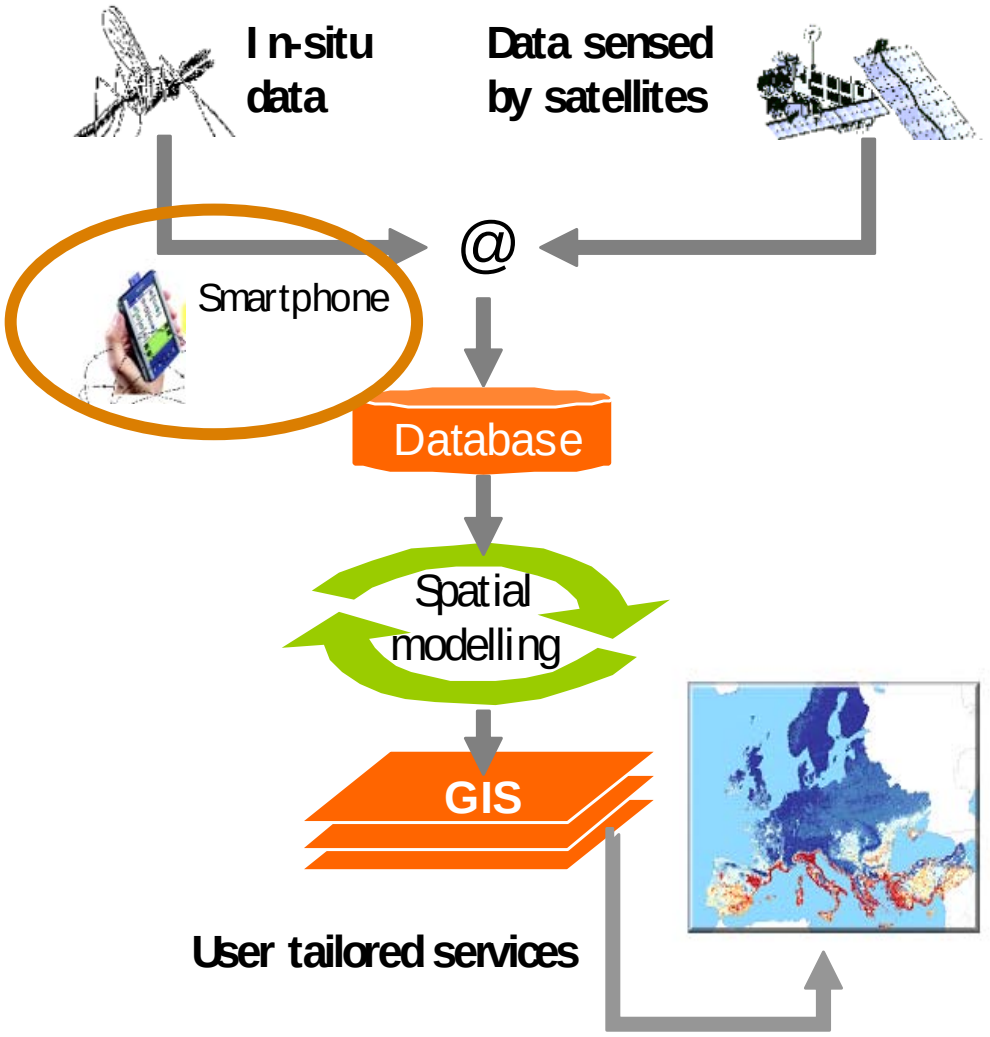
VECMAP Services

- **Sampling strategy & routing service**



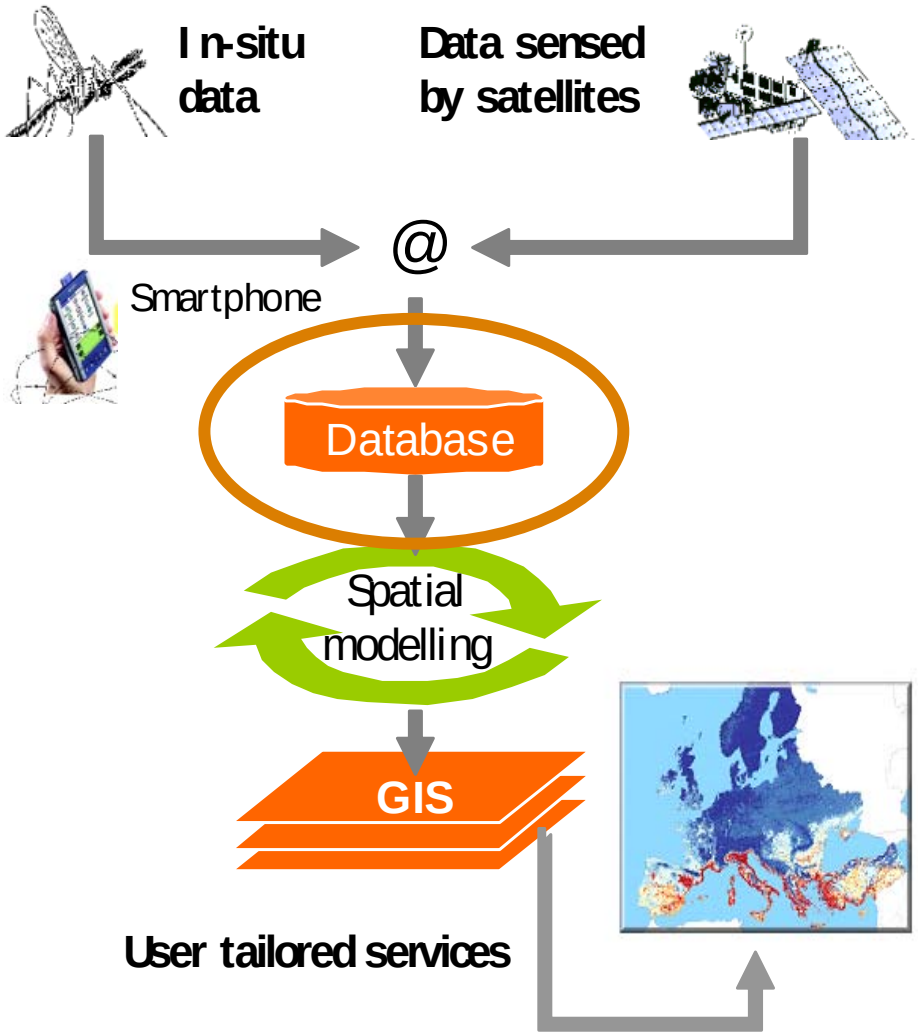
VECMAP Services

- Sampling strategy & routing service
- Field-data synchronization with dBase incl. GNSS position



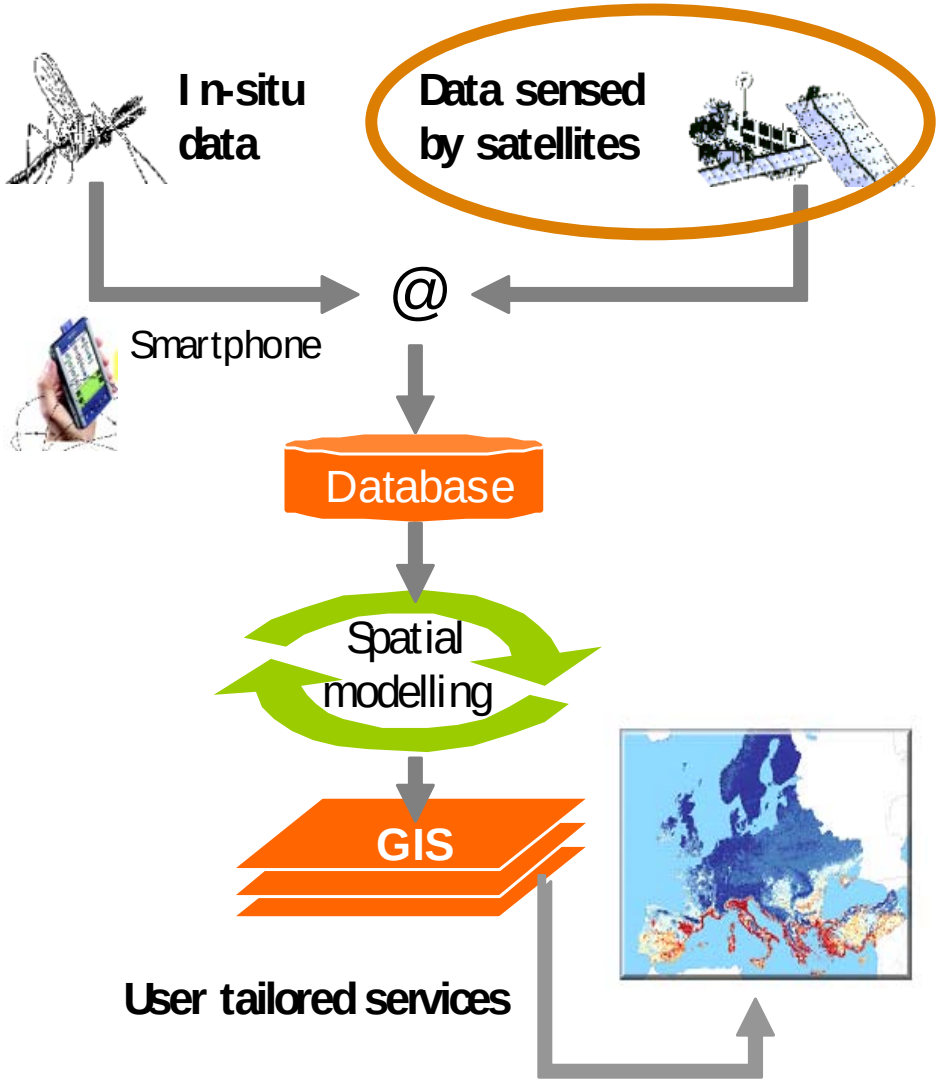
VECMAP Services

- Sampling strategy & routing service
- Field-data synchronization with dBase incl. GNSS position
- Synchronization of laboratory data



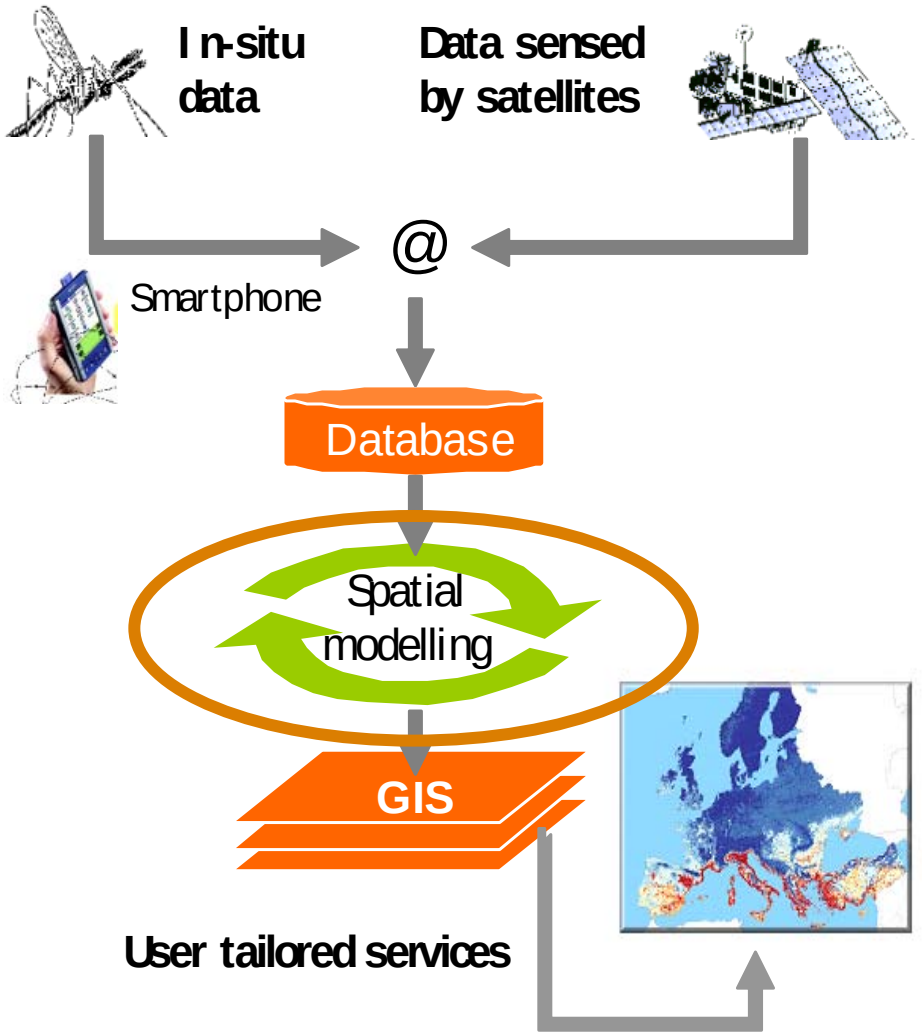
VECMAP Services

- Sampling strategy & routing service
- Field-data synchronization with dBase incl. GNSS position
- Synchronization of laboratory data
- Continuous set of processed EO data



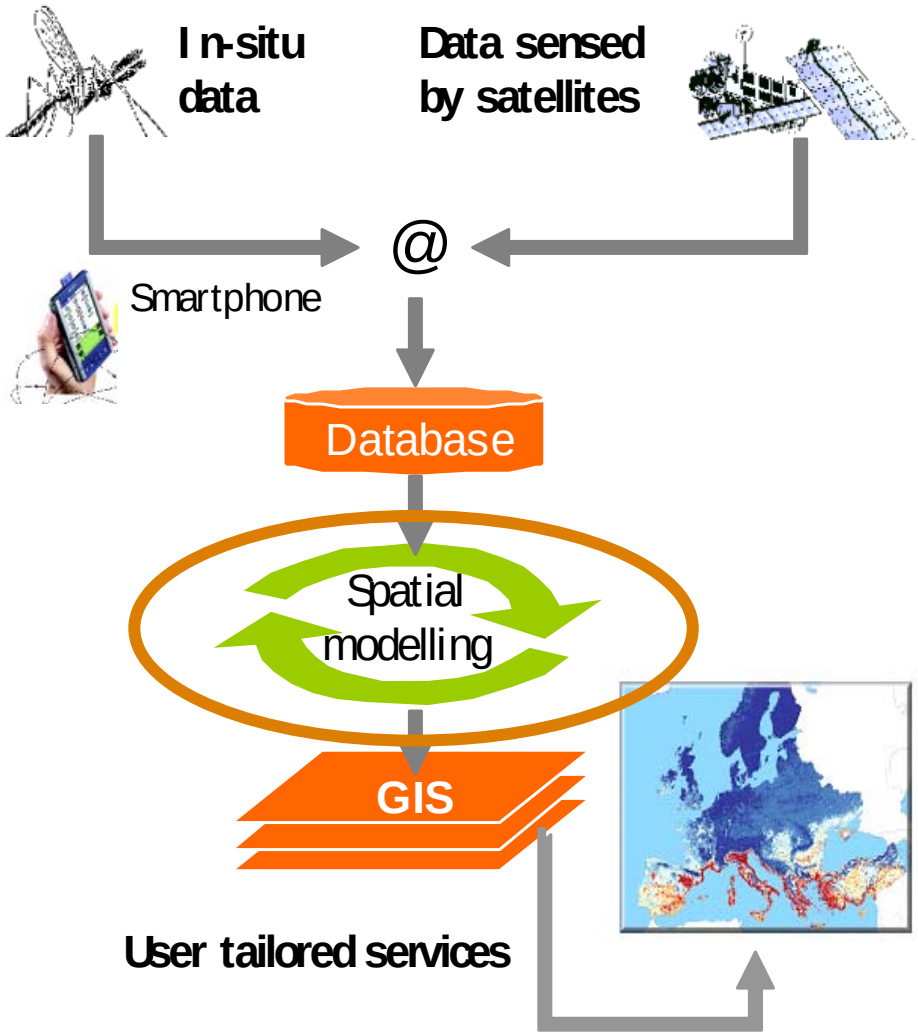
VECMAP Services

- Sampling strategy & routing service
- Field-data synchronization with dBase incl. GNSS position
- Synchronization of laboratory data
- Continuous set of processed EO data
- Habitat suitability mapping service



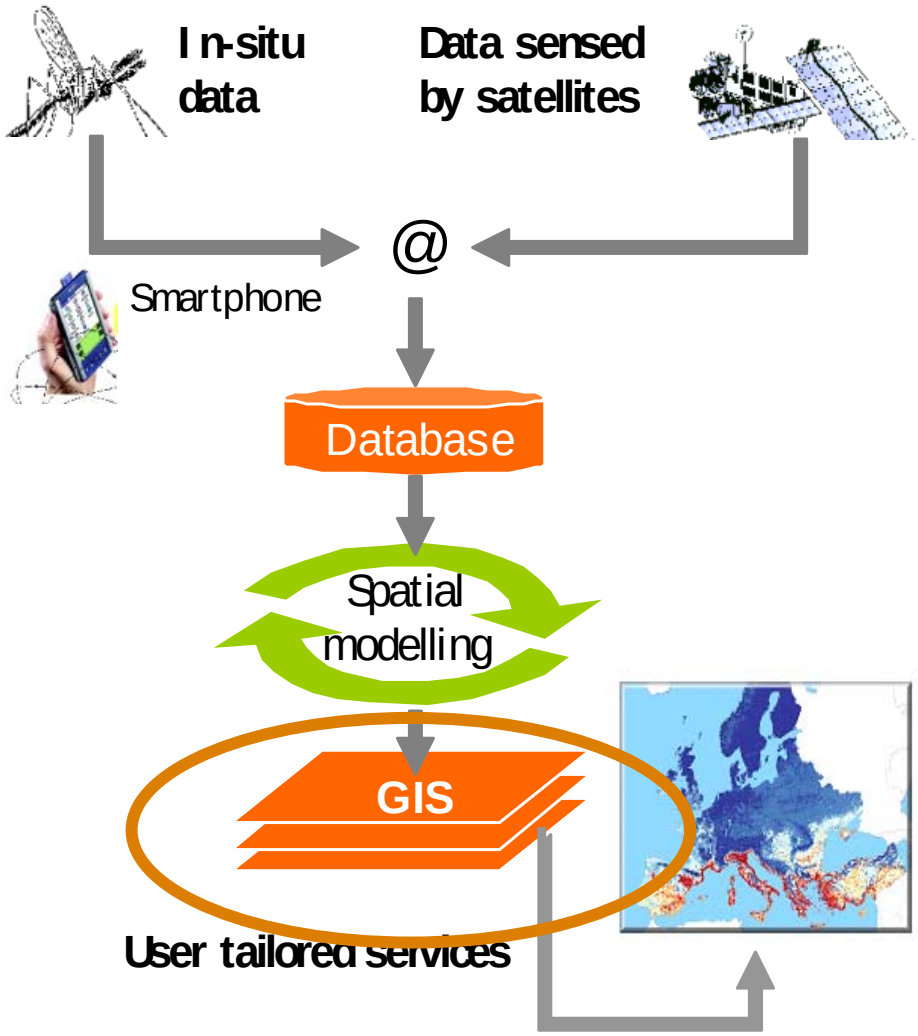
VECMAP Services

- Sampling strategy & routing service
- Field-data synchronization with dBase incl. GNSS position
- Synchronization of laboratory data
- Continuous set of processed EO data
- Habitat suitability mapping service
- Landscape suitability mapping service



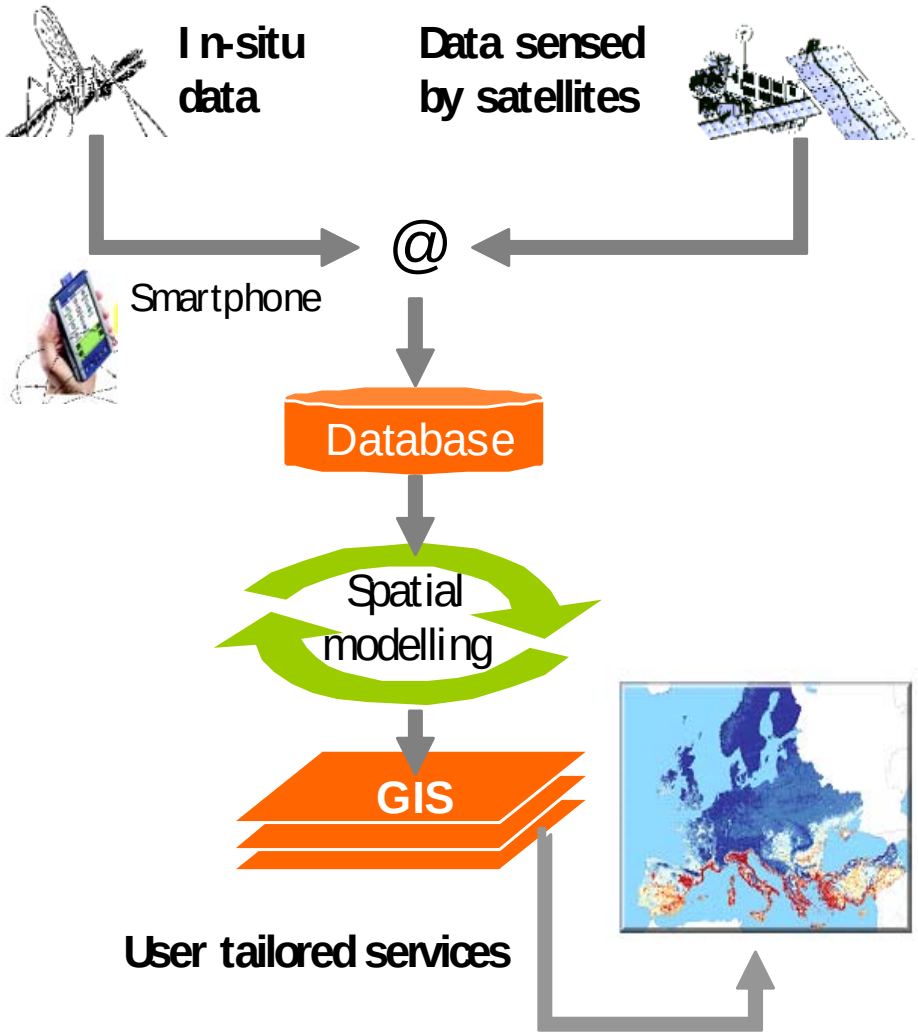
VECMAP Services

- Sampling strategy & routing service
- Field-data synchronization with dBase incl. GNSS position
- Synchronization of laboratory data
- Continuous set of processed EO data
- Habitat suitability mapping service
- Landscape suitability mapping service
- GIS & raster functions by web interface



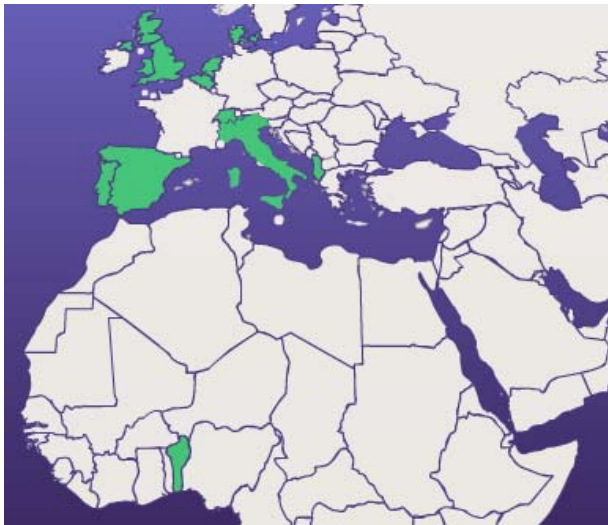
VECMAP Services

- Sampling strategy & routing service
- Field-data synchronization with dBase incl. GNSS position
- Synchronization of laboratory data
- Continuous set of processed EO data
- Distribution modelling service
- Landscape mapping service
- GIS & raster functions by web interface

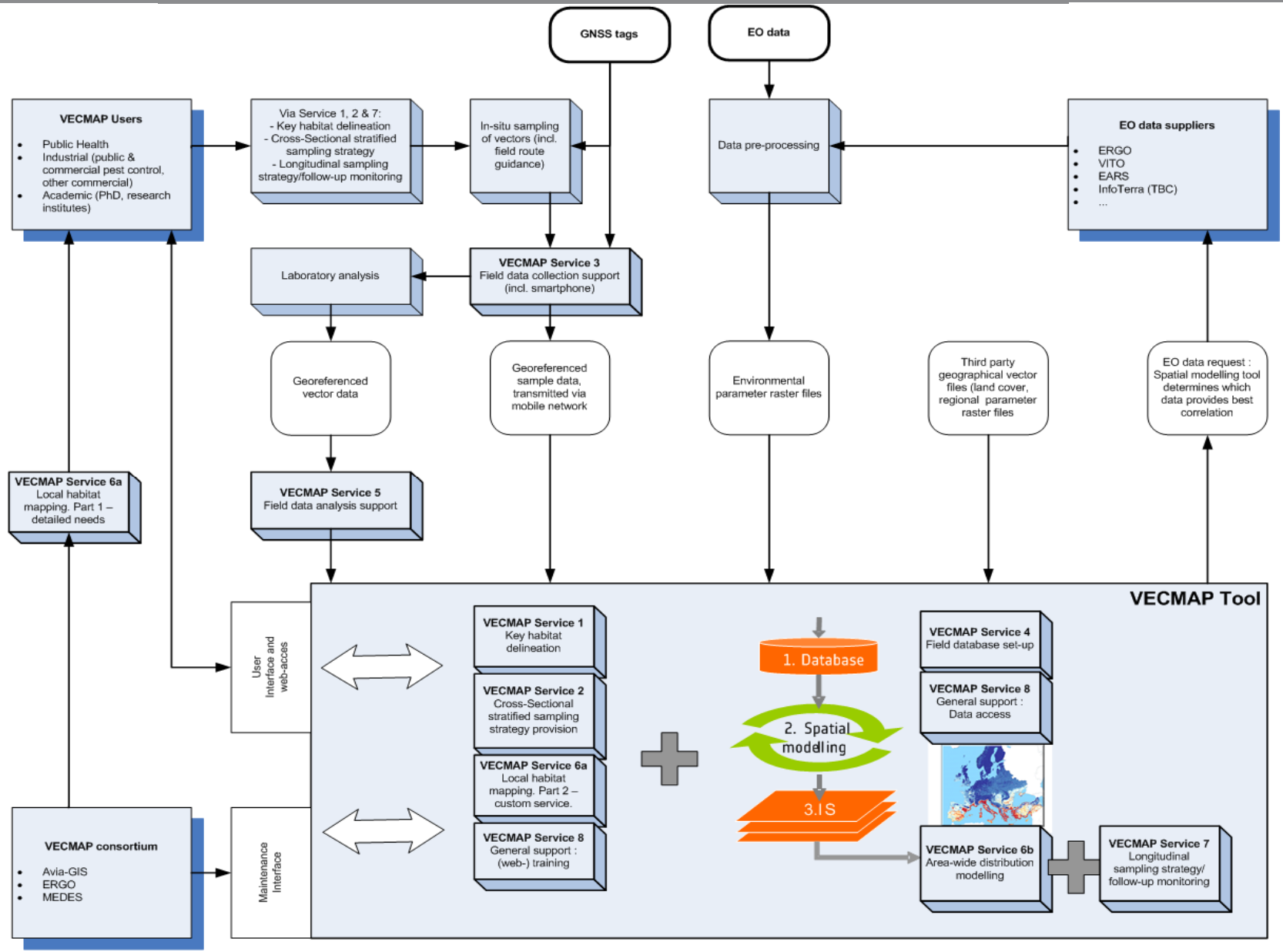


VECMAP Demonstration Project (2011-2013)

- Following successful feasibility study and system demonstration
- Mosquitoes, ticks, midges, mammals
- Demo services in 12 countries



Satellite/Sensor	Environmental data time series	Spatial resolution	Time Series Period
METEOSAT SEVIRI	Precipitation	3km	2004 onwards
	Net Radiation	3km	2004 onwards
	Sensible Heat Flux	3km	2004 onwards
	Actual Evapotranspiration	3km	2004 onwards
	Relative Evapotranspiration	3km	2004 onwards
MODIS TERRA AQUA	Day-time Land Surface Temperature	1km	2001 onwards
	Night-time Land Surface Temperature	1km	2001 onwards
	Middle Infrared	1km	2001 onwards
	Normalised Difference Vegetation Index	1km	2001 onwards
	Enhanced Vegetation Index	1km	2001 onwards
SPOT-VGT	fAPAR	1km	1998 onwards
	Normalised Difference Vegetation Index	1km	1998 onwards
ENVISAT MERIS	fAPAR	1km	2003 onwards
	LAI	1km	2003 onwards
	fCOVER	1km	2003 onwards
	MTCI	1km	2003 onwards
	Normalised Difference Vegetation Index	1km	2003 onwards


GNSS tags
EO data
VECMAP Users
Public Health
Industrial (public & commercial pest control, other commercial)
Academic (PhD, research institutes)
Via Service 1, 2 & 7:
- Key habitat delineation
- Cross-Sectional stratified sampling strategy
- Longitudinal sampling strategy/follow-up monitoring
In-situ sampling of vectors (incl. field route guidance)
Data pre-processing
EO data suppliers
ERGO
VITO
EARS
InfoTerra (TBC)
...
Laboratory analysis
VECMAP Service 3
Field data collection support (incl. smartphone)
Georeferenced vector data
Georeferenced sample data, transmitted via mobile network
Environmental parameter raster files
Third party geographical vector files (land cover, regional parameter raster files
EO data request : Spatial modelling tool determines which data provides best correlation
VECMAP Service 6a
Local habitat mapping. Part 1 – detailed needs
VECMAP Service 5
Field data analysis support
VECMAP Tool
User Interface and web-acces
VECMAP Service 1
Key habitat delineation
VECMAP Service 2
Cross-Sectional stratified sampling strategy provision
VECMAP Service 6a
Local habitat mapping. Part 2 – custom service.
VECMAP Service 8
General support : (web-) training
1. Database
2. Spatial modelling
3.IS
VECMAP Service 4
Field database set-up
VECMAP Service 8
General support : Data access
VECMAP Service 6b
Area-wide distribution modelling
VECMAP Service 7
Longitudinal sampling strategy/ follow-up monitoring
VECMAP consortium
Avia-GIS
ERGO
MEDES
Maintenance Interface

THANK YOU!

Michiel Kruijff

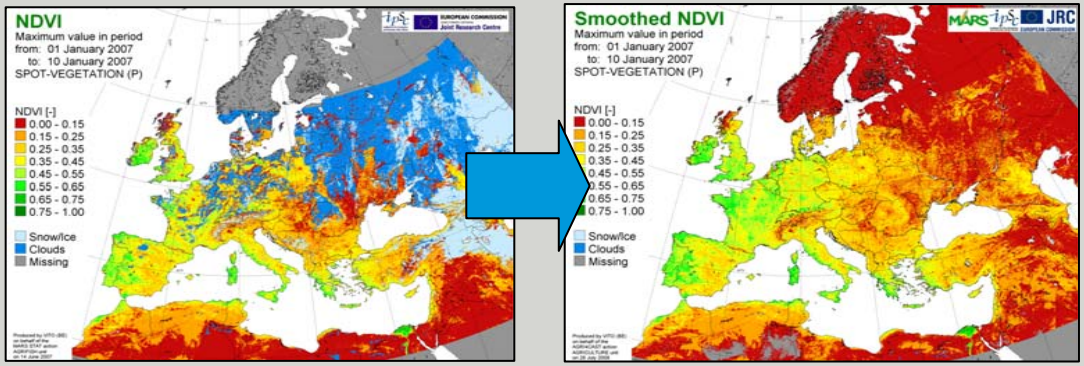
Michiel.Kruijff@esa.int

Integrated Applications Promotion

Data processing steps

1. Raw imagery
2. Georectification
3. Calibration (yielding physical parameters)
4. Atmospheric correction
5. Generate layers (NDVI, LST etc.)
6. Cloud cleaning
7. Standardization for VECMAP : Resampling, Framing, Fourier Analysis
8. Raster functions.

   E.g. One year : extract phenologies, Multiyear : extract calamities, changes



Cloud cleaning

One year phenology

What space assets can bring you

Satellite navigation

- GPS constellation
  - 15 m, no integrity, no guarantee
- SBAS / EGNOS
  - Satellite based augmentation system
  - 5 m + integrity
- Galileo
  - European constellation (2013)
  - Integrity + guarantee of service
- Galileo + GPS
  - 2 m + improved availability

Figure 21 High Sensitivity GPS performance

Figure 22 High Sensitivity GPS + Galileo performance

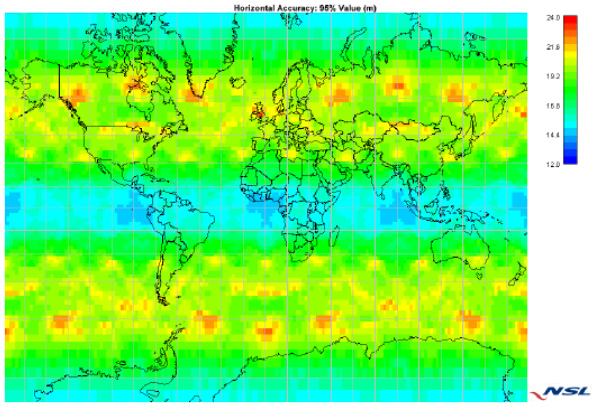


Figure 15 GPS performance

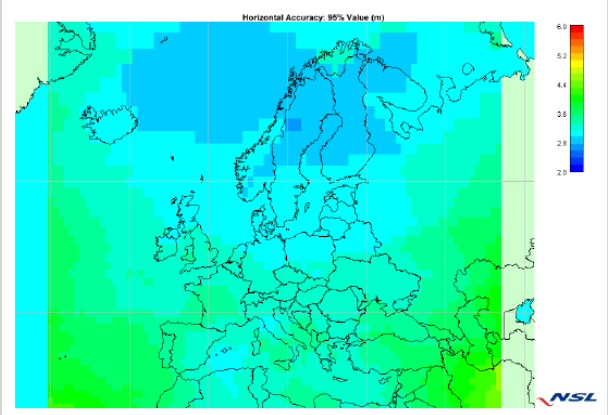


Figure 19 EGNOS performance

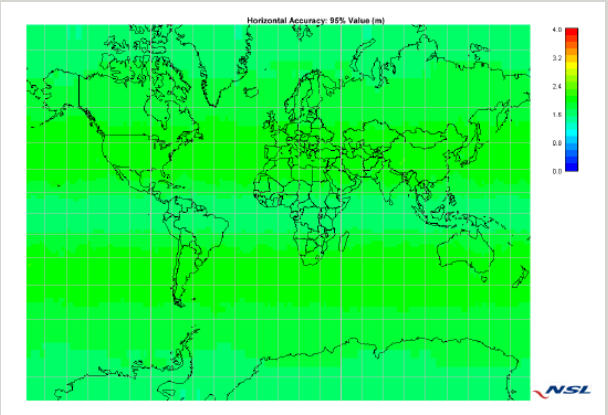


Figure 16 GPS + Galileo performance

What space assets can bring you

Satellite Communication

What space assets can bring you

Satellite Communication

- **Applications**
  - **Remote locations**
  - **Infrastructure breakdown**
  - **Broadcasting**

What space assets can bring you

Satellite Communication

- Applications
  - Remote locations
  - Infrastructure breakdown
  - Secure link
  - Broadcasting
- Services

Services

–Voice, data, video

–Messaging

–Broadband internet

–Broadcast

What space assets can bring you

Satellite Communication

- Applications
  - Remote locations
  - Infrastructure breakdown
  - Secure link
  - Broadcasting
- Services
- Typical systems
  - VSAT

VSAT (Very Small Aperture Terminal)

–Small dish antenna, ~1 m

–Eutelsat, Astra (geostationary)

–Broad band, Ku band, 0.5 MB/s

–Telephony, transactions, internet, maritime communications, video

What space assets can bring you

Satellite Communication

- Applications
  - Remote locations
  - Infrastructure breakdown
  - Broadcasting
  - Secure link
- Services
- Typical systems
  - VSAT
  - BGAN

BGAN (Broadband Global Aera Network)

–Portable terminals

–Internet modem

–Up to 400 Mbit/s

–E.g. Inmarsat

What space assets can bring you

Satellite Communication

- Applications
  - Remote locations
  - Infrastructure breakdown
  - Broadcasting
  - Secure link
- Services
- Typical systems
  - VSAT
  - BGAN
  - Satellite phones & modems

Satellite phones and modems

- Iridium (Low Earth Orbit constellation)
- Thuraya (Geostationary)
- Inmarsat (Geostationary)
- 1 to 144 kbit/s
- voice, data

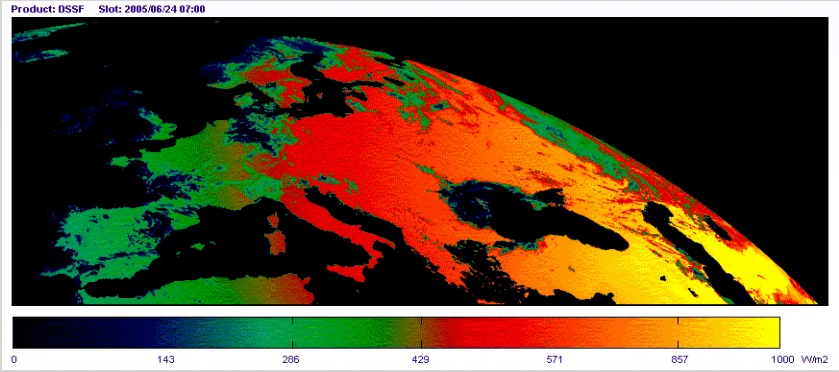
Earth Observation sensors

Earth Observation sensors

- **Geostationary passive sensors**

Geostationary passive sensors

- Altitude 36000 km, fixed position over Earth equator
- Each satellite covers about 1/3rd of Earth
- Visual/Infrared
- High temporal resolution (minutes/hours)
- Low spatial resolution (3-10 km)
- Meteosat/MSG, GOES

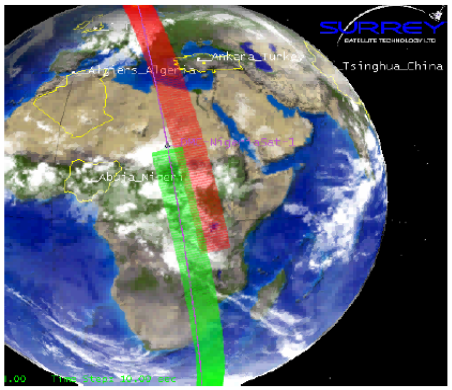


Earth Observation sensors

- Geostationary passive sensors
- Low Earth Orbit passive sensors

Low Earth Orbit passive sensors

– Altitude ~800 km, polar orbit
– Usually providing wide and narrow swath
– Visual / Infrared, L-band (moisture)
– Low temporal resolution (day(s))
– High spatial resolution (0.5 -1000 m)
– Envisat (MERIS), Aqua / Terra (Modis)
DMC, SPOT-VGT, METOP / NOAA (AVHRR)

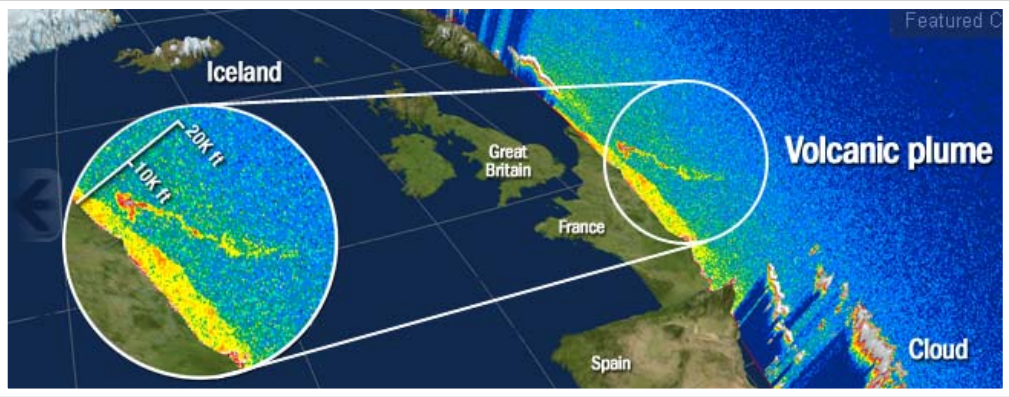


Earth Observation sensors

- Geostationary passive sensors
- Low Earth Orbit passive sensors
- Low Earth Orbit active sensors

Low Earth Orbit active sensors

– Altitude ~800 km, polar orbit
– Radar (X, C band), Lidar, Scatterometer
– Cloud penetration, sea wind, altimetry
– Resolution 1-1000 m
– Low temporal resolution (days / weeks)
– Envisat (ASAR), TerraSAR-X, CosmoSkyMed, Calipso



What space assets can bring you

Earth Observation data

Precipitation / Radiation / Flux

fAPAR, NDVI

Land Surface Temperature

Spatial Resolution	Temporal Resolution	Past	Present	Future

What space assets can bring you

Earth Observation data

Precipitation / Radiation / Flux

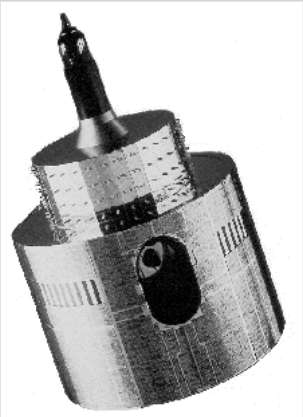
fAPAR, NDVI

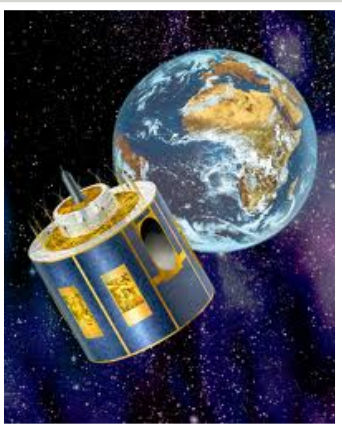
Land Surface Temperature

Spatial Resolution	Temporal Resolution	Past	Present	Future
LOW	HIGH			

Precipitation / Radiation / Heat flux, Evapotranspiration

- Requires VIS, NIR and also (rare) Thermal IR
- High temporal resolution, to remove clouds -> GEO sats.
- 1977 : Meteosat (MVIRI)
- 2004 : Meteosat Second Generation (SEVIRI, 3 km)
- 2013 : Meteosat Third Generation (1 km)





What space assets can bring you

Earth Observation data

Precipitation / Radiation / Flux

fAPAR, NDVI

Land Surface Temperature

Spatial Resolution	Temporal Resolution	Past	Present	Future
LOW	HIGH			
HIGH	LOW			

fAPAR, NDVI

- Requires only VIS & NIR
- High spatial resolution required (30 m – 1 km)
- Terra / Aqua (MODIS)
- SPOT (VGT)
- Envisat (MERIS, 250 m), until 2013
- Sentinel 3 (OLCI), after 2013

What space assets can bring you

Earth Observation data

Precipitation / Radiation / Flux

fAPAR, NDVI

Land Surface Temperature

Spatial Resolution	Temporal Resolution	Past	Present	Future
LOW	HIGH			
HIGH	LOW			
HIGH	LOW			

Land Surface Temperature

- Requires Thermal IR, day and night data
- High spatial resolution
- Terra / Aqua (MODIS), may go out of operation
- Since 1981 : NOAA / METOP (AVHRR), at least until 2020

What space assets can bring you

Earth Observation data

Precipitation / Radiation / Flux

fAPAR, NDVI

Land Surface Temperature

Spatial Resolution	Temporal Resolution	Past	Present	Future
LOW	HIGH			
HIGH	LOW			
HIGH	LOW			

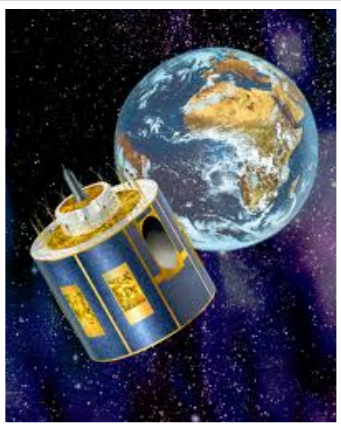


Figure 21 High Sensitivity GPS performance

Figure 22 High Sensitivity GPS + Galileo performance

Platform	NOAA	METOP	SPOT	TERRA	MSG
Country / Organisation	USA NOAA	ESA EuMetSat	France (Bel, Ital, Swe)	USA NASA	ESA EuMetSat
Launch date (YYYY/MM)	N17: 2002/06 N18: 2005/05	2006/10	SPOT4: 1998/03 SPOT5: 2002/05	1999/12	2002/08
Orbit	Near-Polar	Near-Polar	Near-Polar	Near-Polar	Geostationary
Equatorial Crossing time	N17: 10h24' N18: 13h55'	9h30'	10h30'	10h30'	*NA*
Sensor	**AVHRR**	**AVHRR**	**VEGETATION**	**MODIS**	**SEVIRI**
Swath (km)	2926	2926	2250	2330	12000
Glob. Cover in	1 day	1 day	1 day	1 day	15 minutes
Nadir pixel size (km)	1.1 (LAC) 4.4 (GAC)	1.1 (LAC) 4.4 (GAC)	1.15	1.00 (29 bands) 0.50 (5 bands) 0.25 (2 bands)	3.0
Spectral Bands	**5**	**5**	**4**	**36**	**11**
VIS: 0.40 – 0.75	1	1	2	11	1
NIR: 0.75 – 1.10	1	1	1	5	1
SIR: 1.10 – 3.00			1	4	1
MIR: 3.00 – 7.00	1	1		7	2
TIR: 7.00 - 14.00	2	2		9	6
Simultan. HiRes images	No	No	HRVIR (30/10m)	ASTER (15/30/90m)	No
Processing & Distribution	No centralized facilities	Local reception EuMetCast	CTIV-VITO	NASA	EuMetSat LandSAF