Satellite data products suitable for land surface analysis

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ESTEC, The Netherlands
10/11/2009

OVERVIEW

1. ESA's SMOS Activities

2. ESA's Snow Activities
   - Snow Water Equivalent from CoReH2O
   - STSE SnowRadiance Study
   - DUE GlobSnow

3. Future Vegetation Products
   - Vegetation Data Sets from Sentinel-2/-3
   - Leaf Area Index
   - Beyond LAI

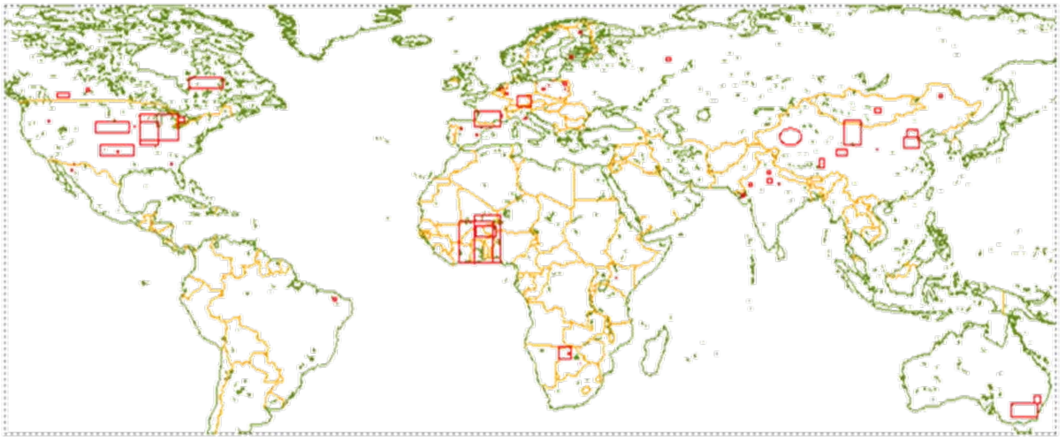
4. Conclusions

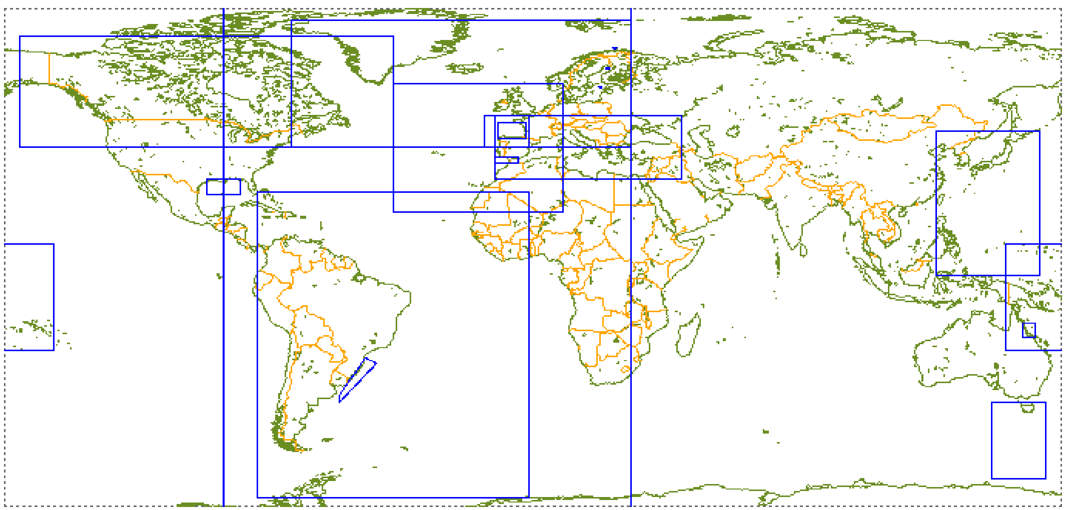
SMOS – ESA ACTIVITIES

- Data Assimilation Study with ECMWF (ongoing).
- In-situ Soil Moisture Network Study with University of Vienna (KO 16.11.2009) (in collaboration with GEWEX and ISMWG).
- SMOS sea ice retrieval study with University of Bremen (completed).
- SMOS Level-2 Sea Ice Study (ITT to be released in 11/2009).
- Cal / Val activities (ongoing).

SMOS – CALIBRATION / VALIDATION

Soil Moisture





Ocean Salinity

Expert Support Laboratories, strongly linked to Principle Investigators Yann Kerr and Jordi Font

43 teams worldwide supporting cal & val activities

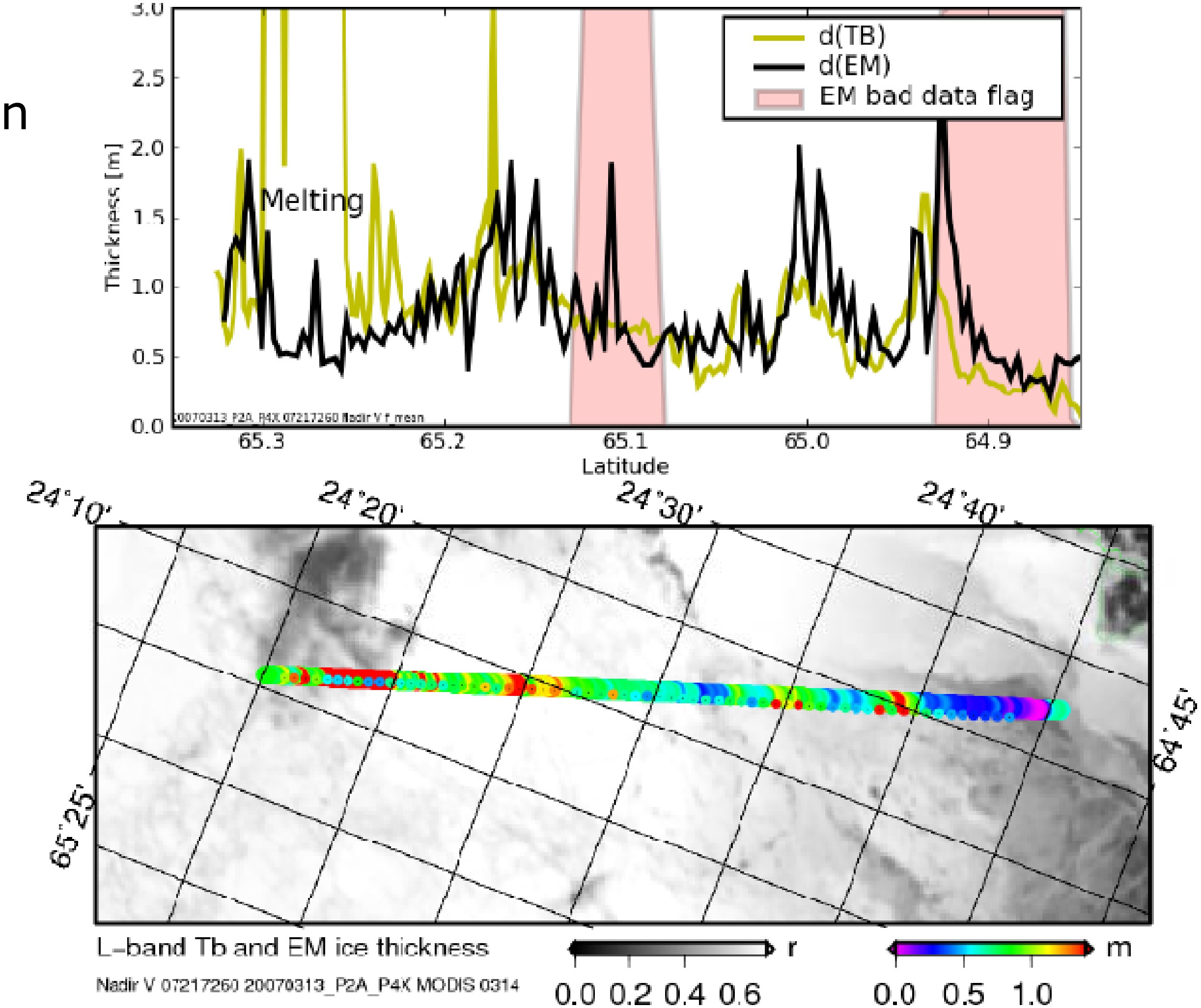
Airborne campaigns over ocean and land

In-situ data –
<u>Land</u>
ESA key validation sites in Germany and Spain; soil moisture network
<u>Ocean</u>
Argo floats and surface drifters

Working closely with NASA teams on Aquarius and SMAP

SMOS – SEA ICE THICKNESS RETRIEVAL

Pol-Ice Campaign 2007



Kaleschke et al. 2009

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CoReH2O – OBSERVATION REQUIREMENTS

Primary parameters	Spatial scale Regional / Global	Sampling (days)	Accuracy (rms)
Snow water equivalent	200 m / 500 m	3-15	3 cm for SWE ≤ 30 cm, 10% for SWE > 30 cm
Snow extent	100 m / 500 m	3-15	5% area at hill slope scale
Snow accumulation on glaciers	200 m / 500 m	≤ 15	10% of maximum

Secondary parameters

Snow

Melting snow area, snow depth

Glaciers

extent, glacial lakes

Lake and river ice

Ice area; freeze up and melt onset

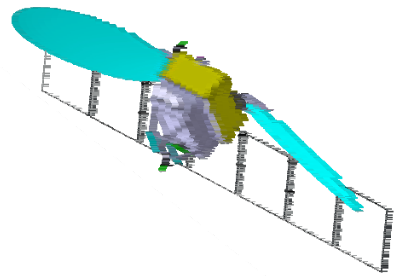
Sea ice

Snow on ice (SWE, melt onset and area); type and thickness of thin ice

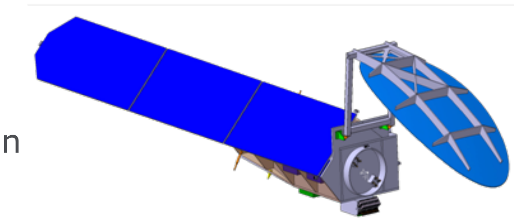
CoReH2O – ACTIVITY OVERVIEW

Industrial preparations

- parallel industrial phase A activities
- payload related bread boarding activities



technical concepts further analysed in Phase A



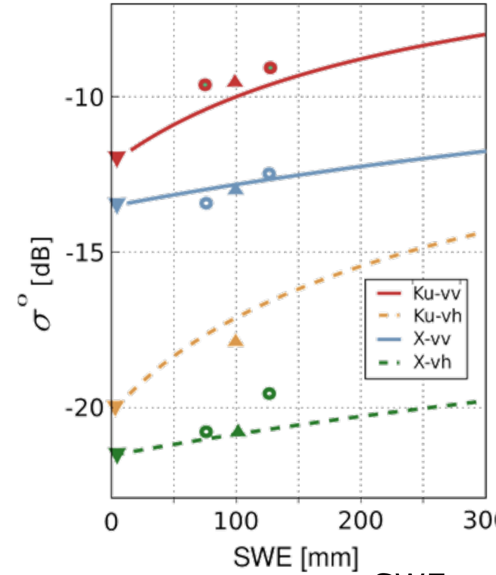
Scientific preparations

- scientific studies (Retrieval study, synergy study active/passive microwave, COSDAS, Synergy of different SARs for snow and ice parameter retrieval)
- campaigns (NoSREX, CAN-CSI, POLSCAT/CLPX)

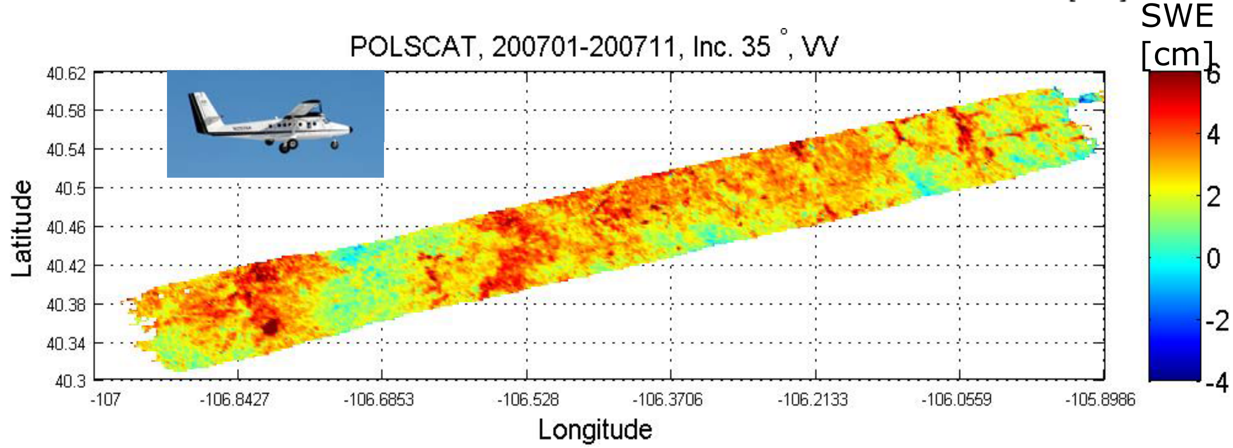
CoReH2O – RECENT CAMPAIGN RESULTS

Backscatter sensitivity to SWE for different snow conditions demonstrated

○ HeliSnow ▲ SARAlps



Campaign data are the basis for validation of theoretical backscatter models and development of retrieval algorithms



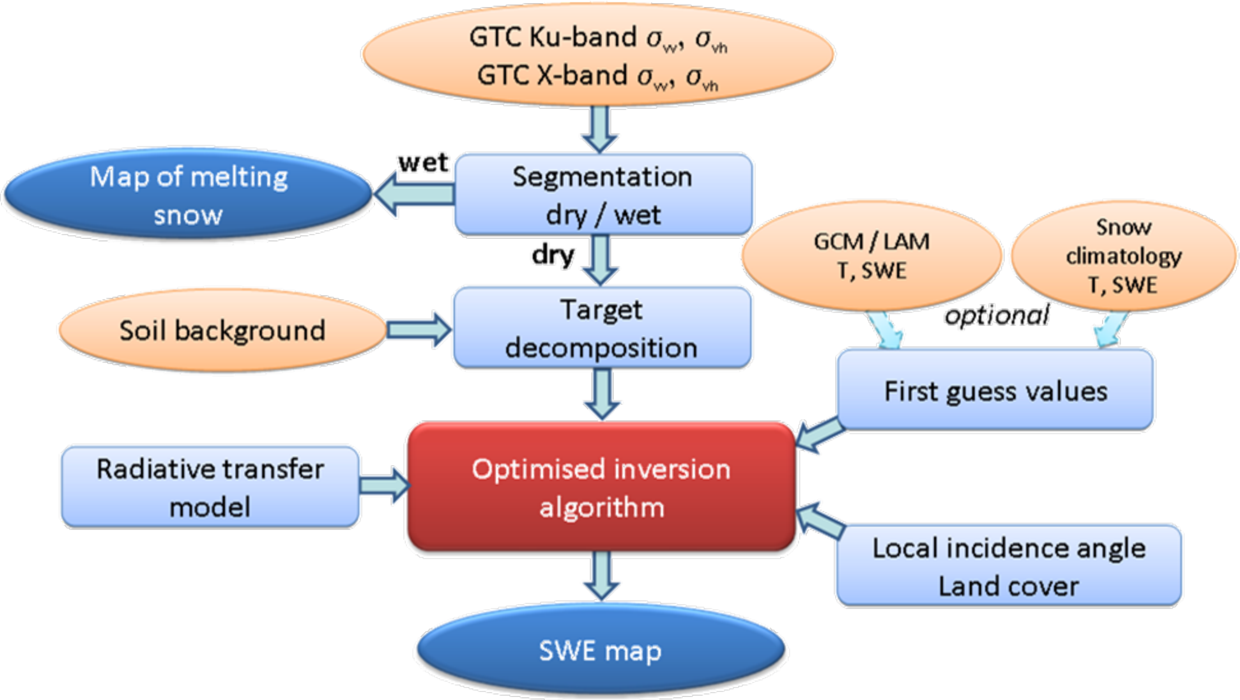
POLSCAT / CLPX-II Colorado and Alaska

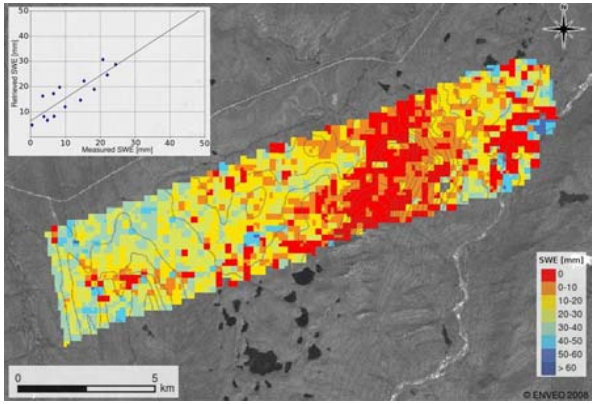
CoReH2O – RETRIEVAL ALGORITHM

Several retrieval methods were investigated and tested.

The baseline method applies an optimised statistical inversion of a radiative transfer model.

The **retrieval performance is compliant with CoReH2O requirements.**





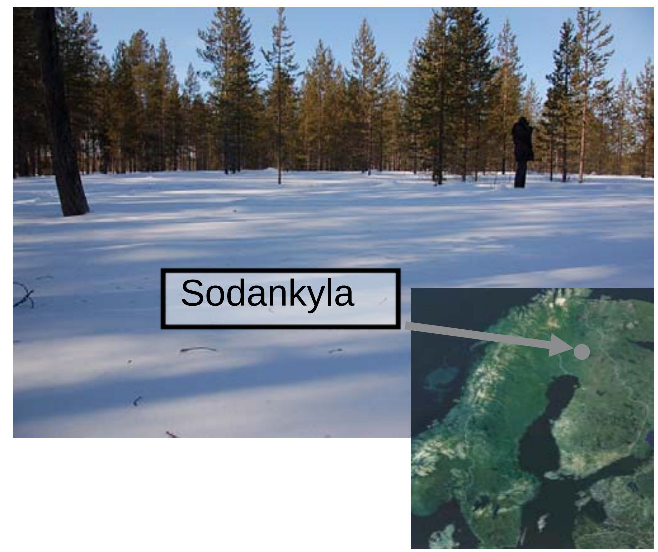
CoReH2O – ONGOING NoSREX CAMPAIGN

Aims

- Study the effects of snow accumulation (SWE) and temporal evolution of snow morphology on backscatter signatures, starting from the first snowfall until melting.
- Validation of theoretical backscattering models of snow at Ku- and X-band frequencies.
- Sensitivity studies for Ku- and X-band backscattering in regard to physical parameters of the snow pack.
- Validation of SWE retrieval algorithms.
- Acquisition of L-band radiometer data for synergy studies.

Experiment details

- Leverage FMI infrastructure at Sodankylä Observatory test site, northern Finland, 67° 22' N, 26° 38' E, 180 m
- Deployment of ESA SnowScat and ELBARA instruments from October 2009 to May 2010 to cover full range of snow conditions



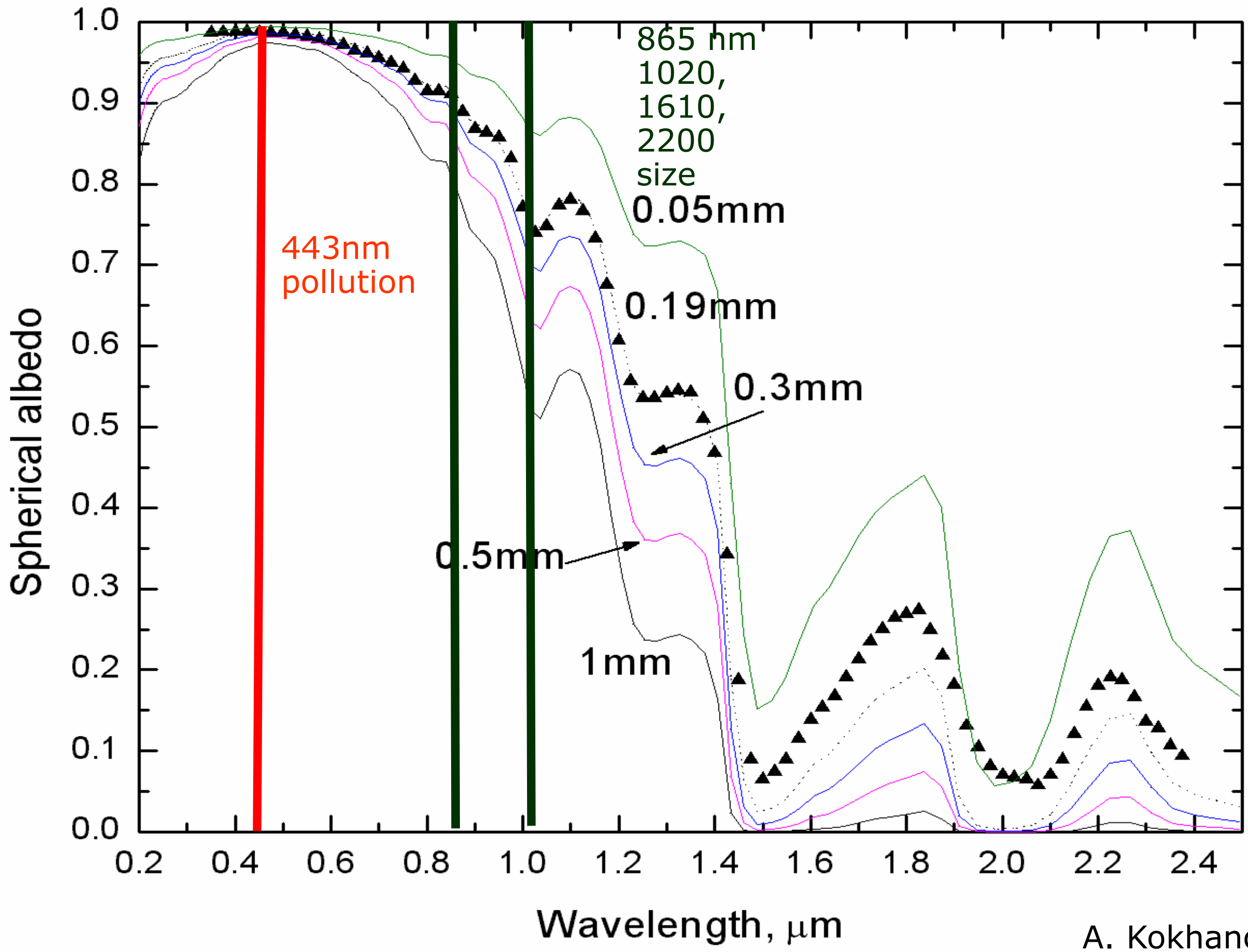
STUDY OVERVIEW

The Support To Science Element (STSE) aims at providing “scientific support for both future and on-going missions, by taking a proactive role in the formulation of new mission concepts and of the related scientific agenda, by offering a multi-mission support to the scientific use of ESA Earth Observation missions data and to the promotion of the achieved results.” (ESA/C(2005)143).

SnowRadiance Study objectives:

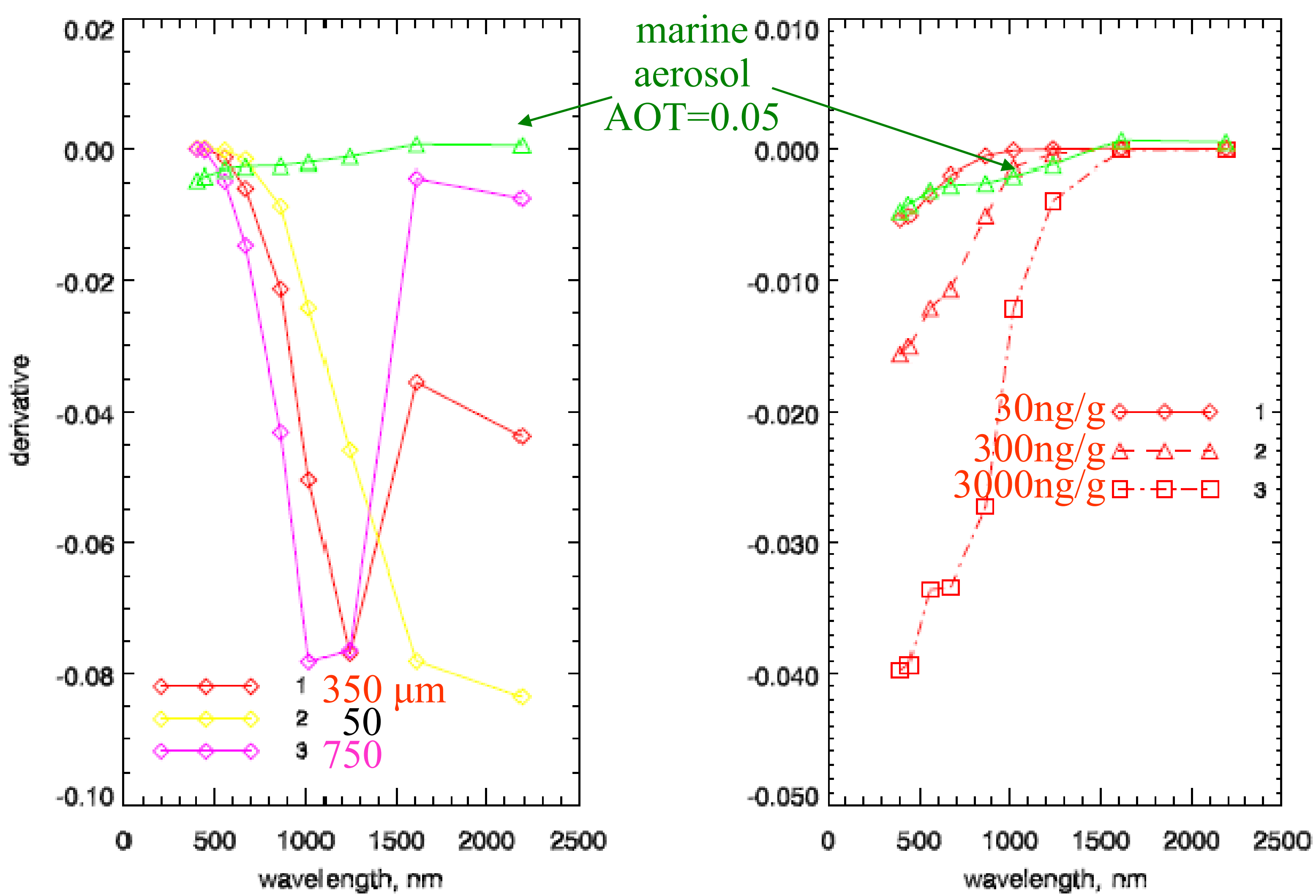
- Investigate the potential for snow parameter retrievals from current and future ESA passive imaging instruments operating in the UV and TIR spectral range, namely Envisat, Sentinel-2 and Sentinl-3.
- Develop the algorithm theoretical basis for retrievals.
- Provide a toolbox for the scientific user community.

GRAIN SIZE SENSITIVITY



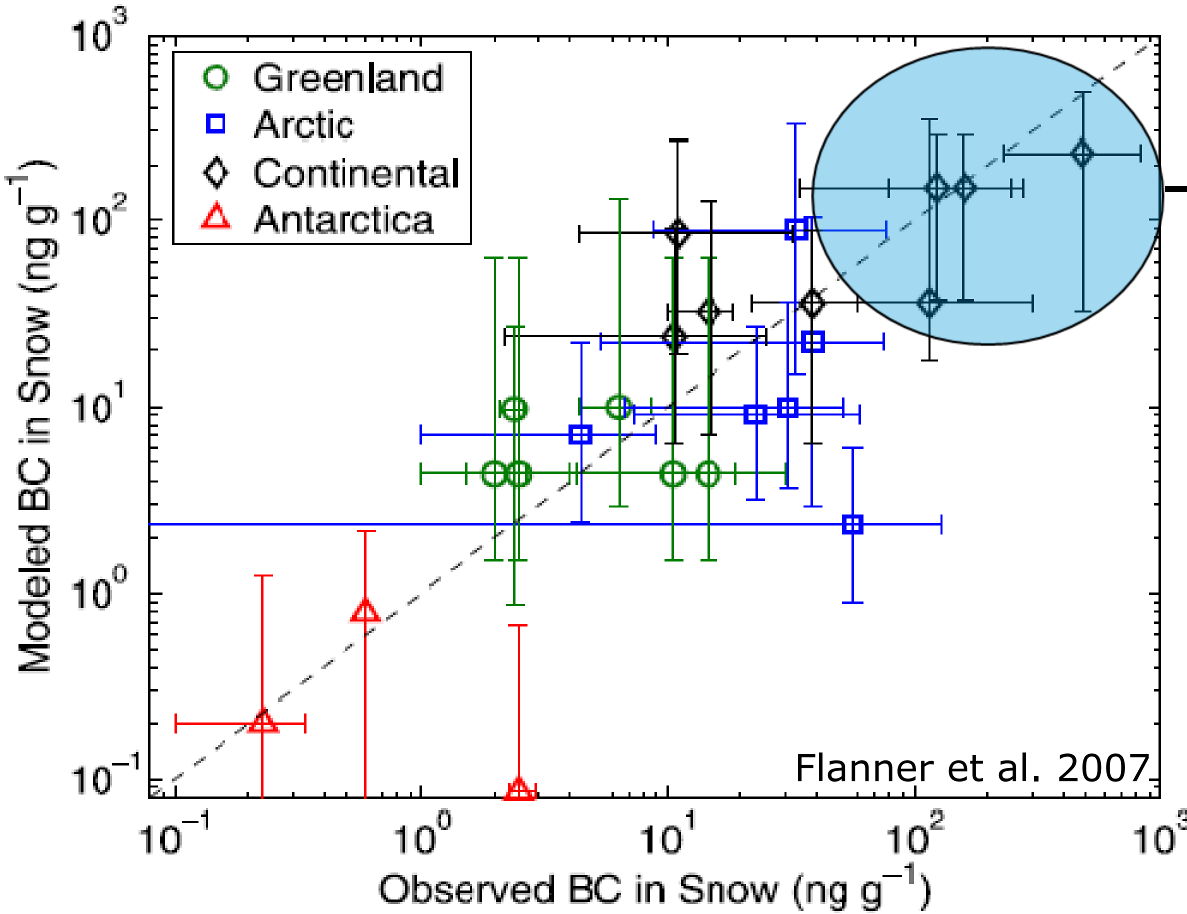
A. Kokhanowski

GRAIN SIZE & SOOT SENSITIVITY



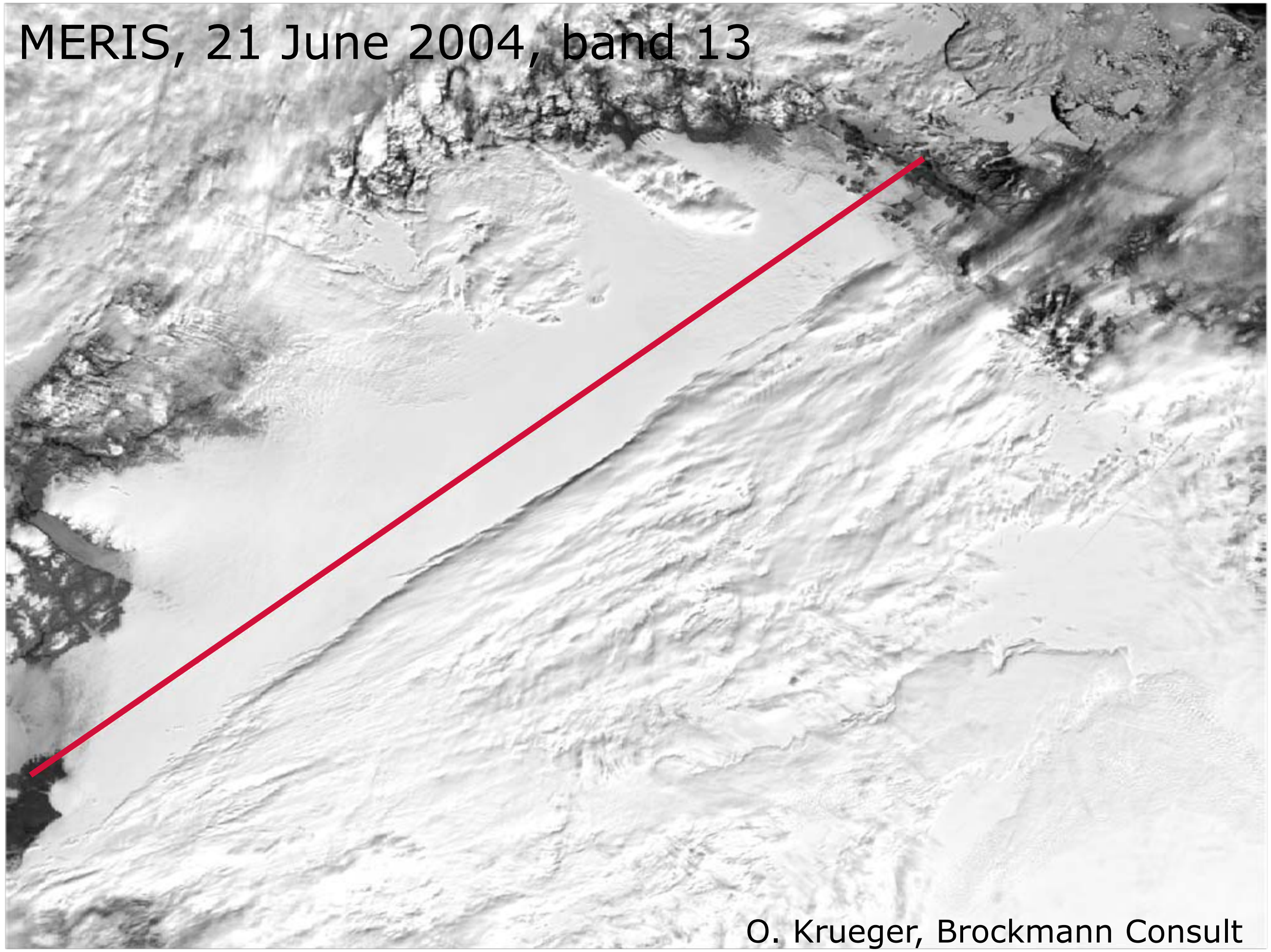
A. Kokhanowski

SOOT CONCENTRATION

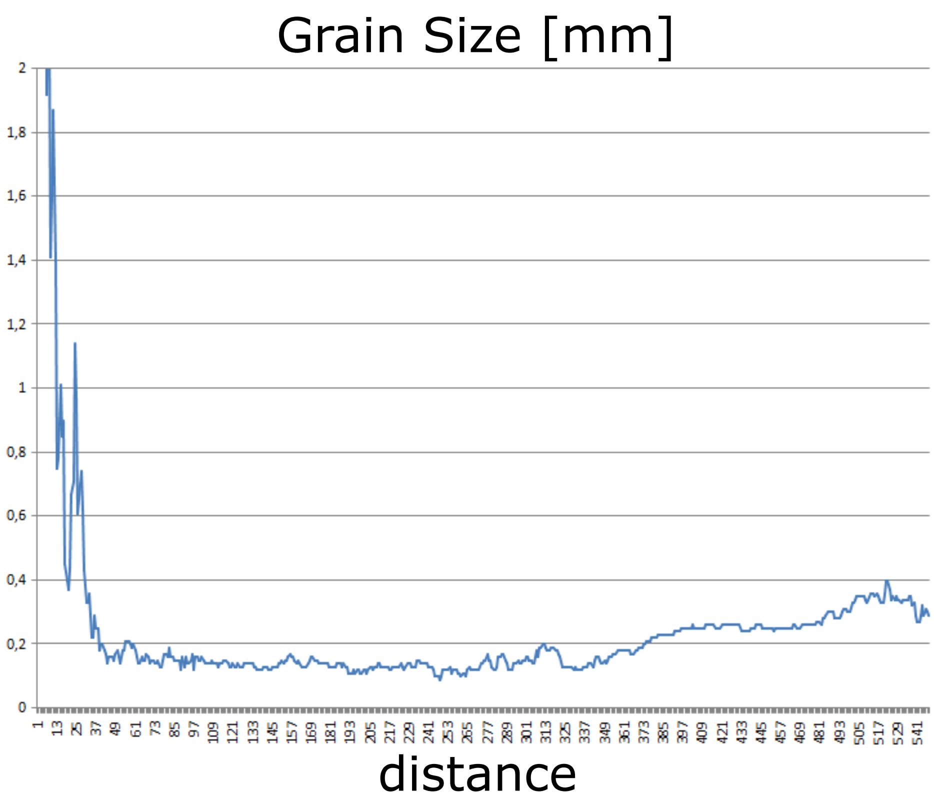


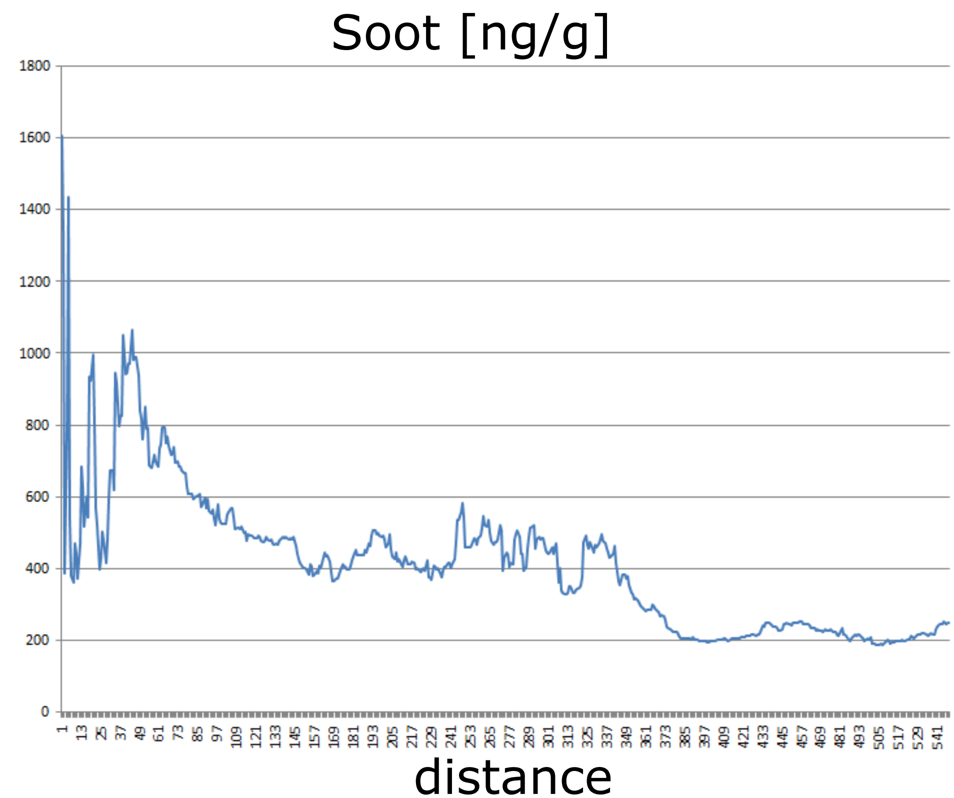
retrieval possible

MERIS GRAIN SIZE RETRIEVALS (1)



MERIS GRAIN SIZE RETRIEVALS (2)



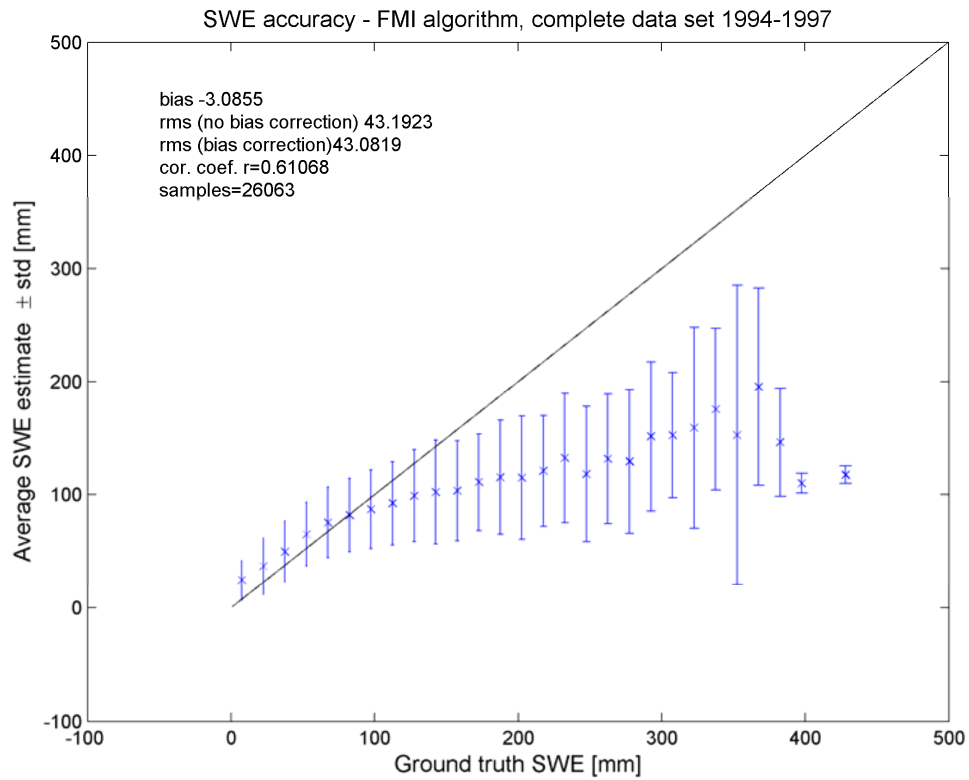


SUMMARY

- Snow layers can be correctly modelled through ice clouds at the ground.
- Soot retrieval may be possible in the blue spectral region, but will be limited to high soot concentrations.
- For grain size retrievals wavelengths from 800 to 2000 nm can be used.
- Grain size retrievals based on MERIS (band 13) over Greenland show promising results and compare well with MODIS derived estimates. Soot concentration retrieval gives too high values and needs further data analysis.
- Currently the retrievals are limited to homogeneous snow areas, i.e. after cloud/ice/snow screening.
- Algorithms will be implemented as BEAM Toolboxes.
- More information under: http://dup.esrin.esa.int/stse

GLOBSNOW – FIRST SWE RESULTS

- DUE GlobSnow is a 3 year project begun in November 2008
- Led by FMI (FI), with SYKE(FI), NR(N), Enveo (A), Gamma (CH), Environment Canada and NORUT (N)
- Objective is to generate 15+ years of global Snow Extent (SE) and Snow Water Equivalent (SWE) time-series with full uncertainty characterization
- A new SE algorithm has been developed for the (A)ATSR series instruments
- http://globsnow.fmi.fi/



GLOBSNOW – SWE VERIFICATION

Eurasia 09/1994 – 12/1997
Evaluation with 450 INTAS snow stations

Name	*RMSE*	*bias*	*Corr*	*Unbiased RMSE*	*Samples*
FMI algorithm	**43.2 mm**	**-3.1 mm**	**0.611**	**43.1 mm**	**26063**
EC algorithm	**67.6 mm**	**-28.2 mm**	**0.210**	**61.5 mm**	**18109**
Chang et al. 1987 (asc node) **Chang et al. 1987 (desc node)**	**71.6 mm** **70.7 mm**	**-8.4 mm** **1.6 mm**	**0.011** **0.029**	**71.1 mm** **70.8 mm**	**26726** **27521**
SPD algorithm (asc node) **SPD algorithm (desc node)**	**67.1 mm** **63.9 mm**	**-12.7 mm** **-3.1 mm**	**0.052** **0.121**	**65.9 mm** **63.9 mm**	**29559** **29451**
Armstrong et al. 2001 (asc node) **Armstrong et al. 2001 (desc node)**	**72.3 mm** **73.7 mm**	**-44.1 mm** **-42.9 mm**	**0.044** **0.029**	**57.3 mm** **59.9 mm**	**21796** **24791**

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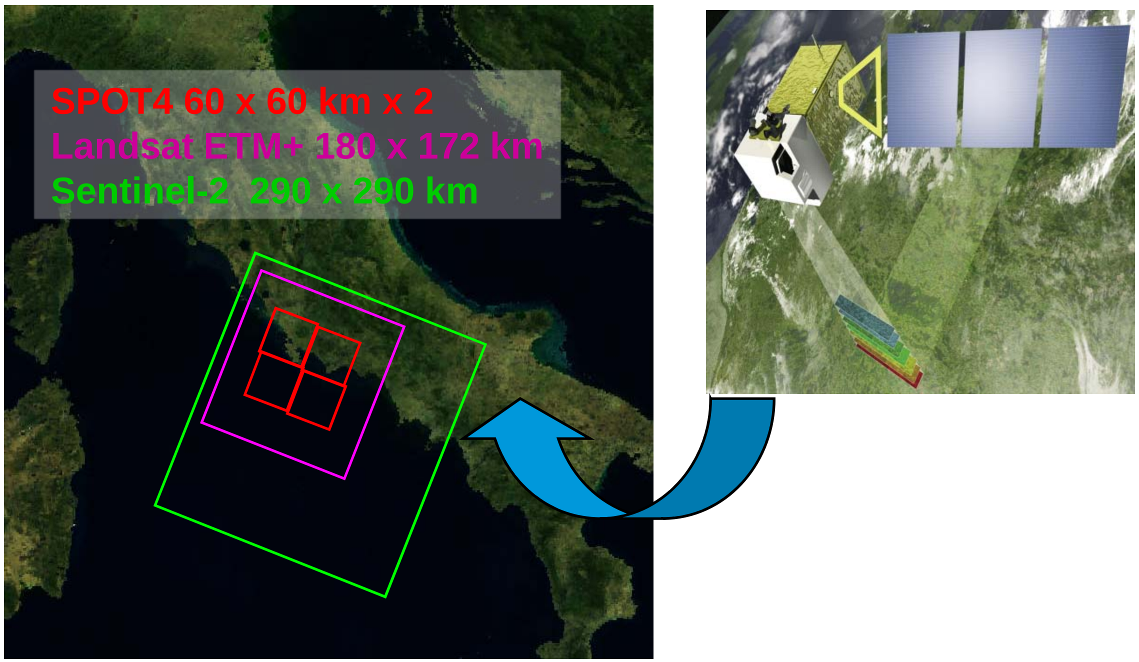
VEGETATION – SENTINEL-2 and -3 (1)

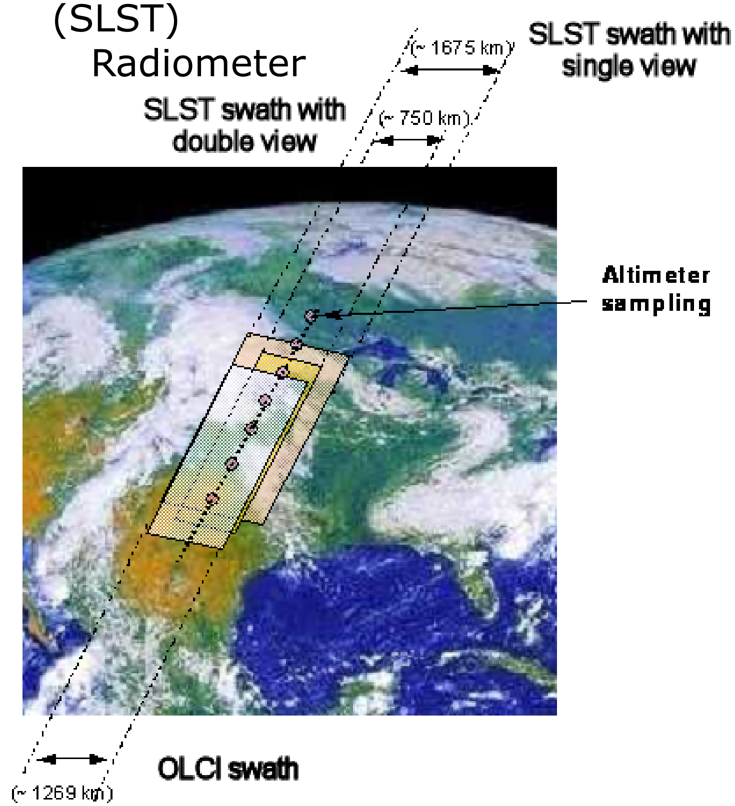
S-2 Optical Mission Payload

- Multi-Spectral Instrument (MSI)



S-3 Optical Mission Payload

- Ocean and Land Color Instrument (OLCI)
- Sea and Land Surface Temperature (SLST) Radiometer



VEGETATION PRODUCTS – SENTINEL-2 / -3

Band	λ [nm]	res [m]	Band	λ [nm]	res [m]
#1	443	60	#8	842	10
#2	490	10	#8a	865	20
#3	560	10	#9	945	60
#4	665	10	#10	1375	60
#5	705	20	#11	1610	20
#6	740	20	#12	2190	20
#7	783	20	-	-	-

Land cover and change detection map,
Leaf Area Index,
Fraction of Vegetation Cover,
Fraction of Absorbed Photosynthetically Active Radiation,
Leaf chlorophyll content,
Leaf water content,
Surface albedo,
Crown density,
Forest age

OLCI – Open ocean	1.2 km
OLCI – Coastal ocean	300 m
OLCI - Land	300 m
SLST – solar channels	500 m
SLST – Thermal channels	1 km

Land Cover and Vegetation:

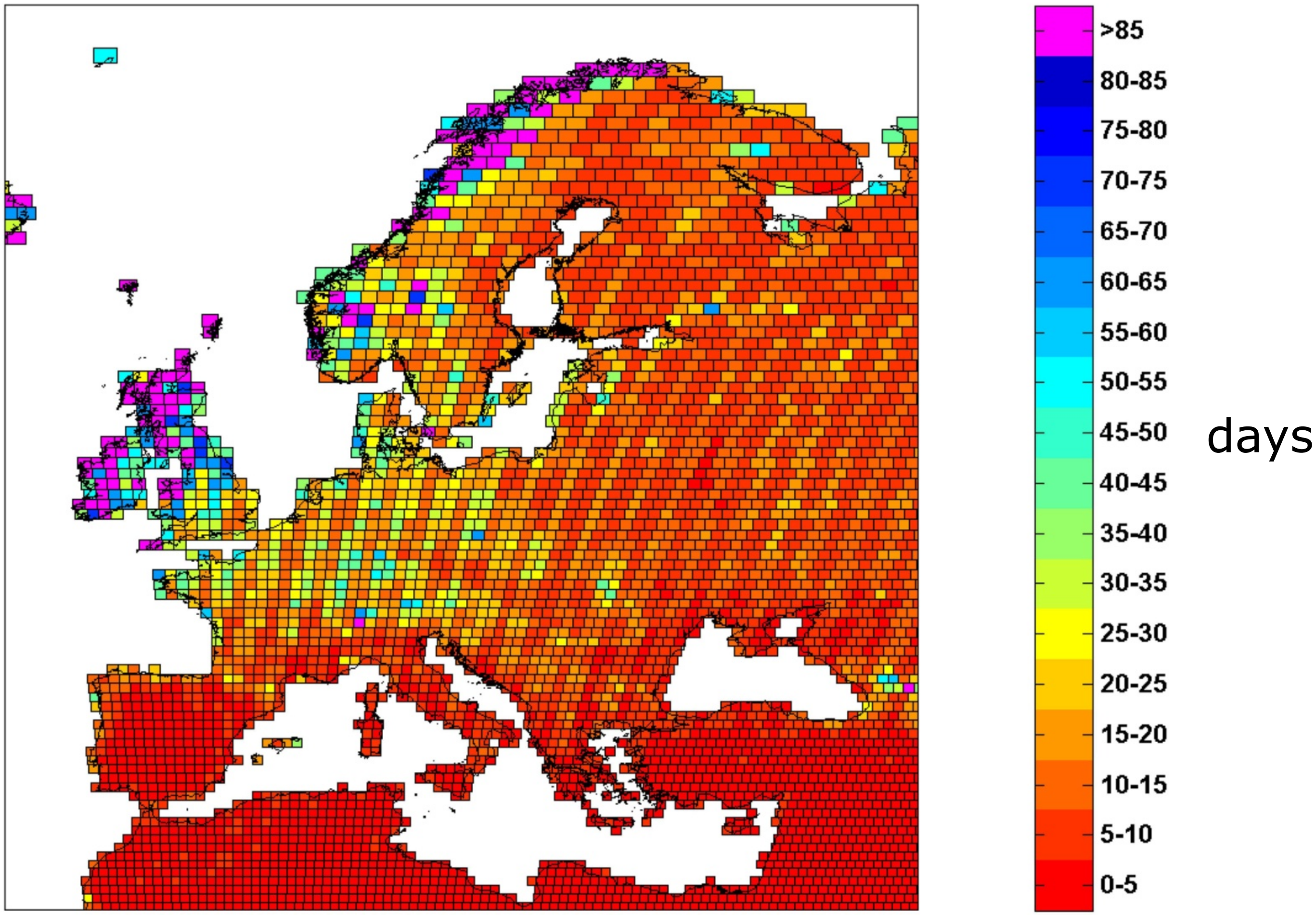
Normalized Difference Vegetation Index,
Meris Global Vegetation Index,
Meris Terrestrial Chlorophyll Index,
Fraction of Absorbed Photosynthetically Active
Radiation,
Leaf Area Index

Land Surface Temperature

By-products:

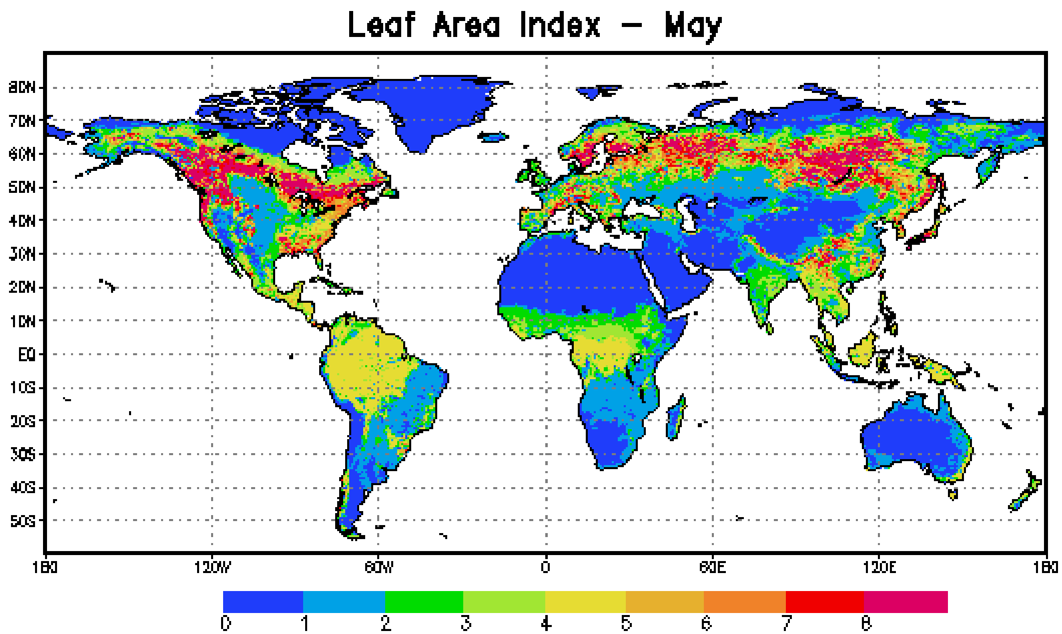
atmospheric aerosols, clouds

S-2 EFFECTIVE TEMPORAL COVERAGE (SUMMER)



LAI

LAI: Ratio of total upper leaf surface of vegetation divided by the surface area of the land on which the vegetation growth.

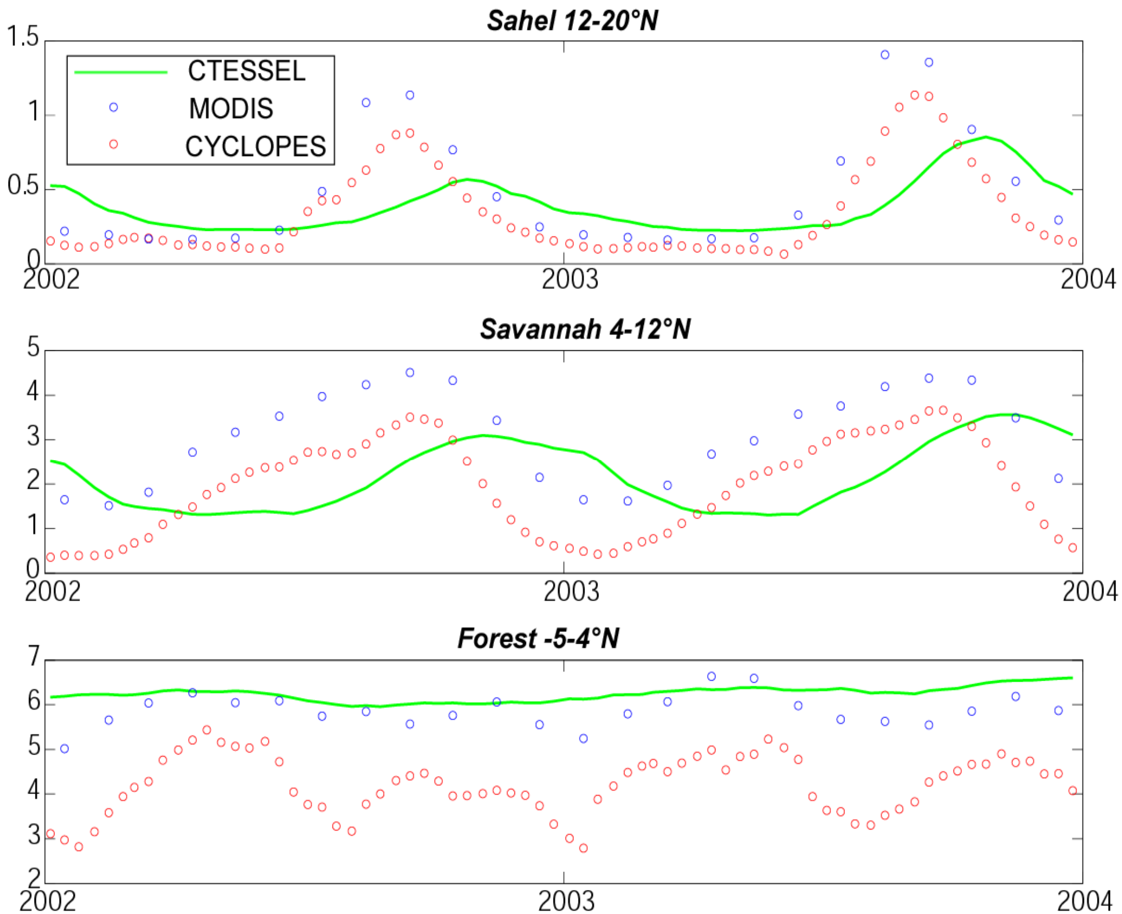


LAI is a structural parameter that can hardly describe vegetation processes.

e.g.: $GPP = Net_{sw} * 0.45 * FAPAR * LUE$

LAI - GEOLAND APPLICATION (1)

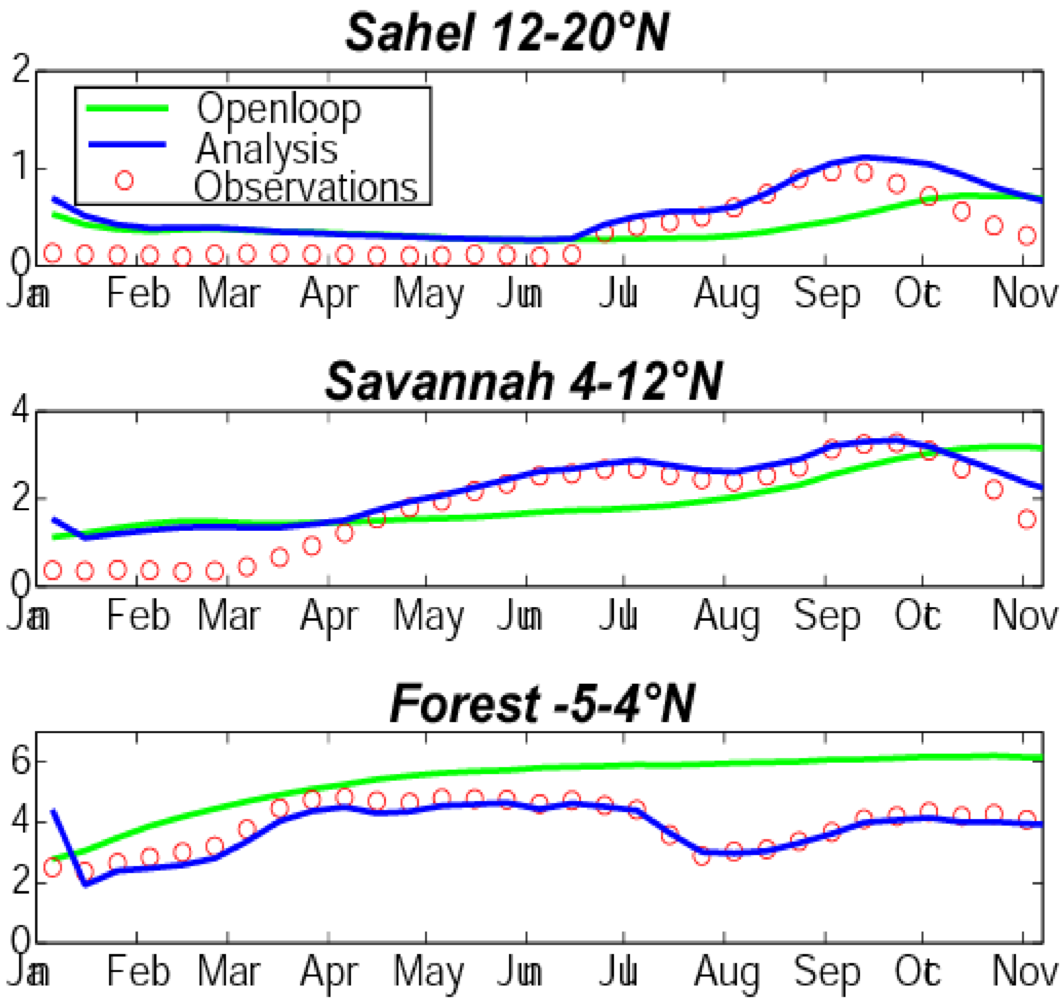
LAI time series



- Strong time shift of CTESSEL
- Vegetation cycle better depicted by MODIS
  - stable value over forest
  - minimum value over Savannah

Jarlan et. al 2008

LAI - GEOLAND APPLICATION (2)



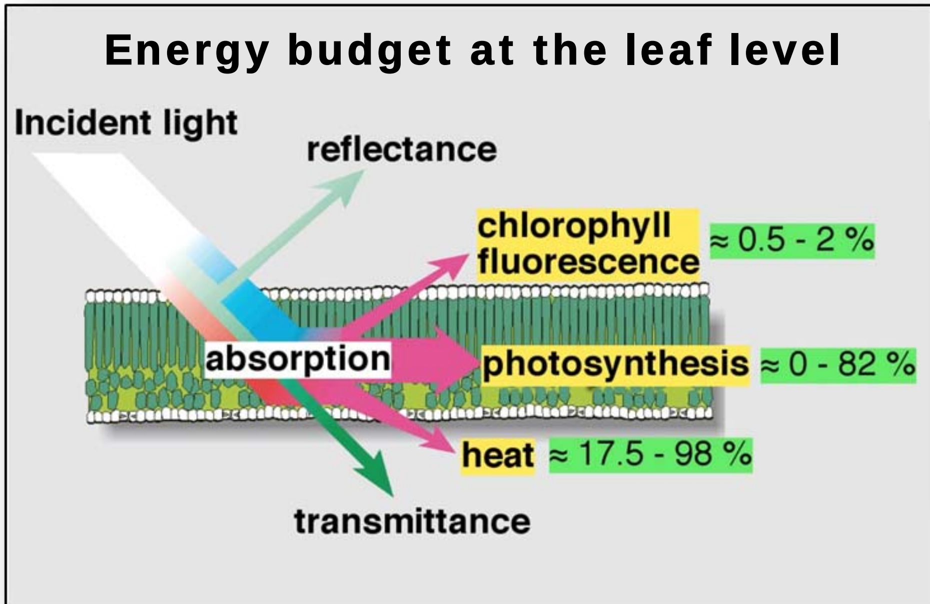
Assimilation of CYCLOPS

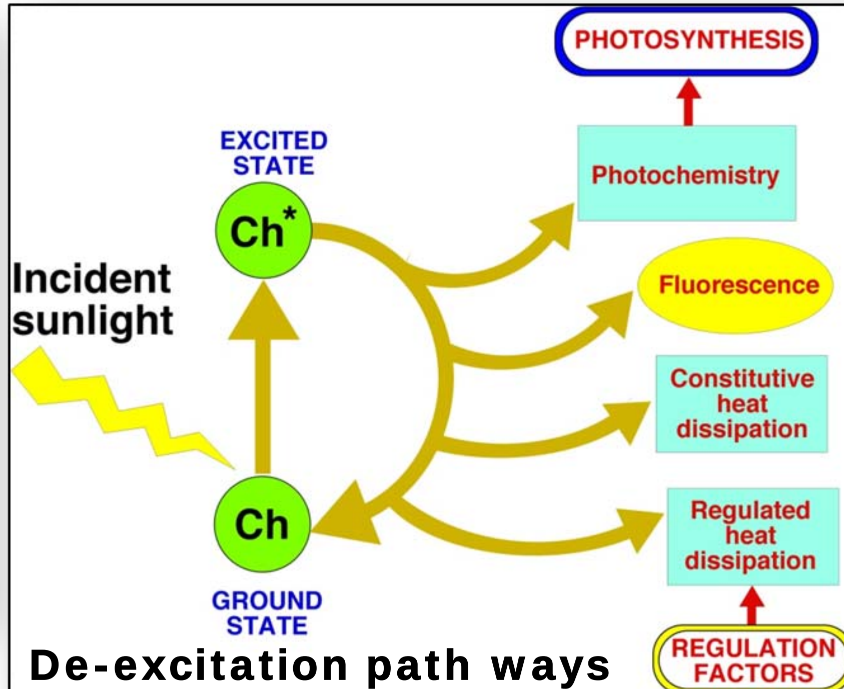
- The strong delay of CTESSEL is corrected
- Poor correction during the dry season (Sahel and Savannah)
- Poor quality data over rain forest

Jarlan et. al 2008

FLUORESCENCE - BEYOND LAI (1)

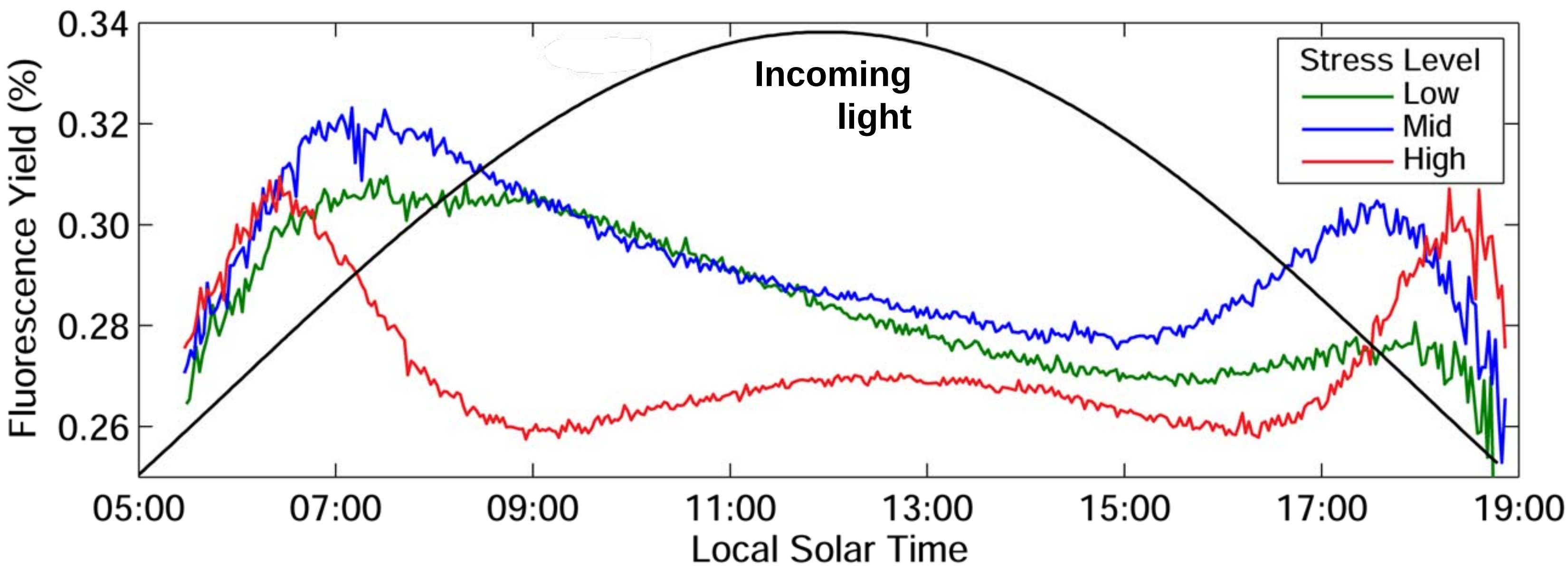
- Fluorescence is emitted from the core of the photosynthetic machinery and can be correlated to plant functional status.





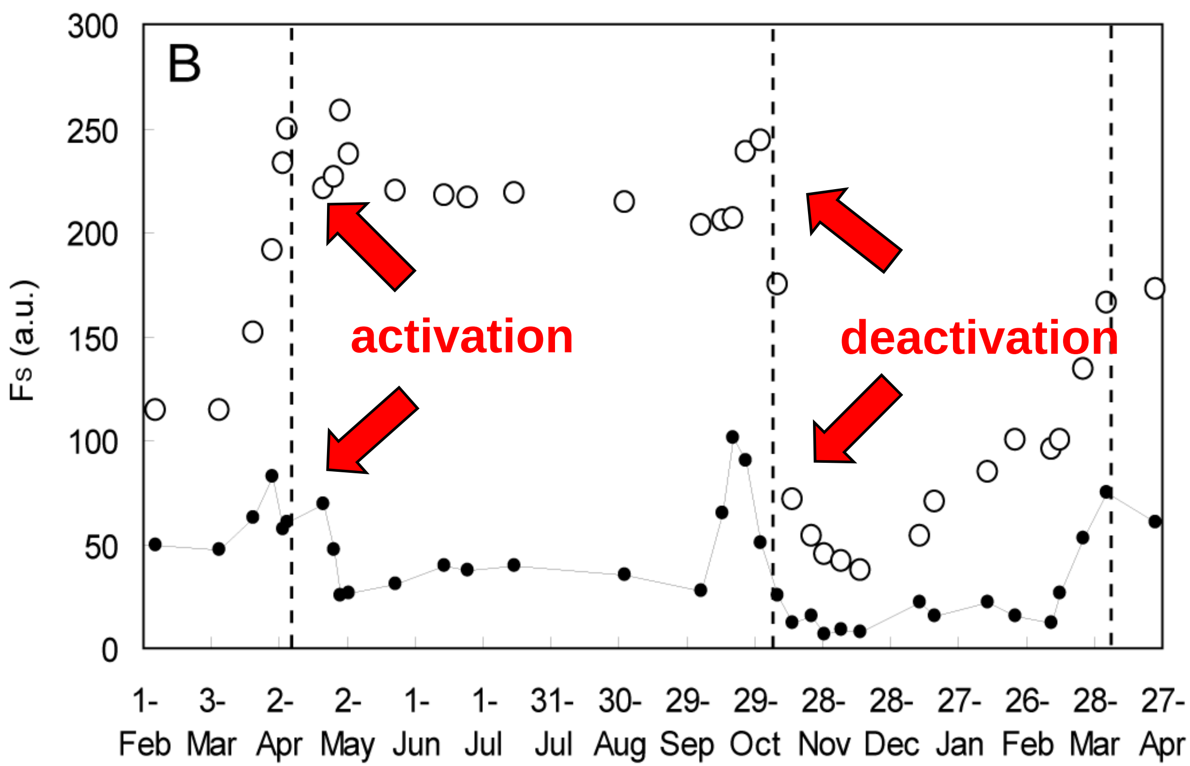
- Fluorescence is emitted from the core of the photosynthetic machinery and can be correlated to plant functional status.

FLUORESCENCE - BEYOND LAI (2)



FLUORESCENCE - BEYOND LAI (3)

Fluorescence tracks the seasonal activity of actual photosynthesis.



boreal forest
(Nove Hrady, Czech Republic)

○ steady-state fluorescence

● standard deviation of fluorescence

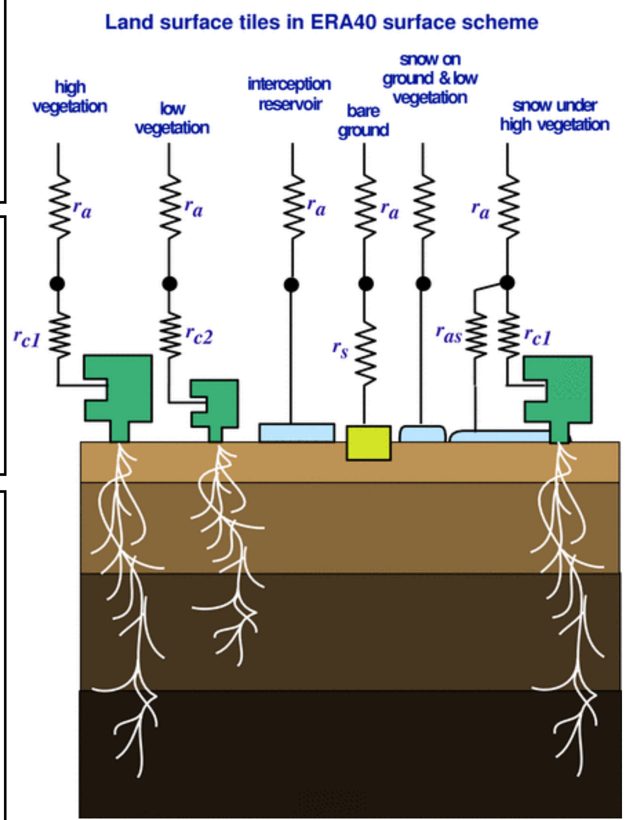
Activation and deactivation determine the annual balance of carbon assimilation.

CONCLUSION (1)

Surface Soil Moisture
- ERS scatterometer (1991- present)
- ASCAT (2006 – present)
- AMSR (2002 – present)
- SMOS (2009 – 2012 [2014])
- SMAP (2014)

Surface (Snow) Temperature
- AVHRR (1978 – present)
- Meteosat / GOES (1975/77 –present)
- MODIS (1999 – present)
- MERIS (2002 – present)
- SLST (Sentinel-3) (from 2013)

Snow (Water Equivalent, Fractional Coverage, Albedo)
- SMMR (1978 – 1986)
- SSM/I (1987 – present)
- AMSR (2002 – present)
- AVHRR (1978 – present)
- Meteosat / GOES (1975/77 –present)
- MODIS (1999 – present)
- MERIS (2002 – present)
- MSI (Sentinel-2) and OLCI (Sentinel-3) (from 2013)



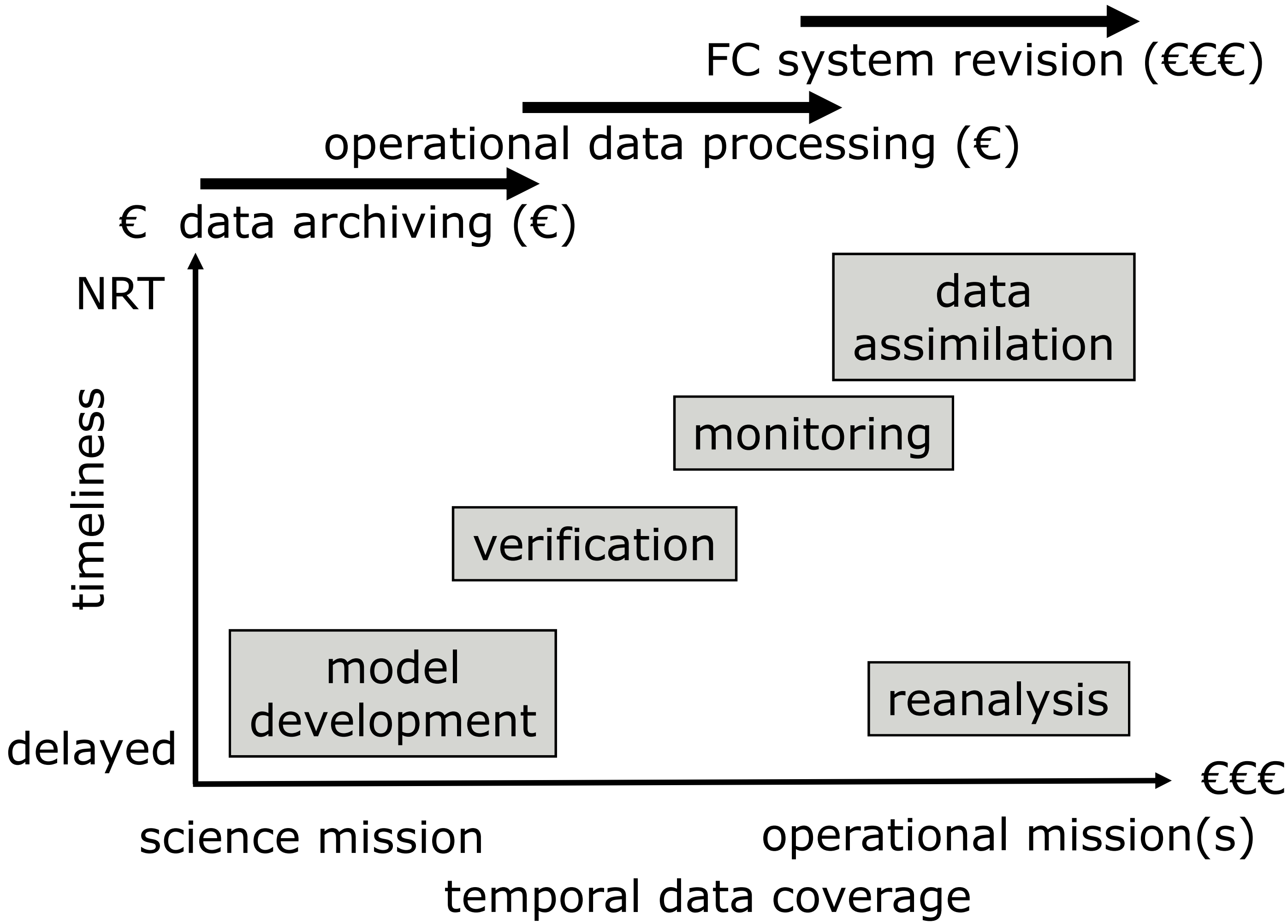
Vegetation Parameters:

- **Albedo**
- **Land Cover Type**
- **Land Cover Dynamics**
- **Leaf Area Index**
- **Normalized Vegetation Difference Index**
- **Burned Area**
- **Surface IR Emissivity**
- **Fraction of Photosynthetically Active Radiation**
- **Gross Primary Productivity**
- **etc …**

- AMSR (2002 – present)
- AVHRR (1978 – present)
- Meteosat / GOES (1975/77 –present)
- MODIS (1999 – present)
- MERIS (2002 – present)
- MSI (Sentinel-2) and OLCI (Sentinel-3) (from 2013)

There have been plenty of satellite data continuously available for a long time.

CONCLUSION (2)



CONCLUSION (3)

Many different satellite derived land surface data sets have been available for a long period, but they have hardly been used by the NWP community.

Satellite missions are expensive; RD to OD is expensive … there is a need for a consolidated roadmap for implementations. (recommendations and priorities)

Interest in snow and soil moisture observations is there and NWP centres started exploiting satellite observations / products. (following recommendations from the 2004 workshop)

So far, data from the TIR, NIR, SWIR and VIS spectral range have received very little attention and the description of vegetation is still rather poor (e.g. re-analyses use a fixed climatology). (not following recommendations)

There is a need to quantify the impact of observing systems (to ensure continuity).

SOME OPEN QUESTIONS

Would land surface data enter the DA system as Level 1 or Level 2 products?

Are there any specific requirements for radiative transfer codes / LUTs to address atmospheric corrections?

Which (vegetation) parameters would be most beneficial for NWP?

Is there a need to derive new (advanced) vegetation parameters describing the state of the vegetation and processes (e.g. stress) rather than vegetation structure?

The requirements for land missions are not coming from the NWP community. How will you quantify the value of a satellite mission / a specific parameter for your application?

Are the classical skill scores (z500) sufficient to evaluate the impact of land surface parameters?

THANK YOU

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