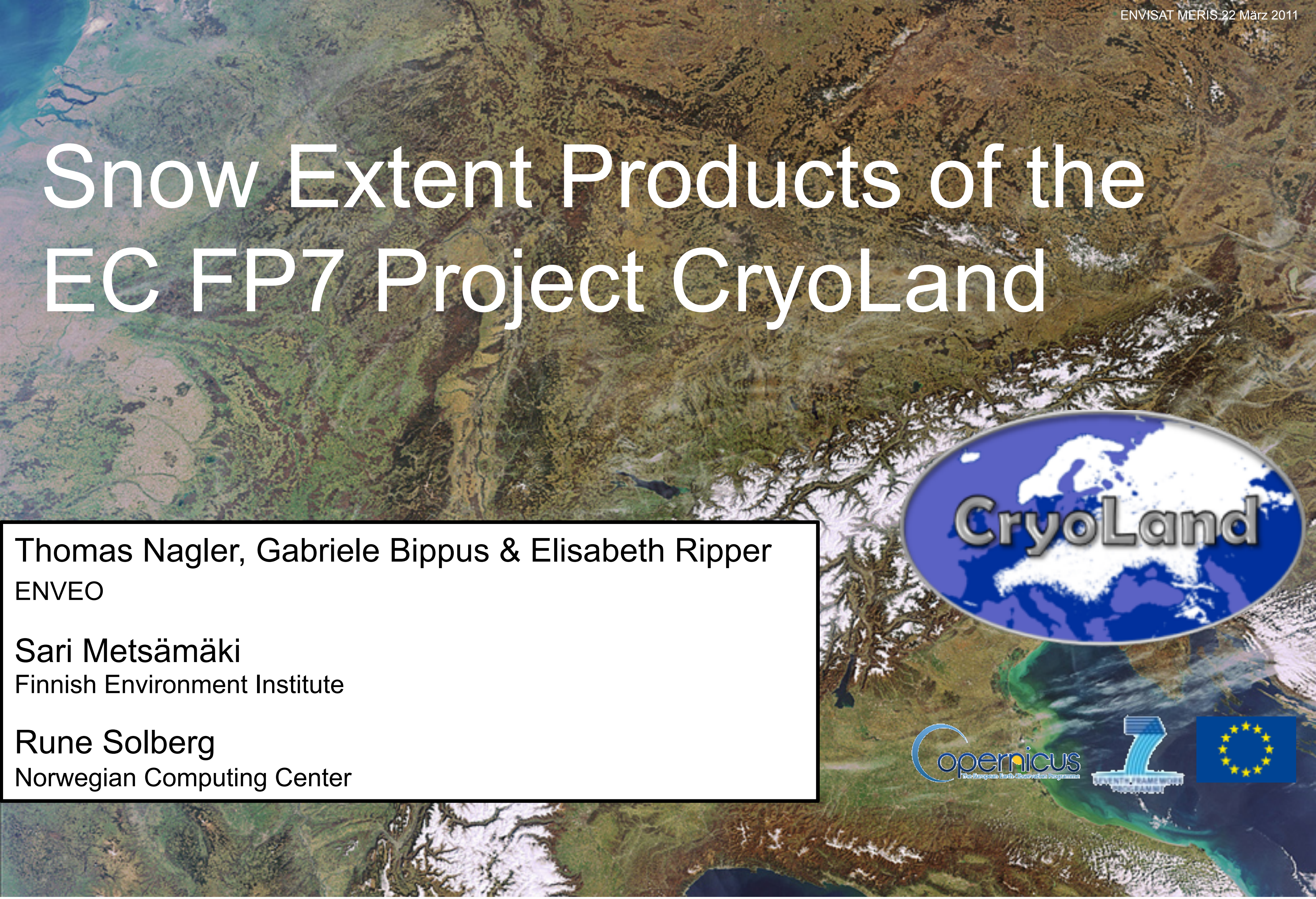

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Snow Extent Products of the EC FP7 Project CryoLand

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CryoLand – Copernicus Services Snow and Land Ice (EC FP7 Project 2011-2015)

PRIMARY OBJECTIVE

Develop, implement and validate an operational, sustainable service for monitoring snow and land ice as a Downstream Service within Copernicus Initiative of European Commission and ESA.

The project prepares the basis for a future cryospheric component of the Copernicus Land Monitoring Service.

Contents:

- Overview of CryoLand Snow Product
- Specs and Example Product of Pan European product
- Processing Line and Algorithm
- FSC Uncertainty map
- Validation method and results
- Intercomparison with other SE products
- Strength and weaknesses of the product

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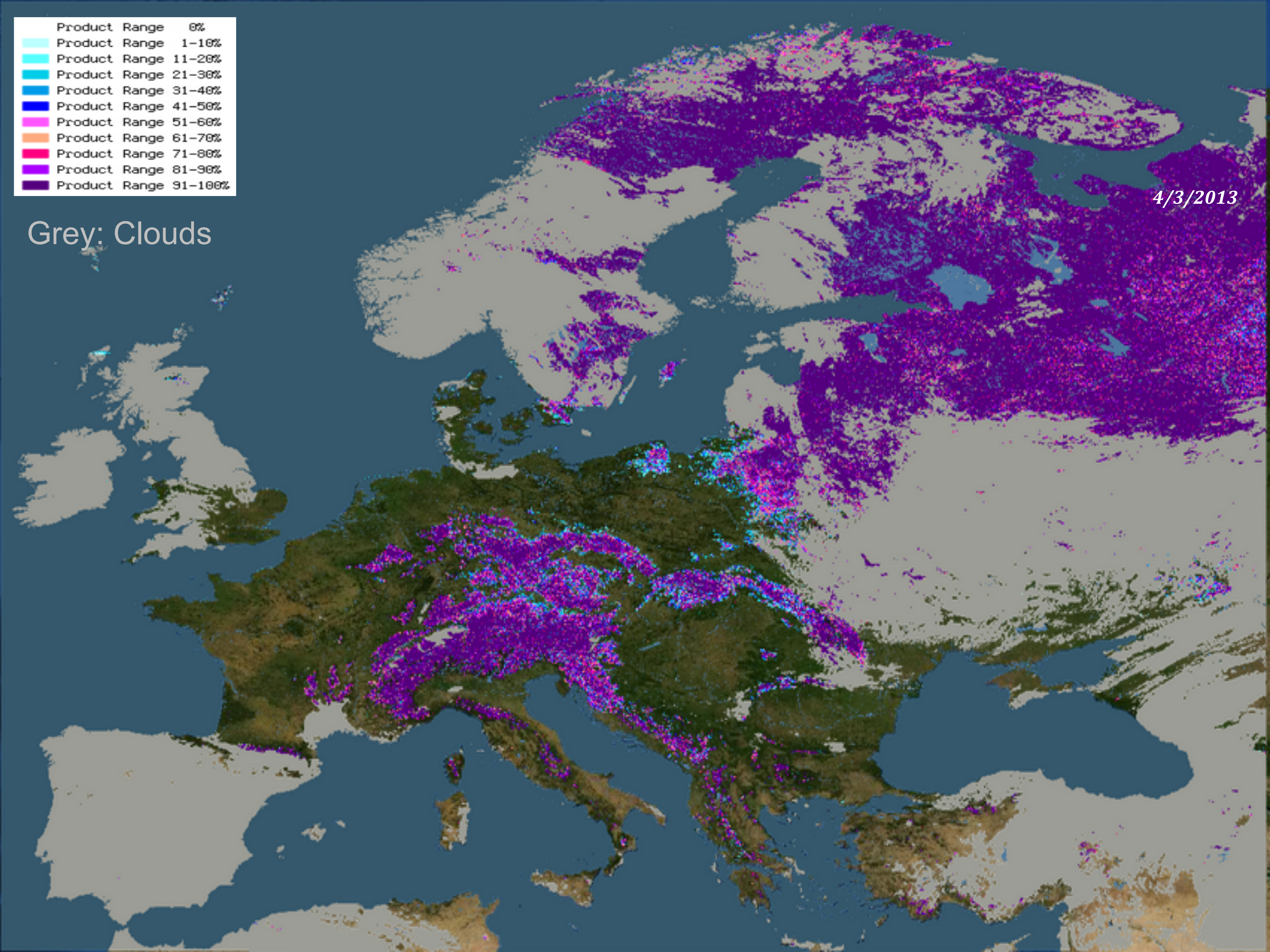
Cryoland Snow Products

Product Type	Spatial Resolution	Temporal Coverage	Coverage	Latency Time	EO Sensors
Snow extent, Pan-European	**500 m**	**Daily, full year**	**35N – 72 N 11W – 45E**	**<1 day**	**MODIS, (VIIRS, Sentinel 3)**
Snow Water Equivalent Pan-European	**10 – 25 km**	**Daily, dry snow season**	**35N – 72 N 11W – 45E**	**<2 day**	**SSMI/S, AMSR2**
Melting snow area	**50-100 m**	**Daily, Melting Period**	**Mountain Regions**	**<1 day**	**Radarsat, ASAR (archived), Sentinel S1**
Snow extent FSC ALPS	**250 m**	**Daily, full year**	**Alps**	**<1 day**	**MODIS Sentinel S1, S3**
Snow extent FSC, Baltic region	**500 m**	**Daily, winter / spring**	**Baltic Sea area**	**<1 day**	**MODIS Sentinel S1, S3**
Multitemp.. Snow extent, Scandinavia	250 m	Daily, full year	Scandinavia	< 1day	MODIS, SAR
Snow Surface Wetness	1000 m	Daily	Scandinavia	<1 day	MODIS, Sentinel S3
Snow Surface Temperature	1000 m	Daily	Scandinavia	<1 day	MODIS, Sentinel S3

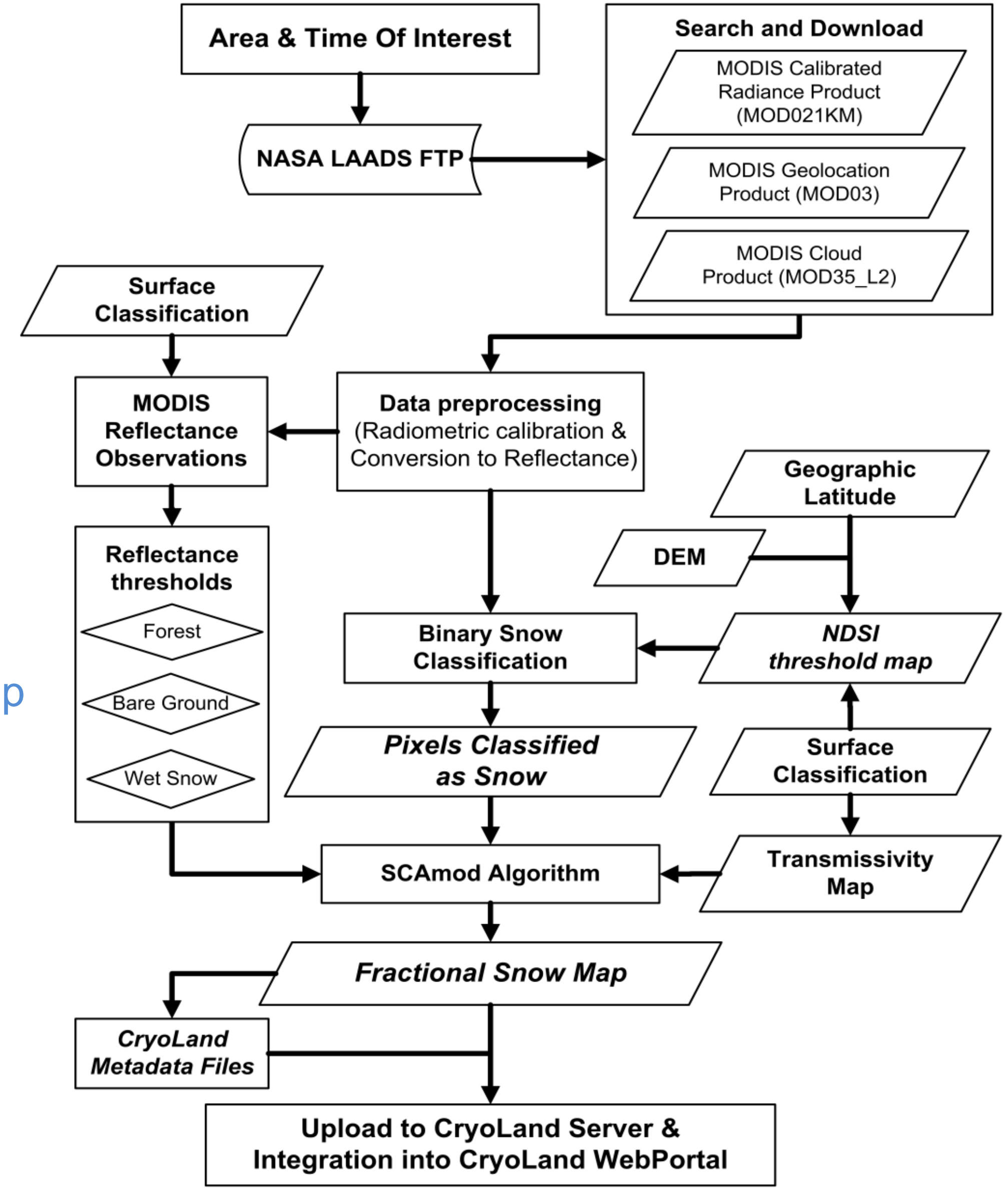


Product Range 0%
Product Range 1-10%
Product Range 11-20%
Product Range 21-30%
Product Range 31-40%
Product Range 41-50%
Product Range 51-60%
Product Range 61-70%
Product Range 71-80%
Product Range 81-90%
Product Range 91-100%
Grey: Clouds
4/3/2013

Product Name	CryoLand PanEuropean Fract. Snow Extent
Sensor and applied spectral bands	MODIS (VIIRS; Sentinel-3 SLSTR & OLCI): 550 mm; NDSI
TEMPORAL CHARACTERISTICS	
Period (Start – End)	Nov 2000 → Current
Temporal resolution (1 day, 1 week, ..)	Daily; since Dec 2013 in NRT (Latency < 1 day)
SPATIAL CHARACTERISTICS	
Spatial resolution / Pixel size	~500 m (0.05 deg)
Spatial Coverage	Pan-European Domain; 72°N 11°W – 35°N 50°E
Map Projection / Datum	Geographic Lat / Lon, WGS84
IF APPLICABLE: CLOUD SCREENING	
Algorithm / Product	MODIS Cloud product
IF APPLICABLE: VALID / NON-VALID AREAS	
Invalid/masked areas	Open Water Areas
Product Format	GEOTIFF
Products accessible at	http://cryoland.eu
Contact Person Name email	Thomas Nagler Thomas.nagler@enveo.at

Processing Chain

- Input Satellite Data:
  MODIS (VIIRS, Sentinel 3)
- Auxiliary Data: Surface Classes (Corine 2006, ESA GlobCover 2009, SRTM Water Body Map)
- Cloud Screening: apply MODIS Cloud product
- Binary snow pre-classification using NDSI threshold map (temporally and spatially variable thresholds)
- SCAmod algorithm applied on pixels classified as snow (500 m transmissivity map and predefined reflectance thresholds for forest canopy, bare ground and wet snow)
- Merging of FSC maps of different swaths looks for highest solar elevation angle and lowest sensor look angle.
- Product: Fractional Snow Cover Map and Uncertainty Map



Snow Mapping Algorithm

Algorithm is similar to GlobSNOW SE

STEP 1: Detection if SNOW is possible

- *NDSI threshold is linearly changing with:*
  - Latitude: **58°N (-0.10) - 35°N (+0.50)**
  - Elevation: **above 500 m a.s.l.** decrease of NDSI with **0.01 per 100 m** elevation
  - Seasonal Cycle of NDSI threshold
  - Specific surface classes: rice fields, permanent irrigated lands, salt marshes, salines, and inter-tidal flats from Corinne Land Cover 2006 data set: **+0.70**
- *Brightness Temperature: if* T_B(10.78µm-11.28µm) >= 283 K *then* FSC = 0

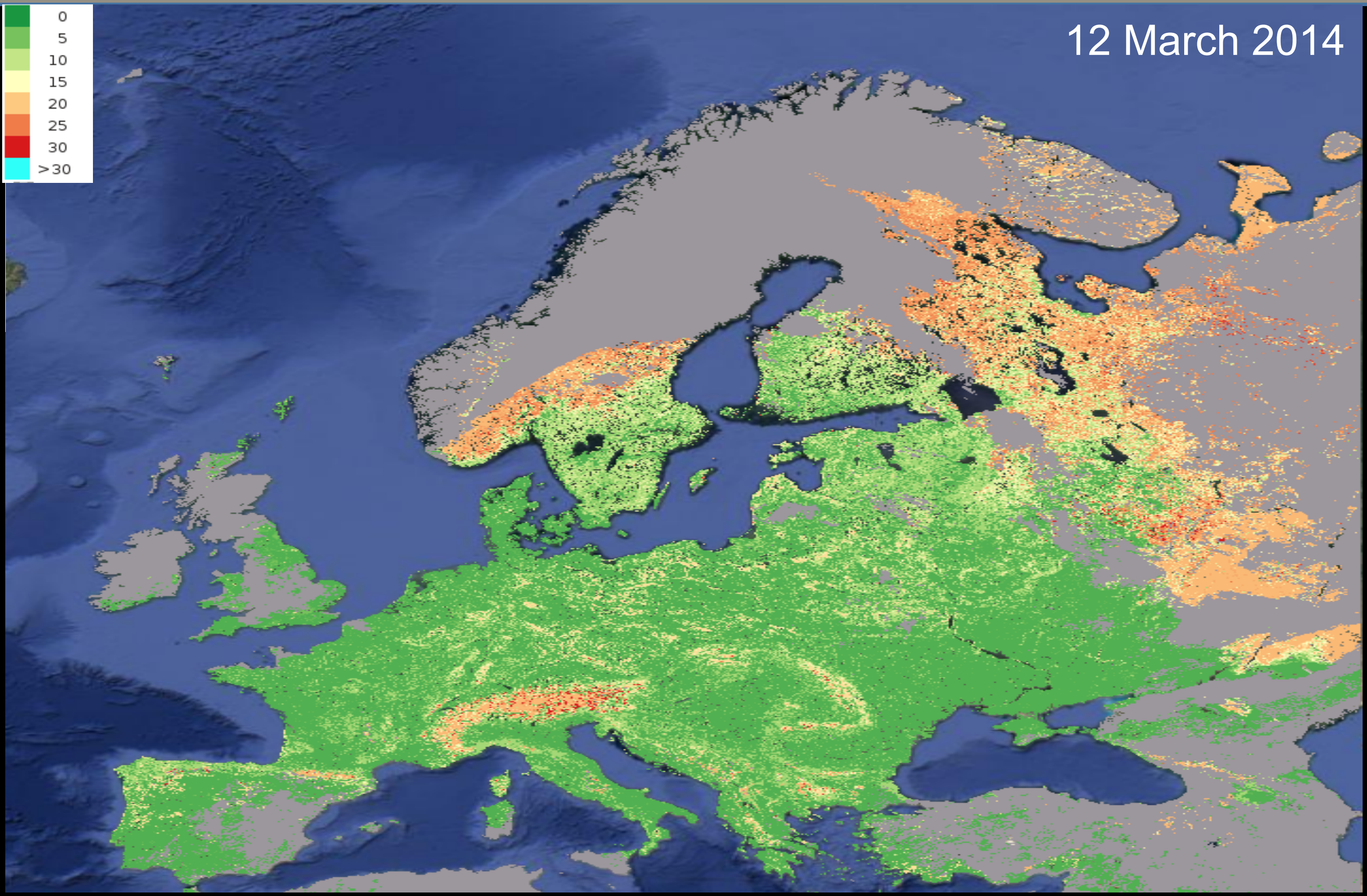
STEP 2: For regions where SNOW is possible , apply SCAMOD for calculating FSC (Metsämäki et al, 2005, 2012):

$$FSC = \frac{1}{t^2} \rho_{obs} + \left(1 - \frac{1}{t^2}\right) \rho_{forest} - \rho_{ground} / \rho_{w}$$

(ρ_{obs} observed reflectance at 0.550 µm)

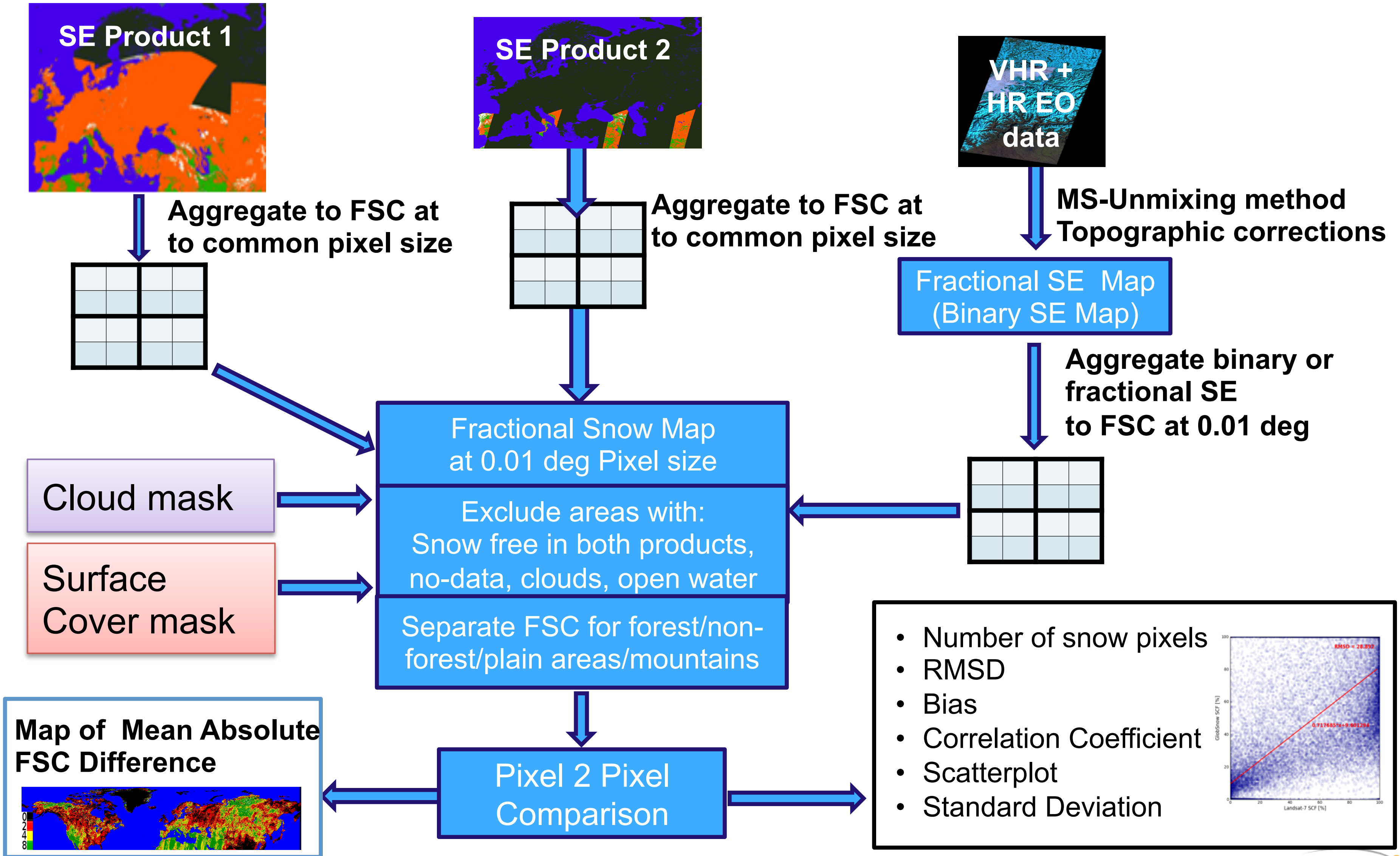
Typical reflectance values for: *$\rho_{wetsnow}$= 0.65 ρ_{forest}= 0.08 ρ_{ground}= 0.10*

FSC and Uncertainty map

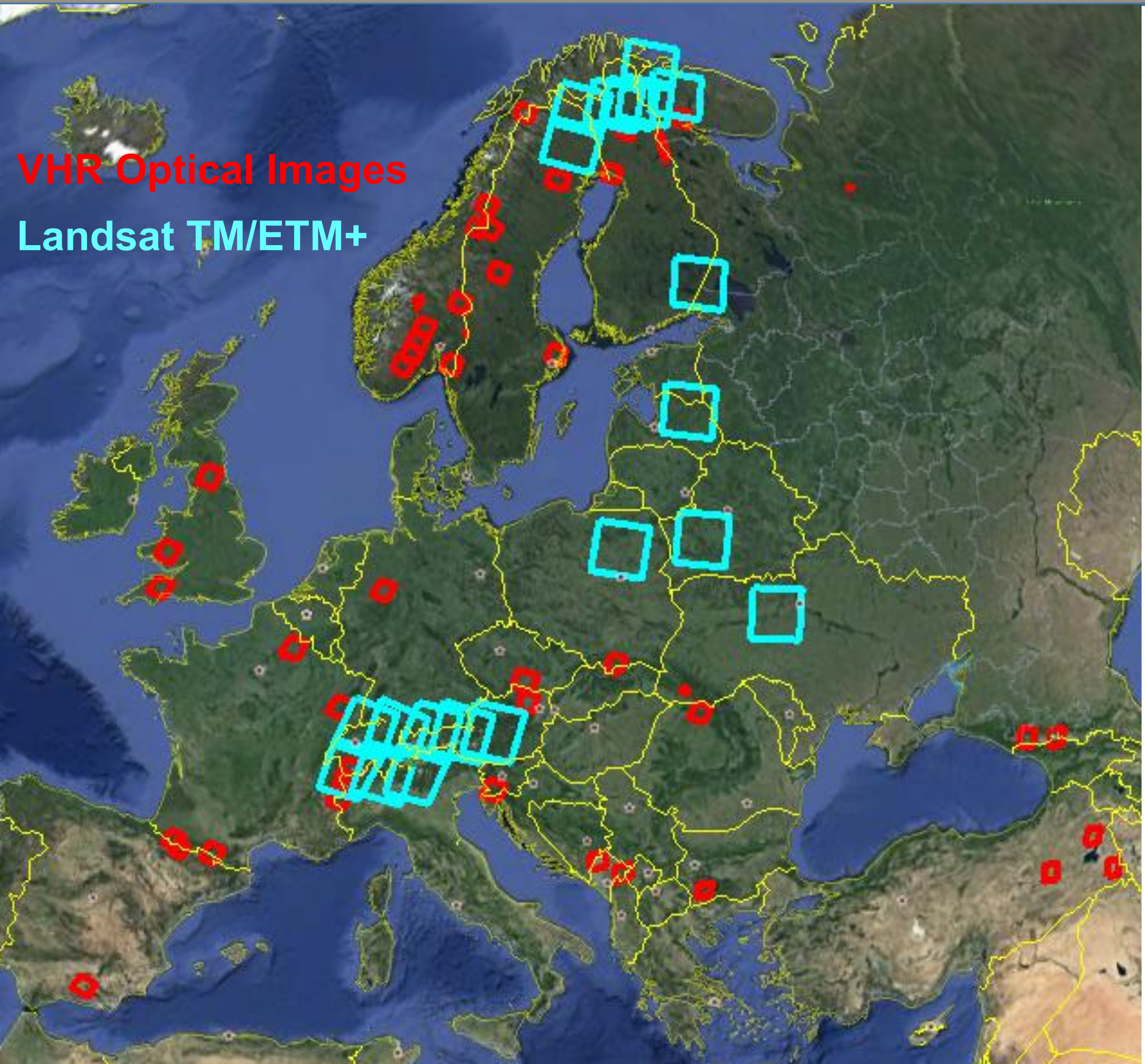


Uncertainty calculation applies law of error propagation to SCAMOD Function.
Total error is the sum of the error of the variables transmissivity $\mathbf{t^2}$, reflectance of ground, forest, swet now (ρ_{ground}, ρ_{forest}, ρ_{snow}). Variables are assumed to be inde[…].

Processing Line for SE Product Intercomparisons



Reference Data Sets for Quality Assessment



Quality Assessment of SE Products is performed in different environments:

- Fractional SE products from high resolution optical images:
  - Very High resolution images (IKONOS, SPOT5, Quickbird)
  - Landsat TM/ETM+
- In-situ snow transects measured operationally by SYKE, in Finland

Landsat ETM+ SE Maps

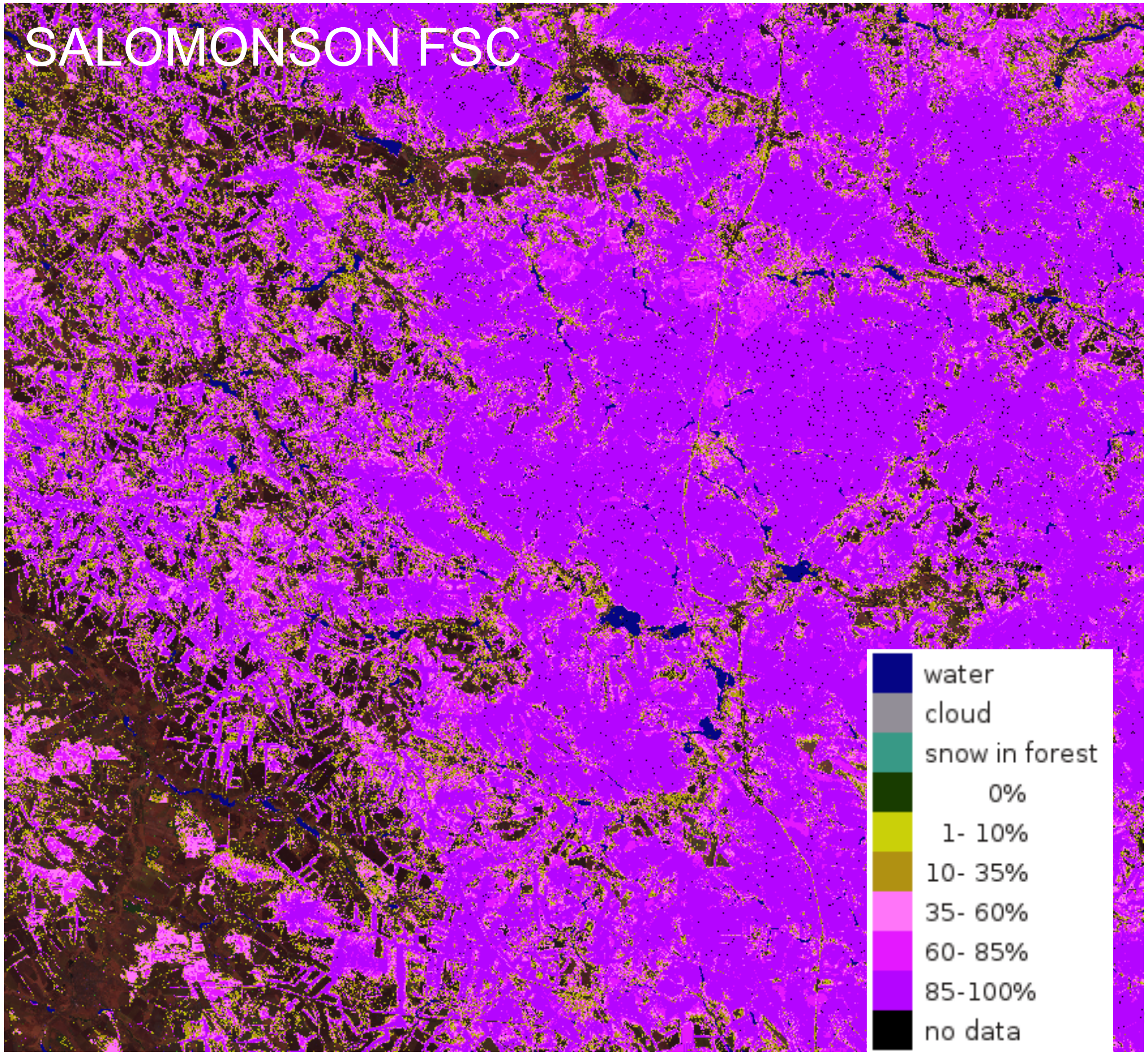
Dozier & Painter (2004)
- NDSI + NIR
- Added thresholds for $B_{0.55\mu m}$, $B_{0.8\mu m}$ and $B_{1.6\mu m}$

Klein et al (1998)
- NDSI and NDVI based
- Added thresholds for $B_{0.55\mu m}$, $B_{0.8\mu m}$ and $B_{1.6\mu m}$

ENVEO MS Unmixing
- MS Unmixing Bnd 1-5 with 2 endmembers (snow/ snowfree)

Salomonson & Appel (2006)
- NDSI
- Added Thresholds for $B_{0.55\mu m}$, $B_{0.8\mu m}$ and $B_{1.6\mu m}$

Ukraine 23 March 2010

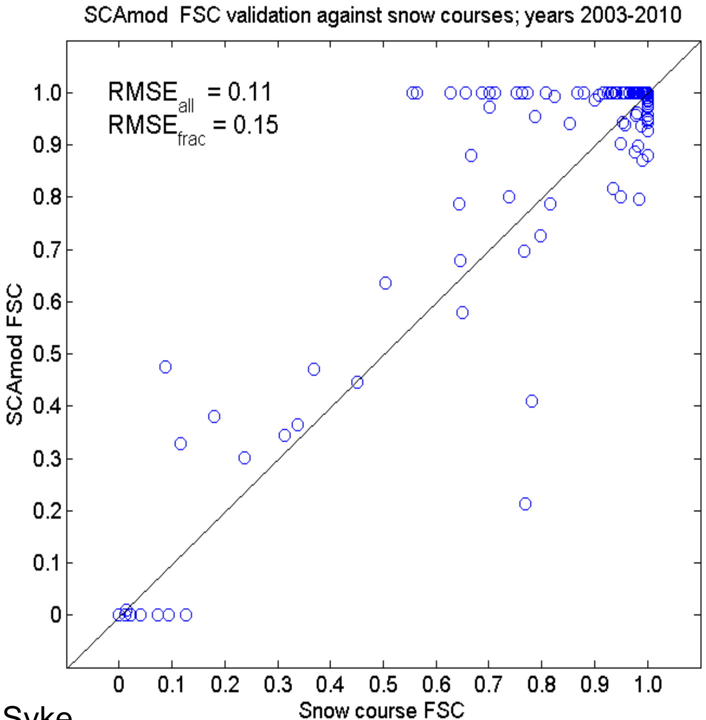


Intercomparison of Cryoland FSC vs. LS

Date	Location	Nui	Corr Coef	unbiased RMSE	BIAS	Corr Coef	unbiased RMSE	BIAS
			Salomonson (fsc)			Klein (bin)		
			TOTAL area					
5 Apr 2005	ALPS (mountains)	137219	0.91	16.84	-1.44	0.90	17.24	-1.10
30 Apr 2005	SWEDEN (forest)	135765	0.90	17.69	-6.89	0.87	20.10	7.26
7 Mar 2010	ROMANIA (gentle)	127492	0.95	14.38	2.66	0.92	17.38	4.43
23 Mar 2010	UKRAINE (flat)	140086	0.88	18.15	13.74	0.87	20.03	13.81
			FORESTED area					
5 Apr 2005	ALPS	46855	0.71	19.21	-4.15	0.69	19.33	-3.47
30 Apr 2005	SWEDEN	80501	0.89	18.55	-7.48	0.85	21.39	10.33
7 Mar 2010	ROMANIA	5552	0.94	16.41	-5.59	0.96	12.43	3.49
23 Mar 2010	UKRAINE	15611	0.72	25.58	14.68	0.70	29.04	20.43
			UNFORESTED area					
5 Apr 2005	ALPS	90364	0.94	15.24	-0.03	0.93	15.93	0.13
30 Apr 2005	SWEDEN	55264	0.91	16.31	-6.04	0.90	17.11	2.78
7 Mar 2010	ROMANIA	121940	0.95	14.17	3.03	0.92	17.56	4.48
23 Mar 2010	UKRAINE	124475	0.91	16.99	13.62	0.90	18.41	12.98

Validation Results CryoLand FSC vs. In-Situ

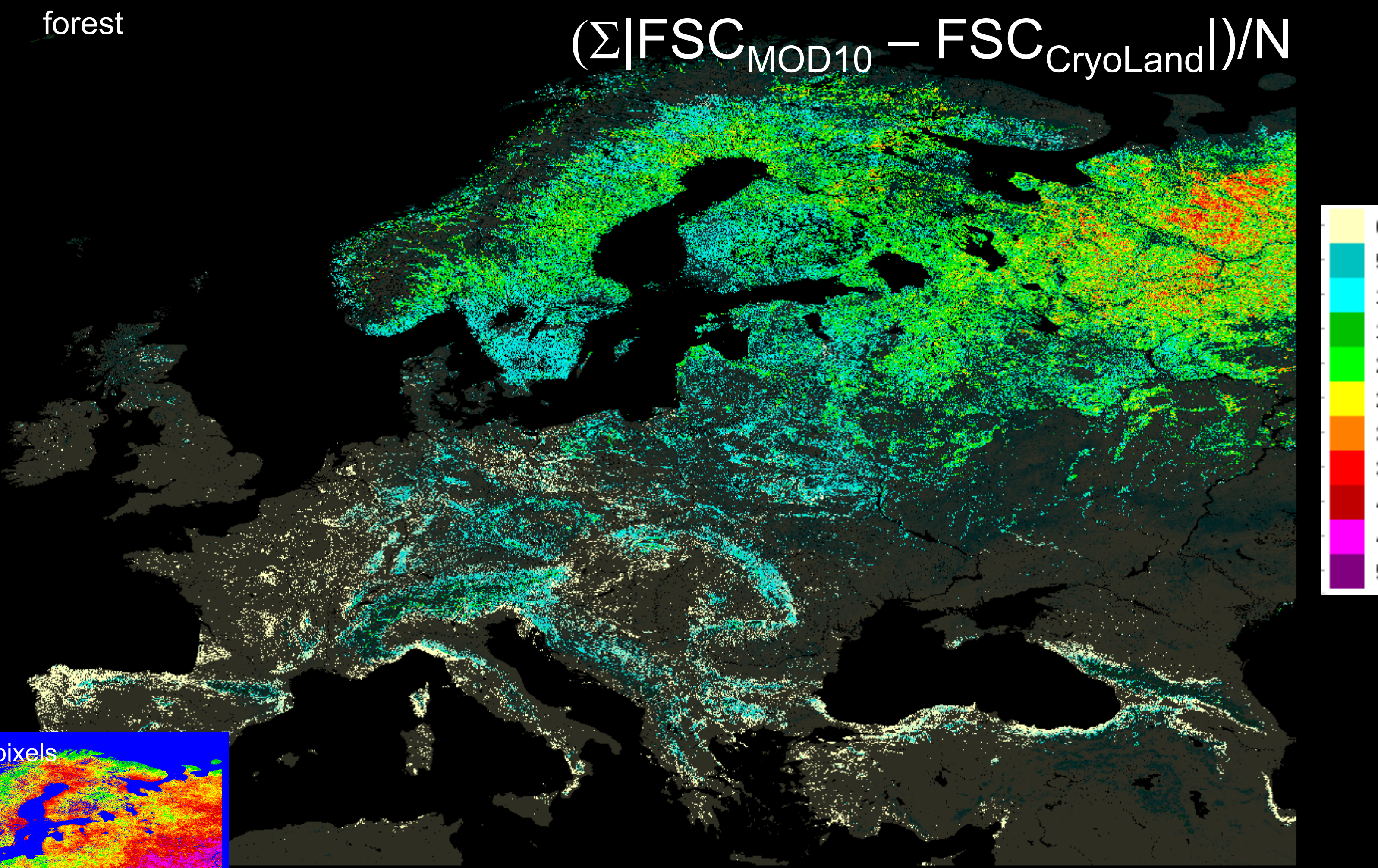
MODIS SCAMOD –
Pan European Product
In-situ Snow transects vs. FSC
Finland

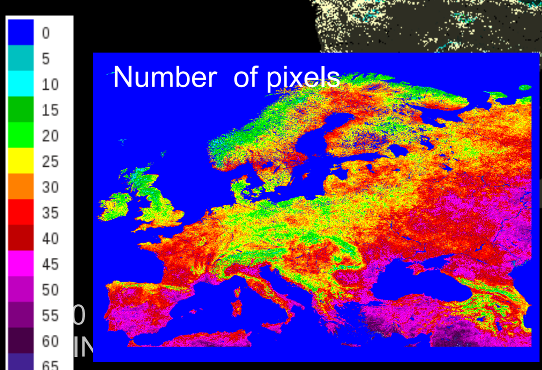


Syke

SYKE snow course network covers the entire Finland with over 100 active locations of observations.

Mean Absolute FSC Difference MOD10 versus CryoLand / MODIS 1.3.-31.5.2010





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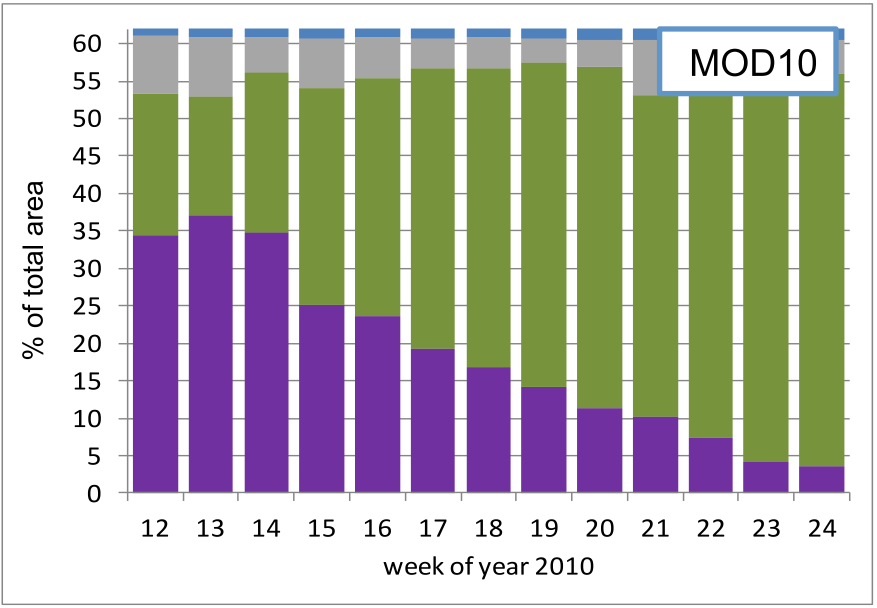
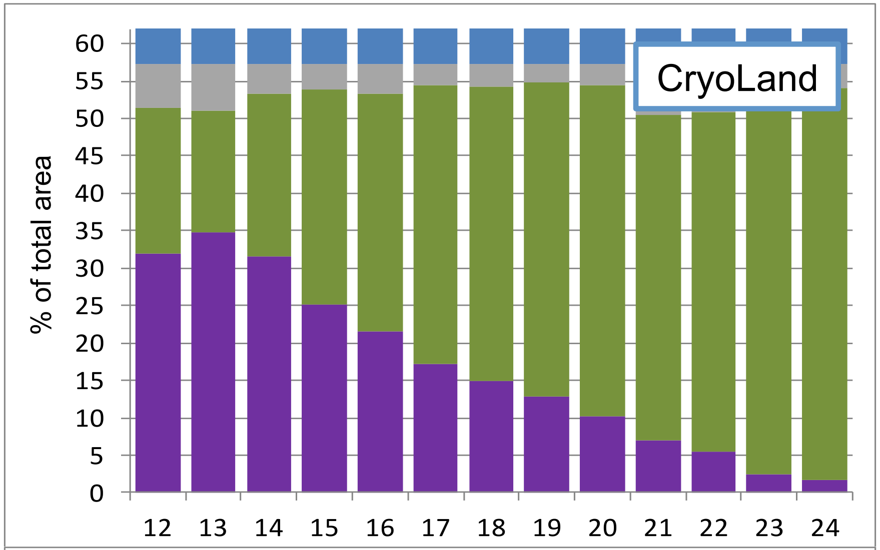
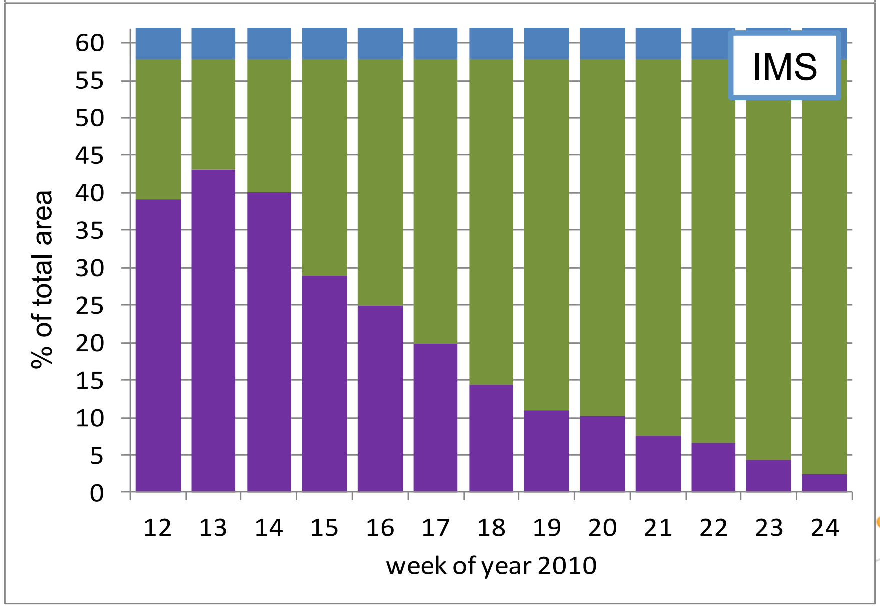
Time series of weekly Max. Snow Extent







Pan-European Domain
March – May 2010

- snow extent
- snow free
- cloud
- open water

Strength and Weaknesses

- Each FSC map is provided with uncertainty map.
- FSC product has been validated with independent snow information (snow data from high resolution sensors, insitu data) in different environments (ongoing).
- Cloud screening (MODIS Cloud product) problems in patchy snow areas, cumulus clouds in late spring/summer are not detected show often up as snow.
- Snow Algorithm:
  - Need of accurate and up-to-date auxiliary information (transmissivity map, reflectance values of different surfaces, inaccuracies / errors in auxiliary data directly propagate to FSC.
  - In mountain regions, topographic correction is critical. Currently, a statistical topographic correction is used.
- 14 years time series of daily FSC product of Europe available (Dec 2000).
- Covers only Pan-European Domain, an extension is possible but currently not planned.

Strength and Weaknesses of Cryoland PanEuropean FSC product

- FSC Retrieval
  + Multi-spectral Pre-classification rules significantly reduces misclassifications, and extend the applicability of the algorithm, which was original designed for boreal forests, to other environments.
  + Algorithm is applicable to the main surface classes, with and without canopy layer, and accounts for forest canopy.
  + Low computational costs and fully automatic processing; therefore suitable for global / hemispheric time series production
  – Need of accurate and up-to-date auxiliary information (transmissivity map, reflectance values of different surfaces), generation of these data sets is currently labor intensive.
  – Inaccuracies / errors in auxiliary data directly propagate to FSC.
  – Complex terrain: sensitive to topopgraphy (variations of illumination) as only one band is used for FSC calculation. Simple topographic corrections improves results, but not sufficient in rugged terrain. Better topographic correction of reflectance would improve product in mountain terrain.