Overview on the GlobSnow SE Product

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Outline

- **Work towards the SE product**
- **Current prototype product types**
- **Algorithms**
- **Product examples**
- **Preliminary evaluation results**
- **Most important known issues**
- **Towards a global product**
- **Conclusions**

Work towards the SE product

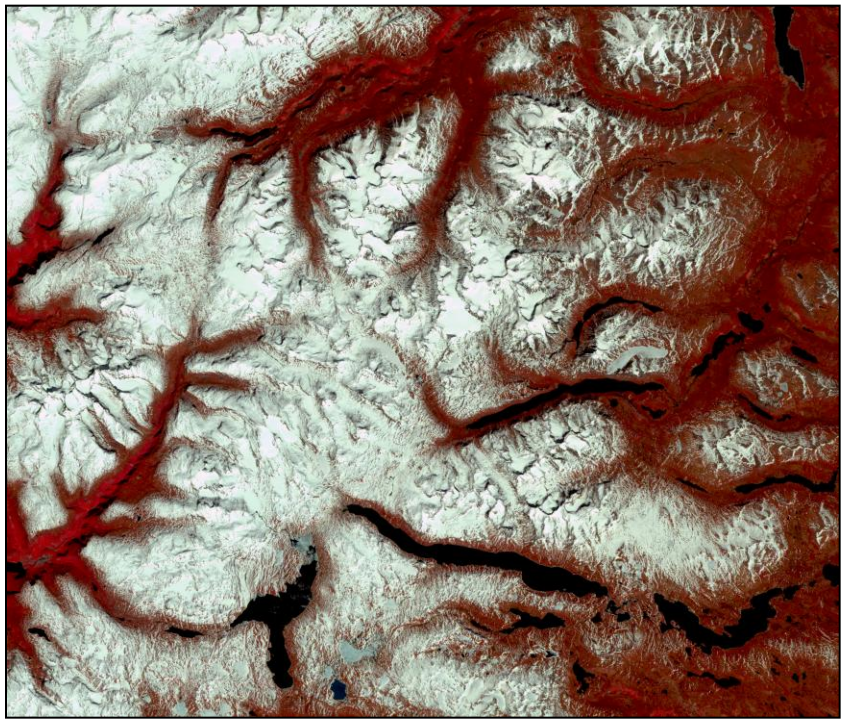
- **Requirements Baseline Document (January 2009)**
- **User Requirement Workshop (3 February 2009, Geneva)**
- **Evaluation of alternative algorithms at three test sites (May-June 2009):**
  - Finland (boreal forest)
  - Norway (mountains, non-alpine)
  - The Alps (alpine mountains)
- **Developed a lab processing system based on two selected algorithms generating pan-European products – stepping stone towards global coverage (June-September 2009)**
- **Evaluated pan-European maps against test site data, SYNOP data and NSIDC maps (September 2009)**
- **Generation of 3.5 years prototype product set (October-November)**

Proposed specification of SE product (RB)

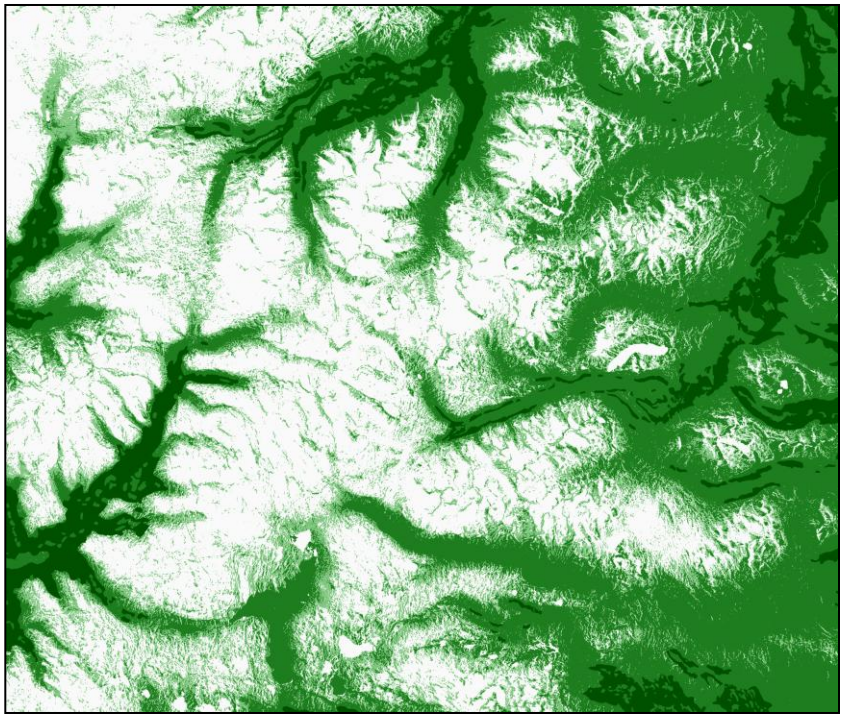
Parameter	***Specifications/Comments***
Coverage	Global
Time period	Starting 1995 (16 years of historical products at the end of the project in 2011)
Temporal frequency • Basic product • Secondary product	Weekly and monthly, with full global coverage, based on medium resolution optical imagery Daily. Daily repeat is not possible for global products; in case of optical imagery because of clouds; in case of SAR because of its insensitivity to dry snow (only wet snow can be detected) and because of limitations in data availability and costs. The relevance of such an intermittent product needs to be discussed with the users.
Spatial resolution	1 km globally for 1995-1999 (proposed sensor: ATSR-2) 2000 onwards 1 km globally and 250 m to 500 m for complex terrain (proposed sensors: ATSR-2, AATSR, MODIS)
Geometric accuracy	Sub-pixel (aiming at 0.5 pixel)
Thematic accuracy	Binary classification (snow/no-snow) with global total (pooled) error ≤ 5 % for open terrain, sparse forest and non-steep mountainous regions, at solar elevation > 20°. Temporal inference of snow in dark regions or masked as 'not observed'
Grid/projection	Geographic Grid (Latitude-Longitude)

Example of evaluation reference data

Jotunheimen mountain region, Norway, 30 May 2004, Landsat TM



Original Landsat TM image



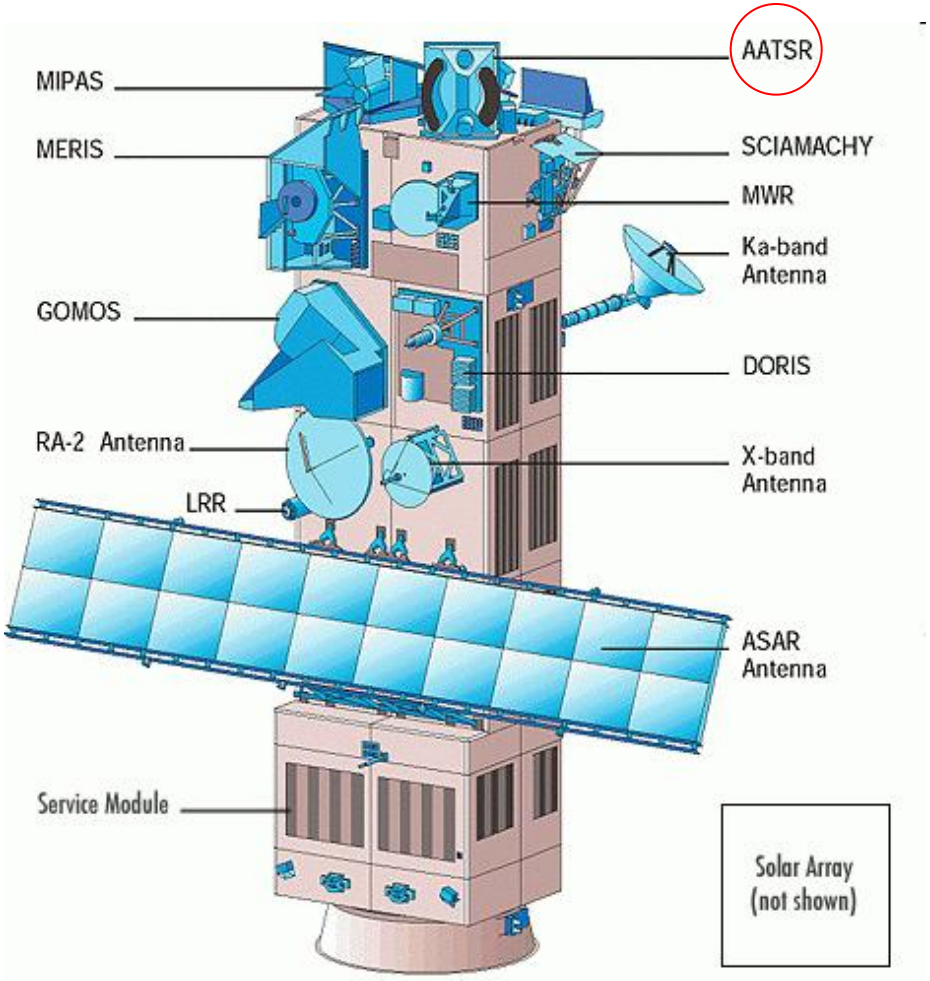
Semi-automatic classification result – reference snow map

Current prototype product types

- **Daily Fractional Snow Cover (FSC), snow fraction (%) per grid cell for all satellite overpasses of a given day**
- **Daily classified snow cover (4CL), snow cover classified into four categories per grid cell for all satellite overpasses of a given day**
- **Aggregated Fractional Snow Cover, FSC for all satellite passes within a given time period. (This is an experimental product currently covering ten days)**

Satellites and sensors

- **All products are based on:**
  - ERS-2 ATSR-2 (1995)
  - ENVISAT AATSR (2002)
- **Sensor bands:**
  - 0.555, 0.659 and 0.865 µm
  - 1,6, 3.7, 10.85 and 12 µm
- **Swath width:** 500 km
- **Pixel resolution:** 1 km at nadir



ENVISAT

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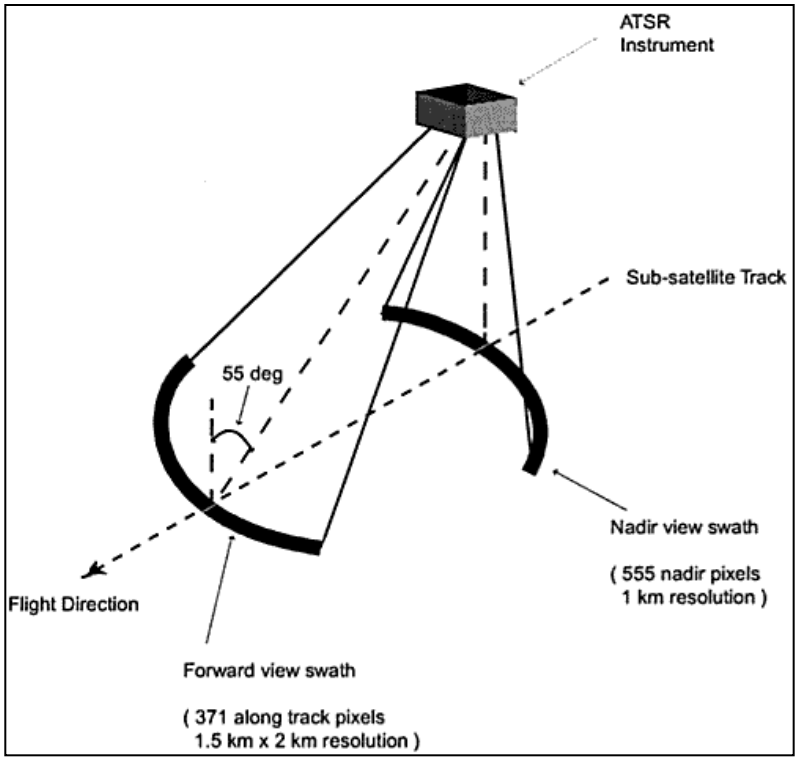
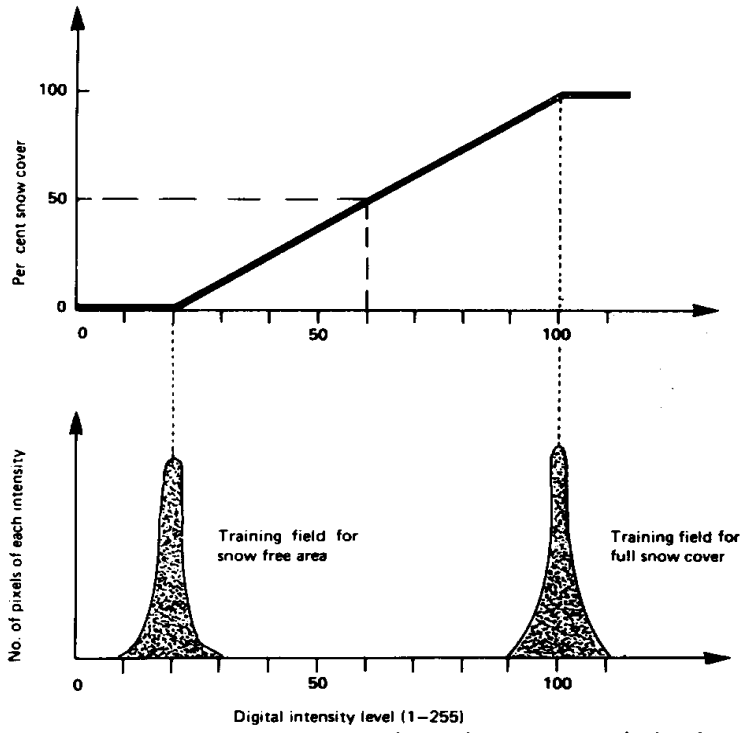


NLR: Two-class linear spectral unmixing

- **Two-class linear spectral mixing model applying VIS channel**
- **Regional calibration targets**
- **Implicit regional atmospheric correction**
- **Topographic correction**
- **Non-forested areas**
- **Tested on AVHRR, MODIS, MERIS and now AATSR**
- **References:**



Solberg R. and T. Andersen, 1994. An automatic system for operational snow-cover monitoring in the Norwegian mountain regions. *Proceedings of the International Geoscience and Remote Sensing Symposiu*m, 8-12 August 1994, Pasadena, California, USA: 2084-2086.

Solberg, R., J. Amlien, H. Koren, 2006. *A review of optical snow cover algorithms*. Norwegian Computing Center Note, no. SAMBA/40/06.

SCAmod algorithm

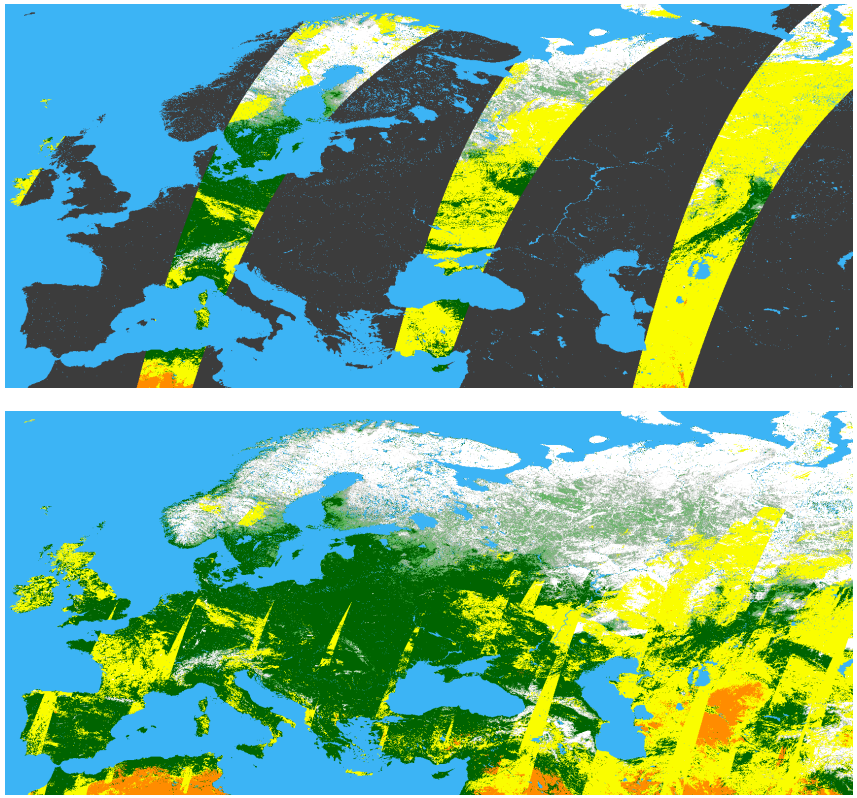
- **Reflectance constants for snow-free ground, forest canopy and wet snow (e.g. 7, 6, and 66)**
- **Transmissivity map giving the amount of reflected sunlight from the ground that could be observed from a satellite in forest areas ('local forest transmissivity')**
- **FSC can then be derived from observed reflectance based on the reflectance constants and the transmissivity values**
- **References:**

Metsämäki, S., S. Anttila, M. Huttunen, J. Vepsäläinen, 2005. A feasible method for fractional snow cover mapping in boreal zone based on a reflectance model. *Remote Sensing of Environment,* Vol. 95 (1):77-95.

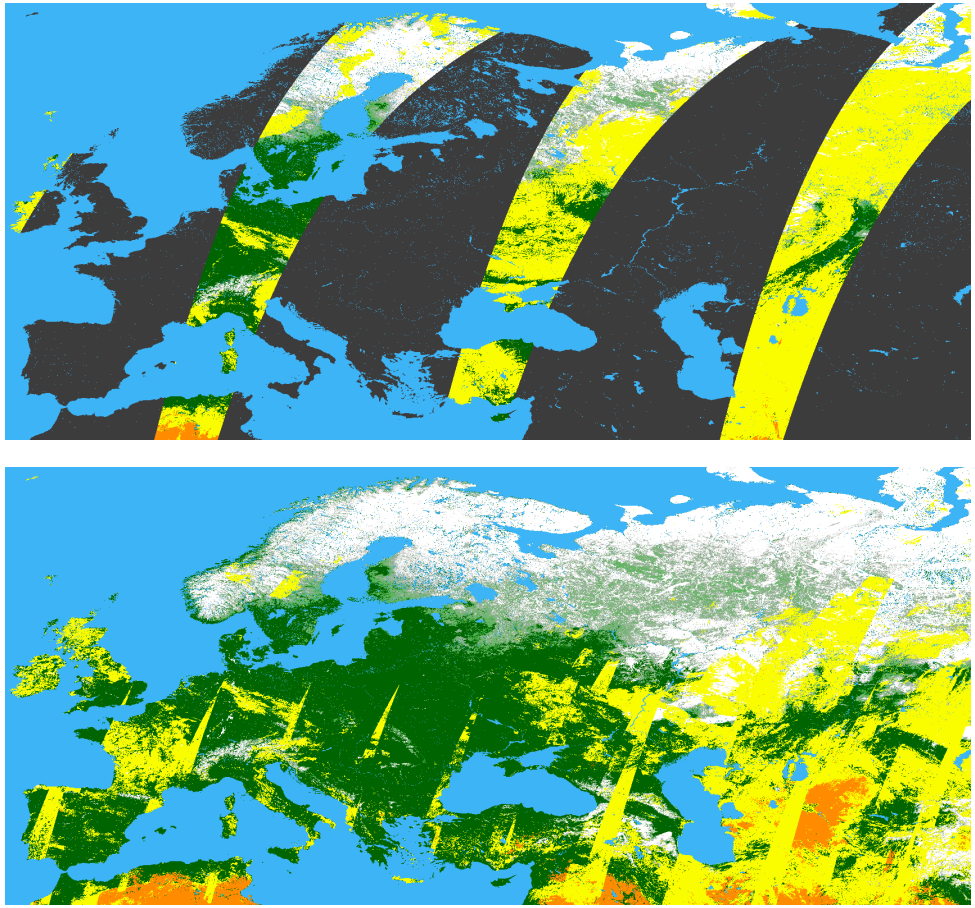
Salminen, J. Pulliainen, S. Metsämäki, A. Kontu, H. Suokanerva, 2009. The behaviour of snow and snow-free surface reflectance in boreal forests: Implications to the performance of snow covered area monitoring. *Remote Sensing of Environment*, vol. 113 (2009): 907-918.

Pan-European prototype product

- **Satellite data: ERS-2 ATSR-2 and ENVISAT AATSR**
- **Domain: 33N - 72N and 11W – 75E**
- **Geographical coordinate system (latitude/longitude)**
- **Reference system: WGS 84**
- **Grid resolution: 0.01 × 0.01 degrees**
- **Grid data:**
  - Snow variable: FSC (%) or 4CL (4 category labels)
  - The confidence of FSC retrieval. This is not included in version 0.9
  - Both layers are in 8 bit format



Product examples



Outside mapping area

Water

Not mapped in product time frame

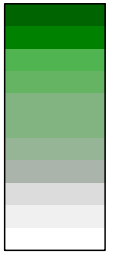
Too low solar angle for snow retrieval

Missing or invalid satellite data

Cloud

Snow retrieval algorithm breakdown

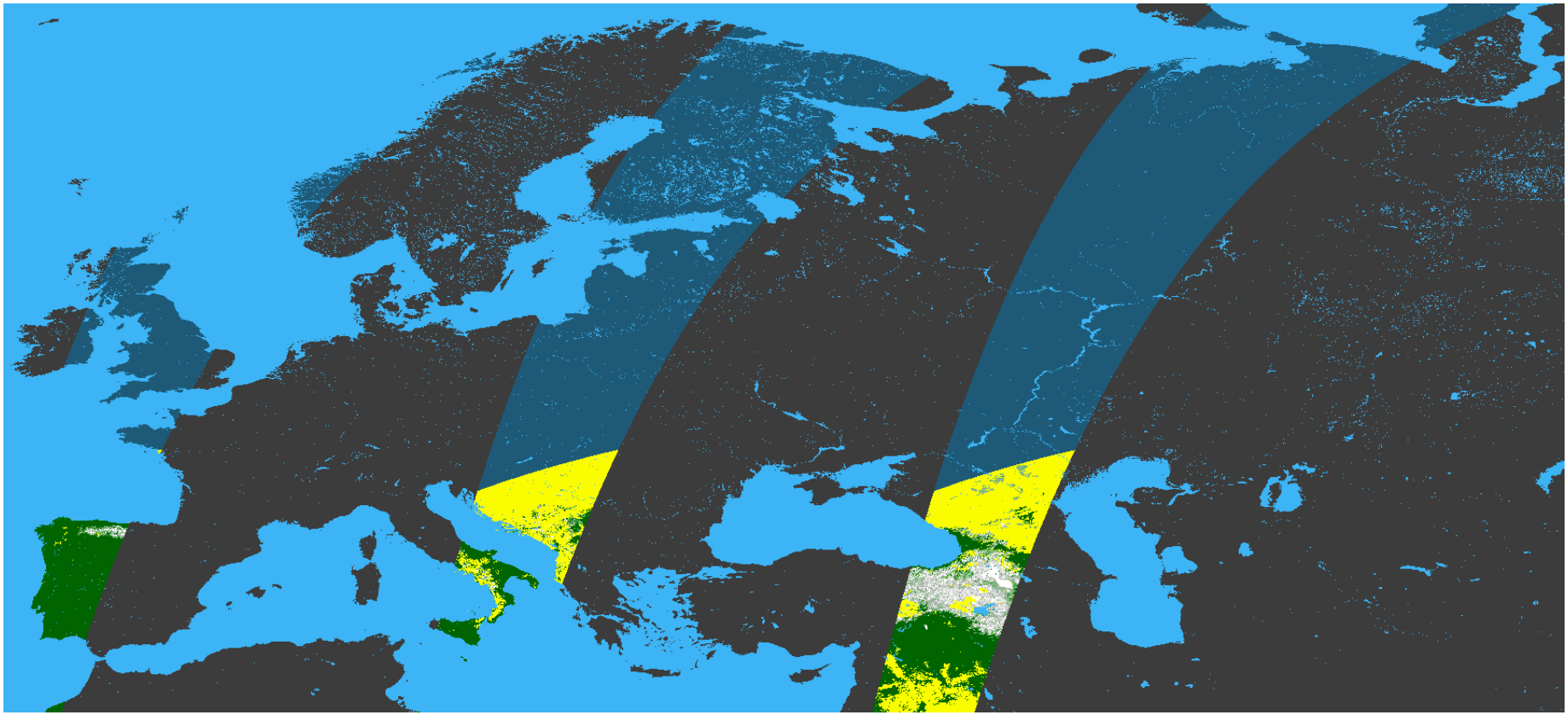
No snow retrieval algorithm applicable



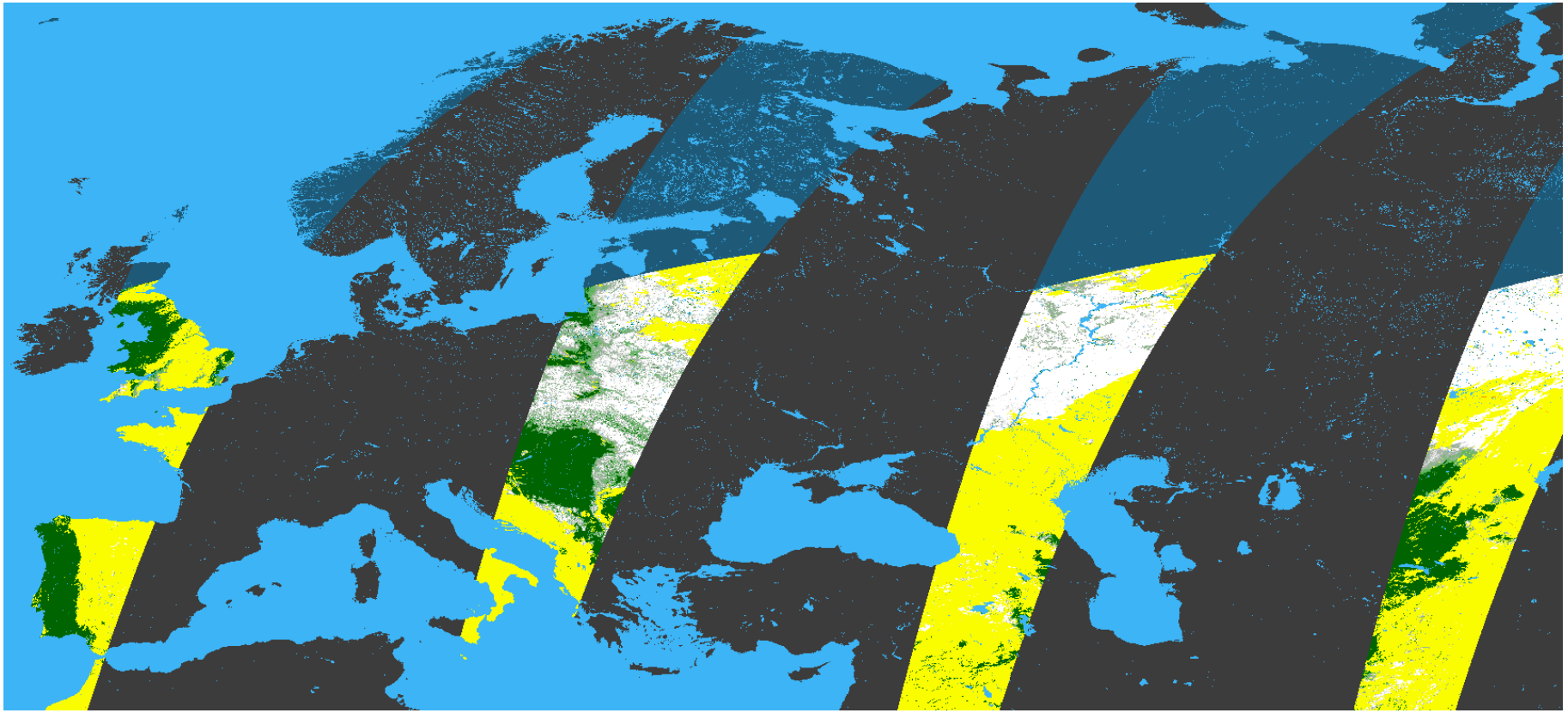
Fractional snow cover

Steps of 1% in product, steps of 10% in colour legend

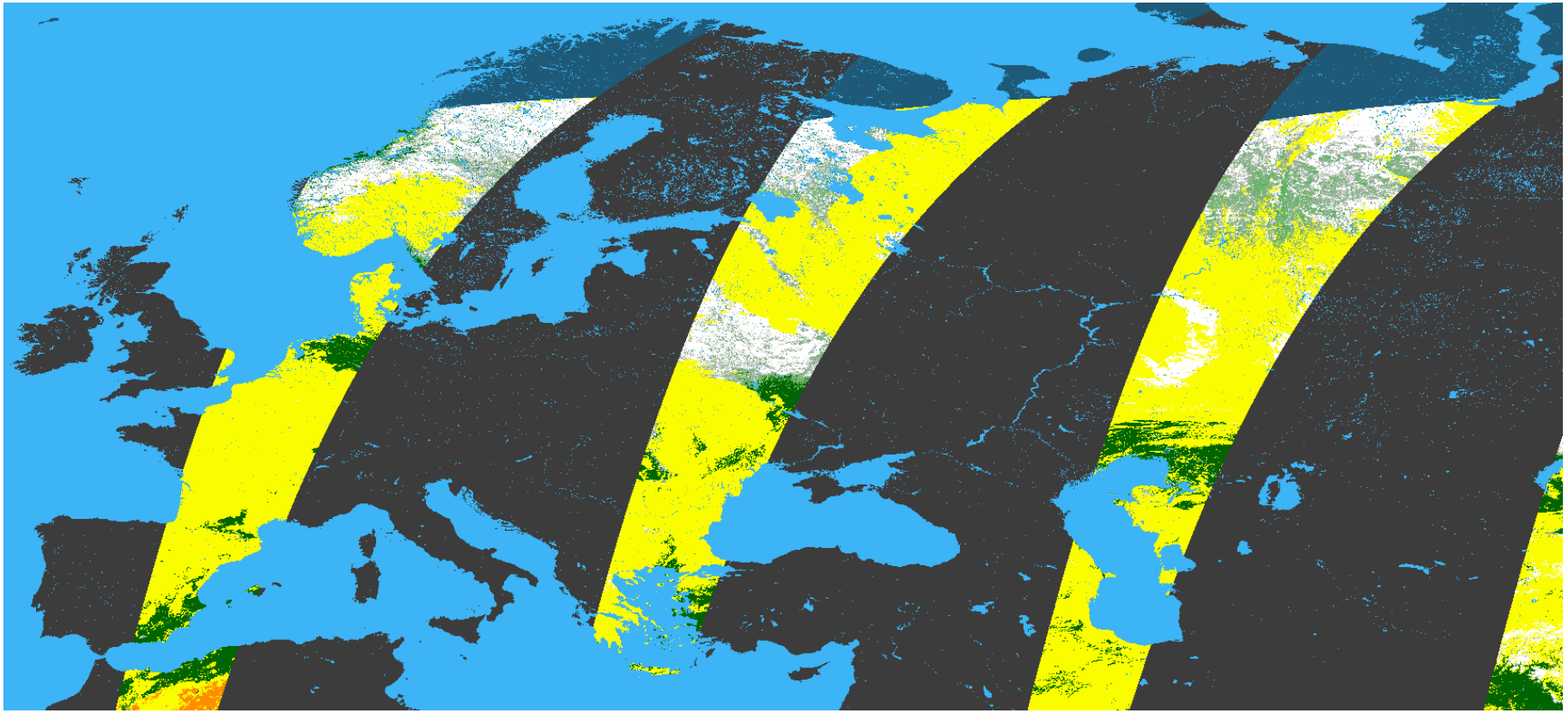
L3A 20.01.2004



L3A 21.02.2004



L3A 12.03.2004



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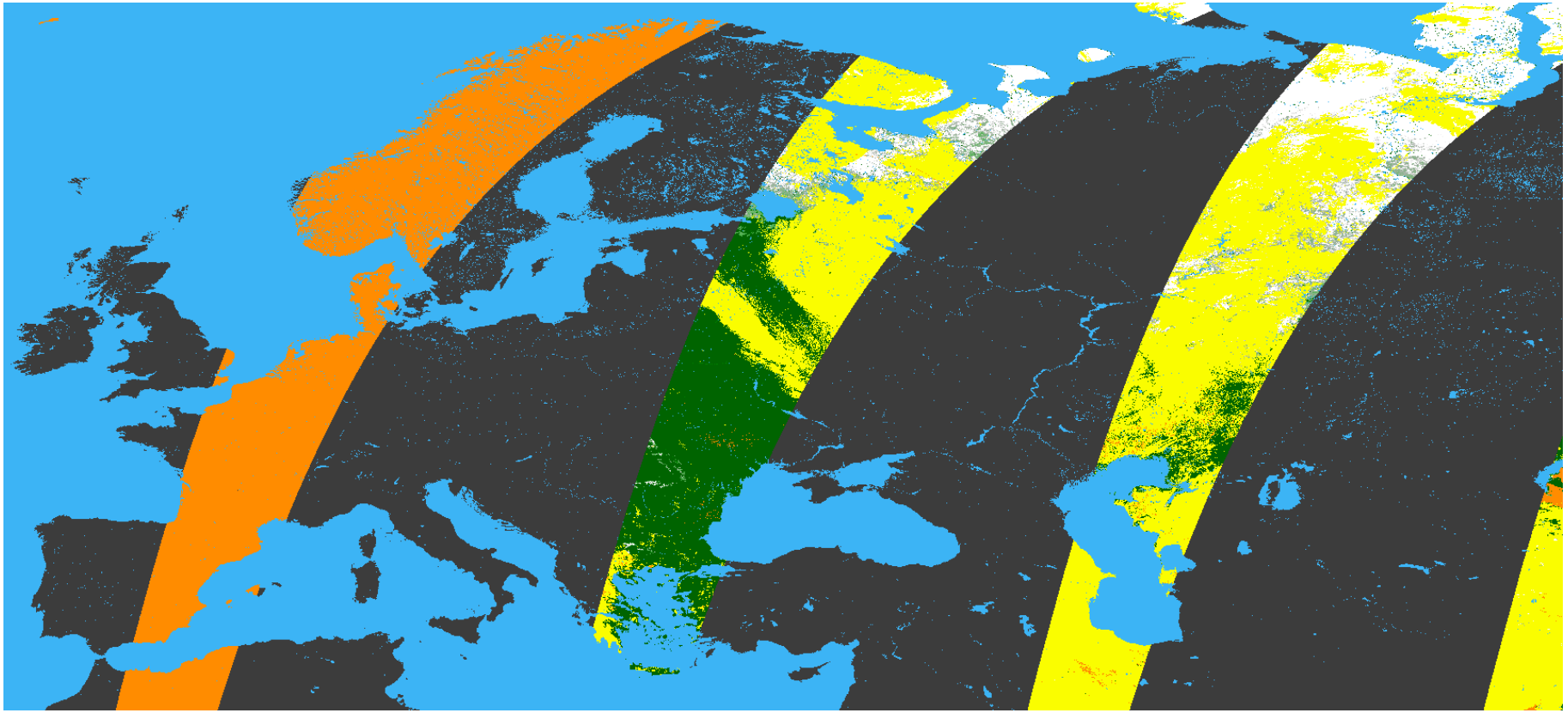

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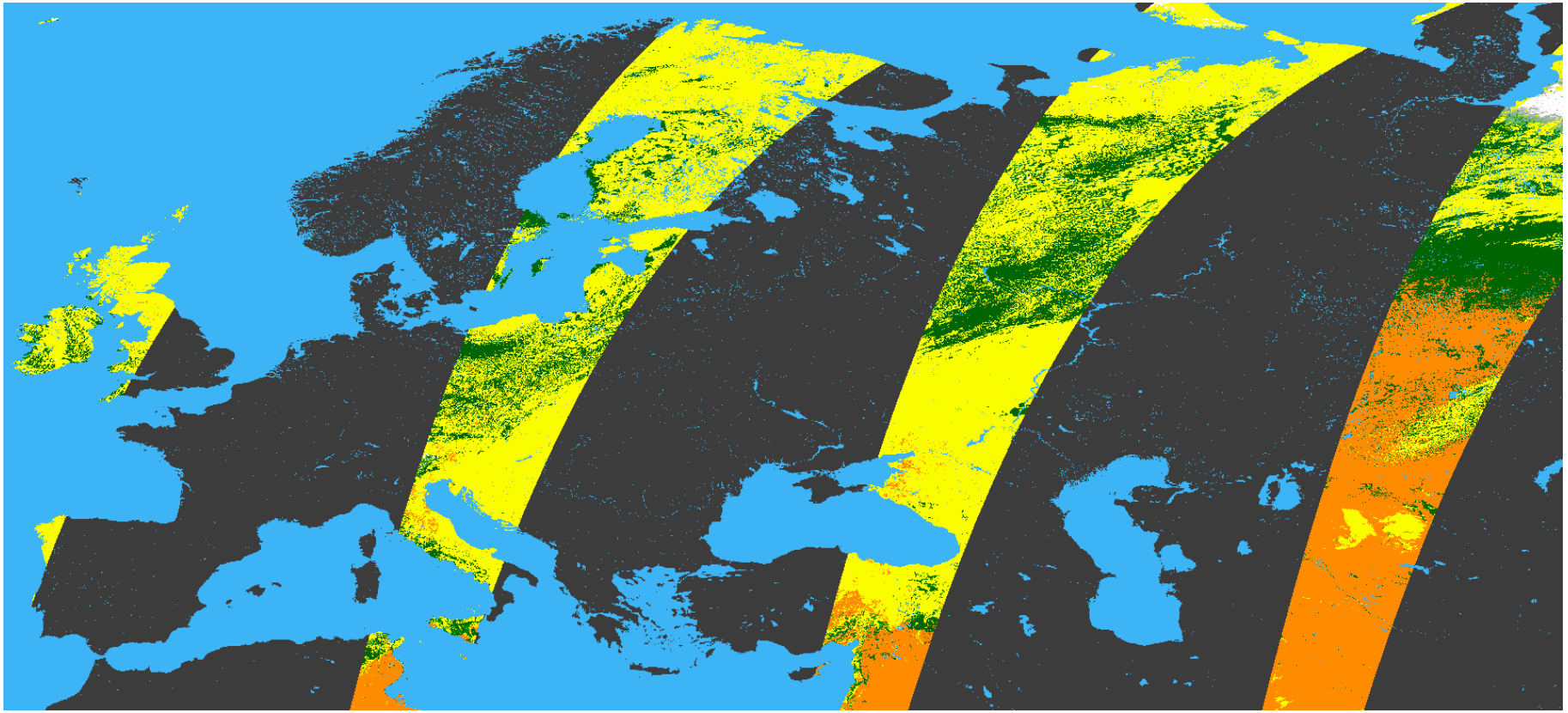
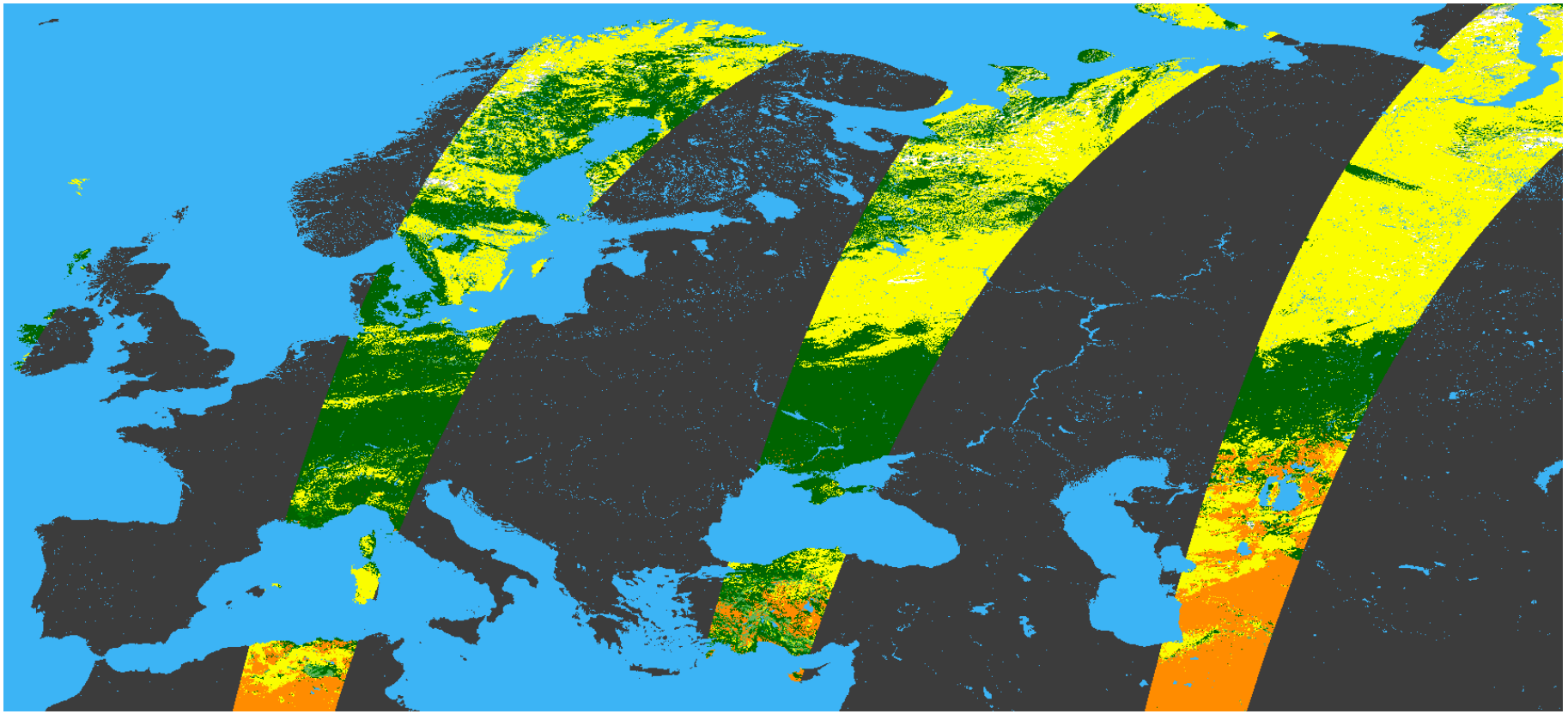
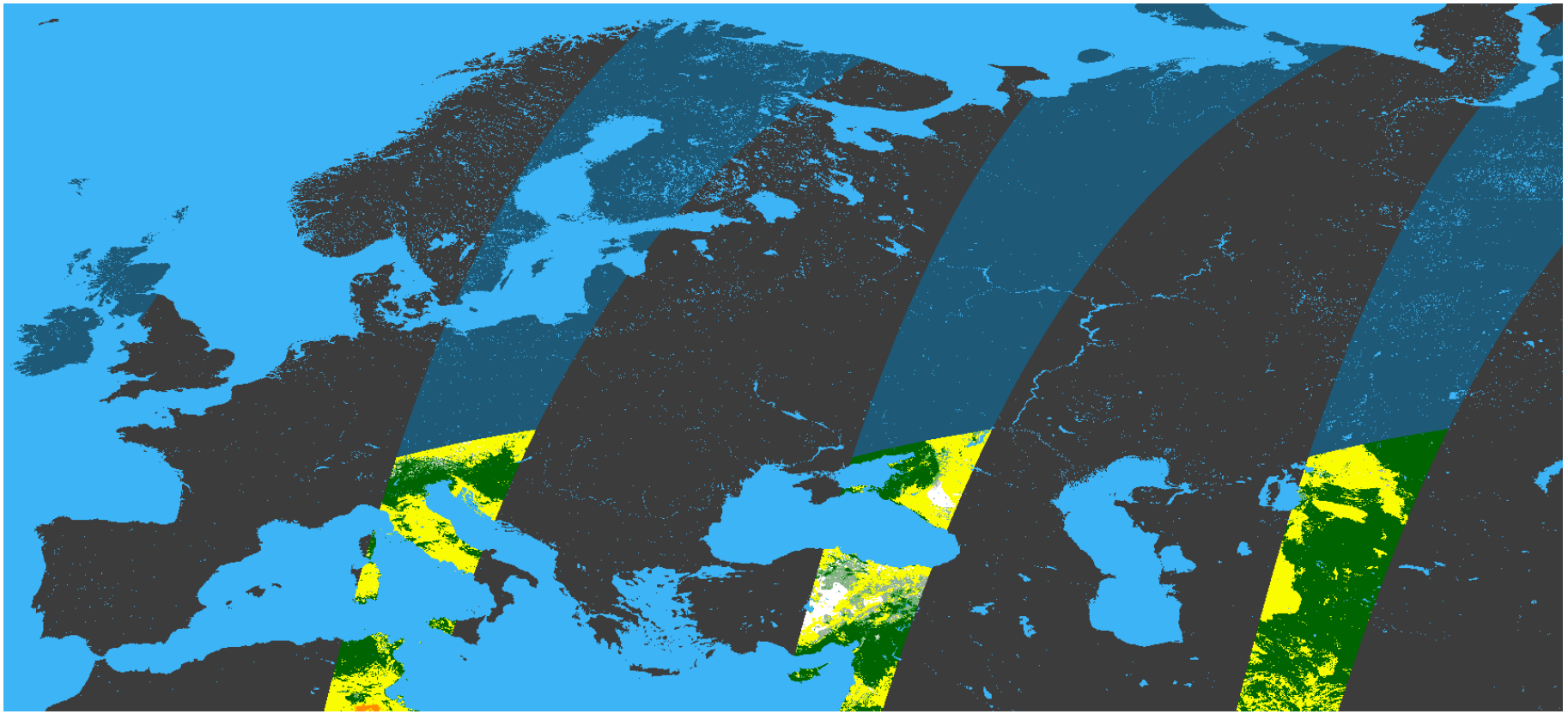
L3A 29.05.2004



L3A 07.09.2004



L3A 23.11.2004



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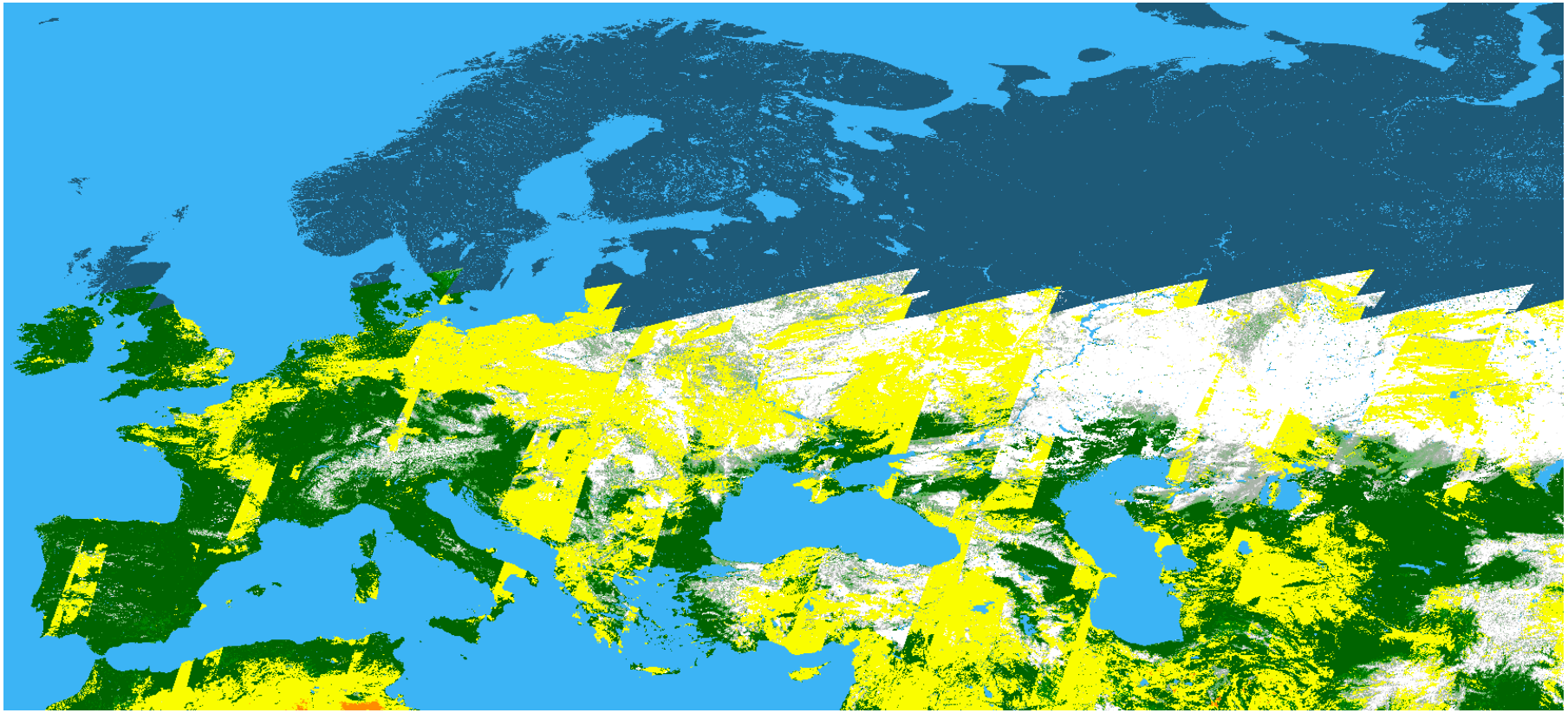

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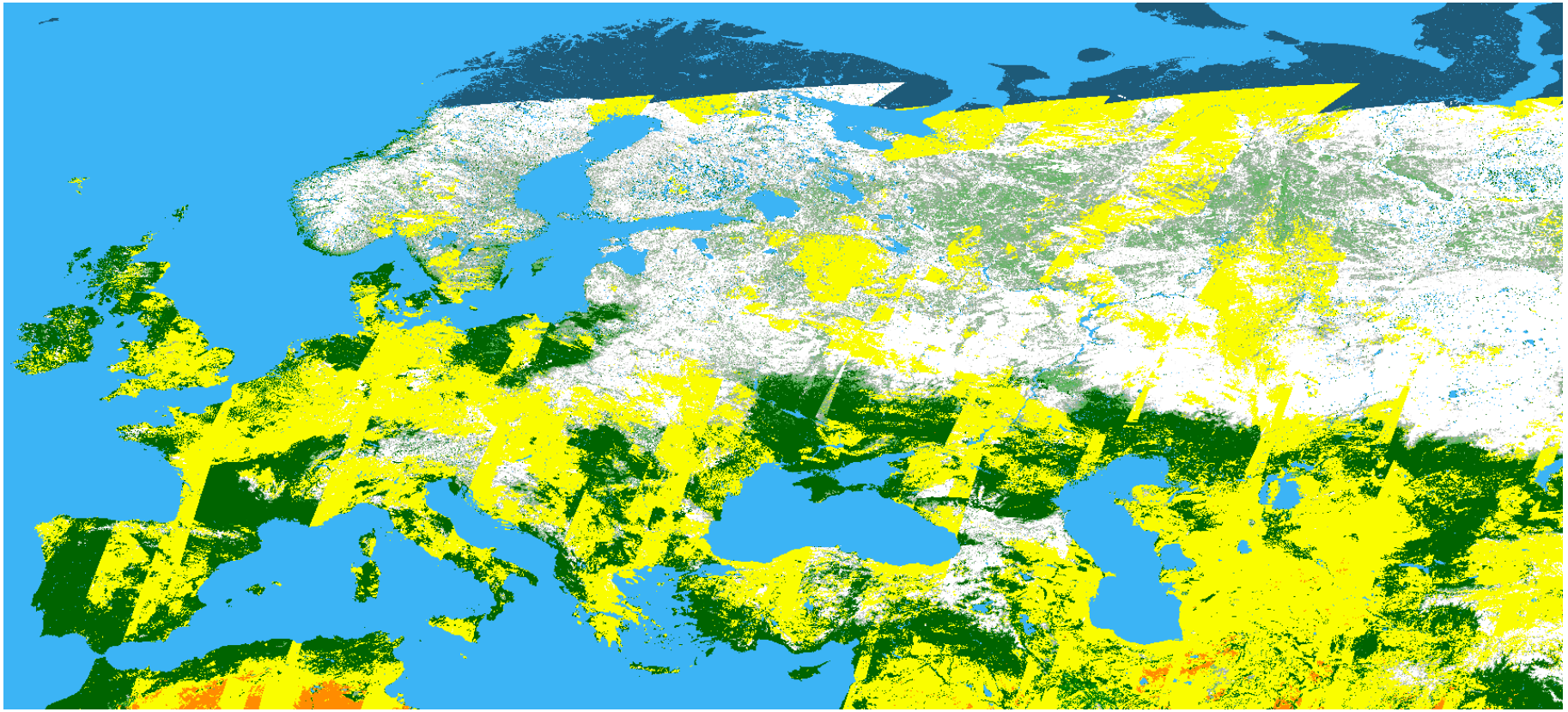
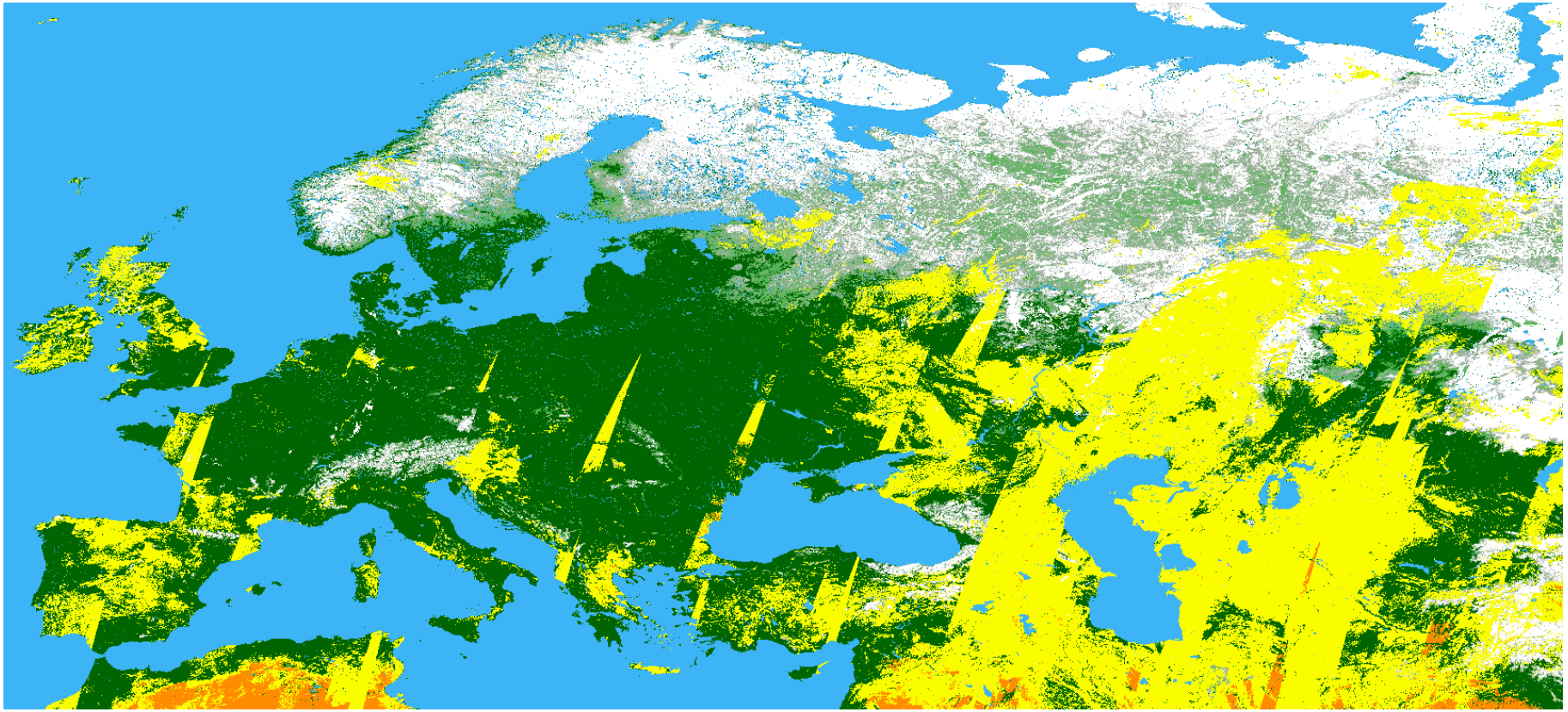
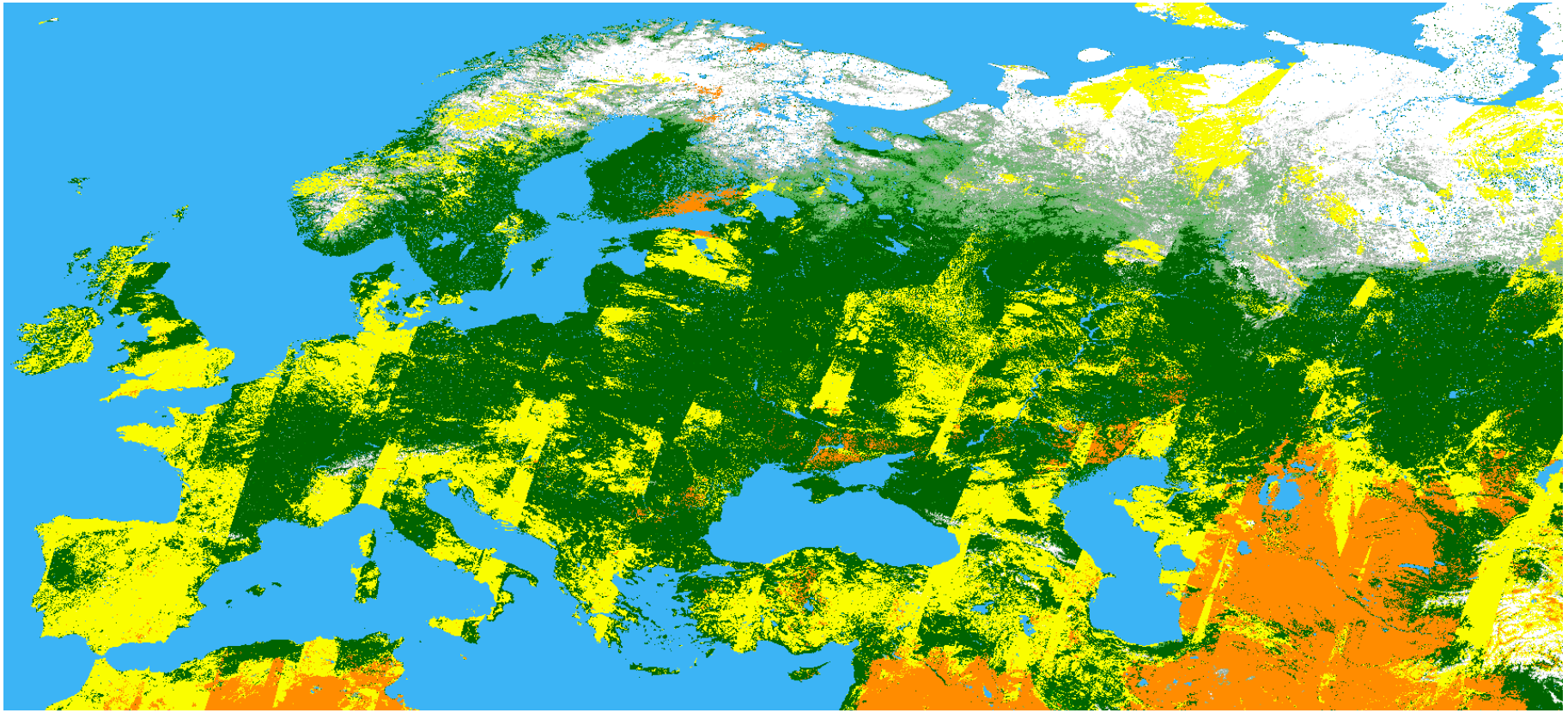


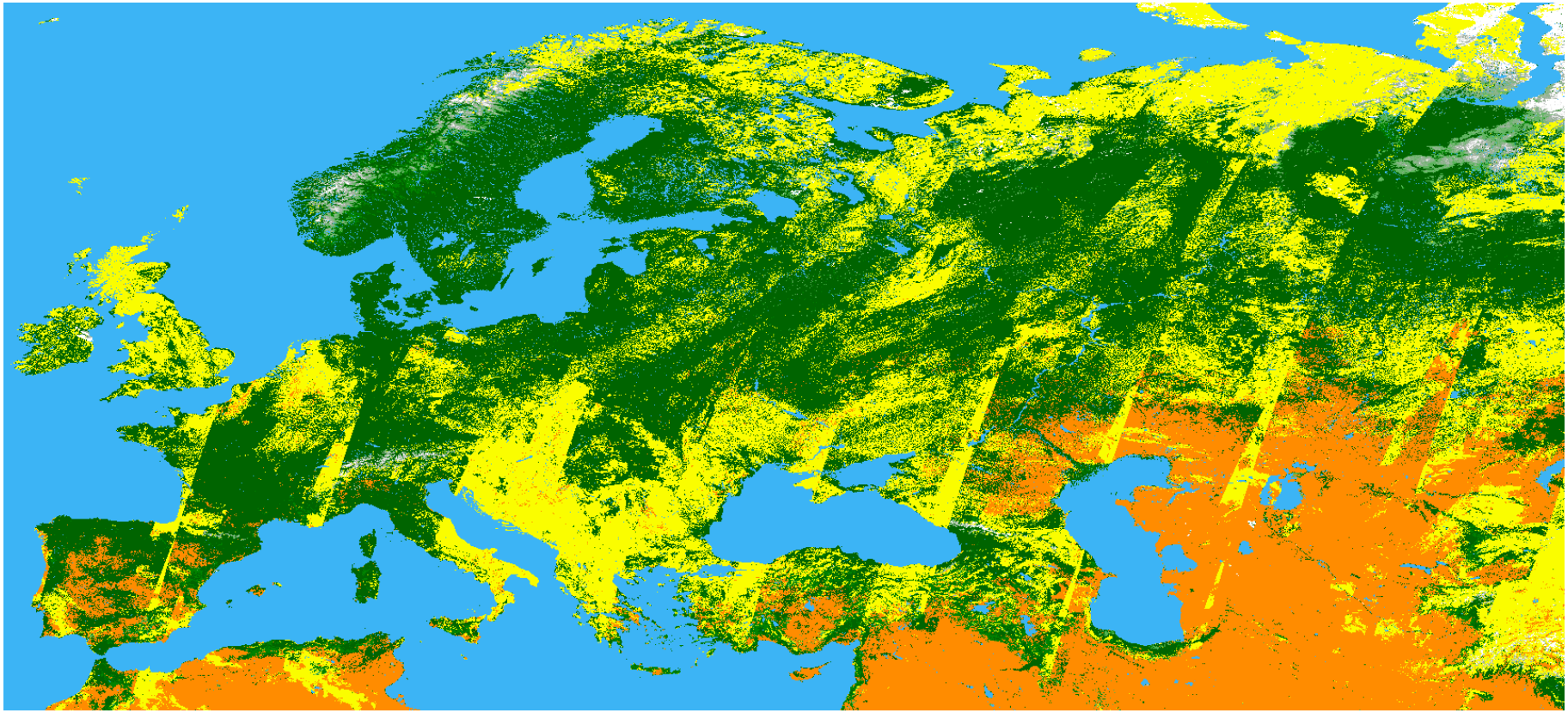
L3B 05.04.2004



L3B 05.05.2004



L3B 07.06.2004



Preliminary evaluation results

- **Comprehensive evaluation – limited to the pan-European area**
- **Covers open plains, boreal forest, mixed forest, forested mountains, high-mountains**
- **Focus:**
  - Dedicated experiments to investigate algorithm performance etc.
  - Pan-European experiment in order to obtain experience with SE mapping on a larger scale
- **Results in general (RMSD):**
  - Mountains: 10-15% in spring, 15-25% in the winter
  - Forest: Typically around 25%

Most important known issues

- **Bare ground reflectance calibration of retrieval algorithms (reference targets) are currently regional (or constant), local calibration is needed**
- **Performance for snow with high content of impurities**
- **Cloud detection needs to be further investigated at the global level (different atmospheric schemes, aerosols & seasonal variability)**
- **A suitable measure of confidence of retrieval result linked to the algorithms**

Grid data encoding

- **For Fractional Snow Cover (FSC):**
  - 100: FSC = 0%
  - 101: FSC = 1%
  - …
  - 200: FSC = 100%
- **For 4-snow-classes system (4CL):**
  - 6: 0% ≤ FSC ≤ 10%
  - 7: 10% < FSC ≤ 50%
  - 8: 50% < FSC ≤ 90%
  - 9: 90% < FSC ≤ 100%

- **Other class codes:**
  - 0: No data
  - 20: Cloud
  - 30: Forest
  - 40: Water body
    - 41: Ocean
    - 42: Lake and river
  - 50: Exception codes:
    - 51: Outside mapping area
    - 53: Not mapped in product time frame
    - 54: Too low solar angle for snow retrieval
    - 55: Missing or invalid satellite data
    - 57: Snow retrieval algorithm breakdown
    - 58: No snow retrieval algorithm applicable

Metadata

- **Data content, field 1:**
  - 'Level 3A Fractional Snow Cover (%)'
  - or 'Level 3A 4-class Snow Extent (CATEGORY)'
  - or 'Level 3B Fractional Snow Cover (%)'
- **Data content, field 2: 'Reliability of FSC retrieval (%)' [Not included in this version]**
- **Data date: <yyyymmdd>**
- **Processing date: <yyyymmdd>**
- **Coordinate system: 'Lat/Lon'**
- **Latitude range: '33N - 72N'**
- **Longitude range: '11W – 75E'**
- **Spatial Resolution: '0.01 × 0.01 degrees'**
- **Processing software name: 'NR SE/ATSR processing chain'**
- **Processing software version: '0.9'**
- **Processing organisation: 'Norwegian Computing Center'**
- **Auxiliary data, open water mask name: 'GLOBCOVER ENVEO water mask'**
- **Auxiliary data, open water mask version: '0.9'**
- **Auxiliary data, unforested mountain mask name: 'GLOBCOVER ENVEO unforested mountain mask'**
- **Auxiliary data, unforested mountain mask version: '0.9'**
- **Auxiliary data, transmissivity map name: 'GLOBCOVER SYKE transmissivity map'**
- **Auxiliary data, transmissivity map version: '0.9'**

Towards a global product

Tasks to be done until summer 2010 include:

- **Processing chain needs to be tailored to global processing**
- **Global mapping area needs to be defined**
- **Prepare ancillary data:**
  - Masks
  - Transmissivity map
- **Algorithm issues:**
  - Dynamic, local calibration
  - Retrieval confidence estimation
- **Validation/evaluation:**
  - At selected sites globally spanning natural variability, also seasonal
  - Study snow retrieval and cloud detection performance
  - Issues include aerosols, atmosphere in general, snow impurities
  - Study geolocation accuracy

Conclusions

- **The longest time series (15+ years) of high-resolution global Snow Extent products from optical data soon to be available**
- **First long time series of global Snow Extent products from a European sensor**
- **Products based on radiometric very stable sensors (ATSR-2 and AATSR), which is important to minimise bias in time series of a climate variable**
- **The sensor's conical scanning pattern gives constant spatial resolution over the whole scan**
- **Two algorithms have been combined to achieve optimal results for type of terrain and land cover given locally**

GlobSnow SE team and roles

- **NR: Leading development work, lab processing chain, NLR algorithm, evaluation, prototype product production**
- **SYKE: SCAmod algorithm, cloud detection algorithm, evaluation, transmissivity map generation**
- **ENVEO: Shi/ENVEO algorithm, evaluation, mask generation, SAR study**
- **GAMMA: Software prototype system validation**
- **FMI, NORUT and EC: Lots of indirect contributions**