Time Series Processing and Analysis of Terrestrial Daily Snow Cover Datasets to Describe Status and Development of Global Snow Cover

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DLR

Some background

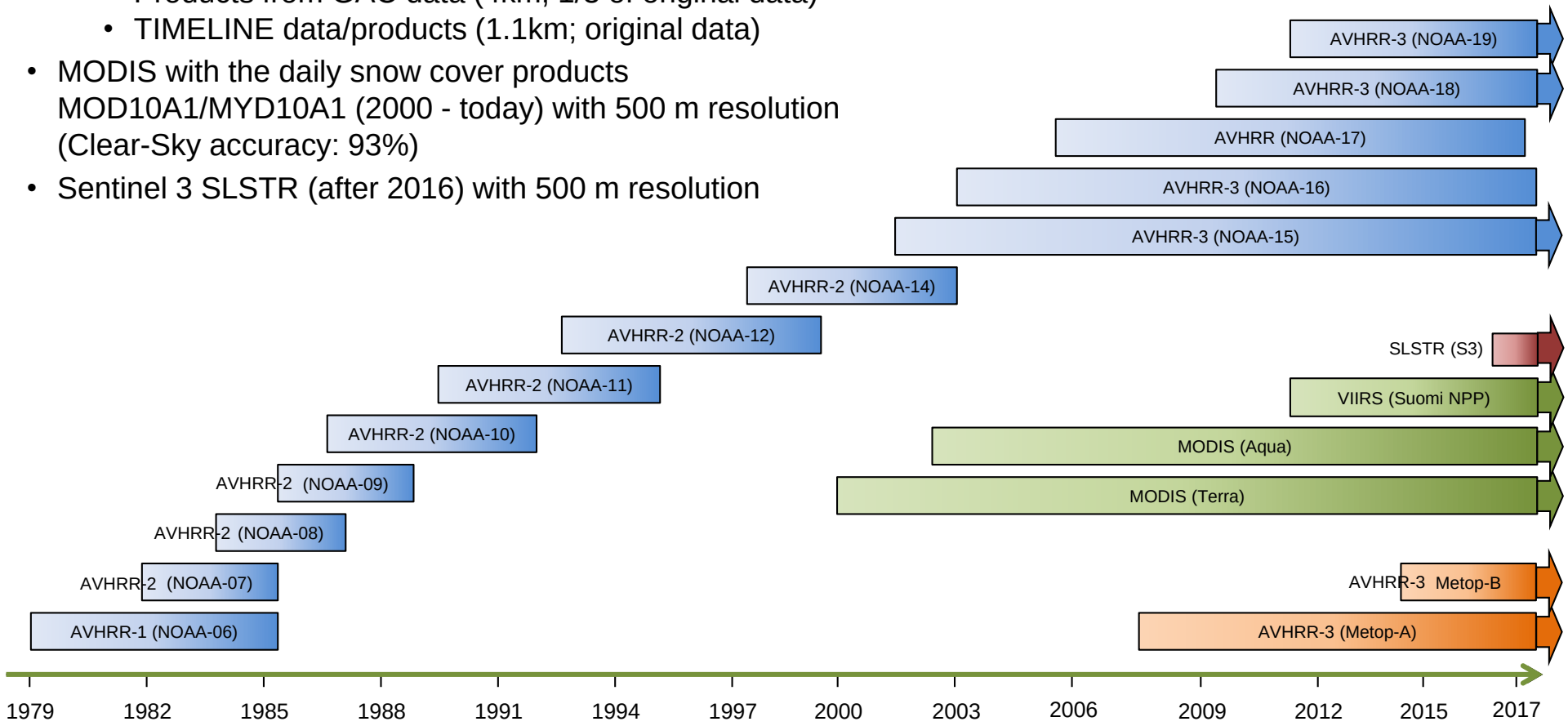
- Snow covers up to 50% of the Northern Hemisphere
- Snow influences the global radiation budget, hydrology, vegetation, fauna, energy, tourism, natural disasters
- Terrestrial snow cover is an extremely variable land cover type

➡ Development of the Global SnowPack product



Data Sources for long term time series of snow cover and the Global SnowPack

- AVHRR
  - Products from GAC data (4km; 1/3 of original data)
  - TIMELINE data/products (1.1km; original data)
- MODIS with the daily snow cover products MOD10A1/MYD10A1 (2000 - today) with 500 m resolution (Clear-Sky accuracy: 93%)
- Sentinel 3 SLSTR (after 2016) with 500 m resolution



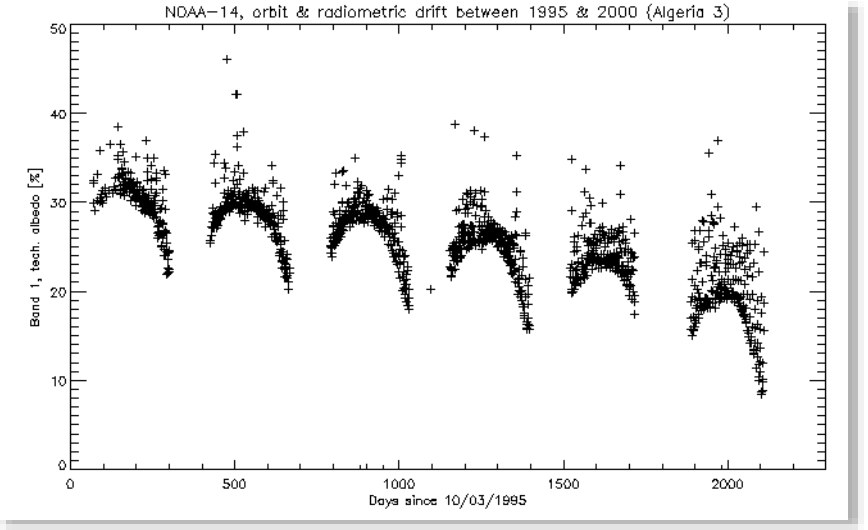
DLR

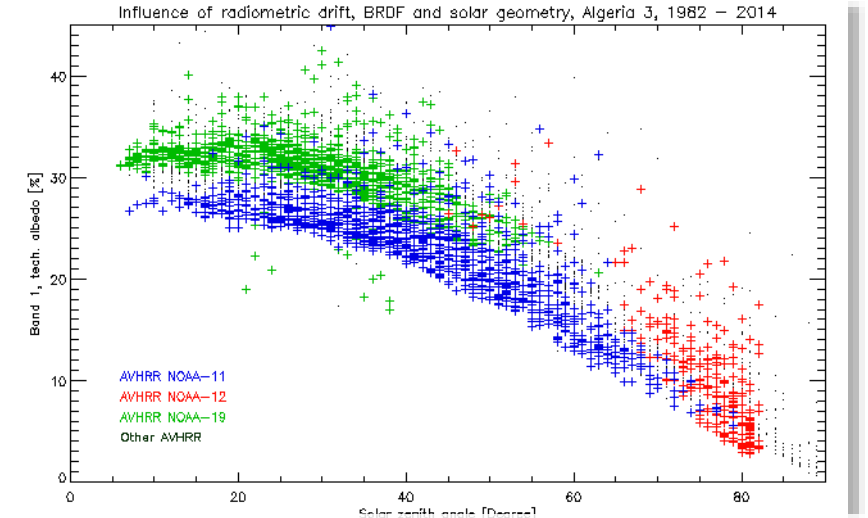
Data Sources for long term time series of snow cover and the Global SnowPack: AVHRR

TIMELINE

http://www.dlr.de/eoc/en/desktopdefault.aspx/tabid-9035/15754_read-38904/

- Data Consolidation
- Harmonization:
  - NOAA OSPO calibration not perfect
  - Strong BRDF and observation geometry effects
  - Radiometric Harmonization of time series using CEOS sites and BRDF models
- Chip Matching to overcome imprecise geolocation accuracy
- Orthorectification



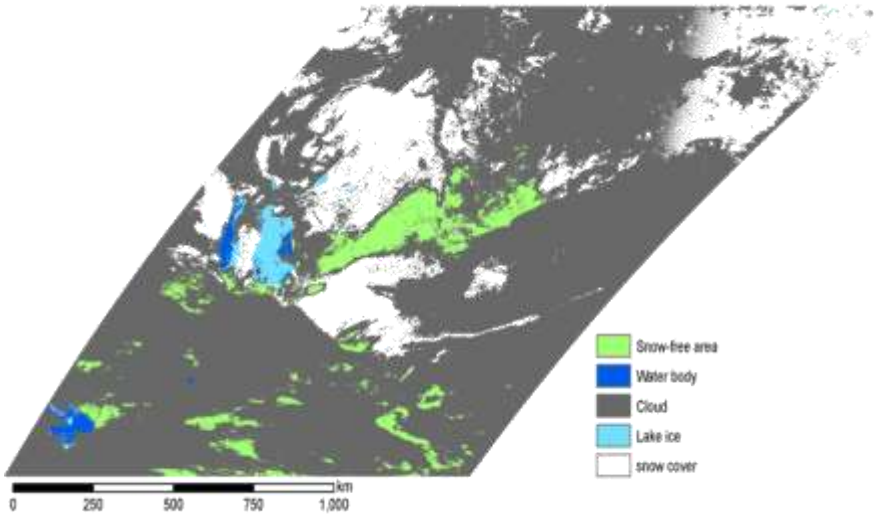


CEOS Algeria 3, band 1, above figure: NOAA-14 time series (1995-2000). Below: ~9700 observations (1982-2014)

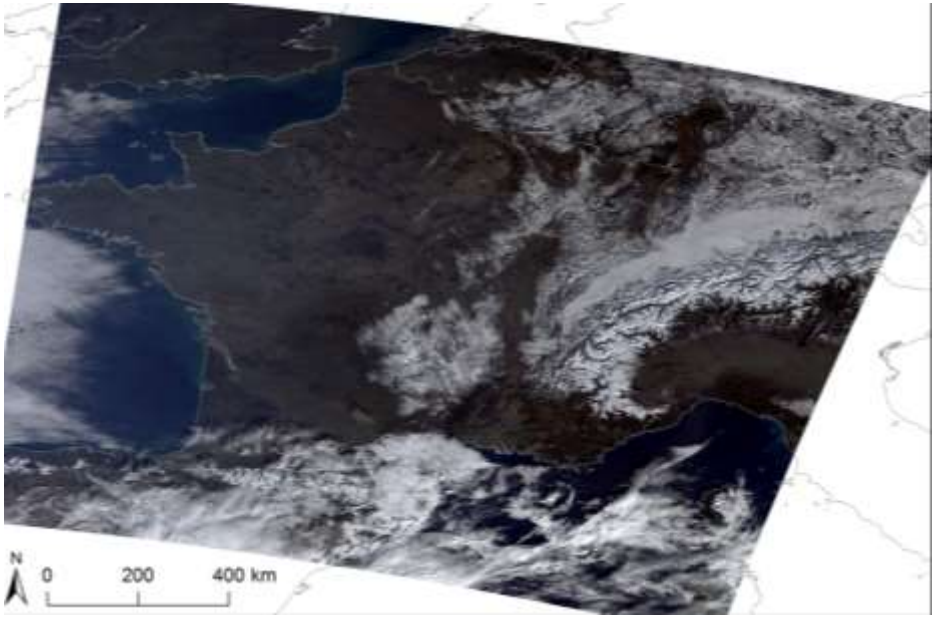
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Data Sources for long term time series of snow cover and the Global SnowPack: MODIS, Sentinel 3

- MODIS MOD10A1, MYD10A1 version 5 and 6 daily snow cover products
- 500m spatial resolution
- Available from 2000 – today



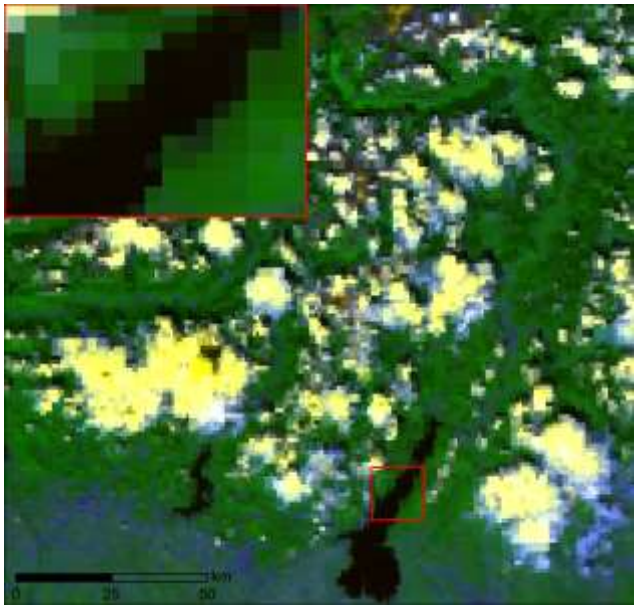
- Sentinel 3 SLSTR
- 500m spatial resolution
- Available since late 2016



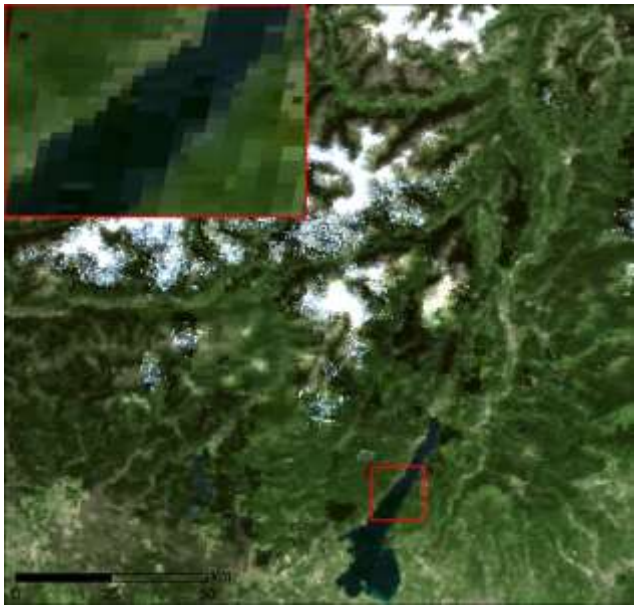


Data Sources for long term time series of snow cover and the Global SnowPack

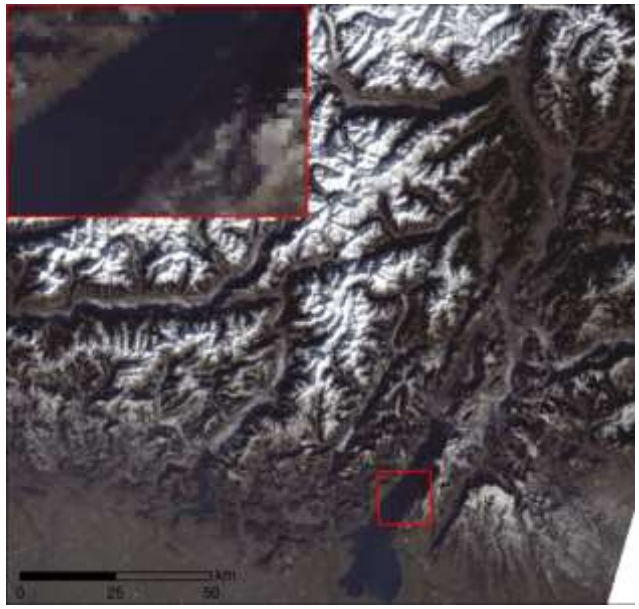
Different sensors and their resolutions in a quick overview: Even though a higher spatial resolution would be desired, the increased processing effort and the lack of daily data make it unfeasible to rely on Landsat (or Sentinel 2). Therefore, AVHRR, MODIS, and Sentinel 3 are the ideal choices.



AVHRR



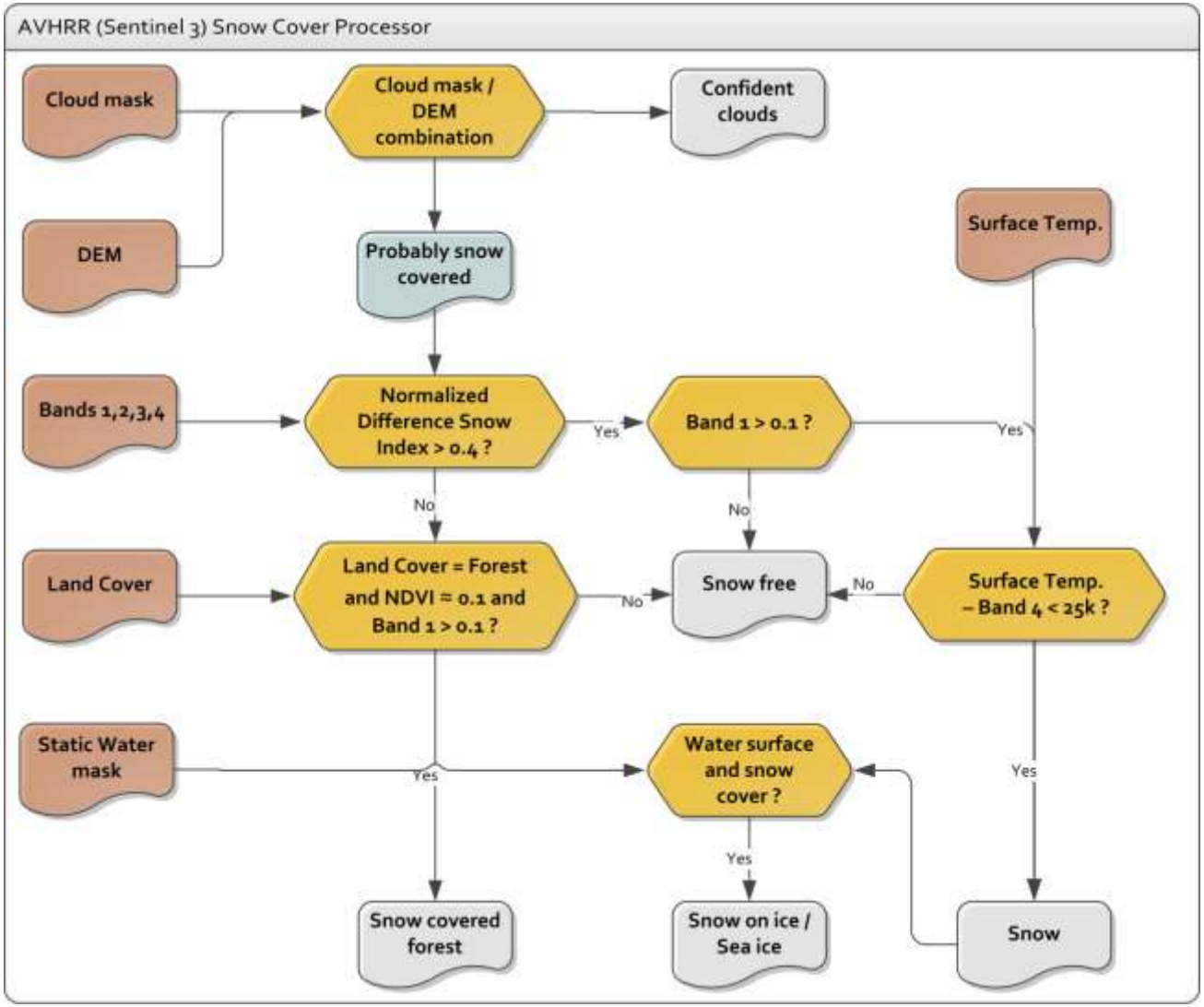
MODIS



Sentinel 3

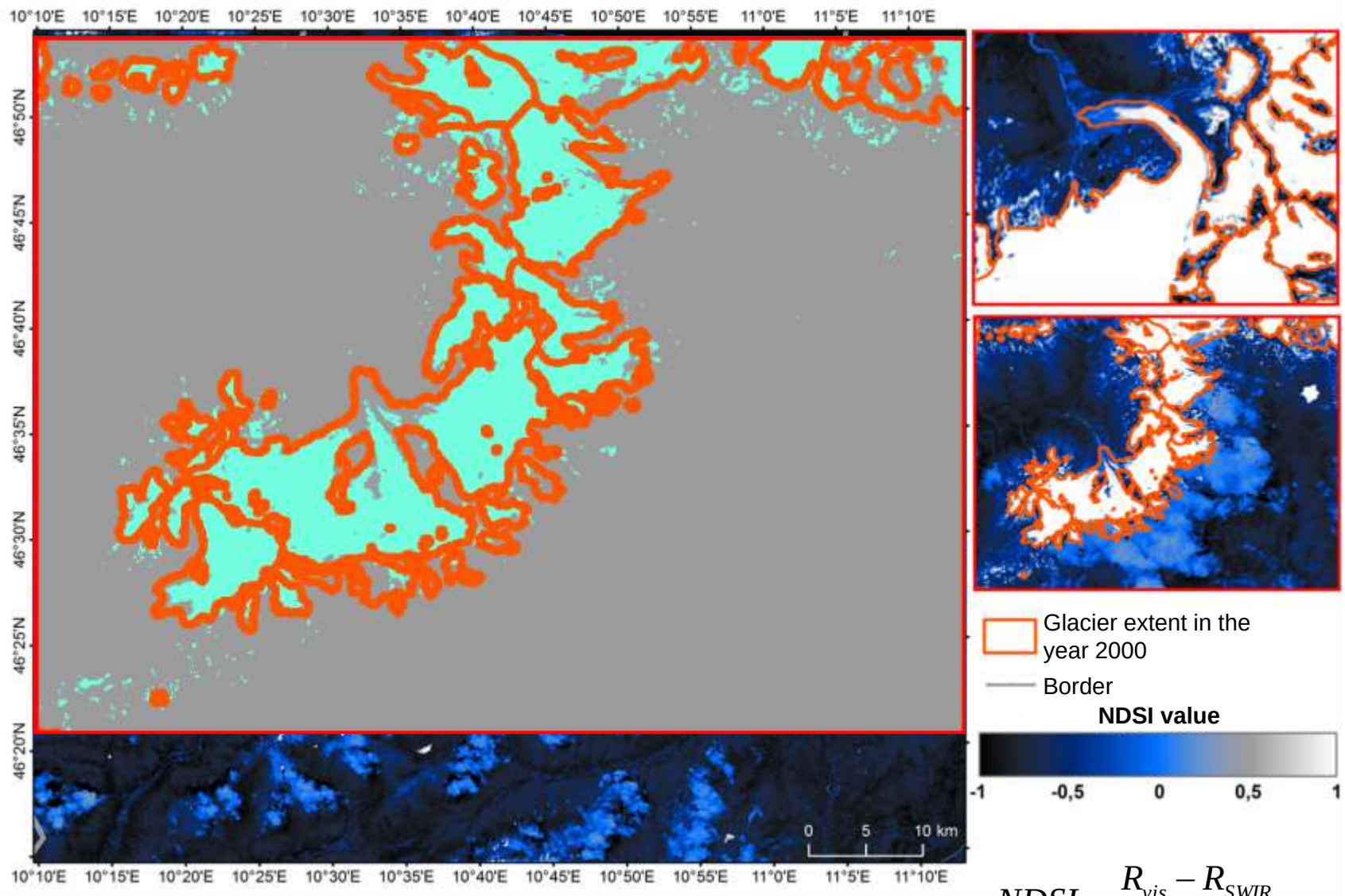


Methods – snow cover classification





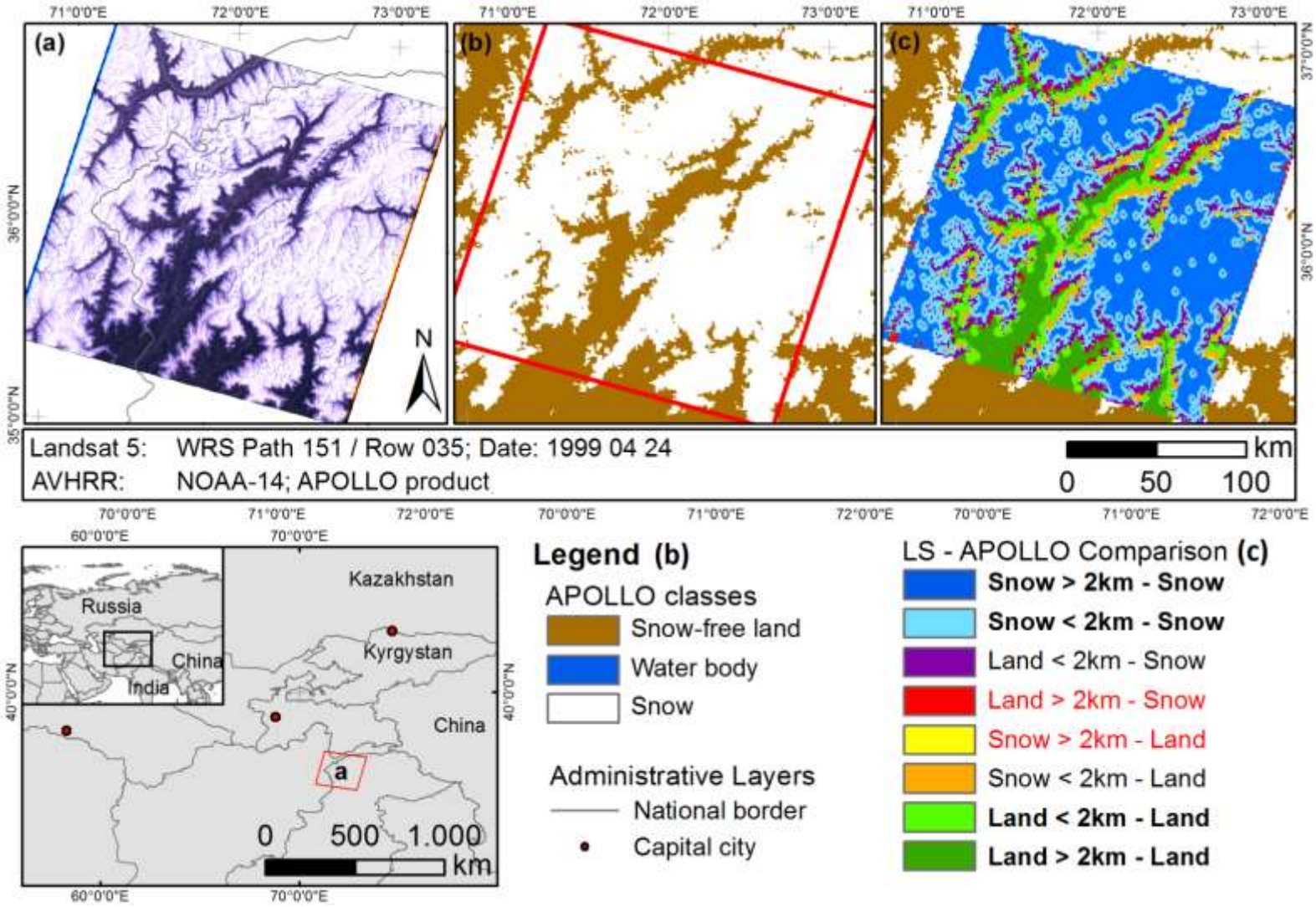
Snow as seen from space



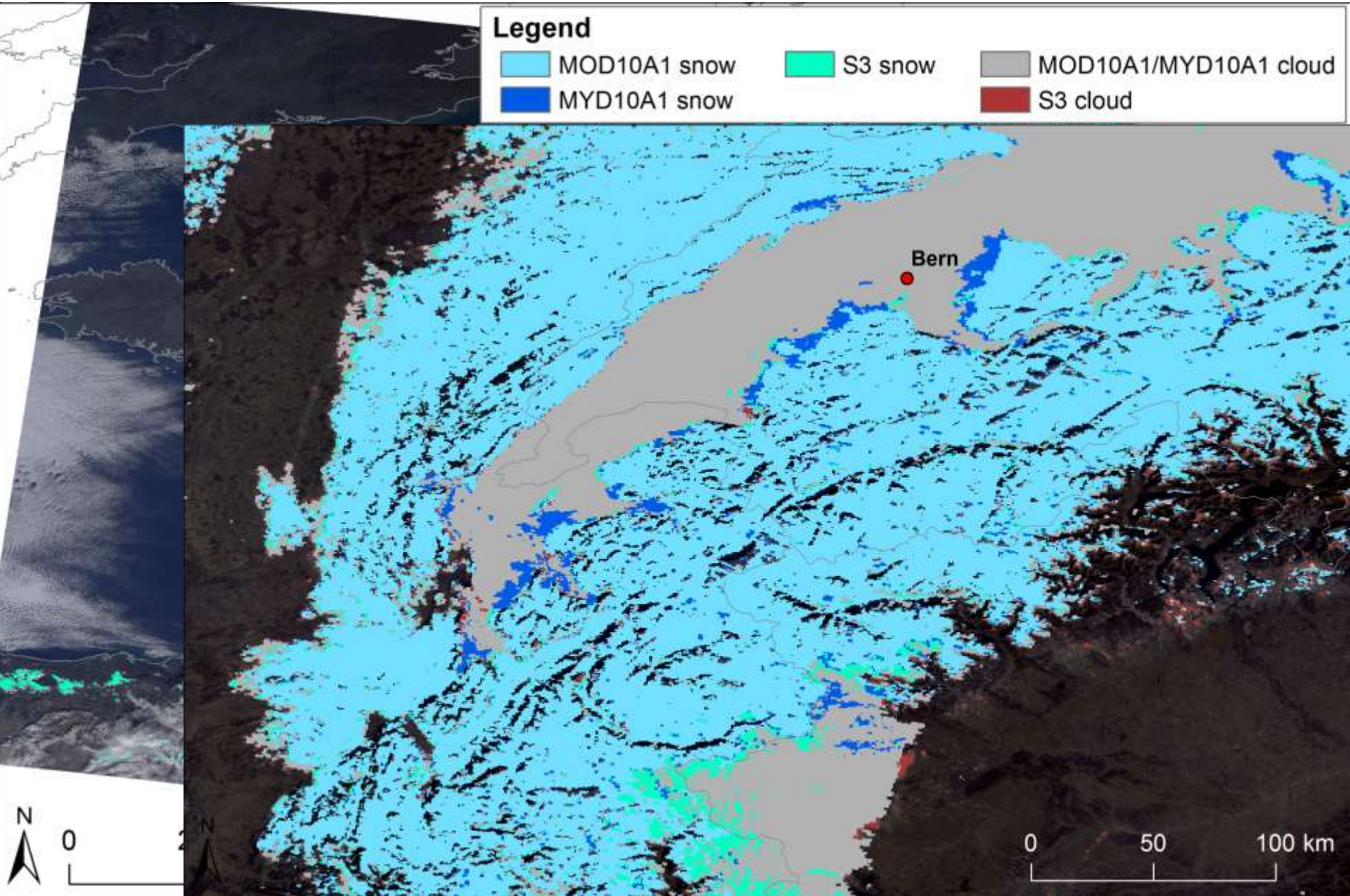
$$NDSI = \frac{R_{vis} - R_{SWIR}}{R_{vis} + R_{SWIR}}$$

Methods – accuracy assessment

Validation of AVHRR snow cover for Central Asia: Landsat image on the left, AVHRR snow cover product in the middle, comparison between both products on the right



Methods – snow cover classification



Methods – Time series processing

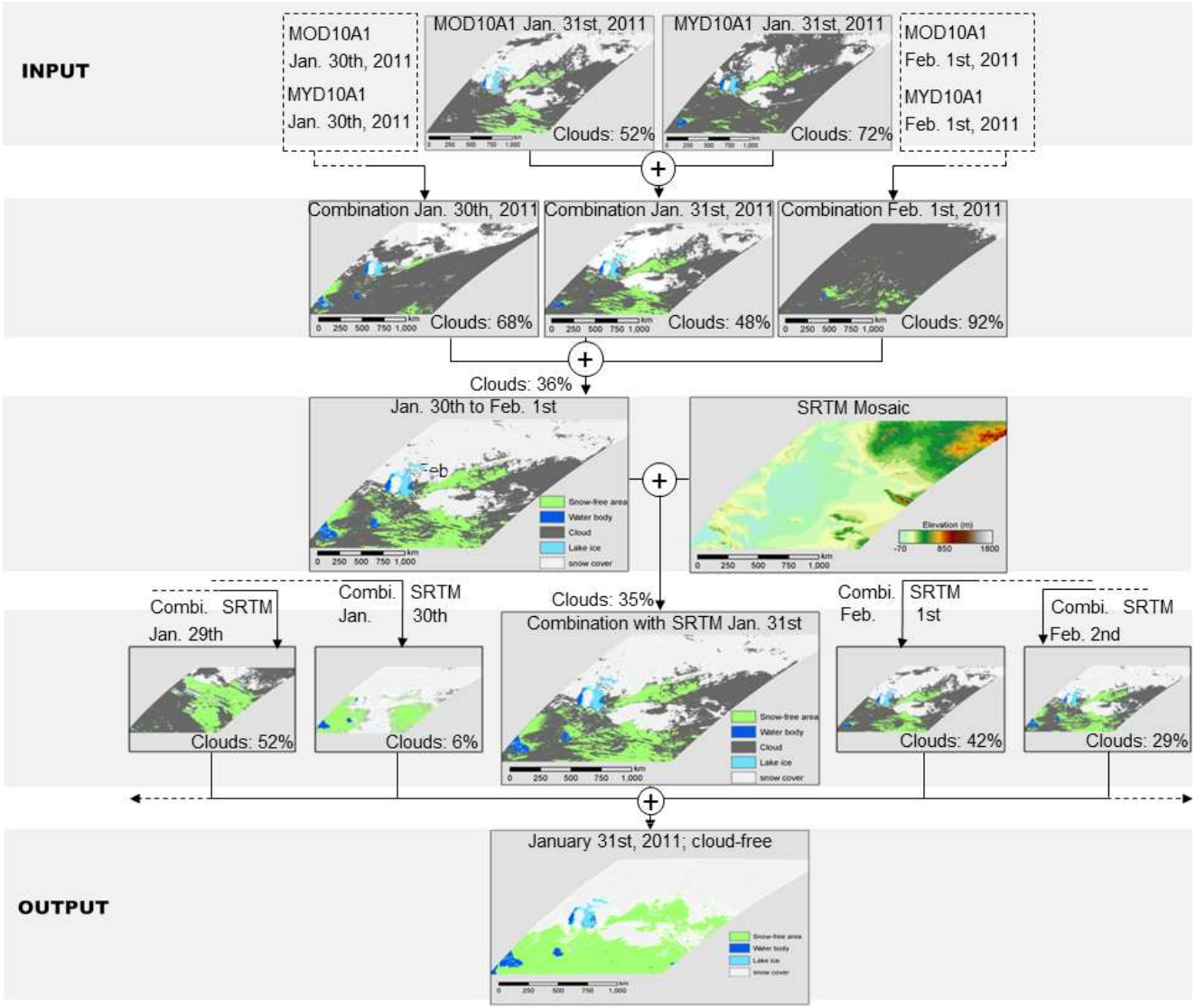
Post-Processing of satellite data time series to be able to estimate the snow cover status below clouds (example for MODIS):

Step 1: Daily mosaic

Step 2: Combination of several days

Step 3: Regional snowline detection using a DEM

Step 4: Seasonal filter



Methods – calculation of Global SnowPack parameters

- Snow cover duration (SCD)

$$SCD = \sum_{i=1}^{n} (s_i)$$

- Early Season SCD (SCD_{ES})

$$SCD_{ES} = Fd - SCD_{bFd}$$

- Late Season SCD (SCD_{LS})

$$SCD_{LS} = Fd + SCD_{aFd}$$

n: number of observations (beginning on Sept. 1st of a year and ending on Aug. 31st of the following year)

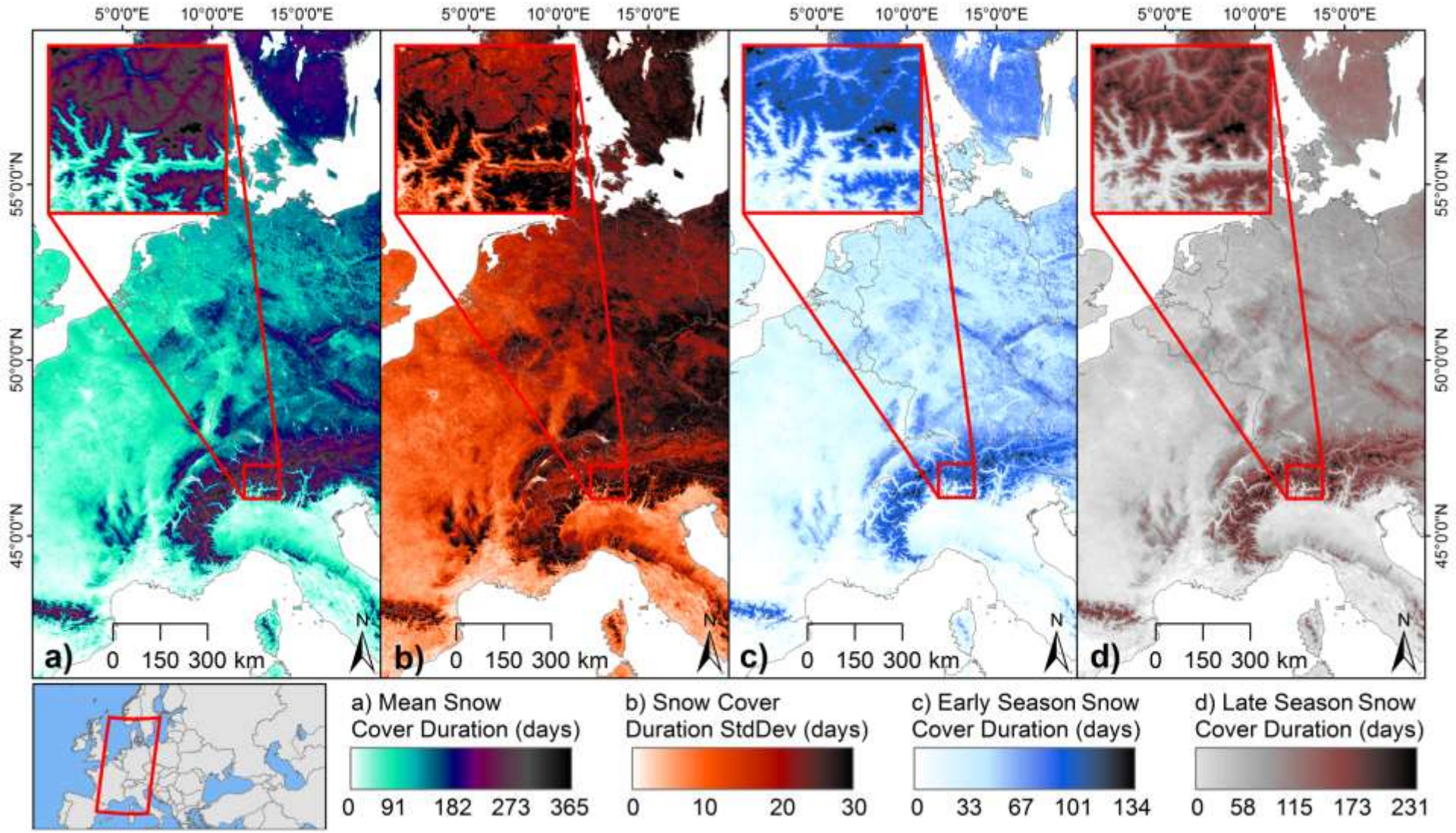
s: cloud-free snow cover dataset

Fd: Date of maximum snow cover extent (Jan. 15th for Central Asia)

bFd/aFd: SCD before (bFd) and after (aFd) the date of maximum snow cover extent



Global SnowPack – overview of all products



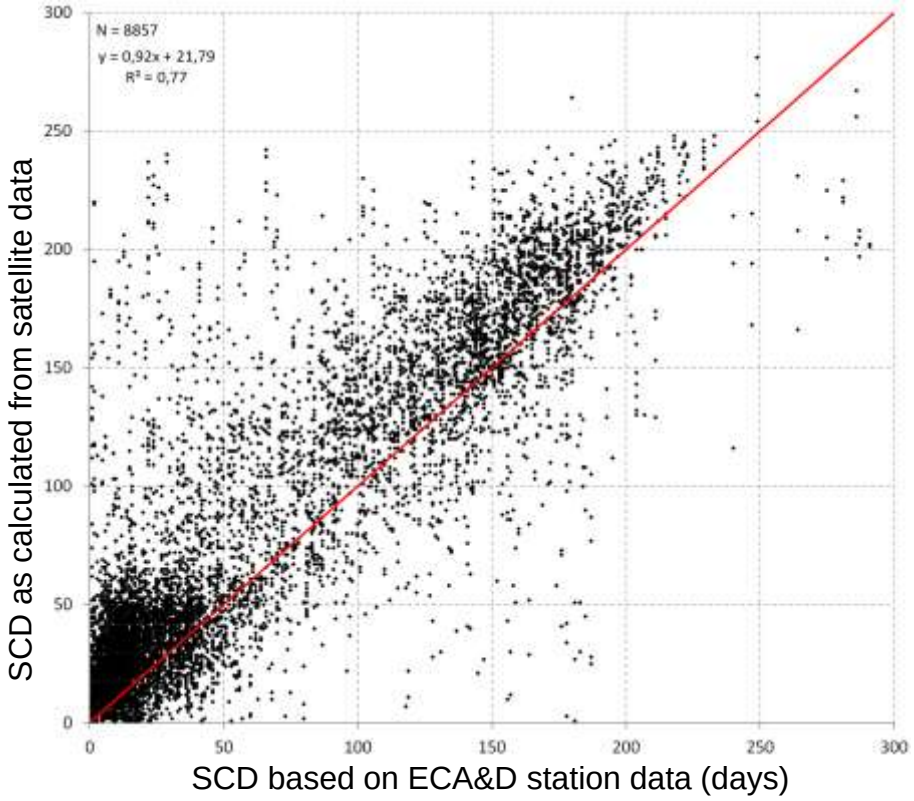
DLR

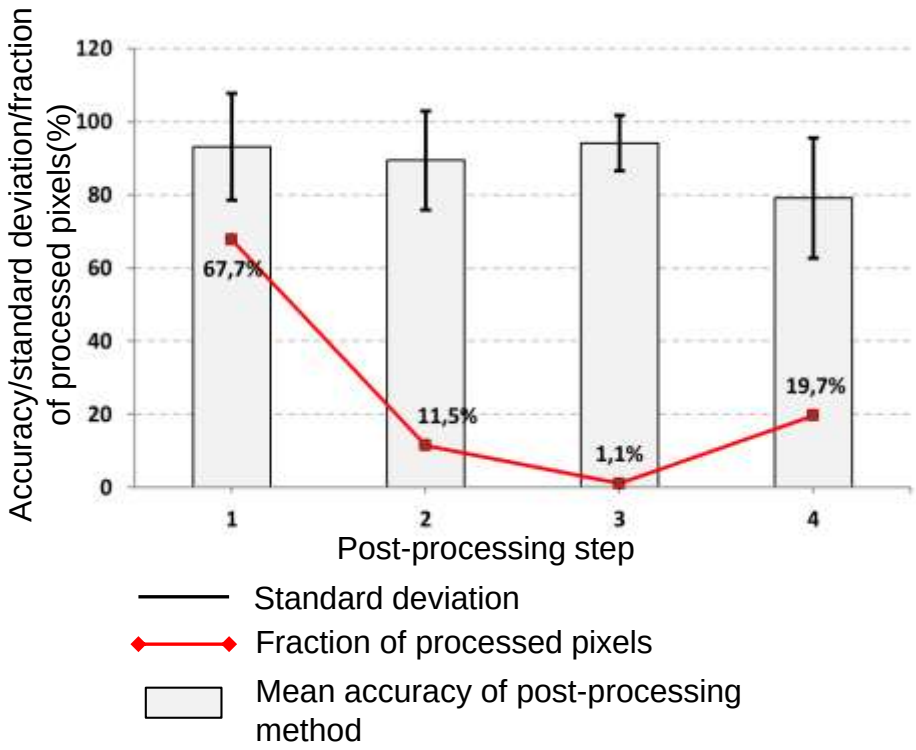


Methods – accuracy assessment

Accuracy assessment of post-processing steps relying on 2 methods:

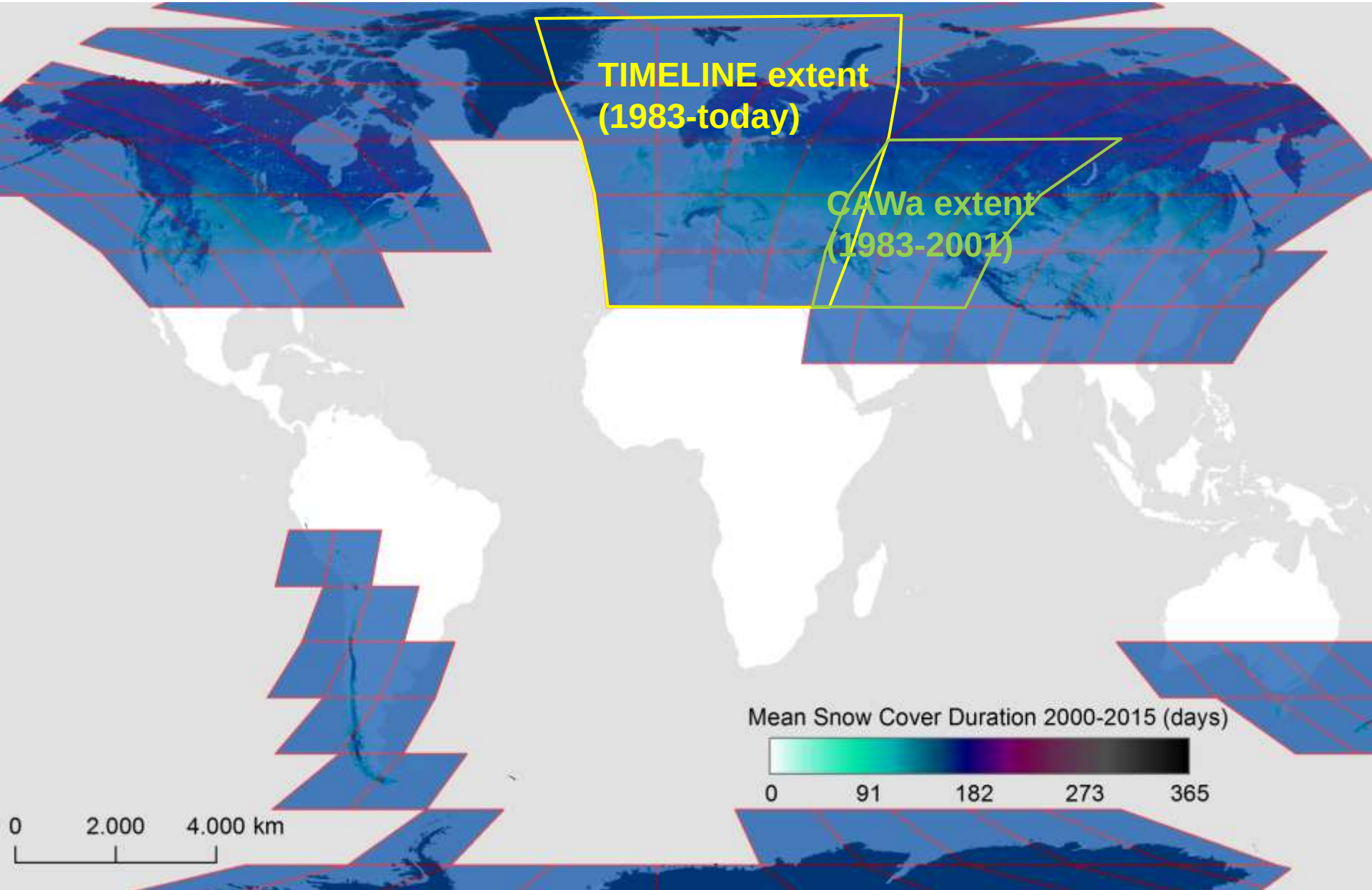
- Comparison with station data (not available everywhere)
- Simulation of cloud cover in cloud-free scenes and subsequent cloud-removal





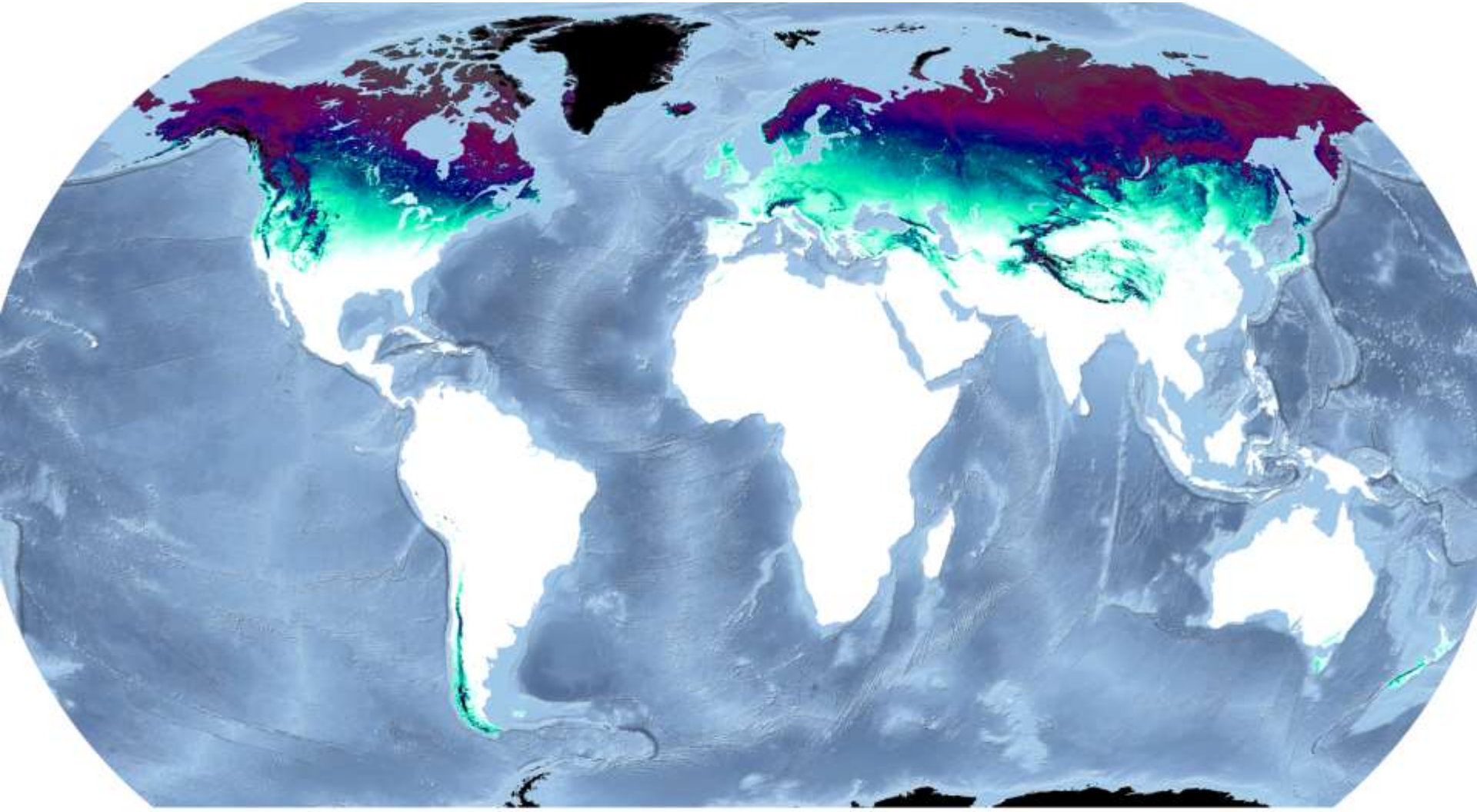


Global SnowPack extent and availability



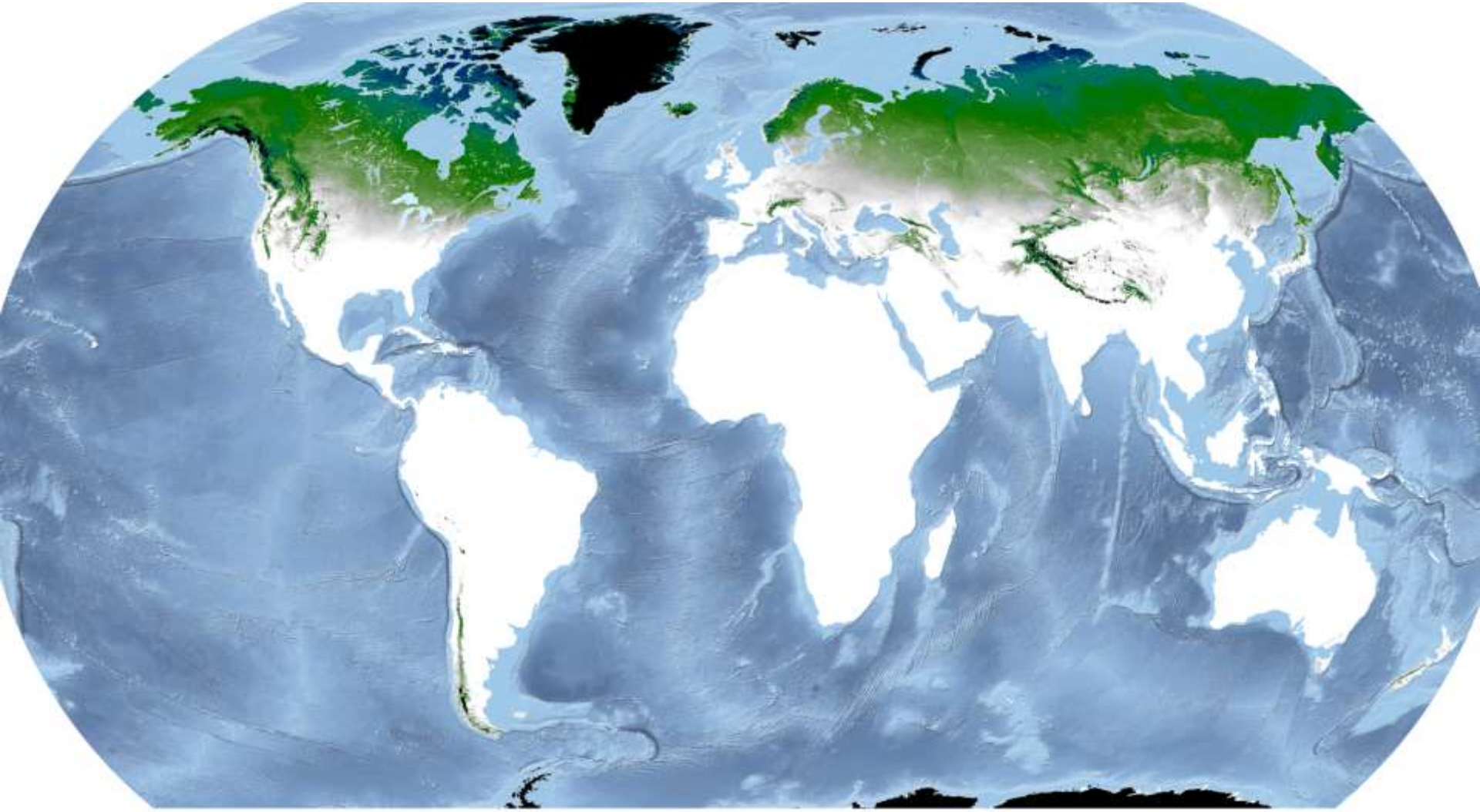
Global SnowPack

Mean Snow Cover Duration 2000-2015



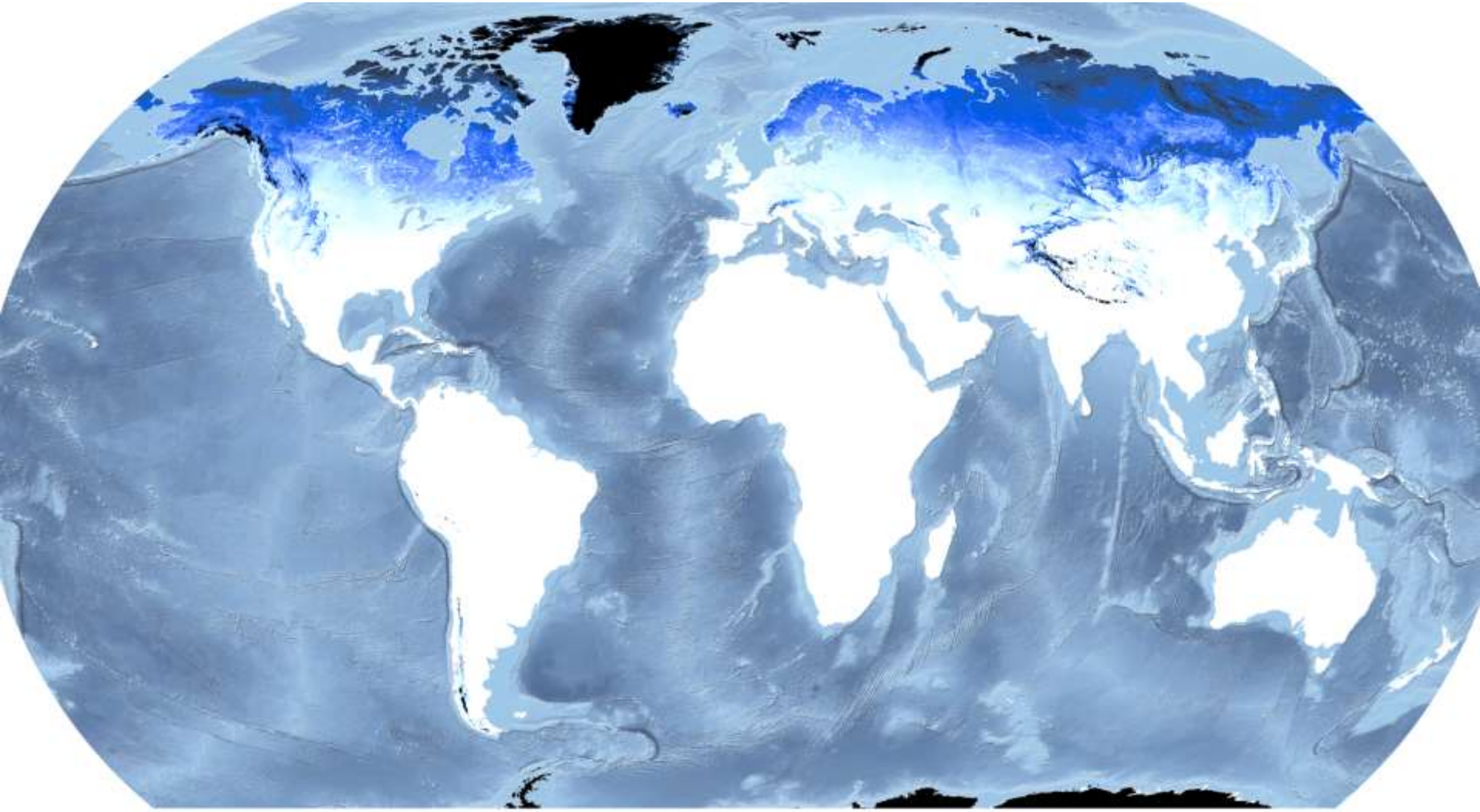
Global SnowPack

Mean Late Season Snow Cover Duration 2000-2015

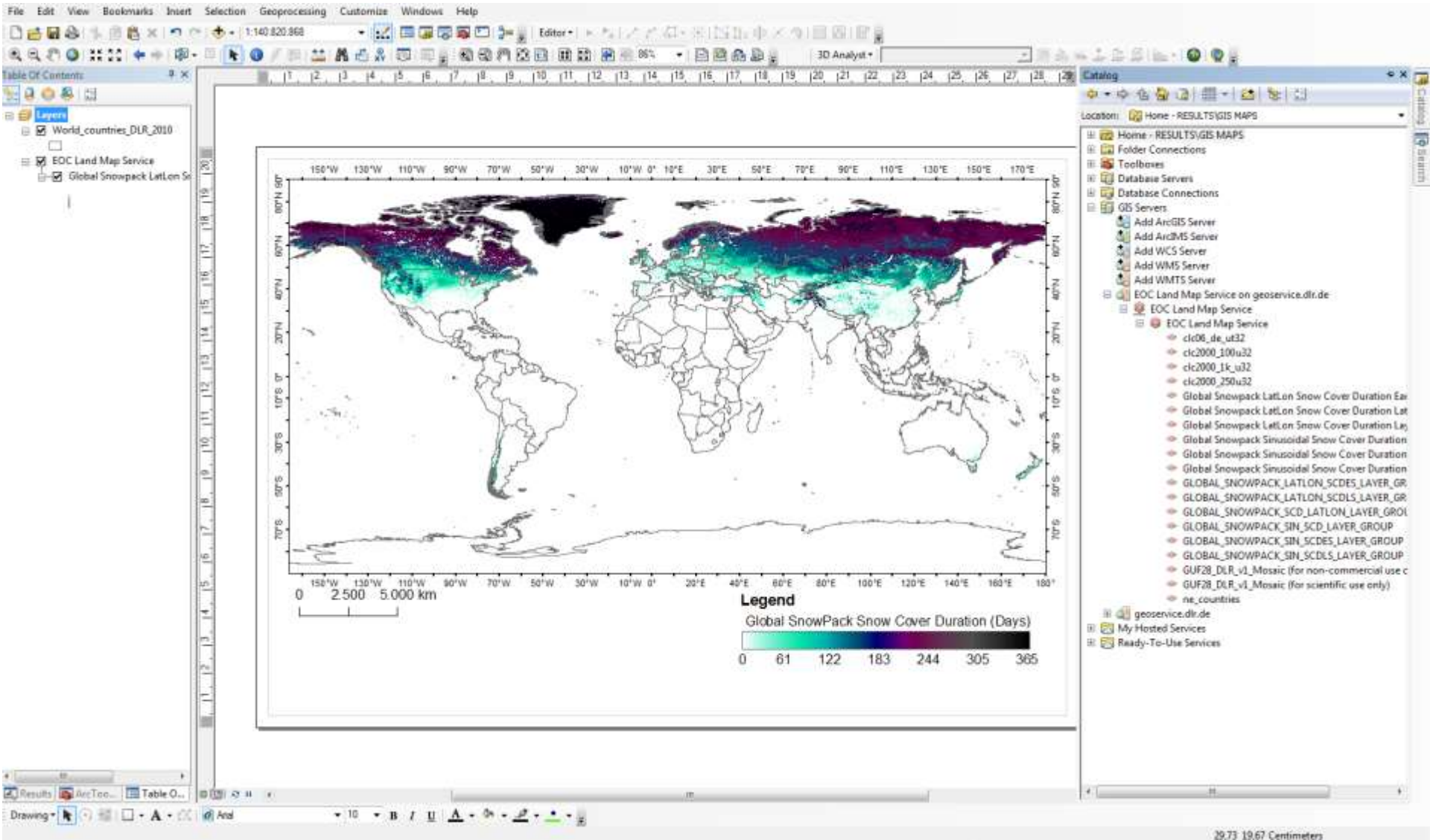


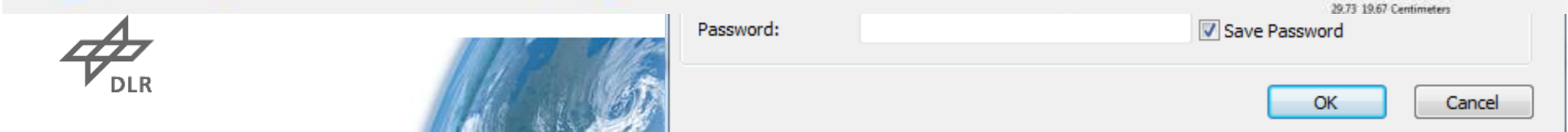
Global SnowPack

Mean Early Season Snow Cover Duration 2000-2015

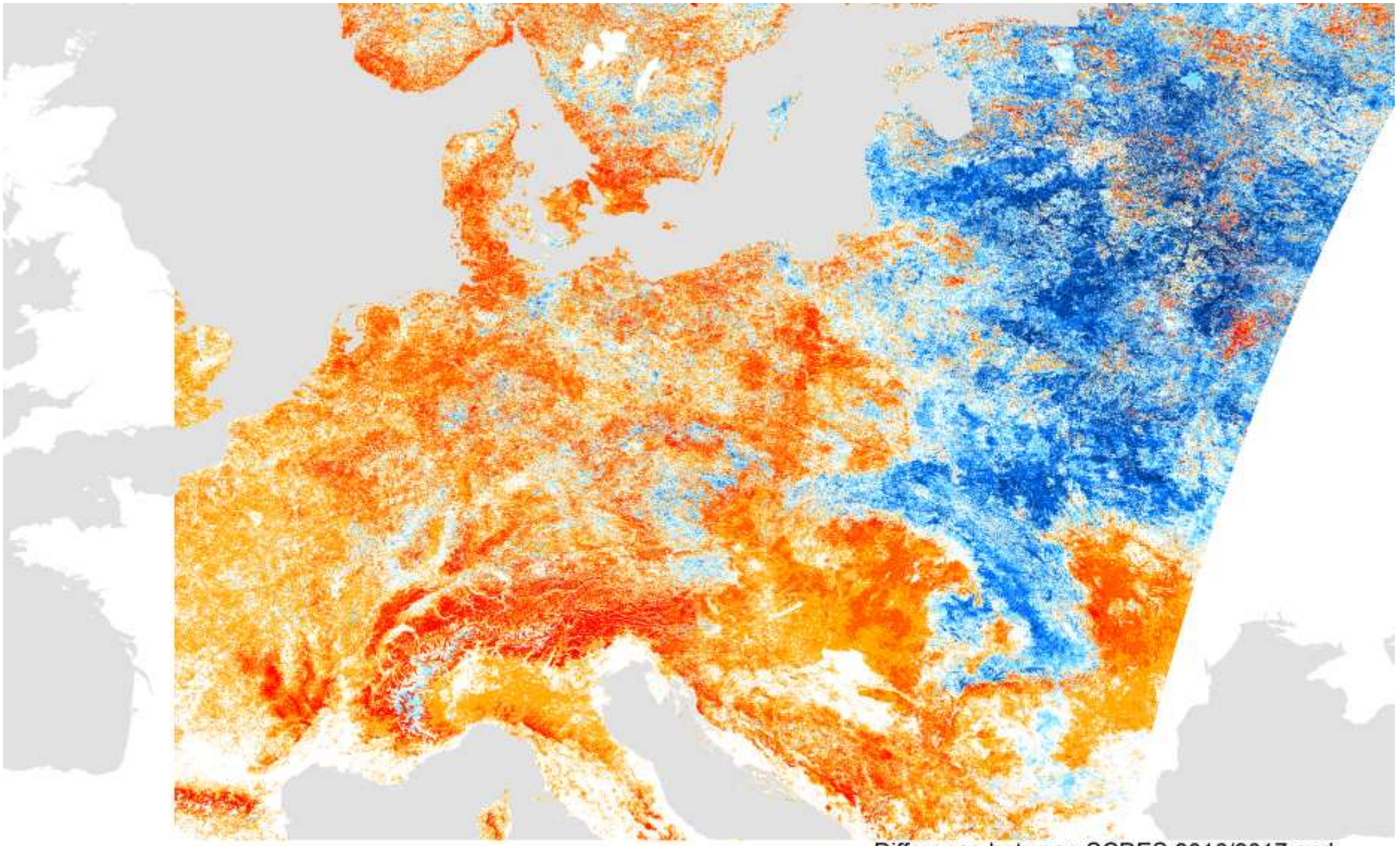


Global SnowPack available as WMS service

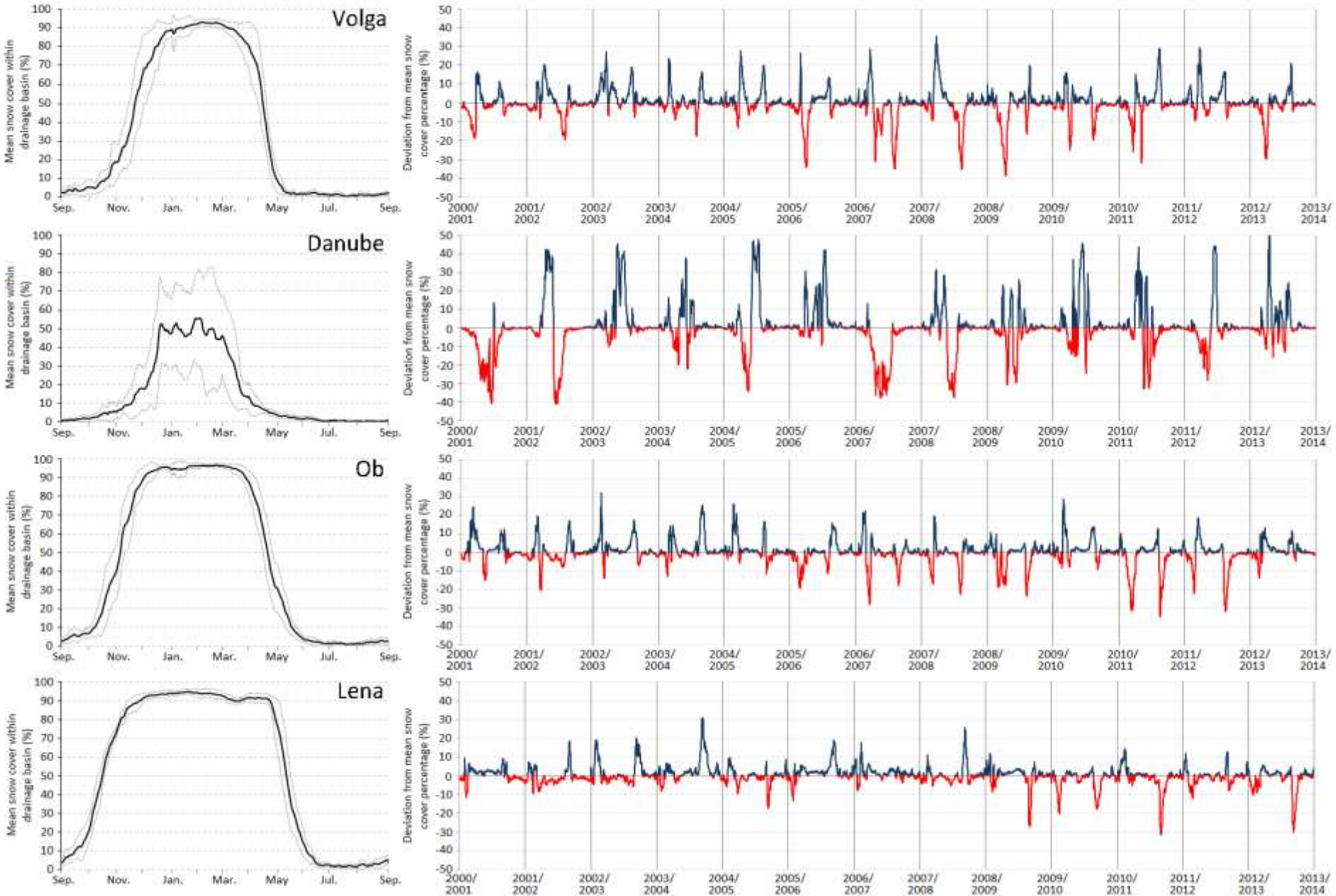




Global SnowPack – Europe

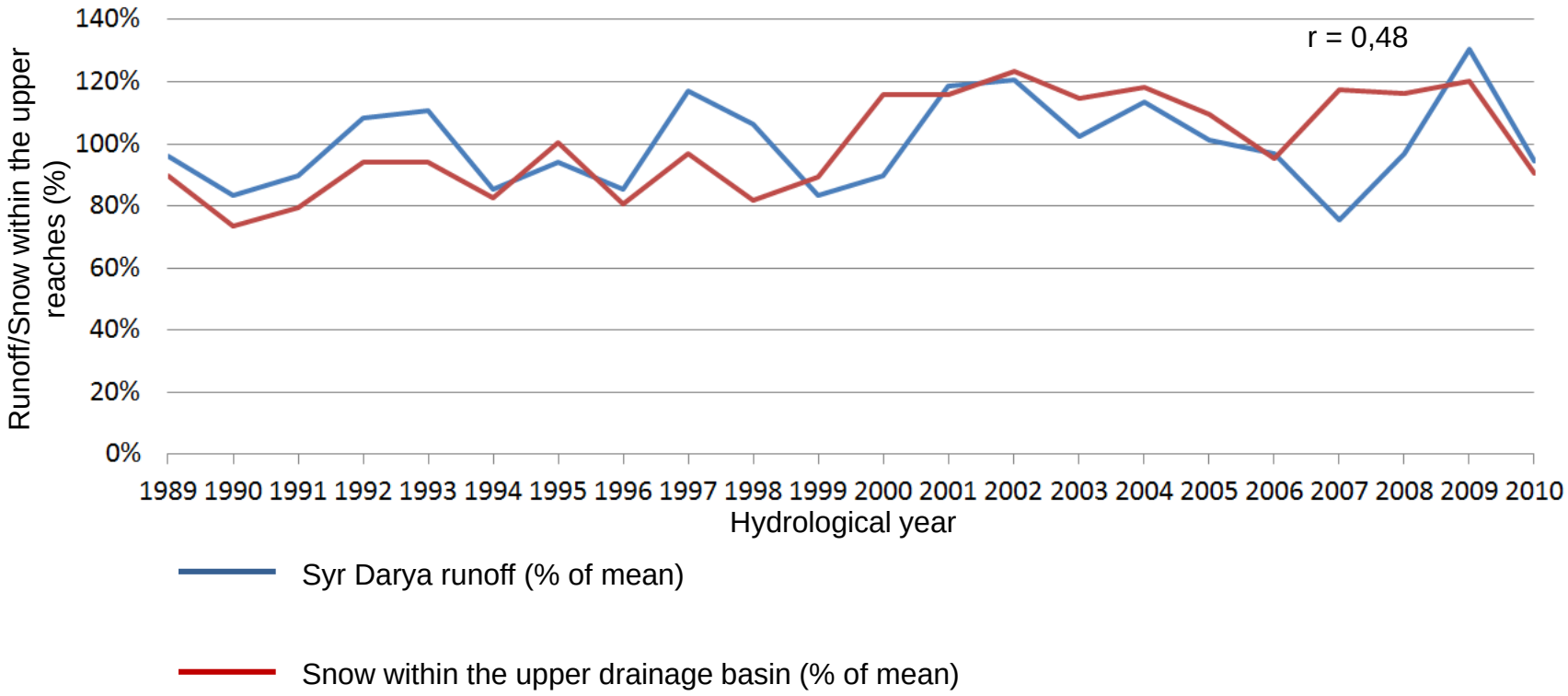


Global SnowPack – Hydrology



Global SnowPack – Central Asia

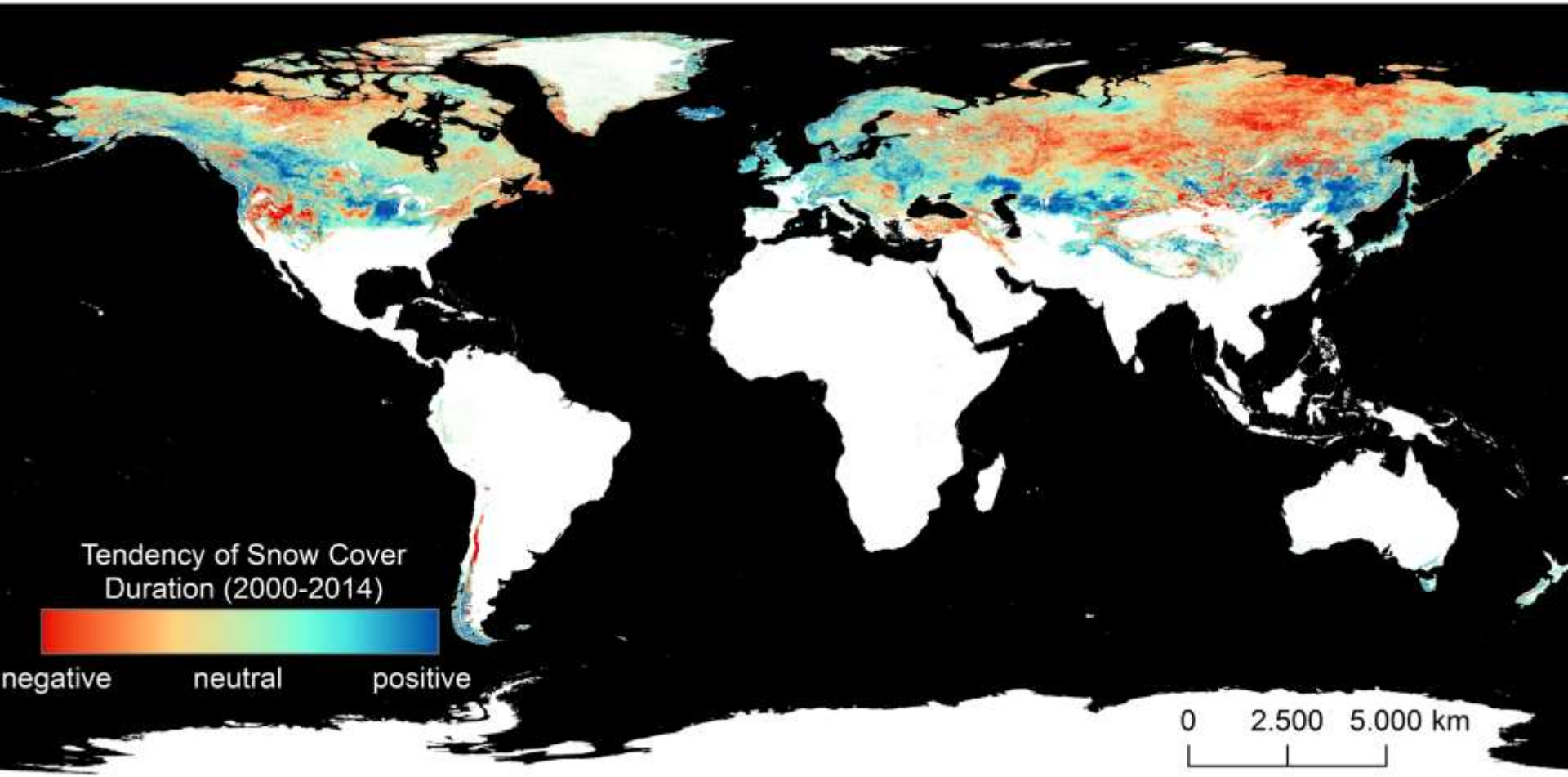
Syr Darya runoff amounts compared to snow cover within the upper reaches of the drainage basin. Many rivers in the Northern Hemisphere are characterized by a snowmelt dominated runoff regime. Syr Darya is one of them.





Global SnowPack – World

Tendency of global SCD between 2000/2001 and 20014/2015






AUG 28 2015

Global SnowPack – Links and contacts

TIMELINE

http://www.dlr.de/eoc/en/desktopdefault.aspx/tabid-9035/15754_read-38904/

GLOBAL SNOWPACK byEOC

https://geoservice.dlr.de/web/

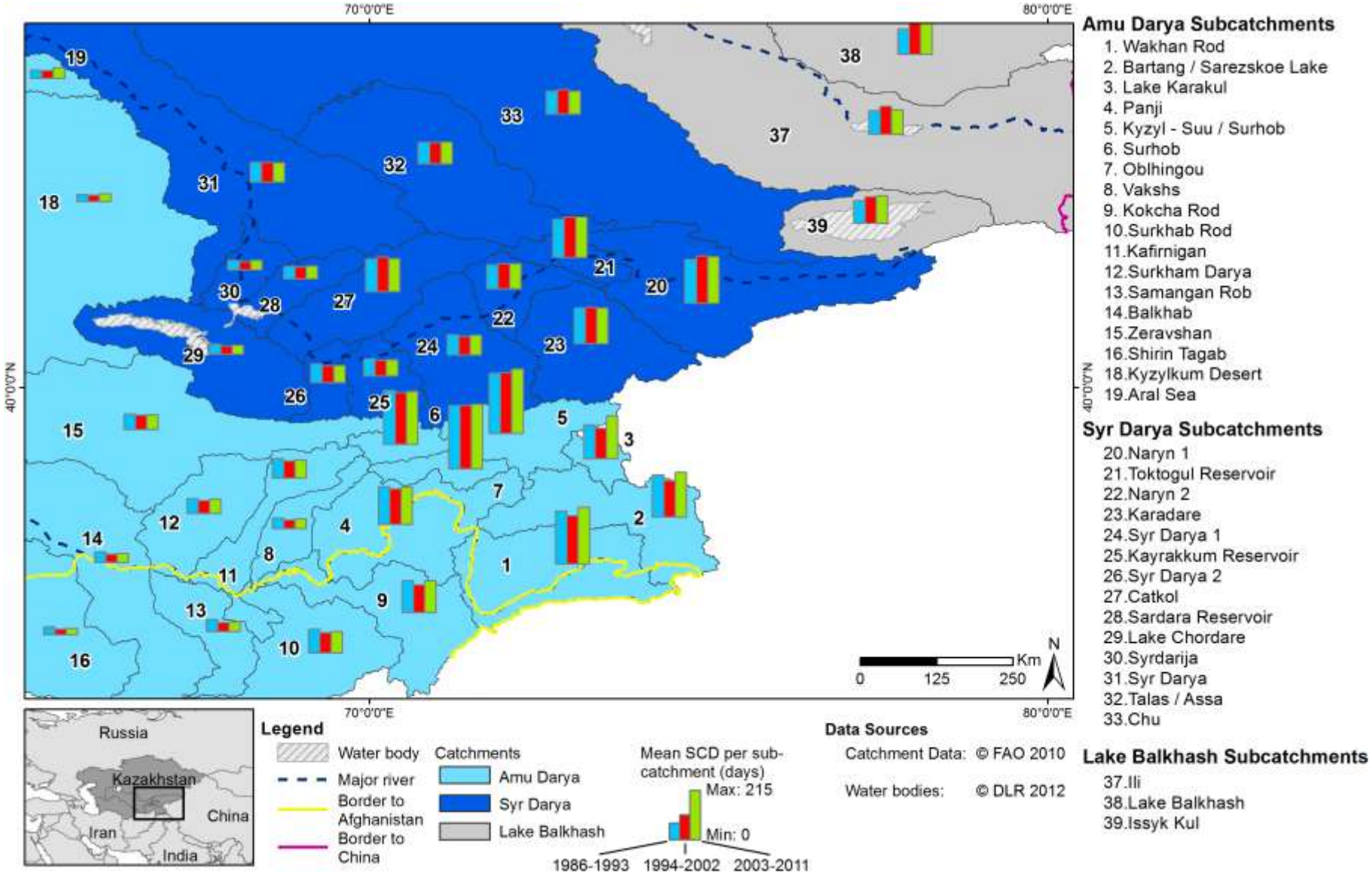
Contact: Global-SnowPack@dlr.de
Andreas.Dietz@dlr.de

DLR



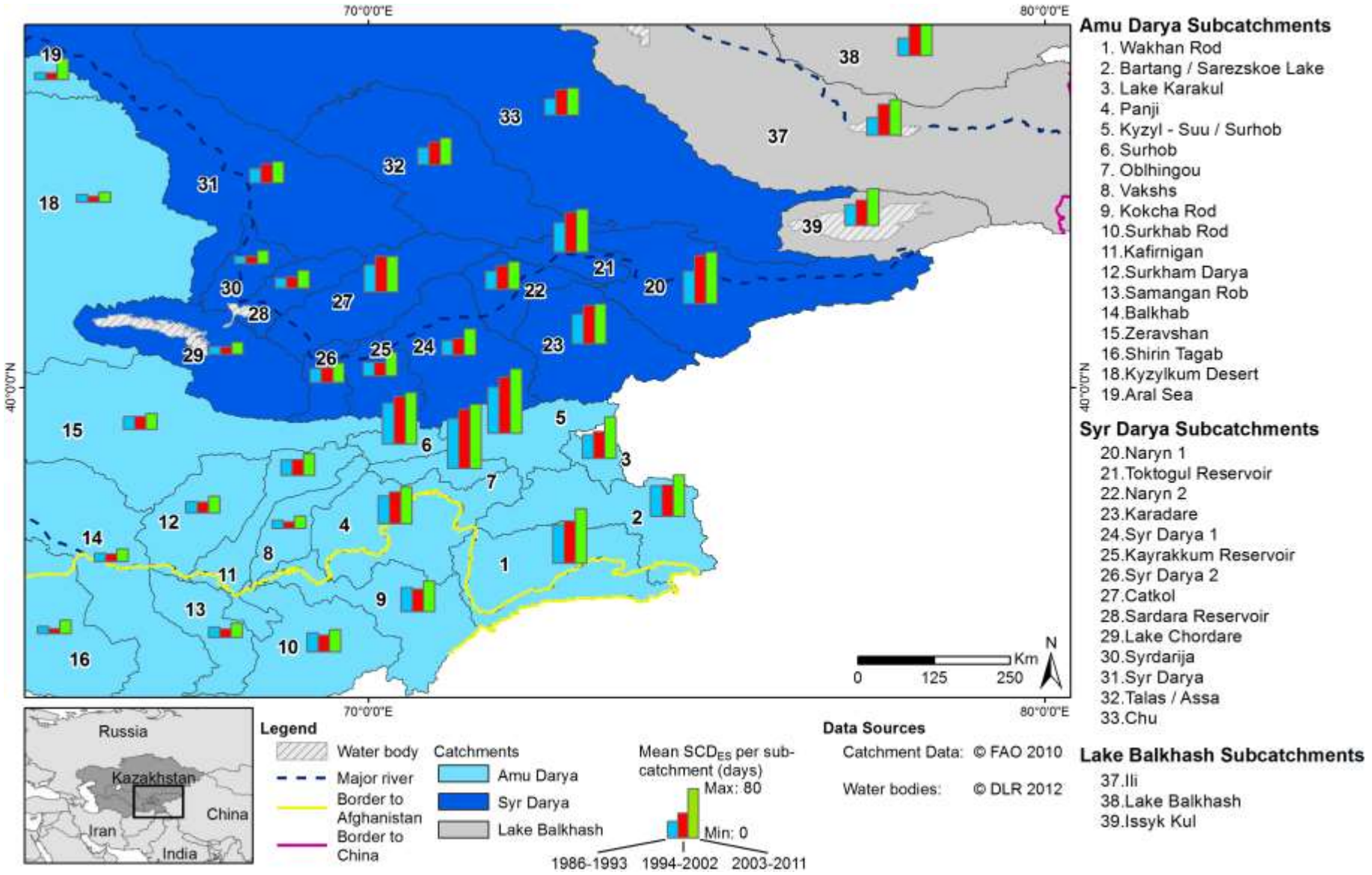
Global SnowPack – Central Asia

SCD development within major hydro catchments



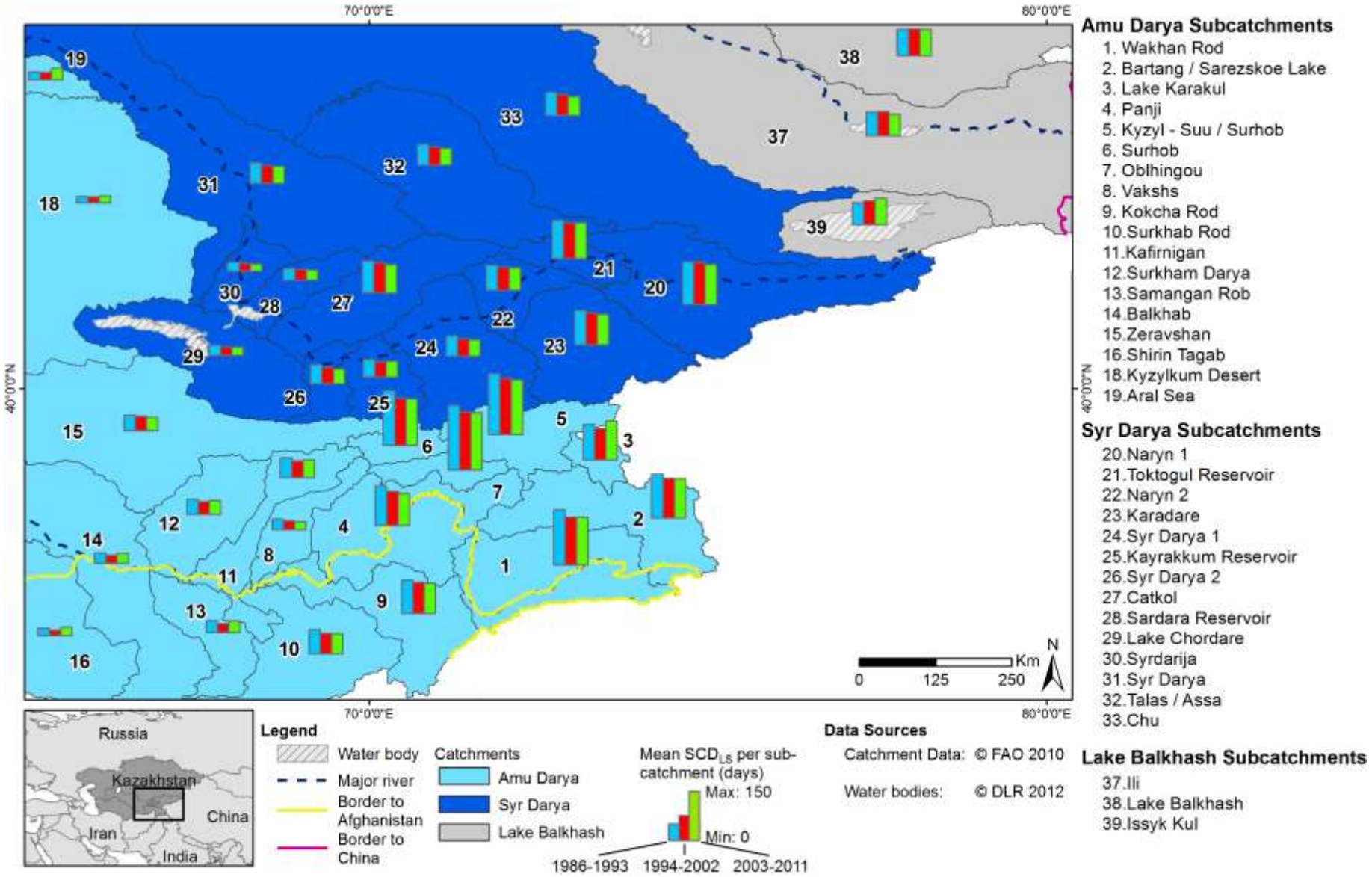
Global SnowPack – Central Asia

SCD_{ES} development within major hydro catchments



Global SnowPack – Central Asia

SCD_{LS} development within major hydro catchments




AUG 28 2014

Global SnowPack – Central Asia

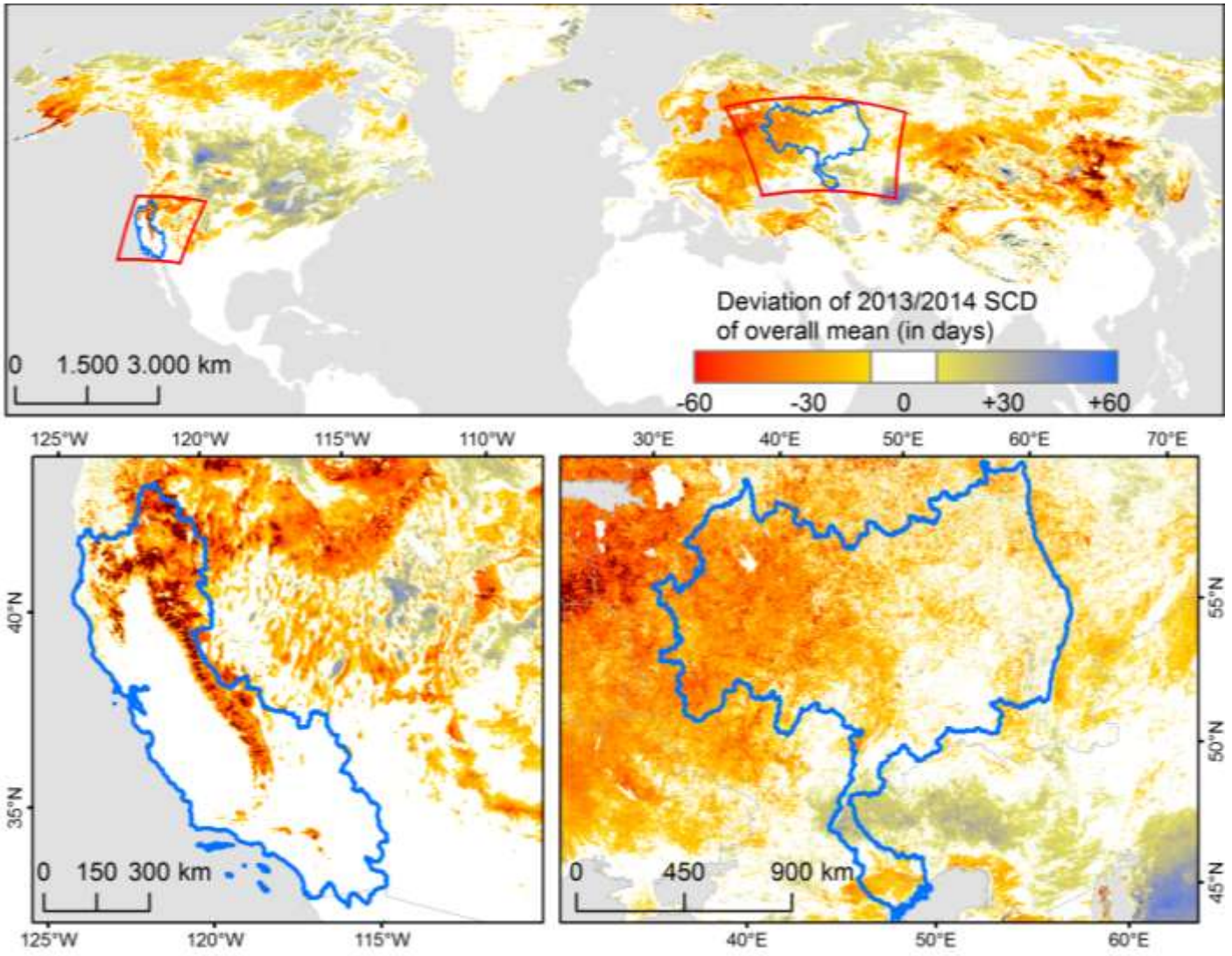
Conclusions for Central Asia

- SCD increases by ~ 5 days per degree latitude. In mountain regions, SCD increases by ~ 4 days per 100 m elevation
- SCD only changed significantly in few areas within the last 26 years
- The snow cover season has shifted two weeks towards earlier start and melt since 1986 within the mountainous regions.
- SCD is highly variable in mountain regions and between 45°N and 50°N
- Runoff of Syr Darya (and in some years also Amu Darya) corresponds to the snow coverage within the hydro catchment. Changes of snow cover characteristics therefore also influence the region's runoff behavior, leading to various possible consequences:
  - Reservoirs of the region will have to collect and store the melt water earlier
  - Earlier start of the snow cover season influences the pasture farming
  - Earlier snow melt in the mountain region releases the water before the downstream irrigated regions can make use of it.



Global SnowPack – World

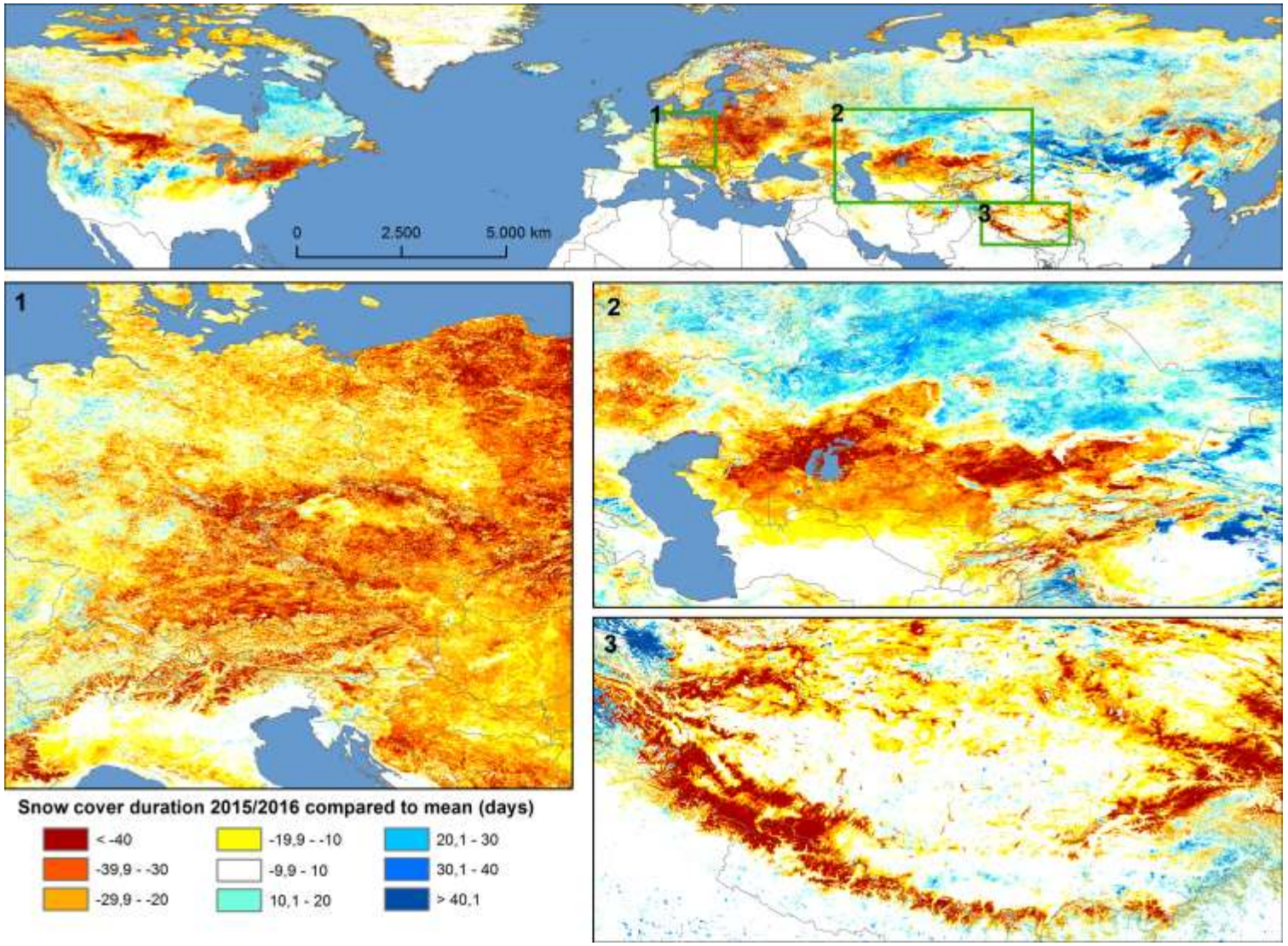
- Difference between SCD 2013/2014 and mean SCD 2000-2013
- Two basins have been selected for a detailed view:
- Volga basin features an overall lower SCD
- California basin also shows very low SCD for the Sierra Nevada – the main source of fresh water in the whole region



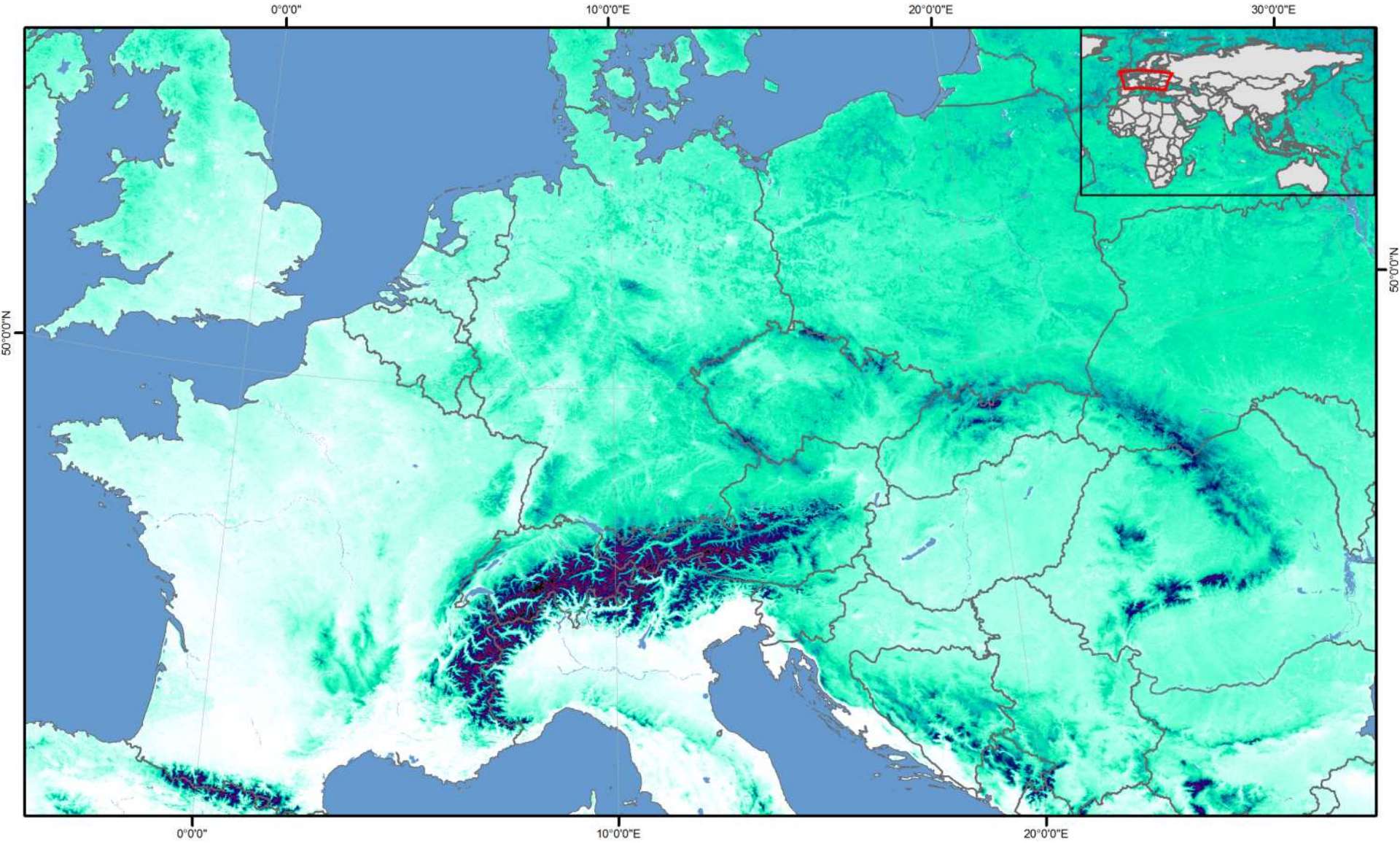


Global SnowPack – World

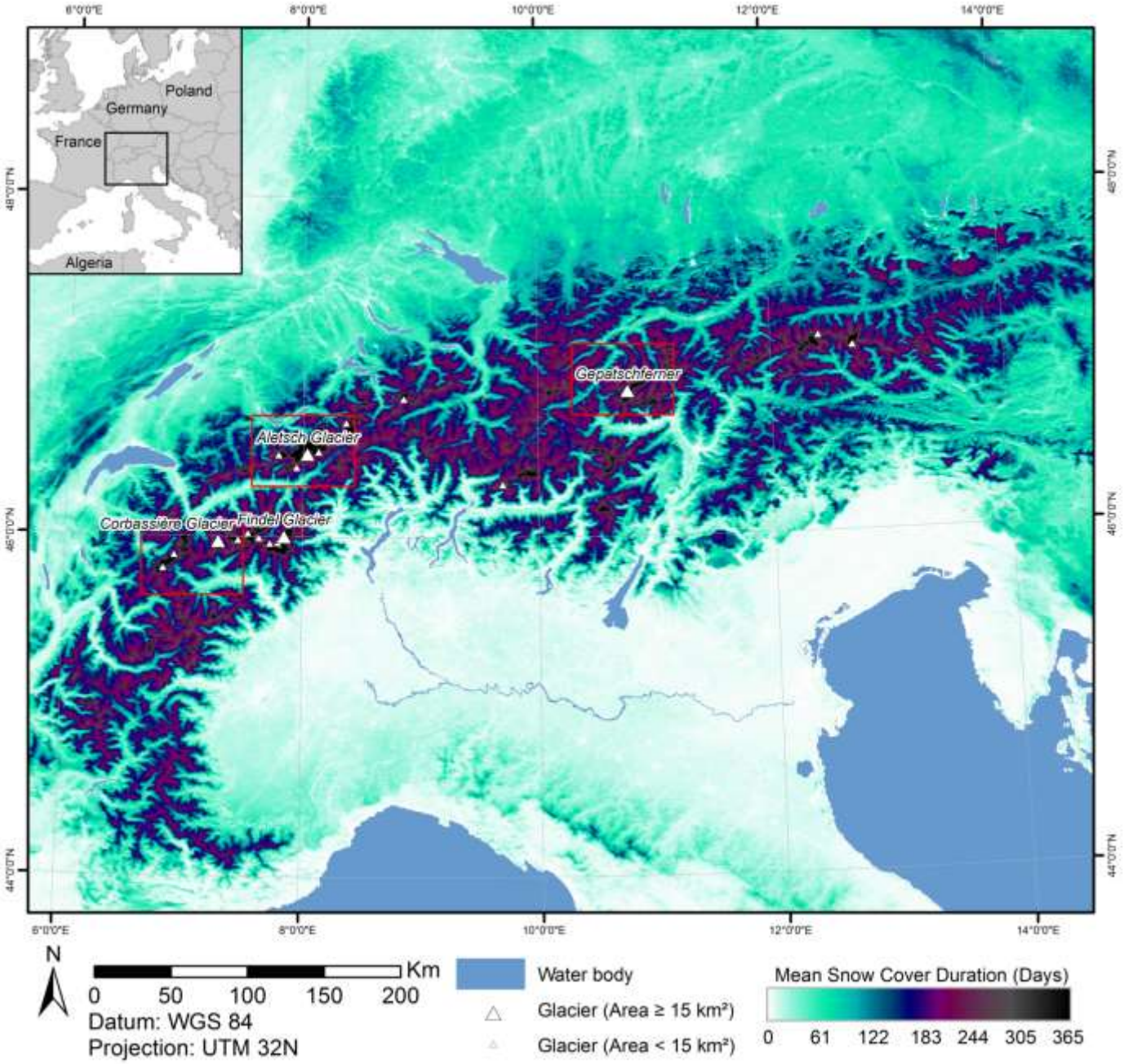
- Difference between SCD 2015/2016 and mean SCD 2000-2015
- Very low SCD in parts of Europe, Central Asia, Tibet Plateau/ Himalaya.
- High SCD in Central USA, Mongolia, Central Siberia, Northern Central Asia



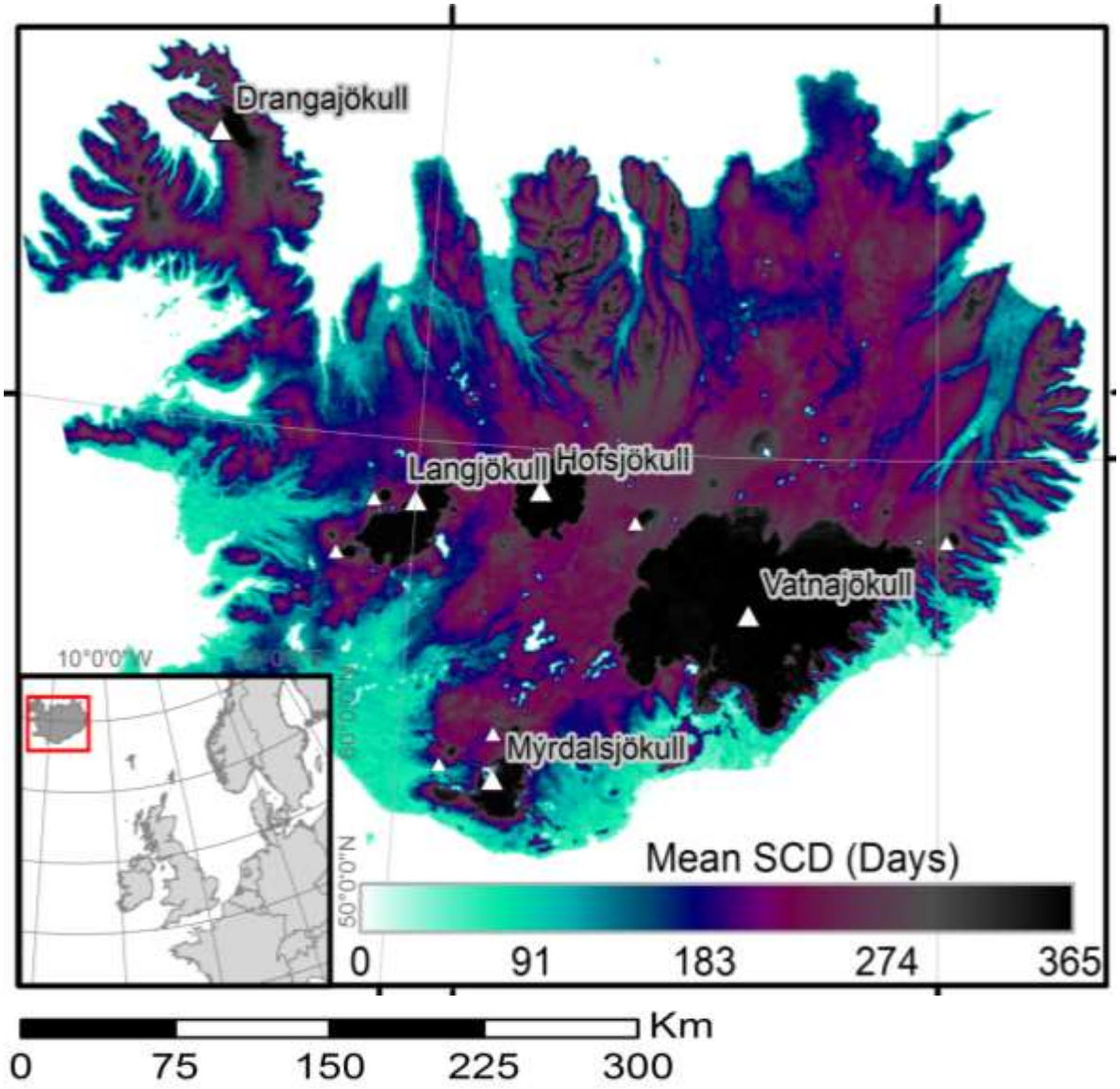
Global SnowPack



Global SnowPack

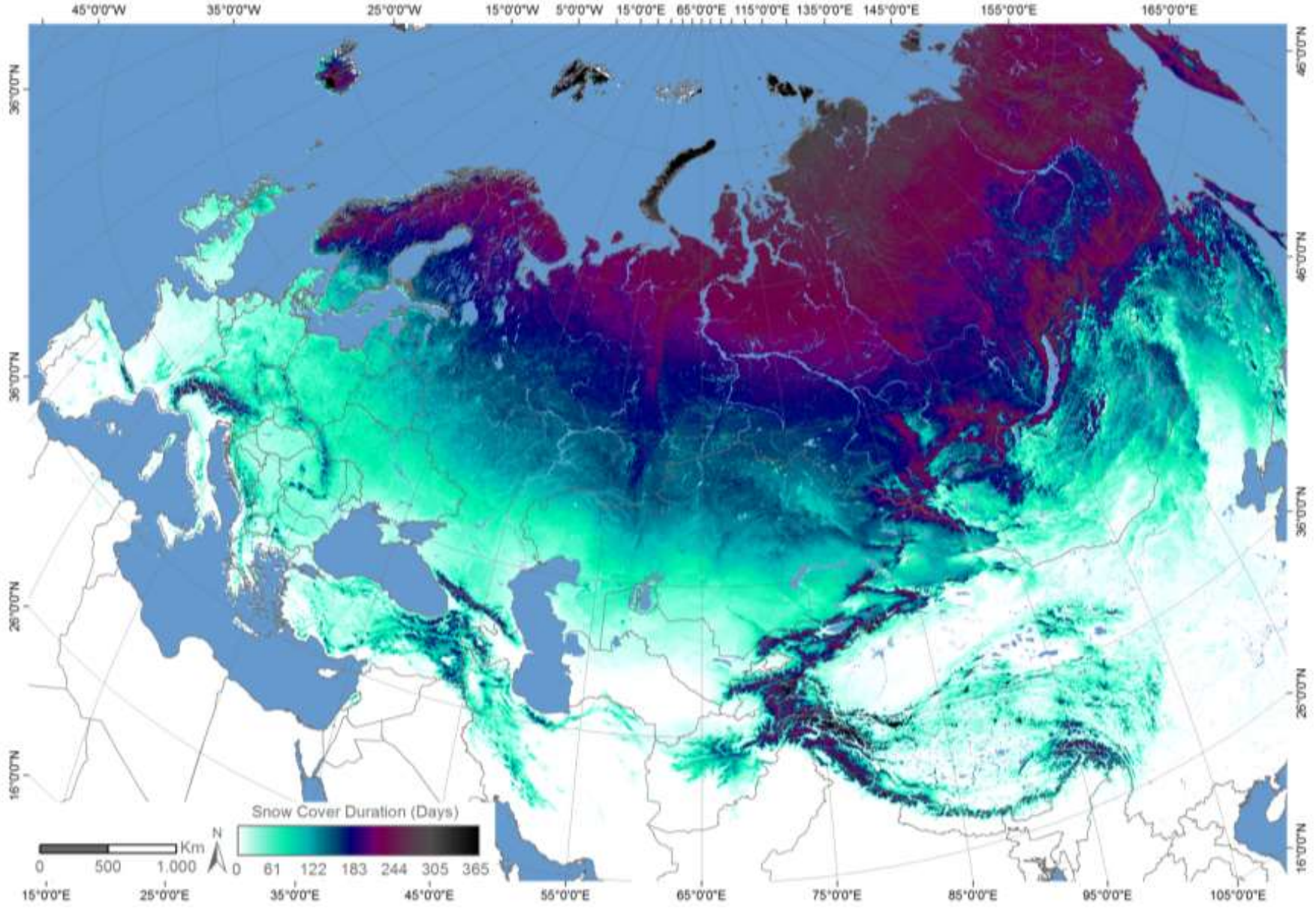


Global SnowPack

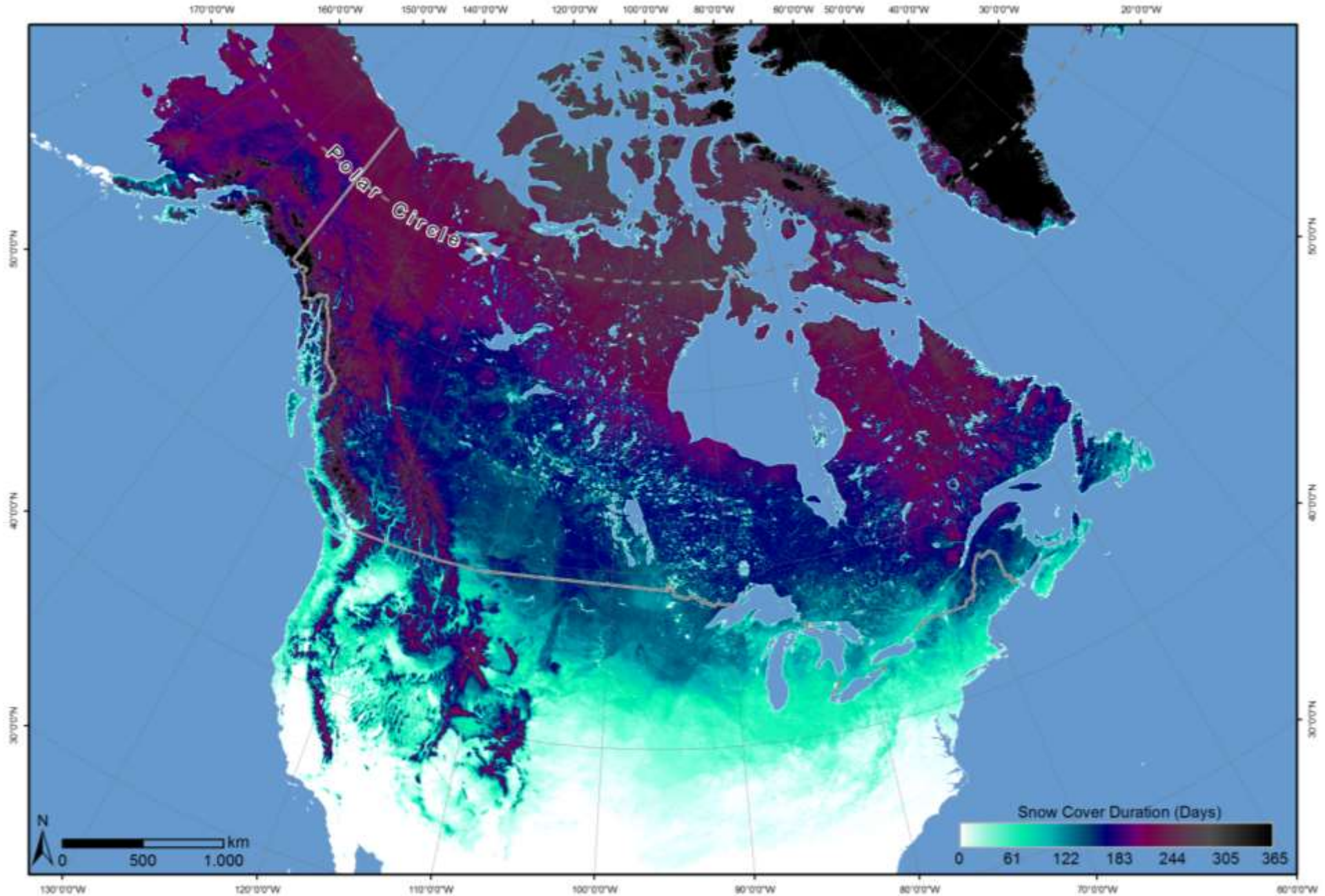




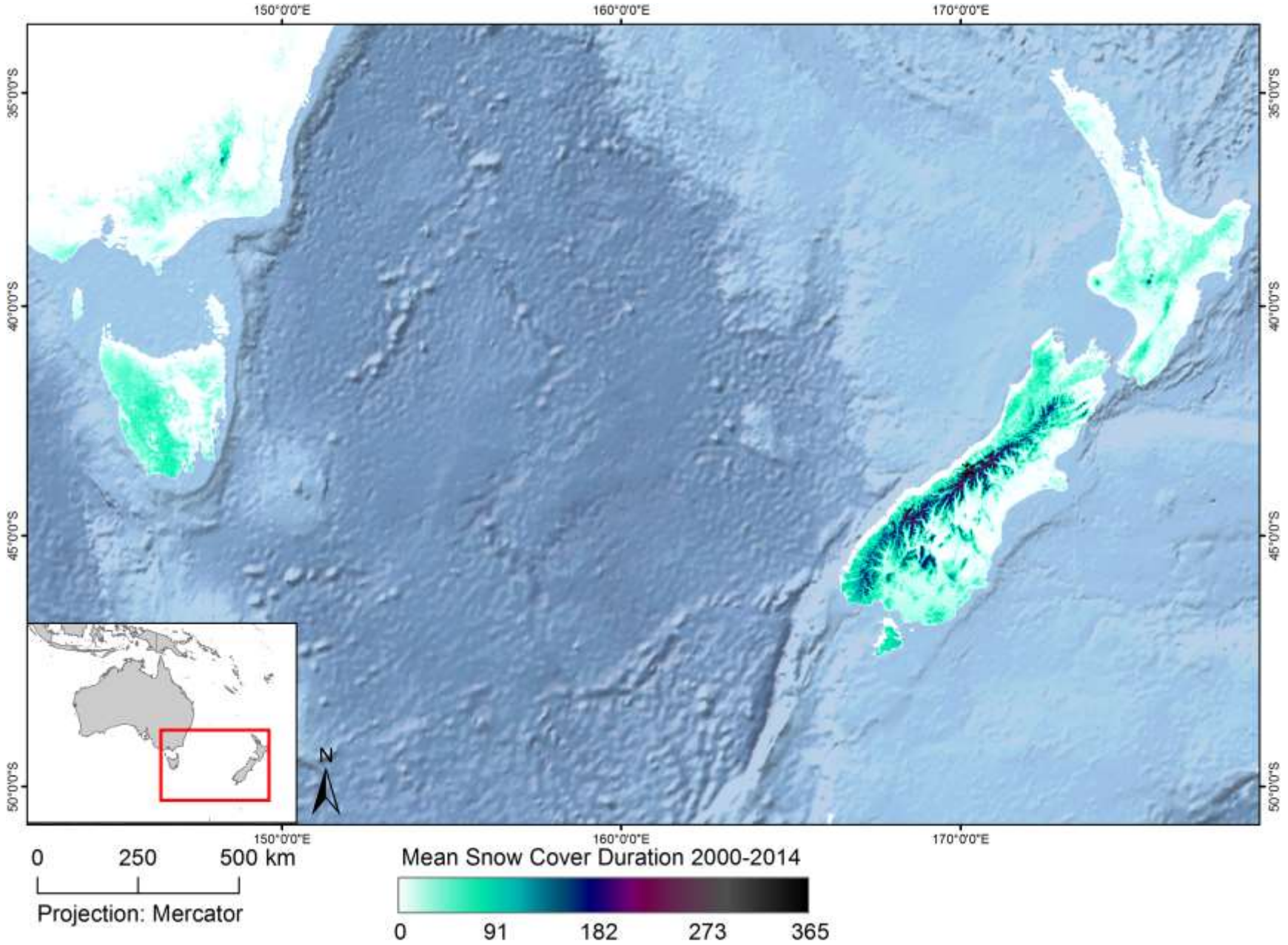
Global SnowPack



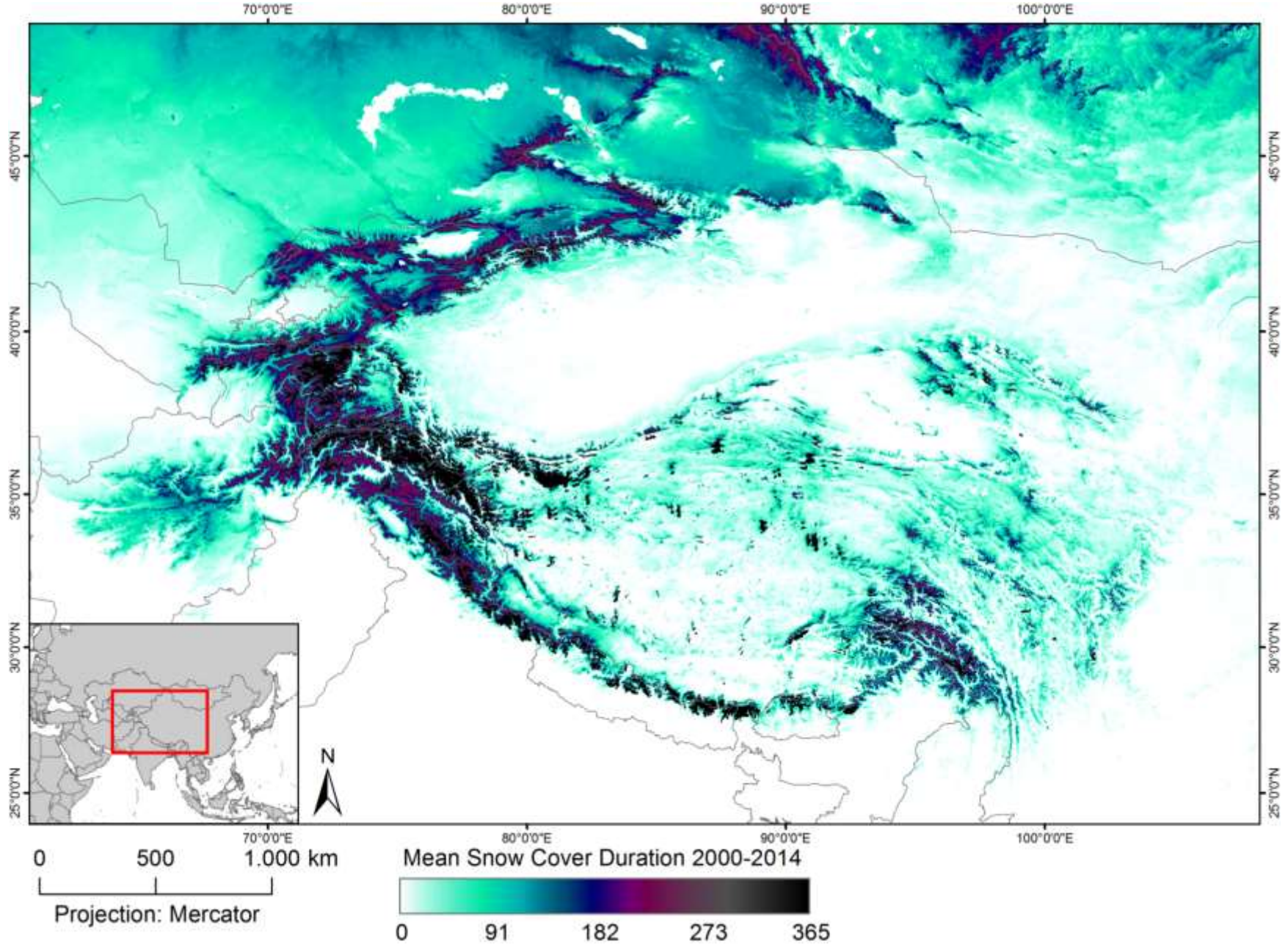
Global SnowPack



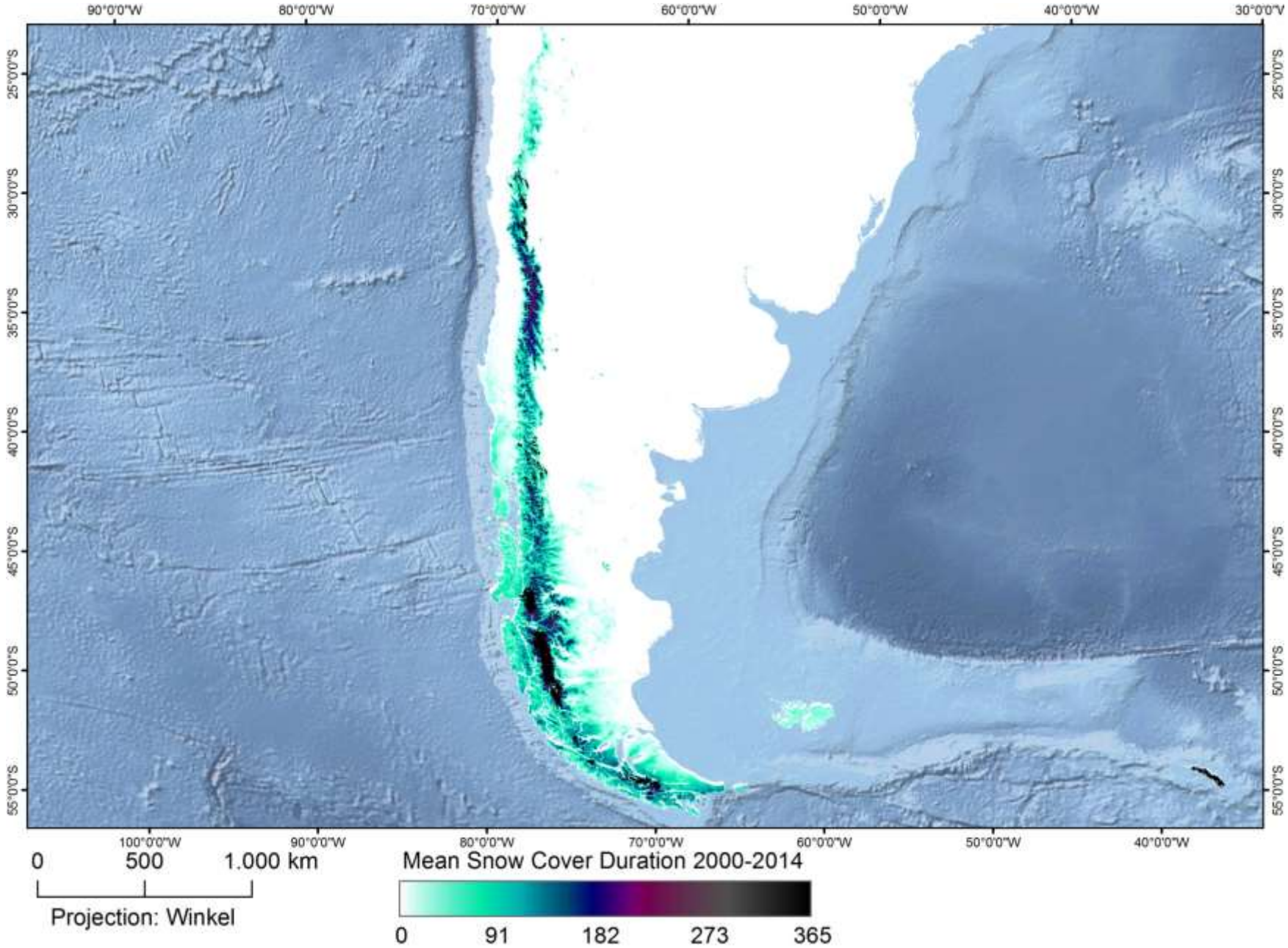
Global SnowPack



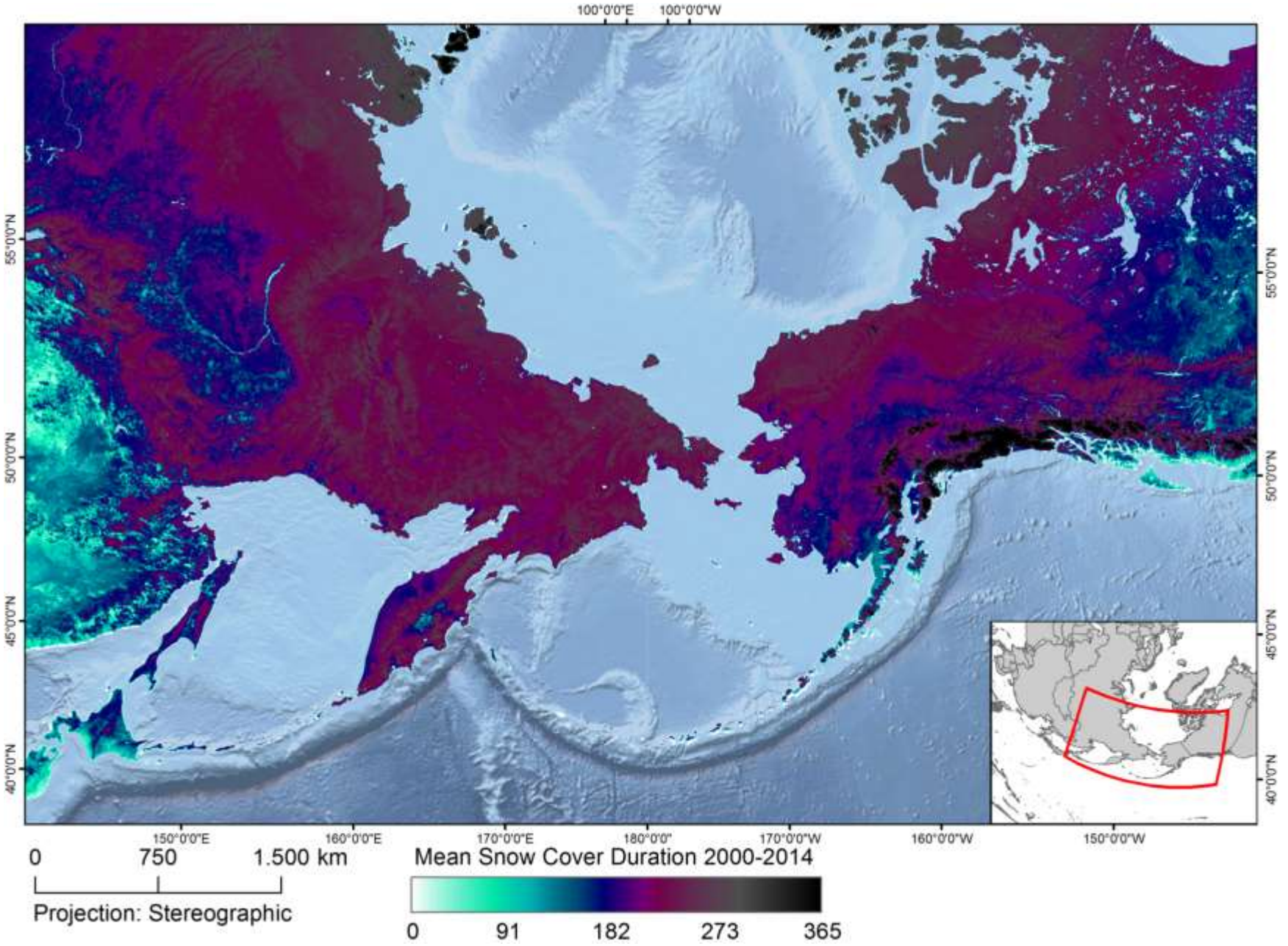
Global SnowPack



Global SnowPack



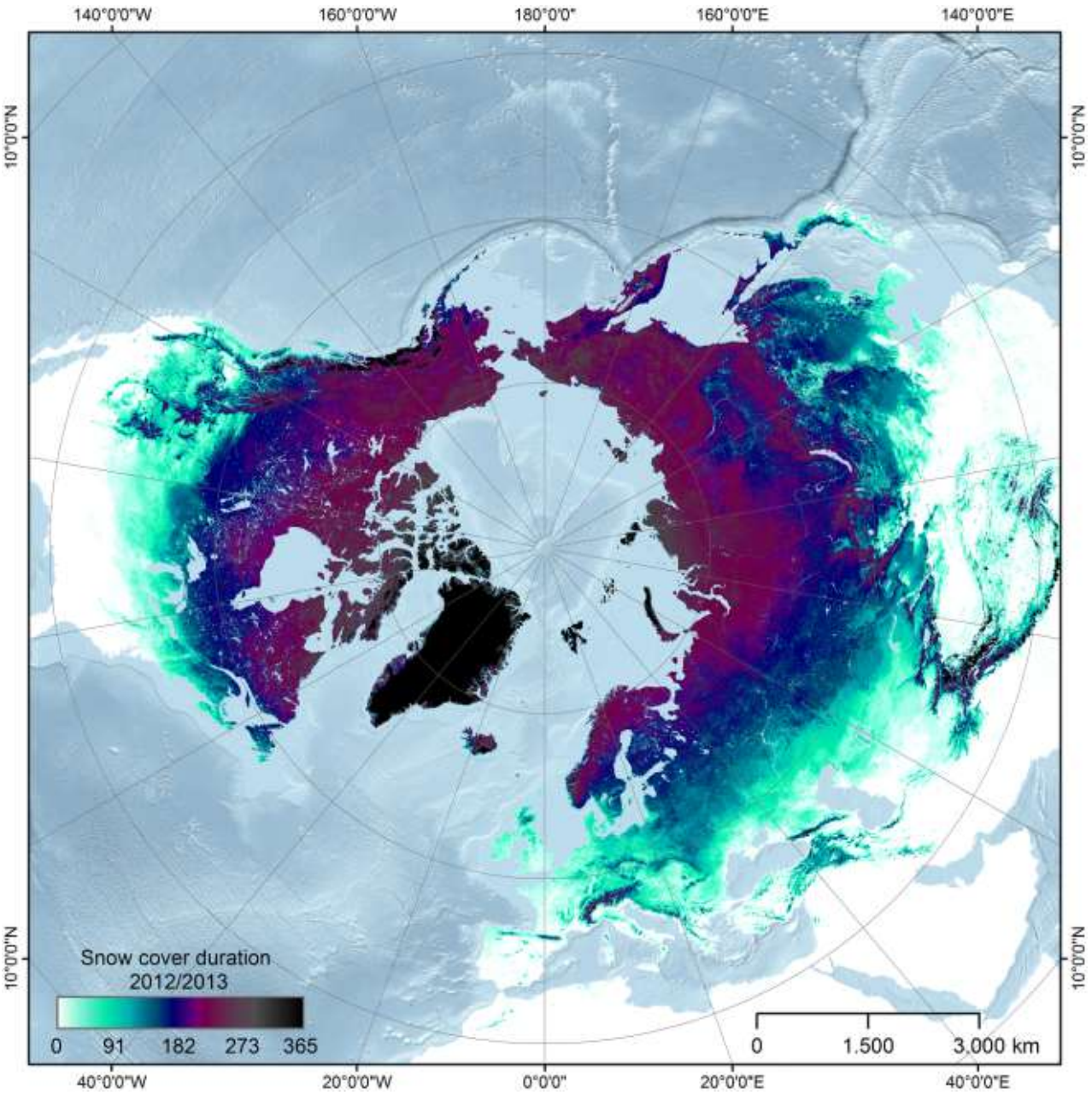
Global SnowPack



Global SnowPack

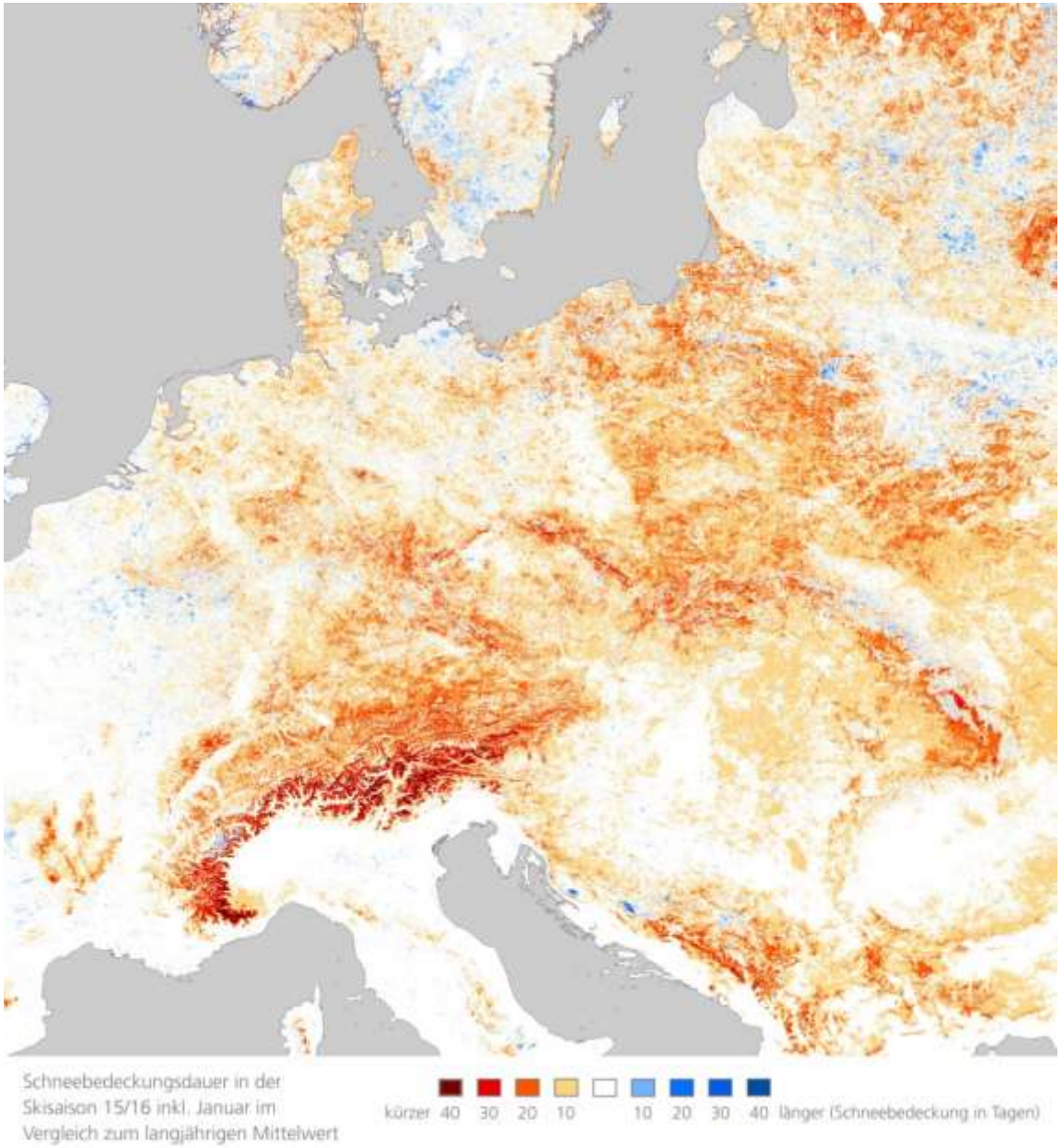
Attributes:

- 500m spatial resolution
- Daily snow cover information
- Products: Snow cover duration, Early Season SCD, Late Season SCD, Standard Deviation on a global scale
- Consistent since 2000
- Processing of AVHRR time series under development (1km spatial resolution, daily data since ~ 1985)
- Sentinel 3 data will replace MODIS in the near future



Global SnowPack – Germany

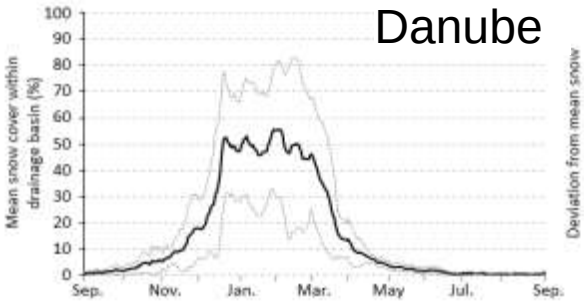
- Severe anomalies of early season SCD in 2015/2016 in Germany
- Up to 40 days later snow cover onset in mountainous regions.
- Massive effects for tourism industry

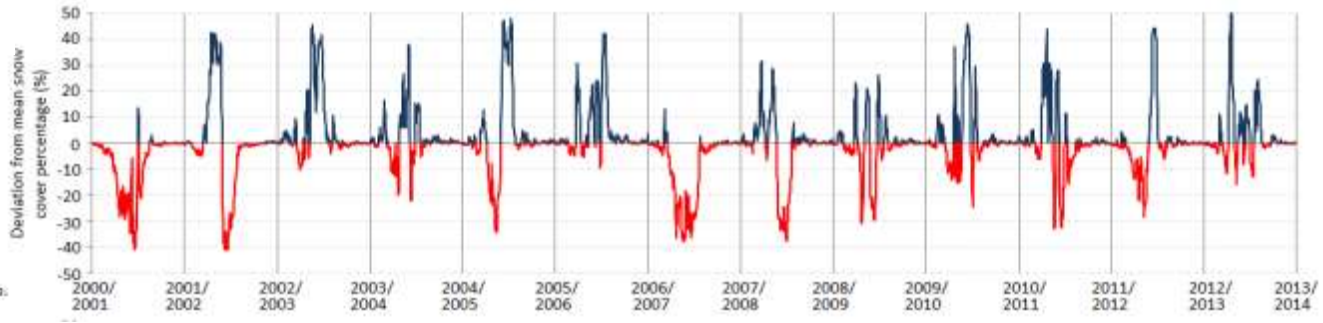


Global SnowPack – Hydrology

Observation of daily snow cover can help analyzing and predicting possible events within river catchments.

- Many rivers worldwide (more than 50% within Northern Hemisphere) are dominated by snowmelt runoff
- Abrupt changes in snow cover percentages within a river basin can lead to flood events.
- Analyzing the long term development within each catchment can help identifying possible trends in snow cover characteristics and therefore, future runoff regimes





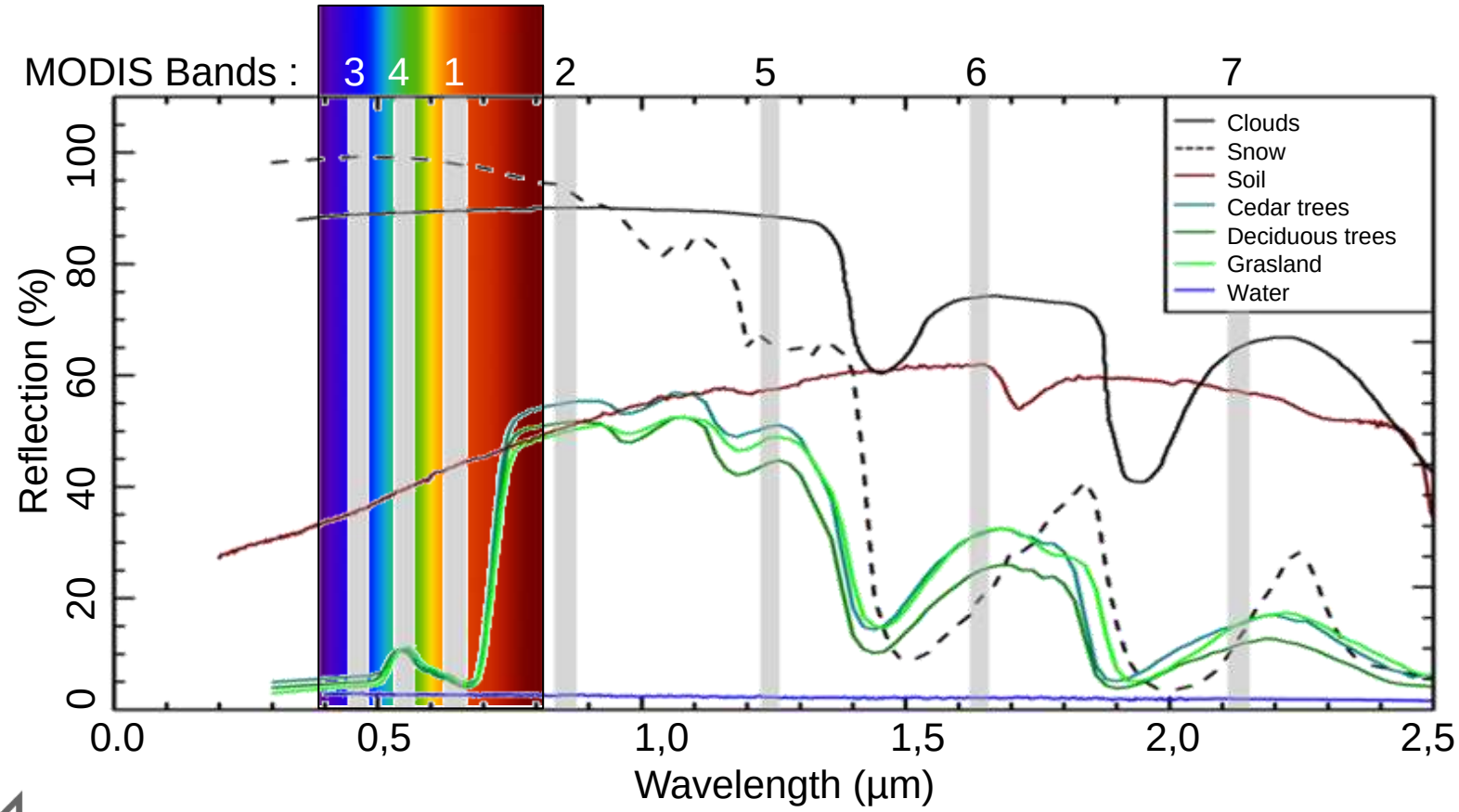
DLR



Methods

Spectral characteristics of snow

- High reflection in the visible part
- Very low reflection in the short wave infrared
- Freeze and thaw processes affect the reflection.





Methods

Normalized Difference Snow Index (NDSI):

$$NDSI = \frac{R_{vis} - R_{SWIR}}{R_{vis} + R_{SWIR}}$$

R_{vis}: Reflection in the visible part
R_{SWIR}: Reflection in shortwave infrared

NDSI > 0.4 is a good indicator for the presence of snow

As the reflection of water is very low in the visible, but even lower in the short wave infrared, the NDSI of water surfaces can be similar to the one of snow. Therefore, a simple reflectance test for the visible part needs to be included to prevent confusion.

