

Snow Cover Mapping for Yield Forecasts and Photovoltaic System Monitoring

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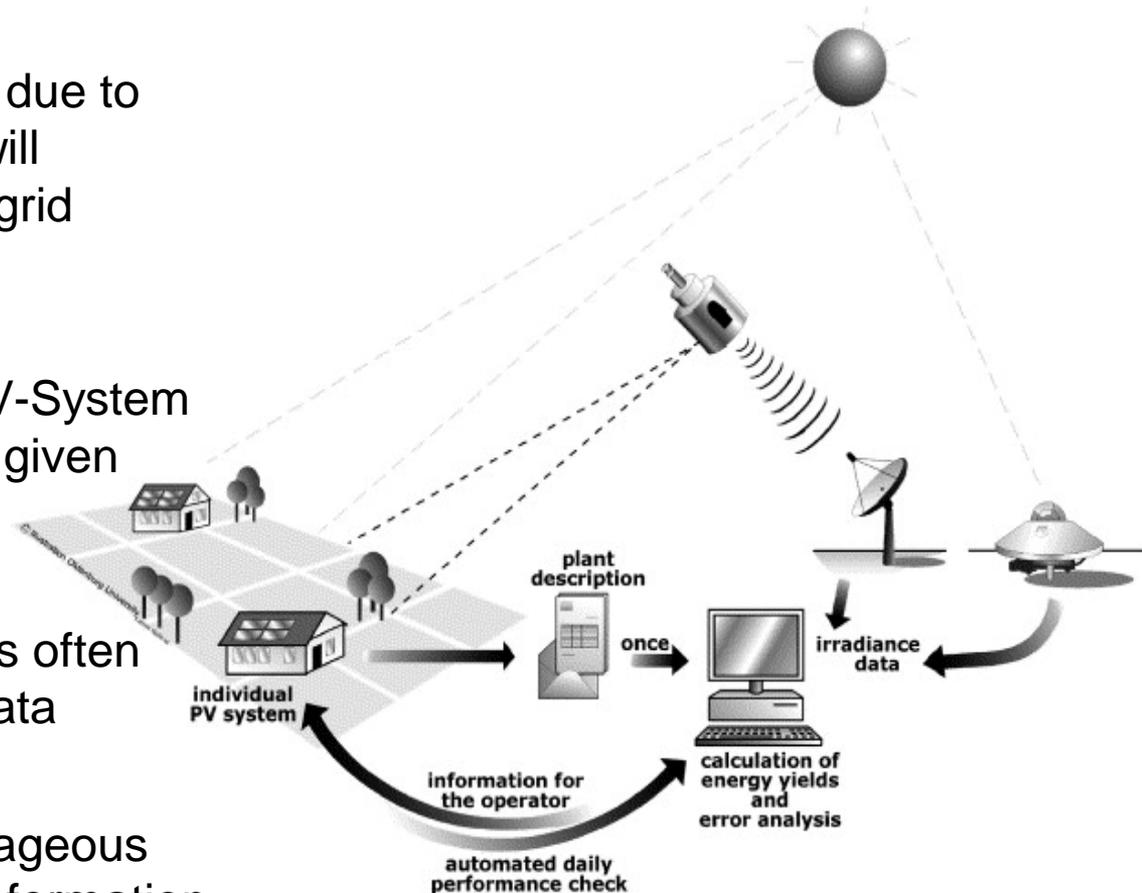
Outline

- Influence of Snow on Monitoring PV Systems
 - Monitoring of PV Systems
 - Effects of a Snow Cover
 - Available Snow Cover Datasets
 - Validation of the Datasets
- Snow Cover Mapping for Yield Prognosis
 - General Information on Yield Prognosis
 - Satellite Record Used for the Snow Cover Maps
 - Snow Cover Maps for Europe and the US



Monitoring PV-Systems

- Monitoring is important due to financial reasons and will become necessary for grid stability
- The actual yield of a PV-System can be calculated for a given solar radiation
- Irradiance information is often derived from satellite data
- Satellite data is advantageous because of its spatial information

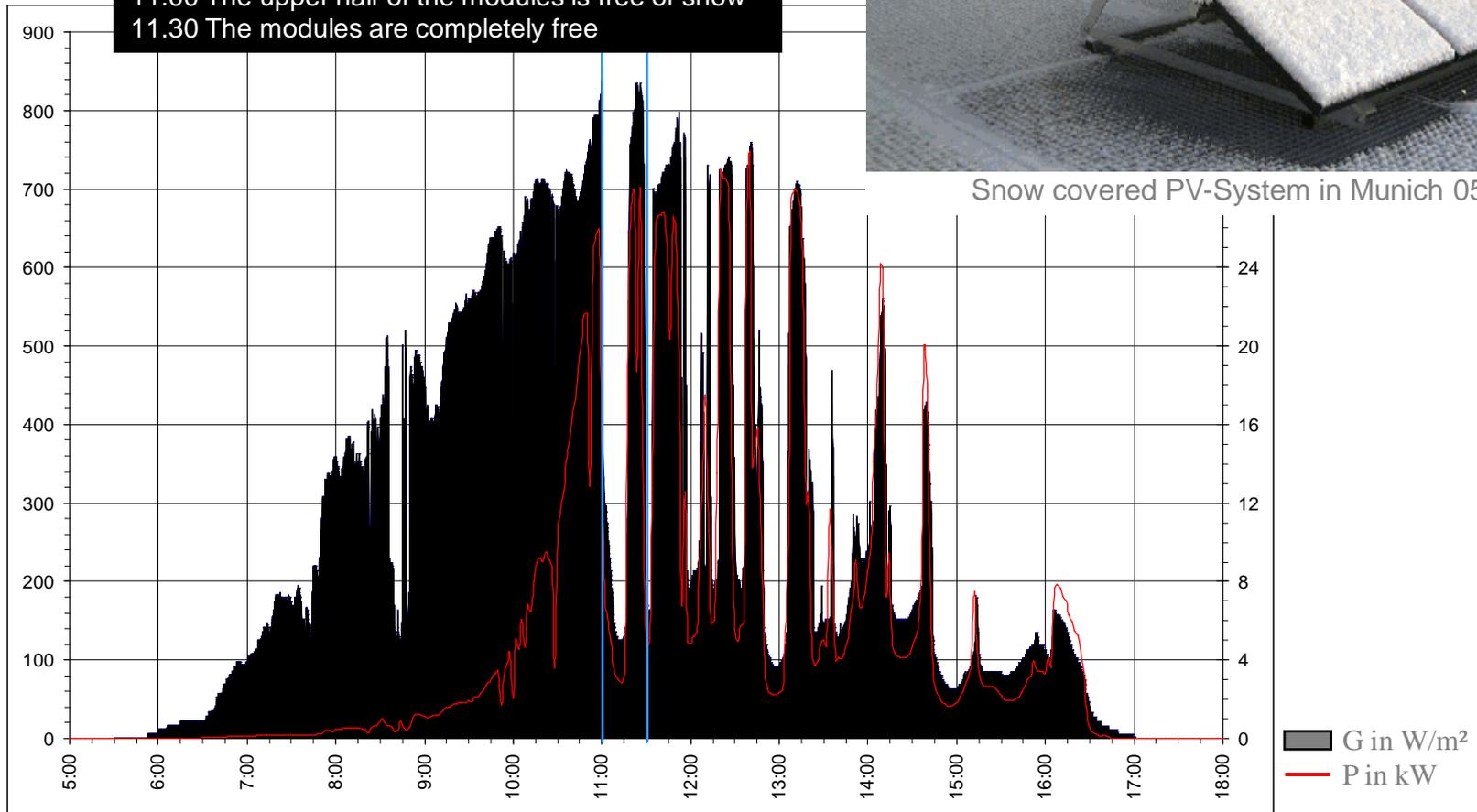


Effects of Snow Cover



Snow covered PV-System in Munich 05.03.2008

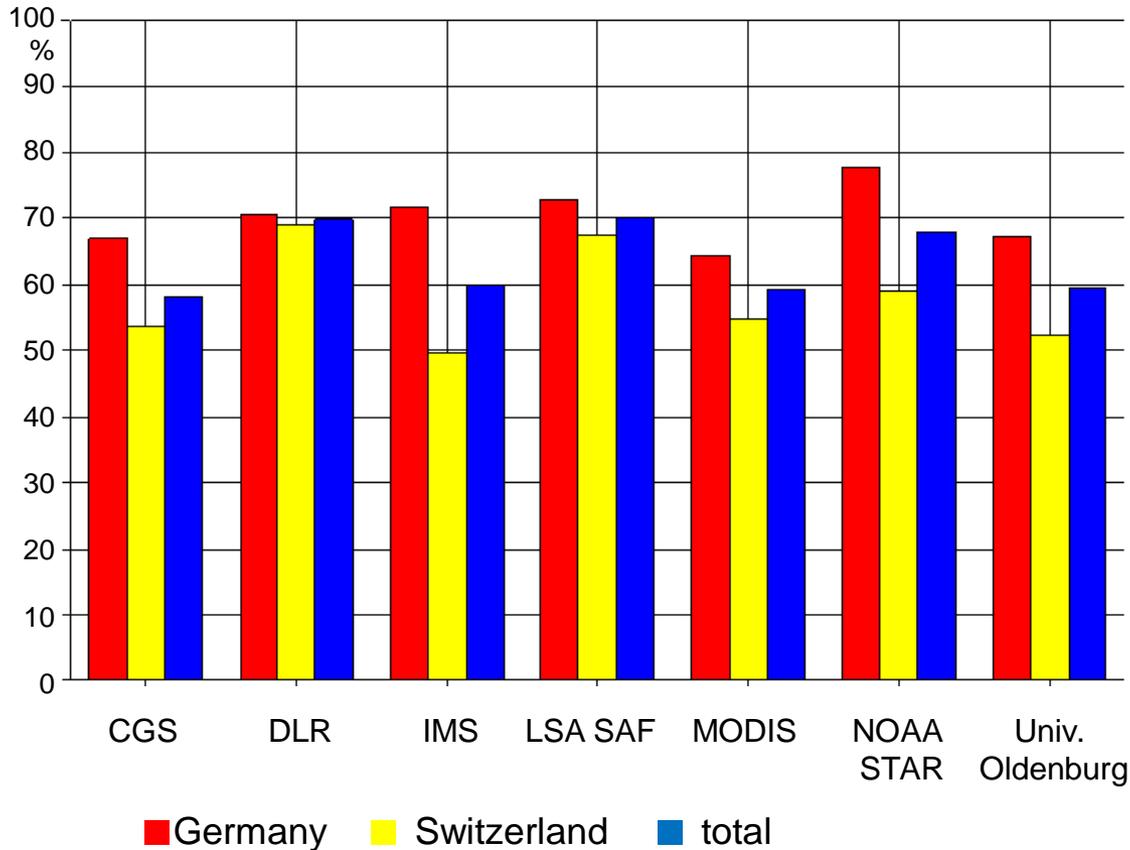
11.00 The upper half of the modules is free of snow
11.30 The modules are completely free



Provider	Satellit	Sensor	Resolution	Coverage	Data Type
Automated snow mapping system (NOAA – STAR)	MSG	SEVIRI	4 km	Europe	Binär
Carl von Ossietzky Universität Oldenburg	MSG	SEVIRI	On demand	Europe	CSV
Carlo Gavazzi Space (CGS)	Terra	MODIS	250 m	European Alps	Binär
Deutsches Zentrum für Luft u. Raumfahrt – DLR	MSG	SEVIRI	4 km @ Nadir	Europe, Africa, South America	HDF
IMS NSIDC	Aqua, Terra, MSG, POES	MODIS, SEVIRI, AVHRR, SSM/I, AMSU	4 km	Northern Hemisphere	GeoTIF ASCII
LSA SAF (EUMETSAT)	MSG	SEVIRI	4 km @ Nadir	Europe, Africa, South America	HDF 5
MODIS (MOD10A1)	Terra	MODIS	500 m	Worldwide	HDF EOS



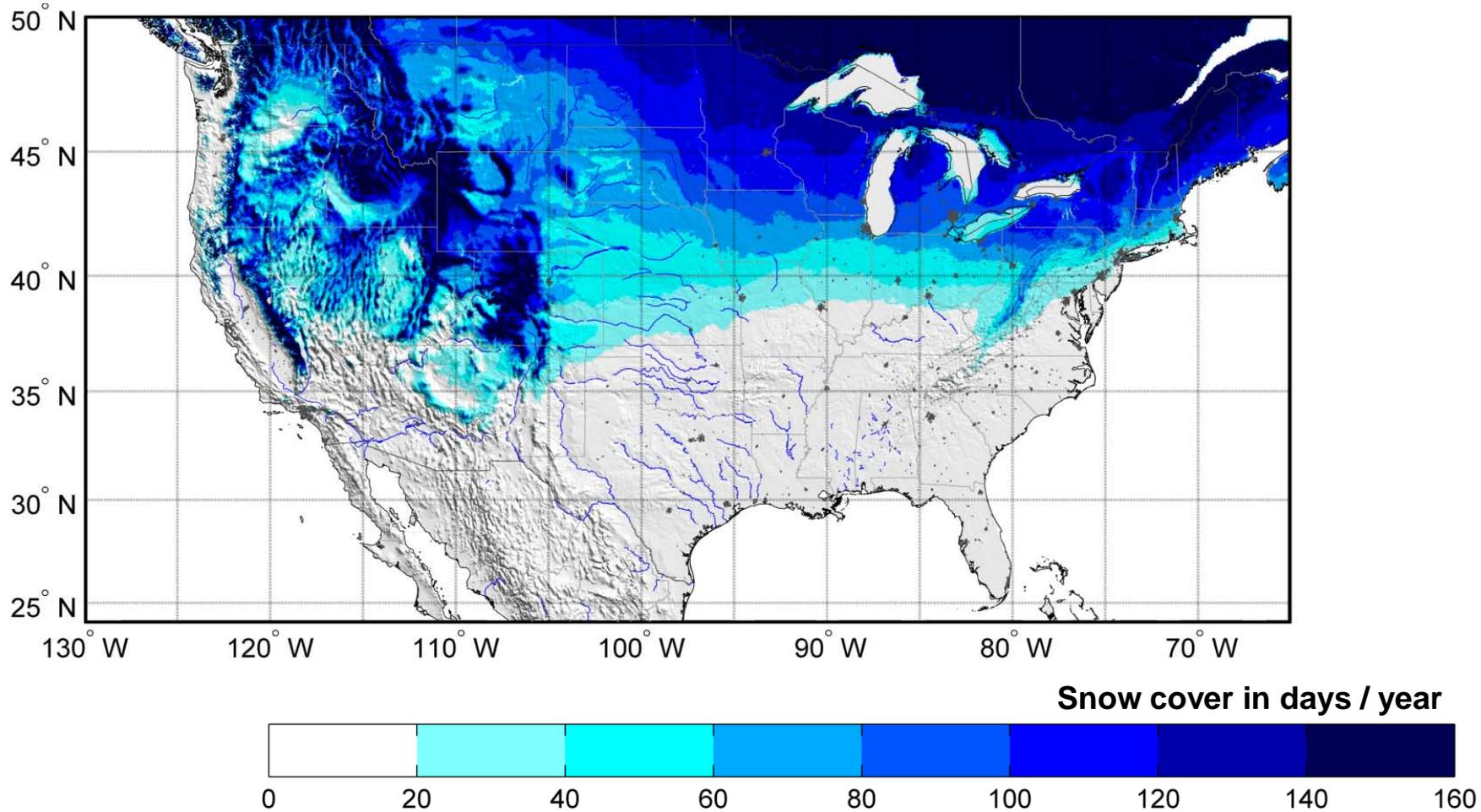
Classification Accuracy



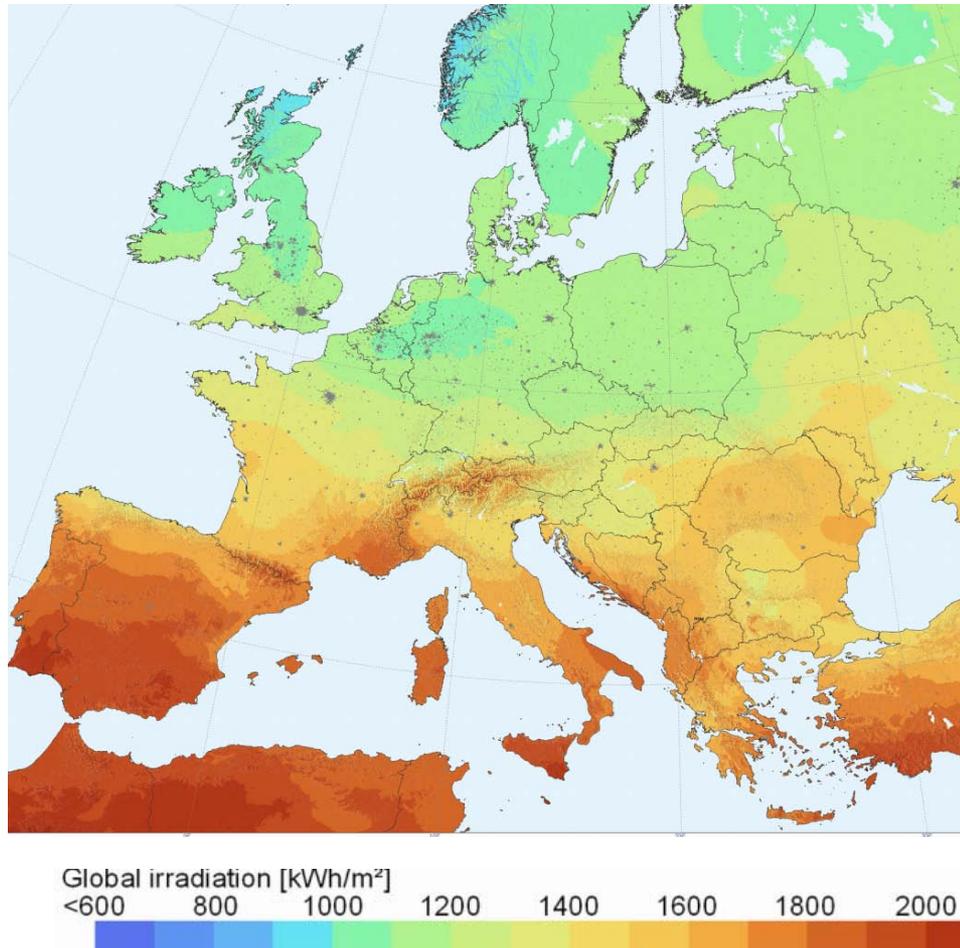
- LSA SAF and DLR show the best overall accuracy
- Both show the benefit of the high temporal resolution of Meteosat
- Global products show good values in Germany but have a low performance in difficult areas like Switzerland.



Snow Cover Maps



Yield Prognosis



- For a yield prognosis it is common to use long time series of global irradiation data
- Data based on satellite and / or ground measurements
- A minimum of 5 years is recommended for significant results
- Hardly information on snow cover available



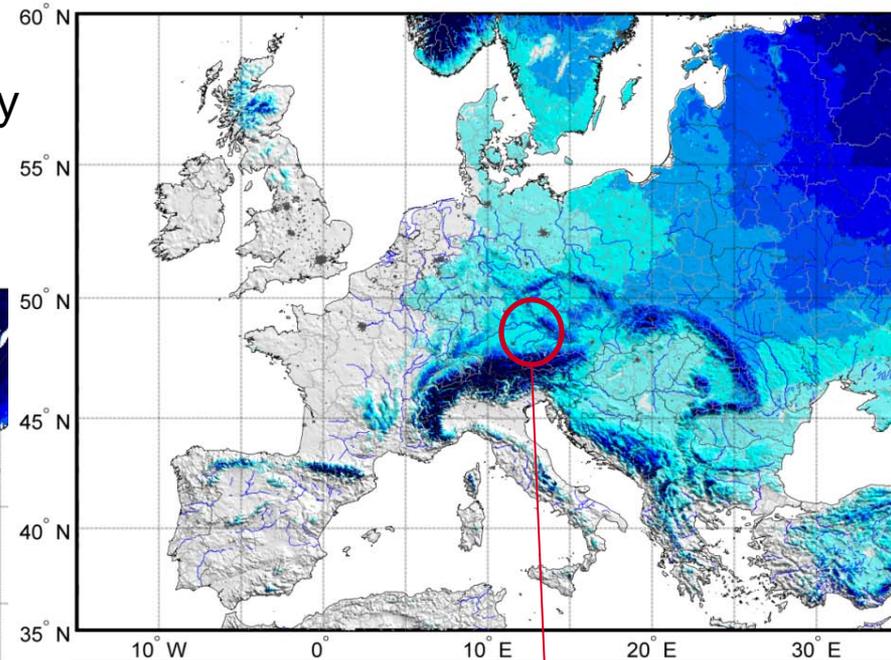
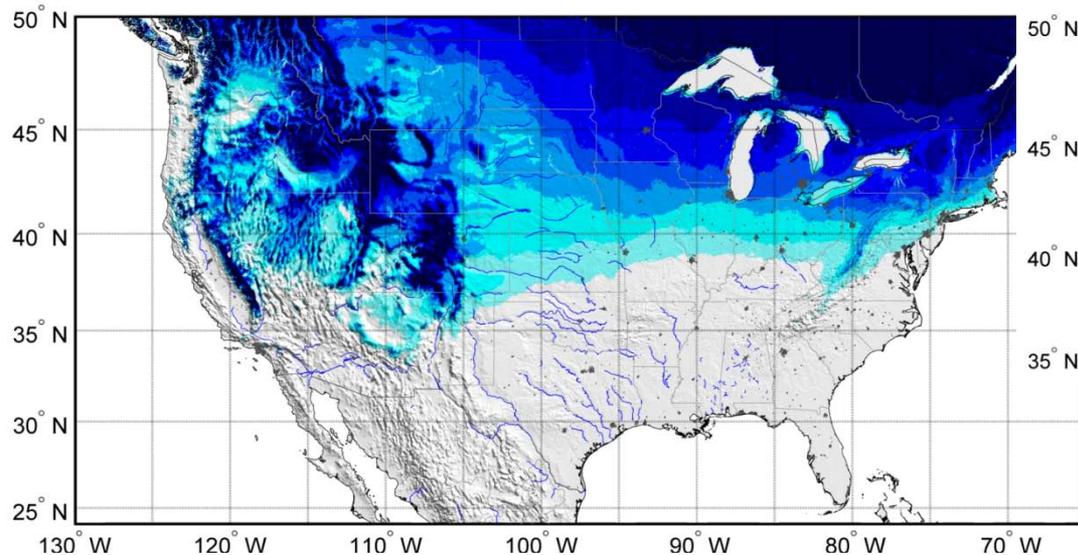
Data Used for the Snow Cover Maps

- NOAA / NESDIS
- Interactive Multisensor Snow and Ice Mapping System (IMS)
 - Snow Cover Mapping since 1966
 - Daily data on a 24 km x 24 km resolution since 1997
 - Daily data on a 4 km x 4 km resolution since 2004

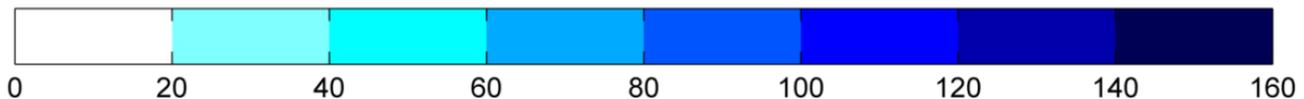


Yearly Snow Cover Maps

- Between 20 and 60 snow covered days in areas used for PV in Germany
- Considerably more snow in the north of the US

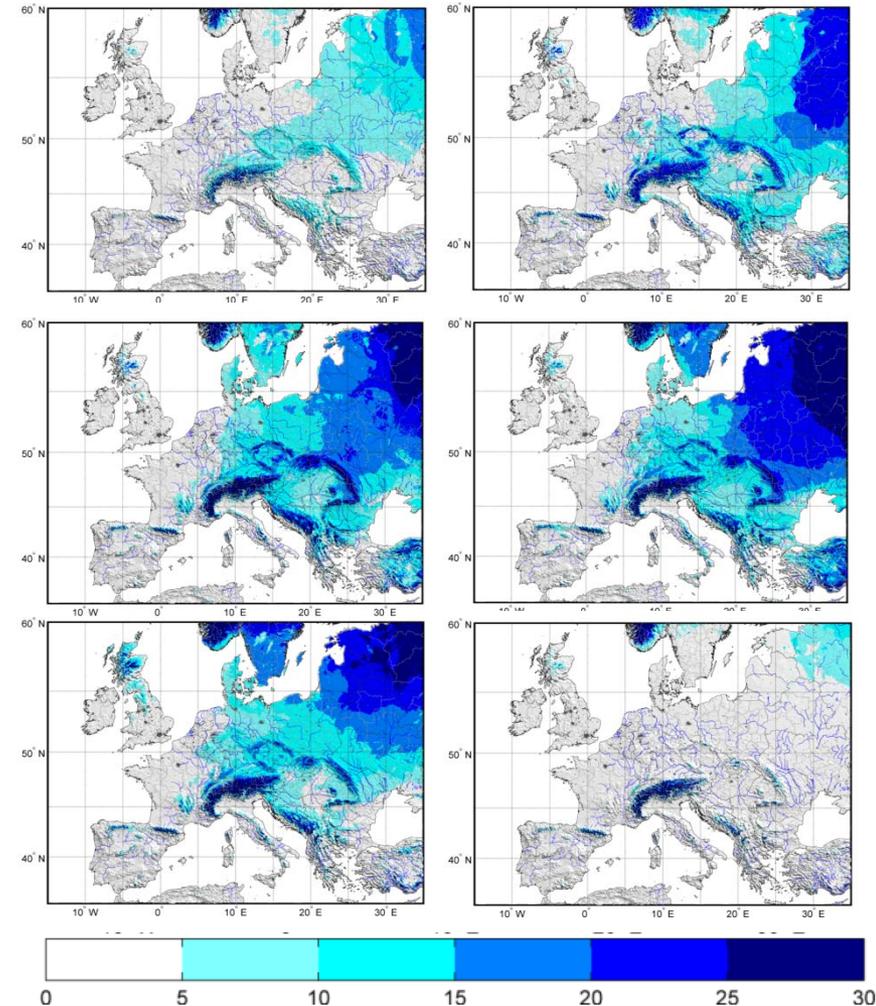


Bavaria: ~ 4 GW of PV installed
3,5 % of the yearly consumption



Monthly Snow Cover in Europe

- Snow cover from November till March
- Little losses in November because there are only few snow covered days
- Small losses in December and January due to low zenith angle
- Most losses appear in March since there is considerable radiation and snow cover



06.0

2008-03-05 CET 09:56:46

Thank you for your attention



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Backup



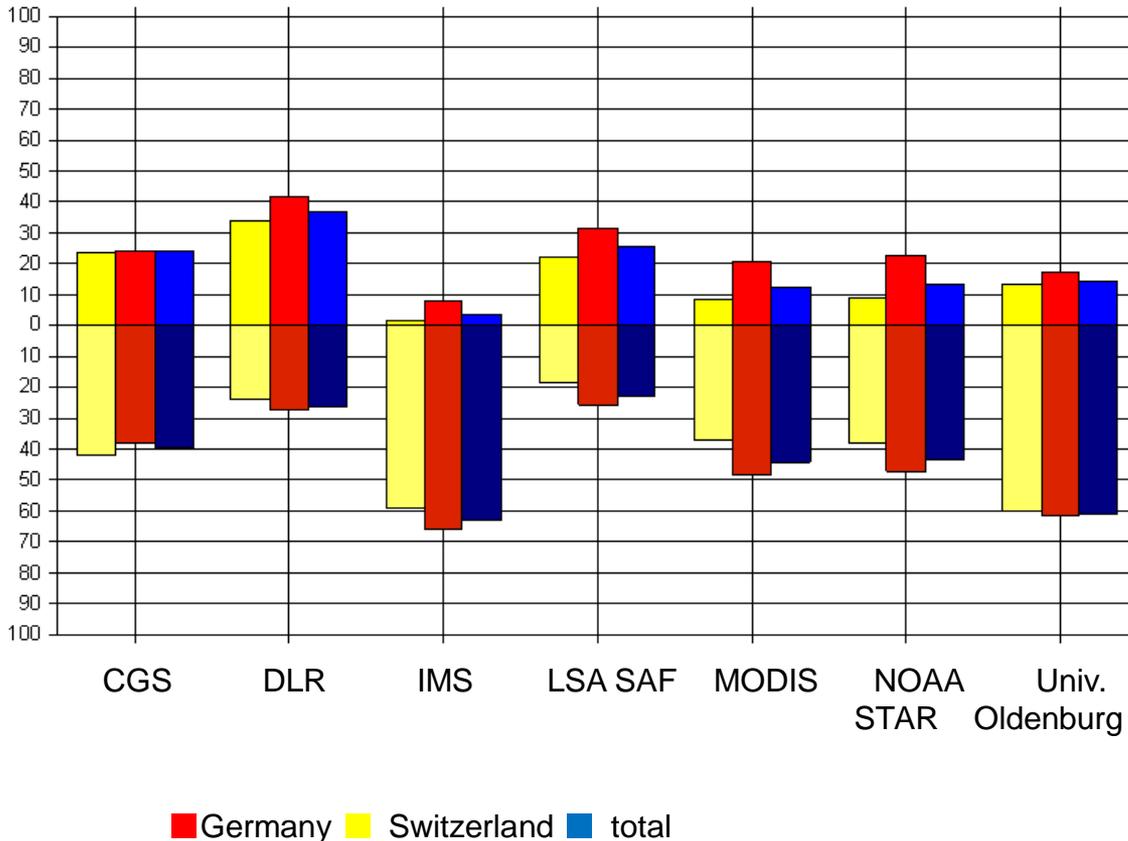
Validation of the Datasets

Schweiz		
Name	Länge	Breite
Aigle	6° 55' O	46° 20' N
Altdorf	8° 38' O	46° 52' N
Basel-Binningen	7° 35' O	47° 32' N
Bern-Liebefeld	7° 25' O	46° 56' N
Buchs-Suhr	8° 4' O	47° 23' N
Chur-Ems	9° 32' O	46° 52' N
Fahy	6° 56' O	47° 25' N
Genève-Cointrin	6° 7' O	46° 15' N
Zürich	8° 34' O	47° 23' N
Lugano	8° 58' O	46° 0' N
Luzern	8° 18' O	47° 2' N
Magadino	8° 53' O	47° 00' N
Payeme	6° 57' O	46° 49' N
Sion	7° 20' O	46° 13' N
St. Gallen	9° 24' O	47° 26' N

Deutschland		
Name	Länge	Breite
Weissenburg/Bay	10° 58' O	49° 1' N
Nürnberg-Kra.	11° 3' O	49° 30' N
Straubing	12° 34' O	48° 50' N
Augsburg-Mühlheim	10° 57' O	48° 26' N
Landsberg	10° 54' O	48° 4' N
Ingolstadt	11° 32' O	48° 43' N
München-Stadt	11° 33' O	48° 10' N
Fürstenzell	13° 21' O	48° 33' N
Konstanz	9° 11' O	47° 41' N
Obersdorf	10° 17' O	47° 24' N
Altenstadt	10° 52' O	47° 50' N
Hohenpeissenberg	11° 1' O	47° 48' N
Garmisch-Partenkirchen	11° 4' O	47° 29' N
Wendelstein	12° 1' O	47° 42' N



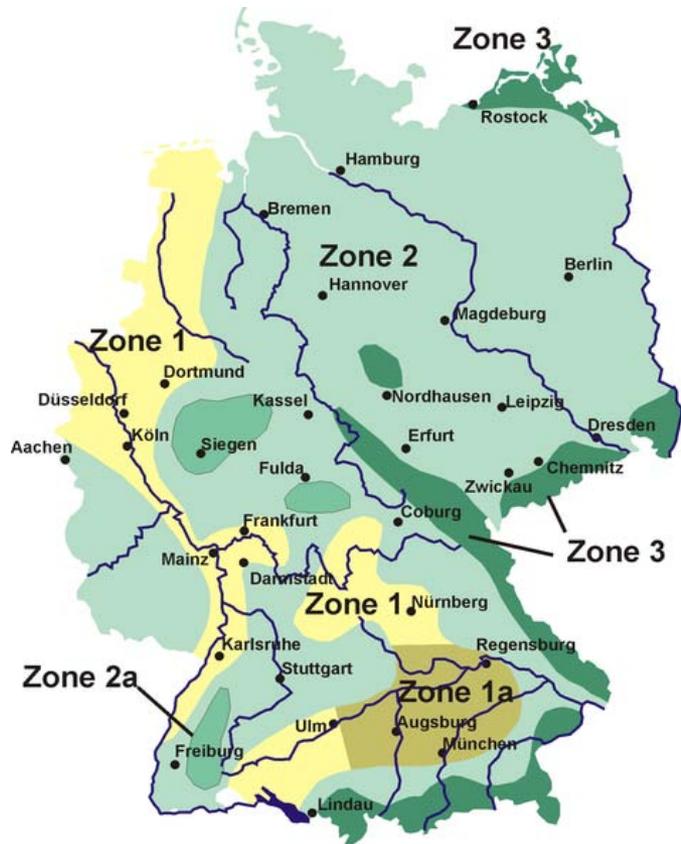
Total Error



- *False Alarm Rate* (Snow not identified) upward
- *Error due to underestimation* (to much snow) downward
- The orientation around the zero line shows the handling of identified snow
- The error should be small and symmetrical
- LSA SAF has the most symmetrical pattern



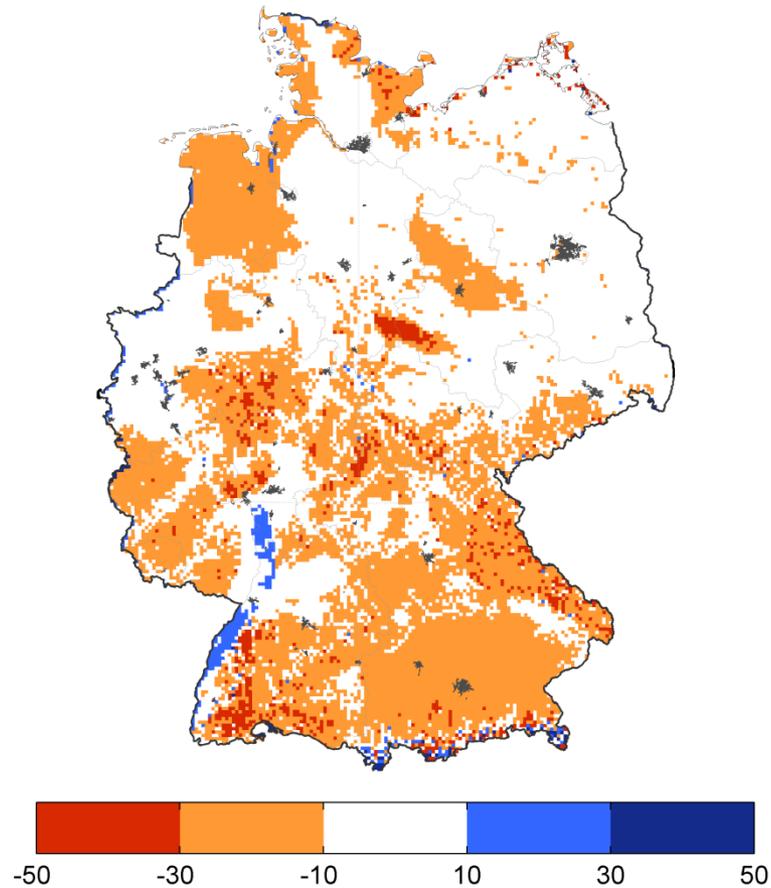
Snow Load Maps



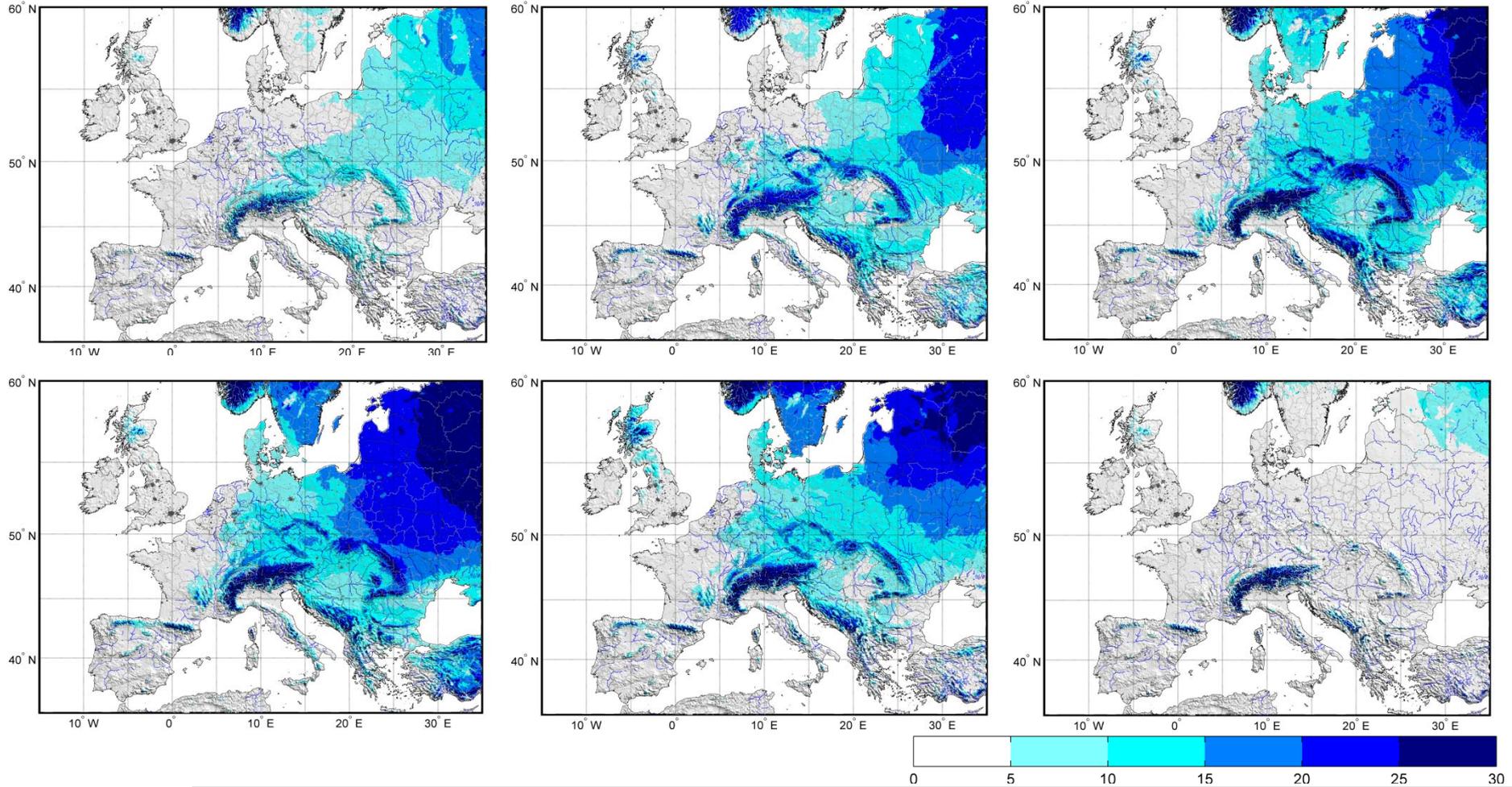
- Hardly information on snow cover duration available
- Snow load maps are often used for a rough estimation of losses
- The maps are not applicable as they show the maximum load and not the duration



Validation in with Data of Germany's National Meteorological Service (DWD)



Monthly Snow Cover in Europe



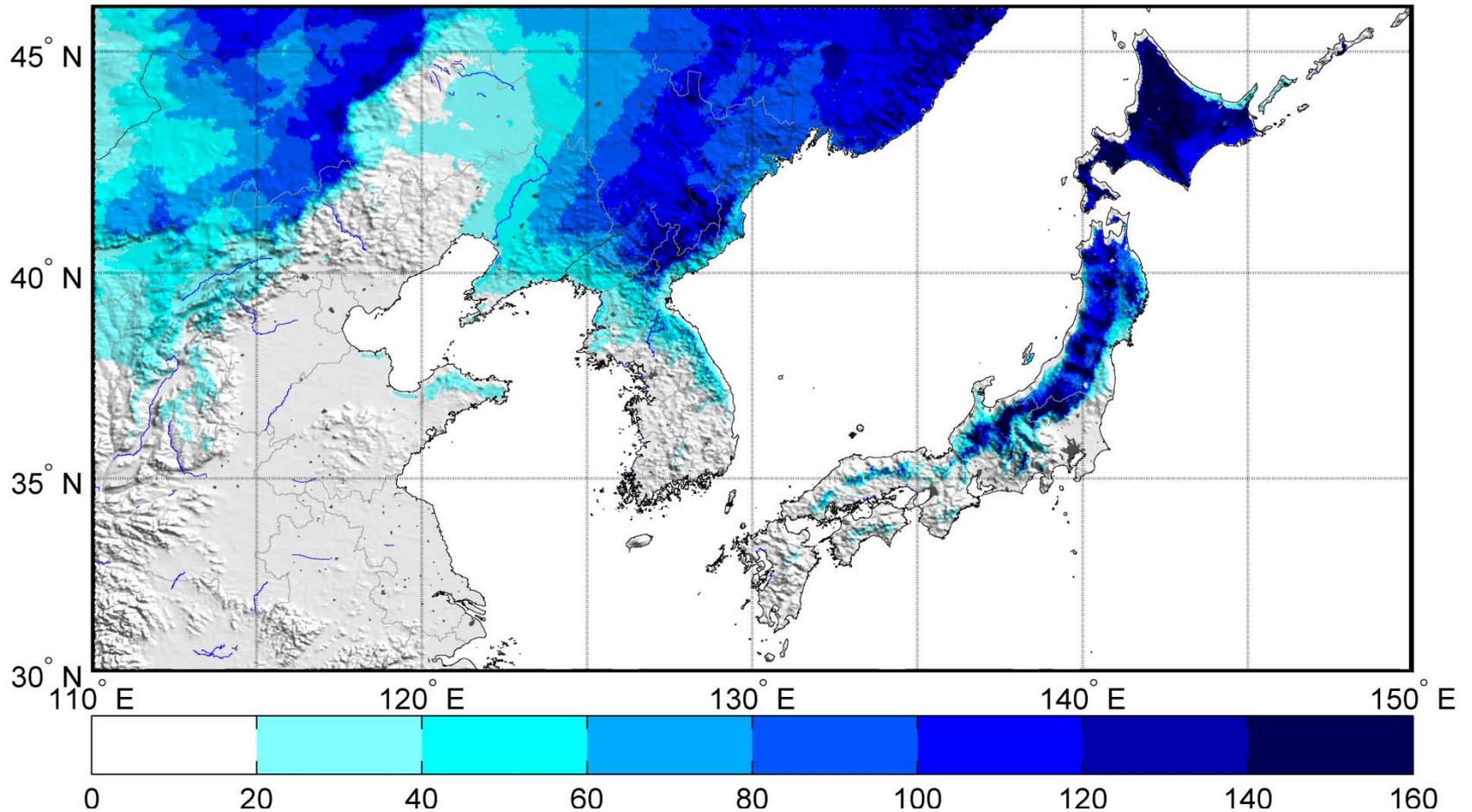
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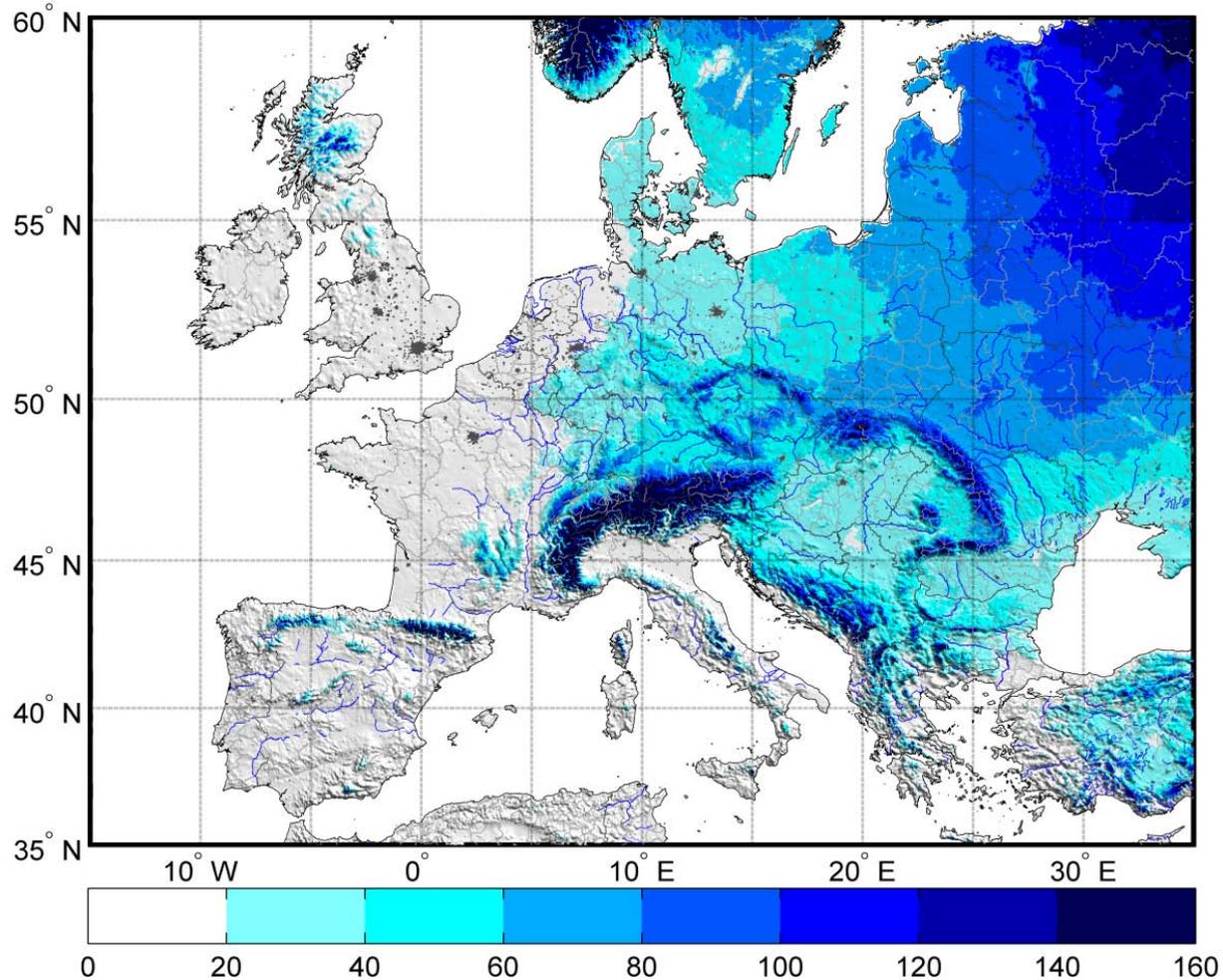
Dezember 10

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Yearly Snow Cover in Asia



Yearly Snow Cover in Europe



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Yearly Snow Cover in the US

