

Reference data for assessing satellite snow products in Europe and Canada



snowpex

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- SE:
 - High resolution satellite data (Landsat, SPOT)
 - Very high resolution satellite data (WorldView, Quickbird)
- SE + SWE:
 - In-situ observations / measurements:
 - Snow depth
 - E-code
 - Snow cover fraction
 - Meteorological parameter

Reference Satellite and Ancillary data currently available for Northern Hemisphere



Input Satellite data:

Northern Hemisphere:

- Landsat 5 TM (MS + TIR)
- Landsat 7 ETM+ (MS + TIR)
- Landsat 8 OLI/TIRS (MS + TIR)

Selected regions in Europe:

- SPOT-4 HRVIR (MS)
- SPOT-5 HRG2 (MS + PAN)
- Quickbird (MS + PAN)
- WorldView-1 (PAN)
- WorldView-2 (MS + PAN)

Ancillary Data (freely avail.):

Digital Elevation Model:

- EU DEM
- SRTM V4.1
- ASTER GDEM2

Surface Classification:

- Forest & Data (Water) mask
(Hansen et al. 2013)
- SRTM Water bodies

Cloud mask:

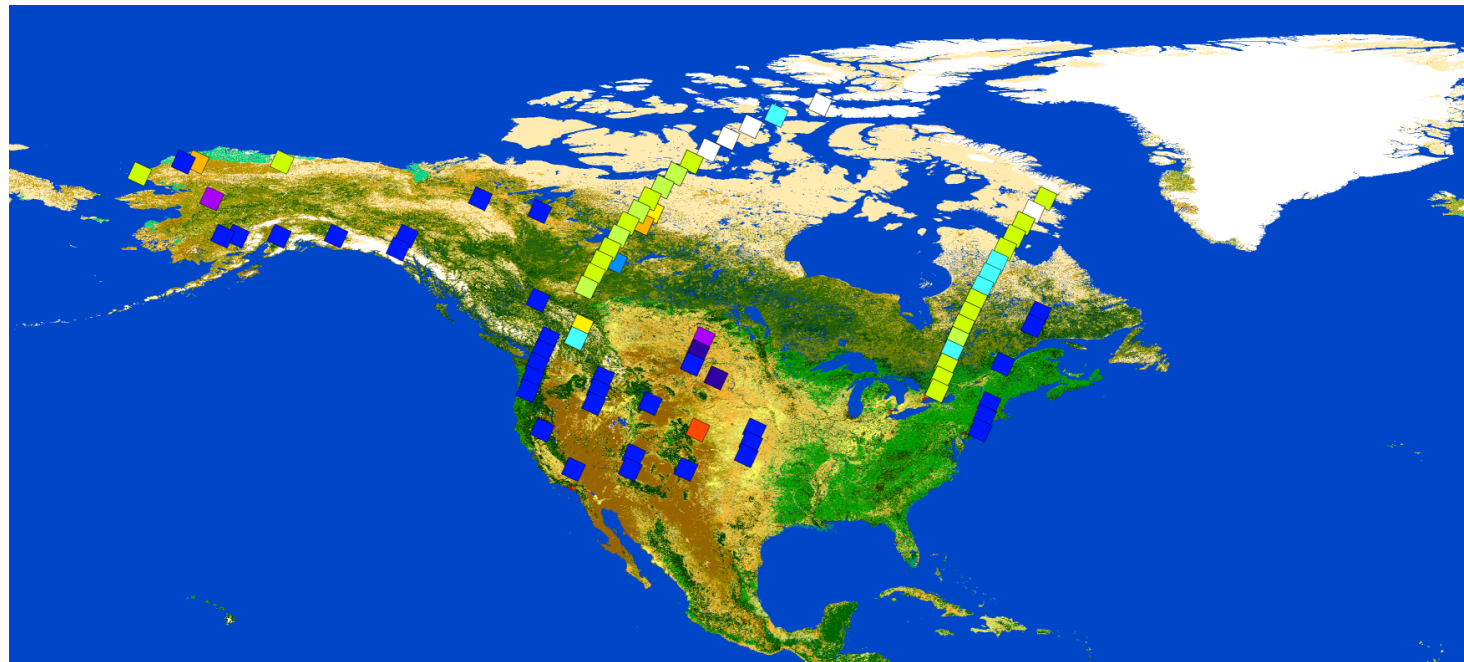
- Generated manually per scene

Hansen et al. (2013): "High-resolution global maps of 21st-Century Forest Cover Change", *Science* 342 (850), DOI: 10.1126/science.1244693.

URL: <http://earthenginepartners.appspot.com/science-2013-global-forest/download.html>

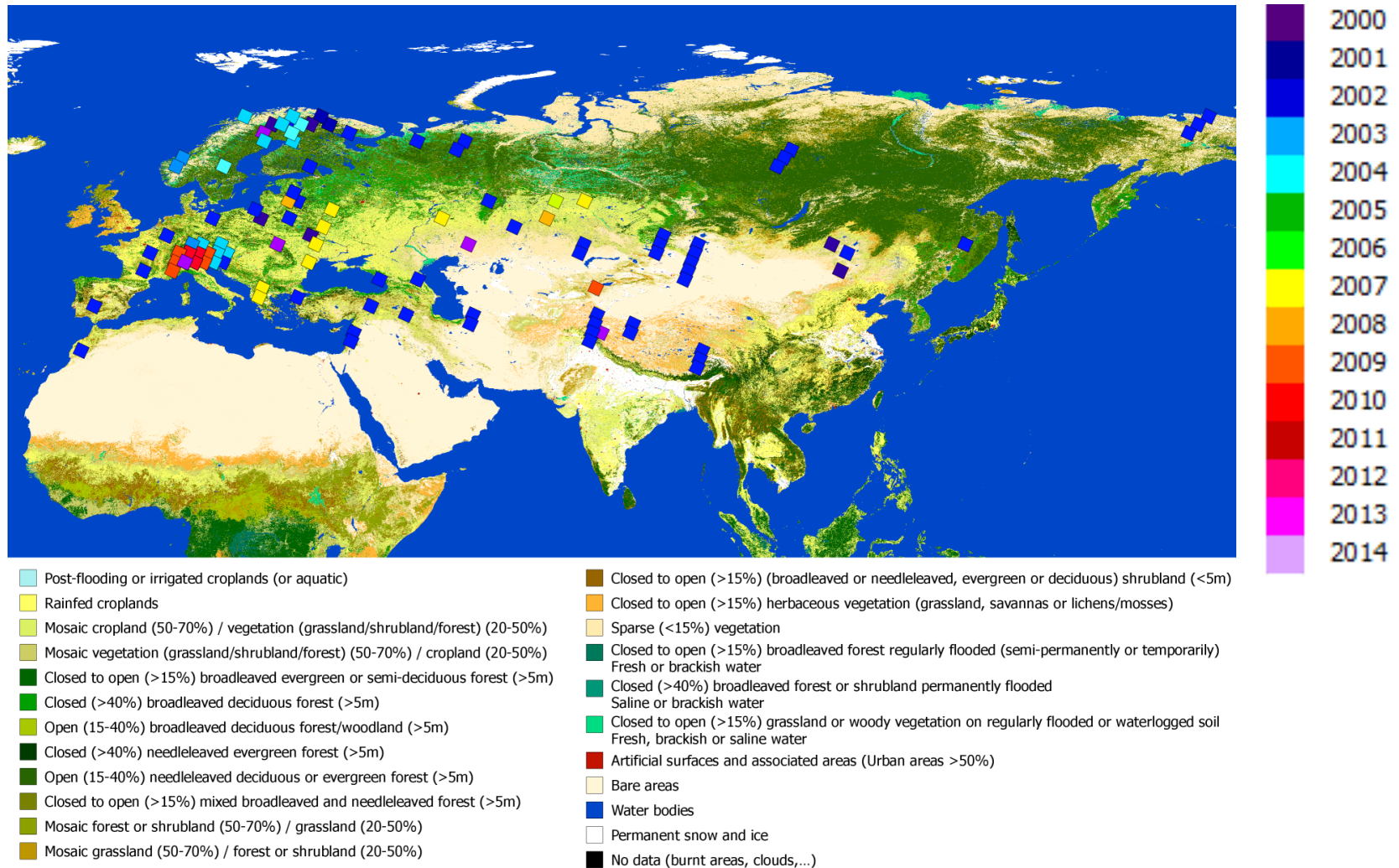


Status of Landsat scene selection for SE Evaluation in North America and Canada

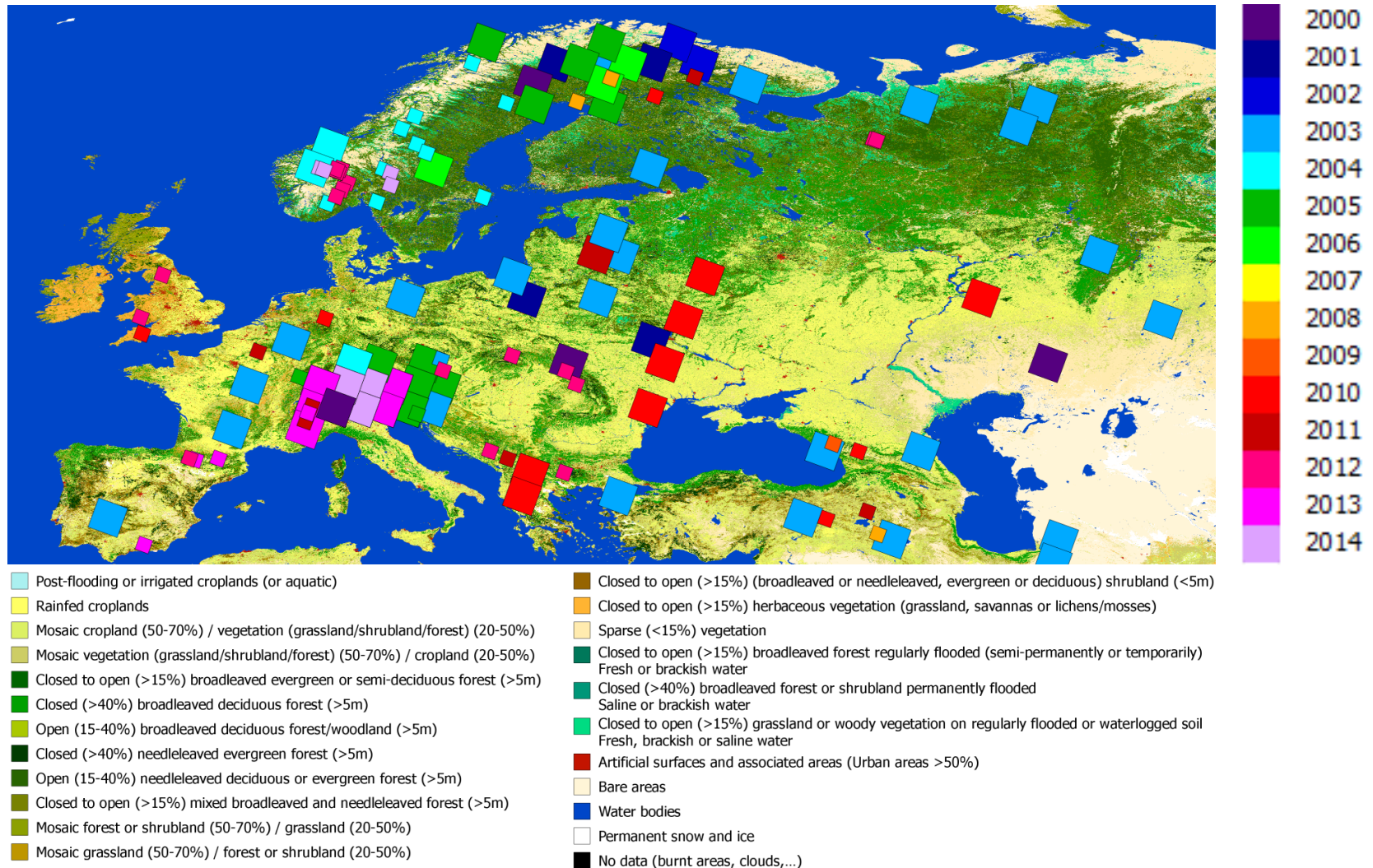


- | | |
|---|---|
| <ul style="list-style-type: none"> Post-flooding or irrigated croplands (or aquatic) Rainfed croplands Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%) Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%) Closed to open (>15%) broadleaved evergreen or semi-deciduous forest (>5m) Closed (>40%) broadleaved deciduous forest (>5m) Open (15-40%) broadleaved deciduous forest/woodland (>5m) Closed (>40%) needleleaved evergreen forest (>5m) Open (15-40%) needleleaved deciduous or evergreen forest (>5m) Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m) Mosaic forest or shrubland (50-70%) / grassland (20-50%) Mosaic grassland (50-70%) / forest or shrubland (20-50%) | <ul style="list-style-type: none"> Closed to open (>15%) (broadleaved or needleleaved, evergreen or deciduous) shrubland (<5m) Closed to open (>15%) herbaceous vegetation (grassland, savannas or lichens/mosses) Sparse (<15%) vegetation Closed to open (>15%) broadleaved forest regularly flooded (semi-permanently or temporarily) Fresh or brackish water Closed (>40%) broadleaved forest or shrubland permanently flooded Saline or brackish water Closed to open (>15%) grassland or woody vegetation on regularly flooded or waterlogged soil Fresh, brackish or saline water Artificial surfaces and associated areas (Urban areas >50%) Bare areas Water bodies Permanent snow and ice No data (burnt areas, clouds,...) |
|---|---|

Status of Landsat scene selection for SE Evaluation in Europe and Asia



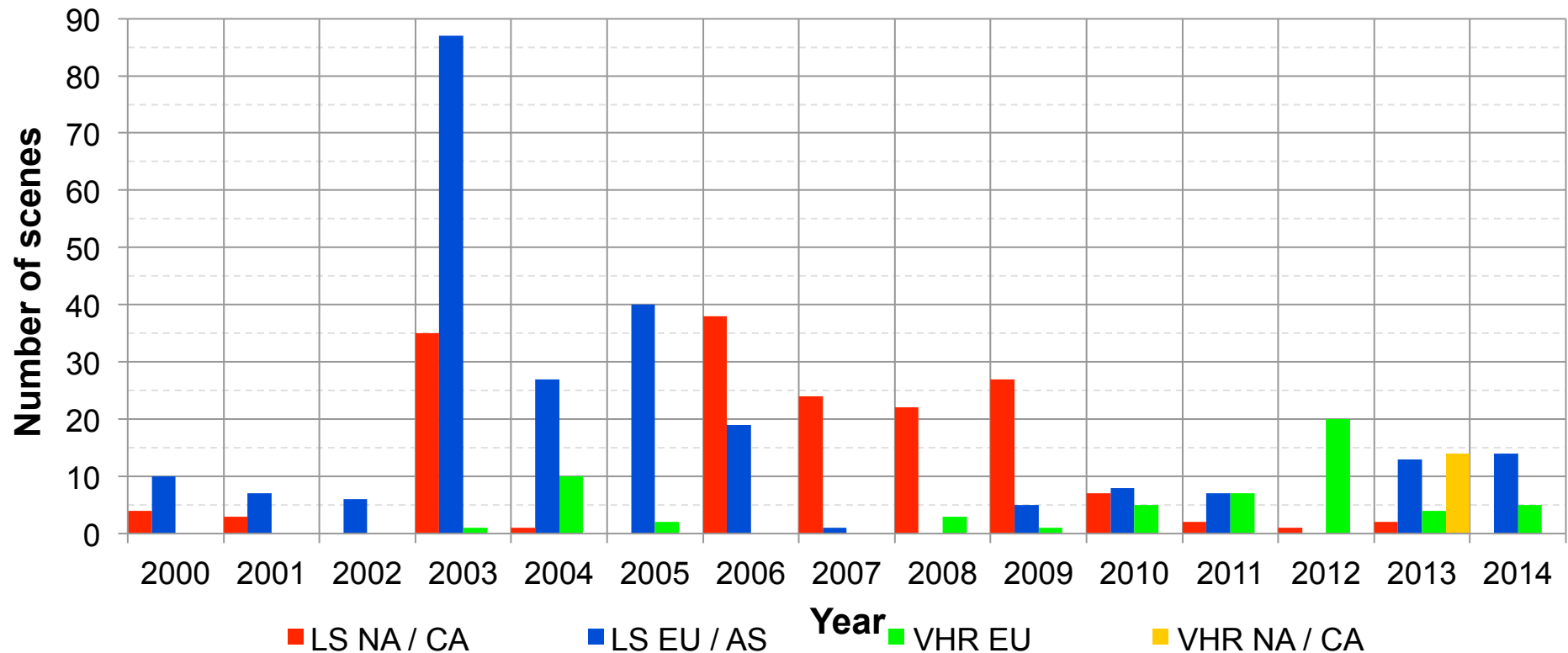
Status of selected Landsat and available VHR scenes for SE Evaluation in Europe



Temporal distribution of selected reference satellite data on Northern Hemisphere



Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
#LS	14	10	6	122	28	40	57	25	22	32	15	9	1	15	14
#VHR	0	0	0	1	10	2	0	0	3	1	5	7	20	18	5
Total	14	10	6	123	38	42	57	25	25	33	20	16	21	33	19



Selected SE Algorithms for snow map generation from HR reference data



Landsat data:

NDSI based Algorithms:

- Klein et al. (1998): binary classification
- Dozier and Painter (2004): binary classification
- Salomonson and Appel (2006): fractional classification
- *Optional algorithm adaptations:*
 - Pre-classification (snow cover/free) using $B_{0.55\mu\text{m}}$ (VIS) and $B_{0.8\mu\text{m}}$ (NIR)
 - Correction for cast shadows applying thresholds on $B_{0.55\mu\text{m}}$ (VIS), $B_{1.6\mu\text{m}}$ (SWIR), and NDVI
 - Brightness temperature threshold
- Multi-spectral Unmixing with local end-member selection for high-alpine un-forested areas:
 - Müller et al. (2010): fractional classification

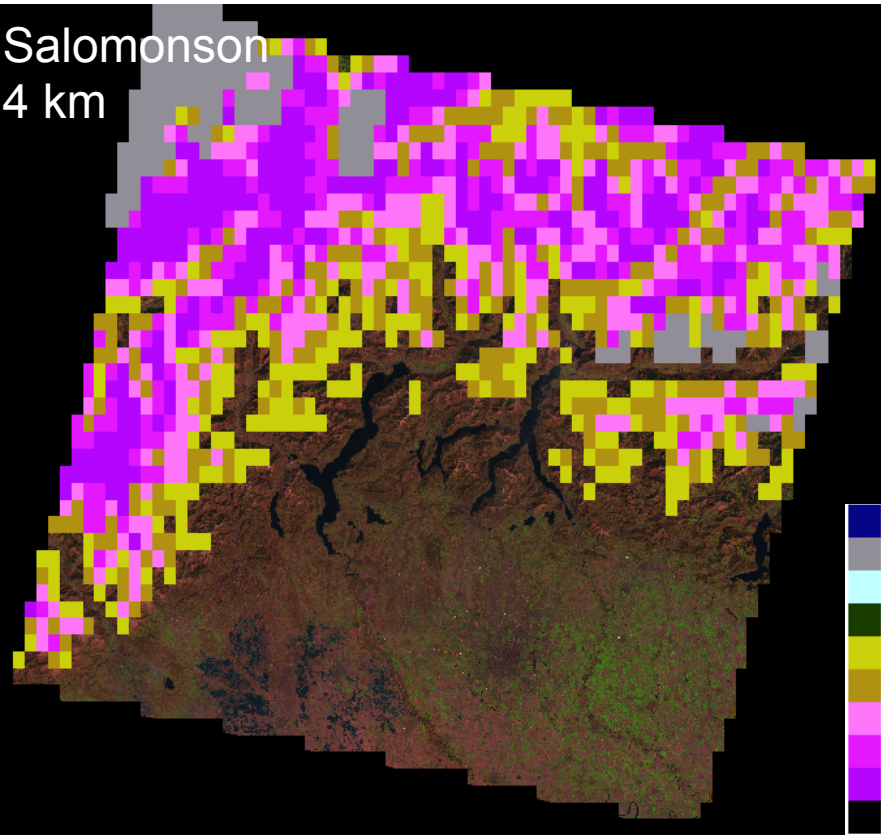
VHR data:

- Manual classification using Mahalanobis-distance supervised classifier:
 - Solberg et al. (2013): binary classification

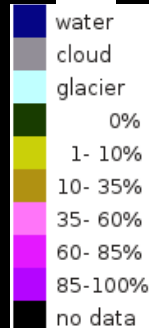
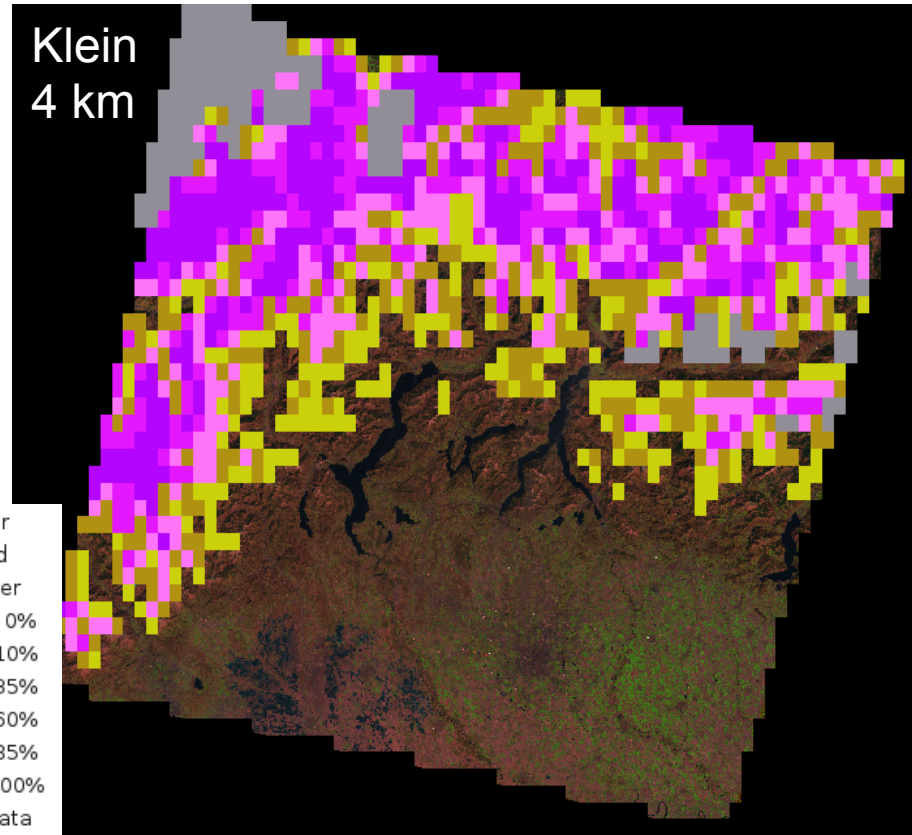


Resampling of binary and fractional reference data

Salomonson
4 km



Klein
4 km



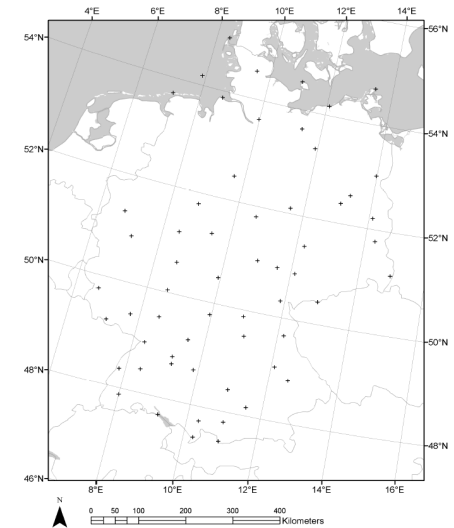
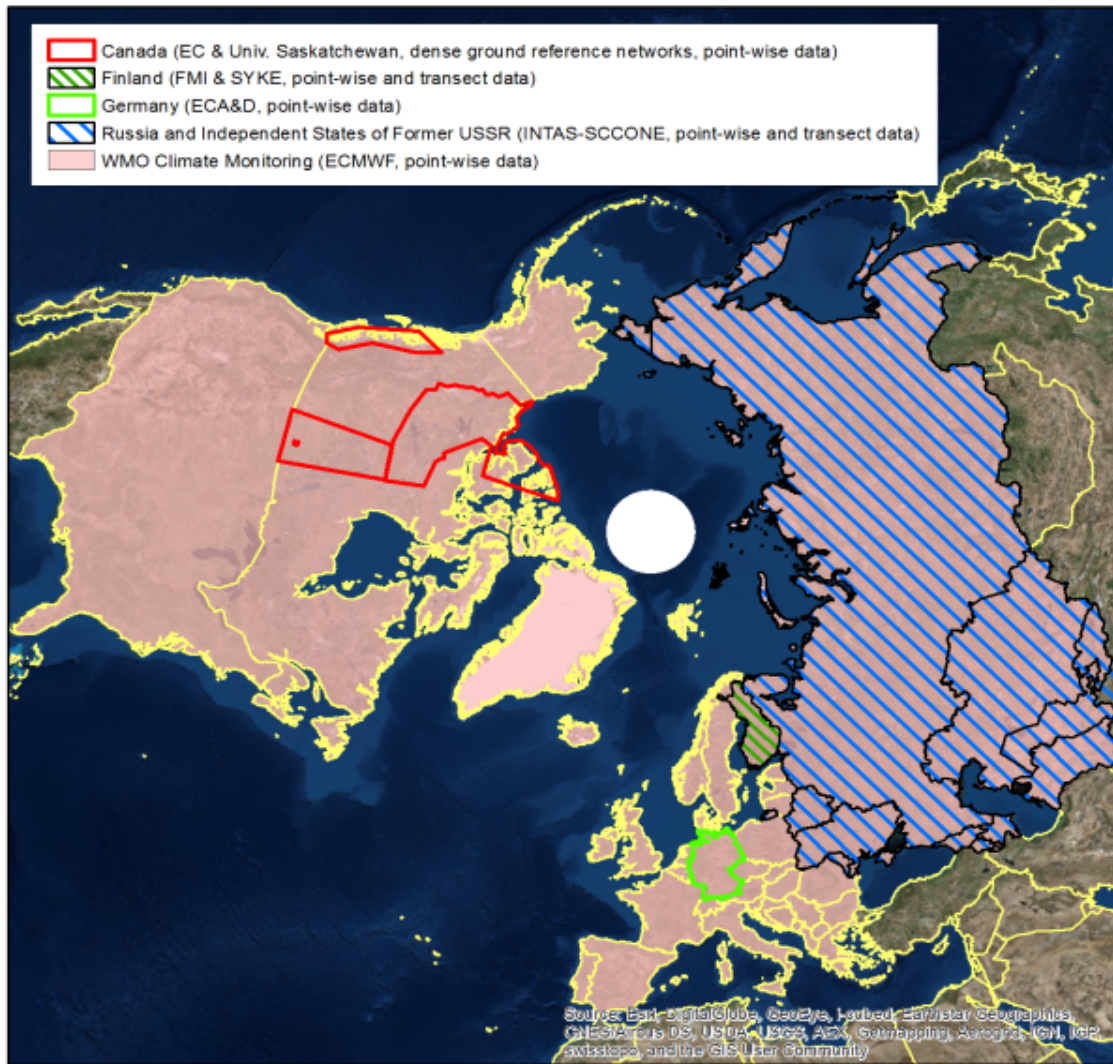
Point-wise in-situ observations



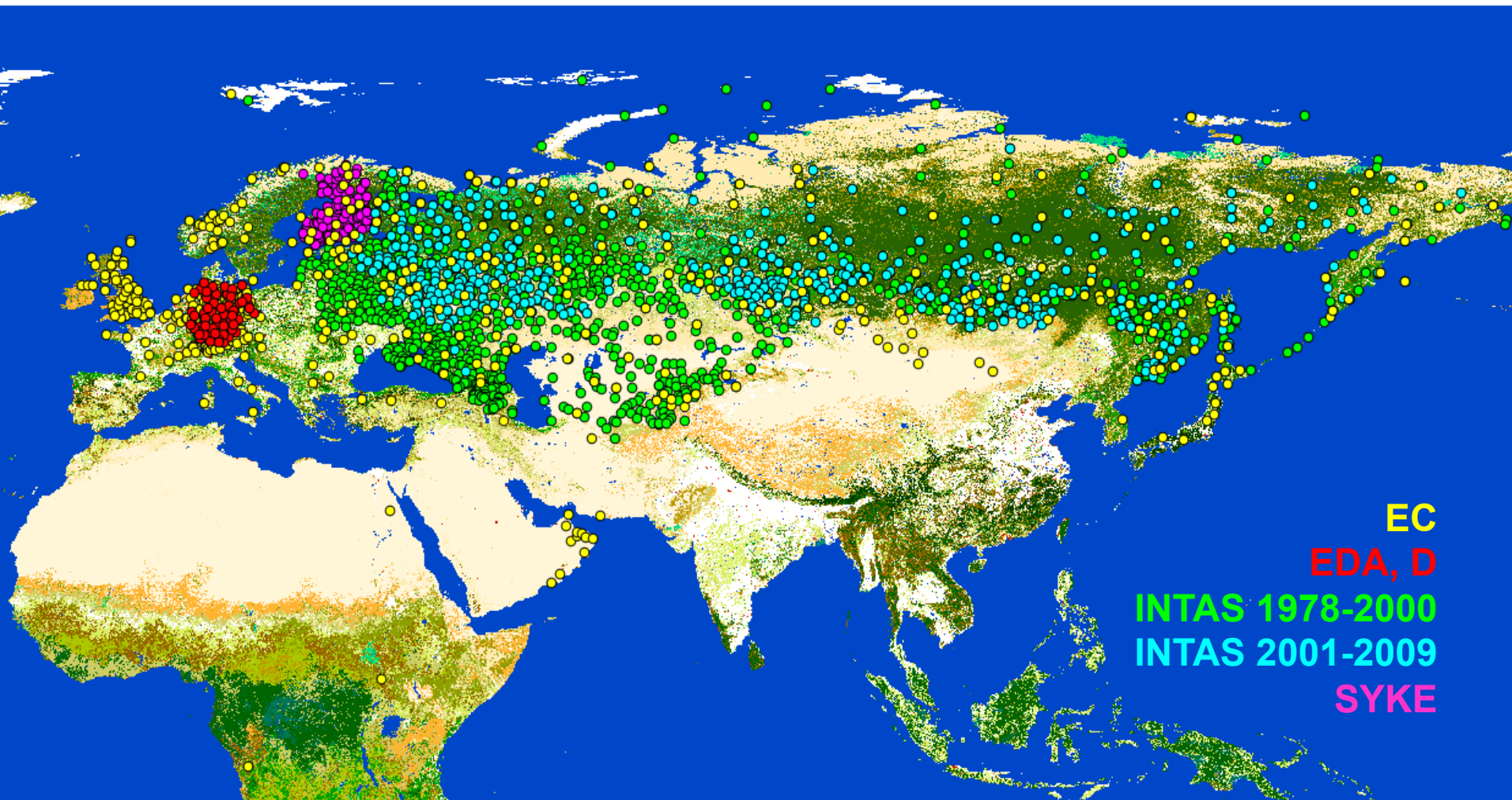
ECMWF	Snow depth; E-code – fraction of snow cover	1979 – present / daily	Europe
FMI/National network (Finland)	Snow depth; E-code – fraction of snow cover	1979 – present / daily	Finland
ECA&D/National dataset (Germany)	Snow depth	1979 – present / daily	Germany
RIHMI/ National network INTAS-SCCONE -project	Snow depth; Fraction of snow cover; General snow status (Q-flag); Snow depth –consecutive observations quality flag; Snow depth – temperature quality flag	1979 – 2000 / daily	Russia and former USSR countries
Univ. of Saskatchewan	Snow depth	1997 – present / daily	Saskatchewan, Canada
Environment Canada	Snow depth	2011 – present / daily	Bratt's Lake
Environment Canada	Snow depth	2008 – 2010 / daily	Southern coast mountains
Canadian Meteorological Centre (available via NSIDC)	Snow depth	1998 – 2013 / daily (updated annually)	Northern hemisphere
WLU (???)	Snow depth	2002 – present	Trail Valley Creek, Northwest Territories



In-situ Observations – spatial coverage



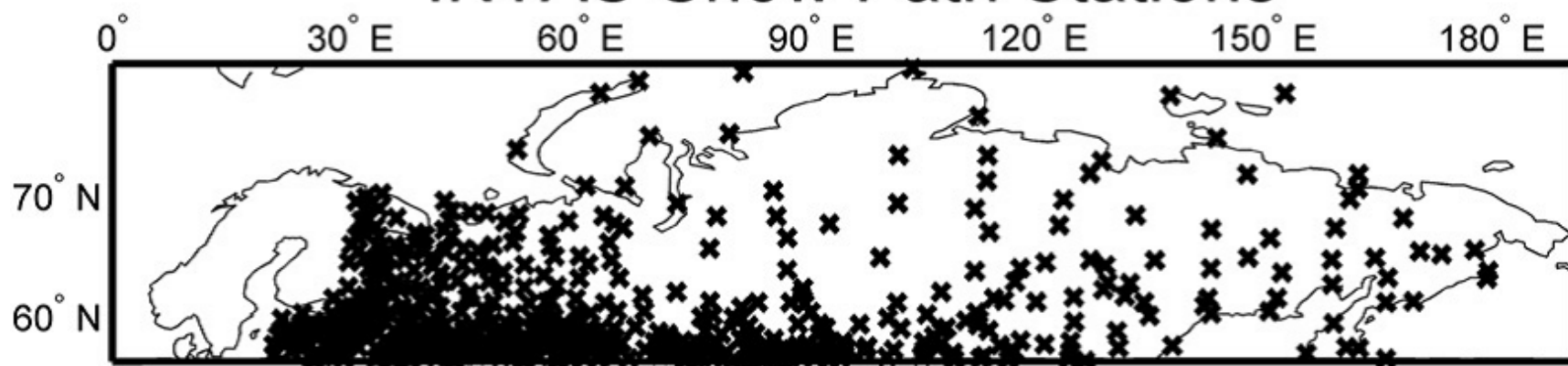
Status of identified in-situ measurement locations on Northern Hemisphere



In-situ Snow Courses

SYKE/National network (Finland)	Snow depth ; Patchiness (fraction of open ground); Snow water equivalent	2002 – present / monthly	Finland
RIHMI/National network INTAS-SCCONE - project Russia)	Snow depth; Snow cover fraction; Snow depth; Ice layer thickness; Snow/total water equivalent; Terrain type; Snow quality descriptions (wind, temperature, compactions, obs. wetness)	1979 – 2000 / monthly	Russia

INTAS Snow Path Stations



Availability of further reference data? – TBD at Splinter Sessions



- Landsat(-like) data (processing to L1T)
- Snow products from Landsat(-like) data
 - Applied algorithm
 - Binary / fractional snow extent
 - Used ancillary data (DEM, surface types, ...)
 - Cloud screening
- Spatial coverage / resolution
- Temporal coverage / resolution
- Map projection / Datum
- In-situ snow measurements
 - point measurements / transects
 - SWE measurements
 - snow extent observation (binary / fractional)
 - Meteorological data
- Contact / URL for accessing data

