

CCI+ Info Day

- Snow
- Land Surface Temperature
- Water Vapour

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- Snow has a major influence on the Earth's shortwave radiation budget: high reflectivity drives a positive feedback to climate warming. Partly responsible for the observed rapid warming of the Arctic?
- Northern Hemisphere June snow cover has decreased by $\sim 50\%$ since 1960's.
- Snow provides a measure of the balance between precipitation and warming in a changing climate
 - Affected by changes in snow albedo (black carbon, dust) from wildfire, industry and farming
- Influences Surface-Atmosphere water and energy fluxes, *e.g.*
 - Insulates ecosystems and agriculture from severe cold
 - Affects permafrost
- Source of freshwater
 - Agriculture, Hydropower, Lakes, Soil Moisture
 - Glaciers
- Important indicator of climate variability and change
- WCRP Grand Challenge: Melting Ice and Global Consequences
- Problem in CMIP5: Majority of climate models greatly over-estimate springtime snow mass.

GCOS Requirements

ECV	Res.	Freq.	Uncertainty	Stability (10yr)
Snow Extent	1km/100m*	Daily	5%	4%
Snow Depth	1km/100m*	Daily	10mm	10mm
Snow Water Equ.	1km	Daily	10mm	10mm

*100m in complex terrain

GCOS Action T29: Obtain integrated analyses of snow over both hemispheres

NB: Snow Extent required as both visible snow and snow on ground for radiative vs. hydrological applications.

Snow: Key Users



European and international climate science organisations that:

- Quantify the radiative forcing due changes in snow cover
- Investigate the snow-albedo feedback and its effect on climate sensitivity
- Analyse impacts of changes in snow on permafrost
- Impact of changes in snow on water availability for ecosystems, biodiversity, human activities such as agriculture and tourism, and its use for research into climate adaptation
- The role of snow in climate-related changes to the hydrological cycle
- The role of snow in climate-related changes to surface-atmosphere energy fluxes
- Develop and verify of snow-related processes in land surface models
- Study effects of changes in snow on global and regional weather patterns

e.g. CMIP-6: Land Surface, Snow and Soil Moisture Model Intercomparison Project (LS3MIP), and ESM-SnowMIP

[Also other CCI projects: Permafrost, Lakes, Land Cover, LST, Cloud, Aerosol, ...]



Snow: International Context



WMO Global Cryosphere Watch

- SnowPEX
- Snow Watch

WCRP CliC

GEO Cold Regions Initiative

IACS - International Association of Cryospheric Sciences

TOPC – link to GCOS

NOAA/NASA: IMS, NSIDC, iSWGR

European Projects, *e.g.*

- EUMETSAT Hydrology-SAF and Land-SAF: NRT snow mapping service
- Copernicus Climate Change (C3S) and Global Land Services



Snow Water Equivalent (or Depth):

Passive Microwave Imagers: SMMR, SSM/I, AMSR, SSMIS, ...

- All-sky, daily, daytime and nighttime observations
- Low spatial resolution (25-50km)
- 1978–onwards

Snow Extent

Vis/NIR Imaging Instruments: AVHRR, SPOT-VGT, ATSR, MERIS, MODIS, SLSTR, OLCI, ...

- Daily, but only during daytime and when cloud-free
- 1km resolution
- 1982–onwards

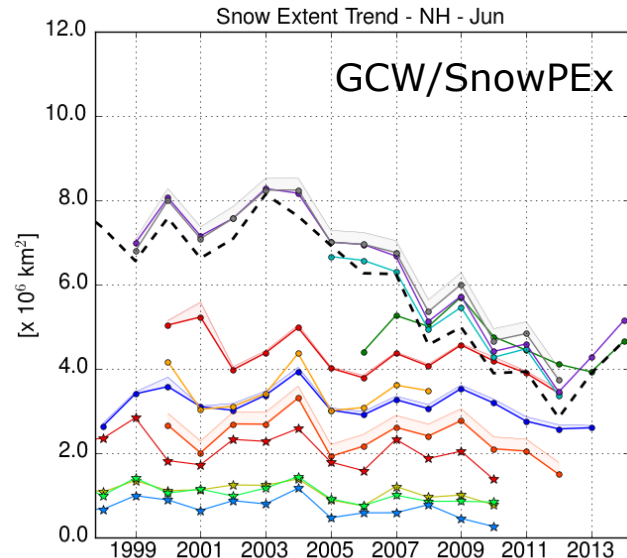
High res optical (e.g. Sentinel-2) and SAR-based snow products

Snow: Key Issues for CCI+ (1)

- Little agreement in satellite-based long term trends
- Product uncertainties, and validation of uncertainties
- Consistent algorithms to be applied to multiple instruments

Snow Extent

- Snow extent needed both under and above canopy
- Cloud clearing
- AVHRR data problems
- Patchy snow
- Validation with in-situ snow measurements, and high-res optical and SAR



Snow Water Equivalent

- Good accuracy at global scale is difficult to achieve
- Varying biases as a function of land cover type
- Quality of *in situ* snow depth measurements is variable
- Saturation at high snow depths and insensitivity to low snow depths
- Assumptions of fixed snow density (=> snow pack modelling, SMOS, ...?)
- Improve snowpack microwave emission models
- Bring AMSR-E and AMSR2 into the SSM/I long term data record
- Consistency and possible merging with optical Snow Extent (snow line?)