CCI+ Info Day

- Snow
- Land Surface Temperature
- Water Vapour

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Snow & Climate

• 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 ~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.
**Snow: GCOS ECV Requirements**

### GCOS Requirements

<table>
<thead>
<tr>
<th>ECV</th>
<th>Res.</th>
<th>Freq.</th>
<th>Uncertainty</th>
<th>Stability (10yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snow Extent</td>
<td>1km/100m*</td>
<td>Daily</td>
<td>5%</td>
<td>4%</td>
</tr>
<tr>
<td>Snow Depth</td>
<td>1km/100m*</td>
<td>Daily</td>
<td>10mm</td>
<td>10mm</td>
</tr>
<tr>
<td>Snow Water Equ.</td>
<td>1km</td>
<td>Daily</td>
<td>10mm</td>
<td>10mm</td>
</tr>
</tbody>
</table>

*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: Satellite Instruments

**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: Key Issues for CCI+ (2)

**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?)