ESM-SnowMIP

Concept, first results and plans

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Model Intercomparison Projects

Intercomparison:

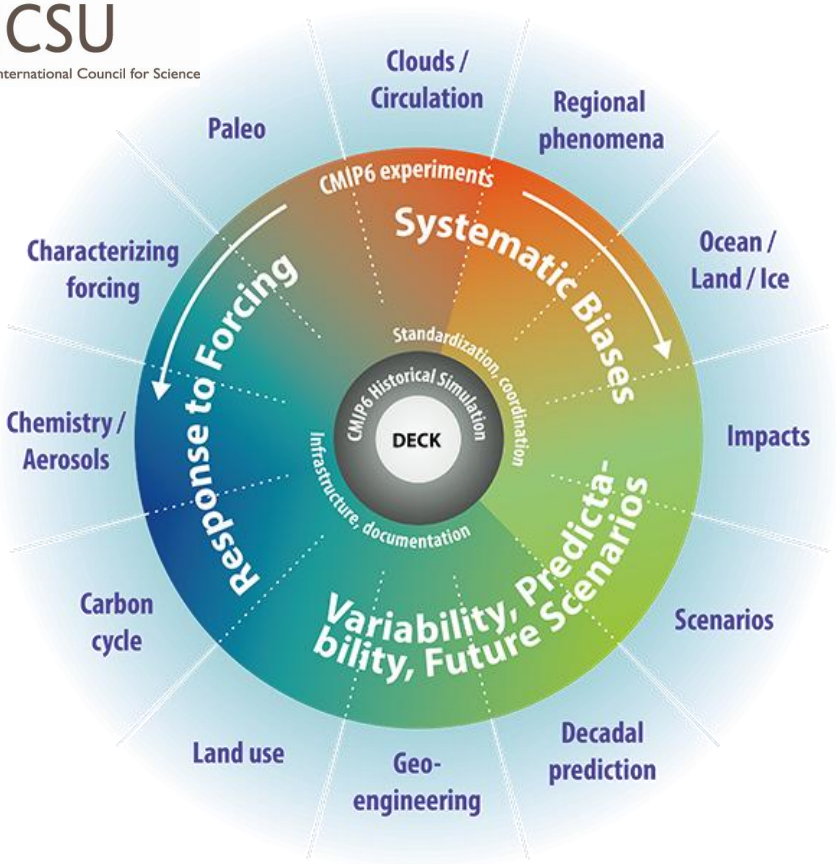
- is not a word in the dictionary
- makes convenient project acronyms
  (AMIP, CMIP, LS3MIP, LUMIP, PMIP, SnowMIP, ...)
- often provides "limited insight into the causes of differences in model behaviour". Martyn Clark et al. (2015), *Water Resources Research*, **51**
- is "a tedious and thankless task of dubious scientific merit" (John Pomeroy)
- shows that models differ and there is no single "best" model; so what?
- is an important part of the IPCC process

Some words about CMIP6

WCRP World Climate Research Programme

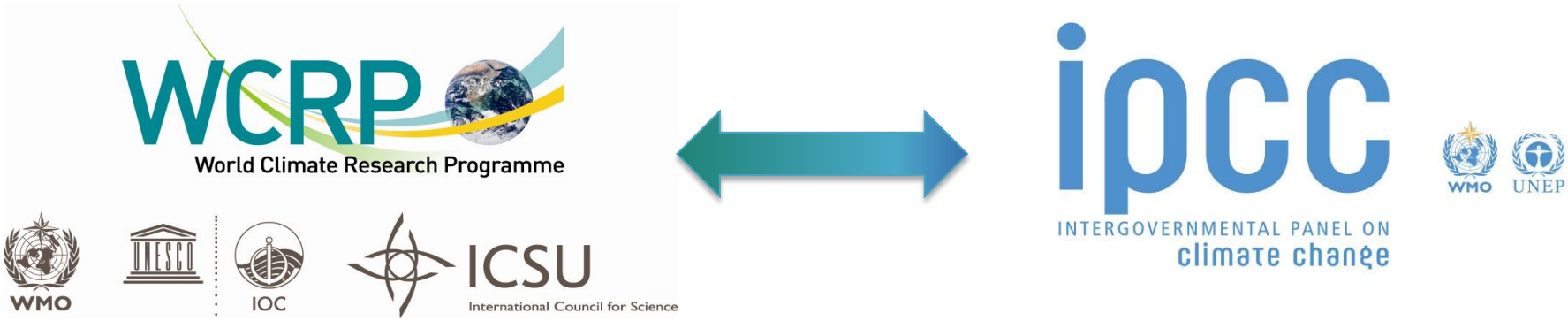
WMO UNESCO IOC ICSU International Council for Science

- Organized by WCRP
- Model evaluation
- Coordinated projections
- Studies of processes and climate-relevant mechanisms
- About 20 sub-projects: Land use, carbon feedbacks, response to volcanic eruptions,…
- About 30 participating groups
- Data freely available via ESGF



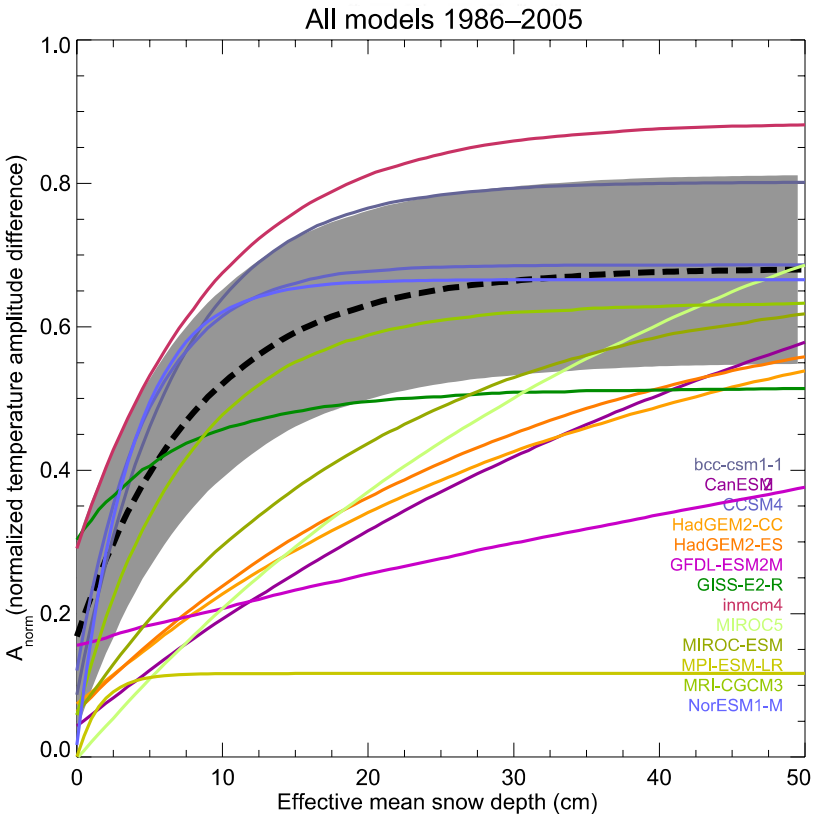
Link between CMIP and IPCC

- IPCC bases much of its assessment, in particular climate model evaluation and climate projections, on CMIP6.
- CMIP and IPCC assessment reports are phased (CMIP6 currently ongoing).
- BUT: CMIP6 is a research activity - does not depend on IPCC. There are no “IPCC climate models”.



Snow-related errors in climate models

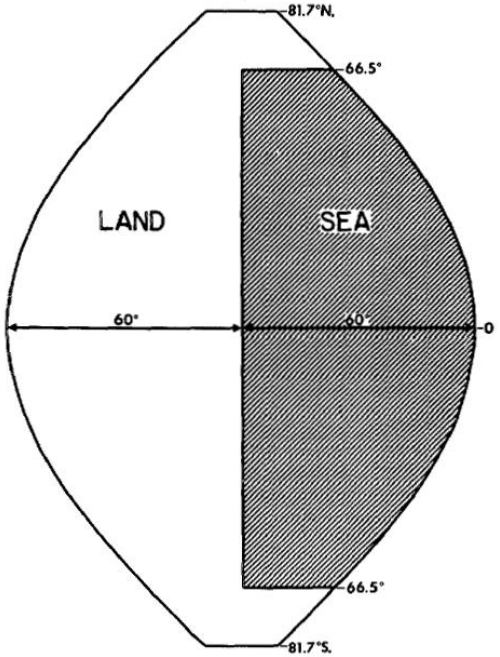
- Observed snow extent trends
- Seasonality of snow depth and extent
- Snow albedo and snow albedo feedback
- Snow cover fraction
- Thermal insulation

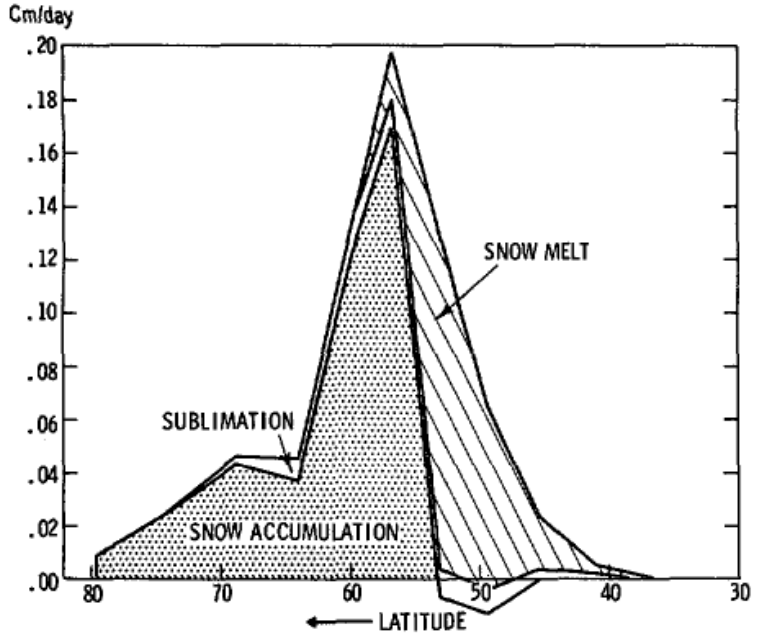


(Slater et al., 2017)

Climate modelers didn't discover snow recently…

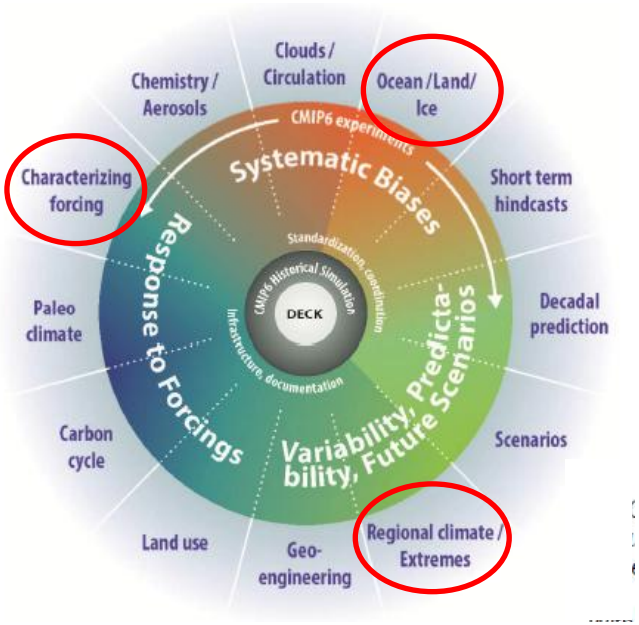
"One of the most important hydrologic factors affecting the climate is snow cover, with its large albedo for solar radiation."
Manabe (1969). *Monthly Weather Review*, **97**

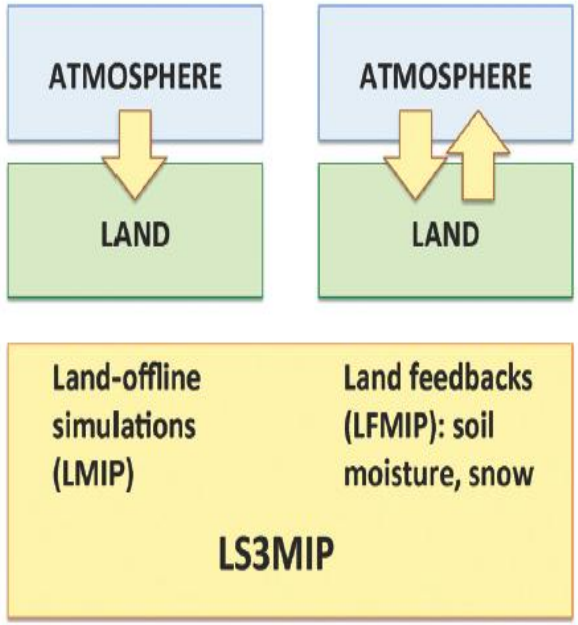




Snow in CMIP6

LS3MIP (van den Hurk et al., GMD, 2016): Land Surface, Snow and Soil humidity





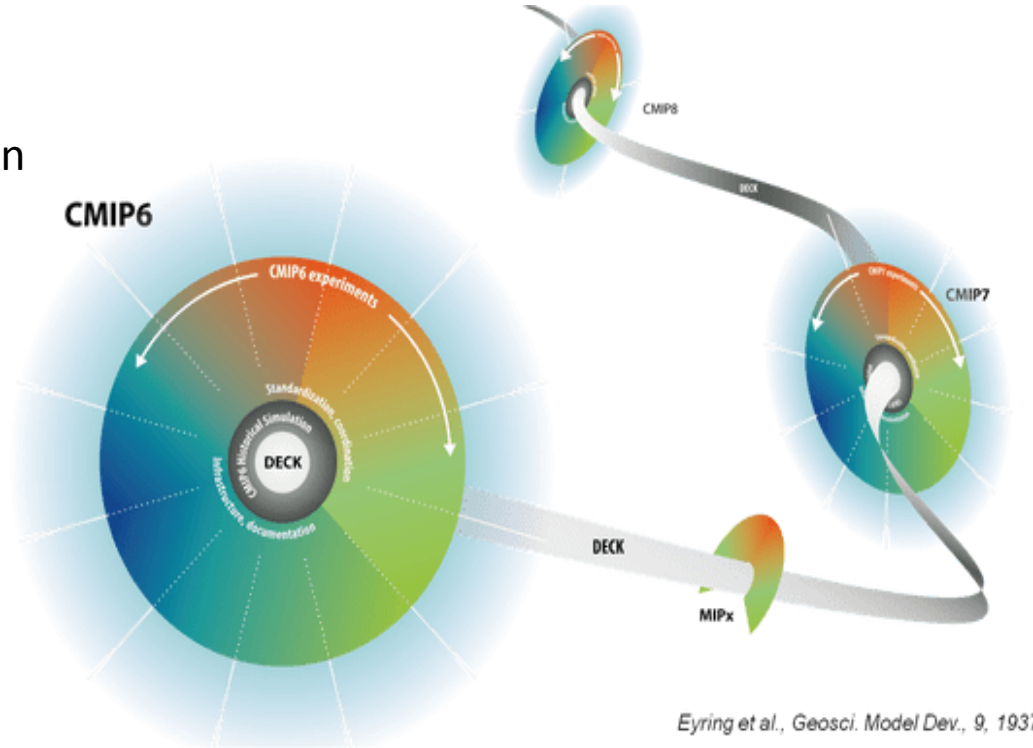
Snow around CMIP6

ESM-SnowMIP (Krinner et al., GMDD, submitted):

"Intermediate MIP": Global simulations after CMIP6.

Specific analyses of snow-related processes and feedbacks

Example: Viewable snow fraction as a function of SWE



Eyring et al., Geosci. Model Dev., 9, 1937-1958, 2016

ESM-SnowMIP: A hierarchy of simulation setups

- Site simulations
- Land models driven on global scale by “observed” meteorological forcing (LMIP: 1901-2014)
- Land-Atmosphere models driven by observed sea-surface conditions (AMIP: 1980-2014)
- Land-Atmosphere-Ocean models over the historical period (1850-2014)

- ➢ Continuity of previous SnowMIPs
- ➢ Provides an opportunity to identify the sources of climate model biases: Ocean? Bad atmosphere? Bad snow parameterizations?
- ➢ Sensitivity tests: evaluate parameterizations
- ➢ Snow feedback analysis

http://www.climate-cryosphere.org/activities/targeted/esm-snowmip

ESM-SnowMIP: A variety of model types

ESM land surface schemes
BCC_AVIM
CABLE
CLASS
CLM
CoLM
ECEARTH
HTESSEL, HTESSEL_ML
ISBA
JULES
JSBACH, JSBACH_PF
MATSIRO
MOSES
ORCHIDEE-E, ORCHIDEE-I

Snow physics models
Crocus
SNOWPACK

Hydrology / land surface models
CRHM
ESCIMO
RUC
SPONSOR
SWAP
VEG3D
ORCHIDEE High Lat

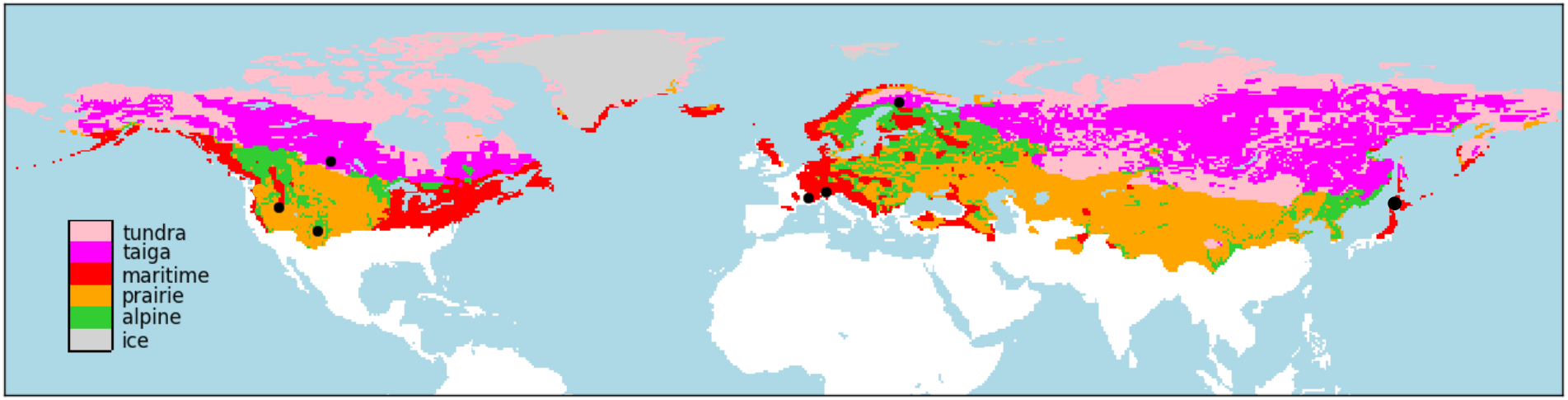
Multi-physics models
ESCROC (35 member ensemble)
FSM (32 member ensemble)

– all are physics-based models with data requirements that are hard to meet in snowy environments

MIPs with snow components

Extent \ Forcing	Coupled to an atmospheric model	Prescribed meteorology
Global	CMIP ESM-SnowMIP	GSWP ESM-SnowMIP
Regional	CORDEX	PILPS
Local	GABLS	PILPS, SnowMIP ESM-SnowMIP

Reference sites – First Phase



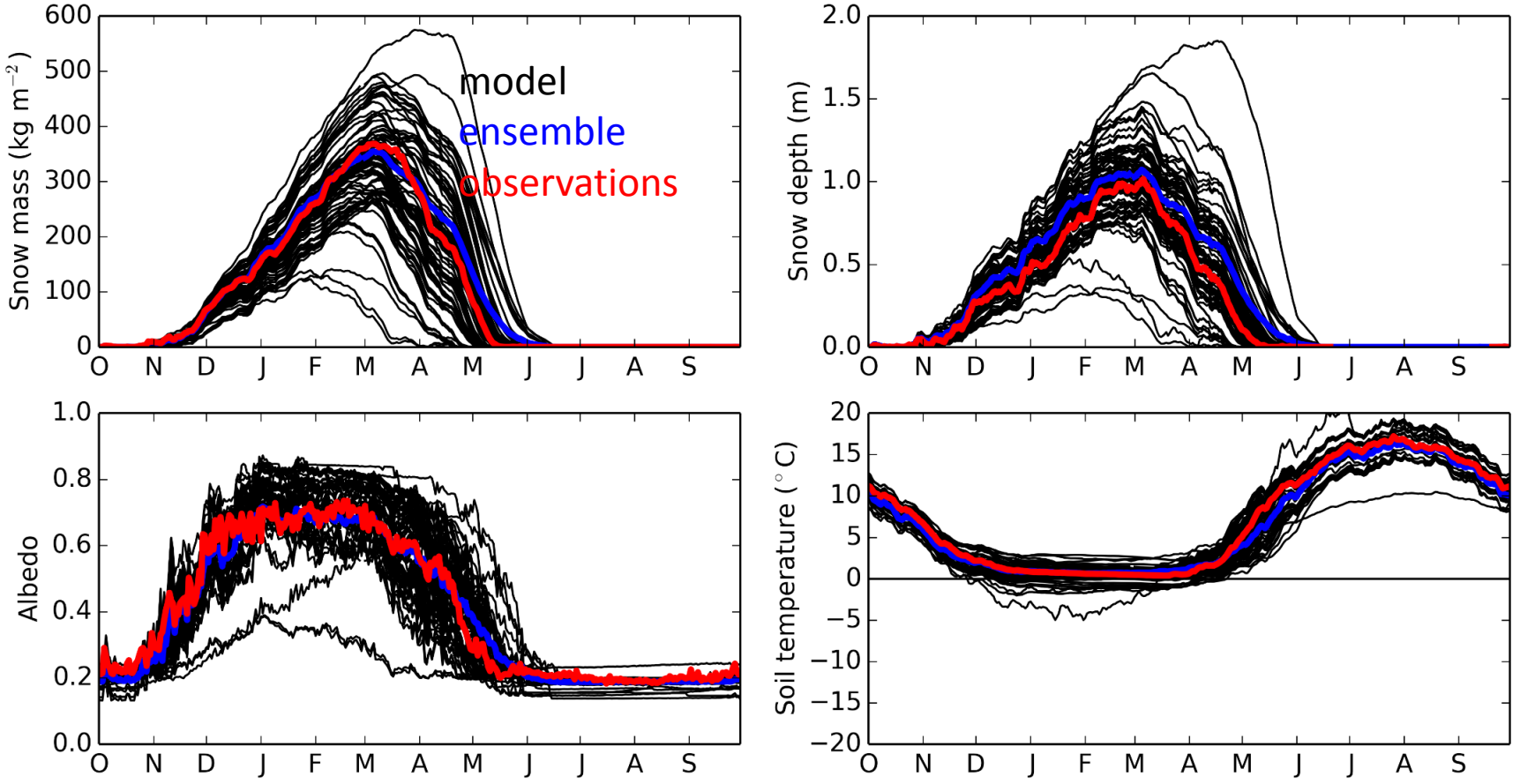
Map: Sturm et al. (1995) seasonal snow cover classification

- BERMS pine, Saskatchewan
- BERMS spruce, Saskatchewan
- BERMS aspen, Saskatchewan
- Col de Porte, France
- Reynolds Creek, Idaho
- Sapporo, Japan
- Senator Beck, Colorado
- Sodankylä, Finland
- Swamp Angel, Colorado
- Weissfluhjoch, Switzerland

+ additional glacier, tundra, mountain and ice sheet sites to follow

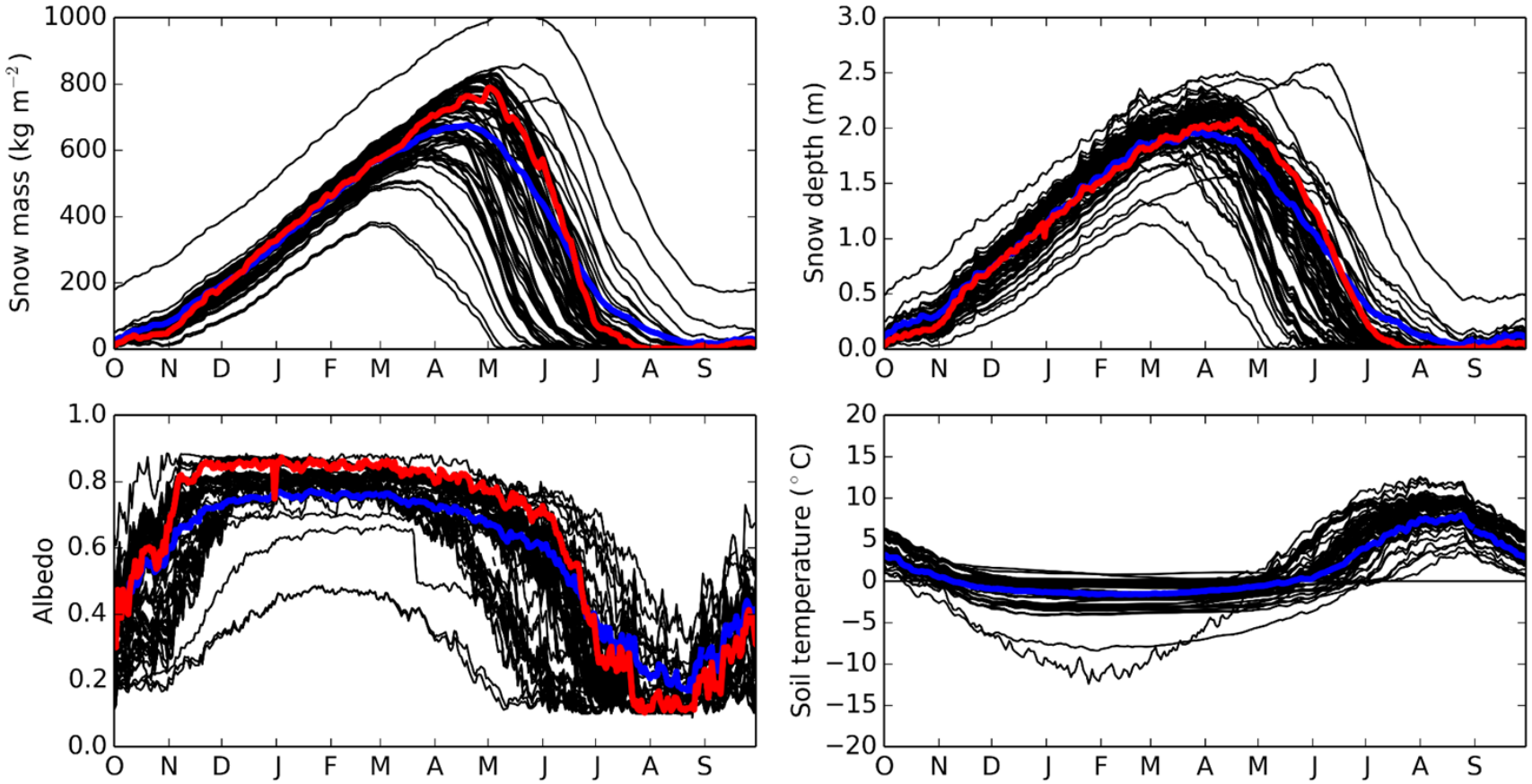
ESM-SnowMIP multi-model ensemble

Col de Porte 1994-2014 averages
winter temperature -1°C
annual snowfall 630 mm



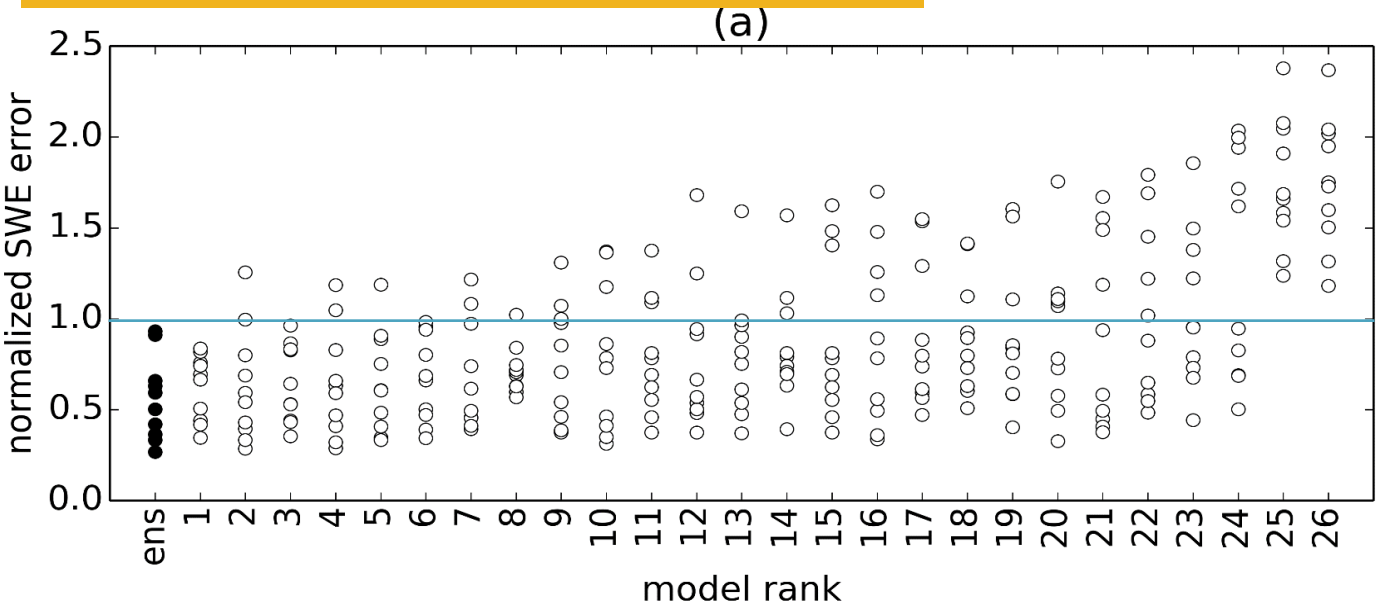
ESM-SnowMIP multi-model ensemble

Weissfluhjoch 1996-2016 average
winter temperature -7°C
annual snowfall 1250 mm

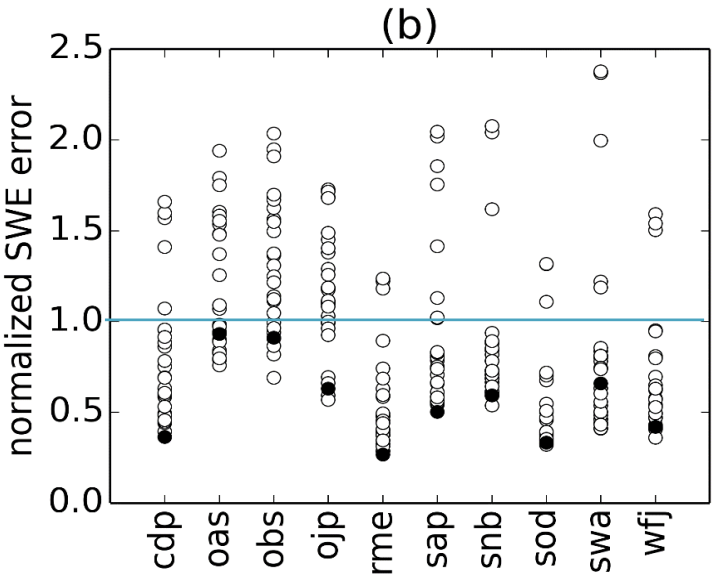


ESM-SnowMIP model errors

Models ranked by average error for all sites



All models and ensemble average at each site



Conclusions

- Models differ and there is no single “best” model
  (but in the climate model context, we want to help improve the bad ones)
- Only a few models perform well at all sites, but the multi-model ensemble is robust
- Warm sites highlight model uncertainty and cold sites highlight outliers
- Input, user and evaluation data errors contribute significantly to uncertainty

Next steps

- Site simulations:
  - Large-scale forcing data extracted and bias corrected for reference sites
  - Constrained albedo, surface exchange and thermal conductivity experiments
  - Additional “challenging” sites
  - Benchmarking – compare against a “minimum” standard model
- Global simulations:
  - Global offline simulations with varying meteorological datasets
  - Sensitivity tests: Snow fraction, snow insulation parameterizations
  - Snow Shortwave Radiative Effect analysis in coupled historical simulations
  - Snow feedback analyses