Relationship between snow cover and temperature trends in observational and earth-system model ensembles

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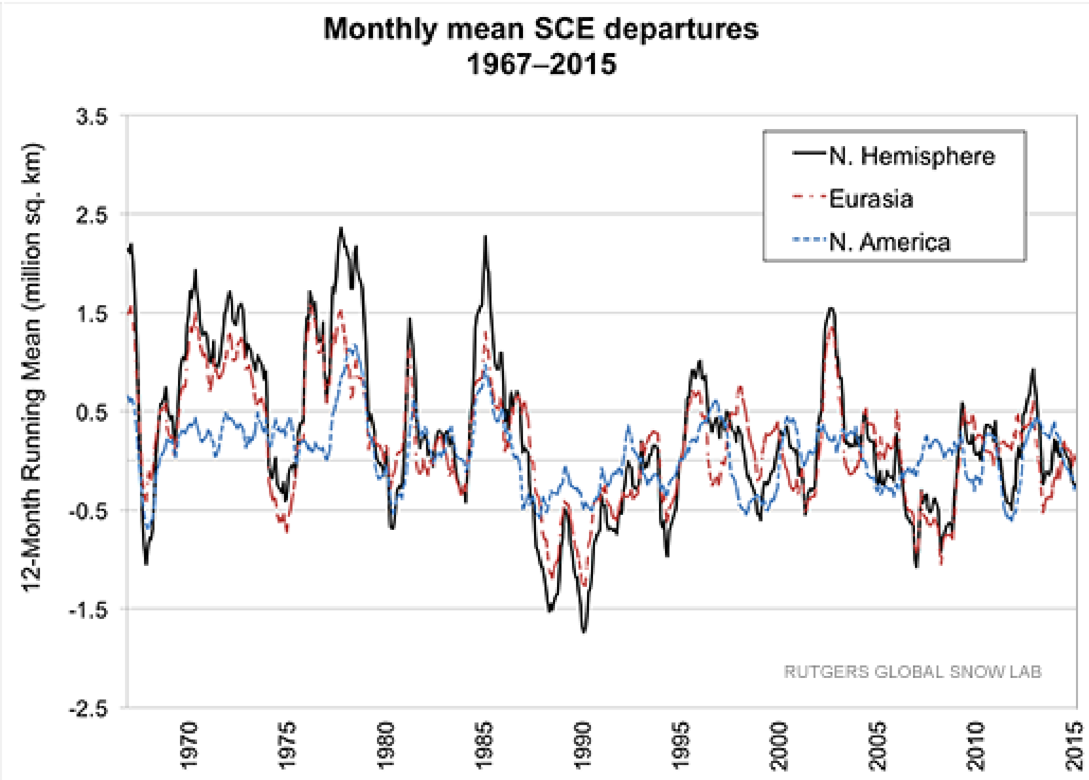
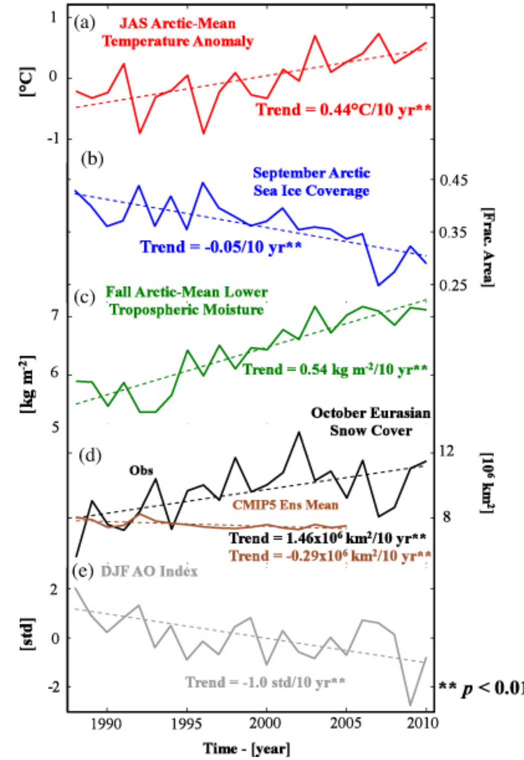
Mudryk et al., GRL, in press.

Multi-decadal Satellite Derived Snow Observations



NOAA Climate Data Record

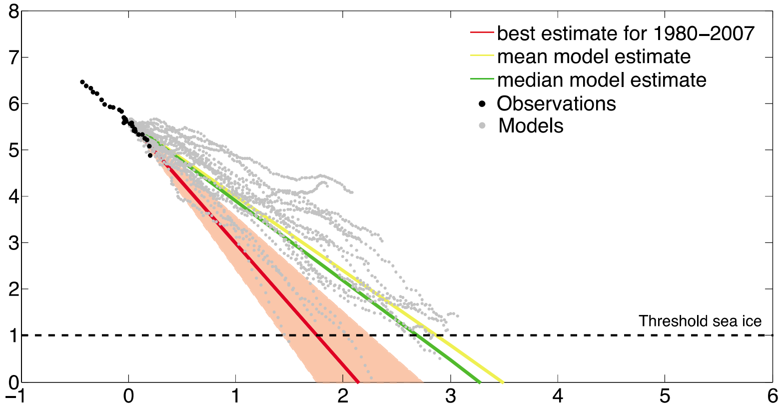


Cohen et al. 2012

- The 50-year NOAA CDR is a go-to resource for climate analysis and seasonal prediction.
- We can now place it in the context of several snow and temperature trend estimates.
- This observational ensemble can be combined with earth system model simulations for further insight.

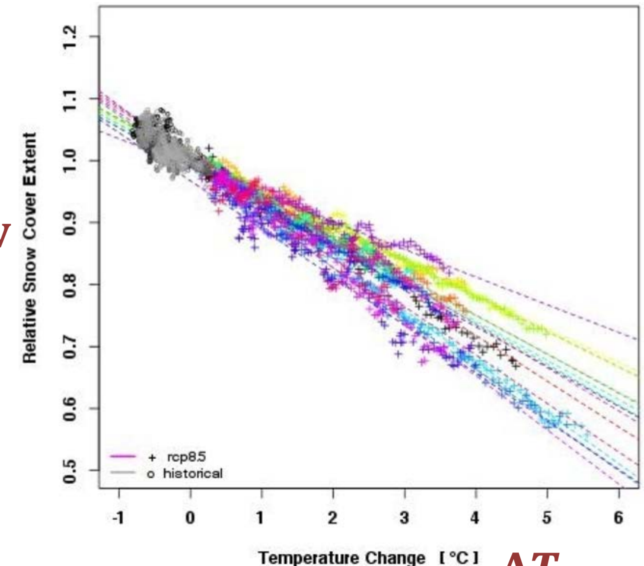
Observed and Modeled Sea Ice/Snow Sensitivity

ΔSea Ice



ΔT_{global}

ΔSnow



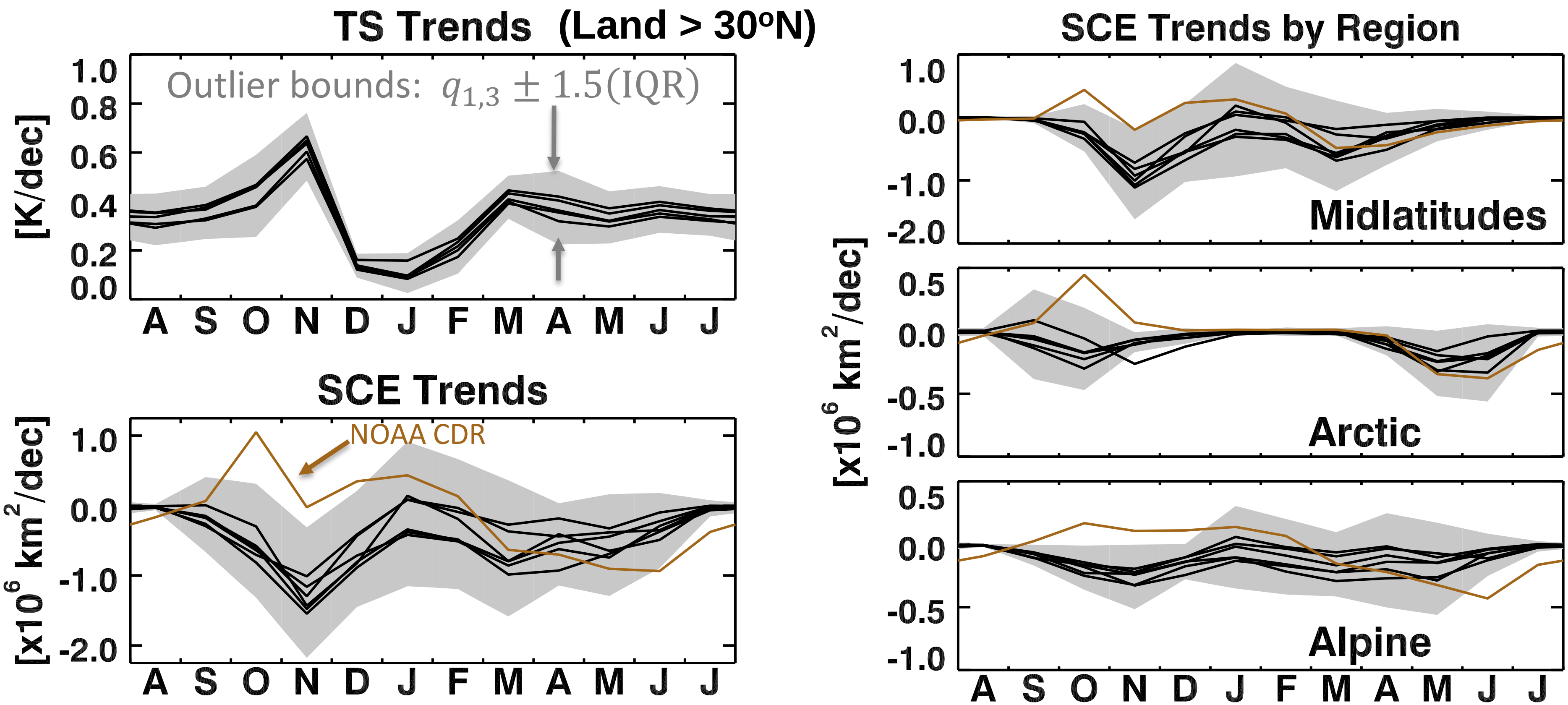
ΔT_{global}

Mahlstein & Knutti 2012, Brutel-Vuilmet et al. 2013

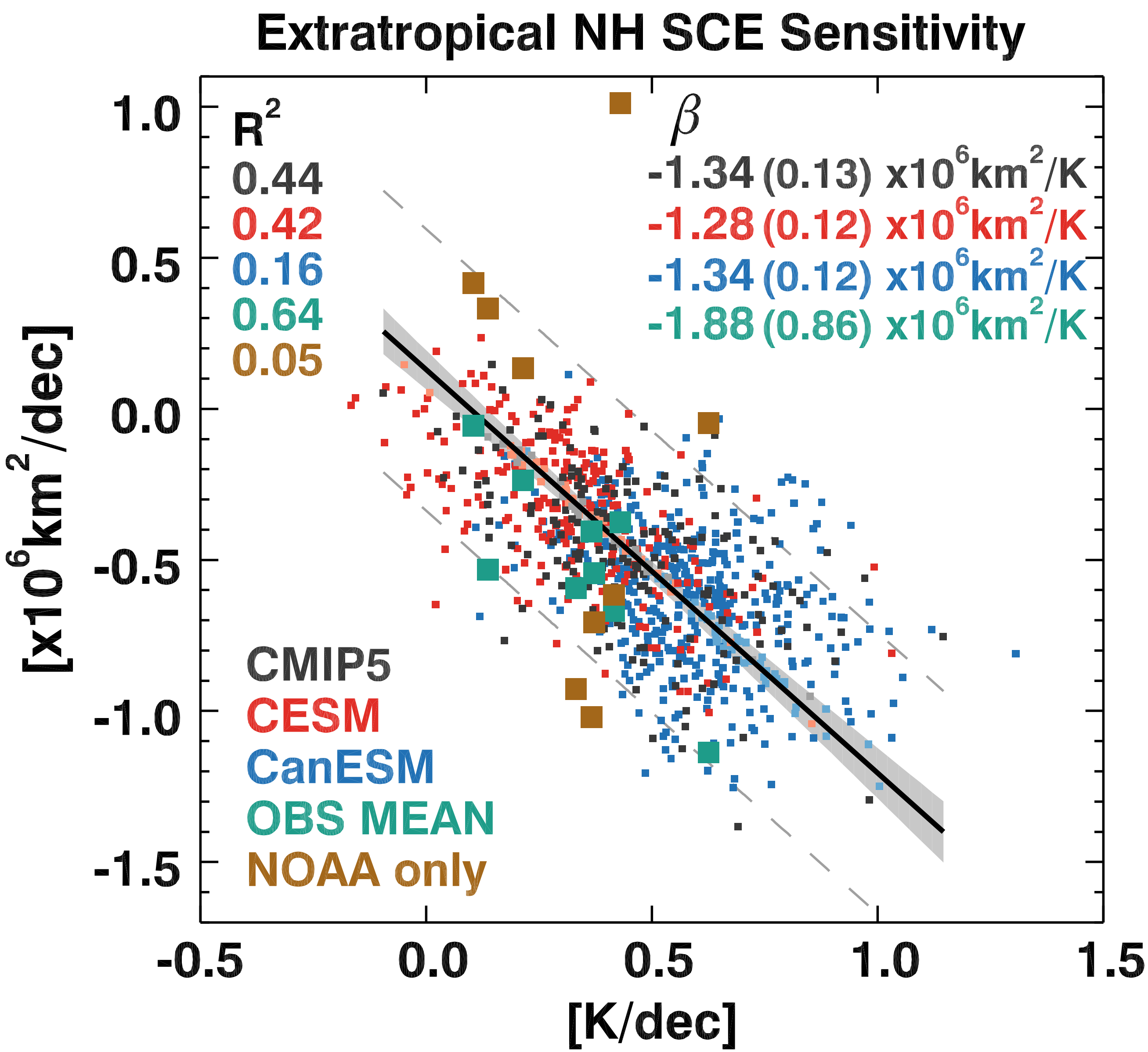
- We assess model and observational snow cover sensitivity across ensembles, seasons, and regions.
- Common analysis period 1980-2010.

Temperature	Snow: Satellite, Assimilation, Reanalysis	Earth System Model Temperature, SCE
• NASA GISTEMP • HadCRUT4 • NOAA CDC • Willmott-Matsura • BEST	• NOAA-Rutgers CDR Snow Cover Extent (SCE) • GlobSnow v2 Satellite • MERRA Reanalysis • ERA-Interim Land • GLDAS • CROCUS (ERA-I) • Brown (ERA-I) → • SCE from daily snow water equivalent (SWE). • Use 4mm SWE threshold to convert to SCE • See CanSISE Blended SWE (nsidc.org/data/NSIDC-0668) • Mudryk et al. 2015	**Ensemble of Opportunity (historical forcing):** • 25 CMIP5 models, 50+ realizations **Large Initial-Condition Ensembles:** • NCAR CESM1 Large Ensemble (30) • CanESM2 Large Ensemble (50)
Sample $\Delta SCE/\Delta T$ trends across ensemble of observations for 1980-2010		Sample across climate variability and model uncertainty.

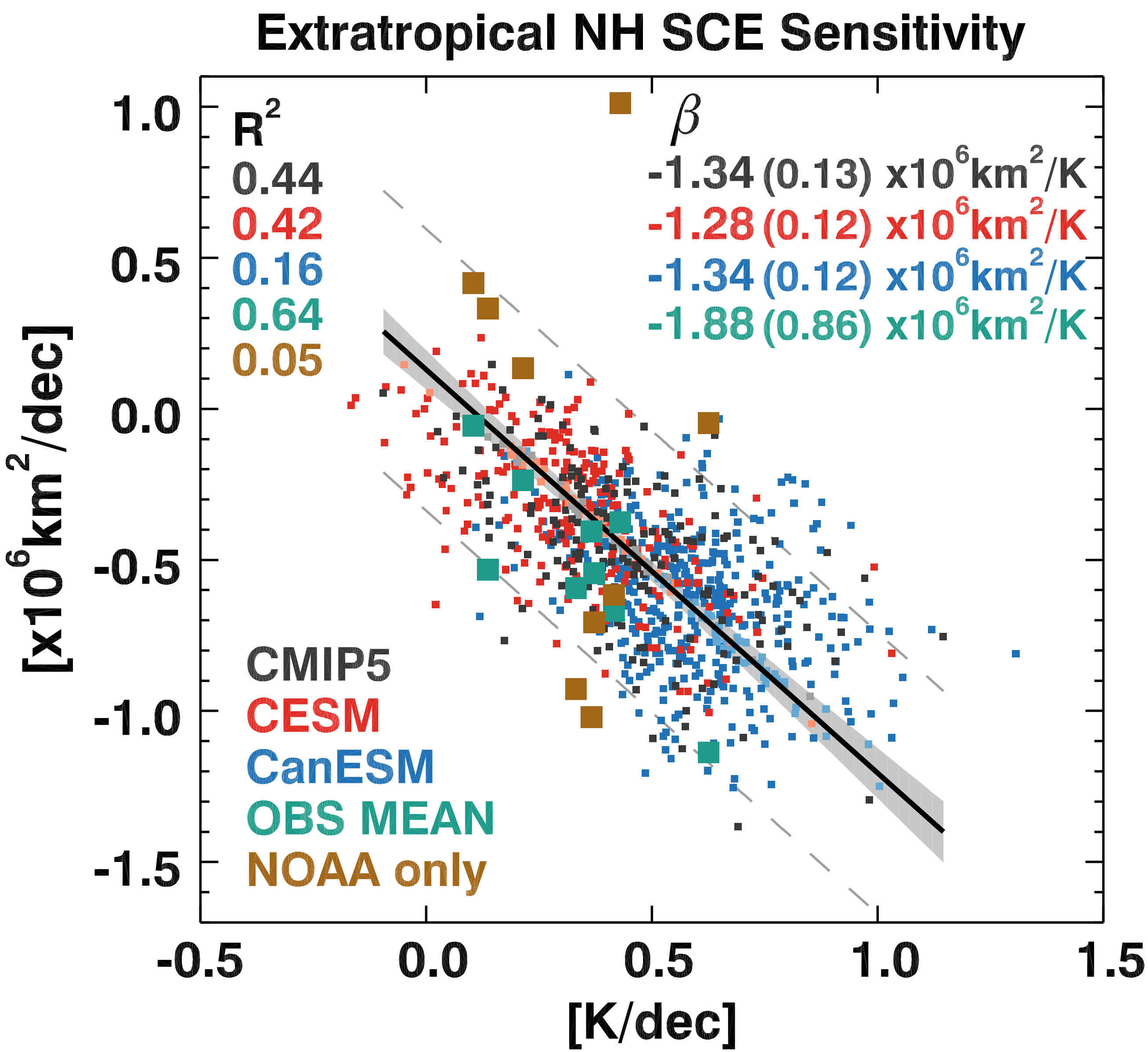
Trends in Temperature and Snow Cover Extent



- Observed temperature and SCE trends generally consistent across datasets.
- NOAA CDR is an outlier for October-November-December (Brown and Derksen 2013, Hori et al. 2017) for NH and some subregions.

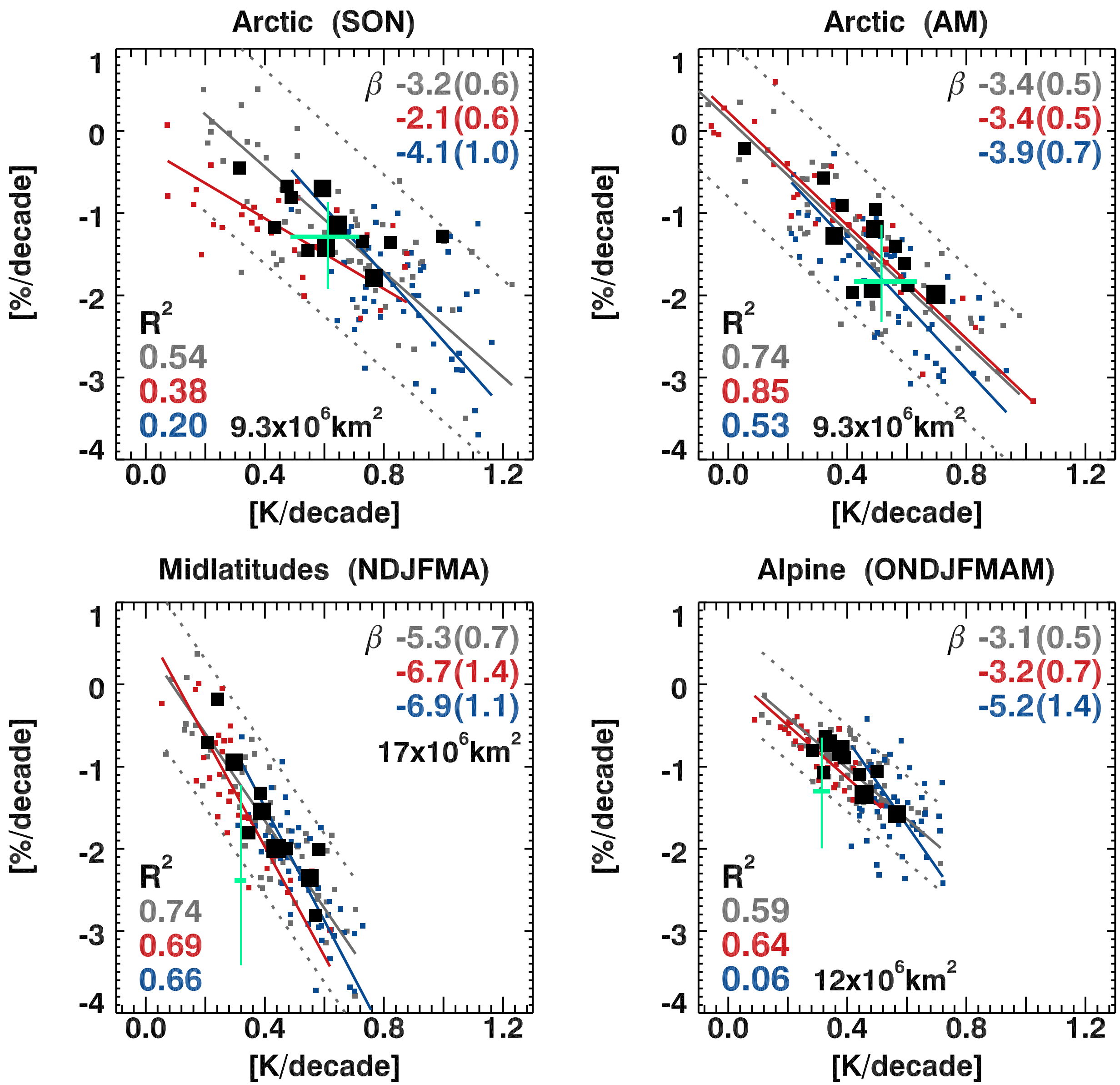


- Each point is a pair of trends for each calendar month for October-June
- Larger squares are obs:
  - Gold: NOAA CDR
  - Teal: Other obs
- Small squares are models: individual realizations, months.
- The β is snow cover sensitivity.

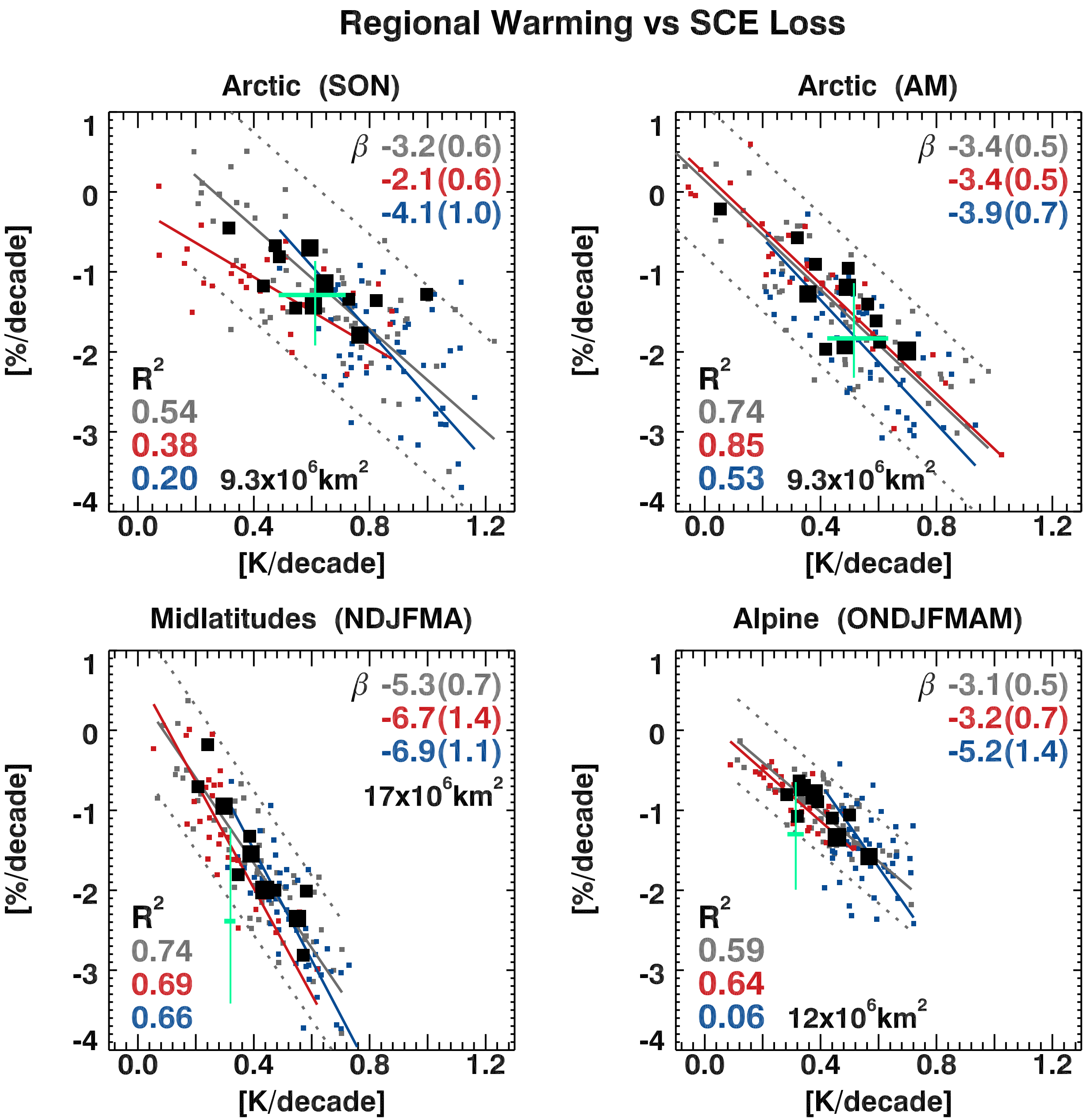


- NOAA-CDR SCE trends not consistent with other obs.
  - Several months with increasing snow and increasing temperature
- Internal variability (red cloud or blue cloud) generates a lot of spread:
  - Half of CMIP5 spread is from internal variability.
- Model and obs are consistent on hemispheric scale, β are also consistent.

Regional Warming vs SCE Loss

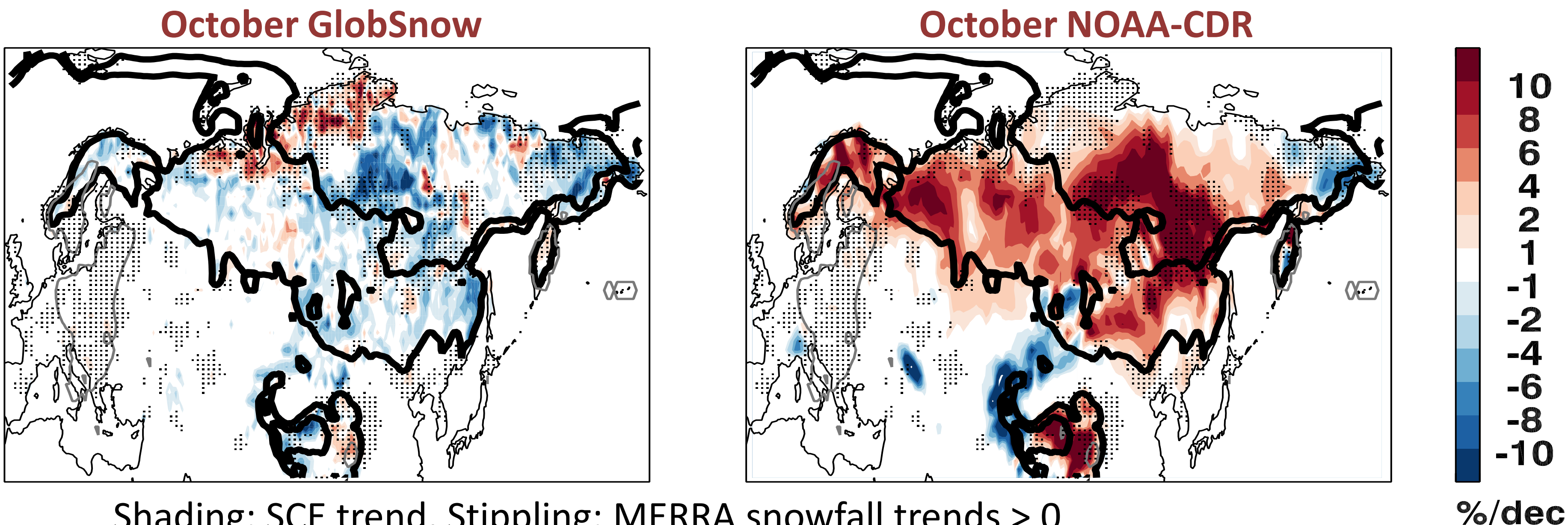


- Grey, red, and blue small squares: individual realizations.
- Black squares: CMIP5 multi realization means.
- Green crosses: range of observed trends (without NOAA CDR).



- Arctic fall is less controlled by temperature than Arctic spring.
- Simulated midlatitude and alpine sensitivities underestimate SCE loss per degree warming
- Model differences required to explain CMIP5 spread outside of Arctic springtime

Why Is the SCE Trend Inconsistent in Fall?



Shading: SCE trend, Stippling: MERRA snowfall trends > 0
Grey contours: BEST temperature trends < 0
Black contours: BEST Oct. 1 and Oct. 31 0^oC climatological isotherm

- In snow margin region, NOAA-CDR SCE increases even without cooling or increases in snowfall.
- GlobSnow shows weak decrease of snow.

Conclusion

- Ensembles help account for natural variability and observational uncertainty.
- Modelled SCE sensitivity is weaker than observed in midlatitude and alpine regions but well-modelled in Arctic.
- In the CMIP5 and CESM ensembles the SCE response is principally controlled by the TS response but this coupling may be model-dependent, e.g. CanESM in alpine regions
- Spread in SCE trends reflects roughly equal contributions from natural and inter-model variability.

Conclusion

- We are in a good position to cross compare snow products and create multi-source products.
- There is an opportunity to reconcile the NOAA CDR and the other datasets in terms of trends and temperature sensitivity.
- At this point we recommend caution for using NOAA CDR SCE for fall snow trends. In disagreement with recent claims, there is no obvious mismatch between observed and simulated snow cover trends in fall.
- Mudryk et al., GRL, in press.