Projected change of Arctic summer cyclone activity by CMIP3 models

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Cyclones over the Arctic in summer

- Extra-tropical cyclones strongly influence cloudiness, radiation budget and poleward transport of heat, momentum and water vapour
- There exists a pronounced storm track over the Arctic in summer (Arctic Ocean Cyclone Maximum) (Serreze and Barrett (2008; Orsolini and Sorteberg, 2008). Cyclones are generated over the Eurasian continent and developing over the Arctic frontal zone, along the subpolar summer jet.
- While important climate change is occurring in the Arctic in summer (e.g. sea ice retreat), little work has been done on summer cyclones across the Arctic; yet the AOCM poorly represented in climate models.

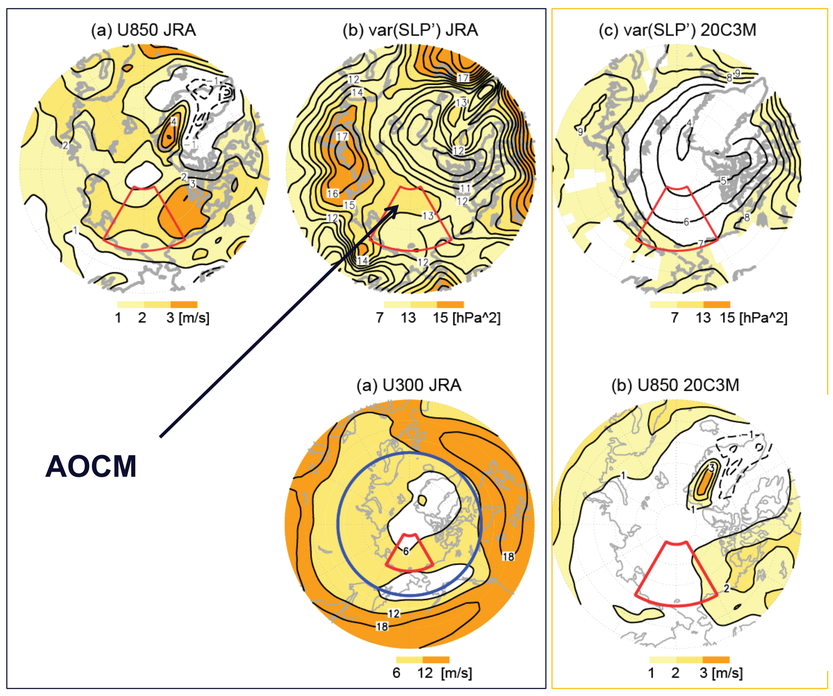
Purpose of this study.

- Assess the reproducibility of storm-track activity in multi-model ensemble of 20C3M experiments, and of future projections based on SRES-A1B scenario, and benchmark with meteorological re-analyses
- Examine factors (e.g. surface temperature gradient, jet strength, ..) governing the inter-model variability in current and future climate

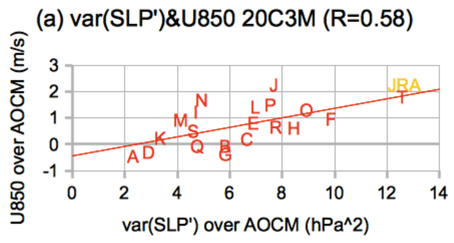
Data and Method

- The Japanese 25-year Reanalysis (JRA-25) [*Onogi et al.,* 2007] from 1979 through 2008.
- CMIP3 models daily-mean data from 17 models for current climate (20C3M) and future climate (SRES -A1B) (Single realisation)
- Climatological summer means (JJA) over years 1982-1998, or 2082-2098
- Eulerian diagnostic of eddy activity: sub-weekly (8-day high-pass filtered) SLP variance; that JJA variance averaged over the AOCM region is here called "Arctic storm track activity".

JRA-25 **20C3M**



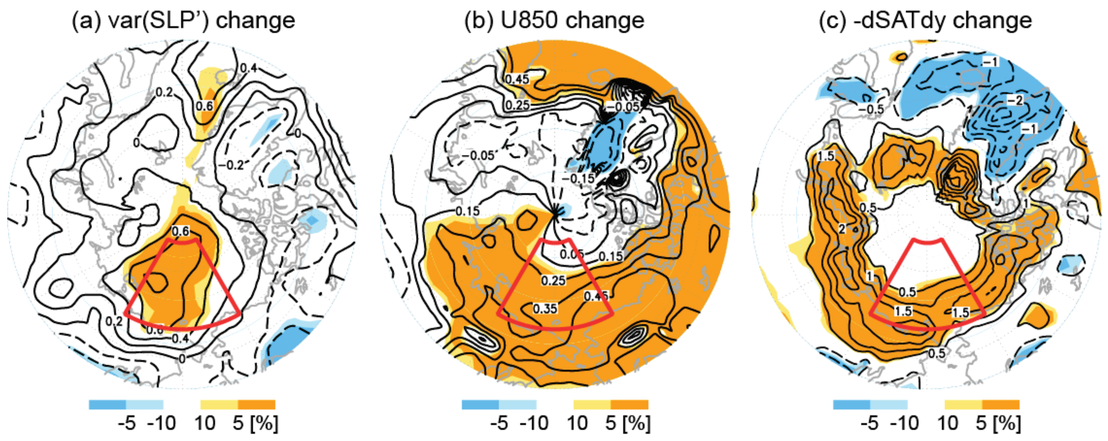
20C3M : models have negative bias vs re-analyses in strength of subpolar, low-level jet and Arctic storm track activity. Yet, models with strong AOCM tend to have a strong subpolar jet.



JRA-25 reanalyses: JJA-mean climatology of low-level (850-hPa) and upper-level zonal wind velocity (m/s) and Arctic storm track activity (hPa^2).
20CM3 : multi-model ensemble mean of the 20C3M experiment for JJA-mean climatology of low-level (850-hPa) and storm track activity (hPa^2).
Red lines outlines the AOCM region (70°N-85°N, 150°E-210°E).

20CM3 : Scatter plot of inter-model correlations between Arctic storm track activity and 850-hPa westerlies averaged over AOCM region.
Alphabets designate respective models and "JRA" reanalysis data.

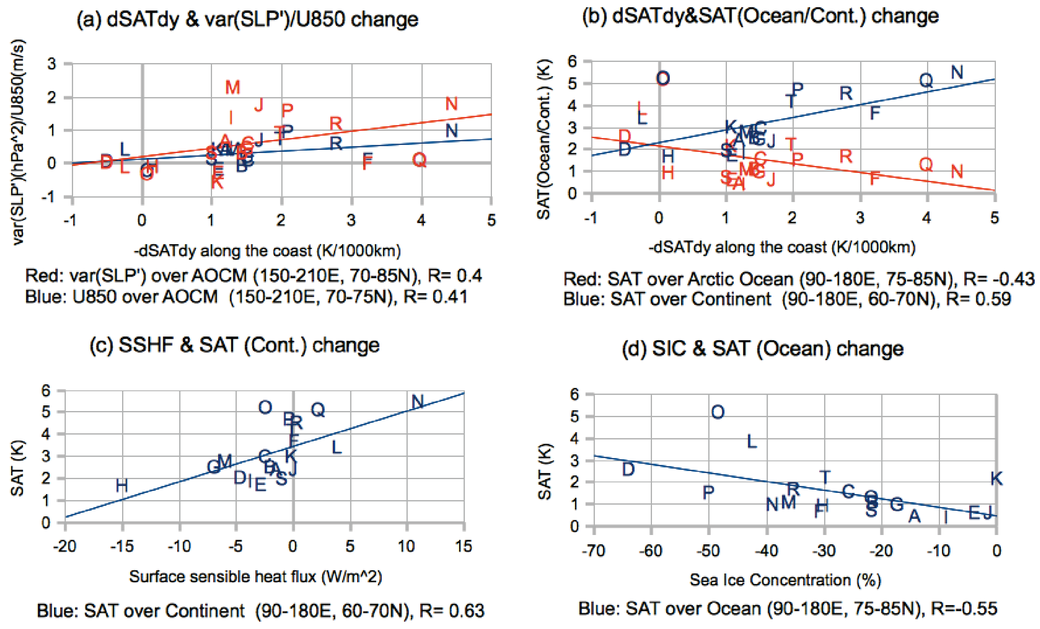
SRES-A1B



SRES A1B : in multi-model mean, projected enhancement in storm track activity, consistent with enhancement in wind and meridional gradient in SAT

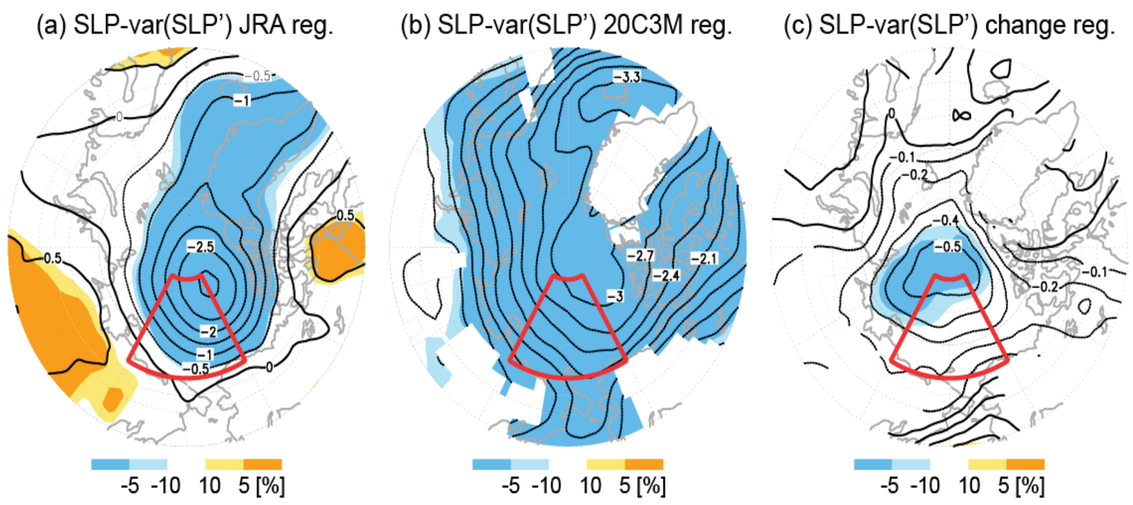
SRES A1B : Future multi-model mean change (SRES-A1B minus 20C3M) in Arctic storm track activity , 850hPa westerlies (m/s), and for meridional gradient of surface air temperature with sign reversed (K/1000km).

SRES-A1B



SRES A1B : models that project strong enhancement in Arctic storm track activity consistently show enhancement in meridional gradient of SAT, esp. due to a warming of the Siberia

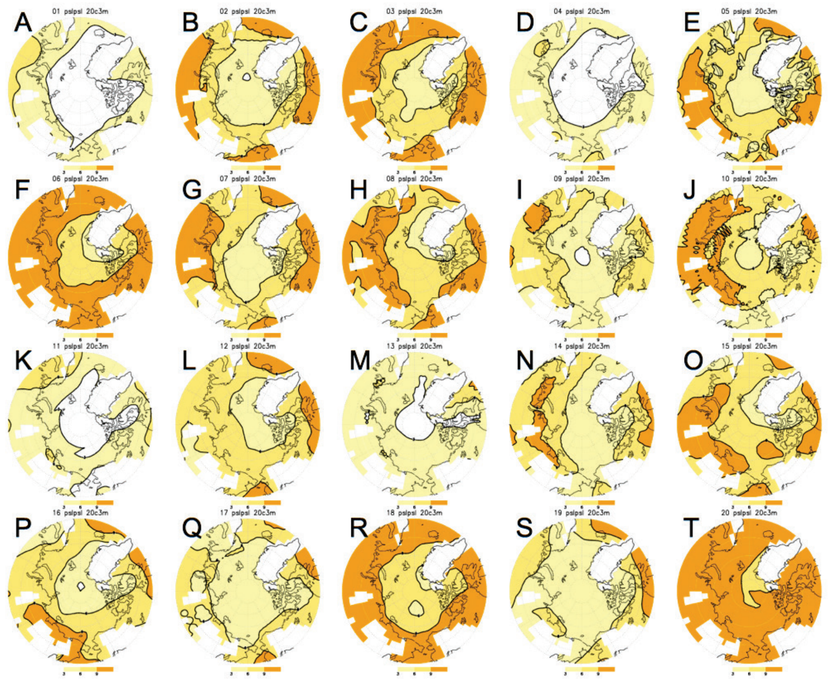
SRES A1B : Scatter plots showing inter-model correlations between JJA-mean future changes in meridional SAT gradient (K/1000km) along the Siberian coast and those in storm-track activity (red; hPa2) and 850-hPa westerlies (U850) (blue; m/s) (b) As in (a), but for the corresponding future changes in meridional SAT gradient (K/1000km) averaged along the Siberian coast against those in SAT (K) averaged over Siberia, and SAT over the Arctic Ocean off Siberia (c) As in (a), but the corresponding future changes in surface sensible heat flux (Wm-2) against SAT (K) both averaged over Siberia. (d) for the corresponding future changes in sea ice concentration (%) against SAT (K) both averaged over the Arctic Ocean off Siberia.



Arctic storm track acvity negatively correlated to global SLP pattern (summer Arctic Oscillation) (Ogi et al., 2004)

JRA-25 reanalyses/ 20CM3 /SRES A1B : Observed inter-annual regression of Arctic storm-track activity with JJA-mean SLP, for JRA, for inter-model regression of 20C3M, and for future projection.

20C3M



20CM3 : Arctic storm-track activity in individual models

Conclusions

- Few CMIP3 models can reproduce the AOCM (large inter-model diversity)
- In contrast, future changes in storm track activity, lower westerlies and in land-sea contrast are simulated consistently
- Intensification of storm track activity predominantly linked to warming Siberia

References:

Ogi, M., K. Yamazaki, and Y. Tachibana, 2004: The summertime annular mode in the Northern Hemisphere and its linkage to the winter mode. J. Geophys. Res. 109, D20114, doi:10.1029/2004JD004514.
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KN and HN have been supported by the Japanese Ministry of Education, Culture, Sports, Science and Technology under the Grant-in-Aid for Scientific Research (A) #18204044 and #22340135 and also by the Global Environment Research Fund (S-5) of the Ministry of Environment. YO has been supported by the Norwegian Research Council through the DECCEN.