SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	Links between warming Arctic and climate extremes in northern Eurasia (LAWINE)
Computer Project Account:	spfiuoti
Start Year - End Year :	2017 - 2019
Principal Investigator(s)	Petteri Uotila
Affiliation/Address:	University of Helsinki (was Finnish Meteorological Institute)
Other Researchers (Name/Affiliation):	

The following should cover the entire project duration.

Summary of project objectives

(10 lines max)

We use ECMWF computational resources to assist us in completing model simulations on the EC-Earth climate model to address the LAWINE scientific objectives which aim to better understanding of complex processes linking Arctic amplification with mid-latitude climate extremes. Specifically, we carry out surface temperature perturbed climate model simulations to determine teleconnections between the Arctic and lower latitutes. Most simulations are carried out on CSC and FMI supercomputers in Finland, some on the ECMWF system when deemed necessary due to heavy computational load on the Finnish computers.

Summary of problems encountered

(If you encountered any problems of a more technical nature, please describe them here.)

No bigger problems. File transfers of order of 100s Gbs from ECMWF to CSC computers on sftp stopped occasionally, but this may not be an issue any more. Not sure whether the issue was in our end of transfer.

Experience with the Special Project framework

(Please let us know about your experience with administrative aspects like the application procedure, progress reporting etc.)

I think the SP framework works well and does not have too high administrative burden from the user perspective, at least for small projects such as this one.

Summary of results

The project had three science objectives to improve the understanding of teleconnections affecting northern Eurasia. *Objective 1 was to identify remote regions that generate teleconnections affecting the occurrence*, intensity and duration of extreme climate events in northern Eurasia.

Related to this objective, Vihma et al. (2019b) studied factors influencing European winter temperatures with the focus on Arctic warming. They identified that European winter temperatures were primarily linked to the Atlantic and Scandinavian large-scale weather conditions. Nygård et al. (2019) found that much of the moisture provided by the evaporation in the Arctic is transported southwards. Tyrrell et al. (2019) studied a case when anomalous Siberian forcing in October 2016 generated a response in atmospheric circulation over northern Europe and Atlantic. In summary, the results highlight that combinatory interactions of regional air-ice-ocean systems surrounding the northern Eurasia play crucial roles in determining its weather, including extreme events.

Objective 2 was to analyse how well state-of-the-science climate models simulate the identified associations. The determination of the realism of climate models can be divided to four categories: 1) the analysis of model features, such as what physical processes has been implemented; 2) the analysis of the design of model experiments, such as how well ensemble simulations capture the internal variability of climate system; 3) the analysis of model's initial and boundary conditions, for instance the realism of ocean states for decadal prediction experiments; and 4) the analysis of the realism of climate model output itself. Fox-Kemper et al. (2019) reviewed recent progress in the development of ocean and sea-ice model physics and as such assessed what factors might still be missing or are inadequately implemented in climate models. They concluded that the coupling to sea ice, ice shelves, and high-resolution atmospheric models has stimulated new ideas and driven improvements in numerics and in forecasting in general. Benestad et al. (2017) addressed the problem of climate model experiment design. They questioned whether climate model information could be used more effectively and argued that statisticians could contribute substantially to designing 'smarter' ensemble experiments.

Uotila et al. (2019) assessed physical environmental states derived from an ensemble of ocean reanalysis products in the polar regions, which are also used as initial conditions for long-term coupled atmosphere-ocean forecasts, such as decadal. They identified large variability between individual products, but also that the product mean state is a useful product. Norling et al. (2019) carried out climate model simulations with two climate models to quantify impacts of aerosols on global climate dynamics. Their results imply that differences between the two climate models originate from atmospheric dynamics and snow/ice cover responses. Jonassen et al. (2019) used independent historical observations from the Antarctic to assess the performance of global atmospheric reanalyses. They identified a common warm bias which has persisted over decades and is therefore independent of assimilated observations. To address the issue of sparse observation network in the marine Arctic, Vihma et al. (2019) called for the establishment of a marine Arctic component of the Pan-Eurasian Experiment (MA-PEEX) as a component of the PEEX research infrastructure. In summary these six studies were able to identify a number of issues which decrease the forecast skill when simulating the teleconnections affecting the northern Eurasian weather and climate.

Objective 3 was to identify physical mechanisms of the teleconnections affecting the northern Eurasian climate extremes. Several important findings related to the physical mechanisms behind teleconnections were uncovered. First, Vihma et al. (2019b) found that the divergence of dry static energy transport was related to winter cold spells, while warm anomalies were associated with convergence of latent heat transport. Tyrrell et al. (2019) discovered that the record strong warm Arctic - cold Siberian continent pattern led to weak polar vortex and negative North Atlantic Oscillation. Nygård et al. (2019) revealed a strong, causal dependence of moisture, clouds and longwave radiation on atmospheric pressure fields. Regarding statistical modelling, Kämäräinen et al. (2019) applied advanced methods to explore the importance of various factors potentially affecting near surface air temperature over northern Europe. Importantly, these derived statistical relationships could be utilised in long-term prediction applications.

List of publications/reports from the project with complete references

1. Benestad, R., Sillmann, J., Thorarinsdottir, T. L., Guttorp, P., d. S. Mesquita, M., Tye, M. R., **Uotila, P.** et al., New vigour involving statisticians to overcome ensemble fatigue, *Nature Climate Change*, 7(10), 697–703, doi:10.1038/nclimate3393, 2017.
2. Fox-Kemper, B., A. Adcroft, A., C. W. Böning, E. P. Chassingnet, E. Curchitser, G. Danabasoglu, C. Eden, M. H. England, R. Gerdes, R. J. Greatbach, S. M. Griffies, R. W. Hallberg, E. Hanert, P. Heimbach, H. T. Hewitt, C. H. Hill, Y. Komuro, S. Legg, J. Le Sommer, S. Masina, S. J. Marsland, S. G. Penny, F. Qiao, T. D. Ringler, A. M. Trequier, H. Tsujino, **P. Uotila** and S. G. Yeager, Challenges and Prospects in Ocean Circulation Models, *Front. Mar. Sci.*, doi:10.3389/fmars.2019.00065, 2019.
3. Gibson, P. B., Perkins-Kirkpatrick, S. E., **Uotila, P.**, Pepler, A. S., & Alexander, L. V. (2017). On the use of self-organizing maps for studying climate extremes. Journal of Geophysical Research, 122(7), 3891–3903. https://doi.org/10.1002/2016JD026256
4. Jonassen, M., I. Välisuo, T. Vihma, **P. Uotila**, A. P. Makshtas, and J. Launiainen, Assessment of Atmospheric Reanalyses with Independent Observations in the Weddell Sea, Antarctica, *J. Geophys. Res.*, under review, 2019.
5. Kämäräinen, M., **P. Uotila** et al., A new statistical forecasting method for seasonal temperatures in Europe, *Journal of Climate*, doi:10.1175/JCLI-D-18-0765.1, 2019.
6. Nordling, K., H. Korhonen, P. Räisänen, E. Alper, P. Uotila et al., Role of climate model dynamics in estimated climate responses to anthropogenic aerosols, *Atmospheric Chemistry and Physics*, doi:10.5194/acp-2018-1335, under review but available online, 2019.
7. Nygård, T., R. G. Graversen, **P. Uotila**, T. Naakka and T. Vihma, Strong dependence of wintertime Arctic moisture and cloud distributions on atmospheric large-scale circulation, *J. Climate*, under review, 2019.
8. Tyrrell, N., A. Karpechko, **P. Uotila** and T. Vihma, Atmospheric Circulation Response to Anomalous Siberian Forcing in October 2016 and its Long-Range Predictability, *Geophys. Res. Lett.*, doi:10.1029/2018GL081580, 2019.
9. **Uotila, P.**, Goosse, H. and the Polar ORA-IP team, An assessment of ten ocean reanalyses in the polar regions, *Climate Dynamics*, doi:10.1007/s00382-018-4242-z, 2019.
10. Vihma, T., **Uotila P.**, et al. Towards the Marine Arctic Component of the Pan-Eurasian Experiment, *Atmospheric Chemistry and Physics*, doi:10.5194/acp-19-1941-201, 2019a.
11. Vihma, T., Björnsson, H., Chen, L., Dethloff, K., Francis, J., Graversen, R., Handorf. D., Hanna, E., Hall, R., Karpechko, A., Overland, J. E., Skific, N., Tyrrell, N., and **Uotila, P.**, How does Arctic change affect European weather and climate? *International Journal of Climatology*, under review, 2019b.

Future plans

(Please let us know of any imminent plans regarding a continuation of this research activity, in particular if they are linked to another/new Special Project.)

I do not plan to continue this research activity. Our recent activities are more related to ocean modelling and if extra computational capacity provided by the ECMWF is needed in addition to national providers, a new application will be submitted. I would like to keep my access to the ECMWF computers though, mainly due to the available model and forecasting data which I am keen to continue analysing.