Responsible Development of the Arctic:
Opportunities and challenges – Pathways to Action

Highlights 2019
CLINF Nordic Centre of Excellence in Arctic Research

Climate change effects on the epidemiology of infectious diseases and the impacts on northern societies

Success stories and unexpected results

The CLINF data repository

Most of the diseases addressed by CLINF are zoonotic, meaning that they can be transmitted from animals to humans. The CLINF data repository contains diseases data collected from human as well as from animal diseases data archives in Finland, Greenland, Iceland, Norway, Russia and Sweden. Data for the following diseases were compiled:

- Human diseases data regarding borreliosis, brucellosis, cryptosporidiosis, leptospirosis, haemorrhagic fever with renal syndrome, Q-fever, tick-borne encephalitis, and tularemia;
- Animal diseases data of sufficient quantity on anaplasmosis, babesiosis, brucellosis, *Erysopelothrix*, leptospirosis, listeriosis, rabies, and trichinellosis.

In order to infer how the spatiotemporal variation of the above disesas co-vary with landscape and weather variables, the CLINF data repository has been supplemented with large volumes of landcover data (36 variables), weather and hydrology data (22 variables), and data related to greening and the presence of chlorophyll (2 variables). Based on these primary "landscape and weather" variables, 12 additional derived variables were calculated, e.g. duration of snowcover (based on primary snowcover). With the CLINF data repository approaching its final state, CLINF is now starting to take the initiatives required for OPEN public dissemination, and expects this to become one of its most important legacies.

The inference of CLINF data

Since the CLINF study region encompasses many different regional climate zones, the rate and direction of geographically translating diseases depends very much on the choice of region. CLINF has therefore subdivided its study region, from Nuuk to Yakutsk, into subregions such as individual nations, the Scandinavian penninsula, Finland and western Russia combined, Siberia, etc. Based on the CLINF study of diseases geography, it can be suggested that diseases carried by vectors such as ticks, midges, mosquitos, and rodents, seem to generally follow the landscape transitions introduced with the warming of the North. This corroborates the basic hypothesis of CLINF. These types of assessments can be used for quantifying the rates with which diseases have translated geographically through different regions.

As a result of regressing CLINF "landscape and weather" data on the spatiotemporal variation of diseases, using a broad arsenal of regression techniques, the observed variation (district-by-district and year-by-year) of almost all CLINF diseases could be explained at very high precision, although with varying degrees of explanation. It is suggested that these differences reflect the complexity of the respective CSI vector processes. As an example, the variation of "purely" tick-borne diseases, such as borrelia and tick-borne encephalitis (TBE), seem to be relatively easy to explain as compared with the more complex vector processes of tularaemia. One obvious interpretation of these results is that what CLINF is actually inferring are latent vector processes that have been observed via diseases incidences, rather than the explicit variation of the diseases themselves.

Forecasting of CSI geographies

Fundamental to understanding and predicting the viability and spread of climate sensitive infections (CSI) is identification of the environmental envelopes within which they can flourish, though this will almost certainly need to be supplemented by knowledge about the host and affected species and their risk of exposure to the disease (including for humans). Coherent, integrated environmental information is increasingly becoming available, both from enhanced observational capabilities, especially from satellites, and advances in bio-geophysical models. Hence, the framework needed to assess CSI risk and how this will develop is essentially in place. However, the value of this framework for CSI prediction is limited by two factors, spatial scale and uncertainty.

As regards CSI analysis, spatial scale is not a major limitation for many of the variables derived from satellite data. However, a basic factor in the spatial resolution of the land-surface-models (LSMs) and hydrological models is the grid-size of the climate models used to drive them. The models may attain an effective finer resolution by exploiting higher resolution land cover, for example, but this may still be insufficient to characterise the variety of environmental conditions within a landscape that affect CSI viability. Nonetheless, the analysis of tularemia performed as a case-study in CLINF makes clear that, while detailed mapping of disease hotspots is unlikely to be provided by models, the effect of changing conditions can be investigated by these models and this yields significant policy-relevant conclusions.

Uncertainty is intrinsic to any measurement or model estimate. Uncertainty in LSM or hydrological model calculations is difficult to characterise because it contains many cumulative factors that cannot be adequately described simply by statistical methods, especially when it comes to prediction. First is the uncertainty of how humanity will respond to climate change. Although the four Representative Concentration Pathways defined by the Intergovernmental Panel on Climate Change set out possible atmospheric greenhouse gas concentration trajectories, no probability is attached to them. Secondly, for a given Representative Concentration Pathway different global climate models make different predictions about how climate will behave, with particular disagreement on precipitation. The ensuing uncertainty feeds through into the climate drivers of LSMs and hydrological models. However, as shown by CLINF, the models themselves differ, even with the same drivers, either because of differences in process representation or in model parameterization. This adds another layer of uncertainty, all of which propagates into CSI models based on the values of land surface and hydrological variables. The implication is that, at our current level of understanding and capability, long-term prediction of CSI behavior is probably of little value for policy decisions. Much more useful will be the development of predictions looking no more than a decade or two into the future, since these will be strongly constrained by current observations of the state of the Arctic. Furthermore, the large set of observations we already have, provide a major resource to winnow out the models that do not perform very well and to motivate model improvement.

It is an interesting ongoing discussion among climate scientists of all disciplines about how we cater to stakeholders and address uncertainty and scale. CLINF has an opportunity to contribute to this discussion.

Societal CSI effects

The methodological and analytical conundrum of cascading, interacting and cumulative CSI effects on reindeer herding practices is immense; studying them requires an unprecedented openness between different scientific disciplines and practitioners. The CLINF approach has been two-fold by including herders in a knowledge co-production process, and by drawing on a range of scientific disciplines in order to understand the nature and magnitude of exposure-sensitivities and change.

The most critical message from the study of how CSI affect reindeer herding is that the multiple stressors and changes must be considered in a holistic perspective. CSI is currently not perceived as a threat on its own, but when seen together with the other challenges herding may become severely affected. The adaptation options are gradually diminishing and beyond the herders' current and traditional adaptation responses. Only by focusing on the challenges and consequences identified by both herders and scientists, are we prepared and able to understand how the different drivers of change create risks and stresses for herding. The CLINF project has provided a unique interdisciplinary basis for understanding the different pieces of the puzzles inherent in CSI. As in earlier studies of the impacts of climate change on society, we have in CLINF come up against finding out how a scientific problem that has not yet manifested as a societal problem will nevertheless require adaptation strategies and understanding of risks. We have yet again learned that an interdisciplinary team of scientists is required for addressing "wicked problems". Additionally, the social science portion of the project has followed the initial, and often controversial, design of involving stakeholders in the identification of the challenges, and is therefore transdisciplinary. Transdisciplinarity and a co-production of knowledge approach generates other types of data, including qualitative, than what is common in the physical sciences (e.g. climatology, biology, hydrology), and vice versa. To bring the different data sets together in a broad analysis relevant to reindeer herders or other practitioners requires a high level of respect for each other's scientific fields. This is very hard to achieve in practice, and not necessarily because of ill will. We adhere to the requirements of our own scientific disciplines with respect to approach, research questions and methodology, which in turn shape the outcome. When we readily accept each other's spheres and publish freely together we have reached an important milestone in generating knowledge that is relevant and useful for society. In CLINF we are on the road towards this goal, and have learned valuable lessons for future studies.

Without a holistic understanding of the local context, originating from the co-production of knowledge of how the changes interact and cumulate, we will not be prepared to analyze how CSI will affect reindeer herding. The local context is always situated in a broader national and international policy scape. The newfound understanding of CSI therefore comes with significant management, policy and research implications for future studies.