Identifying changing climate responses of boreal forest trees in northwestern Canada

J. Barichivich[1], K. Briffa[1], K.J. Anchukaitis[2], D. Sauchyn[3], and T. Melvin[1]

[1]: Climatic Research Unit (CRU), University of East Anglia, UK.
[2]: Lamont-Doherty Earth Observatory of Columbia University, USA. [3]: Prairie Adaptation Research Collaborative (PARC), University of Regina, Canada.

Introduction

Tree growth at high northern latitudes has provided a detailed history of extra-tropical Northern Hemisphere temperature variability over most of the last millennium. Contrary to what might have been expected, recent tree growth in some circumpolar locations does not appear to be tracking the strong warming trend of the past few decades. This apparent sensitivity change in tree growth has been described as the *"divergence problem"*. It has important implications for the interpretation of paleoclimatic reconstructions based on tree-rings and for the global carbon cycle. There is no consensus on the causes or if the problem is real or is just an statistical artifact of tree-ring methods.

We use an integrated empirical and process-based modelling approach to examine the extent to which apparent divergence of *Picea glauca* growth in northwestern boreal Canada may be explained in terms of changes in limiting environmental factors or statistical distortions of the techniques used to remove the age-related trend from tree-ring data. Here we present some preliminary results of this ongoing research.

Methods

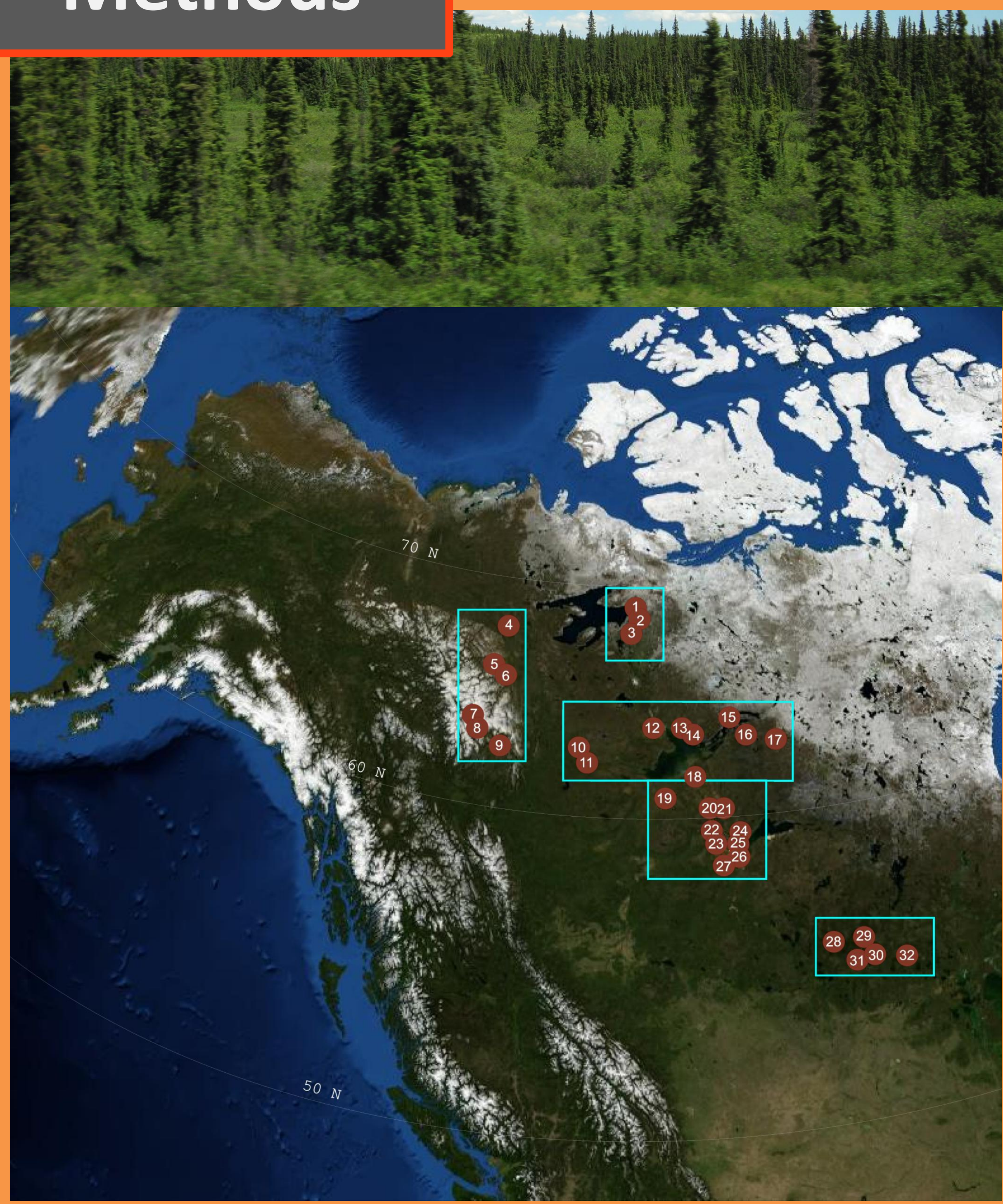

FIG. 1. Location of the tree-ring sites in northwestern Canada and panoramic view of the boreal forest. The cyan boxes indicate the 5 regions of the tree-ring network.

Tree-ring processing

A network of 32 tree-ring width sites of *Picea glauca* located north of 55ºN were used for analysis. Five regions were defined based on correlation-distance decay rate (*e-folding* distance) of tree-ring and climate data (Fig.1). A representative series of mean monthly temperature and total precipitation was created for each region from neighbour meteorological stations.

Different standardisation techniques were used to remove internal, non-climate related growth trends in series of ring-widths. Only one technique preserves long-timescale variability ["Signal-free" Regional Curve Standardization (MRCS 2)] while the others based on curve-fitting are unable to retain variability beyond a specified wavelength or timescales longer than the length of the individual series [Cubic spline (10-yr spline), Negative exponential (Neg. Exp.), "Signal-free" Negative exponential (Neg. Exp. Signal-free)].

Kalman filter

In each region, the tree-ring chronologies were compared to the monthly climate series using the Kalman (KF) filter as a dynamic regression modelling procedure. It allows for the estimation of linear regression models with *time-varying* coefficients based on maximum likelihood estimation. This procedure is especially suited for an objective detection of changes in tree growth (predictand) response to climate (predictor). The KF was applied on 10-yr high and low-pass data to detect changes in response at both interannual and longer than decadal timescales.

Vaganov-Shashkin model

The Vaganov-Shashkin (VS) forward model of conifer tree-ring formation was used to simulate synthetic tree-ring chronologies for the northernmost region (sites 1-3). The model is driven by daily environmental forcing represented by temperature, soil moisture, and solar radiation to simulate tree-ring growth cell-by-cell as a function of the most limiting environmental control. We used the Coppermine meteorological station to simulate the growth of *Picea glauca* in the northenmost sites using a model parameterization previously developed for high-latitude sites of the species.

Results

Climate response

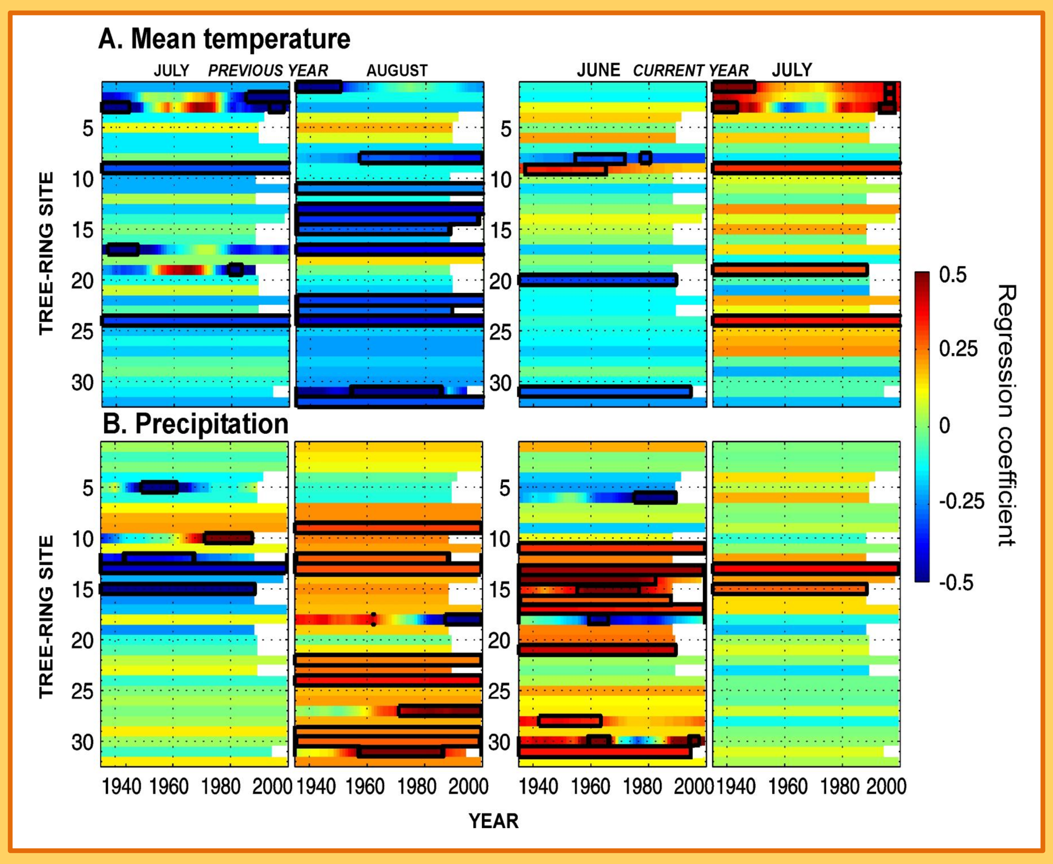

FIG. 2. Kalman filter regression coefficients on 10-yr high-pass filtered data. Tree-rings were standardized using a fixed 10-yr cubic spline. The black contour indicates significant coefficients. A constant coefficient represents a stable response of tree growth (predictand) to the climate variable (predictor).

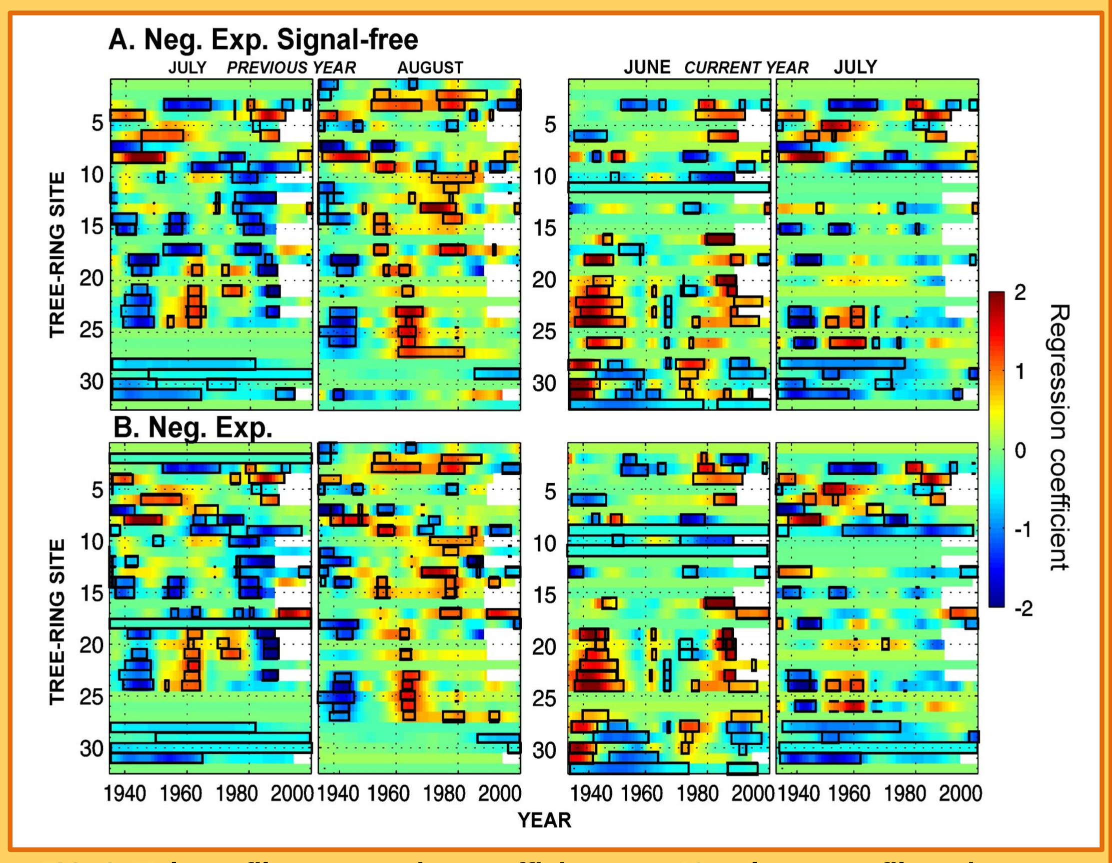

FIG. 3. Kalman filter regression coefficients on 10-yr low-pass filtered temperature and tree-ring data standardized with 'traditional' detrending (B) and with the 'signal-free' method (A). The black contour indicates significant coefficients.

Closeup – northern sites

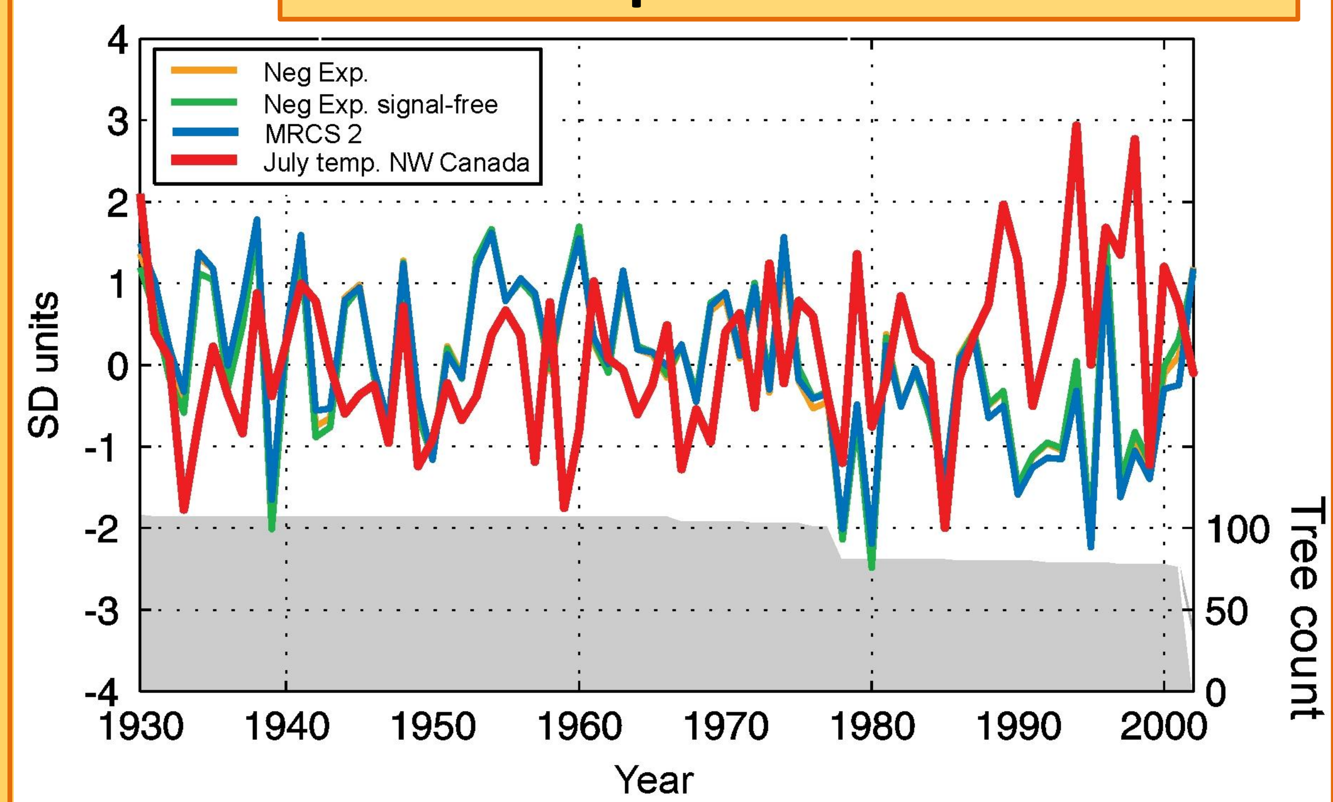

FIG. 4. Composite standard tree-ring width chronology of the northernmost sites (1-3 in FIG. 1) resulting from different standardisation methods and regional temperature (>60ºN).

Simulation – northern sites

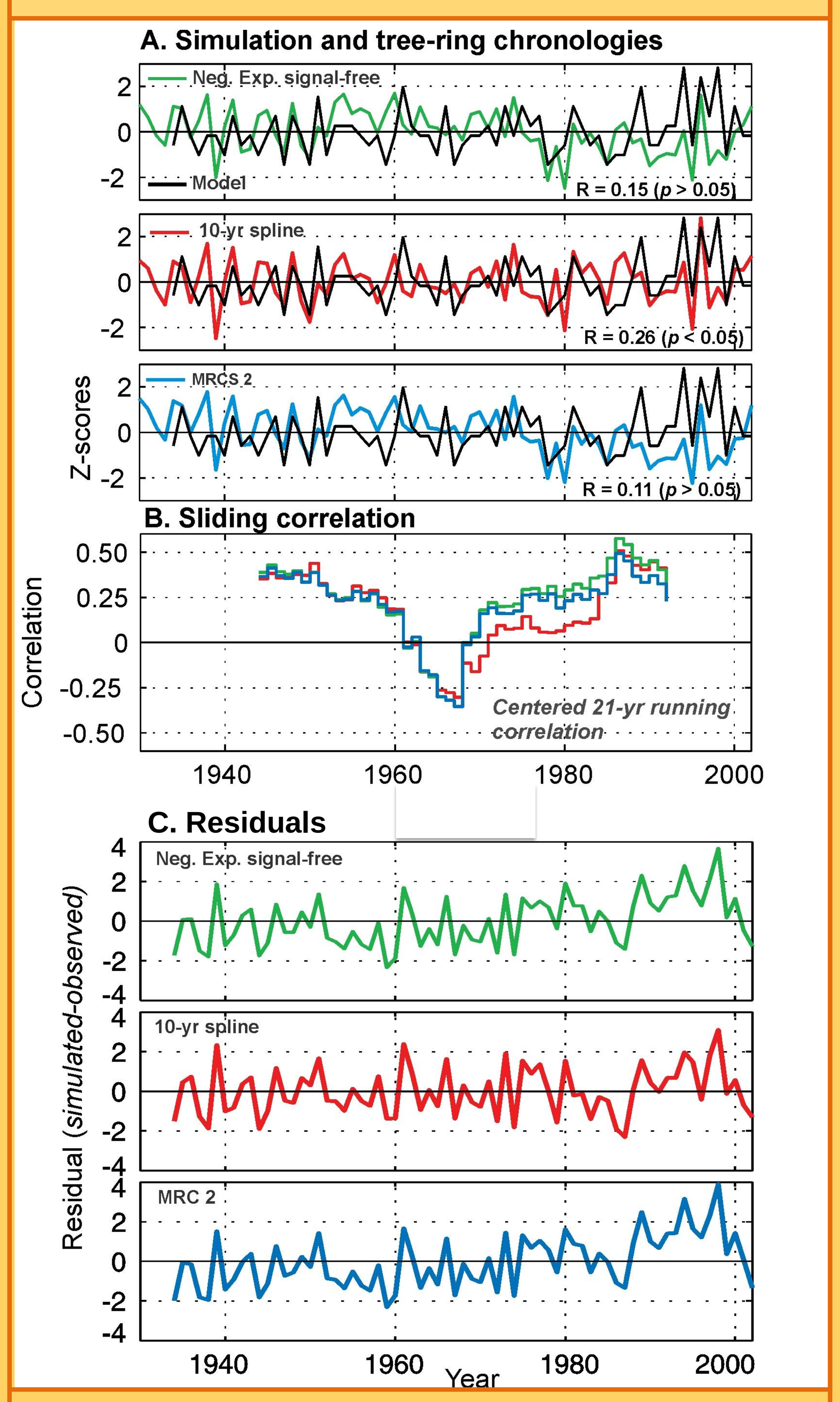

FIG 5. Comparison between the simulated and the actual tree-ring width chronologies of the northernmost sites (1-3 in FIG. 1) .

Main findings

[1]. *Picea glauca* growth has an ubiquitous response to summer moisture balance, with previous August and current June being the most limiting months (Fig. 2). This moisture signal is stable in time, at least within short timescales.

[2]. Near tree-line sites have a significant positive July temperature signal in the earlier and final decades, but this desappeared between 1960-1970 (Fig. 2A). These sites also have an inverse and unstable relationship between tree growth and July temperature during the previous year. Interestingly, the signal recovery at high-frequencies during recent decades is concurrent with a weak but significant divergence at lower frequencies (Figs. 2A, 3 and 4).

[3]. There is almost no difference in the low-pass Kalman filter results with temperature when using 'traditional' or improved 'signal-free' standardisation for tree-rings (Fig. 3).

[4]. The simulated chronology for the northernmost three sites closely follows the July temperature of the current year and is only significantly correlated with the 10-yr spline chronology version that contains no variability at timescales >20-yr., indicating the ability of the model at high-frequencies (Fig. 5). At least with the parameterization used here, the model fails to simulate tree growth during the period of reduced signal between 1960-1980 (Fig. 5C) and during the divergent period since 1980 (Fig. 5C).

Conclusions

The results suggest that even in these far north sites there is an ubiquitous and time-stable summer moisture signal in the growth of *Picea glauca.* In contrast, the temperature signal at sites near the latitudinal tree-line can be time-dependent at both high and low frequencies.

It appears that there is little influence from the potential end distortion of the standardization methods in the instance of weak divergence identified in the three northernmost sites.

As parameterized here, the VS model simulates well the interannual component of tree growth variability but it does not reproduce the divergent growth trends. More detailed work on model parameterization will be carried out in order to better understand the nature of the changing growth responses to temperature in some of these high northern latitude sites.

Acknowledgments

Ed Cook kindly provided advise and the code for Kalman filter analysis. JB thanks PAGES, the QUEST program for Earth System Science from the University of Bristol and the Prairie Adaptation Research Collaborative (PARC) for providing travel support.

PAGES 1ST YOUNG SCIENTISTS MEETING – RETROSPECTIVE VIEWS ON OUR PLANET'S FUTURE – 6-7 JULY 2009 • CORVALLIS • USA

PAGES 3RD OPEN SCIENCE MEETING – RETROSPECTIVE VIEWS ON OUR PLANET'S FUTURE – 8-11 JULY 2009 • CORVALLIS • USA