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Climate Scenarios into Policy Research: Downscaling from GCMs to Regional Scale

Workshop #5: Meeting the Challenges of Rapidly Changing Climate Policy Environment

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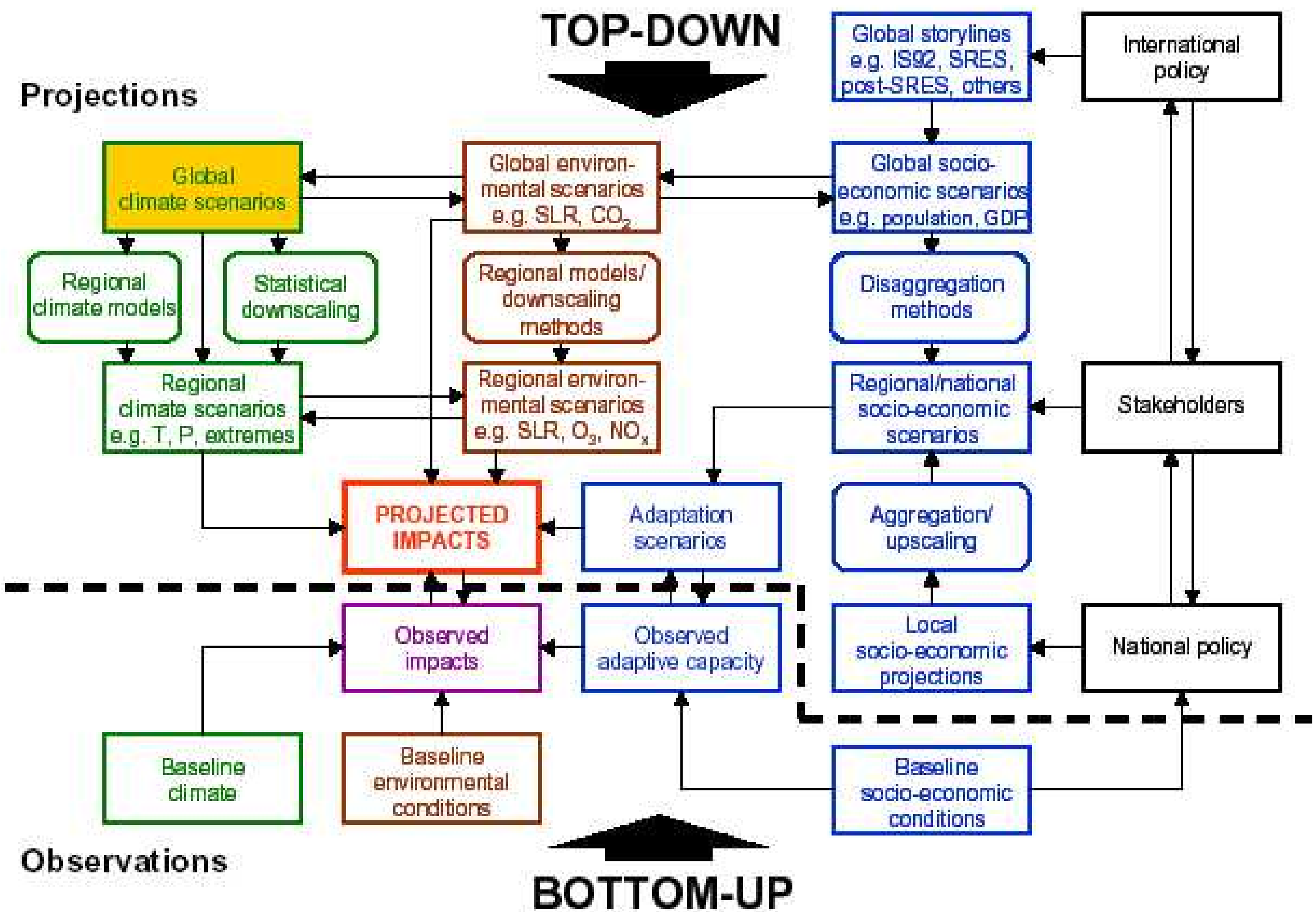
Canada

Climate Change and Policy



Source: T.R. Carter (2007) General guidelines on the use of scenario data for climate impact and adaptation assessment, Task Group on Data and Scenario Support for Impact and Climate Assessment, IPCC

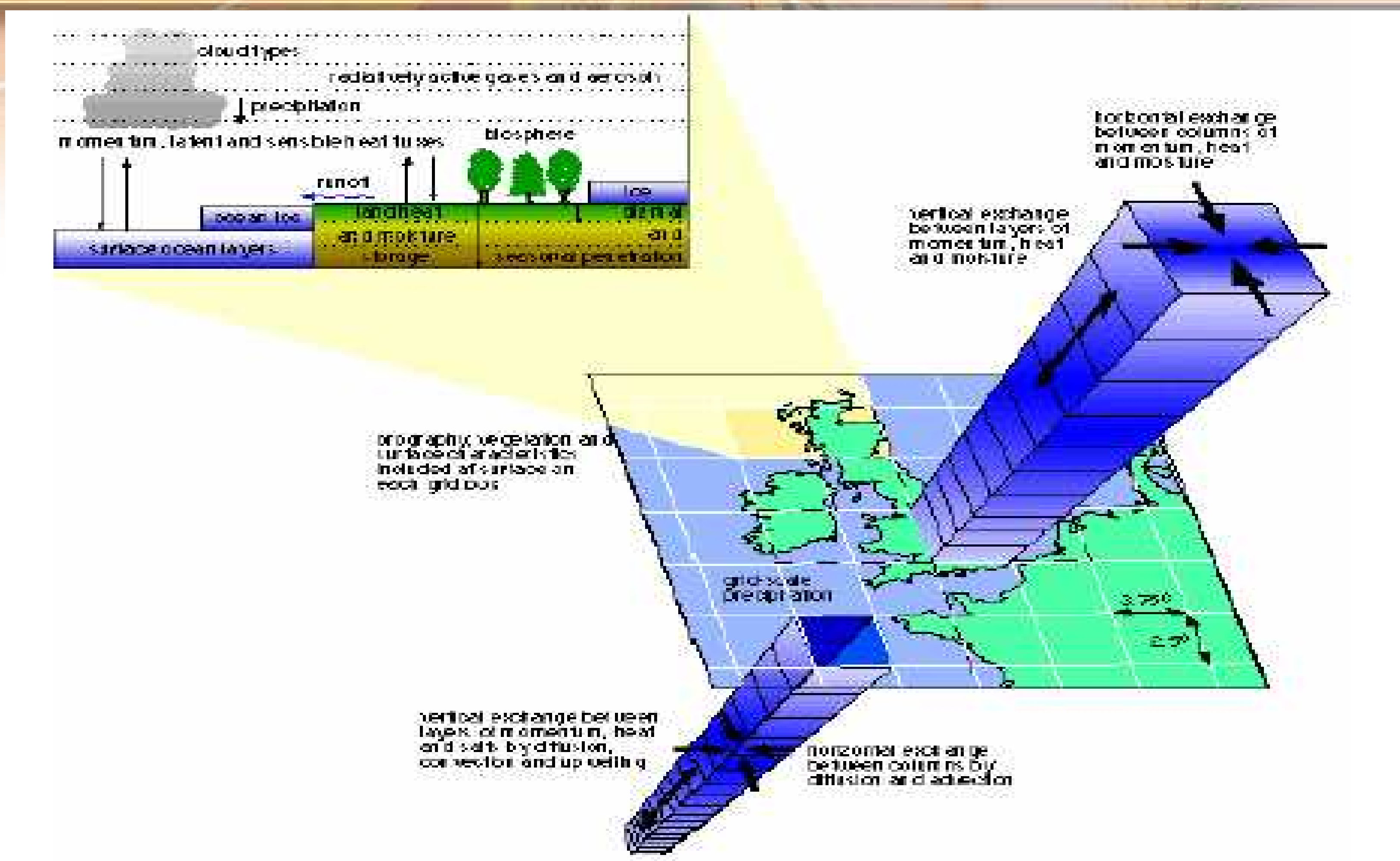
Climate Inputs

- In order to have a basis for assessing future impacts of climate change, it is necessary to obtain a quantitative description of the changes in climate to be expected (climate scenarios).
- It is also important to characterize the present-day or recent climate in a region– often referred to as the climatological baseline.
- The choice of both baseline and scenarios can strongly influence the outcome of a climate impact assessment.

Climate Scenarios

- There is increasing confidence among atmospheric scientists that increased atmospheric GHG concentrations will increase global temperatures.
- There is much less confidence in estimates of how the climate will change at a regional scale.
- It is precisely at this regional or local level (e.g. at the scale of a watershed, a farm, or even an individual organism) that climate change will be felt.

GCMs



Source: Viner, D. and M. Hulme, 1997: *The Climate Impacts LINK Project: Applying Results from the Hadley Centre'sClimate Change Experiments for Climate Change Impacts Assessment*. Climatic Research Unit, Norwich,UK, 17 pp.

Direct GCM Outputs

- Direct GCM outputs could be used as inputs to impact models.
- Their resolution is quite coarse relative to the scale of exposure units in most impact assessments.
- Many physical processes, such as those related to clouds, also occur at smaller scales and cannot be properly modelled.
- Previous attempts have shown that the discrepancies between AOGCM outputs and observed climate are too large to provide useful estimates of present-day impacts.

Dynamical Downscaling of GCM Outputs

- Recent experiments at higher resolution using AGCMs or regional climate models (RCMs) nested within AOGCMs or AGCMs, suggest that the use of direct model outputs may soon become worthy of consideration by impact analysts.
- Though high resolution model outputs may provide reliable information when driven by realistic boundary conditions (e.g. using reanalysis data), it is still GCMs that supply the boundary conditions for climate change simulations, and these are prone to large errors.

Statistical Downscaling of GCM Outputs

- Transfer functions utilize statistical relationships between large-area and site-specific surface climates or between large-scale upper air data and local surface climate.
- Large-area climates or large-scale upper air data from GCMs are reliable.
- The statistical relationships observed from present-day climate remain valid under a changing/changed future climate.

Weather generators

Weather generators are

- Computer models that generate synthetic series at a site conditional on the statistical features of the historically observed climate.
- Different model parameters are usually required for each month, to reflect seasonal variations both in the values of the variables themselves and in their cross-correlations.
- The "Richardson" and "serial" types.

Weather generators (pros)

- The possibility to substitute large quantities of daily observational station data.
- The opportunity to obtain representative weather time series in regions of data sparsity, by interpolating the statistical distribution parameters.
- The ability to generate time series of unlimited length, which may be useful in long-term (e.g. multiple-century) or ensemble simulations with impact models.
- The option to alter the statistical characteristics (parameters) of selected variables according to scenarios of future climate change.

Weather generators (cons)

There are also potential limitations or hazards in using weather generators that should be noted:

- They are not expected to describe all aspects of the climate accurately. Some weather generators do not simulate well persistent events like droughts and warm spells.
- One of the main assumptions in stochastic weather generation is that a stationary climate record is used to calibrate the model, thus they seldom reproduce decadal- or century-scale variability.
- They rely on statistical correlations between climatic variables derived from historical observations that may not be valid under a changed climate.
- They are usually designed for use, independently, at individual locations and few account for spatial correlation of climate.

AAFC-WG

- Richardson-type WG
- Second-order Markov chain instead of the first-order
- Empirical distributions estimated from observed data for flexibility
- Compared with other WGs, such as LARS-WG
- Evaluated for agricultural applications based on agroclimatic indices
- Examined for daily climate extremes
- Developed schemes for perturbing weather generator parameters based on GCM-simulated changes in the statistics of daily climate variables

Scenarios data generated to date

Two sets of daily climate scenarios data

- CGCM1 IS92a GHG+A and HadCM3 A2.
- On 0.5° grids for south of 60° N in Canada.
- For the future time period of 2040-2069.
- Including daily Tmax, Tmin, P and Rad.
- Generated by AAFC-WG.

Scenarios data applications

- Agroclimatic indices, such as frost-free days, the last spring frost and the first fall frost, GDD, EGDD, CHU, precipitation deficit.
- Annual and growing-season extreme values of daily Tmax, Tmin and precipitation, their 10yr, 20yr and 50yr return values.
- Relative changes to 1961-1990 baseline climate.

Scenarios data for ecodistricts

- Two data sets for CGCM1 IS92a (GHG+A) and HadCM3 A2.
- Developed with the “delta” method.
- For the future period of 2040-2069.
- Daily Tmax, Tmin, precipitation and Rad.
- Centroids of ecodistricts where daily weather data are available at neighboring stations.
- These data sets have been used as climate input to EPIC model for simulating crop yields on the Canadian Prairies.

Application to Nitrogen Leaching in PEI

- Localized daily climate scenarios of CGCM3 and HadCM3 forced by IPCC SRES A2 and B2.
- Agricultural adaptation management scenarios.
- Canadian Agricultural Nitrogen Budget model.
- Versatile Soil Moisture Budget model.

De Jong, R., B. Qian, and J. Y. Yang, 2008. Modelling nitrogen leaching in Prince Edward Island under climate change scenarios. Can. J. Soil Sci., 88, 61-78.

Application to Nitrogen Leaching in PEI

Province-wide average components of the N balance (kg N ha^{-1}) as simulated with historic crop and animal husbandry practices and with an adapted agricultural management scenario

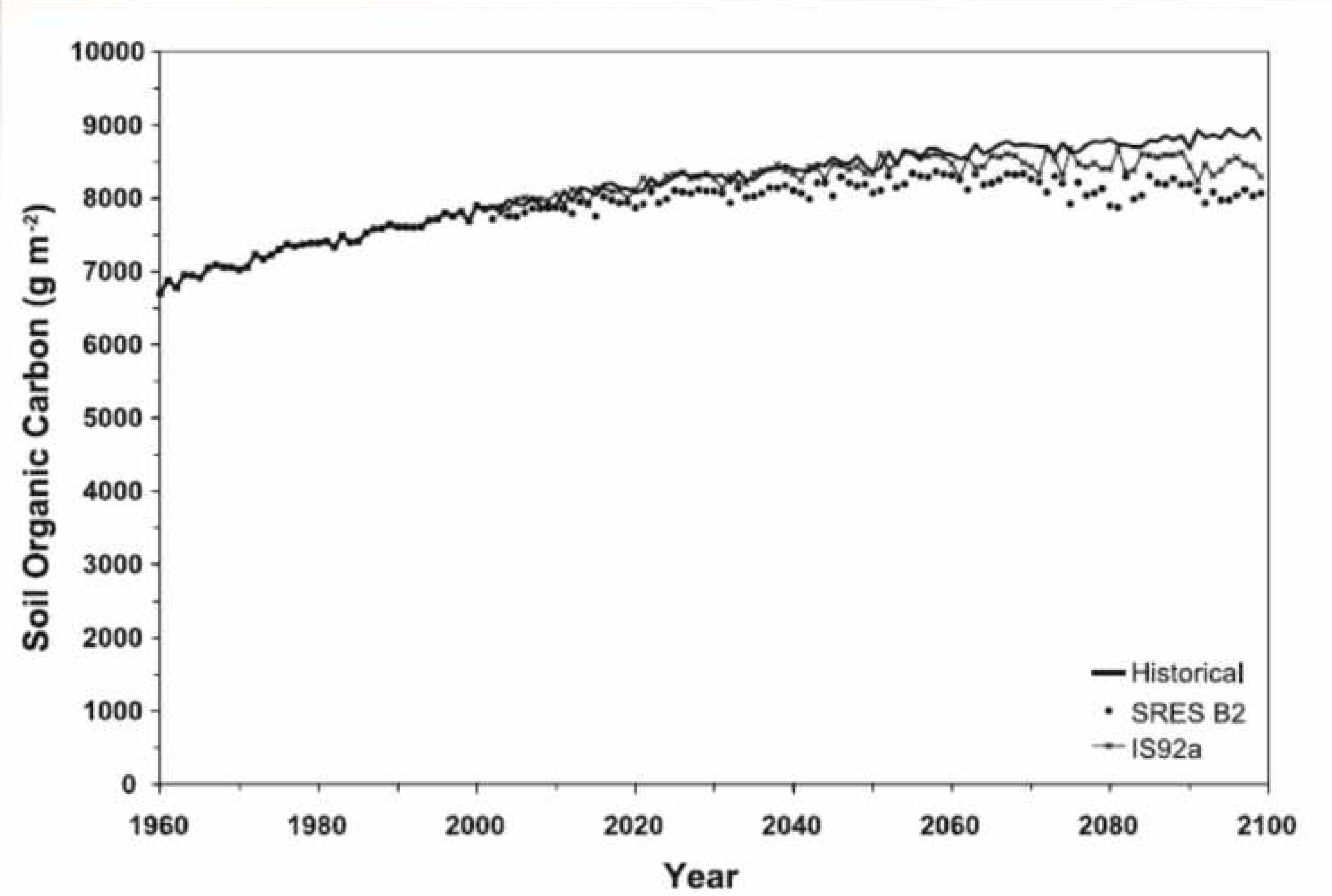
	Input				Output		
	$N_{fertilizer}$	N_{manure}	$N_{fixation}$	$N_{deposition}$	N_{crop}	N_{gas}	RSN
Historical	52.8	17.4	29.6	2.5	70.3	1.2	30.8
Adapted	61.2	16.8	30.1	2.5	73.2	1.6	35.7

Potential Impact on Carbon in Agricultural Soils in Canada

- Localized daily climate scenarios of CGCM1 forced by IS92 emission scenario and CGCM2 forced by IPCC SRES B2 emission scenario.
- Impact of climate change scenarios on soil carbon stocks in Canada.
- Potential for agricultural management practices to improve or maintain soil quality.
- Century model.

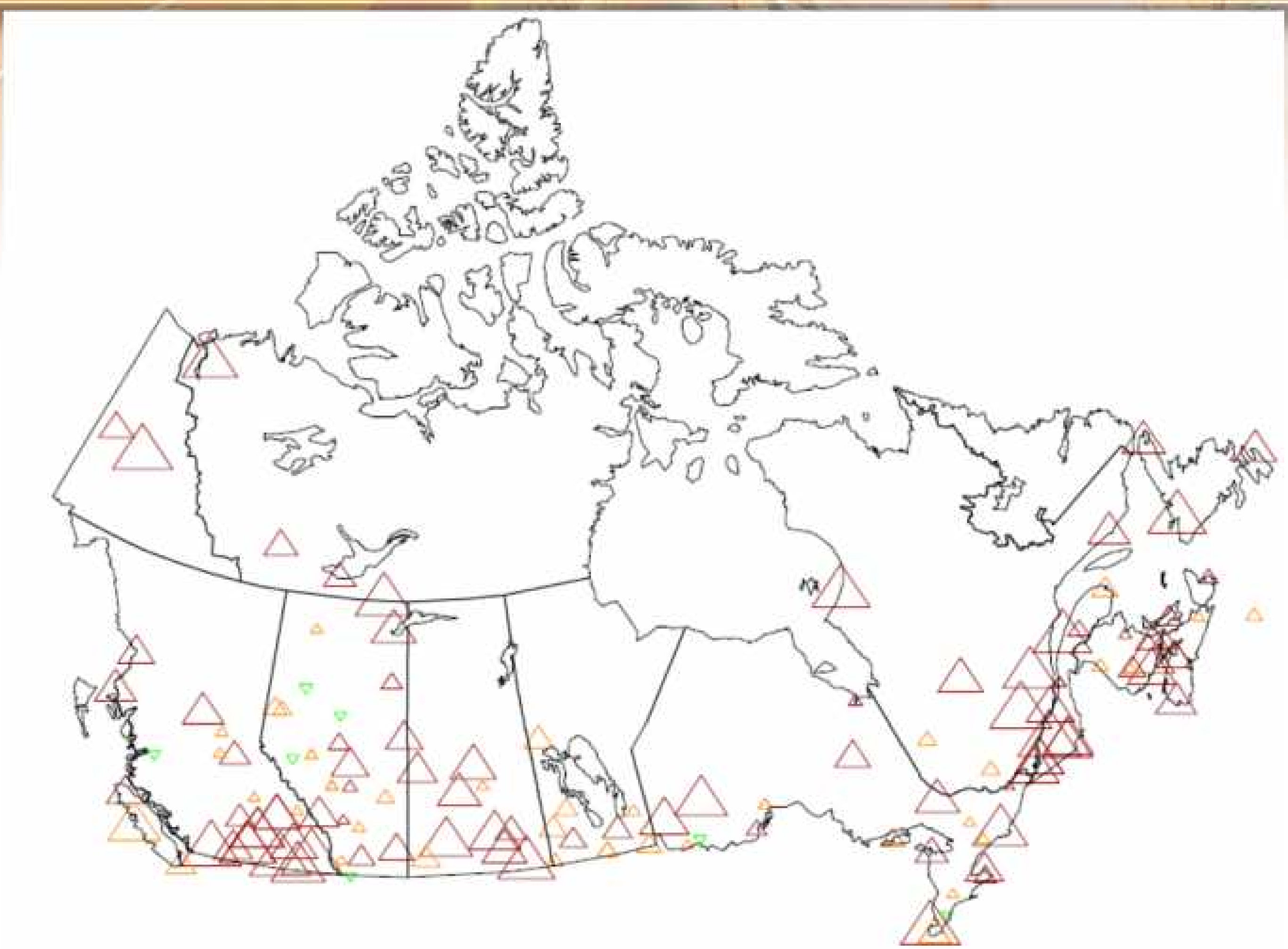
Smith, W. N., B. B. Grant, R. L. Desjardins, B. Qian, J. Hutchinson, and S. Gameda, 2009. Potential impact of climate change on carbon in agricultural soils in Canada 2000-2099. Climatic Change, DOI 10.1007/s10584-008-9493-y.

Potential Impact on Carbon in Agricultural soils in Canada



Estimated soil organic carbon (0–20 cm) for continuous wheat on a Black Chernozem soil (1960–2099)

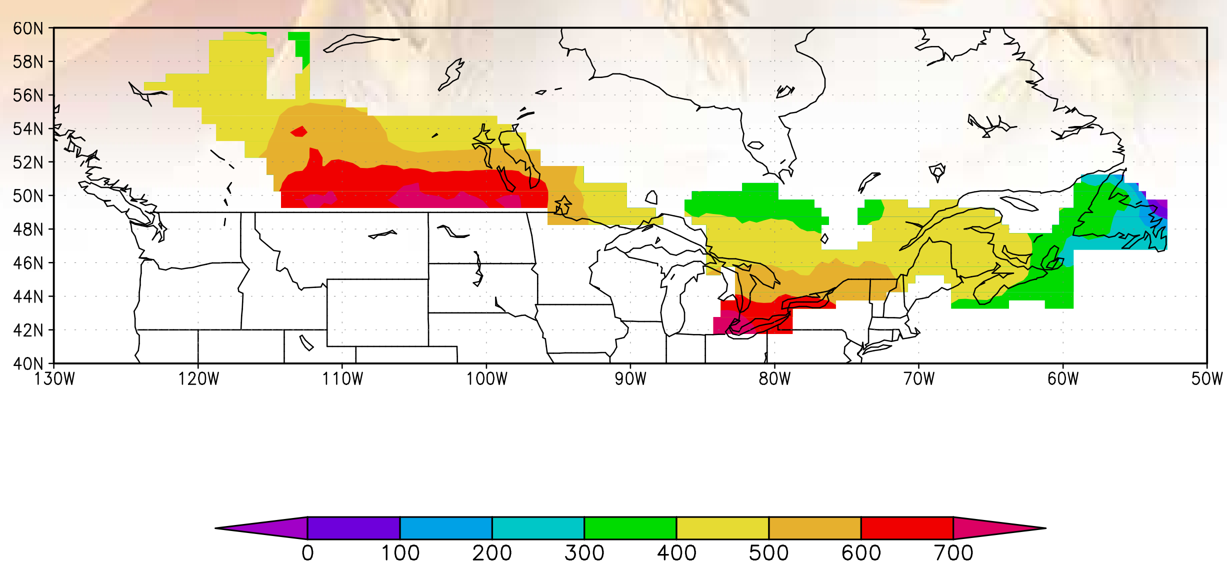
Growing-Degree Days (observed trends in 1895-2007)



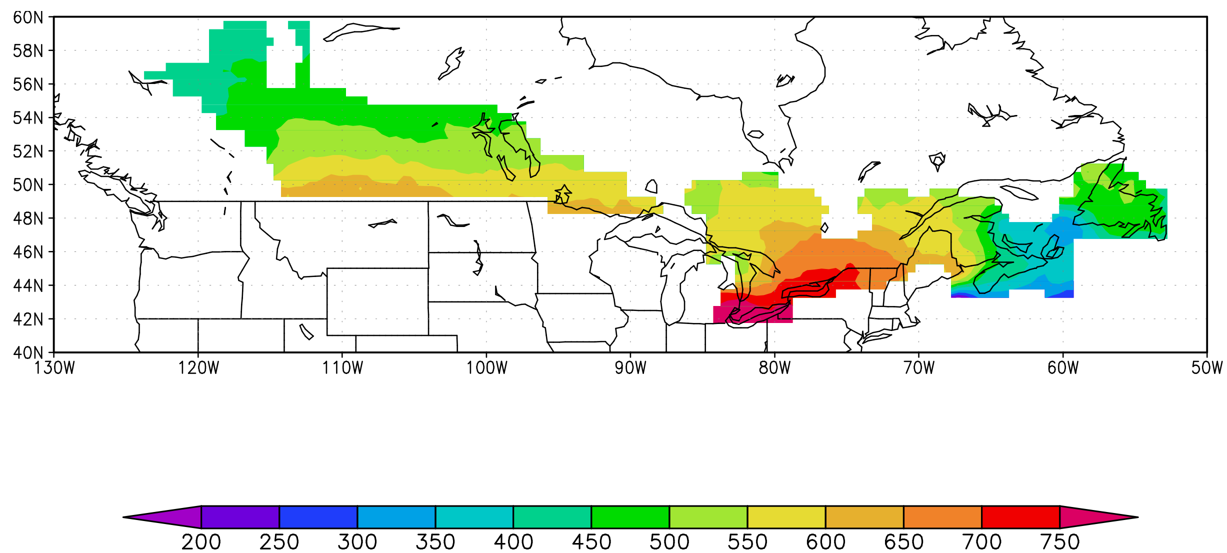
Qian, B., X. Zhang, K. Chen, Y. Feng, and T. O'Brien, 2009. Observed long term trends for agroclimatic conditions in Canada. (in preparation)

Growing-Degree Days
(Changes of 2040-2069 compared to 1961-1990)

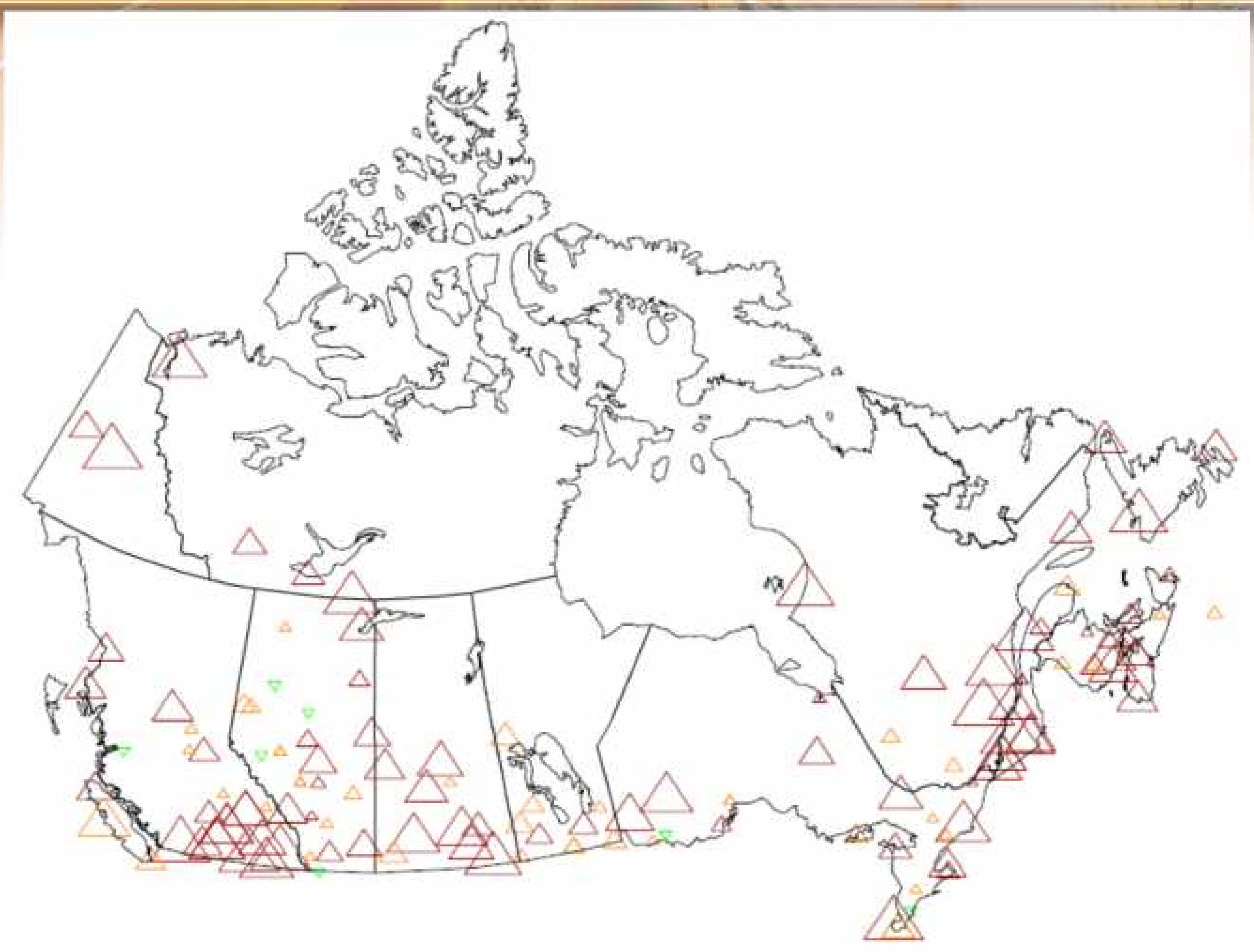
CGCM1



HadCM3



Crop Heat Units (observed trends in 1895-2007)



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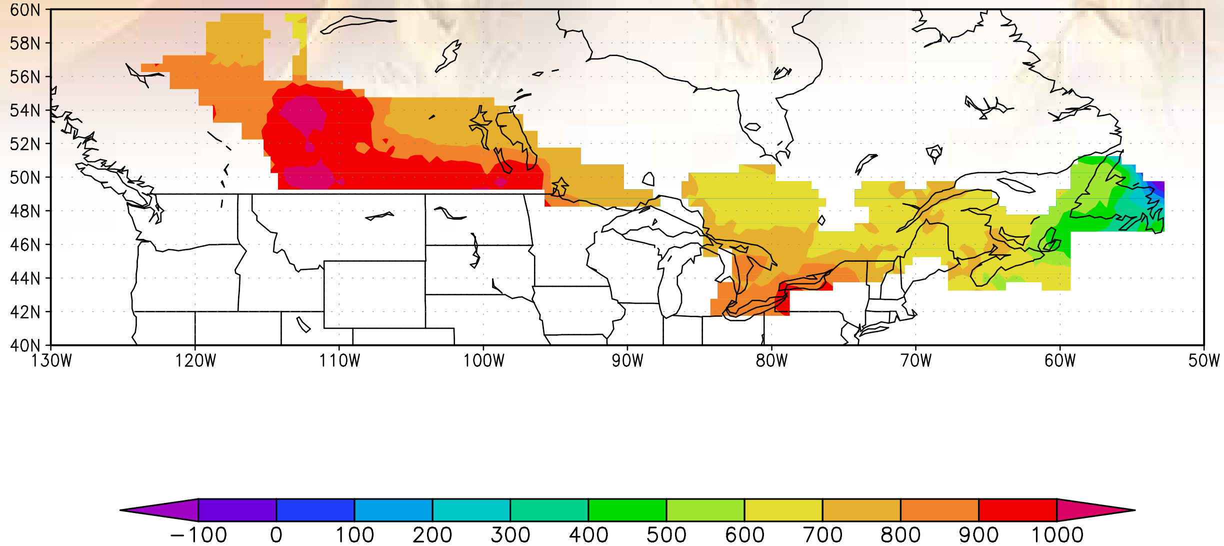
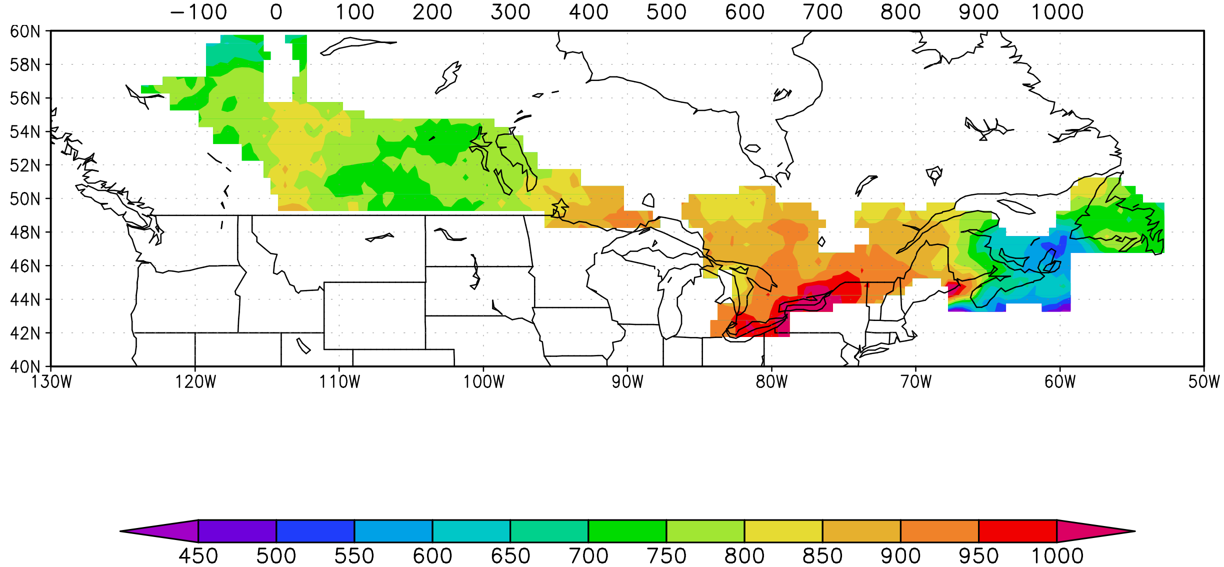
Crop Heat Units
(Changes of 2040-2069 compared to 1961-1990)

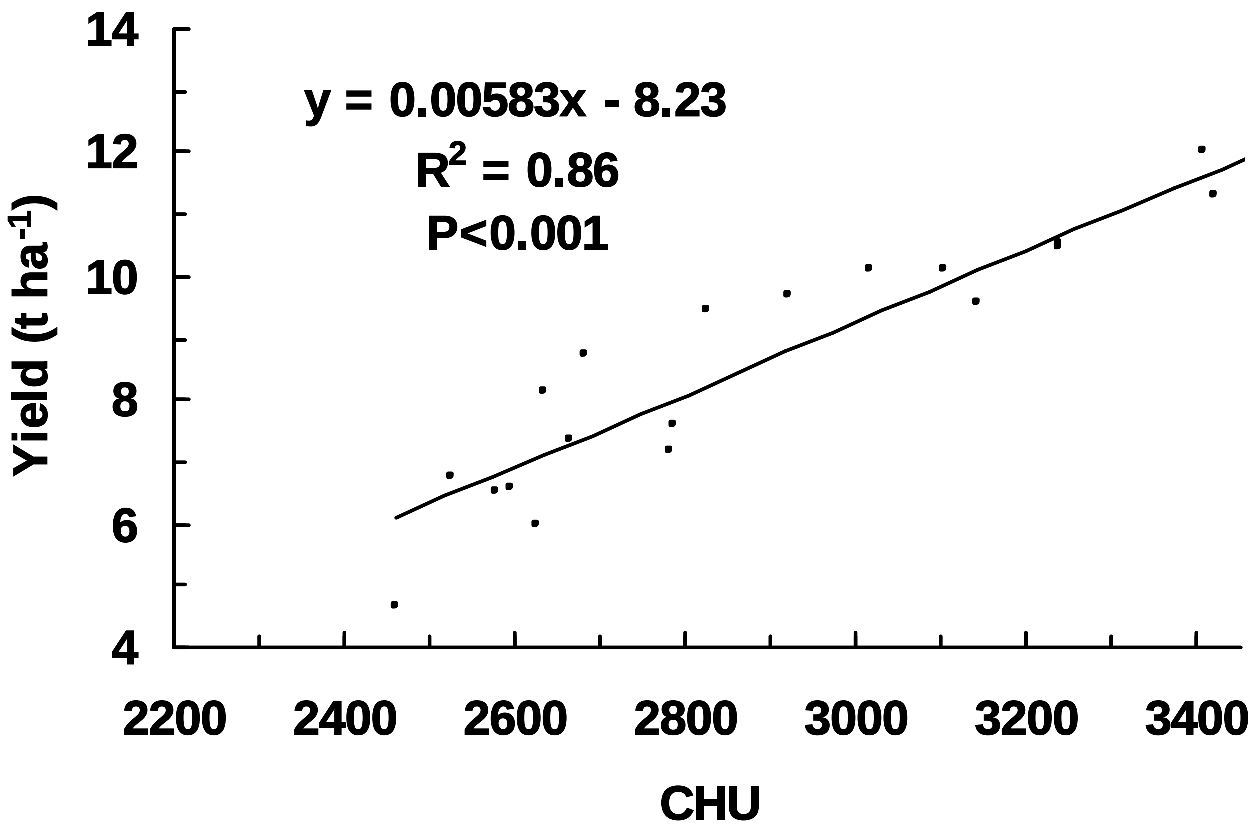
CGCM1



HadCM3



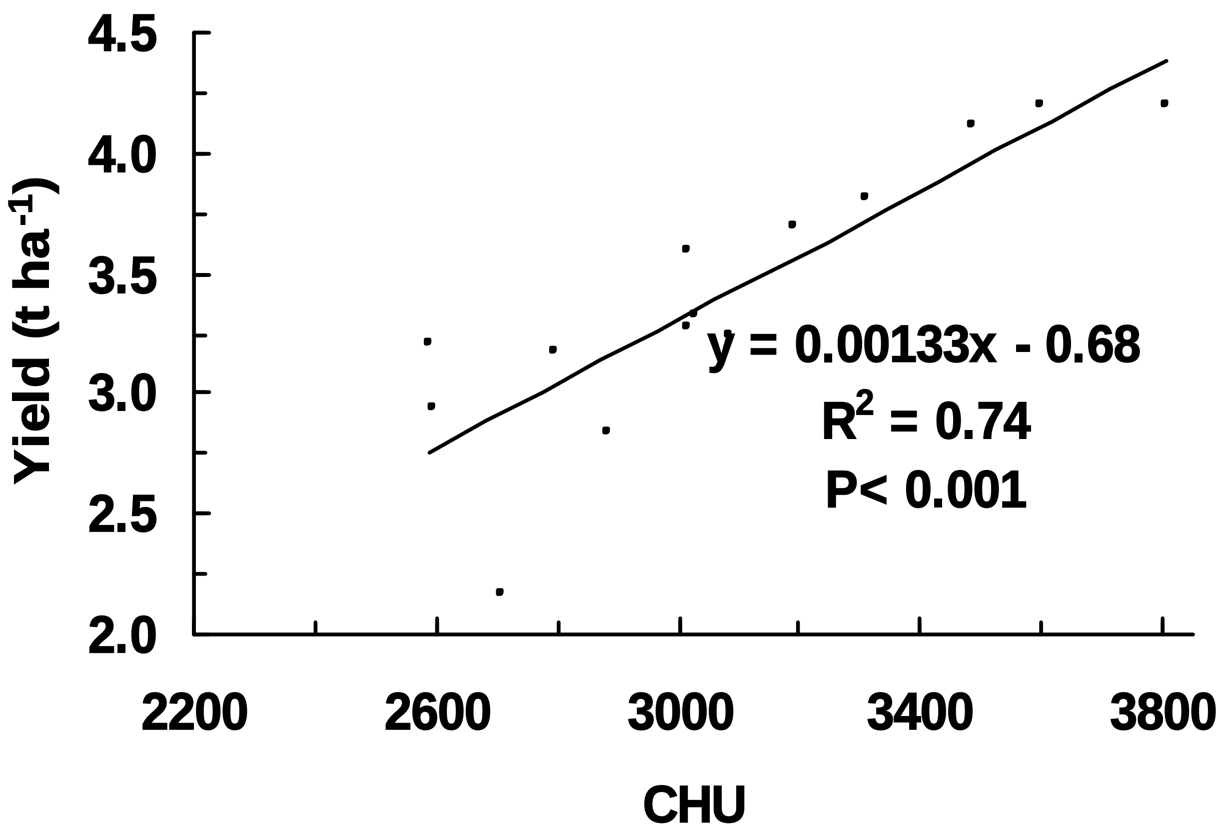
CHU versus grain corn yields in eastern Canada



Corn yields increase about 0.6 t ha^{-1} for each increase of 100 CHU

Bootsma, A., S. Gameda, and D. W. McKenney, 2005: Potential impacts of climate change on corn, soybeans and barley yields in Atlantic Canada. *Can. J. Soil Sci*., **85**, 345-357.

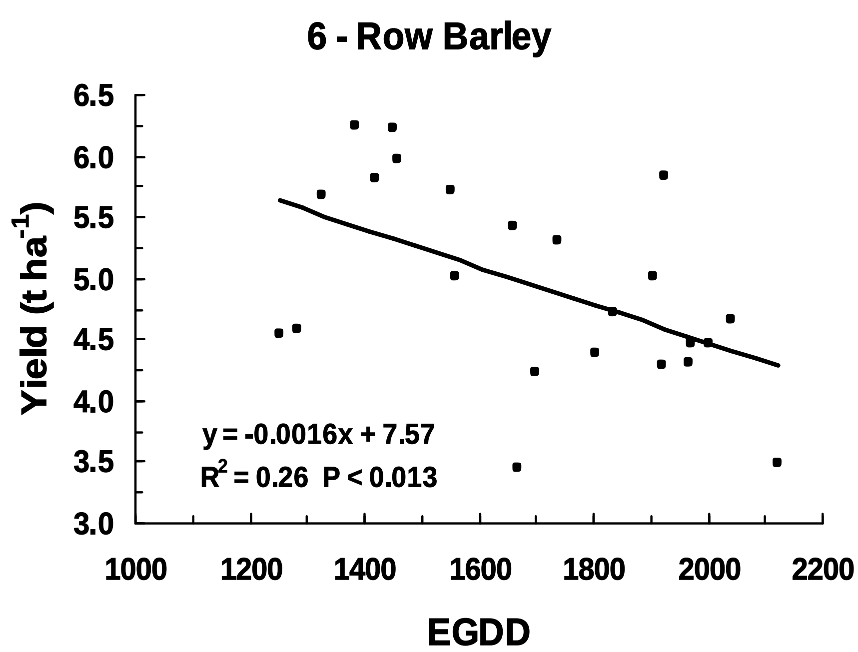
CHU versus soybeans yields in eastern Canada

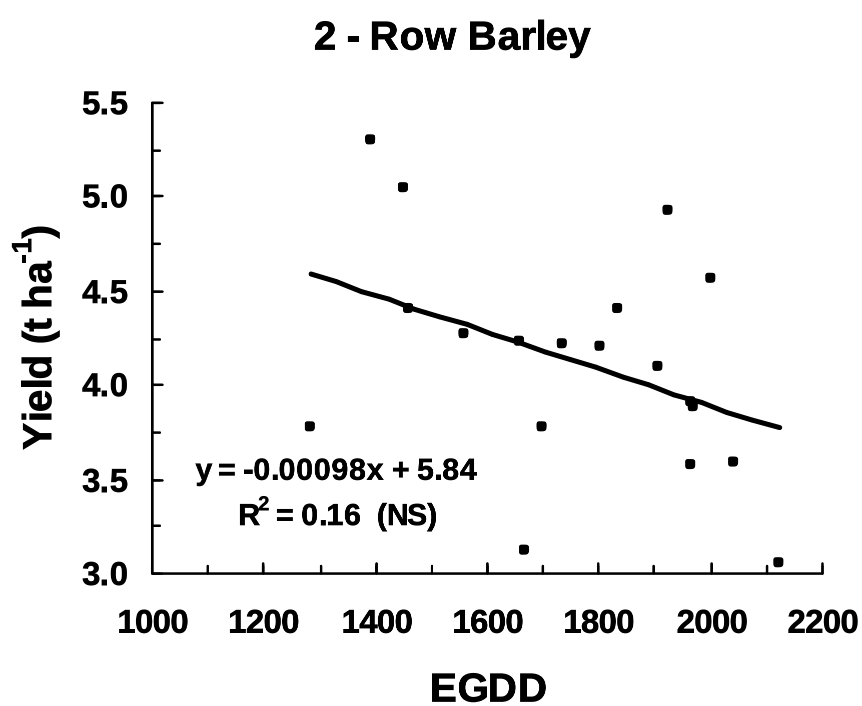


Soybean yields increase about 0.13 t ha^{-1} for each increase of 100 CHU

Bootsma, A., S. Gameda, and D. W. McKenney, 2005: Potential impacts of climate change on corn, soybeans and barley yields in Atlantic Canada. *Can. J. Soil Sci.*, **85**, 345-357.

Barley yields versus Effective Growing Degree-Days above 5ºC (EGDD)





Increasing EGDD by 400 units reduces yield of 6-row and 2-row barley about 0.6 and 0.4 t ha^{-1}, respectively

Bootsma, A., S. Gameda, and D. W. McKenney, 2005: Potential impacts of climate change on corn, soybeans and barley yields in Atlantic Canada. *Can. J. Soil Sci.*, **85**, 345-357.

Uncertainties

- Sources

  GCMs

  GHG emission scenarios

  Downscaling methods

  Impact models

- Solutions

  Multiple climate scenarios

  A range of impact scenarios

  Probabilistic information



THANK YOU!

Canada