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Predictability of RCM:
Few thoughts and examples
i.e. To stimulate thinking about

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Predictability of RCM
How to define ? For what purpose ?

- Variables of interest considering:
  - Mean
  - Variability and extremes (i.e. from daily and sub-daily climate information)
  - Hydro-meteorological hazards (high impact event with combined factors)
- Ranges of changes related to:
  - Seasonal, annual and/or decadal scales
  - Spatial scale (regional or higher resolution as point scale)
- Vulnerability, Impacts and Adaptation study:
  - To identify or isolate key climatic mechanisms responsible for the anticipated changes or drift of one particular natural or human system (i.e. resilience or perturbation)
  - To analyze the sensitivity of a system to stresses from various combination of climate and other environmental or human stimuli (combination of forcing factors)
  - To help to identify key principles or strategy to better adapt or to mitigate the anticipated impact of climate changes

Predictability of RCM
Summary of Main Expectations?

- Mean climate state
- Variability and Extremes
- Hydro-meteorological hazards (high impact event): right and plausible combination of variables
- Temporal distribution: occurrence, frequency, intensity and duration/persistence
- Spatial patterns during months, seasons, years, and decades

Predictability of RCM depends on or is related to:

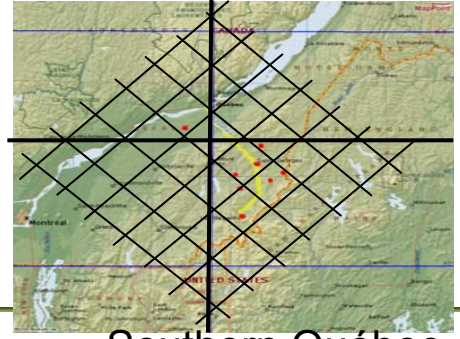
- Boundary forcing: AOGCM (i.e. large-scale features)
- Physical parameterization (i.e. sub-grid scale processes)
- Domain size and resolution
- Downscaling approaches (nudging, one or two way nesting, numerical scheme, etc.)
- Complexity of systems or variables that need to be simulated

Predictability of RCM Criteria of Measures

(in keeping in mind the purpose and end needs):

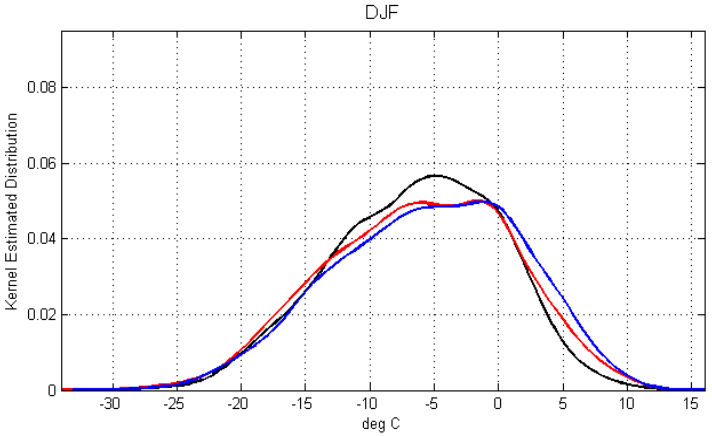
- Ability of RCM to simulate current climate from “perfect” boundary conditions, i.e. considering:
  - Reproduction of considered variables:
    - Bias, correlation, explained variance or variance ratio, or another measure of correspondence with observed (i.e. gridded products)
  - Reproduction of trends or contrasting climate states:
    - Linear between observed value and zero, or based on test statistic for equality of regression lines / correlation coefficients
- Ability of RCM to simulate current and future climate conditions, i.e. considering:
  - Reproduction of variables in the lateral boundary conditions (i.e. AOGCM)
    - Pattern correlation between observed-reanalysis and simulated
  - Stability of physical parameterizations (their independence of climatic change) as dynamical cores of RCMs (as well as parameterizations) originate from a few “families” (i.e. same holds for driving AOGCMs)
  - The study area (i.e. intrinsic climate conditions and physiographic features as resolved or not by AOGCM/RCM cascade)
  - In all cases a scrupulous analysis of the climate change regime and its temporal and spatial distribution at the scale of interest is essential for it to be useful in impact studies (i.e. make physical sense).

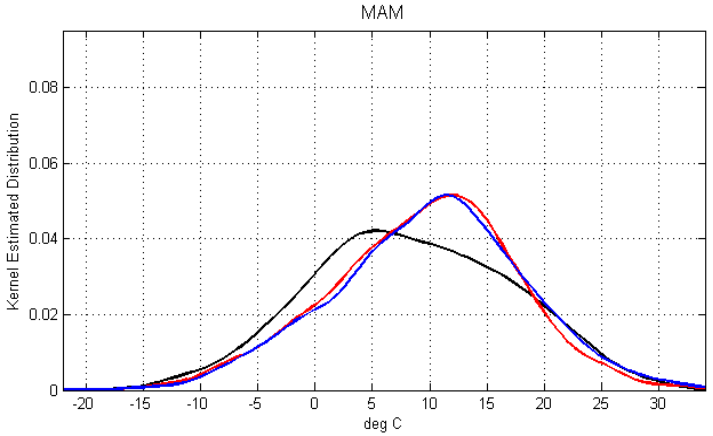
Examples of predictability/uncertainties related to Boundary conditions (reanalysis driven) Median vs extremes values – Seasonal daily Tmax. (available RCM runs from Ouranos, ouranos.ca)

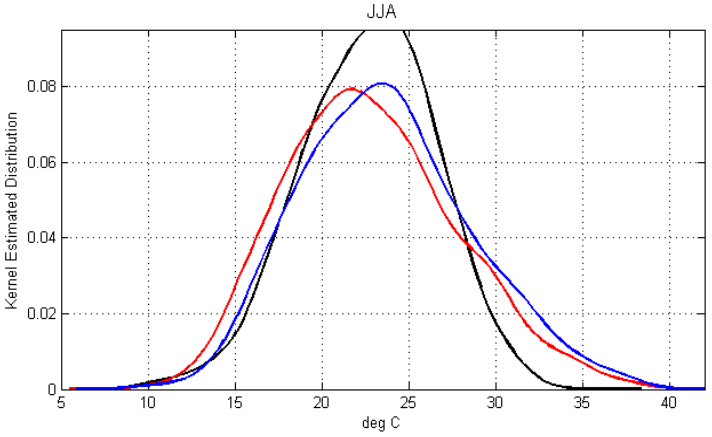


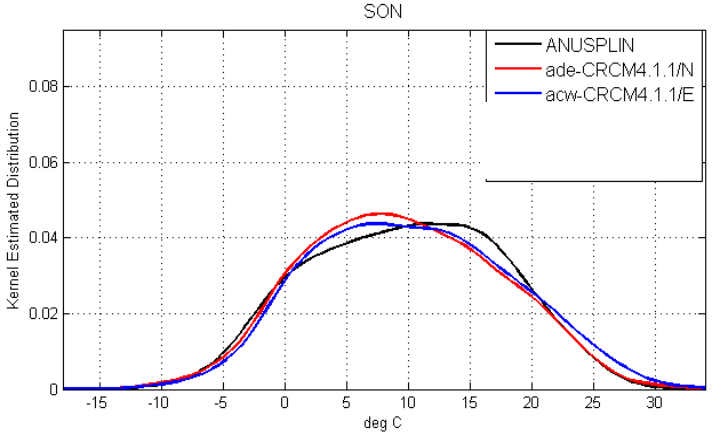
Southern Québec

Comparison of the CRCM outputs against gridded observations (ANUSPLIN, 10-km grid downgraded to 45-km) 1971-2000









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Median vs extremes values – Seasonal daily Tmax.

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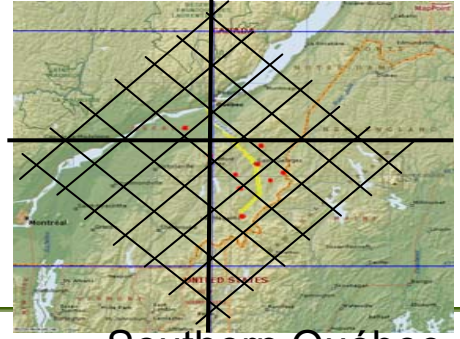

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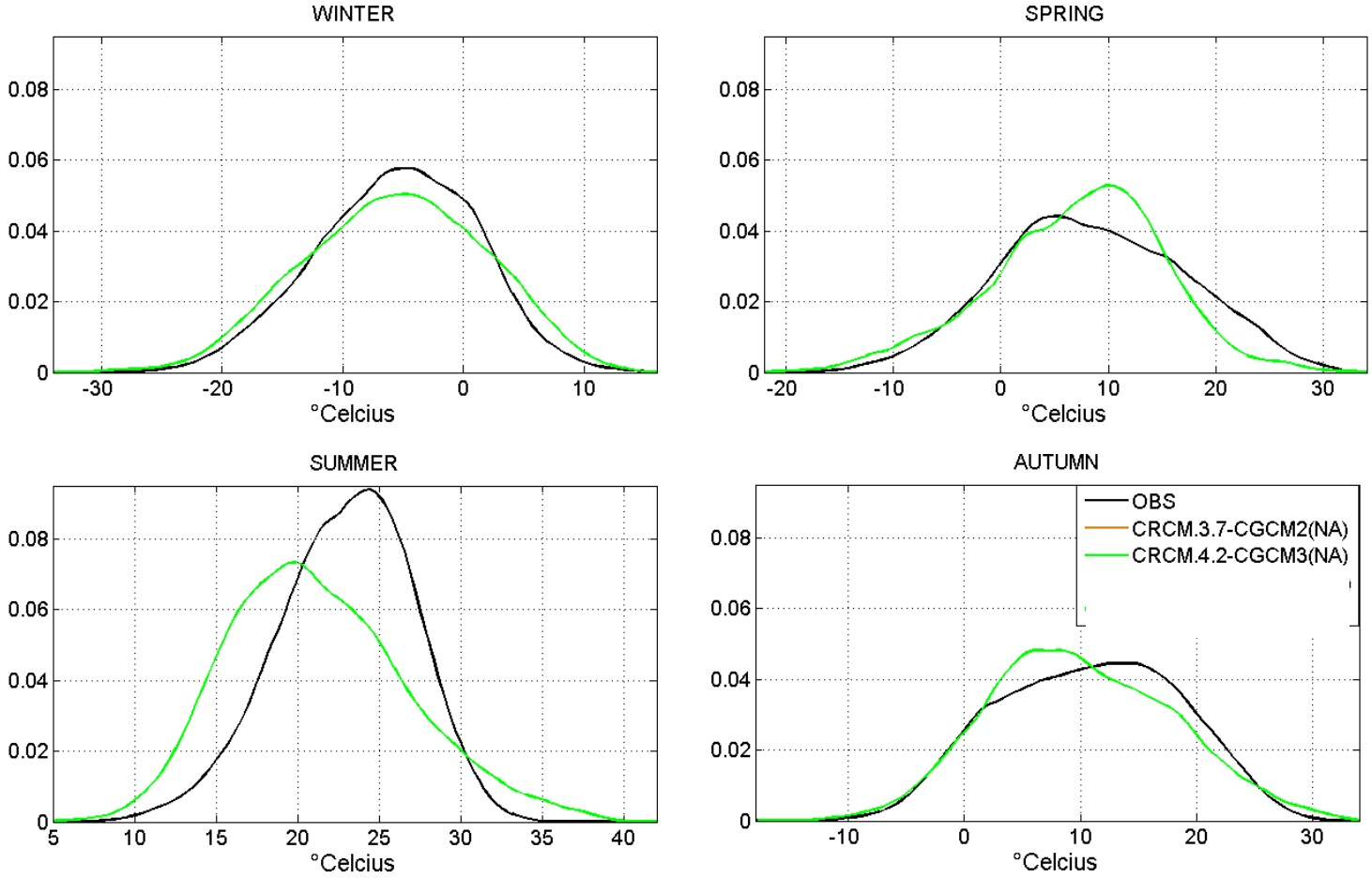
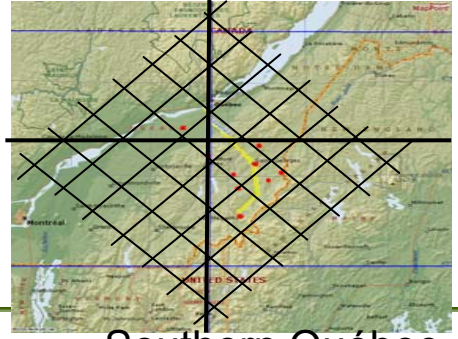


Example of uncertainties related to Physical parameterizations : OLD vs NEW version of the CRCM (bucket model vs more sophisticated land surface scheme) - Seasonal daily Tmin. (RCM runs from Ouranos)



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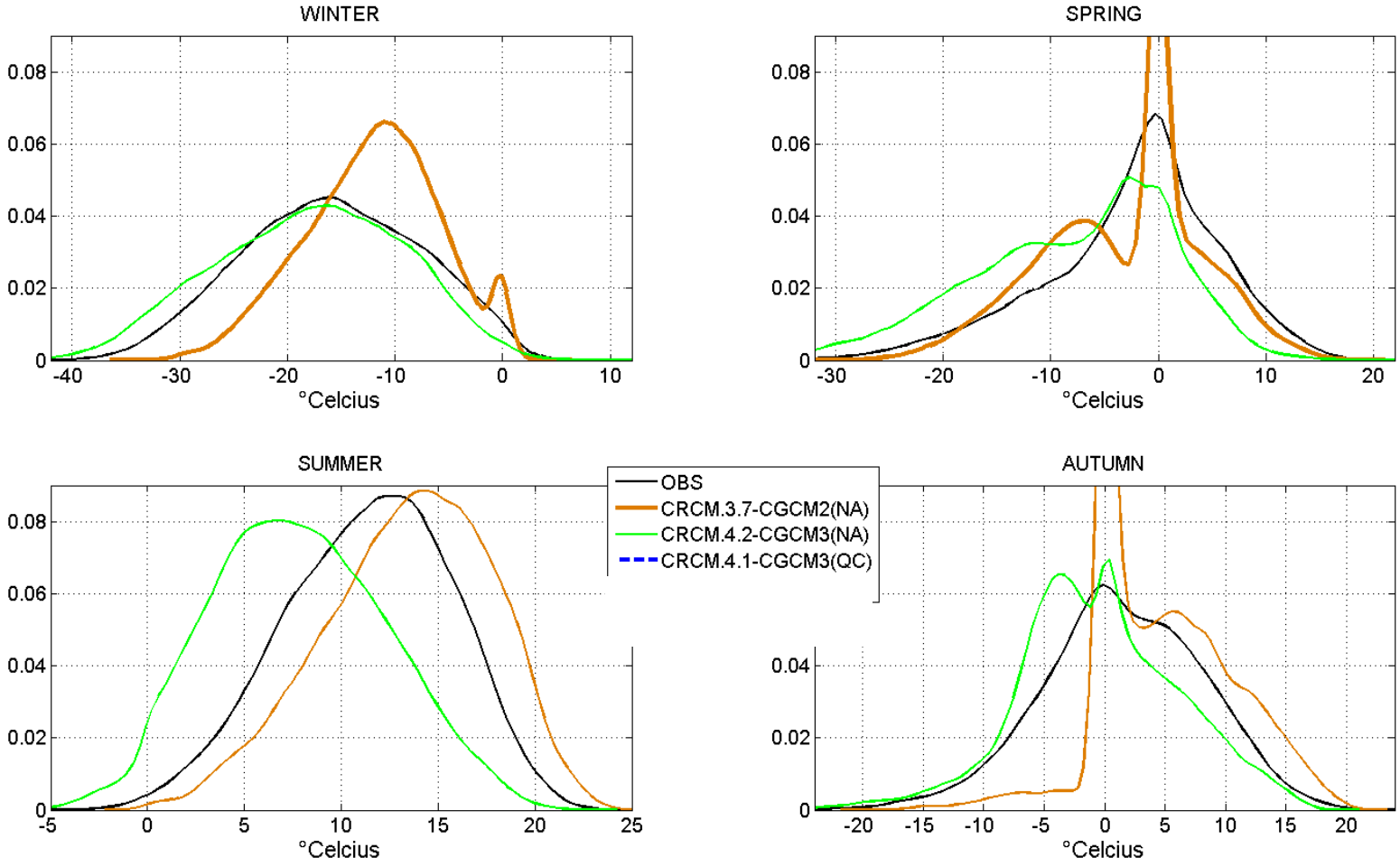
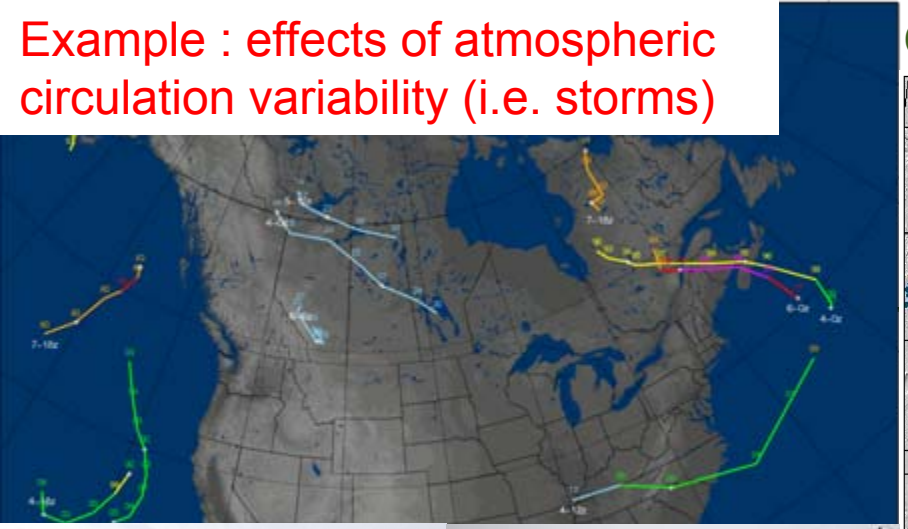
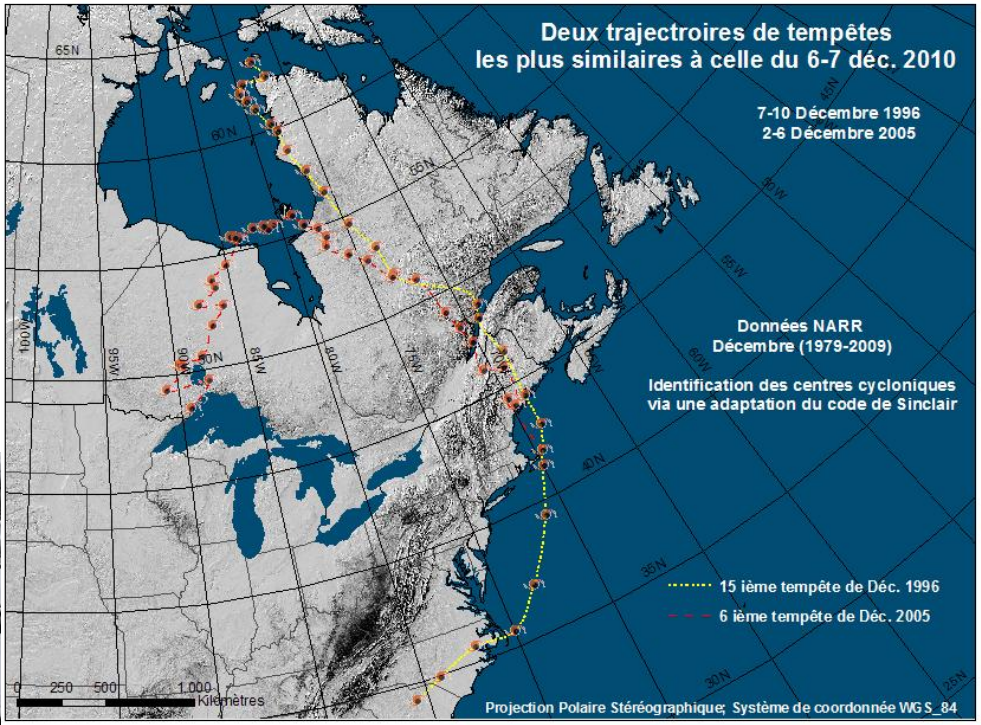
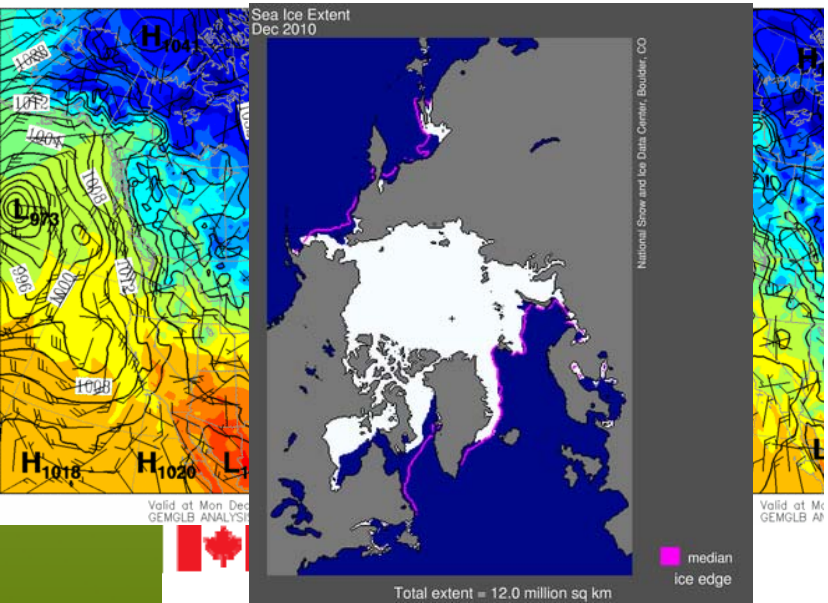


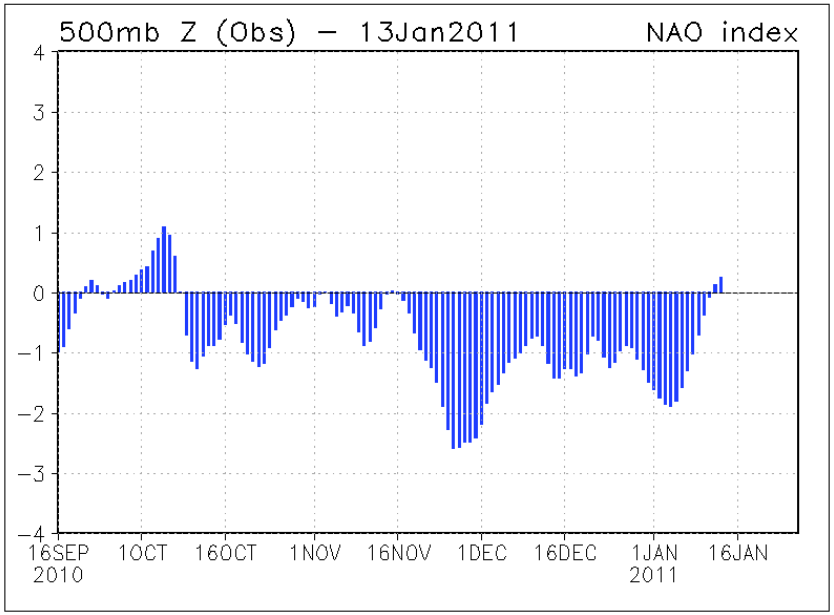
Example : effects of atmospheric circulation variability (i.e. storms)

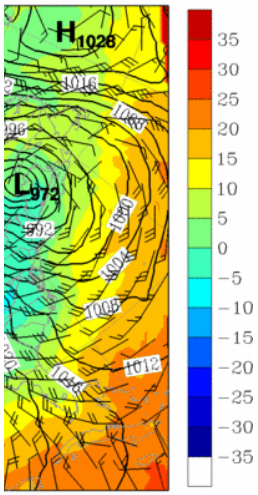


Complexity of systems/variables to simulate

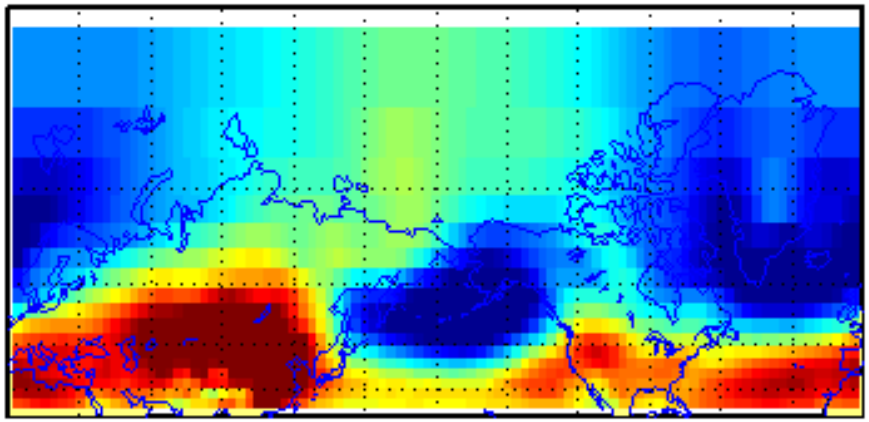




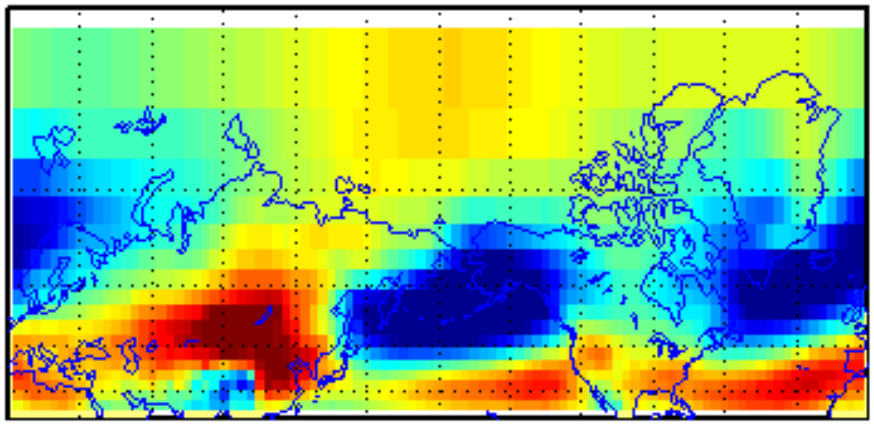




Comparison of leading modes of variance in mean sea level pressure (annual scale) between CGCM2/3 and NCEP/NCAR

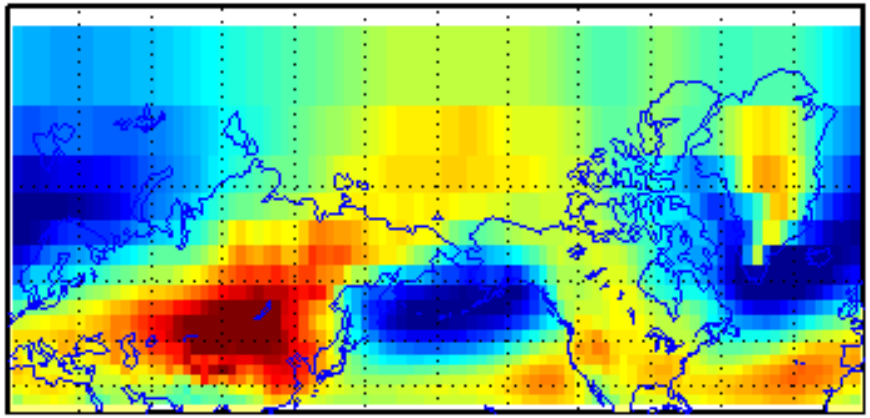


CGCM2
(96.6% of total variance)



CGCM3 (96.8%)

NCEP-NCAR
(97.0%)



… the greatest contributor towards a strong replication of the NAO

Source: Harding *et al*., 2010

Predictability analysis using a weighting procedure ? (ex. Eum et al., 2010 or other in ENSEMBLES project)

Weighting scheme can be potentially useful to have comprehensive & independent evaluation against reanalyses/observations & to treat uncertainties or combined predictability from various criteria

$$W_i = \prod_j f_j^{n_j}$$

5 Attributes (RCM or reanalysis against observations):

- Relative Absolute Mean Error (from daily values): **ATT1**
- Annual variability (mid-term): **ATT2**
  - Difference in annual anomalies between observation and RCMs/reanalysis
- Spatial Pattern: **ATT3**
  - Spatial similarity of mean value between observation and RCMs/reanalysis at a grid point
- Extreme & median values: **ATT4**
  - 0.1, 0.5 and 0.9 percentile values
- Multi-decadal trend (long-term): **ATT5**

  Temporal trends in climate variables

Conclusion

Predictability of RCMs:

- ✓Boundary conditions (AOGCM): improvement of skill during the time but still a limitation for certain variables, certain teleconnection indices, and mode of internal climate variability (ex. atmospheric-oceanic coupling in Arctic and sub-Arctic regions)
- ✓Physical parameterization: regular improvement, but still a limitation when those are same or holds from driving AOGCMs (ex. ocean-ice regional climate model and coupling with RCM, as a majority of RCMs is atmospheric only)
- ✓Complex systems as storm track (synoptic scale) or meteorological hazards: quite good improvement but again depend on oceanic processes resolved at the regional scale (ex. storms and their links with storm surge oceanic waves, and sea state)

BUT as suggested in recent study of Deser at al. (2010): "The dominant source of uncertainty in the simulated climate response at middle and high latitudes is internal atmospheric variability associated with the annular modes of circulation variability. …Uncertainties (i.e. limitation of predictability) in the forced response are generally larger for sea level pressure than precipitation, and smallest for air temperature."

REFERENCES

Deser et al. 2010: Uncertainty in climate change projections: the role of internal variability. *Climate Dynamics*, DOI 10.1007/s00382-010-0977-x

Eum, H.-I., P. Gachon, R. Laprise, T. Ouarda, and A. St-Hilaire (2010). Evaluation of regional climate model simulations versus gridded observed and regional reanalysis products using a combined weighting scheme. *Climate Dynamics* (Submitted, Nov. 2, 2010).

Harding, A.E., P. Gachon and V-T-V. Nguyen (2010) Replication of atmospheric oscillations, and their patterns, in predictors derived from Atmosphere–Ocean Global Climate Model output. *International Journal of Climatology*. doi: 10.1002/joc.2191

Many Thanks for your attention !