GEMCLIM-LAM

GEM-LAM applied to regional climate modelling

Ayrton Zadra
RPN / MRD / EC

and many collaborators from
RPN, UQAM and Ouranos

Outline

CRCM5 development
- Ouranos consortium
- CRCMD network
- EC contribution

GEMCLIM
- running GEM in climate mode

Results from regional climate simulations
- studies at RPN
- studies by CRCMD network

Ongoing work and plans

Brief history of regional climate modelling in Canada

- **1991**: development of first **Canadian Regional Climate Model (CRCM)** at UQAM
  - dynamical core: fully elastic, semi-implicit, semi-Lagrangian, nested model of Tanguay et al.* (**core of MC2 model**)
  - physics package of CGCM2 (CCCma/EC)
- **since 1991**: further developments within the Canadian Regional Climate Modelling (and Diagnostics) network – **CRCM(D) network**
  - new convection scheme (Bechtold et al., 2001)
  - CGCM3 physics package including CLASS
  - mixed-layer model for Great Lakes (Goyette et al. 2000)
  - other updates and options (e.g. coupling to regional ocean model)
- **2002**: creation of **Ouranos** consortium
  - including Climate Simulations Team (CST, in charge of operational versions of CRCM and regional climate-change projections), led by Daniel Caya

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Tanguay, M. A. Robert and R. Laprise, 1990: "A semi-implicit semi-lagrangian fully compressible regional forecast model", Mon. Wea. Rev. 118(10), 1970-1980

About Ouranos

List of members

MSP Sécurité publique
MRNF Ressources naturelles et Faune
MSSS Santé et Services sociaux
MDDEP Développement durable, de l'Environnement et des Parcs
MAMR Affaires municipales et des Régions
MAPAQ Agriculture, des Pêcheries et de l'Alimentation
MTQ Transport
MDEIE Développement économique, Innovation et Exportation
HQ Hydro-Québec
EC Environnement Canada
UQÀM Université du Québec à Montréal
LAVAL Université Laval
MCGILL Université McGill
INRS Institut national de la recherche scientifique
ETS École de technologie supérieure (membre affilié)
MH Manitoba Hydro (membre affilié)

Mission

- **Assist & advise members** regarding adaptation strategies
- Identify and evaluate **potential impacts** due to climate change
- **Inform decision-makers** about climate change and adaptation
- Collect, analyse and provide access to **data** and information **on past climate variations**
- Analyse processes in **current climate**
- Improve knowledge and **modelling of regional climate**
- Estimate probable **evolution and uncertainty of regional climate**
- **Recrute & join multidisciplinary teams** of university, government and parapublic researchers

Ouranos & EC

EC commitments to Ouranos (2004-2009)

Contribute to

• **development of a new RCM** based on EC's regional model

• production and analysis of **high-resolution simulations**

• generation of climate and hydroclimate **projections at regional scales**

• development of **methods for statistical analysis** for climate, climate variability, frequency of extreme events and extreme

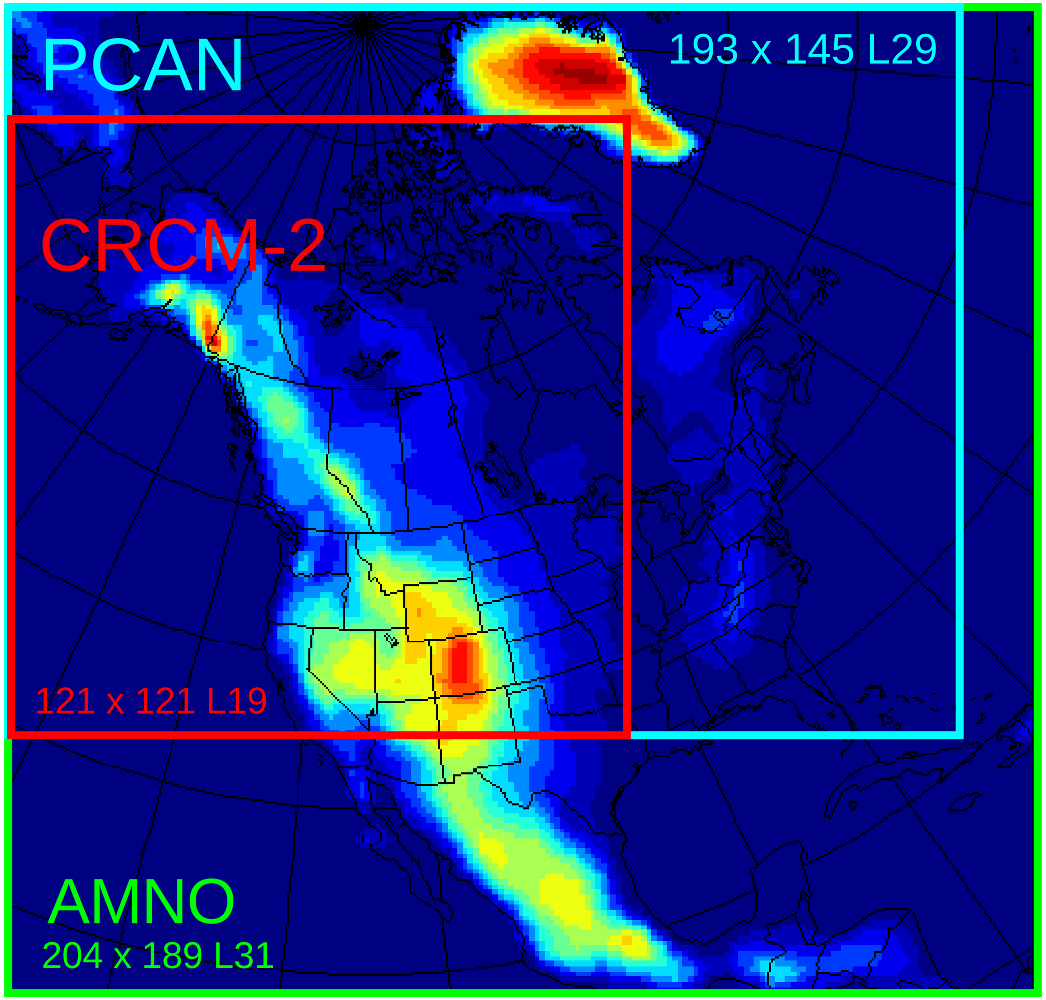
List of participants from EC

Name	Expertise
L. Lefaivre (PC)	Coordination EC and climate analysis
P. Poudret (CS)	Data management
K.-H. Lam (PC)	Scenarios, acces to data
A. Bokoye (PC)	Statistical downscaling, scenarios
J.F.Cantin (ENG) / J. Morin (PC) / D. Rioux (PC)	Hydrology modelling
R. Harvey (MT)	Regional climate modelling
R. Brown (PC)	Scenarios, cryosphere
D. Plummer (RES)	Air quality and scenarios
J. Côté, A. Zadra, **B. Dugas,** **P. Vaillancourt,** **M. Desgagné,** **R. McTaggart-Cowan**, J. Sninocca, M. Lazare, L. Solheim (RES/MT)	Participation in R&D for regional climate modelling

Ouranos: Climate Simulations Team

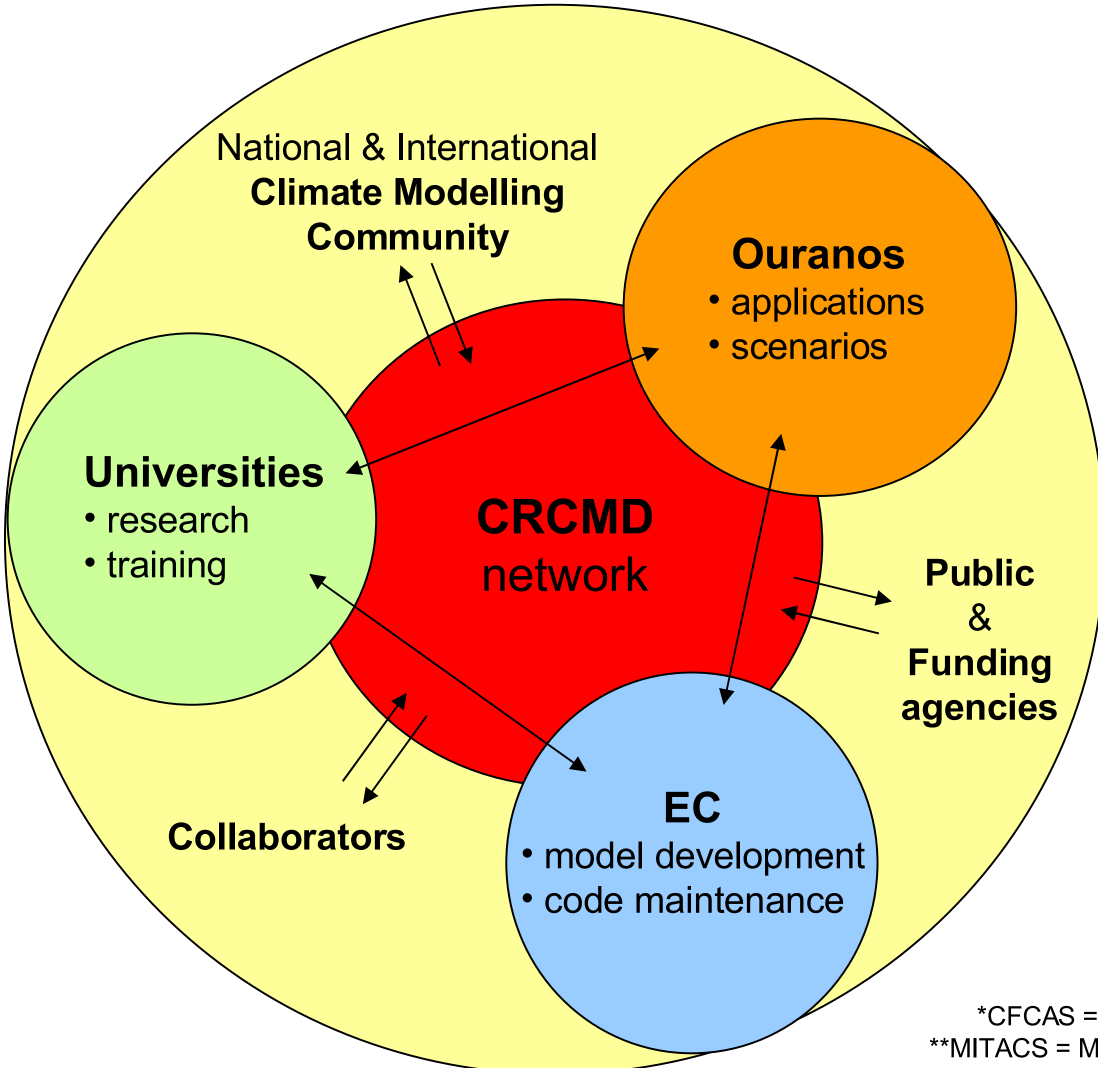
Main achievements (2002-2007)

- Oct-2002: **CRCM-2**
- automated operational environment
- implementation of Great Lakes model (from CCCma)
- development of **4 operational versions of CRCM**
- **first regional climate change projection over N. America** (2x25 years; domain PCAN; MRCC 3.6)
- implementation and simulation of ARPEGE-Climate (France) and REMO (Allemagne) at Ouranos
- adapted simulations of CRCM (ex. hydrology)
- implementation of CLASS
- **first estimate of regional projection uncertainties using an ensemble approach** (N. America)



- Simulations for NARCCAP (North American Regional Climate Change Assessment Program) and ICTS (later on)
- Partial transfer of data to CCCma and GEC3/CCSN

The Canadian Regional Climate Modelling and Diagnostics (CRCMD) Network



Continuation of previous CRCM network

Funding

- CFCAS* (75%)
- MITACS**
- other supporting organisations (e.g. EC, Ouranos, US-DoE, Quebec Provincial Gov. grant, UQAM, McGill, CLUMEQ Consortium)

Duration

4 years: 2006 - 2010

Network lead

Colin Jones (UQAM)

*CFCAS = Canadian Foundation for Climate and Atmospheric Sciences
**MITACS = Mathematics of Information Technology and Complex Systems
(a network of Centres of Excellence for Mathematical Sciences)

CRCMD
Canadian Network for Regional Climate Modelling and Diagnostics

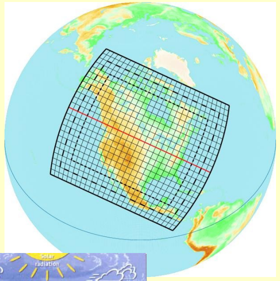
The CRCMD Network 4 primary aims

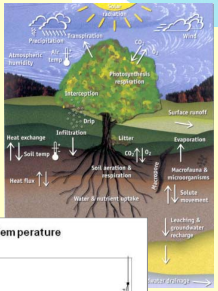
1. Further **develop the new Canadian RCM (CRCM5) based on GEM** for optimum performance at **high-resolution (~10-20km)**

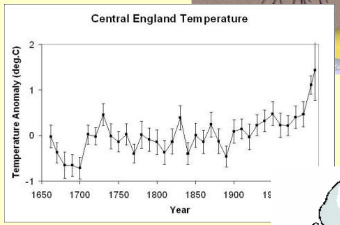
2. Increase the physical realism of **surface-atmosphere interactions in CRCM5**

3. Improving **diagnostic techniques for regional climate** information

4. **Training of Highly Qualified Personnel** (HQPs) in the field of regional climate modelling and diagnostics







About GEMCLIM

GEMCLIM: a way of running climate-long simulations with GEM

- automatic re-launching **multi-month jobs**
- optional, automatic and large amount of **post-processing**
  (comprehensive set of time averages and variances on pressure- and model-levels, and time series of frequently used variables)

GEMCLIM: a library (routines, scripts)

- **GEMCLIM versus GEMDM**
  - compared with GEMDM 3.3: 92% of 570 dynamics routines are the same
  - compared with PHY 4.5: 98% of 577 physics routines are the same
- "**mode-backward" compatible**: can run non-climate mode with GEMCLIM
- Main differences:
  - post-processing / diagnostic scripts
  - size-reducing of pilot files from analyses data on pressure levels

GEMCLIM: people involved in development at Dorval

M. Desgagné, B. Dugas, P. Vaillancourt, K. Winger (UQAM), A. Zadra
(in alphabetical order) + plus several others

About GEMCLIM

GEMCLIM: raison d'etre

- test bed for new code and model development
  - changes can be implemented relatively rapidly (e.g. CCCma Corr.-K radiation; GCM4 physics in GEM)
  - code changes may be evaluated with robust statistics
- collaboration with climate modelling community

GEMCLIM: documentation and support

GEMCLIM versions 3.2.1 and 3.2.2 are currently documented on

http://collaboration.cmc.ec.gc.ca/science/rpn/gem/gem-climate/

Version 3.3.0 on web site is in preparation.

GEMCLIM: computer time per simulation

- "short" 2-year simulation, global uniform at 2º resolution:
  - as little as 1 day with 16 CPUs on the Dorval AIX clusters
- a 41-year simulation, LAM over Europe, 0.22º resolution:
  - nearly a month, with 4X the resources above

About GEMCLIM

GEMCLIM: simulations performed at Dorval (and UQAM)

- various **simulations to test new versions of model / physics**:
  - e.g. mesoglobal, meso-strato, new radiation, aerosols, geophysical fields, etc.
- climate-related projects

(Global)

SGMIP1: 12-year 1987-1998, 0.45 - 1.8 deg SG, 318x226 (core 135x146 NA)
SGMIP2: 26-year 1978-2004, 0.5 - 1.5 deg SG, 304x204 (core 79x110 NA/EU)
26-year 1978-2004, 1.0 deg UG, 360x180

And with each new model version, at least one AMIP2 1978-200* global 1.5 deg and

one 2.0 deg reference simulations are run.

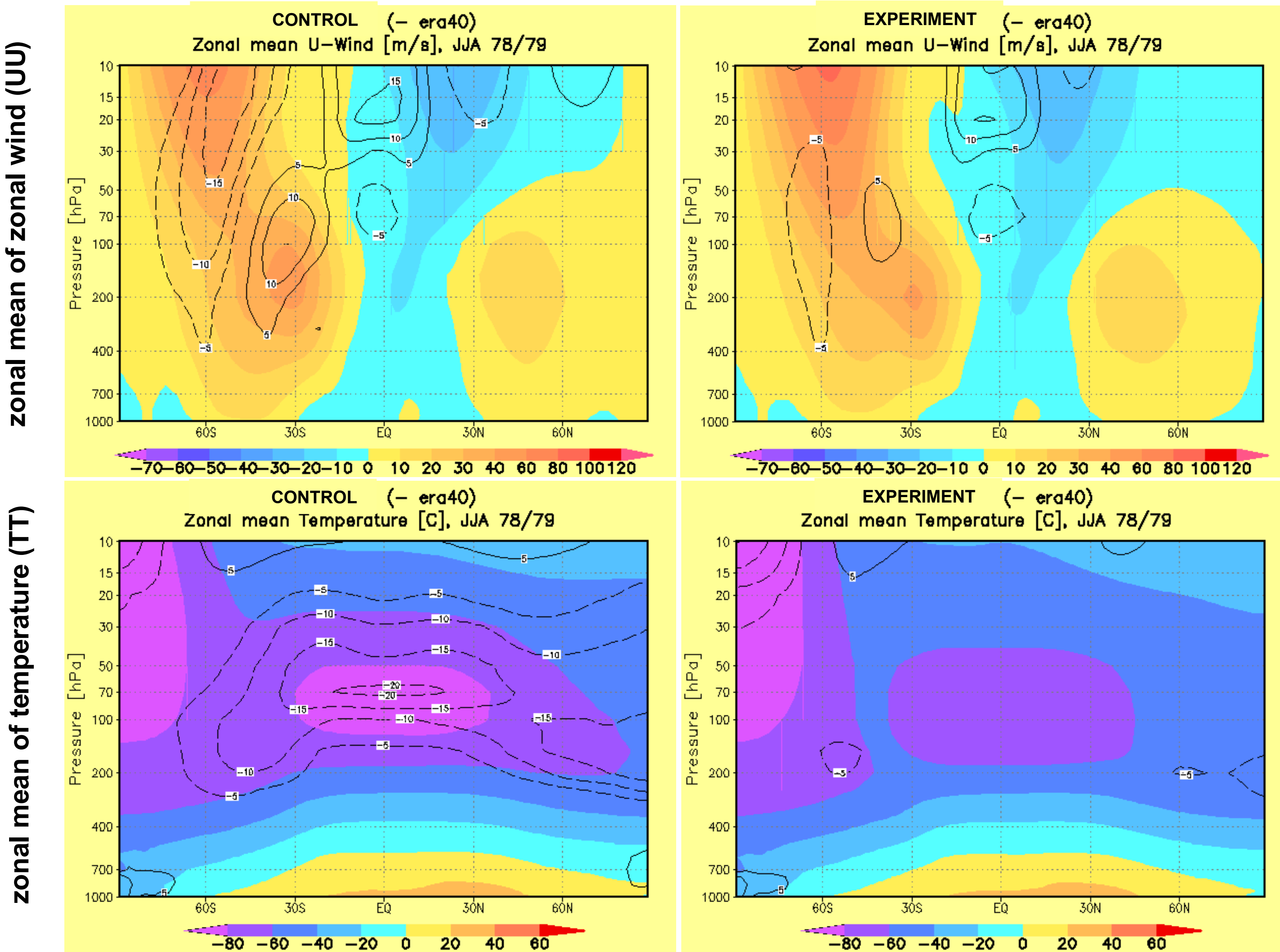
(LAM)

ICTS (multiple sets, after finding a problem with the SSTs
NA/EU domains driven by GEMCLIM or ERA40, usually at 0.5 deg
EU ENSEMBLES 41-year ERA40 at 0.22 deg

Recently, GEMCLIM configured for CLUMEQ LAM Benchmarks

1) 45-day runs, 640x592x48 0.125 deg, delt= 450 s,
   MAIA: 10 x 11h with 112 CPUs (7x 4x4)
   UQAM: 10 x 17h with 84 CPUs (7x12x1)
2) 45-day runs, 320x296x48 0.25 deg, delt= 900 s
   MAIA: 20 x 2h45 with 64 CPUs (4x 4x4)
   UQAM: 20 x 4h30 with 56 CPUs (8x 7x1)

Example: Impact study on a new radiative scheme (cccmarad) using GEMCLIM



Another example:

Lead-fraction correction term: 3% of lead fractions added to sea-ice cover

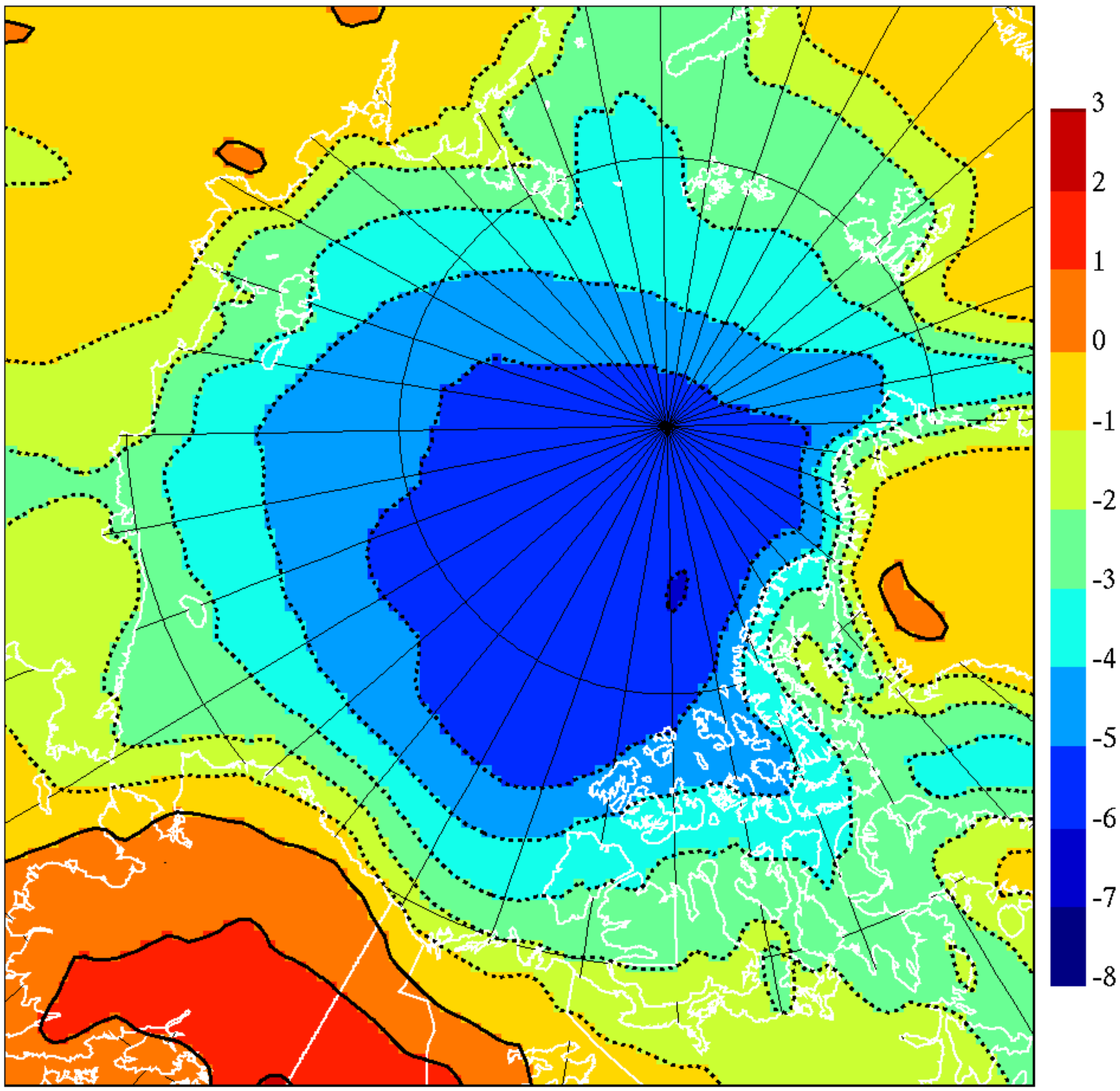
Simulations: global uniform 2º, 26 years

EXP1: lead-fraction correction non-active

EXP2: lead-fraction correction active

Figure: impact on surface temperature, winter (DJF) average over Arctic

Impact on surface temperature (ºC) : EXP2-EXP1



About GEMCLIM

GEMCLIM: transfer to Ouranos and UQAM

- at **UQAM** (CRCMD network)
  - 48 Sunfire node cluster
  - each node has 2 dual-core opteron (total of 192 cores for the whole system)
  - GEMCLIM v_3.3.2 installed 2 years ago
  - GEMCLIM v_3.3.0 installed in the summer 2007
  - currently used extensively
- at **Ouranos**
  - SX6 machine
  - GEMCLIM v_3.3.2 installed 2 years ago
  - not currently used

Footnote about CLUMEQ

CLUMEQ = Consortium Laval, Universite du Québec, McGill and Eastern Québec

- 1 of 7 regional HPC consortia that make up **ComputeCanada**
- supercomputer consortium based at McGill University
- modern supercomputing equipment available to researchers
- courses & workshops in computational science and large-scale parallel programming
- sharing its MPI coding expertise with small and medium enterprises in Quebec
- currently preparing a RFT (request for tender) for a 20K core system -- <u>**GEMCLIM** will feature extensively in the tender exercise</u>

GEMCLIM-LAM integration over North America for period 1978-2002 using ECMWF reanalysis LBCs

RPN recherche en prévision numérique

Ayrton Zadra, Bernard Dugas, Paul Vaillancourt and Katja Winger

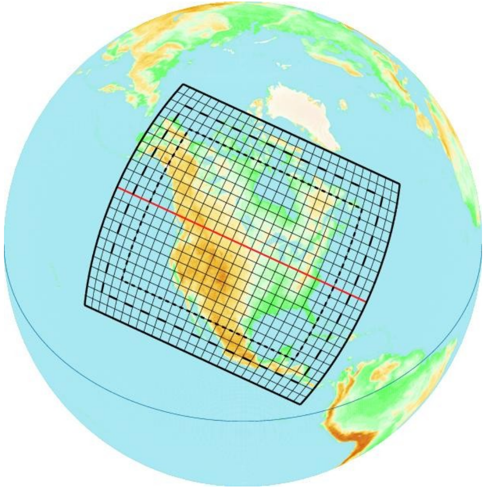
UQÀM Université du Québec à Montréal

Objectives

- **study and document** model behavior
- **provide data to collaborators** (e.g. surface & hydrology groups at RPN; researchers and students at UQAM)

Model configuration

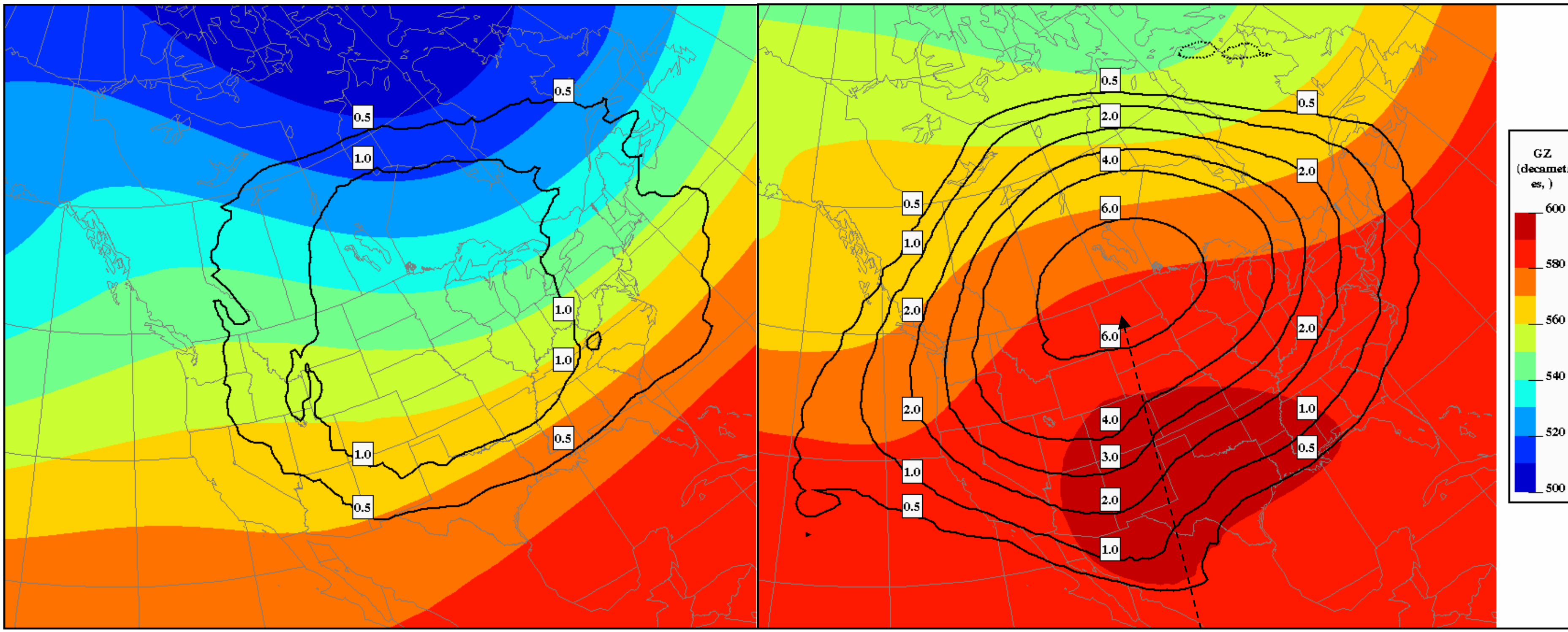
- 0.5° uniform
- 3x2 MPI domains @ 4 OpenMP threads
- 1800s time-step, $\nabla 6$ horizontal diffusion
- 53 vertical hybrid levels, top at 10 hPa
- Kain-Fritsch deep convection
- Sundquist large-scale condensation
- ISBA land-surface scheme
- Li & Barker Correlated-K radiation
- pilot: ERA40 2.5° 1957-2002 (atmos.) and AMIP2 (SST, sea-ice)
- Results for 1978-2002 presented



LAM grid: 140 x 120, including a 10 point pilot area and a 10 point blending area at boundaries (1 in 5 shown here).

DJF/JJA 500hPa GZ (-ERA40) (dm)

winter summer



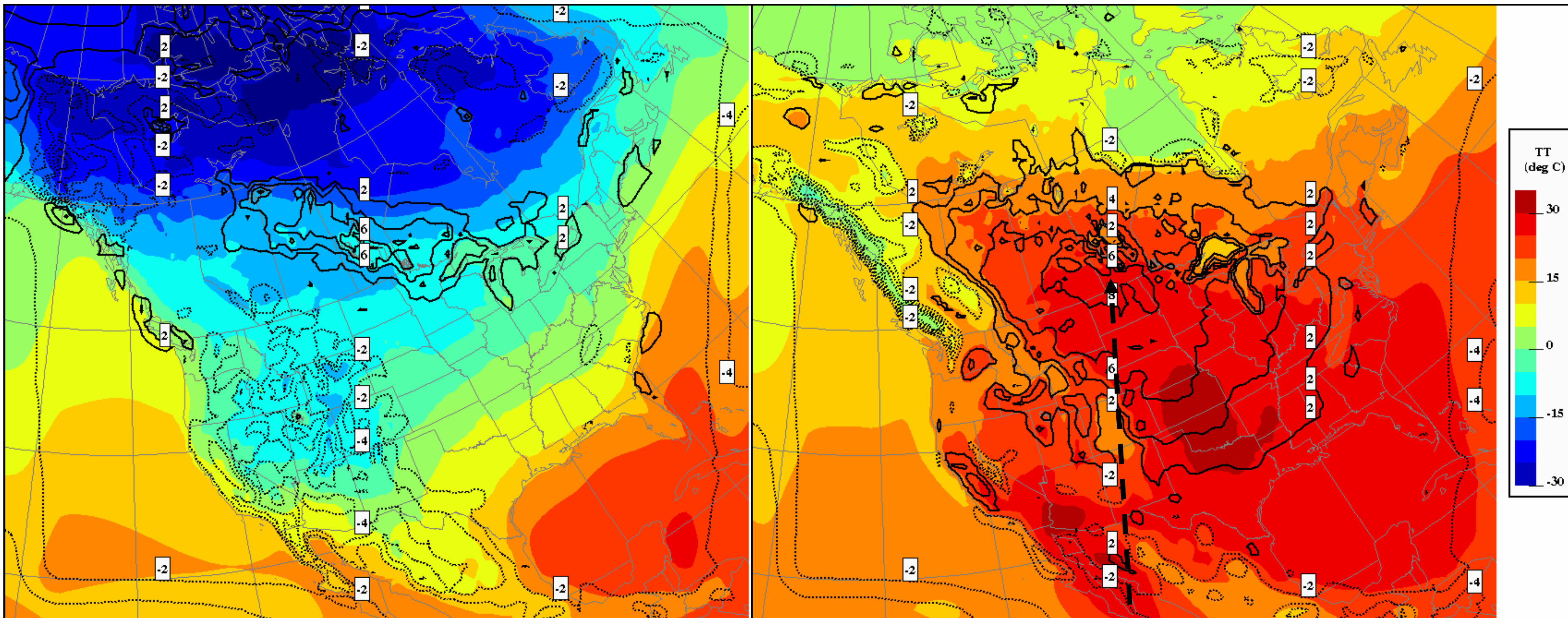
color field: *model climatology*

contour lines: *difference w.r.t. ERA40 climatology*

positive (warm) bias over central N. America, most notably in the summer

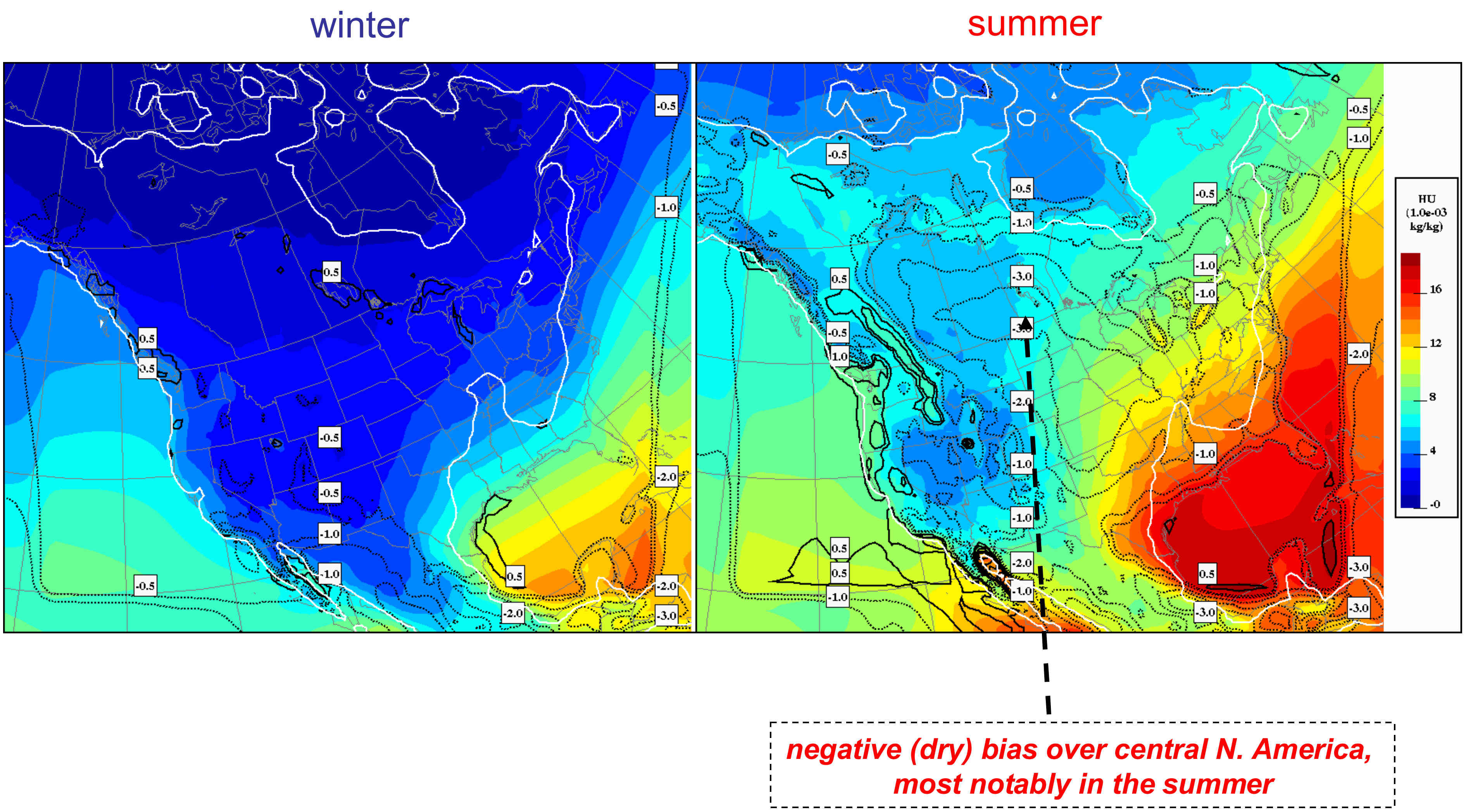
DJF/JJA Surface Temp (-ERA40) (°C)

winter summer



positive (warm) bias over central N. America, most notably in the summer

DJF/JJA 1000 hPa Sphum (-ERA40) (g/kg)



Documentation

- A. Zadra's web page (**GEM-LAM project**):
  http://iweb.cmc.ec.gc.ca/~armnaza/proj_LAM.html

- **Paper** to appear in 2008 April-June issue of Physics in Canada
  Zadra, A., D. Caya, J. Côté, B. Dugas, C. Jones, R. Laprise, K. Winger and L.-P. Caron, "***The next Canadian Regional Climate Model***"

- M.S. Fox-Rabinovitz, J. Côté, B. Dugas, M. Déqué and J.L. McGregor, 2006: *"Variable resolution general circulation models: Stretched-grid models Intercomparison project (**SGMIP**)",* J. Geophys. Res., 111, D16104.

- 2 papers in preparation (GEMCLIM, global and LAM modes) precipitation

cloud-radiation interaction

various regions/climates

CRCMD

Canadian Network for Regional Climate Modelling and Diagnostics

internal variability

results from studies by network participants

(students, post-docs, researchers)

based on GEMCLIM simulations

tropical cyclones

boundary layer

surface processes

The Transferability of Regional Climate Models to non-native domains

Zav Kothavala, Colin Jones, Katja Winger

Dominique Paquin

Bernard Dugas, Paul Vaillancourt, Ayrton Zadra*

Objective:

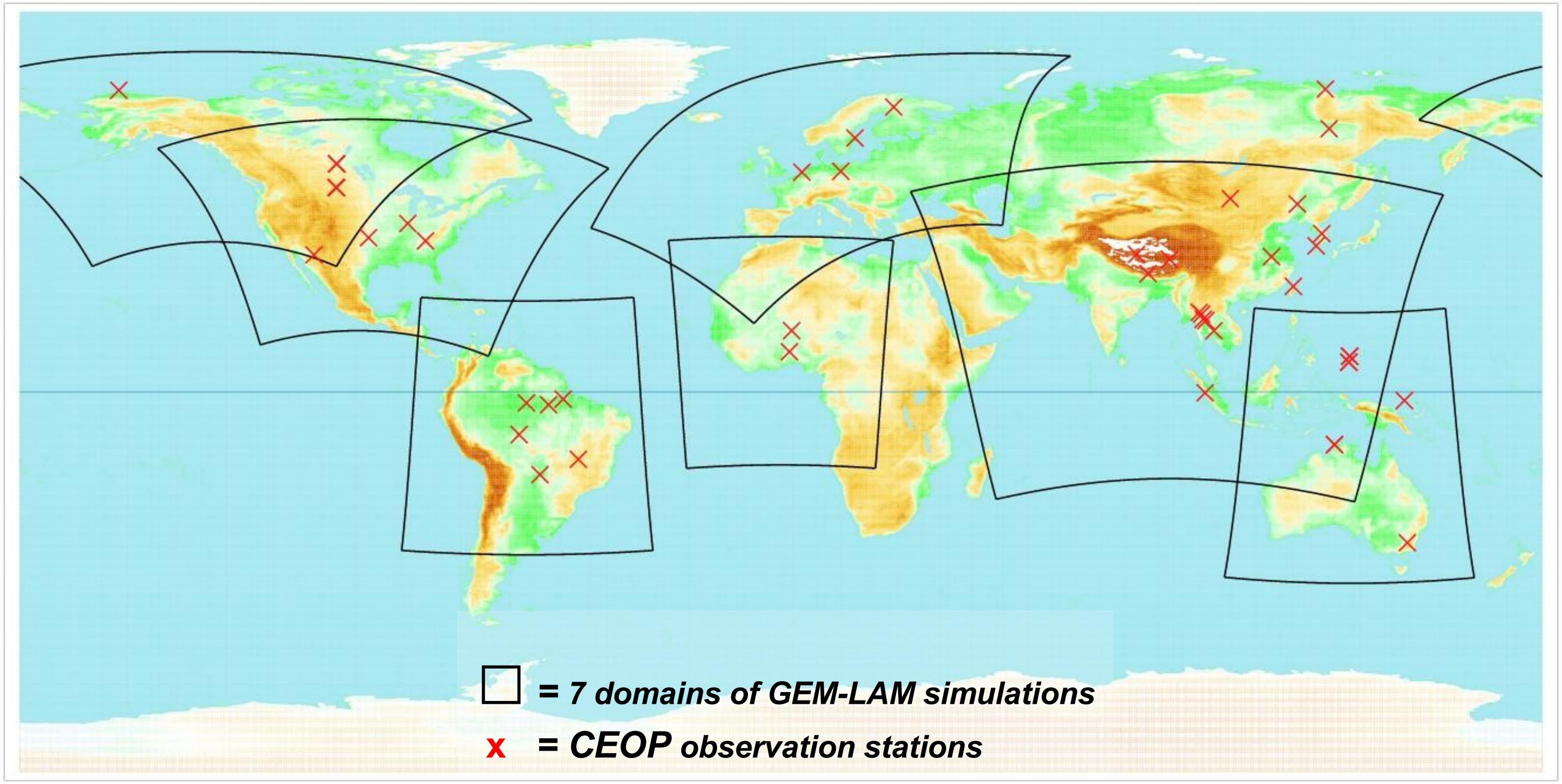
Assess and improve global transferability of RCMs, i.e.

- to determine that RCMs can realistically **simulate climate variability in all regions of the globe**
- to evaluate **parametrizations against observations in all possible climates**

* *A.Z. thanks Ron McTaggart-Cowan for his help in configuring the GEM-LAM ICTS grids and in preparing the pilot data from NCEP2 reanalyses .*

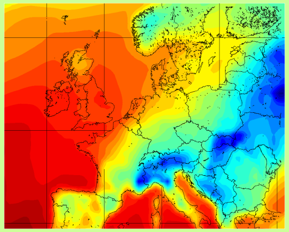
ICTS protocol [http://icts.gkss.de/]:

- **ICTS** = Inter-CSE Transferability Study (CSE = Continental Scale Experiments)
- Unmodified RCMs were transferred from their "native domain" and run on a variety of domains around the globe
- Comparison against data from **CEOP** (Coordinated Enhanced Observing Period) observation stations



Requested output

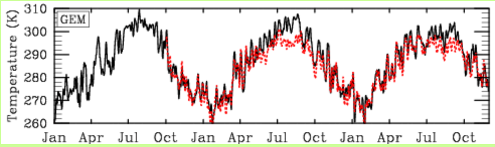
Data period: 5 years, 2000/01/01 – 2004/12/31



Common grid data:

- **area**: geographical lat/ton grid, entire area of each domain
- **interval**: daily (mean, accumulated, or min/max)
- **parameters**: 34 bidimensional fields (e.g. 2-m temperature)

Station data:

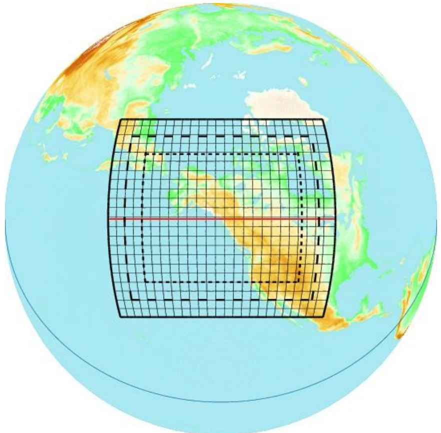


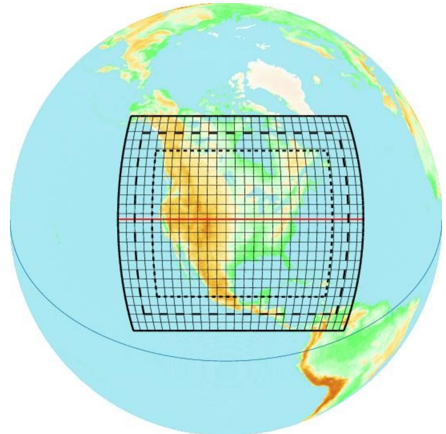
- **location**: nearest gridpoint to each station, and 8 adjacent points
- **interval**: 3h (mean, accumulated, min/max or integrated)
- **parameters**: 8 profiles (e.g. TT) and 34 single-level data (e.g. PS)

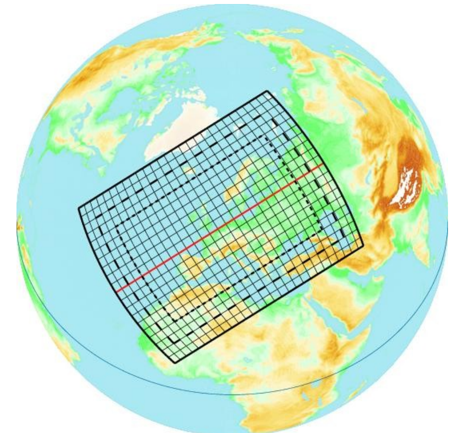
Participating RCMs*

RCA3	**Rossby Centre (Sweden)**
CLM	**GKSS Research Centre (Germany)**
RSM	**Scripps Institution of Oceanography (USA)**
RegCM3	**Iowa State University (USA)**
GEM-LAM	**RPN, Environment Canada (Canada)**
MRCC	**Ouranos-UQAM, Montréal (Canada)**
MM5	**Iowa State University (USA)**

* *Takle, E.S., J. Roads, B. Rockel, W.J.Gutowksi, Jr., R.W. Arritt, I. Meinke, C.G. Jones and A. Zadra, 2007: "Transferability intercomparison: An opportunity for new insight on the global water cycle and energy budget", Bulletin of the AMS, 88, Issue 3, 375-384.*

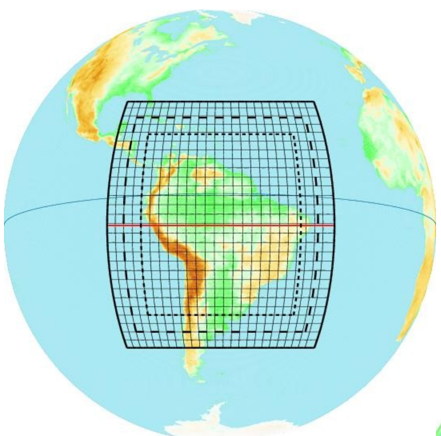


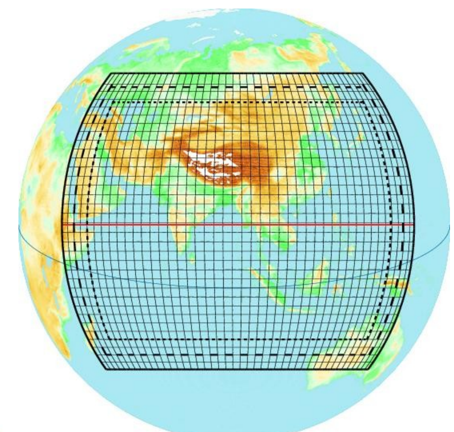


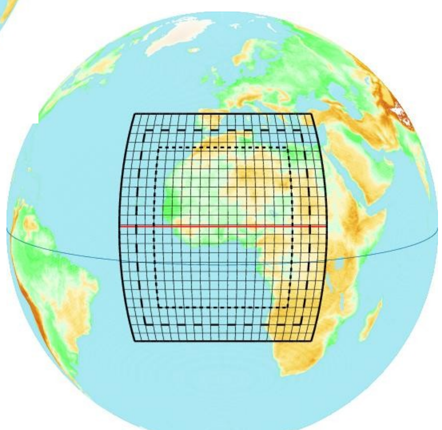


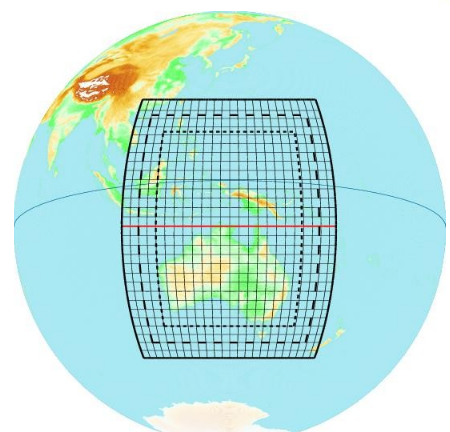
GEM-LAM *v3.2.1*

- *0.5º horizontal* ***resolution***
- *53 vertical* ***levels*** *(top at 10 hPa)*
- *30-min* ***timestep***
- ***physics****: that of mesoglobal, except radiation (cccmarad)*
- ***boundary forcing****: NCEP2 reanalyses (every 6h) & AMIP2 SSTs and sea-ice*



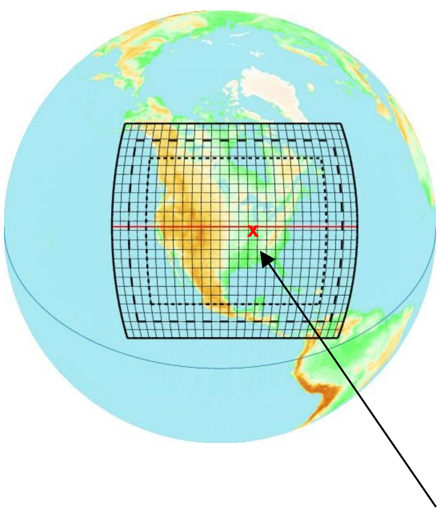






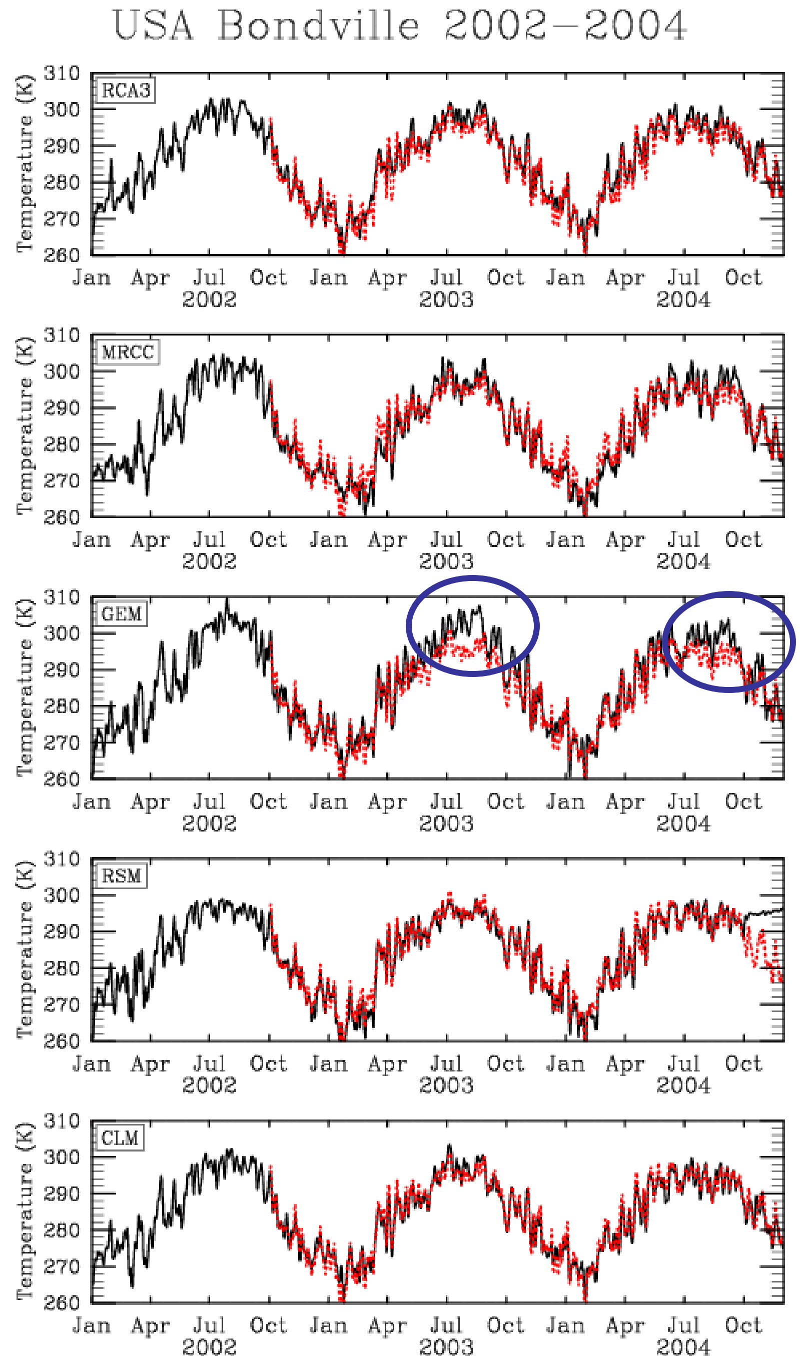
Example:
timeseries of 2m-temperature (3h mean)
for a station located in a native domain

model
observation



Bondville, IL, USA
(40N, 88W)

GEM

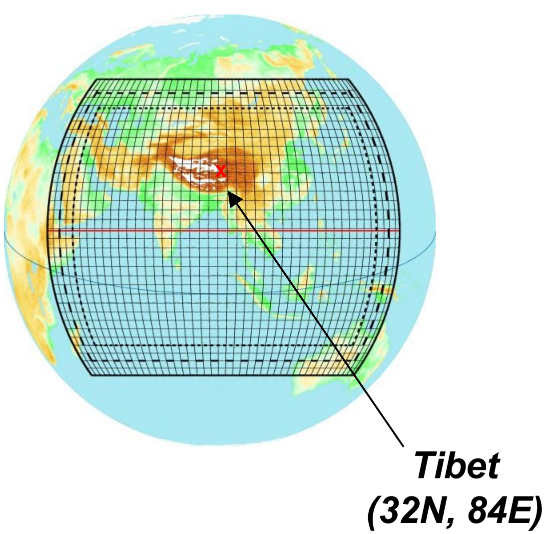


Example:

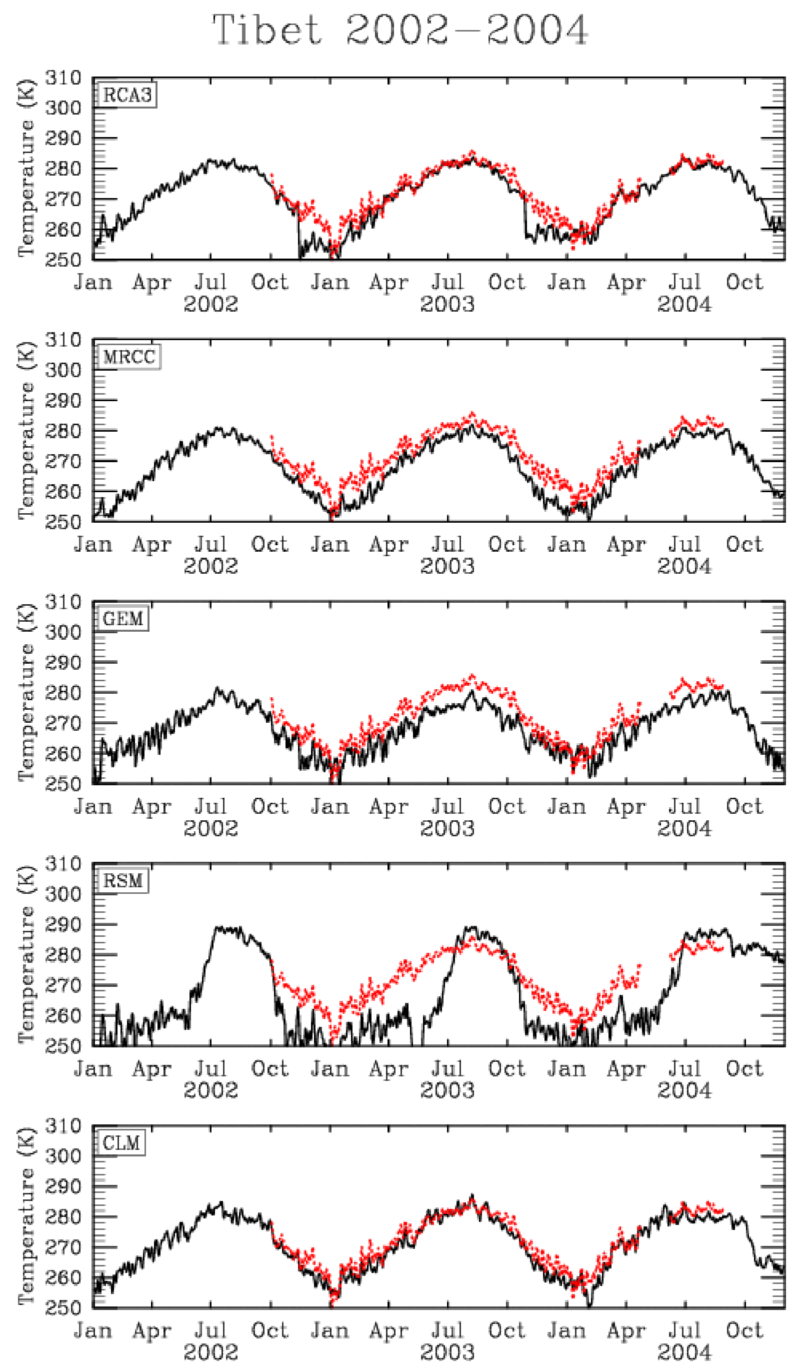
timeseries of 2m-temperature (3h mean) for a station located in a <u>non-native domain</u>

— model

— observation

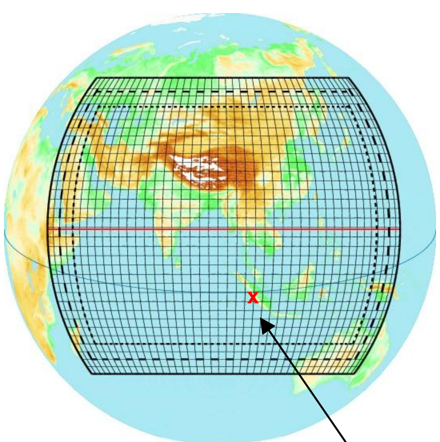


GEM



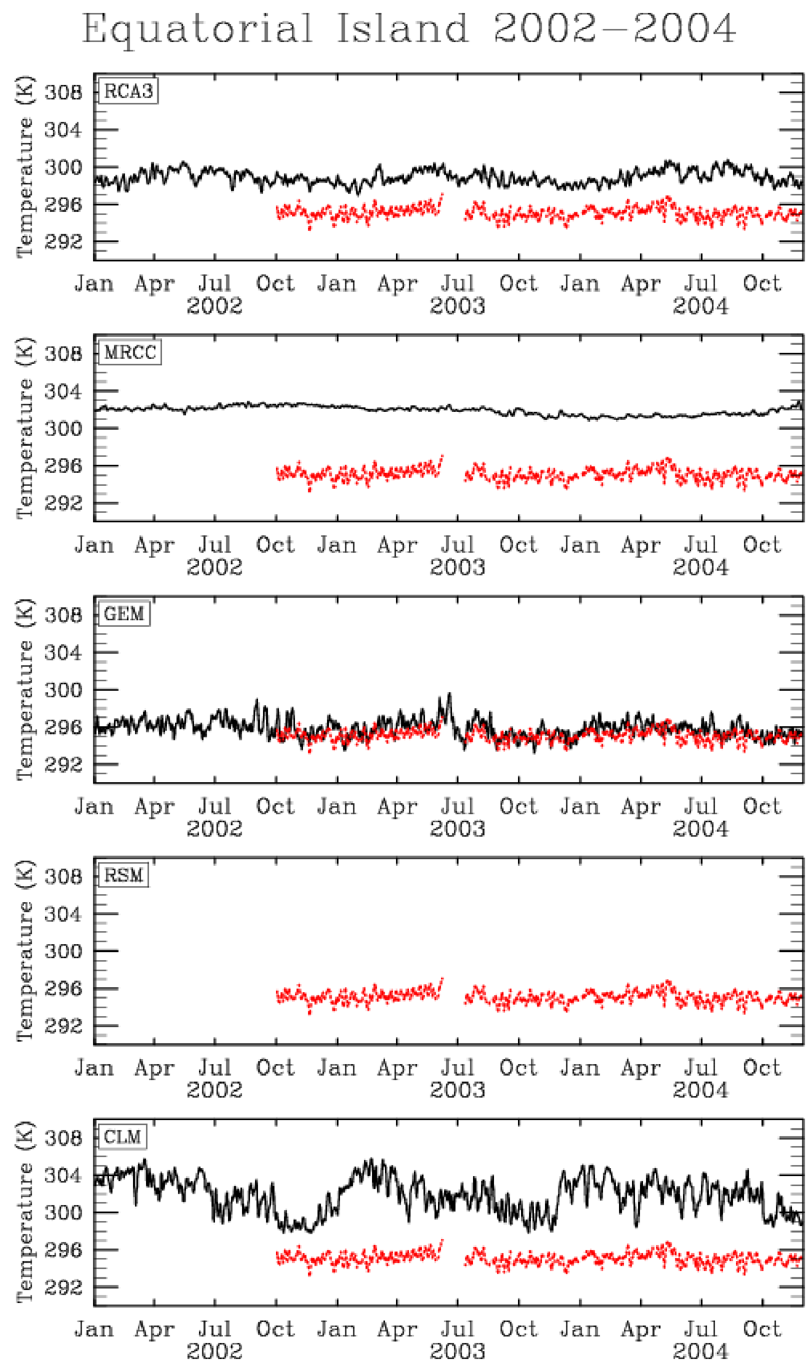
Example:
timeseries of 2m-temperature (3h mean) for a station located in a <u>non-native domain</u>

- model (black line)
- observation (red line)



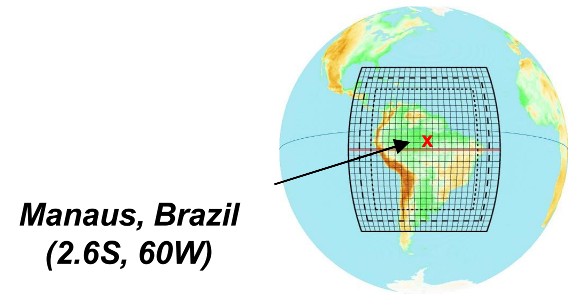
Equatorial island (0.2S, 100E)

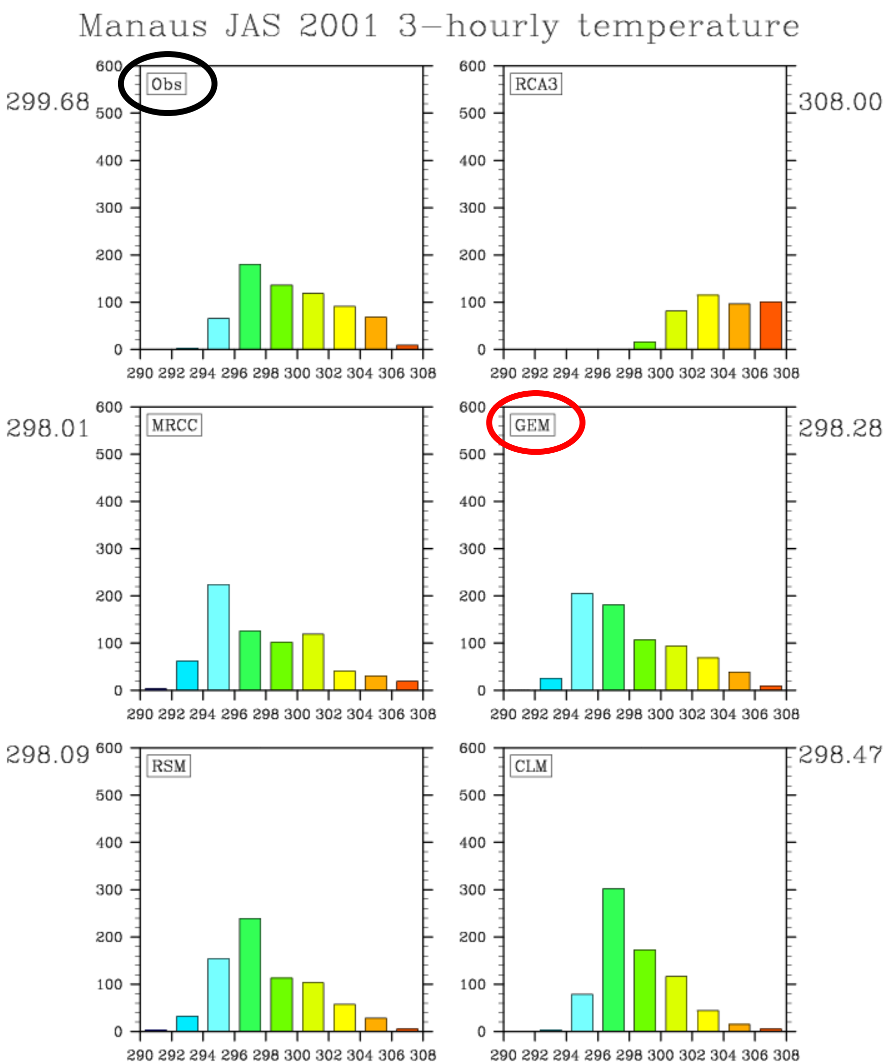
GEM

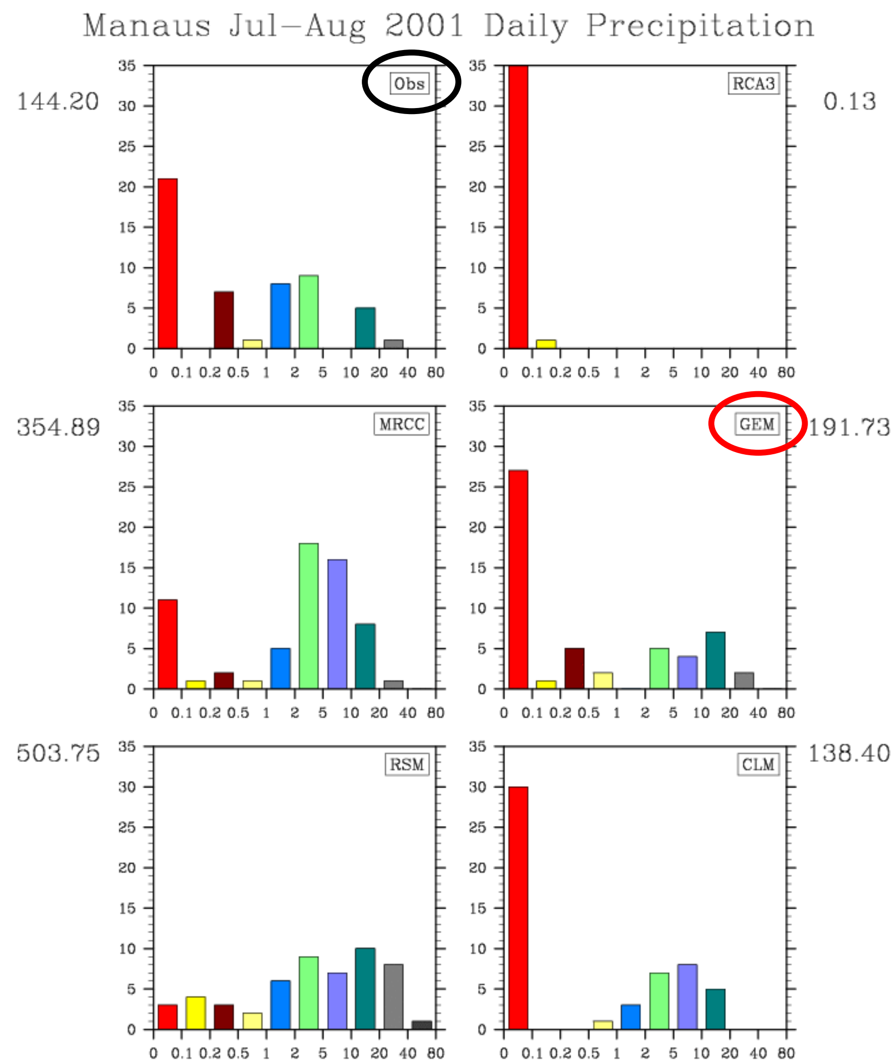


Example:

Frequency distribution of 2m-temperature and daily precipitation for a station located in a <u>non-native domain</u>, for JAS 2001







Evaluation of the Surface Radiation Budget Over North America for a Suite of Regional Climate Models

CRCMD Canadian Network for Regional Climate Modelling and Diagnostics

RPN recherche en prévision numérique

<u>Marko Markovic</u>
Colin Jones, Paul Vaillancourt
Dominique Paquin, Katja Winger, Danahé Paquin-Ricard

UQÀM

OURANOS

Objective

Evaluate parameters of **SRB** (surface radiation budget) in RCMs against surface observations for North America.

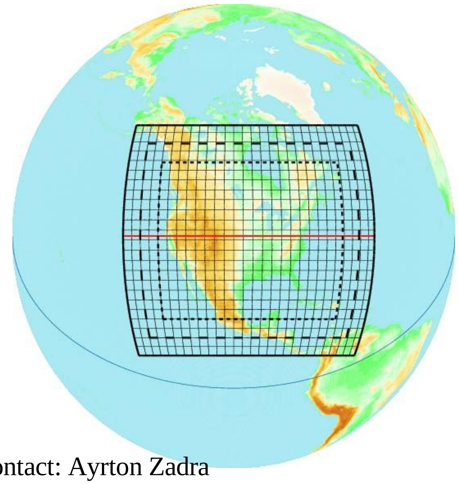
Motivation

SW and LW are the main terms in surface energy balance that control evolution of surface temperature and moisture in RCMs.

Methodology

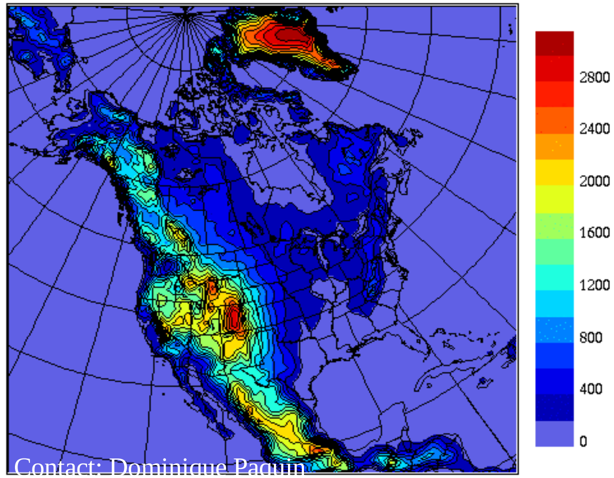
- Surface parameters evaluated: ISR (global solar, direct+diffuse, radiation) and DLR (downwelling long-wave atmospheric radiation).
- 3 RCMs: GEM-LAM (EC), CRCM (Ouranos) and RCA3 (Sweden)
- Observation data from the NOAA SURFRAD network

GEM-LAM



Vert. Levels: 53 hybrid levels
Hor. Resol.: ~ 42km
Time Step: 1800s
Domain Size: 140x120 grid points
SST: prescribed
LBCs: ERA40
Radiation: cccmrad (every 4 steps) (Li and Barker 2004)
Convection:
- -Kain-Fritsch (deep)
- -conres+ktrsnt (shallow)

CRCM-Version 4.0.1



Vert. Levels: 29 Gal Chen levels
Hor. Resol.: ~ 45km
Time Step: 900s
Domain Size: 241x217 grid points
SST: prescribed
LBSc: NCEP II
Radiation : SW (every 12step)

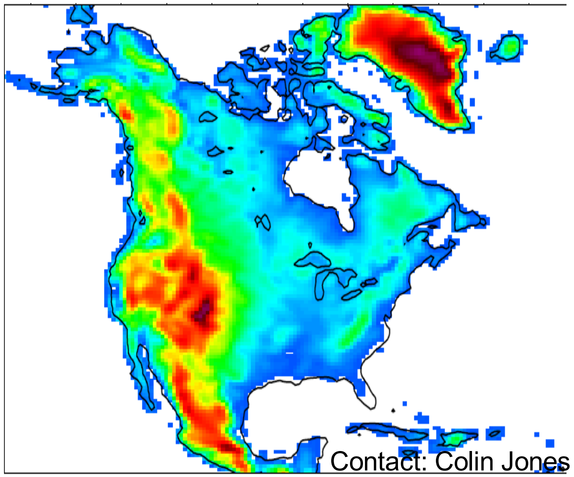
Fouquart et Bonnel (1980)

LW (every 4 step)

Morcrette (1984)

Convection : Bechtold Kain-Fritsch

RCA3

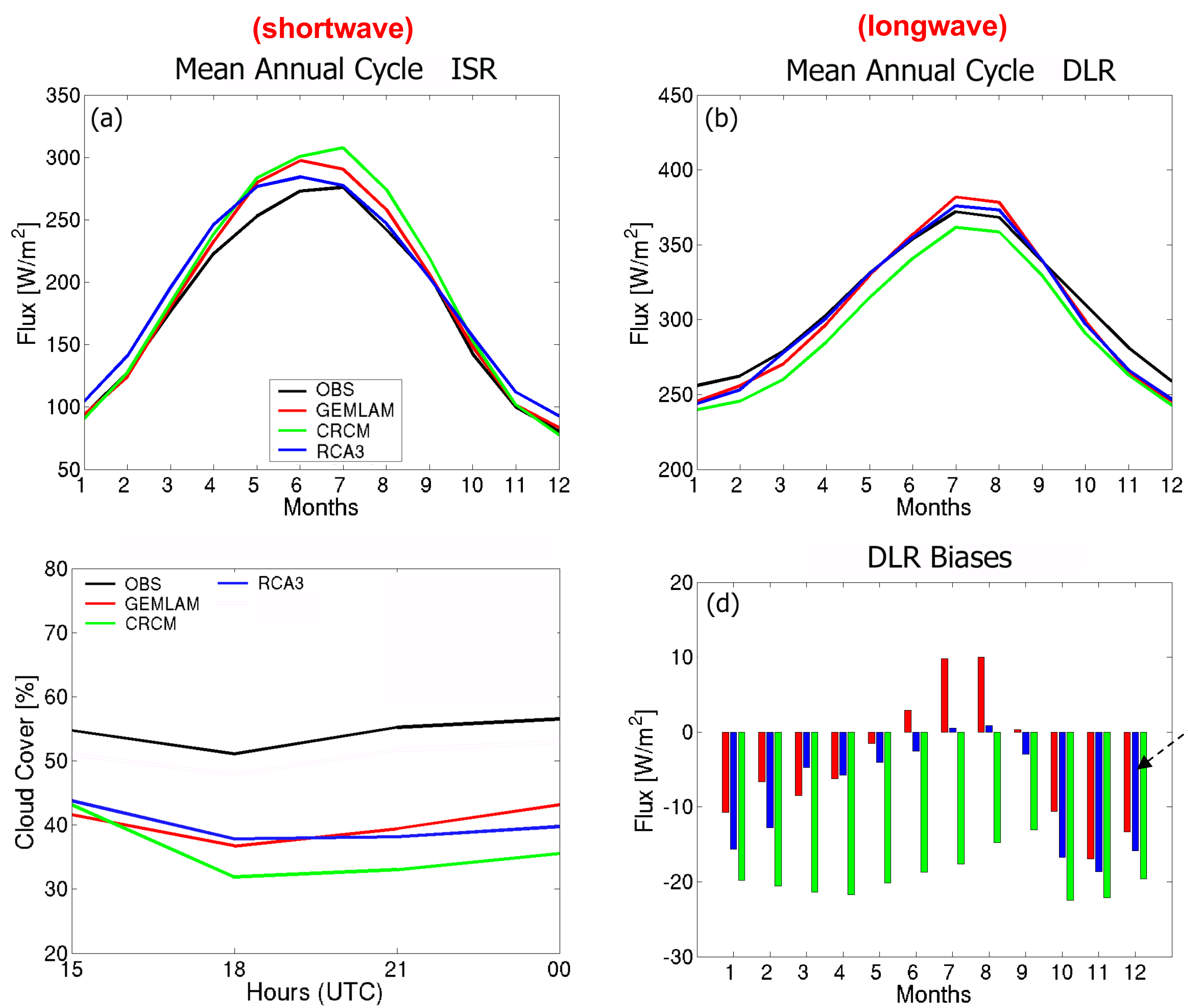


Vert. Levels: 24 using ETA coor.
Hor. Resol.: ~ 0.5 degree
Time Step: 1800s
Domain Size: 150x138 grid points
SST: prescribed
LBSc: ERA40
Radiation : SW Savijarvi (1990)
LW Savijarvi(1990)
Stephens (1984)
Rogers(1977)
Convection : Kain-Fritsch (deep+shallow)

Station Comparison, Models against Observations over 6 SURFRAD stations

Climatological mean annual cycle (2000-2004), entire diurnal cycle included.

positive bias in summer

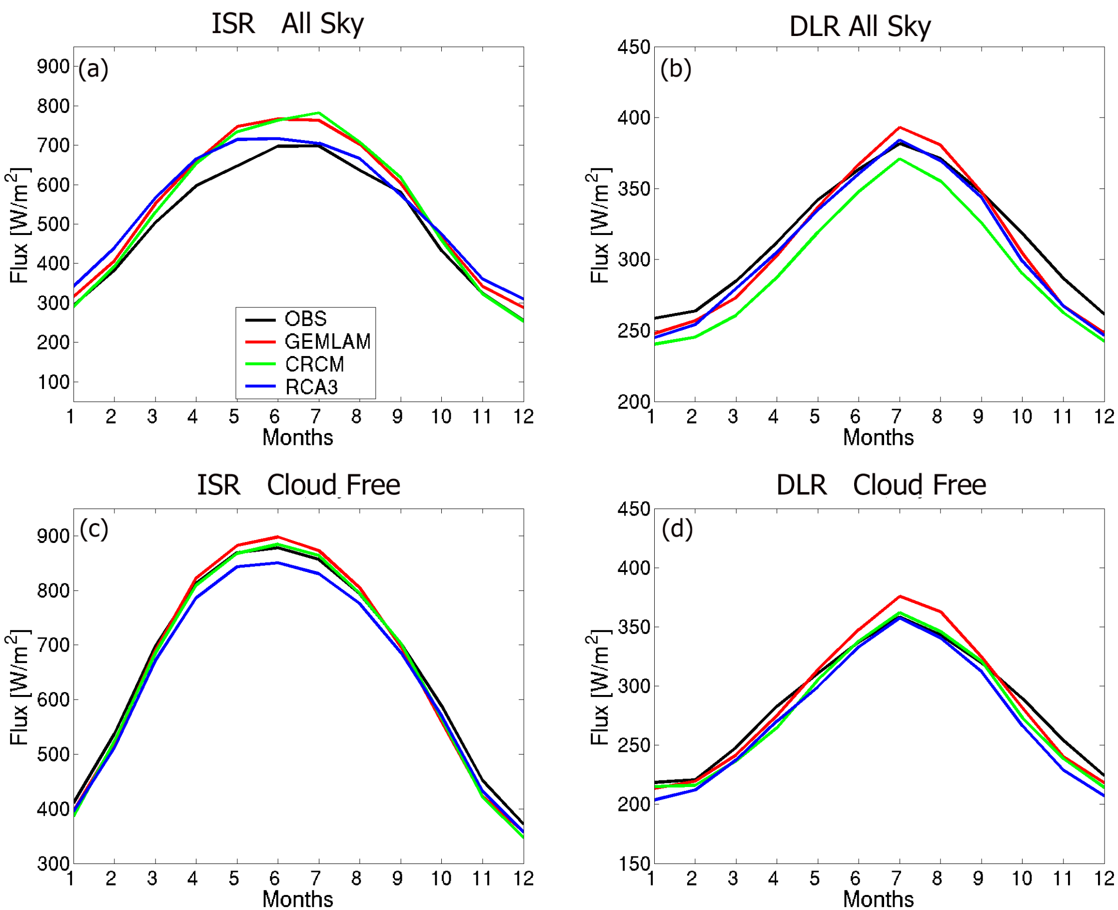


negative bias In winter

Station Comparison, Models against Observations
Total-sky against Cloud-Free

Climatological mean annual cycle (2000-2004), daytime 15-21 UTC.

(shortwave) **(longwave)**



Clear Sky < 10 % of cloud cover

Overcasted Sky > 90 % of cloud cover

Shortwave: All-sky biases are mostly influenced by biases produced in overcast conditions

Longwave: Principal errors in all-sky conditions, for GEM-LAM and RCA3 come from clear-sky while for CRCM from cloudy-sky biases.

Differences between the models and ERA40, **DJF** 4-year mean

Station comparisons, **DJF**:

SW: GEM-LAM et MRCC good representation, RCA3 overestimates
LW: underestimate by all models
CC: underestimate by all models

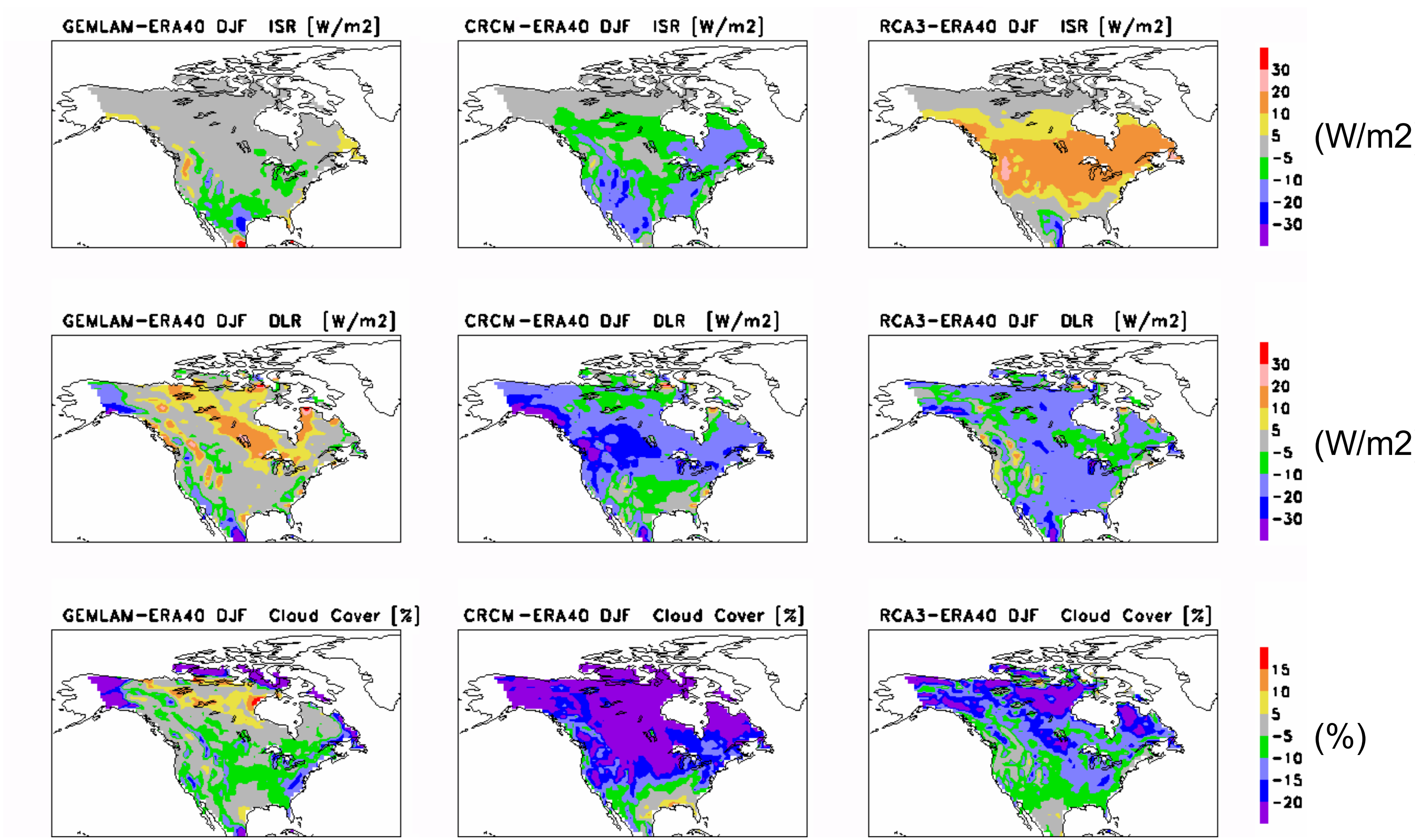
WINTER

GEM-ERA40 | CRCM-ERA40 | RCA3-ERA40

Δ SW

Δ LW

Δ clouds

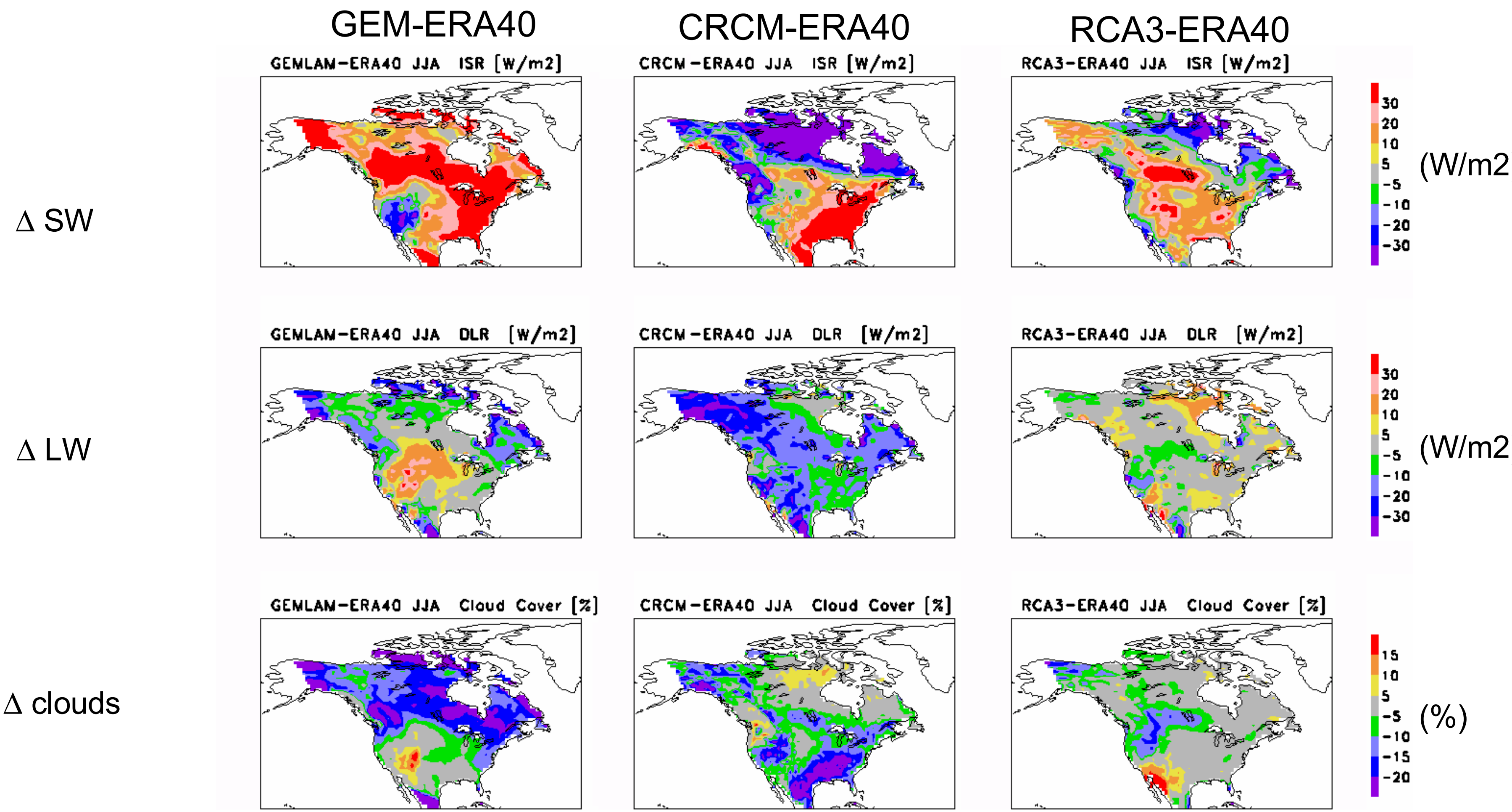


Differences between the models and ERA40, **JJA** 4-year mean

Station comparisons, **JJA**:

SW: overestimate by all models
LW: GEM-LAM and RCA3 acceptable representation, CRCM underestimates
CC: underestimate by all models

SUMMER



A study on the representation of cloud microphysics and its interaction with radiation in the GEM model

Danahé Paquin-Ricard, Colin Jones

UQÀM Université du Québec à Montréal

and Paul Vaillancourt

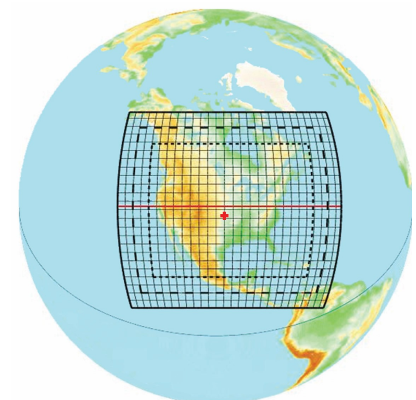
RPN recherche en prévision numérique

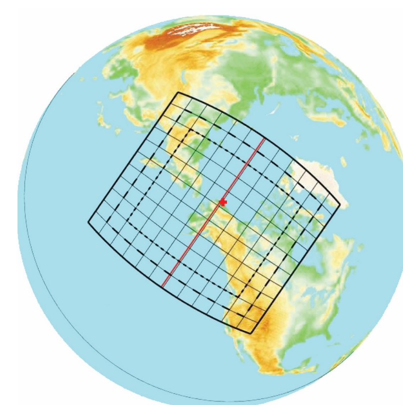
Objectives

- Evaluate and improve the cloud microphysics and its interaction with radiative processes in the GEM physics
- Study the impact of the cloud microphysics on the surface radiation budget

Methodology

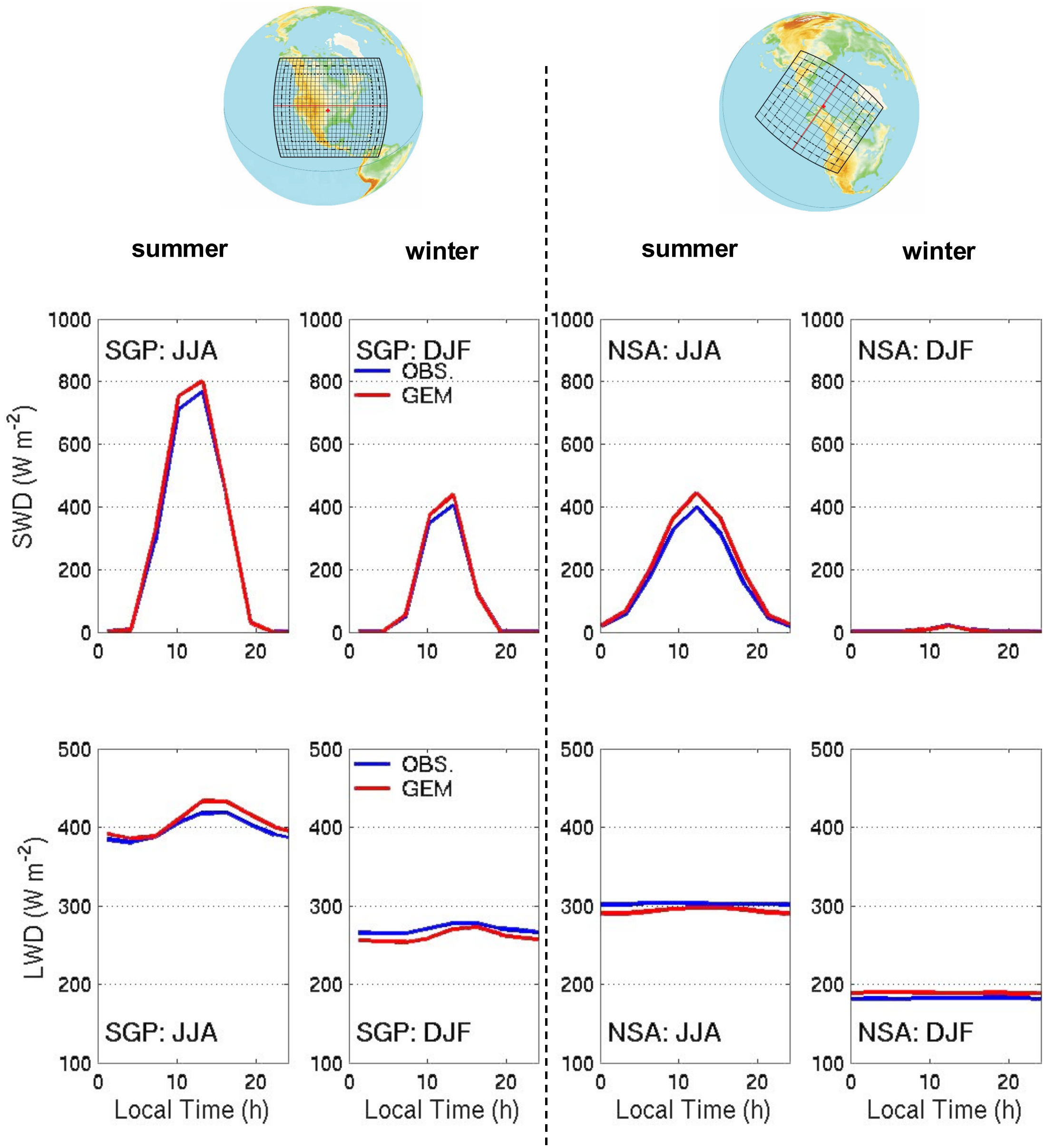
- Compare model simulations (1998 – 2005) with observations (sites ARM-SGP in Oklahoma, and ARM-NSA in Alaska)* using diurnal cycle averages (for JJA and DJF), frequency distributions (PDFs) and co-variabilities
- Surface variables considered: downwelling short-wave (SWD) and long-wave (LWD) radiation, cloud fraction, integrated water vapor (IWV), liquid water path (LWP), precipitation, and surface temperature





*ARM = Atmospheric Radiation Measurement program ; SGP = Southern Great Plains ; NSA = Northern Slope Alaska

Example: Diurnal cycle of **SWD** and **LWD** (all-sky conditions)



observations
model

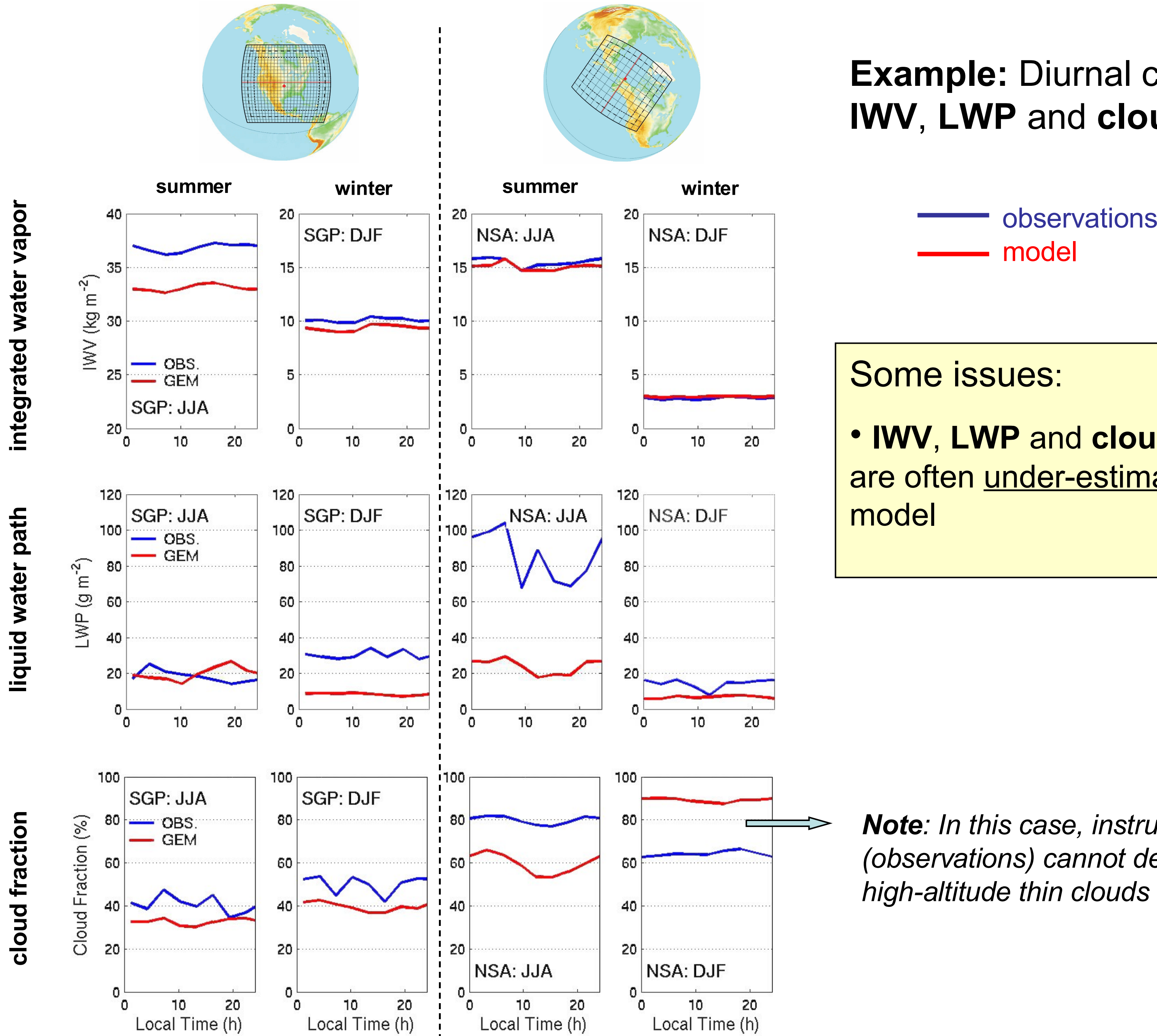
To understand these all-sky biases, one must look at

3. cloud-fraction bias
4. bias in clear-sky conditions
5. bias in cloudy-sky conditions

Results are most sensitive to cloud fraction, LWP, IWV, temperature profile, …

Some of these biases may partly cancel each other.

Example: Diurnal cycle of **IWV**, **LWP** and **cloud fraction**



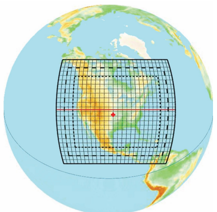
Some issues:

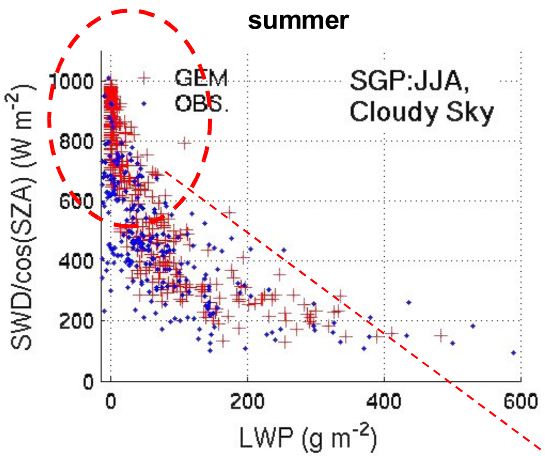
- **IWV**, **LWP** and **cloud fraction** are often under-estimated by the model

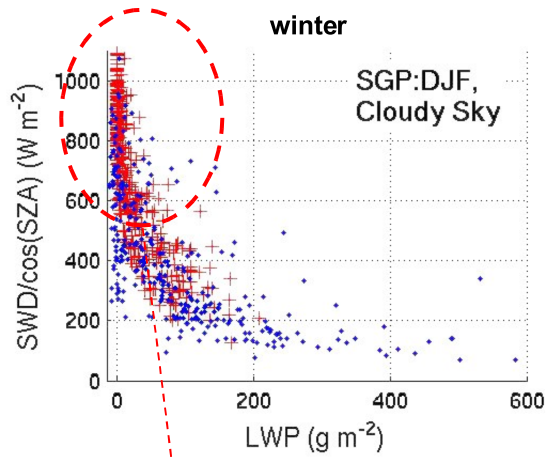
***Note**: In this case, instruments (observations) cannot detect high-altitude thin clouds*

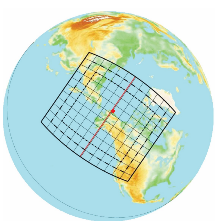
Example: Co-variability between **LWP** and **SWD** for cloudy-sky conditions

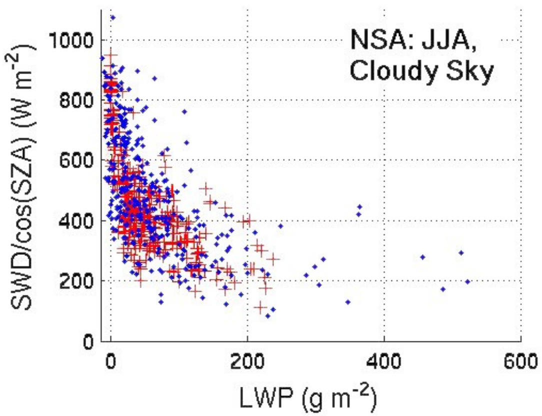
▪ observations
\+ model









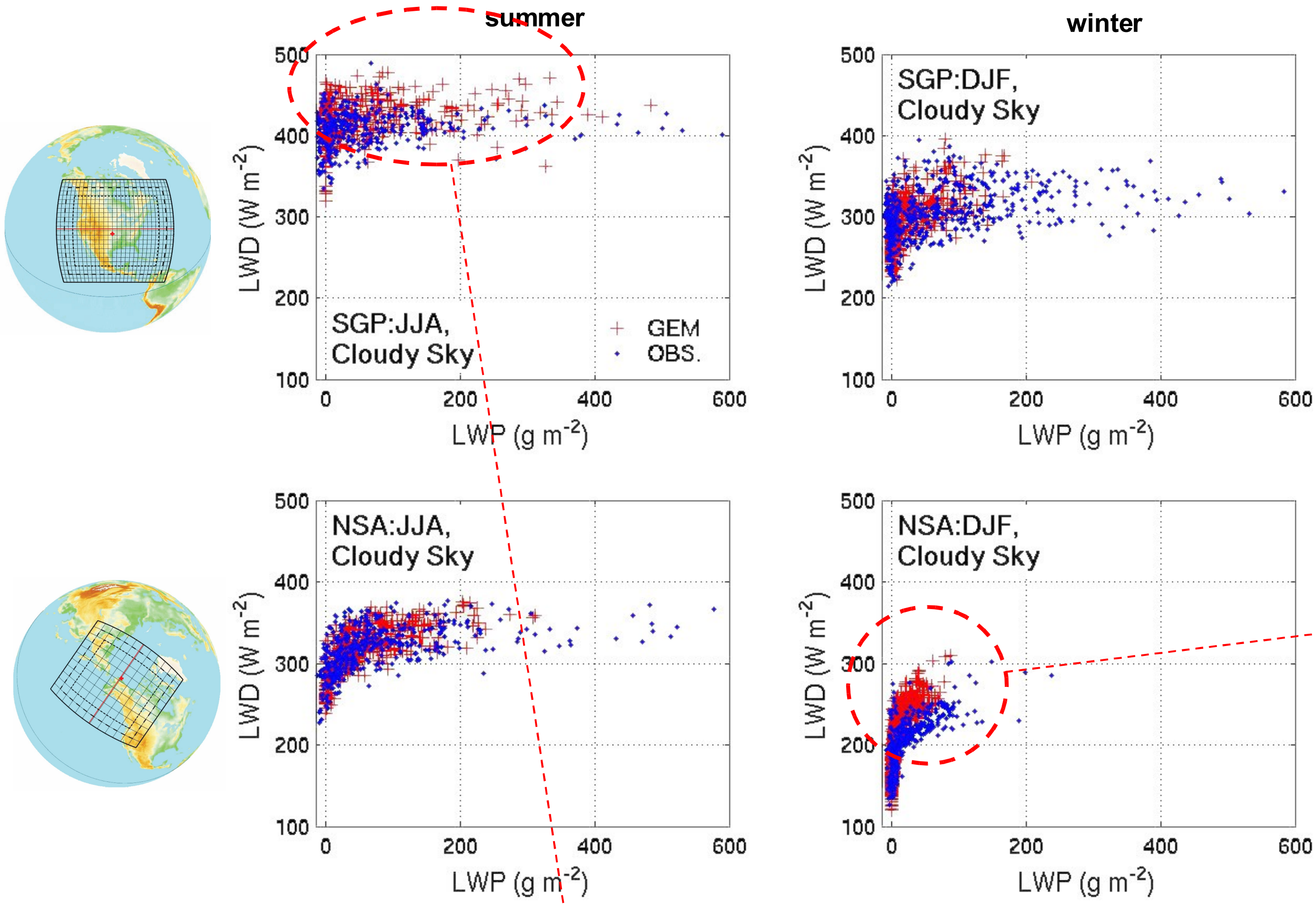


- over-estimated SWD for LWP < 100 g/m²
- hypothesis: parametrisation for effective radius of liquid droplets fails for low values of LWP

***Note**: SZA = solar zenith angle ; "cloudy sky" = cloud fraction > 90%*

Example: Co-variability between **LWP** and **LWD** for cloudy-sky conditions

▪ observations
\+ model



- over-estimated LWD, possibly due to contribution from clear-sky portion

- over-estimated LWD, possibly due to warm bias near-surface temperature

The behaviour of GEM-LAM over the Arctic using different simulation domains

CRCMD
Canadian Network for Regional Climate Modelling and Diagnostics

Minwei Qian,
Colin Jones and Katja Winger

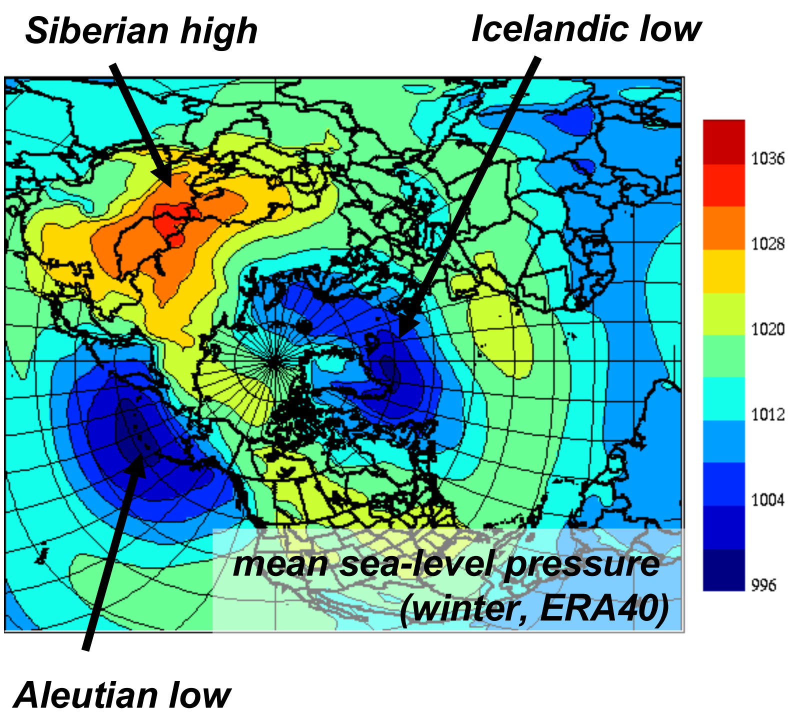
UQÀM

Motivation

• **Icelandic low**: associated with storm track and cyclonic activity in North Atlantic, and with winter anomalies in the Arctic climate.

• **Change in cyclonic activity** in that region is expected, as a result of **climate change** (changes in baroclinicity).

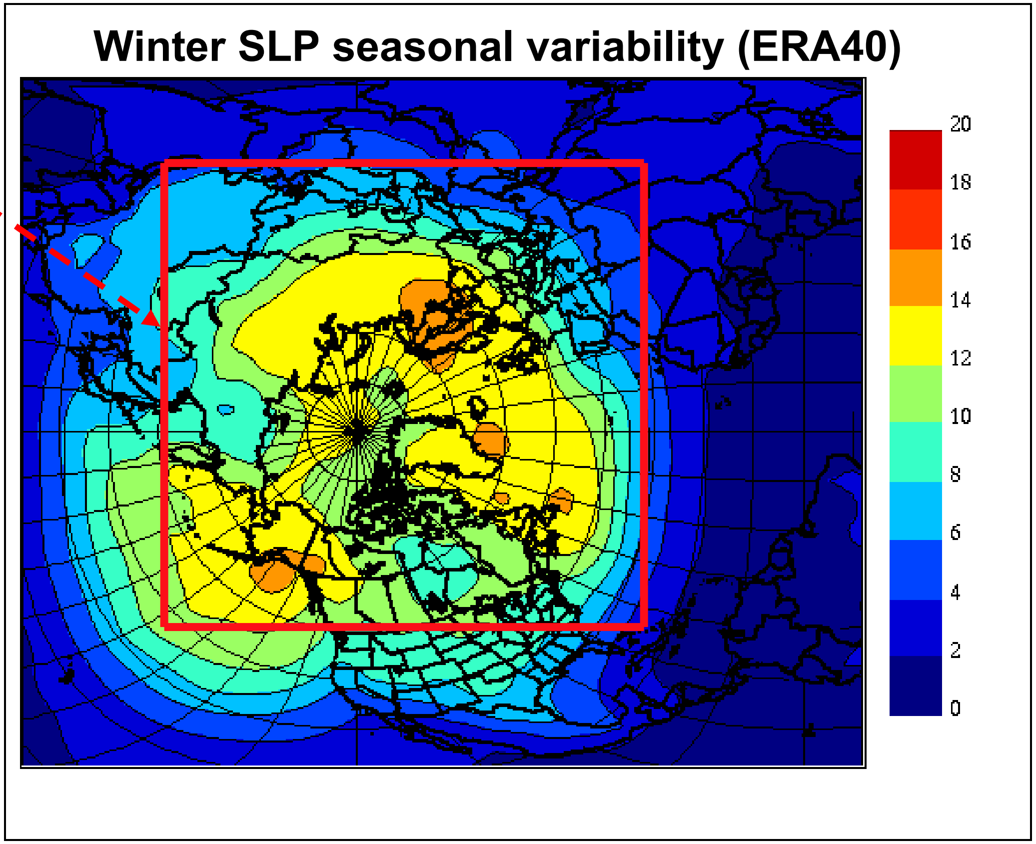
• Thus the interest in correctly simulating the Icelandic low and the Arctic climate.



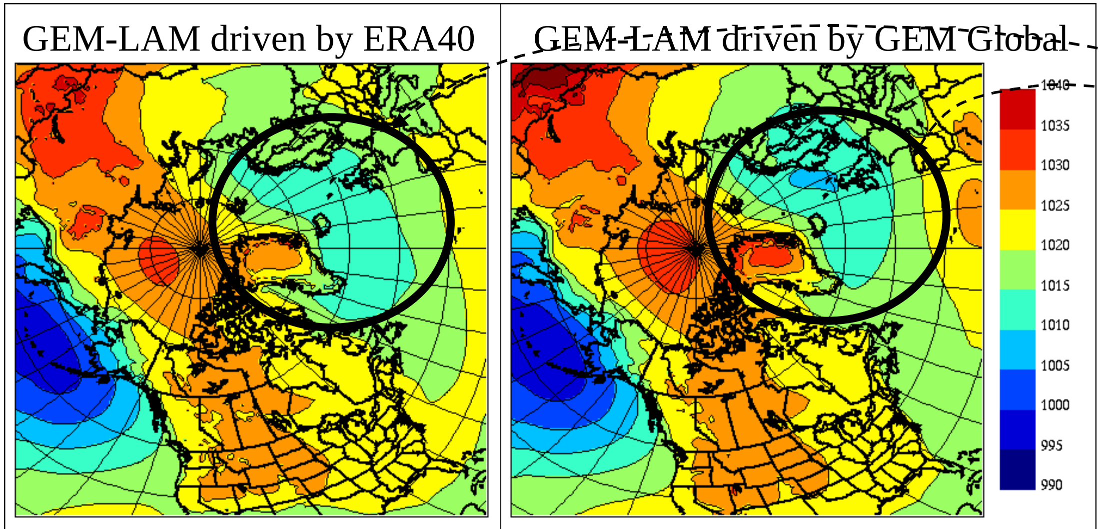
Configuration of the first simulation with GEM-LAM

- domain: chosen to cover storm tracks

- gridpoints: 216 x 208
- resolution: 0.5º
- time step: 20 min
- period: 1979 - 2001 +18 months (spinup)
- pilot: ERA40 or global GEM (2º)

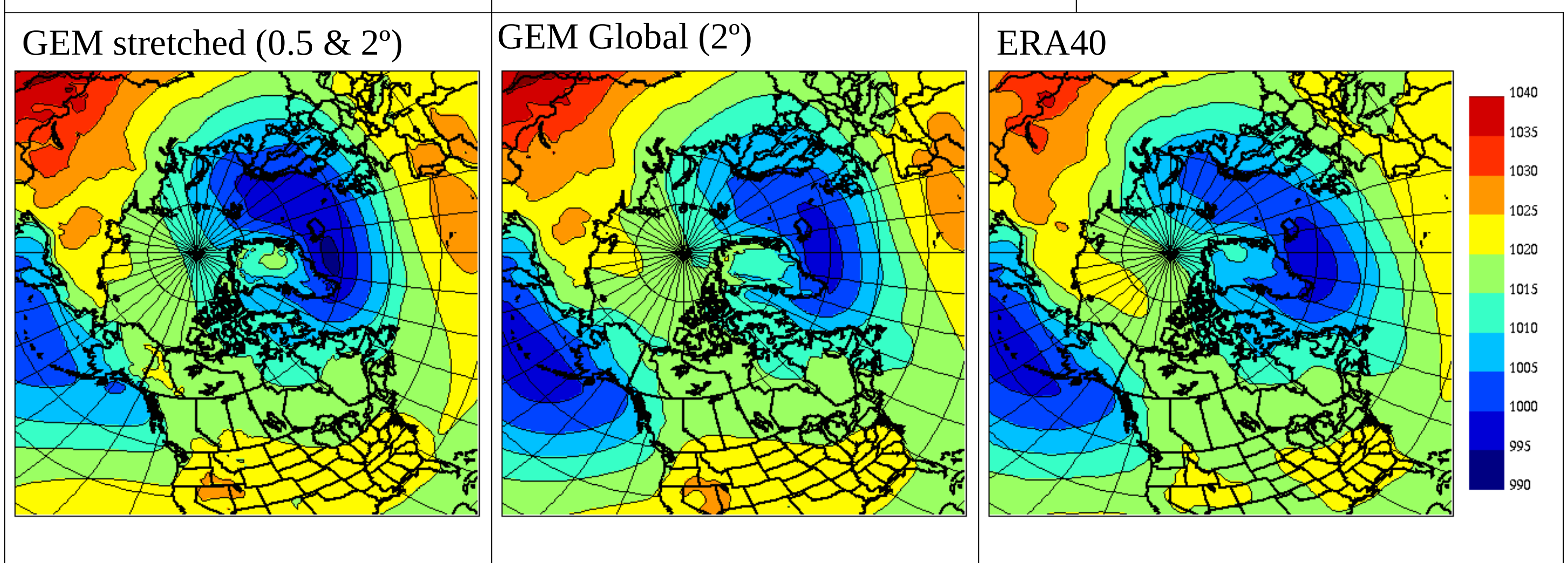


Results from the first simulation with GEM-LAM and comparison with other simulations: average winter (DJF) SLP for 1979-2001

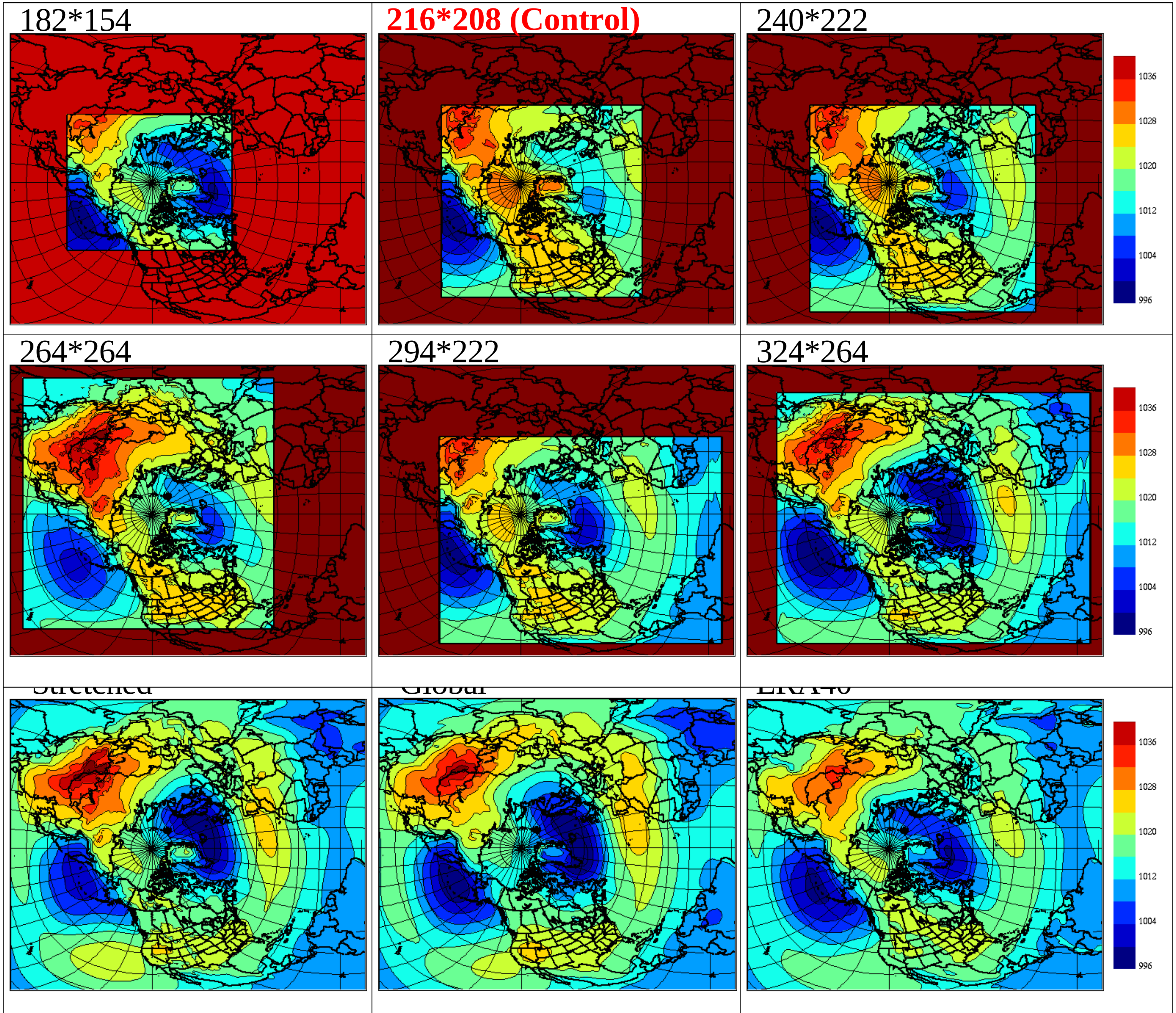


- GEM-LAM underestimates depth of Icelandic low, whereas GEM global (uniform and stretched) don't

- Possible reason: critical baroclinicity information not adequately transferred through lateral boundaries?



Results from other simulations with GEM-LAM



average winter (DJF) SLP for 1979-2001

Summary of Arctic experiments

• Various parameters (seasonal and interannual variability of various fields at various levels, timeseries of SLP near Iceland, etc.) were considered and diagnosed, for all simulations and for ERA40

• Results are improved when simulation domain of GEM-LAM is extended (compared to first simulation) and are **best when the subtropical jet is included in the domain**

• When domain is too small, simulation follows (too closely) the pilot data

• A careful choice of the model domain is essential to correctly simulate the regional climate over the Arctic

• **Note of caution**: results were based on 3-year simulations only

• **Ongoing / future work**: longer simulations; coupling with ocean model; possibly spectral nudging

Evaluation of the stable boundary layer processes in GEM over the Arctic ocean during SHEBA

CRCMD
Canadian Network for Regional Climate Modelling and Diagnostics

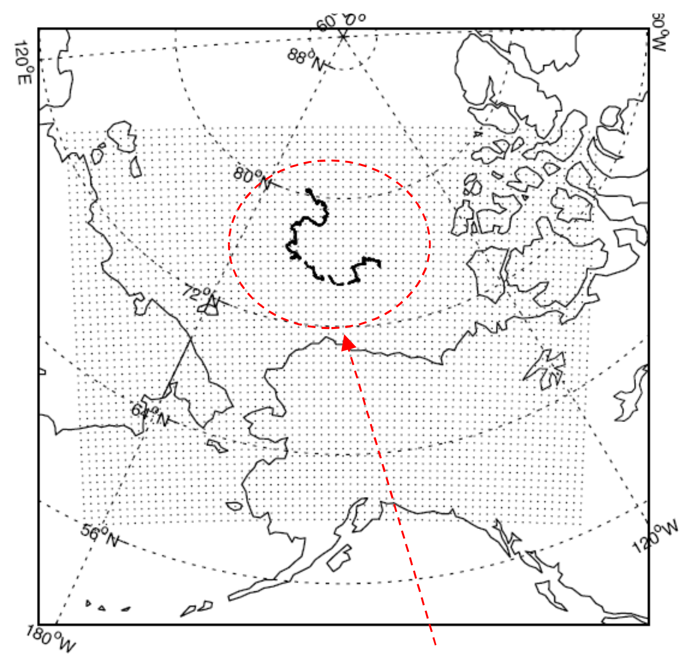
Pierre-Luc Carpentier, Colin Jones

UQÀM

Project objectives

- Evaluate GEM model simulated near-surface climate* and turbulent processes, by comparison with observations from the SHEBA** year

- Study and evaluate sensitivity of GEM simulations to stability functions and roughness length parametrizations

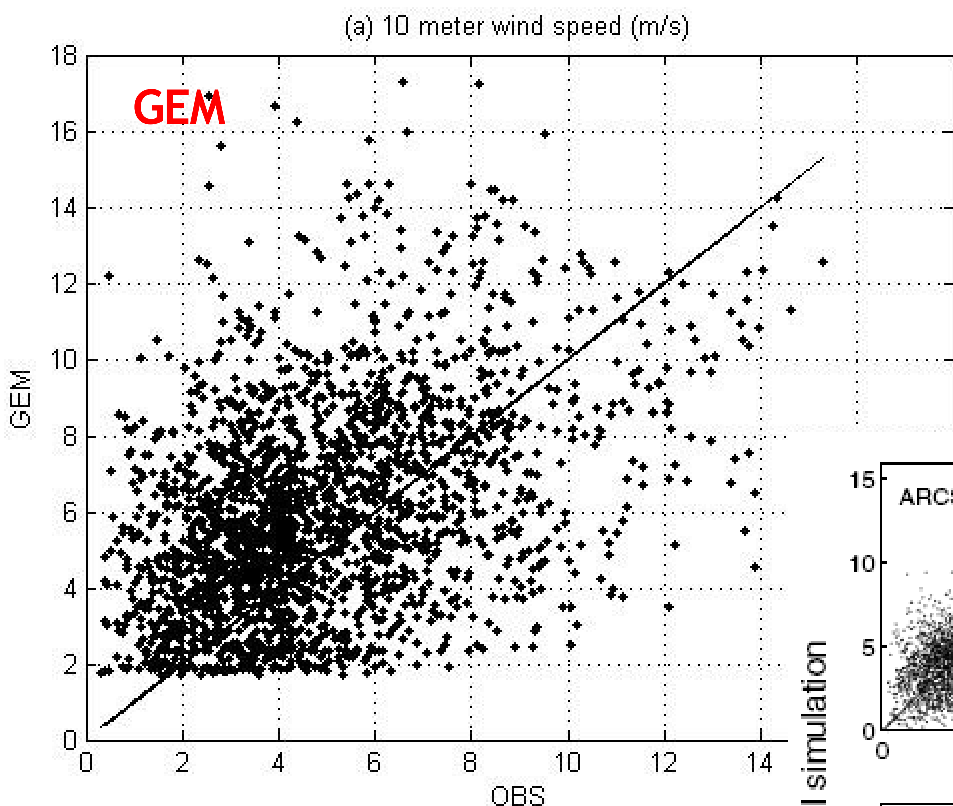


SHEBA ice drift track

**   70 x 80, 0.5º resolution, 53 levels (top 10hPa), timestep 30min, period Sep 1996 – Oct 1998, pilot ERA40*
*** SHEBA = Surface Heat Budget of the Arctic ocean period Oct 1997 – Oct 1998*

Example of results:

10m wind speed (GEM versus OBS)



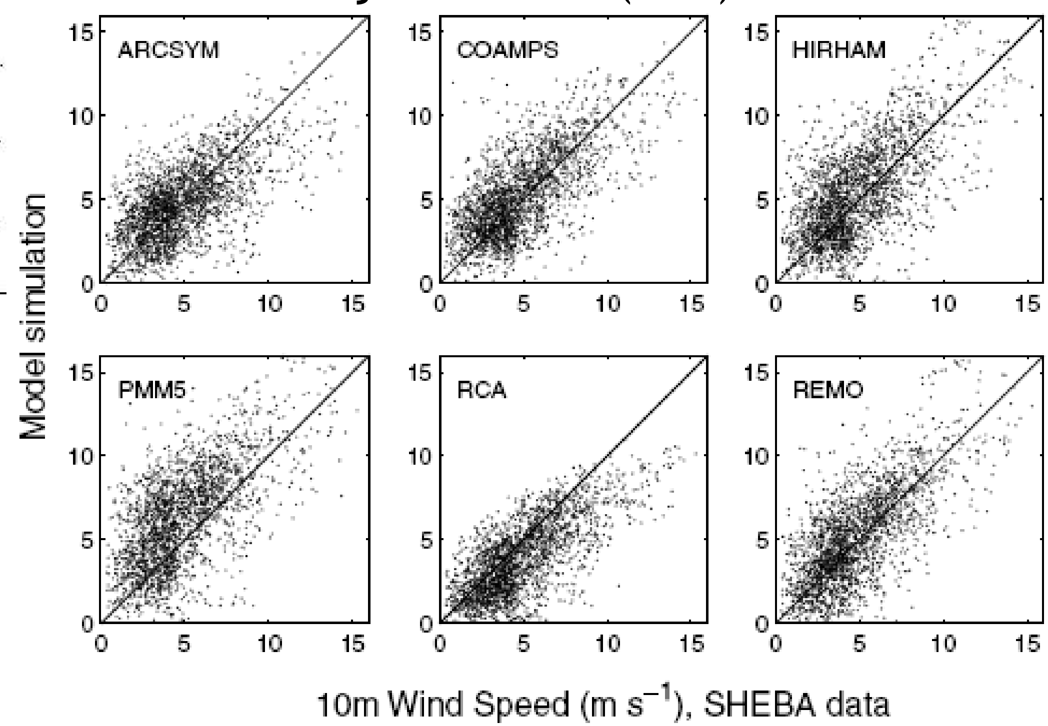
- *large errors under calm conditions*
- *bias: + 1.14 m/s*

vertical profile of wind ***u*** in surface layer

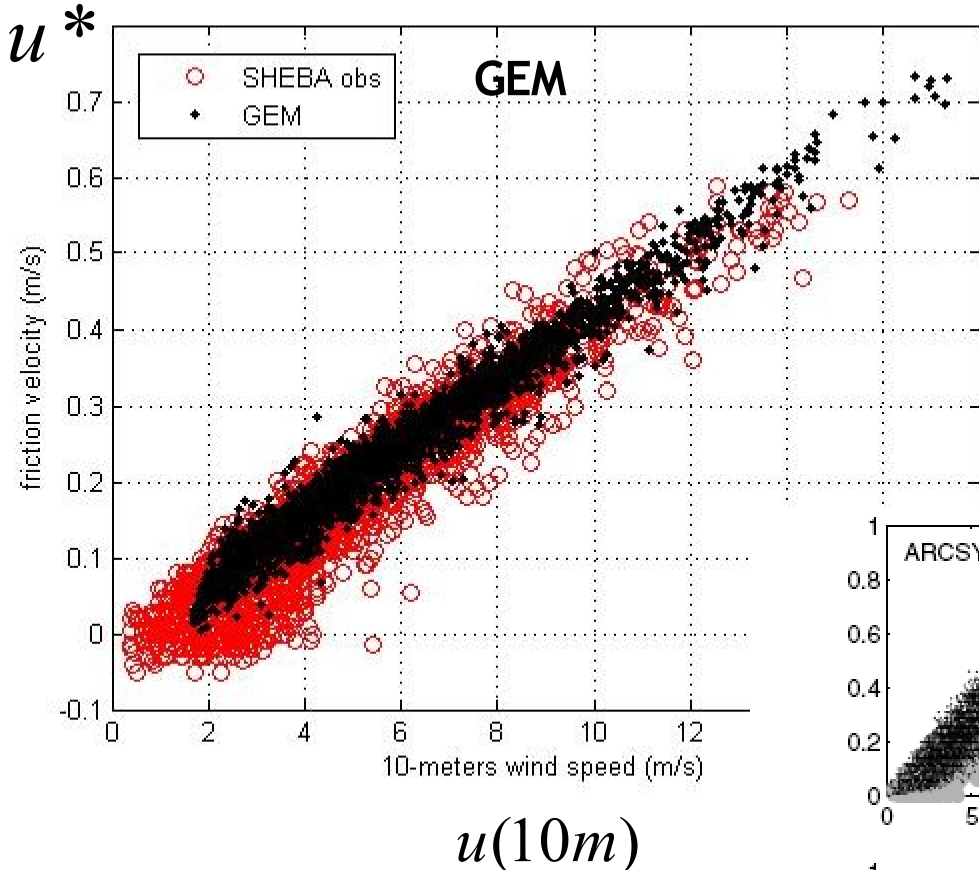
$$u(z) = \frac{u_*}{k}\int_{z_{0M}}^{z+z_{0M}} \left(1 - \frac{z}{h_e}\right)\varphi_M\left(\frac{z}{L}\right)\frac{dz}{z}$$

- friction velocity
- roughness length
- stability function
- von Karman constant
- height of boundary layer
- Monin-Obukhov length

Tjemström et al.(2004)

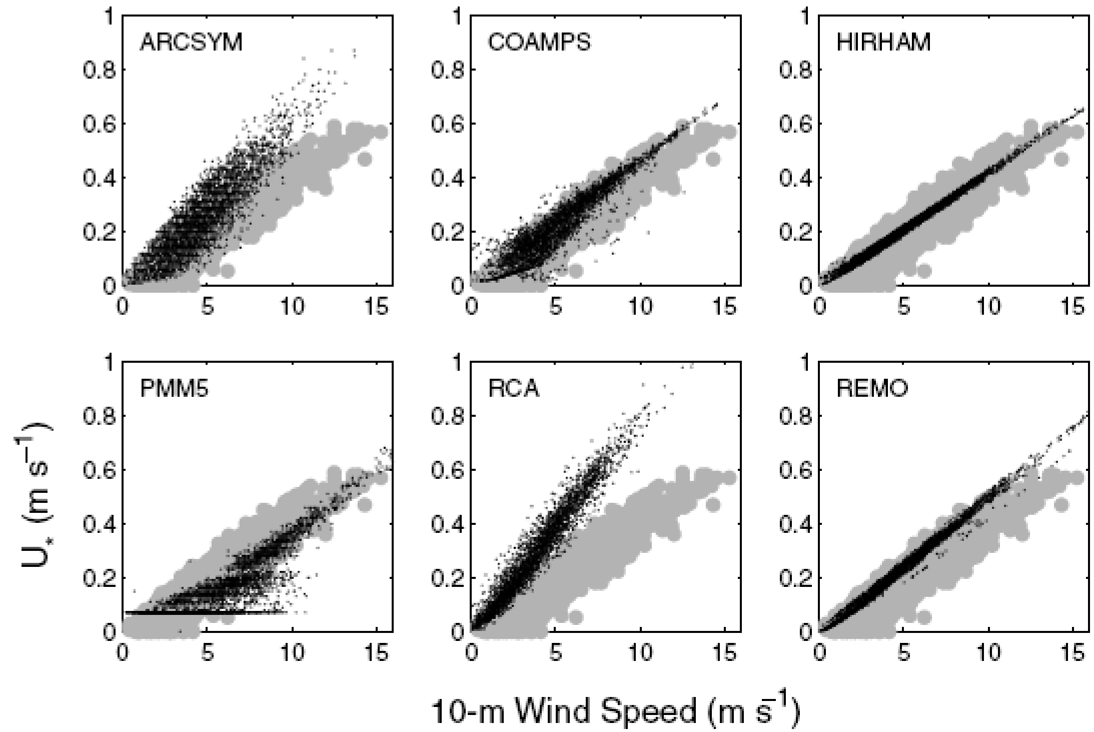


Example of results: covariability of turbulent momentum flux and 10m wind speed (GEM versus OBS)

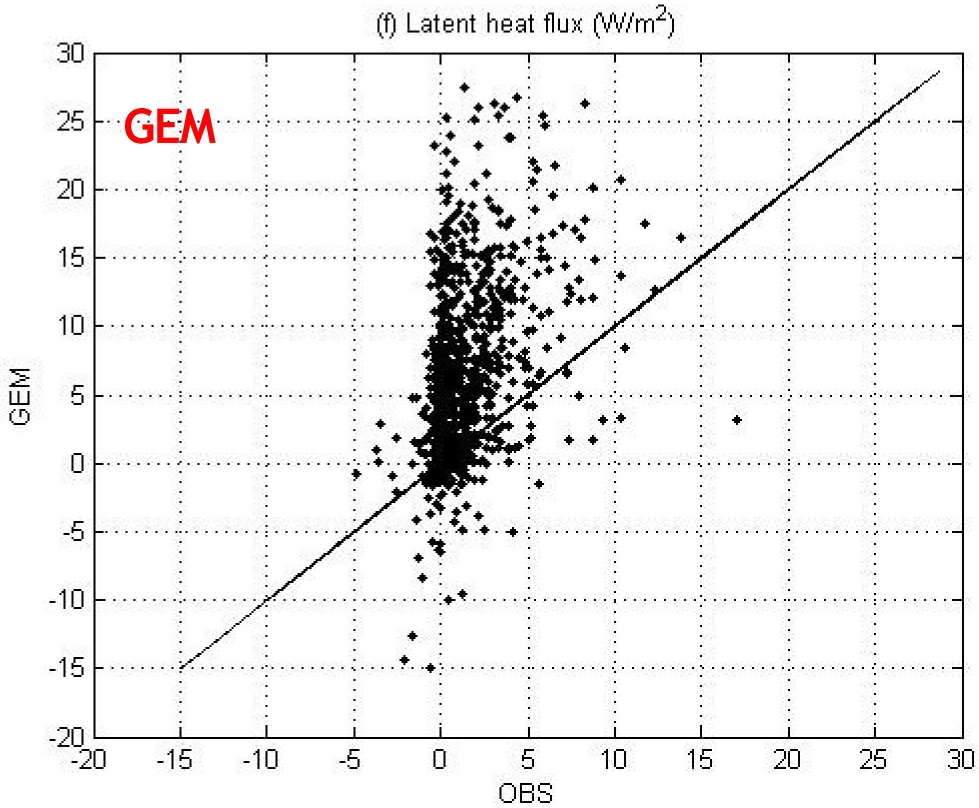


$$u(z)=\frac{u_*}{k}\int_{z_{0M}}^{z+z_{0M}}\left(1-\frac{z}{h_e}\right)\varphi_M\left(\frac{z}{L}\right)\frac{dz}{z}$$

Tjemström et al. (2004)



Example of results: latent heat flux (GEM versus OBS)



- *latent heat flux largely overestimated*
- *bias: + 4.03 W/m²*

Surface wind probability distributions over N. American regions: observations and RCM simulations

Yanping He (Postdoc, UVic), Adam Hugh Monahan (UVic),
Colin Jones (UQAM), Aiguo Dai (NCAR), Sebastien Biner (Ouranos), Daniel Caya (Ouranos)

Objective

Study **10m wind probability distributions** generated by **3 RCMs** (RCA3, GEM-LAM and CRCM4) and compare with distributions derived from **observations** (weather stations) and **analyses** (ERA40 and NCEP).

Methodology

Model data

- 0.5º resolution
- 3-hourly 10m winds
- nearest gridbox to obs station within 100km

Analyses (ERA40, NCEP)

- 2.5º resolution
- 6-hourly 10m winds

Period: 1979-1999

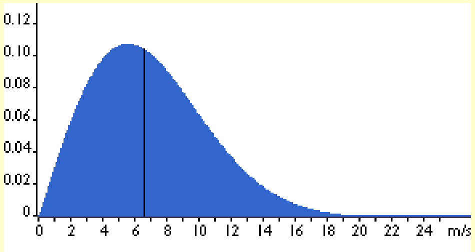
Choice of gridpoint values for comparison

- nearest gridbox to obs station within 100km

Stations and dominant surface type

- forest: 206
- open land: 440
- open water: 130

Weibull distribution



$$F(u) = \frac{k}{\lambda}\left(\frac{u}{\lambda}\right)^{k-1} e^{-(u/\lambda)^k}$$

$k =$ **shape parameter**

$\lambda =$ **scale parameter**

Day time (solid) and night time (dashed) summer PDFs of 10m wind over forest (left) and open water (right)

OBS

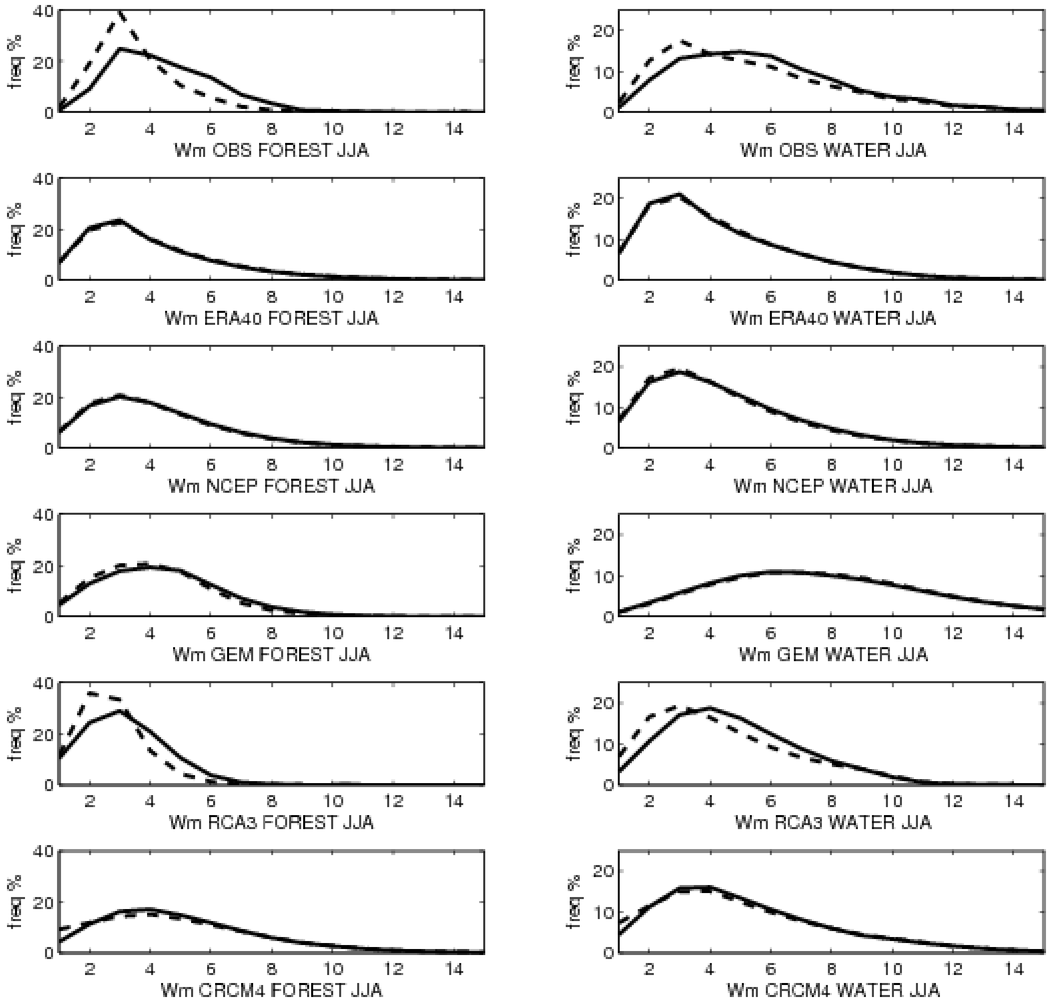
ERA40

NCEP

GEM

RCA3

CRCM4



day time

night time

GEM fails to show the observed day-night difference

dominant surface type: forest

dominant surface type: open water

Night time PDFs of 10m wind over forest (solid), open land (dashed) and open water (solid-star); for winter (left) and summer (right)

OBS

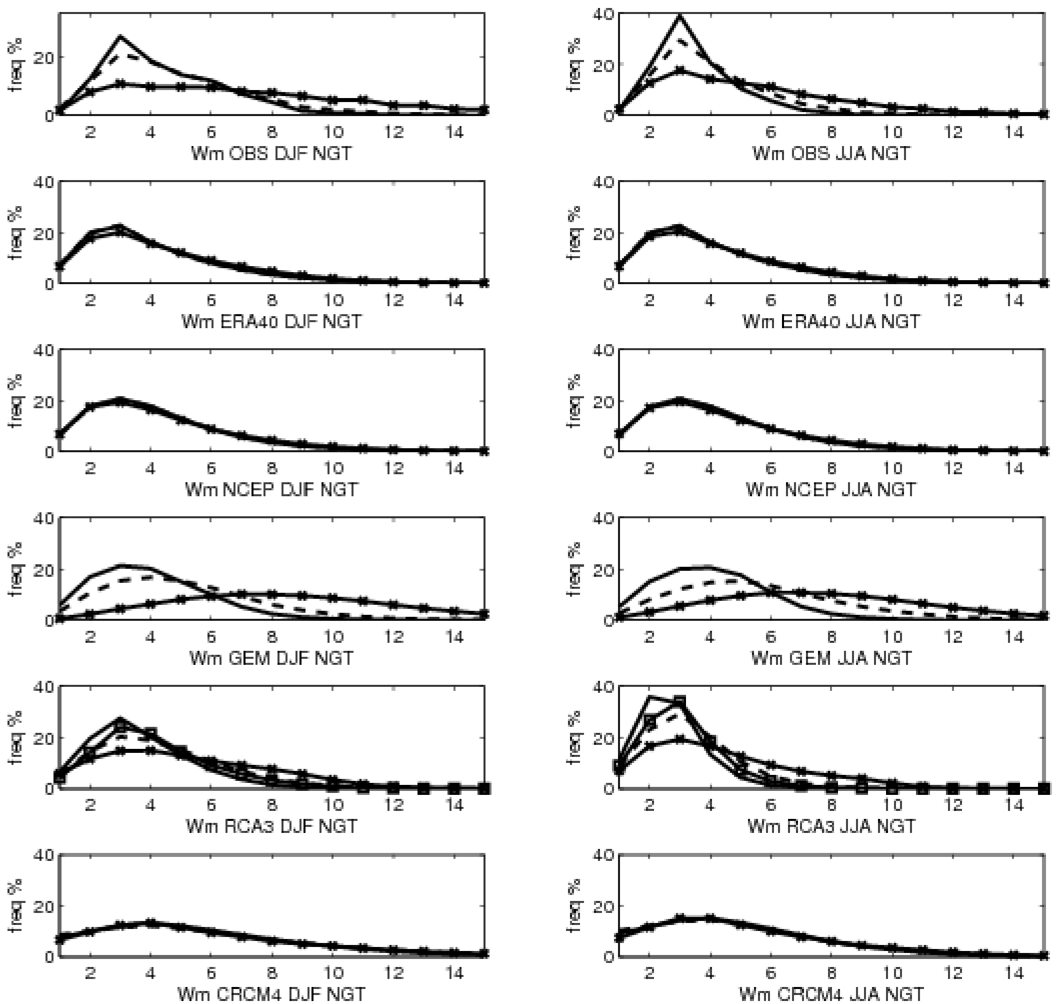
ERA40

NCEP

GEM

RCA3

CRCM4



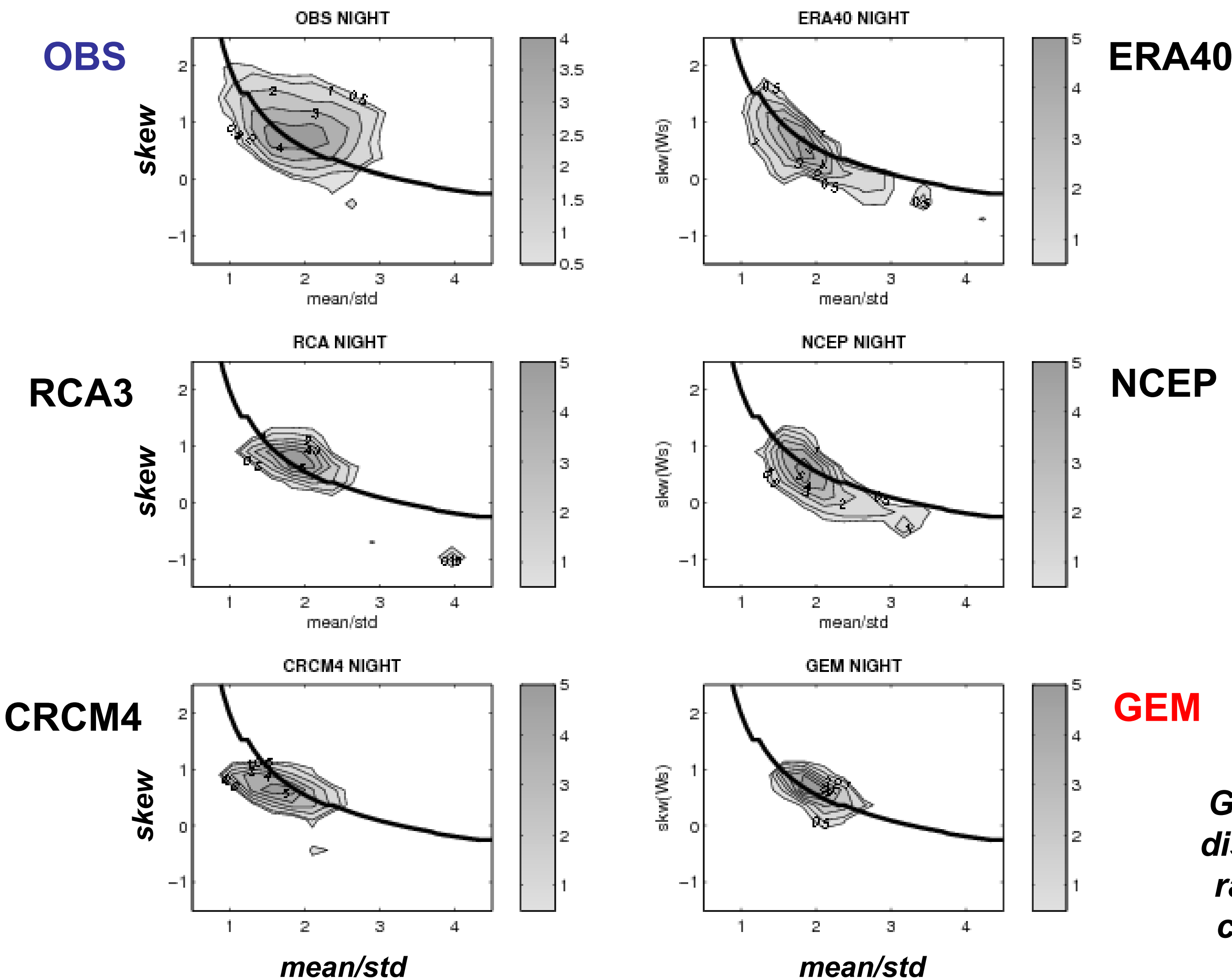
forest
open land
open water

GEM able to represent observed differences over various surface types

winter

summer

Relationship between grid-point skewness of night-time 10-m surface wind and its normalized (mean/std) value



$$\mathbf{mean} = \mu = \frac{1}{N}\sum x_i$$

$$\mathbf{std} = \sigma = \left[\frac{1}{N-1}\sum (x_i-\mu)^2\right]^{1/2}$$

$$\mathbf{skew} = \gamma = \frac{1}{N}\frac{\sum (x_i-\mu)^3}{\sigma^3}$$

GEM simulates Weibull-like distribution, but with narrow range and small skewness compared to observations

A study on tropical cyclone activity using the GEM model

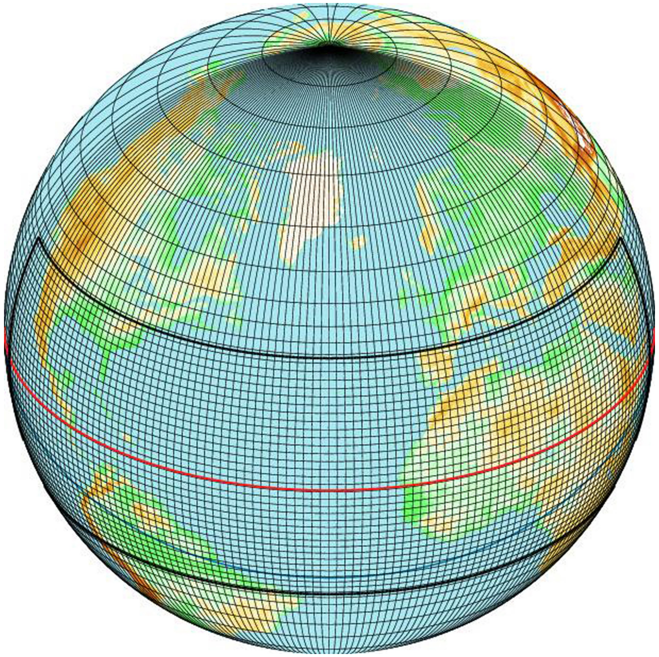
CRCMD
Canadian Network for Regional Climate Modelling and Diagnostics

Louis-Philippe Caron and Colin Jones

UQÀM

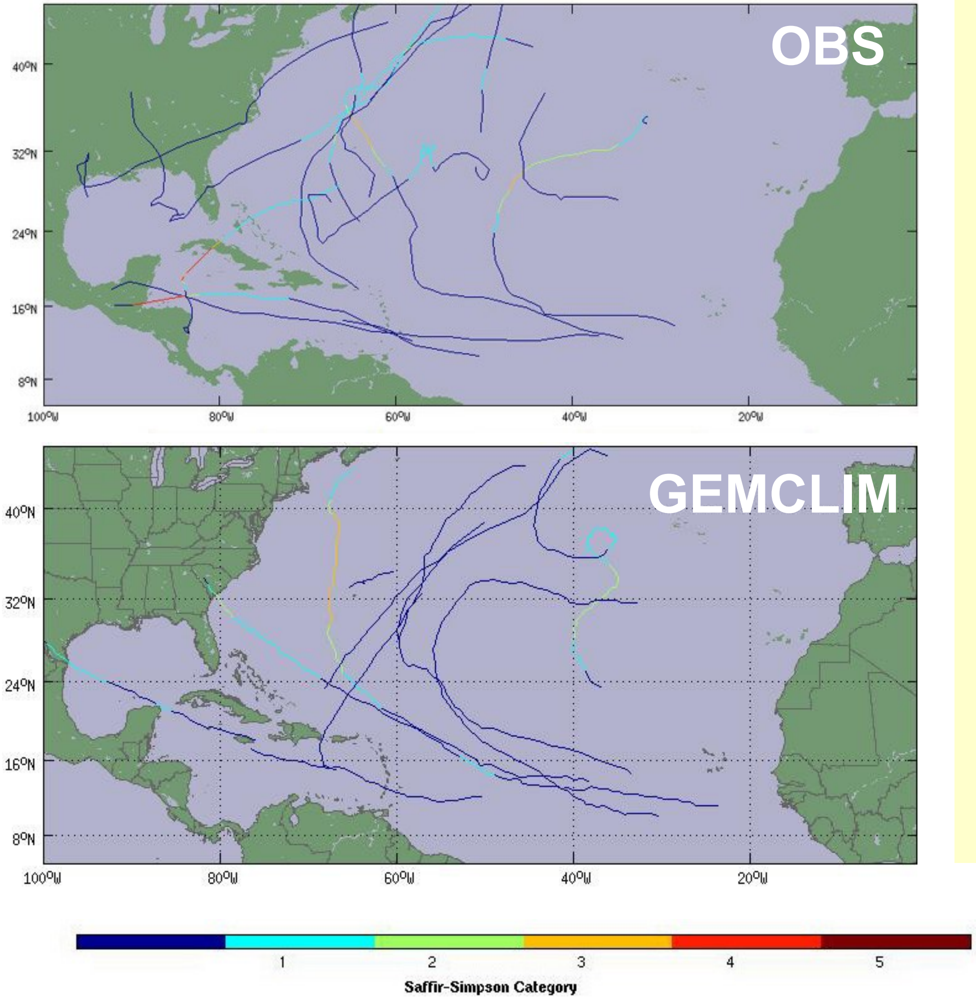
Goals and methodology

- First step: Evaluate the ability of GEM to simulate past observed Atlantic tropical cyclone (TC) activity
- Integration period: 1979-2004
- Prescribed SSTs
- Comparison with observations:
  - frequency of occurrence
  - wind speed distribution
  - minimum central pressure distrib.
  - tracks
  - intra- and inter-annual variability

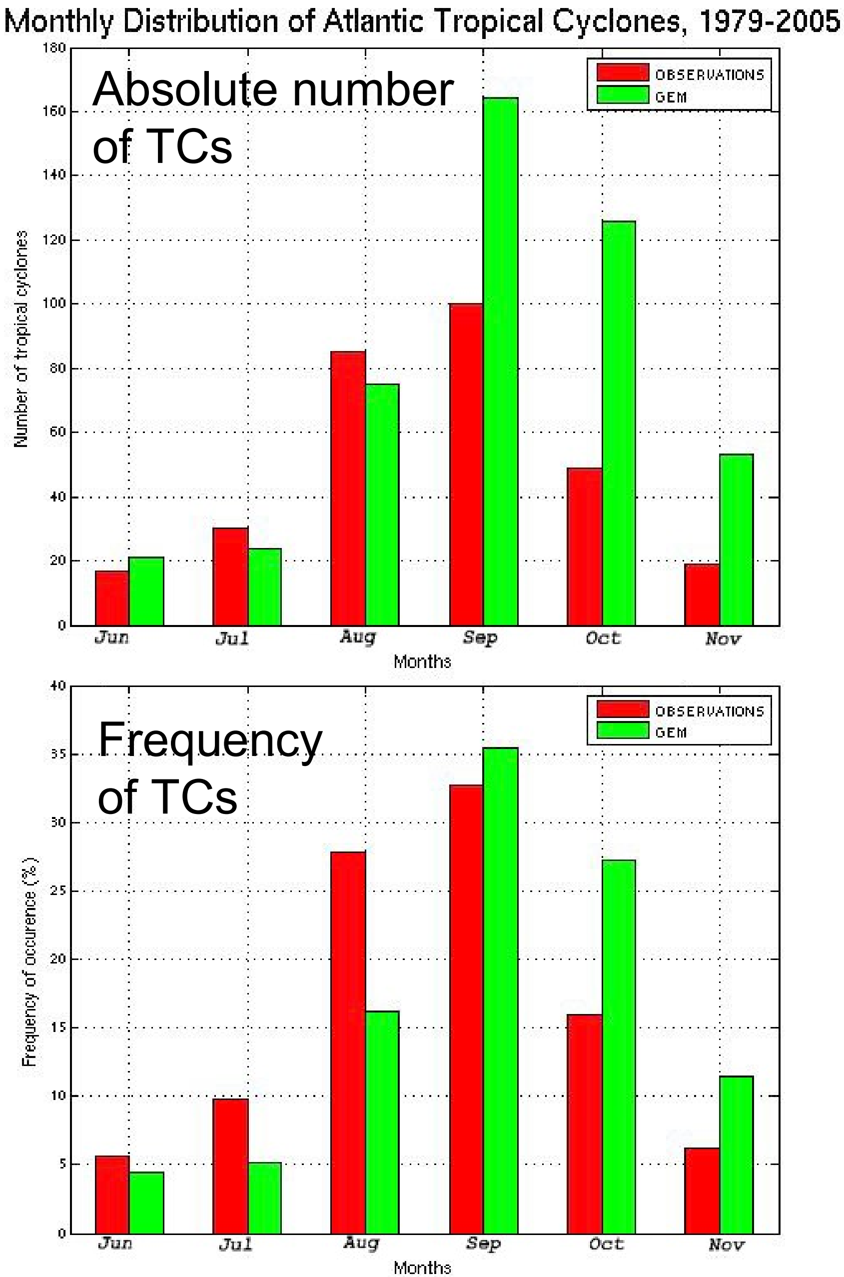


Streched grid (0.3º – 2º) used in this hurricane study. The high-res area covers the entire TC track in the Atlantic.

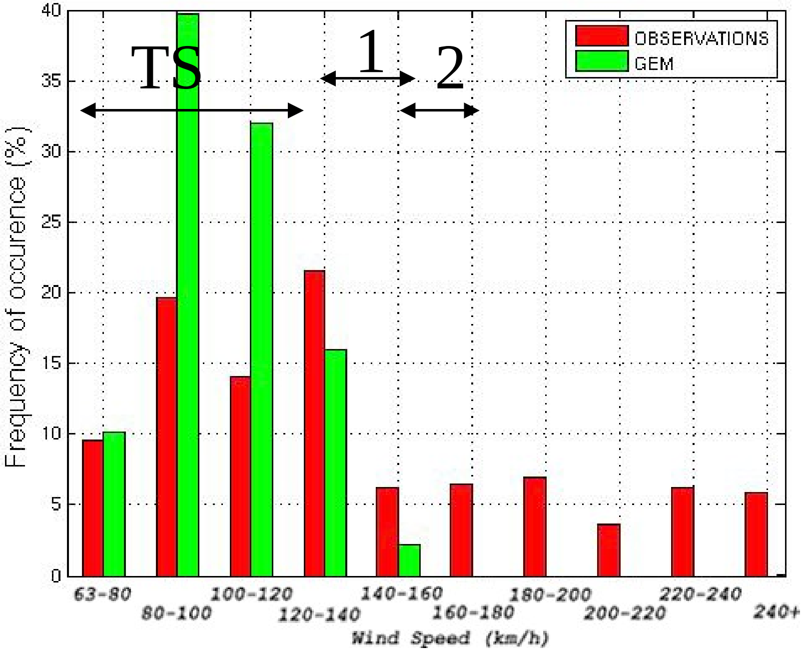
Tropical Cyclones Tracks

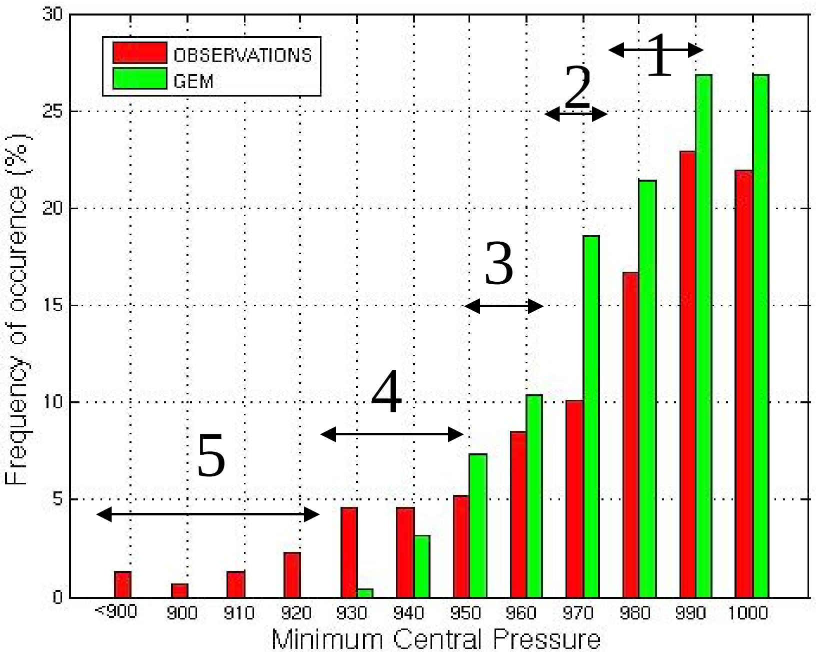


- Upper left: observations
- Lower left: GEMCLIM
- Year: 2001
- Intensity of GEM based on minimum central pressure
- Good reproduction of cyclogenesis originating from African Easterly Waves



- Intraseasonal distribution of tropical cyclones
- Upper left: absolute numbers
- Lower left: relative numbers
- Seasonality well reproduced, but biased activity towards end of season
- Absolute number of TCs too high
- Matter under investigation





- Intensity comparison: observations vs GEM
- Based on maximum wind speed: up to category 1
- Based on minimum central pressure: up to category 4
- Possible explanation: maximum wind in eye, which cannot be resolved at 33km
- Matter under investigation

TS = Tropical Storm

1, 2, … 5 = hurricane category

Study of the benefits of increased resolution on the precipitation in Sub-Saharan Africa

Anne-Sophie Daloz, Colin Jones

Objective

Various GEM simulations (global uniform at 2° and 1°, and stretched 0.33°-2°) forced by AMIP SSTs for the period 1979-2004 are being analysed to assess the representation of African Easterly waves and the seasonal and diurnal cycle of precipitation over Africa.

Methodology

Climatology (large-scale and convective precipitation; fequency distribution and histograms) and interannual variability (Hovmoeller diagrams of meridional winds and precipitation).

Observations / analyses from:

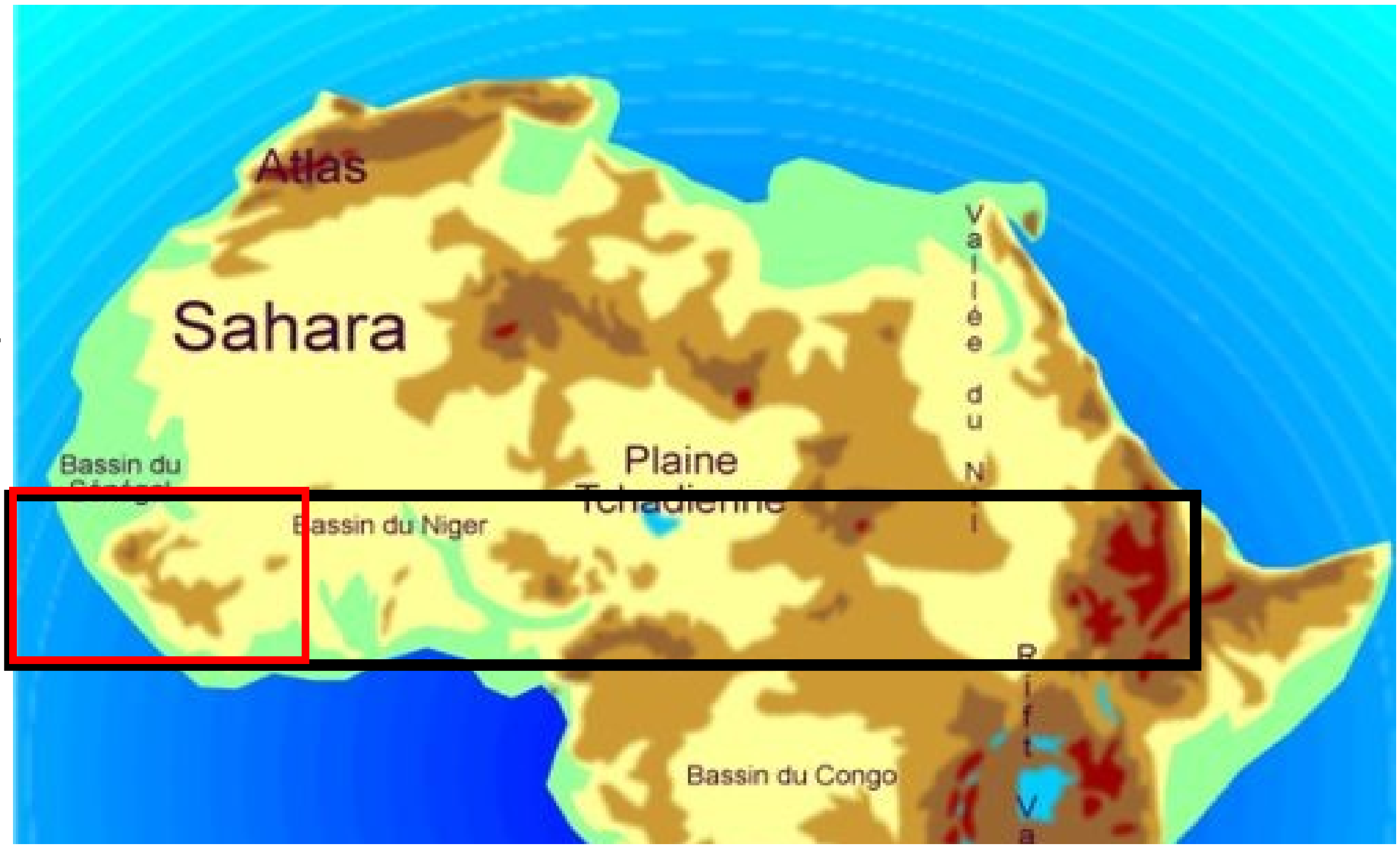
- **TRMM** = Tropical Rainfall Measuring Mission (0.25º; satellite data)
- **GPCP** = Global Precipitation Climatology Project (2.5º; satellite, gauges, etc.)
- **ERA40** = ECMWF reanalyses (for meridional wind VV)

All data interpolated onto common 1° grid for the period 1998-2003.

Area of climatology study
Zones I & II

Zone I
5°N-15°N
20°W-40°E

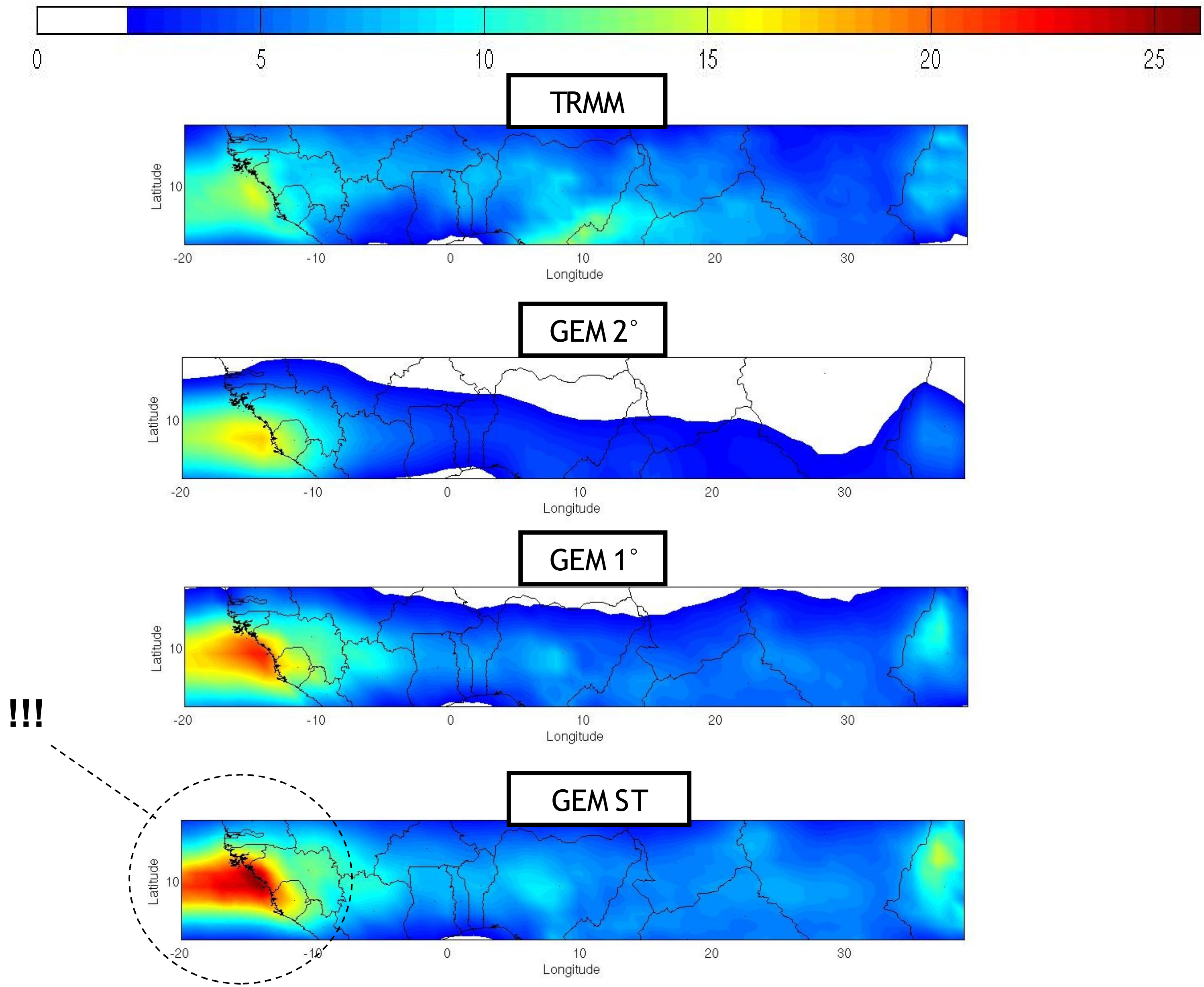
Zone II
5°N-15°N
20°W-8°W



TRMM

Climatological Mean JAS 1998-2003 (Zone I)

Precipitation (mm/day)

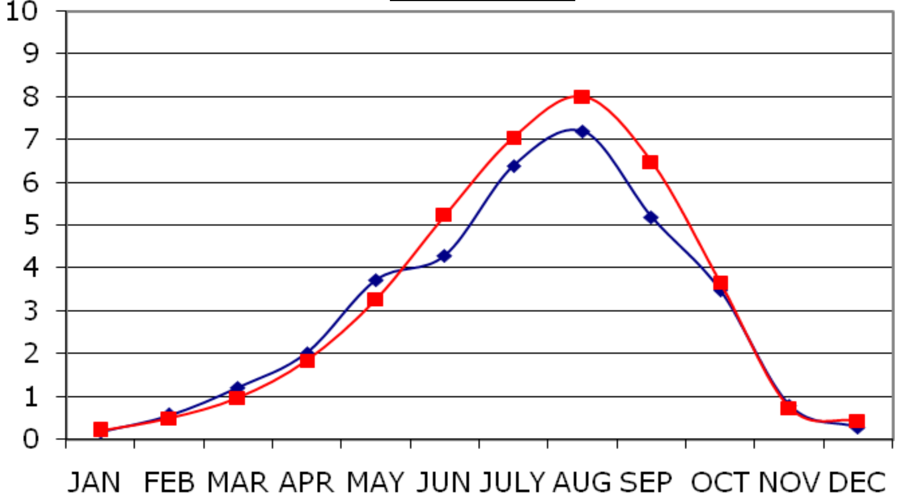


Averaged cycle of precipitation (Zone I)

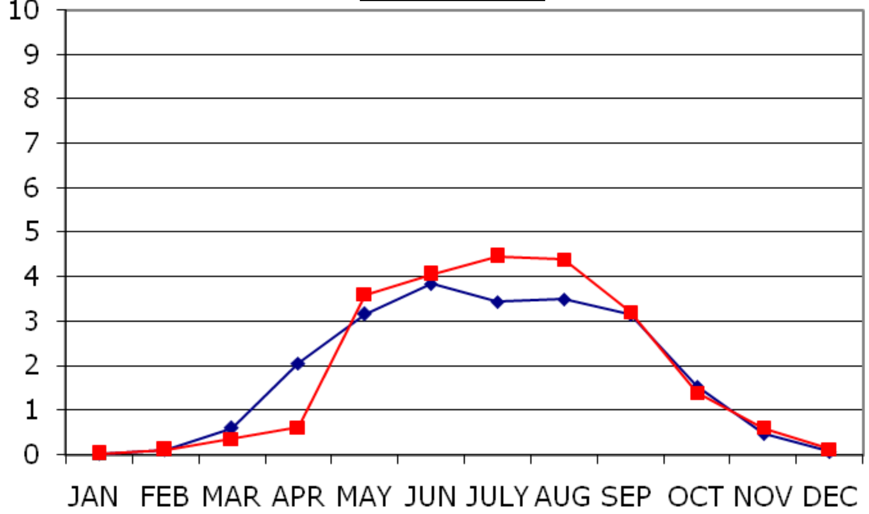
GPCP

1988, 1995, 1999 = Wet Years &
1982, 1986, 1991 = Dry Years Precipitation (mm/day)

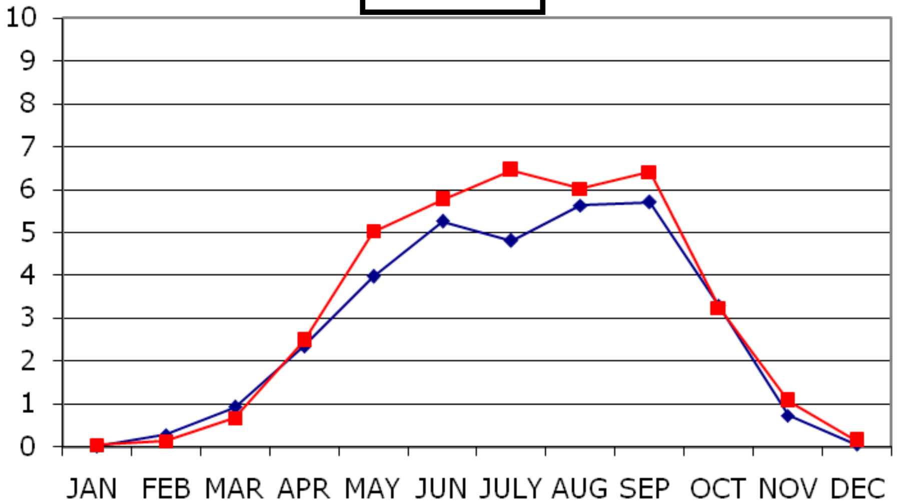
GPCP



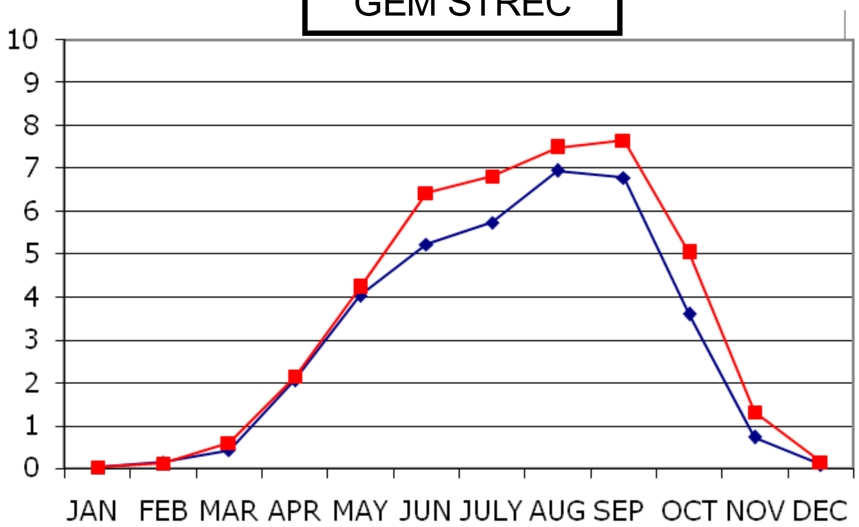
GEM 2°



GEM 1°

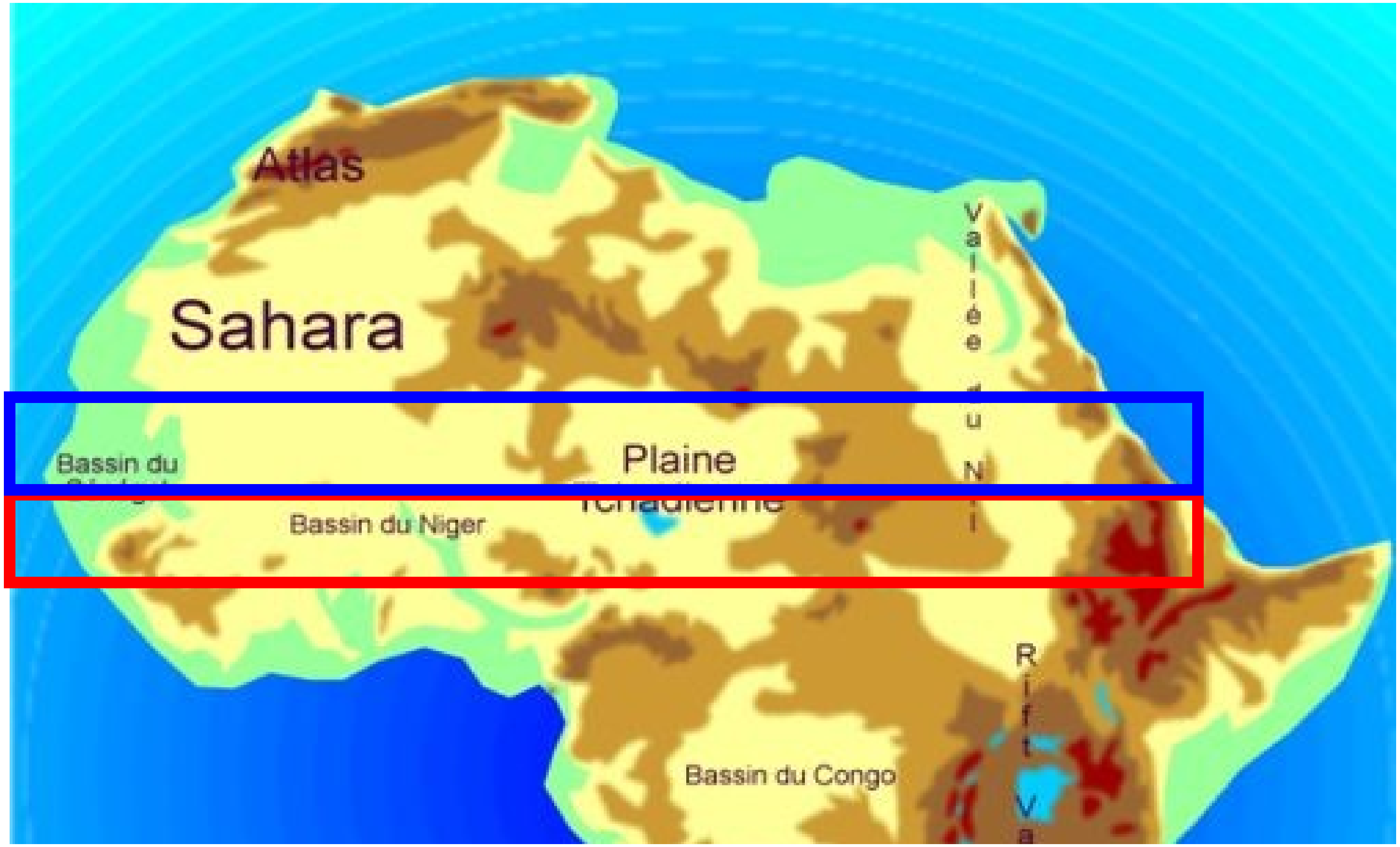


GEM STREC



Area of variability study
Zones 1 & 2

Zone 1
Wet
Zone 2
Dry

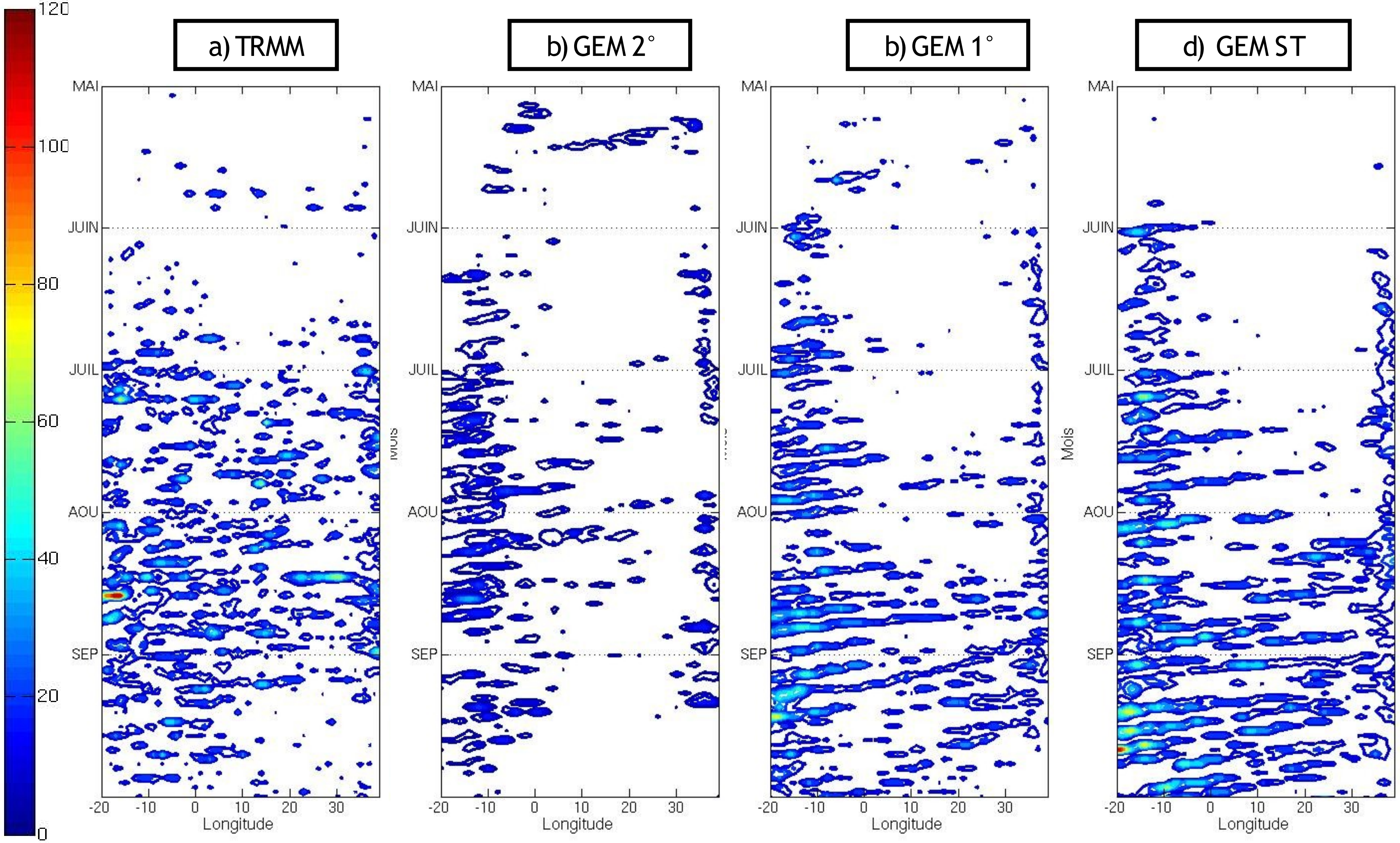


Hovmöller Diagrams (Zone 1)

TRMM

1999 = Wet Year

Precipitation (mm/day)



Implementation & Validation of CLASS v3.3.0 in GEMCLIM v3.3.0 at UQÀM

Jean-Philippe Paquin, MSc., Research Assistant

1st Problem

- Integration is done => results physically impossible (next slide)
- Communication/memory problems supposed between ISBA, CLASS and GEM variables

2nd Problem

GEM-CLASS crashes when ocean points are present in the domain.

3rd Problem

MPI problems with CLASS
Mostly Solved (Luis Duarte, UQAM)

GEMCLIM3.3.0-CLASS3.3.0

– Code works at UQAM (B. Dugas)

– No validation done (J.-P. Paquin)

– CLASS3.3.0 works in stand-alone mode no feedback on GEM (V. Fortin)

– Last coupled version : GEMCLIM3.2.2-CLASS3.0.1 (V. Fortin)

Very important RPN collaborators to the project

2. Bernard Dugas
3. Katja Winger

Project Hydrology/Oceanography in the Arctic

Implementation & validation of a dynamic river routing scheme in GEM and sensibility of the thermohaline oceanic circulation of the Arctic Ocean to surface runoff

CRCMD Canadian Network for Regional Climate Modelling and Diagnostics

Jean-Philippe Paquin, L. Sushama and R. Laprise

UQÀM

1st Objective

Implement WATROUTE in CLASS & validate river runoff using for major Arctic Basin Rivers : Mackenzie, N Diva, Ob Yenisey, Lena, Kolyma, (and potentially others)

Methodology

- GEM coupled with CLASS-WATROUTE
- Approaches : constant 0.5º river mesh or adaptative to model resolution

Collaboration :
E. Soulis (U. Waterloo, potential co-supervisor)
Project with 2 MSc students for Canadian River Basins (1 at UQAM, 1 U. Waterloo)

2nd Objective

Evaluate **sensibility of the ocean circulation in the Arctic to changes in runoff** using Rossby Center Regional Ocean Model (RCO)

Methodology

- Stand-alone RCO simulations with runoff prescribed at river mouths
- Coupled GEM-RCO regional coupled system

Collaboration :
B. Tremblay (U. McGill, potential co-supervisor)
C. Jones (Rossby Center)

Implementation of an updated Bechtold-Kain-Fritsch mass flux convection scheme in GEM and evaluation along a cross-section over the Pacific Ocean

CRCMD
Canadian Network for Regional Climate Modelling and Diagnostics

Yanjun Jiao and Colin Jones

UQÀM

Motivation

Previous results* obtained with CRCM4 and a modified version CRCMM:

- modifications:
  - triggering and closure of **shallow convection**
  - cloud and updraft characteristics of **deep convection**
  - parametrization of large-scale **cloud fraction**
  - calculation of eddy diffusivity in **boundary layer**
  - evaporation of falling **large-scale precipitation**
- **improvements found in CRCMM over tropical Pacific**:
  - seasonal mean cloud, convection and precipitation
  - total column water vapour, total cloud cover
  - maximum frequency of shallow convection shifts from ITCZ region to subtropics
  - representation of clouds in shallow cumulus region
  - vertical structure of relative humidity, cloud cover and vertical velocity

* *Jiao, Y. and C. Jones, 2008: Comparison studies of cloud and convection related processes simulated by the Canadian Regional Climate Model over the Pacific, MWR, accepted.*

Analysis of Internal Variability of a Regional Climate Model using Singular Vectors

CRCMD Canadian Network for Regional Climate Modelling and Diagnostics

NSERC CRSNG

Emilia Paula Diaconescu, René Laprise
and Ayrton Zadra

UQÀM

RPN recherche en prévision numérique

Motivation and objectives

- Due to nonlinearities, RCM simulations are characterised by **Internal Variability** (**IV**)
- Apply the technique of **Singular Vectors** (SV) to study and understand processes leading to periods of large internal variability in CRCM

Methodology

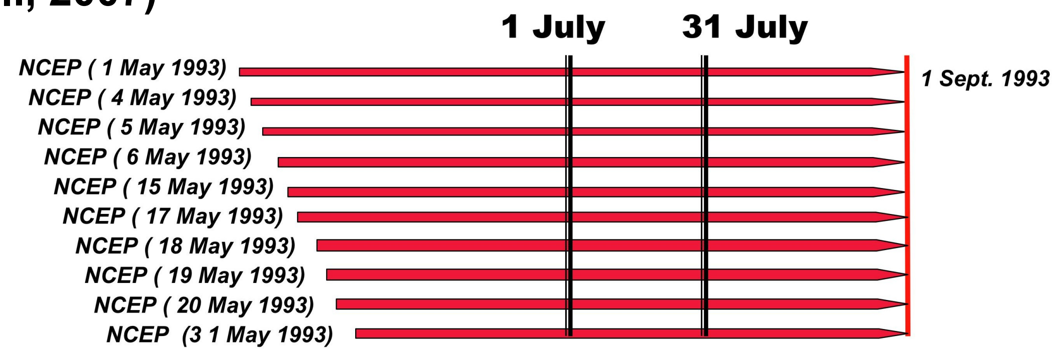
- Identify episodes of rapid growth of IV in CRCM (using available ensemble of simulations)
- Compute a set of SVs for those episodes
- Study the behaviour of an ensemble of simulations, using combinations of SVs as disturbances added to the CRCM nonlinear trajectory
- Analyse to what extend the set of SVs can explain episodes of high IV

Example: An episode with rapid growth of IV in RCM

Classical ensemble:

20 CRMC simulations with different initial conditions beginning in May and finishing 1st September 1993 (from Alexandru and al., 2007)

- **GCMii physics**
- **120 by 120 grid points at 45 Km**
- **18 vertical levels**
- **time step: 15 min**
- **nested by 6-hourly NCEP re-analyses**



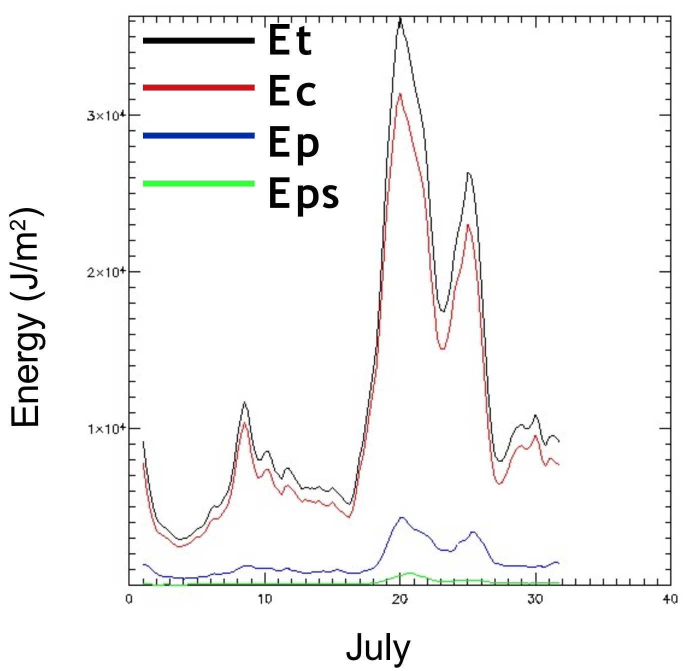


Figure:

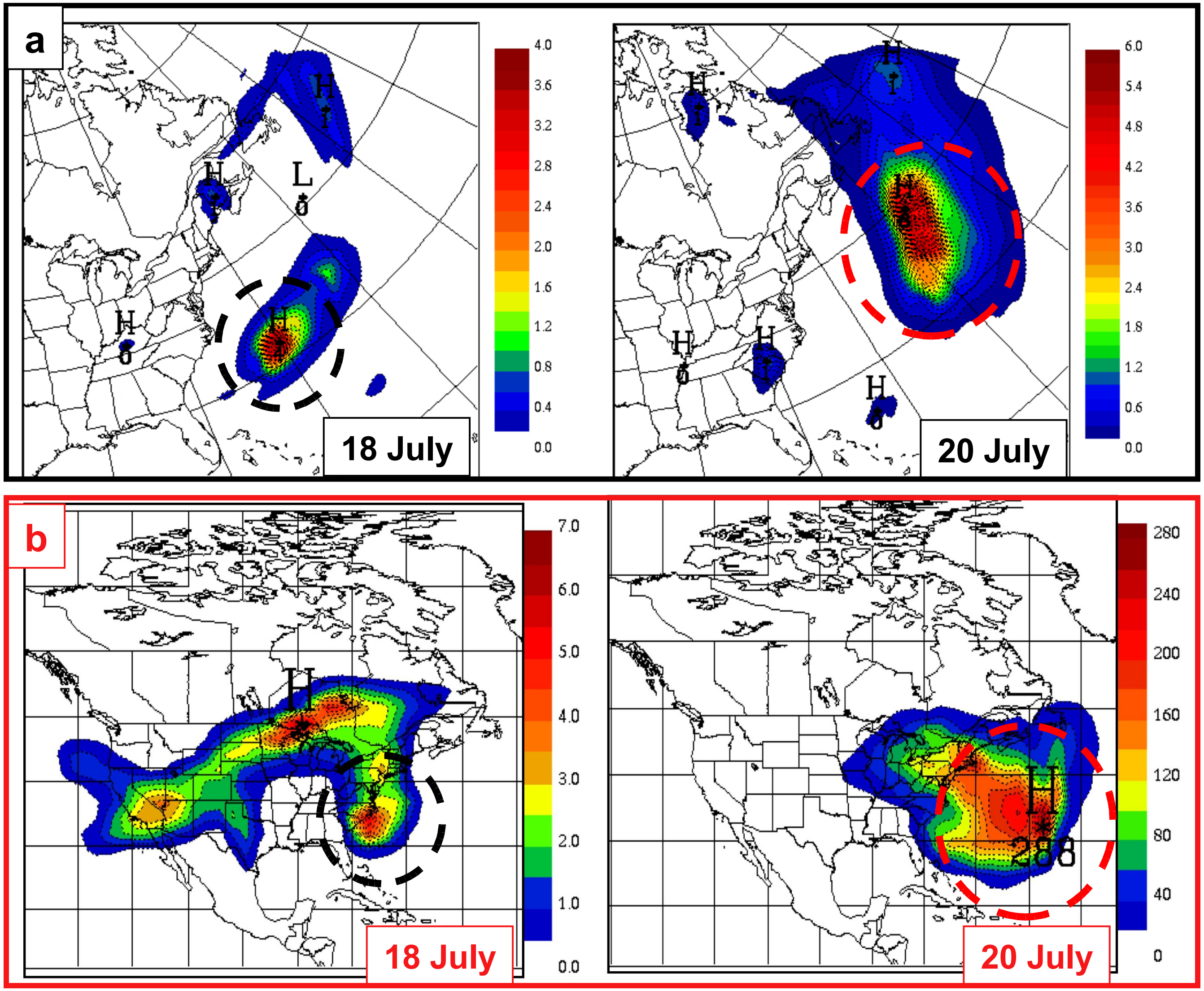
- **Disturbances energy** (volume integral over RCM domain)

- The **maximum growth rate** of energy is found in the period 18 – 20 Jul

- Most of **total energy** is in form of kinetic energy, followed by potential energy, while the surface-pressure term is comparatively negligible

Comparison of total-energy horizontal distribution

➢**Average horizontal distribution of the total energy (x 10^5 J/m^2) for (a) the classical ensemble deviations, and (b) the set of SVs; the vertical integral is made between the 100 hPa and 1000 hPa vertical levels.**



➢**Both the deviations of the classical ensemble energy (a), and the SVs energy (b) exhibit maxima over the Atlantic Ocean. The energy growth rate of SVs is larger than the energy growth rate of ensemble.**

Comparison of two regional climate modelling approaches using the GEM model

Global variable-resolution versus one-way nested limited-area

Marc Verville, René Laprise
Université du Québec à Montréal

Bernard Dugas, Ayrton Zadra
recherche en prévision numérique

Objectives:

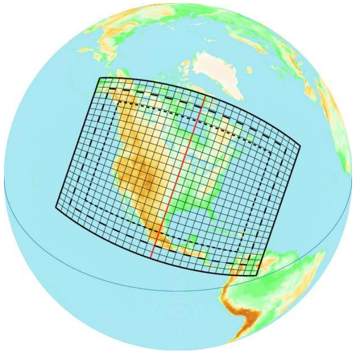
- The objective of this project is to develop objective diagnostic tools to allow this comparison
- These tools will be applied to climatological fields generated by VRGCM and LAM simulations, and will include estimates of significant differences based on the student's t-test, comparison of EOF (Empirical Orthogonal Function) patterns, and comparison of various spectral properties

GEM simulations

Same dynamical core and physics package

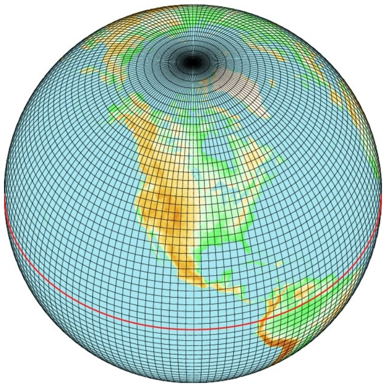
January 1978 to February 2004

GEM-LAM



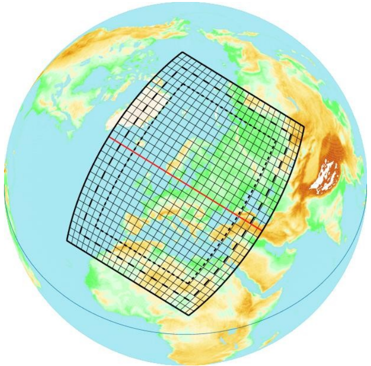
Horizontal resolution : 0.5°
Driver : GEM – 1.5°

GEM-uniform



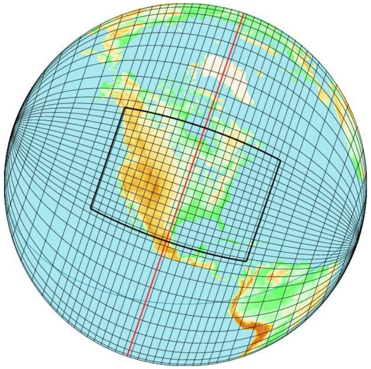
Horizontal resolution : 1.5°

GEM-LAM



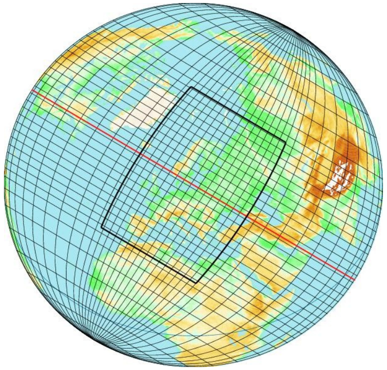
Horizontal resolution : 0.5°
Driver : GEM – 1.5°

GEM-stretched



Horizontal resolution : 0.5°- 1.5°

GEM-stretched

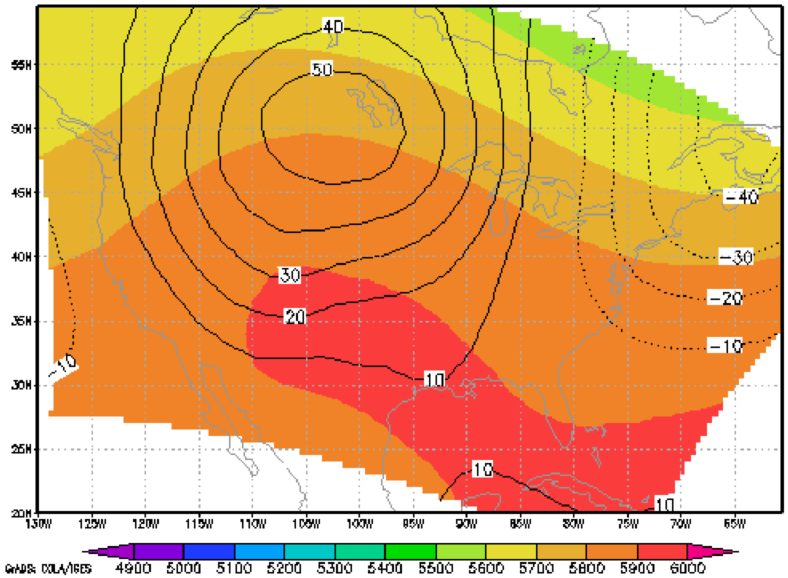


Horizontal resolution : 0.5°- 1.5°

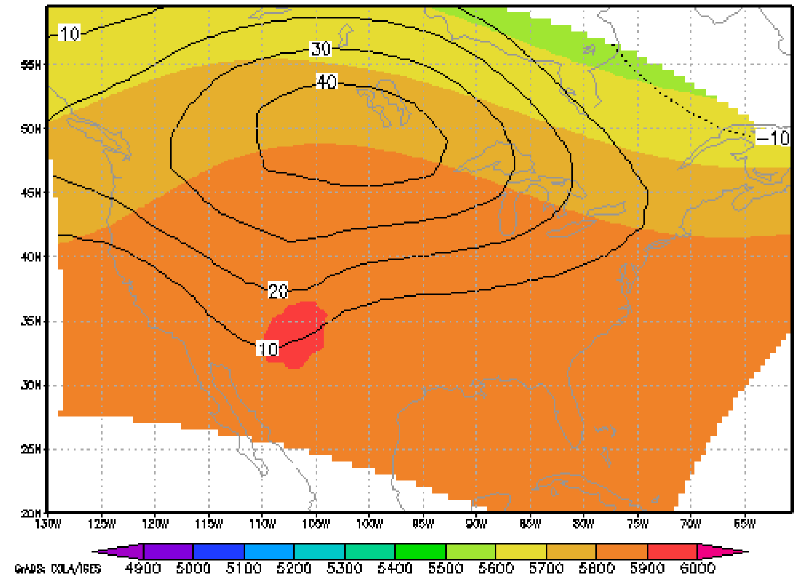
SUMMER

Geopotentiel 500 mb – ERA40 [m]

LAM

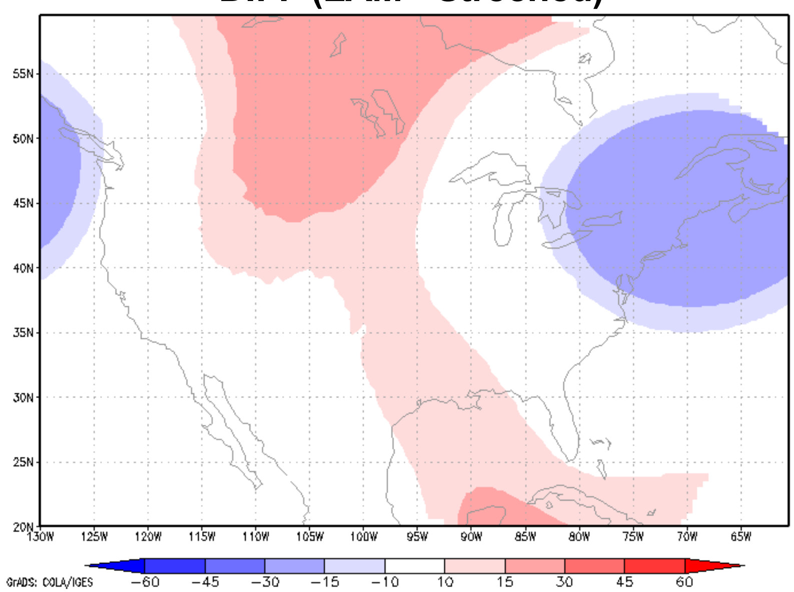


Stretched

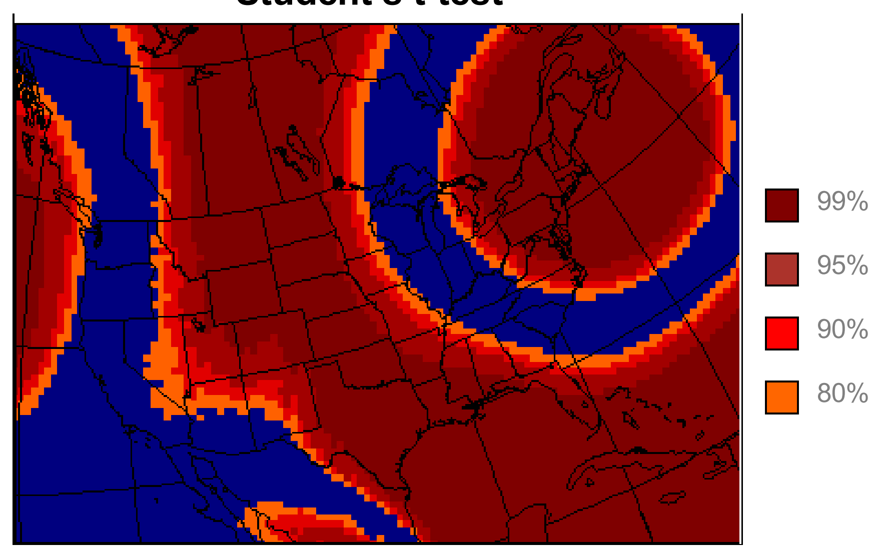


Geopotentiel 500 mb [m]

DIFF (LAM - Streched)



Student’s t-test



Summary

- transfer of GEMCLIM to UQAM/Ouranos: **phase 1 completed**
- behavior of CRCM5: **remarkably good**
- training of personnel: **dozens of students & post-docs**

Future work

- modified/new schemes and modules in GEMCLIM
- CCCma GCM4 physics package in GEMCLIM
- improvements in nesting technique
- Big-Brother experiment protocol in CRCM5
- coupling of ocean model(s) to CRCM5
- uncertainty, scale-selective studies and added-value of CRCM5
- 20-year projection in regional Arctic climate (IPY project)

Upcoming related activities

- CRCMD Workshop, 4-7 May 2008, Esterel (QC)
- National Workshop on Climate Scenarios and Extremes for Impact and Adaptation Studies, 6-8 May 2008, Montreal
- Mini-conference of the UQAM M.Sc. Students in Atmospheric Sciences, 13-14 May 2008, Montreal

thank you…

… and special thanks to

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Marc Verville
Louis-Philippe Paquin
Yanjun Jiao
Dragan Simjanovski
Yanping He

This talk in: http://iweb.cmc.ec.gc.ca/~armnaza/proj_LAM.html