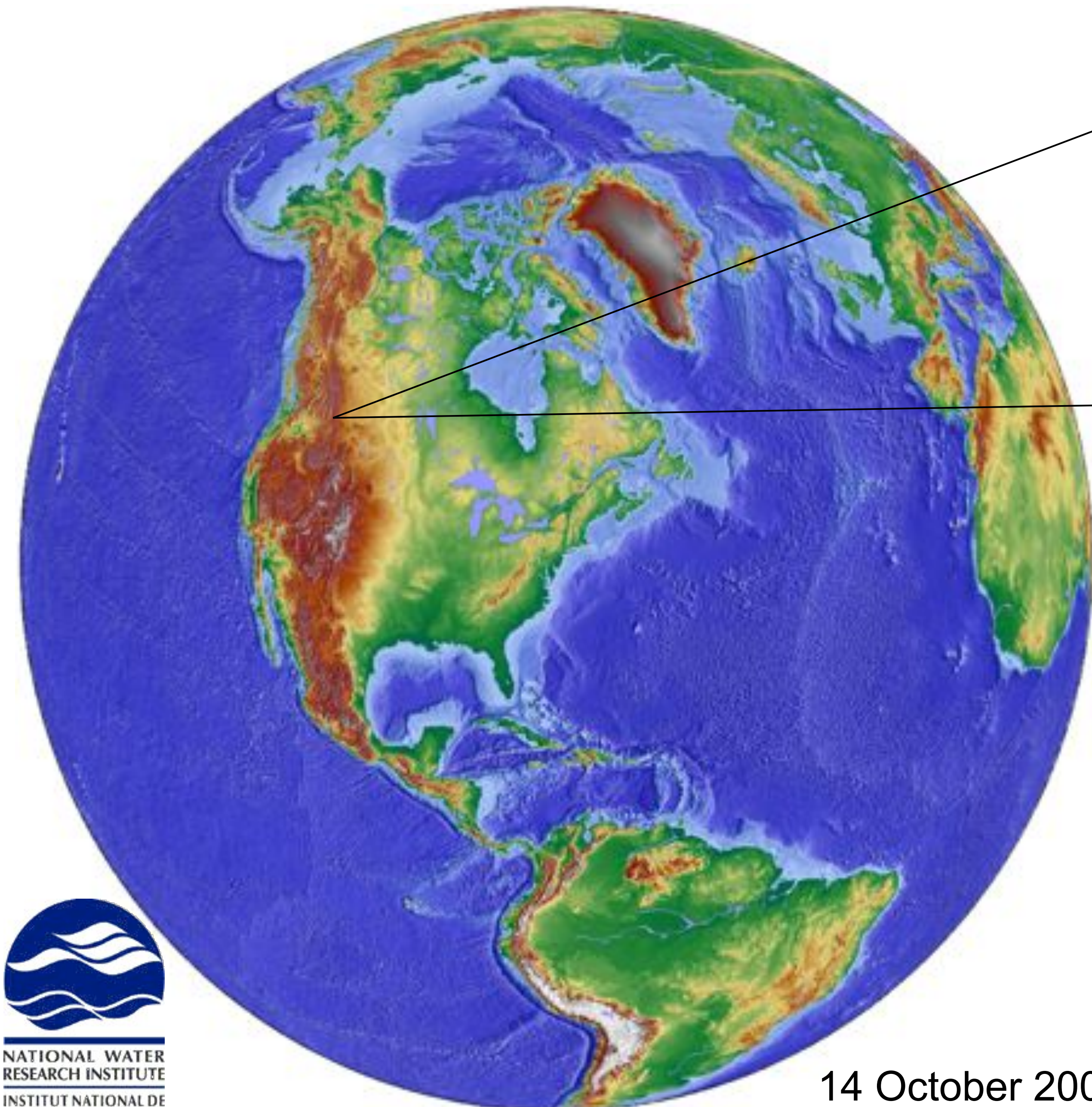
GEM Modeling update for IP3



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14 October 2009 – Lake Louise

Outline

- Overview
- Objectives
- Dynamical downscaling
  - Marmot Creek
  - Numerical Models
- Interpolation of atmospheric fields
- Example of the dynamical downscaling technique in IP3 basins
- Status and next steps

Overview

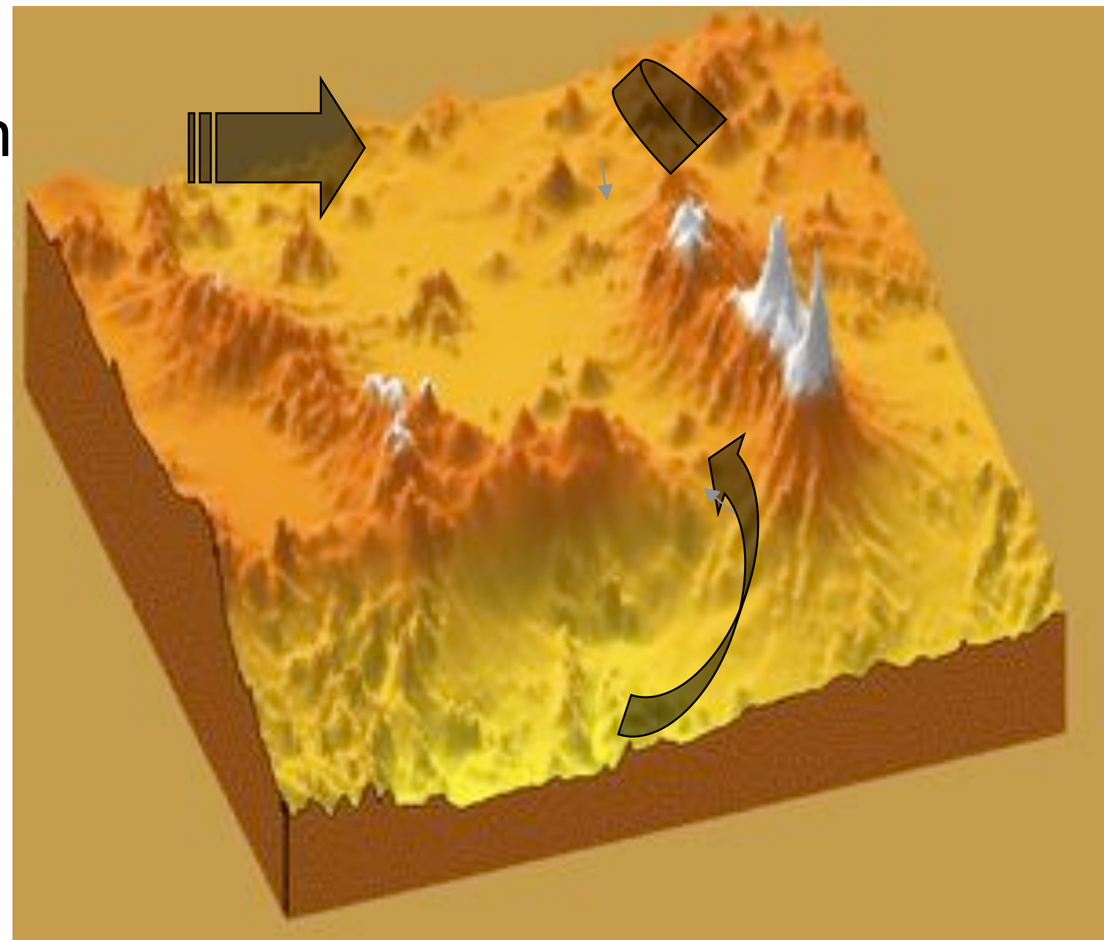
- Wind speed, turbulent transfer and wind flow direction are crucial for many IP3 processes
  - Blowing snow, intercepted snow unloading
  - Snow/ice turbulent transfer before and during melt
  - Evaporation, soil thaw

- IP3 Basins are complex terrains and so require mesoscale prediction of wind fields

- This presentation will focus on current efforts to achieve long simulations and to interpolate the output fields in order to drive the CRHM model to study snow transport flow over Marmot Creek

Objectives

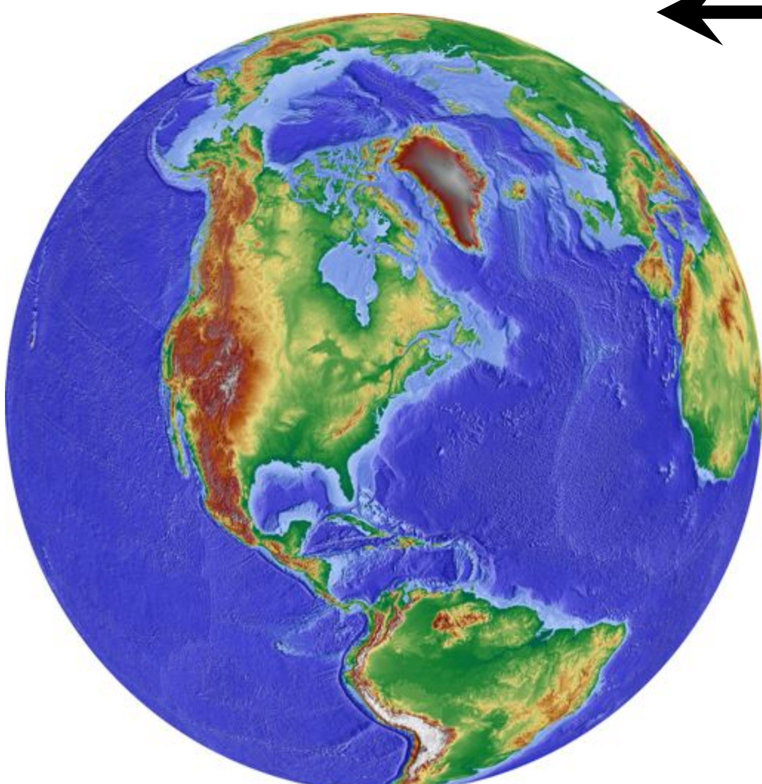
- Relationship between topography and windflow. Are there preferred regions of convergence, divergence, acceleration, deceleration, flow separation?
- Evaluate the ability of GEM to drive the CRHM model
- Evaluate the sensitivity of the GEM model wind field outputs to initial conditions
- Demonstrate GEM for IP3 basin



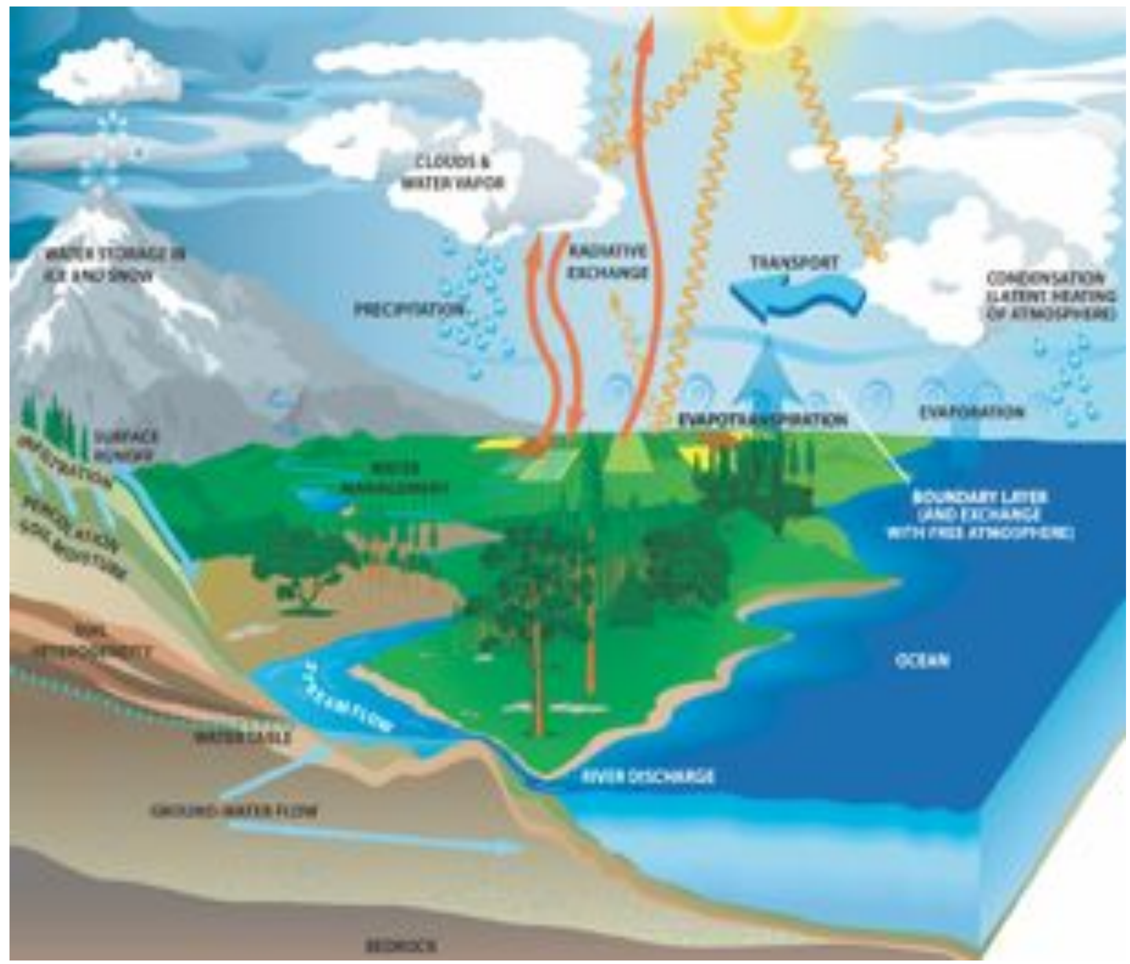
Dynamical downscaling

Coupling Atmospheric / Hydrological Models ?

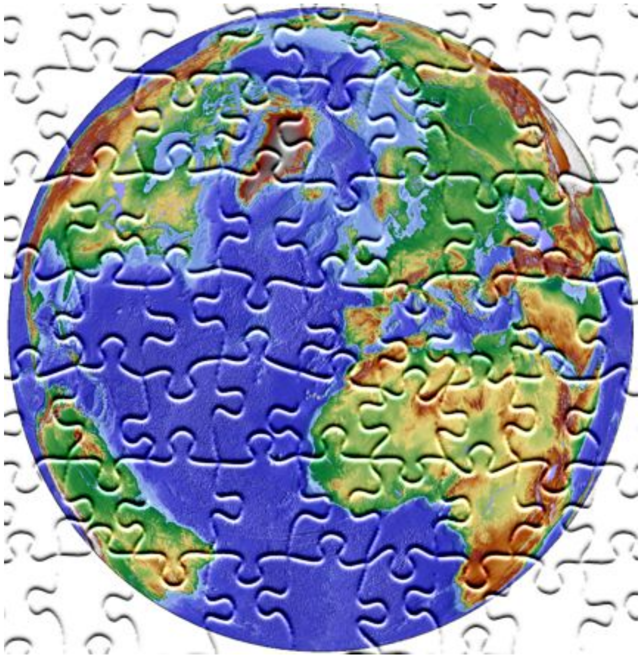
Hydro (meteoro) logical cycle



Fluxes and feedbacks

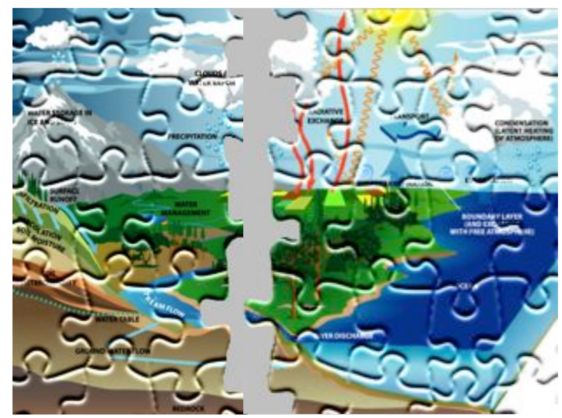


Dynamical downscaling

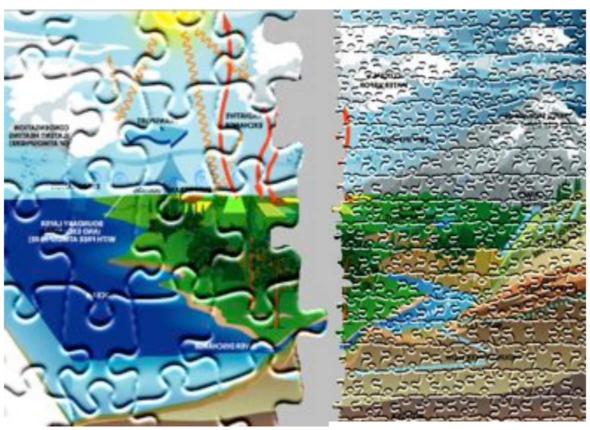


Scale does Matters !

Downscaling



Coupling



?

Dynamical downscaling

- **Measurements and Regional Climate Model simulations will be used to address the project objectives**

• Comparison of simulations **VS** **•Measurement campaigns** / **•Small scale models**

Case of study: 3rd – 4th November, 2007

Marmot Creek (50° 57’ N, 115° 10’ W):

Montane and sub-alpine forest with alpine tundra ridgetops (Rocky Mountains Front Ranges); 9.4Km^2

Atmospheric Models

Global Environmental Multiscale Limited Area Model (GEM-LAM)

- GEM is a grid-point based numerical model of the atmosphere suitable for weather forecasting applications which can be used in different configurations:

  Global-regular, global-stretched or limited area model

  Modélisation Environmentale Communautaire (MEC)
- Modeling system designed for coupling different models in order to produce operational forecasts
- The present version couples land-surface and hydrological models

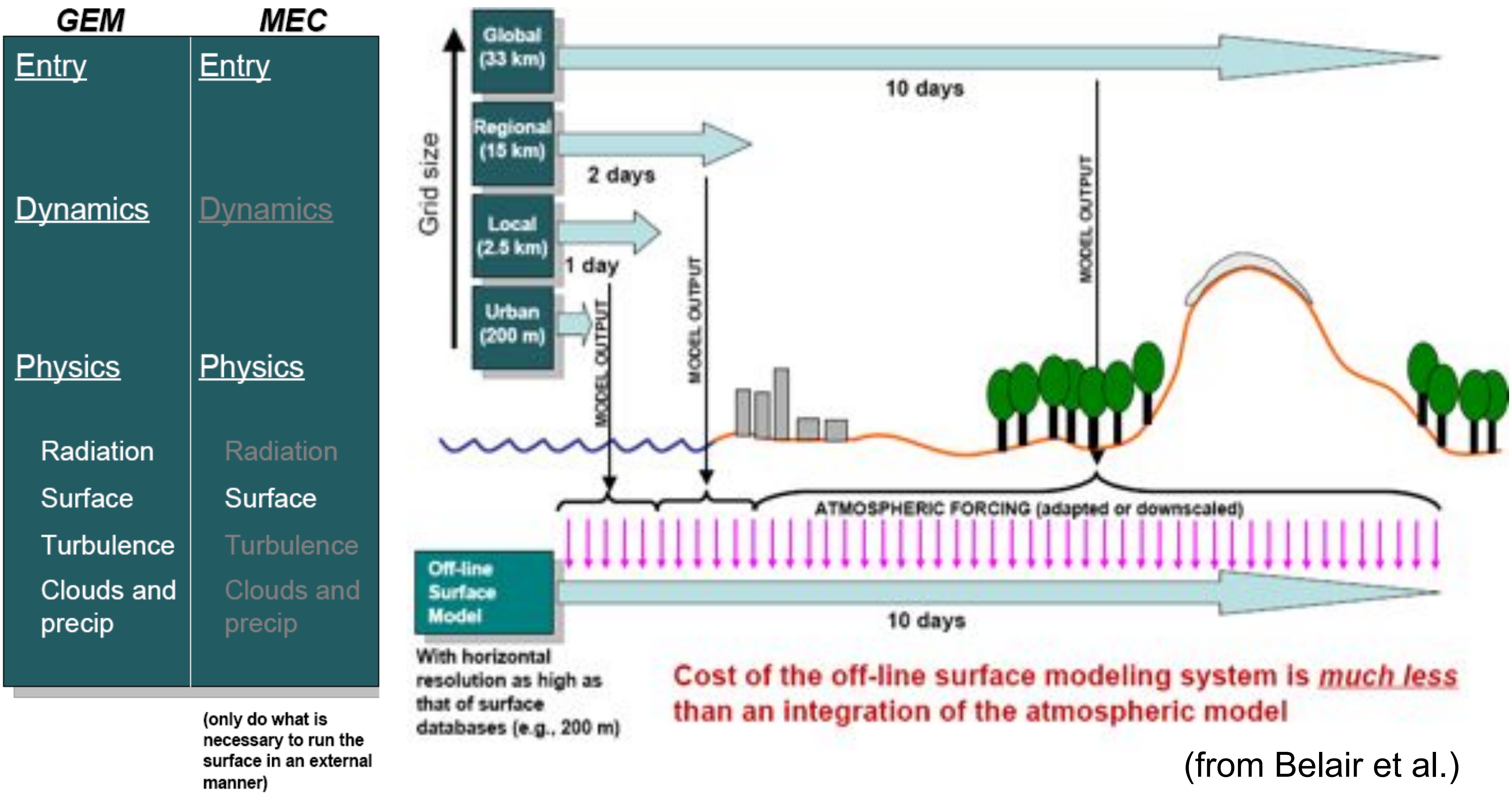
  Soil scheme:
- Interactions between Soil, Biosphere, and Atmosphere (ISBA)

  Soil-vegetation-atmosphere transfer (SVAT) scheme is used to model the exchange of heat, mass and momentum between the land or water surface and the overlying atmosphere

Atmospheric Models

Numerical Models: GEM (Canadian Global Environment Model)

MEC (Modélisation Environmentale Communautaire)

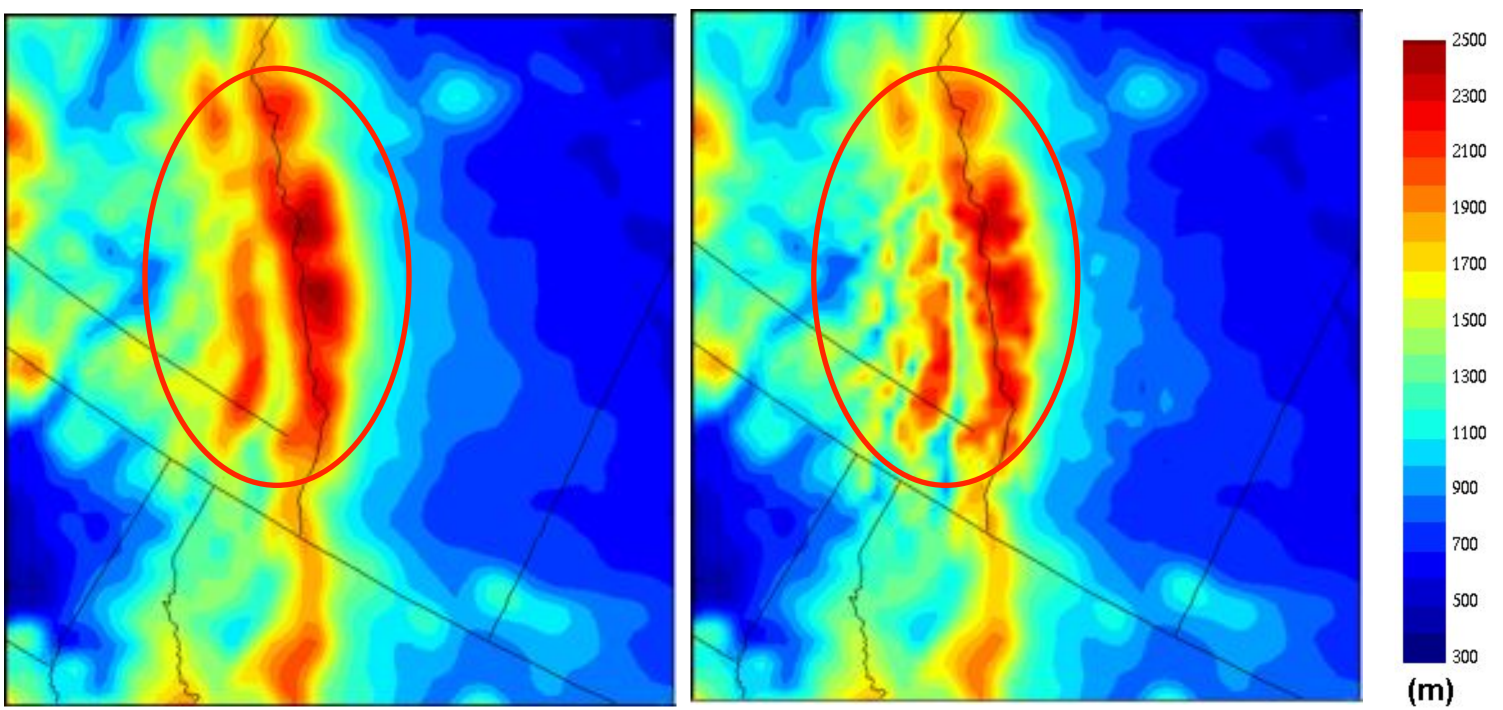


(from Belair et al.)

Atmospheric Models

Mesoscale Compressible Community (MC2) Model

- Fully compressible, non hydrostatic Euler equations
- Fully 3D Semi-Lagrangian advection and Semi-implicit time differencing formulation
- Arakawa C (horizontal) and Tokioka B (vertical) grids
- Hybrid Terrain Following Vertical coordinate
- Open boundaries for one-way nesting implemented for semi-Lagrangian advection
- Adjustable topography at startup
- Full CMC/RPN Physic



Time step 0

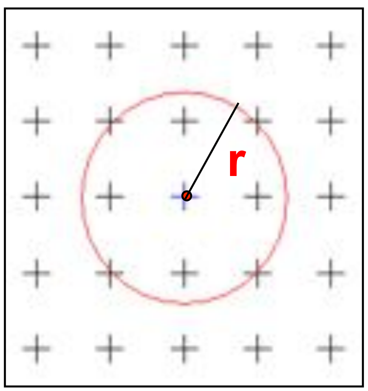
Time step 18

Example of the adjustment of the topography in 18 time steps.
dx = 15km
dt = 300s

Interpolation

Nearest-Neighbor Method

$$Q_i = \frac{\sum_{j=1}^{J} Q_{r_j}}{J}$$



$$r = \sqrt{2}\,\Delta x$$

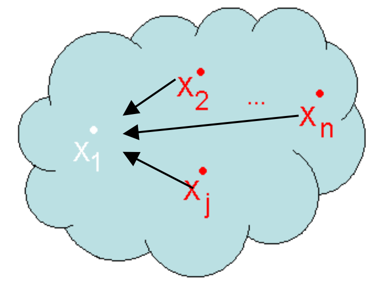
Jackknife Resampling Method

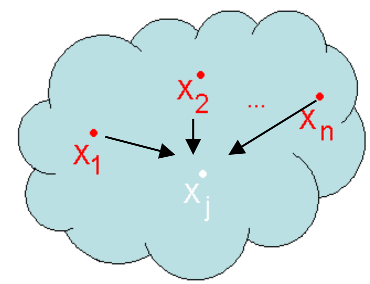
$$\hat{\varphi} = \frac{\sum_{i=1}^{n} \hat{\varphi}_i}{n}$$

$$\hat{\sigma}_{jack}^2 = \frac{\sum_{i=1}^{n} (\hat{\varphi}_i - \hat{\varphi})^2}{n(n-1)}$$

$\hat{\varphi}_i$: jackknife sample i

$\hat{\varphi}$: jackknife sample average





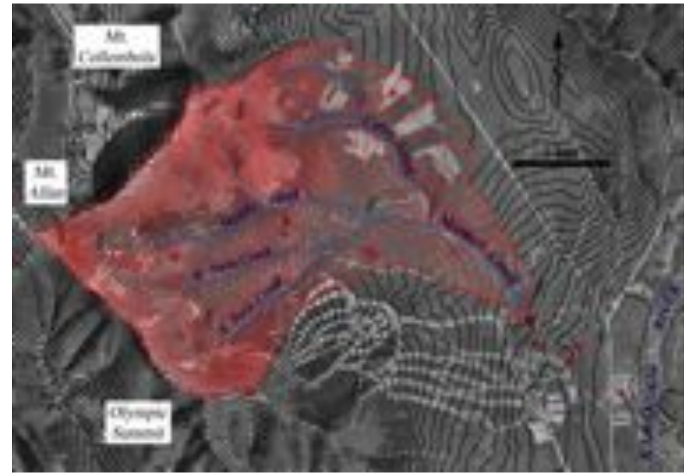
Mean Relative Bias

$$MRB = \frac{1}{k}\sum_{i=1}^{k}\left[\frac{\hat{X}_i - X_i}{X_i}\right]$$

Mean Relative Square Error

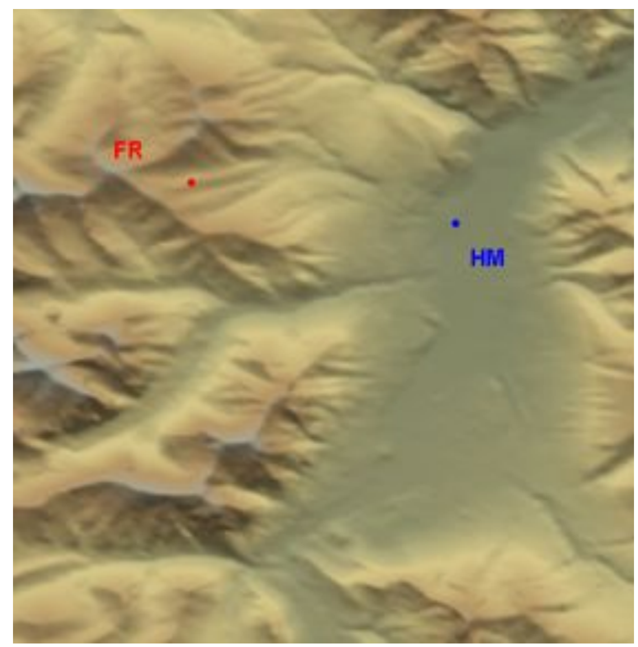
$$MRSE = \frac{1}{k}\sum_{i=1}^{k}\left[\frac{\hat{X}_i - X_i}{X_i}\right]^2$$

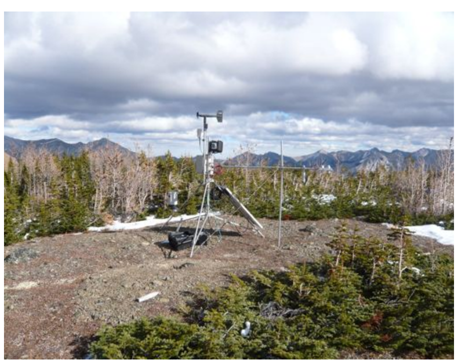
Marmot Creek



Description:
Area: 9.4 km^2
Location: 50° 57’ N, 115° 10’ W
Average slope: 39%

	Fisera Ridge Station (FR)	HayMeadow Station (HM)
Location	115° 12' 15.95 W	115° 8' 20.18 W
	50° 57' 24.58 N	50° 56' 38.80 N
Elevation	2325.3 m	1436.8 m
Data	2007 -	2007 -
Instrumentation	air temperature (TT)	air temperature (TT)
	relative humidity (RH)	relative humidity (RH)
	wind (UV)	wind (UV)
	up/downwelling shortwave radiation	up/downwelling shortwave radiation
	up/downwelling longwave radiation	up/downwelling longwave radiation
	snow depth (SD)	snow depth (SD)
	precipitation gauge (PR)	precipitation gauge (PR)
		barometric pressure (P0)
		visibility





How to achieve long term simulations (weeks/months)?

Reanalysis from CMC:

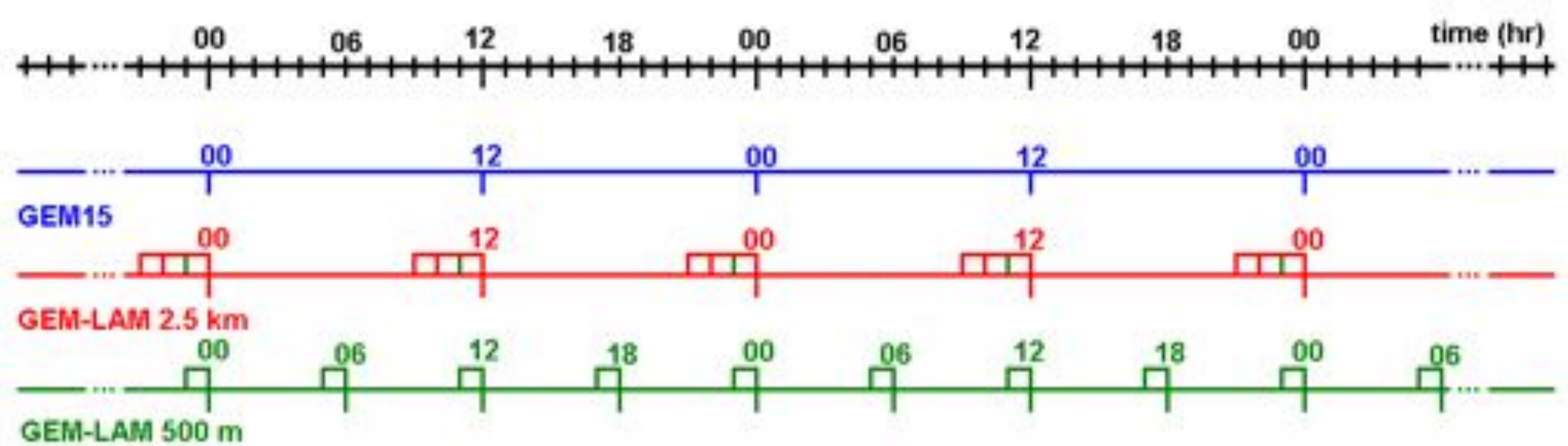
- GEM15: 15km of resolution
- forecast: 48h recorded hourly every 00Z and 12Z

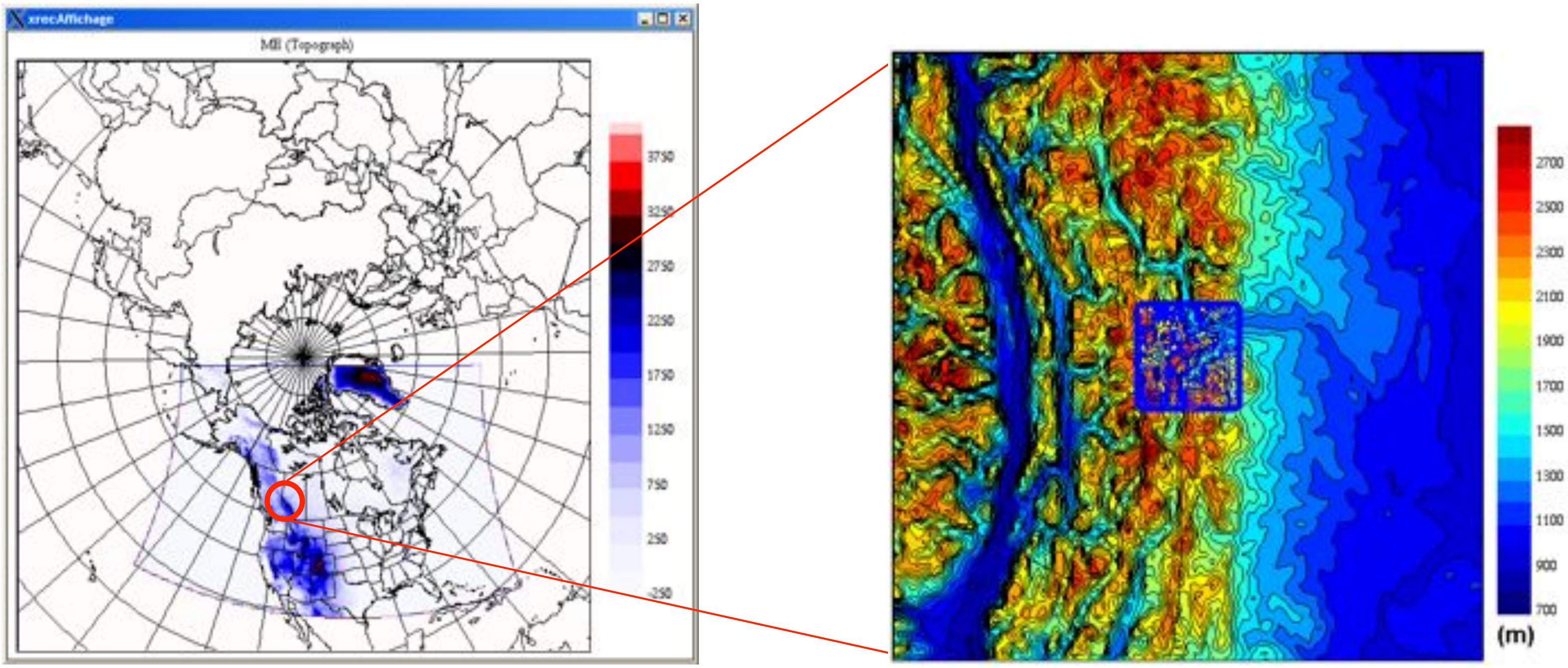
LAM2.5km:

- spin-up: 3h
- 12h simulations
- Grid 99 x 99, dx=2.5 km, dt=60 s
- Driver : GEM15 data
- Physiographic fields: 90m

LAM & MC2, 500m:

- spin-up: 1h
- 6h simulations
- Grid 88 x 88, dx=500 m, dt=10 s
- Driver : LAM2.5km
- Physiographic fields: 90m





GEM15

GEM-LAM 2.5km

GEM-LAM 500m / MC2 500m

Centre: (50° 56’ 50” N, 115° 8’ 30” W)

Conditions for November 3rd – 4th, 2007

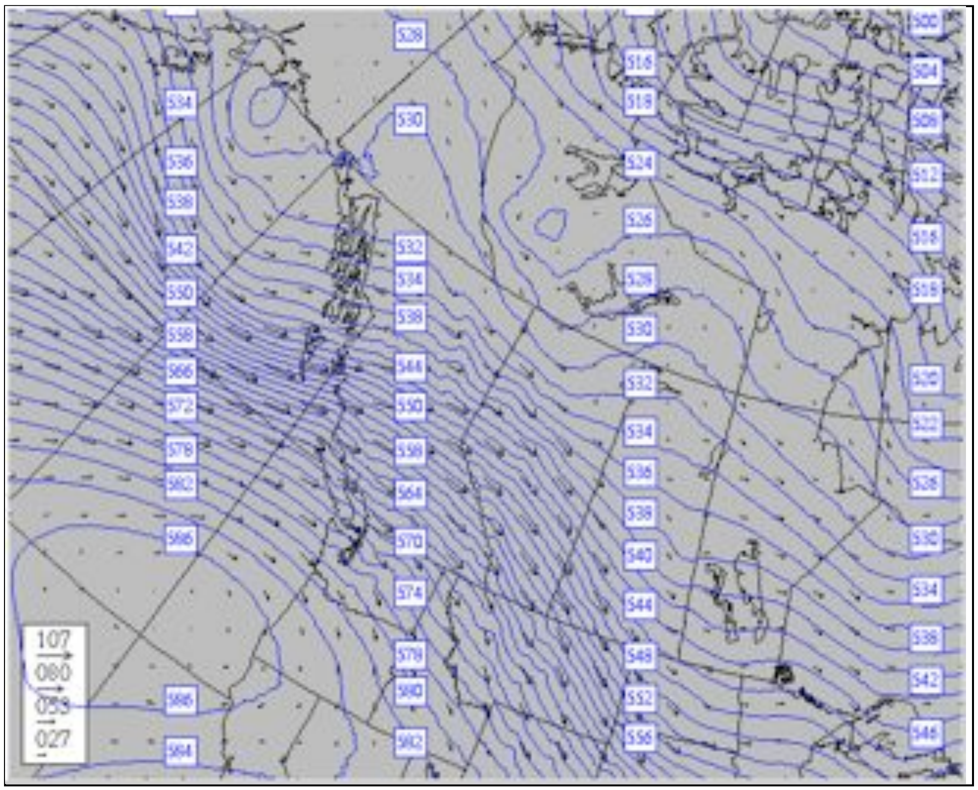
- Spin-up limitation
- One way nesting
- Wide range of circulation (all scales)

Results

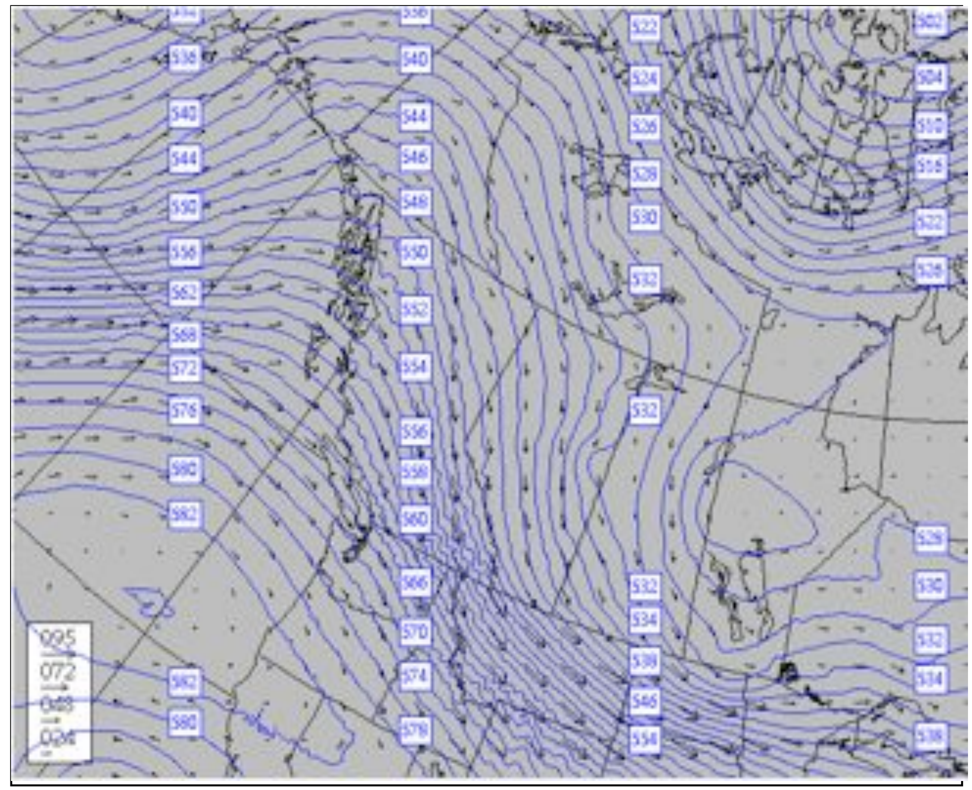
Synoptic Conditions

Contours: **Geopotential 500 mb**

Vectors: **Wind Field**



4/11/2007 00UTC



5/11/2007 00UTC

GEM15

Application of the Jackknife Method

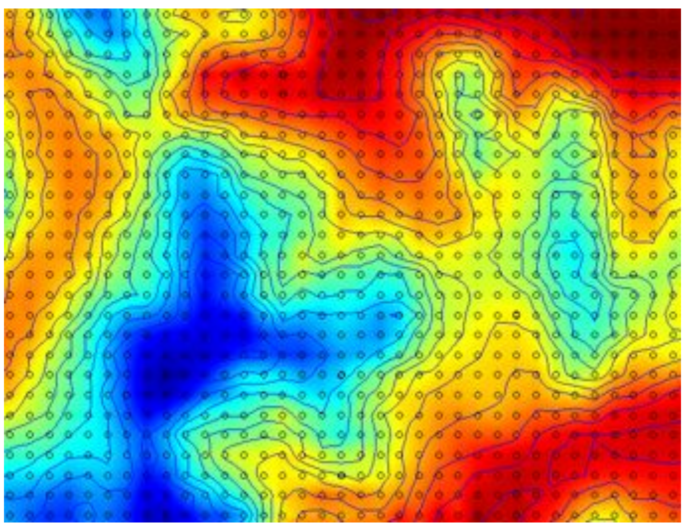
4096 (64 x 64) grid-points

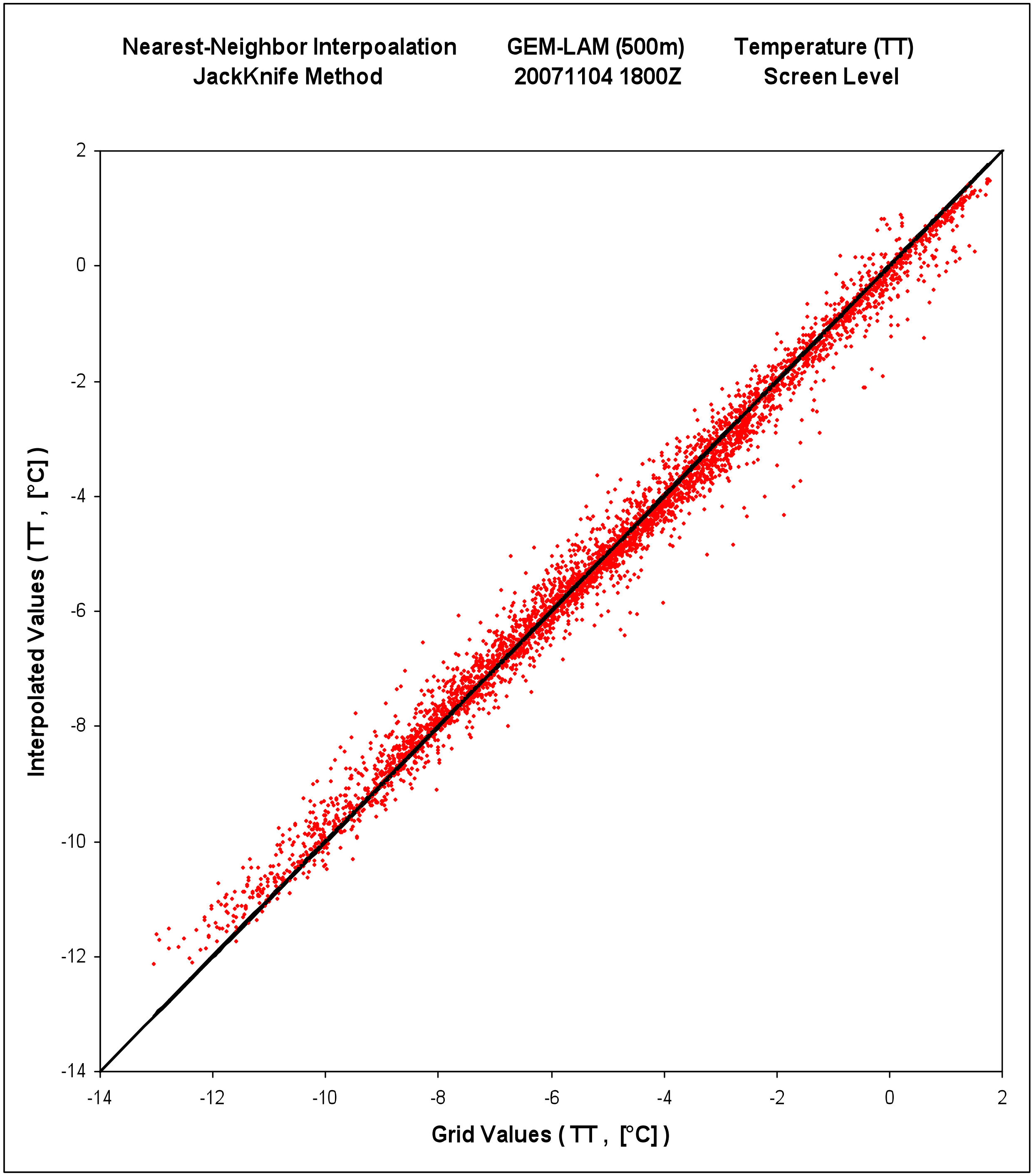
Overestimation = 54.08%
(Frequency = 2215)

Underestimation = 45.92%
(Frequency = 1881)

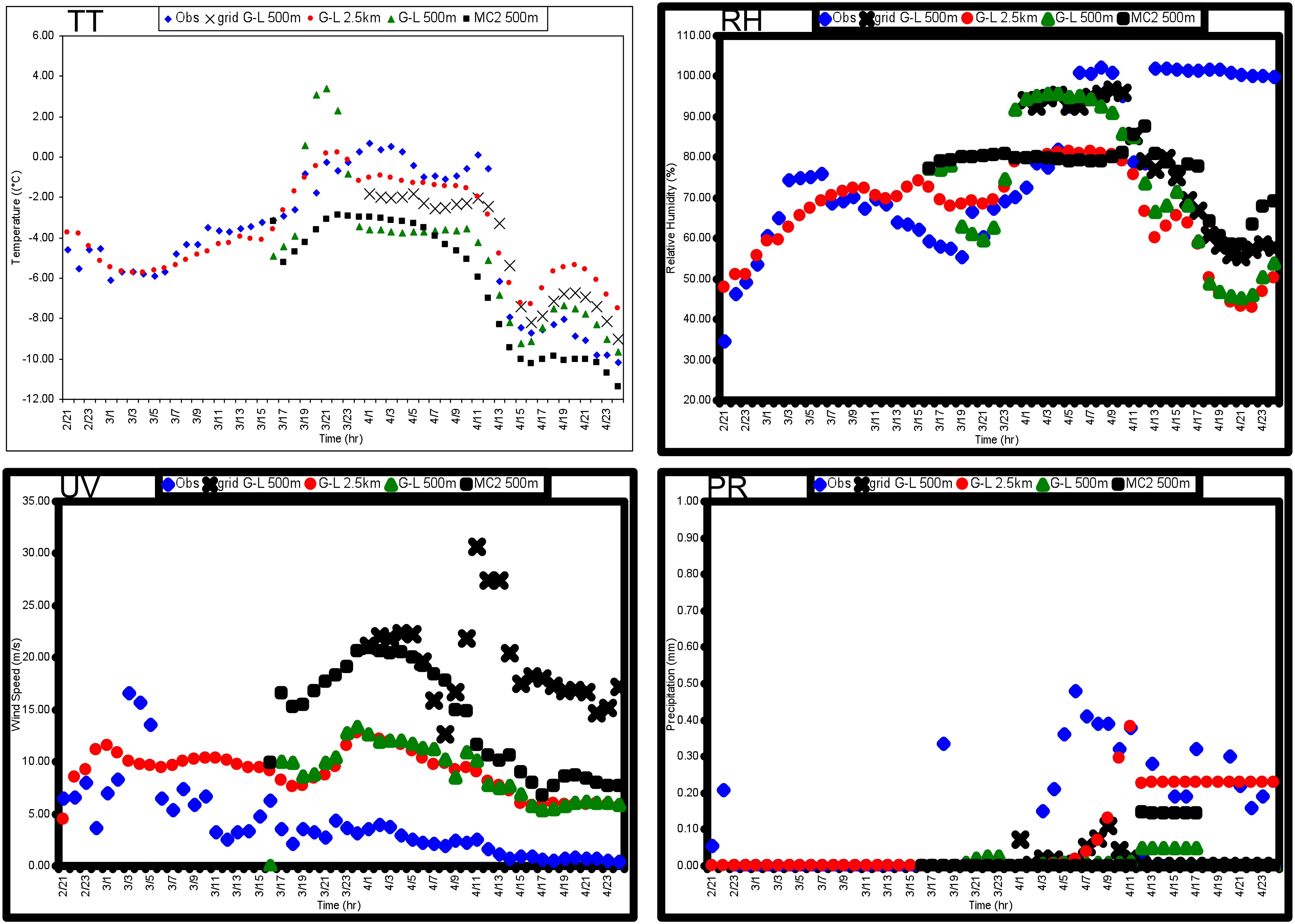
Mean Relative Bias:
MRB = 2.70%

Mean Relative Square Error:
MRSE = 439.80%

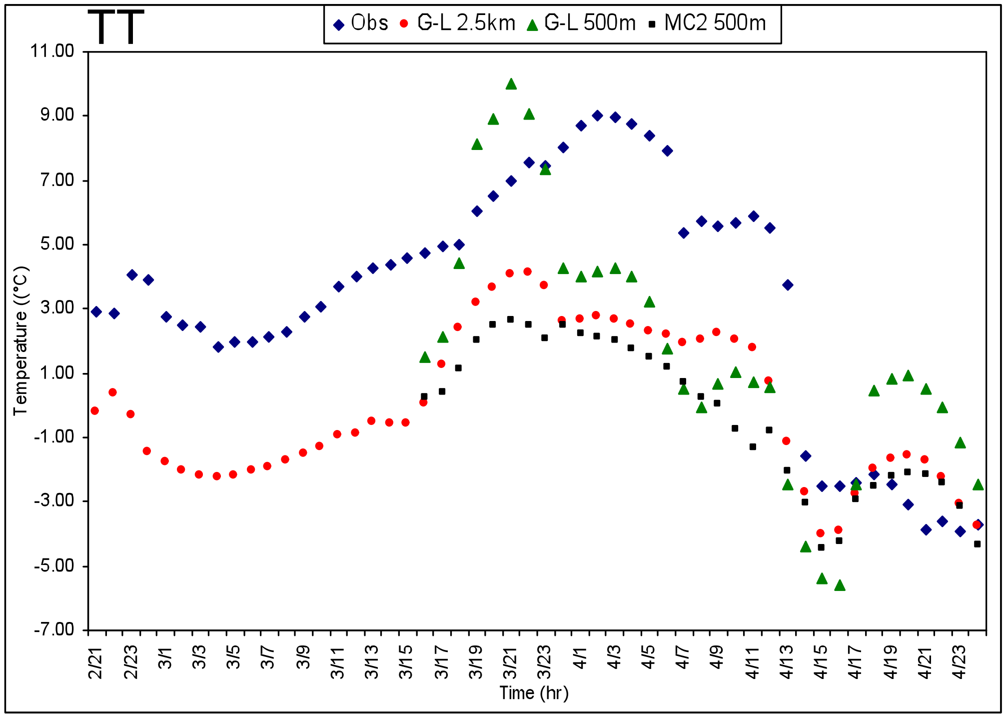


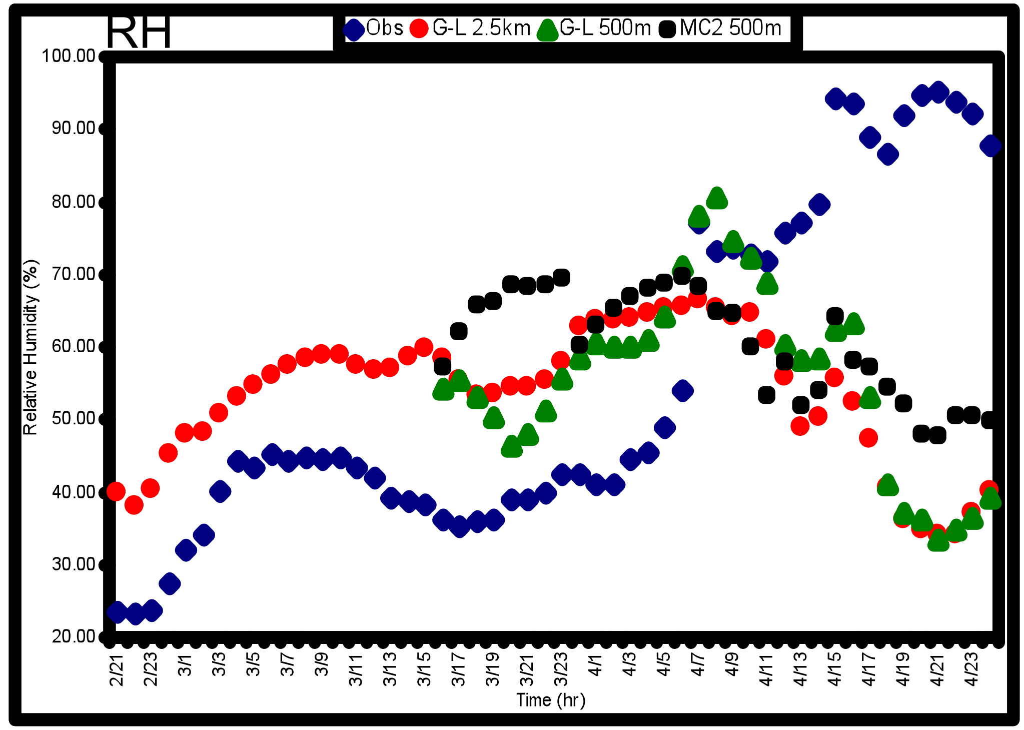


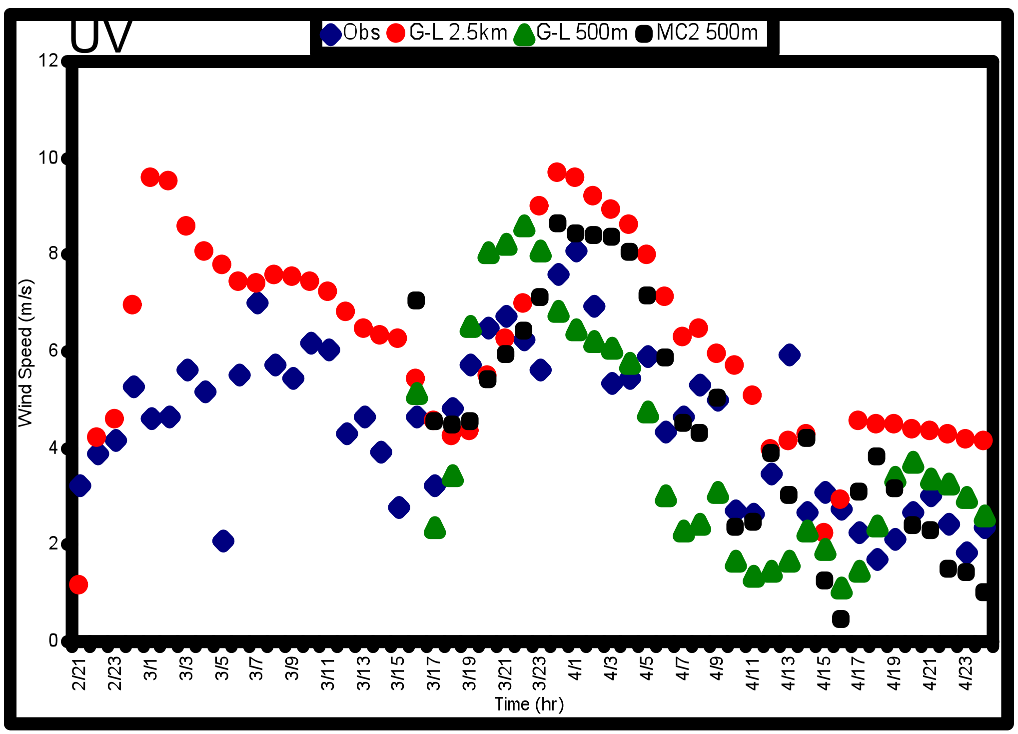
GEM-LAM: 500m Date: 3-4 / Nov / 2007 Obs: Fisera Ridge

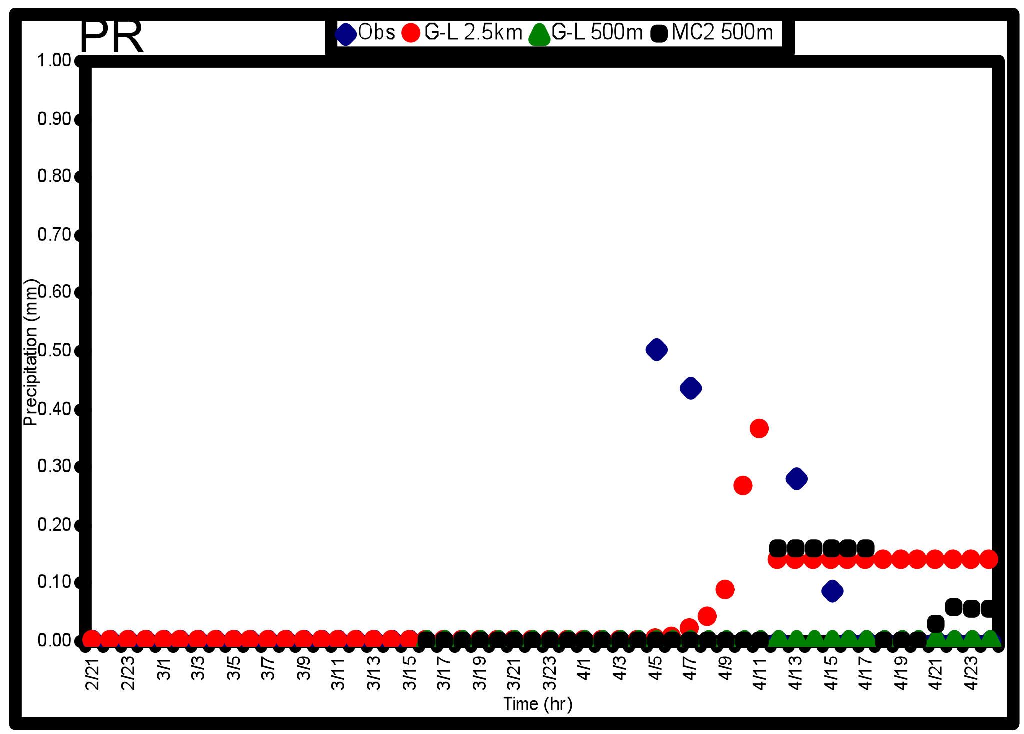


GEM-LAM: 500m Date: 3-4 / Nov / 2007 Obs: HayMeadow









Status and Next Steps

Nearest-neighbor interpolation method produces better results than grid point values.

Long-term simulations strategy eliminates the constriction of short periods of forecasts (few days) from atmospheric simulations.

MC2 model use old versions of the CMC/RPN physical package, which seems to limit its performance

GEM-LAM wind fields patterns and values were improved with the nearest-neighbor.

GEM-LAM patterns of surface temperature are greatly influenced by the topography and match surface observations.

Next Steps

- Use 500m and 2.5km resolution in the GEM-LAM for simulate December 2007
- Drive the CRHM model with the atmospheric fields generated by the GEM-LAM model
- Use new meso-scale parameterisations of blowing snow (e.g. MacDonald et al.)
- Simulate other IP3 basins and compare model results with observations of temperature, wind speed, direction, SWE
- Transfer the simulation data to the IP3 database and make them available to other IP3 researchers


Thank you !
51.00