Environmental Numerical Prediction Research:
- Atmosphere-Hydrology
- Atmosphere-Ocean-Ice
- Urban

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Plan and objectives:

Three scientific projects which allowed or will allow a direct improvement in the services offer to the Canadian community.

- To demonstrate the capacity and utility between the:
  1) Atmospheric and Hydrologic
  2) Atmospheric and Ocean-Ice
  3) Urban modeling

Key partnerships:
- EC: CCCma, CRD, MSC, NWRI
- Universities: Waterloo, UQAR
- International: CERFACS, Météo-France
Atmosphere-land-hydrology:

How:
- These models focus on the vertical water and energy budget.
- Attempt to close the water budget at a basin scale.
- Best available data and models to assess surface state variables in real time.
- ISBA and CLASS can now better represent hydrological controls on soil moisture
  with the addition of surface runoff, subsurface flow, and groundwater recharge parameterizations.

Why:
- Produce real time estimates and forecasts of surface state variables in the water cycle
  (soil moisture, soil temperature, snow, vegetation…).
- Provide surface fluxes to the atmospheric components (coupled).
- Allow to address water availability needs.
- New products available to the Canadian community (Hydrology, Agriculture, Great-Lakes, IJC….)
Case: (19-20-21 April 1993)

“The weather during the 3 days was quite varied in type and scale. To the northeast of the radar, one area reported all of snow, freezing rain, thunderstorms, hail, and strong winds. During the period the precipitation was mainly stratiform but there were several convective periods.”

Precipitation Accumulation 72H

**3 km**
- Precipitation Schemes
  - Conv: Aucun
  - Strat: Microphysics

**10 km**
- Precipitation Schemes
  - Conv: Kain-Fritsch
  - Strat: Microphysics
Simulation: 3km Radar

Precipitation events correctly seen by the model grid 20-04-1993

Errors
1) Atmospheric Model
   - Space shift
   - Time shift
2) Radar Observations
   - Decreasing Amount/distance
3) Hydrological Model

Comparaisons des simulations atmos:
35 km
10 km
3 km
observations

Prévisions Hydrologiques
Comparisons de résolutions spatiales:
Modèle Atmosphérique
35 km
10 km
3 km
Conclusions:

- The increase of resolution has allowed to better resolve the observed events.
- The model has the capacity to approximate the observed weather events.
- MRD continues to improve the models and data assimilation techniques.
- The hydrological simulations, combined with hydrological observations, give essential information on the amount of precipitation and on future soil moisture conditions.
- The coupling Atmosphere-Hydrology will allow to improve the operational environmental forecasts.
- The atmospheric components are operational at the CMC and we work with NWRI, WSC on the validation of the hydrological component.

Goal: To improve the exchanges (fluxes) between Atmospheric-Ocean-Ices. To improve the Canadian Environmental Forecasts.
Atmospheric-Ocean-Ice

Why:
- Coastal weather forecasts are very affected by the ocean conditions.
- During the ice period, both systems are particularly interdependent.
- To improve the atmospheric forecasts (icing, clouds, fog,...)
- To improve the ocean-ice forecasts (ice, currents, temperature, waves…)
- To improve the services:
- Users: EC, coast-guard, DFO, maritime transportation

Introduction

Atmosphere - Ocean - Ice Interactions in Eastern Canada

Models & Coupler

- Global Environmental Multi-scale (GEM, Côté et al. 1998):
  - Regional configuration LAM @ 15km and 58 levels;
  - Dynamic 3.2.2+, physics 4.0+;
- Gulf of St. Lawrence Model (ROM, Saucier et al. 2003):
  - 3D Ocean @ 5km and 73 levels; version 4.9.5 (5.2.2);
  - Sea-ice (dynamic - thermodynamic);
    - Elastic-viscous-plastic (EVP) model (Hunke & Dukowicz, Los Alamos CICE model, 1997);
    - Thermodynamic: Semtner, 1976;
- OASISv3-Gossip (Valcke 2004)

Methodology

Atmosphere Ocean-Ice

Each: 600 seconds

Heat and Vapour Flux
IR flux

15 km timestep=600s

Coupler

Ocean-Ice

IR and Vis flux, Humidity, Pressure, Winds, Precipitation, Temperature.

5 km timestep=300s

Coupler

Coupling description
Ice fraction on the 4 km atmos. grid 48h forecast 2 way coupling

Case: Particularly interesting given that the intense atmospheric circulation that dramatically changed the ice conditions in only 48 hours was preceded by a cold and relatively quiet period.

Valid: 14/03/97 20 Z after 44 hours
2 way Coupling - 1 way Coupling
Surface temperature V 00Z 15 (24 km)

Clouds, Ice and Water

AVHRR

Nova-Scotia
New-Brunswick

P.E. I.
Cape-Breton

Clots over Ice

2 way
Experimental Operational System at CMC

**Winter**

- The coupled system seems to produce very good results.
- The fully interactive coupling allows to improve:
  - Ice forecasts
  - Clouds (best fluxes)
  - Temperatures
  - Precipitations
  - Surface pressure
- Has been transferred to CMC development and operations
- S&T continues (with DFO) to work on the physical processes (fluxes).

**Conclusions:**
- Strong Collaboration between EC-DFO-Coast Guard-Universities
- This expertise is or will be used:
  - to develop the global atmosphere-ocean system (Mercator project)
  - to develop a similar system for Great-lakes and Hudson bay
  - to develop a coupled Atmospheric-Ice system for the Arctic
- Better services delivered by the departments.

**Summer**

- Coupled System better (> 50%)
Towards an Operational Urban Modeling System for CBRN Emergency Response and Preparedness

Objectives of the main project:

- To respond effectively to an attack, rapid decisions need to be made concerning the transport, dispersion, deposition and fate of the CBRN agent and its concomitant effects on the exposed population.
- Development of a prototype for Environmental Emergency Response
- Multi-scale CBRN Hazard Prediction Model for the Urban Environment
- To provide decision making framework to minimize consequences injuries, casualties, and contamination

- Improve the representation of cities in Canadian meteorological models:

- Project partners:
  - R&D Defence Canada, AECL
  - Universities of Waterloo and Calgary
  - CFD models at street- and building-scales

Purpose: Microscale Modeling project:

- To test the feasibility of adapting an atmospheric model code into an urban model code, producing a single code that is valid for both. A Unified Dynamical Model for Atmospheric and Urban modeling. (fully compressible, non-hydrostatic, terrain following coordinate, solid objects, turbulence 3D, TEB,).
- 1 model with thermodynamic and dynamical effects.
- To improve the coupling between atmospheric and CFD models.
  - Better representation of the dynamical effects (drag, building) in the atmospheric model.
  - Better initial and boundary conditions for the CFD model.

Motivation

- Share scientific expertise with CFD community.
- Identify approach for GEM or other future models (emergencies and air quality).
- The dynamical kernel of the Canadian atmospheric model is very sophisticated (without main approximations) allowing to run at very high resolutions.
The Solid objects

Actions:
1) Calculate trajectories
2) Interpolations
3) Solver

Small amount of Numerical noise => Allow to produce realistic vortex
Small amount of Numerical diffusion => Allow to maintain the vortex

Solid Objects: Von Karman Vortex Streets
Laboratory Experiment Re=140 Cylinder
Summary:
- The first theoretical tests: the Canadian atmospheric model can be used at very high resolution.
- The solid object seems to give very good results.

Project: next 3 years:
- Final validation of theoretical cases in collaboration with the CFD community.
- To add the physical processes (thermodynamic effects).
- To use field measurement campaigns in urban environment to improve the validations.

Conclusion:
- The Environmental modelling is essential to improve the Canadian Atmospheric forecasts.
- We now have the scientific and technical capabilities to build comprehensive environmental prediction systems integrating expertise from a wide range of disciplines and addressing important R&D and operational issues (hydrology, Ocean-Ice, Lakes, soil, snow, vegetation, ecosystem...).

- Develop the capability to understand past, current and future water balances resulting from weather-climate variability and human activity;
HIGH-RESOLUTION OFFLINE MODELING of URBAN HEAT ISLANDS – RADIATIVE SURFACE TEMPERATURES

Landsat 5, 11 August 2001, 1500 UTC
(Guay and Beaudouin 2005, UQAM)
Pixel size : 120 m

External land surface model,
With Town Energy Balance model,
27 June 2005, 1500 UTC
Grid size : 120 m

Project: next 3 years:
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2-way coupling: Atmospheric-Ocean-Ice.

Atm. 15 km
Atm. 4 km
Ice 5 km
Ocean 5 km
Québec
Saguenay
Operational system developed with and for the CMC
From Mesoscale to Microscale to CFD

Regional
GEM
15 km

OPERATIONAL 48-h RUN (00 or 12 UTC)

GEM-LAM
2.5 km

T-9
21-h run
T+12

IC + LBC

GEM-LAM
1 km

T-6
18-h run
T+12

IC + LBC

GEM-LAM
250 m

T-3
15-h run
T+12

IC + LBC

LAM
201 x 201
Timestep = 30 s
53 levels (two levels of packing near surface)
3D turbulence
TEB

11/24/2008

LAM
201 x 201
Timestep = 7.5 min
58 levels (for NWP)
3D turbulence
No TEB

GEM-LAM
576 x 641
Timestep = 7.5 min
58 levels (for NWP)
3D turbulence
No TEB

Building scale

CFD
Urban flow
Plume dispersion model
10-5 m

Operational system developed with and for the CMC
From Mesoscale to Microscale to CFD

Canadian Numerical Modelling For Environmental Prediction

Systems - MEC - System
(Modelling Environmental Community System)
(Modelisation Environnementale Communautaire)

A collaborative effort between:
SMC-MSC
DFO-MPO
DND
NHRC Saskatoon
Canadian Space Agency
Canadian Universities
Canadian Companies
Provinces
Countries

For:
Atmospheric Models
Chemistry Models
Environmental Emergency Models
Ocean Models
Ice Models
Waves Models
Land-vegetation Models
Hydrological Models
Hydrodynamic Models
Ecosystem Models

Partnerships collaborations based on joint investment for mutual benefits