CLIMATE CHANGE ASSESSMENT OVER THE ASSINIBOINE DELTA AQUIFER

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Acknowlgements

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  - Drought Research Initiative
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  - Manitoba Climate Change Action Fund

Who is DRI?

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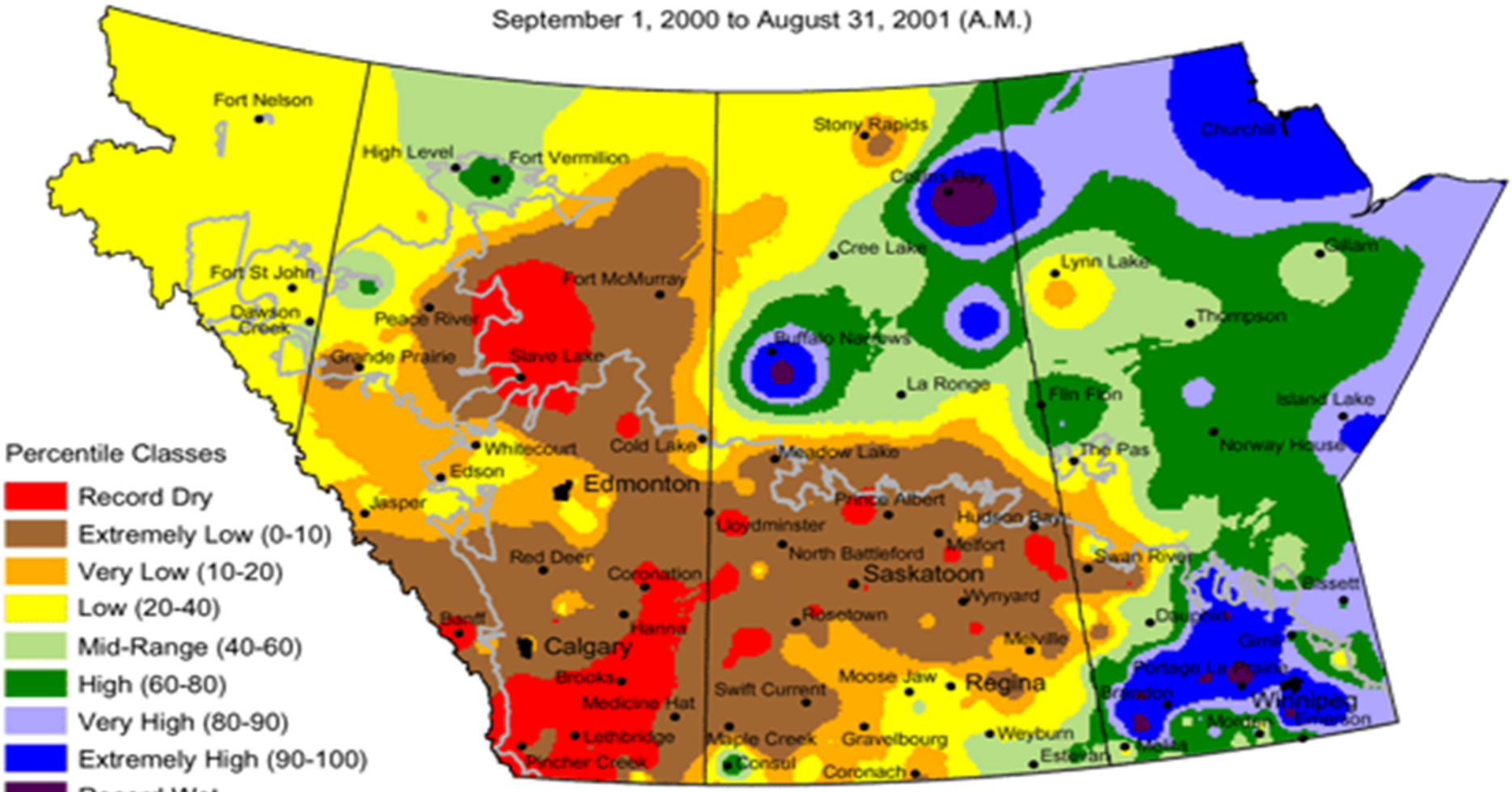
  Boer (*MSC*), Cayas (*Ouranos*), Derome (*McGill*), Donaldson (*MSC*), Granger (*NHRC*), Johnston (SRC), Martz (*Sask*), Prowse (NWRI), Raddatz (*Man*), Ritchie (*MSC*), Shabbar (*MSC*), Sills (*MSC*), Szeto (*MSC*), Wittrock (*SRC*), Papakyriakou (*Man*)

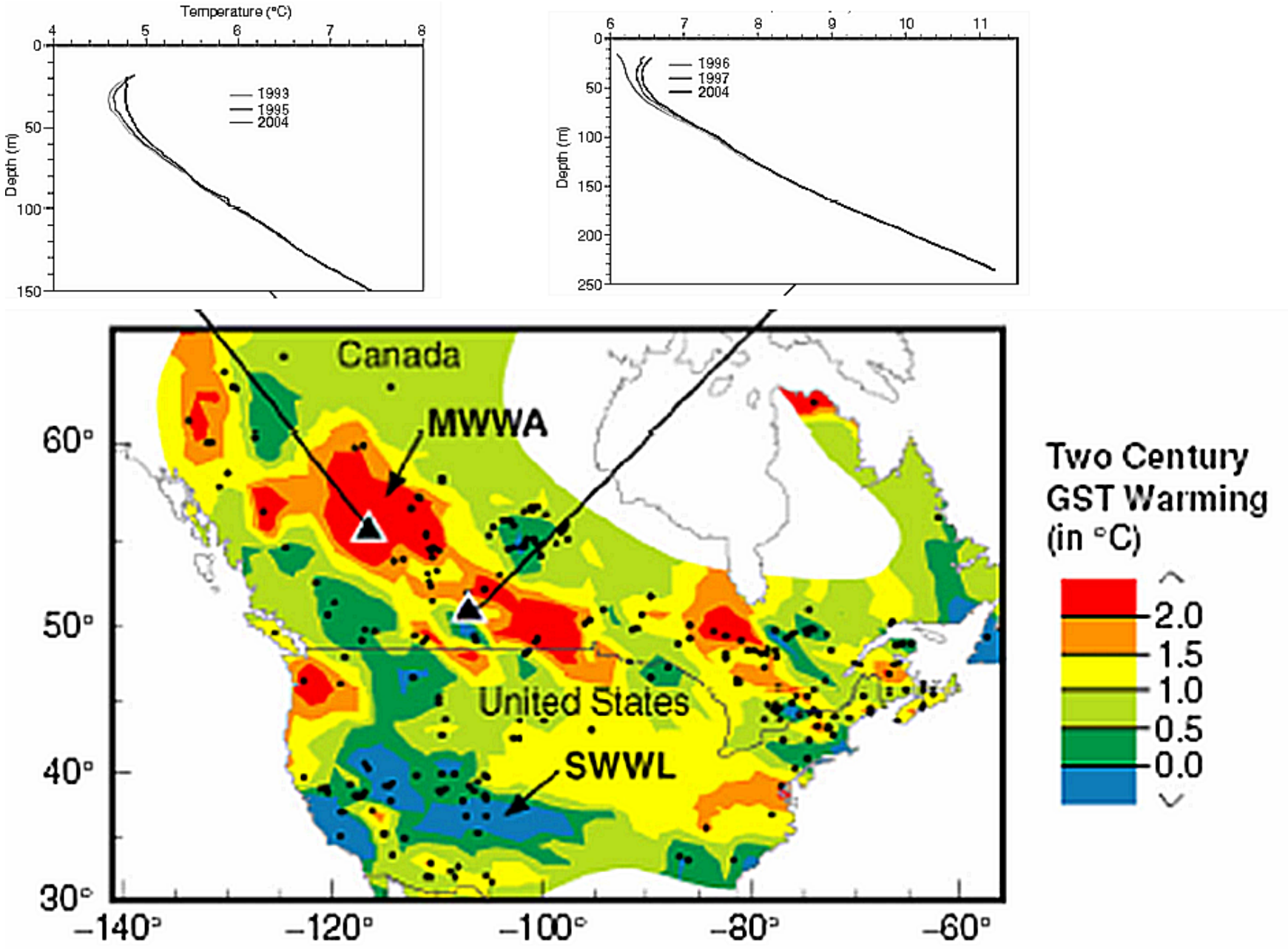
Current Precipitation Compared to Historical Distribution

September 1, 2000 to August 31, 2001 (A.M.)



Prepared by PFRA (Prairie Farm Rehabilitation Administration) using data from the Timely Climate Monitoring Network and the many federal and provincial agencies and volunteers that support it.

Source: Majorowicz and Safanda (2005)

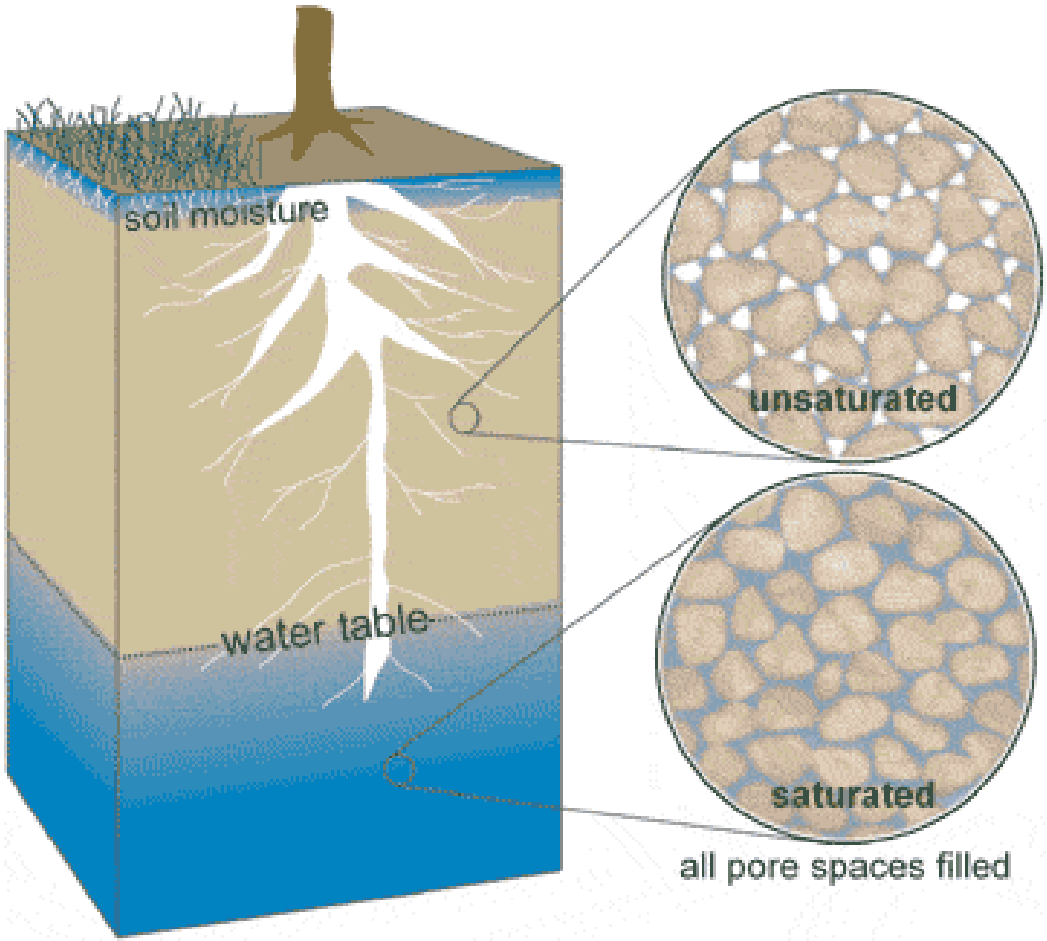


Overview

1. Objectives and background
2. Hydrogeology of the ADA
3. Groundwater modelling (MODFLOW)
4. Land surface modelling (CLASS)
5. Atmospheric modelling (MM5)
6. Coupling strategy
7. Software working tools
8. Field data required
9. Initial simulations and conclusions

Objectives

- Climate change impacts and adaptations for the ADA
- Couple atmosphere, surface and groundwater models

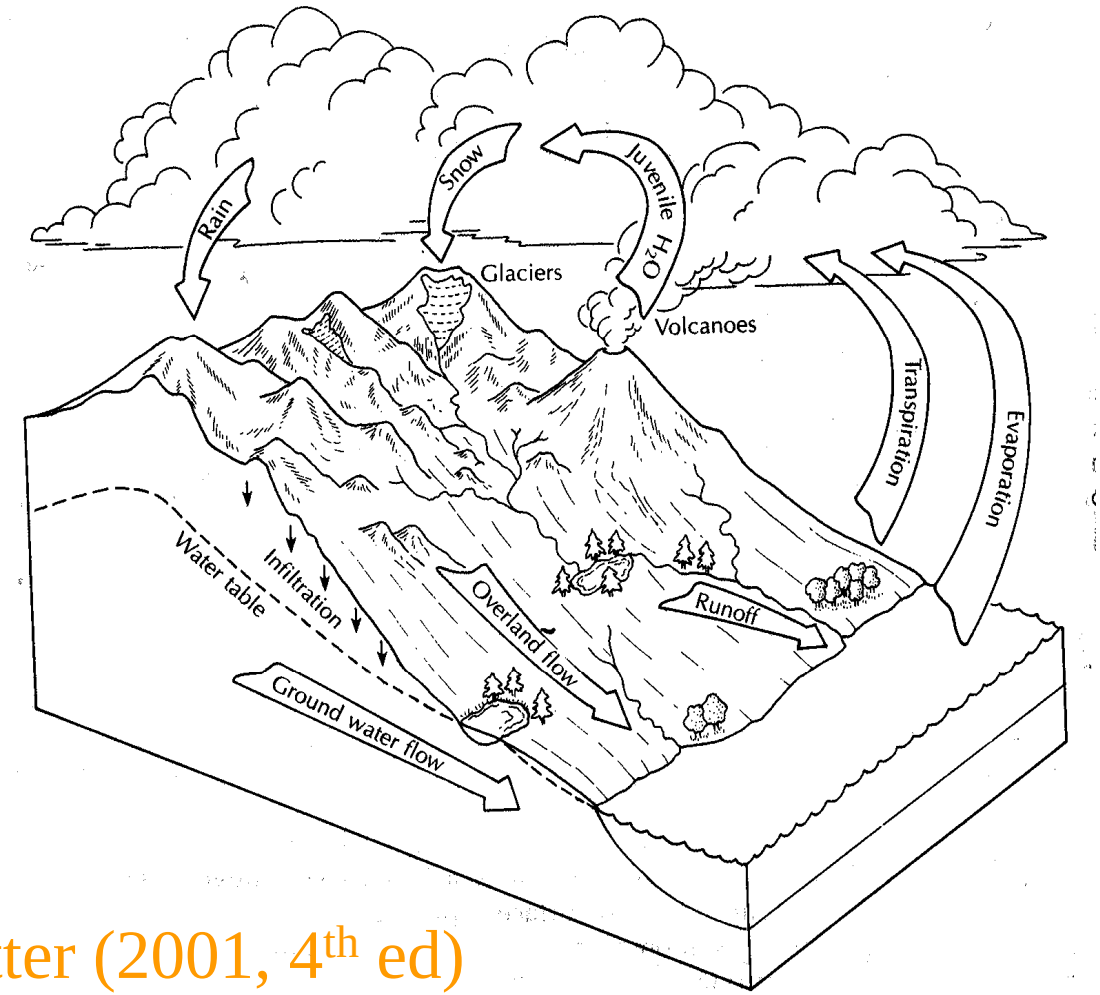


Provide :

1. **Lower boundary condition for the atmospheric model**
2. **Management schemes for sustainability of water quantity / quality**
3. **Prediction of pollution stemmed from human practices over ADA**

Prelude

- How do we deal with climate change now?



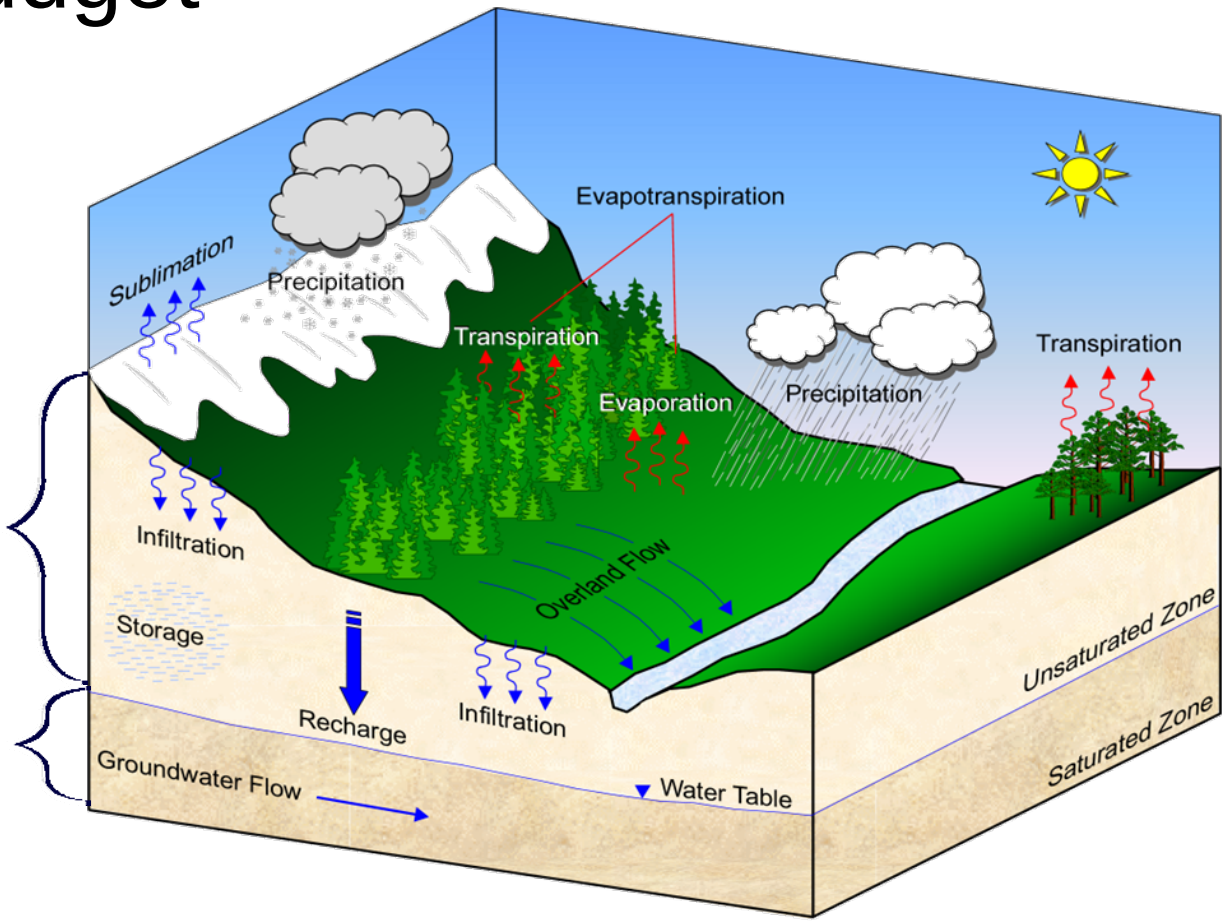
Source: Fetter (2001, 4th ed)

University of Waterloo

- Water Budget

HELP3

MODFLOW

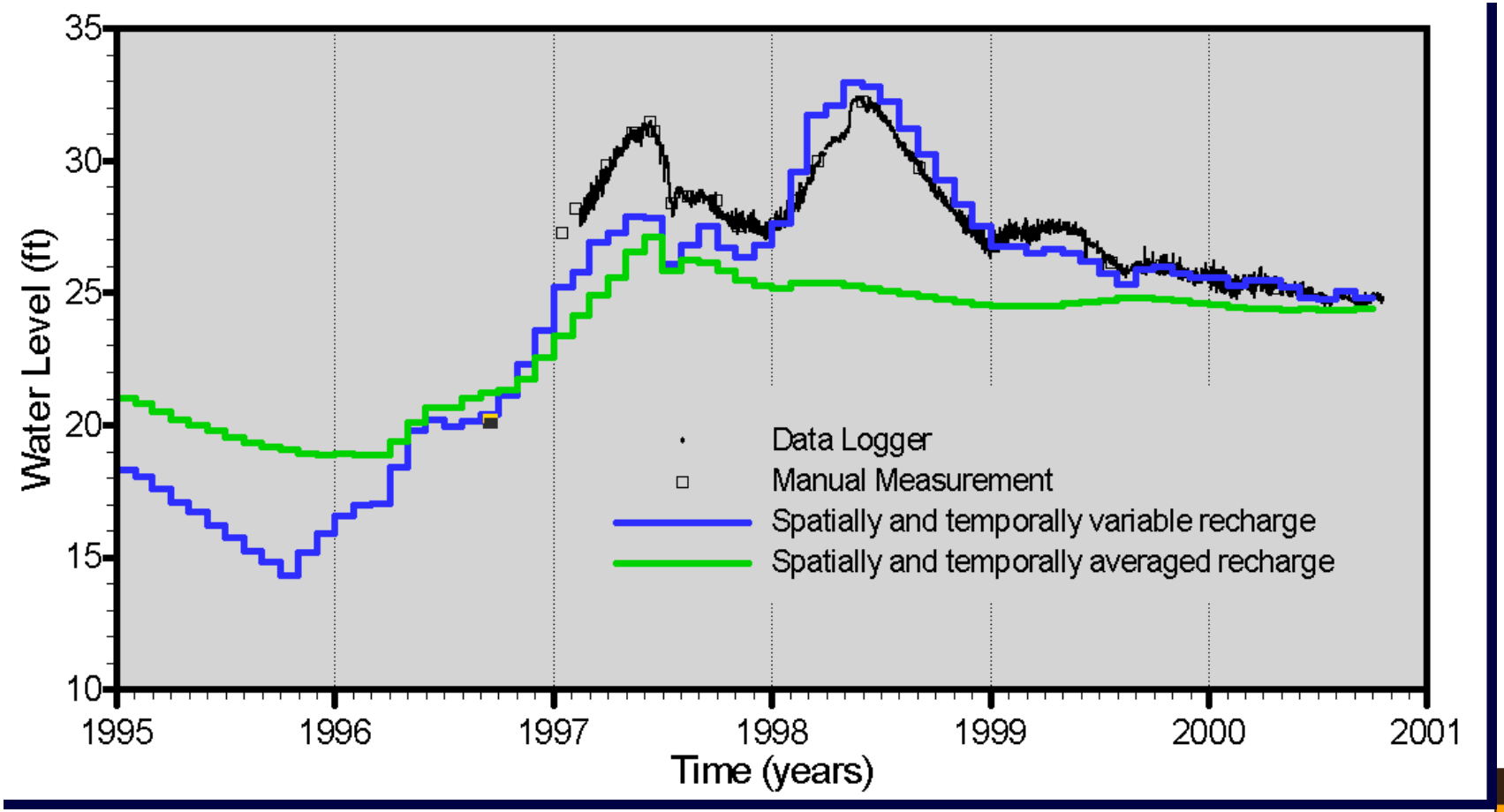


M.I. Jyrkama, J.F. Sykes, and S.D. Normani, 2002.
Recharge Estimation for Transient Ground Water Modeling.
Ground Water, 40(6), 638-648.

Laural Creek Results

Courtesy of M.I. Jyrkama

- Impact of **recharge** boundary condition on **groundwater** flow



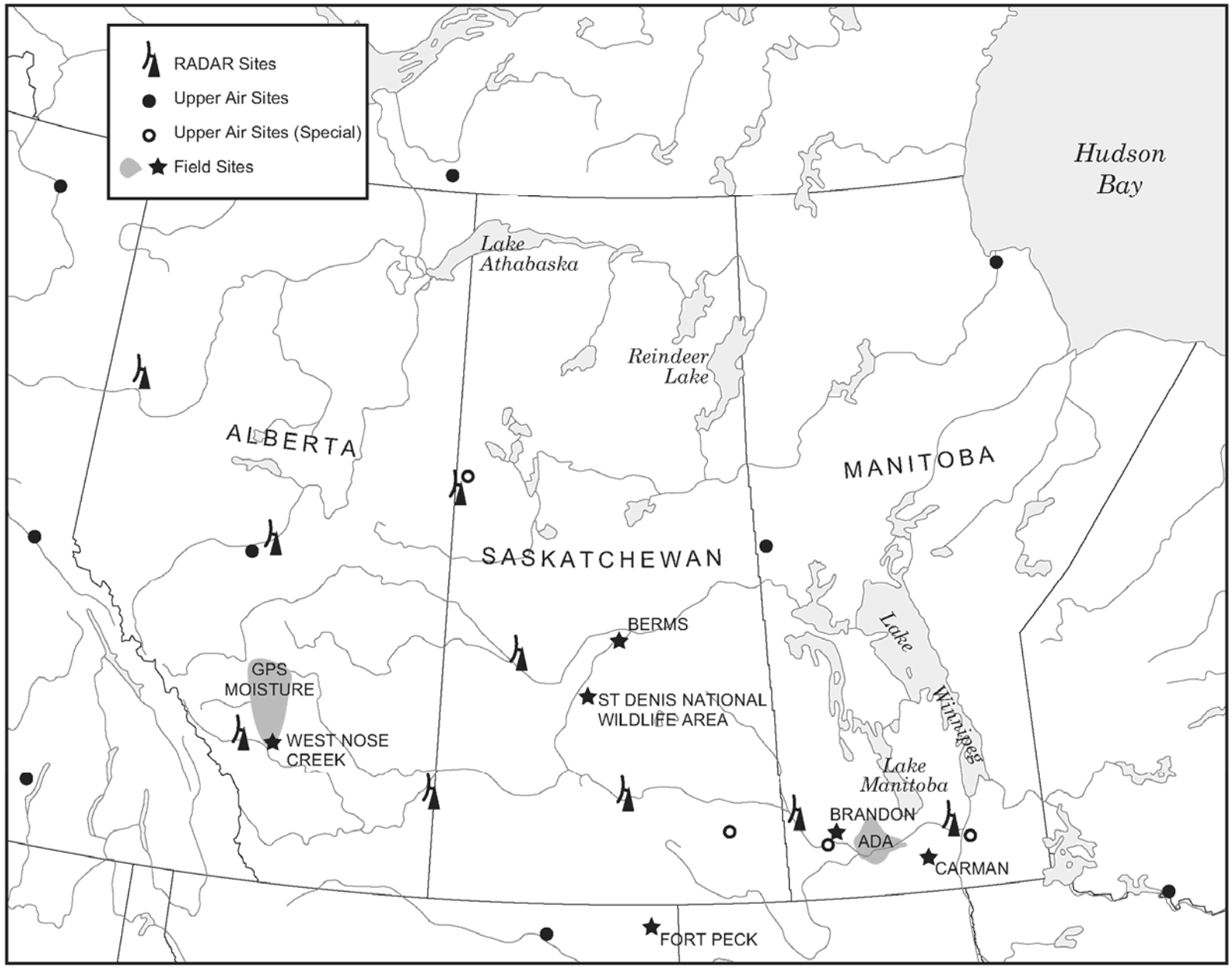
Simulated vs. observed water levels at a monitoring well

Enhancements

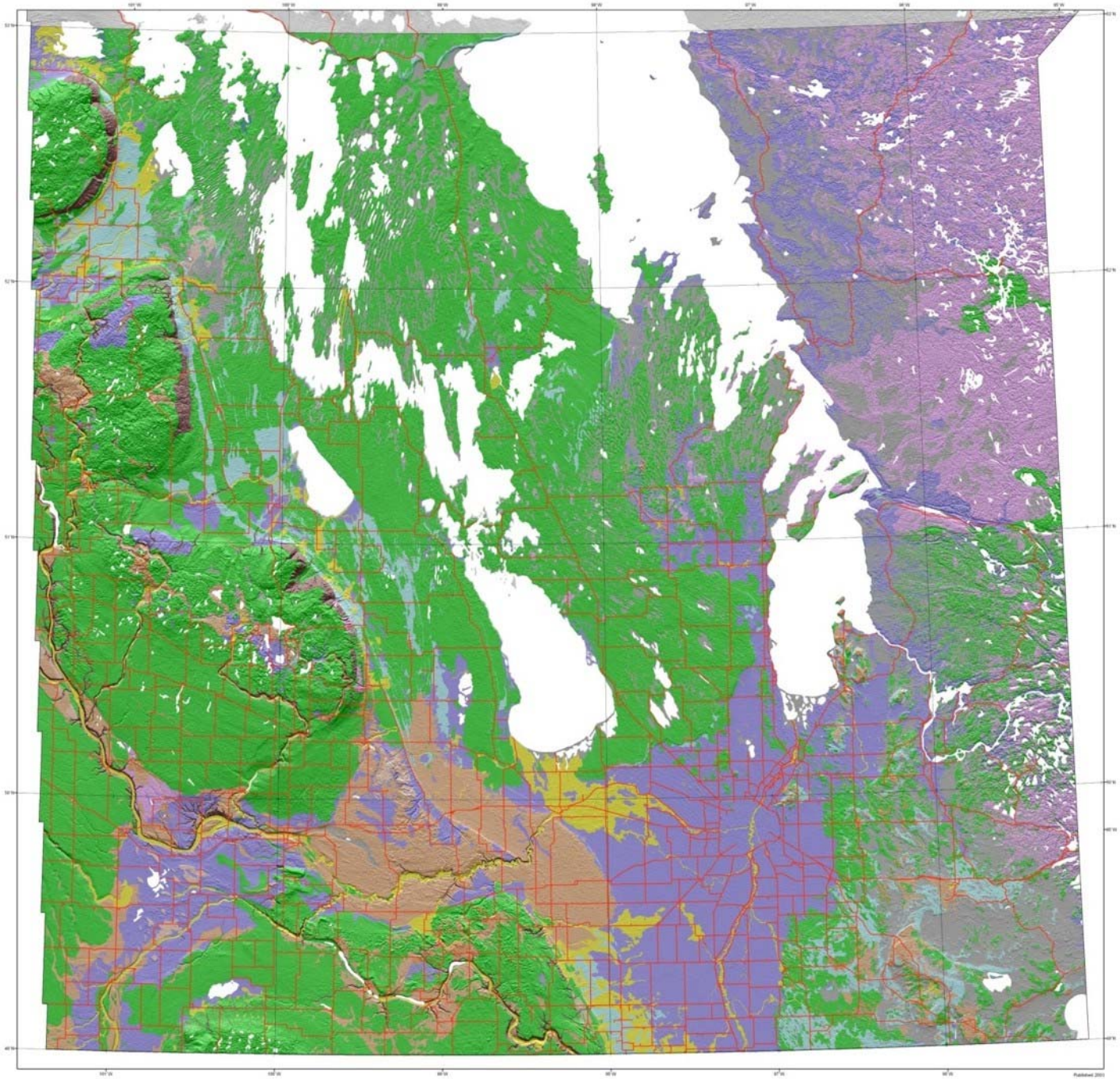
- WatCLASS Development
  - Motivation for adding streamflow to atmospheric models
  - Coupling WATFLOOD and CLASS (Snelgrove, 2002)

- Results
  - BOREAS Tower simulations – Point Scale
  - BOREAS Study Areas – Headwater Scale
  - Mackenzie River – Atmospheric Domain

ADA Hydrogeology



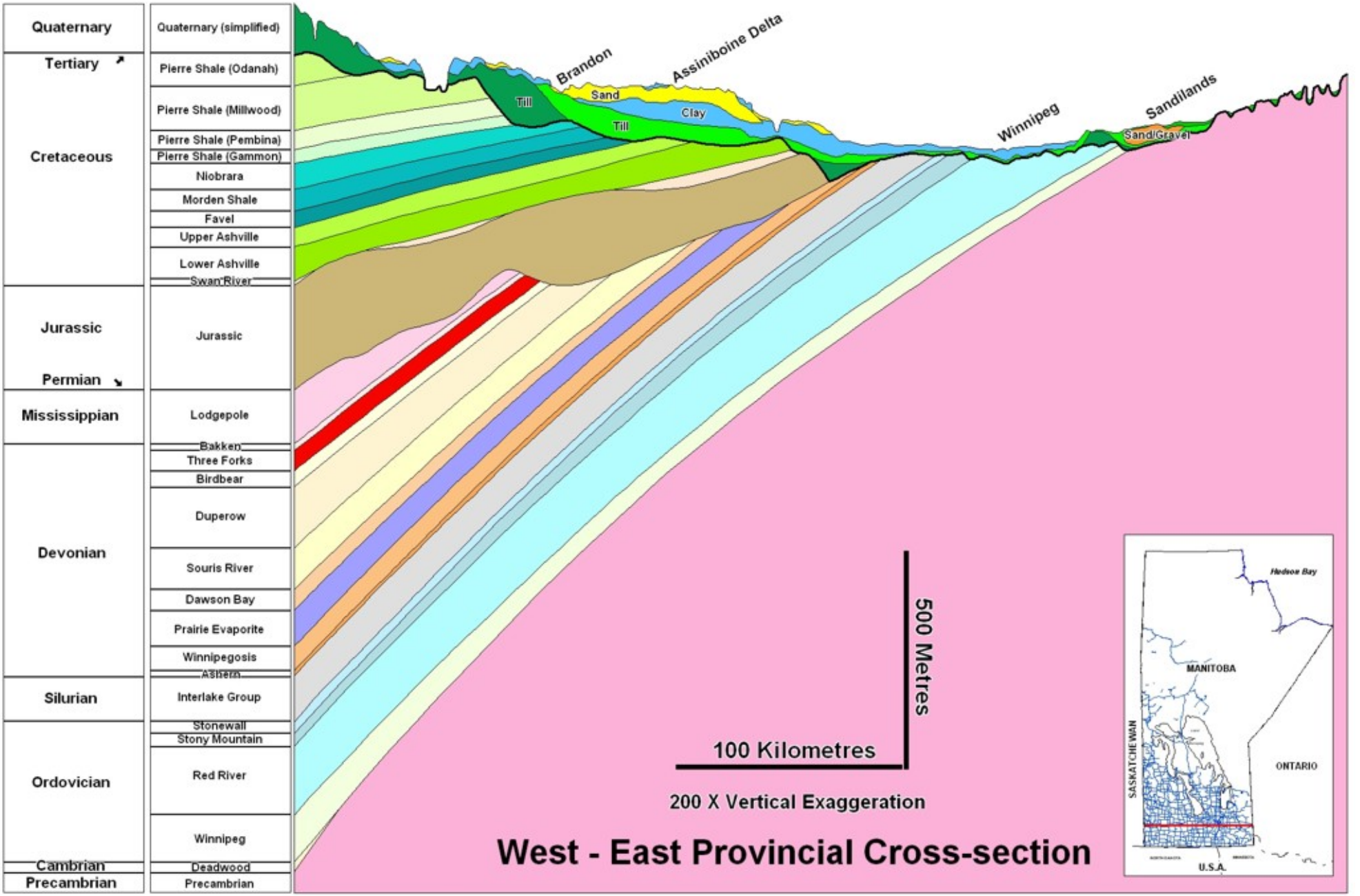
Quaternary Geology with Shaded Relief Elevation for Southern Manitoba

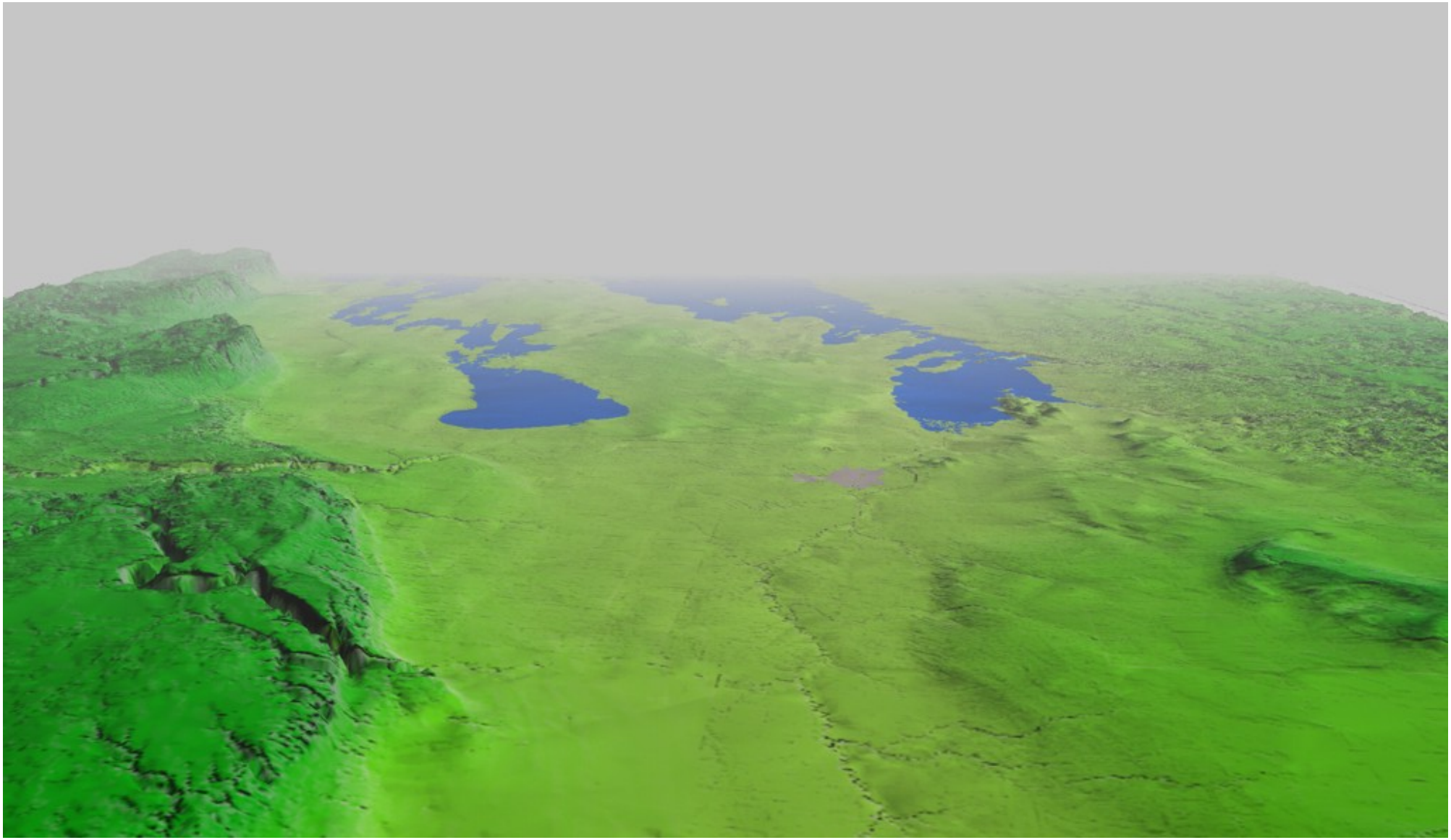


North American Datum 1983
Transverse Mercator Projection
Zone 14

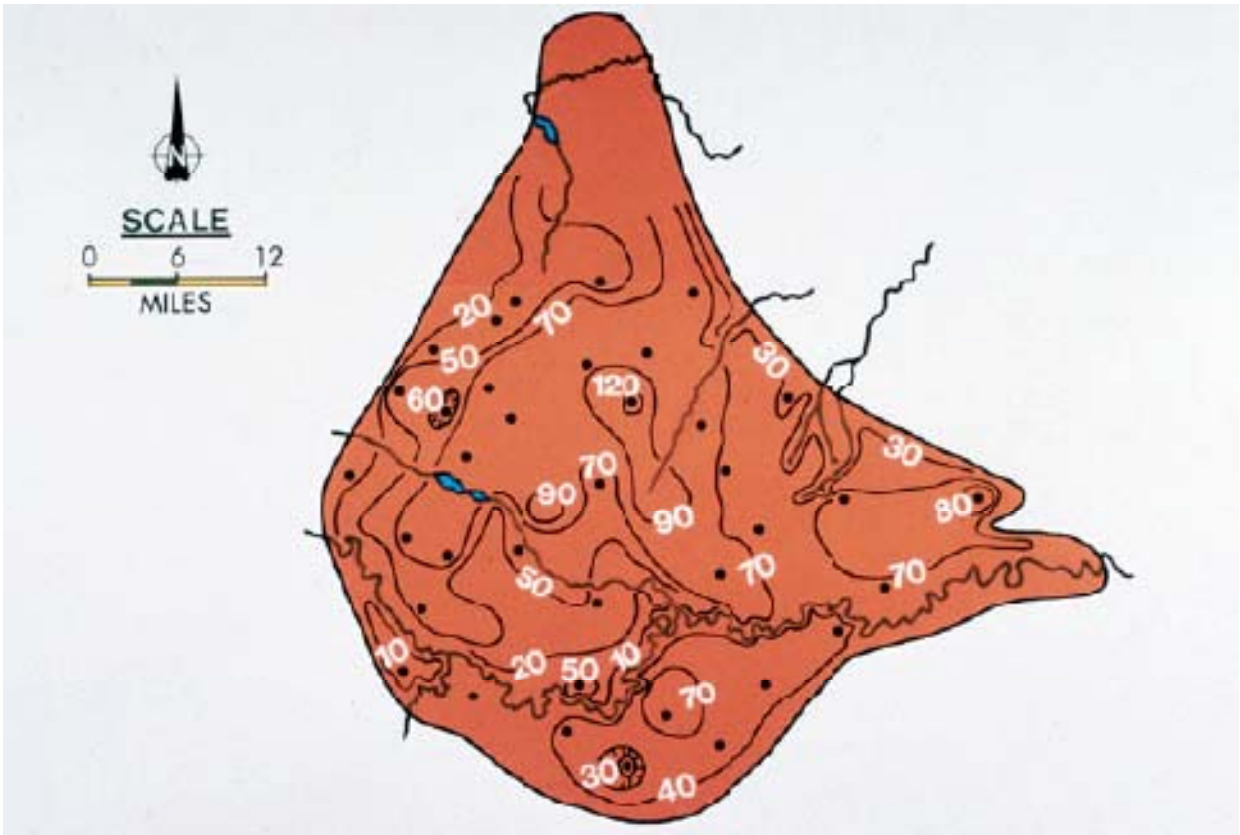
Manitoba Industry, Trade and Mines
Manitoba Geological Survey
2003

Published 2003


Quaternary
Tertiary
Cretaceous
Jurassic
Permian
Mississippian
Devonian
Silurian
Ordovician
Cambrian
Precambrian
Quaternary (simplified)
Pierre Shale (Odanah)
Pierre Shale (Millwood)
Pierre Shale (Pembina)
Pierre Shale (Gammon)
Niobrara
Morden Shale
Favel
Upper Ashville
Lower Ashville
Swan River
Jurassic
Lodgepole
Bakken
Three Forks
Birdbear
Duperow
Souris River
Dawson Bay
Prairie Evaporite
Winnipegosis
Ashern
Interlake Group
Stonewall
Stony Mountain
Red River
Winnipeg
Deadwood
Precambrian
Brandon
Assiniboine Delta
Till
Sand
Clay
Till
Winnipeg
Sandilands
Sand/Gravel
500 Metres
100 Kilometres
200 X Vertical Exaggeration
West - East Provincial Cross-section
Hudson Bay
MANITOBA
SASKATCHEWAN
ONTARIO
U.S.A.



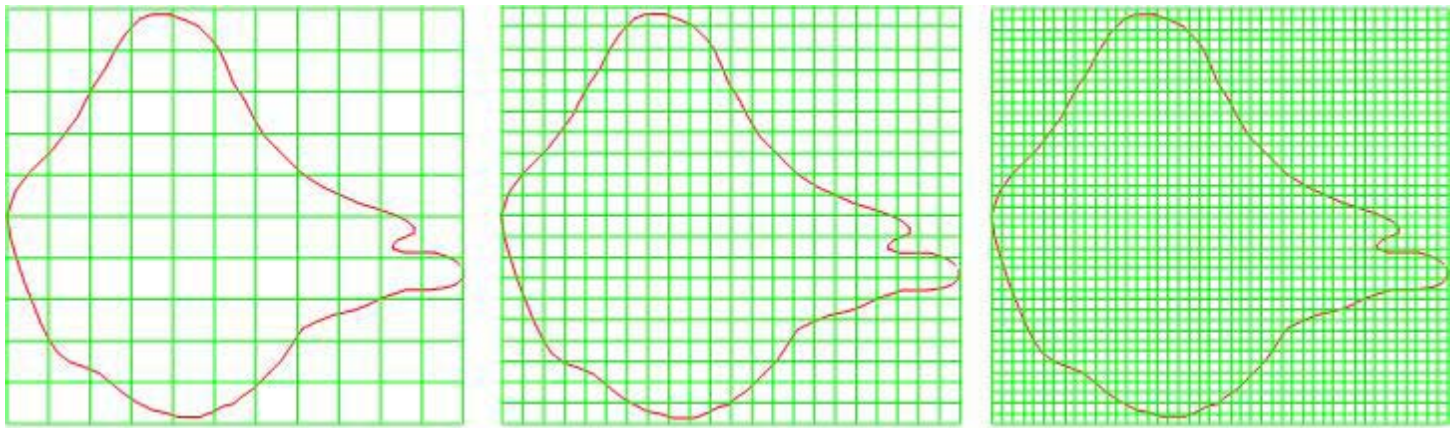
Sand and Gravel Isopach of the Assiniboine Delta Aquifer (ft)

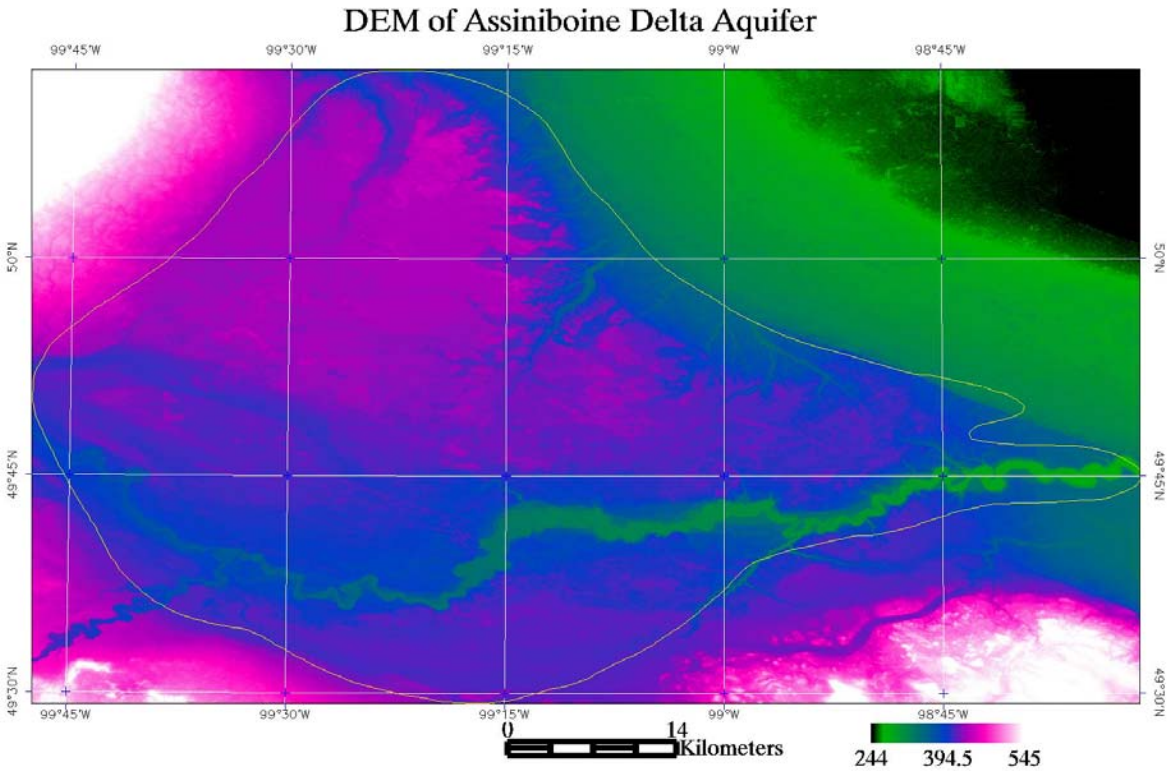


L.H. Frost and F.W. Render, 2002

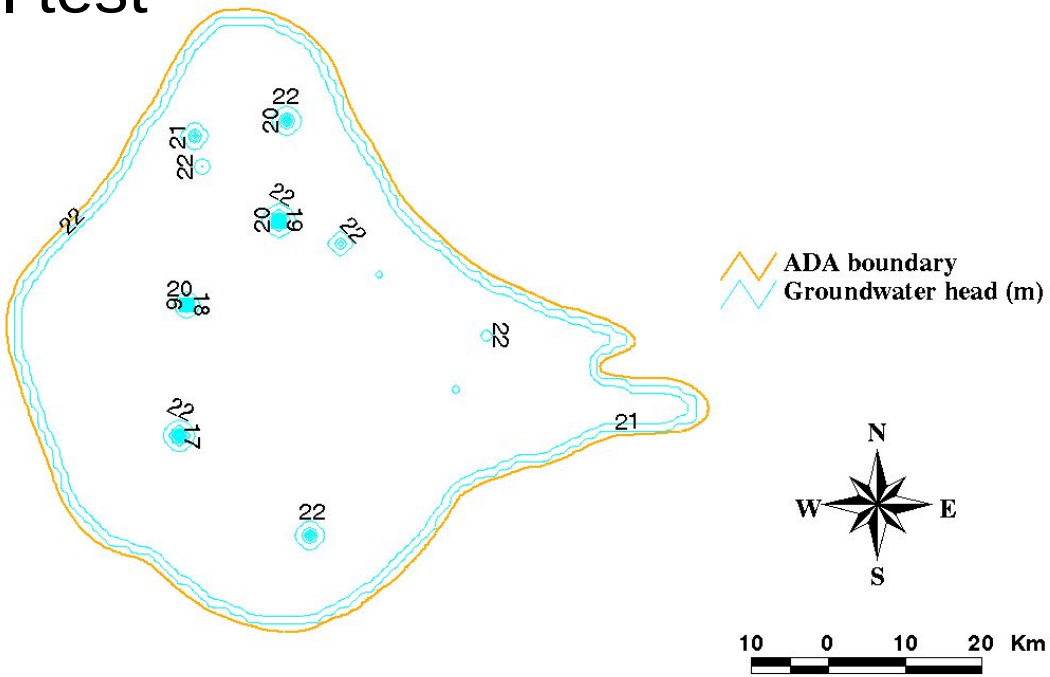
- Bedrock 180 – 460 m
- Hydraulic Conductivity: 4 – 120 m/d
- Specific yield: 0.1 – 0.29

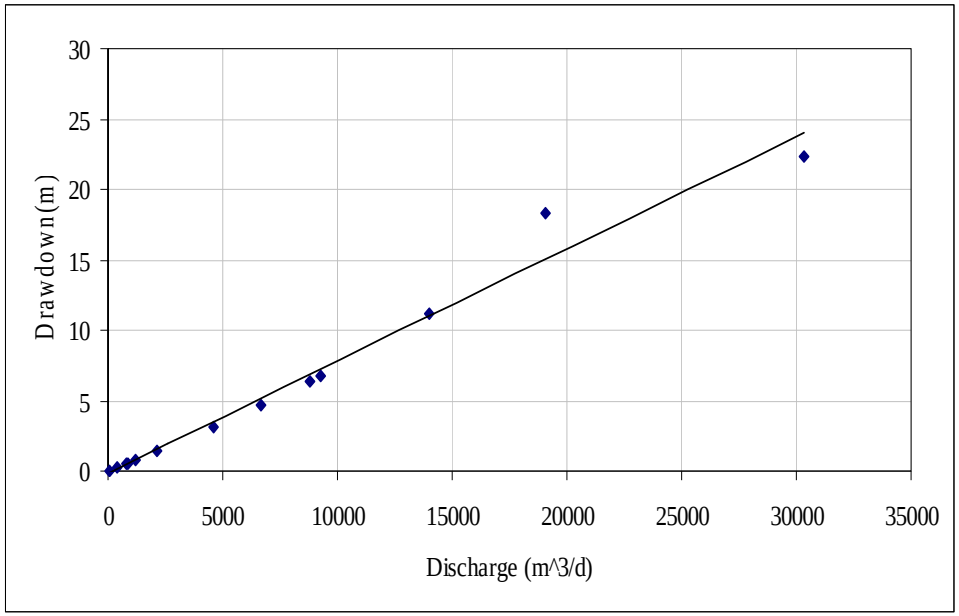
Groundwater: MODFLOW



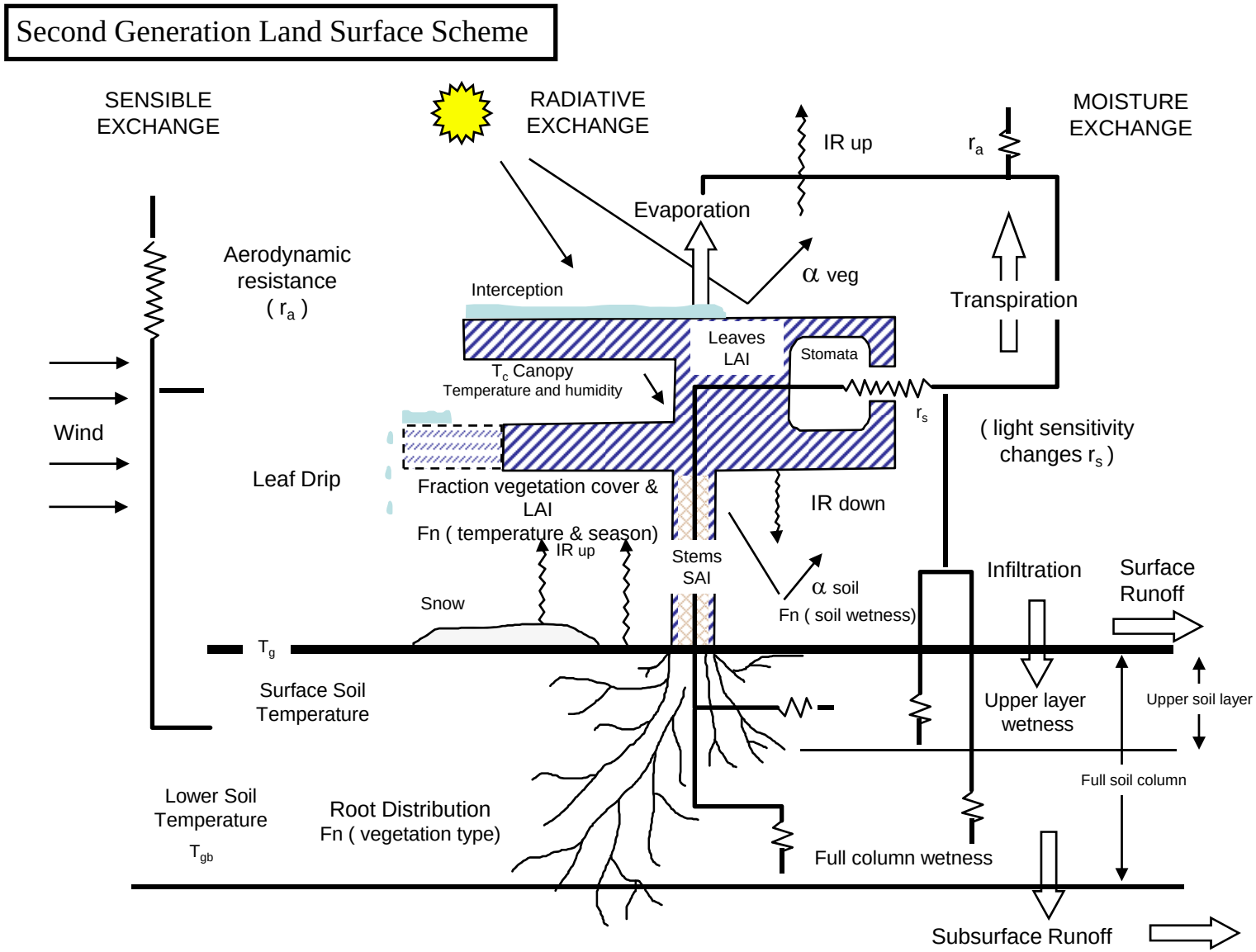


MODFLOW model test

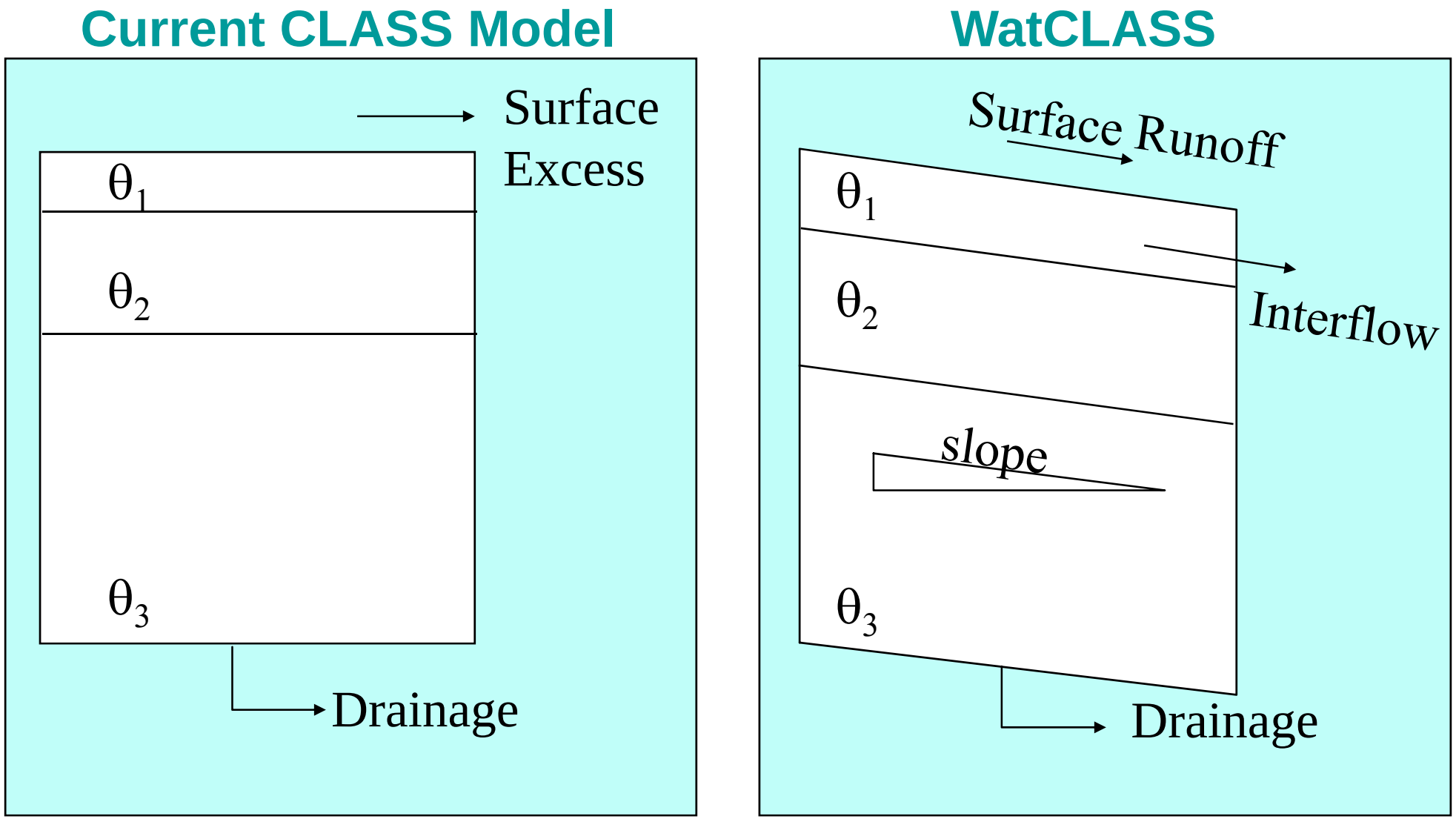




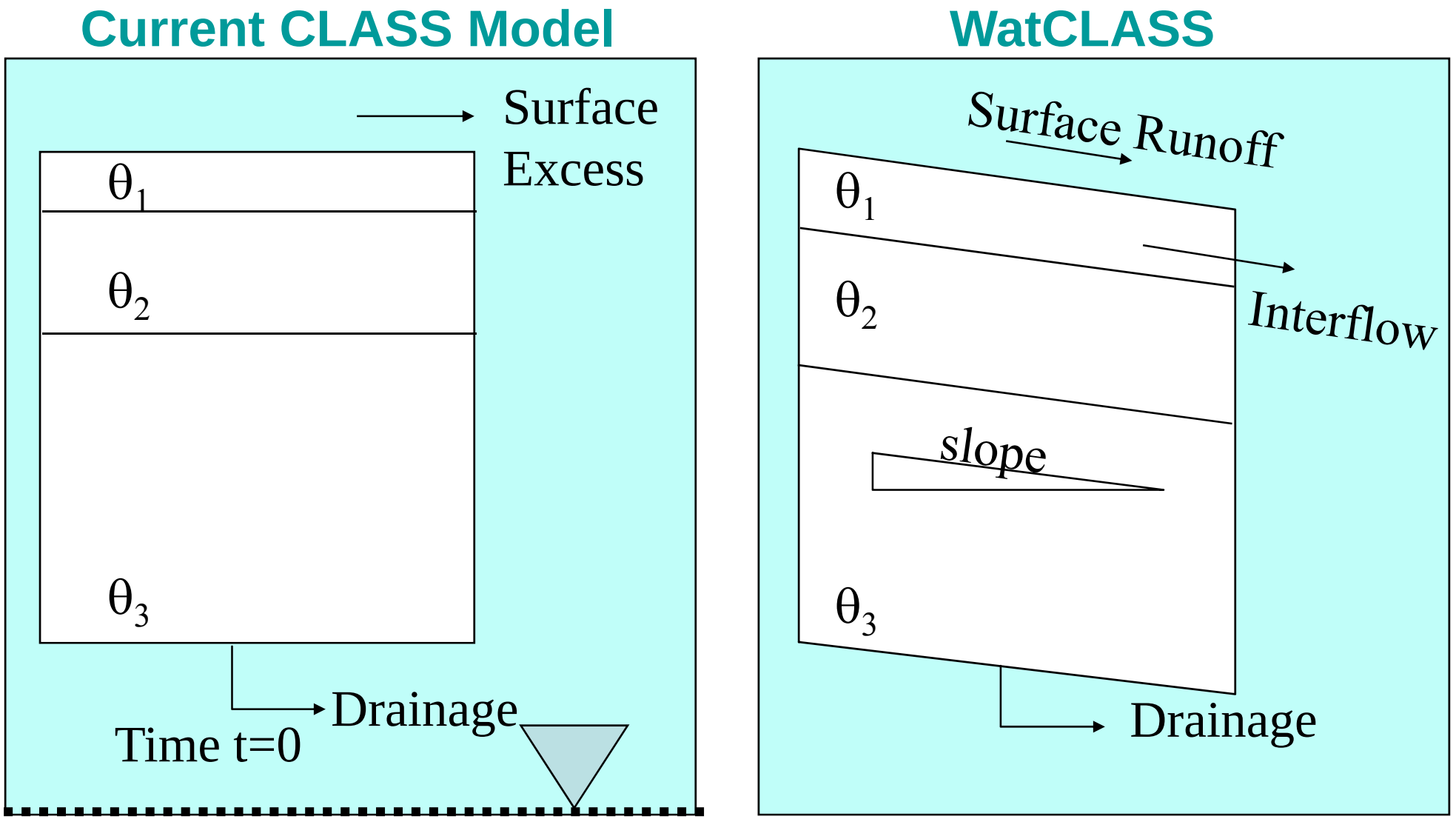
Land Surface Scheme (Class)



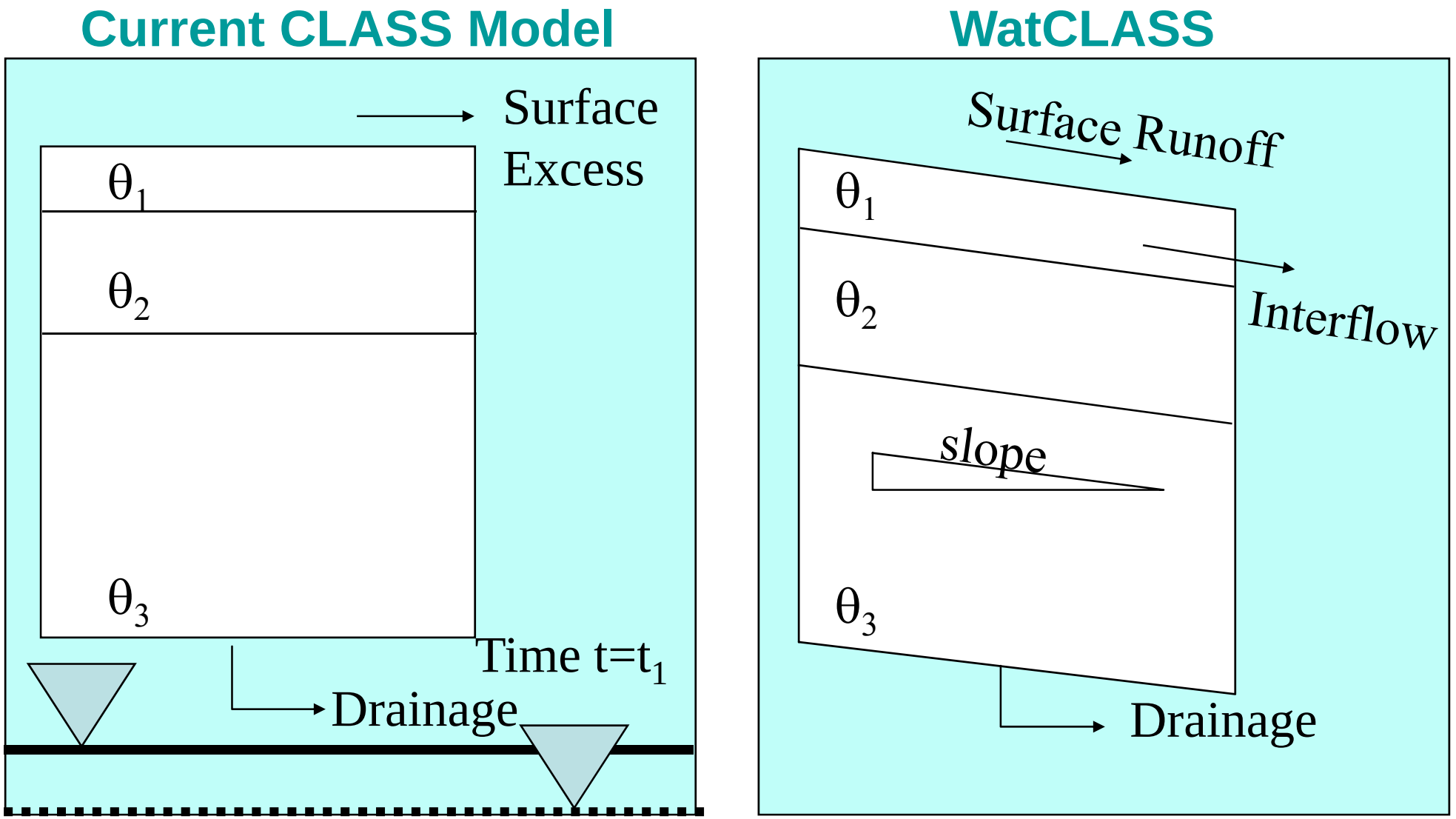
Improved CLASS Soil Column



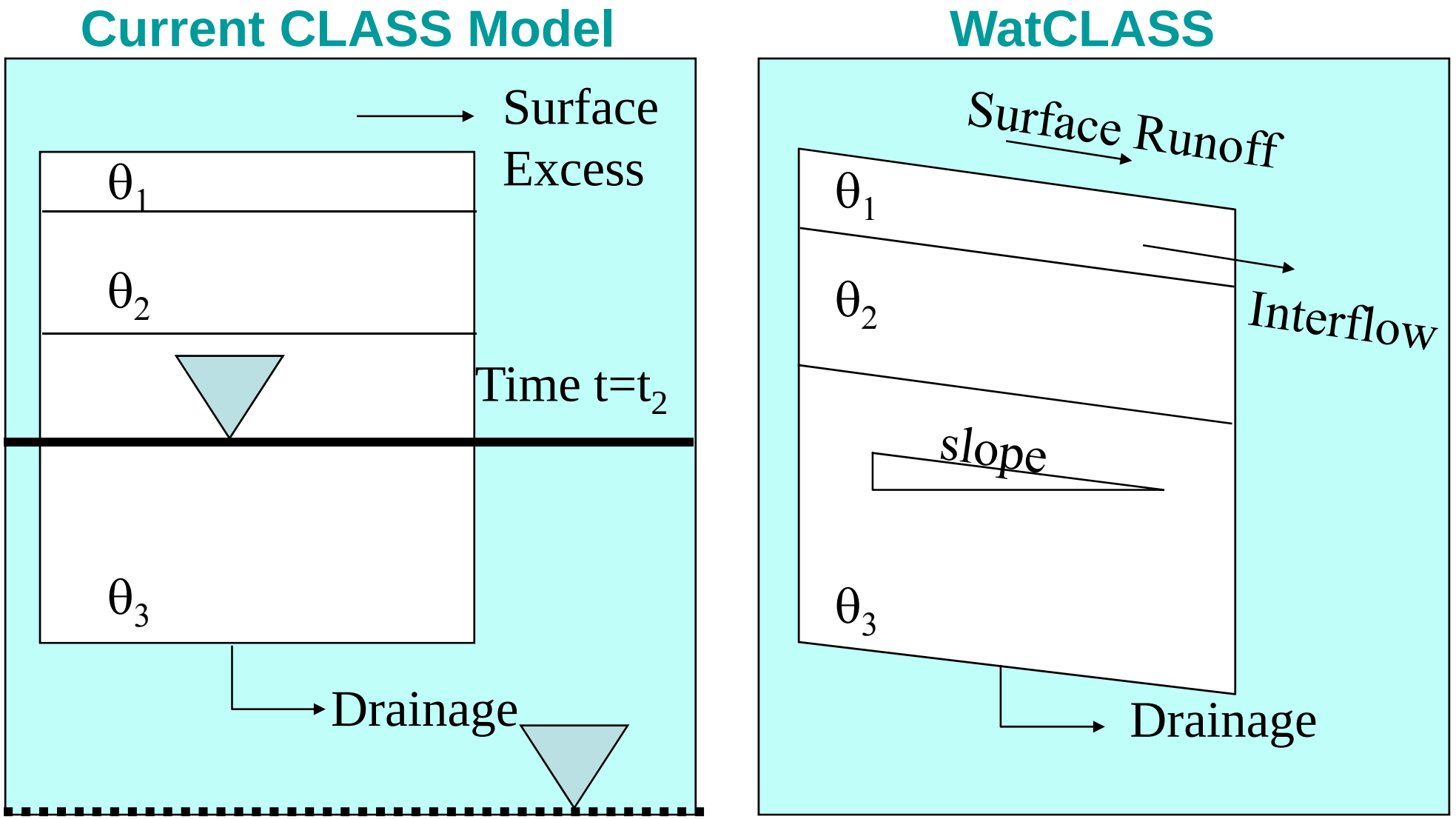
Improved CLASS Soil Column



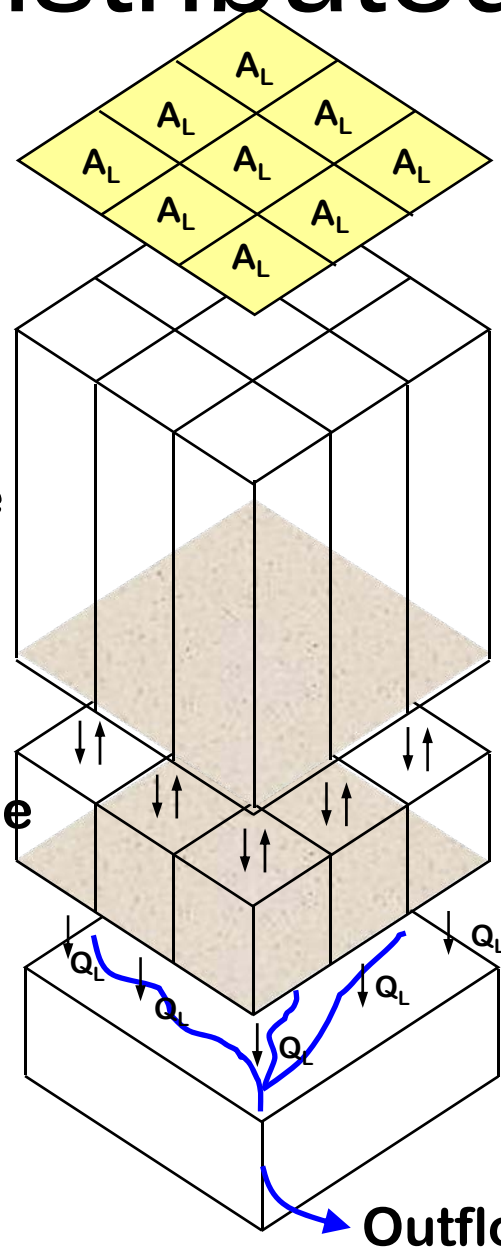
Improved CLASS Soil Column



Improved CLASS Soil Column



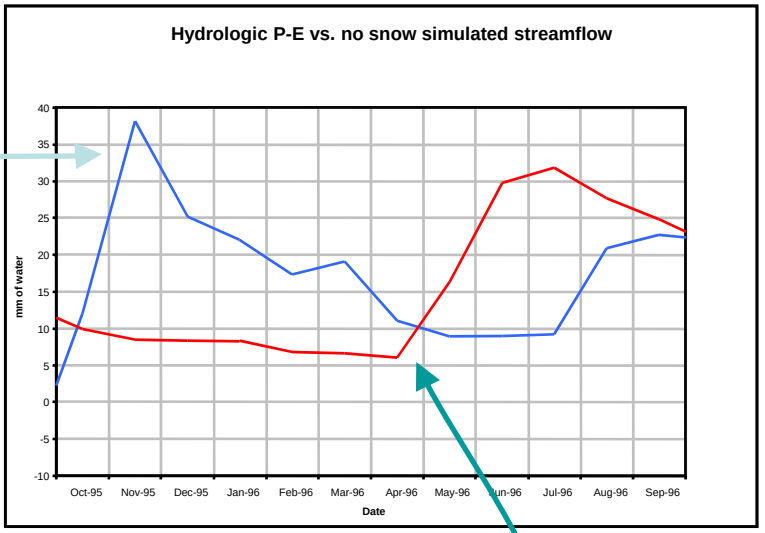
Distributed Water Balance



$=A_B$

Atmosphere (A)

P-E



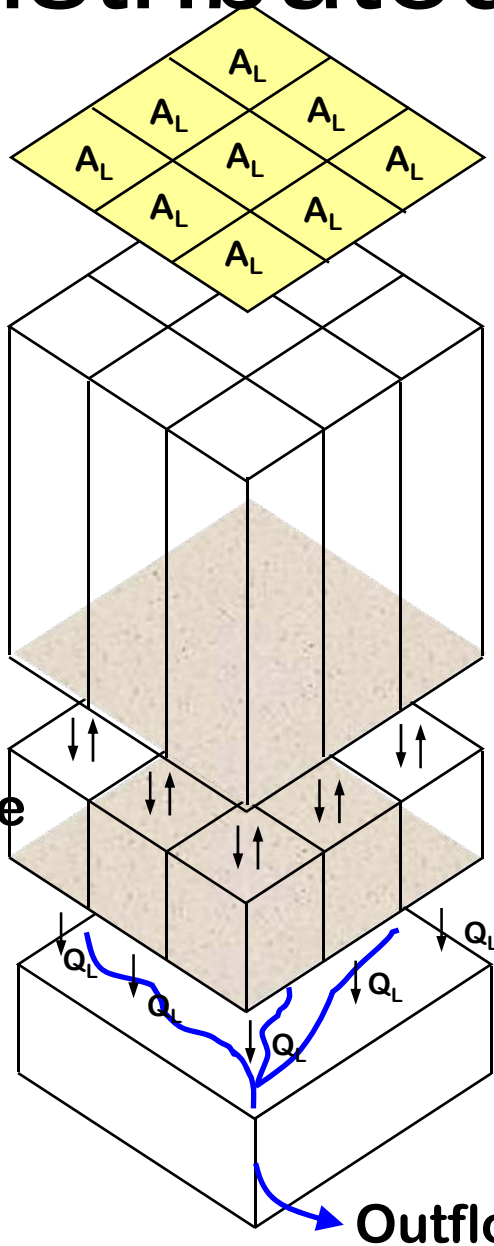
Land Surface (L)

Outflow = Q_L, Runoff = R_L

Channel Network (C)

Outflow Q_B,Runoff $R_B=Q_B/A_B$

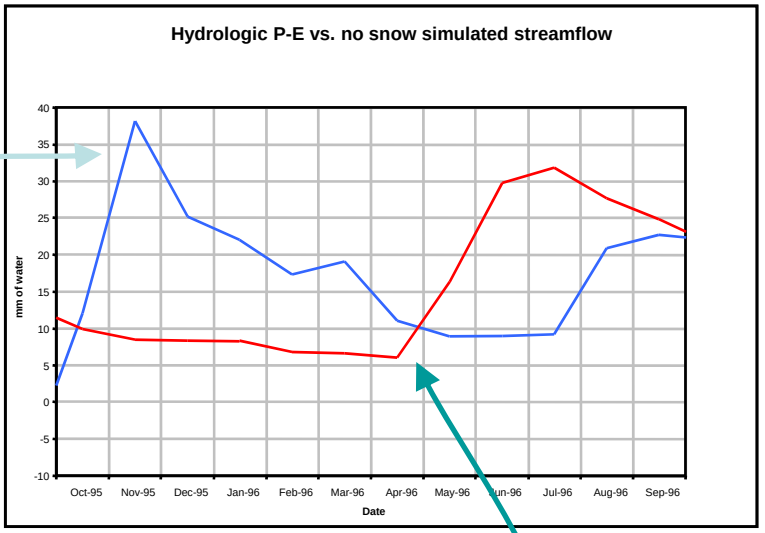
Distributed Water Balance



$=A_B$

Atmosphere (A)

P-E



Land Surface (L)

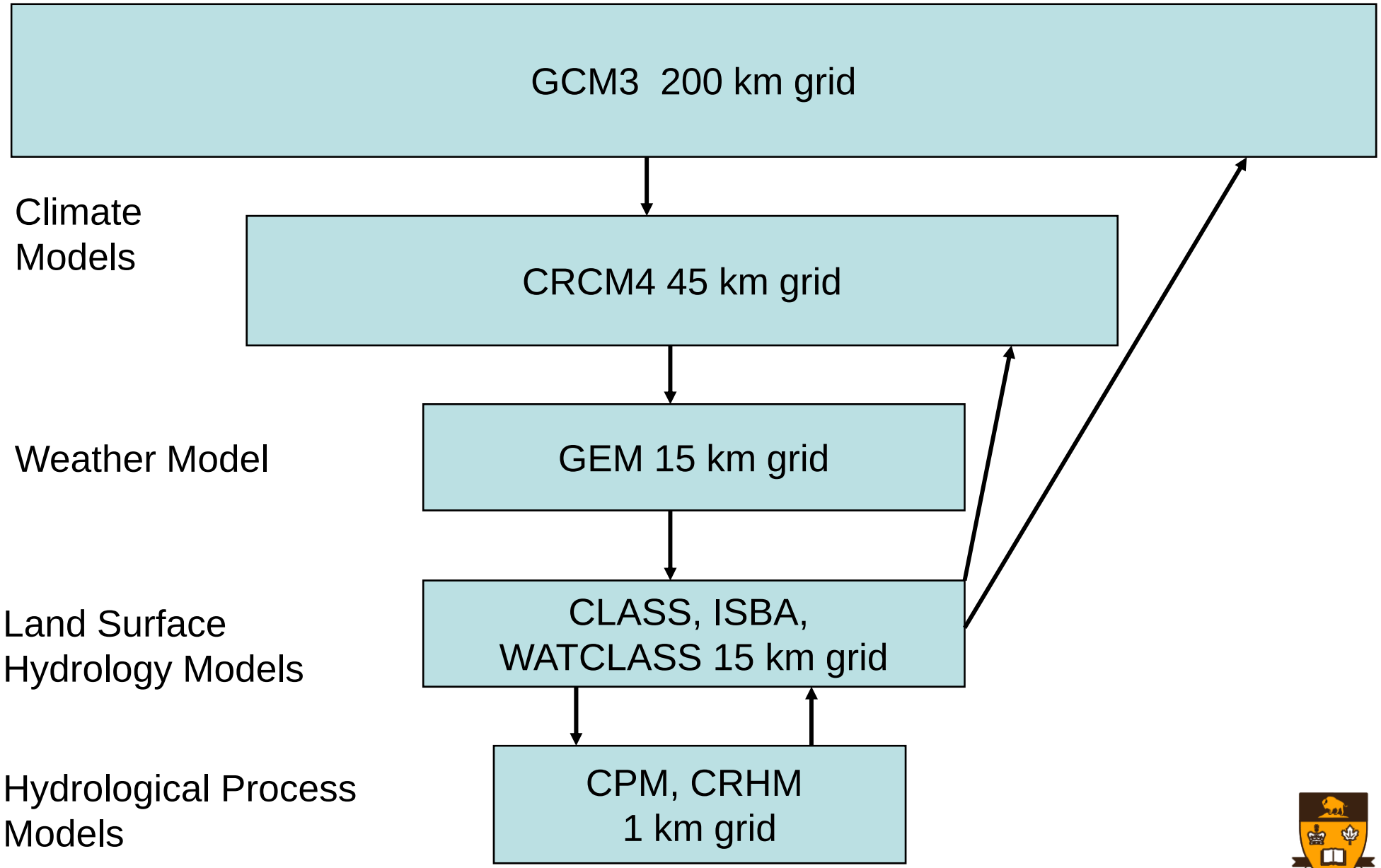
Outflow = Q_L, Runoff = R_L

Channel Network (C)

Outflow Q_B,Runoff $R_B=Q_B/A_B$

Groundwater (G)

Atmospheric Models



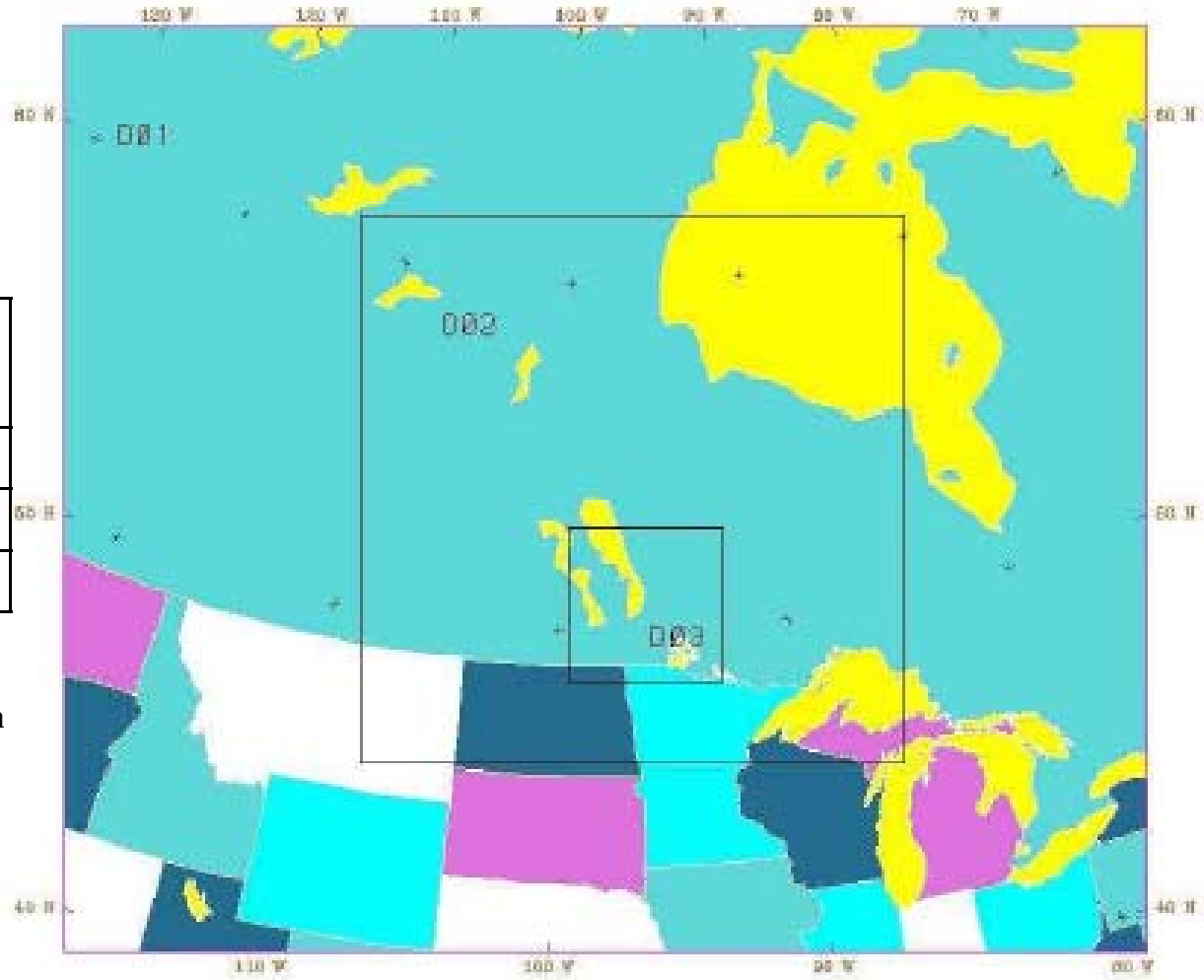
Atmospheric Modelling (MM5)

Domain set-up for MM5 run

Center of the Course Domain:
54 ^{O} North , 98 ^{O} West

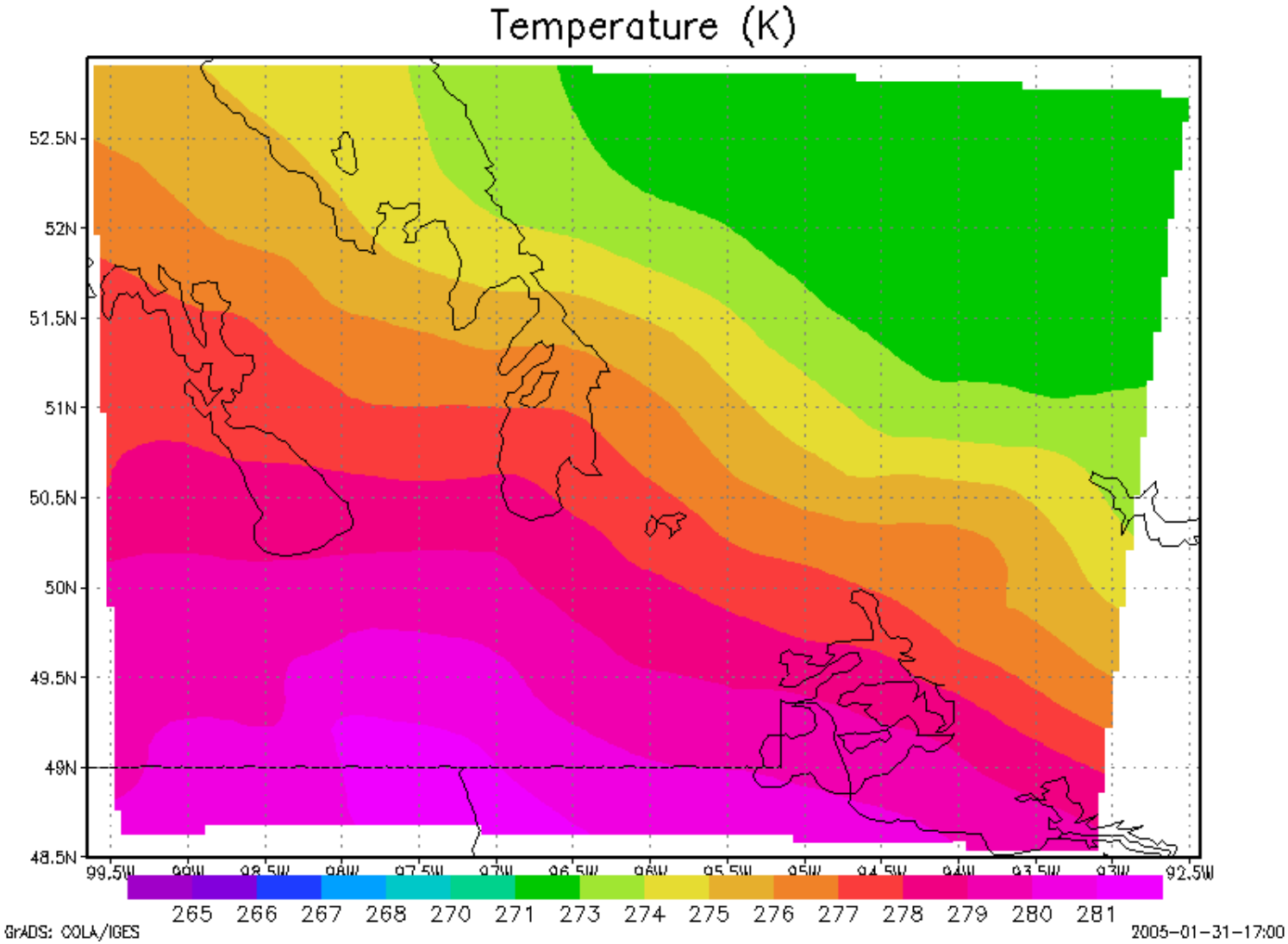
Domain/ Grid dist.	Grids E-W	Grids N-S
D01/90 Km	41	35
D02/30 Km	61	61
D03/10 Km	52	52

National Center for Environmental Prediction (NCEP) Reanalysis II data has been used to drive the model.



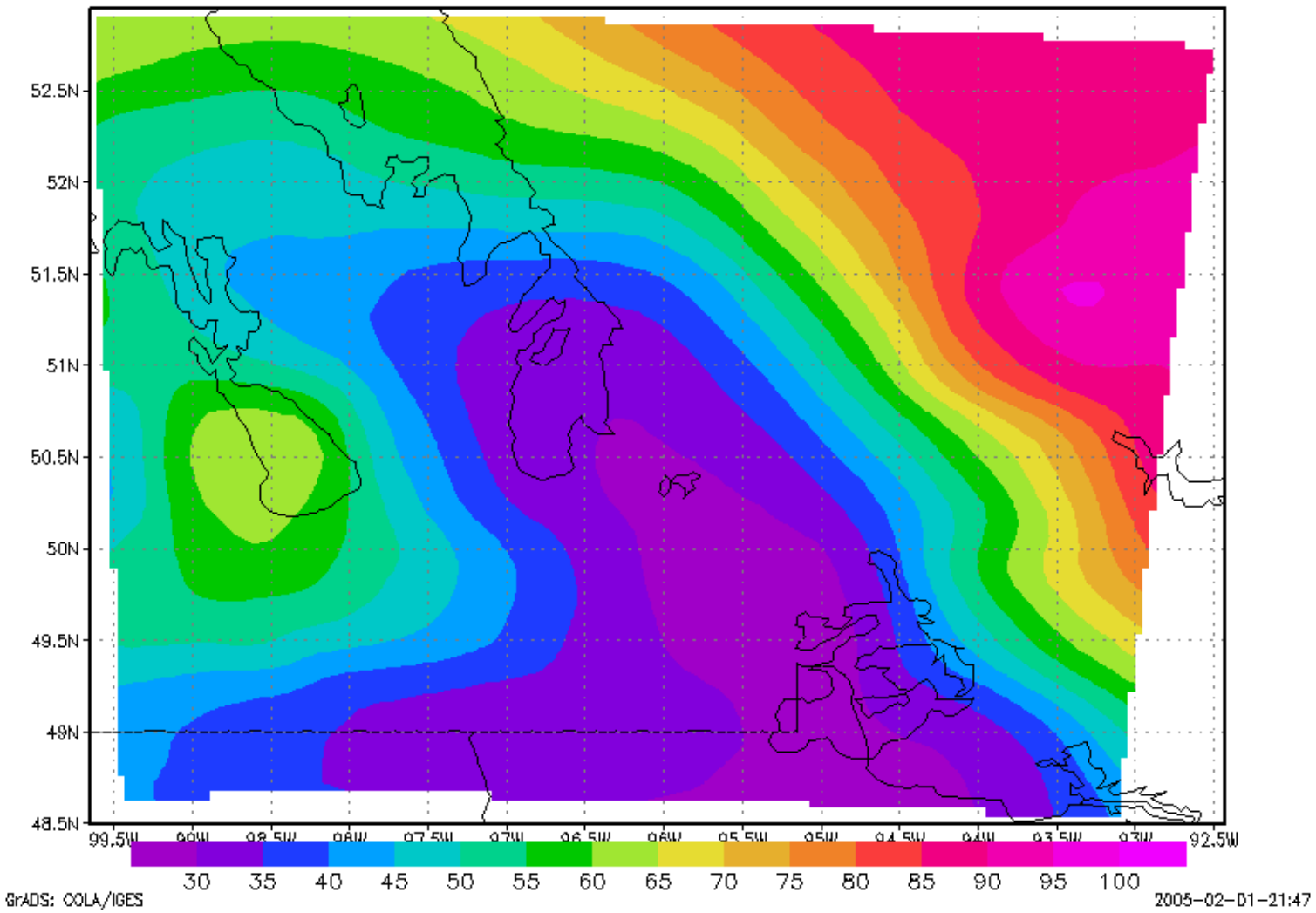
Model Output :

Animated Hourly Temperature output: From 00Z01MAY2004 to 00Z02MAY2004

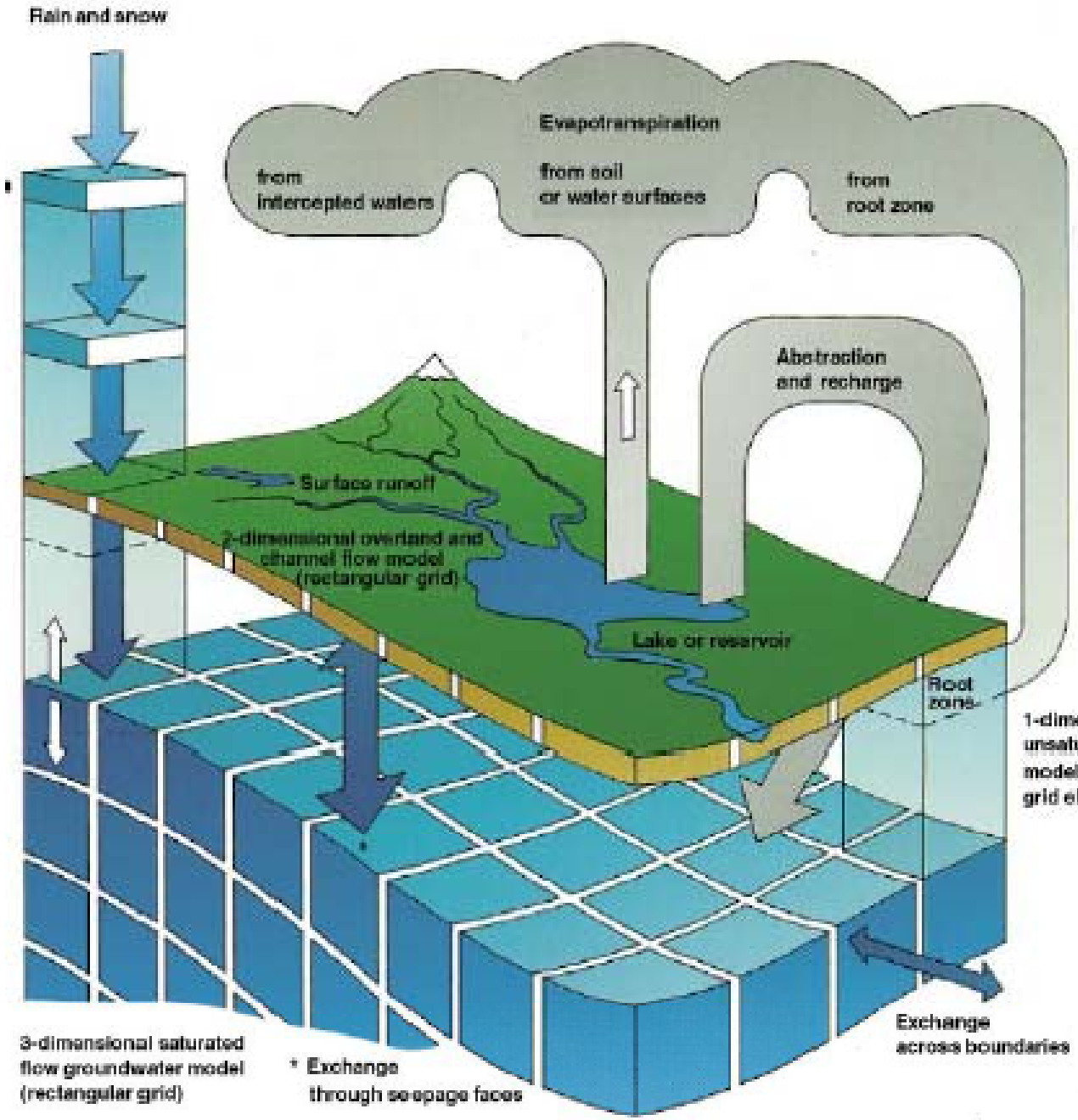


Model Output :

Animated Hourly Relative Humidity output: From 00Z01MAY2004 to 00Z02MAY2004



Coupling Strategy

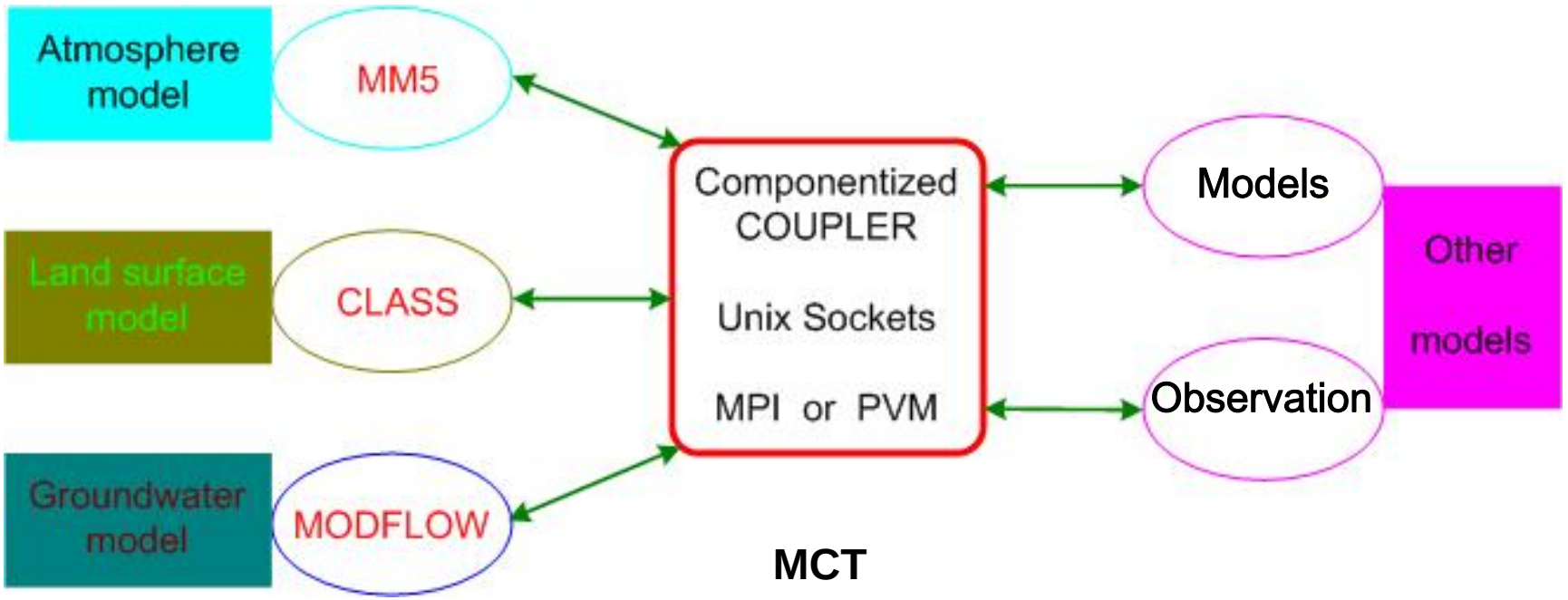


MM5

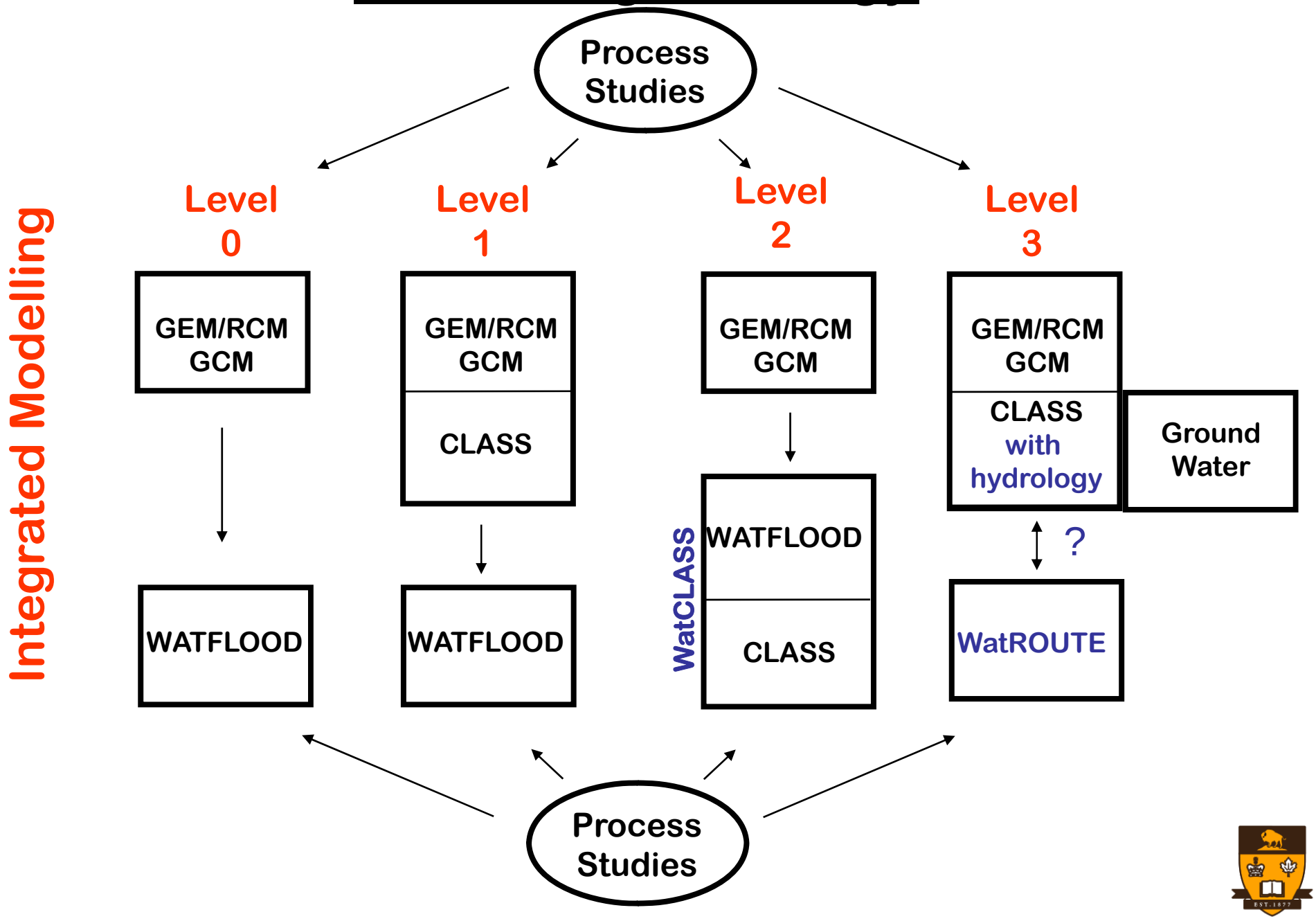
CLASS

MODFLOW

Parallelized / coupled modelling environment



Modelling Strategy



Software Working Tools

Basics

- Numerical / hydrological modeling
- Computational analysis and optimization
- High performance computing

Development

- MODFLOW : 70,000 code lines
- CLASS : 10,000 code lines
- Code structure analysis
- Scientific / industrial programming

GIS : ArcView, ArcInfo, etc.

Field Data Required

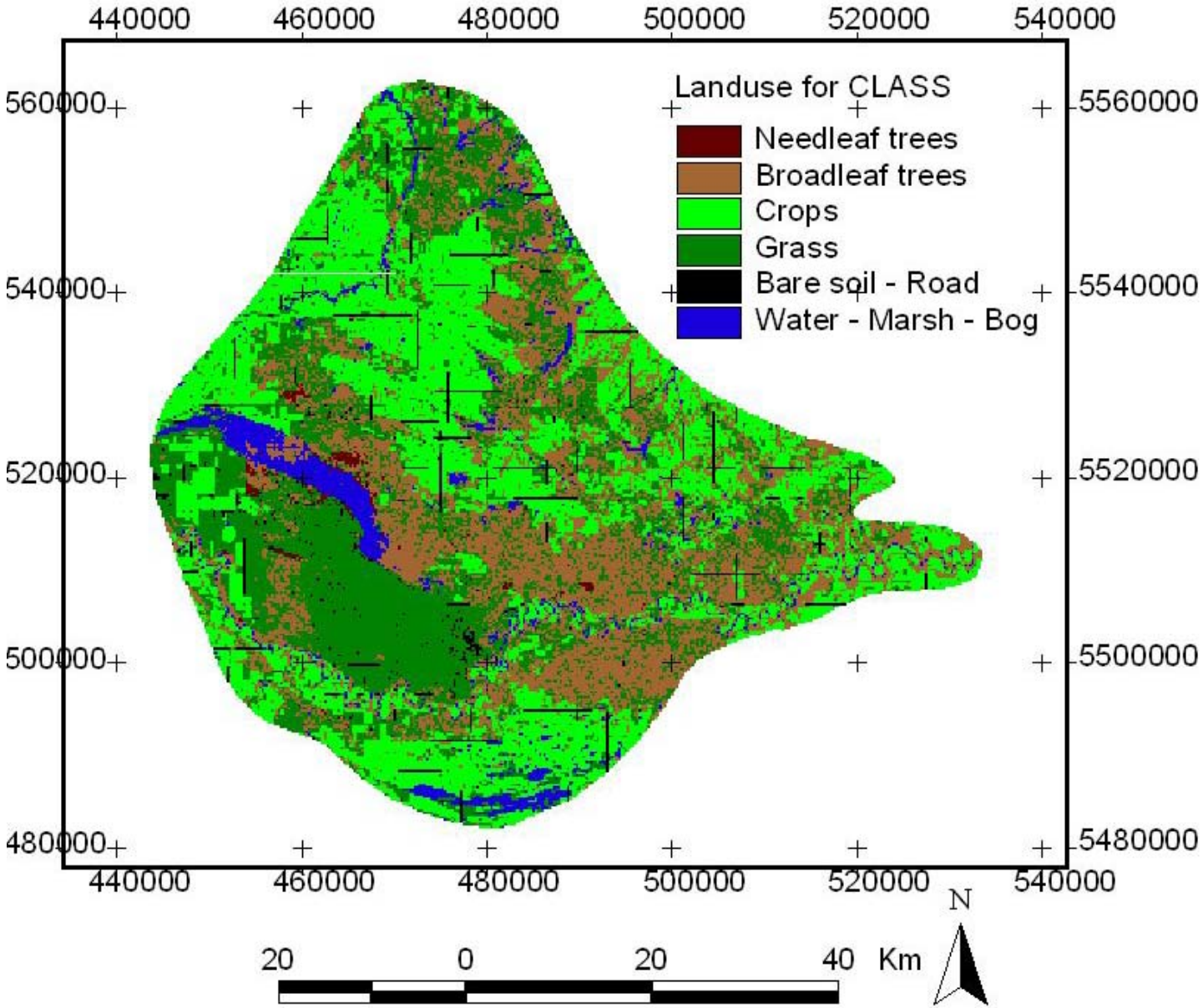
Land-Surface, Streams

- Vegetation type
- Surface Soils
- Precipitation, Temperature
- Wind velocity, Humidity
- Radiation (long/shrt waves)
- Pressure
- Stream flow
- Snow depth
- Soil moisture

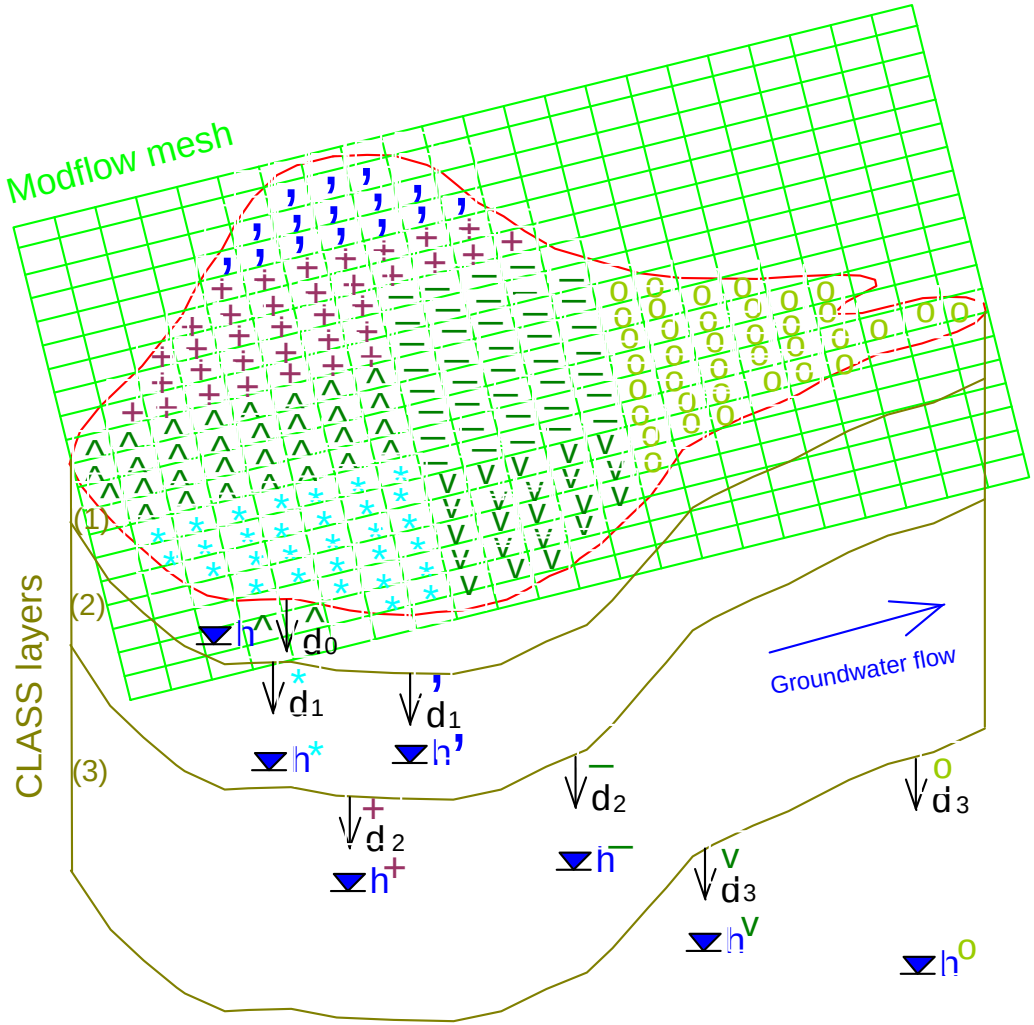
Groundwater

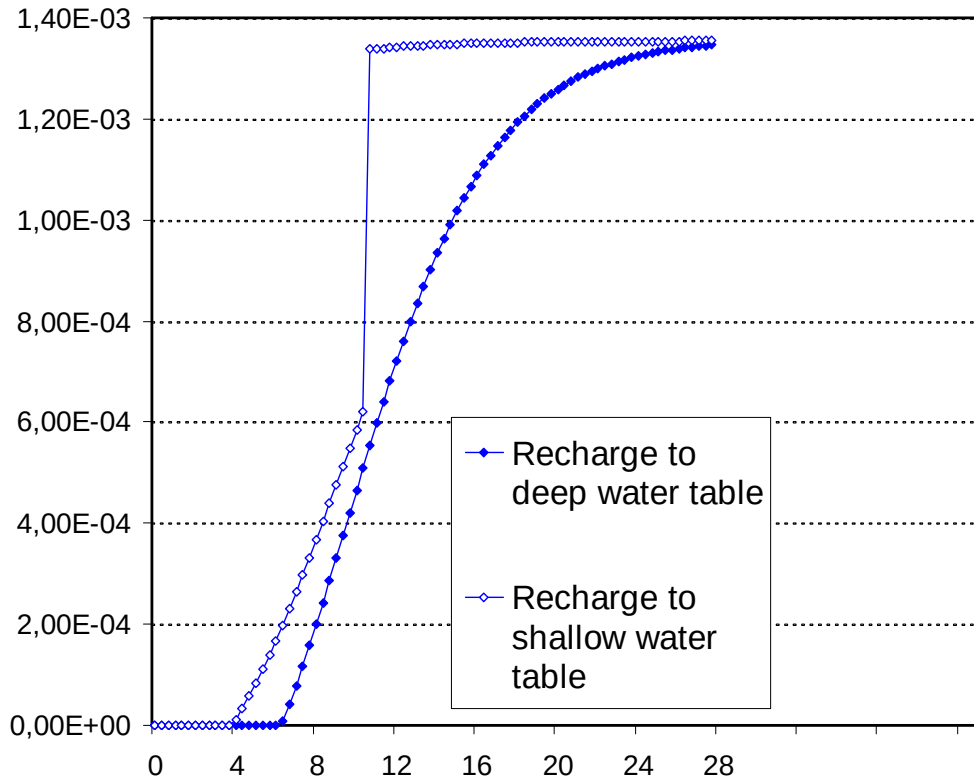
- Statigraphy
- Well Observations
- Pumping test
- Soil Samples
- Transmissivity
- Time series heads
- Evaporation and Runoff

Land Use

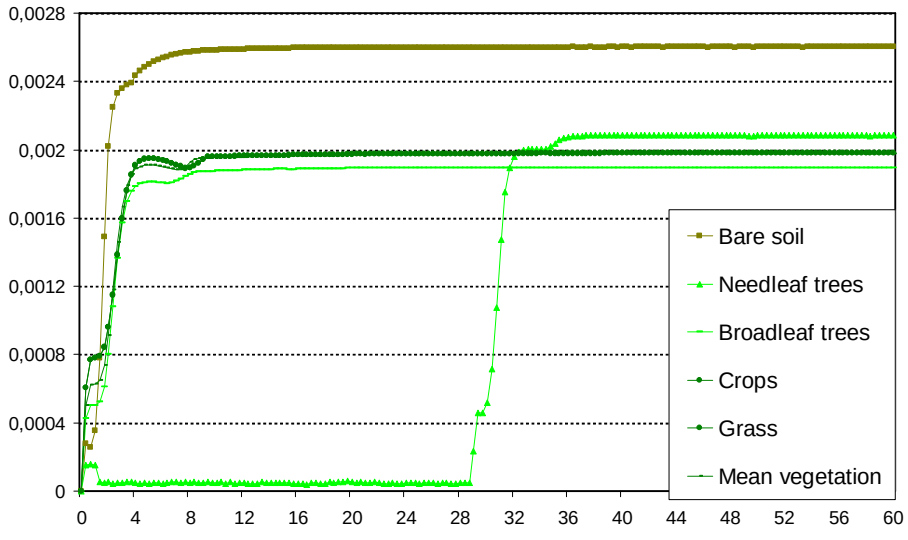

440000
460000
480000
500000
520000
540000
560000
540000
520000
500000
480000
5560000
5540000
5520000
5500000
5480000
Landuse for CLASS
Needleaf trees
Broadleaf trees
Crops
Grass
Bare soil - Road
Water - Marsh - Bog
N
20
0
20
40
Km

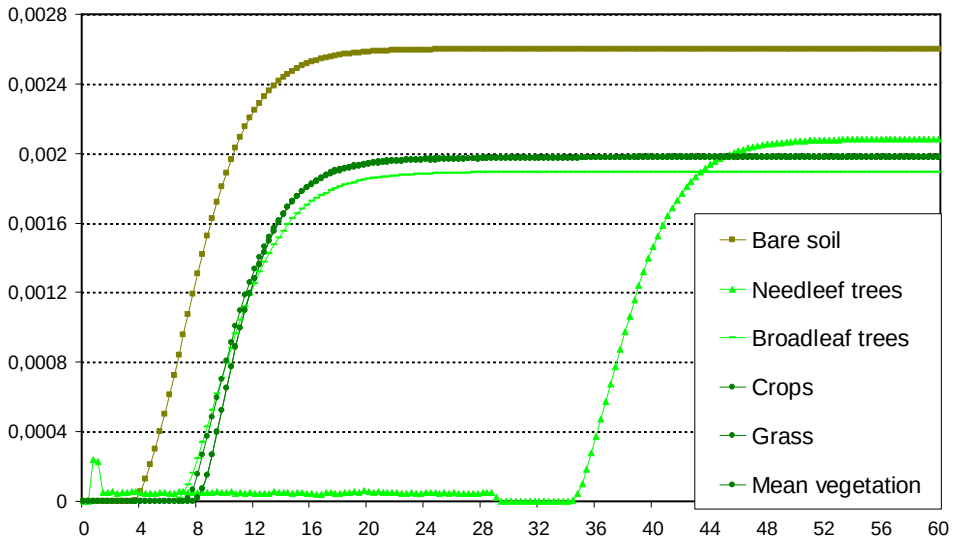
Initial Coupled Simulations



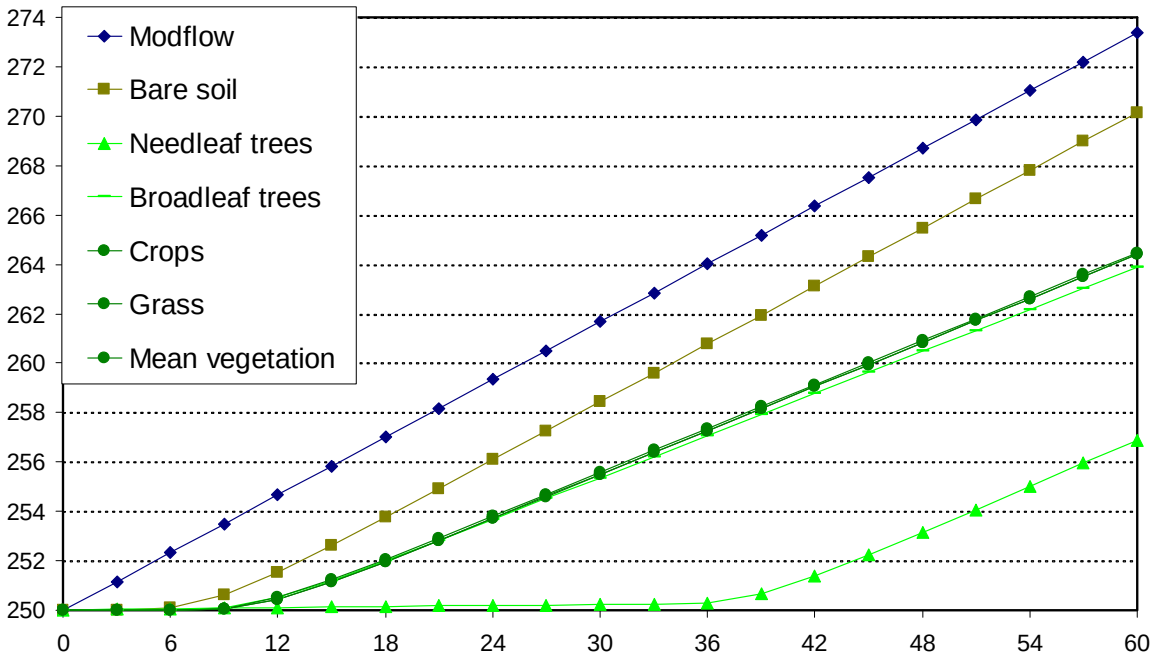


Coupling Modflow with 7 CLASS runs. Recharge affected according to mean head below





Drainage from Layer 2 (left) and Layer 3 (right) in m/day , for different soil coverage



Increase of deep water table according to recharge from Layer 3 , for different soil coverage

Future Work

- Compare coupled MODCLASS model to carefully controlled field observations
- Obtain necessary data for Assiniboine Delta Aquifer
- RCM and look at climate change scenarios
- Imbed economics and policy alternatives

Conclusions

- Early versions of a linked atmosphere (MM5), land-surface scheme (CLASS), stream flow (WATFLOOD) and groundwater (MODFLOW)
- MODCLASS?
- Incompatibility of codes

Novelty of Research

- Aspects of internet technologies
- High resolution numerical simulations
- Scientific questions
- Societal impacts, economic analysis
- Integration of disciplines
- Maximize impact