GRACE Satellite Observations for Drought Monitoring

by

Kenneth R. Snelgrove[1]

Sitotaw Yirdaw-Zeleke[2]

Clement Agboma[1]

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[1] **Faculty of Engineering and Applied Science, Memorial University of Newfoundland**

[2] **Department of Civil Engineering, University of Manitoba**

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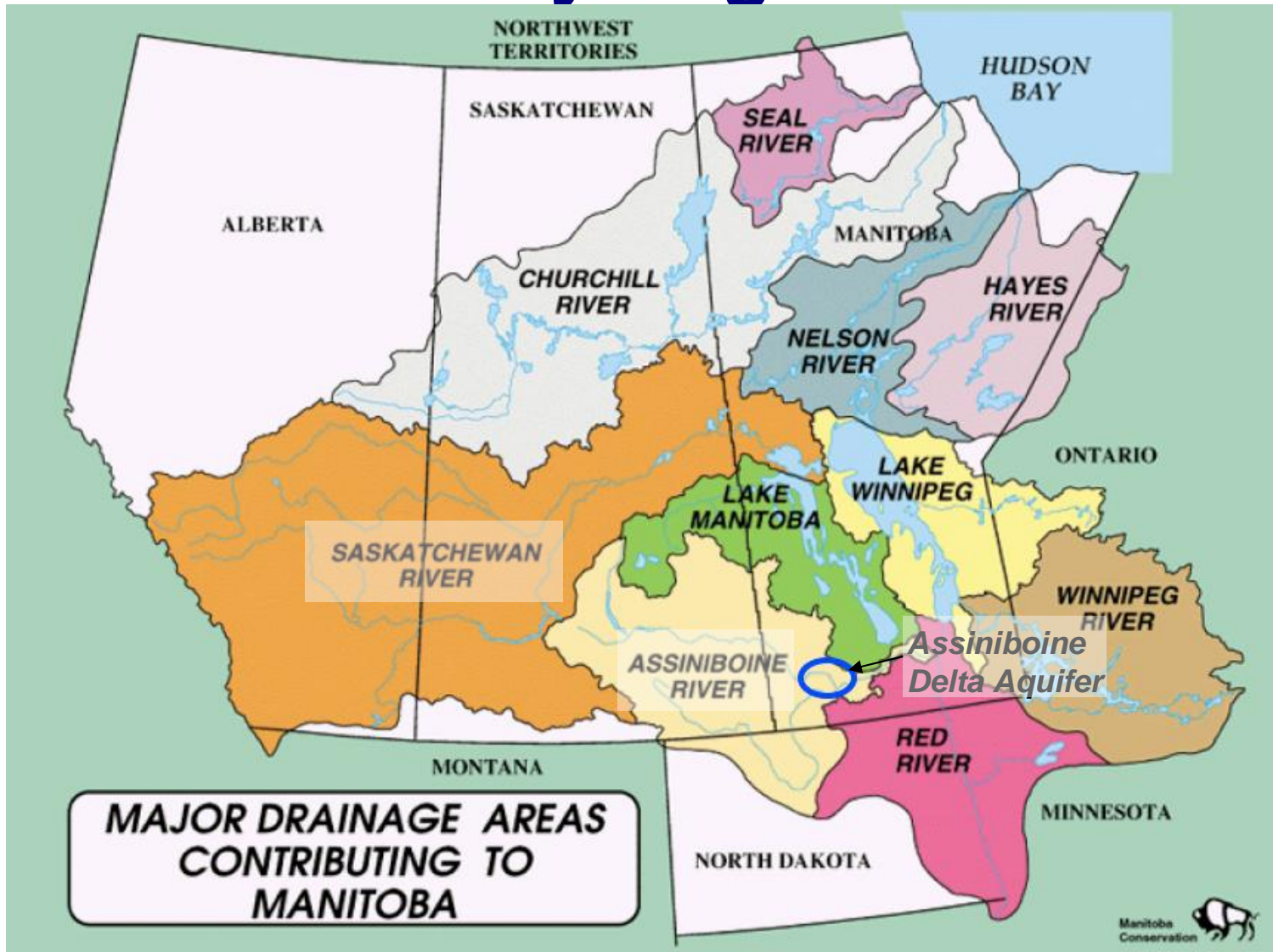**UNIVERSITY**

Overview

Model Development

- Ø Adding groundwater for Atmospheric Models
- Ø Improved CLASS Model with Groundwater Model

GRACE Gravity Variation

- Ø Assess changes in moisture storage over Western Canada for Drought study
- Ø Hydrological Model Calibration and Validation
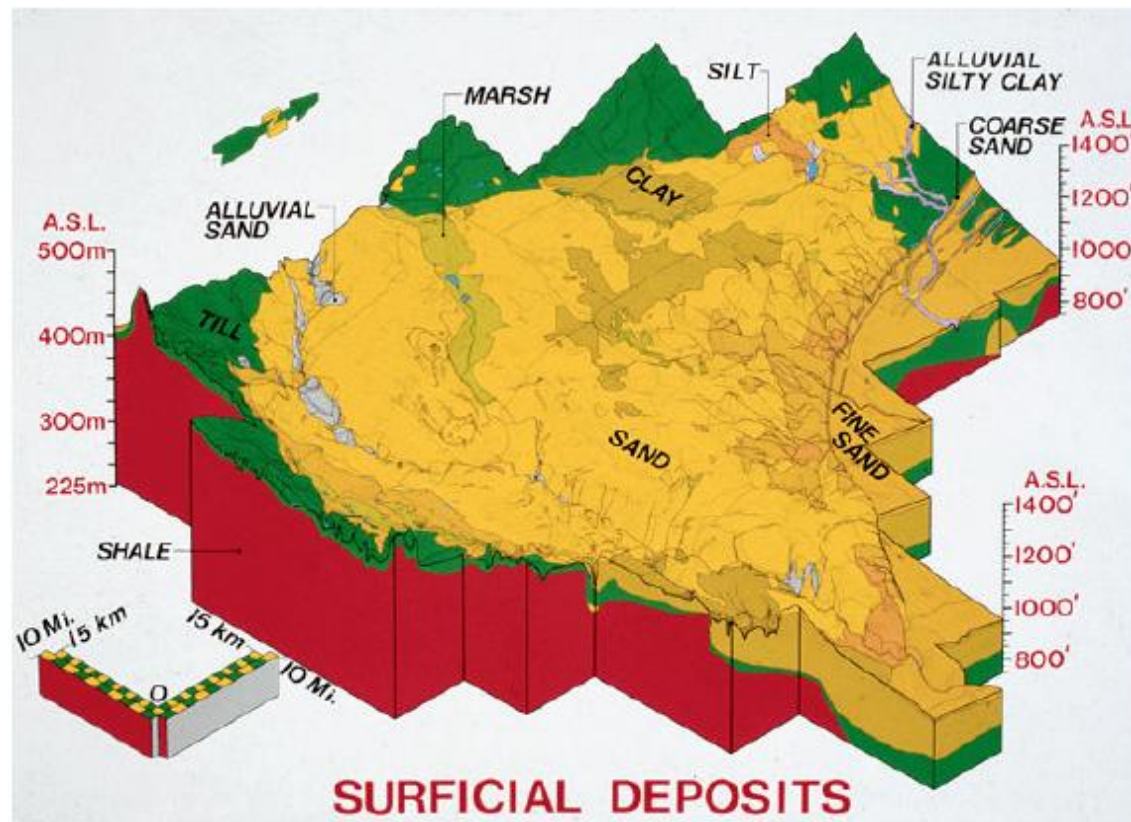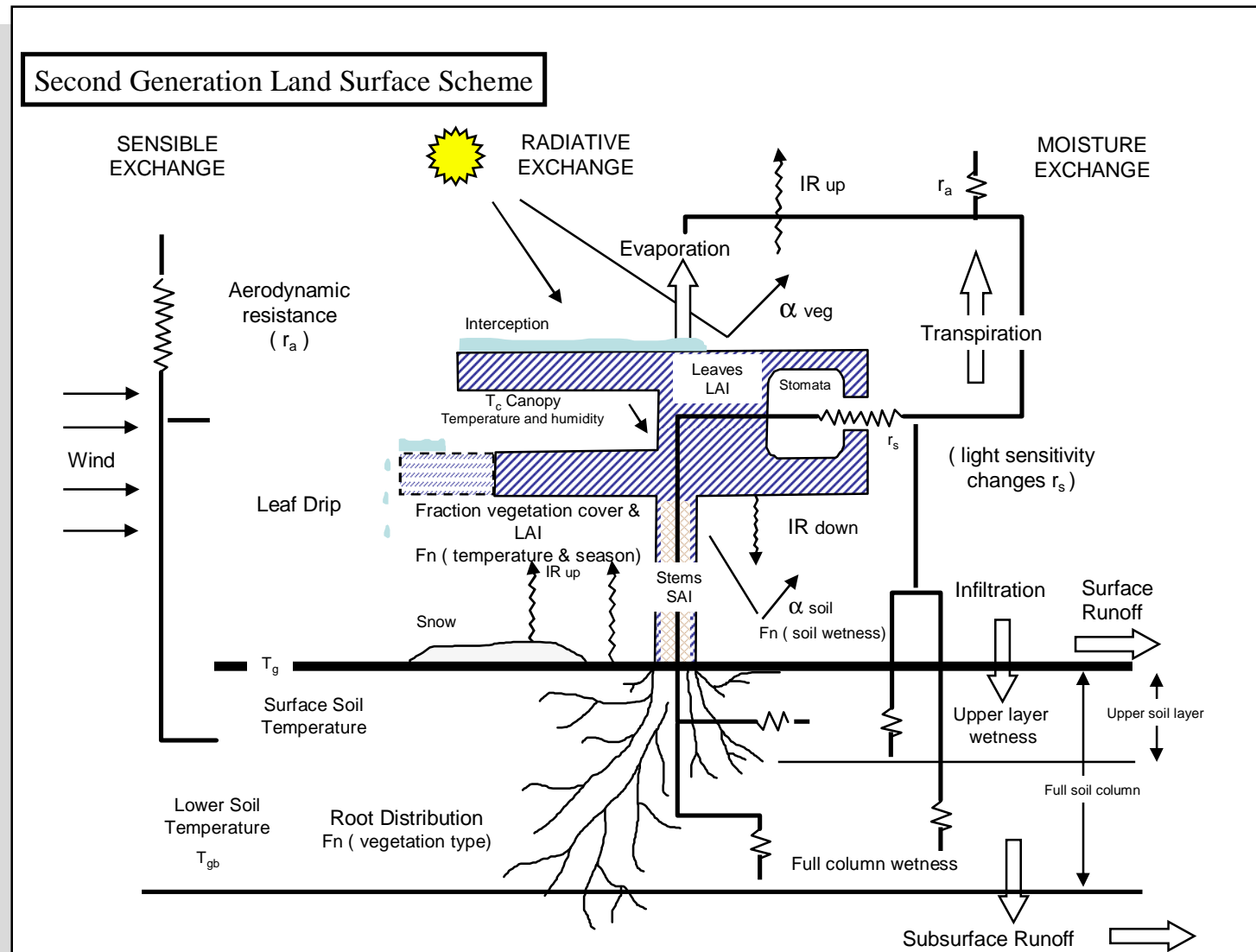
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Study Region

Assiniboine Delta Aquifer

Assiniboine Delta Aquifer

Distribution of Surficial Deposits of the Assiniboine Delta Aquifer

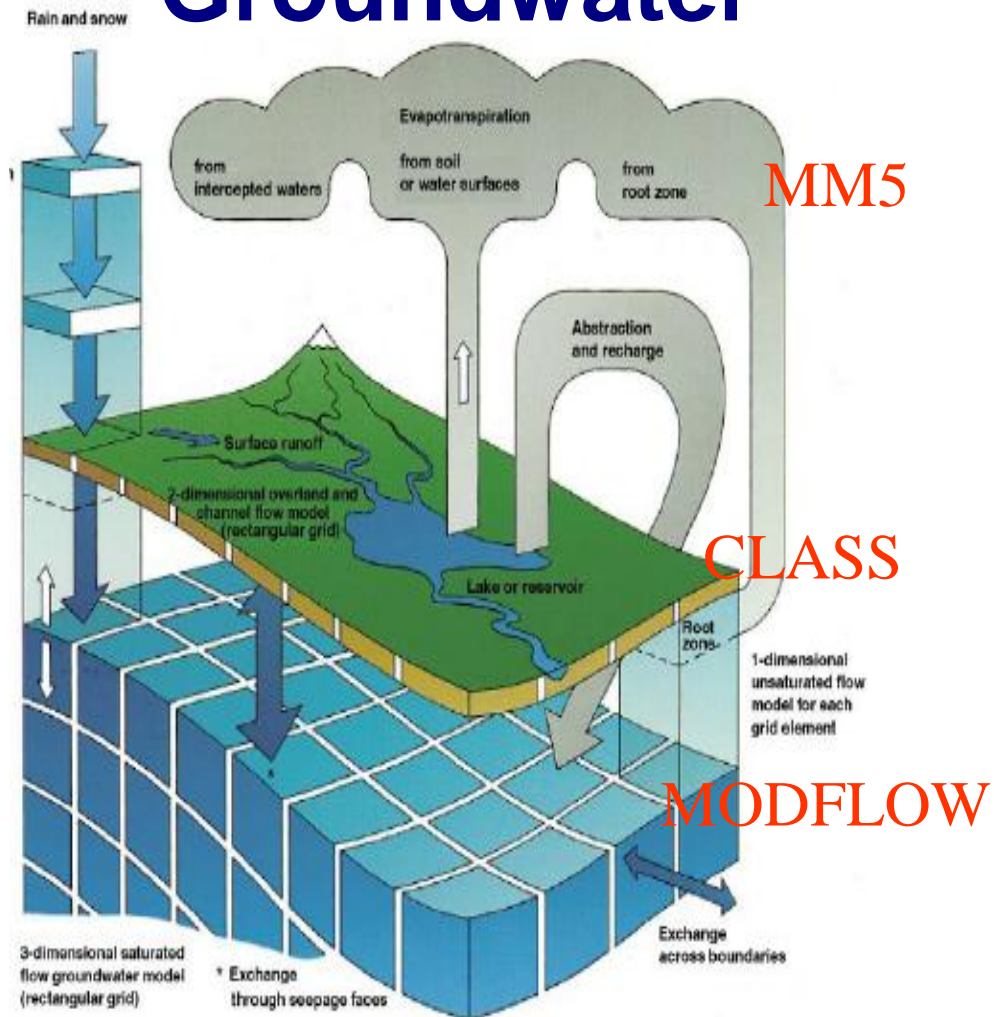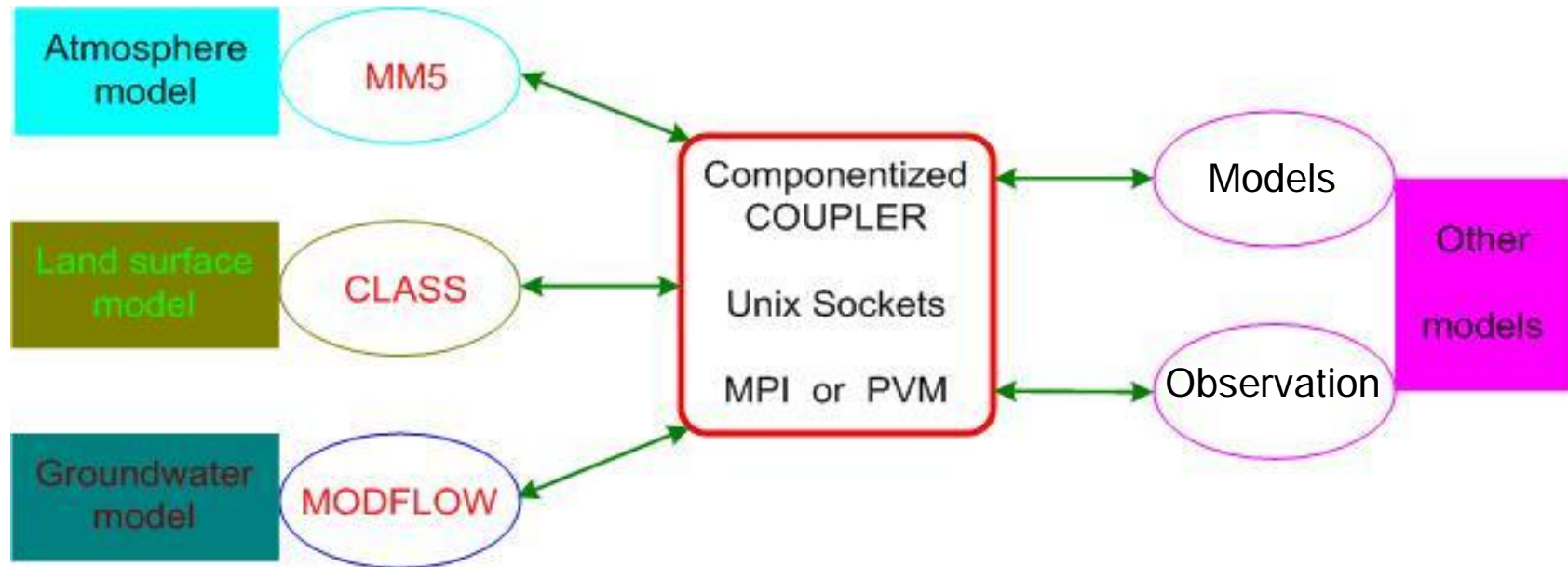**L.H. Frost and F.W. Render, 2002**

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CLASS

Second Generation Land Surface Scheme

Coupling CLASS to Groundwater

Rain and snow

Evapotranspiration

from intercepted waters

from soil or water surfaces

from root zone

MM5

Abstraction and recharge

Surface runoff

2-dimensional overland and channel flow model (rectangular grid)

Lake or reservoir

Root zone

CLASS

1-dimensional unsaturated flow model for each grid element

MODFLOW

3-dimensional saturated flow groundwater model (rectangular grid)

* Exchange through seepage faces

Exchange across boundaries

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Coupling CLASS to Groundwater

Distributed Water Balance

$=A_B$

Atmosphere (A)

Land Surface (L)

Outflow = Q_L, Runoff = R_L

Channel Network (C)

$P-E$

Outflow Q_B, Runoff $R_B = Q_B/A_B$

Groundwater flow (G)

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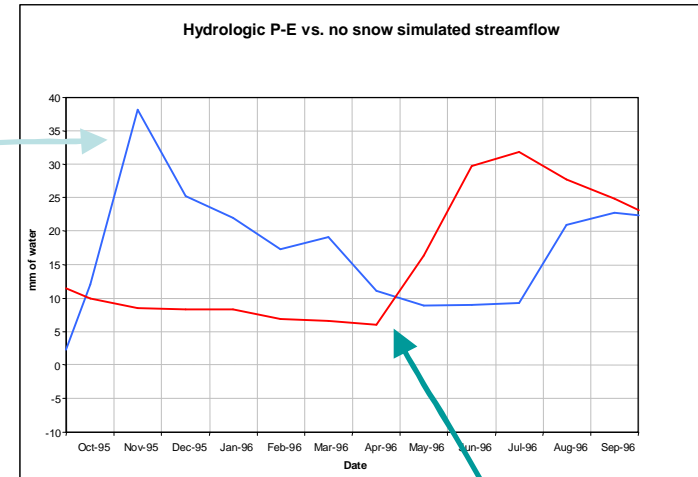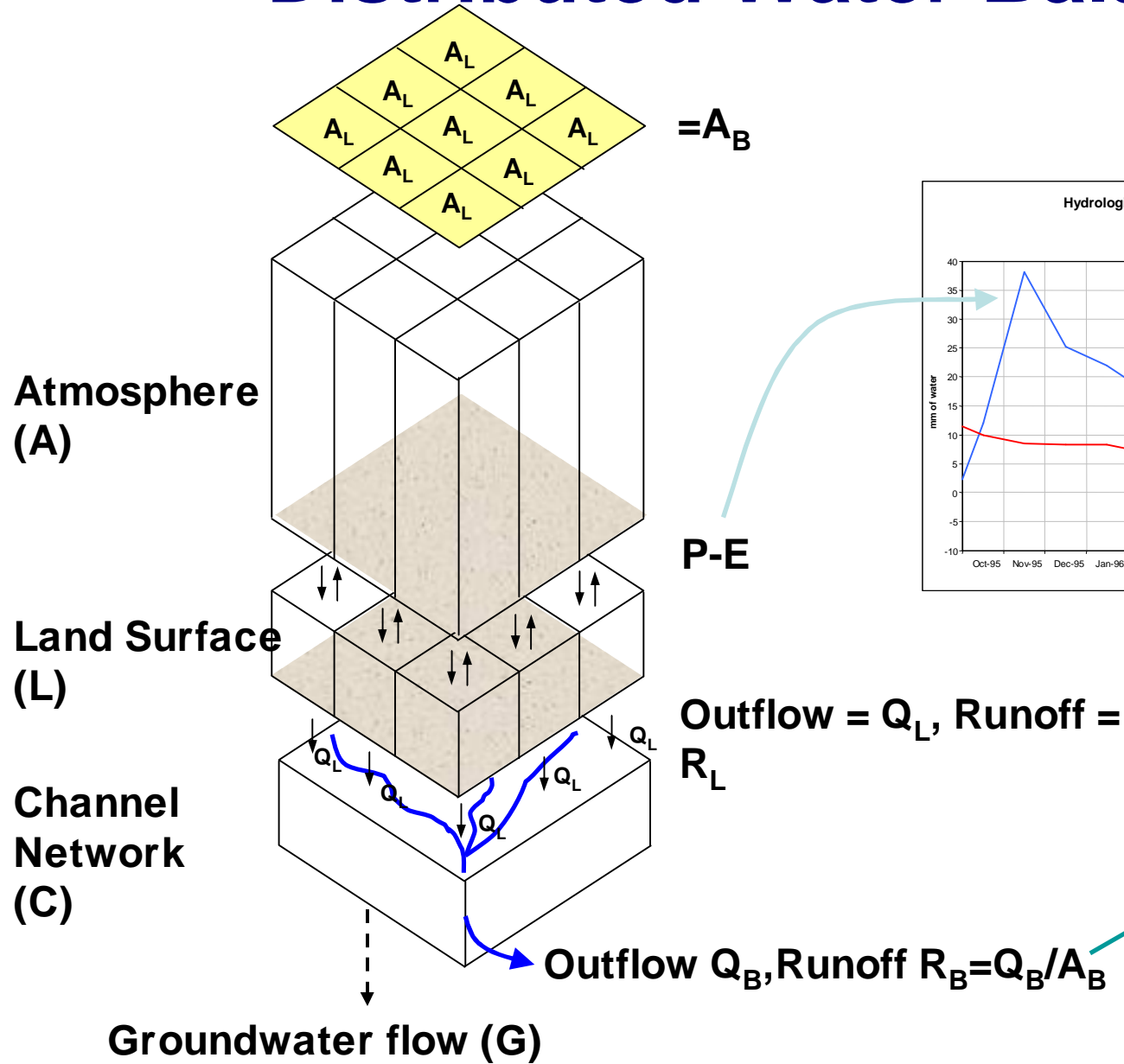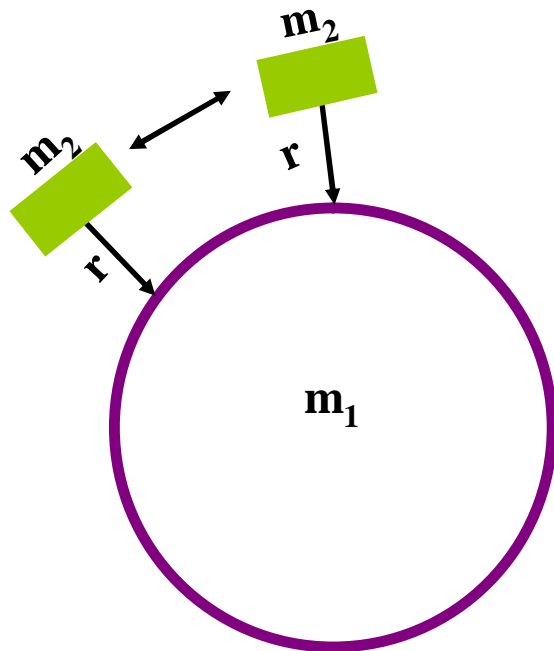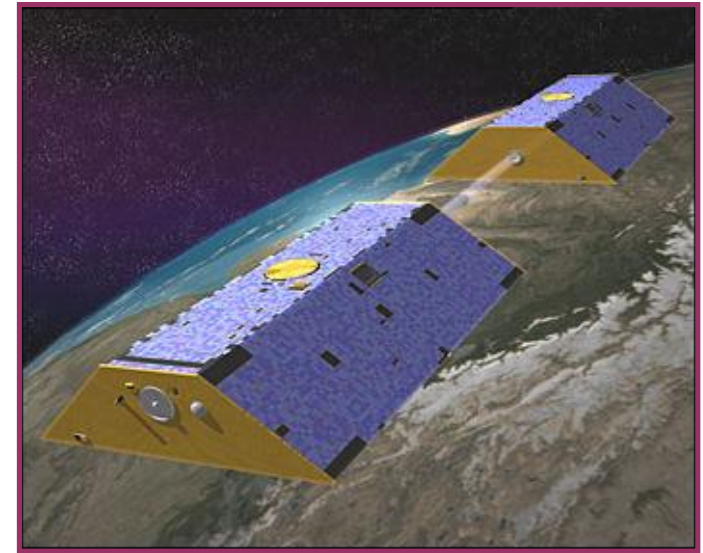
GRACE Terrestrial Moisture Changes

Introduction

Twin GRACE Satellites

Launch on 2002 March 17

Flying approximately 220 km apart

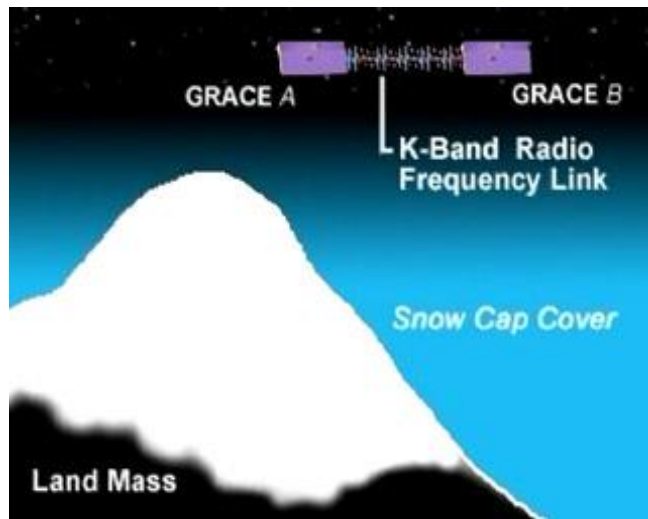Altitude of 400-500 km

Newton's Law of Gravitation
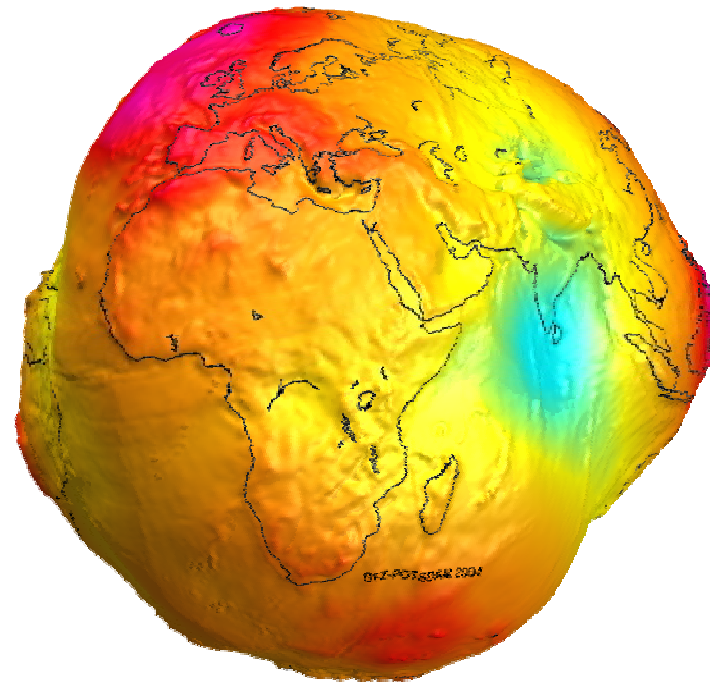
$$F = k \frac{m_1 m_2}{r^2}$$

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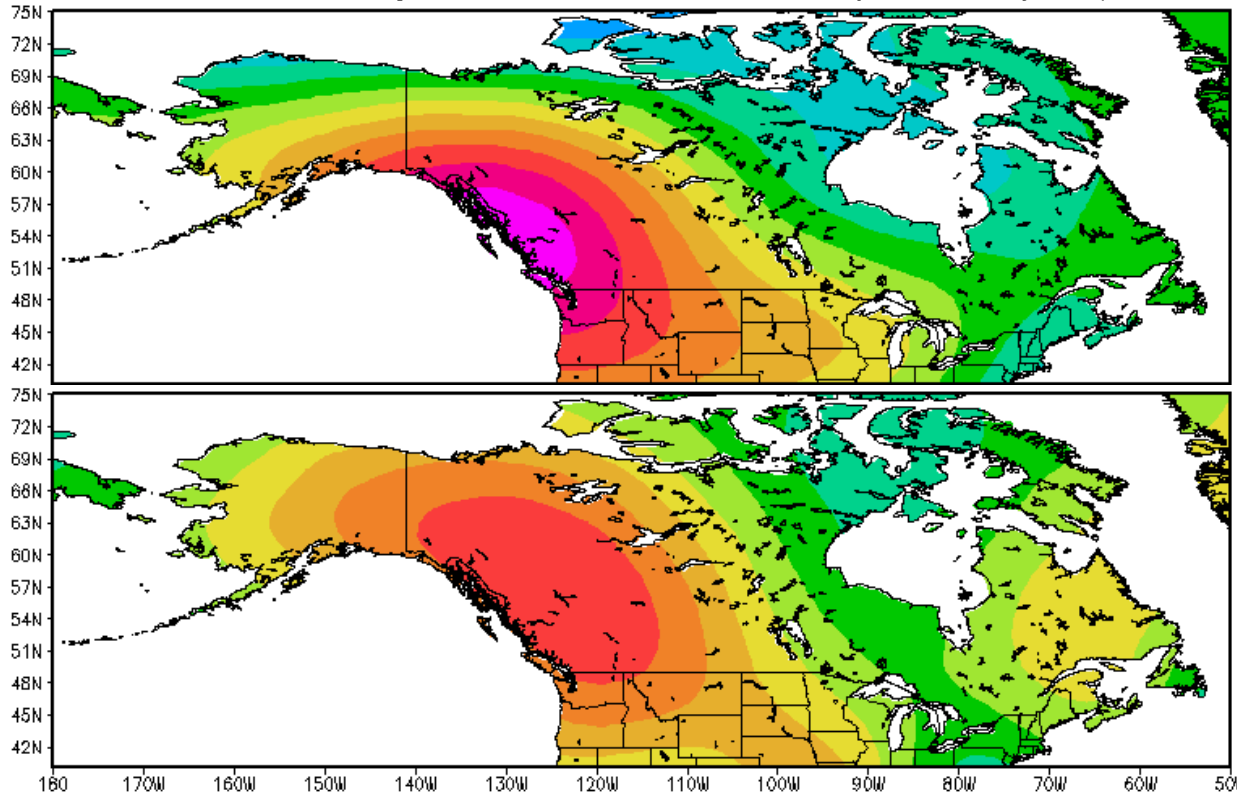# GRACE Primary Mission

Gravity Model

- Develop geoid from averages over 5 year life
- Monthly variations related to surface moisture changes

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Creation of Earth Geopotential Map

Time-variable geopotential $\delta G(t)$ solution of Laplace Equation

$$dG(t) = \sum_{n=1}^{N} \sum_{m=0}^{n} (dC_{nm}(t)\cos ml + dS_{nm}(t)\sin ml)P_{nm}(\cos q)$$

where:
l is the latitude
q is the longitude
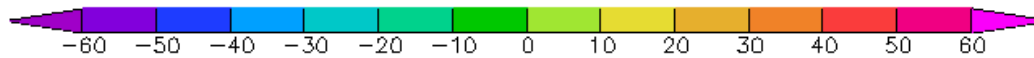m & n are harmonic degree and order
P is Legendre's polynomial

Monthly Difference Result

Water Storage relative to mean Geopotential(mm)

April 2002

April 2003

mm of Equivalent water thickness

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Water Balance Methods

Atmospheric Moisture Budget:

$$\langle P - E \rangle_a = - \langle \partial q / \partial t \rangle - \langle \tilde{N} \bullet Q \rangle$$

Where: (P-E) = difference between precipitation and evapotranspiration,

q = the vertically-integrated vapour mass or precipitable water,

$\tilde{N} \cdot Q$ = the moisture flux divergence,

Q = qV ; V is wind speed

Hydrologic Water Budget:

$$\langle P - E \rangle_h = \langle \partial S / \partial t \rangle + \langle R \rangle$$
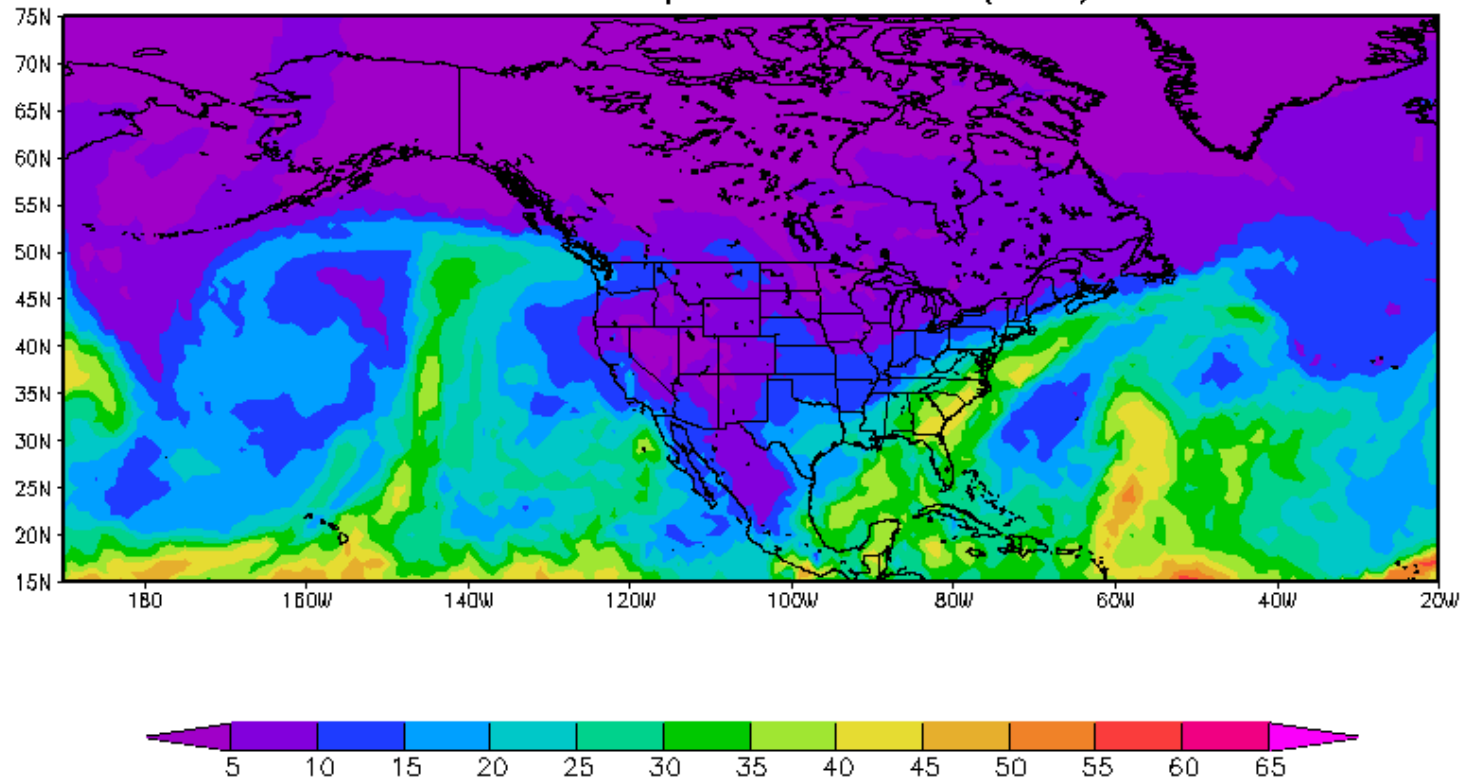
where: S = surface water storage

R = basin runoff

$$\text{Grace Result} := \langle \partial S / \partial t \rangle + \langle \partial q / \partial t \rangle$$

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Water Balance Methods

Atmosphere (A)

Land Surface (L)

Channel Network (C)

q – Atmos. Storage

$\nabla \bullet Q$ – Atmos. Runoff

$(P\text{-}E)_a = (P\text{-}E)_h$

S – Basin Storage

R – Basin Runoff

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q - Atmospheric Storage

water content in the atmospheric column(mm) 00Z01APR2002

Data Source: CMC 4x Daily Analysis

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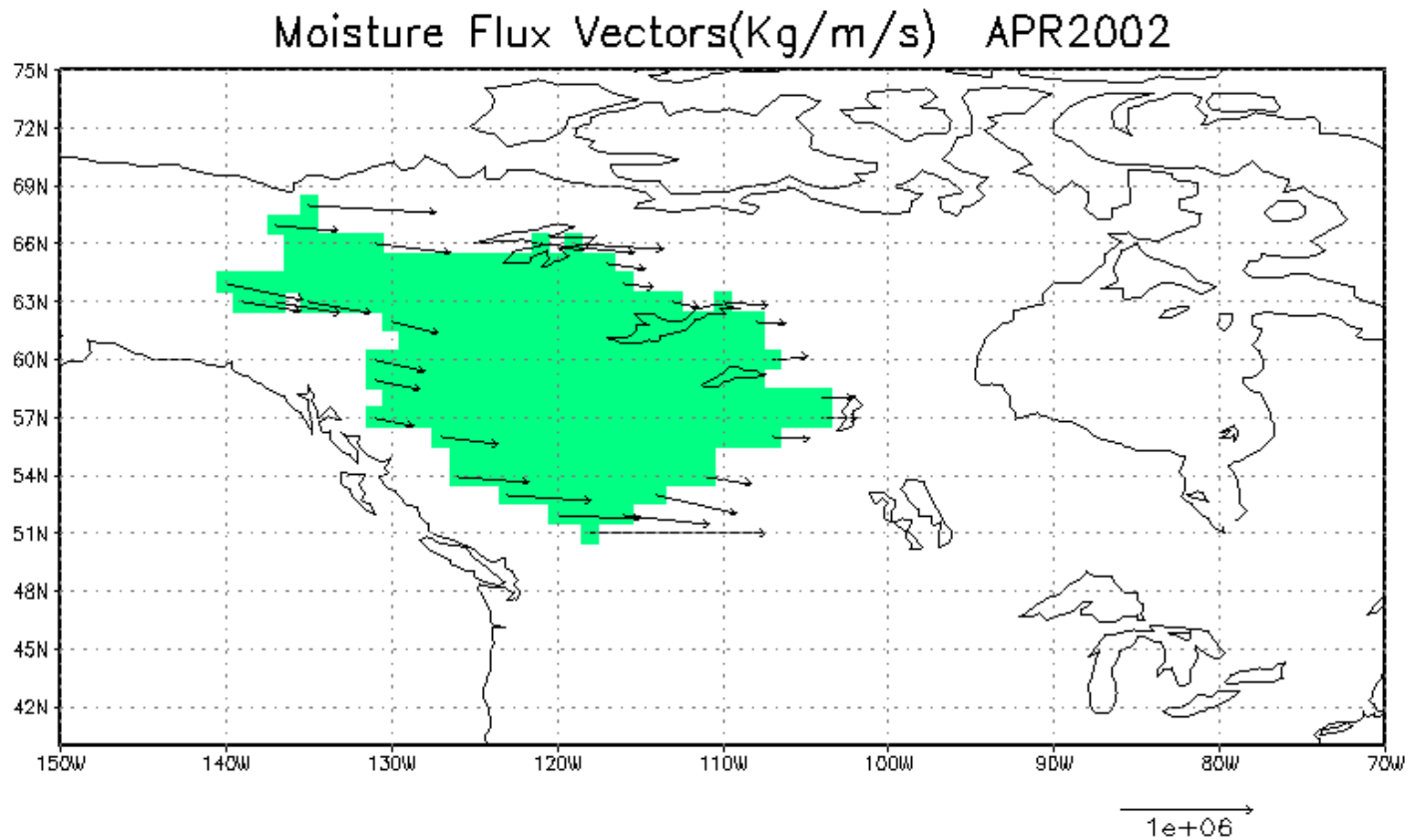UNIVERSITY

Ñ·Q - Atmospheric Runoff

Net flux(mm) 00Z01APR2002
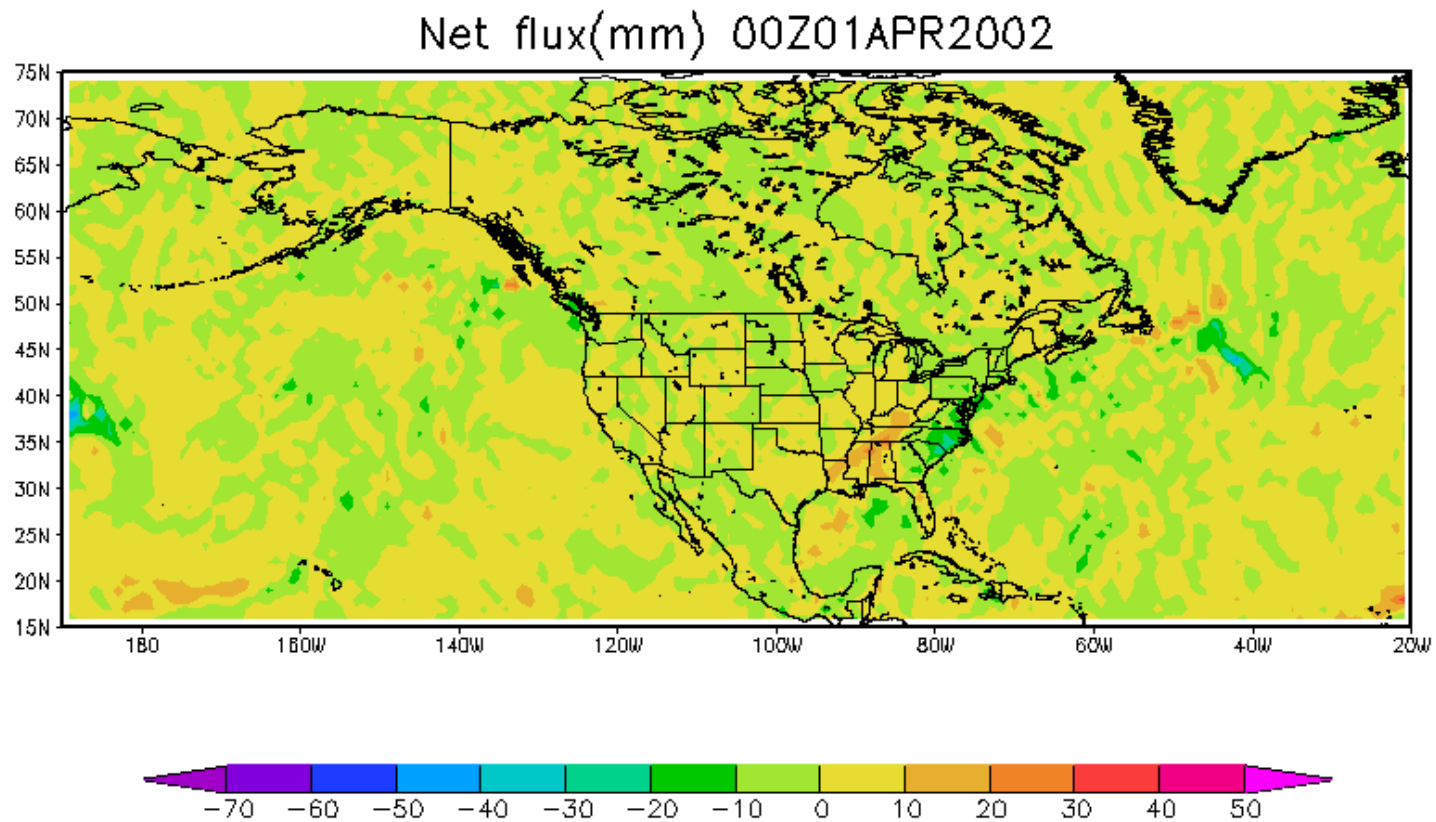
Data Source: CMC 4x Daily Analysis

Alternate $\tilde{N} \cdot Q$ - Calculation

Moisture Flux Vectors(Kg/m/s) APR2002

via Green's Theorem

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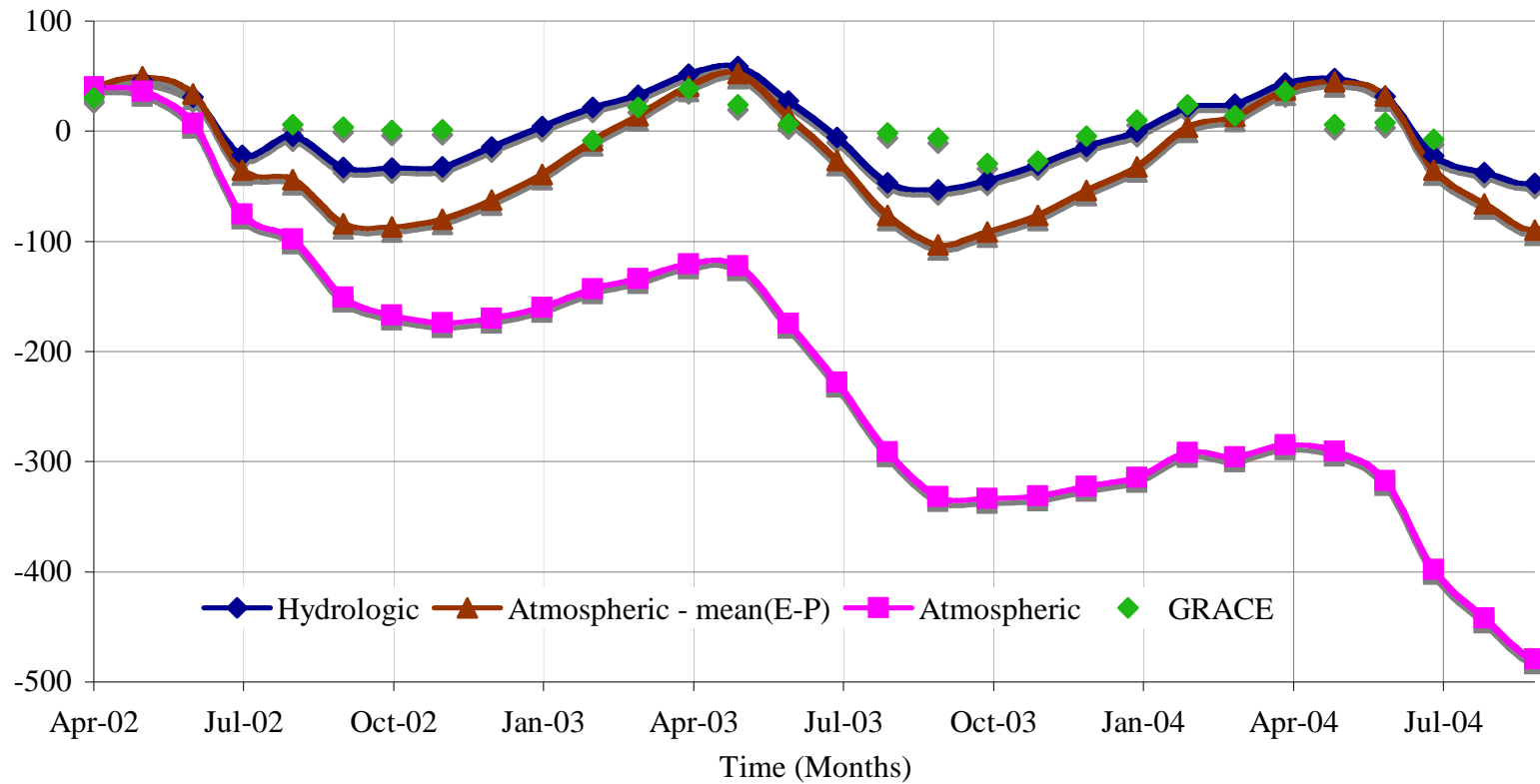UNIVERSITY

Atmospheric and Hydrologic Basin Change in Storage For Water Years 2002-2004 (Mackenzie River Basin)
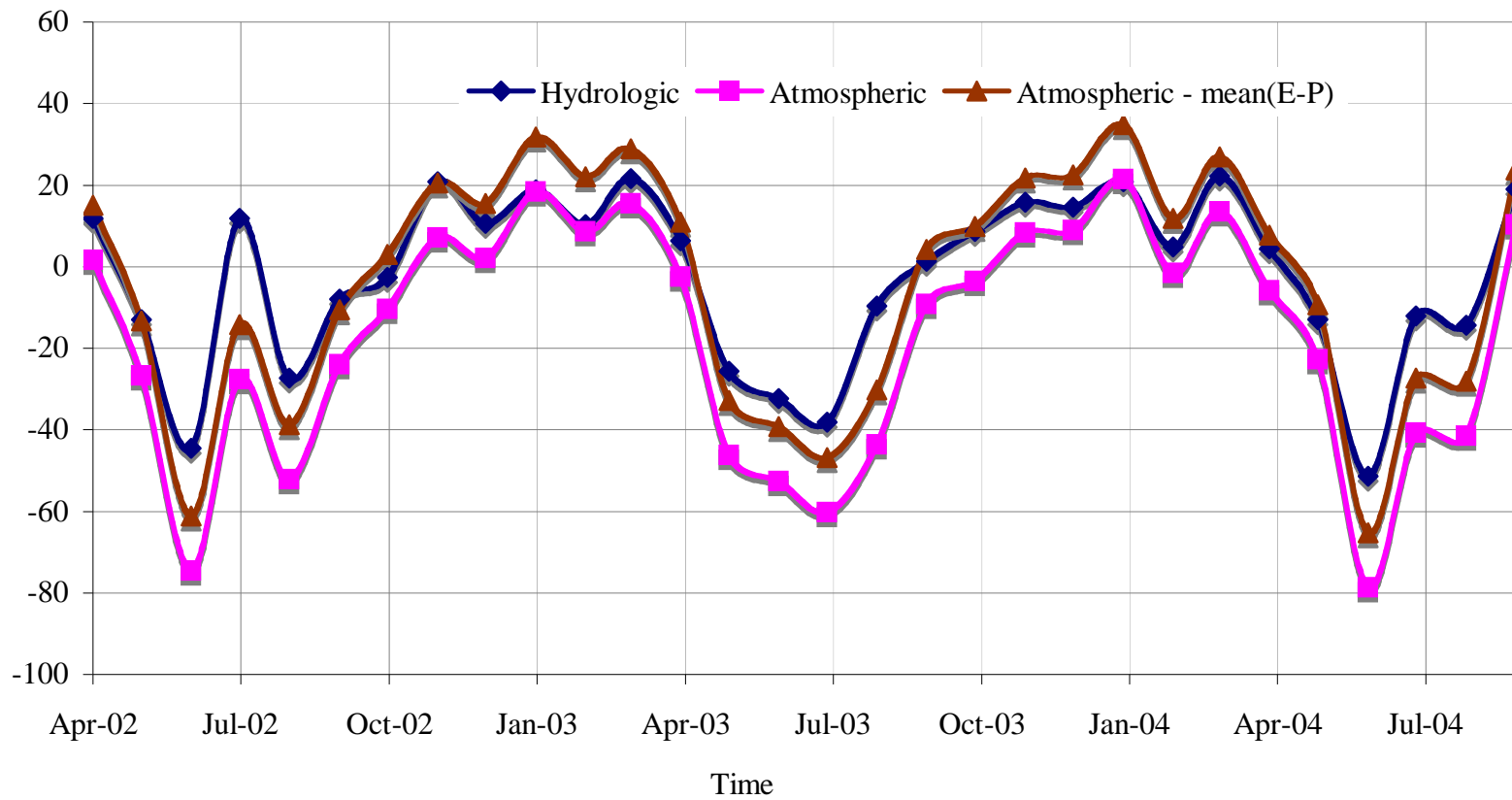
Atmospheric, Hydrologic and GRACE based Change in Storage relative to mean Geopotential For Water Years 2002-2004 (Mackenzie River Basin)

Comparison of Precipitation minus Evaporation with month-to-month GRACE storage coupled with measured runoff for Saskatchewan River basin. The measured runoff is taken at the outlet of the river basin at Grand Rapids.

Saskachewan River Basin Water Balance
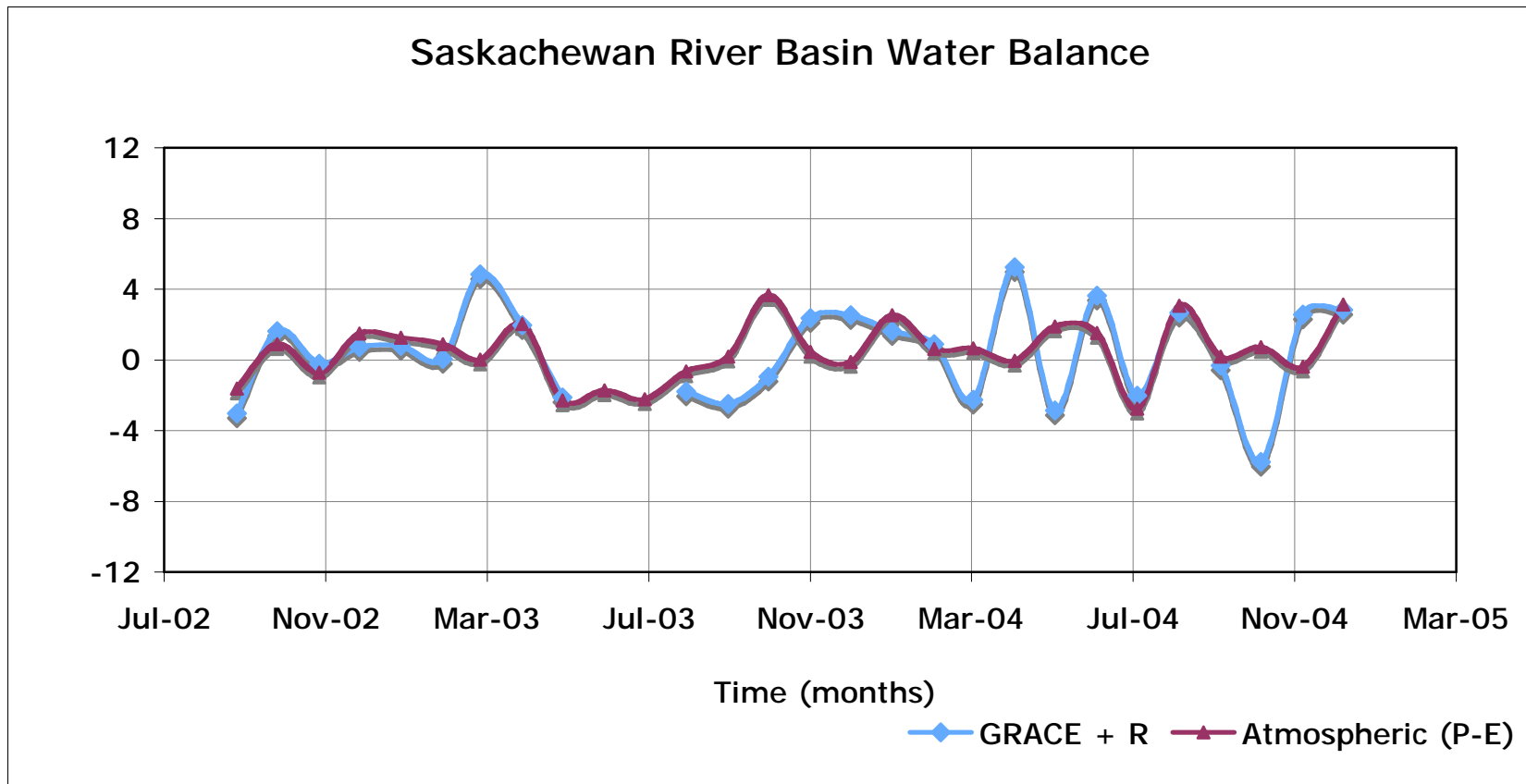
GRACE and Surface storage relative to mean earth's geopotential for Saskatchewan River basin. The surface storage is computed as:

$$S_n = S_{n-1} + \int_{t_1}^{t_2} (P - E - R)\,dt$$

GRACE and Surface storages from Atmospheric P-E and Measured
Saskatchewan River Basin

Time (Month

Atmospheric based
Surface Storage — GRACE Storage