Land Surface Hydrological Processes and Modelling

John Pomeroy[1], Raoul Granger[2], Newell Hedstrom[2], Tom Brown[1],
Alain Pietroniro[2], Lawrence Martz[1], Robert Armstrong[1] and Logan Fang[1].

Centre for Hydrology, University of Saskatchewan and
National Water Research Institute, Environment Canada

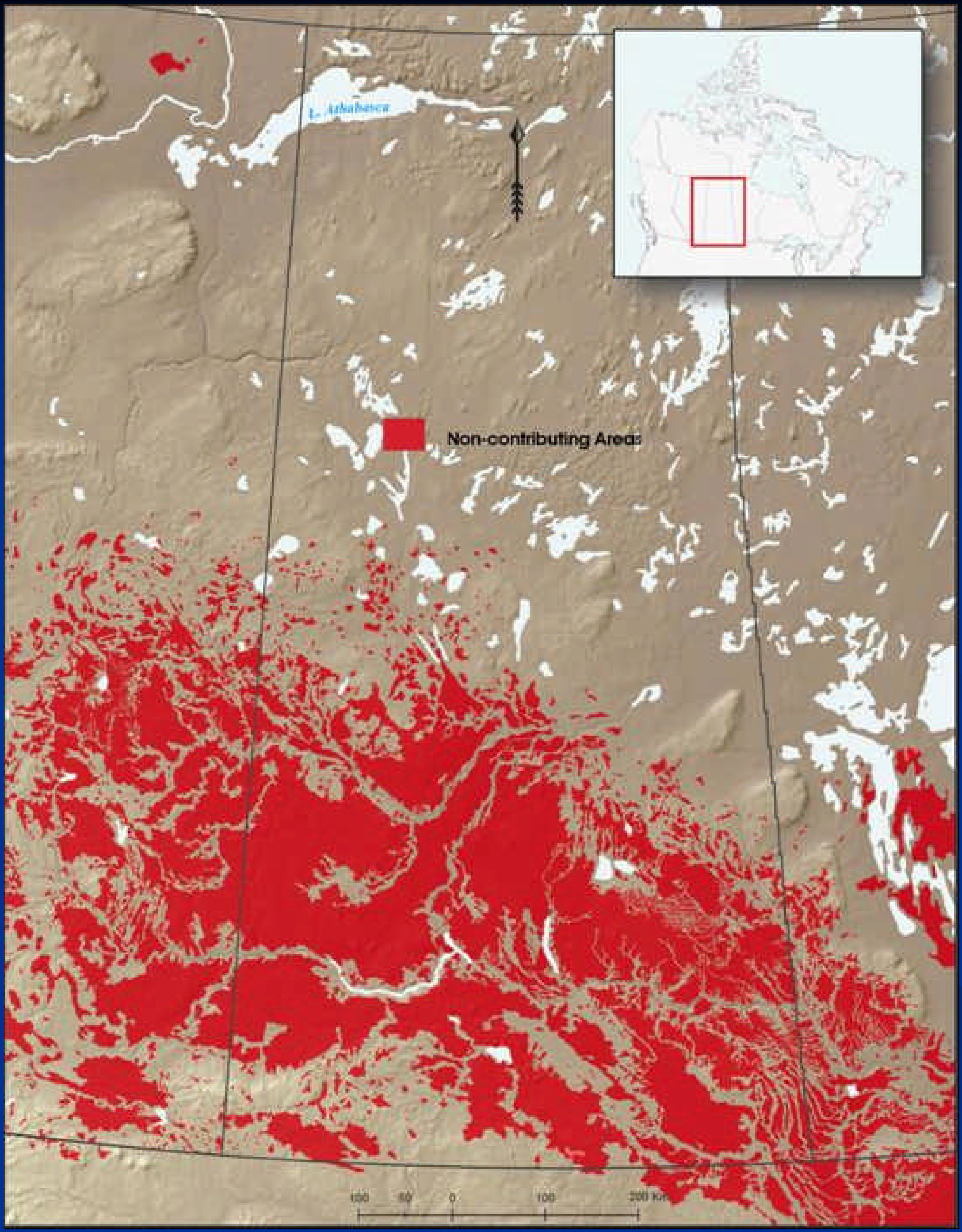
Overview

- OBJECTIVE

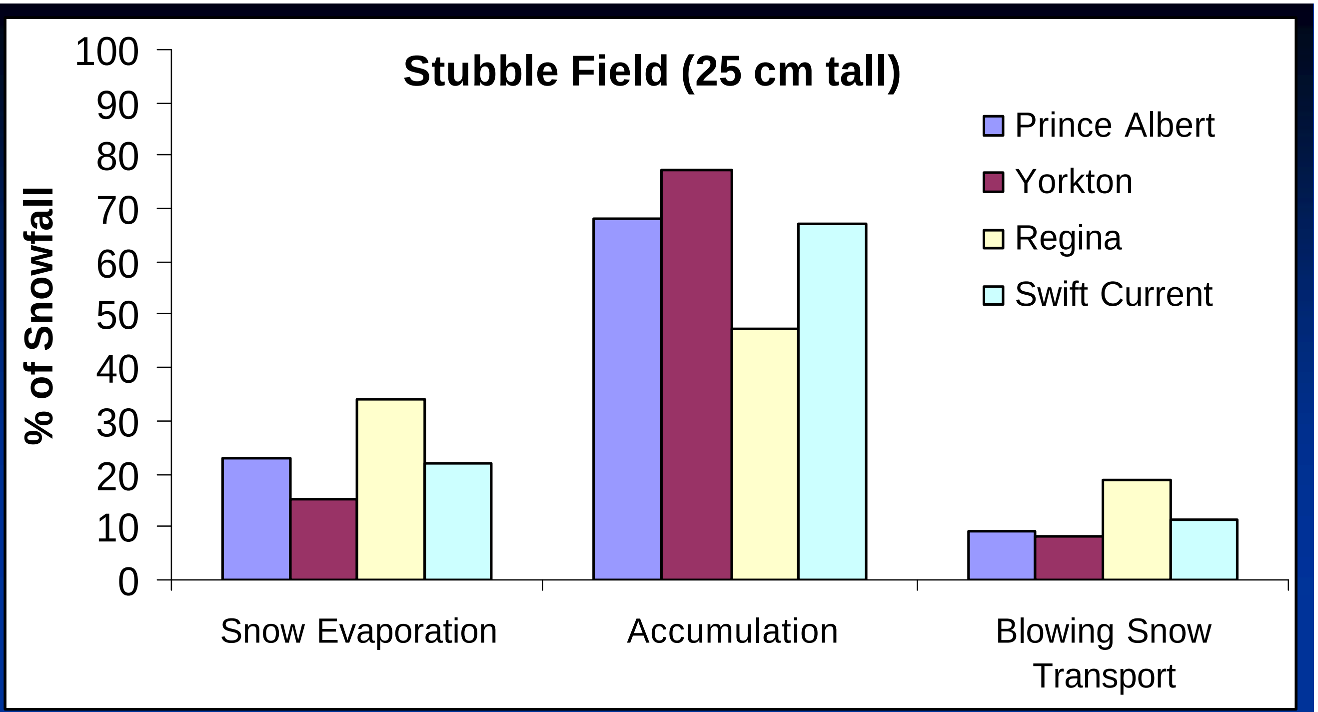
  To better understanding, describe and model the evolution of hydrological drought on the prairies, from frozen and unfrozen land surface fluxes, to soil moisture and surface water storage to streamflow generation

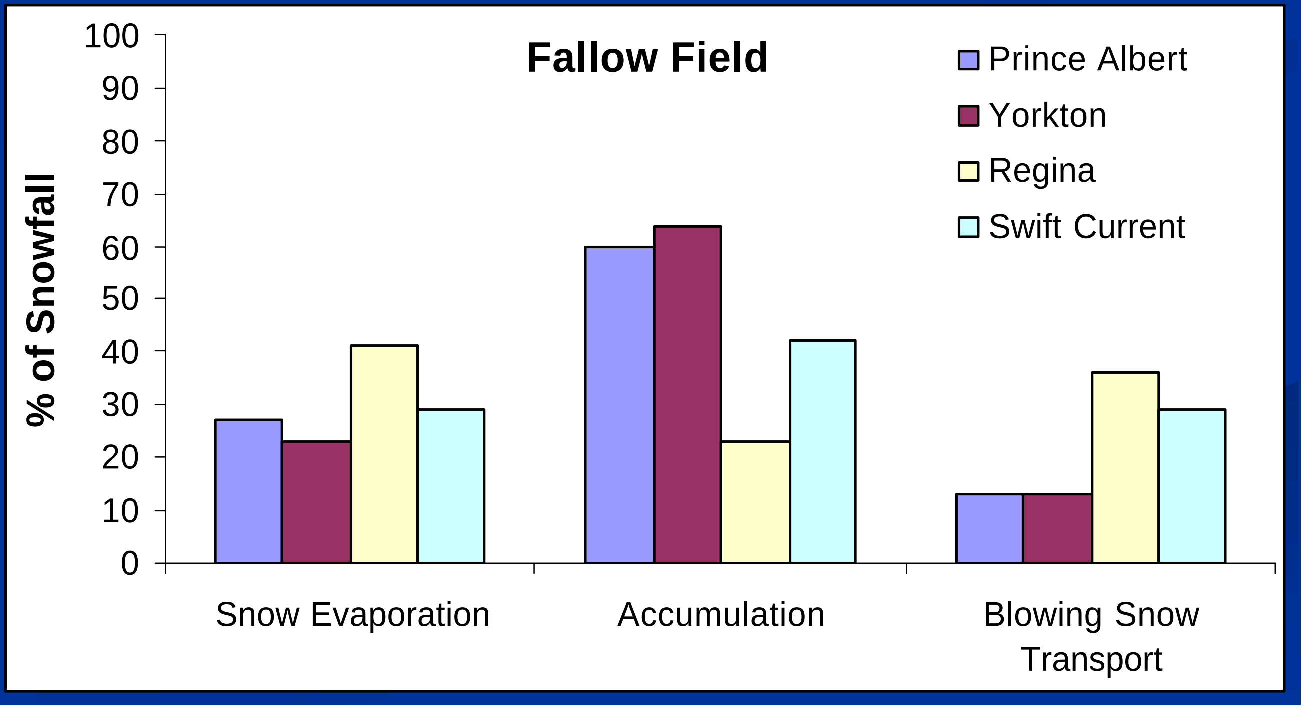
- FOCUS – evaluation and drought sensitivity of
  - Snowmelt Runoff
  - Areal Evaporation
  - Small Basin Hydrological Modelling

Much of the prairie does not contribute runoff: *Non-contributing Areas for River Flow*

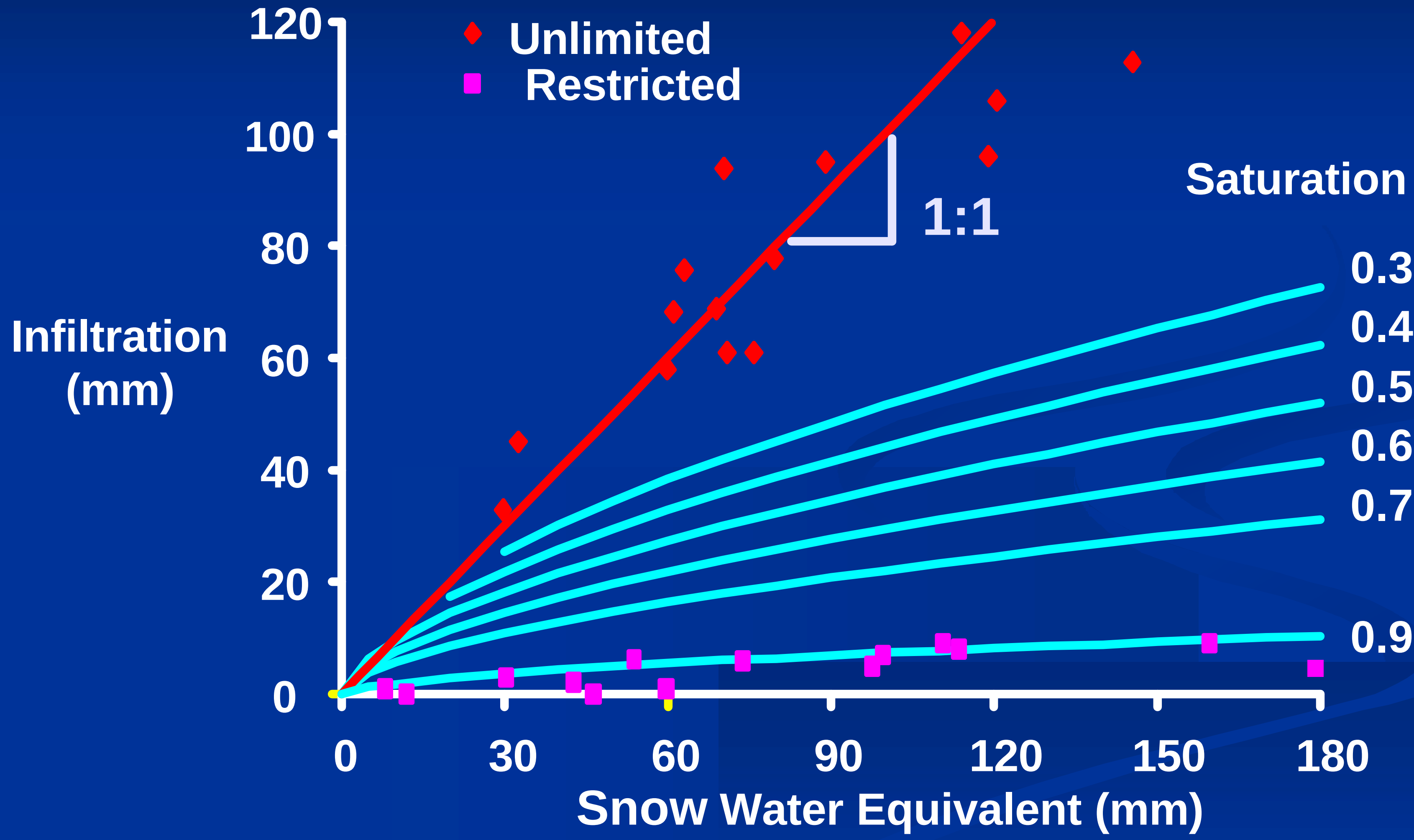


Grain Stubble to Trap Blowing Snow

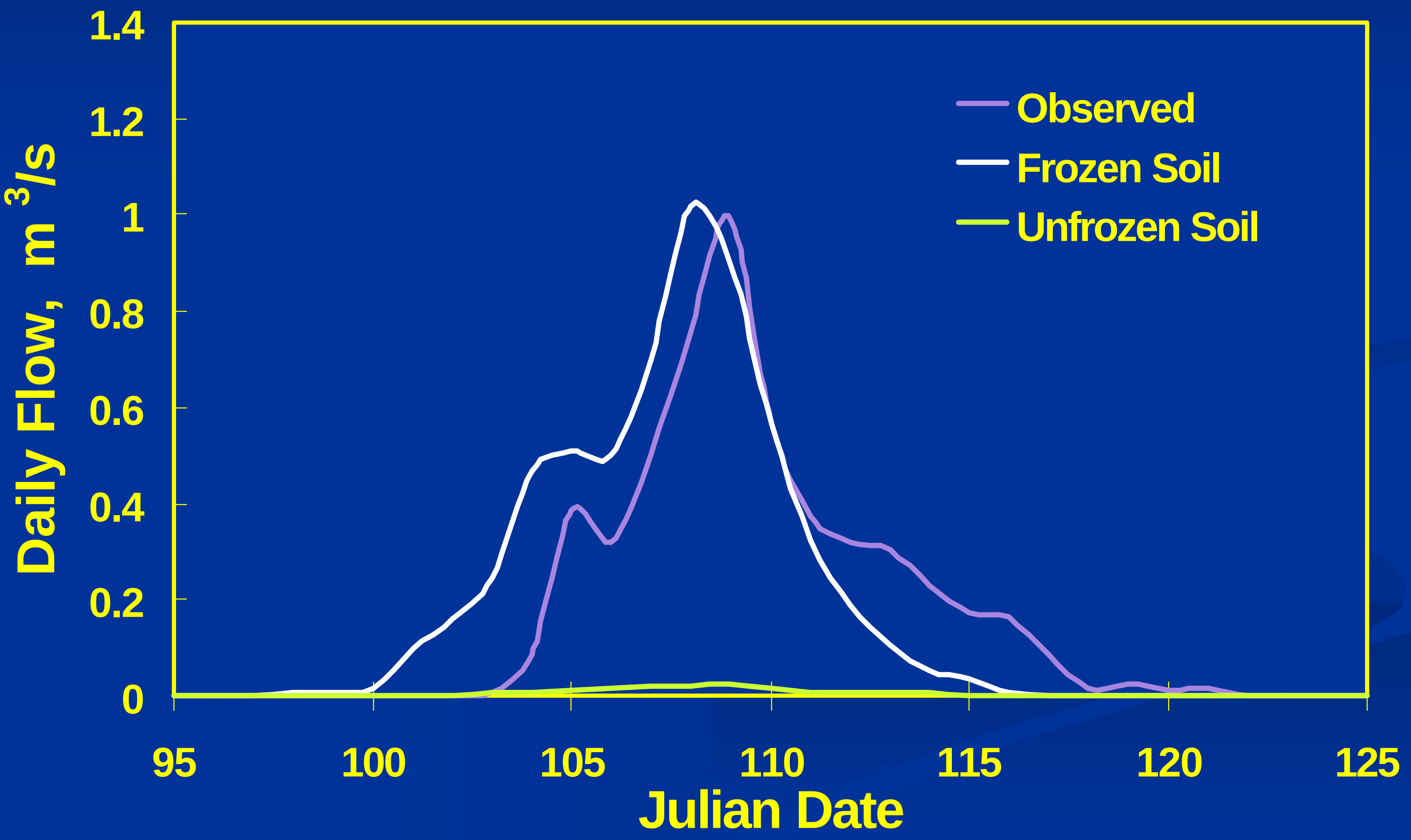




Empirical Model of Infiltration into Frozen Soils - Prairie Environment



Effect of Thawed Soils on Prairie Spring Runoff

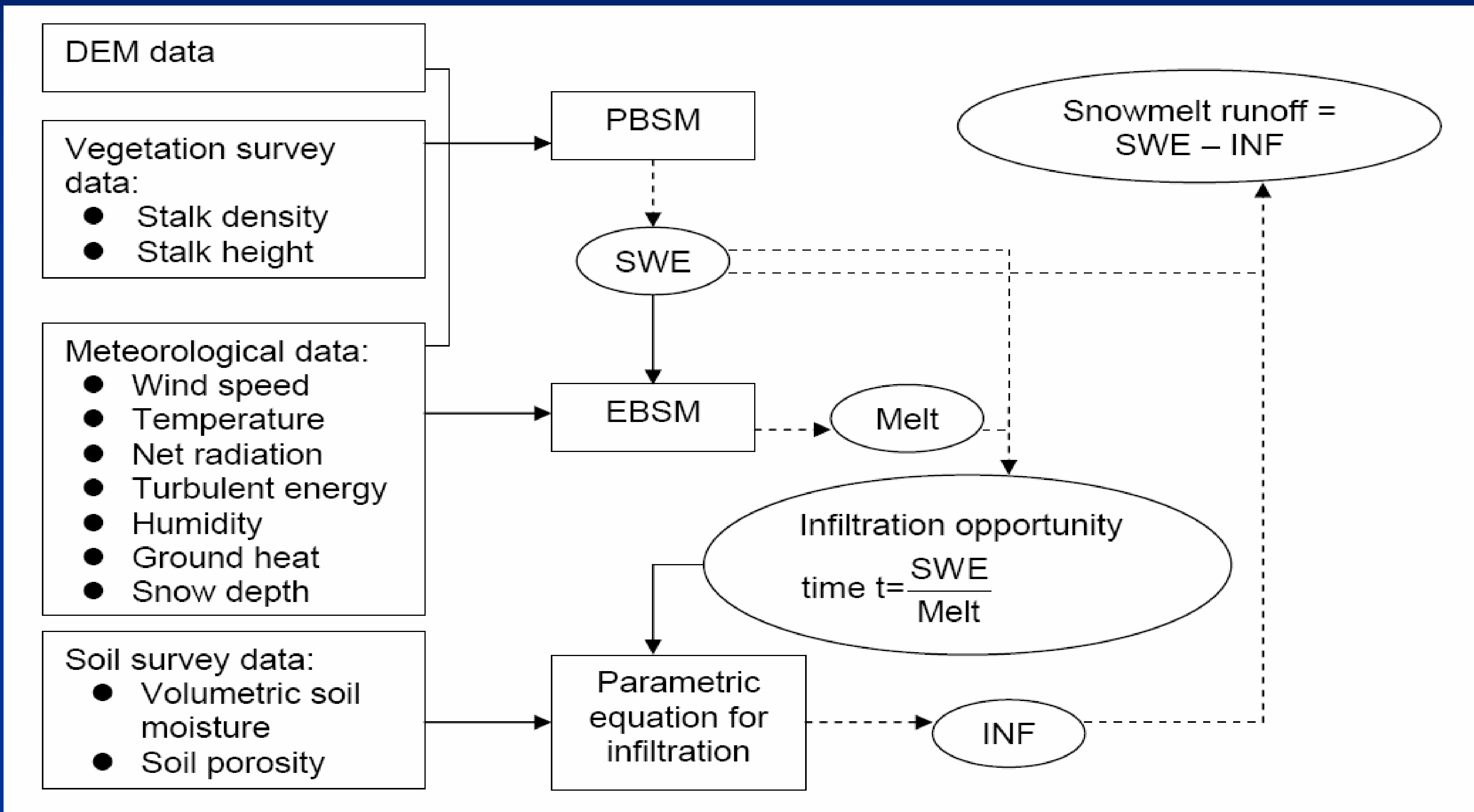


Snowmelt Runoff in a Prairie Environment

Logan Fang, M.Sc. Student

- Implement spatially distributed model of snowmelt runoff based on SWE and snowmelt infiltration (INF):
  - snowmelt runoff = SWE - INF
- Assemble modules in CRHM (Cold Region Hydrological Model Platform) using meteorological data from St. Denis, Bad Lake, other
  - Key modules including PBSM (Prairie Blowing Snow Model), EBSM (Energy-Budget Snowmelt Model), and Gray's parametric equation for snowmelt infiltration
- Find appropriate aggregation techniques for runoff calculation.
- Examine the drought condition sensitivities of snowmelt runoff
  - low snowfall
  - low soil moisture

Flowchart for Calculating Snowmelt Runoff



Granger-Gray General Equation

$$E ? \frac{? G Q_a ? ? G E_a}{? G ? ?}$$

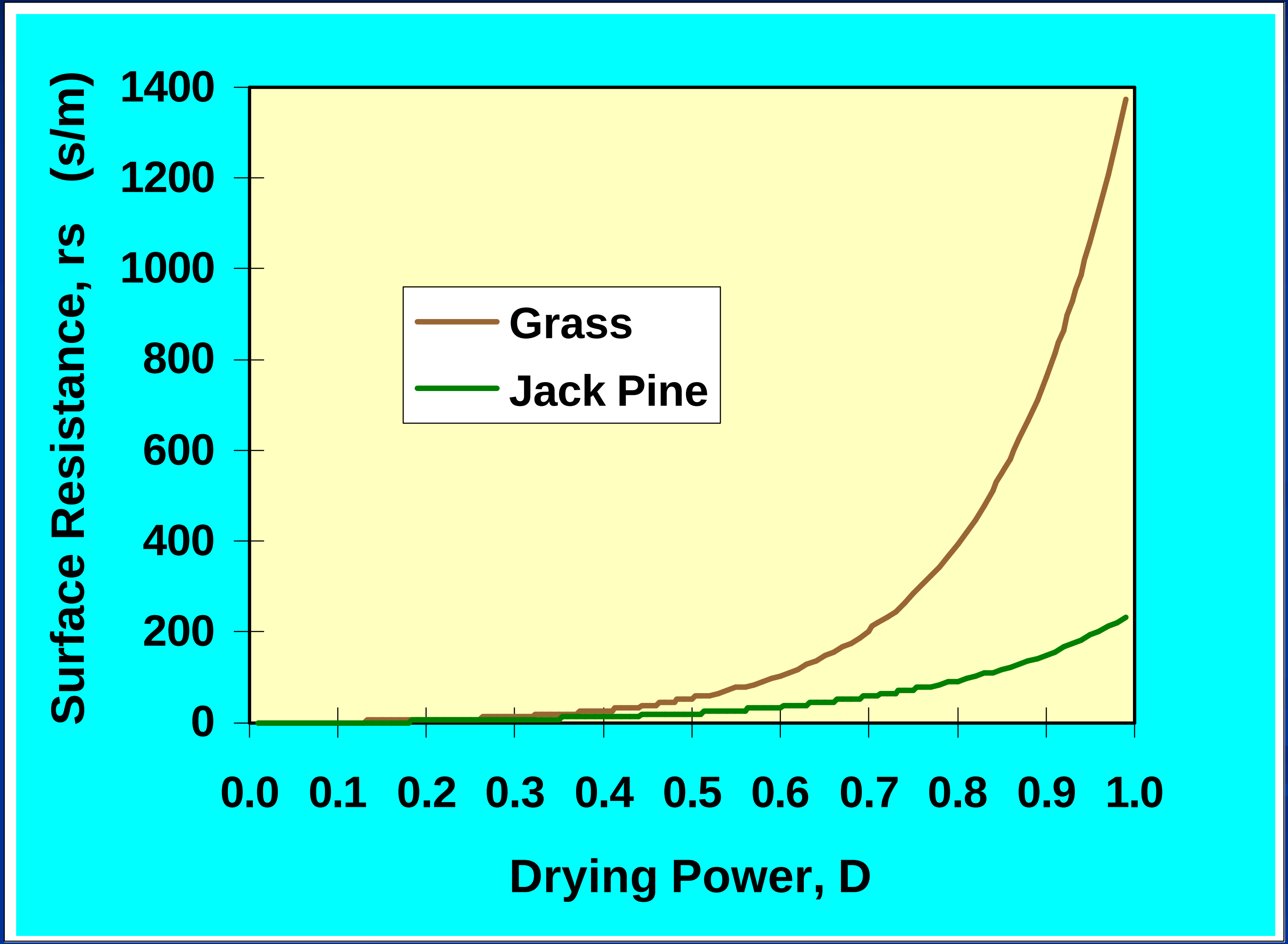
G = relative evaporation = ratio of actual to saturated surface E (dimensionless)

G is related to the Relative Drying power, D;

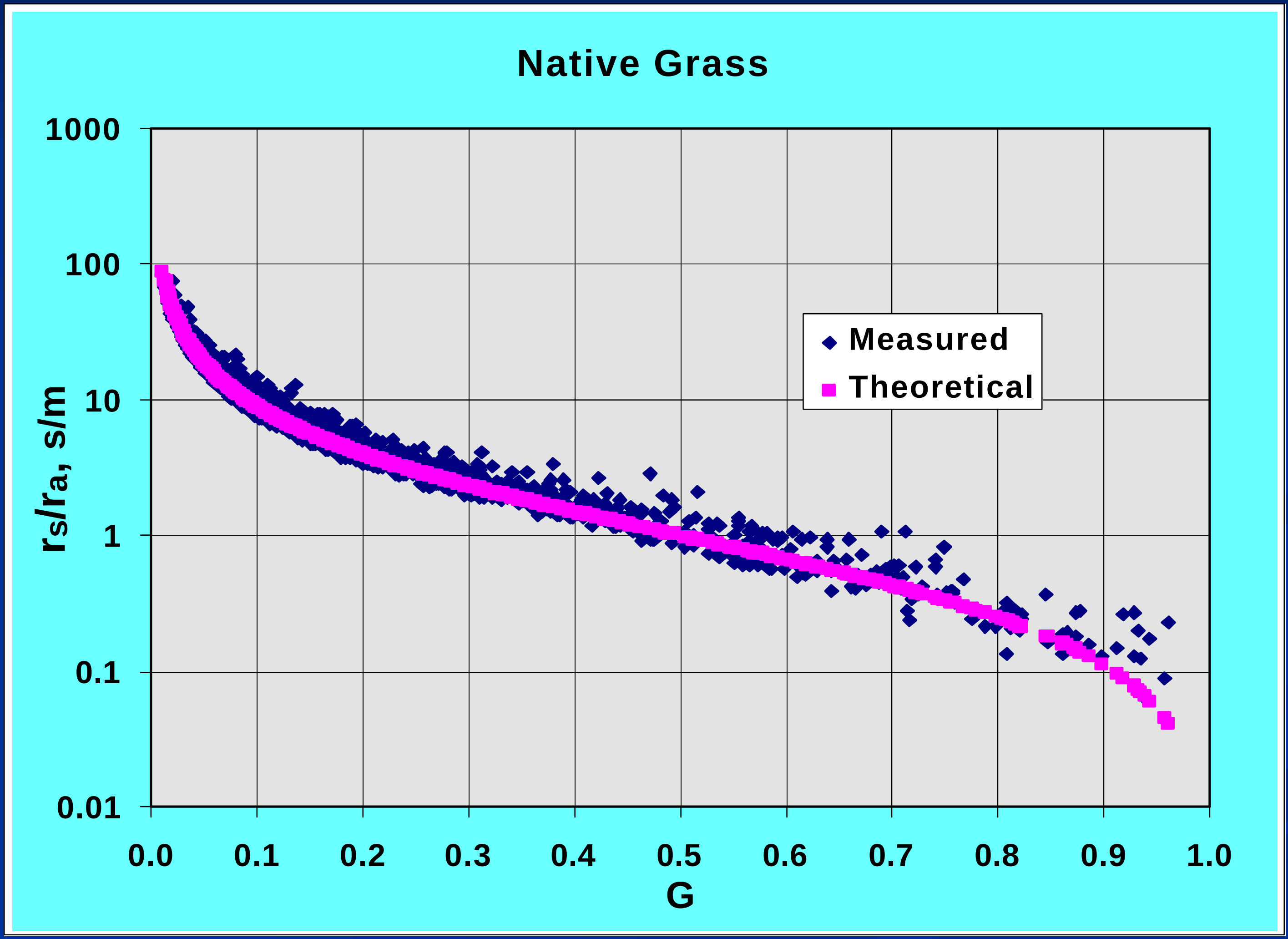
D = $E_a/(E_a + Q_a)$ (dimensionless)

$$G ? 1/?0.793 ? 0.2 \exp ?4.902 D ?? ? 0.006 D$$

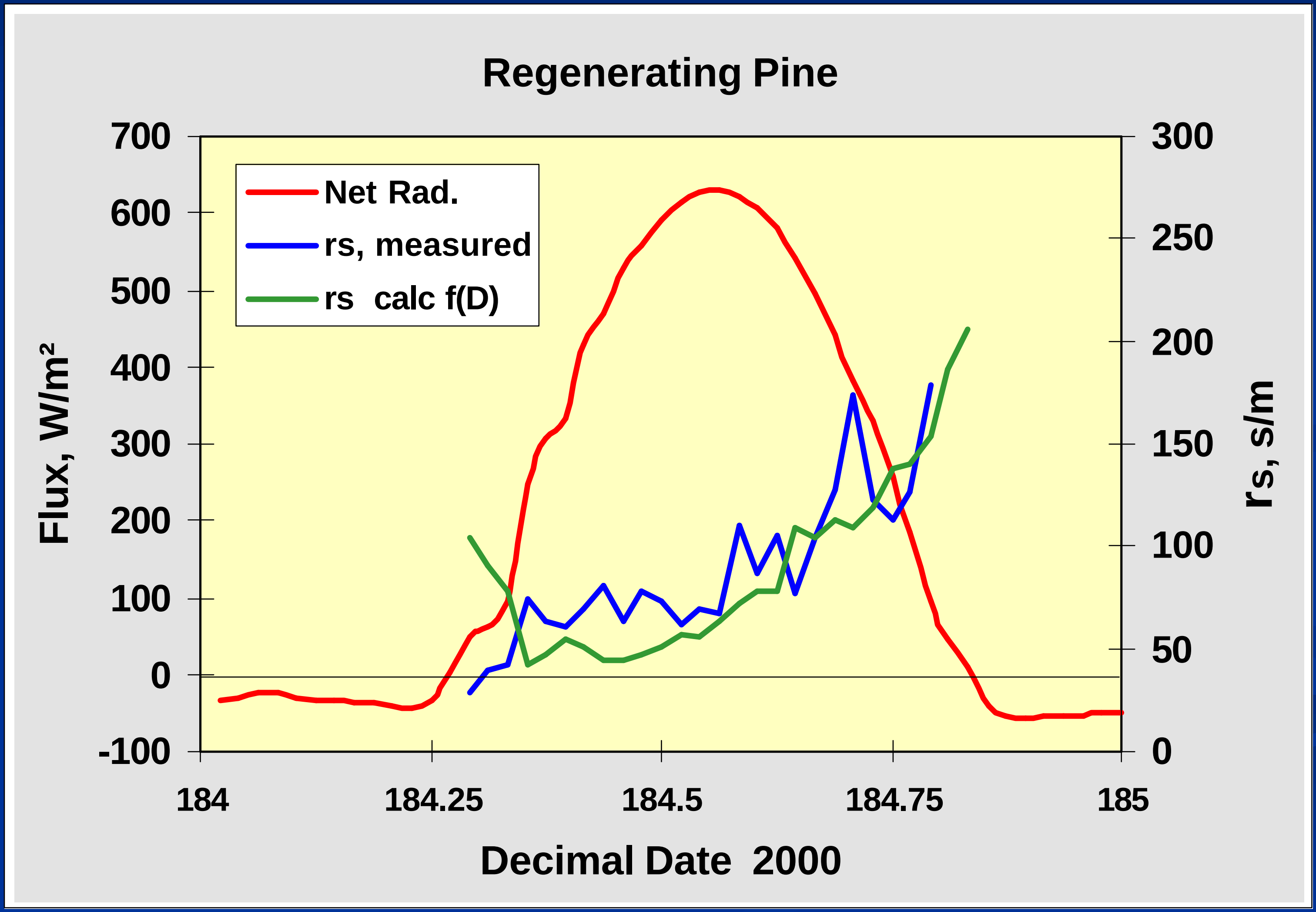
Surface Resistance



Relationship between r_s / r_a and G



Estimating surface resistance, r_s, using The G-D relationship

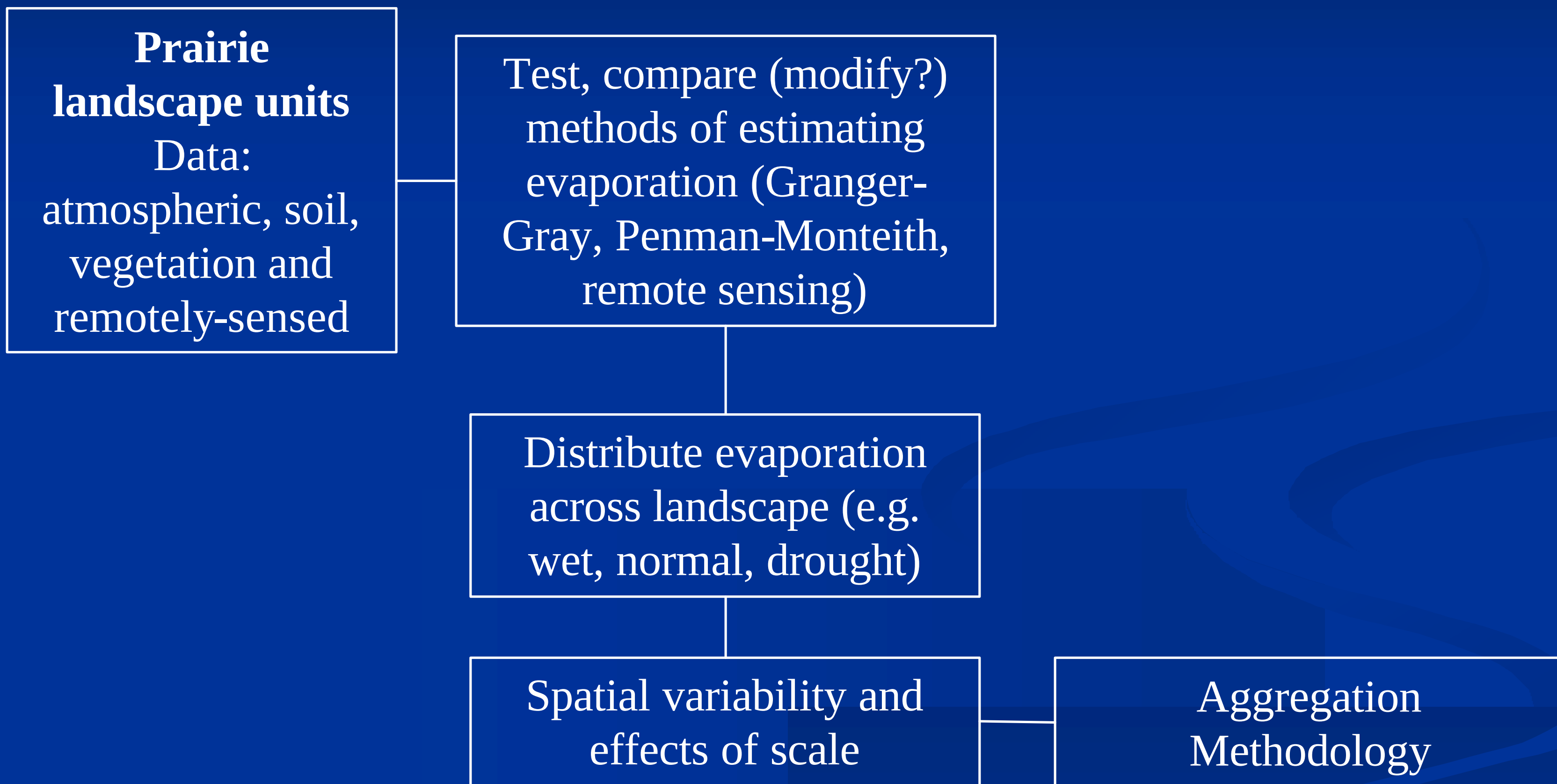


Spatial Variability of Evaporation in a Prairie Landscape

Robert Armstrong, Ph.D. Student

- Test and compare observational and modelling methods of estimating evaporation – including remote sensing
- Assess feasibility of remotely-sensed, distributed estimates of evaporation over a heterogeneous prairie landscape
- Examine the spatial variability of soil, vegetation and atmospheric parameters and the effects of spatial variability on larger scale estimates of evaporation (i.e. linear and non-linear relationships)
- Suggest improved methods to estimate spatially aggregated evapotranspiration.

Evaporation Methodology



Issues

- Complex Terrain
  - Topography
  - Vegetation
  - Soils
- Data
  - Archives need QA/QC
  - Algorithm development and testing will require **new field data**
  - Parameterisation
  - Supplement surface observations with assimilated data

Cold Regions Hydrological Model

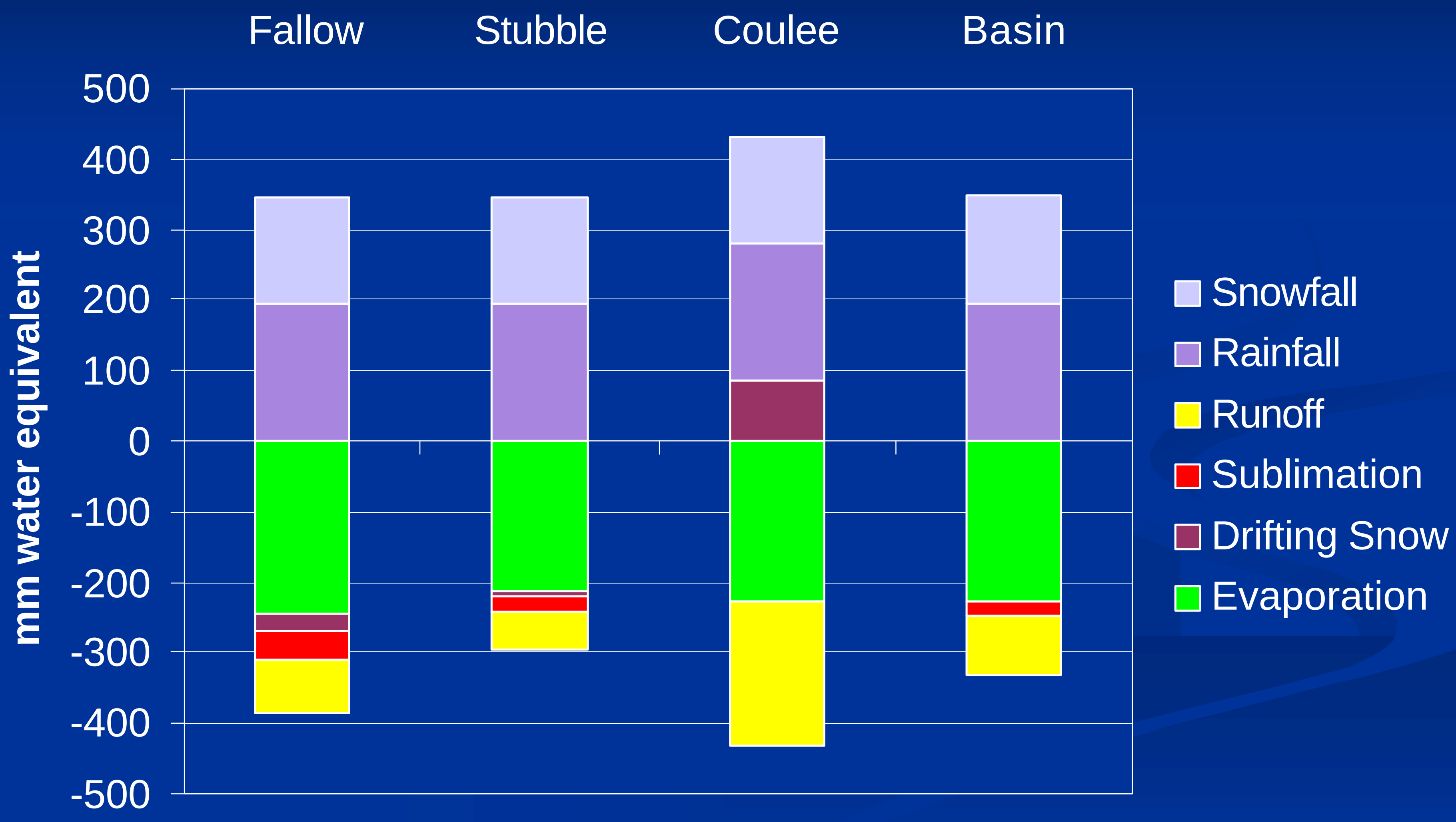
- Object oriented, modular modelling platform in Windows (C++)
- Library of basin, process and data modules – user friendly interface
- *Ability to write new modules from within the model*
- User assembles & 'compiles' the model using the CRHM platform – make what you want
- Applied to Hydrological Response Units
  - Scaling problems minimised within HRU (~process scale, internally uniform response)
  - Characteristic sequences of water flow between HRU governs the basin response
- Water and snow fluxes from HRU to HRU and outside of basin.
- Parameters set *apriori*. No calibration
- Visualisation, mapping and sensitivity tools, GIS interface for inputs and outputs

Cold Regions Hydrological Model Process Modules

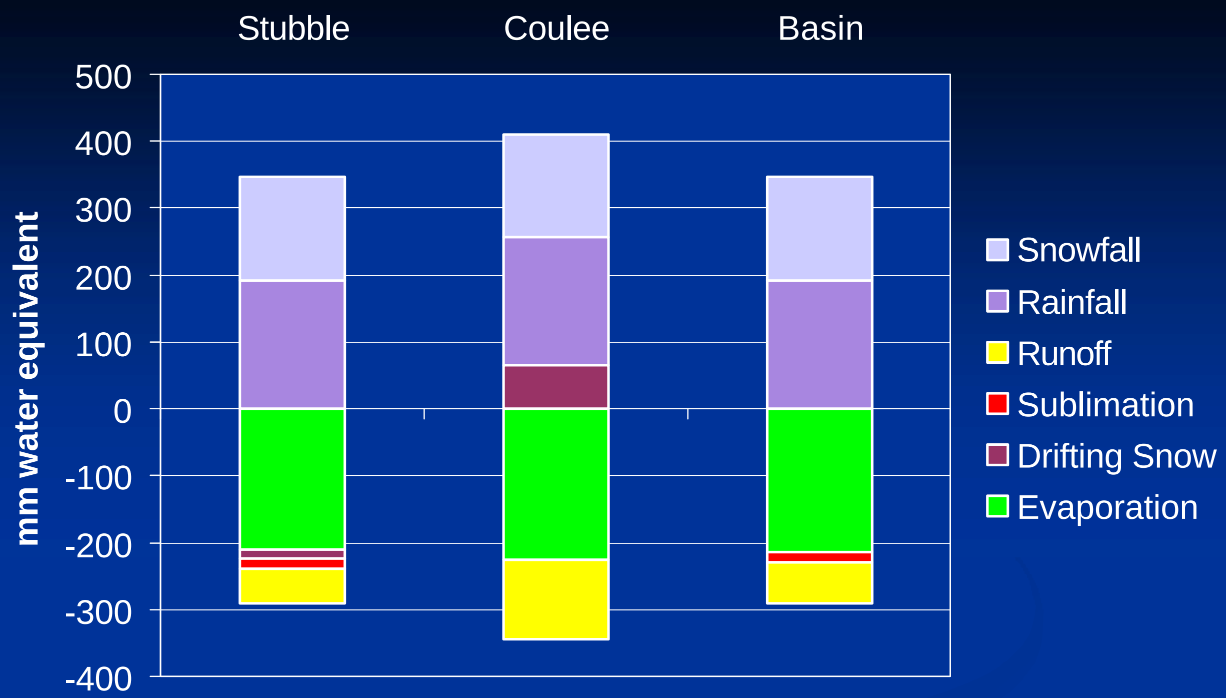
- Developed from research at University of Saskatchewan and NHRC over several decades
- Radiation (slopes, estimation procedures)
- Blowing snow (snow transport & sublimation)
- Interception (rain and snow)
- Snowmelt (open & forest, advection, energy balance & degree day options)
- Infiltration (frozen and unfrozen soils)
- Evaporation (unsaturated surfaces)
- Soil moisture balance (with groundwater interaction)
- Routing (hillslopes, sub-surface and streamflow)

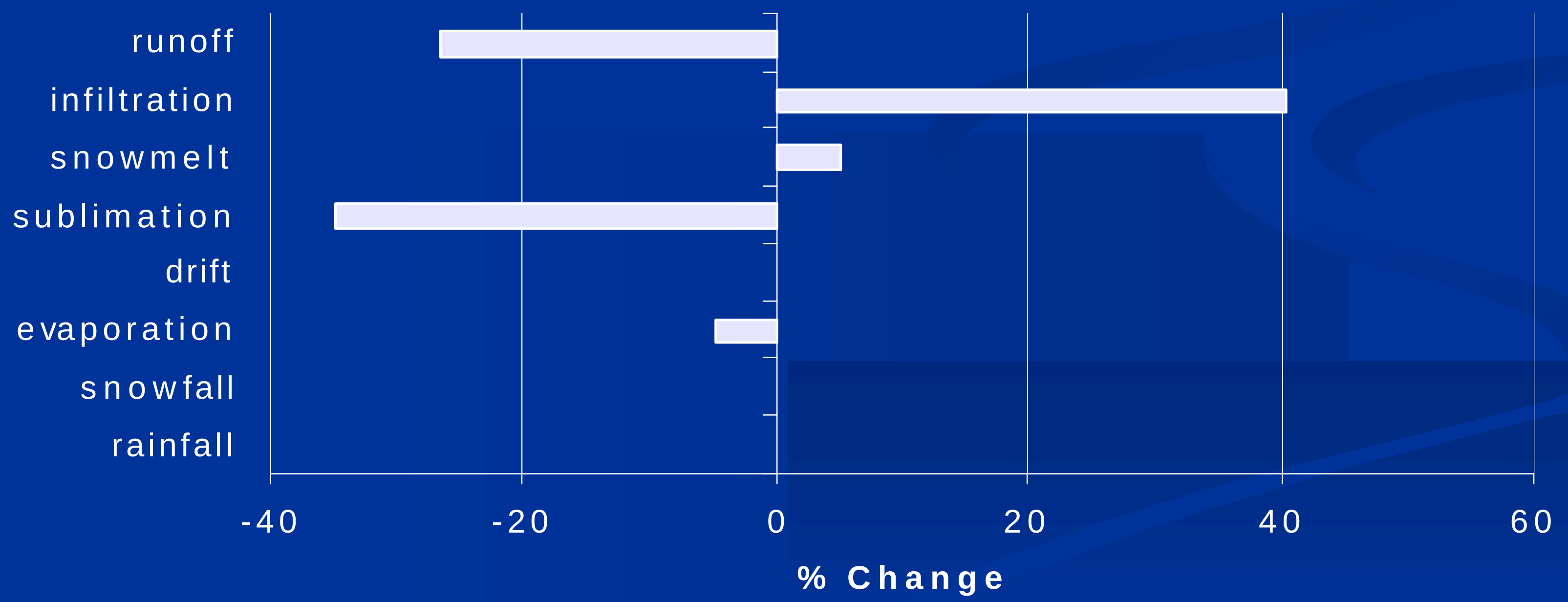
Cold Regions Hydrology Model - Prairie Basin Water Balance

With 30% Summer Fallow



Changed to Continuous Grain Cropping





CRHM Use for DRI

- Hydrological evolution and feedbacks in drought
- Hydrological Drought Indices based on small basin soil moisture, streamflow and slough levels
- Scaling methodology and process test bed
- Evaluate prairie land surface parameterisations and aggregation for MESH
- Test prairie hydrology routing for MESH