Predicting hydrologic sensitivities to climate and land cover change at the urban interface in the Puget Sound basin

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LA's Water Resource Future
Workshop 1: Understanding Local Stormwater Capture Potential

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UCLA Center for Climate Change Solutions

UCLA DEPARTMENT OF Geography

Outline of this talk

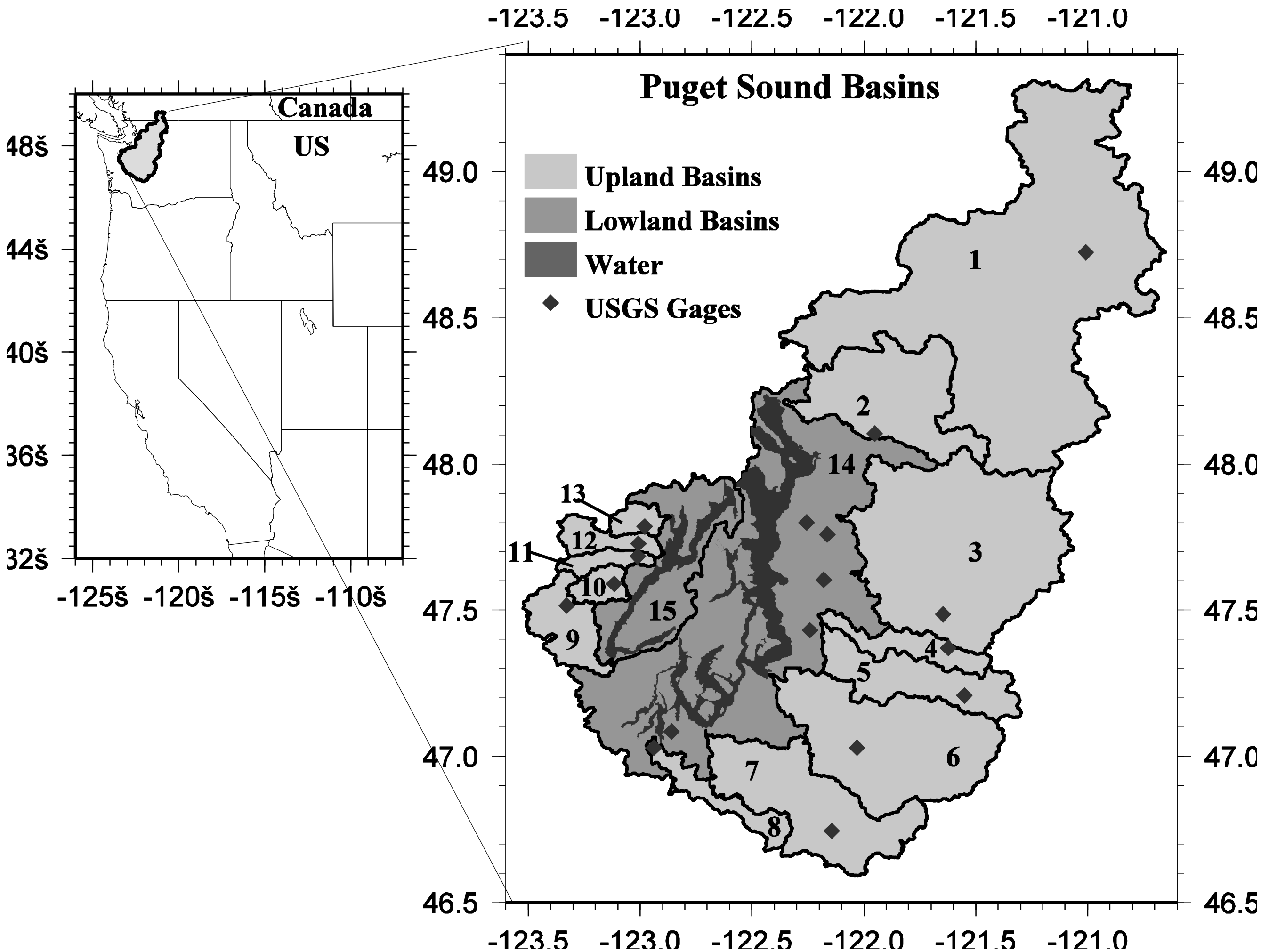
1) Reconstructing historical land cover and climate change effects on hydrology
2) Future projections
3) Stream temperature
4) What are the lessons for the LA area, and stormwater recapture in particular?

What are the "grand challenges" in hydrology?

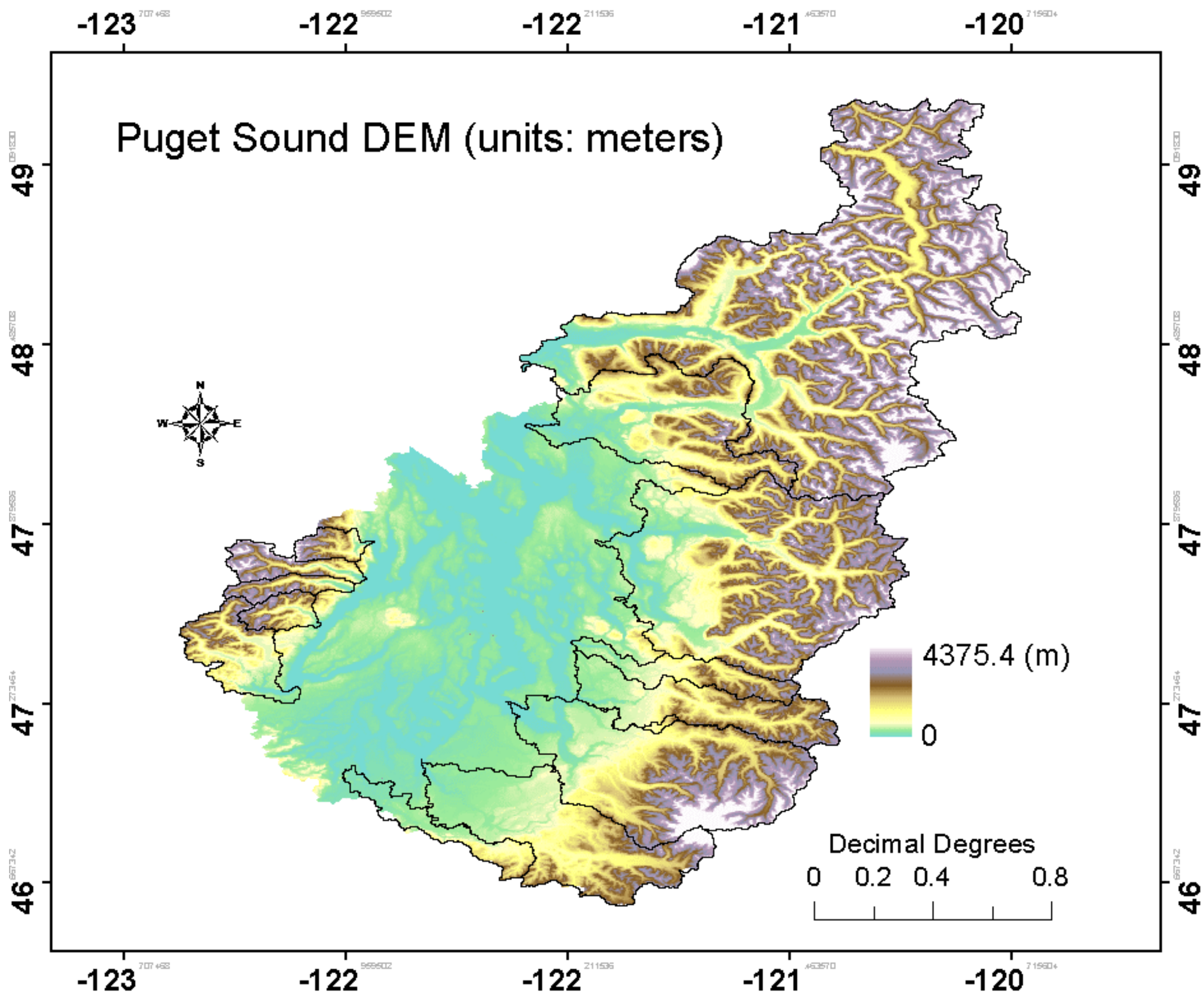
- From *Science* (2006) 125th Anniversary issue (of eight in Environmental Sciences): ***Hydrologic forecasting – floods, droughts, and contamination***
- From the CUAHSI Science and Implementation Plan (2007): ***… a more comprehensive and … systematic understanding of continental water dynamics …***
- From the USGCRP Water Cycle Study Group, 2001 (Hornberger Report): ***[understanding] the causes of water cycle variations on global and regional scales, to what extent [they] are predictable, [and] how … water and nutrient cycles [are] linked?***

Important problems all, but I will argue instead (in addition) that *understanding hydrologic sensitivities to global change should rise to the level of a grand challenge to the community*.

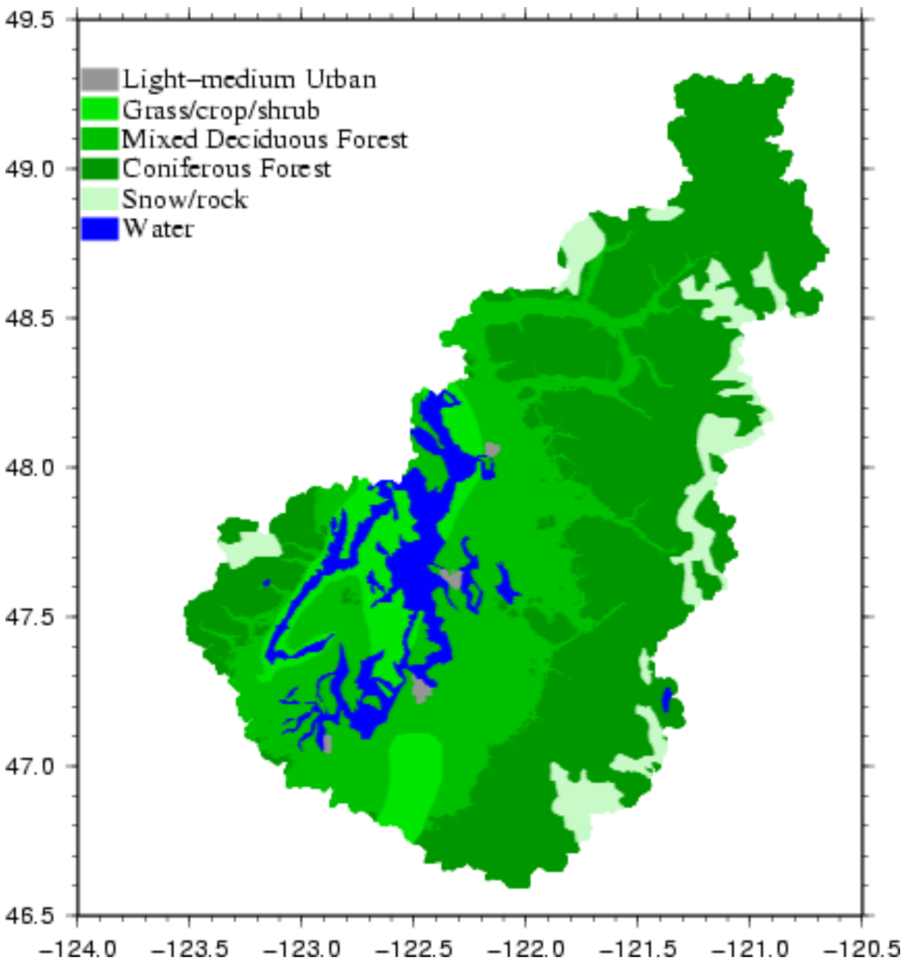
Understanding hydrologic change: The Puget Sound basin as a case study



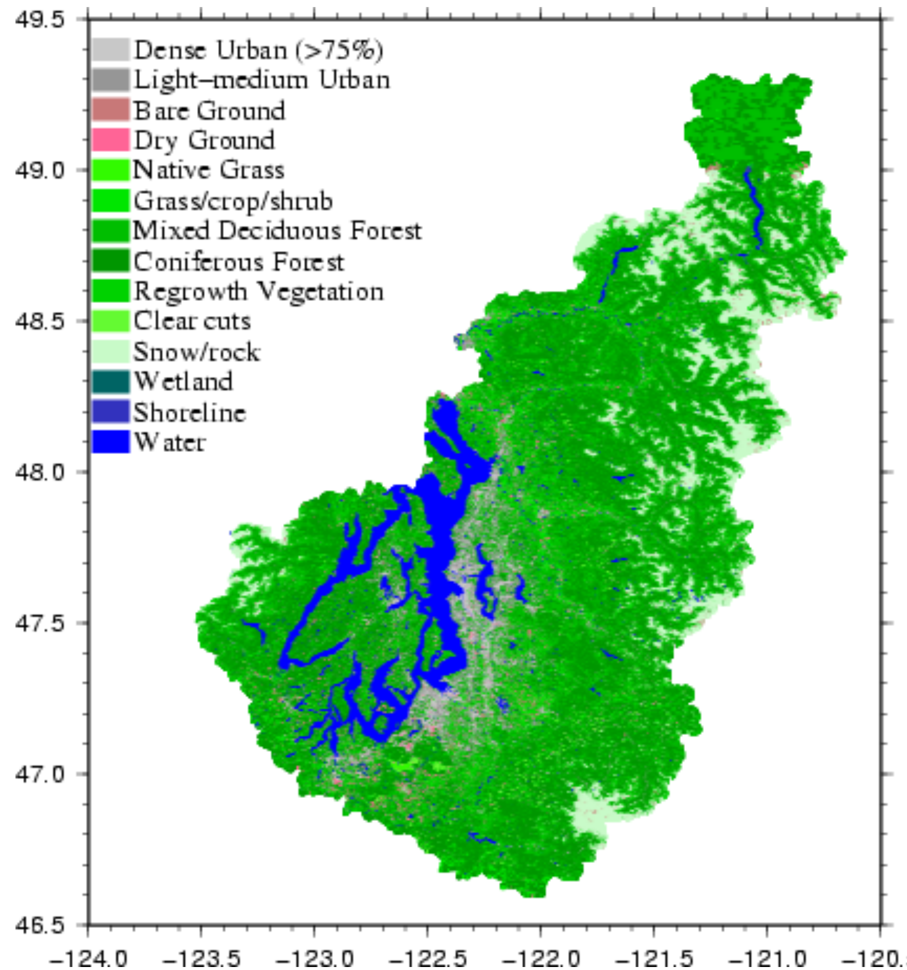
Topography of the Puget Sound basin



The role of changing land cover – 1880 v. 2002

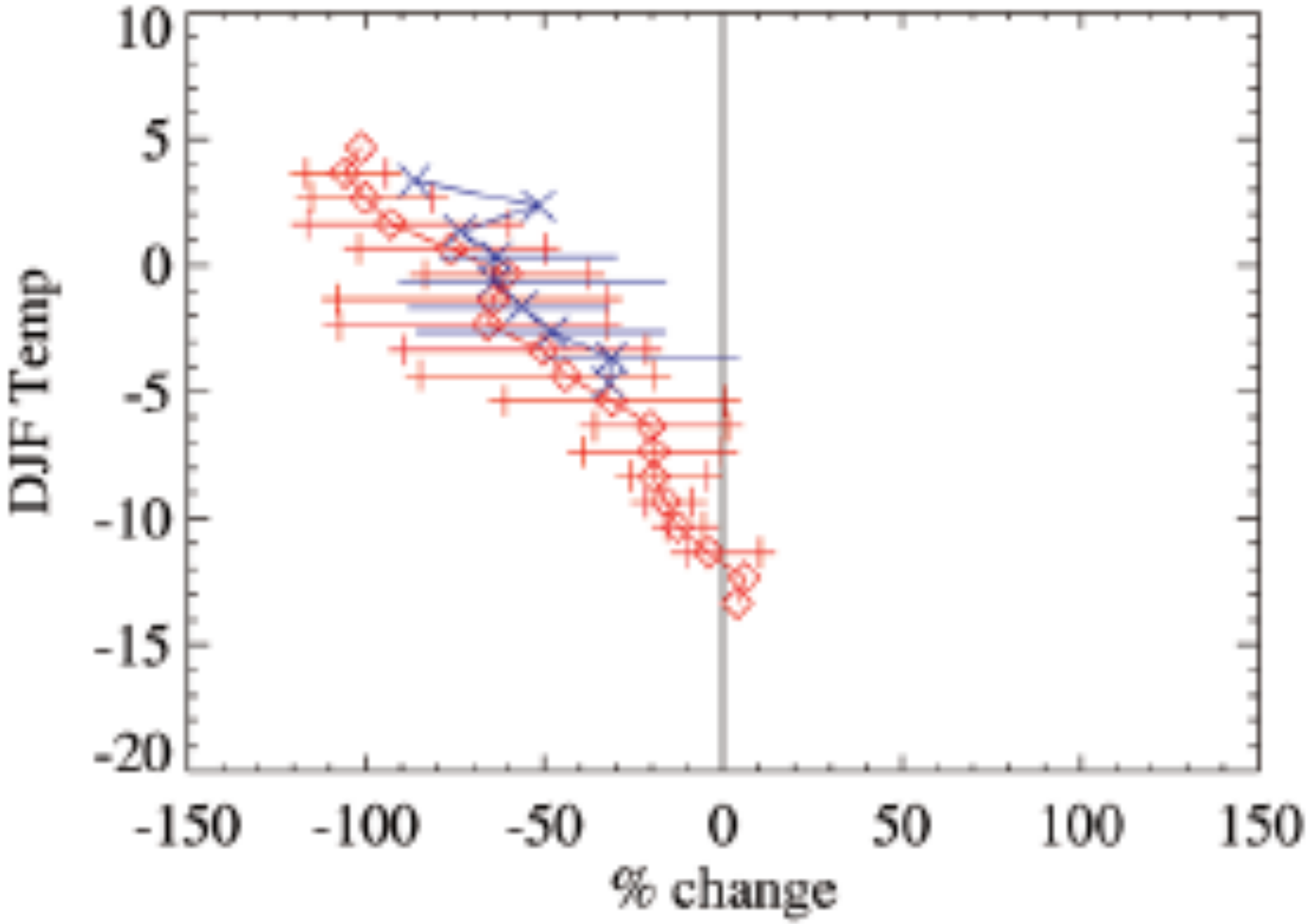


1880



2002

The role of changing climate, 1950-2000



source: Mote et al (2005)

Understanding hydrologic change: The modeling context

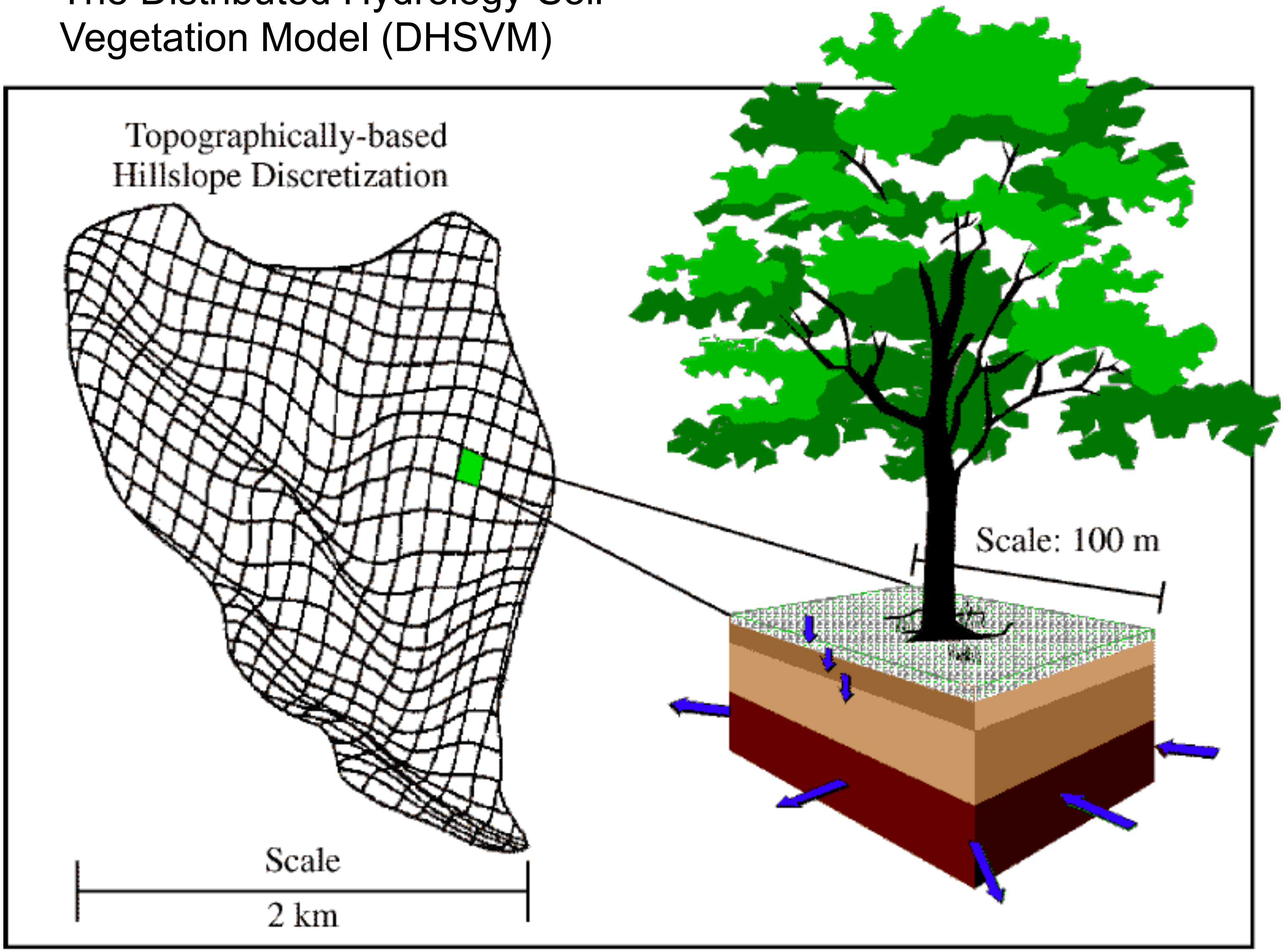
Fundamental premises

a) Simulation modeling must play a central role, because we rarely have enough observations to diagnose change on the basis of observations alone (and in the future, the “experiment” hasn’t yet been performed)

b) If the hydrological processes are changing, we need to represent those processes

c) Hence, prediction approaches that are “trained” to observations won’t work well

The Distributed Hydrology-Soil-Vegetation Model (DHSVM)



Surface / Subsurface Flow
Redistribution to / from
Neighboring Pixels

1-D Vertical Water Balance

Evaporation (E)

Interception (E_{io} E_{iu})

Soil (E_s)

Transpiration

Overstory (E_{to})

Understory (E_{tu})

Storage (S)

Overstory (S_{io})

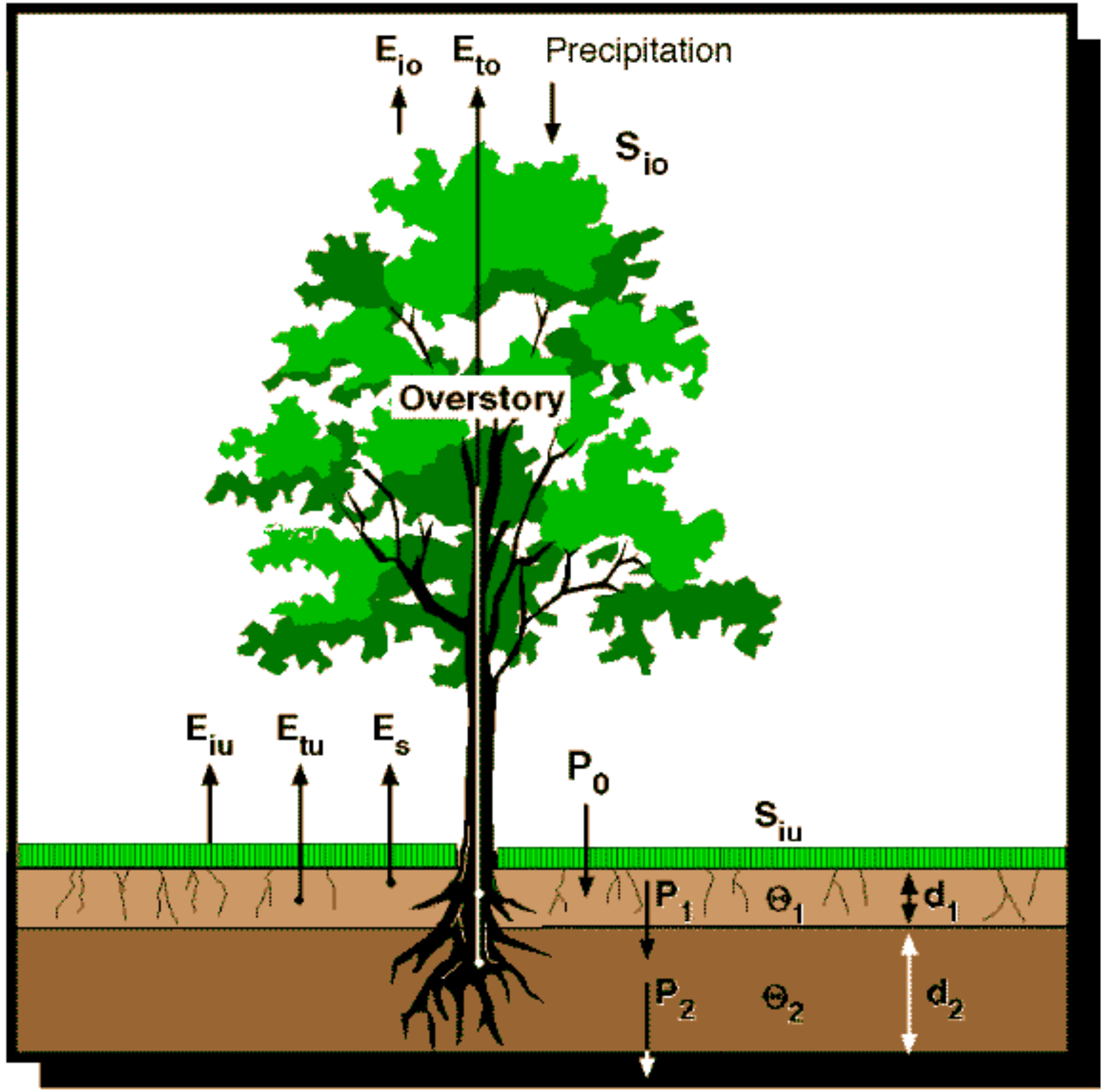
Understory (S_{iu})

Soil layer 1 ($\theta_1 d_1$)

Soil layer 2 ($\theta_2 d_2$)

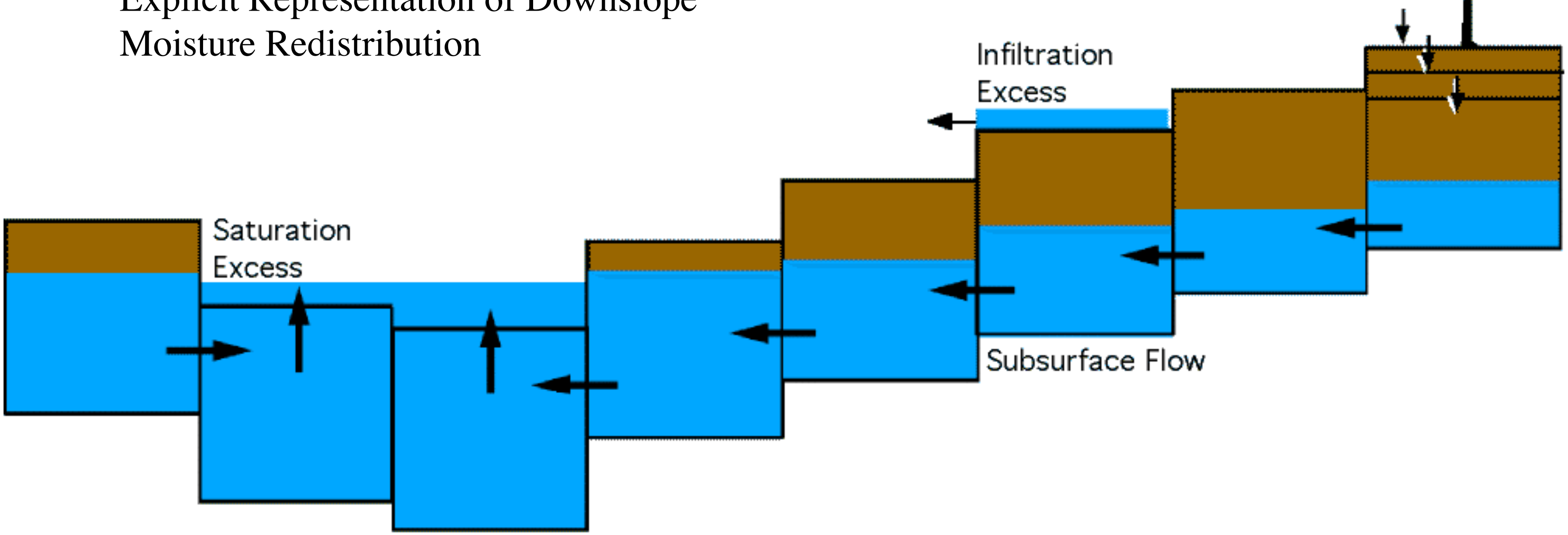
Rooting Zones

$$S_s = \Theta_1 d_1 + \Theta_2 d_2$$

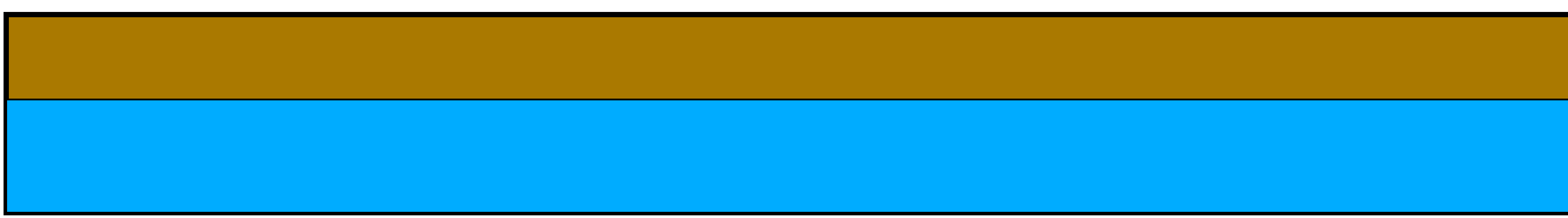


Surface - Subsurface Flow Routing and Runoff Generation

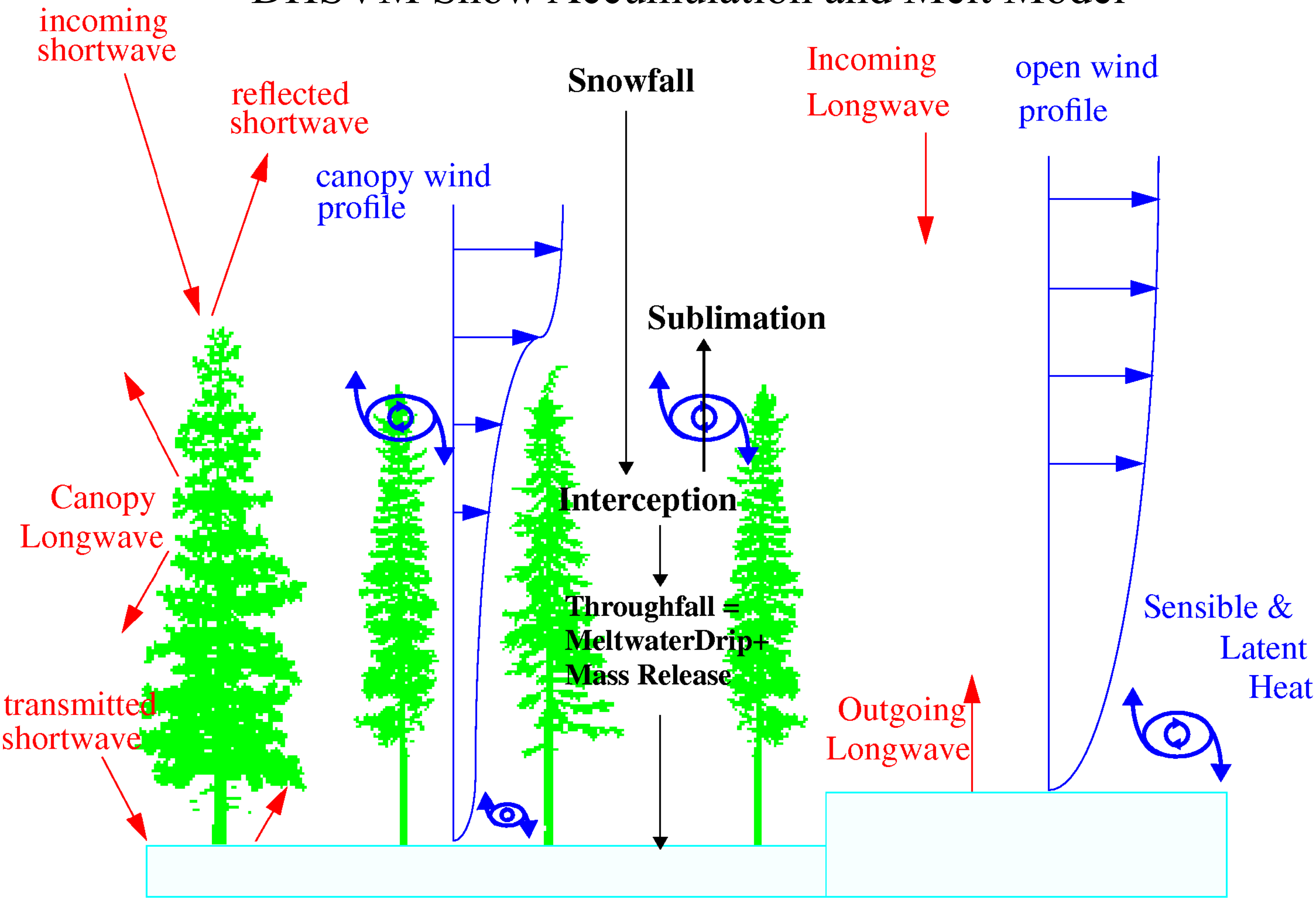
Explicit Representation of Downslope
Moisture Redistribution



Lumped Conceptual (Processes parameterized)



DHSVM Snow Accumulation and Melt Model



Representing urbanization effects in DHSVM

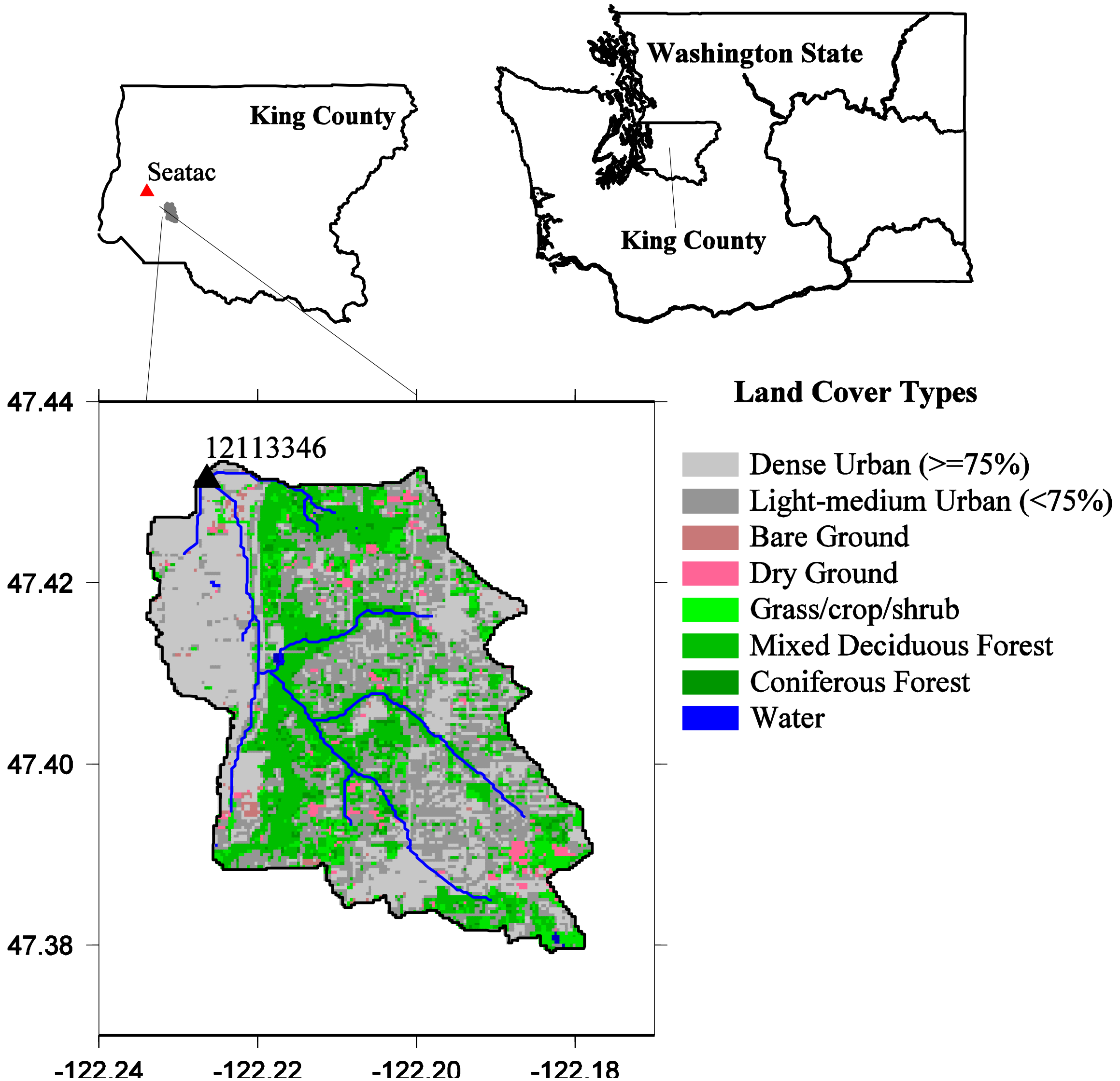
Hydrologically relevant features of urbanization not found in “natural” watersheds:

1) surface components such as streets, rooftops, ditches
2) subsurface components such as pipes and other manmade stormwater drainage conduits
3) In fully urbanized catchments, these elements are linked through street curb inlets and manholes
4) In partially urbanized catchments, these urban drainage elements are often mixed with the natural channel drainage system

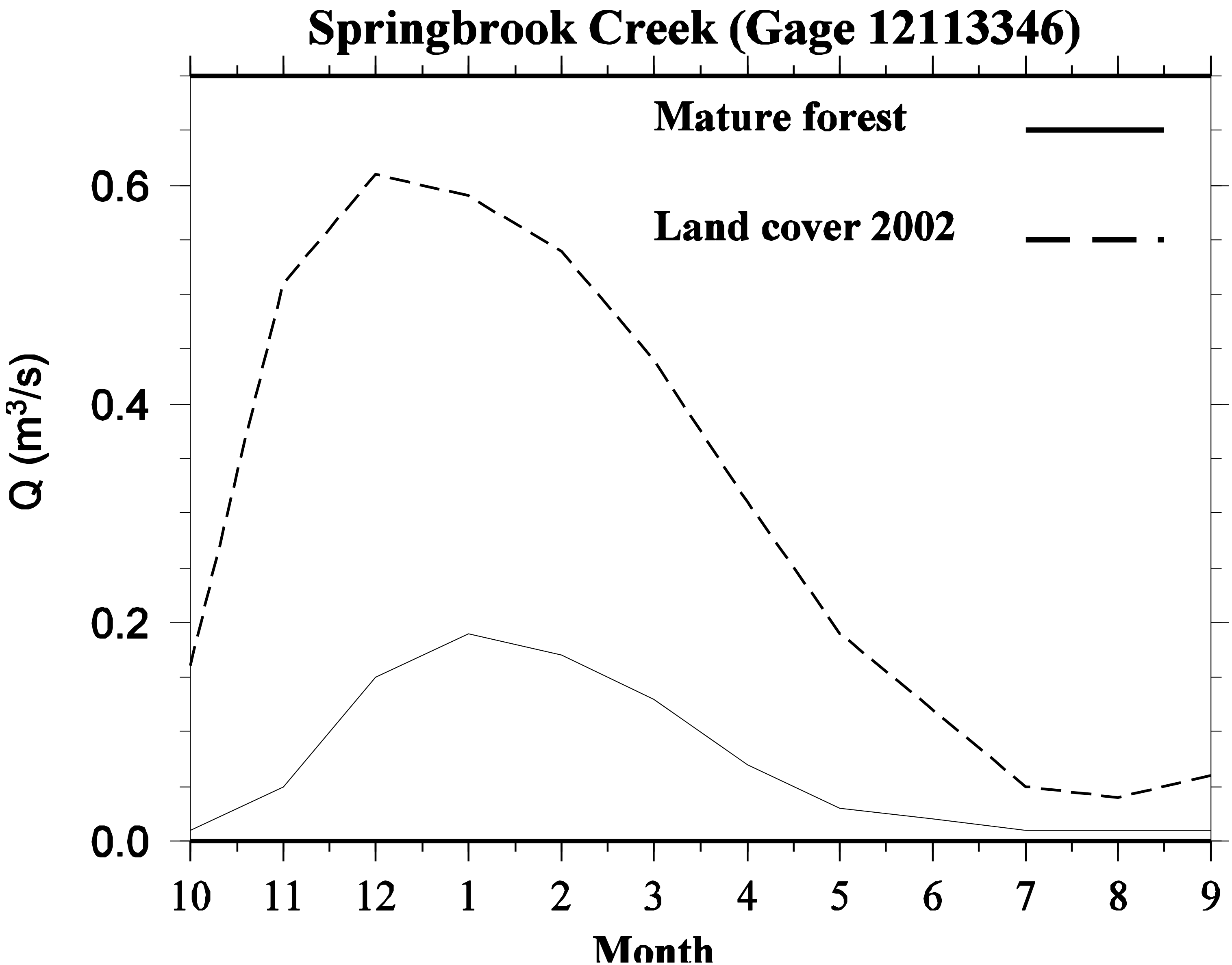
Modifications of DHSVM for urban areas

- **For pixels with land cover category "urban", a fraction of impervious surface area is specified.**
- **For the fraction that is not impervious, DHSVM handles infiltration using the same parameterizations as for non-urban pixels.**
- **A second parameter, the fraction of water stored in flood detention, was also added. Runoff generated from impervious surfaces is assumed to be diverted to detention storage.**
- **The runoff diverted to detention storage is allowed to drain as a linear reservoir, and re-enters the channel system in the pixel from which it is diverted.**
- **Surface runoff that is not diverted is assumed to enter the channel system directly, i.e., all urban channels are connected directly to the channel system**
- **We assume that the natural channel system remains intact, and we retain the support area concept that defines the connectivity of pixels to first order channels. However, impervious surface runoff (and drainage from detention reservoirs) is assumed to be connected to the nearest stream channel directly**
- **Once impervious surface runoff has entered a stream channel, it follows the "standard" DHSVM channel flow routing processes.**

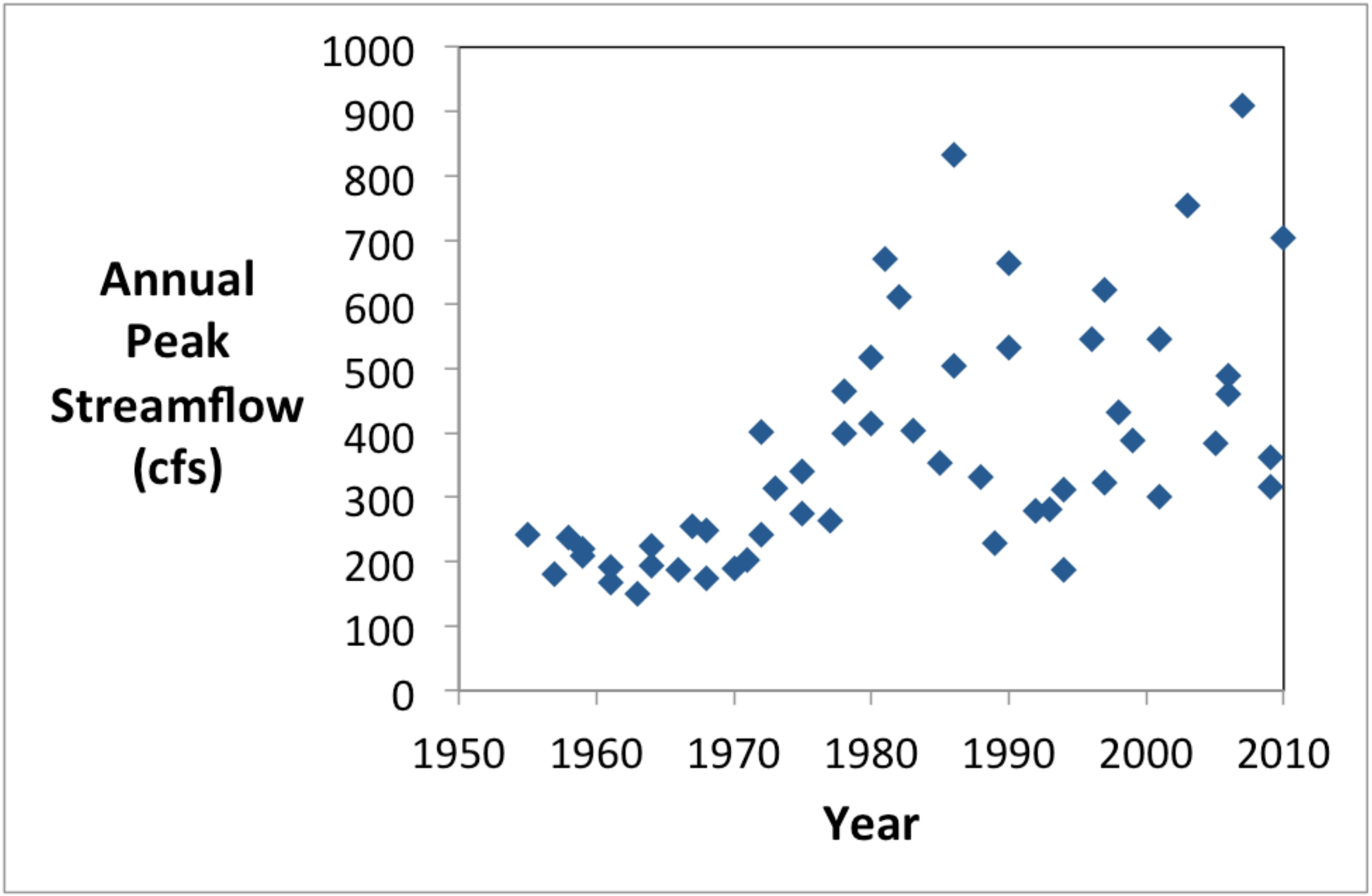
Springbrook Creek catchment



Springbrook Creek mean seasonal cycle simulated current land cover and all mature forest

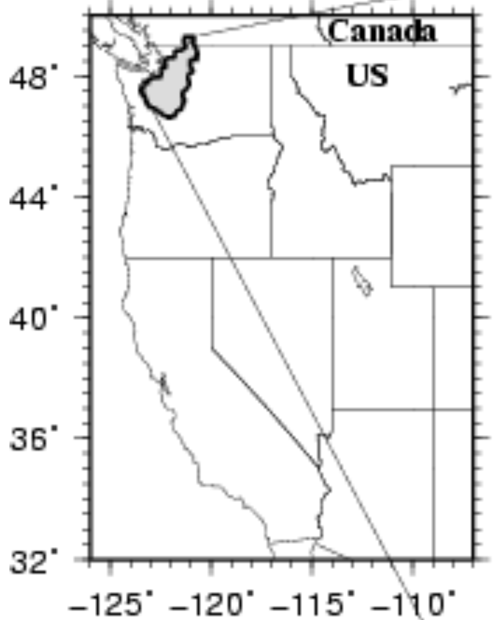


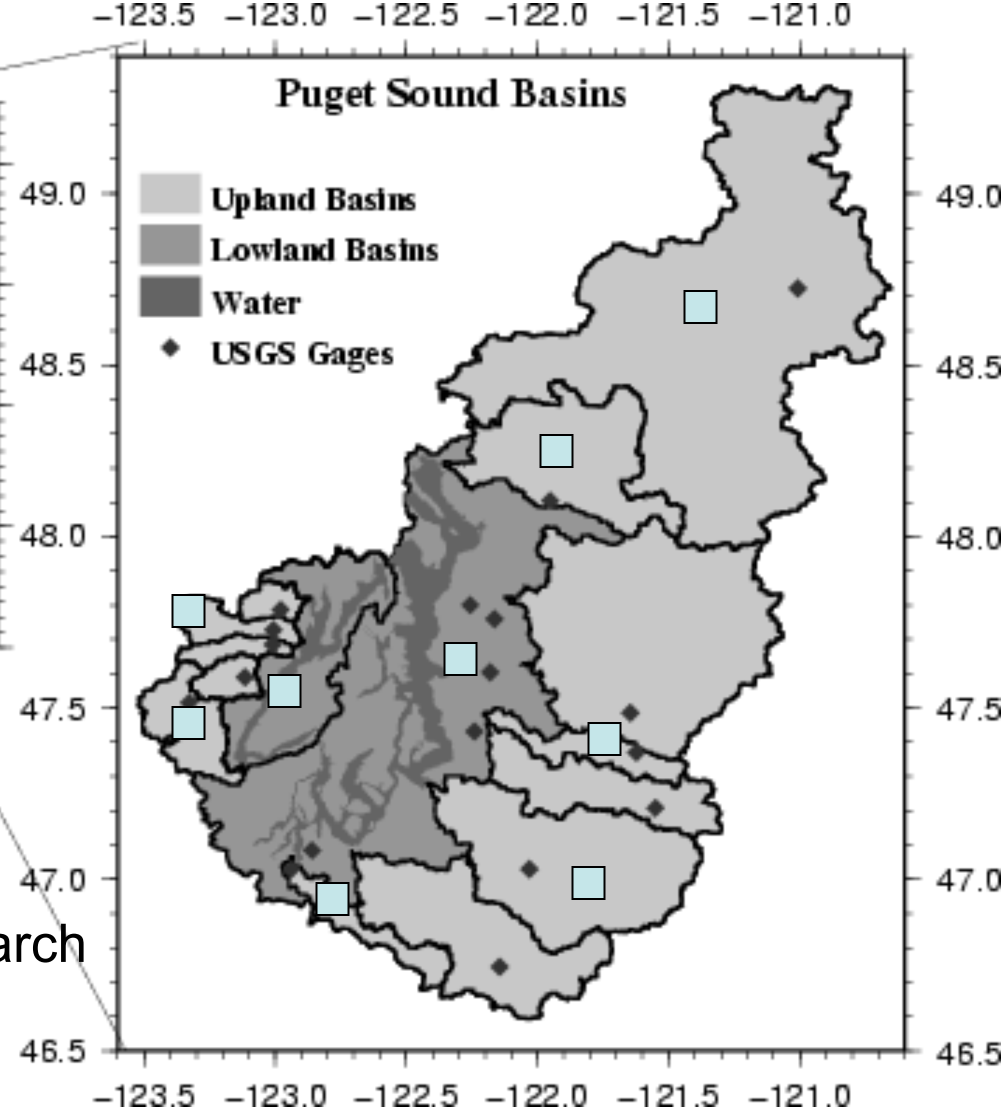
Mercer Creek peak flows 1956-2010



Understanding the effects of historical land cover and climate change on the Puget Sound basin – modeling and analysis

Study Areas





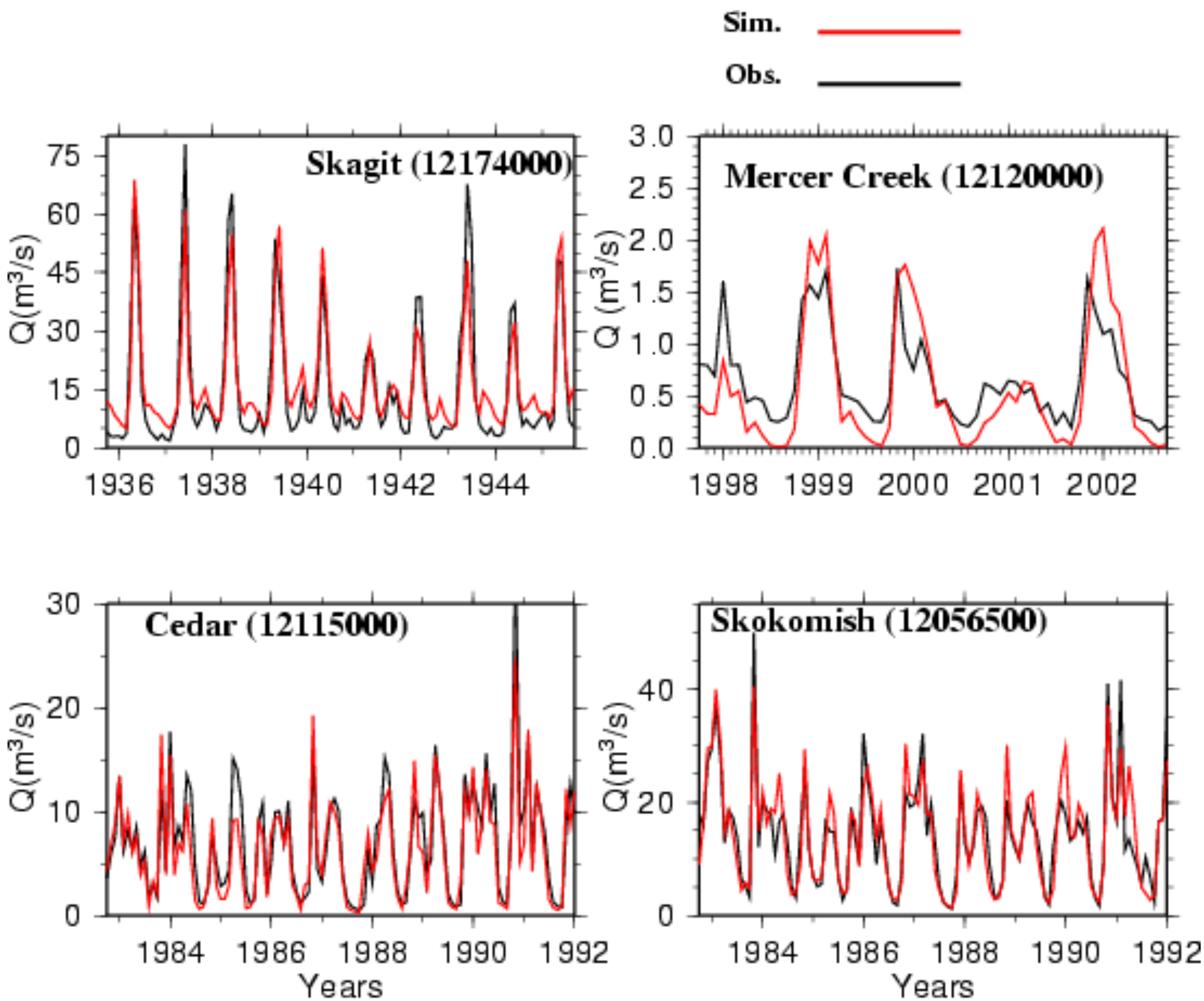
Puget Sound basin,
Washington State, USA
Temperate marine climate,
Precipitation falls in October – March
Snow in the highland,
rare snow in the lowland

Targeted sub-basins

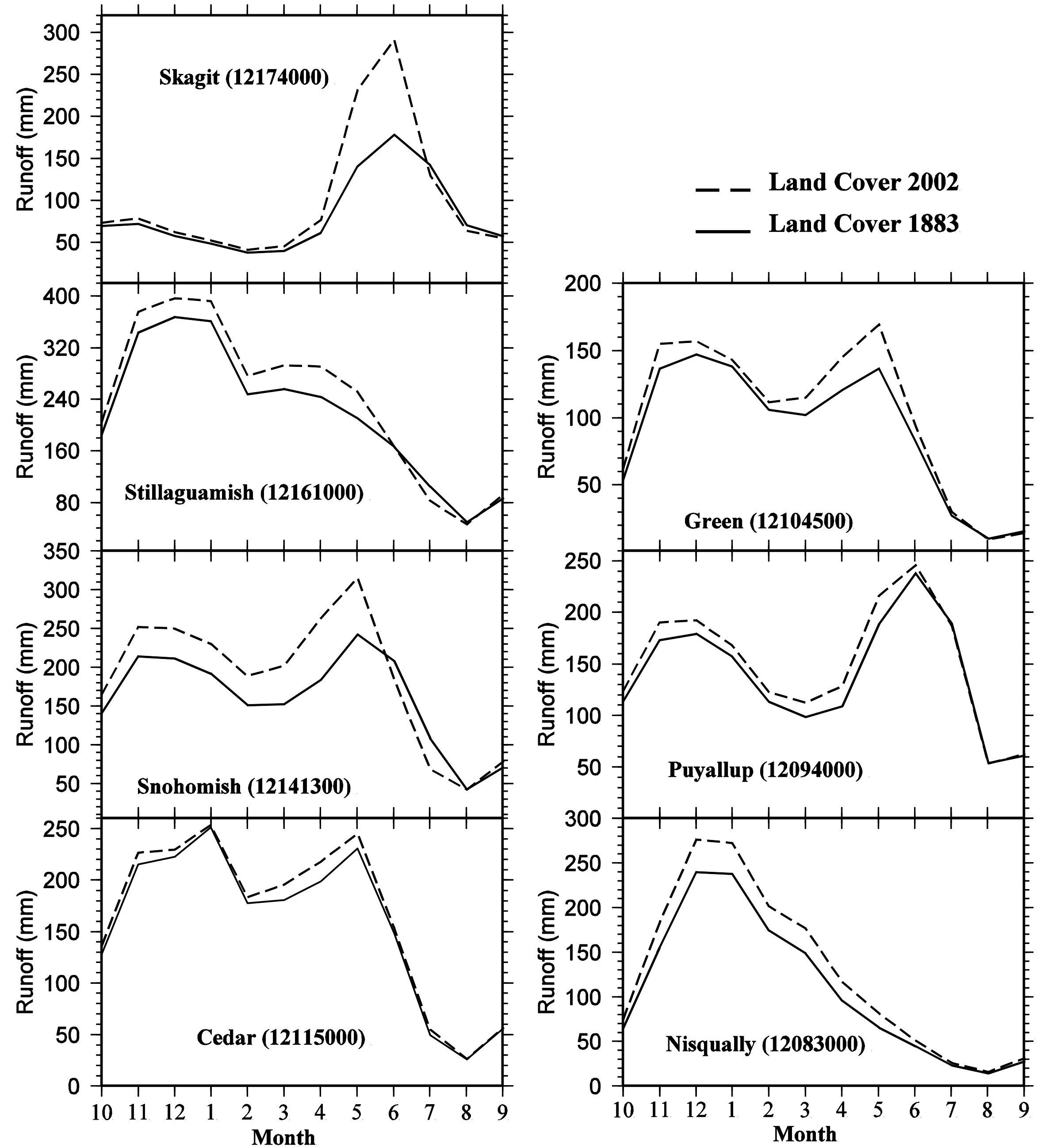
Climate change signal last ~100 years

- Precipitation mostly flat
- Increasing temperature, 0.5-1.0 C on average; larger trends in Tmin than Tmax

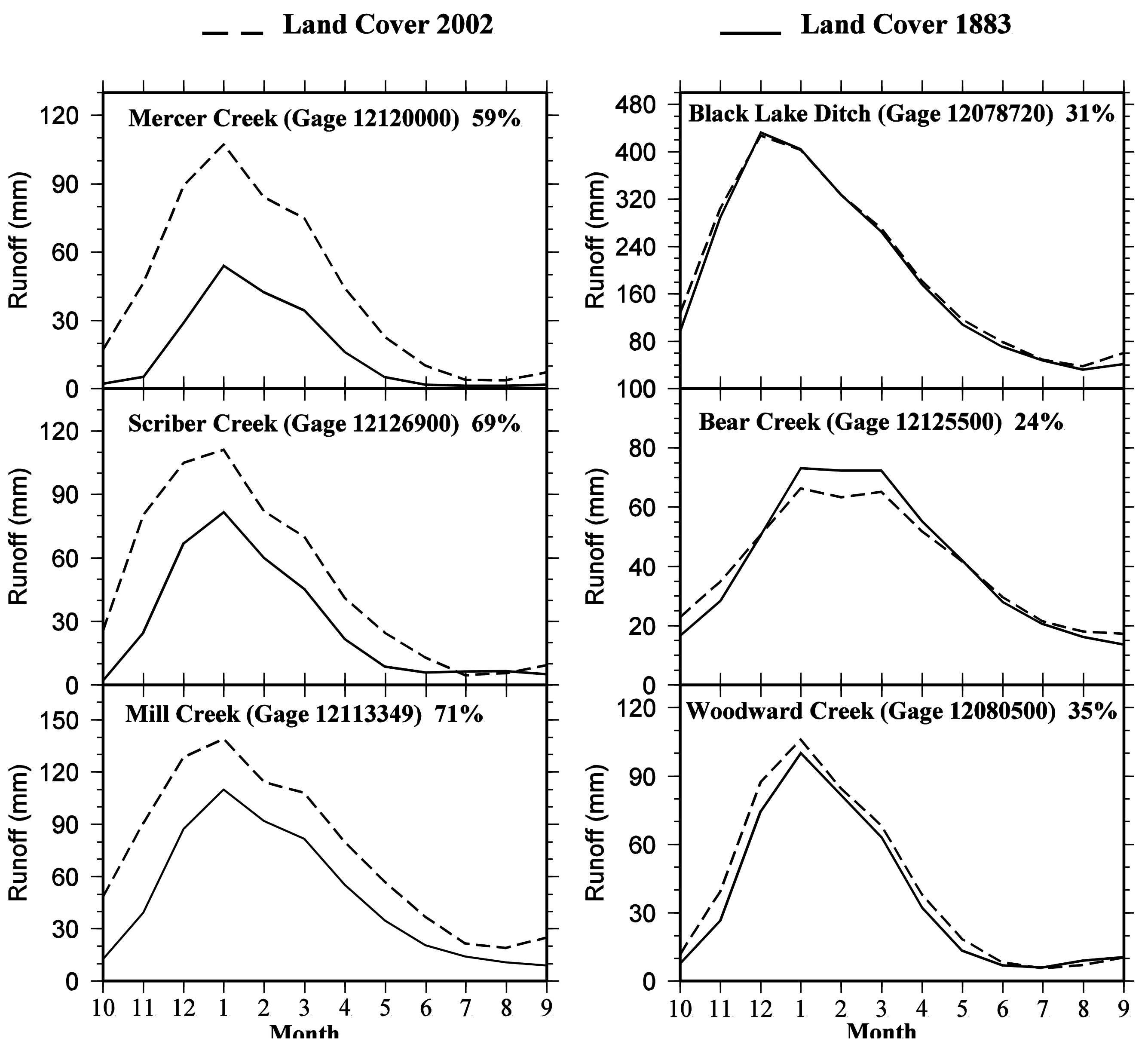
Model Calibration



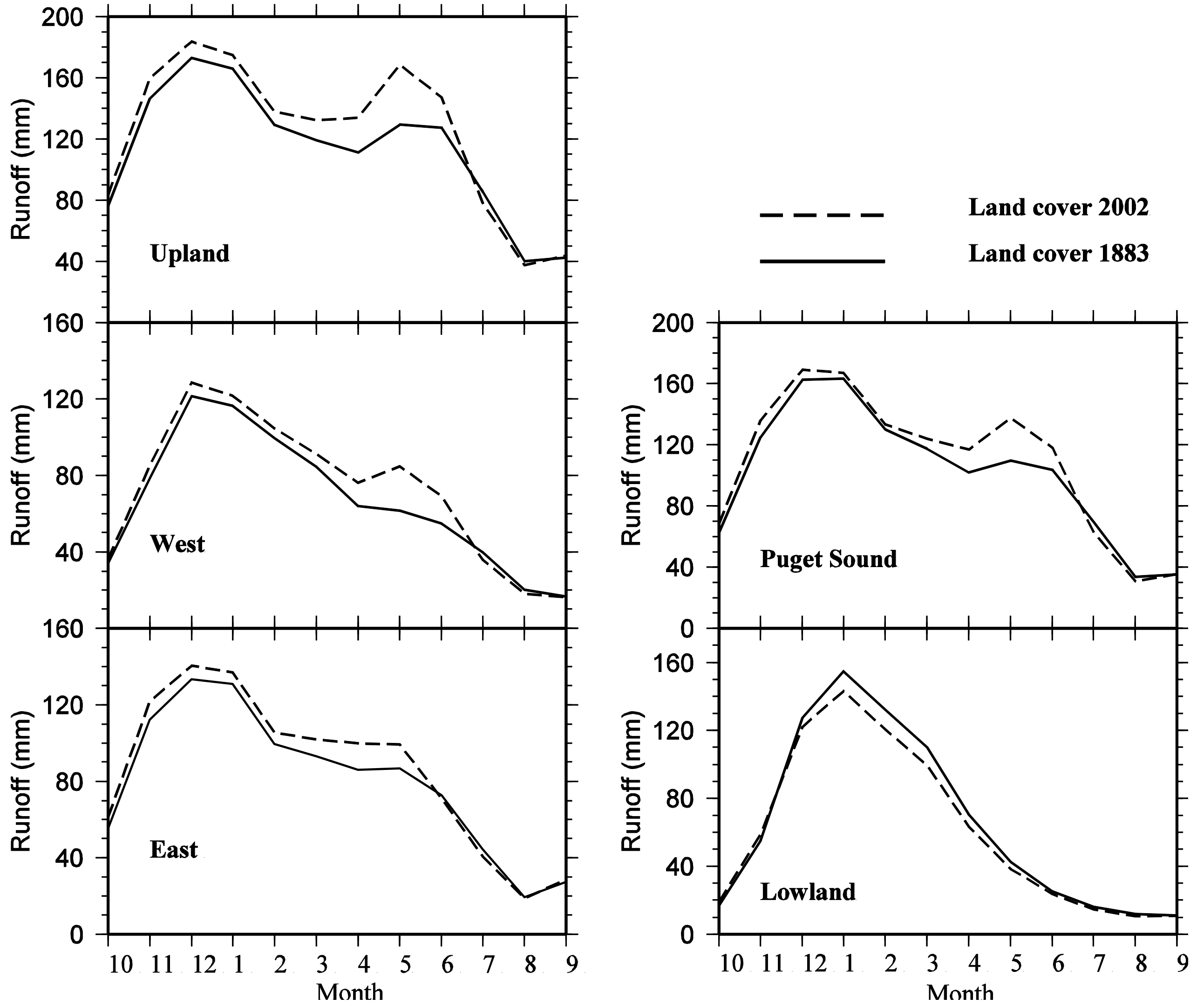
Land cover change effects on seasonal streamflow for eastern (Cascade) upland gages



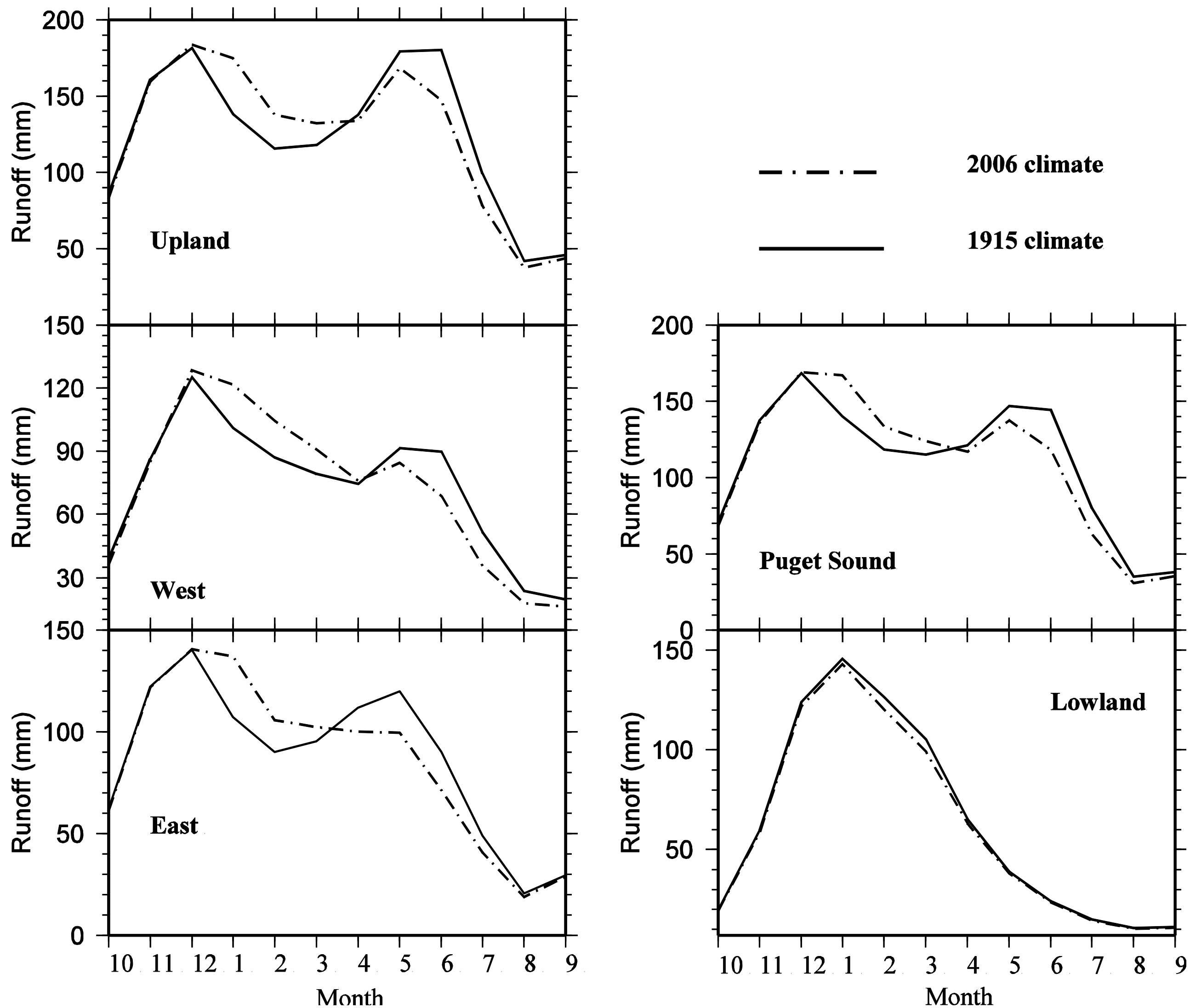
Land cover change effects on seasonal streamflow at selected eastern lowland (Greater Seattle area) gages



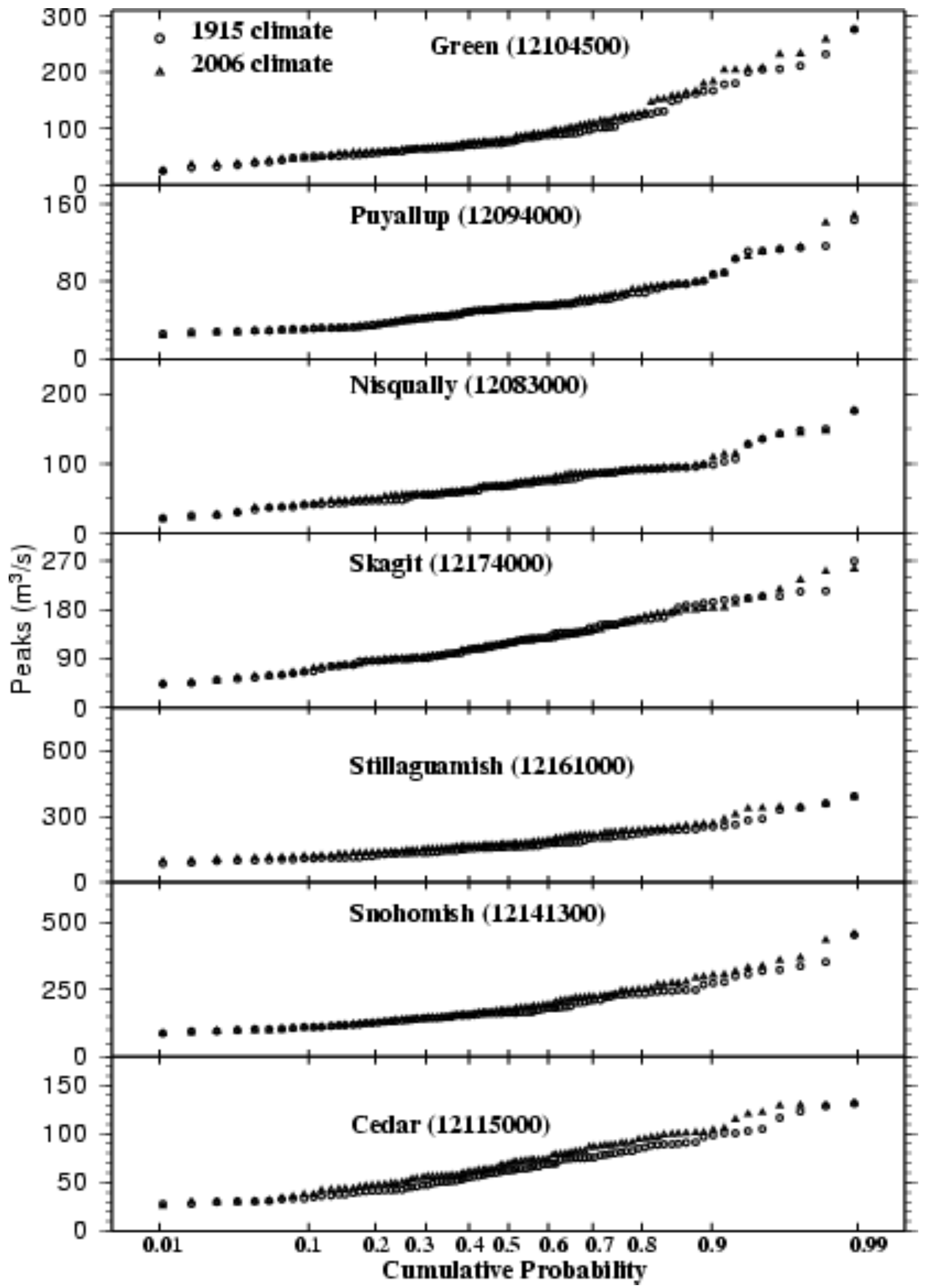
Land cover change effects by region



Predicted temperature change effects on seasonal streamflow by region



Predicted temperature change effects on annual maximum flow at eastern (Cascade) upland gages

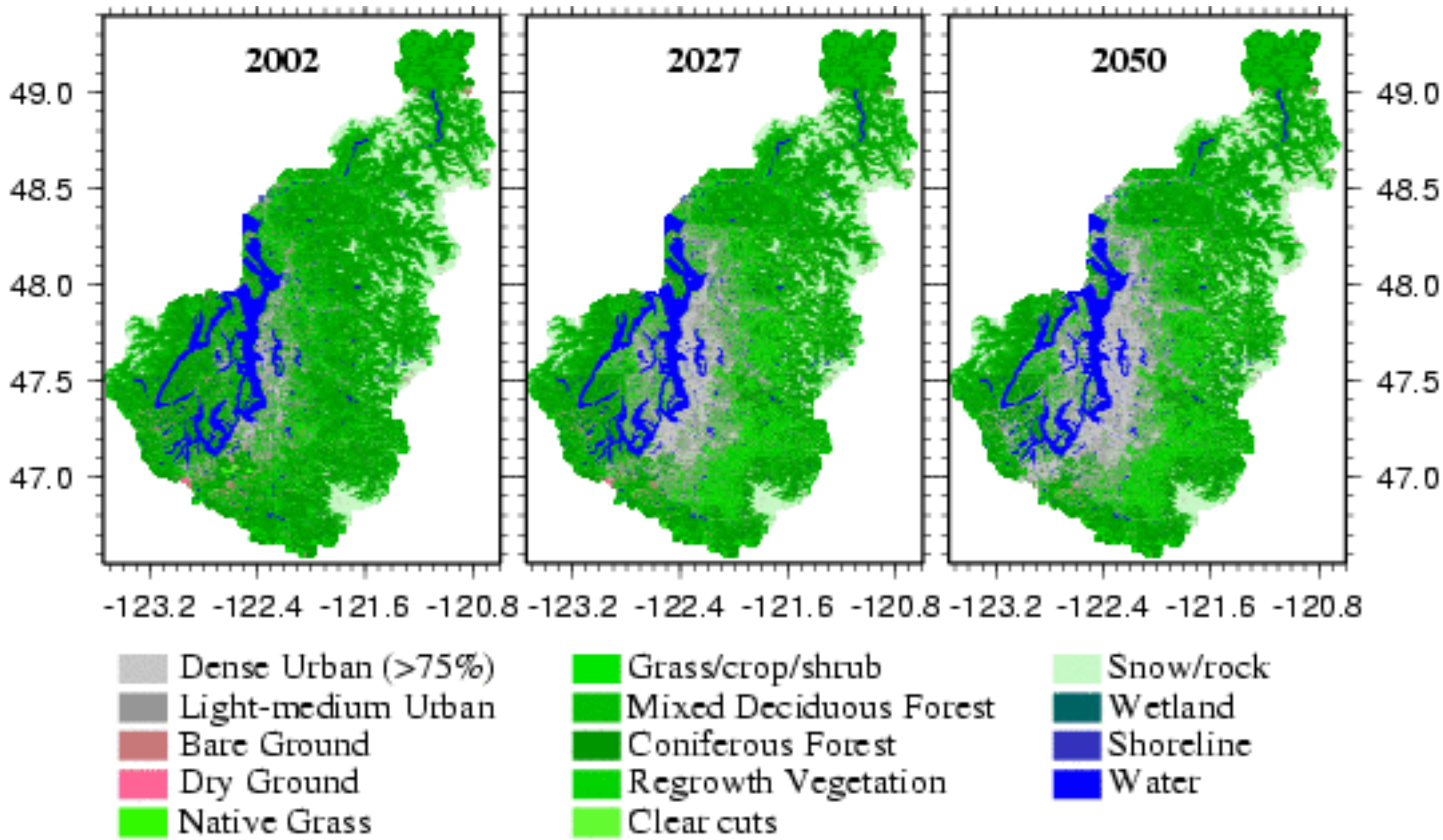


Projected Future Climate Conditions A1B Scenario

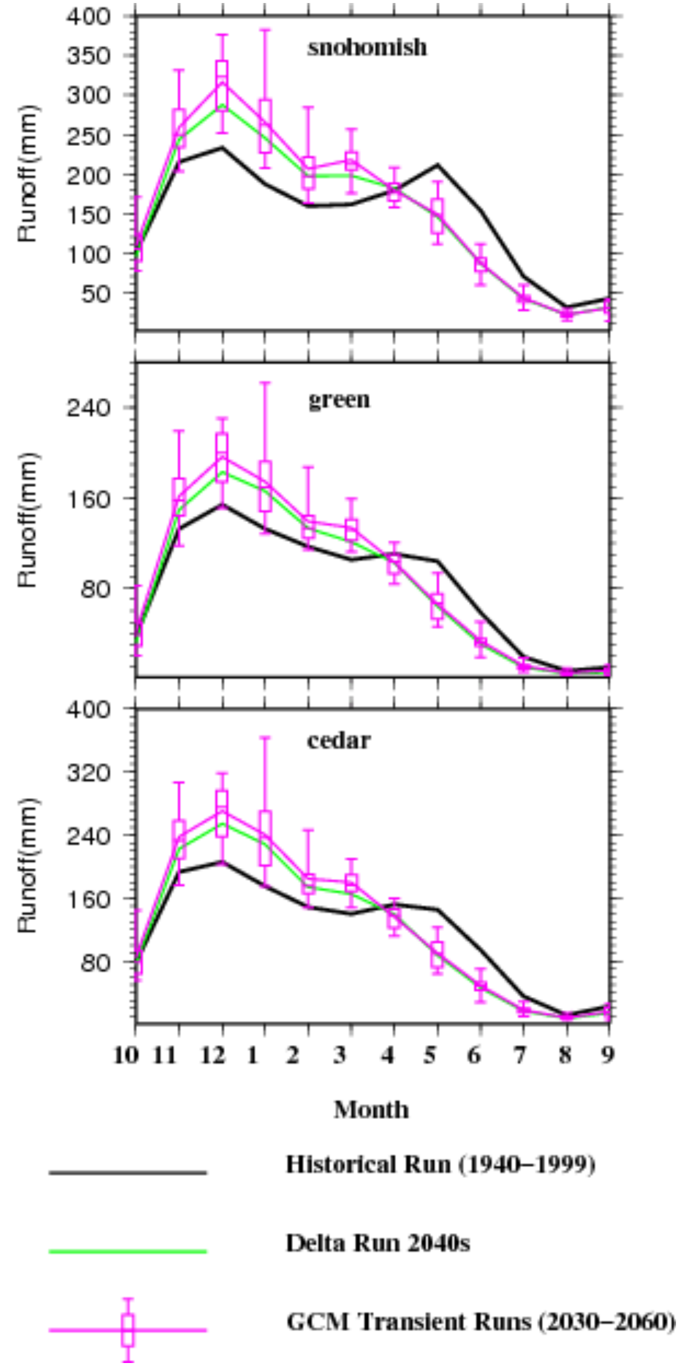
Basins	Tmin/Year (˚ C)	Tmax/Year (˚ C)	Prcp/Year (%)	Tmin hist vs. future (˚ C)	Tmax hist vs. future (˚C)	Prcp hist vs. future (%)
Deschutes	0.03	0.03	2.02	2.12	2.13	4.53
Cedar	0.04	0.04	1.90	1.88	1.91	3.24
Skokomish	0.03	0.04	2.16	2.04	2.05	6.59
Dosewallips	0.04	0.04	2.00	2.09	2.10	6.63
Lowland-west	0.04	0.04	2.03	2.11	2.12	6.45

Annual change rate in 2000 – 2099;
Historical vs. future change: 2000 – 2099 vs. 1960 – 1999.
Average of Models: Hadgem1, Echam5, Cnrm_cm3, Hadcm, Cgcm3.1_t47, Ipsl_cm4

Puget Sound basin land cover projections, 2027 and 2050



Mid-century seasonal mean streamflow projections averaged over 20 GCMs, 2040s (current land cover)



What (if anything!) can be transferred to LA Basin issues (and stormwater recapture in particular)?

The differences:

1) Fewer storms, more intensity
2) Enhanced role of infiltration excess (vs saturation excess) overland flow
3) Many/most ephemeral streams
4) Much different role of environmental considerations (few or no fish!)

But – there are some common considerations

1) Necessity for a ***regional*** modeling construct to understand the spatial construct, and where the "big numbers" are
2) Need to consider both climate and land cover change (not clear that climate change is a big deal for hydrology in the urban area)
3) Water quality is a key consideration, especially in the urban area
4) Role of partially urbanized areas (it's not all concrete!)