Advancing Modeling and Understanding of Hydroclimate Extremes in the Puget Sound Coastal Region

Ning Sun, L. Ruby Leung, Sourav Taraphdar, Xiaodong Chen, Ian Kraucunas

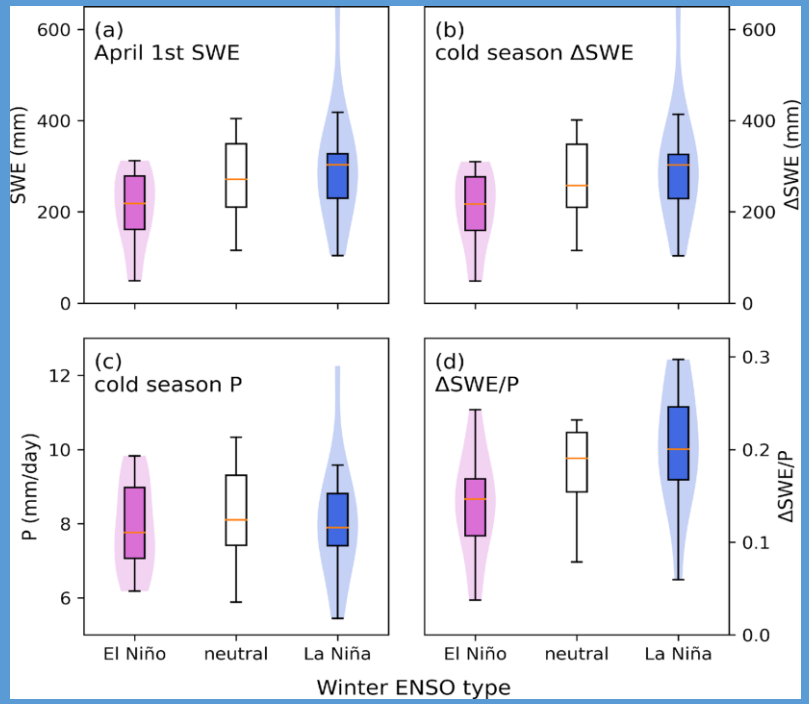
EESM PI Meeting 2024

Overview of Puget Sound Coastal Region

- Second largest estuary in the U.S.
- Maritime climate system
- Sharp rural-urban gradient constrained by orography
- Mountain-coast terrain
- Extreme events – Atmospheric Rivers, Rain-on-Snow, Flooding, Heatwave
- Hydropower-dominated power system

Linking Large-Scale Climate Variabilities with Regional Hydroclimate Extremes

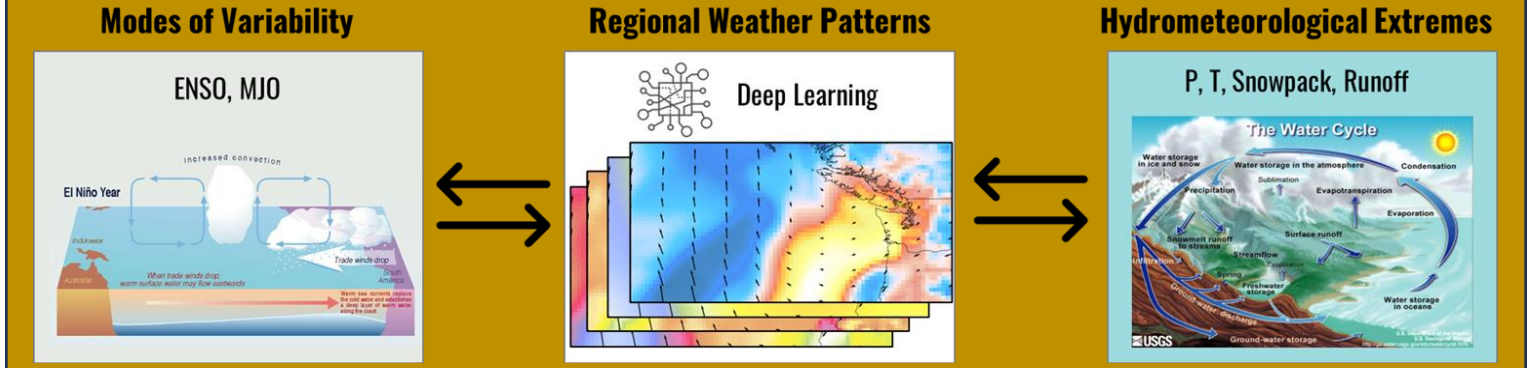
ENSO/MJO impact on regional hydroclimate extremes



- More snow droughts following El Niño winter
- MJO phases 6-7 cause more hydrologic extremes

(Chen et al., in rev, JHM)

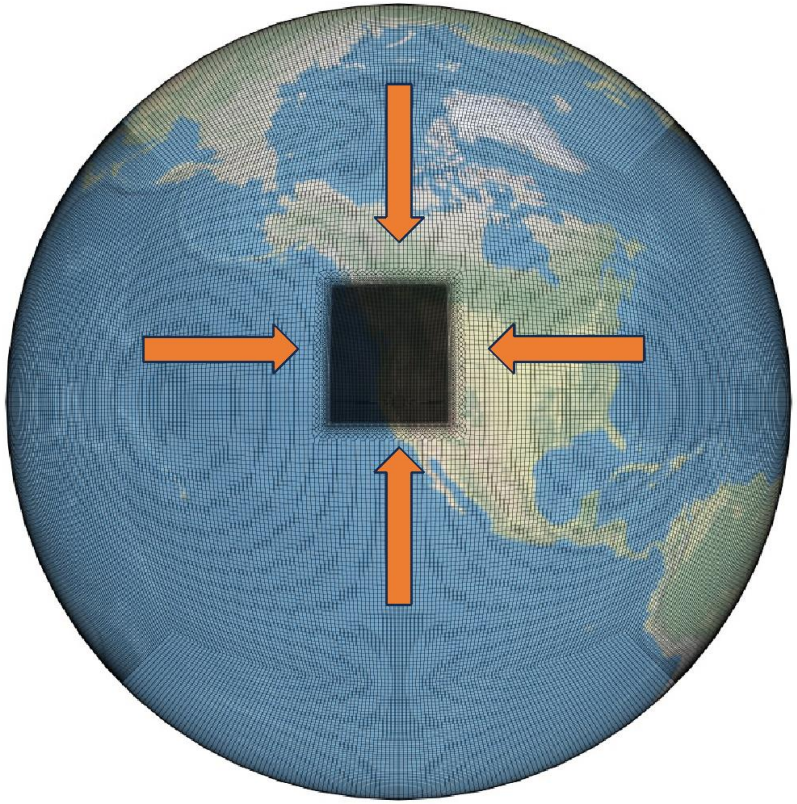
Regional Weather systems connect ENSO and regional hydroclimate extremes



- Deep learning model identifies 12 weather patterns with unique P and T responses
- Weather patterns reveal two flooding mechanisms: precipitation-driven and rain-on-snow driven flooding

(Chen et al., 2023, GRL)

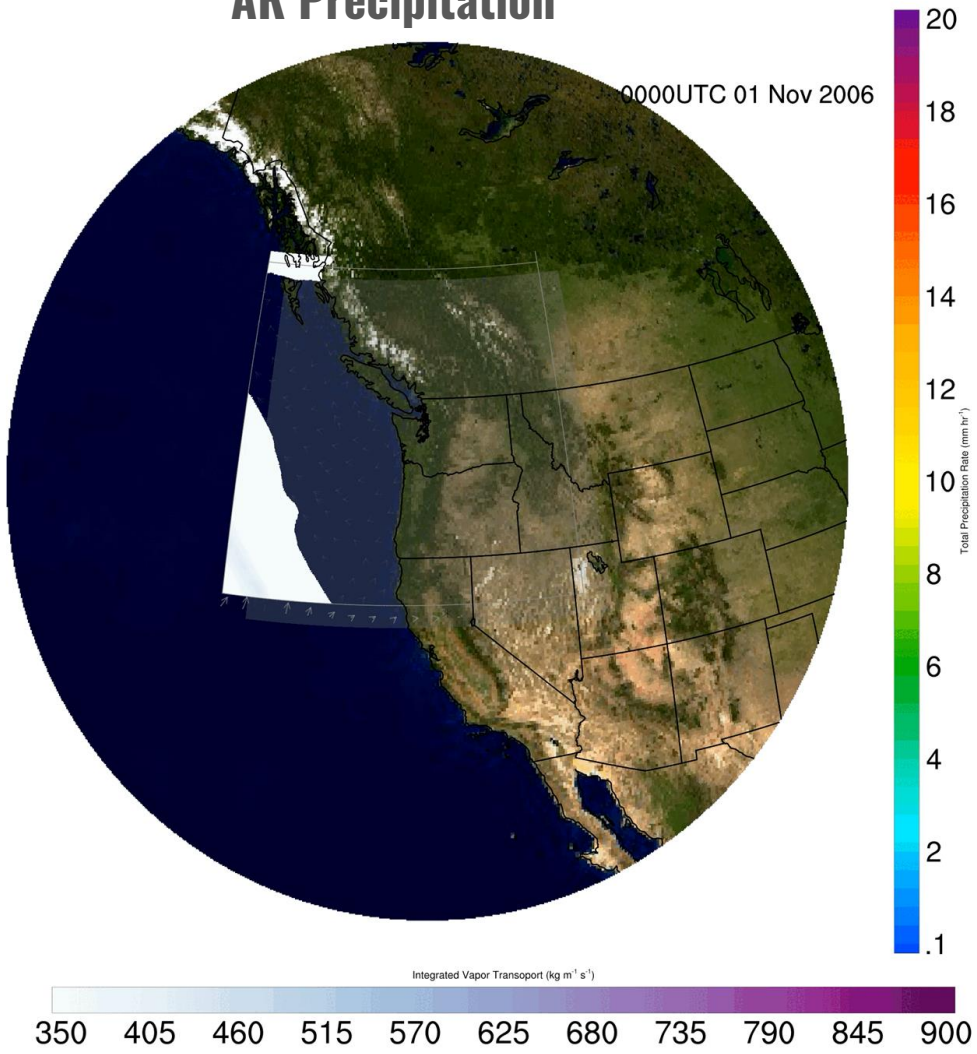
SCREAM 3-km Simulation of Regional Weather during AR Events



SCREAM domain:
25 km outside;
3.125 km inside;
128 vertical levels

Physics parameterizations:
(1) P3 for cloud microphysics; (2) SHOC for shallow convection and turbulence; (3) RTE + RRTMGP for radiative

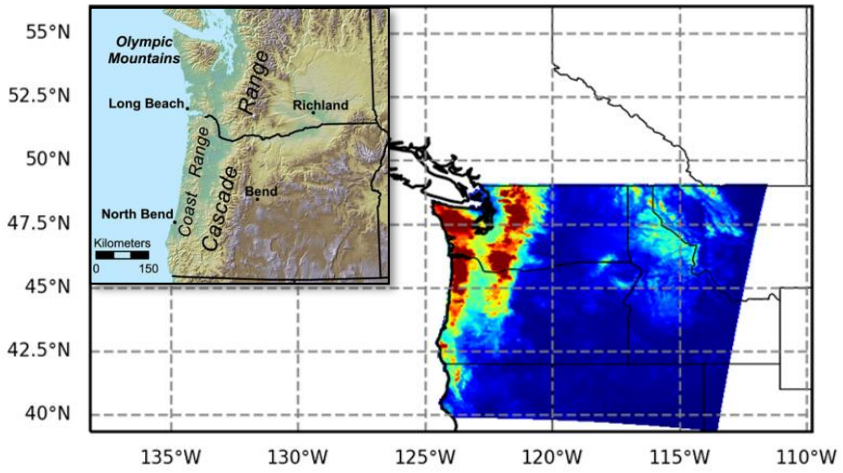
SCREAM Simulation of the 2006 Atmospheric River (AR) Event



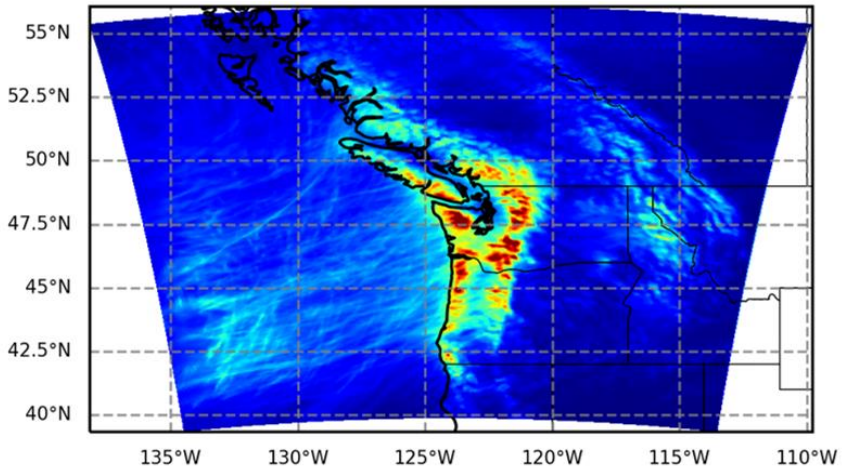
White – Violet Shading: IVT

Improved 3-km SCREAM simulation of AR precipitation along Mountain Ranges

PRISM Observed Precipitation



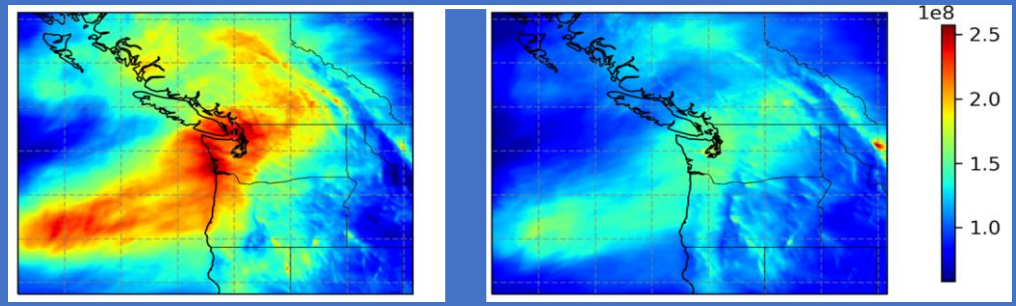
3-km SCREAM Precipitation



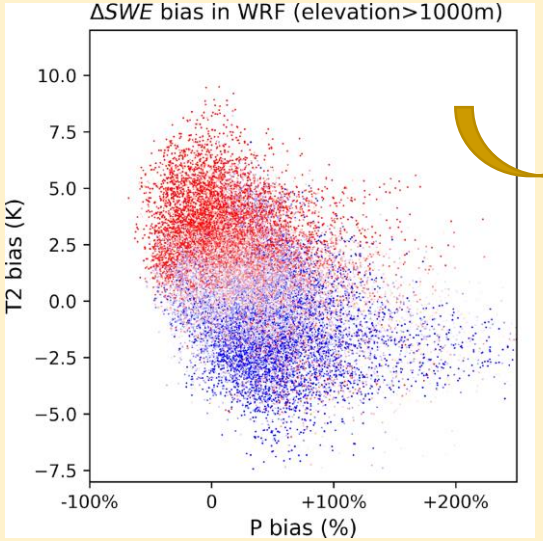
Atmospheric River: 2006 Nov

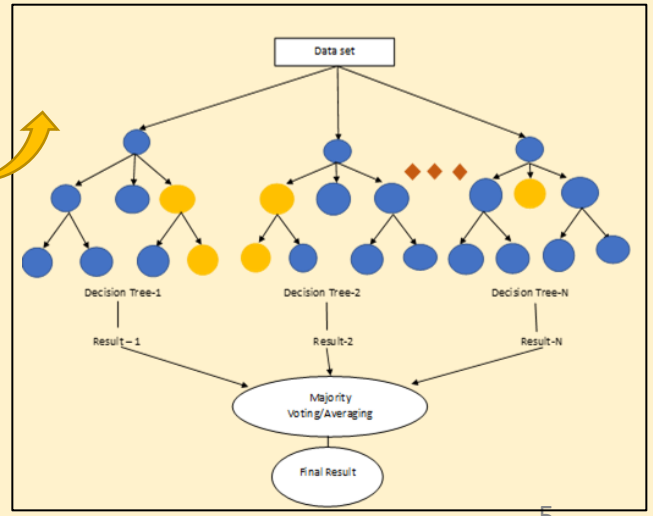
Changes in cloud microphysics in SCREAM impact modeling orographic precipitation in the region

Ice Number Concentration

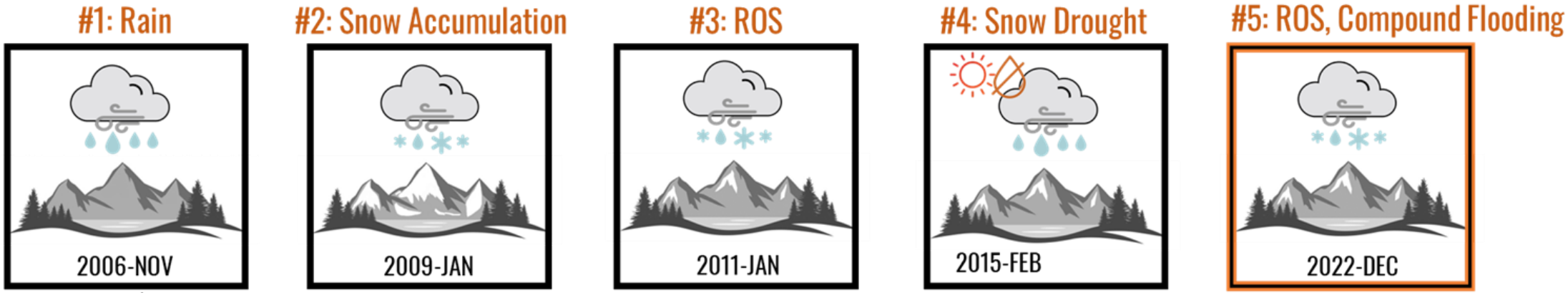


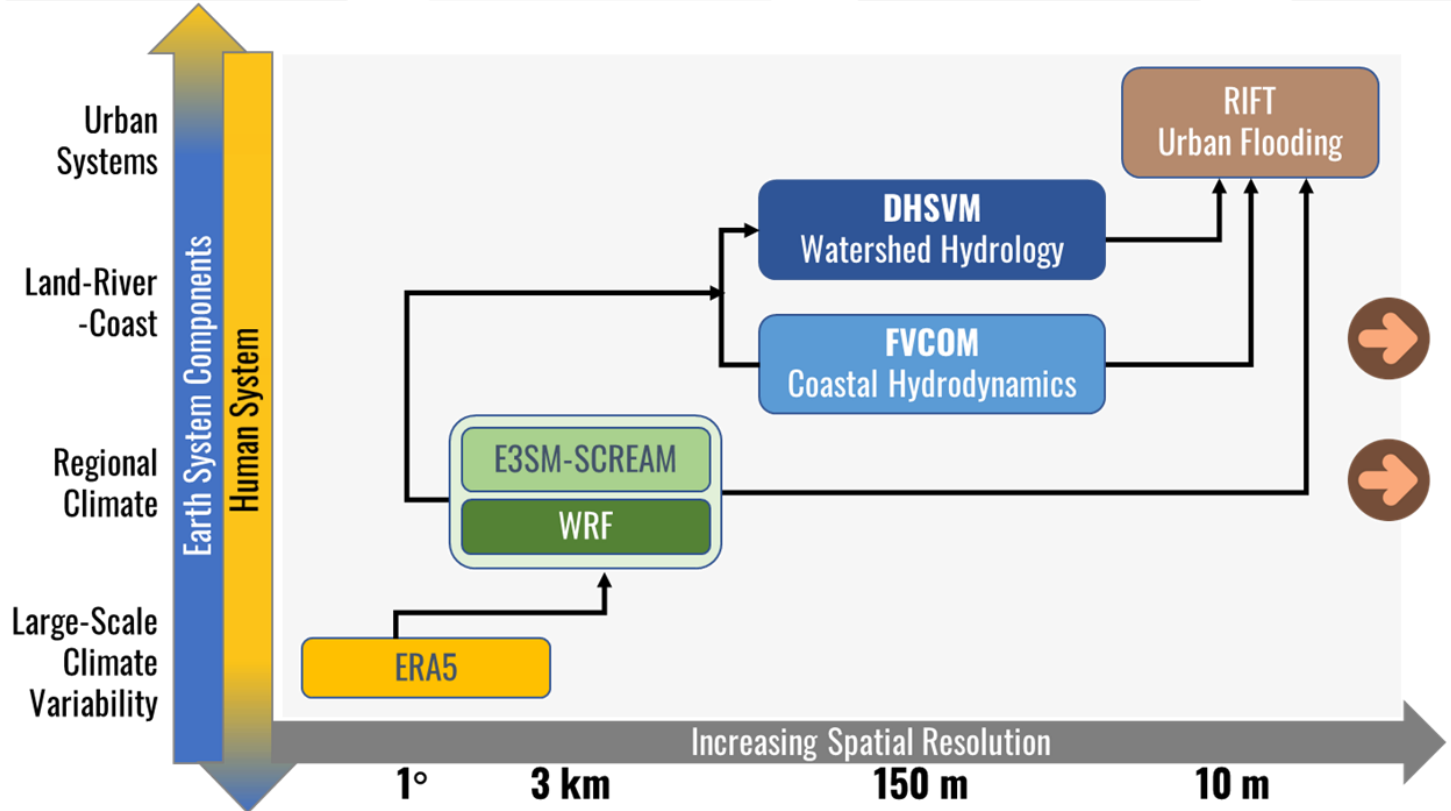
Understanding and predicting the bias of SCREAM in AR modeling through AI/ML

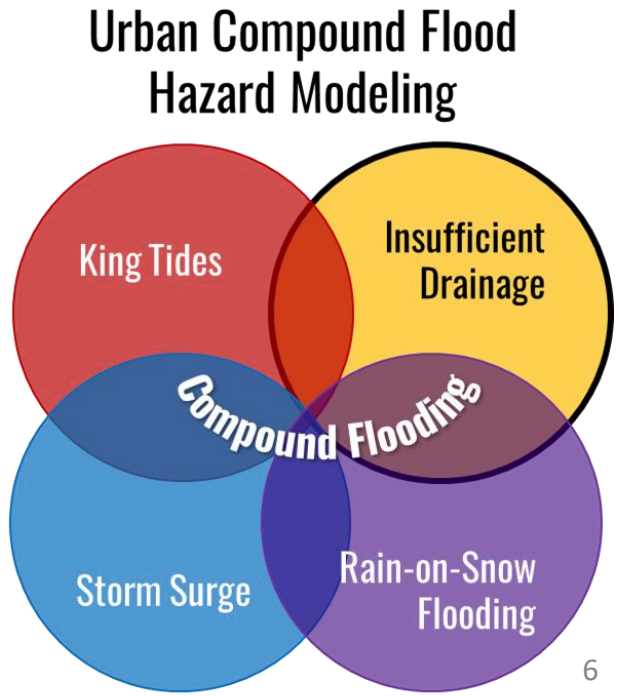




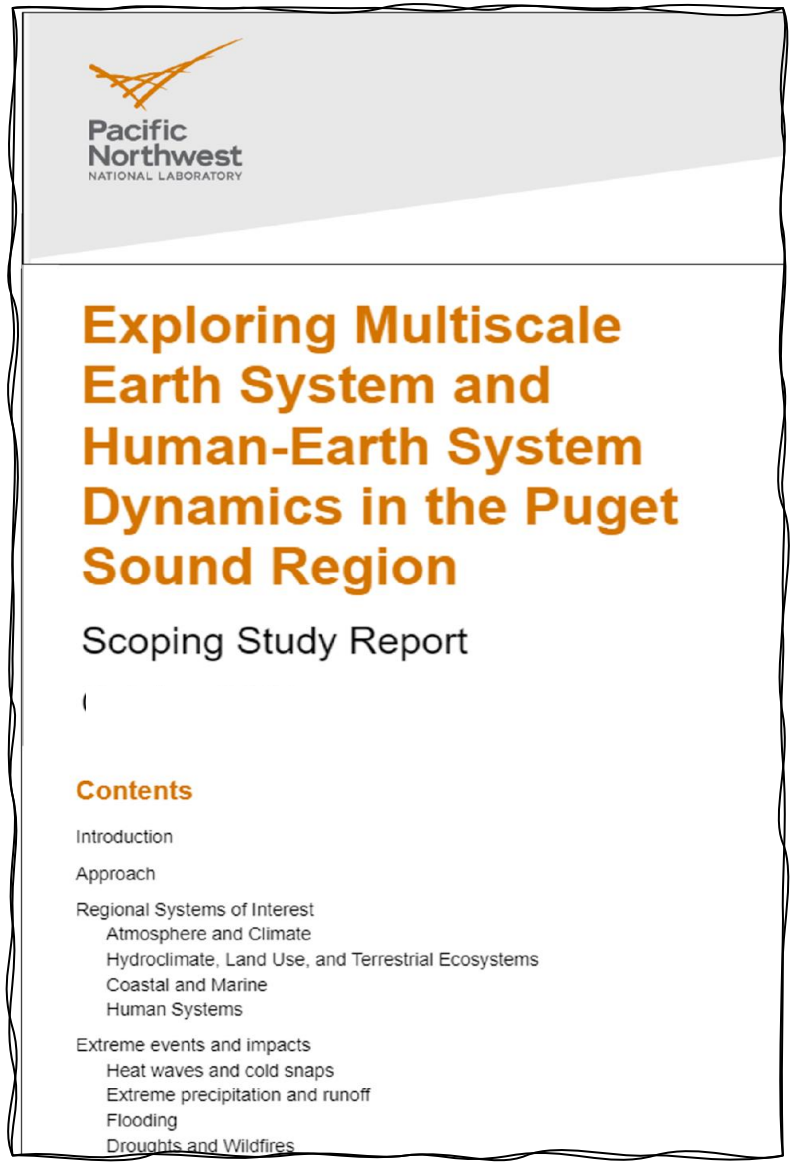
Multi-Scale Atmospheric-Terrestrial-Coastal Modeling Framework







Challenges and Opportunities in Modeling Puget Sound Human-Earth System



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Exploring Multiscale Earth System and Human-Earth System Dynamics in the Puget Sound Region

Scoping Study Report

Contents

- Predictive understanding of extreme events
  - Atmospheric River
  - Rain-on-snow
  - Flooding (compound)
  - Heatwave
  - Snow drought
- Human system modeling on the terrestrial-coastal interface
- Human-Earth interactions

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SALISH SEA MODELING CENTER UNIVERSITY of WASHINGTON

DEPARTMENT OF ECOLOGY State of Washington

USGS science for a changing world

NATIONAL WEATHER SERVICE

PUGETSOUND PARTNERSHIP

Voisin N., D.J. Rose, D.P. Broman, N. Sun, I.P. Kraucunas (2023). "Exploring Multiscale Earth System and Human-Earth System Dynamics in the Puget Sound Region". https://doi.org/10.2172/1906804

Research Opportunities: Coupled Earth-Human Modeling in a Mountain-to-Coast Regional Hydroclimate

Improve understanding and modeling of Earth-Human System in Puget Sound Coastal Environments, and their vulnerability to climate change and other stresses.

GCAM-USA

Climate Change

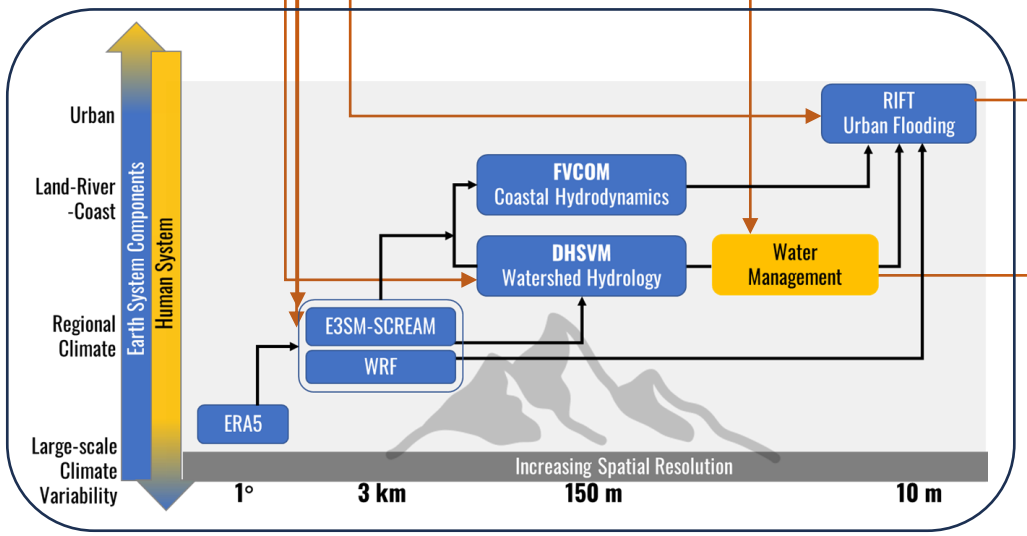
Demeter*

Tethys*

LULCC

Water Demand

Human System



- Flash flood
- Heat extremes (e.g., 2021 PNW heatwave)
- Snow drought

Urban Flood Risk

Infrastructure Development

*Chance-C

Water Availability