PRISM: A Knowledge-Based Approach to Mapping Precipitation in Complex Regions

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BIOGRAPHICAL SKETCH

Chris' professional background spans several disciplines, including marine meteorologist and forecaster, air quality modeler, and forest geographer and ecologist. Since 1990, Chris has been at Oregon State University. He is currently a research professor with a dual appointment in the Department of Geosciences, College of Science, and the College of Oceanographic and Atmospheric Sciences. He is the founder and director of the Spatial Climate Analysis Service (SCAS), a group dedicated to producing high-quality spatial climate data sets worldwide. His group is developing an emerging sub-discipline of climatology called "geospatial climatology," which is a powerful combination of climatology and spatial analysis.

Chris is the developer of the PRISM spatial climate modeling system, which produces state-of-the-science spatial climate products currently used in thousands of applications worldwide. Spatial data sets include official USDA temperature and precipitation maps for the United States and possessions, a new U.S. climate atlas, detailed climate maps for China/Mongolia and the European Alps, and a 109-year monthly time series of digital maps of temperature, precipitation, and dew point for the U.S. spanning 1895-present. For his efforts in developing PRISM spatial climate data sets for users worldwide, Chris received the 2004 Applied Meteorology Award from the American Meteorological Society.

EDUCATION:
B.S. 1978, atmospheric sciences, University of California, Davis
M.A. 1984, geography, University of Colorado, Boulder
Ph.D. 1994, general science, Oregon State University, Corvallis

PRISM: A Knowledge-Based Approach to Mapping Precipitation in Complex Regions

Christopher Daly and George Taylor
Spatial Climate Analysis Service
Oregon State University
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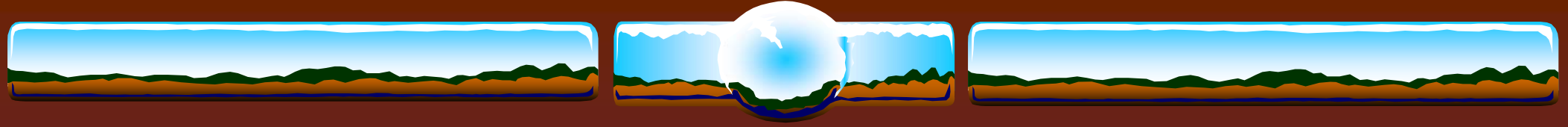


Rationale

- Observations are rarely sufficient to directly represent the spatial patterns of climate

- Human-expert mapping methods often produce the best products, but are slow, inconsistent, and non-repeatable

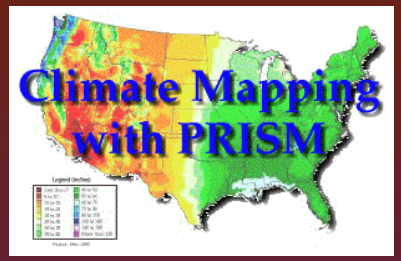
- Purely statistical mapping methods are fast and repeatable, but rarely provide the best accuracy, detail, and realism

Therefore…

- The best method may be a statistical approach that is developed, guided and evaluated with expert knowledge

Knowledge-Based System KBS

- Knowledge acquisition capability – Elicit expert information
- Knowledge base – Store of knowledge
- Inference Engine – Infer solutions from stored knowledge
- User interface – Interaction and explanation
- Independent verification – Knowledge refinement

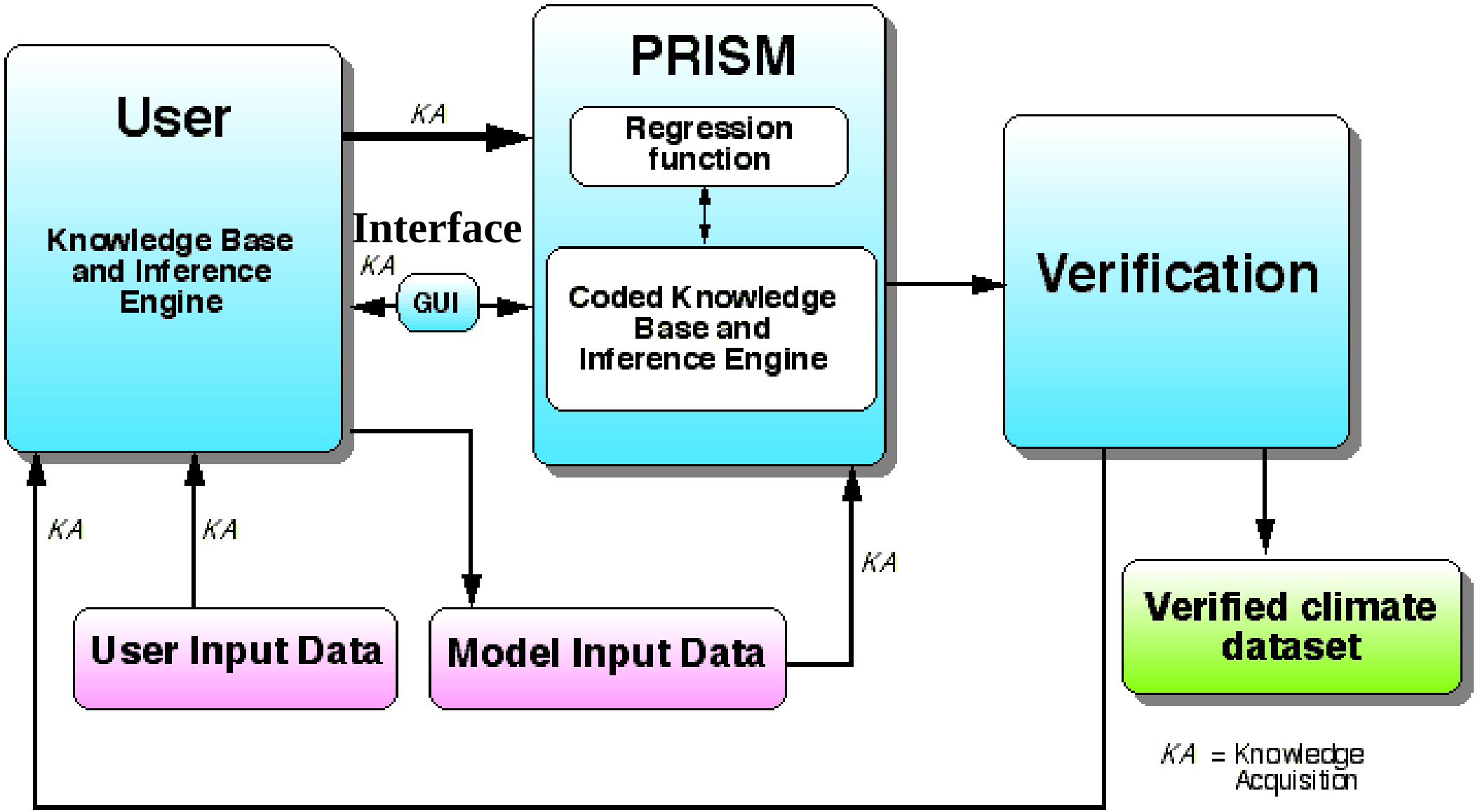


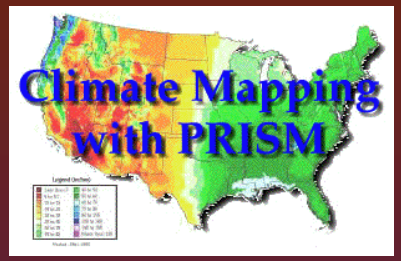
PRISM

Parameter-elevation Regressions on Independent Slopes Model

- Generates gridded estimates of climatic parameters
- Moving-window regression of climate vs. elevation for each grid cell
  - Uses nearby station observations
- Spatial climate knowledge base weights stations in the regression function by their climatological similarity to the target grid cell

The PRISM Knowledge-Based System



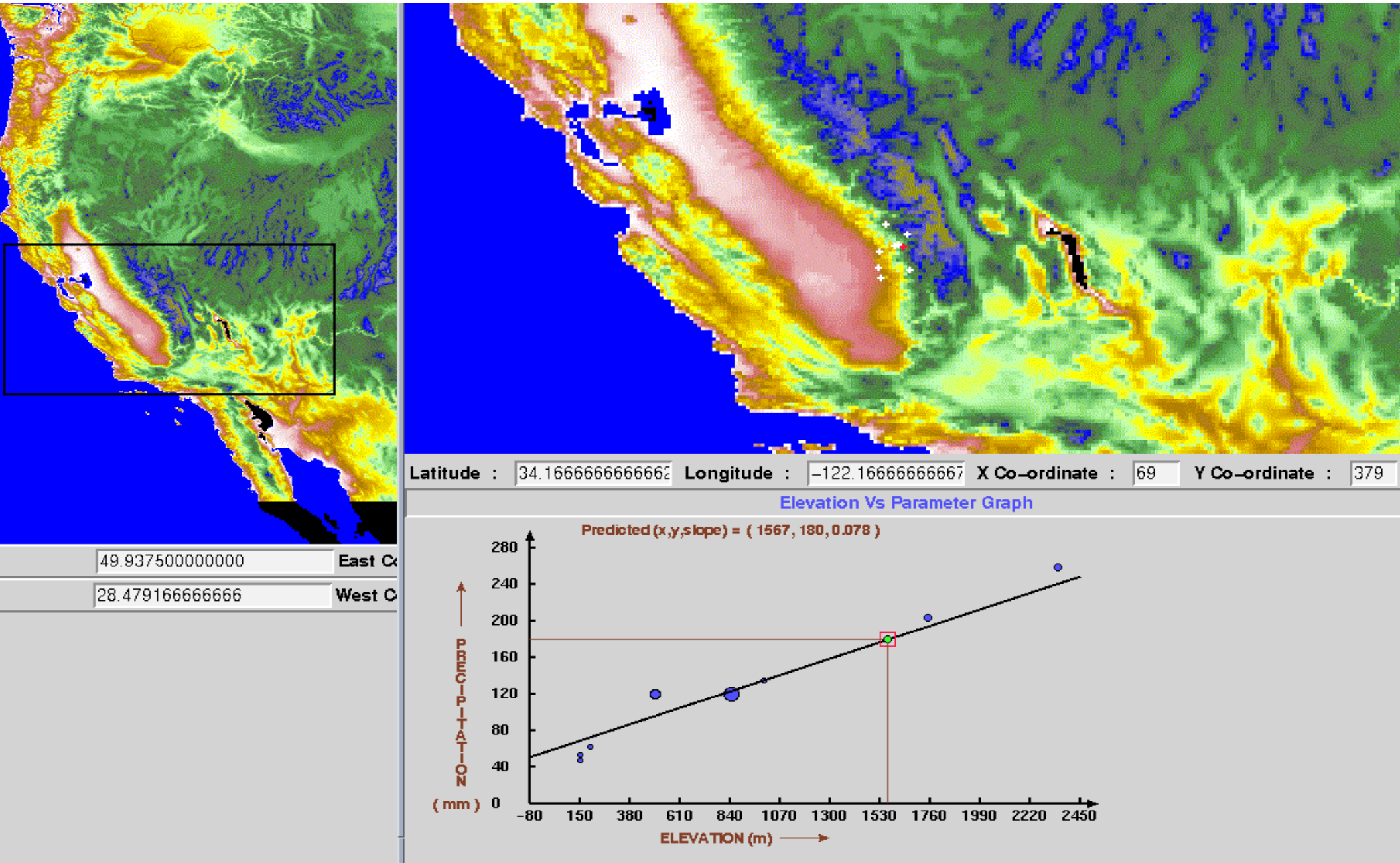


PRISM

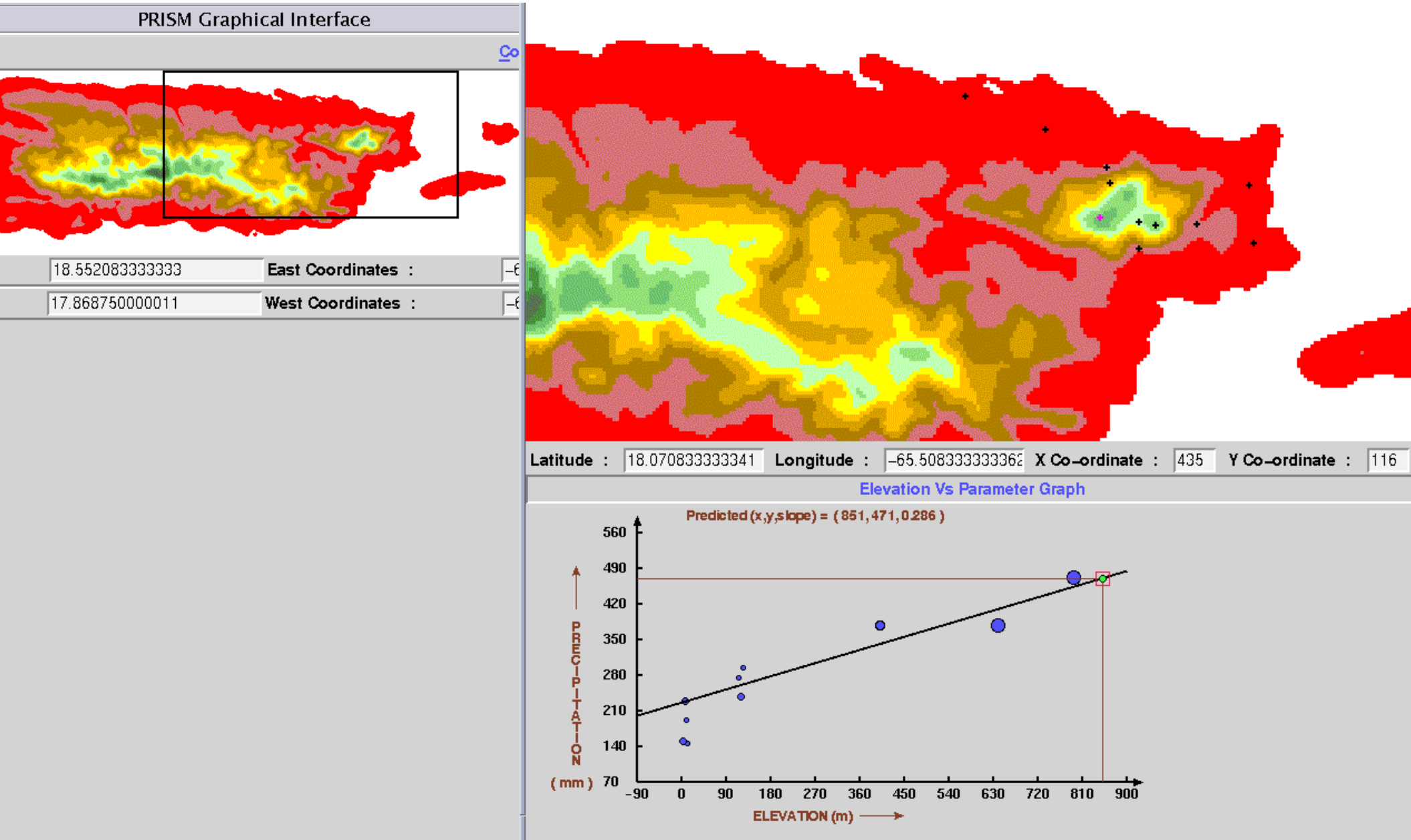
Knowledge Base

- Elevation Influence on Climate

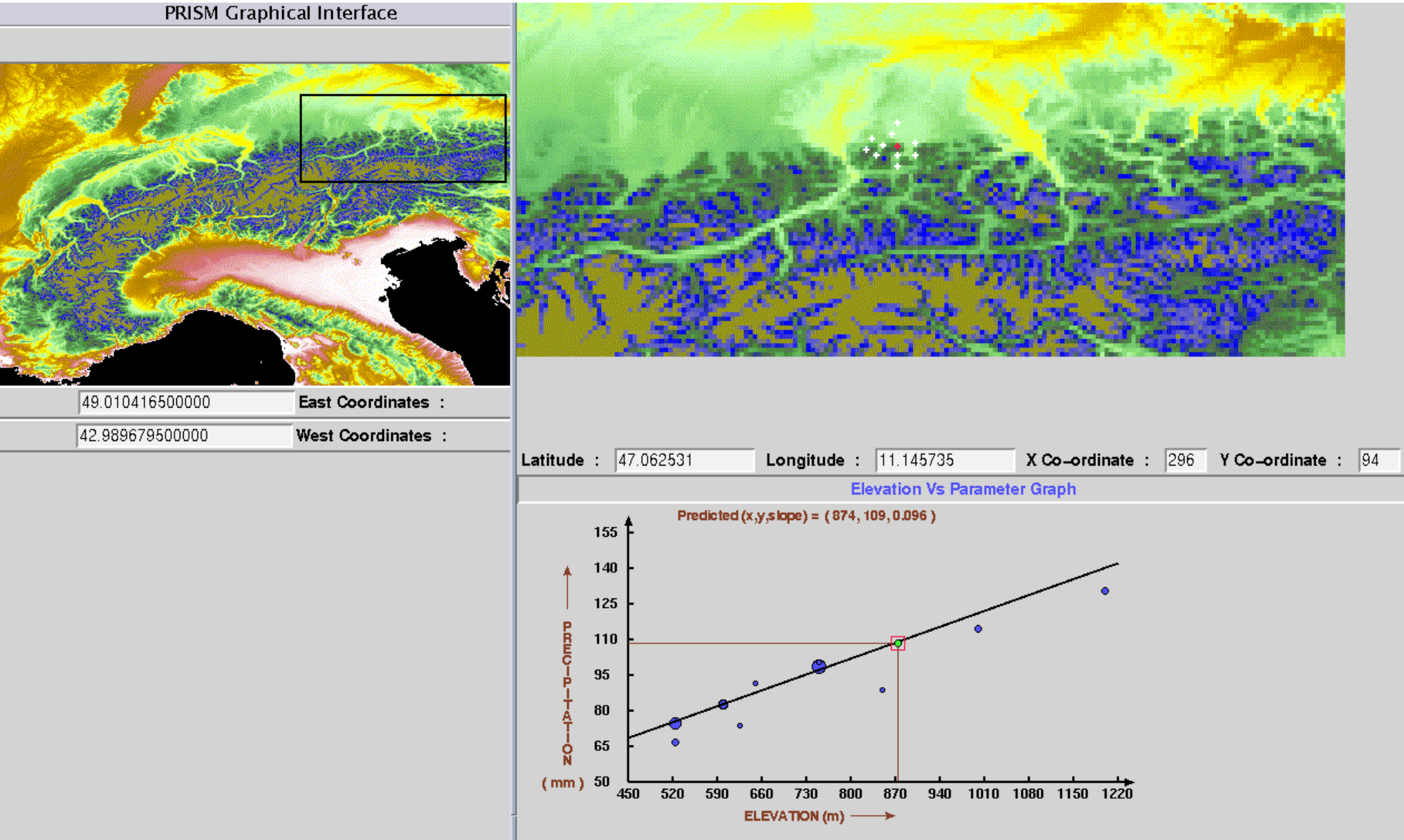
1961-90 Mean January Precipitation, Sierra Nevada, CA, USA



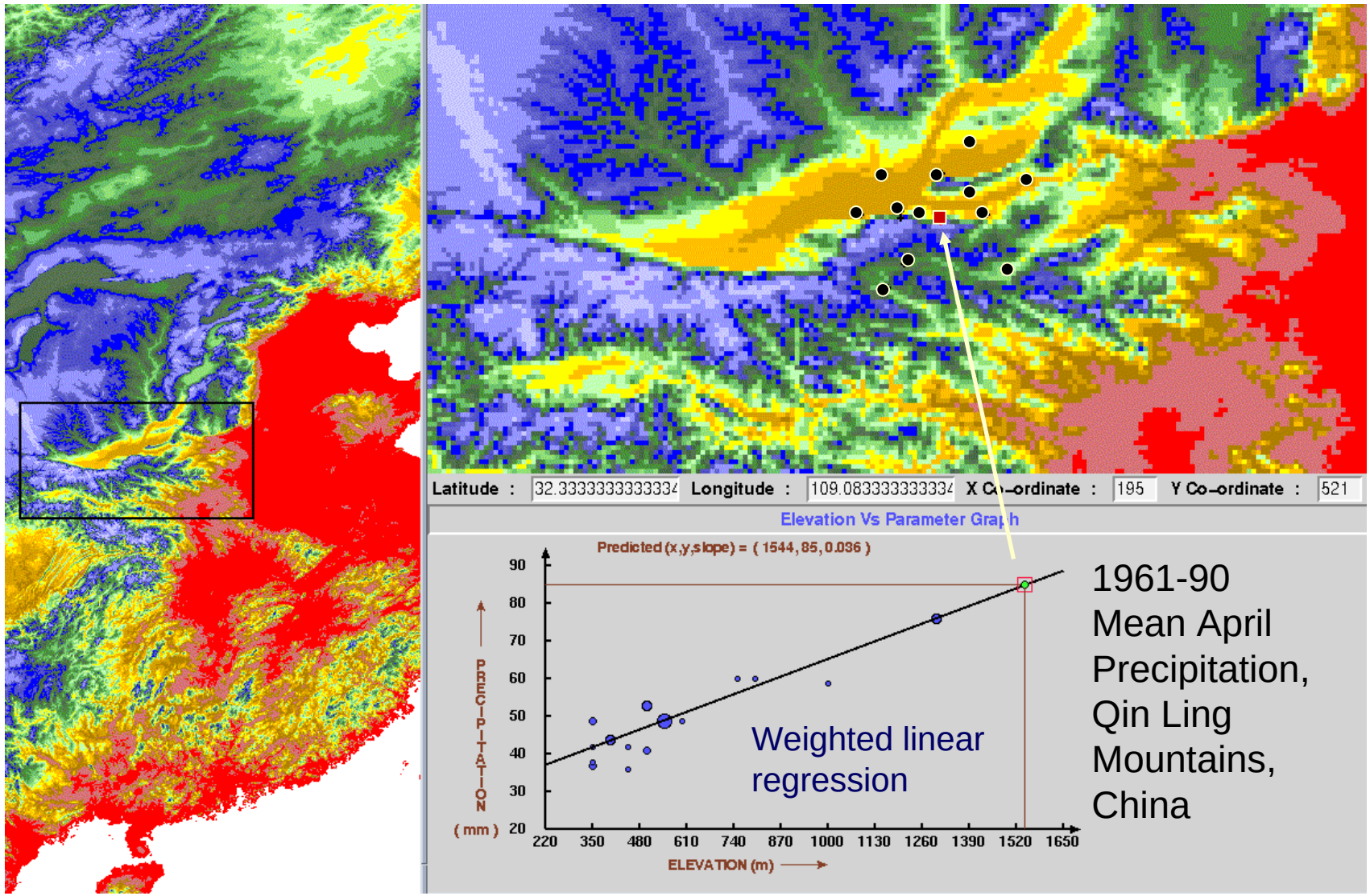
1963-1993 Mean November Precipitation, Puerto Rico

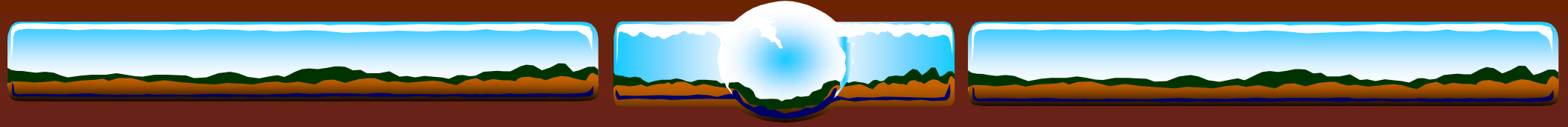


1971-90 Mean February Precipitation, European Alps



PRISM Moving-Window Regression Function





Governing Equation

Moving-window regression of climate vs elevation

$$y = \alpha_1 x + \alpha_0$$

Y = predicted climate element

x = DEM elevation at the target cell

α_0 = y-intercept

α_1 = slope

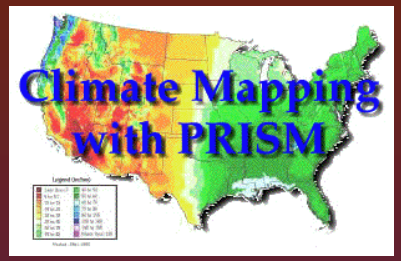
x,y pairs - elevation and climate observations from nearby climate stations

Station Weighting

Combined weight of a station is:

$$W = f\{W_d, W_z, W_c, W_f, W_l, W_p, W_e\}$$

- Distance
- Elevation
- Clustering
- Topographic Facet (orientation)
- Vertical Layer (inversion)
- Coastal Proximity
- Effective Terrain Height (steepness)

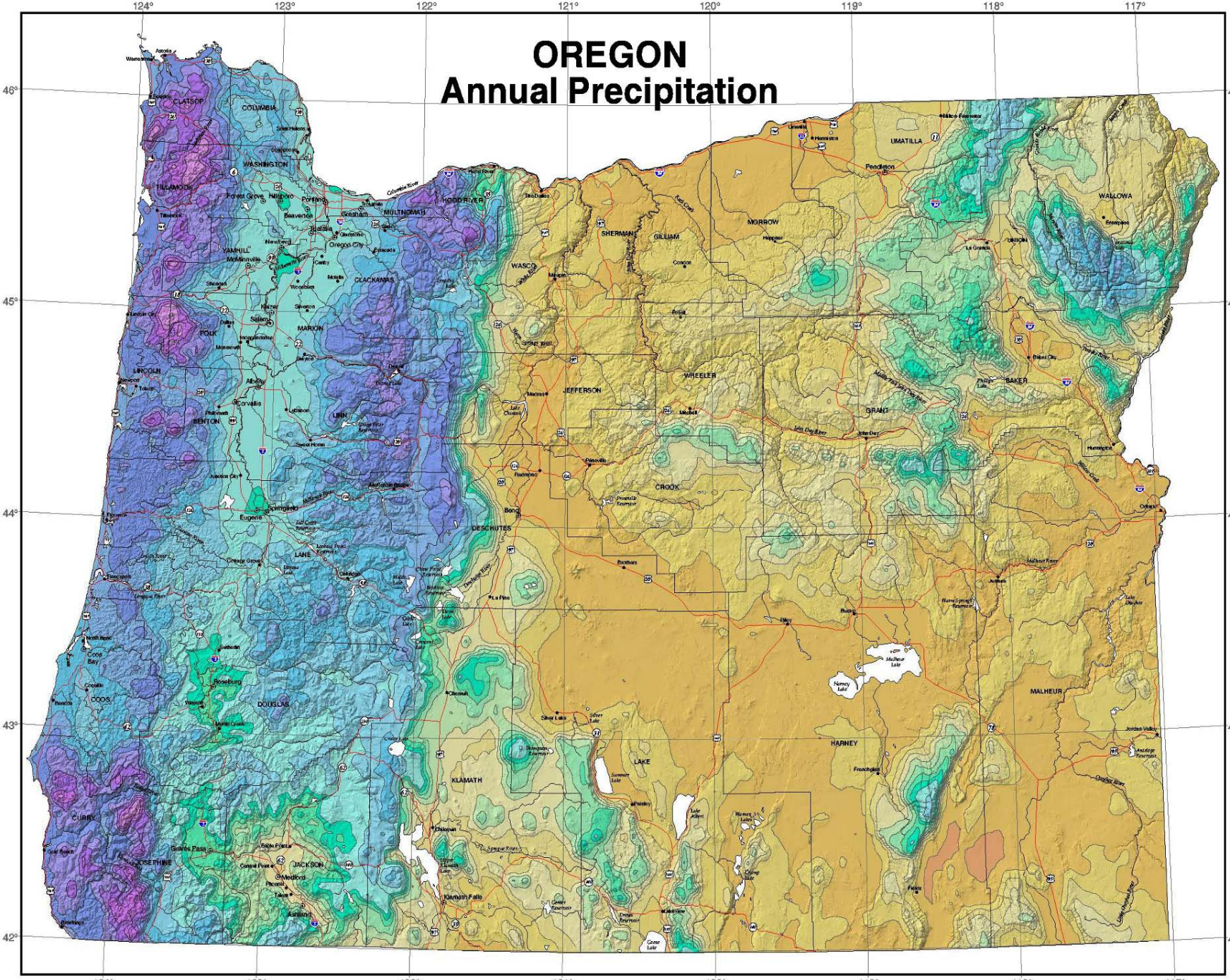


PRISM

Knowledge Base

- Elevation Influence on Climate
- Terrain-Induced Climate Transitions (topographic facets, moisture index)

OREGON
Annual Precipitation



Average Annual Precipitation 1961 - 1990

inches	millimeters
< 4	< 100
4 - 8	100 - 200
8 - 12	200 - 300
12 - 16	300 - 400
16 - 20	400 - 500
20 - 24	500 - 600
24 - 28	600 - 700
28 - 32	700- 800
32 - 35	800 - 900
35 - 39	900 - 1000
39 - 49	1000 - 1250
49 - 59	1250 - 1500
59 - 69	1500 - 1750
69 - 79	1750 - 2000
79 - 98	2000 - 2500
98 - 118	2500 - 3000
118 - 138	3000 - 3500
138 - 158	3500 - 4000
158 - 177	4000 - 5000
> 177	> 5000

30 0 30 60 Kilometers

Scale 1 : 3,000,000

Map prepared with the PRISM climate modeling system by the Spatial Climate Analysis Service, Oregon State University.
http://www.ocs.orst.edu/prism/
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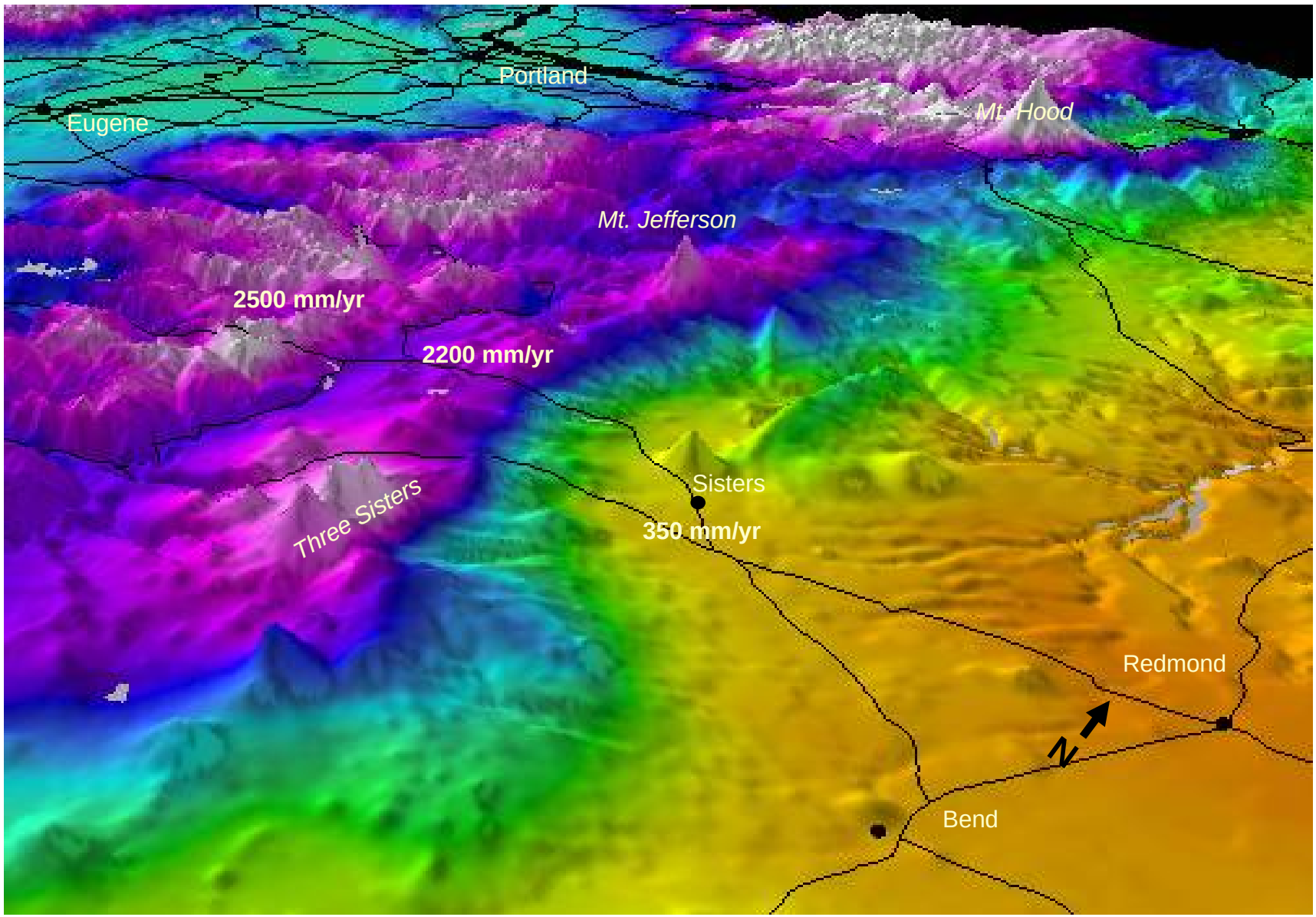
Rain Shadow: 1961-90 Mean Annual Precipitation Oregon Cascades



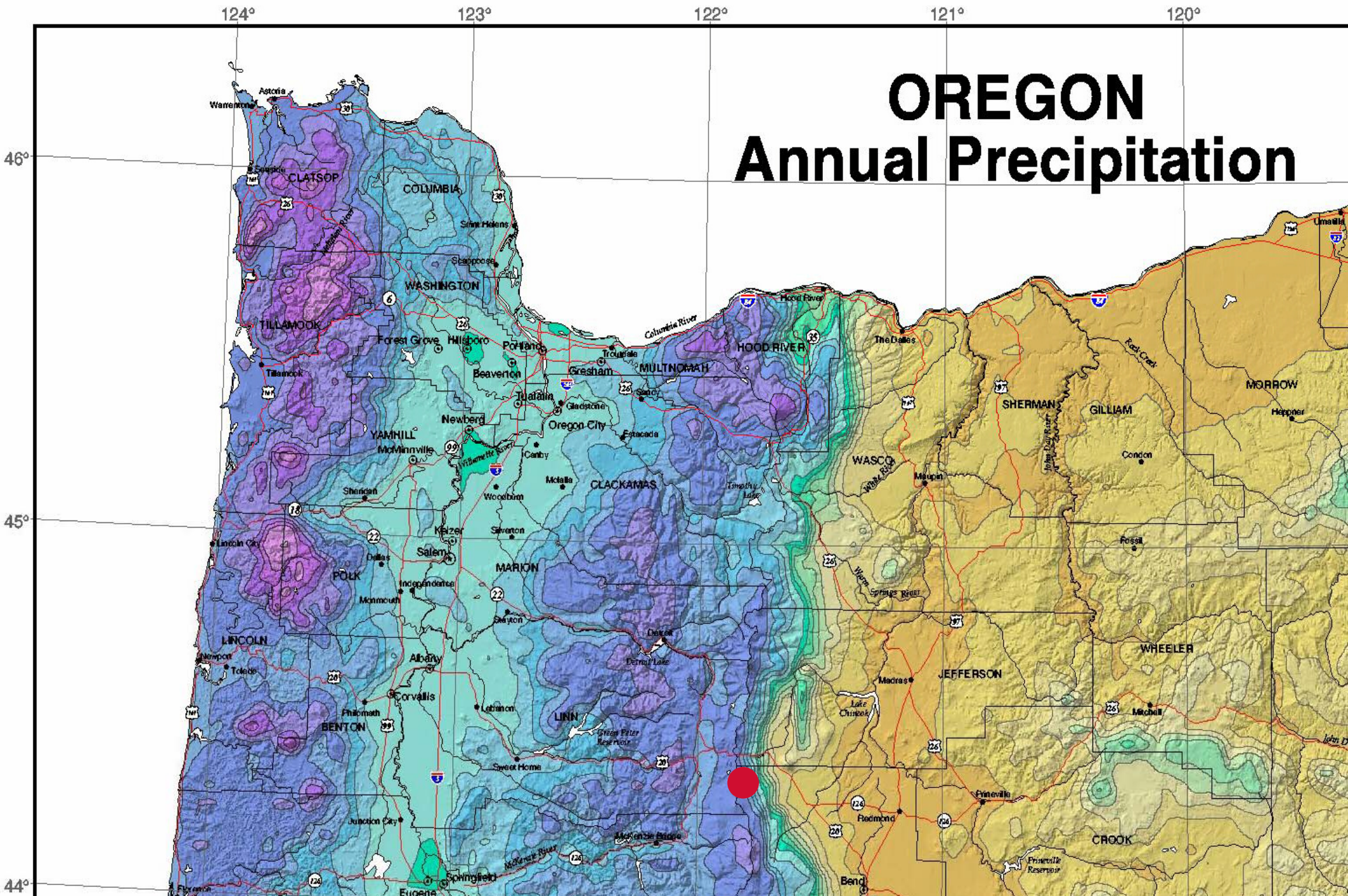
Dominant PRISM KBS Components

Elevation

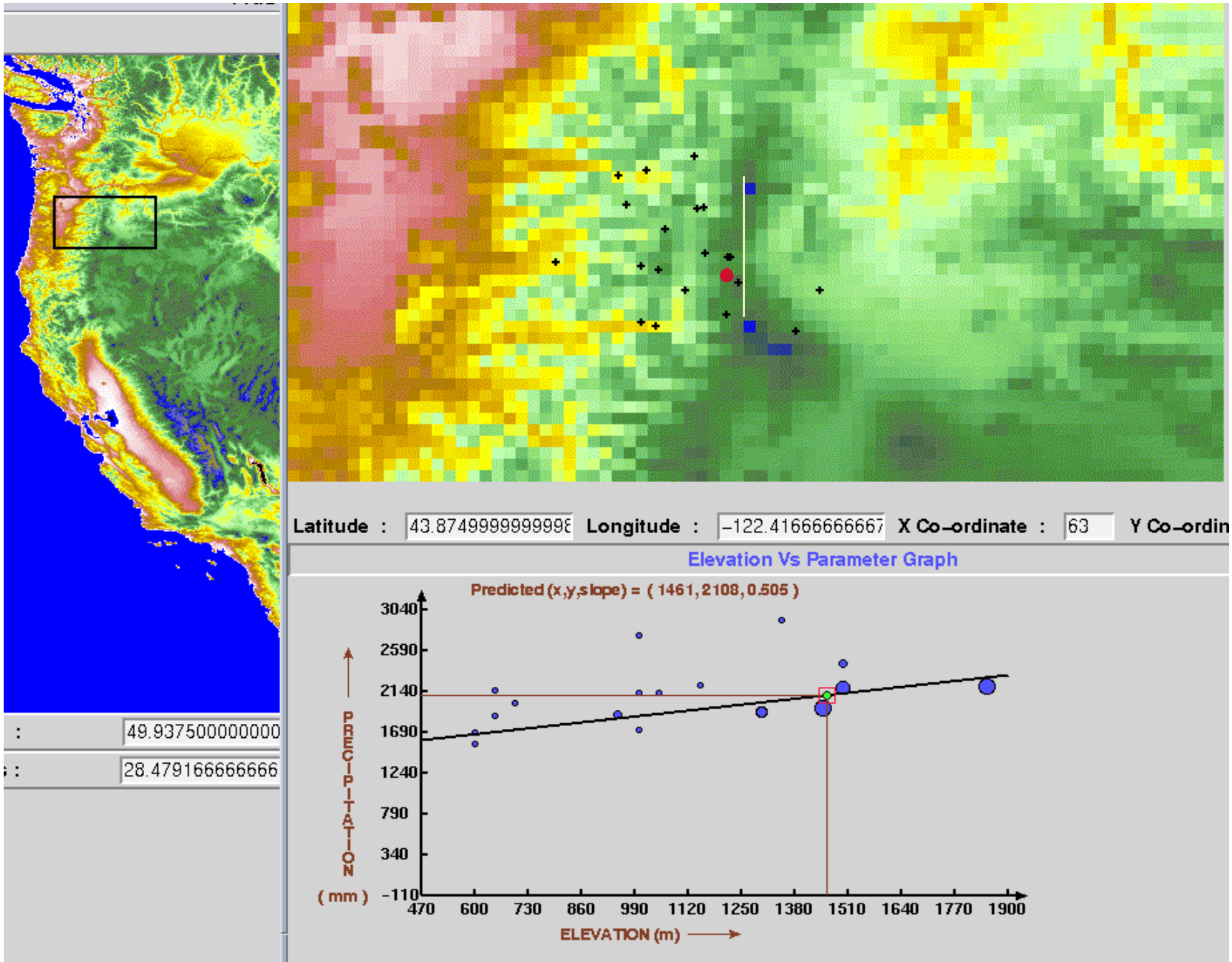
Terrain orientation

Terrain steepness

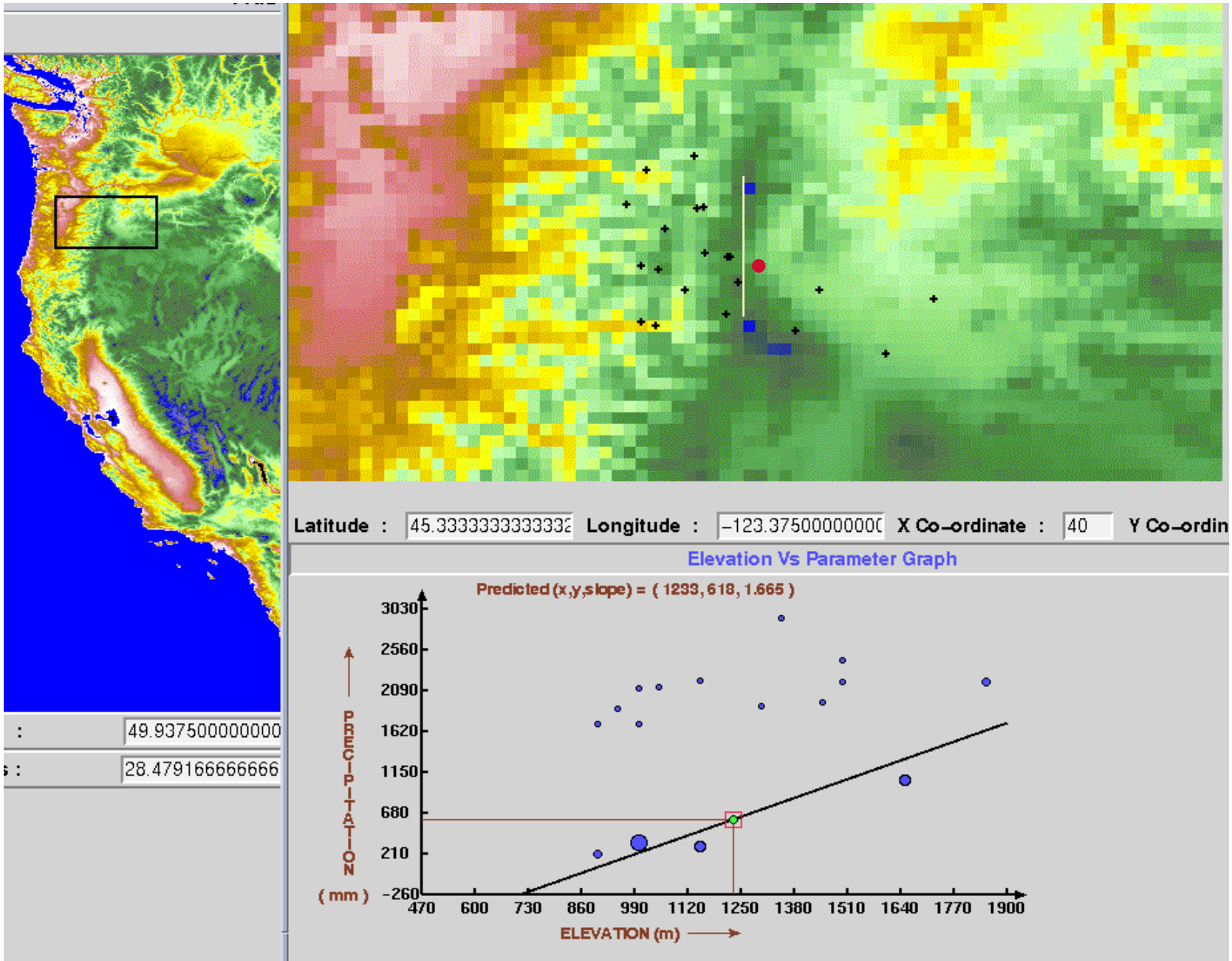
Moisture Regime


OREGON
Annual Precipitation
124°
123°
122°
121°
120°
46°
45°
44°
CLATSOP
COLUMBIA
WASHINGTON
TILLAMOOK
YAMHILL
MULTNOMAH
HOOD RIVER
CLACKAMAS
MARION
POLK
LINCOLN
BENTON
LINN
WASCO
SHERMAN
GILLIAM
MORROW
JEFFERSON
WHEELER
CROOK
Astoria
Warrenton
Seaside
Tillamook
Forest Grove
Hillsboro
Portland
Beaverton
Gresham
Troutdale
Hood River
The Dalles
Columbia River
Willamette River
McMinnville
Newberg
Oregon City
Canby
Molalla
Estacada
Sandy
Gladstone
Tualatin
Sherwood
Woodburn
Silverton
Salem
Keizer
Dallas
Independence
Monmouth
Lincoln City
Newport
Toledo
Albany
Corvallis
Philomath
Lebanon
Sweet Home
Junction City
Detroit Lake
Green Peter Reservoir
Lake Chinook
Madras
Maupin
Condon
Fossil
Mitchell
Prineville
Redmond
Prineville Reservoir
Bend
McKenzie Bridge
Springfield
Eugene
Florence
Umatilla
Hepner
Timothy Lake
Rock Creek
White River
John Day River
Warm Springs River
McKenzie River

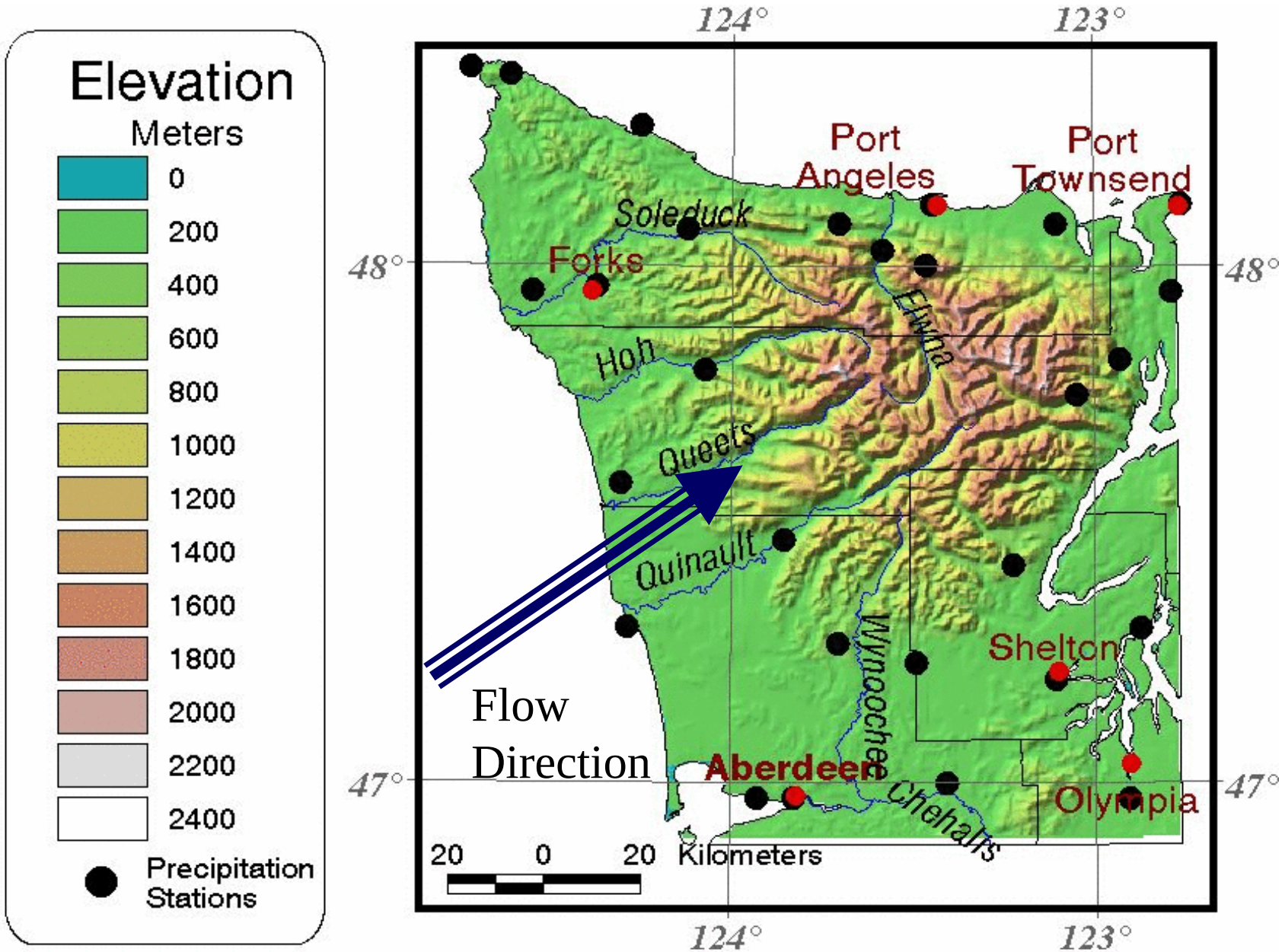
1961-90 Mean Annual Precipitation, Cascade Mtns, OR, USA



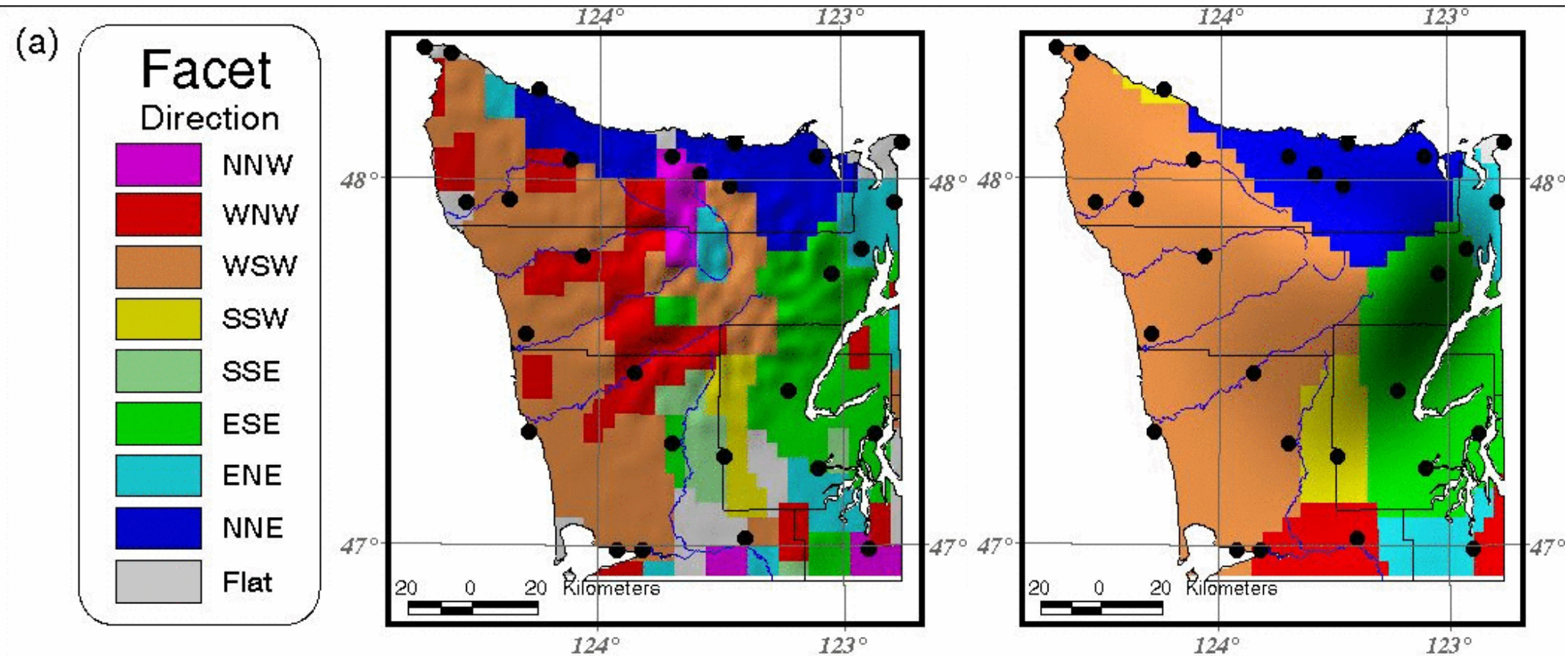
1961-90 Mean Annual Precipitation, Cascade Mtns, OR, USA



Olympic Peninsula, Washington, USA



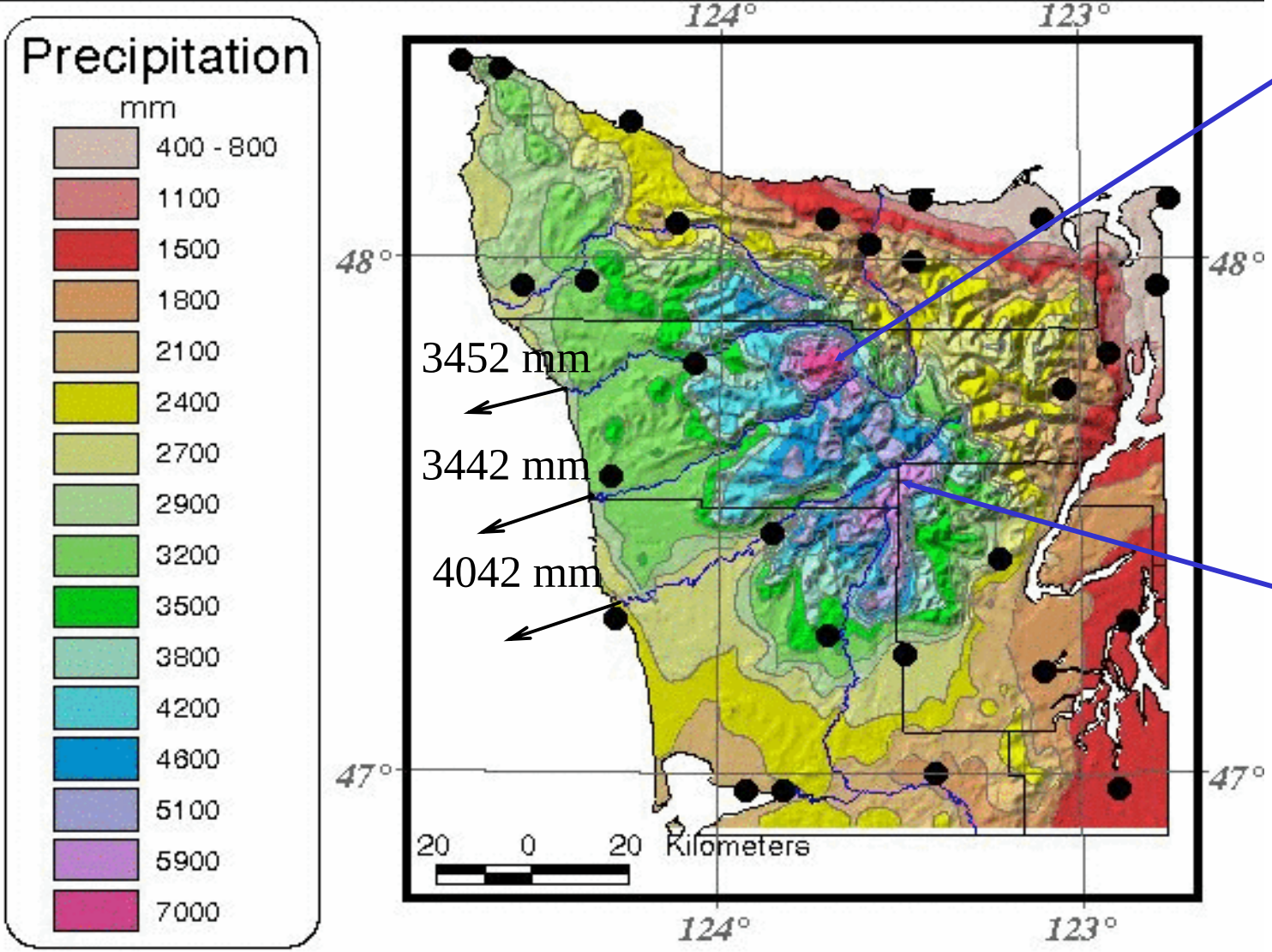
Topographic Facets



= 4 km

= 60 km

Mean Annual Precipitation, 1961-90

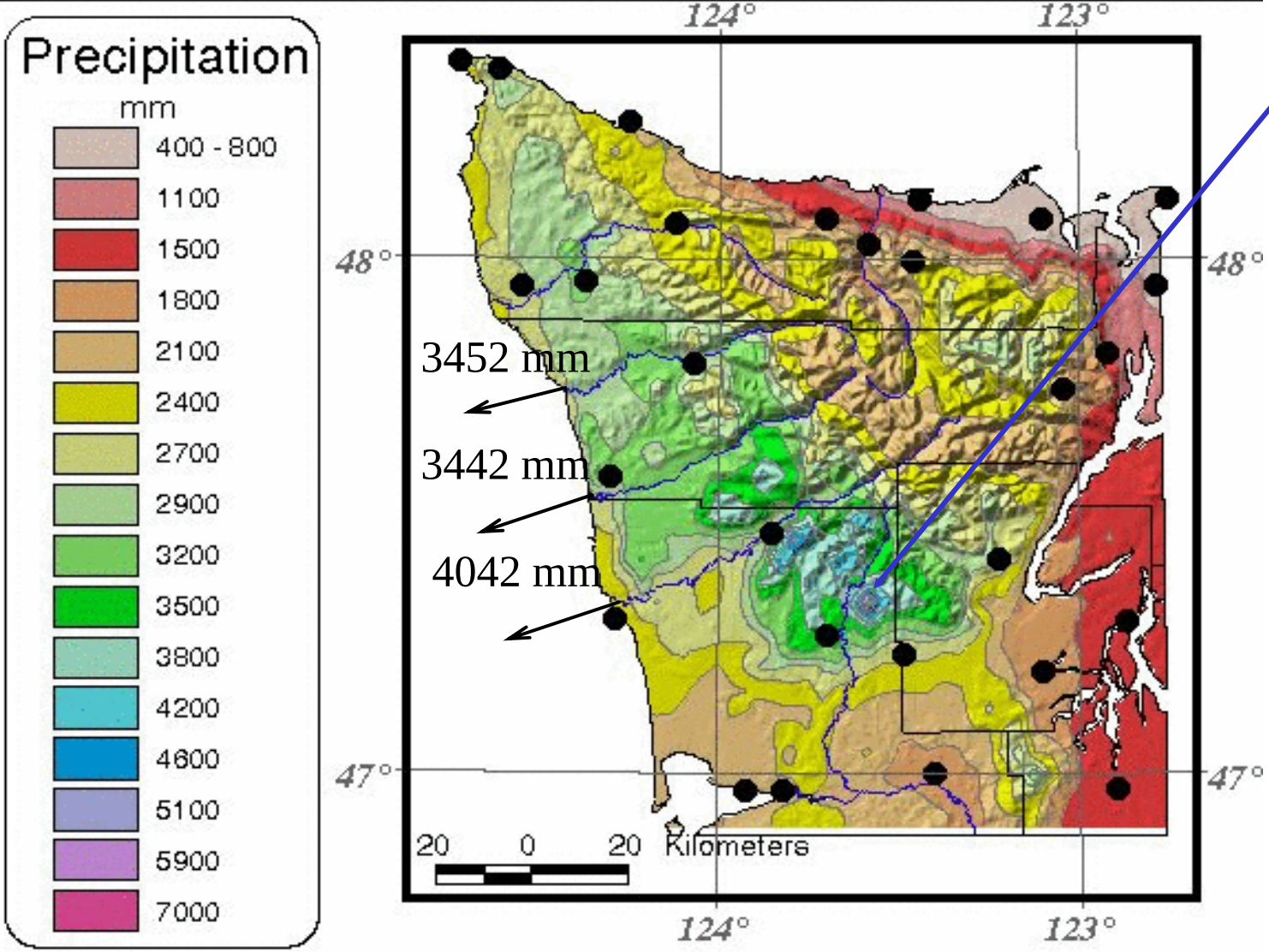


Max ~ 7900 mm

Full Model

Max ~ 6800 mm

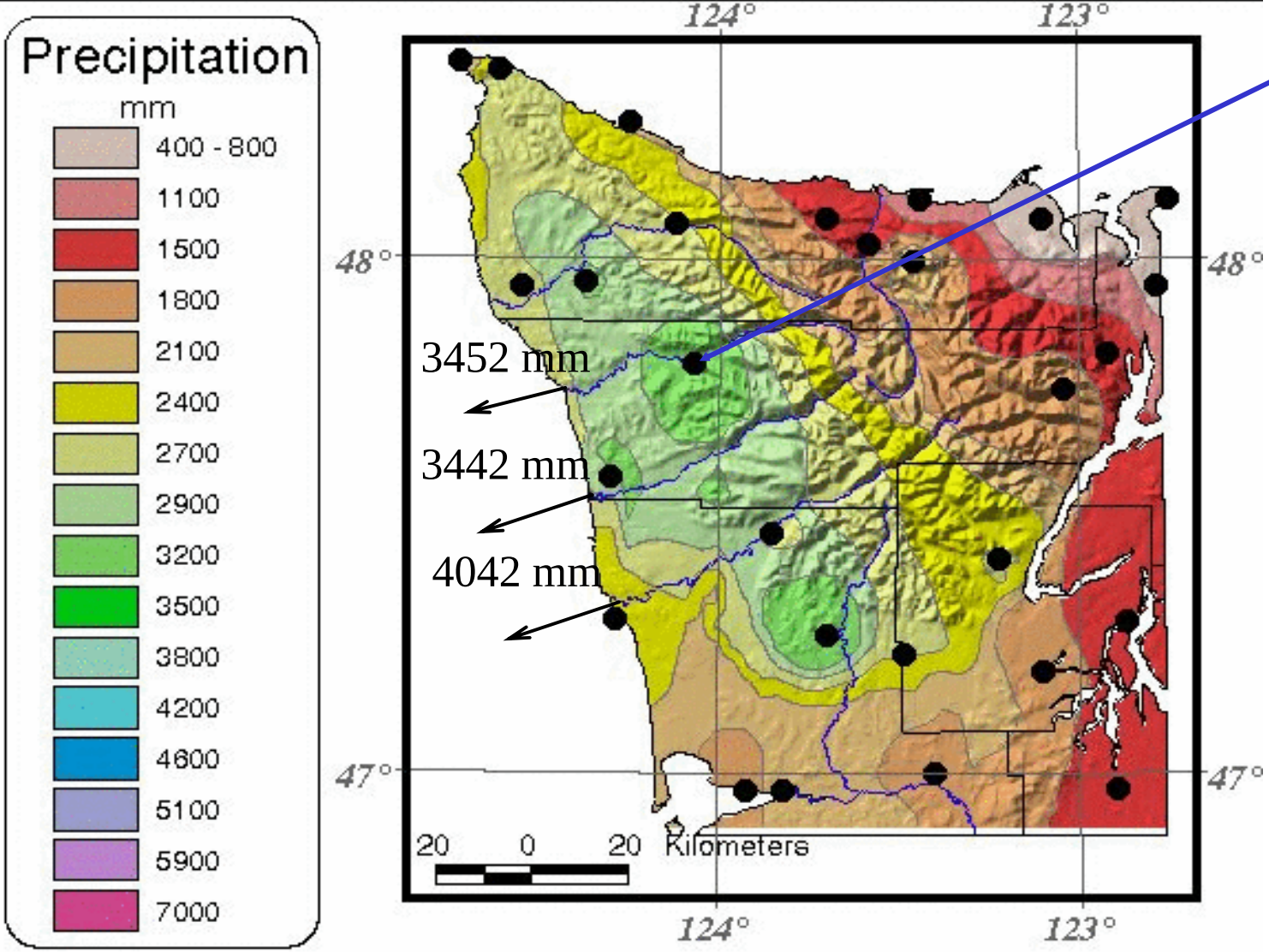
Mean Annual Precipitation, 1961-90



Max ~ 4800 mm

Facet Weighting Disabled

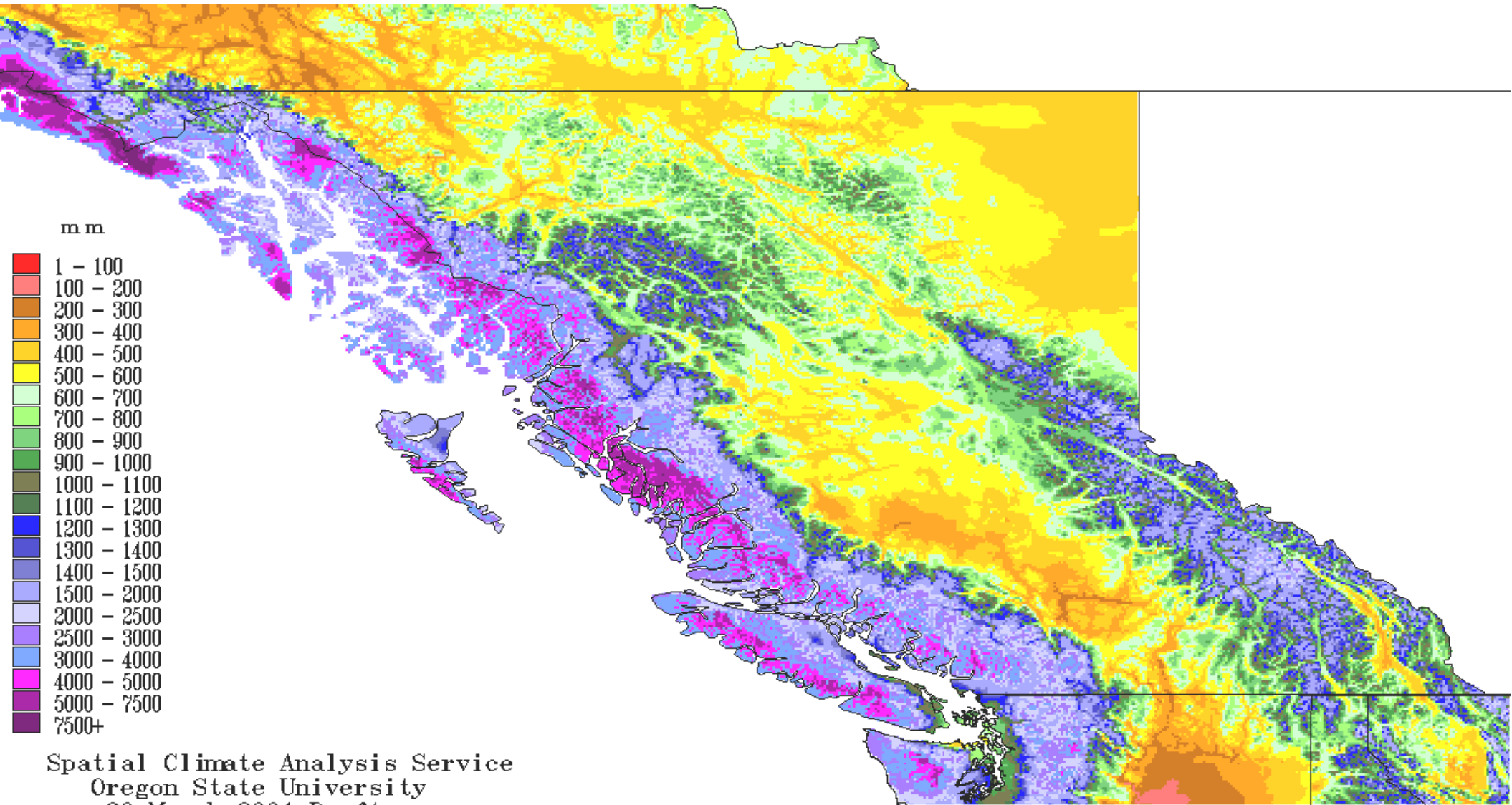
Mean Annual Precipitation, 1961-90



Max ~ 3300 mm

Elevation = 0

PRISM 1961-1990 Mean Annual Precipitation



Spatial Climate Analysis Service
Oregon State University
30 March 2001 Draft

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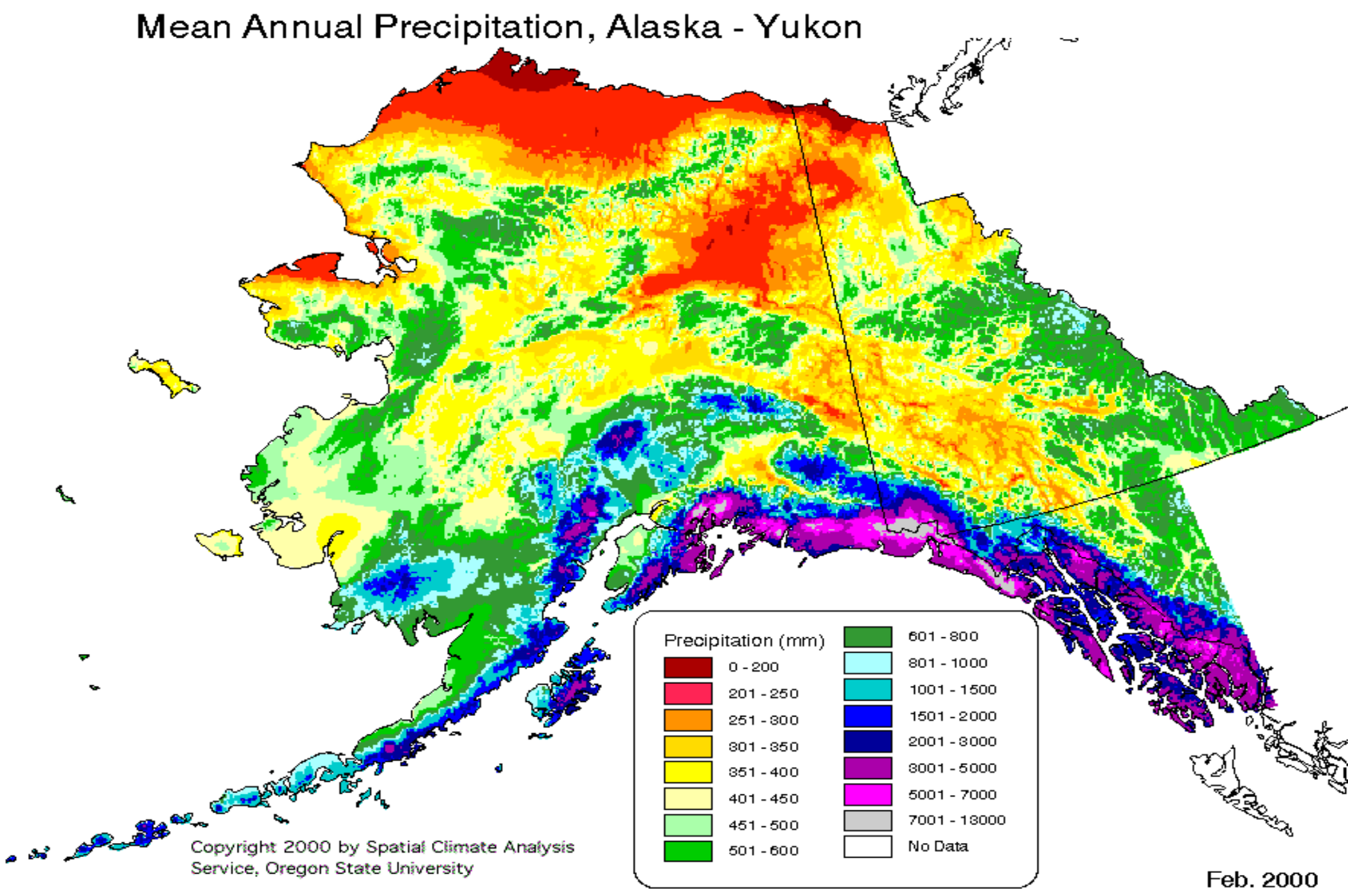
Mean Annual Precipitation, Alaska - Yukon



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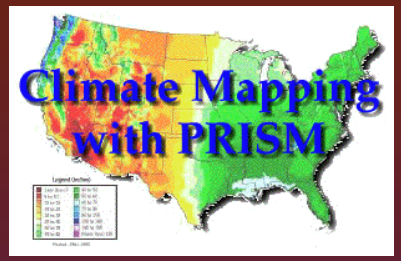
Feb. 2000



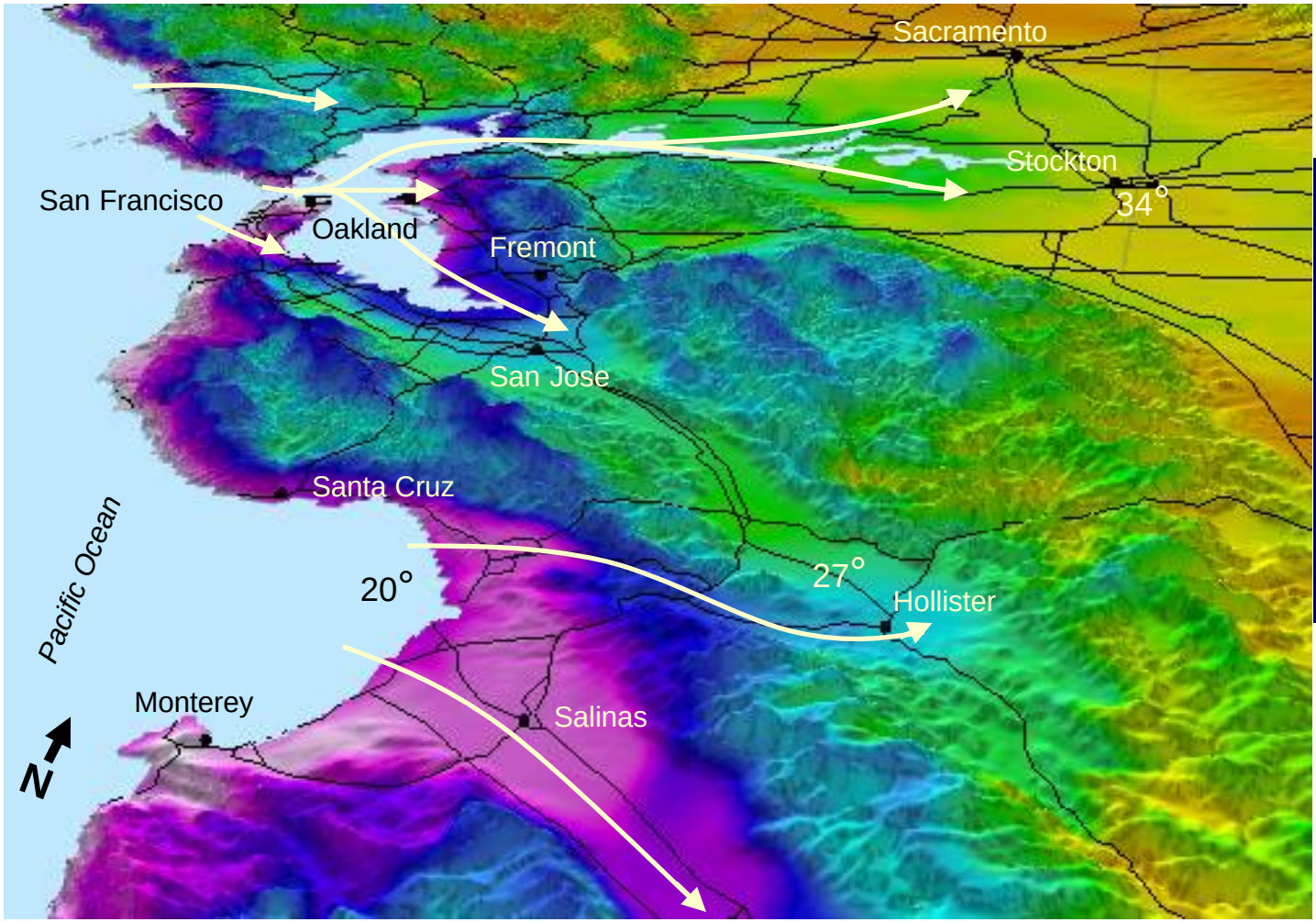
PRISM

Knowledge Base

- Elevation Influence on Climate
- Terrain-Induced Climate Transitions (topographic facets, moisture index)
- Coastal Effects

Coastal Effects: 1971-00 July Maximum Temperature
Central California Coast – 1 km

Preferred Trajectories →

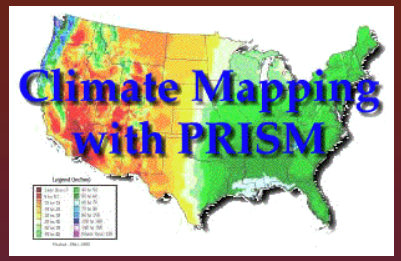


Dominant PRISM KBS Components

Elevation

Coastal Proximity

Inversion Layer

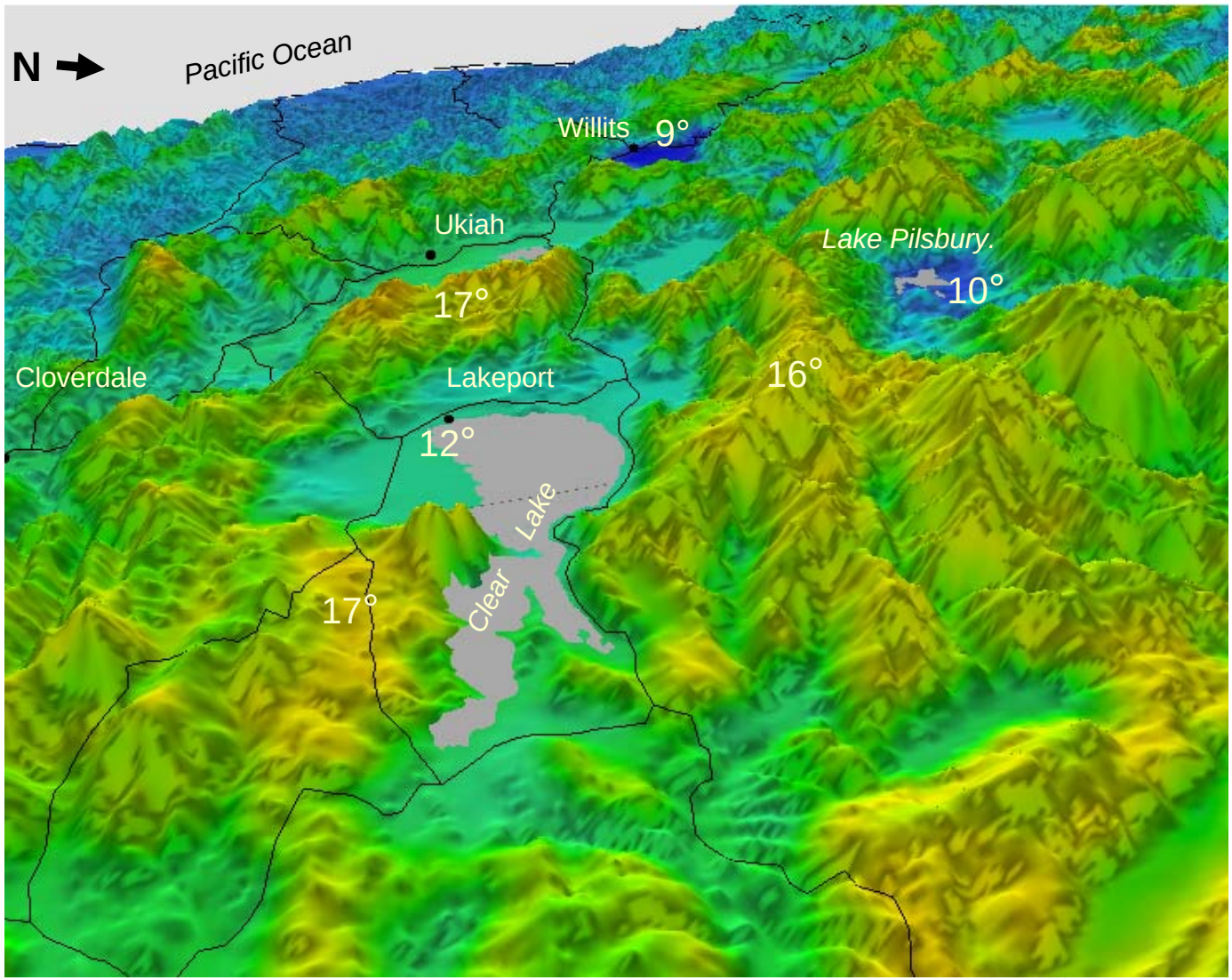


PRISM

Knowledge Base

- Elevation Influence on Climate
- Terrain-Induced Climate Transitions (topographic facets, moisture index)
- Coastal Effects
- Two-Layer Atmosphere (inversions)

Inversions – 1971-00 July Minimum Temperature Northwestern California



Dominant PRISM KBS Components

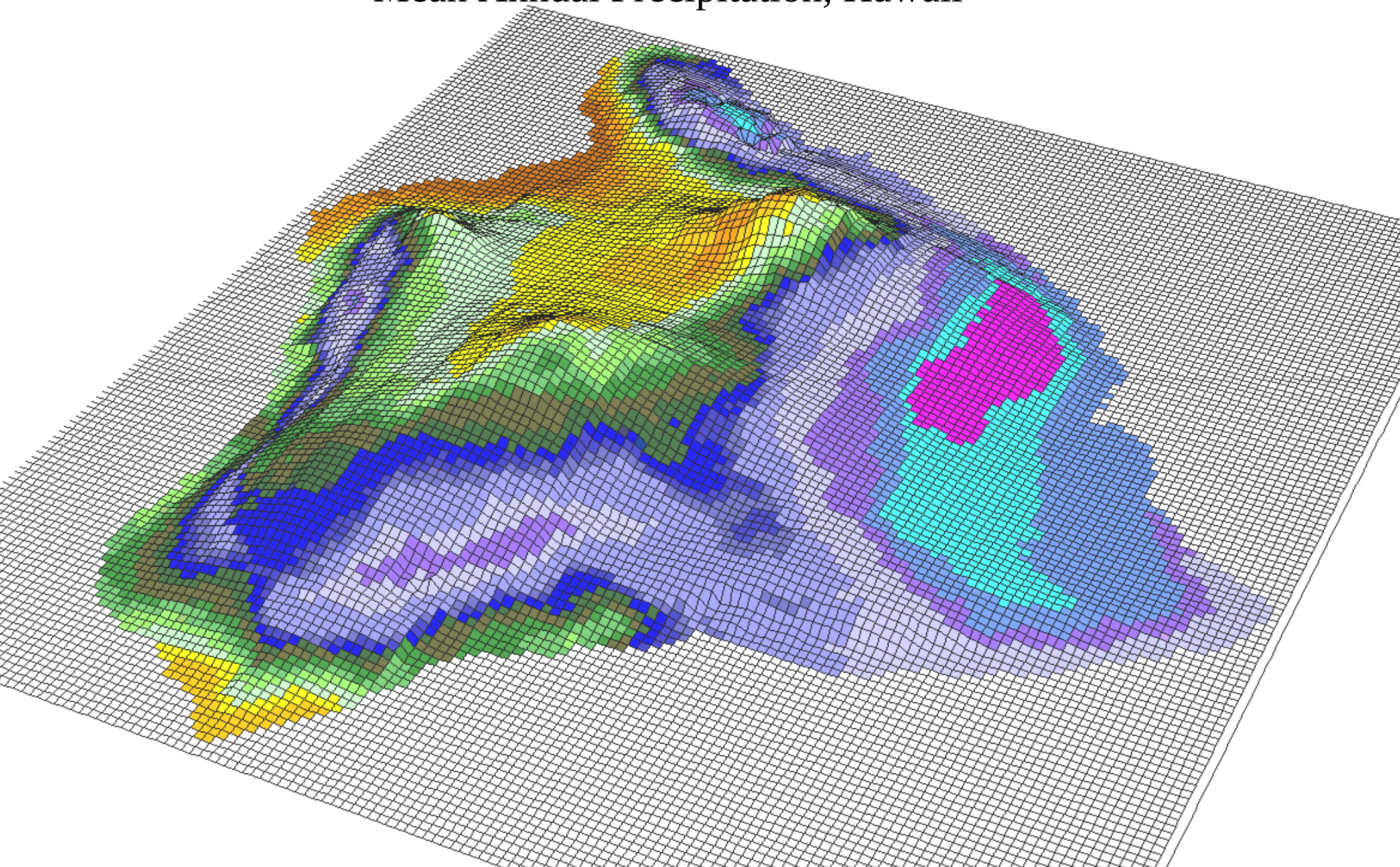
Elevation

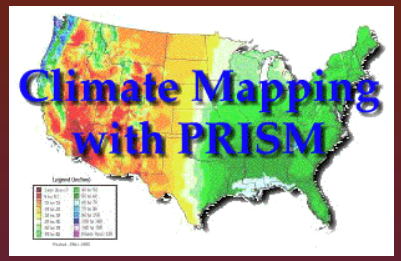
Inversion Layer

Topographic Index

Coastal Proximity

Mean Annual Precipitation, Hawaii



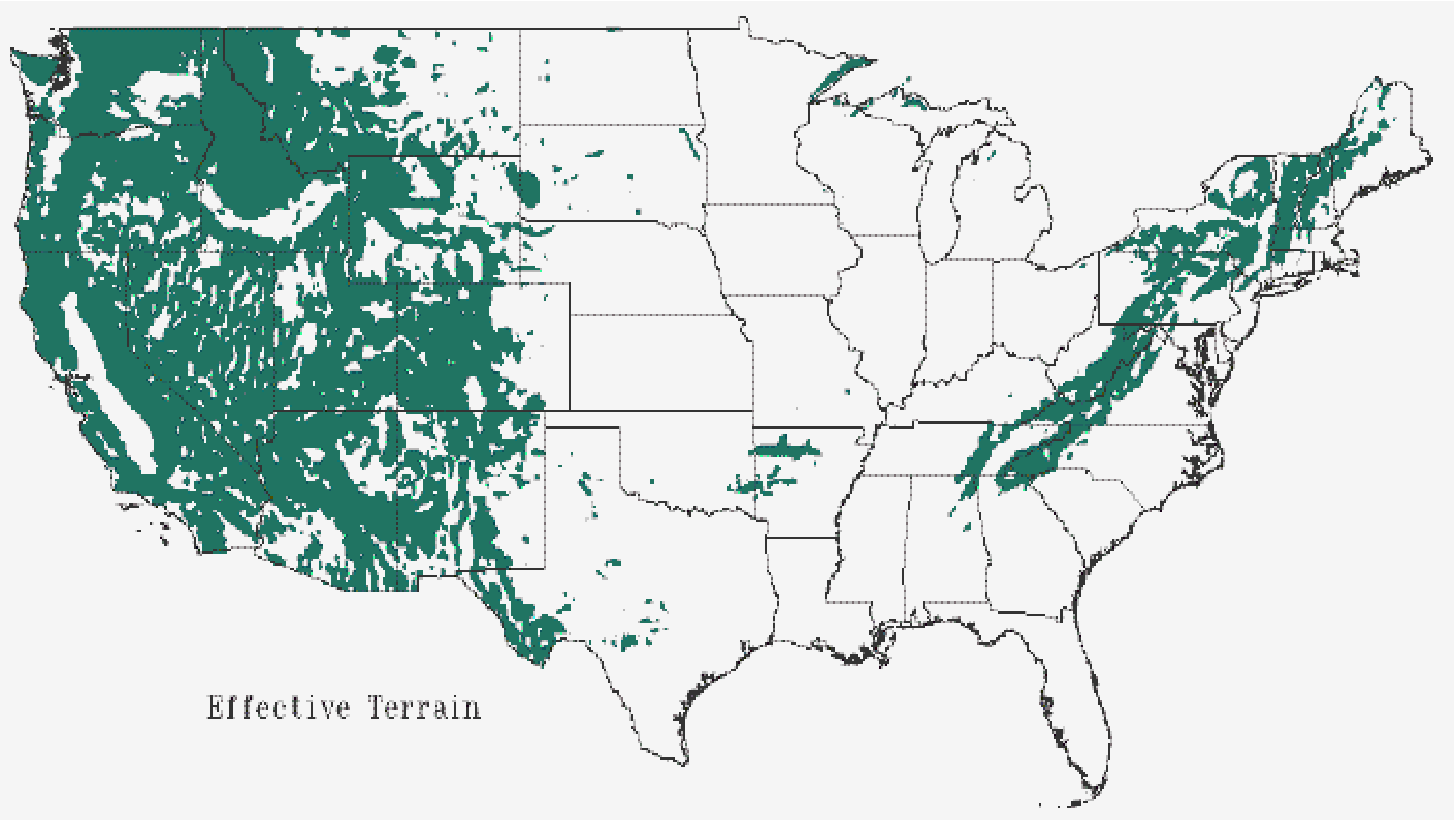


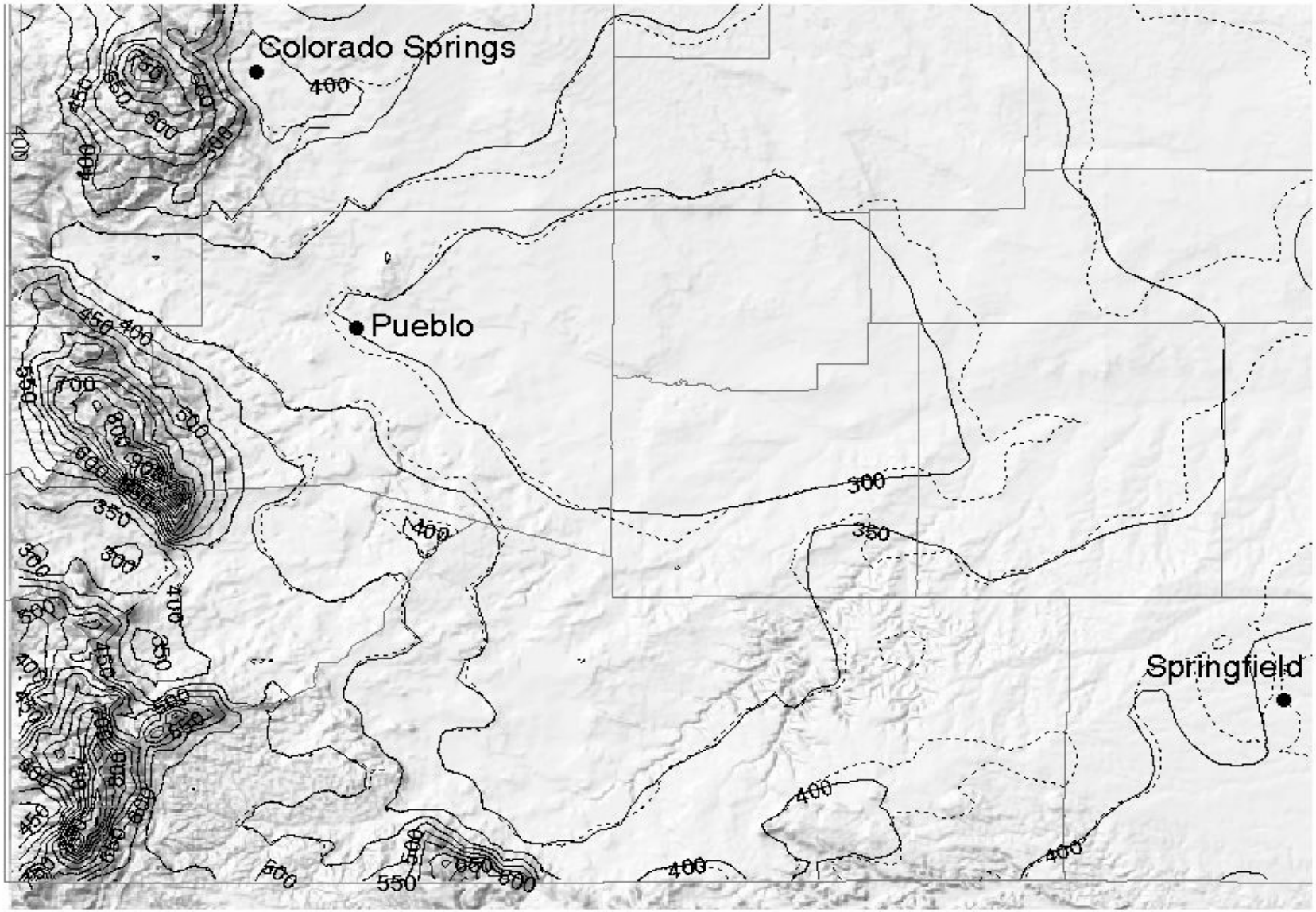
PRISM

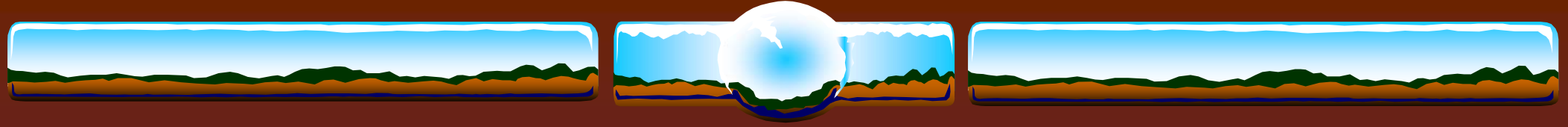
Knowledge Base

- Elevation Influence on Climate
- Terrain-Induced Climate Transitions (topographic facets, moisture index)
- Coastal Effects
- Two-Layer Atmosphere (inversions)
- Orographic Effectiveness of Terrain (Steepness)

United States Orographically Effective Terrain




Colorado Springs
Pueblo
Springfield
Precipitation (mm)
3D
2D-3D
50 0 50 100 Kilometers



Some Future Work

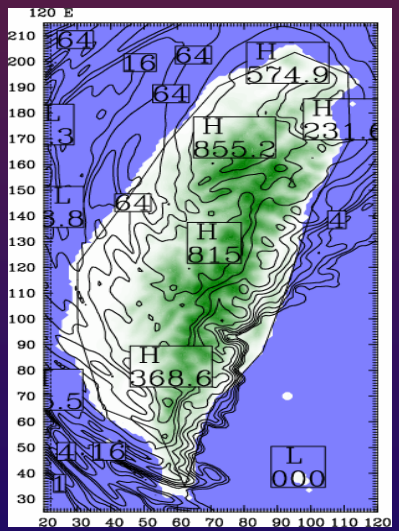
- Explore using numerical model output as the predictor grid in under-sampled areas
- Use remotely-sensed data (radar, satellite) to improve model accuracy in under-sampled areas
- Expand use of climatologies as the predictor grid

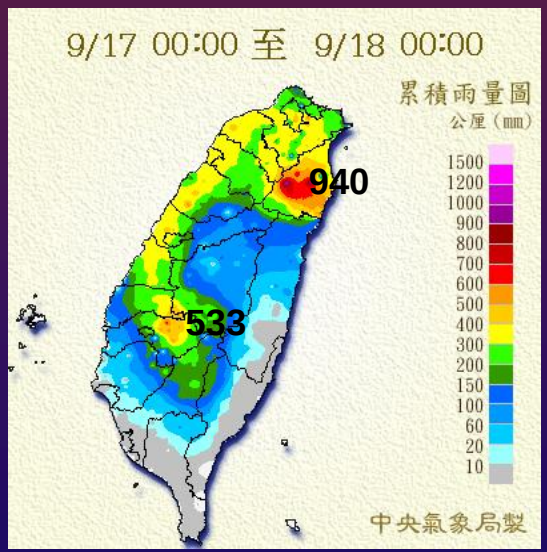
Linking PRISM with MM5 for Improved Storm Precipitation Mapping

Yang Ming-Jen, National Central University, Taiwan
Christopher Daly, OSU SCAS

Typhoon Nari, September, 2001

MM5 Simulated 24-h Rainfall



- Use a “good” MM5 rainfall simulation as the base grid for PRISM rain gauge interpolation.
- Use PRISM interpolated surface climate as hi-res initial conditions for MM5 simulations.

Observed 24-h Rainfall (IDW interpolation)