

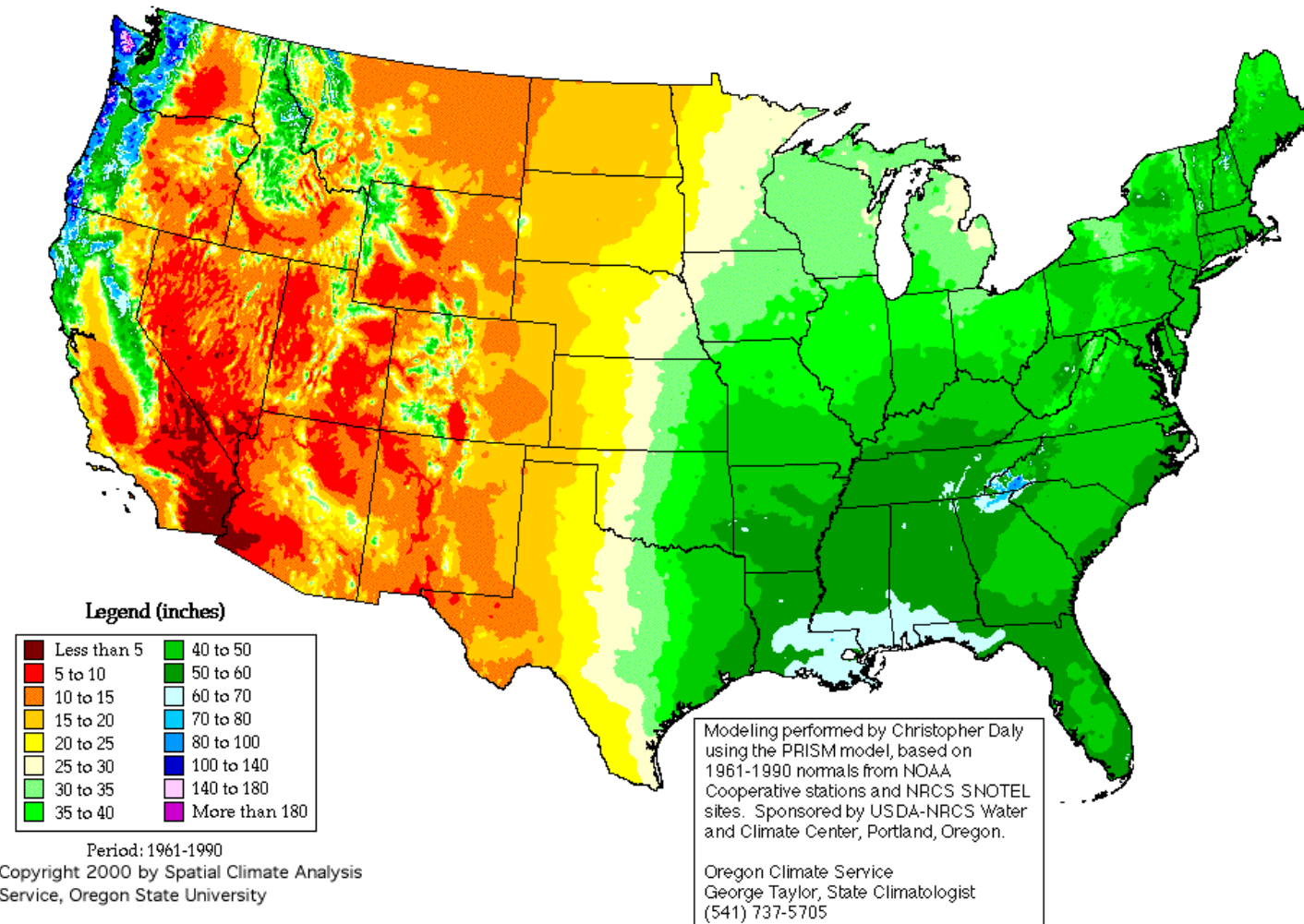
Predicting Precipitation over the Pacific Northwest

**Clifford F. Mass, University of
Washington, Seattle, WA**

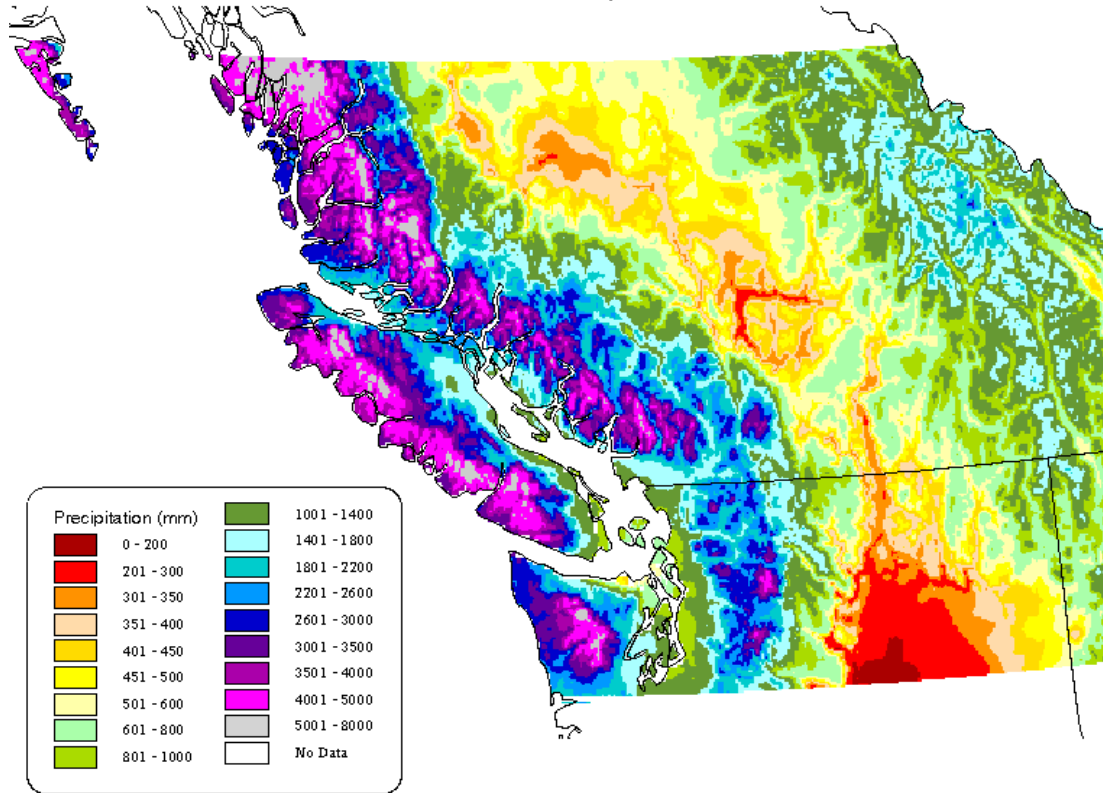
Few Areas of North America Experience Such Large Amounts and Gradients of Precipitation

Annual Average Precipitation

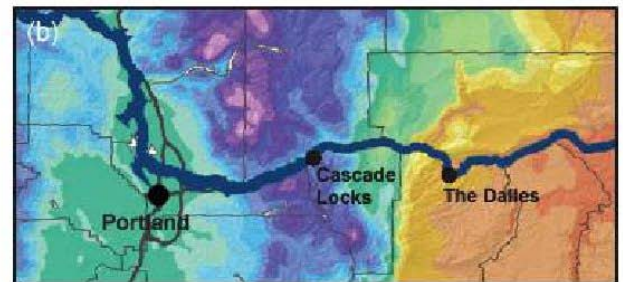
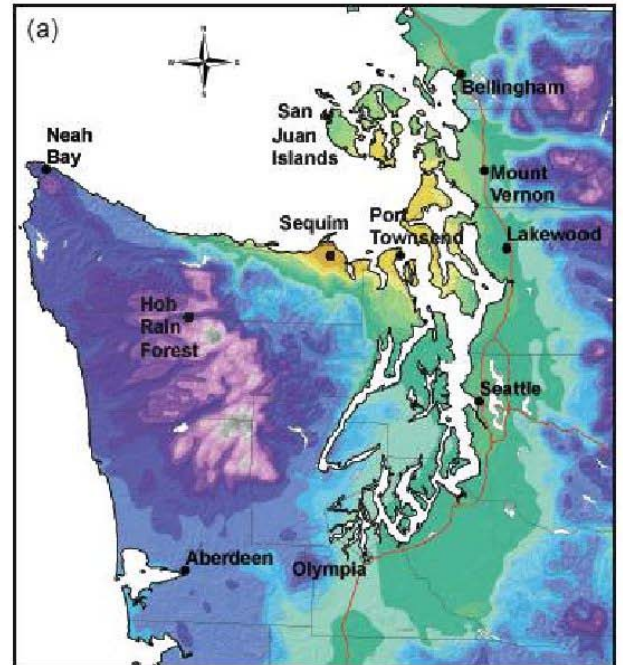
United States of America



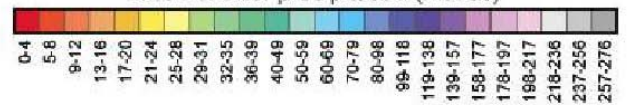
Mean Annual Precipitation, Southern British Columbia



Spatial Climate Analysis Service



Mean annual precipitation (inches)

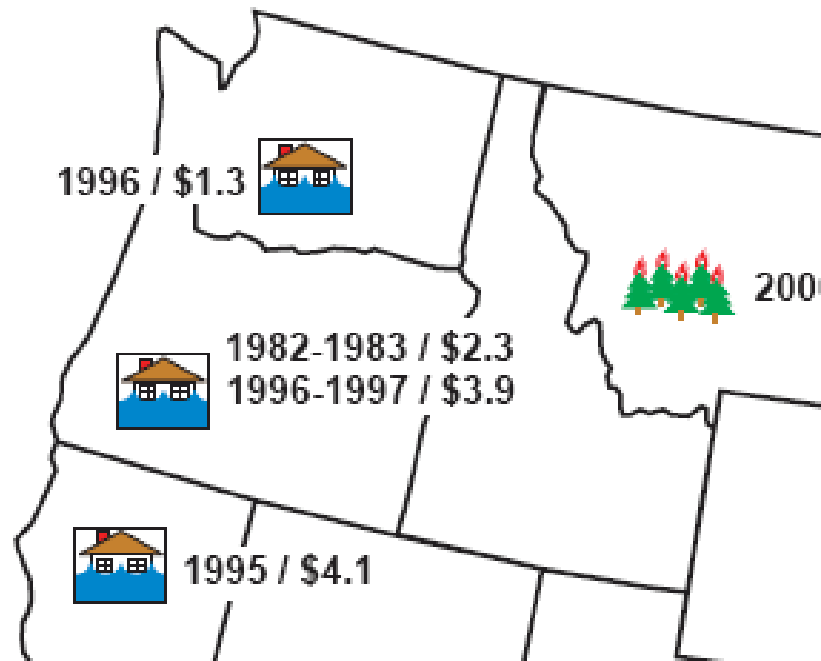


Northwest Precipitation Has Major Societal Impacts



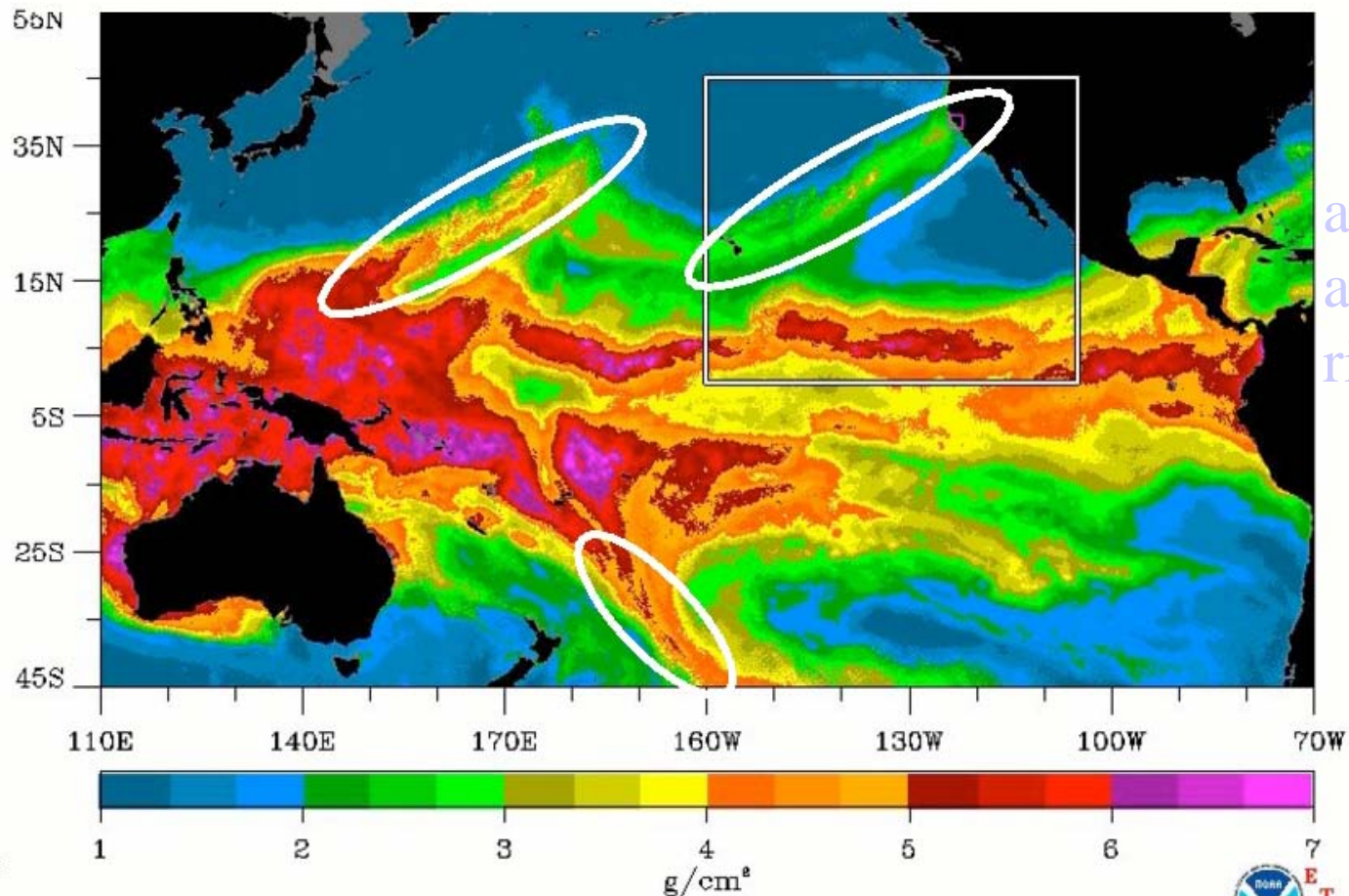
Flood Control on Dozens of Dams (Wynochee Dam shown)

Billion-Dollar Storms Are All Associated with Orographic Precipitation



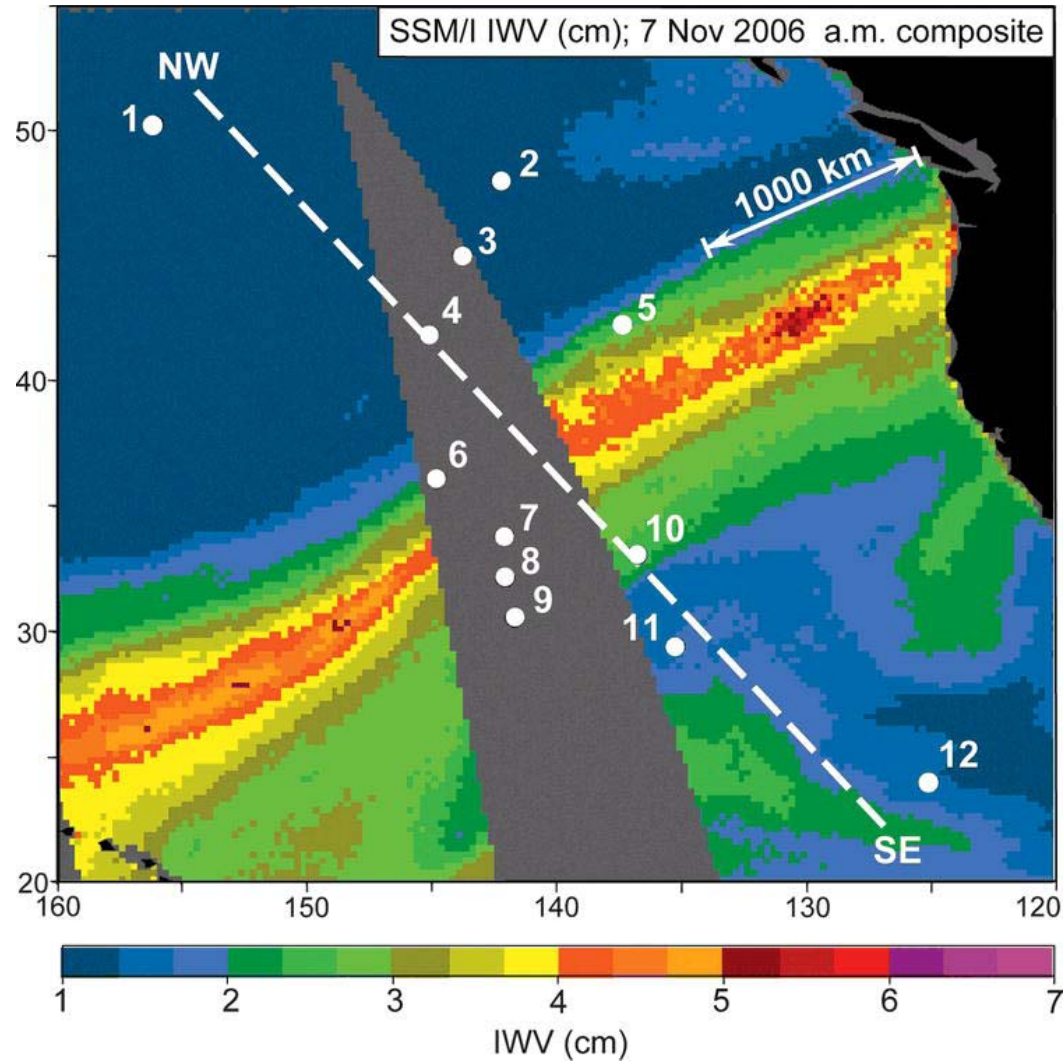
Most are associated with the “Pineapple Express”

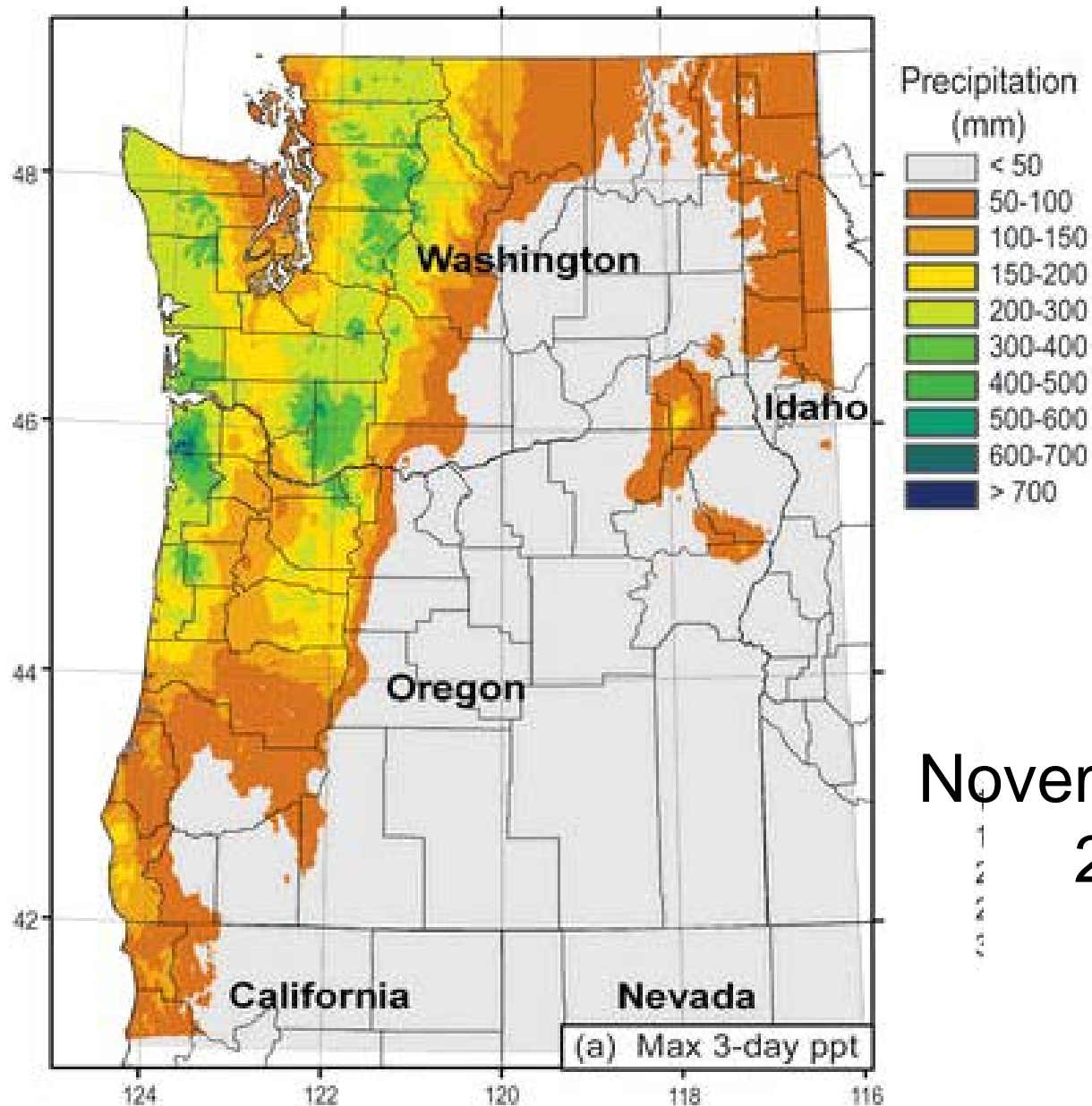
A relatively narrow current of warm, moist air from the subtropics...often starting near or just north of Hawaii.



a.k.a.
atmospheric
rivers

A Recent Devastating Pineapple Express: November 6-7, 2006





November 6-9,
2006

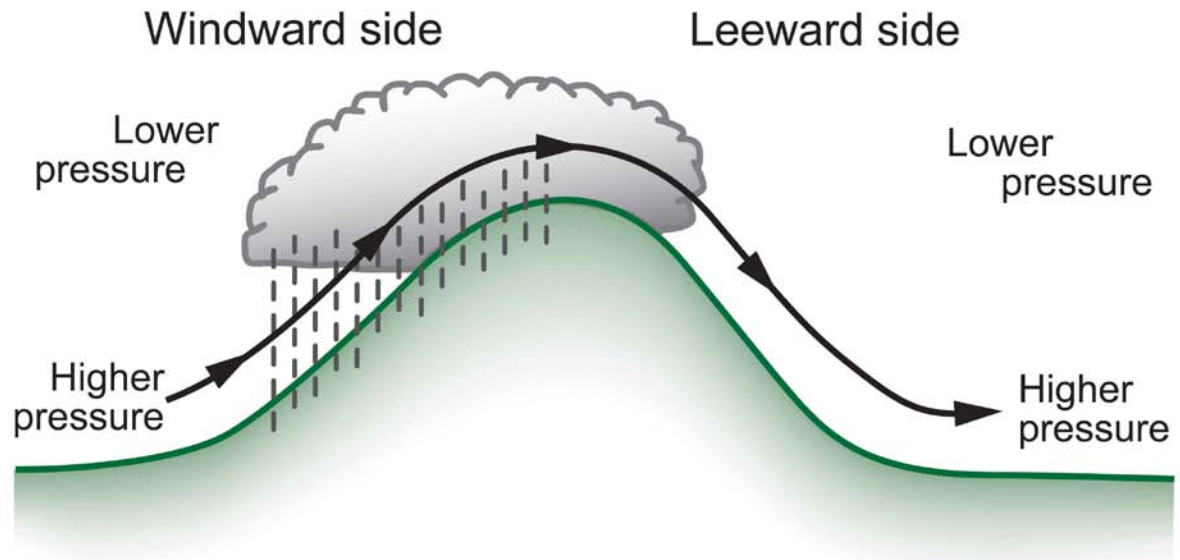
Dark Green: about 20 inches

Mount Rainier National Park 18 inches in 36 hr (Nov 8, 2006)



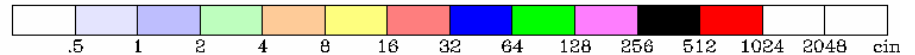
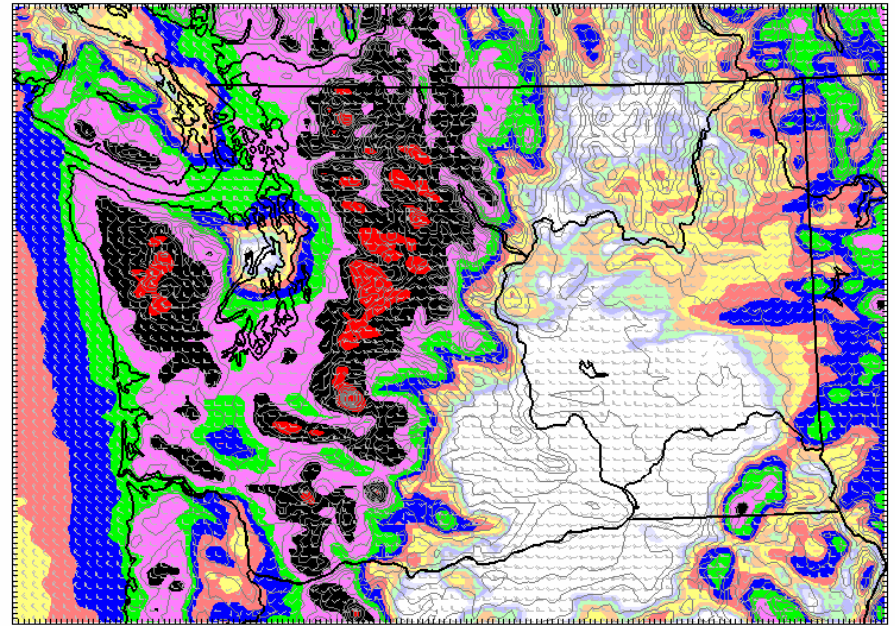
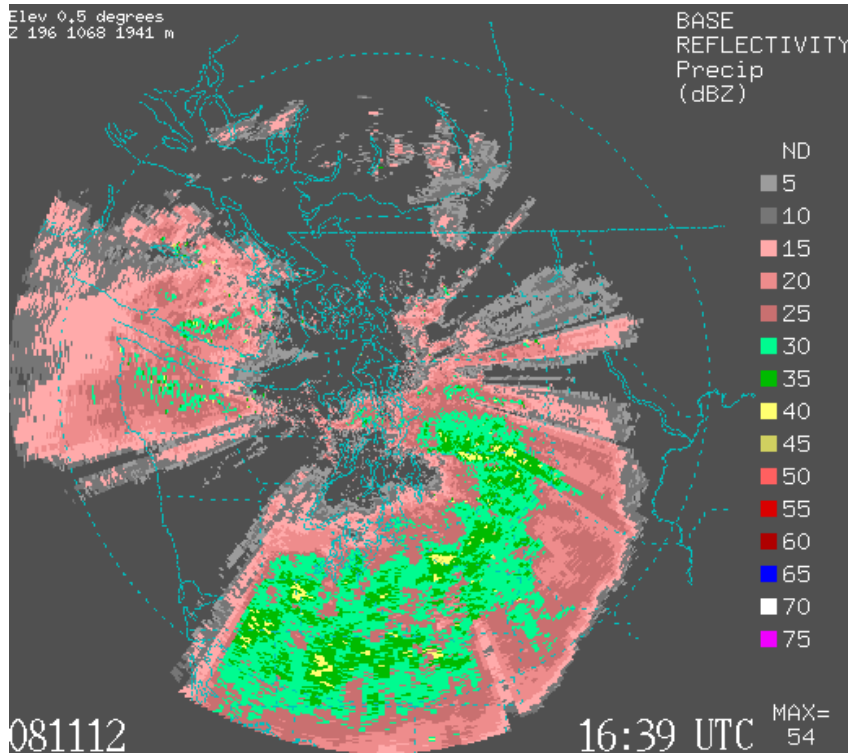
Terrain and Local Effects Greatly Modify the Precipitation Distribution

- Upslope enhancement
- Leeward drying and rain shadowing
- Convergence zones



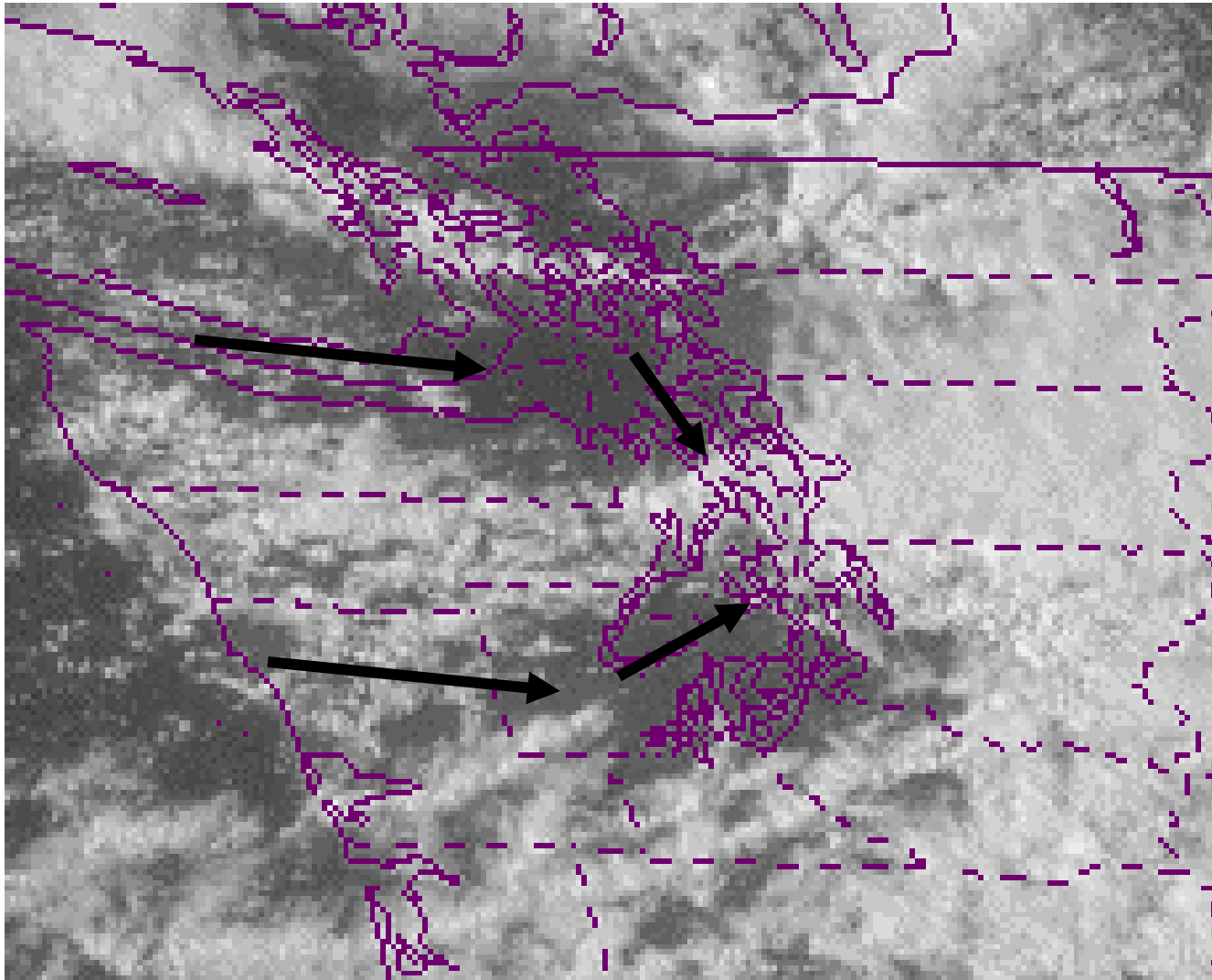
Example of westerly flow

WRF-GFS 4km Domain
 Start: 48 h Valid: 12 UTC Thu 13 Nov 08 (04 PST Thu 13 Nov 08)
 Total Precip in past 24 hrs (.01in)
 Wind at 10m (full barb = 10kts)



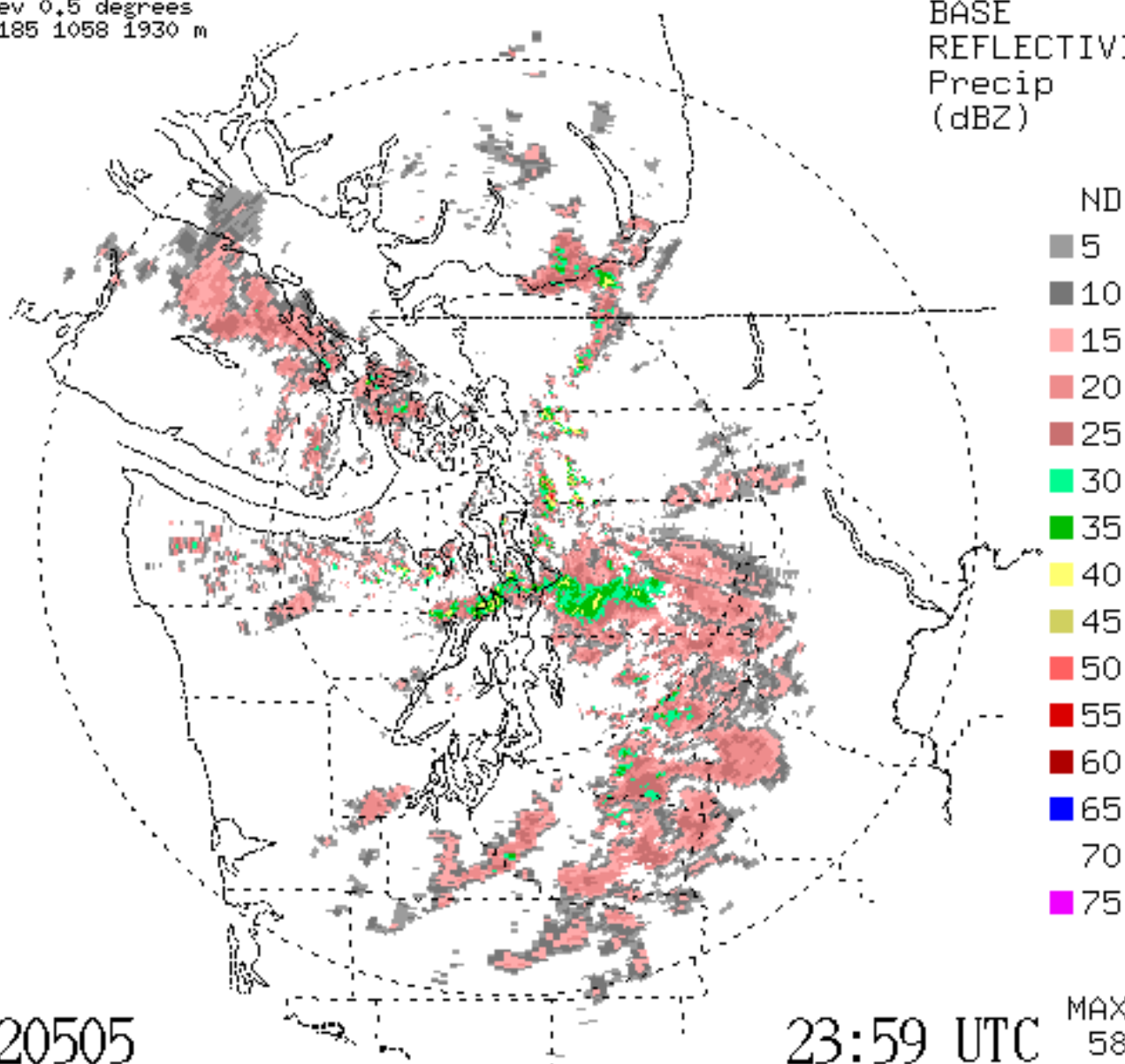
Model Info: V2.2.1 KF YSU PBL Thompson Noah LSM 4.0 km, 37 levels, 24 sec
 LW: CAM SW: CAM DIFF: simple KM: 2D Smagor

Puget Sound Convergence Zone



Elev 0.5 degrees
Z 185 1058 1930 m


BASE
REFLECTIVITY
Precip
(dBZ)



020505

23:59 UTC

MAX=
58



**There have been major progress in
understanding and predicting
precipitation over this region during the
past several decades**

**High resolution numerical simulation
has become a central tool**

Numerical Forecasting Models

- Begin with an **initialization**--a 3D description of the atmosphere.
- The **primitive equations** are then used to start with this initialization to forecast the future 3D states of the atmosphere.
- Generally solved on a 3D grid.
- More grid points, closer together, provides increased **resolution**.
- Faster computers allows more resolution and more physical detail.

Numerical Weather Prediction

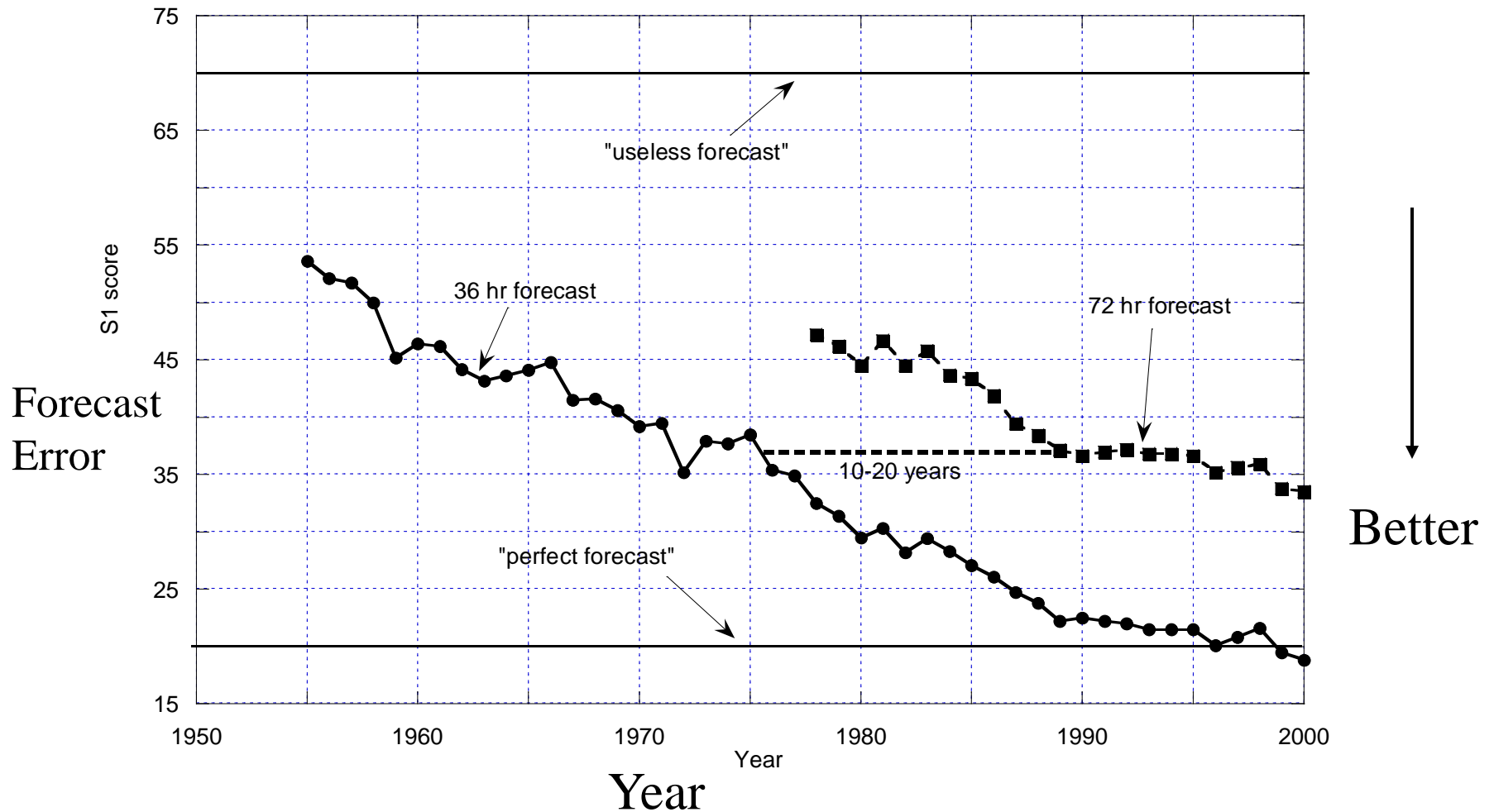
One of the equations used to predict the weather is **Newton's Second Law**:

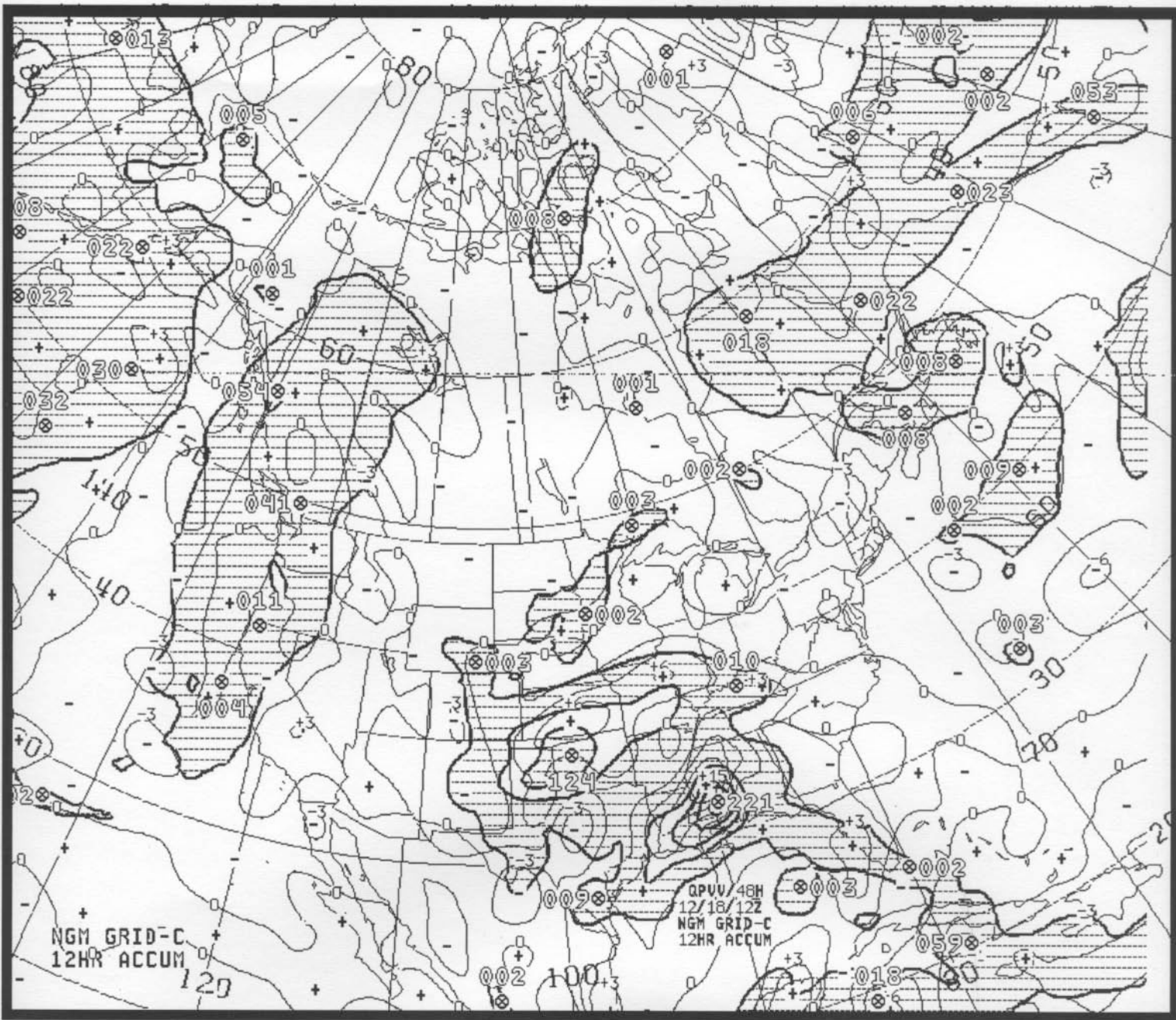
$$F = ma$$

A Time Machine!



**NCEP operational S1 scores at 36 and 72 hr
over North America (500 hPa)
National Weather Service**





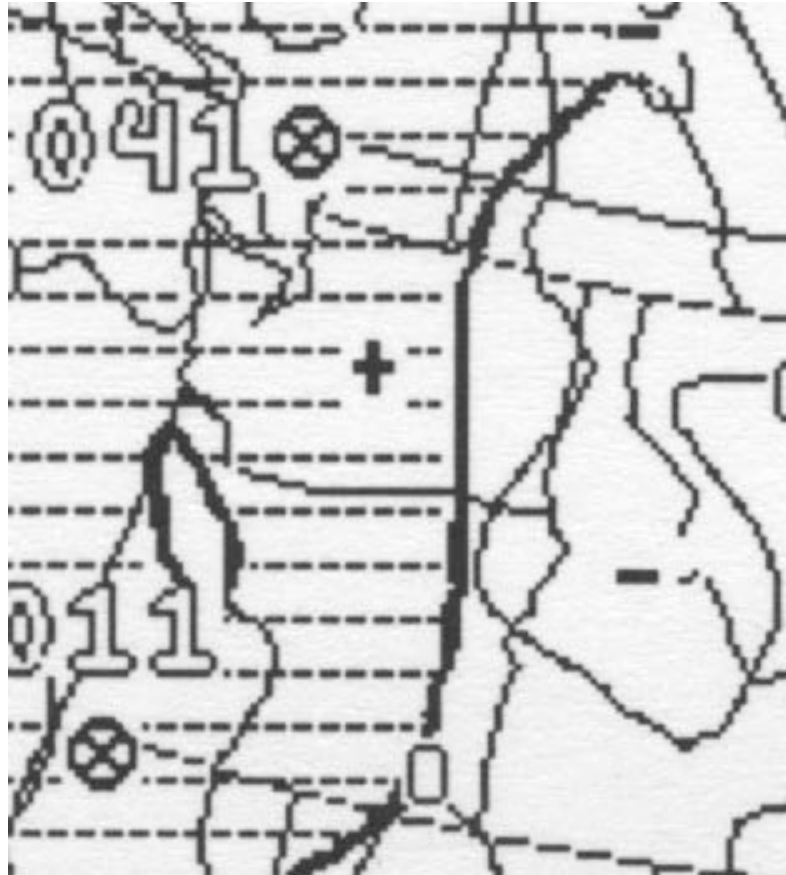
NGM,
80 km,
1995

D180 .. 48HR FCST

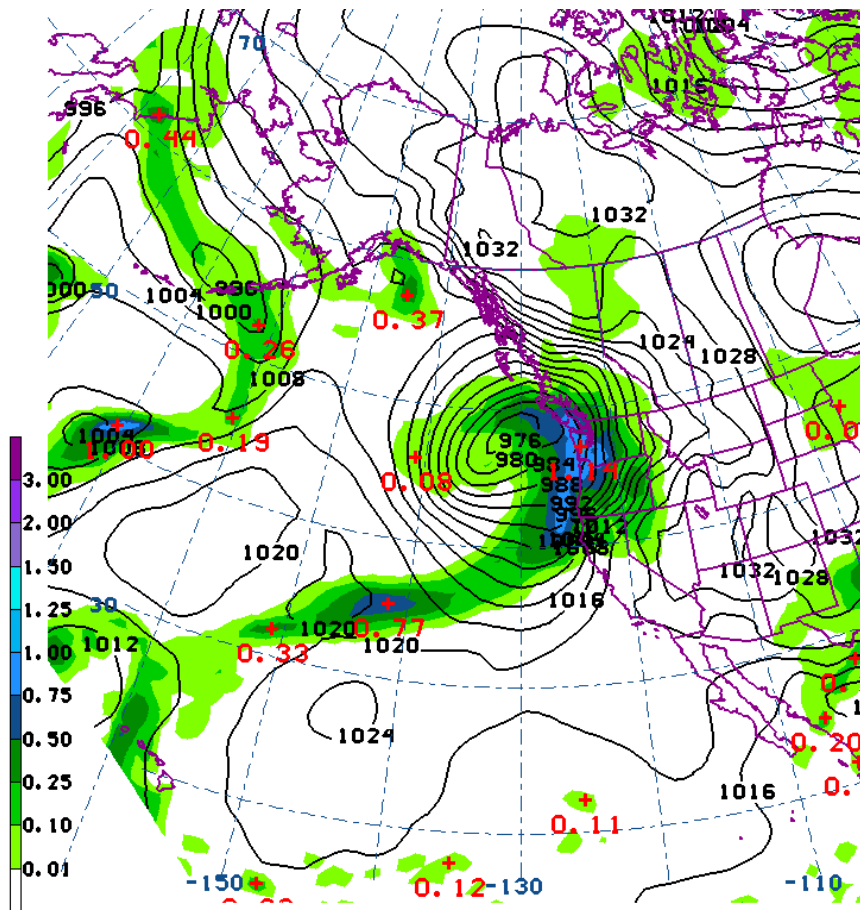
PRECIP./700 VERT VEL

VALID 12Z MON 18 DEC 95

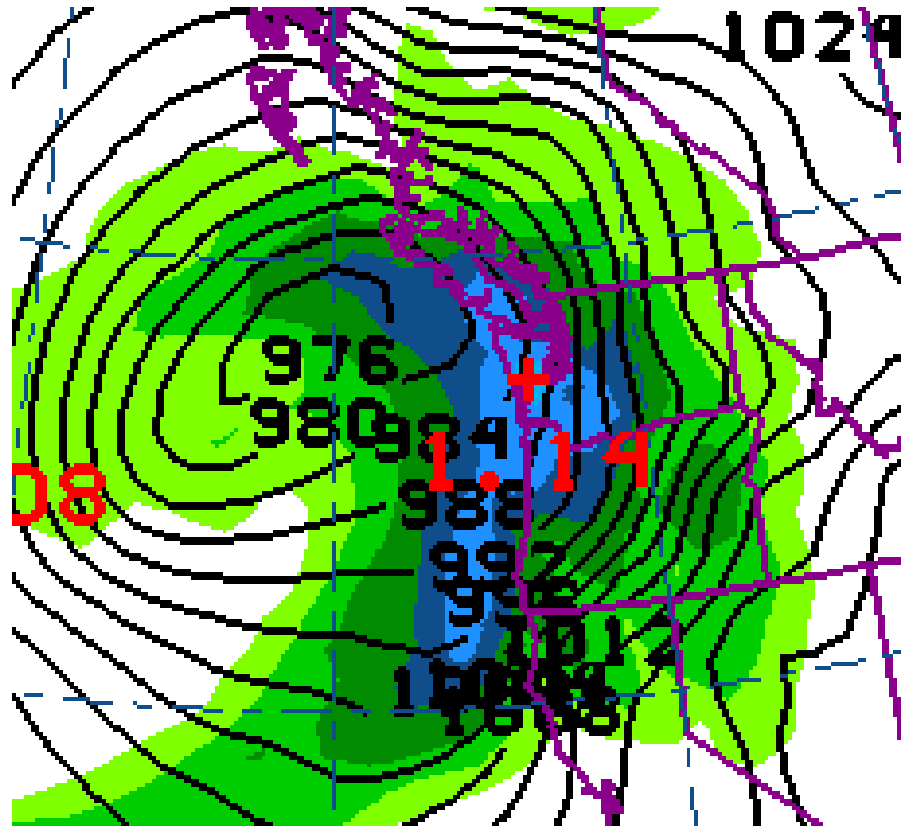
NGM, 1995



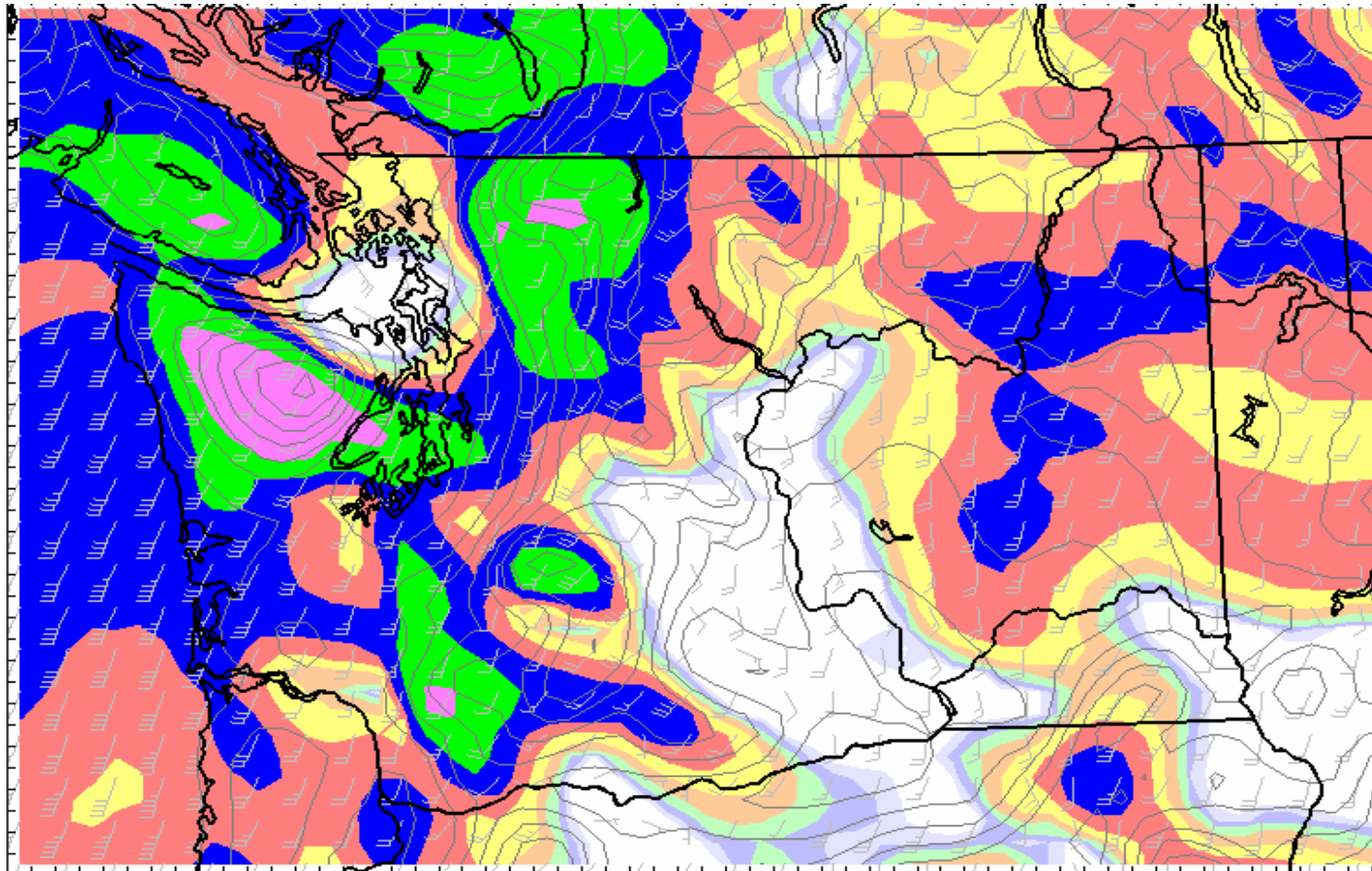
2001: Eta Model, 22 km



18Z Wed 28 Nov 2001 F06 ETA PMSL & 6-H PCPN



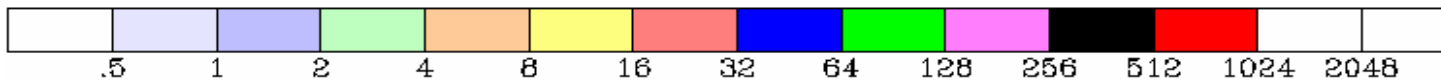
2007-2008



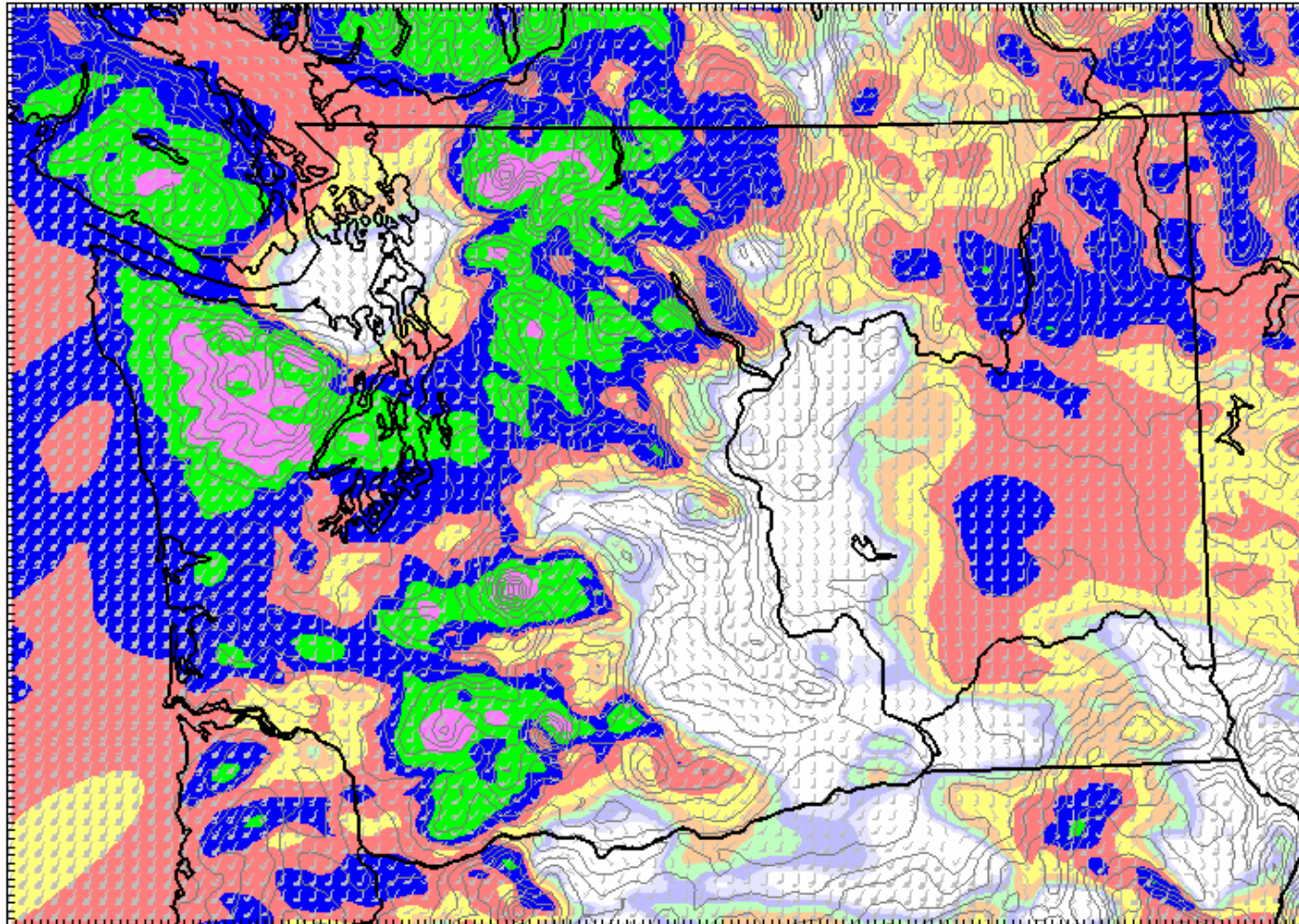
12-km
UW MM5
Real-time

December 3, 2007
0000 UTC Initial
12-h forecast
3-hr precip.

1/100 inch

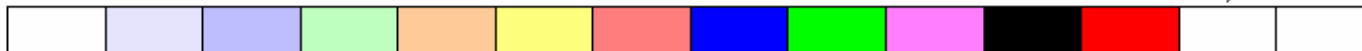


2007-2008



4-km MM5
Real-time

1/100 inch



Model info: V3.7.4 Kain-Frsch MRF PBL Reisner 2 4 km, 37 levels, 1 sec

2009 1.3 km grid spacing!

UW WRF-GFS 1.33km Domain

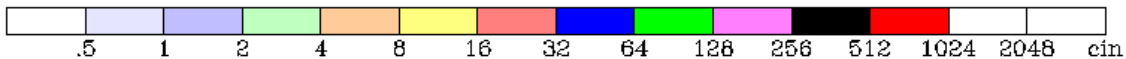
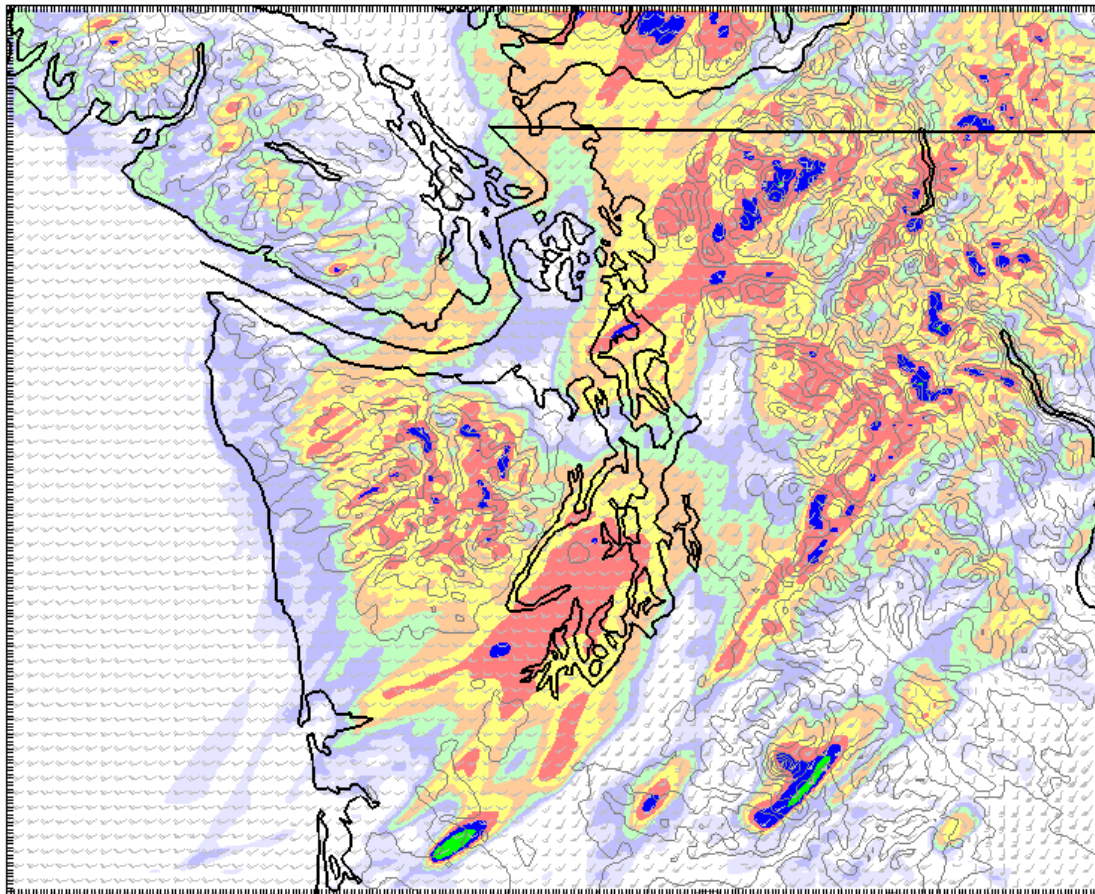
Init: 12 UTC Wed 04 Nov 09

Fcst: 39.00 h

Valid: 03 UTC Fri 06 Nov 09 (19 PST Thu 05 Nov 09)

Total Precip in past hour (.01in)

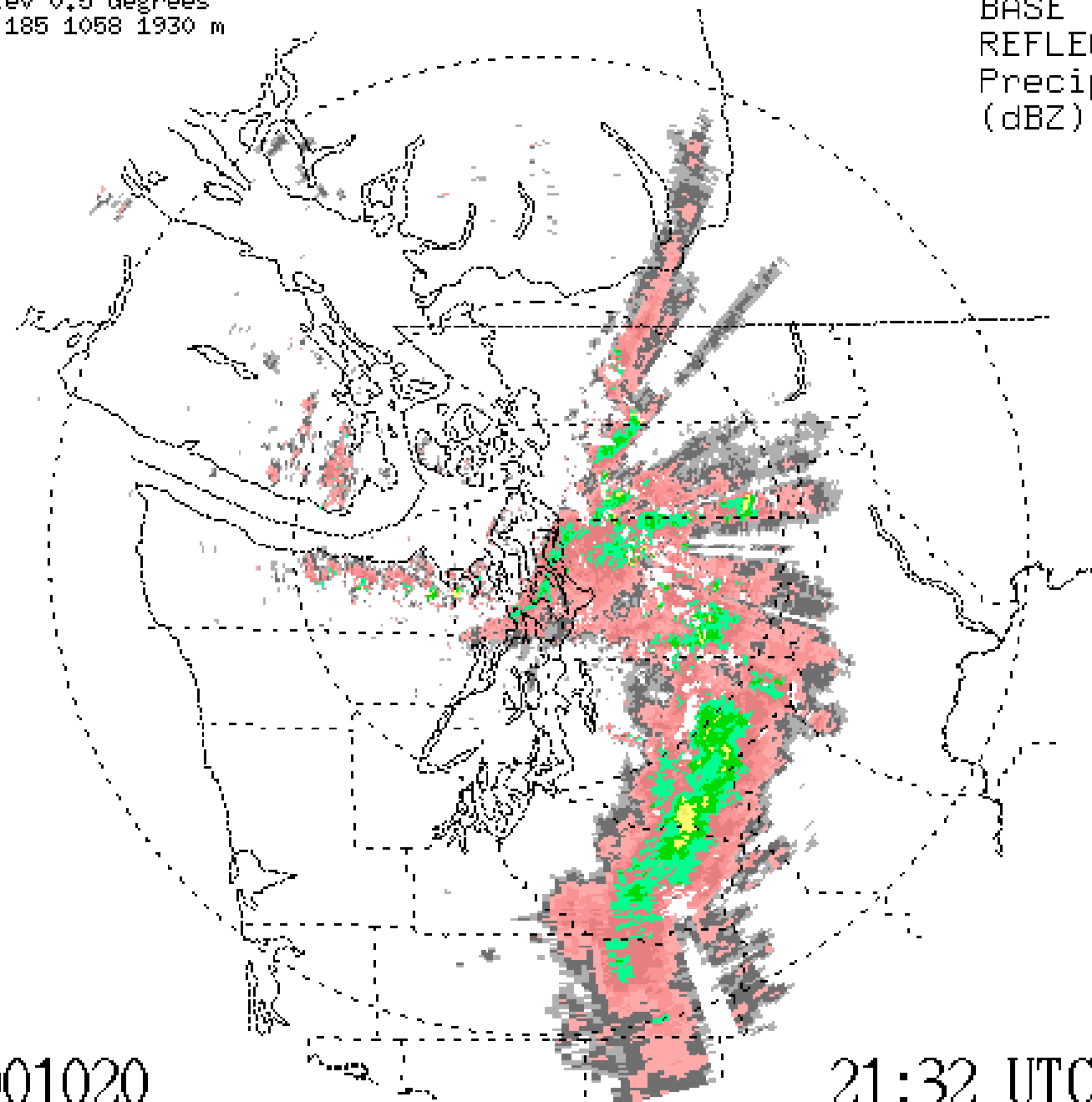
Wind at 10m (full barb = 10kts)



Model Info: v3.1 KF YSU PBL Thompson Noah LSM 1.3 km, 37 levels, 8 sec
LW: RRTM SW: Dudhia DIFF: simple KM: 2D Smagor

Elev 0.5 degrees
Z 185 1058 1930 m

BASE
REFLECTIVITY
Precip
(dBZ)



- ND
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- 60
- 65
- 70
- 75

001020

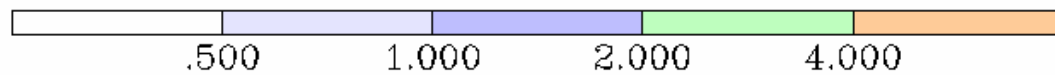
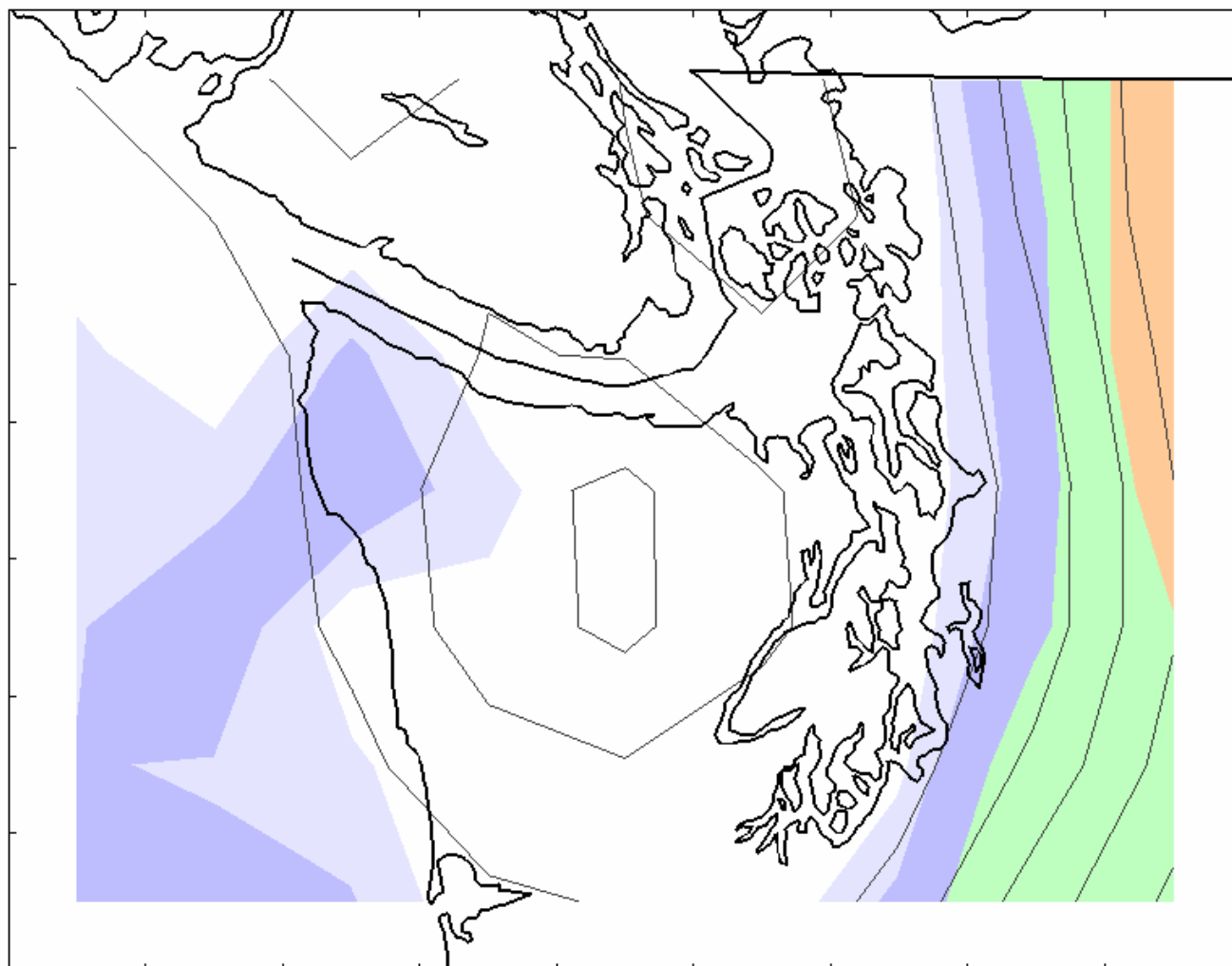
21:32 UTC MAX=58

UW MM5 36km Domain 21-hr Fest
Initialized: 00 UTC FRI 20 OCT 00

Valid: 21 UTC FRI 20 OCT 00
14 PDT FRI 20 OCT 00

Precip (.01 in)
Terrain

Contour Interval 200 m Low = 100 High = 1100

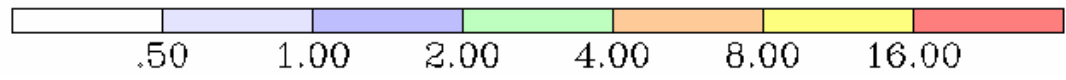
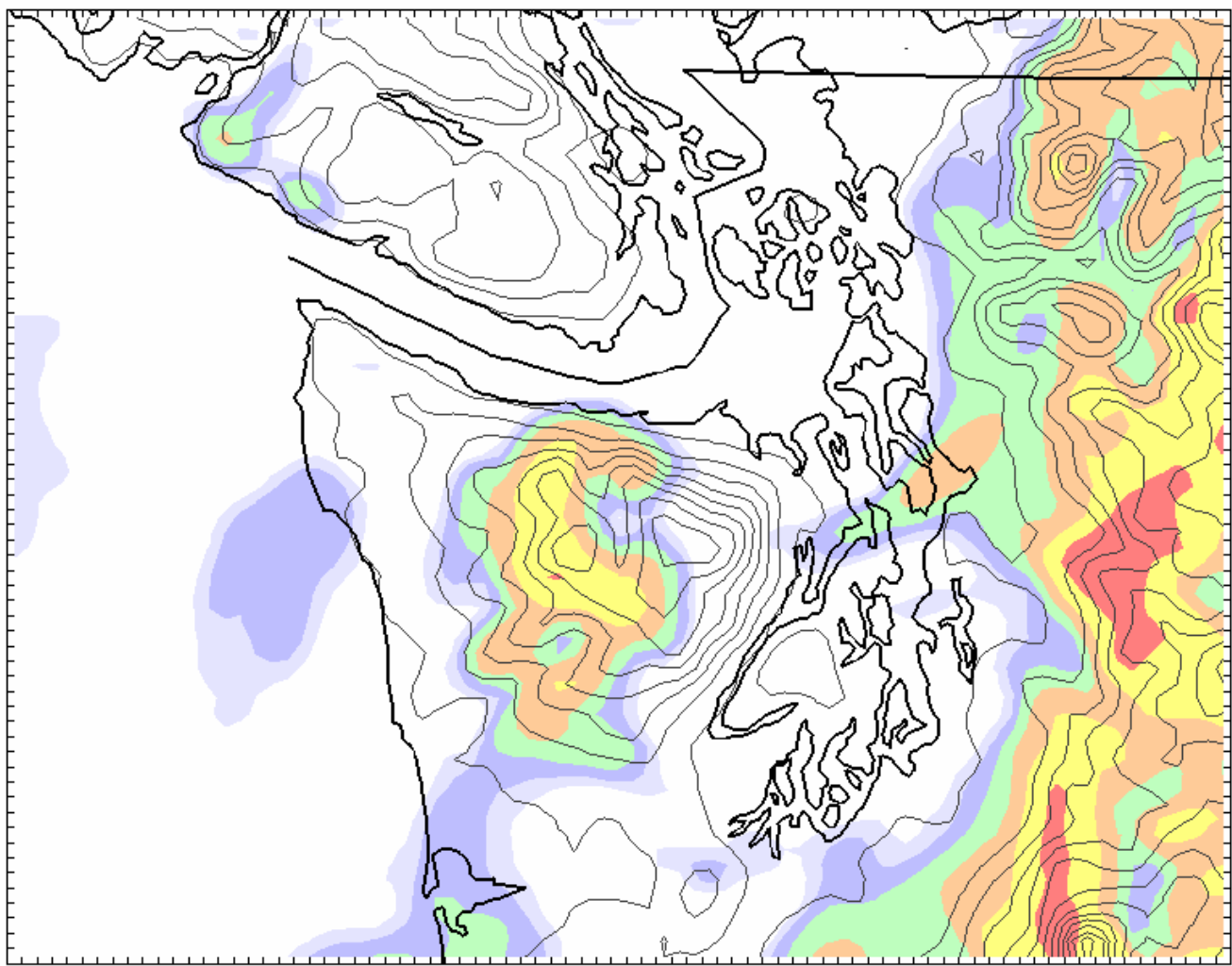


UW MM5 4km Domain 21-hr Fcst
Initialized: 00 UTC FRI 20 OCT 00

Valid: 21 UTC FRI 20 OCT 00
14 PDT FRI 20 OCT 00

Precip (.01 in)
Terrain

Contour Interval 200 m Low = 100 High = 2500

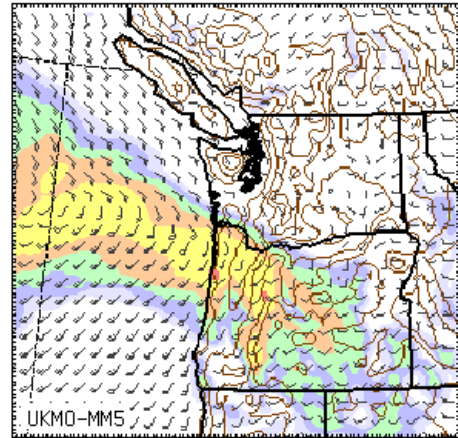
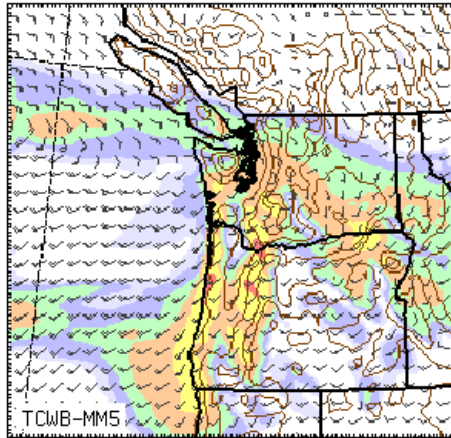
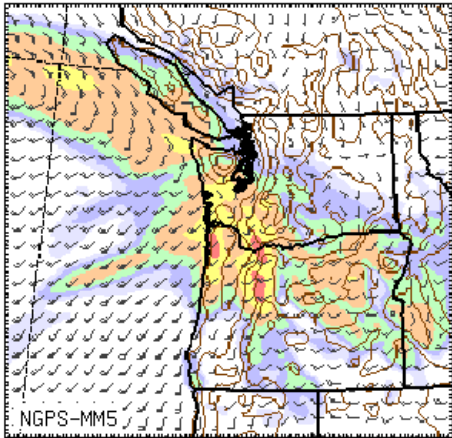
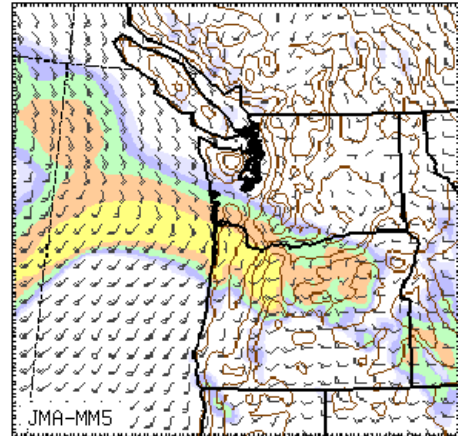
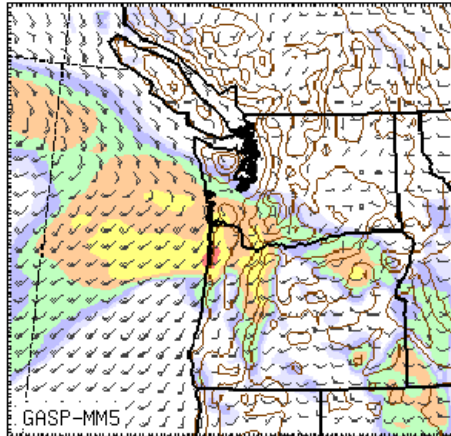
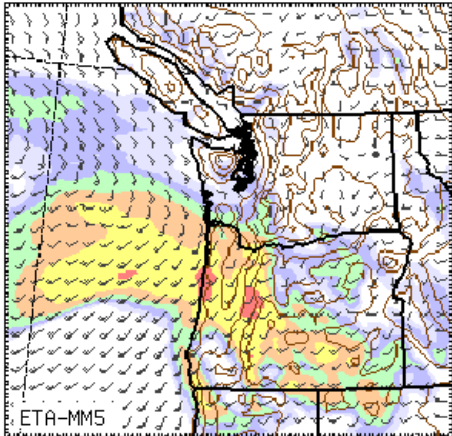
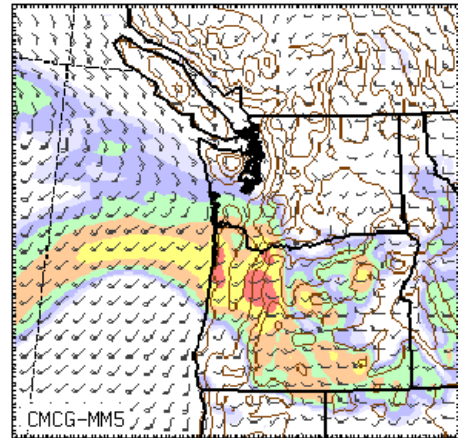
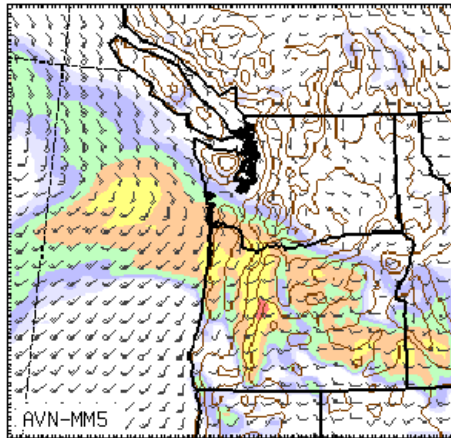
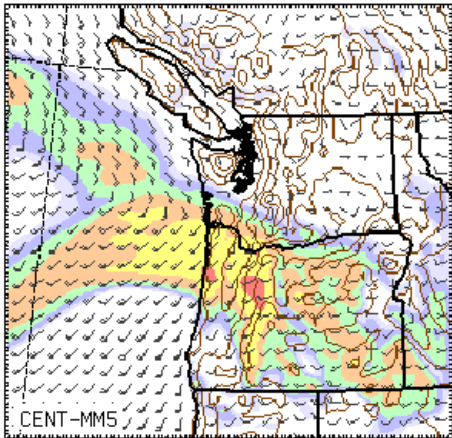


How good are the predictions?

- The high resolution forecasts are often quite good, but problems do exist.
- Deficiencies with initial conditions, produce bad forecasts.
- Clearly, some weaknesses in model physics (e.g., lack of light precipitation as fronts approach, overprediction over mountain slopes)
- It is deceiving to provide a single forecast--even one at high resolution.

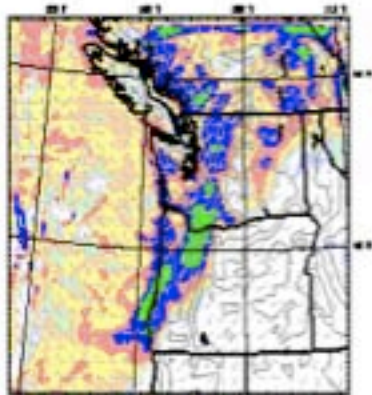
The newest approach: probabilistic prediction using ensembles

- Running computer models many times with slightly different initial conditions and model physics.
- Can be used to provide uncertainty information and probabilities.



MM5 ENSEMBLE CENTROID

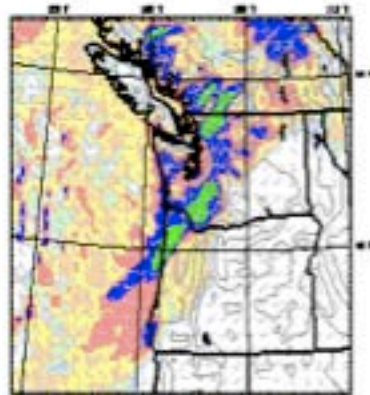
CMC-604 Scenario 2
Units: 10³ mm
Precip: 48.3
Total Precip in year 10 Jan (100%)
Time of Day: 00:00:00



0 20 40 60 80 100
Total Precip (mm) 0 20 40 60 80 100
Time of Day: 00:00:00

GFS-MM5

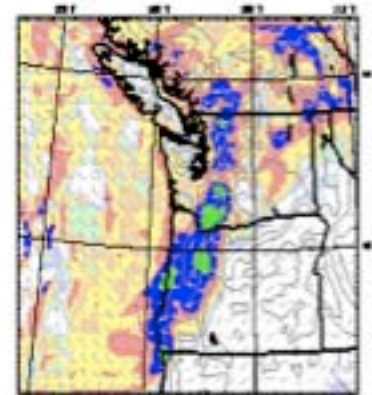
CMC-604 Scenario 2
Units: 10³ mm
Precip: 48.3
Total Precip in year 10 Jan (100%)
Time of Day: 00:00:00



0 20 40 60 80 100
Total Precip (mm) 0 20 40 60 80 100
Time of Day: 00:00:00

CMCG-MM5

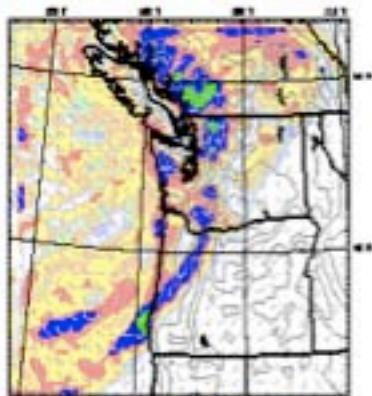
CMC-604 Scenario 2
Units: 10³ mm
Precip: 48.3
Total Precip in year 10 Jan (100%)
Time of Day: 00:00:00



0 20 40 60 80 100
Total Precip (mm) 0 20 40 60 80 100
Time of Day: 00:00:00

ETA-MM5

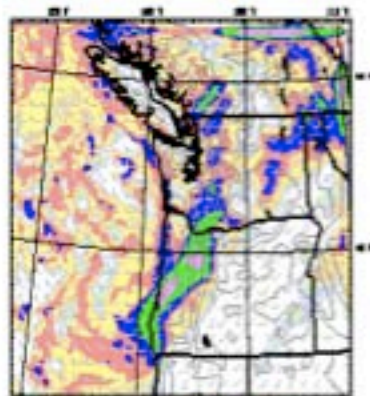
ETA-604 Scenario 2
Units: 10³ mm
Precip: 48.3
Total Precip in year 10 Jan (100%)
Time of Day: 00:00:00



0 20 40 60 80 100
Total Precip (mm) 0 20 40 60 80 100
Time of Day: 00:00:00

GASP-MM5

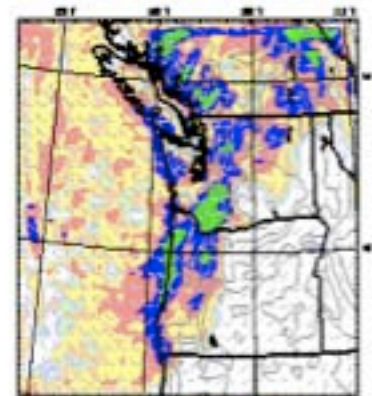
GASP-604 Scenario 2
Units: 10³ mm
Precip: 48.3
Total Precip in year 10 Jan (100%)
Time of Day: 00:00:00



0 20 40 60 80 100
Total Precip (mm) 0 20 40 60 80 100
Time of Day: 00:00:00

JMA-MM5

JMA-604 Scenario 2
Units: 10³ mm
Precip: 48.3
Total Precip in year 10 Jan (100%)
Time of Day: 00:00:00



0 20 40 60 80 100
Total Precip (mm) 0 20 40 60 80 100
Time of Day: 00:00:00

UWME PROB Domain 2

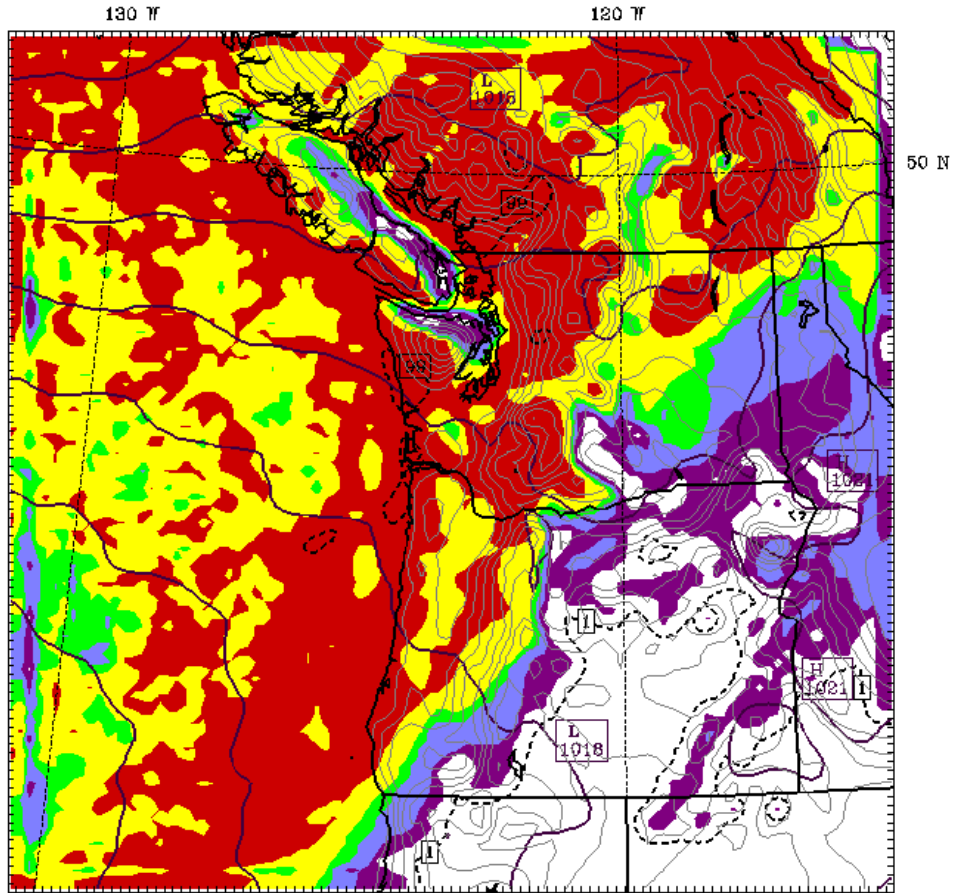
Init: 12 UTC Mon 09 Nov 09

Fest: 48 h

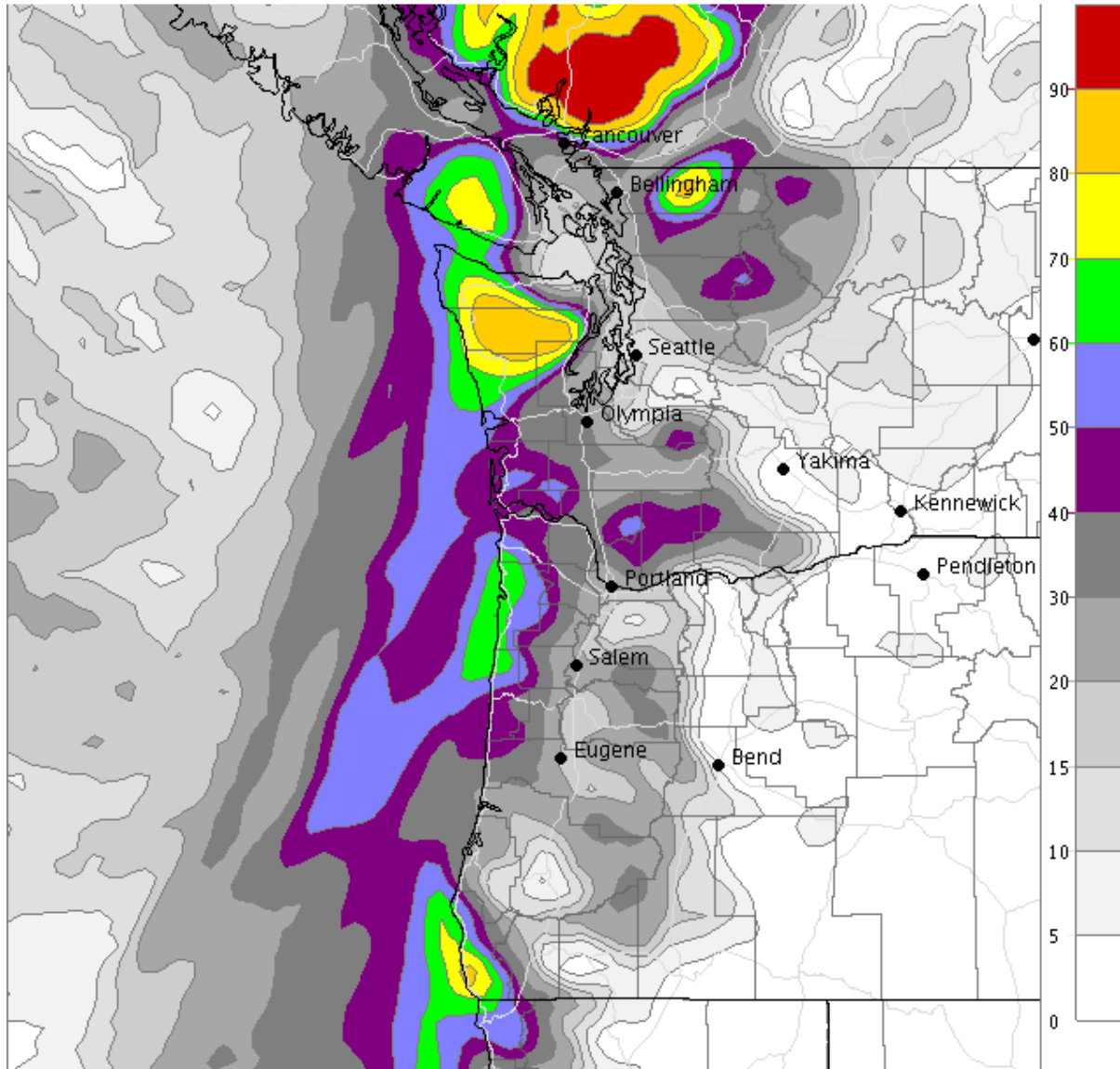
Valid: 12 UTC Wed 11 Nov 09 (04 PST Wed 11 Nov 09)

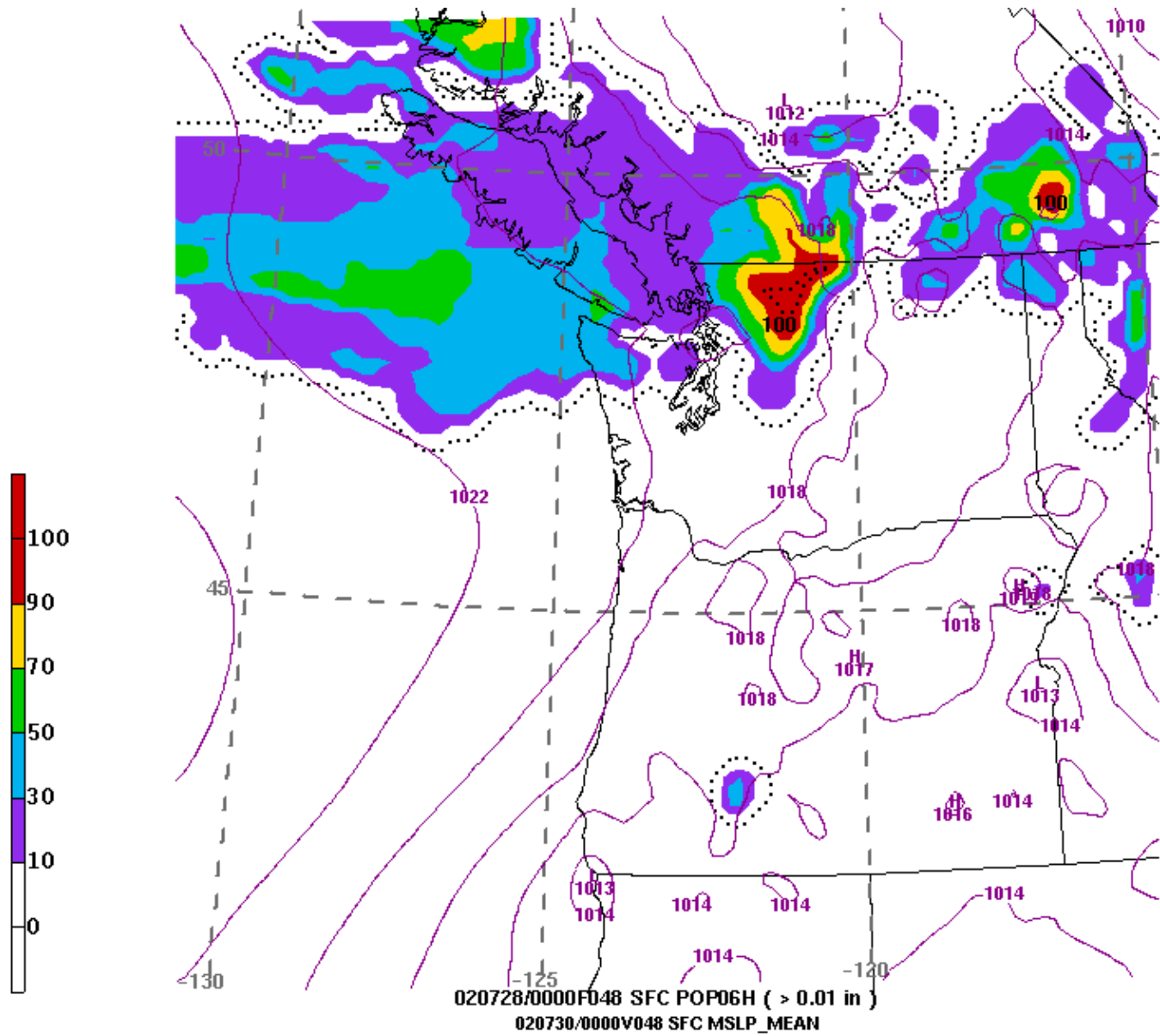
Probability of Accum Precip in 12h GT 0.01 in

Sea-Level Pressure (mb)



% Prob. RAINTOT above 25.0 hlnch, Init: 11/8/09 12:00 AM UTC (11/7/09 4:00 PM) Valid:11/9/09 4:00 AM to 11/9/09 4:00 PM PT
Weights: gfs=0.039 cmcg=0.336 eta=0.041 gasp=0.000 jma=0.082 ngps=0.148 tcwb=0.000 ukmo=0.354

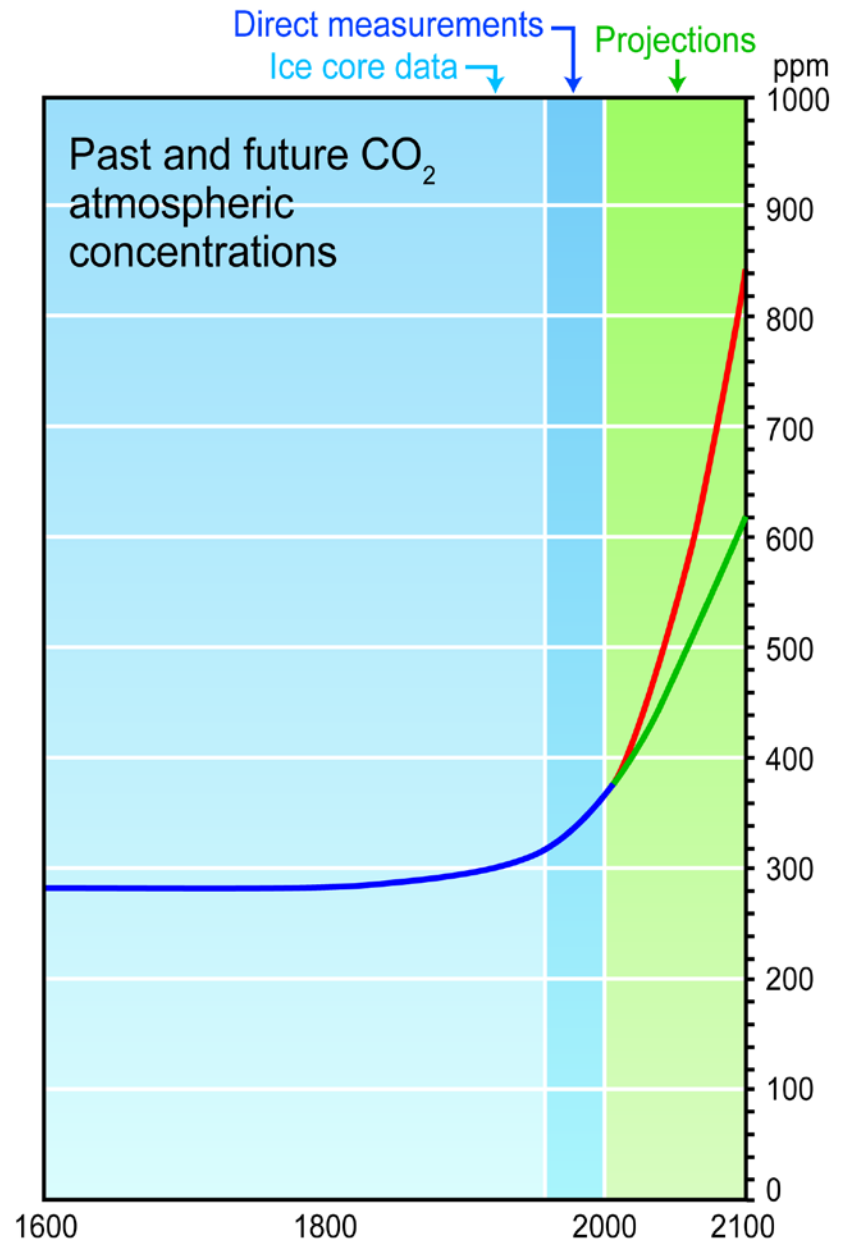




Ensemble-Based Probabilistic Products

Global Warming: What will be
the effects on Northwest
precipitation?

The Problem:
greenhouse
gases are
increasing

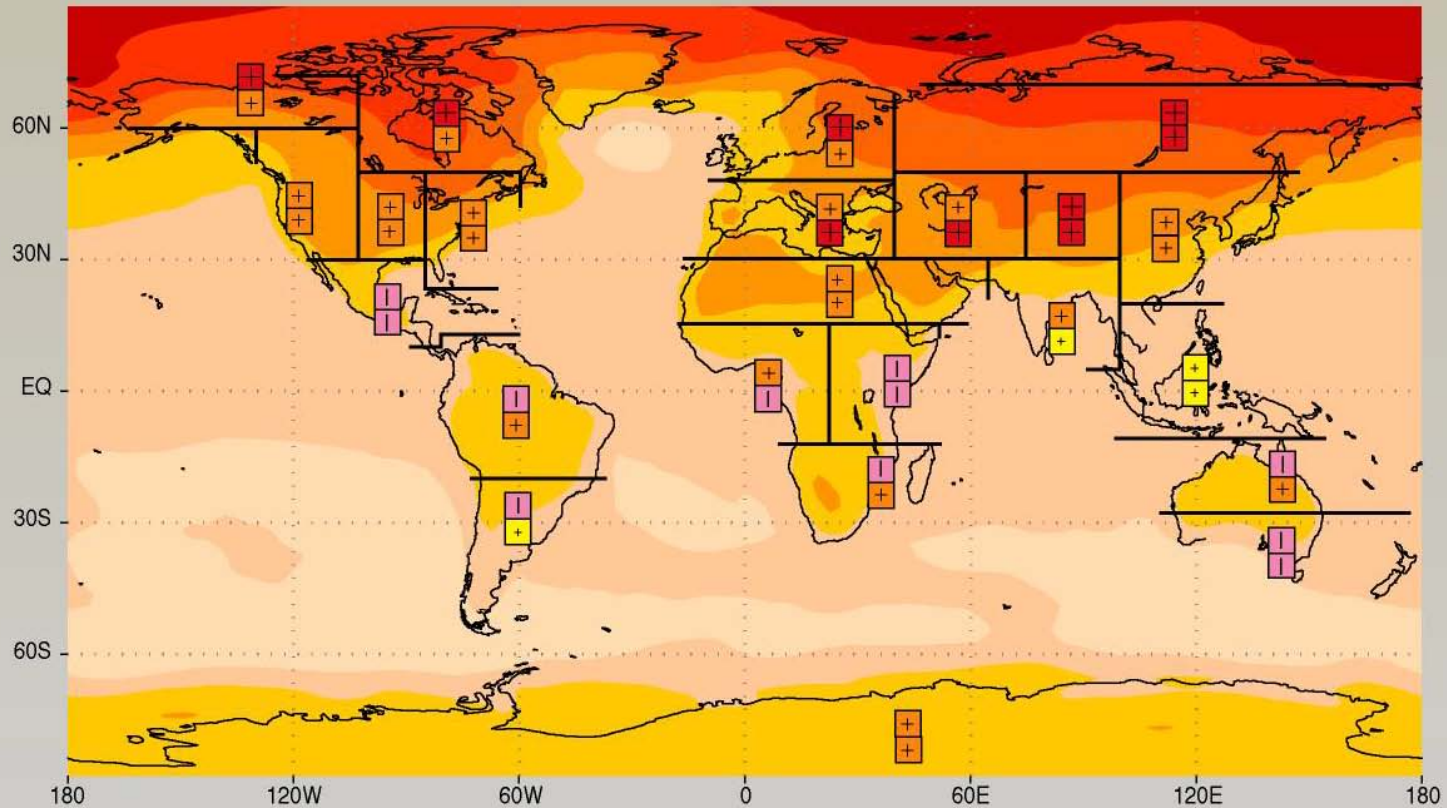


Key Forecasting Technology: General Circulation Models (GCMs)

- Basically low-resolution global numerical weather forecasting models, with gases allowed to change in time.
- Includes both atmosphere and ocean components.
- Uncertainties of model physics and in mankind's fossil fuel use.

Climate Model Output for 2100

Change in temperature for scenario A2

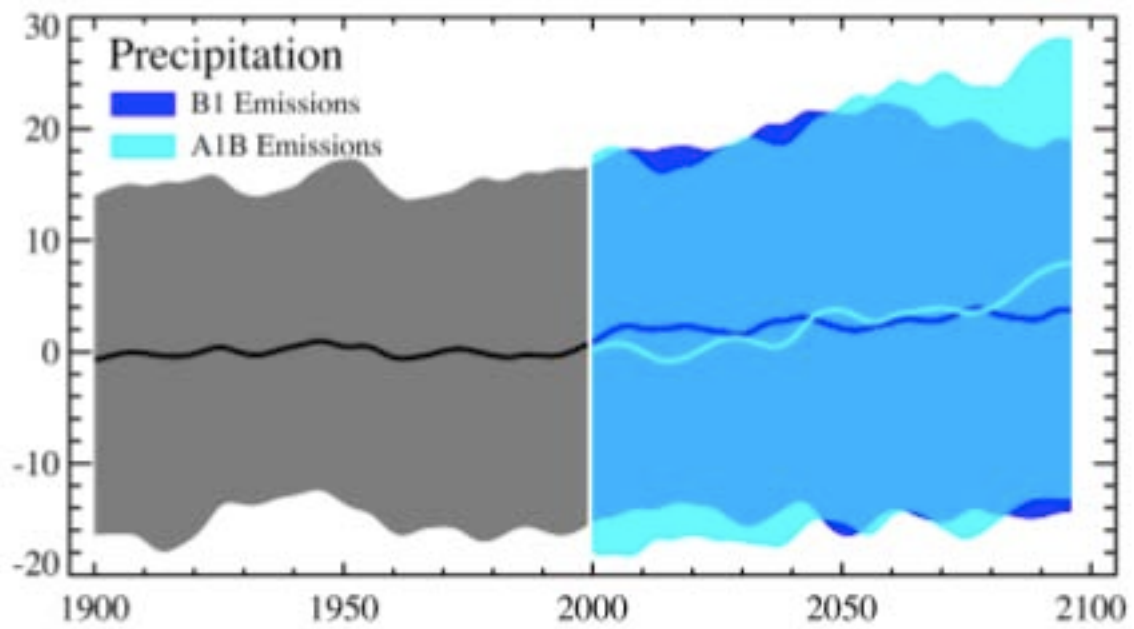


Change in temperature relative to model's global mean

- + Much greater than average warming
- + Greater than average warming
- + Less than average warming
- i Inconsistent magnitude of warming
- Cooling

Change in global mean temperature (°C)

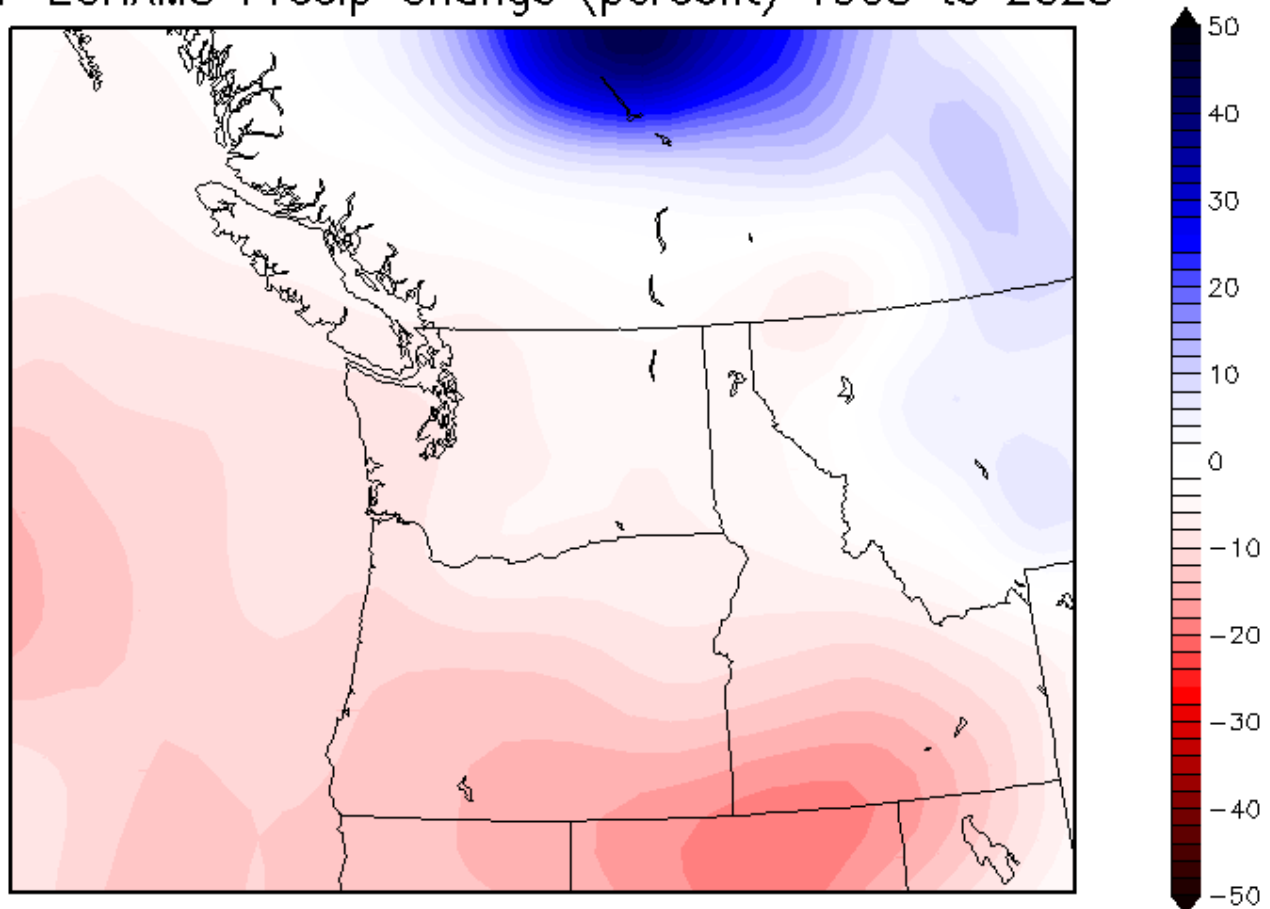




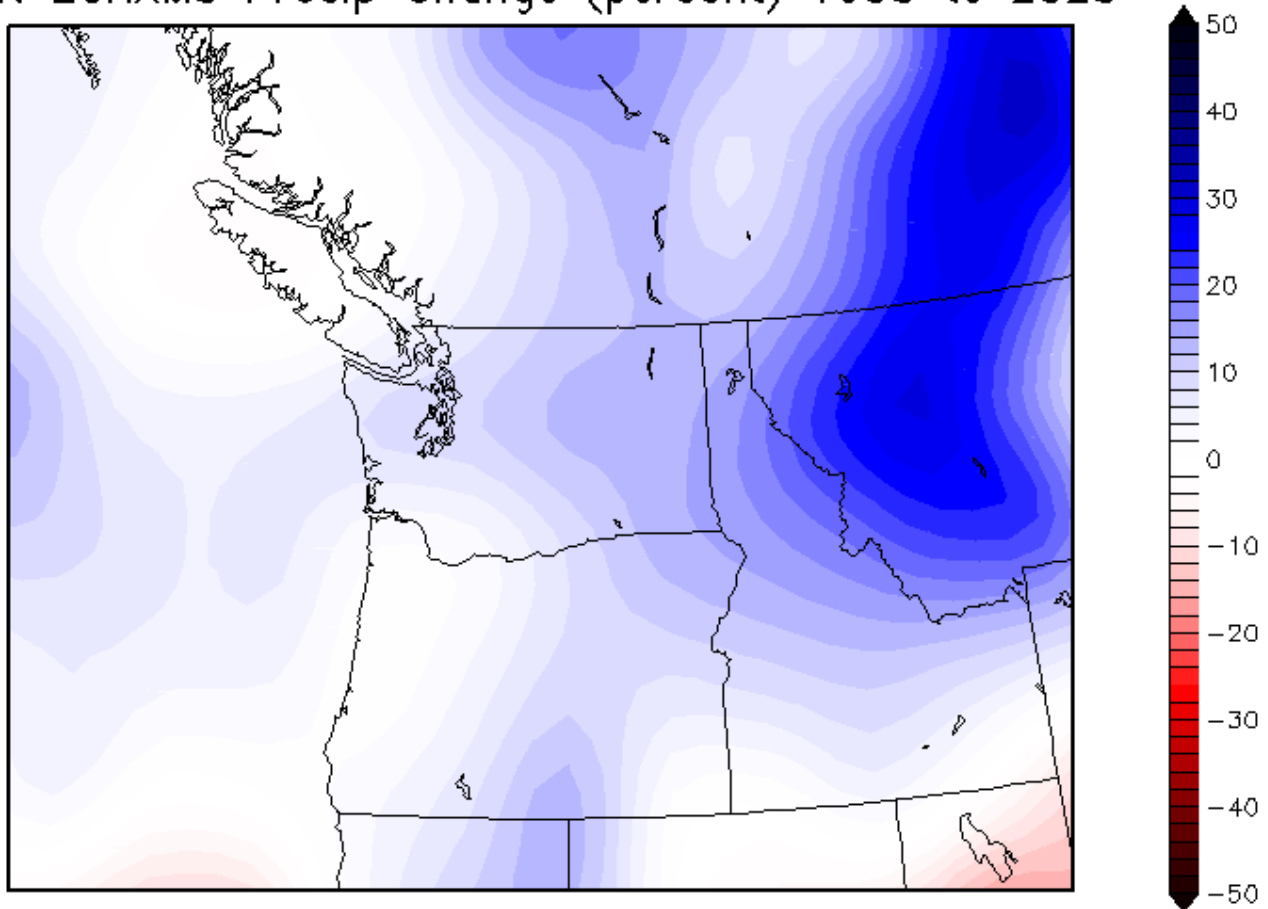
Implications for Water Resources in the NW

QuickTime™ and a
decompressor
are needed to see this picture.

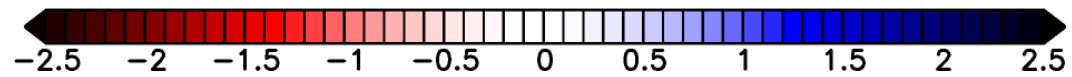
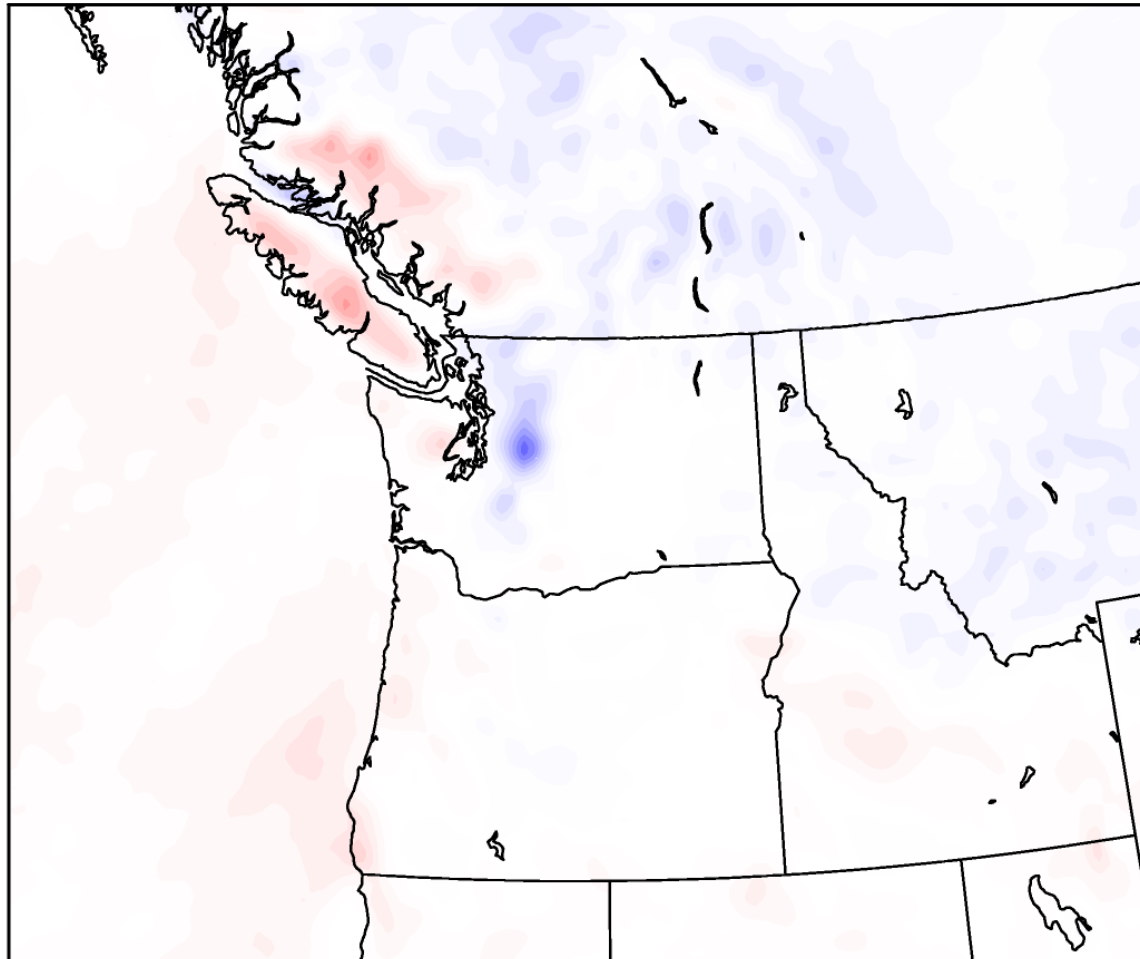
DJF ECHAM5 Precip Change (percent) 1995 to 2025



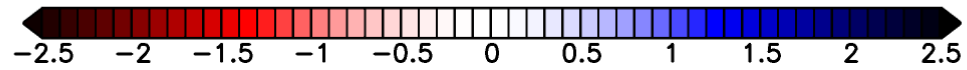
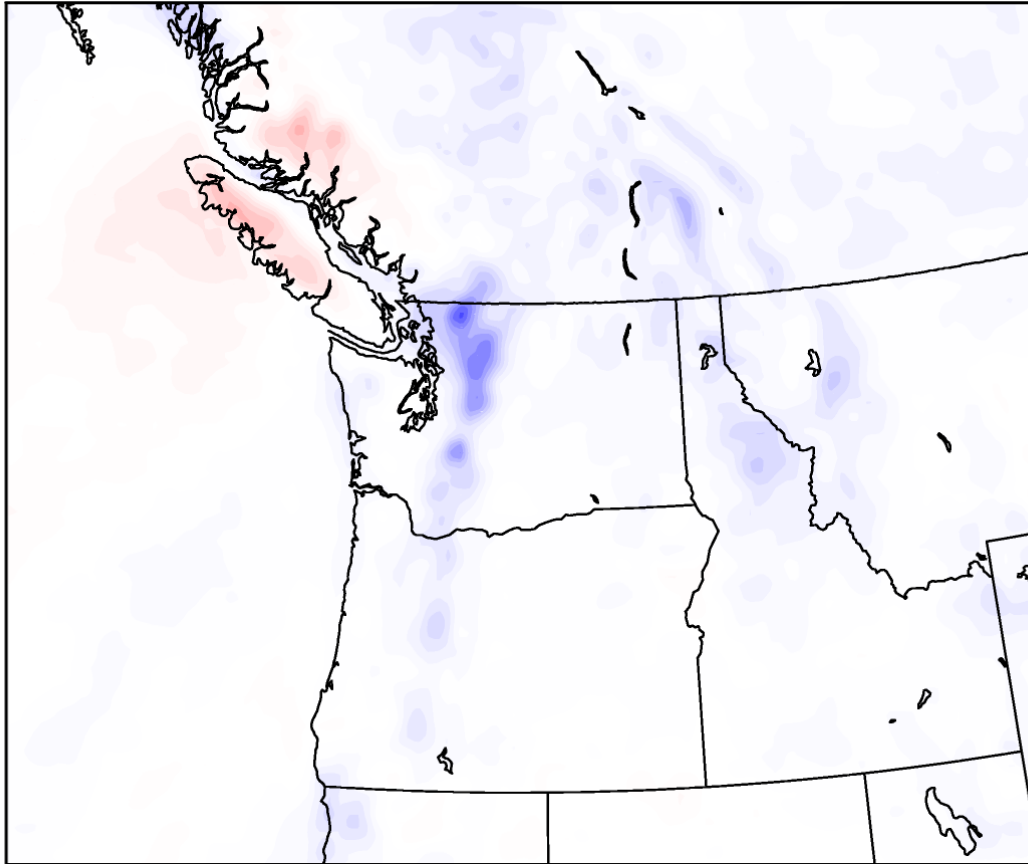
SON ECHAM5 Precip Change (percent) 1995 to 2025



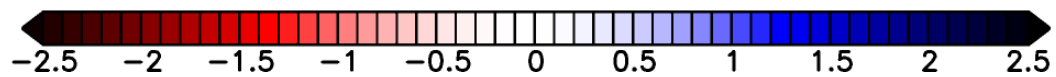
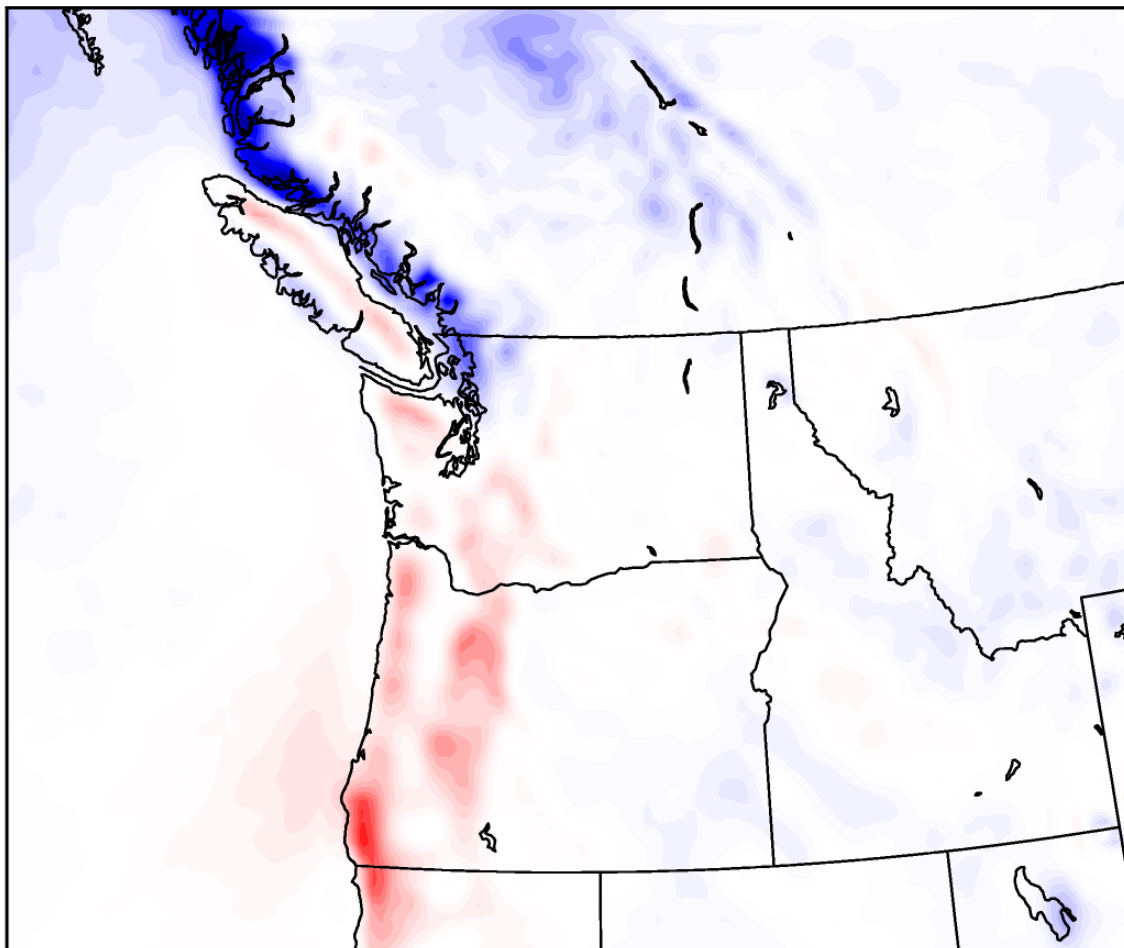
range 1990s to 2020s Annual Total Precip (mm/da)



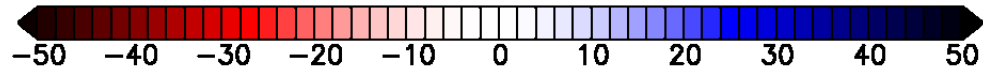
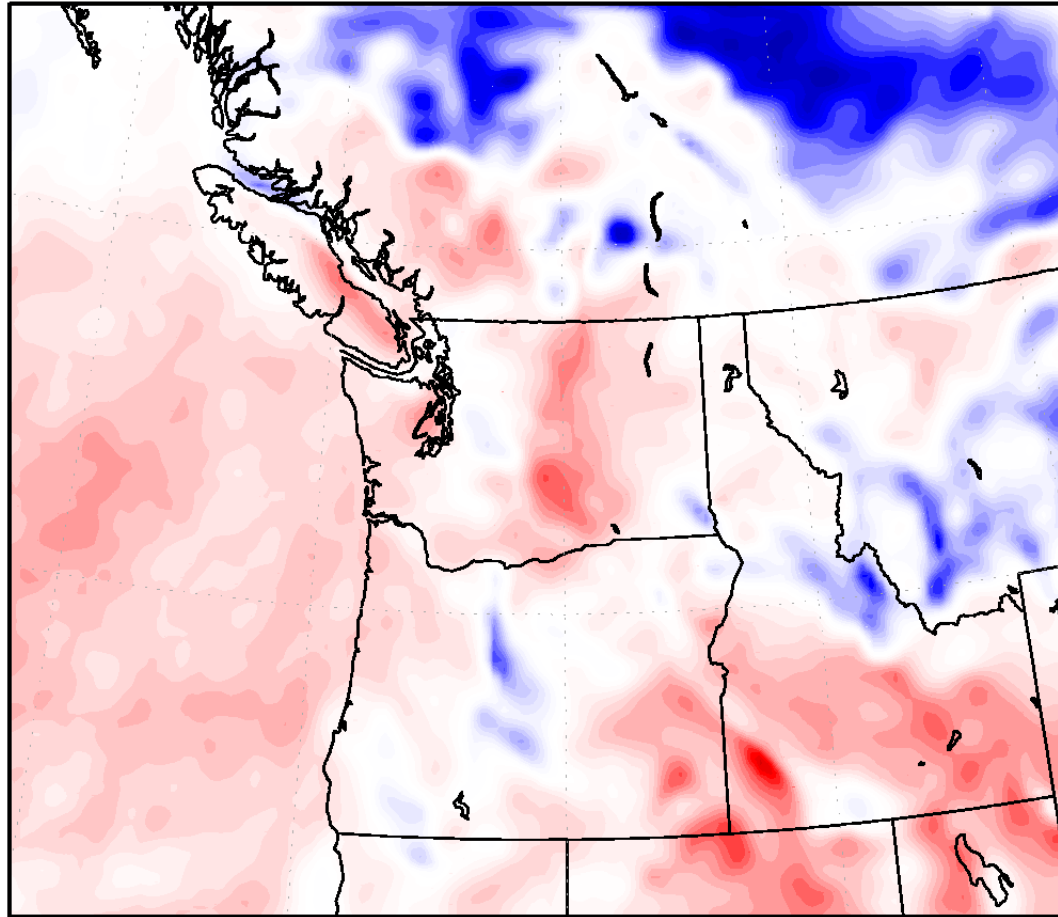
range 1990s to 2050s Annual Total Precip (mm/da:



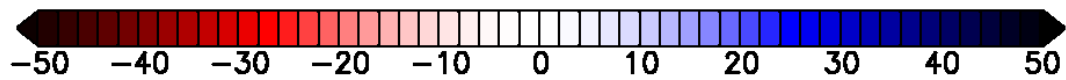
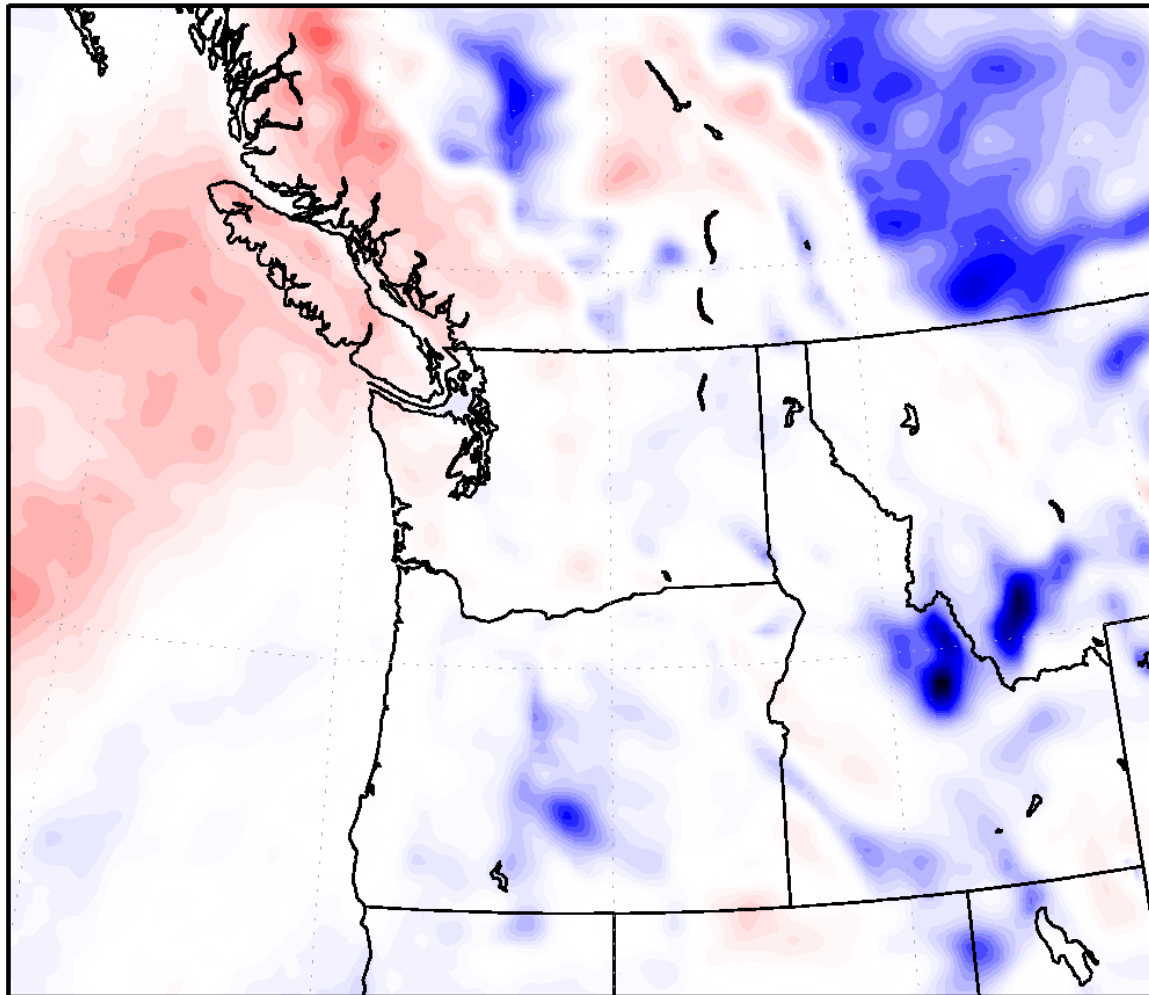
range 1990s to 2090s Annual Total Precip (mm/da)



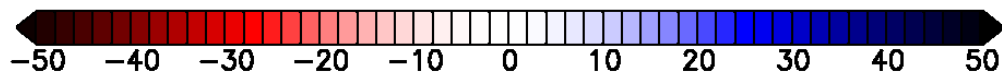
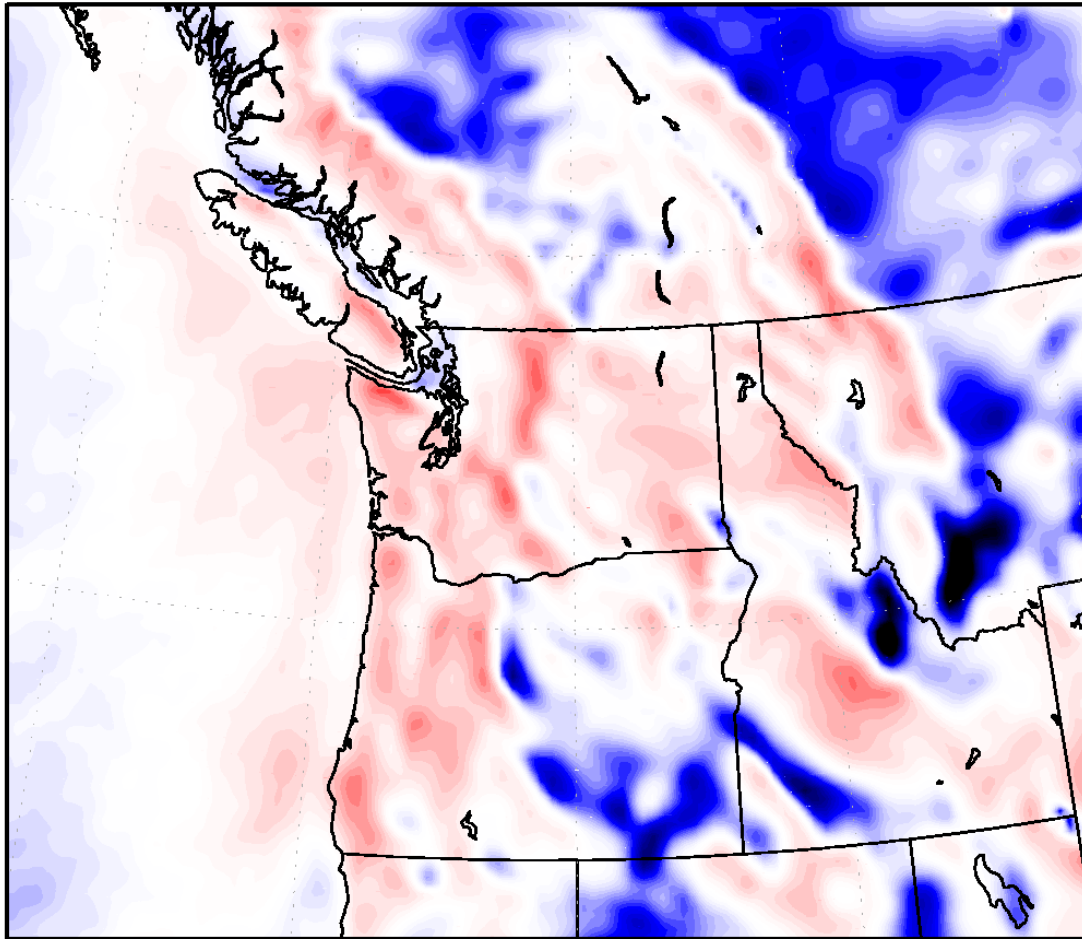
Percent Change 1990s to 2020s DJF Total Precip



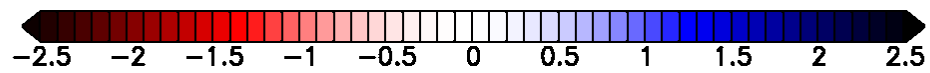
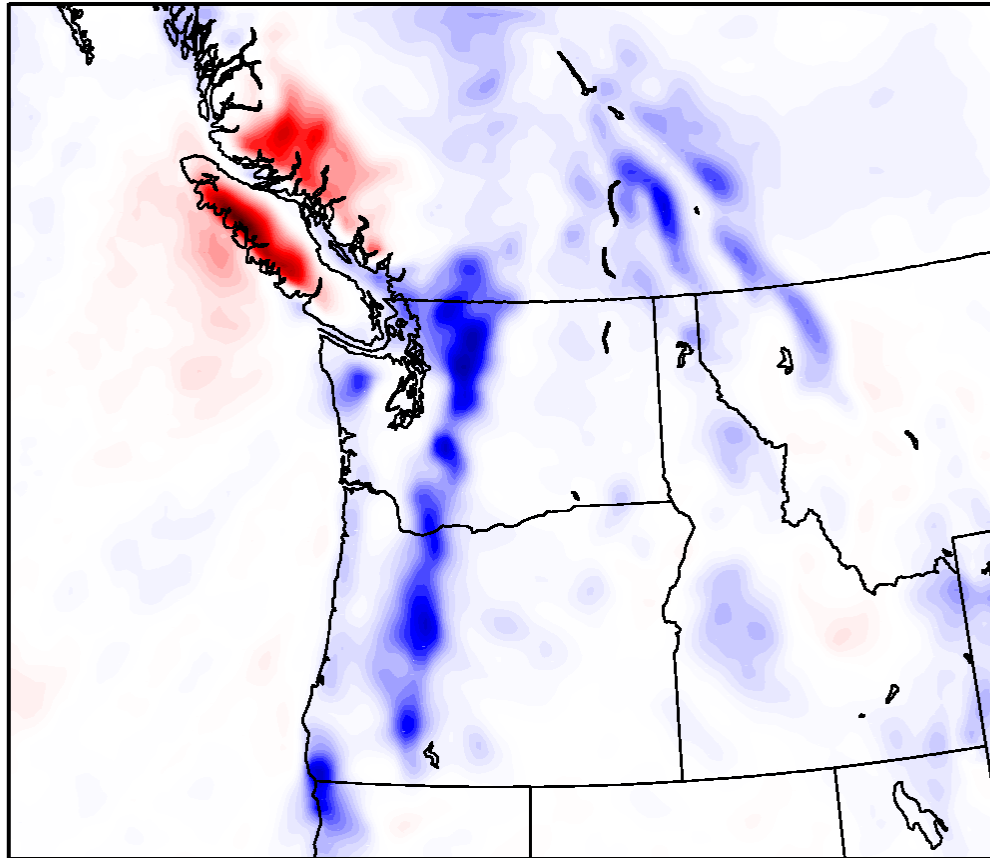
Percent Change 1990s to 2050s DJF Total Precip



Percent Change 1990s to 2090s DJF Total Precip



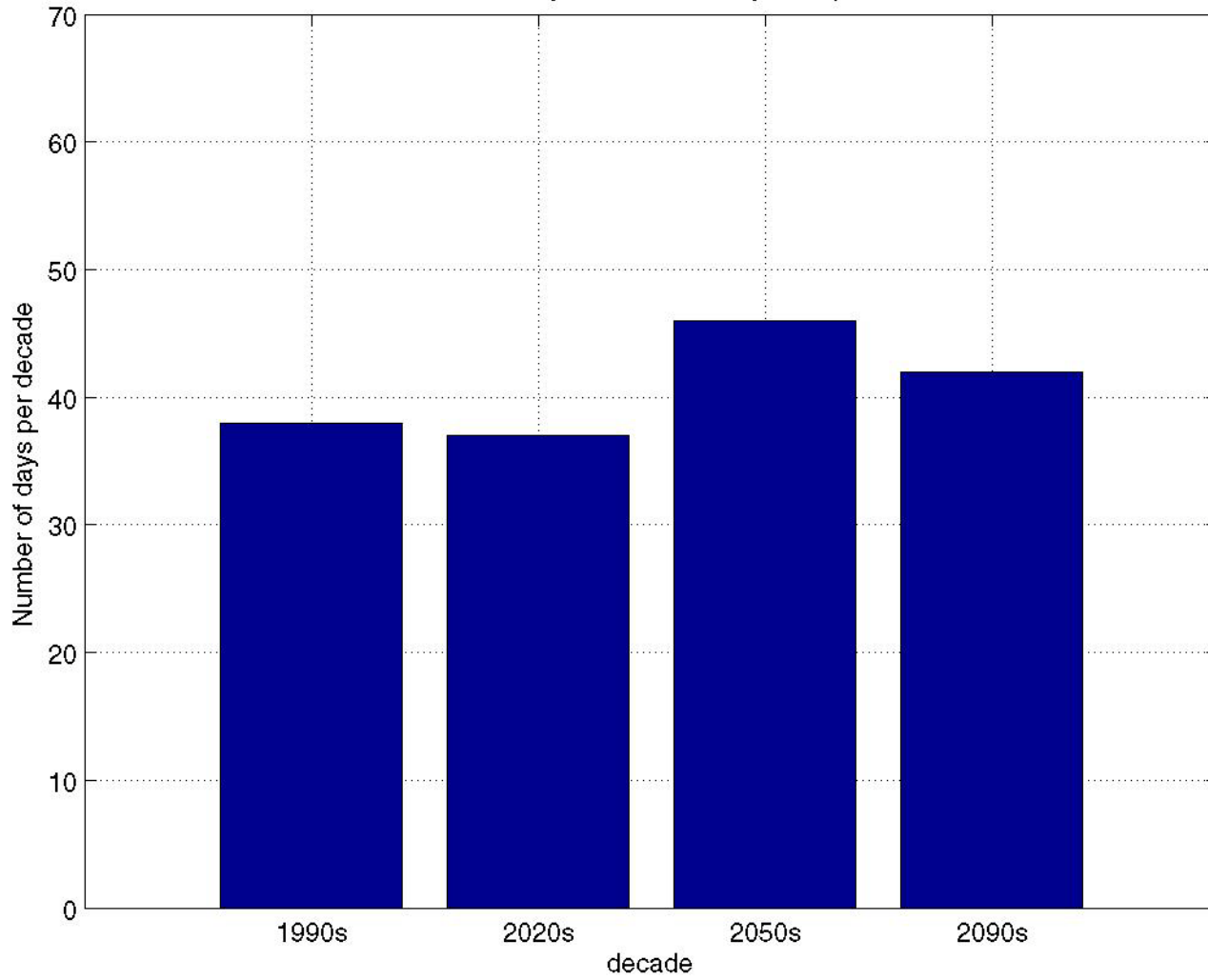
Change 1990s to 2050s SON Total Precip (mm/day)



Bottom Line

- No major change in annual precipitation
- November rainfall up, rest of the winter down
- But plenty of uncertainties in these predictions
- Freezing level moving up, so higher percentage of precipitation will be rain at mid-levels on the mountains.
- Changes in extreme precipitation are highly uncertain.

Number of Wintertime Days with Total Daily Precip >2cm at SeaTac



Extreme Precipitation

- There is no consistent result among the various regional climate model simulations.
- With the jet stream and atmospheric rivers/pineapple expresses going north, could even decline.

The end

Cascade snowpack hasn't changed in the last 30 years

