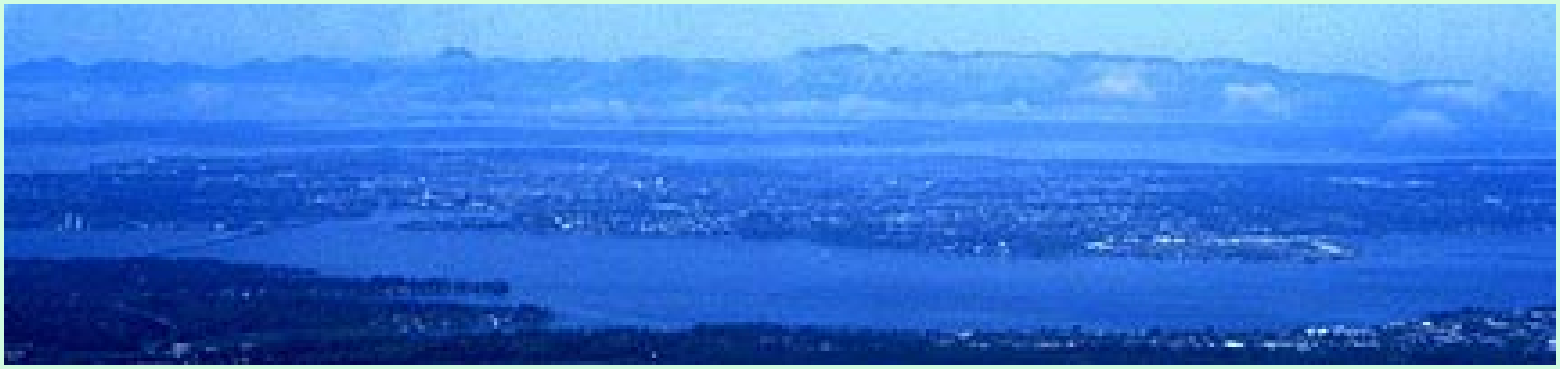
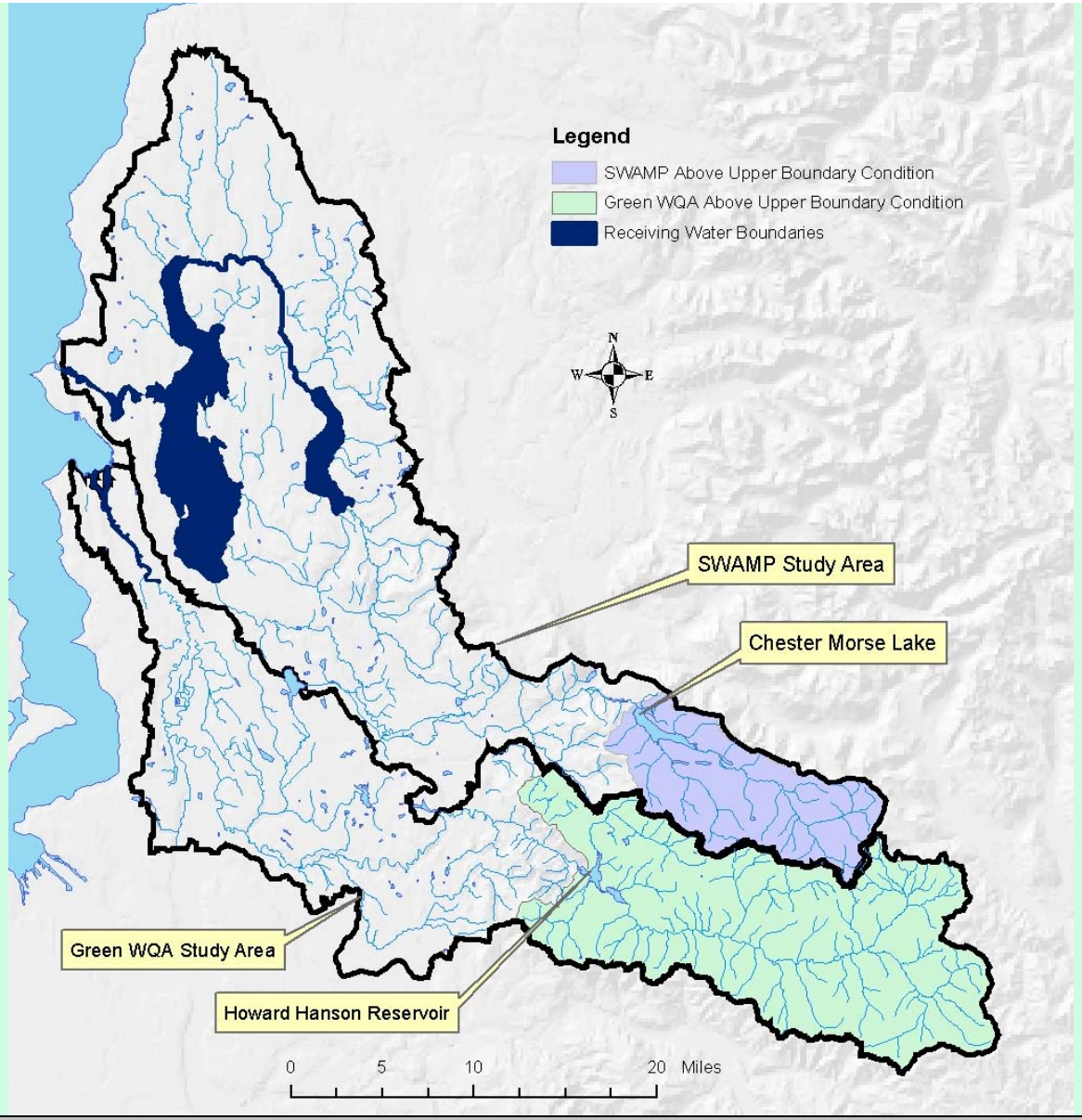
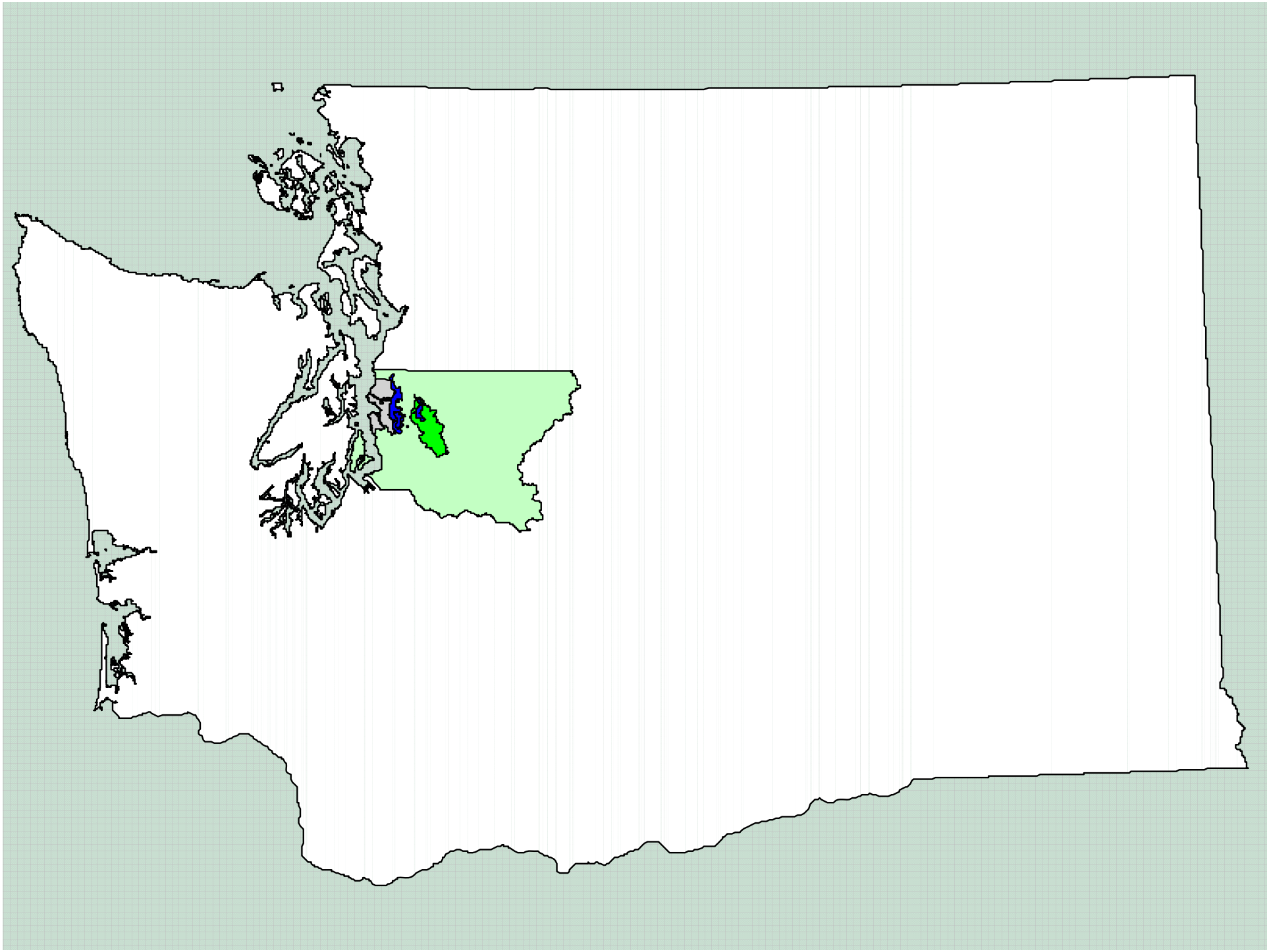


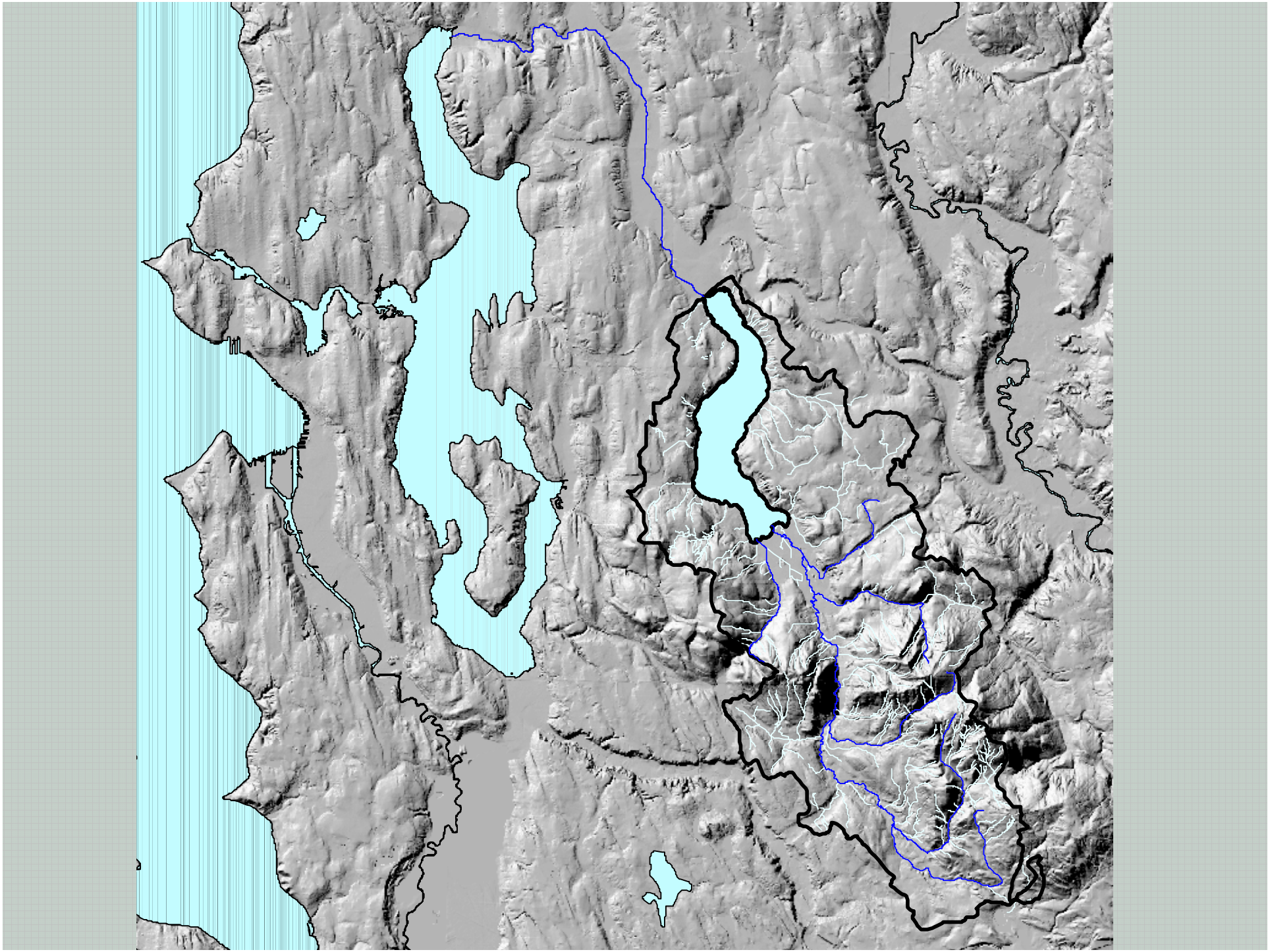
Development of a 3-D Hydrodynamic Model for Lake Sammamish

Curtis DeGasperi
King County DNRP, WLRD
Science Seminar
November 23, 2004



King County's Freshwater Program (formerly SWAMP and GDWQA)





Lakes Background - Washington

	Metric	English
Drainage Basin Area	1,274 km^2	314,800 ac
Cedar Basin	495 km^2	122,300 ac
Lake Surface Area	87.6 km^2	21,500 ac
Lake Volume	$2.9x10^9$ m^3	$2.35x10^6$ ac-ft
Mean Depth	33 m	108 ft
Maximum Depth	65.2 m	214 ft
Mean Residence Time	2.3 years	

Lakes Background - Sammamish

	Metric	English
Drainage Basin Area	230 km^2	57,000 ac
Issaquah Basin	145 km^2	35,600 ac
Lake Surface Area	19.8 km^2	4,900 ac
Lake Volume	$3.5x10^8$ m^3	283,860 ac-ft
Mean Depth	17.7 m	58 ft
Maximum Depth	32 m	105 ft
Mean Residence Time	1.8 years	

Model Selection

Lakes

CH3D

CE-QUAL-ICM

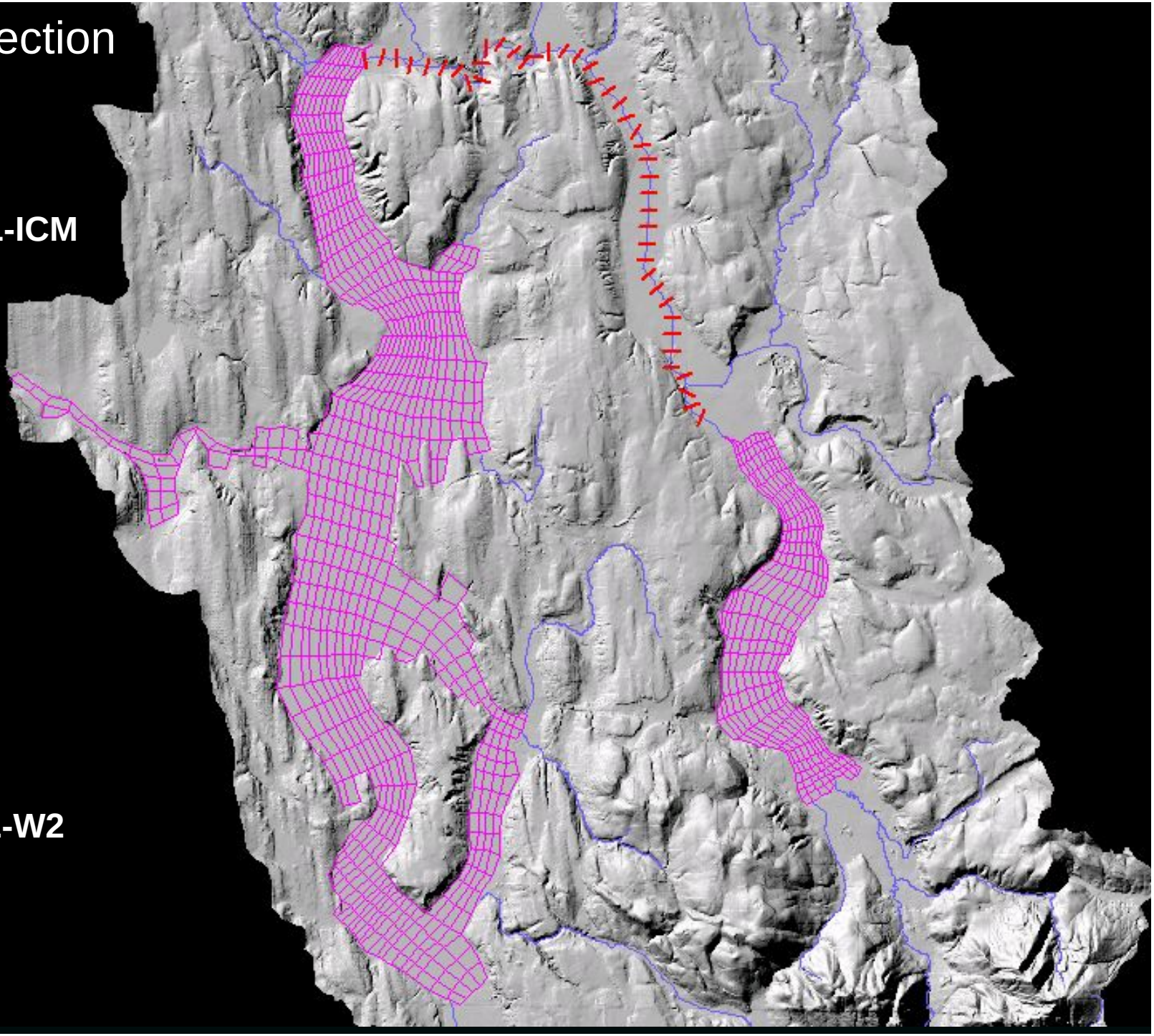
Watershed

HSPF

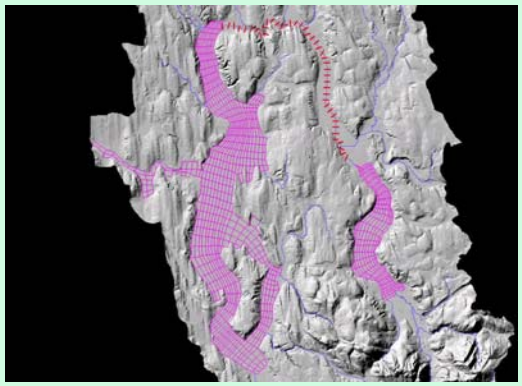
UrbanSim

River

CE-QUAL-W2



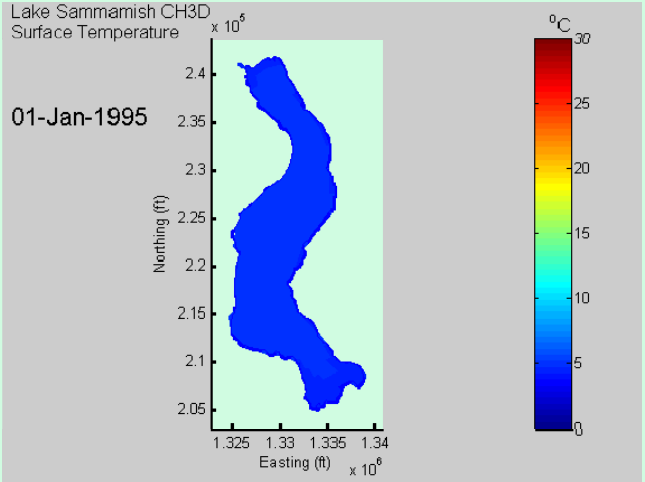
Lake Models Background

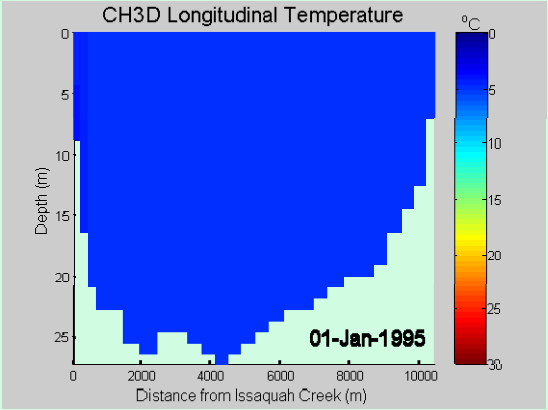


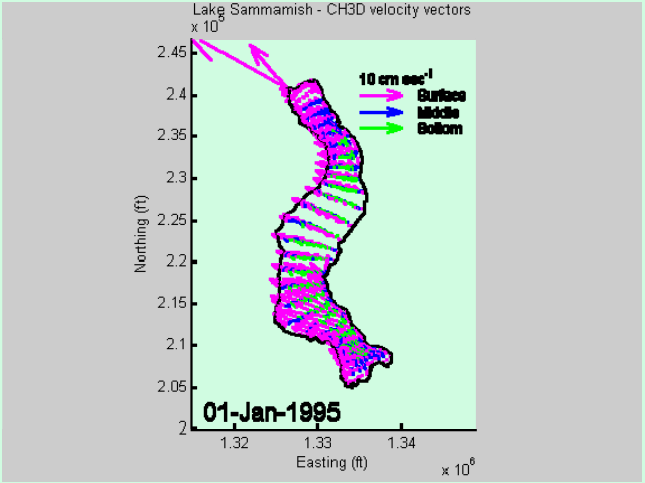
- Initially developed for Chesapeake Bay
- ACOE-ERDC set up and calibrate Lake Washington models
- King County set up and calibrate Lake Sammamish models

CH3D Model

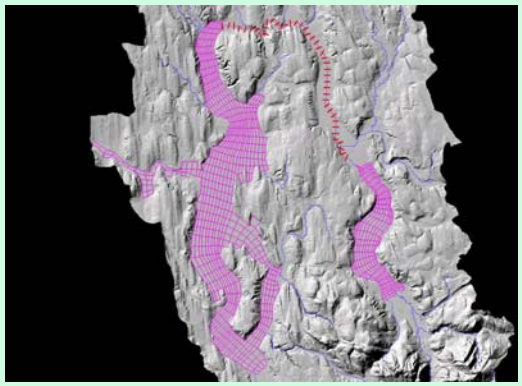
- 3-D model
- Temperature
- Salinity
- Horizontal and vertical velocity





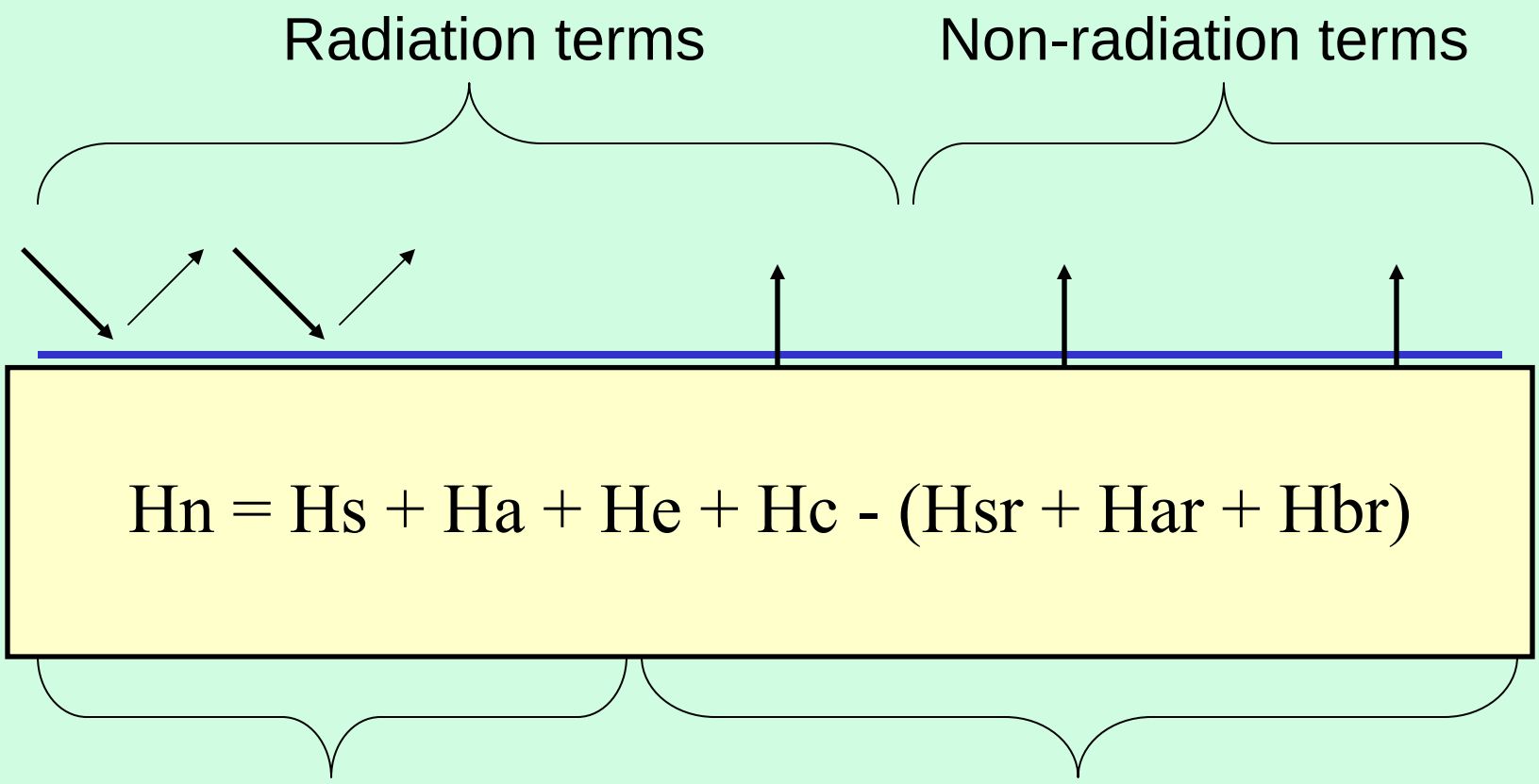


ACOE-ERDC Lake Washington CH3D Model



- Boundary fitted z-coordinate grid
- k-ε turbulence closure scheme (Rodi 1980)
- Heat exchange confined to surface layer
- Externally processed Equilibrium Temperature (ET) heat exchange
- Solar radiation calculated in ET program
- Simple convective vertical mixing scheme

Temperature Modeling



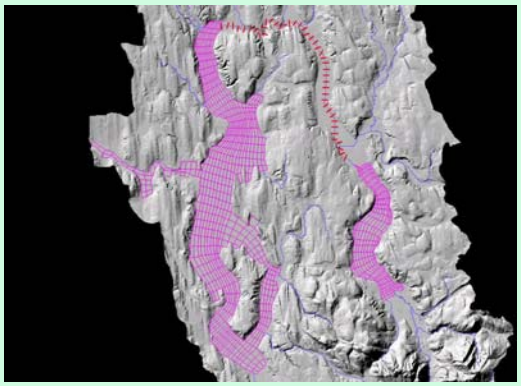
Equilibrium Temperature

- Conceptually simple
- Computation may be performed externally
- Closed-form analytical solution
- Assumes heat loss is linearly related to water temperature

$$H_{aw} = -K_{aw}(T_w - T_e)$$

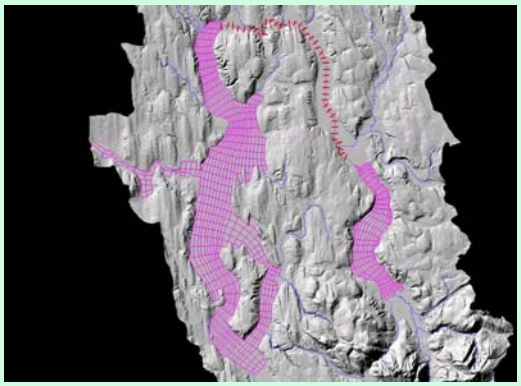
James Martin and Steven McCutcheon. 1999. Hydrodynamics and Transport for Water Quality Modeling. page 372.

Model Setup



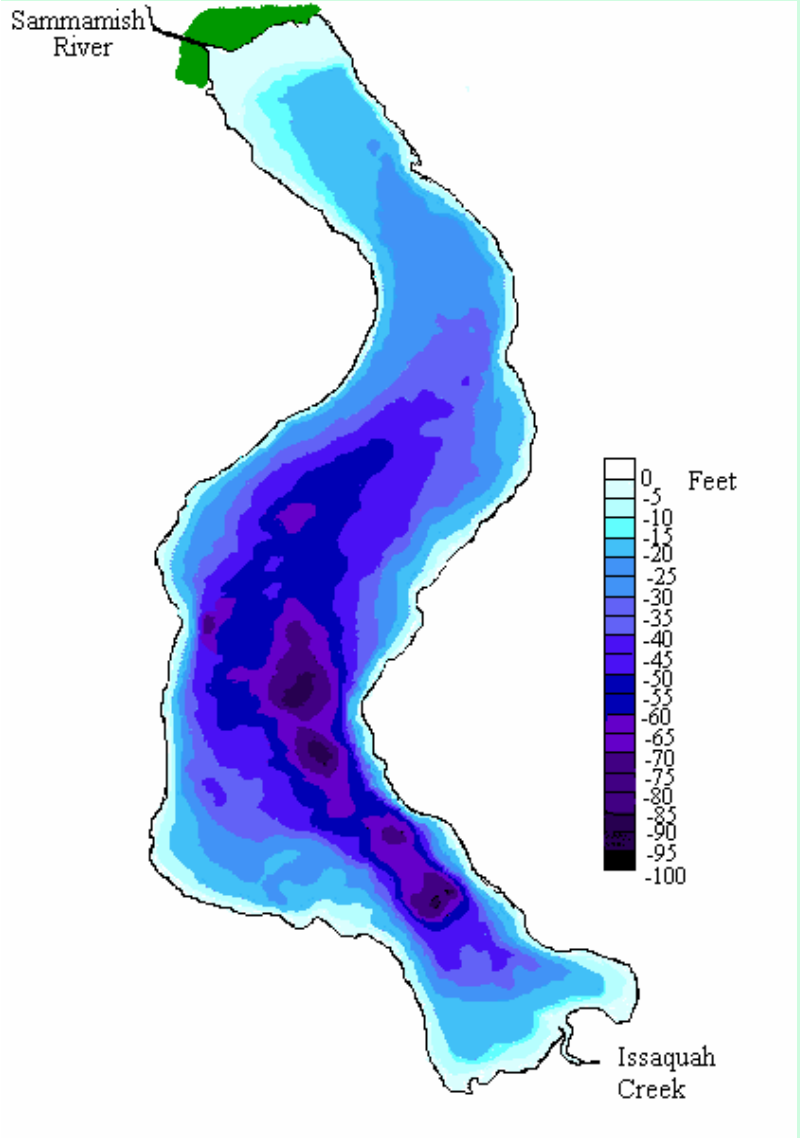
- Bathymetry
- Meteorology
- Constituent Inputs (trib/precip)

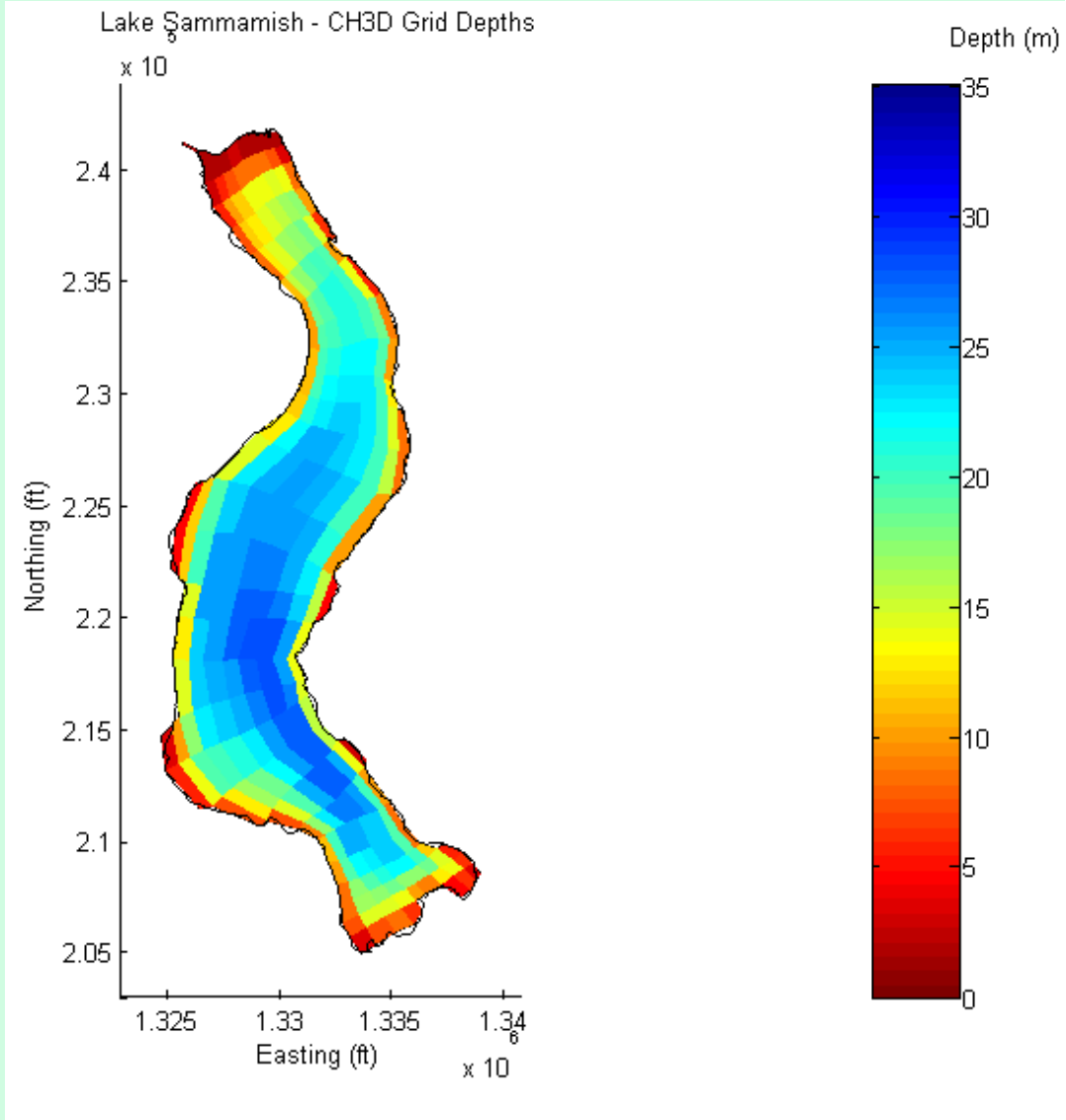
Data Sources



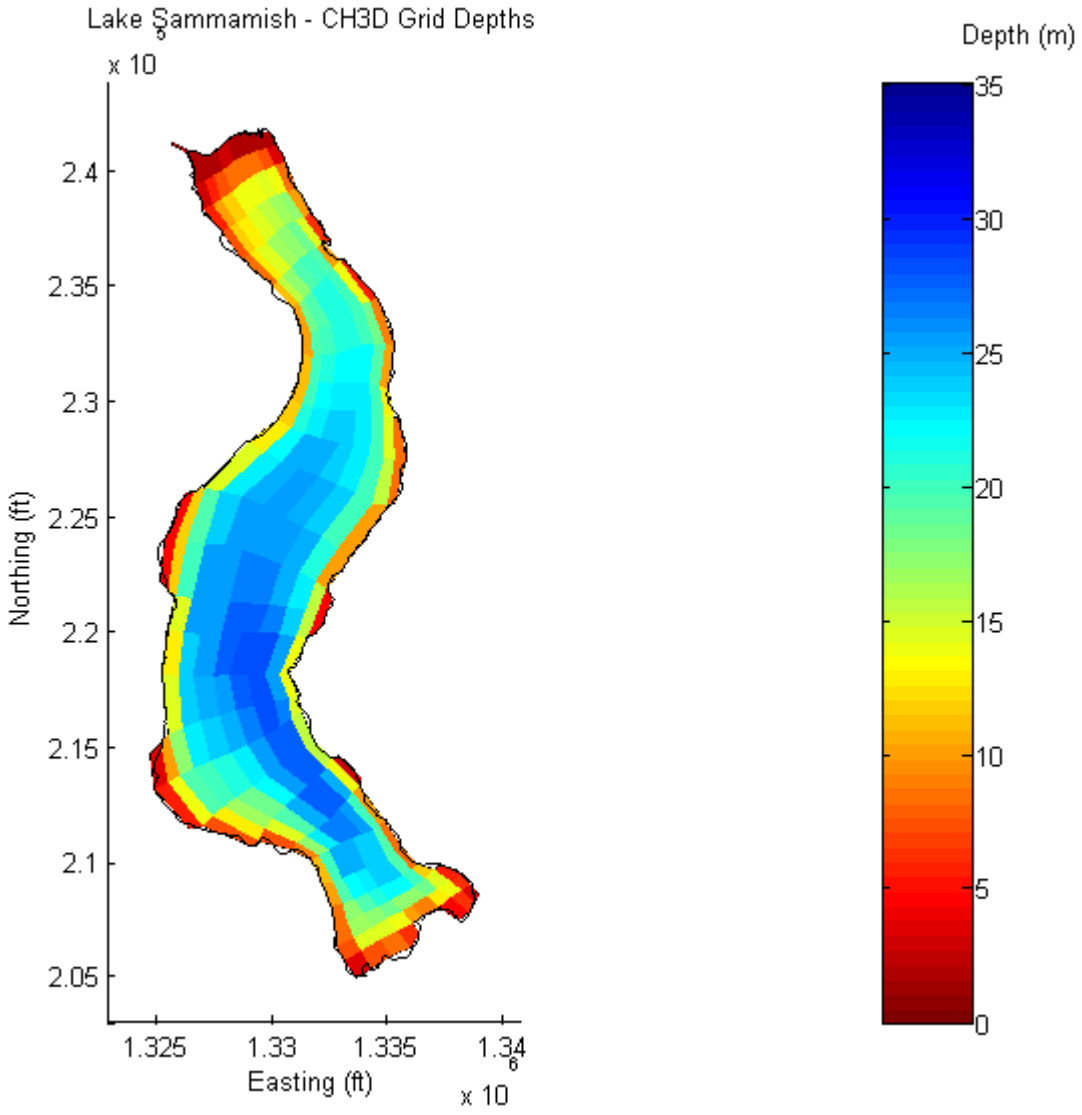
- Bathymetry (JC Headwaters/King County)
- Meteorology (Sea-Tac/Sand Point)
- Hydrology and stream temperature (WLRD, USGS)
- Water quality data (WLRD)
- Lake water surface elevations (USGS/ACOE)

Bathymetry


Sammamish River
Issaquah Creek
Feet
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
-90
-95
-100


Lake Sammamish - CH3D Grid Depths
x 10^6
2.4
2.35
2.3
2.25
2.2
2.15
2.1
2.05
Northing (ft)
1.325
1.33
1.335
1.34
Easting (ft)
x 10^6
Depth (m)
35
30
25
20
15
10
5
0

Lake Sammamish Grid



4,283 cells

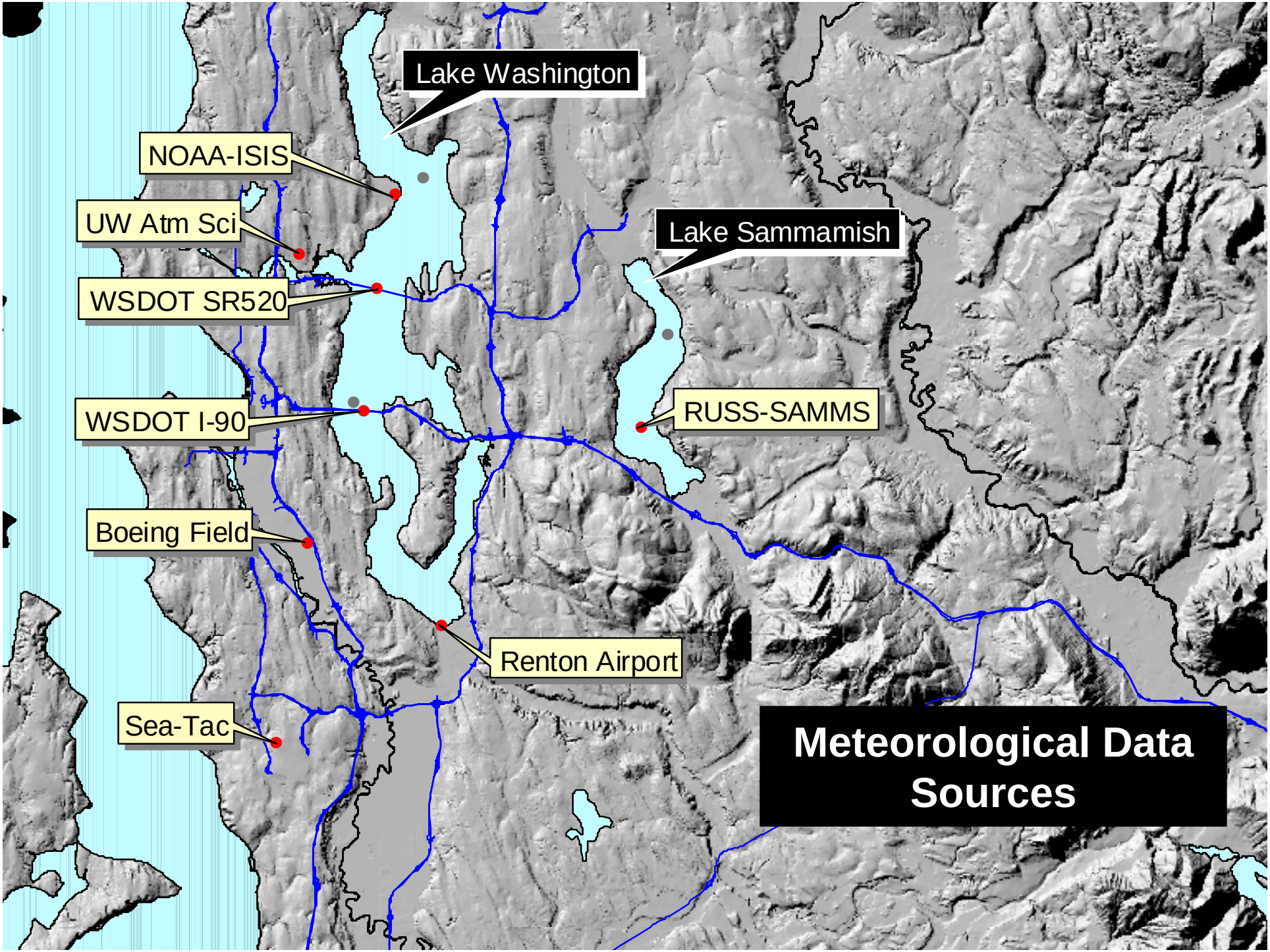
249 surface cells

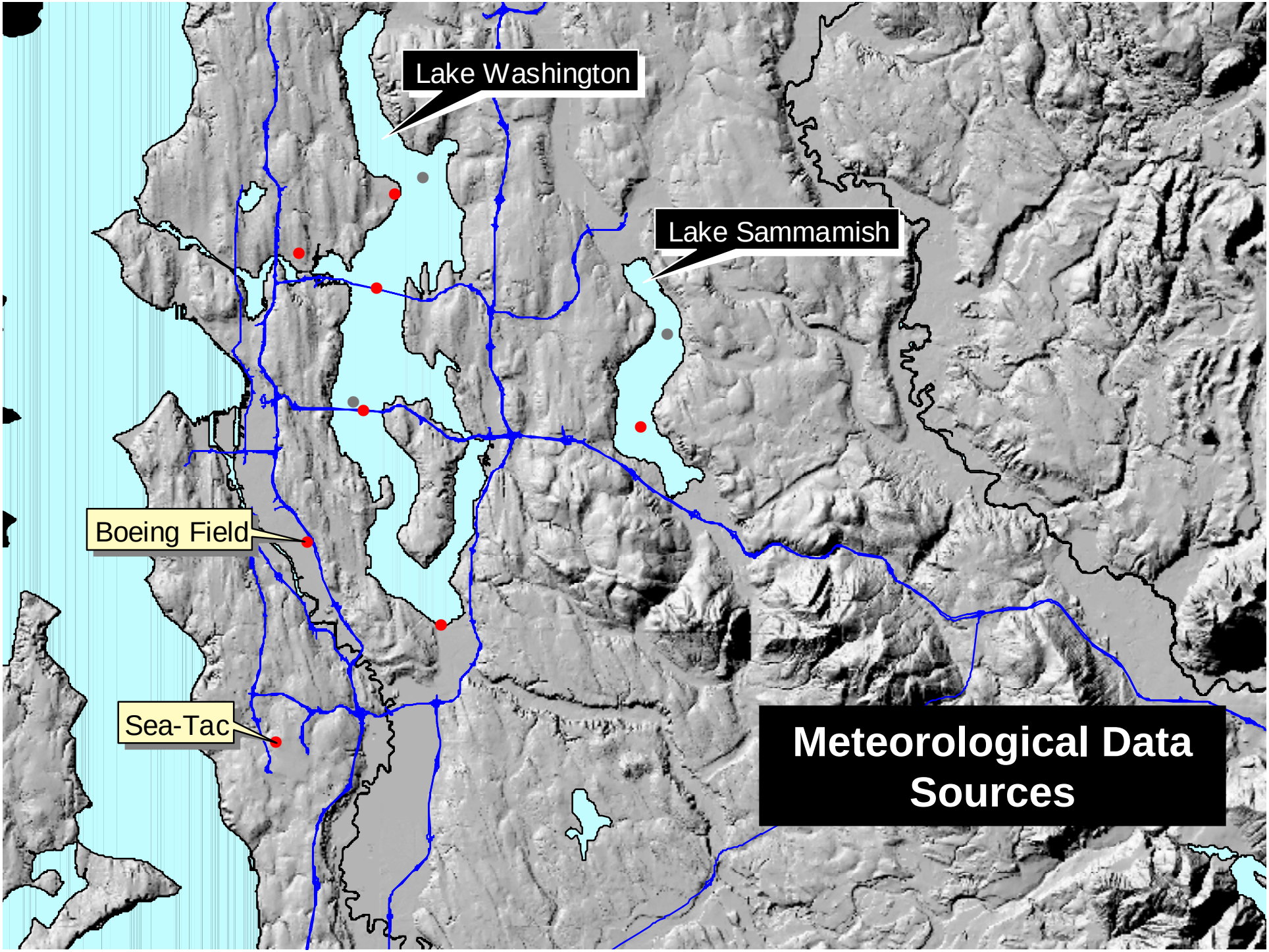
30 layers

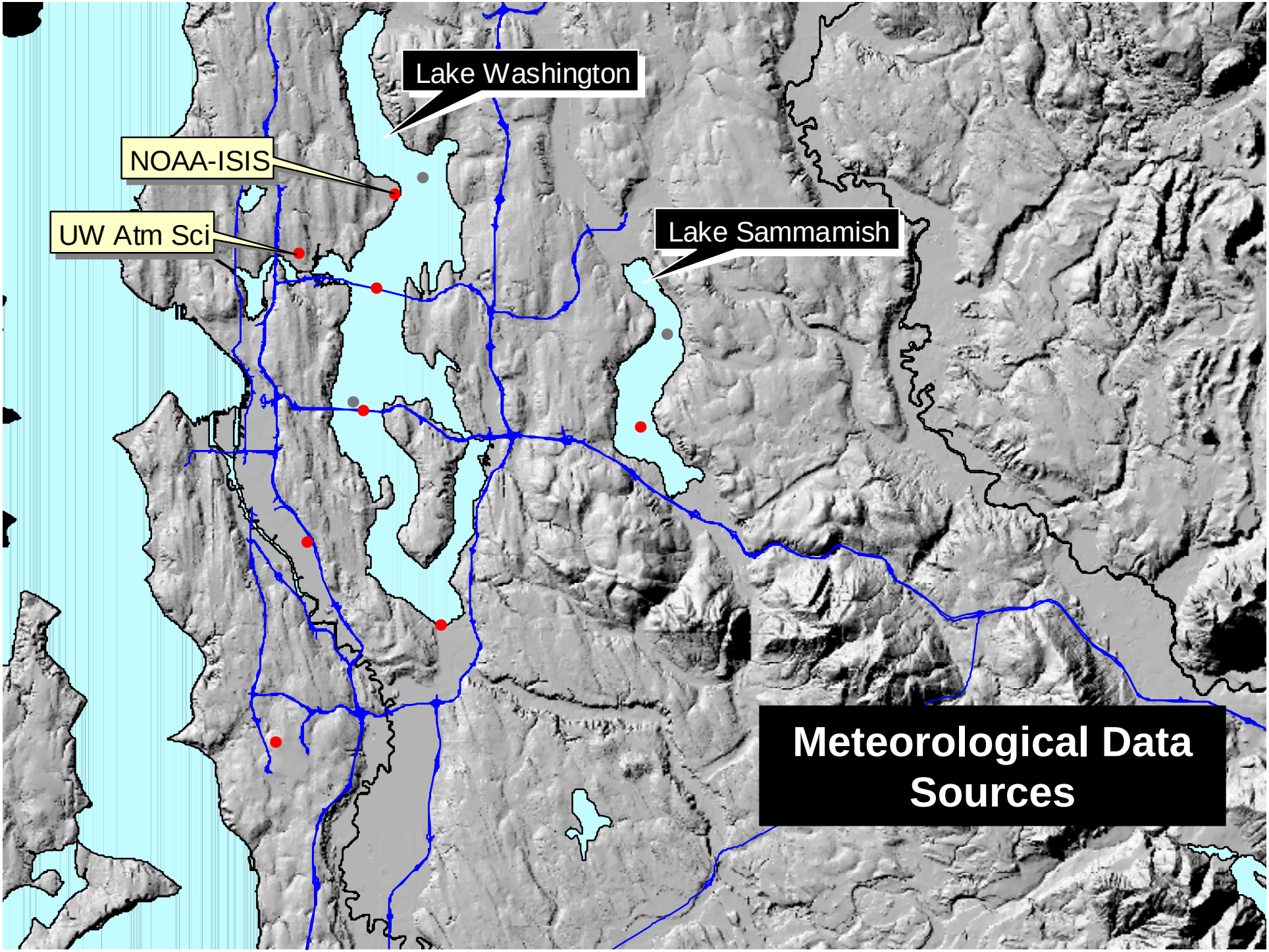
layers 3 feet (0.91 m) thick

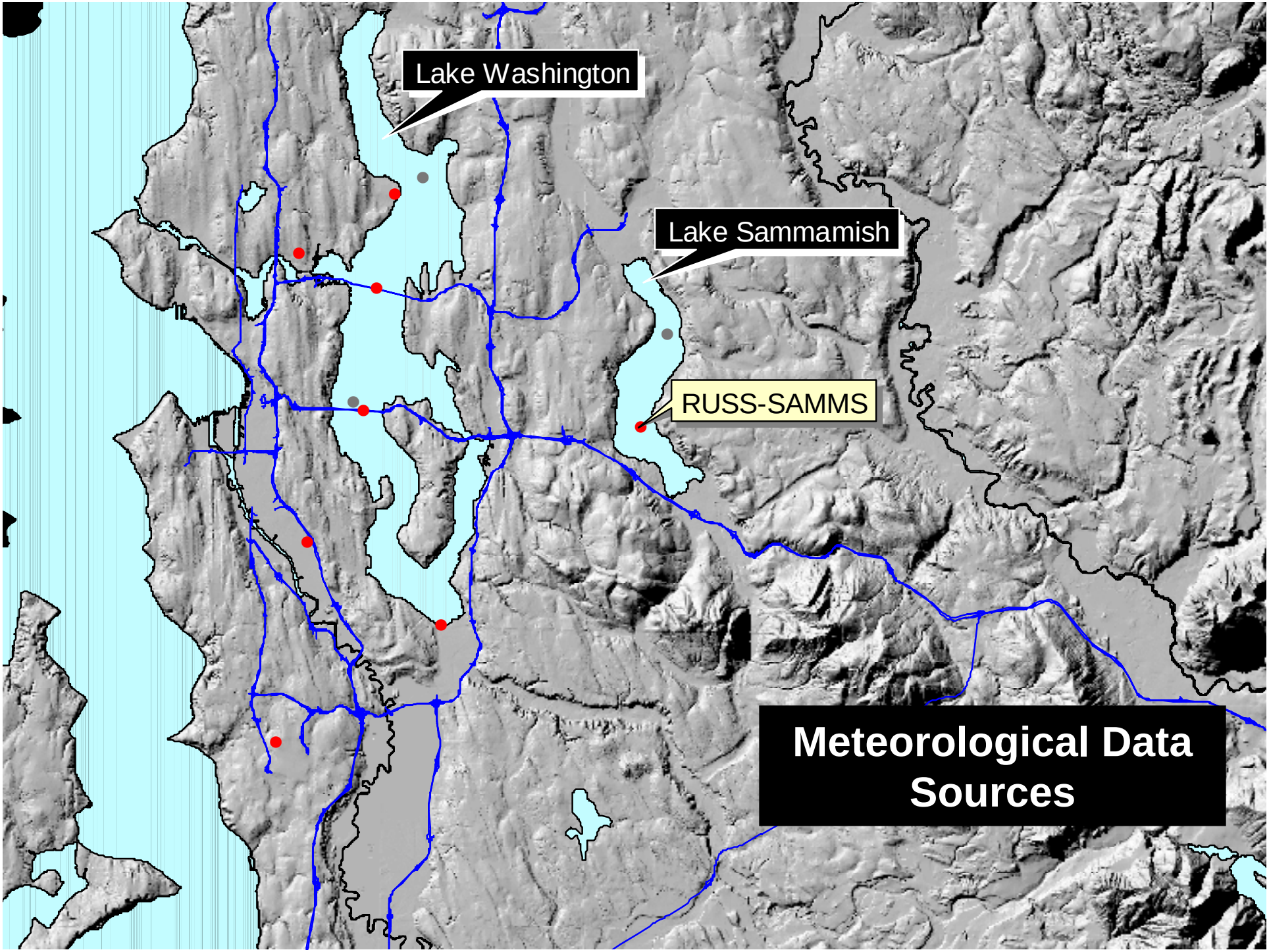
Average cell area 0.08 km^2 (19.8 ac)

Average cell length 280 m (920 ft)


Lake Washington
NOAA-ISIS
UW Atm Sci
WSDOT SR520
Lake Sammamish
WSDOT I-90
RUSS-SAMMS
Boeing Field
Renton Airport
Sea-Tac
Meteorological Data Sources


Lake Washington
Lake Sammamish
Boeing Field
Sea-Tac
Meteorological Data Sources


Lake Washington
NOAA-ISIS
UW Atm Sci
Lake Sammamish
Meteorological Data Sources

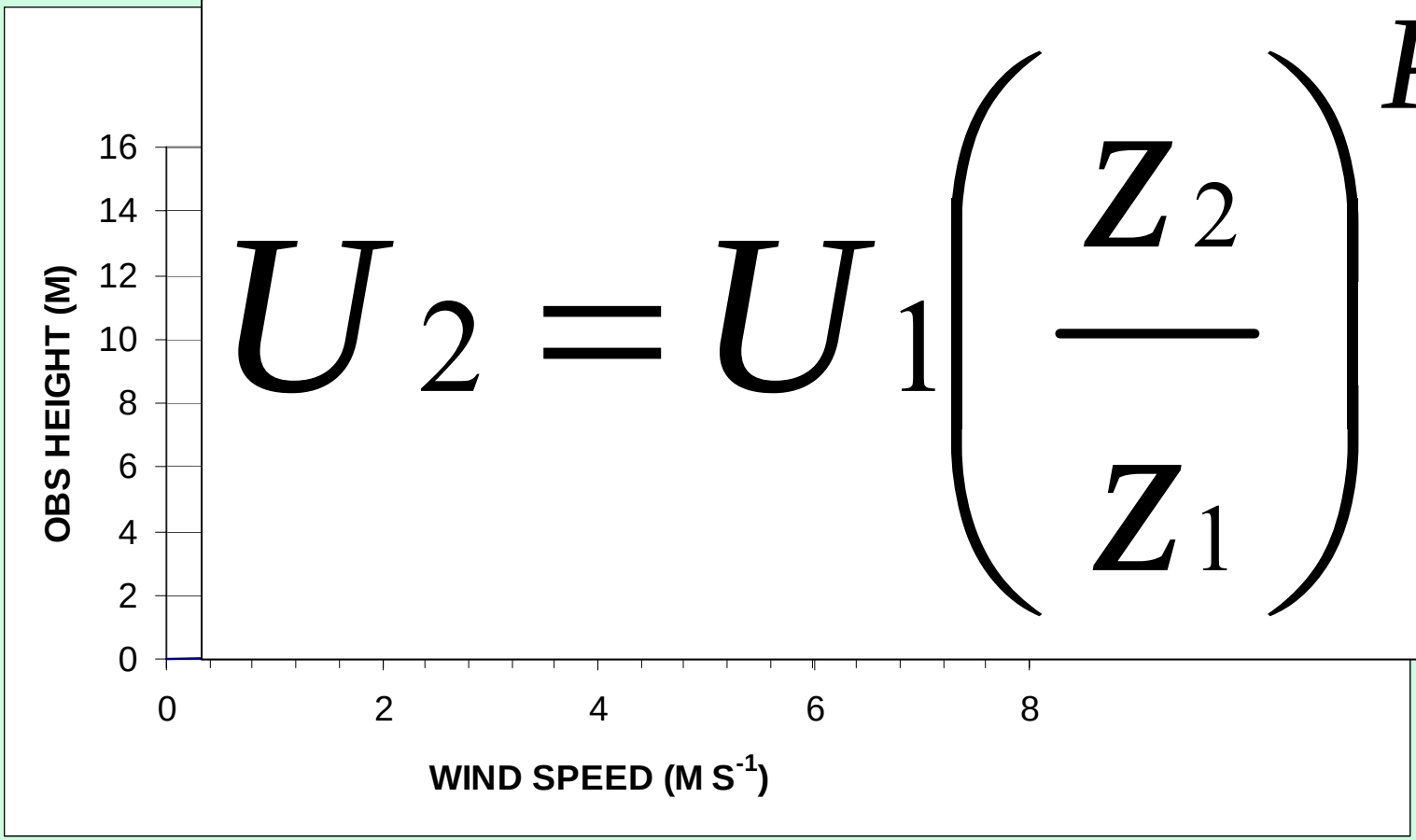

Lake Washington
Lake Sammamish
RUSS-SAMMS
Meteorological Data Sources


2003. 10.

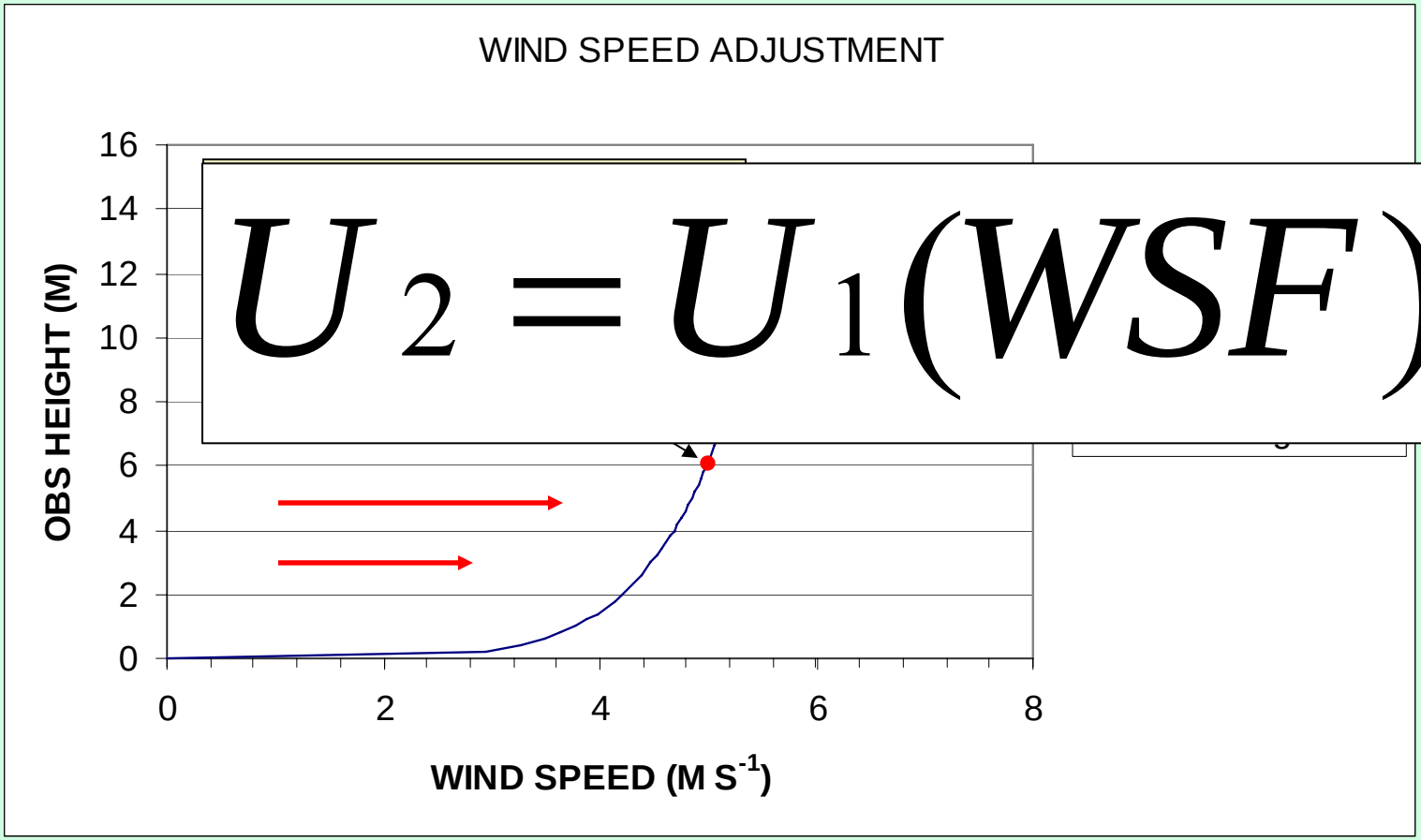

2003. 10. 24 11

Wind Speed Scaling

$$U_2 = U_1 \left(\frac{Z_2}{Z_1} \right)^P$$



Wind Speed Scaling



$$U_2 = U_1(WSF)$$

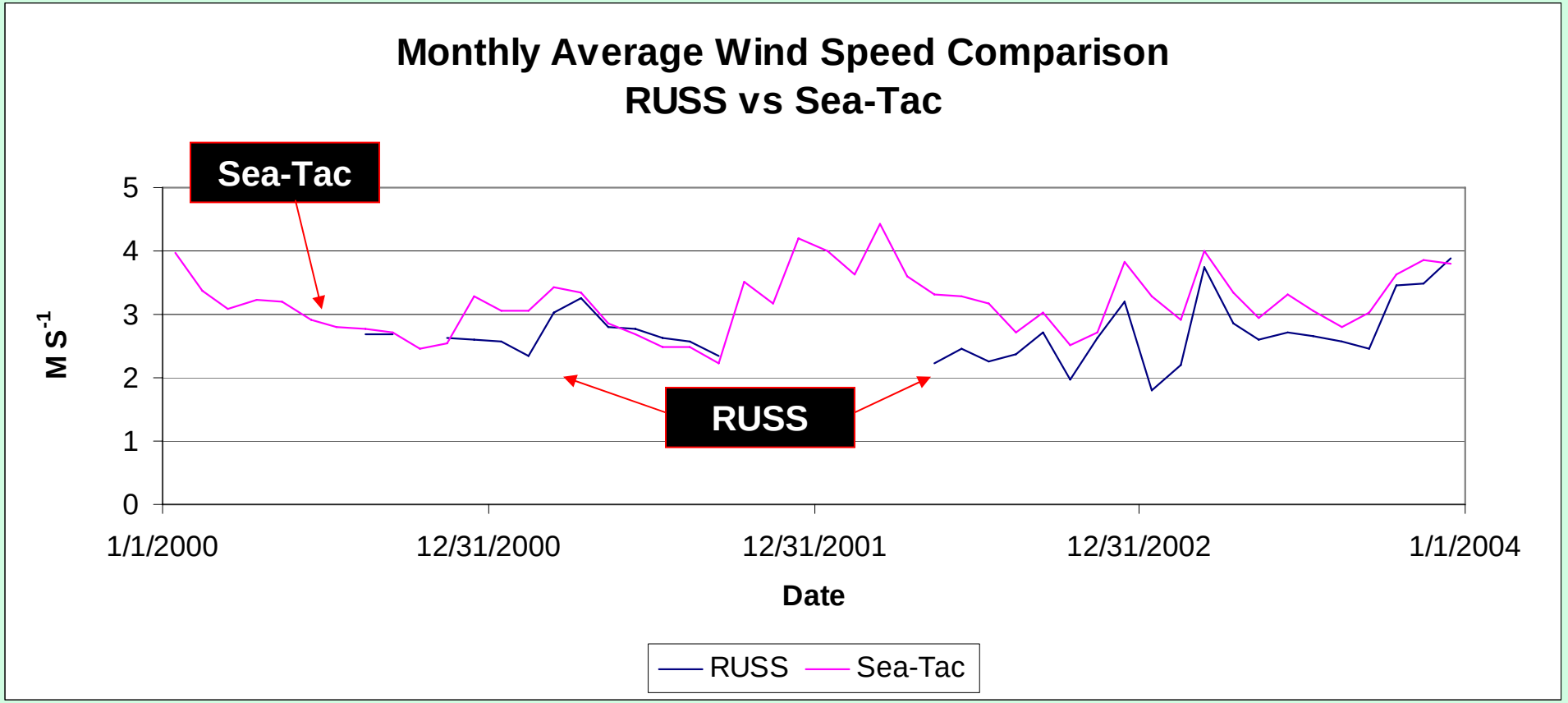
Wind Adjustment Factor (WAF)

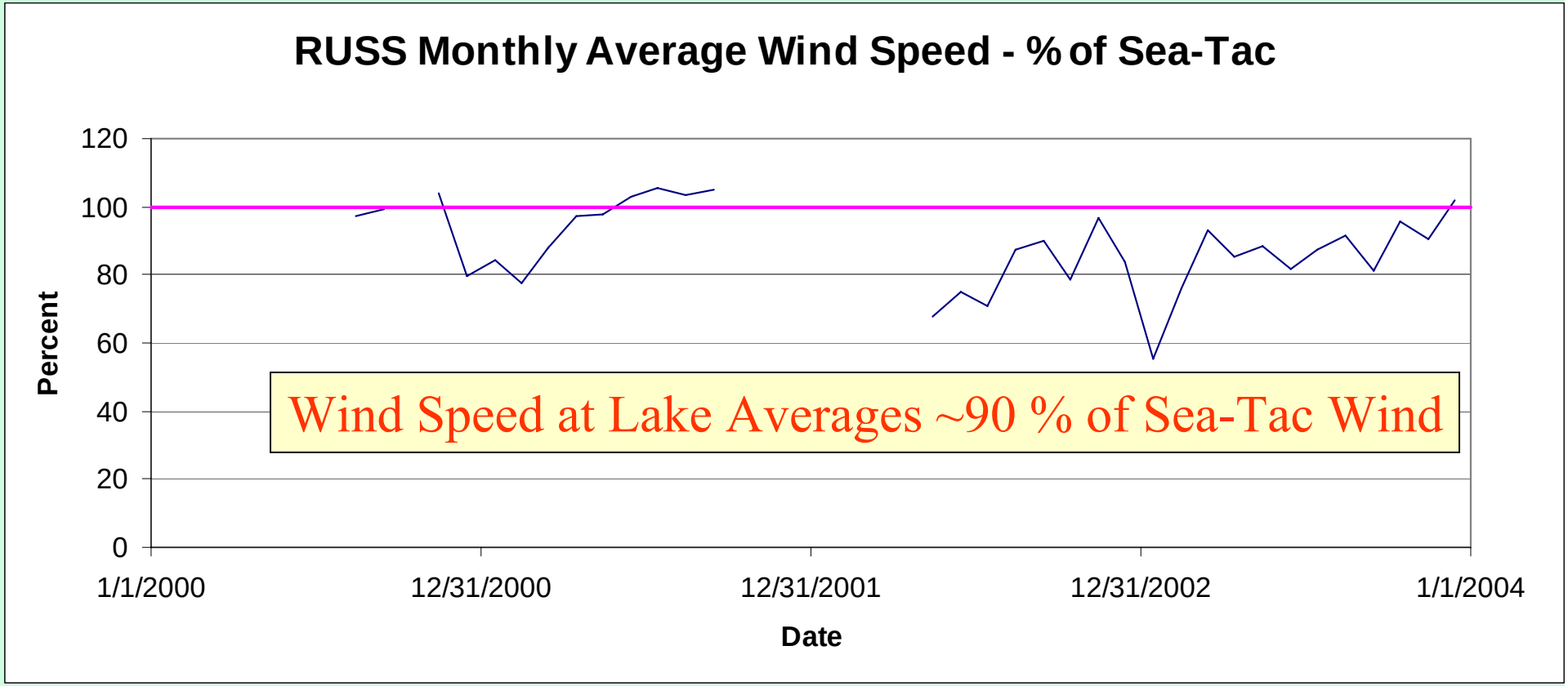
Surface Shear Stress

$$U_{10m} = U_{6.1m} \times WSF \times WAF$$

Surface Heat Exchange

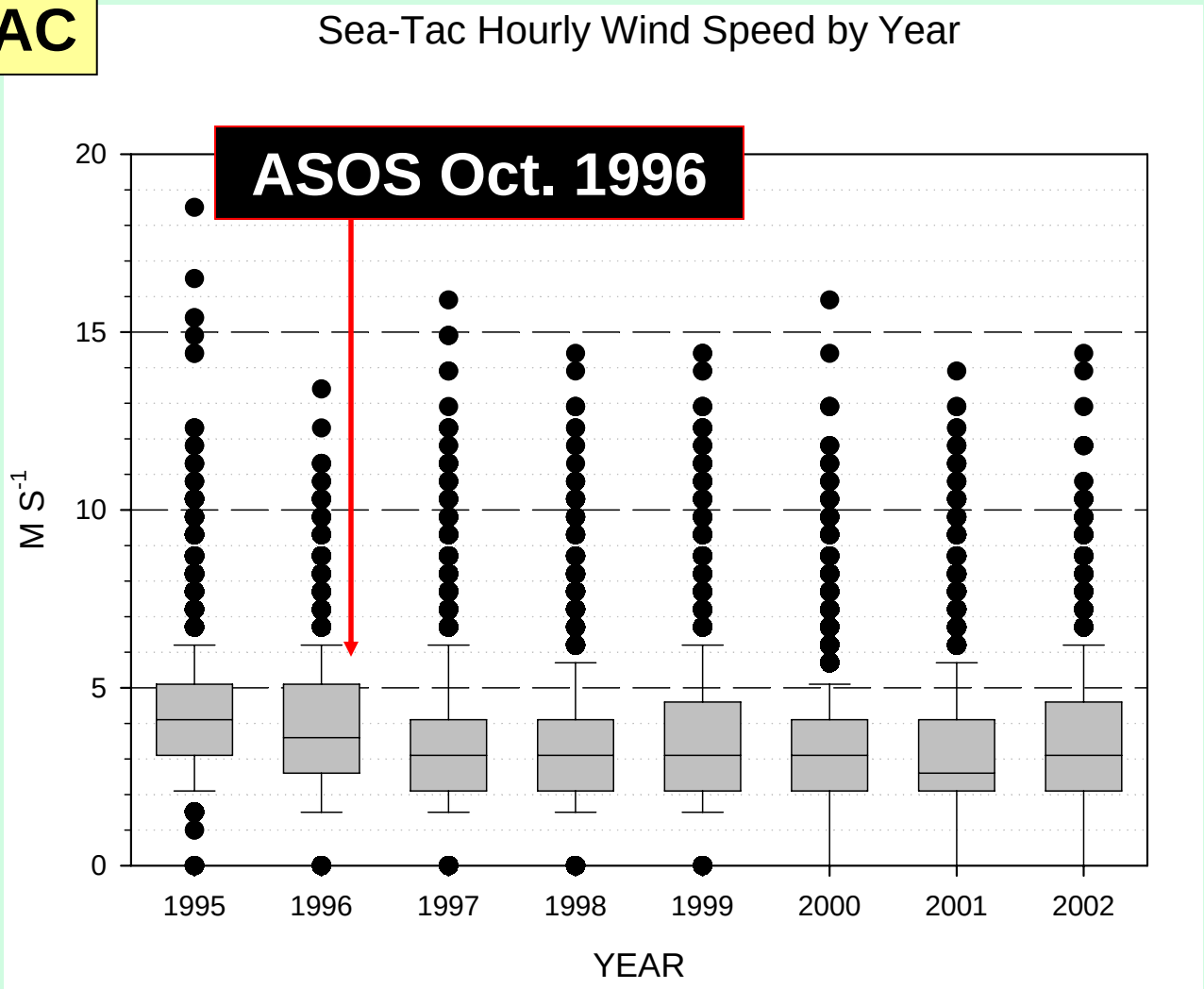
$$U_{2m} = U_{6.1m} \times WSF \times WAF$$


Monthly Average Wind Speed Comparison
RUSS vs Sea-Tac
Sea-Tac
RUSS
5
4
3
2
1
0
M S-1
1/1/2000
12/31/2000
12/31/2001
12/31/2002
1/1/2004
Date
RUSS
Sea-Tac


RUSS Monthly Average Wind Speed - % of Sea-Tac
120
100
80
60
40
20
0
Percent
Wind Speed at Lake Averages ~90 % of Sea-Tac Wind
1/1/2000
12/31/2000
12/31/2001
12/31/2002
1/1/2004
Date

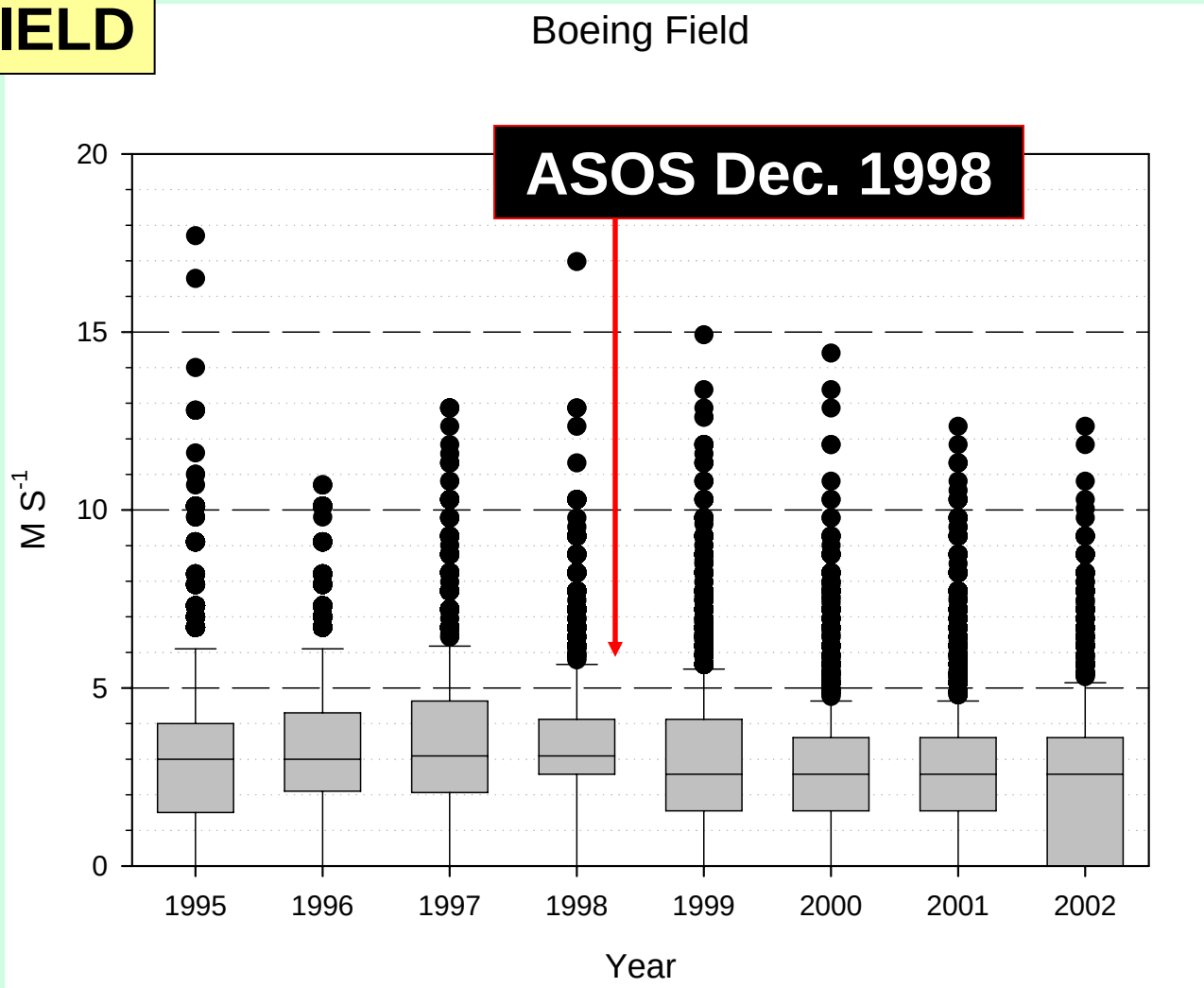
Wind Data Evaluation

SEA-TAC

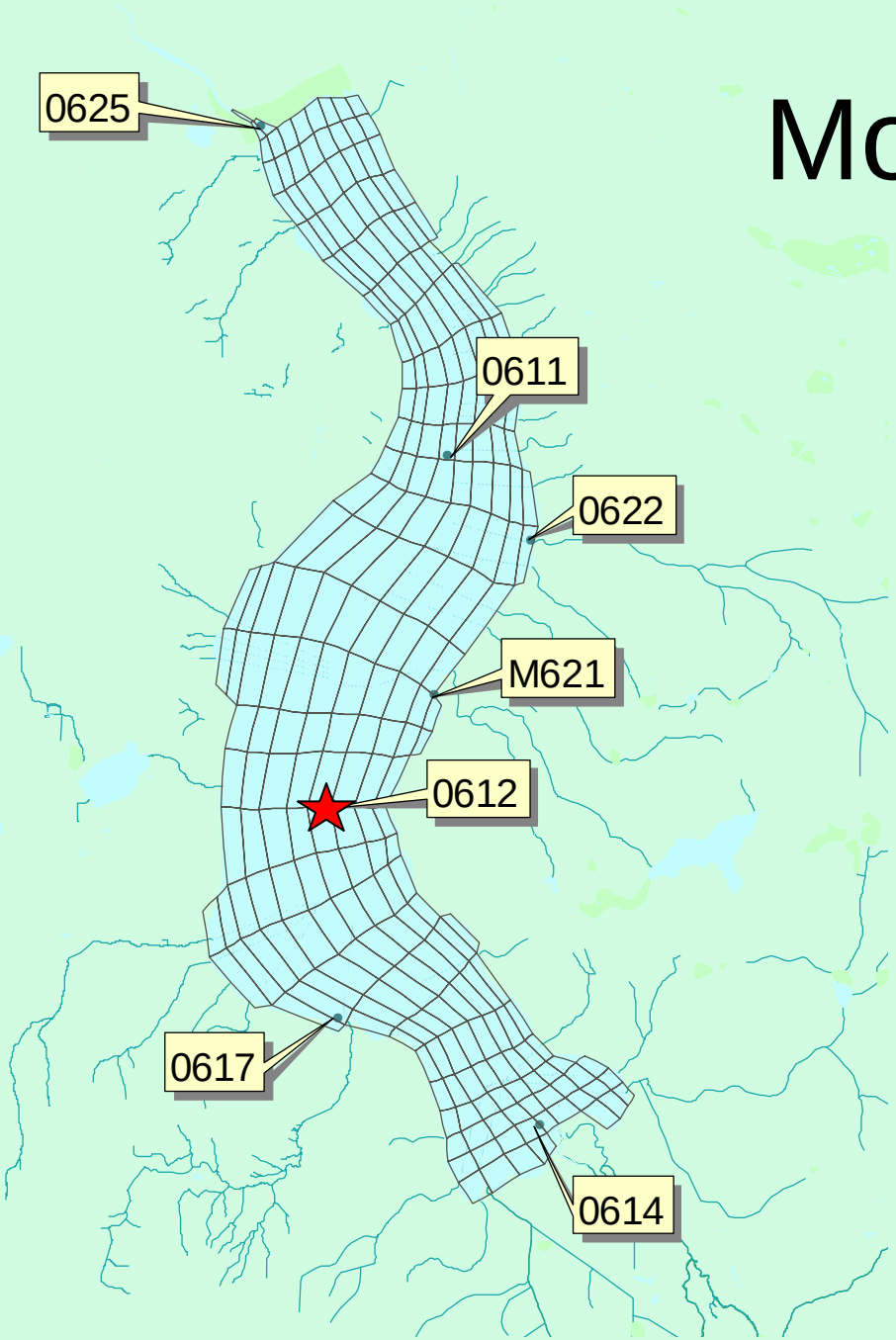


Wind Data Evaluation

BOEING FIELD

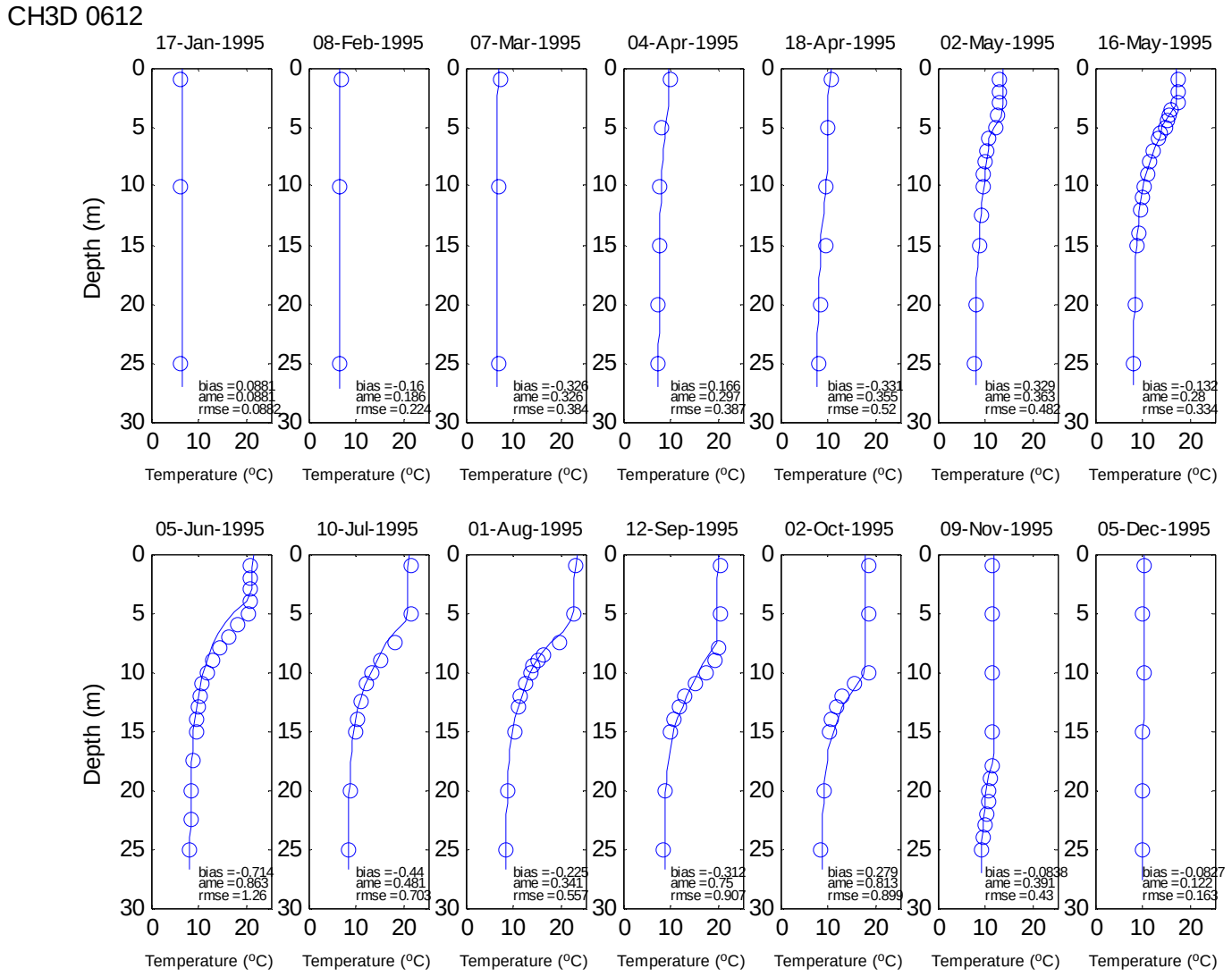


Model Calibration 1995 - 2002

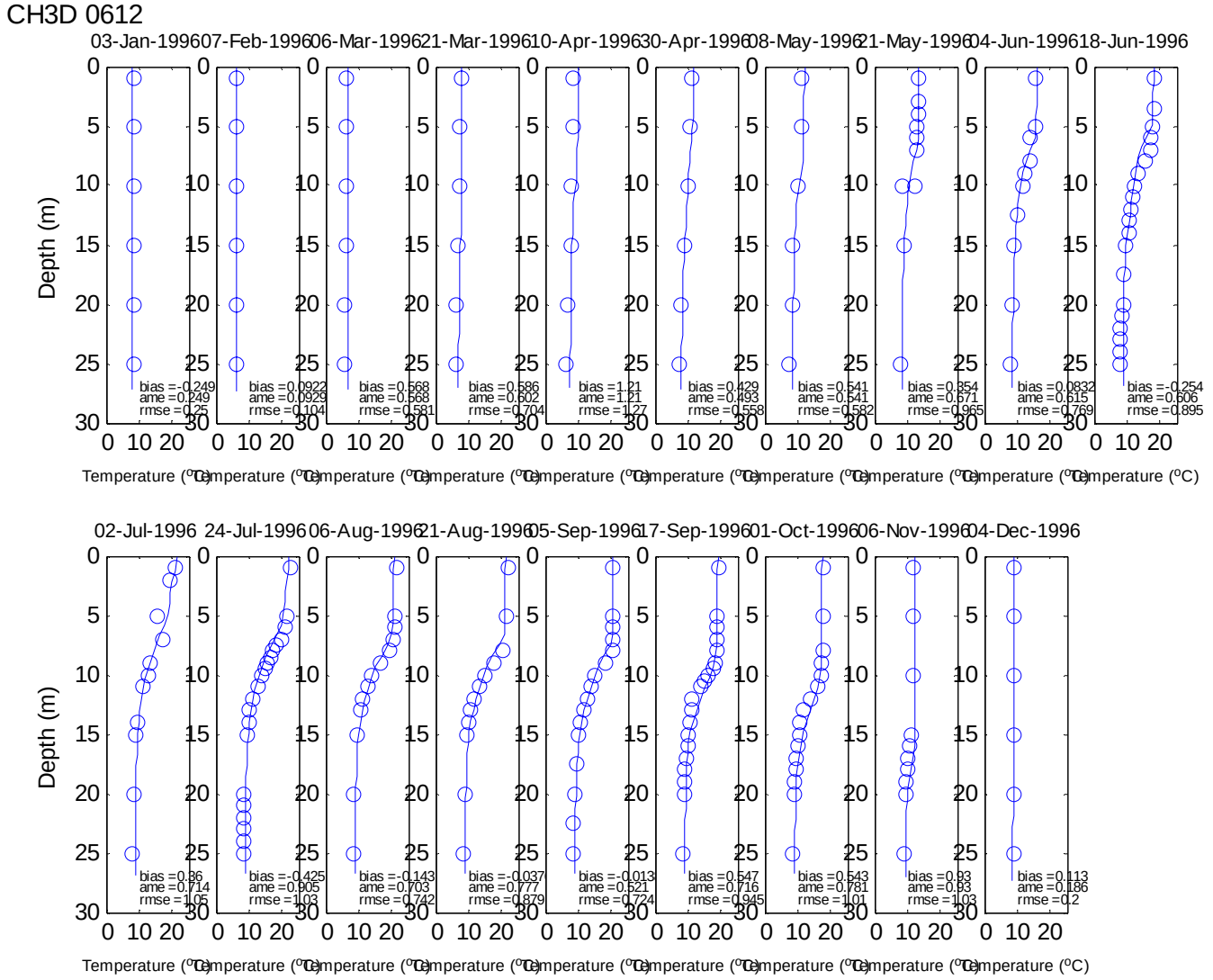


CH3D Temperature Results
1995 - 2002

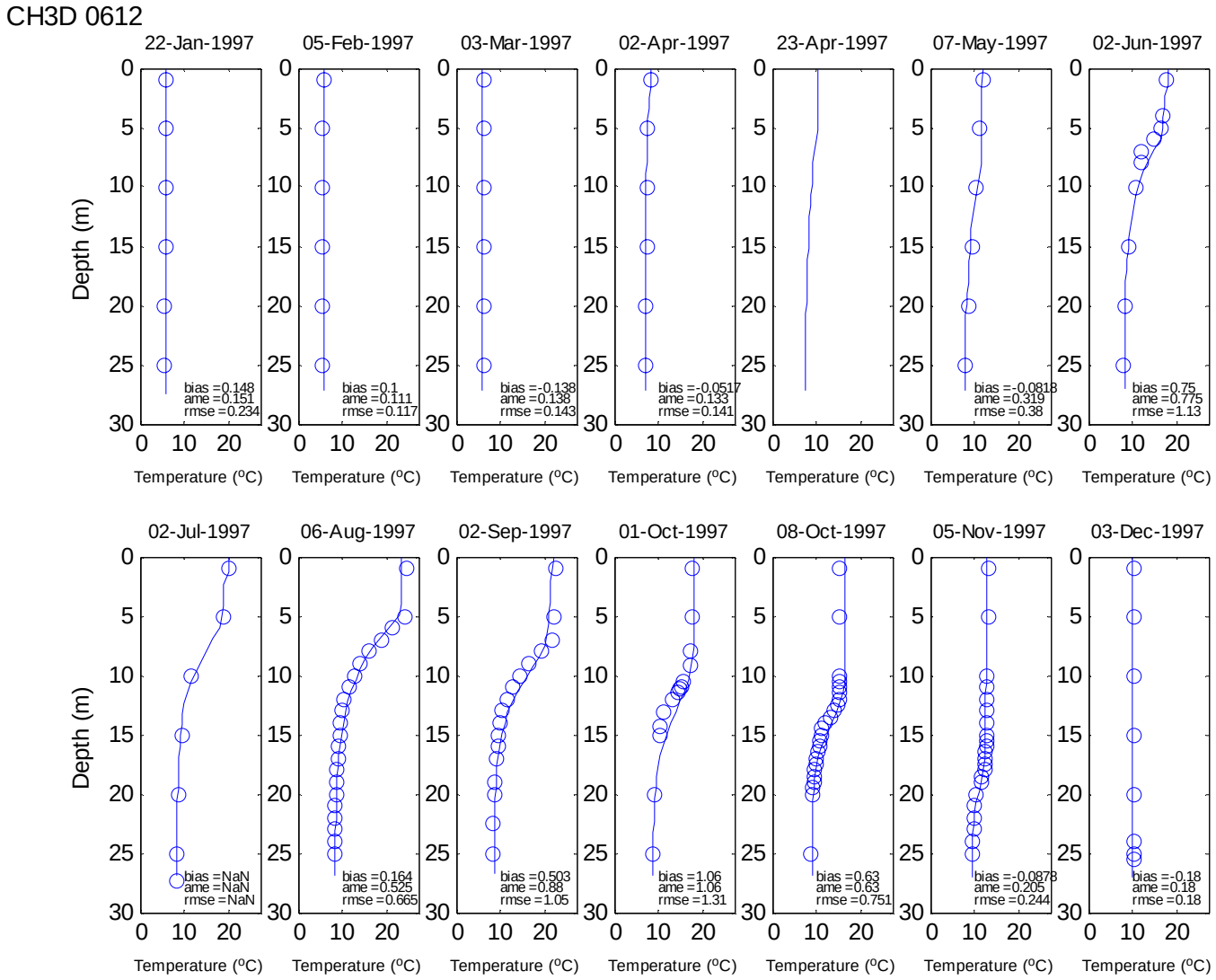
CH3D 1995 - 0612



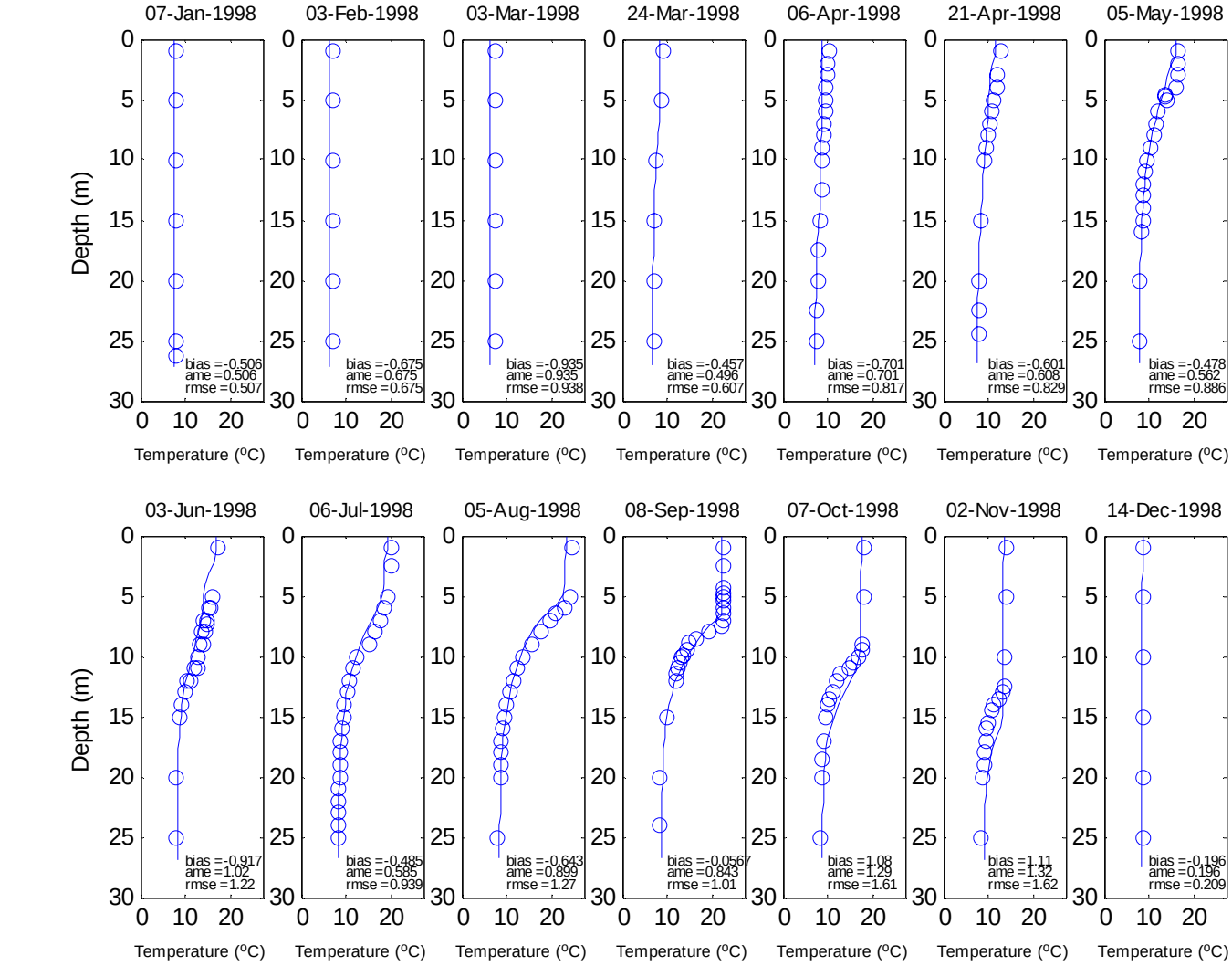
CH3D 1996 - 0612



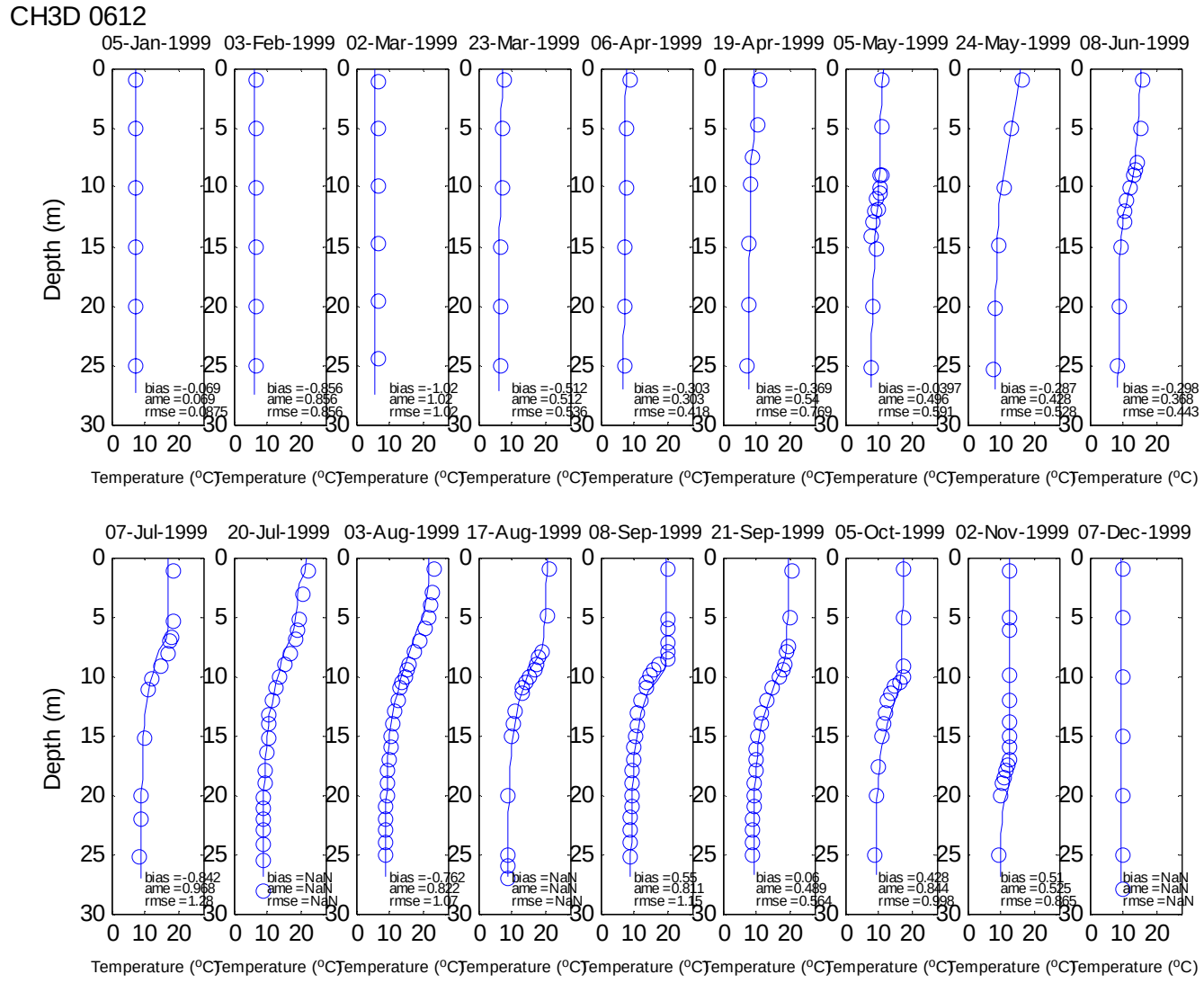
CH3D 1997 - 0612



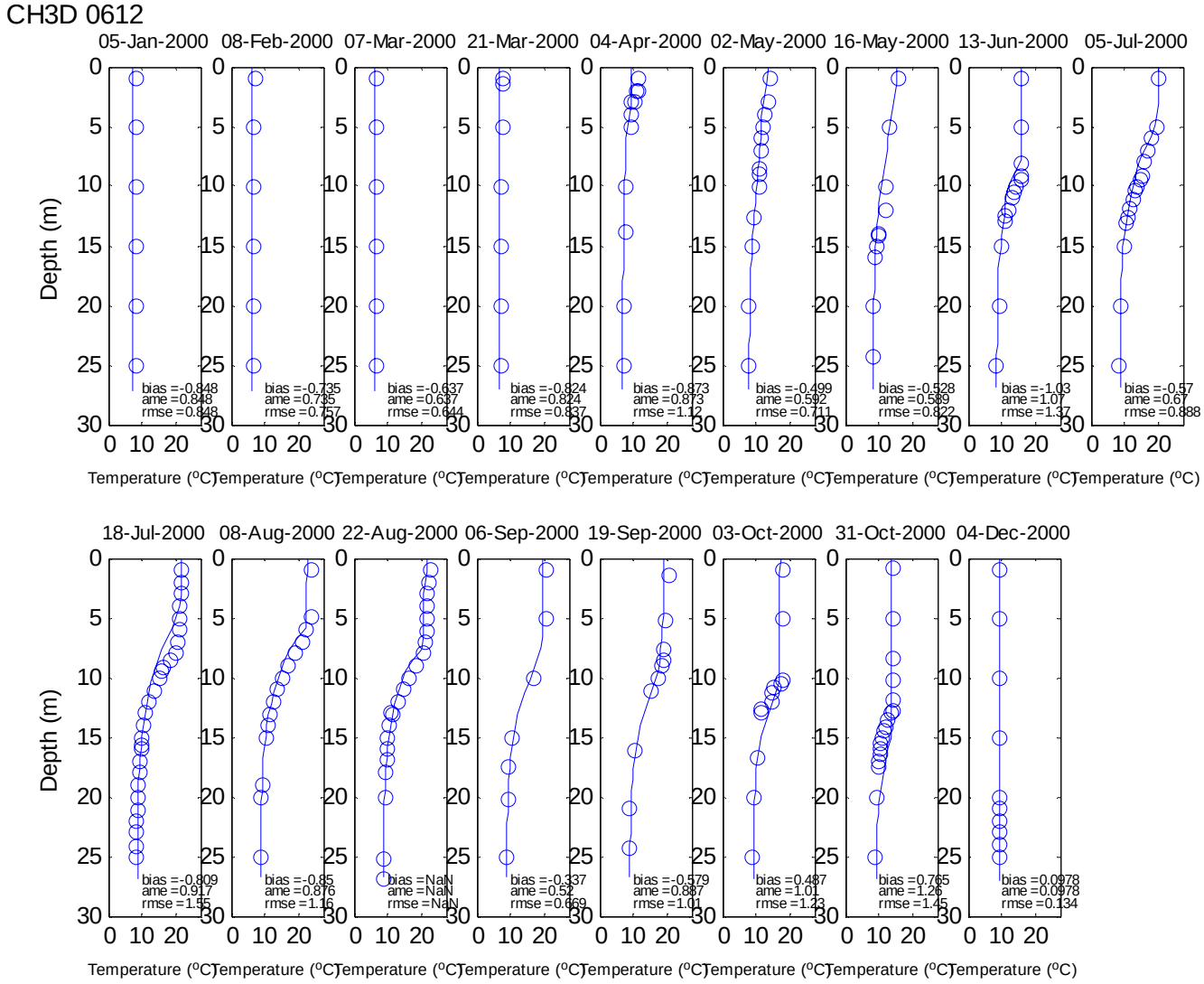
CH3D 1998 - 0612



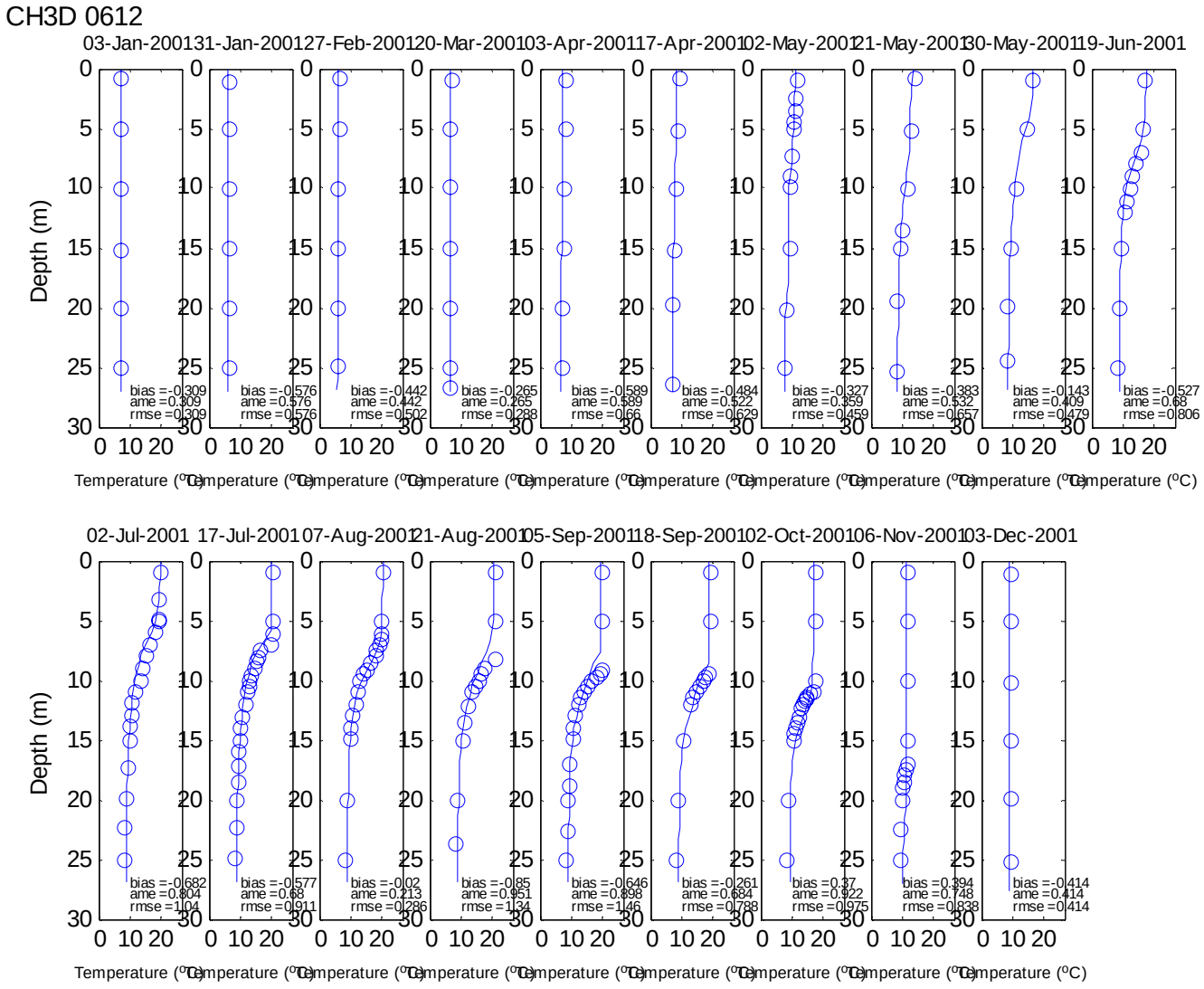
CH3D 1999 - 0612



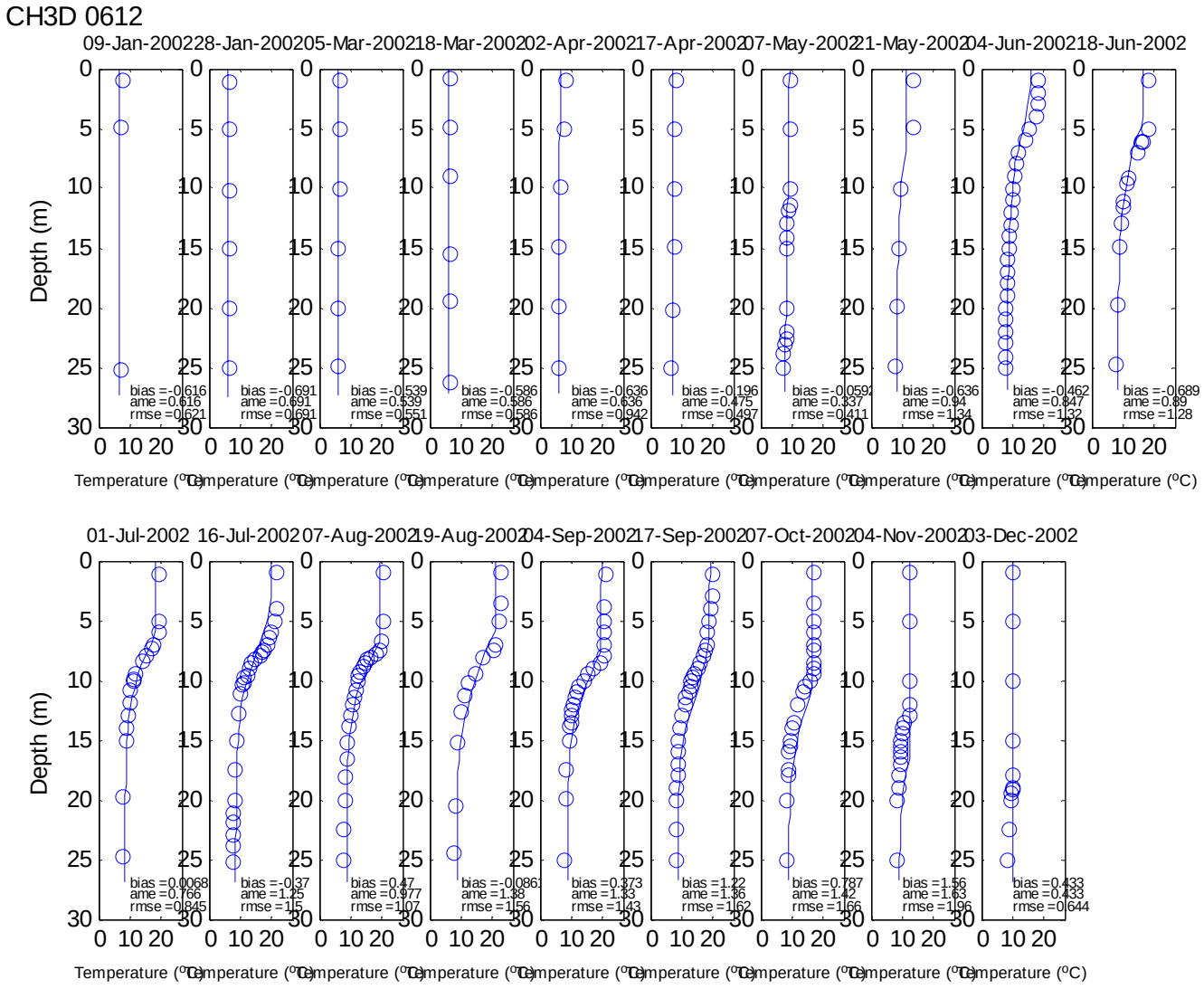
CH3D 2000 - 0612



CH3D 2001 - 0612



CH3D 2002 - 0612



Model Error Statistics

Mean Error (Bias)

$$ME = \frac{\Sigma (P - O)}{N}$$

Absolute Mean Error

$$AME = \frac{\Sigma \left| P - O \right|)}{N}$$

Root Mean Square Error

$$RMSE = \sqrt{\frac{\Sigma (P - O)^2}{N}}$$

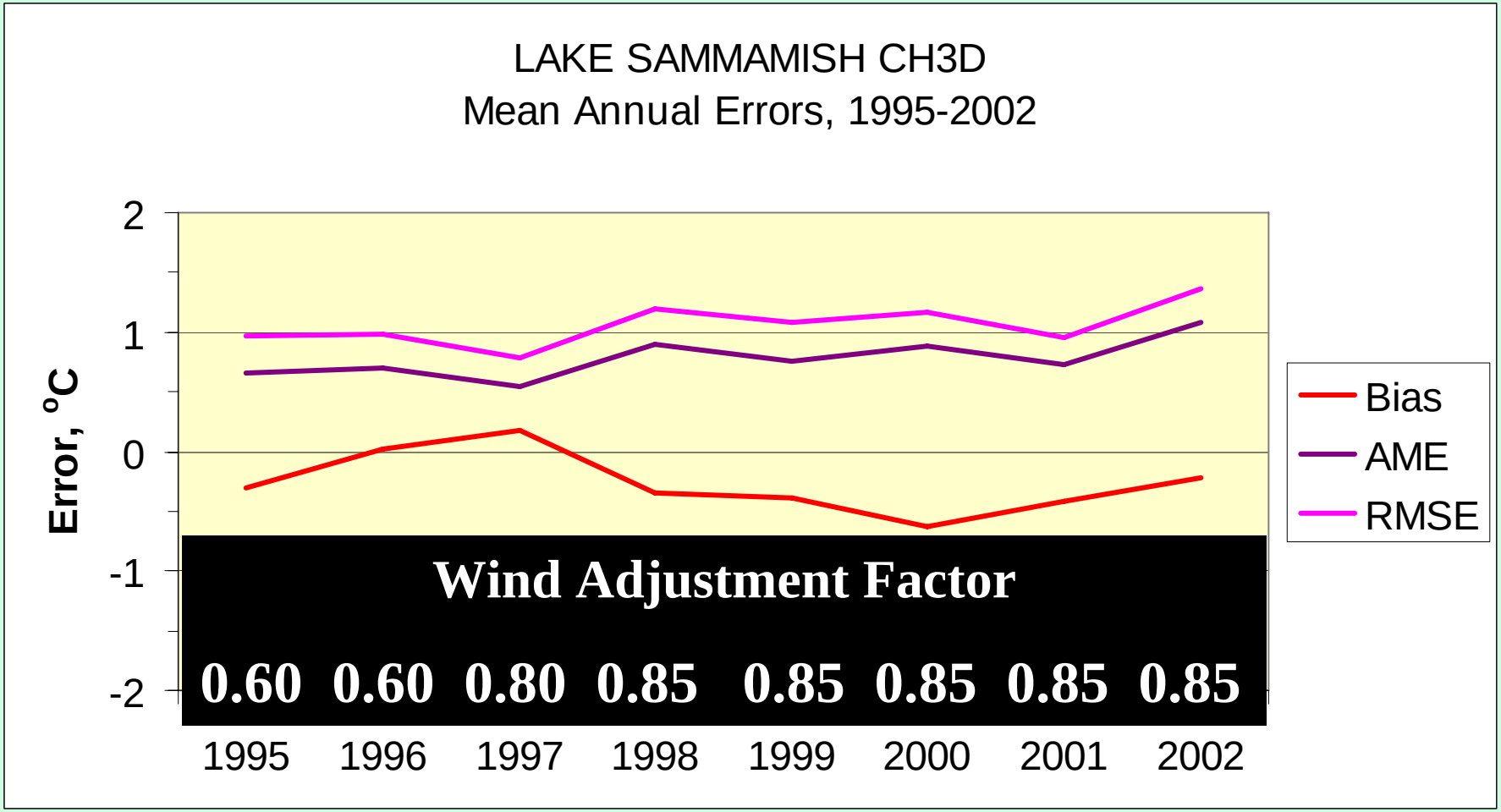
Relative Error

$$RE = \frac{\Sigma (\left| P - O \right|)}{\Sigma O}$$

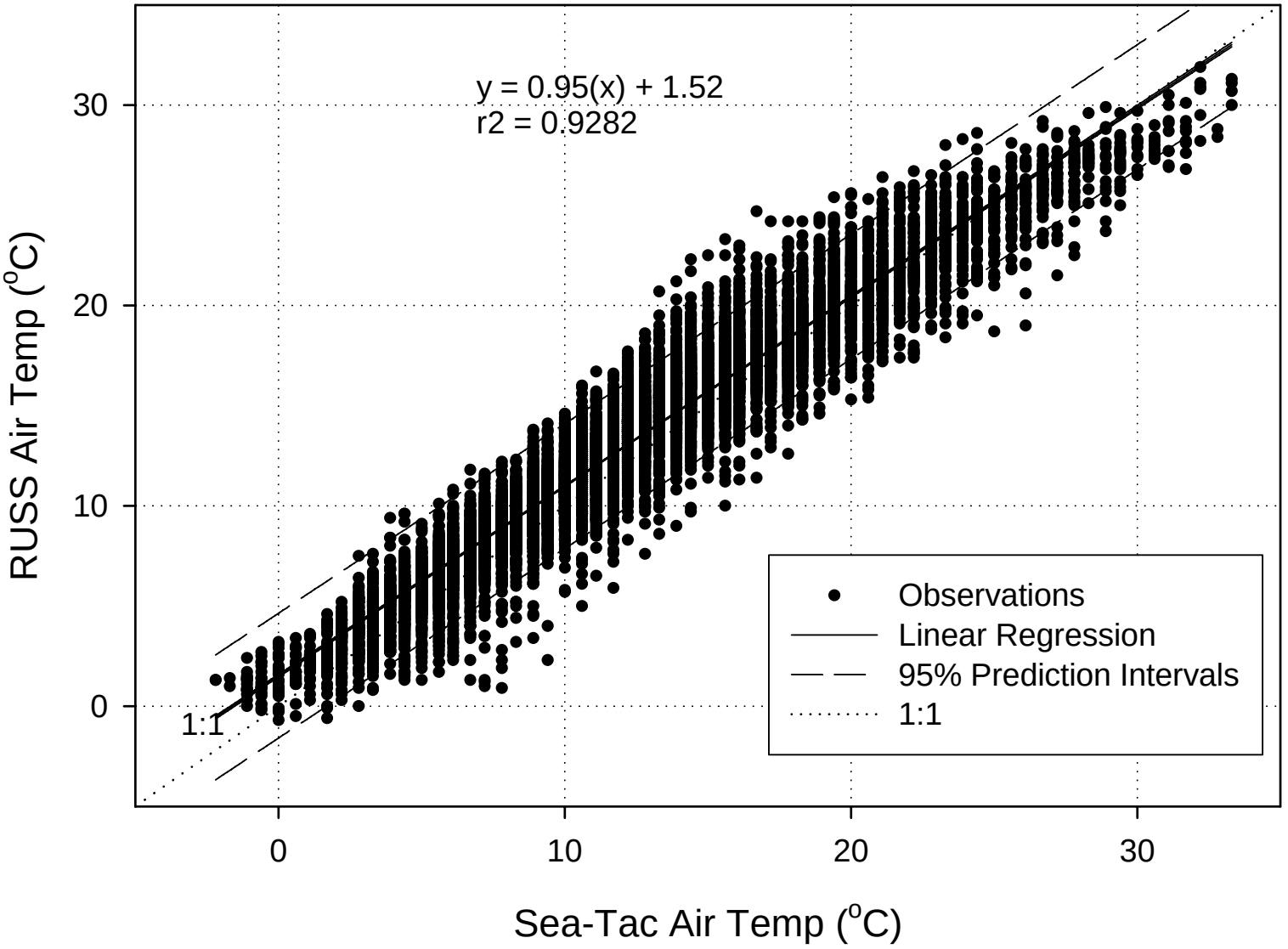
Lake Sammamish CH3D Model Error Statistics

Number of Comparisons	4,891
Mean Error (bias)	-0.28 ^{o}C
Absolute Mean Error (AME)	0.80 ^{o}C
Root Mean Square Error (RMSE)	1.10 ^{o}C
Relative Mean Error (%)	6.4

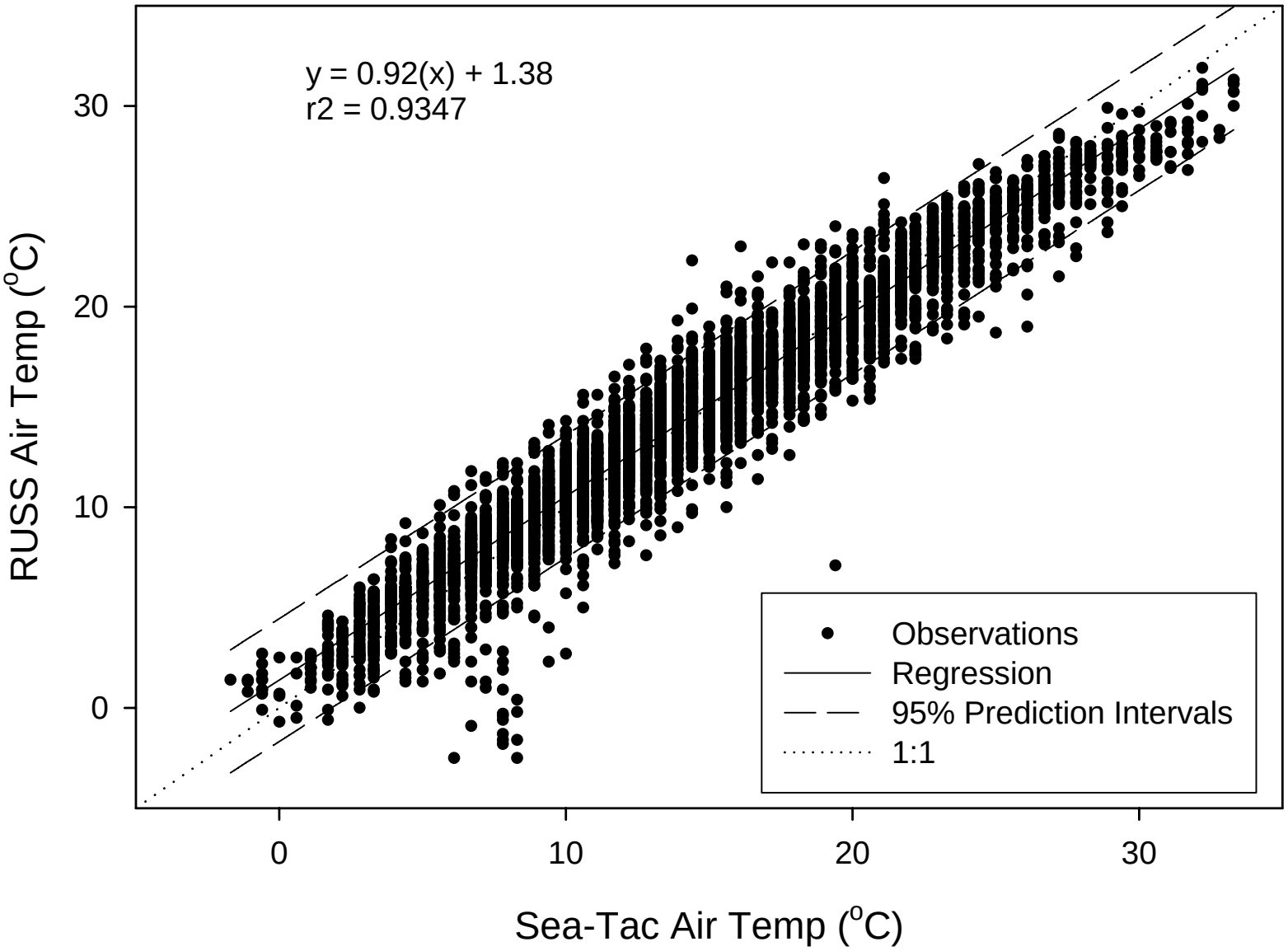
Lake Sammamish CH3D Model Error Statistics



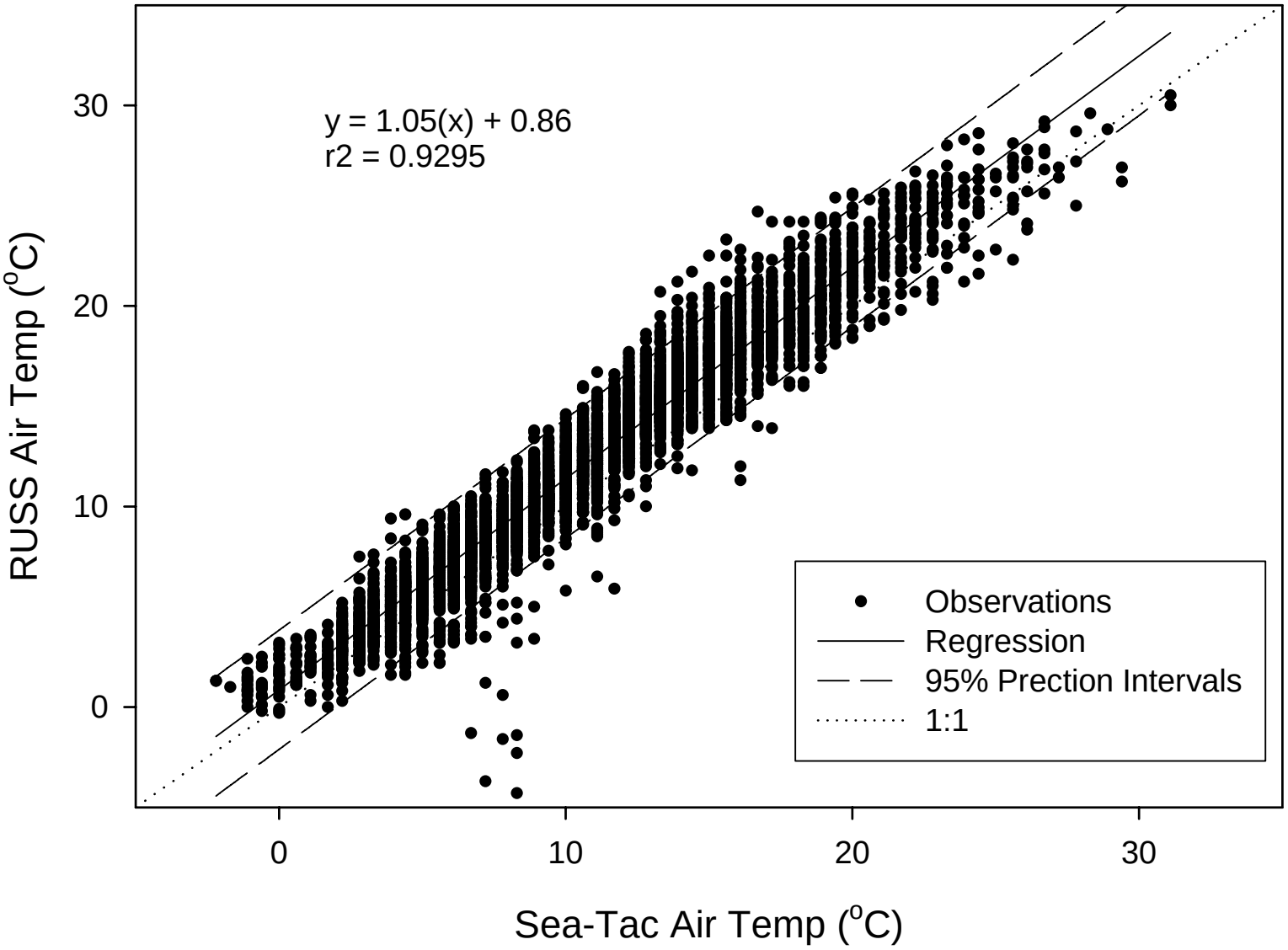
Sea-Tac vs. SSAMM RUSS
Air Temperature Comparison
All data (outliers removed)



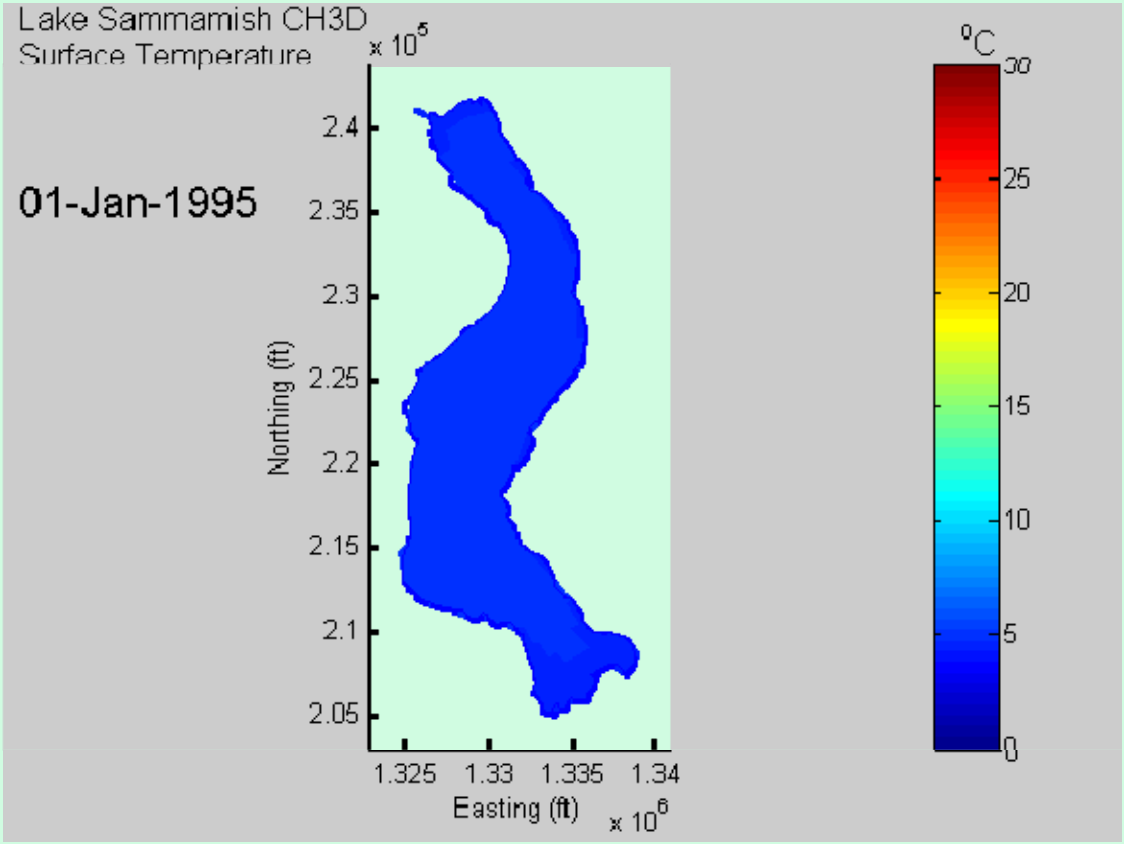
Sea-Tac vs. SSAMM RUSS
Air Temperature Comparison
7 AM to 6 PM



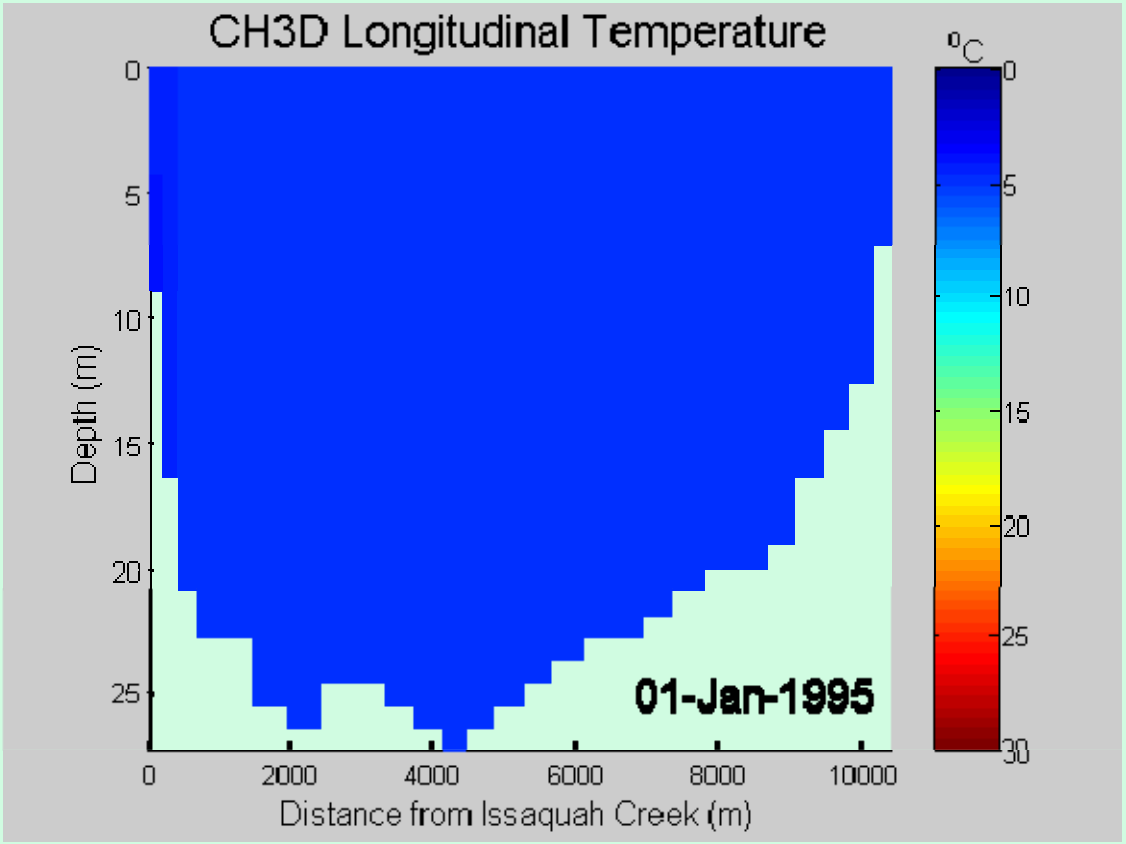
Sea-Tac vs. SSAMM RUSS
Air Temperature Comparison
7 PM to 6 AM



Lake Sammamish CH3D Surface Temperatures



Lake Sammamish CH3D Longitudinal Temperatures



CH3D Velocity Animation