Table 4. Selected tributary monitoring locations in the Sammamish basin.

Locator	Description	Northing	Easting	Begin Date	End Date
0631	Issaquah Creek	203781	1340488	1/4/1972	Active
A630	Tibbetts Creek	204628	1335438	4/2/1975	12/16/1997
X630	Tibbetts Creek	204534	1335165	4/8/1997	Active
A617	Lewis Creek	210684	1329654	1/11/1995	Active
A620	Idylwood Creek	237117	1327518	8/15/1995	Active
A670	Laughing Jacobs Creek	208691	1339421	5/19/1987	4/25/1988
A680	Pine Lake Creek	221738	1332844	5/19/1987	Active
A685	Ebright (Thompson) Creek	224362	1334757	1/9/1996	Active
A690	Inglewood (Eden) Creek	226949	1335868	5/19/1987	Active
25A †	Issaquah Creek at SE 56th ST	203897	1340807	8/6/2001	Active

Northing/Easting in State Plane feet, Washington North, North American Datum 1983

† Continuous (15-minute) temperature recording only. Remaining tributary monitoring stations are part of King County's routine stream monitoring network.

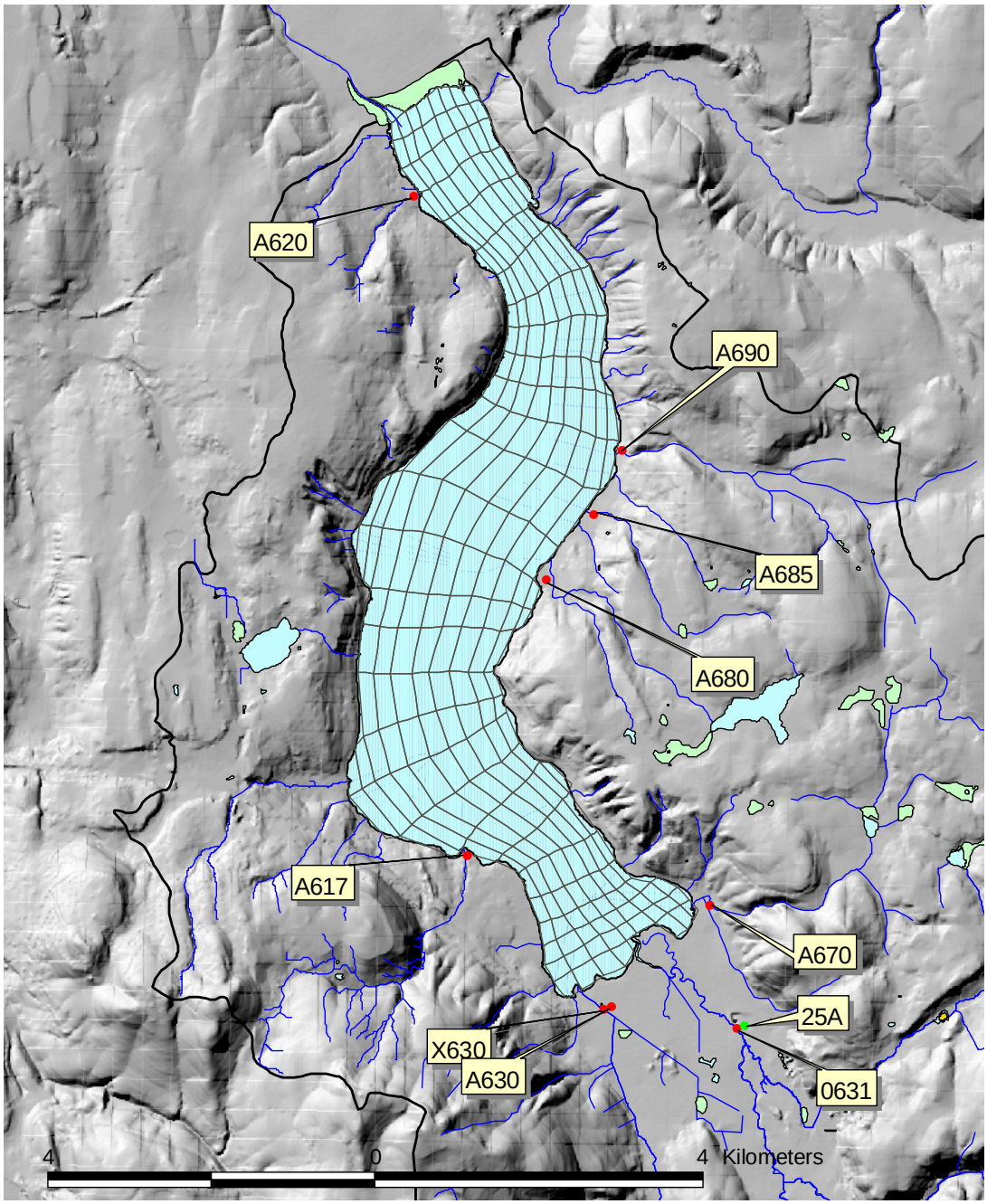

Figure 13 Locations of selected King County routine streams monitoring stations.

Table 5. Lake Sammamish CH3D-Z tributary assignments and temperature data sources.

CH3D tributary input	IJ Index		No. of Layers	Temperature data
Issaquah	2	5	10	Issaquah Creek (0631)
South Sammamish	1	9	3	Lewis Creek (A617)
Lewis Creek	8	9	7	Lewis Creek (A617)
Middle Sammamish	10	11	5	Lewis Creek (A617)
Vasa Creek	11	11	3	Idylwood Creek (A620)
Phantom Creek	13	9	13	Idylwood Creek (A620)
North Sammamish	16	11	4	Idylwood Creek (A620)
Wilkins Creek	17	9	15	Idylwood Creek (A620)
Idylwood South	19	9	12	Idylwood Creek (A620)
Idylwood North	27	9	5	Idylwood Creek (A620)
50% East Lake Sammamish 1 (ELS1)	23	2	5	Inglewood (Eden) Creek (A690)
50% East Lake Sammamish 1 (ELS1)	20	2	13	Inglewood (Eden) Creek (A690)
Inglewood (Eden)+25% ELS2	18	1	8	Inglewood (Eden) Creek (A690)
Thompson (Ebright)+25% ELS2	17	2	10	Inglewood (Eden) Creek (A690)
Pine Lake Creek	16	2	10	Thompson (Ebright) Creek (A685)
25% East Lake Sammamish 2 (ELS2)	7	2	10	Thompson (Ebright) Creek (A685)
25% East Lake Sammamish 2 (ELS2)	5	2	8	Thompson (Ebright) Creek (A685)
Laughing Jacobs Creek	1	1	3	Thompson (Ebright) Creek (A685)
Tibbetts Creek	1	8	7	Tibbetts Creek (X630)

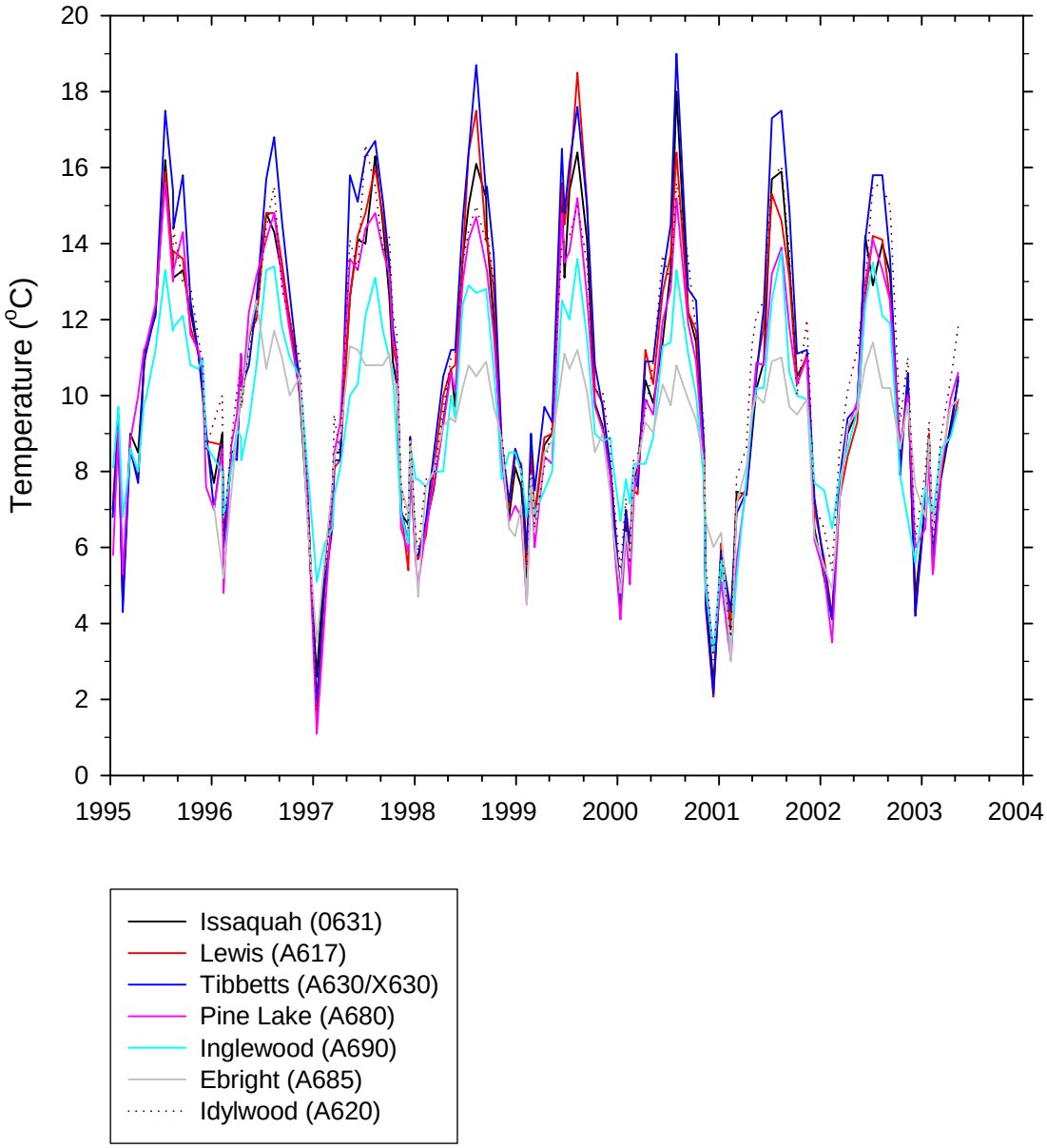

Figure 14 Temperatures reported for selected Lake Sammamish tributaries as part of King County's routine stream monitoring program, 1995-2002.

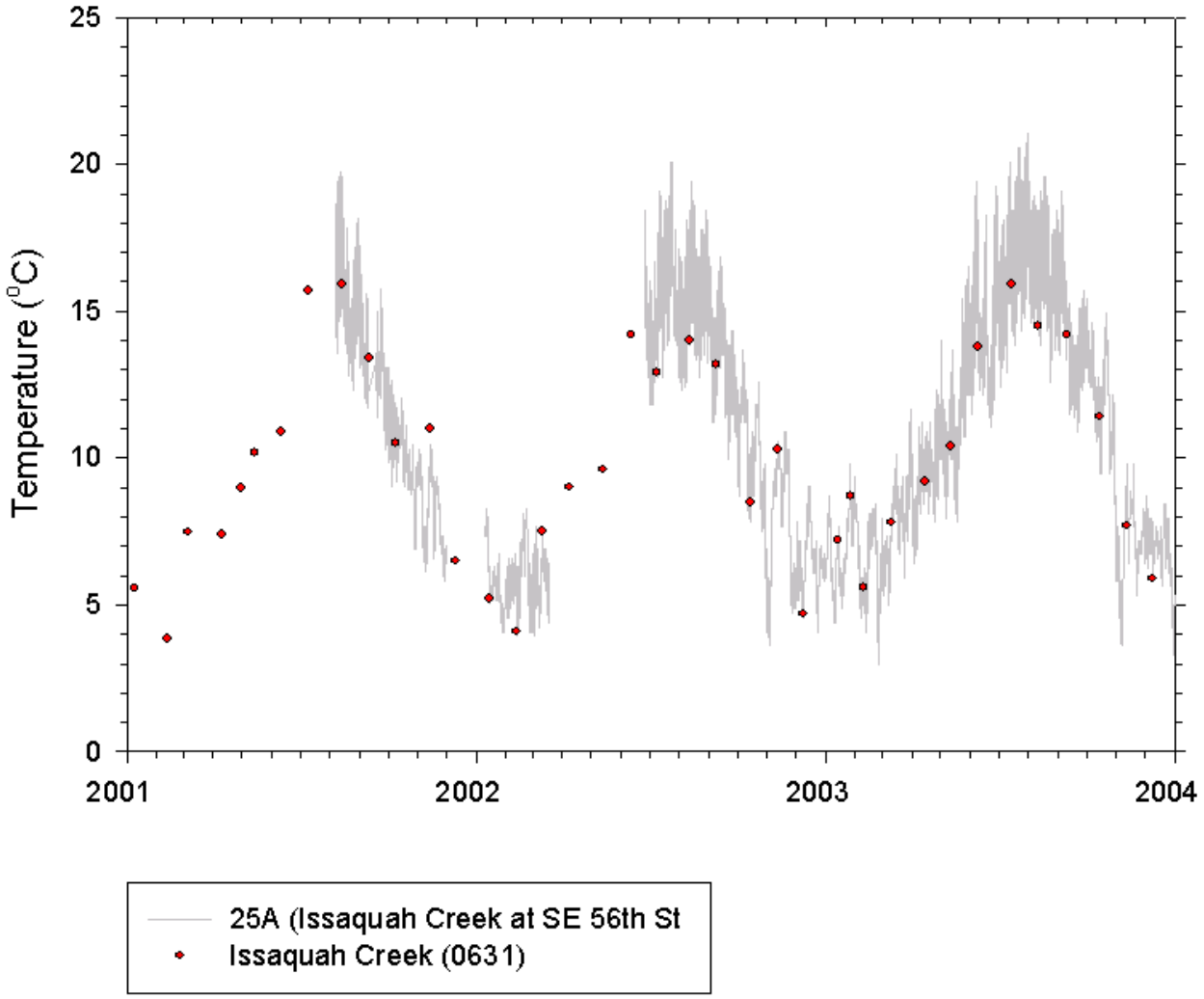

Figure 15 Comparison of Issaquah Creek continuous (15-minute) vs. routine grab (~monthly) temperature records, 2001-2003.

Table 6. Lake Sammamish CH3D-Z tributary assignments and temperature data sources.

CH3D tributary input	IJ Index		No. of Layers	Temperature data
Issaquah	2	5	10	Issaquah Creek (0631)
South Sammamish	1	9	3	Lewis Creek (A617)
Lewis Creek	8	9	7	Lewis Creek (A617)
Middle Sammamish	10	11	5	Lewis Creek (A617)
Vasa Creek	11	11	3	Idylwood Creek (A620)
Phantom Creek	13	9	13	Idylwood Creek (A620)
North Sammamish	16	11	4	Idylwood Creek (A620)
Wilkins Creek	17	9	15	Idylwood Creek (A620)
Idylwood South	19	9	12	Idylwood Creek (A620)
Idylwood North	27	9	5	Idylwood Creek (A620)
50% East Lake Sammamish 1 (ELS1)	23	2	5	Inglewood (Eden) Creek (A690)
50% East Lake Sammamish 1 (ELS1)	20	2	13	Inglewood (Eden) Creek (A690)
Inglewood (Eden)+25% ELS2	18	1	8	Inglewood (Eden) Creek (A690)
Thompson (Ebright)+25% ELS2	17	2	10	Inglewood (Eden) Creek (A690)
Pine Lake Creek	16	2	10	Thompson (Ebright) Creek (A685)
25% East Lake Sammamish 2 (ELS2)	7	2	10	Thompson (Ebright) Creek (A685)
25% East Lake Sammamish 2 (ELS2)	5	2	8	Thompson (Ebright) Creek (A685)
Laughing Jacobs Creek	1	1	3	Thompson (Ebright) Creek (A685)
Tibbetts Creek	1	8	7	Tibbetts Creek (X630)

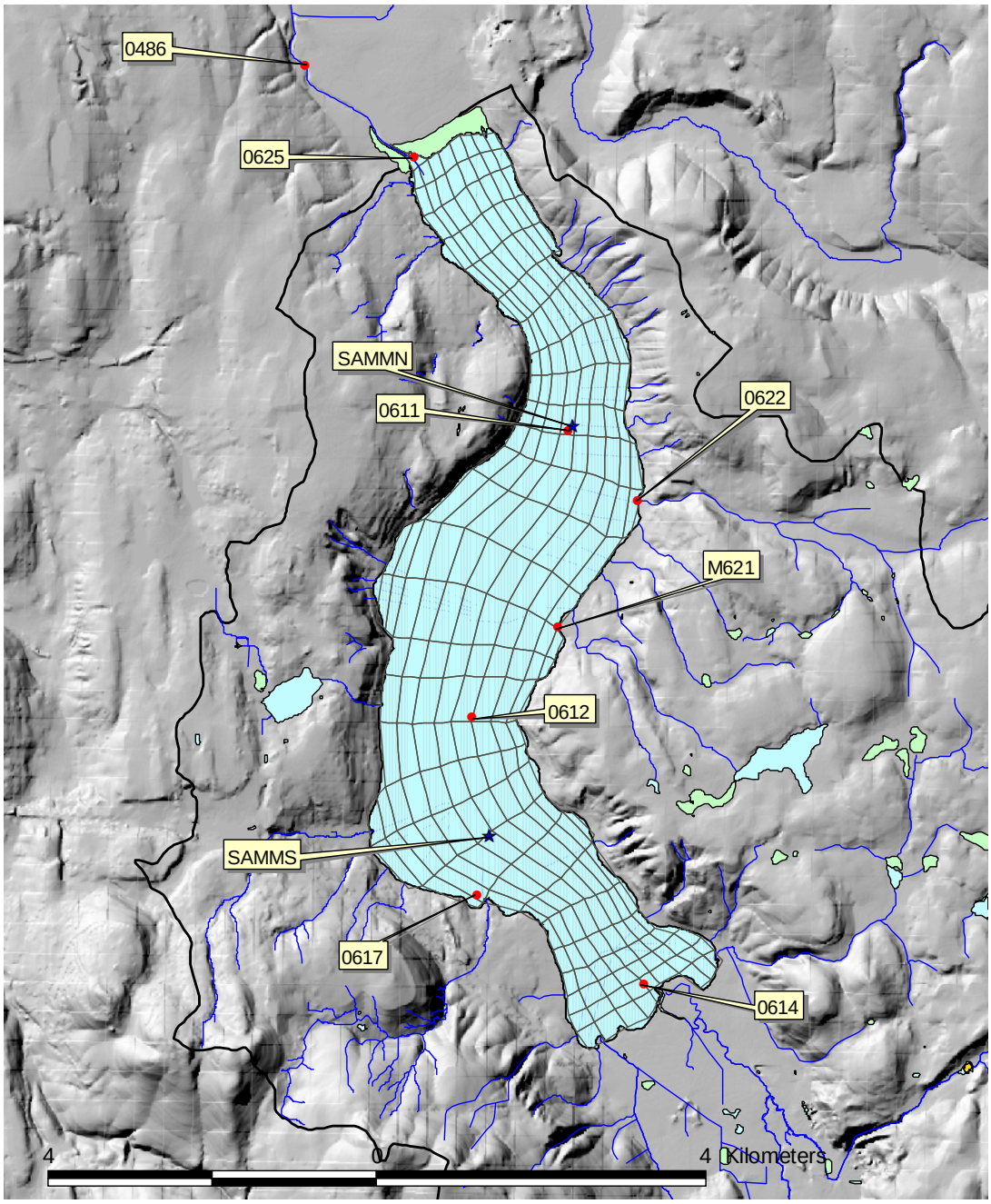

Figure 16 Locations of selected King County Lake Sammamish and Sammamish River routine monitoring locations.

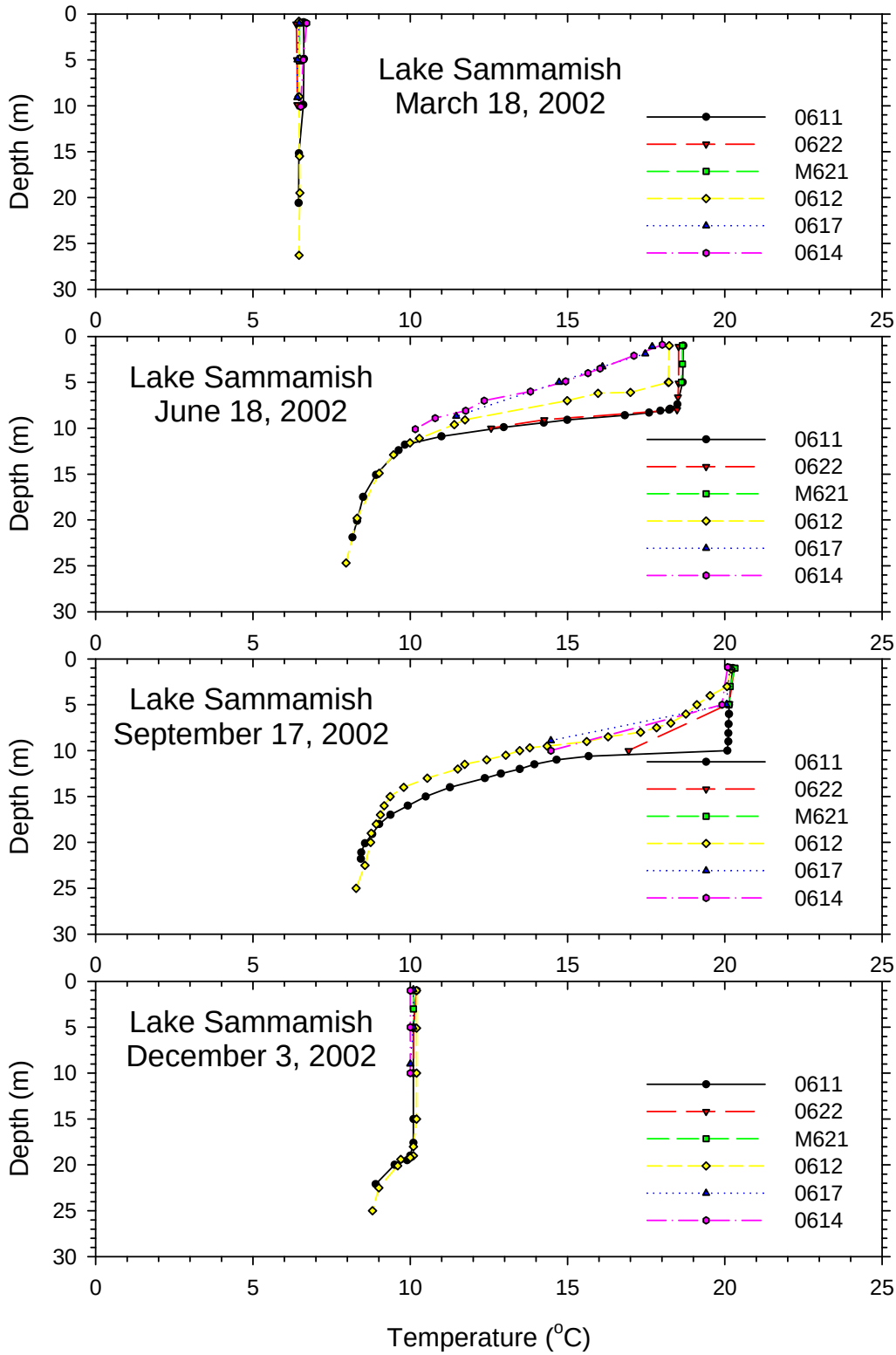

Figure 17 Selected temperature profiles from Lake Sammamish routine monitoring stations, 2002.

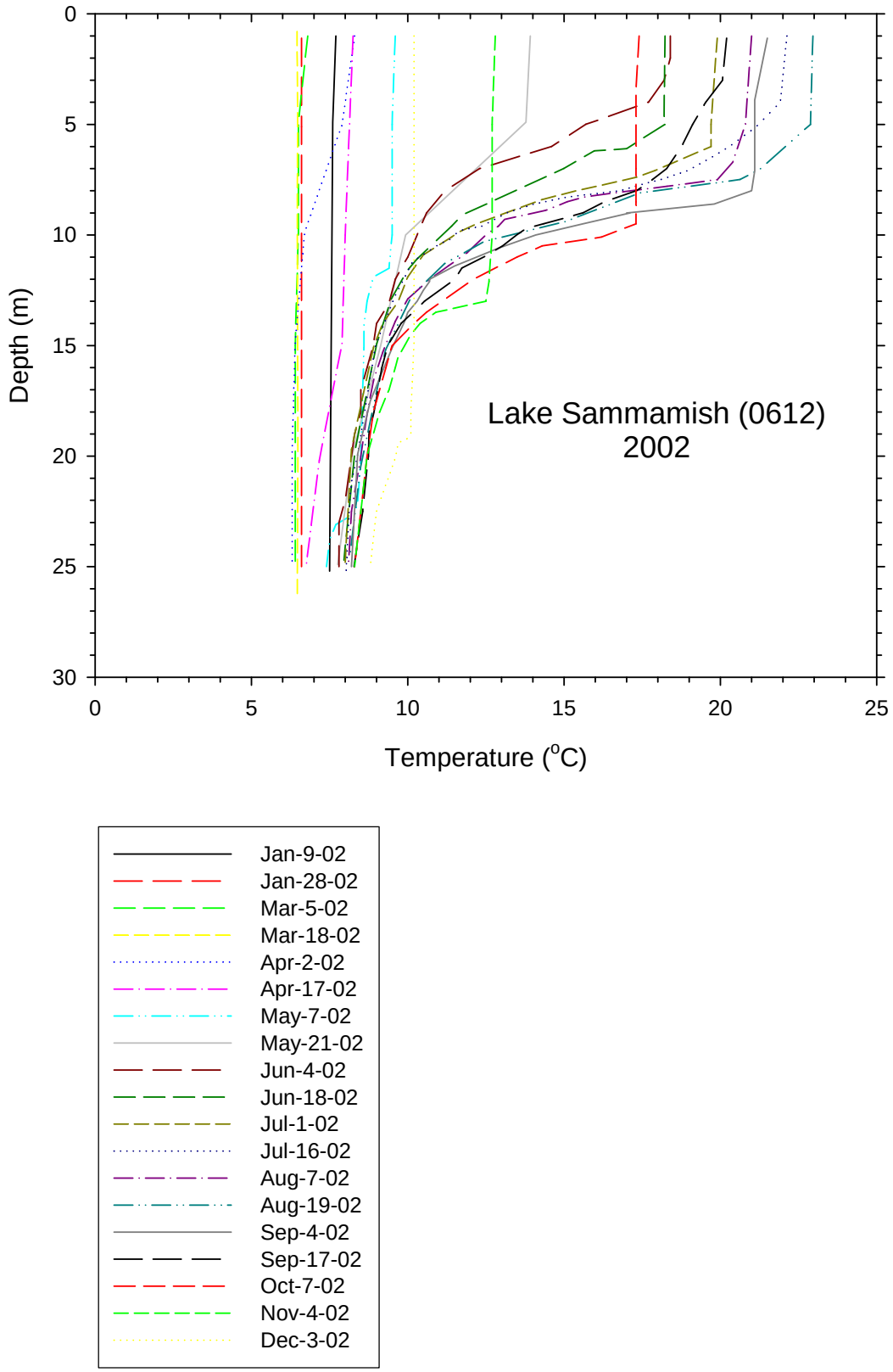

Figure 18 Temperature profiles from Central Lake Sammamish routine monitoring station 0612, 2002.

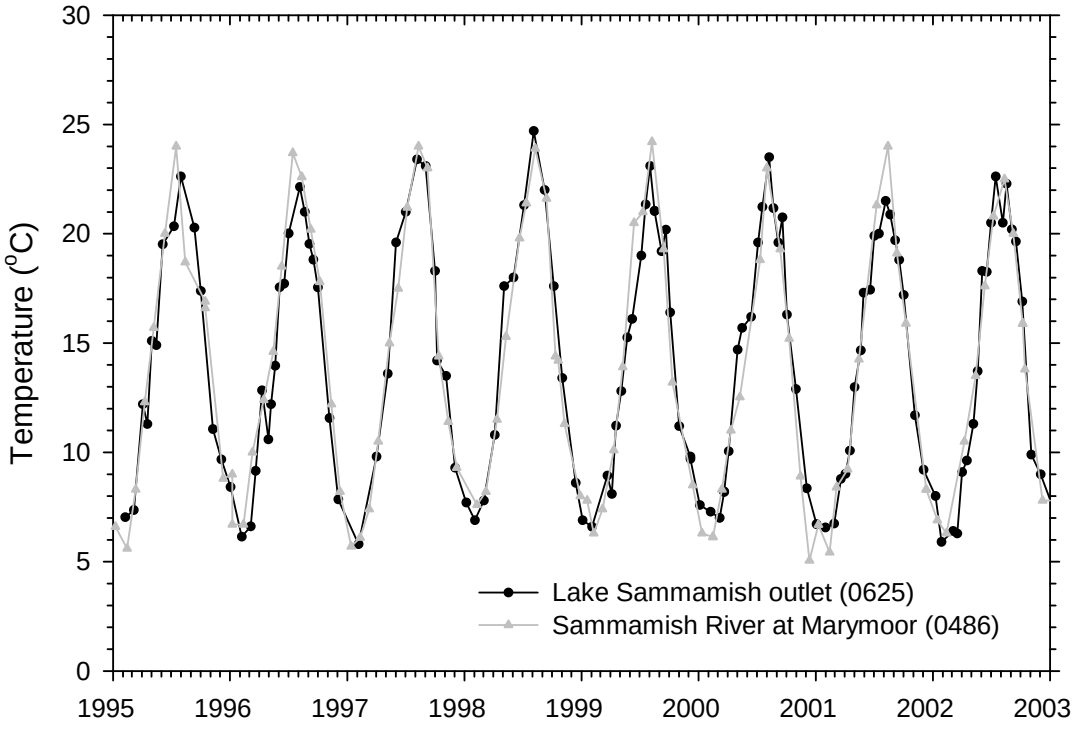

Figure 19 Near-surface (~1 m depth) temperature time series from Lake Sammamish routine monitoring station 0625 and Sammamish River at Marymoor Park (0486), 1995-2002.

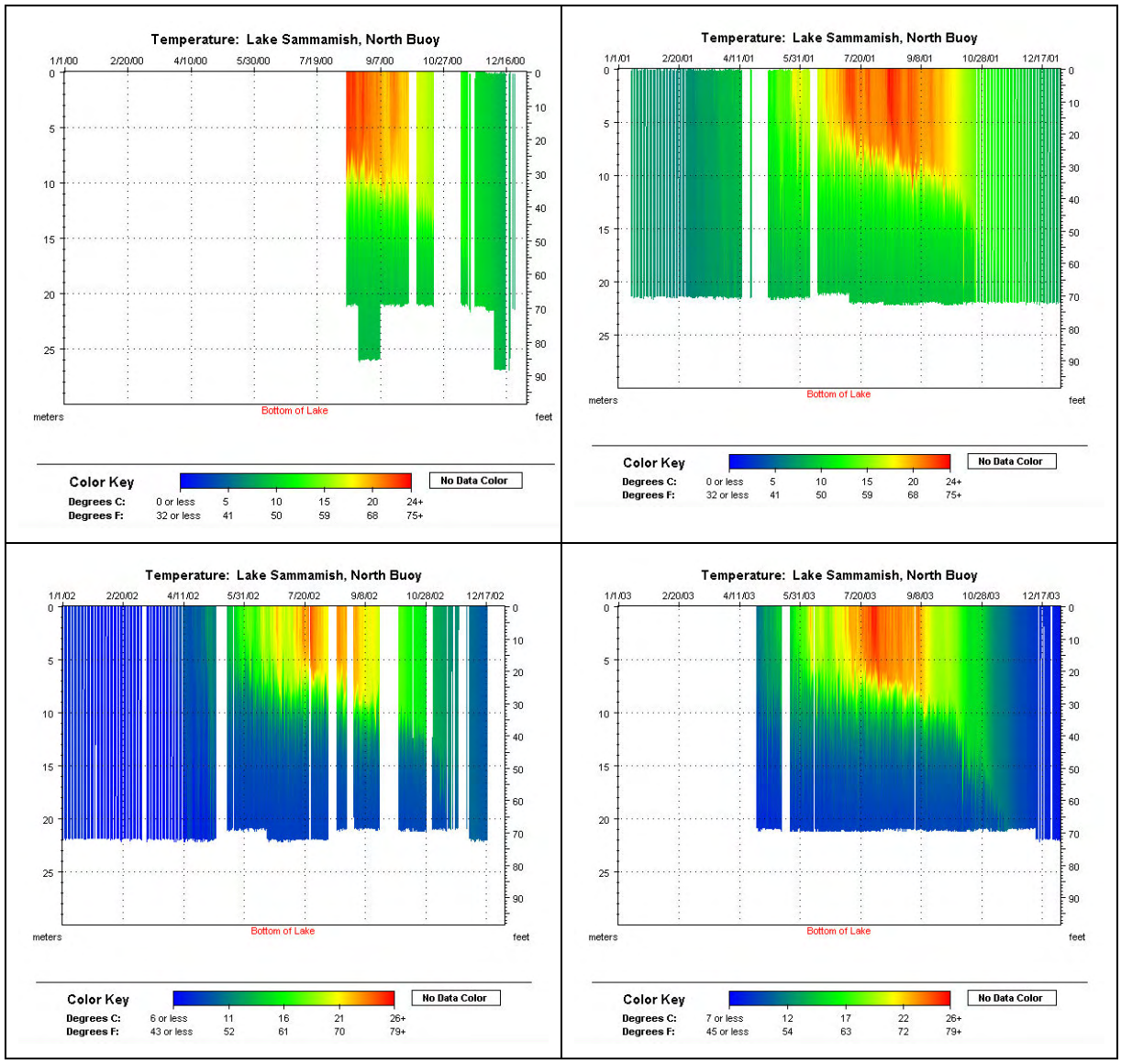

Figure 20 North Sammamish (SAMMN) RUSS buoy temperature color contour plots, 2000-2003.

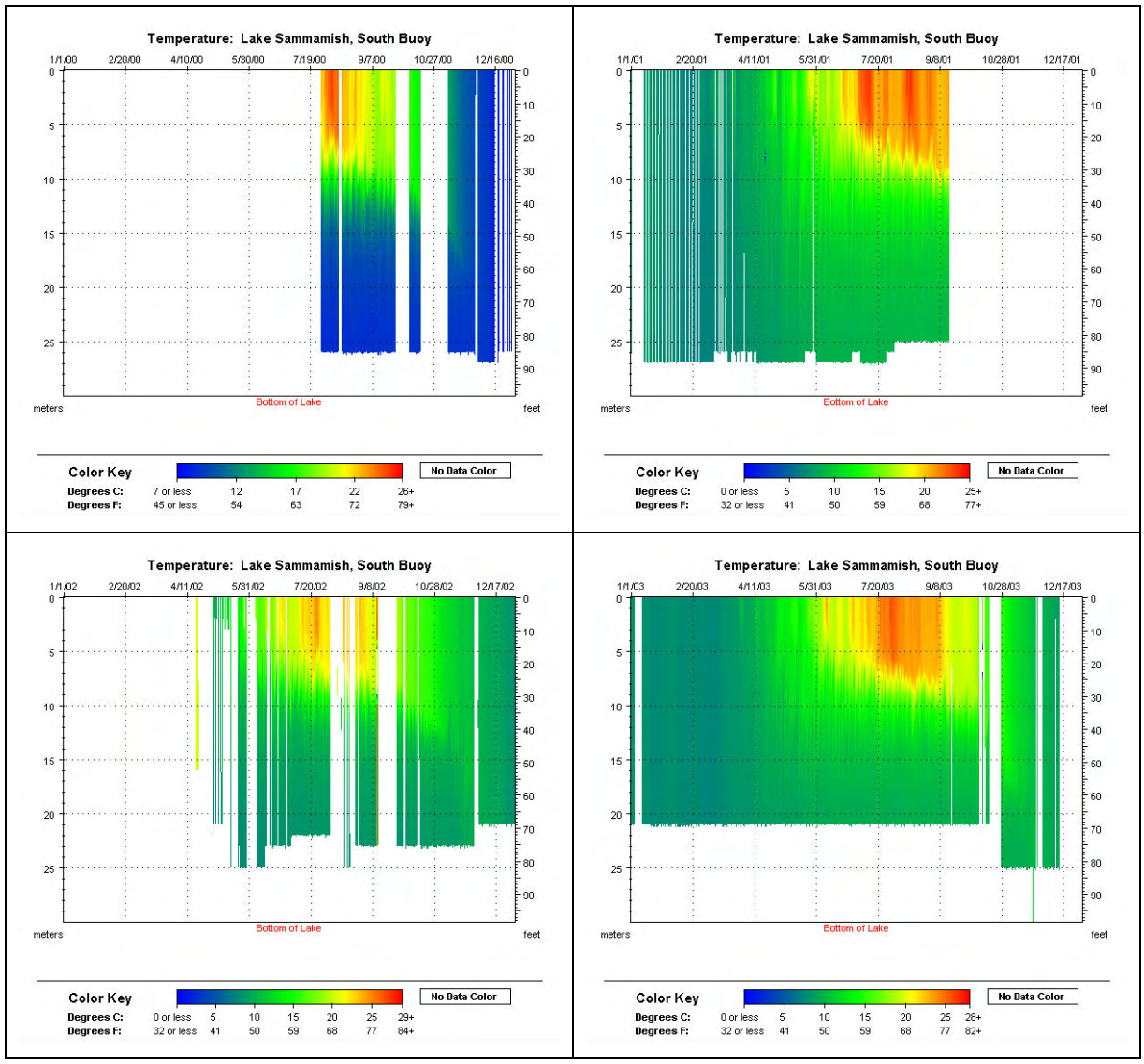

Figure 21 South Sammamish (SAMMS) RUSS buoy temperature color contour plots, 2000-2003.

4.4 Meteorological Data

Hourly or more frequent observations of air temperature, dew point, wind speed, wind direction, cloud cover, and solar radiation are needed as inputs to the pre-processing program that prepares the wind and equilibrium heat exchange input files for the model. Because Lake Sammamish is located on the fringe of the Seattle metropolitan area, meteorological data are available from a variety of locations (Table 7, Figure 22). Due to the length and quality of available records, data from Sea-Tac International Airport, approximately 21 km southwest of Lake Sammamish have

Table 7. Selected meteorological stations in the vicinity of Lake Sammamish.

Site Code	Site Name	Northing	Easting	Date Installed	Date Removed	Ground elevation in meters (NGVD 1929)
WBAN # 24233	Sea-Tac International Airport	167684 †	1273425 †	1-Nov-44	active	112.8 (4/2/02-) 121.9 (1/50-4/02)
SAMMS	Lake Sammamish RUSS buoy	215739	1329082	27-Jul-00	active	8.0
UW	University of Washington Atm. Sci. Bldg.	242133	1276750	30-Jul-99	active	Roof top
I-90	WASHDOT I-90 Bridge	218357	1286598	Fall 1994	active	4.3
SR520	WASHDOT SR 520 Bridge	236899	1288697	Fall 1994	active	4.3
	NOAA ISIS at Sandpoint	251256	1291462	21-Mar-95	active	20
WBAN # 24234	Boeing Field	197997	1278128	1-Jan-30	active	6.1 (10/22/65-
	Renton Municipal Airport	185459	1298492	1-Sep-61	active	8.8 (1/1/93-

Northing/Easting in State Plane feet, Washington North, North American Datum 1983

†The Sea-Tac meteorological observation location has changed a number of times over the last 50+ years. This is the current location as of 2/4/2002. Sea-Tac was converted to the Automated Surface Observation System (ASOS) beginning on October 1, 1996.

The Boeing Field station coverted to ASOS beginning on December 9, 1998.

The Renton Municipal Airport station converted to ASOS beginning on October 8, 1998.

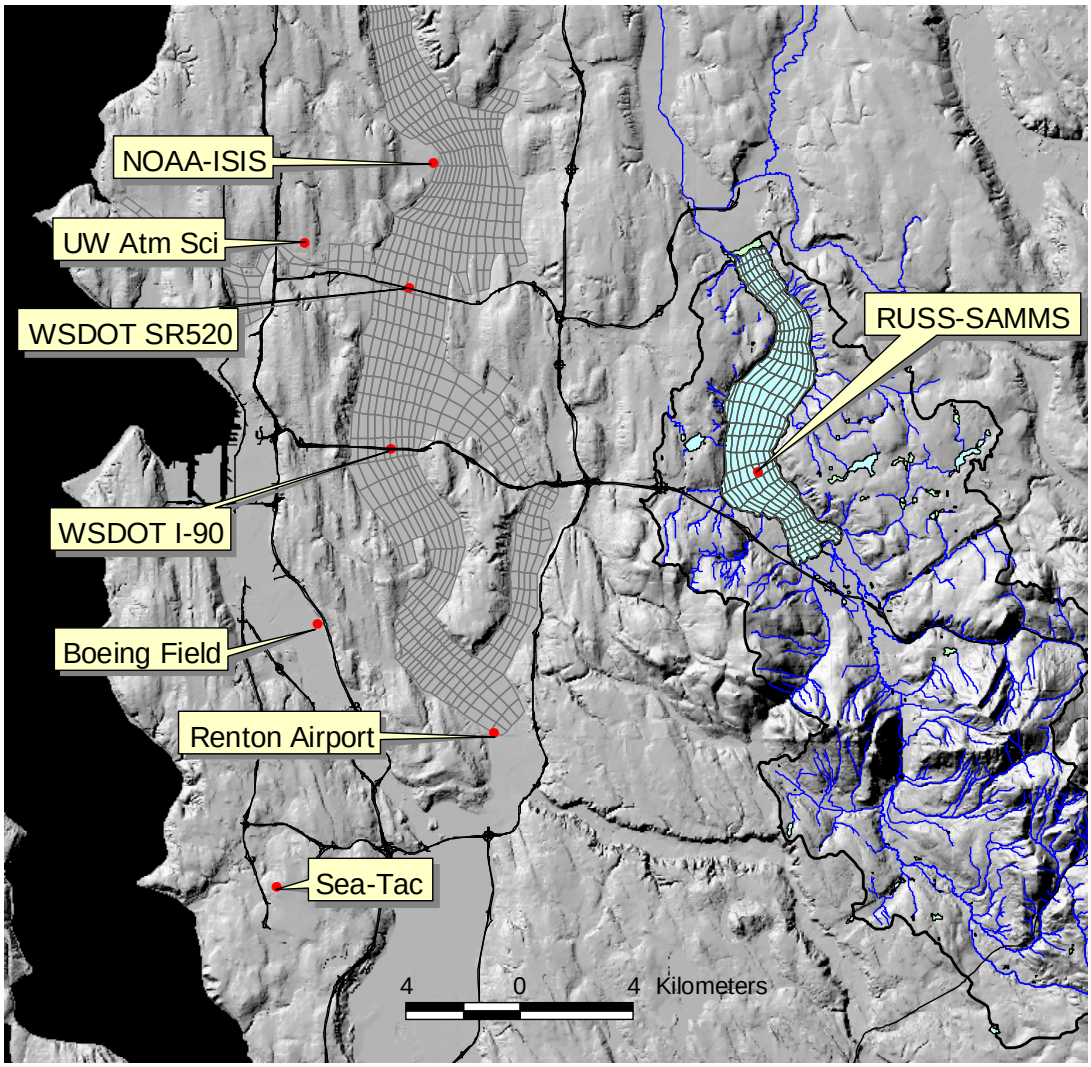

Figure 22 Selected meteorological stations in the vicinity of Lake Sammamish.

been the primary source of meteorological model inputs. Solar radiation observations at Sea-Tac ended in 1990[3], but beginning in March 1995 observations were initiated at the NOAA Sandpoint Facility on the western shores of Lake Washington approximately 11 km from Lake Sammamish as part of the Integrated Surface Irradiance Study (ISIS). The Atmospheric Science Department at the University of Washington (UW), located just west of Lake Washington 15 km from Lake Sammamish has also been measuring solar radiation – 1 minute data are available from their website beginning in July 1999. Sea-Tac meteorological data and solar radiation observations from UW and NOAA Sandpoint are currently used to provide meteorological inputs to the model.

[3] Hourly records for the period 1960-1990 are available from the National Climatic Data Center (NCDC) National Solar Radiation Database (NSRDB) and online at http://rredc.nrel.gov/solar/old_data/nsrdb/.

A RUSS buoy (SAMMS) equipped with a meteorological observation station was deployed on Lake Sammamish in July 2000. However, due to technical difficulties and vandalism, there are data gaps and some of the data are of questionable quality – particularly wind direction. When the meteorological data have been reviewed and suspect data identified and censored from the data set, these data will also be used to evaluate model performance. Currently, the RUSS buoy wind speed data have been used primarily to support the Wind Adjustment Factor used in the model calibration.

The Sea-Tac, UW, NOAA Sandpoint, and SAMMS RUSS buoy data are described in more detail below.

4.4.1 Sea-Tac International Airport

Hourly records for air temperature, dew point, wind speed, wind direction, and cloud cover are available from the NOAA's National Climatic Data Center (NCDC) for Sea-Tac International Airport since 1948. The specific location and heights of the instruments above the ground have changed over time (Table 8).

Beginning in October 1996, the station was converted to the Automated Surface Observation System (ASOS). Some of the most relevant changes that occurred due to system automation were standardization of the anemometer height (10 m) and conversion from strip chart recording of wind and estimation of 10-minute average wind speeds by eye to computerized recording and averaging of wind data. Conversion to ASOS also eliminated the reporting of cloud cover in tenths of sky. ASOS also does not report cloud cover above 12,000 ft. Cloud cover is currently reported for one or more ceiling heights using text descriptions (e.g., CLR-clear, SCT-scattered, OVC-overcast) that translate into Octa ranges (eights of sky).

Hourly data supplied by EarthInfo, Inc. through 2003 on CD-ROM were extracted into TD1440 ASCII format and processed using a Fortran program developed to extract data to a comma-delimited file format suitable for importing into an electronic database. Hourly and three hourly data were purchased from NCDC in DATSAV3 format and processed using a Fortran program to develop hourly cloud cover in tenths for model input for the post-ASOS period. Comparisons were made between pre- and post-ASOS sky cover summation codes[4] and reported cloud cover in tenths to derive conversions between the sky cover summation codes and cloud cover in tenths for the ASOS records (Table 9). Table 9 also presents the conversions used to develop the cloud cover inputs for the HSPF watershed models. Note that the values and the details of the two methods differ. An effort will be made to adopt a consistent method for both models in the future.

The hourly meteorological data and monthly averages for the period 1995-2002 are shown in Figure 23.

[4] The DATSAV3 code that denotes the portion of the total celestial dome covered by all layers of clouds and other obscuring phenomena at or below a given height.

Table 8. Station history for Sea-Tac International Airport meteorological observations.

Location	Occupied		Latitude North	Longitude West	Elevation Above (meters)						
					Sea Level	Ground					
	From	To			Ground Temperature	Wind Instrument	Extreme Temperature.	Psychrometer	Sunshine Switch	Weighing Rain Gauge	8 in Rain Gauge
Sea-Tac Airport	Apr. 2, 2002	Present	47°27’	122°19’	112.8	10.0	?	?	?	?	?
Sea-Tac Airport	Oct. 1, 1996	Apr. 2, 2002	47°28’	122°19’	121.9 (136.2 j)	10.0	?	?	?	?	?
Admin Bldg.	Dec. 11, 1959	Oct. 1, 1996	47°27’	122°18’	121.9	6.1	1.8 (23.5)	1.5 (23.5)	27.7 **%**	0.9 **f** (23.5 **g**)	0.9 (22.9)
Admin Bldg.	Nov. 1, 1956	Dec. 11, 1959	47°27’	122°18’	117.7	34.1 (6.1 **c**)	1.5 **b**	1.5 **b**	--	--	0.9
Admin Bldg.	Mar. 24, 1955	Nov. 1, 1956	47°27’	122°18’	114.6	33.2	1.5 **a**	1.5 **a**	--	--	0.9
Admin Bldg.	Nov. 17, 1949	Mar. 24, 1955	47°27’	122°18’	115.5	33.2	1.8	1.5	--	--	0.9
Control Tower	Nov. 21, 1944	Nov. 17, 1949	47°27’	122°18’	115.5	13.1	1.5	1.5	--	--	0.9
Source: 2002 Local Climatological Summary, National Climatic Data Center, Asheville, NC.											

a Moved 1000 ft NNE of previous site.

b Moved 210 ft WSW of previous site.

c Moved to field site 11/21/1959.

d Standby equipment. Roof site effective 9/23/1967.

f Added 1/1/1965.

g Moved to roof site 2/1/1966

% Commissioned 10/7/1968

j Ground elevation of ASOS station

Table 9. Cloud Cover code descriptions and translation from Octas to tenths.

Code	Description	Equivalent in Octas	CH3D Decimal Equivalent	HSPF Decimal Equivalent †
CLR	Clear	0/8	0.0	0.0
FEW	Few clouds	1/8 to 2/8	0.2	0.1875
SCT	Scattered clouds	3/8 to 4/8	0.28	0.4375
BKN	Broken clouds	5/8 to 7/8	0.79	0.75
OVC	Overcast	8/8	1.0	1.0
POB	Partly obscured	unknown	0.47	Not specified
OBS	Obscured	8/8	1.0	Not specified

† Details of the approach used to develop cloud cover inputs to the HSPF models is provided in (King County in progress)

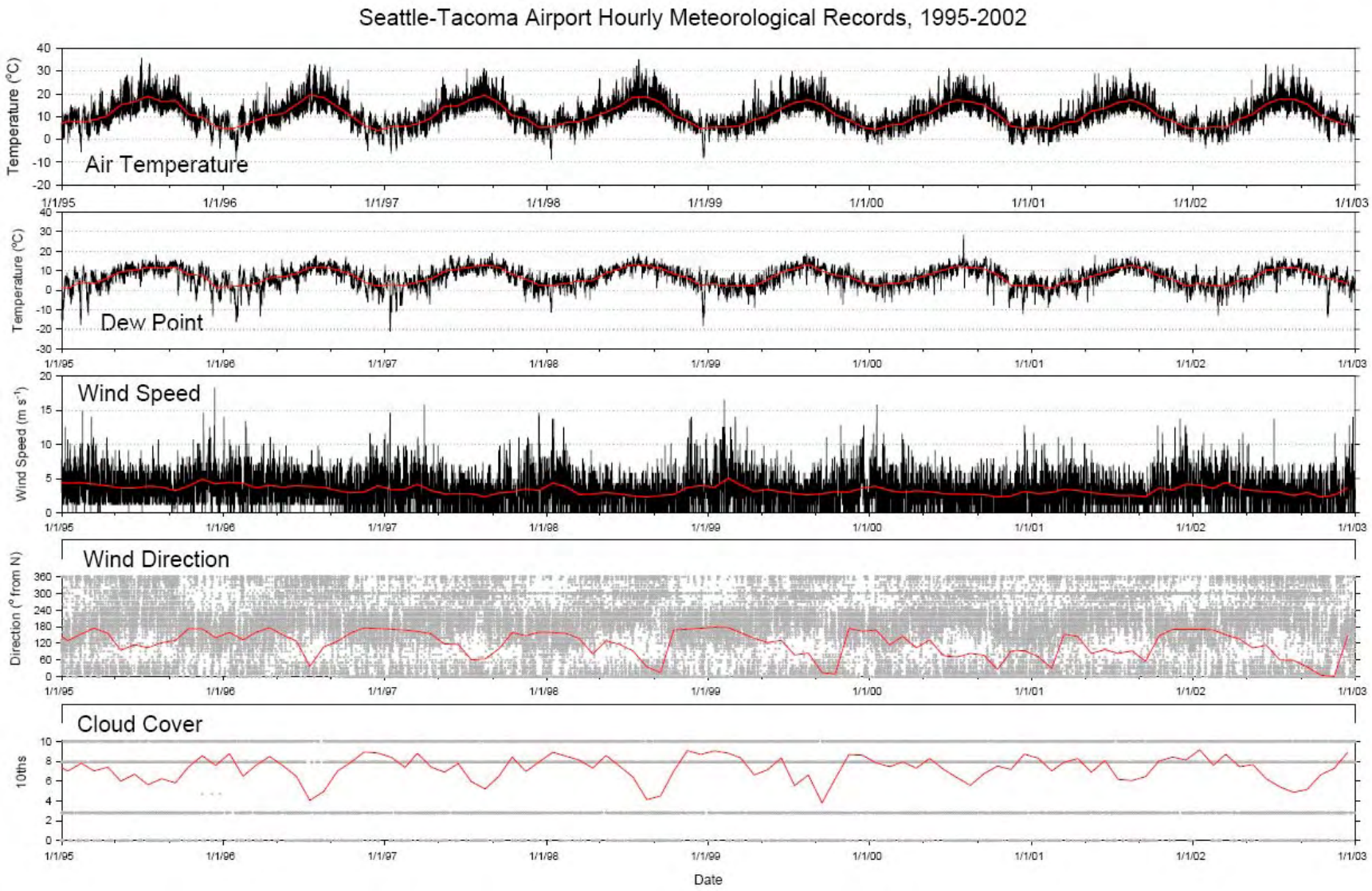

Figure 23 Sea-Tac meteorological data used in the Lake Sammamish model, 1995-2002.

4.4.2 NOAA Sandpoint Solar Radiation

As part of the Integrated Surface Irradiance Study (ISIS) conducted by NOAA (http://www.srrb.noaa.gov/isis/), solar radiation has been monitored since March 21, 1995. The annual hourly data in ASCII format were downloaded from their ftp site and compiled into a database. These data were reviewed and suspect data were identified. These data were supplemented with data collected at the University of Washington (see below) when available. Remaining data gaps were filled using the solar radiation computations in CE-QUAL-W2 (Cole and Wells 2003) and Sea-Tac cloud cover data in tenths. The hourly solar radiation data used in the model are presented in Figure 24.

4.4.3 University of Washington Atmospheric Sciences

The Atmospheric Sciences Department at the University of Washington has been collection meteorological data for many years, but only data collected since July 1999 is readily accessible from their website (http://www-k12.atmos.washington.edu/k12/grayskies/nw_weather.html). The available 1-minute data were downloaded by year and compiled into a database. These data include air temperature, dew point, wind speed, wind direction, and solar radiation. The solar radiation data were processed into hourly average values and reviewed for use in the model. These data were used to supplement the solar radiation data collected at the NOAA Sandpoint facility (see Figure 24).

4.4.4 South Lake Sammamish RUSS Buoy

A meteorological station was installed as part of the RUSS buoy deployed in the southern basin of Lake Sammamish (SAMMS) in July 2000. The station is equipped an R.M. Young™ weather station with sensors for air temperature-relative humidity, wind speed, wind direction (magnetic), and barometric pressure. The station is also equipped with a pyranometer (LiCor LI-200) that measures global solar radiation. The anemometer (wind speed and direction monitor) is approximately 2 m above the lake surface. Sampling frequency has varied from 6 minute to hourly intervals, but has been recording at 20 minute intervals since July 2003. There are a number of data gaps and some of the data are of suspect quality – primarily the initial air temperature and relative humidity measurements due to sensor failure and wind direction due to an act of vandalism in September 2001 that required the buoy to be rebuilt. Following reconstruction of the buoy, some difficulties were encountered in orienting the anemometer, which were compounded by a second act of vandalism a year later in which the anemometer orientation was changed. Data gaps have also occurred due to problems associated with the water column profiler, telecommunications, and power supply.

Figure 25 presents the available meteorological and solar radiation data collected from July 2000 through the end of 2003 along with annotations of significant problems associated with the data.

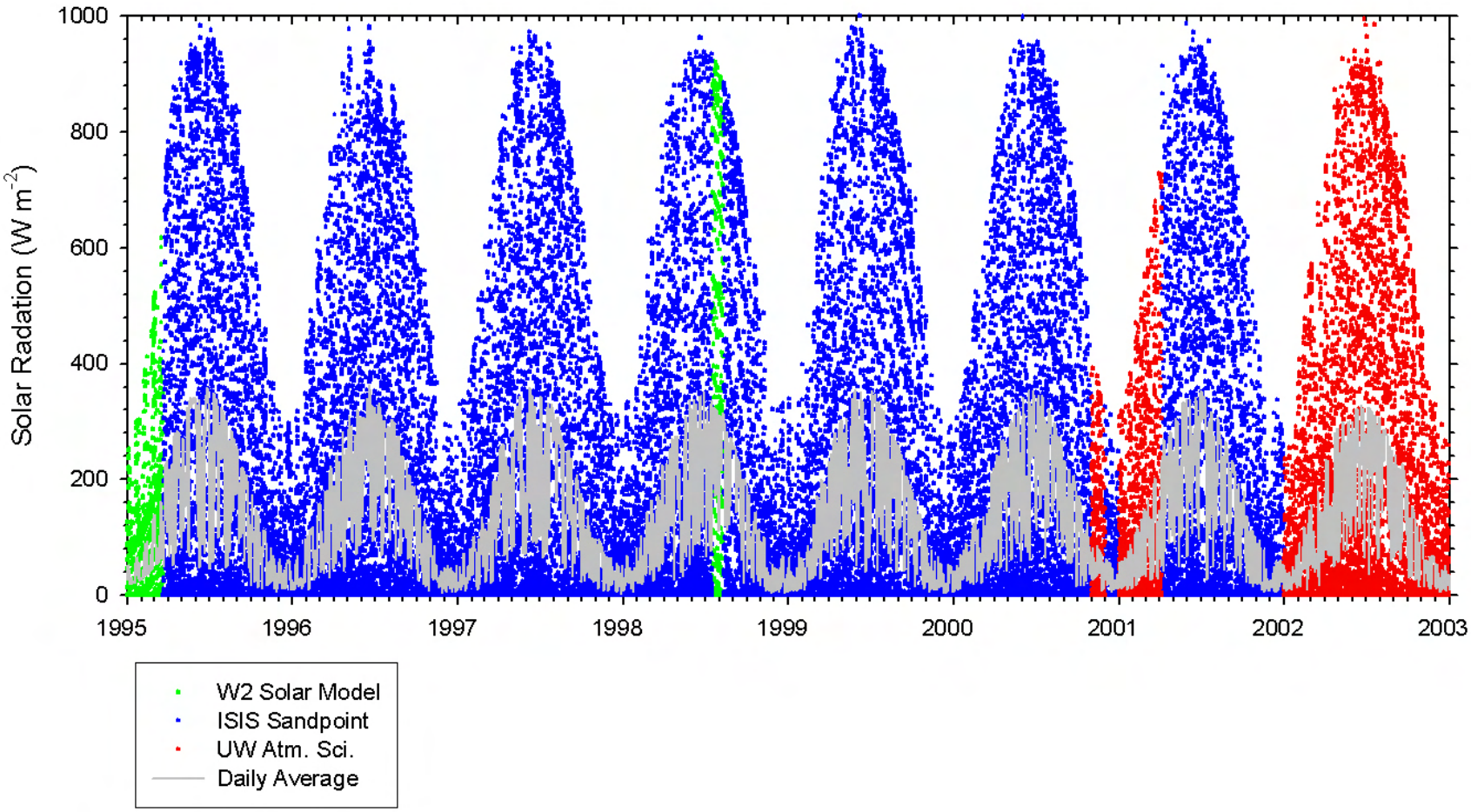

Figure 24 Solar Radiation data used in the Lake Sammamish model, 1995-2002.

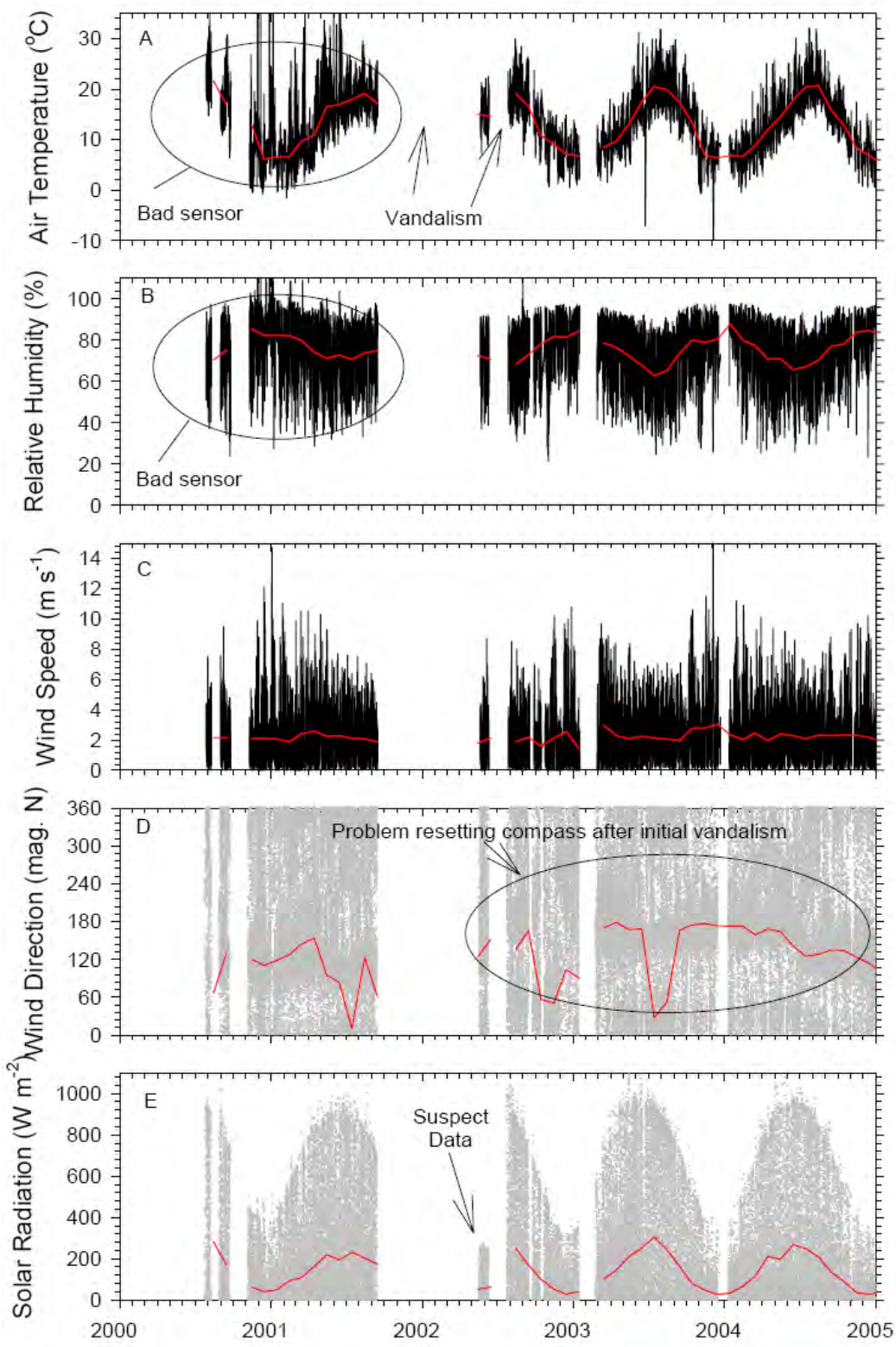

Figure 25 Meteorological and solar radiation data recorded by the SAMMS RUSS buoy, 2000-2004.

5.0. MODEL CALIBRATION

Initial calibration of the Lake Sammamish CH3D-Z hydrodynamic model has been achieved through three independent steps.

1. The ACOE-ERDC modified the Fortran turbulence closure subroutine in the Chesapeake Bay version of CH3D-Z as part of the initial Lake Washington hydrodynamic model calibration (Johnson and Kim 2004). This modification reduced the modeled suppression of turbulent energy transfer at density gradients, which allowed the model to better predict the degree of thermal stratification during summer. A comparison of model-predicted temperatures using the initial and final turbulence code is presented in Figure 26

2. The second step involved the replacement of calculated solar radiation in the heat exchange pre-processing program (using cloud cover and solar position algorithms) with local observations of solar radiation. This change was made as a result of comparisons of the solar radiation predicted by the heat exchange algorithm and local observations, which indicated that the heat exchange program over-predicted solar radiation by about 30 percent on average (see Figure 27). Although replacement of the original solar radiation algorithm with the one used in CE-QUAL-W2 v. 3.2 (Cole and Wells 2003) resulted in much less error (about 3 percent), the availability of reliable and almost continuous local observations of solar radiation for the period selected for model calibration argued for use of observed over predicted inputs to the heat exchange program. Therefore, the heat exchange program was adapted to use observed solar radiation. Long-term simulations may require re-implementation of a solar radiation prediction algorithm.

3. The third step was iterative with step 2, but essentially involved the realization that the Wind Adjustment Factor required a step change beginning in 1997 as a result of a systematic decrease in reported wind speeds at Sea-Tac International Airport (Figure 28). The change is thought to be due primarily to the conversion to ASOS in October 1996. As a result of station automation, hourly wind speed (average of winds recorded during the 10 minutes before the top of the hour) was no longer estimated by a human observer reading a strip chart recorder but were calculated digitally by computer. It is suspected that observers biased their ten-minute averages by over-weighting large peaks on the strip chart, although changes in station location could also explain some or all of the differences (Hill, C. and B. Colman, NOAA/National Weather Service, pers. comm., 25 October 2004). Other changes in instrumentation and instrument location have occurred at this station in the past and some effects on the historical climate record have been documented (Albright, M., Washington State Climate Office, pers. comm., 24 October 2004).

Once these steps were accomplished, calibration became a trial and error testing of various annual Wind Adjustment Factors to best match the available routine temperature profiles at the 6 in-lake stations recorded in 1995-2002. The final annual wind adjustment factors and relevant model parameters are summarized in Table 10. Comparison of modeled and observed

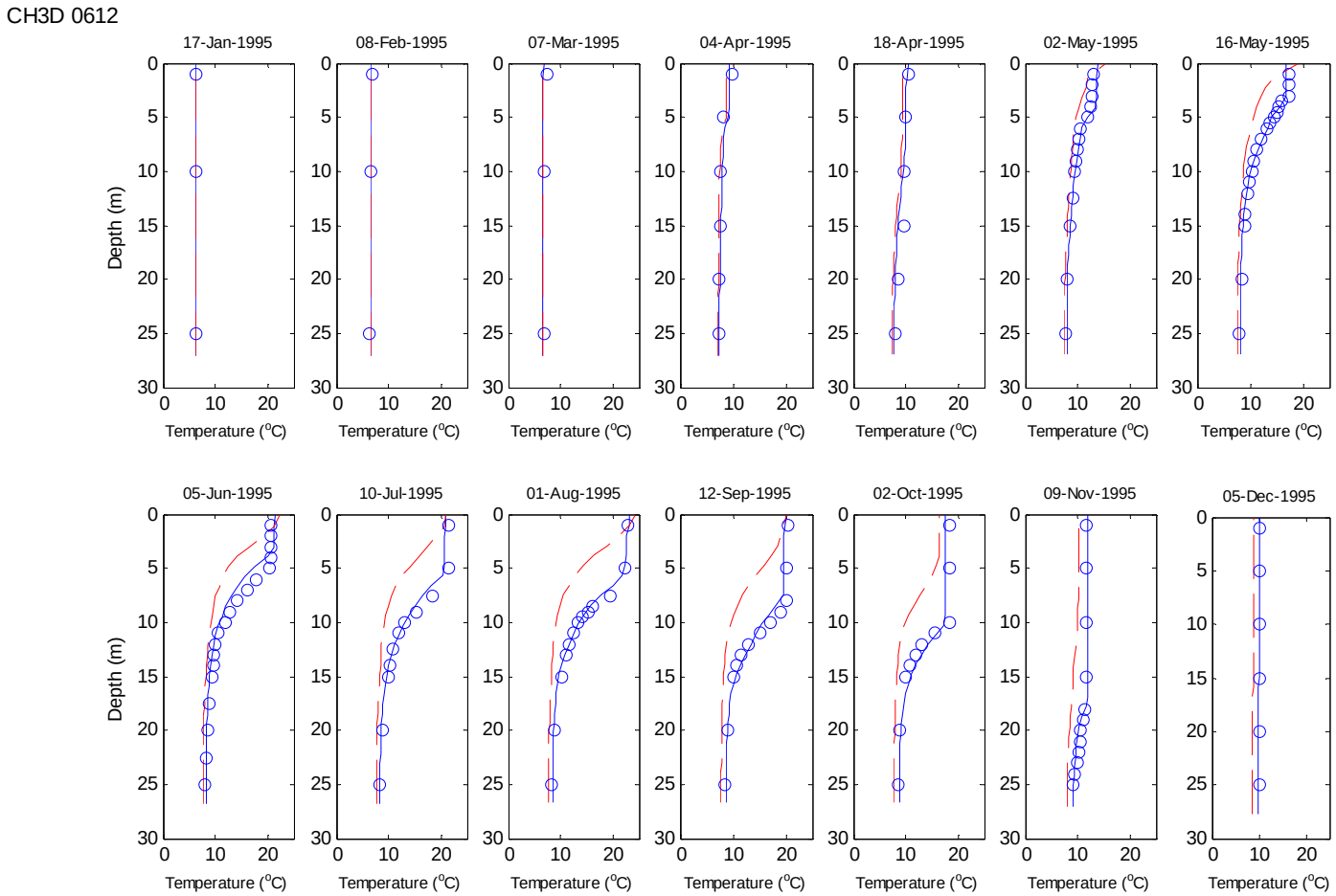

Figure 26 Comparison of initial model with additional turbulence suppression (solid blue lines) with final model without additional turbulence suppression (dashed red lines) – Lake Sammamish Station 0612, 1995. Observed temperature profiles (open circles) also shown.

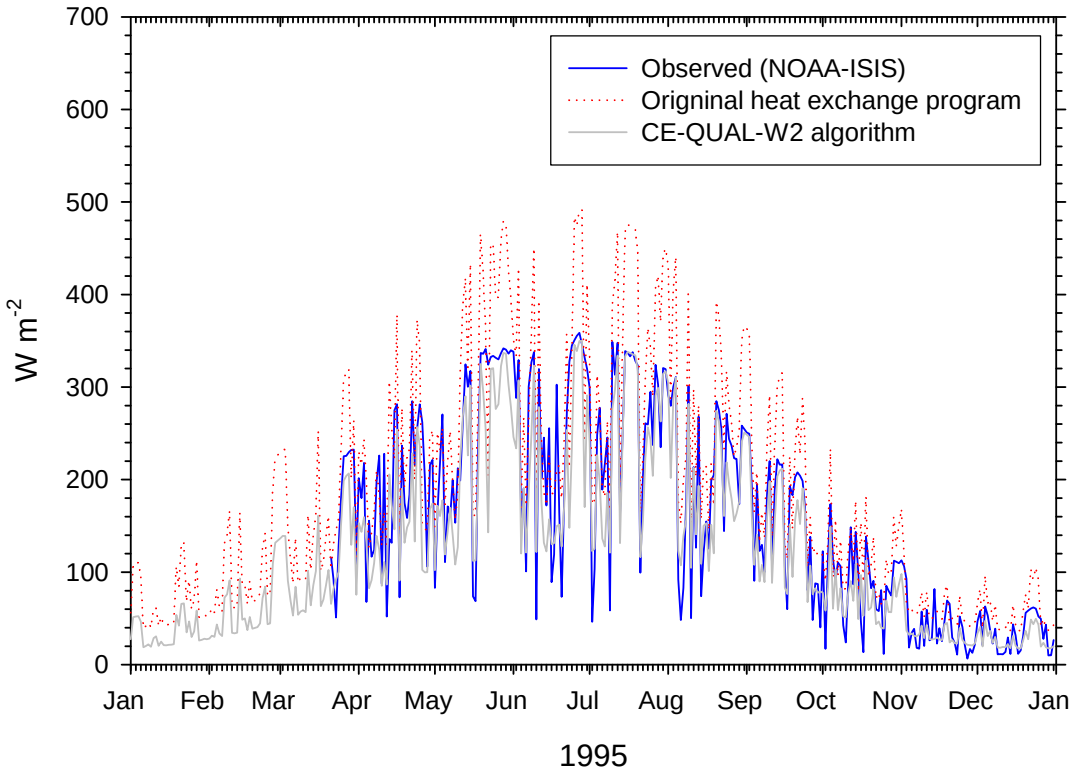

Figure 27 Comparison of 1995 observed daily average solar radiation to predictions from the original heat exchange program and CE-QUAL-W2.

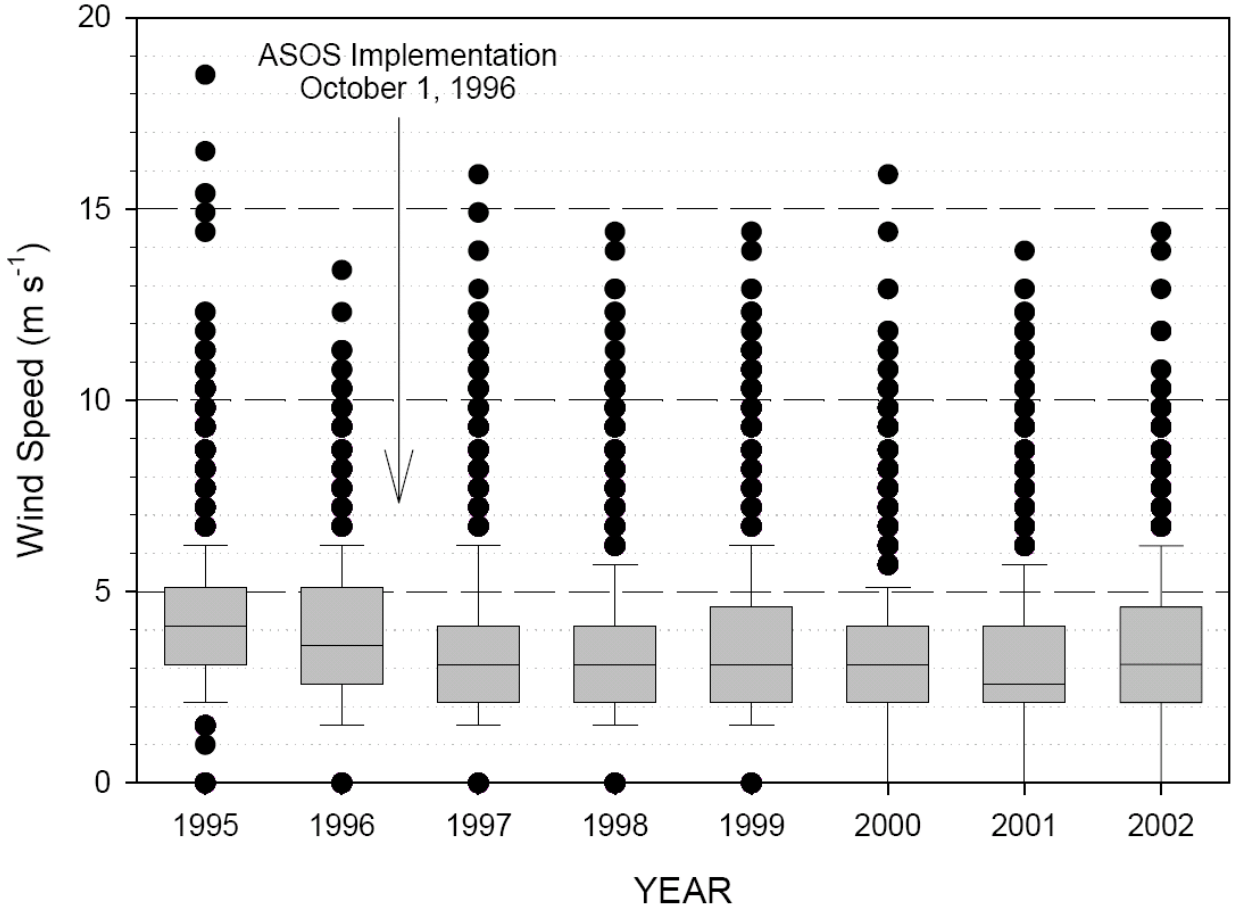

Figure 28 Box plot of hourly wind speeds recorded each year at Sea-Tac International Airport from 1995 to 2002.

Table 10. Summary of Lake Sammamish CH3D-Z Model Calibration Parameters.

Wind Adjustment Factor							
1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
0.60	0.60	0.80	0.85	0.85	0.85	0.85	0.85

Selected Model Parameters			
Parameter	**Value**	**Units/Comments**	**Recommended Value (Johnson and Kim 2004)**
Time Step (DT)	60	Seconds	
Crank-Nicholson Weighting Factor (THETA[S])	1.0	Fully implicit	0.55
Horizontal Eddy Viscosity (AHR)	1000	cm^2/sec	1,000 – 100,000
Minimum Vertical Eddy Viscosity (AVM)	1.0	cm^2/sec	0.2 – 5.0
Minimum Vertical Eddy Diffusivity (AVM1)	0.002	cm^2/sec	0.0001 – 0.001
Maximum Vertical Eddy Viscosity (GAMAX)	100	cm^2/sec	100 – 1000
Maximum Vertical Eddy Diffusivity (GBMAX)	750	cm^2/sec	100 – 1000

temperature profiles are provided in Appendix B. An example comparison of modeled and observed temperature profiles for the central 0612 station in 1995 is shown in Figure 29. A comparison of model-predicted lake outlet temperatures with surface temperatures recorded at Station 0625 and the Sammamish River at Marymoor Park (0486) just below the lake outlet weir is provided in Figure 30. Summary statistics based on comparison of modeled to observed temperatures are provided in Table 11. Scatterplot comparisons of observations with modeled temperatures for midlake (0611 and 0612) and nearshore (0614, 0617, M621, 0622) stations are presented in Figure 31. Selected error statistics aggregated by year for each station are presented in Figure 32. Selected error statistics aggregated by depth for Midlake (0612 and 0611) and Nearshore (0614, 0617, M621, and 0622) stations are presented in Figure 33.

The model error statistics place the performance of the Lake Sammamish hydrodynamic model in the upper 50th percentile among mechanistic water quality models reviewed by Arhonditsis and Brett (2004). Although overall model performance with respect to seasonal and spatial temperature changes in the lake between 1995 and 2002 is reasonably good, seasonal, interannual, and spatial patterns in model temperature prediction errors are apparent. There is a general tendency for the model to under predict surface temperatures and over predict bottom temperatures (Figure 33). This pattern is reflected in the spatial statistics for midlake vs. nearshore stations (Table 11), with lower bias and RMSE reported for midlake stations due to the canceling of errors at the surface and bottom – shallow stations have an overall negative bias and higher RMSE. Seasonal patterns are also evident with overall under prediction of temperatures January – September and over prediction October through December. Interannual errors are evident as well (Figure 32), with the most distinct shift occurring after the implementation of ASOS at Sea-Tac – the current source of meteorologic inputs to the model. A distinct negative bias occurs at shallower stations (indicating a stronger negative bias in surface temperature prediction) after the implementation of ASOS. Schock (2005) also noted the seasonality of and inter annual variation in model prediction errors with respect to the Lake Washington CH3D-z hydrodynamic model.

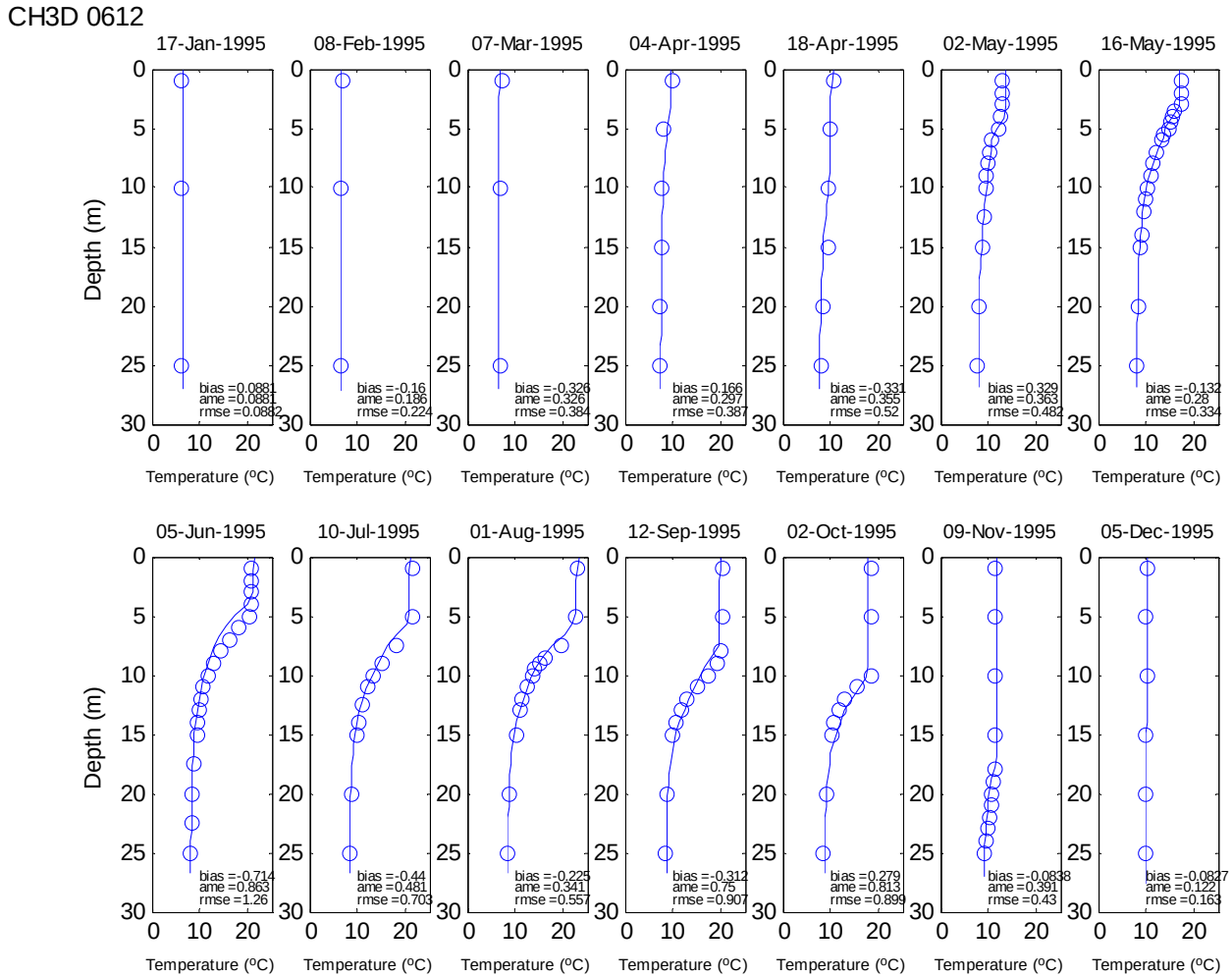

Figure 29 Comparison of modeled (lines) with observed (open circles) temperature profiles – Lake Sammamish Station 0612, 1995.

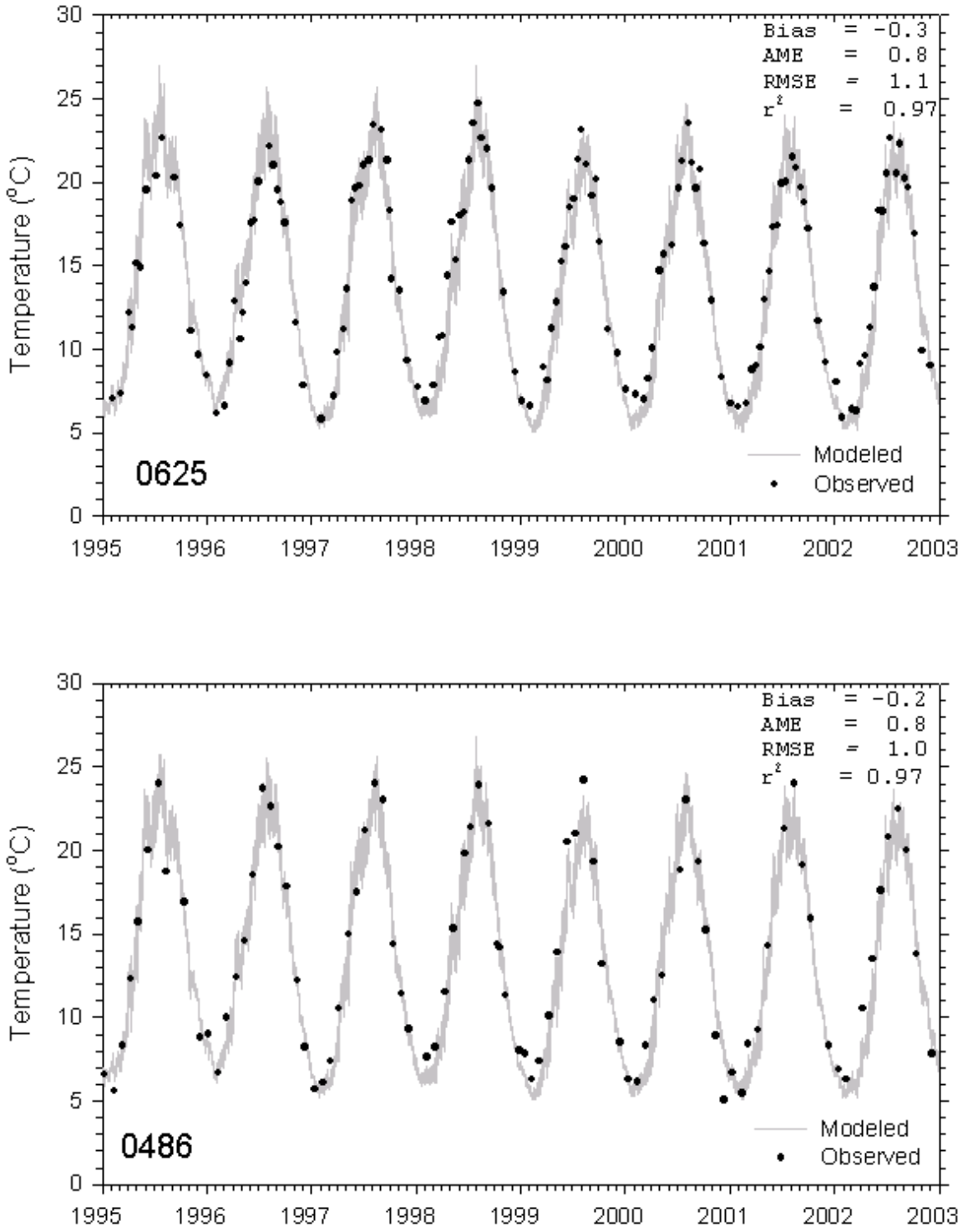

Figure 30 Comparison of modeled (lines) with observed (open circles) lake outlet surface temperature data – Lake Sammamish Stations 0625 and 0486, 1995-2002.

Table 11. Lake Sammamish CH3D-Z Model Temperature Prediction Errors – 1995-2002.

Overall						
	n	Bias (ME)	AME	RMSE	REM (%)	SE
6 stations	4844	-0.14	0.84	1.12	6.70	1.05
By Station						
StationID	N	Bias (ME)	AME	RMSE	REM (%)	SE
0612	1604	0.01	0.76	1.02	6.43	1.01
0611	1548	-0.04	0.87	1.14	7.24	1.06
0614	451	-0.34	0.95	1.28	7.11	1.08
0617	421	-0.43	0.87	1.14	6.44	0.98
M621	405	-0.36	0.79	1.06	5.59	0.97
0622	415	-0.39	0.92	1.25	6.75	1.04
By Season						
	n	Bias (ME)	AME	RMSE	REM (%)	SE
January-March	674	-0.32	0.62	0.71	8.97	0.78
	n	Bias (ME)	AME	RMSE	REM (%)	SE
April-June	1339	-0.27	0.86	1.16	7.54	1.04
	n	Bias (ME)	AME	RMSE	REM (%)	SE
July-September	1908	-0.22	0.93	1.24	6.08	1.09
	n	Bias (ME)	AME	RMSE	REM (%)	SE
October-December	923	0.35	0.77	1.04	6.23	0.96
By Spatial Location						
	n	Bias (ME)	AME	RMSE	REM (%)	SE
Midlake	3152	-0.01	0.81	1.08	6.83	1.04
Nearshore	1692	-0.38	0.89	1.19	6.48	1.02

ME = Mean Error (bias)
AME = Absolute Mean Error
RMSE = Root Mean Square Error
REM (%) = Relative Error of the Mean (percent)
SE = Standard Error

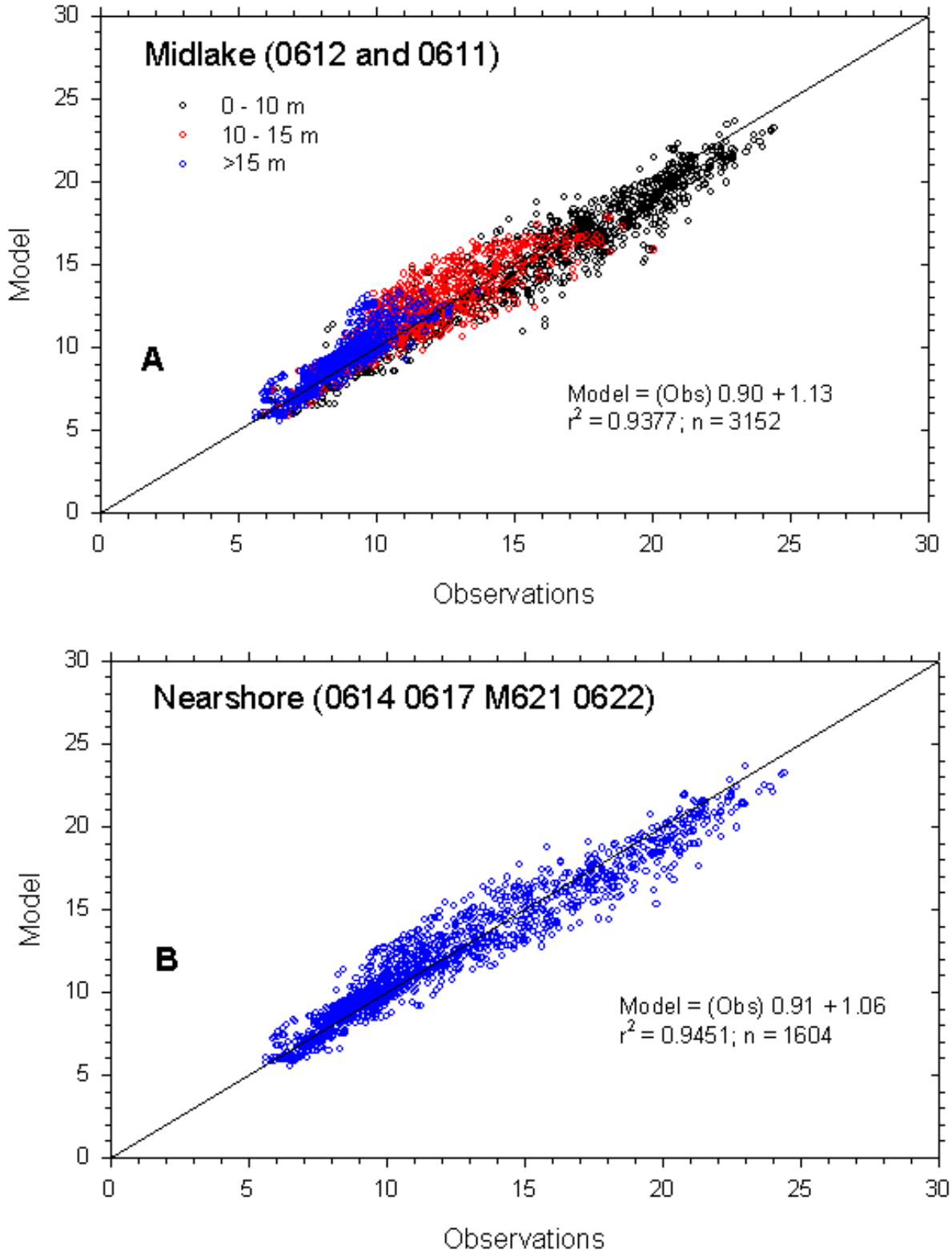

Figure 31 Comparison of modeled with observed Lake Sammamish temperature data – Midlake (A) and Nearshore (B) stations, 1995-2002.

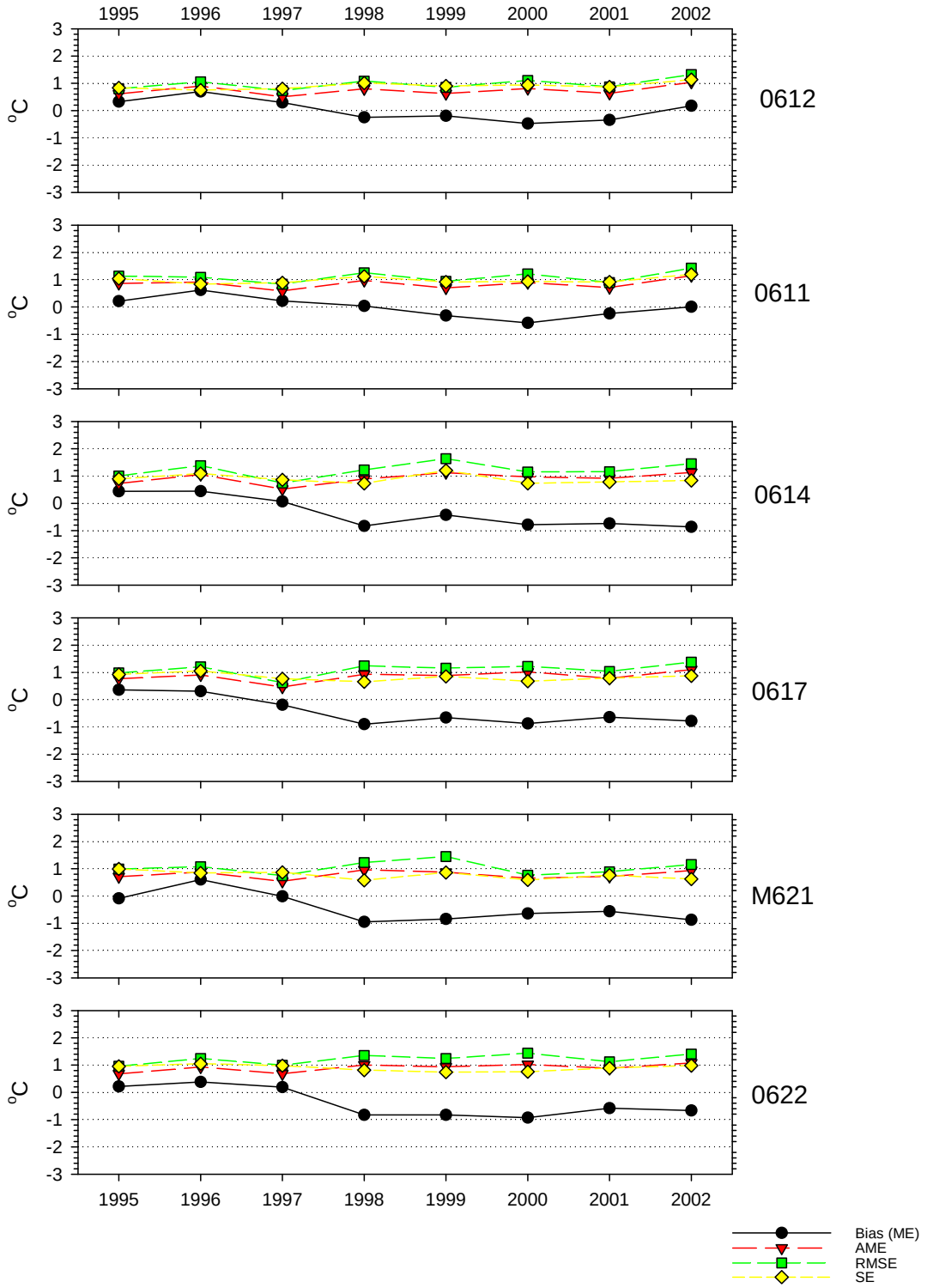

Figure 32 Annual average error statistics for Lake Sammamish CH3D model temperature predictions by station, 1995-2002.

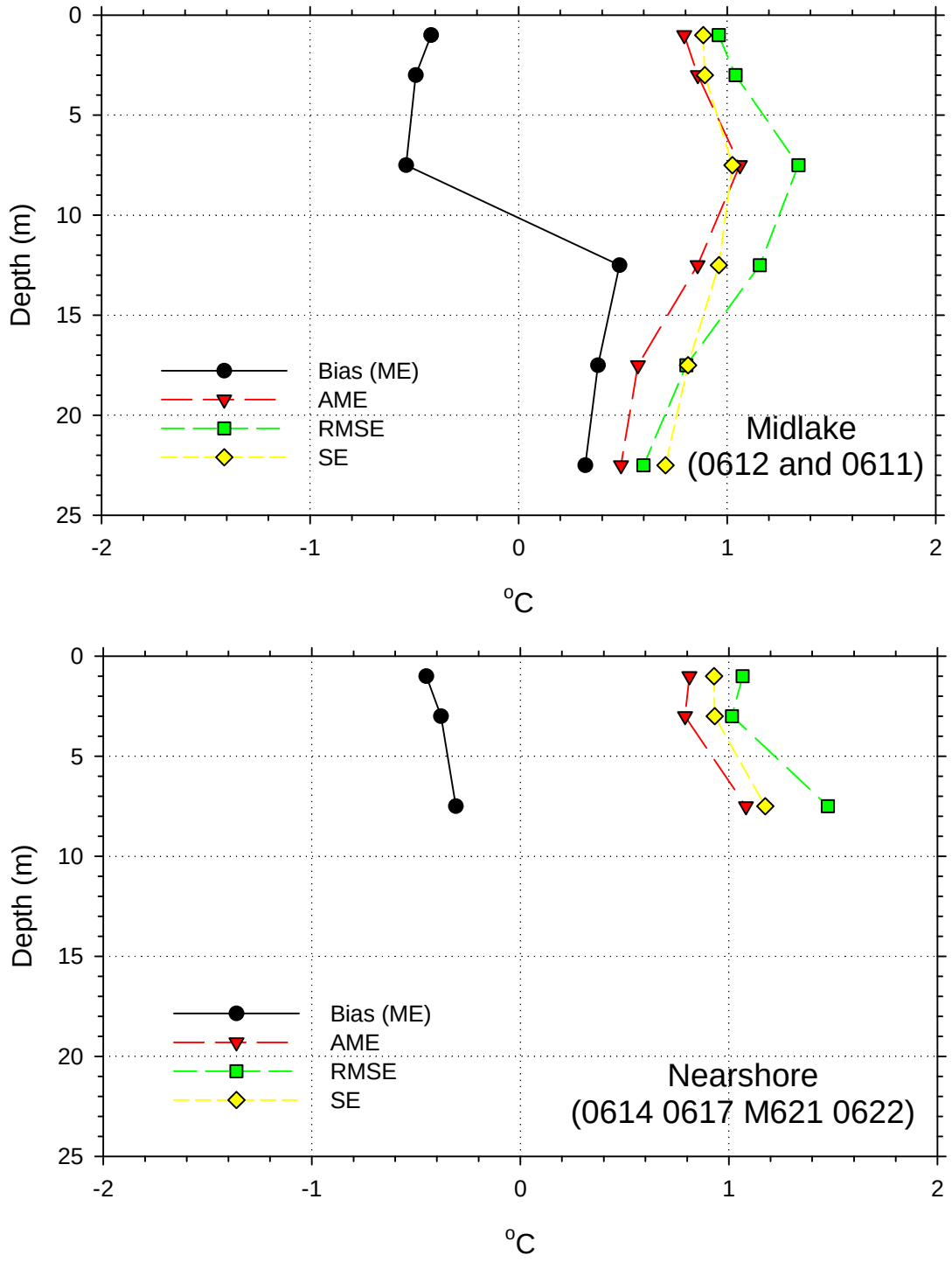

Figure 33 Lake Sammamish CH3D model temperature prediction errors aggregated by depth for Midlake and Nearshore stations, 1995-2002.

6.0. CONCLUSIONS AND RECOMMENDATONS

A great deal of progress has been made in the development of a hydrodynamic model of Lake Sammamish capable of simulating the temporal and spatial dynamics of water temperature. The current model does produce systematic seasonal, interannual, and spatial (primarily vertical) temperature prediction errors. The sources of the errors are not well understood, but model testing by Schock (2005) suggested potential problems associated with the turbulence closure scheme and possible influence of numerical diffusion at the time steps currently used in the Lake Sammamish and Lake Washington models.

Further improvements in the model's capabilities will only come with additional data collection and further model testing and development. One potential improvement would be the incorporation of an improved turbulence closure scheme. Kim et al. (2004) describe the implementation of a non-equilibrium stability parameter (Canuto et al. 2001) in the Lake Washington CH3D-z model, which improved the model's prediction of surface layer mixing under stratified conditions. Based on the testing results of the current version of the model, at a minimum, the next version of the model should be based on an evaluation of the revised turbulence closure scheme of Kim et al. (2004) and an evaluation of the influence of model time step on numerical diffusion. A much lower time step may be required to minimize numerical diffusion, which may dramatically affect model run times.

The development of other water quality models capable of predicting temperature with similar or greater accuracy should also be considered. For example, a laterally-averaged 2-dimensional model (CE-QUAL-W2) of the lake has already been developed, but has not been thoroughly tested. Initial testing suggests that similar temperature prediction accuracy can be obtained with the advantages of shorter model run times and greater ease in coupling the hydrodynamic model to the water quality routines available in CE-QUAL-W2 and greater ease in linking a CE-QUAL-W2 lake model to the existing Sammamish River CE-QUAL-W2 model (King County 2007).

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