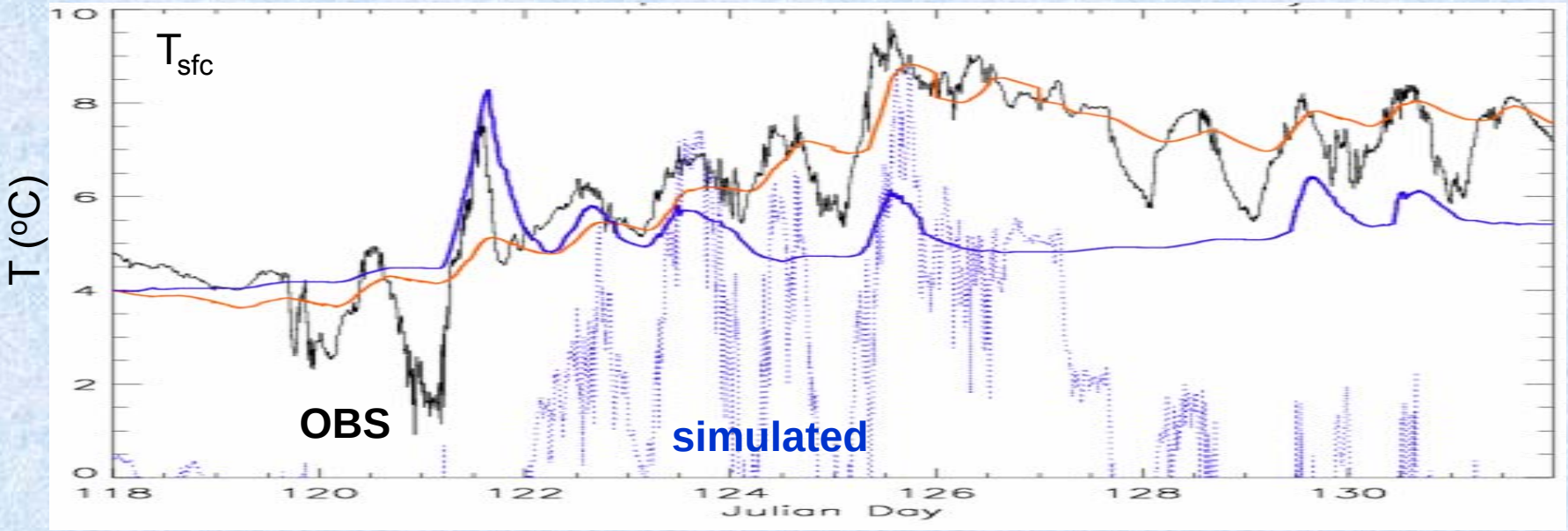
The CLASS Lake Module

Murray D. MacKay
Environment Canada

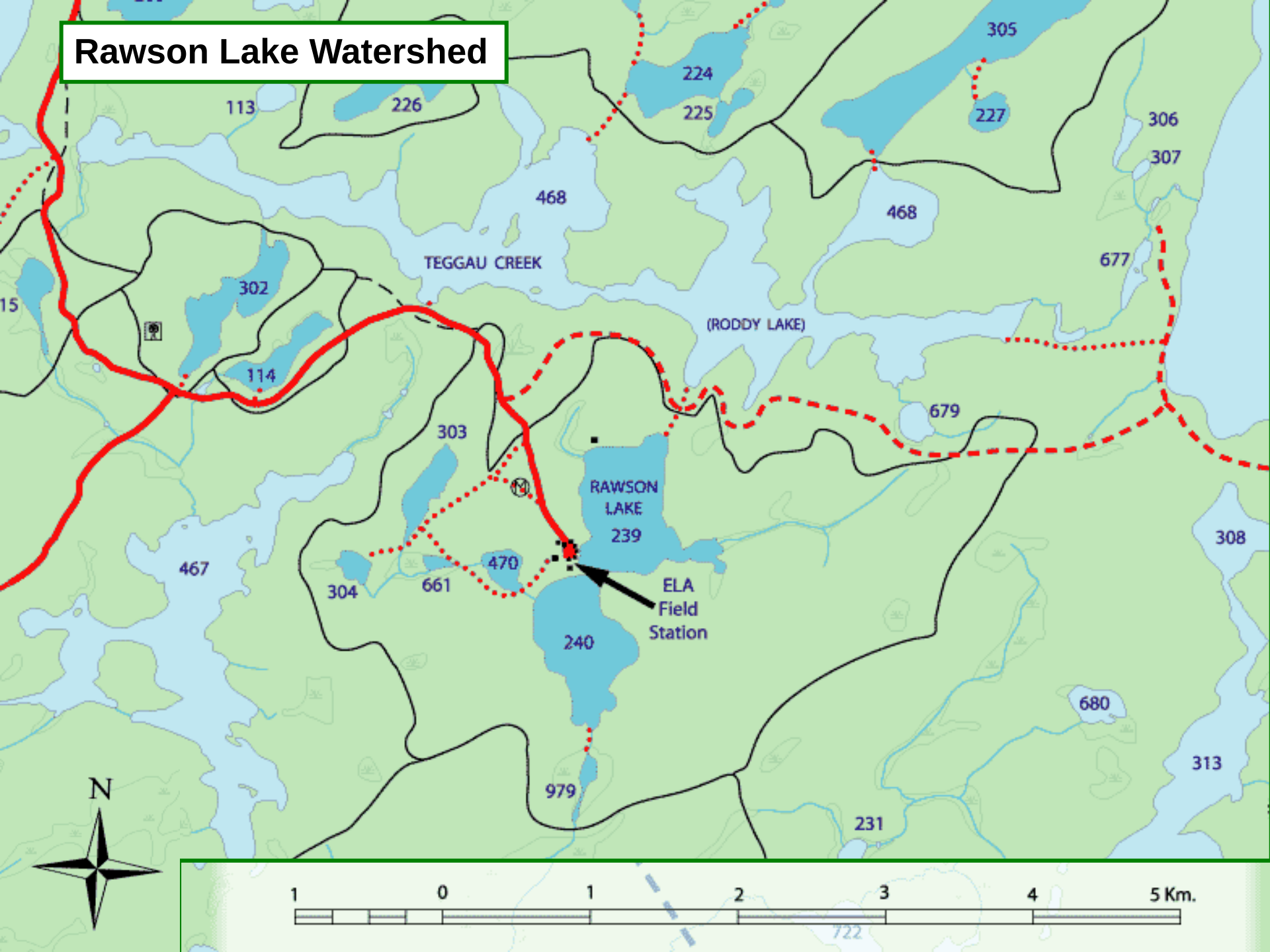
Last year …

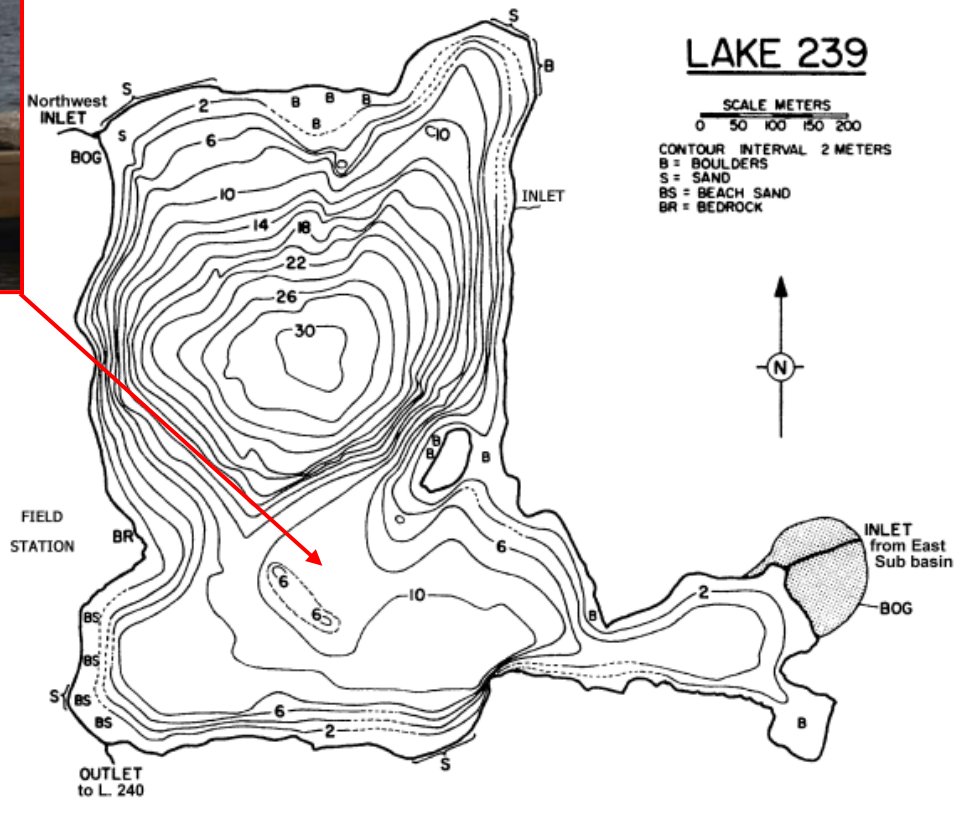
Lake Råksjön
April 28 – May 12 1995



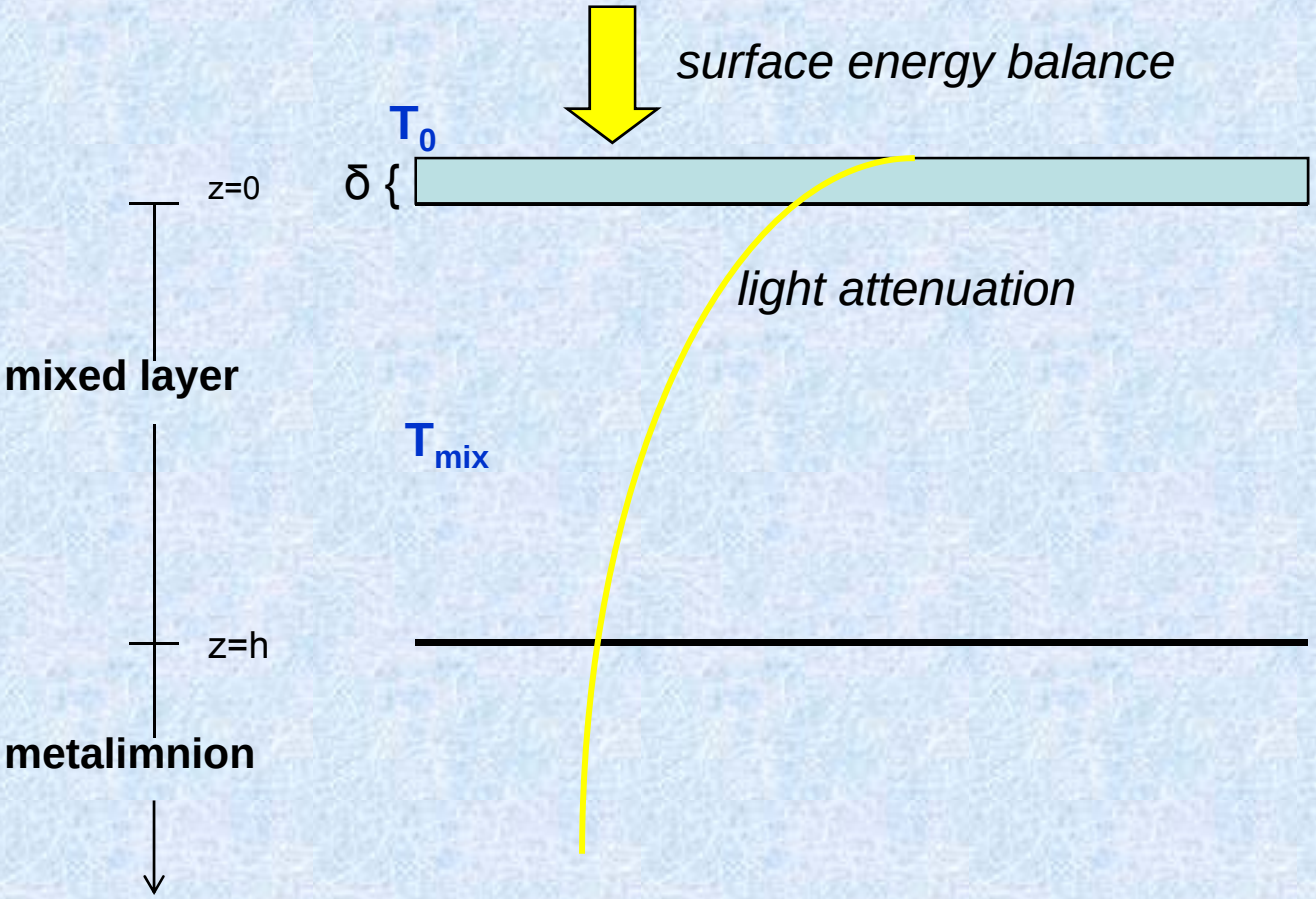
… not enough data to understand problems

Experimental Lakes Area


Rawson Lake Watershed
113
226
224
225
305
227
306
307
468
468
TEGGAU CREEK
(RODDY LAKE)
677
679
302
114
303
RAWSON
LAKE
239
308
467
304
661
470
ELA
Field
Station
240
680
313
979
231
N
1 0 1 2 3 4 5 Km.

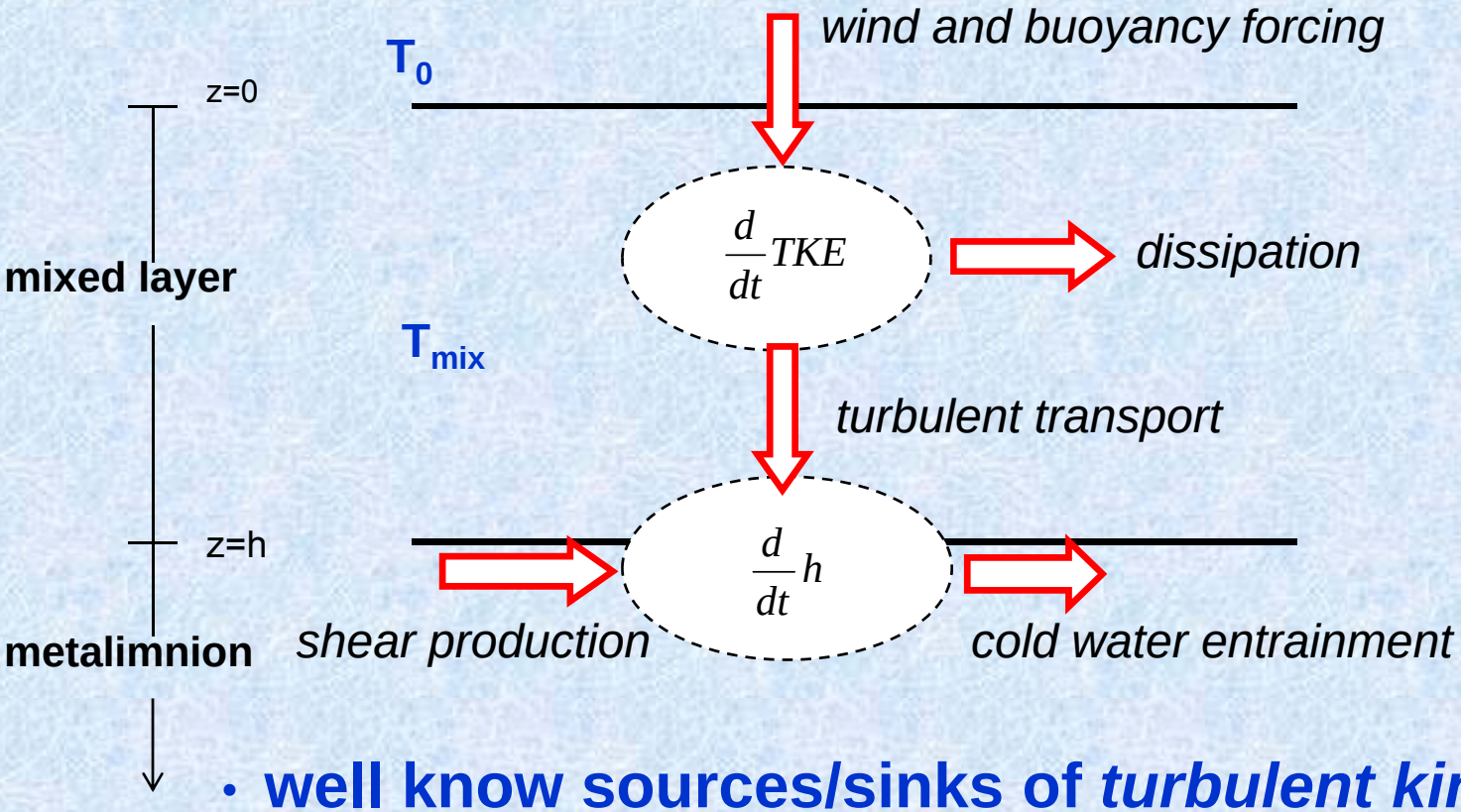

LAKE 239
SCALE METERS
0 50 100 150 200
CONTOUR INTERVAL 2 METERS
B = BOULDERS
S = SAND
BS = BEACH SAND
BR = BEDROCK
Northwest INLET
BOG
INLET
FIELD STATION
BR
INLET from East Sub basin
BOG
OUTLET to L. 240
N

CLASS Lake Module



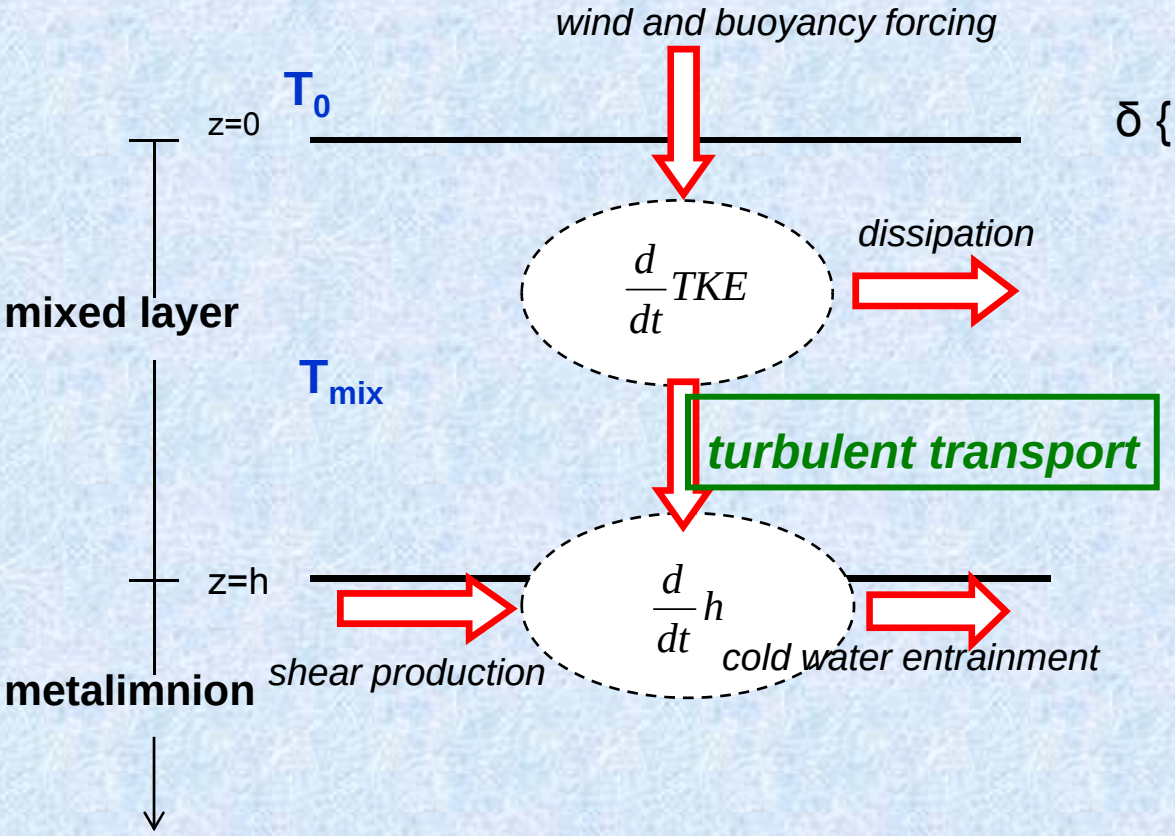
- **thermal model computes surface energy balance and light attenuation through column**

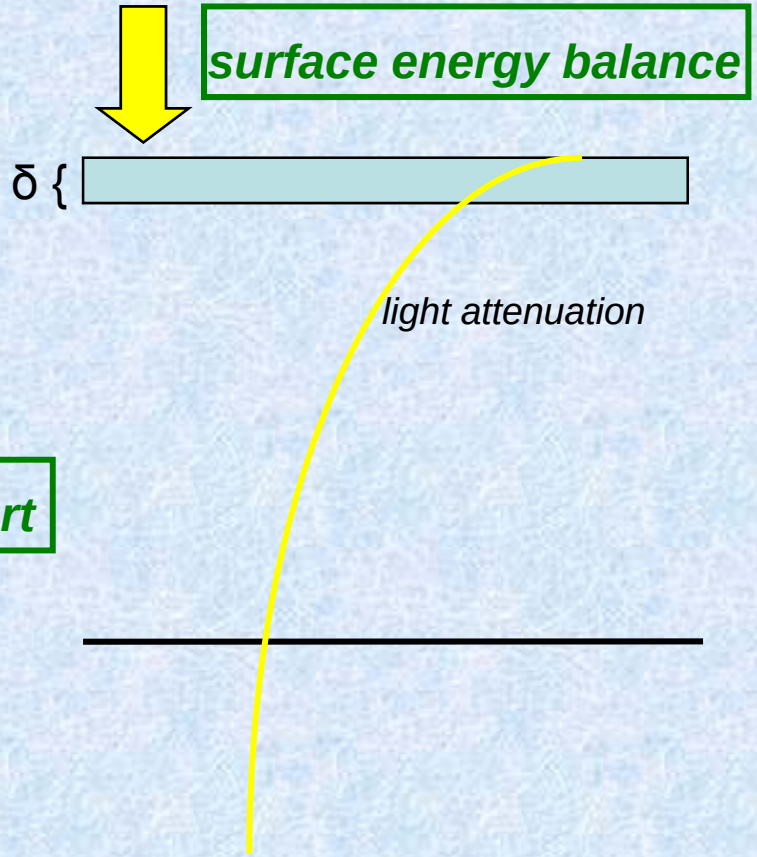
CLASS Lake Module



- **well know sources/sinks of *turbulent kinetic energy* govern depth of mixed layer**
- **both surface energy balance and mixed layer depth affect surface temperature**

CLASS Lake Module





Transport of TKE to thermocline less efficient than expected

Surface energy balance generalized

Turbulence Model

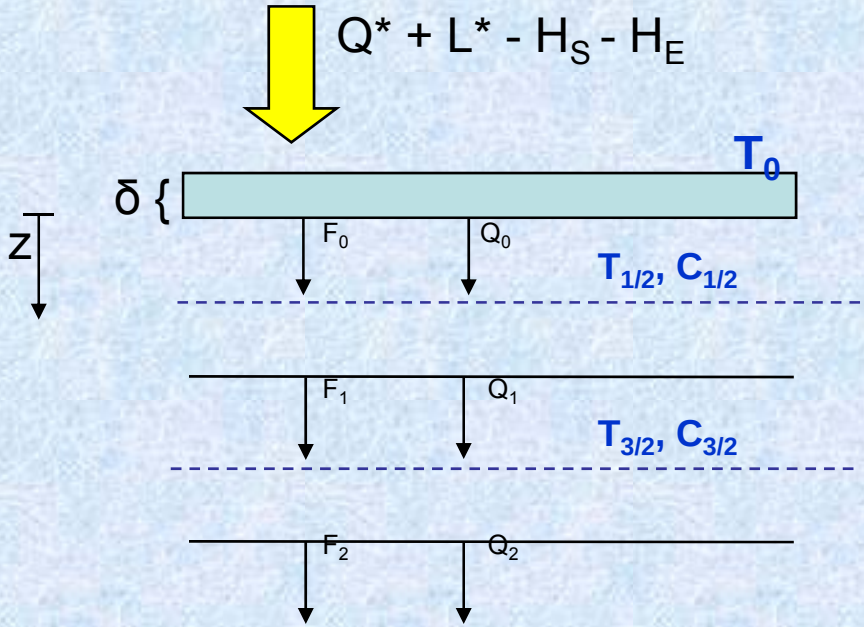
Thermal Model

Generalized Surface Energy Balance

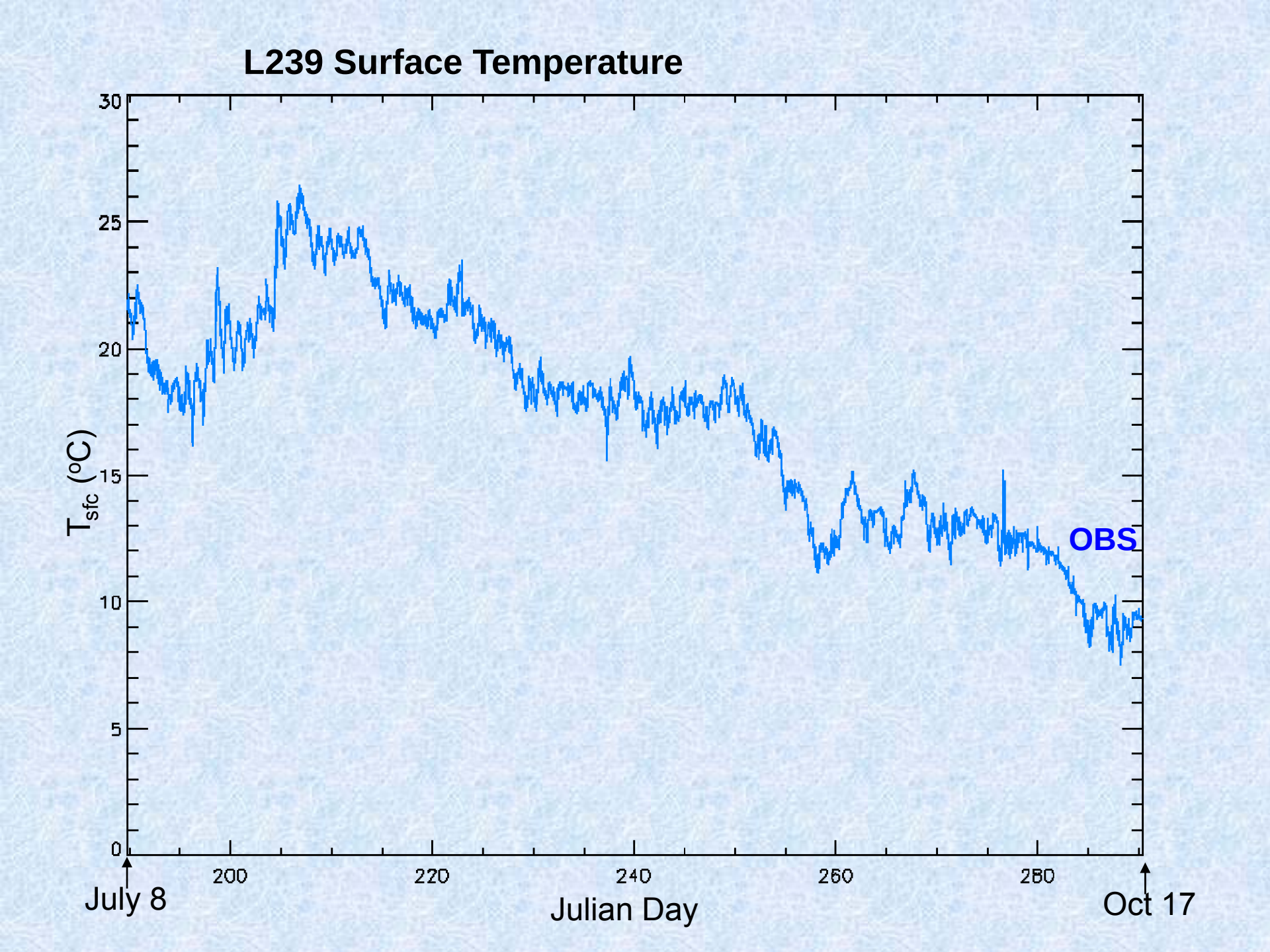
$$\frac{\partial T}{\partial t} = -\left(\frac{1}{\rho c_w}\right)\frac{\partial F}{\partial z} - \left(\frac{1}{\rho c_w}\right)\frac{\partial Q}{\partial z}$$

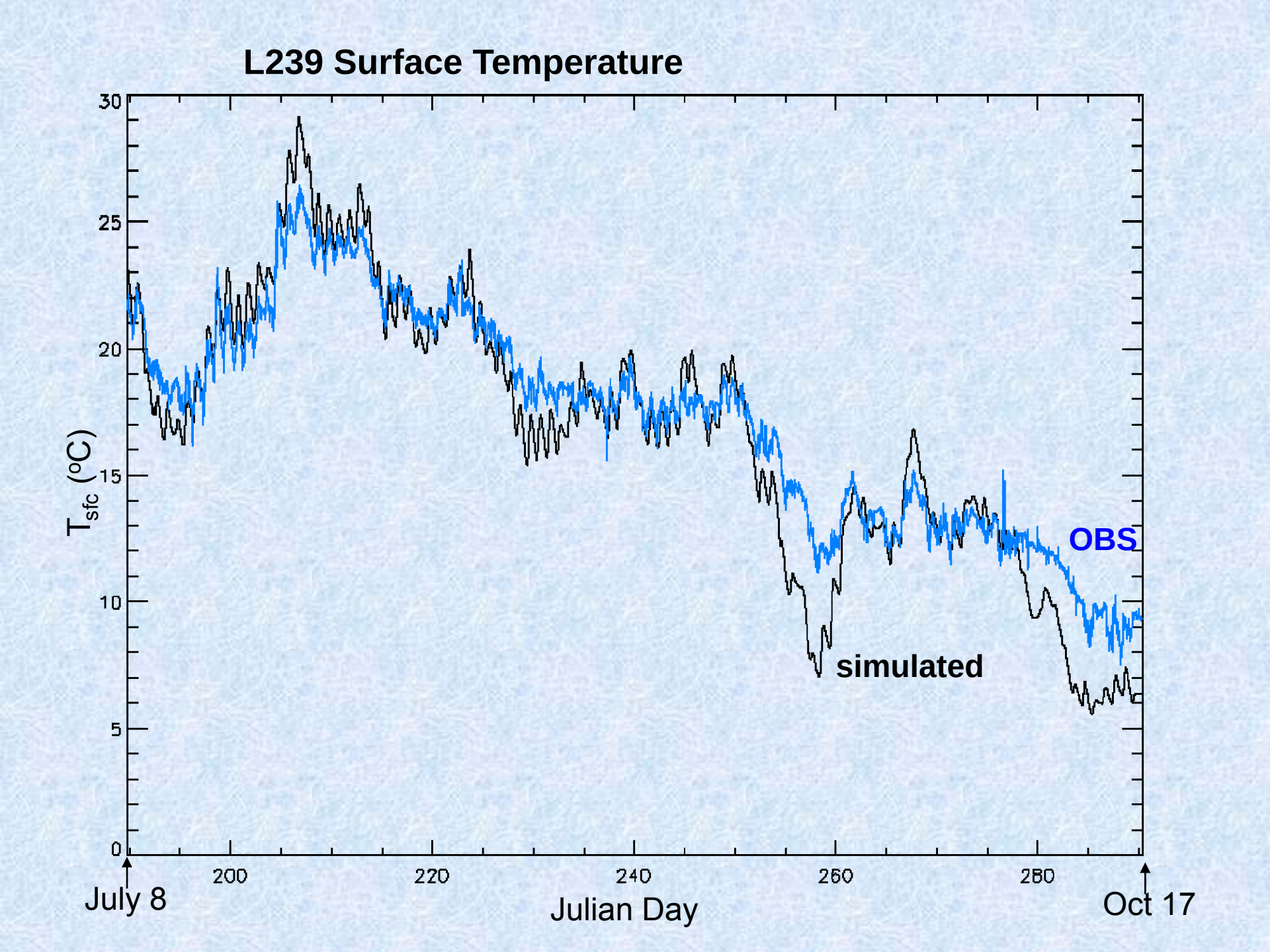
$$F(z) = -K\frac{\partial T}{\partial z}$$

$$Q(z) = Q^*\left\{\sum_{i=1}^{3} a_i \exp\left(-b_i z\right)\right\}$$

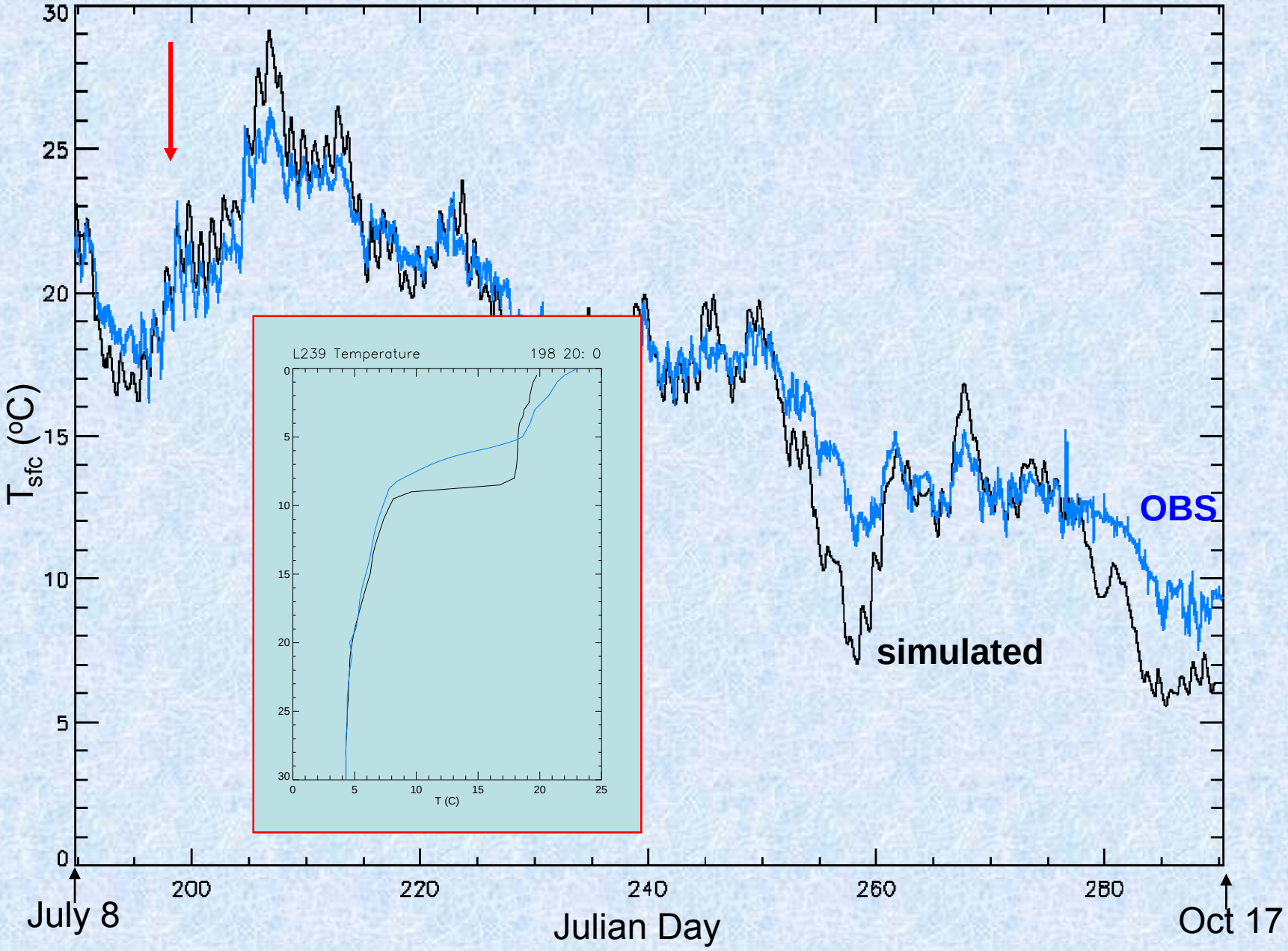


$$\frac{\partial T_0}{\partial t} = -\left(\frac{1}{\delta \rho c_w}\right)\left[F_0 - \left(\frac{1}{\rho c_w}\right)\frac{\partial Q}{\partial z} - H_E\right) + Q_0 - Q^*\right]$$

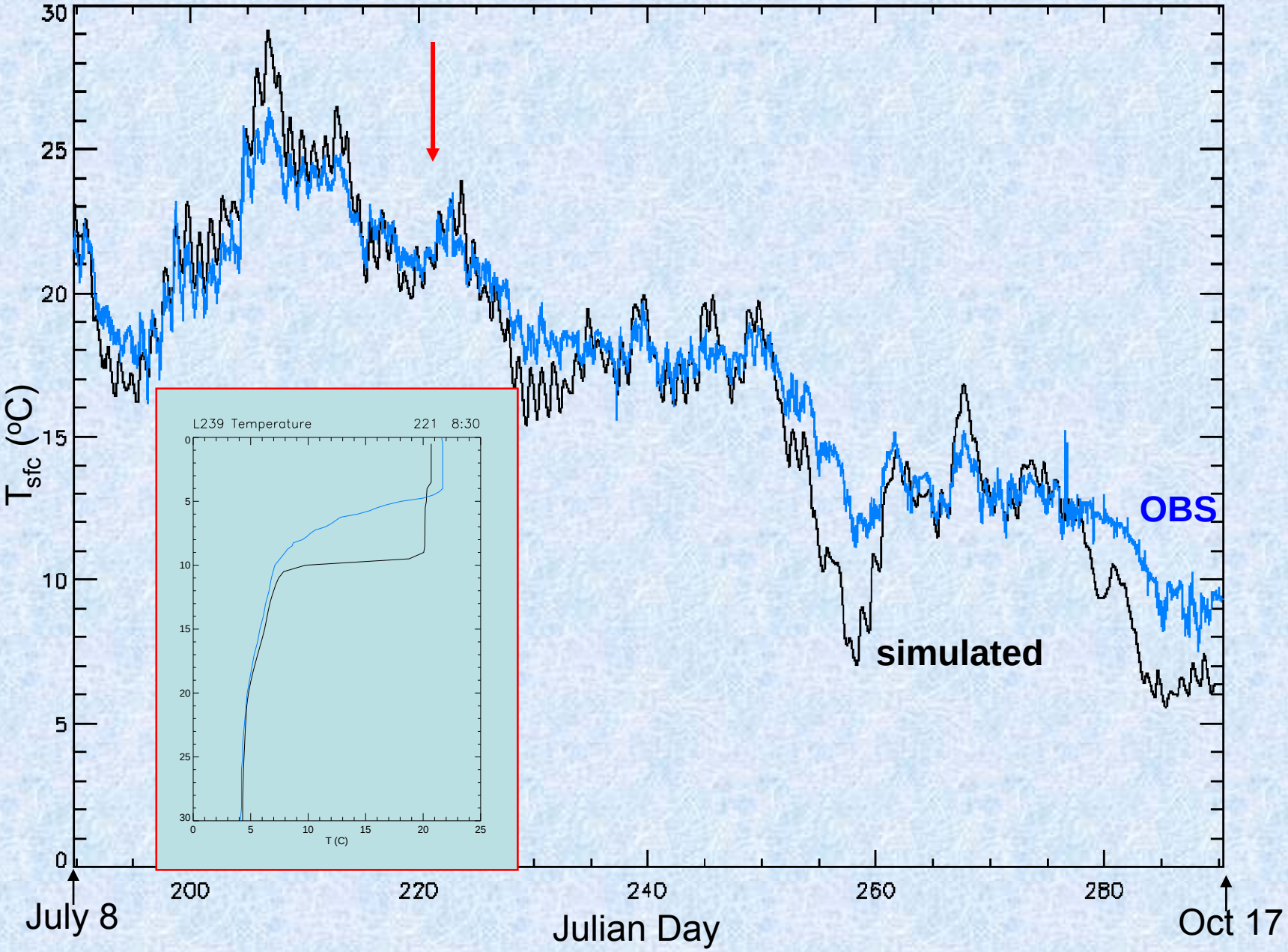

L239 Surface Temperature
30
25
20
15
10
5
0
T_{sfc} (°C)
OBS
200
220
240
260
280
July 8
Julian Day
Oct 17


L239 Surface Temperature
30
25
20
15
10
5
0
T_{sfc} (°C)
OBS
simulated
200
220
240
260
280
July 8
Julian Day
Oct 17

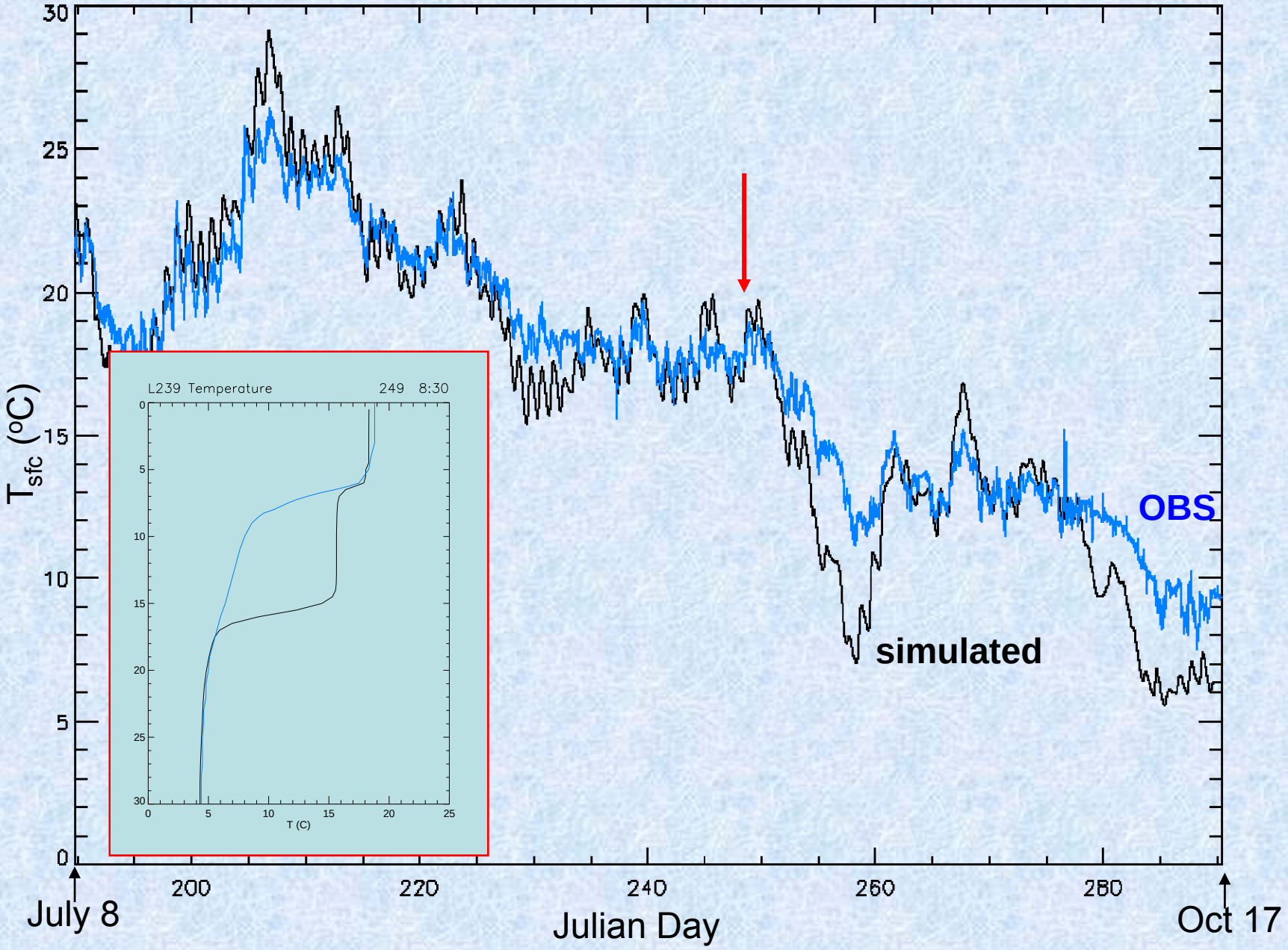
L239 Surface Temperature



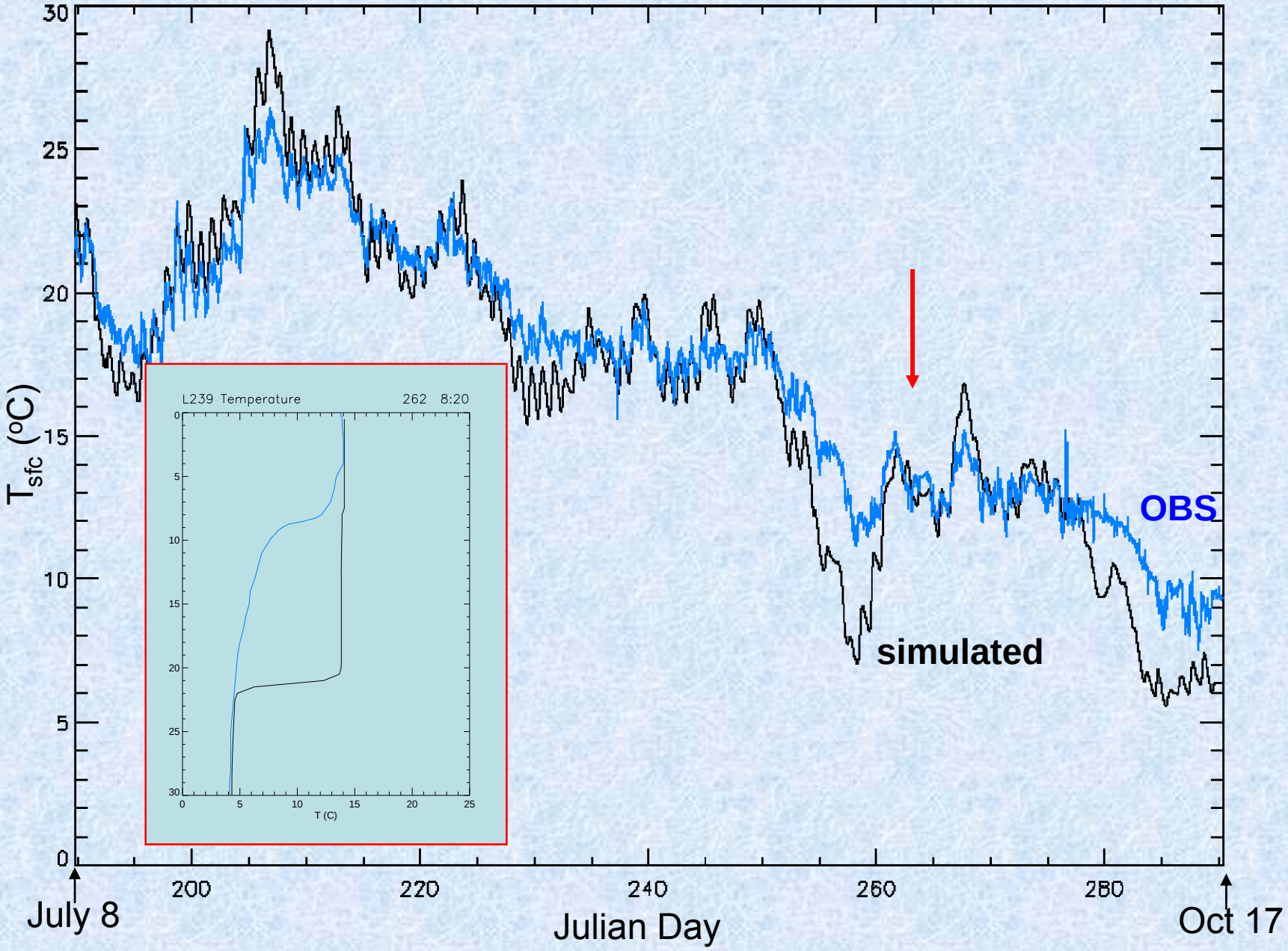
L239 Surface Temperature

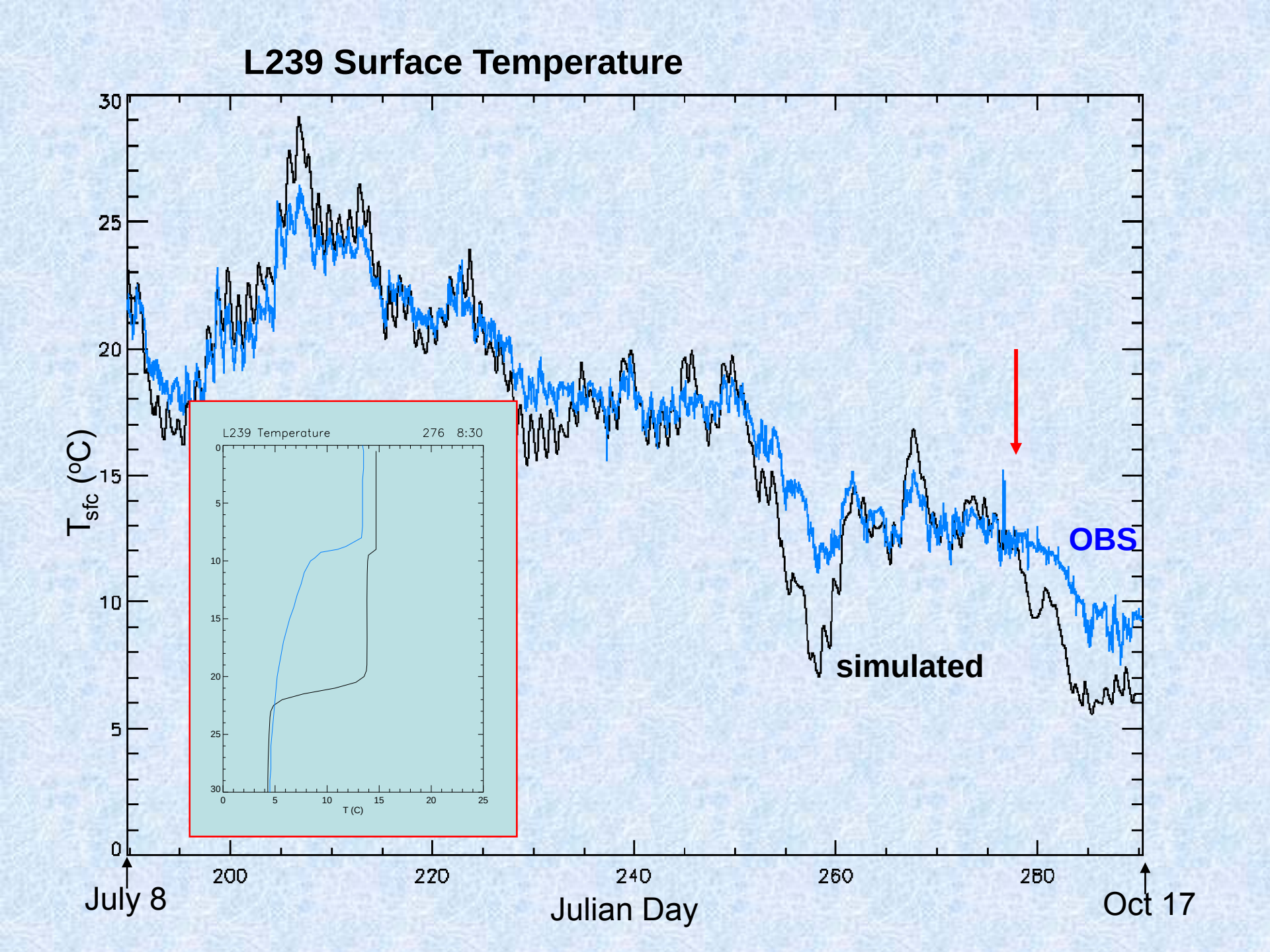


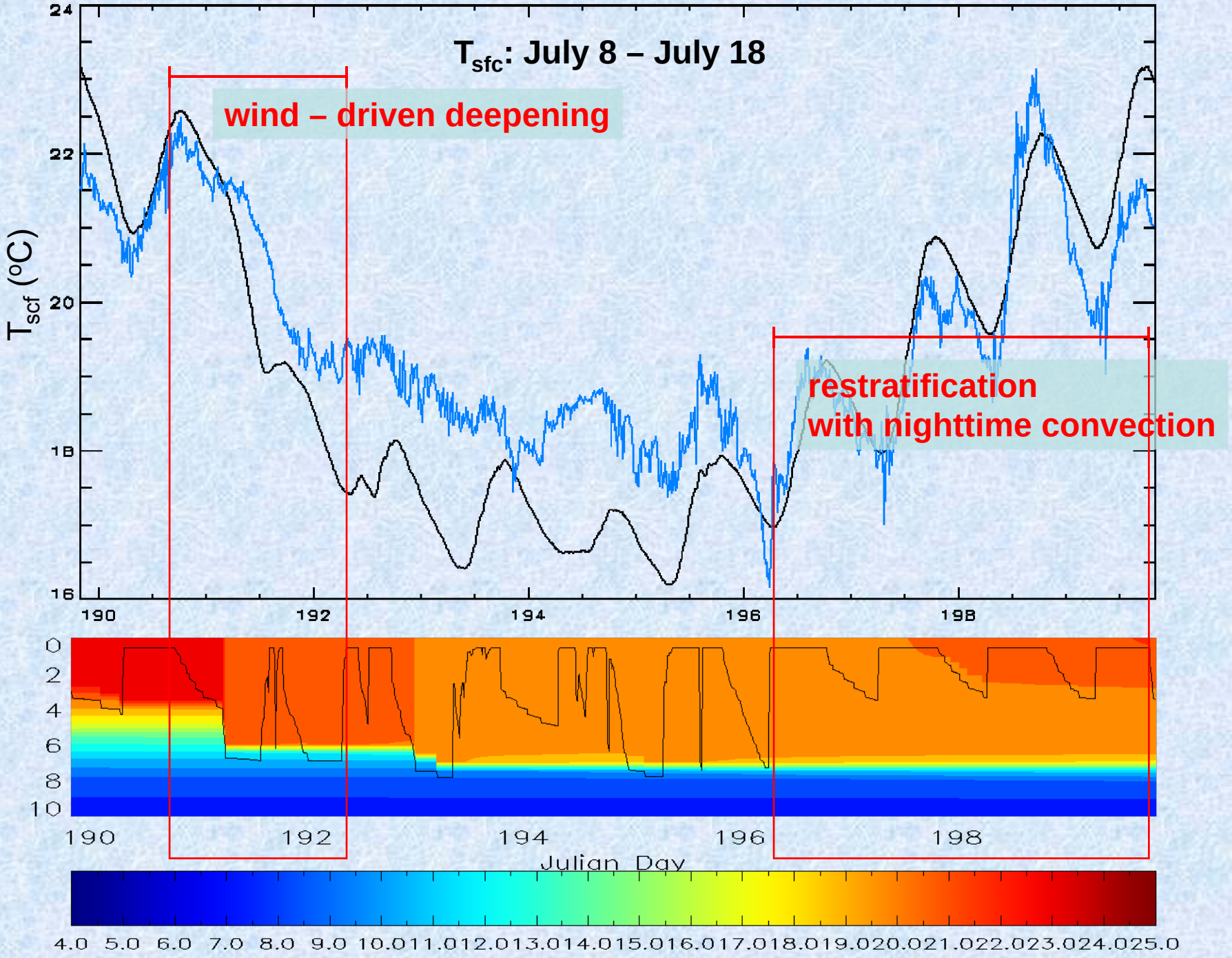
L239 Surface Temperature

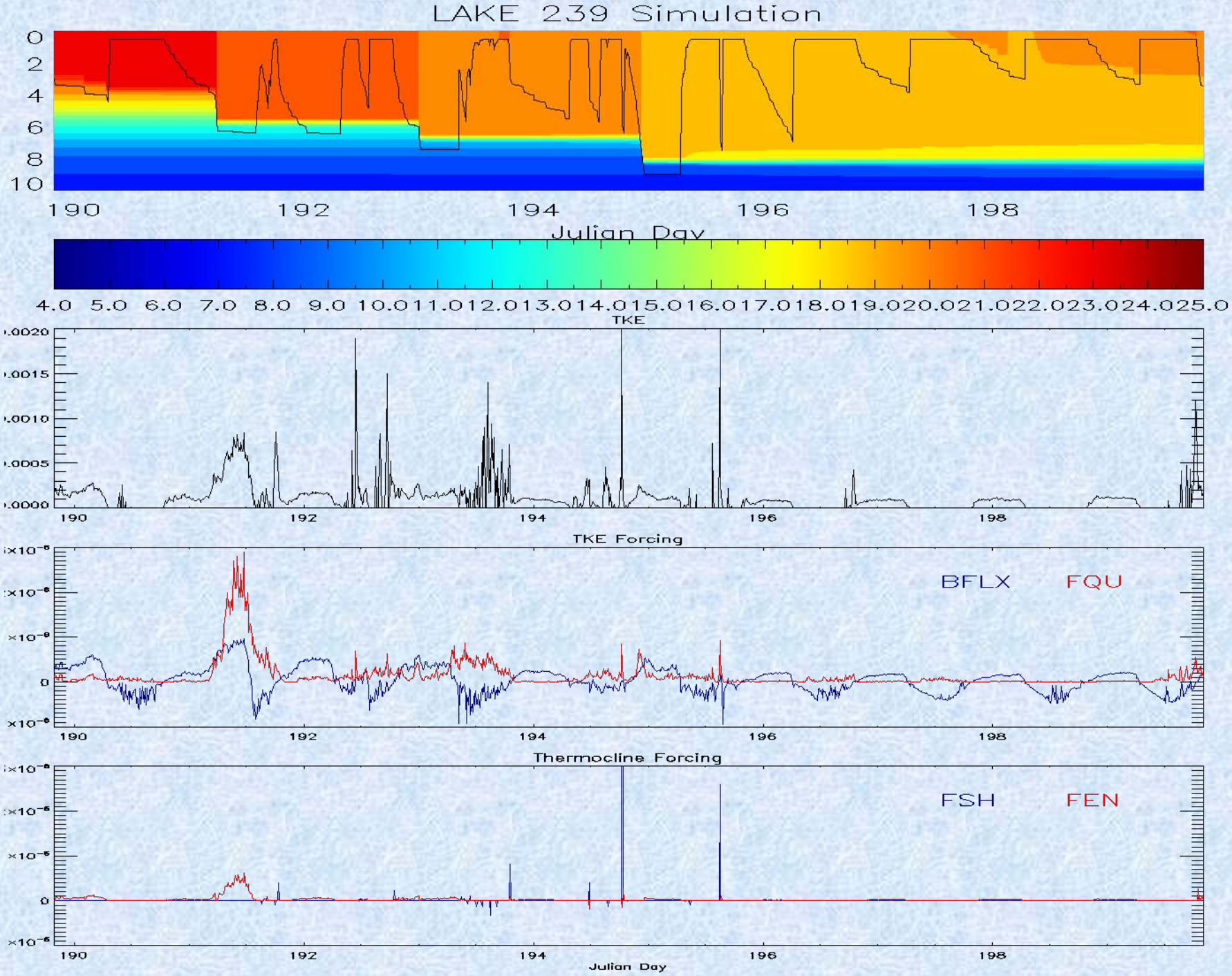


L239 Surface Temperature



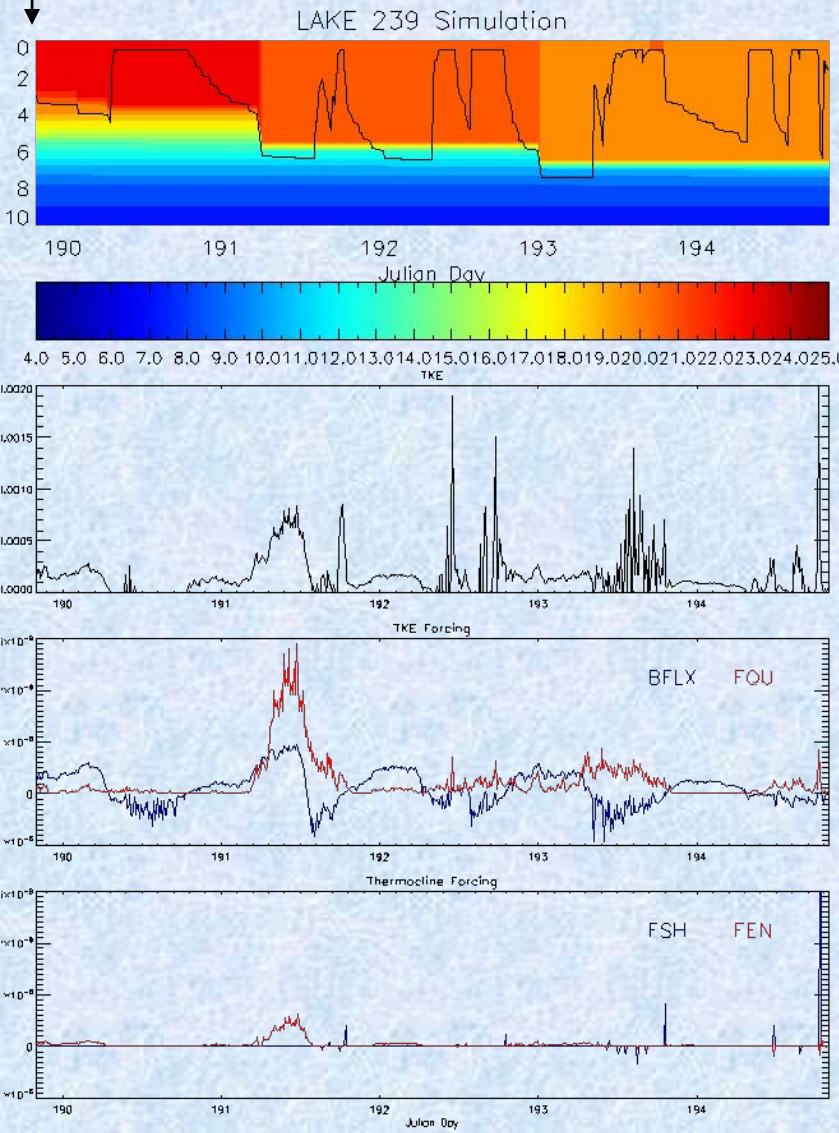

L239 Surface Temperature
30
25
20
15
10
5
0
T_{sfc} (°C)
L239 Temperature
276 8:30
0
5
10
15
20
25
30
T (C)
OBS
simulated
200
220
240
260
280
July 8
Julian Day
Oct 17


T_sfc: July 8 – July 18
wind – driven deepening
restratification
with nighttime convection
T_scf (°C)
24
22
20
18
16
190
192
194
196
198
0
2
4
6
8
10
Julian Day
4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0

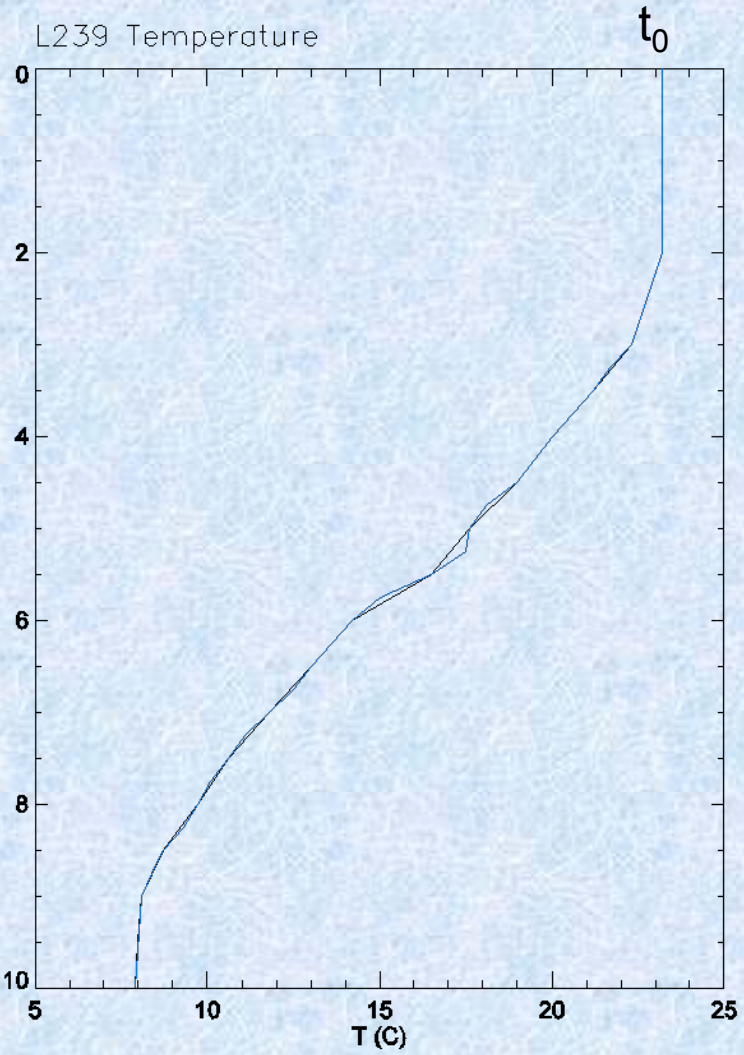

LAKE 239 Simulation
0
2
4
6
8
10
190
192
194
196
198
Julian Day
4.0 5.0 6.0 7.0 8.0 9.0 10.011.012.013.014.015.016.017.018.019.020.021.022.023.024.025.0
TKE
.0020
.0015
.0010
.0005
.0000
190
192
194
196
198
TKE Forcing
BFLX
FQU
190
192
194
196
198
Thermocline Forcing
FSH
FEN
190
192
194
196
198
Julian Day

t_0

20:00 July 8

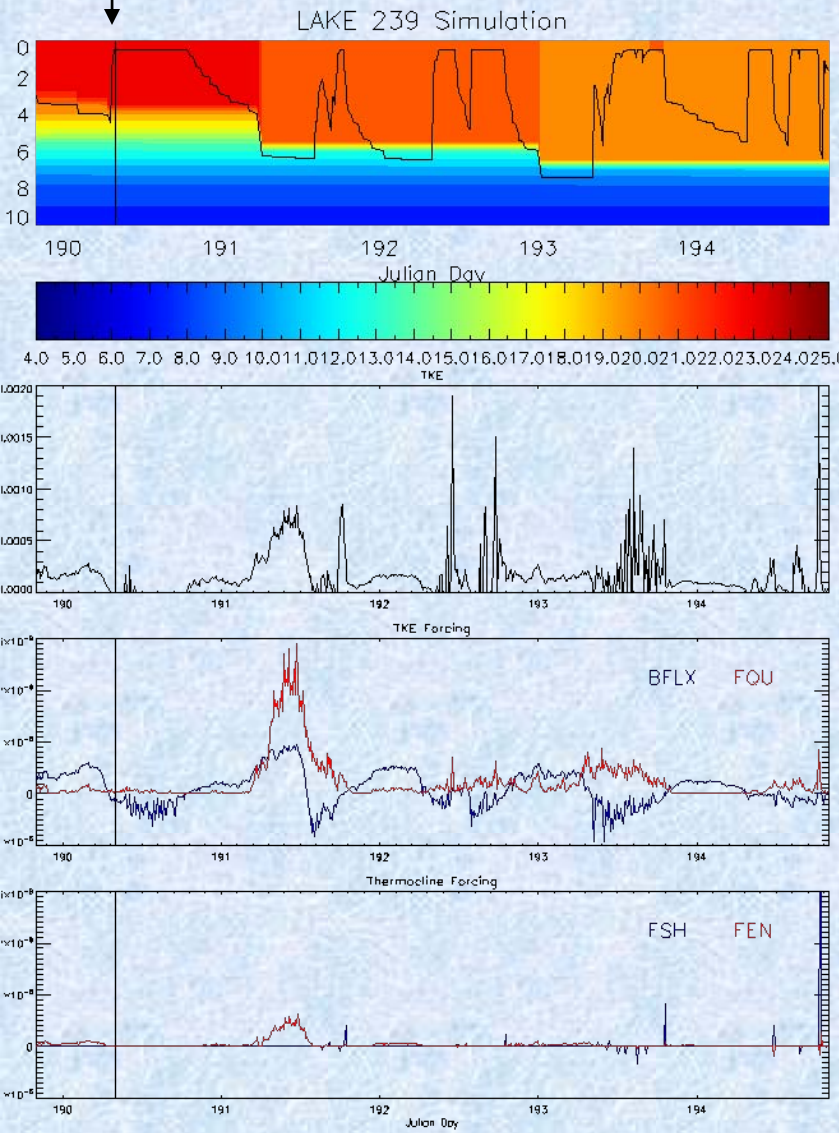


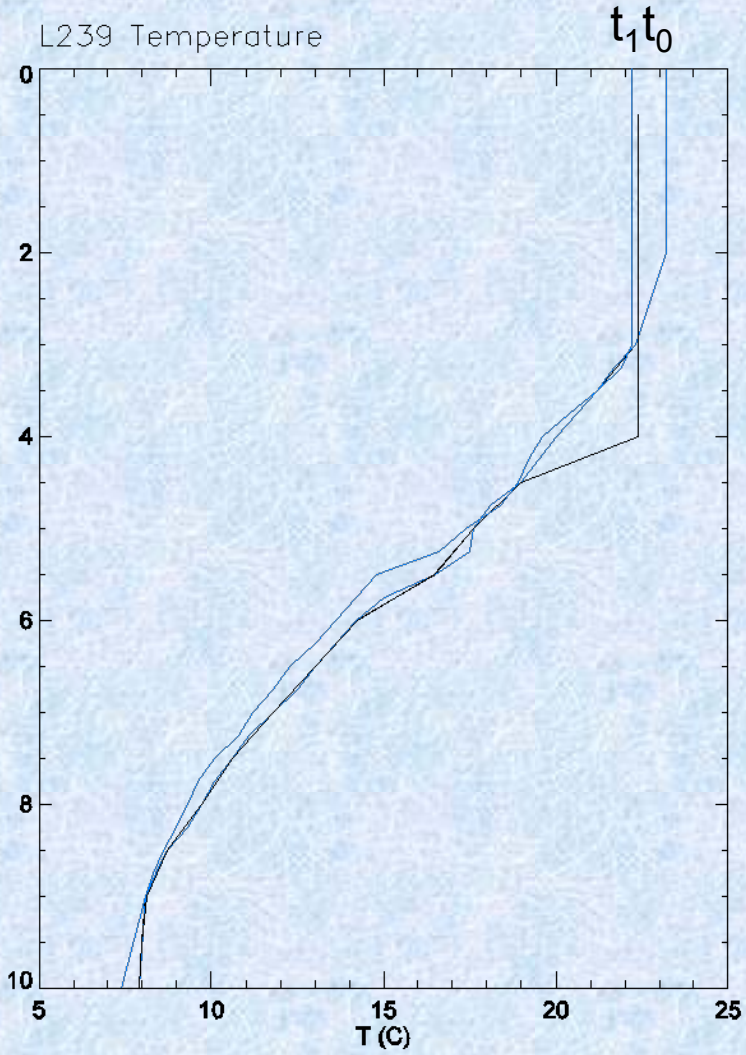
Initial Conditions

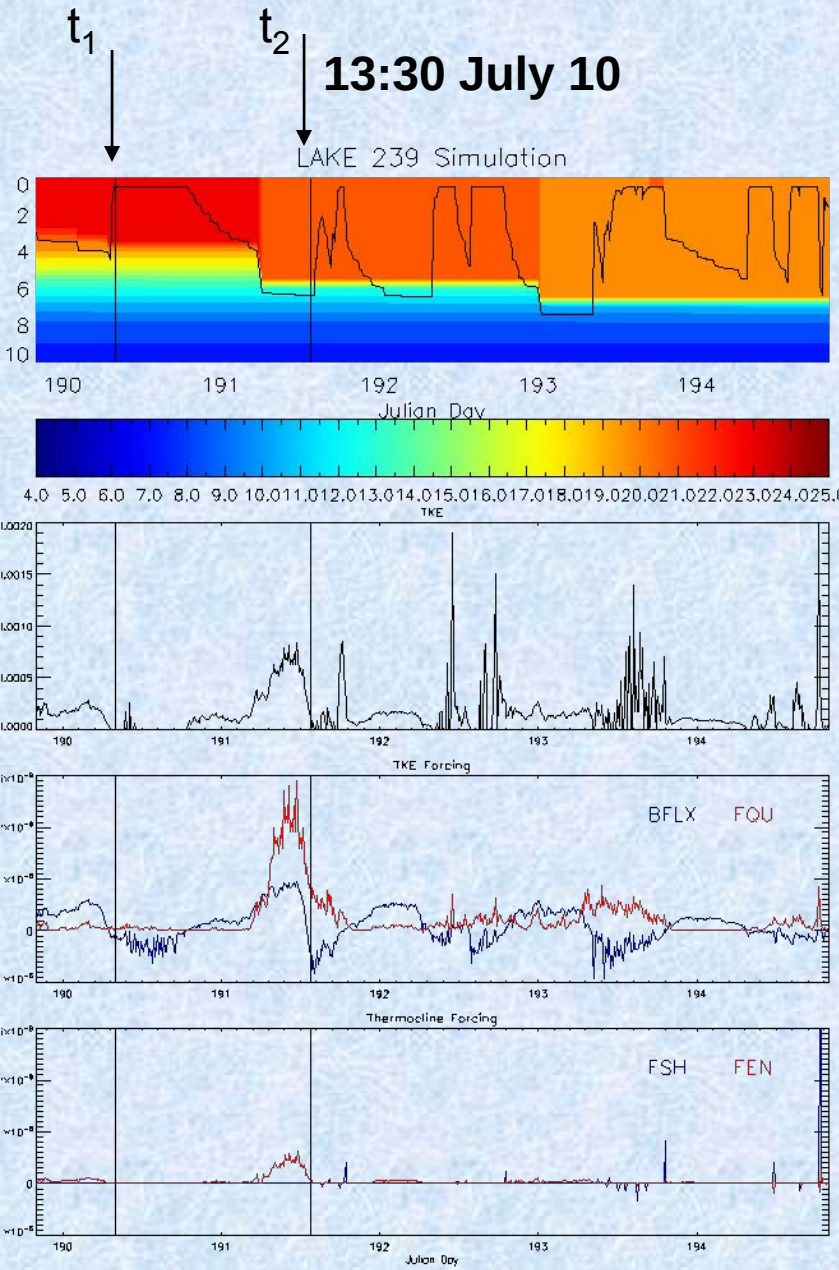


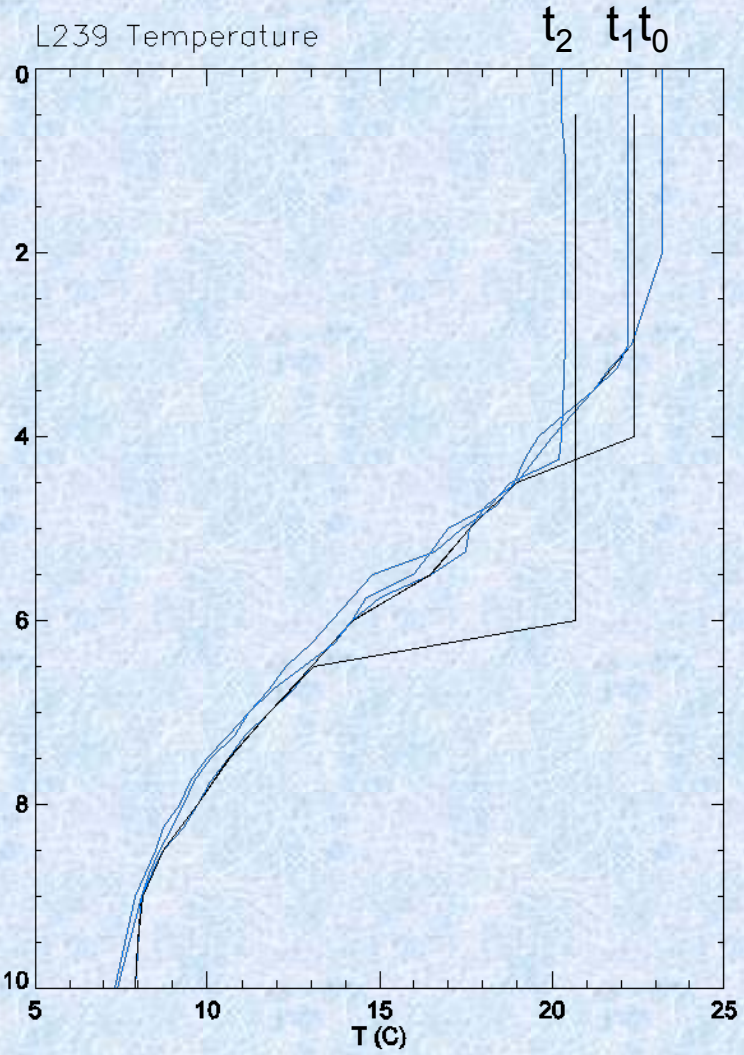
t_1

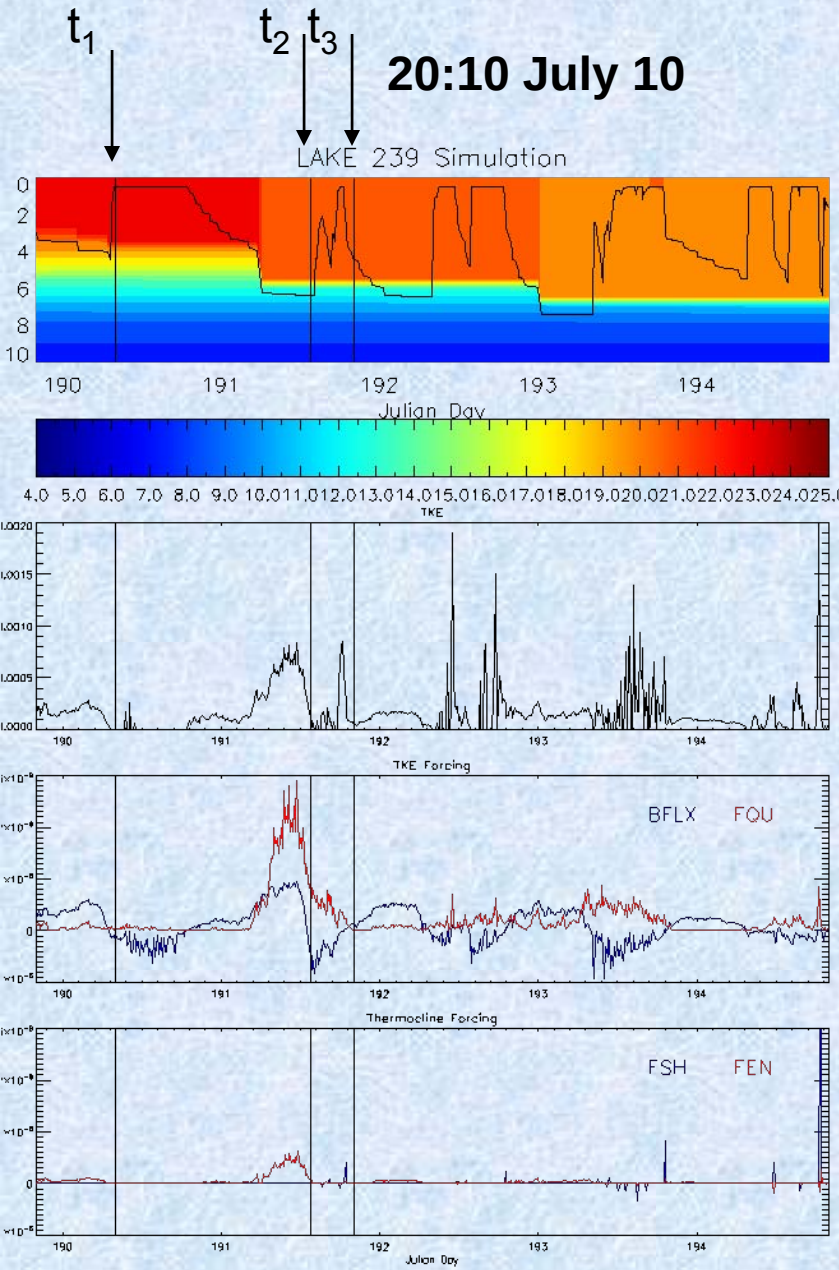
08:00 July 9

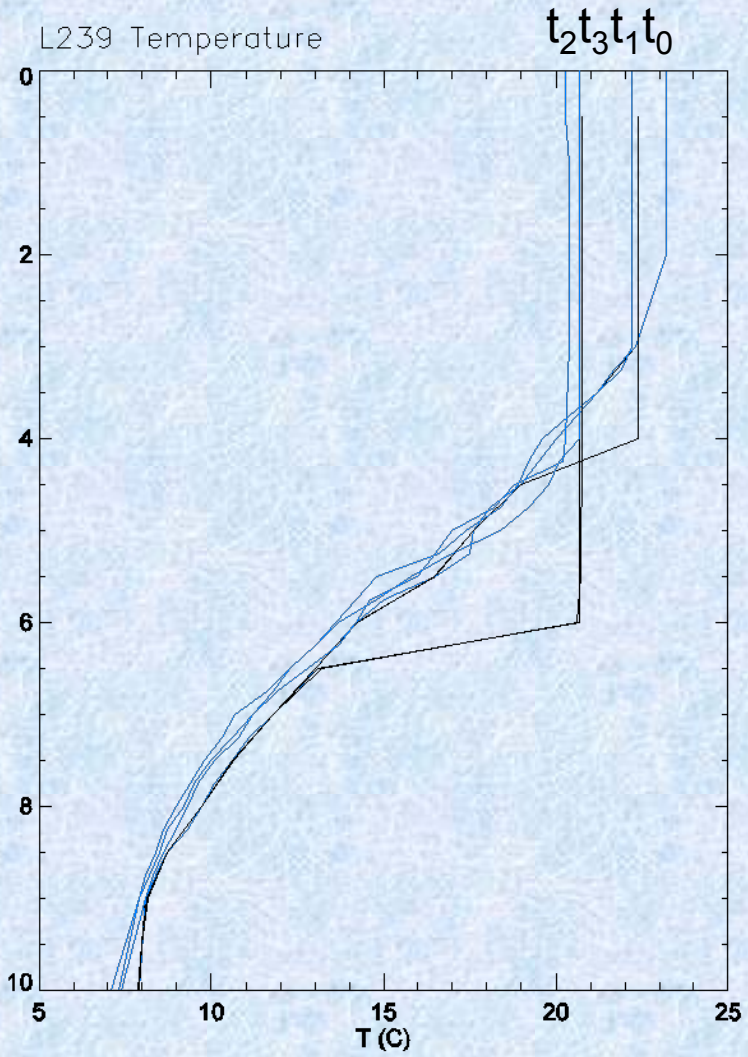


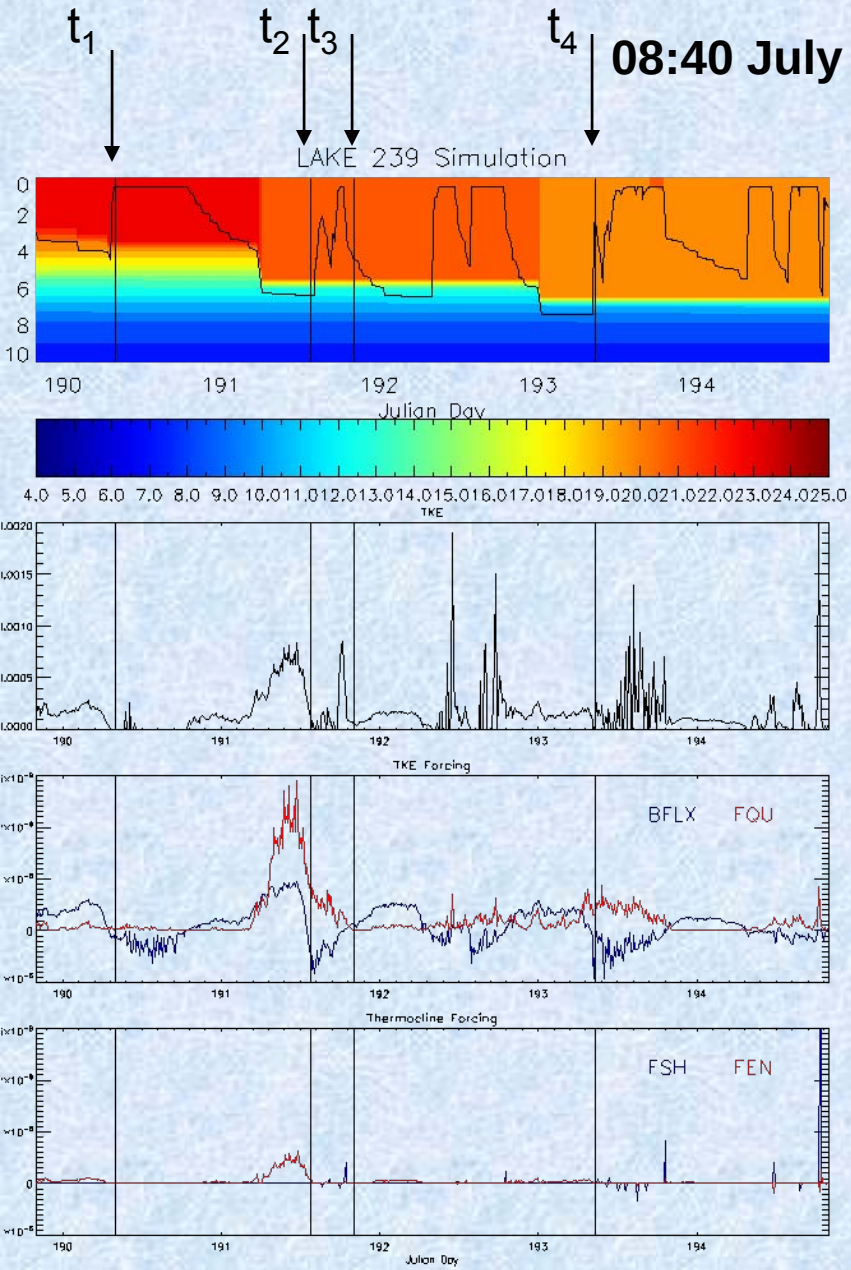


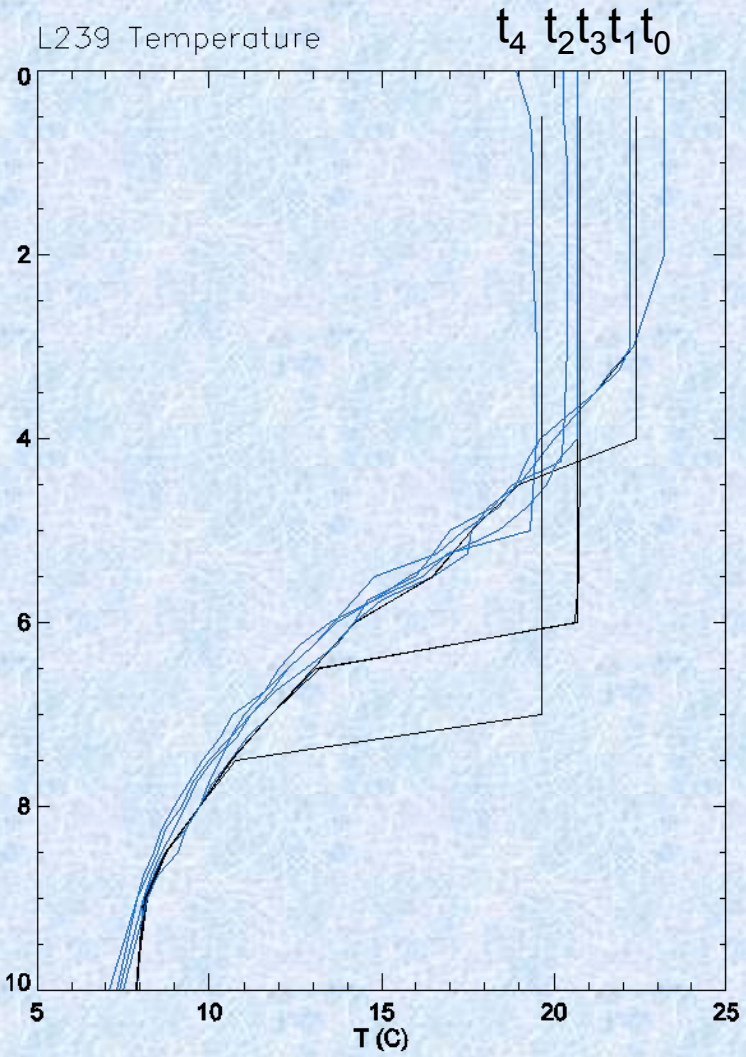

t1
t2
13:30 July 10
LAKE 239 Simulation
0
2
4
6
8
10
190
191
192
193
194
Julian Day
4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0
TKE
TKE Forcing
BFLX
FQU
Thermocline Forcing
FSH
FEN
Julian Day


L239 Temperature
t2
t1
t0
0
2
4
6
8
10
5
10
15
20
25
T (C)


t1
t2 t3
20:10 July 10
LAKE 239 Simulation
0
2
4
6
8
10
190
191
192
193
194
Julian Day
4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0
TKE
TKE Forcing
BFLX
FQU
Thermocline Forcing
FSH
FEN
Julian Day


L239 Temperature
t2t3t1t0
0
2
4
6
8
10
5
10
15
20
25
T (C)


t1
t2 t3
t4
08:40 July 12
LAKE 239 Simulation
0
2
4
6
8
10
190
191
192
193
194
Julian Day
4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0
TKE
TKE Forcing
BFLX
FQU
Thermocline Forcing
FSH
FEN
Julian Day


L239 Temperature
t4 t2t3t1t0
0
2
4
6
8
10
5
10
15
20
25
T (C)

SUMMARY

- Surface layer simulations much more realistic but:
  - still problems at thermocline
  - don't know yet if lake overturn and ice formation will be well simulated

Ongoing Work:

- turbulent flux to atmosphere assumes neutral drag coefficient
- light extinction coefficients estimated (but data exist)