Field And Numerical Investigation of High Frequency Temperature Profiles in Lakes

Sultan Ahmed

Advisor: Cary Troy

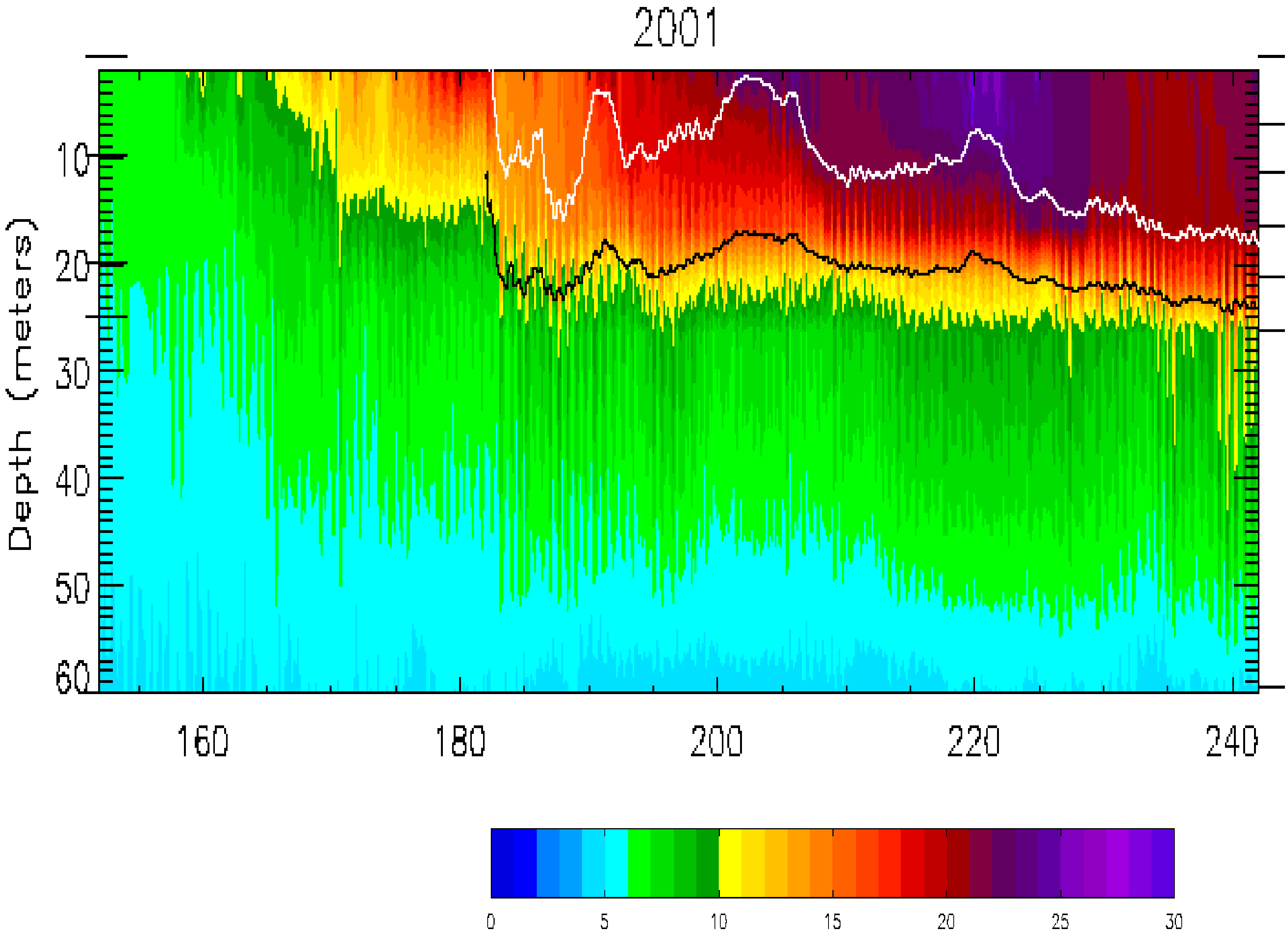
School of Civil Engineering

Purdue University

Measured temperature profile in Lake Maxinkuckee, Culver, Indiana

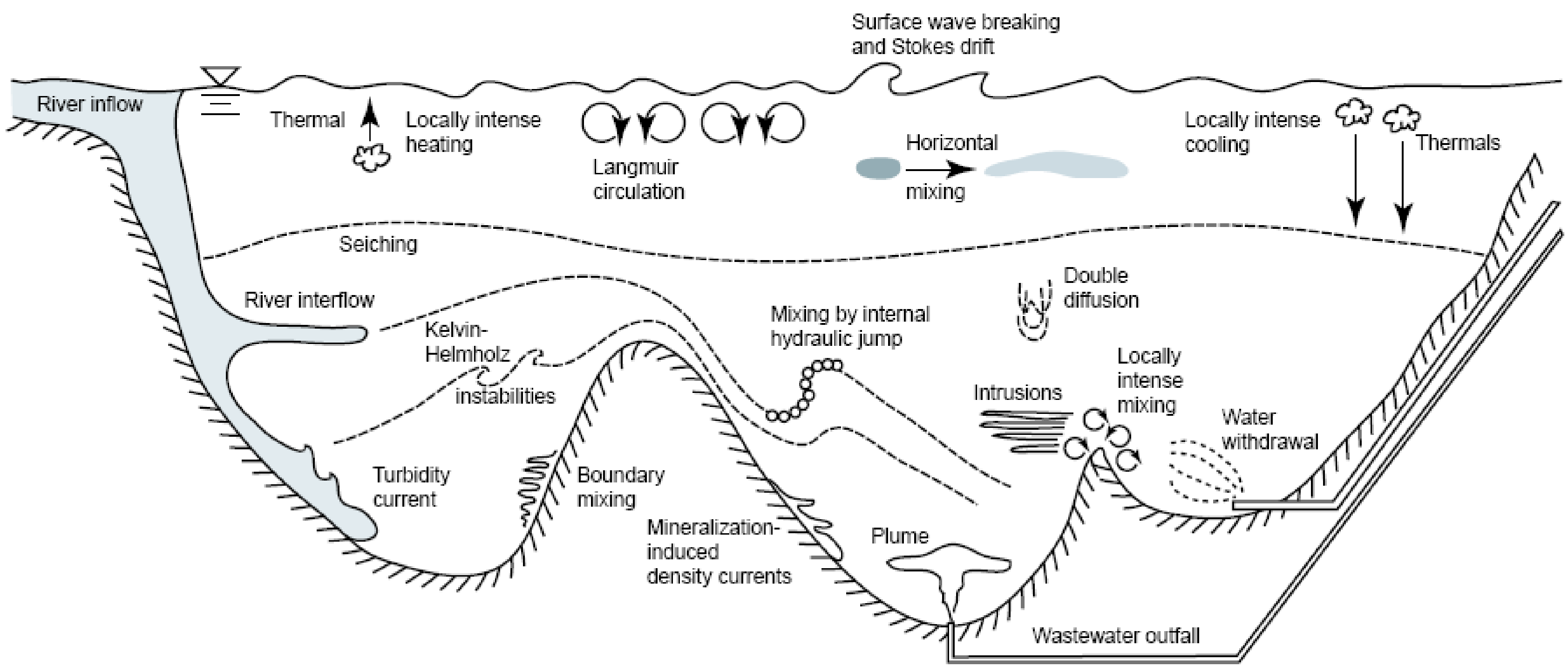
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Measured temperature in Lake Michigan(Beletsky et al, 2001)



Research goals

Study the effect of intermittent wind events on the thermal structure in large lakes

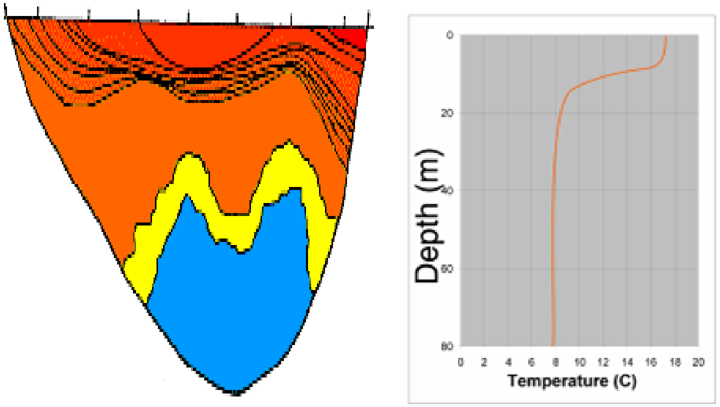


Imboden and Wuest(1995)

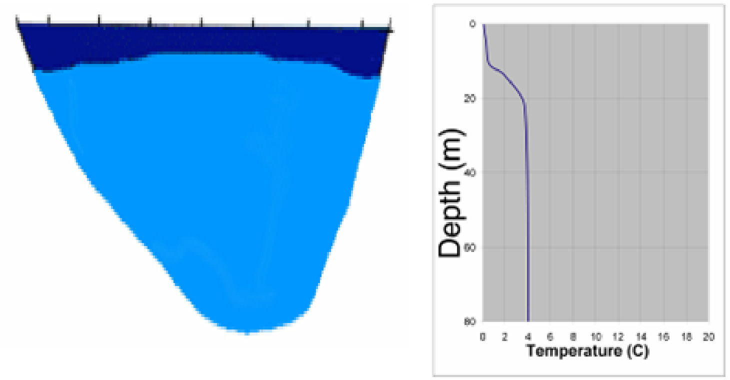
Research goals

Study the seasonal evolution of thermal structure in large lakes

Summer



Winter



Spring

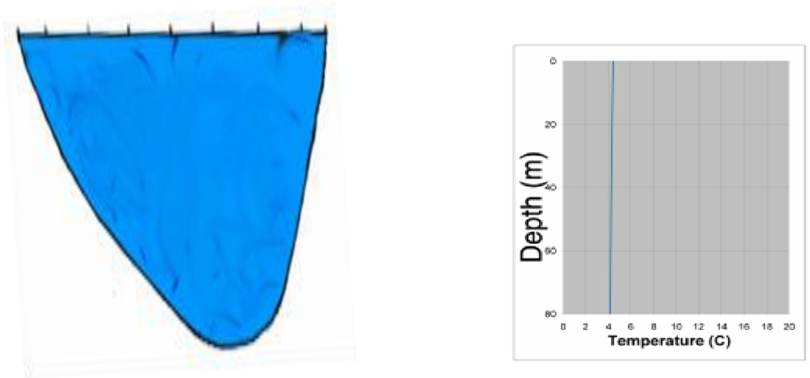
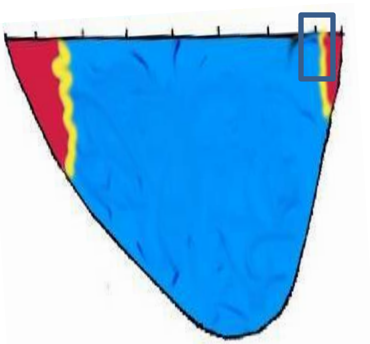


Image source: Dr. John R. Schott

Research goals

Study its effect on transport processes in large lakes

Thermal bar formation



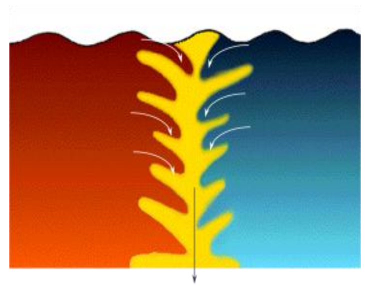
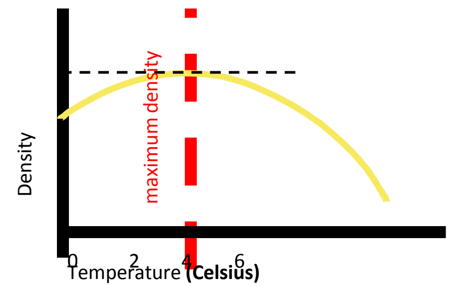
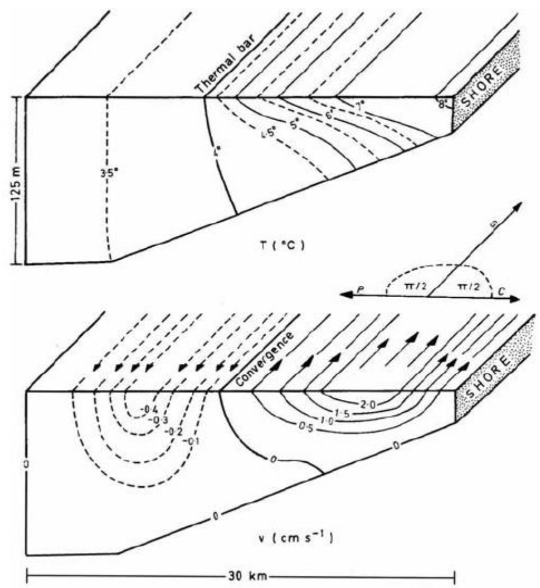


Image source: Dr. John R. Schott





(Rao et al 2007)

March 28-April 14, 1972

180 m offshore, 3 m depth:

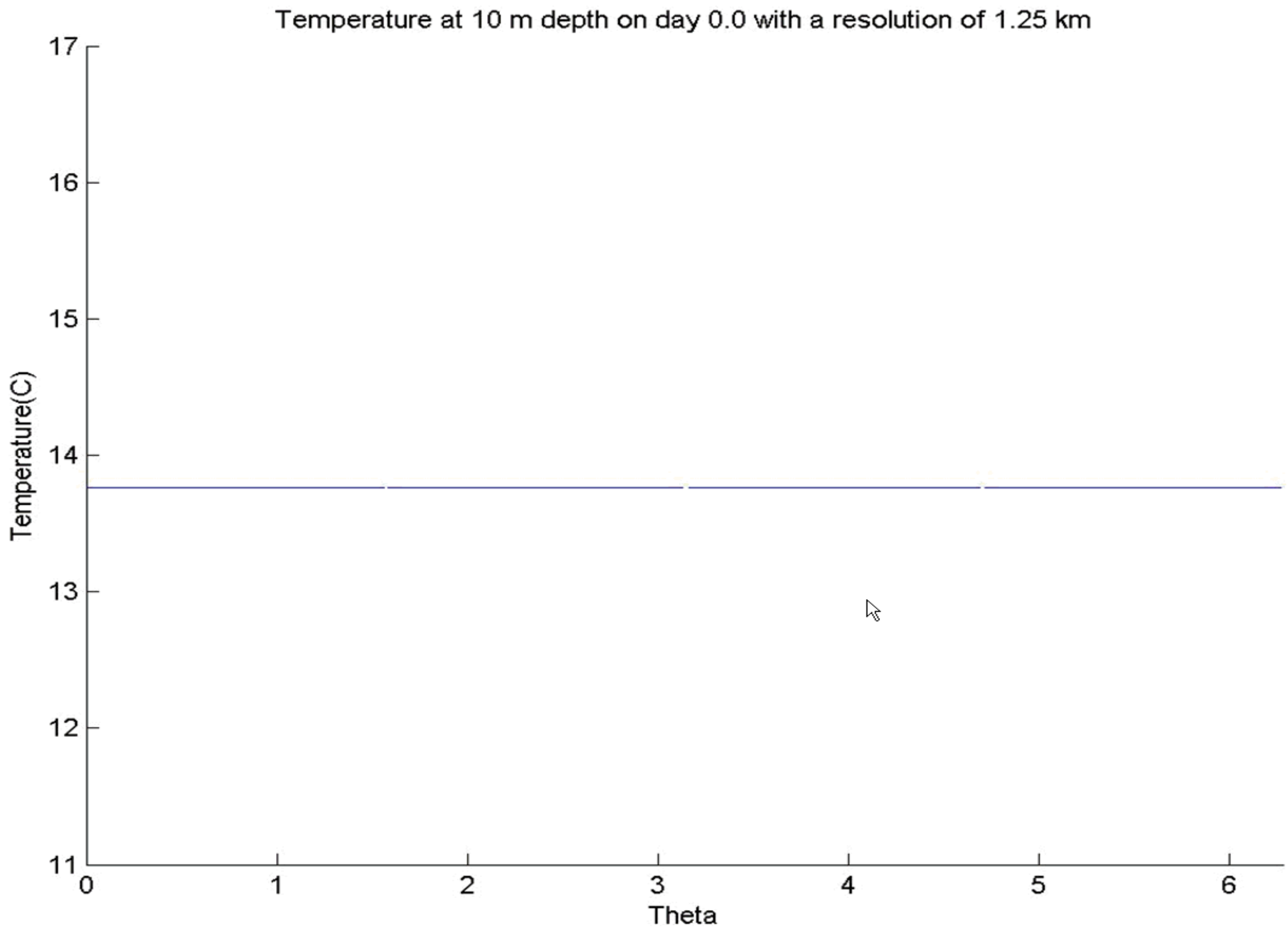
1.7 C --> 5.9 C

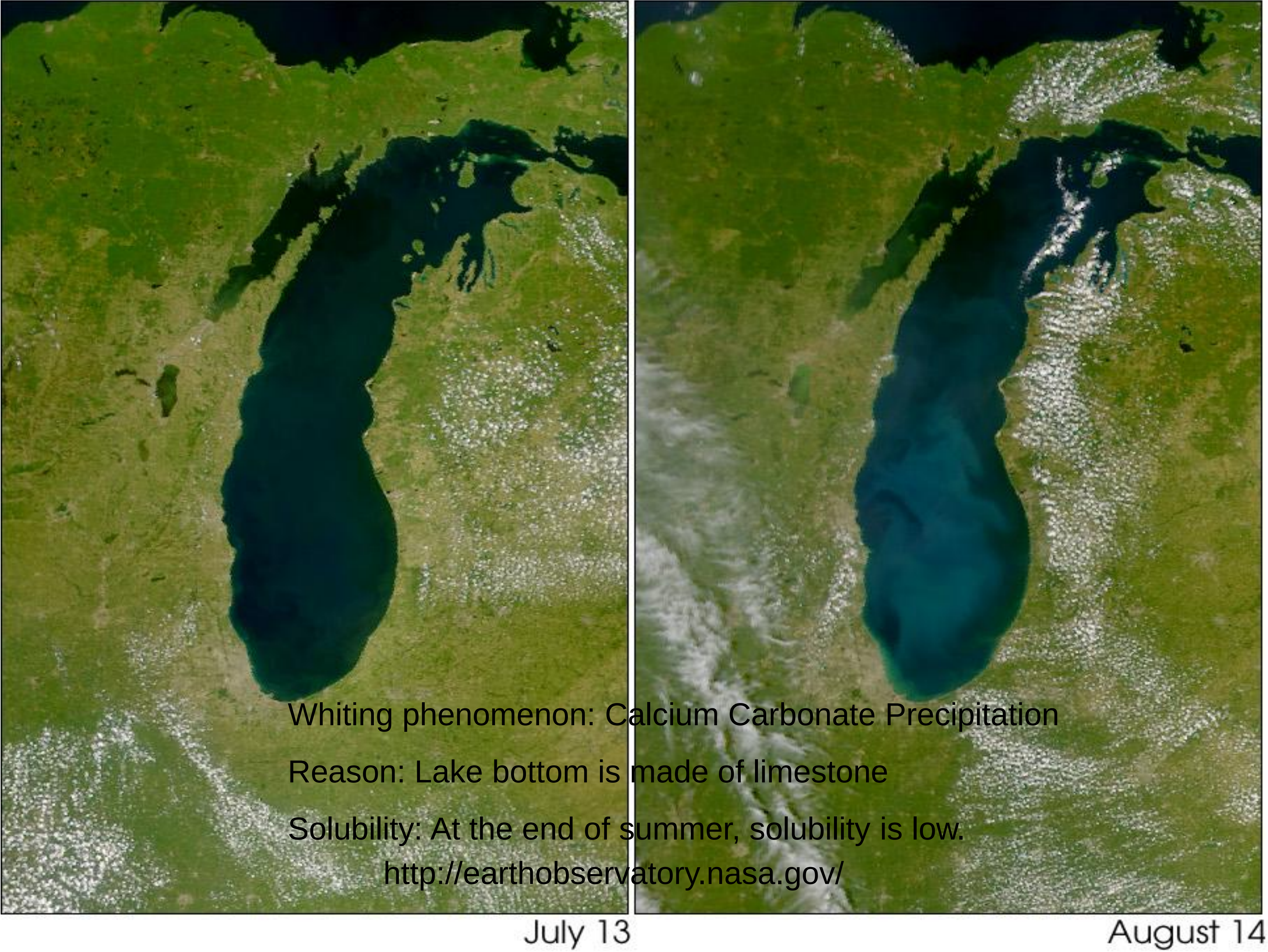
7.4 km offshore, 33 m depth: 0.8 C --> 1.4 C

(Mortimer 2004)

Research goals

Study the generation of internal waves and their role in mixing



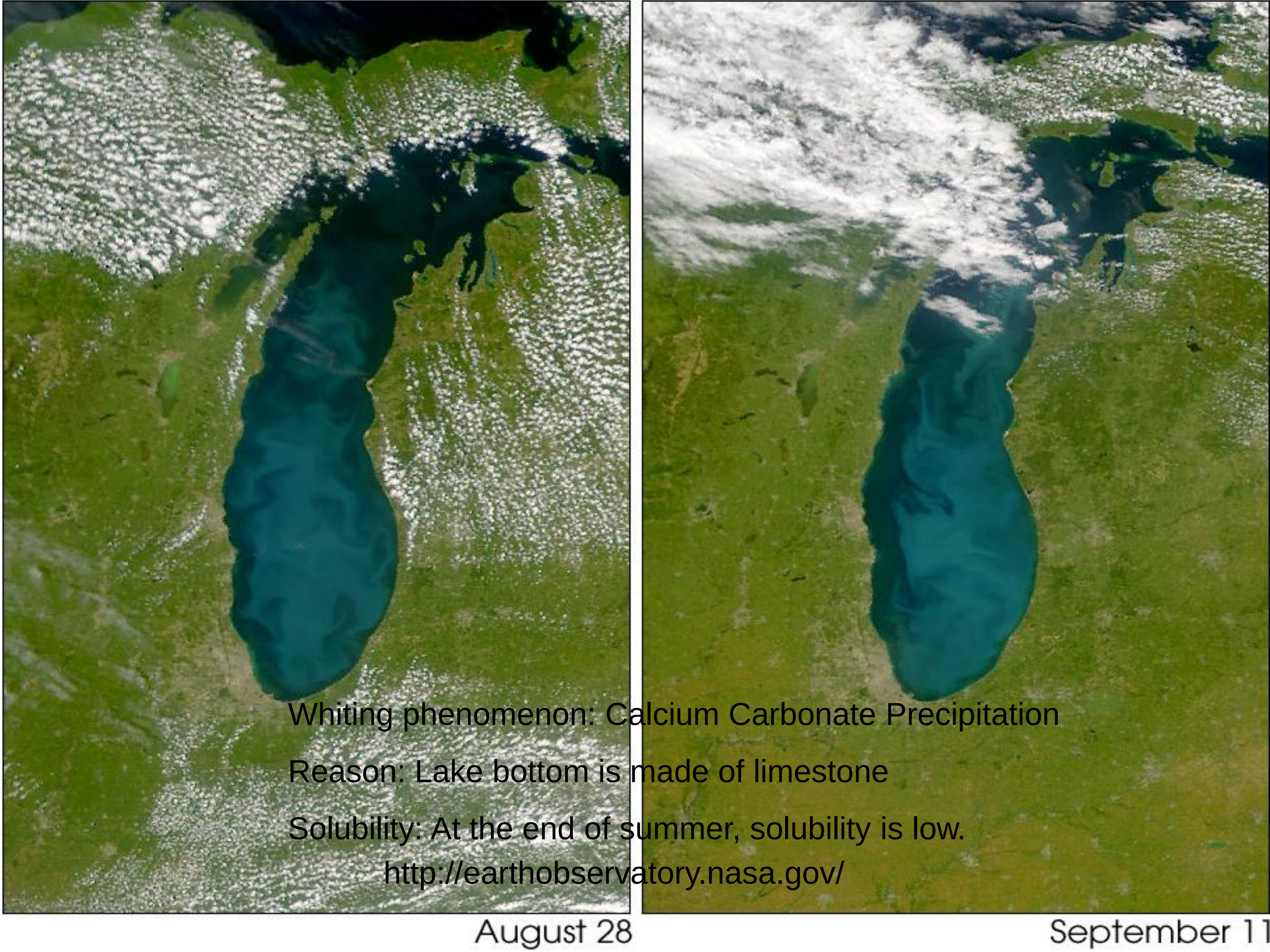


Whiting phenomenon: Calcium Carbonate Precipitation

Reason: Lake bottom is made of limestone

Solubility: At the end of summer, solubility is low.

http://earthobservatory.nasa.gov/



Whiting phenomenon: Calcium Carbonate Precipitation

Reason: Lake bottom is made of limestone

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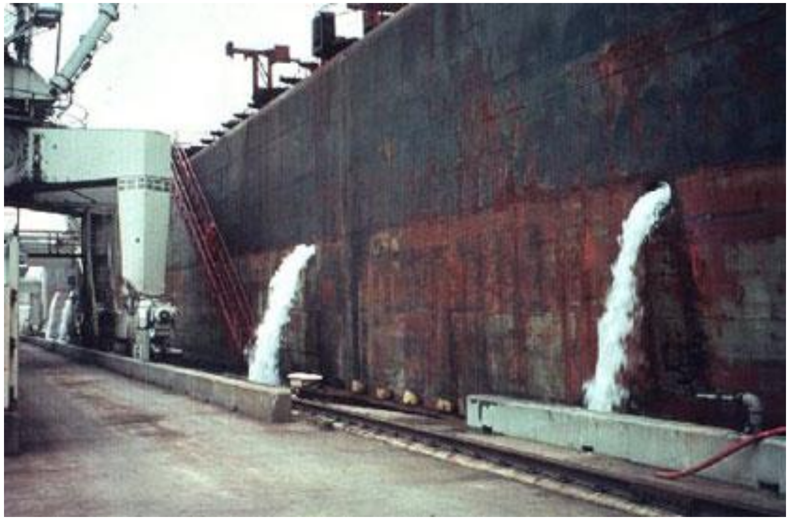
http://earthobservatory.nasa.gov/

Aquatic invasive species(AIS)

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

http://www.glerl.noaa.gov/res/Programs/ais/

http://coseegreatlakes.net/weblog/wp-content/uploads/2007/08/Lamprey.jpg



http://massbay.mit.edu/exoticspecies/ballast/index.html

Zebra mussels

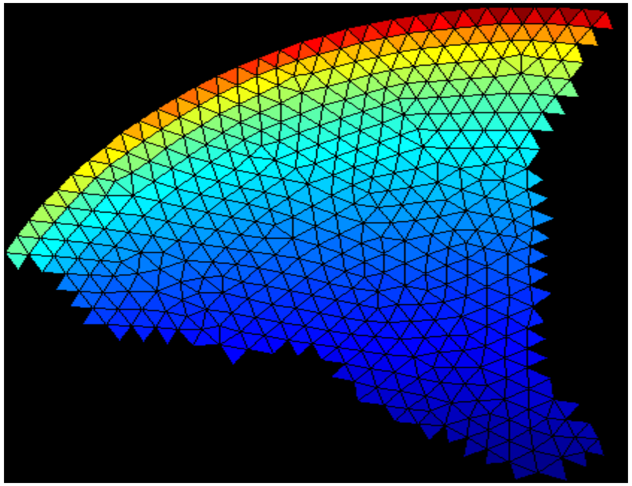
Economic Impacts of AIS in Great Lakes

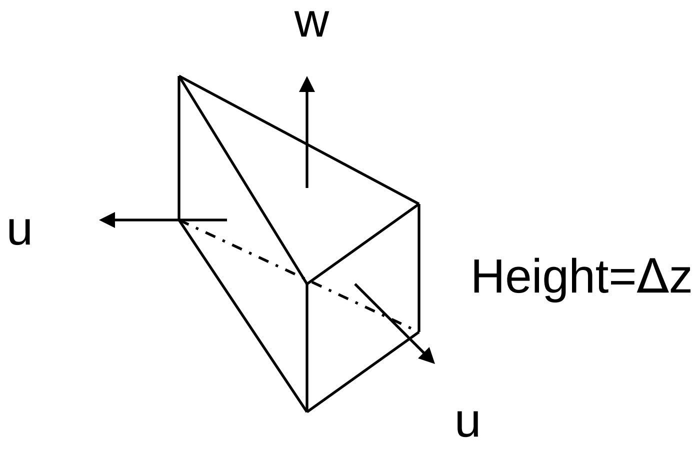
Species	Estimated Loss(US $s)
Sea lamprey	13.5 million annually
Zebra mussels	6.5 billion over 10 years

(Lovell et al. 2006)

SUNTANS

- Stanford Unstructured Nonhydrostatic Terrain Following Adaptive Navier-Stokes Simulator
- Grid elements (horizontal plane): Triangular
- Vertical grid elements   : Prisms
- Parallel implementation using MPI and C





Cases considered for validation

- Cases considered(Beletsky *et al,* 1997):

1. Circular Lake with parabolic bathymetry

   Grid Resolutions used:

   0.50 km, 1.25 km, 2.50 km, 5.00 km, variable resolution(50 m to 2.00 km resolution)

2. Circular Lake with flatbottom

   Grid Resolutions used:

   1.25 km

3. Lake Michigan

   Grid Resolutions used: 50m to 2500m(growth rate 1.25), 1 km, 2.5 km & 5.0 km

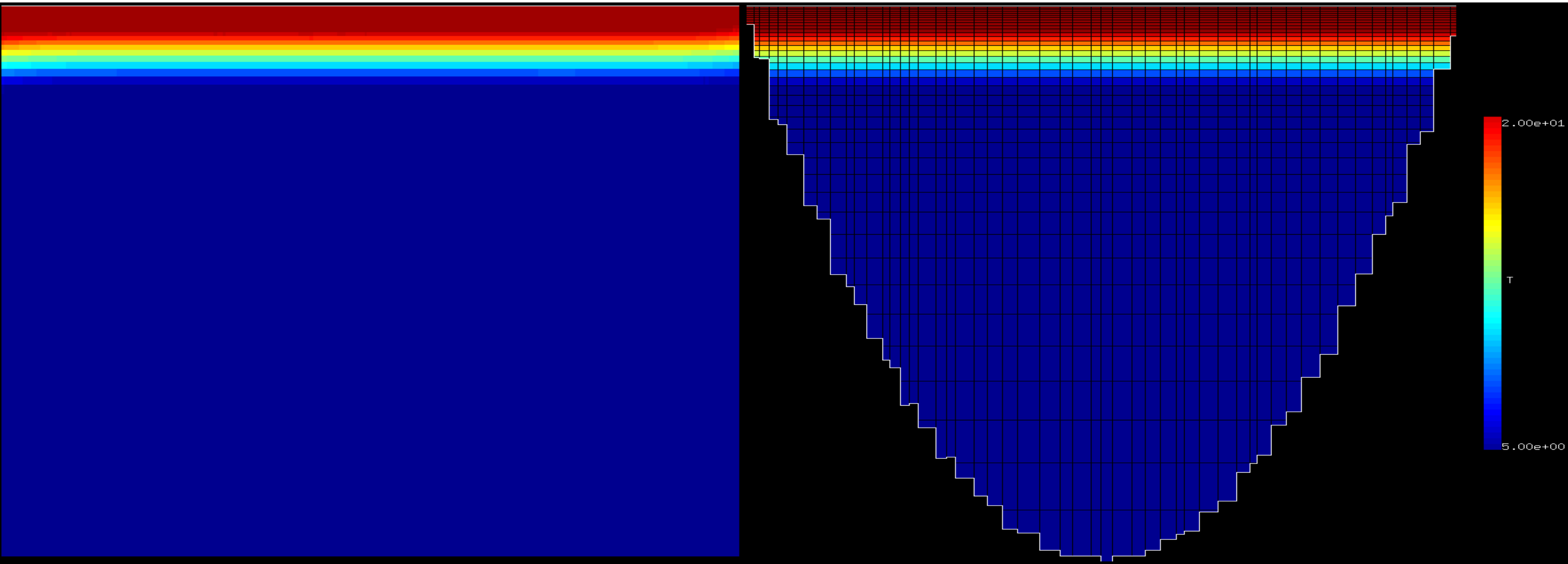
Atmospheric forcing & initial temperature distribution

- Meteorological forcing:

  Wind stress: 0-0.01/0.3 N/m^2(18 hrs), 0.01/0.3 N/m^2(18-23 hrs), 0.01/0.3-0 N/m^2 (23-29 hrs), 0 N/m^2 (29+ hrs)

  Wind characteristics: Northerly, Spatially uniform

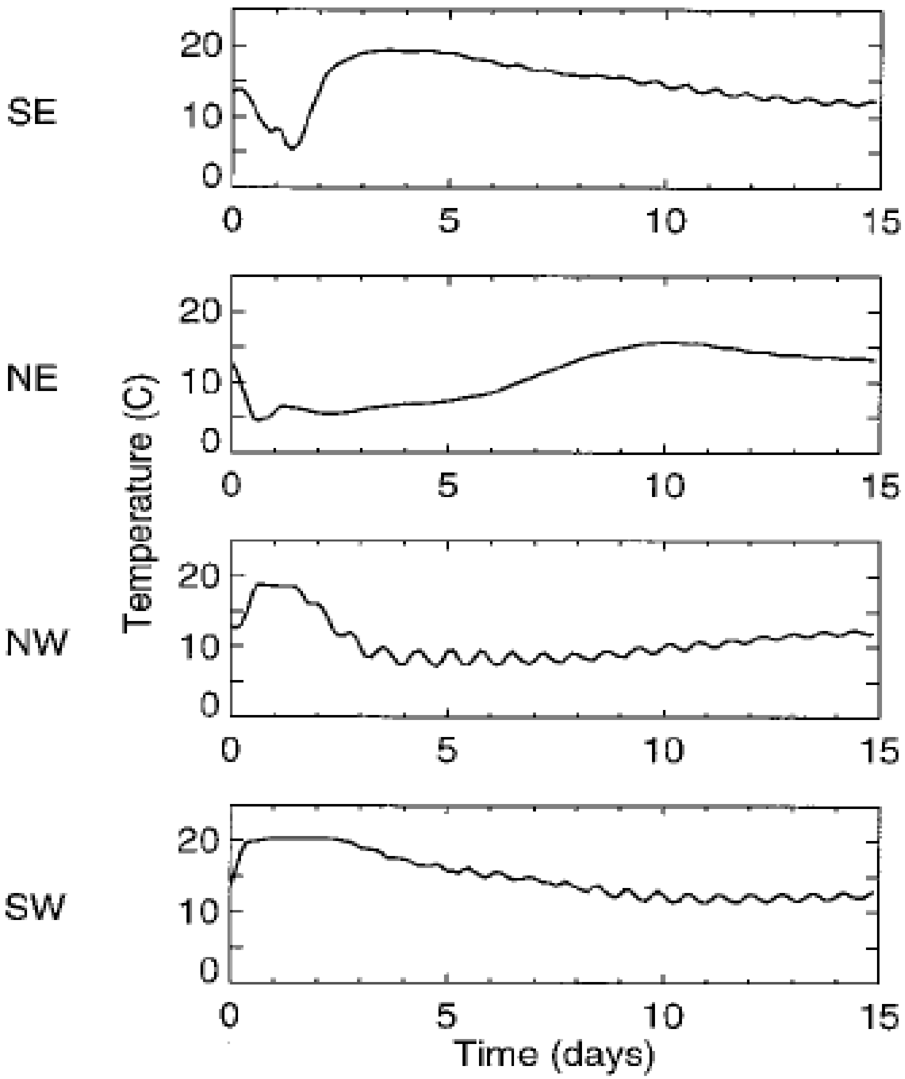
- Heat Flux: None



Results (temperature) for dt= 50s, 75s, 100s, 150s, 200s, 250s

Case: Paraboloid bathymetry high wind stress Resolution: 1.25km

Princeton



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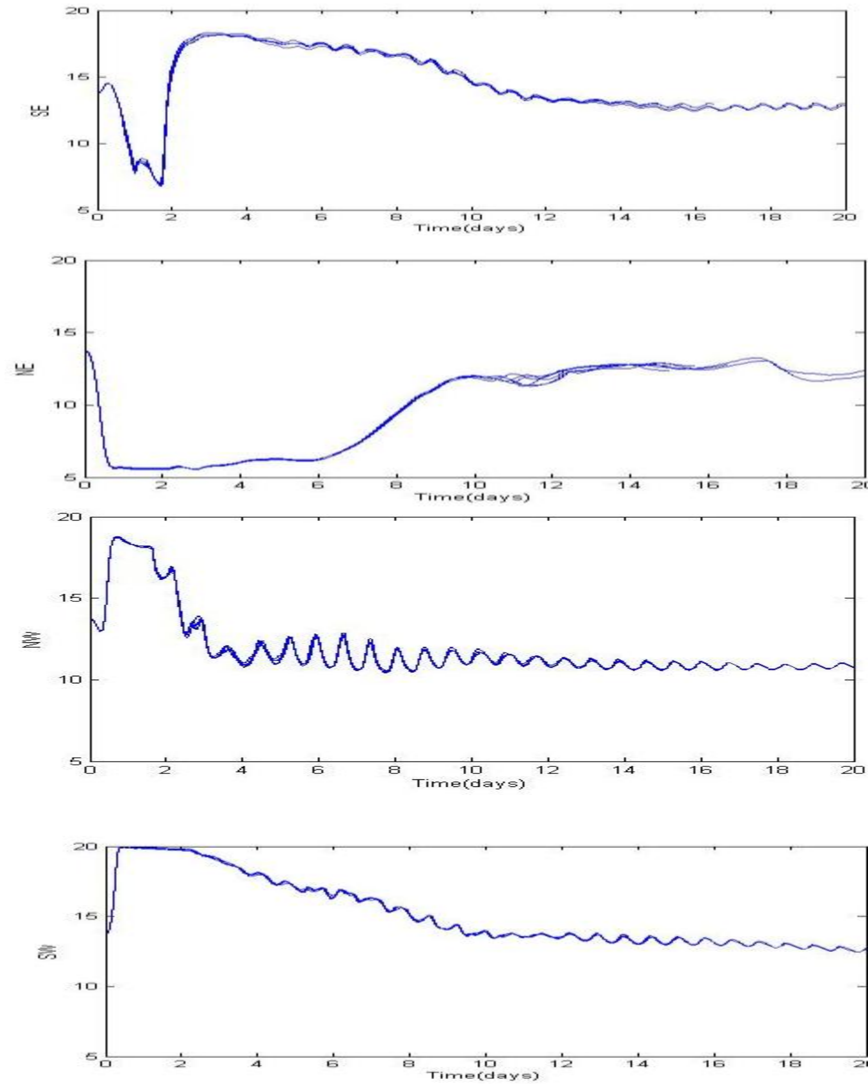
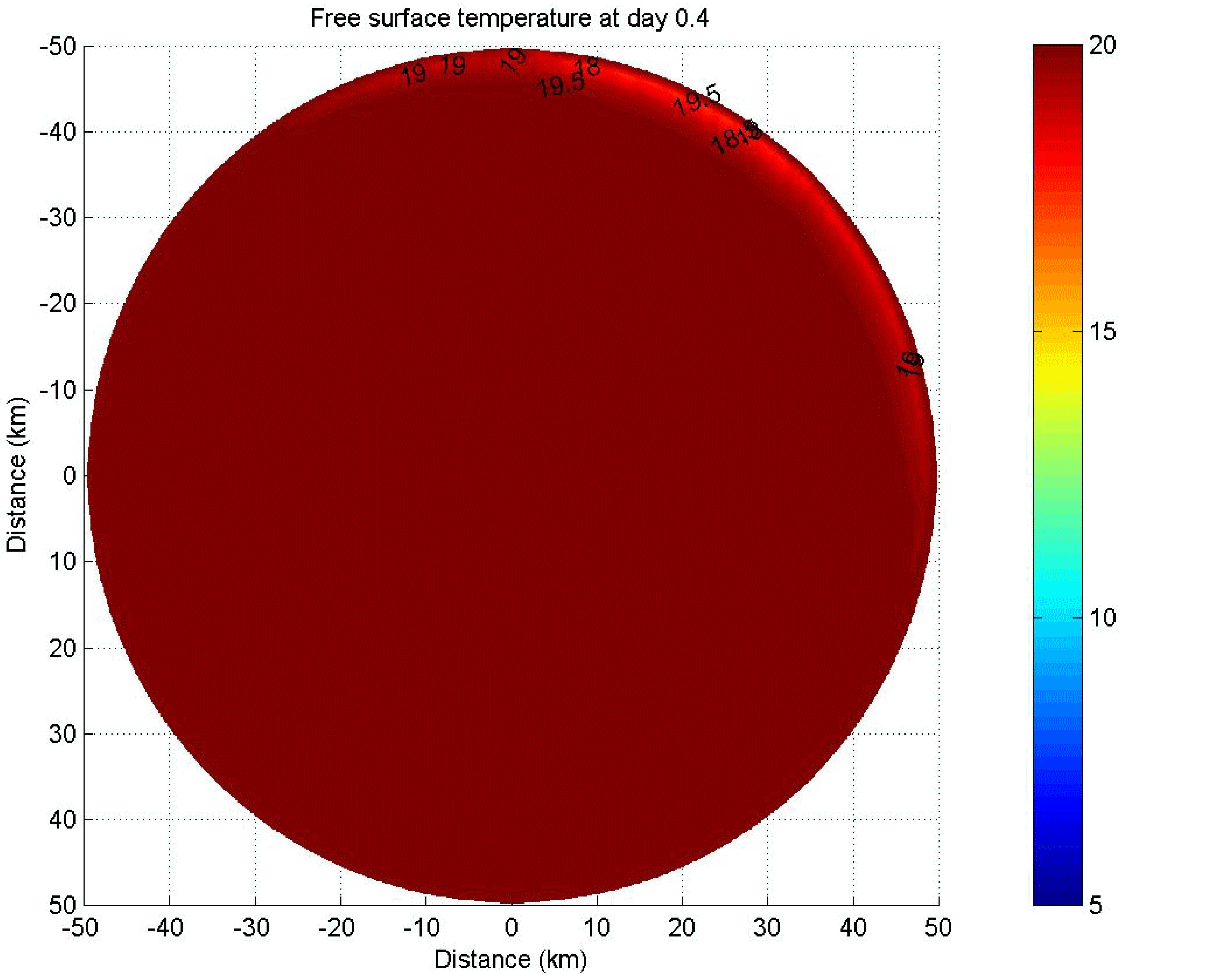
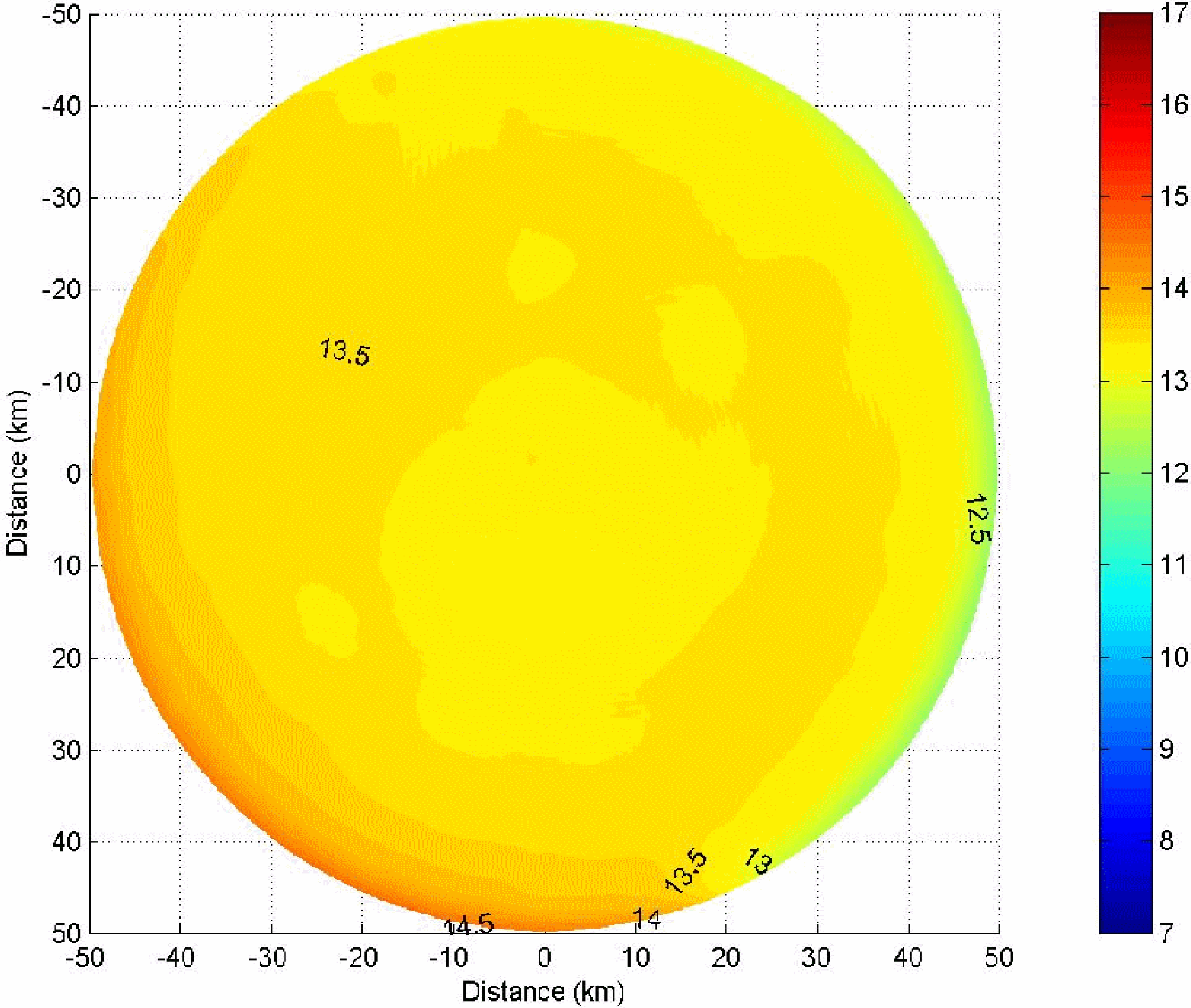


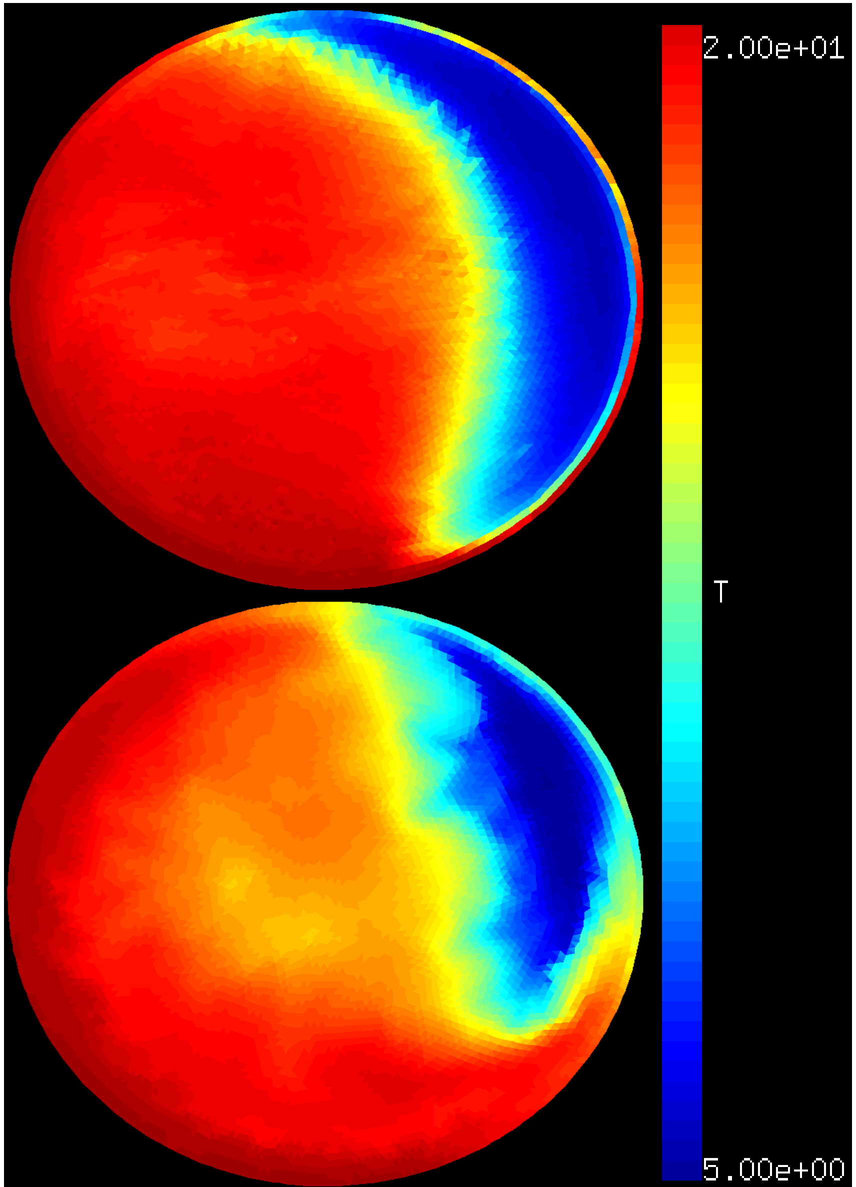

Free surface temperature at day 0.4
Distance (km)
Distance (km)
-50
-40
-30
-20
-10
0
10
20
30
40
50
19
19
19
18
19.5
19.5
18
18
18
20
15
10
5

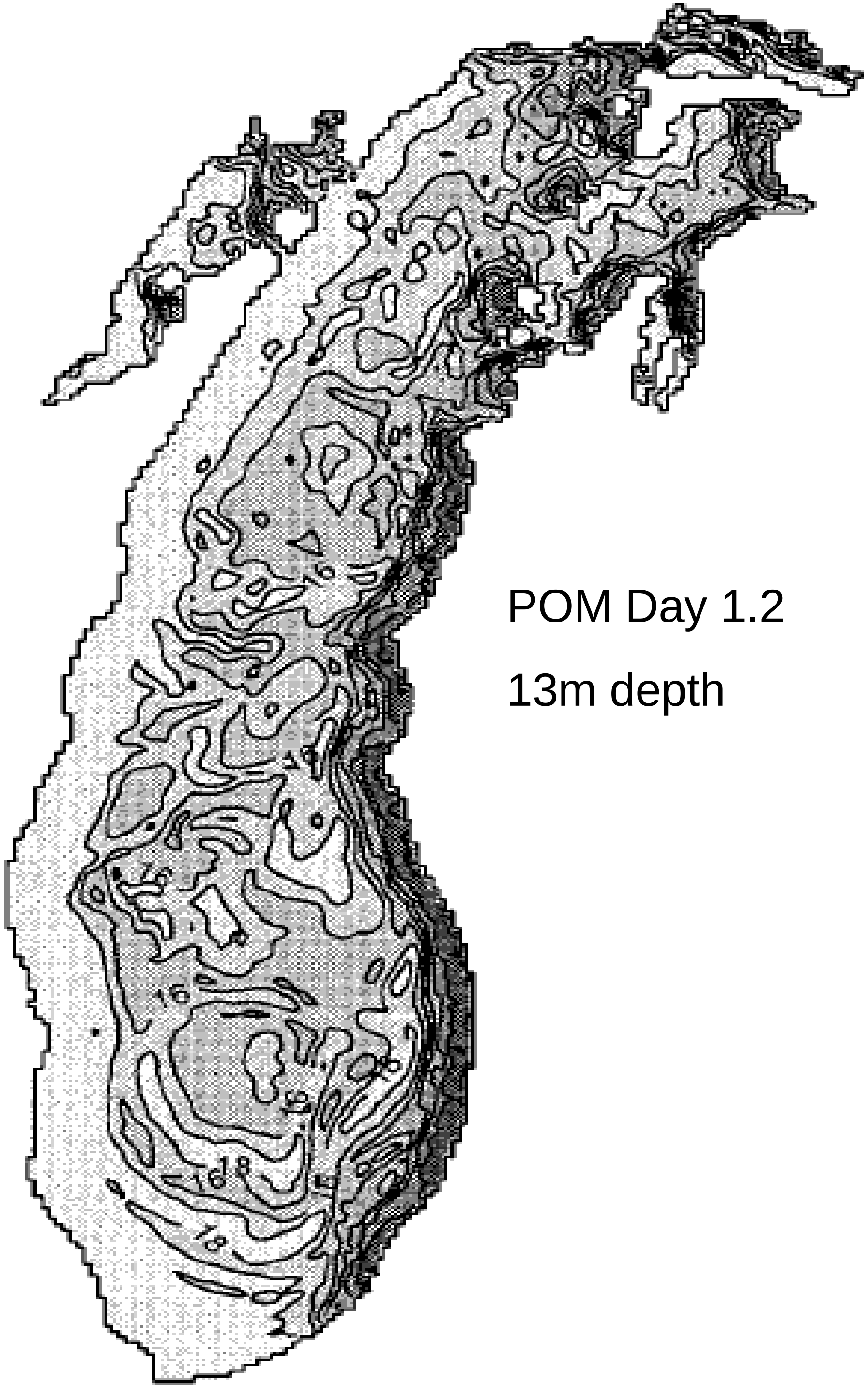
Temperature at 10m depth showing Kelvin Wave Propagation : Day 12.8

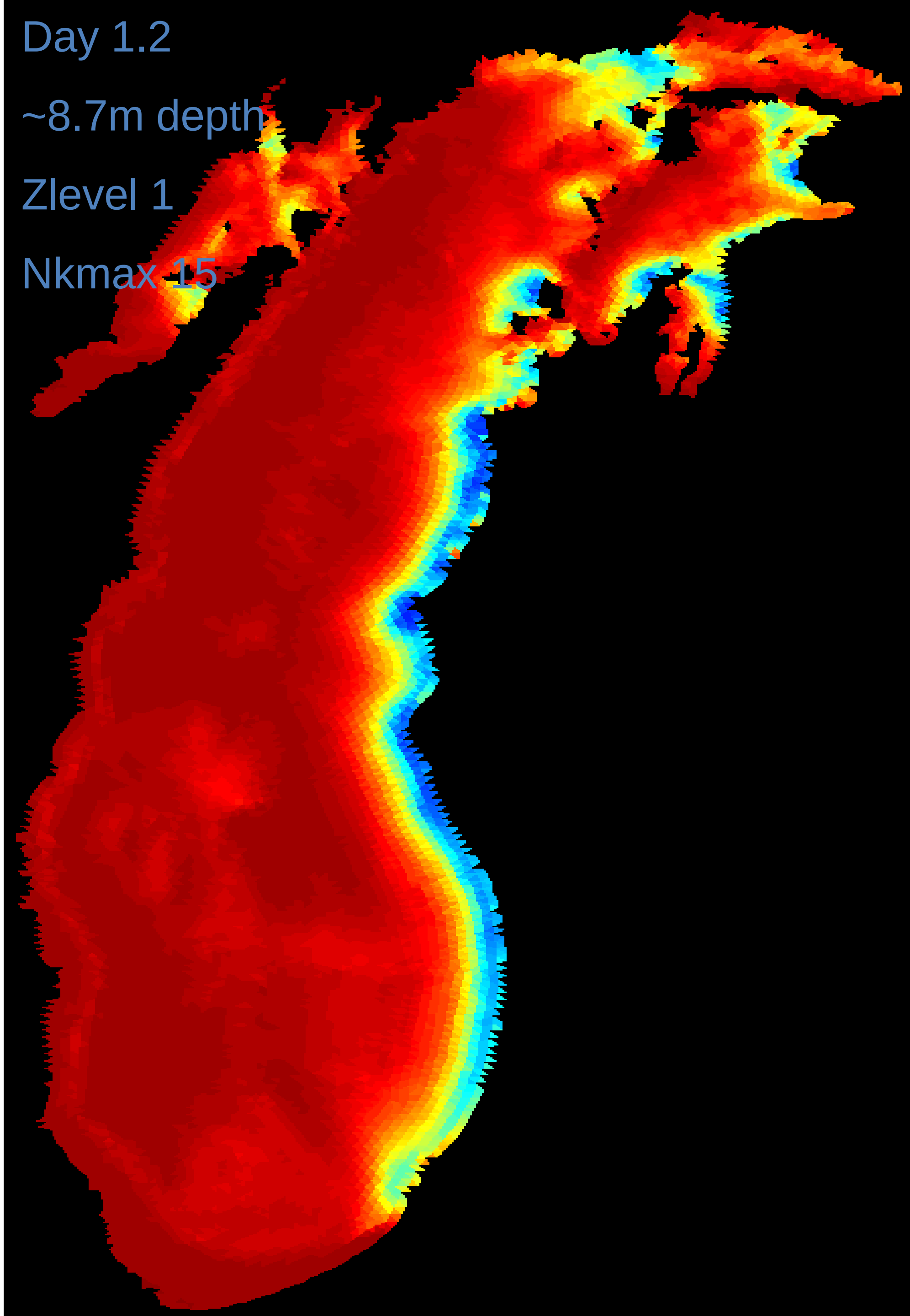


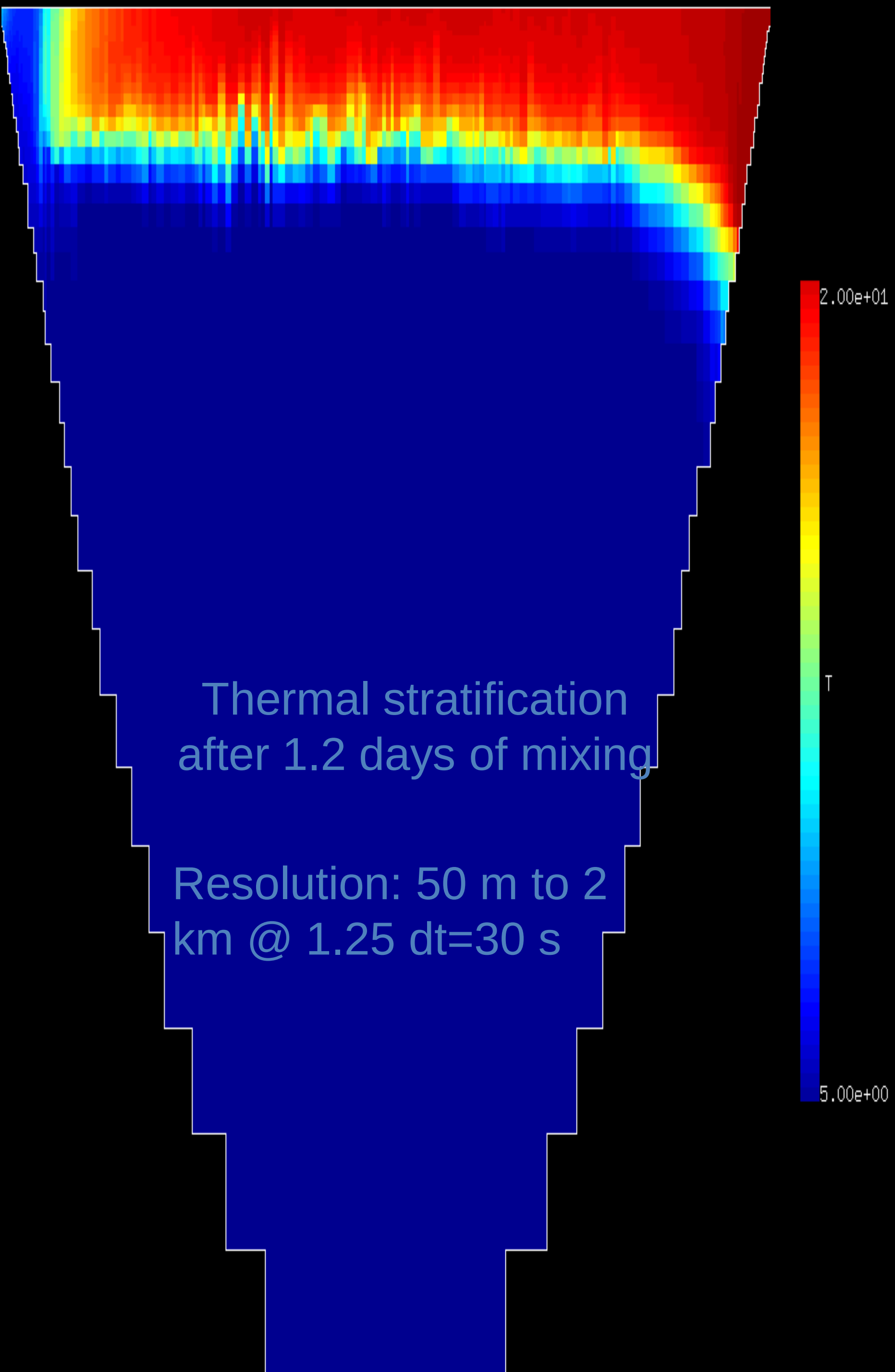
Temperature at 10 m depth Case: Paraboloid-high windstress

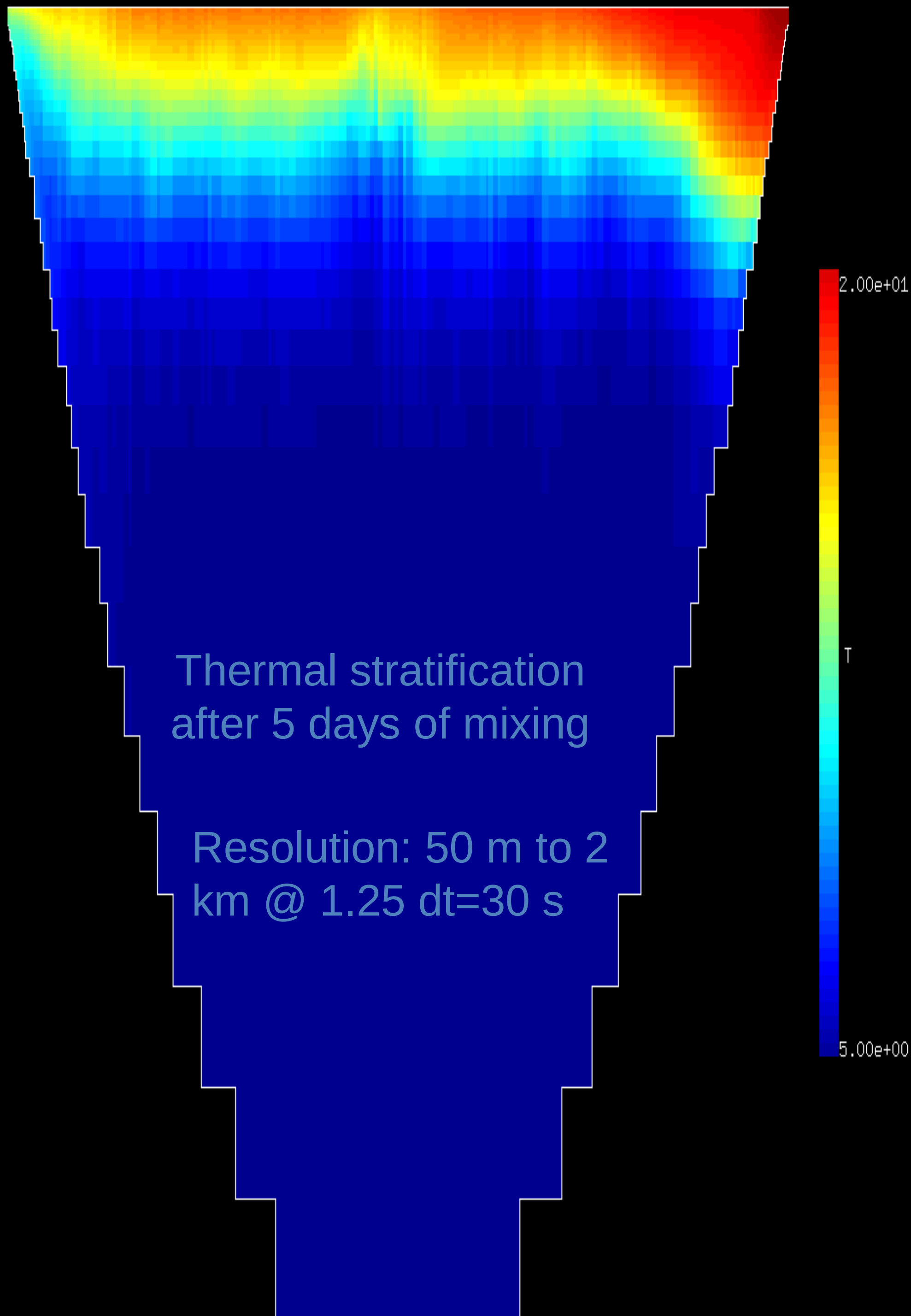
SUNTANS

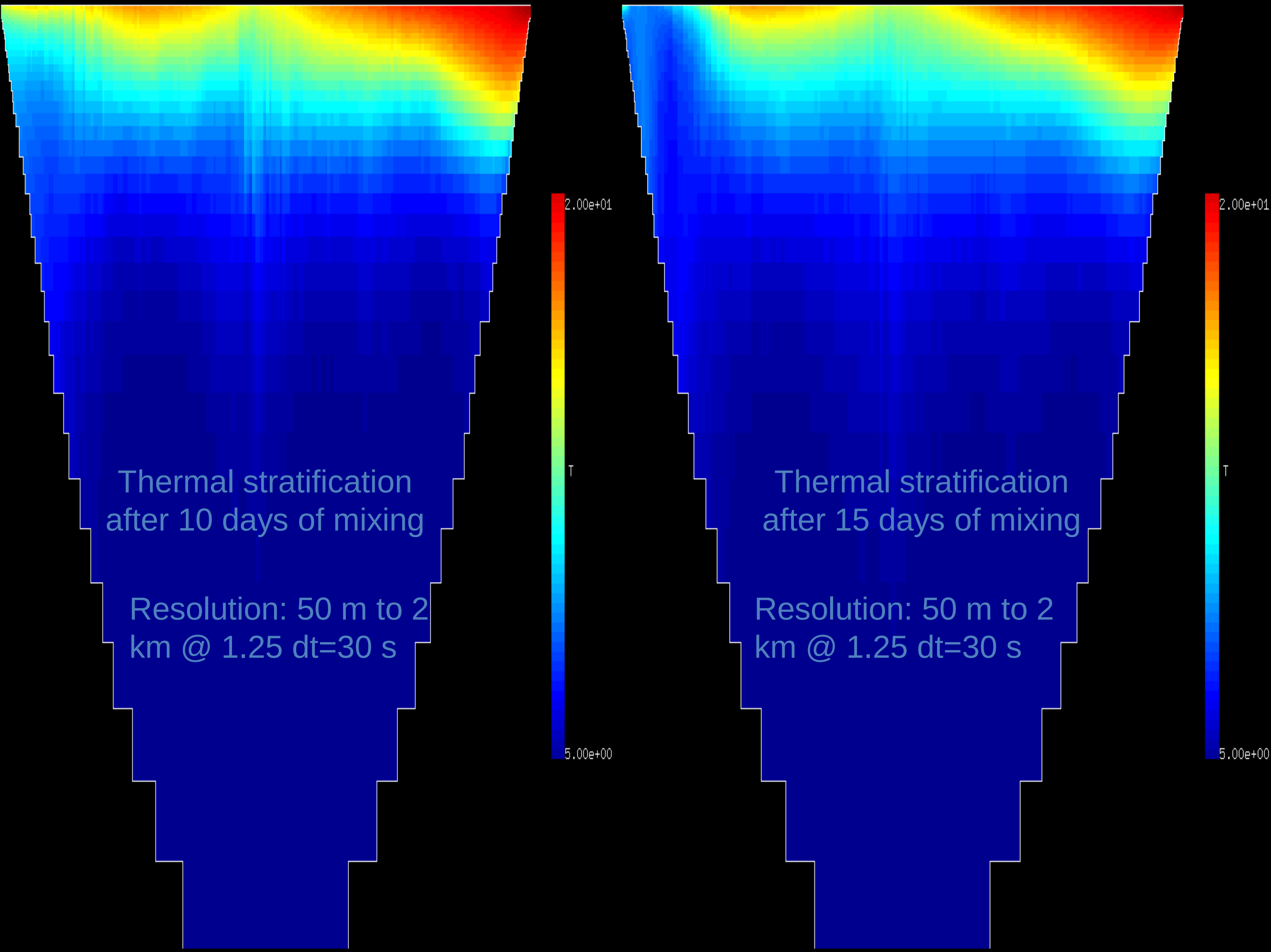



POM Day 1.2
13m depth


Day 1.2
~8.7m depth
Zlevel 1
Nkmax 15


2.00e+01
T
5.00e+00
Thermal stratification
after 1.2 days of mixing
Resolution: 50 m to 2
km @ 1.25 dt=30 s


2.00e+01
T
5.00e+00
Thermal stratification
after 5 days of mixing
Resolution: 50 m to 2
km @ 1.25 dt=30 s


Thermal stratification
after 10 days of mixing
Resolution: 50 m to 2
km @ 1.25 dt=30 s
2.00e+01
T
5.00e+00
Thermal stratification
after 15 days of mixing
Resolution: 50 m to 2
km @ 1.25 dt=30 s
2.00e+01
T
5.00e+00

References

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