Simulating Lake Water Surface Temperature for USCONUS

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Many Lakes On The Earth

- About 304 million lakes (4.2 million km² in area) on the earth (J. A. Downing et al., 2006).
- The majority are fresh water, & most lie in the NH at higher latitudes (R. P. Schwarzenbach et al., 2003).
- More lakes & Fresh bodies in NA continent.
  1. Minnesota--The Land of Ten Thousand Lakes.
  2. Manitoba claims more than 100 thousand lakes.
  3. The Great Lakes form the largest group of freshwater lakes on Earth by total surface and volume.
Importance of Lakes

- Lakes are important in human society
  1. Vital water resources, contributing 90% of the liquid freshwater on the surface of our planet
  2. Engines for economic growth in millions of communities,
  3. An important role in maintaining the ecological health of the planet.

- Lakes are important in Hydrological Cycle
  1. Lake storage of runoff regulates stream outflow by sustaining low flows and suppressing peak discharges
  2. Lake-effect precipitation
  3. Evaporation from the lakes are larger than from the land

- Lakes are important in Carbon Cycle
  1. Lakes are aquatic habitat; the chemical and ecological cycles are strongly influenced by physical limnological processes (e.g., upwelling & downwelling, spring & fall turnover, currents)
  2. Important component of ecosystem carbon cycle through both organic carbon sequestration and carbon dioxide and methane emissions.
  3. Lake sediments are considered to be one of the rather permanent sinks of carbon in boreal regions.
  4. Freshwater ecosystems process large amounts of carbon originating from terrestrial sources
Many World’s Lakes in Jeopardy
Two causes: Climate Change & Man activities.

Walking along the bone-dry 1956 Olympics rowing course in Melbourne

Lake Mead Area reduced by 61%

Blue-green algae in Taihu Lake, China

Bicaz Lake, Romania

Uttra Lake, India
Sentinels of climate change

- Lakes are sensitive to climate, respond rapidly to change, and integrate information about changes in the catchment.

- Indicators:
  1. Temperature
  2. Ice phenology
  3. Chemical variables
  4. Dissolved organic carbon
  5. Oxygen concentration
  6. Changes in spring and early summer phenology
  7. Growth rates, abundance, and species composition
  8. Other climate-related responses of lake biota
     a) Primary productivity
     b) zooplankton body size
     c) increased bacterial cell densities
     d) benthic net photosynthesis a& dark respiration
     e) species diversity & composition

Schneider & Hook, 2010: Space Observations of inland water bodies show rapid surface warming since 1985.

Zheng & Ek, 2010: Many lakes are missing from GFS model.

Water density varies with temperature.
The Flake Model

- One-dimension, two-layer: mixed-layer & thermocline
- Temperature & energy budget
- Sediment module
- Snow-ice module
- Specified depth & turbidity
- Atmospheric forcing inputs

Schematic representation of lake stratification and the corresponding temperature profile in the Flake Model.
Typical Temperature Profiles in FLAKE

Typical Temperature Profile for Summer Stratified Lakes

Typical Temperature Profile for Winter Stratified Lakes
The Concept of Self-similarity

\[ T(z,t) = \begin{cases} 
T_s(t) & 0 \leq z \leq h \\
T_s(t) - (T_s(t) - T_b(t))\Phi_T(\zeta) & h < z \leq D
\end{cases} \]  

(1)

\[ \Phi_T = \left( \frac{40}{3}C_T - \frac{20}{3} \right)\zeta + (18 - 30C_T)\zeta^2 + 
(20C_T - 12)\zeta^3 + \left( \frac{5}{3} - \frac{10}{3}C_T \right)\zeta^4 \]  

(2)

\[ \zeta = \frac{(z - h)}{(D - h)} \]  

(3)
A 2-D driver was developed, the Flake is called for each lake grid point.

The Flake was run at 4km for the lakes in USCONUS with NARR data as the driving force.

The HR_RTG_SST of 2006 to 2010 year and the average of the 5 year were interpolated into the Flake domain at 4km resolution, the values for land is flagged out.

The differences between Flake TsfC and the average HR_RTG_SST on 4 different days.

Annual variations of HR_RTG_SST and Flake of lakes.
Differences between HR_RTG_SST and Flake Tsfc
Lake water surface temperature for USCONUS was simulated using Flake driven by NARR data forcing.

Flake Tsfc was compared with HR_RTG_SST.

In general, Flake has larger annual variation, and is warmer in warm seasons, colder in cold seasons.

In Winter and Summer, the difference between flake and HR_SST can be larger than 10 degree. In Spring and Fall, the difference is less than 10 degree.

Flake can be used in lake climotologies for high res grids (e.g. fire weather) where lakes are not resolved by the HR_RTG_SST.

Flake can be a part of the model physics in NAM as well as NLDAS and GFS/CFS.

Flake is a useful tool for lake management.
Thank You