Developing a new lake model in CCSM4

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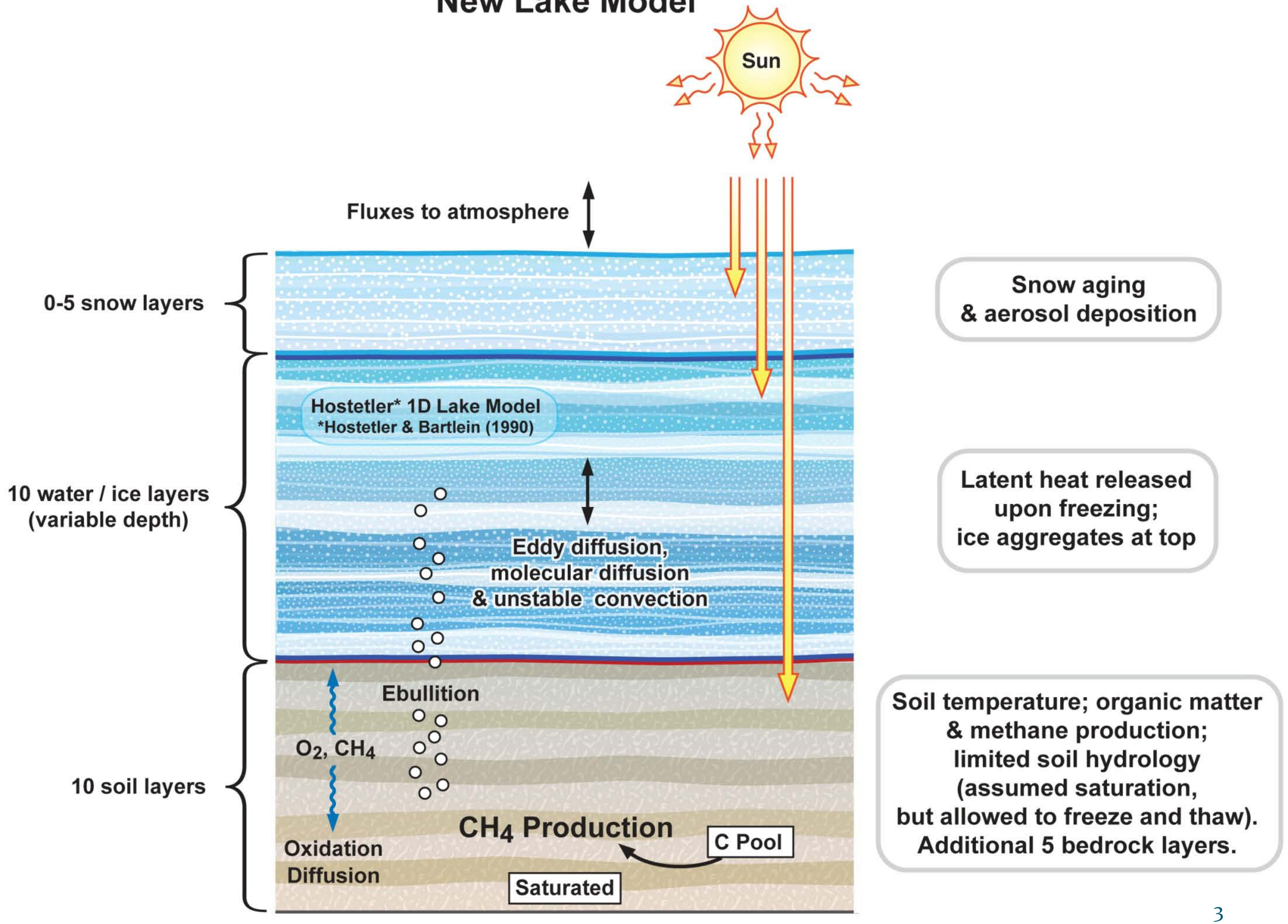
6/29/10

Work Funded by DOE and Lawrence Berkeley National Lab

Deficiencies in CCSM 3.5 / 4 Lakes

- Problems with surface energy budget and mixing
  - Error in partitioning fluxes
  - Only molecular conductivity between lake skin & top lake layer
  - Error in eddy diffusion calculation
- Simple bulk snow scheme with no thermal insulation; no soil layers beneath lake
- Fixed 50 m depth & optical properties for all lake columns
- No phase change physics: no change in thermal properties or exchange of latent heat for freezing or melting

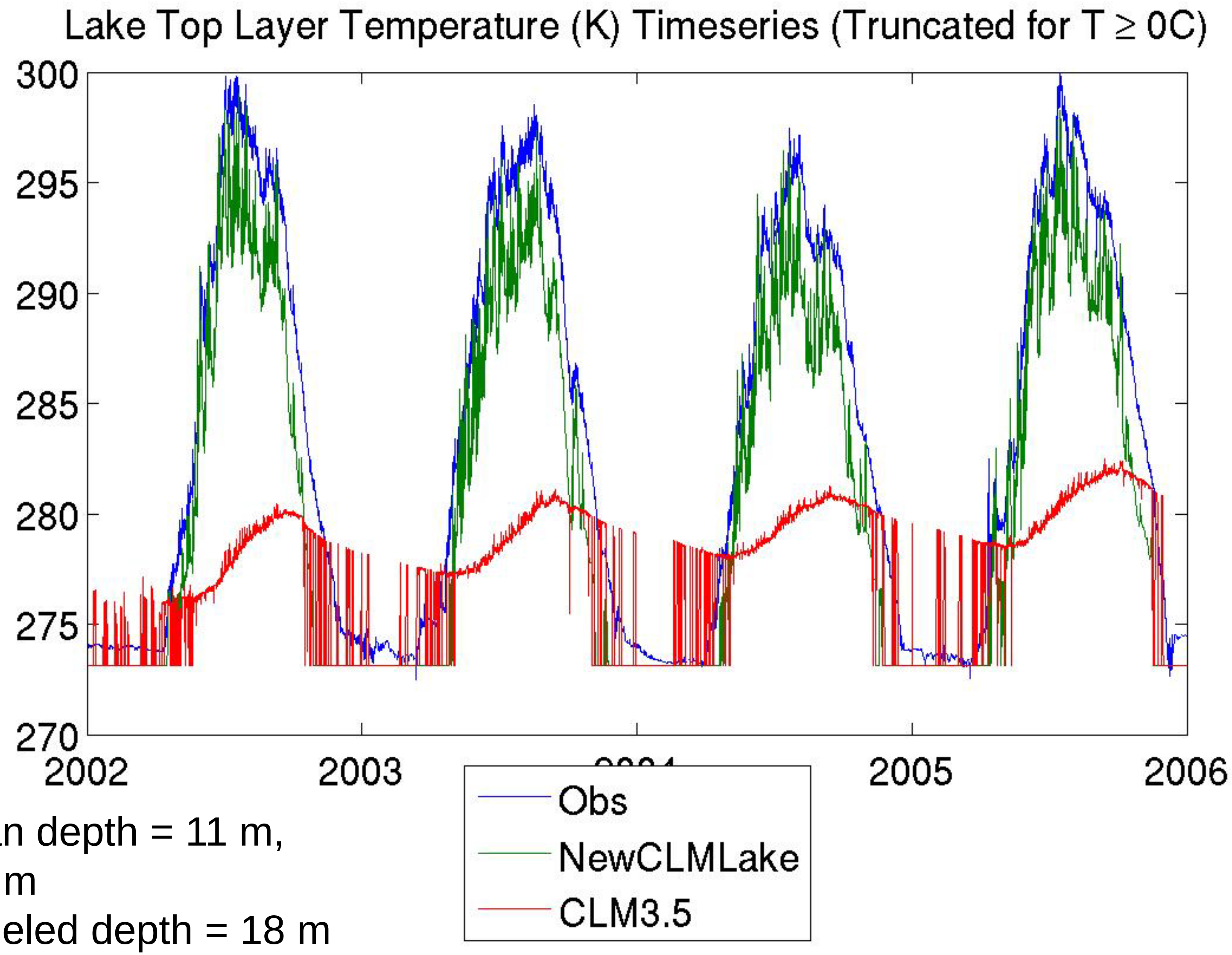
New Lake Model



New Lake Physics

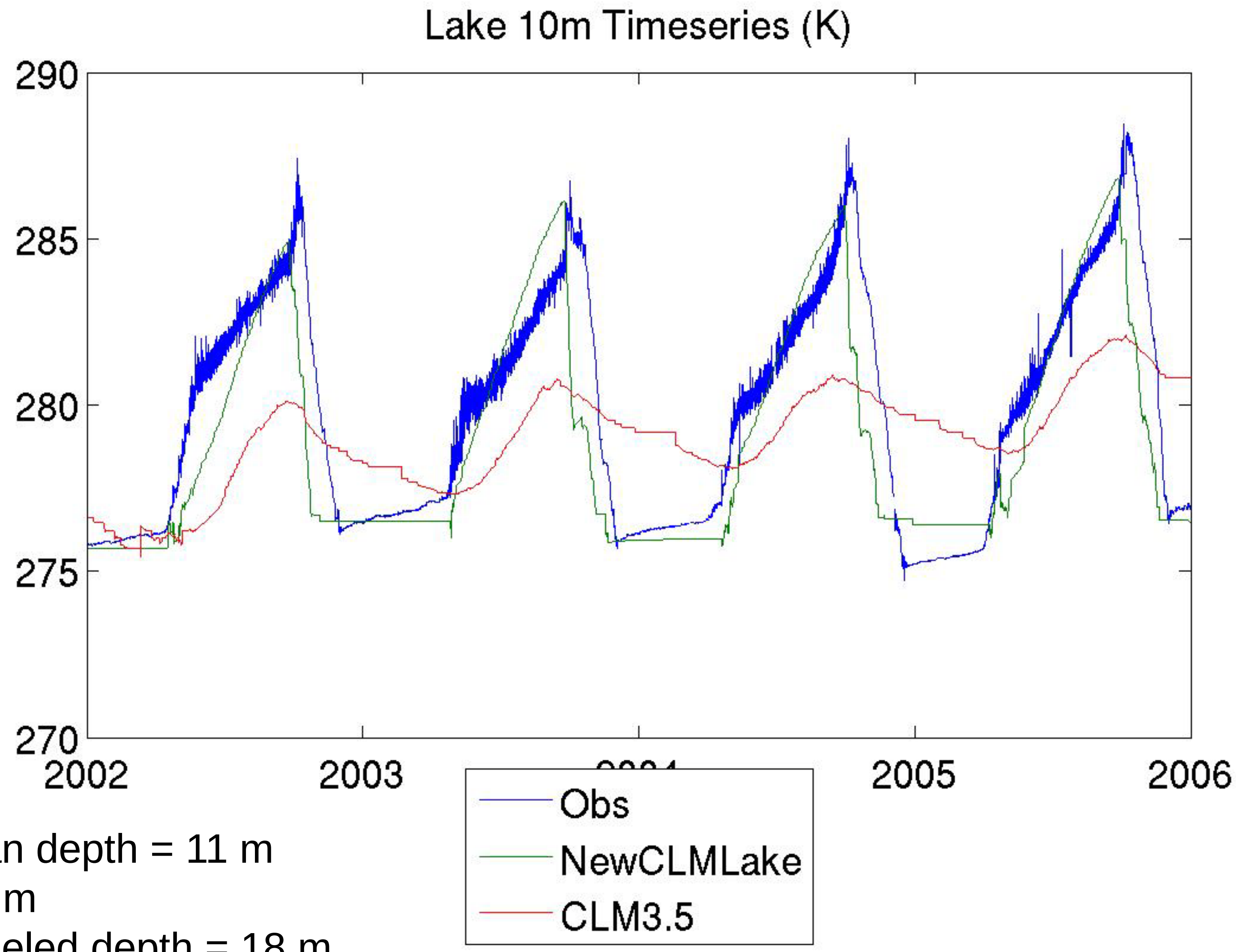
- Ice fraction in each lake layer
- Phase change solved similarly to soil layers
- Lake skin has eddy diffusion and convective mixing with top lake layer
- Heat diffusion includes snow, lake, & soil
- Full CLM 4 snow capabilities over lakes
- Variable lake depth & optics

Sparkling Lake @ 5 cm



Lake mean depth = 11 m,
max = 20 m
Lake modeled depth = 18 m
Temp. probe depth = 18 m

Sparkling Lake @ 10m



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(Climatic Change, 1993)

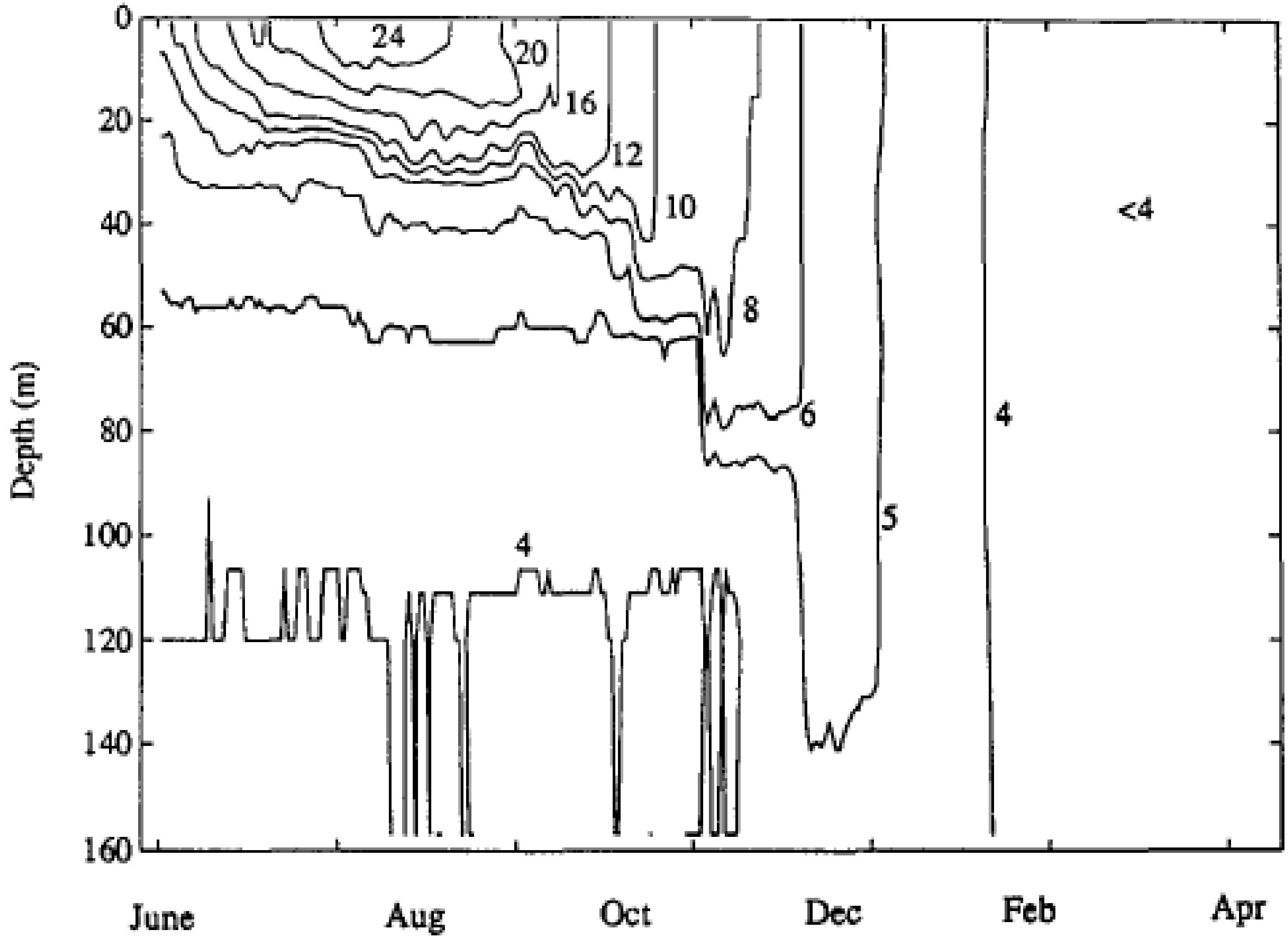
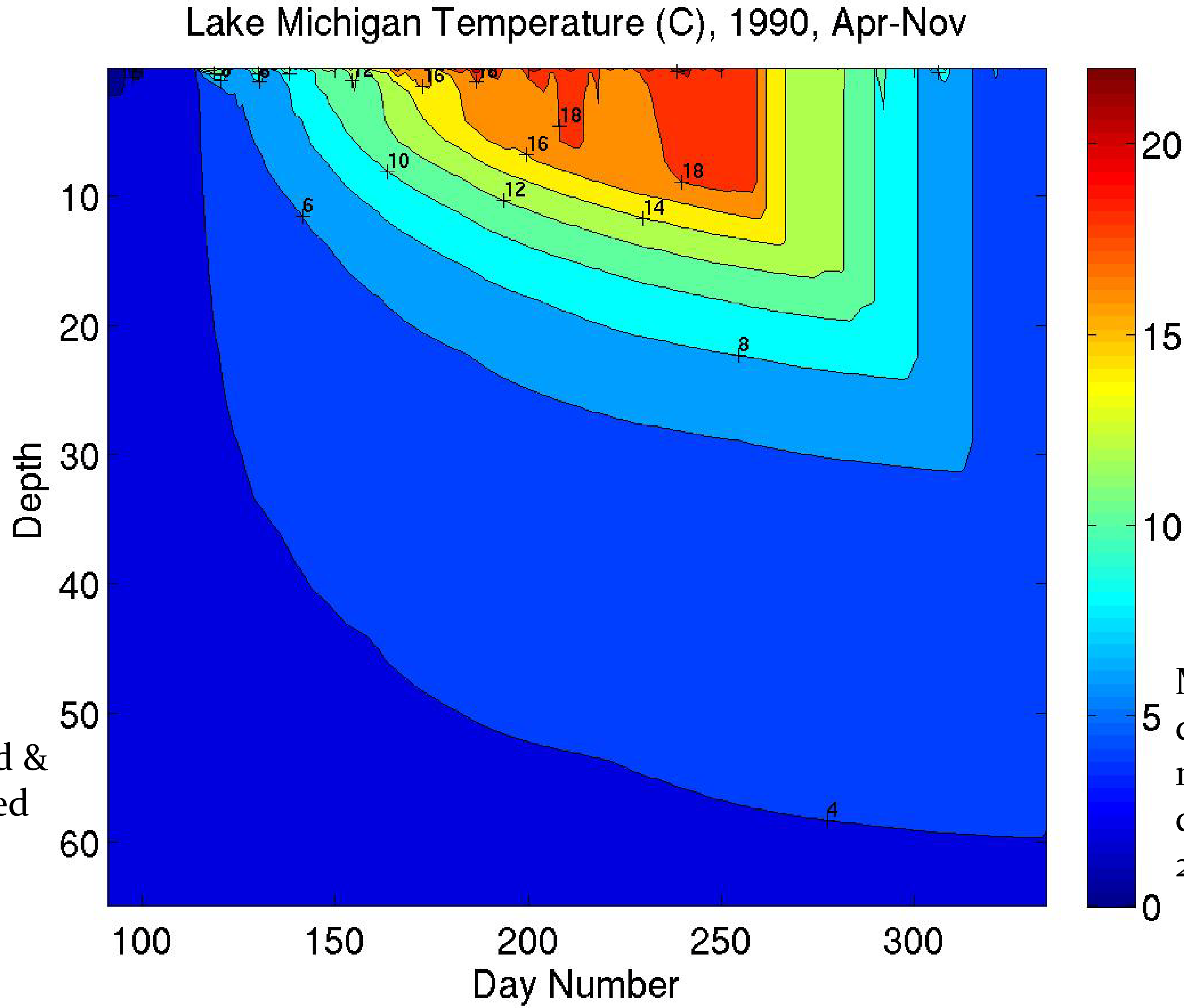


Fig. 2. Temperature contours for the offshore waters of Lake Michigan from 7 June 1990 through 18 April 1991. Contours were generated from daily averaged data.

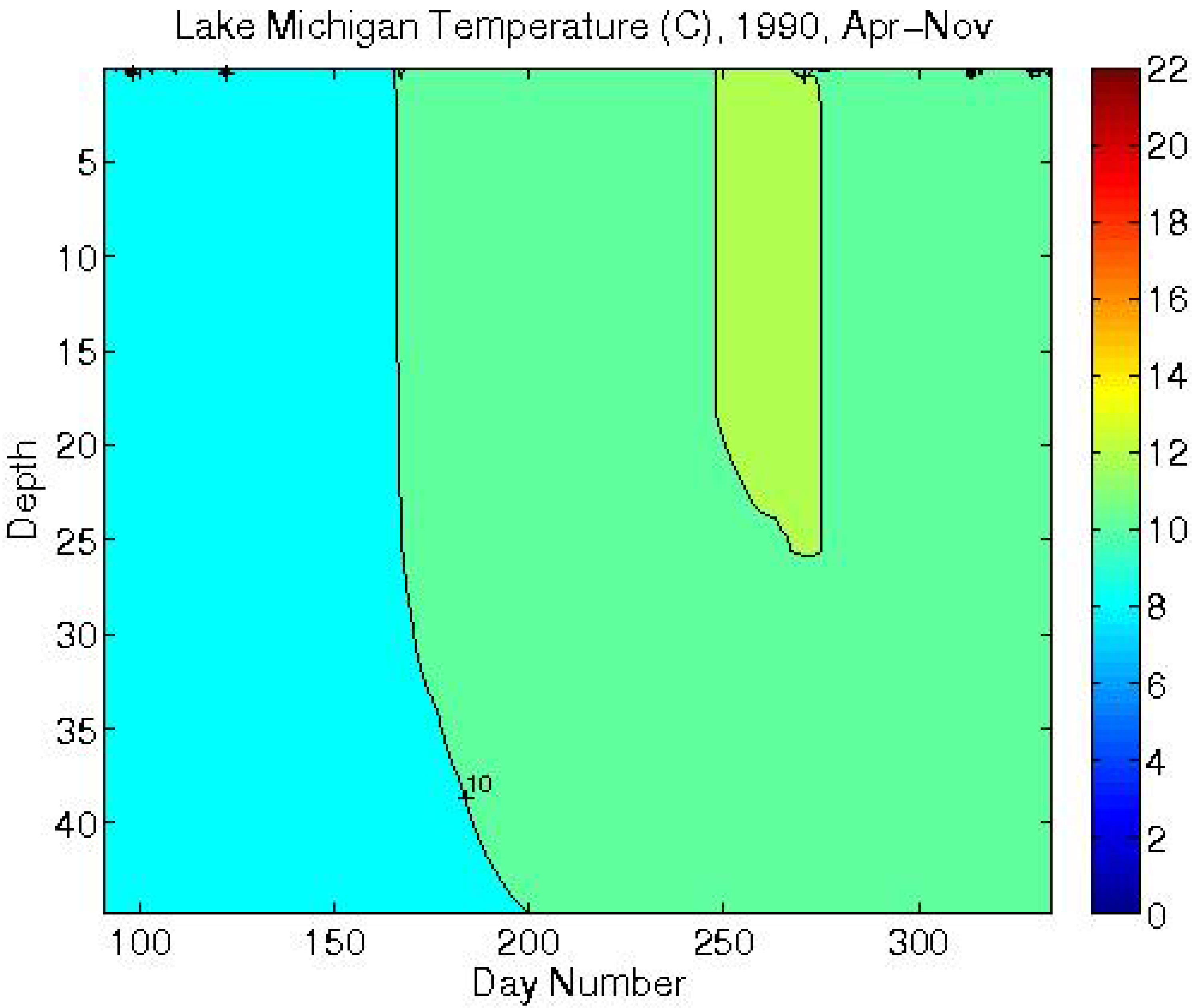
Lake Michigan, Apr-Nov 1990, New Lake Model



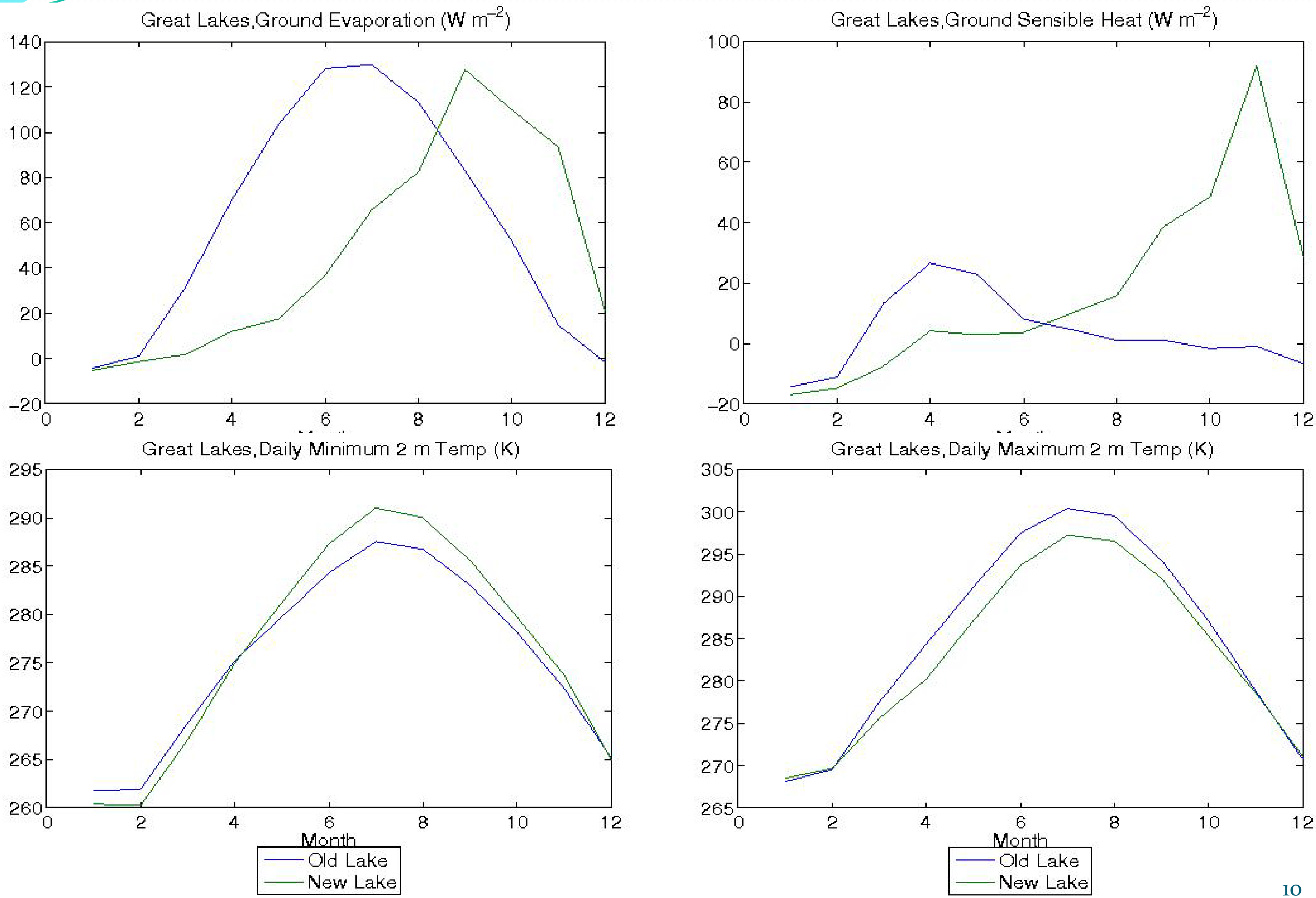
Modeled & measured depth = 160 m

Mean depth = 85 m; Max. depth = 281 m

Lake Michigan, Apr-Nov 1990, CLM 3.5



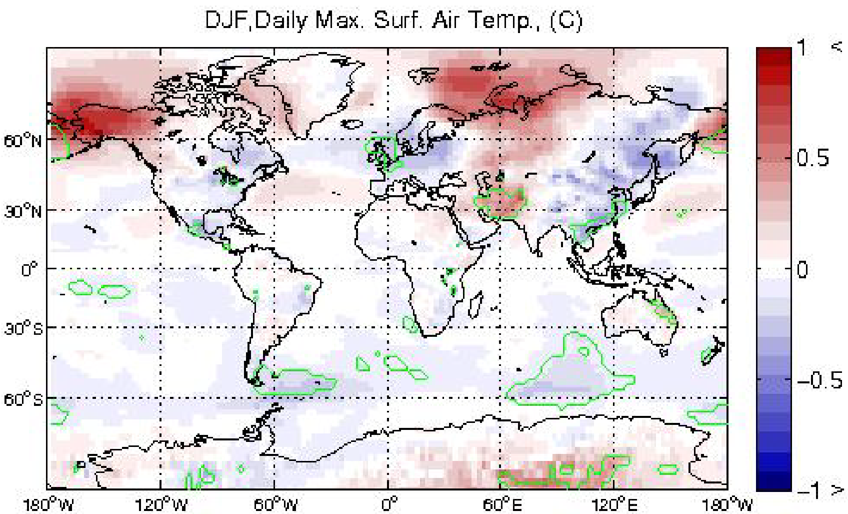
Uncoupled CLM 3.5, 24 yr, Great Lakes Fluxes

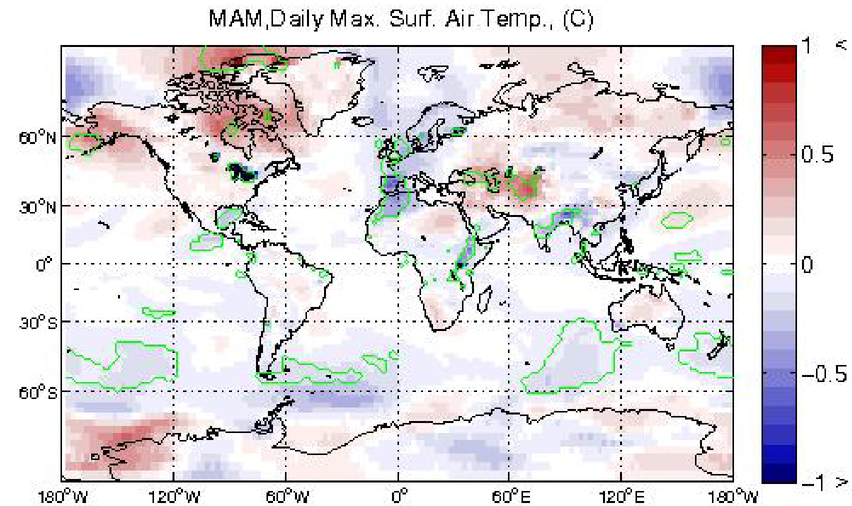


Effects of Lake Model on Year 2000 Climate in CCSM

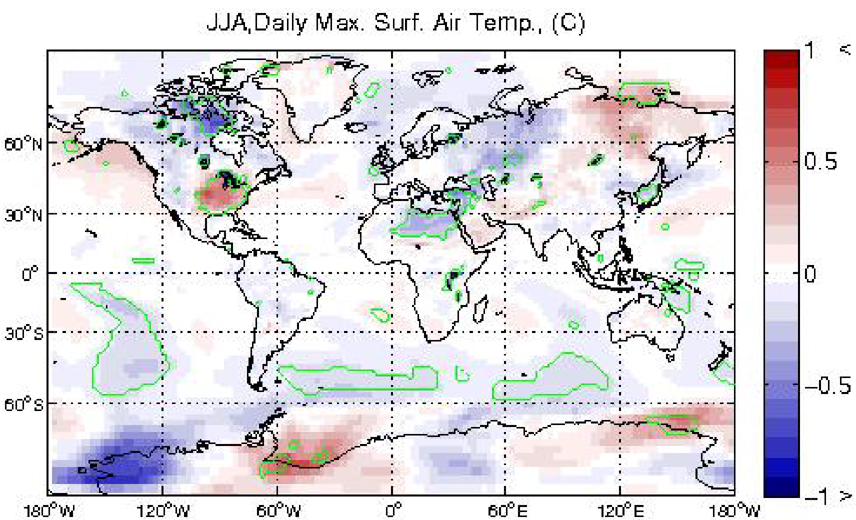
- New – Old Lake Model in CLM-CAM 4 with slab ocean
- **New Lake Model with 0.7M km^{-2} vs. 2.9M km^{-2} Lake Area**

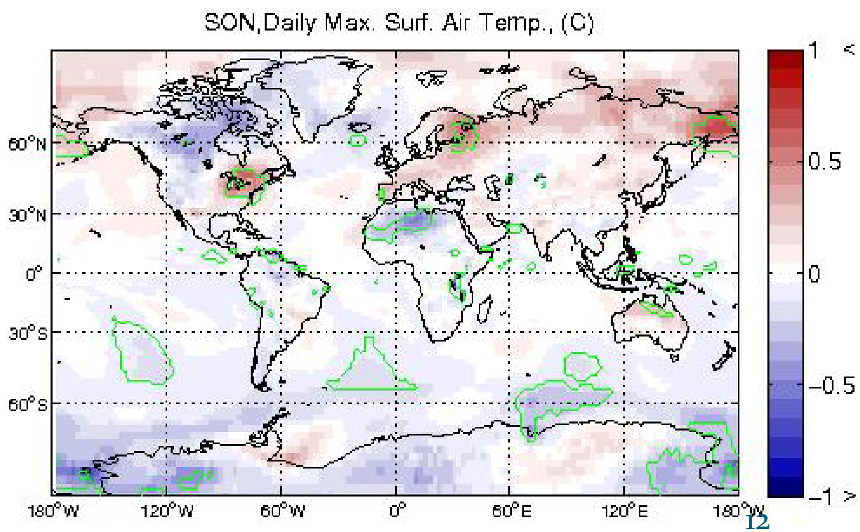
CAM-CLM4, 100 yr, New – Old Lake Daily Max. Surf. Air Temp. (C)



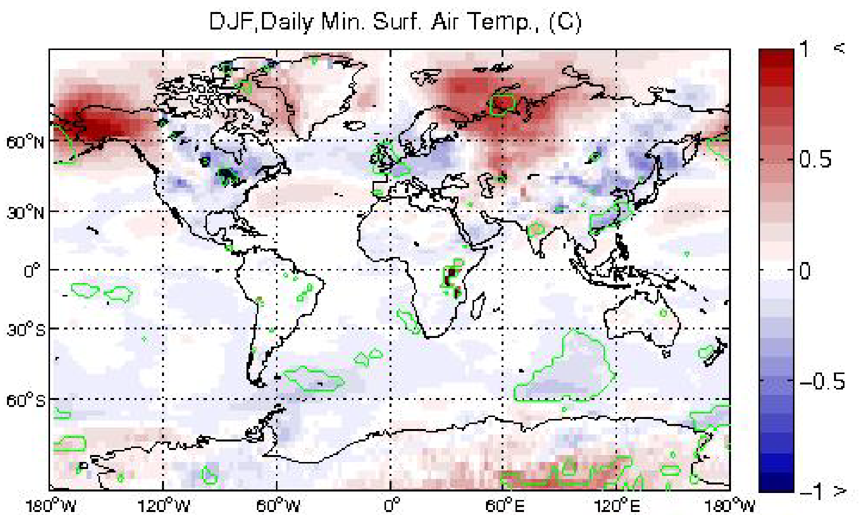


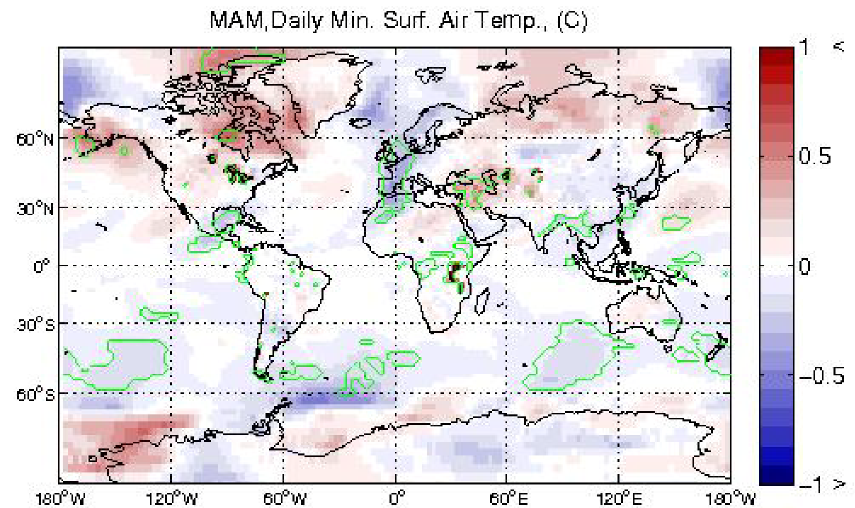
Green contours = significance at 5%





CAM-CLM4, 100 yr, New – Old Lake Daily Min. Surf. Air Temp.(C)





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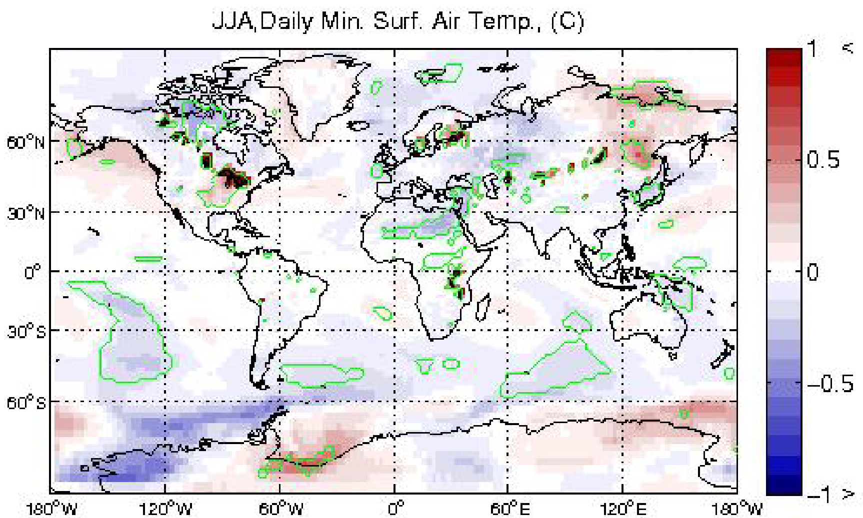
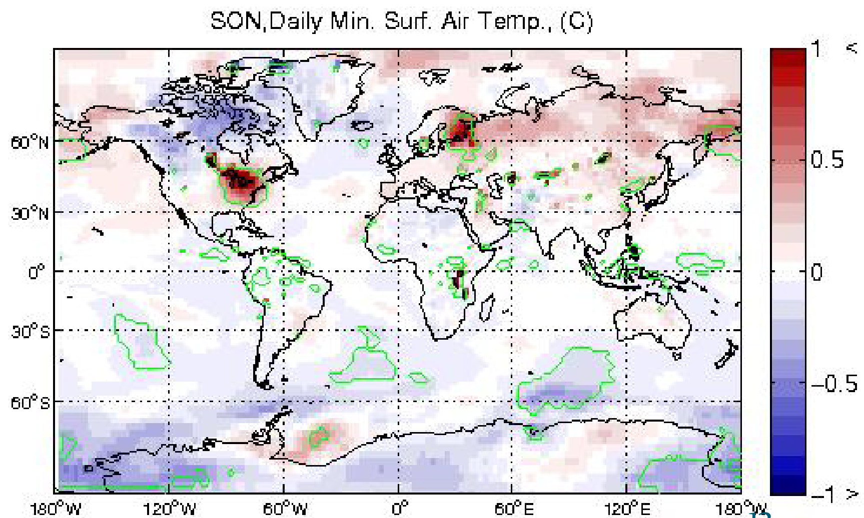
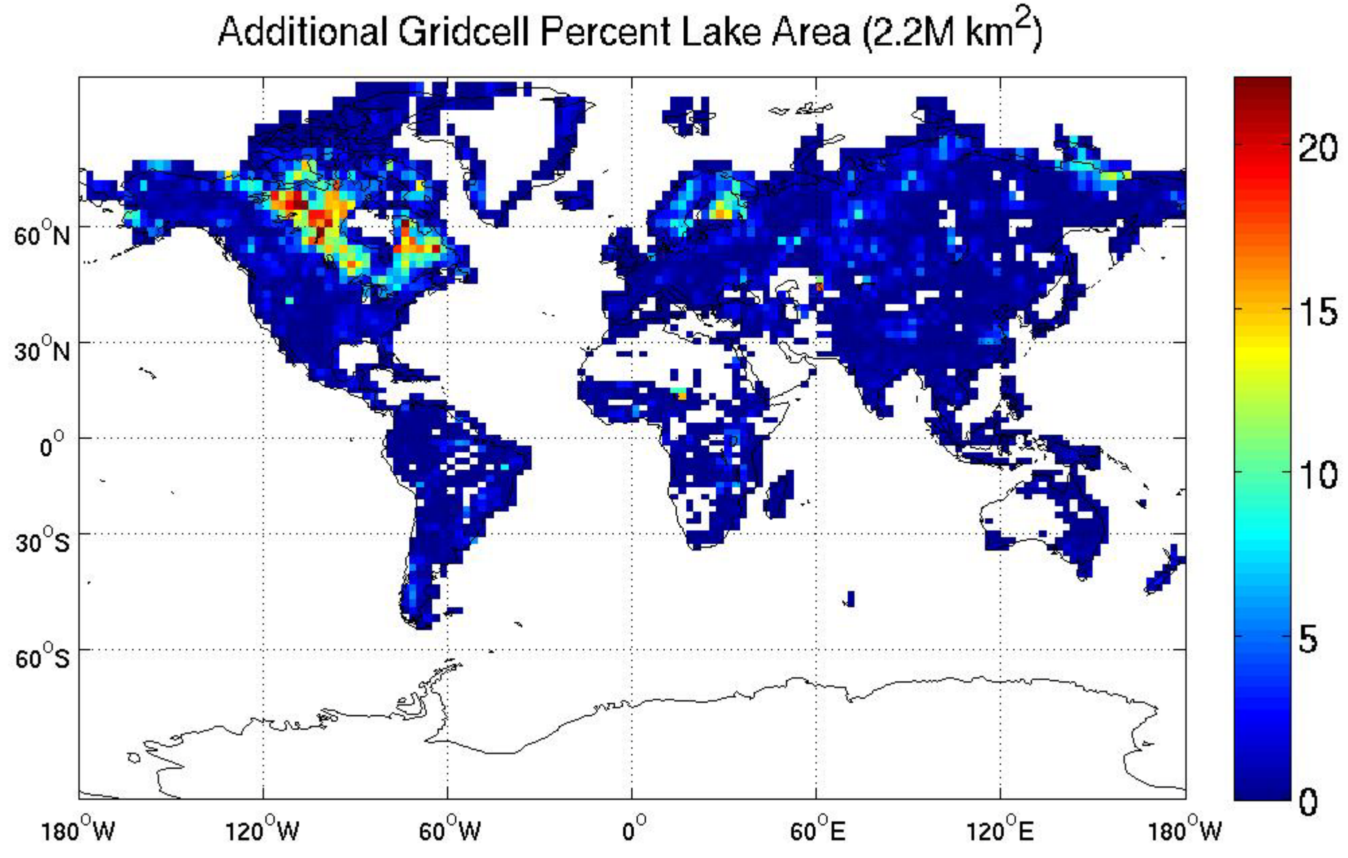
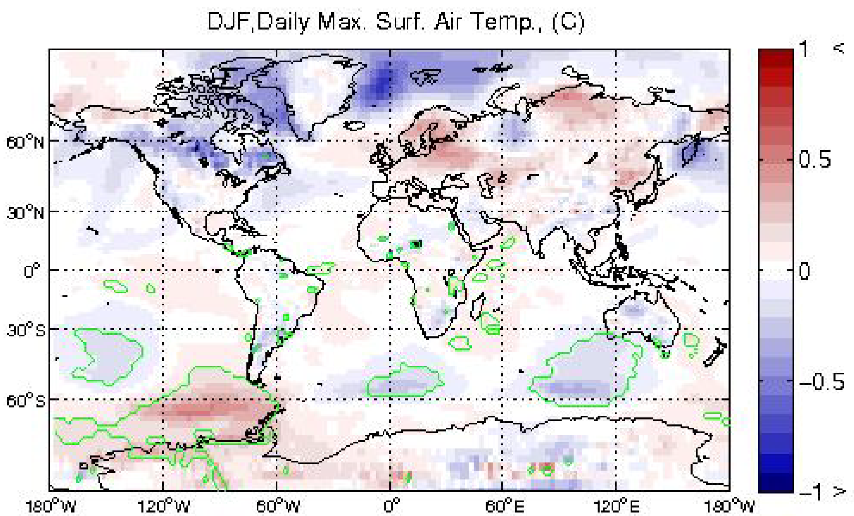


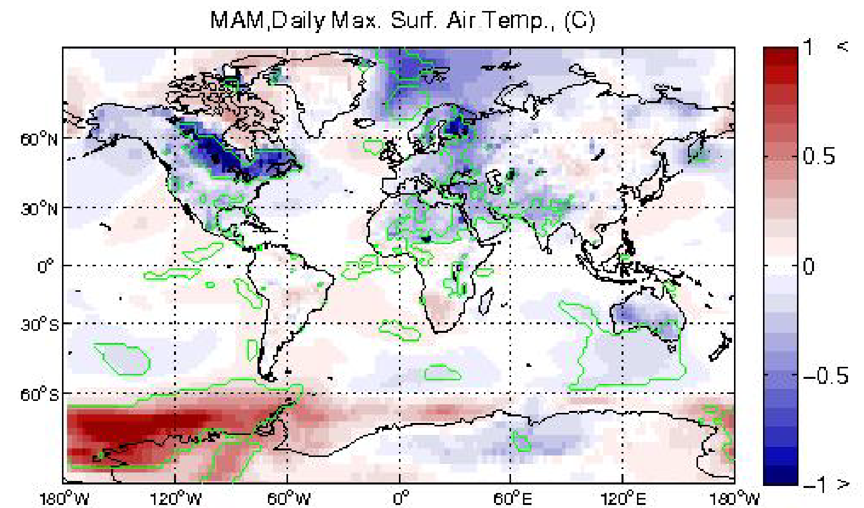


Low Estimate of Missing (Small) Lake Area in CCSM 4 from GLWD



CAM-CLM4, 100 yr, High – Low Lake Area
Daily Max. Surf. Air Temp. (C)





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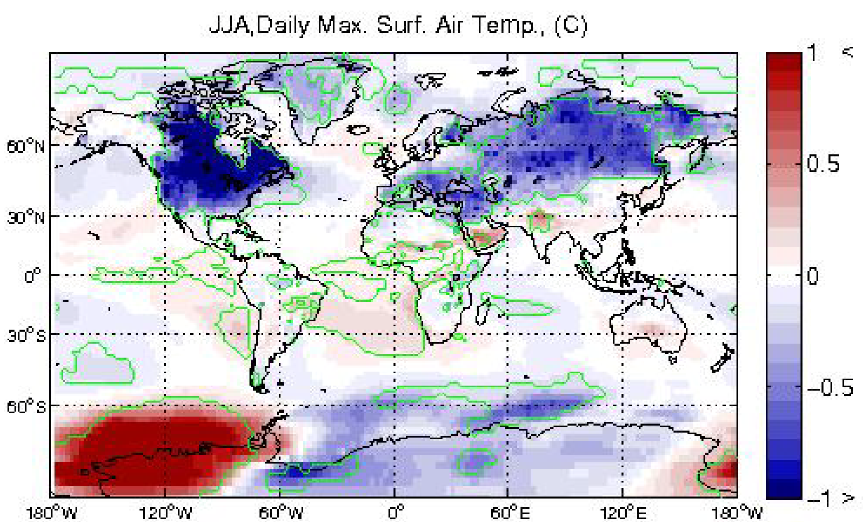
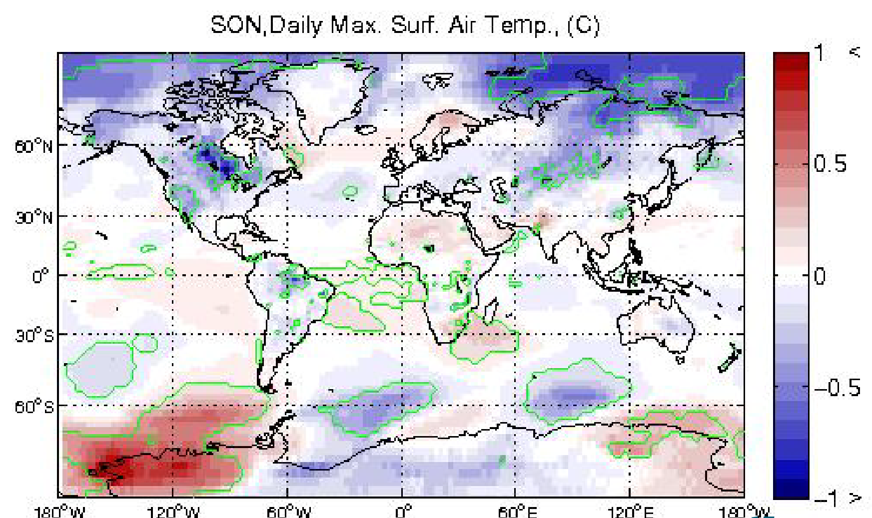
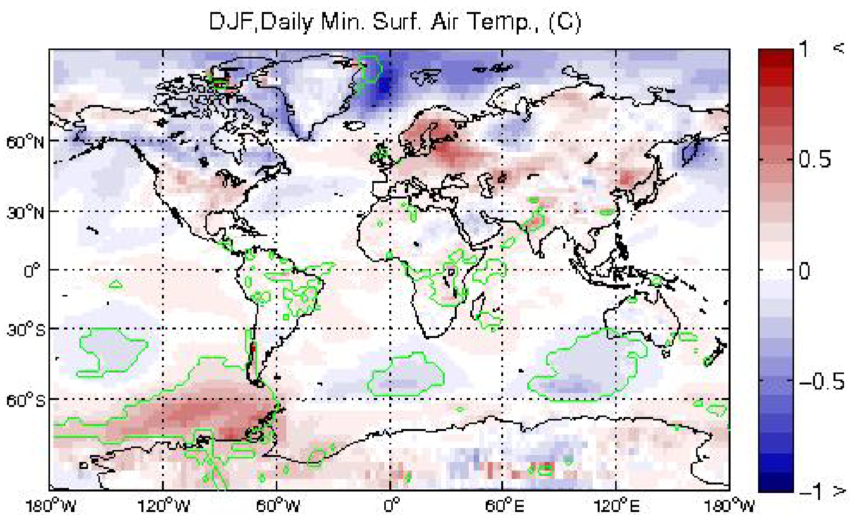
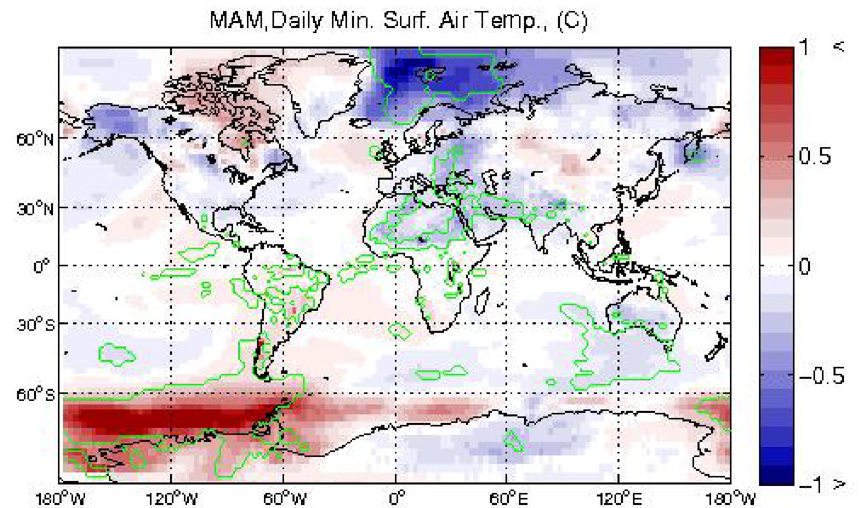




CAM-CLM4, 100 yr, High – Low Lake Area Daily Min. Surf. Air Temp. (C)





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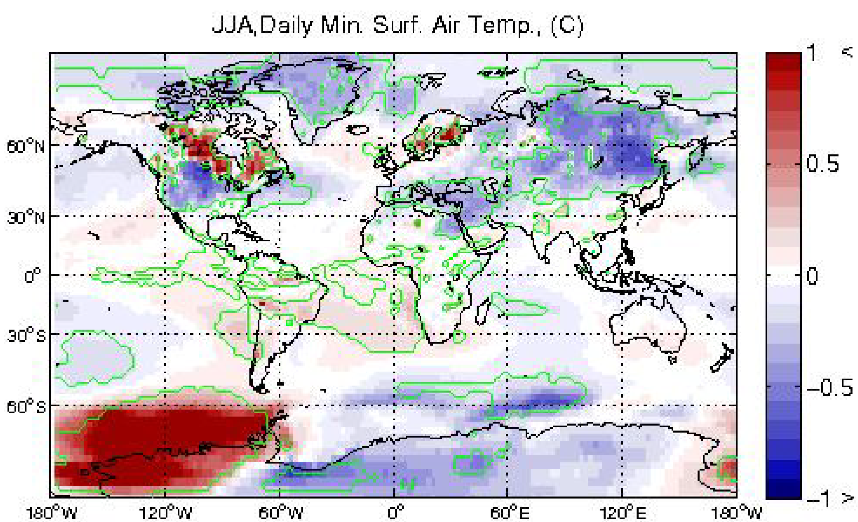
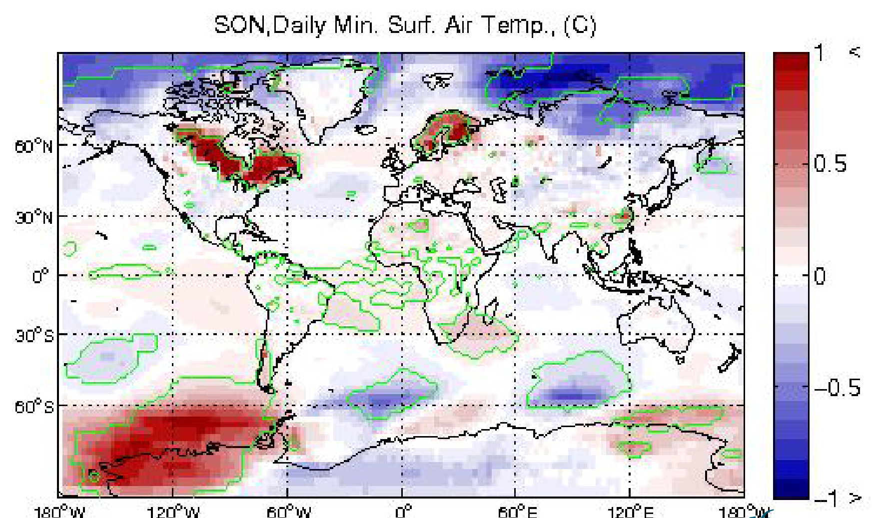
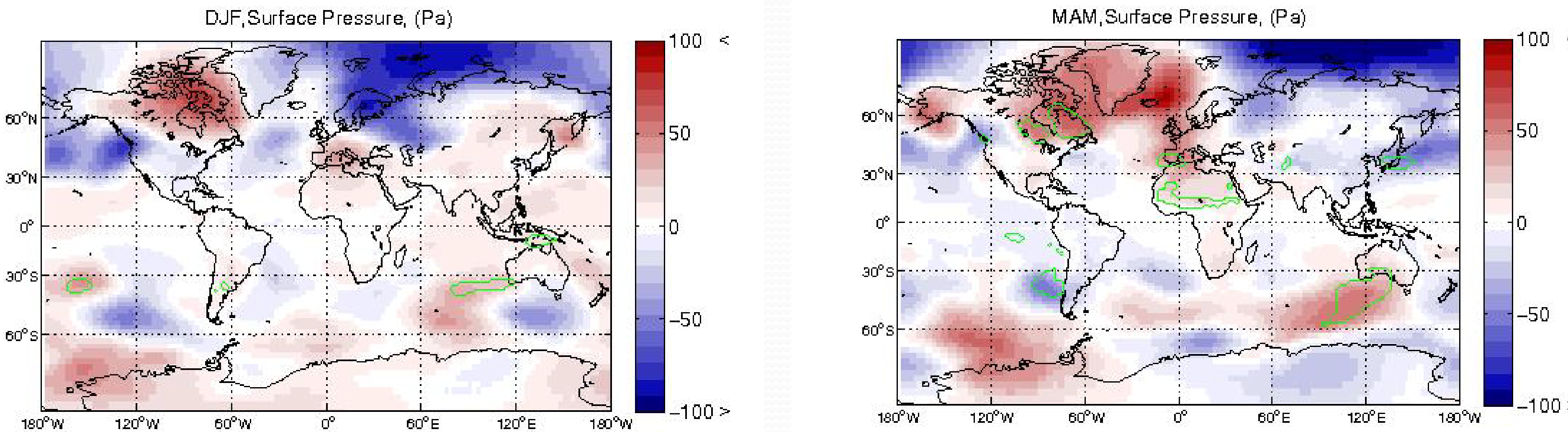
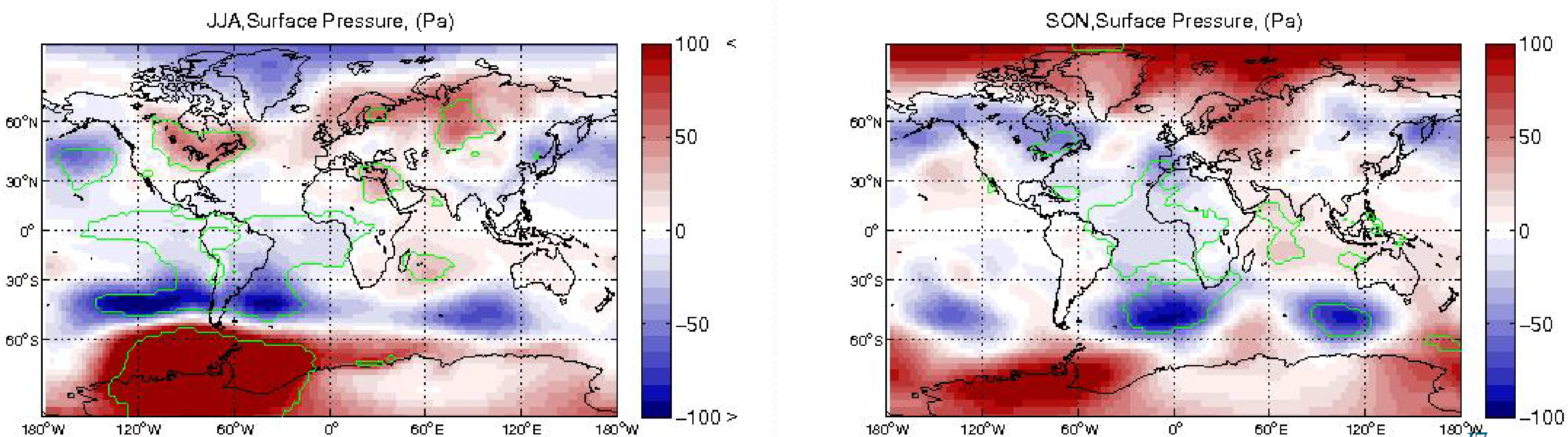




CAM-CLM4, 100 yr, High – Low Lake Area Surface Pressure (Pa)



Green contours = significance at 5%



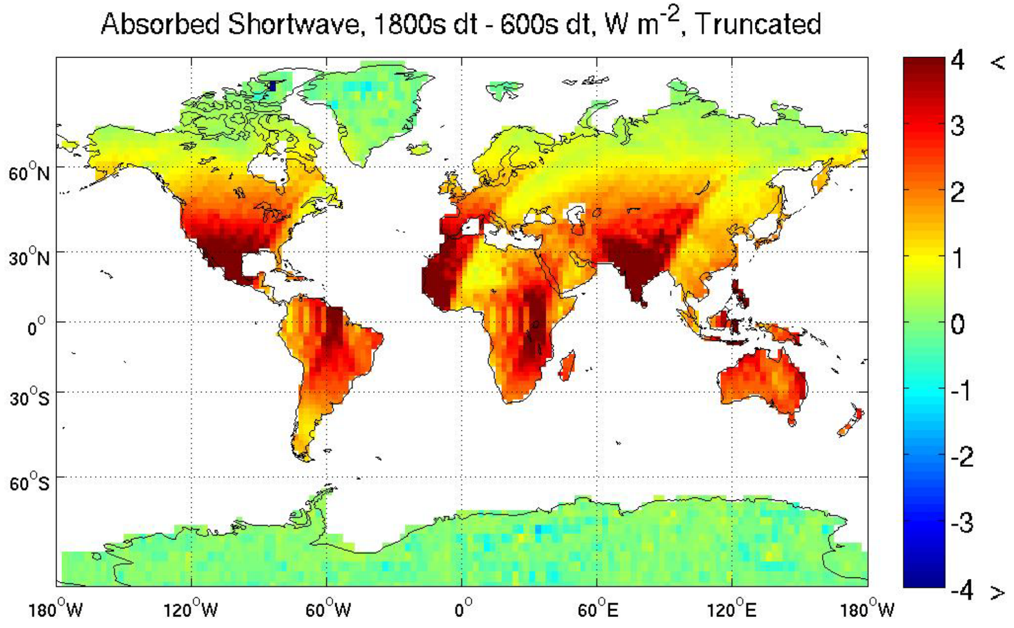
Conclusions

- A new CCSM 4 lake model substantially improves representation of lakes across climates and geometries.
- The new lake model changes offline gridcell surface fluxes by up to 100 W/m^2.
- Surface fluxes are sensitive to lake optics and lake depth, which vary widely between real lakes.

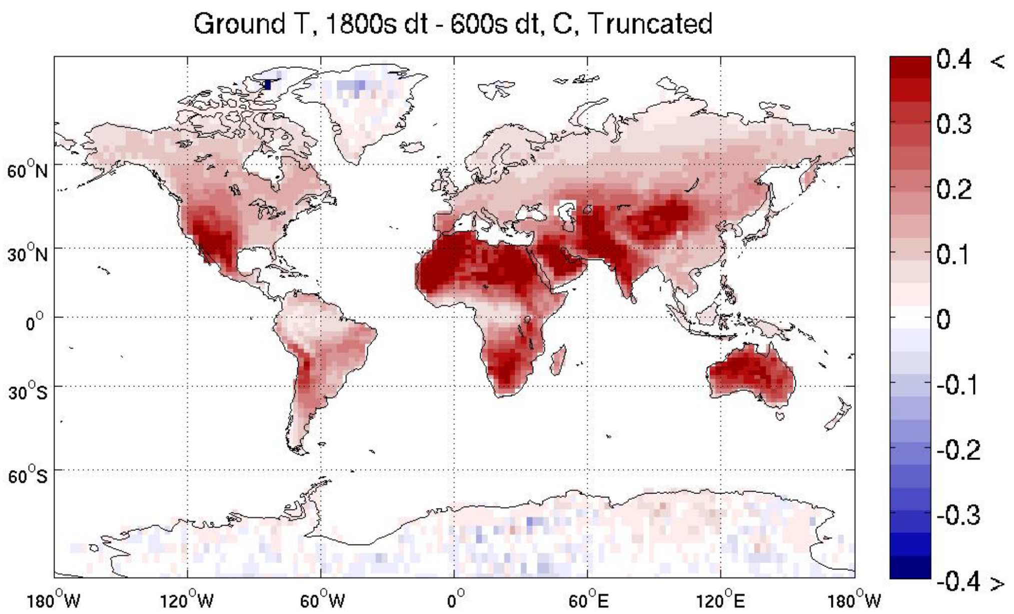
Conclusions (cont'd)

- CCSM 4 may have regional (e.g. Great Lakes) biases because the current lake model is poor.
- CCSM 4 may have substantial biases in Canada and other regions with high lake area, because of insufficient lake area.
- The underestimation of lake area may influence the climate of remote locations (e.g. Southern Ocean).

Addendum: High CLM Timestep Sensitivity



Discretization error in evaluation of zenith angle?



Acknowledgements

- Margaret Torn (LBNL / UC-Berkeley) and David Lawrence (NCAR)
- Andrey Martynov (UQAM)
- Funding from DOE & LBNL