# An effective lake depth for FLAKE model

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*thanks to*:

Dmitrii Mironov, Arkady Terzhevik, Yuhei Takaya,
Ekaterina Korzeneva and Netfam



ECMWF

# OUTLINE

- **Introduction**
  - Lake in global models
- **FLAKE model in HTESSEL**
  - Offline model runs
  - Observational dataset
- **The lake depth issue**
  - How important is lake depth for modelling T and LE/H?
  - A possible solution
- **Tuning the lake depth**
  - a “simplified variational” method
  - Preliminary results
- **Conclusions**

# Land and Inland water bodies modelling

- **TESSEL**

  Van den Hurk et al. (2000)
  Viterbo and Beljaars (1995),
  Viterbo et al (1999)

  Up to 8 tiles (binary Land-Sea mask)

  GLCC veg. (BATS-like)

- **Hydrology-TESSEL**

  Balsamo et al. (2008)

  Global Soil Texture Map (FAO)

  New formulation of Hydraulic properties

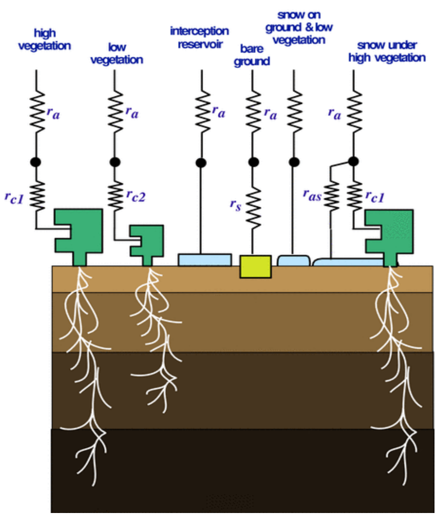
  Variable Infiltration capacity (VIC) surface runoff

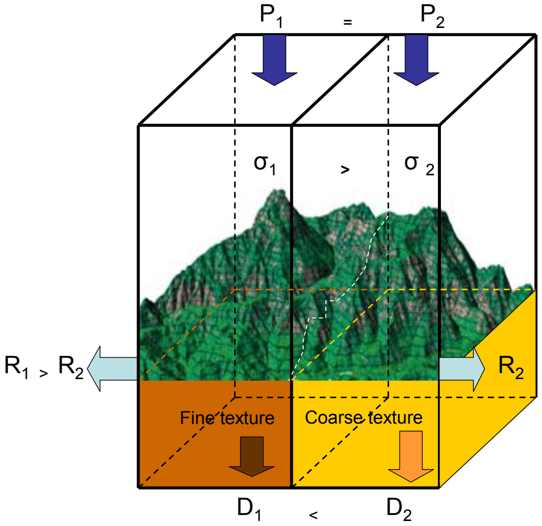
- **FLAKE**

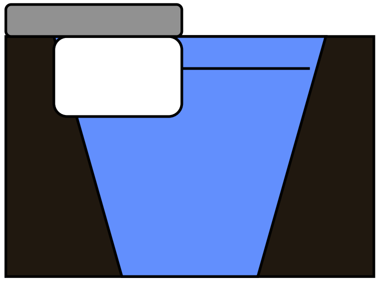
  Mironov (2003), Dutra et al. (2008)

  Extra tile (9) to account for sub-grid lakes

  Work in progress…



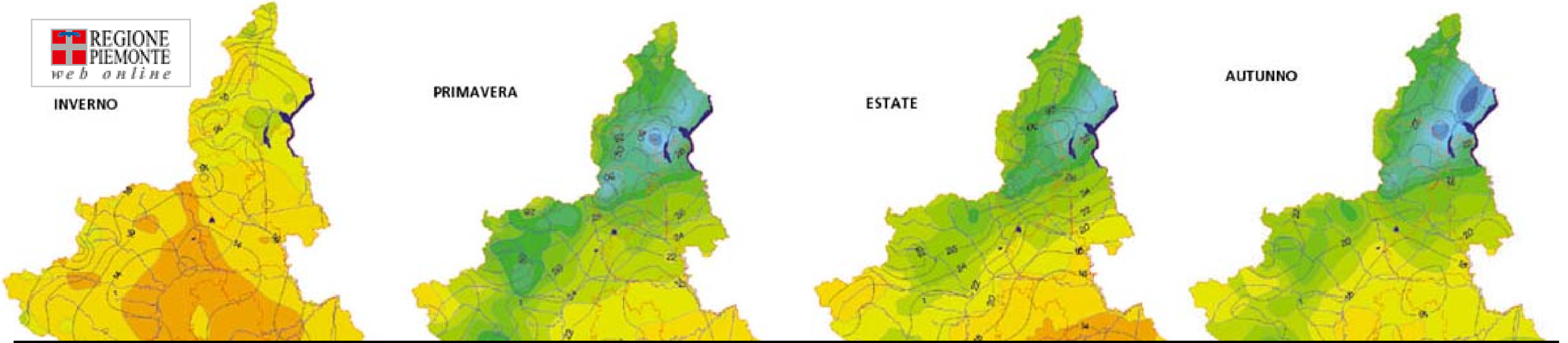



# Introduction

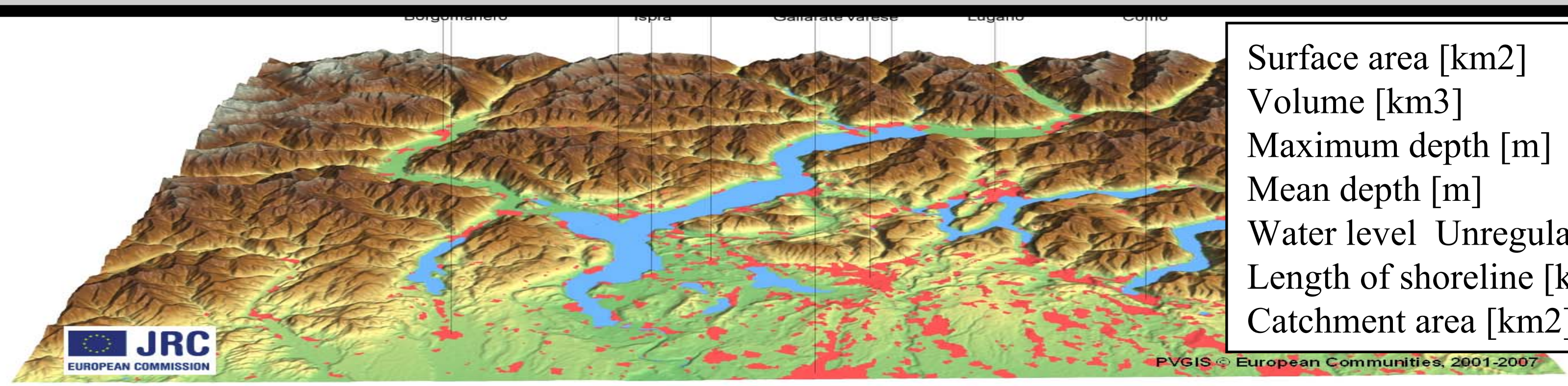
- **Lake in global models are necessary to**
  - correctly represent surface boundary conditions in NWP systems (forecast + data assimilation):
    - Albedo (e.g. freezing lakes)
    - Thermal capacity (linked to mass)
    - Evaporation
    - Soil moisture (what happens now when lakes are missing?)
    - SMOS (2009) microwave signal will sense land+water bodies and need to be modelled!

- **The lake schemes for NWP need to be**
  - Simple(&fast), Constrained:
    - Reduced set of equations that can represent lake daily/seasonal/inter-annual variability (the Land surface scheme are generally designed in this way)
    - Simplified hydrology: lake hydrology is too sophisticated to be fully represented in current GCM at 20-200 km resolution
    - Reduced set of parameters and variables that can be initialized also on global domain (e.g. Satellite observations to be used to constrain/initialize)
    - Numerically stable and physically sound at all latitudes

# LAKEs in NWP: current state at ECMWF




Lake “Maggiore” is largely subgrid and basically absent in the ECMWF deterministic forecast model and it will remain subgrid due to its elongated shape. This is the wettest area in Italy with 1.8 m annual precipitation (mechanisms concurring are water uptake from the lake and orography enhancement)



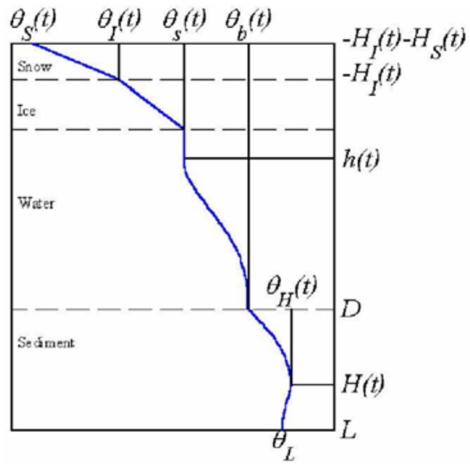

| | |
|---|---|
| Surface area [km2] | 213 |
| Volume [km3] | 37.5 |
| Maximum depth [m] | 370 |
| Mean depth [m] | 176.5 |
| Water level | Unregulated |
| Length of shoreline [km] | 170 |
| Catchment area [km2] | 6,387 |



ECMWF

# LAKE models for NWP

- **At ECMWF the FLAKE (Mironov, 2003, DWD, 1D shallow lake model) is considered for implementation**




- **Kourzeneva E. and Braskavsky D. (2006) : "*Depth of a lake is the main parameter to which model is sensitive…*"**
  - **for 16 - 40 m deep lakes: annual cycle amplitude changes for 1 K when depth changes for 3 m;**
  - **for 7 - 16 m deep lakes: annual cycle amplitude changes for 1 K when depth changes for 2 m;**
  - **for 1 - 7 m deep lakes: annual cycle amplitude changes for 1 K when depth changes for 1 m.**



ECMWF

# FLAKE coupled to HTESSEL

- Thanks to E. Dutra, V. Stepanenko, P. Viterbo, P. Miranda
- A new tile (n=9) for sub-grid lakes is present
- Technically validated (if CLAKE=0. the model is bit-identical).
- Scientific validation (see presentation of Dutra et al., 2008)
- No snow on top of the ice

| Variable | GRIB shortname | GRIB code.table |
|---|---|---|
| LAKE DEPTH | DL | 7.228 |
| LAKE MIX-LAYER TEMPERATURE | LMLT | 8.228 |
| LAKE MIX-LAYER DEPTH | LMLD | 9.228 |
| LAKE BOTTOM TEMPERATURE | LBLT | 10.228 |
| LAKE TOTAL LAYER TEMPERATURE | LTLT | 11.228 |
| LAKE SHAPE FACTOR | LSHF | 12.228 |
| LAKE ICE TEMPERATURE | LICT | 13.228 |
| LAKE ICE DEPTH | LICD | 14.228 |

# LAKE depth in FLAKE

- Lakes in a global NWP model need approximations.
- Full knowledge of the lake is necessary for field site experiment but at global scale might be a “mirage” (E.g. turbidity, bottom sediments, and also lake depth are not globally available).
- Even knowing most of the lakes parameters, lakes are still dynamical (e.g. inflow cold water from rivers, variable hydrometric levels).
- The main target of lake modelling in NWP is to be able to reproduce lake surface temperatures LSTs (and evaporation).
- Question: Can we then use observed LSTs to infer lake unknown parameters (and particularly lake depth)?
- Satellite SSTs dataset often can observe lakes (e.g. MODIS SSTs products, at 4km resolution)

# LAKE depth in FLAKE (II)

- 0) Use a "state of the art" atmospheric forcing (ERA-Interim) to drive a validated model HTESSEL+FLAKE
- 1) Use "Perpetual-year" simulations allowing the model prognostic variables to reach an equilibrium.
(We can assume that is the "Model climatology")
- 2) Use a satellite-based SSTs climatology to compare with lake surface temperature in the model.
- 3) Repeat the procedure from 1) with a different lake depth.

- This procedure is similar to a variational technique and it can be written as a cost function J for which the optimized lake depth is obtained from grad J =0

# Optimized single point LAKE depth

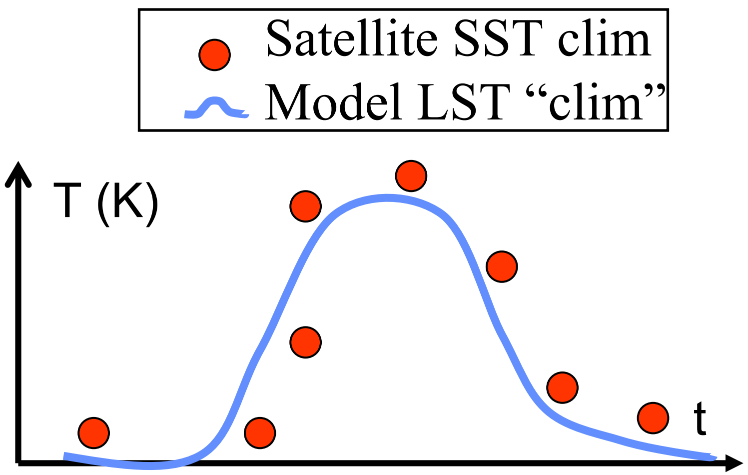
- The cost function J can be written as

$$J = Jo + Jb$$

- In our case we do not consider a Jb term as we do not have a reliable guess for the model lake depth

J=1/2* [(LST(h_l)-SST_o)/sig_obs]**2

With h_l being the lake depth



# Datasets

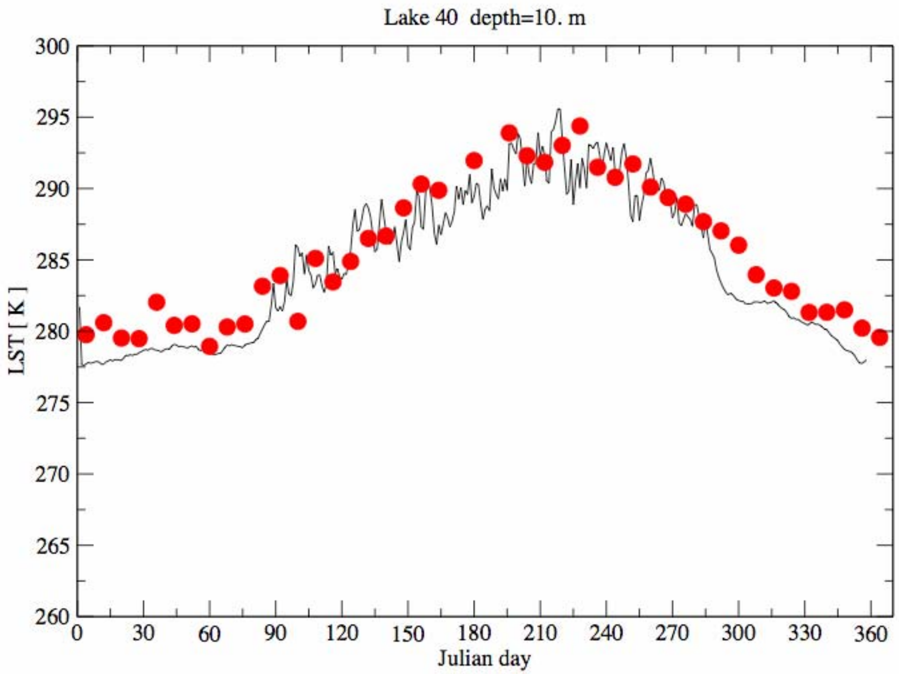
- From the original dataset (E. Kourzeneva)
- 48 Eurasian lakes have been selected for this study
- More than 80% available obs (8-daily LSTs)
- Mean and Max depth

Table 1: Eurasian lakes dataset v1.0 by (E. Kourzeneva): n, latitude, longitude, mean and maximum depth ($d_{mean}$, $d_{max}$), and surface (A). Lakes with A > $100 km^2$ and > 80% valid satellite observations are considered.

| n | lat | lon | $d_{mean}$ | $d_{max}$ | A | name |
|---|---|---|---|---|---|---|
| 1 | 63.12 | 25.67 | 6.50 | 66.20 | 502.00 | Nameless |
| 2 | 62.80 | 29.72 | 11.80 | 58.60 | 279.70 | HoooytiSinen |
| 3 | 66.16 | 28.73 | 4.60 | 42.00 | 240.20 | Yli-Kitka |
| 4 | 62.60 | 26.54 | 10.80 | 56.00 | 186.90 | Konnevesi |
| 5 | 62.97 | 30.79 | 10.80 | 47.40 | 169.60 | Koitere |
| 6 | 62.82 | 26.98 | 17.20 | 34.50 | 164.90 | Iisvesi |
| 7 | 63.09 | 25.16 | 8.40 | 45.00 | 156.20 | Kivijarvi |
| 8 | 60.99 | 22.32 | 5.50 | 26.20 | 154.00 | PyhSjarvi |
| 9 | 65.03 | 29.11 | 21.50 | 43.00 | 152.70 | Kiantajarvi (N43 199.30) |
| 10 | 62.72 | 29.30 | 6.00 | 58.30 | 135.40 | Viinijarvi |
| 11 | 64.13 | 29.19 | 14.50 | 29.00 | 102.00 | Ontojarvi-Nurmesjarvi |
| 12 | 63.30 | 25.74 | 8.70 | 66.00 | 101.30 | Kolima |
| 13 | 61.98 | 35.22 | 30.00 | 120.00 | 9690.00 | ONEZGSKOE |
| 14 | 58.12 | 38.67 | 5.60 | 30.40 | 4550.00 | VDHR RYBINSKOE |
| 15 | 58.02 | 28.07 | 7.10 | 16.60 | 3512.00 | CHUDSKO-PSKOVSKOE |
| 16 | 63.60 | 34.60 | 7.40 | 20.50 | 1270.00 | VDHR VYGOZERSKOE |
| 17 | 58.35 | 31.63 | 2.70 | 4.50 | 1110.00 | ILMEN |
| 18 | 65.70 | 32.00 | 16.00 | 56.00 | 986.00 | TOPOZERO (VDHR KUMSKOE) |
| 19 | 51.00 | 30.50 | 4.00 | 18.40 | 922.00 | VDHR KIEVSKOE |
| 20 | 67.93 | 32.97 | 12.80 | 67.00 | 876.00 | IMANDRA |
| 21 | 63.17 | 33.93 | 29.00 | 103.00 | 815.00 | VDHR SEGOZERSKOE |
| 22 | 65.05 | 31.57 | 11.00 | 36.00 | 655.00 | VDHR YUSHKOZERSKOE |
| 23 | 62.00 | 34.00 | 6.00 | 12.00 | 547.00 | VYGOZERO |
| 24 | 62.23 | 36.88 | 2.20 | 18.00 | 367.00 | VDHR VODLOZERSKOE |
| 25 | 60.20 | 37.70 | 1.80 | 5.60 | 351.00 | LACHA |
| 26 | 67.55 | 34.33 | 57.50 | 115.00 | 313.00 | UMB-OZERO |
| 27 | 61.88 | 33.32 | 6.50 | 24.00 | 266.00 | SYAMOZERO |
| 28 | 58.30 | 26.00 | 2.50 | 5.60 | 259.00 | VYRTSYARV |
| 29 | 64.95 | 30.55 | 8.50 | 44.00 | 240.00 | VERHNEE KUJTO |
| 30 | 67.98 | 35.08 | 5.70 | 35.00 | 223.00 | LOVOZERO |
| 31 | 66.05 | 31.80 | 8.00 | 41.00 | 209.00 | TIKSHEOZERO |
| 32 | 61.00 | 31.00 | 10.20 | 57.00 | 200.00 | VDHR YANISYARVI |
| 33 | 62.60 | 33.75 | 9.50 | 58.00 | 185.00 | VDHR SANDALSKOE |
| 34 | 63.83 | 30.82 | 8.50 | 34.00 | 166.00 | LEKSOZERO |
| 35 | 59.70 | 39.30 | 1.30 | 2.00 | 166.00 | KUBENSKOE |
| 36 | 65.78 | 33.93 | 4.50 | 18.00 | 122.00 | ANGOZERO |
| 37 | 62.52 | 33.67 | 18.50 | 74.00 | 109.00 | PALE (VDHR PALZERSKOE) |
| 38 | 53.48 | 12.44 | 6.60 | 28.10 | 102.70 | Muuuritzddot davon Auenmuuurit |
| 39 | 53.37 | -9.09 | 5.00 | 46.00 | 173.80 | Corrib |
| 40 | 52.92 | -8.33 | 7.60 | 36.00 | 117.50 | Derg |
| 41 | 60.50 | 10.36 | 65.50 | 131.00 | 140.10 | Randsfjorden |
| 42 | 53.74 | 21.75 | 5.80 | 23.40 | 113.40 | SHNIARDWY |
| 43 | 61.83 | 35.33 | 30.00 | 120.00 | 9890.00 | Onego |
| 44 | 58.90 | 13.25 | 27.00 | 106.00 | 1 5648.00 | Vanern |
| 45 | 58.32 | 14.56 | 39.90 | 128.00 | 1856.00 | Vattern |
| 46 | 59.52 | 17.03 | 11.90 | 61.00 | 1140.00 | Malaren |
| 47 | 59.22 | 15.77 | 6.10 | 22.00 | 478.00 | Hjaelmaren |
| 48 | 54.60 | -6.50 | 8.90 | 34.00 | 385.00 | Lough Neagth |

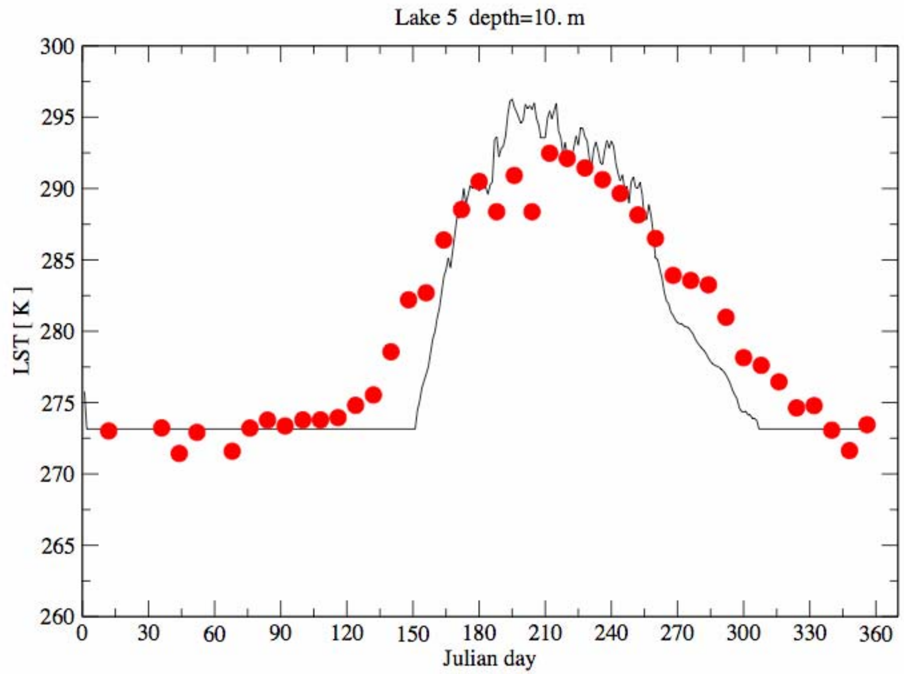
# Preliminary results (I: unfrozen lakes)

- Lake n. 40) “Derg” <u>link</u>
  Lat 52.92
  Lon -8.33
  Mean depth 7.60m
  Max depth 36.0m
  Area 117.50 $Km^2$



# Preliminary results (II: frozen lakes)

- Lake n. 5) “Koitere”
  Lat 62.97
  Lon 30.79
  Mean depth 10.80m
  Max depth 47.40m
  Area 169.69 $Km^2$



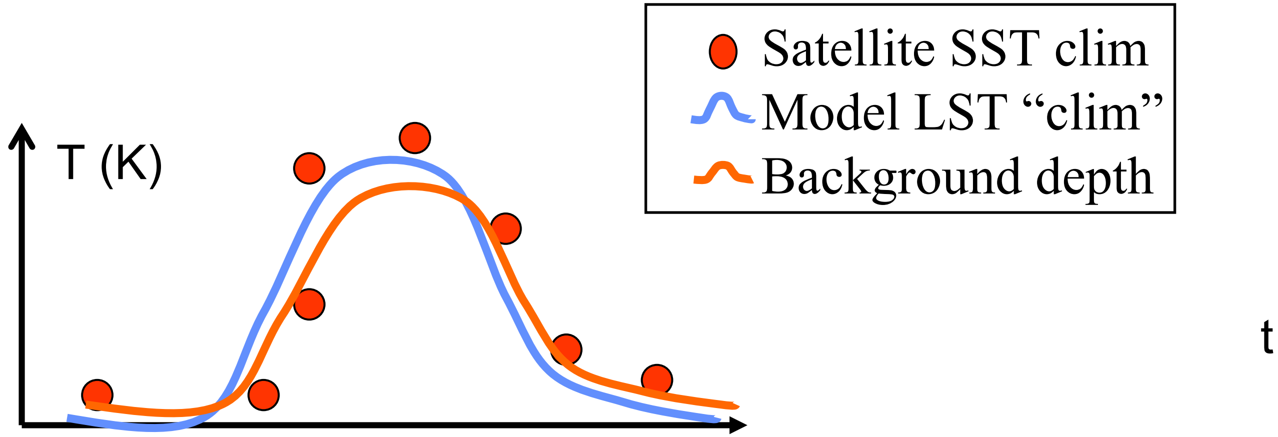
# Optimized multiple-point LAKE depth (the next step for large lakes)

- Back to cost function J

J = Jo + Jb

In case of large lakes spatial correlation in the lake depth can be assumed therefore a Jb term Is obtained by the neighbouring lake points

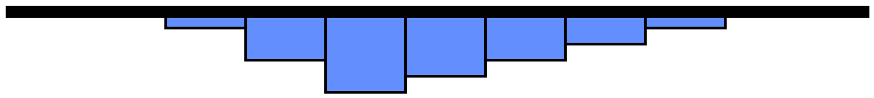
J=1/2* [(LST(h_l)-SST_o)/sig_o]**2 +1/2*[(d-d_B)/sig_B]**2



# Large lakes (III: frozen lakes)

## ...with a bit of speculation

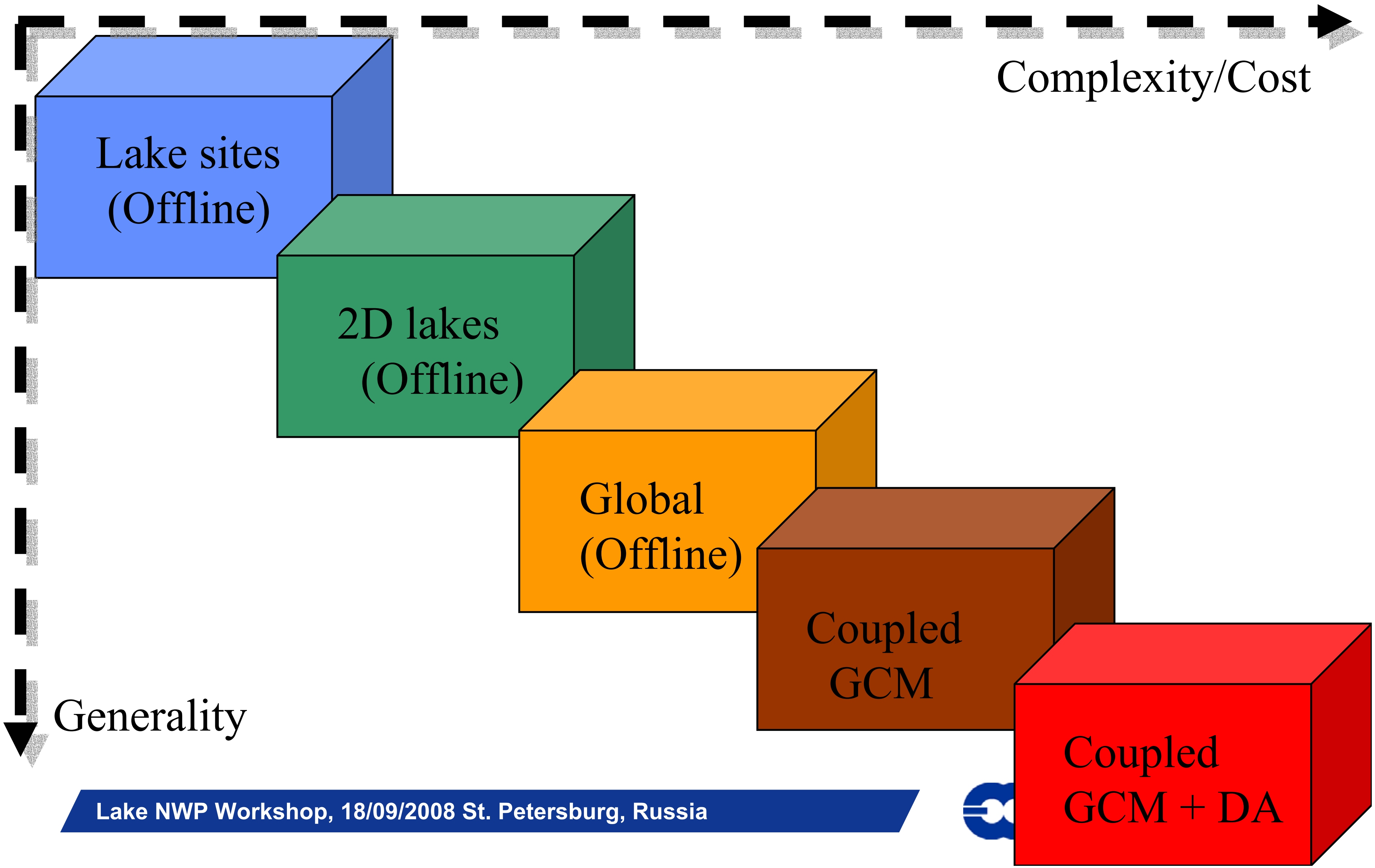
Supposing a "typical" lake bathymetry. Can we obtain a reasonable evolution of ice formation?



| Depth (m) | FLAKE unfrozen (days) | Unfrozen days (from SSTs) diff |
|---|---|---|
| 5 | 136 days | (210) 74 |
| 50 | 198 days | 12 |

First results suggest that we may get a built in of ice from lakes borders into lake inner parts (although neglecting circulation and more sophisticated treatments).

# Verification Strategy



# CONCLUSIONS

- **FLAKE model in HTESSEL**
  - Implemented in cycle 33R1 offline for research
  - Observational dataset SST from TERRA
- **The lake depth issue**
  - How important is lake depth for modelling T and LE/H?
  - Lake depth dataset are useful for local validation but a pragmatic approach with a d_eff is a proposed way for global implementation
- **Coupling with the atmosphere**
  - Fixed depth approximation
- **FLAKE will be pre-operational after IFS cycle 35 (winter ‘08) for impact studies.**
- **Ocean mixed layer model (SST/SSS profiles) complete surface modelling component**

# OUTLOOK

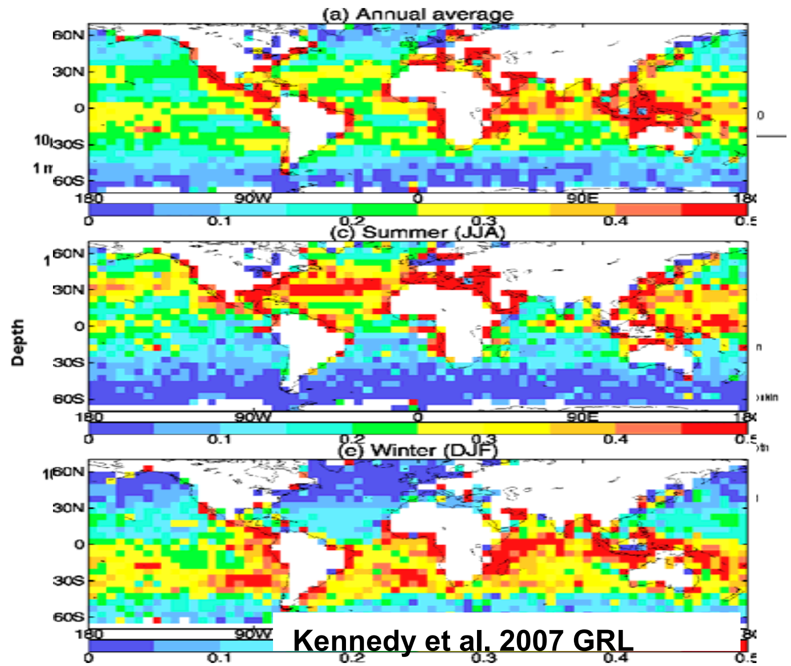
- Atmospheric reanalysis projects (ERAI, JRA, ERA40, NCEP-DOE) are comprehensive and extremely valuable for land/lake offline studies.
- Introduce snow on top of the lake to remove the large bias.
- Extend to 2D simulations the lake depth tuning methodology to build an "effective lake depth" dataset and compare with available datasets (e.g. E. Kourzeneva, v1.0, bathymetry datasets: Great Lakes).
  - Can we get something the looks like bathymetry and can time ice/lst?
  - Coordinated efforts may get us to build a global dataset at given resolution (0.5/0.25 degree)?
- An Earth-surface system modelling including Land-Lakes-Ocean with associated EO data assimilation may allow testing of several LSMs (2-3 order of magnitude less expensive in terms of computational cost therefore opens up research avenues!):
  - resolution increase
  - sophisticated data assimilation systems (e.g. Ensemble Kalman Filters)
  - extensive testing/tuning (e.g. 50-years hindcasts)

# Thank you for attention

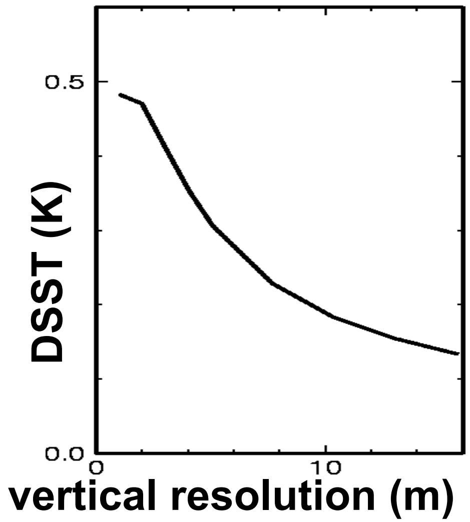
# An ocean mixed layer model in IFS

Yuhei Takaya

- A nonlocal K-profile model (KPP), Large et al. 1994)
- 1-D column model (source from Woolnough et al. 2007).
- Bulk model with parameterizations of the shear instability mixing, internal wave breaking and double diffusion.
- High resolution near the surface with stretch vertical grid arrangement (top layer ~1 m)
- Air-sea interaction (SST/SSS profiles)
- Diurnal cycle of SST (only with res.) →



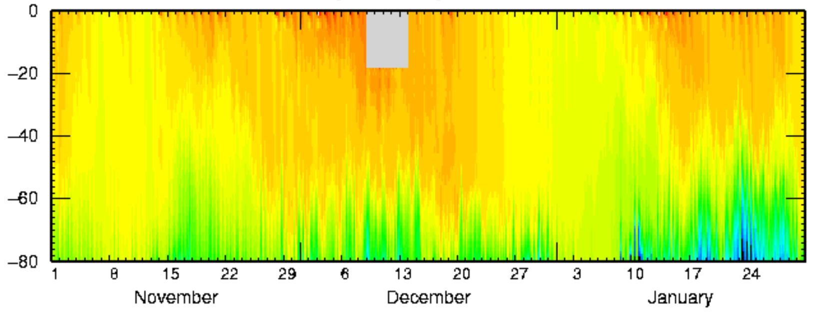

Kennedy et al. 2007 GRL



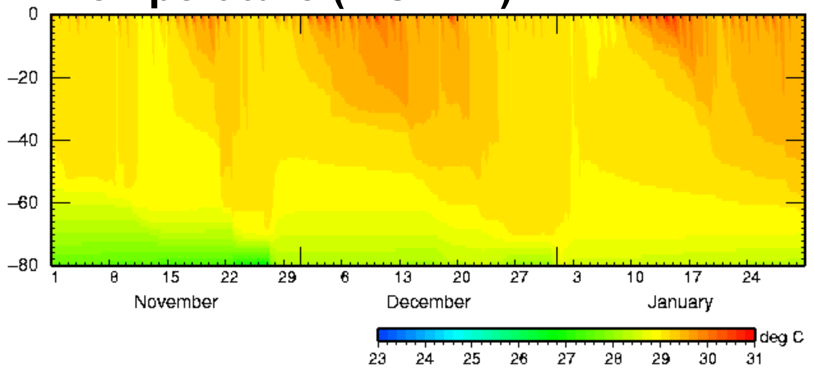
# TOGA-COARE experiment

## Yuhei Takaya

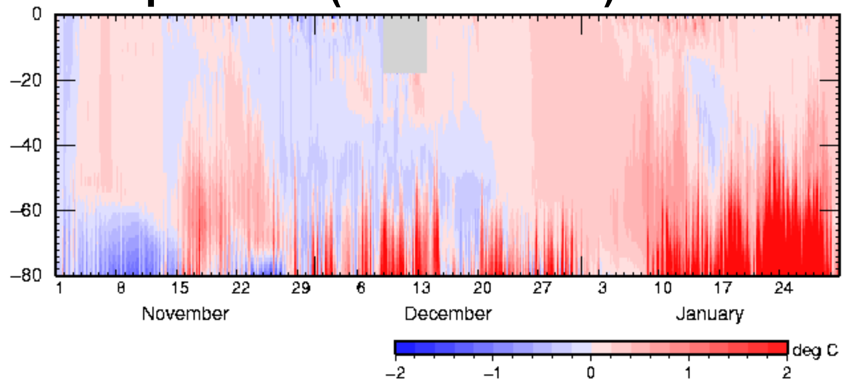
### Temperature (OBS)

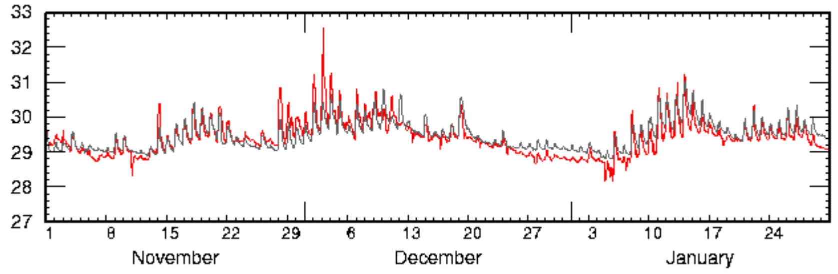



### Temperature (MODEL)




### Temperature (MODEL-OBS)




**Red: Observation**
**Grey: Model**

Stretched grid (29 layers in 200 m, top layer ~ 1.5 m)

KPP model is forced with TOGA-COARE observation data.

Initial condition is given from the ECMWF ocean analysis.

# A draft roadmap to global

**For discussion purposes**

- 1) Survey of suitable global SSTs climatology including lakes
- 2) Interpolation onto target lake map (CLAKE>0.)
- 3) Apply on both grid and sub-grid scale lakes the tuning method
- 4) Check in offline runs.