Impact of lakes in the ECMWF IFS: Preliminary results and a roadmap to implementation

Gianpaolo Balsamo Rui Salgado, Emanuel Dutra, Souhail Boussetta, Tim Stockdale

ABSTRACT: A set of simulations performed with the ECMWF tiled land surface scheme (HTESSEL) including the Fresh water Lake model (FLake) treated as an extra surface tile and coupled with the ECMWF Numerical Weather Prediction (NWP) model is presented in order to show progress and current issues. In particular, the impact of fully resolved vs. subgrid (unresolved) lakes and the benefits of a more realistic treatment of lake bathymetry and lake state initial conditions as opposed to a fixed depth and a simplified initialization will be illustrated. A roadmap to a future operational implementation will be discussed.



2nd LAKES in NWP Workshop, Norrköping, 15/09/2010

Role of land surface at ECMWF

ECMWF model(s) and resolutions

R

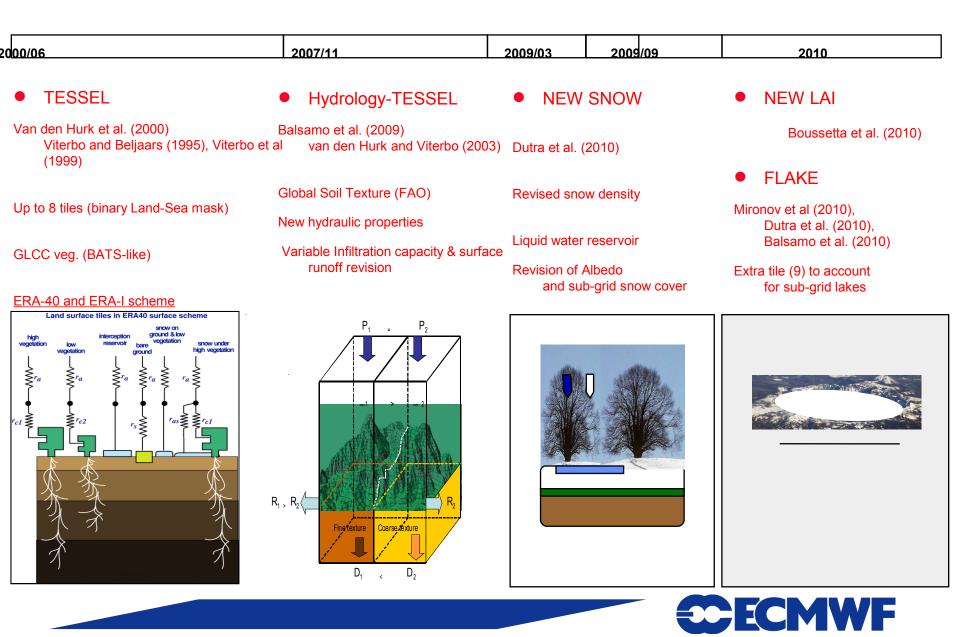
			Length	Horizontal	Vertical
Remarl	<s< td=""><td></td><td></td><td></td><td></td></s<>				
-	Deterministic	10 d	T1279 (16 km)	L91	00+12 UTC
-	Monthly/VarEPS (N=51)	0-10d	T639(30 km)	L62	(SST tendency)
		11-32d	T399(60 km)	L62 (Ocean	coupled)
-	Seasonal forecast	6 m	T159 (125 km)	L62	(Ocean coupled)
-	Assimilation physics inner	12 h	T255(80 km)/ T159(125 km)	L91	T95(200 km)
-	ERA-40 Reanalysis 195 Ol	8-2002	T159(125 km)	L60	3D-Var+surface

- ERA-Interim Reanalysis 1989-today T255(80 km) L91 4D-Var+surface

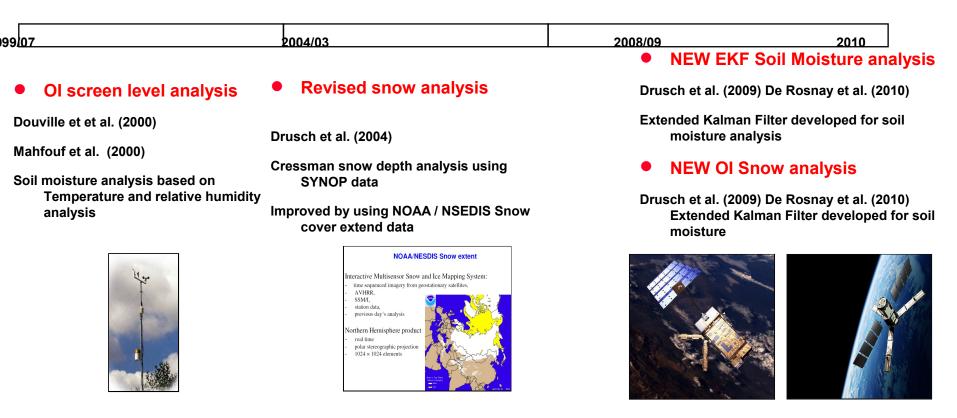
Land surface modelling (and LDAS systems) need flexibility & upscalability (conservation) properties to be used by at a wide range of spatial resolutions in spite of natural heterogeneity of land surfaces.

Errors in the treatment of land surface are likely to affect all forecasts products.

Land surface model evolution



Land surface data assimilation evolution



•Potential for re-analysis to exploit land surface satellite data, such as long time series of soil moisture data (e.g. ASCAT).

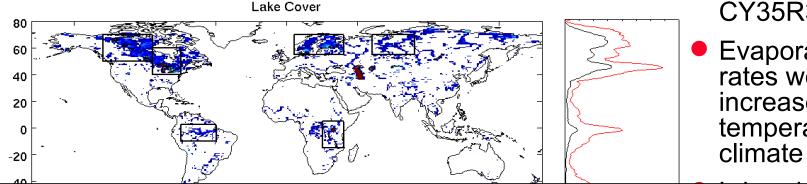
•Potential to extend the surface analysis to use vegetation parameters from satellite data (e.g. AVHRR).

•Stand alone surface analysis: opens the possibility to run re-analysis at high resolution for land surfaces.



Lake modelling

Dutra et al. (2009), Balsamo et al (2009), Boreal Env. Res.



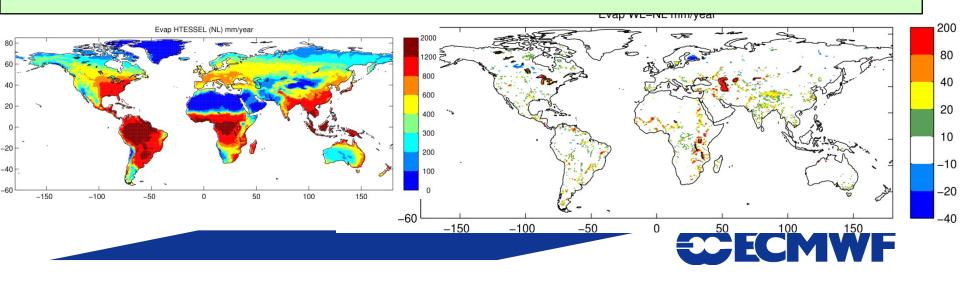
tested in CY35R3. **Evaporation** rates were increased in temperate

FLAKE Lake

model was

This studies have been using ERA-Interim 1989-present as a 3-hourly forcing dataset to test the introduction of lakes in HTESSEL in offline mode (similarly to GSWP-type experiment).

This made possible to compare the and surface models output with recent satellite data in particular MODIS-based lake surface temperatures available from 2000. FLAKE-HTESSEL



A roadmap to implementation

In order to add the lake modelling component into the IFS, initialization is required for ancillary fields:

- lake cover (fraction of a given grid box of an atmospheric model covered by lake water), and
- lake depth (mean depth of lakes present in a given grid box).

and for the prognostic variables:

- mixed-layer temperature,
- mixed-layer depth,
- bottom temperature (temperature at the water-bottom sediment interface),
- mean temperature of the water column,
- shape factor with respect to the temperature profile in the thermocline,
- temperature at the ice upper surface, and
- ice thickness

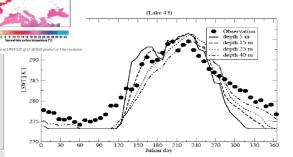


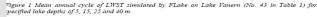
Norrköning 15/00/2010

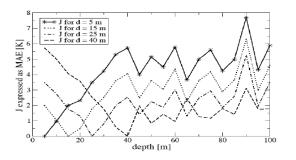
The lake depth

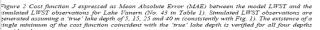
- Several authors have shown that lake depth is a crucial parameter.
- Balsamo et al. (2010) and Dutra et al. (2010) have shown that a lake depth tuning would be possible in absence of depth data but present the caveat of model dependency.

10 62.72 29.30 6.00 58.30 135.40 Vinsjanvi 11 64.13 29.19 1.50 29.00 102.00 Cottojarvi 12 63.30 25.74 8.70 66.00 101.30 Kollma 12 63.30 25.74 8.70 66.00 101.30 Kollma 13 61.81 85.22 30.00 120.00 Onega 15 58.02 28.07 7.10 16.60 361.20 Vygozerskoe 16 63.30 34.60 7.40 20.50 1270.00 Vygozerskoe 19 51.00 30.20 15.00 56.00 87.00 Hand 21 63.71 33.33 29.00 11.00 36.50 Segozerskoe 22 65.05 31.57 11.00 36.70 Vygozerskoe 23 62.00 31.50 11.00 367.00 Vygozerskoe 24 62.23 31.63 5.50 31.00	Table 1: Subset of European lake-depth dataset (developed by E. Kourzenava) for all lak larger than 100 km2 and at least 80% coverage by MODIS data. Subset of European lake v1.0 by E. Kourzeneva								
1 25.70 6.50 66.20 502.00 Nimeton 2 62.80 29.72 11.80 56.60 29.70 11.80 56.60 29.70 11.80 56.60 29.70 11.80 56.60 29.70 11.80 56.60 29.70 11.80 56.60 29.70 11.80 56.60 164.90 Kornevesia 5 62.97 20.79 10.80 47.40 186.60 Kornevesia 6 63.90 22.12 5.50 28.20 154.00 Pytajarvi 0 65.03 21.11 21.50 43.00 152.70 Kinanjarvi (M43199. 10 64.13 29.11 15.00 43.00 162.00 Ontejarvi 11 64.13 29.11 15.00 10.200 Ontejarvi Ontejarvi 12 63.30 25.74 80.00 12.00 160.00 164.00 Stano 13 61.83 34.60 7.40 20.50 170.00 Vgozerskoe <th>N</th> <th>latitude</th> <th>longitude</th> <th>dmean</th> <th>dmax</th> <th>Area*</th> <th>Name of the lake (c</th>	N	latitude	longitude	dmean	dmax	Area*	Name of the lake (c		
1 66.16 28.73 4.60 42.00 240.00 Yin-Kika 4 62.60 26.54 10.80 56.00 186.90 Kornevesia 6 62.27 20.79 10.80 47.40 186.90 Kornevesia 6 62.23 20.79 10.80 47.40 156.20 Kirijarvi 6 60.90 22.12 5.50 20.20 154.00 Pytajjarvi 0 65.03 23.11 21.50 43.00 152.70 Kirijarvi 10 64.13 29.19 14.50 29.00 102.00 Ontojarvi 12 63.30 25.74 87.00 120.00 Ontojarvi Ontojarvi 13 61.80 34.60 7.40 20.50 127.00 Vygozenskoe 15 88.02 28.07 7.10 16.60 986.00 Topazeno (Tucppaja 19 51.00 31.63 2.70 4.50 110.00 Immandr 22 <t< td=""><td>1</td><td>63.12</td><td>25.67</td><td>6.50</td><td>66.20</td><td>502.00</td><td>Nimetön</td></t<>	1	63.12	25.67	6.50	66.20	502.00	Nimetön		
4 62.60 26.54 10.80 56.00 186.90 Komevesi 6 62.97 90.79 10.80 47.40 189.60 Romevesi 6 62.92 26.98 17.20 34.50 164.90 Investi 7 63.09 22.32 5.50 26.20 154.00 Kreipari 0 66.33 29.11 21.50 43.00 152.70 Kanagirvi (M3199. 1 64.13 29.19 14.50 29.00 101.20 Ontojarvi (M3199. 12 63.30 28.74 8.70 66.00 101.30 Kolma 13 61.98 35.22 30.00 120.00 960.00 Onega 14 88.12 38.67 5.56 30.40 45.00 Robox Onega 15 86.02 28.07 7.10 16.60 317.00 Incon Incon 16 33.03 29.00 118.40 922.00 Kieeskoe 17	2	62.80	29.72	11.80	58.60	279.70	Höytiäinen		
5 82.97 80.79 10.80 Koltere 6 62.82 65.89 17.20 34.50 164.90 Insvesi 7 63.09 25.16 8.40 45.00 154.20 Krejarri 8 60.99 22.32 5.50 26.20 154.00 Pyhäjarvi 9 65.03 29.11 21.50 43.00 152.70 Kantajarvi (N43199. 10 64.13 29.19 14.50 29.00 102.00 Ontojarvi 12 63.30 25.74 8.70 66.00 101.30 Kalma 31 61.98 52.22 30.00 120.00 Ontojarvi Ontojarvi 13 61.80 34.60 7.40 20.50 127.00 Vygozerskoe 16 63.00 31.63 2.70 4.50 110.00 Imma 18 85.70 30.50 67.00 186.00 Keyskoe 21 63.157 11.00 36.00 65.00	3	66.16	28.73	4.60	42.00	240.20	Yli-Kitka		
6 2.8.2 26.98 17.20 34.50 164.90 Inversion 7 63.09 22.32 6.50 26.20 154.00 Pyhajarvi 9 60.99 22.32 6.50 26.20 154.00 Pyhajarvi 9 65.03 29.11 21.50 43.00 152.70 Kintajarvi (M4319) 10 64.13 29.19 14.50 29.00 102.00 Ontojarvi (M4319) 12 63.30 25.74 6.70 66.00 98.00 Ontojarvi (M4319) 13 61.98 35.22 30.00 120.00 986.00 Ontojarvi (M450) 14 68.12 28.07 7.10 16.60 35.100 Chucko-Pakowa 15 68.02 28.07 7.10 18.40 92.200 Kieskoe 17 88.33 31.83 2.90 110.00 18.00 Seggerskee 22 65.05 31.57 11.00 36.00 14.00 Yugkozerskoe	4	62.60	26.54	10.80	56.00	186.90	Konnevesi		
7 8.3.09 25.16 8.40 45.00 165.20 Kregard 8 60.90 22.32 5.50 26.20 154.00 Phylipin' 9 65.03 22.32 5.50 26.20 154.00 Phylipin' 10 62.72 29.30 6.00 58.30 135.40 Vingjarvi 11 64.13 29.19 14.50 29.00 102.00 Ontojsivi 12 63.30 25.74 8.70 66.00 101.30 Kolma 13 61.80 3.6.22 30.00 120.00 Ontojsivi 0ntojsivi 14 86.12 38.67 56.00 30.40 456.00 Rejunskoe 15 86.02 28.07 7.10 16.60 3512.00 Chuckko-Pskoskoe 16 63.80 34.60 7.40 20.50 Tepcerer (Tuoppaja 19 51.00 31.57 11.00 36.00 85.00 Separerskoe 21 63.157	5	62.97	30.79	10.80	47.40	169.60	Koitere		
Image 22.32 5.50 26.20 154.00 Pyhajarvi 0 65.03 29.11 21.50 43.00 152.70 Kantajarvi (M4319) 10 62.72 29.30 6.00 58.30 153.40 Virejarvi 11 64.33 25.74 8.70 66.00 101.00 Ortsjinvi 12 63.30 25.74 8.70 66.00 101.00 Ortsjinvi 14 88.12 38.67 5.60 30.40 455.00 Ryhmskoe 15 68.02 28.07 7.10 16.60 351.20 Chucko-Piskowskoe 17 58.35 31.63 2.70 4.50 110.00 Imand 19 15.70 32.00 16.00 56.00 965.00 Topazero (Tuoppaja 21 63.17 33.39 29.00 103.00 815.00 Seggerskee 22 56.05 31.57 11.00 367.00 Vyukozerskee 23 62.00 31.5	6	62.82	26.98	17.20	34.50	164.90	lisvesi		
0 65.03 29.11 21.50 43.00 152.70 Kamfuner (Mar19). 10 62.72 29.30 6.00 53.30 135.40 Vingianer (Mar19). 11 64.13 29.19 14.50 29.00 102.00 Ontojarvi 12 63.30 25.74 8.70 66.00 101.30 Kalma 13 61.98 52.22 30.00 120.00 9650.00 Ontojarvi 14 86.12 38.67 5.60 30.40 4550.00 Rybinskoe 15 68.02 28.07 7.10 16.60 581.20 Tutuko-Pakovskoe 16 63.60 34.60 7.40 20.50 170.00 Vygozerskoe 19 51.03 0.50 40.00 18.40 92.20 Kiewskoe 20 67.03 31.33 2.20 13.00 67.00 Wgozerskoe 21 63.13 0.50 6.00 36.00 65.00 Yugozerskoe 22	7	63.09	25.16	8.40	45.00	156.20	Kivijärvi		
10 62,72 29,30 6,00 58,30 15,40 Viergarvi 11 64,13 9,919 1,550 29,00 102,00 Ortsjinvi 12 63,30 25,74 8,70 66,00 101,30 Kolima 13 61,98 35,22 30,00 120,00 0490,00 Ortsjinvi 14 88,12 38,67 5,60 30,40 4550,00 Ortsjinvi 15 86,02 28,07 7,10 16,60 312,00 Crustshor-Piskowskoe 17 58,35 31,63 2,70 4,50 110,00 Immen 19 65,70 32,00 16,00 56,00 96,00 Topazero (Tuoppaja 21 63,17 33,39 29,00 103,00 815,00 Seggerskee 22 56,05 31,57 11,00 36,70 Vyadozerskee 24 62,23 36,88 2,20 18,00 313,00 Lacha 24 62,23	8	60.99	22.32	5.50	26.20	154.00	Pyhäjärvi		
11 44.13 29.19 14.50 29.00 102.00 Onteginvi 12 63.30 25.74 8.70 66.00 101.30 Kolima 14 84.12 38.67 5.60 30.40 455.00 Rybinskoe 15 86.02 28.07 7.10 16.60 3512.00 Chutsko-Pskowskoe 16 63.60 34.60 7.40 20.50 127.00 Vygozerskoe 18 56.70 32.00 15.00 56.00 986.00 Topzero (Tuoppaja 19 51.03 0.50 4.00 18.40 922.00 Kiewskoe 20 67.93 32.97 12.80 67.00 876.00 Imandra 21 63.73 32.97 12.80 67.00 876.00 Imandra 21 63.73 32.97 12.80 67.00 876.00 Imandra 21 63.02 31.70 11.00 36.00 65.00 Vugozero 23	9	65.03	29.11	21.50	43.00	152.70	Kiantajärvi (N43199.3		
12 3.3.0 2.5.7.4 8.7.0 66.00 10.1.30 Kolima 13 61.9.8 5.5.2 3.0.00 120.00 960.00 Onega 14 8.8.12 3.8.6.7 5.6.0 30.4.0 455.00 Rybinskoe 15 8.9.12 2.8.0.7 7.10 16.00 351.2.00 Chuckso-Pskovskoe 16 33.00 34.6.0 7.40 20.5.0 127.00 Vygozerskoe 17 58.35 31.6.3 2.7.0 18.40 922.00 Kievskoe 19 51.00 30.5.0 4.00 18.40 922.00 Kievskoe 21 63.71 3.3.3 2.9.00 10.3.00 815.00 Segozerskoe 22 65.05 31.5.0 15.00 36.00 Vyalskozerskoe 23 62.00 31.7.0 1.8.0 36.00 14.00 Vydozerskoe 24 62.23 31.03 1.5.00 31.0.0 Lacha 25 60.02 <t< td=""><td>10</td><td>62.72</td><td>29.30</td><td>6.00</td><td>58.30</td><td>135.40</td><td>Viinijärvi</td></t<>	10	62.72	29.30	6.00	58.30	135.40	Viinijärvi		
13 13.98 35.22 30.00 120.00 9630.00 Onega 14 68.12 38.67 5.60 30.40 4550.00 Rybinskoe 15 88.02 28.07 7.10 16.60 3512.00 Rybinskoe 16 63.60 34.60 7.40 20.50 127.00 Vygozenskoe 17 88.35 31.33 2.70 4.50 98.60 Topazero (Tuopaja) 18 65.70 32.00 16.00 56.00 986.00 Topazero (Tuopaja) 19 51.00 30.50 4.00 18.40 922.00 Kiewskoe 20 67.93 32.97 12.80 67.00 87.60 Imman 21 63.73 33.93 2.90 13.00 815.00 Segozerskoe 22 65.05 31.57 11.00 36.00 65.00 Yugozero 24 62.23 65.80 35.100 Lacha Lacha 26 67.55 <td< td=""><td>11</td><td>64.13</td><td>29.19</td><td>14.50</td><td>29.00</td><td>102.00</td><td>Ontojärvi</td></td<>	11	64.13	29.19	14.50	29.00	102.00	Ontojärvi		
14 88.12 38.67 5.60 30.40 4550.00 Ryhmskoe 15 58.02 28.07 7.10 16.00 3512.00 Tucksko-Pskovskoe 16 33.00 28.07 7.10 16.00 3512.00 Tucksko-Pskovskoe 17 58.35 31.63 2.70 4.50 1110.00 Immen 18 65.70 32.00 16.00 56.00 960.00 Topozero (Tuoppaja 19 51.00 30.50 4.00 18.40 922.00 Kievskoe 21 63.17 33.33 29.00 103.00 815.00 Segozerskoe 22 65.05 31.57 11.00 36.00 65.00 Yushkozerskoe 23 62.00 31.63 12.00 54.00 Sigozerskoe Yushkozerskoe 24 62.23 31.63 15.00 313.00 Umbozero Yushkozerskoe 25 60.02 37.70 1.80 5.60 31.00 Loha	12	63.30	25.74	8.70	66.00	101.30	Kolima		
15 8.0.02 28.07 7.10 16.60 312.00 Crustsko-Pskorskee 16 63.60 34.60 7.40 20.50 1270.00 Vipszerskoe 17 58.35 31.63 2.70 4.50 1110.00 Imen 18 65.70 32.00 16.00 56.00 96.00 Topzære (Tuoppaja 20 67.33 32.97 12.80 67.00 87.60 Imandra 21 63.17 33.93 2.90 13.00 815.00 Segozerskoe 22 65.05 31.57 11.00 36.00 65.00 Yushkozerskoe 23 62.00 31.00 10.00 36.00 65.00 Yushkozerskoe 24 62.23 36.88 2.00 13.00 Urbozerskoe 25 62.00 7.70 1.00 36.00 51.00 Lacha 26 60.03 31.60 2.60 2.60 2.60 2.60 2.60 2.60 2.60 <	13	61.98	35.22	30.00	120.00	9690.00	Onega		
16 83.60 14.60 7.40 20.50 127.00.00 Vypszerskoe 17 58.35 31.63 2.70 4.50 1110.00 Imm 18 65.70 32.00 15.00 56.00 960.00 Topozero (Tuoppaja 19 51.00 30.50 4.00 18.40 922.00 Kievskoe 10 63.17 33.33 29.00 103.00 876.00 mandra 21 63.71 33.33 29.00 10.30 875.00 Segozerskoe 22 65.05 31.57 11.00 36.00 655.00 Yushkozerskoe 23 62.00 34.00 6.00 12.00 547.00 Vydozerskoe 24 62.23 36.88 2.20 18.00 313.00 Lacha 25 60.20 37.70 1.80 5.60 313.00 Umbozero 26 47.65 81.33 35.75 15.50 24.00 Verthneekujo 0 <td< td=""><td>14</td><td>58.12</td><td>38.67</td><td>5.60</td><td>30.40</td><td>4550.00</td><td>Rybinskoe</td></td<>	14	58.12	38.67	5.60	30.40	4550.00	Rybinskoe		
17 88.35 31.6.3 2.70 4.50 1110.00 Immen 18 65.70 32.00 16.00 56.00 96.00 Topzaro (Tuoppaja) 19 51.00 30.50 4.00 18.40 922.00 Kiewskoe 20 67.33 32.97 12.80 67.00 876.00 Imandra 21 63.17 33.33 29.00 13.30 89.00 13.00 85.00 Segozerskoe 22 65.05 31.57 11.00 36.00 655.00 Yushkozerskoe 23 62.00 37.70 18.00 56.00 351.00 Lacha 26 60.20 37.70 18.00 56.00 250.00 Symmozero 28 68.30 26.00 2.50 5.60 250.00 Vytsyarv 26 61.03 31.00 8.00 41.00 200.00 Tikshezro 31 66.05 31.00 8.00 13.00 180.00 200.00 T	15	58.02	28.07	7.10	16.60	3512.00	Chudsko-Pskovskoe		
18 65.70 32.00 16.00 56.00 986.00 Topozero (Tuoppaja 19 51.00 30.50 4.00 18.40 922.00 Kievskoe 19 51.00 30.50 4.00 18.40 922.00 Kievskoe 20 67.33 32.97 12.80 67.00 876.00 Imandra 21 63.17 33.33 28.00 103.00 815.00 Segozerskoe 22 65.05 31.57 11.00 36.00 655.00 Vyalskozerskoe 23 62.00 34.00 6.00 12.00 547.00 Vyagozero 24 62.23 36.88 2.20 13.00 Lacha Lacha 26 67.65 5.60 31.00 Lacha 206.00 Syannozero 27 61.88 33.32 6.50 24.00 266.00 Syannozero 26 60.05 31.00 8.00 41.00 209.00 Tikhzezro 26 <t< td=""><td>16</td><td>63.60</td><td>34.60</td><td>7.40</td><td>20.50</td><td>1270.00</td><td>Vygozerskoe</td></t<>	16	63.60	34.60	7.40	20.50	1270.00	Vygozerskoe		
19 51.00 30.50 4.00 18.40 92.200 Kierskee 20 67.33 32.97 12.40 67.00 876.00 Imandra 21 63.17 33.93 29.00 103.00 875.00 Imandra 22 65.05 31.57 11.00 36.00 655.00 Yushkozerskoe 23 62.03 31.67 11.00 36.00 657.00 Vugbozerskoe 24 62.23 36.88 2.20 18.00 351.00 Lacha 26 67.25 34.33 57.50 115.00 313.00 Urbozero 27 71.88 33.32 6.50 24.00 24.000 Vyspavro 28 68.30 26.00 2.50 5.60 250.00 Vystavro 29 64.05 31.00 4.000 240.00 Verthreekujo 31 66.05 31.00 4.000 290.00 Itkhezoro 31 66.05 31.00 4.00 </td <td>17</td> <td>58.35</td> <td>31.63</td> <td>2.70</td> <td>4.50</td> <td>1110.00</td> <td>limen</td>	17	58.35	31.63	2.70	4.50	1110.00	limen		
19 51.00 30.50 4.00 18.40 92.200 Kierskee 20 67.33 32.97 12.40 67.00 876.00 Imandra 21 63.17 33.93 29.00 103.00 875.00 Imandra 22 65.05 31.57 11.00 36.00 655.00 Yushkozerskoe 23 62.03 31.67 11.00 36.00 657.00 Vugbozerskoe 24 62.23 36.88 2.20 18.00 351.00 Lacha 26 67.25 34.33 57.50 115.00 313.00 Urbozero 27 71.88 33.32 6.50 24.00 24.000 Vyspavro 28 68.30 26.00 2.50 5.60 250.00 Vystavro 29 64.05 31.00 4.000 240.00 Verthreekujo 31 66.05 31.00 4.000 290.00 Itkhezoro 31 66.05 31.00 4.00 </td <td>18</td> <td>65.70</td> <td>32.00</td> <td>16.00</td> <td>56.00</td> <td>986.00</td> <td>Topozero (Tuoppaiäry</td>	18	65.70	32.00	16.00	56.00	986.00	Topozero (Tuoppaiäry		
12 33.17 33.33 29.00 103.00 815.00 Seggerskoe 22 65.05 31.57 11.00 36.00 655.00 Yushkozerskoe 23 62.00 34.00 6.00 12.00 547.00 Vygozero 24 62.23 36.88 2.20 18.00 367.00 Vodozerskoe 25 62.23 37.70 1.80 5.60 351.00 Lacha 26 67.25 34.33 57.50 115.00 313.00 Urbozero 27 61.88 33.22 6.50 24.00 26.00 Syannozero 28 58.30 26.00 2.50 5.60 240.00 Verhnekujo 30 67.98 31.80 8.00 41.00 20.00 Lekozero 31 66.05 31.00 46.9 23.00 Lekozero 31 66.05 31.00 160.00 Lekozero 32 61.00 31.30 2.00 166.00	19	51.00		4.00	18.40	922.00			
12 63.05 31.57 11.00 36.00 65.05 Yushkozerskoe 23 62.00 34.00 60.00 12.00 547.00 Vyspozero 24 62.23 16.80 2.20 18.00 367.00 Vodozerskoe 25 60.20 37.70 1.80 56.00 12.00 13.00 Lacha 26 67.25 34.33 57.50 115.00 313.00 Lacha 27 61.88 3.3.2 65.05 24.00 260.00 Syannozare 28 88.30 30.50.68 5.70 35.00 223.00 Levozero 29 64.05 35.08 5.70 35.00 1760.00 Lavozero 21 61.00 31.00 8.00 41.00 209.00 Tikshezro 21 61.00 31.00 8.00 180.00 1760.00 Lavozero 23 62.60 33.01 13.00 160.00 Lavazero 24 63.03 </td <td>20</td> <td>67.93</td> <td>32.97</td> <td>12.80</td> <td>67.00</td> <td>876.00</td> <td>Imandra</td>	20	67.93	32.97	12.80	67.00	876.00	Imandra		
12 63.05 31.57 11.00 36.00 65.05 Yushkozerskoe 23 62.00 34.00 60.00 12.00 547.00 Vyspozero 24 62.23 16.80 2.20 18.00 367.00 Vodozerskoe 25 60.20 37.70 1.80 56.00 12.00 13.00 Lacha 26 67.25 34.33 57.50 115.00 313.00 Lacha 27 61.88 3.3.2 65.05 24.00 260.00 Syannozare 28 88.30 30.50.68 5.70 35.00 223.00 Levozero 29 64.05 35.08 5.70 35.00 1760.00 Lavozero 21 61.00 31.00 8.00 41.00 209.00 Tikshezro 21 61.00 31.00 8.00 180.00 1760.00 Lavozero 23 62.60 33.01 13.00 160.00 Lavazero 24 63.03 </td <td>21</td> <td>63.17</td> <td>33.93</td> <td>29.00</td> <td>103.00</td> <td>815.00</td> <td>Segozerskoe</td>	21	63.17	33.93	29.00	103.00	815.00	Segozerskoe		
124 36.28 2.20 18.00 367.00 Vordozerskoe 25 60.20 37.70 1.80 5.60 351.00 Lacha 26 67.55 34.33 57.50 115.00 313.00 Umbozero 27 61.88 33.32 6.50 24.00 266.00 Syannozero 28 83.83 26.00 2.50 5.60 24.00 Verbneekujb 29 64.05 30.50 5.70 35.00 223.00 Lovozero 31 66.05 31.80 8.00 41.00 209.00 Tikshezro 32 61.00 31.00 4.60 23.00 Lakozero Lakozero 33 62.60 31.30 1.60 180.00 180.00 Lakozero 34 63.33 30.42 8.50 34.00 180.00 Lakozero 35 59.70 39.30 1.30 2.00 166.00 Lekozero 35 58.70 31.80									
124 36.23 36.88 2.20 18.00 367.00 Vordozerskoe 25 60.20 37.70 1.80 5.60 351.00 Lacha 26 67.55 34.33 57.60 15.00 351.00 Lacha 26 67.55 34.33 57.60 15.00 313.00 Umbozero 27 61.88 33.22 6.50 26.00 260.00 Vyrtsyar 28 88.30 30.50 5.70 35.00 223.00 Lovozero 20 64.05 31.60 86.00 41.00 200.00 Tikshezro 31 66.05 31.80 8.00 41.00 200.00 Takshezro 32 61.00 31.00 46.09 23.00 Lackaz Sandalskoe 33 62.60 33.70 16.00 180.00 Leksozero 35 59.70 39.30 1.30 2.00 166.00 Leksozero 34 63.33 7.60	23	62.00	34.00	6.00	12.00	547.00	Vygozero		
158 67.55 14.33 57.60 115.00 313.00 Umbozero 27 61.88 33.32 6.50 24.00 266.00 Syammozero 28 83.03 26.00 2.50 56.00 250.00 Vyrtsyarv 29 64.45 30.55 8.50 44.00 240.00 Vertmeekujto 20 64.45 30.56 8.57 73.50 223.00 Levozero 31 66.05 31.80 8.00 41.00 209.00 Tikshezero 32 61.00 31.00 4.69 230.00 Tikshezero 33 62.60 33.75 9.50 58.00 185.00 Sandalskoe 34 63.33 30.42 8.50 34.00 166.00 Leksozero 35 59.70 39.30 1.30 2.00 166.00 Leksozero 36 65.78 33.93 4.60 28.10 12.02 Fileosensee 37 62.52 33.6	24	62.23	36.88	2.20	18.00	367.00			
12 61.88 33.32 6.50 24.00 266.00 Syannozaro 28 68.30 26.00 2.50 56.00 259.00 Vertsyav 29 64.95 30.55 8.50 44.00 240.00 Vertsyav 29 64.95 30.55 8.50 44.00 223.00 Leovazero 31 66.05 31.80 8.00 41.00 223.00 Leovazero 32 61.00 31.80 8.00 41.00 209.00 Tichszero 33 62.60 33.75 9.50 58.00 185.00 Ladogn 34 63.83 30.82 8.50 34.00 166.00 Lekszero 35 59.70 33.03 1.30 2.00 166.00 Lekszero 36 65.78 33.33 4.50 18.00 12.20 Engozero 38 53.44 12.44 6.60 28.10 102.70 Fleessnese 35.39 10.36	25	60.20	37.70	1.80	5.60	351.00	Lacha		
28 88.30 26.00 2.50 5.60 259.00 Vertynav 29 64.05 30.55 8.50 44.00 240.00 Vertynavkujo 20 64.05 31.60 5.70 35.00 223.00 Vertynavkujo 31 66.05 31.80 8.00 41.00 209.00 Tikshezero 32 61.00 31.00 46.0 230.00 Tikshezero 33 62.60 33.75 9.50 58.00 185.00 Sandalskoe 34 63.83 0.92 51.00 166.00 Leksozero 35 59.70 39.30 1.30 2.00 166.00 Leksozero 36 65.78 33.93 4.50 18.00 122.00 Engozero 37 62.52 33.67 18.50 74.00 109.00 Pale (Palzerskoe) 38 53.48 12.44 6.60 28.10 12.20 Flesomse 40 62.52 33.37	26	67.55	34.33	57.50	115.00	313.00	Umbozero		
129 64.95 30.55 8.50 44.00 240.00 Vertmeekujo 30 67.98 35.08 5.70 35.00 223.00 Lexvazero 31 66.05 31.80 8.00 41.00 223.00 Tikshezoro 32 61.00 31.80 8.00 41.00 209.00 Tikshezoro 33 62.60 33.75 9.50 58.00 186.00 Leksozero 34 63.83 30.02 8.50 34.00 166.00 Kubernskoe 36 65.78 33.33 4.50 18.00 122.00 Engozero 38 53.44 12.44 6.60 23.10 102.70 Fleessnese 39 53.37 9.09 50.00 45.00 173.80 Corth 41 6.50 23.40 13.40 Sniardwy 43 Sniardwy 31 53.37 21.75 5.80 23.40 13.40 Sniardwy 31 68.03	27	61.88	33.32	6.50	24.00	266.00	Syanmozero		
29 84.95 30.55 8.50 44.00 240.00 Verfneekujo 30 67.98 30.68 5.70 35.00 223.00 Lovozero 31 66.05 31.80 8.00 41.00 223.00 Lavozero 32 61.00 31.00 46.05 23.00 Lavozero 33 82.60 31.75 9.50 58.00 185.00 Ladogn 34 63.83 30.82 8.50 34.00 166.00 Leksozero 35 59.70 39.30 1.30 2.00 166.00 Leksozero 36 63.78 1.80 12.00 120.00 Pale (Palzerskoe) 38 3.43 1.44 6.60 23.10 127.00 Flexsmase 39 5.33.7 9.09 45.00 45.00 173.80 Cornb 41 6.50 23.10 102.00 Randsforden 13.40 Sniardwy 31 63.03 13.55 2.00	28	58.30	26.00	2.50	5.60	259.00	Vyrtsyarv		
11 66.05 31.80 8.00 41.00 209.00 Tikshezro 32 61.00 31.00 46.0 23.00 1780.00 Ladsgn 33 62.60 33.75 9.50 58.00 186.00 Ladsgn 34 63.83 30.62 8.50 34.00 166.00 Leksozero 35 59.70 39.30 1.30 2.00 166.00 Kubernskoe 36 65.78 33.63 18.50 74.00 109.00 Paie (Paizerskee) 38 53.44 12.44 6.60 28.10 102.70 Fiessnese 39 53.37 -0.90 50.00 45.00 173.80 Corrib 40 52.92 -8.33 7.60 36.00 173.60 Randsforden 41 63.63 131.00 140.00 Namerica Namerica 43 58.37.4 21.75 5.80 23.40 13.40 Sniardwy 43 58.32 14.6	29	64.95	30.55	8.50	44.00	240.00			
32 61.00 31.00 46.9 230.00 1780.00 Ladogn 33 62.60 33.75 9.50 185.00 185.00 Sandalskoe 34 63.83 30.82 8.50 34.00 186.00 Leksozero 35 59.70 39.30 1.30 2.00 166.00 Leksozero 36 65.73 39.30 1.30 2.00 166.00 Engozero 37 62.52 33.67 18.50 18.00 122.00 Pale (Palzerskoe) 38 53.48 12.44 6.60 28.10 102.70 Fleesomse 39 53.37 -9.09 5.00 46.00 173.80 Corrib 40 52.92 -8.33 7.60 36.00 17.50 Derg 41 63.51 131.00 140.10 Randsjorden 42 53.74 21.75 5.90 23.40 13.40 Narer 43 58.32 14.65 39.00	30	67.98	35.08	5.70	35.00	223.00	Lovozero		
33 62.60 33.75 9.50 58.00 185.00 Sandalskoe 34 63.83 30.82 8.50 34.00 166.00 Leksozero 35 59.70 39.30 1.30 2.00 166.00 Kubernkee 36 65.78 33.33 4.50 18.00 122.00 Pale (Palzerskoe) 38 53.48 12.44 6.60 28.10 122.70 Fleesonsee 39 53.37 -0.90 5.00 46.00 173.80 Corrib 40 52.92 -8.33 7.60 36.00 17.50 Derg 41 6.63 53.10 14.00 Xandsdyoten Sandsdyoten 42 53.74 21.75 5.80 23.40 13.40 Sniardwy 43 56.8.2 14.66 39.90 128.00 166.00 Vatern 45 59.52 17.03 118.00 148.00 Malaren	31	66.05	31.80	8.00	41.00	209.00	Tikshezero		
34 34.83 30.82 8.50 34.00 166.00 Leksorro 35 \$9,70 39.30 1.30 2.00 166.00 Kubenskoe 36 65,78 33.33 4.50 18.00 122.00 Engozero 37 62.52 33.67 18.50 74.00 109.00 Pale (Palzerskoe) 38 53.48 12.44 6.60 28.10 102.70 Fleesonsee 40 52.92 -8.33 -6.06 28.10 102.70 Derg 41 65.50 13.00 140.10 Randsforden 42 53.74 21.75 5.80 23.40 13.40 Sniardwy 43 58.90 13.25 27.00 106.00 5648.00 Vatern 44 58.92 14.63 39.90 13400 Vatern	32	61.00	31.00	46.9	230.00	17800.00	Ladoga		
35 59.70 39.30 1.30 2.00 166.00 Kubenskee 36 65.78 33.93 4.50 18.00 122.00 Engozero 37 62.52 33.67 18.50 74.00 120.00 Pale (Palzerskoe) 38 53.48 12.44 6.60 28.10 102.70 Fleesamsee 39 53.37 -0.90 5.00 46.00 173.80 Corrib 40 52.92 -8.33 7.60 36.00 173.80 Corrib 41 6.63 13.00 140.10 Randsforden 42 53.74 21.75 5.80 23.40 13.40 Sniardwy 43 58.92 14.55 39.00 128.00 166.00 Vatern 44 68.32 14.65 39.00 128.00 136.00 Vatern	33	62.60	33.75	9.50	58.00	185.00	Sandalskoe		
36 65.78 33.93 4.50 18.00 122.00 Engozero 37 62.52 33.67 18.50 74.00 109.00 Pale (Palzerskoe) 38 53.48 12.44 6.60 28.10 102.70 Felesomsee 39 53.37 -9.09 5.00 46.00 173.80 Corrib 40 52.92 -8.33 7.60 36.00 175.50 Derg 41 60.50 13.100 140.10 Randsforden Saindray 42 53.42 21.75 5.80 23.40 13.40 Snindray 43 58.90 13.25 27.00 106.00 5648.00 Vatern 45 59.62 17.03 118.00 140.00 Matern	34	63.83	30.82	8.50	34.00	166.00	Leksozero		
37 62.52 33.67 18.50 74.00 109.00 Paie (Patzerskoe) 38 53.48 12.44 65.00 28.10 102.70 Fleesomsee 39 53.37 -0.90 5.00 46.00 173.80 Corrib 40 52.92 -8.33 7.60 36.00 117.50 Derg 41 60.30 10.36 65.50 131.00 140.10 Randsforden 42 53.74 21.75 5.80 23.40 13.40 Sniardwy 3 68.30 13.25 27.00 166.00 5648.00 Vainern 44 58.32 14.65 39.90 128.00 134.00 Wainern	35	59.70	39.30	1.30	2.00	166.00	Kubenskoe		
38 53.48 12.44 6.60 28.10 102.70 Fleesensee 39 53.37 -9.09 5.00 46.00 173.80 Comb 40 52.92 -8.33 7.60 36.00 173.50 Derg 41 60.50 10.36 65.50 131.00 140.10 Randsforden 42 53.74 21.75 5.80 23.40 13.40 Sniardwy 43 58.90 13.25 27.00 106.00 548.00 Vanern 44 58.32 14.56 39.90 128.00 1856.00 Vatern 45 59.52 17.03 1.90 61.00 140.00 Malaren	36	65.78	33.93	4.50	18.00	122.00	Engozero		
39 53.37 -0.09 5.00 46.00 173.80 Corrib 40 52.92 -8.33 7.60 36.00 177.50 Derg 41 60.50 10.36 65.50 131.00 140.10 Randsfjorden 42 53.74 21.75 5.80 23.40 113.40 Sniardwy 43 58.90 13.25 27.00 106.00 5648.00 Vanern 45 59.52 17.03 11.90 61.00 148.00 Malaren	37	62.52	33.67	18.50	74.00	109.00	Pale (Palzerskoe)		
40 52.92 -8.33 7.60 36.00 117.50 Derg 41 60.50 10.36 65.50 131.00 140.10 Randstjorden 42 53.74 21.75 5.80 23.40 113.40 Sniardwy 43 58.90 13.25 27.00 106.00 5648.00 Vanern 44 58.32 14.56 39.90 128.00 1866.00 Vattern 45 59.52 17.03 11.90 61.00 140.00 Malaren	38	53.48	12.44	6.60	28.10	102.70	Fleesensee		
41 60.50 10.36 65.50 131.00 140.10 Randsförden 42 53.74 21.75 5.90 23.40 113.40 Sniardwy 43 58.90 13.25 27.00 106.00 548.00 Vanwr 44 58.32 14.56 39.90 128.00 134.00 Vatern 45 59.52 17.03 11.90 61.00 144.00 Malaren	39	53.37	-9.09	5.00	46.00	173.80	Corrib		
42 53.74 21.75 5.80 23.40 113.40 Sniardwy 43 58.90 13.25 27.00 106.00 5648.00 Vanern 44 58.32 14.56 39.90 128.00 1856.00 Vattern 5 59.52 17.03 11.90 61.00 1140.00 Malaren	40	52.92	-8.33	7.60	36.00	117.50	Derg		
42 53.74 21.75 5.80 23.40 113.40 Sniardwry 43 58.90 13.25 27.00 106.00 5648.00 Vanern 44 58.32 14.56 39.00 128.00 1856.00 Vattern 45 59.52 17.03 11.90 61.00 1140.00 Malaren	41	60.50	10.36	65.50	131.00	140.10	Randsfjorden		
44 58.32 14.56 39.90 128.00 1856.00 Vättern 45 59.52 17.03 11.90 61.00 1140.00 Mälaren	42	53.74	21.75	5.80	23.40	113.40			
45 59.52 17.03 11.90 61.00 1140.00 Malaren	43	58.90	13.25	27.00	106.00	5648.00	Vänern		
	44	58.32	14.56	39.90	128.00	1856.00	Vättern		
46 59.22 15.77 6.10 22.00 478.00 Hiselmaran	45	59.52	17.03	11.90	61.00	1140.00	Mälaren		
	46	59.22	15.77	6.10	22.00	478.00	Hjäelmaren		
47 54.60 -6.50 8.90 34.00 385.00 Neagh	47	54.60	-6.50	8.90	34.00	385.00	Neagh		









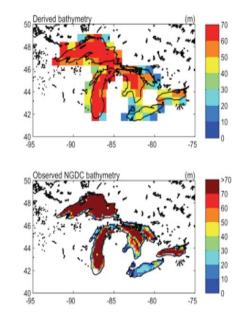
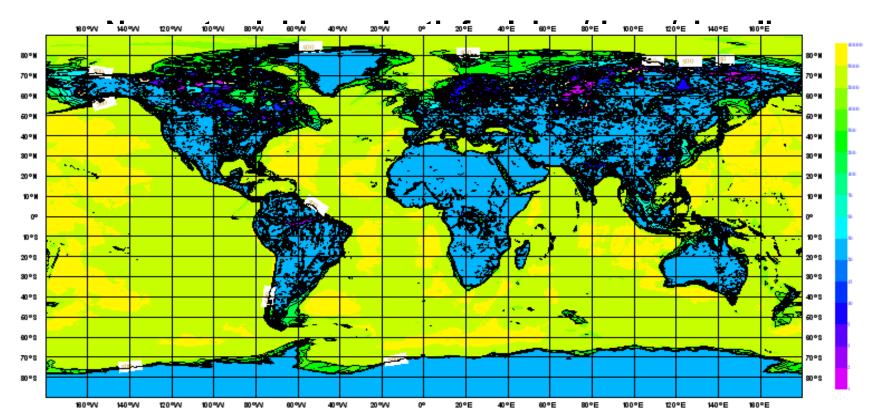


Figure 7: Derived bathymetry of the American Great Lakes at ERA-Interim model resolution (top panel) as compared to the NGDC observed bathymetry, limited to 70 m (bottom panel).

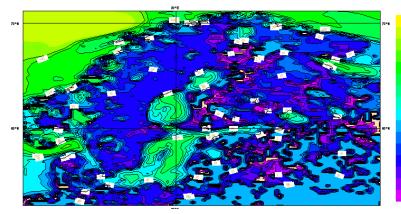
The lake depth (II)

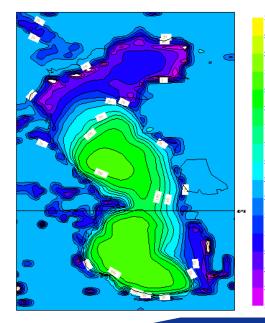
- A new 1km dataset was produced (Kourzeneva, 2009)
- Combined with the ETOPO-5km bathymetry and with the a Caspian Sea bathymetry (Cavalieri, 2008)
 - background value of 25m



The lake depth (III)

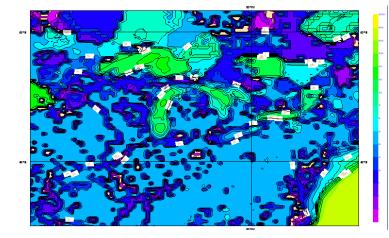
Scandinavia&Baltic



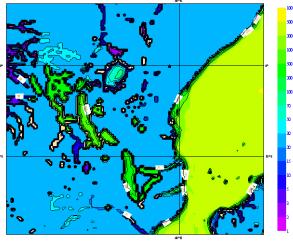


Caspian Sea

American Great Lakes



Lake Victoria



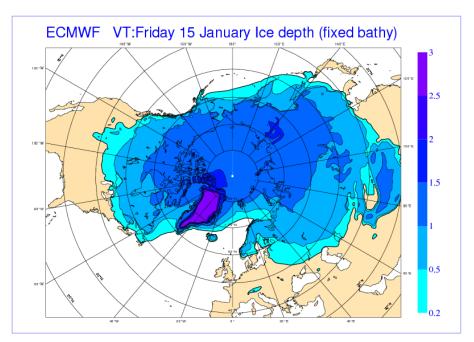


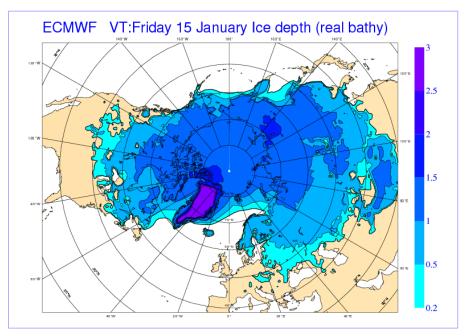
A 20-year long FLAKE-HTESSEL run

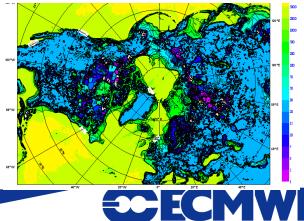
- In order to create initial conditions for the FLAKE-HTESSEL model for all points/resolutions, a long offline integration is performed
- Each grid-point on the globe is set to be a lake (strong test)
 LAKEPLANET experiment, using the lake/ocean depth previously obtained.
- The ERA-Interim 3-hourly forcing at T255 resolution (about 80 km) is used to drive FLAKE-HTESSEL
- The advantage of this model output is a set of spatially continuous lake model output which can be interpolated into higher resolution grid.
- The output is also resilient to changes of the land-sea mask or lake cover dataset.

NOTE: see the presentation by Rui Salgade for indepth look
Norrekäning 45/00/2010

Impact of lake depth on offline mean lake ice depth







Fixed 25m depth

2nd LAKES in NWP Workshop, Norrköping, 15/09/2010

A roadmap to implementation

In order to add the lake modelling component into the IFS, initialization is required for ancillary fields:



lake cover (fraction of a given grid box of an atmospheric model covered by lake water), and lake depth (mean depth of lakes present in a given grid box).

and for the prognostic variables:

- mixed-layer temperature,
- mixed-layer depth,
- bottom temperature (temperature at the water-bottom sediment interface),
 - mean temperature of the water column,
 - shape factor with respect to the temperature profile in the thermocline,
 - temperature at the ice upper surface, and
 - ice thickness

Due to the global continuity of the LAKEPLANET output the Initial conditions can be interpolated onto all resolution used by the IFS (from T21 to T2047).

Coupled lake-land atmosphere experiments

• Forecast runs

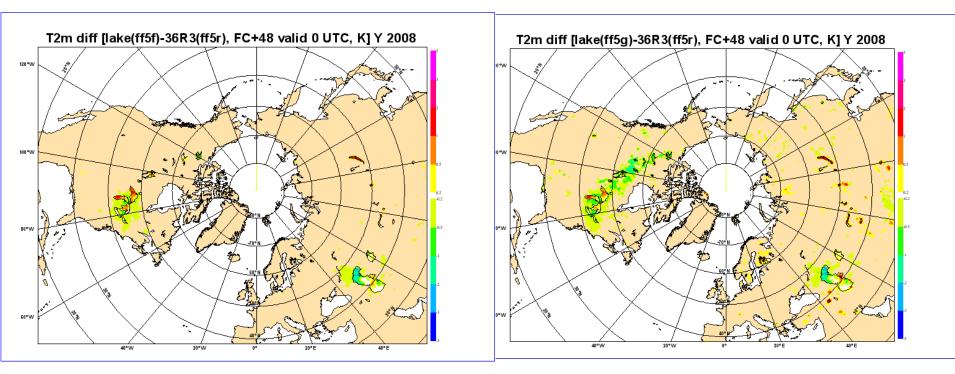
- 37 10-day forecasts spaced one every 10 days covering 2008 are run at resolution T399 (about 50km) initialized with the operational IFS analysis for all variables.
- Lake initial conditions are provided by the LAKEPLANET simulations with "realistic" lake depth and forced by ERA-Interim near-surface meteorology at T255 (about 80 km) interpolated onto T399 target resolution
- Climate runs
 - 4 members AMIP-type experiment where the IFS model is integrated for 13-months (from August 2001) at T159 (about 125 km). Initial conditions are provided by ERA-Interim together with daily SSTs.
 - Lake initial conditions provided by the LAKEPLANET simulation



Forecasts experiments: Sensitivity (2008)

Resolved lakes only

Resolved +Unresolved lakes

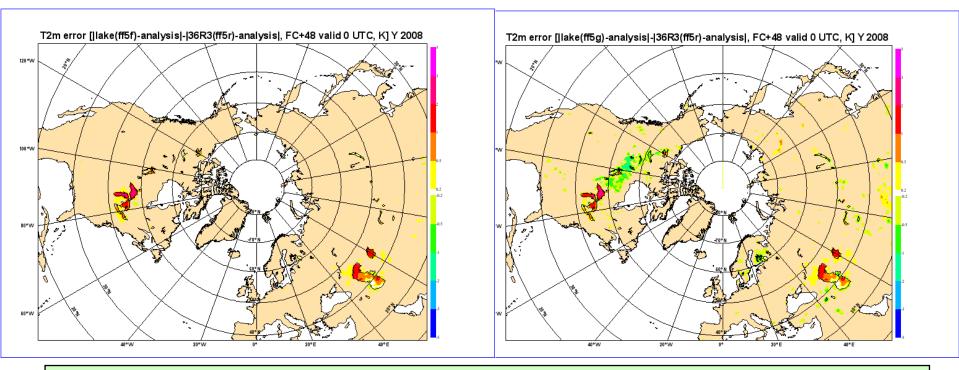


The sensitivity of 2m temperature forecasts (FC+48 shown here) see a co-located cooling over lakes (expect the Great Lakes). The addition of unresolved lakes extend the impact on large part of Northern Canada (where sub-grid lakes are vastly present).

Forecasts experiments: Impact (2008)

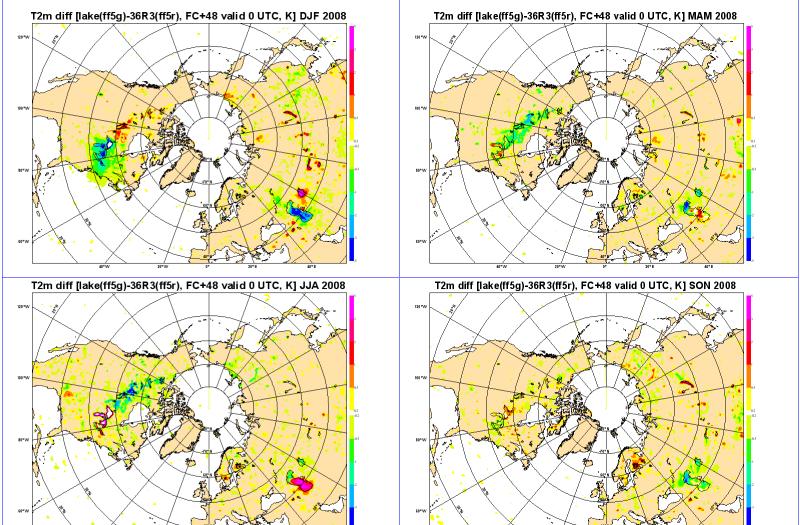
Resolved lakes only

Resolved +Unresolved lakes



The impact evaluated against the operational 2m temperature analysis indicate an improvement (Mean Absolute Error reduction) over lakes (expect the Great Lakes and Caspian). The addition of unresolved lakes extend the positive impact on large part of Northern Canada and in the vicinity of Ladoga. Note: Green colour indicate 0.5-1.0K better

Forecasts experiments: sensitivity seasons

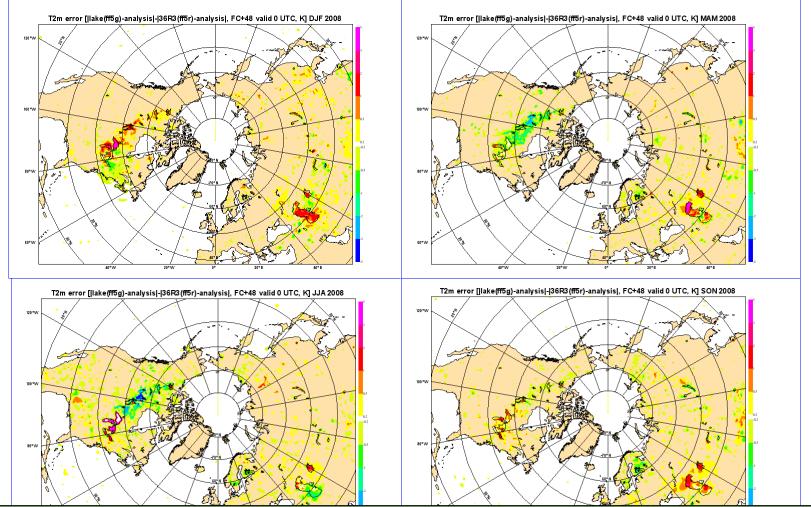


Resolved +Unresolved lakes

Mainly cooling in 2m temperature in Winter Spring and Summer over Canada. Warming Autumn effect over Scandinavia. Dipole in Winter between Central/Eastern Canada.

Forecasts experiments: Impact seasons

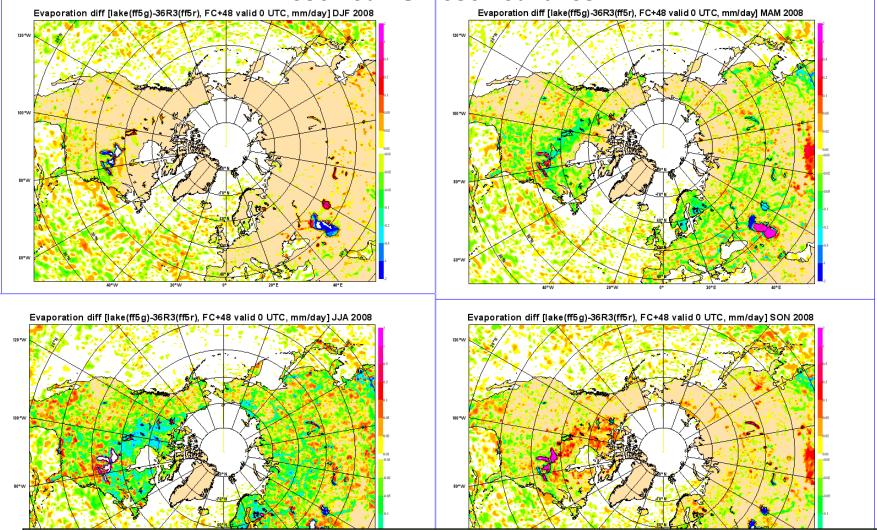




The largest positive impact is Spring over Canada and Autumn over Scandinavia. Small negative impact over central Canada in Winter (maybe related to lake ice initial conditions?). Positive winter impact east of the Great-Lakes (downwind lake effect?).

Forecasts experiments: Evaporation

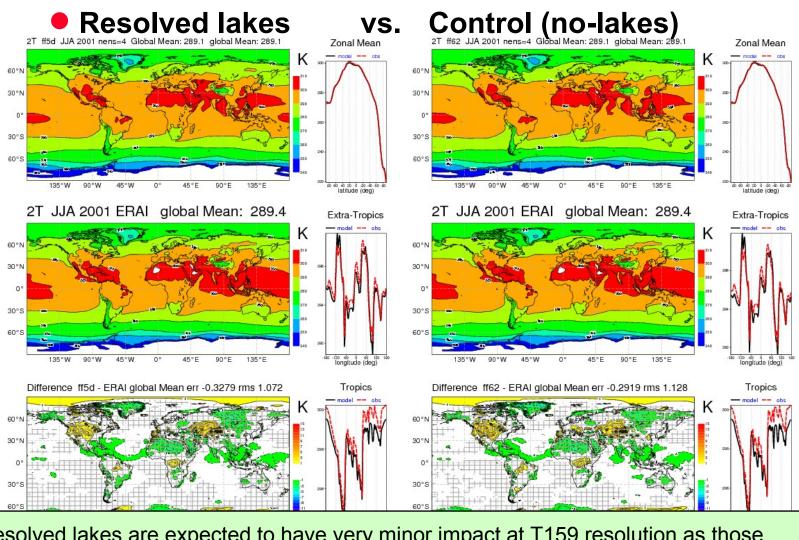
Resolved +Unresolved lakes



Evaporation is reduced in Spring/Summer and increased in Autumn. Overall it seems not an increased (unlike offline simulations

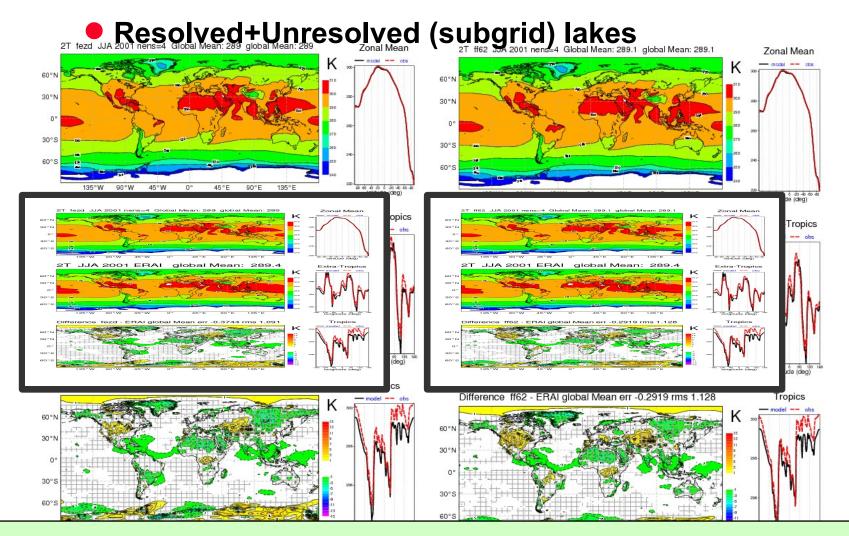
possibly an unbalance in soil initial conditions?)

Climate (lake-coupled) experiments



Resolved lakes are expected to have very minor impact at T159 resolution as those concerns only 180 grid-points (Great-Lakes, Ladoga, Caspian, Aral, Victoria)

Climate (lake-coupled) experiments



The summer North American impact on 2m temperature is confirmed in long coupled simulation although the signal is not passing the 95% significance (ensemble size of only 4-members)

Summary and Conclusions

- The land surface model at ECMWF successfully integrates FLAKE for both resolved and sub-grid lakes.
- A "cold-start" procedure (Lake-Planet) has been setup to initialize the lakes in any date between 1989 and present day and produce a monthly climatology
- Preliminary results from fully coupled atmospheric forecasts suggests that FLAKE can bring improvements on large portion of Canada and part of Scandinavia. Need to be confirmed by larger validation.
- The use of SSTs for Caspian and Great-Lakes is suggested for initializing the lake temperatures. Possible the extension to Baltic?
- Future tests will involve data assimilation cycles (autumn/winter 2010).
- The new surface analysis structure may allow for an assimilation of the 2m temperature analysis to correct for lake temperature errors.

THANK YOU FOR YOUR ATTENTION.