Recent progress on the parameterization of land surface processes at ECMWF

Gianpaolo Balsamo

Thanks to

Souhail Boussetta, Andrea Manrique-Sunen, Emanuel Dutra, Rui Salgado,
Clement Albergel, Patricia de Rosnay, Anton Beljaars, Jean-Cristophe Calvet (MF),
Bart van den Hurk (KNMI), Pedro Viterbo (IM), Dmitrii Mironov (DWD) and other colleagues

ECMWF

Role of land surface at ECMWF

ECMWF model(s) and resolutions

	Length	Horizontal	Vertical	Remarks
- 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	12 h	T255(80 km)/ T95(200 km) inner T159(125 km)	L91	
- ERA-Interim Reanalysis	1979-today	T255(80 km)	L91	4D-Var+surface OI

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 status

2000/06	2007/11	2009/03	2009/09		2010/11

- **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)

  ERA-40 and ERA-I scheme

- **Hydrology-TESSEL**

  Balsamo et al. (2009)
  van den Hurk and
  Viterbo (2003)

  Global Soil Texture (FAO)

  New hydraulic properties

  Variable Infiltration capacity &
  surface runoff revision

- **NEW SNOW**

  Dutra et al. (2010)

  Revised snow density

  Liquid water reservoir

  Revision of Albedo
  and sub-grid snow
  cover

- **NEW LAI**

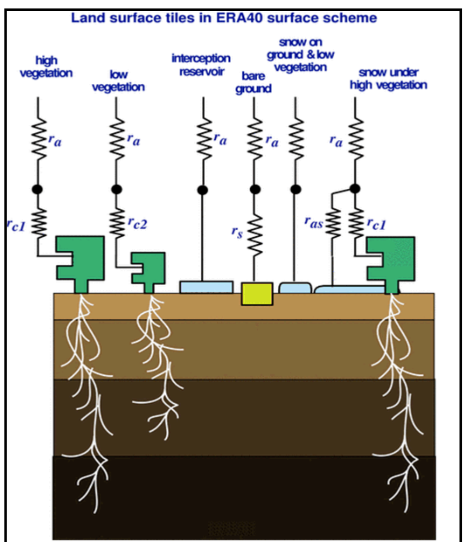
  Boussetta et al. (2011)

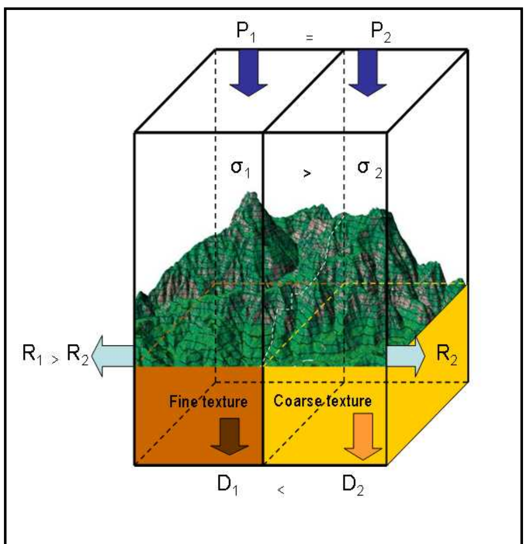
  New satellite-based

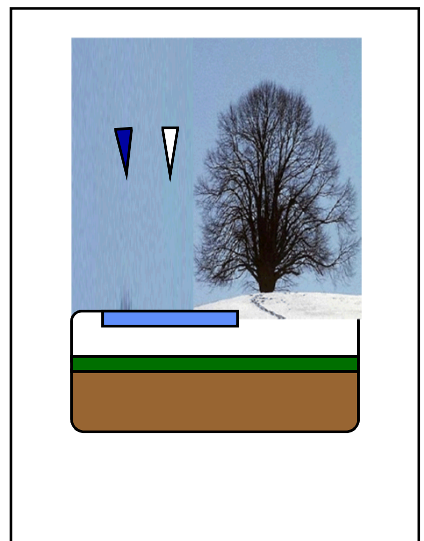
  Leaf-Area-Index

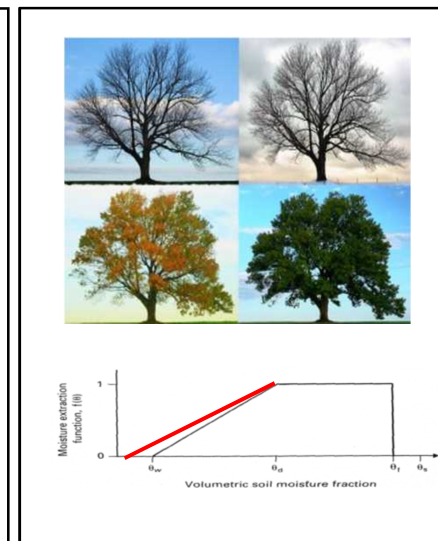
- **SOIL Evaporation**

  Mahfouf and Noilhan (1991)









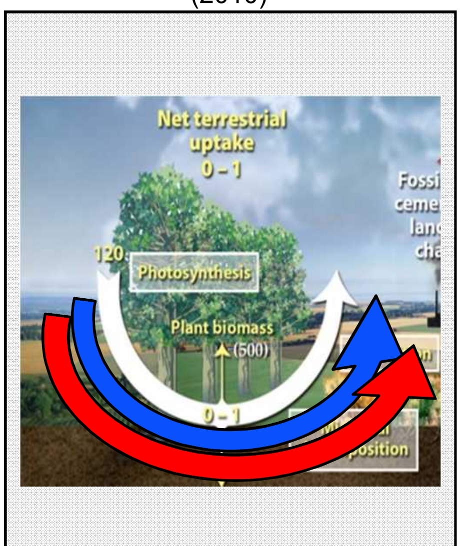
Land surface model perspectives

2011	2012	2013-2015

- H_2O / E / CO_2

  Integration of Carbon / Energy / Water cycles at the surface (GEOLAND-2 based & GMES funded)

  Calvet et al. (1998)
  Jarlan et al (2007)
  Boussetta et al. (2010)



- **FLake**

  Mironov et al (2010),
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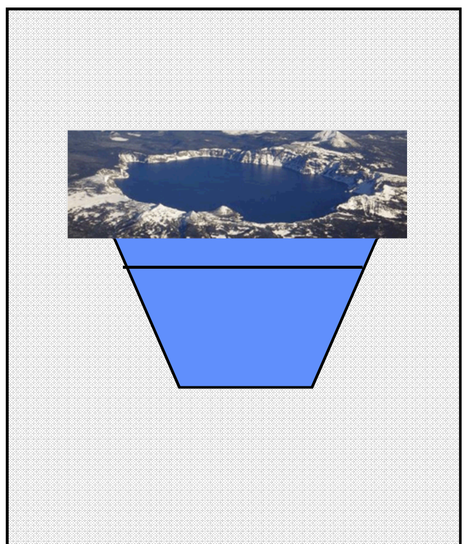
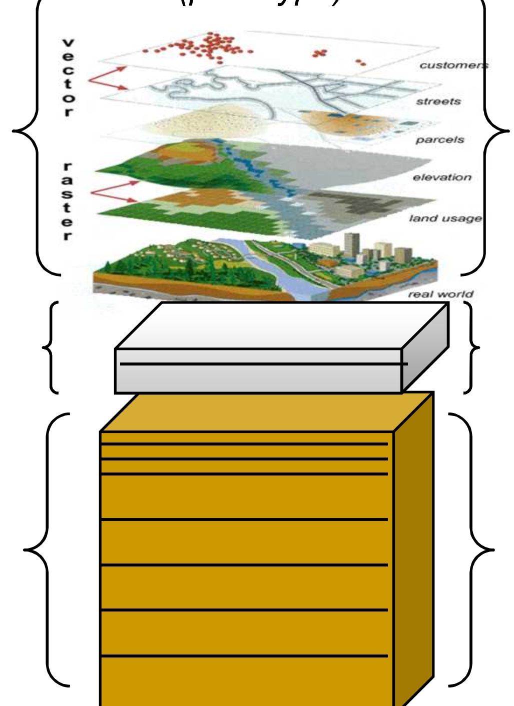
  Extra tile (9) to account for sub-grid lakes



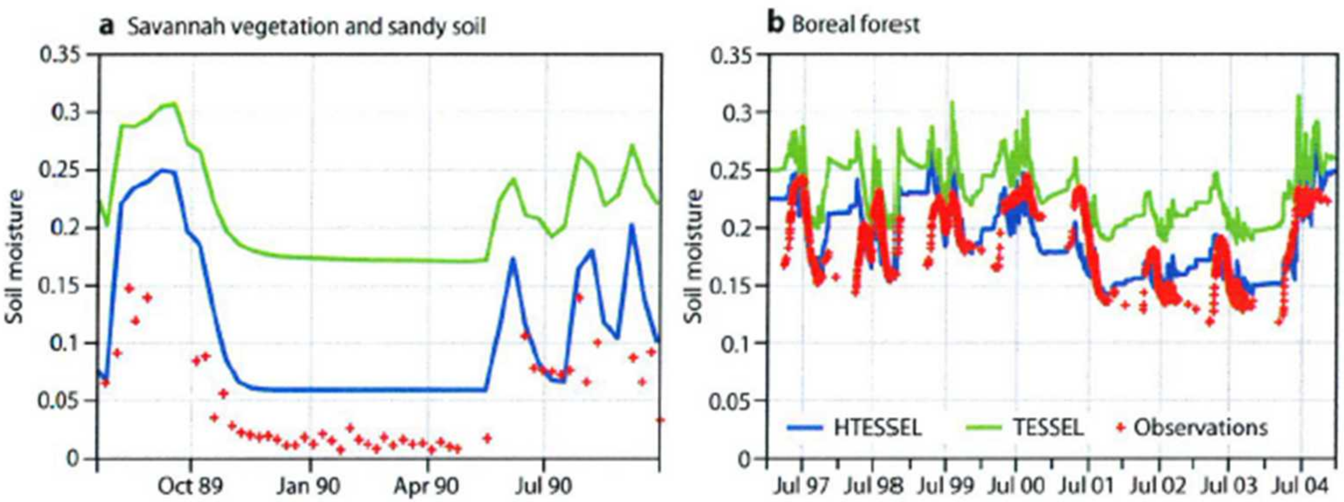
- Towards **Interactive Ecosystem** modelling to respond to several applications needs

  (prototype)



Soil hydrology

(Balsamo et al. 2009, JHM)



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  Van Genuchten hydraulic properties

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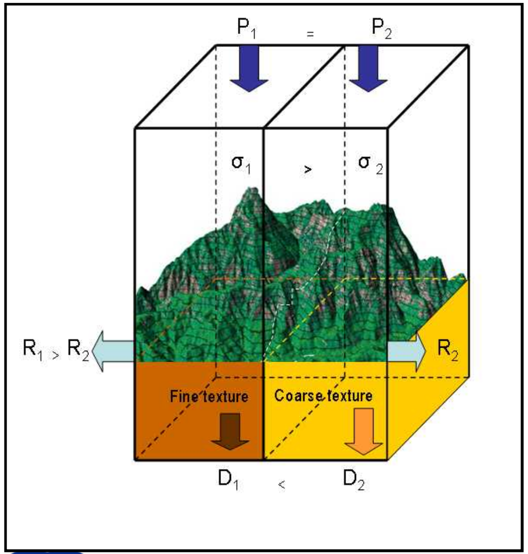
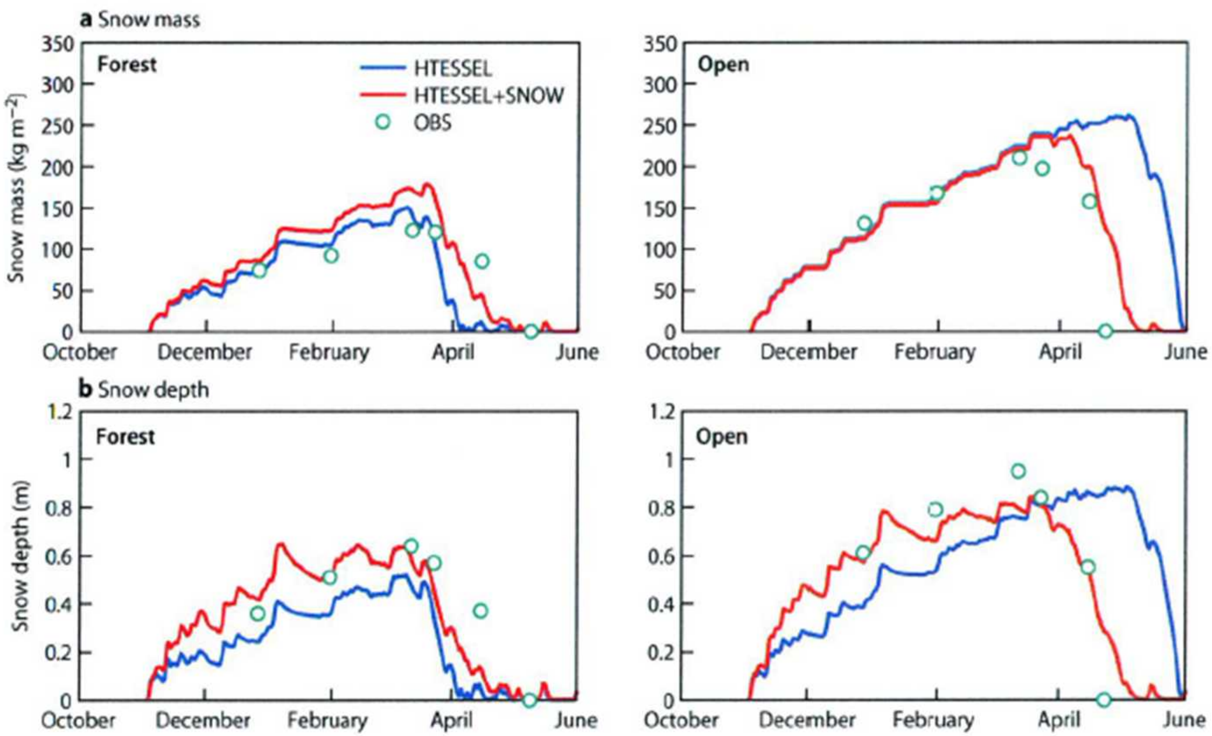


New snow scheme

(Dutra et al. 2010, JHM)



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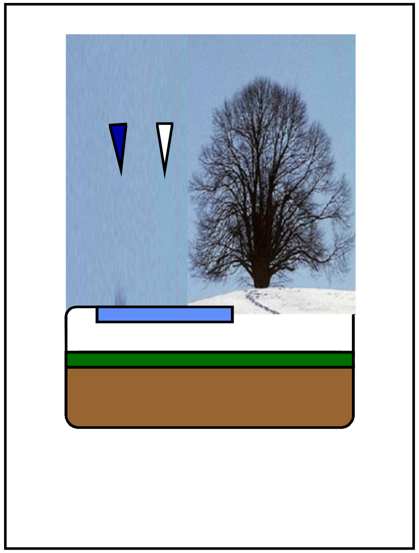
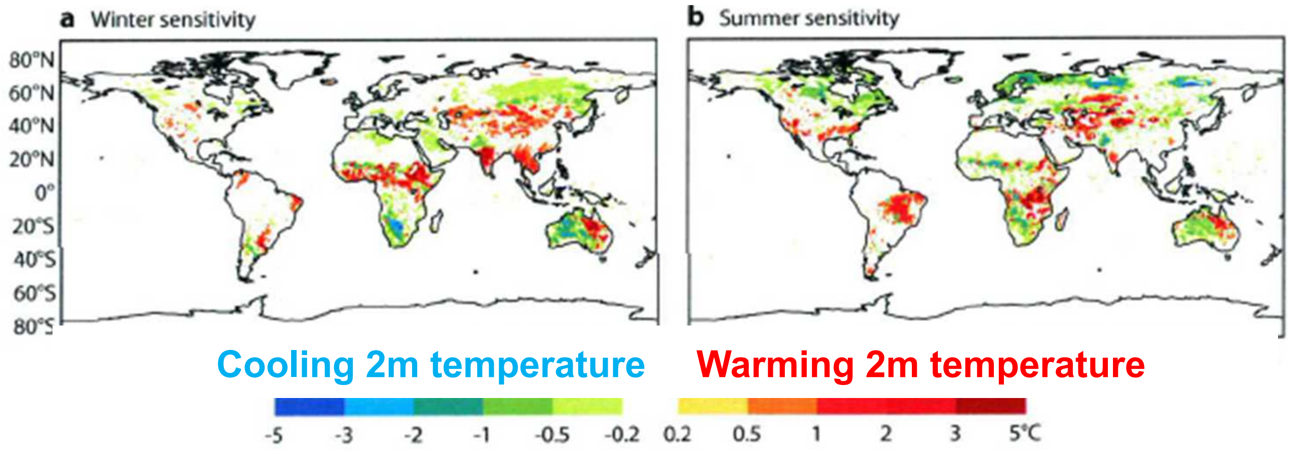
  Liquid water reservoir

  Revision of Albedo and sub-grid snow cover

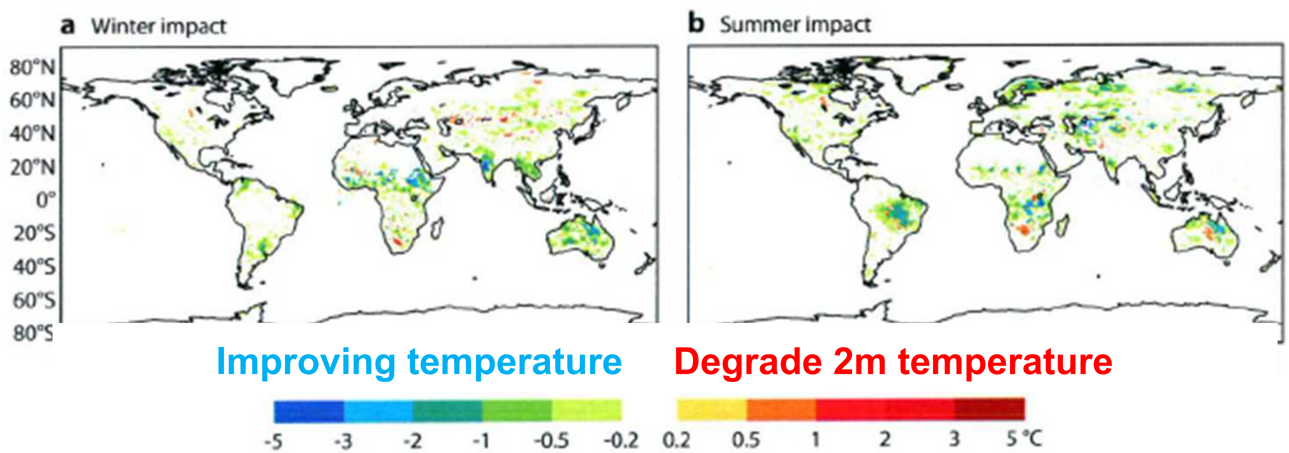


Forecasts sensitivity and impact

Forecast sensitivity



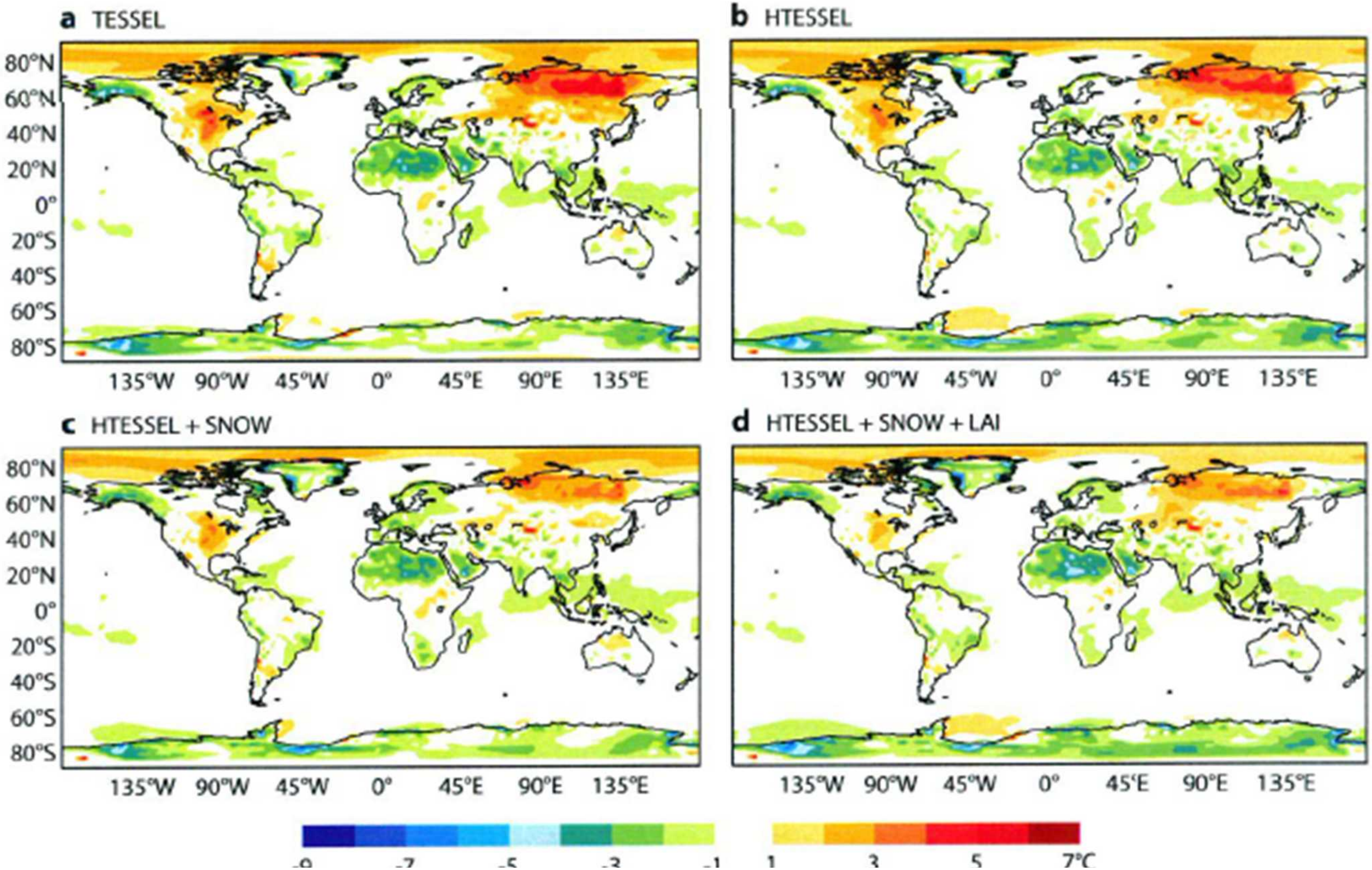
Forecast Impact



The revised soil/snow scheme introduce additive improvements respectively in summer/winter seasons forecasts of 2m temperatures

Climate impact

Hindcasts, 4-member 13-month temperature difference



simulations colder than ERA-Interim

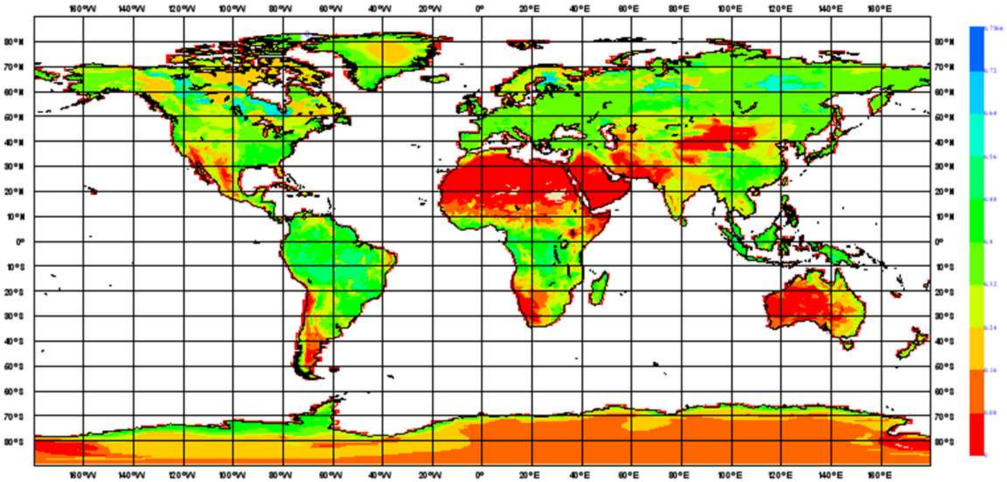
Warmer than ERA-Interim

Re-actualizing land surface from ERA-Interim

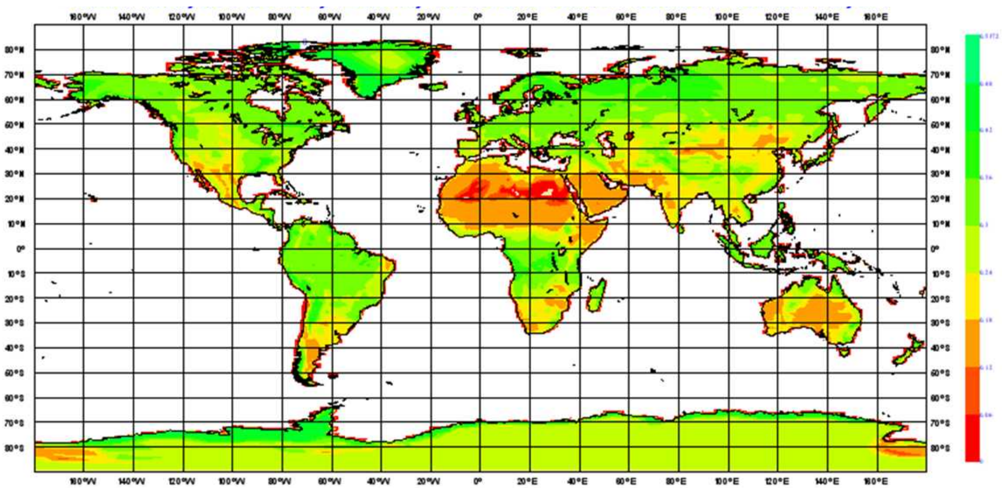
- Substantial modification to the (land surface) model raise the issue of "model climate consistency" for all anomaly-based product (monthly-seasonal forecast products but also for data assimilation purposes [e.g. ASCAT]).
- Ideally a new re-analysis should be realized after each major model cycle
  - Land surface presents a spin-up of the order of 1 year, therefore Initial conditions (ICs) can not be affordably re-balanced when running AN/FC experiments.
- ERA-Interim land surface ICs are not properly adapted to the current land surface model (since CY31R2 changes in soil and snow hydrology, vegetation, evaporation, surface-atmosphere coupling)
- ERA-Interim provides good quality meteorology allowing to force the current land surface model and create a new set of initial conditions for soil moisture, soil temperature and snow conditions aligned with the current model version (CY36R4). This allows also to test new modelling components are Lakes and Carbon developments.
- Consistency (& Conservation) w.r.t. water/energy/mass balance is preserved
- New 1979-2011 land surface state (6-hourly archived) have been generated.

A new soil moisture from ERA-Interim land surface offline-runs

New



EI



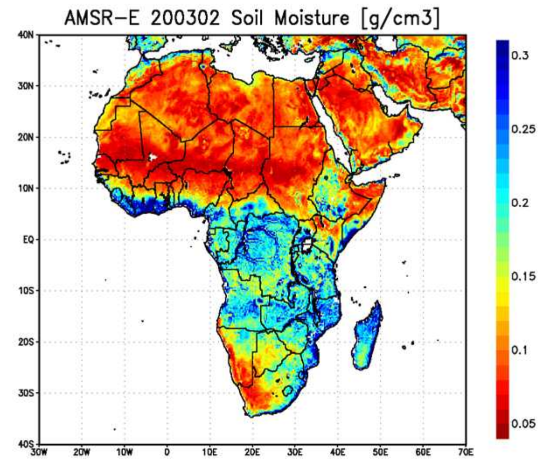
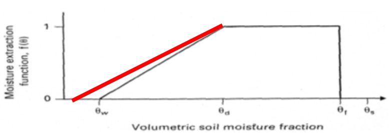


Figure: Global plots show the 1st of January 1989 from ERA-Interim and from a 10 spin-up run.

NB: the new bare-soil evaporation in particular allows to reach a much drier level in soil moisture

- **SOIL Evaporation**



ERA-Interim surface soil moisture is very homogeneous and present unrealistically high values over deserts (as visually comparable with AMSR-E soil moisture product). The new ICs has a larger range of values with drier deserts.

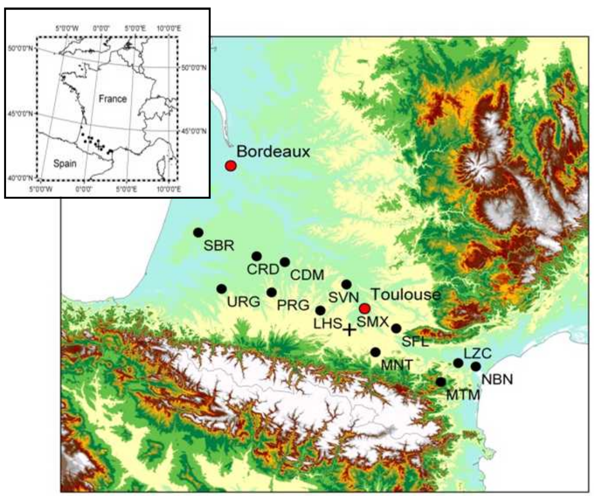
Soil moisture verification for the stand-alone land surface runs forced by ERA-Interim

In Collaboration with Meteo France thanks to C. Albergel and P.de Rosnay

rmse

Layer 1	TESSEL		LSH-TESSEL		LSH_TESSEL-PP	
	rmse	rmse	rmse	rmse	rmse	rmse
SBR	0,182	0,182	0,233	0,233	0,239	0,239
URG	0,170	0,077	0,119	0,054	0,108	0,051
CRD	0,126		0,183		0,194	
PRG	0,095		0,064		0,056	
CDM	0,100		0,064		0,056	
LHS	0,081	0,067	0,057	0,057	0,058	0,063
SVN	0,073		0,080		0,088	
MNT	0,142	0,091	0,101	0,060	0,092	0,069
SFL	0,056		0,057		0,085	
MTM	0,045	0,074	0,095	0,112	0,096	0,118
LZC	0,127		0,160		0,167	
NBN	0,074		0,105		0,111	
	0,106	0,098	0,110	0,103	0,113	0,108

Layer 2	TESSEL		LSH-TESSEL		LSH_TESSEL-PP	
	rmse	rmse	rmse	rmse	rmse	rmse
SBR	0,176	0,176	0,217	0,217	0,224	0,224
URG	0,090	0,061	0,065	0,058	0,050	0,053
CRD	0,117		0,167		0,180	
PRG	0,076		0,080		0,073	
CDM	0,135		0,094		0,079	
LHS	0,135	0,053	0,105	0,044	0,094	0,042
SVN	0,044		0,087		0,096	
MNT	0,048	0,040	0,041	0,046	0,085	0,091
SFL	0,040		0,057		0,099	
MTM	0,040	0,079	0,044	0,114	0,040	0,122
LZC	0,110		0,149		0,156	
NBN	0,078		0,106		0,115	
	0,091	0,082	0,101	0,096	0,108	0,106

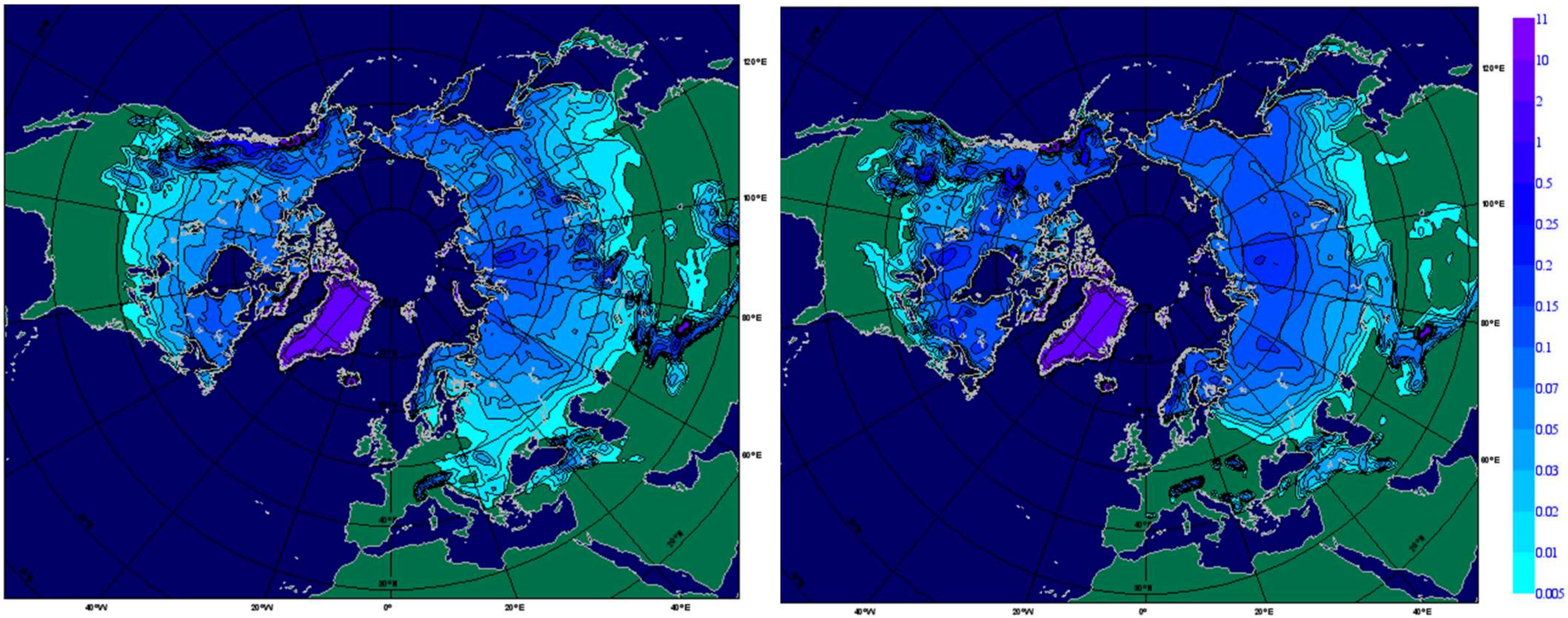


correlation

Layer 2	TESSEL		LSH-TESSEL		LSH_TESSEL-PP	
	r	r	r	r	r	r
SBR	0,508	0,508	0,527	0,527	0,522	0,522
URG	0,886	0,787	0,881	0,778	0,895	0,792
CRD	0,766		0,776		0,772	
PRG	0,561		0,497		0,493	
CDM	0,818		0,847		0,838	
LHS	0,848	0,894	0,843	0,894	0,832	0,887
SVN	0,926		0,926		0,925	
MNT	0,890	0,888	0,912	0,907	0,804	0,813
SFL	0,860		0,877		0,786	
MTM	0,890	0,901	0,894	0,917	0,891	0,918
LZC	0,885		0,901		0,901	
NBN	0,882		0,870		0,868	
	0,810	0,796	0,813	0,805	0,794	0,786

A new snow evolution from ERA-Interim surface-only offline-runs

New EI

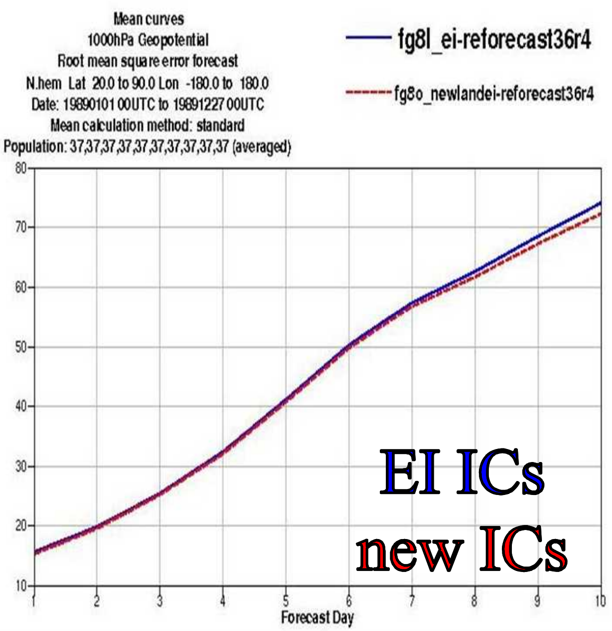


ERA-Interim snow mass before 2003 (here shown for 1st of January 1989) is artificially smooth as a result of the relaxation to a climatology. Orographic areas are more marked in the new ICs field. Snow line is quite comparable (except for Himalayas)

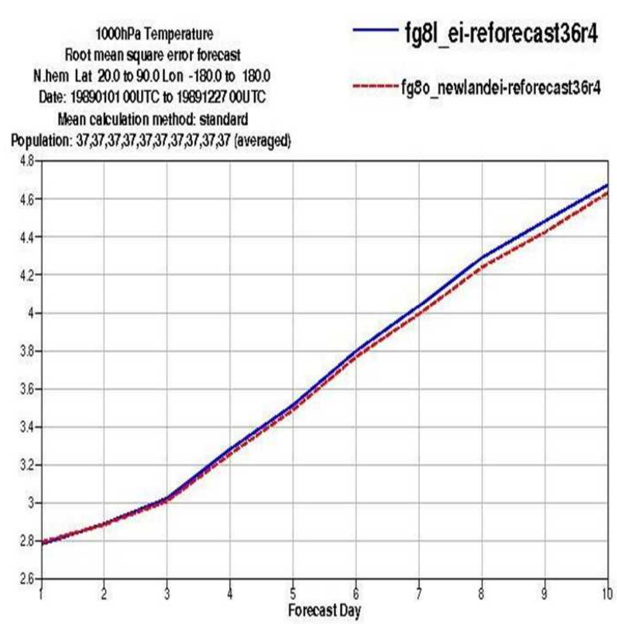
Forecast experiments with the new land ICs

- A 1-year of re-forecasts (36-FC T255L91, between 1/1/1989-27/12/1989, 10-day spaced) is run with the new ICs (fg8o) and with ERA-Interim ICs (fg8I)

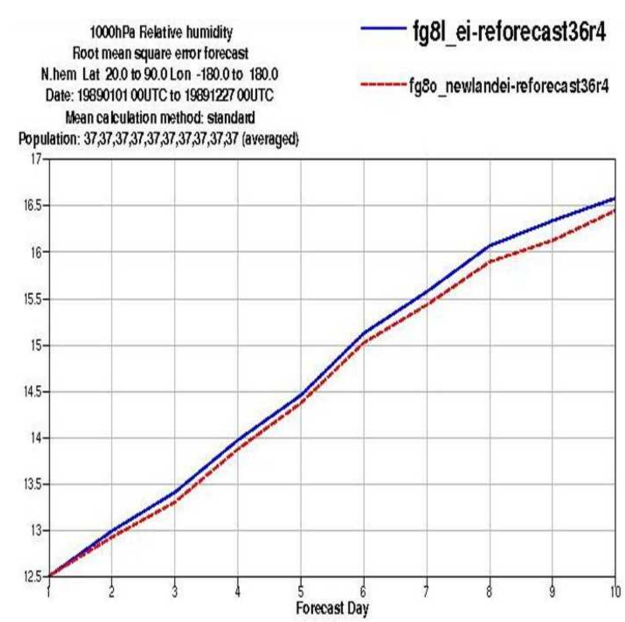
Mean Northern Hemisphere RMSE evolution in the 10-day forecasts



Z 1000hPa



T 1000hPa

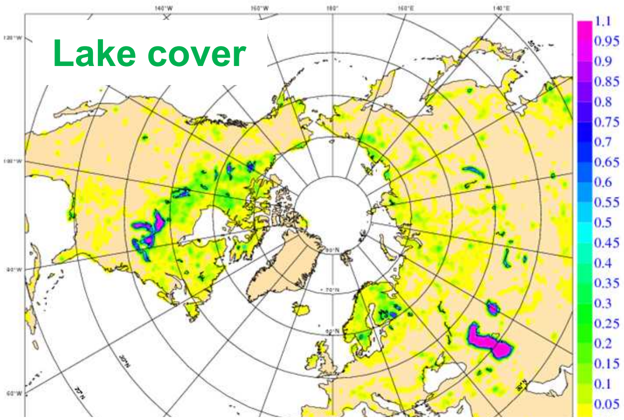


RH 1000hPa

Land surface initial conditions generated from ERA-Interim are assessed in forecast experiments with slight improvement in temperature and relative humidity. Further tests in the Seasonal Forecasting System registered improvement too (not shown).

Assessing a Fresh-water Lake model in IFS

(Balsamo et al. 2011, ECMWF TM 648)

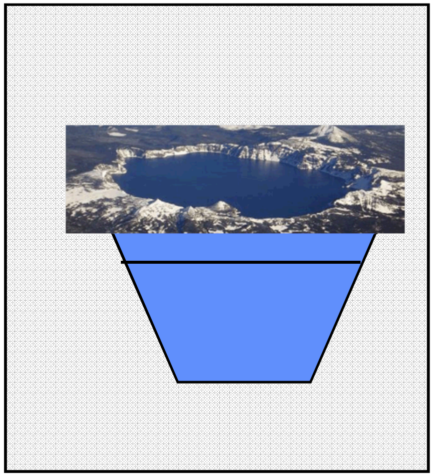


- **Offline surface runs are used to prepare ICs for a new lake modelling component and permit the forecast assessment.**

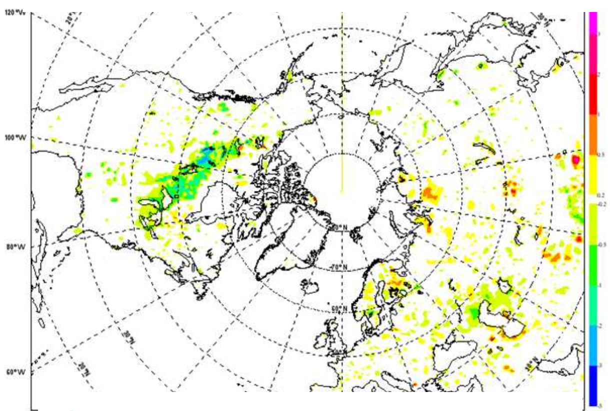
- **FLake**

Mironov et al (2010),
Dutra et al. (2010),
Balsamo et al. (2010)
Balsamo et al. (2011)

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

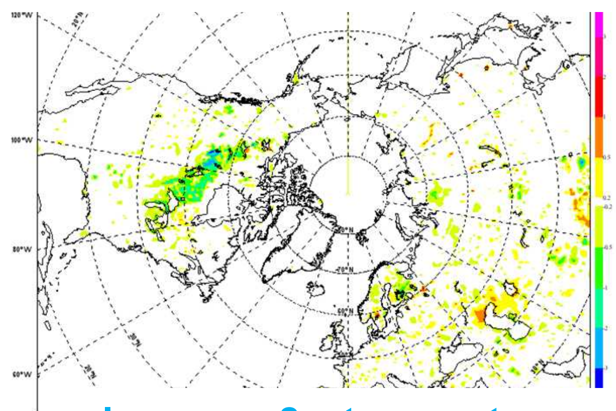


Forecast sensitivity



Cooling 2m temperature
Warming 2m temperature

Forecast impact



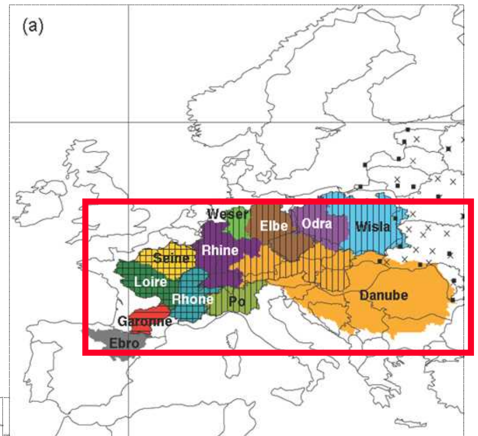
Improves 2m temperature
Degrades 2m temperature

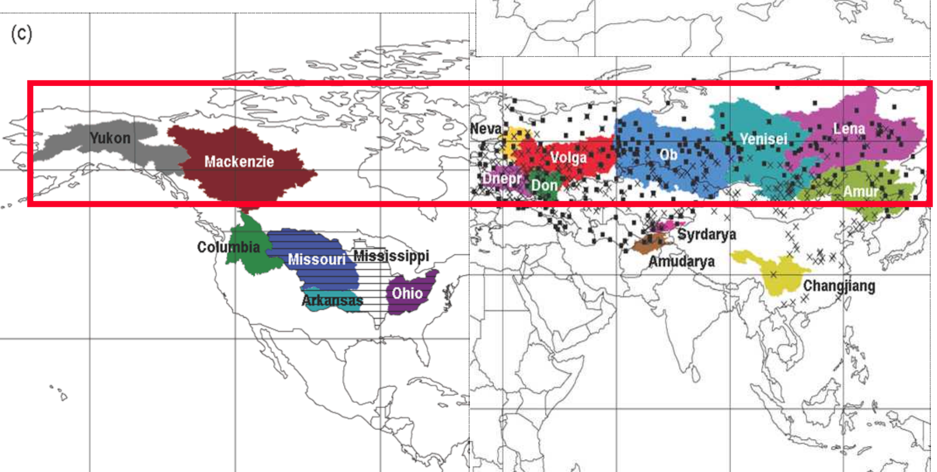
ERA-Interim forced runs of the FLAKE model are used to generate a lake model climatology which serves as IC in forecasts experiments (Here it is shown spring sensitivity and error impact on temperature when activating the lake model).

Assessing impact on hydrological cycle

ECMWF Newsletter No. 127 – Spring 2011

In collaboration with ETH-Zurich, see also: Hirschi et al. 2006, J. Hydromet., 7(1), 39-60





Parametrization scheme	Runoff RMSE (mm/day)	Observed area-weighted average runoff from GRDC (mm/day)
Area-weighted average of snow-free basins (~1,632,601 km^2): Northeast-Europe and Central-Europe		
TESSEL	0.28	0.76
HTESSEL	0.17	
Area-weighted average of snow basins (~12,334,161 km^2): Yukon, Podka., Lena, Tom, Ob, Yenisei, Mackenzie, Volga, Irtish and Neva		
HTESSEL	0.75	1.96
HTESSEL+SNOW	0.51	

Table 1 Runoff root-mean-square error (RMSE) for GSWP2 from global offline simulations (1986–1995) verified with GRDC observations on snow-free basins for TESSEL, HTESSEL, and snow-dominated basins for HTESSEL, HTESSEL+SNOW.

Using an equal forcing (this time based on ERA40GPCP corrected forcing) TESSEL and the new land surface model version currently operational can be evaluated against river discharges of main Northern Hemisphere river at monthly timescales (no routing). New activities with river-routing schemes can assess hydrological impact on daily timescale (Pappenberger et al.)

Conclusions and perspectives

- **The current status of the land surface model is summarized in the ECMWF Newsletter n. 127 [link].**
- **The land surface model development at ECMWF is moving towards Ecosystem modelling including Carbon Dioxide natural cycle (***see ppt by Souhail Boussetta***) linked to Water and Energy cycles.**
- **Several IFS applications can benefit from the current land surface scheme (e.g. MACC/GAS, crop modelling, river modelling) and land surface benefits from a larger community of scientific users.**
- **A methodology to re-actualize the land surface state in reanalyses has been designed and integrated with ECMWF facility and already serves operational applications (output soon available to external access).**
- **Offline runs represent (also) an affordable land surface testing environment for new modelling components (e.g. lakes) and are linked to a land surface benchmarking database.**
- **Offline surface-only will be used for land data assimilation of Leaf Area Index and presents potential also for future application in the reanalyses**