Global runoff forecasting for data scarce regions with the hydrological component of the ECMWF NWP system

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Outline

- Land Surface hydrology
- Soil moisture
- River Routing

Role of land surface at ECMWF

- Numerical Weather Prediction models need to provide near surface weather parameters (temperature, dew point, wind, low level cloudiness) to their customers.

ECMWF model(s) and resolutions

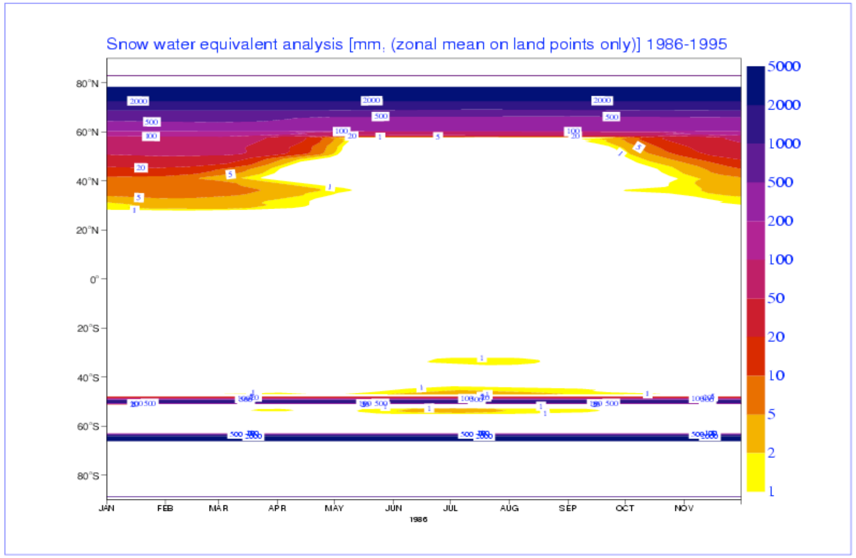
	Length	Horizontal	Vertical	Remarks
Deterministic	10 d	T799 (25 km)	L91	00+12 UTC
Ensemble prediction	15 d	T399 (50 km)	L62	2x(50+1)
Monthly forecast	1 m	T159 (125 km)	L62	(Ocean coupled)

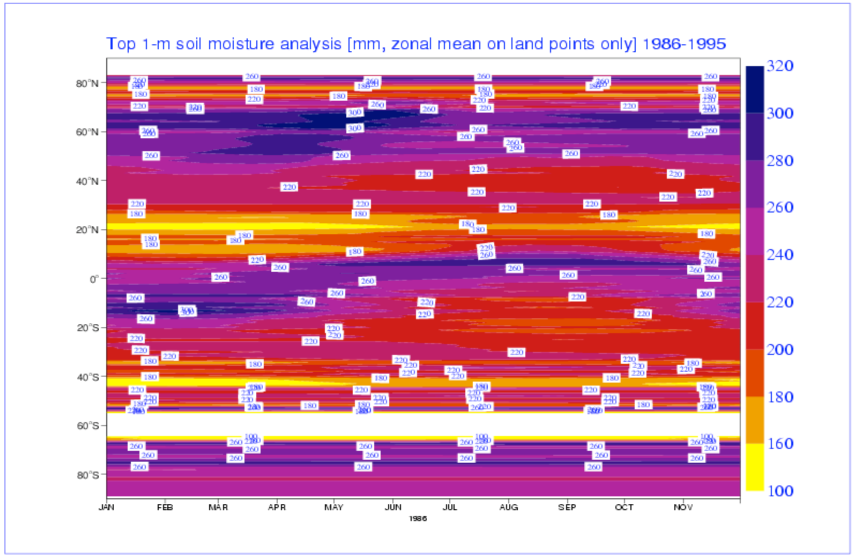
The land surface modelling and data assimilation systems need flexibility and have to include upscalability (&conservation) properties despite the natural heterogeneity of land surfaces

ERA-40 Reanalysis +surface OI	1958-2002	T159(125 km)	L60	3D-Var
ERA-Interim Reanalysis +surface OI	1988-today	T255(80 km)	L91	4D-Var

Surface Water reservoirs (ERA-40)

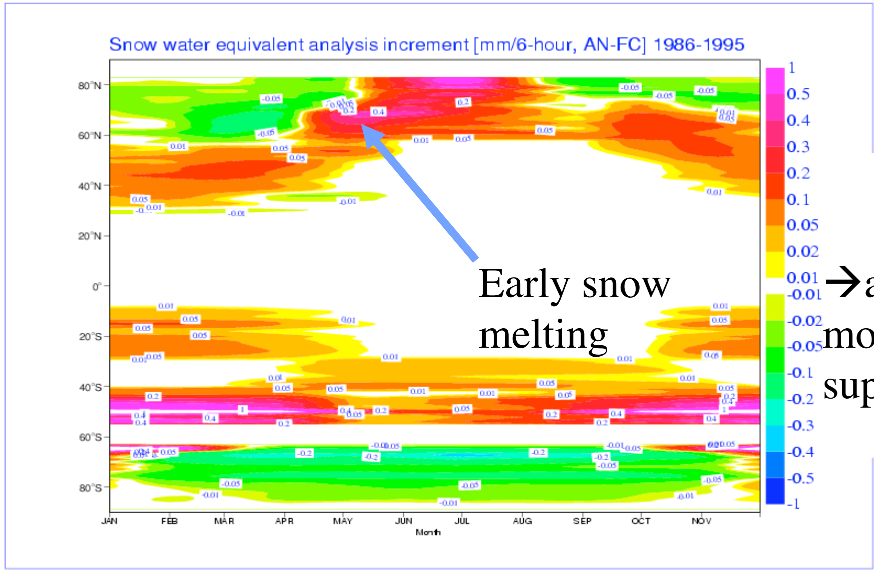
snow



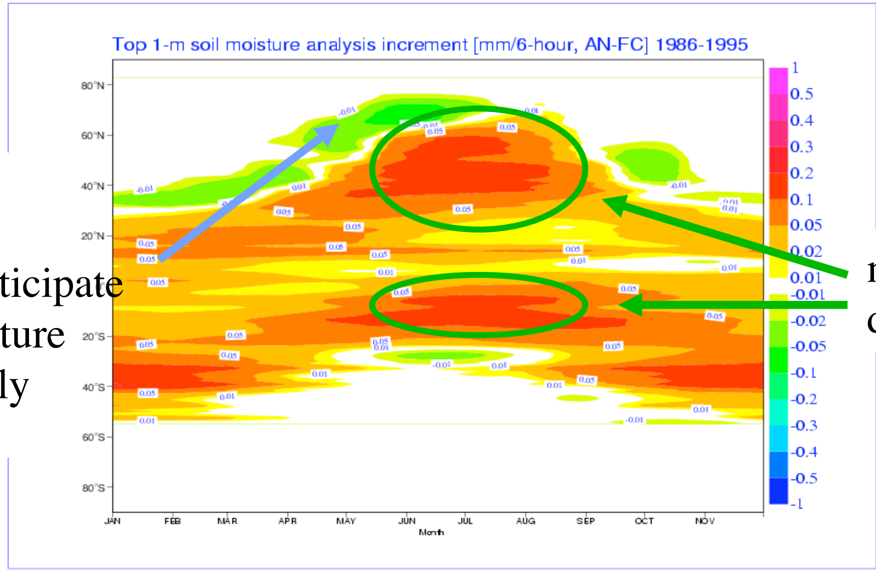


Soil moisture

- DA increments redistribute water and constraint near-surface errors

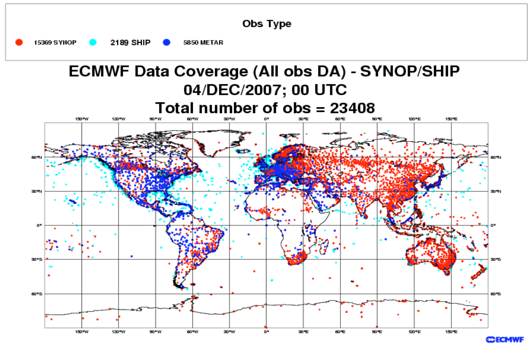


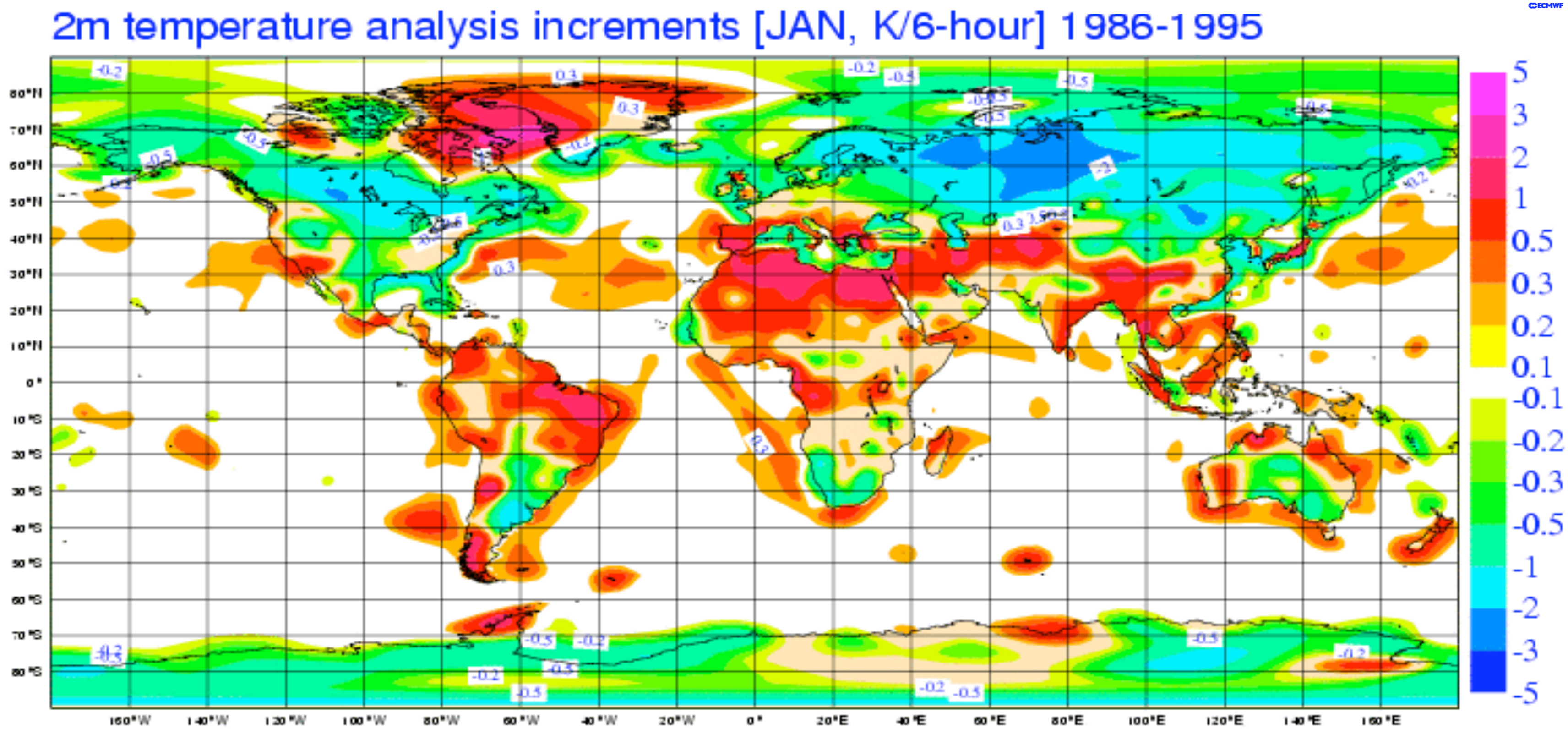
→anticipate moisture supply



moisture deficit

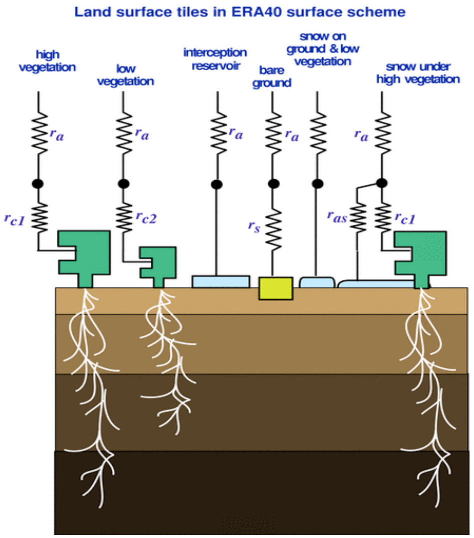
Screen level DA increments

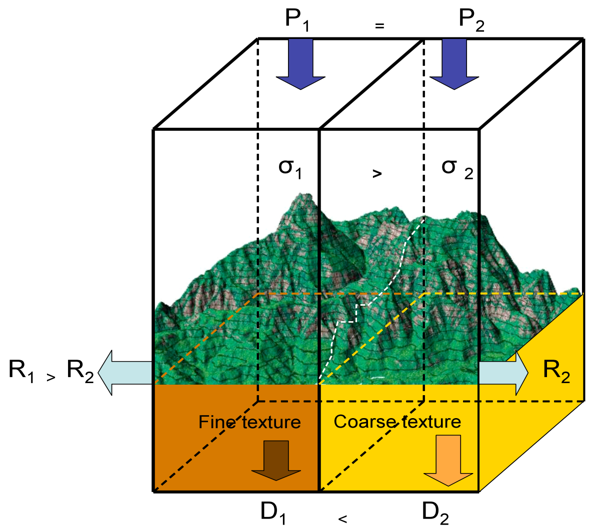




Land surface modelling

- HTESSEL (Improved Hydrology: validation at monthly scales over 41 large World basins and daily scales only on Rhone basin
- HTESSEL became operational the Nov. 2007

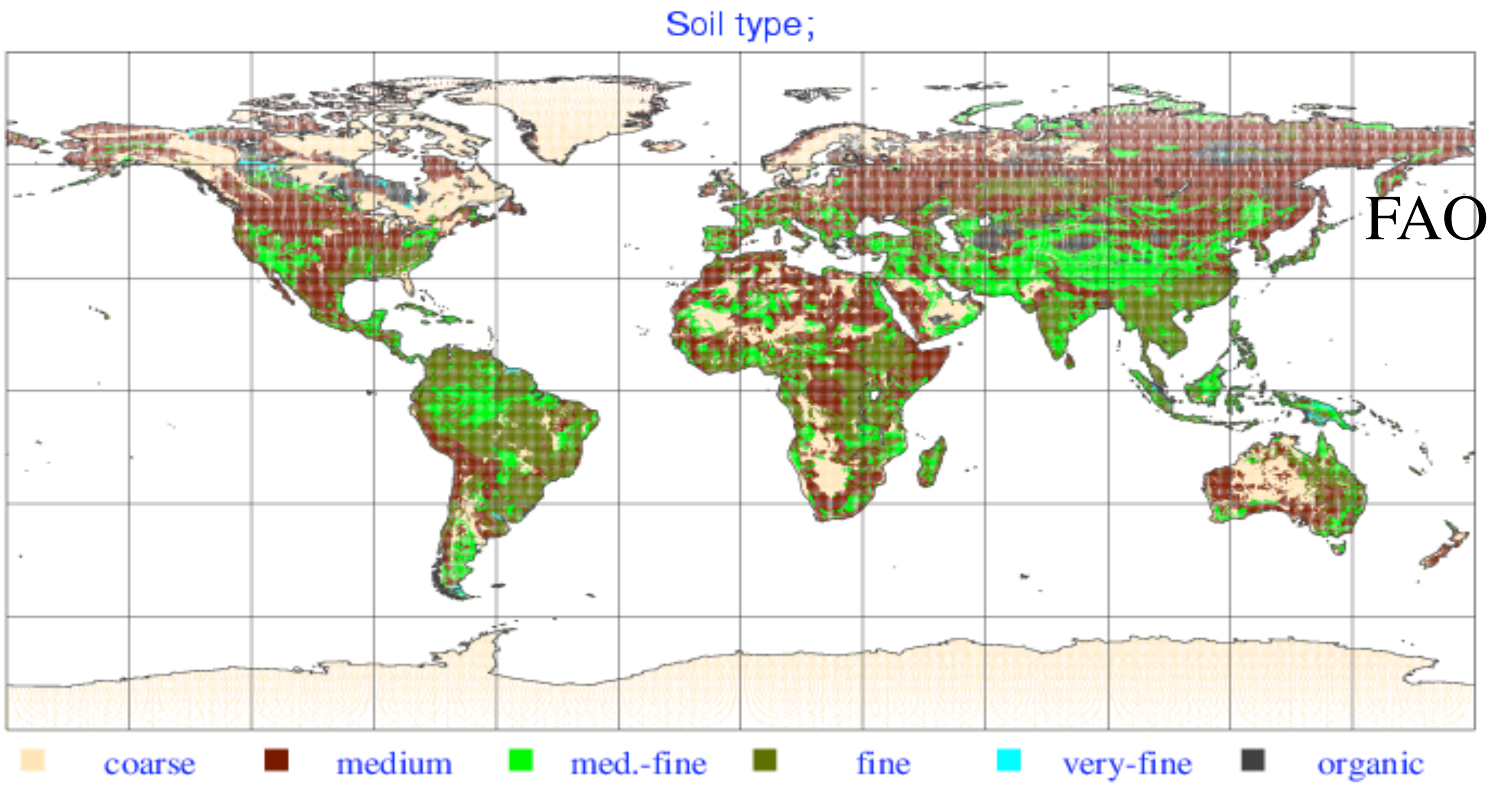




- Hydrology-TESSEL
  - Global Soil Texture Map (FAO)
  - New formulation of Hydraulic properties
  - Variable Infiltration capacity (VIC) surface runoff

- **Balsamo et al. 2008 (*J. of Hydromet.*), van den Hurk et al. 2003, Viterbo and Beljaars 1996**

A global soil texture characterizes diverse soil water regimes



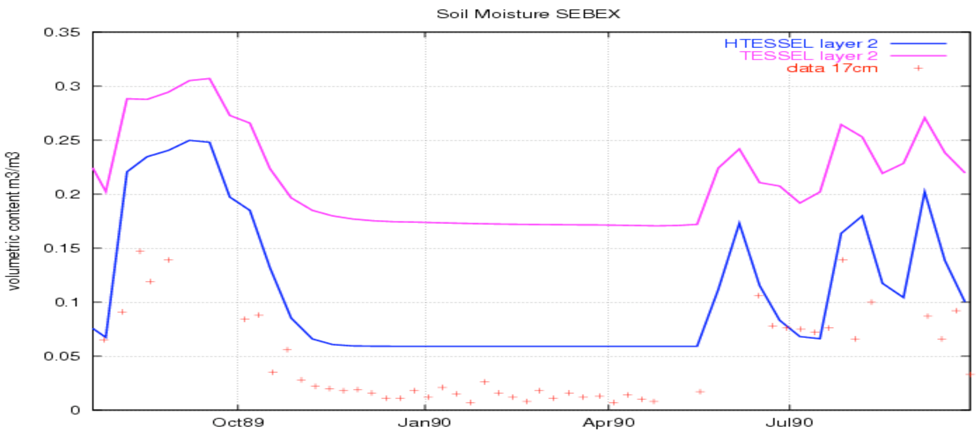
6 Dominant
Soil texture from FAO (2003)

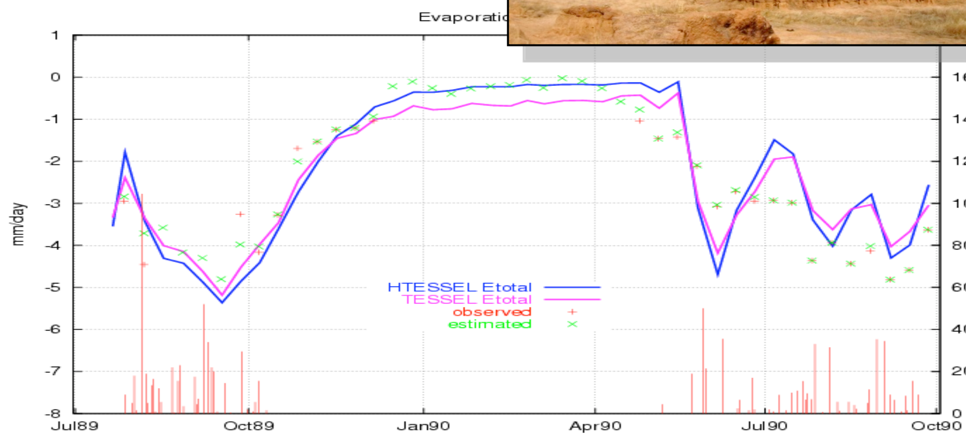
__Used to assign:__

hydraulic properties (for drainage and surface runoff) characterizing different soil water regimes.

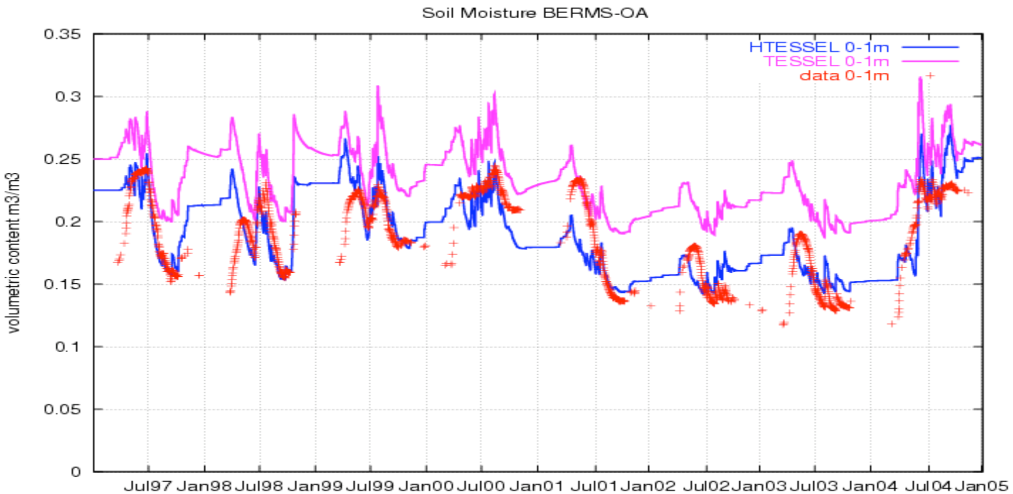
Improved soil moisture and evaporation

SEBEX (Savannah, Sandy soil)



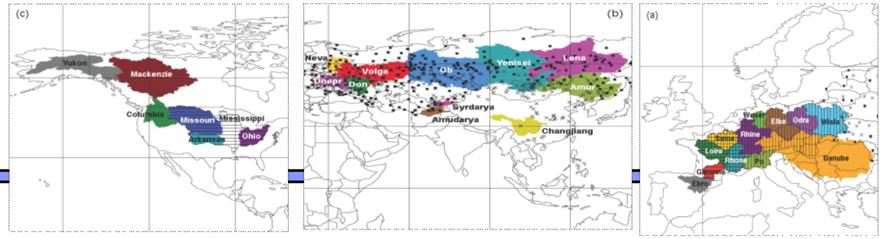


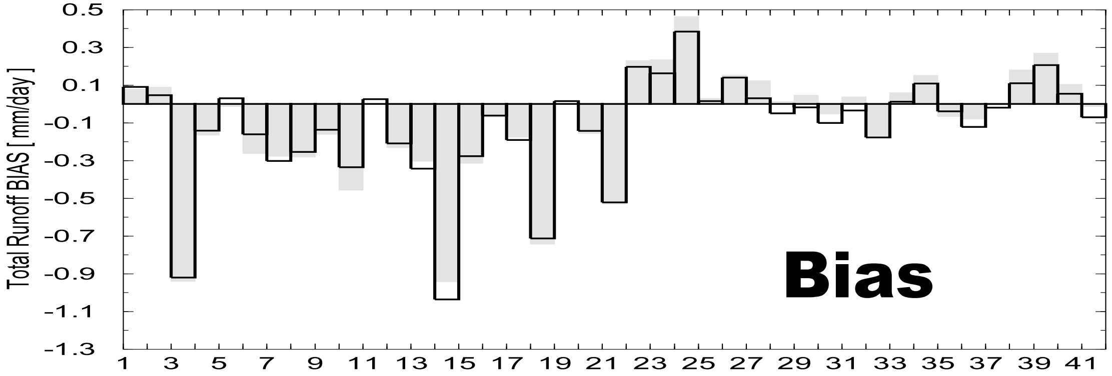
BERMS (Boreal Forest)

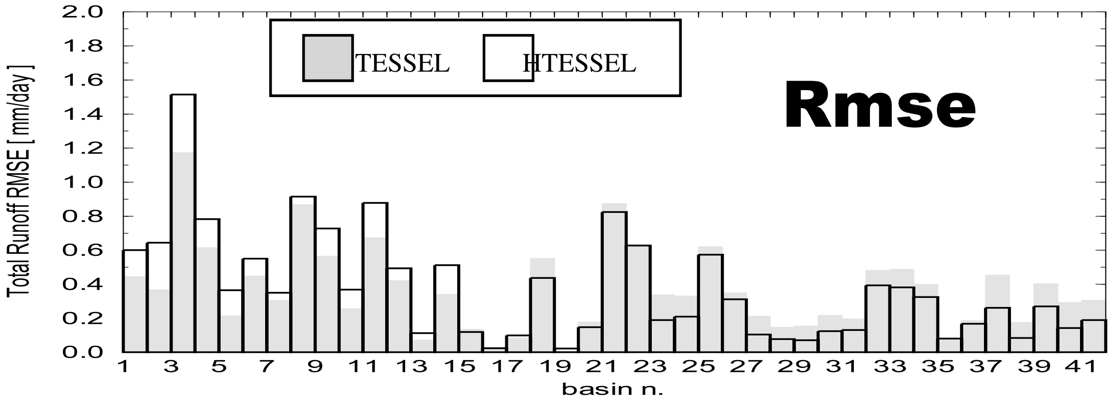


HTESSEL improves soil moisture and evaporation with respect to TESSEL in dry climates and leads to a better represented soil moisture inter-annual variability in continental climate

Improved river runoff

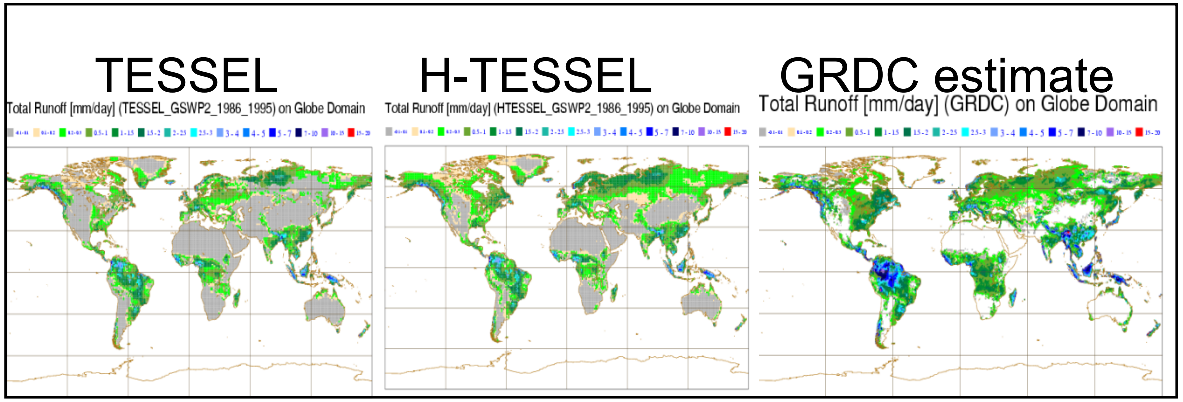






List of basins considered for the runoff verification

N. Basin	N. Basin
1 Ob 22 Volga	
2 Tura	23 Don
3 Tom	24 Dnepr
4 Podkamennaya-Tunguska	25 Neva
5 Irtish	26 Baltic
6 Amudarya	27 Elbe
7 Amur	28 Odra
8 Lena	29 Wisla
9 Yenisei	30 Danube
10 Syrdarya	31 Northeast-Europe
11 Yukon	32 Po
12 Mackenzie	33 Rhine
13 Mississippi	34 Weser
14 Ohio	35 Ebro
15 Columbia	36 Garonne
16 Missouri	37 Rhone
17 Arkansas	38 Loire
18 Xhangjiang	39 Seine
19 Murray-darling	40 France
20 Selenga	41 Central-Europe
21 Vitim	



HTESSEL improves river runoff (qualitatively and quantitatively) on major World river basins where the soil control is dominant. Snow errors still affect runoff at Northern latitudes.

In-land water bodies (in progress)

- The HTESSEL scheme (CY33R1) has been extended to consider lakes.
- Both sub-grid lakes and grid-point lakes can be simulated.
- The FLAKE (Mironov, 2003) shallow-lake model is implemented (thanks to E. Dutra V. Stepanenko, P. Viterbo, P. Miranda)
- Adapted to simulate dynamics of lakes up to 50m depth (but can be used for deeper water bodies as the depth sensitivity saturates).

Global simulations set-up

•**Forcing:**

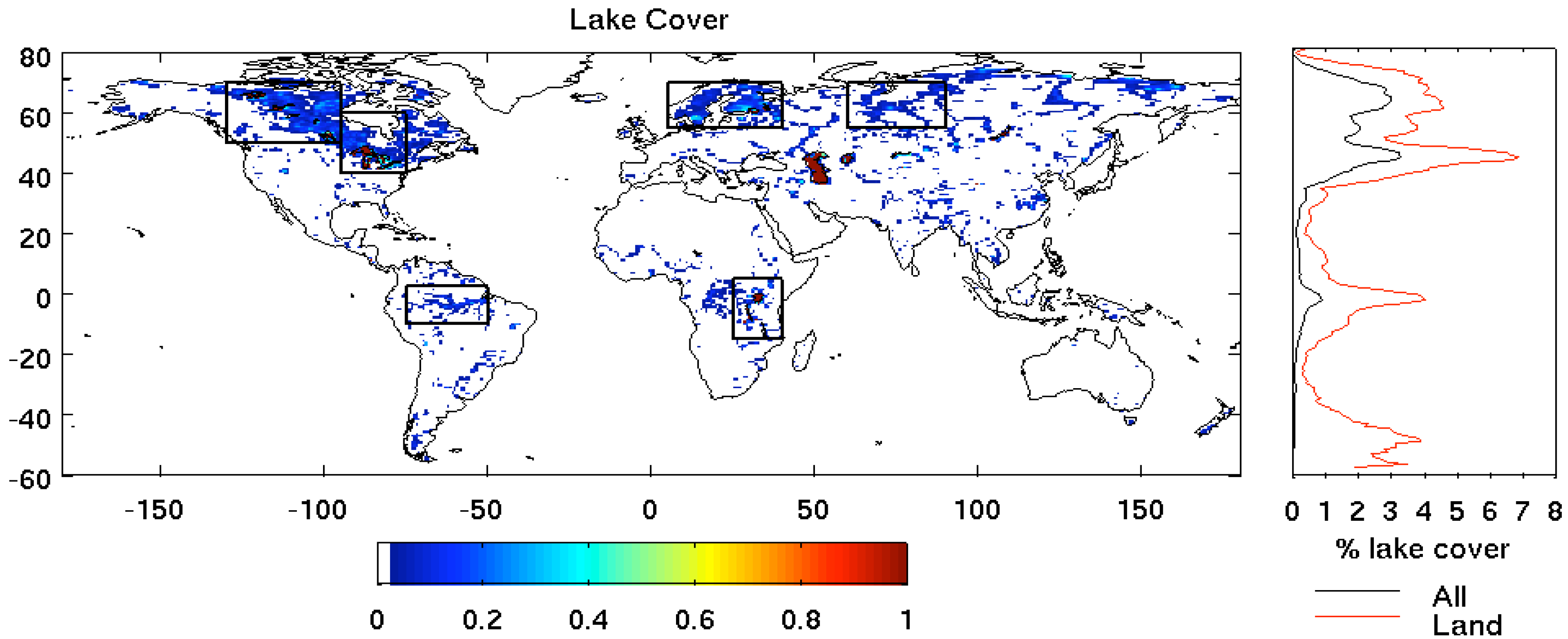
•**Near Surface meteorology and radiative fluxes from ERA-INTERIM 1989-1998;**
•**Spatial resolution Gaussian reduced N128 (0.7ºX0.7º);**

•**Surface/Lake characteristics:**

• **Surface coverage == ERA-INTERIM (including lake cover);**
• **Lake depths -> constant = 10, 30 and 50 meters;**

•**Initial conditions:**

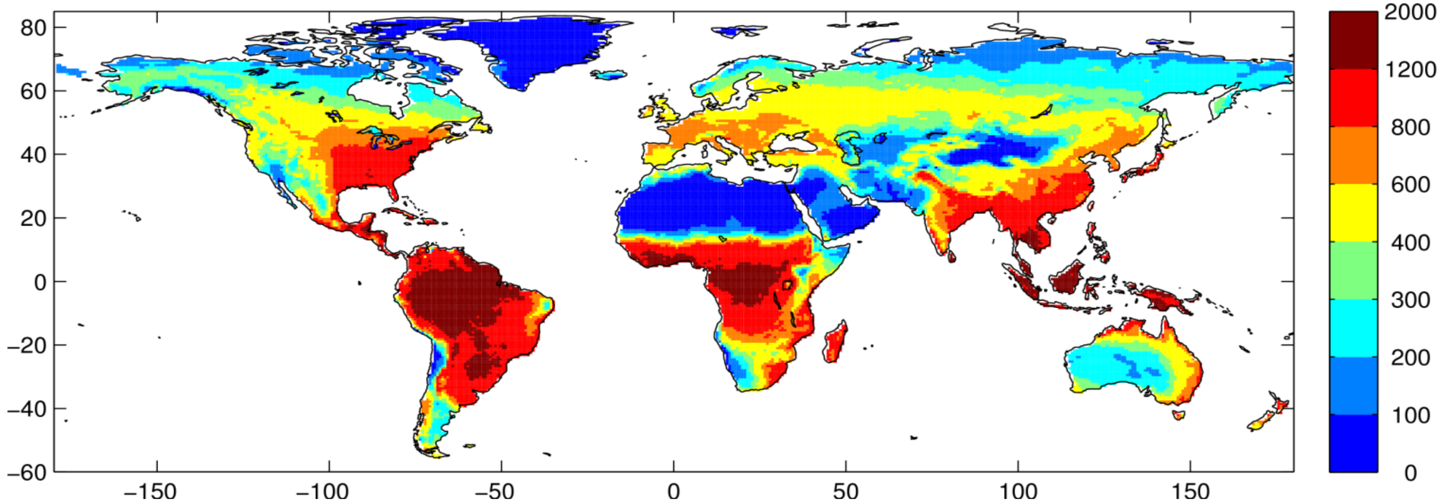
• **4 years spin-up with 1989 forcing**



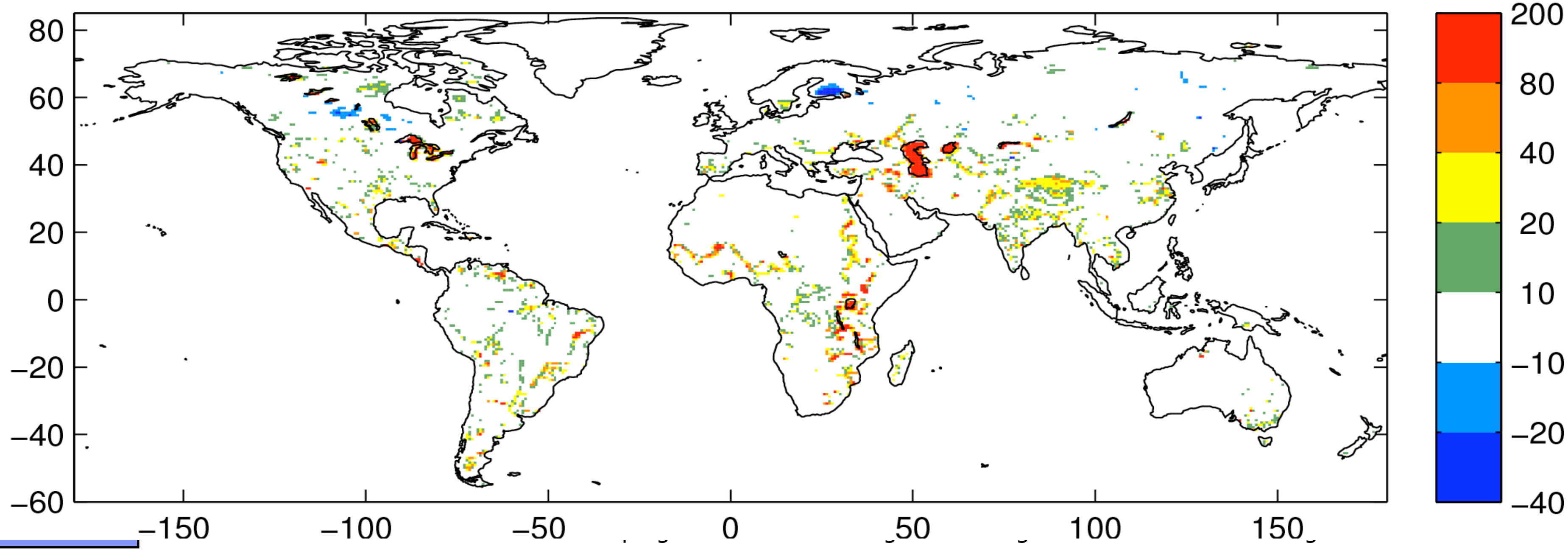
Global impact on Evaporation

Colorbar with different spacing!

Evap HTESSEL (no lake) [mm/year]



Evap WL-NL [mm/year]



The GLACE2 experiment at ECMWF

B. van den Hurk, G. Balsamo, F. Doblas-Reyes, F. Vitart

- The aim:
  - Assess predictability due to the “realistic” Land Surface I.C. in a VAREPS-type run (2-month, 10-members, 10-starting dates, 10-year)
- The method:
  - Use GSWP2(“realistic land surface state to initialize HTESSEL)
  - Use “unrealistic” soil moisture (an Open Loop 10-year sim.)

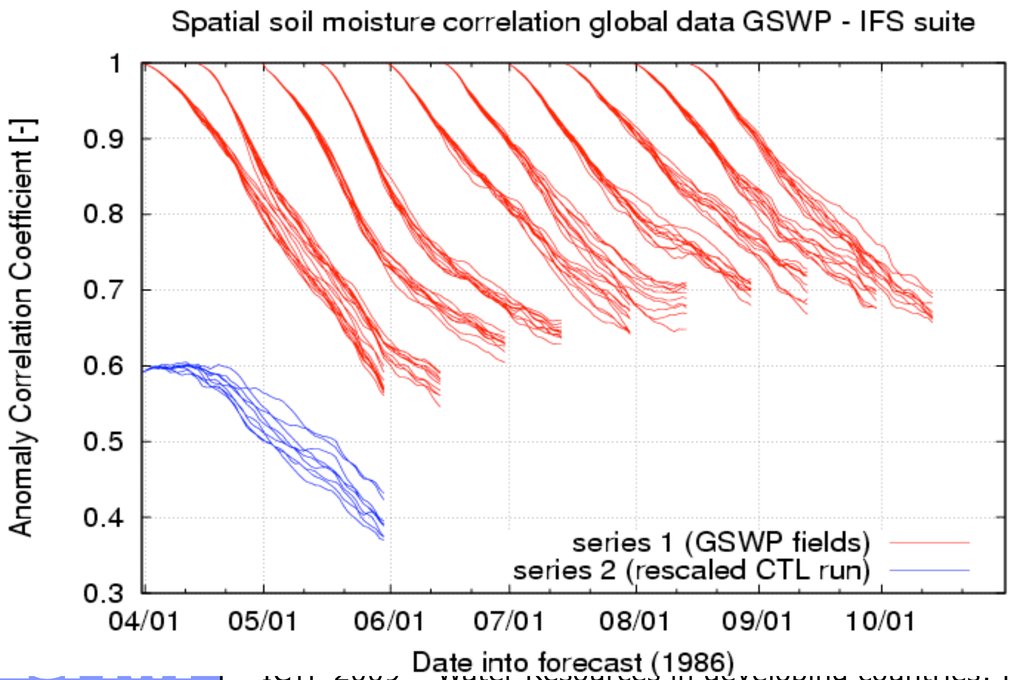


Figure (courtesy of B. van den Hurk)

Soil moisture ACC (calculated against GSWP2 derived soil moisture)

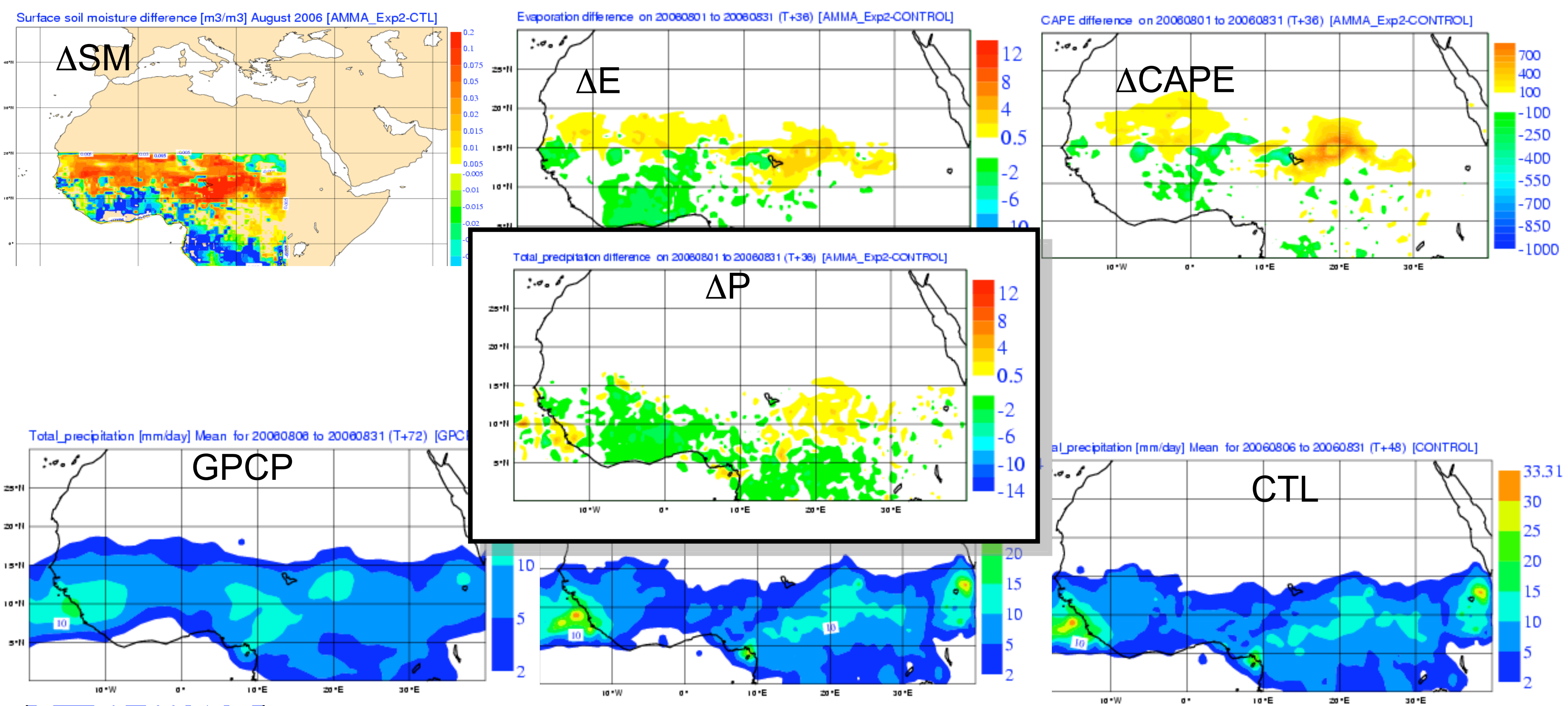
10-date 10-member for 1986

Soil moisture sensitivity in AMMA

A. Agusti-Panareda, G. Balsamo, A. Beljaars

(report *submitted as AMMA deliverable*)

- "Realistic" soil moisture merged onto AMMA-reanalysis for August 2006



AMMA-ALMIP-MEM project soil moisture & µwaves Tb

P. de Rosnay, A. Boone, M. Drusch, T. Holmes, G. Balsamo, many others

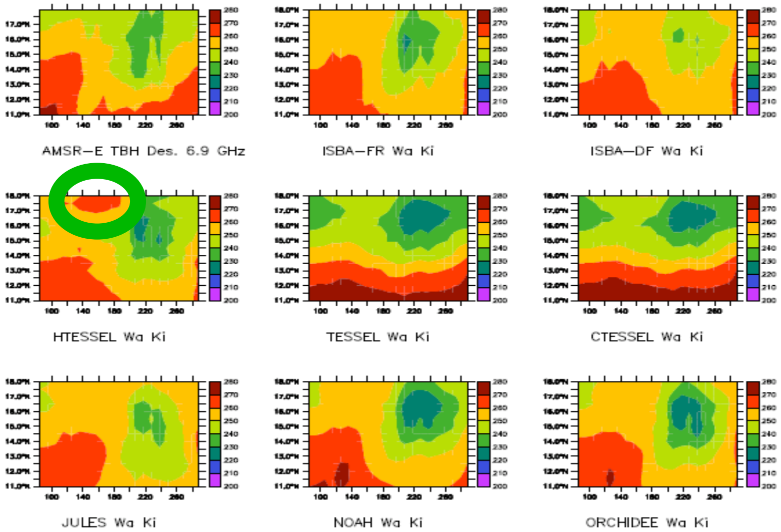
ALMIPers

(paper *submitted to IGARSS*)

- AMMA-ALMIP-MEM first spatial verification of SM/Tbs C-band

AMSR-E C-band Tb

HTESSEL



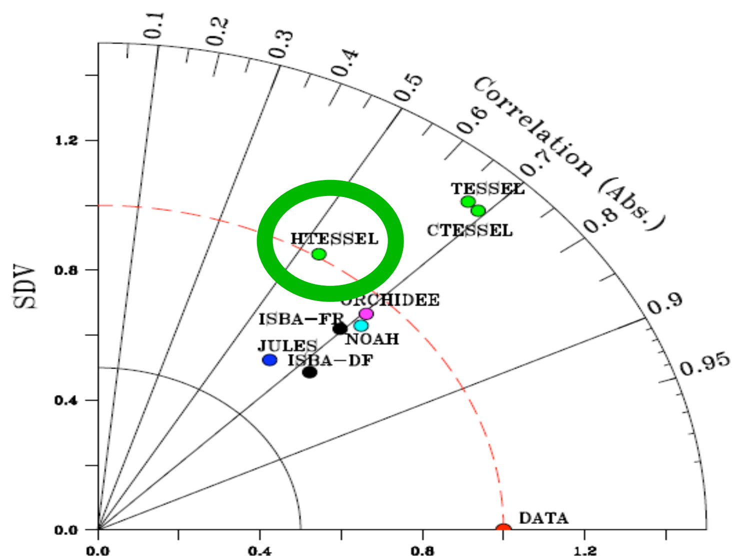
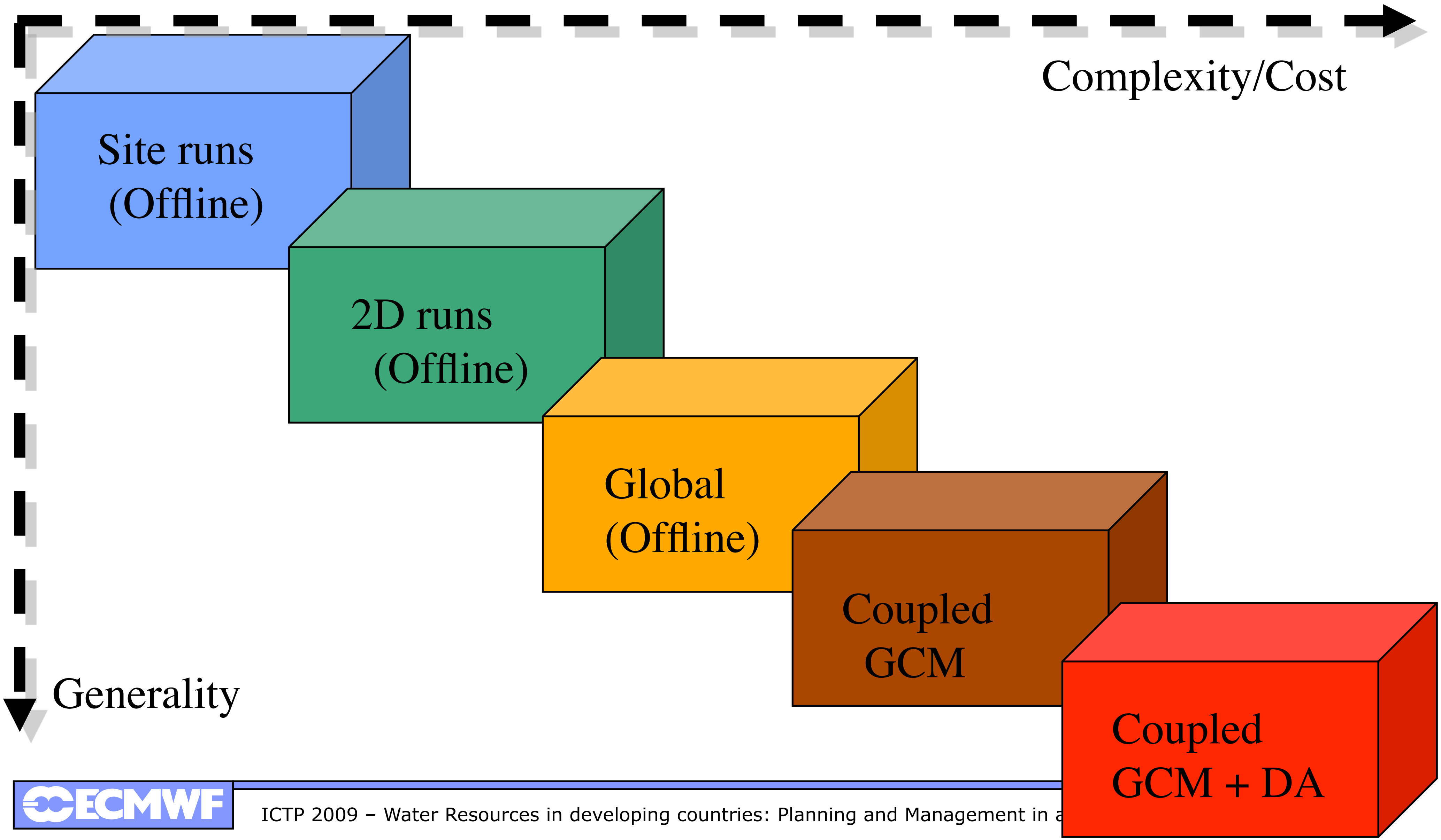


Fig. 2. Time-latitude diagram of the horizontally polarized brightness temperature (K) observed by AMSR-E and simulated by ALMIP-MEM. Time axis is in Day of Year. For each ALMIP-MEM simulation a bias correction was applied, specifically computed for each LSM when comparing simulated and observed brightness temperature.

Result: HTESSEL+CMEM is un-biased and reproduces satellite obs. statistics!

Question: What happens in HTESSEL that deteriorates correlation?

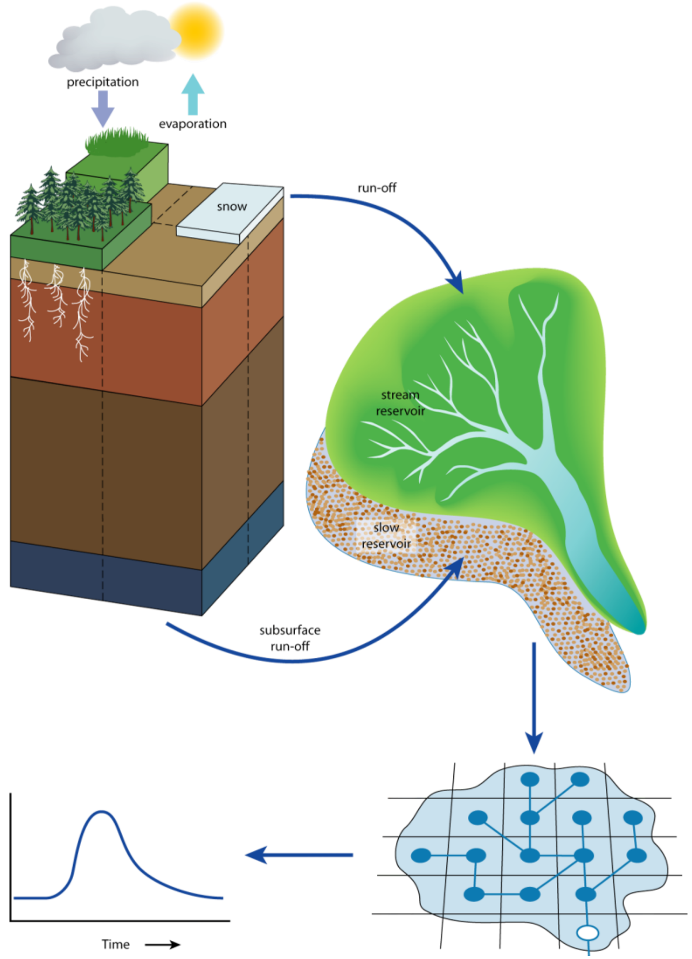
Verification Strategy for surface physics



HTESSEL and hydrological applications

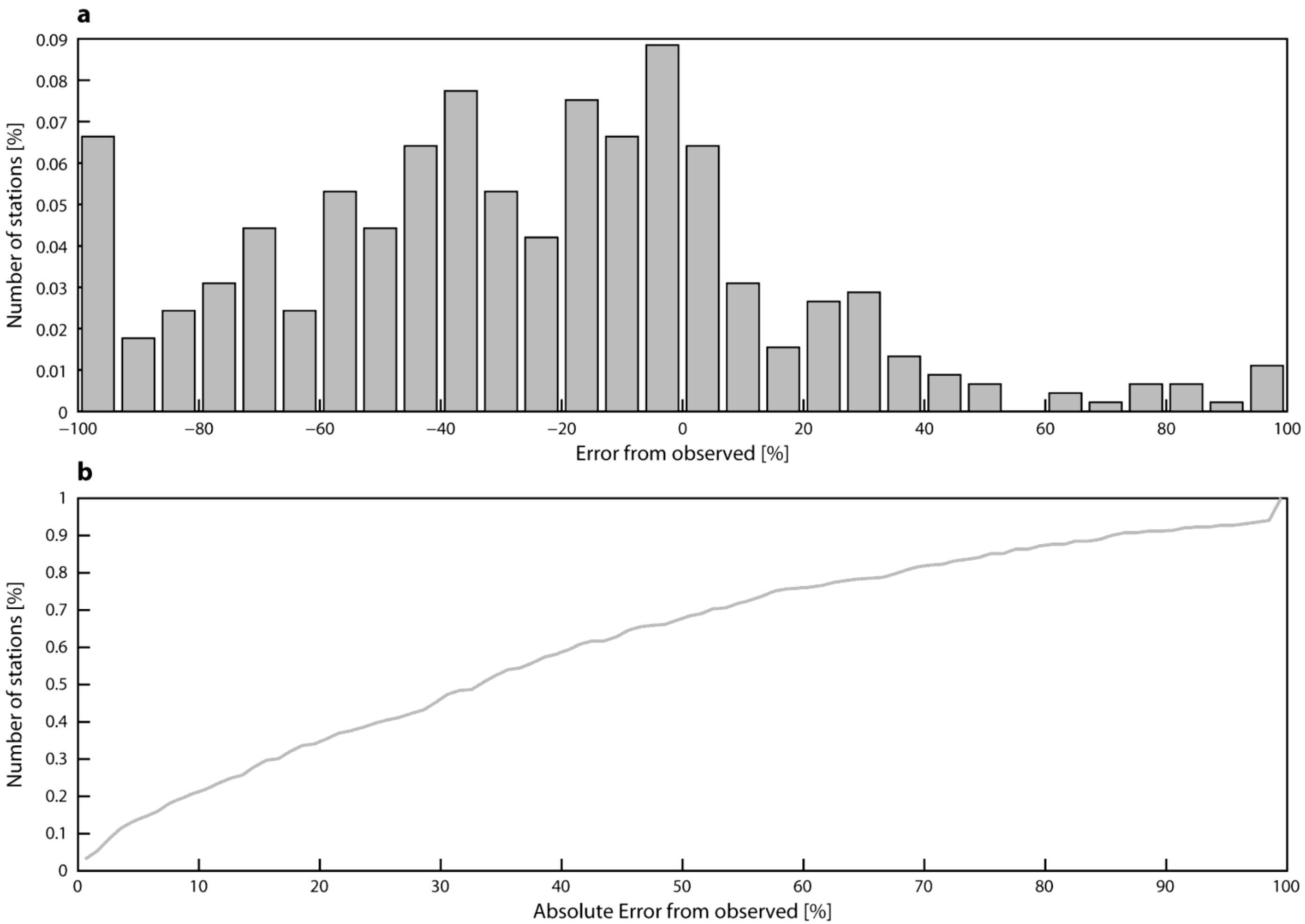
F. Pappenberger, G. Balsamo, H. Cloke, N.D. Thanh, T. Oki (*submitted to Int. J. of climatol.*)

- A routing scheme [TRIP2 evolution of TRIP , Oki and Sud, 1998)] is coupled to HTESSEL to account water path into rivers.
- The aim is to assess skill of the land surface models water output (Runoff) for river discharge modelling and to evaluate the possibility of a global flood alert system



Global Routing

Global Evaluation is difficult as a large proportion of stations are unsuitable for comparison

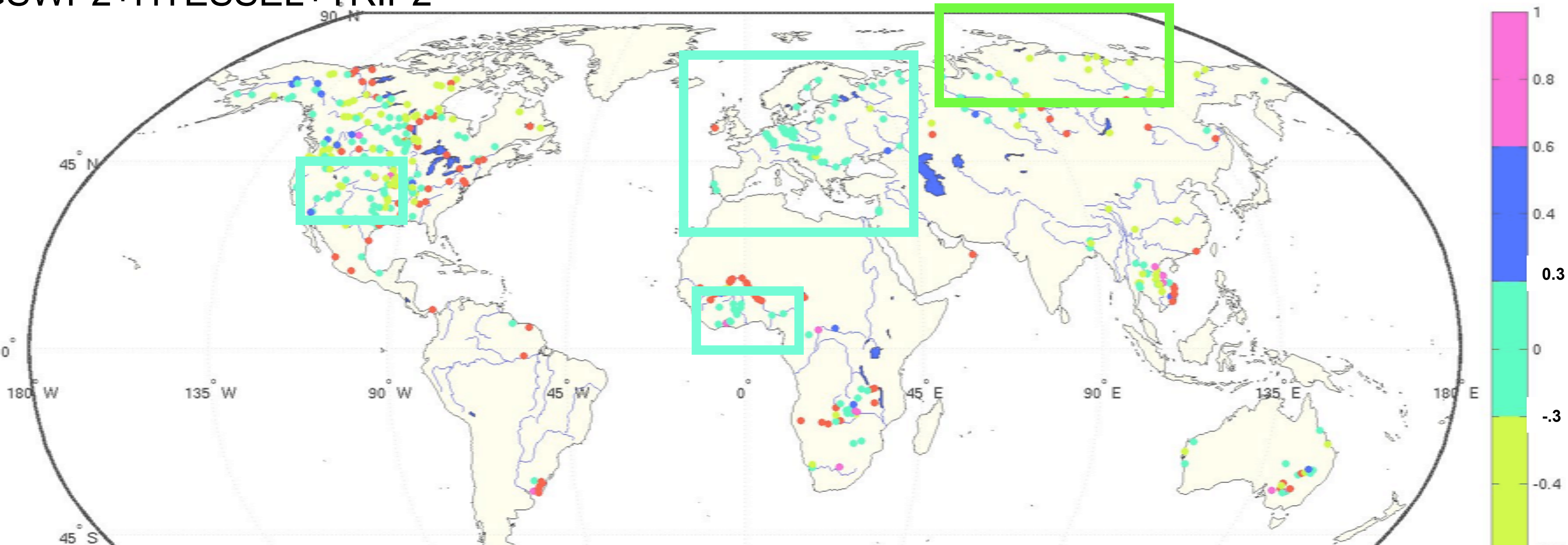


Histogram and cumulative distribution function of observed mass balance error (precipitation – discharge, 1o year record) *vs* the number of stations for HTESSEL-TRIP2. A maximum error of 100% and a minimum error of -100% have been imposed for display purposes

Global Routing

F. Pappenberger, G. Balsamo, H. Cloke, N.D. Thanh, T. Oki

GSWP2+HTESSEL+TRIP2



POWERFUL VERIFICATION OF LAND SURFACE HYDROLOGICAL CONSISTENCY

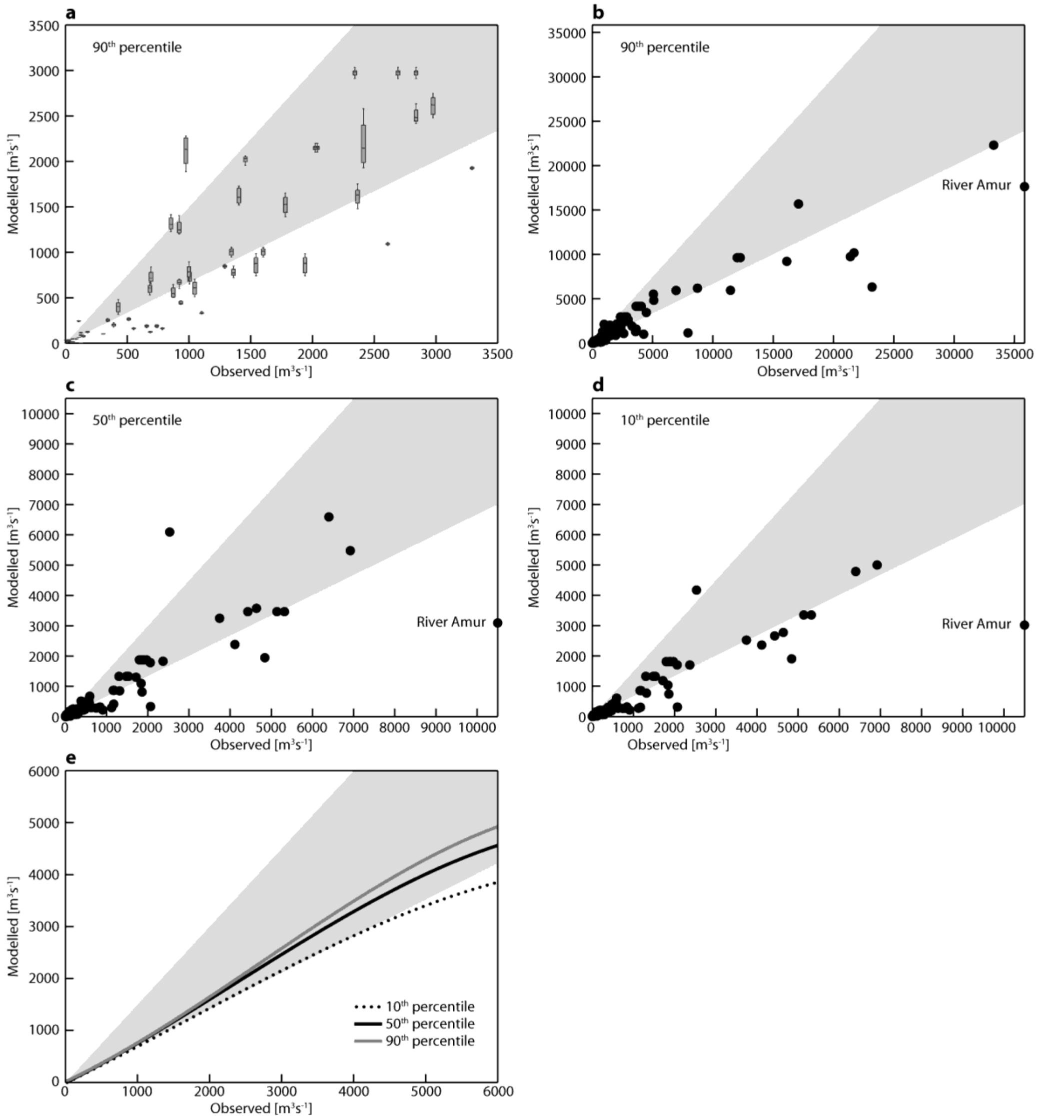
MODELLING THE WATER CYCLE (IMPORTANT FOR CLIMATE)

POTENTIAL FOR HYDROLOGICAL FORECASTS

Mass balance error in HTESSEL (greenish is good performance |ERROR| <30%) measured at river hydrometric stations (data courtesy of GRDC)

Global routing

Figure of observed versus modelled discharge. The grey shaded area in all figures indicates uncertainty in the observations (+- 20% of the observed value). Figure 5a shows 90% quantile of the predicted flow up to 3500 m3s-1 for selected rivers is presented by a box plot. The box has lines at the lower quartile, median, and upper quartile values. Whiskers extend from each end of the box to the 5th and 95th percentile of the data. The box is located on the abscise in respect to the observed flow for the 90th percentile. Figure (b) is the same as figure (a) however the axis extend to 35,000 m3s-1 and only the median of each modelled flow is presented. Figure (c) and (d) shows the median of the 50% and 10% quantile of the forecasted flow for selected rivers is presented by dots respectively. Figure (e) shows fitted cubic polygons through the three quantiles (10%, 50% and 90%) of figure 5b-d. Axes cut at 7000 m3s-1 to eliminate influence of high discharge outliers



Global Routing

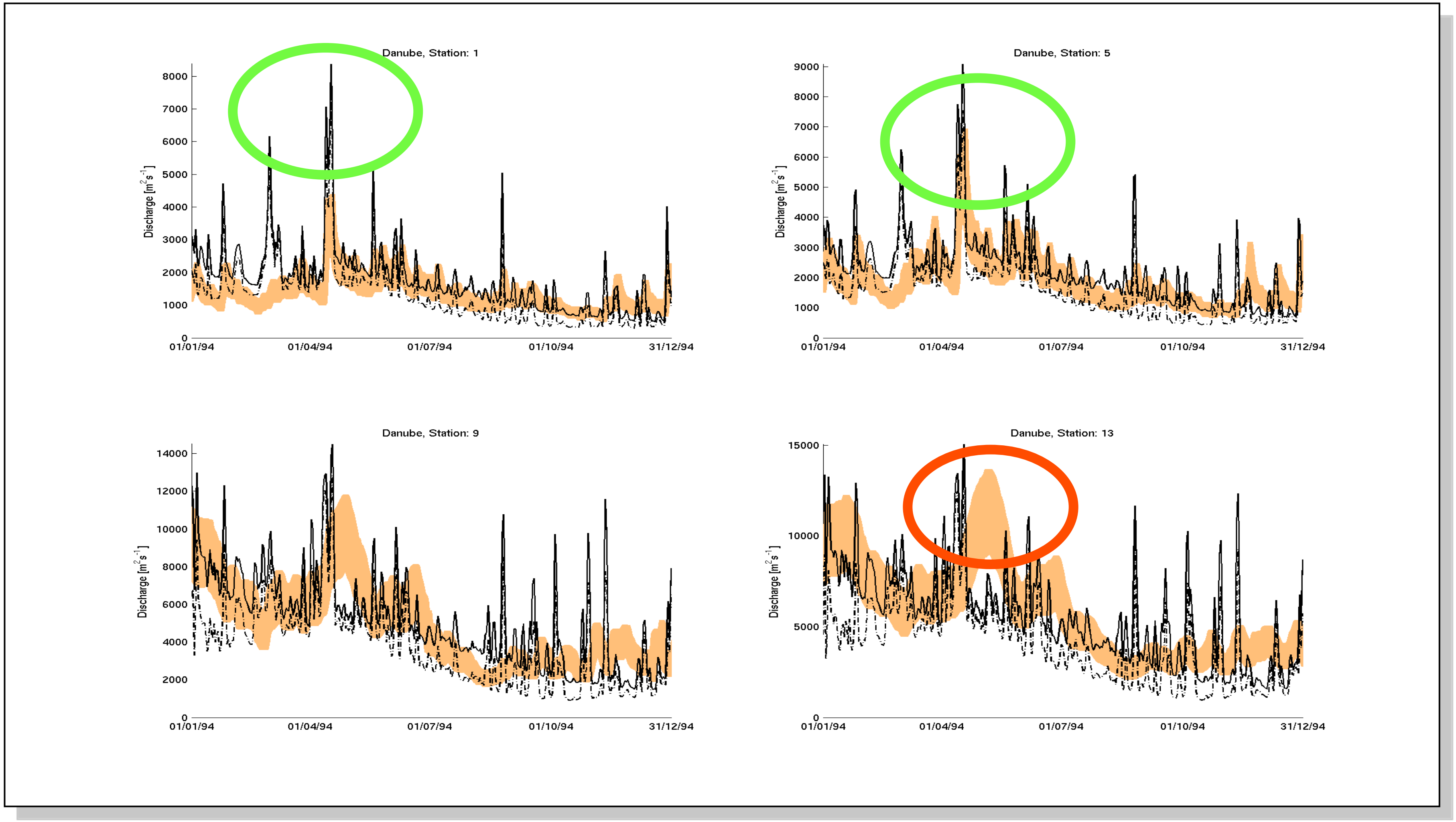


Figure 10: Observed and modelled hydrographs (using HTessel) for four stations on the Danube river for the year 1994. The orange area indicates the observed data with its uncertainties. The dotted black line represents the 5th and 95th percentiles of the modelled flow.

Conclusions

- Soil hydrology and snow hydrology in NH are profoundly linked both for timing fresh-water recirculation and for governing the strength of land surface atmosphere feedbacks.
- Reanalysis are fundamental tools for improving the understanding of these mechanisms.
- “Better” physics for land surface processes in global models can be verified in a step-wise procedure where core RD is done on sites and regional experiments, and generality is achieved with a much higher computational cost (as necessary step).
- Land surface is characterized by longer memory (w.r.t.) atmosphere and that puts even stronger emphasis on the initial condition and on development of LDAS.
- Preliminary results for land surface predictability experiments confirmed that joint effort of land surface modelling and analysis can bring benefit and large experiments as GLACE2 will try to quantify it.
- Further data assimilation of EO data for land surface will highlight model shortcomings and guide future developments.

Thanks for listening!

- References can be provided on request, just email me florian.pappenberger@ecmwf.int

" In case of flooding "