Land surface modelling activity at ECMWF

Gianpaolo Balsamo

Outline

Land surface hydrology
Soil moisture sensitivity
Carbon and vegetation
Cold processes
In-land water bodies and SSTs
Land assimilation aspects

Acknowledgements to:

Soumia Serrar, Sebastien Lafont, Lionel Jarlan (Carbon), Florian Pappenberger (River discharge), Emanuel Dutra, Pedro Viterbo, Pedro Miranda, Victor Stepanenko (Snow/Lakes), Anton Beljaars (Antarctica), Patricia de Rosnay, Matthias Drusch, Klaus Scipal (Soil moisture), Anna Agusti-Panareda (SM/P sensitivity), Bart van den Hurk (GLACE2), and others

Role of land surface

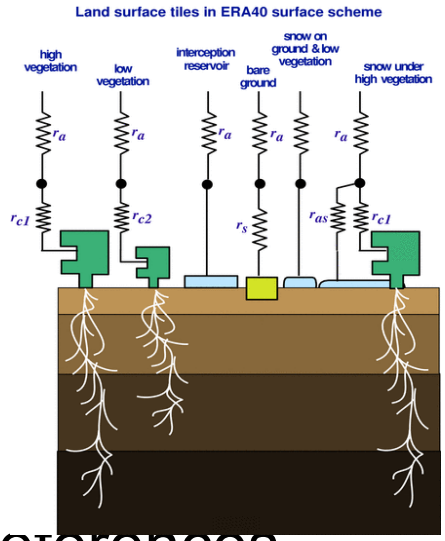
- Numerical Weather Prediction models need to provide near surface weather parameters (temperature, dew point, wind, low level cloudiness) to their customers.

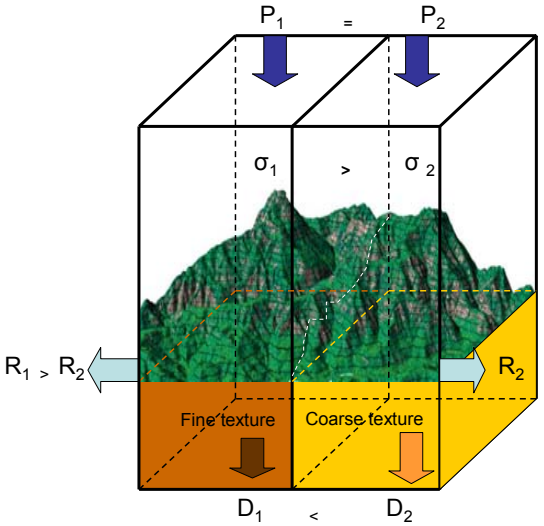
ECMWF model(s) and resolutions

	Length	Horizontal resolution	Vertical levels	Remarks
– Deterministic	10 d	T799 (25 km)	L91	00+12 UTC
– Ensemble prediction	15 d	T399 (50 km)	L62	2x(50+1)
– Monthly forecast coupled)	1 m	T159 (125 km)	L62	(Ocean
Since 11 March 2008				
– Monthly/VarEPS (N=51)	0-10d	T399(50 km)	L62	(SST tendency)
	11-32d	T255(80 km)	L62	(Ocean coupled)
– Seasonal forecast	6 m	T95 (200 km)	L40	(Ocean coupled)
– Assimilation physics	12 h	T255(80 km)/	L91	T95(200 km)

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

References

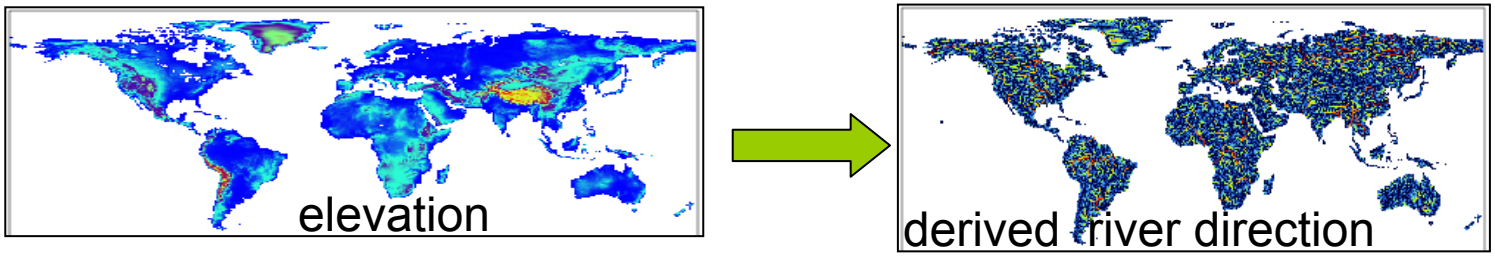
- Balsamo et al. 2008, *ECMWF tech. memo.* 563, also to appear in *J. of Hydromet.*)

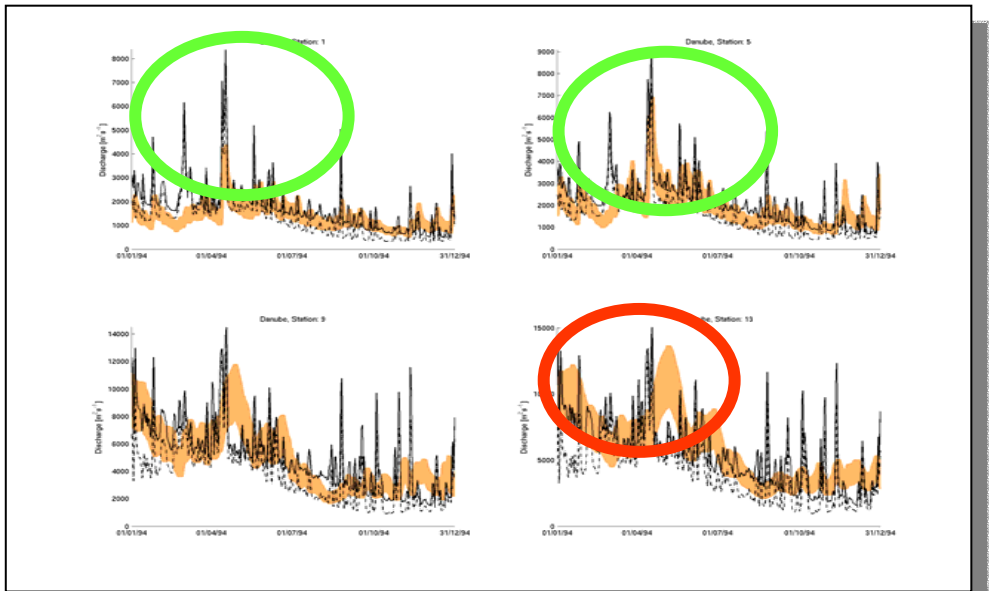
HTESSEL and hydrological applications

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

(paper *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





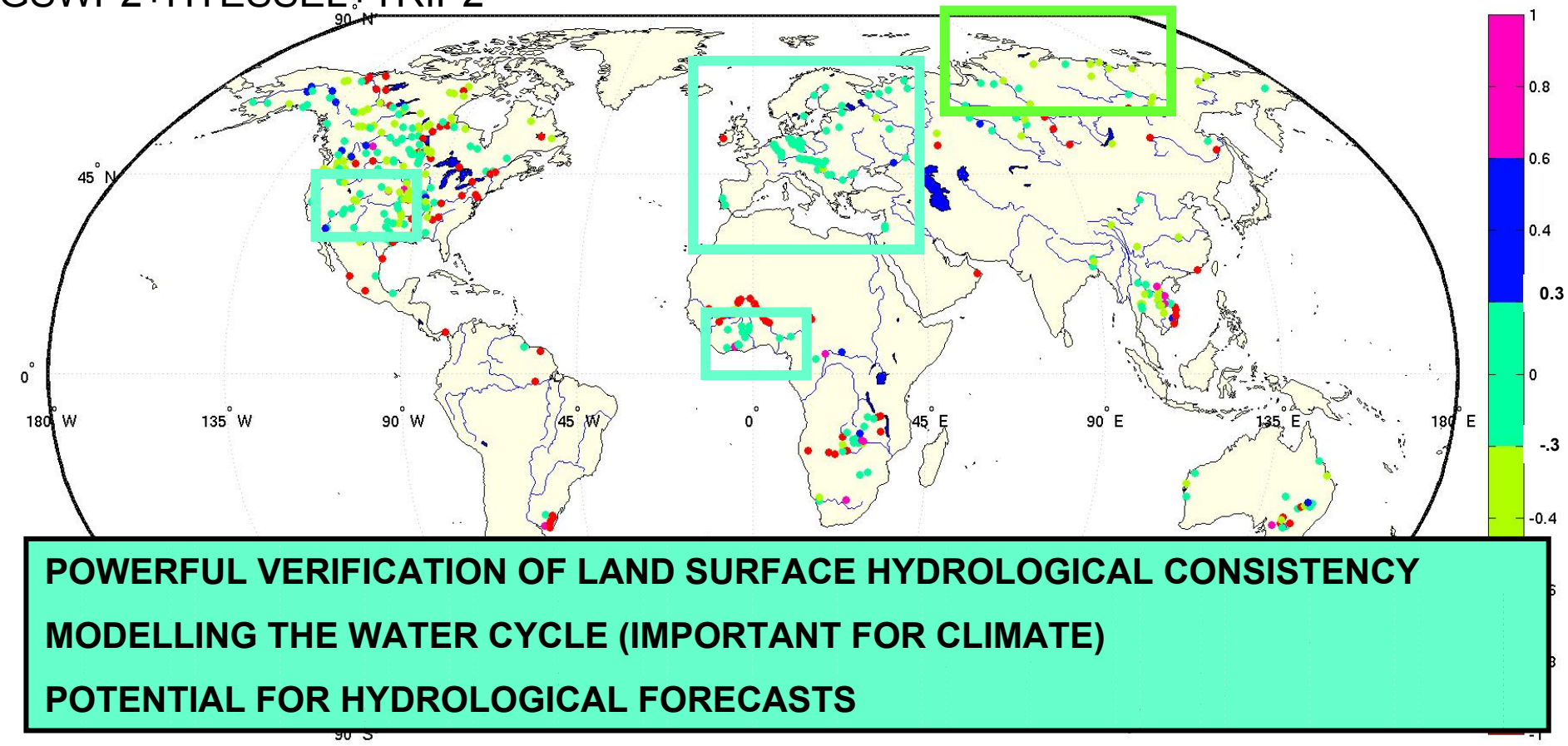
GSWP2+HTESSEL+TRIP2

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.

HTESSEL and hydrological applications

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)**

Soil Moisture & predictability (the GLACE2 experiment)

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

- 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.)

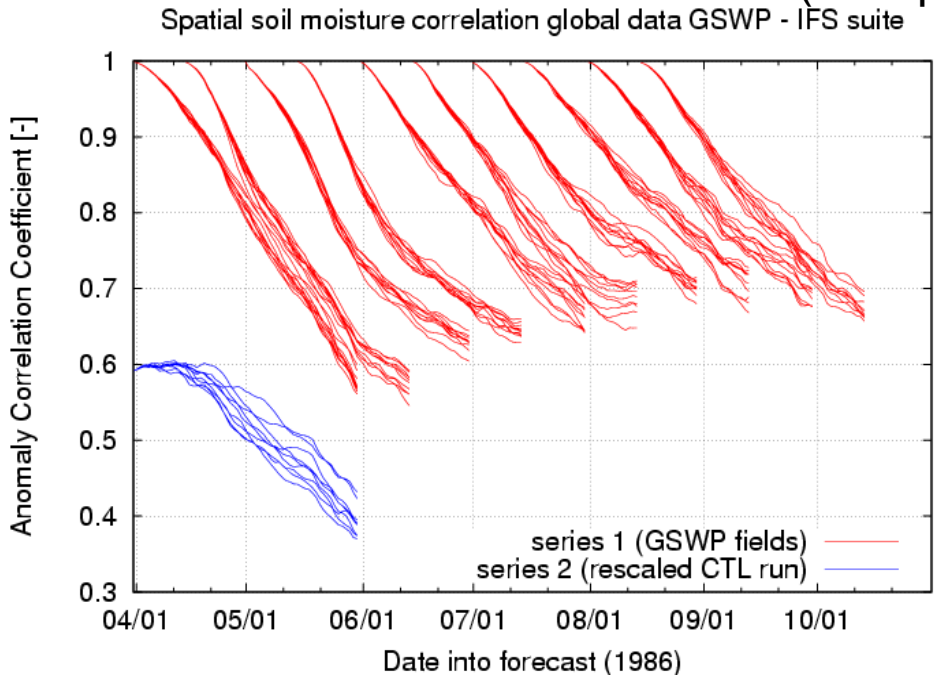


Figure (courtesy of B. van den Hurk)

Soil moisture ACC (calculated against GSWP2 derived soil moisture)

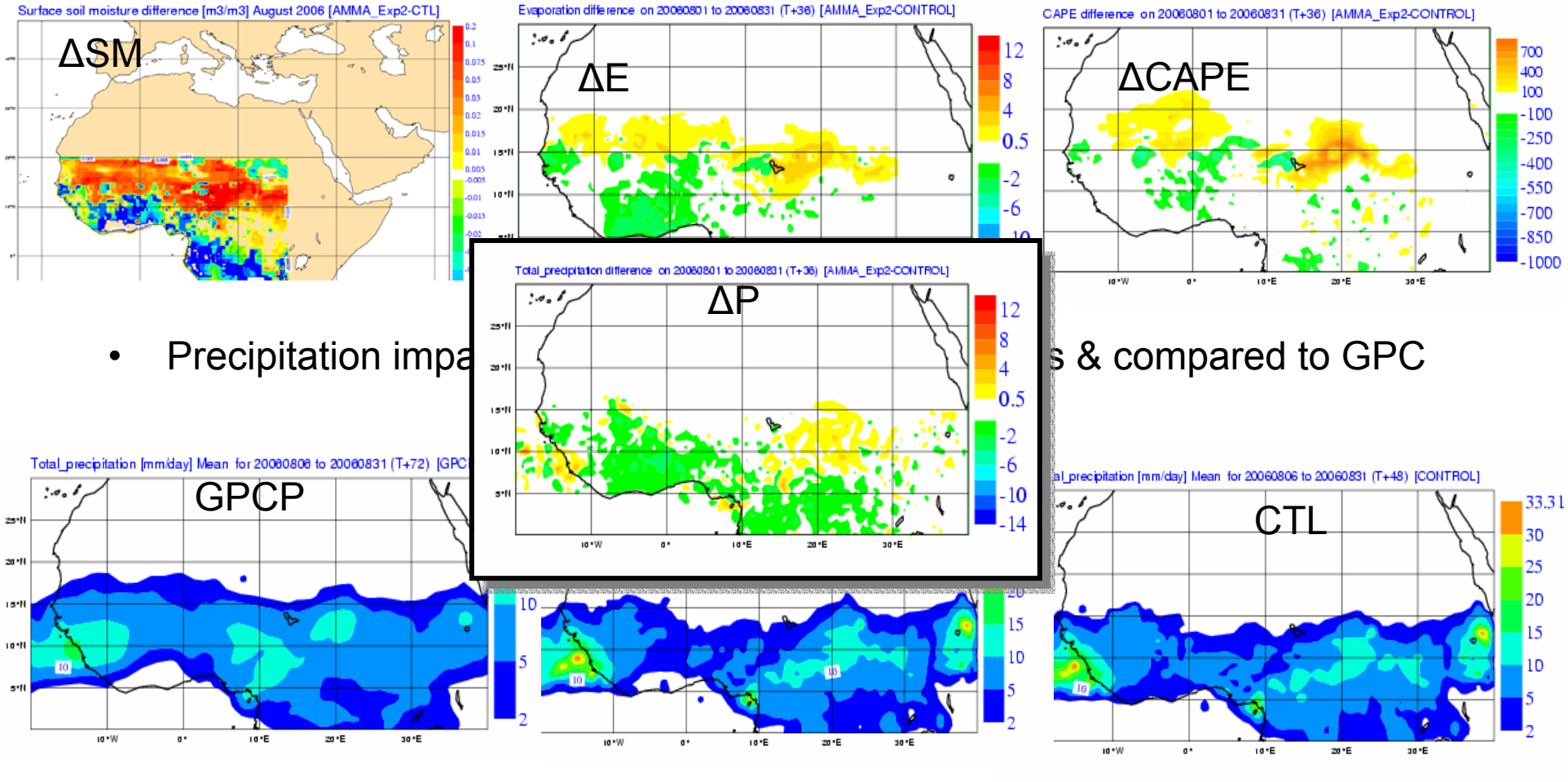
10-date 10-member for 1986

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



- Precipitation impa s & compared to GPC

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

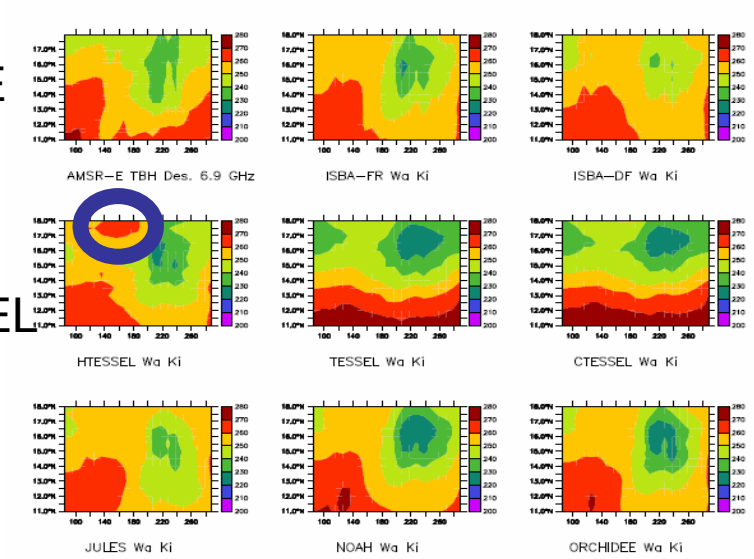
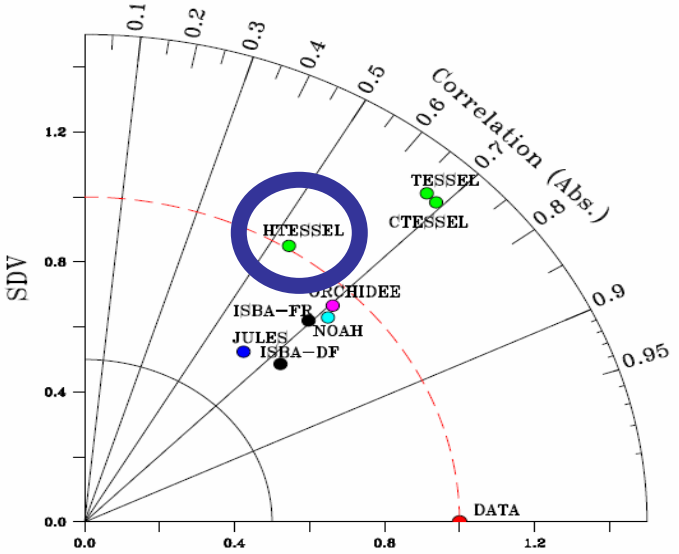


Fig. 2. Time-latitude diagram of the horizontally polarized brightness temperature (K) observed by AMSR-E and simulated by ALMIP-MEM. Time axis is in Day of Year. For each ALMIP-MEM simulation a bias correction was applied, specifically computed for each LSM when comparing simulated and observed brightness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



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

Question: What happens in HTESSEL that deteriorates correlation?

CTESSEL global evaluation

S. Serrar, S. Lafont, L. Jarlan, G. Balsamo

- Based on offline simulation of C-TESSEL 2001-2005 driven by IFS op. forecasts (using FC+12-36-hour concatenated to build 3-hourly time-series of atmospheric forcing).
- The Net Ecosystem Exchange is calculated by equilibrium on 2001-2005 (this procedure is needed to estimate the Soil respiration unknown and not modelled in CTESSEL)
- The LAI is freely evolving (built by the photosynthesis)

- CTESSEL link to the web page

Question: Is CTESSEL offline driven by OPER capable of providing CO2 fluxes (alternative to CASA climatology)?

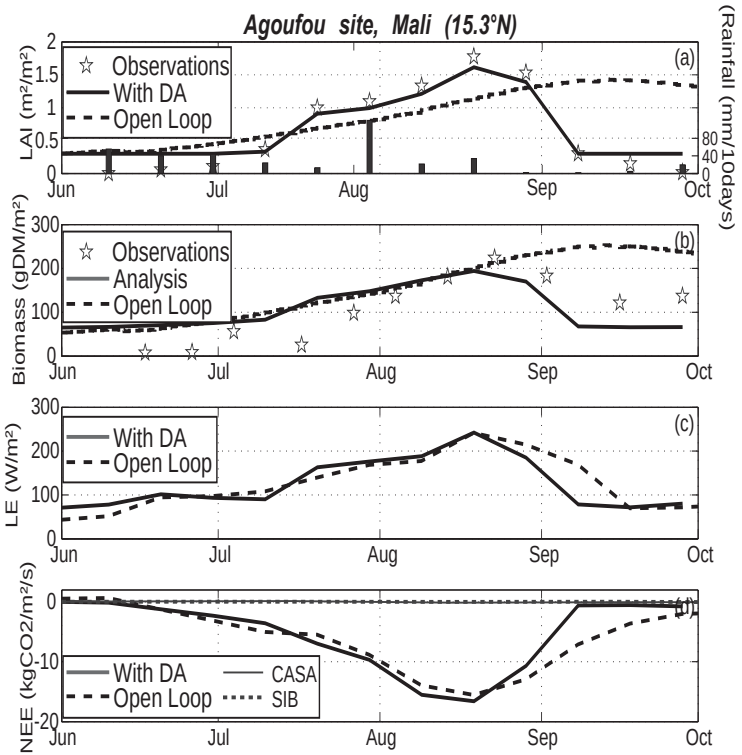
Results: Accuracy not globally verified. Concentrations drifts! Next step: a more constrained CTESSEL for test within GEMS. Clim. LAI and annually equilibrated fluxes.

CTESSEL in AMMA project

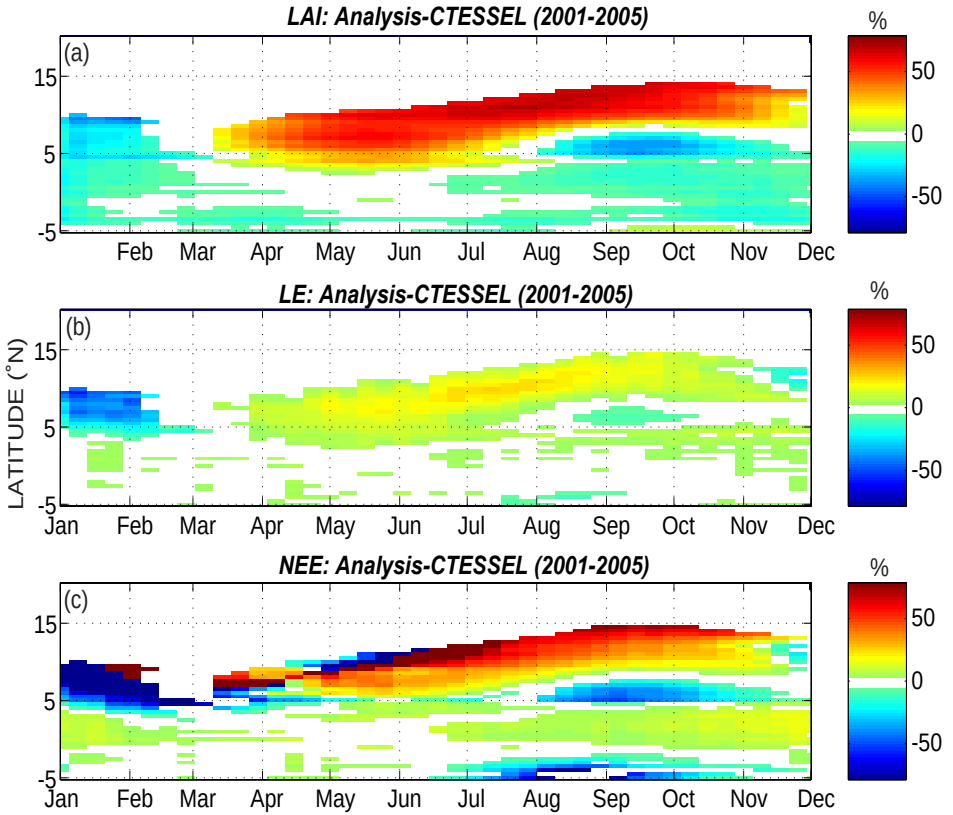
L. Jarlan, G. Balsamo, S. Lafont, A. Beljaars, J.C. Calvet and E. Mougin

paper in *JGR accepted*

Impact of precip on prognostic LAI



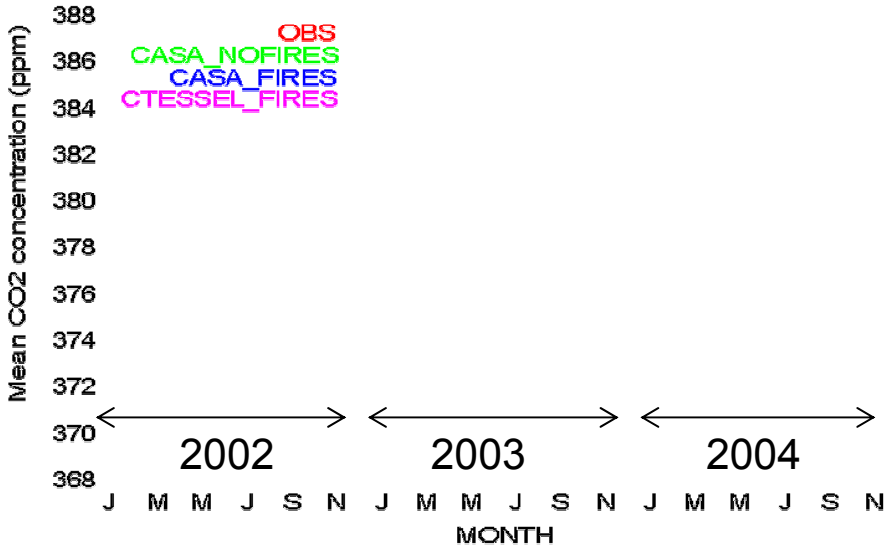
- AMMA ALMIP Exp2/Exp1 are used in CTESSEL and a LAI assimilation prototype



Accurate LAI is essential for Carbon

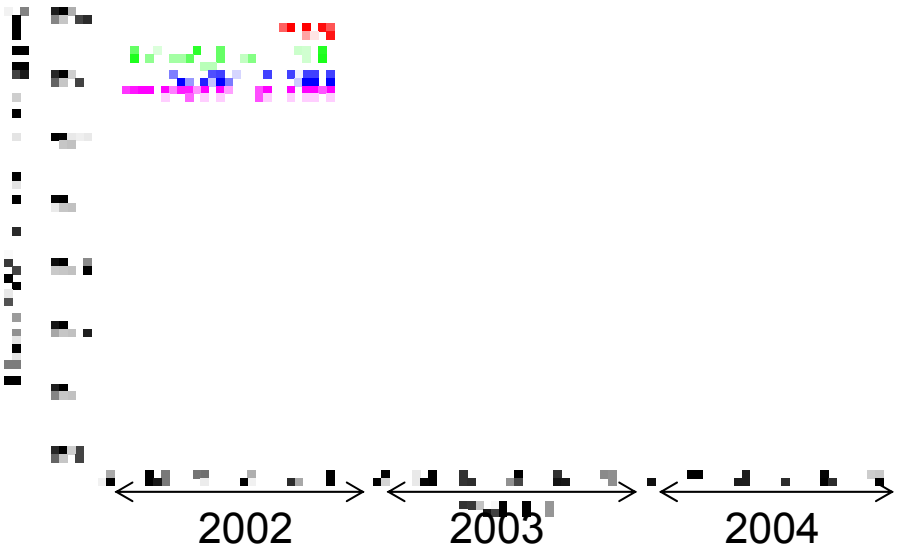
CTESSEL global evaluation

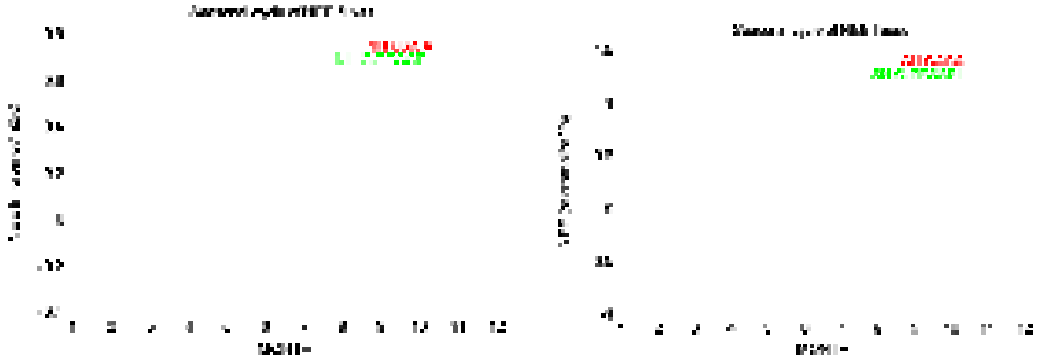
S. Serrar, S. Lafont, L. Jarlan, G. Balsamo



Mean Seasonal cycle of atmospheric CO_2 concentration in the NH (calculated from 8 marine stations in the NH)

Mean Seasonal cycle of atmospheric CO_2 concentration in the SH (calculated from 8 marine stations in the SH)

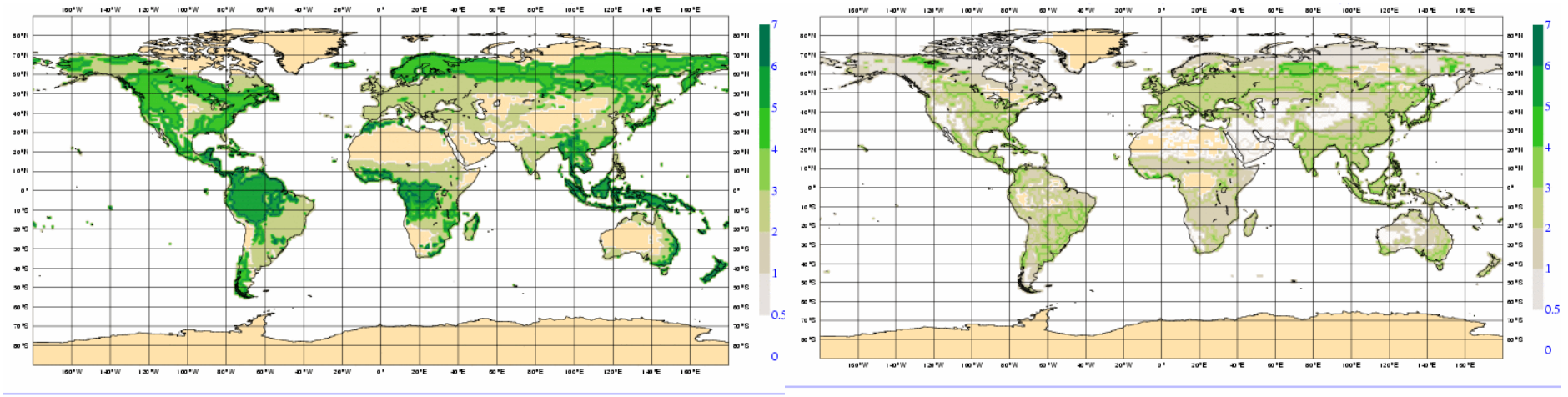




Mean Seasonal of NEE In CTESSEL and CASA

roadmap to CTESSEL: seasonal LAI

G. Balsamo, L. Jarlan

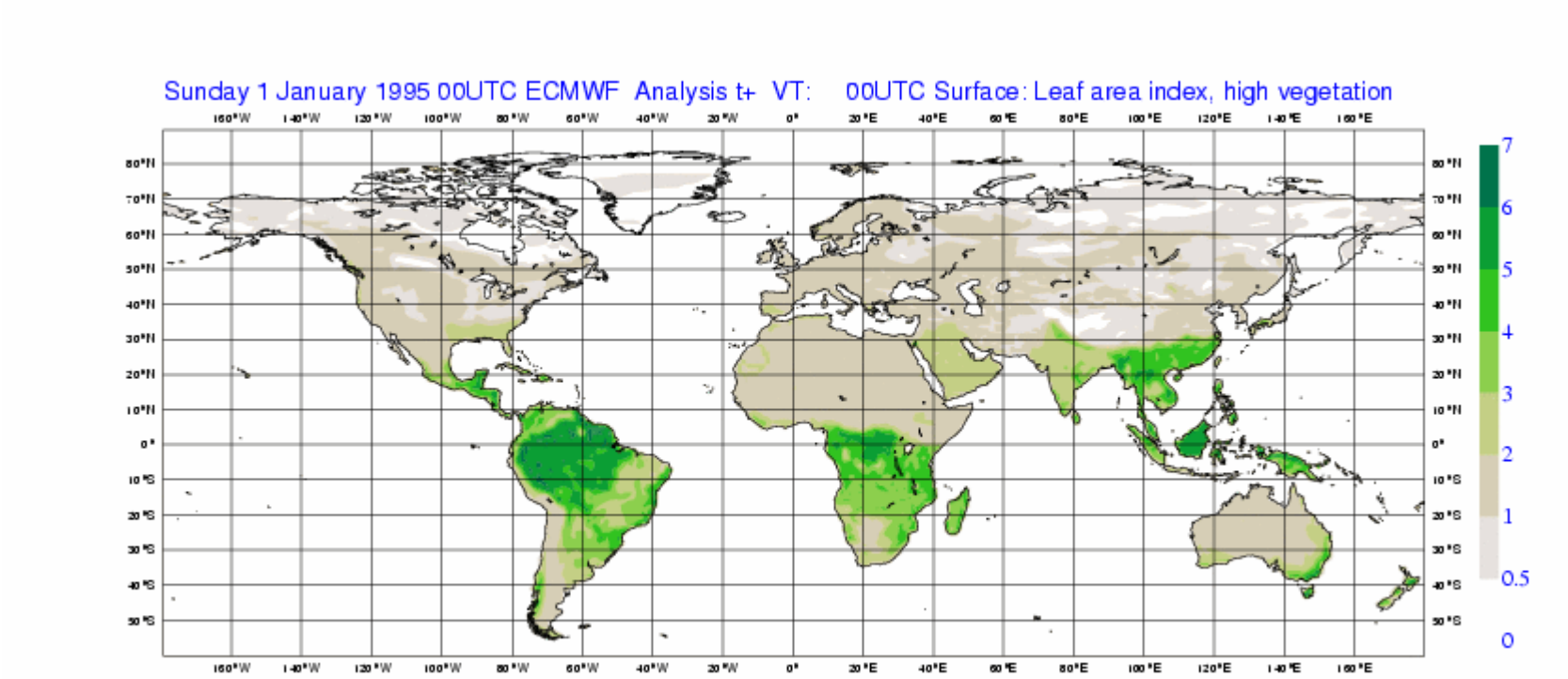


- LAI is connected to vegetation phenology and is now constant in time for High and Low vegetation types (the “golf course assumption”?)
- Monthly means LAI Con’s are on the methods used (NDVI-based on 1year of AVHRR data)
- have been derived from ECOCLIMAP and in principle can be implemented
- Pro’s of this datasets is that it allows distinction of H/L vegetation
- MODIS LAI collection 5 seems the most promising alternative to be investigated (Lionel’s visit, end of July).

A monthly LAI

G. Balsamo, L. Jarlan

- LAI for High vegetation (from ECOCLIMAP)



- Seasonal LAI has to be introduced in the code which can then hosts CTESSEL (passively)
- GEOLAND2 will reinforce land carbon modelling activity

Cold processes

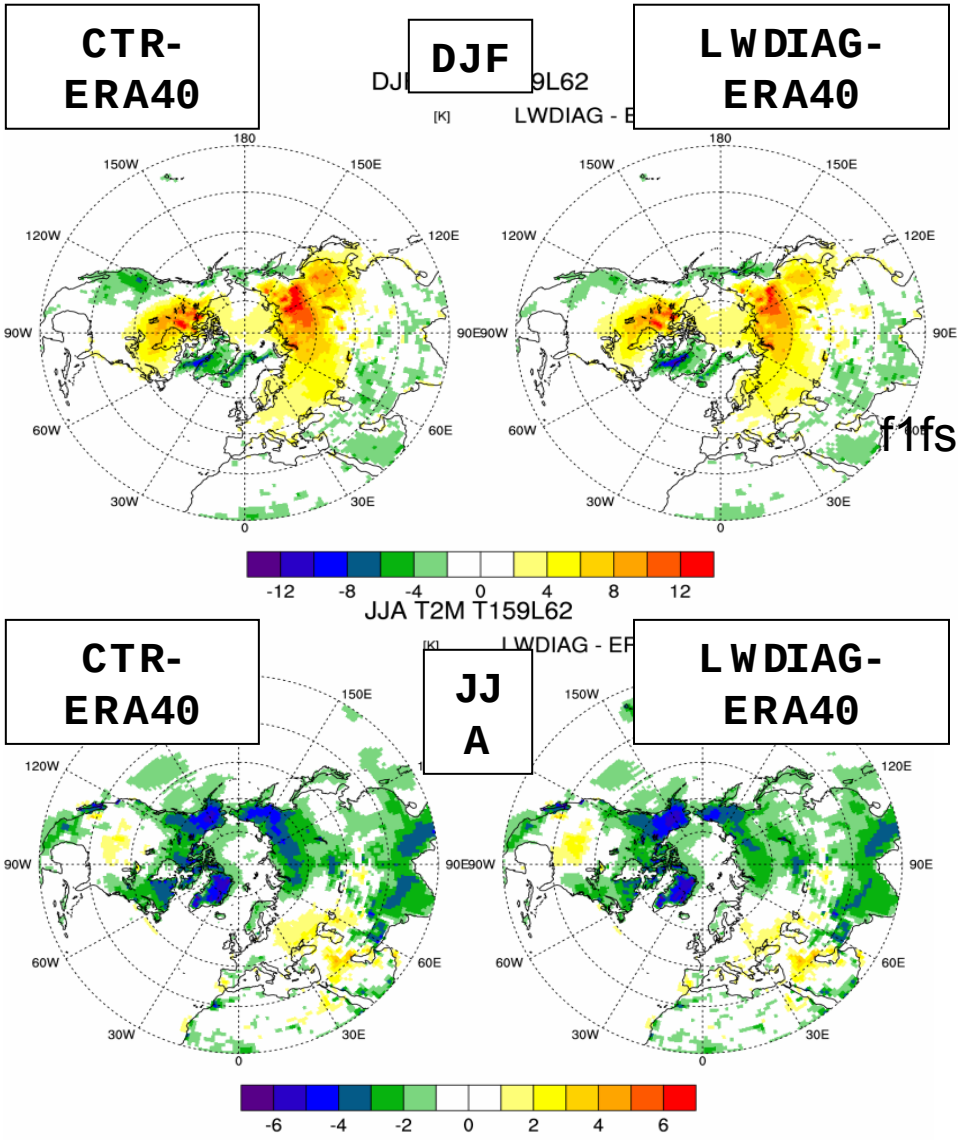
- HTESSEL has been evaluated also for cold processes several NH sites in SnowMIP2.
- A revised snow scheme was developed by E. Dutra et al. (2008) in collaboration with IM (P. Viterbo) and Univ. of Lisbon (P. Miranda)
- Iceland was studies following a report of soil temperature drift in the deterministic model (see ref.) and a fix to soil temperature analysis was introduced in cycle 33R1. [not shown]
- The revised snow scheme has been tested here in cycle 33R1 and is proposed for implementation in cycle 35R2.
- Permanent snow albedo impact over antarctica in CY33R2 [not shown]

References:

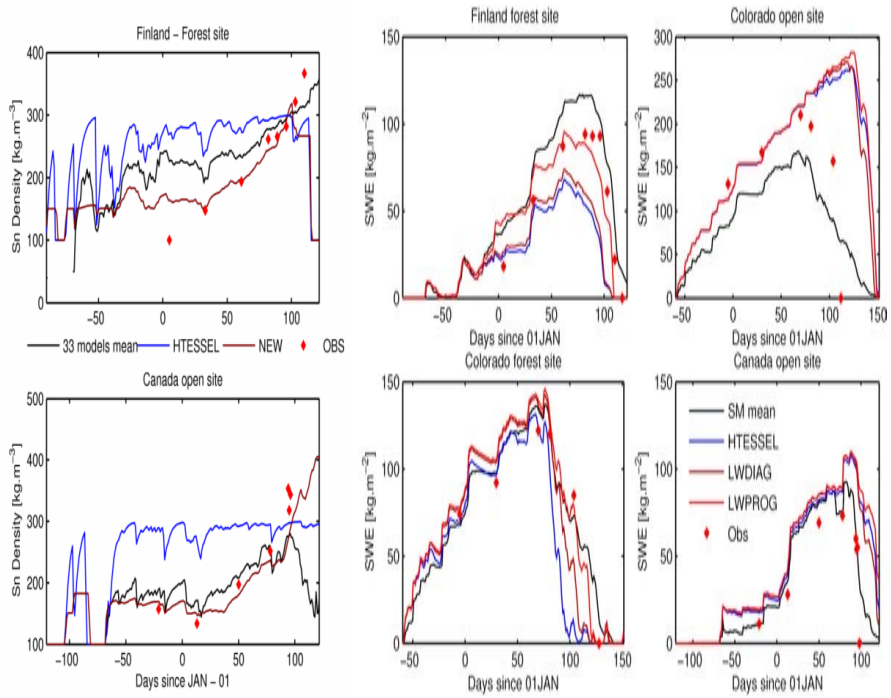
- SnowMIP2 intercomparison: First results [Dec. 2007, internal RD memo, link]
- Iceland soil temperature drift [Feb. 2008, daily report, link]
- Antarctica warm bias and impact of permanent snow albedo [Jul. 2008, internal RD memo, link]

Revised snow model (EC-Earth CY31R1)

E. Dutra, P. Viterbo, P. Miranda



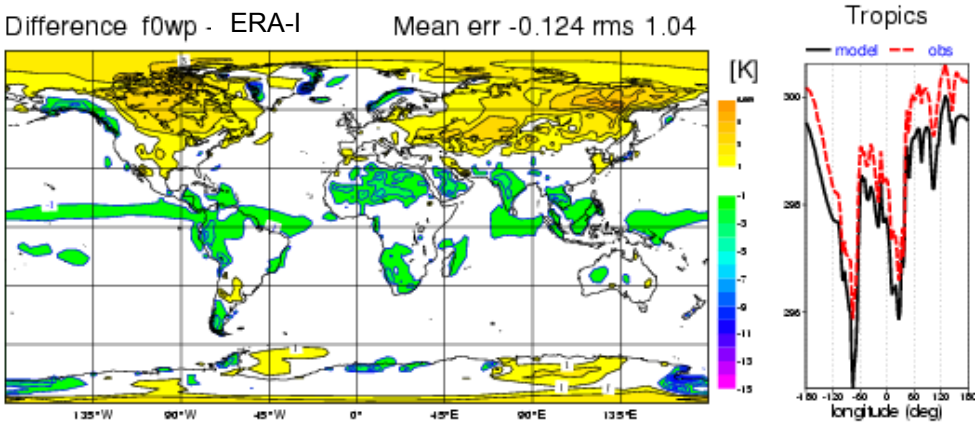
- A new treatment of snow density
- Diagnostic liquid water in the snow-pack



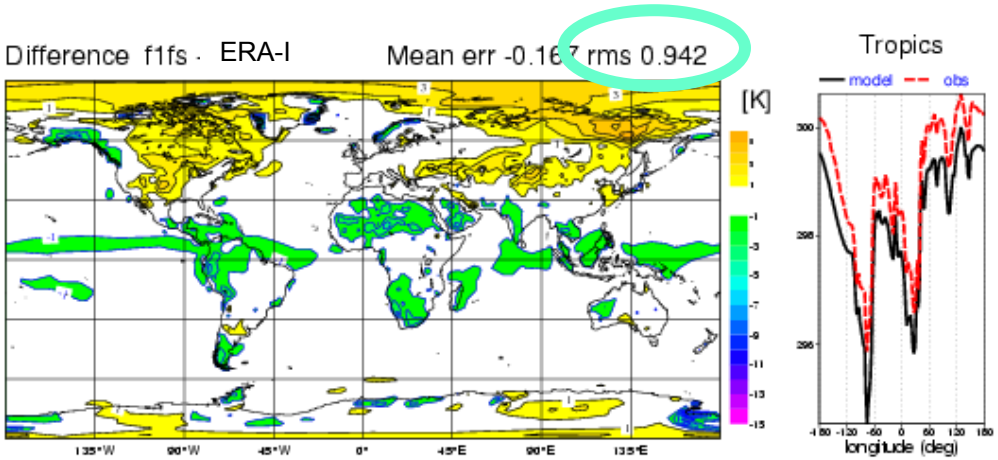
Evaluation of the revised snow in CY33R1

Long integrations (13-months) evaluated against several datasets indicate a consistent improvement (RMSE reduction)

CY33R1



Rev Snow

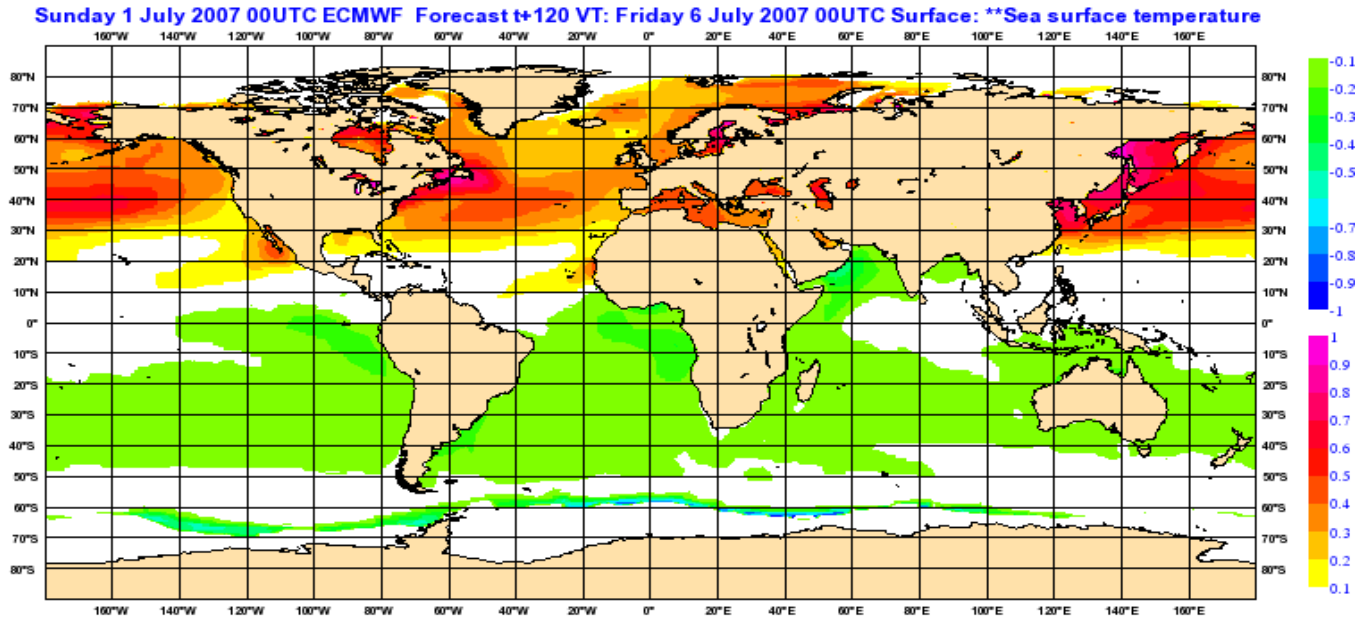


In-land water bodies and SSTs

- 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).
- SSTs daily evolution in 10-day forecasts from the analysis by adding the climatological tendency (calculated from ERA40). Operational from CY32R4

SSTs from persistence to anomaly persistence (op. in CY33R1)

- Based on idea from F. Vitart and daily ERA40 clim by M. Leutbecher.
- Relax the hypothesis of persistence



- Small positive forecast impact visible beyond day 5, more evident in MF.

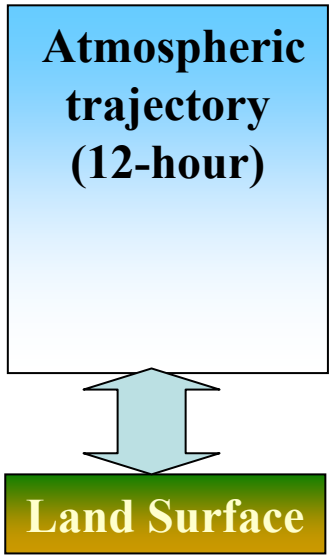
Reference:

- Introduction of SST anomaly persistence [internal RD memo, 11/2007, link]

Data assimilation using stand-alone land surface and a simplified Extended Kalman Filter (sEKF)

M. Drusch, P. de Rosnay, K. Scipal, G. Balsamo

Atmospheric-coupled

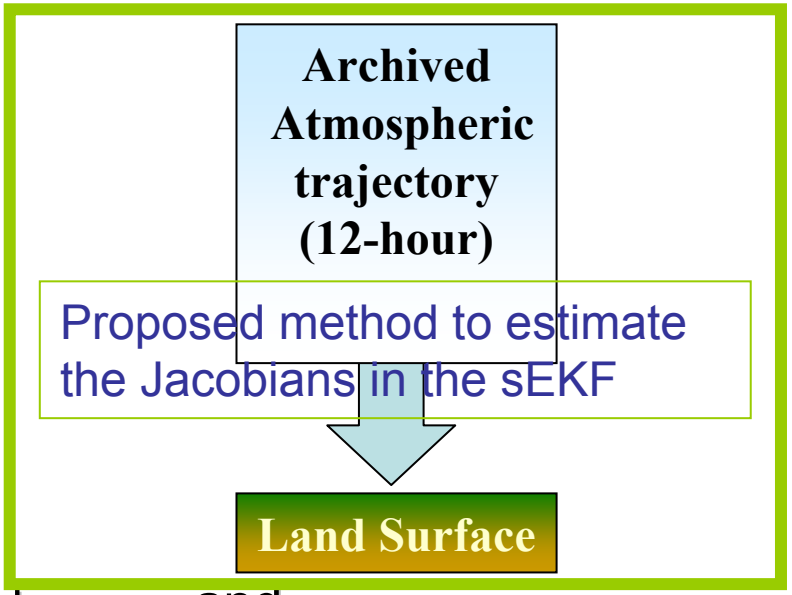


+ and -

*at high-res. no approx. (proper traj)
*full feedback

*Expensive for SM
*Not affordable for all the LSM variables
*Noisy Jacobians in convective areas
*Unnecessary comput. over water bodies and large part of atmosphere

Stand-alone



+ and -

*affordable for all LSM variable
*approx well fully-coupled Jacobians
*modular extension (LAI, AL)
*Allow use better forcing (Prec, SW/LW)
*GEMS / ERA-40 / SF compatible

*neglects feedback
*requires Offline setup in fully in IFS

Equivalence of stand-alone & atmospheric-coupled Jacobians

Mahfouf et al. 2008 (JGR, *submitted*), Jarlan et al. 2008 (JGR *accepted*), Balsamo et al 2007 (JHM)

Atmospheric-coupled Stand-Alone

T2m

Q2m

TIR

Tb(C)

Tb(L)

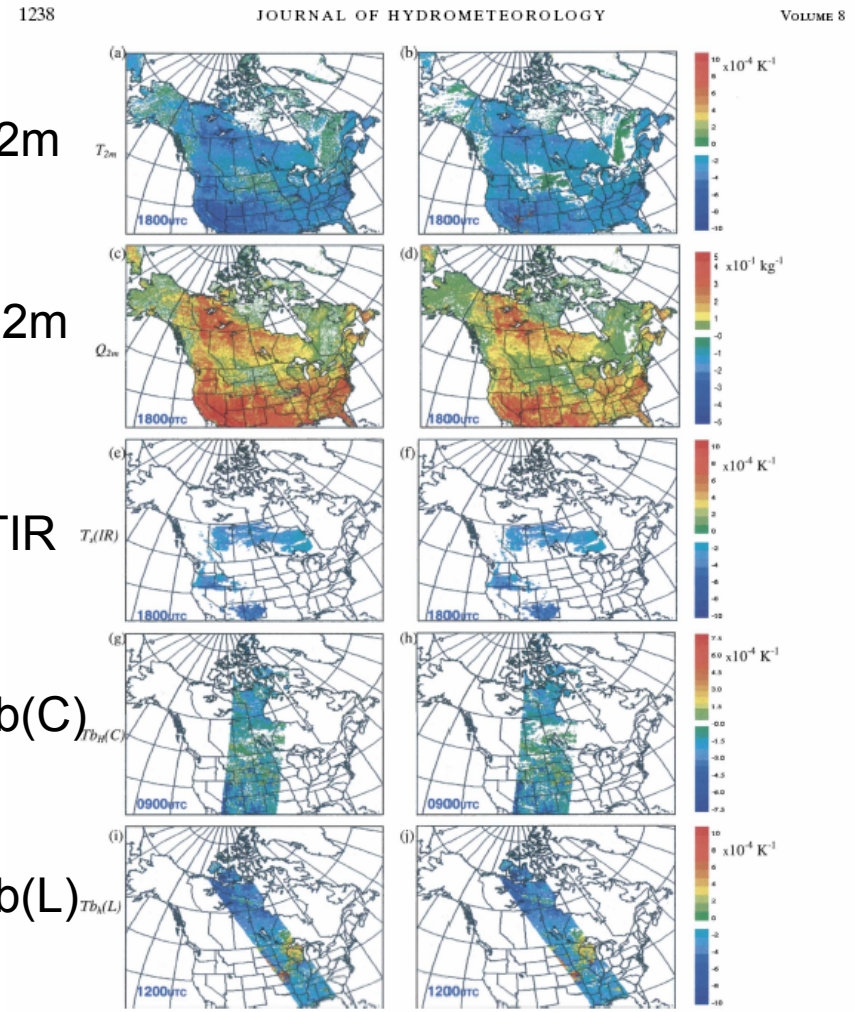


FIG. 9. Gain matrix elements k_i for the assimilated observation types (same as in Fig. 8) obtained with the (a), (c), (e), (g), (i) atmospheric-coupled and (b), (d), (f), (h), (j) offline systems.

Balsamo et al 2007 (JHM)

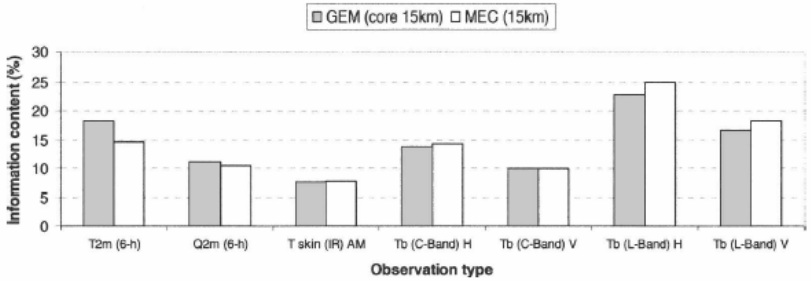


FIG. 8. Relative information content [Eq. (11)] of the observations in a daily soil moisture analysis assimilating 6-hourly screen-level observations and satellite observations using the atmospheric-coupled system (GEM 15 km) and the offline system (MEC 15 km) for 5 Jul 2004 (number of considered points = 89 223).

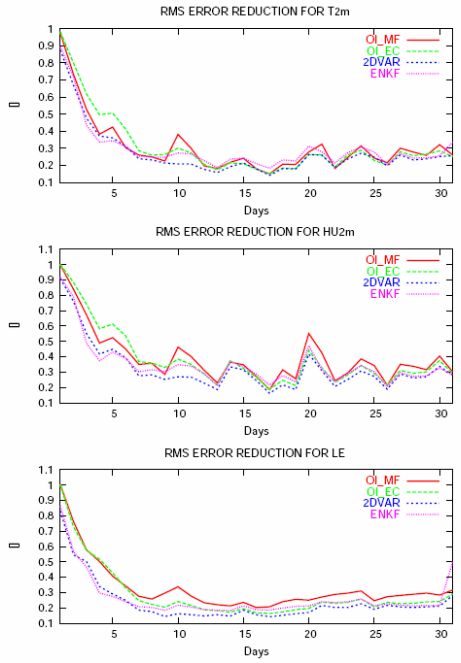


Figure 4.14: Réduction de l'erreur quadratique moyenne des assimilations par rapport à un contrôle et à une référence pour la température à 2 mètres (haut), l'humidité spécifique à 2 mètres (milieu) et le flux d'évaporation (bas). Les observations considérées pour l'assimilation sont T_{2m} et HU_{2m}.

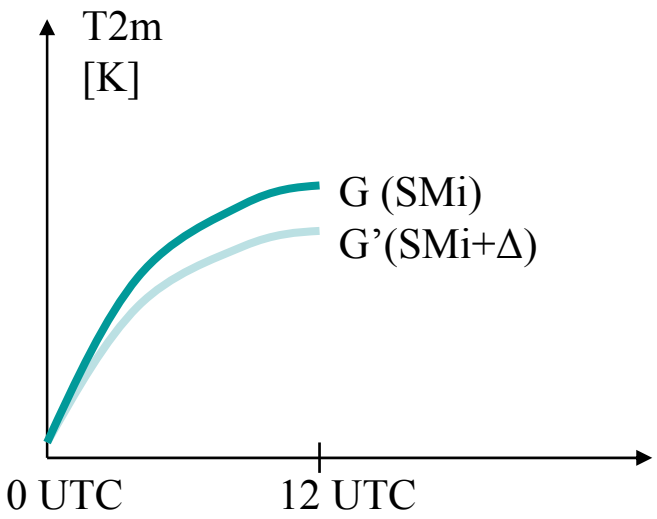
Comparison of OI and stand-alone 2DVAR, EKF

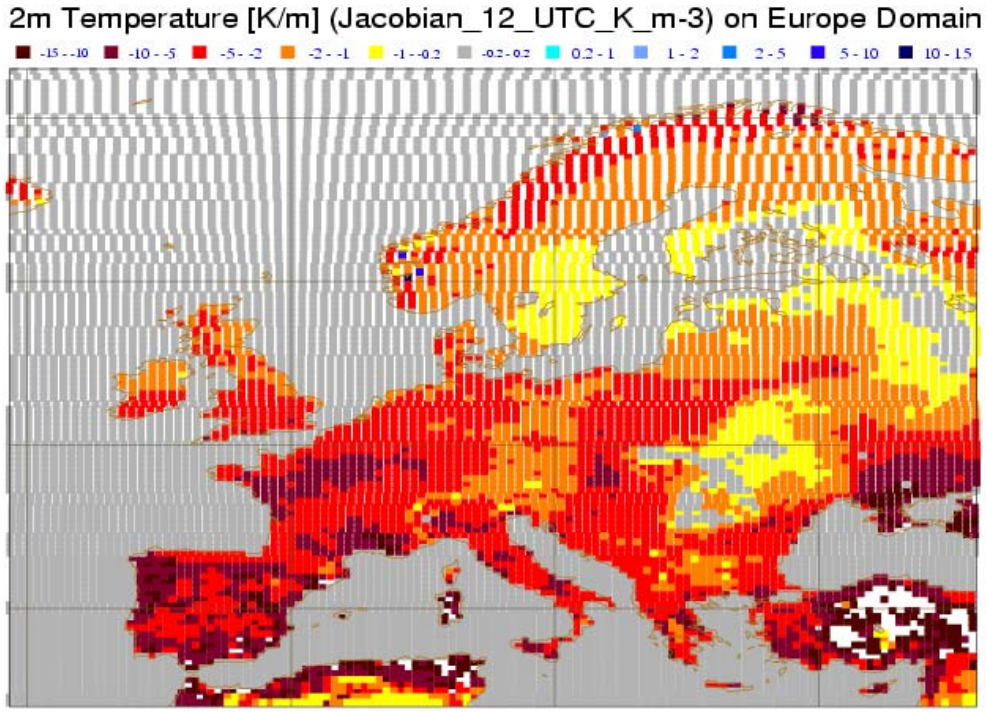
Mahfouf 2007 (Meteo-France internal note)

Offline Jacobians of T2m/soil moisture in IFS (preliminary tests)

G. Balsamo and P. Derosnay

- Similarly to LAI DA the SM DA could make use of the surface model in stand-alone to estimate the Jacobians (no need to integrate the atmospheric model).
- A first test is performed for a summer case





Stand-alone Jacobians are comparable in magnitude and structure to the operational OI coefficients but they are dynamically estimated on current Land/Atm conditions

Conclusions

- Many parallel land surface research activities at ECMWF and with research institutes thanks to fruitful collaborations (mostly is work in progress!)
- A key element is the portability of the “stand-alone” land surface code (GSWP2, RhoneAGG, AMMA ALMIP, C-TESSEL global demo for GEOLAND)
- Scientific outcomes are sometimes not far from operational implementation (example: Revised snow scheme)
- An improved soil hydrology is implemented and the snow is under test…but no lakes yet.