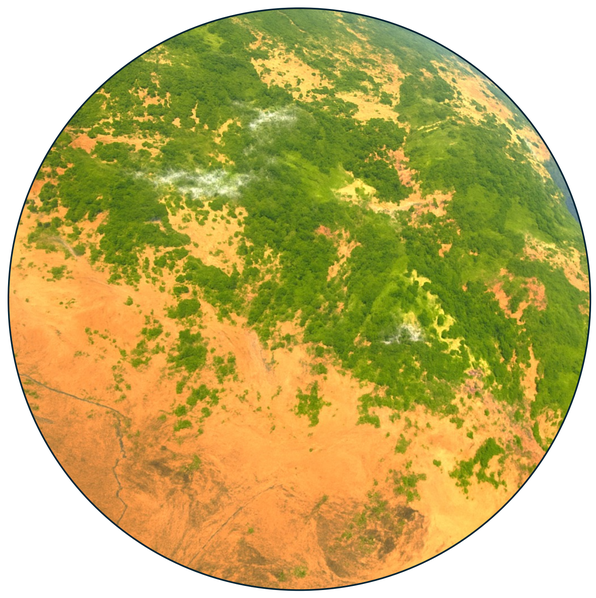
LET THERE BE RIVERS!

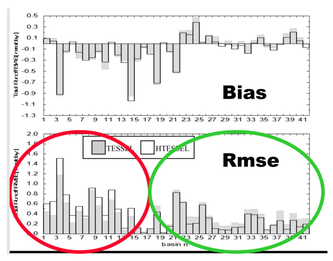
From a planet without water…



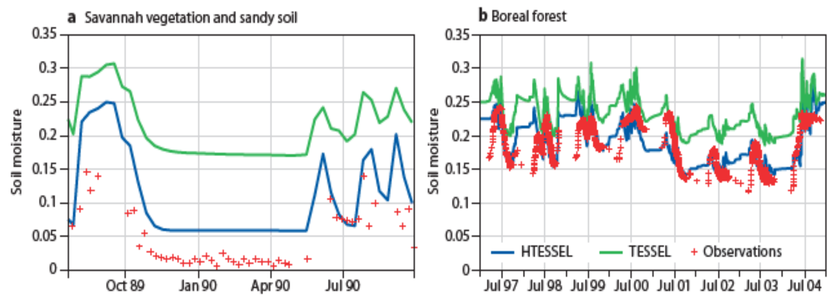
2009 – A new hydrology in IFS

New **infiltration** and **runoff** schemes with a dependency on the soil texture and standard deviation of orography

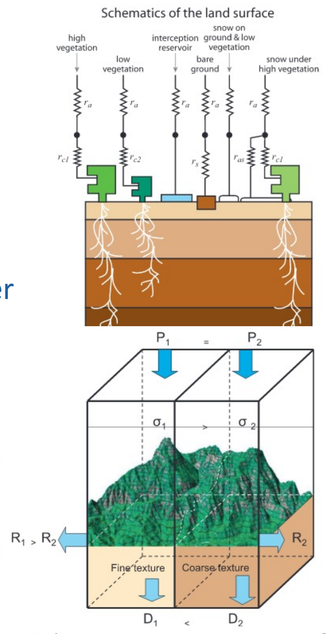
- Improved prediction of **soil moisture** at the local scale against field site observations
- Improved prediction of **river runoff** on major river catchments (except snow-dominated regions)



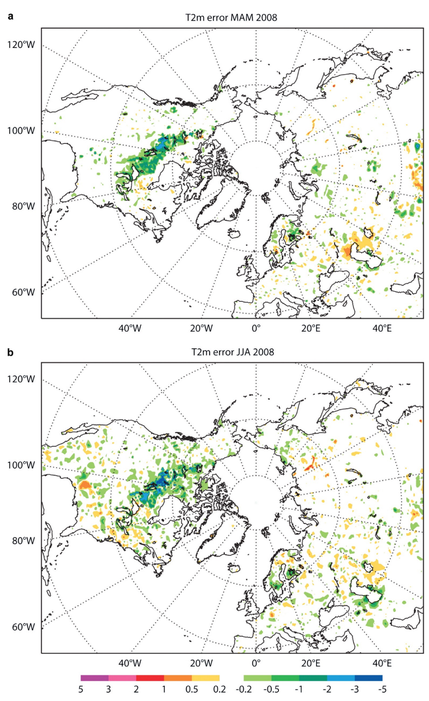
HTESSEL improves runoff on major world river basins where soil control is dominant



Evolution of soil moisture in TESSEL and HTESSEL in terms of volumetric content (m^3/m^3) compared to observations for two contrasting sites used for field experiments: (a) savannah vegetation and sandy soil (SEBEX, Sahel) and (b) boreal forest (BERMS, Canada). From Meteorology section of ECMWF Newsletter No. 127 – Spring 2011, pp. 17–22. Evolution of land-surface processes in the IFS. Gianpaolo Balsamo, Souhail Boussetta, Emanuel Dutra, Anton Beljaars, Pedro Viterbo, Bart Van den Hurk



Schematic representation of the structure of (a) TESSEL land-surface scheme and (b) spatial structure added in HTESSEL (for a given precipitation P_1=P_2 the scheme distributes the water as surface runoff and drainage with functional dependencies on orography and soil texture respectively).



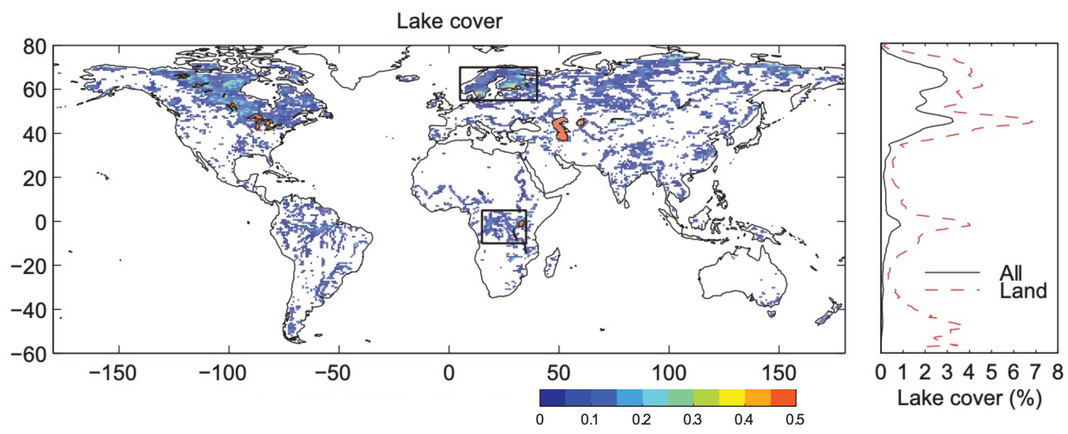
Lake fraction in the Gaussian reduced grid N128 and zonally averaged fractional lake cover with respect to land points only (dashed) and all points (solid). From E. Dutra, V.M. Stepanenko, G. Balsamo, P. Viterbo, P.M.A. Miranda, D. Mironov, and C. Schär (2009). Technical Memorandum 608. Impact of lakes on the ECMWF surface scheme, ECMWF.

2015 – Lakes appear

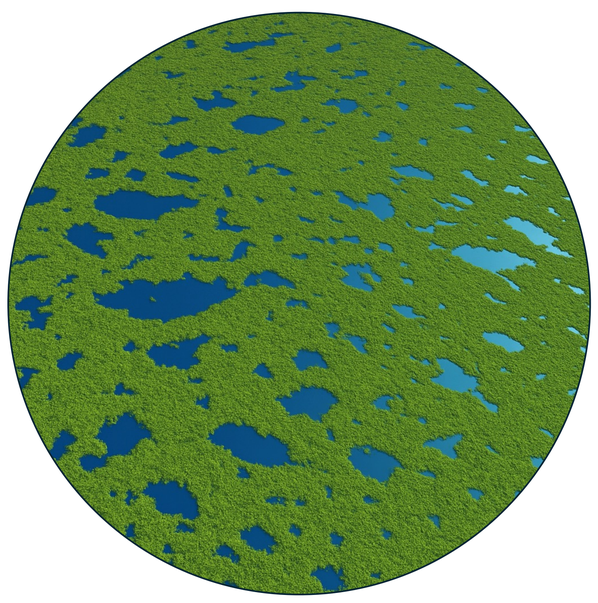
A new **lake tile** (unit land cover characteristic) based on **FLake** is introduced in HTESSEL

- Realistic delay in seasonal evolution of temperature
- Improvement on **near-surface air temperature**

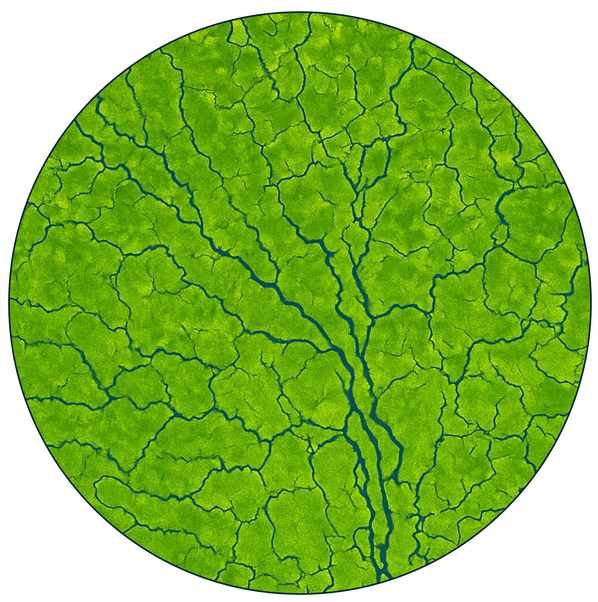
Impact of 48-hour T2m forecasts (valid at 00 UTC) for LAKE compared with NOLAKE, verified against the ECMWF T2m analysis: Mean Absolute Error difference for (a) spring (MAM) and (b) summer (JJA). Negative values indicate an improvement (MAE reduction). From Balsamo, G., Salgado, R., Dutra, E., Boussetta, S., Stockdale, T., & Potes, M. (2012). On the contribution of lakes in predicting near-surface temperature in a global weather forecasting model. Tellus A: Dynamic Meteorology and Oceanography, 68(s1). https://tellusjournal.org/articles/10.3402/tellusa.v64i0.15829



… to the first blue imprints…



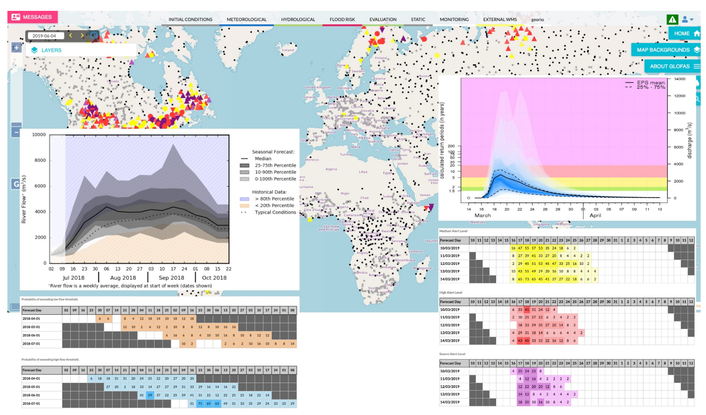
… to a network of rivers.



2018 – Connecting rivers in HTESSEL

Connecting land tile to rivers introduced by routing runoff from HTESSEL with LISFLOOD river model

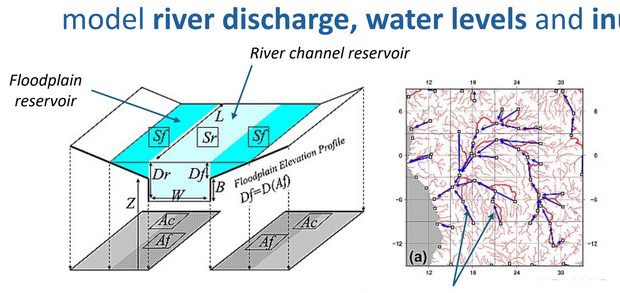
- **Realistic** horizontal water movement
- Pave the way for **land-atmosphere feedback** through 2-way coupling of floodplain



The Global Flood Awareness System from Copernicus Emergency Management Service becomes operational pioneering a global ensemble forecasting system driven by ECMWF forecasts (Harrigan et al., 2020)

2020 – ecLand meets CaMa-Flood

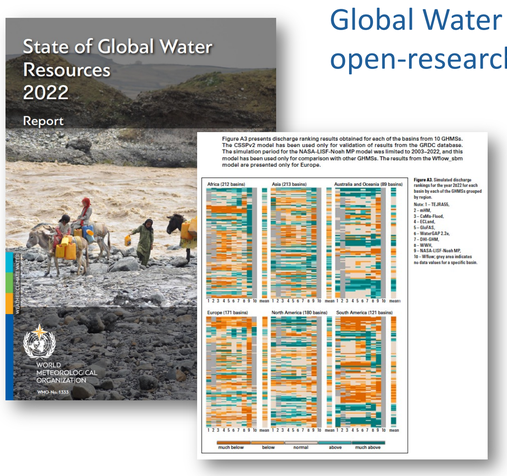
CaMa-Flood hydrodynamic river routing model **is coupled to ecLand** to model **river discharge, water levels** and **inundated areas.**



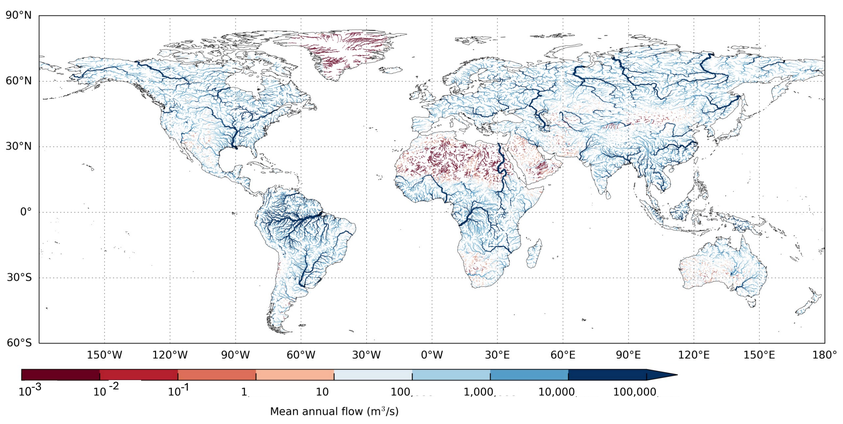
CaMa-Flood is a physics-based hydrodynamic model connecting ecLand tiles through river network. The complex river channel and floodplain topography is represented by sub-grid-scale parameters. The model has been developed and validated for continental to global scales (Yamazaki et al, 2011)

2025 and beyond – Pre-operational river discharge monitoring and forecasting system

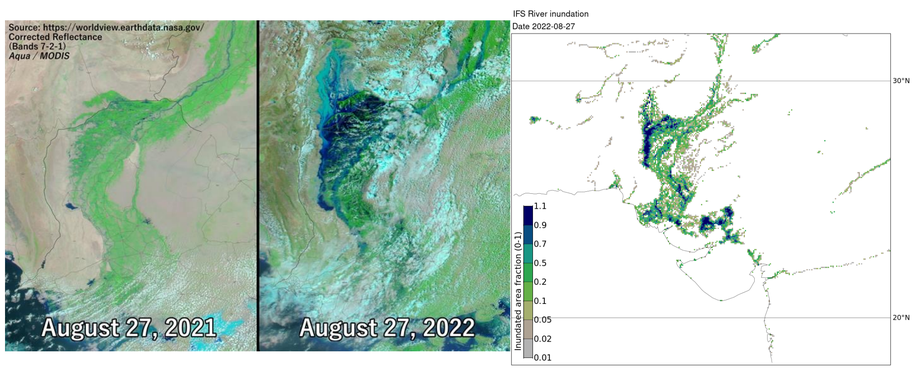
ecLand as part of multi-model assessment of WMO's state of Global Water Resources. Source code available on GitHub for open-research at *https://github.com/ecmwf-ifs/ecland*



Rivers contain an integrated catchment response that can be leveraged to analyse the model. Their implementation in **ecLand** ensures reciprocal improvement of NWP and river discharge prediction.



Global mean annual flow from ERA5 forced ecLand and 15 arcmin CaMa-Flood. From ECMWF's contribution to the 2024 WMO State of Global Water Resources Report.



Pakistan inundation area on the 27th August 2022, as observed by MODIS (left, 2021 compared to 2022 image) and as simulated by CaMa-Flood running at 3arcmin (about 5km) resolution, forced by the Operational IFS at 9km.

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