Coupling ocean & land processes at ECMWF

Differences and similarities and what can we learn from them?

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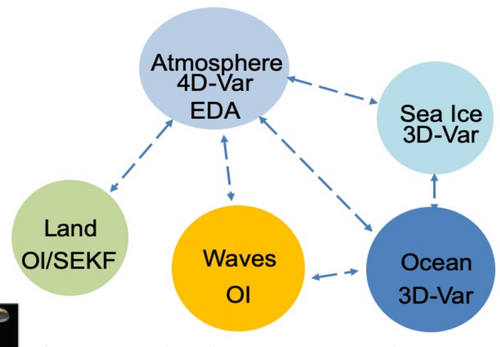
Introduction

Land & **Ocean** processes in the ECMWF coupled system are represented by a variety of dedicated surface 1D, 2D, and 3D models (**ECLand**, **ECWAM**, **NEMO**). More modular developments are under way that will allow to directly connect the land water cycle to the ocean fresh-water inflow (via the **CAMA-Flood** river-discharge).

To face future challenges of global **kilometre-scale modelling** and fully exploit the advantages of representing inland & coastal water gradients, and **biosphere/cryosphere** heterogeneity / complexity, we analyse how to increase the modularity of the developments, with a few examples.

Earth System Approach @ECMWF

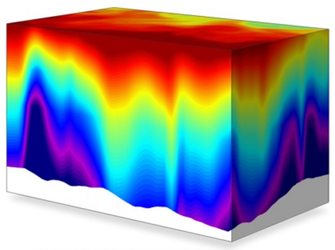
- Integrated Forecasting System Data Assimilation schemes
- Coupled Ocean-Land-Atmosphere Ensemble Modelling
- Use of Satellite + In-situ EO data



Current setup (2021) includes a variety of 1D 2D 3D 4D methods: Simplified Extended Kalman filters, Optimal Interpolation, Variational, and Ensemble Data Assimilation

Coupling Earth Surface Modelling Components: Ongoing research

Ocean, waves and ice modelling



•NEMO4.0 ocean

•Key elements
- •Major code restructuring
- Collaborations
  - Ocean-Model WG
  - JMMP
- Offline/Coupling test
  - Ongoing
  - Coupled testing

NEMO3.4 coupled in Mogensen et al, 2018, Effects of ocean on weather forecasts https://www.ecmwf.int/en/newsletter/156/news/effects-ocean-coupling-weather-forecasts

•EC-WAM wave model

•Key developments
- Ardhuin (2010) physics in 46r1
- Freak waves parameters upgraded (Peter) in 46r1
- Charnock change for strong winds in 47r1
- Ongoing/Planned
  - NEMO4 wave effects
  - Grid-resolution/extension TCO grid

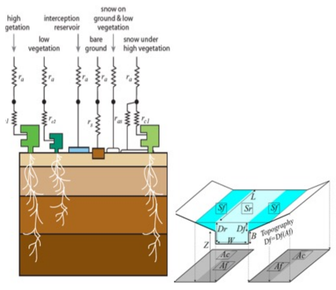
Wave Physics impact in ECMWF news item for 46r1 https://www.ecmwf.int/en/about/media-centre/news/2019/upgrade-boost-quality-ocean-wave-forecasts

SI3 sea-ice model

•Key elements
- Multi-category ice model
- Thermo-halo-dynamics (salt-effects)
- Melt ponds and updated albedo
- Prather advection or UMx under testing
- EVP rheology
- Offline/Coupling test
  - Ongoing with LIM2 in APPLICATE (tight coupling)
  - Optimising performance SI3 w.r.t. LIM2

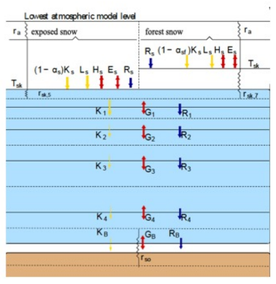
Sea-ice coupling in Keeley, S and K Mogensen, 2018, Dynamic sea ice in the IFS https://www.ecmwf.int/en/newsletter/156/meteorology/dynamic-sea-ice-ifs

Land hydrology, biosphere and anthropogenic surface modelling



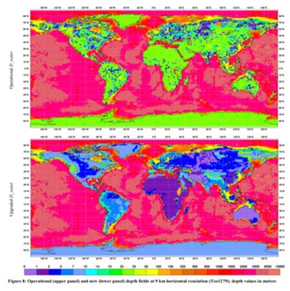
•HTESSEL-CAMA-Flood

•Improvements
- •River discharge coupled to runoff passive in 2019
- •Post-processing of tiles diagnostics in 2020
- Collaborations
  - CMEMS
  - CONTROL
  - Global Routing
  - HTESSEL-Calibration



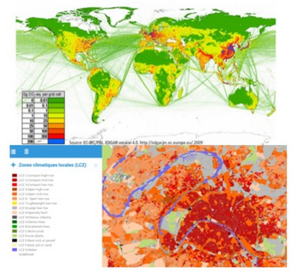
•SNOW ML5

•Improvements
- •ML5 Snow physics passive in 2019
- Ongoing/Planned
  - ML GRIB input/output (collaboration with FD/IFS)
  - ML coupled to ice (APPLICATE)
  - Snow Albedo revision (SnowAPP/APPLICATE-2)
  - Blowing snow (ISSI-BJ-HTP) Orsolini et al. (2019) Arduini et al. (2019)



•WATER Tile Mapping

•Improvements
- •GLDBv3 + new LSM/CL ready in 2020
- Ongoing/Planned
  - Extend to other physiography fields
  - Focus ESA-CCI Maps
  - Orography and Bathymetry at native 1km
  - Choulga et al. (2019) on Water Mapping



URBAN Tile+CO2 Mapping

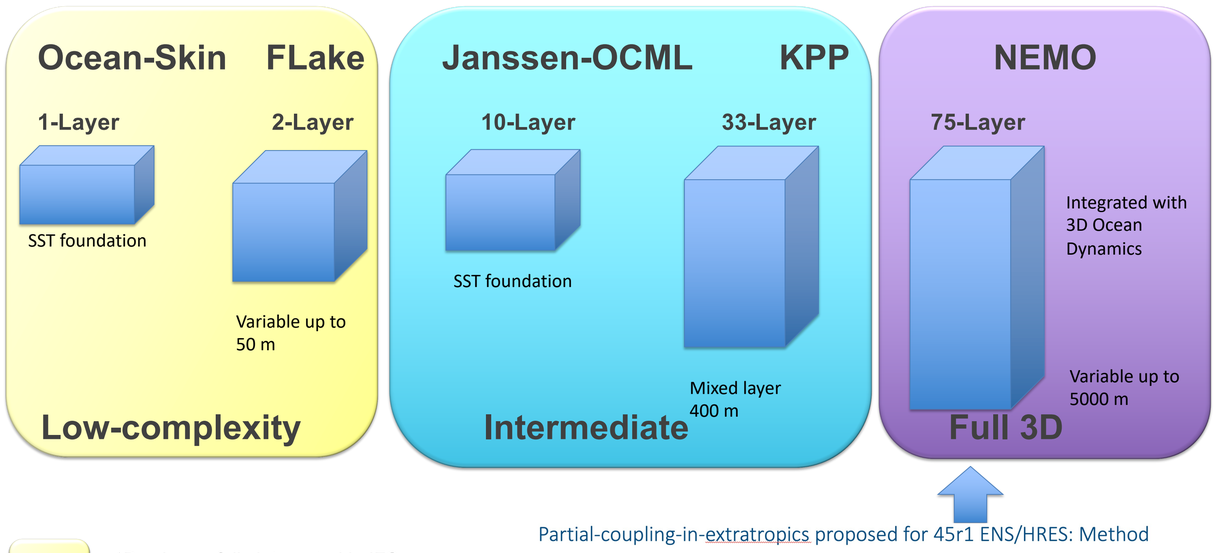
•Improvements
- City mapping (C3S ITT)
- Multi-cities OSM
- CO2 mapping
- CO2 uncertainties
- CO2 ensemble
- Offline/Coupling test
  - Ongoing CHE Tier-2 runs

McNorton et al. (2019) on CO2 model error specification

Choulga et al (2020) on CO2 emissions & uncertainties

Ocean Surface Layer: A modularity call?

Ocean/water surface modelling on atmospheric grid and ocean grid.



1D scheme fully integrated in IFS
Also in the 4D-Var inner loops.
Works on the atmospheric grid

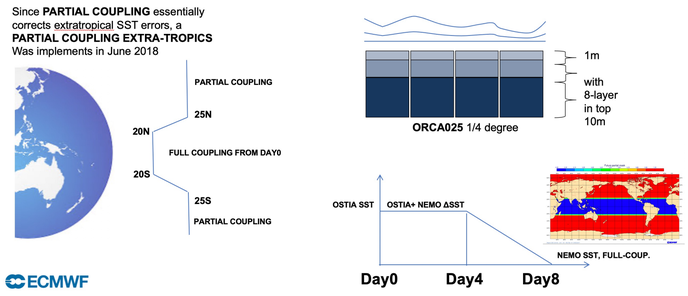
1D scheme integrated in IFS forecast
Works on the atmospheric grid. Need BC / DYN
Can store surface temperature information in multiple layers that are connect to 3D ocean

3D scheme coupled to IFS forecast
Works on the ocean grid.
Can store temperature in multiple layers with Initial conditions provided by Ocean5

Partial-coupling-in-extratropics proposed for 45r1 ENS/HRES: Method

- OCEAN5 and NEMO Tropical Oceans are best performing (ENS/SEAS5 testing)
- Extra-Tropics do benefit from OSTIA-SST initialization (Especially Gulf Stream)

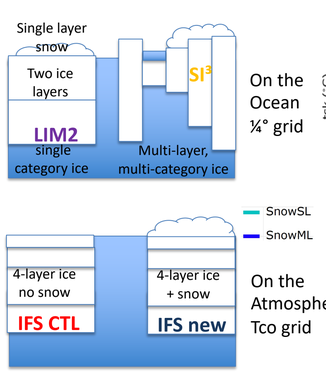
Since **PARTIAL COUPLING** essentially corrects extratropical SST errors, a **PARTIAL COUPLING EXTRA-TROPICS** Was implements in June 2018

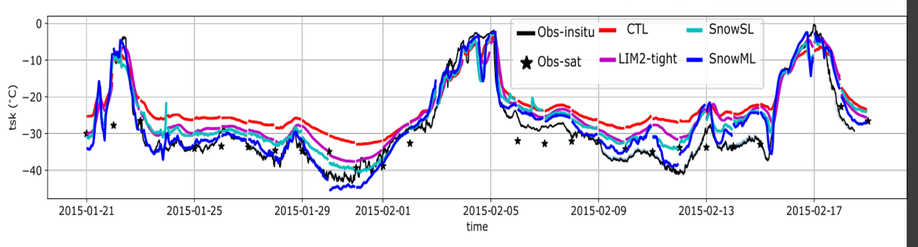


ECMWF

Cryosphere modelling on atmospheric grid & ocean grid. Lesson learnt from APPLICATE and N-ICE-2015 field campaign

APPLICATE.eu Advanced prediction in polar regions and beyond



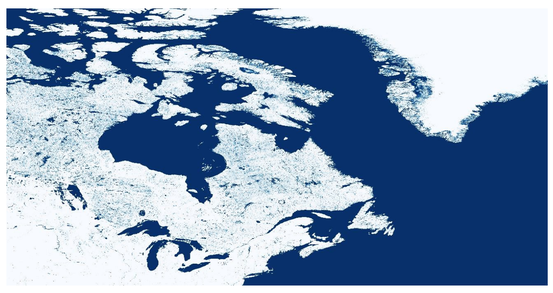


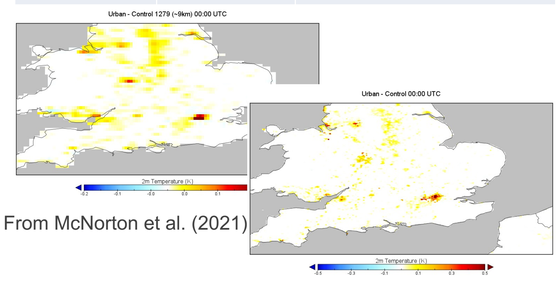
Tested on the N-ICE-2015 field campaign the snow single-layer and multi-layer schemes show sizeable improvements comparing to the IFS control (CTL without snow) and comparable with LIM2, in representing the skin temperature evolution, evaluated with both insitu and co-located DMI satellite observations (in black). From Arduini et al. (2021).

ECLand: Offline Surface Model benefits

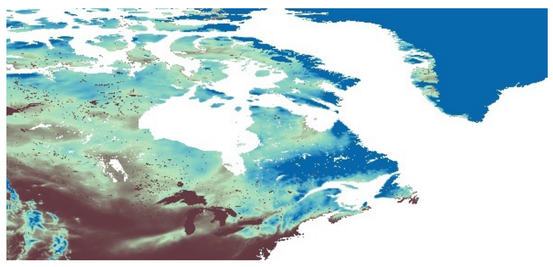
Offline modelling capabilities for land surface have driven annual updates of the model components & fostered process understanding

Resolution	Configuration	Performance (simulated years per day)
9km (**HRES** & **ERA5Land**)	TCo1279	with MPI (**8 year/day**)
1km (**VHRES**) & prepare for ERAL 1km	TCo7999	with MPI (**0.8 year/day**)





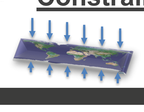
From McNorton et al. (2021)



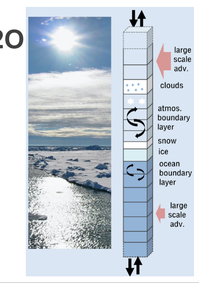
Global 1km simulations of the land surface and lakes permit to benefit from high resolution features brought in by land sea mask and snow cover in interaction with the orography and coastal complexity (as well as all other high resolution physiography fields). The land schemes are 1D-layer schemes representing the vertical columns exchanges of energy, water, carbon, coupled to 2D or 3D dynamics.

Summary: why Ocean & Land 1D-scheme?

- **Operationalising coupled model improvements require provision of initial conditions (present/past). What's the 1D benefit & constraint?**
- **Advantage for faster/more frequent Earth surface reanalysis, reforecasts & R2O**
- **Potential for integration of Coupled Data Assimilation & Ensemble Prediction**
- **Efficiency for testing new parameterisations for Copernicus / DestinE**
- **Constraints for the needs of accurate forcing to support offline testing**



Meteorological (incoming surface fluxes, T, q, p, wind), Dynamical-Ocean (found. SST, Ice %/depth), Physiography (e.g. albedo, LSM, bathymetry) for 1D-Layer schemes, to be tested at any resolution.



Further Reading

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