An EO-driven surface model development

To face global kilometer-scale Earth system monitoring challenges

Gianpaolo Balsamo, Anna Agustì-Panareda, Souhail Boussetta, Gabriele Arduini, Margarita Choulga, Joe McNorton, Nicolas Bousserez, Jerome Barré, Patricia de Rosnay, Joaquin Muñoz-Sabater, Richard Engelen, Nils Wedi - RD-COP Teams.

Contact email: gianpaolo.balsamo@ecmwf.int

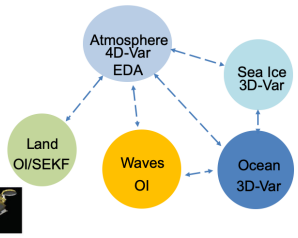
Introduction

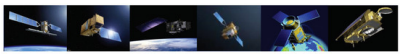
Improving the monitoring and forecasting of the thermodynamical and biogeochemical state of the Earth surface, as well as the surface-atmosphere fluxes for **Water, Energy and Carbon**, is a high priority at ECMWF to improve Services for **Global Weather/Environmental Applications** and for the **European Copernicus Programme**.

To face future challenges for a global kilometre-scale **Earth System** approach significant community effort is needed to further develop the surface models that can make better use of existing and new **Earth Observations** (EO).

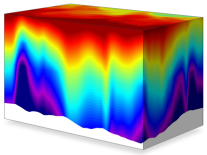
Earth System Approach @ECMWF

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





Ocean, waves and ice modelling



·NEMO4.0 ocean

·Key elements
- ·Major code restructuring

• Collaborations
- Ocean-Model WG
- JMMP

• Offline/Coupling test
- Ongoing
- Coupled testing foreseen end 2019

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 (test planned)

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

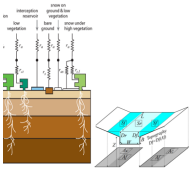
SI3 sea-ice model

·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
- Coupled SI3 testing foreseen end 2019

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

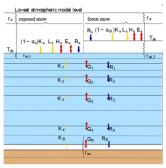


·HTESSEL-CAMA-Flood

·Improvements
- ·River discharge coupled to runoff passive in 2019
- ·Post-processing of tiles diagnostics in 2020

• Collaborations
- CMEMS
- CONTROL
- Global Routing
- HTESSEL-Calibration

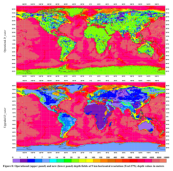
• Offline/Coupling test
- Ongoing offline testing
- ML10 soil coupled test 2020
- Coupled inundation test 2020



·SNOW ML5

·Improvements
- ·ML5 Snow physics passive in 2019

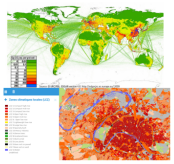
• Ongoing/Planned
- ML GRIB input/output (collaboration with FD/IFS)
- ML coupled to ice (APPLICATE)
- Snow Albedo revision (SnowAPP/APPLICATE-2)
- Blowing snow (ISSI-BJ-HTP) Orsolini et al. (2019) Arduini et al. (2019)



·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

A roadmap for enhanced CO_2 modelling

Representing CO_2 emission processes in IFS

Natural processes

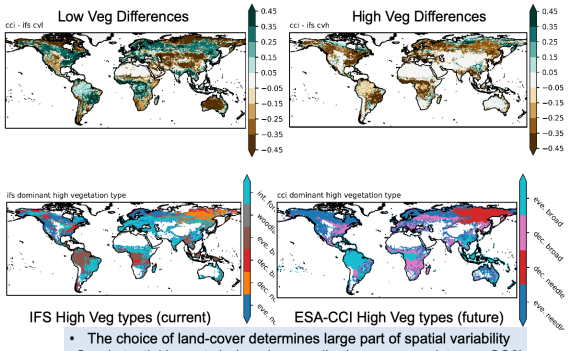
Complexity chain	Application	Year	Parameters/data required	Atmospheric impact/ Error reduction
Prescribed annual LAI map	EI	2006	1 LAI map	Albedo,2m T,RH and CO2
Prescribed 12 LAI maps (EO clim)	EI-Land, ERA5	2013	12 LAI maps	Albedo,2m T,RH and CO2, O3 (seasonal cycle)
Prescribed 12 LAI maps + EO IAV	Research experiment (Imagines)	2015	NRT LAI	Albedo,2m T,RH and CO2, O3 (IAV)
Dynamic vegetation Model (DVM)	Future developments (PhD, COST-Action)	2019-2022	NRT LAI, C3/C4 type, Vcmax,Jmax	Albedo,2m T,RH and CO2, O3 (seasonal leadtimes)
DVM + DA	Future developments (CAMS41, SIF)	2021-	NRT LAI, NRT SIF, ECV, COS + RT model (parameter estimation)	Albedo,2m T,RH and CO2, O3 (high resolution)

Anthropogenic processes

Complexity chain	Application	Testing/Due date	Parameters/data required	Atmospheric impact/ Error reduction
Prescribed annual total emission map	CAMS (2017) CHE T1 Nature Run	2017/2017	1 inventory map	CO2
Prescribed 12 mon. total emission maps	CAMS (2018) CHE T2 Nature Run	2018/Dec 2019	12 inventory maps	CO2 (seasonal cycle)
Prescribed daily and weekly profiles	CAMS research CHE T2 Nature Run	Early 2019/Dec 2019	Table with scaling factors per country	CO2 diurnal cycle, synoptic variability
Urban model (residential heating)	CHE research experiments	2019-2020/2020	Human settlement tile, type (building/street)	CO2, radiation, 2mT,RH (high resolution)

A crucial role for the choice of land cover

Land mapping a key component for CO2 & NWP: ESA-CCI vs GLCC1.2



- The choice of land-cover determines large part of spatial variability
- ➔ substantial impact via (roughness, albedo, canopy resistance, CO2)

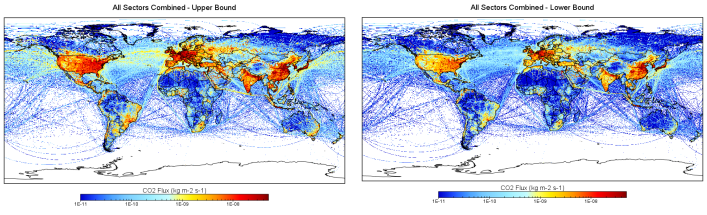
Including Anthropogenic CO_2 emissions

Sectoral emissions and their uncertainties (EDGAR + IPCC)

№	ECMWF group	EDGAR sector	EDGAR sector note	Emission global budget 2015, Mton	Prior uncertainties, % WDS countries Lower	WDS countries Upper	LDS countries Lower	LDS countries Upper
1	ENERGY_S	ENE	Power industry: SUPER emitting power plants	**13'704**	8.6	3.0	12.2	3.0
2	ENERGY_A	ENE	Power industry: AVERAGE emitting power plants		8.6	8.6	12.2	12.2
		SWD_INC	Solid waste incineration	137	40.3	40.3	41.2	41.2
3	MANUFACTURING	IND	Combustion for manufacturing	**6'183**	8.6	8.6	12.2	12.2
		IRO	Iron and steel production	234	37.1	37.1	37.1	37.1
		NFE	Non-ferrous metals production	91	73.2	73.2	73.2	73.2
		NEU	Non energy use of fuels	10	121.7	121.7	124.0	124.0
		NMM	Non-metallic minerals production	1'748	70.9	70.9	93.0	93.0
		CHE	Chemical processes	534	107.8	89.9	107.8	89.9
4	SETTLEMENTS	RCO	Energy for buildings	**3'322**	12.2	12.2	26.0	26.0
5	AVIATION	TNR_Aviation_CRS	Aviation cruise	412	5.5	6.4	50.1	106.8
		TNR_Aviation_CDS	Aviation climbing&descent	306	5.5	6.4	50.1	106.8
		TNR_Aviation_LTO	Aviation landing&takeoff	98	5.5	6.4	50.1	106.8
6	TRANSPORT	TRO	Road transportation	**5'530**	5.4	5.4	7.1	7.1
		TNR_Ship	Shipping	819	5.4	5.1	50.0	50.0
		TNR_Other	Railways, pipelines, off-road transport	255	50.3	106.9	50.5	107.0
7	OTHER	REF_TRF	Oil refineries and Transformation industry	1'917	54.4	149.3	57.7	151.4
		PRO	Fuel exploitation	258	191.1	339.1	210.9	364.5
		COL	Coal production	7	115.8	300.5	115.8	300.5
		AGS	Agricultural soils	99	70.7	0.0	70.7	0.0
		PRU_SOL	Solvents and products use	61	25.0	25.0	50.0	50.0

Representing CO_2 uncertainty

Perturbing the anthropogenic CO2 emissions along with transport and biogenic emissions permit to characterise CO2 uncertainties



Acknowledgements

Supported by CO2 Human Emission (CHE) **project**. The CHE project has received funding from the **European Union's Horizon 2020 research and innovation programme** under grant agreement No 776186. This poster reflects the views only of the authors, and the European Commission cannot be held responsible for any use which may be made of the information contained therein.

Further Readings

Agusti-Panareda et al. 2019: **Modelling CO2 weather – why horizontal resolution matters?** Atmos. Chem. Phys., 19, 7347–7376, https://doi.org/10.5194/acp-19-7347-2019

Balsamo et al. 2018: **Satellite and In Situ Observations for Advancing Global Earth Surface Modelling: A Review.** Remote Sensing, 10(12), 2038, https://doi.org/10.3390/rs10122038

Choulga et al. 2019: **Upgraded global mapping information for Earth system modelling**, Hydrol. Earth Syst. Sci., 23, 4051–4076, https://doi.org/10.5194/hess-23-4051-2019