Description of CMCC-CM2-v20191201 C3S contribution

1. Forecast system version

System name: CMCC-SPS3.5

First operational forecast run: 1st October, 2020

2. Configuration of the forecast model

Is it a coupled model? YES

Coupling frequency:
Atmosphere-Ocean: 90 minutes (every third full time-step of atmospheric model)

Atmosphere-Land: 30 minutes (also full time-step of atmospheric model)

Atmosphere-Sea Ice: 30 minutes (also full time-step of atmospheric model)

Detailed documentation:

CMCC technical documentation Gualdi et al (2020) CMCC Technical Note RP0288 DOI: https://doi.org/10.25424/CMCC/SPS3.5

2.1 Atmosphere and land surface

Model	CESM 1.2 - CAM 5.3 (Atmosphere) CESM 1.2 - CLM 4.5 (Land surface)
Horizontal resolution and grid	1/2° lat-lon approx
Atmosphere vertical resolution	46 levels in the vertical
Top of atmosphere	0.2 hPa (60 km approx.)
Soil levels (layers)	15 (10 soil layers plus 5 bedrock layers) Layer 1 (soil): 0-0.0175m Layer 2 (soil): 0.0175-0.0451m Layer 3 (soil): 0.0451-0.0906m Layer 4 (soil): 0.0906-0.1655m Layer 5 (soil): 0.1655-0.2891m Layer 6 (soil): 0.2891-0.4929m Layer 7 (soil): 0.4929-0,8289m Layer 8 (soil): 0.8289-1.3828m Layer 9 (soil): 1.3828-2.2961m Layer 10 (soil): 2.2961-3.8019m
Time step	Main (Physics) Time-step: 30 minutes. “Tracer” Advection Time step: 225 seconds (1/8 of the Physics time step) Fluid-Dynamics Time step: 56.25 seconds (1/32 of the Physics time step).

Detailed documentation:

CAM Model documentation **http://www.cesm.ucar.edu/models/cesm1.2/cam/**

CLM Model documentation **http://www.cesm.ucar.edu/models/cesm1.2/clm/**

CMCC technical documentation **Gualdi et al (2020) CMCC Technical Note RP0288** **DOI:** **https://doi.org/10.25424/CMCC/SPS3.5**

2.2 Ocean and cryosphere

Ocean model	NEMO v3.4
Horizontal resolution	1/4°
Vertical resolution	50 levels in the vertical
Time step	18 minutes
Sea ice model	CICE 4.0
Sea ice model resolution	1/4°
Sea ice model levels	1 thickness only
Wave model	NO
Wave model resolution	N/A

Detailed documentation:

Nemo Model documentation **https://www.nemo-ocean.eu/doc/**

CMCC technical documentation **Gualdi et al (2020) CMCC Technical Note RP0288** **DOI:** **https://doi.org/10.25424/CMCC/SPS3.5**

3. Initialization and initial condition (IC) perturbations

3.1 Atmosphere and land

	Hindcast	**Forecast**
Atmosphere initialization	ERA5	ECMWF IFS operational analysis
Atmosphere IC perturbations	10	10
Land Initialization	Forced monthly run from a continuous transient simulation with initial-date January 1993, started after a 10 year spinup (with climatological forcings)	Forced monthly run from a continuous transient simulation with initial-date January 1993, started after a 10 year spinup (with climatological forcings)
Land IC perturbations	3	3
Soil moisture initialization	From land initialization	From land initialization
Snow initialization	From land initialization	From land initialization
Unperturbed control forecast?	NO	NO
Horizontal resolution of perturbation	N/A	N/A

Perturbations in +/- pairs	NO	NO
Data assimilation method for control analysis	ERA5	ECMWF operational

Detailed documentation:

For more details on atmospheric DA, see ECMWF operational analysis documentation at: https://www.ecmwf.int/en/elibrary/16666-part-ii-data-assimilation

For more details on ERA5: https://doi.org/10.1002/qj.3803.

CMCC technical documentation Gualdi et al (2020) CMCC Technical Note RP0288 DOI: https://doi.org/10.25424/CMCC/SPS3.5

3.2 Ocean and cryosphere

	Hindcast	Forecast
Ocean initialization	C-GLORS Global Ocean 3D-VAR	C-GLORS Global Ocean 3D-VAR
Ocean IC perturbations	4	8
Unperturbed control forecast?	NO	YES

Detailed documentation:

More details on ocean data assimilation at http://c-glors.cmcc.it/index/index.html

CMCC technical documentation Gualdi et al (2020) CMCC Technical Note RP0288 DOI: https://doi.org/10.25424/CMCC/SPS3.5

4. Model uncertainties perturbations:

Model dynamics perturbations	NO
Model physics perturbations	YES (Ocean Model only, only during perturbed data assimilation cycles)
If there is a control forecast, is it perturbed?	There is no control forecast

Detailed documentation: For more info on ocean DA perturbations, see Brankart (2013) DOI: https://doi.org/10.1016/j.ocemod.2013.02.004

CMCC technical documentation Gualdi et al (2020) CMCC Technical Note RP0288 DOI: https://doi.org/10.25424/CMCC/SPS3.5

5. Forecast system and hindcasts

Forecast frequency	Monthly
Forecast ensemble size	50
Hindcast years	1993-2016
Hindcast ensemble size	40
On-the-fly or static hindcast set?	static

6. Other relevant information

The 10 atmospheric perturbed initial conditions, the 3 land perturbed initial conditions and the 9 ocean initial conditions (8 perturbed plus the unperturbed, only 4 perturbed in hindcast mode) are combined to yield 270 (120 in hindcast mode) possible perturbed forecast system initial conditions from which 50 initial conditions (40 in hindcast mode) are chosen at random, to produce the Forecast Ensemble.

Detailed documentation:

CMCC technical documentation **Gualdi et al (2020) CMCC Technical Note RP0288** **DOI: https://doi.org/10.25424/CMCC/SPS3.5**

7. Where to find more information

Sanna, A., A. Borrelli, P. Athanasiadis, S. Materia, A. Storto, S. Tibaldi, S. Gualdi, 2017: CMCC-SPS3: The CMCC Seasonal Prediction System 3. Centro Euro-Mediterraneo sui Cambiamenti Climatici. CMCC Tech. Note RP0285, 61pp. **https://www.cmcc.it/publications/rp0285-cmcc-sps3-the-cmcc-seasonal-prediction-system-3**

Gualdi, S., A. Sanna, A. Borrelli, A. Cantelli, M. del Mar Chaves Montero, S. Tibaldi, 2020: The new CMCC Operational Seasonal Prediction System SPS3. 5. Centro Euro-Mediterraneo sui Cambiamenti Climatici. CMCC Tech. Note RP0288, 26pp. DOI: **https://doi.org/10.25424/CMCC/SPS3.5**