Description of GCFS2.1-v20200320 C3S contribution

1. Forecast system version

System name: GCFS 2.1

First operational forecast run: November 2020

2. Configuration of the forecast model

Is it a coupled model? Yes

Coupling frequency: 1 hour

2.1 Atmosphere and land surface

Model	ECHAM 6.3.05 (atmosphere) JSBACH 3.20 (land)
Horizontal resolution and grid	T127 (~100 km) on regular Gaussian grid
Atmosphere vertical resolution	L95
Top of atmosphere	0.01 hPa
Soil levels (layers)	5 Layer 1: 0 - 0.065 m Layer 2: 0.065 - 0.319 m Layer 3: 0.319 - 1.232 m Layer 4: 1.232 - 4.134 m Layer 5: 4.134 - 9.834 m
Time step	200 s

Detailed documentation:

ECHAM6: **Stevens et al., 2013**

Soil scheme: **Hagemann and Stacke, 2014**

Runoff scheme: HD **Hagemann and Dümenil-Gates, 2003**

2.2 Ocean and cryosphere

Ocean model	MPIOM 1.6.3
Horizontal resolution	TP04 (0.4°) on a tripolar grid
Vertical resolution	L40

Time step	1 h
Sea ice model	Thermodynamic and sea-ice dynamics
Sea ice model resolution	same as ocean model
Sea ice model levels	zero-layer model
Wave model	N/A
Wave model resolution	N/A

Detailed documentation: MPIOM: **Jungclaus et al., 2013**

3. Initialization and initial condition (IC) perturbations

3.1 Atmosphere and land

	Hindcast	Forecast
Atmosphere initialization	ERA5	ERA5T
Atmosphere IC perturbations	none	none
Land Initialization	indirect via atmosphere initialization	indirect via atmosphere initialization
Land IC perturbations	none	none
Soil moisture initialization	indirect via atmosphere initialization	indirect via atmosphere initialization
Snow initialization	indirect via atmosphere initialization	indirect via atmosphere initialization
Unperturbed control forecast?	yes	yes

The assimilation for the atmosphere employs Newtonian relaxation of the reference data with the following variable-dependent relaxation times:

- divergence (48 hrs)
- vorticity (6hrs)
- temperature (~4hrs)
- logarithm of surface pressure (~4 hrs)

Data assimilation method for control analysis: no ensemble data assimilation

3.2 Ocean and cryosphere

	Hindcast	Forecast
Ocean initialization	ORAS5	ORAS5
Ocean IC perturbations	The very first hindcast ensemble in 1990 starts with lagged initialisation of the 30 members by each one day. Subsequently, bred vectors add small disturbances to the global three-dimensional ocean temperature and salinity fields	bred vectors add small disturbances to the global three-dimensional ocean temperature and salinity fields
Unperturbed control forecast?	yes	yes

More ocean data assimilation details:

- Assimilation of 3D temperature and salinity (ORAS5 data) using Newtonian relaxation with ~10 days of relaxation time
- Assimilation of sea-ice concentration (ORAS5 data) using Newtonian relaxation with ~20 days of relaxation time

Detailed documentation: GCFS ocean data assimilation: Baehr & Piontek, 2014

4. Model uncertainties perturbations:

Model dynamics perturbations	no
Model physics perturbations	atmosphere: perturbation of diffusion in uppermost layer
If there is a control forecast, is it perturbed?	unperturbed control forecast

Detailed documentation: Baehr et al. (2015)

5. Forecast system and hindcasts

Forecast frequency	monthly
Forecast ensemble size	50
Hindcast years	1993 - 2019
Hindcast ensemble size	30
On-the-fly or static hindcast set?	static

6. Other relevant information

The forcing database for radiative parameters like ozone, aerosol and greenhouse gases is provided by CMIP6 for the historical period up to 2014. Afterwards, data of RCP 4.5 future scenarios is used.

7. Where to find more information

www.dwd.de/seasonalforecasts