MODELS: MPI-ESM – EC-EARTH & NEMO-LIM3 – SALSA & UCLALES-SALSA – CTDAS

(1a) MPI-ESM – Max-Planck-Institute Earth System Model

(3) Available modes for the model runs: Research

(4) Components & processes: Atmosphere, Hydrosphere, Pedosphere, Biosphere & Physical, Chemical, Biological

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(5a) Brief model description

The **MPI-ESM** – Earth System Model with component models: ECHAM – atmosphere, MPI-OM – ocean and JSBACH – land surface, including YASSO for soils and HIMMELI for wetland. MPI-ESM couples the atmosphere, ocean and land surface through the exchange of energy, momentum, water and important trace gases such as carbon dioxide (Giorgetta et al., 2013). It is based on the components of ECHAM6 for atmosphere and MPIOM for ocean as well as JSBACH for terrestrial biosphere and HAMOCC for the ocean´s biogeochemistry. The coupling of atmosphere and land on the one hand and ocean and biogeochemistry on the other hand is made possible by the separate coupling program OASIS3. Energy, momentum, water and CO2 are exchanged with the help of this coupling. MPI-ESM has been used for comparative model calculations in the context of CMIP5.

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(1b) EC-EARTH – Earth System Model
(IFS - atmosphere, NEMO - ocean, and LIM - sea-ice, coupled through OASIS)

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(5b) Brief model description

EC-EARTH (Hazeleger et al., 2012) is an Earth system model that currently contains the following component models: IFS for the atmosphere, NEMO for the ocean, and LIM for the sea-ice, coupled through OASIS. Carbon cycle and aerosols are currently being introduced into EC-Earth via implementation of C-Tessel, LPJ-Guess, PISCES and TM5. EC-Earth is developed as part of a Europe-wide consortium and took successfully part in the CMIP5 simulations. Ongoing development by the consortium ensures that increasingly more reliable projections can be offered to decision and policy makers at regional, national and international levels.

Sea ice is a key component of the Arctic climate system and its realistic simulation is crucial. EC-EARTH is being updated to the new LIM3 version of the LIM sea-ice model which, most importantly, has subgrid-scale ice thickness categories and ice types resulting in, for example, a better simulation of the atmosphere-ocean energy exchange (Vancoppenolle et al. 2009). FMI's ocean-ice modellers are already running and developing the NEMO-LIM3 ocean-ice model. This long-term effort towards global modelling of marine environment will serve for relevant Arctic information services in FMI. FMI is participating in the development of LIM by upgrading physical parameterisations based on FMI's operative Baltic Sea ice model (Mårtensson et al. 2013). Additionally, an alternative thickness module describing the ice cover in terms of segments in high resolution spatial is implemented (Lensu 2003). Because an effective optimisation approach of a sea-ice model is needed as new parameterisations are implemented, FMI is planning to use a novel approach to optimise the LIM model (Järvinen et al. 2012, Uotila et al. 2012). Accordingly, FMI is an active member of the NEMO-LIM community and has a strong expertise in sea-ice modelling.

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(1c) UCLALES-SALSA & SALSA – University of California, Los Angeles Large Eddy Simulations Model coupled to Sectional Aerosol Module for Large Scale Applications

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(5c) Brief model description

SALSA - the sectional aerosol module has been designed to be implemented in large scale climate models, which require both accuracy and computational efficiency (Kokkola et al., 2008). SALSA uses multiple methods to reduce the computational burden of different aerosol processes to optimize the model performance without losing physical features relevant to problematics of climate importance. The optimizations include limiting the chemical compounds and physical processes available in different size sections of aerosol particles; division of the size distribution into size sections using size sections of variable width depending on the sensitivity of microphysical processing to the particles sizes; the total amount of size sections to describe the size distribution is kept to the minimum; furthermore, only the relevant microphysical processes affecting each size section are calculated. SALSA can be run in a box model mode and it has also been coupled to the climate model ECHAM6 and the air quality model MATCH.

UCLALES-SALSA is a Large Eddy Simulation model including aerosol module SALSA. The model can be used to study aerosol-cloud interactions in a cloud resolving scale. The UCLALES model without SALSA has been used to study the dynamics of different cloud types (e.g. Stevens and Seifert 2008), microphysics for aerosol, clouds and precipitation (Tonttila et al. 2017), and with SALSA it has been used in marine stratocumulus geoengineering and radiation fog studies. Currently the model development is ongoing to conduct more detailed studies on aerosol-cloud interactions with the main emphasis on cloud processing, aerosol aging, and wet removal of different chemical aerosol components.

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(1d) CTE – CarbonTracker Europe atmospheric inverse model

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(5d) Brief model description

CTE CarbonTracker - the atmospheric inverse model, developed by NOAA-ESRL (National Oceanic and Atmospheric Administration's Earth System Research Laboratory) & Wageningen University, the Netherlands, consists of an ensemble Kalman filter -based data assimilation scheme and atmospheric transport model TM5. It optimizes surface fluxes on the basis of atmospheric concentration observations. The model was originally designed to optimise CO2 fluxes (Peters *et al.* 2010), and has now been developed for global CH4 fluxes (Bruhwiler *et al.,* 2014). FMI has developed an independent CTDAS CH4 version with zoom over Europe.

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