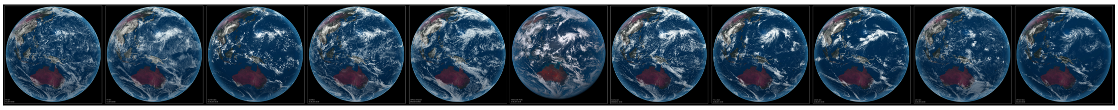

PROJECT DYAMOND 2^{nd} PHASE - THE WINTER

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Synopsis

In the initial phase of the DYAMOND (DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains) project nine models were run successfully at storm resolving scales for 40 days and nights from the 1^{st} August 2016 (Stevens et al., 2019). Here two additional experiments are proposed, which will complement the boreal summer period with a winter period. In the second phase, the experiment will be conducted with both, atmosphere only and (if possible) with coupled atmosphere-ocean models. The modelling groups of the first phase present at the ESIWACE Hackathon in Mainz in June 2019 (NICAM, ICON, GEOS, MPAS, IFS, SAM and FV3) agreed on a winter simulation as common area of interest. Only a sub-group is currently able to run the coupled experiments at this stage (NICAM and IFS). Other groups are actively working towards a coupled setup of their models (SAM, GEOS, and ICON) and hope to be able to contribute by the time of the experiment. The project remains open to other groups to participate and closely follows the protocol of the first DYAMOND runs.

The DYAMOND project is a framework for the intercomparison of an emerging class of atmospheric circulation models, that, through their resolution of the major modes of atmospheric heat transport, endeavor to represent the most important scales of the full three-dimensional fluid dynamics of the atmospheric circulation. Phase 0 of DYAMOND will be complemented by a boreal winter period and coupled models with the goal to: (i) compare the representation of the Madden-Julian-Oscillation in this class of models; (ii) investigate the effect of the atmosphere-ocean coupling at storm and ocean-eddy resolving scales on convection and the general circulation; and (III) link to the EUREC^{4}A[1] campaign, which targets meso-scale convection patterns and the coupling to the upper ocean processes.

1. Protocol

(1) Simulations will be initialised on 20 January 2020 (or slightly before) so as to encompass the EUREC4A tropical field study (as well as parts of the MOSAiC arctic expedition) which will start on the 20 January 2020 and will last until 1^{st} March 2020. The initialization will be from a common (ECMWF) atmospheric

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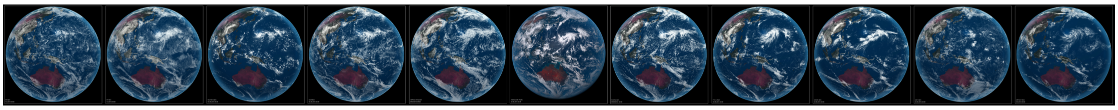
[1] A Field Campaign to Elucidate the Couplings Between Clouds, Convection and Circulation



analysis, and run for forty days and forty nights with specified sea-surface temperatures (7 day running mean) for the atmosphere only experiments. Groups are left free to initialize soil moisture according to their sense of best practice.

(2) The same period will be simulated by coupled atmosphere-ocean models by groups capable of running coupled systems at storm resolving scales. Groups are free on how to initialize the ocean (nudged run-up to the initial date, or ocean analysis at initial date).

(3) To participate the host model must be run at a grid spacing of 5 km or less for the atmosphere and a comparable resolution for the model ocean (if possible) and not incorporate a parameterized representation of atmospheric deep convection. The vertical domain should extend to well above the troposphere (25 km or higher), and the convening participants are targeting model versions with about 75 levels or more for the atmosphere and a sufficient number of levels for the ocean to approximate observed SSTs and that allows to study atmosphere-ocean coupling on the meso-scale.

(4) Models are expected to be of a form capable of representing the actual atmospheric general circulation, and thereby incorporate a full representation of fine-scale physical processes (microphysics, radiation, small-scale turbulence) as well as a realistic lower boundary conditions like topography.

(5) Analysis will be split into a ten day spin-up period and a thirty day analysis period, with two and three dimensional output as discussed below (see also Tables 1,2,3 and Tables 4,5 for the ocean models).

2. Model output and data policy

As for the initial phase of DYAMOND, data archiving and access, including provision of and access to input data, will be provided through the DKRZ, supported and disseminated by the DKRZ led Center of Excellence ESiWACE. All simulation output will be made publicly available as quickly as is technically possible.

Based on the first DYAMOND simulations, the total output per model varied between 21 TB (UM) and 147 TB (GEOS), depending on horizontal and vertical resolution, output frequency, number of variables and compression. The total data amount, including sensitivity experiments and experiments at coarser resolutions amounted to about 1 PB. Resources have been applied for within the framework of the ESiWACE project, the project will also set up a coordination page to share this protocol and establish points of contact. Variable lists will be slightly adjusted, based on experience from the initial phase of DYAMOND and complemented through an output variable list for the ocean models.

Groups may have additional output that they may wish to provide, and depending on their microphysical representation different variables may be appropriate, or certain integral quantities may not be well defined (i.e., CAPE or CIN). A output list is specified for the atmosphere models in the Tables 1-3 for guidance. Groups should try to conform to the specified output, and document what and how they provide output, but in recognition of the challenges in writing output from such large simulations conformance to the output requirements is left up to the individual groups best judgement, which worked well in the first DYAMOND experiment.

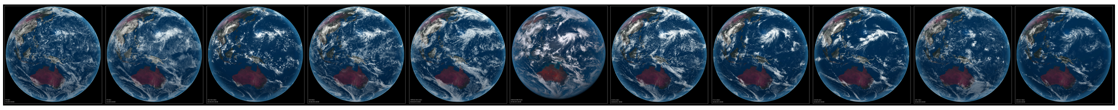


Table 1. 3D Output (3 h interval). On model levels below 20 km

Atmosphere Variable	Long Name	Units
u	Zonal wind on model level	$\mathrm{m\,s^{-1}}$
v	Meridional wind on model level	$\mathrm{m\,s^{-1}}$
w	Vertical wind on model level	$\mathrm{m\,s^{-1}}$
T	Temperatureon model level	K
P	Pressure on model level	Pa
q_{v}	specific humidity on model level	$\mathrm{g\,kg^{-1}}$
q_{c}	specific cloud water on model level	$\mathrm{g\,kg^{-1}}$
q_{i}	specific cloud ice on model level	$\mathrm{g\,kg^{-1}}$

In addition some basic time-independent information about the horizontal and vertical grid, topographic height, bathymetry, surface roughness, and land fraction should be made available.

3. Timeline & Next steps

The project timeline is given in Table 6, this includes a couple of action items that need to take place before the simulations can be started. One is the exact specification of the output data (especially ocean), the other is the provision of the initial data. It is expected that all information and data is available by the 1^{st} of March 2020.

4. Perspective

Project DYAMOND is working toward an intercomparison of global storm $\mathcal{O}(3\,\mathrm{km})$ resolving model representations of the atmospheric circulation on the decadal time scale. It will explore the ability of such models to better represent the atmospheric general circulation, and its sensitivity to surface temperature, as compared to traditional approaches, which use a statistical representation using statistical representations of major modes of convective heat transport. One pressing question is whether changes in clouds, precipitation and cloud controlling factors is similar to what has been gleaned from cruder (traditional) models of the atmospheric circulation. The coupled simulations specifically target the atmosphere-ocean interactions on the meso-scale and the impact on the general circulation, when convection and ocean eddies are resolved.

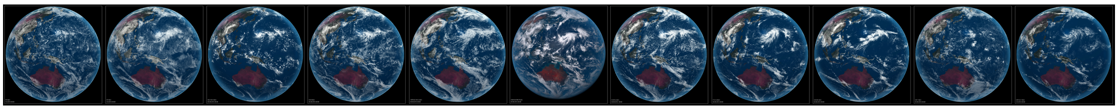


TABLE 2. 2D Output (15 min interval). In ICON both CAPE and CIN are computed with respect to the mean properties of a surface layer parcel.

Variable	Long Name	Units
$U_{10\mathrm{m}}$	Zonal wind at 10 m	$\mathrm{m\,s^{-1}}$
$V_{10\mathrm{m}}$	Meridional wind at 10 m	$\mathrm{m\,s^{-1}}$
$T_{2\mathrm{m}}$	Temperature at 2 m	K
P_{sfc}	Surface pressure	K
$q_{\mathrm{v,2m}}$	Specific humidity at 2 m	$\mathrm{g\,kg^{-1}}$
$\int q_{\mathrm{v}}\rho\,\mathrm{d}z$	Vertically integrated specific humidity	$\mathrm{kg\,m^{-2}}$
$\int q_{\mathrm{c}}\rho\,\mathrm{d}z$	Vertically integrated cloud water	$\mathrm{kg\,m^{-2}}$
$\int q_{\mathrm{i}}\rho\,\mathrm{d}z$	Vertically integrated cloud ice	$\mathrm{kg\,m^{-2}}$
$\int q_{\mathrm{r}}\rho\,\mathrm{d}z$	Vertically integrated rain water	$\mathrm{kg\,m^{-2}}$
$\int q_{\mathrm{s}}\rho\,\mathrm{d}z$	Vertically integrated snow	$\mathrm{kg\,m^{-2}}$
$\int q_{\mathrm{g}}\rho\,\mathrm{d}z$	Vertically integrated graupel	$\mathrm{kg\,m^{-2}}$
C	Vertically projected cloud cover	–
$\rho l_{\mathrm{v}}\overline{w'q_{\mathrm{v}}'}$	Surface latent heat flux	$\mathrm{W\,m^{-2}}$
$\rho c_p\overline{w'T'}$	Surface sensible heat flux	$\mathrm{W\,m^{-2}}$
$\rho\overline{w'u'}$	Surface zonal momentum flux	$\mathrm{N\,s^{-1}\,m^{-2}}$
$\rho\overline{w'v'}$	Surface meridional momentum flux	$\mathrm{N\,s^{-1}\,m^{-2}}$
R	Surface precipitation (accumulated)	$\mathrm{kg\,m^{-2}}$
T_{g}	Ground temperature (land)	K
q_{g}	Surface specific humidity (land)	$\mathrm{g\,kg^{-1}}$
$F_{\mathrm{sfc}}^{\mathrm{sw,net}}$	Surface net shortwave (accumulated)	$\mathrm{J\,m^{-2}}$
$F_{\mathrm{toa}}^{\mathrm{sw,net}}$	TOA net shortwave (accumulated)	$\mathrm{J\,m^{-2}}$
$F_{\mathrm{sfc}}^{\mathrm{sw,d}}$	Surface downward shortwave (accumulated)	$\mathrm{J\,m^{-2}}$
$F_{\mathrm{sfc}}^{\mathrm{lw,net}}$	Surface net longwave (accumulated)	$\mathrm{J\,m^{-2}}$
$F_{\mathrm{toa}}^{\mathrm{lw,net}}$	TOA net longwave (accumulated)	$\mathrm{J\,m^{-2}}$
$F_{\mathrm{sfc}}^{\mathrm{lw,d}}$	Surface downward longwave (accumulated)	$\mathrm{J\,m^{-2}}$
CAPE	Convective available potential energy	$\mathrm{J\,m^{-2}}$
CIN	Convective inhibition	$\mathrm{J\,m^{-2}}$

TABLE 3. Output (15 min interval) on select pressure levels (200 Pa, 500 Pa, 700 Pa and 850 Pa)

Variable	Long Name	Units
RH	Relative humidity	–
ω	Pressure velocity	$\mathrm{Pa\,s^{-1}}$
Z	Geopotential height	m

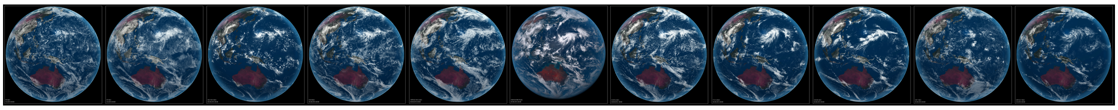


TABLE 4. 3D Output (3 h interval).

Variable	Long Name	Units
U_o	Zonal velocity on model level	$m\,s^{-1}$
V_o	Meridional velocity on model level	$m\,s^{-1}$
W_o	Vertical velocity on model level	$m\,s^{-1}$
T_o	Temperature on model level	K
S_o	Salinity on model level	0.001

TABLE 5. 2D Ocean Output (1 h interval).

Variable	Long Name	Units
H_{os}	Surface height above geoid	m
T_{os}	Surface temperature	K
S_{os}	Surface salinity	0.001
P_{os}	Surface sea water pressure	Pa
U_{os}	Surface zonal current	$m\,s^{-1}$
V_{os}	Surface meridional current	$m\,s^{-1}$
Mlt_{os}	Mixed layer thickness defined by vertical temperature gradient	m
Mls_{os}	Mixed layer thickness defined by mixing scheme	m
Wfd_{os}	Water flux into sea water without correction	$kg\,m^{-2}\,s^{-1}$
$Wfcorr_{os}$	Water flux correction	$kg\,m^{-2}\,s^{-1}$
Sfd_{os}	Downward sea ice basal salt flux	$kg\,m^{-2}\,s^{-1}$
Hfd_{os}	Downward heat flux at surface without correction	$W\,m^{-2}$
$Hfld_{os}$	Downward latent heat flux at surface	$W\,m^{-2}$
$Hfsd_{os}$	Downward sensible heat flux at surface	$W\,m^{-2}$
$Hfcorr_{os}$	Downward heat flux correction at surface	$W\,m^{-2}$
$tauu_{os}$	Downward X stress at surface without correction	$N\,m^{-2}$
$tauv_{os}$	Downward Y stress at surface without correction	$N\,m^{-2}$
$tauucorr_{os}$	Downward X stress correction at surface	$N\,m^{-2}$
$tauvcorr_{os}$	Downward Y stress correction at surface	$N\,m^{-2}$
sia_{os}	Fraction of grid cell covered by sea ice	1
$sith_{os}$	Sea ice thickness	meter
sit_{os}	Sea ice surface temperature	kelvin
siu_{os}	Sea ice zonal velocity	$m\,s^{-1}$
siv_{os}	Sea ice meridional velocity	$m\,s^{-1}$

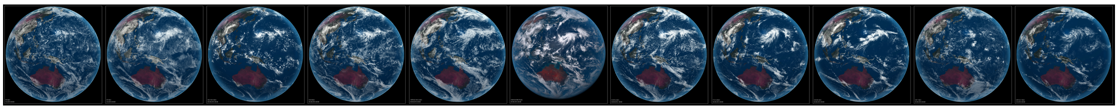
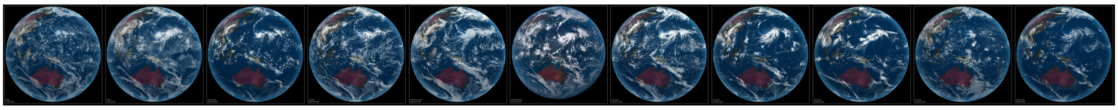


TABLE 6. Project winter DYAMOND atmosphere only and coupled atmosphere-ocean timeline

Date	Action to be completed
15.07.2019	Initial protocol to be circulated
26.09.2019	Finalization of initial protocol & EUREC4A meeting in Paris
20.01.2020	Finalization of output lists & release of web page
01.03.2020	Input prepared
xx.05.2020	Discussion of simulations at ESIWACE meeting Hamburg
01.07.2020	Completion of simulation
xx.07.2020	Hackathon in Berlin
31.12.2020	Finalize Publication
xx.08.2021	Present results at AOGS meeting Singapore
01.01.2022	Phase II Kickoff



5. Specific Open Questions

(1) Should the timelines be the same for atmosphere-only and coupled experiments?
(2) Ocean variable list needs further refinement.
(3) How do we specify the initialisation of the ocean models and do we need some pre-study to determine the ocean minimum ocean requirements (number of level and spacing close to surface)?
(4) Were we missing any output variables in the previous phase? What about heating rates from radiation, there were several requests?
(5) Should we ask for brightness temperatures as output?
(6) Should we actively approach other groups (who is out there who could participate)? Environment Canada and the Naval Research Laboratory expressed interest.
(7) There is a potential issue related to the choice of ocean equation of state. The ocean modelling community is supposed to move from the EOS-80 (potential temperature/practical salinity) to TEOS-10 (conservative temperature/absolution salinity), but not all models have done this transition. So different contributors might have different definitions of temperature/salinity make model inter comparisons difficult.