Options for NorESM2 for CMIP6
- with emphasis on the atmosphere

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NorESM belongs to the “family” of models based on the Community ESMs.

• The ocean model → iso-pycnic co-ordinate, developed from MICOM;
• Ocean bio-geochemistry is based on HAMOCC (HAMburg Ocean Carbon Cycle Model);
• Aerosol life-cycling, physics, and interactions with clouds (CAM-Oslo);
• Adjusted processing of sea-ice and snow on sea-ice.
NorESM2_CAM – the CMIP6-versions

• intended to be based on CESM1.5 / CAM5.5 or newer.

• preliminary version is based on CESM1.2_CAM5.3.
  • But: CICE5 and CLM5 are needed in NorESM2

• Alternative:
  • trace-back CAM5.3 / 5.4 from CESM1.5_CAM5.5,
  • e.g. with 48 levels
  • and WACCM stratospheric physics
    (→QBO, SSW possible impacts on tropospheric dynamics)

• A version based on CESM2_CAM6 to be considered later

• The MICOM-based Ocean model can be run with 1x1 deg and 0.25x0.25 deg resolution
Sea ice component in NorESM2

• **The sea ice component based on CICE5**
  – Most likely with prognostic sea-ice salt.
  – Possibly include changes in the horizontal distribution of snow on sea ice, and a simple parameterization of the effects of wind blowing snow.
NorESM-Ocean Resolution

Based on monthly snapshots from early NorESM2 tests where NorESM-O was coupled to standard CAM5.3
Experience from NorESM2 coupled experiments with 1° and 0.25° ocean resolution

1: CAM4, 1° deg Ocean
N1850_f19 tn11_01_default
CAM4/CLM4 2°, MICOM/CICE 1°

2: CAM5-Oslo, 1° deg Ocean
N1850C5OL45_f09 tn11
CAM5-Oslo/CLM4.5 1°, MICOM/CICE 1°

3: CAM5, 1/4° deg Ocean
ATM_F09_MICOM_tnx025
CAM5/CLM4 1°, MICOM/CICE 0.25°

4: CAM5-Oslo, 1/4° deg Ocean
CAM5O1MICOMFINAL2
CAM5-Oslo/CLM4.5 1°, MICOM/CICE 0.25°

Global Mean Ocean pot. temp. difference.

TOA heat balance
Max. AMOC
Increase no. of levels
Inspired by Yaga Richter’s work

Two CAM5.3-OSLO test simulations planned,
• one with 32 layers and standard gravity wave drag parametrisation
• one with 48 levels and WACCM gravity wave drag parametrisation.

1 deg resolution with prescribed SST/sea-ice climatology; 50 years.
### Six possible configurations of NorESM2 for CMIP6.

Low, Medium, or High atmospheric and oceanic resolution; Preliminary: 53 ocean & 32 atmos. levels.
Process complexity: Emission-driven GHG and atmospheric Chemistry.

<table>
<thead>
<tr>
<th>NorESM2</th>
<th>_MH</th>
<th>_HH</th>
<th>_MM</th>
<th>_LM</th>
<th>_LME</th>
<th>_LMEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmos. – Land</td>
<td>M: 0.9x1.25 deg.</td>
<td>H: 0.23x0.31 deg.</td>
<td>M: 0.9x1.25 deg.</td>
<td>L: 1.9x2.5 deg.</td>
<td>L: 1.9x2.5 deg.</td>
<td>L: 1.9x2.5 deg.</td>
</tr>
</tbody>
</table>

**RESOLUTION**

**GHG**
- Concentration-driven
- Emission-driven

**Aerosol**
- Emis-driven, Compl physics
- Emis-driven, Simple physics
- Emis-driven, Compl physics
- Emis-driven, Compl physics
- Emis-driven, Compl physics
- Emis-driven, Compl physics

**Atmos. Chem.**
- Simplified; Simplified; Simplified; Simplified; Simplified; C: Complex

**Ocean BioGeoC.**
- OFF
- OFF
- OFF
- OFF
- E: ON
- E: ON

**CMIP-DECK + CMIP6 Hist**
- ALL
- Only AMIP
- OPTIONAL: ALL if _MH fails
- AMIP, PrelInd, Historic
- ALL except AMIP
- Only AMIP

**MIPs**
- AerChemMIP
- CFMIP
- RFMIP
- DAMIP
- OMIP
- ScenarioMIP
- SIMIP
- HighResMIP
- OPTIONAL. If _MH fails:
  - AerChemMIP
  - CFMIP
  - RFMIP
  - DAMIP
  - OMIP
  - ScenarioMIP
  - SIMIP
- AerChemMIP
- CFMIP
- DAMIP
- DCPP
- LS3MIP
- LUMIP
- OMIP
- PMIP
- RFMIP
- ScenarioMIP
- VolMIP
- SIMIP
- C4MIP
- LUMIP
- LS3MIP
- OMIP
- PMIP
- RFMIP
- ScenarioMIP
- VolMIP
- SIMIP
- AerChemMIP
- VolMIP
Remarks on Status for NorESM2

CMIP DECK:

NorESM2_MH (or _MM) should be ready by end 2016/early 2017
ScenarioMIP, AerChemMIP, DAMIP

NorESM2_LM & LME should be ready before summer 2017.
ScenarioMIP, C4MIP, DAMIP, LUMIP, LS3MIP, AerChemMIP
Important aerosol related updates:
CAM4-Oslo → CAM5-Oslo:

1) “Oslo aerosols” as an option alongside CAM5’s MAMx
2) Explicit treatment of aerosols in cloud-water
3) New sea-salt emission parametrization (Salter et al., 2015)
4) Terrestrial BVOC-emissions from CLM4.5 → SOA
5) Explicit aerosol nucleation of H2SO4 + SOA
6) Online oceanic biogenic POM and DMS emissions
7) Improved heterogeneous ice nucleation treatment
8) Conservation of energy-consistency – fix implemented
9) Several bug fixes since CAM4-Oslo (alas!)
10) Nitrate aerosols: in progress
Indirect RF in CAM4-Oslo vs. ERF ACI in CAM5-Oslo (W m\(^{-2}\)):
(Only minor changes in direct radiative forcing, ca. -0.1 - 0.0 W m\(^{-2}\))

<table>
<thead>
<tr>
<th></th>
<th>SW</th>
<th>LW</th>
<th>Main new features/bug-fixes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CAM4-Oslo</strong></td>
<td>-0.91</td>
<td>+0.01</td>
<td>(Indirect RF; NorESM1 for CMIP5)</td>
</tr>
<tr>
<td><strong>Ind. RF</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CAM5.3-Oslo</strong></td>
<td>-0.92</td>
<td>+0.14</td>
<td>Most recent CAM5.3-Oslo version</td>
</tr>
<tr>
<td><strong>ERF ACI</strong></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>-1.27</td>
<td>+0.22</td>
<td>New emissions, chemistry and aerosol cloud interactions, assumed hygroscopicity for CCN activation, and b.b. OM/OC=1.4 (reduced from 2.6)</td>
</tr>
<tr>
<td></td>
<td>-1.16</td>
<td>+0.22</td>
<td>New sea-salt parameterization</td>
</tr>
<tr>
<td></td>
<td>-1.46</td>
<td>+0.26</td>
<td>Bug-fixes for aerosol condensation, halved dust emissions</td>
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<tr>
<td></td>
<td>-1.82</td>
<td>+0.34</td>
<td>On-line terrestrial BVOC $\rightarrow$ SOA life-cycling</td>
</tr>
<tr>
<td></td>
<td>-1.71</td>
<td>+0.41</td>
<td>New Ice-Nucleation scheme and daily oxidants</td>
</tr>
<tr>
<td></td>
<td>-1.20</td>
<td>+0.33</td>
<td>On-line DMS &amp; oceanic biogenic POM</td>
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</tbody>
</table>
Hypotheses studied:
- Nucleation over oceans is high in PI due to inefficient condensation combined with large BVOC emissions upwind.
  - In NH, this is compensated by large PD SO2-emissions.
- Organic aerosols influence sea salt hygroscopicity
- Feedback to DMS emissions
- Different oxidant levels in PD and PI
Thank you for the attention.
Different effect of nucleation NH/SH

Difference in nucleation-rate PD – PI in REF-simulation. Increased nucleation in NH (due to larger SO2 I guess), but decreased nucleation over the areas where there are mostly sea-salt. (Due to more pulluted atmosphere in PD acting as “condensation sink for H2SO4(g)"

**Diagram:**

- **Positive values**
- **Negative values**

**Legend:**

- **Nucleation rate (#/cm3/s)**
- **Data Min = -2.6, Max = 28.8**
Cloud water and ice

Free-running model has 10% higher LWP than the nudged version.
Cloud-fraction

M-G 1.0

CLDTOT  avg = 0.62

M-G 1.5

CLDTOT  avg = 0.65

CLDLOW  avg = 0.38

CLDLOW  avg = 0.41
Complex aerosol-scheme extended since NorESM1 (CMIP5):

- Improved treatment of SOA/\(\text{SO}_4\) nucleation and condensation.
- BVOC-->SOA explicit.
- Interactive marine DMS, bio-particles, sea-salt, and dust.
- Explicit concentrations in cloud droplets.

25 transported components
CAM5.3-Oslo

with nudging towards CAM5.3-AMIP U,V,T-fields

6 year simulations PD and PI, 2 final years used for statistics.

- M-G 1.0
  NorESM2-version 18.
  January 2016

- M-G 1.5
  Morrison-Gettelmann 1.5 is used instead of MG