Experiments preparing for a coarse resolution NorESM2

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AMWG Meeting, 28 February 2017
The NorESM belongs to the “family” of models based on the CESM.

- **Aerosol life-cycle, physics, and cloud interactions**: CAM-Oslo (MET Norway/UiO)
- **NorESM-O**: is a modified version of MICOM (Miami Isopycnic Coordinate Ocean Model)
- **Ocean bio-geochemistry**: based on HAMOCC (HAMburg Ocean Carbon Cycle Model)
- **Adjusted processing of sea ice and snow on sea ice**
NorESM2 – the CMIP6 versions
to be based on the CESM2 (with CLUBB or preCLUBB)

<table>
<thead>
<tr>
<th>NorESM2</th>
<th>_MM (MH?)</th>
<th>_LM</th>
<th>_LME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Based on</td>
<td>CESM2</td>
<td>CESM2</td>
<td>CESM2</td>
</tr>
<tr>
<td>Atmos. – Land</td>
<td>M: 0.9x1.25 deg.</td>
<td>L: 1.9x2.5 deg.</td>
<td>L: 1.9x2.5 deg.</td>
</tr>
<tr>
<td></td>
<td>Atm:32 levels</td>
<td>32 levels (48 ?)</td>
<td>32 levels (48 ?)</td>
</tr>
<tr>
<td></td>
<td>(H: 0.25 deg.)</td>
<td>Conc. driven</td>
<td>E: Emis. driven</td>
</tr>
<tr>
<td>GHG</td>
<td>Conc. driven</td>
<td>Conc. driven</td>
<td></td>
</tr>
<tr>
<td>Ocean BGC.</td>
<td>ON(OFF?)</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>CMIP-DECK + CMIP6 Hist</td>
<td>ALL</td>
<td>ALL</td>
<td>Prelnd, Historic</td>
</tr>
</tbody>
</table>

- **NorESM2_MM:**
  - Medium resolution
  - Calibration initiated with pre-release (beta) versions

- **NorESM2_LM & NorESM2_LME:**
  - Low/Medium resolution with/without Emission-driven GHGs
Coupled NorESM2_LM

- Atm./land res.: 1.9 × 2.5 degrees
- CESM2_beta02
- Coupled to MICOM
- CAM6 with CLUBB
- CLM5
- Oslo aerosols
- 1850 conditions
- 80 years
- clubb_gamma_coef = 0.238

Radiative balance (-0.35 W/m²)
Blue line is for NorESM1_M and red line is for NorESM2_LM
**Coupled NorESM2_LM**

- Atm./land res.: $1.9 \times 2.5$ degrees
- CESM2_beta02
- Coupled to MICOM
- CAM6 with CLUBB
- CLM5
- Oslo aerosols
- 1850 conditions
- 80 years
- clubb_gamma_coef $= 0.238$

**Radiative balance (-0.35 W/m²)**

Blue line is for NorESM1_M and red line is for NorESM2_LM

**2-m temperature**
Uncoupled NorESM2_LM (REF)

- Prescribed SSTs and sea ice
- 2000 conditions
- 5-year runs

- Five sensitivity runs and one reference
- Land model uninitialized
Uncoupled NorESM2_LM (REF)

- Prescribed SSTs and sea ice
- 2000 conditions
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- Five sensitivity runs and one reference
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**SWCF: REF – CERES-EBAF**

```
mean = -1.17  rmse = 12.48  W/m²
Min = -60.87  Max =  70.52

```

**LWCF: REF – CERES-EBAF**

```
mean =  0.28  rmse =  7.46  W/m²
Min = -26.87  Max =  34.11

```

**LHFLX: REF – JRA25**

```
mean = -5.50  rmse = 18.76  W/m²
Min = -77.84  Max = 158.07

```

**CLDLOW: REF – CLOUDSAT**

```
mean = -4.79  rmse = 17.74  W/m²
Min = -56.00  Max =  72.07

```
### CLUBB parameters used for tuning

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Test Values</th>
<th>REF Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>clubb_gamma_coef</code></td>
<td>Controls the variance of the PDFs in the vertical velocity coordinate</td>
<td>0.1, 0.6</td>
<td>0.29</td>
</tr>
<tr>
<td><code>clubb_beta</code></td>
<td>Skewness of the PDF for liquid water potential temperature and total water mixing ratio</td>
<td>0, 3</td>
<td>2.8</td>
</tr>
</tbody>
</table>
Changes in low-level cloud cover (CLDLOW)

\[ \Delta \text{CLDLOW: gamma } = 0.1 \text{ vs. } 0.29 \]

\[ \Delta \text{CLDLOW: gamma } = 0.6 \text{ vs. } 0.29 \]

\[ \Delta \text{CLDLOW: beta } = 0 \text{ vs. } 2.8 \]

\[ \Delta \text{CLDLOW: beta } = 3 \text{ vs. } 2.8 \]
Changes in liquid water path (LWP)

\[ \Delta \text{LWP: gamma} = 0.1 \text{ vs. 0.29} \]

\[ \Delta \text{LWP: beta} = 0 \text{ vs. 2.8} \]

\[ \Delta \text{LWP: gamma} = 0.6 \text{ vs. 0.29} \]

\[ \Delta \text{LWP: beta} = 3 \text{ vs. 2.8} \]
Changes in short-wave cloud forcing (SWCF)

$\Delta \text{SWCF: } \gamma = 0.1 \text{ vs. } 0.29$

$\Delta \text{SWCF: } \gamma = 0.6 \text{ vs. } 0.29$

$\Delta \text{SWCF: } \beta = 0 \text{ vs. } 2.8$

$\Delta \text{SWCF: } \beta = 3 \text{ vs. } 2.8$
Changes in long-wave cloud forcing (LWCF)

\[ \Delta \text{LWCF: gamma } = 0.1 \text{ vs. } 0.29 \]

\[ \Delta \text{LWCF: gamma } = 0.6 \text{ vs. } 0.29 \]

\[ \Delta \text{LWCF: beta } = 0 \text{ vs. } 2.8 \]

\[ \Delta \text{LWCF: beta } = 3 \text{ vs. } 2.8 \]
Changes in latent heat flux (LHFLX)

$\Delta$LHFLX: $\gamma = 0.1$ vs. 0.29

$\Delta$LHFLX: $\gamma = 0.6$ vs. 0.29

$\Delta$LHFLX: $\beta = 0$ vs. 2.8

$\Delta$LHFLX: $\beta = 3$ vs. 2.8
Zhang-McFarlane parameter used for tuning

zm_c0_lnd

Test: 0.03

Precipitation efficiency over land

REF = 0.0075
Changes in response to modifying zm_c0_lnd

\[ \Delta \text{LWP: zm}_c_0\_\text{lnd} = 0.03 \text{ vs. } 0.0075 \]

\[ \Delta \text{CLDTOT: zm}_c_0\_\text{lnd} = 0.03 \text{ vs. } 0.0075 \]

\[ \Delta \text{SWCF: zm}_c_0\_\text{lnd} = 0.03 \text{ vs. } 0.0075 \]

\[ \Delta \text{LWCF: c}_0\_\text{lnd} = 0.03 \text{ vs. } 0.0075 \]
## Changes in the globally-averaged values

<table>
<thead>
<tr>
<th></th>
<th>FSNT-FLNT</th>
<th>SWCF</th>
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<th>LHFLX</th>
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<tbody>
<tr>
<td>REF</td>
<td>6.8</td>
<td>-48.2</td>
<td>26.8</td>
<td>82.4</td>
</tr>
</tbody>
</table>

**clubb_gamma_coef**

- Test: 0.1, 0.6
  -11.2, 8.6
  -13.6, 9.9
  1.9, -1.2
  3.0, -2.8

REF = 0.29

**clubb_beta**

- Test: 0, 3
  -12.6, 1.4
  -15.4, 1.6
  2.0, -0.2
  3.4, -0.6

REF = 2.8

**zm_c0_lnd**

- Test: 0.03
  -0.6
  -0.7
  -0.7
  0.6

REF = 0.0075
Summary

- **NorESM2** to be based on the CESM2, with CAM6-Oslo, NorESM-O, CLM5, and CICE5

- Reducing `clubb_gamma_coef` and/or `clubb_beta` improves the low-level cloud cover and SWCF and LWCF in the marine stratocumulus regions

- Increasing `zm_c0_lnd` improves the SWCF and LWCF over low-latitude continents, but *biases still remain*
Additional slides
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<td><strong>clubb_gamma_coef</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test: 0.1, 0.6</td>
<td>-4.5, 15.4</td>
<td>-61.9, -38.4</td>
<td>28.6, 25.6</td>
<td>85.4, 79.7</td>
</tr>
<tr>
<td>REF = 0.29</td>
<td>-11.2, 8.6</td>
<td>-13.6, 9.9</td>
<td>1.9, -1.2</td>
<td>3.0, -2.8</td>
</tr>
<tr>
<td><strong>clubb_beta</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test: 0, 3</td>
<td>-5.8, 8.2</td>
<td>-63.8, -46.7</td>
<td>28.8, 26.5</td>
<td>85.8, 81.8</td>
</tr>
<tr>
<td>REF = 2.8</td>
<td>-12.6, 1.4</td>
<td>-15.4, 1.6</td>
<td>2.0, -0.2</td>
<td>3.4, -0.6</td>
</tr>
<tr>
<td><strong>zm_c0_Ind</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test: 0.03</td>
<td>-6.2</td>
<td>-47.5</td>
<td>26.1</td>
<td>83.0</td>
</tr>
<tr>
<td>REF = 0.0075</td>
<td>-0.6</td>
<td>-0.7</td>
<td>-0.7</td>
<td>0.6</td>
</tr>
</tbody>
</table>
Resolution: $0.9 \times 1.25$ vs. $1.9 \times 2.5$

2-m T: high res - low res

PSL: high res - low res

IWP: high res - low res

LWP: high res - low res
Resolution: $0.9 \times 1.25$ vs. $1.9 \times 2.5$
Resolution: $0.9 \times 1.25$ vs. $1.9 \times 2.5$

**PRECT:** high res - low res

**CLOUD:** high res - low res

**CLED:** high res - low res

**CLDHGH:** high res - low res