Model Uncertainty Intercomparison Project
WGNE Update

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WGNE35, 2-5 November 2020
Joint initiative of Predictability, Dynamics and Ensemble Forecasting (PDEF) working group and Working Group on Numerical Experimentation (WGNE)

A primary joint interest of the two working groups is model error identification and its representation in ensemble forecasts
- Systematic and random error

At the joint WGNE/PDEF meeting in Tokyo, October 2018, a coordinated activity was proposed to evaluate model error across a number of forecast models

Some key questions:
- How should we best represent model uncertainty (random error)?
- To what extent should this representation be model specific or a fundamental property of atmospheric models?
- Are current approaches justified? How can they be improved?
- Can we design scale-aware schemes?
- What data or measurements are available to address these questions?
- ...
Summary of protocol: use high-resolution dataset as ‘truth’

1. Coarse grain high resolution dataset to forecast model grid

2. Use forecast model to step forward coarse-grained fields

3. Compare at later time

Christensen et al, 2018, JAMES. Christensen, 2020, QJRMS
Use SCM as forecast model

• Use coarse-grained high resolution simulation to prescribe
  – Initial conditions
  – Forcing: advective tendencies, geostrophic winds, vertical velocity
  – Boundary conditions: Surface sensible and latent heat fluxes, Skin temperature

Why use the SCM?

• Supply dynamical tendencies \(\rightarrow\) target uncertainty in the parametrization schemes
• The SCM is more portable than the full model, and is cheap to run. Potential to run SCM on computer where high-res data is stored
• (Spectral models cannot be run over a limited domain, but we can tile many independent SCM to cover the limited domain.)
Cf. existing approaches to identify model error

- **E.g. Initial tendency approach** in which physics tendencies in data assimilation cycle are compared to the analysis
- **E.g. Transpose AMIP** in which climate models are run in weather forecasting mode from common initial conditions

<table>
<thead>
<tr>
<th></th>
<th>Initial tendency</th>
<th>Transpose AMIP</th>
<th>My SCM approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decompose model evolution (&amp; error) into single processes</td>
<td>🎉</td>
<td>🎉</td>
<td>🎉</td>
</tr>
<tr>
<td>No data assimilation capabilities needed to evaluate forecast model</td>
<td>🎉</td>
<td>🎉</td>
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<tr>
<td>Comparison of model with its native analysis may mask errors</td>
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<td></td>
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<tr>
<td>Inconsistencies in IC can lead to systematic drifts</td>
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</table>
What information do we have?

- **Total change in** \((T, q, U, V)\) **in high-resolution dataset over 1hr time interval as a function of model level, location and forecast start time**

- **Change in** \((T, q, U, V)\) **in SCM over 1 hr, decomposed into dynamics and individual parametrised tendencies, as a function of model level, location and forecast start time**

For examples of analysis that can be carried out with this data, please see Christensen, 2020, QJRMetS

Case study using UKMO limited area high-res simulation and OpenIFS SCM
DEPHY common SCM format

- New standardised SCM protocol has been proposed by a group of French researchers involved in the High Tune and DEPHY communities.
  - standardises the format of input/output files needed to run an SCM.
- Many SCM groups participated at an interactive workshop in June 2020
  - protocol was discussed, and groups each began to implement this protocol
- Ideally, all SCM participating in this intercomparison will use DEPHY format
Stage 1: Benchmark simulations

Produce new simulations?

Yes

Select an existing, validated simulation.

No

Stage 2: Coarse Graining

Is data available at suitable resolution for all variables?

No

Test SCM resolution sensitivity?

Stage 3: SCM simulations

Coarse grain benchmark simulations to chosen resolution(s)

Prioritise resources?

Stage 4: Analysis

Larger/longer or more benchmark simulations

Cross-test SCM against nonnative benchmarks

Random parameter sensitivity studies

Model error sensitivity to resolution
Kick-off meeting, 22 September 2020

- **Attendees:**
  - Lisa Bengtsson (NOAA)
  - Ligia Bernardet (NOAA)
  - Judith Berner (NCAR)
  - Hannah Christensen (U. Oxford)
  - Grant Firl (NCAR)

- **Apologies:** John Methven (U. Reading)

**Aims**

- Find out who is interested in the project and in what capacity
- Come to a consensus on the main scientific goals and priorities of the project
- Make practical decisions regarding domains etc.

- Daniel Klocke (HErZ, DWD)
- Martin Leutbecher (ECMWF)
- Mark Rodwell (ECMWF)
- Nils Wedi (ECMWF)
- Keith Williams (Met Office)
Kick-off meeting summary

• Agreed on protocol

• Comparison of model uncertainty characteristics between models is main priority

• Chose ICON Dyamond (2.5km) simulation as first benchmark
  • To be coarse grained to NWP model resolution: 10-20 km.
  • In future, aim to coarse-grain ICON to coarser resolution (say 1 degree), as well as choose a second benchmark, also coarse-grained to 10-20km.

• Will first consider a tropical ocean domain (Pacific v Atlantic TBC)

• Each party present indicated their anticipated participation in the project.
  • Coarse graining: Hannah Christensen
  • Three SCM groups hope to participate: UKMO (Keith Williams), ECMWF (Nils Wedi?), NOAA/NCAR (Ligia Bernadet/Grant Firl/Judith Berner).
  • Translation of results to inform stochastic parametrisations (Lisa Bengtsson, Martin Leutbecher)
  • Linking up existing approaches with this new analysis (Mark Rodwell).
Looking ahead

Follow up meeting TBC! Space for more participants!

References

Christensen, Dawson and Holloway, 2018, JAMES, 10(8) 1833-1857

Christensen, 2020, QJRMetS, 146(727), 938-962

Coarse-grained Cascade data published on UK CEDA archive

NCL coarse graining scripts, and python SCM deployment scripts on github
Thanks for listening
Coarse graining details 1

- Local area averaging for coarse graining.
  \[
  \bar{\psi}_{n,k} = \sum_{i} W_{n,i} \psi_{i,k}
  \]

- Linearly interpolate in time.
  - High-resolution simulations not stored every timestep
  - Do we have fine enough temporal resolution for our needs?

- Vertical interpolation
  - Evaluate coarse-scale grid box mean \( p_{sfc} \)
  - Coarse-grain other fields along model levels
  - Interpolate from native model levels to target model levels
  - Only an issue over orography → propose that we focus exclusively on ocean regions.

Christensen et al, 2018, JAMES.
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Christensen et al, 2018, JAMES.
• Above high-resolution model top, pad data using ECMWF analysis

• Advective tendencies estimated from the coarsened fields

\[ \text{adv}(\psi)|_{n,k} = -\overline{\mathbf{u}}_{n,k} \cdot \overline{\nabla}_{k}(\overline{\psi}_{n,k}) \]

• Specify sensible and latent heat fluxes from high-resolution dataset

• Static boundary conditions (e.g. orography, land surface type) from operational model at chosen resolution

Christensen et al, 2018, JAMES.
Implementation details

1. Verify coarse-graining procedure by taking IFS forecast data at T639
   - Linearly interpolate 1hr -> 15 mins
   - Estimate advective fluxes from gridpoint fields
   - Supply sensible and latent fluxes instead of interactive land scheme
   - Interpolate from native model levels to target model levels

Christensen et al, 2018, JAMES.
How does the SCM compare to Cascade?

(a) Precipitation flux / mm hr⁻¹
(b) Precipitation flux / mm hr⁻¹
(c) Precipitation flux / mm hr⁻¹
(d) Precipitation flux / mm hr⁻¹

W. Pacific Ocean
West of Australia
Maritime Continent Land
Maritime Continent Ocean
How does the SCM compare to Cascade?

-> discard first hour of SCM, and compare evolution over 2\textsuperscript{nd} hour