MUMIP

Model Uncertainty – Model Intercomparison Project

WGNE Update

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Background

- Joint initiative of WGNE and Predictability, Dynamics and Ensemble Forecasting (PDEF) working group

- 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

- Funding secured to support work
  - NCAR/NOAA DTC – June 2021-June 2025
  - Leverhulme Trust: Oxford (ECMWF), Exeter (UK Met Office), Météo-France – September 2023-September 2026

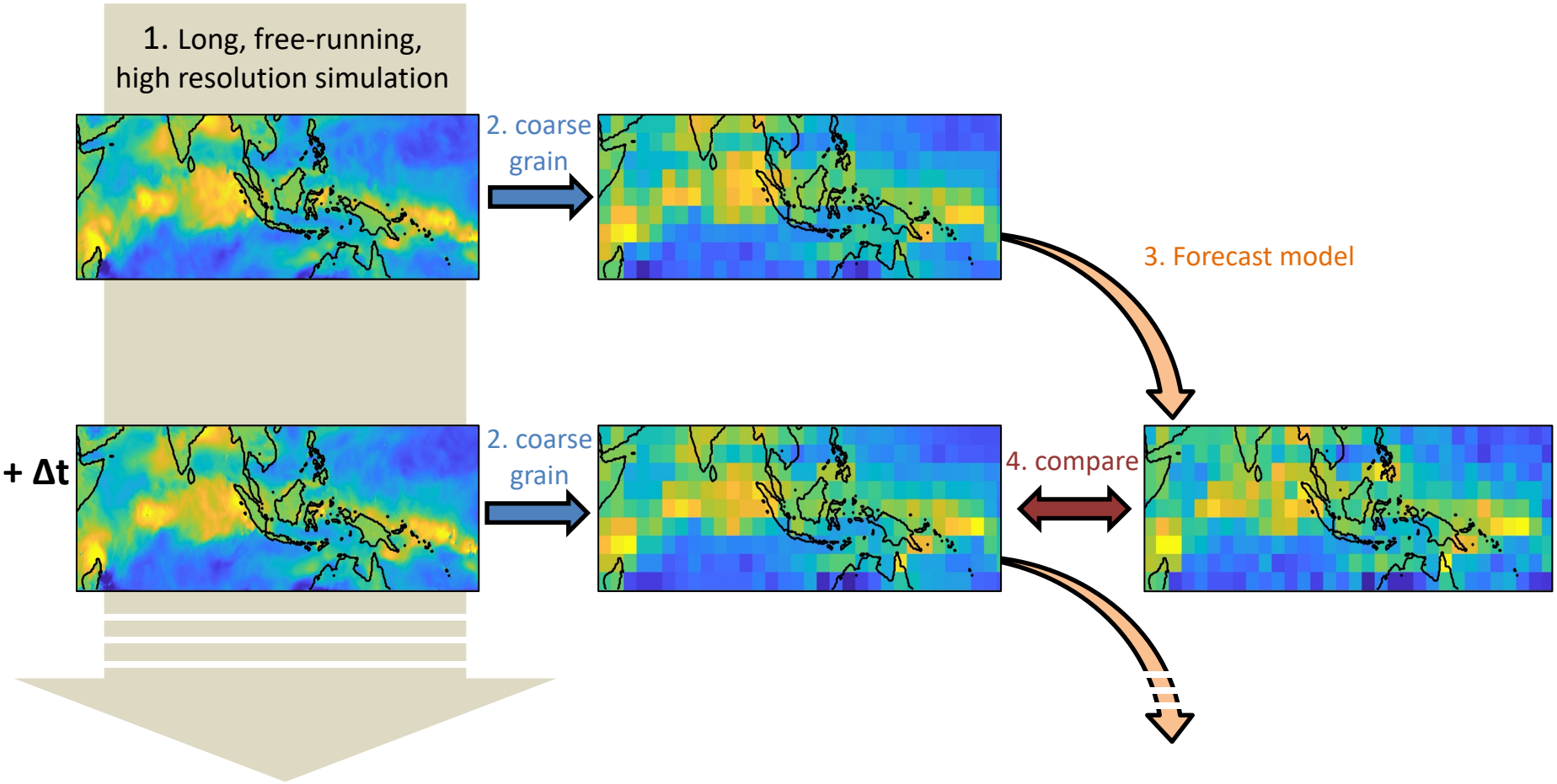
- Some key questions:

  Stochastic parametrisation
  - How should we best represent model uncertainty (random error)?
  - Are current approaches justified? How can they be improved?

  Systematic errors
  - How structurally diverse are deterministic parametrisations?
  - How different are systematic errors on short timescales?

  High resolution simulations
  - Can we use coarse-graining as a validation tool for high-resolution models?

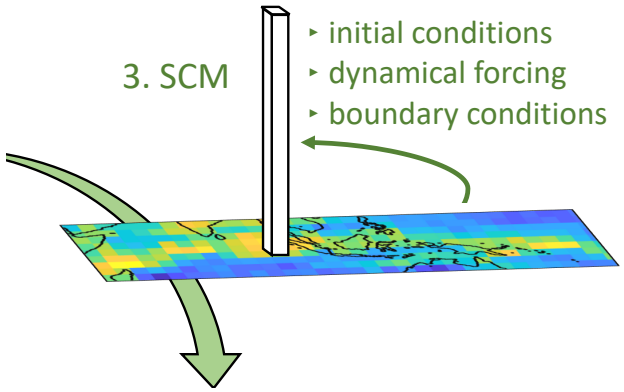
Summary of protocol: use high-resolution dataset as reference



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 allows target uncertainty in the parametrizations
- SCMs are computationally cheaper and more portable than the full model. Potential to run SCM on computer where high-res data is stored
- Few models can be run over a limited domain, while independent SCMs can be used to tile the targeted limited domain

What information do we have?

- ✓ **Total change in (T, q, U, V) in high-resolution dataset** as a function of model level, location and start date/time

- ✓ **Change in (T, q, U, V) in SCM**, **decomposed into dynamics and individual parametrised tendencies**, as a function of model level, location and start date/time

→ Model error statistics as a function of space and time

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

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

e.g. assess SPPT multiplicative noise

$$\mathbf{T}_X := \frac{\partial X}{\partial t}$$
$$= \mathbf{D}_X + (1+e)\sum_{i=1}^{I} \mathbf{P}_{i,X}$$
$$= \mathbf{D}_X + (1+e)\mathbf{P}_X,$$

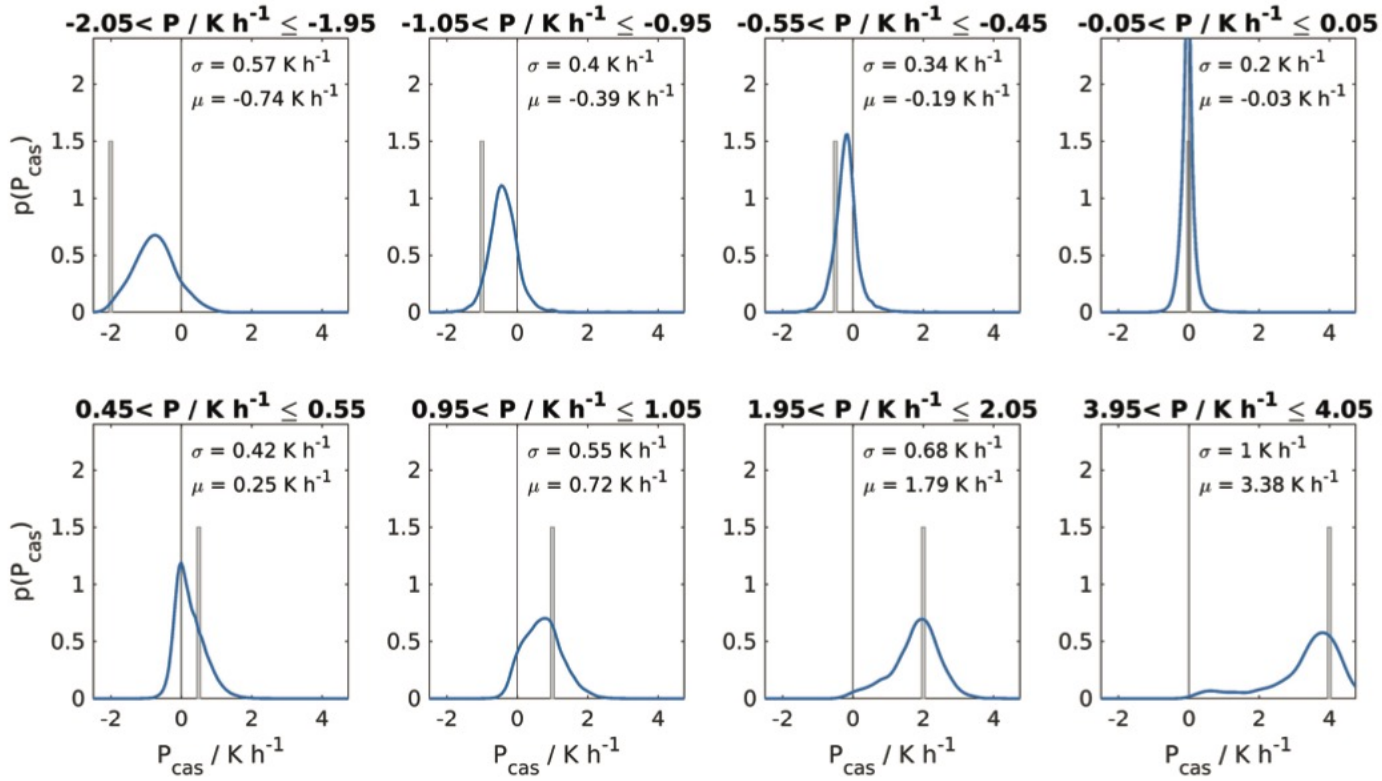
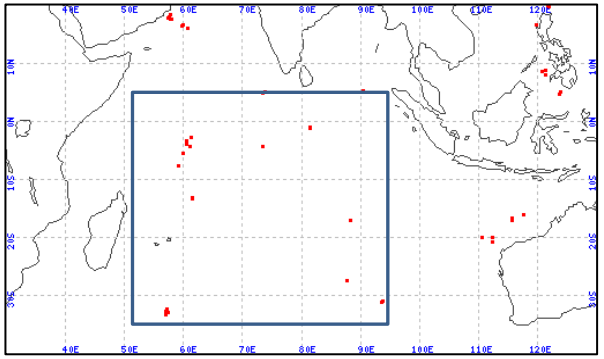


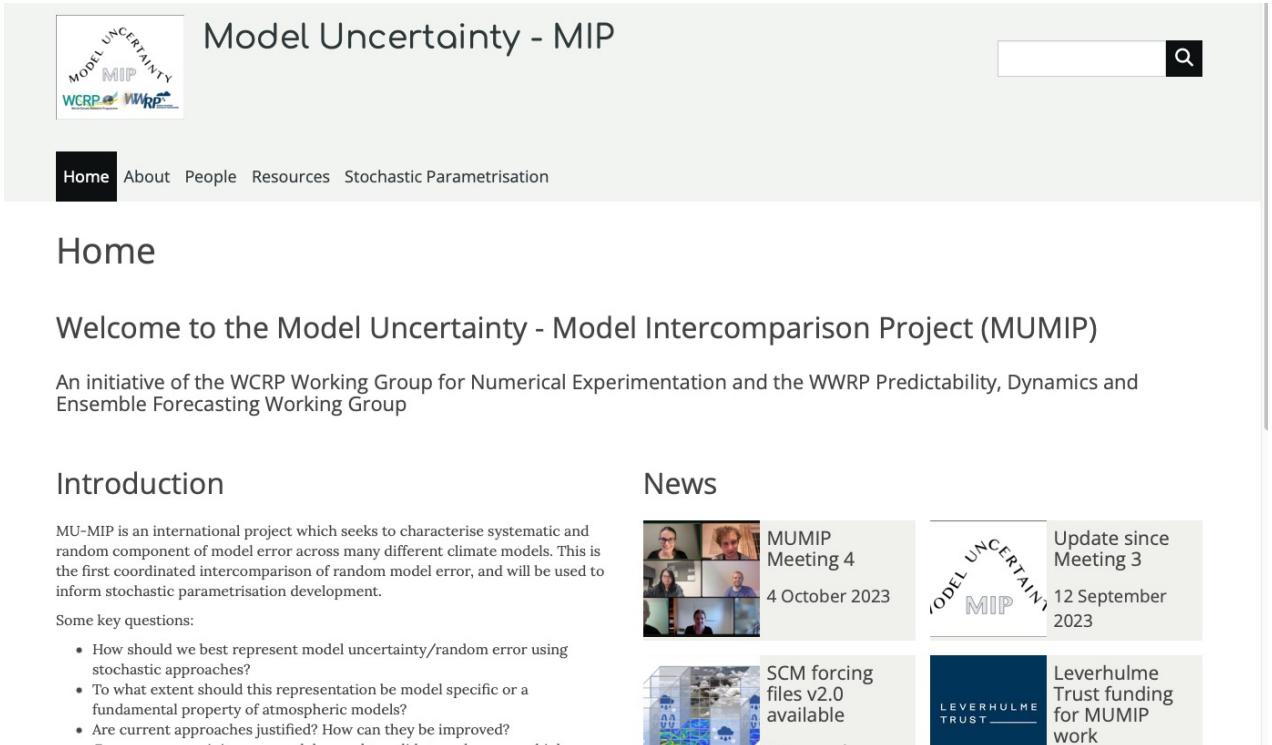
FIGURE 3 Testing the multiplicative noise hypothesis. Results are shown for the T tendency at model level 77 (approximately 850 hPa). Each subplot shows the distribution of $\mathbf{P}_{cas}$ conditioned on the physics tendency predicted by the SCM indicated by the title of each panel. The mean and standard deviation of the conditional $\mathbf{P}_{cas}$ distribution are shown in each panel. The rectangle shows the $\mathbf{P}$ distribution for each panel, though note that the height of this distribution is truncated to 1.5 for clarity: it should extend to 10. The numbers of data points used to estimate the pdf for each panel, respectively, are as follows: 131; 4,123; 29,438; 1,114,817; 87,759; 27,608; 4,020; and 162. PDF, probability density function [Colour figure can be viewed at wileyonlinelibrary.com]

Christensen (2020, QJRMS)

Progress - Oxford

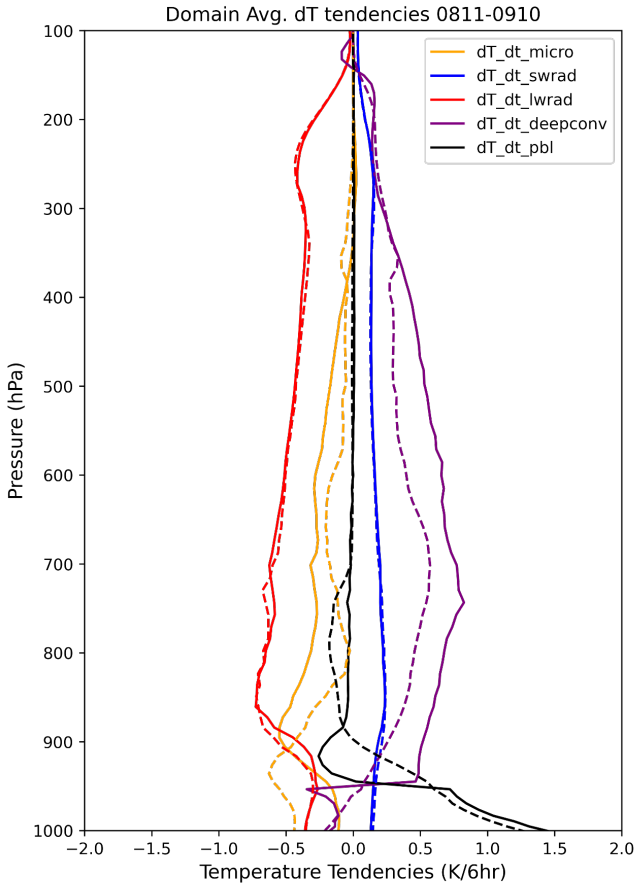
- First set of coarse-grained input fields available
  - 40-day ICON 2.5km DYAMOND Summer simulation
  - Coarse-grained to 0.2 degrees (~22 km)
  - Domain in Indian Ocean [51-95E, 5N-35S]
  - Data on DKRZ Swift system
  - See website: mumip.web.ox.ac.uk

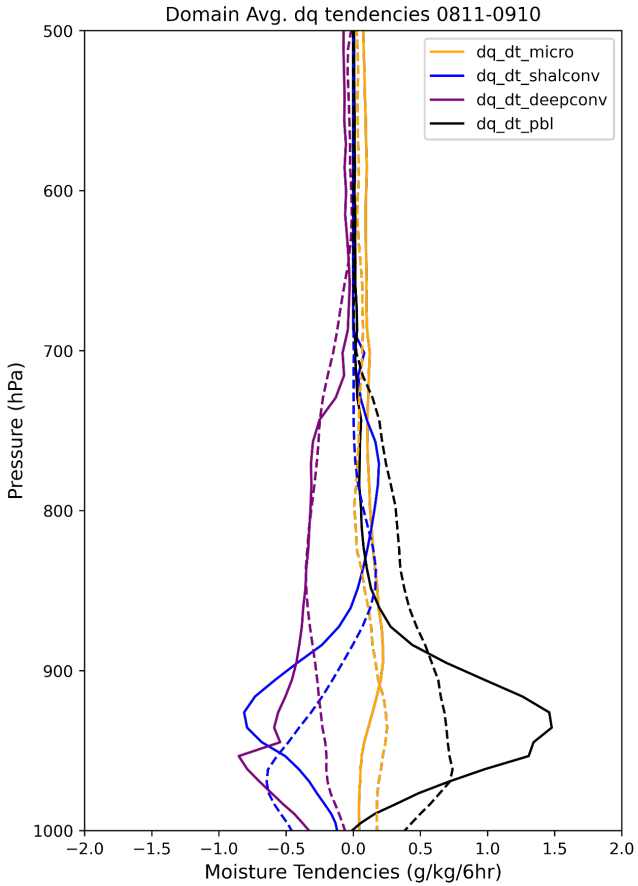




Progress – NCAR/NOAA

- Followed MUMIP protocol using Indian Ocean dataset:
  - CCPP SCM runs using GFS_v17_p8 and RAP physics suites



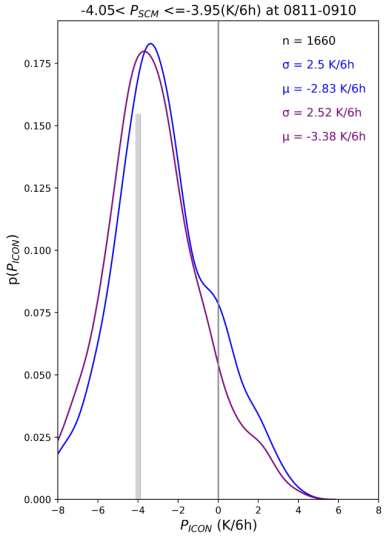


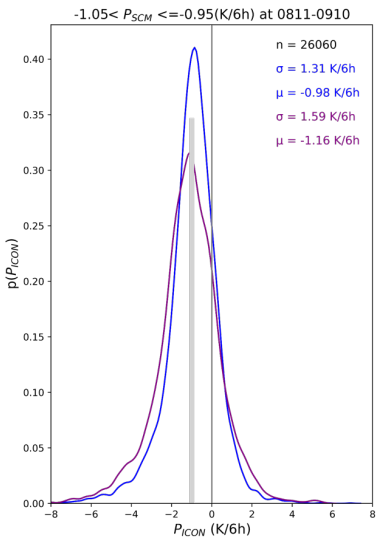
Dash: RAP
Solid: GFS_v17_p8

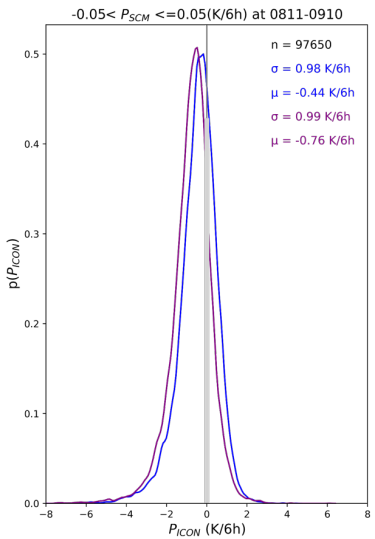
< Compare behaviour of two physics suites across many test cases

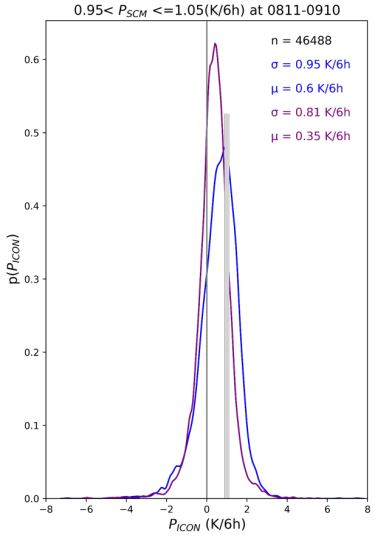
Courtesy K. Newman and X. Sun

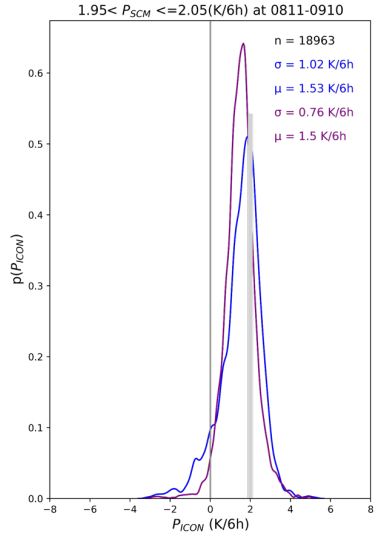
Progress – NCAR/NOAA

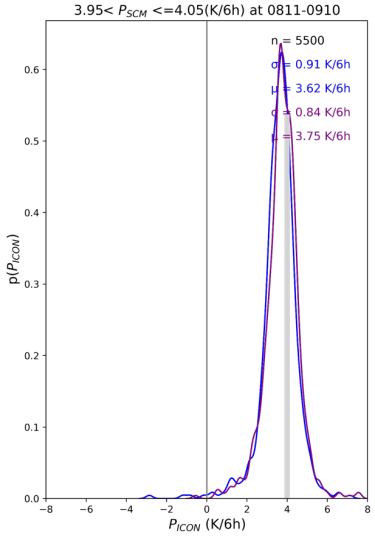












- Repeat diagnostics from Christensen (2020) to test robustness
- e.g. T850 tendency
- ICON CG physics tendency conditioned on **RAP**
- ICON CG physics tendency conditioned on **GFS**
- ICON physics tendency estimated as change in T minus CCPP dynamics tendency for each run

Courtesy K. Newman and X. Sun

Looking ahead

Next steps

- New hires will produce equivalent datasets for ECMWF, UKMO, and Météo-France SCMs

- Prepare implementation paper describing protocol, and with first analysis across models (e.g. for BAMS. Lead: Christensen)

- Each institute to analyse dataset with unique angle and diagnostics
  - University of Oxford: stochastic parametrisations/random error
  - University of Exeter: continuous structural parameterization
  - Météo-France: parametric uncertainty and structural (systematic) error

Partners

Representatives of WGNE and PDEF

- Nils Wedi, Romain Roehrig
- Judith Berner, John Methven, Mark Rodwell

Modeling groups/ SCMs

- NCAR/NOAA DTC CCPP
- IFS (University of Oxford)
- UM (UKMO/University of Exeter)
- Météo-France

Benchmark simulations

- MPI (ESIWACE)

Analysis

- All

Knowledge transfer (RTO)

- ECMWF
- NOAA
- Met Office

Thanks for listening

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