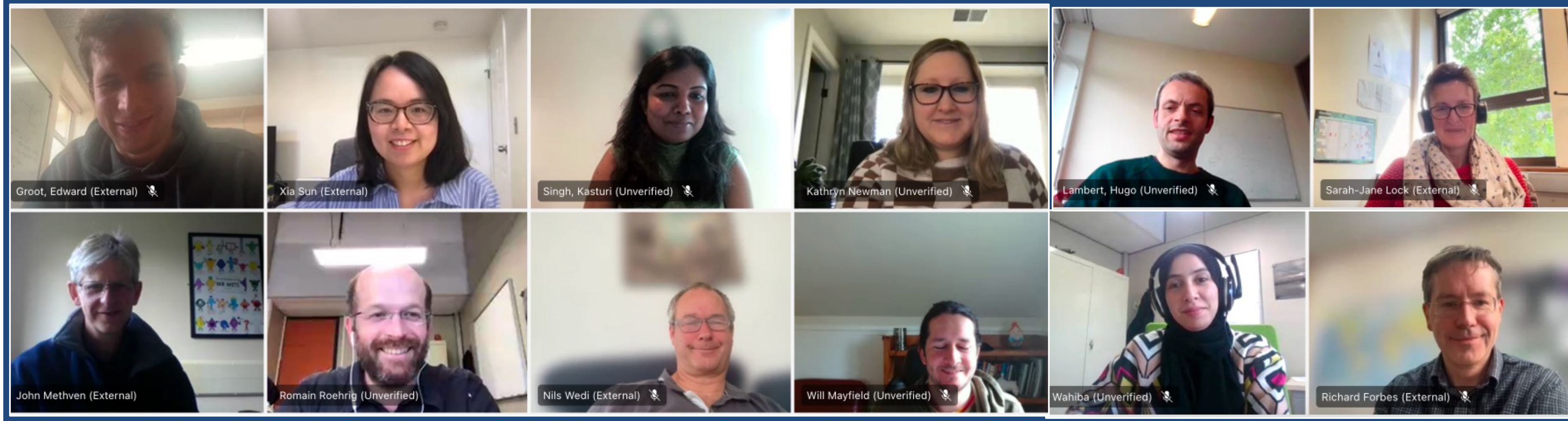
Model Uncertainty – MIP

Hannah Christensen, University of Oxford



WGNE update, Tuesday 5 November 2024

Background

- Joint initiative of Predictability, Dynamics and Ensemble Forecasting working group and Working Group on Numerical Experimentation

- 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), Meteo 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?

How can we begin to answer these questions?

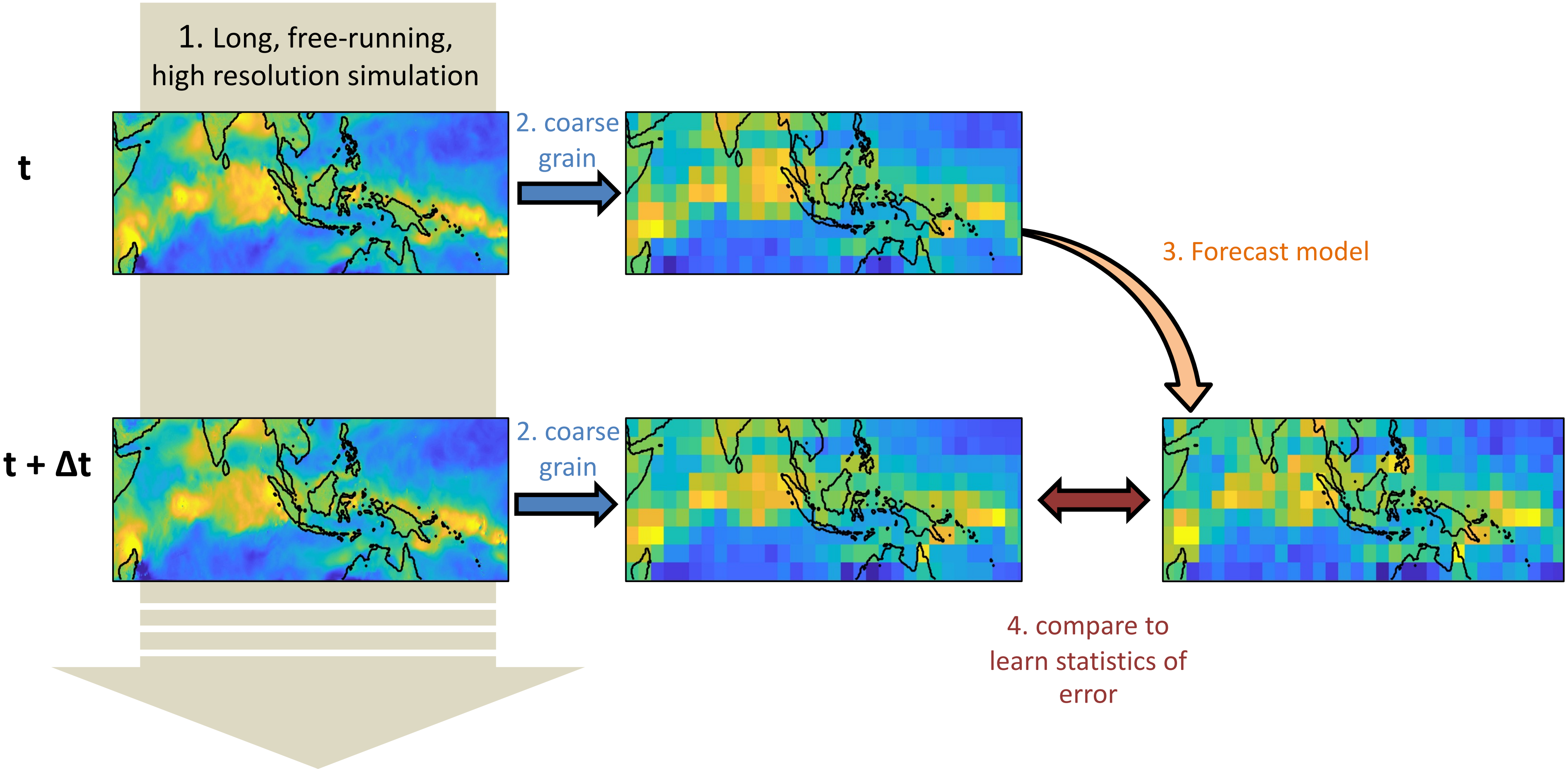
→ **Require a large database of model error**

- For different models
- For different global regions
- For different seasons
- For different model resolutions

Ideally accompanied by

- Information on model parametrised tendencies

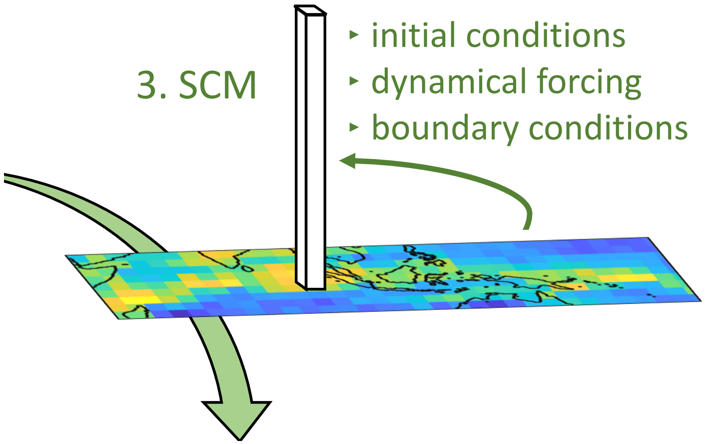
Use a high resolution simulation as ‘truth’



Christensen et al, 2018, JAMES.
Christensen, 2020, QJRMS

Single Column Model (SCM) as Forecast Model

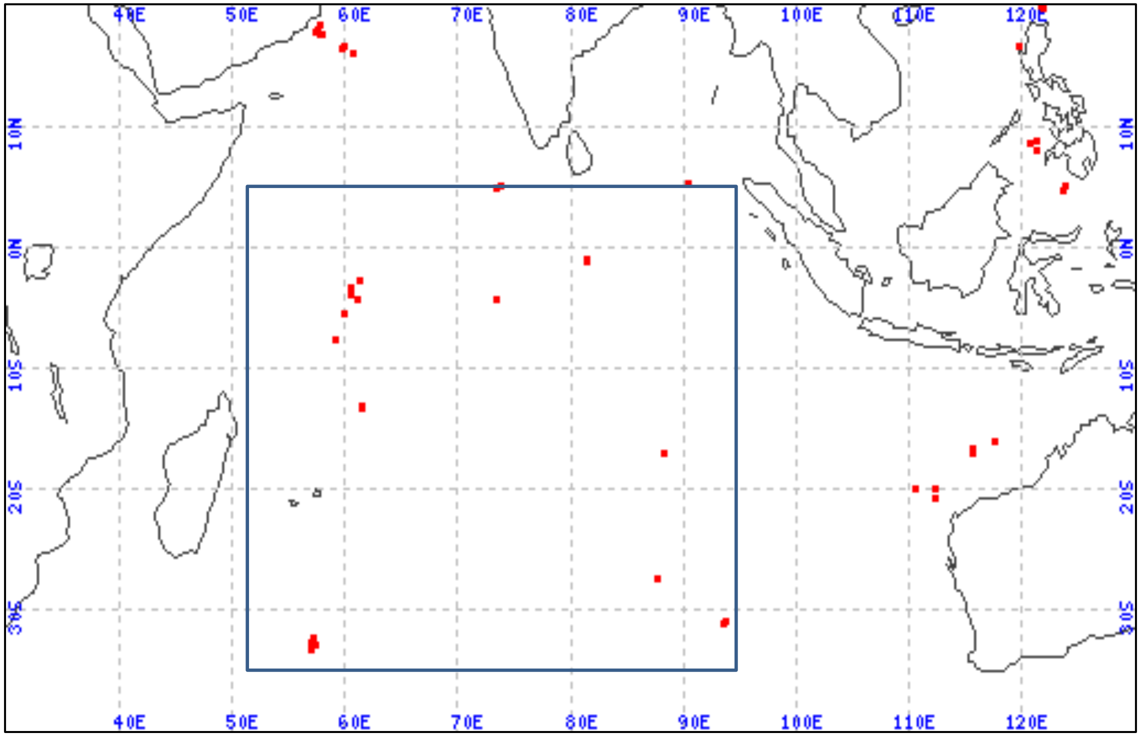
- A SCM consists of:
  - subgrid parametrisations from parent model
  - forced with dynamical tendencies
- How do we use an SCM?
  - Use coarsened high-res simulation to prescribe Initial conditions, Dynamical forcing and Boundary conditions
- Benefits of using SCM?
  - Supply dynamical tendencies targets uncertainty in the parametrisation schemes
  - SCM portable and cheap
  - Tile many SCM to cover domain
  - New DEPHY format facilitates sharing of SCM driver files



Christensen, Dawson and Holloway, 2018, JAMES

First MUMIP experiment: Indian Ocean domain

- Last 30 days of **ICON 2.5km Dyamond Summer** simulation
- CG to resolution of 0.2 degrees (~22 km)
- Domain in Indian Ocean: (51-95E,5N-35S)
- Produce 6-hour simulations, initialised every 3 hours
- See website: mumip.web.ox.ac.uk



Participant	Key contacts	SCM	Progress over IO domain	Comment
NOAA-NCAR Developmental Testbed Centre	Xia Sun, Kathryn Newman, Will Mayfield, with Lisa Bengtsson, Jeff Beck, Judith Berner, Mike Ek, Ligia Bernardet	Common Community Physics Package with both **RAP and GFS** physics	**Runs complete (x 2 models)**	Additional UFS FV3 high res (3-km) simulations completed and coarse-grained over IO, to provide 2nd benchmark. **Runs underway.**
University of Oxford / ECMWF	Edward Groot, Richard Forbes, Hannah Christensen	ECMWF OpenIFS	**Runs complete**	Sensitivity tests planned exploring impact of forcing SCM with surface fluxes vs surface temperature
University of Exeter / UK Met Office	Kasturi Singh, Keith Williams, Hugo Lambert	UK Met Office	**Runs underway**	
Météo France	Wahiba Lfarh, Romain Roehrig	Météo France ARPEGE-clima	**Runs complete**	Parameter perturbation experiments planned

MU-MIP analysis plans

- Assess structural error across different models
  - Exeter lead: H. Lambert and K. Singh
- Assess parametric uncertainty
  - Meteo France lead: R. Roehrig and W. Lfarh
- Assess random error, foundations of stochastic parametrisations
  - Oxford lead: H. Christensen and E. Groot

Structural errors (Exeter)

Statistical tools being developed using FLUXNET data for land surface processes

Use statistical tools to map between inputs and outputs for observed FLUXNET measurements and land surface models

Statistical fit parameters for different model runs >

- Explore very different parts of parameter space

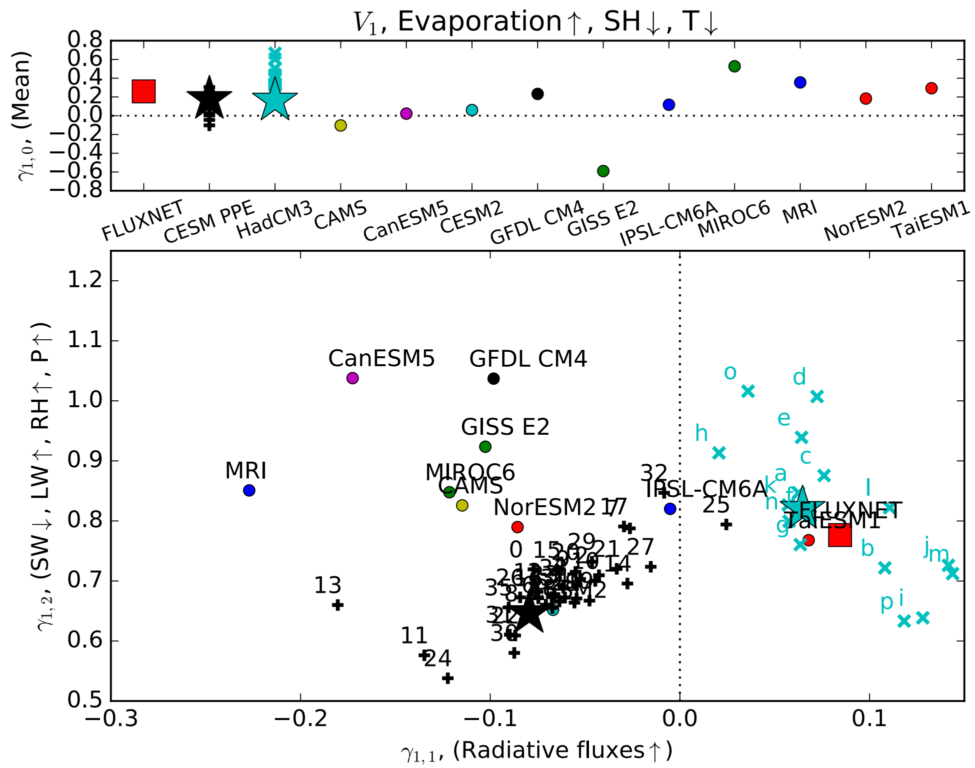


Fig: Hugo Lambert, pers. comm.

Parametric uncertainty (Météo France)

Produce additional parameter perturbation experiments

Use history matching approach to search for consistent to iteratively reduce parameter space by comparing SCM simulations to benchmark
-> "Not Ruled Out Yet" space of acceptable parameter values

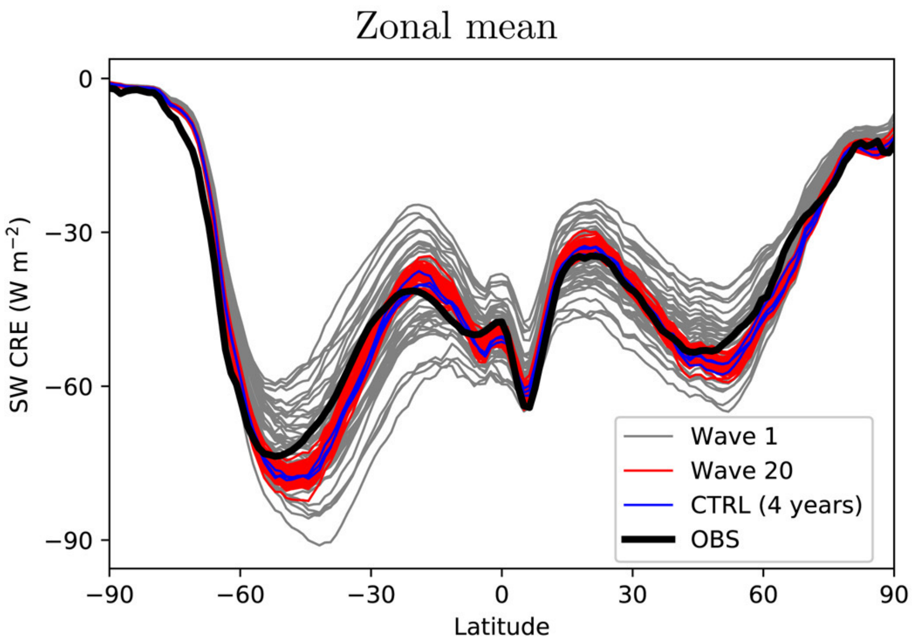
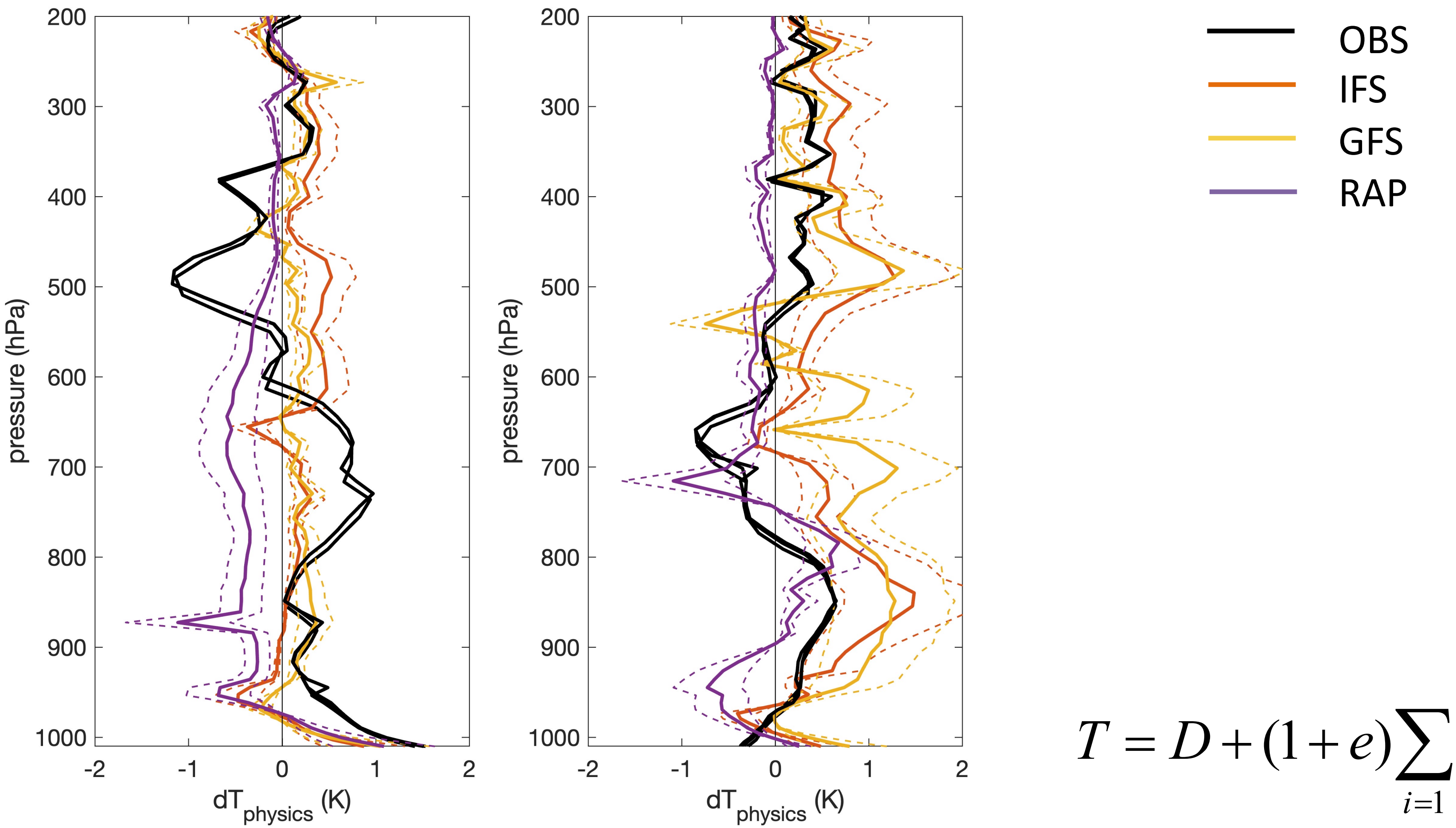


Fig: Hourdin, …, Roehrig, et al, 2020, JAMES

Random error (Oxford)

- E.g. compare multi-model representation to SPPT
- Consider vertical profiles of physics T tendency in two sample columns



$$T = D + (1+e)\sum_{i=1} P_i$$

Partners

- **Representatives of WGNE and PDEF**
  - Nils Wedi, Romain Roehrig
  - Judith Berner, Sarah-Jane Lock
- **Modeling groups/ SCMs**
  - NCAR/NOAA DTC CCPP
  - IFS (U Oxf)
  - UM (UKMO/U Exeter)
  - Meteo France
- **Benchmark simulations**
  - MPI (ESIWACE)
- **Analysis**
  - All
- **Knowledge transfer (RTO)**
  - ECMWF
  - NOAA
  - Met Office

mumip.web.ox.ac.uk

UNIVERSITY OF OXFORD

Model Uncertainty - MIP

Home | About | People | Resources | Stochastic Parametrisation

Home

Welcome to the Model Uncertainty - Model Intercomparison Project (MUMIP)

An initiative of the WCRP Working Group for Numerical Experimentation and the WWRP Predictability, Dynamics and Ensemble Forecasting Working Group

Introduction

MU-MIP is an international project which seeks to characterise systematic and random component of model error across many different climate models. This is the first coordinated intercomparison of random model error, and will be used to inform stochastic parametrisation development.

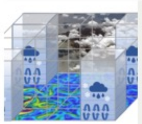
Some key questions:

- How should we best represent model uncertainty/random error using stochastic approaches?
- 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 a coarse-graining approach be used to validate and compare high-resolution simulations and their behaviour across scales?

Contact

The MU-MIP team consists of scientists from 10+ institutes spanning three continents. Please get in touch by emailing Hannah Christensen on hannah.christensen 'at' physics.ox.ac.uk if

News



New MUMIP data available for analysis

29 August 2024

Oxford Workshop on Model Uncertainty, 23-26 Sept

10 June 2024

MUMIP Meeting 5

29 April 2024

LEVERHULME TRUST

Leverhulme Trust Research Project Team Meeting 2

21 February 2024

LEVERHULME TRUST

Leverhulme Trust Research Project team meeting 1

12 January 2024

MUMIP Meeting 4

4 October 2023

1 2 3 next last

Thanks for listening

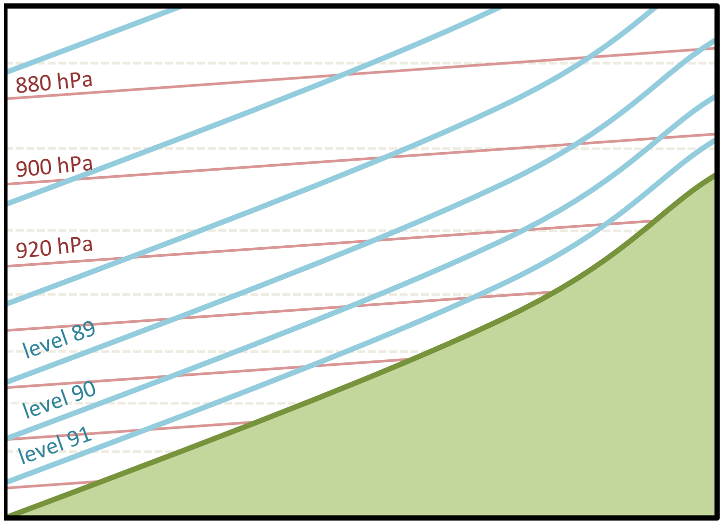
Hannah.Christensen@physics.ox.ac.uk

Extra Slides

Coarse graining details

1. Local area averaging for coarse graining

$$\overline{\psi}_{n,k} = \sum_{i}^{I} W_{n,i}\psi_{i,k}$$



2. Linearly interpolate in time
3. 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
4. Above high-resolution model top, pad data using ECMWF analysis
5. Advective tendencies estimated from the coarsened fields

$$\mathrm{adv}(\psi)|_{n,k} = -\overline{\mathbf{u}}_{n,k} \cdot \overline{\nabla}_k(\overline{\psi_{n,k}})$$

6. Specify sensible and latent heat fluxes from high-resolution dataset, but take static boundary conditions from operational ECMWF model at T639

Christensen et al, 2018, JAMES.

Random error (Oxford)

SPPT:

$$T = D + (1+e)\sum_{i=1} P_i$$

Calculate 'true' total tendency from coarsened ICON

Assume SCM dynamics tendency is 'correct'

Assess error in SCM physics tendencies

Random error (Oxford)

SPPT:

$$T = D + (1+e)\sum_{i=1} P_i$$

Calculate 'true' total tendency from coarsened ICON

Assume SCM dynamics tendency is 'correct'

Assess error in SCM physics tendencies

$$T - D = (1+e)\sum_{i=1} P_i$$

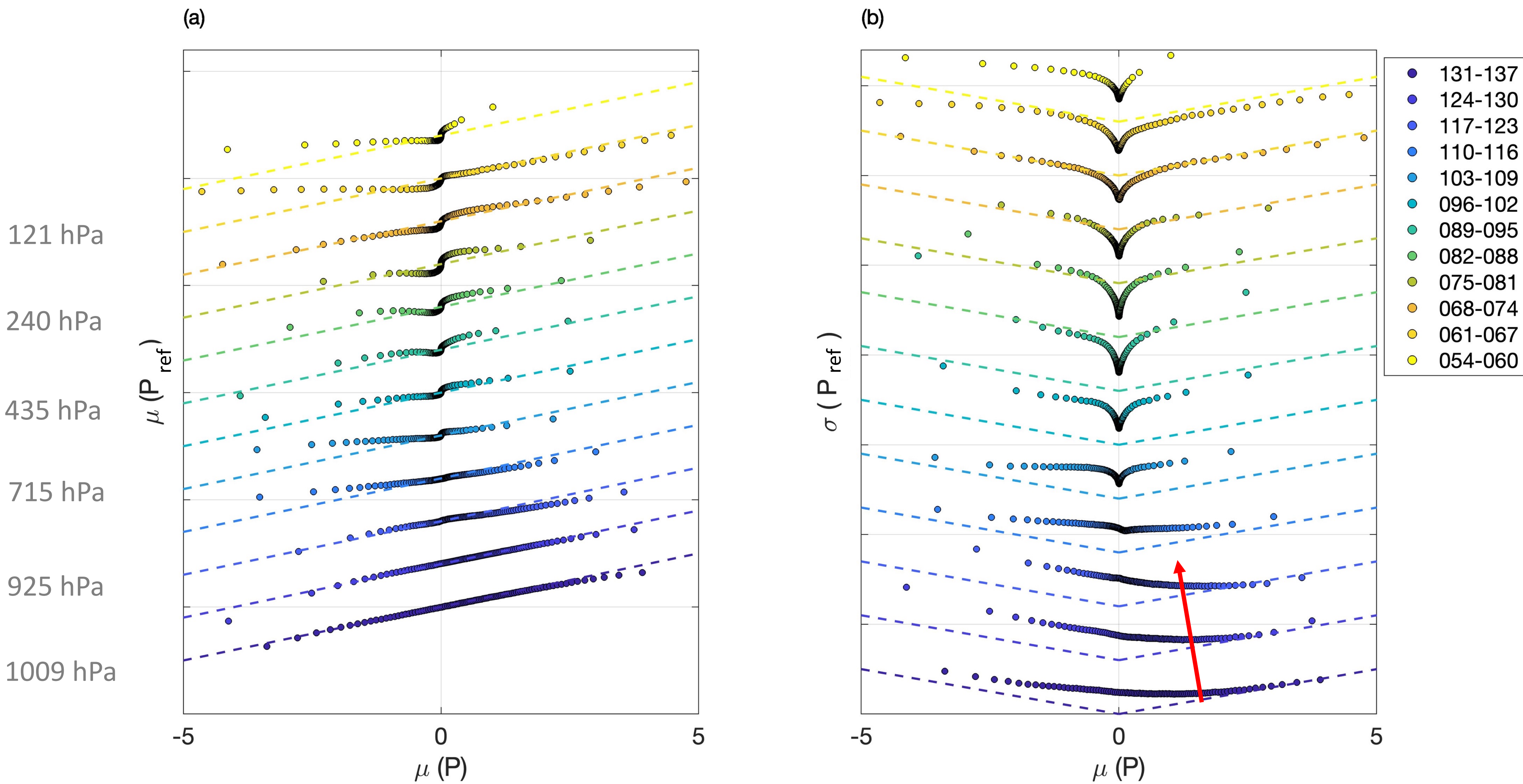
Compare 'true' physics tendency …

… to parametrised physics tendency

IFS

U tendencies

mean and standard deviation of reference conditioned on SCM prediction



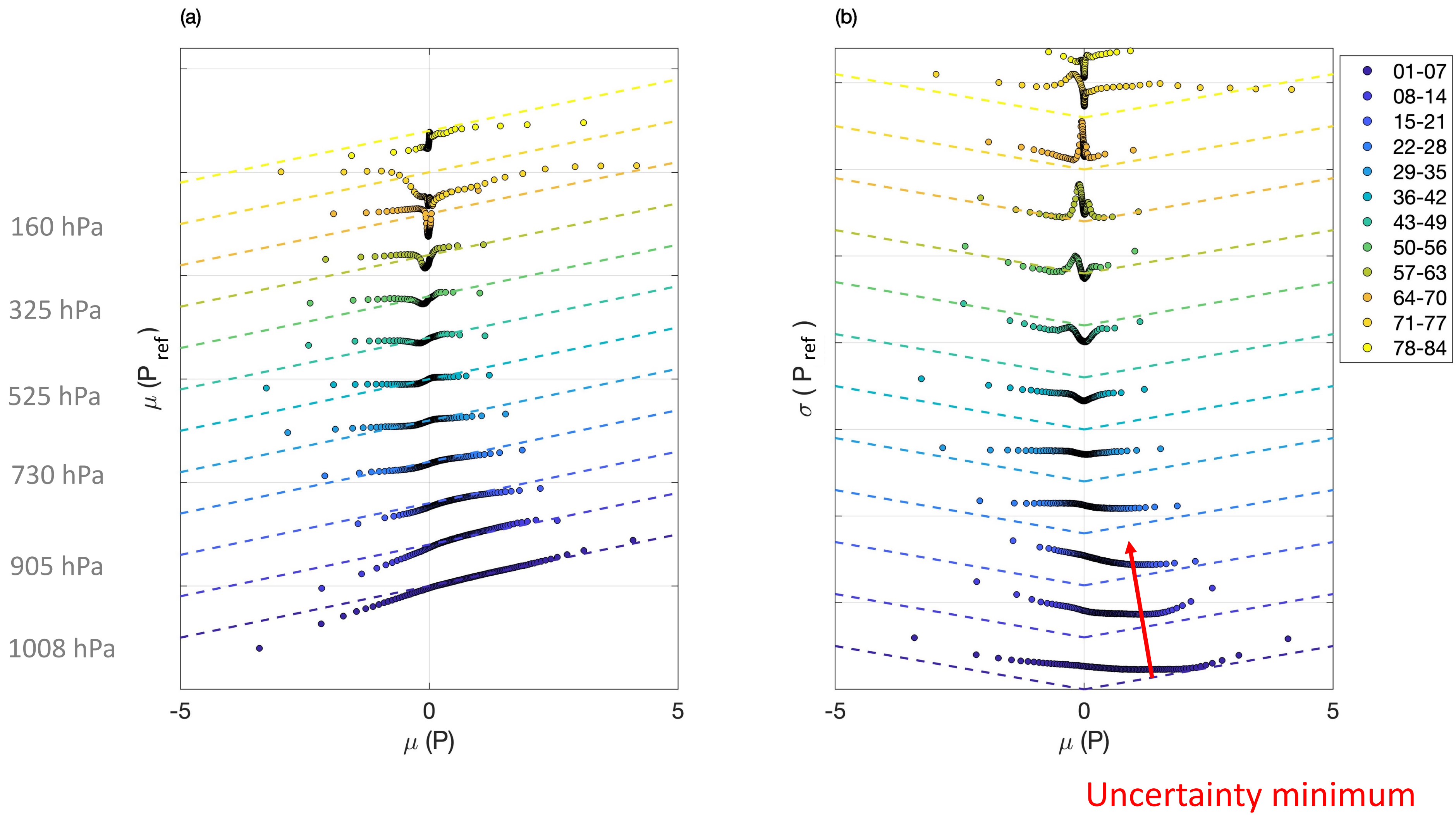
Well calibrated, especially near surface

Uncertainty minimum

U tendencies

GFS

mean and standard deviation of reference conditioned on SCM prediction



RAP

U tendencies

mean and standard deviation of reference conditioned on SCM prediction