Model Uncertainty Intercomparison Project

WGNE Update

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WGNE35, 2-5 November 2020

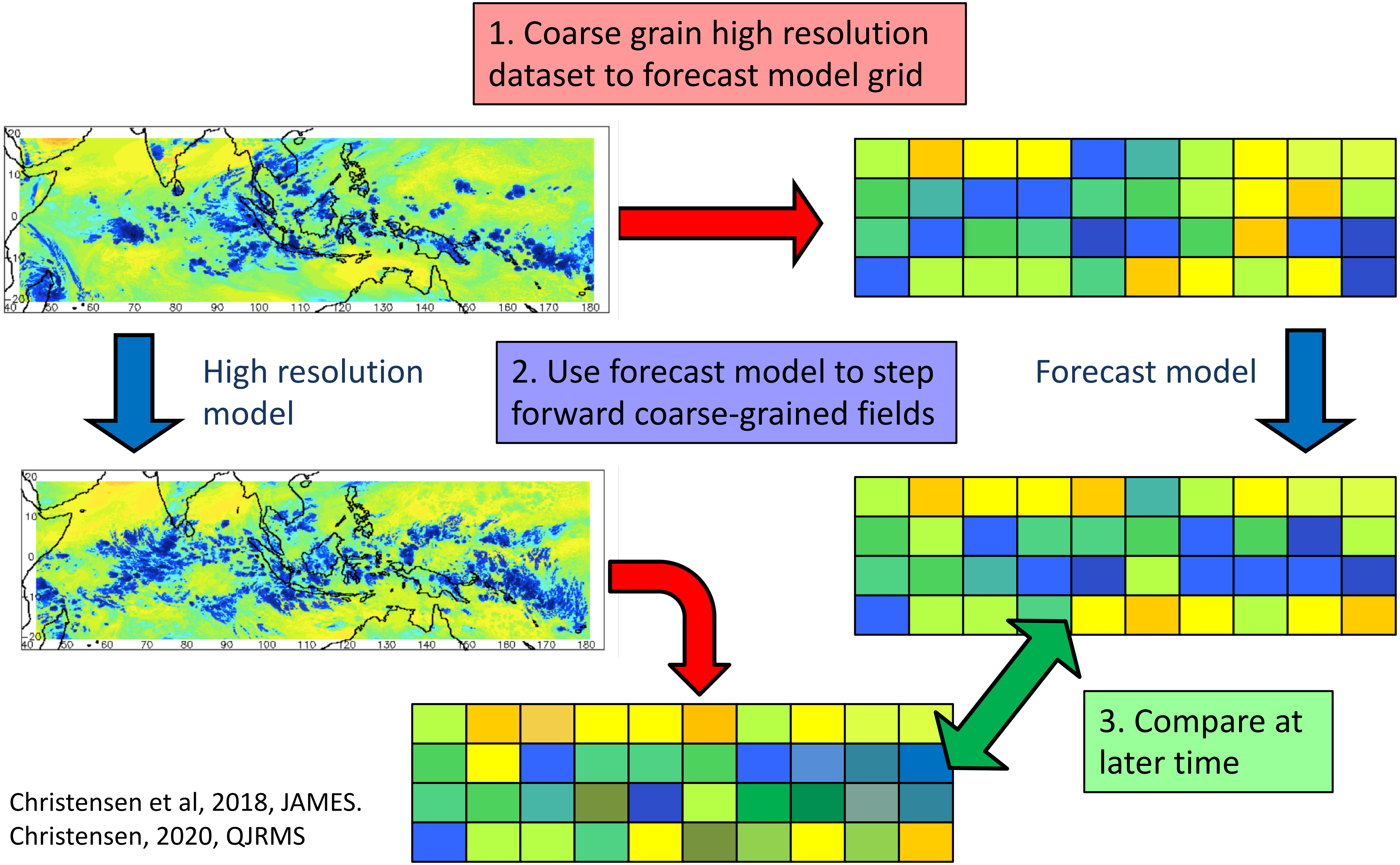
Background

- 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’



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 → 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

	Initial tendency	Transpose AMIP	My SCM approach
Decompose model evolution (& error) into single processes	☺		☺
No data assimilation capabilities needed to evaluate forecast model		☺	☺
Comparison of model with its native analysis may mask errors	☹		
Inconsistencies in IC can lead to systematic drifts		☹	☹

What information do we have?

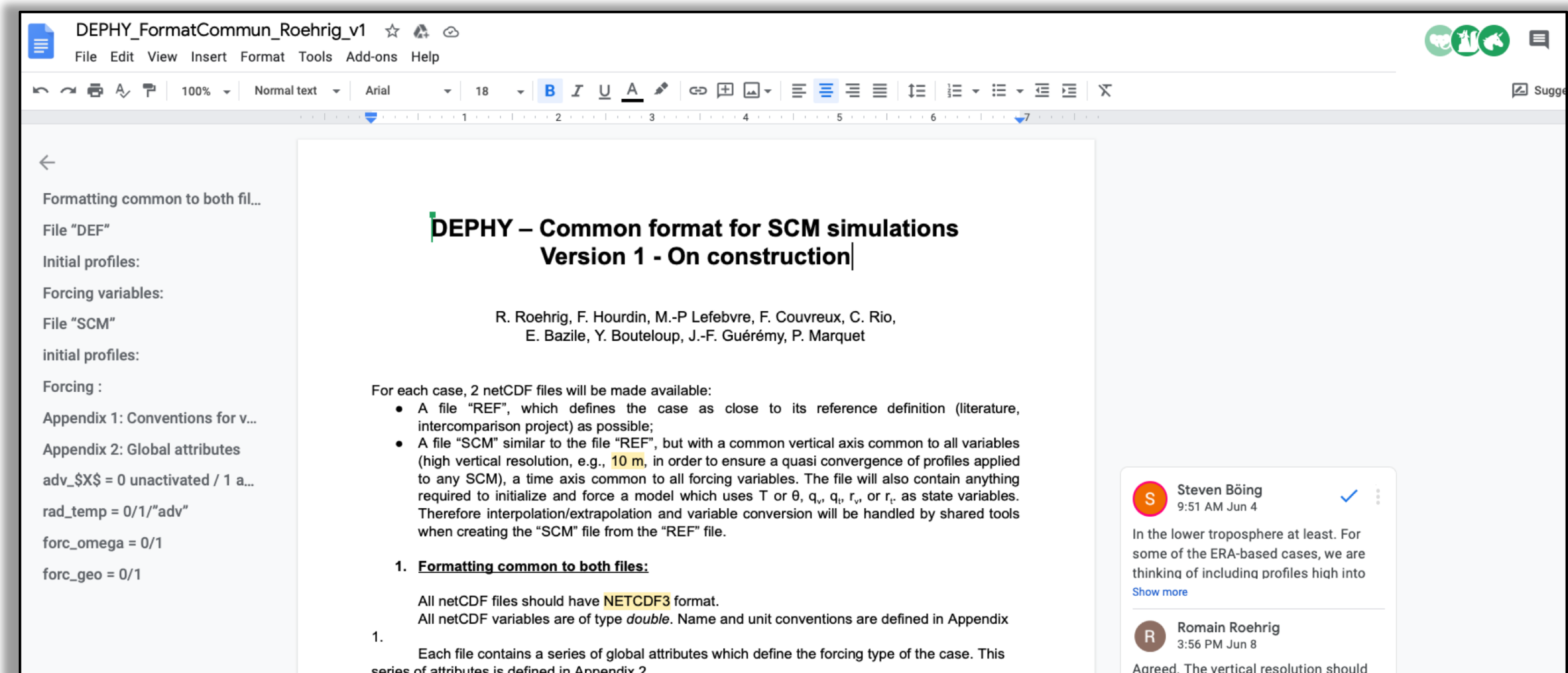
- ✓ **Total change in (T, q, U, V) in high-resolution dataset** over 1hr time interval as a function of model level, location and forecast start time
- ✓ **Change in (T, q, U, V) in SCM** over 1 hr, **decomposed into dynamics and individual parametrised tendencies**, as a function of model level, location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

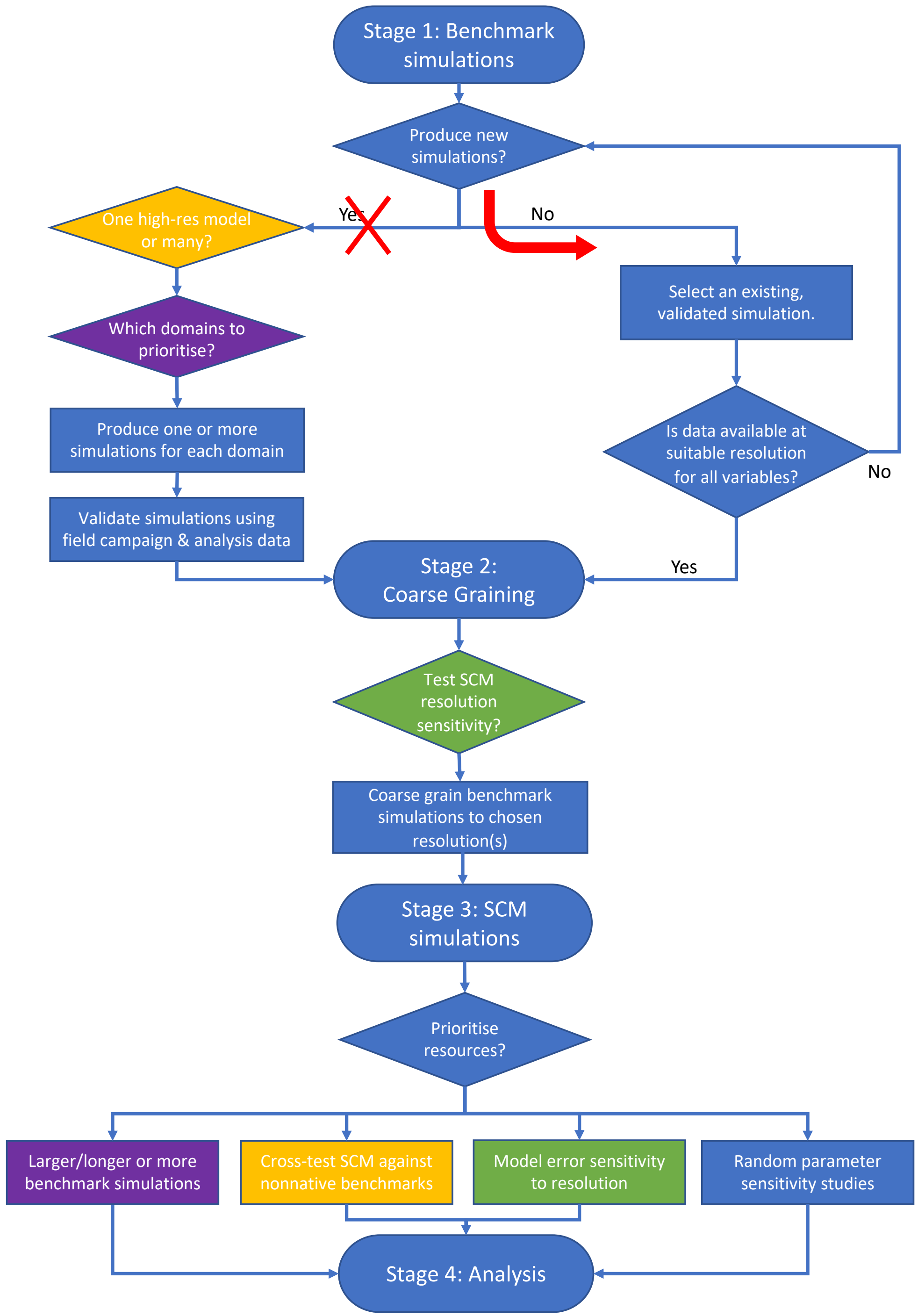
For examples of analysis that can be carried out with this data, please see Christensen, 2020, QJRMetS

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
No
One high-res model or many?
Which domains to prioritise?
Produce one or more simulations for each domain
Validate simulations using field campaign & analysis data
Select an existing, validated simulation.
Is data available at suitable resolution for all variables?
No
Yes
Stage 2: Coarse Graining
Test SCM resolution sensitivity?
Coarse grain benchmark simulations to chosen resolution(s)
Stage 3: SCM simulations
Prioritise resources?
Larger/longer or more benchmark simulations
Cross-test SCM against nonnative benchmarks
Model error sensitivity to resolution
Random parameter sensitivity studies
Stage 4: Analysis

Kick-off meeting, 22 September 2020

- **Attendees:**
  - Lisa Bengtsson (NOAA)
  - Ligia Bernardet (NOAA),
  - Judith Berner (NCAR)
  - Hannah Christensen (U. Oxford)
  - Grant Firl (NCAR)
  - Daniel Klocke (HErZ, DWD)
  - Martin Leutbecher (ECMWF)
  - Mark Rodwell (ECMWF)
  - Nils Wedi (ECMWF)
  - Keith Williams (Met Office)
- **Apologies:** John Methven (U. Reading)

<u>Aims</u>

- 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.

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!

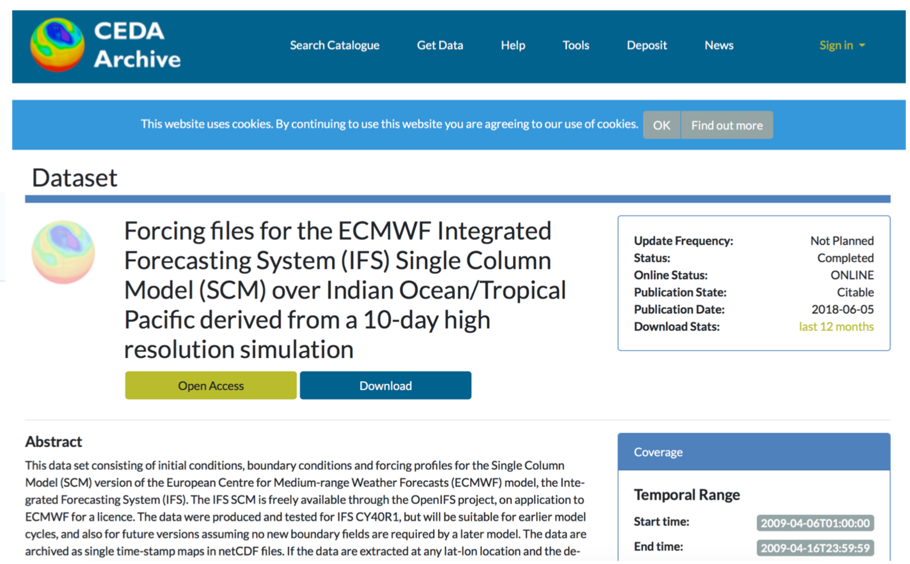
References

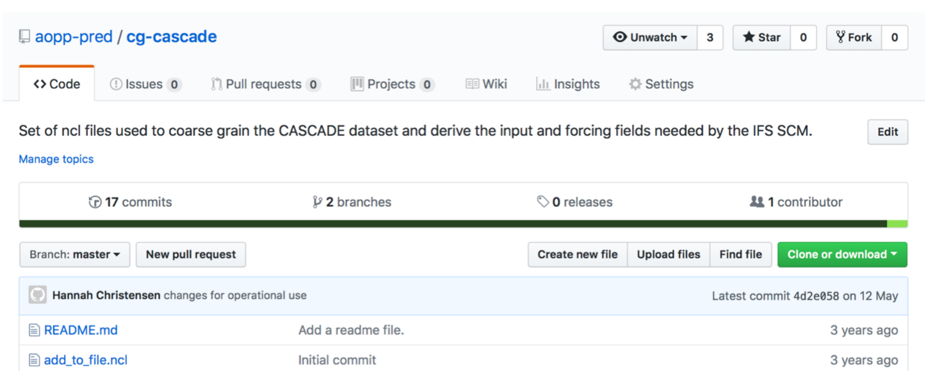
Christensen, Dawson and Holloway, 2018, JAMES, 10(8) 1833-1857

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



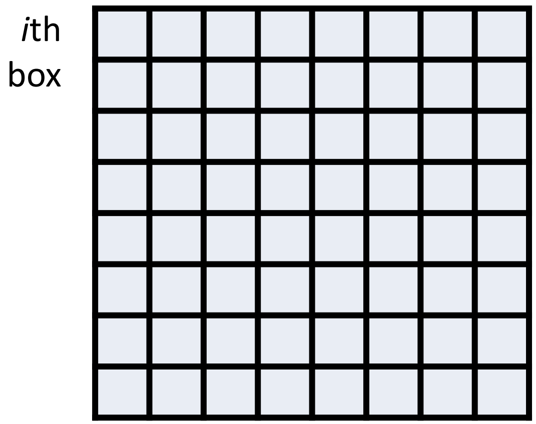


Thanks for listening

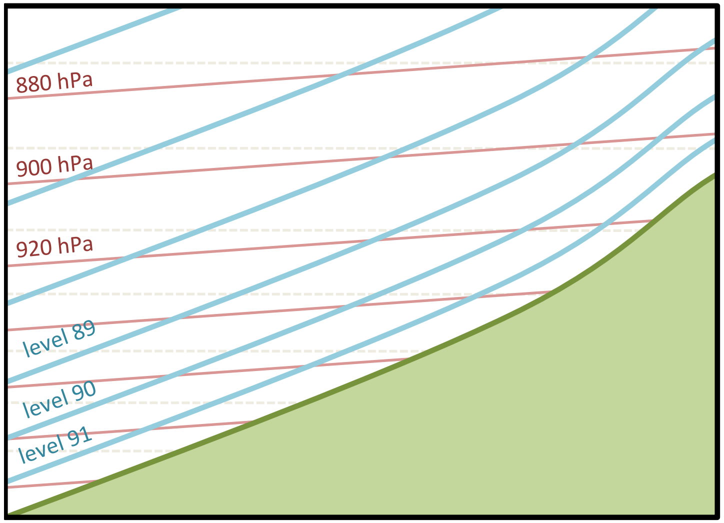
Coarse graining details 1

- Local area averaging for coarse graining.

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



- 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.



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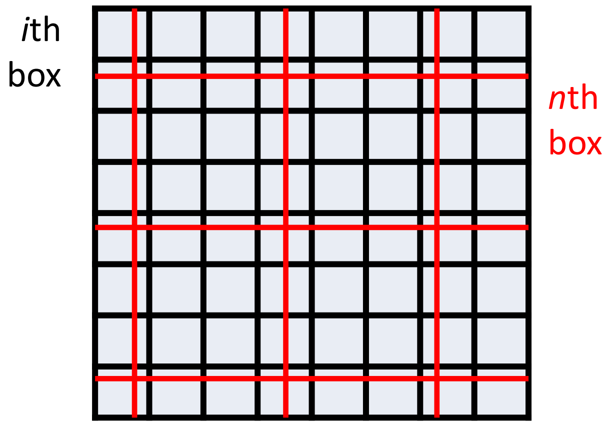

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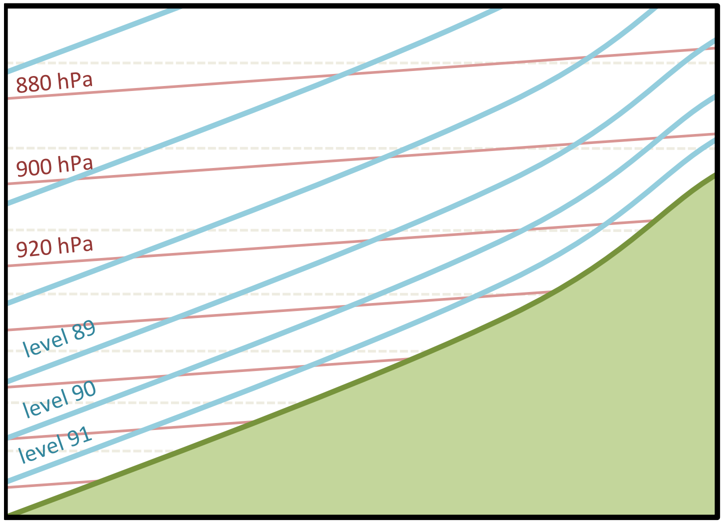

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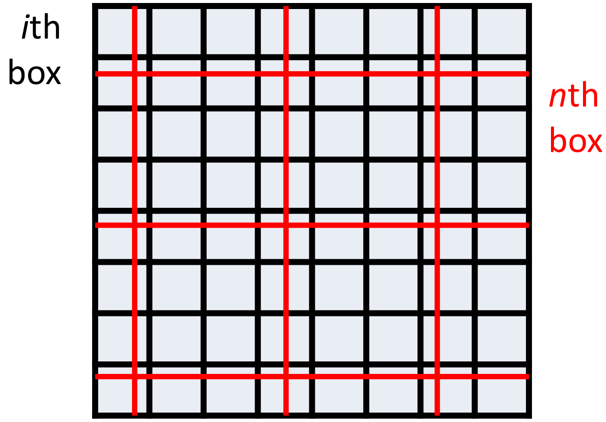

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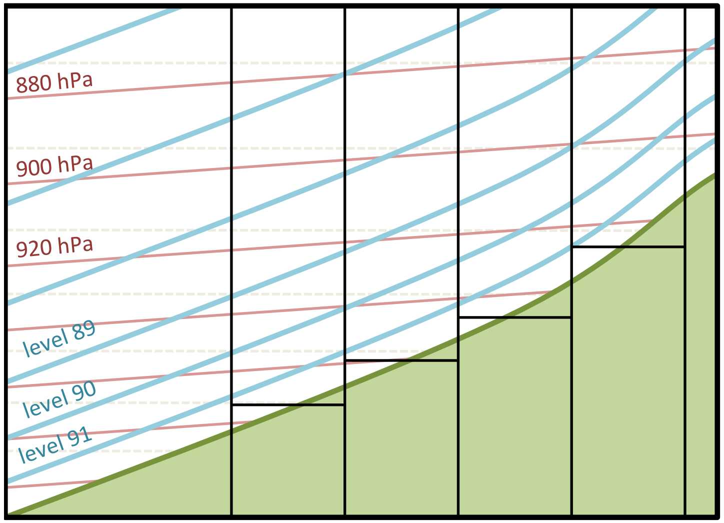

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Coarse graining details 2

- Above high-resolution model top, pad data using ECMWF analysis
- Advective tendencies estimated from the coarsened fields

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

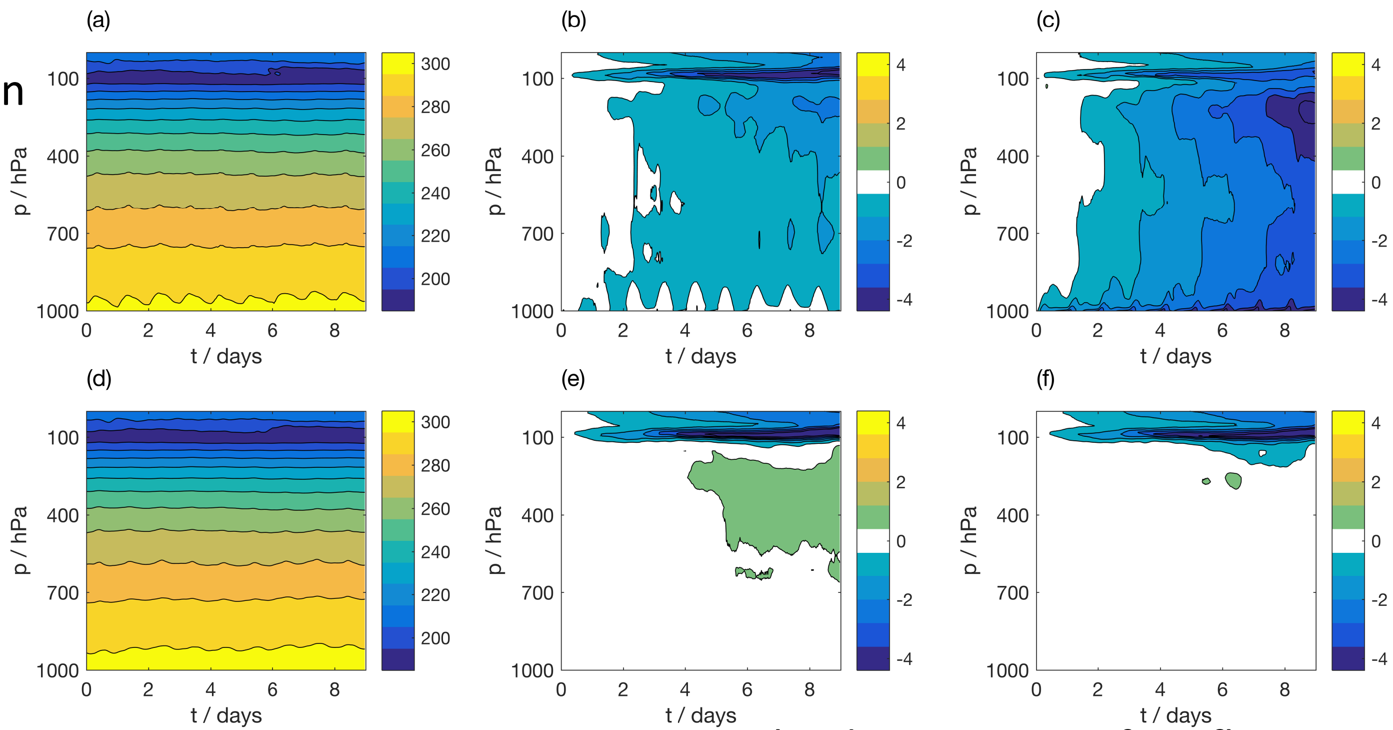
- Specify sensible and latent heat fluxes from high-resolution dataset
- Static boundary conditions (e.g. orography, land surface type) from operational model at chosen resolution

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

T: MC region



Land

Sea

Interactive land scheme

Surface fluxes

Christensen et al, 2018, JAMES.

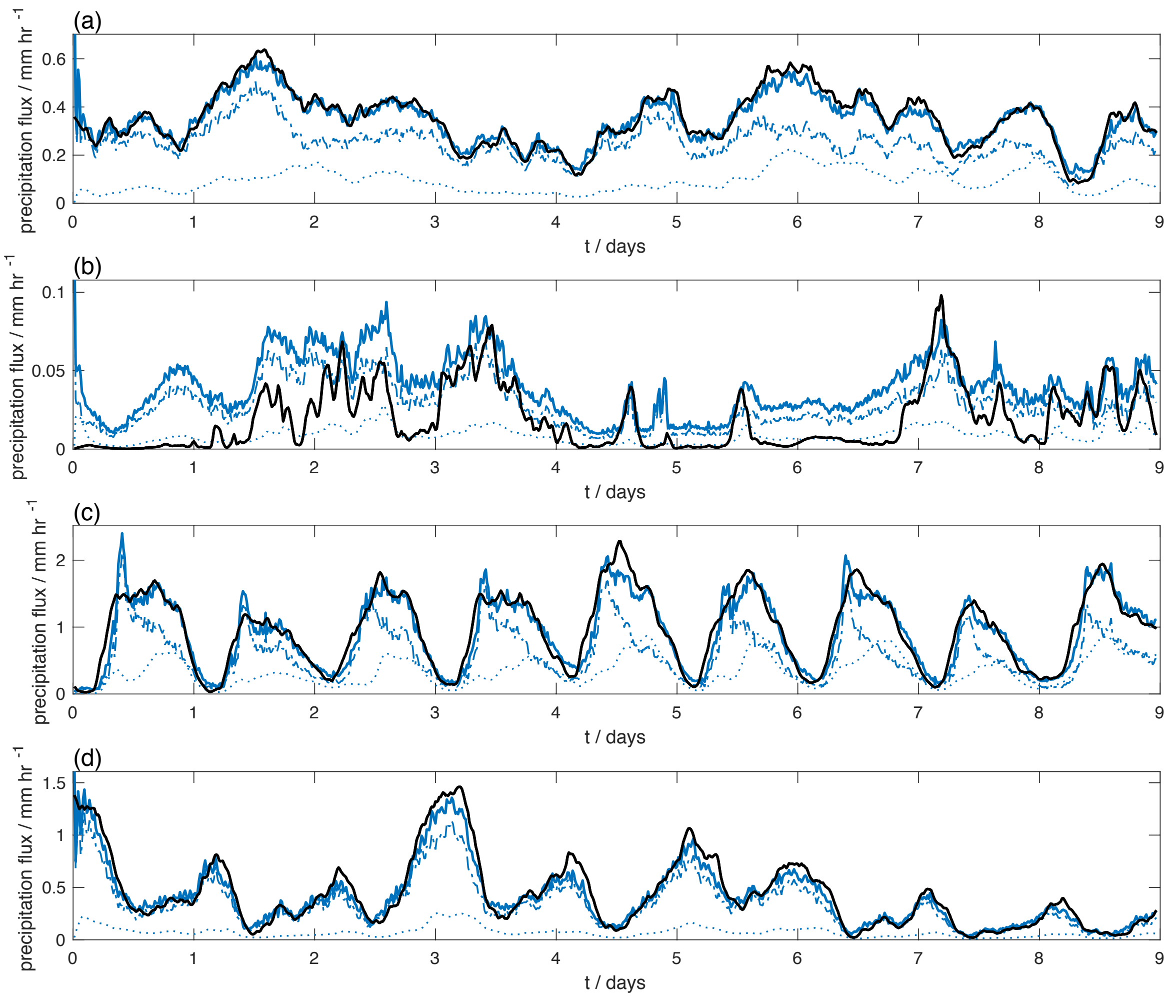
How does the SCM compare to Cascade?

W. Pacific Ocean

Ocean West of Australia

Maritime Continent Land

Maritime Continent Ocean



Precipitation

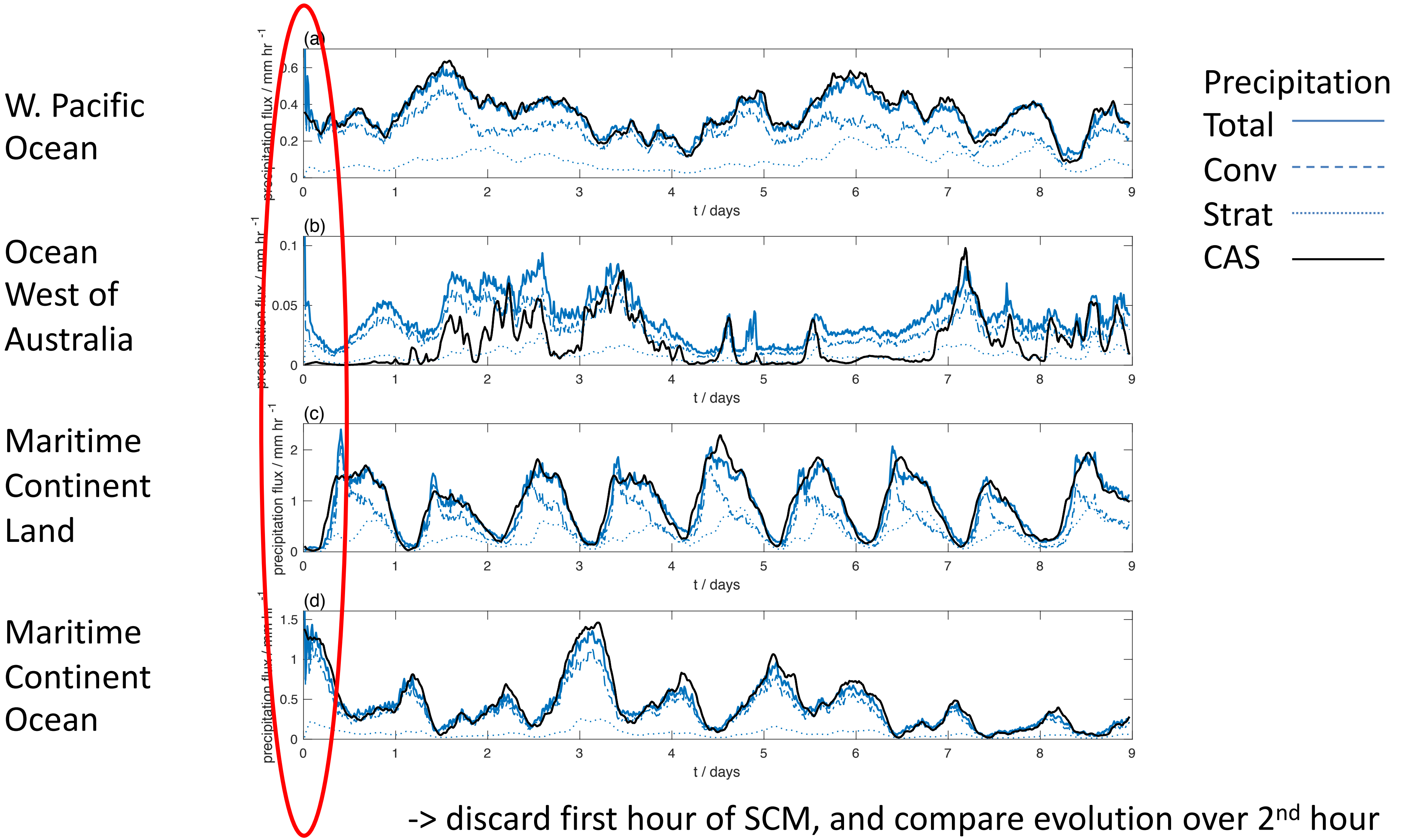
Total

Conv

Strat

CAS

How does the SCM compare to Cascade?



-> discard first hour of SCM, and compare evolution over 2nd hour