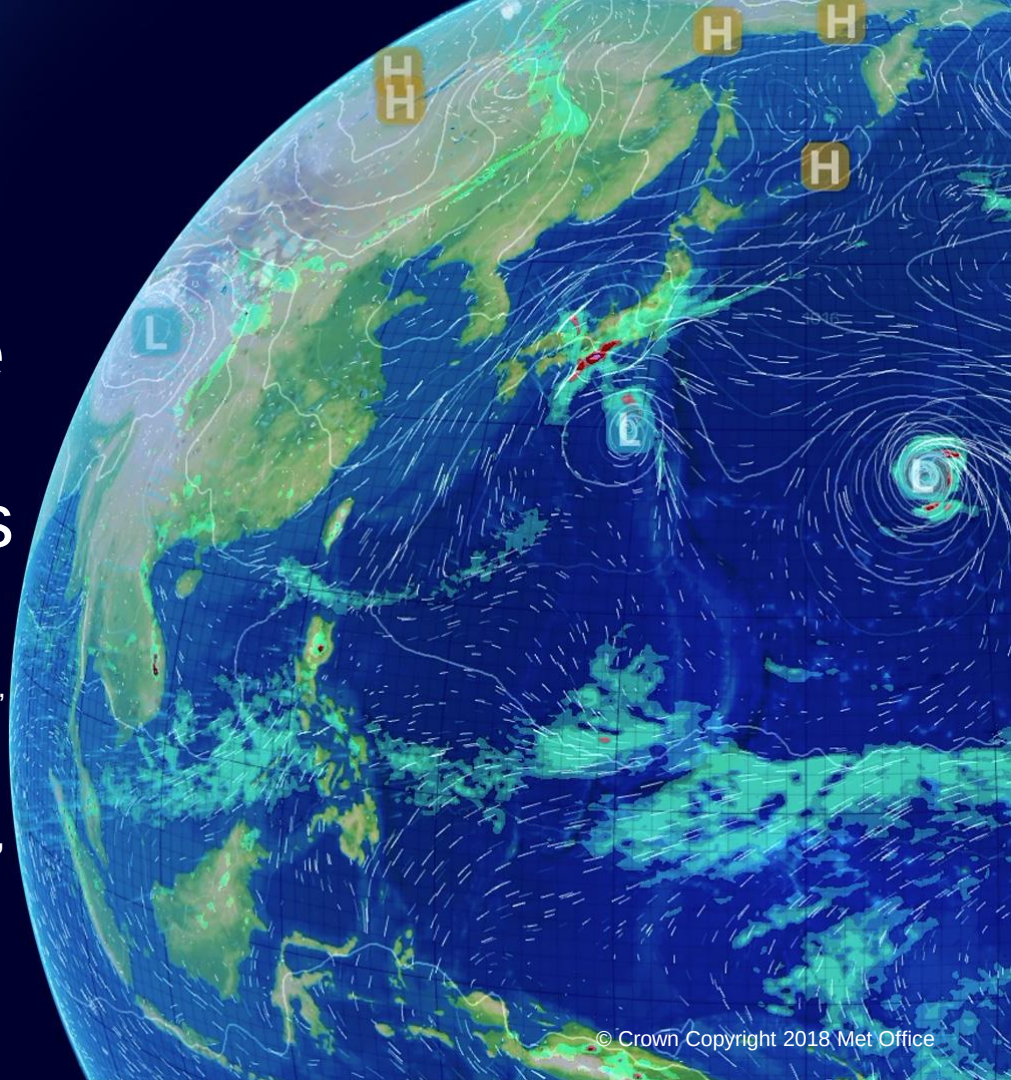
Global and convective scale NWP coupled modelling to improve the representation of convection in the Tropics

Charline Marzin, Sean Milton, Tim Graham, Michael Vellinga, Dan Copsey, Martin Willet, Keith Williams, Alison Stirling, Jon Petch, Stu Webster, Prince Xavier, Paul Barrett, Jose Rodriguez, Chris Harris, Huw Lewis, Claudio Sanchez…

CLIVAR workshop on “Convection and Air-Sea Interactions over the Tropical Oceans”

Tuesday 7 May 2019, Boulder

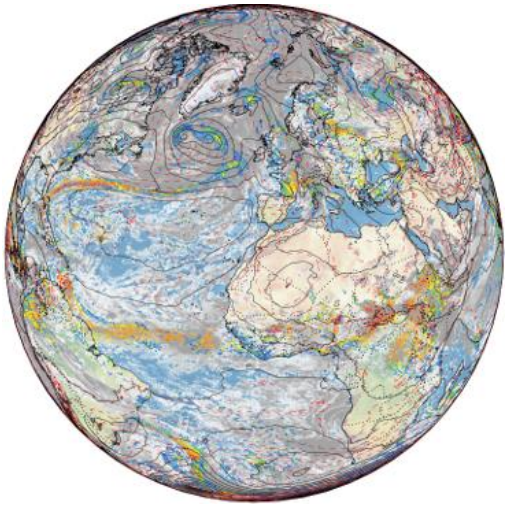


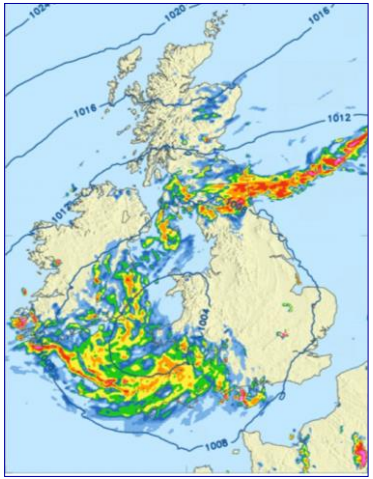
Outline

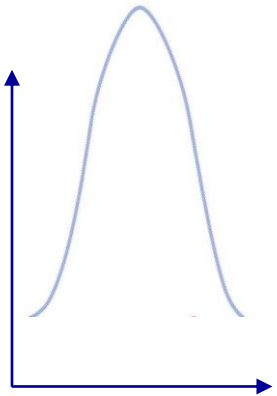
- The Met Office seamless prediction strategy
- Convection processes in global and convective scale NWP
- Recent model developments
- Development of global and regional coupled NWP systems and their benefits

Met Office Modelling Strategy

Seamless across Weather & Climate







N x **Global coupled model** at ~10km with lead times of days to years:
Synoptic drivers

N x **local coupled model** at ~<=1km :
Local meteorology

PDF of local hazard:
Impacts

Global Seamless Physical Model

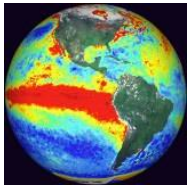
Hours *Days.* *Weeks* *Months* *Seasons* *Decades* *Centuries*

NWP

MOGREPS

Deterministic Atmosphere & Marine

Atmos. Ensemble



CLIMATE

UKESM

GloSea (Seasonal)

DePreSys (Decadal)

Climate Change UKESM1, UKCP18

Component Models

GA6 , GL6, GO5, GSI6

Global Coupled

GC Model

GC2.0, GC3.1...

Met Office Unified Model™ Global Atmosphere

JULES Global Land

NEMO Global Ocean

CICE Global Sea Ice

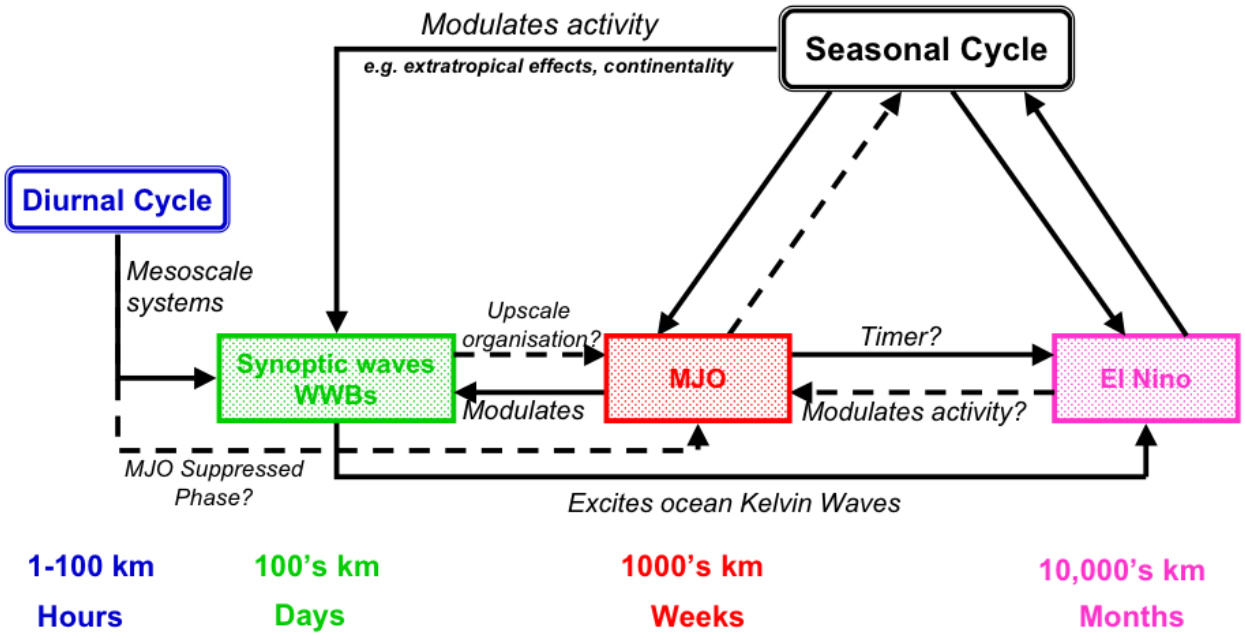
WaveWatch III Global Waves

UKCA

Met Office

Interactions between space and time scales of tropical convection

(Workshop on Organisation and Maintenance of tropical convection and the MJO , Trieste, 2006)



NWP → Deterministic **N1280L70**

Medium Range. MOGREPS-EPS **N640L70**

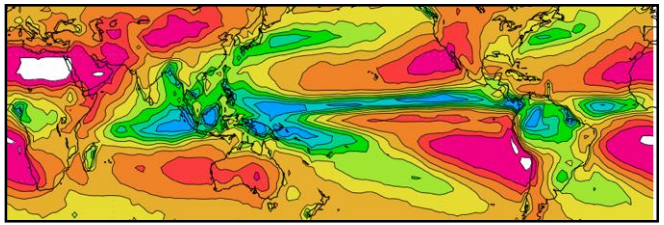
→ **Monthly/Seasonal** GLOSEA5 EPS -Coupled OA **N216L85ORCA025**

Parametrized Tropical Convection & Circulation Biases in global NWP

Tropical Precipitation – Annual Means

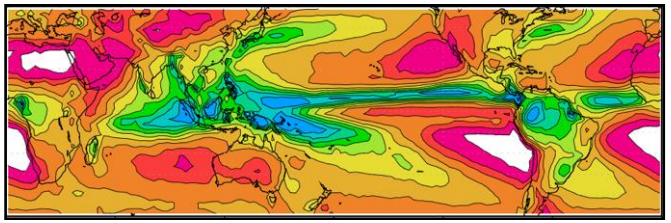
Seamless Model Biases

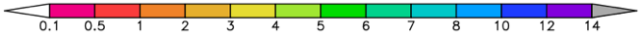
GPCP



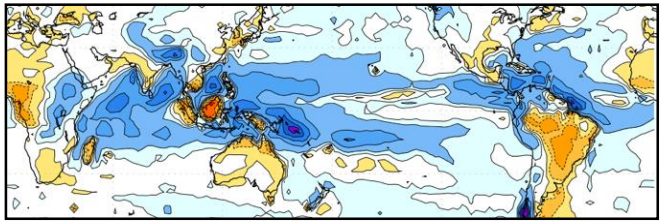
1998-2007

TRMM

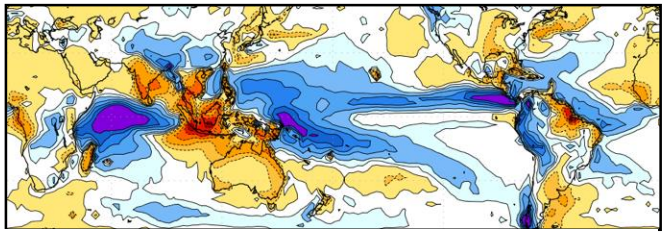




1998-2007 NWP - GPCP Day 1



1979-1998 HadGEM2-A - GPCP



Climate and day 1 NWP biases very similar on largest scales – suggests errors in "local physics" important.

NWP framework to investigate errors.

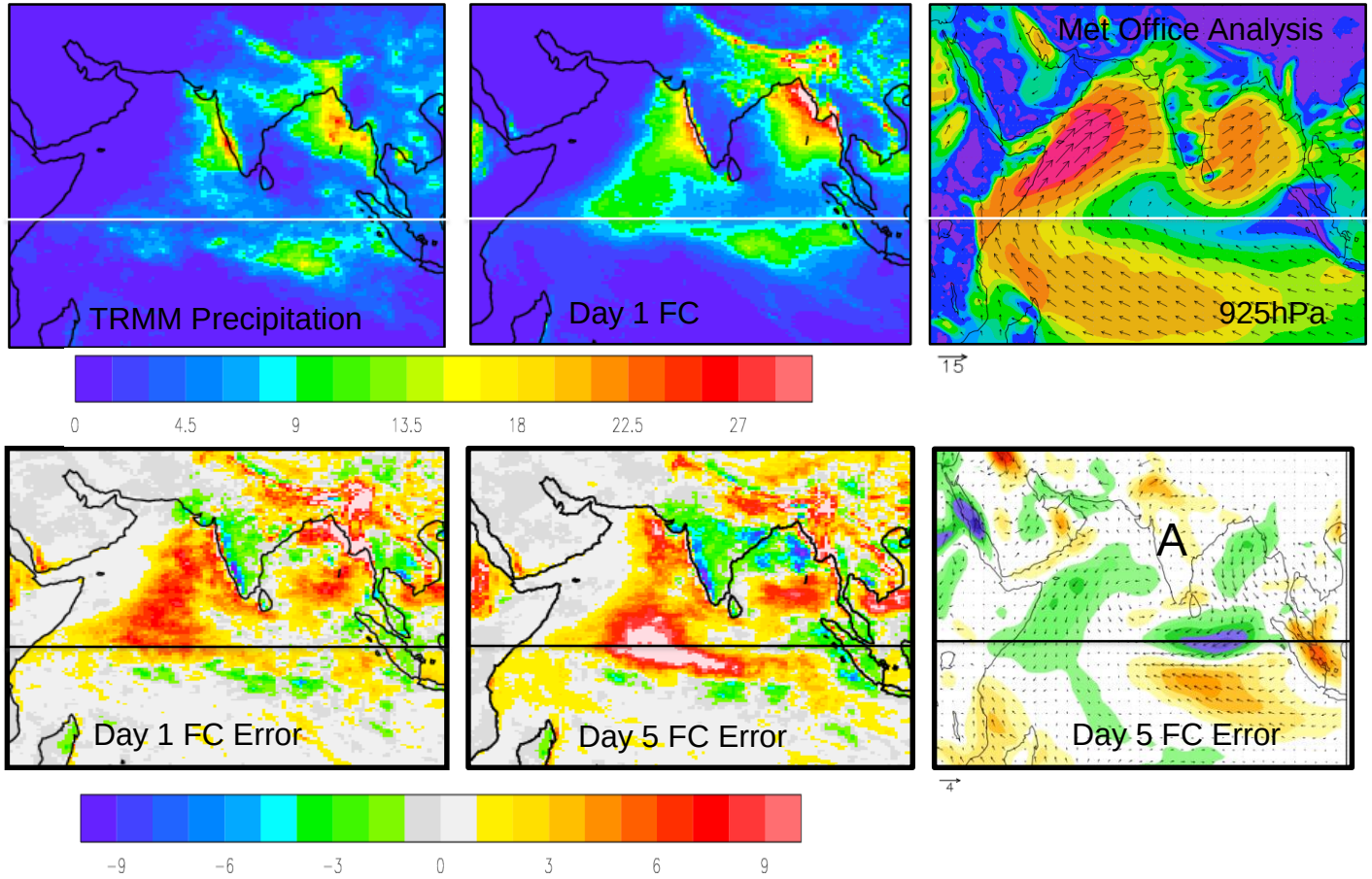
Some errors evolve due to errors in circulation – see Indonesia and Indian Ocean

Asian Monsoon: Met Office Global Day 1 & 5 Forecast Errors

JJA 2009 00UTC - YOTC Period

"Drying Monsoon trend" in forecasts

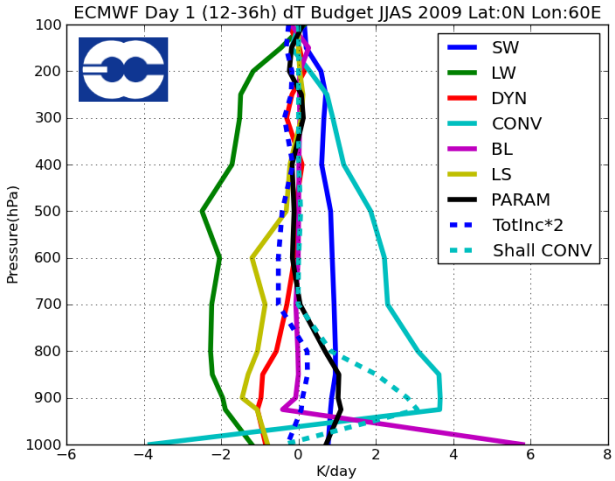
"Wet" Equatorial Indian Ocean

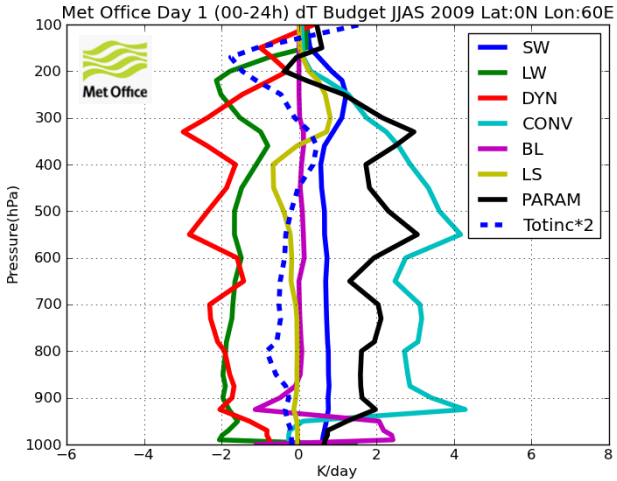


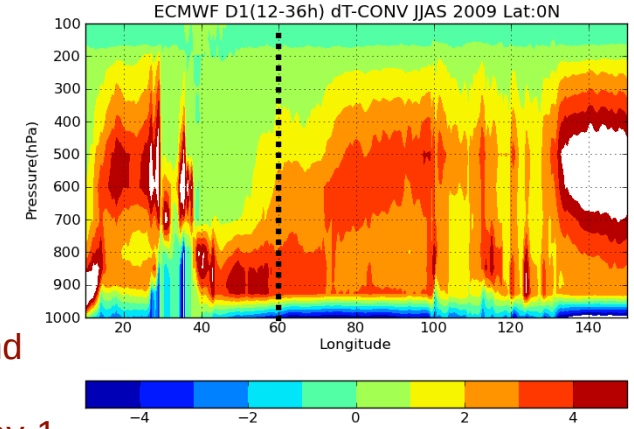
Day 1 forecasts of ECMWF and Met Office Physics tendencies

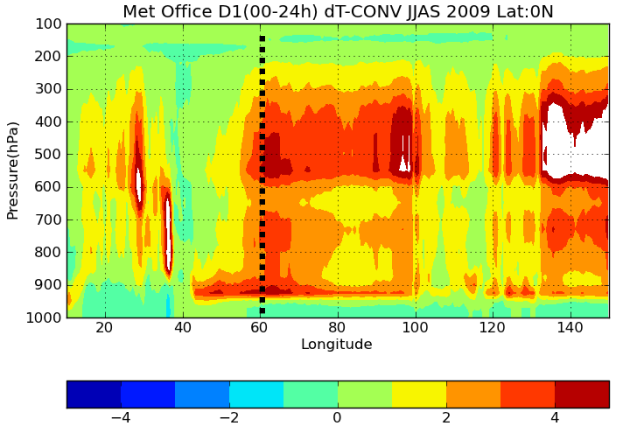
Time mean (JJA 2009) thermal balance profiles 60E 0N

Height-longitude plot of time mean (JJA 2009) convective heating at Equator









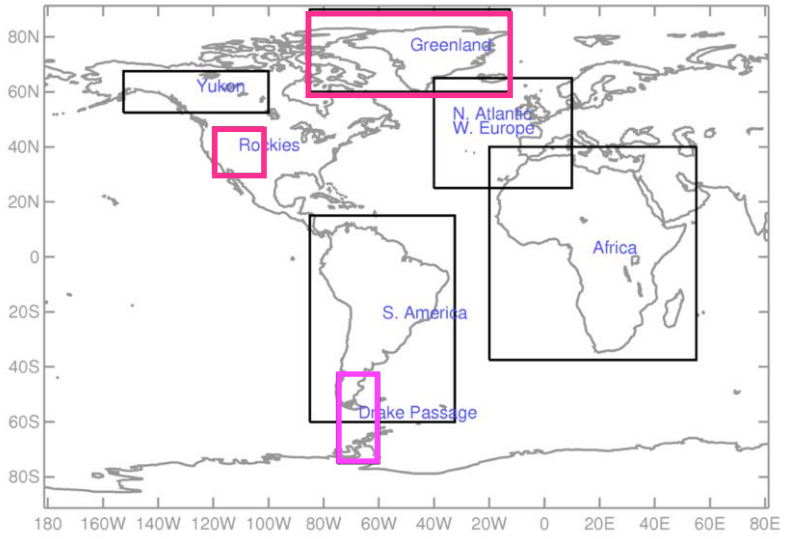
Very different vertical and spatial structures in convective heating in Day-1 forecasts

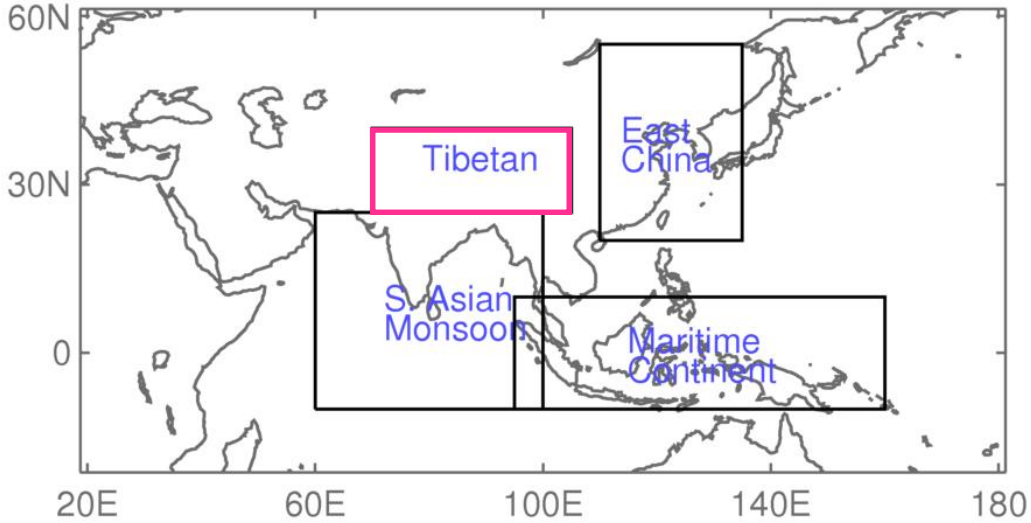
Q - What is the consequence of this different structure in diabatic heating for the evolution of the LS tropical circulation?

Maritime continent nudging example

Nudging experiments- Tropical Dynamics

GA7 climate AMIP @ N96: Nudge to ERAi U,V,T 6hr relaxation timescale.
and GA6 NWP hindcast @ N216: Nudge to UM analysis





Jose Rodriguez (MO)

Nudging: Maritime Continent

Vertically integrated moisture flux divergence

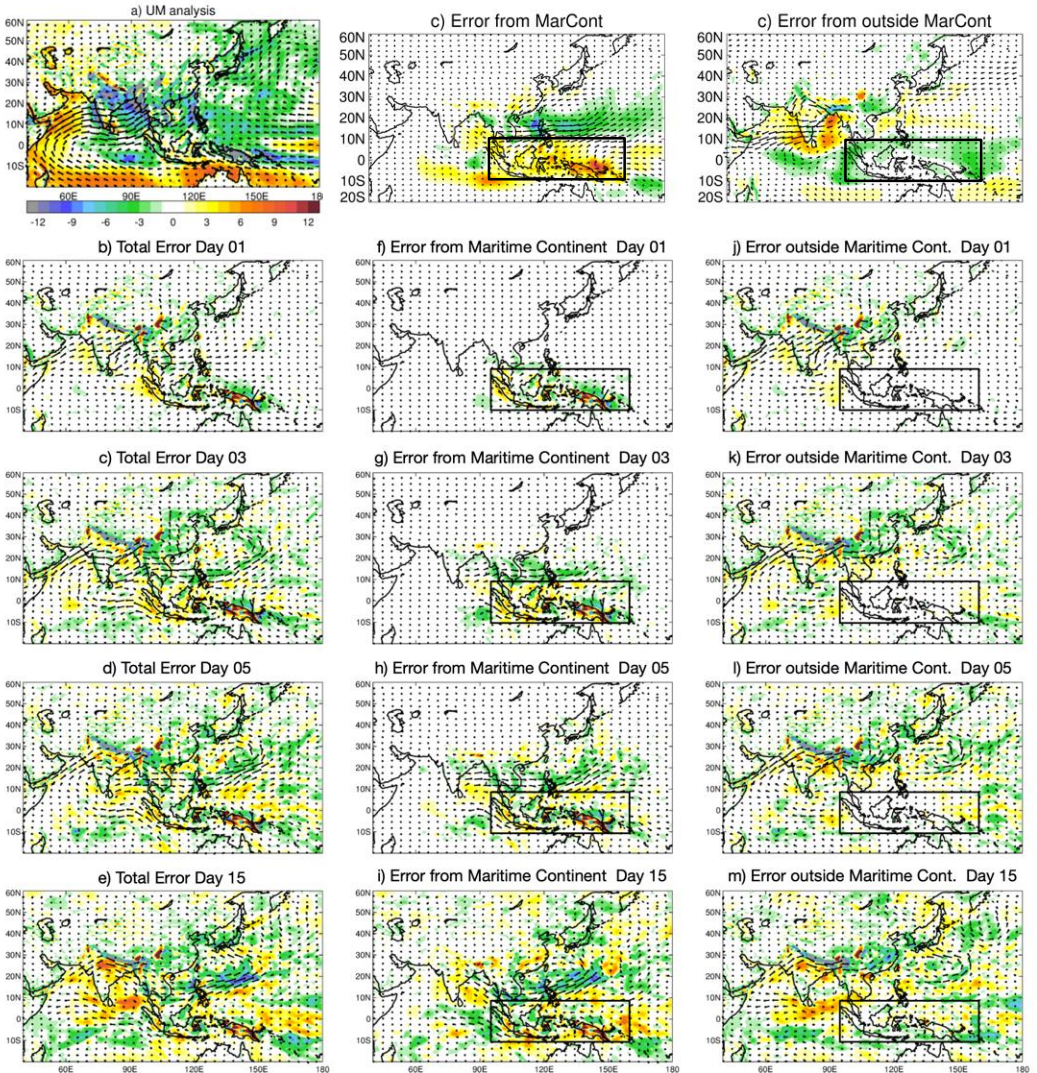
Blue/green = convergence

Red/orange = divergence (drying)

Explore the remote influence of errors in tropical precipitation & diabatic heating & circulation.

AMIP Nudging experiments

NWP days 1-15 Nudging exp.



Analysis & AMIP errors

Day 1 global NWP

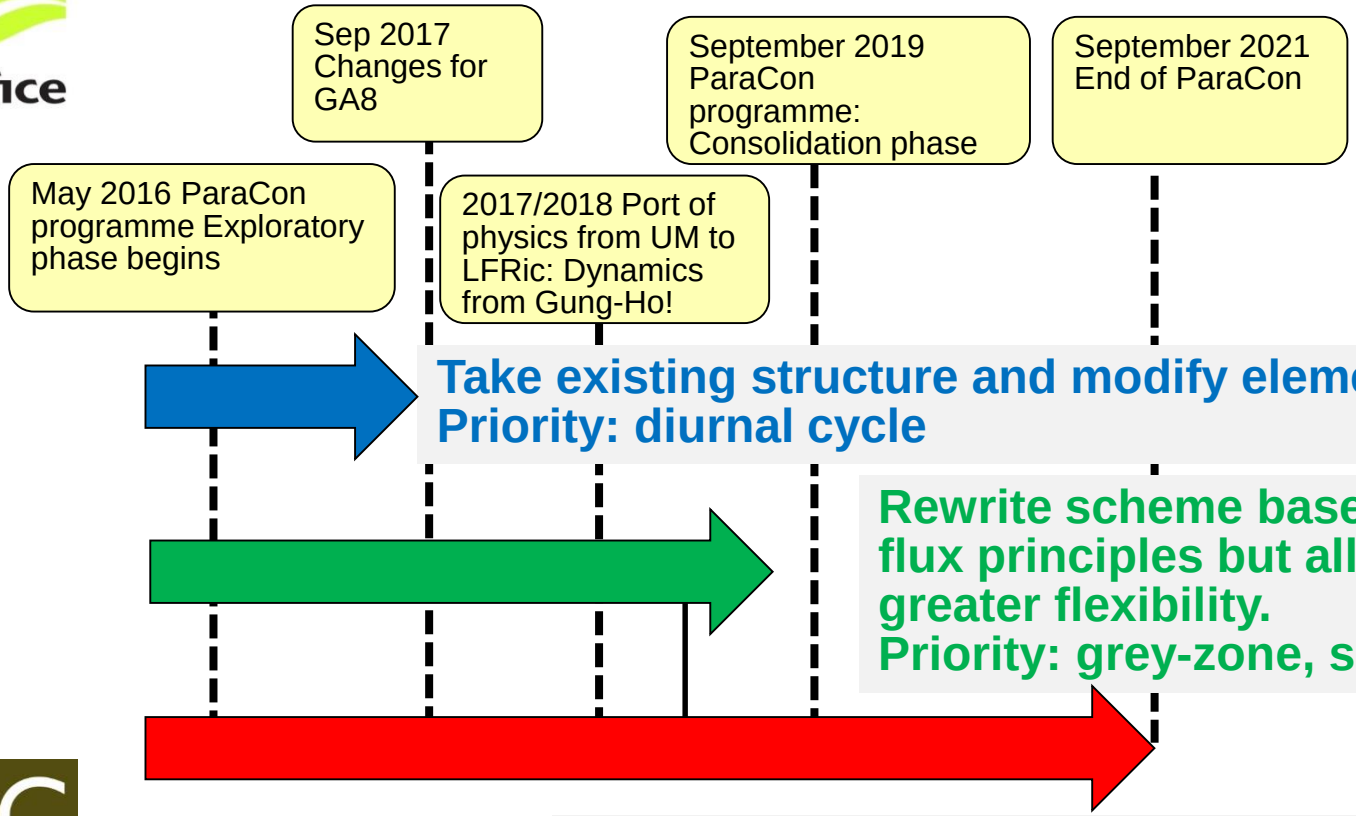
Day 3

Day 05

Day 15

Recent model developments targeting convection

Convection parametrization: 3 timescales, 3 levels of ambition



Recent model developments

W Africa

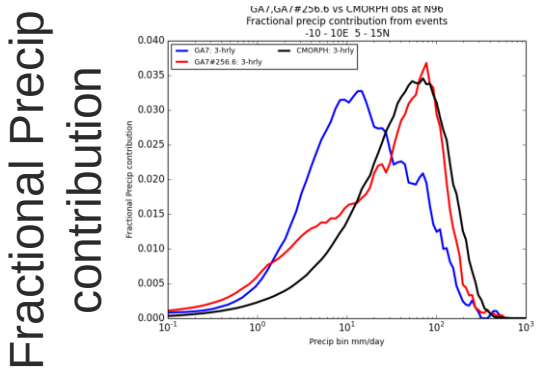
Prototype-GA8GL8:

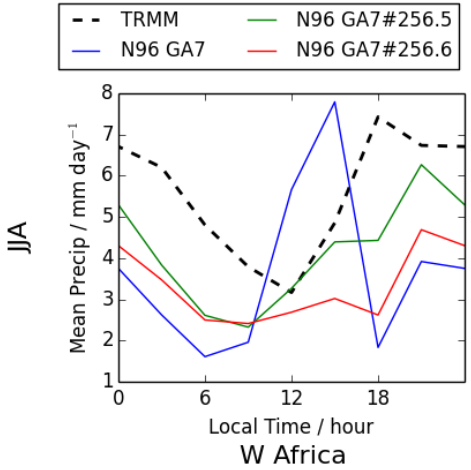
- **#199 prognostic based entrainment rates "Convective memory"**

- New fully advected 3D-prognostic time-smoothed measure of recent convective precip. rate with decay timescale 3hrs – used to rescale entrainment – low (high) activity => larger (smaller) entrainment

  - Improves diurnal cycle and precipitation rates

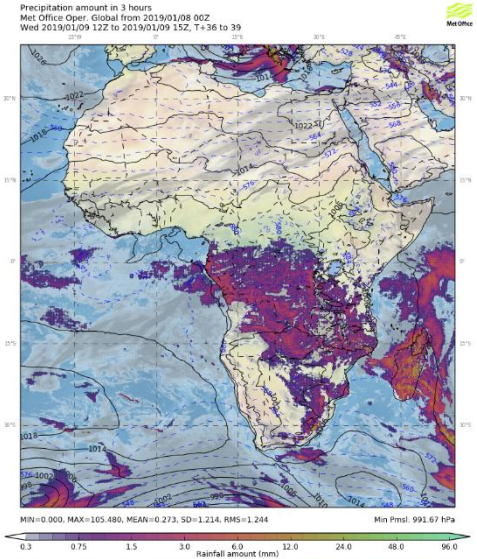
- **#181 New parametrizations for riming**
  - Increases supercooled liquid water cloud and improves southern ocean SW biases



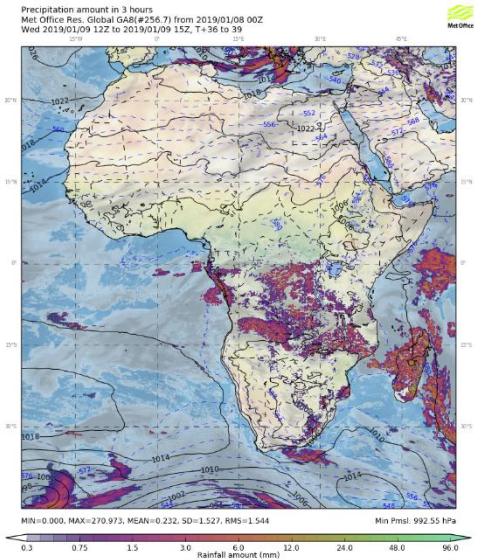


3-hrly Precip Rates: 12Z-15Z

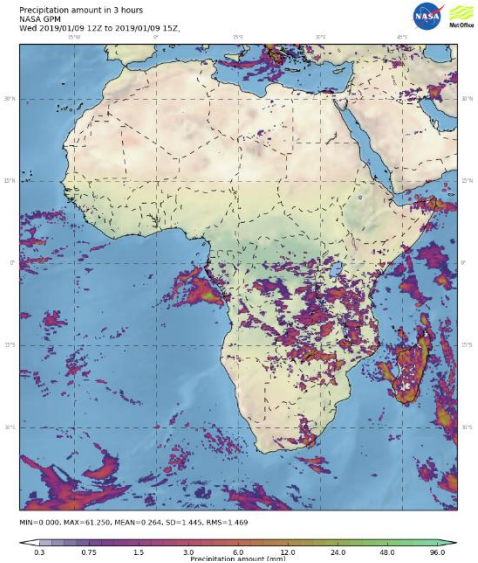
GA6.1 (10km)



Proto-GA8 (10km)



GPM



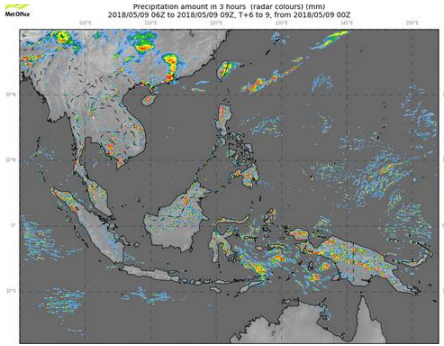
- N1280 Prototype-GA8 is being run in near real time
- Prototype-GA8 produce more realistic precipitation rates and structures

Thanks to Malcolm Brooks

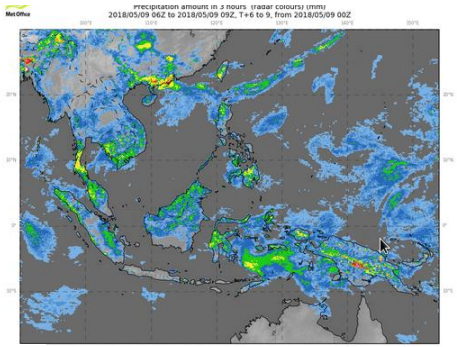
3-hrly Precipitation Rates in Prototype GA8

- GA7#256.5 (almost prototype-GA8) is being run in near real time over SE Asia and Tropical Africa by Stu Webster
- Precipitation rates and structures compare well to observations

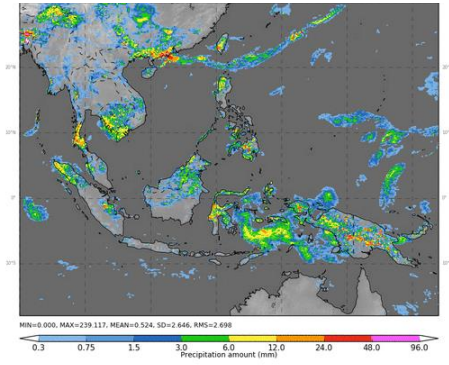
RA1T (4.4km)



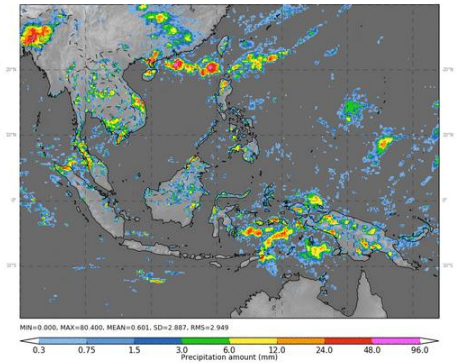
GA6.1 (10km)



GA7#256.5 (10km)



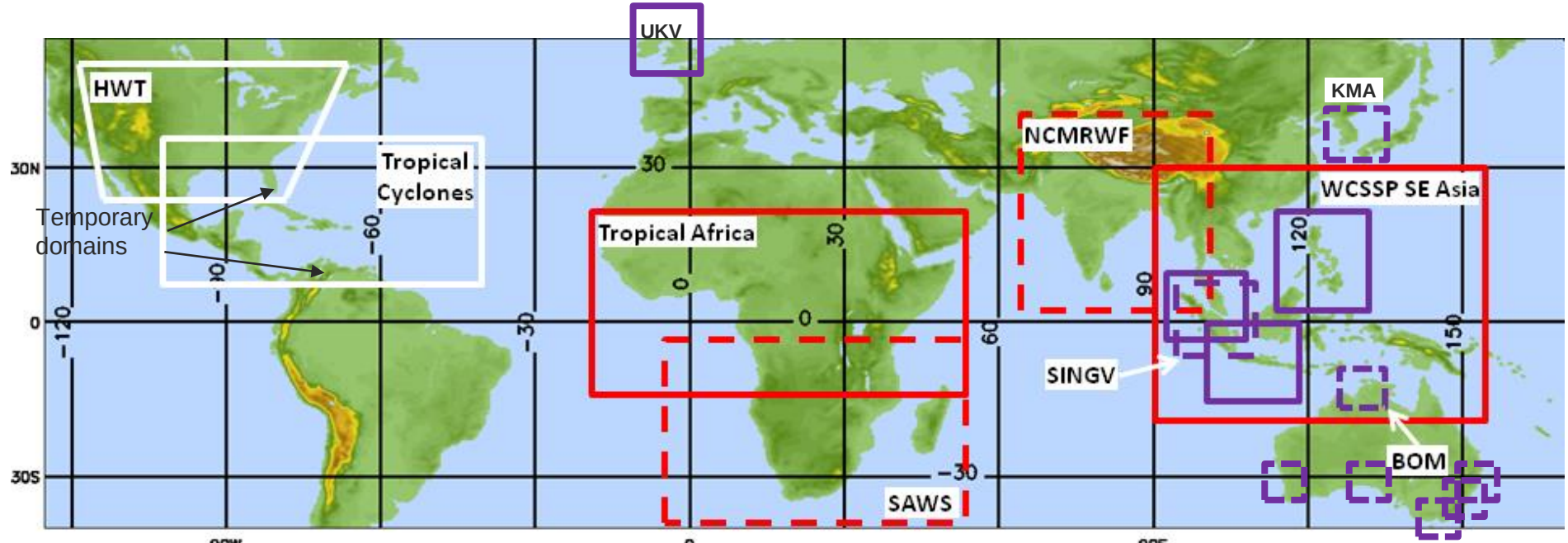
GPM



Thanks to Stu Webster and Malcolm Brooks

Representation of convection in convective scale models

Real-time Regional Model Domains



WCSSP Southeast Asia

Malaysian cold surge case study

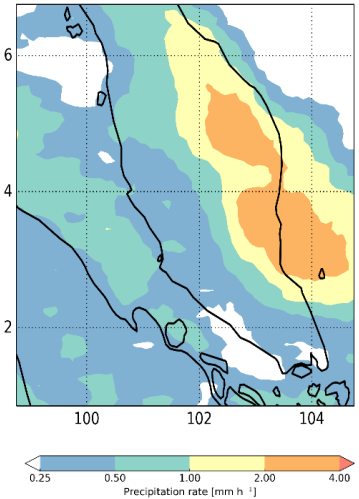
Global UM issues (tropics):
- Rain over land
- Diurnal cycle of rain
- Light rain vs. downpours

All improved with explicit convection (note.. resolution becoming less the issue)

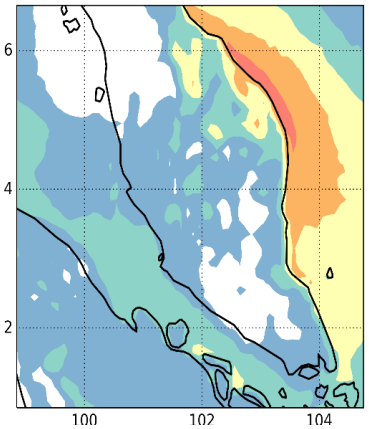
CHALLENGES for regional models:
Location accuracy and timing of events difficult to interpret for forecasters

Evaluation (and proper use) of models becoming a problem as resolution surpasses satellite observations

GPM Satellite Obs

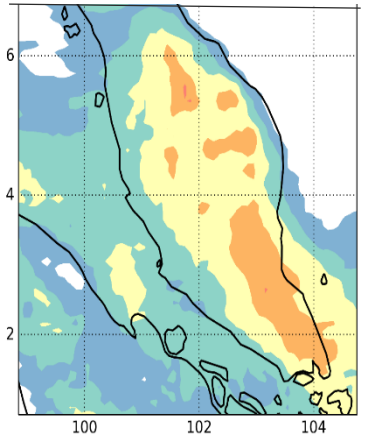


9km UM Global Model



PARAMETRIZED

1.5km UM Regional Model

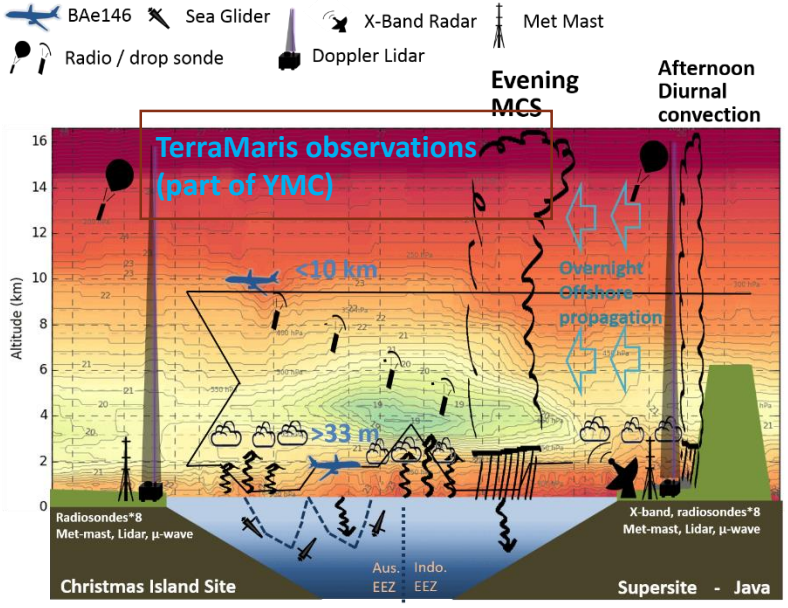


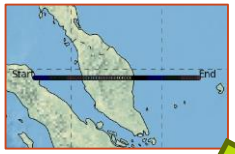
EXPLICIT

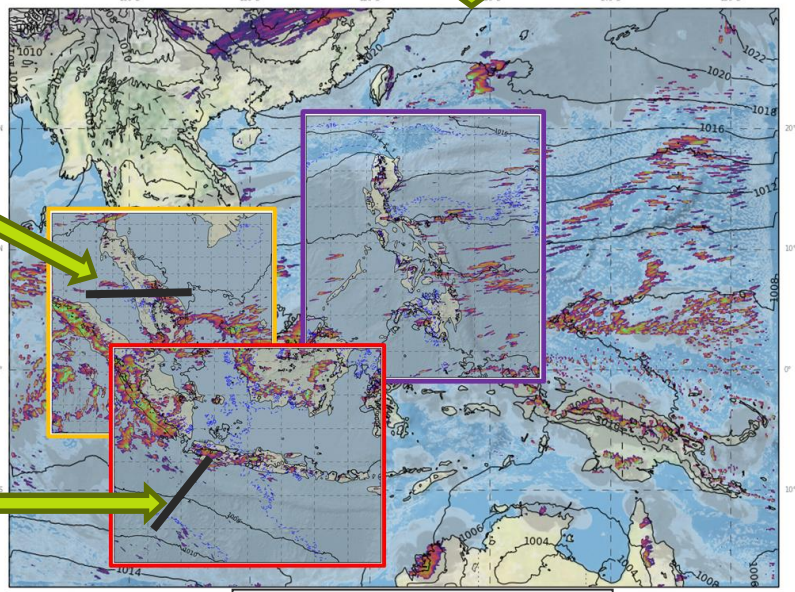
Regional modelling in South East Asia

- Process understanding
- GA/RA model evaluation
- Ensembles research
- A testbed for new physics with meteorologists looking in real time

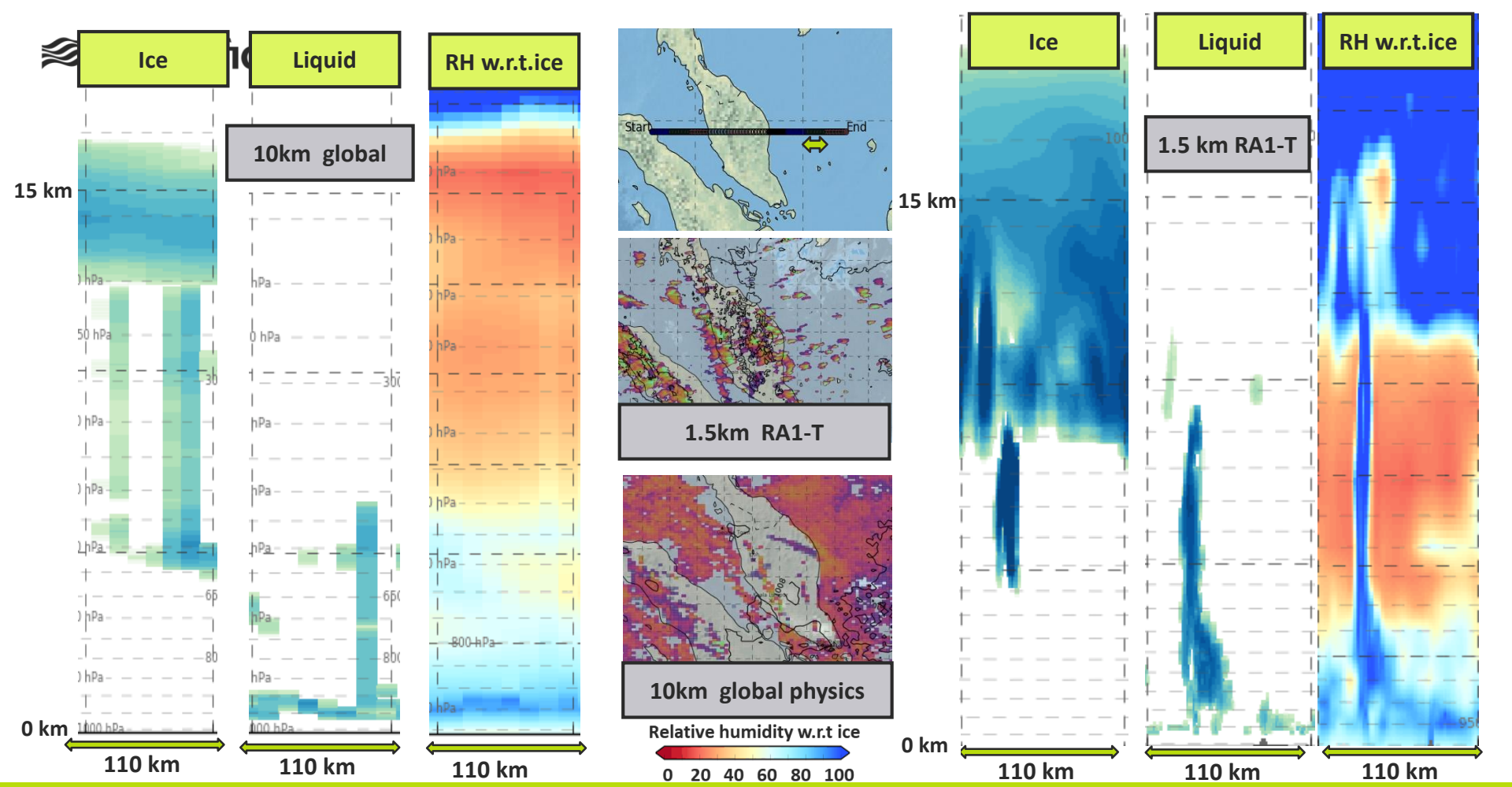
4.4km *120 hrs – 2/day*
+12 member ensemble (for 6 month period)







1.5km *36 hrs 2/day*


Ice
Liquid
RH w.r.t.ice
10km global
15 km
0 km
110 km
110 km
110 km
Start
End
1.5km RA1-T
10km global physics
Relative humidity w.r.t ice
0 20 40 60 80 100
Ice
Liquid
RH w.r.t.ice
1.5 km RA1-T
15 km
0 km
110 km
110 km
110 km

Coupled NWP and role of air-sea interactions

Why Coupled NWP?

Basic scientific rationale is that the real Atmosphere-Ocean-Ice-Land physical system sees 2-way coupling on all timescales.

Improved surface BC (not an infinite heat source or sink as with fixed SST NWP)

Improved ocean diurnal cycle

Improved heat and moisture fluxes

Improved boundary layer and convection and sea-breezes (important for large scale rain patterns, e.g. off N Australia and Maritime continent or India)

For UK regional forecasting problem: tidal impacts on SST (better forecasts of fog, sea-breezes etc)

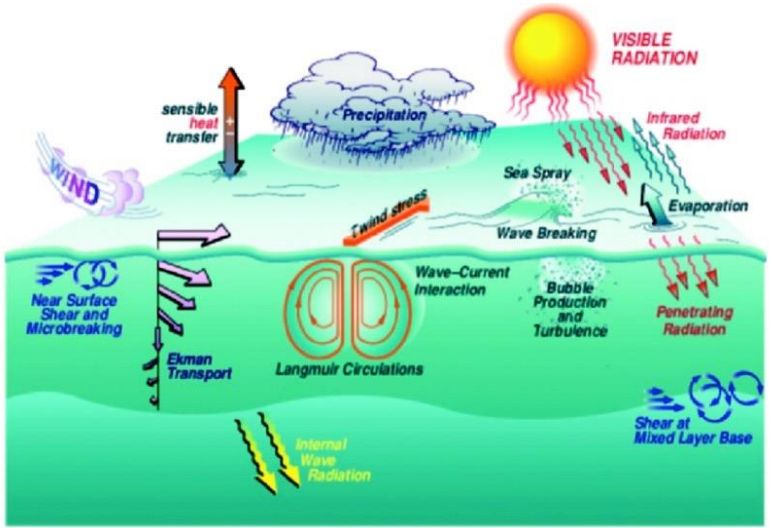


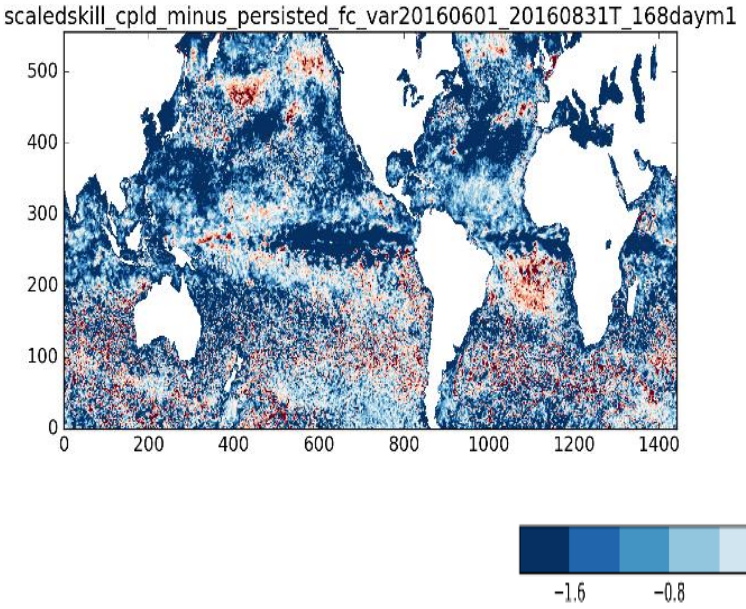
FIG. 1. A few of the physical processes governing air–sea exchange across the coupled boundary layers.

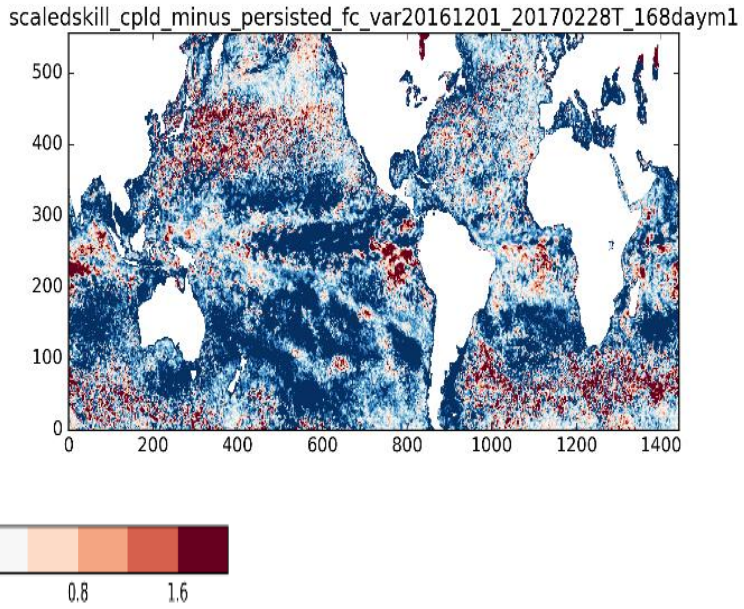
Edson et. al. (2007) - BAMS

Research and near real time coupled NWP

Model configurations	Experimental design
GA3/GO1 (N216-ORCA025 resolution)	**>100 start dates 2008-10**, 15 days, 3-h coupling.
GC2 & GC3 (N216-ORCA025 resolution)	**Annual cycle of daily start dates** Aug 2011-Sept 2012, 15 day runs
GC2 high-resolution (Atmosphere at multiple resolutions coupled to ORCA025)	**N512, N768 and N1280** case studies. Set of cases in Jan-Mar and Jul 2016 aimed at TCs; N768 experiment extended to daily May-Oct 2016, then up to Apr 2017, and now to near real time (until September 2017). N1280 near real time since July 2017. 15 day runs - hourly coupling.
GC2/GC3/GC4 case study test suites (*N512/N768-O025*)	**24 start dates, EC-initialised (atmos)**

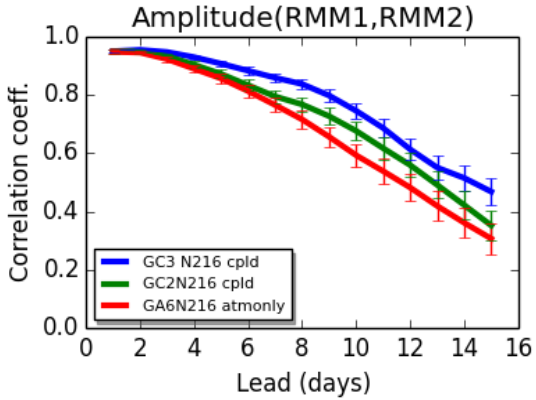
Coupled NWP: Skill vs persistence scaled by variance



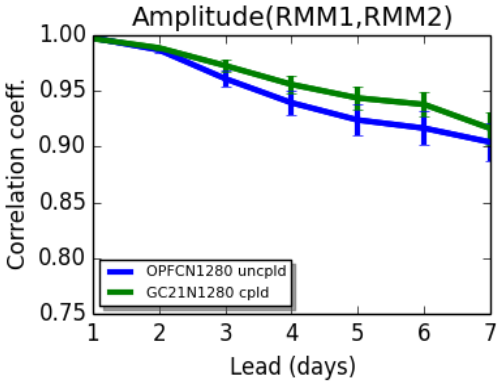


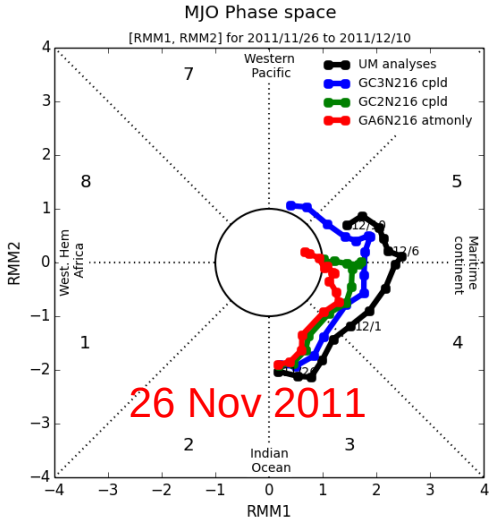
Coupled NWP MJO Performance

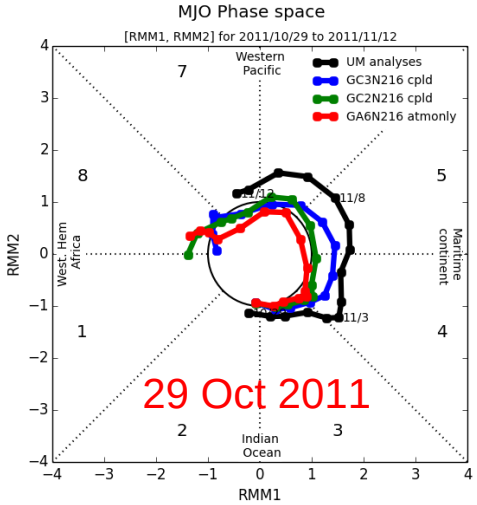
MJO N216

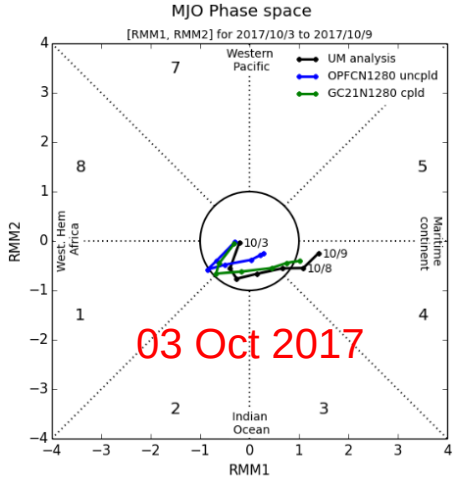


MJO N1280





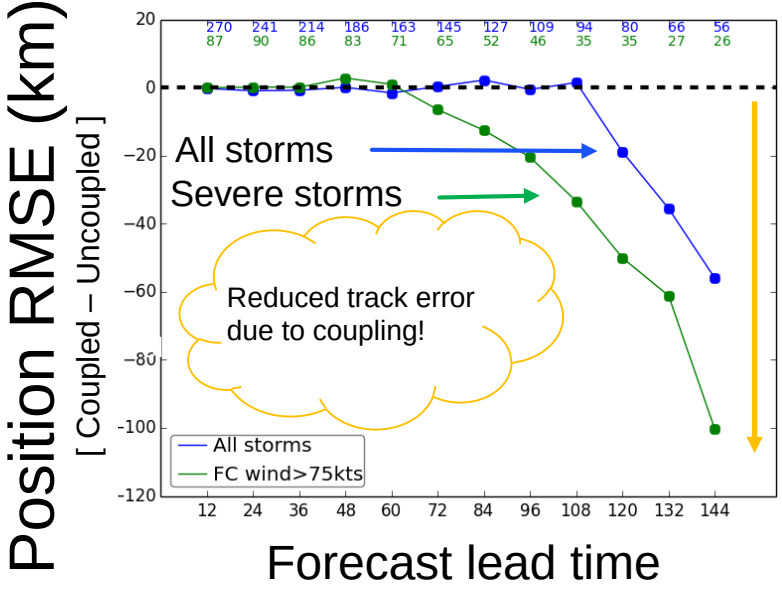




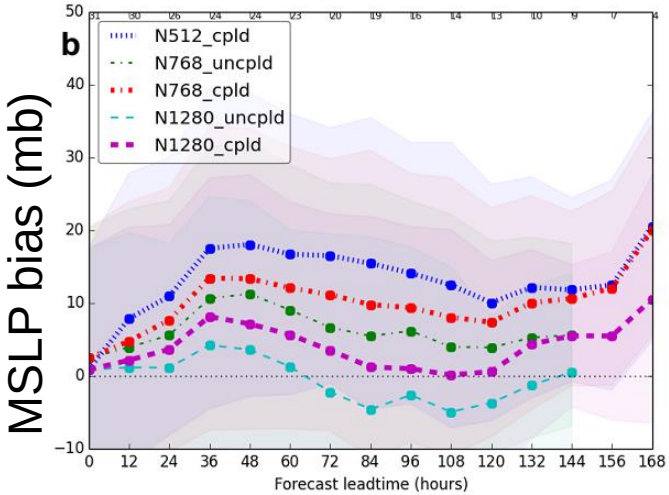
Tropical Storm forecast performance

Coupled vs Uncoupled at 10,17 and 25 km atm resolutions

TRACK ERROR (270 to 50 cases).



DEPTH ERROR (31 Storm cases).

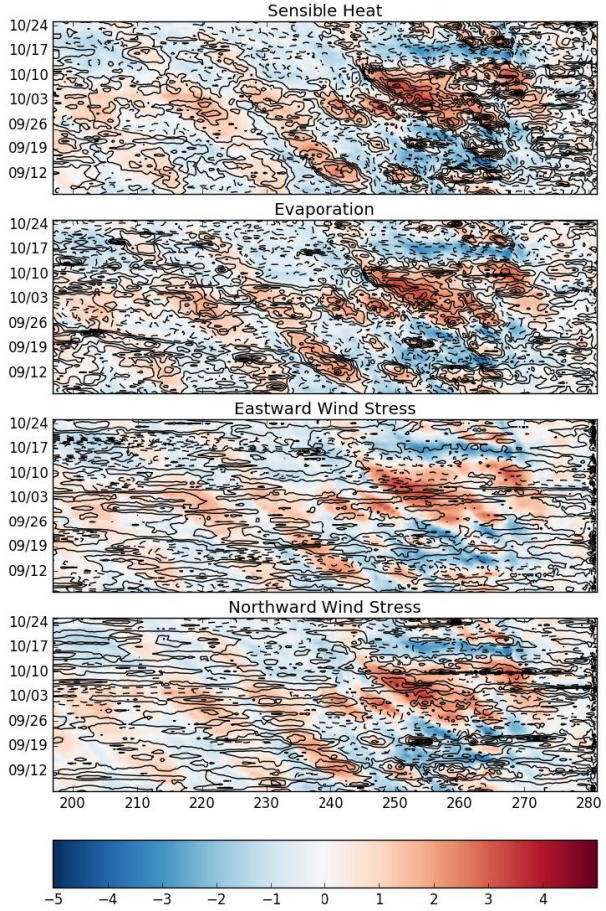


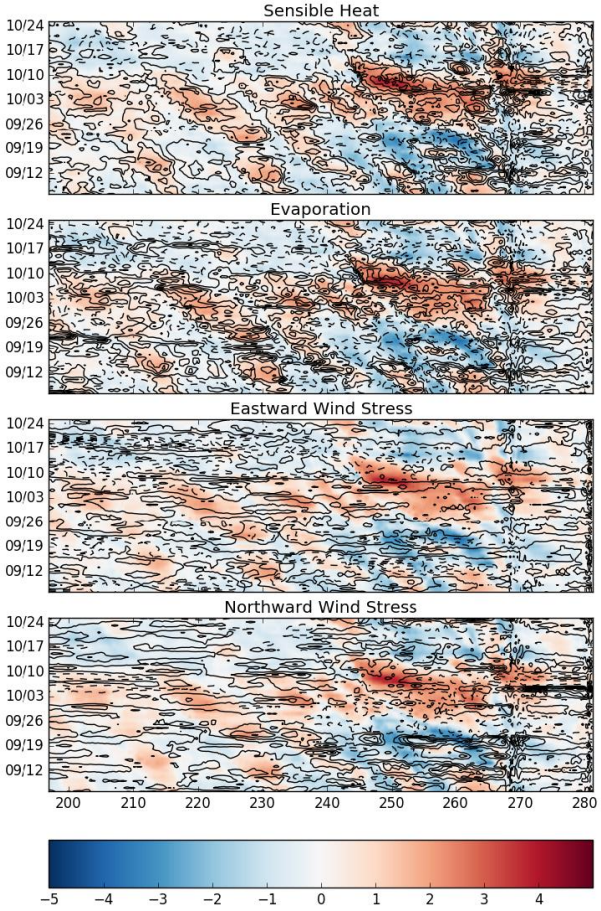
- N1280 UNCPLD over-deepens T+72
- Eliminated between T+84 and T+120 through interactive coupling
- Still missing processes – waves?

Michael Vellinga

Tropical Instability waves in coupled NWP

T+3h





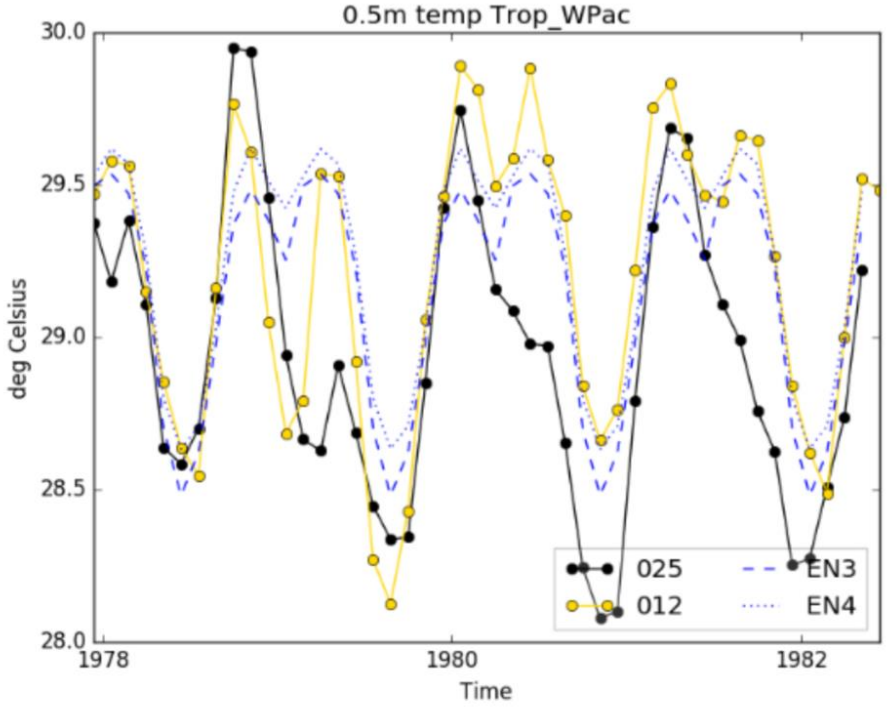
T+99h

Model able to propagate TIWs east to west

Relationship with wind stress not well represented at T+99h

Impact of resolution?

Ocean Resolution Impacts



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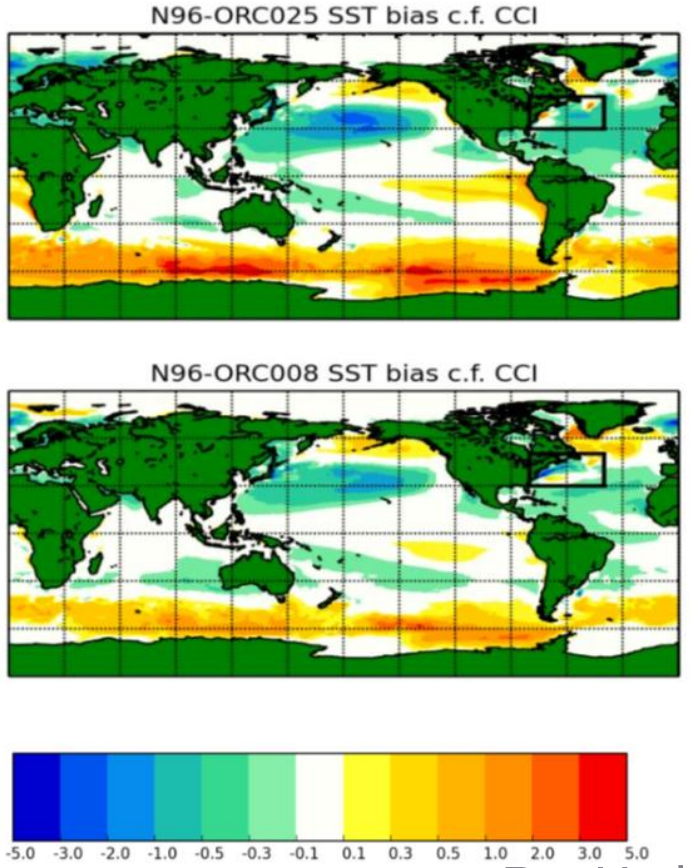
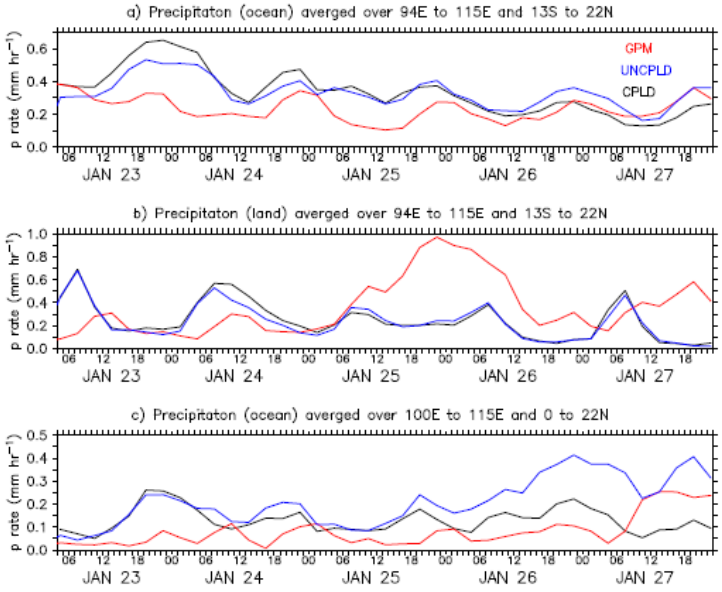


Pat Hyder

Air-sea interactions in convective scale models

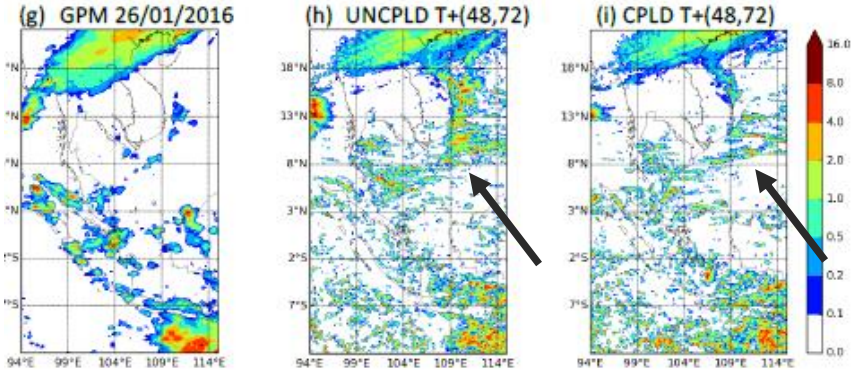
1.5km coupled convective scale model: Cold Surge case

Coupling shows improvement for SSTs and precipitation!



[Top] Timeseries of avg precipitation over (a) land, (b) sea, (c) restricted domain over SCS (ocean only) for **coupled**, **uncoupled atmosphere** and **GPM**

Coupled produces less precip. on the 26th West of Vietnam. Land precip poor on 25th as the system over North Thailand and Laos is weaker



[Left] Acc. precipitation over the 26th (mm/hr)

Thompson et al. 2018

See my poster on cold surges in global coupled NWP

Convective scale coupled environmental prediction model for India

- Established a common domain across ocean and atmosphere interests in collaboration across partnership.
- Atmosphere-only MetUM regional configuration defined, and used for boundary forcing sensitivity experiments (Kerala case study)
- Collaboration with UK National Oceanography Centre, Met Office and INCOIS to develop a NEMO regional ocean model configuration for coupled research
- Atmosphere-ocean coupled configuration developed as a rose suite, in preparation for case study mode testing
- Focus for coming year:
  - Initial research using and evaluation of coupled system
  - Use for other WP activities and India partner interest
  - Addition of interactive wave component (3-way cpl)
  - Supporting UK defrayment on coupled evaluation

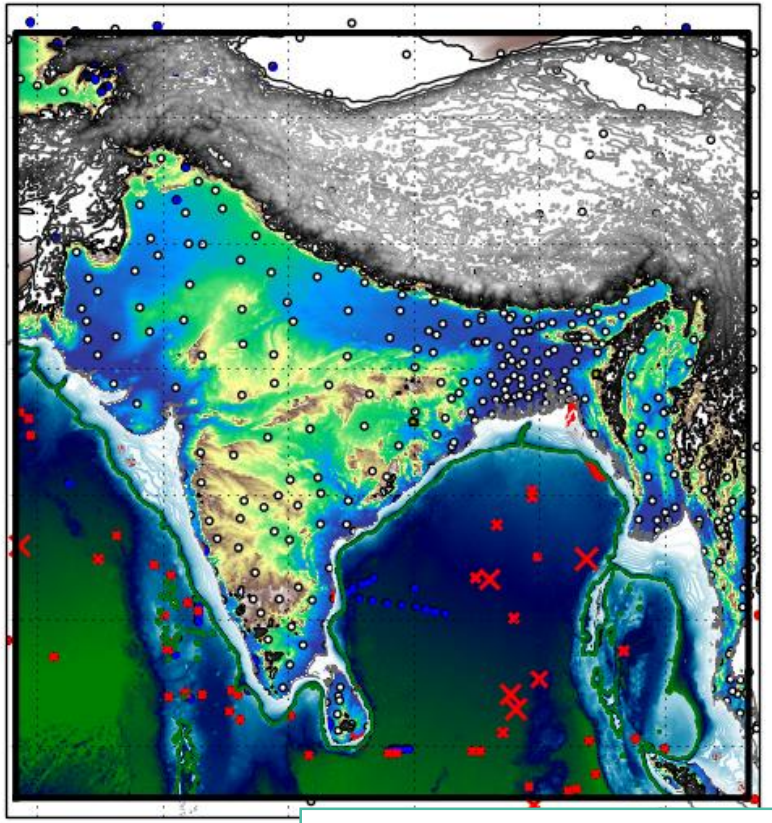


Illustration of regional coupled system domain and operational observations

Huw Lewis, Juan Castillo, Claudio Sanchez

Met Office

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Ministry of
Earth Sciences

Newton-Bhabha Fund

Summary

- Seamless strategy provides opportunities and additional tools to improve convection over the Tropics
- Remaining challenges for both global and regional convective scale models
- Coupling processes important for NWP
- More observations required to test the model against at process-level


Met Office
Thank you