Met Office
Hadley Centre

Diurnal variability of sea surface temperature in a global initialised ocean-atmosphere coupled model

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GHRSST XIV Science Team Meeting, Woods Hole, 21 June 2013

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Outline

- Overview of initialised coupled model.
- Assessment of diurnal variability of SST in the coupled model
- Summary and further work:

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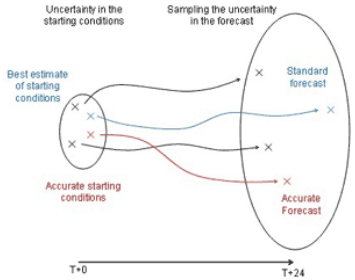
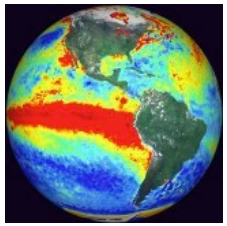
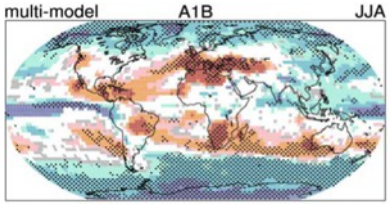
Global Modelling

Unified Prediction across Timescales

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







Deterministic NWP
Atmosphere/Land
25km 70L
FOAM-NEMO
0.25deg 75L
Waves –
WaveWatch III

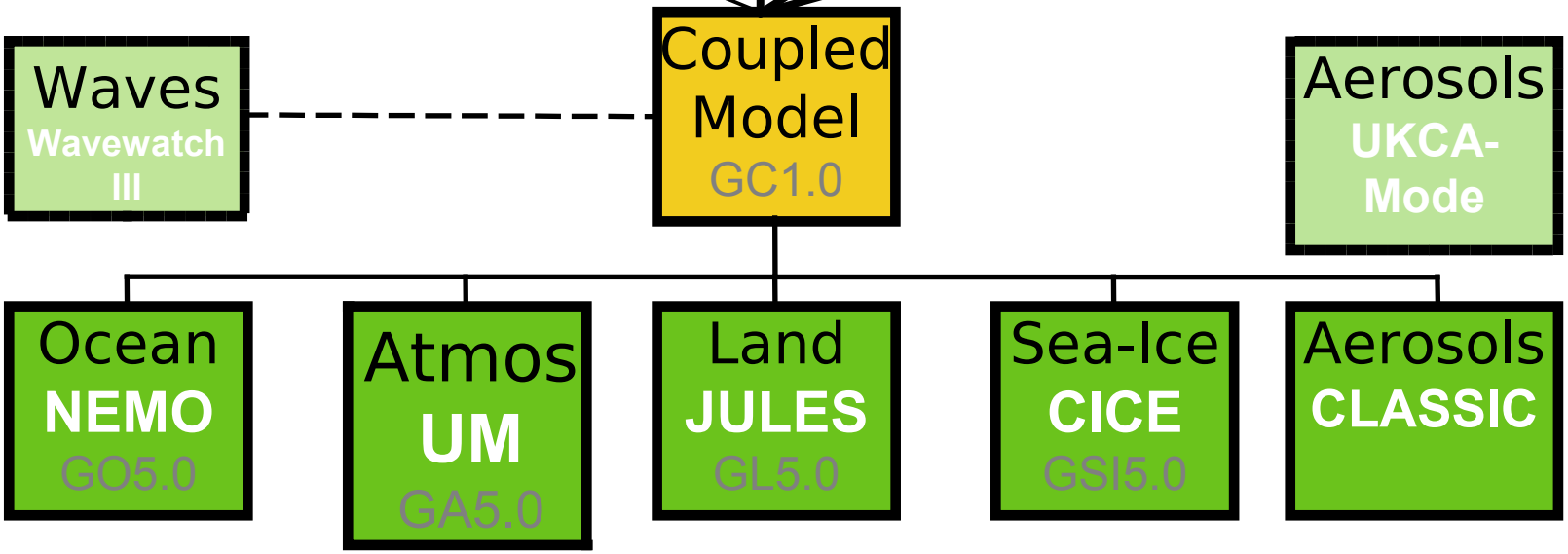
MOGREPS
Atmosphere/Land
MOGREPS-G 35km
MOGREPS-15 60km

GLOSEA5 EPS
HadGEM3 - AOIL
60km Atmos.
0.25deg Ocean

Decadal
HadGEM3 - AOIL
140km Atmos.
1deg Ocean

Climate Change
HadGEM3 - AOIL
HadGEM3
UKESM1

Coupled NWP
Research mode



Key aims of coupled NWP R&D

1. To explore role of air-sea coupling in potentially providing **improved forecast skill** (focusing on the 1-15 day timescale) – for both atmosphere/land surface and ocean/sea ice forecasting purposes
2. To probe systematic model **errors, error-compensations and drifts that are robust across forecast timescales** (short-range to seasonal to climate) to assist the process of tackling model systematic errors 'at source'
3. To deliver an **efficient platform for undertaking global coupled model evaluation** feeding into new Met Office coupled physical model releases, and future operational systems including:
   - [2014] **Global coupled short-range ocean forecasting system** (for MyOcean2)
   - [2014?] **Global coupled medium-range ensemble NWP system** (MOGREPS-15/GloSea merger)
   - [2020 vision] **High resolution global coupled ensemble NWP system**

→ These aims align closely with the Met Office's increasing attention on **seamless model prediction / seamless model assessment**

Experiments: Methodology

200+ Case studies D1-15

- **Coupled model**: Higher resolution global configuration of HadGEM3-AOIL consisting of…

  - **Global Atmos** GA3.0 **@ N216L85** + **Global Land** GL3.0 (Walters et al. 2011 GMD)
  - **NEMO3.2@ORCA025L75** + **CICE** (version 4.1)
  - **OASIS** coupler

- **Initialization**: No coupled DA – atmosphere & ocean initialised separately

  - **Atmosphere+Land:** Met Office 12 UTC operational NWP analyses (interpolated N216L85)
  - **Ocean+Sea Ice:** 12-hour ocean forecasts from ocean analysis at 00UTC, using FOAM-NEMOVAR model (NEMO3.2@ORCA025L75 + CICE), driven with OP NWP fluxes

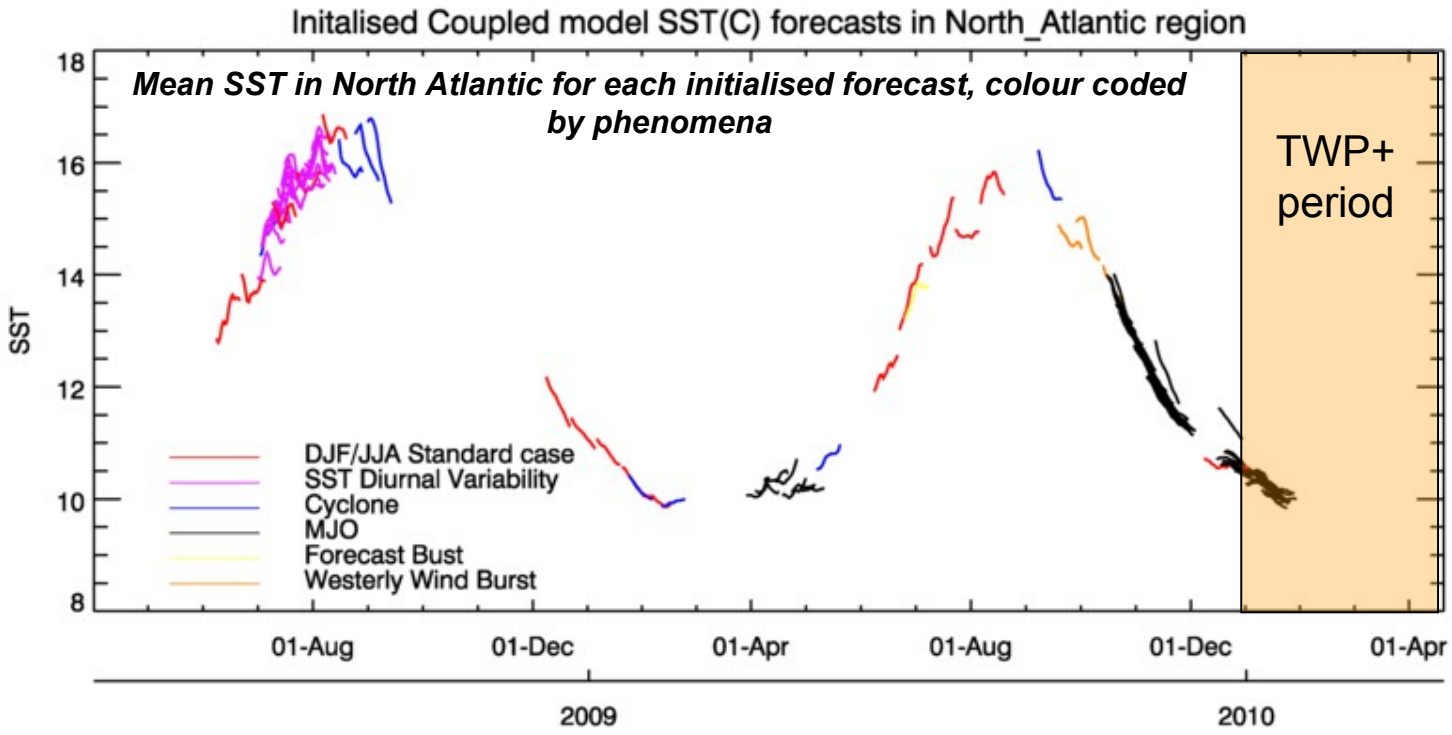
- **Experiments**: Initialised hindcast case study sets (single member) to T+15 days:

  - **Coupled**: Free running (no flux adjustment/bias correction)
  - **Atmosphere-only controls**: Persisted initial SST anomaly, fixed sea ice
  - **Ocean-only controls**: Driven with 3-hourly mean fluxes from atmos-only controls

Experiments: Case study start dates

Core (~150 cases)
- Selected start dates in the range June 2008 to November 2010
- 10 "winter" and 10 "summer" cases, plus MJO periods and other cases

TWP+ (~120 cases)
- Daily start dates over 4 months January-April 2010
- Set-up with 1-hourly coupling frequency instead of 3-hourly



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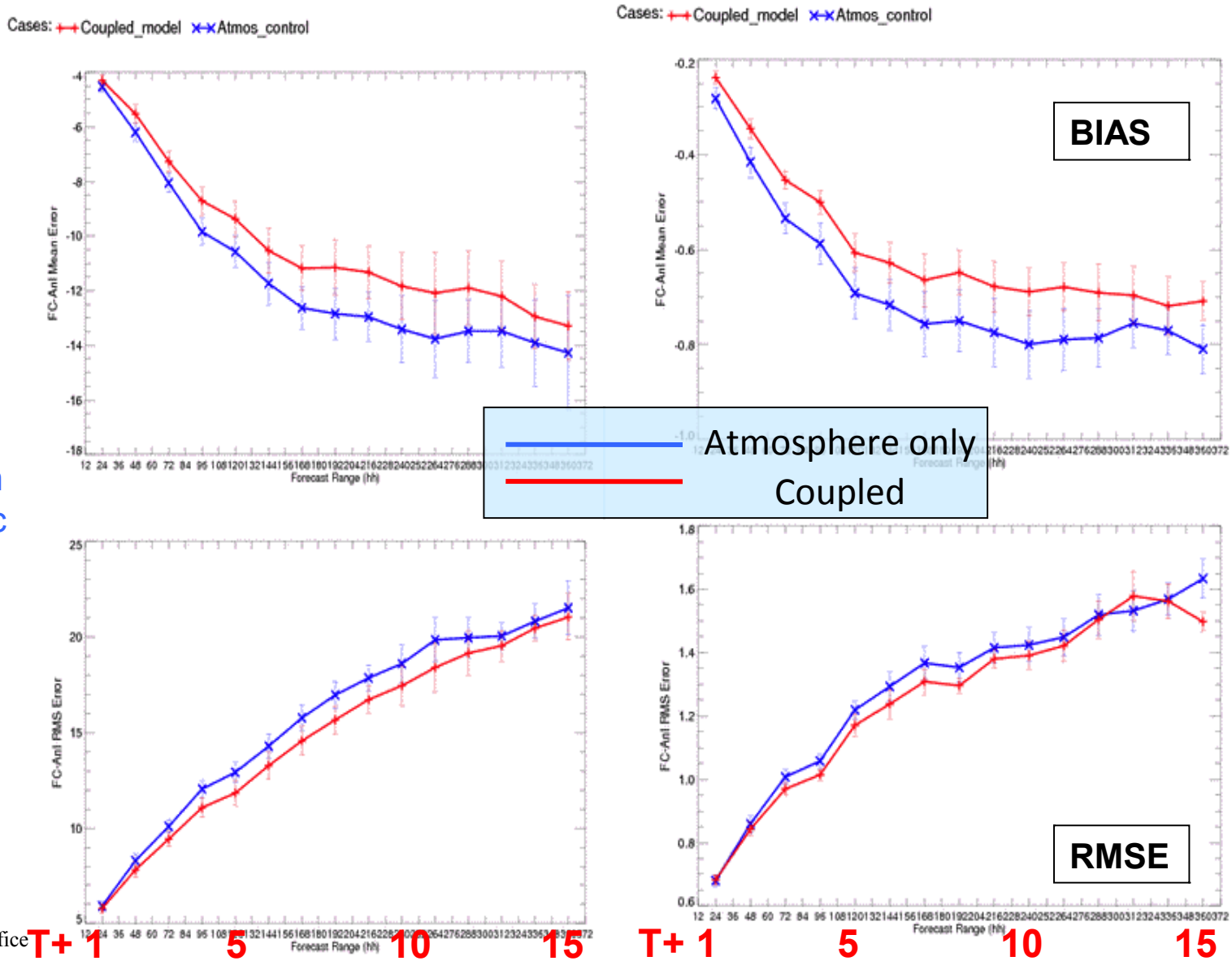
Coupled mode performance: Tropics

- Two examples of good coupled skill relative to atmosphere-only control forecasts
- Tropics is the main area of atmospheric performance difference
- Performance mostly comparable in the extra-tropics

500hPa Height DJF **925hPa T JJA**



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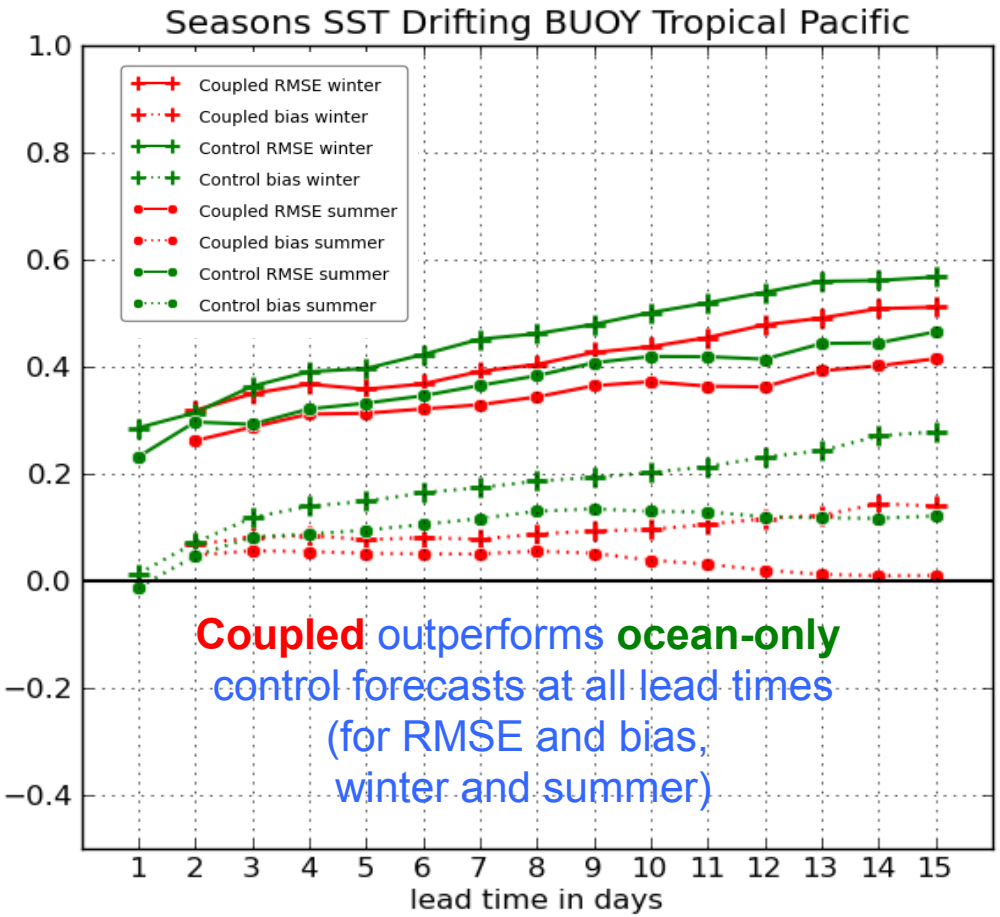
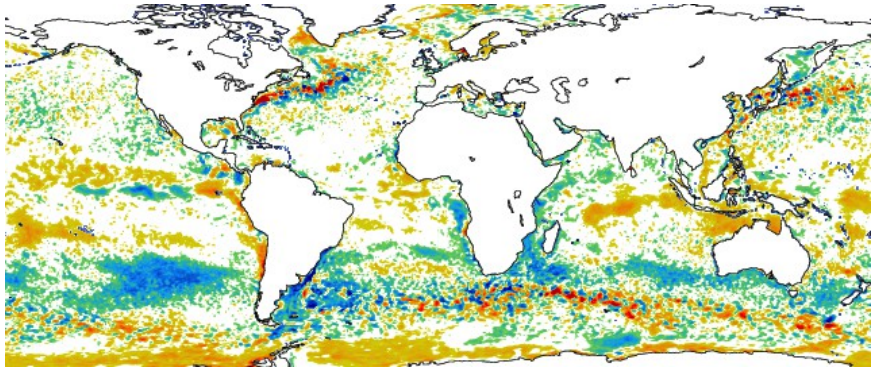
Ocean Verification (SST): Coupled versus ocean-only control forecasts

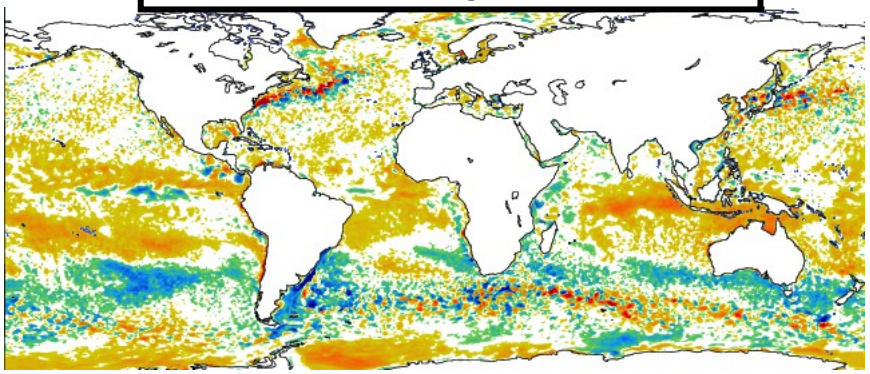


DJF Bias at Day 15

Coupled

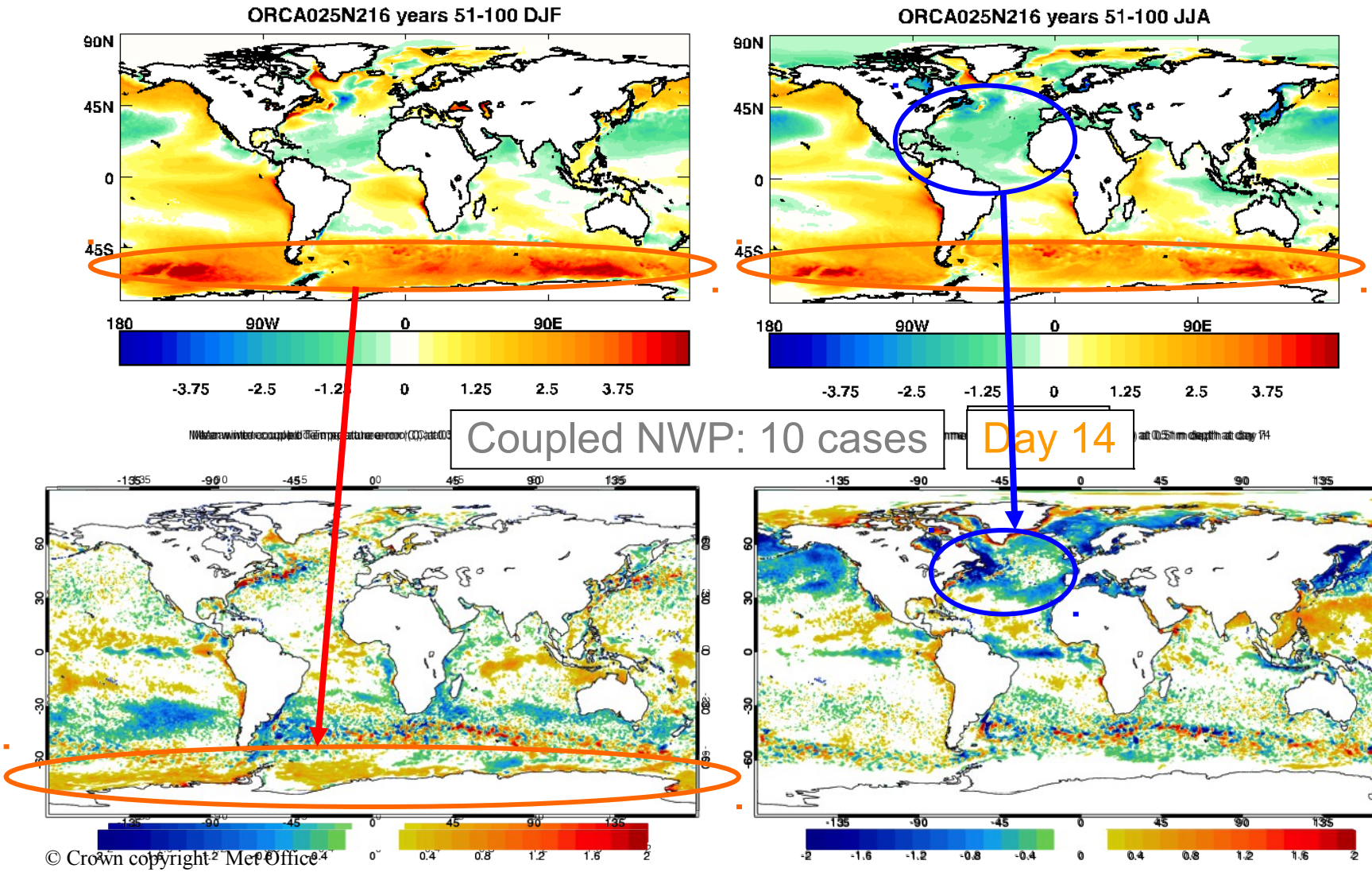


Ocean Only Control



SST biases: Climate vs. Coupled NWP

Climate:50-yr mean



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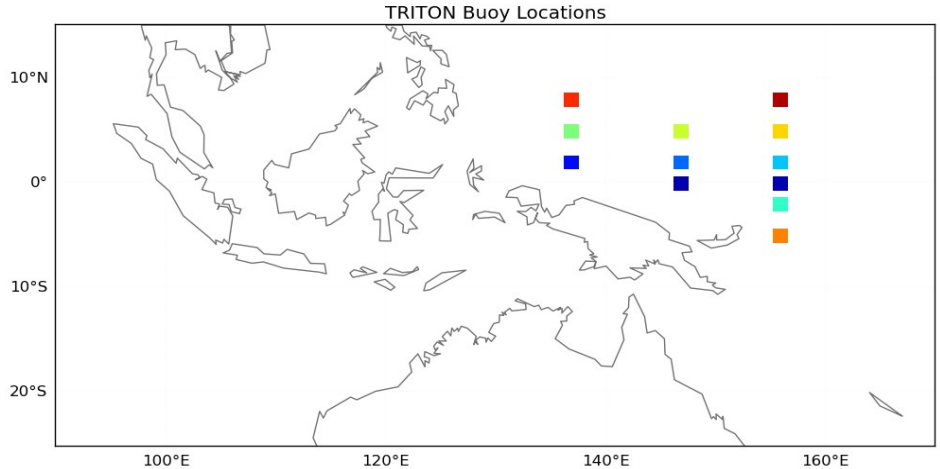
Diurnal variability in SST:in-situ



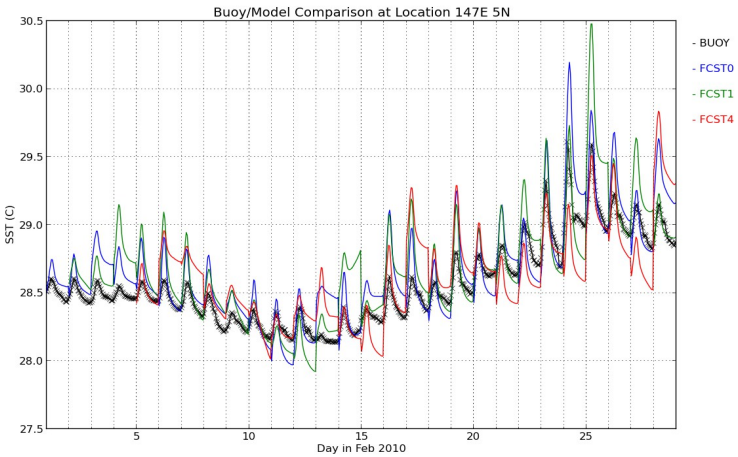
- Assessment of diurnal range and maxima and minima timing.

- In-situ data: 12 buoys from TRITON array.C
  Hourly data, at ~ 1m depth.

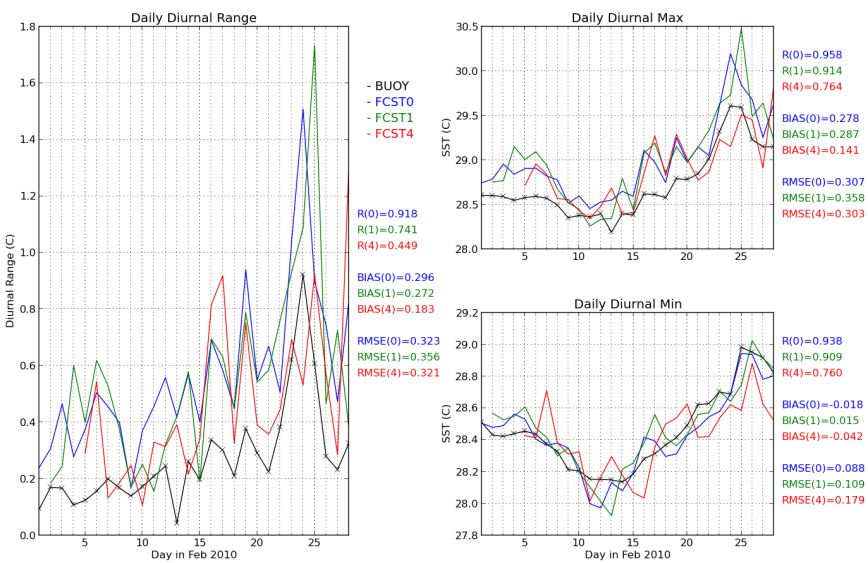
- Model and observational data extracted for February 2010. Model run with 1hr coupling,

- An algorithm has been used to determine daily maximum and minimum values from time series and time of the day of each. (Sykes et al. 2011)

Diurnal variability in SST
Buoy-model comparisons



Hourly time series:
- Model shows similar diurnal varialibity
- Biases vary with forecast time



Daily time series:
- Larger event captured by model
- Model overestimates range and maxima
- Minima exhibit lower bias

Maximum and minimum timing:
- Model maxima ~0.5hr later compared to model.
- Model minima ~ 1.5 later.

147E 5N

Buoy-model comparisons:
statistics across all buoys

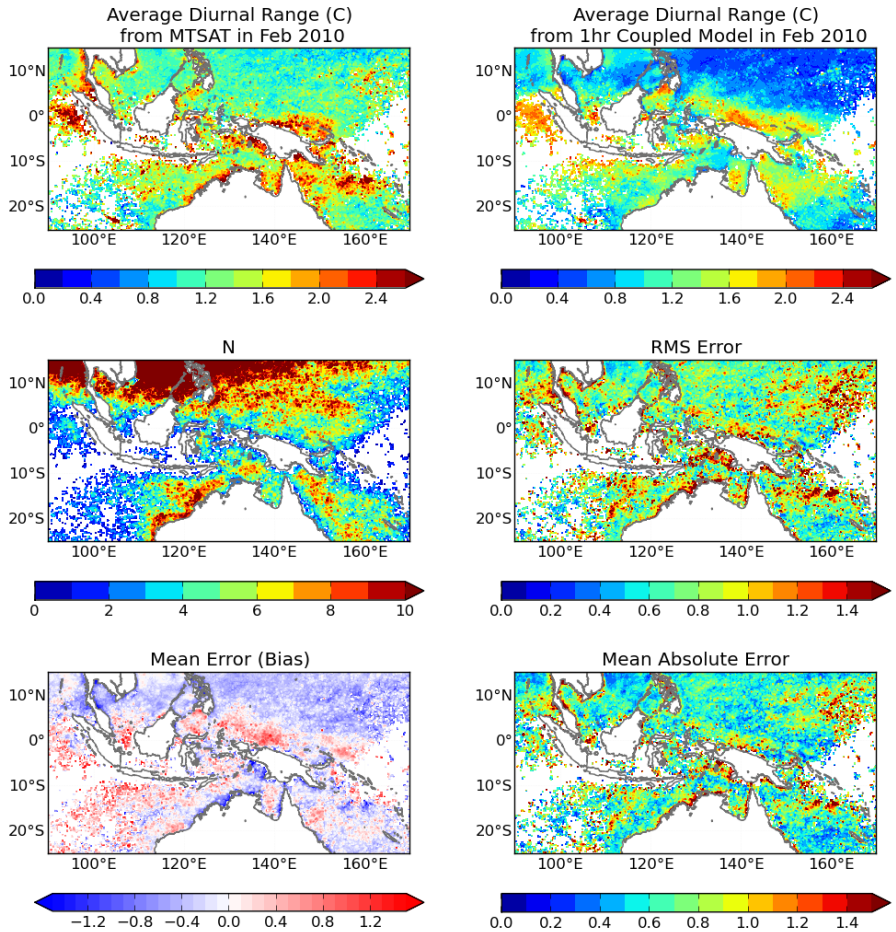
	MIN			MAX			RANGE		
FCST	R (ANOM)	BIAS	RMS	R (ANOM)	BIAS	RMS	R	BIAS	RMS
FCST0	0.78	-0.03	0.18	0.86	0.34	0.44	0.79	0.37	0.46
FCST1	0.69	0.01	0.23	0.78	0.33	0.48	0.69	0.31	0.45
FCST4	0.53	-0.04	0.28	0.49	0.07	0.41	0.23	0.11	0.35

- Assess temporal correlation of model to buoy data with anomaly correlations.
- Warm bias in the model maxima compared to buoys (0.07K -0.34K)
- Range is overestimated.

-As forecast day increases, overestimation decreases.

-Correlation decreases rapidly with day forecast.

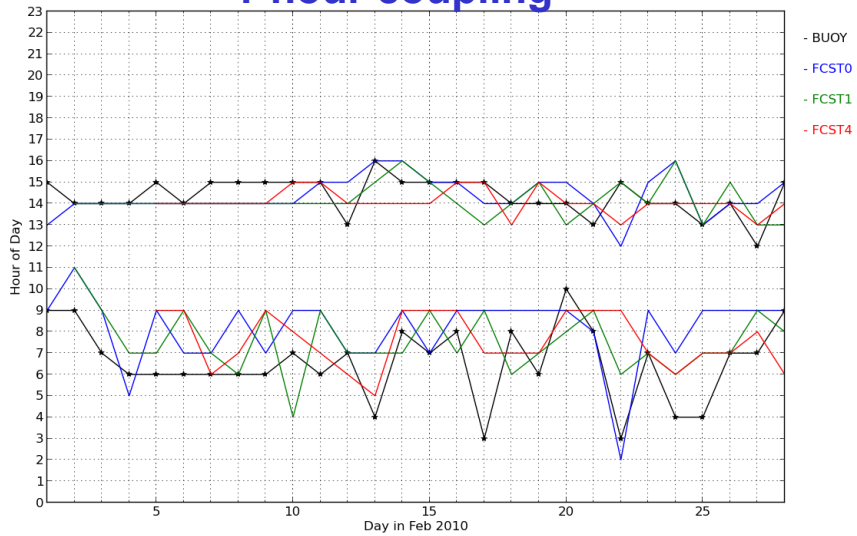
Model-satellite comparisons



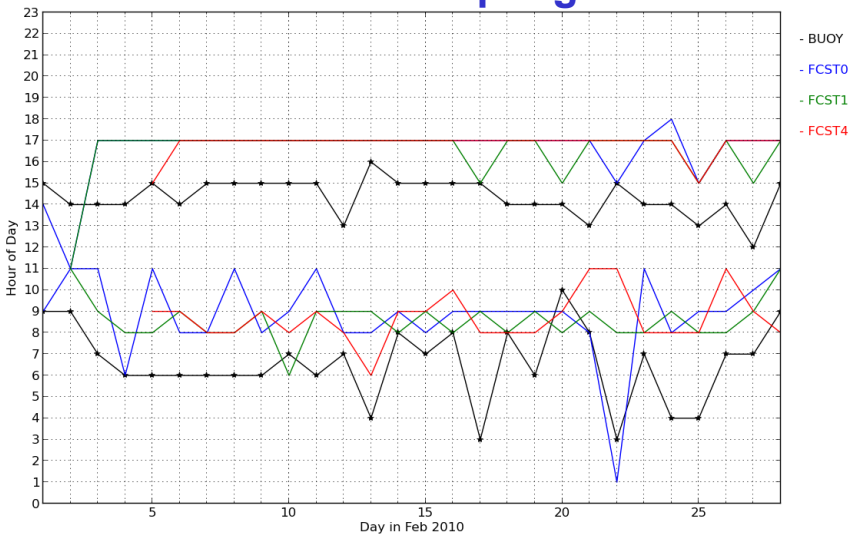
- Satellite: MTSAT-1R SSTskin. (TWP+ product)
- Diurnal max/min algorithm has been used.
- Minima overestimated by model over entire domain, especially at coastal regions.
- Model maxima show smaller (positive) bias.
- Range of diurnal variability is overestimated in most of TWP region.

Sensitivity to air-sea coupling frequency

1-hour coupling



3-hour coupling



Buoy from TRITON array at 147E 0N

•Increasing the coupling frequency does not change significantly the model diurnal amplitude. However, it improves the timing of maxima and minima events.

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Conclusions: Initialised coupled model

- Air-sea-ice coupling in the MetUM (HadGEM3-AOIL) shows promise for improving short to medium range forecasting skill, even without bias corrections – particularly in Tropics.
- Careful diagnosis is required to investigate compensating systematic errors in the two systems – Ocean and Atmosphere
- In the extra-tropics skill is generally competitive in coupled versus uncoupled hindcasts (not shown)

- Coupled NWP shows potential as a framework for studying persistent systematic error seen in climate models – TRANSPOSE CMIP.

Future work: initialised coupled model

- Develop the appropriate diagnostics to understand the impact of air-sea interaction on modelled performance and phenomena, and to characterise robust signals of coupled model systematic errors emergent on short timescales and their underlying causes.

- Evaluate coupled NWP runs against process based field experiment data (e.g. CINDY, DYNAMO)

- In progress
  - Increase resolution to current operational NWP and ocean forecast resolutions: N512 (c. 25km) atmosphere and ORCA025 (c. 25km) ocean
  - N768 (17km) and 1/12 degree ocean.

- Weakly coupled data assimilation – under development
  - The coupled model is used to provide the background state for the ocean and atmosphere data assimilation systems.
  - Test impact on initialisation shock.

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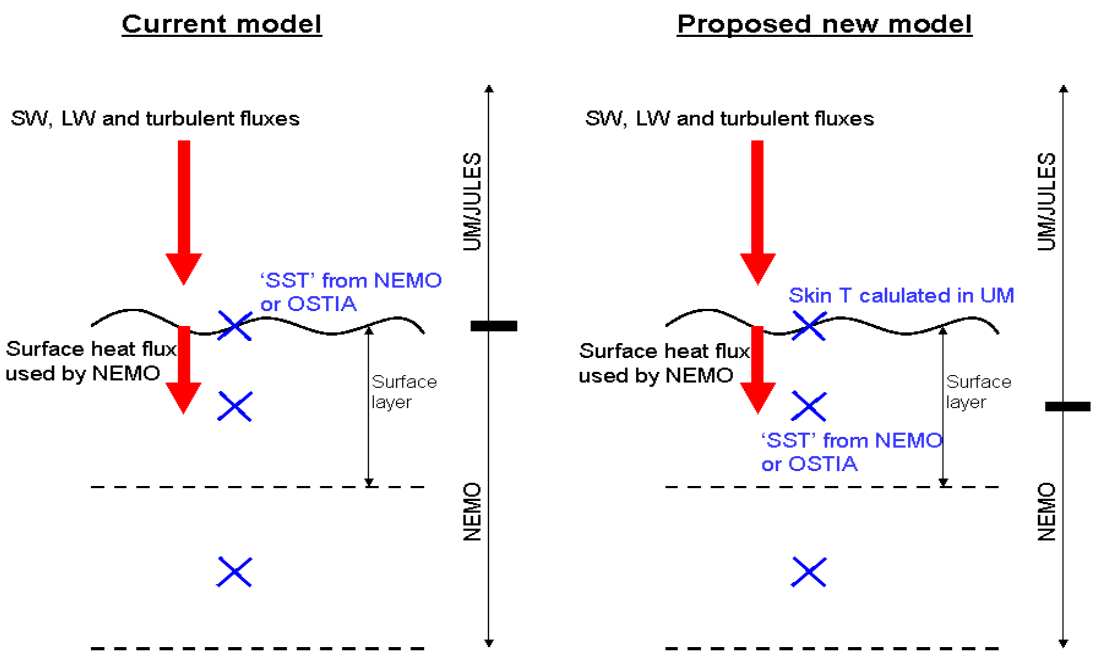
New thermodynamic coupling (SST_{skin})



$$F_{surf} = (\kappa/2h)(T_{skin} - T_{SST})$$

- New scheme allows diurnal cycle of skin T co be captured regardless of coupling frequency.
- It should improve accuracy of surface fluxes.

Future work: diurnal variability of SSTs

- Study physical processes of diurnal variability of SST and assess the capability of couple model to simulate workings of this variability.

- Test thermodynamic coupling scheme and impact on variability of SST. TWP+ observational products provide a good framework for evaluation/tuning of the new scheme.

- Collaboration with TWP+ inter comparison project.

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Questions

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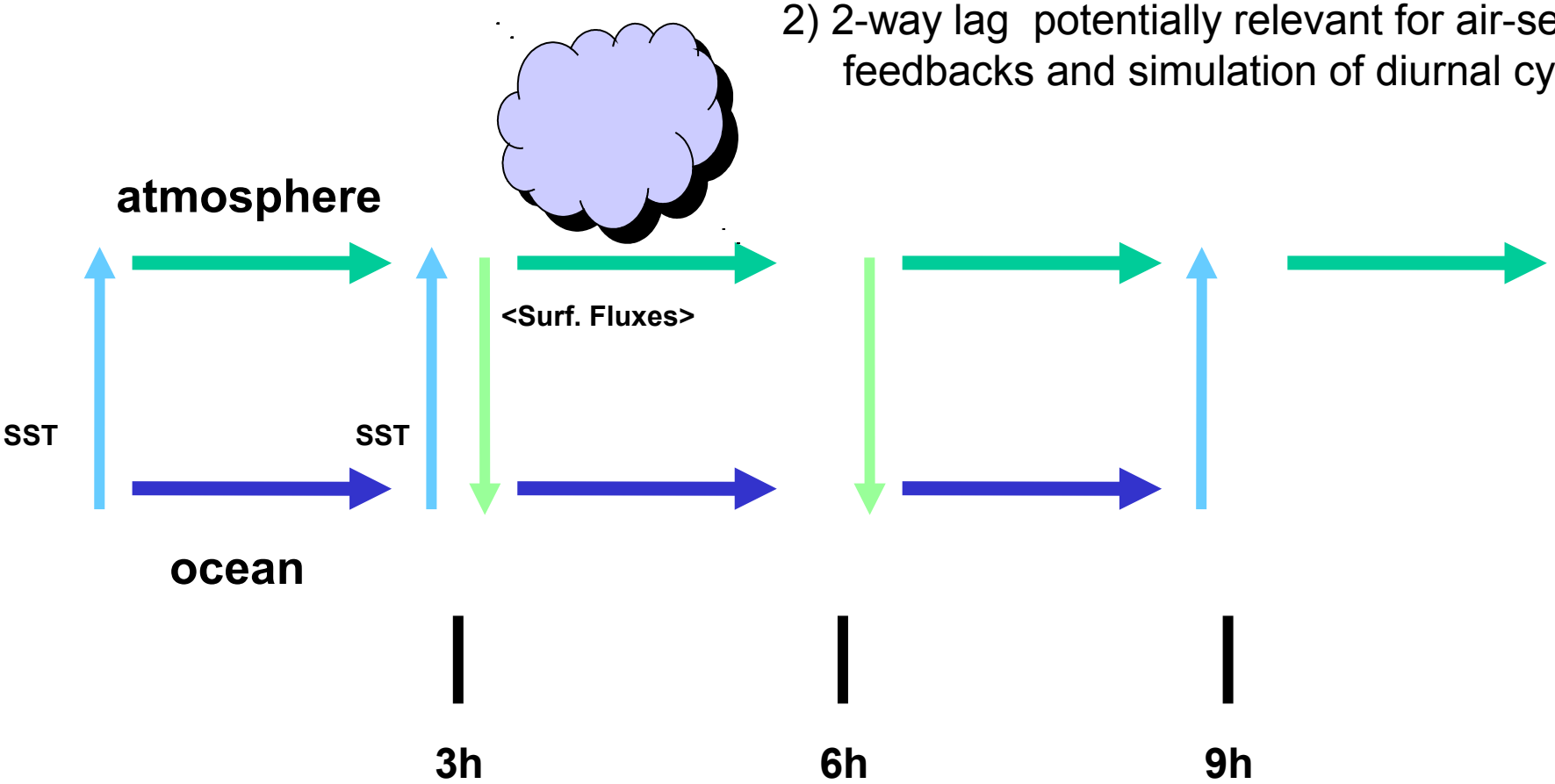
Coupling issues

Difficulties arising from atmosphere and ocean/sea ice components running in parallel :

1) At start of coupled model run.

2) 2-way lag potentially relevant for air-sea feedbacks and simulation of diurnal cycle.



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Model-satellite comparisons:
statistics across all points

	MIN		MAX		RANGE	
FCST	BIAS	RMS	BIAS	RMS	BIAS	RMS
FCST0	0.68	0.94	0.39	0.77	-0.33	0.78
FCST1	0.71	0.97	0.38	0.79	-0.38	0.80
FCST4	0.69	0.98	0.25	0.79	-0.52	0.88

Warm bias in the mininum for all forecasts (~0.7K)

Warm bias in the maximum that decreases with forecast day (0.39K to 0.25K)

Underestimation in diurnal range that increases with forecast day (0.33 Kto 0.5K).