Sensitivity of E3SM Energy and Water Cycles to Ocean Surface Flux Algorithm Design

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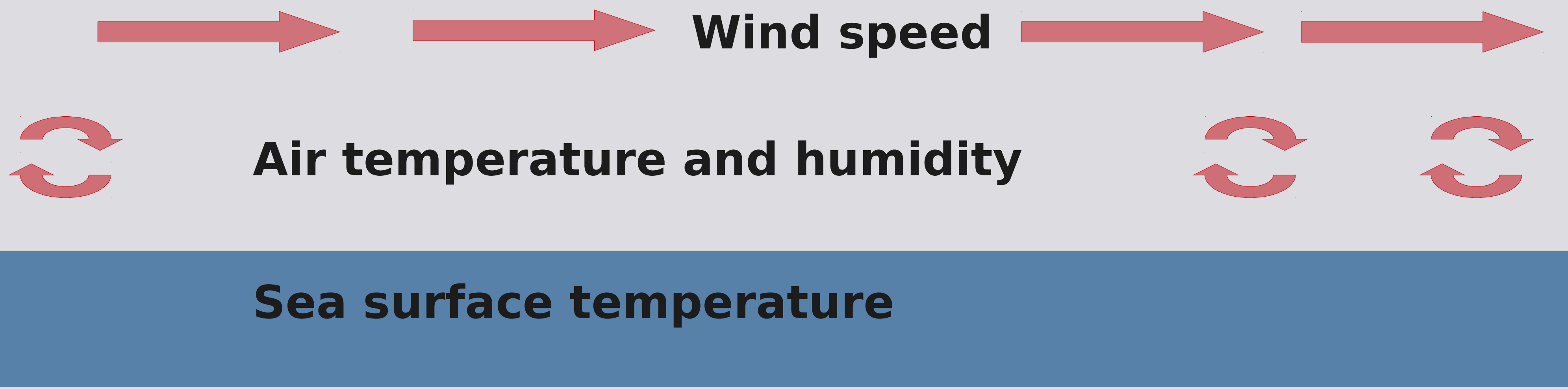
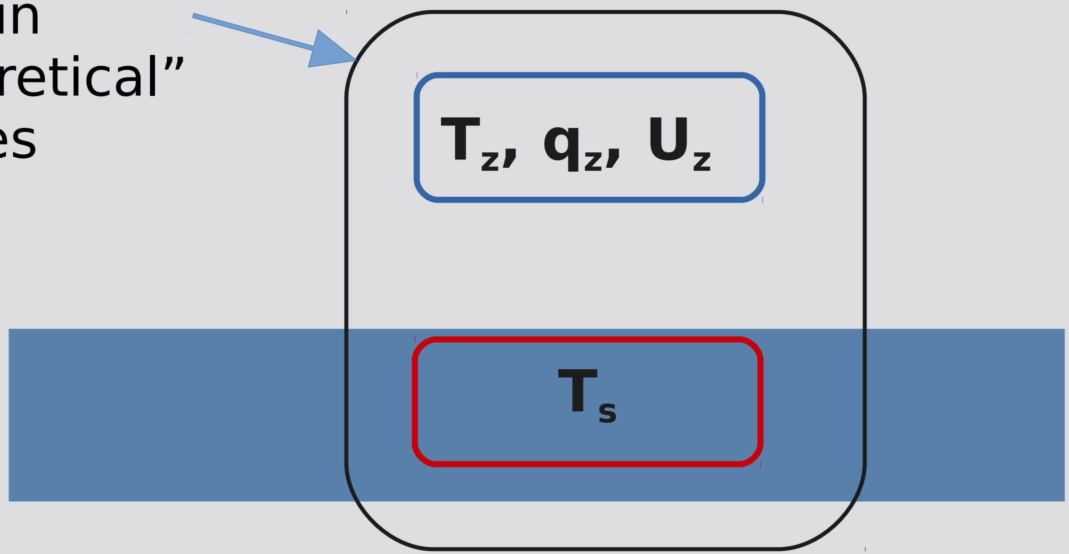
Global data sets and numerical models rely on bulk flux algorithms

...which provide a way to calculate ocean surface fluxes (heat, water, momentum) based on “bulk” properties:



Lots of studies look at "theoretical" aspects of algorithms – few model studies

All bulk variables are fixed in "theoretical" studies



Atmosphere tests:

T_s is fixed

Active: Atmosphere, land

Data: Ocean, sea ice

Ocean tests:

T_z, q_z, u_z are fixed

Active: Ocean, sea ice

Data: Atmosphere, land

Atmosphere and ocean tests have different feedbacks between fluxes and bulk variables.

Science questions

Based on the three flux algorithms in E3SM,

Control | UA | COARE :

Which regions are most sensitive to flux algorithm choice, in terms of changes to ocean fluxes?

Does sensitivity depend on testing framework: ocean vs. atmosphere sensitivity tests?

What other aspects of ocean and atmosphere climate are affected?

Patterns of sensitivity differ between atmosphere and ocean tests

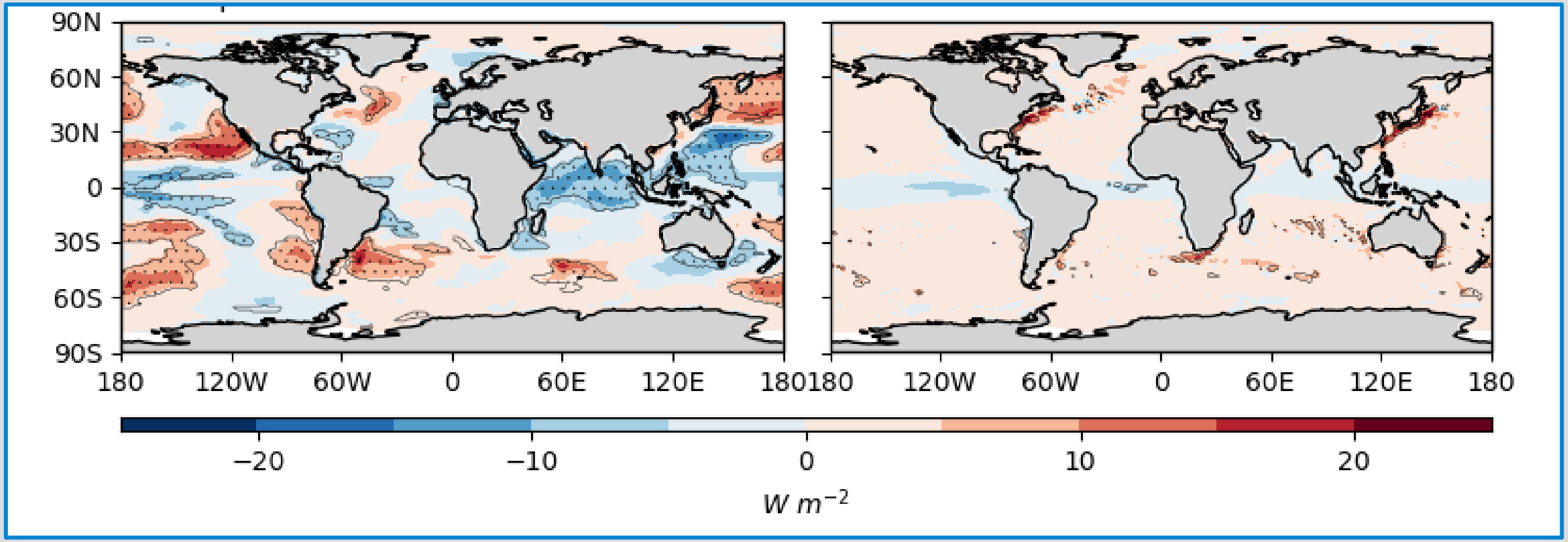
...magnitudes are larger in atmosphere tests, where wind speed can vary:

Latent heat flux annual mean

COARE – UA difference

Atmosphere

Ocean



Global mean sensitivity is more consistent between ocean and atmosphere tests

(Ocean area only)		control	UA	COARE
$Q_E\ (W\ m^{-2})$	atmo	-107.04	-104.32	-104.43
	ocn	-98.35	-96.64	-95.49
$Evaporation\ \ (mm\ day^{-1})$	atmo	3.70	3.68	3.61
	ocn	3.39	3.41	3.30

Latent heat flux (Q_E): control has largest magnitude, then UA and COARE are similar.

This holds for both atmosphere and ocean tests.

However, for evaporation, the order is different due to the (more accurate) latent heat of vaporization calculation in UA...

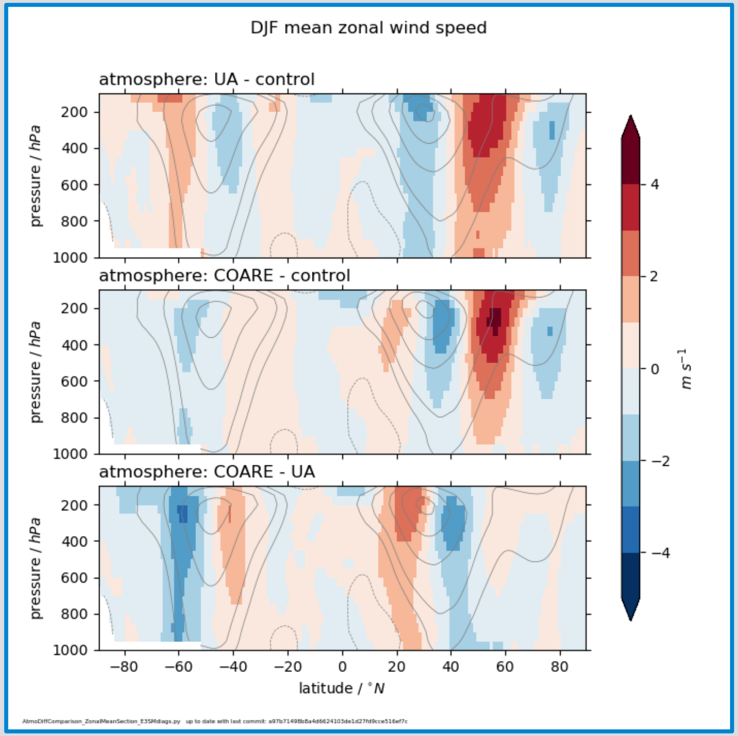
...but this may affect energy conservation so will revert to fixed value for coupled tests.

Precipitation, large scale circulation and global radiation budget are affected by algorithm

	control	UA	COARE
$Precip\ (mm\ day^{-1})$	3.33	3.31	3.24
$Precip\ (global)^{a}$	3.08	3.07	3.01
$T_{2m}\ (°C)$	+16.63	+16.55	+16.46
$q_{2m}\ (g\ kg^{-1})$	11.09	11.02	10.81
$U_{10m}\ (m\ s^{-1})$	7.52	7.14	7.20
$(T_{2m} - T_s)\ (°C)$	-1.05	-1.12	-1.18

[a] For land and ocean combined.

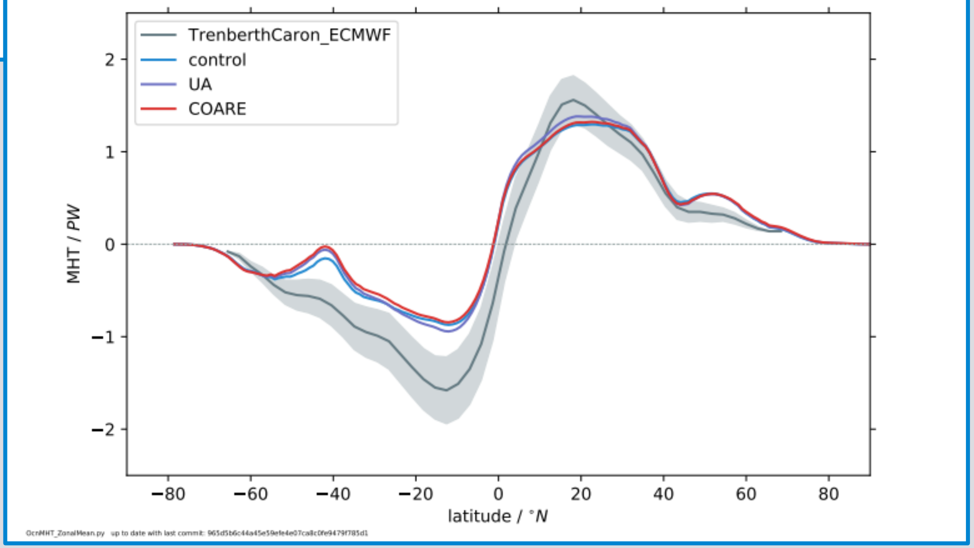
TOA net radiation (vs. CERES-EBAF 4.0)	control	UA	COARE
Bias (W m^{-2})	-0.28	0.19	0.68
RMSE (W m^{-2})	7.98	7.73	8.16



Ocean heat uptake and meridional heat transport are affected by algorithm

	control	UA	COARE
$SST\ (°C)$	+18.23	+18.28	+18.42
$SSS\ (PSU)$	+34.58	+34.58	+34.55
$\Delta SSH\ (cm)^a$	+38.27	+30.99	+70.06
$\Delta OHC\ (10^{22}\ J)^b$	-10.505	-1.254	+3.763
$\|SSS\ restoring\|\ (m\ PSU\ yr^{-1})$	+12.5	+12.2	+12.4
$\|u\|\ (cm\ s^{-1})$	+7.87	+8.30	+8.21
$\|v\|\ (cm\ s^{-1})$	+4.05	+4.24	+4.18

[a] Average SSH over model year 10 relative to initial condition.
[b] OHC in December of model year 10 relative to initial condition.



Summary and future work

Atmosphere tests result in larger magnitude changes than ocean tests – because wind speed can vary

Global mean **sensitivity is more consistent between atmosphere and ocean tests**

Other aspects of atmosphere and ocean model climate are sensitive to algorithm choice:

- **Precipitation, global radiation and circulation**
- **Ocean heat uptake and meridional heat transport**

Coming soon:

- **Coupled model sensitivity tests**

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