Using high resolution CESM to study tropical cyclones.

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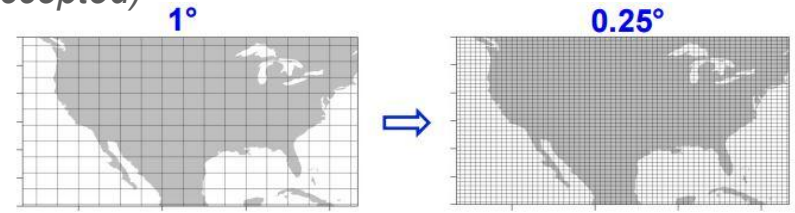
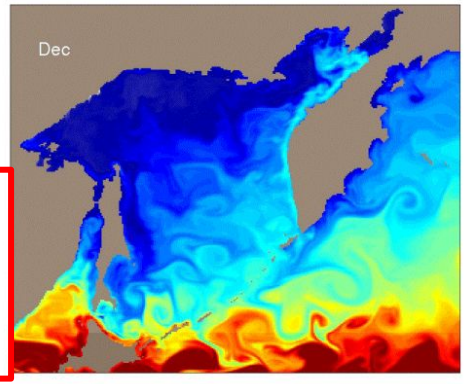
Outline

- Motivation for using high resolution CESM
- What do we mean by high resolution CESM
- Cost vs benefit
- Resolution + dynamical core: FV vs CAM5-SE
- TimeSlice experiments
- Tropical cyclones

Motivation

- Understanding possible changes in the frequency and intensity of tropical storms will become increasingly important in a warming climate. Despite some sensitivities to model physics and dynamical core design, **climate models running at high resolution are capable of capturing many aspects of tropical cyclones with reasonable fidelity**, including geographical, seasonal and even inter-annual variations. *(Bacmeister et al., accepted)*



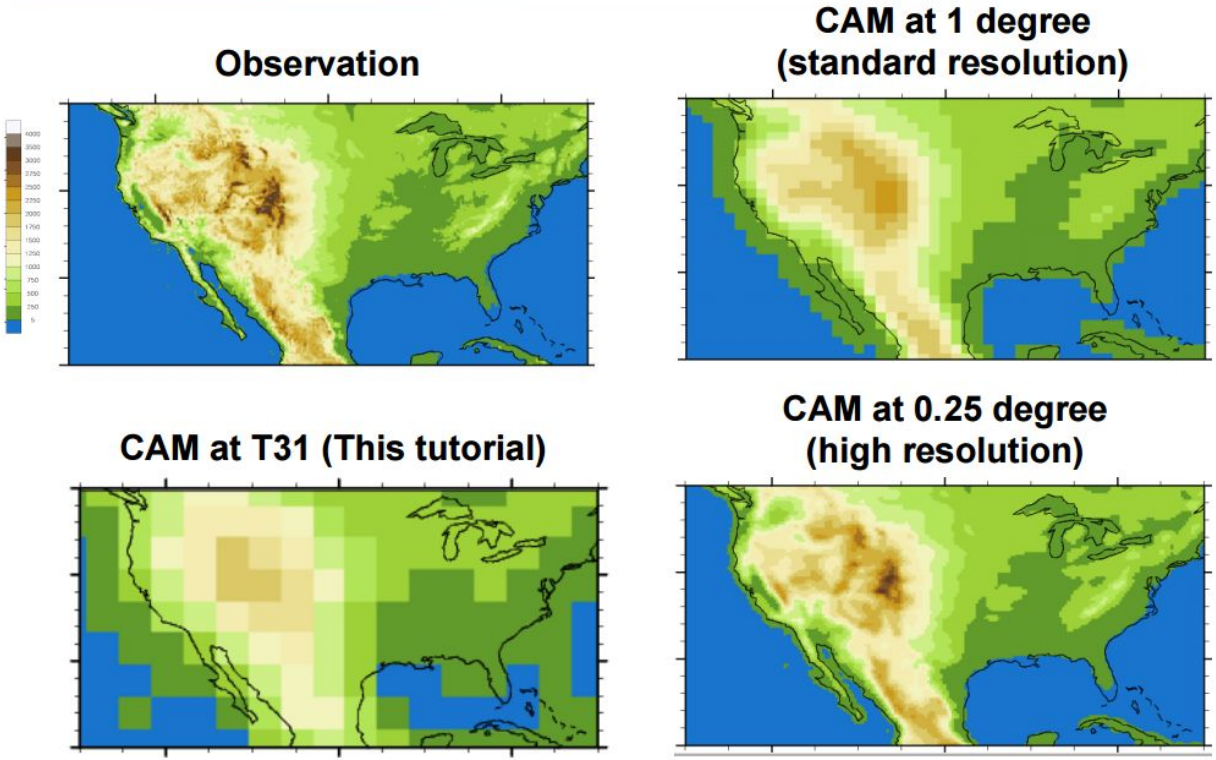


- We use a series of high resolution, atmosphere-only CESM simulations to look at tropical cyclones and mid-latitude storms.

What do we mean by high resolution

	Dynamical core	Resoln	Atm/Land	Ocean/Ice
Tutorial	**Spectral low resolution**	**T31_gx3v7**	**~3.75º**	**~3º**
	Finite volume low resolution	f45_gx3v7	~4º	~3º
	Finite volume low resolution	f19_gx1v6	~2º	~1º
LE	Finite volume moderate resolution	f09_gx1v6	~1º	~1º
	Finite volume high resolution (hdeg)	f05_gx1v6	~0.5º	~1º
	Finite volume high resolution	f02_gx1v6	~0.25º	~1º
	Spectral element moderate resolution	ne30_gx1v6	~1º	~1º
TimeSlice	**Spectral element high resolution**	**ne120_gx1v6**	**~0.25º**	**~1º**
	Spectral element high resolution	ne120_t12	~0.25º	~0.1º

What do we mean by high resolution

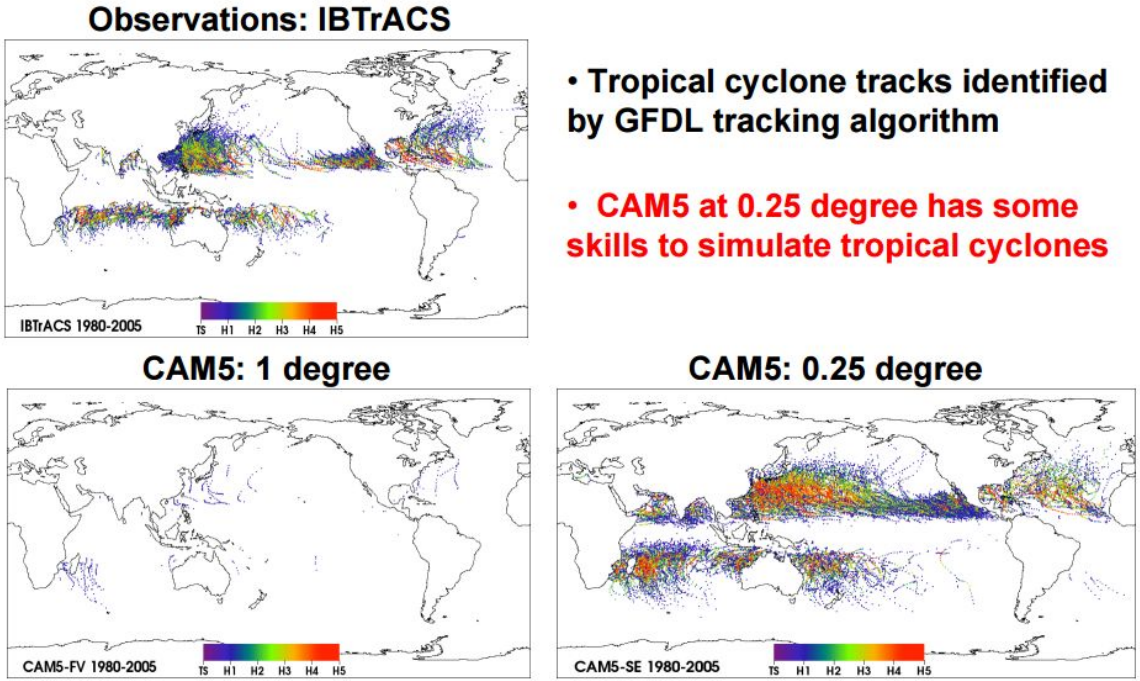


Slide courtesy of Cecile Hannay

Cost vs Benefits

Cons: Higher **cost** to run and process, and we still don't solve all the model biases.

Pros: But the benefits are in **what we can see in highly localized storms** like tropical cyclones and mid-latitude storms



Courtesy: Kevin Reed [See also: Wehner et al. 2014, JAMES]

Resolution and dynamical core

	Atmosphere grid	Resoln	Atm/Land	Ocean/Ice	
Tutorial	**Spectral low resolution**	**T31_gx3v7**	**~3.75º**	**~3º**	**CAM-EUL**
	Finite volume low resolution	f45_gx3v7	~4º	~3º	
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LE	**Finite volume moderate resolution**	**f09_gx1v6**	**~1º**	**~1º**	**Finite Volume**
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TimeSlice	Spectral element high resolution	ne120_gx1v6	~0.25º	~1º	**CAM-SE**
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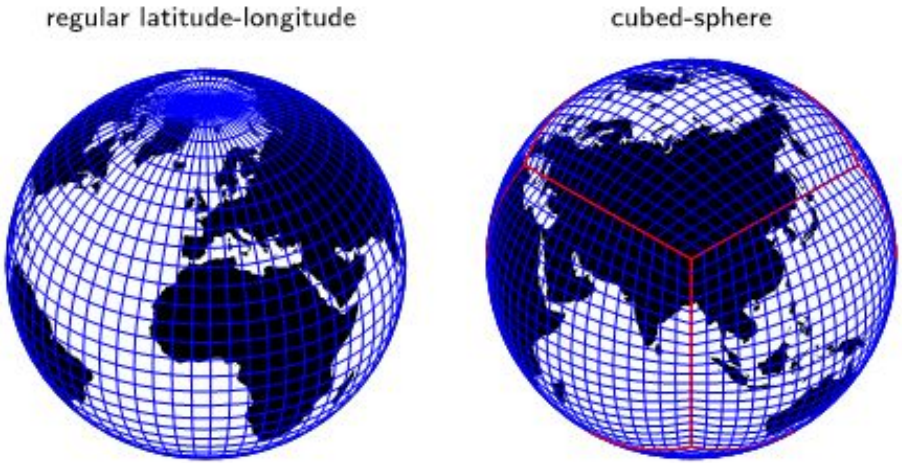
Dycore: Finite Volume vs CAM-SE

- The choice of dynamical core has a significant impact on storm intensity and frequency.
- Both model configurations tend to under-represent TCs relative to observations.
- The CESM spectral element (CAM5-CE) produces stronger TCs and more hurricanes than the FV core.

(Reed et al. 2015)



- For this set of high resolution CESM simulations we use the spectral element dynamical core (CAM-SE) on a 0.25^{o} cubed sphere grid. The atmosphere resolution is ~28km.

Slide courtesy of Peter Lauritzen

TimeSlice experiments

	Tutorial	TimeSlice
Model	Fully coupled	AMIP
Atmosphere version	CAM4	CAM5-SE
Atmosphere Resolution	~400km	~28km
Ocean Resolution	3º	1º
Throughput (24 wallclock)	40+ yrs/day	~2 yrs/day
Data volume (per model year)	2.2Gb	400Gb

Present day: 1979-2012 (4 mbrs)

- Atmosphere-only simulation with observed SST.
- 3 ensemble members, perturbed with *pertlim*.
- Sensitivity test: 4th member, airborne dust → zero

Future RCP8.5: 2070-2099 (10 mbrs)

Set 1: (3 members)

- Bias-corrected SST forcing
- perturbed using *pertlim*

Set 2: (2 members)

- Bias-corrected SSTs that are **cooler in the tropical Pacific** and **warmer in the N. Atlantic** than the SST used for Set 1

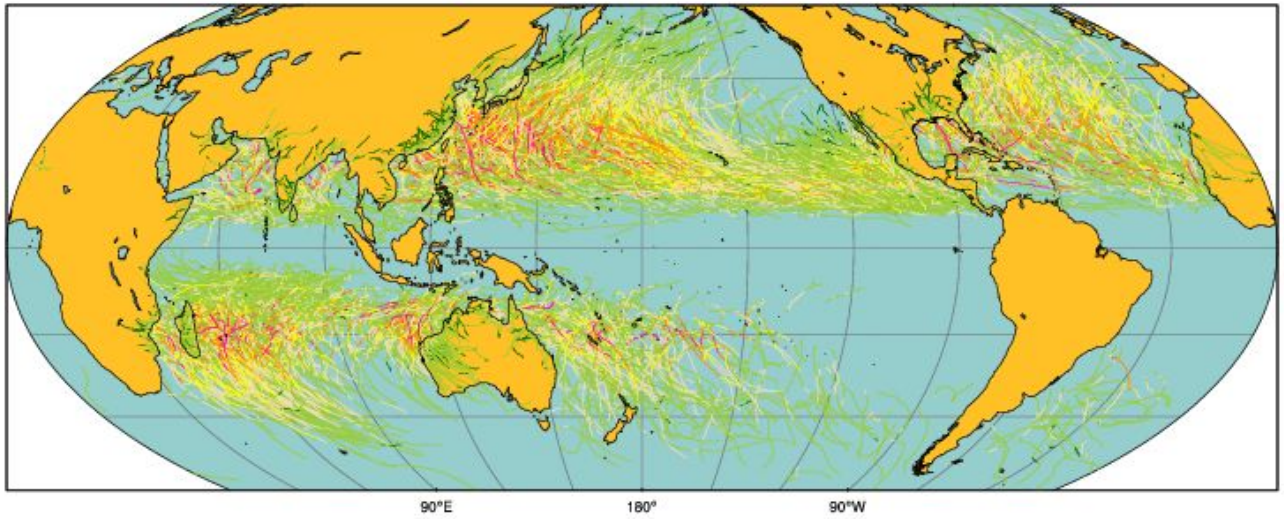
Set 3: (5 members)

- Bias-corrected SST from four RCP8.5 LE members based on the SST difference of that member with the LE ensemble mean (over 2070-2099).
- One member is forced by the LE ensemble mean.

GFDL tropical cyclone tracker

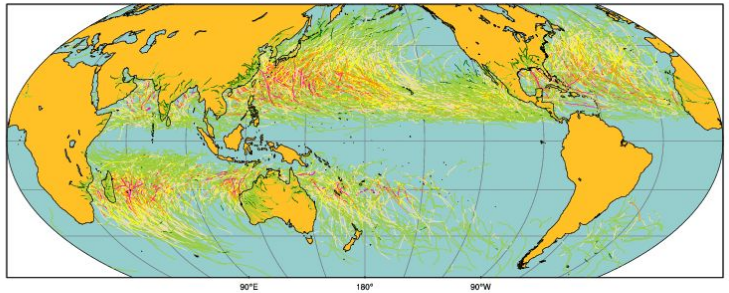
- The TC detection algorithm and tracker used in this study is the GFDL tracker *(Zhao et al. 2009)*
- The tracker requires 3-hourly model output (PSL T200 T500 U850 UBOT V850 VBOT)
- Expensive: high resoln **spatial** and **temporal** output
- Requires a lot of storage space
- Post-processing is expensive
- Vector output format from CAM-SE is not easy to visualize

Tropical Cyclones

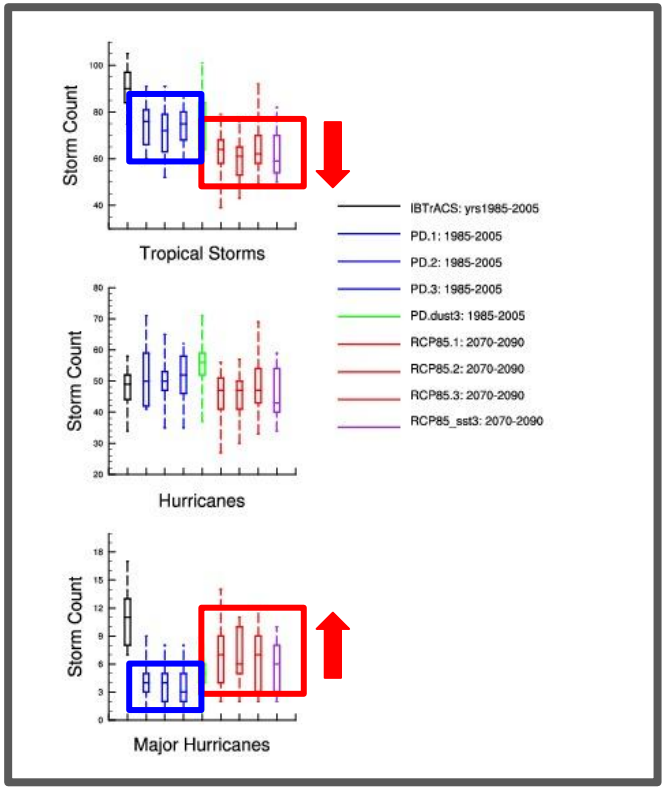


- Understanding how global and regional TC may change in a warming world is important to science and society.
- Model results indicate that 0.25º CAM5-SE has skill in simulating TCs.

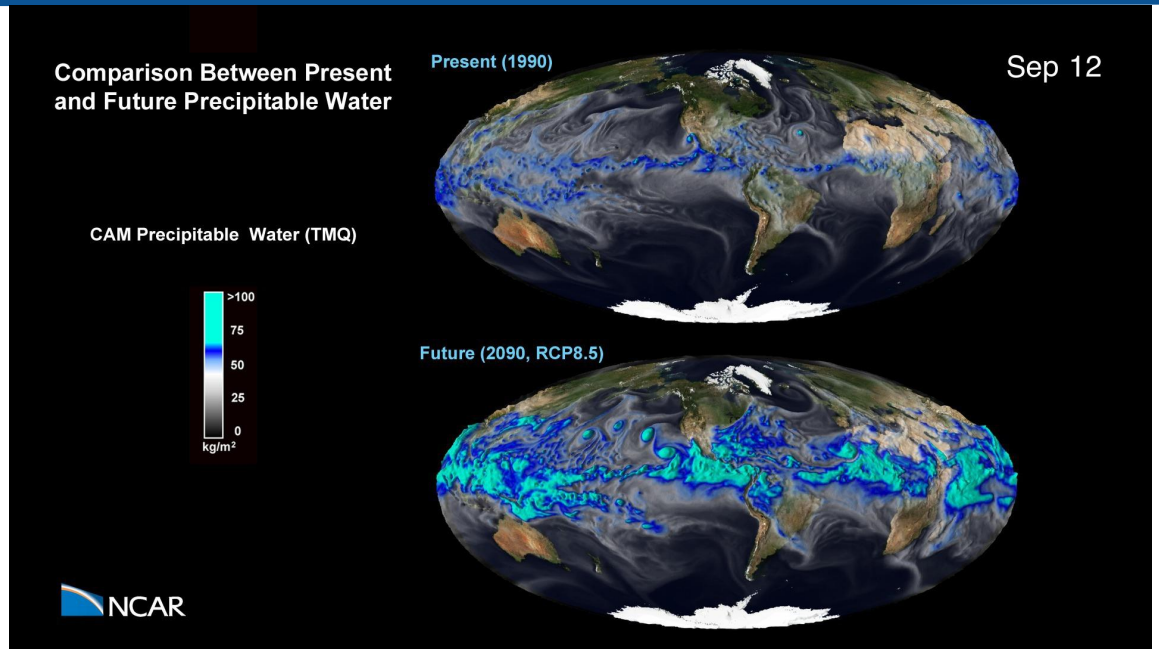
Tropical Cyclones



- The TimeSlice simulations show a **reduction** in overall TC activity with RCP85 warming.
- But the frequency of very intense TCs is projected to **increase** dramatically in a warmer climate. *(Bacmeister et al., accepted)*



Precipitation



Storm-related extreme precipitation events may also be more common as the climate warms. *(Bacmeister et al., accepted)*

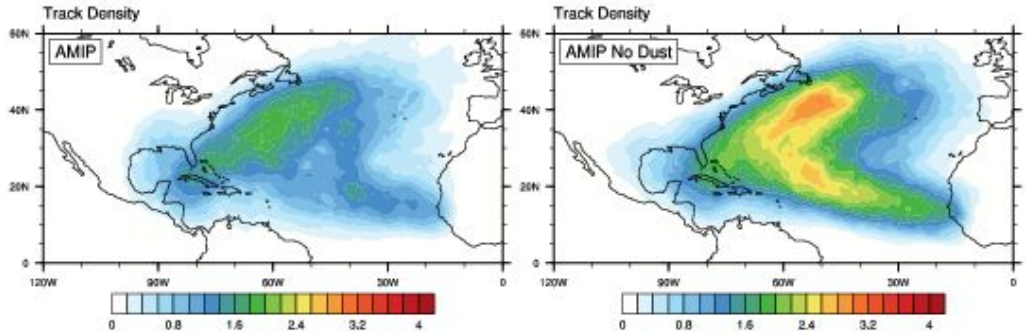
Serendipity in science

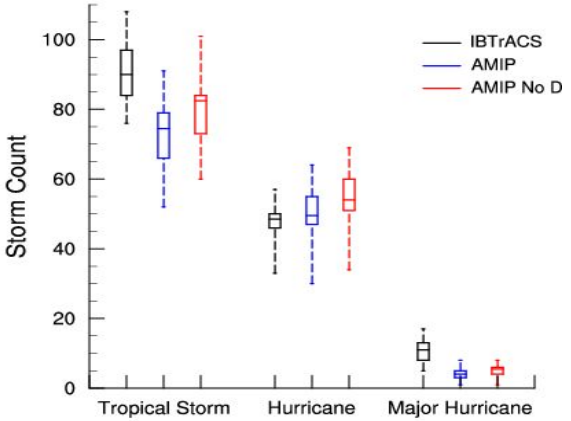
- We discovered that low-level wind and surface fluxes were historically calculated on the ocean grid, but needed to be calculated on the finer of the two grids (ocean vs atmosphere). *(Zarzycki et al., 2015)*

- We also realized that the airborne dust parameterization had not been tuned for the ne120 model. Because the simulations were expensive to reproduce, we modified the dust parameterization in the simulations while they were running. The resulting simulations suggested that dust was having a significant impact on the intensity and location of tropical storms, which lead us to add a present day sensitivity test in which we set airborne dust to zero.

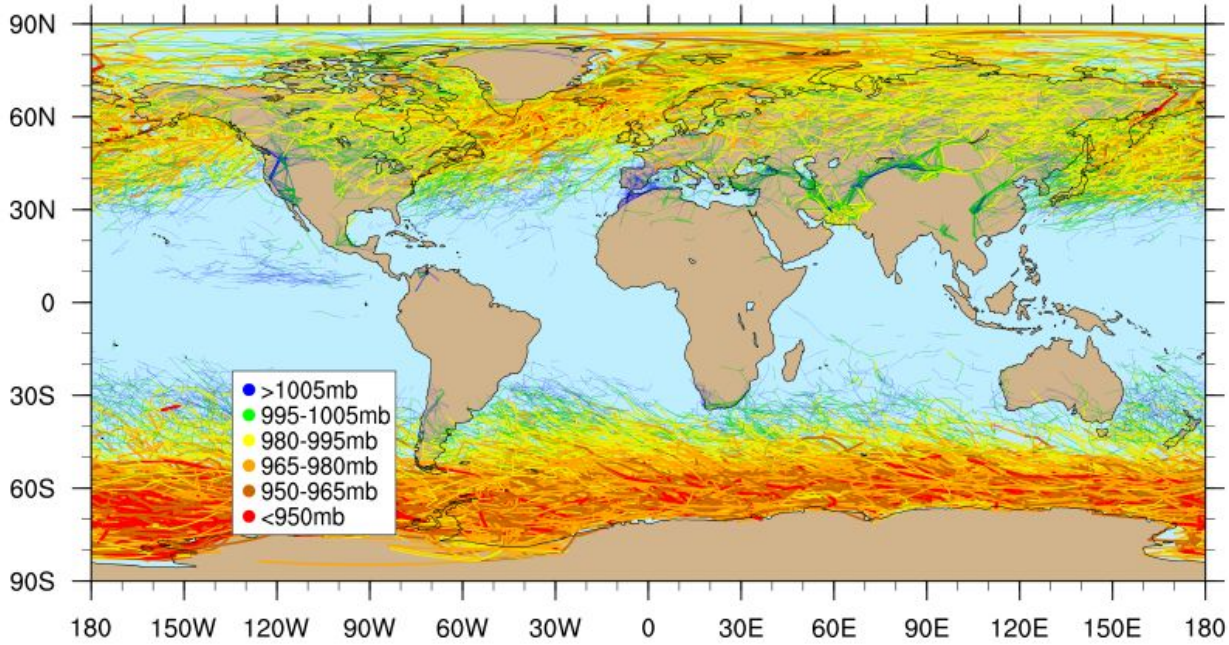
Tropical storms and airborne dust

- Airborne dust appears to have a significant impact on the formation and intensity of tropical cyclones.
- In general, we find an increase in overall TC activity at all intensity levels in model simulations with no dust; this is particularly true in the North Atlantic basin. *(Reed et al., in prep)*



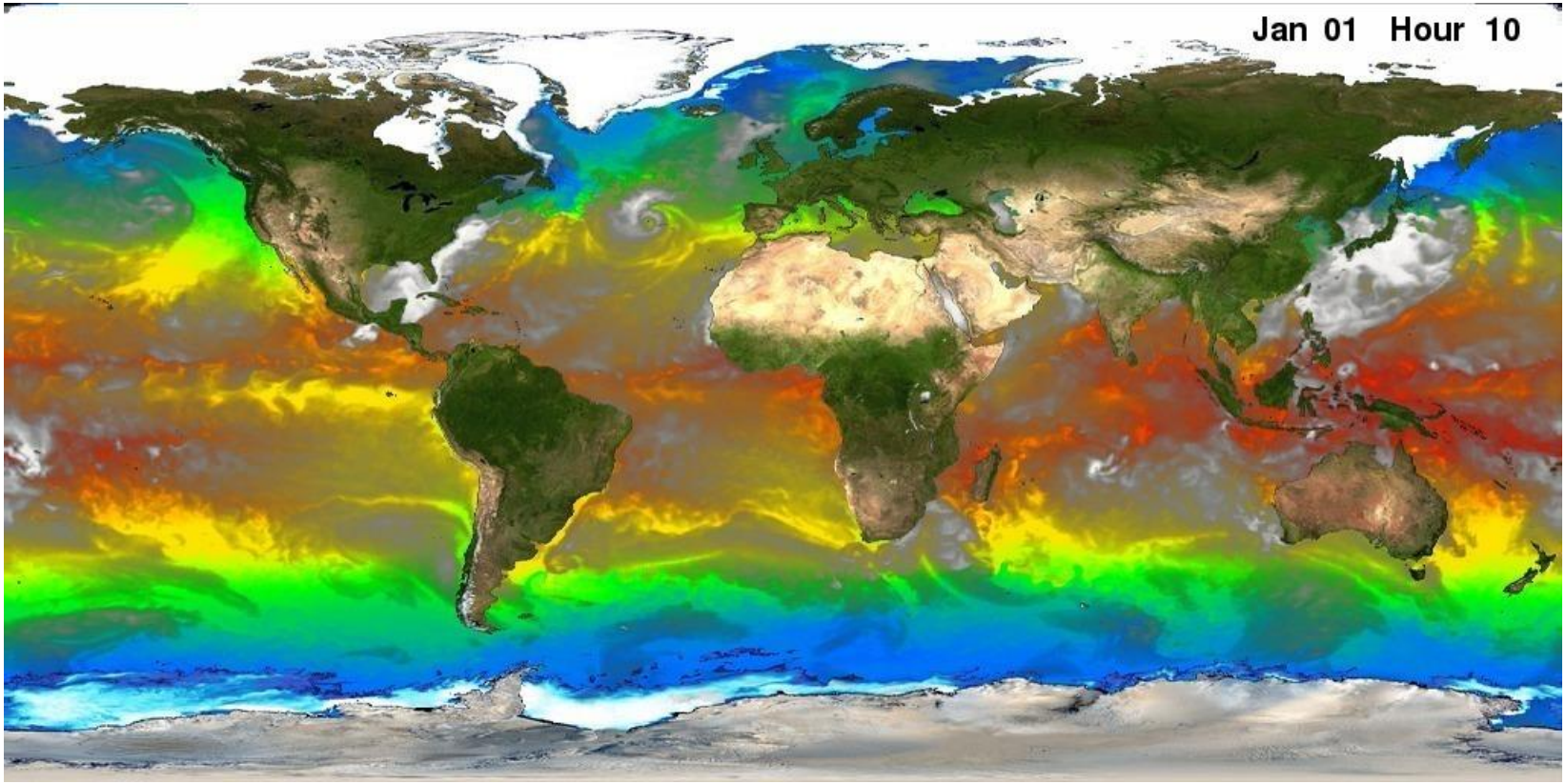


WIP: Mid-latitude storms

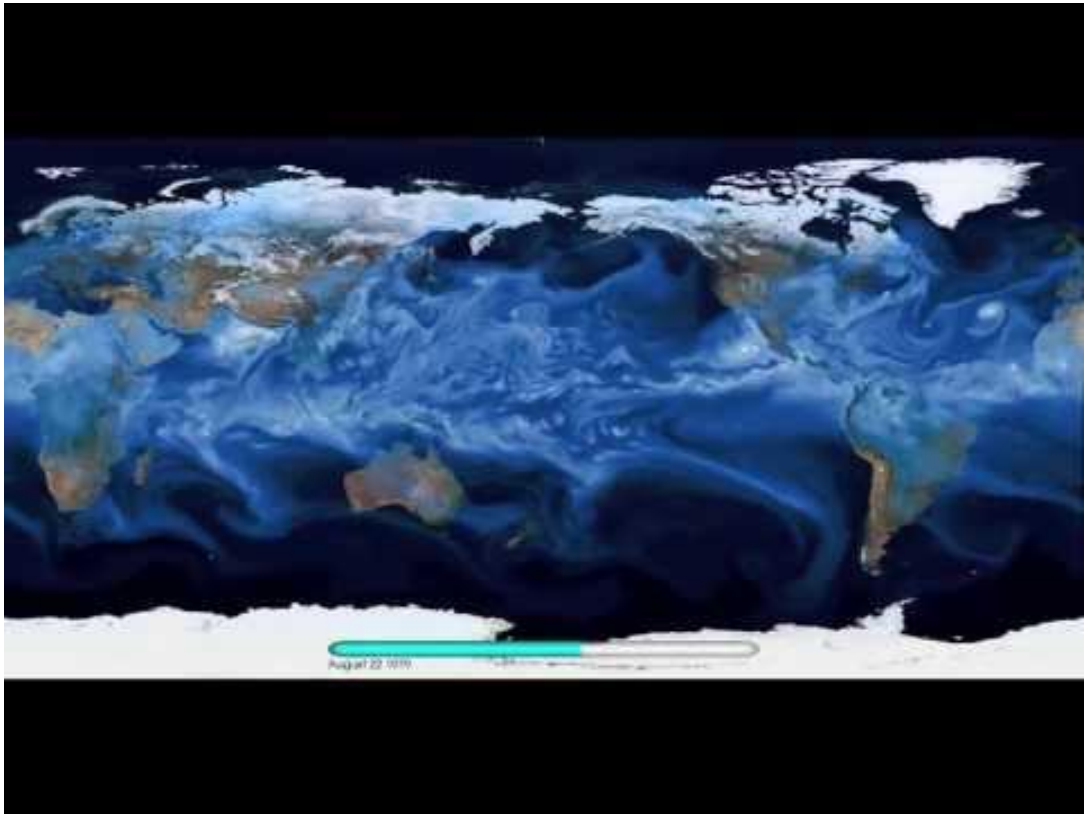


We are also looking at changes in mid-latitude storms. For this work we use a different tracking algorithm developed by P. Ullrich and C. Zarzycki. *(Ullrich and Zarzycki, in prep.)*

Coupled CESM: 0.25º atm + 0.1º ocean



Coupled CESM: FV 0.25º atm



Questions?