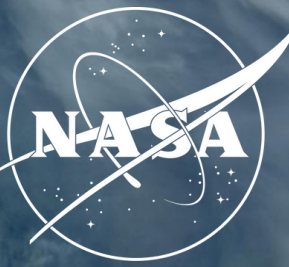


# GEOS-MITgcm Status

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NASA/GSFC GMAO

With: Dimitris Menemenlis, Abdullah Fahad, Atanas Trayanov, Hong Zhang, Jean-Michel Campin,  
Chris Hill, Patrick Heimbach, An Nguyen

# GEOS-MITgcm Status



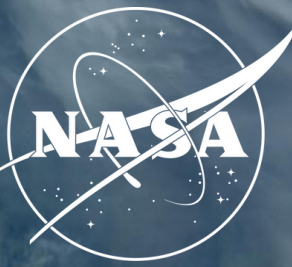
## Outline

- **Presence on GEOS github**
- **“What comes with” GEOS**
- **Green’s Functions tuning using current version of GEOSgcm**
- **Coupled initialization – Impact of Dynamically balanced initial state**

**Motivation for development of the GEOS-MITgcm as part of the GEOS standard release and its benefits:**

- **GMAO/GEOS and ECCO can leverage the expertise within ECCO of simulations at meso- and sub-meso scale resolving ocean resolution and the expertise within GEOS of simulations at mesoscale resolving atmospheric resolution**
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# MITgcm as a Permanent Ocean Model option of GEOSgcm



[GEOSgcm main github site:](https://github.com/GEOS-ESM/) <https://github.com/GEOS-ESM/>  
[GEOSgcm main "fixture" - contains information about included repositories and forks:](https://github.com/GEOS-ESM/GEOSgcm) <https://github.com/GEOS-ESM/GEOSgcm>  
[Current "main" branch of the GEOSgcm fixture:](https://github.com/GEOS-ESM/GEOSgcm/blob/main/components.yaml#L127) <https://github.com/GEOS-ESM/GEOSgcm/blob/main/components.yaml#L127>  
[Contains instructions for checkout/build/run:](https://github.com/GEOS-ESM/GEOSgcm/wiki) <https://github.com/GEOS-ESM/GEOSgcm/wiki>

mom:  
local:  
./src/Components/@GEOSgcm\_GridComp/GEOSogcm\_GridComp/@GEOS\_OceanGridComp/MOM\_GEOS5PlugMod/@mom  
remote: ../MOM5.git  
tag: geos/5.1.0+1.2.0  
develop: geos5

mom6:  
local:  
./src/Components/@GEOSgcm\_GridComp/GEOSogcm\_GridComp/@GEOS\_OceanGridComp/MOM6\_GEOSPlug/@mom6  
remote: ../MOM6.git  
tag: geos/v3.1  
develop: main

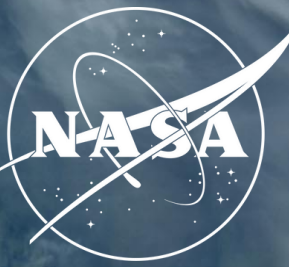
mit:  
local:  
./src/Components/@GEOSgcm\_GridComp/GEOSogcm\_GridComp/@GEOS\_OceanGridComp/MI\_T\_GEOS5PlugMod/@mit  
remote: ../MITgcm.git  
tag: checkpoint68o

cice6:  
local:  
./src/Components/@GEOSgcm\_GridComp/GEOSogcm\_GridComp/GEOSseaice\_GridComp/CICE\_GEOSPlug/@cice6  
remote: ../CICE.git  
tag: geos/v0.1.3  
develop: geos/develop  
ignore\_submodules: true

icepack:  
local:  
./src/Components/@GEOSgcm\_GridComp/GEOSogcm\_GridComp/GEOSseaice\_GridComp/CICE\_GEOSPlug/@cice6/icepack  
remote: ../Icepack.git  
tag: geos/v0.2.0  
develop: geos/develop

sis2:  
local:  
./src/Components/@GEOSgcm\_GridComp/GEOSogcm\_GridComp/GEOSseaice\_GridComp/CICE\_GEOSPlug/@sis2  
remote: ../SIS2.git  
tag: geos/v0.0.1  
develop: dev/gfdl

# “What Comes with GEOS” - Structure of GEOSgcm



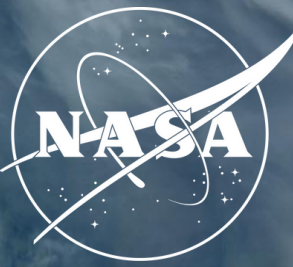
## GEOSgcm general philosophy and structure (MITgcm is the ONLY exception to this structure):

- All included code and repositories are always compiled
- Run-time configuration dictates which components are active and at what horizontal and vertical resolution
- All included code and repositories allocation memory “on the fly” as needed by any run-time configuration
- MANY major sub-models (ocean, atmosphere, cryosphere) have fully interactive as well as “data” components with identical interfaces
- MANY major submodels have different compatible options, many at varied levels of complexity.

## Partial list of ocean-relevant components and experiment configurations (ALL run-time options):

- **Ability to “replay” (nudging with better filters) Ocean (MITgcm only for now), Atmosphere, Atmospheric Aerosol....**
- **Data Assimilation components (Separate Atmosphere, Ocean only as of now, Gas Chemistry soon)**
- MOM5, MOM6, MITgcm(compile time), “DataOcean”
- SIS2, CICE4, CICE6, “DataSealce”
- Ocean Biology, Ocean radiation for ocean biology
- Atmospheric Gas Chemistry: GMI, GEOSchem, StratChem, Pchem
- Atmospheric Aerosol: GOCART(2G), MAM
- Land Model: Option for a component with interactive vegetation

# Green's Functions Tuning: GEOS-MITgcm "c90 llc90"



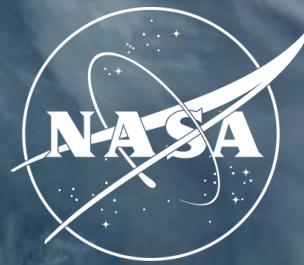
## Recipe:

1. Define a set of parameters to perturb.
2. Run a set of AOGCM experiments, perturbing one parameter at a time.
3. Define a set of observational targets and choose a "cost function".
4. Use the Green's functions methodology (code on github) to choose the set of parameters that minimizes the cost. The computational cost of the minimization is negligible.
5. Assuming linearity, compute the projected cost reduction.
6. Run a new forward "realized" experiment with optimized parameters and assess the "realized" cost reduction.

## Notes:

- Steps 3-6 may be repeated with different observational targets and cost functions without the need for additional AOGCM experiments.
- Steps 1-6 may be repeated to further reduce the cost (in part depends on "how far" from the targets the process began)

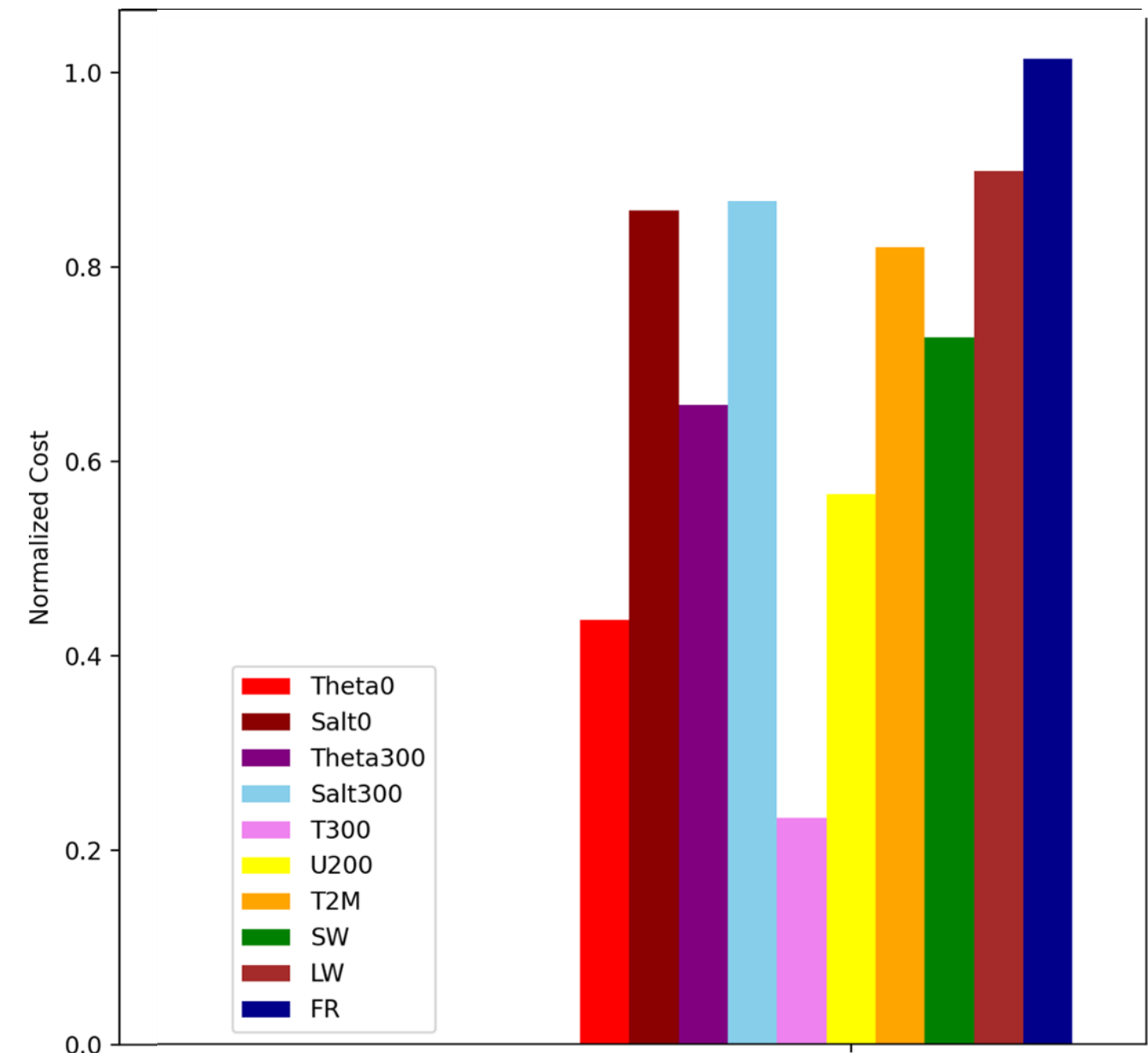
# Green's Functions Tuning: Projected Improvement of Cost



## Evaluation "targets" (2011-2021)

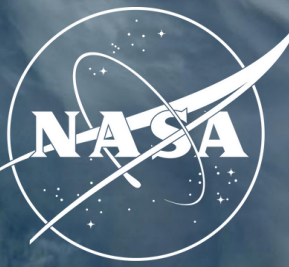
Variable	Dataset
Ice fraction	MERRA-2
300 hPa Temperature	MERRA-2
200 hPa Zonal Wind	MERRA-2
Net surface short-wave radiation	SRB
Net long-wave radiation	SRB
Near surface temperature	HadCRUT4
Sea surface temperature	ECCO
Sea surface salinity	ECCO
THETA at 300m	ECCO
SALT at 300m	ECCO

## Projected (normalized) cost

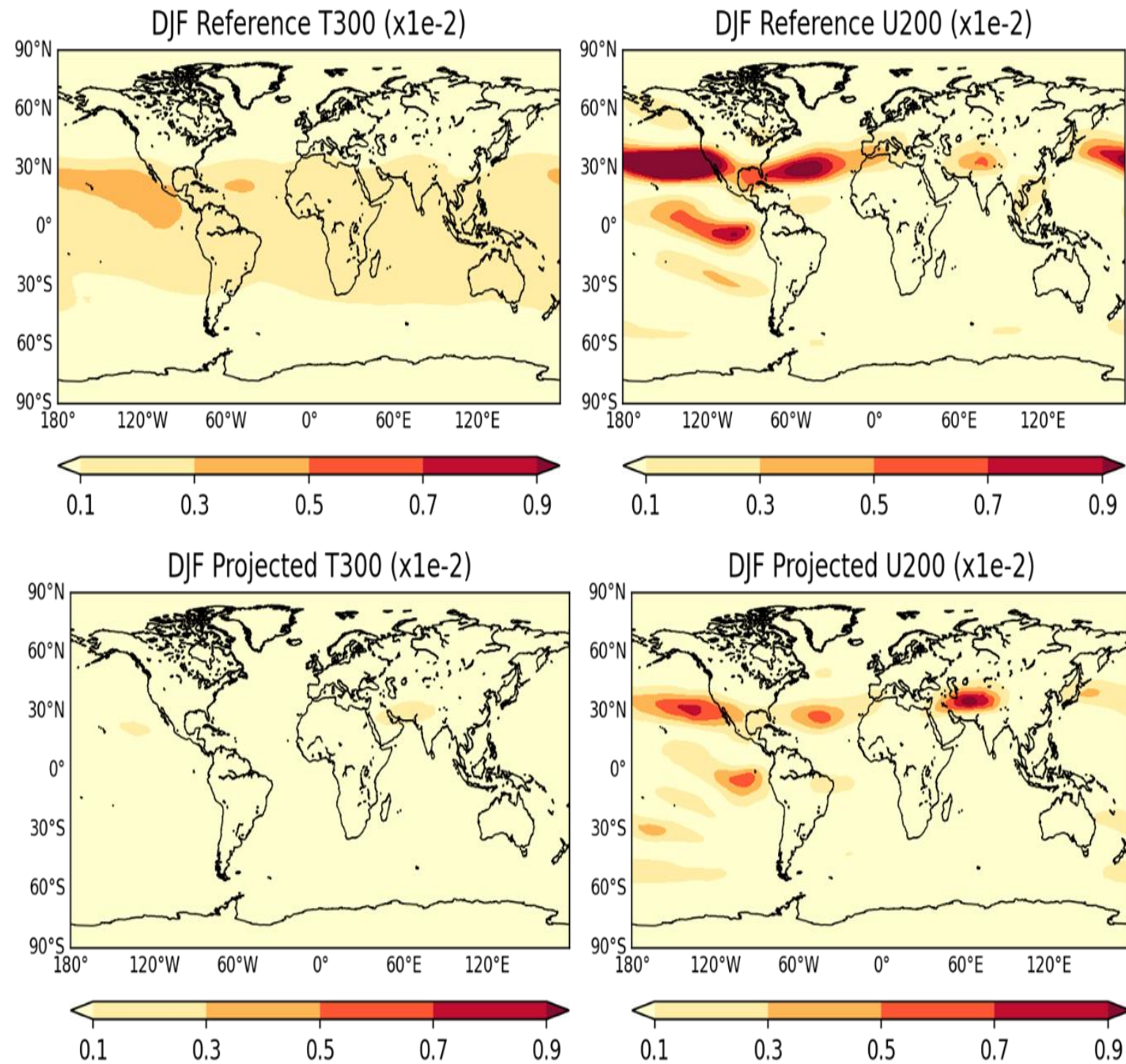


Net improvement: 29.2%

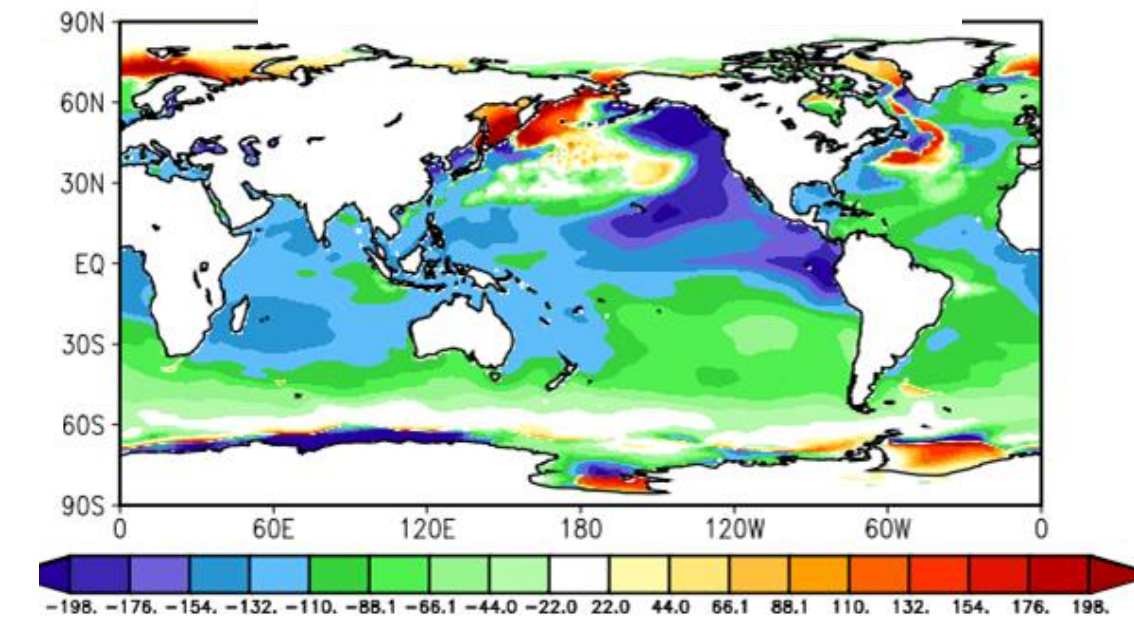
# Green's Functions Tuning: Reference, Projected and Realized



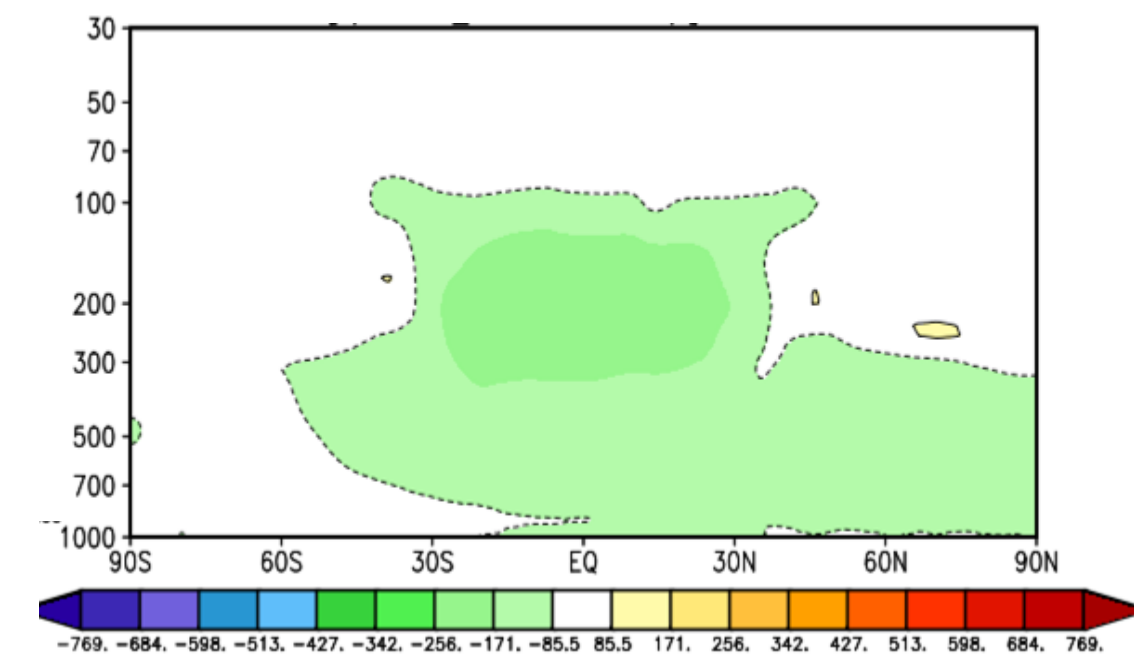
## Reference and Projected (normalized) cost



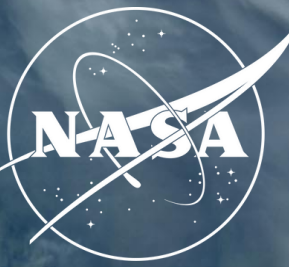
## “Closeness” of Reference vs Realized simulation $ABS(Realized-Obs) - ABS(Reference-Obs)$ (Green/Blue colors indicate improvement in Realized)



OSTIA  
SST



MERRA-2 T

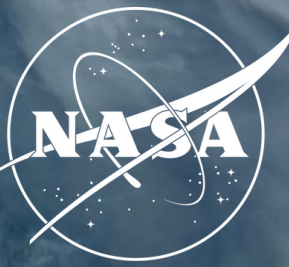


## Experiments:

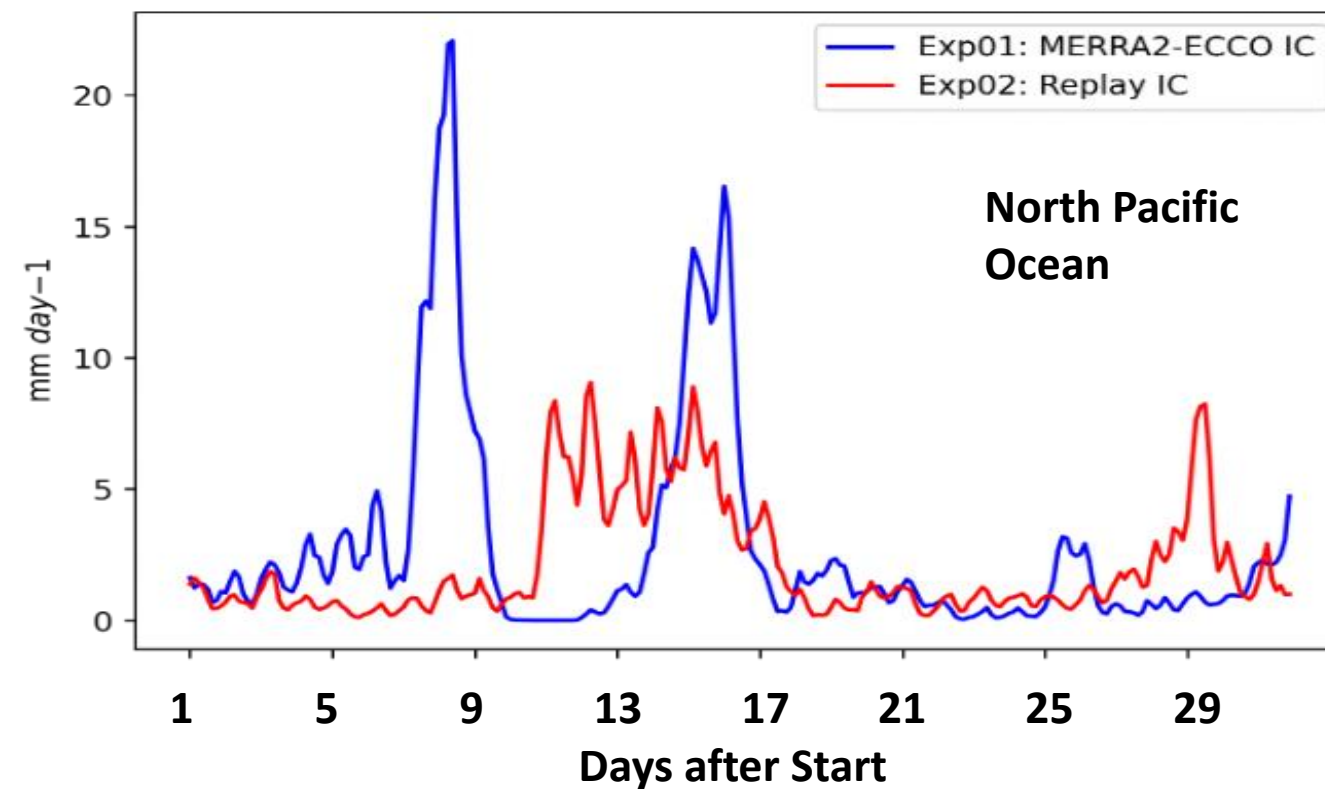
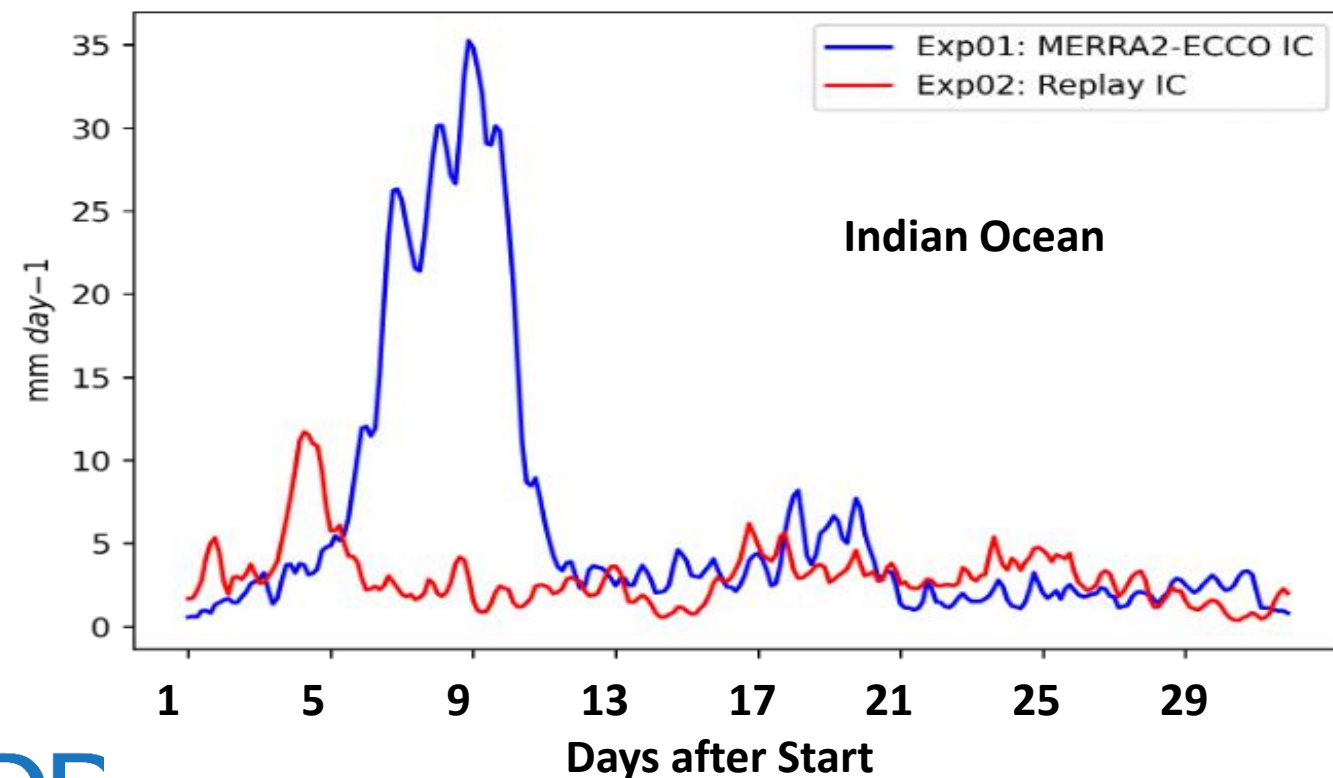
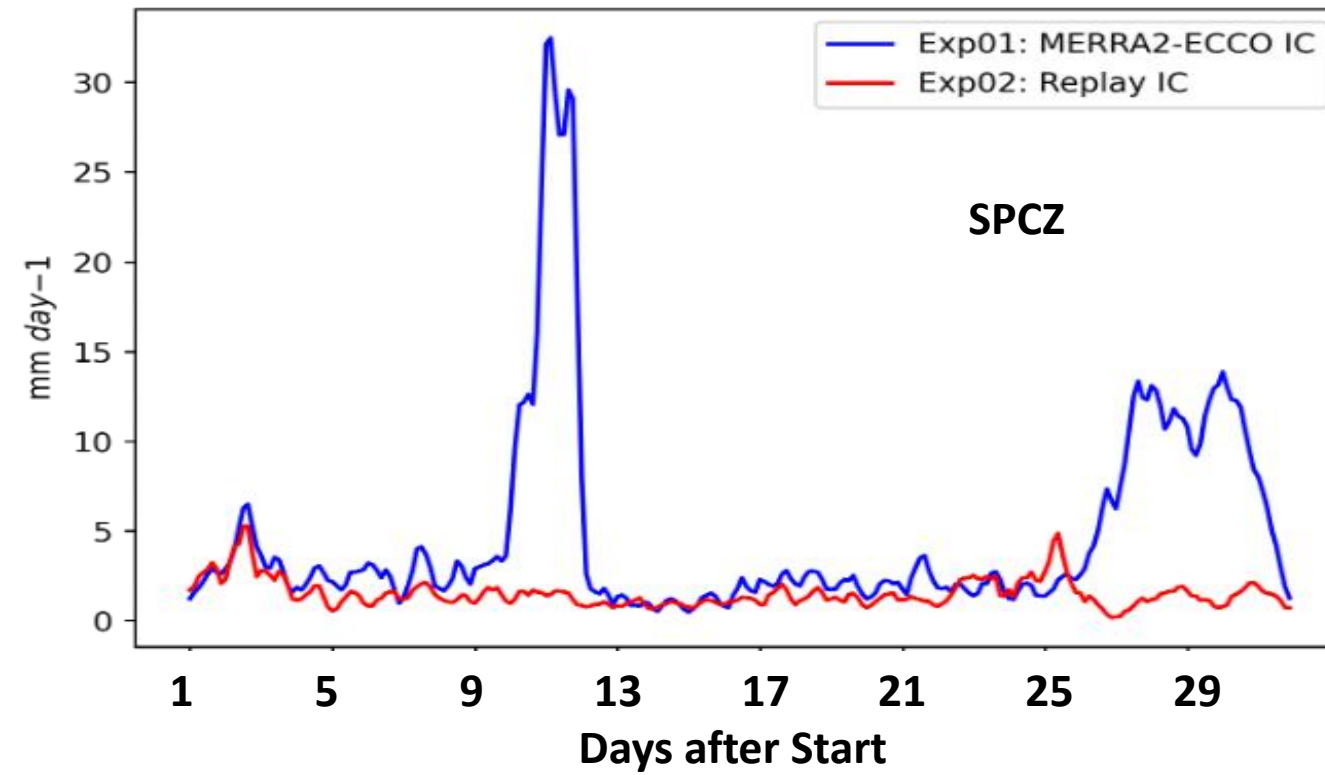
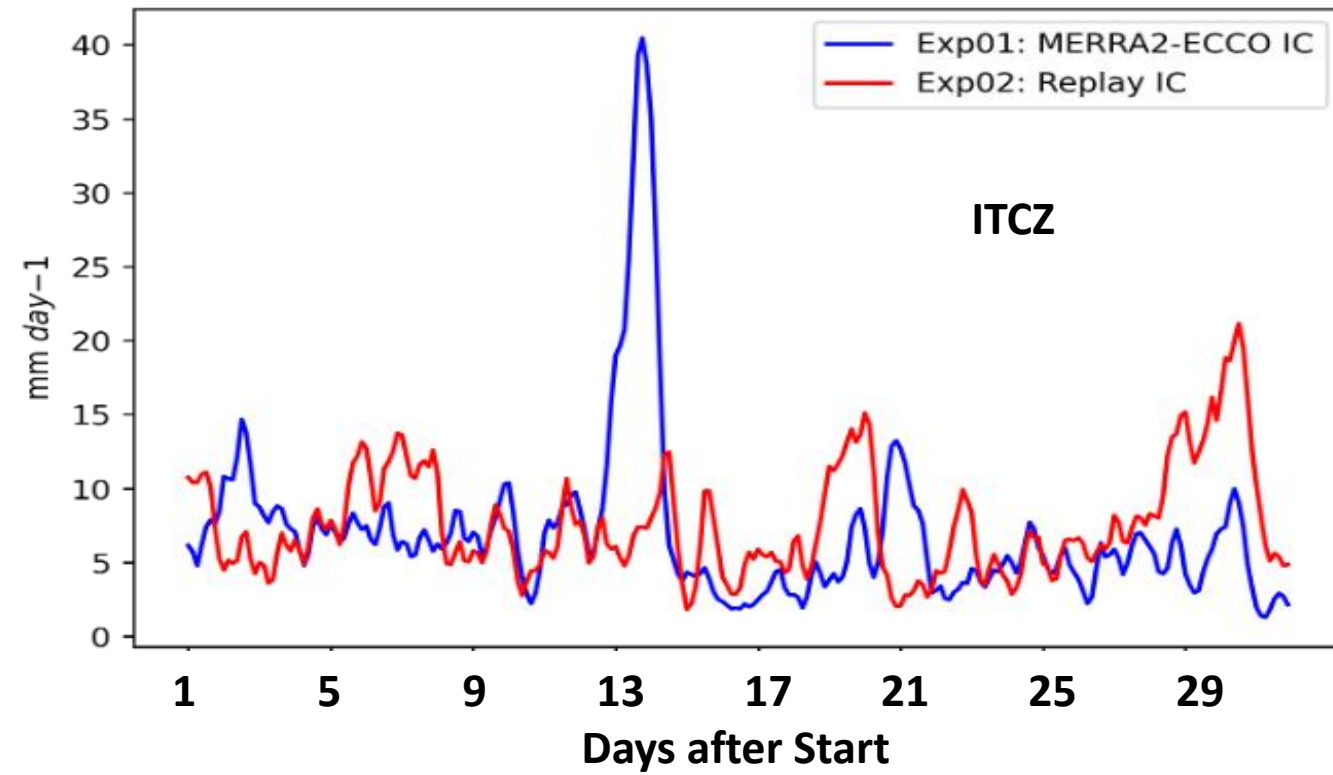
1. **Dynamically imbalanced:** Use “start time” initial states for the atmosphere and land from MERRA-2, and for the MITgcm ocean from ECCO
2. **Dynamically Balanced:** Begin 3 months prior to “start time”
  - Use initial states for the atmosphere and land from MERRA-2 and for the MITgcm ocean from ECCO
  - Run coupled model with “replay” of atmosphere to MERRA-2 for 3 months (ocean runs free)
  - Use the dynamically balanced atmosphere and ocean states from the end of the “replay” to initialize the coupled model
3. **Dynamically Balanced AND both fluids close to observed state (In Progress):** Repeat as in (2) but “replay” both the atmosphere and the ocean



# Coupled initialization: Impact of Dynamically balanced initial state



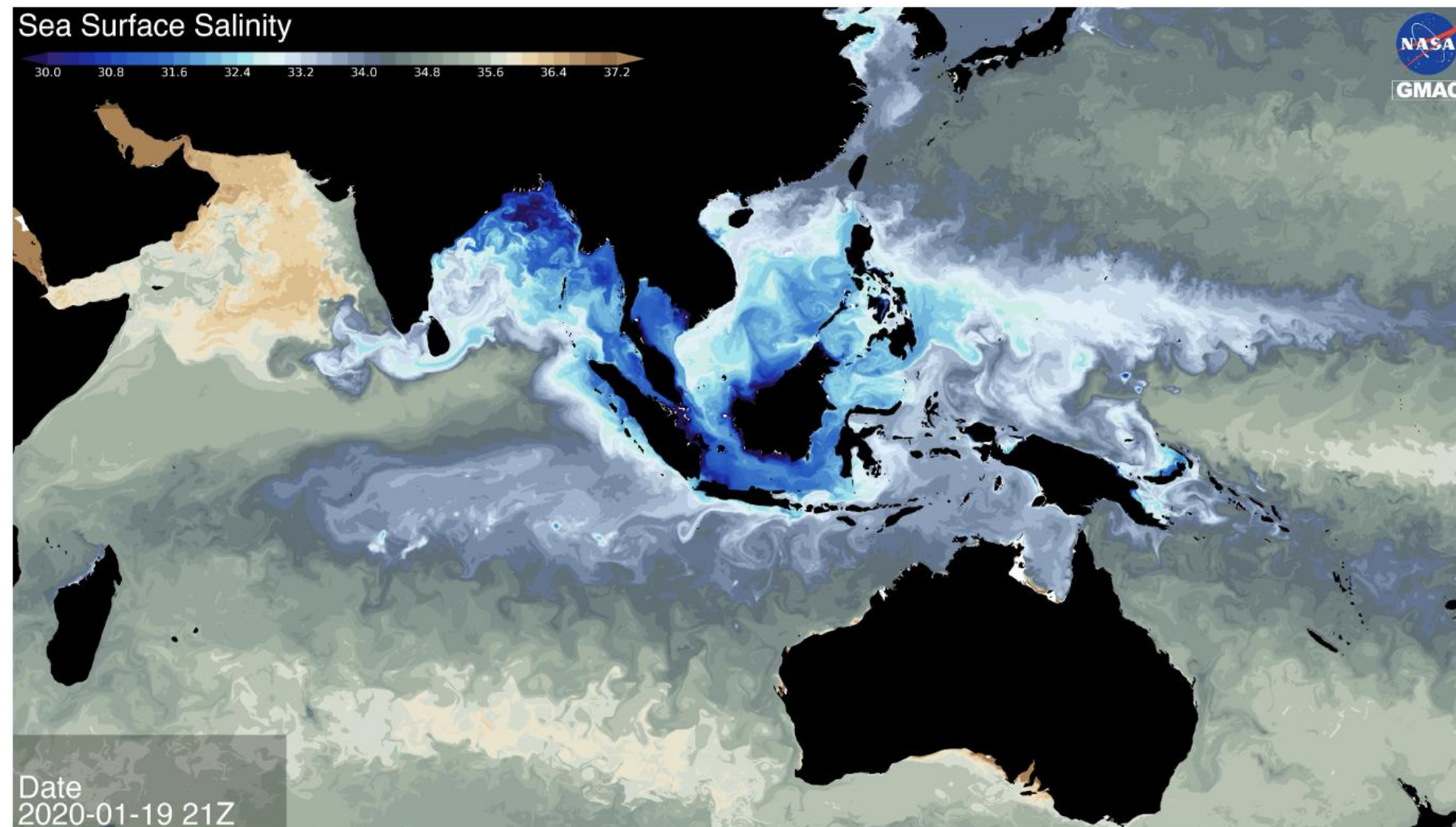
## Total Precipitation



“Spikes” in precipitation with varying time scale around the globe are the atmospheric indicators of the response to a dynamical imbalance

Vertical Motion field in ocean will be examined

# Other Ongoing Projects: Analysis of High Resolution Coupled Simulation



WATCH MOVIE AT

[https://gmao.gsfc.nasa.gov/research/science\\_snapshots/2023/sea-surface.php](https://gmao.gsfc.nasa.gov/research/science_snapshots/2023/sea-surface.php)

**GEOS/ECCO simulation at C1440/LLC2160, initialized from MERRA-2 and ECCO states in January, 2020.**

**Submitted to the Dynamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains (DYAMOND) intercomparison as one of the few coupled simulations.**

**Planned for use as OSSE nature run by UN Decade's Synergistic Observing Network for Ocean Prediction (SynObs) and NOAA's Quantitative Observing System Assessment Program (QOSAP).**

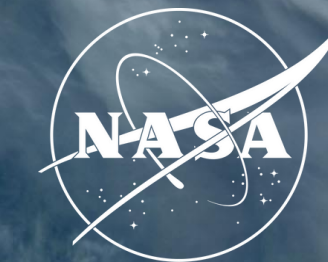
Published studies:

- Torres et al., 2022 - Wind work at the air-sea interface: A Modeling Study in Anticipation of Future Space Missions
- Light et al., 2022 - Effects of grid spacing on high-frequency precipitation variance in coupled high resolution global ocean-atmosphere models
- Strobach et al., 2022 - Local Air-Sea Interactions at Ocean submesoscales in Western Boundary Currents

Current studies:

- Investigate MJO propagation across the Maritime Continent
- Parameterize "mesoscale enhancement" of surface fluxes over the ocean

# Other Ongoing Projects: Decadal Initialization/Forecasts



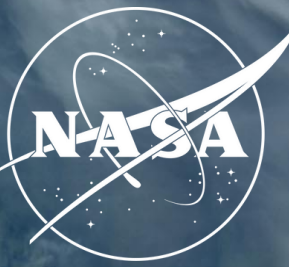
## Motivation/Approach:

Our approach relies on:

- (i) the ECCO state estimation's ability to properly represent the low frequency modes of variability that reside in the ocean
- (ii) the importance of the surface fluxes generated by ECCO estimation for the representation of the low frequency modes in the coupled system
- (iii) The potential for increased decadal prediction skill from the proper initialization of the phase of the decadal modes

<i>GEOS-AODAS experiments</i>	
AODAS, LETKF	10-year AODAS with GEOS/ECCO model
AODAS, existing ECCO	10-year AODAS using precomputed ECCO surface fluxes
AODAS, online ECCO	10-year AODAS using using online ECCO surface fluxes
<i>GEOS/ECCO Retrospective Forecast Suites</i>	
Standard practice	Initialization: separate atmospheric and ocean analysis records
Reduce shocks	Initialization: coupled simulation, constrained atmosphere and SST
Sequential AODAS	Initialization: coupled assimilation with sequential assimilation
GEOS-ECCO AODAS 1	Initialization: coupled assimilation with pre-computed adjoint
GEOS-ECCO AODAS 2	Initialization: coupled assimilation in NRT configuration

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