GEOS-MITgcm High Resolution “Nature Run”

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GEOS/MITgcm Coupled Model (Simulation 2/2020-4/2021)

Atmosphere+Infrastucture (GEOS GCM)

- Recent GEOS AGCM, including interactive aerosol model + aerosol-cloud interaction
- Horizontal Grid: Cubed Sphere, C1440, approximately 6-7 km grid spacing
- Vertical Grid: Hybrid eta-pressure, 72 levels, approximately 8 levels inside boundary layer, 30 above tropopause
- MAPL (Modeling, Analysis and Prediction Layer) interface to ESMF infrastructure

Ocean

- MITgcm, Hydrostatic primitive equations for velocity, potential temperature and salinity, with an implicit free surface
- Includes tidal forcing
- KPP vertical mixing of Large et al. (1994), non-local term disabled
- Horizontal Grid: Latitude-Longitude-polar-Cap 2160 (LLC2160), approximately 2-4 km grid spacing
- Vertical Grid: 90 levels, 1m resolution near surface, ~300m resolution at 5000m depth

Sea Ice

- Sea Ice Thermodynamics of CICE4.0**;**
- Sea Ice Advection (each ice thickness category separately) in MITgcm

Atmosphere-Ocean Interface

- “Skin layer” of Price, et al., 1978
- Implicit backward surface flux calculation assures absolute conservation of energy and water across the interface

GEOS/MITgcm Coupled Model Output - Atmosphere

Hourly “Instantaneous” 3D Prognostic/Diagnostic Fields on “native” horizontal and vertical grid:
U, V, W, H, DELP, P, T, QV, QL, QI RI, RL, FCLD, DTHDT, DTHDTCN, CO, CO2

15-minute “Instantaneous” Prognostic/Diagnostic Fields on “native” horizontal grid:
U10M, V10M, TS, QA, T2M, QS, Q2M, TQV, TQI, TQL, TQR, TQS, CWP, LWP, IWP, CAPE, INHB, OMEGA, RH, ZLE at 800, 700, 500, 200 hPa

Hourly “Time Averaged” 3D Diagnostic Fields on “native” horizontal and vertical grid:
Convective Mass Fluxes, Turbulence Eddy Coefficients, “Tendency terms” from diabatic forcing

Hourly ”Time Averaged” 2D Diagnostic Fields on “native” horizontal grid:
TROPP_EPV, TROPP_THERMAL, TROPP_BLENDED, TROPT, TROPQ, TA, US, VS, SPEED, THAT, QHAT, PLS, PCU, CCWP, TAUTT, TAULO, TAUMD, TAUHI, CLDTT, CLDLO, CLDMD, CLDHI, RUNSURF, BASEFLOW, CT, CQ, CM, LAI, GRN, SNOMAS, ITY, WET1, WET2, WET3, TSOIL1, TSOIL2, FRACI, USTAR, Z0, Z0H, RHOS, U2M, V2M, T10M, Q10M, U50M, V50M, GUST, VENT, ASNOW, ALBVR, ALBVF, ALBNR, ALBNF

15-minute “Time Averaged” 2D Diagnostic Fields on “native” horizontal grid:
PRECANV, PRECCON, PRECLSC, PRECTOT, PRECSNO, ZPBL, RADSRF, FLNS, FLNSC, FLNSA, OLR, OLC, OLA, LWS, LCS, EMIS, LAS, SFCEM, CLDTMP, CLDPRS, OSR, OSRCLR, SWTNET, SWTNETC, SWTNETCNA, SWTNETNA, RADSWT, SWGDWN, SWGDWNC, SWGNET, SWGNETC, SWGNETNA, SWGNETCNA, ALBEDO, EFLUX, EVAP, HFLUX, TAUX, TAUY

GEOS/MITgcm Coupled Model Output - Ocean

<u>Hourly "Instantaneous" Prognostic/Diagnostic Fields on "native" horizontal and vertical grid:</u>

Eta	sea surface height (m)
KPPhbl	mixing layer depth (m)
PhiBot	bottom pressure (m^2/s^2)
SIarea	fractional ice-covered area for 5 categories [0 to 1]
SIheff	effective ice thickness for 5 categories (m)
SIhsnow	effective snow thickness for 5 categories (m)
SItice	ice surface temperature for 5 categories (deg K)
SIuice	zonal (relative to grid) ice velocity, >0 from West to East (m/s)
SIvice	merid. (relative to grid) ice velocity, >0 from South to North (m/s)
Salt	salinity (g/kg)
Theta	potential temperature (deg C)
U.	zonal (relative to grid) velocity, >0 from West to East (m/s)
V.	merid. (relative to grid) velocity, >0 from South to North (m/s)
W.	vertical velocity (m/s)
oceFWflx	net upward freshwater flux, >0 increases salinity (kg/m^2/s)
oceQnet	net upward surface heat flux (including shortwave), >0 decreases theta (W/m^2)
oceQsw	net upward shortwave radiation, >0 decreases theta (W/m^2)
oceSflux	net upward salt flux, >0 decreases salinity (g/m^2/s)
oceTAUX	zonal (relative to grid) surface wind stress, >0 increases uVel (N/m^2)
oceTAUY	meridional (relative to grid) surf. wind stress, >0 increases vVel (N/m^2)

Please note that U, V, oceTAUX, oceTAUY, SIuice, and SIvice are aligned relative to model grid, not geographical coordinates, and that they are specified at the SouthWest C-grid velocity points. All other scalar fields are specified at the tracer point, i.e., the center of each grid box.

GEOS/MITgcm Coupled Model Output - Visualizations

Field-by-field animations of GEOS Atmosphere-related output (interpolated to a lat/lon grid):
https://data.nas.nasa.gov/viz/vizdata/DYAMOND_c1440_llc2160/GEOS/index.html

(Example: https://data.nas.nasa.gov/viz/vizdata/DYAMOND_c1440_llc2160/GEOS/mp4/HD_latlon_EFLUX-15mn.mp4)

Field-by-field animations of MITgcm Ocean-related output (interpolated to a lat/lon grid):
https://data.nas.nasa.gov/viz/vizdata/DYAMOND_c1440_llc2160/MITgcm/index.html

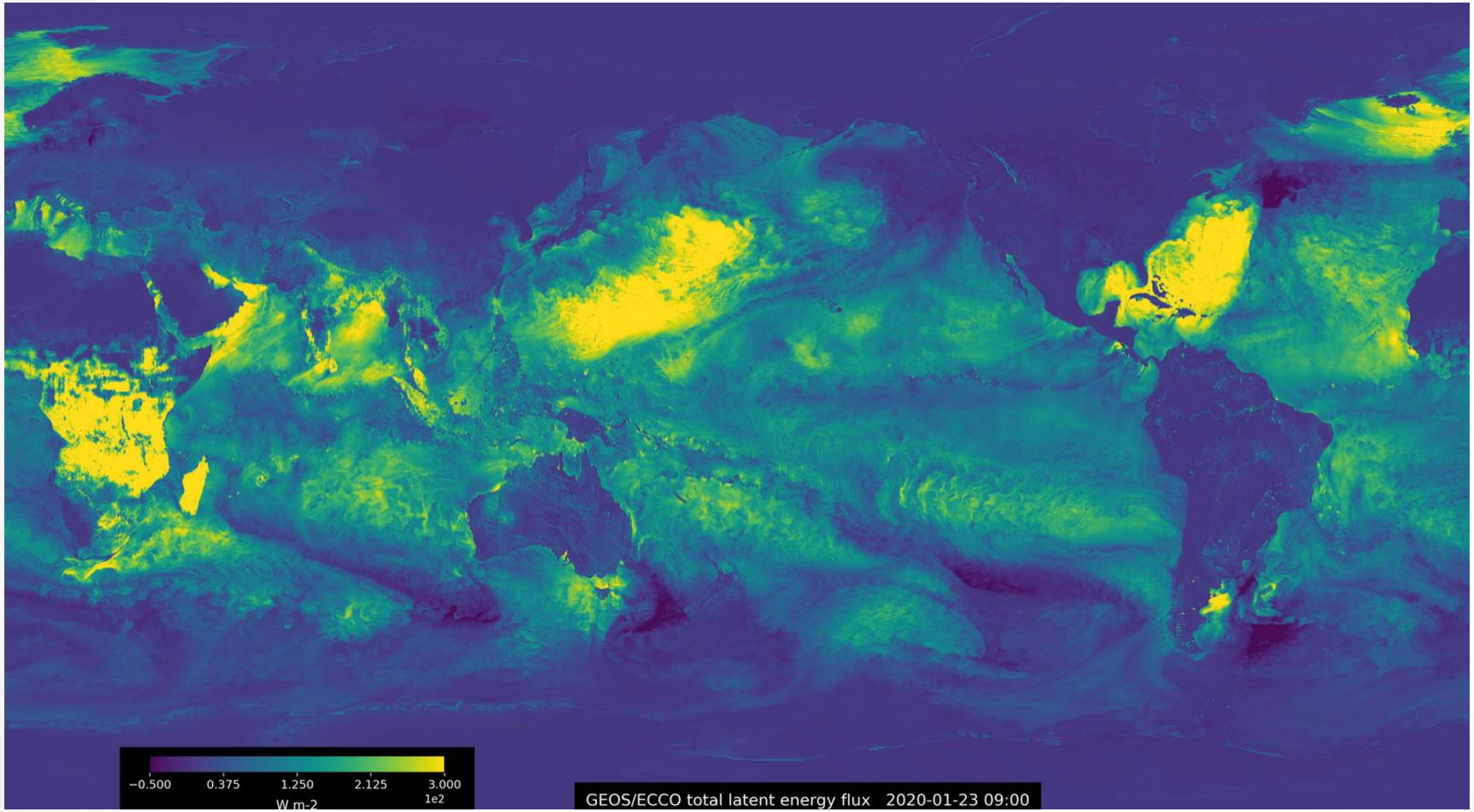
(Example: https://data.nas.nasa.gov/viz/vizdata/DYAMOND_c1440_llc2160/MITgcm/mp4/HD_latlon_SSSPEED.mp4)

Additional selected fields with native grid visualizations:
https://data.nas.nasa.gov/viz/data.php?dir=/vizdata/nmccurdy/DYAMOND_c1440_llc2160/native_grid

Additional regionally-focused animations:
https://portal.nccs.nasa.gov/datashare/g6dev/WebGL/geos_dyamondv2.html

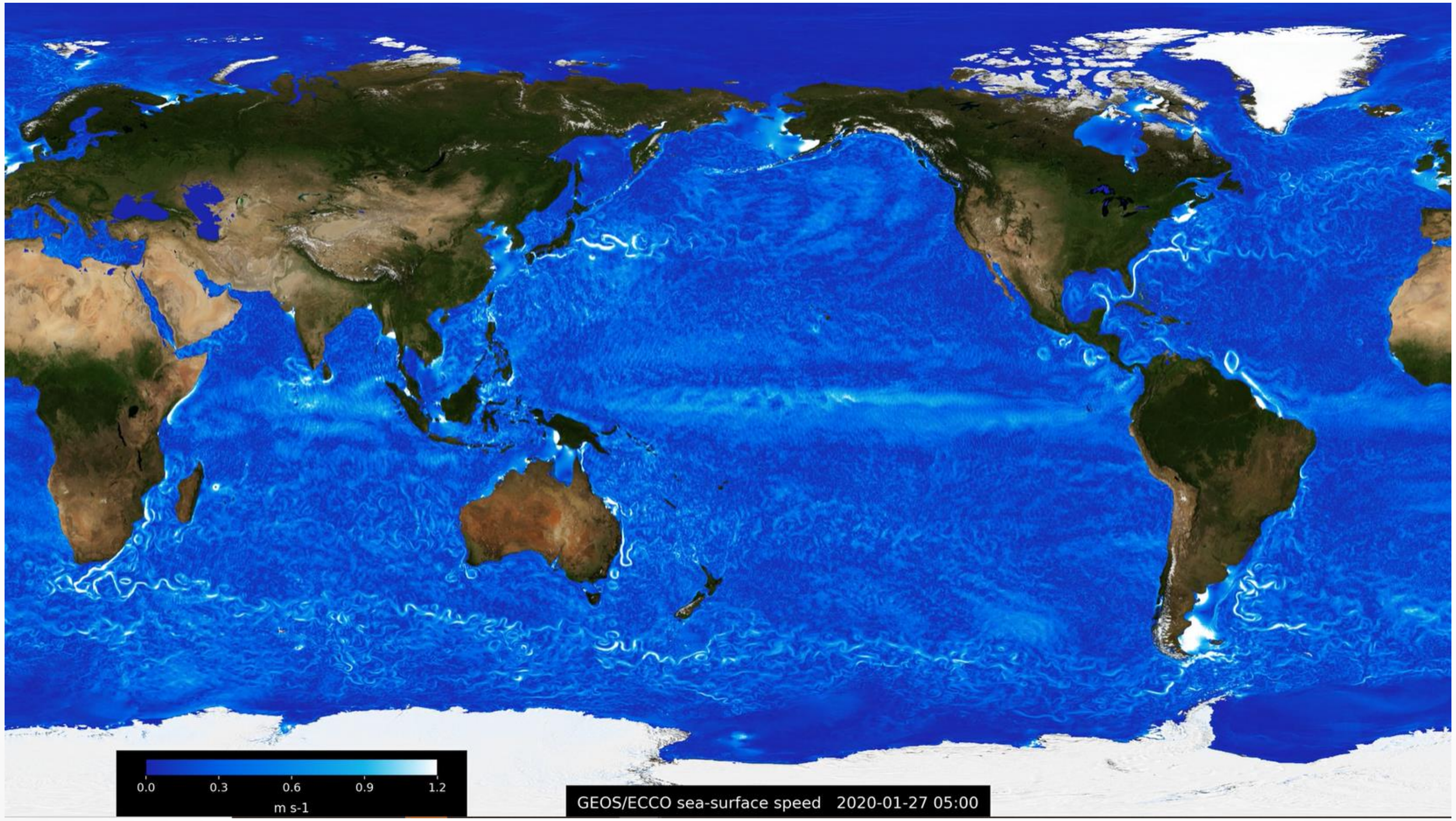
GEOS/MITgcm Coupled Model Output - Visualizations

Still from: https://data.nas.nasa.gov/viz/vizdata/DYAMOND_c1440_llc2160/GEOS/mp4/HD_latlon_EFLUX-15mn.mp4



GEOS/MITgcm Coupled Model Output - Visualizations

Still from: https://data.nas.nasa.gov/viz/vizdata/DYAMOND_c1440_llc2160/MITgcm/mp4/HD_latlon_SSSPEED.mp4



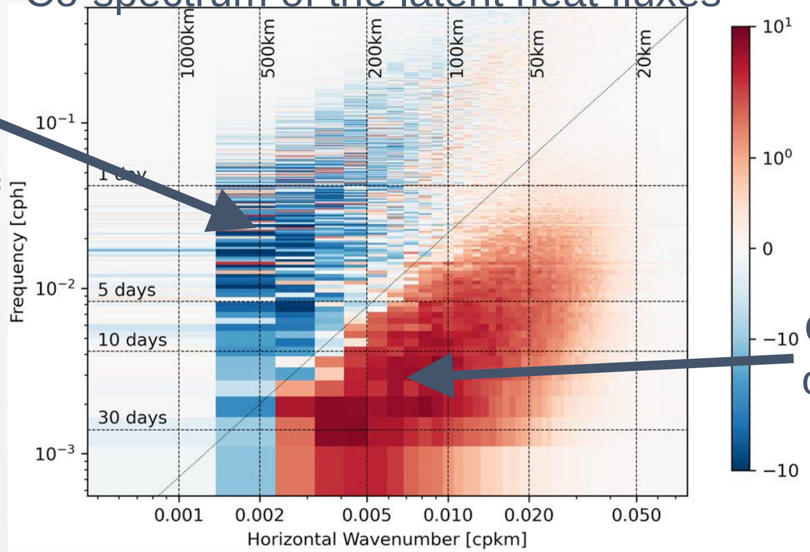
GEOS/MITgcm Coupled Model – Selected Analysis

Local air-sea interactions at ocean mesoscale and submesoscale in a Western Boundary Current – Strobach et al., 2022

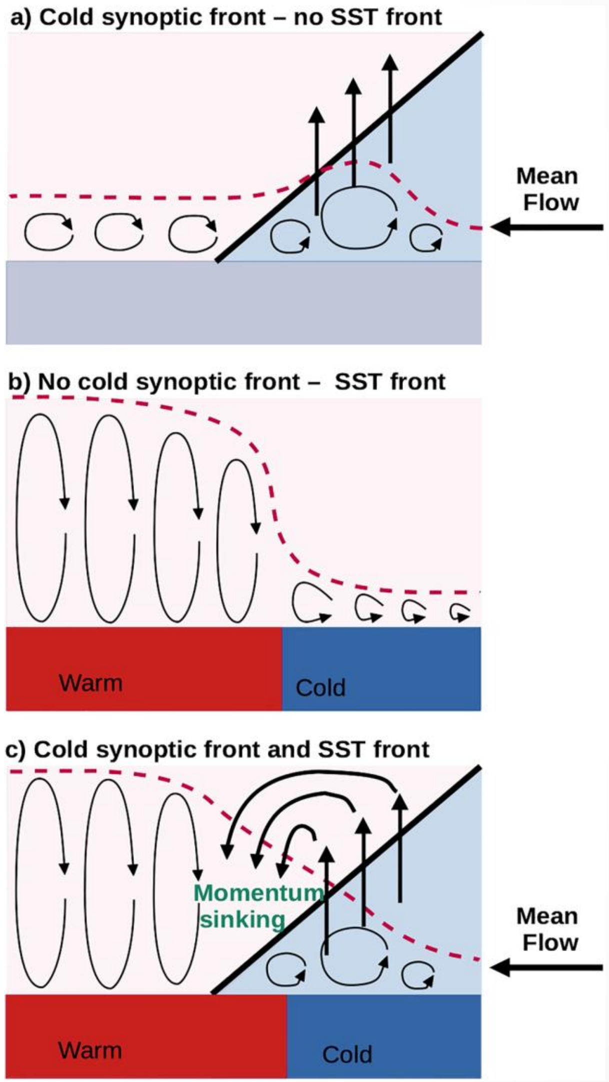
The study focuses on recurring intermittent wind events in the Gulf Stream region associated with SST anomalies with horizontal scales smaller than 500-km. These events are associated with a secondary circulation that acts to fuel the latent heat bursts by transferring dry air and momentum down to the surface.

Co-spectrum of the latent heat fluxes

Larger scale motions dominate in this region of spectrum



Secondary Circulations occur in this region of spectrum



Cold air blows from the right over an SST change from cold to warm. The red dotted line represents the atmospheric boundary layer height (PBL).

a) A cold synoptic front approaches a gradual Sea Surface Temperature (SST) gradient (from right to left), the warmer air at the surface is pushed upward. **No secondary circulation**

(b) Cold air blows over an SST front. Higher atmospheric PBL forms above warmer SST due to higher mixing at no front conditions. **No secondary circulation.**

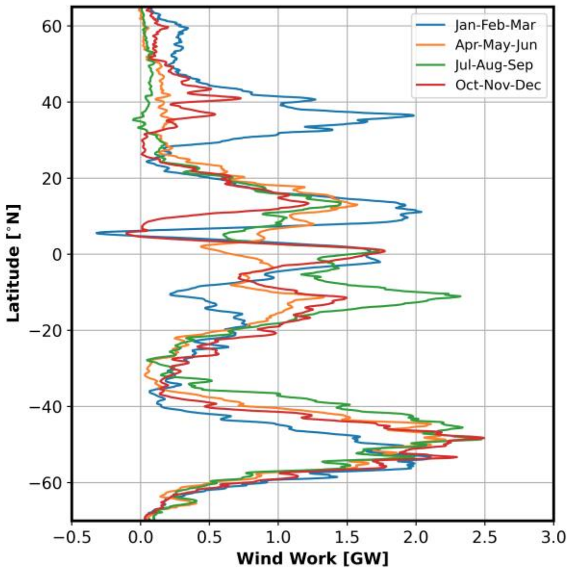
(c) A cold synoptic front approaches an SST front and produces momentum sinking above the front due to mixing. **Secondary circulation enhances the turbulent fluxes and atmospheric gradients.**

GEOS/MITgcm Coupled Model – Selected Analysis

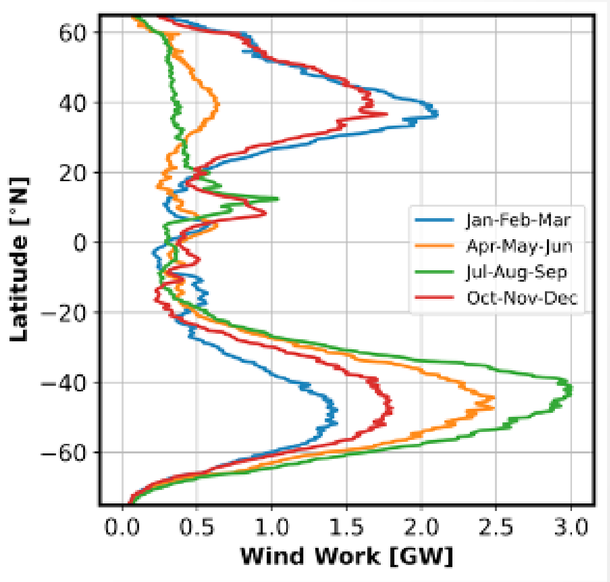
Wind work at the air-sea interface: A Modeling Study in Anticipation of Future Space Missions – Torres, et al., 2022

The study examines the different components of wind work, the transfer of kinetic energy between the ocean and the atmosphere, defined as the scalar product of ocean wind stress and surface current. The wind work spans a broad range of spatial and temporal scales, from 10 to 3000 km and one hour to at least 3 months, emphazing the need to high spatial and temporal scale information to study this multiscale phenomenon.

A methodology is presented to diagnose three different components of wind work in terms of forcing distinct classes of oceanic motions, including seasonally averaged currents, low-frequency mesoscale and larger eddies, and high-frequency internal gravity waves such as near-inertial oscillations.

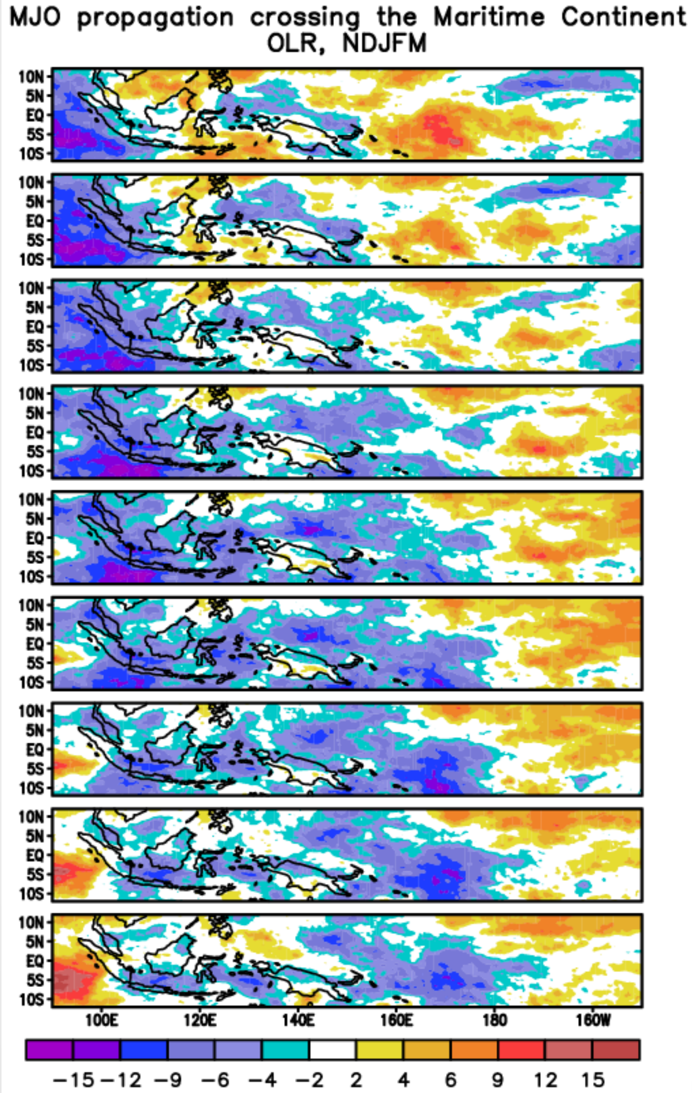


Time-mean wind work



Total time-dependant wind work

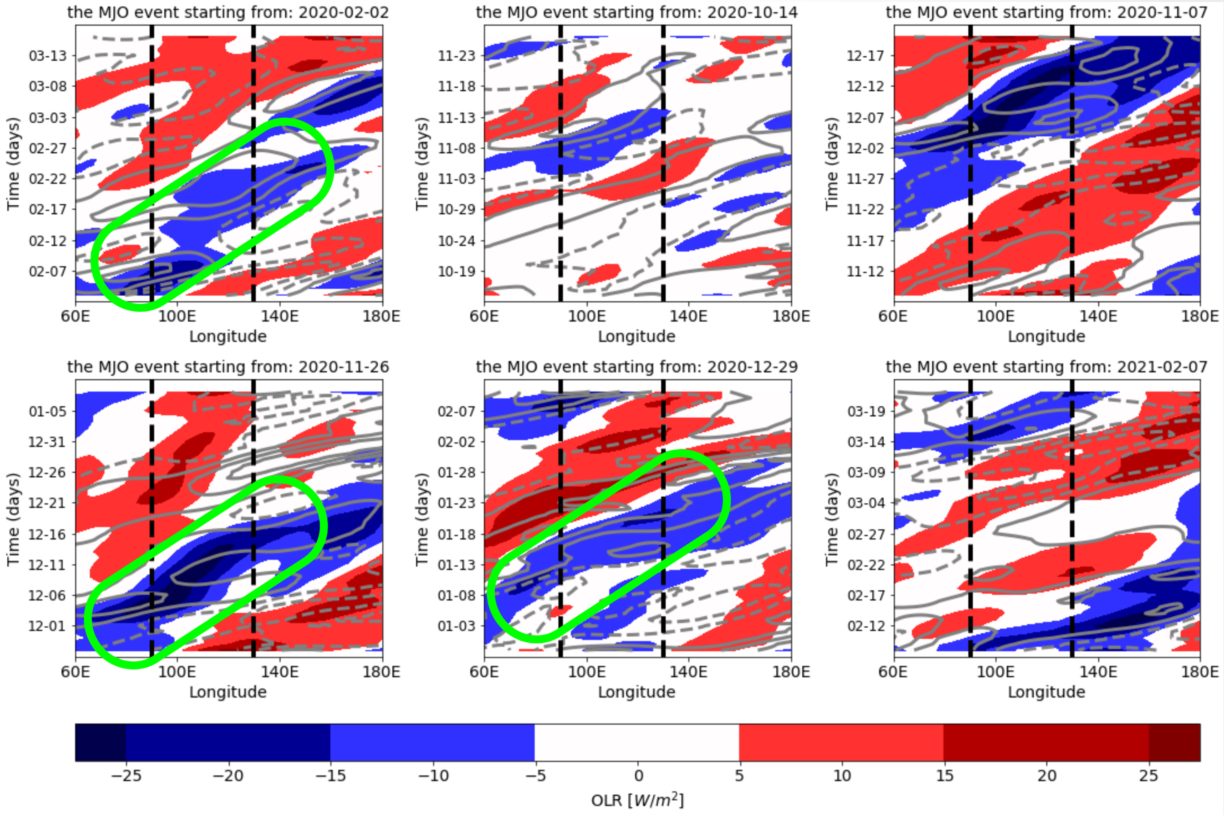
GEOS/MITgcm Coupled Model – Selected Analysis



Examination of the behavior of the Madden-Julian Oscillation – Propagation across the Maritime Continent - Young-Kwon Lim, Danni Du

MJO as represented by OLR.

The simulation MJO composite indicates that it takes about 40~45 days to complete one round along the equator. (45 days => 5m/sec)



During the model simulation period (~430days), there are 3 MJO events propagating across the Maritime Continent.

GEOS/MITgcm Coupled Model – Plans for Analysis

Software to examine seasonal mean behavior of any simulation – requires interpolation of monthly means to lat/lon grid. Plots posted for viewing. Illistrated here using coarse resolution GEOS/MITgcm simulation

- Prognostics
  - Zonal Mean Plots
  - Horizontal Plots
  - Quadratics Plots
- Aerosols (2d)
- Time-Series
- Forecast Statistics
- RC Files
- CCM Diagnostics

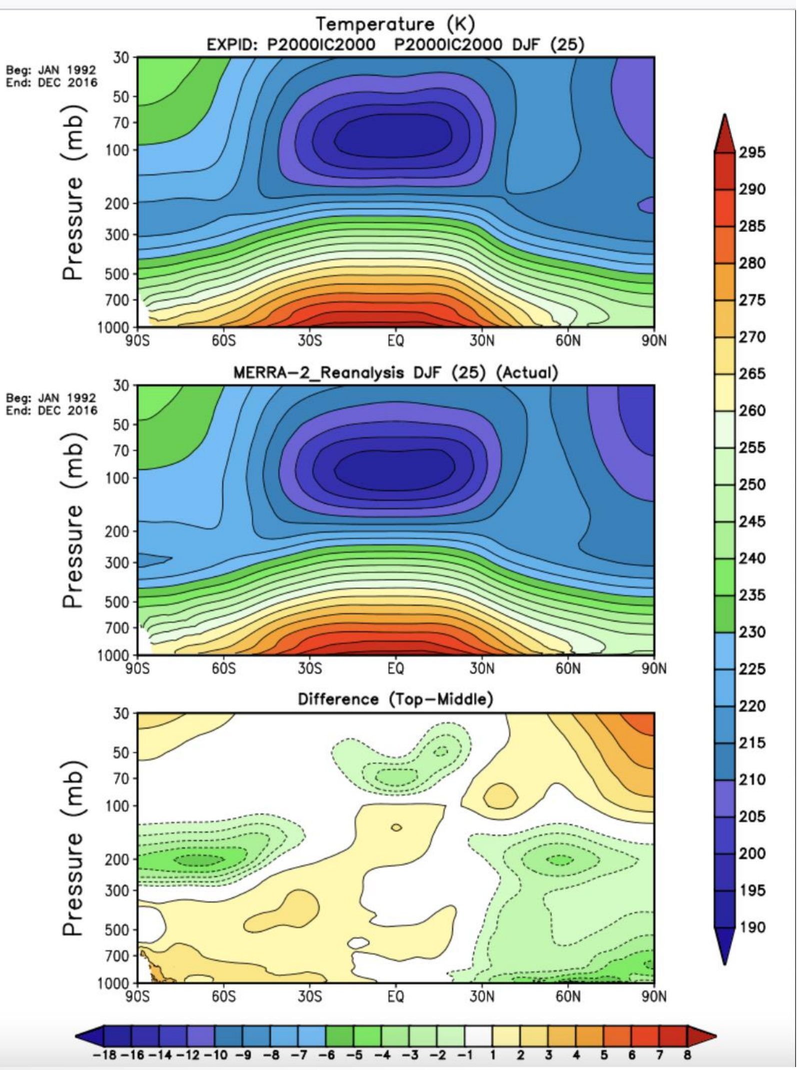
- AGCM Diagnostics
  - Tendencies
  - Moist Processes
  - Radiation
  - Gravity-Wave D
  - Turbulence
  - Clouds
  - Surface/2-D
  - Energetics
  - Taylor Diagrams
  - Miscellaneous
- IAU Error Analysis
- OGCM Coupled Di

Year	Season	Comparison ☑ / Closeness ☑		Type
CLIM	December-January-February	MERRA-2 Reanalysis	none	Mean

Field	Zonal Linear/Log	1000 mb	925 mb	850 mb	700 mb	600 mb	500 mb	400 mb	300 mb	250 mb	200 mb	150 mb	100 mb	70 mb	50 mb	30 mb
Sea-Level Pressure		☑														
Zonal U-Wind	☑ / ☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Meridional V-Wind	☑ / ☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Heights	☑ / ☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Eddy Heights		☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Temperature	☑ / ☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Specific Humidity	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Relative Humidity	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Q-Liquid																
Q-Ice																
Omega	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHI		☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
PSI		☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑

Field	Zonal Linear/Log	70 mb	50 mb	40 mb	30 mb	10 mb	7.0 mb	5.0 mb	4.0 mb	3.0 mb	1.0 mb	0.7 mb	0.5 mb	0.4 mb	0.3 mb	0.1 mb
Ozone	☑ / ☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑

GEOS/MITgcm Coupled Model – Plans for Analysis (cont'd)



Example of DJF mean temperature as compared to MERRA-2 for the year of the simulation.

Comparable examination possible for other prognostic fields, and using ERA5 for comparison.

GEOS/MITgcm Coupled Model – Plans for Analysis (cont'd)

- TOA Zonal Mean Summary

- Shortwave & Longwave Radiative Heating
- Net Radiative Heating
- Ozone

- **TOA Radiative Fluxes**
- **Surface Radiative Fluxes**
- **Aerosol Radiative Forcing**

Year	Season	Comparison / Closeness	
CLIM	December-January-February	SRB	none

- **Surface LW**

- (z) Upward Longwave Radiation at Surface (All-Sky)
- (z) Upward Longwave Radiation at Surface (Clear-Sky)
- (z) Upward Longwave Radiation at Surface (Cloud Forcing)
- (z) Upward Longwave Radiation at Surface (Clear-Sky, Cloud-Cleared<5%)
- (z) Upward Longwave Radiation at Surface (Cloud Forcing, Cloud-Cleared<5%)

- (z) Downward Longwave Radiation at Surface (All-Sky)
- (z) Downward Longwave Radiation at Surface (Clear-Sky)
- (z) Downward Longwave Radiation at Surface (Cloud Forcing)
- (z) Downward Longwave Radiation at Surface (Clear-Sky, Cloud-Cleared<5%)
- (z) Downward Longwave Radiation at Surface (Cloud Forcing, Cloud-Cleared<5%)

- (z) Net Longwave Radiation at Surface (All-Sky)
- (z) Net Longwave Radiation at Surface (Clear-Sky)
- (z) Net Longwave Radiation at Surface (Cloud Forcing)
- (z) Net Longwave Radiation at Surface (Clear-Sky, Cloud-Cleared<5%)
- (z) Net Longwave Radiation at Surface (Cloud Forcing, Cloud-Cleared<5%)

- **Surface Net**

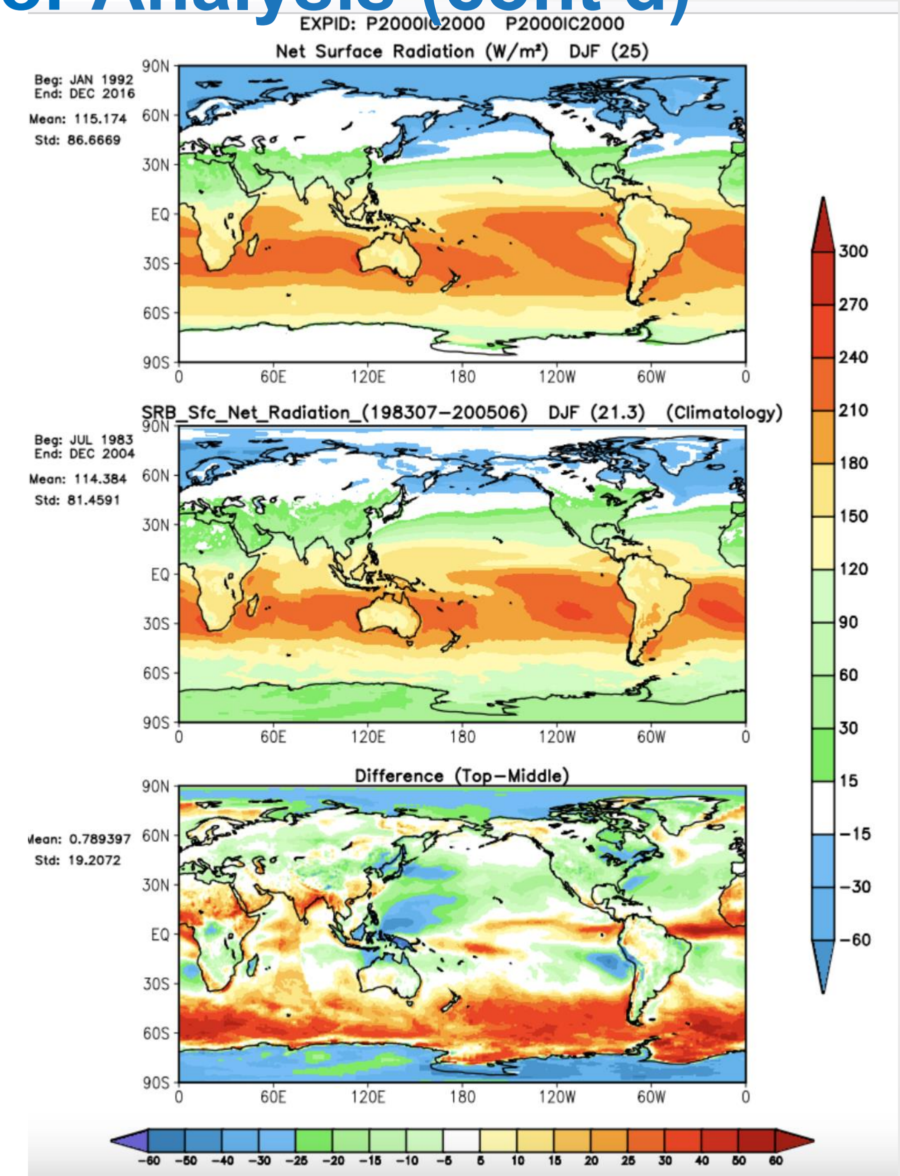
- (z) Net Radiation at Surface (All-Sky)
- (z) Net Radiation at Surface (Clear-Sky)

- **Surface SW**

- (z) Upward Shortwave Radiation at Surface (All-Sky)
- (z) Upward Shortwave Radiation at Surface (Clear-Sky)
- (z) Upward Shortwave Radiation at Surface (Cloud Forcing)

- (z) Downward Shortwave Radiation at Surface (All-Sky)
- (z) Downward Shortwave Radiation at Surface (Clear-Sky)
- (z) Downward Shortwave Radiation at Surface (Cloud Forcing)

- (z) Net Shortwave Radiation at Surface (All-Sky)
- (z) Net Shortwave Radiation at Surface (Clear-Sky)
- (z) Net Shortwave Radiation at Surface (Cloud Forcing)



Summary

- GEOS/MITgcm “Nature Run” simulation was conducted at ~6km atmosphere, ~2-4 km ocean resolution. for the period 2/2020 – 4/2021
- Hourly (or sub-hourly) output is available for the fields needed to conduct (coupled) OSSEs
- Preliminary examination of output included broad-brush examination of visualizations
- Studies using the output of mesoscale air-sea interactions, wind work, and MJO propagation
- Interpolation of monthly means to a lat/lon grid for comparison against observational estimates is under way
- Future plans to examine behavior of tropical cyclones, other fields upon request