NATIONAL WEATHER SERVICE

The Unified Forecast System (UFS) Subseasonal to Seasonal Application with MOM6 at EMC

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Contributors

NCEP

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GFDL

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UCAR/NCAR

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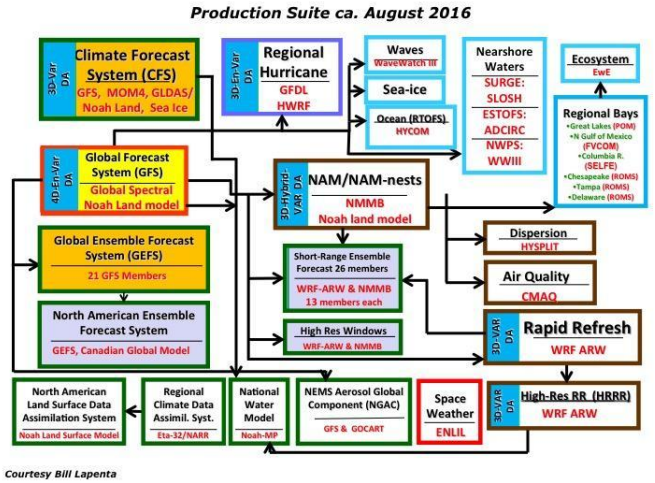
Overview

- Motivation
- Unified Forecast System
- Description of ufs-s2s-model
- Selected results
- Future work

Motivation

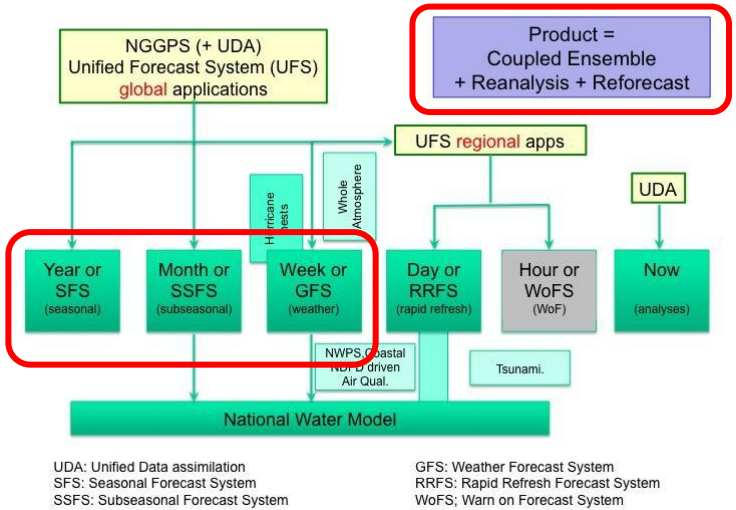
- The NWS issues global forecasts at two time scales – weather (e.g. GFS, GEFS etc) and seasonal (CFSv2)
- The weather act from Congress instructs NWS to provide forecast guidance from weather to *sub seasonal* and seasonal scales
- NWS is in the process of upgrading its operational modeling suite using a new atmospheric dycore (FV3)
- NWS is using this opportunity to upgrade and unify its modeling capability across different scales

Strategic Vision: Simplify modeling suite



Courtesy Bill Lapenta

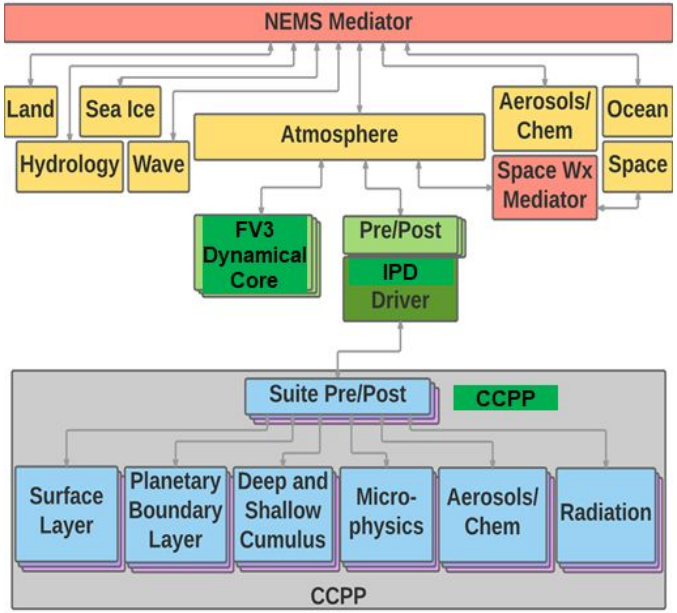
… we will move to a product based system that covers all present elements of the production suite in a more systematic and efficient way



Starting from the quilt of models and products created by implementing solutions rather than addressing requirements ….

Unified Forecast System

- NWS UFS system consists of the following components (at the moment)
  - NEMS for infrastructure
  - CMEPS mediator
  - FV3 dycore with CCPP Physics driver
  - MOM6 ocean model (S2S scales)
  - HYCOM ocean model (weather scales)
  - WW3 wave model
  - CICE5 ice model
  - GOCART aerosol model
  - Noah MP land model
- Each component has its own authoritative repository. NEMS infrastructure allows flexibility to connect instantiations of the repositories together to create a coupled model.
- *https://ufscommunity.org*



Current Developments

- Each of these is a working coupled application which is actively being tested

FV3GFS – WW3
Effects of waves on atmospheric stress at ocean surface

FV3GFS – CHEM
Atmosphere, aerosols interaction

ADCIRC – WW3
Wave and surge coupling (COASTAL ACT)

MOM6 – CICE5
Ocean ice coupled model to look at polar dynamics and for developing a marine DA system

HAFS
Hurricane Analysis and Forecast System

FV3GFS – MOM6 – CICE5 – WW3
S2S scales (25 km atm, ¼ deg ocean and ice, ½ deg waves)

Operational Targets

- For the S2S coupled model, the first operational target is the Global Ensemble Forecasting System (GEFSv13) in FY2023 to be followed by the Seasonal Forecast System (SFSv1) in FY2025.

ufs-s2s-model https://github.com/ufs-community/ufs-s2s-model

Atmosphere
- FV3 dynamical core
- GFS Physics with GFDL microphysics
- CCPP physics driver
- C384 (~25km), 64 levels

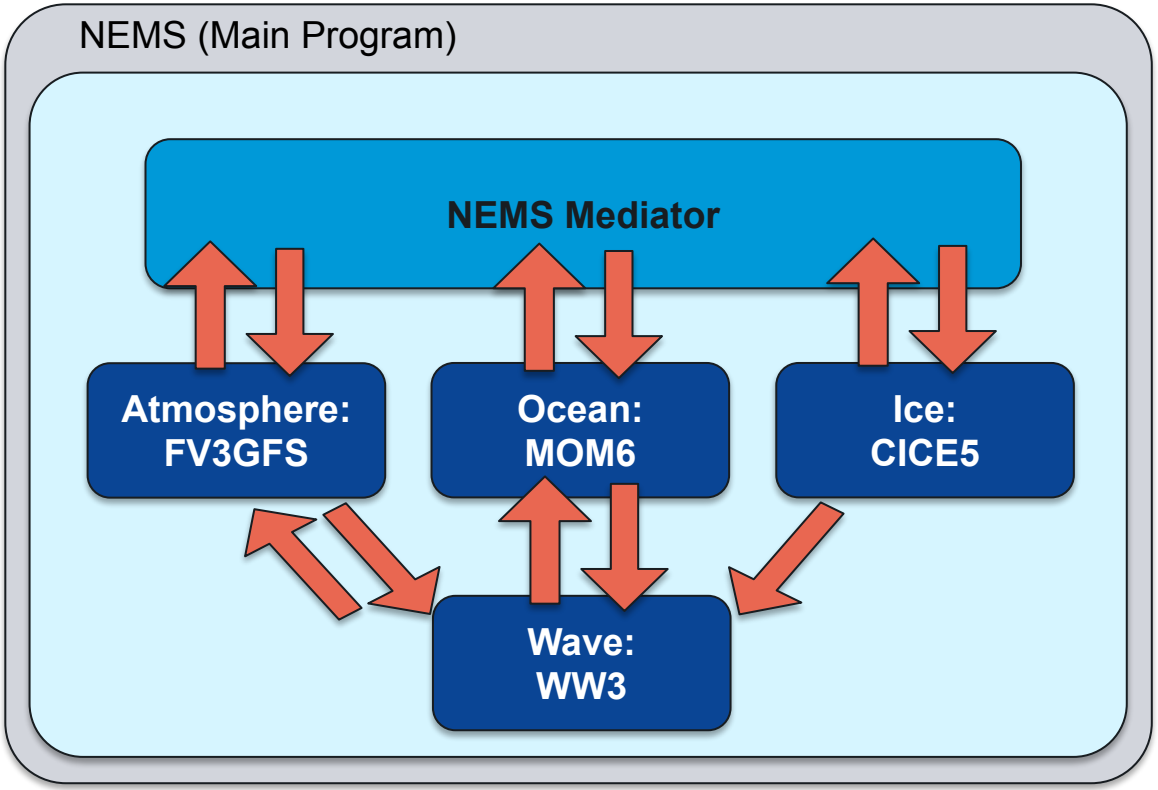
Ocean
- MOM6 Modular Ocean Model
- ¼ degree tripolar grid, 75 hybrid levels
- OM4 Set up [Adcroft, 2019]

Waves
- WAVEWATCH III
- ½ degree regular lat/lon grid
- ST4 Physics [Ardhuin, 2010]

Ice
- CICE5 Los Alamos Sea Ice Model
- ¼ degree tripolar grid (same as ocean)
- 5 thickness categories
- No Mushy thermodynamics

Driver/Mediator
- NEMS driver
- CMEPS or NEMS mediator

Current Coupled Model Configuration



- Atm/Ice Fluxes are computed by ice model
- Atm/Ocn Fluxes are computed by atm model
- Wave model sends z_0 roughness length to atm
- Wave sends Stokes Drift (**u**,**v**) to ocean for sea-state dependent Langmuir mixing

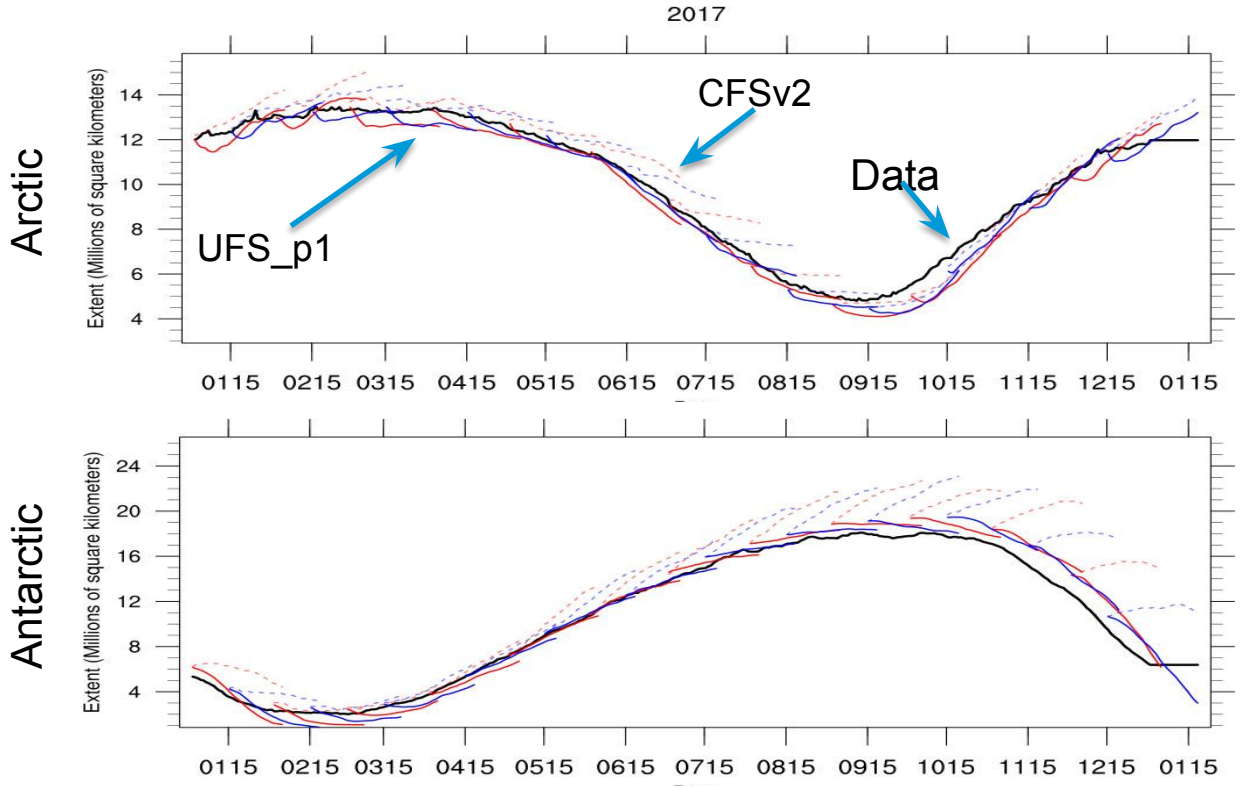
Benchmark Run Descriptions

- 35 day free forecasts
- April 2011 to March 2018
  - Initialized from the 1st and 15th of each month
  - 7 years, 168 forecasts
  - Covers El Niño and La Niña events
  - Years of low ice extent

Prototype Overview

	Initial Conditions			
	FV3 GFS	MOM6	CICE5	WW3
UFS_p1	CFSR	CFSR	CFSR	n/a
UFS_p2	CFSR	CPC 3Dvar	CFSR	n/a
UFS_p3	CFSR	CPC 3Dvar	CPC ice analysis	n/a
UFS_p4	CFSR	CPC 3Dvar	CPC ice analysis	Generated with CFS forcing

Sea Ice Extent



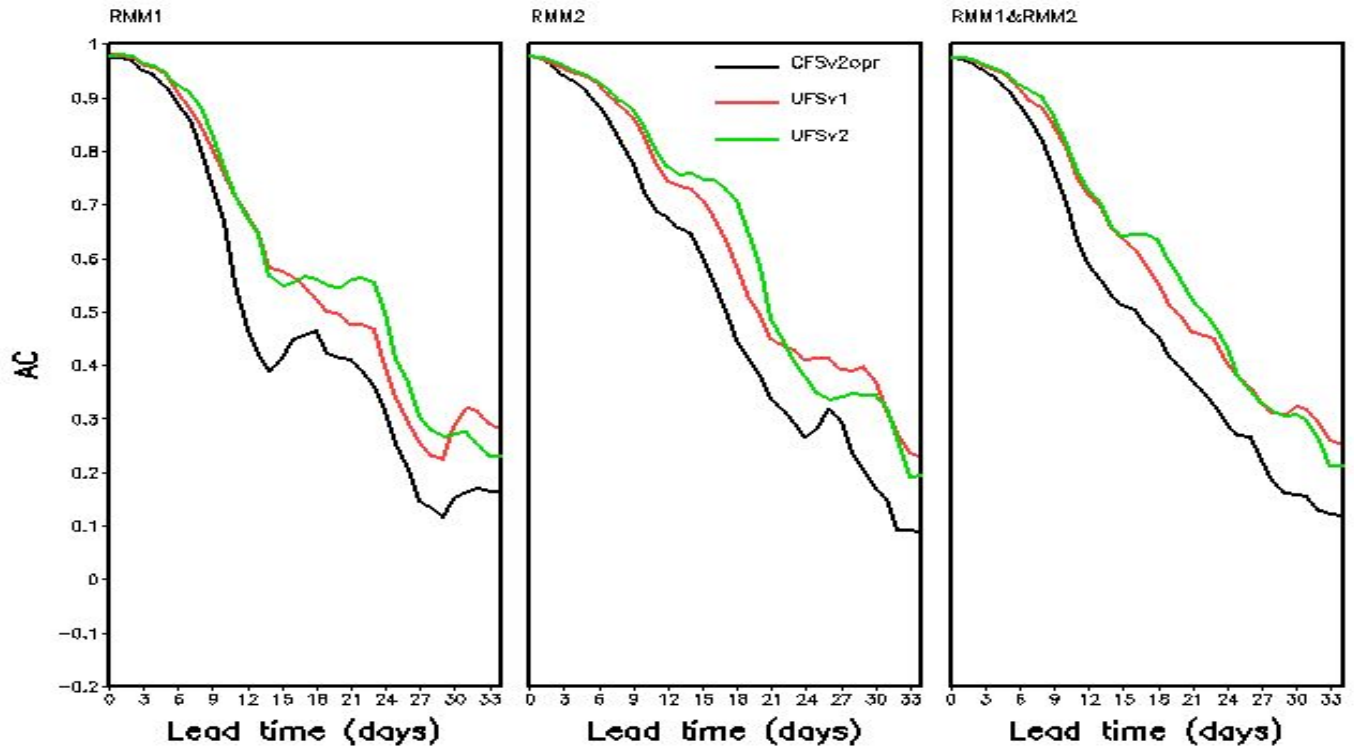
Data Source: NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Version 3 (https://nsidc.org/data/g02202/versions/3)

Global Tropical SST (20N-20S) AC vs. OSTIA

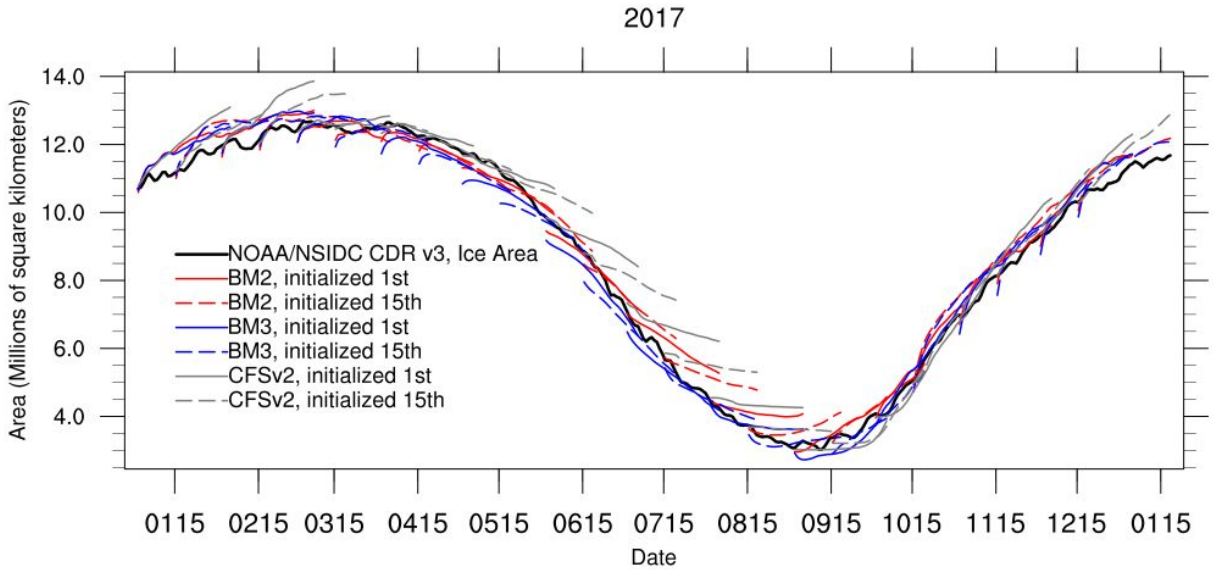
	UFSv2	UFSv2	UFSv1	UFSv1	CFSv2	CFSv2
	Raw	Sec	Raw	Sec	Raw	Sec
week1	80.6	88.2	78.0	83.2	76.0	80.8
week2	70.3	80.6	68.2	76.7	66.6	73.7
week3	61.6	73.0	59.4	69.2	58.2	67.3
week4	55.7	68.0	53.4	64.3	51.2	61.7
week3&4	61.5	74.7	59.4	70.8	57.3	67.9

Red is the best for raw scores **Green** is the best for SEC scores

MJO Correlation Skill for MJO index RMM1 and RMM2 and Bivariate Correlation Skill for MJO index (RMM1+RMM2)



Ice Area



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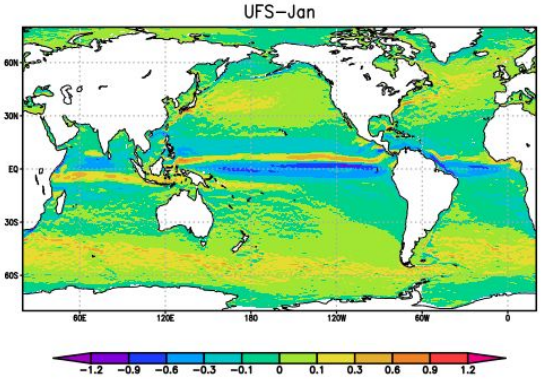
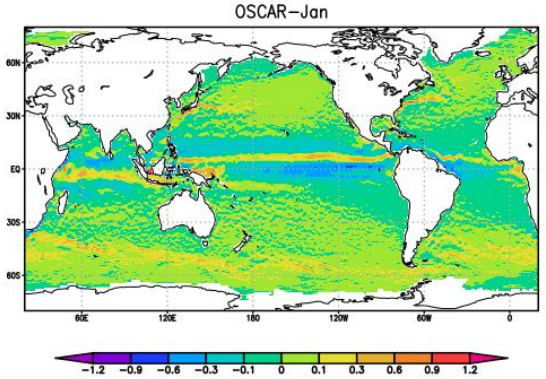
Sea Surface Currents

OSCAR

UFS

January





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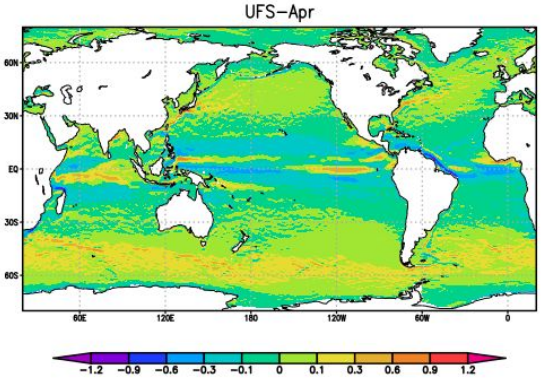
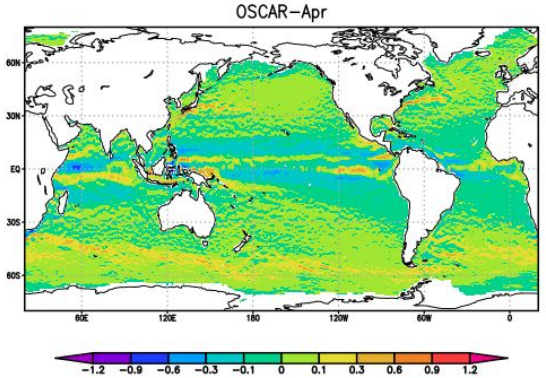




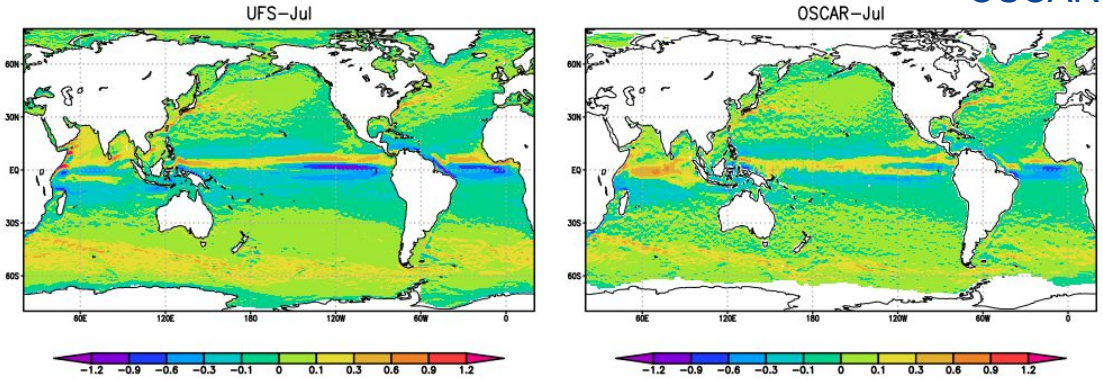
Sea Surface Currents

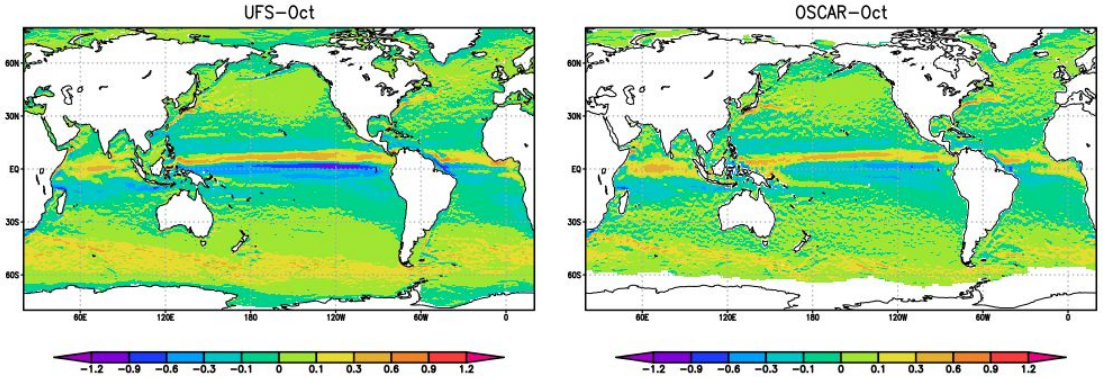
UFS

OSCAR

July

October



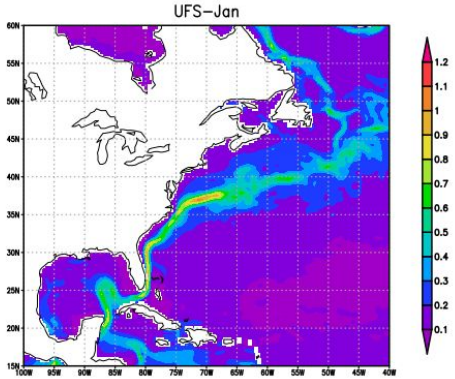


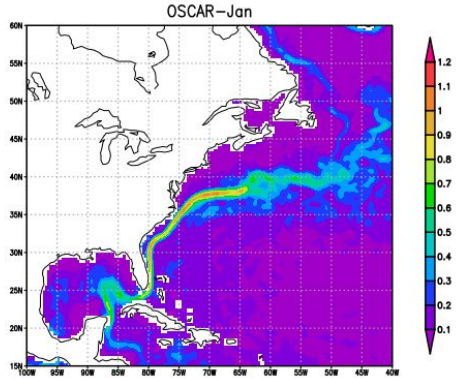
Gulf Stream (surface current speed)

UFS

OSCAR

January





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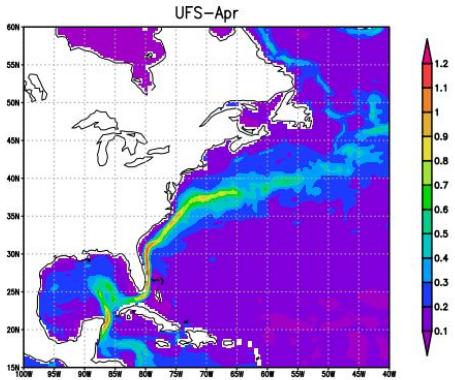

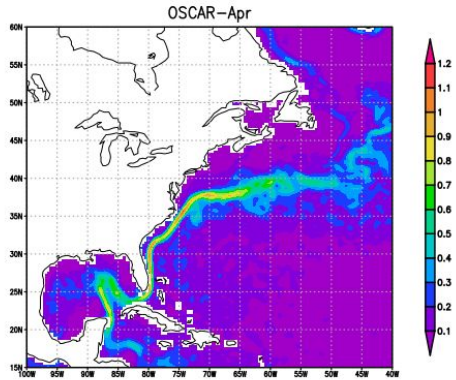

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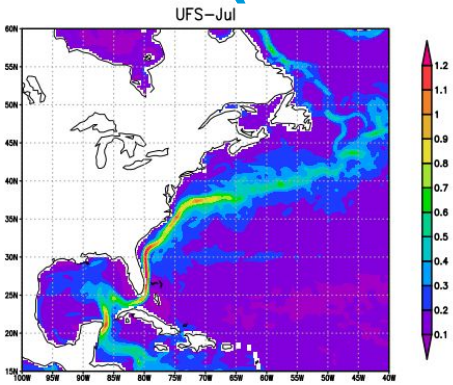
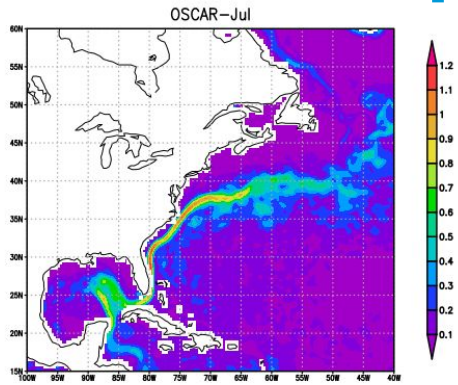
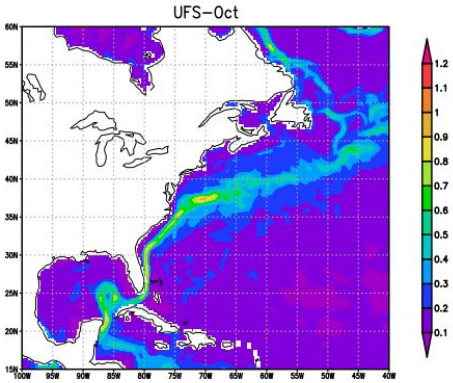
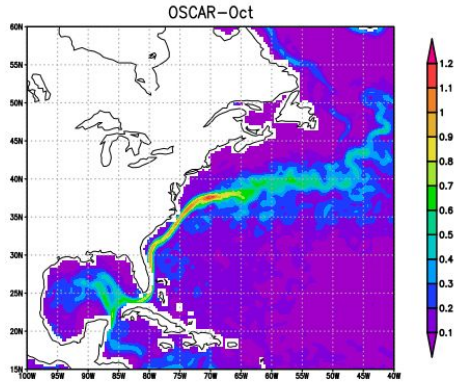




October





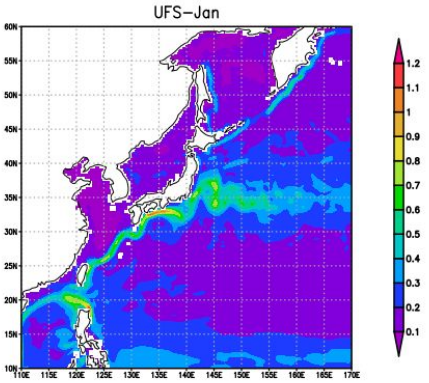
Kuroshio (surface current speed)

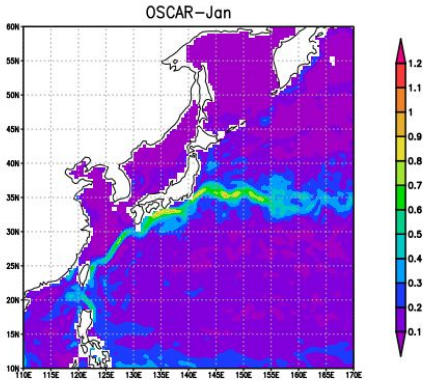
UFS

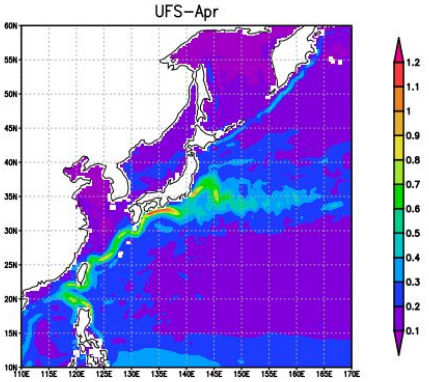
OSCAR

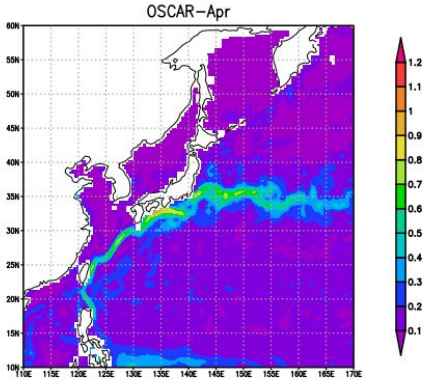
January

April









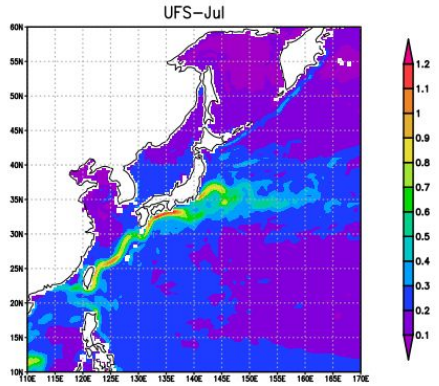
Kuroshio (surface current speed)

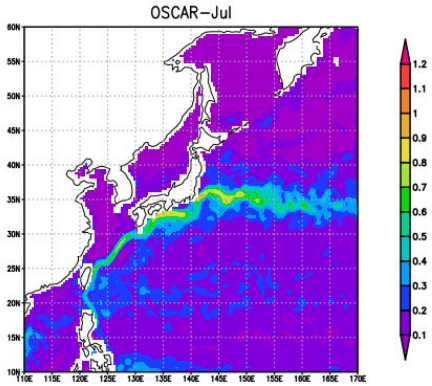
UFS

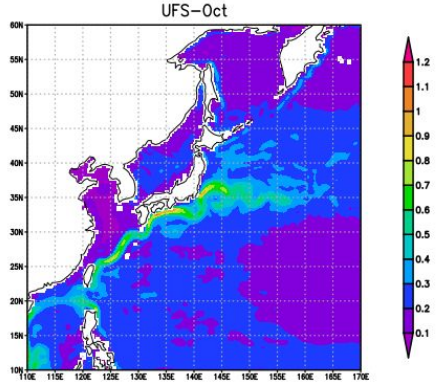
OSCAR

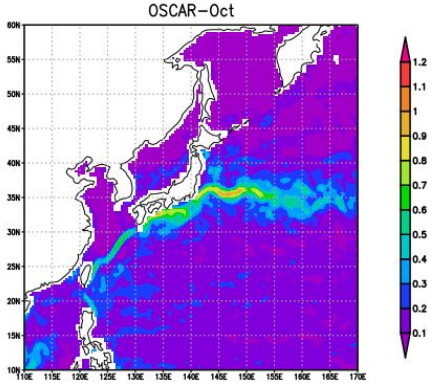
July

October









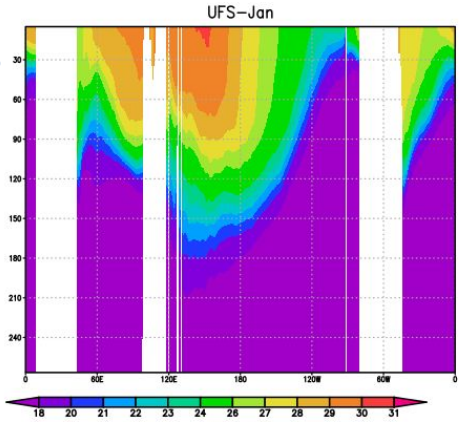
Thermocline (Temp. at Equator)

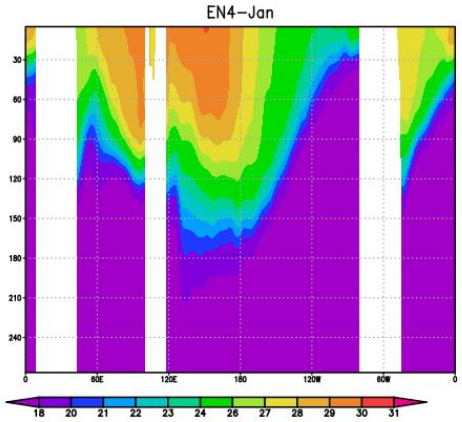
UFS

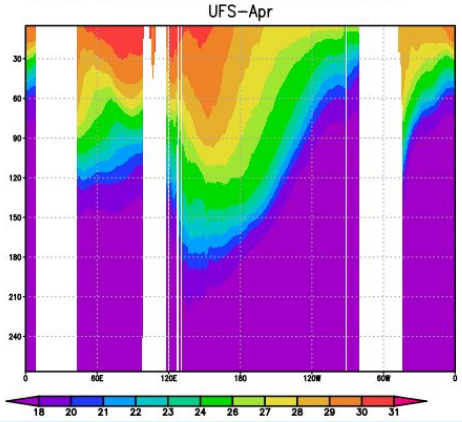
EN4

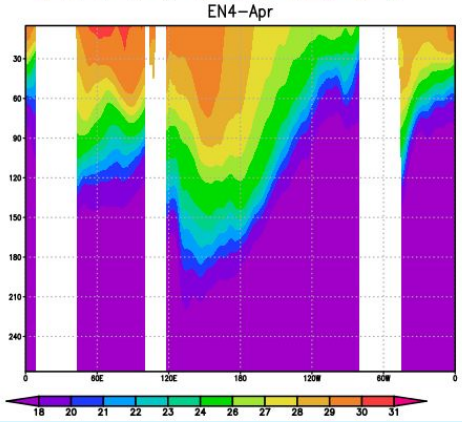
January

April









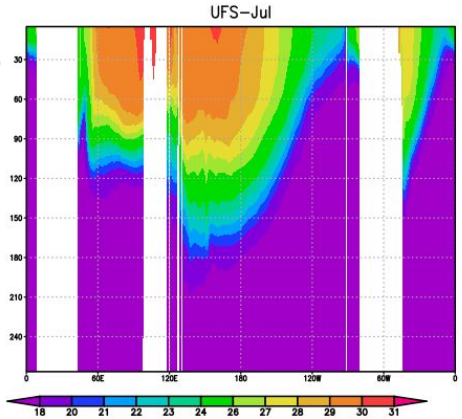
Thermocline (Temp. at Equator)

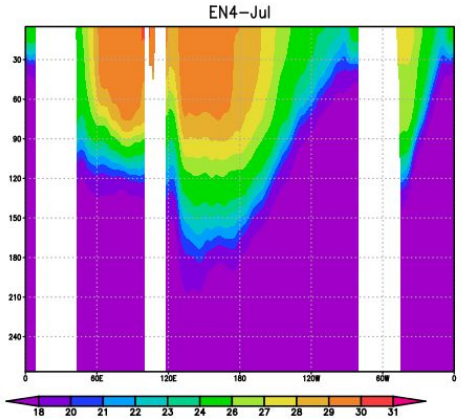
UFS

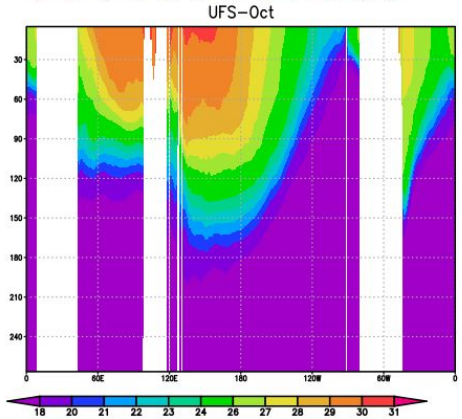
EN4

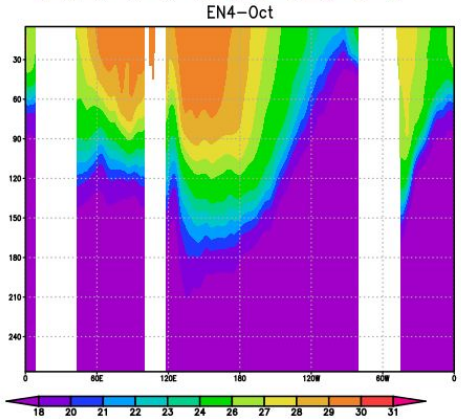
July

October





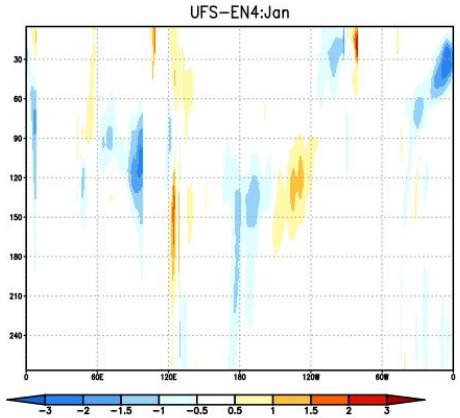


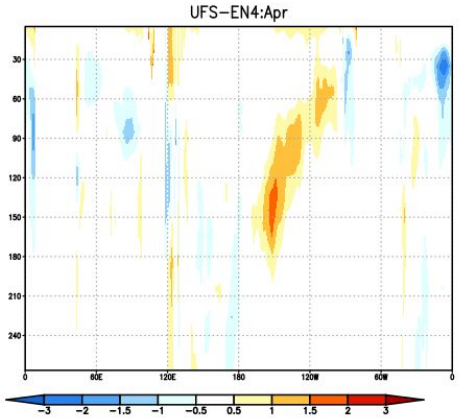


Thermocline (Temp. at Equator)

UFS-EN4

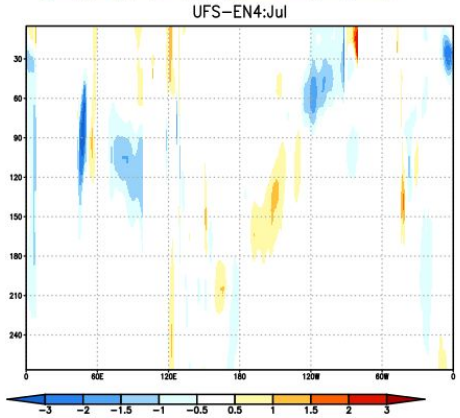
January

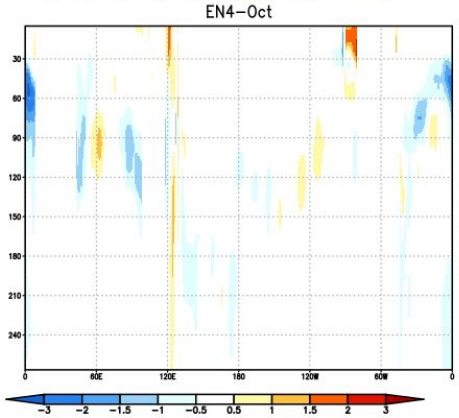




July

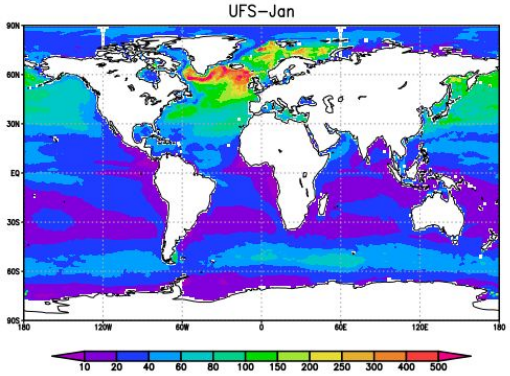
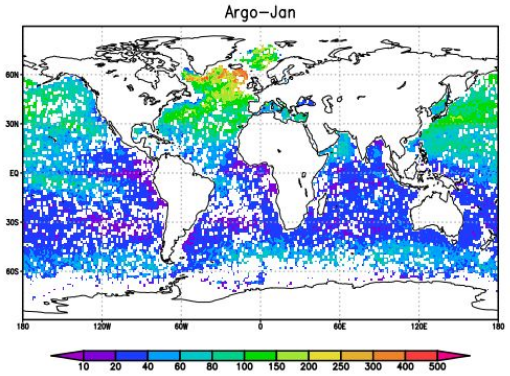
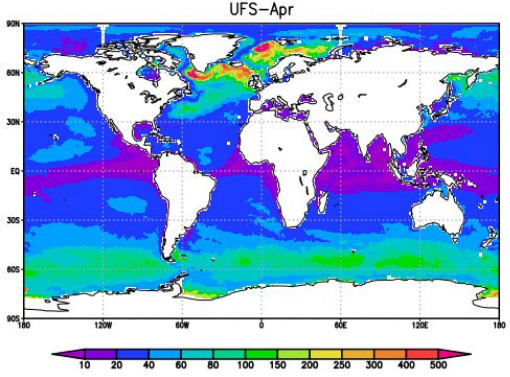
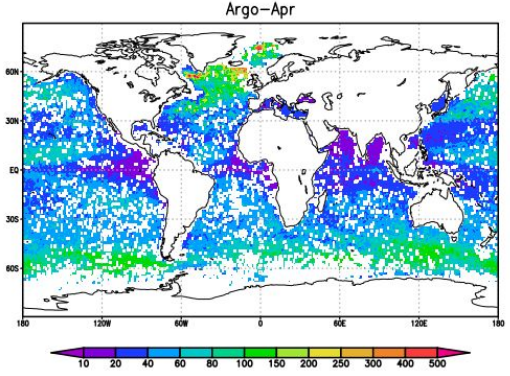
April



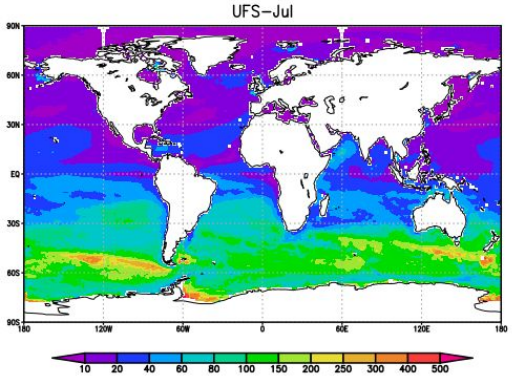
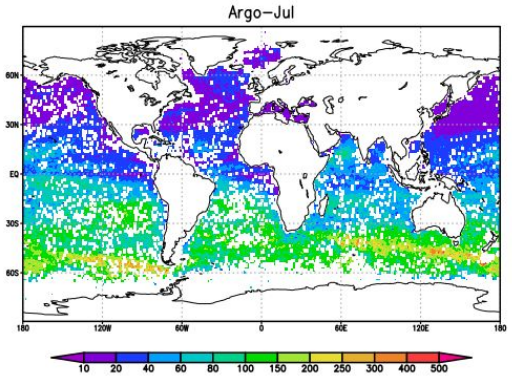
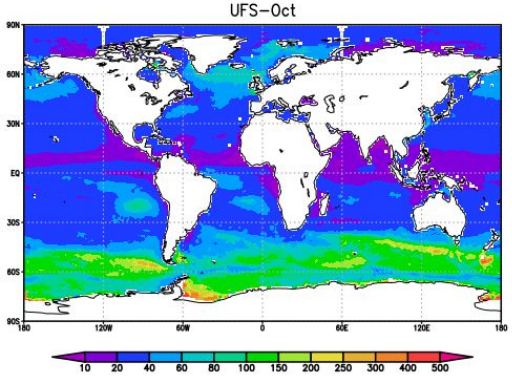
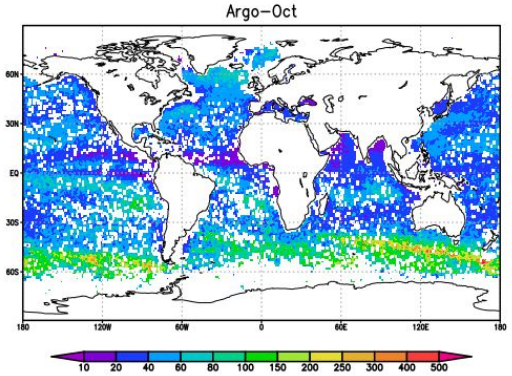


October

MLD v ARGO

	UFS	ARGO
January		
April		

MLD v ARGO

	UFS	ARGO
July		
October		

Summary of Results

- **UFS_p1**
  - Skill comparable to operational CFS (global and CONUS)
  - Skill in ice forecasts significantly better
- **UFS_p2**
  - Similar skill as UFS_p1 in atmosphere
  - Improved SST skill scores
- **UFS_p3**
  - Impact is restricted to polar regions, improvement of ice area
- **UFS_p4** (just completed, under evaluation)
  - Motivation is to improve air-sea interaction with inclusion of sea-state dependent roughness length to the atmosphere and sea-state dependent Langmuir mixing in the ocean.

Future Work

- CMEPS mediator
- CICE6 ice model
- Atmosphere:
  - Fractional grid
  - GFSv16 physics with 127L
- Physics tuning
- Data assimilation