National Weather Service

Ocean Color Data Assimilation in NOAA NCEP's Unified Forecast System (UFS)

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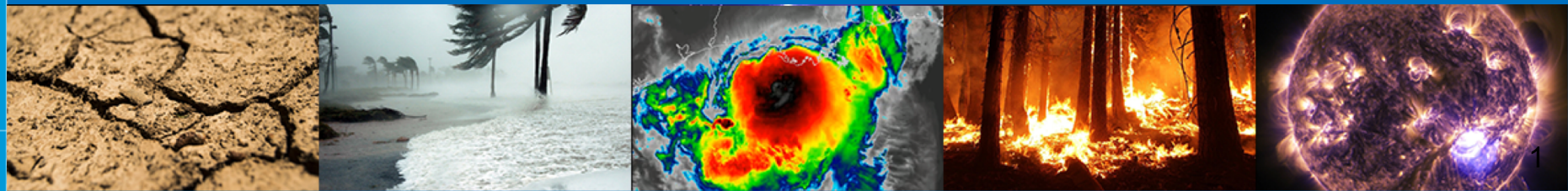
NOCCG Seminar, October 26, 2022



Acknowledgement

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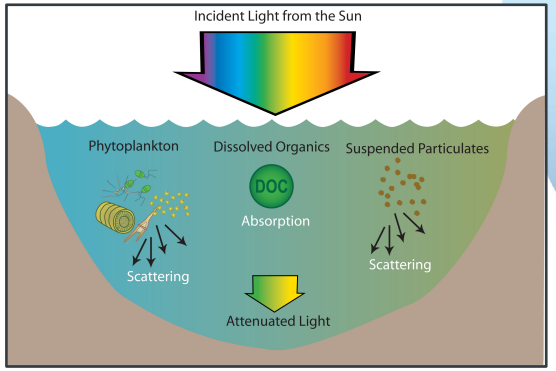
OAR/GFDL: John Dunne
UFS and JEDI active developers and communities

Outline

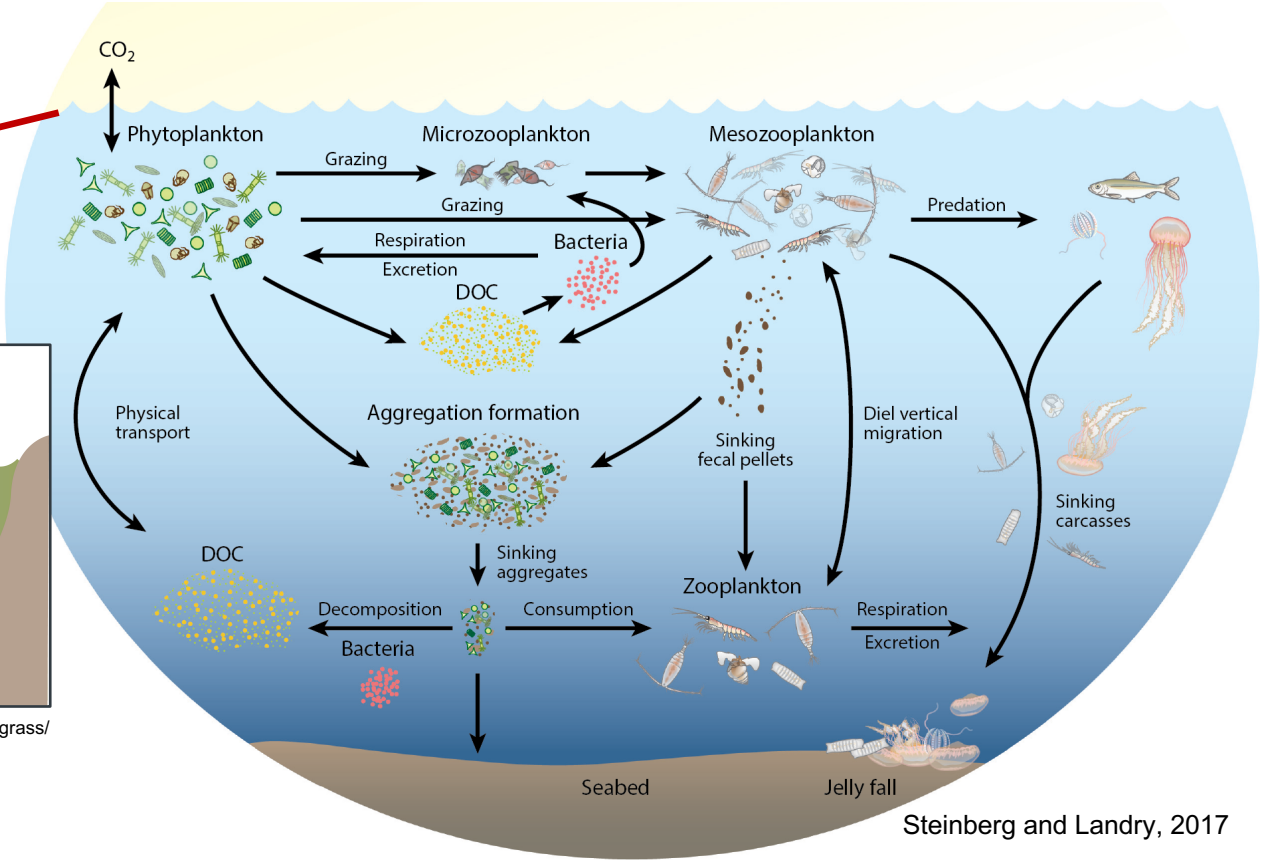
- Why considering ***ocean color*** in NCEP's operational models?
- Intro to NCEP/EMC's JPSS-PGRR (FY21-23) Project
- NCEP's Unified Forecast System (UFS) MRW-S2S application:
  I. Model system structure
  II. Coupled ocean physical-biogeochemical modeling (MOM6-BLING)
  III. Weakly coupled marine data assimilation with ocean color
- *Preliminary results*:
  I. UFS marine initialization experiments
  II. Ocean biogeochemical impact on SST predictions
  III. 3DVAR vs. EnVAR background-error covariance

Ocean biophysical feedback – light penetration

Light penetration and radiative heating is sensitive to water constituents, e.g. phytoplankton

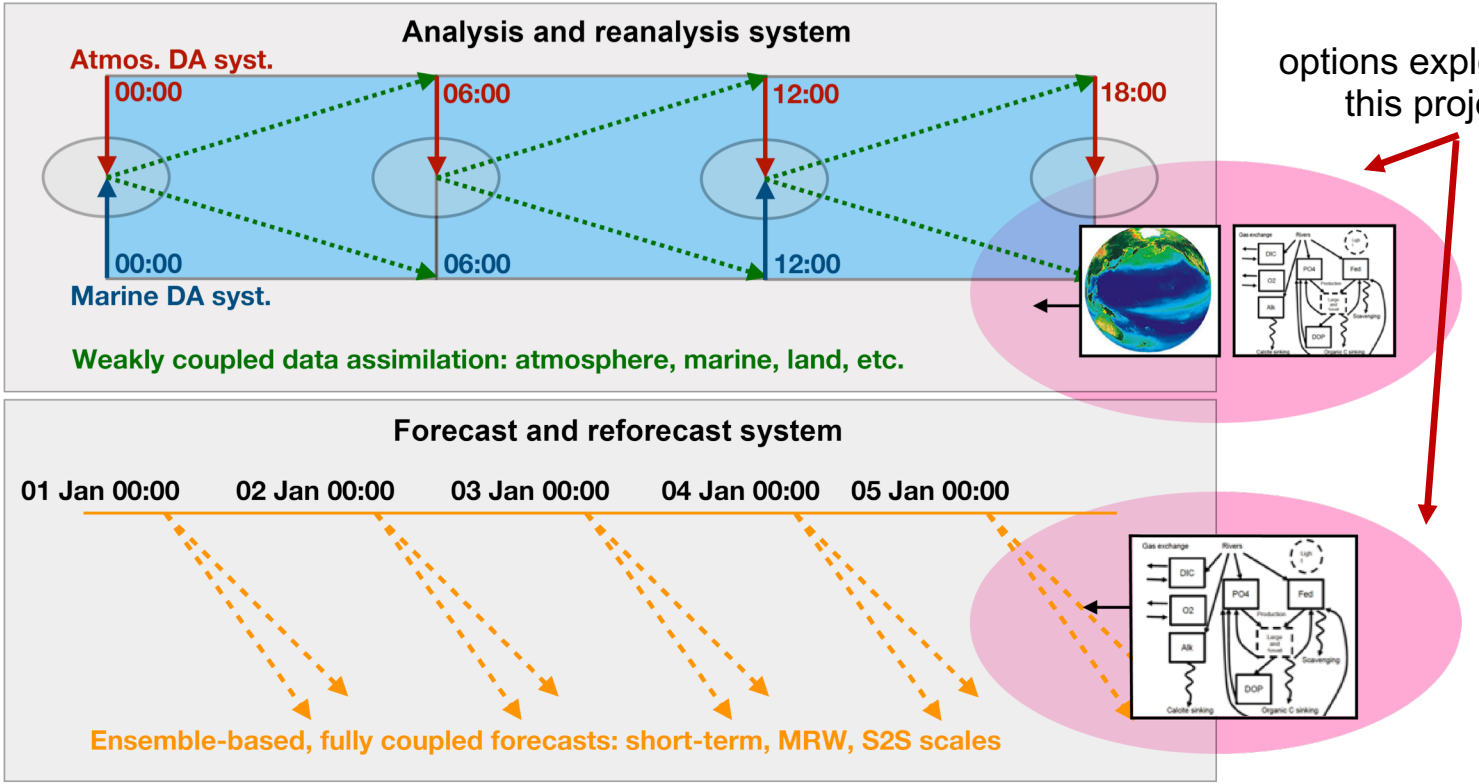


https://ecosystemsontheedge.org/underwater-light-and-seagrass/



Steinberg and Landry, 2017

NCEP's coupled weather forecast models



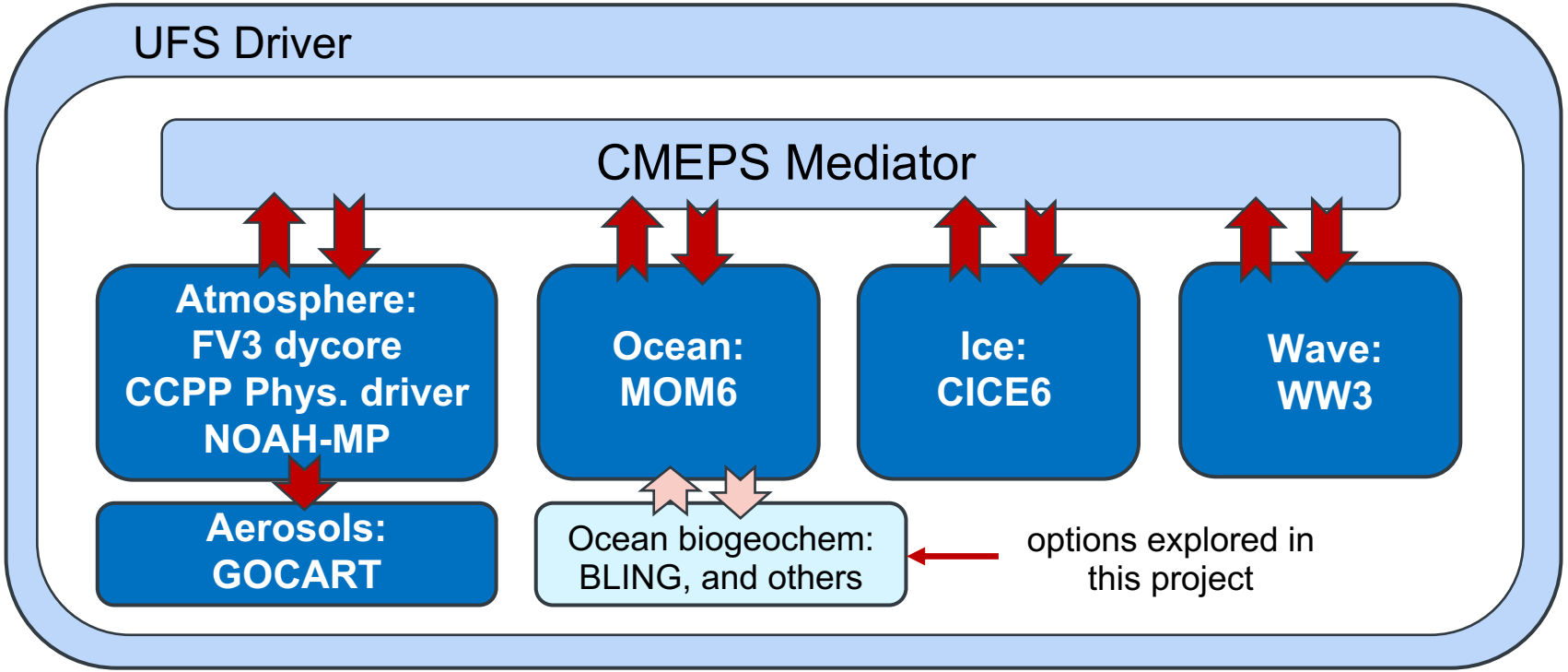
Schematic of an operational, coupled weather forecast system. For illustration purpose only. Adapted from Fig. 1 in Saha *et al.*, 2010.

JPSS-PGRR FY21-23 "Implementation of ocean biogeochemical modeling and ocean color data assimilation in the Unified Forecast System in support of NCEP's MRW, S2S, and ecological predictions"

The **overarching goals** of this project are to …

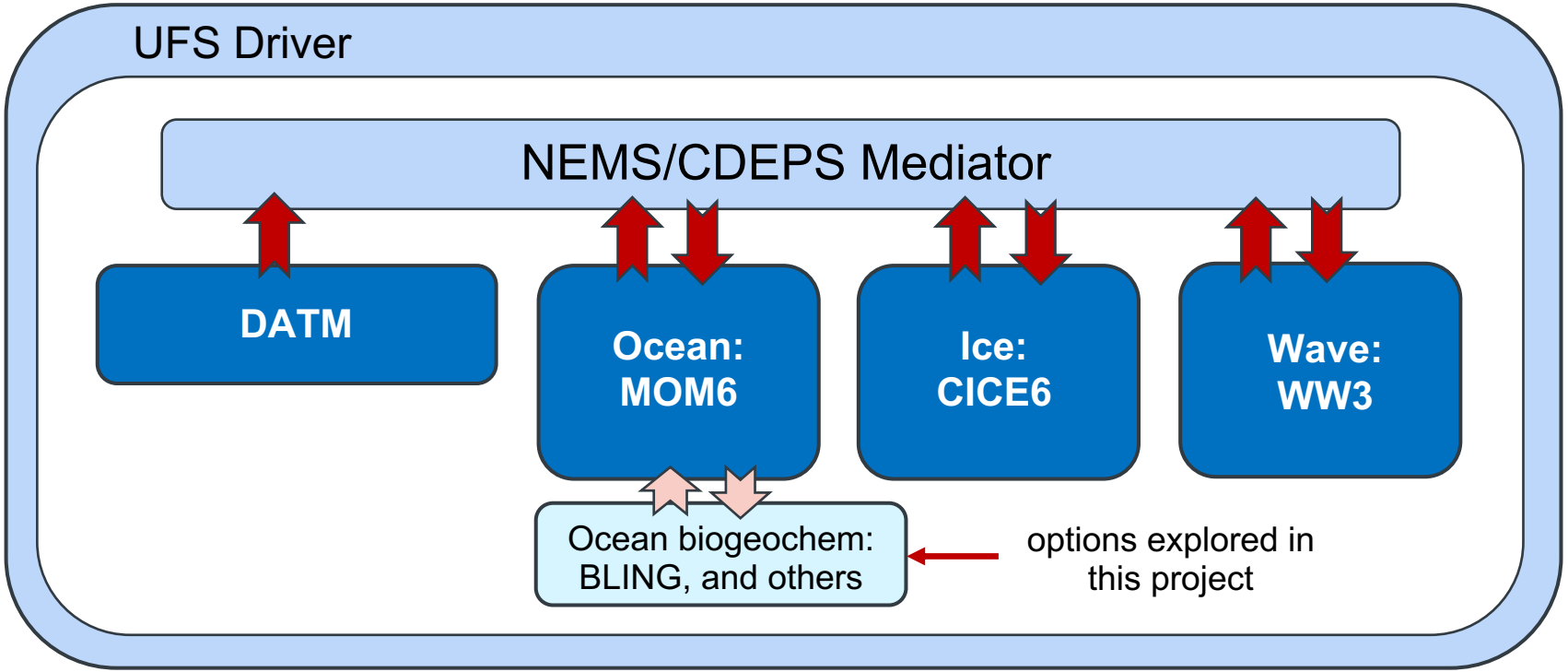
- Support NOAA/NCEP's **operational weather forecasts** at subseasonal-to-seasonal (S2S) scales by improving ocean state initialization through the ingestion of near real-time ocean biogeochemical data and the integration of biophysical feedback in the marine component of the UFS;
- Start building NOAA/NCEP's **ecological forecast capabilities** for monitoring critical changes and "tipping points" in coastal ecosystems.

UFS MRW-S2S application prototype 8
Global coupled model configuration



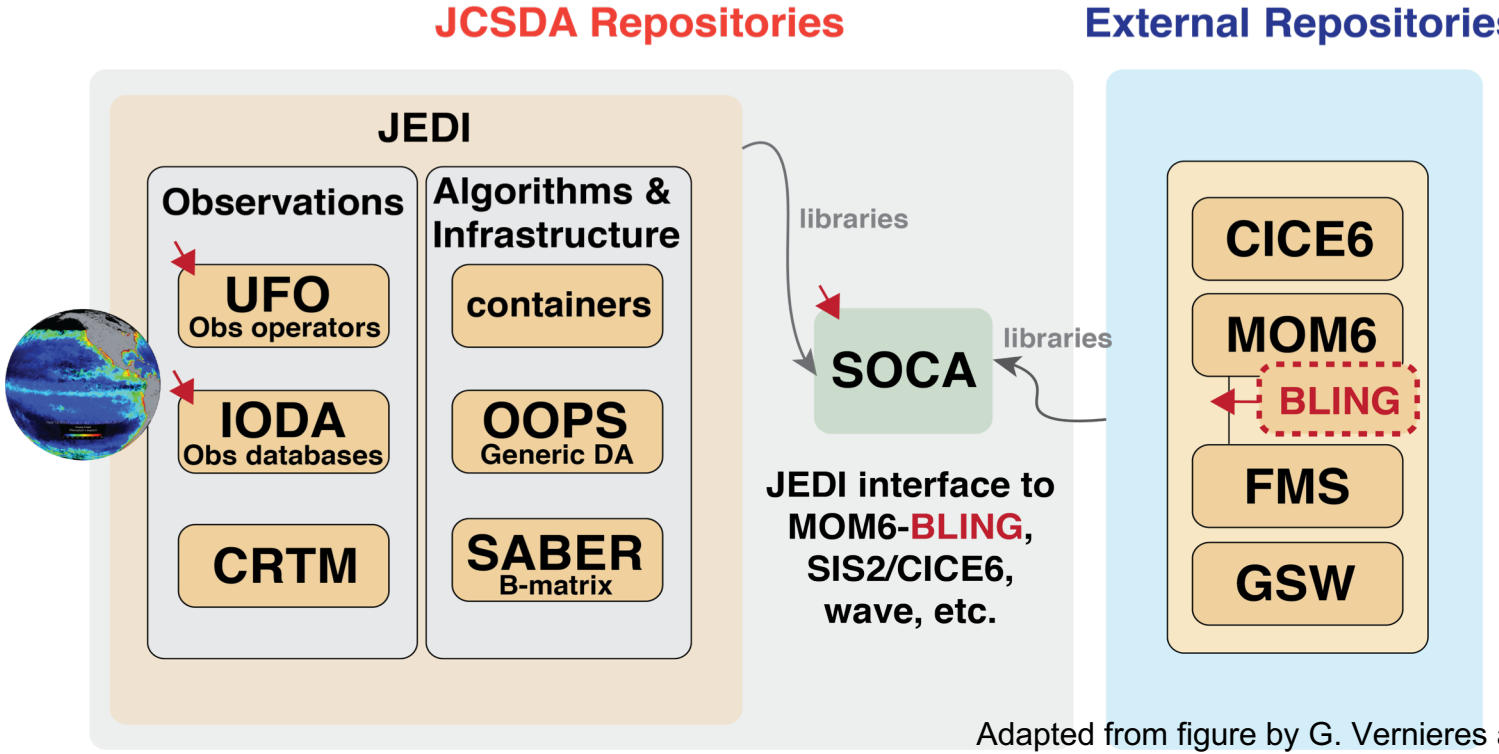
Adapted from figure by Global UFS-coupled team

UFS MRW-S2S application prototype 8
DATM component for weakly coupled marine DA



Adapted from figure by Global UFS-coupled team

Weakly coupled marine DA based on Joint Effort for Data assimilation Integration (JEDI) SOCA Project



Adapted from figure by G. Vernieres and JEDI team

$BLING_{v2}$ – Biogeochemistry with Light Iron Nutrient and Gas

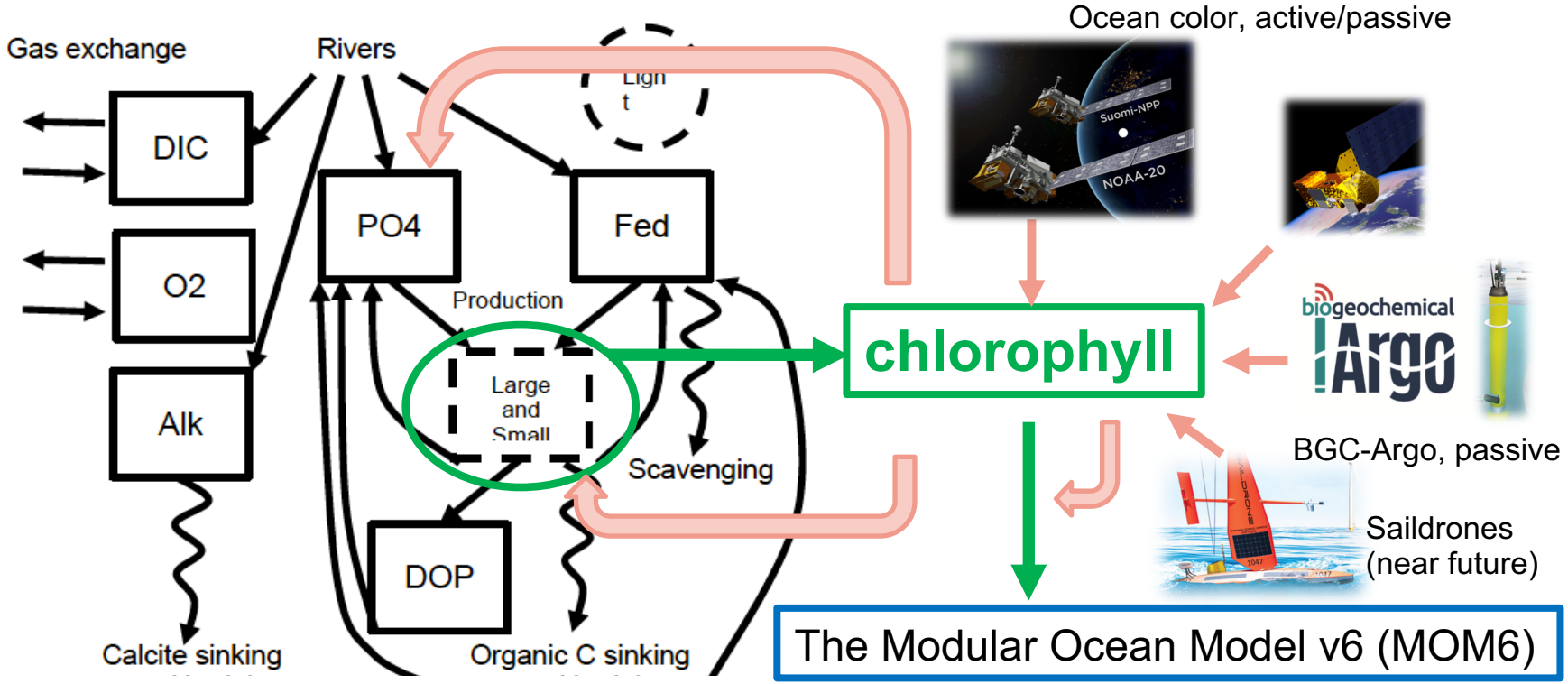


Figure. Simplified model schematic of BLINGv2 ocean biogeochemical model (Dunne *et al*., 2020)

Ocean Sea-ice Retrospective Observation Database

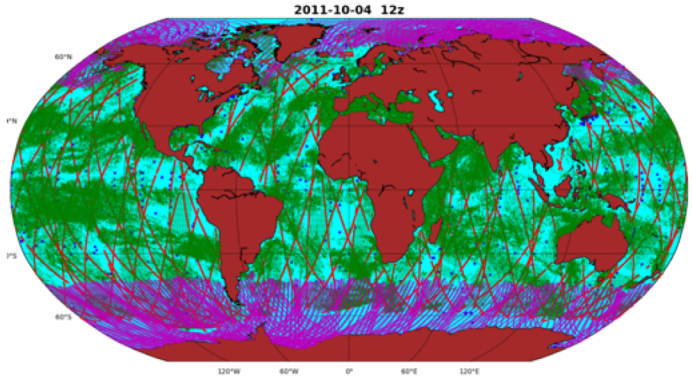
Insitu (T, S, u, v)		
Instrument	Platforms	Provider
Too many to list	TAO,PIRATA, RAMA, Argo, XBT, CTD	NOAA/NCEI
Argos and GPS tracked	drifting buoys	GDP
GPS trackers	Track OB	GODAE/FNMOC
GPS trackers	Track OB	
Too many to list	Drifting and Moored BUOY, CMAN, ERI and Hull of the ship, Bucket	
Too many to list	TESAC, Fixed and Moored BUOY, Argo	
Too many to list	TESAC, Fixed and Moored BUOY, Argo	

MW (sst, sss, ice concentration)		
Instrument	Satellite	Provider
SAR L-band	GPM (SMAP)	NASA/JPL
MIRAS	SMOS	ESA
SSMIS	DMSP F-17, F-18	NSIDC
...		

IR (sst)		
Instrument	Satellite	Provider
AVHRR	MetOp-A	GRHSST
AVHRR	MetOp-B	
AVHRR	MetOp-C	
AVHRR	NOAA-18	
AVHRR	NOAA-19	
VIIRS	Suomi-NPP	
VIIRS	NOAA-20	

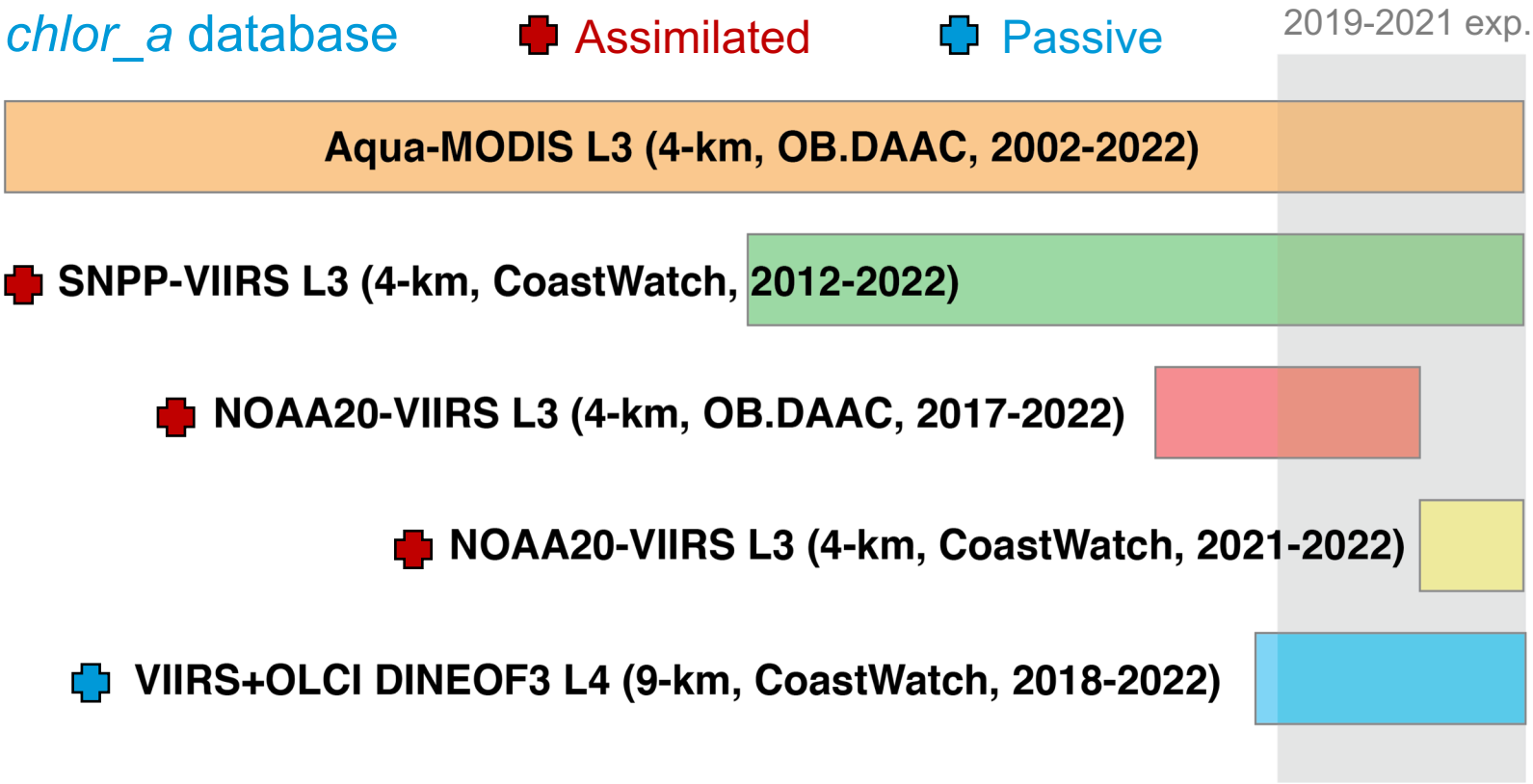
Altimeter (ADT, freeboard)		
Instrument	Satellite	Provider
SARAL	Cryosat-2	RADS
Poseidon-3	Jason-2	
Poseidon-3	Jason-3	
SARAL	Sentinel-3	
Poseidon-4	Jason-CS / Sentinel-6	
ALtiKa/Argos-3	SARAL	
All	All	Copernicus

Example of ocean & seaice observation coverage



Slide credit: G. Vernieres et al.

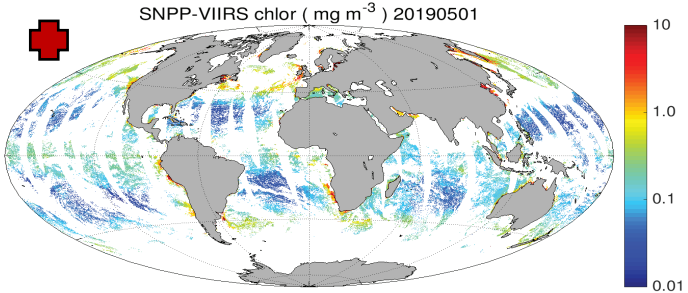
Ocean Sea-ice Retrospective Observation Database



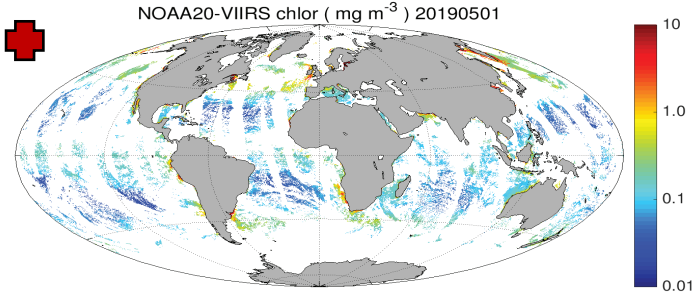
Ocean Sea-ice Retrospective Observation Database

chlor_a database Assimilated Passive

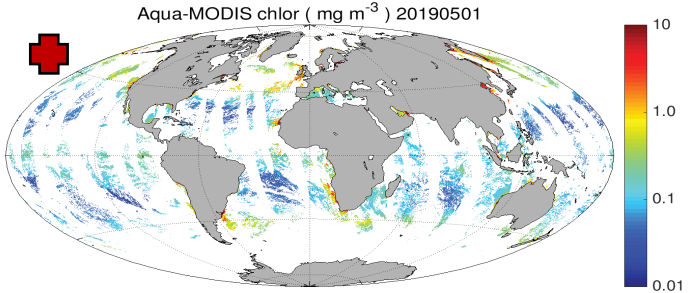
1) SNPP-VIIRS Chlor_a



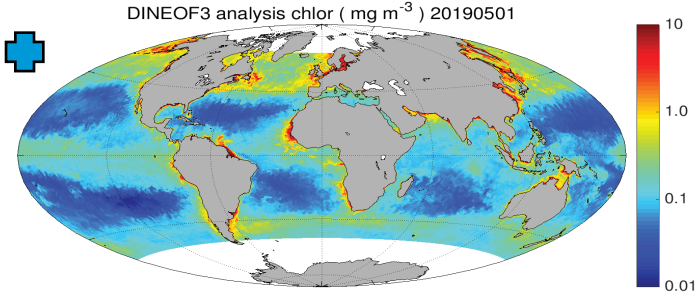
2) NOAA20-VIIRS Chlor_a



3) Aqua-MODIS Chlor_a



4) DINEOF3 (VIIRS+OLCI) Chlor_a

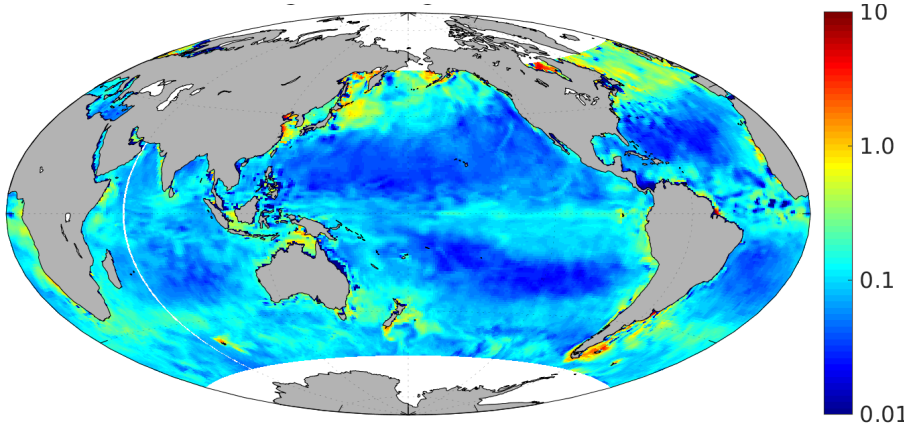


Example of daily ocean color observations ingested in data assimilation (05/01/2019)

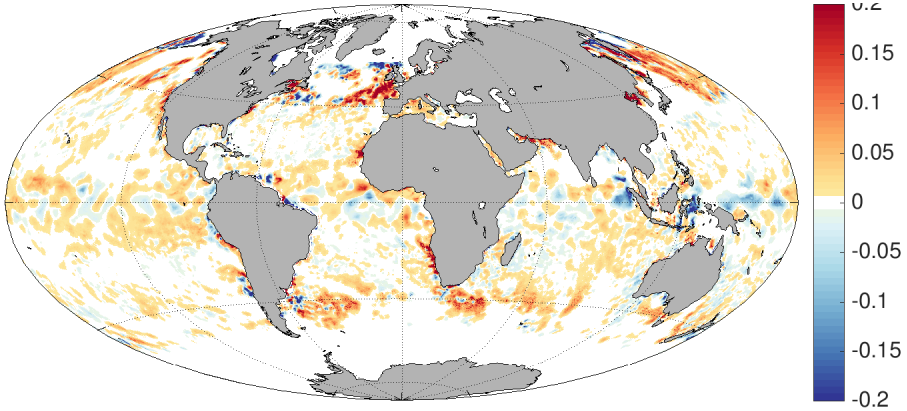
0.25° global ocean reanalysis experiments

UFS *p8* DATM-MOM6-CICE6-BLING, *soca-science* 3DVAR, 2019-2022

a) Model background *chlor_a* (mg m^{-3})



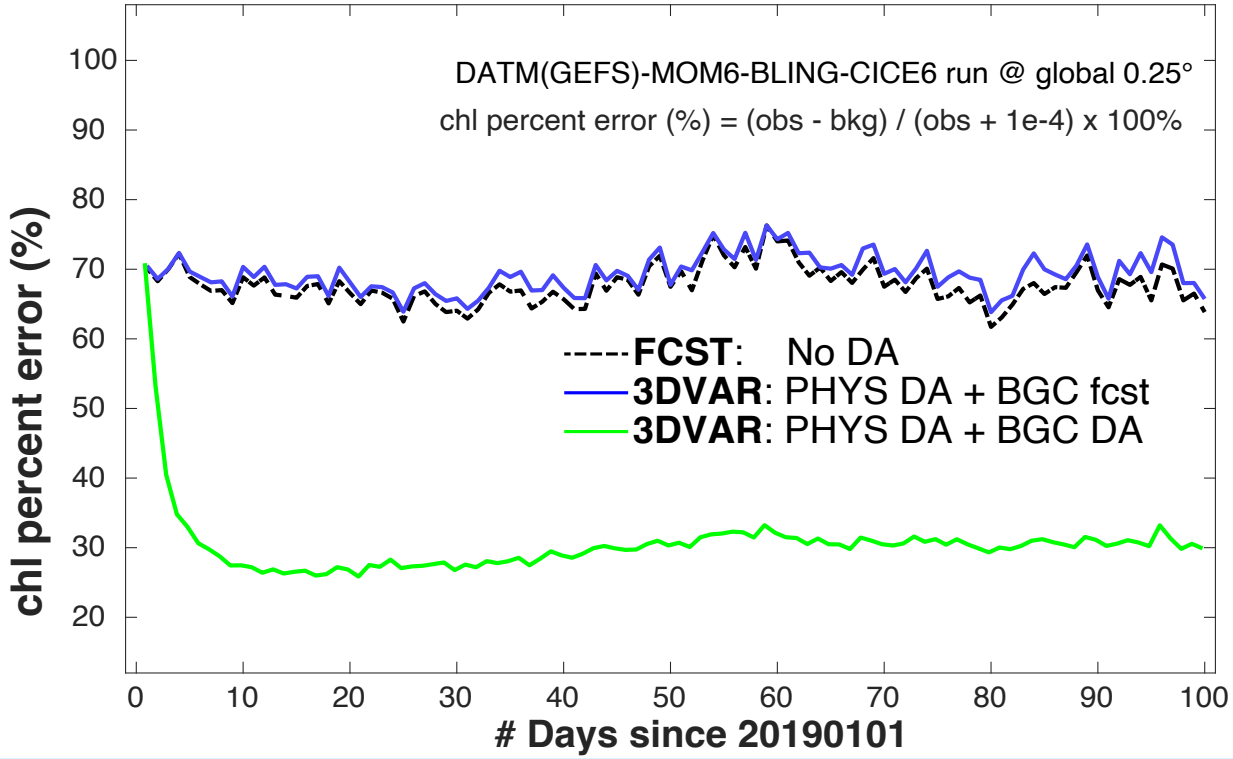
b) *chlor_a* increment (ana - bkg, mg m^{-3})



a) MOM6-BLING$_{v2}$ coupled ocean model simulated *chlor_a* concentration (snapshot of background at 12h, 05/01/2019) and b) *chlor_a* increment applied through data assimilation. *chlor_a* assimilation is based on Joint Effort for Data assimilation Integration (JEDI).

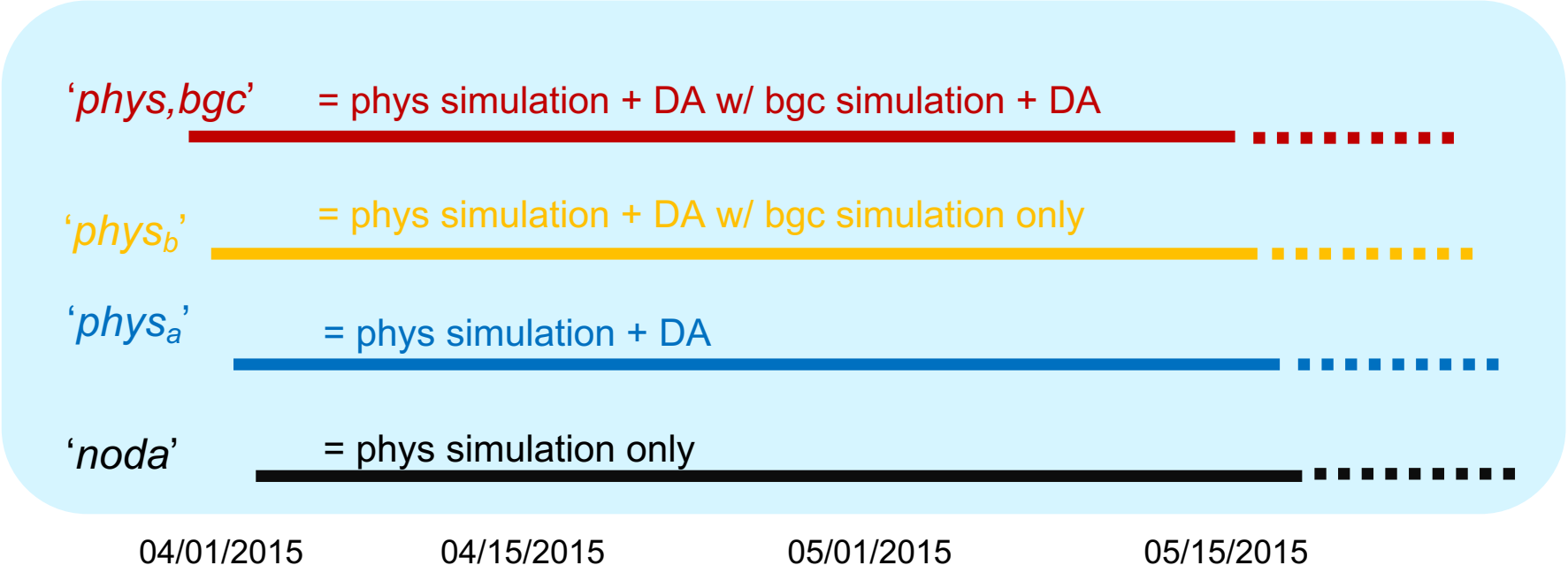
0.25° global ocean reanalysis experiments

UFS *p8* DATM-MOM6-CICE6-BLING, *soca-science* 3DVAR, 2019-2021



UFS prototype marine initialization (*p7c*, 2015 case)

Marine DA syst.

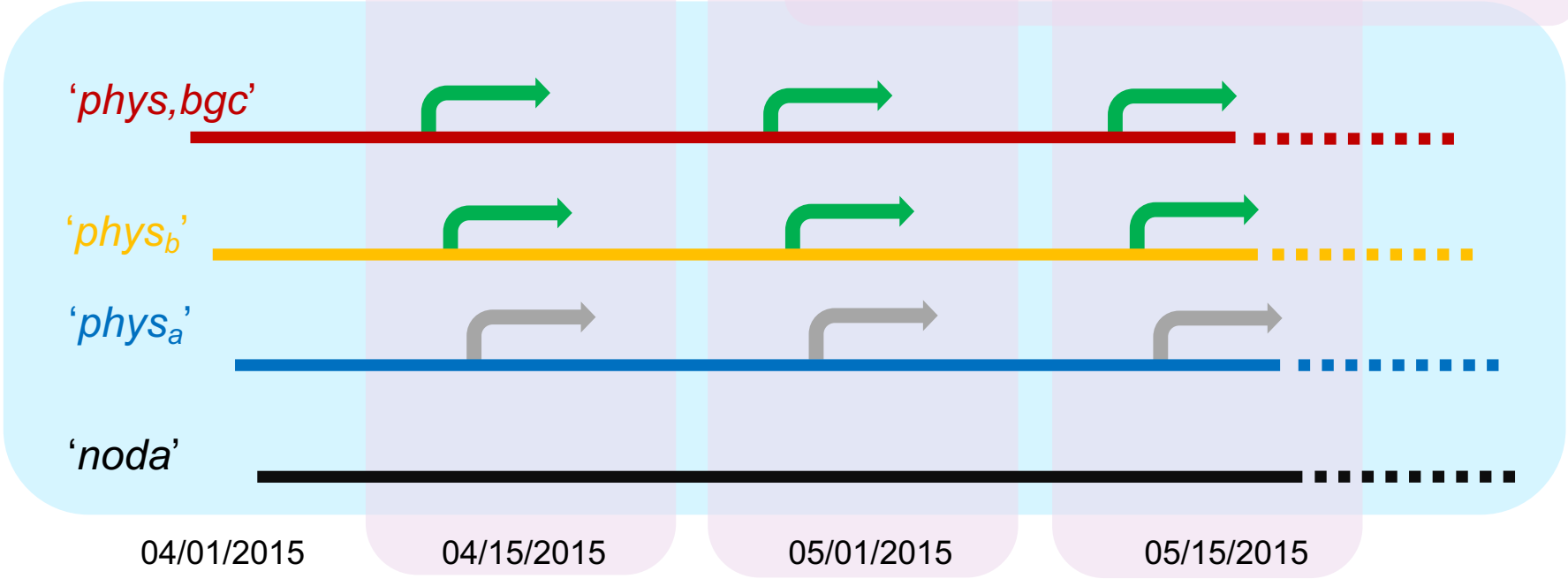


UFS prototype marine initialization (*p7c*, 2015 case)

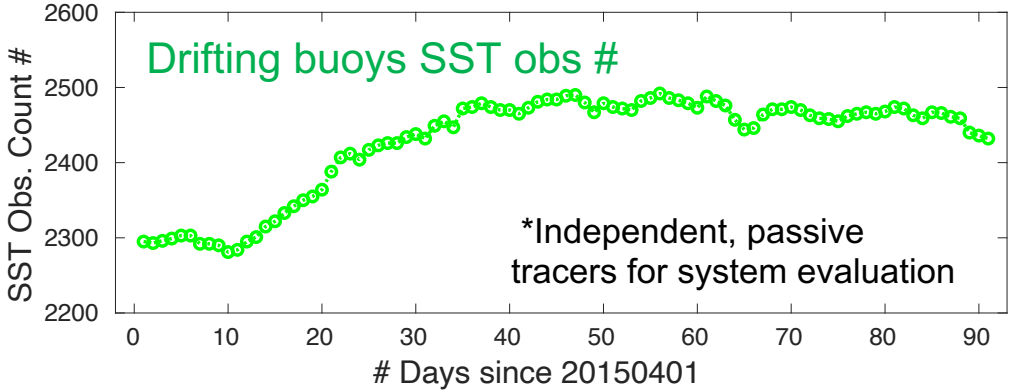
Marine DA syst.

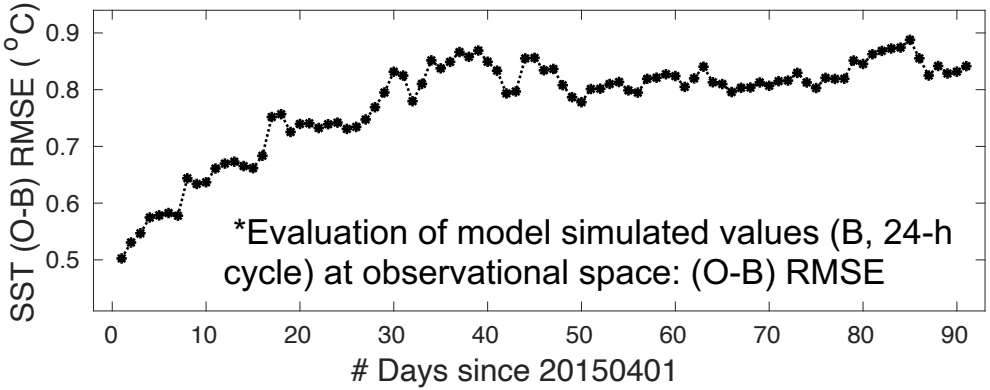
Coupled forecasts **'UFS_*phys* forecast'**

'UFS_*phys,bgc* forecast'



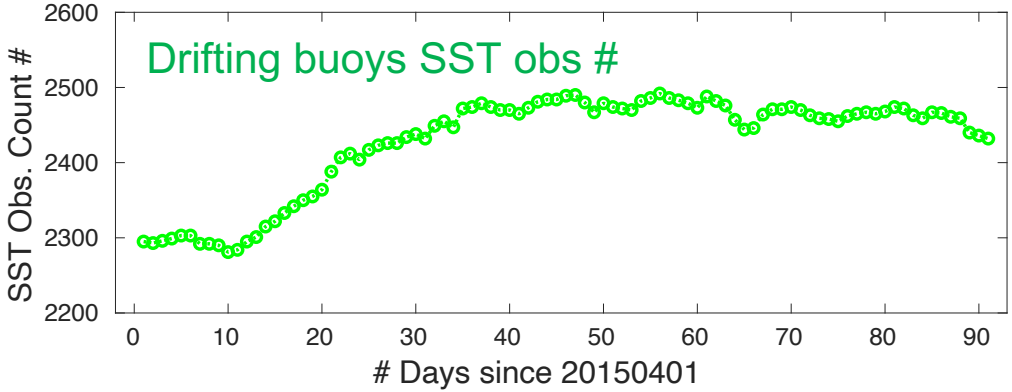
Prelim. results: 0.25° global ocean reanalysis (2015 case)

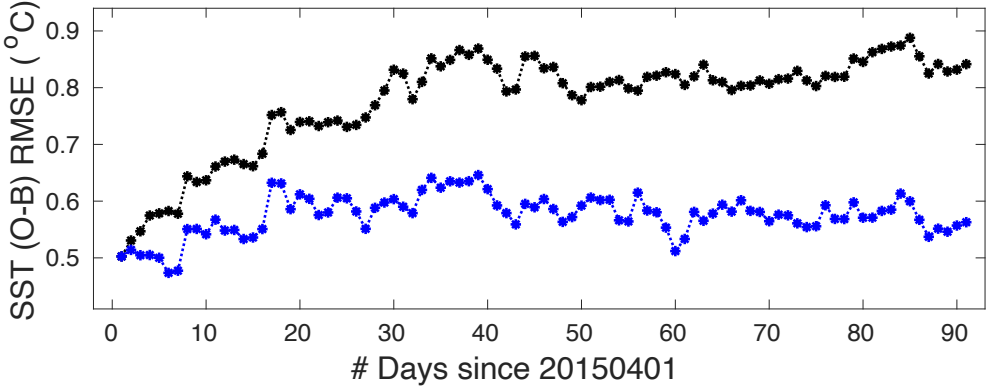




'noda'

Prelim. results: 0.25° global ocean reanalysis (2015 case)

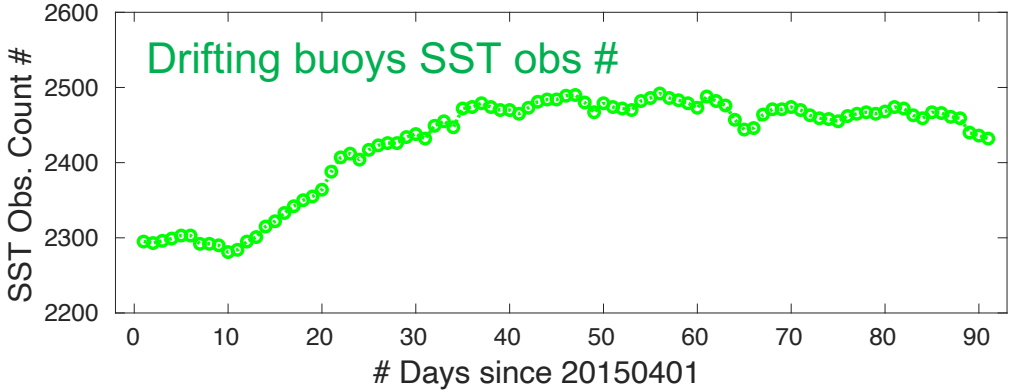


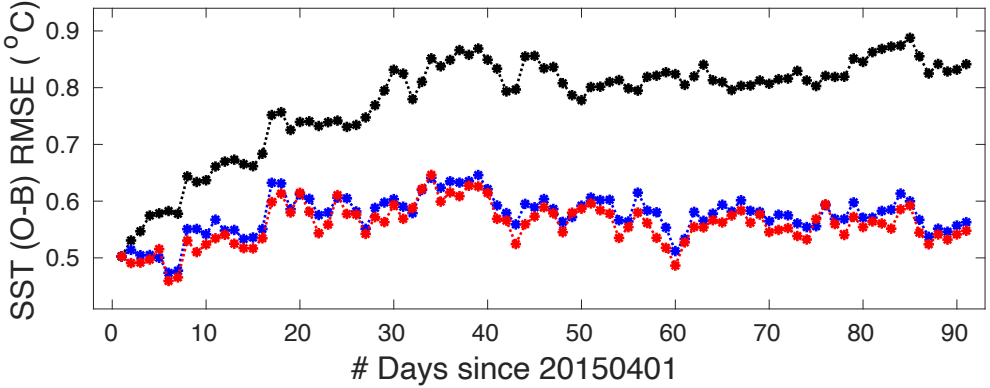


'noda'

'phys$_a$'

Prelim. results: 0.25° global ocean reanalysis (2015 case)





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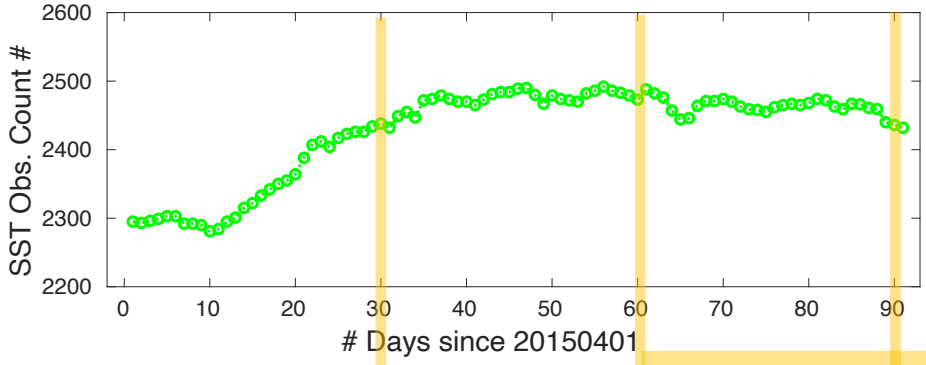
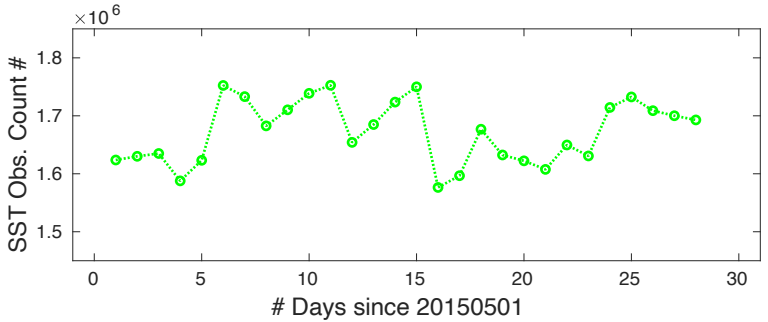
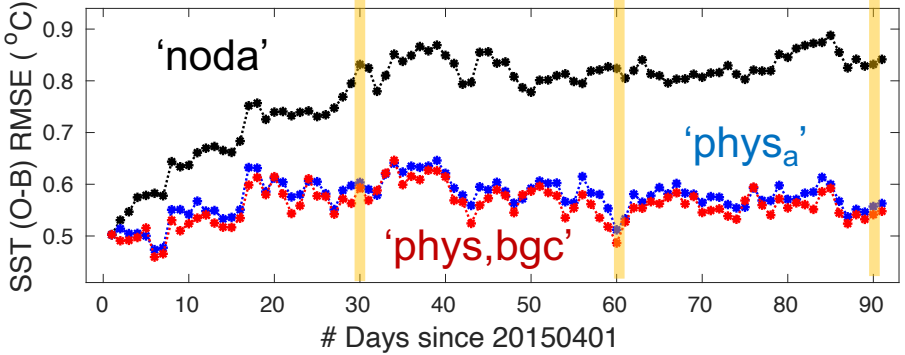
'$phys_a$'

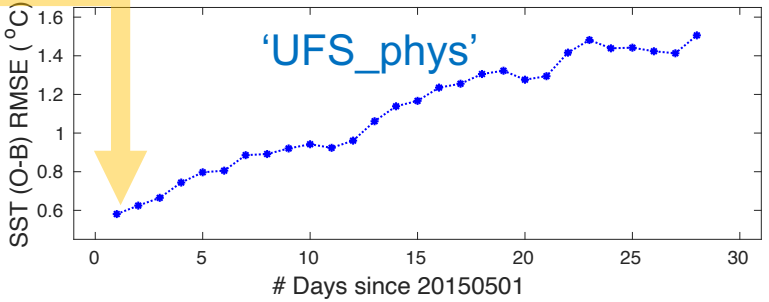
'phys,bgc'

Prelim. results: UFS marine initialization (2015 case)

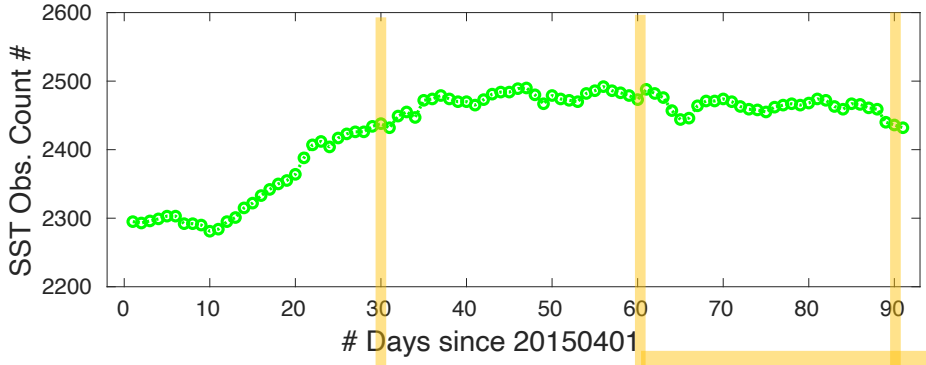


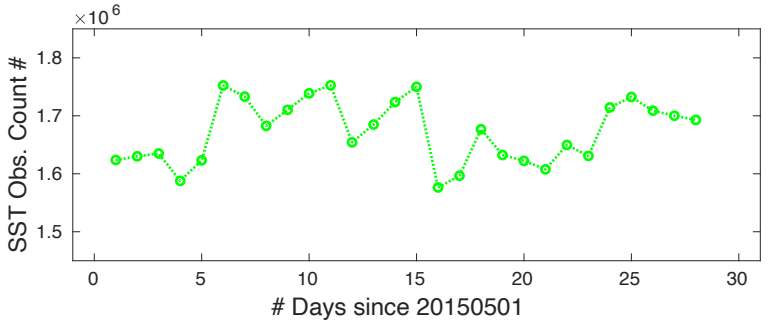


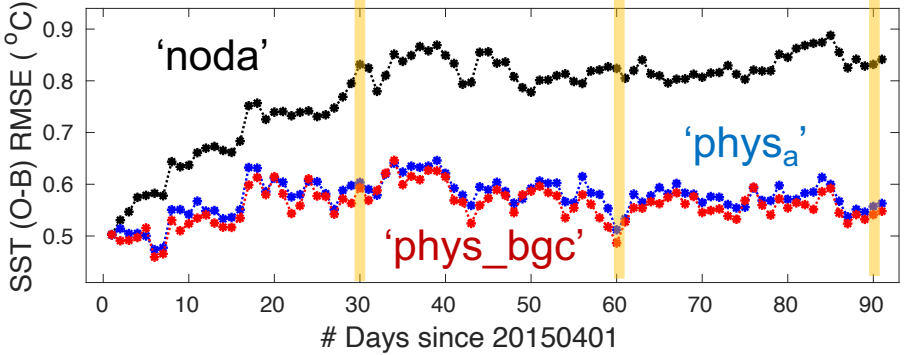


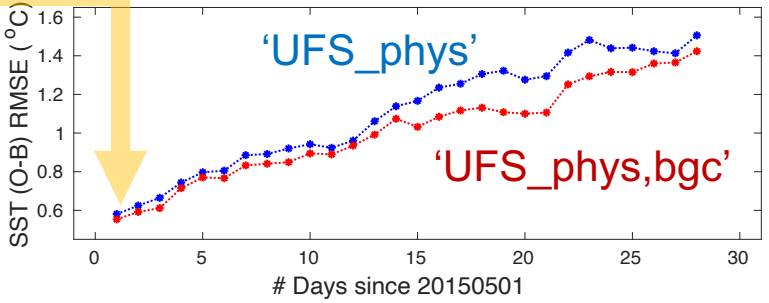


Prelim. results: UFS marine initialization (2015 case)









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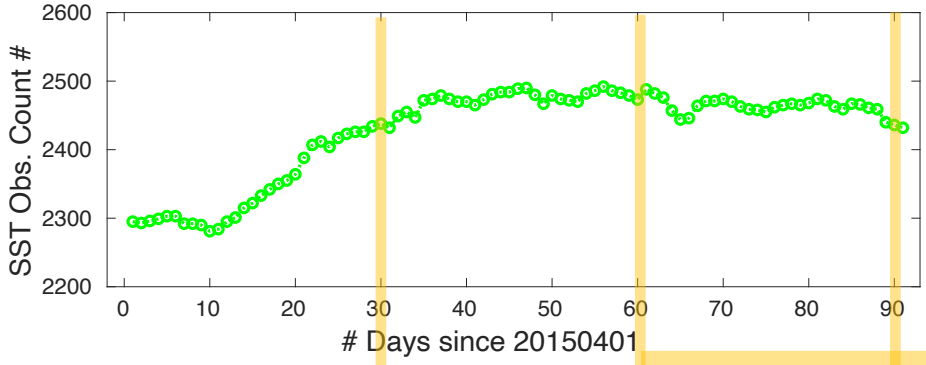
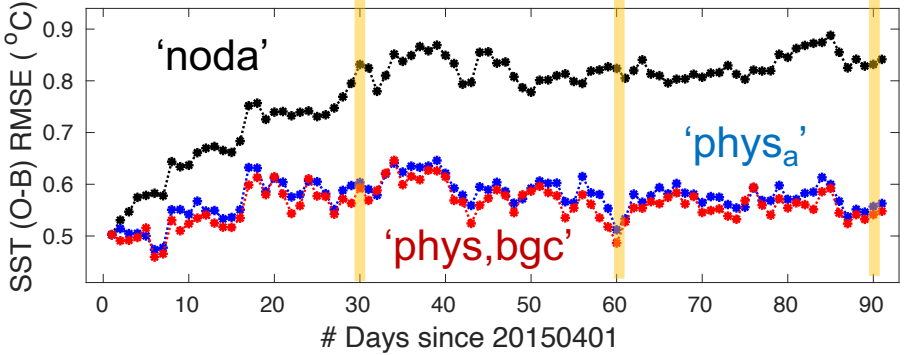
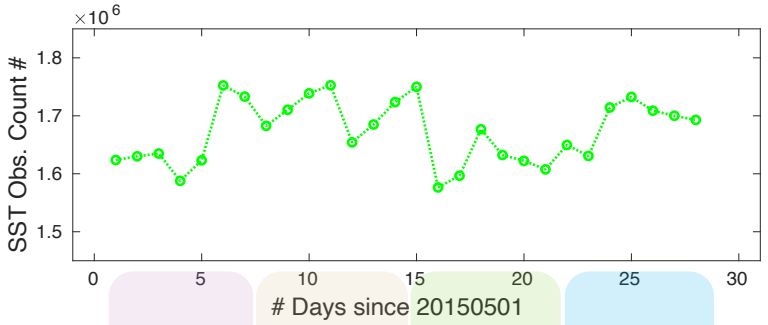
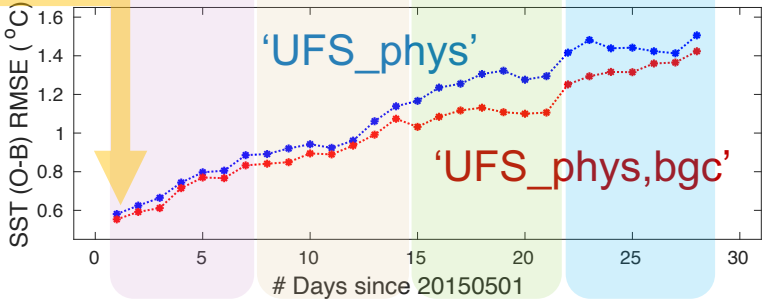


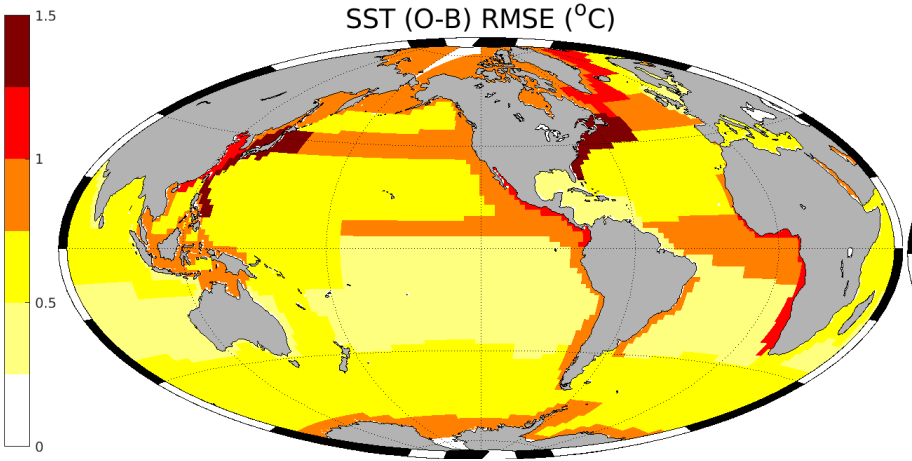


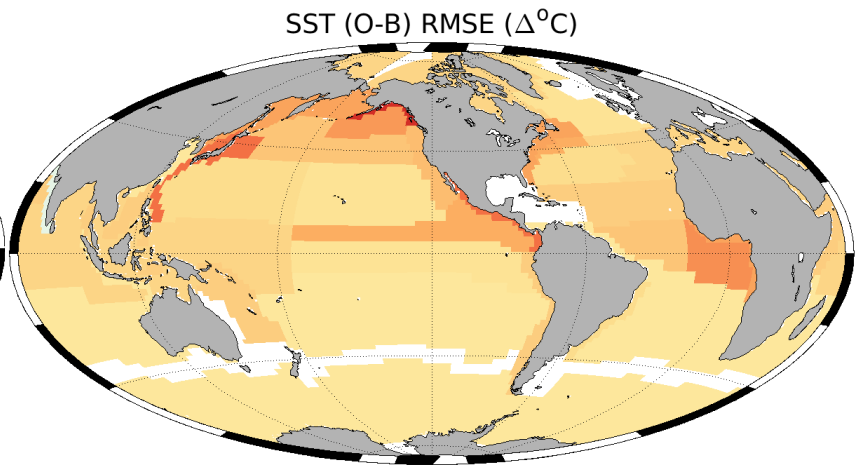




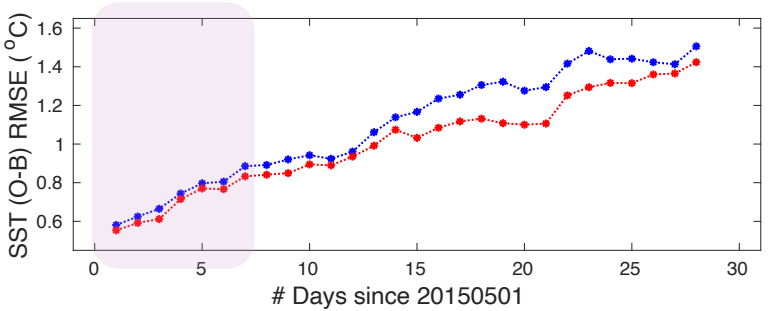
Regional variability – *Week1 SST prediction skill*

Improvement





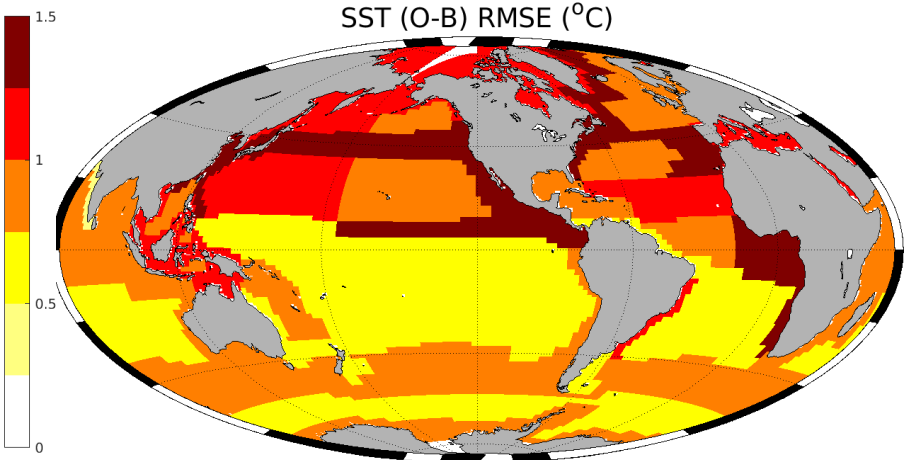
Degradation

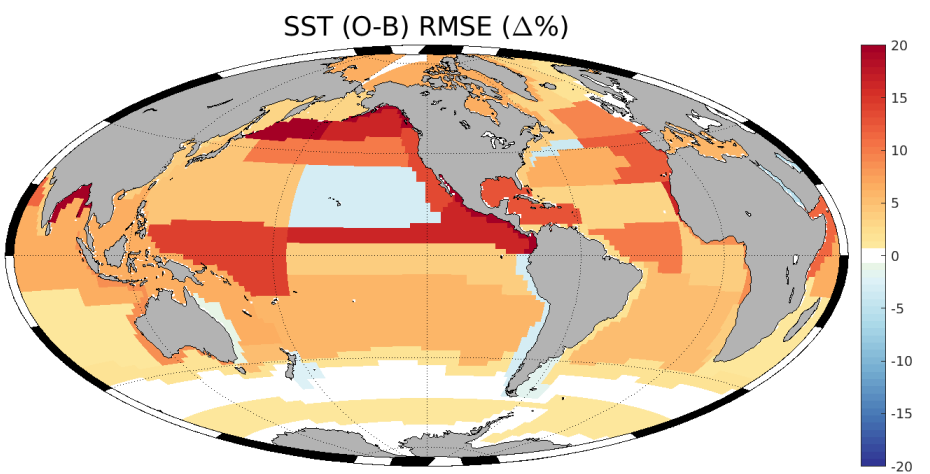


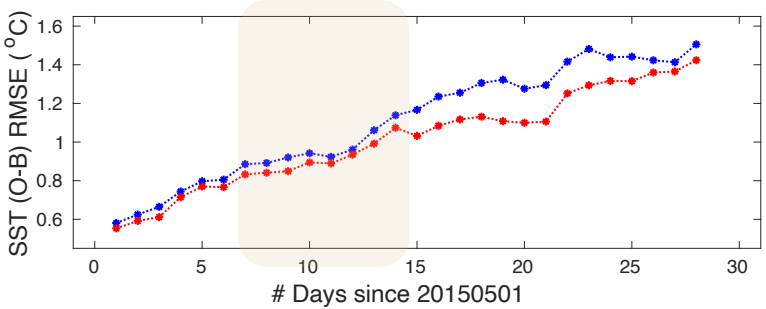
*The global ocean is separated into 56 provinces for statistical analyses according to Longhurst (2007).

Regional variability – *Week2 SST prediction skill*

Improvement





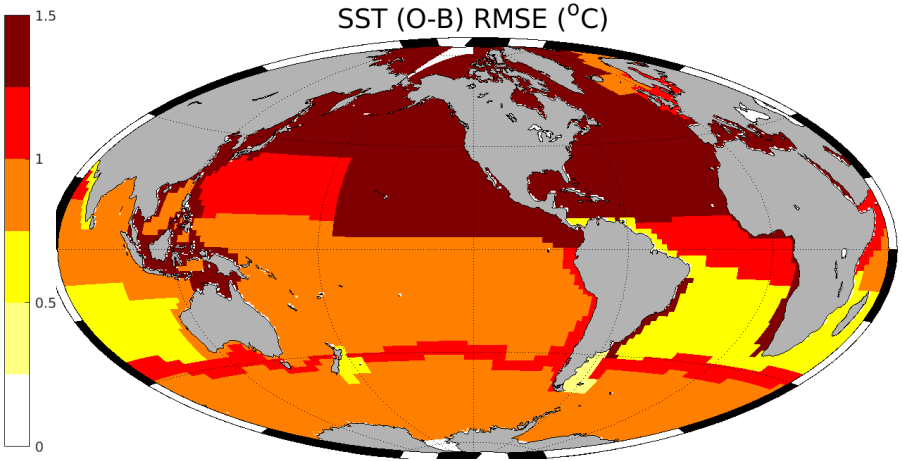


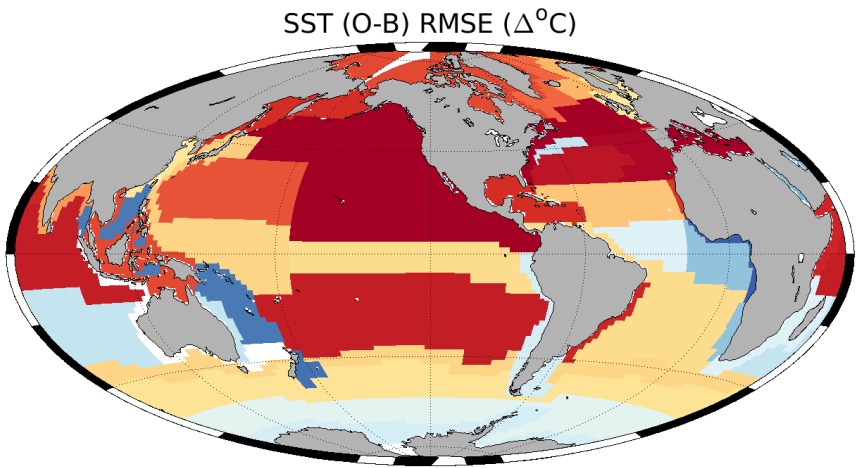
Degradation

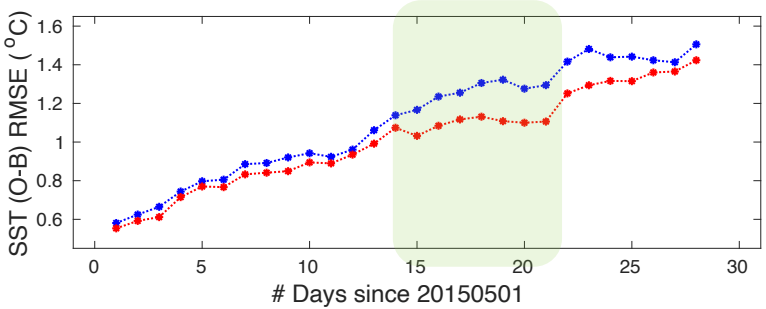
*The global ocean is separated into 56 provinces for statistical analyses according to Longhurst (2007).

Regional variability – *Week3 SST prediction skill*

Improvement





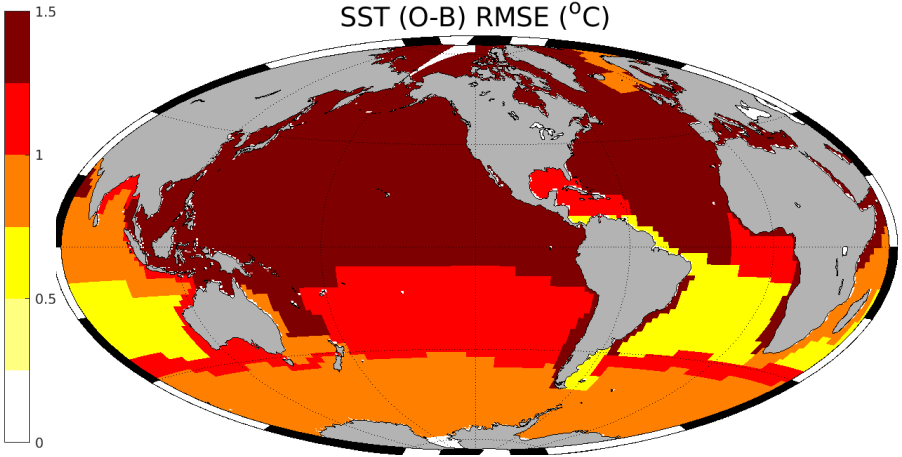


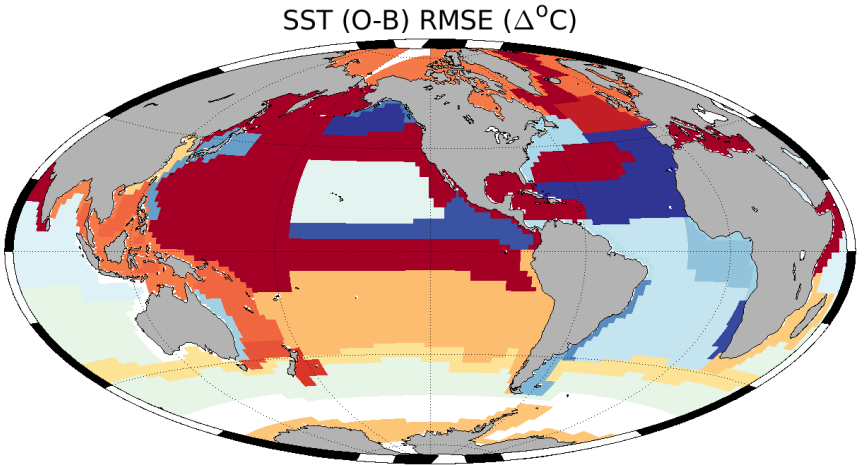
Degradation

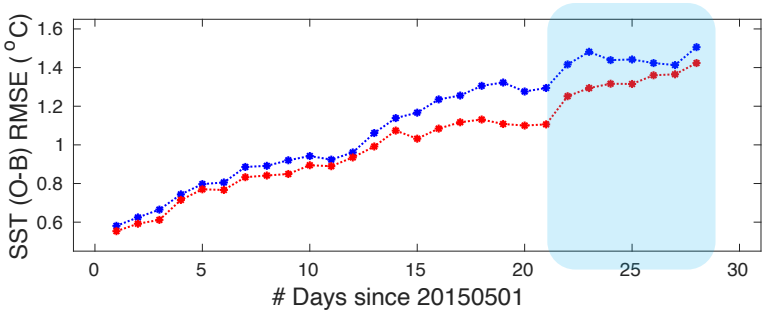
*The global ocean is separated into 56 provinces for statistical analyses according to Longhurst (2007).

Regional variability – *Week4 SST prediction skill*

Improvement







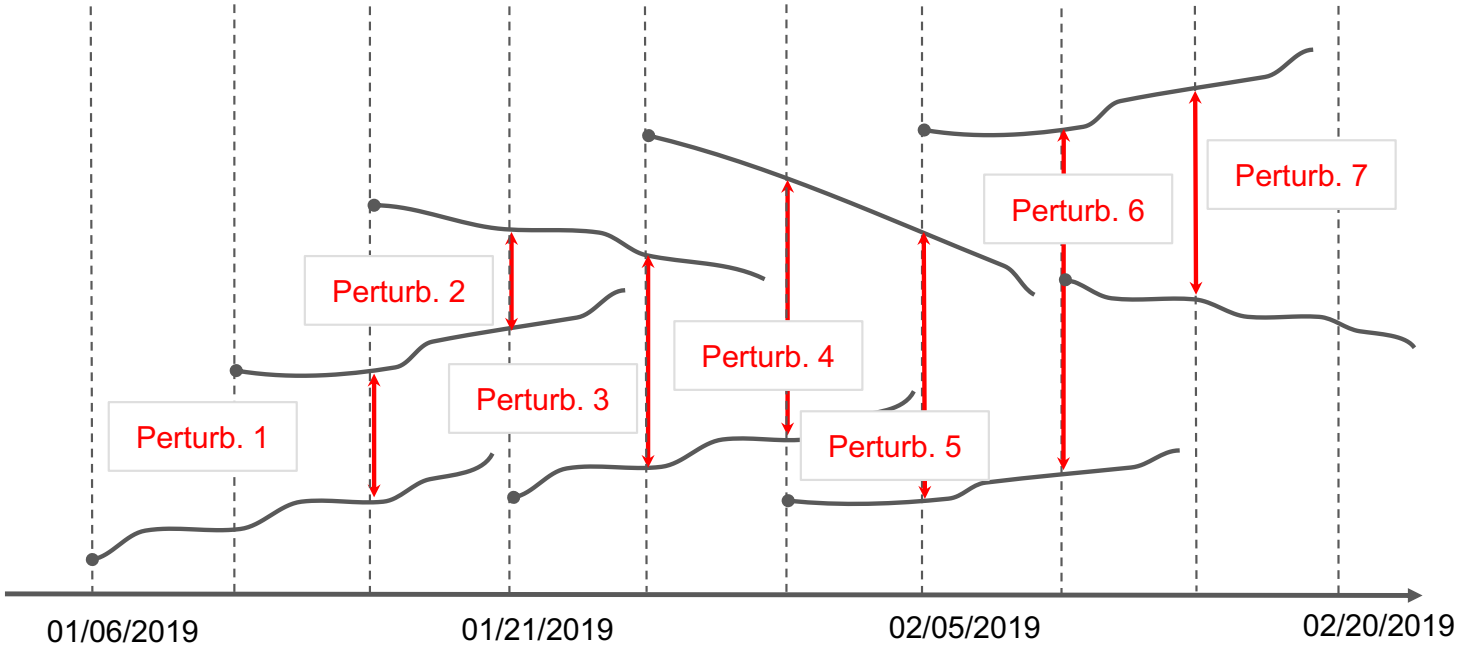
Degradation

*The global ocean is separated into 56 provinces for statistical analyses according to Longhurst (2007).

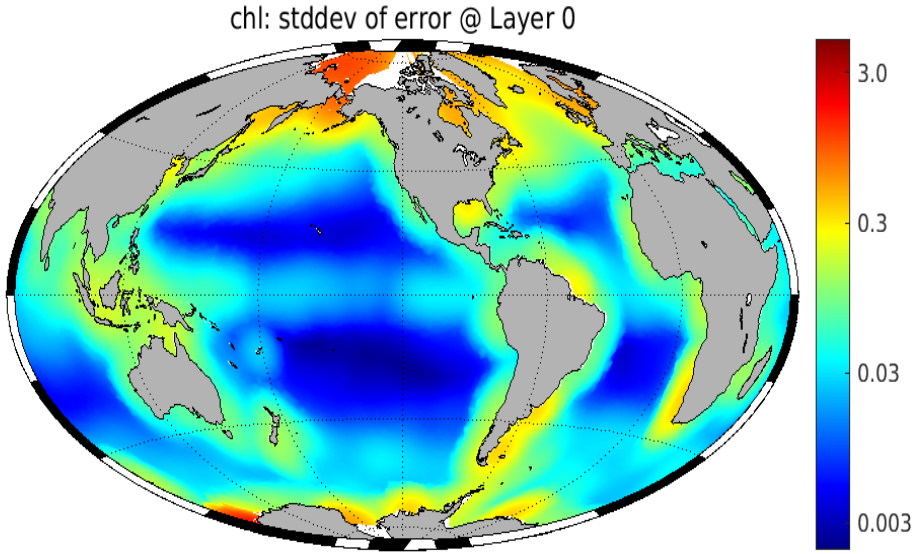
Pure **EnVAR** using static ensemble covariances

Time lagged ensemble perturbations

UFS *p8* coupled forecasts initialized from analysis every 5 days

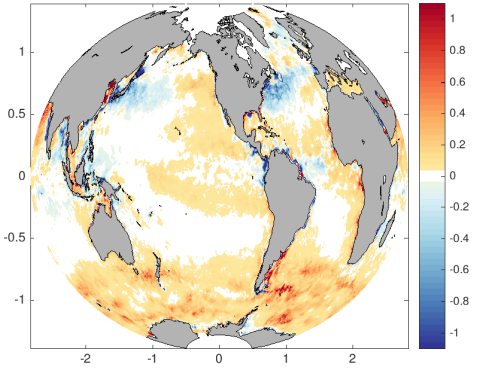


Pure **EnVAR** using static ensemble covariances

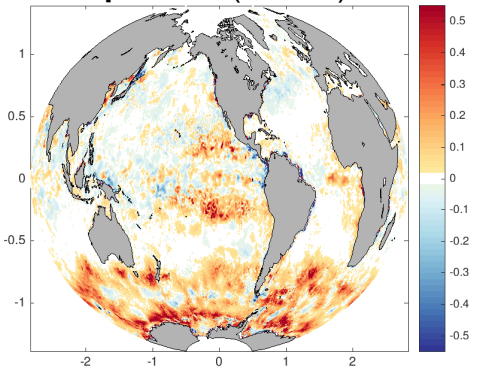


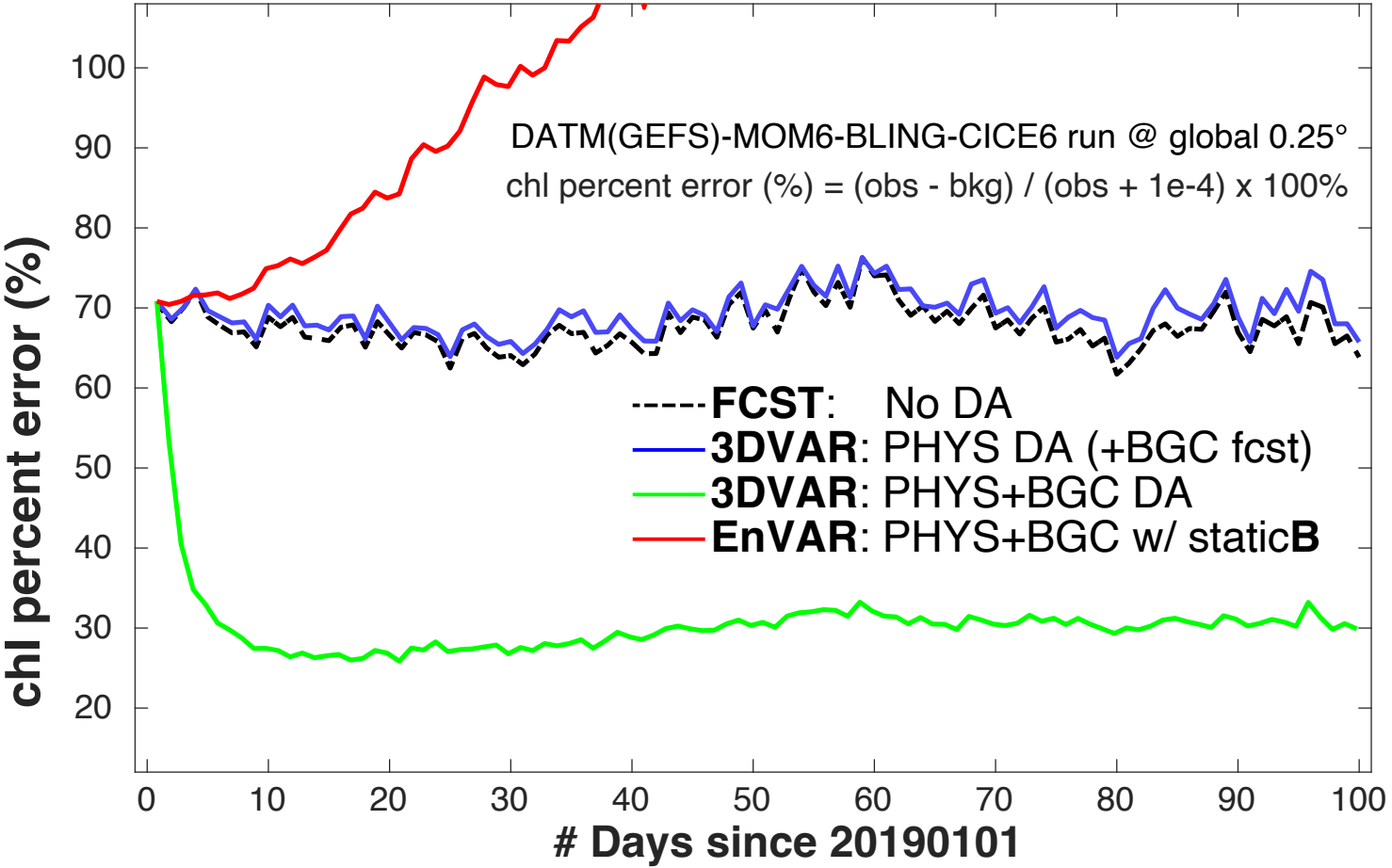
*30 ensemble members so far

Chl incr (assimilating obs)



po4 incr (no obs)




DATM(GEFS)-MOM6-BLING-CICE6 run @ global 0.25°
chl percent error (%) = (obs - bkg) / (obs + 1e-4) x 100%
FCST: No DA
3DVAR: PHYS DA (+BGC fcst)
3DVAR: PHYS+BGC DA
EnVAR: PHYS+BGC w/ staticB
chl percent error (%)
Days since 20190101
100
90
80
70
60
50
40
30
20
0
10
20
30
40
50
60
70
80
90
100

Summary

- Ocean color DA development at NOAA/NCEP:

I. DATM-MOM6-CICE6-BLING component of the global UFS configuration
II. JEDI-based ocean color DA w/ SOCA interface
III. Ingestion of near real-time ocean biogeochem observations (i.e., ocean color, BGC-Argo, etc.) for DA and validation

- Prototype global UFS-S2S coupled forecasts initialized from marine analysis:

I. Mostly positive impact of integrating ocean biophysical feedback on SST prediction skills at sub-seasonal scale (i.e., 2-3 weeks)
II. Distinct regional variability in improvement-degradation pattern

- Ongoing ocean biogeochemical reanalysis effort (0.25° global)