Data Assimilation Seminar
RIKEN AICS, Kobe, Japan, January 20, 2015

科研費
KAKENHI

Development of an Ensemble-Based Data Assimilation System with a Coupled Atmosphere–Ocean GCM

Nobu Komori,[1] T. Enomoto,[1,2] T. Miyoshi,[1,3,4]
A. Yamazaki,[1] A. Kuwano-Yoshida,[1] and B. Taguchi [1]

[1] *Application Laboratory (APL), JAMSTEC, Yokohama, Japan*
[2] *Disaster Prevention Research Institute, Kyoto University, Uji, Kyoto, Japan*
[3] *RIKEN Advanced Institute for Computational Science, Kobe, Japan*
[4] *Department of Atmospheric and Oceanic Science, University of Maryland, College Park, Maryland, U.S.A.*

E-mail: komori@jamstec.go.jp

Outline of Talk

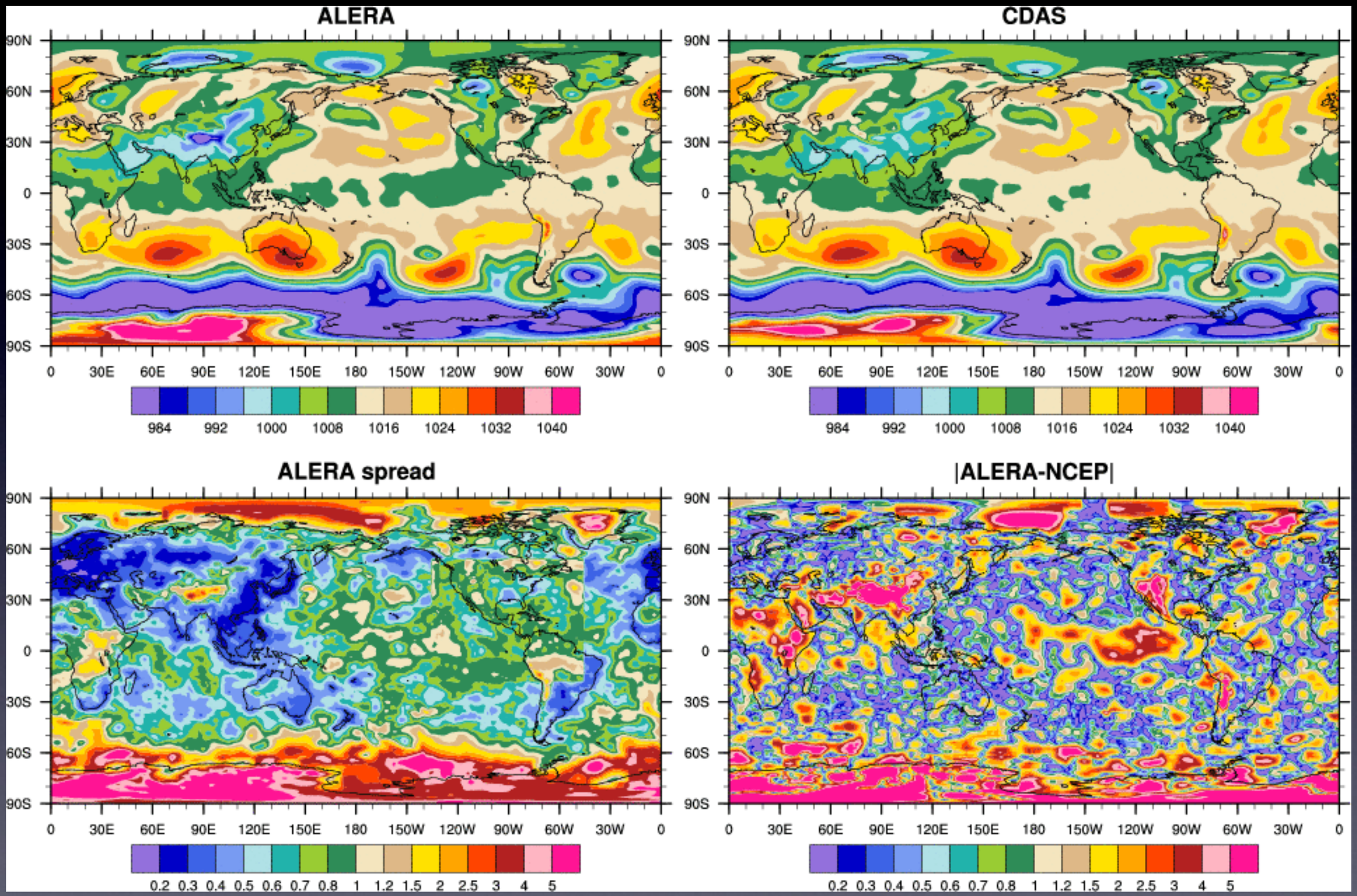
- Observing system research with **ALERA**
- **ALEDAS2** & **ALERA2**
- **CFES**–LETKF ensemble DA system
  - Motivations, Experimental settings
- Preliminary results of **CLERA-A**
  - Comparison with **ALERA2**
  - Comparison with **EnOFES**
  - Ensemble statistics between SST and other variables
- Summary

Observing System Researches with ALERA

ALERA

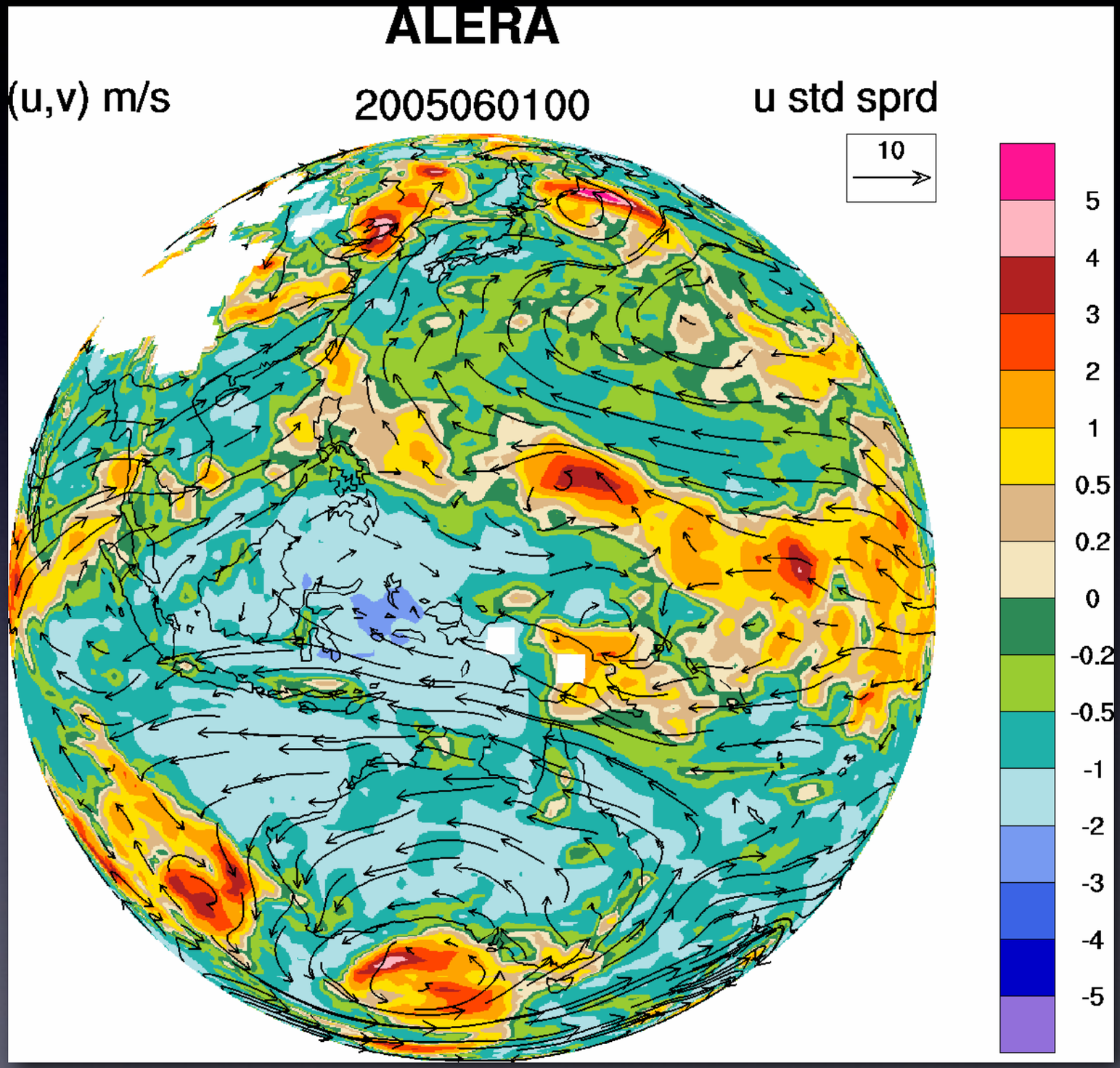
AFES–LETKF experimental ensemble reanalysis
(Miyoshi & Yamane, 2007, *MWR*; Miyoshi et al., 2007, *SOLA*)

- first (*or* second) application of LETKF to full AGCM
  - AFES T159L48M40
  - a product of collaboration among JMA, JAMSTEC and CIS
    - observations used in NWP at JMA
  - from 18UTC 1 May 2005 to 12UTC 11 Jan 2007
  - provides analysis ensemble spread as error estimates
  - available from http://www.jamstec.go.jp/esc/research/oreda/products/



Miyoshi et al. (2007a, *SOLA*)

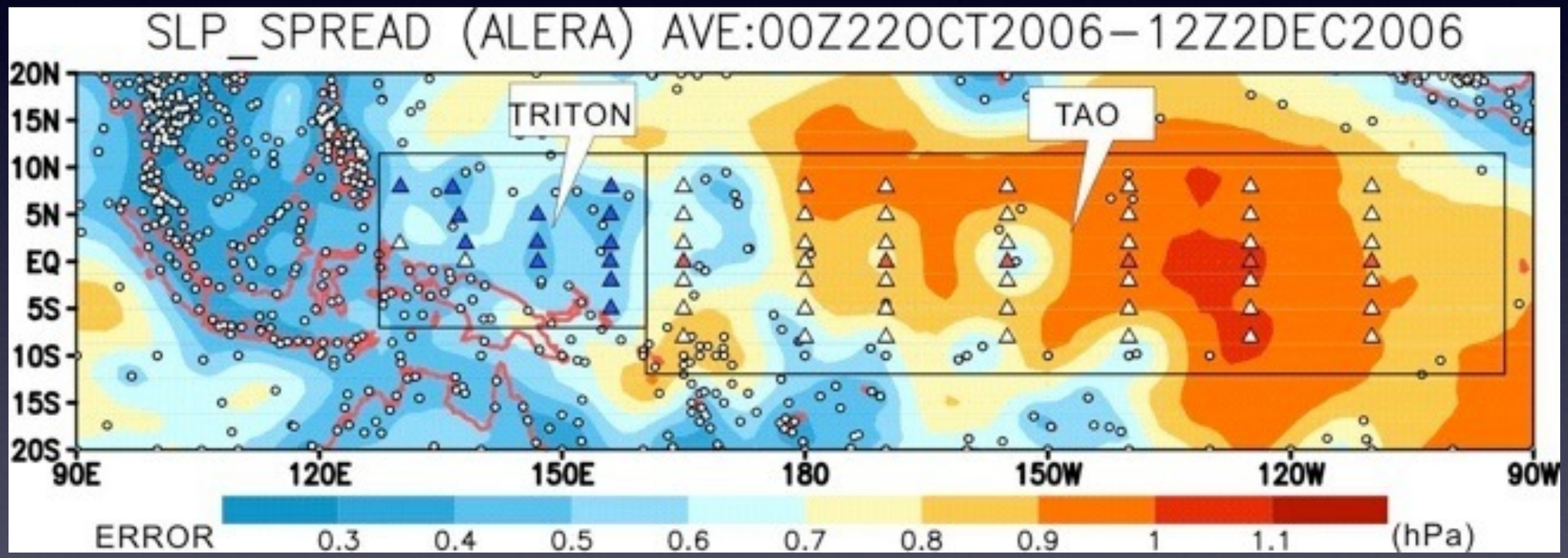
850-hPa (u,v) and standardized U850 spread



Effects of buoy observation

ALL the TRITON buoys (blue Δ) observe surface pressure

ONLY the TAO buoys on the equator (red Δ) observe surface pressure



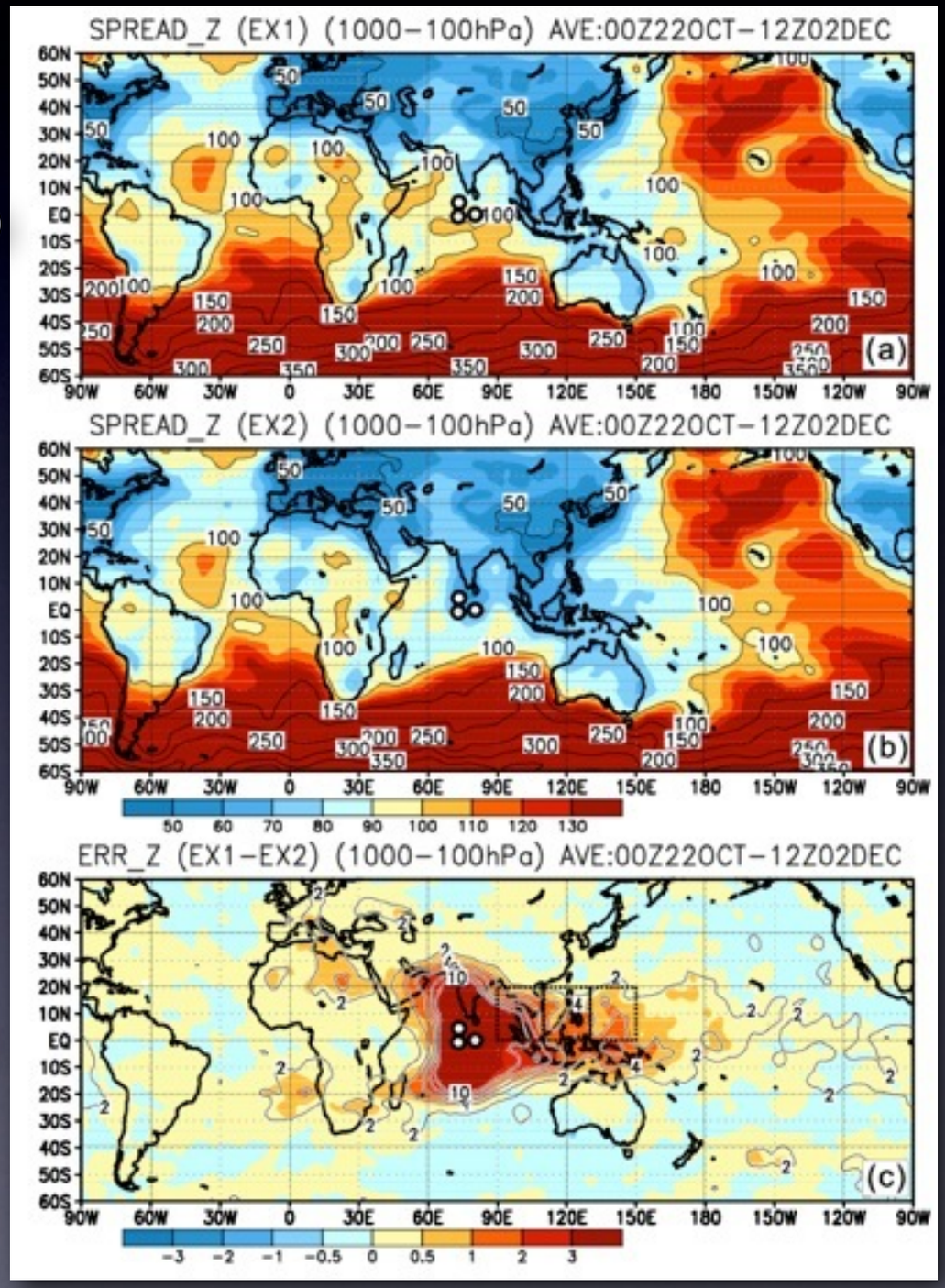
Enomoto et al. (2013, *Springer*)

Influence of MISMO sondes

ALERA (w/o MISMO sondes)

with MISMO sondes

ALERA – with MISMO



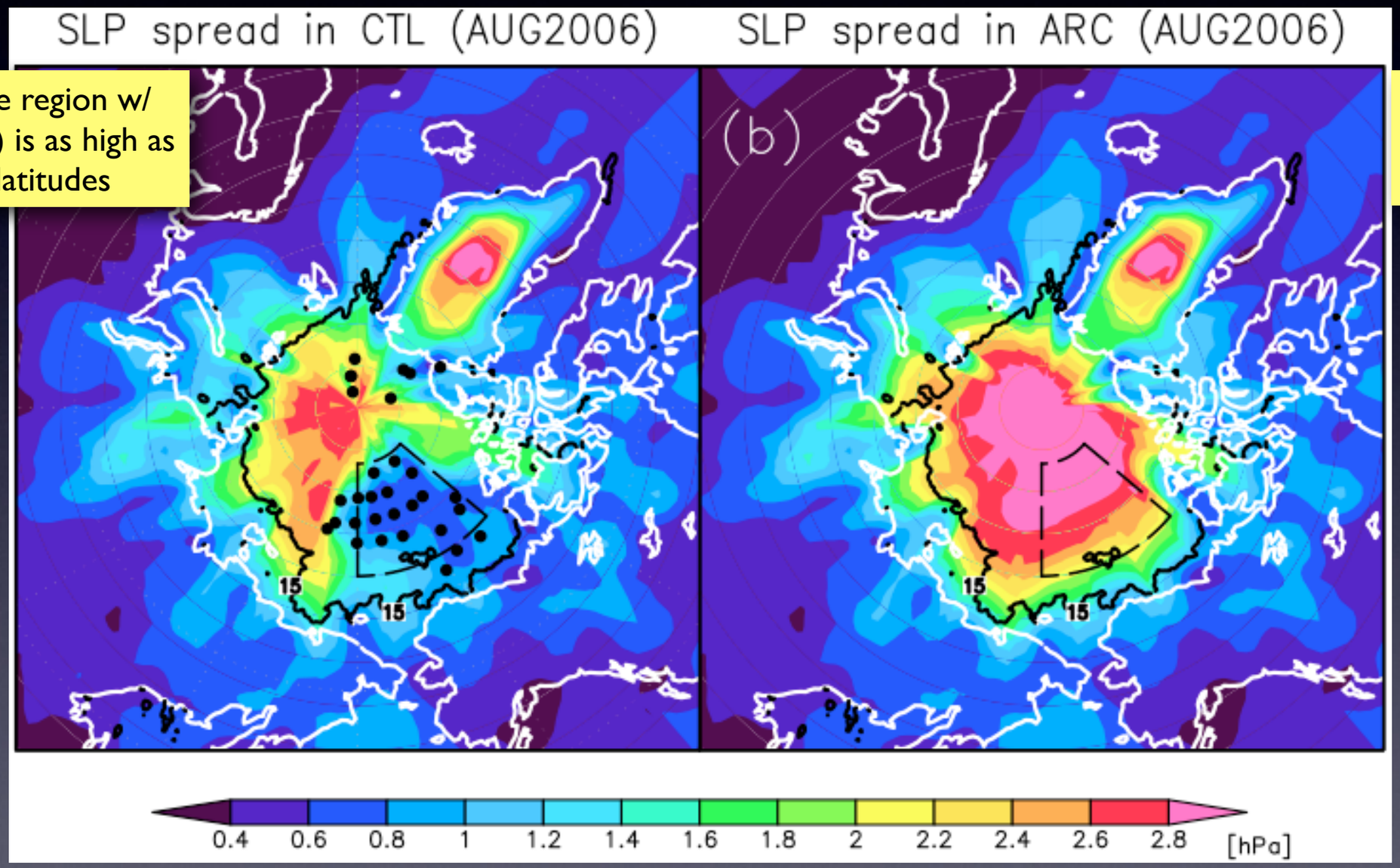
MISMO Oct–Dec 2006
in the Indian Ocean

Influence on
typhoon genesis

Moteki et al. (2011, *QJRMS*)

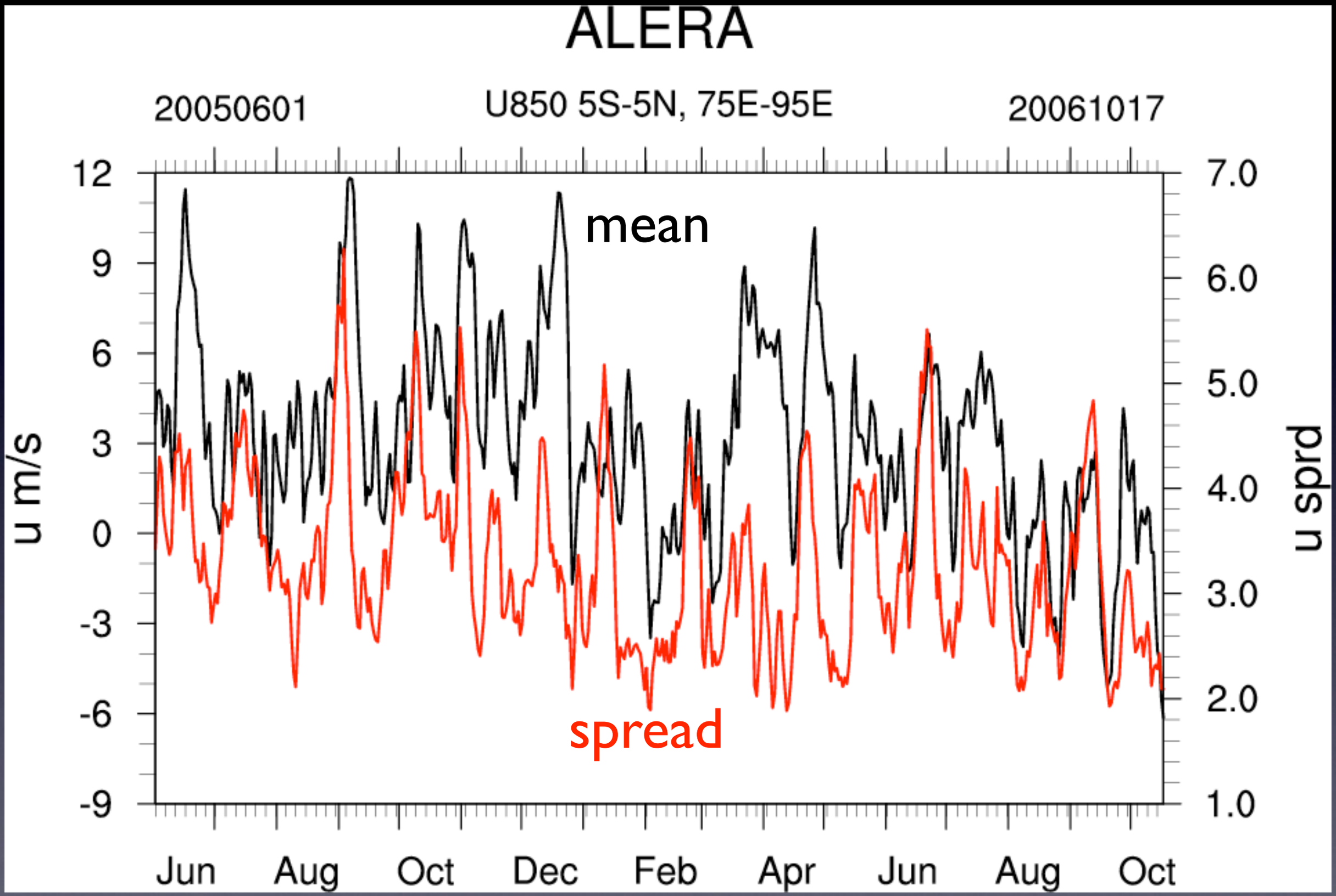
Impact of Arctic buoys

accuracy in the region w/ Arctic buoys (•) is as high as in the mid-latitudes



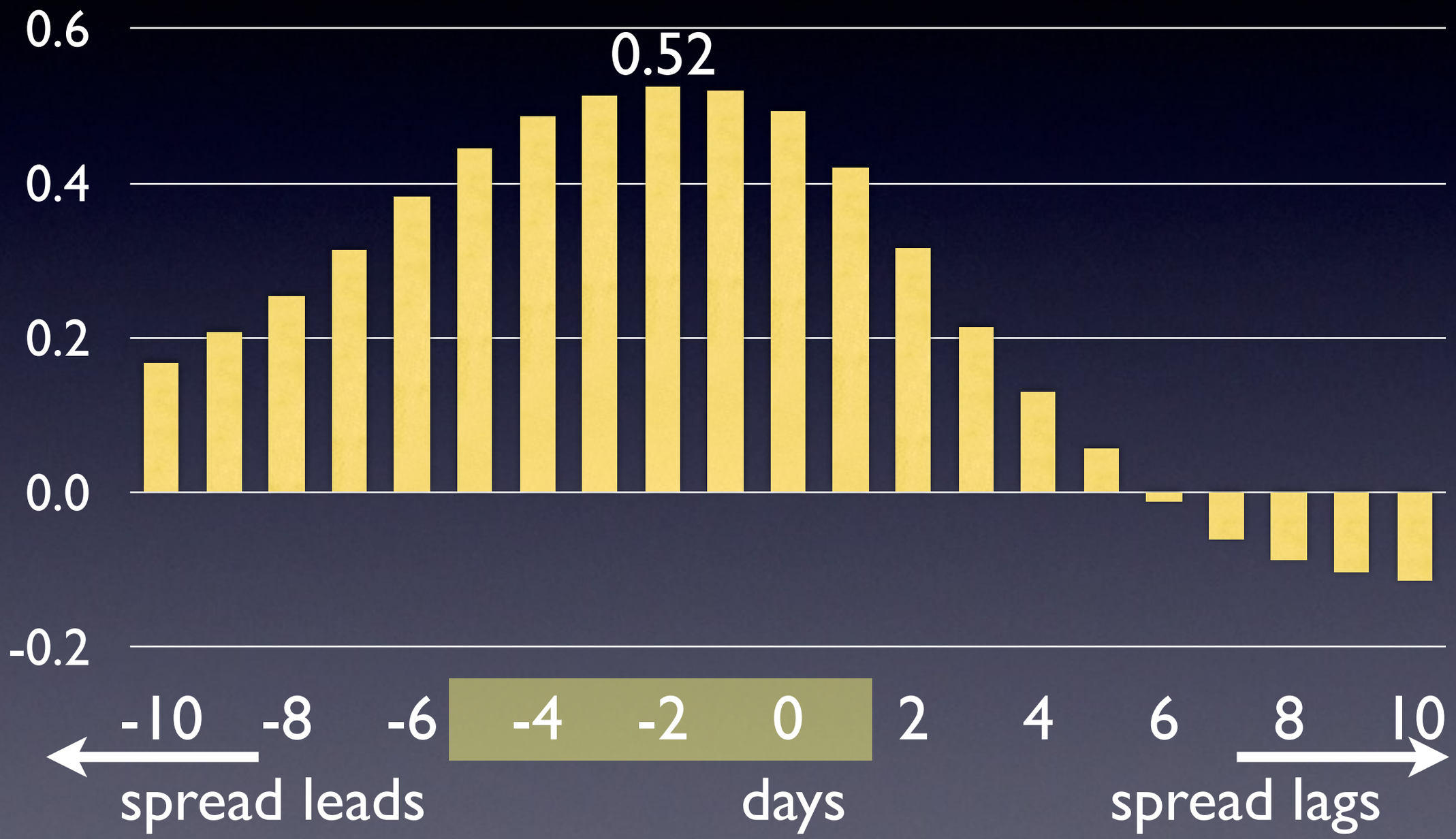
error becomes larger over the entire Arctic

Inoue et al. (2009, *GRL*)



Enomoto et al. (2010, *GRL*)

Lag correlation between mean and spread



Enomoto et al. (2010, *GRL*)

ALEDAS2 and ALERA2

ALEDAS and ALEDAS2 compared

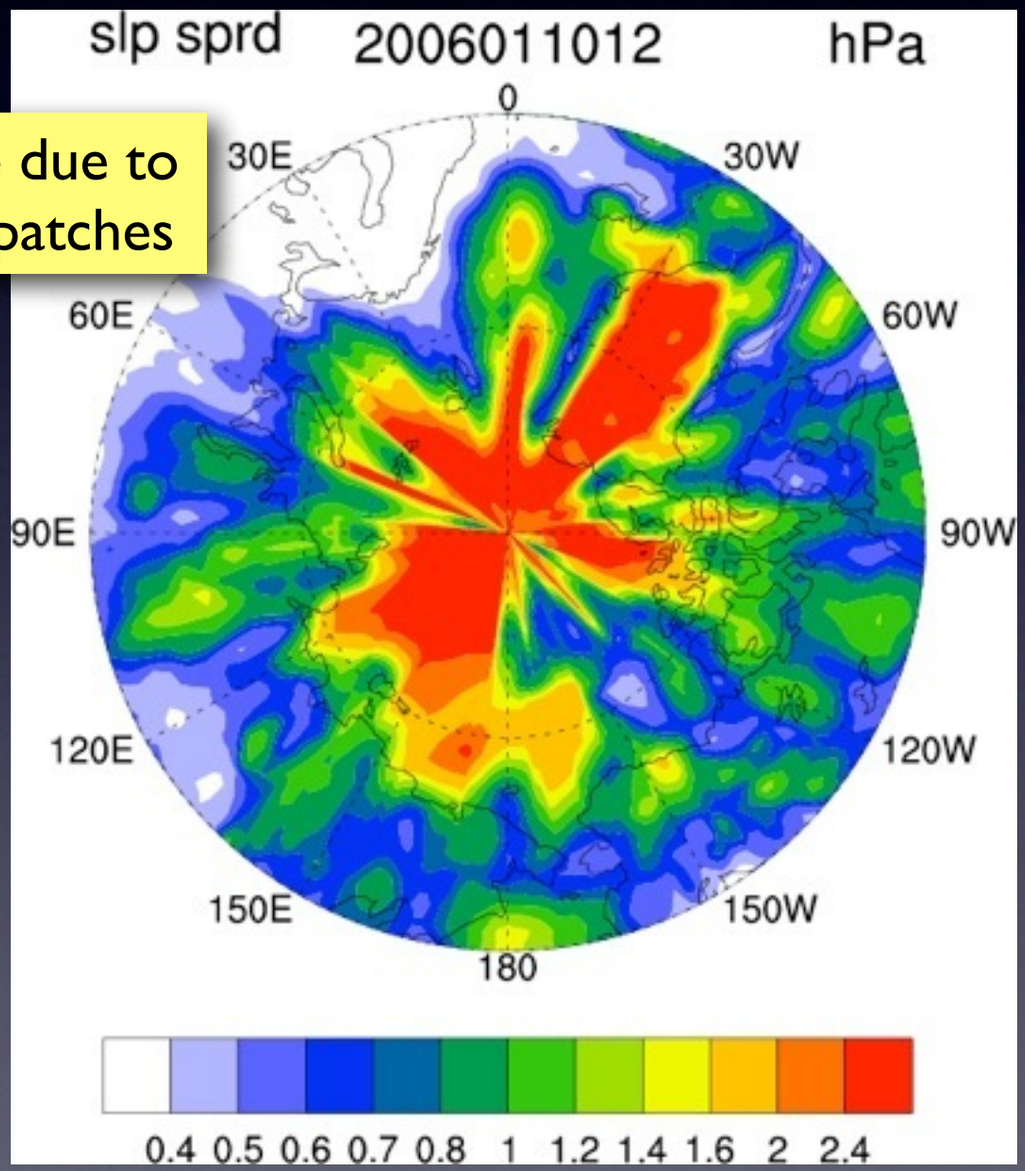
	ALEDAS	ALEDAS2
AFES version	2.2	3.6
Resolution	T159 L48	T119 L48
Ensemble size	40	63+1
Boundary conditions	NOAA OISST weekly 1°	NOAA OISST daily 1/4°
Covariance localization	21x21x13	400 km/0.4 ln$p$
Spread inflation	0.1	
Obs. compiled by	JMA	NCEP

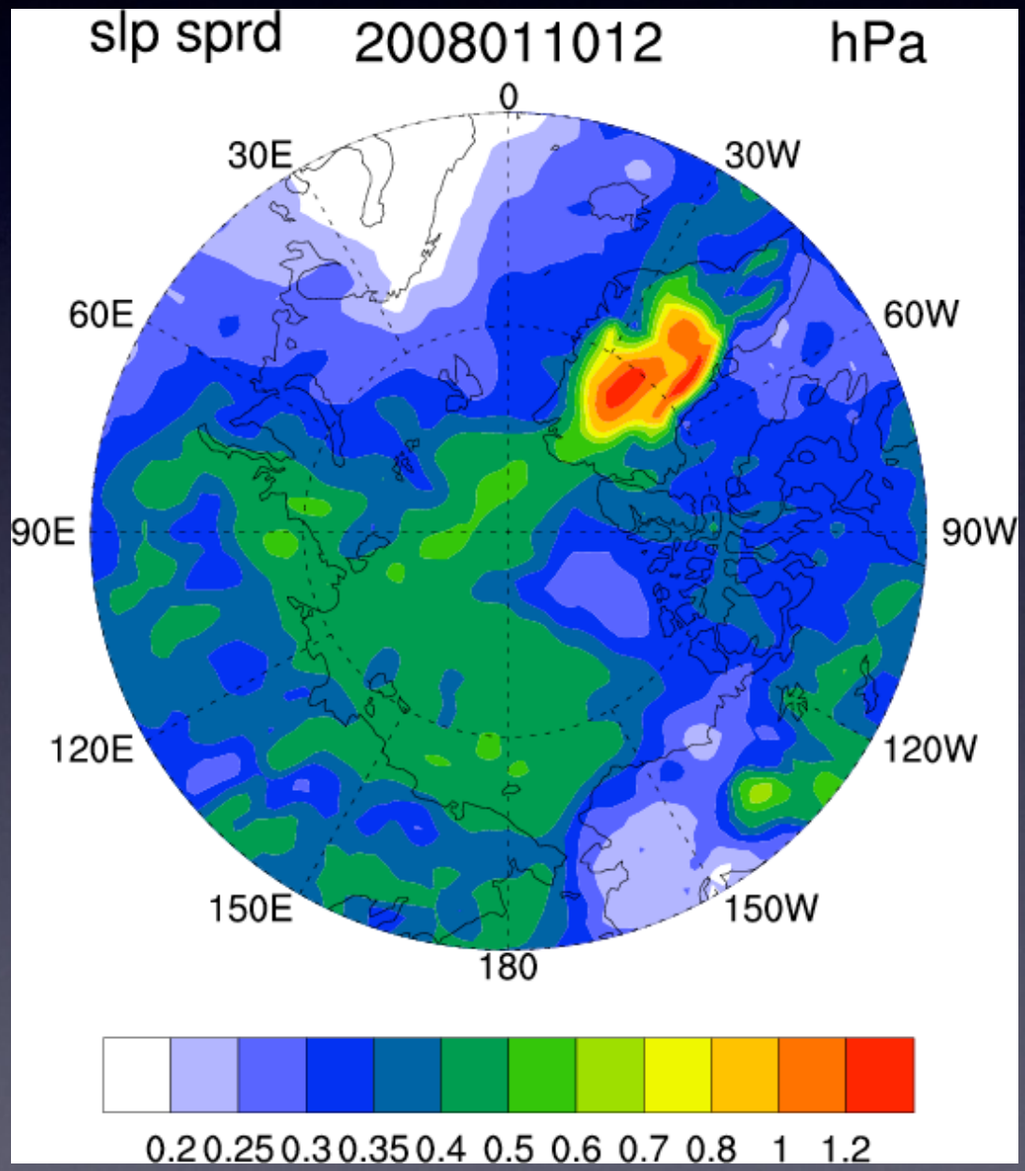
Error covariance localization by distance

ALERA

ALERA2

Noise due to local patches

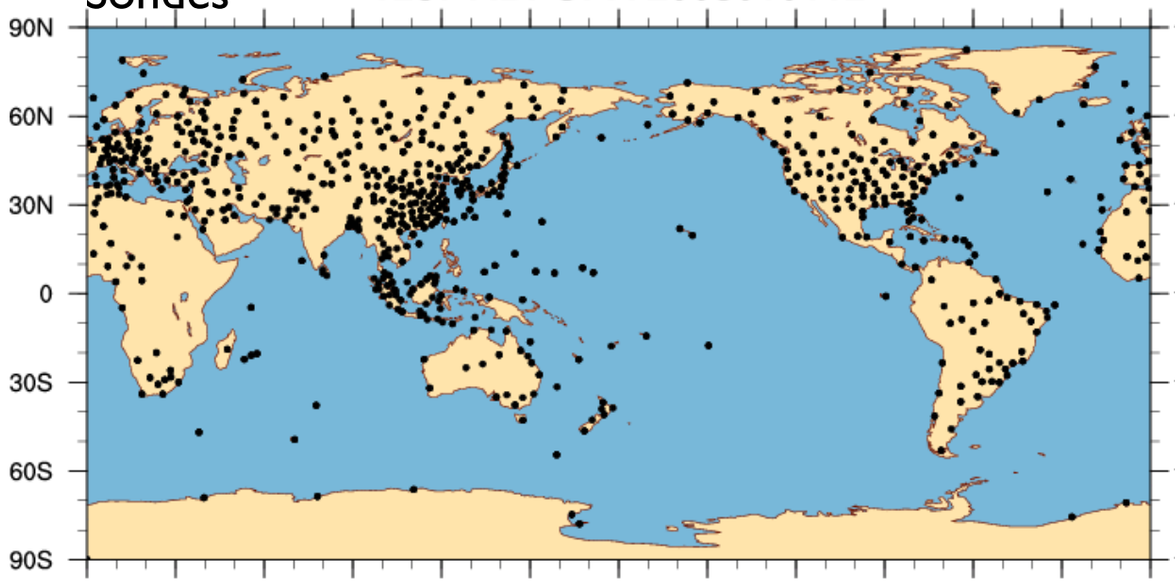




Miyoshi et al. (2007b, *SOLA*)

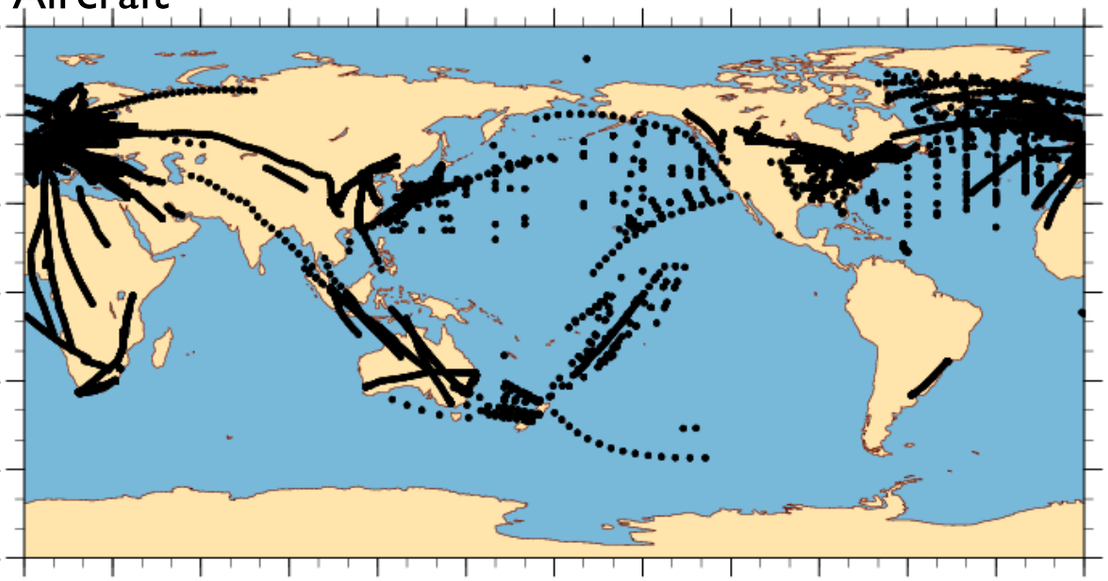
Sondes

1287 ADPUPA 2008010112



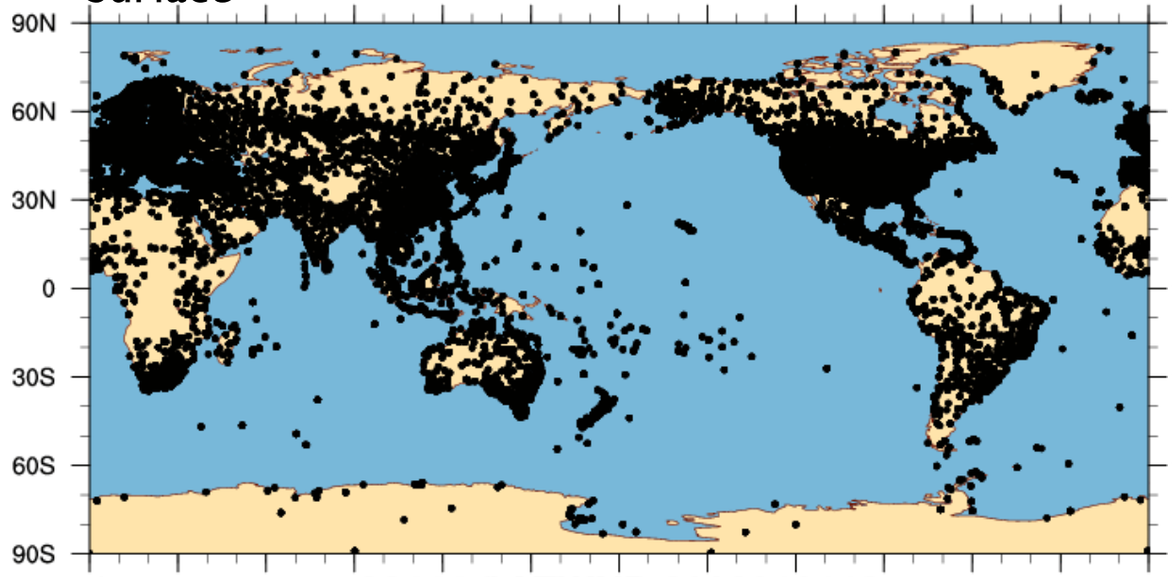
Aircraft

38036 AIRCFT 2008010112



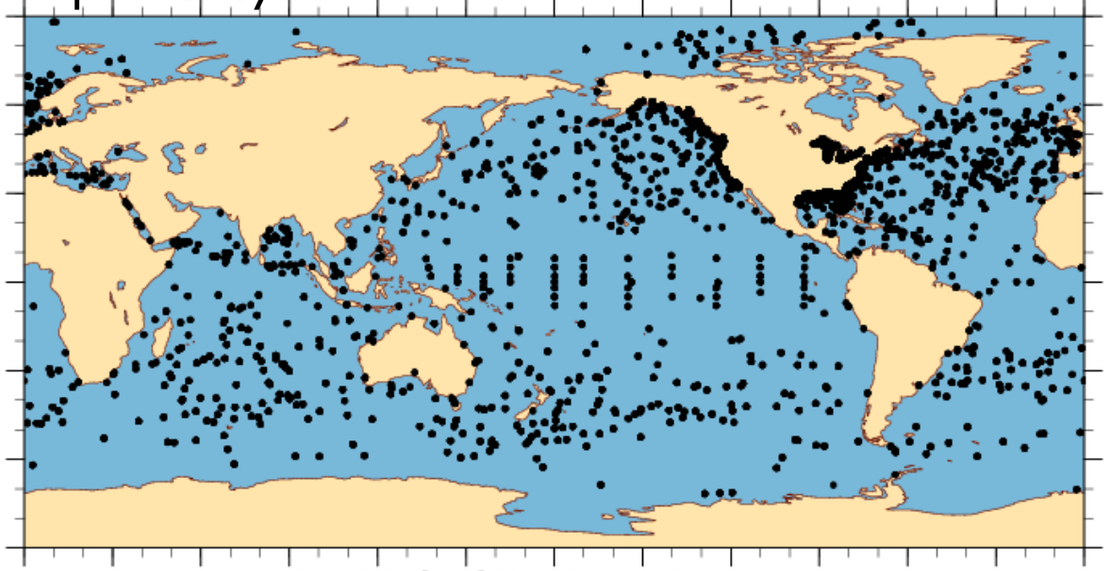
Surface

101758 ADPSFC 2008010112



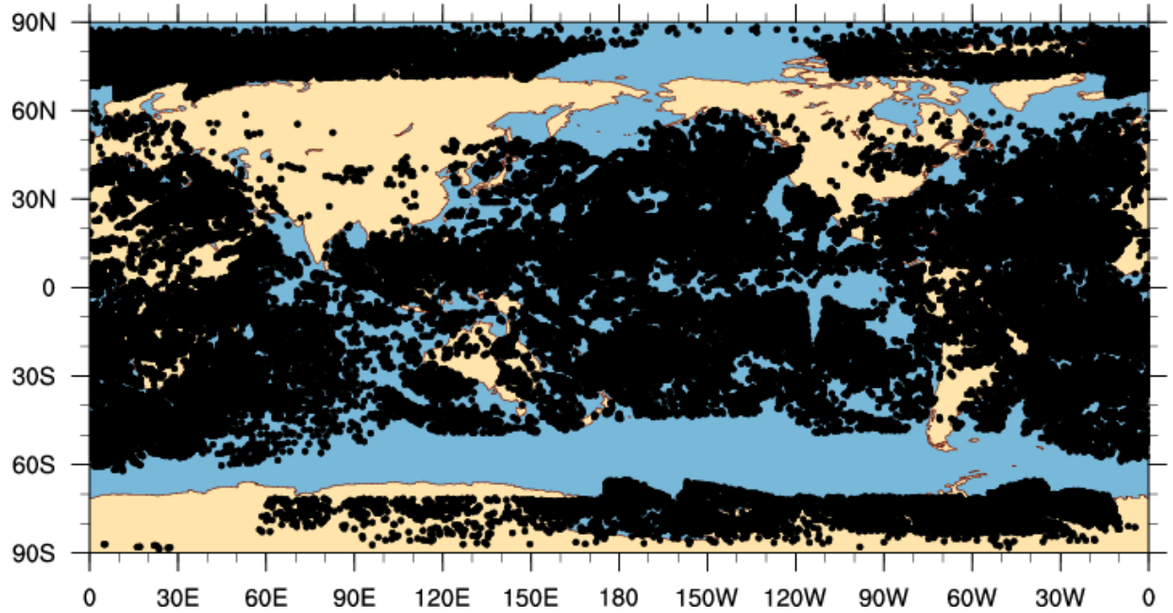
Ships & buoys

10616 SFCSHP 2008010112



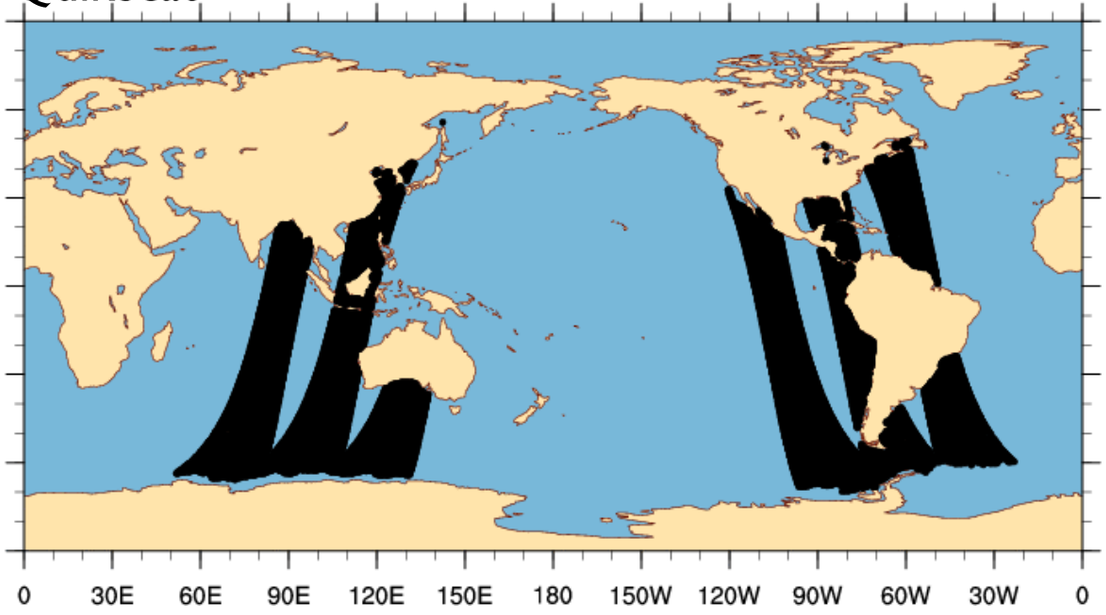
AMV

86444 SATWND 2008010112

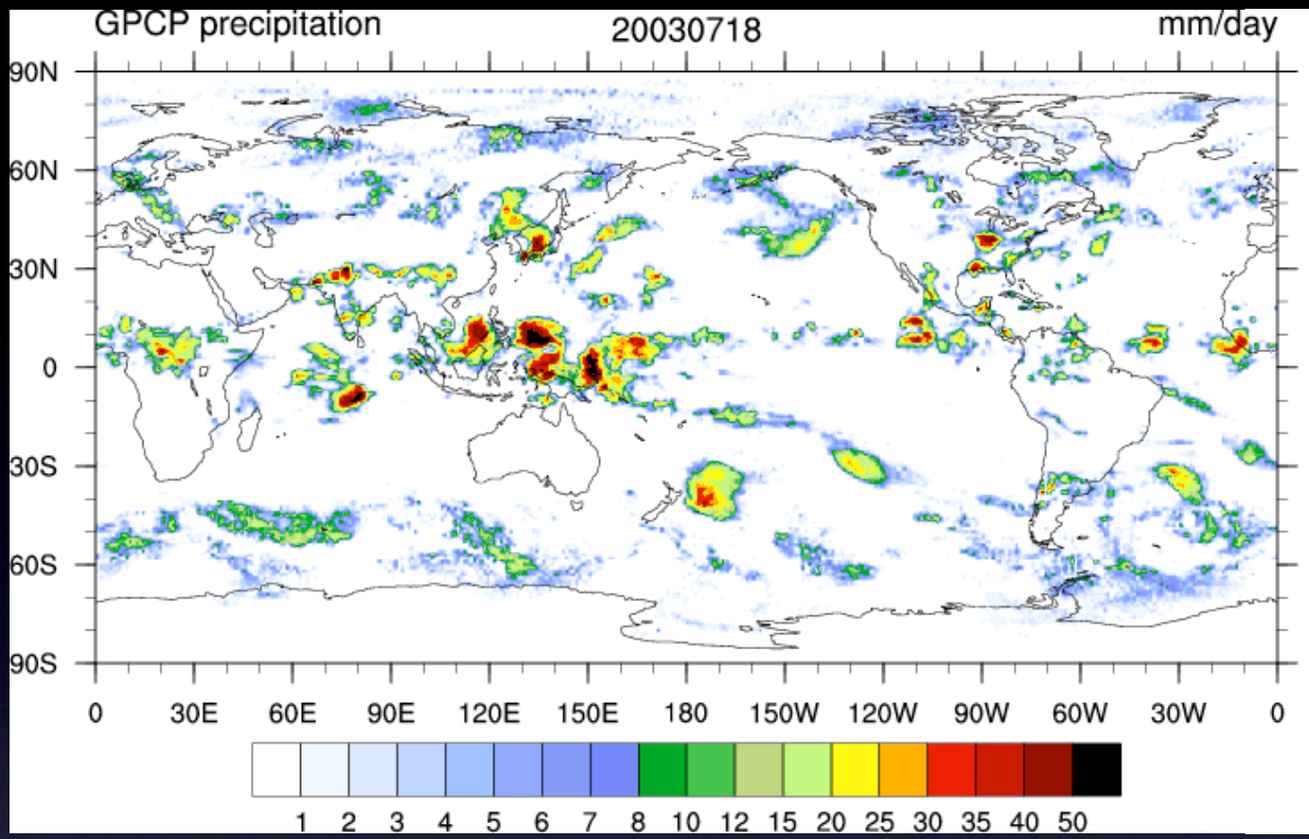


QuikScat

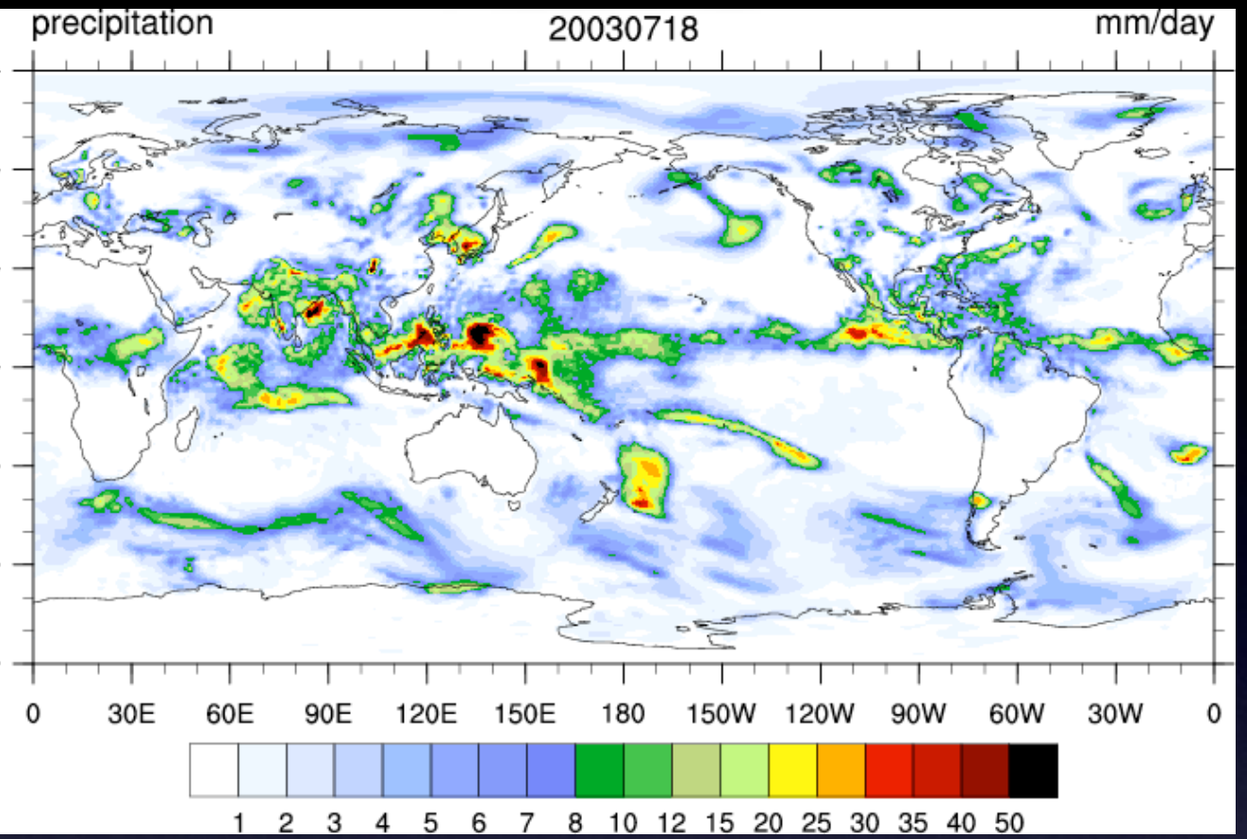
25589 QKSWND 2008010112



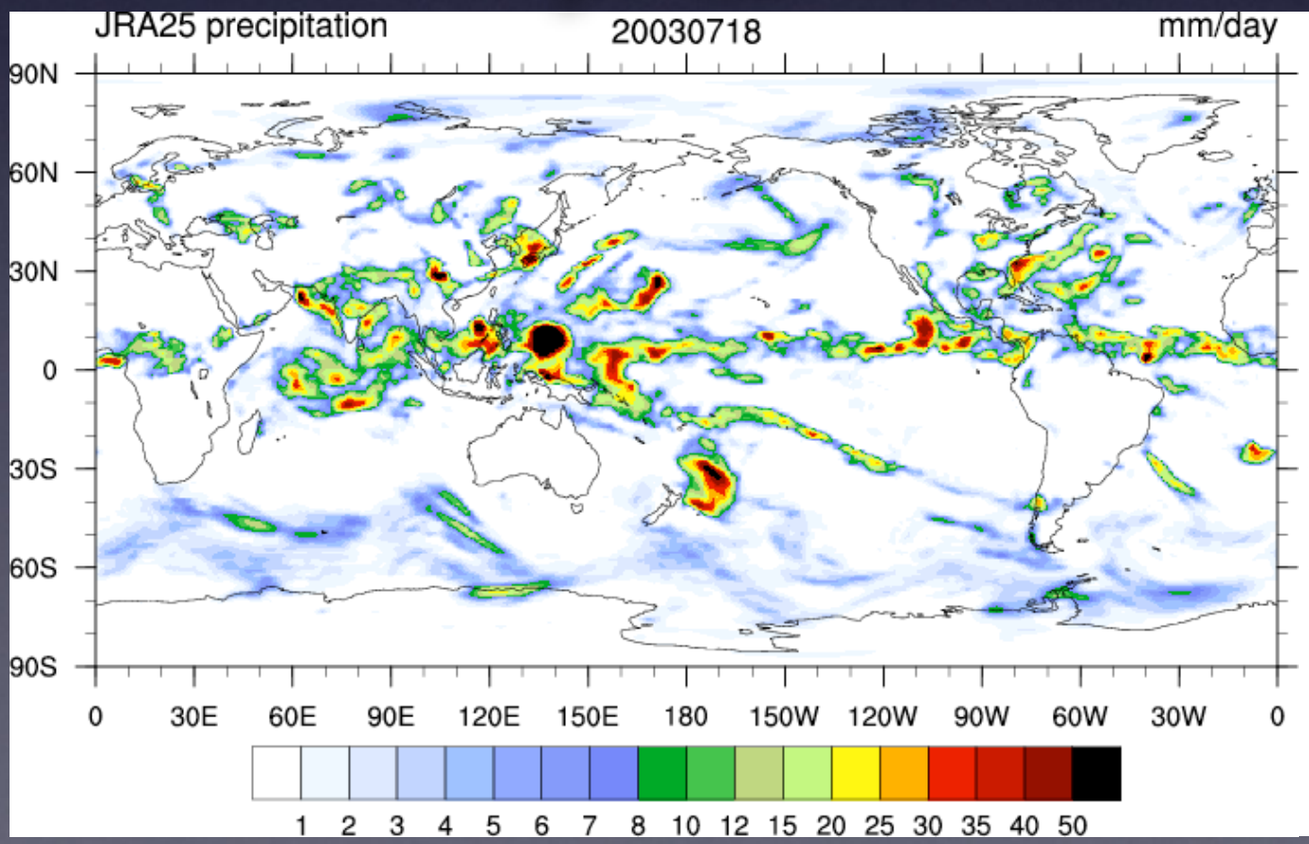
GPCP



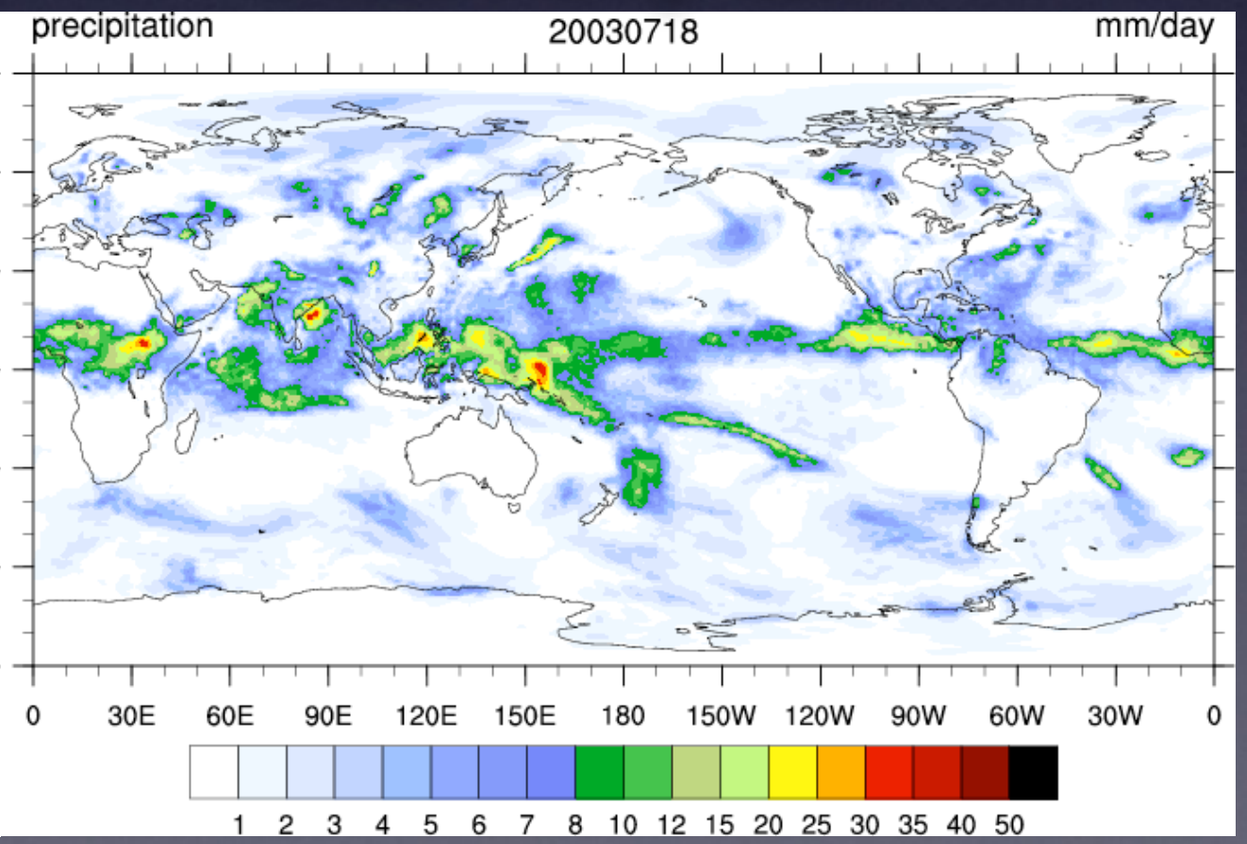
ALERA2



JRA25



ALERA2 spread



ALERA2 streams

2007	2008	2009	2010	2011	2012	2013	2014	2015

stream 2008

PALAU2008
Mirai Arctic Cruise
T-PARC
Winter T-PARC

stream 2010

Mirai Arctic Cruise
VPREX2010
Hakuho-maru Cruise
CINDY2011
"Hotspot" Cruise

stream 2013

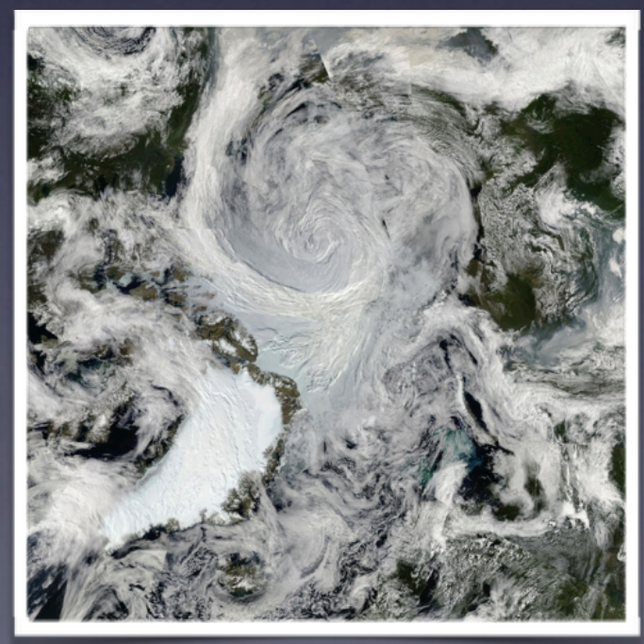
PALAU2013
Mirai Arctic Cruise
Mirai Arctic Cruise

Both stream 2008 and 2010 are now available from our OPeNDAP (DODS) server.

Resent studies using ALERA/ALERA2

- Inoue, J., T. Enomoto, and M. E. Hori, 2013: The impact of radiosonde data over the ice-free Arctic Ocean on the atmospheric circulation in the Northern Hemisphere. *Geophys. Res. Lett.*, **40** (5), 864–869.
- Kuwano-Yoshida, A., and T. Enomoto, 2013: Predictability of explosive cyclogenesis over the northwestern Pacific region using ensemble reanalysis. *Mon. Wea. Rev.*, **141** (11), 3769–3785.
- Yamazaki, A., J. Inoue, K. Dethloff, M. Maturilli, and G. König-Langlo: Impact of radiosonde observations on forecasting summertime Arctic cyclone formation. *J. Geophys. Res.: Atmos.*, submitted.

The 'great' arctic cyclone of 2012
(from NASA)



CFES–LETKF Ensemble DA System

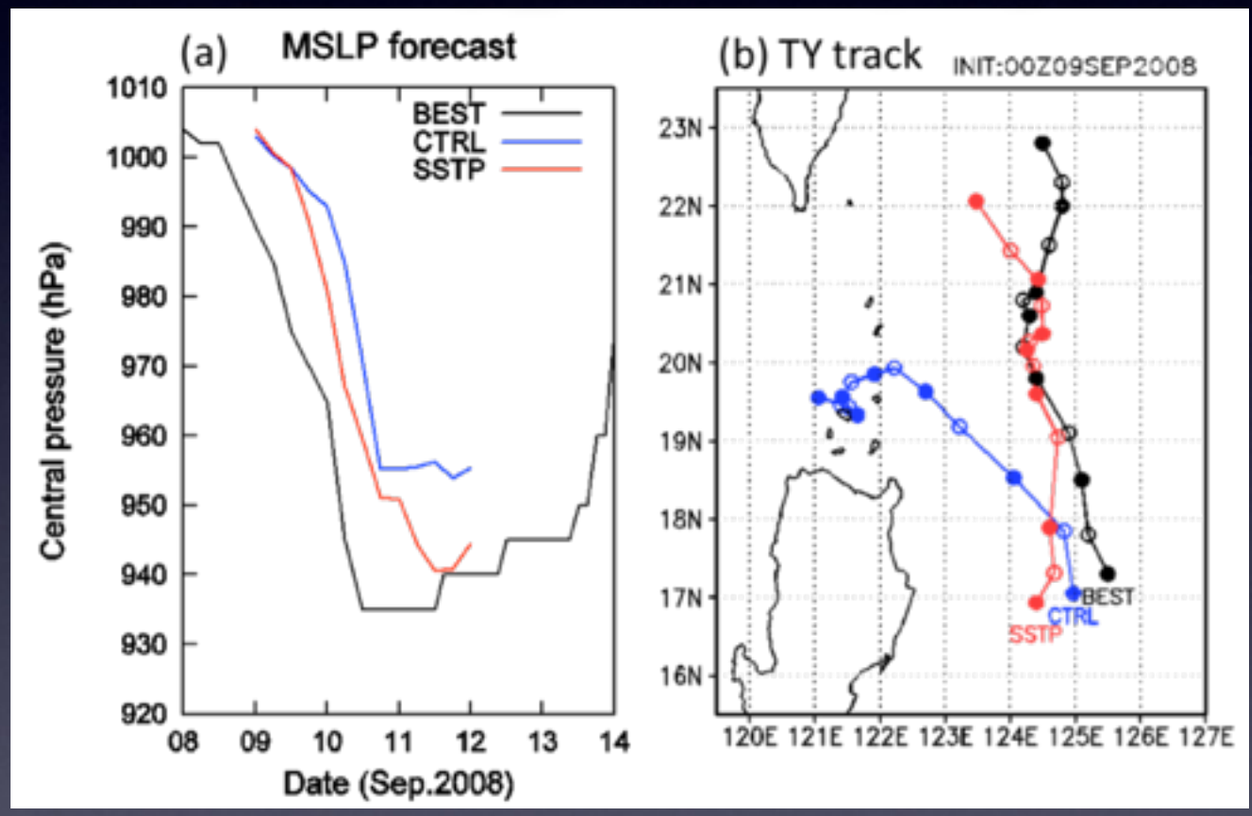
Motivations: from ALERA to CLERA

- Remove underestimation of ensemble spread near the sea surface
- Improve SST–precipitation correlation
- Evaluate observations including ocean buoys

➡ Replace **AFES** with **CFES**

- Atmospheric DA only

Forecast of Typhoon Sinlaku (2008)



Kunii & Miyoshi (2012, *Wea. Forecasting*)

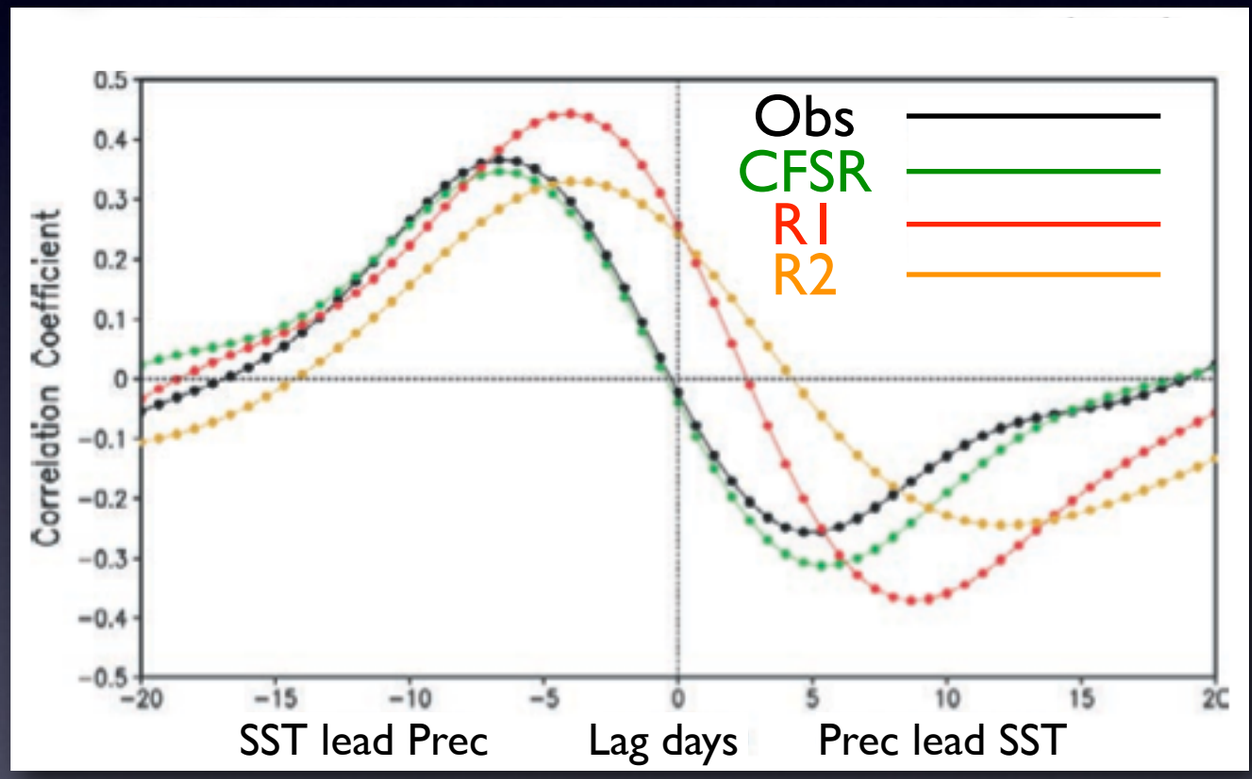
Motivations: from ALERA to CLERA

- Remove underestimation of ensemble spread near the sea surface
- Improve SST–precipitation correlation
- Evaluate observations including ocean buoys

➡ Replace **AFES** with **CFES**

- Atmospheric DA only

Lag Corr. of Prec. and SST over Western Pacific (winter)



Saha et al. (2010, *BAMS*)

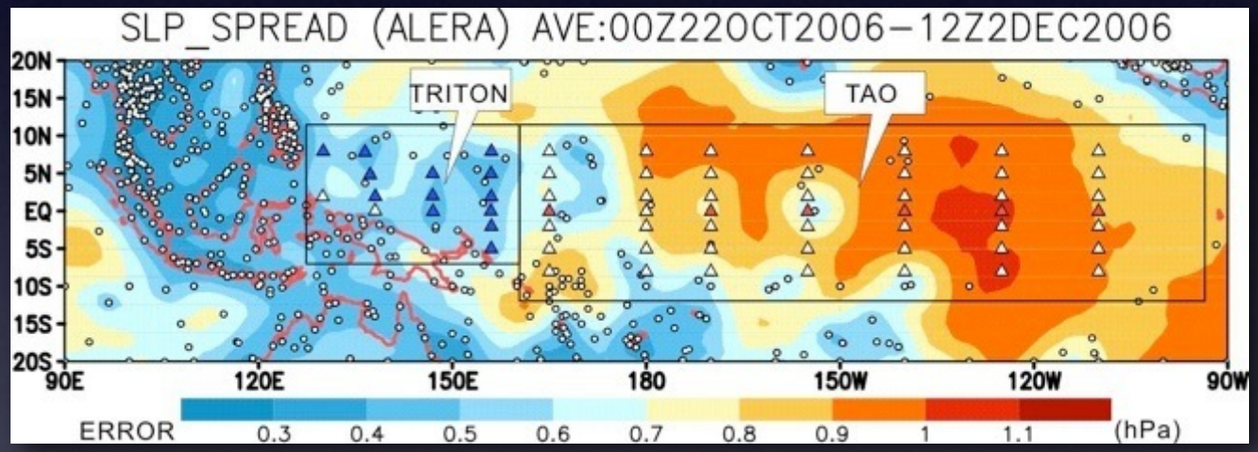
Motivations: from ALERA to CLERA

- Remove underestimation of ensemble spread near the sea surface
- Improve SST–precipitation correlation
- Evaluate observations including ocean buoys

➡ Replace **AFES** with **CFES**

- Atmospheric DA only

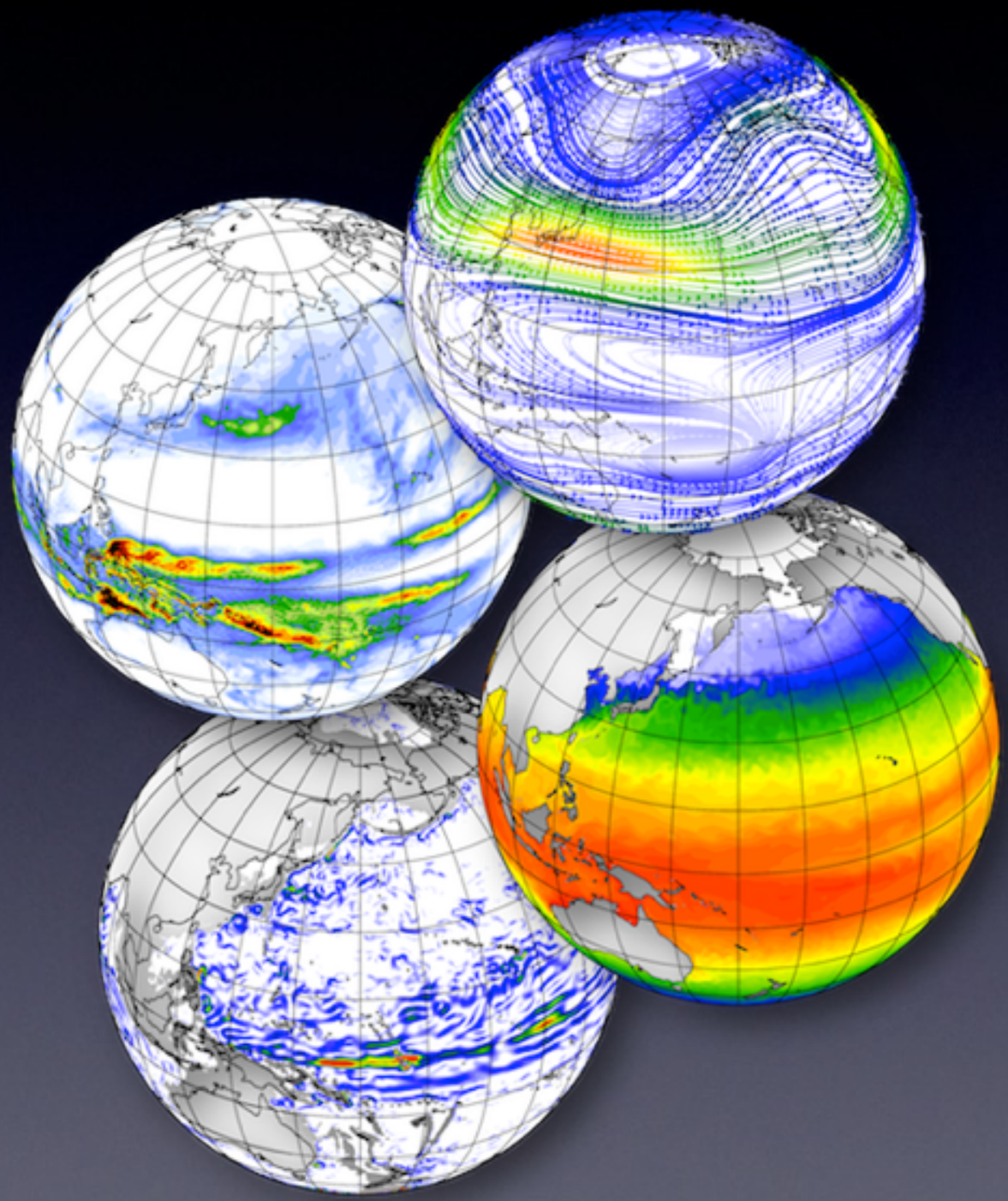
Ens. Spread of SLP in ALERA



Enomoto et al. (2013)

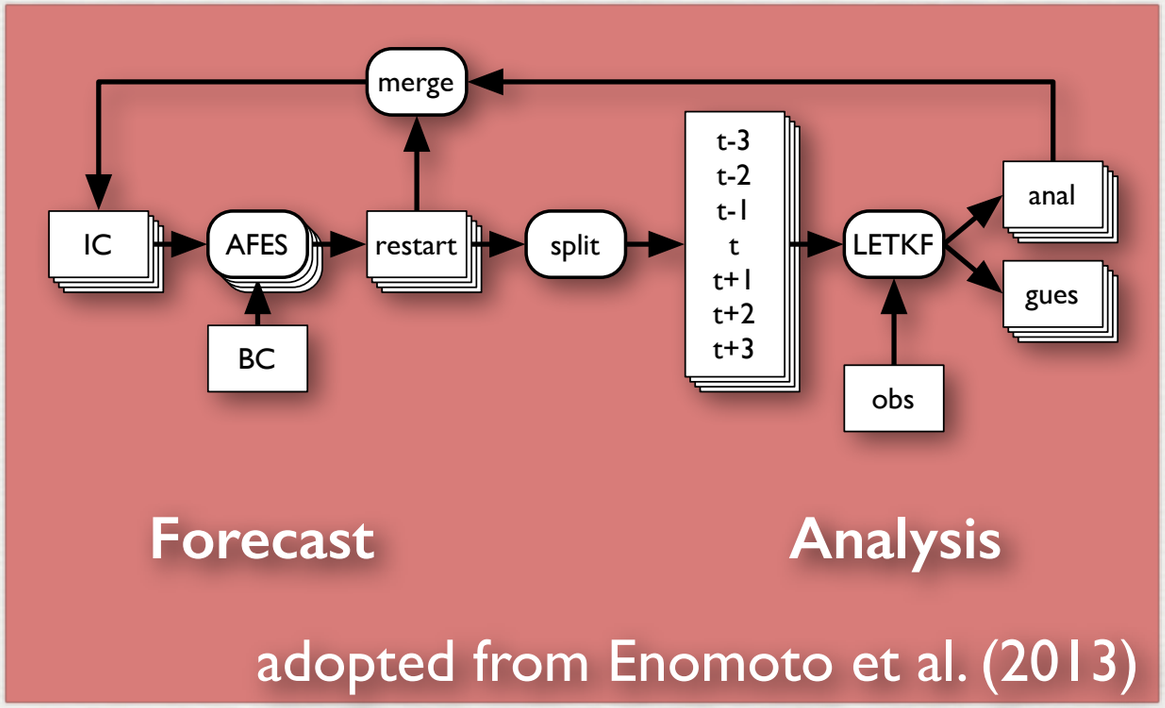
CFES

- Coupled GCM for the ES
  - **AFES** + **OFES**
  - Komori et al. (2008)
- **CFES mini**
  - AFES: T119 L48
  - OFES: 0.5°x0.5° 54 levels
  - Coupling: every hour
  - Richter et al. (2010, *GRL*), Taguchi et al. (2012, *JC*), Bajish et al. (2013, *SOLA*), Nagura et al. (2013, *JGR*), Sasaki et al. (2013, *JC*)



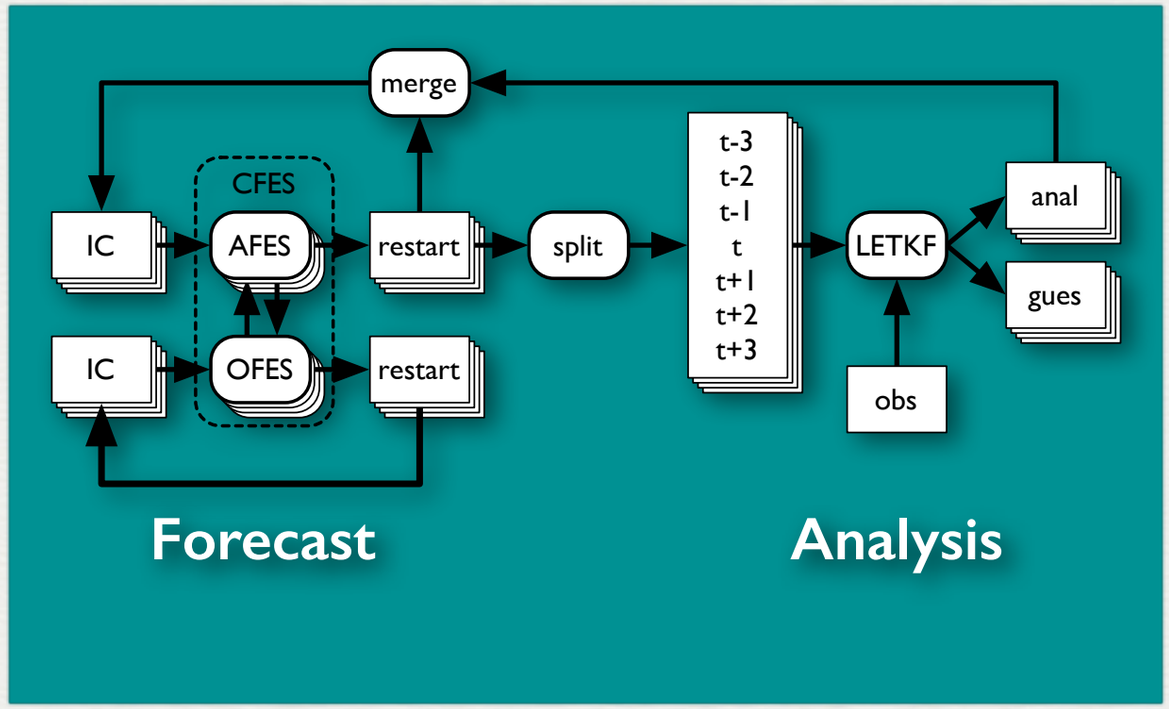
Forecast–Analysis Cycle

AFES–LETKF ensemble DA system



adopted from Enomoto et al. (2013)

CFES–LETKF ensemble DA system



6-hour Cycle

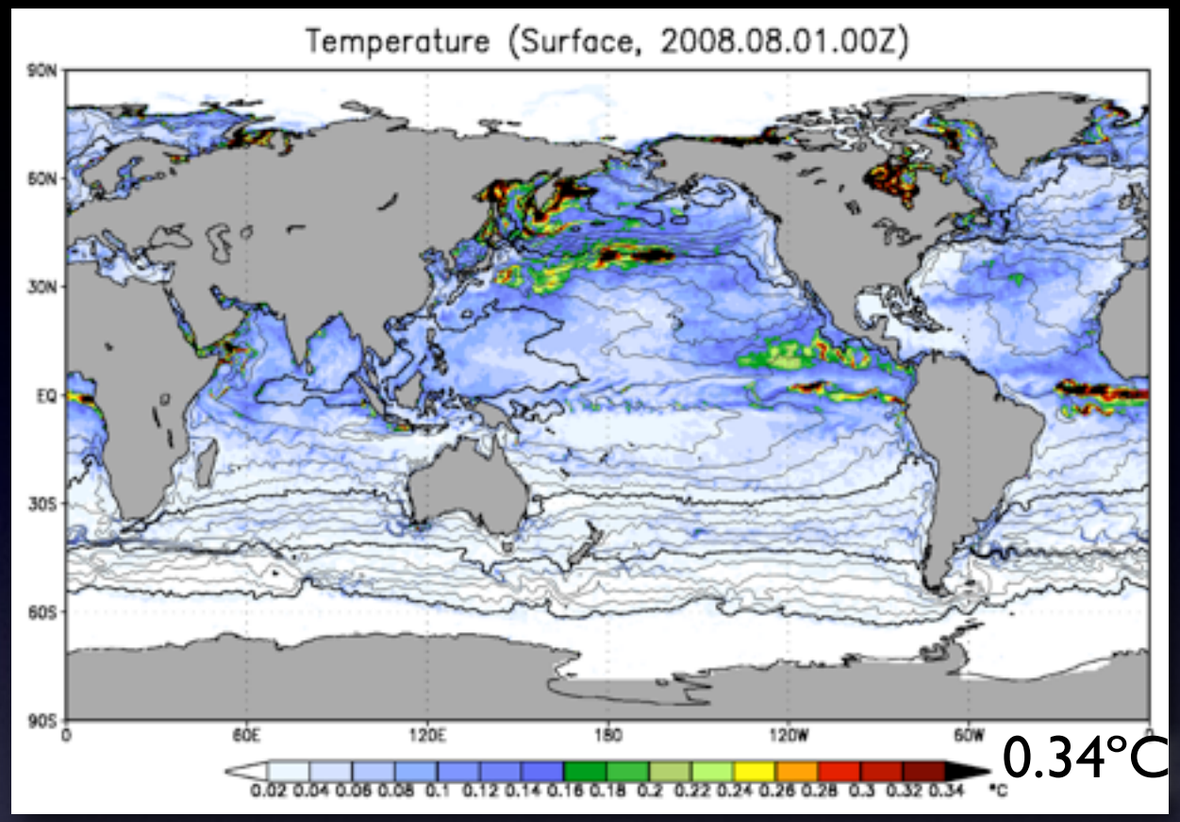
Conduct 9-hour ensemble forecasts from time t-6 to t+3.
Ensemble mean of forecasts at time t is the first guess (gues).

Calculate analysis (anal) at time t from the forecasts and observations (obs) between time t-3 and t+3.

Experimental settings

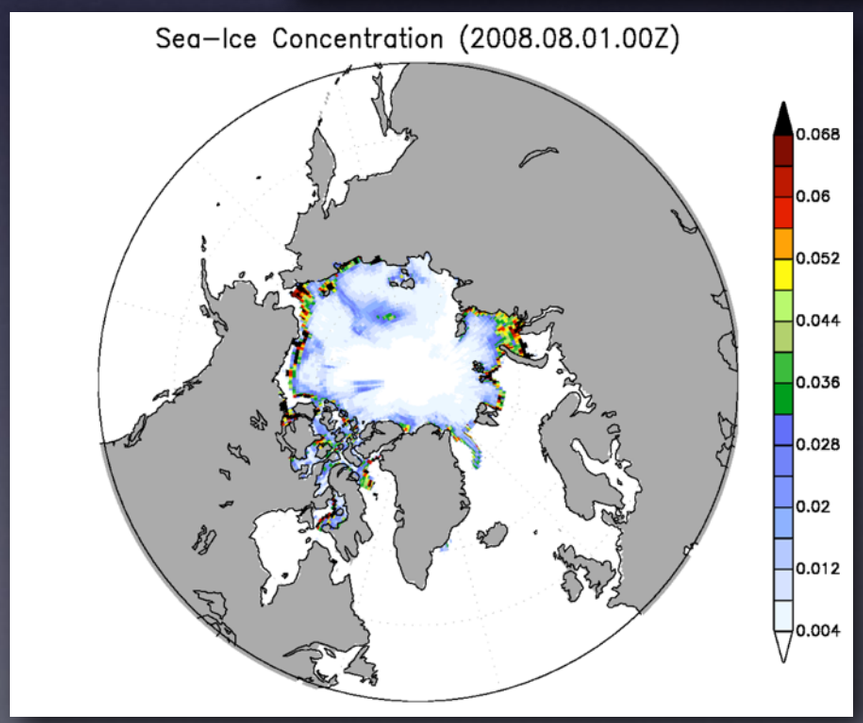
- Ensemble size: 63 members + control
- Assimilation: atmospheric observation (PREPBUFR) only
- Integration from 1 August to 30 September 2008
- Atmospheric ICs: from **ALERA2**
- Oceanic ICs: from ensemble simulation with OFES (**EnOFES**)
  - *Single* spin-up run: CORE v2 (1948–2007), **ALERA2** (2008–)
  - *Ensemble* run: *each member* of **ALERA2** (2 June 2008–)
- Result (**CLERA-A**) is compared with **ALERA2** and **EnOFES**.

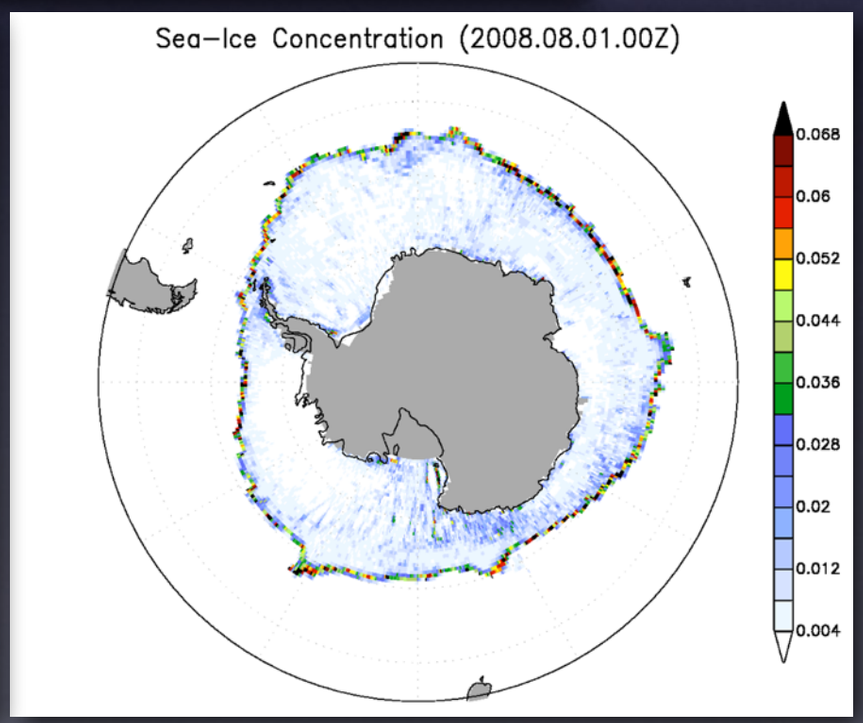
Ensemble *spread* of oceanic ICs (1 Aug)



SST

0.34°C

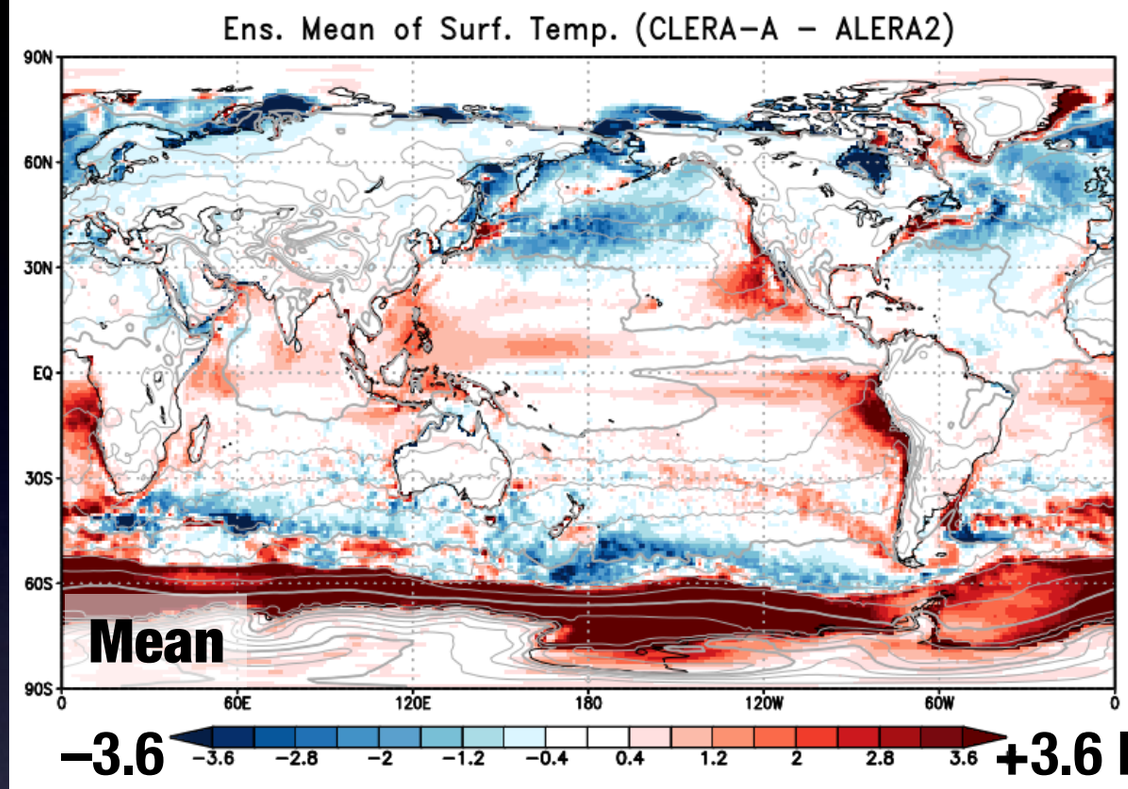


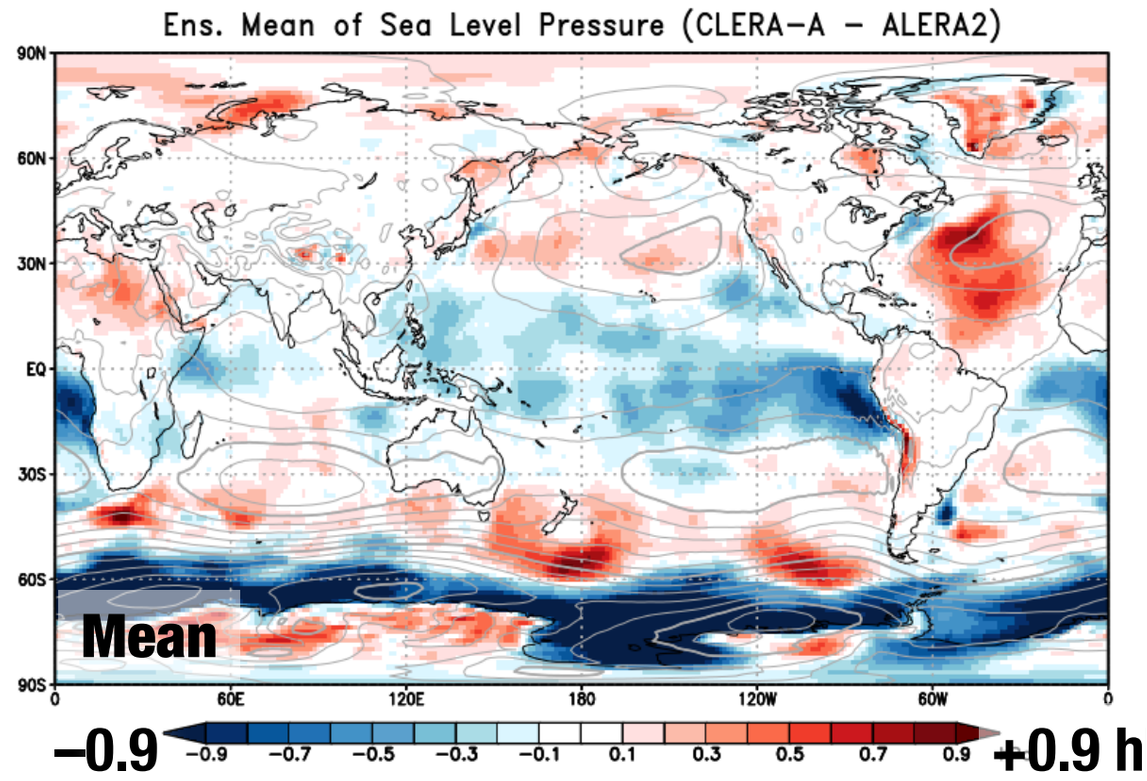


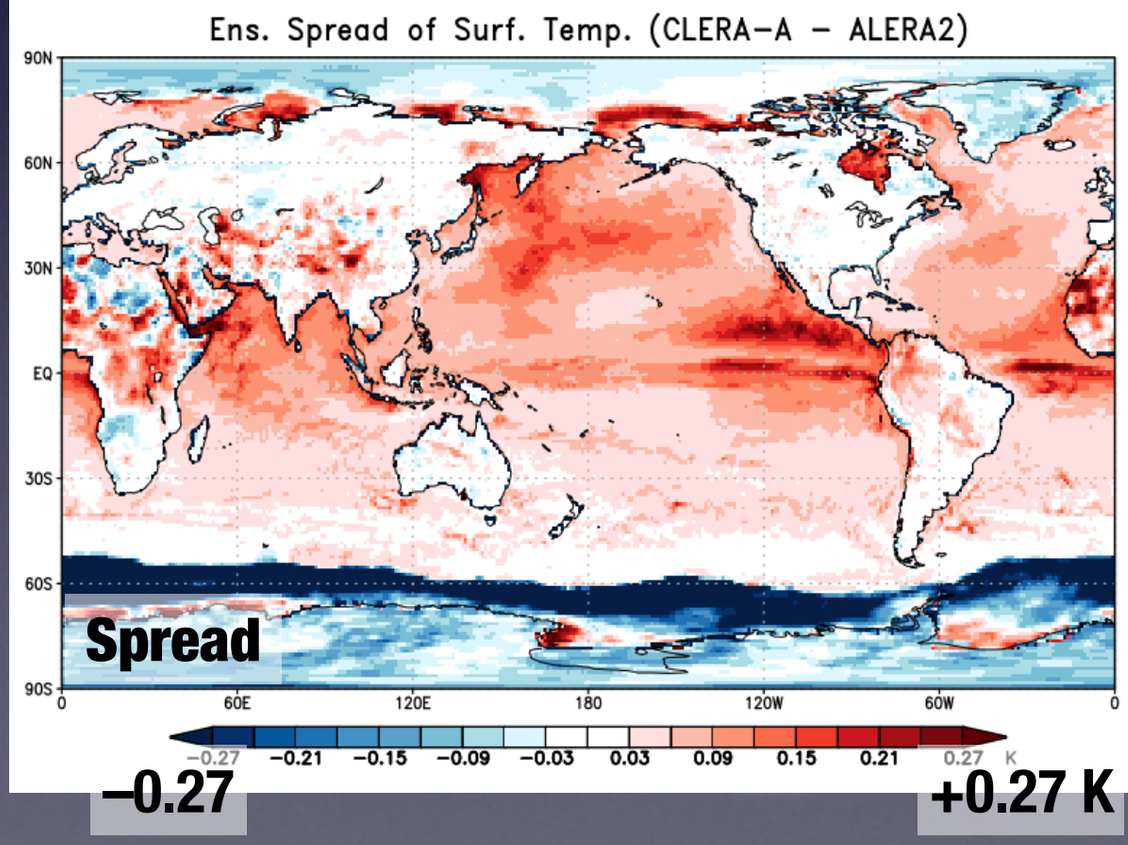
Sea-ice concentration

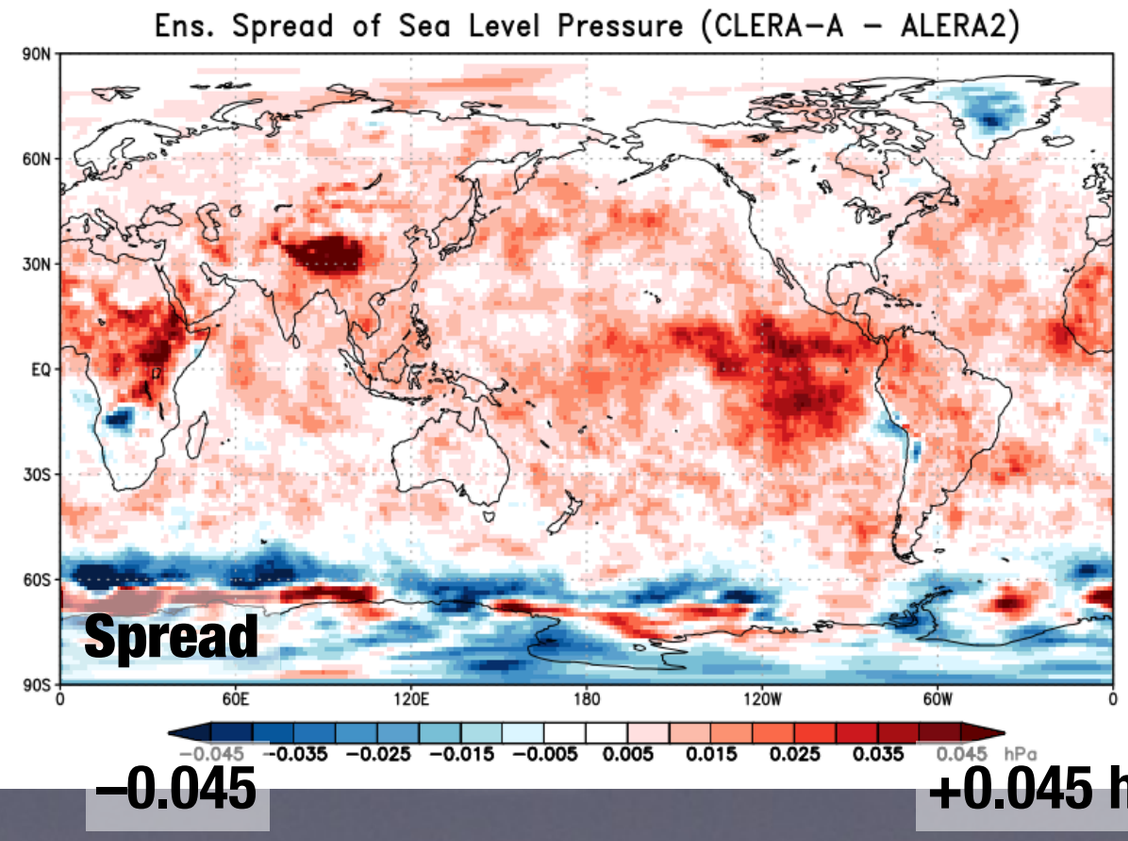
Comparison with ALERA2

Difference in surf. temp. & SLP (2-month ave.)

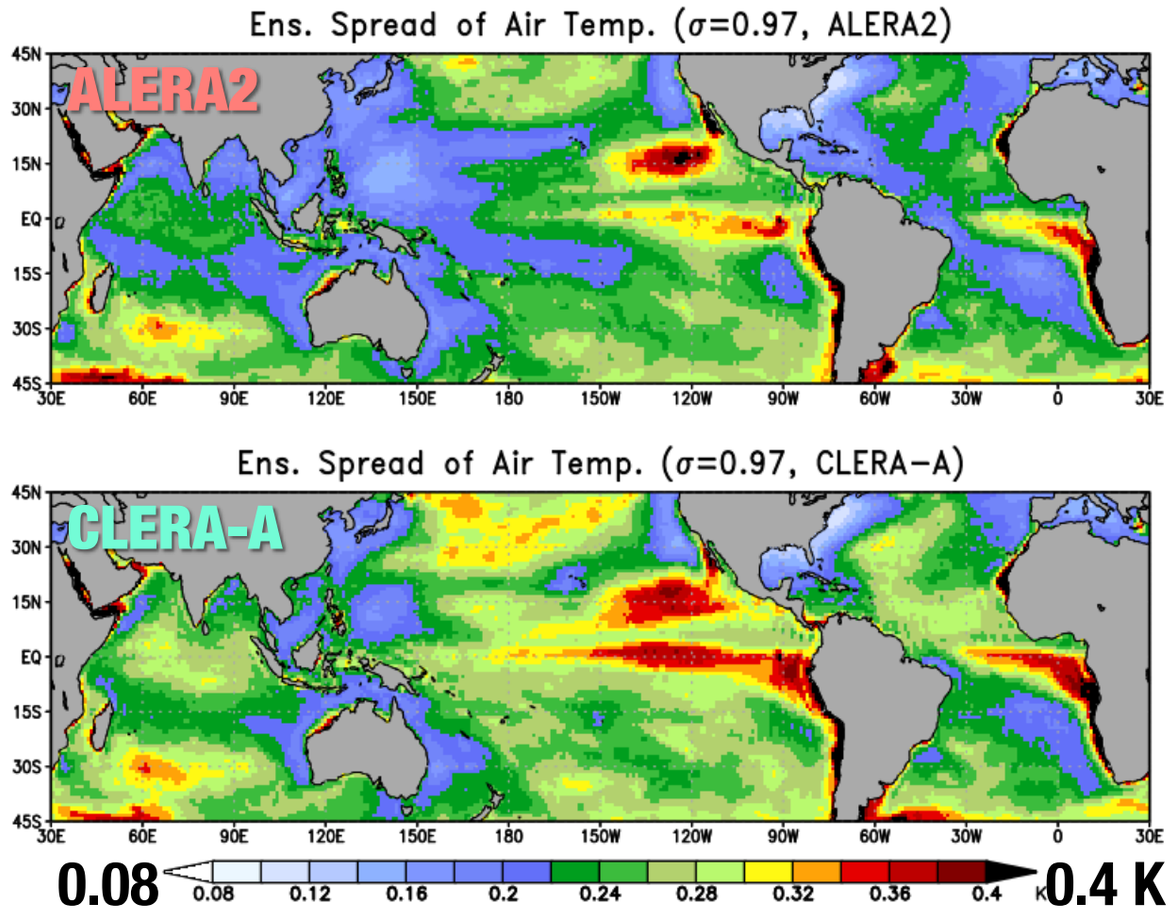


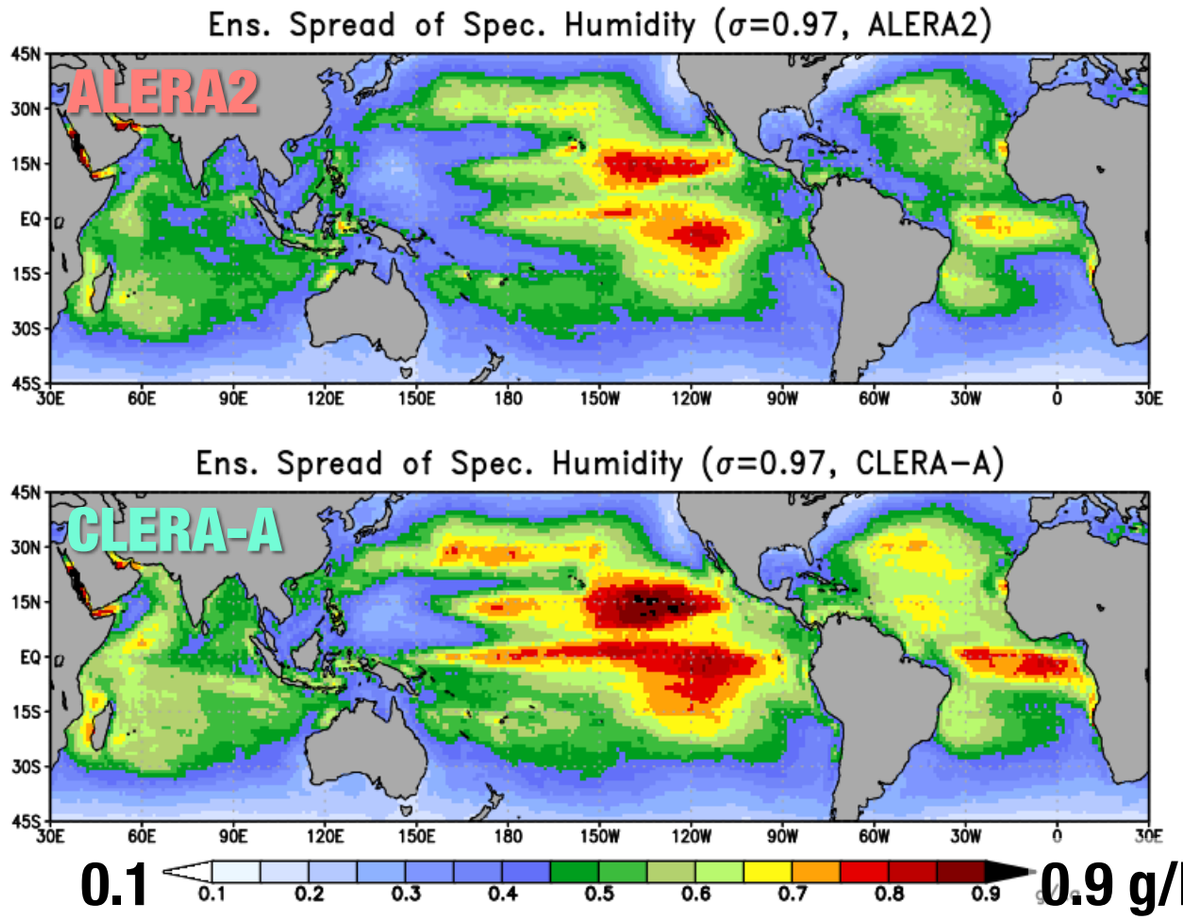


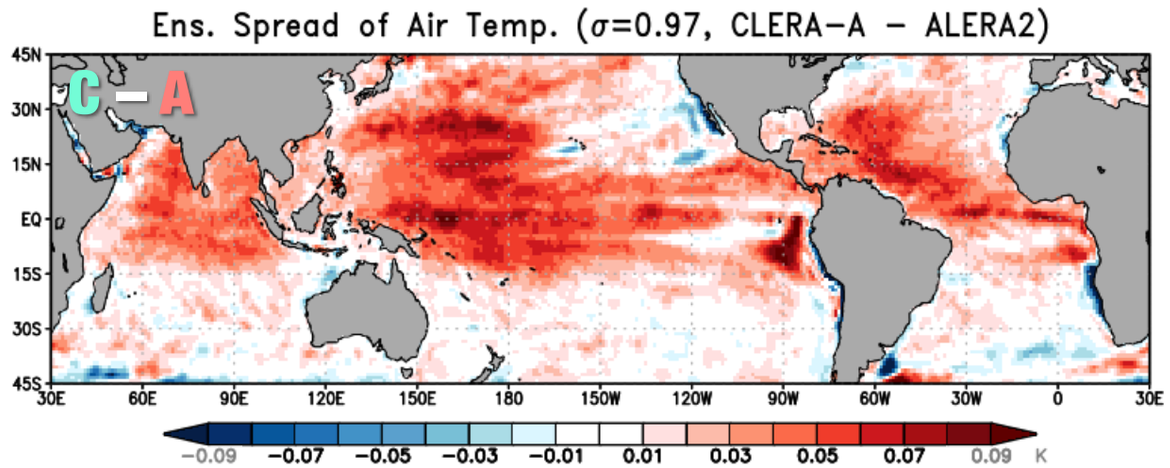


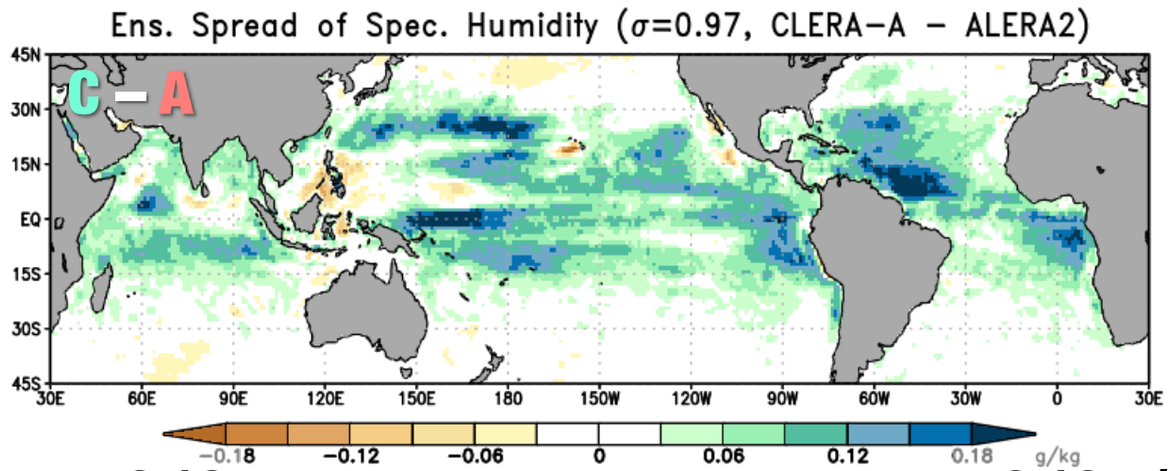


Ensemble spread of T & Q (~975 hPa, 2-month ave.)



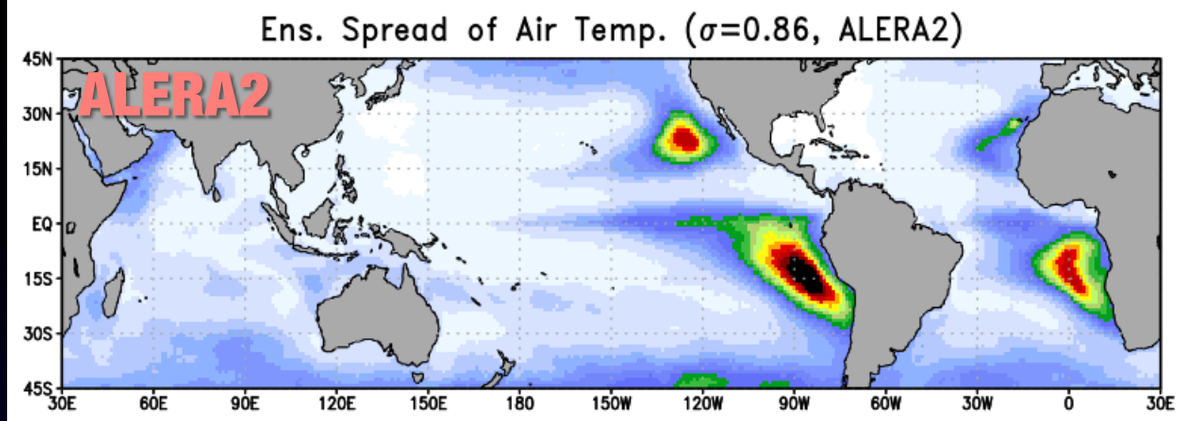


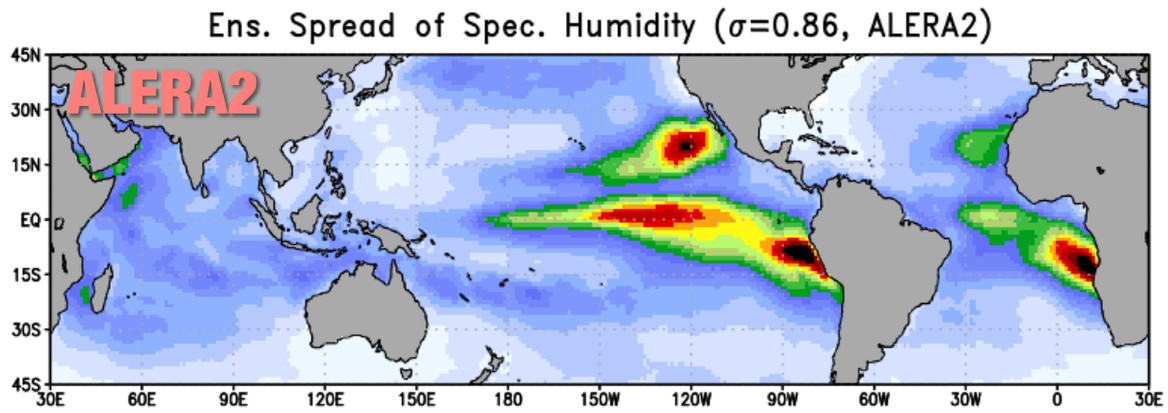


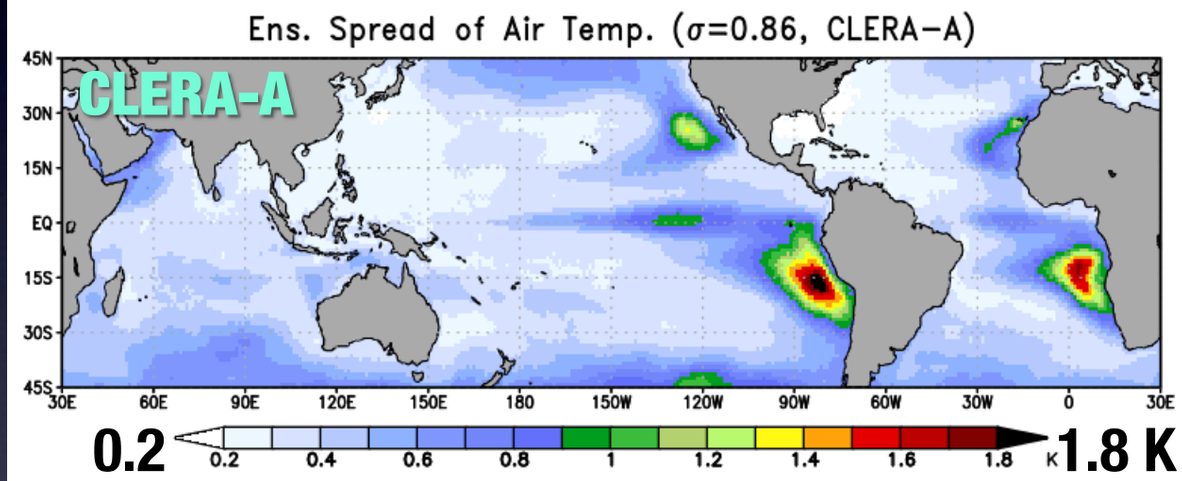


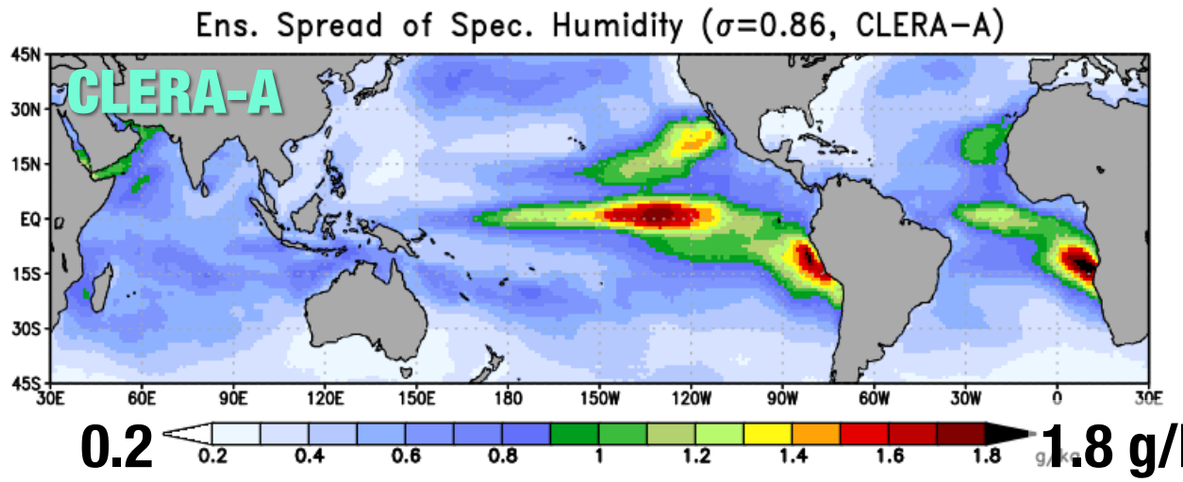
・元々小さい場所では最大で40%程度増加

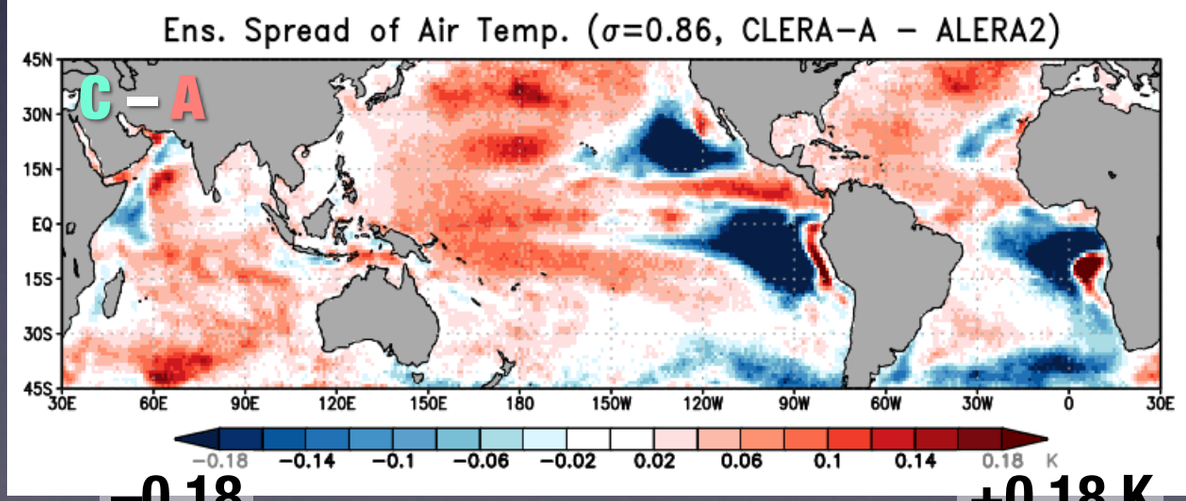
Ensemble spread of T & Q (~850 hPa, 2-month ave.)

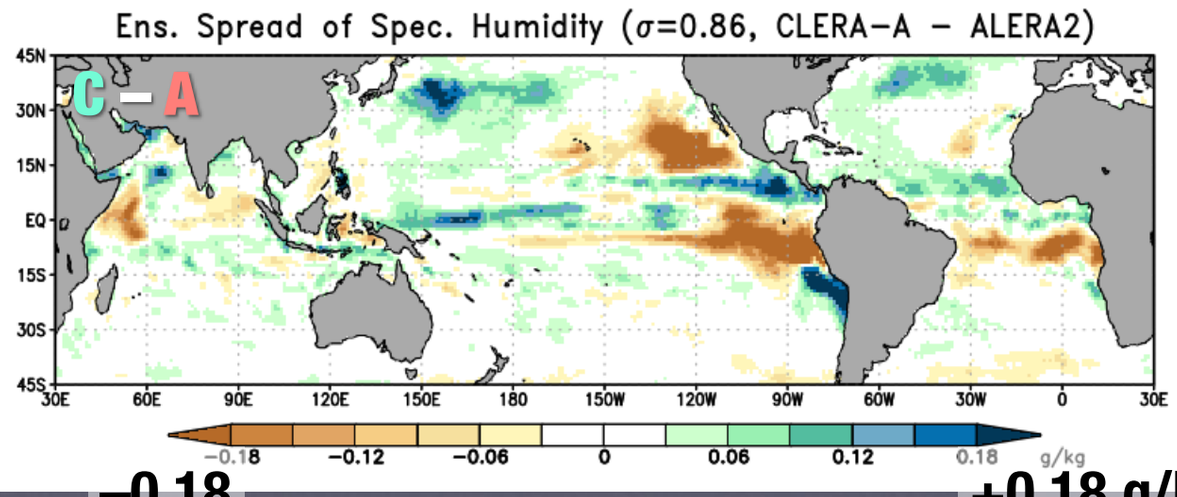








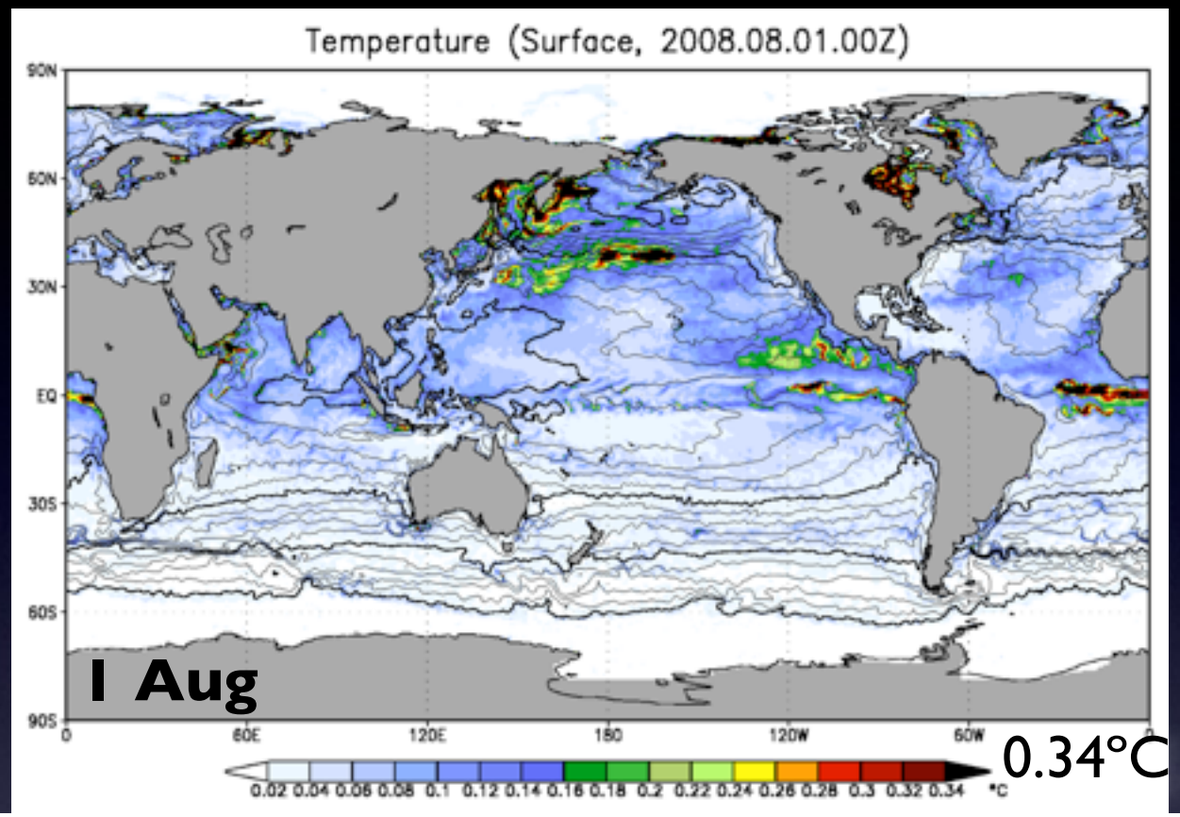




・バイアスの影響で場が変わり減少する場所も

Comparison with EnOFES

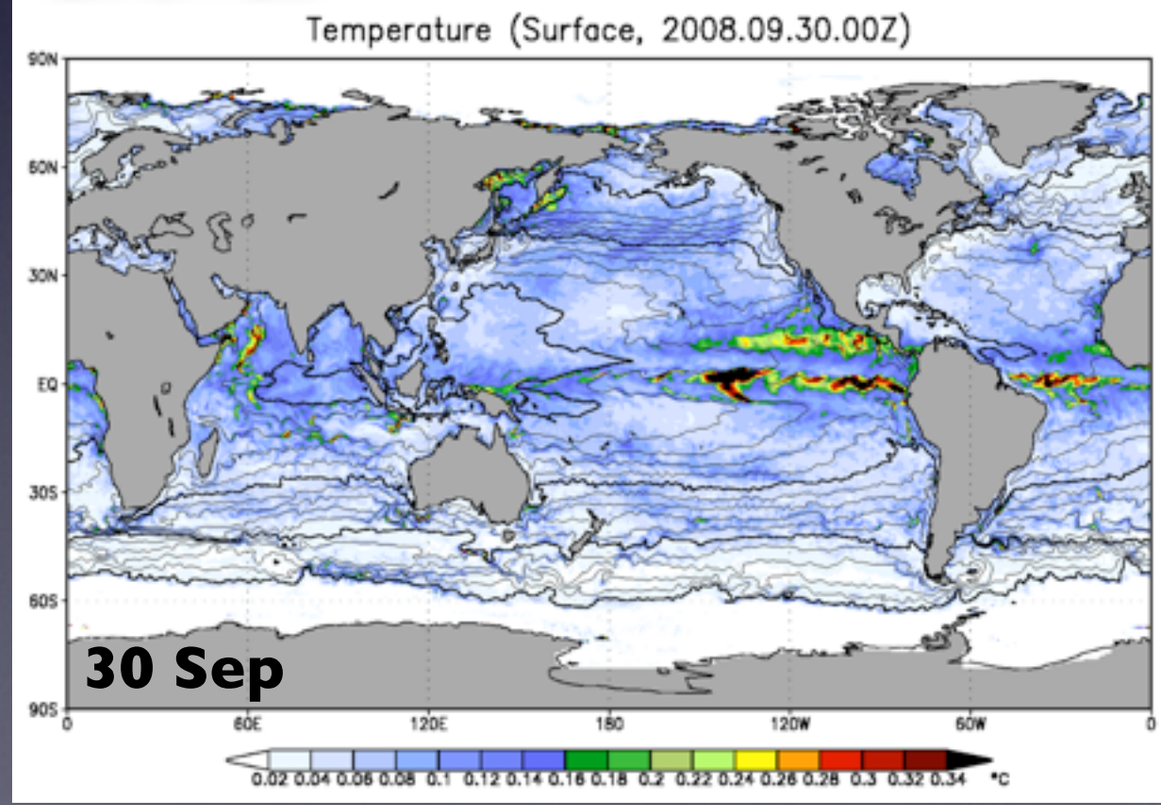
Ensemble *spread* of SST (1 Aug & 30 Sep)

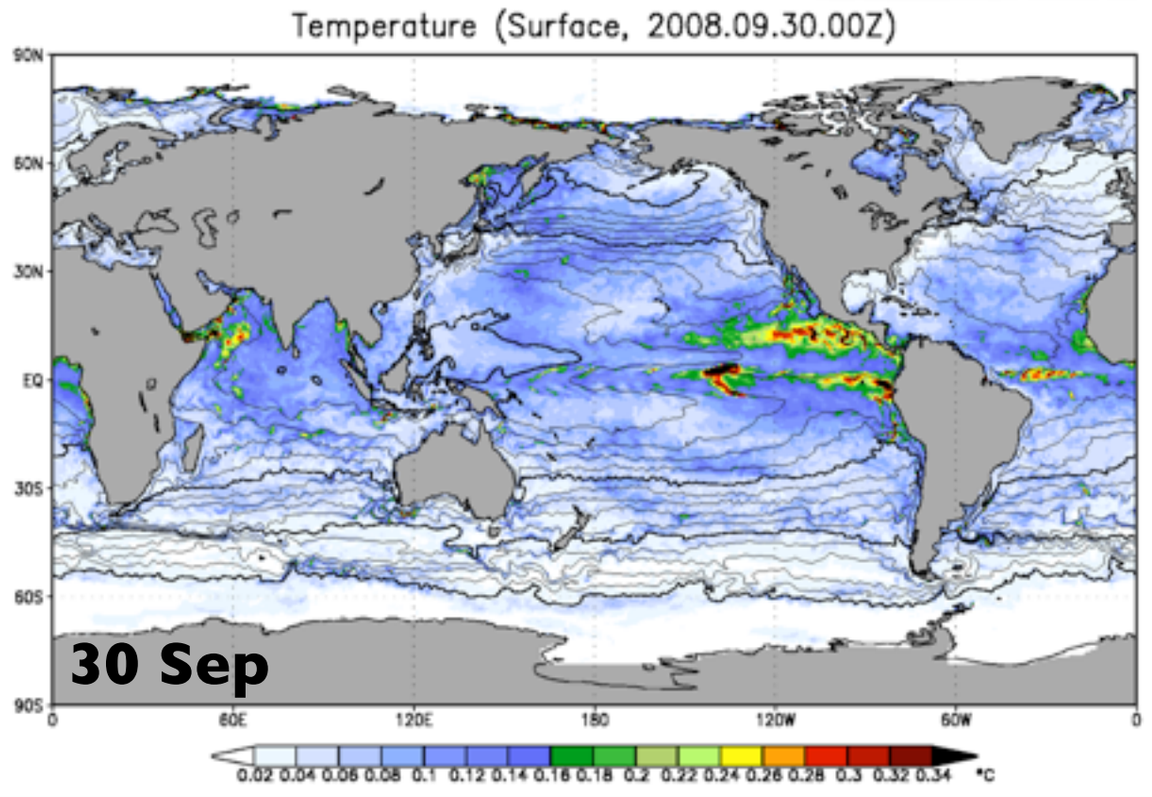


EnOFES

0.34°C

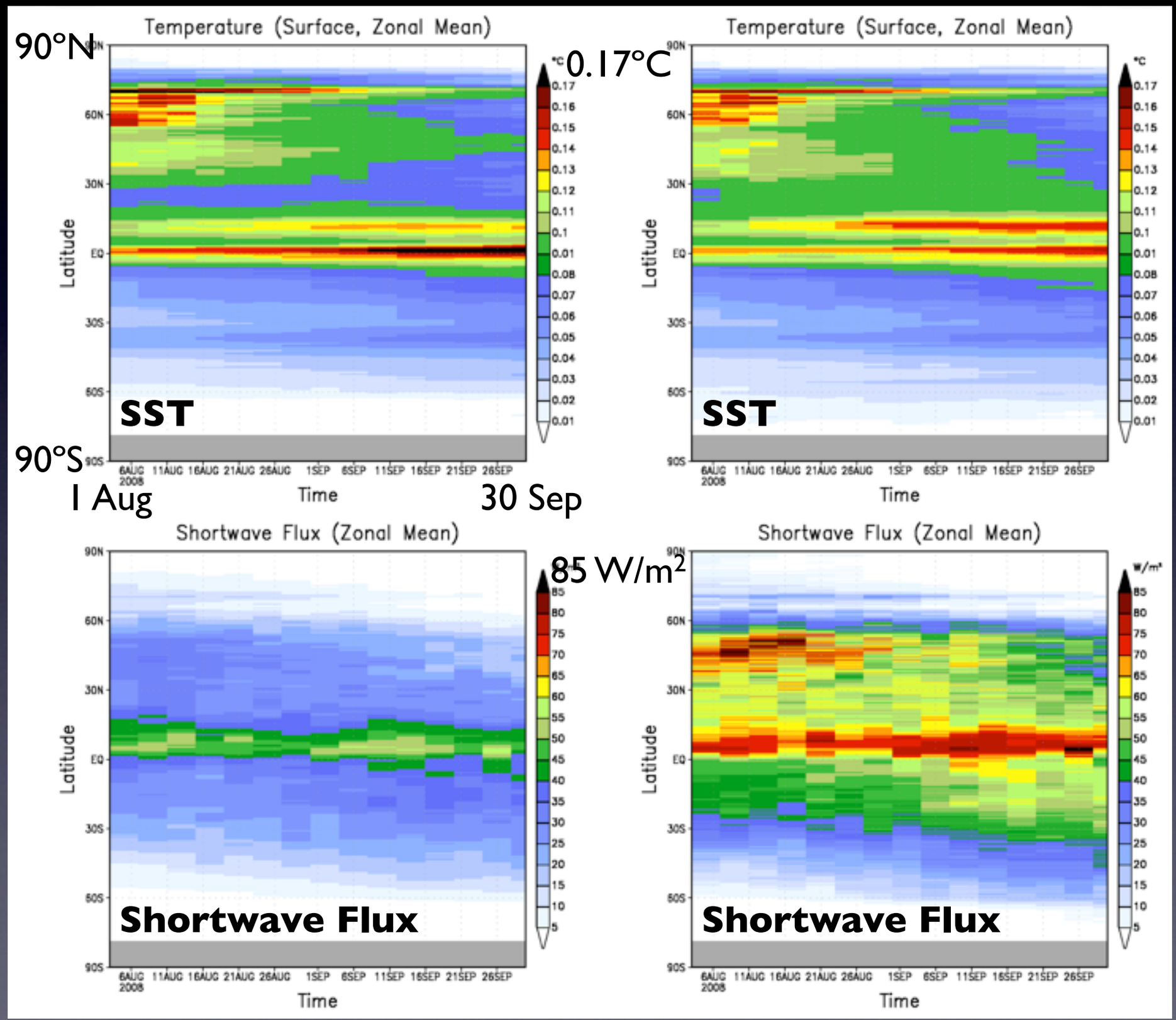
CLERA-A





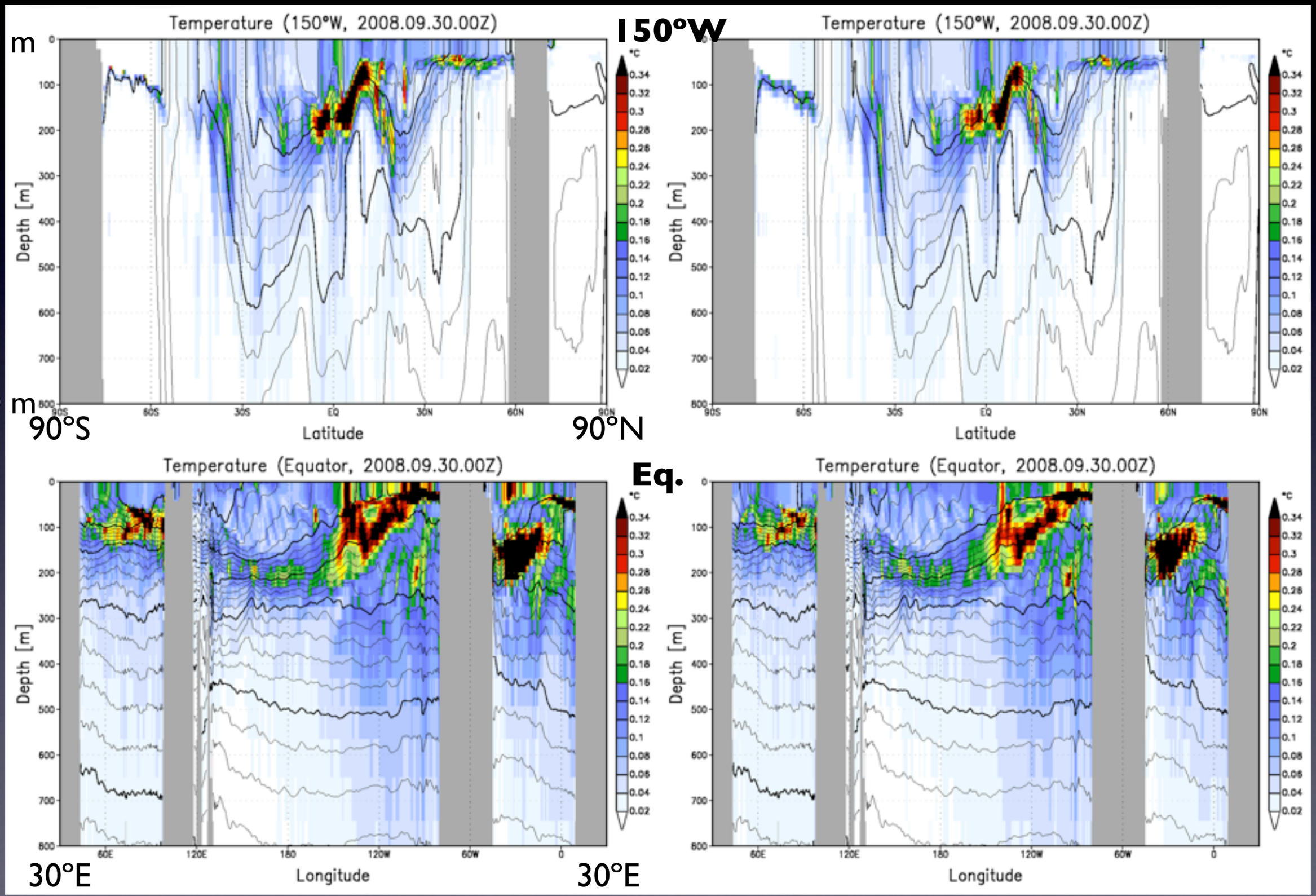
Zonal-mean ensemble *spread*

EnOFES **CLERA-A**



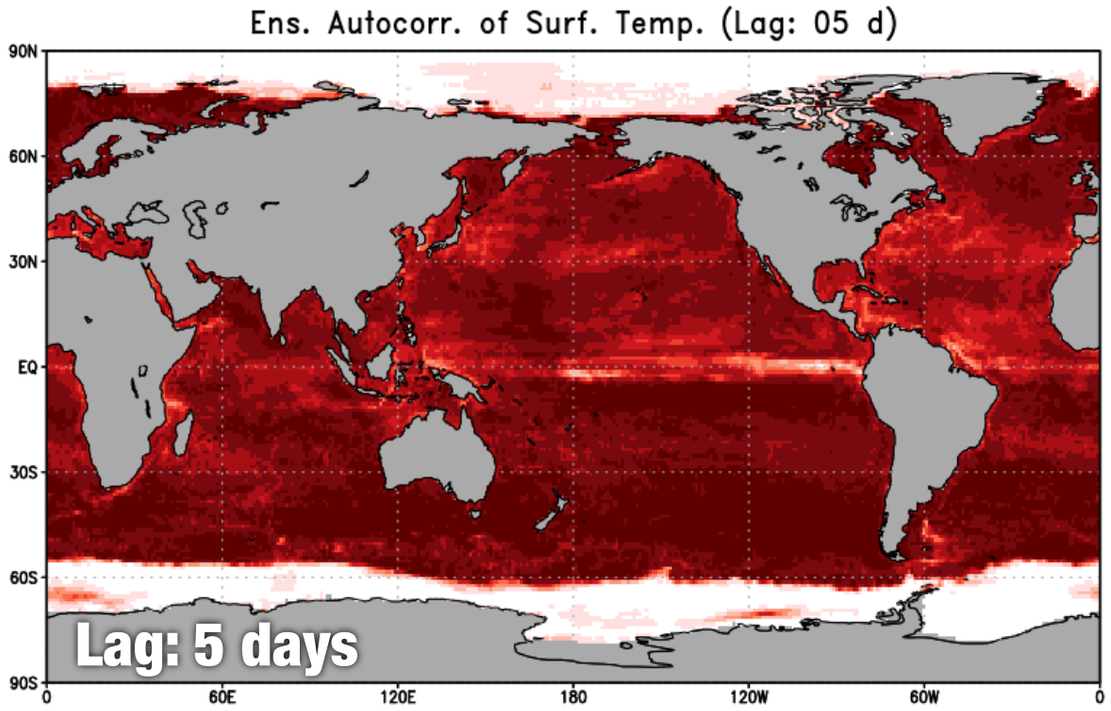
Ensemble *spread* of ocean temp.

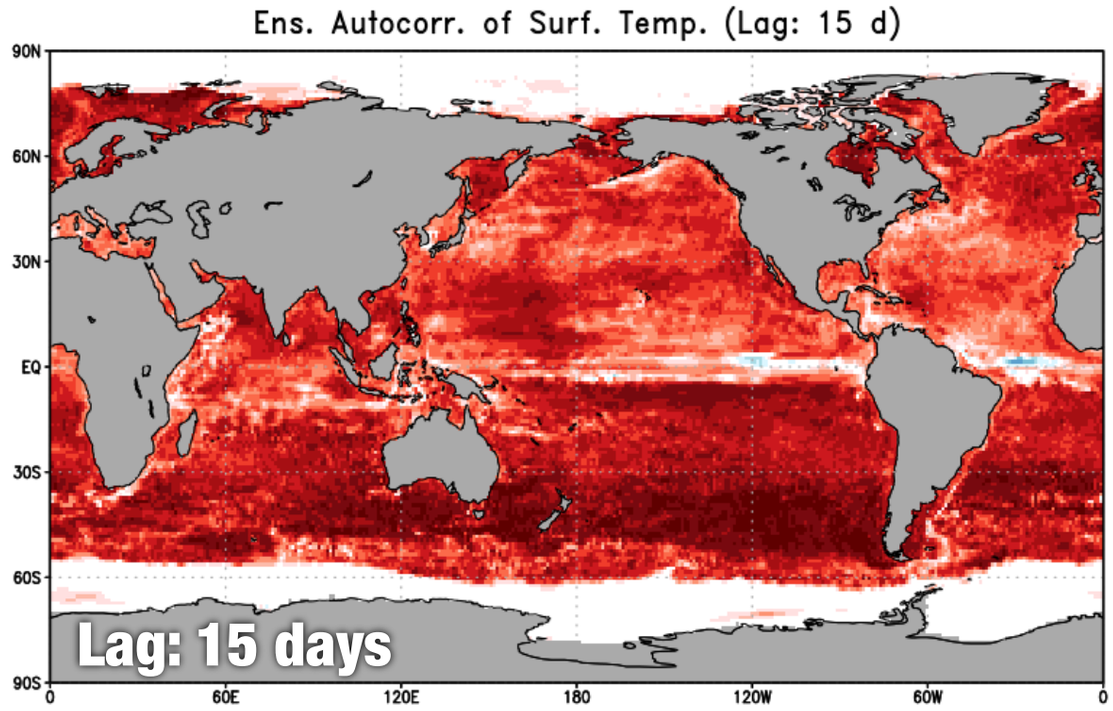
EnOFES **CLERA-A**

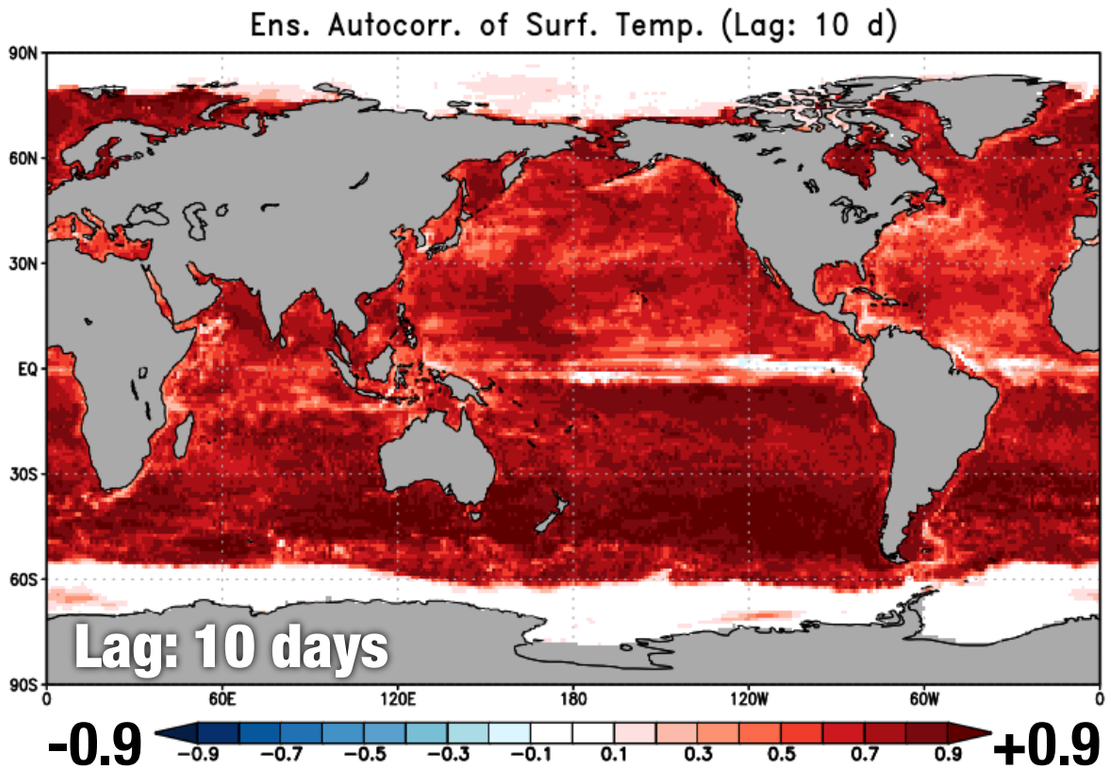


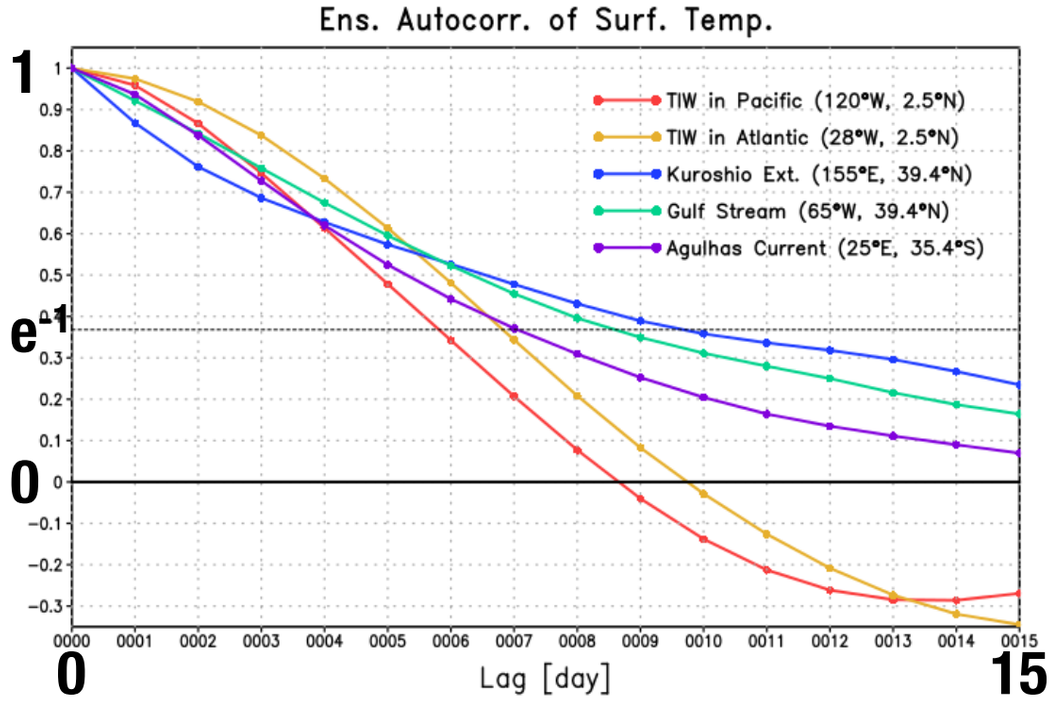
Ensemble Statistics between SST and Other Variables

Ensemble autocorrelation of SST





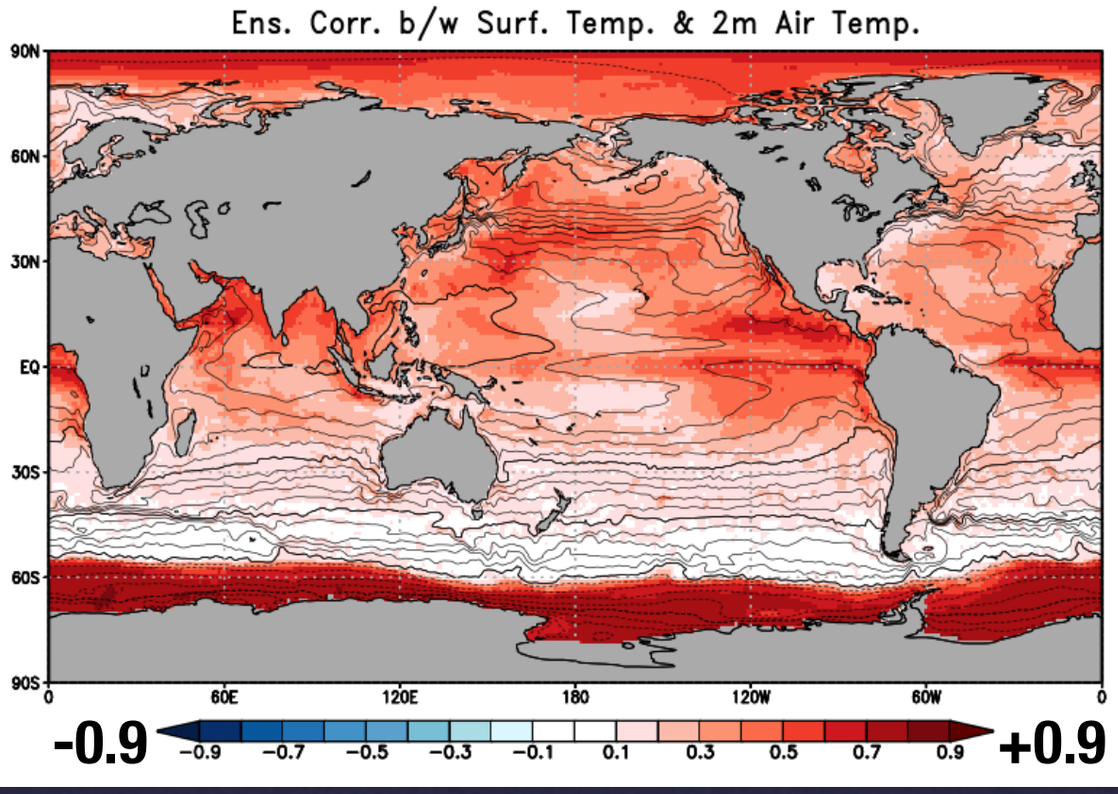


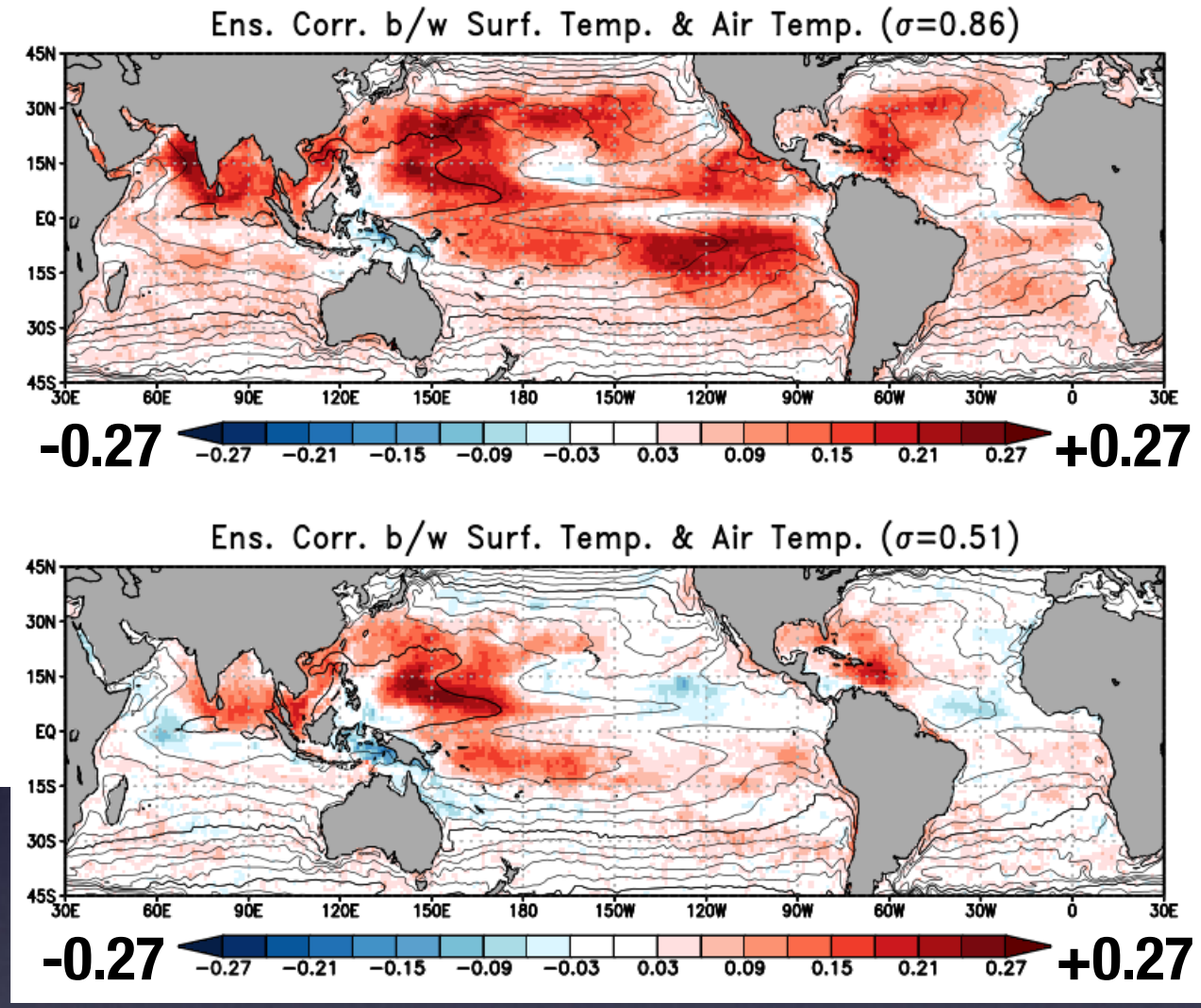


Vertical corr. b/w SST and air temp.

T2

~850 hPa





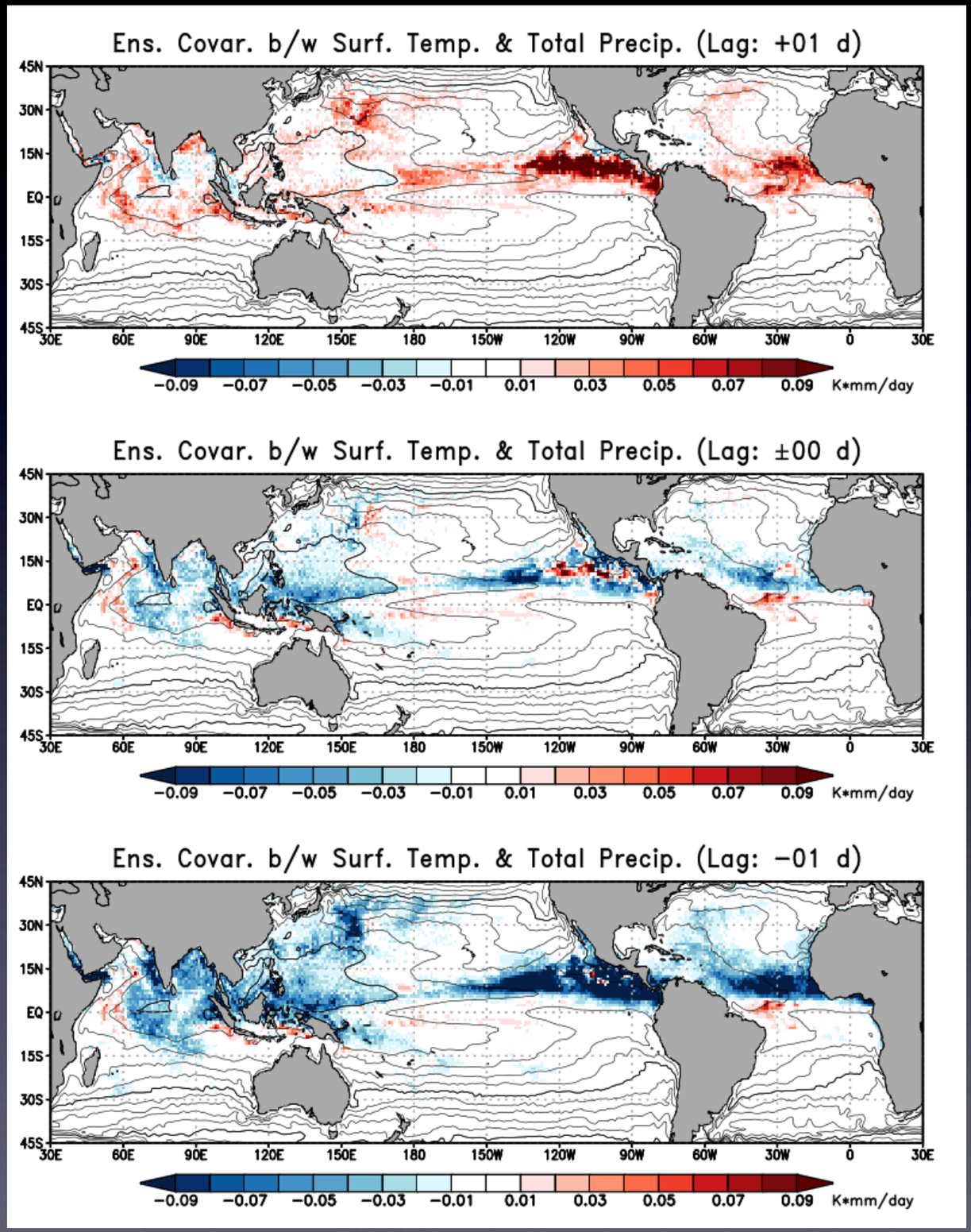
Color: Vertical Corr.

Contours: SST (C.I.: 2℃)

CLERA-A

~500 hPa

Lag-covariance b/w SST and precip. (40-day ave.)

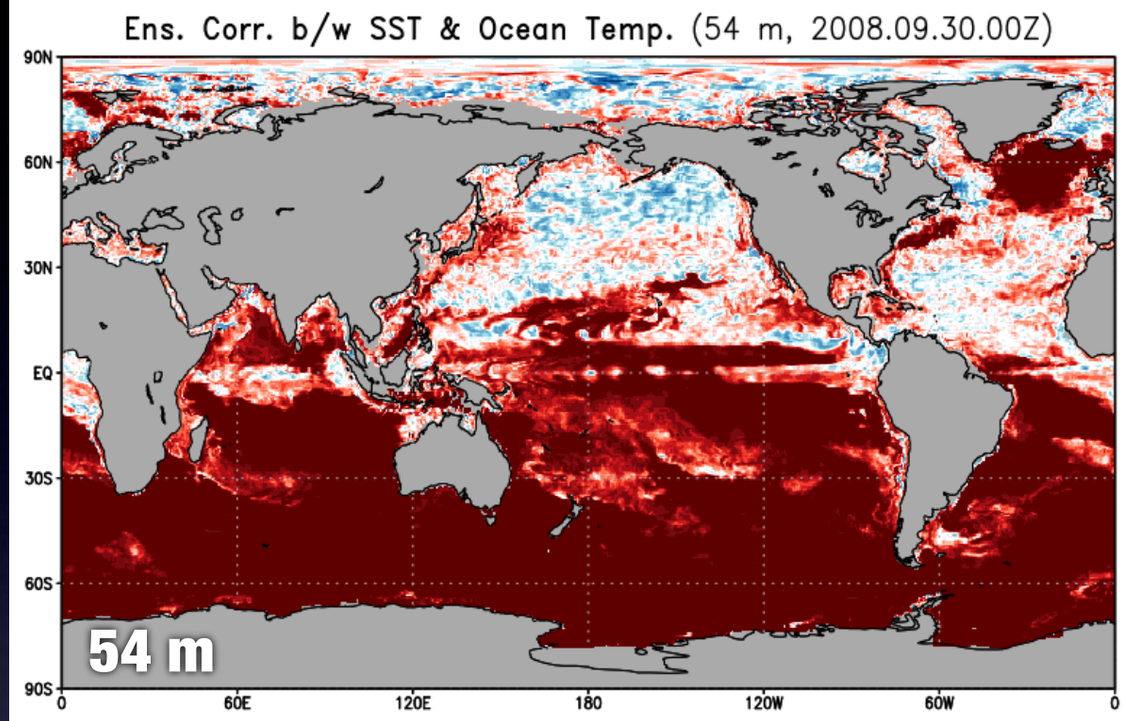


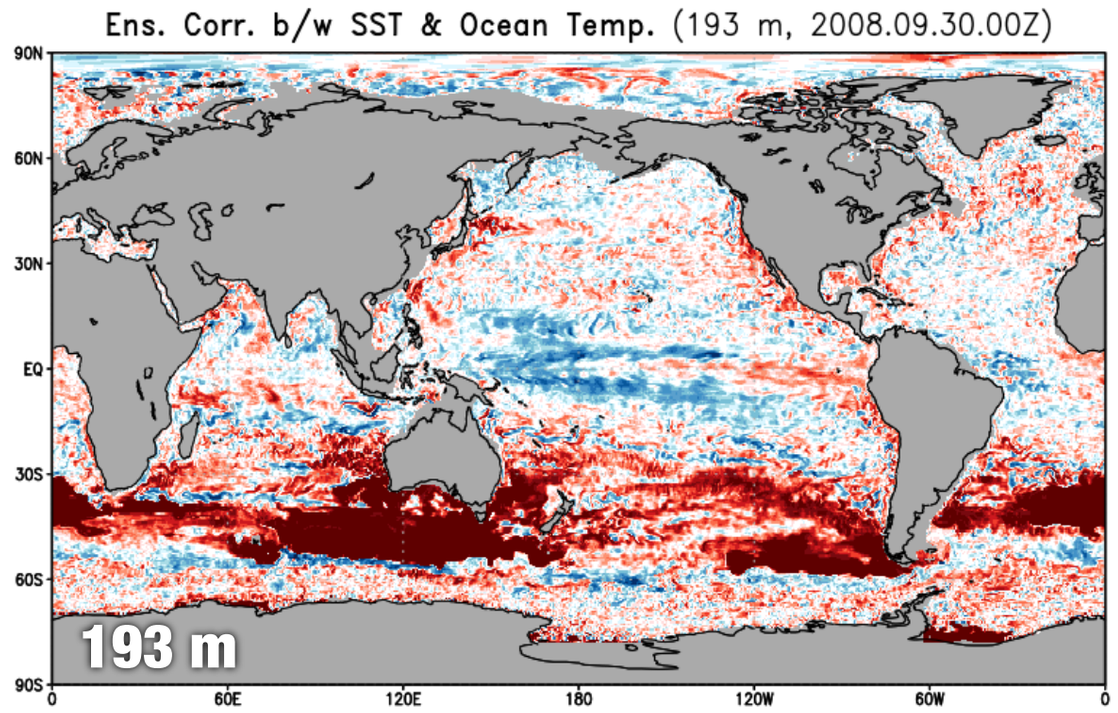
SST leads 1 day

Simultaneous

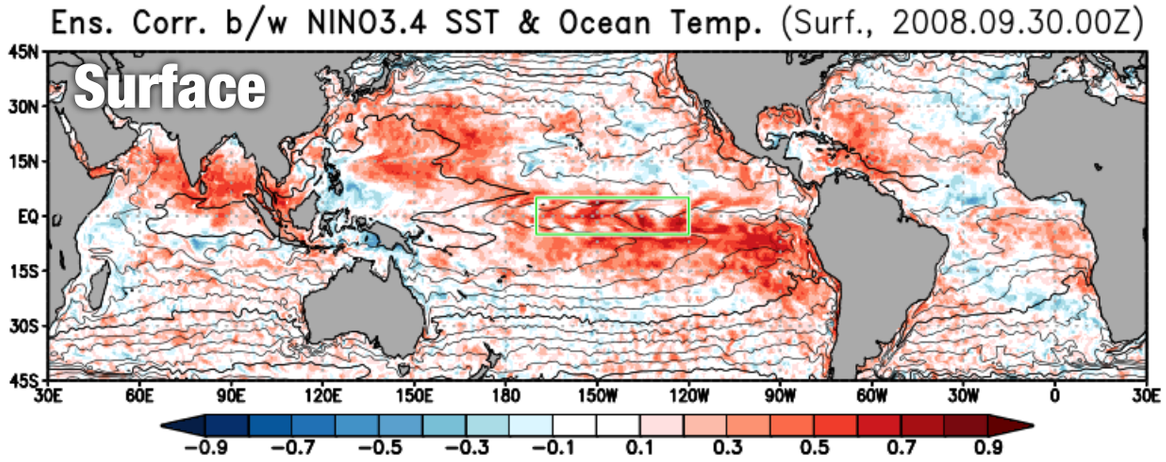
Precip. leads 1 day

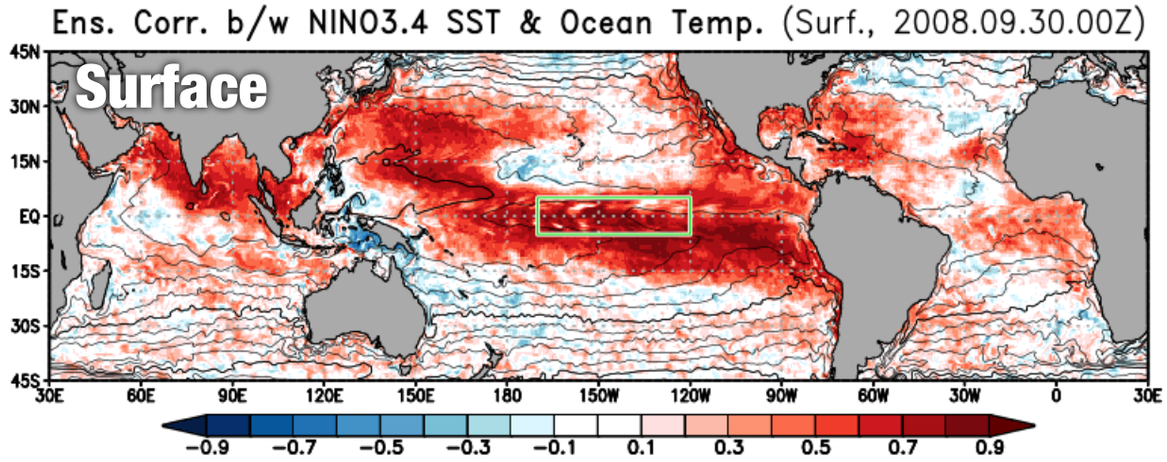
Vertical corr. b/w SST and ocean temp.

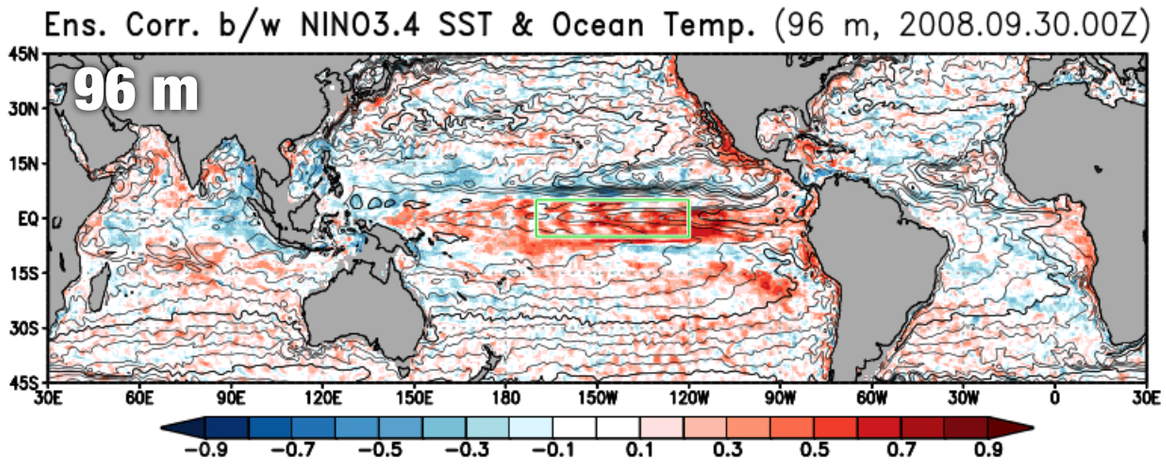


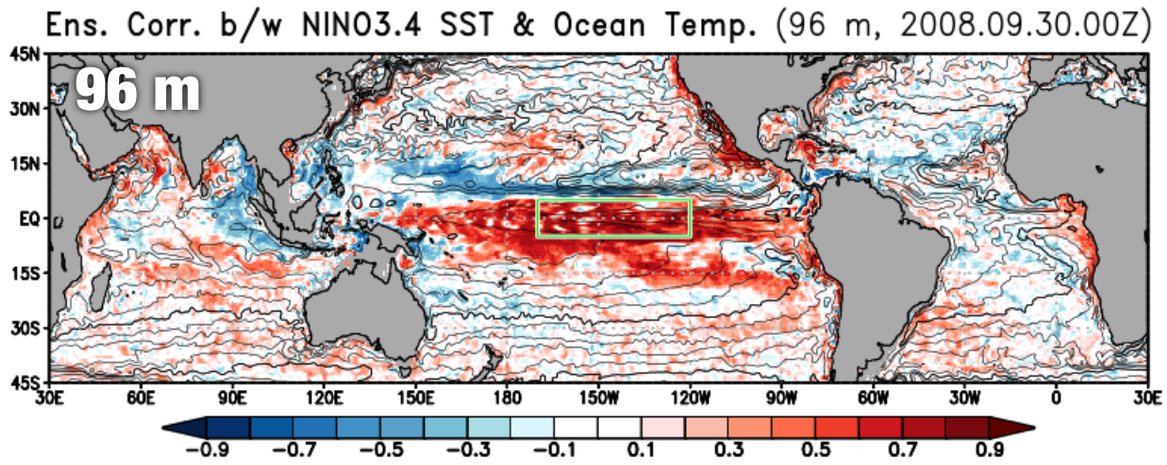


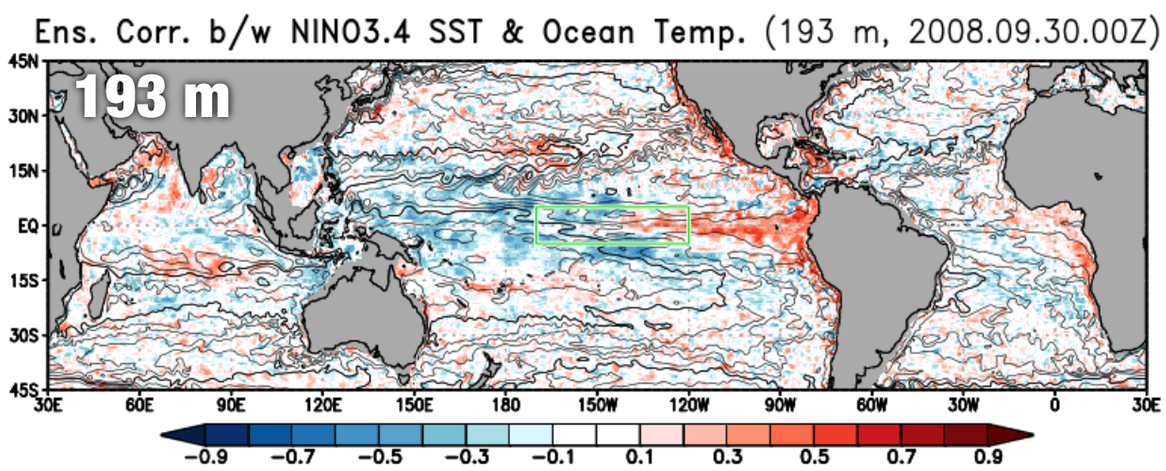
EnOFES Corr. b/w NINO3.4 SST & ocean temp. CLERA-A

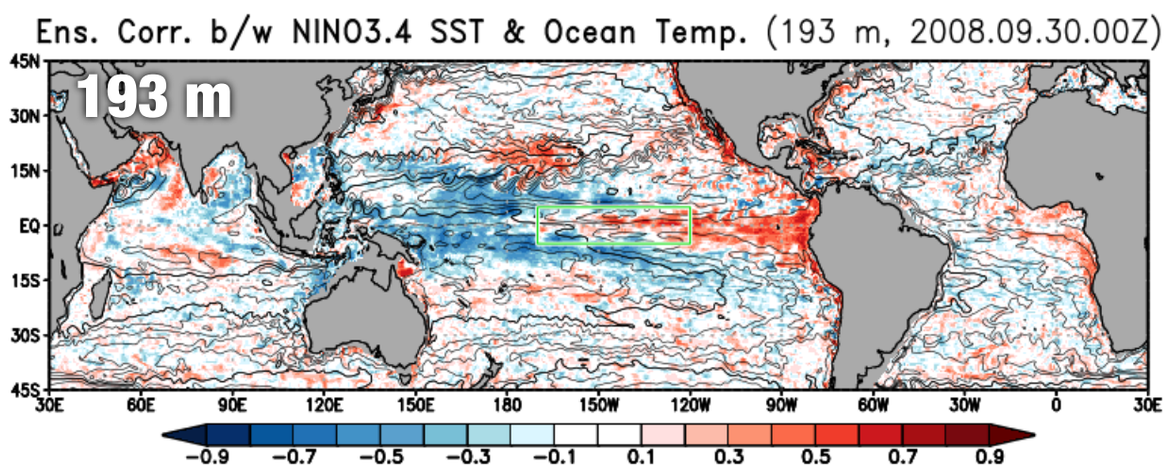




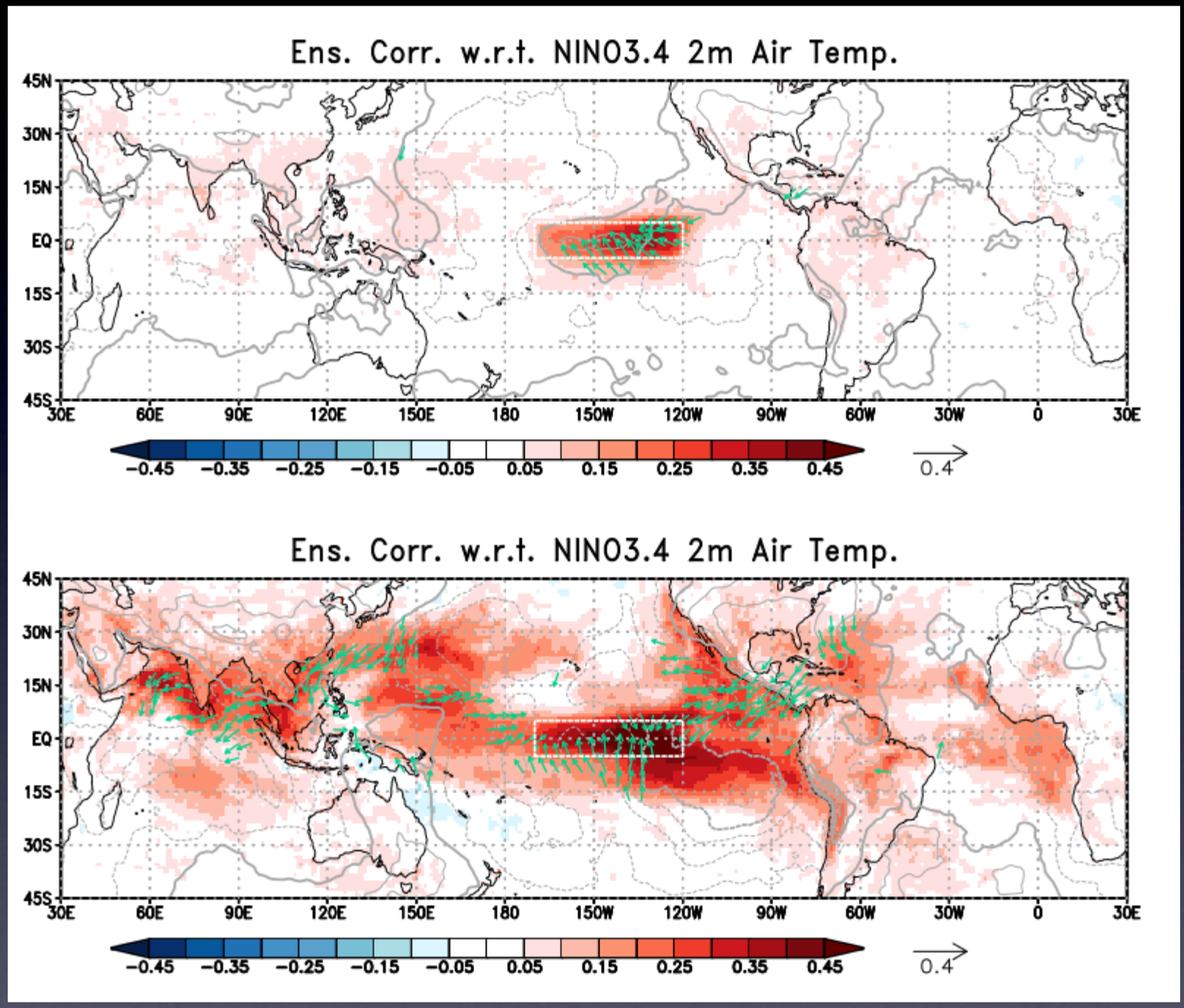








Corr. w.r.t. NINO3.4 2m air temp. (2-month ave.)



ALERA2

CLERA-A

Color: 2m Air Temperature
Arrows: 10m Winds (> 0.1)
Contours: Surface pressure (C.I.: 0.05)

Summary

- The CFES–LETKF ensemble DA system has been constructed.
  - Ocean ensemble creates perturbed surface BC.
  - Ensemble spread in the lower troposphere is successfully increased.
  - Ensemble spread of ocean surface is slightly increased by atmosphere–ocean coupling.
  - Coupled DA system captures the basin-scale structure of ocean temperature.
  - Optimal parameters for DA (e.g., localization scales) could be different b/w atmospheric and coupled DA systems.
- Additional assimilation of oceanic observation is necessary.

Thank You!