# Reanalyzed Oceanic Variability from Updated GFDL Ensemble Coupled Data Assimilation

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S. Zhang, You-Soon Chang, A. Rosati, T. Delworth,
W. Stern, R. Gudgel

**National Oceanic and Atmospheric Administration**
**Geophysical Fluid Dynamics Laboratory**
**Princeton, NJ 08542**
**http://www.gfdl.noaa.gov**

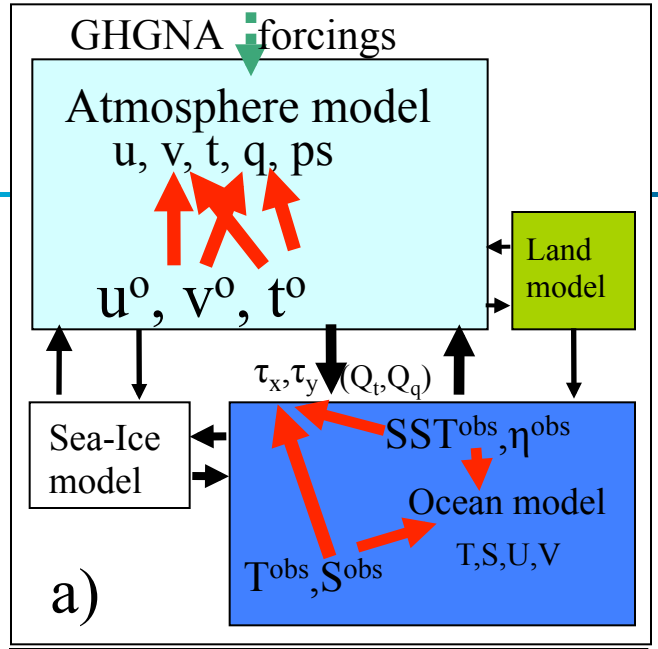
# OUTLINE

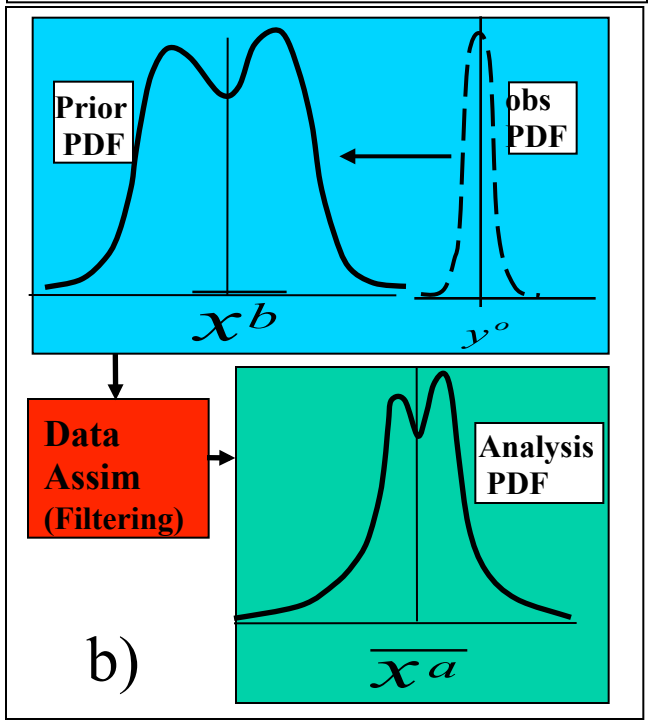
- ✓ Description of GFDL Ensemble Coupled Data Assimilation (ECDA) system
- ✓ Summary of Analyzed Oceanic Variability of ECDA v3.1
- ✓ Problems of ECDA v3.1
- ✓ ECDA v4.0
- ✓ High-Resolution Ensemble Coupled Data Assimilation Toward Seamless Numerical Weather-Climate Studies
- ✓Ongoing researches of GFDL ECDA

# GFDL's ECDA system: (1) System description

**Coupled Ensemble Data Assimilation estimates the *temporally-evolving probability distribution* of climate states under observational data constraint:**

- ✓ Multi-variate analysis maintaining physical balances between state variables such as T-S relationship & geostrophic balance mostly
- ✓ Ensemble filter maintaining the non-linearity of climate evolution mostly
- ✓ All coupled components adjusted by observed data through instantaneously-exchanged fluxes
- ✓ Optimal ensemble initialization of coupled model with minimum initial shocks



# GFDL ECDA system: (2) Product of ECDA v3.1

✓Data on public domain:
http://www.gfdl.noaa.gov/ocean-data-assimilation-model-output

✓ Comparison with other products:
Xue et al., 2012: A comparative analysis of upper ocean heat content variability from an ensemble of operational ocean reanalyses. *JC in press*

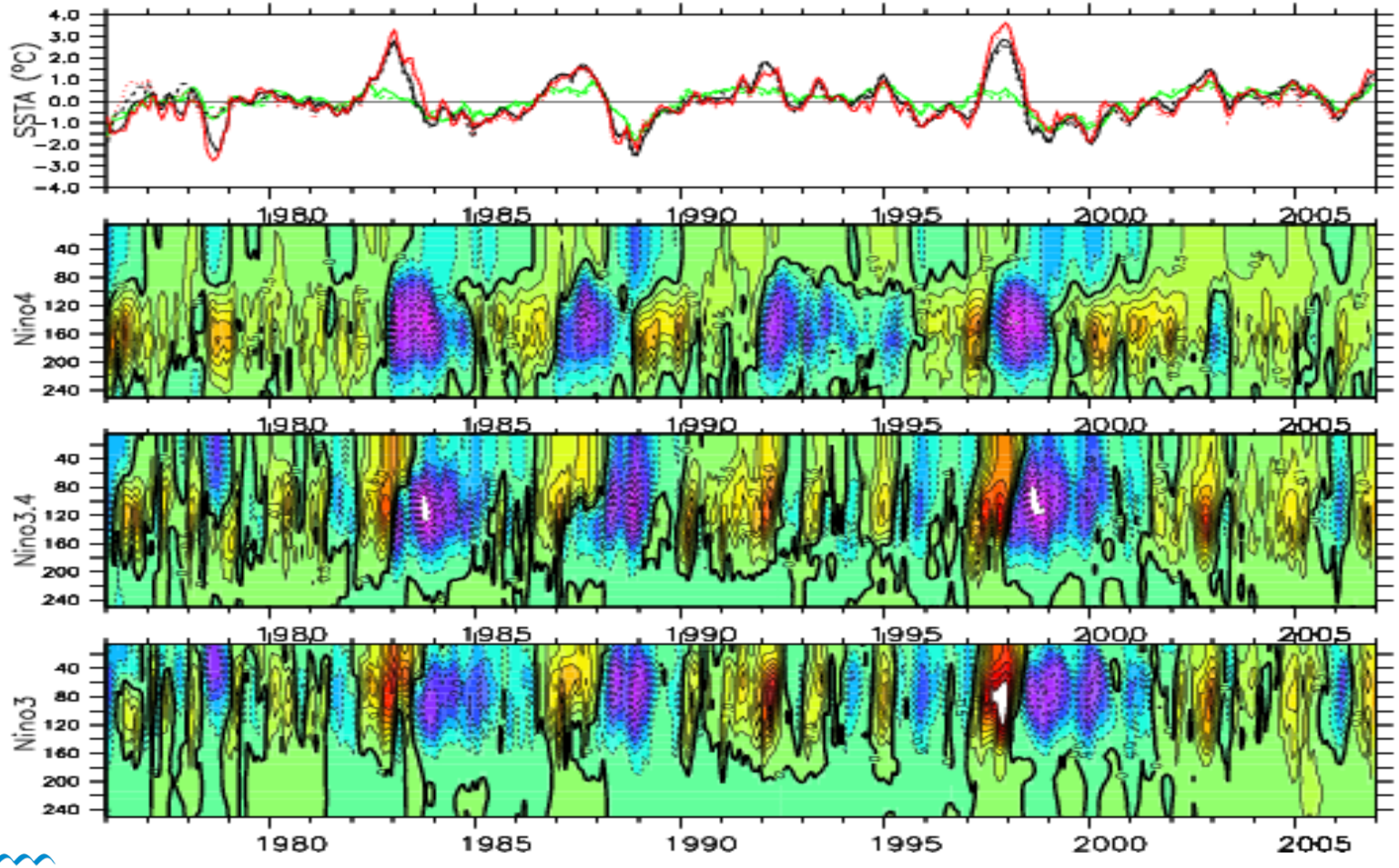
✓Detailed evaluation:
Chang, You-Soon et al., 2012: An assessment of oceanic variability for 1960-2010 from the GFDL Ensemble Coupled Data Assimilation. CD in press

MS available @ ftp://ftp.gfdl.noaa.gov/pub/ysc/ECDA_paper/ECDA_ver3_ysc_et_al.pdf

# Summary of ECDA v3.1 product: (1) ENSO Variability

N4 SSTA Obs  N3.4 SSTA Obs  N3 SSTA Obs

N4 SSTA ECDA  N3.4 SSTA ECDA  N3 SSTA ECDA

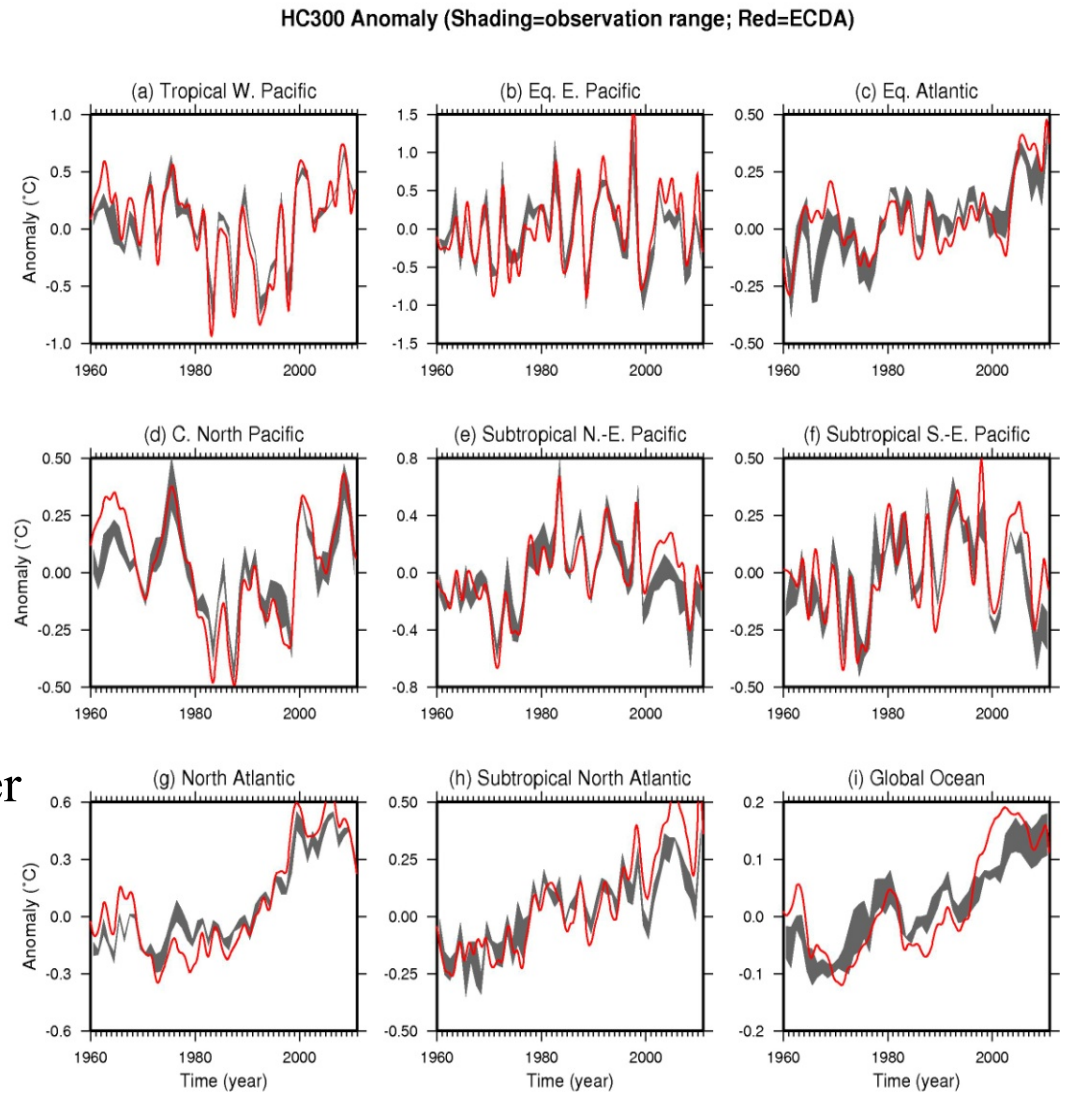


# Summary of ECDA v3.1 product: (2) Basin scale top300 m heat content

Obs & uncertainty (NODC2005, NODC2009, EN3)

ECDA v3.1

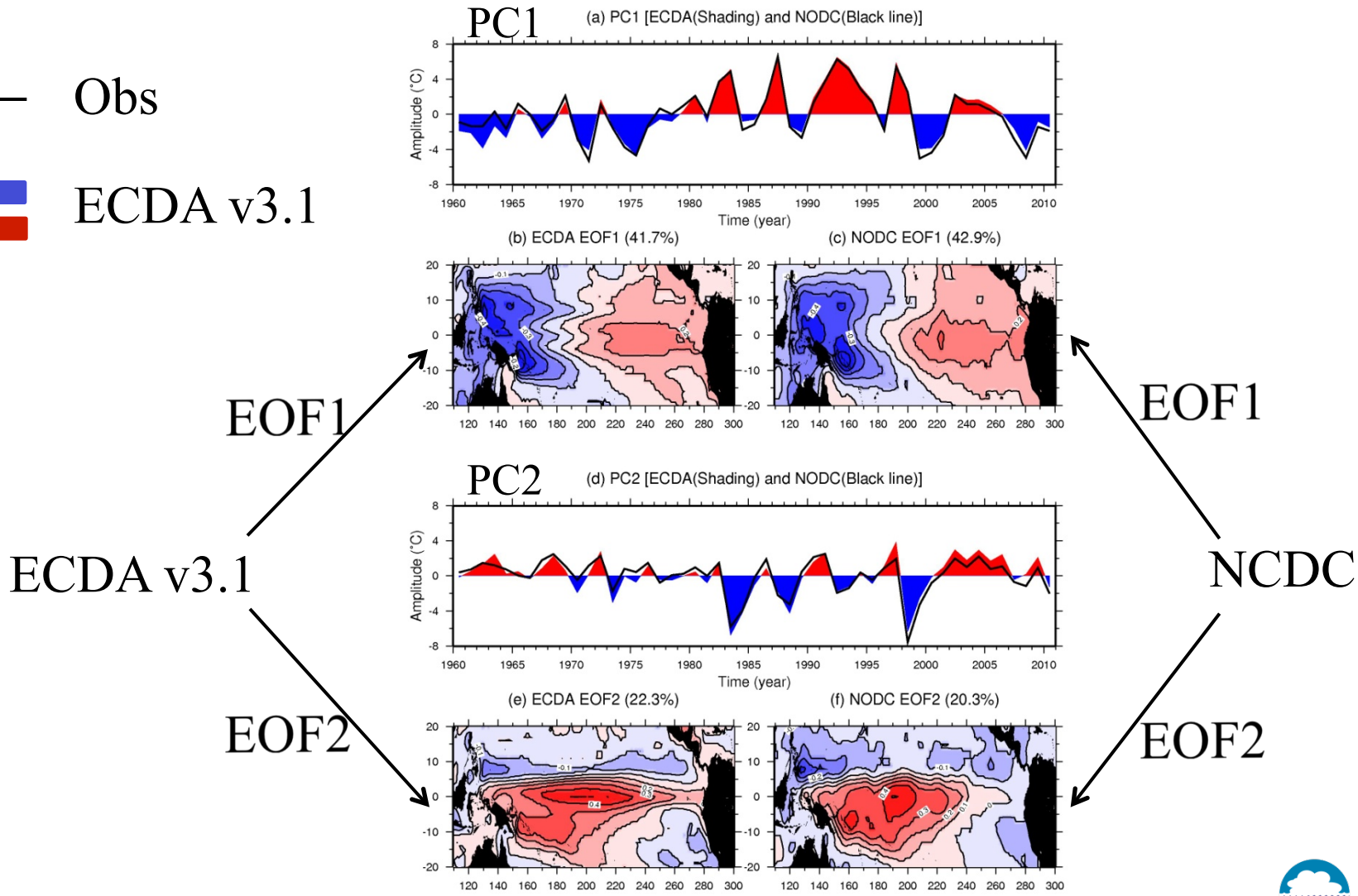
- ✓ Overall capture the observed variability well
- ✓ Tropics are better than extra-tropics
- ✓ The Pacific is a little better than the Atlantic
- ✓ Misfitting exists



# Summary of ECDA v3.1 product: (3) Tropical Pacific HC300 EOF1 and EOF2

Obs

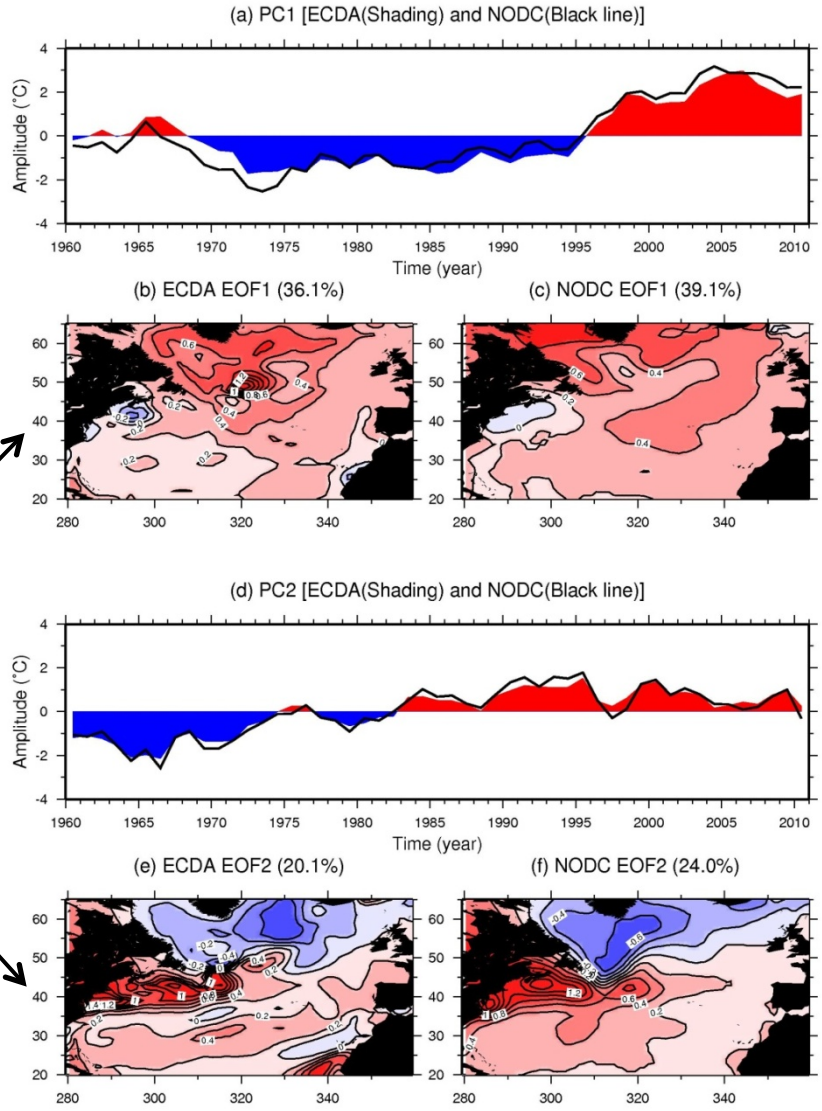
ECDA v3.1



# Summary of ECDA v3.1 product: (4) North Pacific HC300 EOF1 and EOF2

Obs

ECDA v3.1




EOF1

EOF1

ECDA v3.1

NCDC

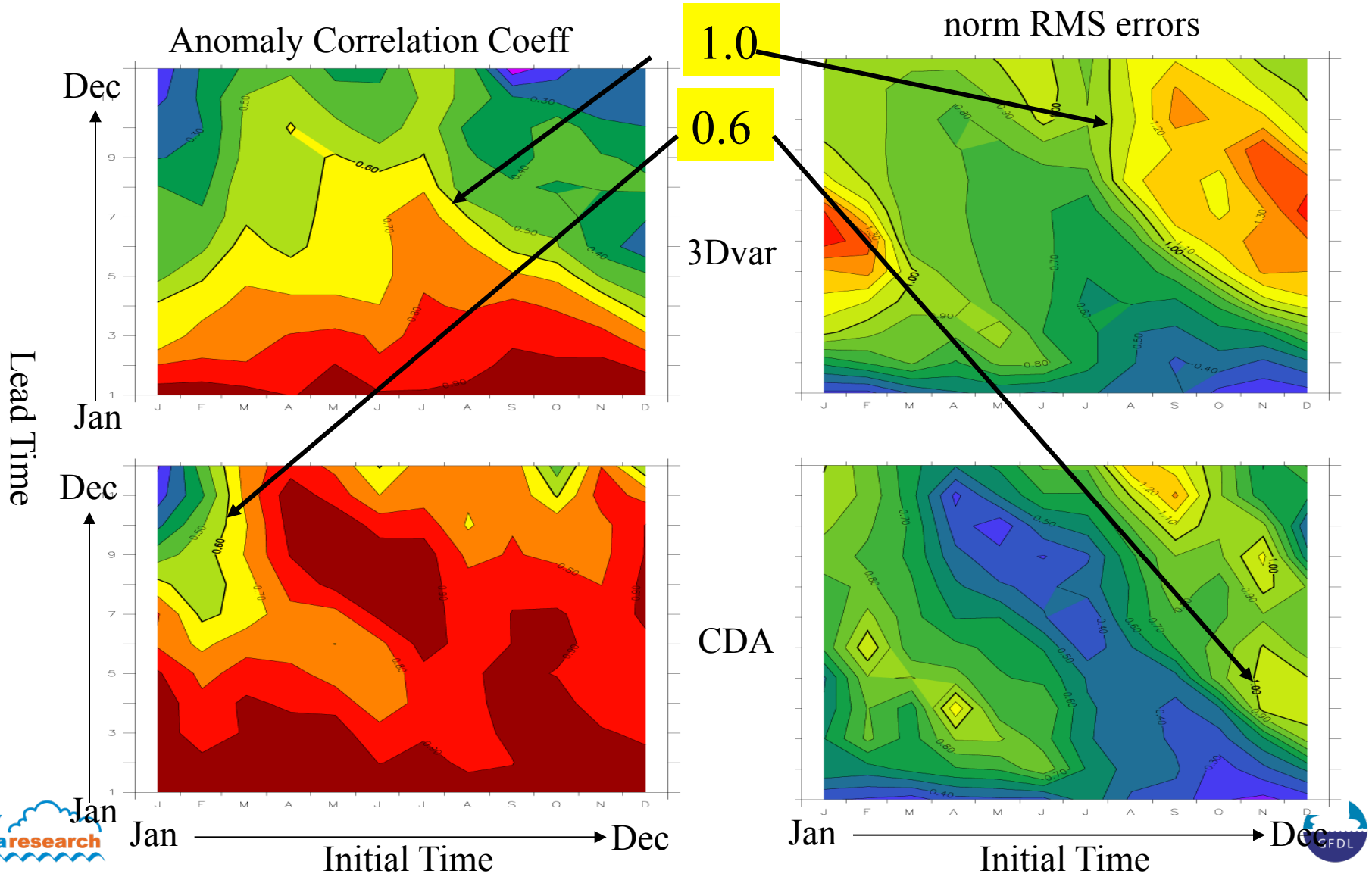
EOF2

EOF2

noaaresearch

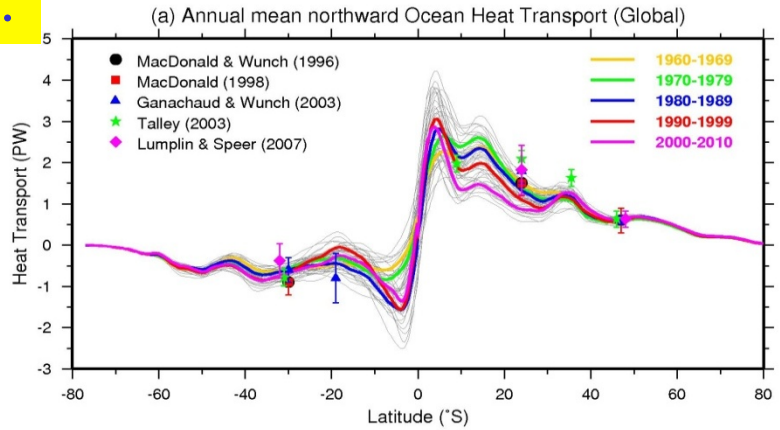
GFDL

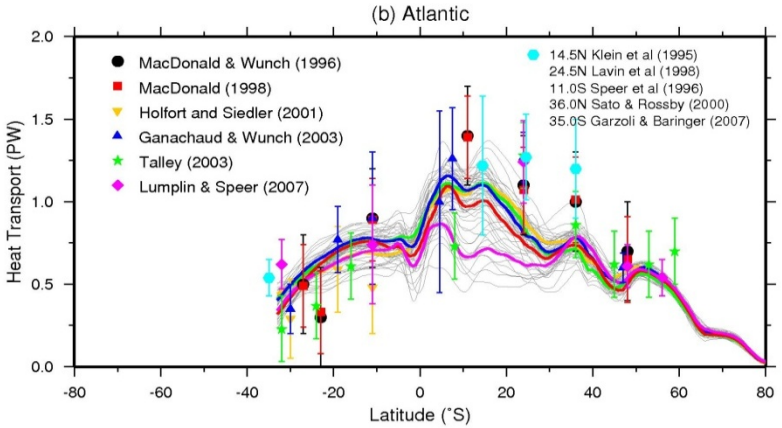
# Summary of ECDA v3.1 product: (5) NINO3 SSTA forecast skills

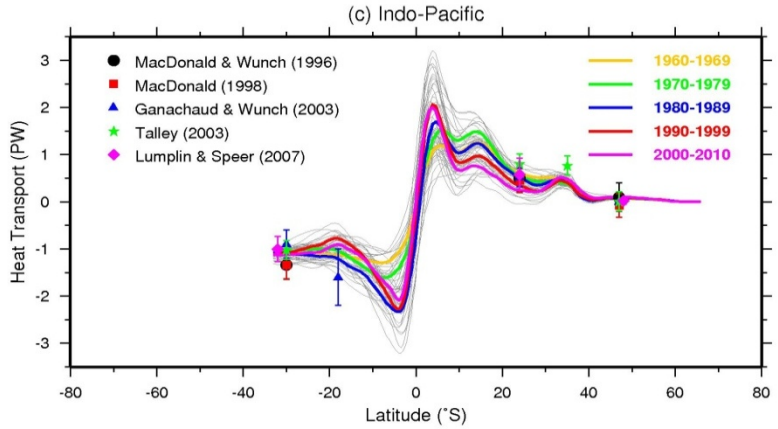


# Summary of ECDA v3.1 product: (6)An outstanding issue

- ✓ Too weak meridional heat transport in the 0-40N Atlantic Ocean in the Argo period
- ✓ Consequently causing too weak AMOC



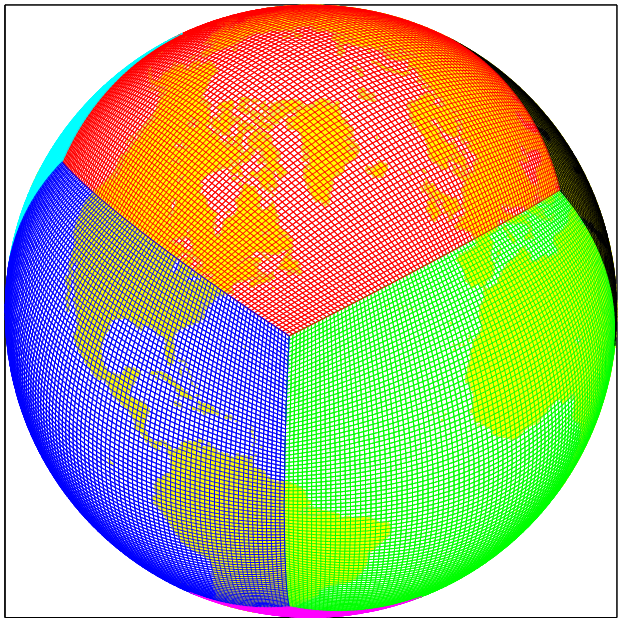



# Motivation of version 4.0

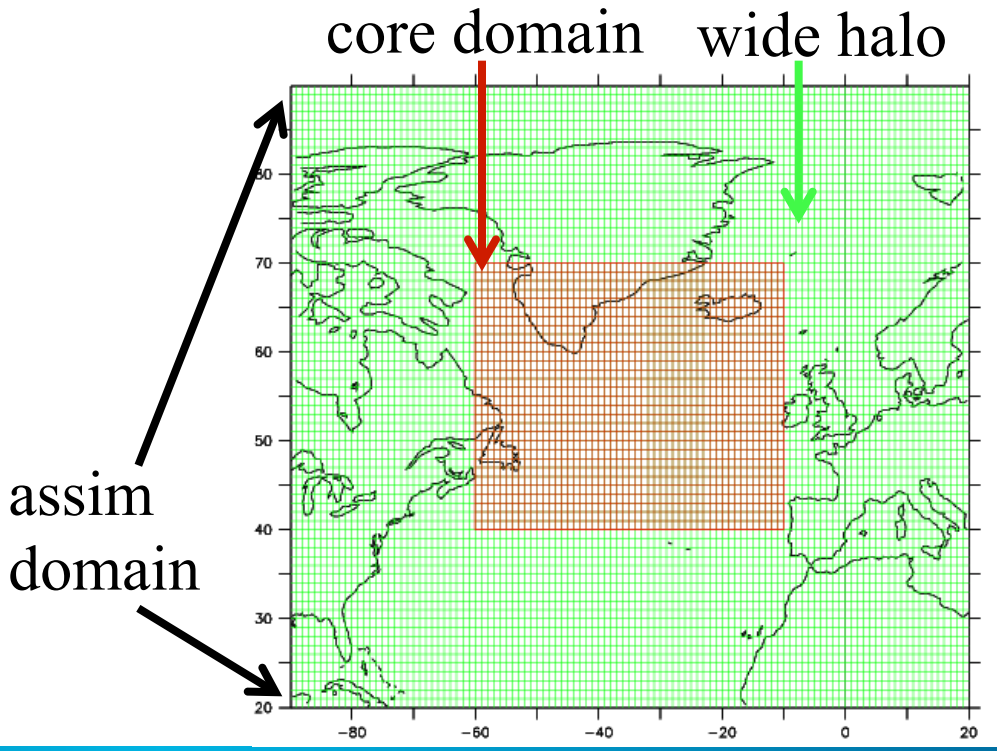
- ✓ Upgrade assimilation algorithms that are suitable for high-resolution ECDA
  - Improve the performance of ADA, assimilating gridded atmospheric reanalysis data
  - Improve the ODA performance of assimilating gridded sea-surface data
- ✓ Enhance the tropical Atlantic transport
  - Refine the impact radius depending on coastal/interior areas
  - Limit the use of cross-covariance Cov(T,u), Cov(T,v), Cov(S,u) & Cov(S,v)

# Upgrade filtering algorithms for the new model structure

- ✓ Cubic sphere atmospheric dynamical core
- ✓ The globe is evenly divided by 6 tiles
- ✓ Good at parallelism with a huge number of PEs as resolution goes higher



- ✓ Gridded data are mapped onto the model space first
- ✓ Filtering is performed in model space with wide halo
- ✓ No data loss due to high-resolution
- ✓ Very good for super- parallelism for ensemble filtering

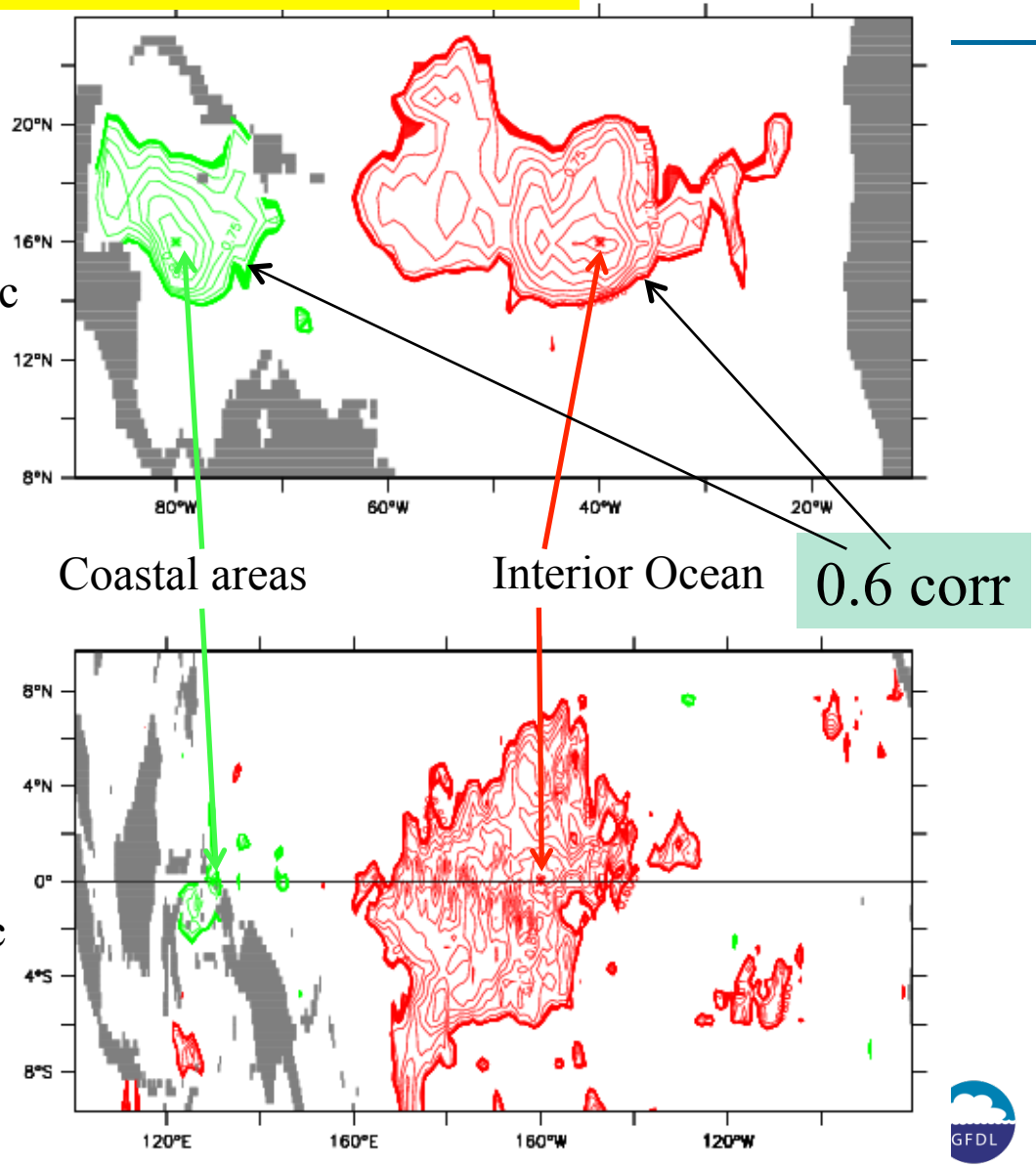


# Refine impact radius (correlation scale) in ODA, depending on topography

v3.1: $\alpha = \alpha_0 \, COS\varphi$, $\varphi \in [0,80]$
$\alpha_0 = 1000$ km

v4.0: $\alpha = \begin{cases} D/D_0 \alpha_0 \, COS\varphi, \text{ if } D<D_0 \\ \alpha_0 \, COS\varphi \text{ if } D \geq D_0 \end{cases}$

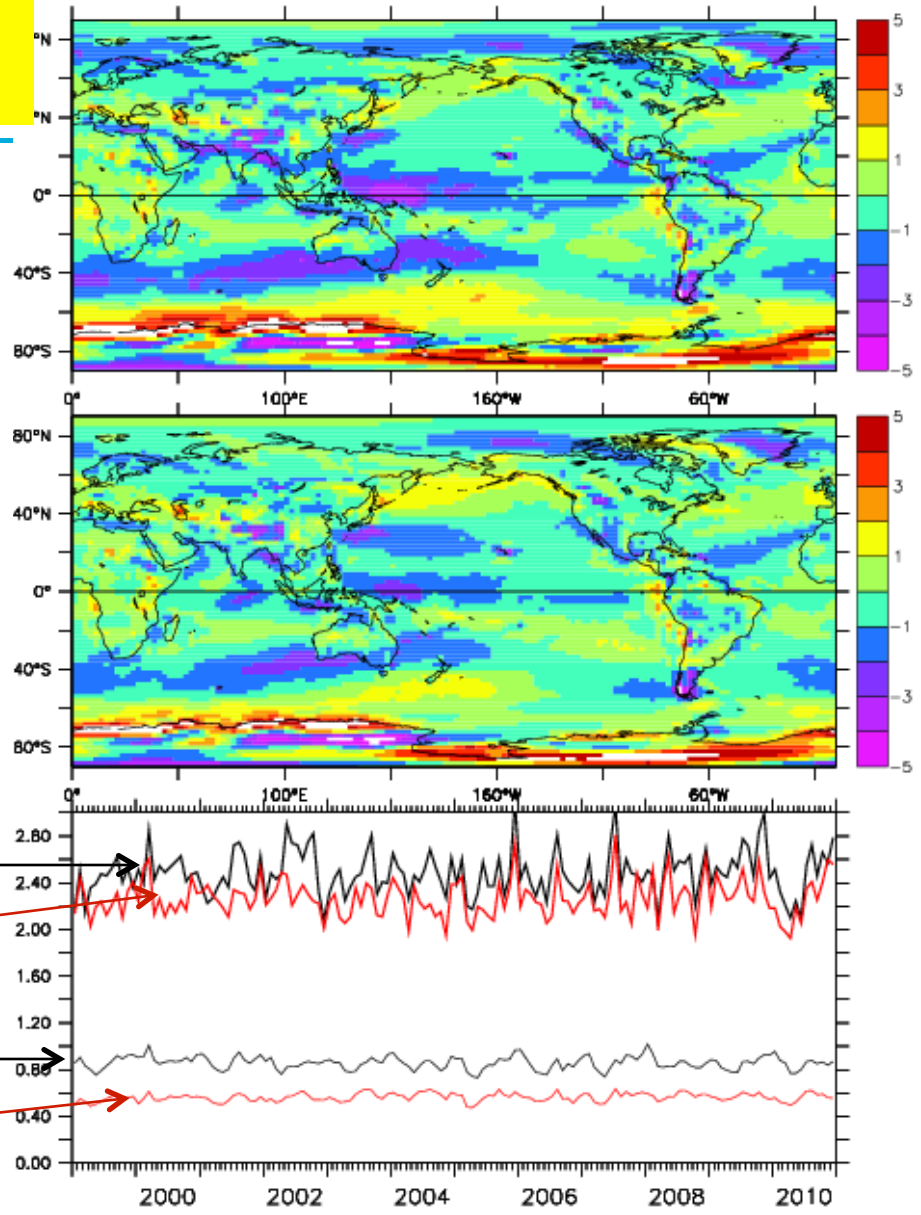
D: ocean depth
$D_0$: reference depth (1 km)



# ECDA v4.0 evaluation: (1) smaller ADA errors

v3.1 mean Us errors

v4.0 mean Us errors




v3.1 wind RMSE

v4.0 wind RMSE

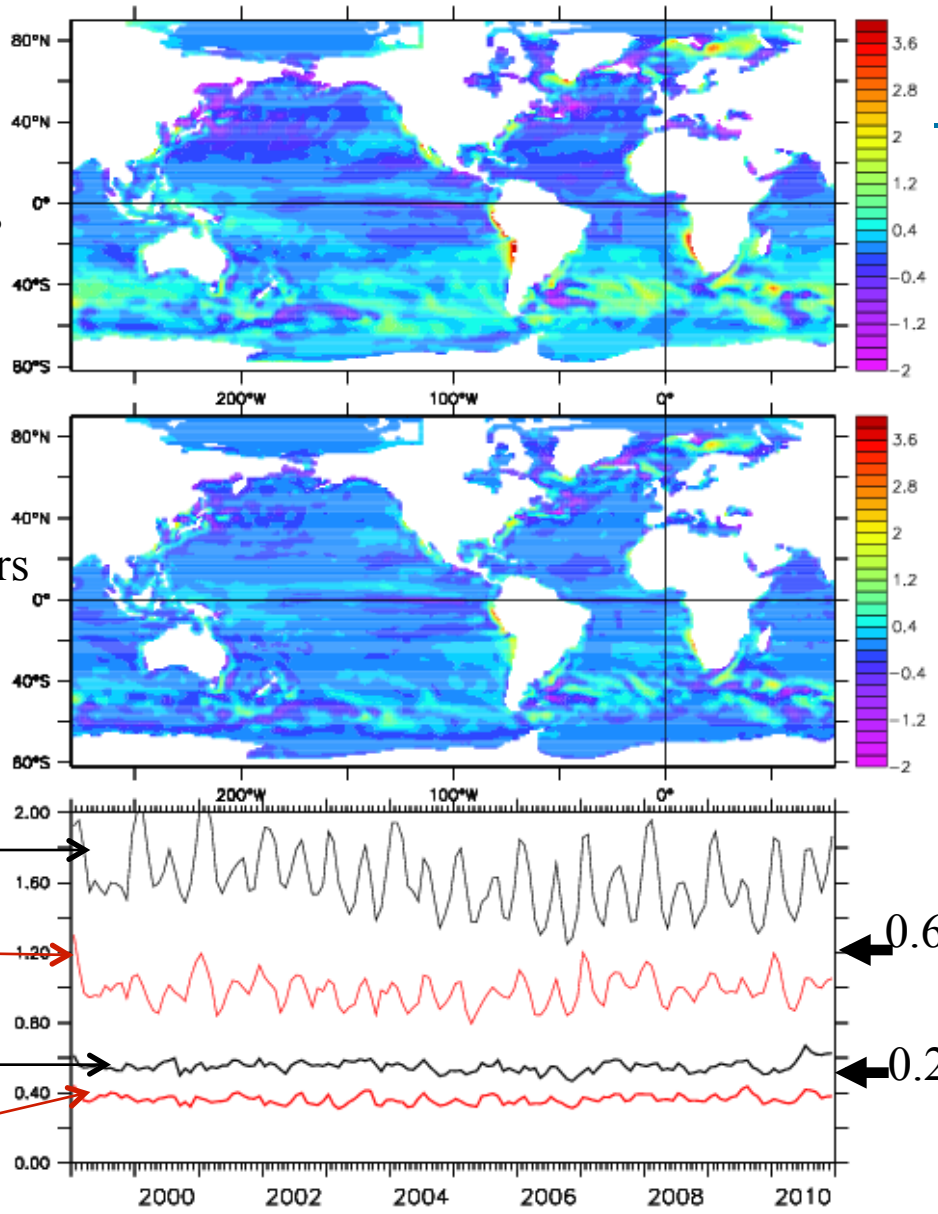
v3.1 T RMSE

v4.0 T RMSE

# ECDA v4.0 evaluation: (2) smaller SST errors

v3.1 mean SST errors

v4.0 mean SST errors




Out of 40(S)N v3.1 SST RMSE

Out of 40(S)N v4.0 SST RMSE

Tropics [40(S)N] v3.1 SST RMSE

Tropics [40(S)N] v4.0 SST RMSE

0.6°C

0.2°C

noaaresearch

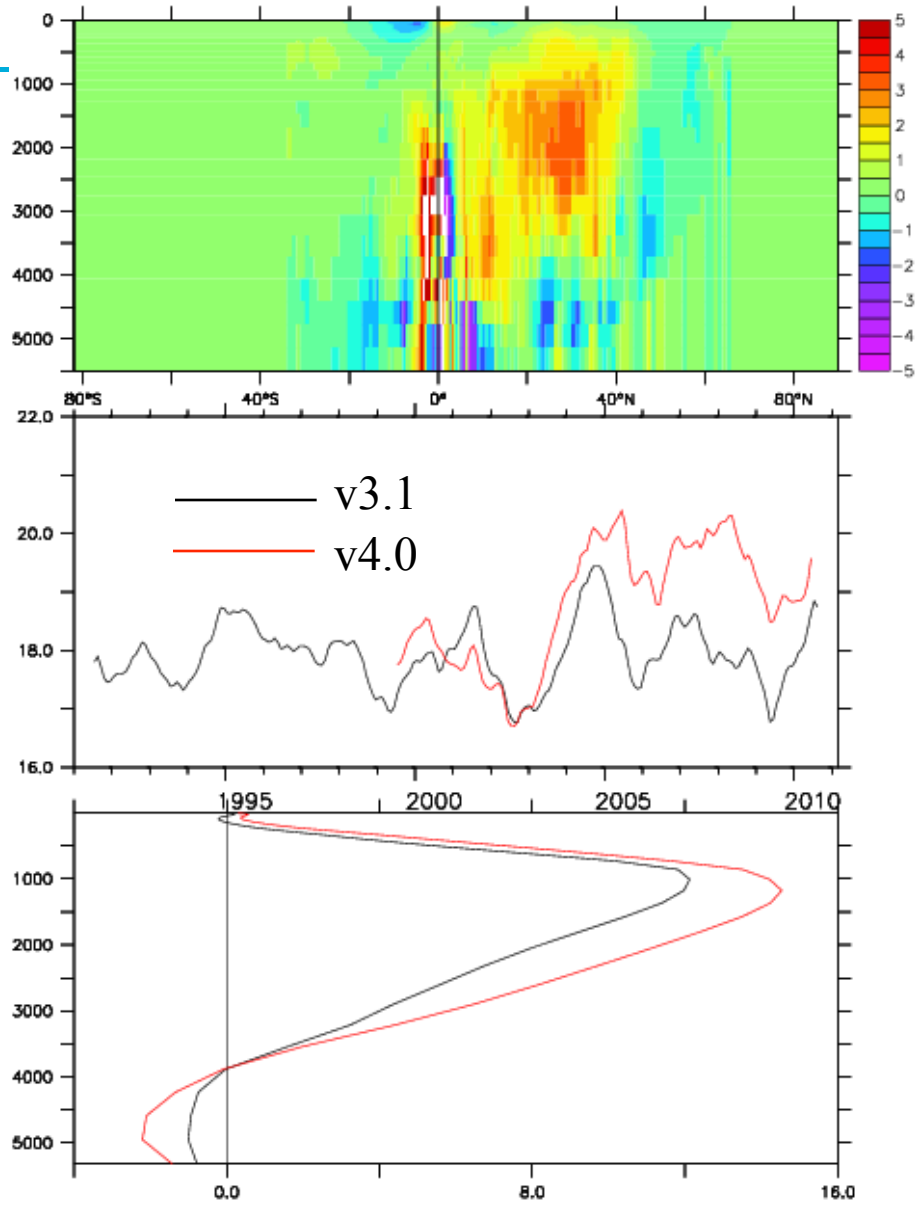
GFDL

# ECDA v4.0 evaluation: (3) Stronger AMOC

V4.0-V3.1 (10-yr mean)

Time series of
$\Psi_{max}$ @30n:70n

Time mean of
$\Psi$ @30n



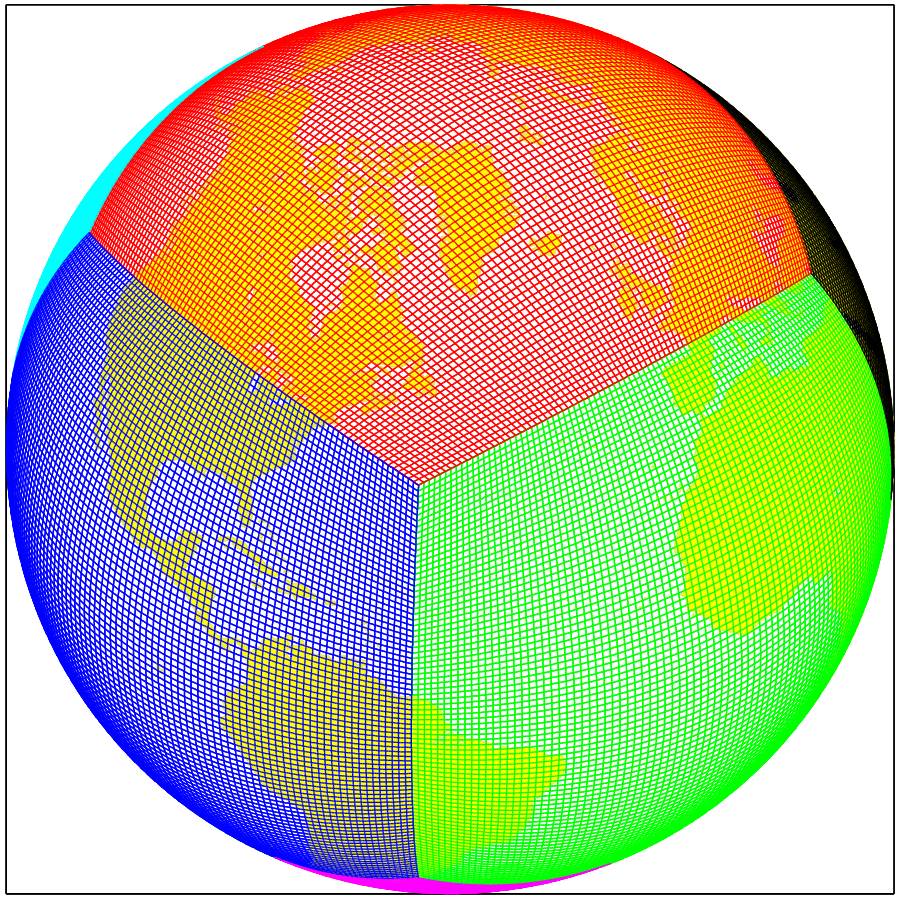
# Ongoing projects and the future direction of ECDA

- ✓ High-Resolution ECDA toward seamless numerical weather-climate studies with CM2.5 – first priority
- ✓ Extended variability estimation and decadal prediction with CM2.1 ECDA v4.0
- ✓ Include Model Parameters into ECDA system to control model drift (GFDL-UW NSF project, 2010-2013)
- ✓ Impact of sea-ice observational constraints on decadal variability estimation and prediction (GFDL-GMU NSF pending project, 2012-2015)
- ✓ Optimal integration of the earth observing system by the ECDA system – Altimetric data and land data assimilation (GFDL-UW NSF-DOE-USDA pending project, 2013-2018)
- ✓ Exploring the possibility to assimilate real atmospheric observations to solve the "double-bias" issue in ADA

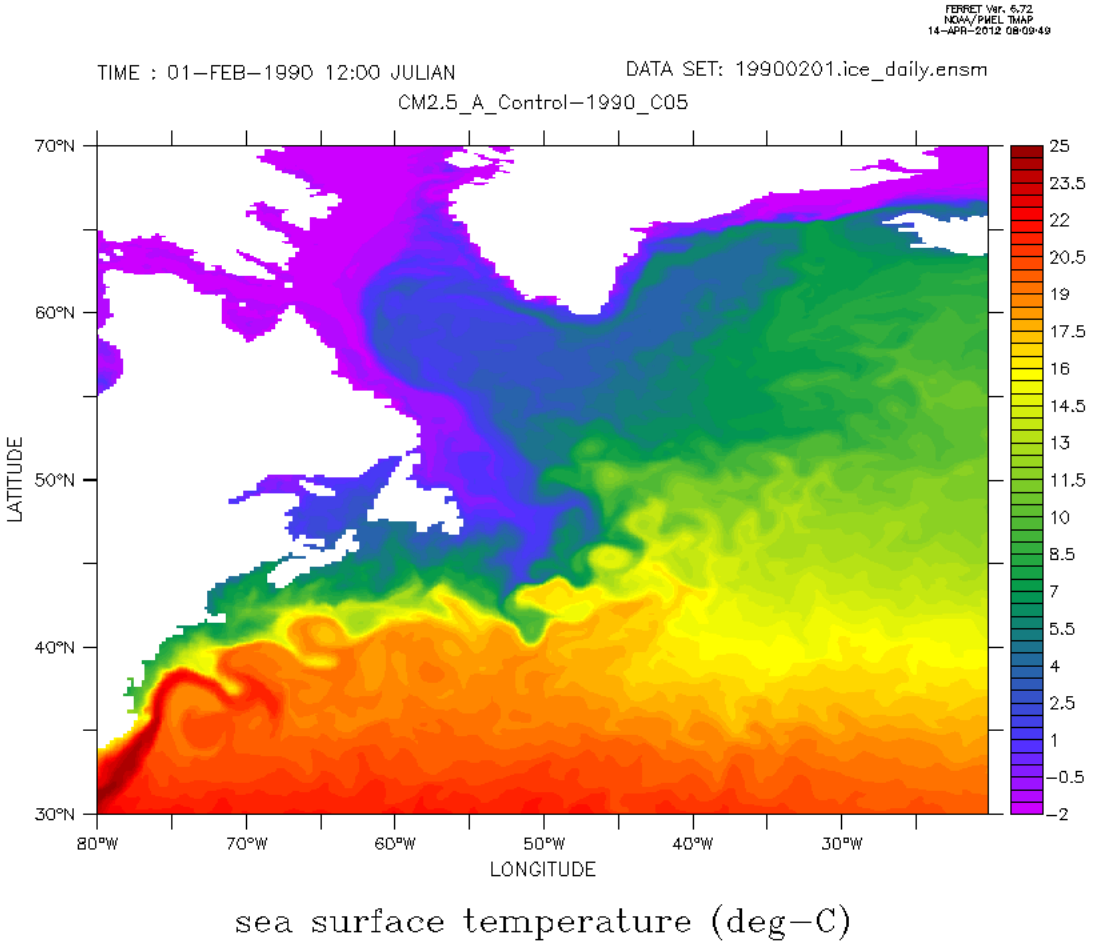
# High-Resolution ECDA Toward Seamless W-C Studies: (1) CM2.5

- ✓ Atmosphere:
  - Cubic sphere horizontal config.
  - 180x180 for each tile (~50x50km)
  - Atm time step = 20 m

- ✓ Ocean:
  - MOM4P1 configuration
  - 1440x1070 for the globe
  - ~1/4°x1/6°
  - Ocn and Cpl time step = 60 m



# High-Resolution ECDA Toward Seamless W-C Studies: (2) An example of ECDA SST

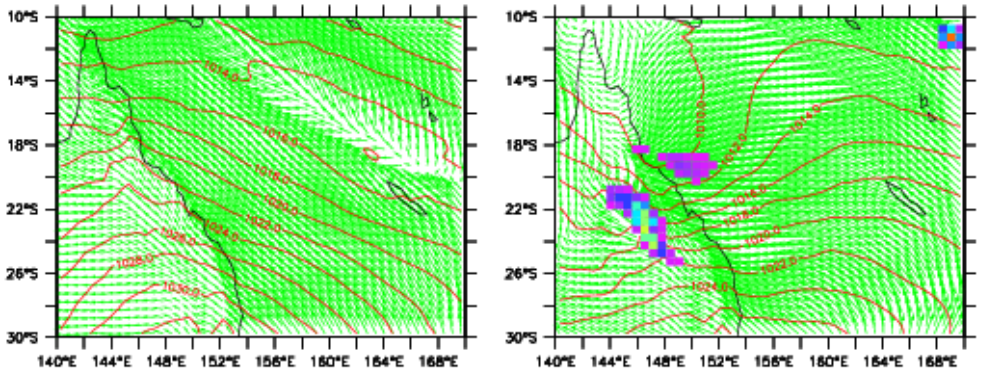


# HRECDA:(4) A Pacific Storm in ECDA

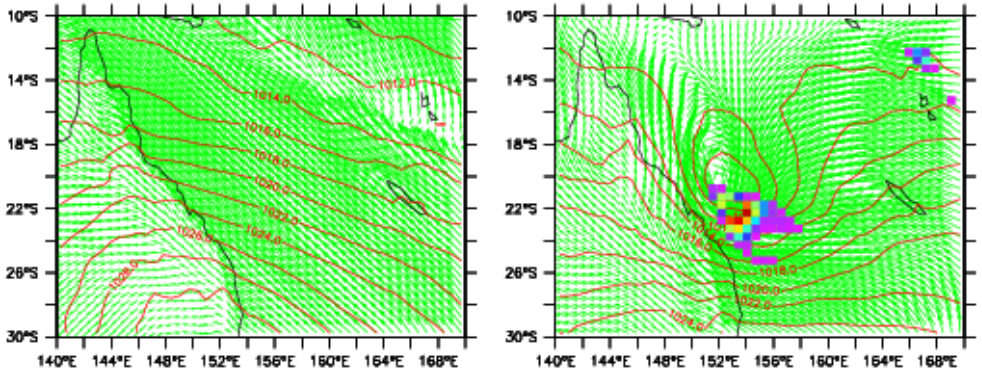
ODA

ECDA

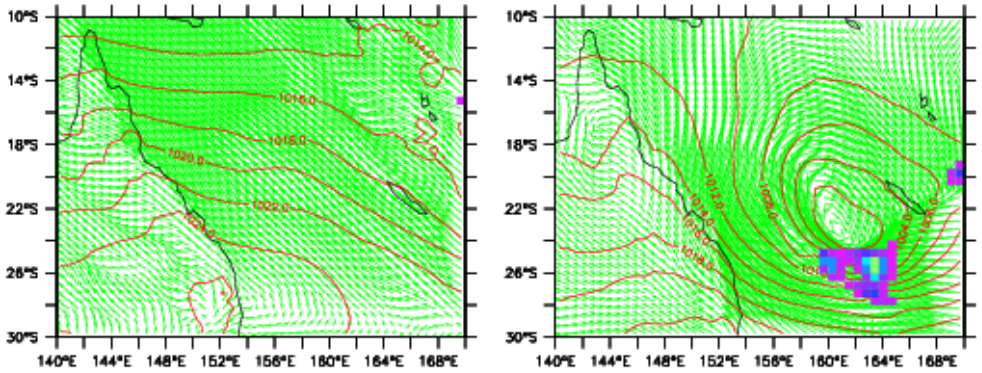
90.6.6




90.6.7




90.6.8



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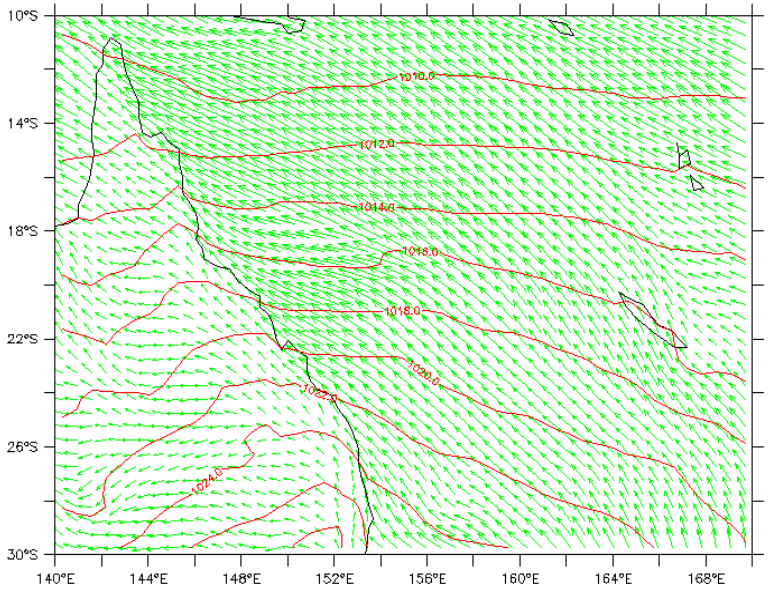
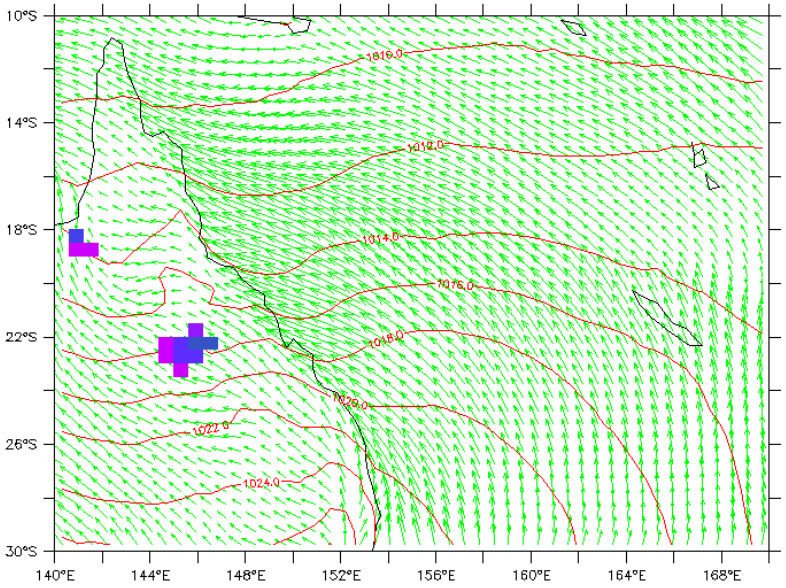
ODA




ECDA



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