



Integrating Earth System Observations by Coupled Model Data Assimilation

WCRP 2011 C19: Coupled Data Assimilation for Earth System Models

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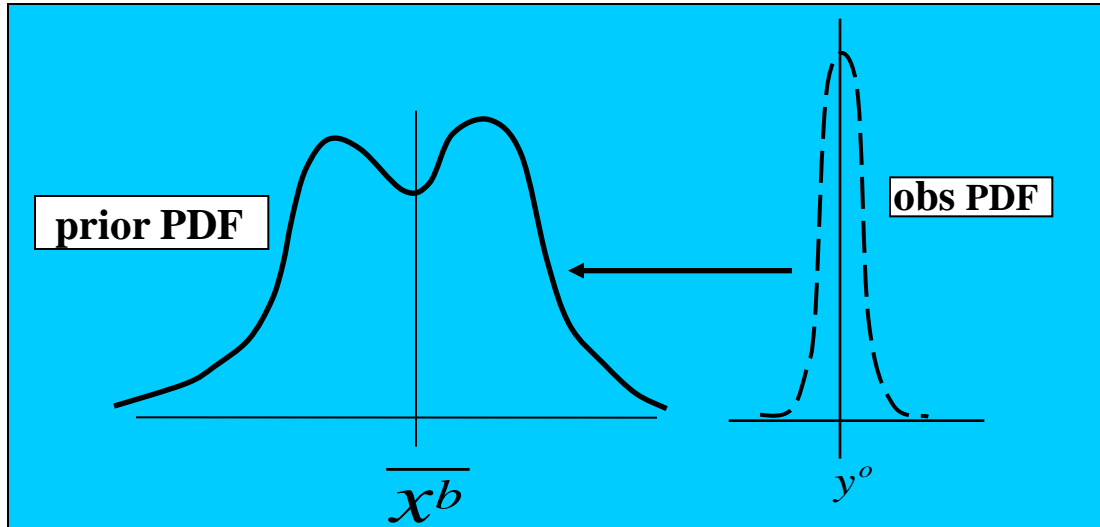
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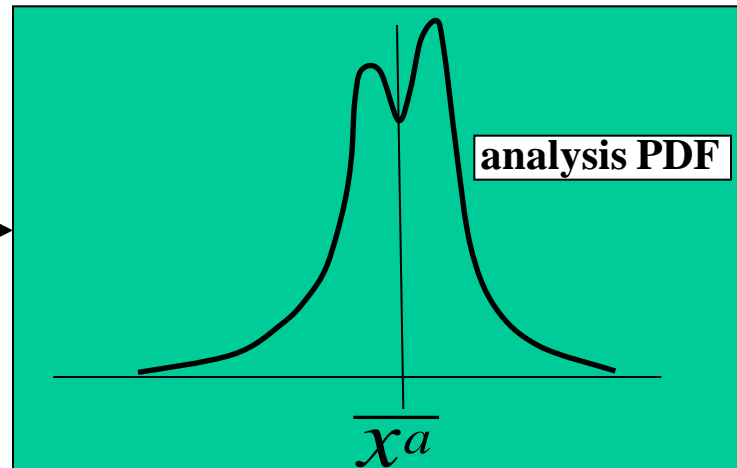
Deterministic (coupled model)

Uncertain (ens sim)

$$d\mathbf{x}_t / dt = f(\mathbf{x}_t, t) + \mathbf{G}(\mathbf{x}_t, t) \mathbf{w}_t$$



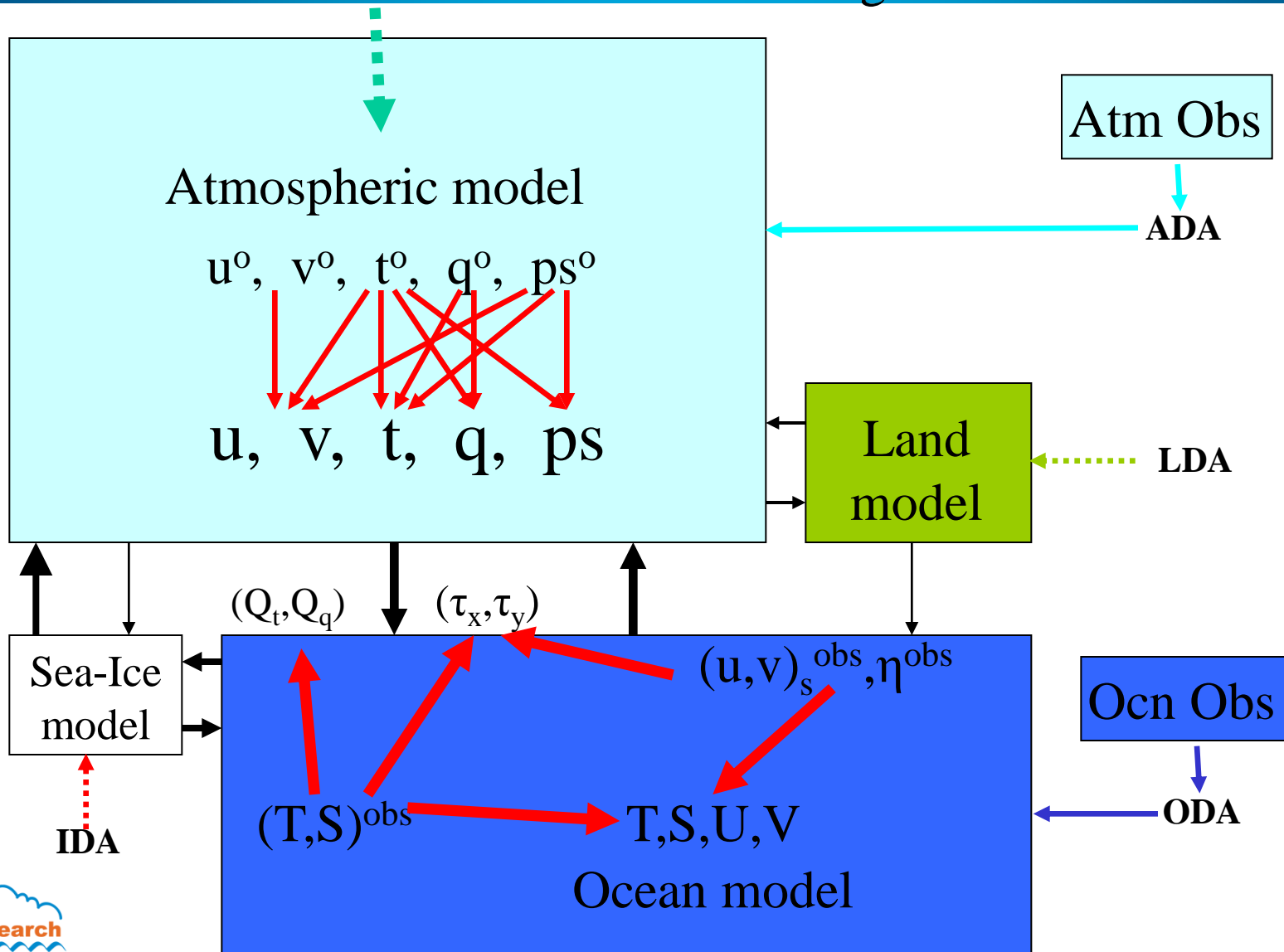
Data Assimilation (Filtering)



- ✓ Atmospheric internal variability
- ✓ Ocean internal variability (model does not resolve)
- ✓ Sea-ice and land parameterization uncertainties
- ✓ Exchanged fluxes uncertainties

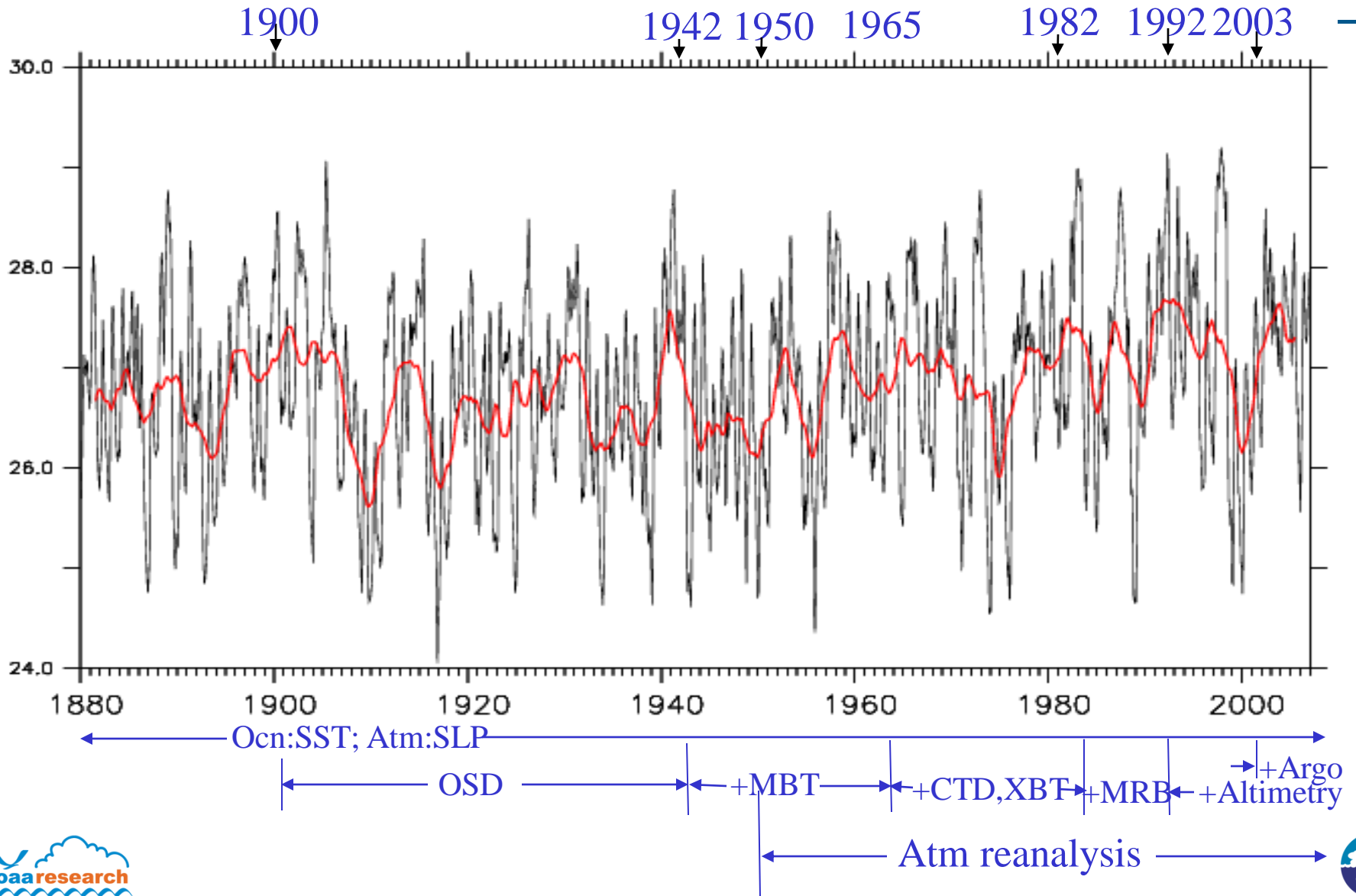


Intr(7):ECDA(4) - Fully-coupled data assimilation system



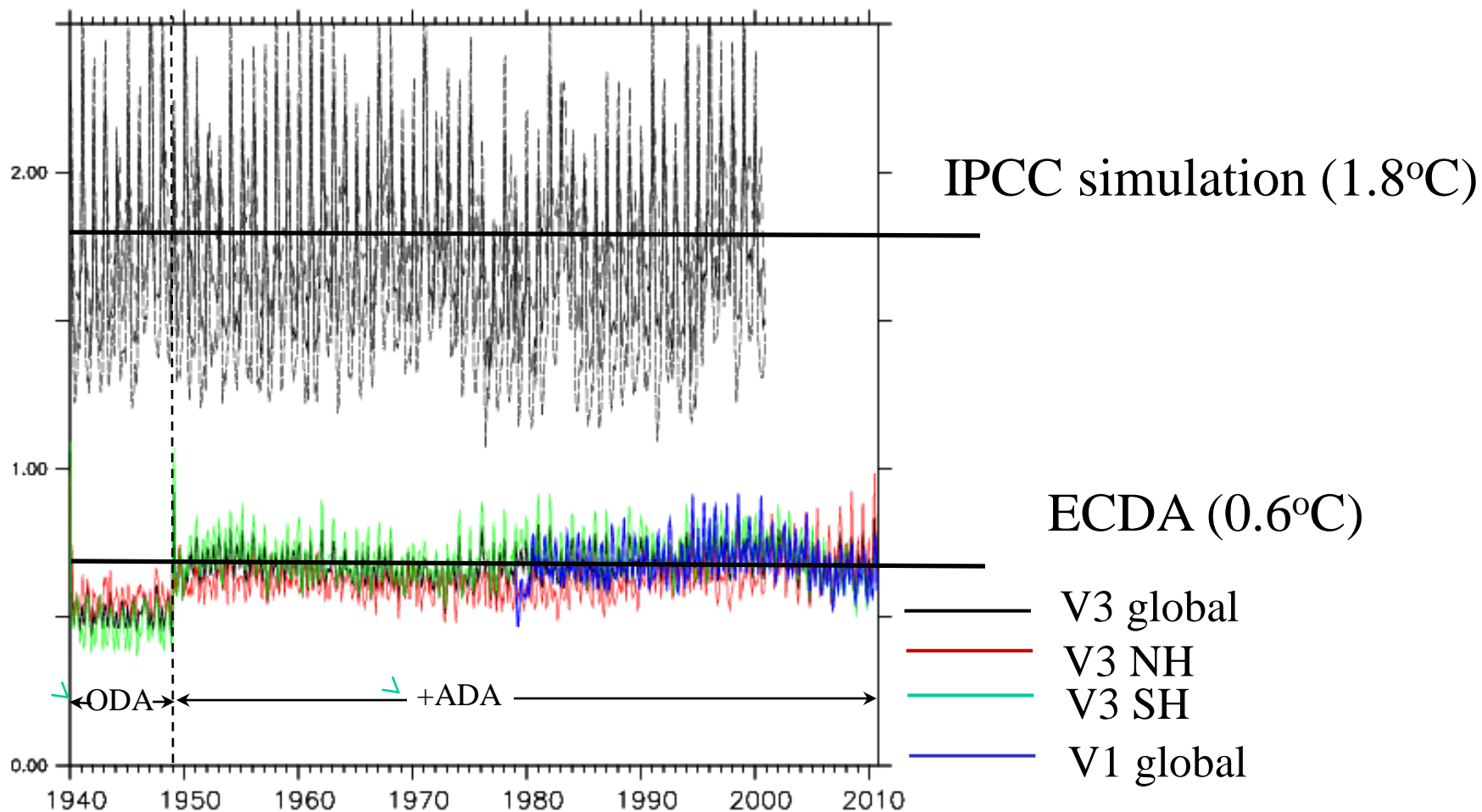


App5 – Climate assessment by integrating the atmospheric and oceanic observations(1): Data availability



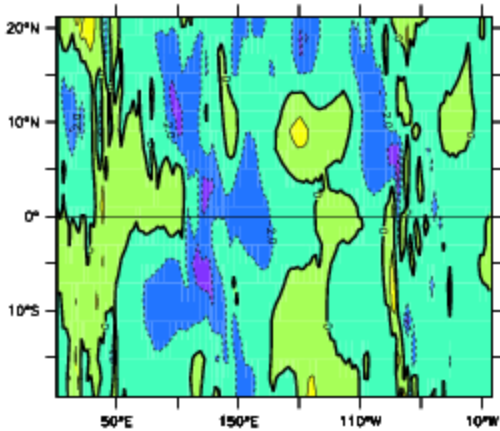


App5 – Climate assessment by integrating the atmospheric and oceanic observations(2): Global SST RMS errors

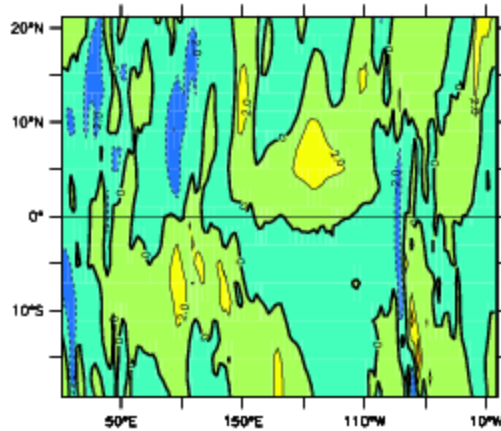


App5 – Climate assessment by integrating the atmospheric and oceanic observations(3): Different balances in CDA

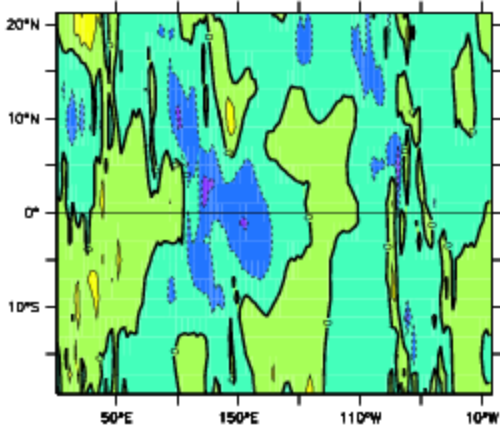
$U_{ECDA49} - U_{RE50}$



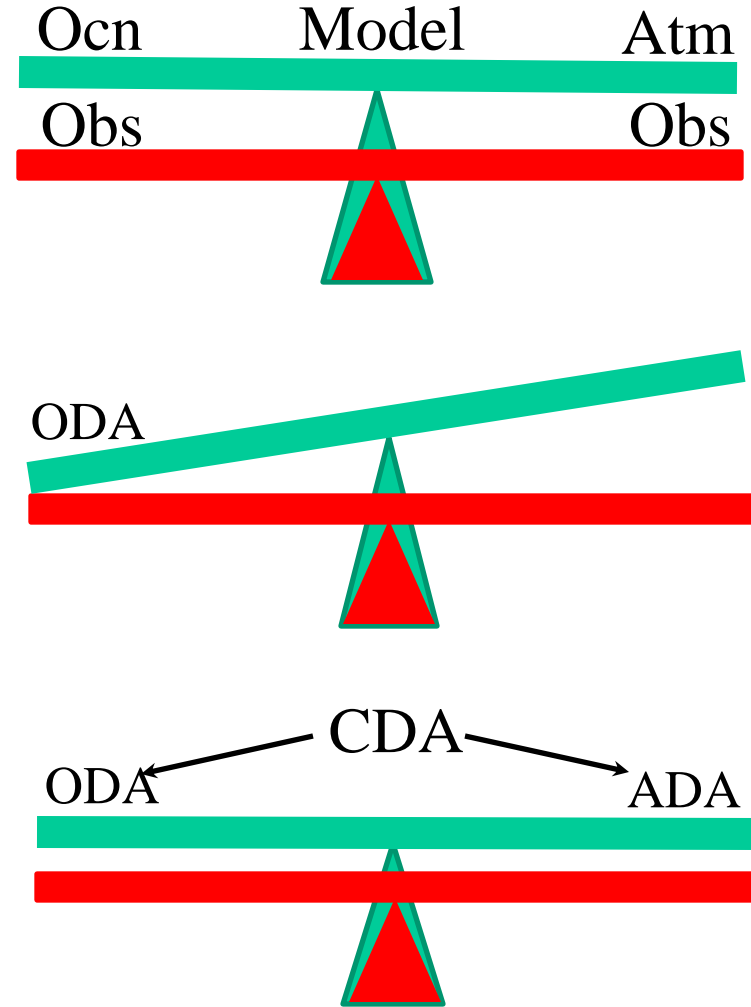
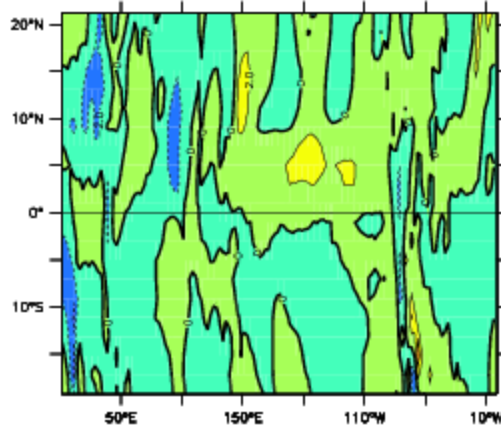
$V_{ECDA49} - V_{RE50}$



$U_{ECDA50} - U_{RE50}$

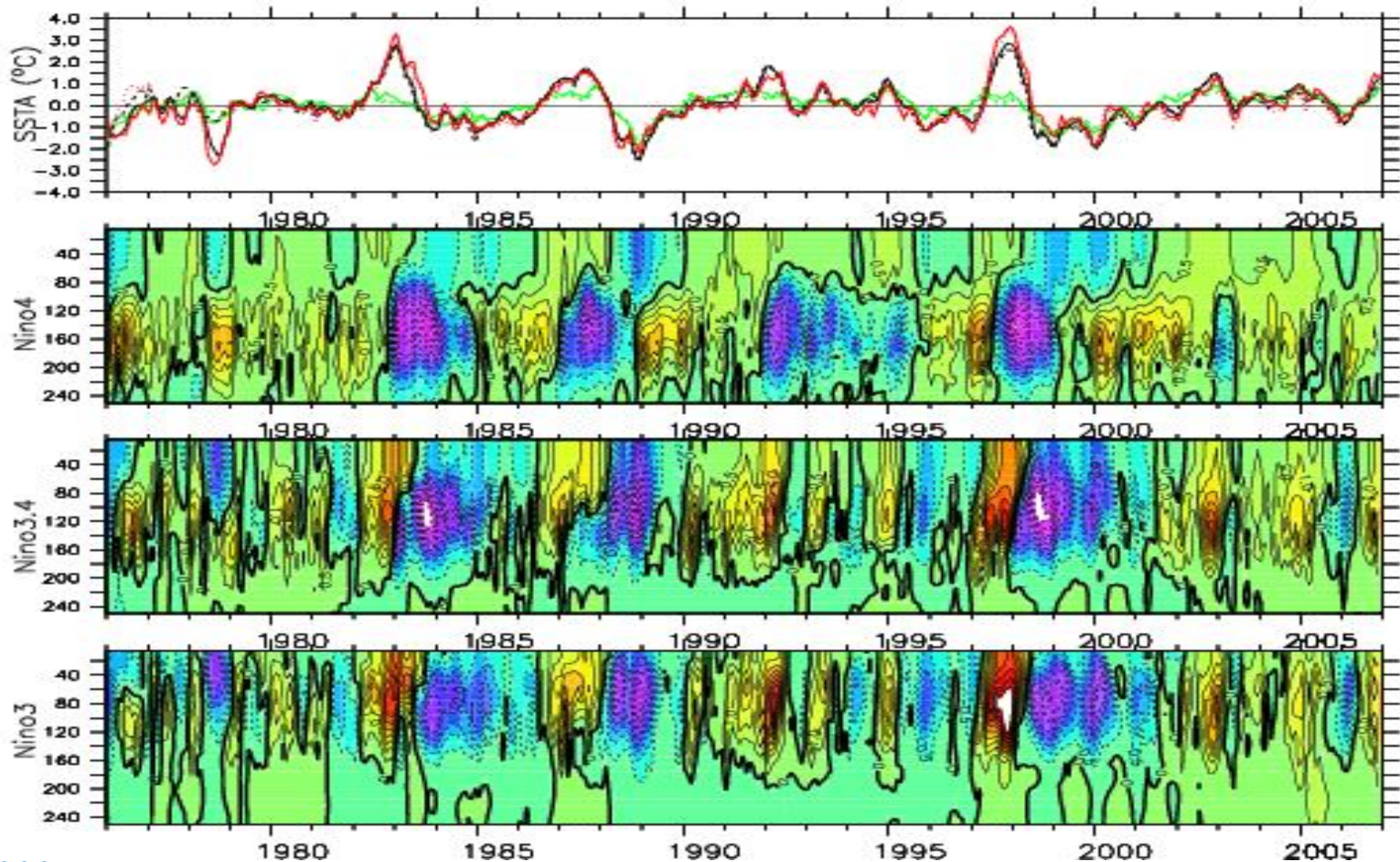


$V_{ECDA50} - V_{RE50}$



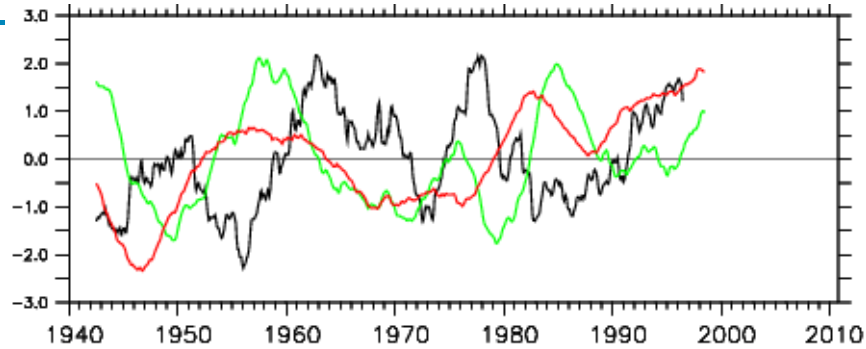
App5 – Climate assessment by integrating the atmospheric and oceanic observations(4): ENSO Variability

..... N4 SSTA Obs
 N3.4 SSTA Obs
 N3 SSTA Obs
—— N4 SSTA ECDA
 —— N3.4 SSTA ECDA
 —— N3 SSTA ECDA



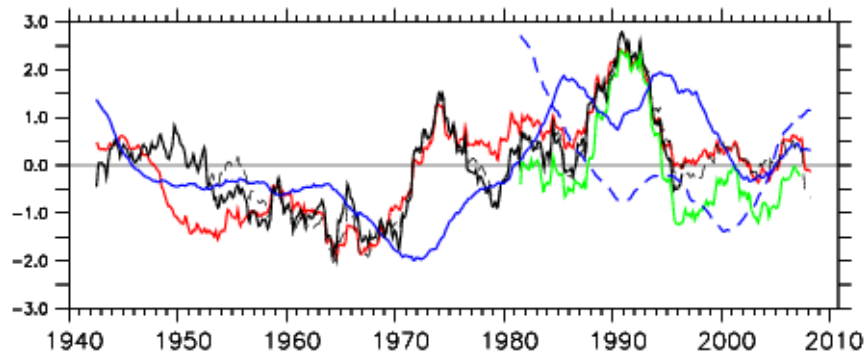
App5 – Climate assessment by integrating the atmospheric and oceanic observations(5): Decadal Variability

IPCC simulation



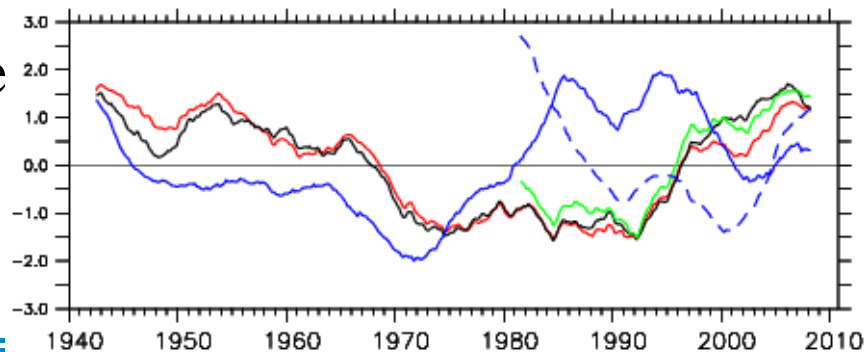
- NAO
- SST dipole
- AMOC

ECDA
NAO & AMOC



- NAO Obs
- NAO V3
- NAO V1
- AMOC V3
- - - AMOC V1

ECDA SST dipole
& AMOC

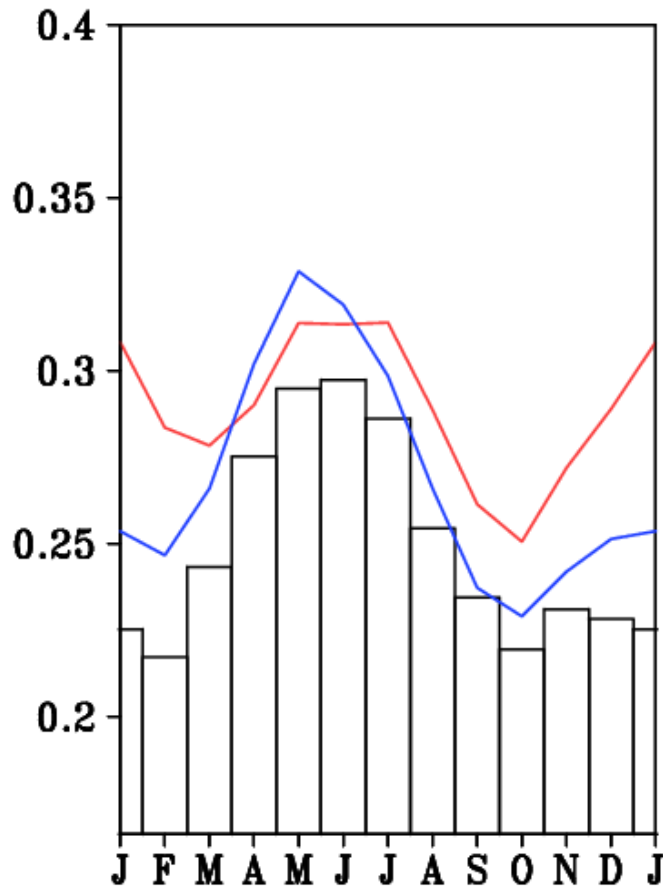


- SSTDP Obs
- SSTDP V3
- SSTDP V1
- AMOC V3
- - - AMOC V1



App5 – Climate assessment by integrating the atmospheric and oceanic observations(6):Improvement on tropical Atlantic

Monthly standard deviation of tropical Atlantic SSTs



Hurricane development region

— Observations

— ECDA_V1

— ECDA_V3

Courtesy to Takashi



App6 – Climate predictions – from SI to decadal time scales(1) ENSO forecast: NINO3 SSTA skills

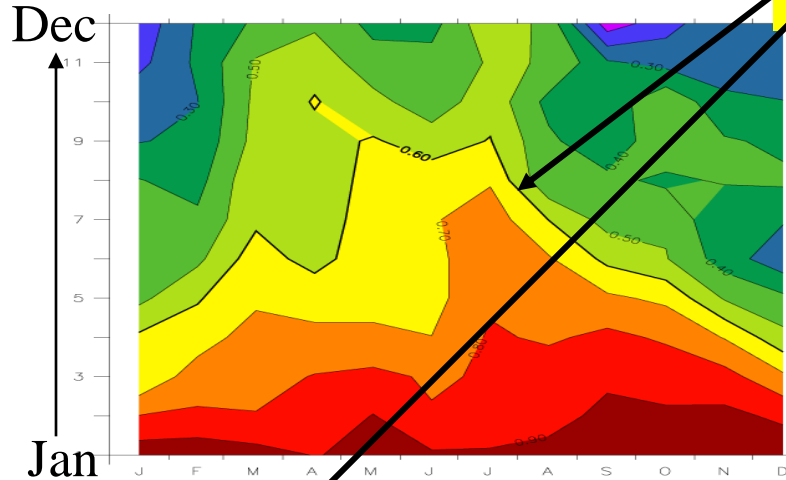
Anomaly Correlation Coeff

1.0

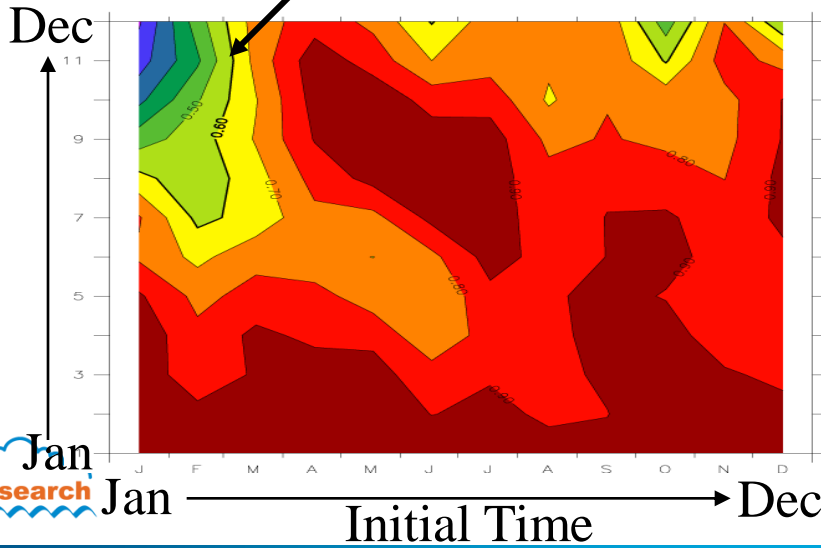
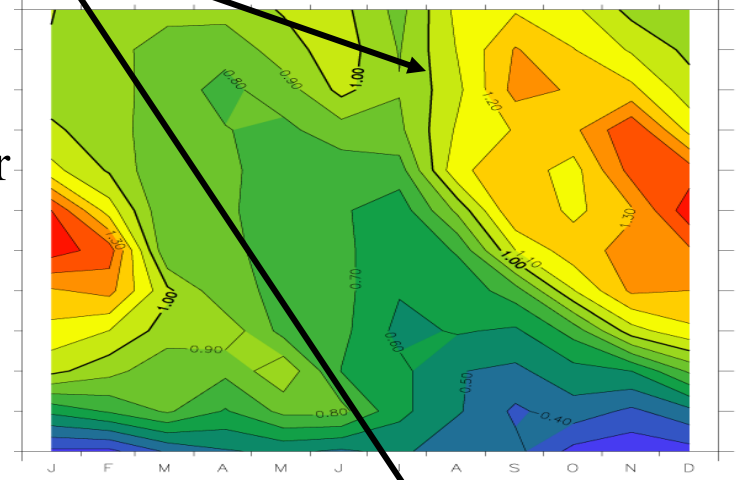
norm RMS errors

0.6

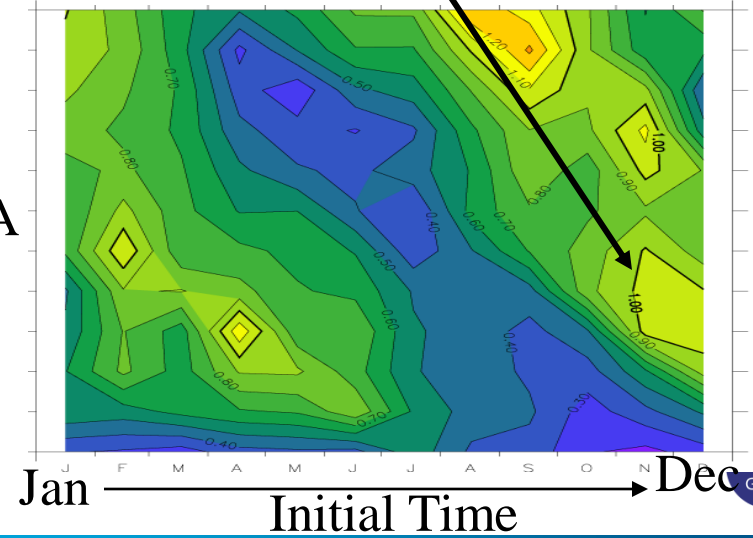
Lead Time



3Dvar



ECDA

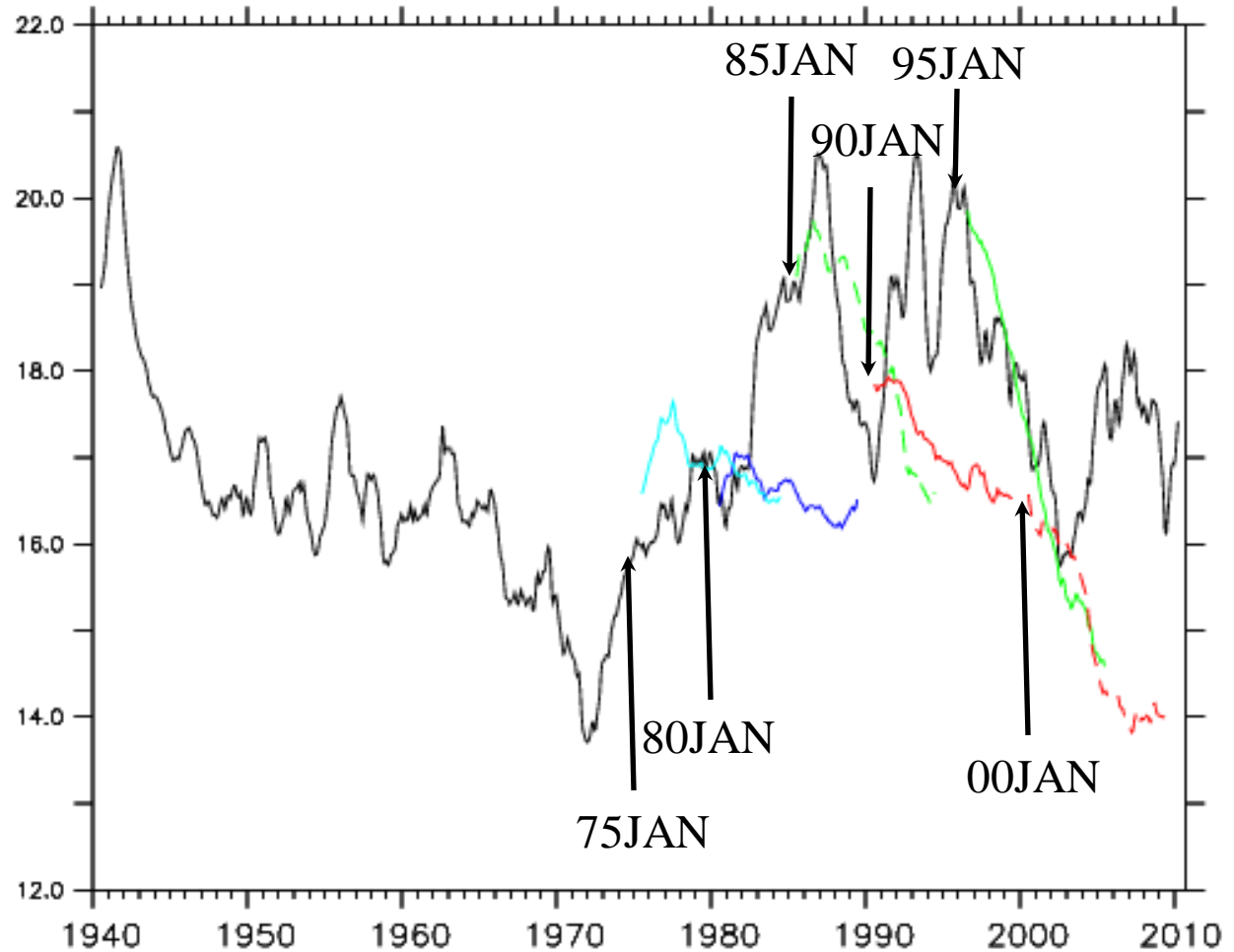




App6 – Climate predictions – from SI to decadal time scales(2): Experimental decadal prediction

Model drift!!

Model drift!!





Ongoing projects and the future direction of ECDA

- Extended estimation and prediction for decadal variability
- Impact of sea-ice observational constraints on decadal variability estimation and prediction
- Parameter estimation using observations –Coupled data assimilation with enhanceive parameter correction
- Multi-model ensemble assimilation and prediction
- High-resolution coupled model's initialization - No-gap weather-climate prediction



Ongoing projects(2): Constraints of atmospheric or/and oceanic observations on sea-ice variability

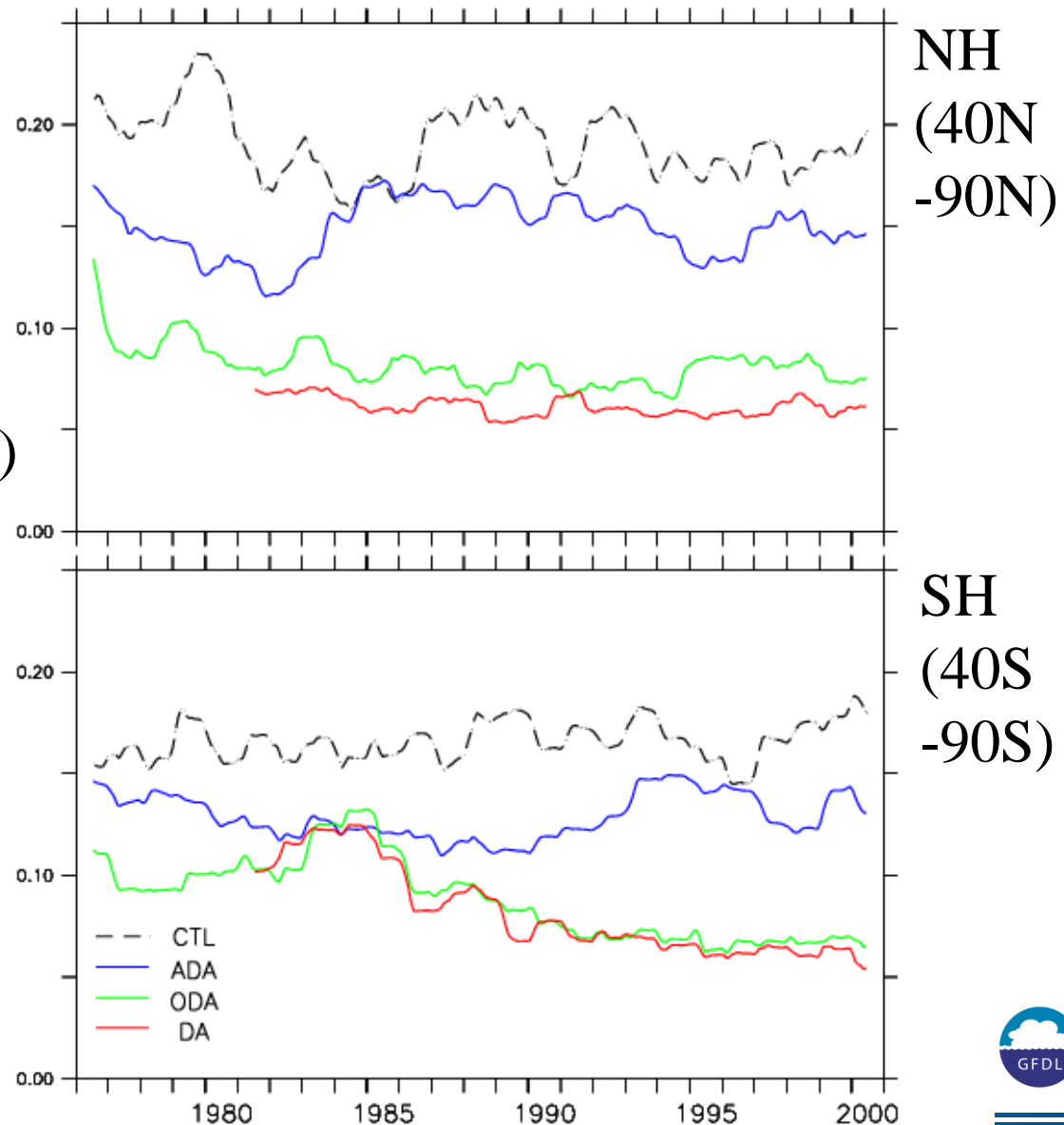
Time series of Rms of sea-ice extent errors

----- CM2.1-CM2.0 (Truth) (.18)

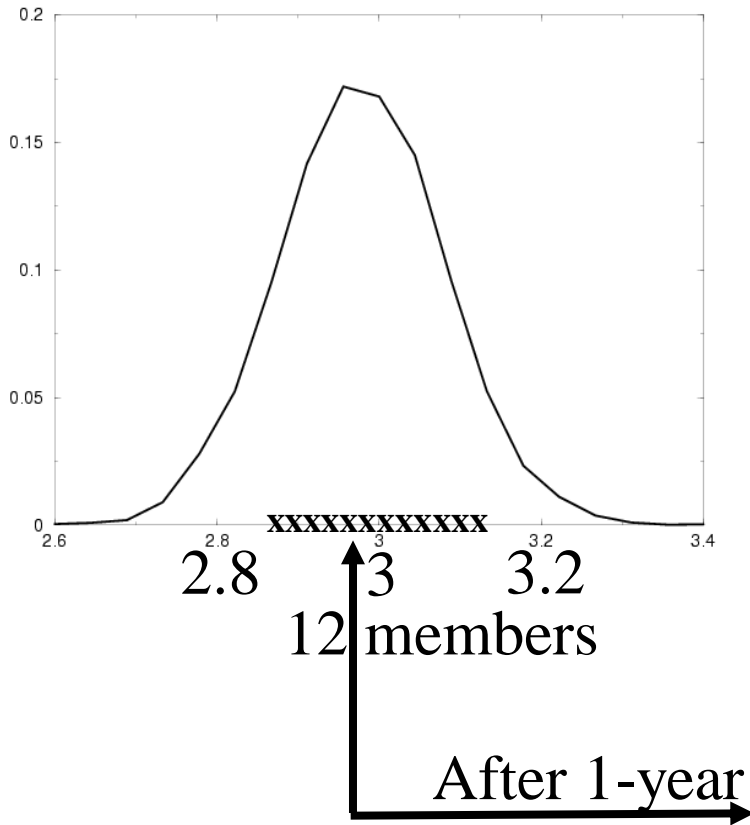
— ADA only (.14, 22%)

— ODA only (.09, 50%)

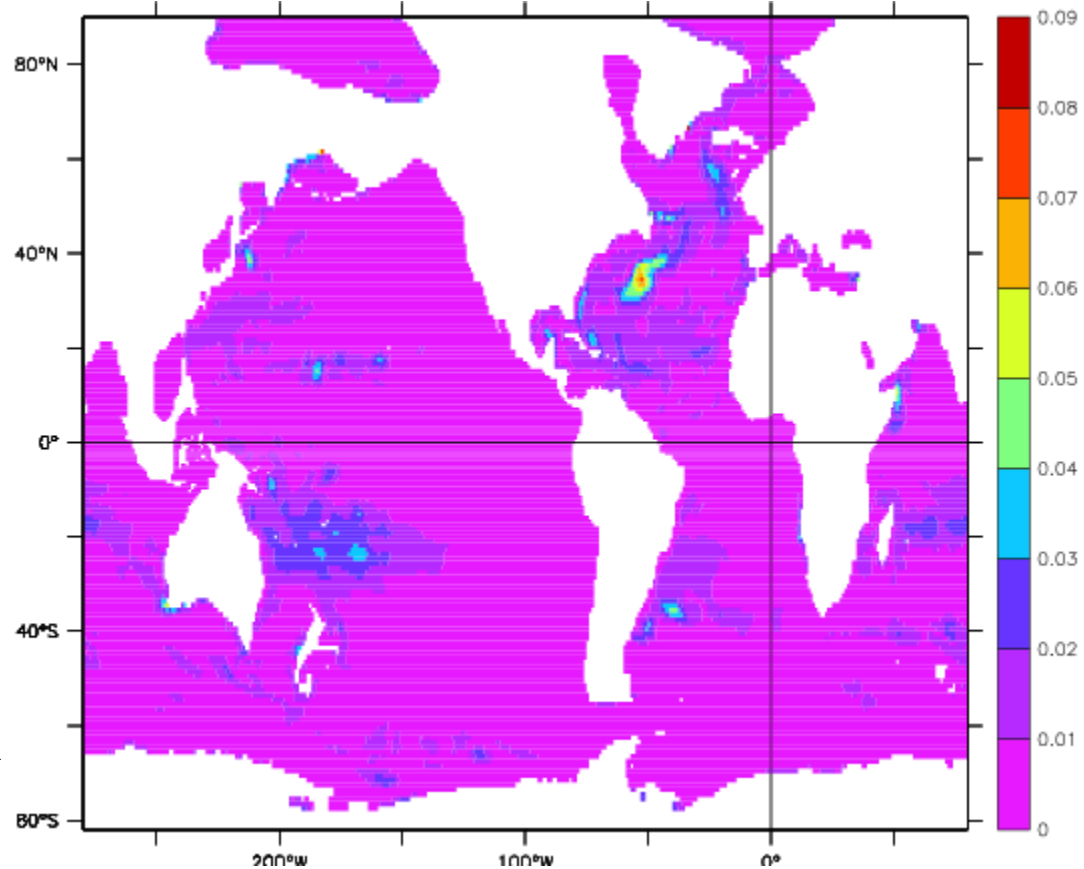
— Ocn and Atm data Assim (.07, 61%)



Ongoing projects(3): Parameter estimation in a fully-coupled system using observations(1)



A Gaussian $N(3,.1)$ simulates a parameter in vertical mixing KPP scheme



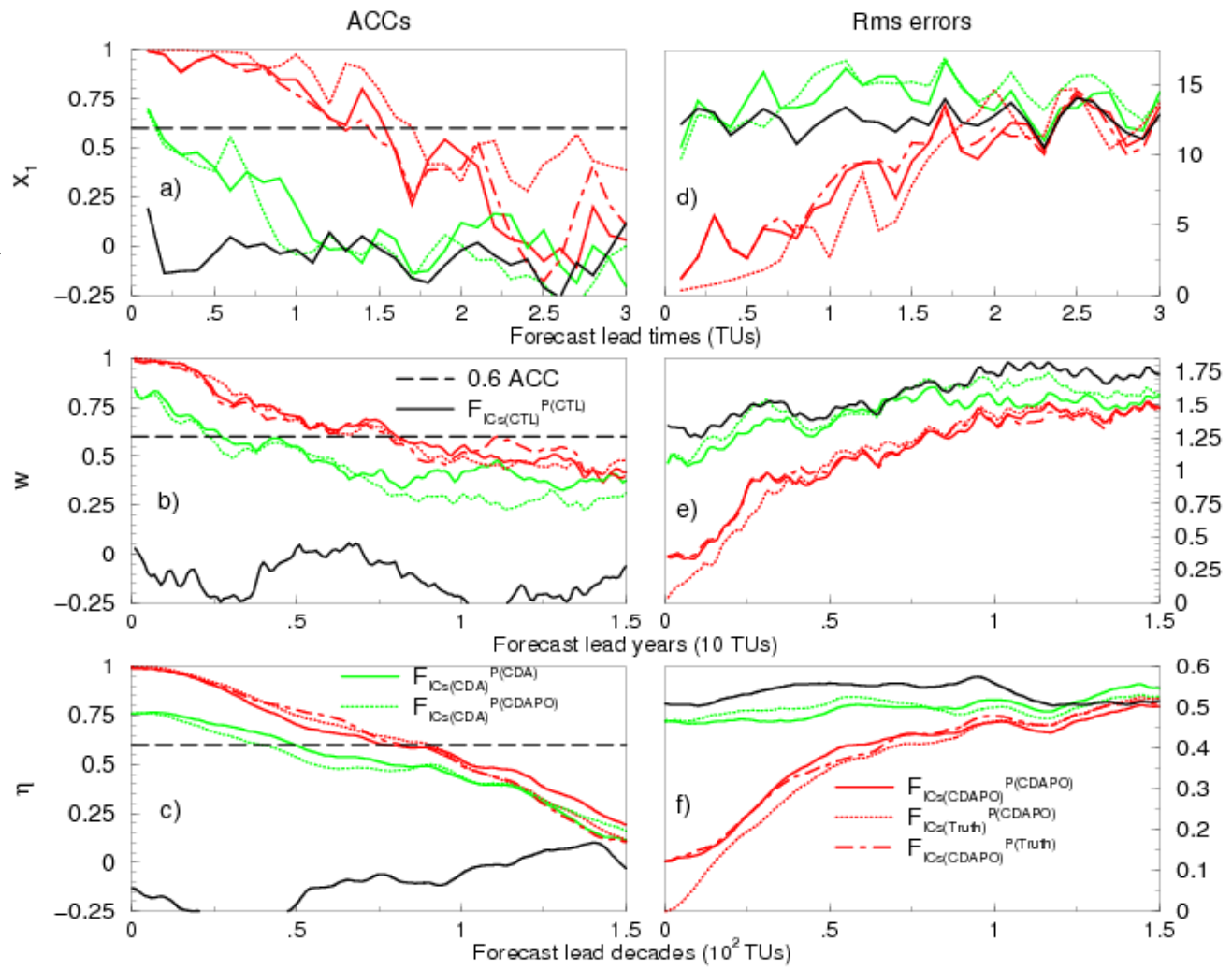
salt ensemble sdv @z=500

Ongoing projects(3): Parameter estimation in a fully-coupled system using observations(2)

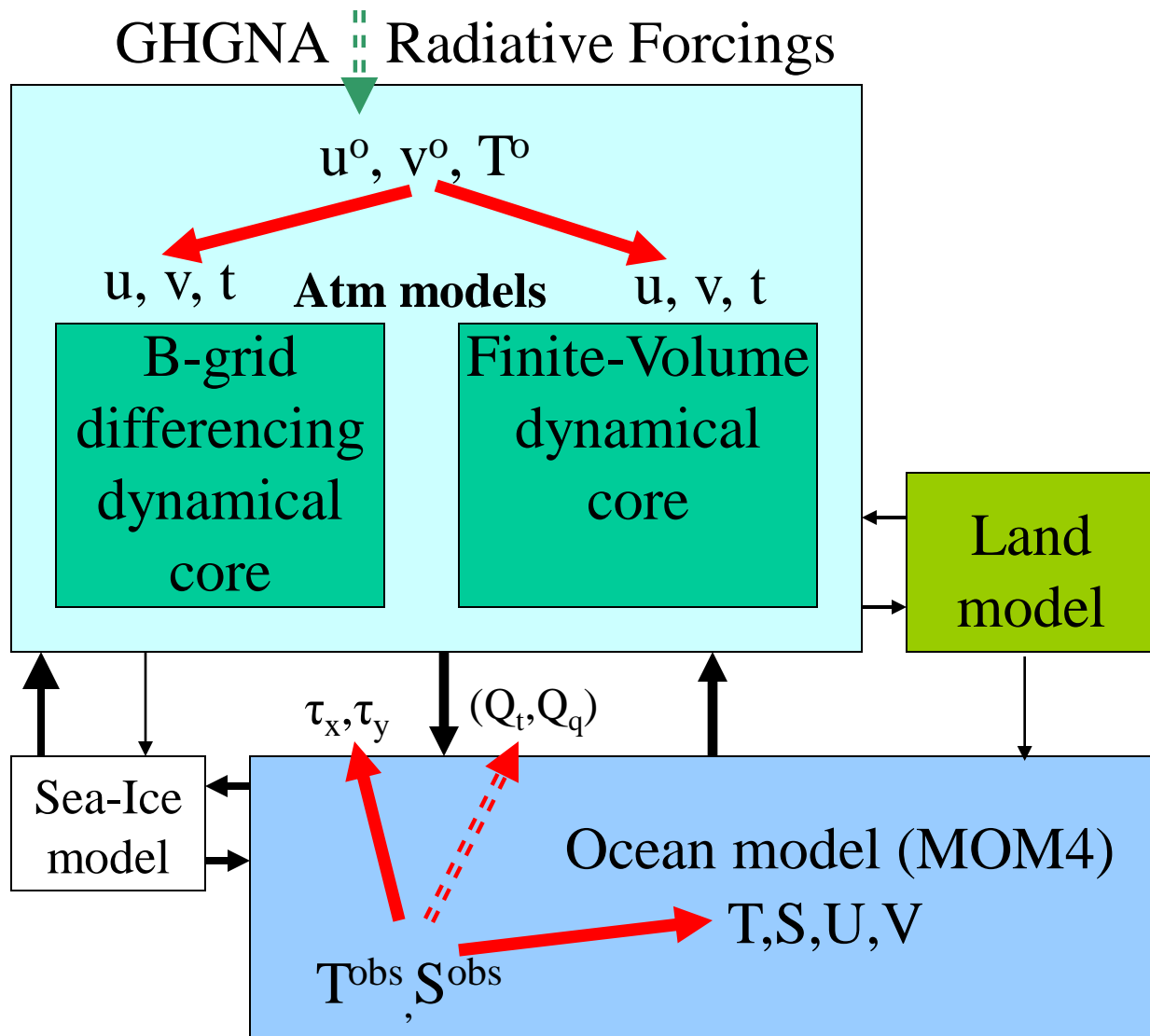
- ✓ A simple pycnocline prediction model includes:
 - Chaotic weather
 - Air-sea interactio with a slab ocean
 - Varying pycnocline at deep ocean
- (GRL2010, under review)

Traditional CDA

CDA with Parameter optimization



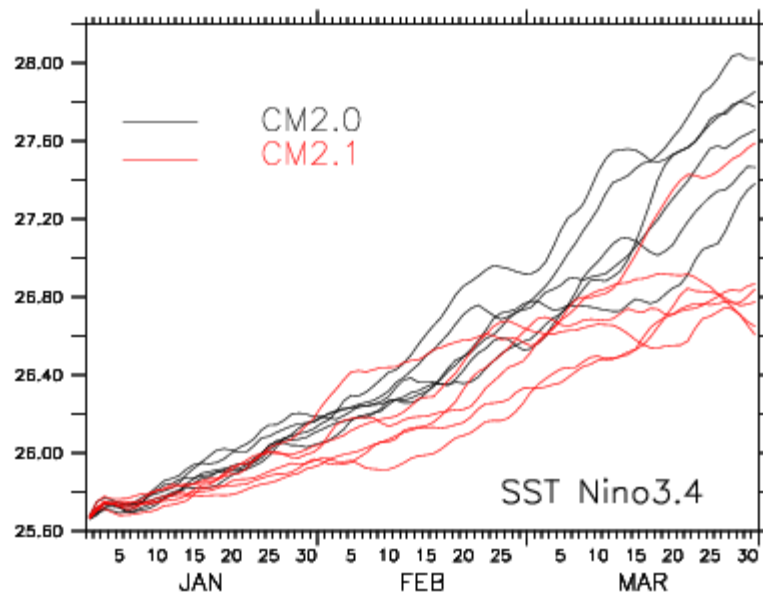
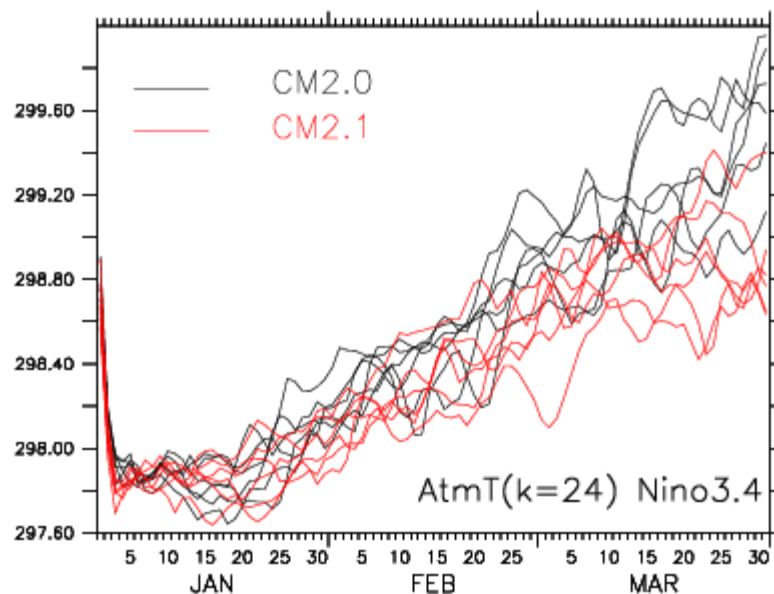
Ongoing projects(4): A prototype of multi-models coupled data assimilation system (under test) (1)





Ongoing projects(4): multi-model ECDA (2)

- ✓ Does it broaden the PDF?
It seems yes!
- ✓ Big impact on assimilation skills?
How?
To be discovered
- ✓ Big impact on forecast skills? How?
To be discovered





Future direction: High-resolution coupled model data assimilation

- ✓ More realistic overturning?
- ✓ Forecasting hurricane's genesis?
- ✓ No-gap numerical weather-climate prediction?

