Assimilation into MOM4/ Coupled Data Assimilation with GMAO ODAS-2

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Outline
- ODAS-2 vs. ODAS-1
- Background covariance modeling issues
- Assimilation into coupled model
- Analysis validation

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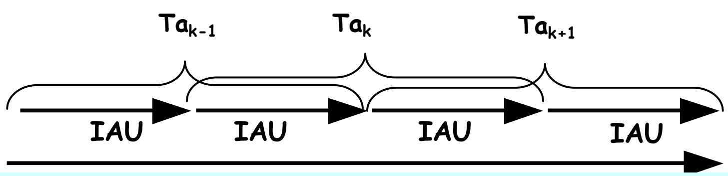
ODAS-2 vs. ODAS-1

ODAS-1

- Production ocean data assimilation system as of 6/10/2008
- Used in the GMAO coupled forecast initialization
- Developed and tuned for Poseidon V4 OGCM run at 538 x 572 x L27 ((1/3° x 5/8° x L27)
- Not model independent
  - Univariate Optimal Interpolation of in situ T and S including synthetic S data
  - Ensemble Kalman Filter assimilates T, S & SSH updating T, S, u & v
  - Online bias correction used when assimilating SSH
- OMF calculation with first guess at analysis time

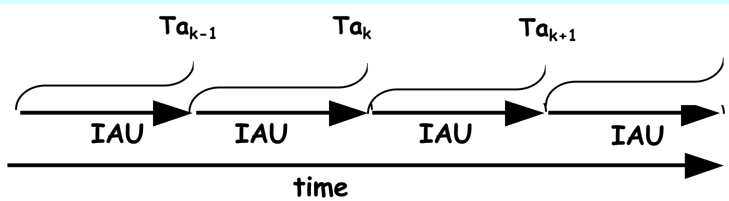


- "Classical" distance-based error covariance localization
- 3-D covariance localization
- rescaling of innovations to account for obs./analysis time discrepancy

ODAS-2 vs. ODAS-1

ODAS-2

- Fully model independent system built on ESMF framework
- Versatile: new observation types or model state variables can be added without recompiling
- Initial testing with Poseidon V5 model
- Currently used with MOM4 either coupled or uncoupled to GEOS-5 AGCM
    - OI of T & S profiles
    - "Error"-EOF based MvOI ("steady state ensemble kalman filter")
    - Online bias correction
    - Ensemble Kalman Filter coming next…
- OMF calculation with first guess at observation time



- Flow dependent error covariance localization in (x, y, z, t, neutral density) space

Adaptive error covariance localization

1. Traditional approach (as in ODAS-1)

$C(\delta x, \delta y, \delta z, \delta t)$ is an approximately Gaussian compactly supported correlation function

$$P_c = P \circ C$$

2. Tried hierarchical ensemble filter (Anderson 2007) but

- Extremely expensive!
- Observations must be processed serially ($\alpha_{kl} P_{kl}$ is not a covariance)

$$\alpha = \frac{1}{m-1}\left(\frac{(\sum_{i=1}^{m}\beta_i)^2}{\sum_{i=1}^{m}\beta_i^2} - 1\right)$$

3. Bishop's (2007) flow adaptive moderation of spurious covariances but

- Some long-range (presumably) spurious features are amplified.
- Assimilation performance (OMFA statistics) worse than case 1

$$c_{ij}^m = \left(\frac{P_{ij}}{\sqrt{P_{ii}P_{jj}}}\right)^m$$

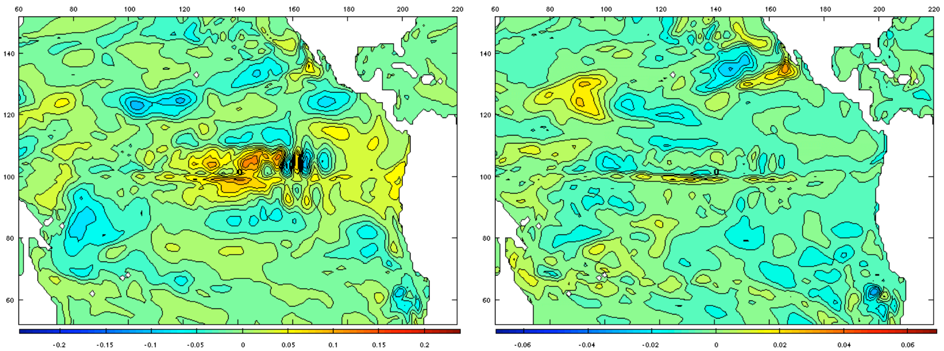
$$G = diag(C^m), \qquad C^{mq} = G^{-1/2}(C^m)^q G^{-1/2}$$

4. Back to case 1 with with localization in (x, y, z, t, neutral density) space

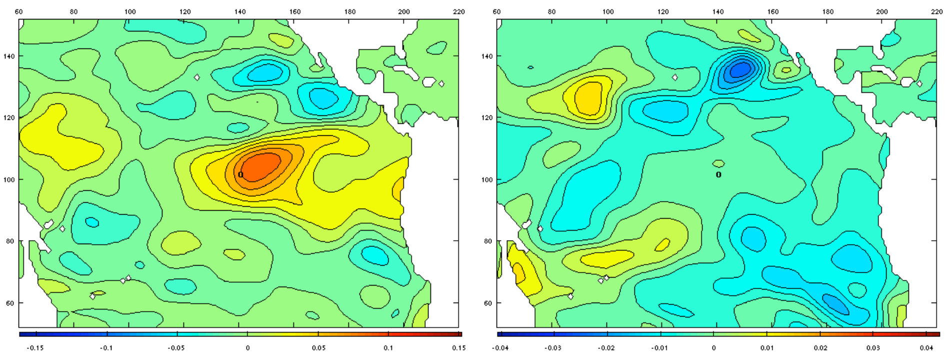
- Respects flow-dependent gradients such as thermocline and fronts
- Assimilation performance better than case 1

Adaptive error covariance localization

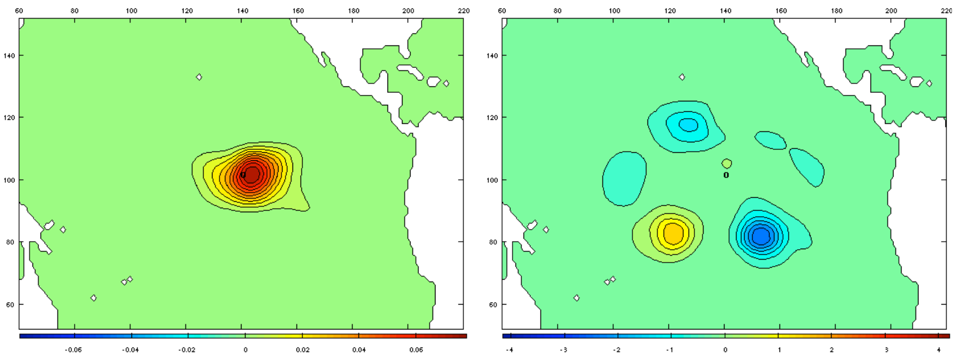
Raw T & S increments – 1C T innovation at (0N, 140W, 100m)



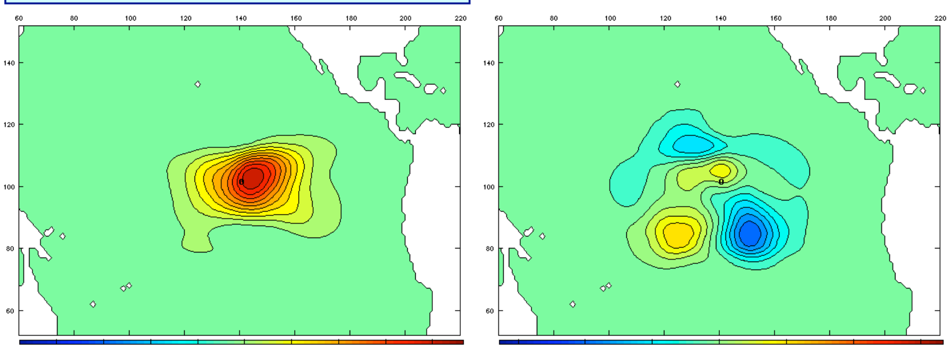
After Gaussian filter



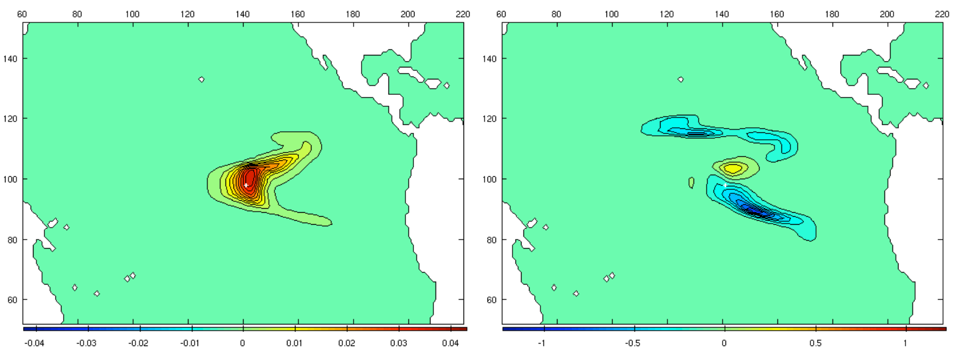
Scheme 3 – m = 2 + Gaussian filter



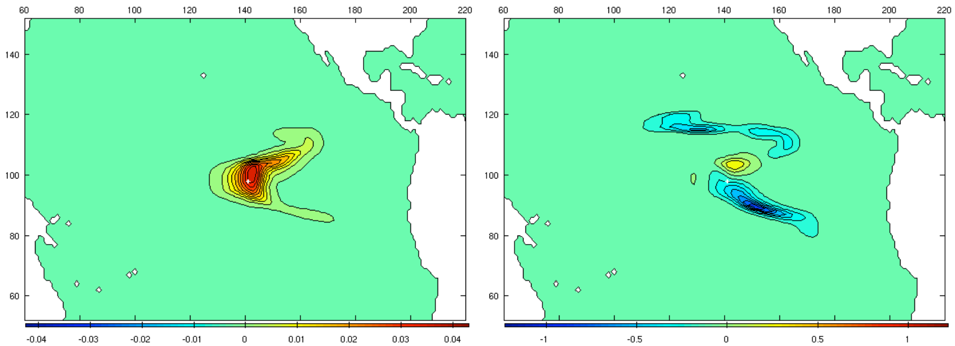
Scheme 1 + Gaussian filter



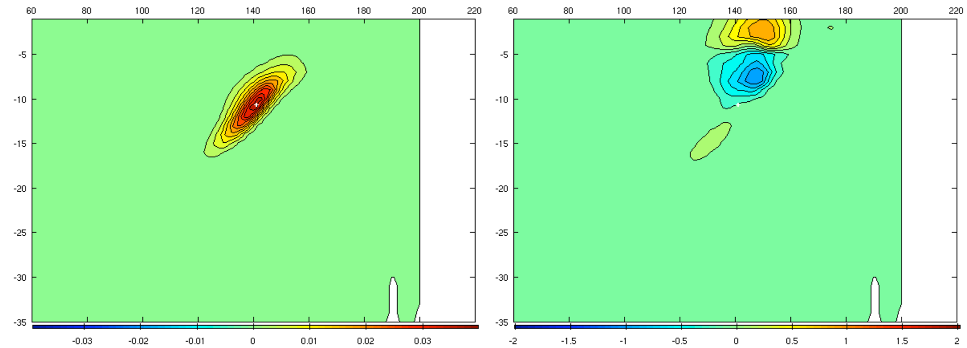
Scheme 4 + Gaussian filter



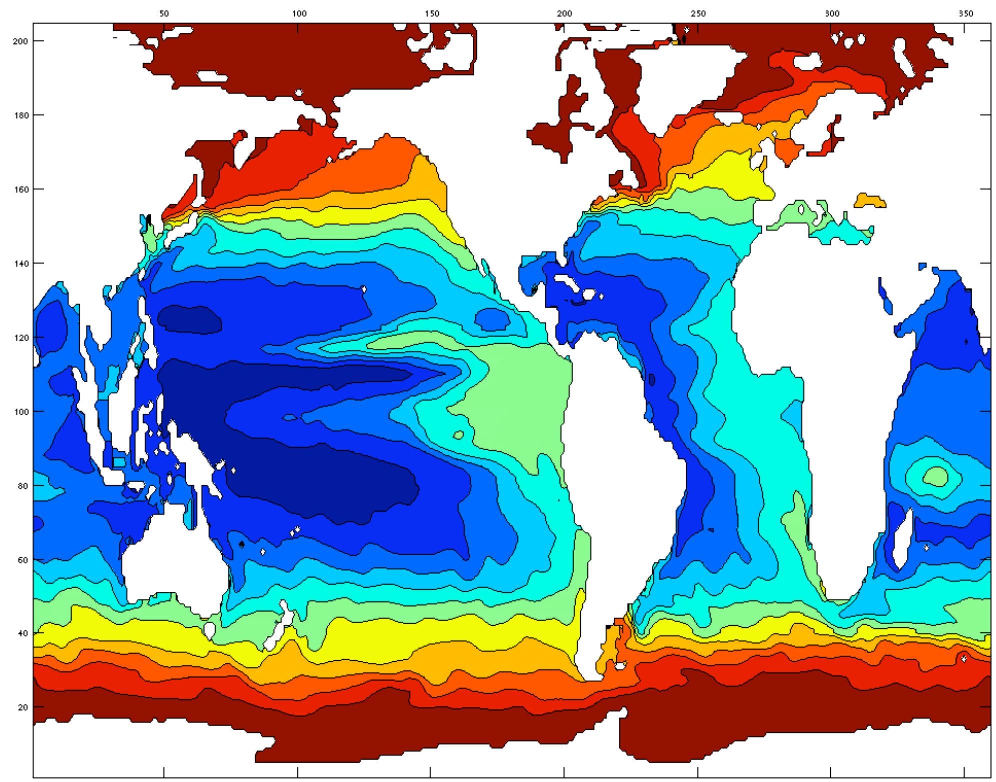
Horiz. sections,T,S,u & v increments – Scheme 4 + Gaussian filter



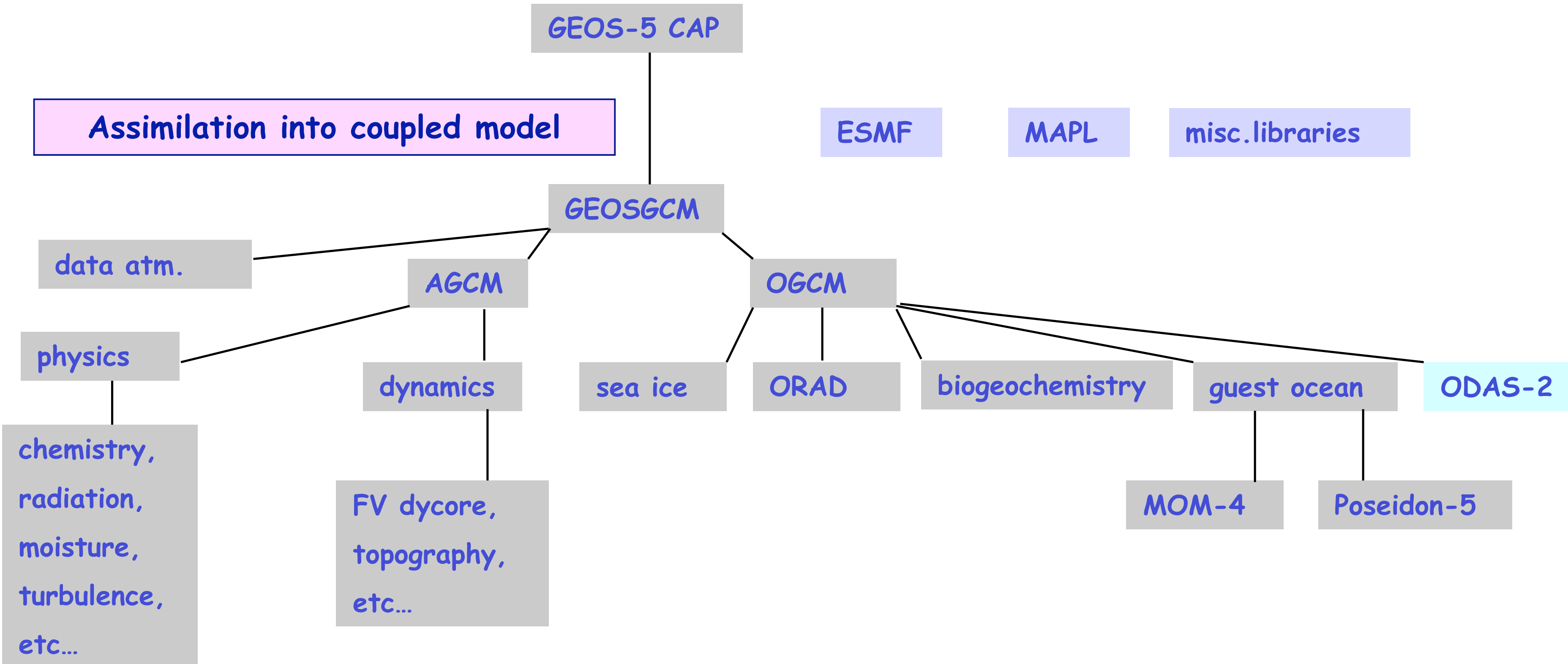
Zonal sections



Adaptive error covariance localization



- The T, increment follows the thermocline
- The T & S increments follow stratification/fronts



Ocean analysis into CGCM while atmospheric analysis is "replayed"

1. (03Z) T_k: Ocean analysis
2. $T_k \rightarrow T_{k+0.5}$: Run AGCM over T_k ocean
3. (06Z) $T_{k+0.5}$: Read atm. analysis and calculate atm. increment (analysis – first guess)
4. $T_{k+0.5} \rightarrow T_k$: Rewind AGCM (OGCM still at T_k)
5. $T_k \rightarrow T_{k+1}$: Run CGCM while incrementally applying atmospheric and ocean increments (IAU)
6. (09Z) T_{k+1}: Ocean analysis

In practice ocean analysis takes place at T_k, T_{k+n}, T_{k+2n},…
Hence ocean IAU is applied over $T_k \rightarrow T_{k+n}$ $T_{k+n} \rightarrow T_{k+2n}$,…

Analysis validation

2005-2006 runs

- ODAS-1 production analysis (TSR2): UOI of T and S data
- ODAS-2 UOI (x, y, z, t): covariance localization in (x, y, z, t) space
- ODAS-2 UOI (x, y, z, t,ϕ): covariance localization in (x, y, z, t, neutral density) space
- ODAS-2 MvOI: as ODAS-2 UOI (x, y, z, t,ϕ) but background covariances from 32 "error EOFs"

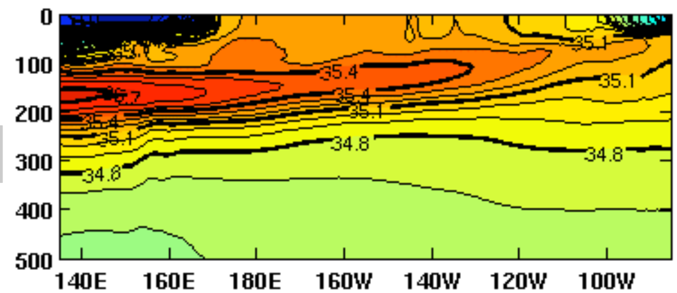
Data

- In situ T profiles: TAO, XBT, PIRATA, ARGO
- In situ S profiles: ARGO
- Synthetic salinity observations corresponding to TAO, XBT & PIRATA T data

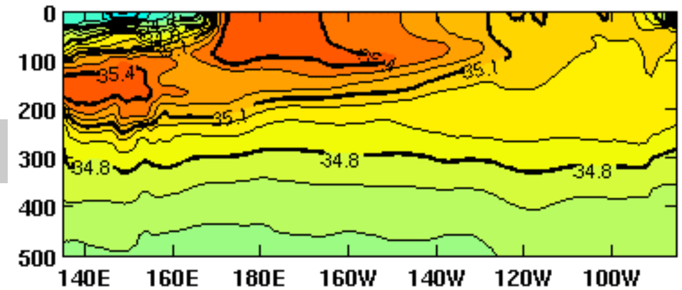
Analysis validation

Equatorial Pacific salinity June 2006

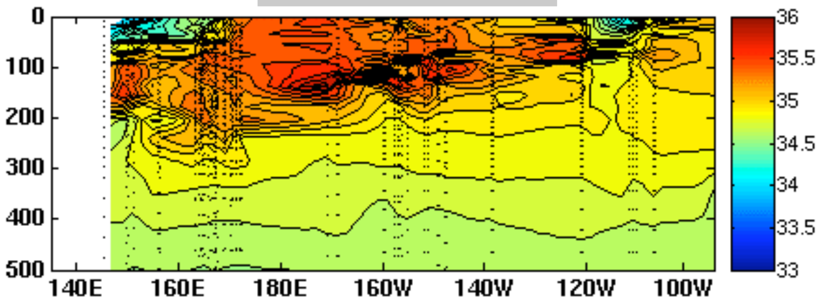
MOM control



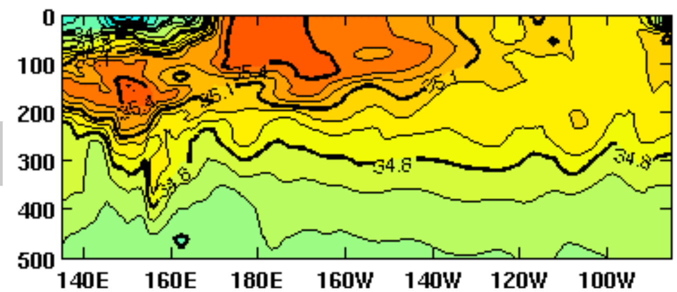
MvOI (x, y, z, t, ϕ)



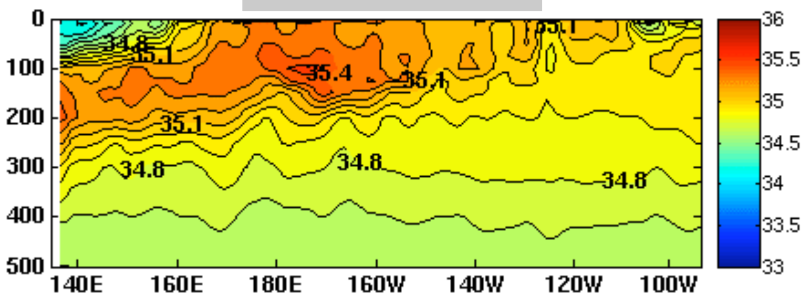
ARGO



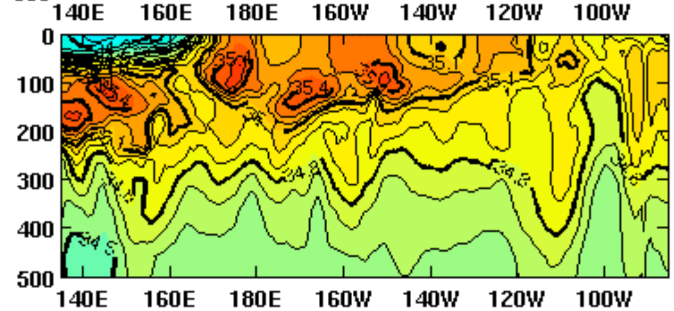
UOI (x, y, z, t, ϕ)



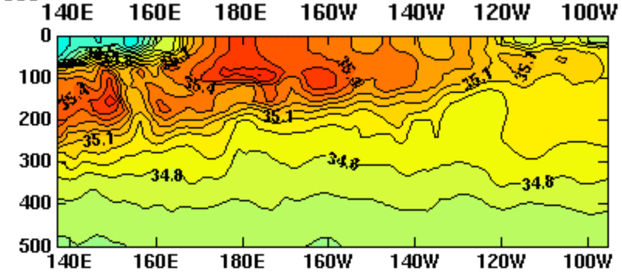
Levitus



UOI (x, y, z, t)



ODAS-1 TSR2

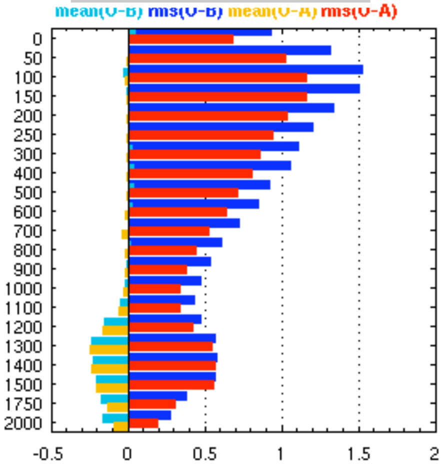


Analysis validation

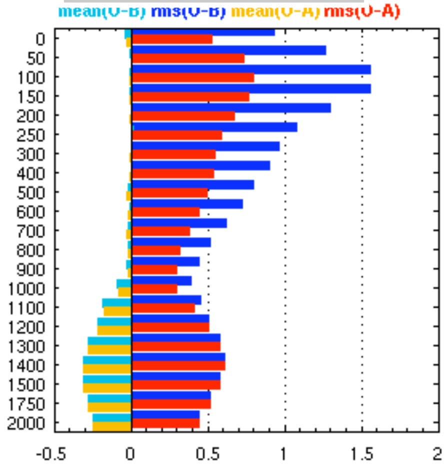
- (x, y, z, t, ϕ) localization beneficial in thermocline
- MvOI has more favorable T OMF statistics than UOI

2005 T OMF and OMA statistics

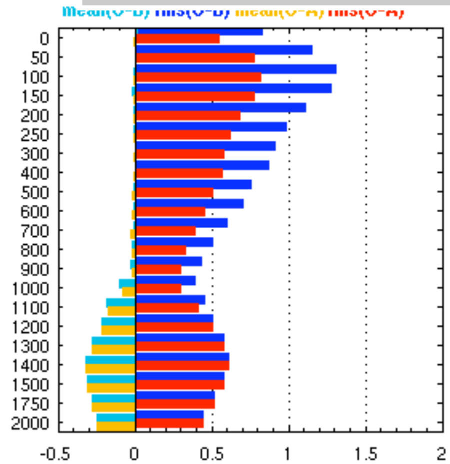
ODAS-1 TSR2



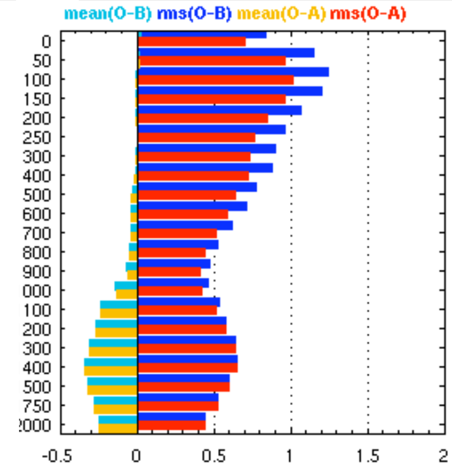
UOI (x, y, z, t)



UOI (x, y, z, t, ϕ)

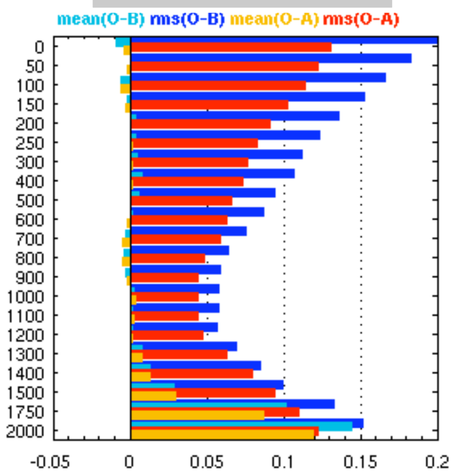


MvOI (x, y, z, t, ϕ)

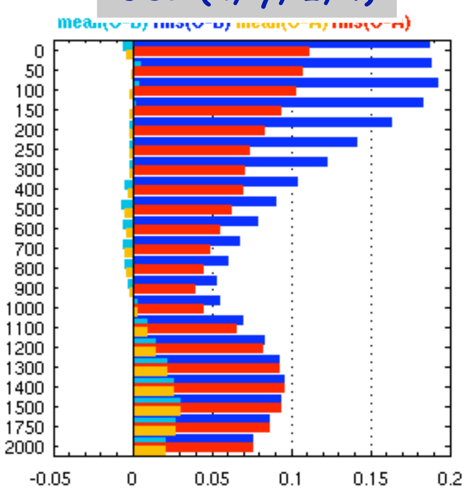


2005 S OMF and OMA statistics

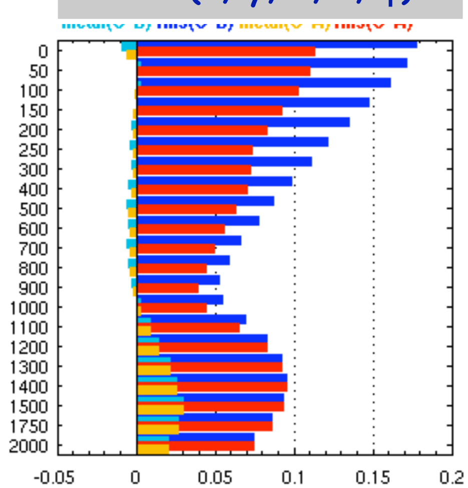
ODAS-1 TSR2



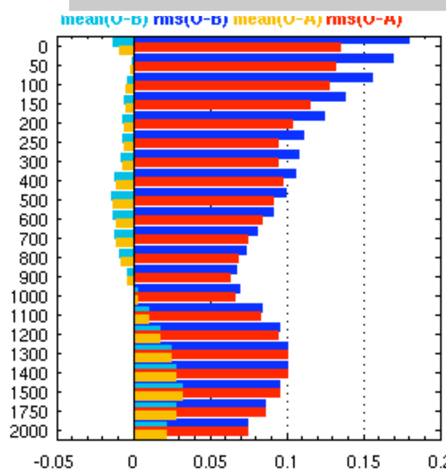
UOI (x, y, z, t)



UOI (x, y, z, t, ϕ)

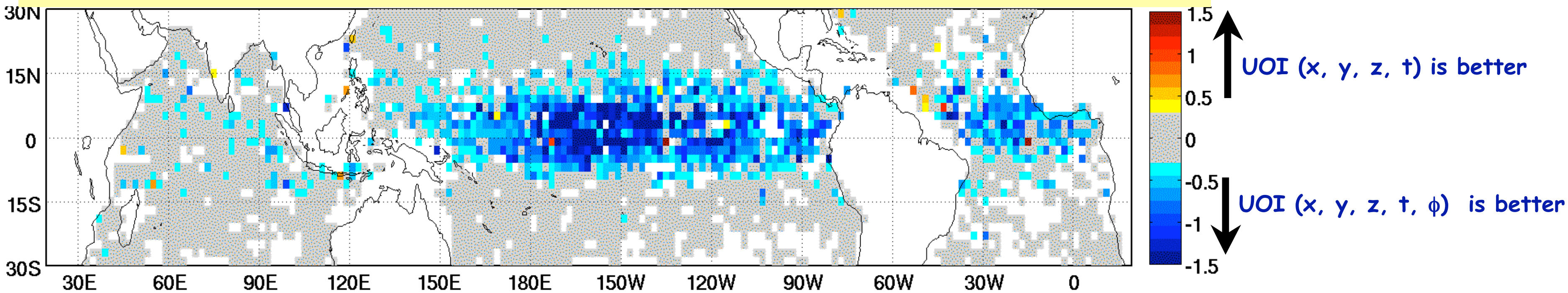


MvOI (x, y, z, t, ϕ)

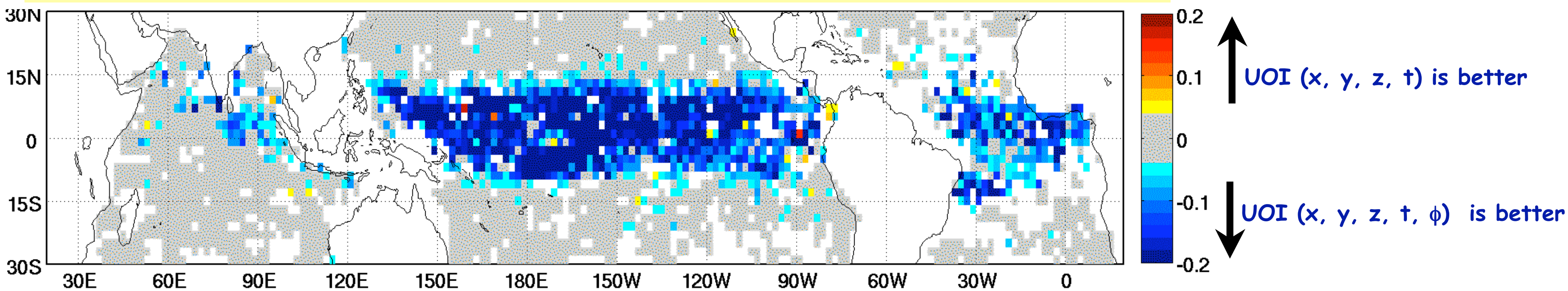


Analysis validation

0-300m 2006 rms T OMF in UOI (x, y, z, t, ϕ) – rms T OMF in UOI (x, y, z, t)

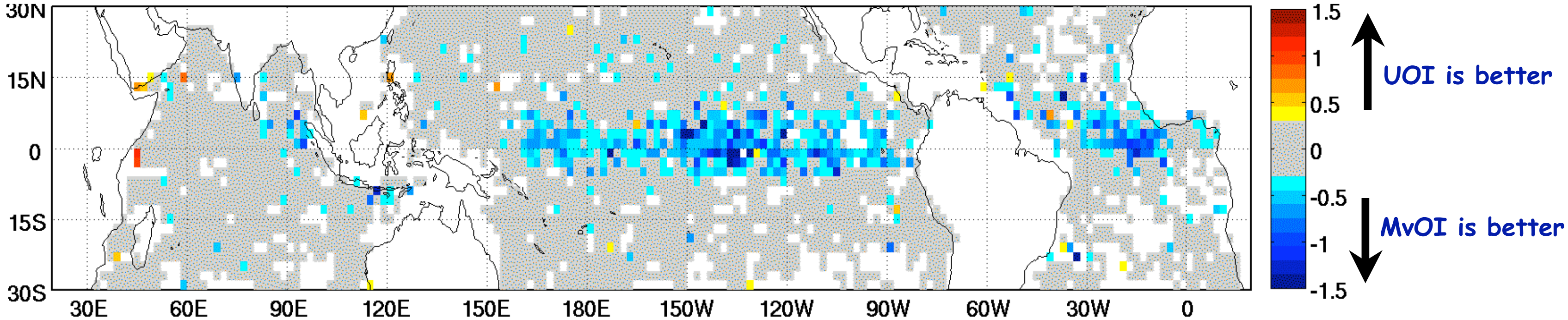


0-300m 2006 rms S OMF in UOI (x, y, z, t, ϕ) – rms S OMF in UOI (x, y, z, t)

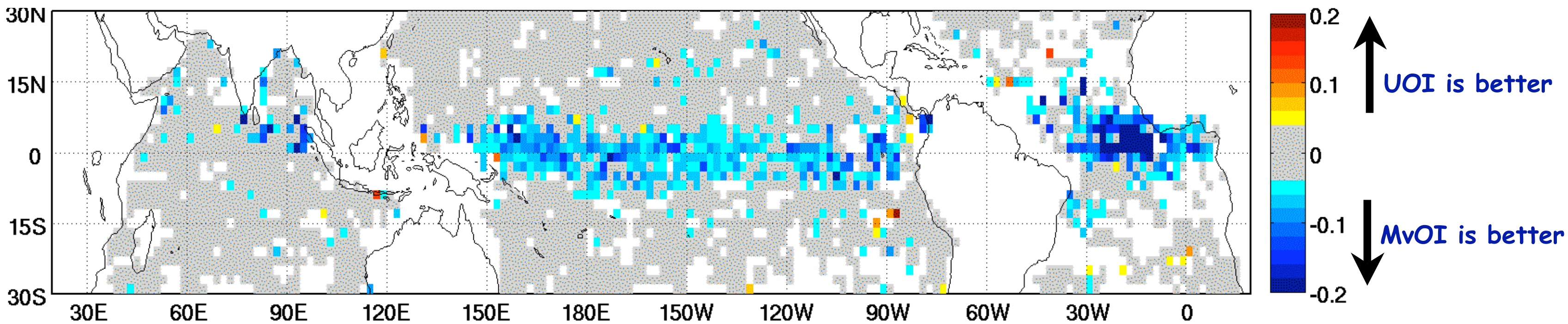


Analysis validation

0-300m 2006 rms T OMF in MvOI (x, y, z, t, ϕ) – rms T OMF in UOI (x, y, z, t, ϕ)

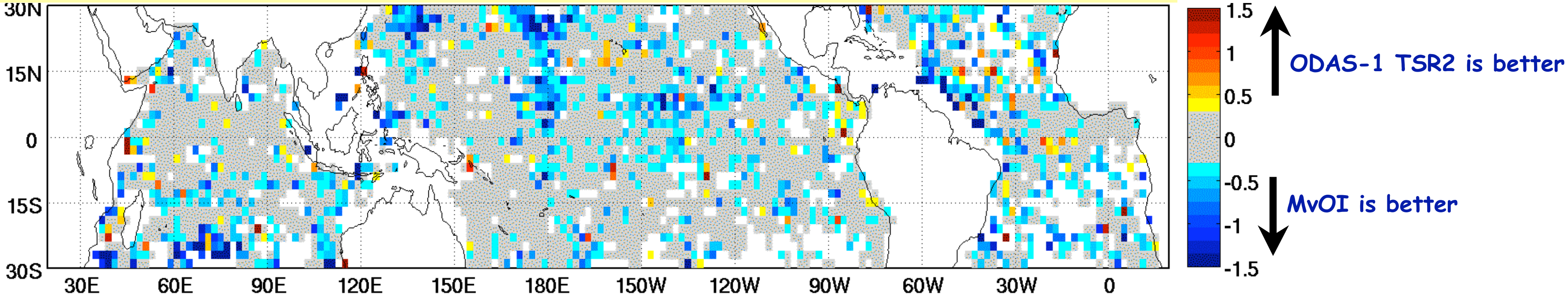


0-300m 2006 rms S OMF in MvOI (x, y, z, t, ϕ) – rms S OMF in UOI (x, y, z, t, ϕ)

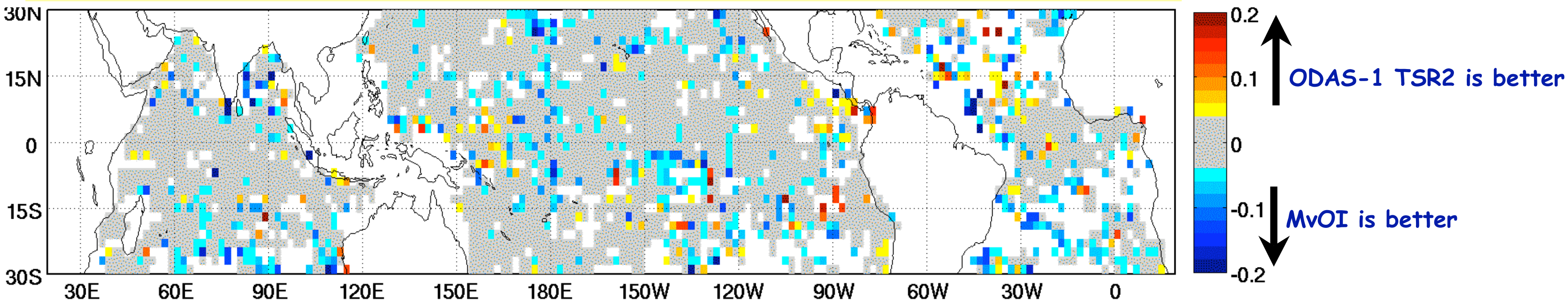


Analysis validation

0-300m 2006 rms T OMF in MvOI (x, y, z, t, ϕ) – rms T OMF in ODAS-1 TSR2



0-300m 2006 rms S OMF in MvOI (x, y, z, t, ϕ) – rms S OMF in ODAS-1 TSR2



Salinity comparison with independent CTD observations: MVOI (x, y, z, t, ϕ)