On the Performance of 4D-Var and an Ensemble Adjustment Kalman Filter applied to the California Current system

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2: Rutgers University

3: NCAR

Lessons Learned by an EnKF Novice

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ROMS-DART: A New Ocean Modeling Community Resource

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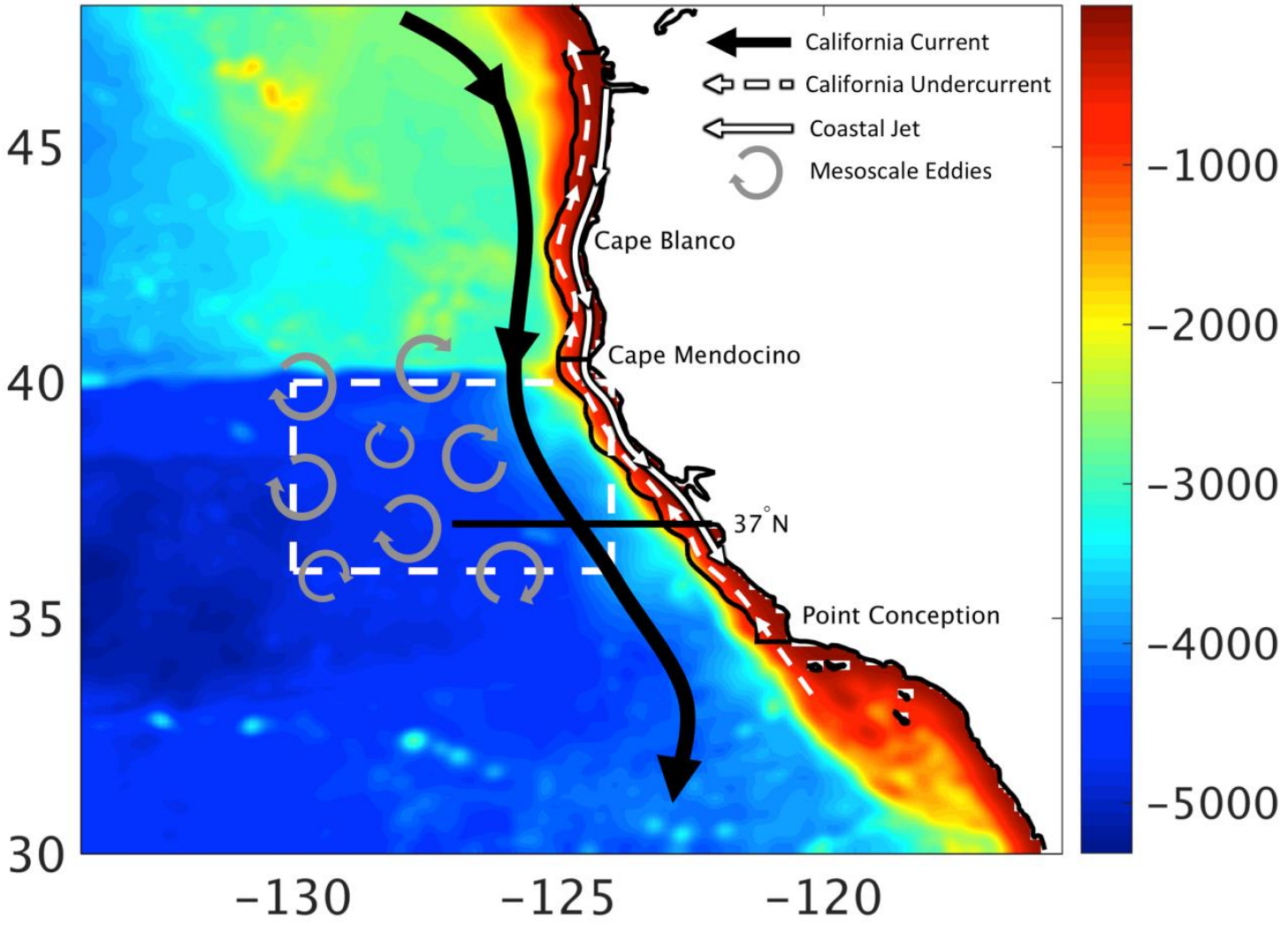
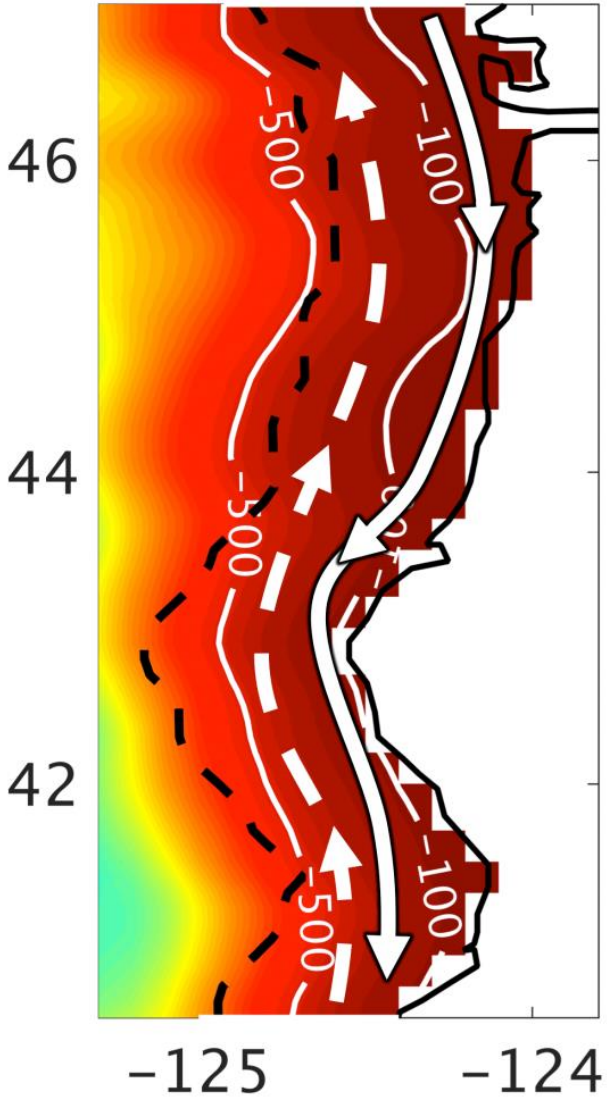
Outline:

- Motivation – development of a hybrid DA system
- Brief intro to California Current system
- Description of DA systems
- EAKF vs 4D-Var: identical twin experiments
- EAKF vs 4D-Var: real observation experiments

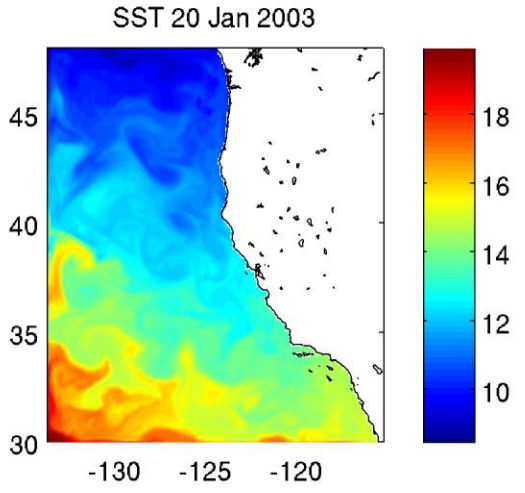
The California Current System (CCS)

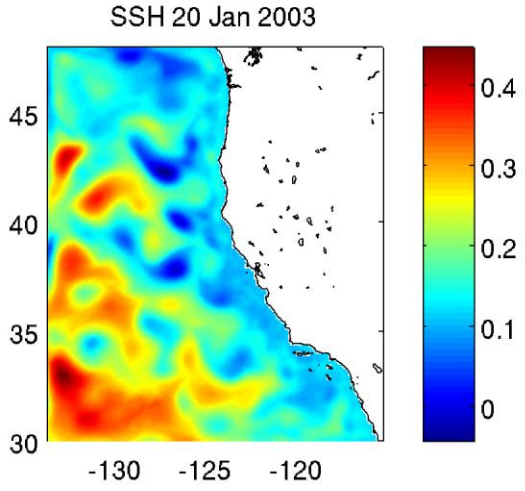




ROMS CCS

- 10km resolution. 42 σ-levels
- Identical twin & real obs expts





EAKF

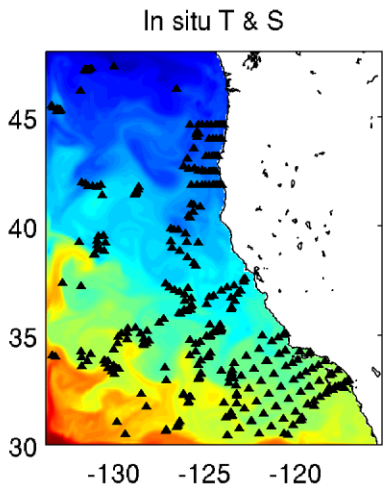
- DART
- FGAT (1, 2 & 4 days)
- Gaspari-Cohn localization (~130 km, 200m)
- Adaptive inflation
- 50 members (no centering)
- 51 members (centered)
- Adjust i.c. only
- QC: ±3σ

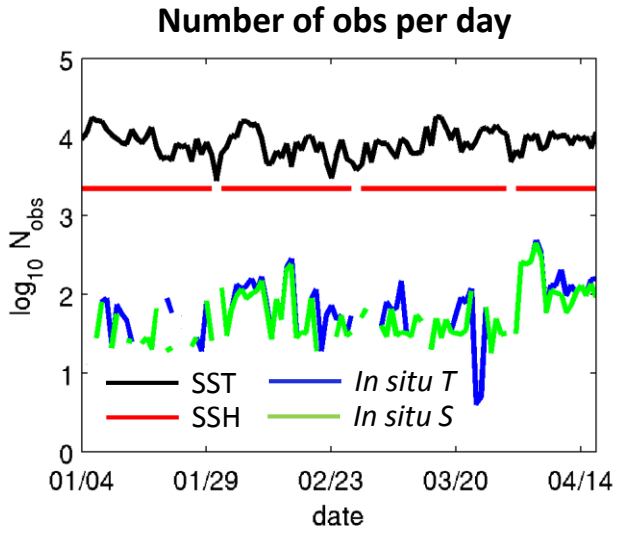
4D-Var

- Dual
- B-preconditioned, Lanczos, RPCG
- 2 outer-loops
- 7-inner-loops
- 1, 2, 4 & 8 day windows
- Adjust i.c. only
- QC: ±3σ

Observations:

- Satellite SST – daily (AVHRR, AMSR, MODIS)
- Aviso gridded SSH - daily
- *In situ* T & S profiles
- 4 Jan – 18 April 2003





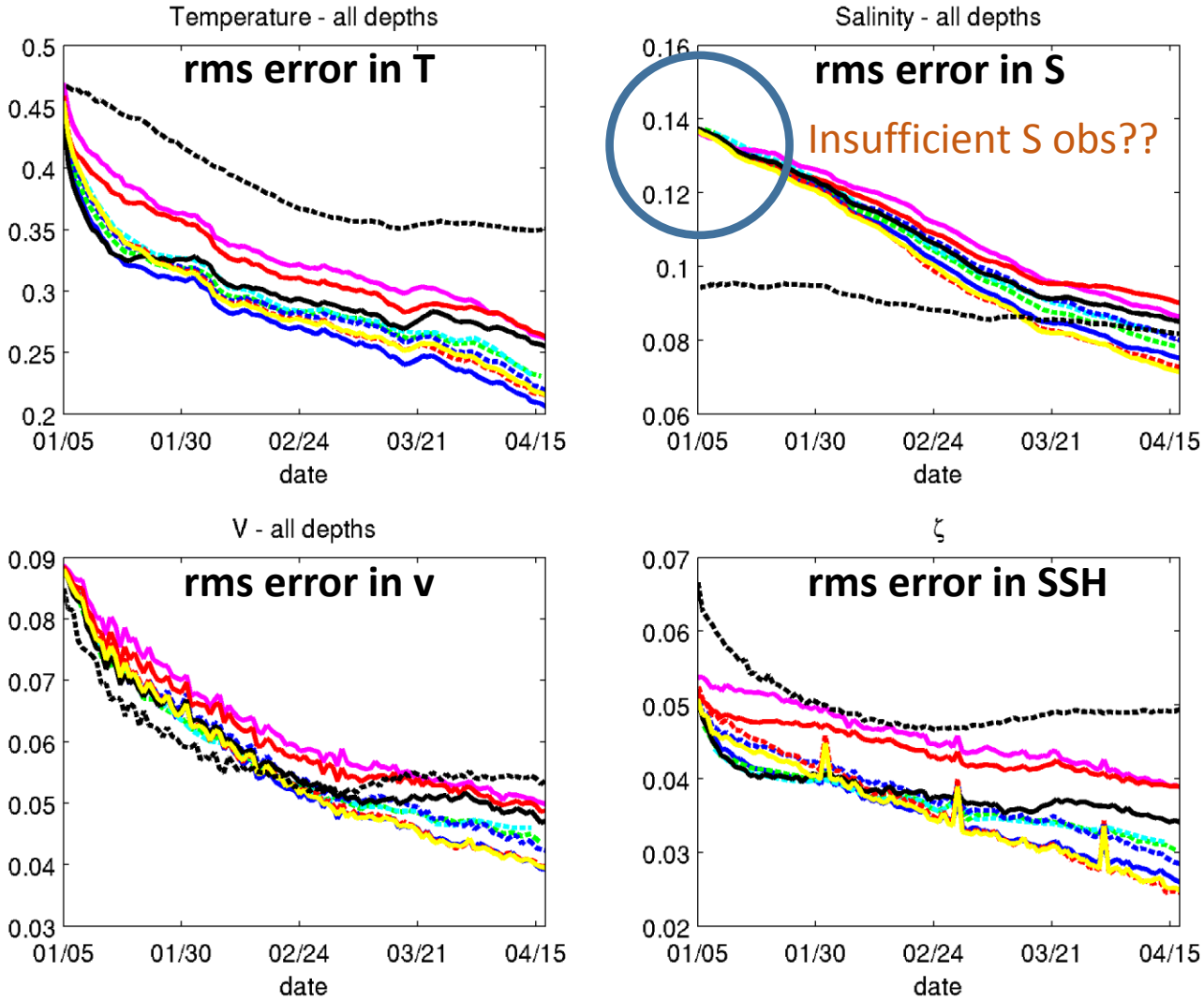
NRL COAMPS forcing
SODA open boundary conditions

Identical Twin Experiments: EAKF

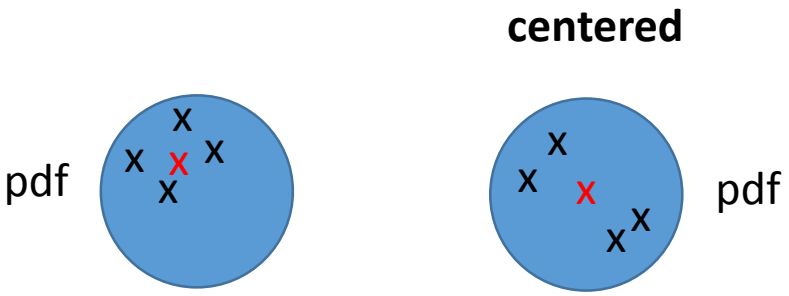
- Error free model, forcing and open boundary conditions
- True solution: forced model solution 1999-2012
- First-guess on 4 Jan – WCRA14 4D-Var analysis
- Obs sampled at actual obs locations and times
- 50 ensemble member cases

No assim
EAKF FGAT 1day
EAKF FGAT 2day
EAKF FGAT 4day
EAKF FGAT 1day, 10 ens members
EAKF FGAT 1day, 30 ens members
EAKF FGAT 1day, loc: 260 km, 200 m
EAKF FGAT 1day, loc: 65 km, 200 m
EAKF FGAT 1day, loc: 130 km, no v. loc
EAKF FGAT 1day, loc: 130 km, 100 m

EAKF FGAT 1day - The best!



Centering the Ensemble

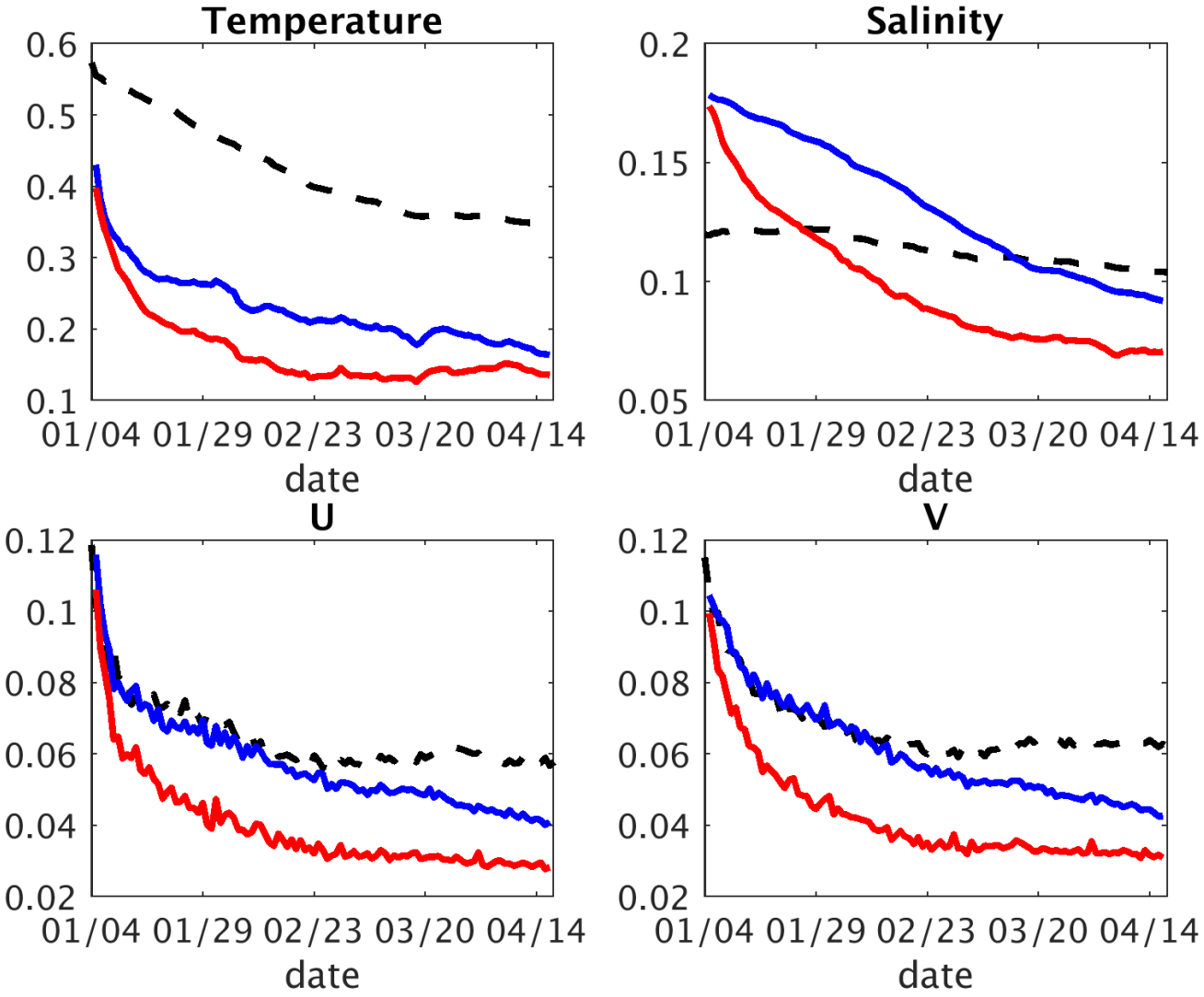


X – ens pert
X – ens mean

No assim

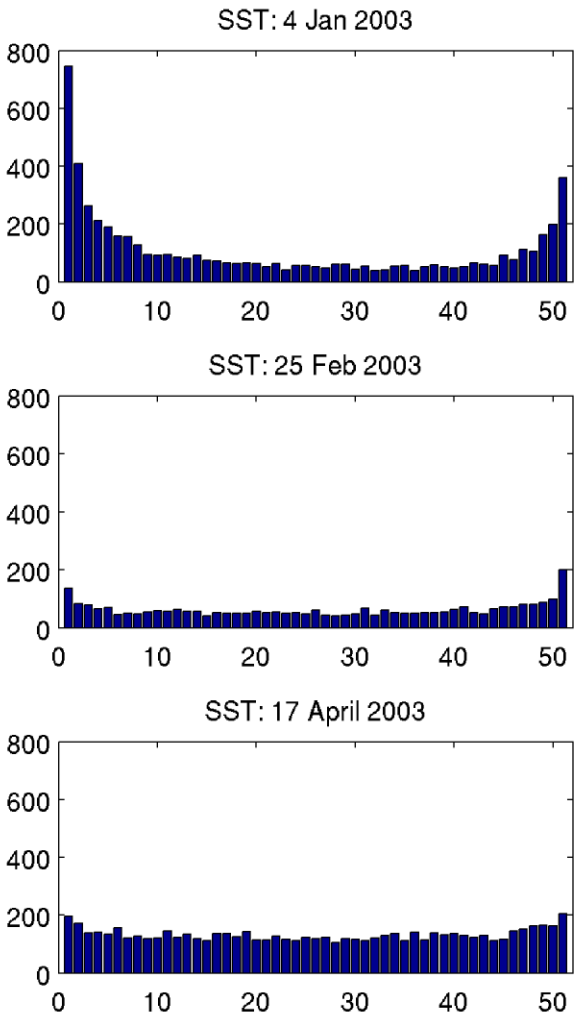
EAKF FGAT 1 day, loc 65km
(centered ensemble)

EAKF FGAT 1 day
(no centering)

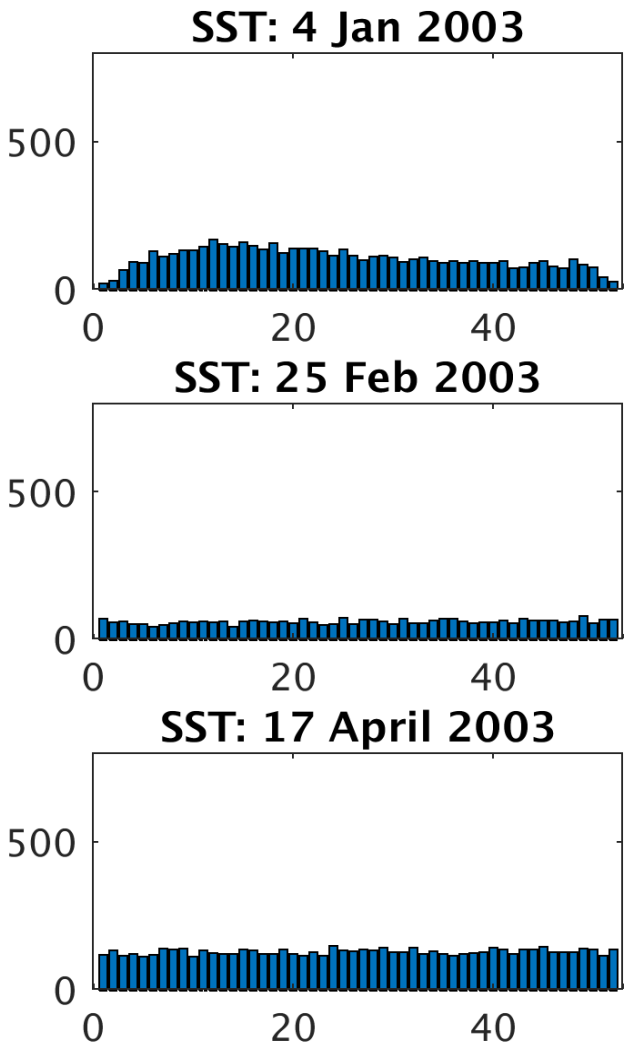


EAKF Rank Histograms (Talagrand Diagrams)

Not enough spread in the ensemble



Adaptive inflation



Too much spread in the ensemble

No centering

Centered

Much better- more "reliable"

Much better- more "reliable"

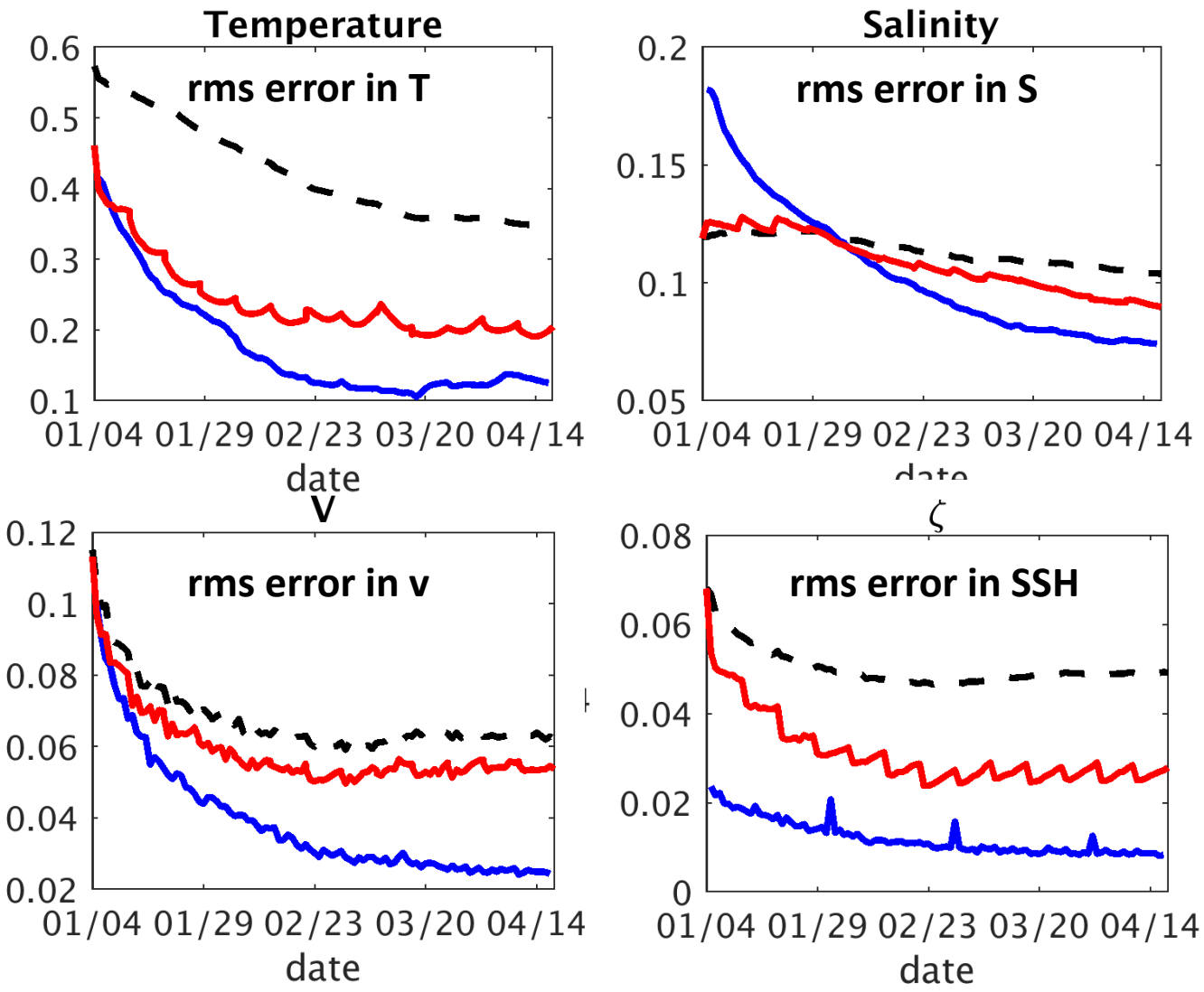
Identical Twin Experiments: EAKF vs 4D-Var

No assim

4D-Var 8 day

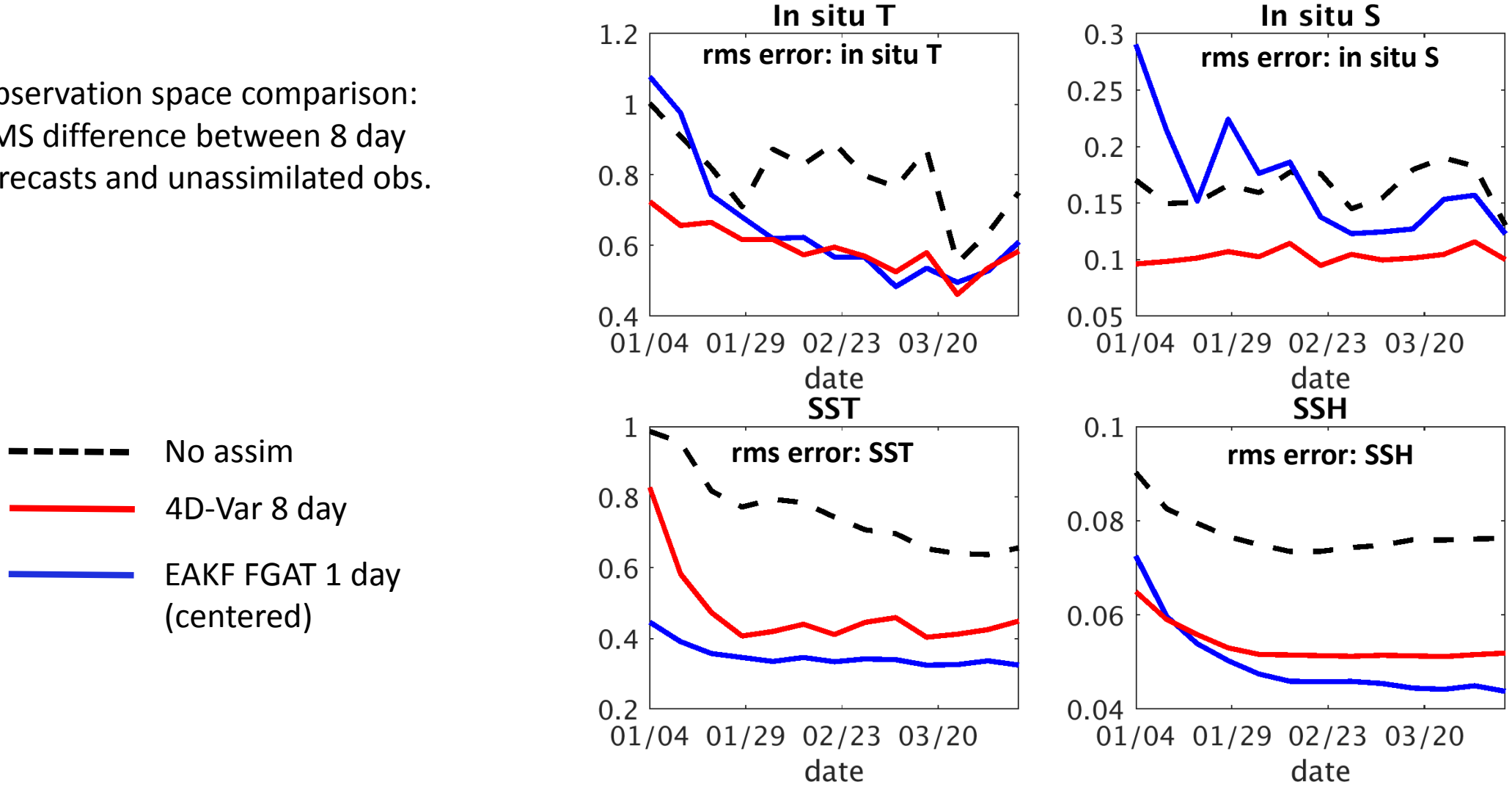
EAKF FGAT 1 day (centered)

Eight 1-day FGAT EAKF cycles per 8-day 4D-Var cycle



Identical Twin Experiments: EAKF vs 4D-Var

Observation space comparison: RMS difference between 8 day forecasts and unassimilated obs.



Real Observation Experiments: EAKF vs 4D-Var

Observation space comparison:
RMS difference between 8 day forecasts and unassimilated obs.

No assim

4D-Var 8 day

EAKF FGAT 1 day
(no centering)

Summary

- Centering of the ensemble improves performance of EAKF
- Twin expts: 4D-Var is best for short analysis periods
  EAKF is best for long analysis periods
- Real data expts: 4D-Var superior to EAKF
- Goal – to develop a hybrid DA system for ROMS that capitalizes on the strengths of both approaches.

4D-Var:

Adjoint

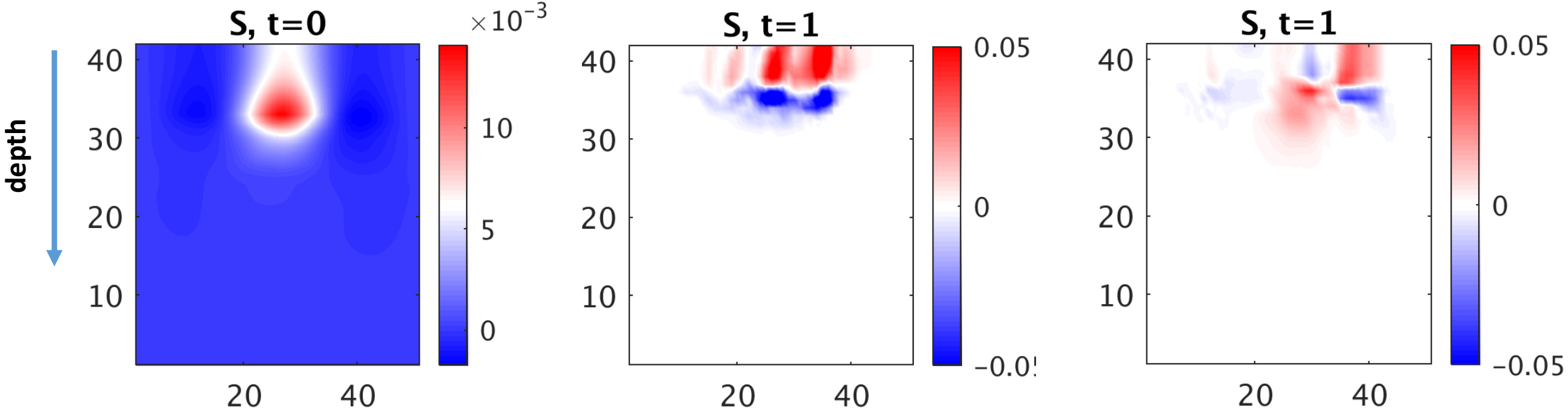
Climatological covariances

Ensemble:

Flow-dependent covariances

Single Observation Experiments

Vertical sections of Salinity



4D-Var Climatological covariance

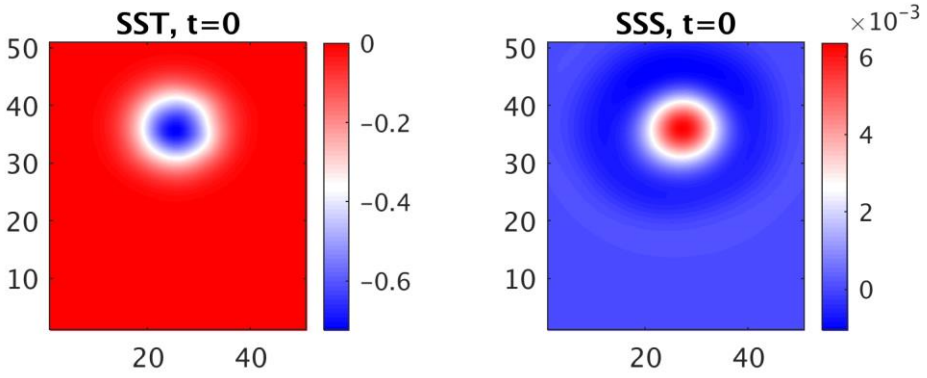
4D-Var implicit flow-dependent covariance

EAKF flow-dependent covariance

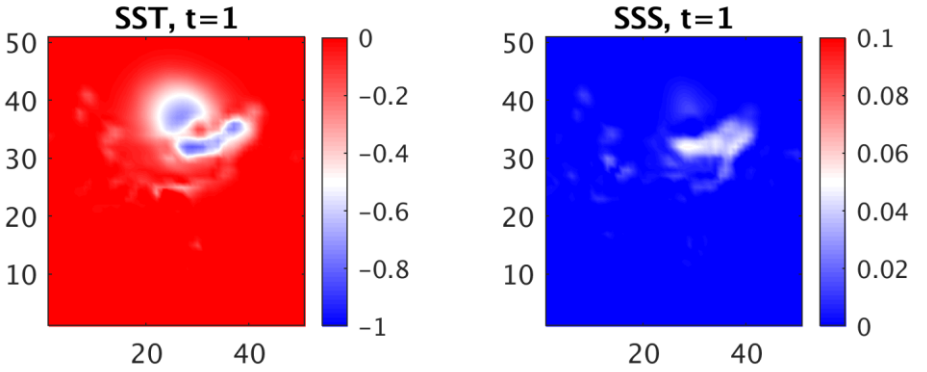
Can interpret increments as superpositions of covariances.

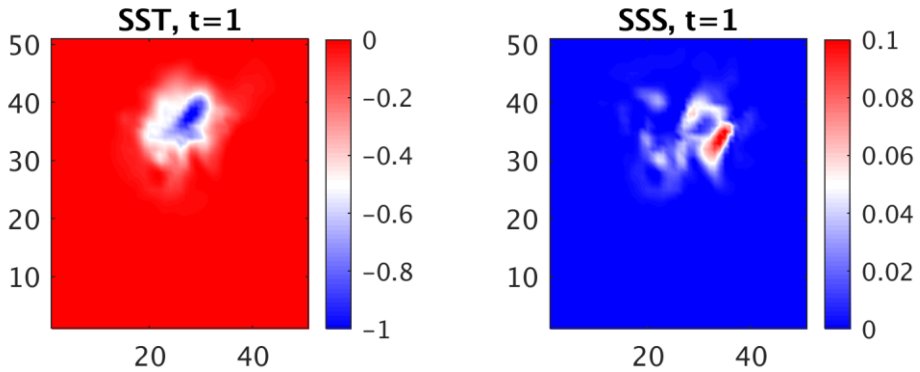
Single Observation Experiments

4D-Var t=0 (no balance)



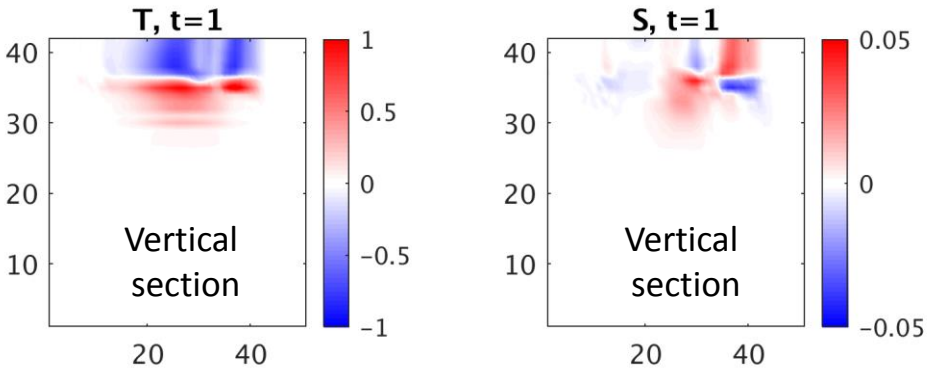
4D-Var t=1

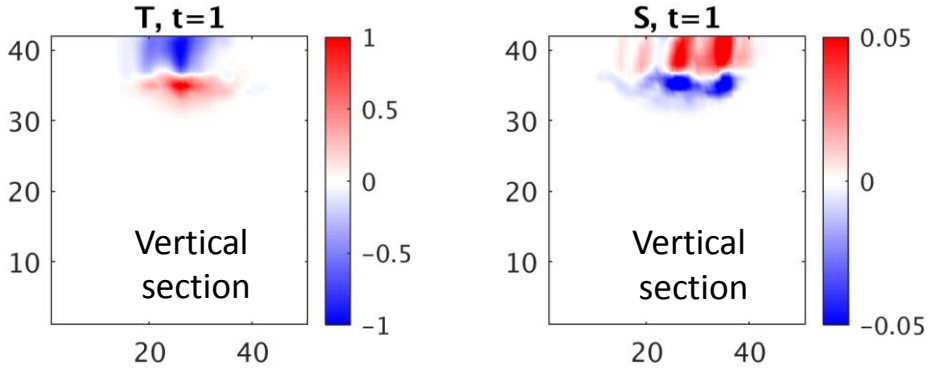




DART t=1

4D-Var t=1





DART t=1

Can interpret increments as superpositions of covariances.