Evolving ocean state & parameter estimation to the SWOT era

Patrick Heimbach, Ivana Escobar, and An T. Nguyen
(with collaborators, especially from SIO)

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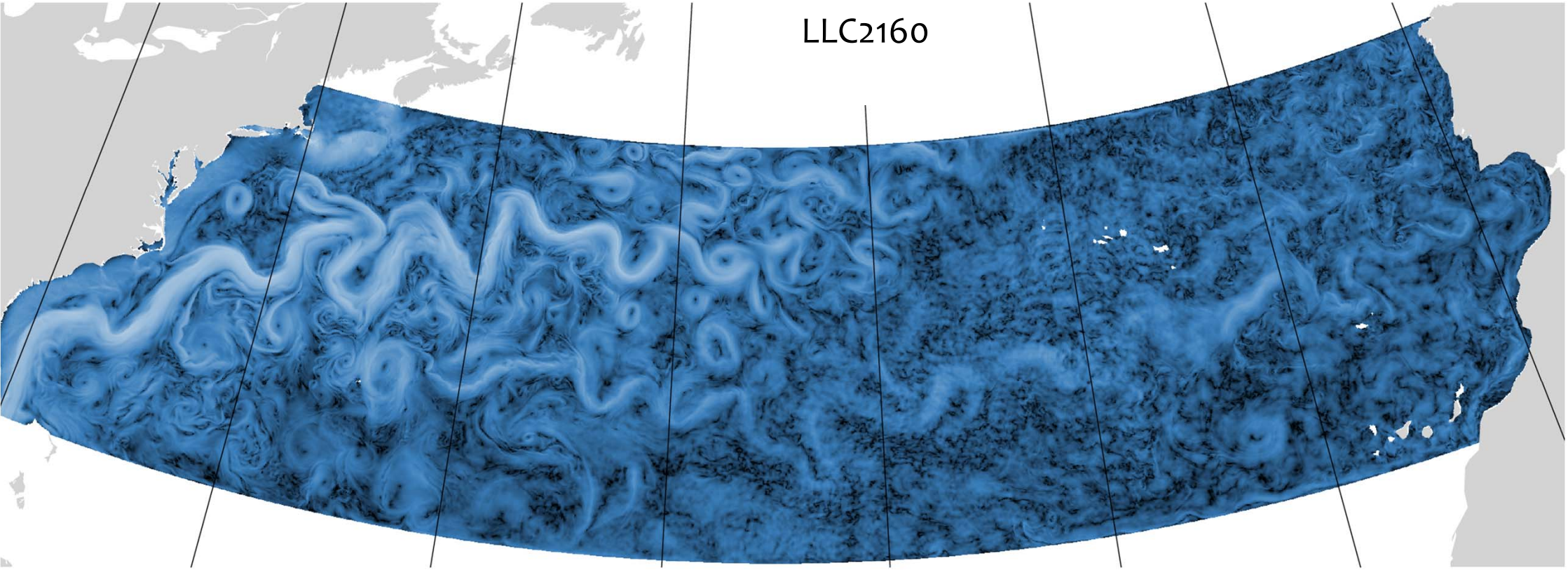
Overall project goals

- Deploy the methods developed within ECCO for assimilating SWOT data, together with the existing diverse data streams
  - *Parameter estimation*: use the adjoint capability for formal **model calibration** (including 2-D and 3-D parameter fields)
  - *State estimation*: move toward "short-window", i.e., **incremental "4D-Var"**
- Focus on a regional domain of the subtropical North Atlantic
  - Similar issues as with California Current regional configs?

ome configuration details

A subtropical North Atlantic configuration at 8, 4, 2 km resolution (LLC1080, LLC2160, LLC4320)



Callies & Nguyen (2015)

ome configuration details

A subtropical North Atlantic configuration at 8, 4, 2 km resolution
LLC1080, LLC2160, LLC4320)

Details:

vana Escobar's poster

N.B.:

Both Jörn Callies and An Nguyen have been involved, along with
Rui Ponte, in tracking down the tidal forcing error in the global
LLC4320, with significant help from Richard Ray.

ome configuration details

- A subtropical North Atlantic configuration at 8, 4, & 2 km resolution
  - Pro: absence of eastern boundary (except Med.!)
  - Con: already computationally expensive at 2 km resolution
- Initial goal of configuration in terms of parameter settings is to stay close to global LLC4320 and to SIO's regional configurations
  - understand in which way our config. gives similar or different result to other configurations
- Choices of open boundaries to be used:
  - from regional Arctic/North Atlantic state estimate (ASTE)
  - from HYCOM

How do we practice ocean state & parameter estimation? And why?

ome of the challenges:

Why adjoints: dynamical & kinematical consistency in DA

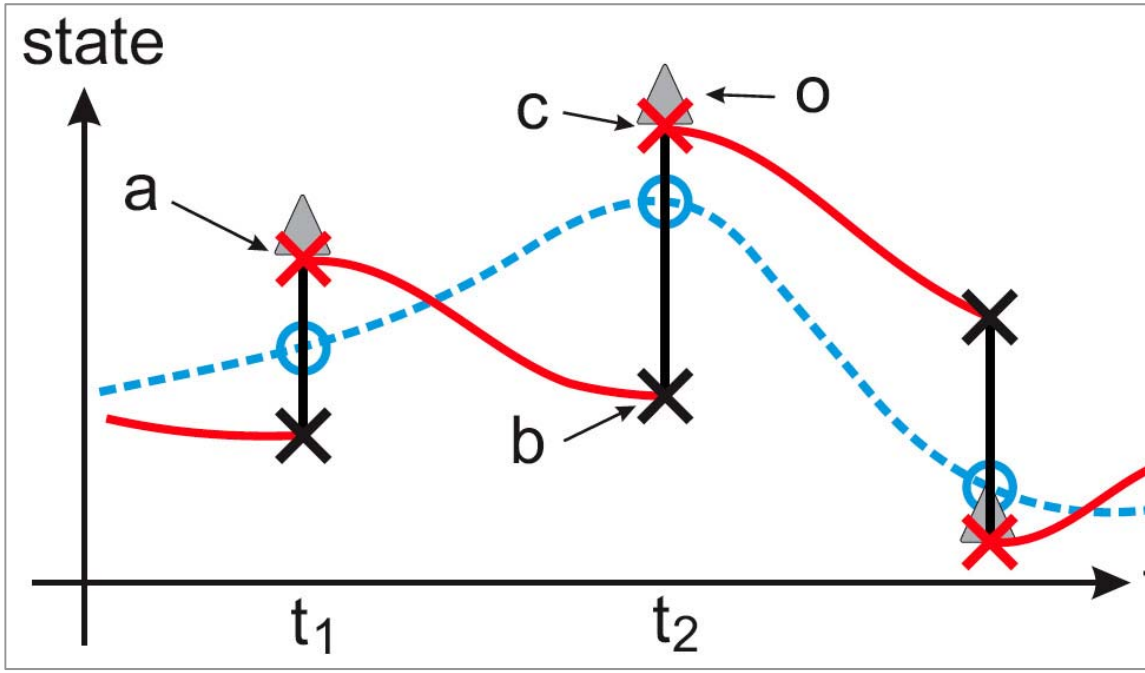
umerical Weather Prediction (NWP) – a filtering problem

elatively abundant data sampling of the 3-dim. atmosphere

WP targets optimal forecasting

➔ find initial conditions which produce best possible forecast;

➔ *dynamical consistency or property conservation NOT required*



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cean state estimation/reconstruction – a smoothing problem

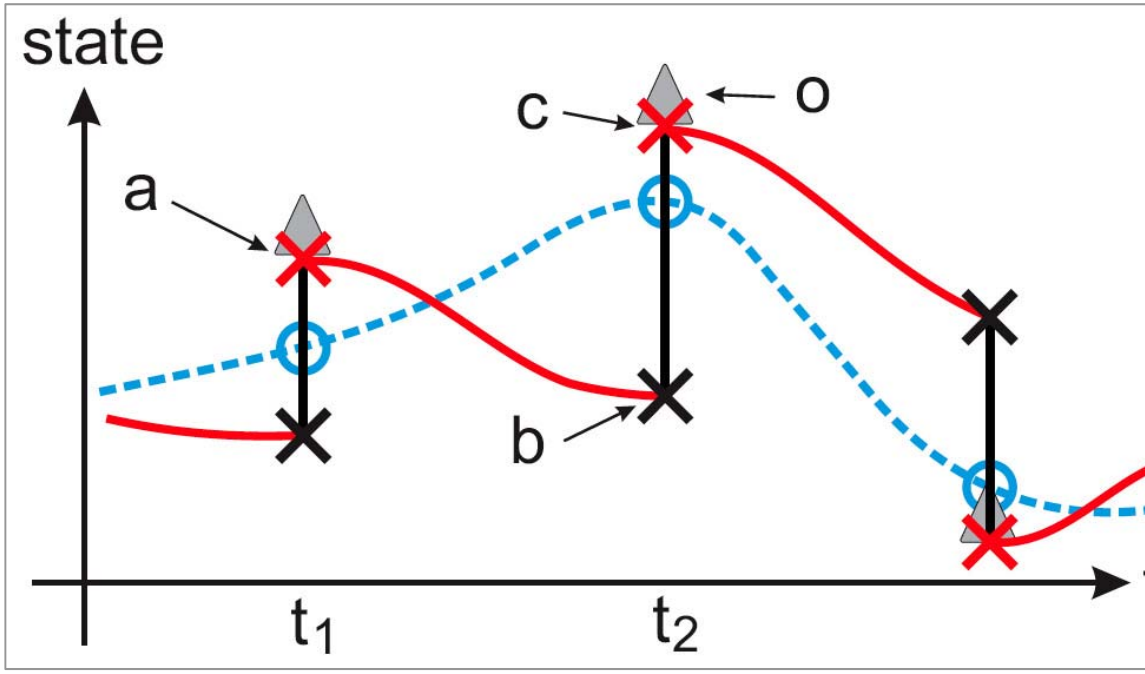
parse data sampling of the 3-D. ocean

nderstanding past & present state of

he ocean is a major goal all by itself

➔ use observations in an optimal way

➔ *dynamic consistency & property conservation ESSENTIAL* for climate



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Why adjoints: dynamical & kinematical consistency in DA

Balancing the
momentum,
reshwater,
and heat
budgets

s it relevant for high-resolution ‘short-window” DA?

s it relevant for "short-window" DA?

ilo et al., Ocean Modelling (2018)

Ocean Modelling 131 (2018) 71–85

Contents lists available at ScienceDirect

Ocean Modelling

journal homepage: www.elsevier.com/locate/ocemod

act of data assimilation on vertical velocities in an eddy resolving ocean del

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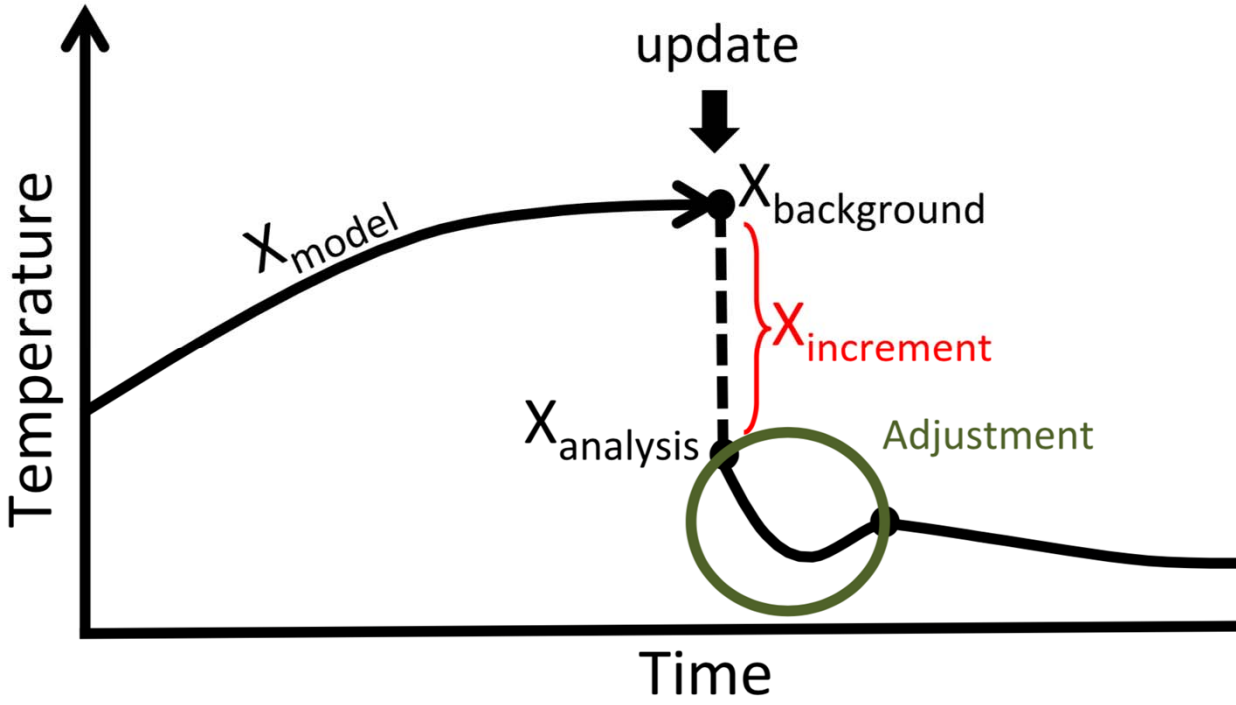
s it relevant for "short-window" DA?

ilo et al., Ocean Modelling (2018)

n their words: "Sequential assimilation:"

- explicit update of the model state at regular intervals
- updates to model state are not "dynamically consistent", i.e., they are generally not solutions to the model equations.
- can be regarded as a non-physical forcing term in the model equations
- Unphysical re-adjustments involve
  - inertial oscillations,
  - unrealistic mixing,
  - artificial baroclinic & barotropic adjustment

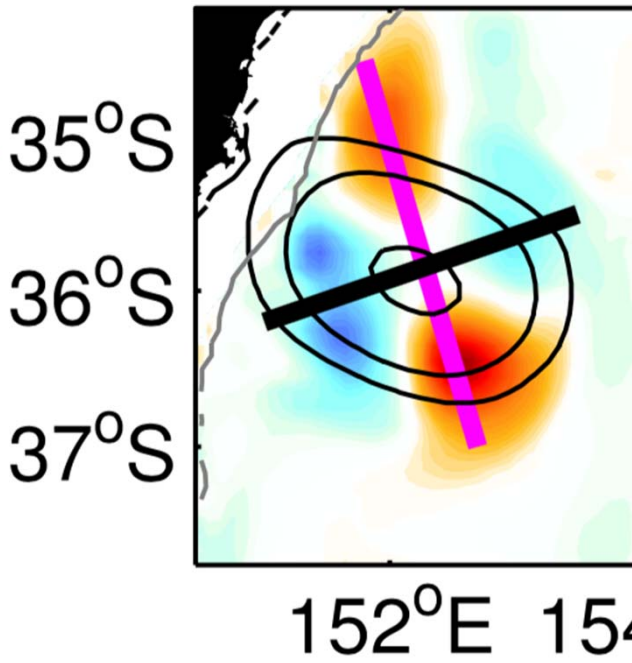


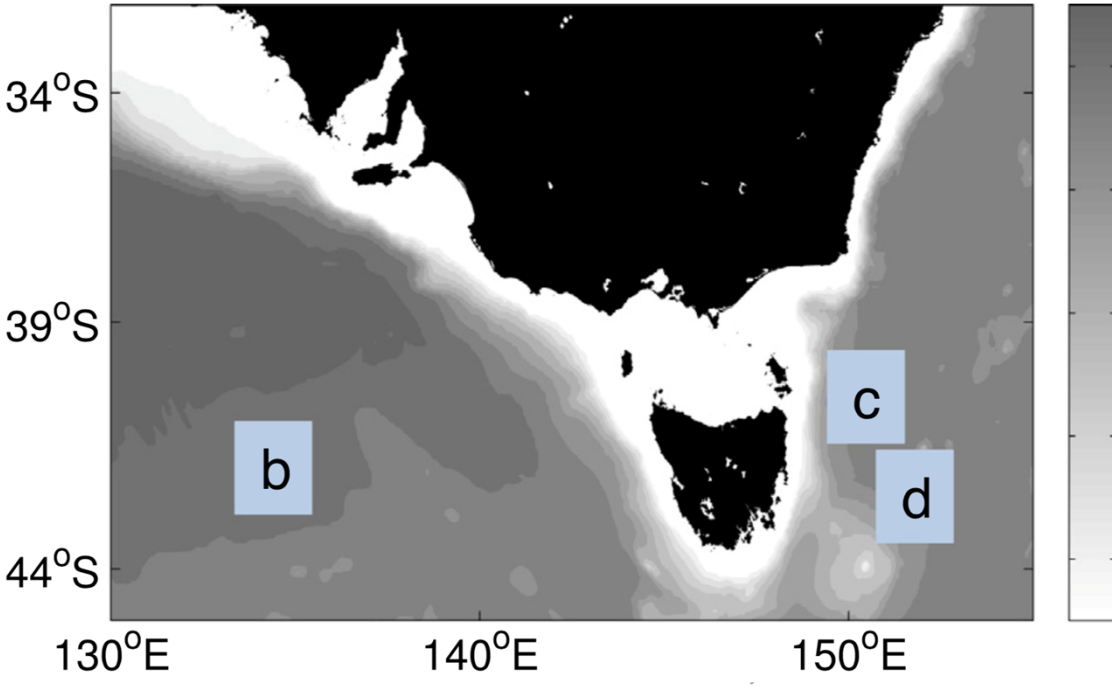
s it relevant for "short-window" DA?

ilo et al., Ocean Modelling (2018)

Sequential assimilation:

- Very few studies have assessed the integrity of the model's dynamical processes in a model run with DA.
- One way to gain insight into this issue is to look at behaviour of unobserved variable in the data-assimilating model
- Investigate vertical velocity field
  - pertinent to SWOT science
- Study of eddies in Tasman Sea





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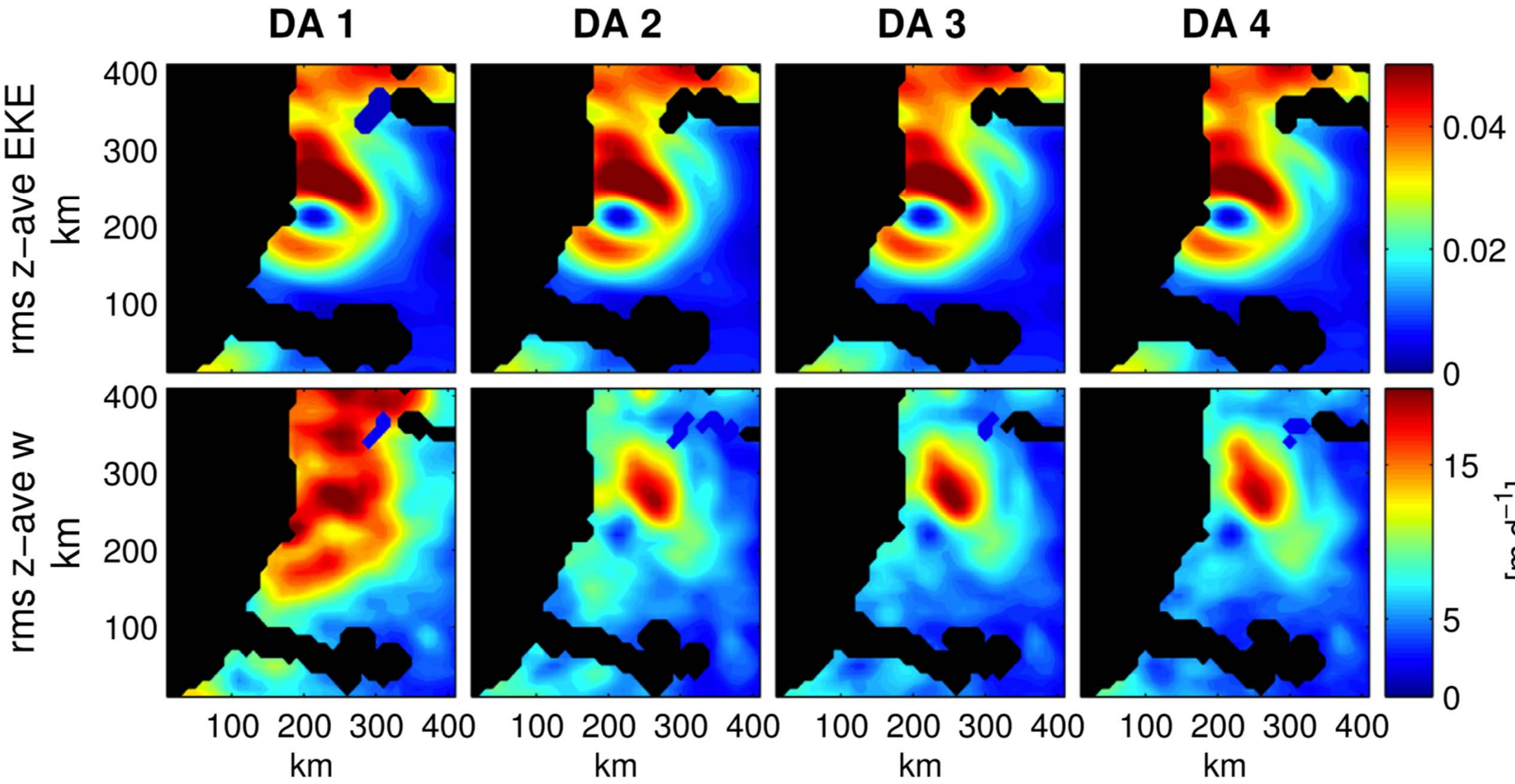
s it relevant for “short-window” DA?

Pilo et al., Ocean Modelling (2018)



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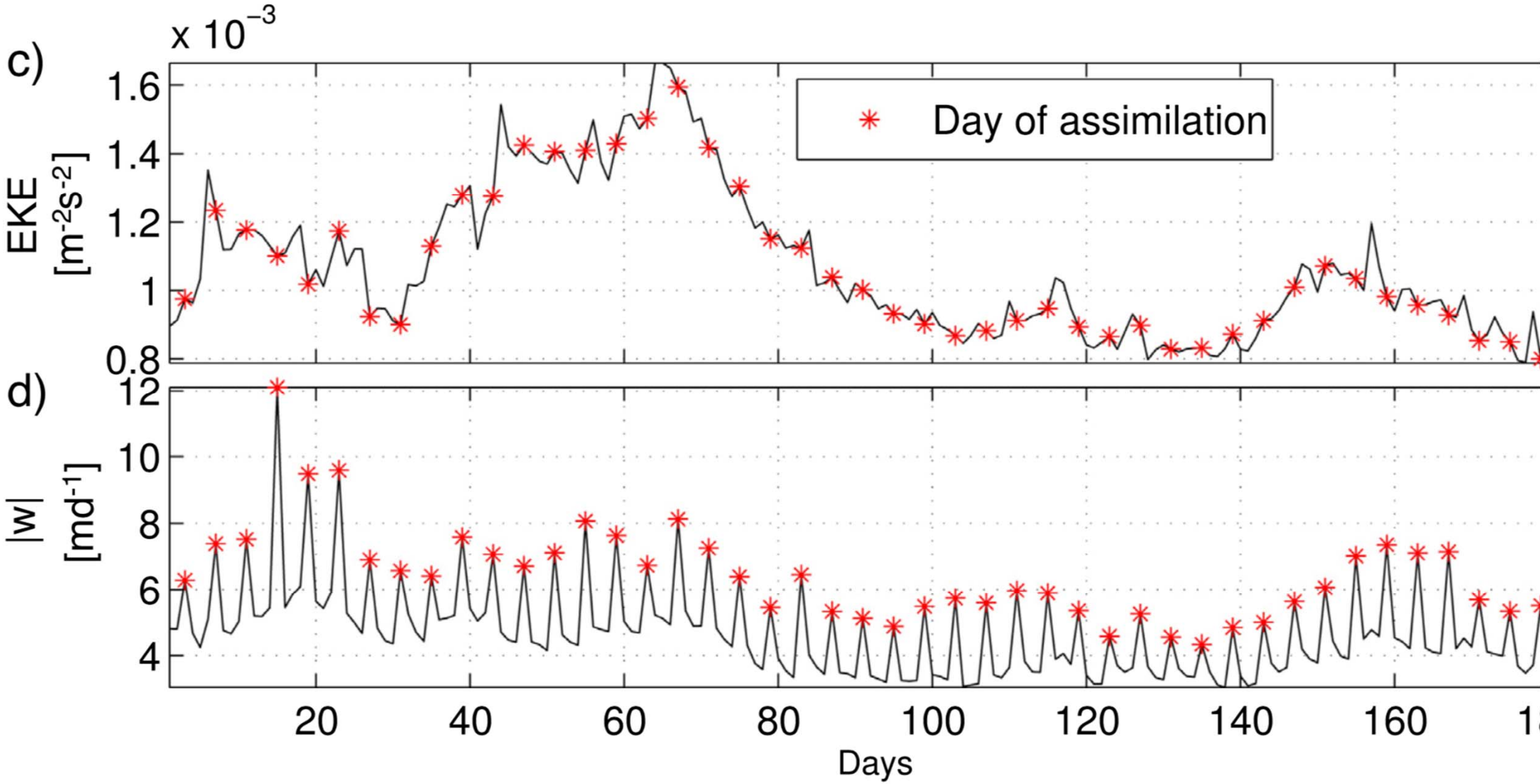

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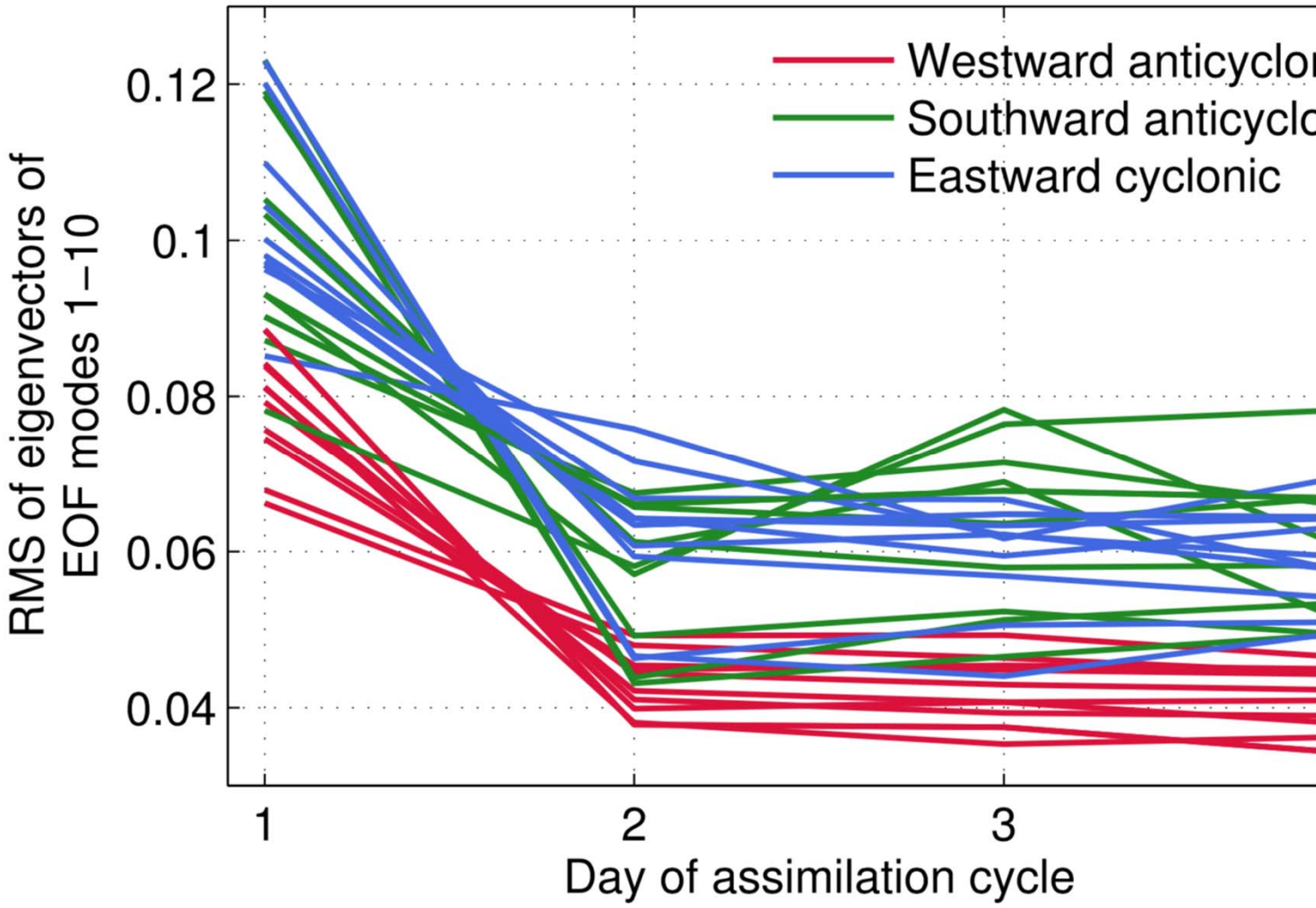

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s it relevant for "short-window" DA?

ilo et al., Ocean Modelling (2018) – Verbatim

- Analyses show that adjustment for vertical velocity is significa
- This also impacts *T* and *S* through vertical advection
- Vertical velocity appears to adjust within ~1 day
- Care should be taken when using vertical velocities "immediately" (i.e., one day) after assimilation
- Impact of artificial eddy distortion on the model's *T* and *S* fiel are typically smaller than the increments applied during the assimilation process itself
- Unfortunately, no analysis of magnitude of increments vs. tot tracer tendencies

hort vs. long-window 4D-Var

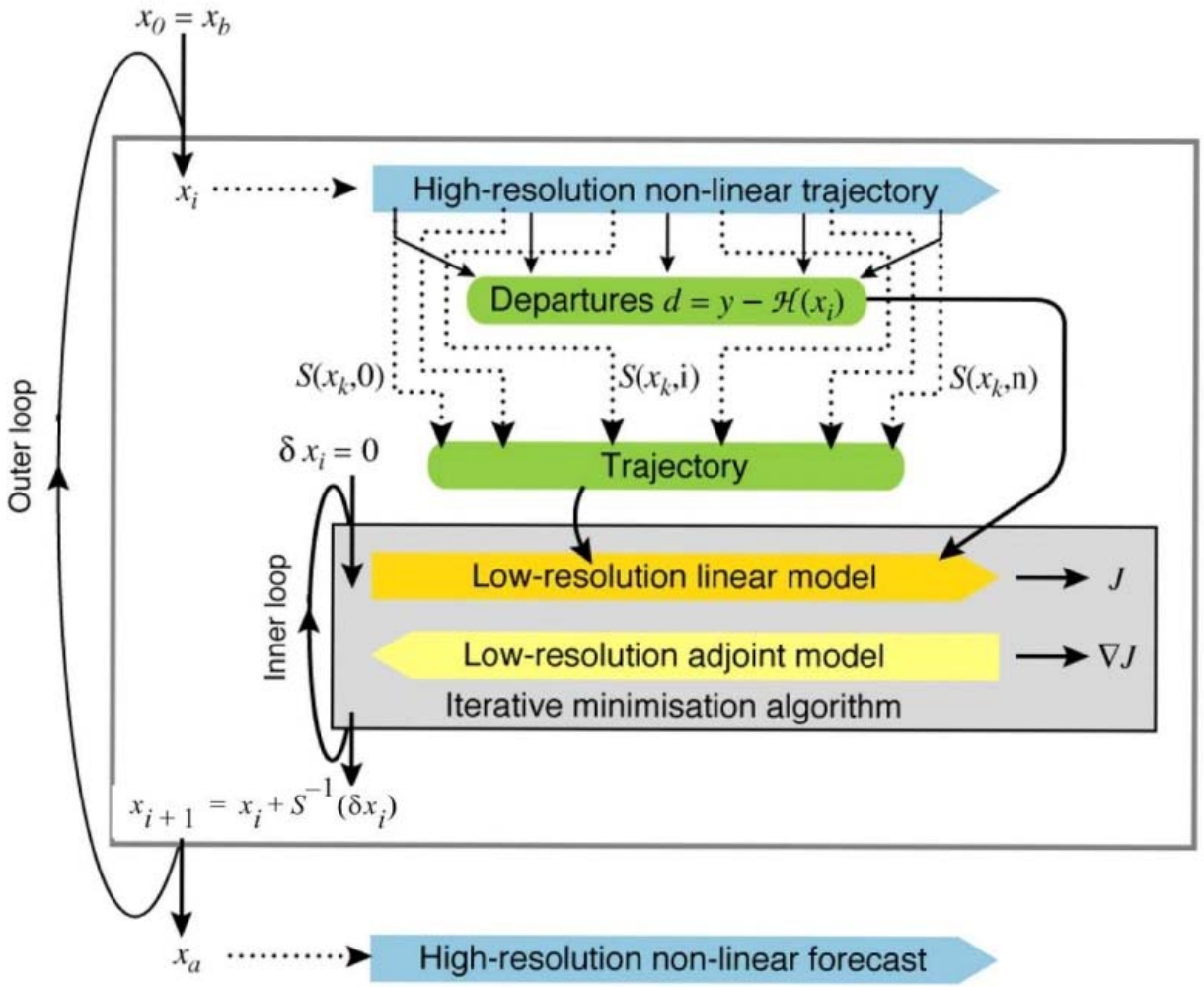
- We recognize that for assimilation at eddy-resolving scales we cannot just "plow on" using ECCO estimation (only one long assimilation window)

- Key change is to shorten assimilation window to stable length with increments between 4D-Var windows
  - preserve dynamics over several periods of the process of interest (synoptic or eddy turnover time scale)
  - Short-window 4D-Var, akin to ECMWF's "Incremental 4D-Va

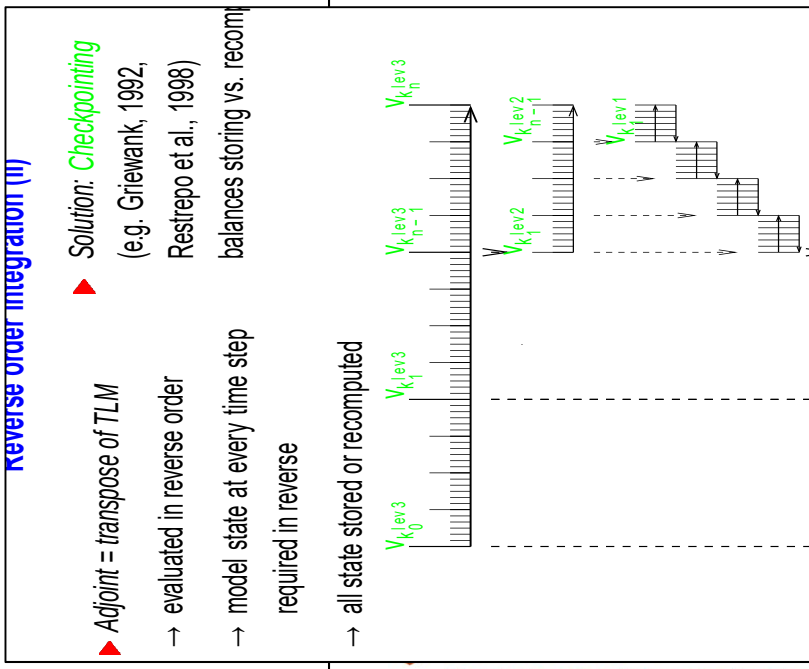
Mitigating approach for increasing assimilation window at high-res.:
Multi-grid (or multi-resolution) 4D-Var (practiced at ECMWF)

ECMWF

Chapter 2: 4D variational assimilation



Collaboration wi
M. Mazloff, A. Ve
… (SIO/UCSD)



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Conclusions

Evolving ocean state & parameter estimation to the SWOT era

- Hierarchy of subtropical North Atlantic simulations underway
- Feasibility of adjoint-based model parameter calibration
- Implementation & testing of 4D-Var
  - Synthetic SWOT data experiments
  - Use of existing/available elements of the GOOS
  - Can we develop "smart online filters" as part of the adjoint?
- Understand length of assimilation windows
- Test multi-grid 4D-Var (collaboration with SIO)
- Looking beyond the fast-repeat orbit period, our perspective is on tackling the global problem (with Brian Arbic)

"Looking at the data through the lens (physical) models"

onstitutive laws are empirical

- uncertain structure & parameters (and which may vary in 3+1-dimensions)

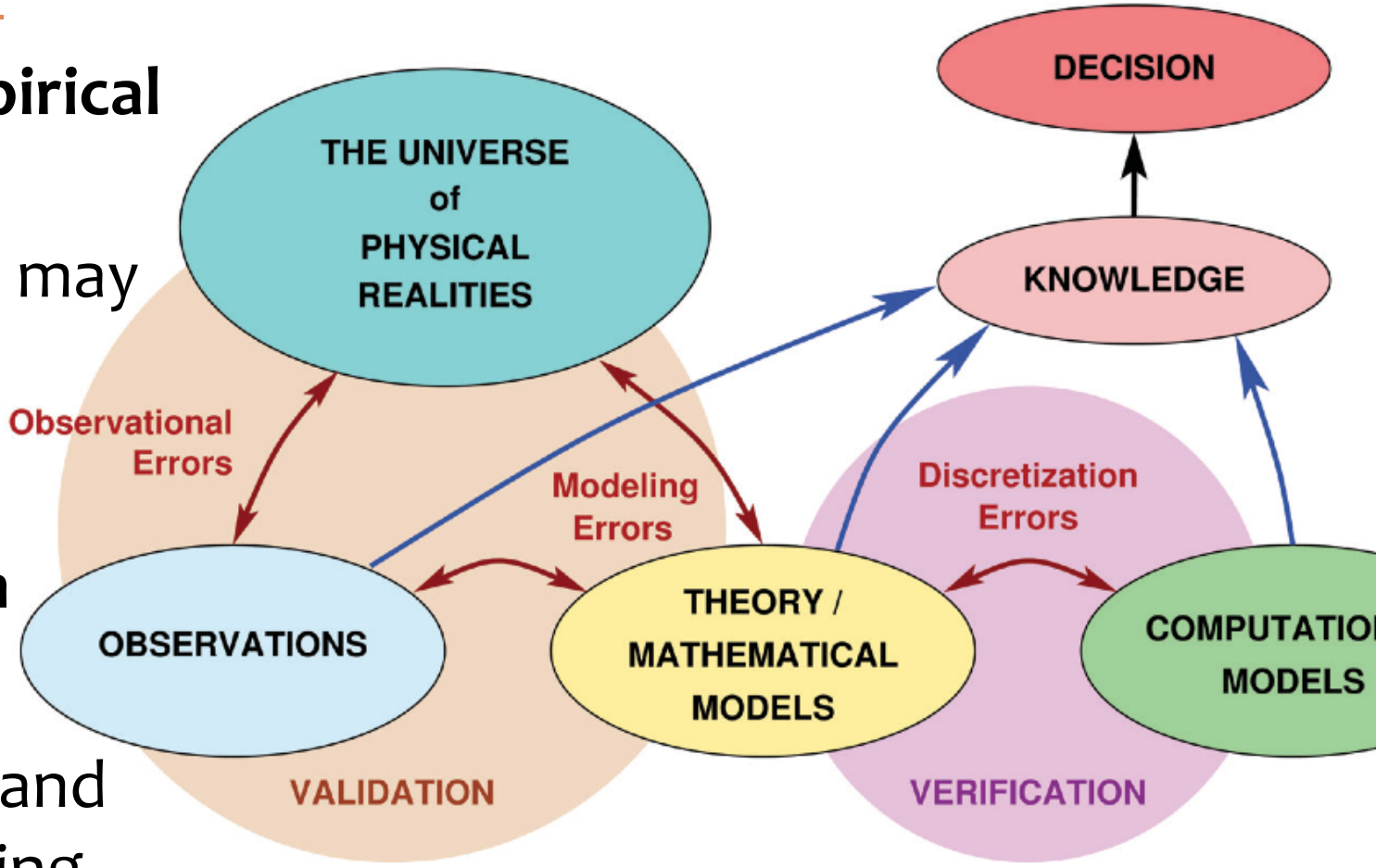
iscretization requires

umerical approximation

& parameterization

- e.g.: related to surface and bottom-intensified mixing

ncertain external forcings



Oden, Moser, Ghattas, SIAM News (2010)
Computer predictions with quantified uncertain