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Coupled Ocean-Acoustic Adjoint Sensitivity: Implications for Coupled DA

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Toulouse, FR, 18-21 October, 2016

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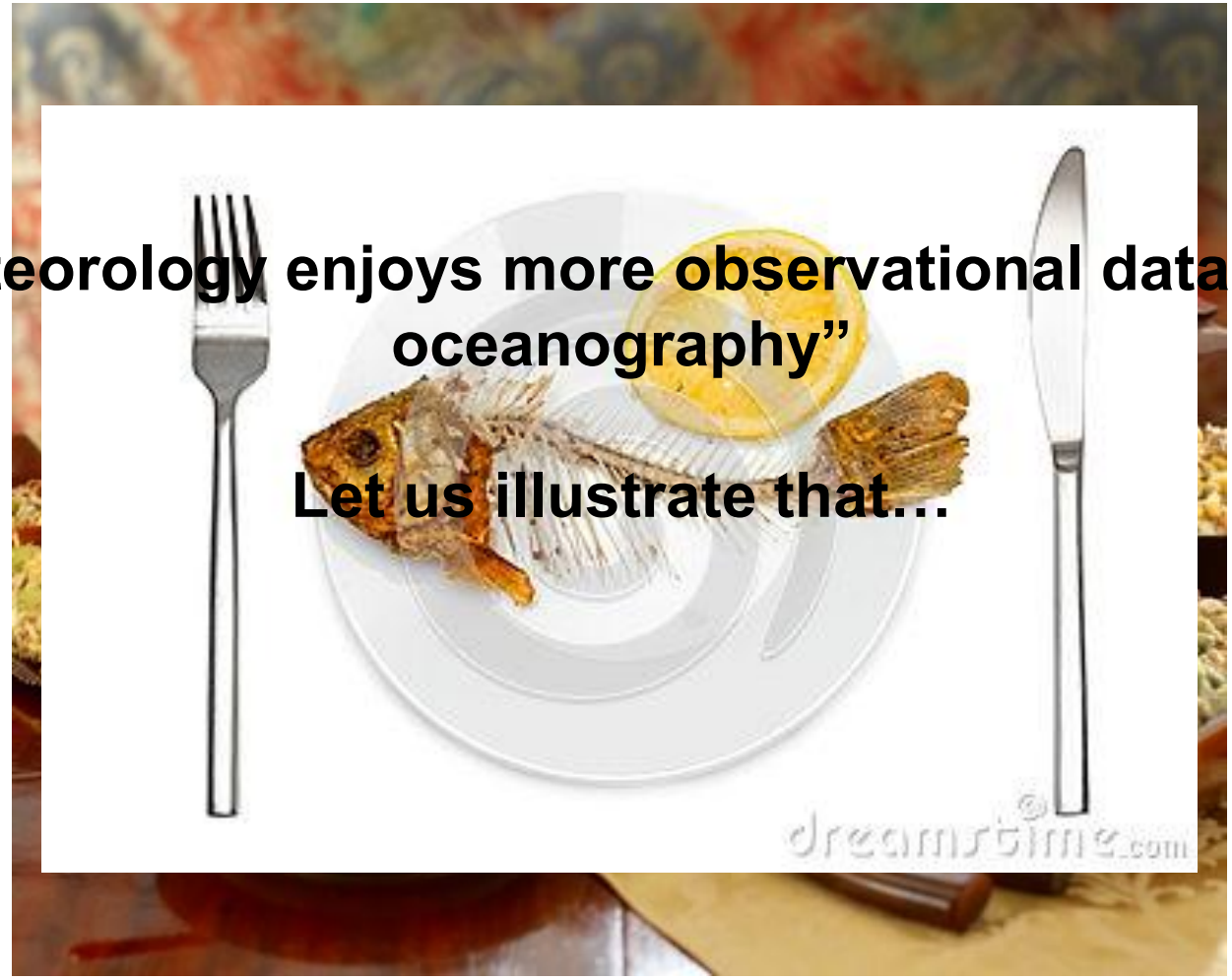
Presentation Overview

- Motivation and Background
- Introduction to Models and their DA Components
- Forward Model and DA Coupling Infrastructure
- Initial Coupled Adjoint Sensitivity Test
- Conclusions/Future Work

Motivation

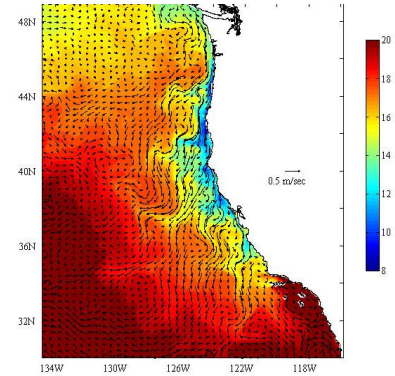
..Meteorological Observations..



Motivation & Approach

Ocean Model
Data Assimilation (DA) System
(variational method)

ocean analysis

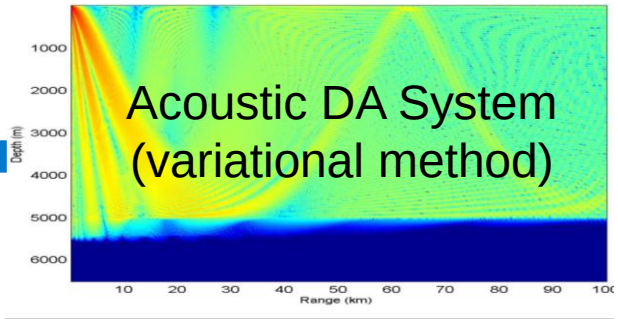


ocean observations
(*T*, *S*, *u*/*v*, *SSH*)

NO ACOUSTIC OBS

NO FEEDBACK OF T/S ADJUSTMENTS TO OCEAN MODEL

acoustic analysis



acoustic pressure observation

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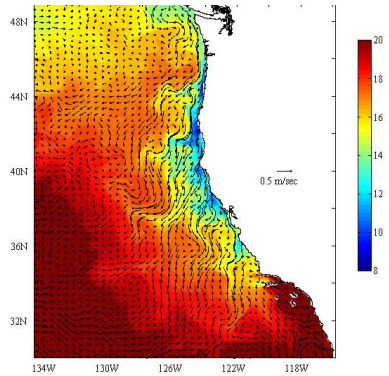
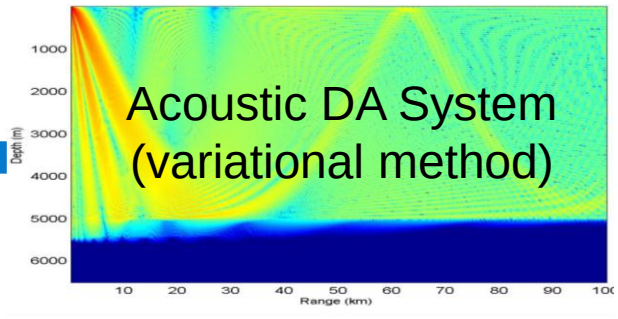


ocean analysis

ocean observations
(*T*, *S*, *u*/*v*, *SSH*)

couple data assimilation systems for ocean and acoustic models



acoustic analysis

acoustic pressure observation

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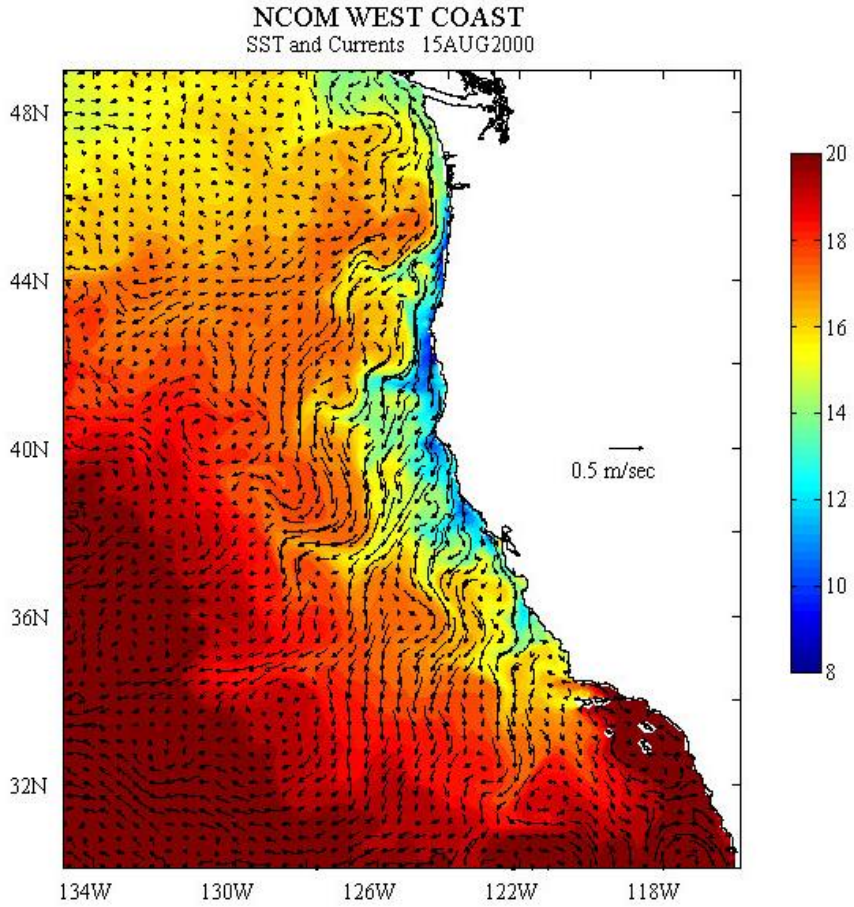
Ocean Model

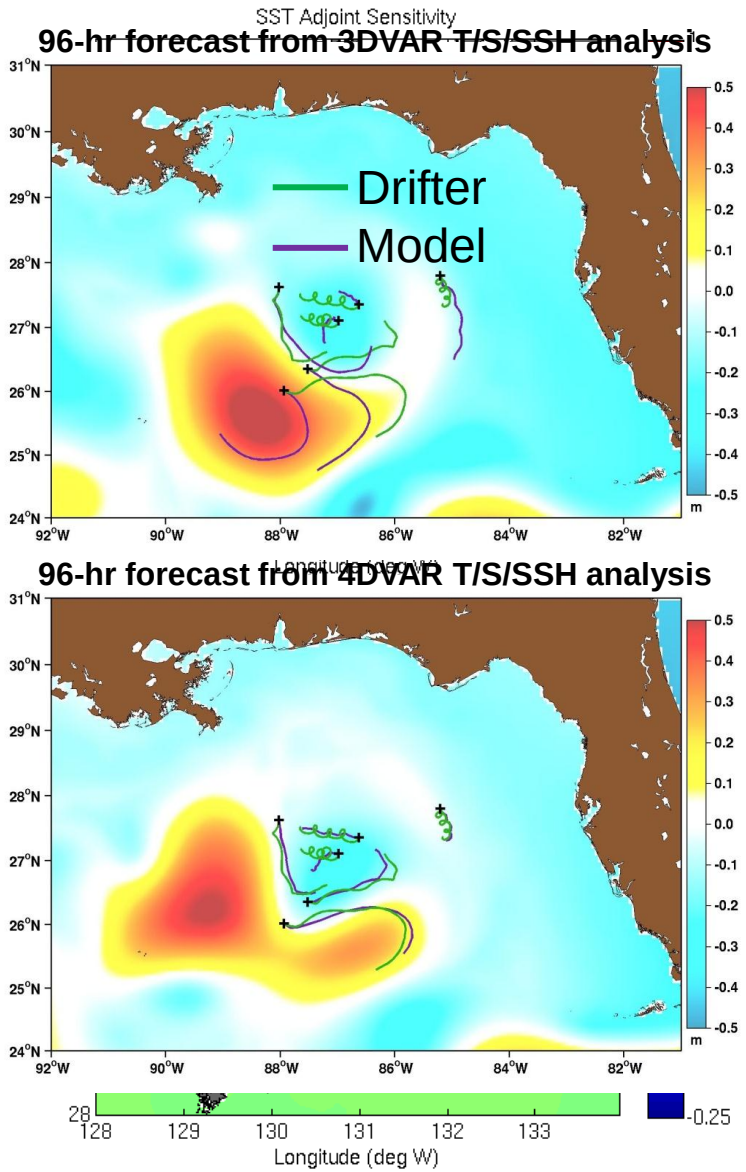
- Navy Coastal Ocean Model (NCOM; Martin 2000)
  - Currently Navy's operational regional model
  - Uses Arakawa-C grid (horizontal) and sigma-Z grid (vertical)
  - Computes time-evolution of 3D fields of **temperature**, **salinity**, ocean **velocity**, and **sea surface height**



Ocean Model (DA Component)

NCOM-4DVAR
(Ngodock & Carrier, 2014)

- Based on in-direct representer method for 4DVAR
- Weak-constraint capable
- Adjoint (AD) and Tangent Linear (TL) models based on dynamical core of NCOM
- Currently in transition to operations at the Navy's Oceanographic Office



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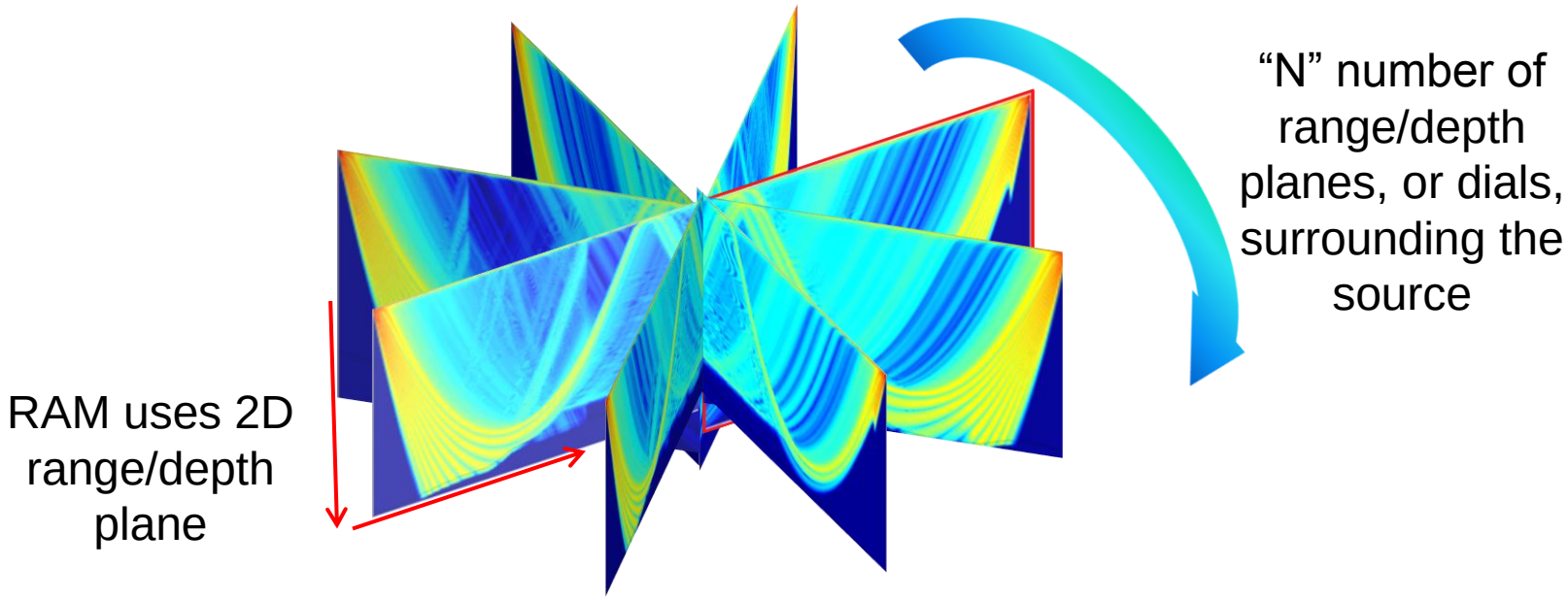
Acoustic Model

- Range-dependent Acoustic Model (RAM; Collins 1994)
  - Navy's operational acoustic propagation model
  - Simulates acoustic pressure along 2D range/depth plane from environmental inputs (sound speed), source location/depth/frequency

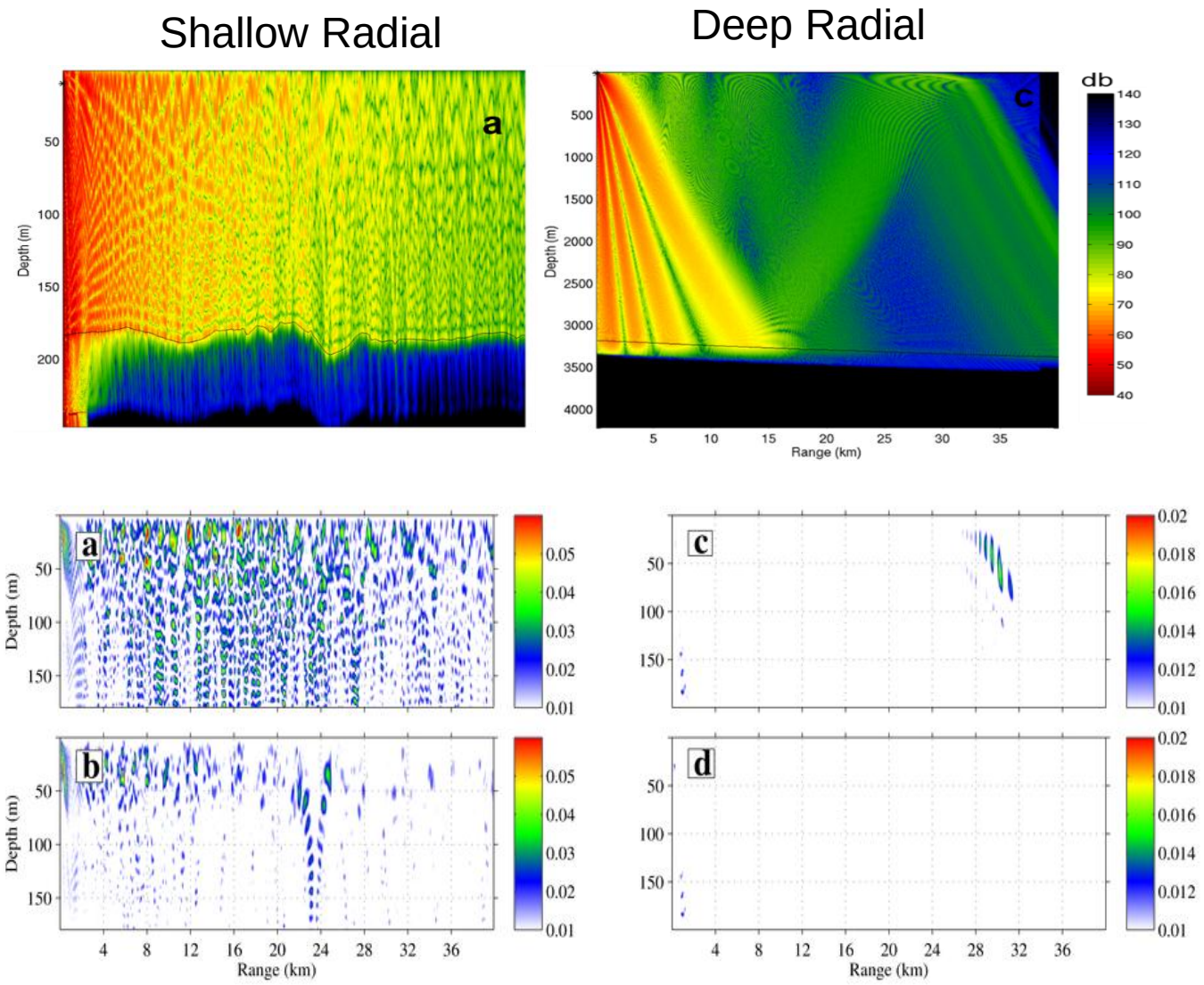


Acoustic Model (DA Component)

RAM-VAR

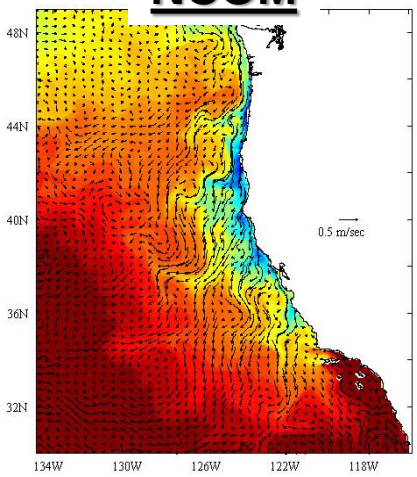
(Ngodock et al, 2016)

- Weak-constraint capable
- AD and TL models based on RAM forward operator
- Assimilates observations of acoustic pressure

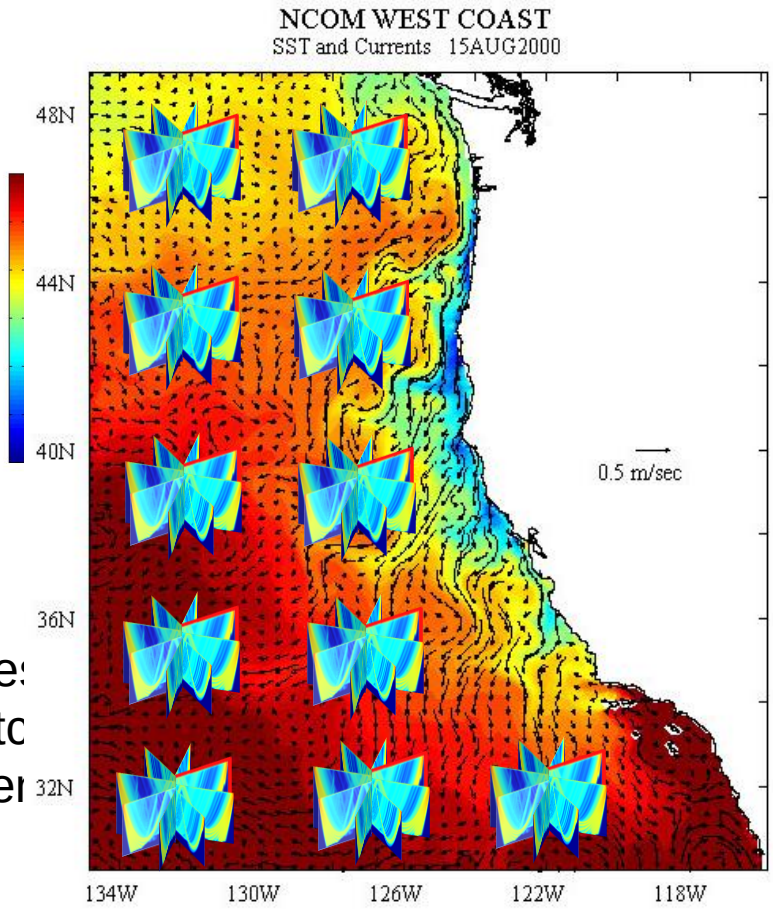


Methodology (Forward Coupling)

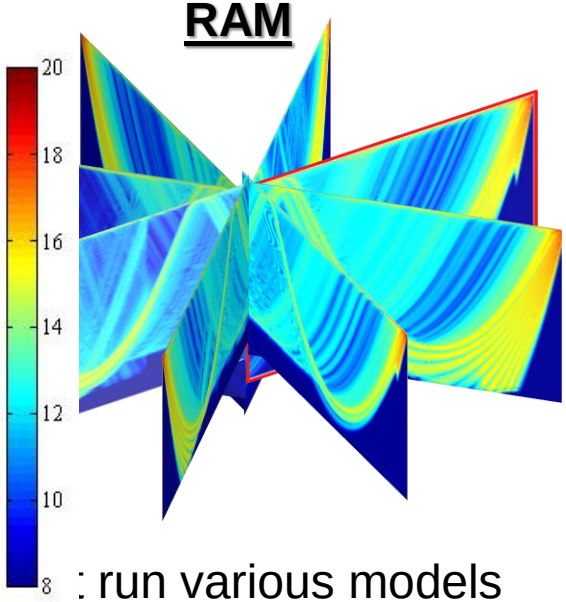
NCOM



COAMPS5 is a serie
(NCOM, SWAN, etc
running environme



RAM



: run various models
nodels in an active
nework, or ESMF)

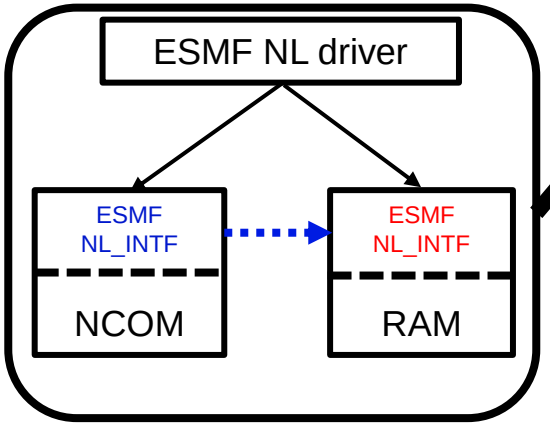
BENEFIT

The acoustic model can be run anywhere in the NCOM domain, at any time, for any acoustic frequency, and as often as needed by the operational modelers

Methodology (DA Coupling)

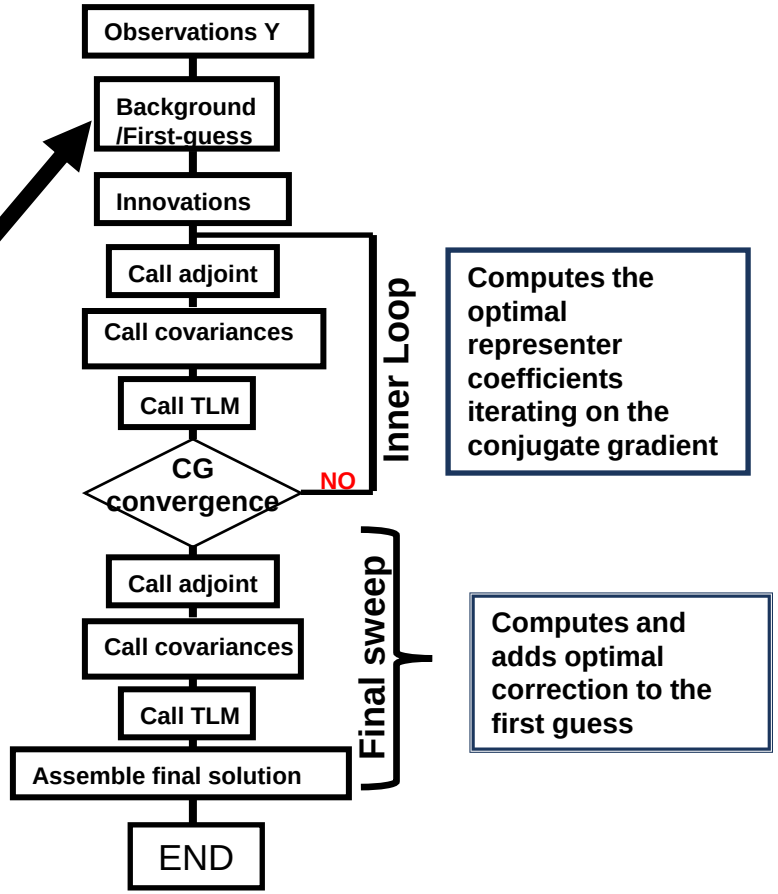
Building the coupled NCOM-RAM 4DVAR

$$\hat{u}(x,t) = u_F(x,t) + \sum_{m=1}^{M} \hat{\beta}_m r_m(x,t)$$



Forward models are coupled

Communication is one-way (RAM acts as a variable transform for ocean fields)



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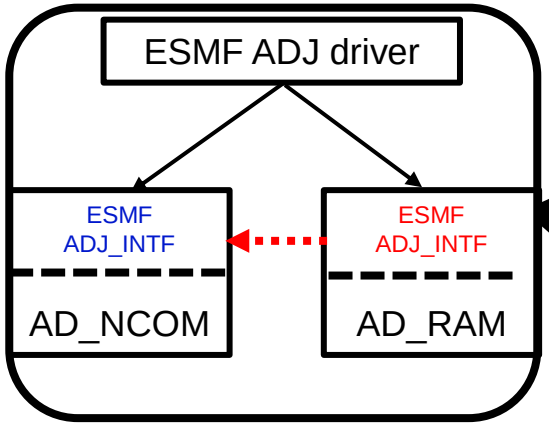
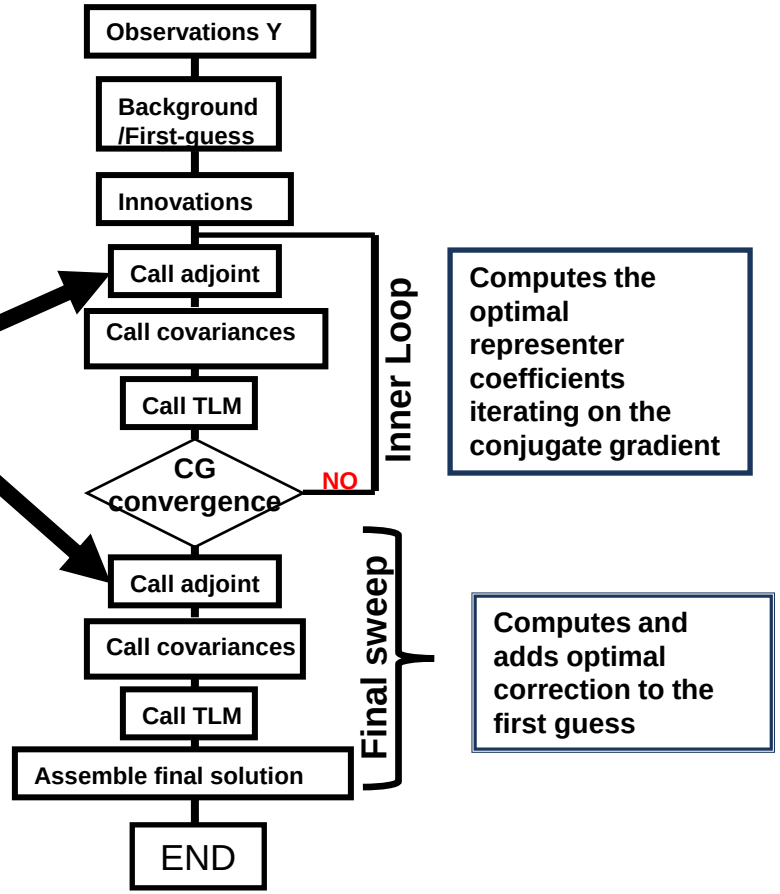


Adjoint models are coupled

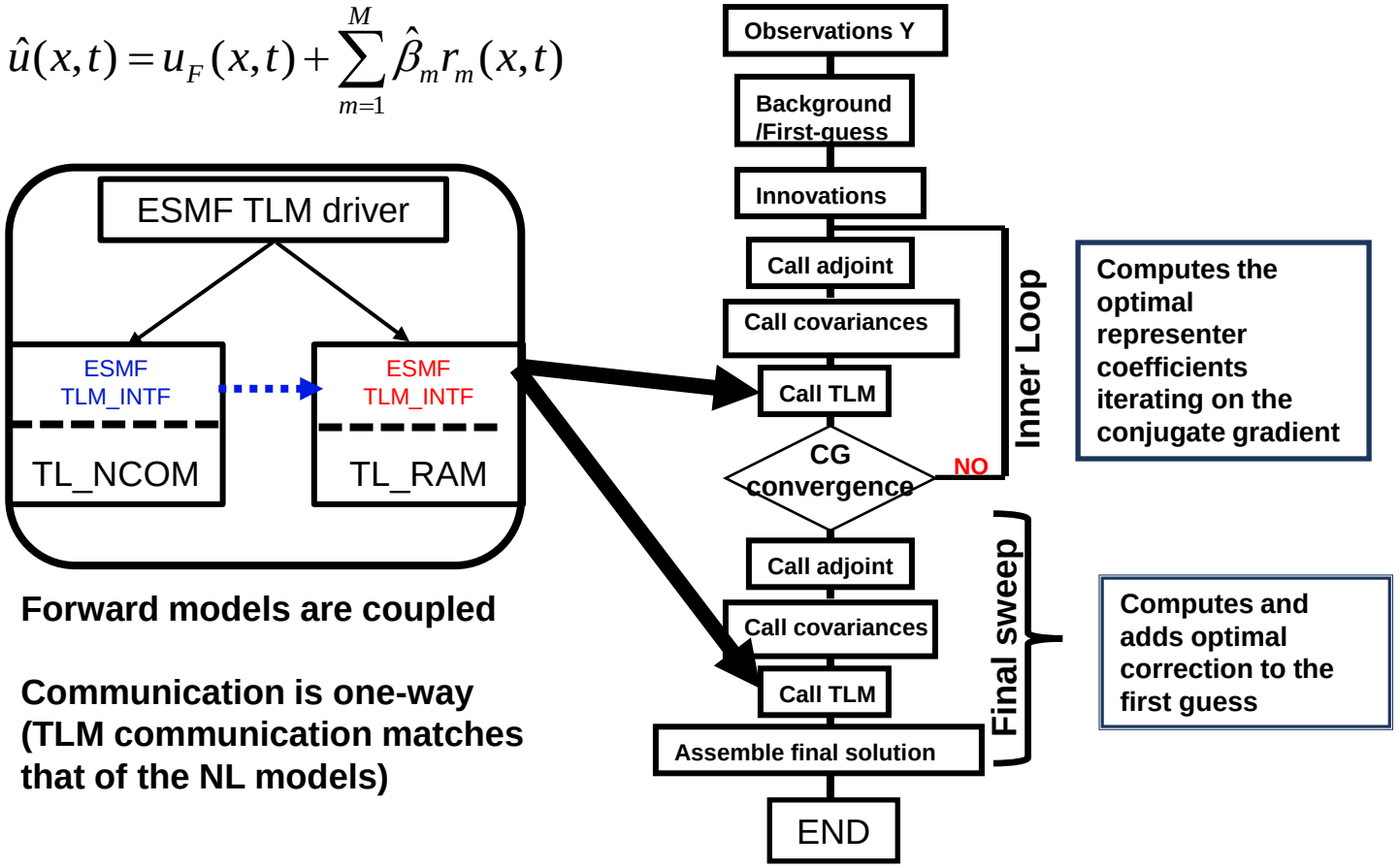
Communication is one-way (adjoint communication is reversed; adjoint updates to T/S are passed from RAM to NCOM)



Methodology (DA Coupling)

Building the coupled NCOM-RAM 4DVAR

$$\hat{u}(x,t) = u_F(x,t) + \sum_{m=1}^{M} \hat{\beta}_m r_m(x,t)$$



Forward models are coupled

Communication is one-way (TLM communication matches that of the NL models)

Adjoint Sensitivity Results (Along Plane)

Examine adjoint sensitivity of acoustic pressure to

Sound Speed

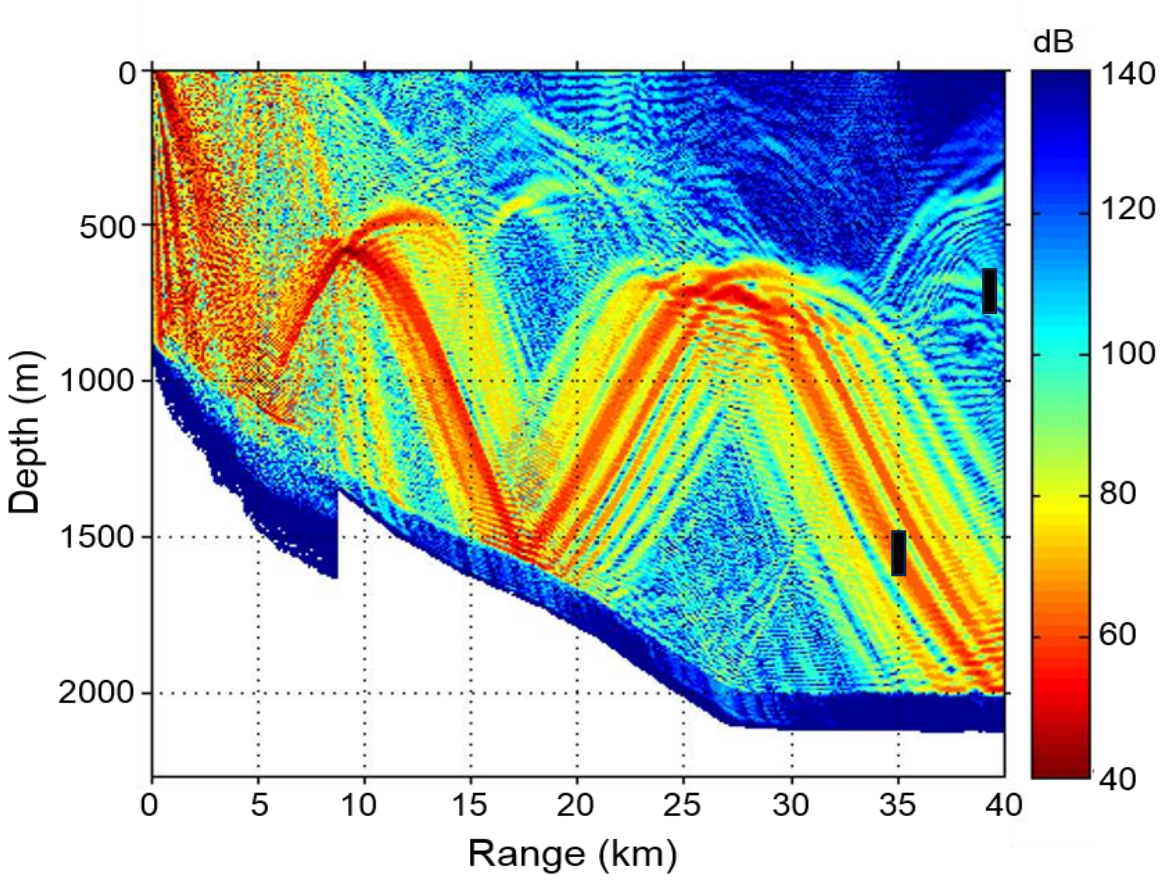
Temperature

Salinity

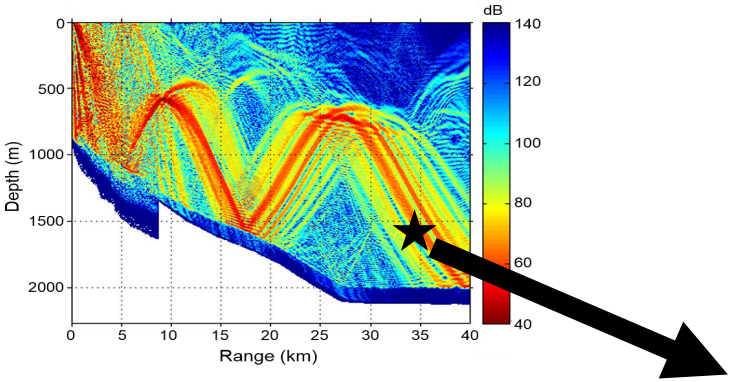
Along the 2D range depth plane

(300 Hz, source at 10 m depth)

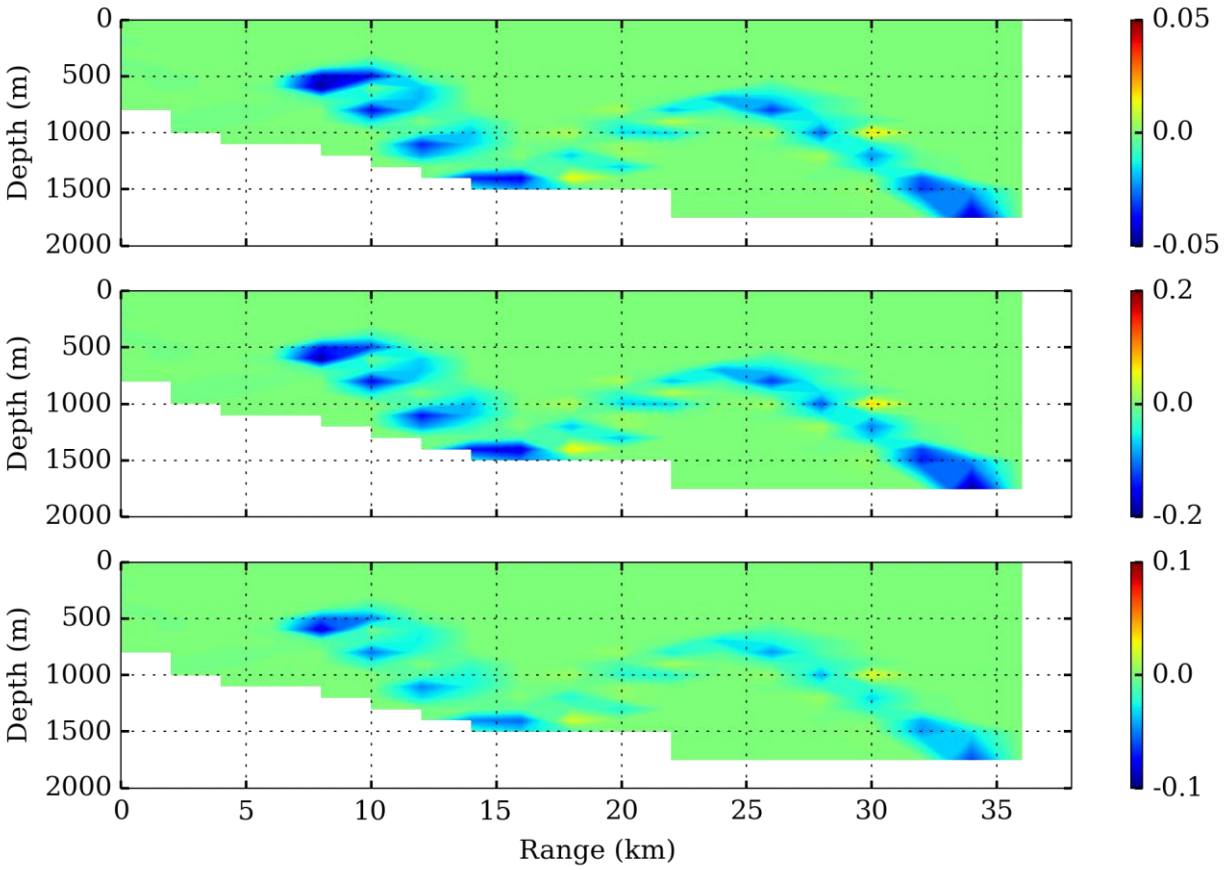
Range plane near Kuroshio current



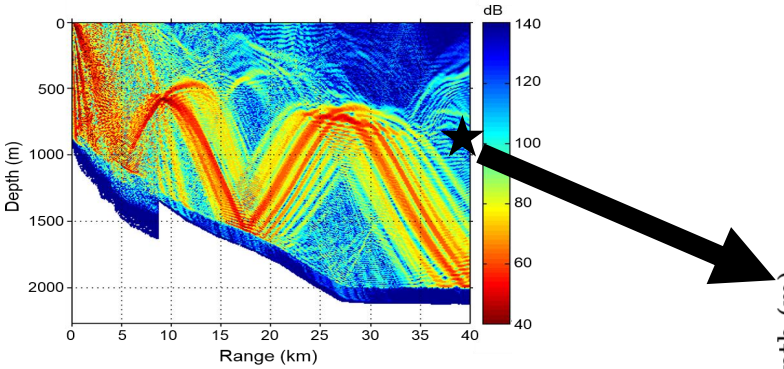
Adjoint Sensitivity Results (Along Plane)



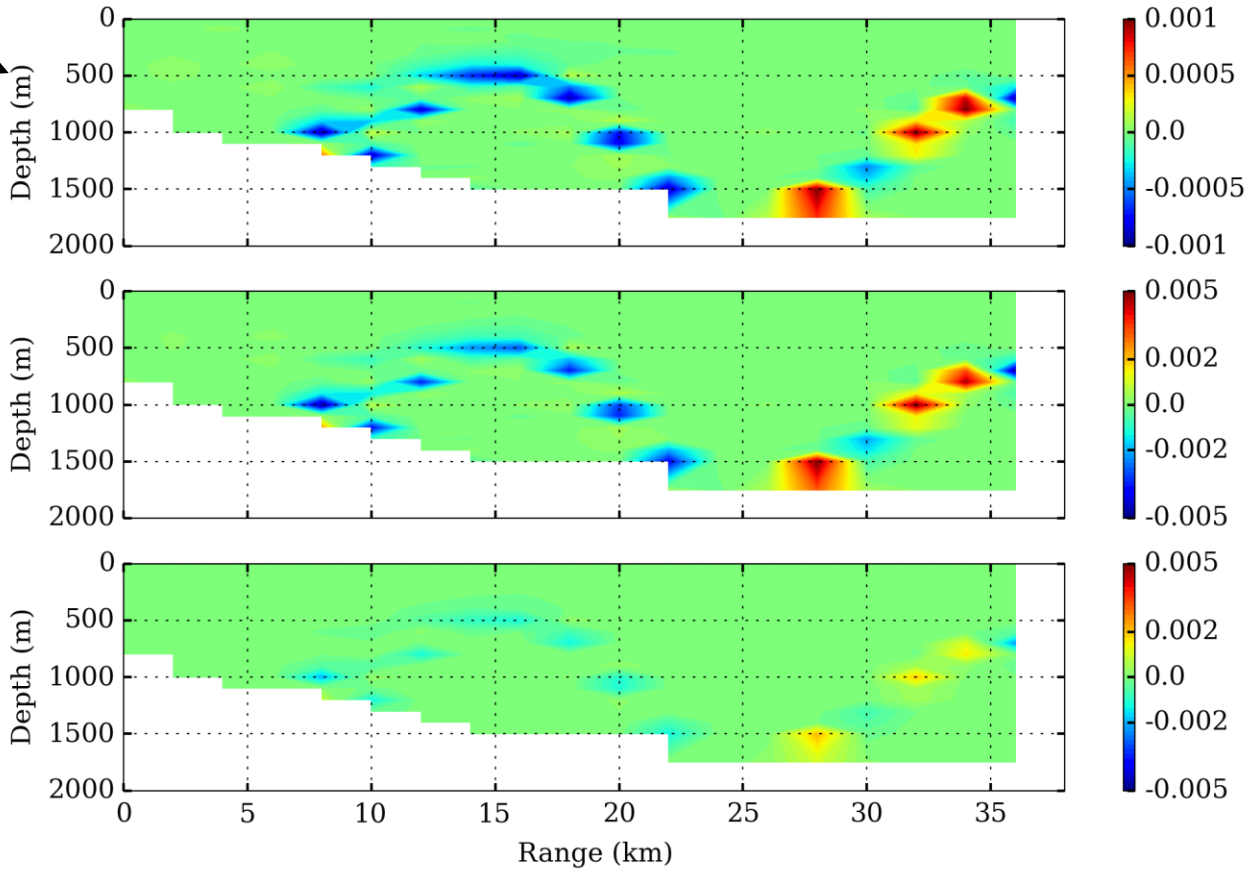
Examine adjoint sensitivity of acoustic pressure at 35 km range 1500-1600 m depth



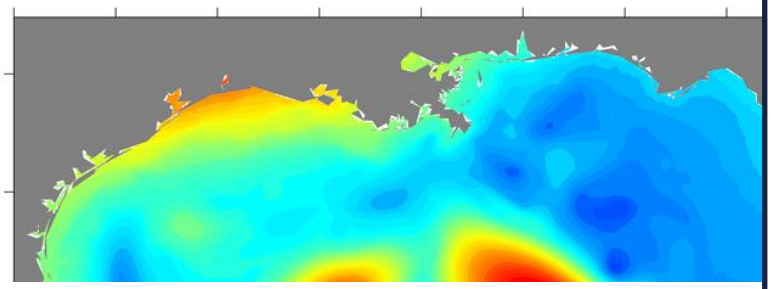
Adjoint Sensitivity Results (Along Plane)

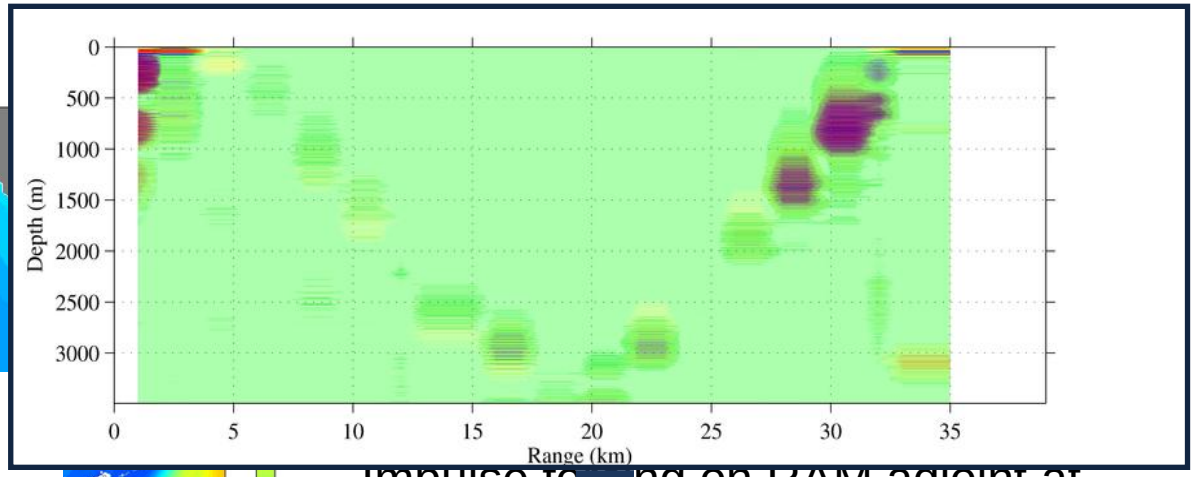


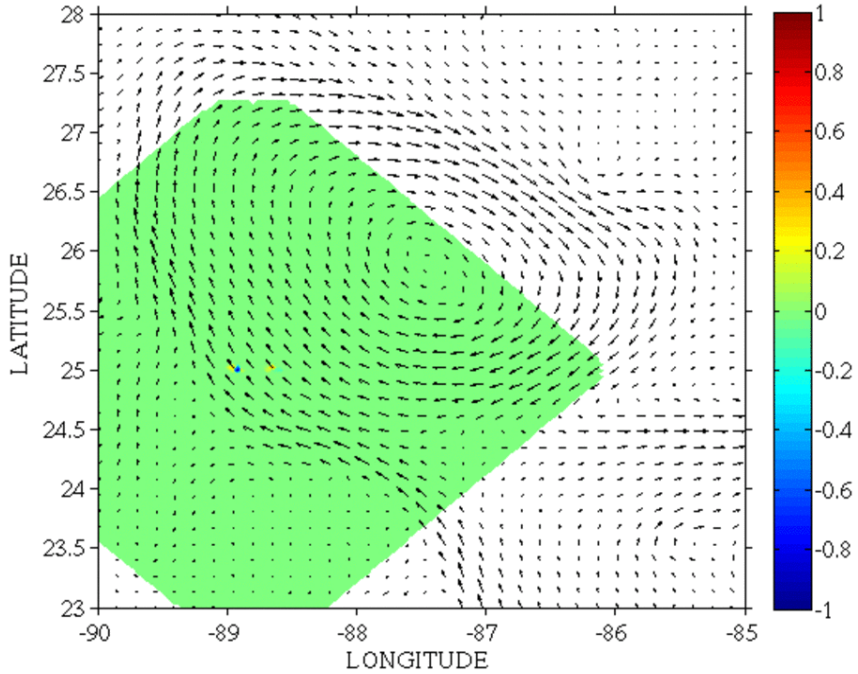
Examine adjoint sensitivity of acoustic pressure at 38 km range 650-750 m depth

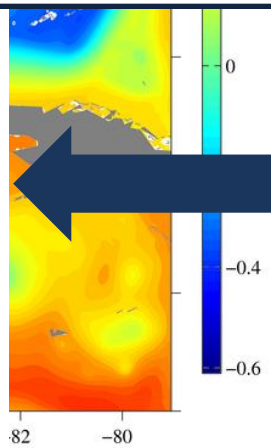


Feedback to Ocean Adjoint









Impulse fo ng on RAM adjoint at 35 km eve 2.5 m from 10 m to 50 m depth

NCOM adjoint run from 16 June to 6 June, 2015

Adjoint sensitivity can be used in adaptive sampling to improve forecast accuracy

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Implications for Ocean DA

- Location of acoustic pressure observations are vital
  - If located within waveguide, acoustic pressure sensitivity to sound speed (and, thus, T/S) is high
- Coupling to ocean adjoint spreads information in 4D, beyond acoustic range/depth plane
  - Acoustic sensitivity can be used for adaptive sampling (acoustic and T/S)
- Acoustic pressure is non-unique
  - Many combinations of T/S will produce same acoustic signature
  - Constrained minimization should help