Ocean Acoustic Tomography in Fram Strait: Past Paths and Future Directions

Brian Dushaw — NERSC

1. Sound speed as a proxy variable for temperature.
   ** B. D. Dushaw, H. Sagen, and A. Beszczynska-Möller, Computation of temperature from tomographic estimates of sound speed in Fram Strait (JASA).*

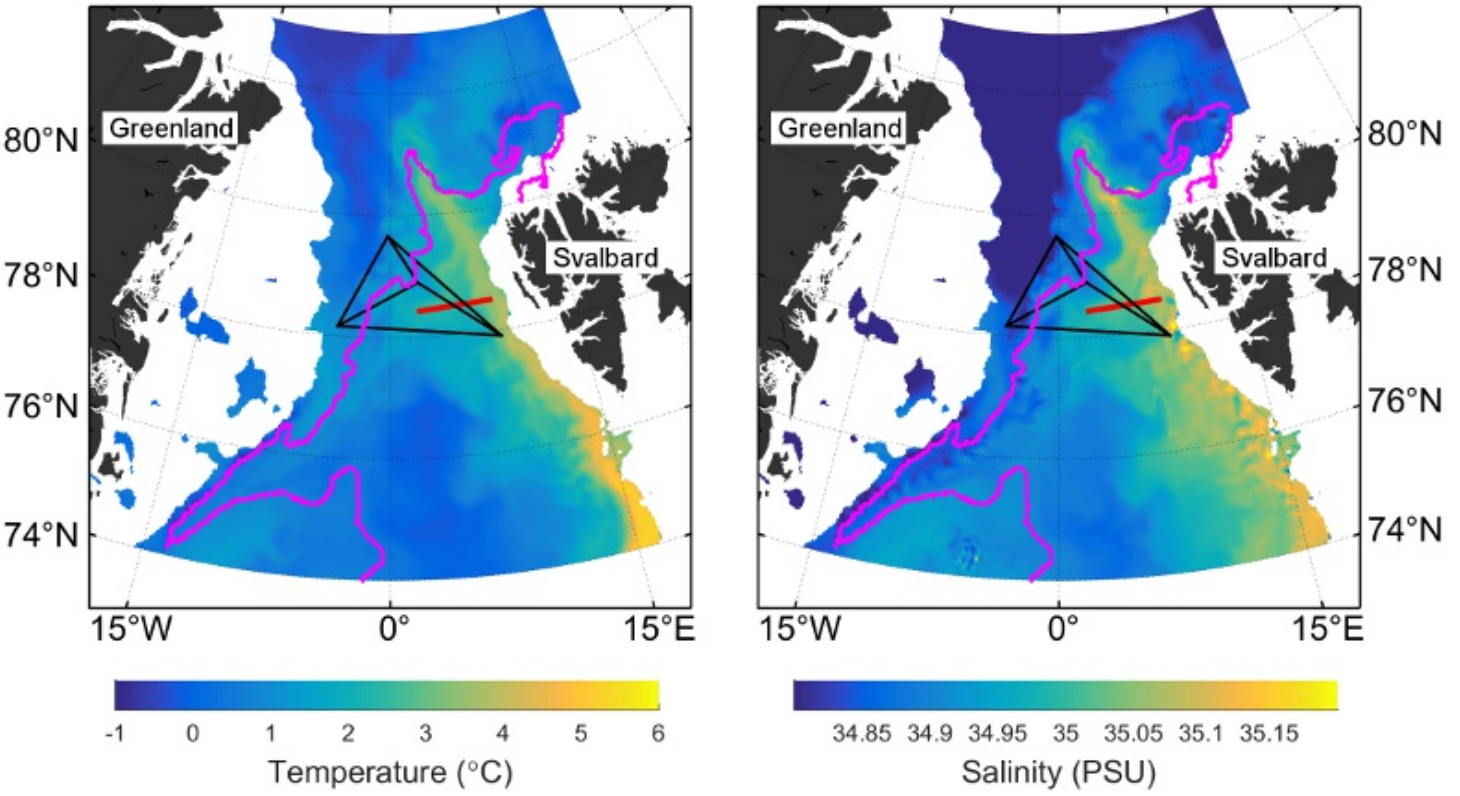
2. Internal waves and mesoscale effects on acoustic propagation: The tomography forward problem.
   ** B. D. Dushaw, H. Sagen, and A. Beszczynska-Möller, A study of the effects of internal waves and mesoscale variability of sound speed on acoustic propagation in Fram Strait: The tomography forward problem (JASA).*

3. A study of moored/point and acoustic tomography/integral observations of Fram Strait by objective maps.
   ** B. D. Dushaw, and H. Sagen, A comparative study of the properties of moored/point and acoustic tomography/integral observations of Fram Strait using objective mapping techniques (JTECH).*

4. Time series of temperature in Fram Strait from 2008-9 DAMOCLES tomography.
   ** H. Sagen, B. D. Dushaw, E. K. Skarsoulis, D. Dumont, M. Dzieciuch, and A. Beszczynska-Möller, Determining time series of temperature in Fram Strait from the 2008-2009 DAMOCLES tomography measurements (JGR)*

5. 2011-2012 ACOBAR, UNDERICE, and Future Directions

Fram Strait Model (HYCOM) T, S - 300 m Depth

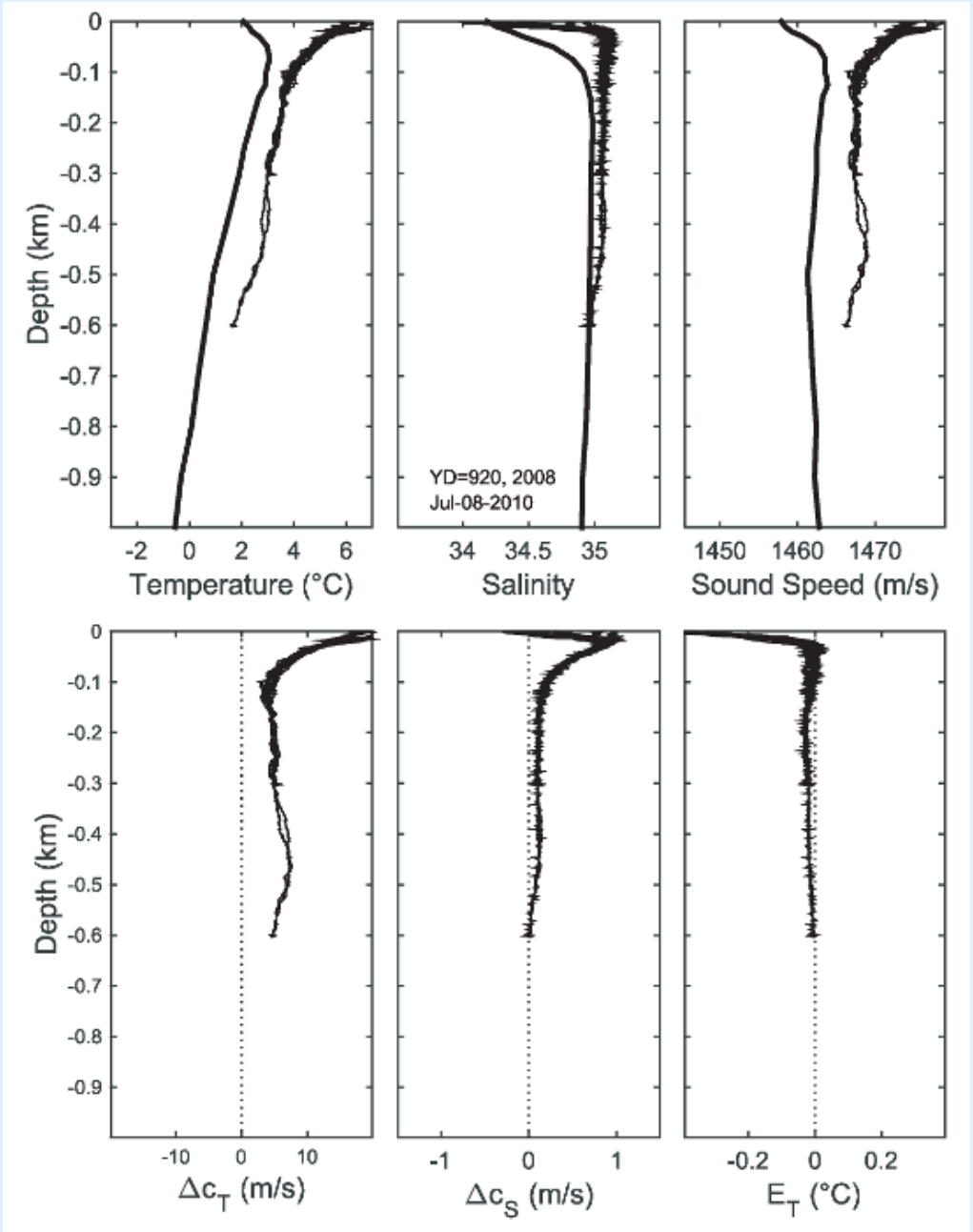


Red: DAMOCLES Black: ACOBAR

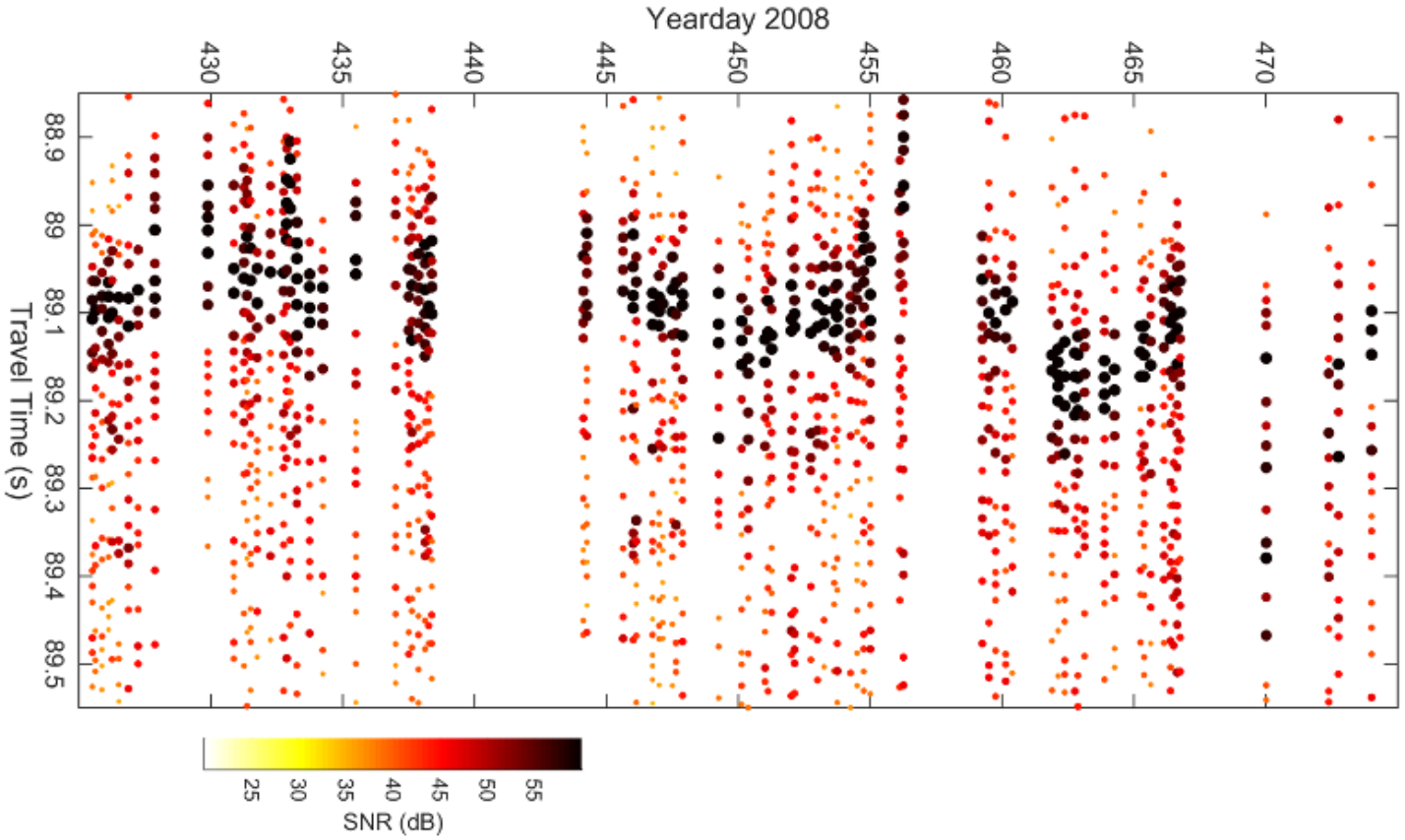
26 March 2008 - Magenta line is ice edge.

ECCO FR4320 1-km Global Simulation

T, S and Sound Speed: The Glider Story



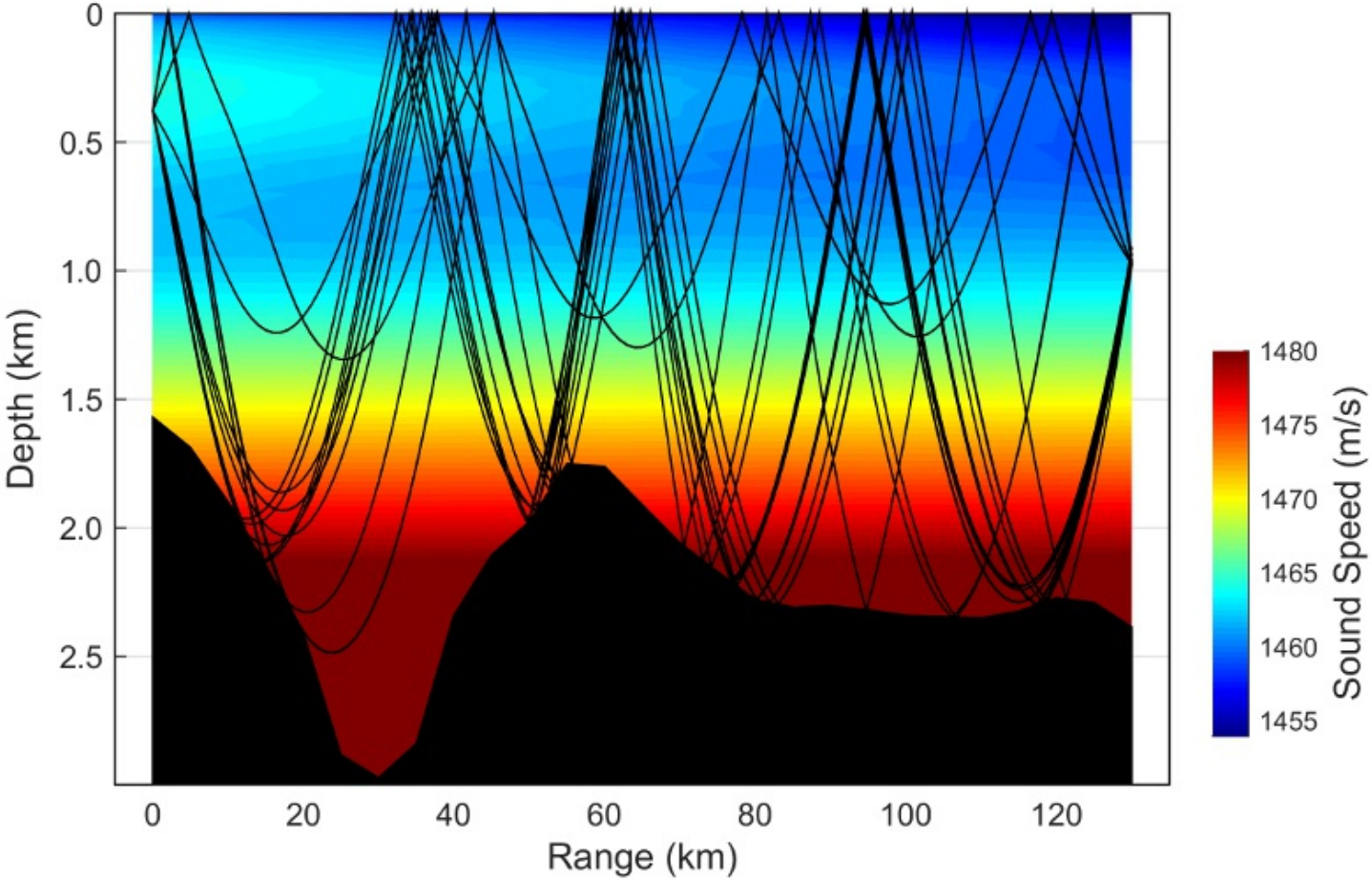
DAMOCLES: Dot Plot – Section of Yearlong Record



Data more complicated than anticipated; no clear ray arrivals.
Scattering effects of small mesoscale (4-10 km).

Weekly fluctuations from large mesoscale.

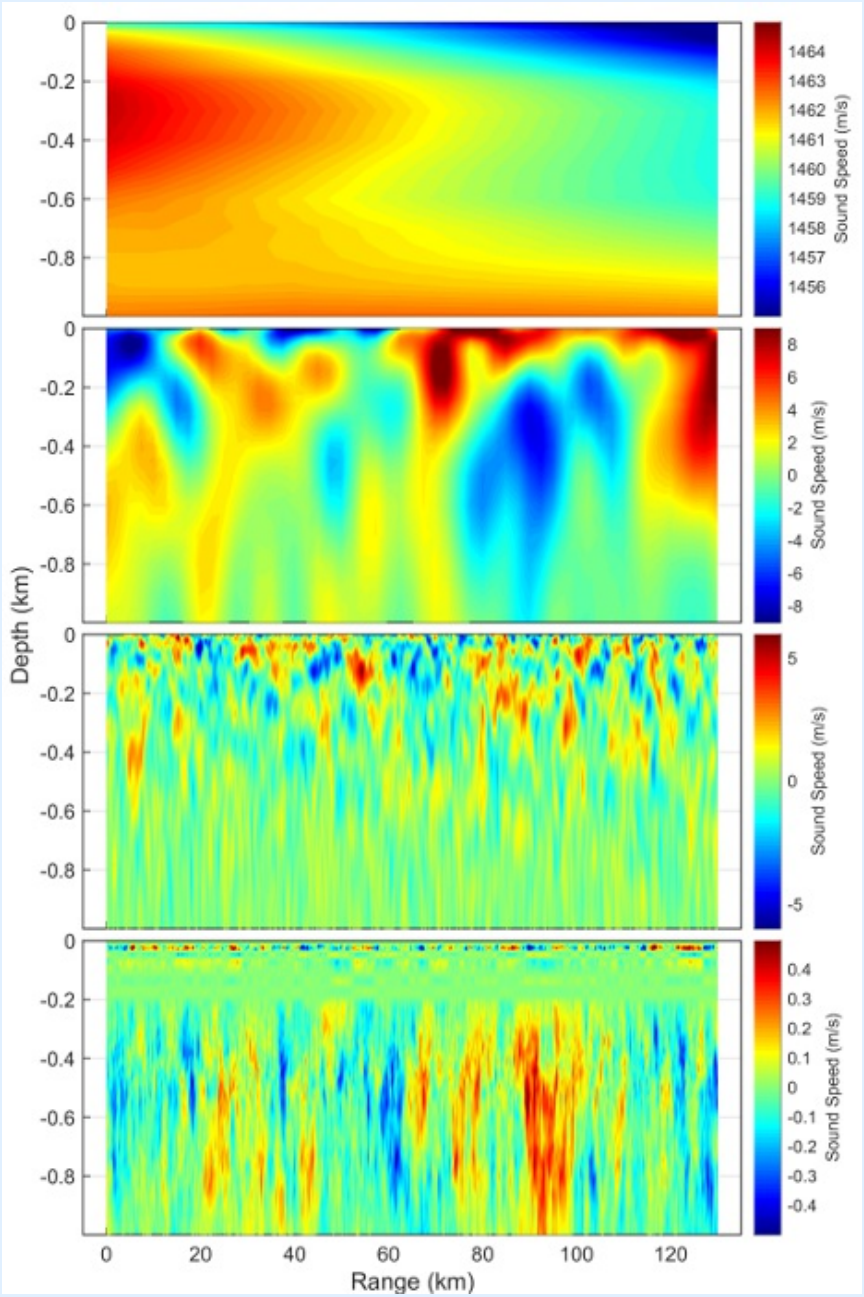
DAMOCLES: WOA'09 Rays



Only two rays are RSR; they give main arrival.

Ignore bottom reflections.

WOA'09, Mesoscale 1, Mesoscale 2, Internal Waves — A Simulation



World Ocean Atlas

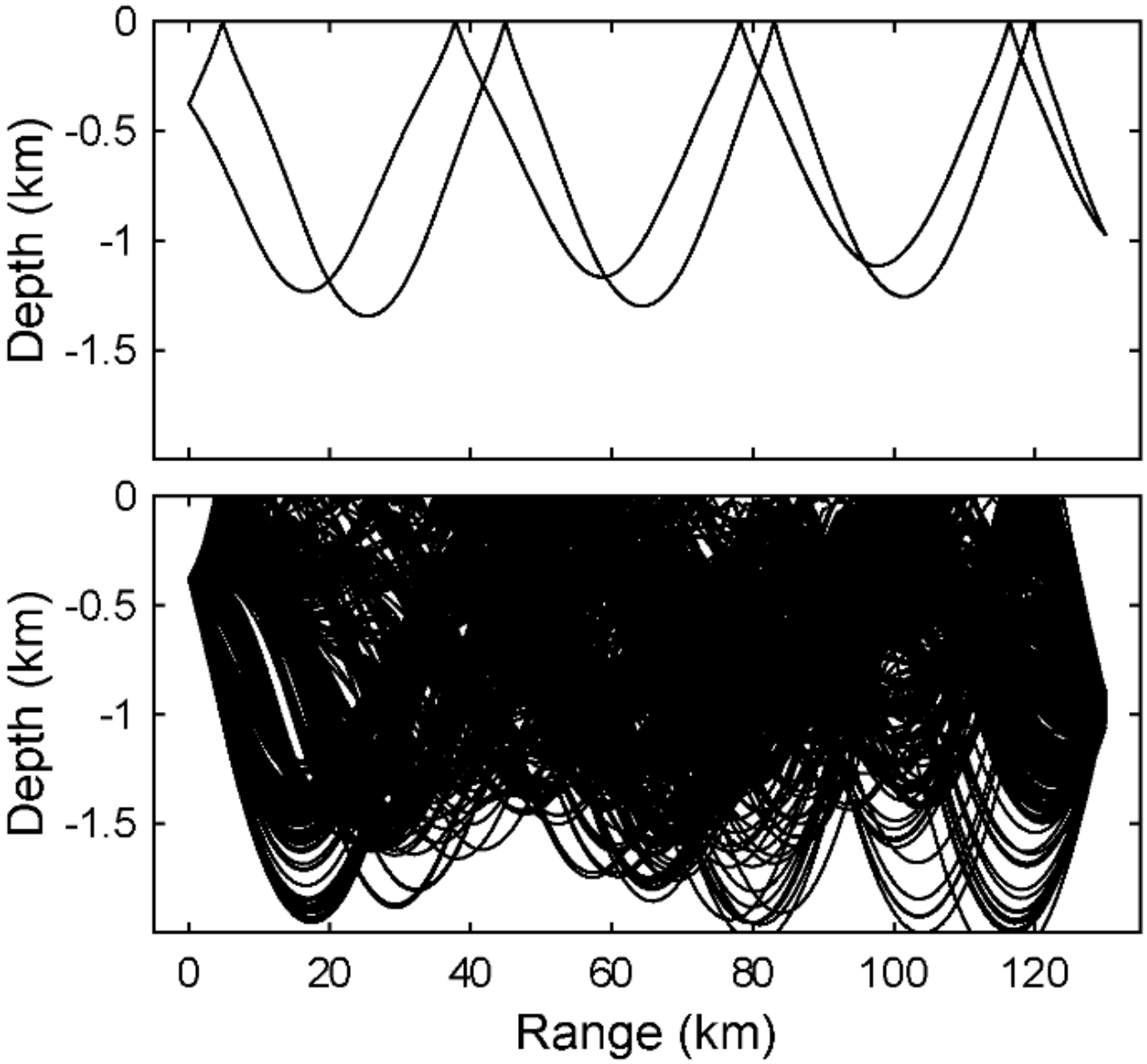
Large Mesoscale

Small Mesoscale

(Recall 4-10 km Rossby radius of deformation)

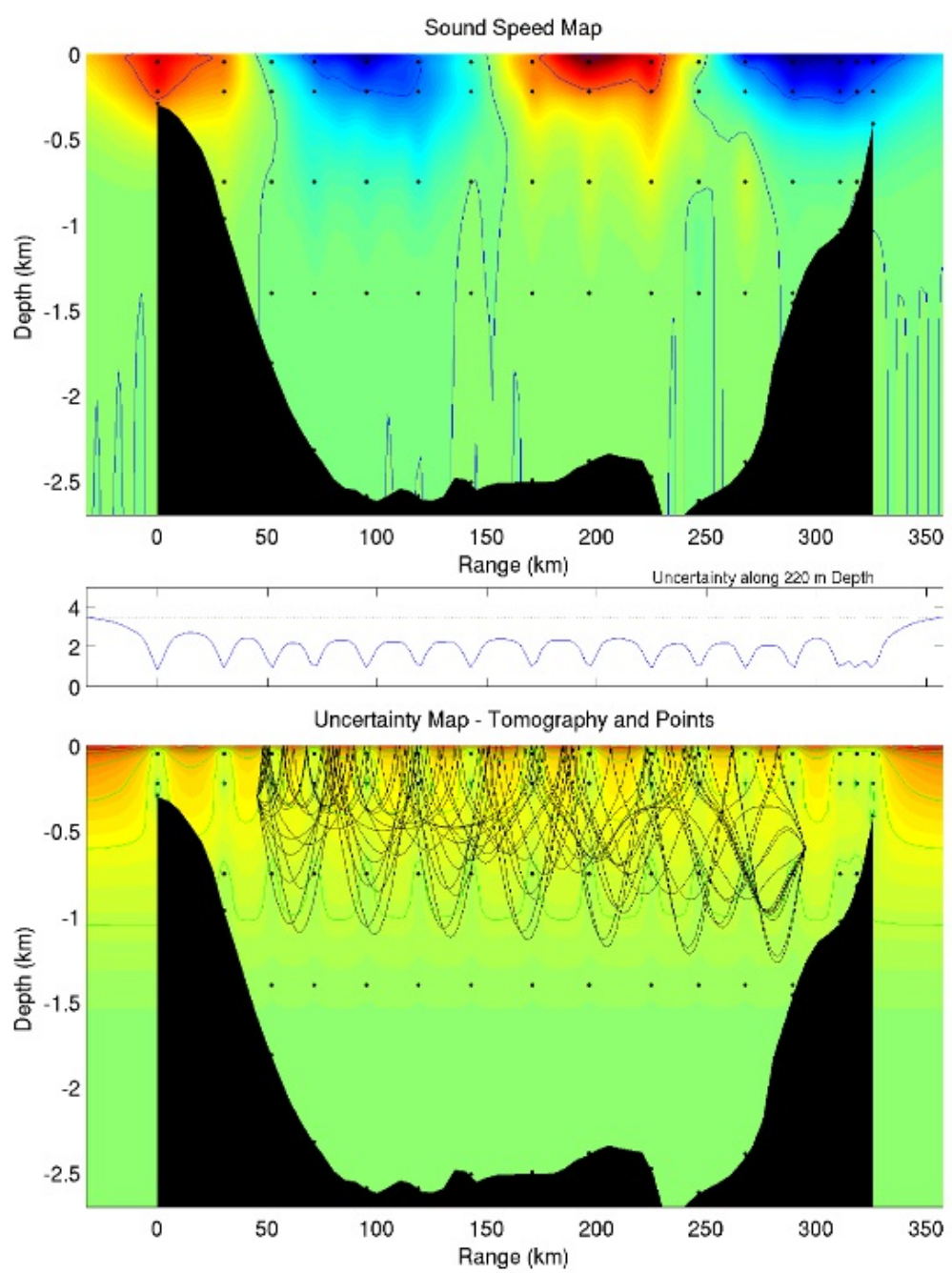
Internal Waves (Weak)

Acoustic Scattering by Small-Scale Scintillations



The "small mesoscale" scintilations generate a multitude of eigenrays.
A breakdown of geometric rays.

Estimate and Uncertainty: Points and Rays, Realistic Wavelengths

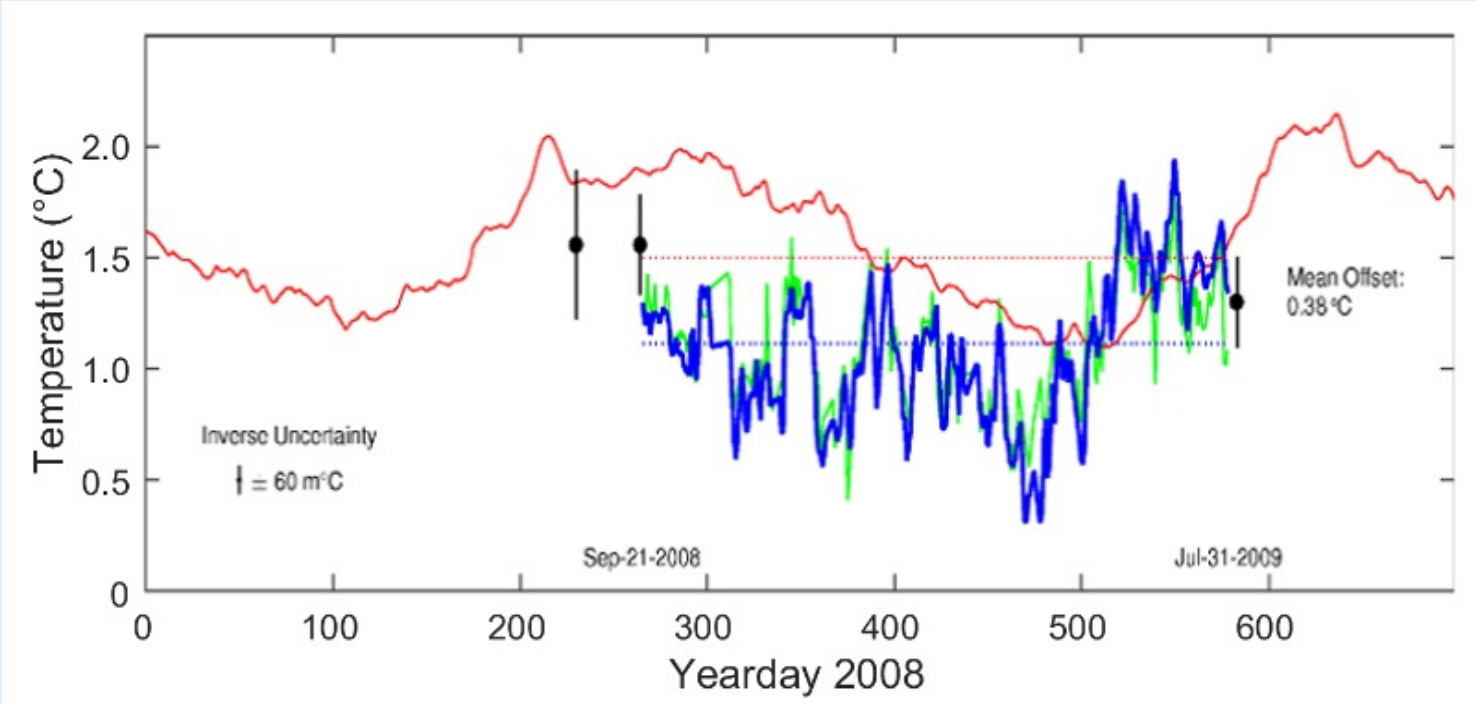


Uncertainties for the Mean: 0–1000 m Depth Average

True Average	$-0.39\ \mathrm{m\ s^{-1}}$
No Data	0.00 ± 1.03
Point Array Only	-0.56 ± 0.29
Tomography Only	-0.40 ± 0.19
Both Data Types	-0.39 ± 0.08
Hydrographic Section	-0.31 ± 0.16

N.B.: The main action is the uncertainties!

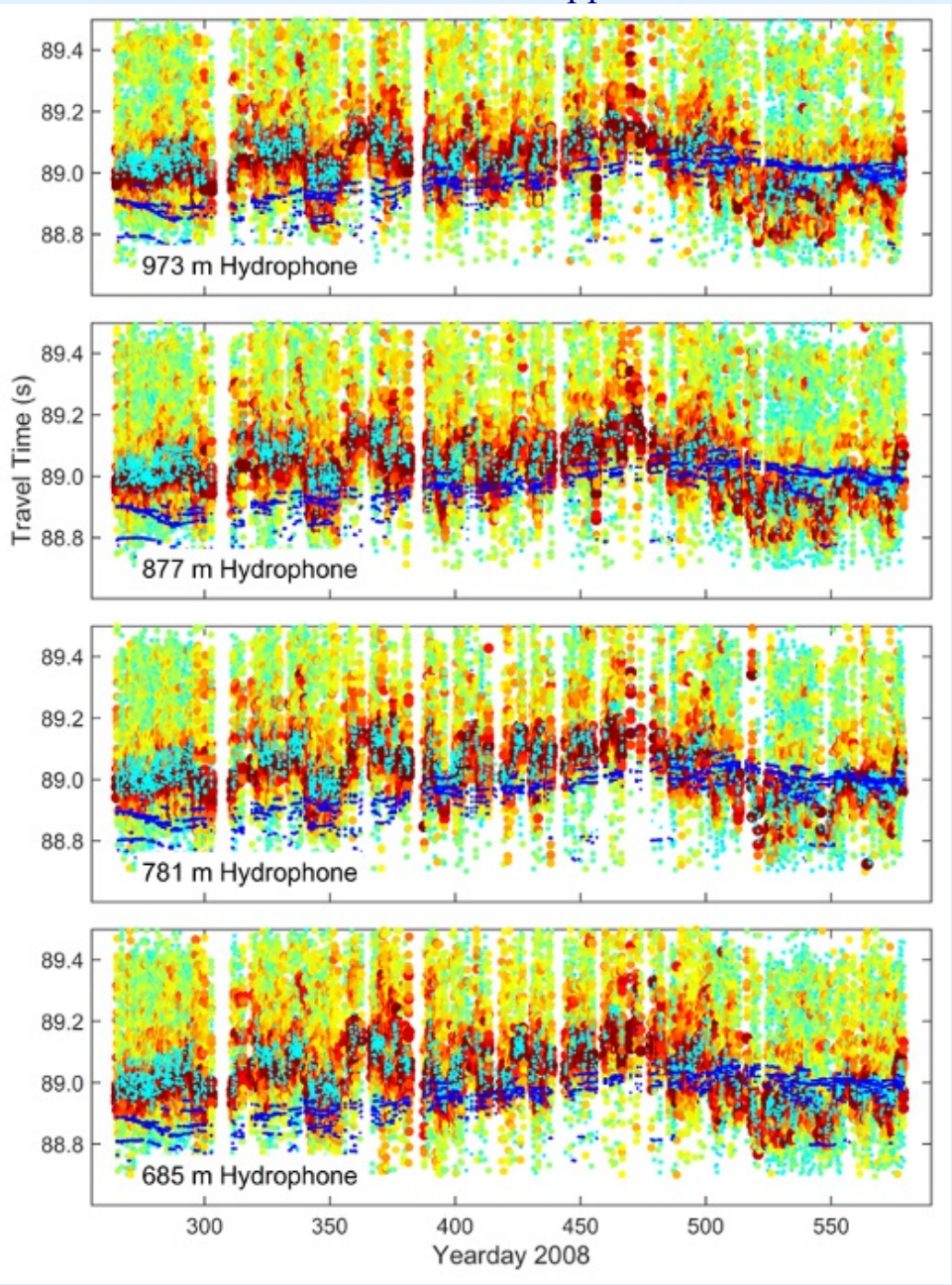
DAMOCLES: Corrections to Model Temperature, 0-1000 m Depth Average



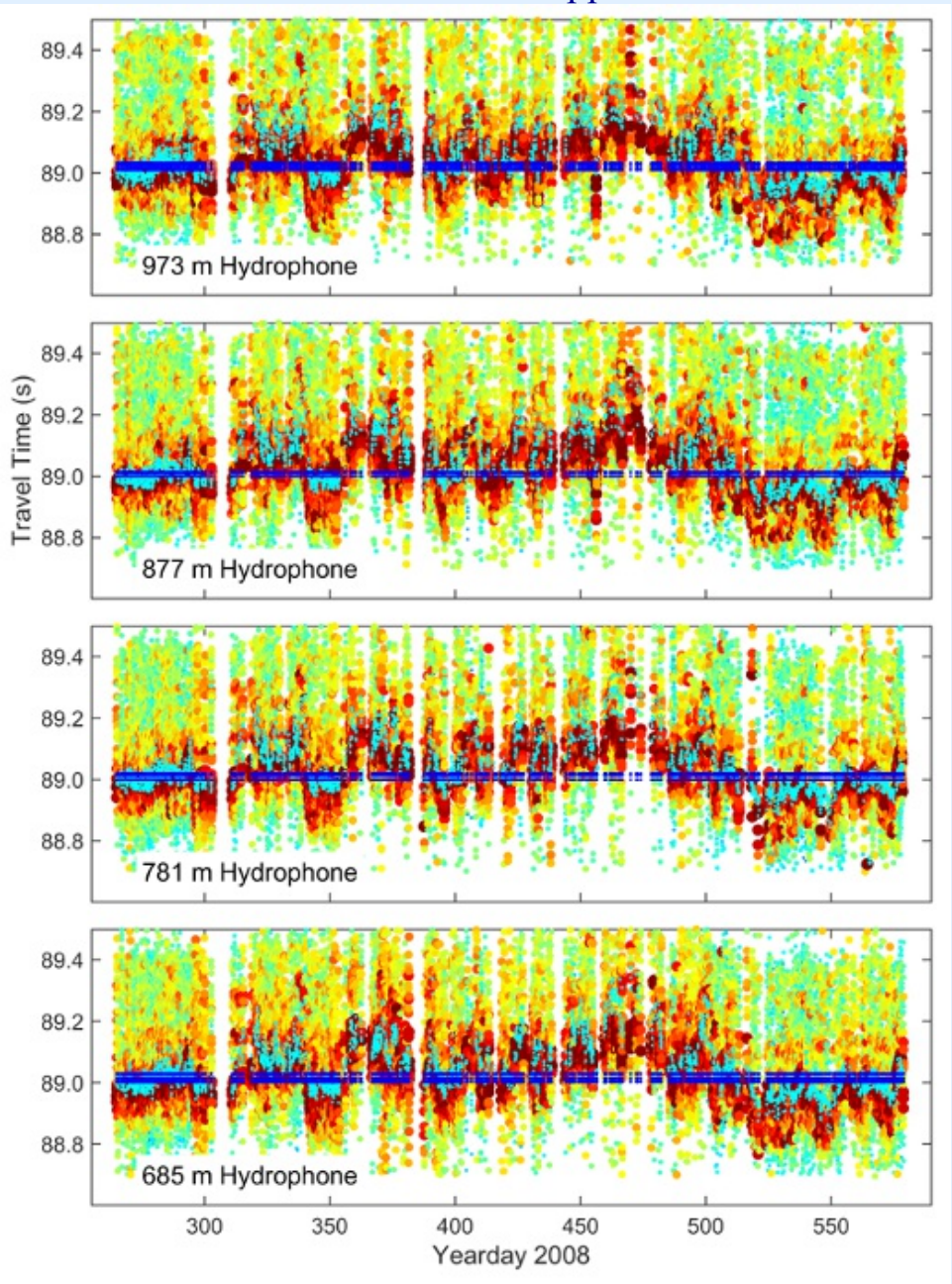
The model...

1. has a temperature bias,
2. grossly underestimates the large mesoscale variations,
3. has the wrong seasonal cycle,
4. has the wrong mean sound speed profile,
5. does not properly model the ubiquitous small mesoscale variations.

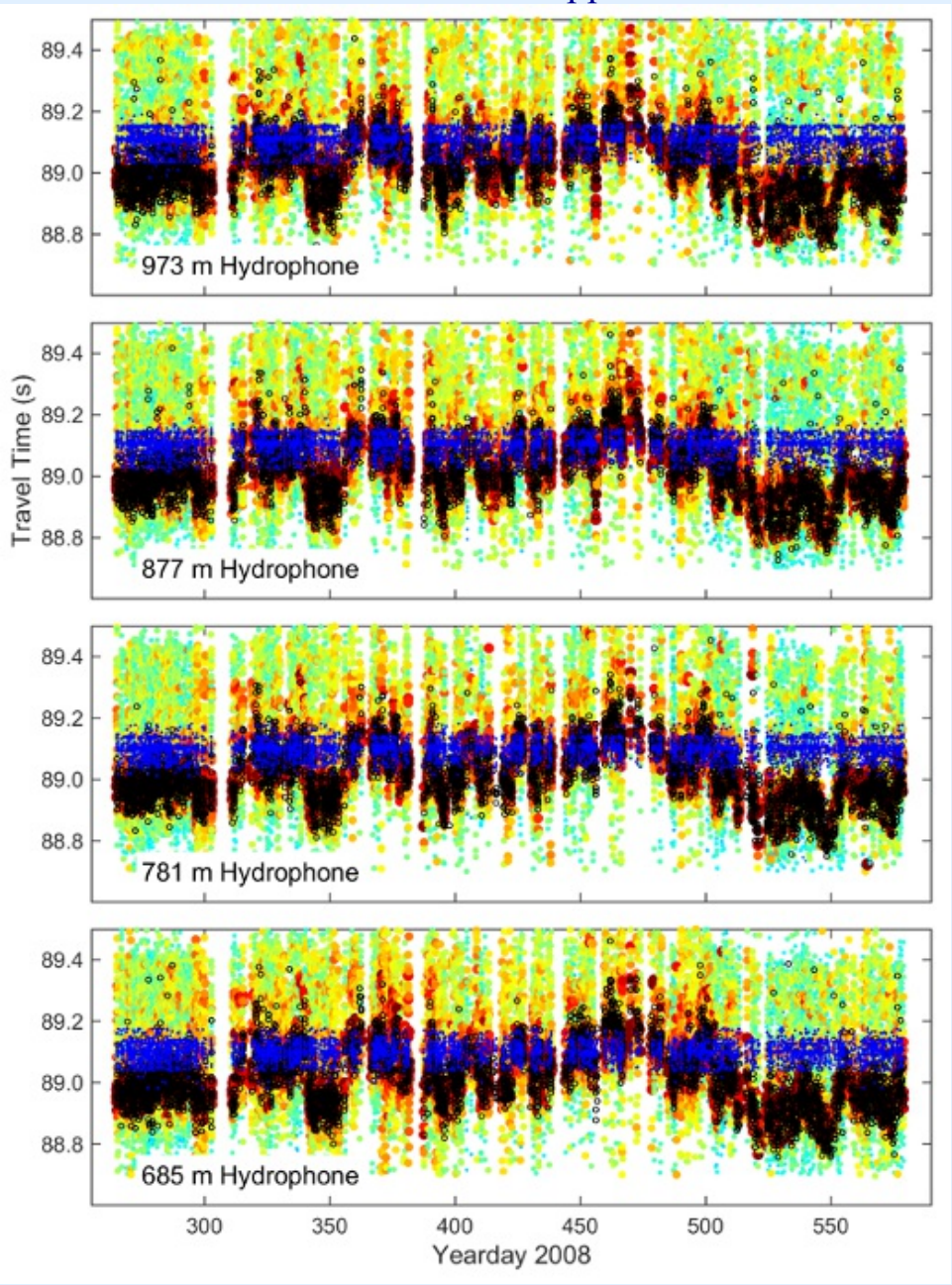
Evolution of Inverse Approaches



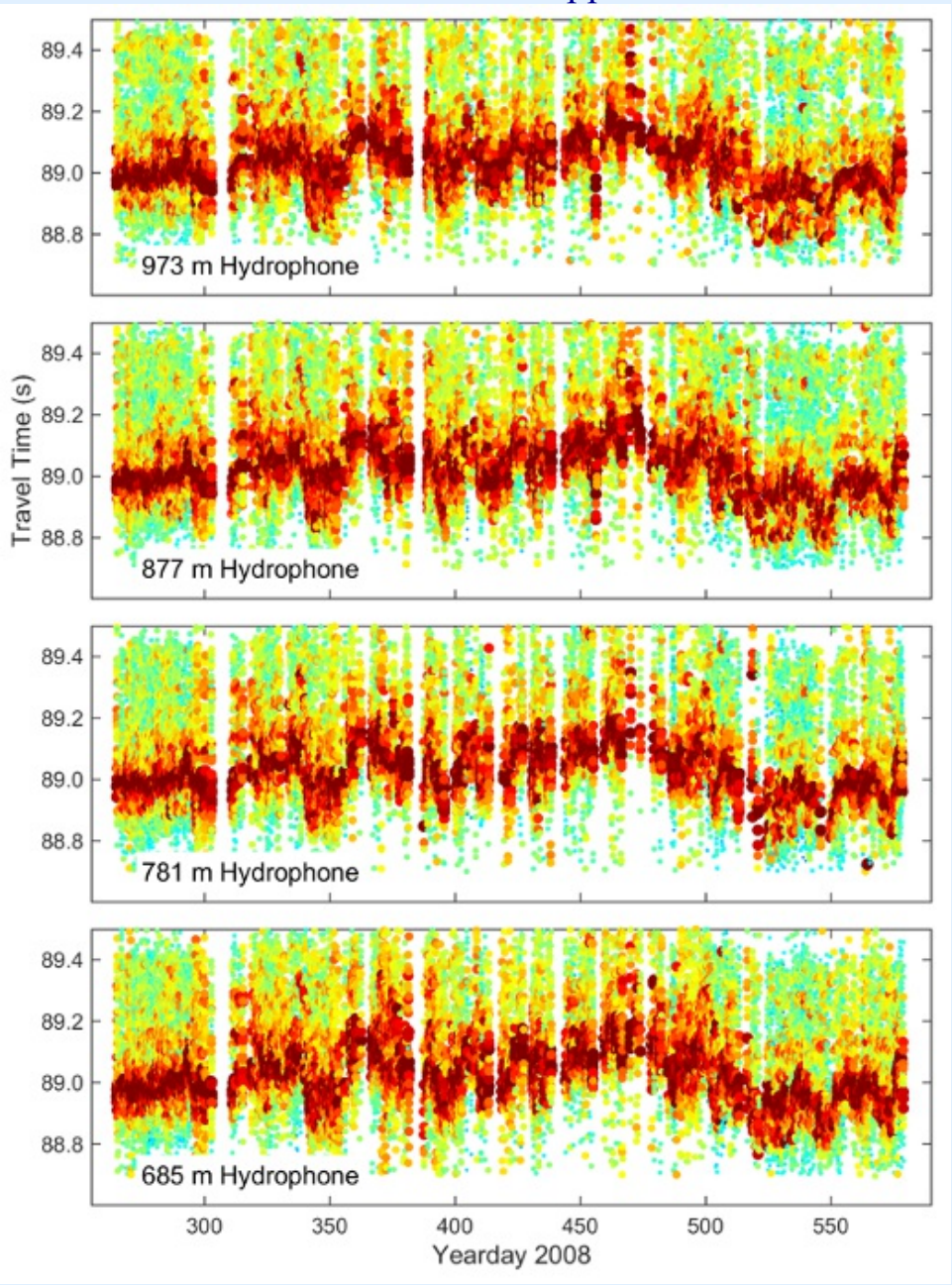
Evolution of Inverse Approaches



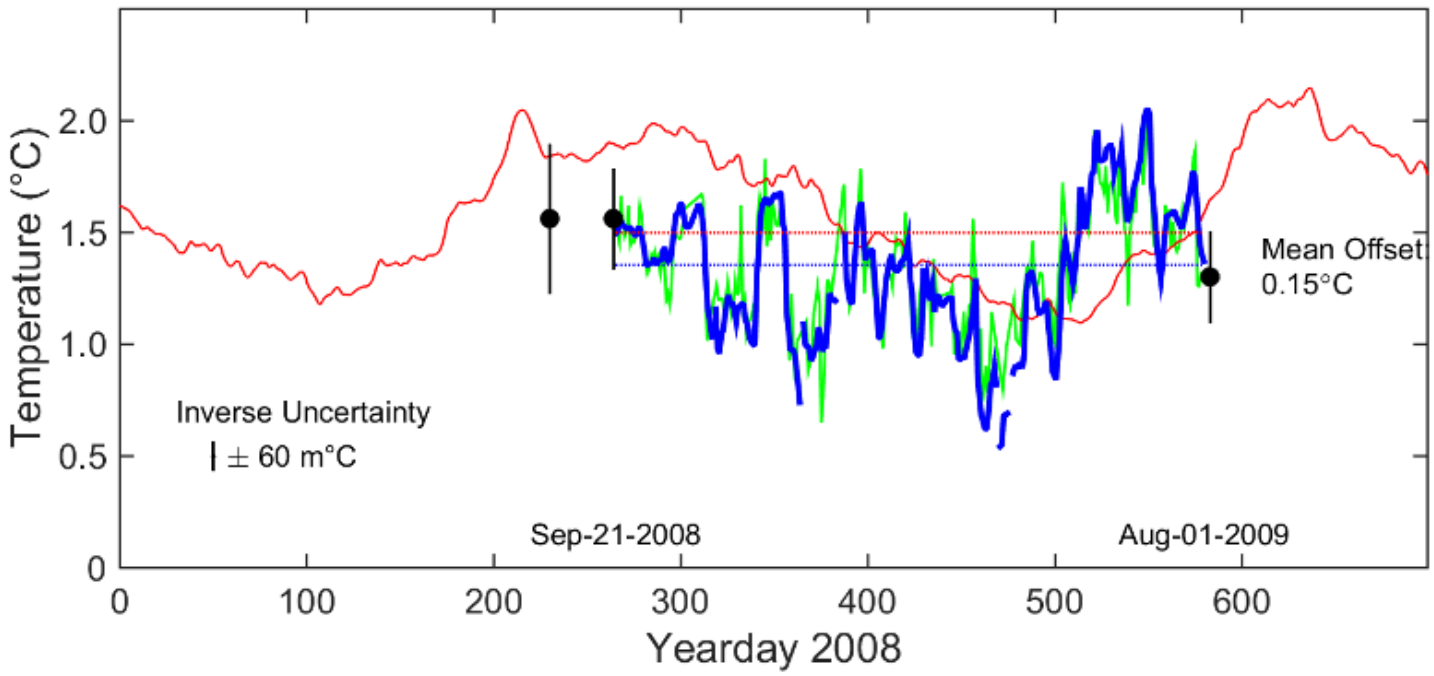
Evolution of Inverse Approaches



Evolution of Inverse Approaches

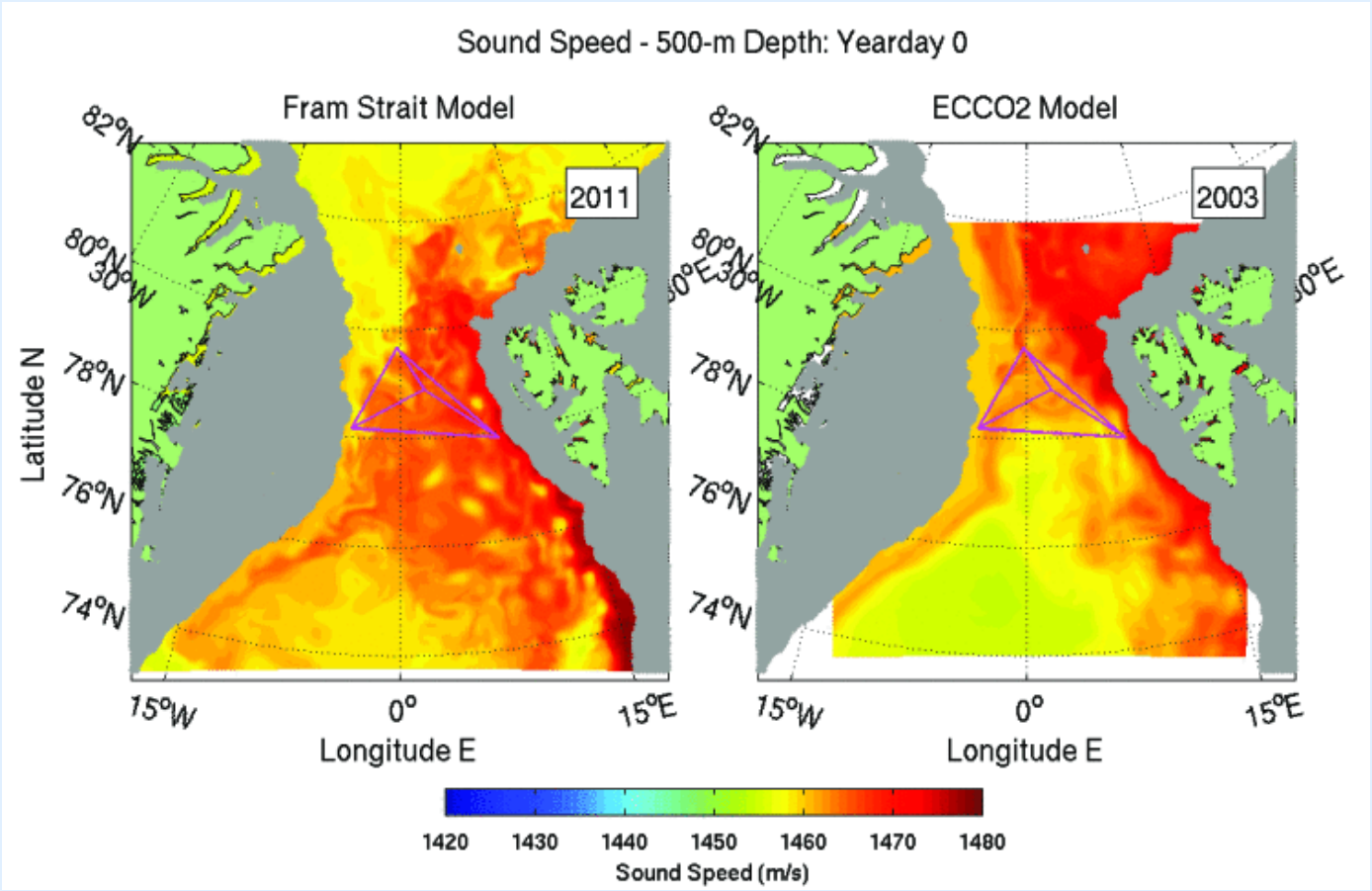


DAMOCLES: Better Temperature Estimates, 0-1000 m Depth Average

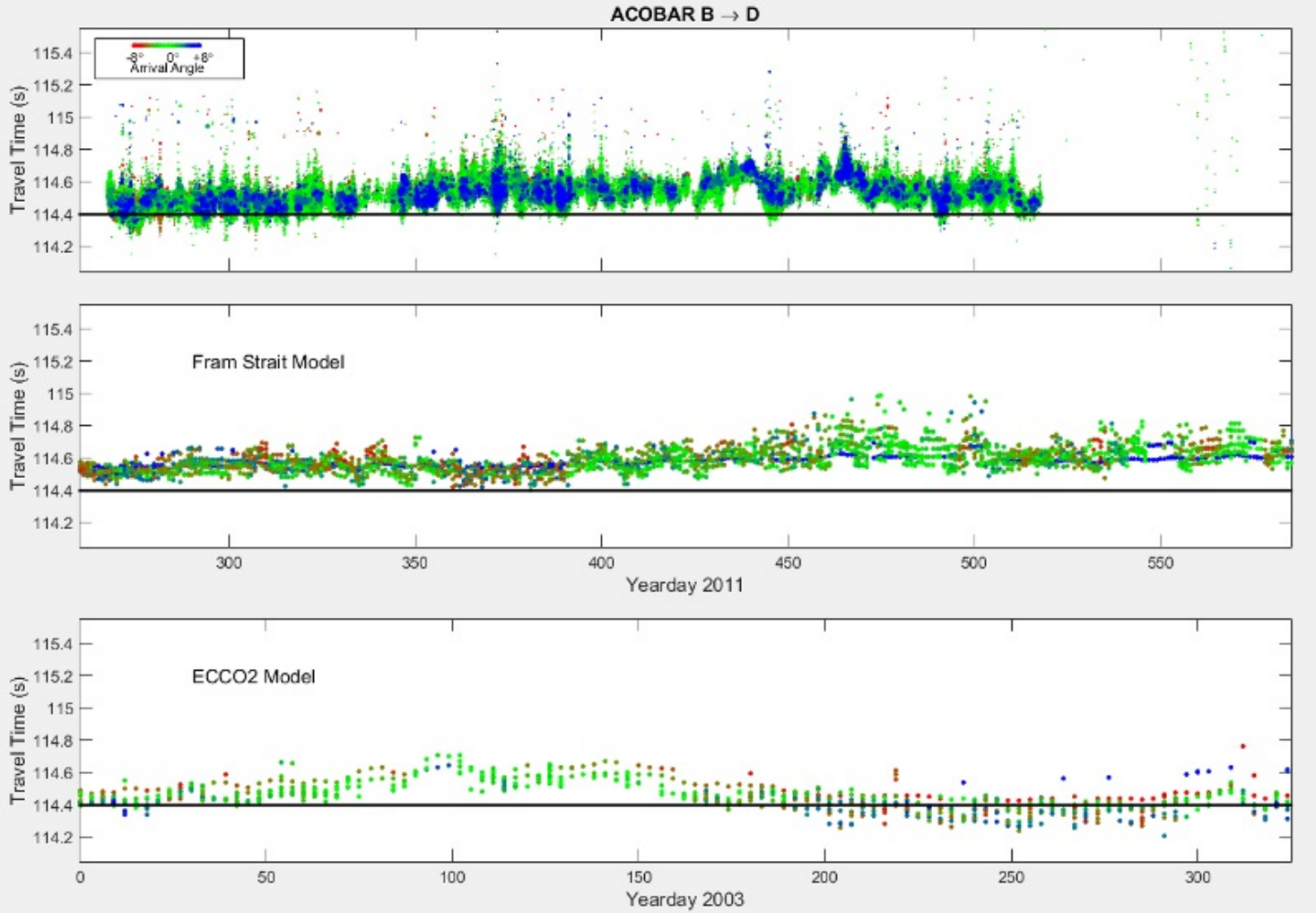


A 0.23°C bias in the estimate has been corrected.
Better agreement with the hydrographic sections.

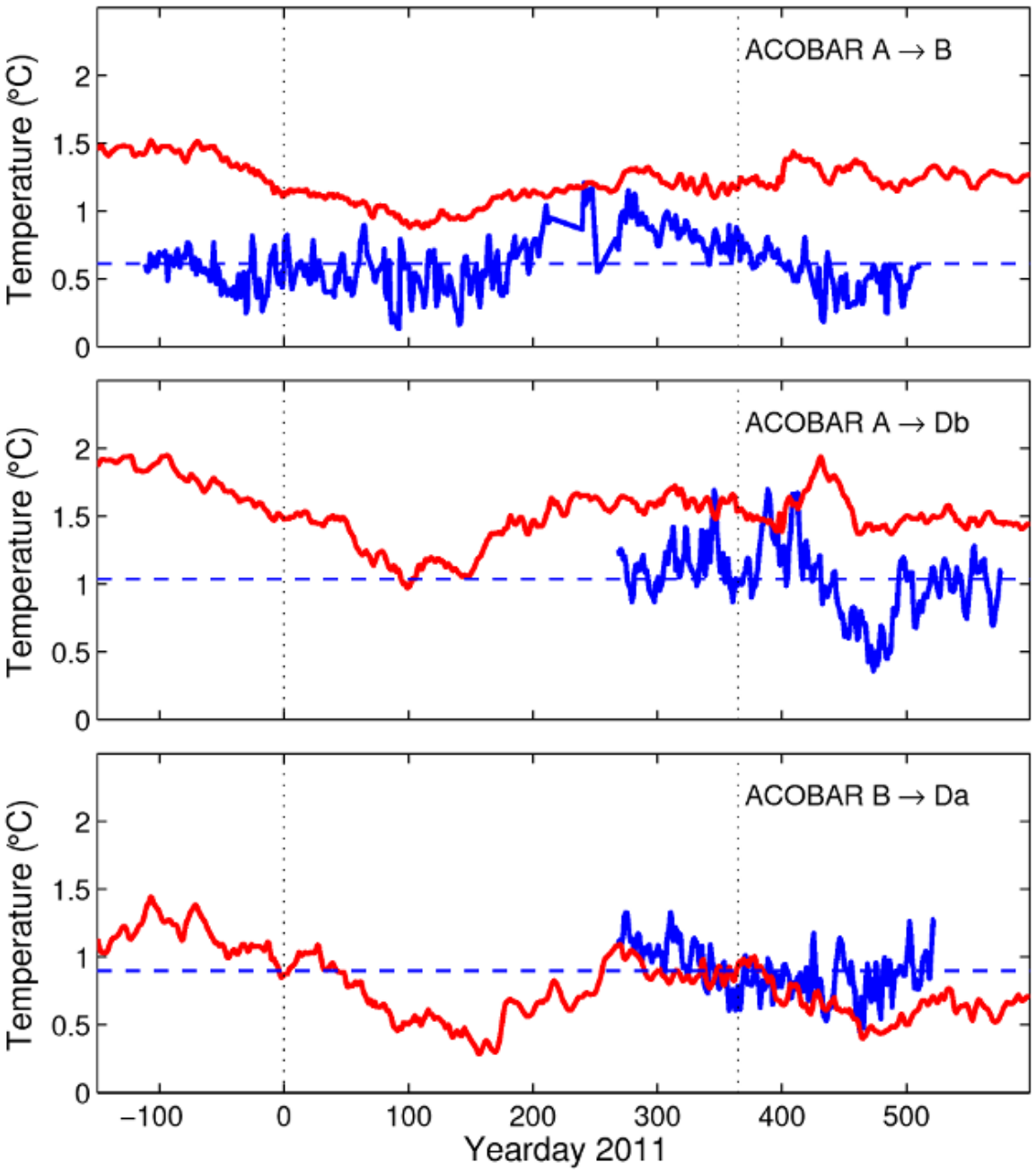
ACOBAR: Fram Strait Model and ECCO2 at 500 m



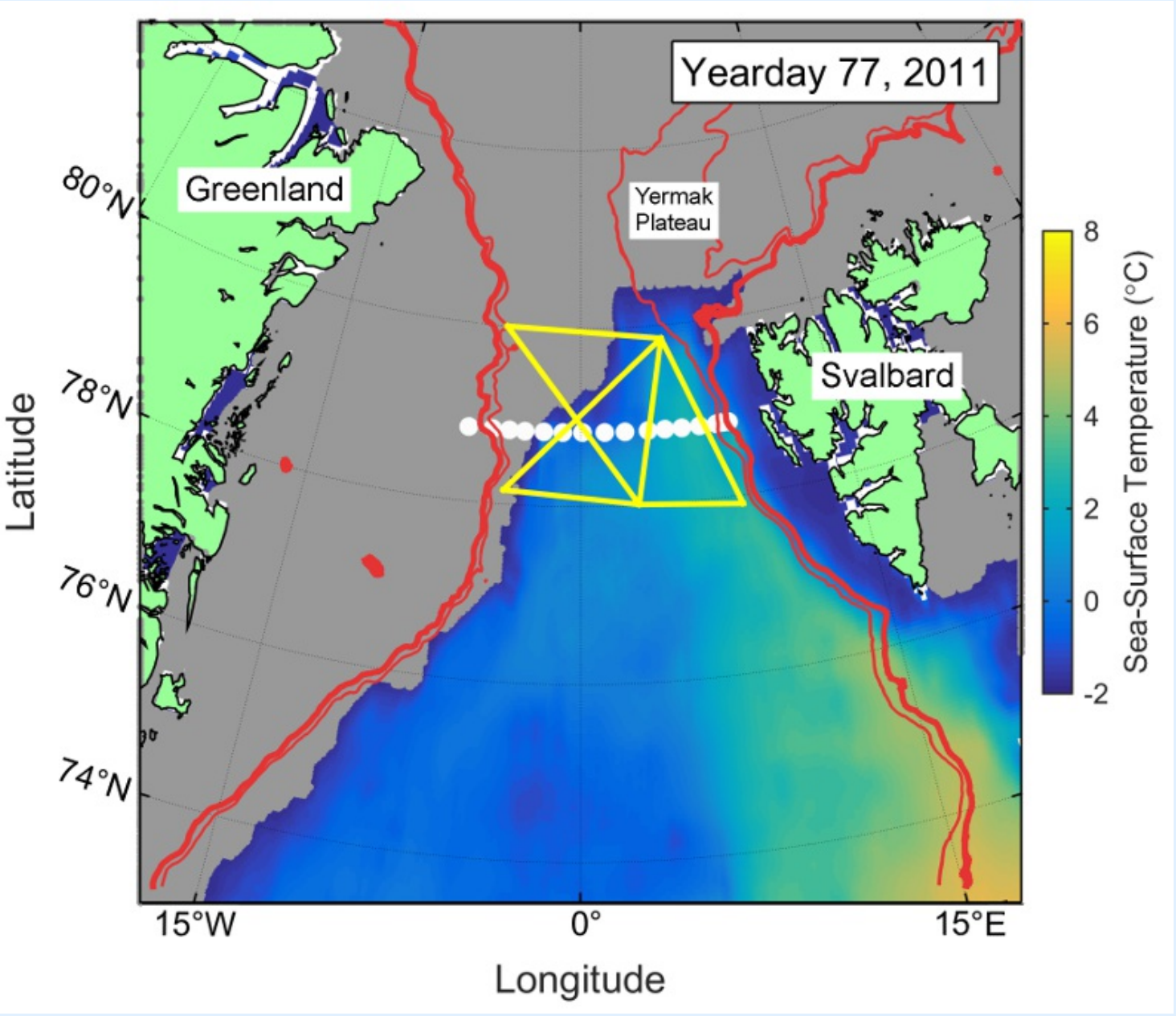
ACOBAR: BD Travel Times



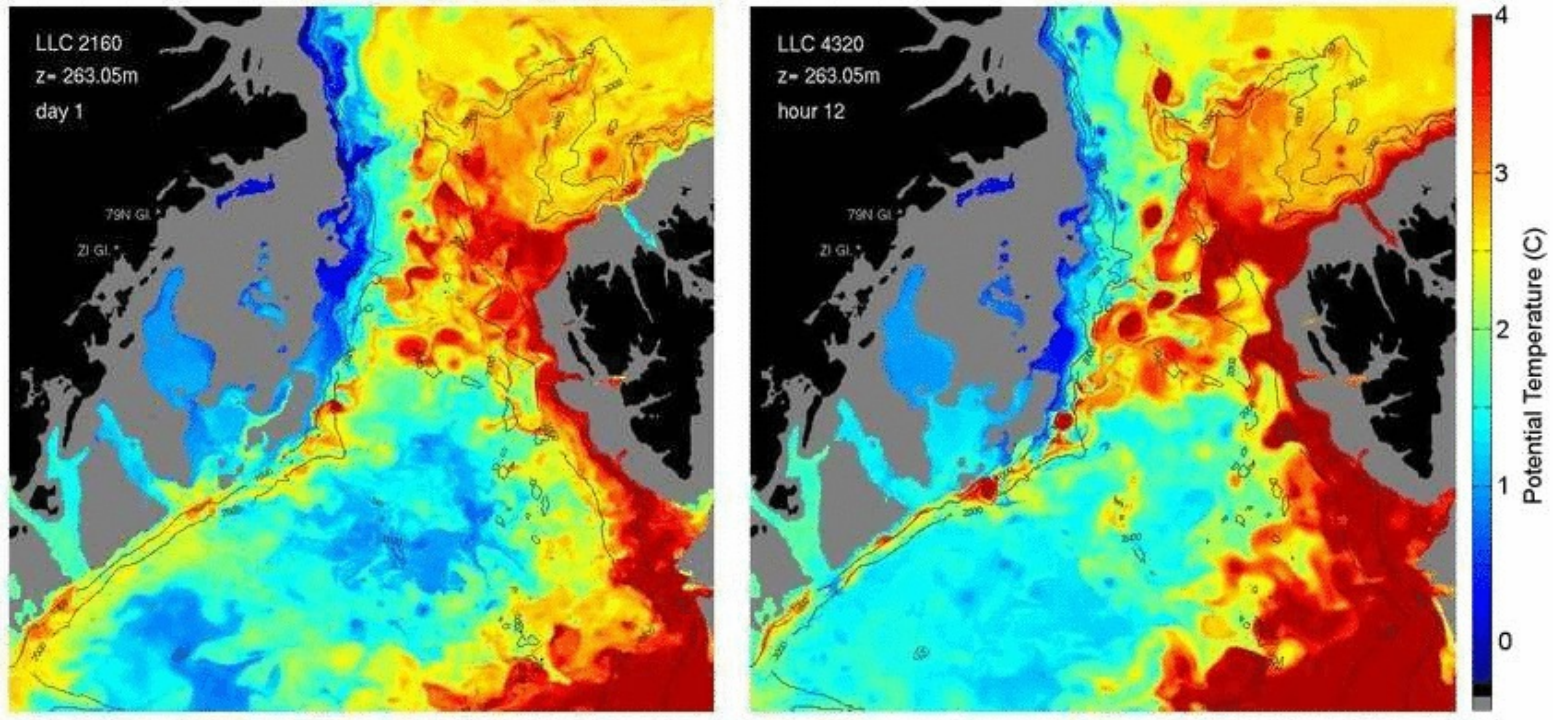
ACOBAR: Temperature Estimates on Three Paths



UNDERICE! 2014–2016



ECCO: FRv3 2160/4320 Global Simulations



30 days of model simulation, potential temperature at 263 m depth.

2-km and 1-km resolutions

Conclusions

- Acoustic arrival patterns are greatly affected by small scales...
  They lack normal precision.
- Nevertheless, inverse estimates provide accurate measure of average temperature.
- No measurements of current.
- Analysis approaches are evolving: e.g., bottom reflections, TSKs — TBD.
- Tomography is complementary to point observations (**here and everywhere!**).
- Inversions relative to an ocean model work ...
  ∴ We are a step closer to model constraints by data assimilation.
- Salinity variations are mostly a non-issue (for tomography/temperature).
- What is the value/impact of the measurements offered by tomography?
  Mean temperature? Mesoscale intensity? Seasonal cycle? —
  Modeling constraints? —
  TBD... Stay tuned! —
- Ubiquitous small scale may be driving factor in exchanges through Fram Strait.
  Models may need to get the small scale right to be effective.