



Field Trial(s) of the UNB Refraction Uncertainty Monitoring Toolkit

Time spent on reconnaissance is seldom wasted.

British Army Field Service Regulations, 1912

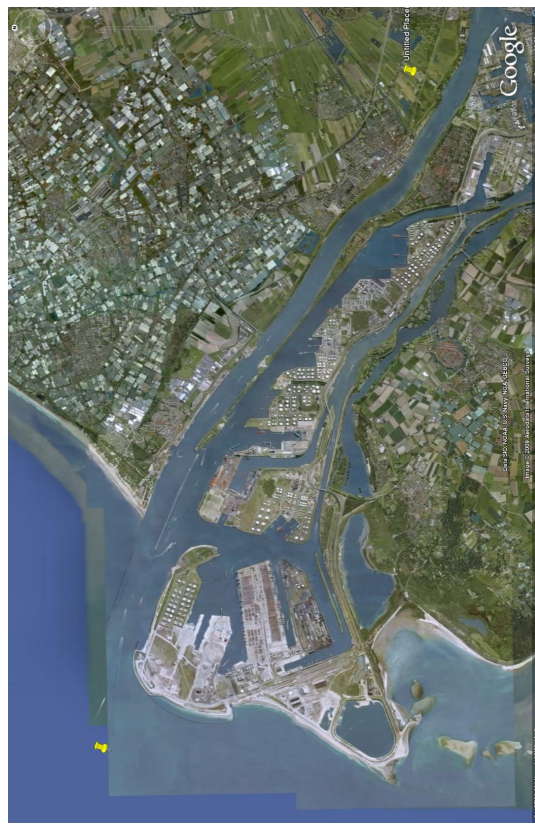
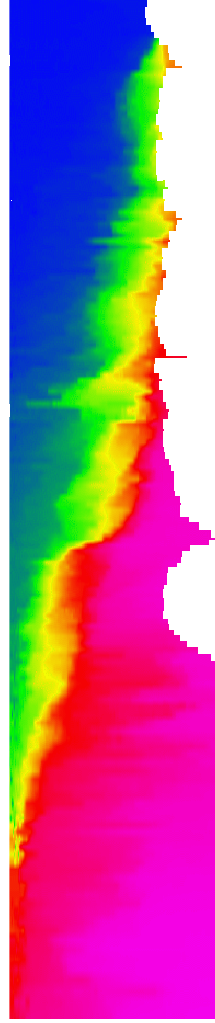
Jonathan D. Beaudoin

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001-506-447-3307

Ocean Mapping Group

University of New Brunswick



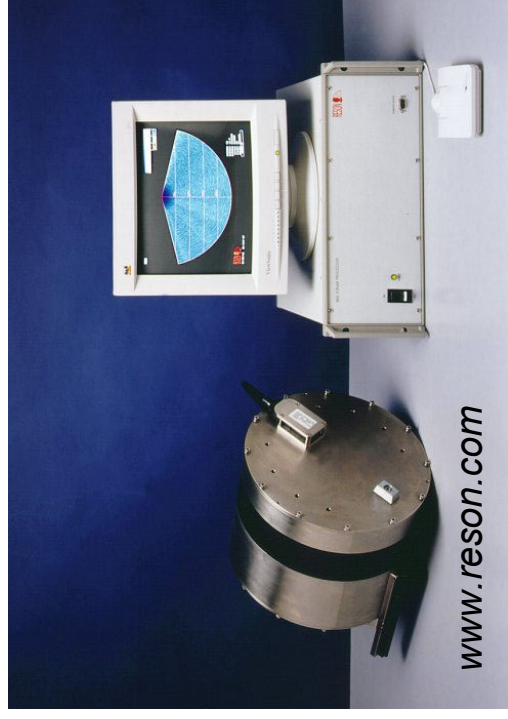
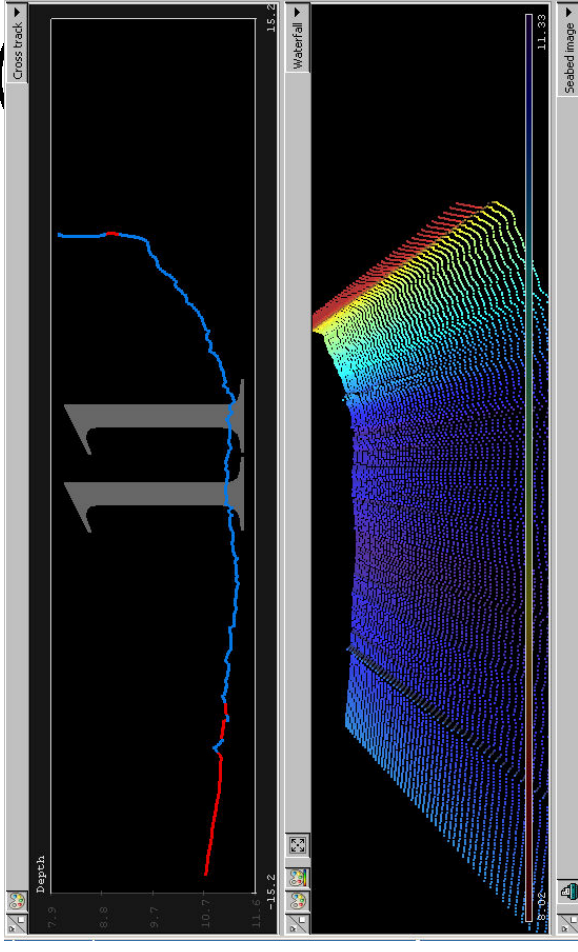


Outline

- Real-time assessment of refraction uncertainty
- Acoustic aiding
- Field Trials:
 - Lower Saint John River estuary
 - Rotterdam Waterway
- Survey REA with MVP and Acoustic Aiding

Assessing Refraction Artifacts in Real-Time

- Highly subjective
- Requires constant vigil
- Can overreact over flat seafloors
- Can “underreact” over complicated topography
- Impossible for iso-velocity displays (e.g. Reson 81XX display)



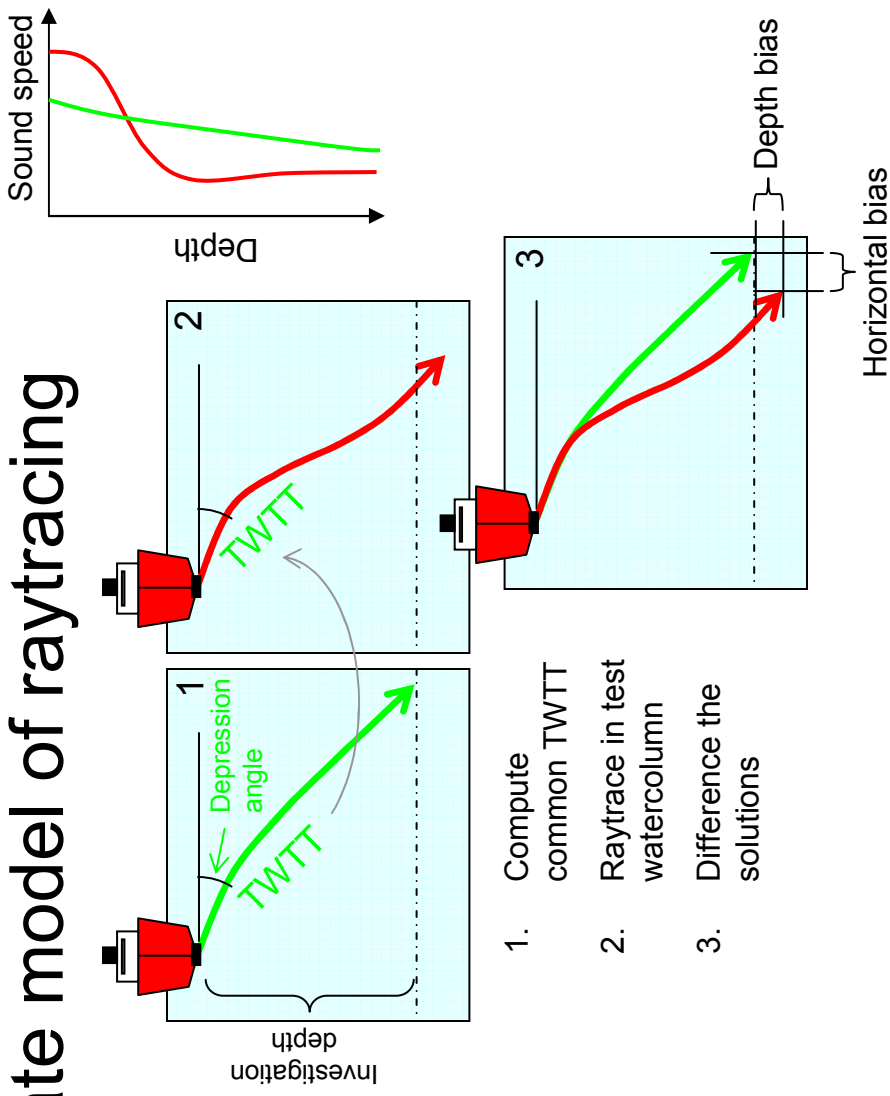
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Lisbon, April 21-24



UNB/OMG Method: Raytracing Simulation

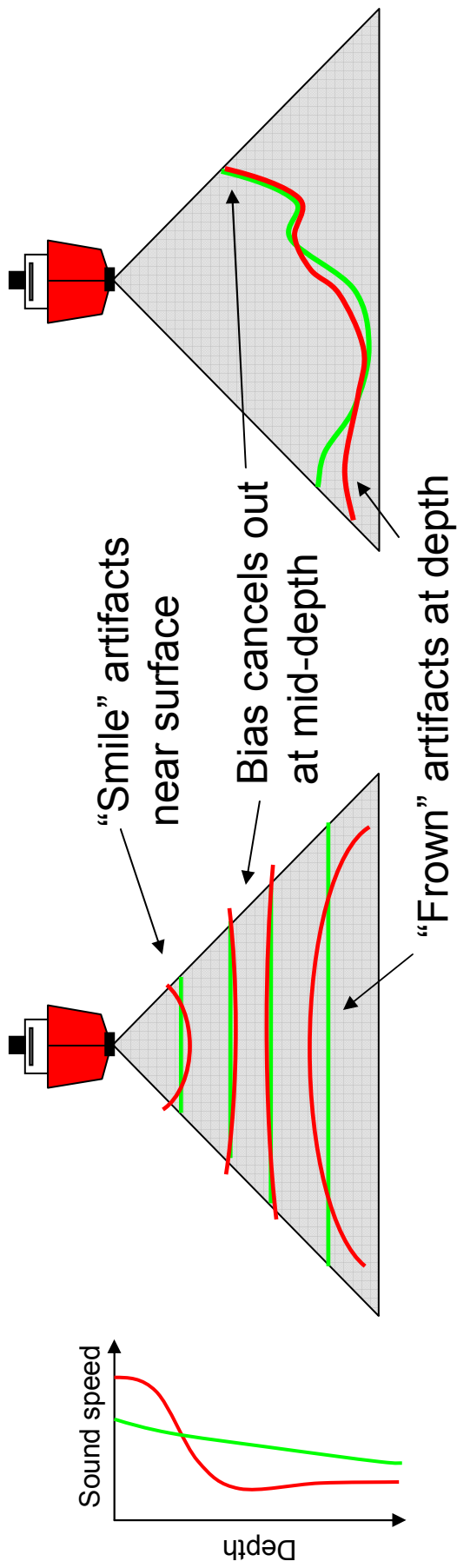
- Isolates raytracing portion of depth reduction procedure: no sounding data required!
- Requires accurate model of raytracing procedure:

- Draft
- Angular sector
- Survey depth
- Surface sound speed probe

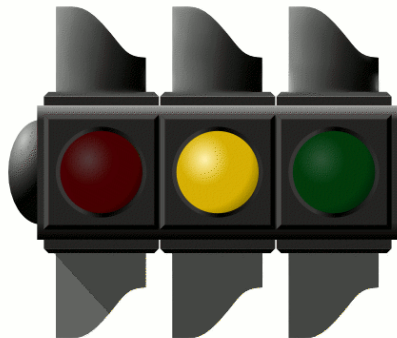




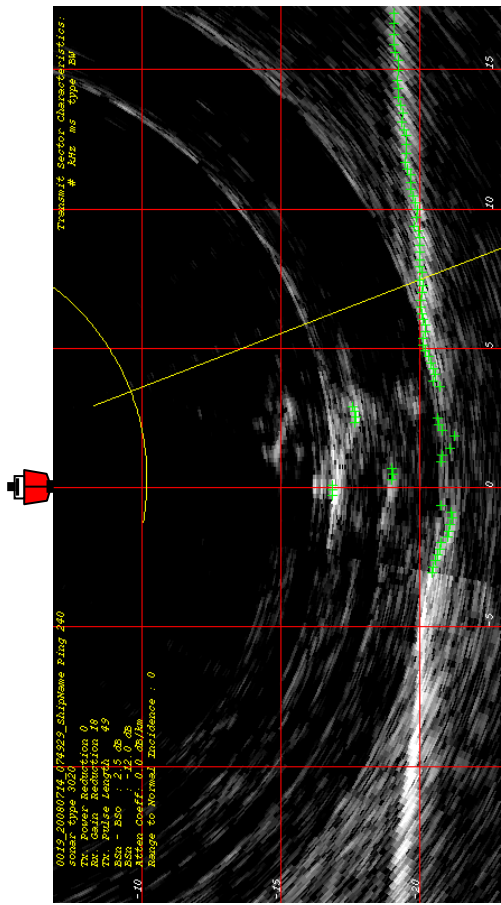
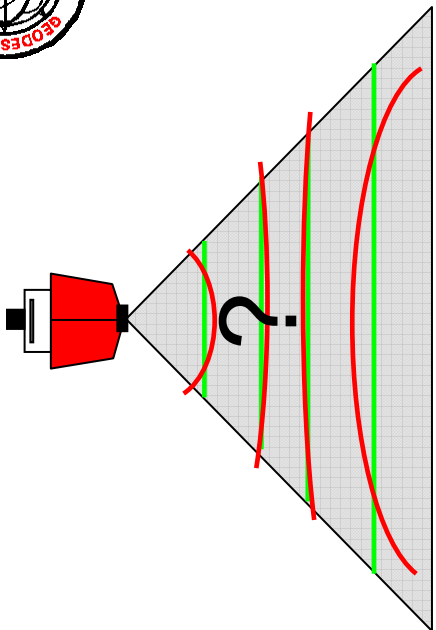
Investigation over Entire Potential Sounding Space



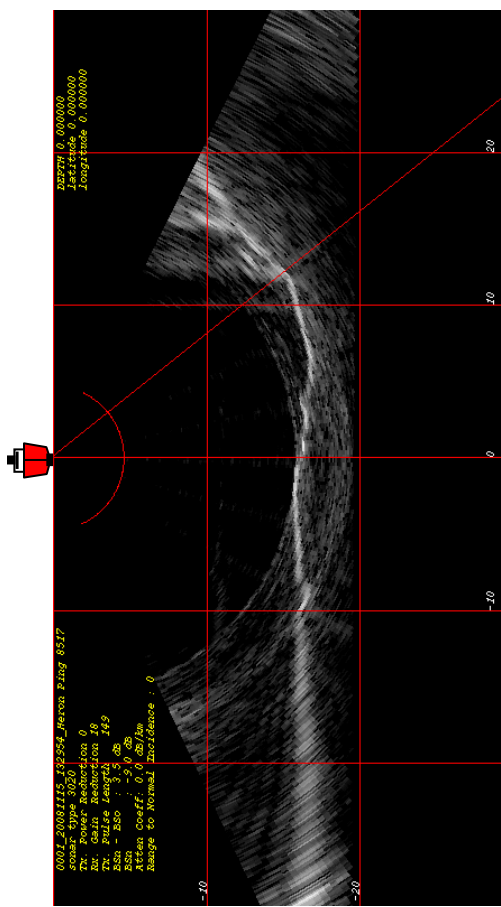
*It's important to see the
whole picture*



Why Examine the ENTIRE Potential Sounding Space?

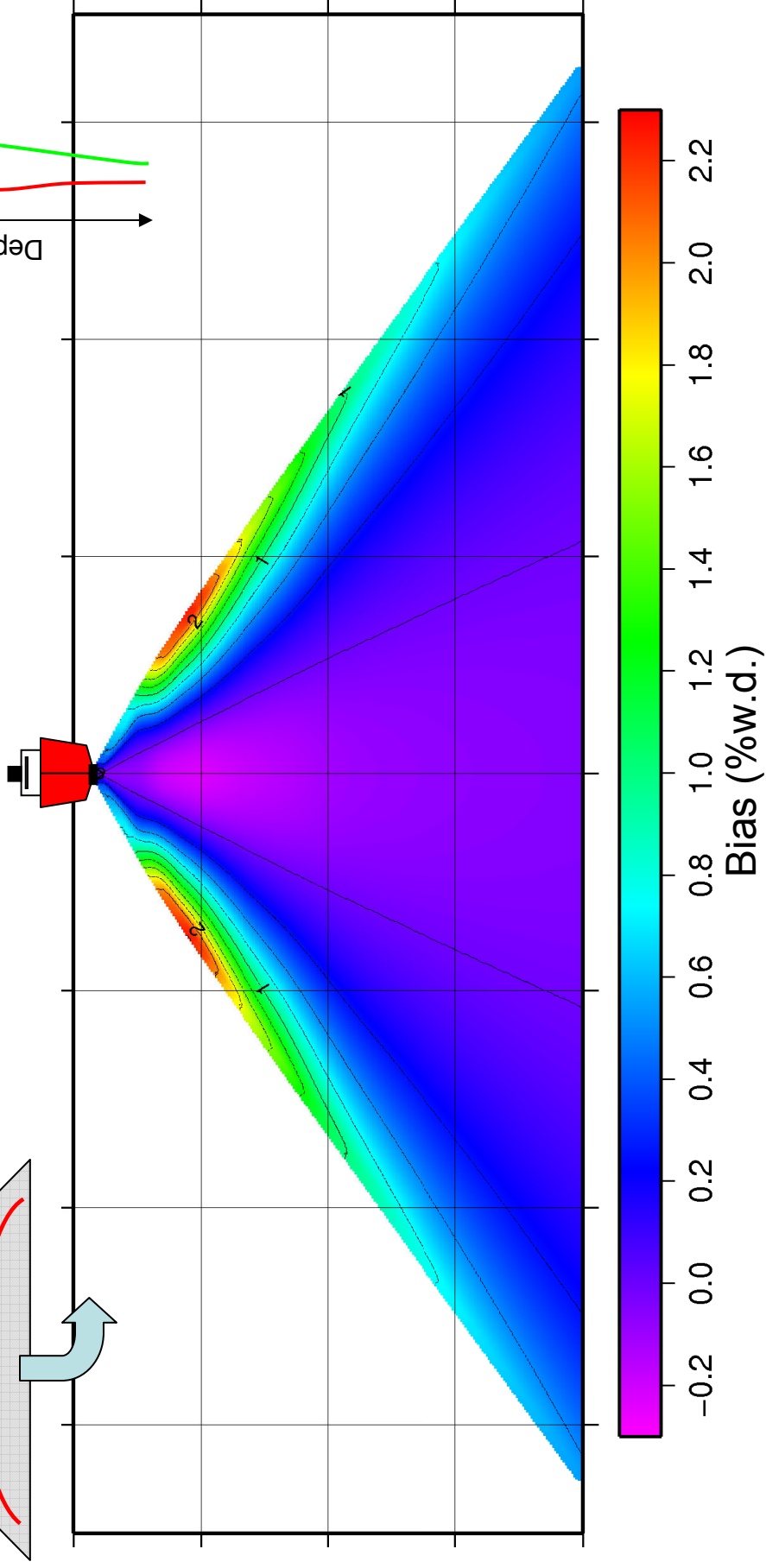
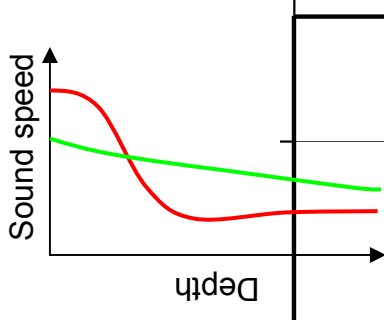
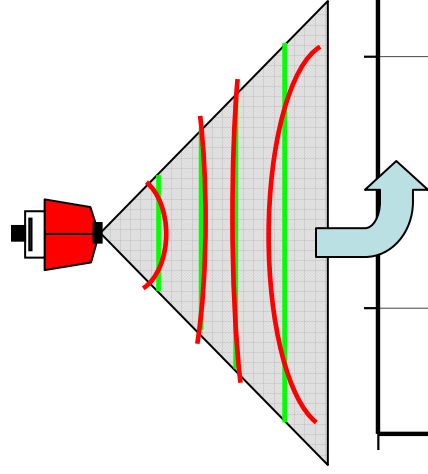


EM3002D watercolumn imagery courtesy of Dutch Navy, processed by A. van der Werf

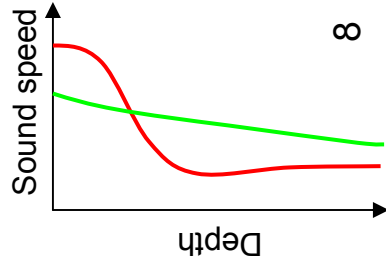
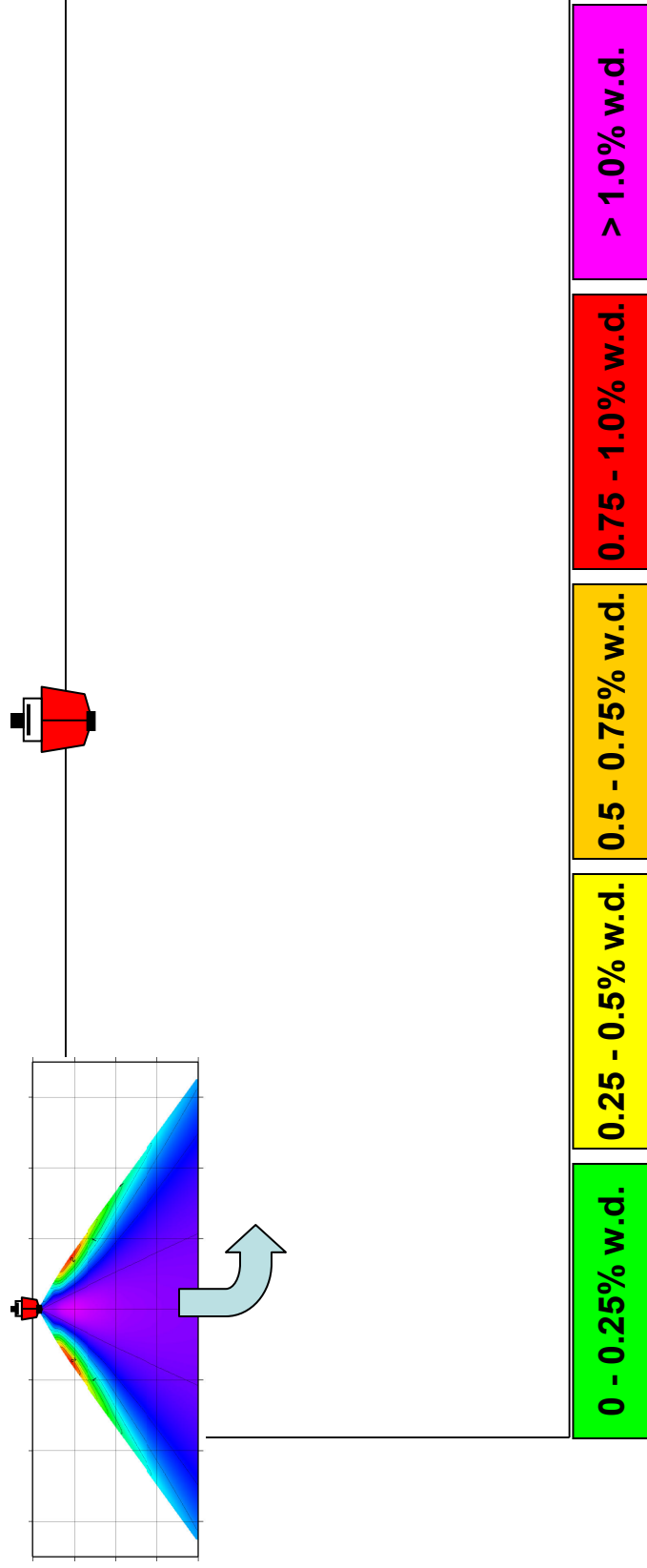


EM3002 watercolumn imagery from CSL Heron, processed by A. van der Werf

Uncertainty Wedge

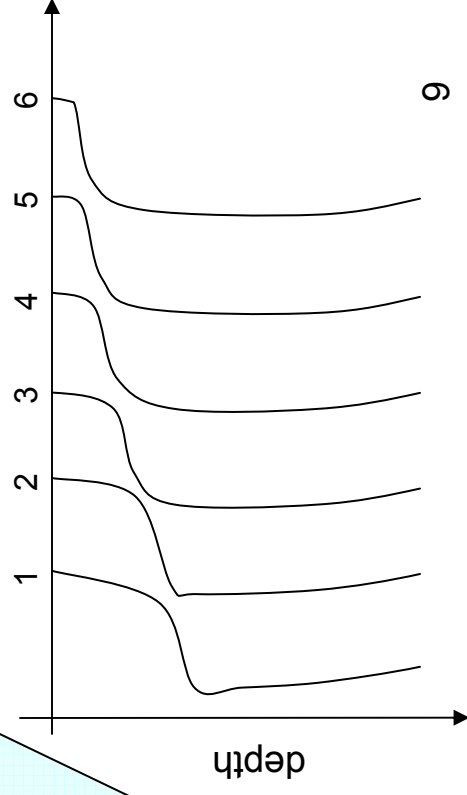
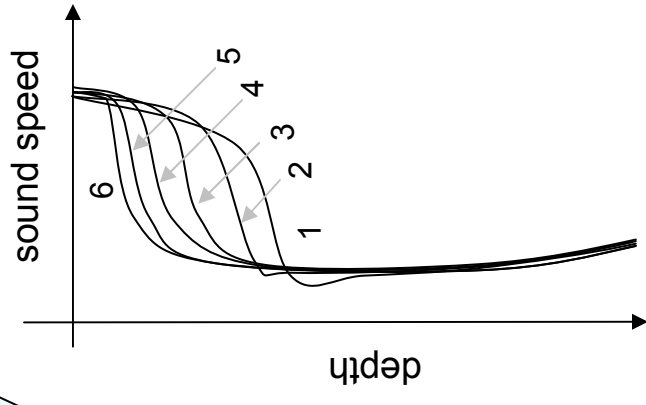
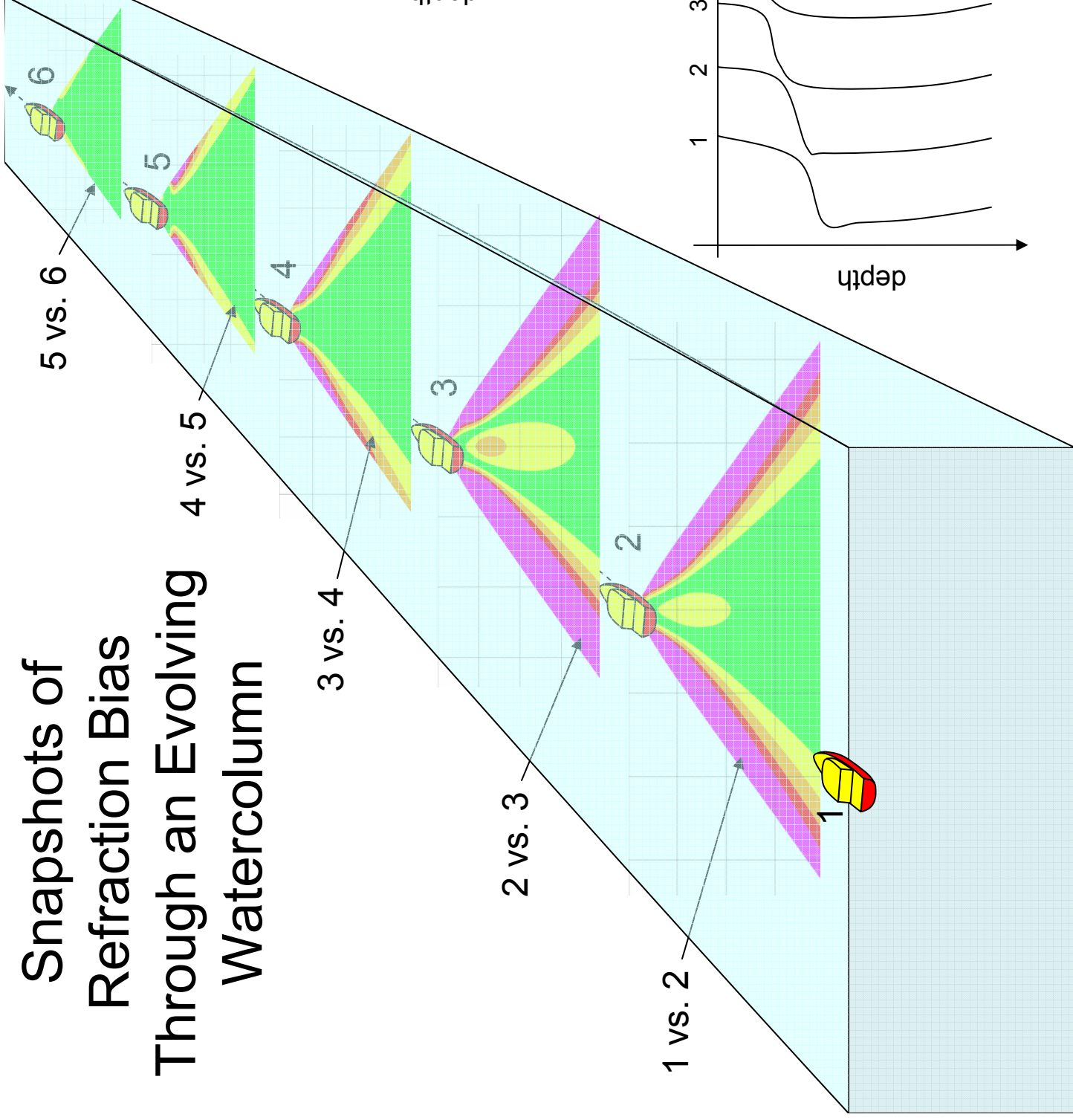


Simplification for Real-Time Decision Making

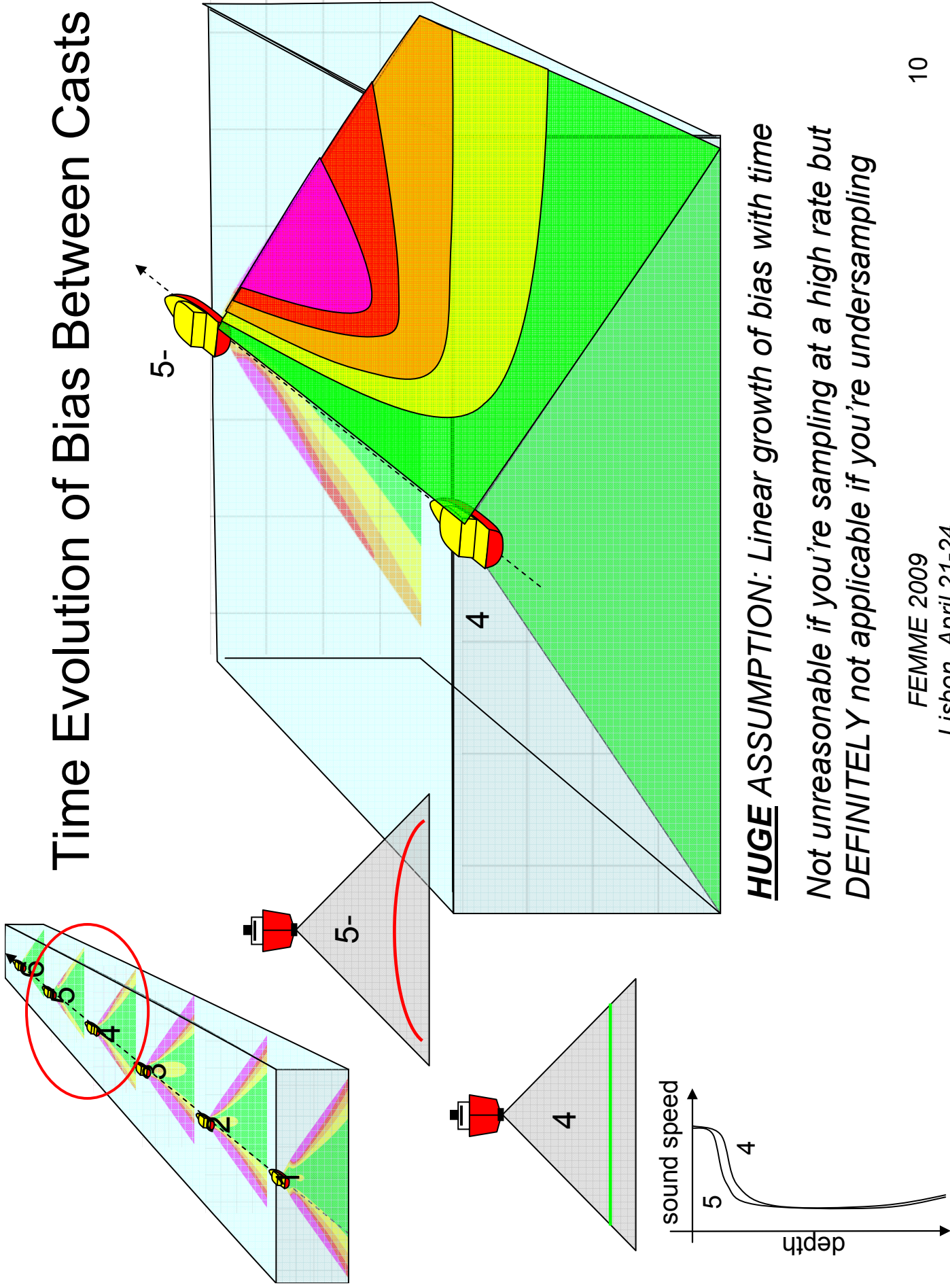


IHO Order	Allowable depth dependant portion of TVU
Special	0.75% w.d.
1a	1.3% w.d.
1b	1.3% w.d.
2	2.3% w.d.

Snapshots of Refraction Bias Through an Evolving Watercolumn

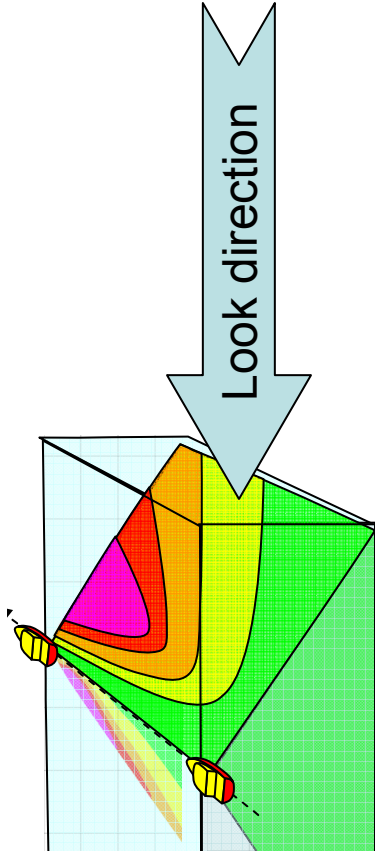


Time Evolution of Bias Between Casts



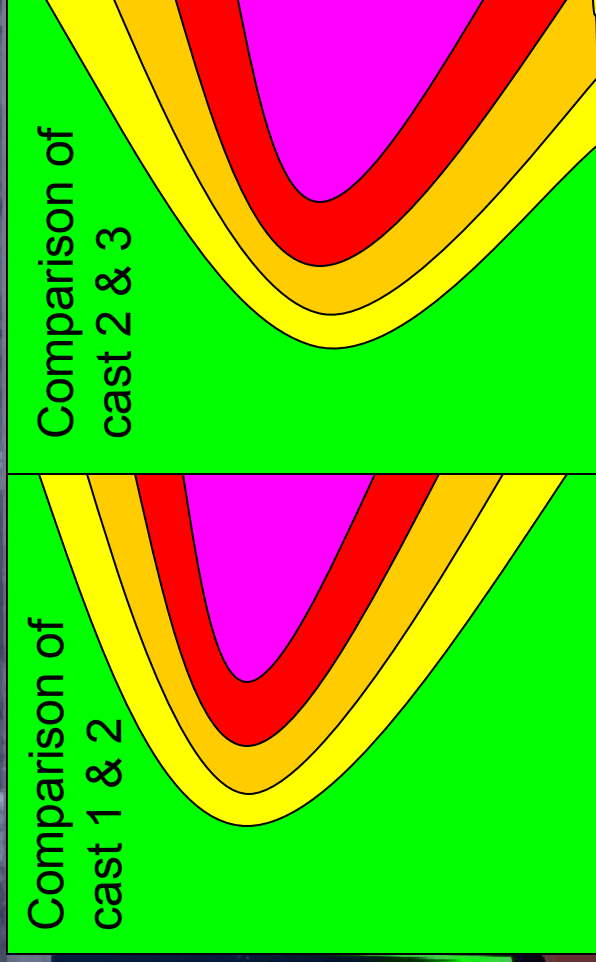
HUGE ASSUMPTION: Linear growth of bias with time

Not unreasonable if you're sampling at a high rate but
DEFINITELY not applicable if you're undersampling

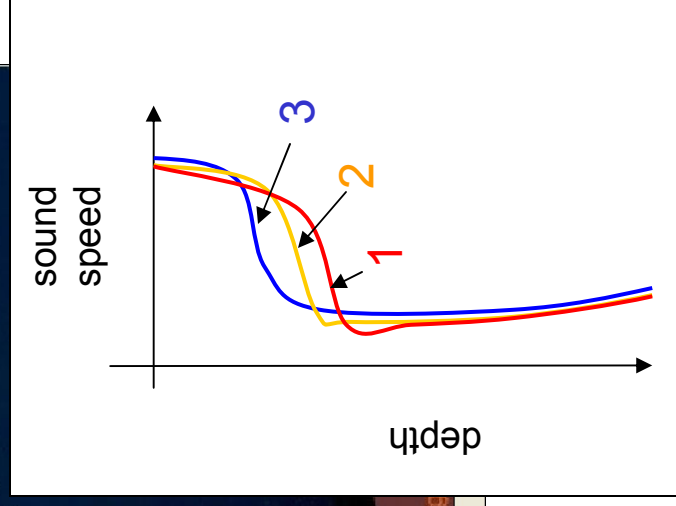


Real-Time Uncertainty Visualization

ODIM Moving Vessel Profiler - Free Fall Fish Profiling Action



flash-MVP-fish_profile.avi

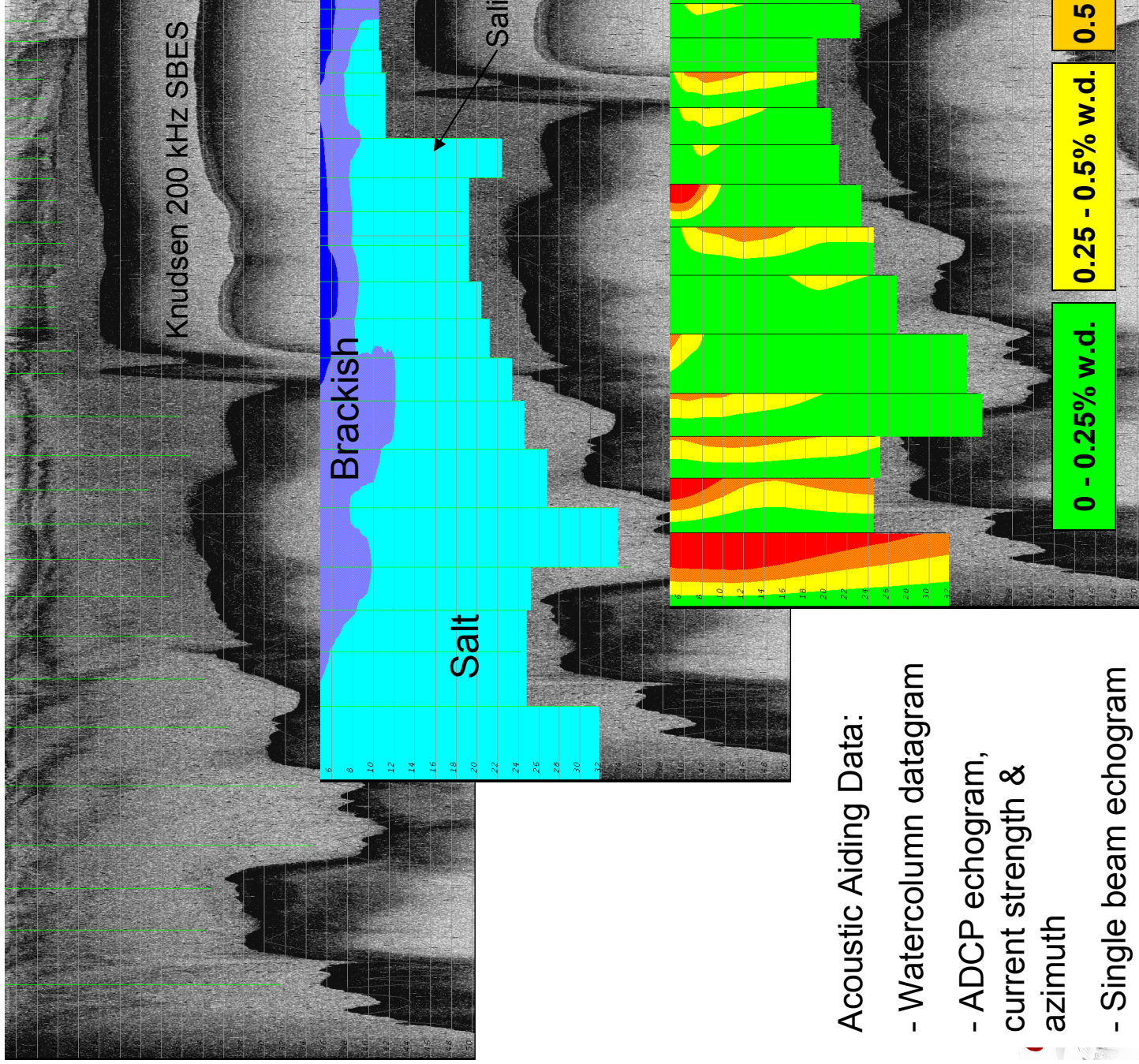


*It's important to be able to visualize
the time evolution and history of error*

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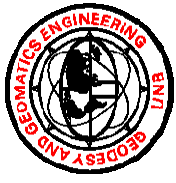


Uncertainty Visualization with Acoustic Aiding



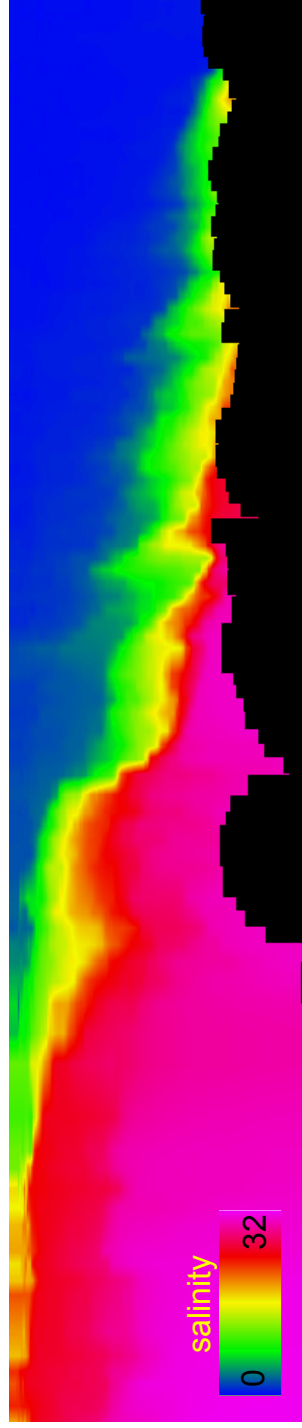
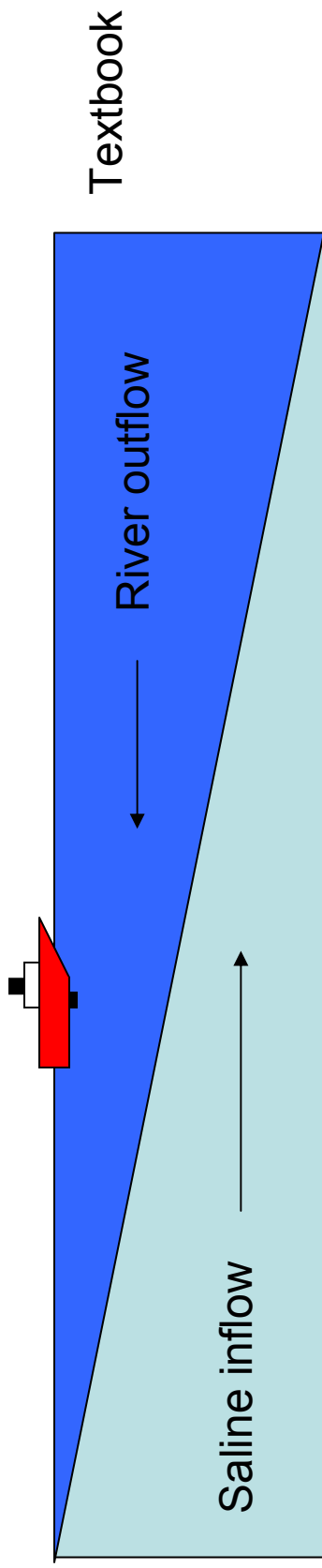
Acoustic Aiding Data:

- Watercolumn datagram
- ADCP echogram, current strength & azimuth
- Single beam echogram



UNB SVP Toolkit Field Trials

- Saint John River, Canada, November 2008
- Rotterdam Waterway, Netherlands, March/April 2009
- Both areas require frequent dredging and resurvey to guarantee minimum clearance
- Salt wedge estuaries, very challenging to survey



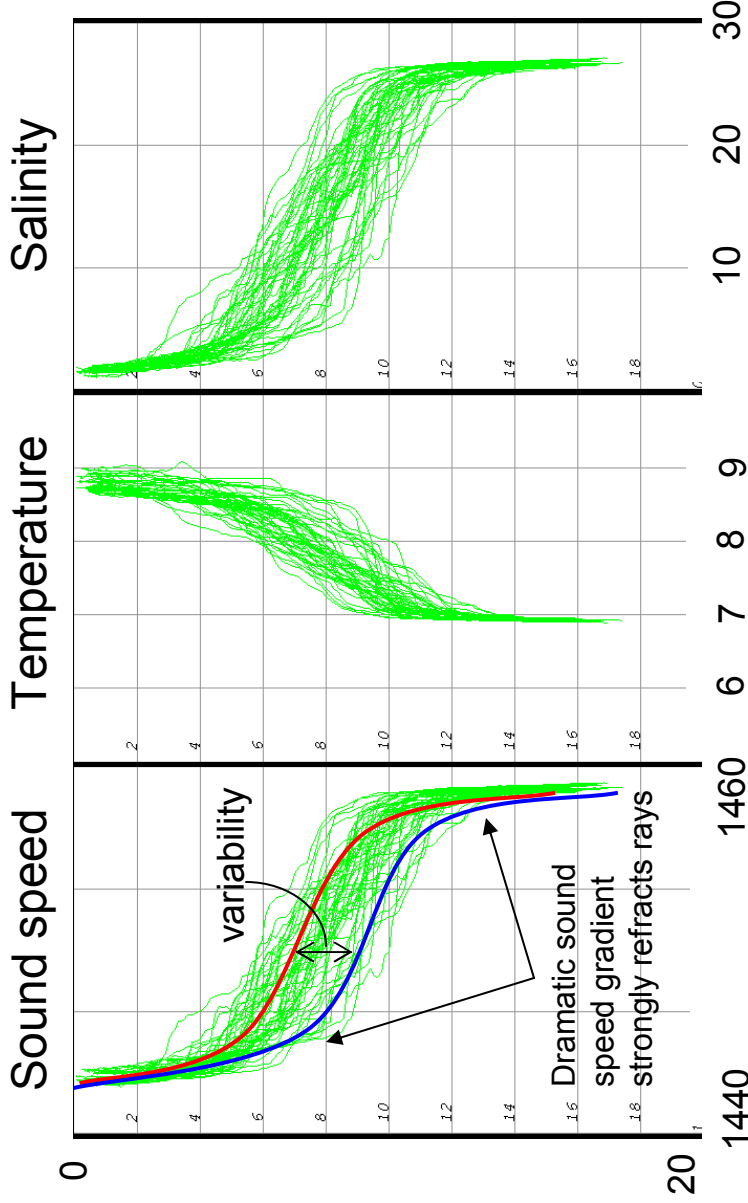
Reality

Ocean Mapping Group

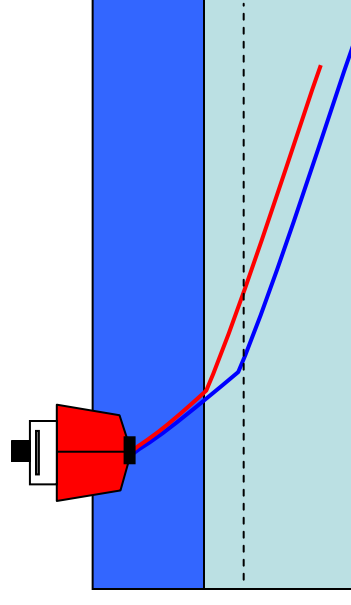
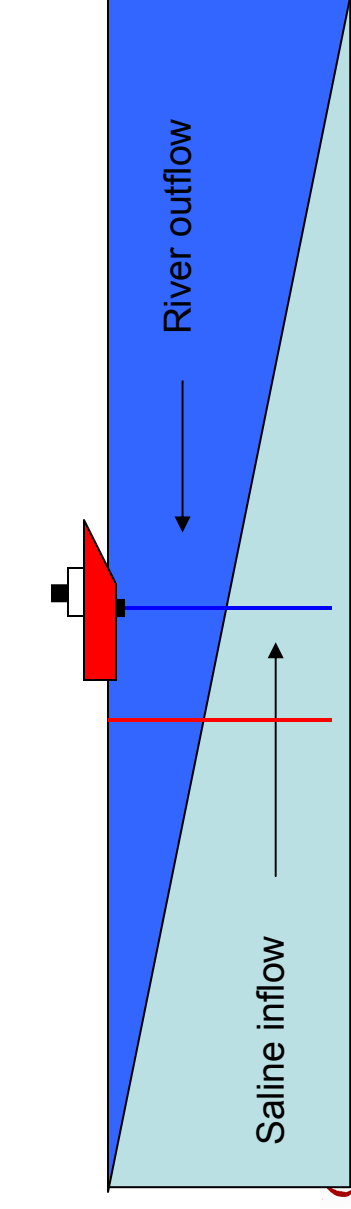


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Why are these Areas So Challenging? (1)



As the change in sound speed can be quite dramatic at the interface between the fresh and salt water (20 m/s), soundings can refract quite strongly and can lead to significant sounding uncertainty with seemingly small variations in the interfacial depth.



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Why are these Areas So Challenging? (2)



Turbulence

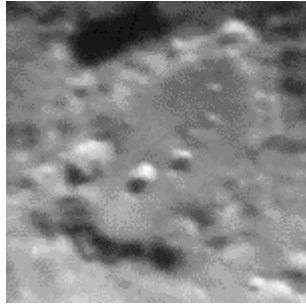
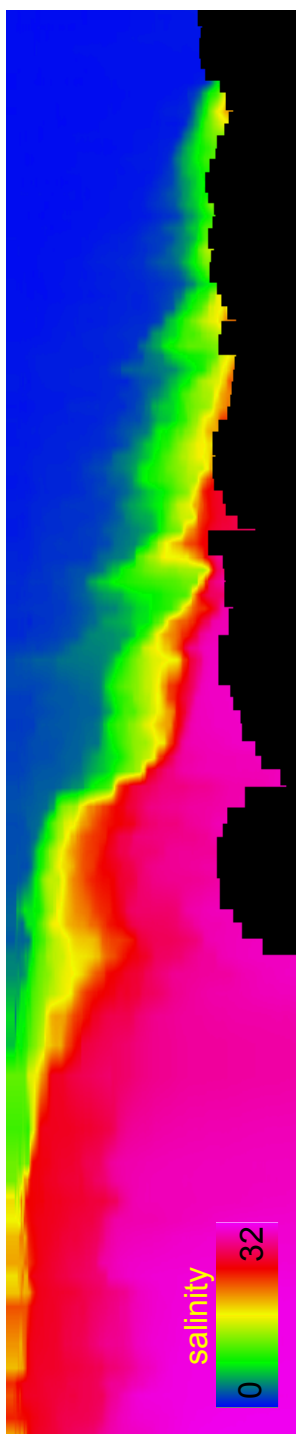
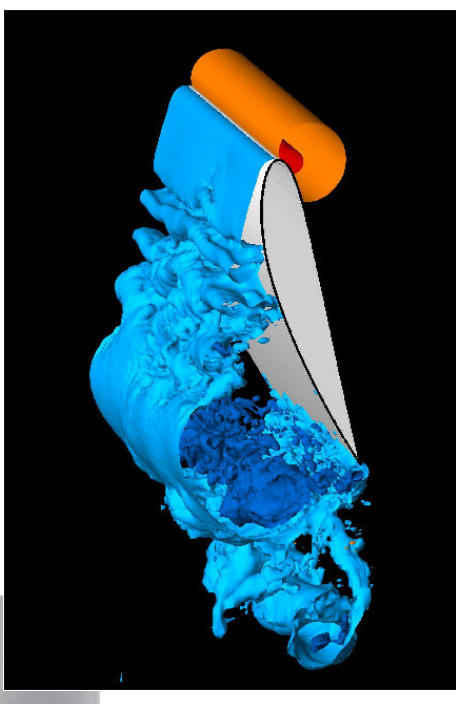
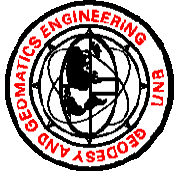
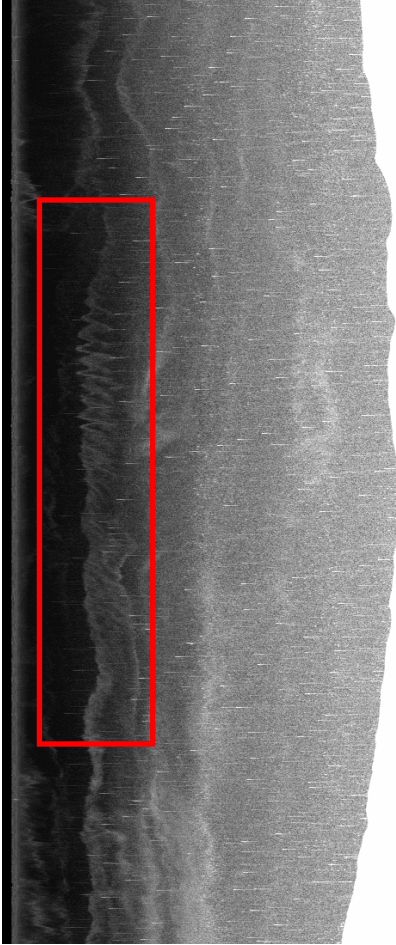


Image: P. Salzgeber

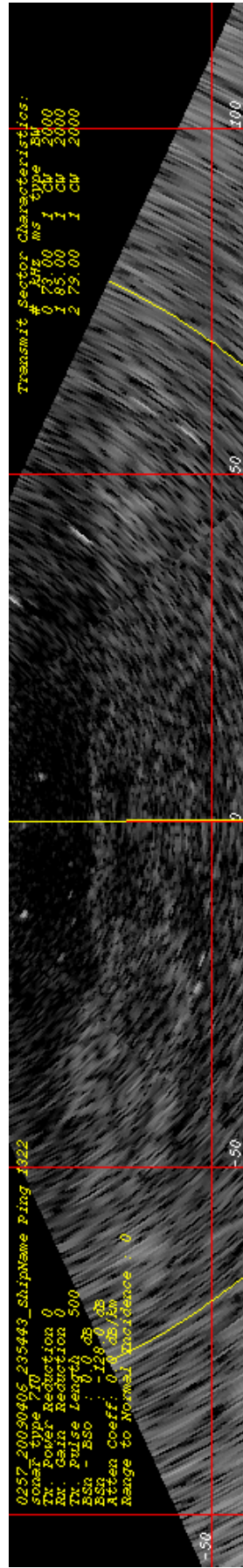
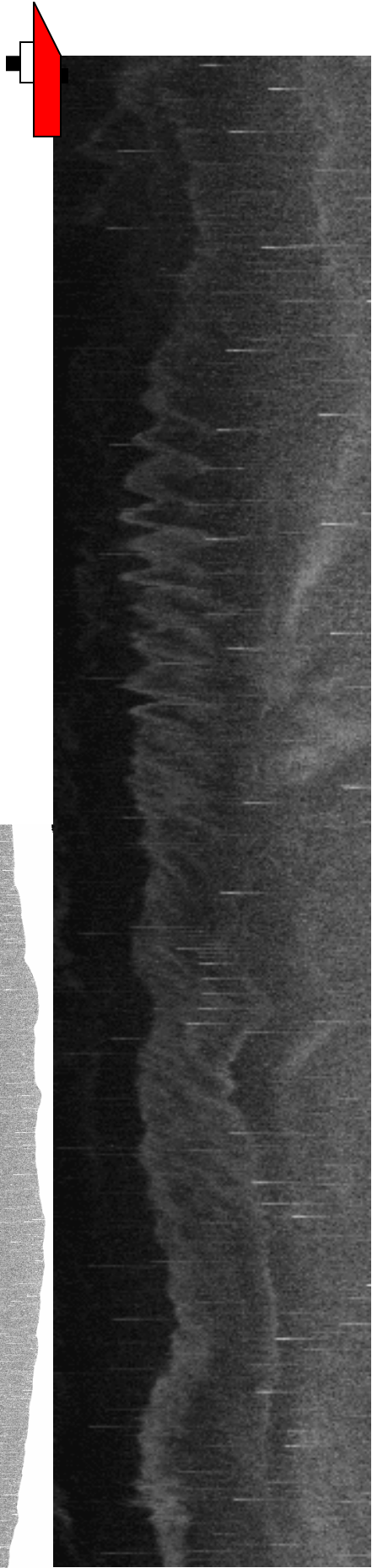
Animated image of the Moon's surface showing the effects of the Earth's turbulent atmosphere on the view through a telescope





CCGS Vector

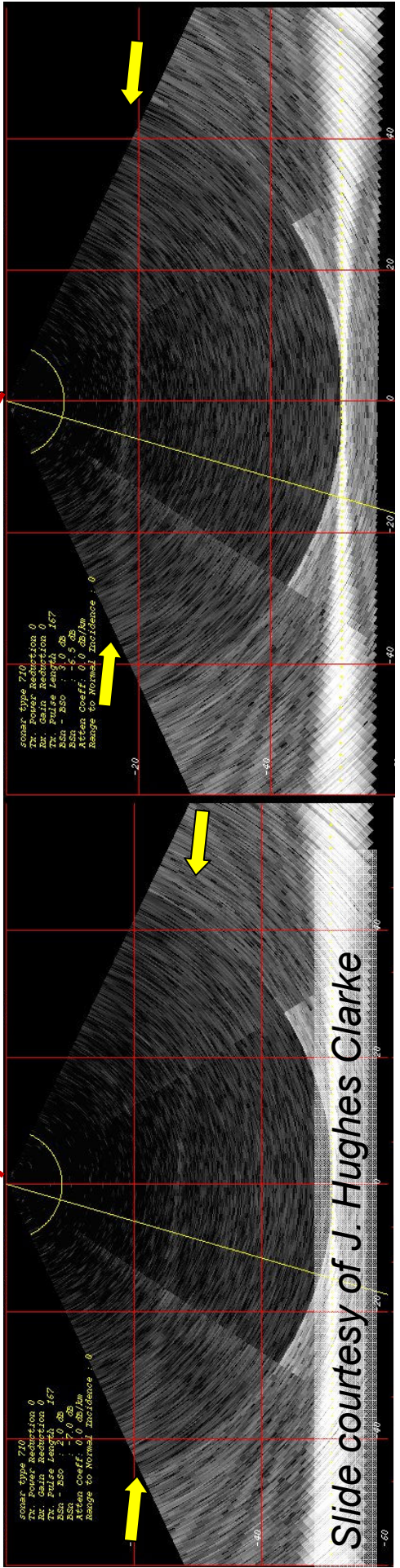
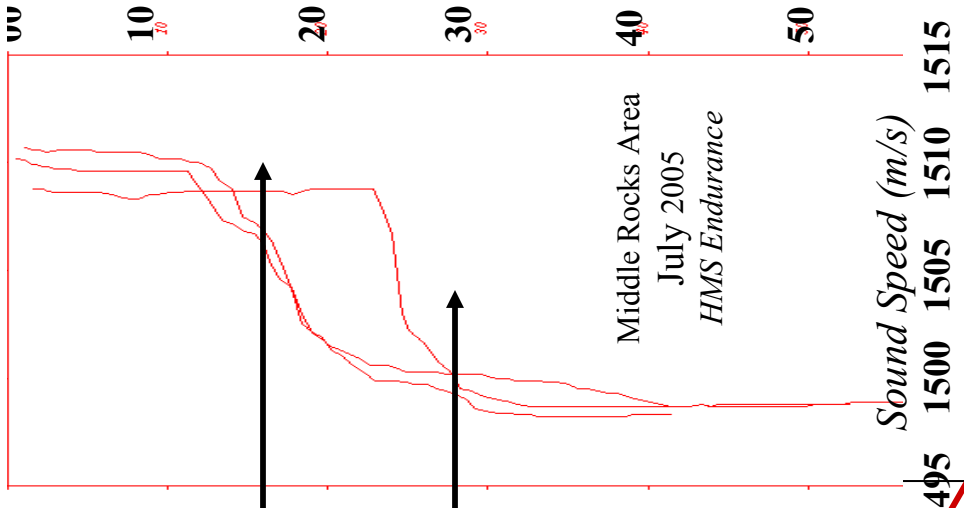
EM710 Watercolumn Imagery,
Race Rocks, April 2009

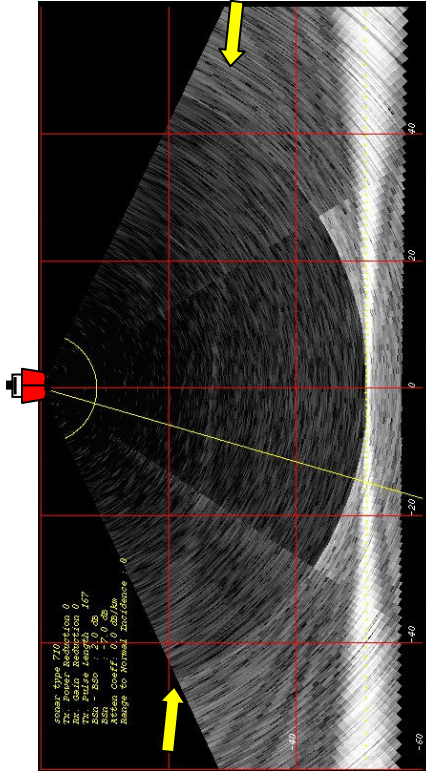


Tilted Interfaces

The interfaces we image are not necessarily flat.

Not really the SVP sensor's fault, problem is invalidity of assumptions in raytracing model.





Effect of Tilted Interfaces

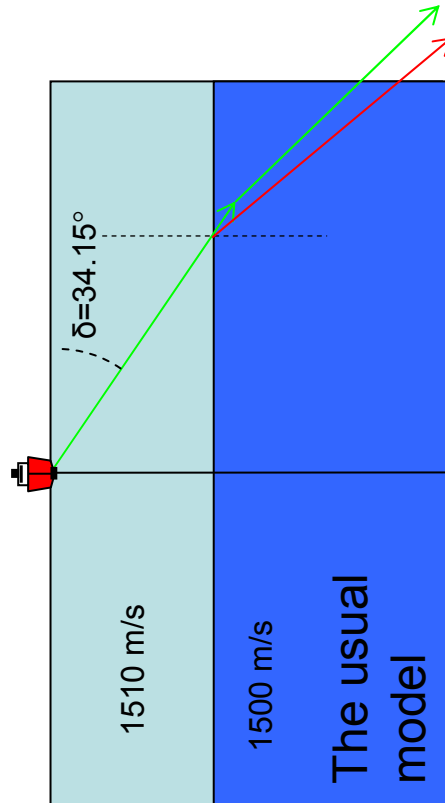
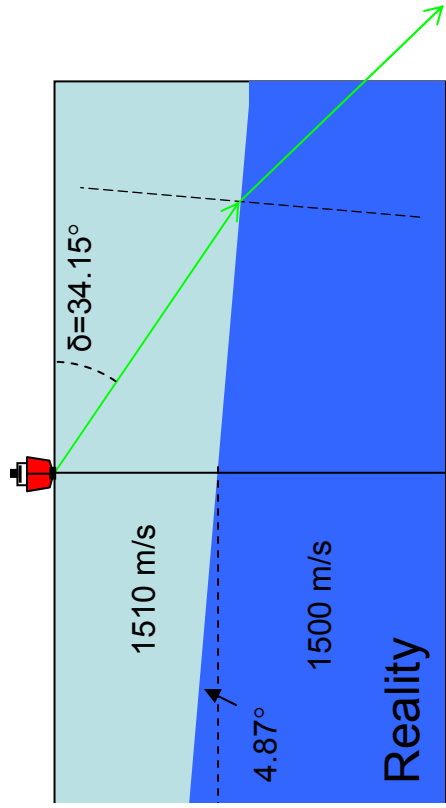
Problem:

Assumption of horizontal homogeneity is invalid: the watermass I can measure below me is **not** representative of the watermass across the entire swath.

Effect:

- We refract by the wrong amount and at the wrong depth for all beams away from nadir.
- Incorrect refraction angle gives angular error, thus error grows with depth.
- Nadir refracts slightly (we always assume it doesn't).

Ray direction is incorrect in bottom layer by 0.11°!!!

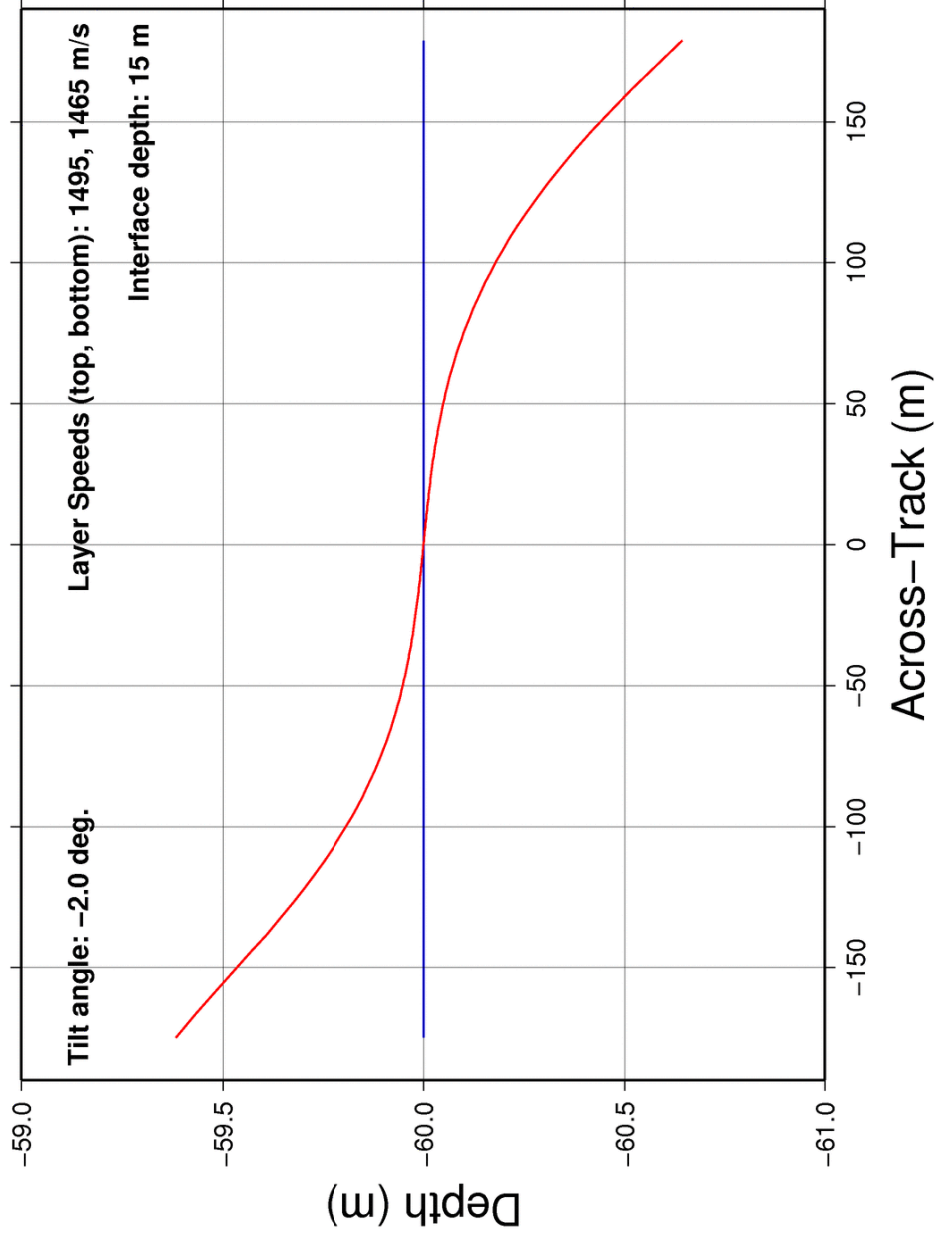


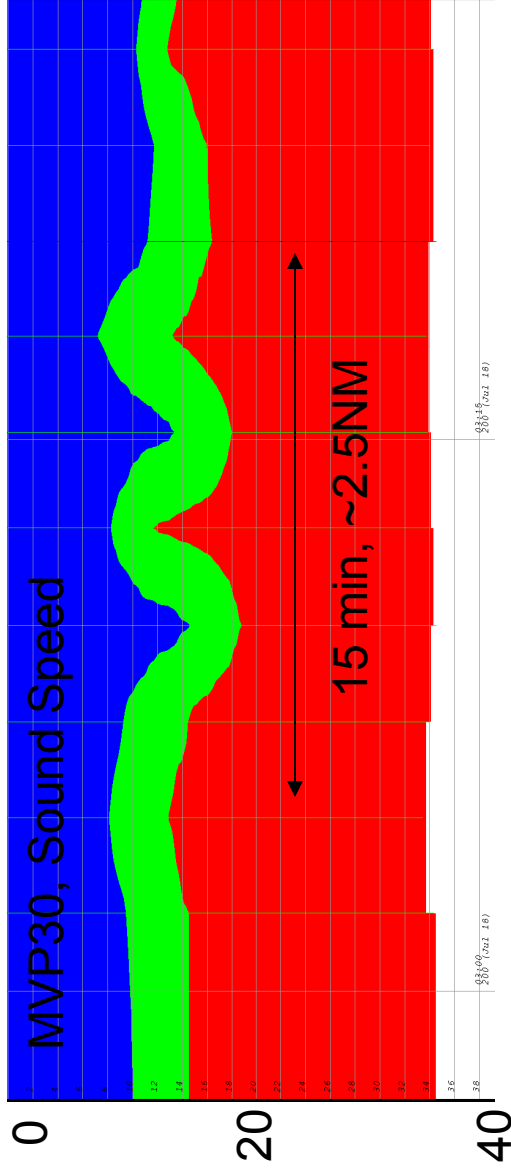
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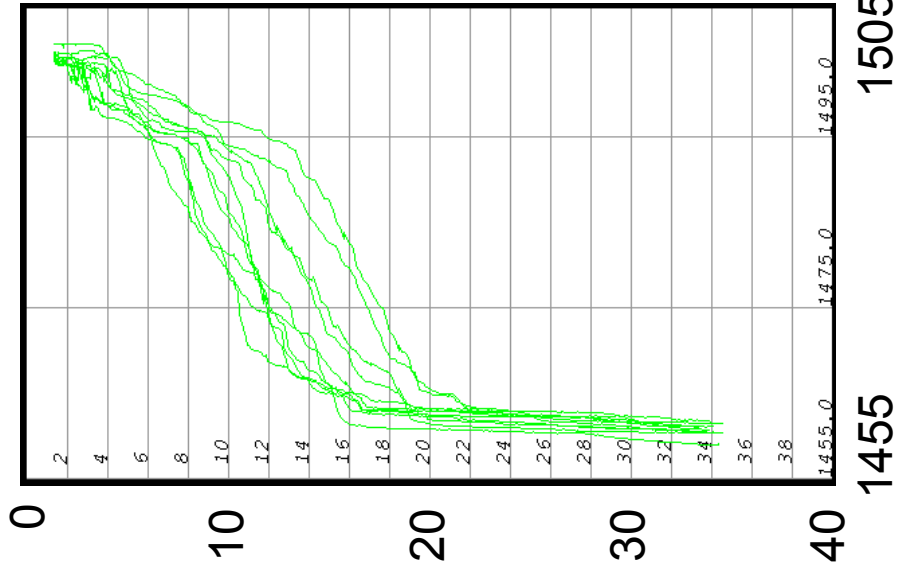
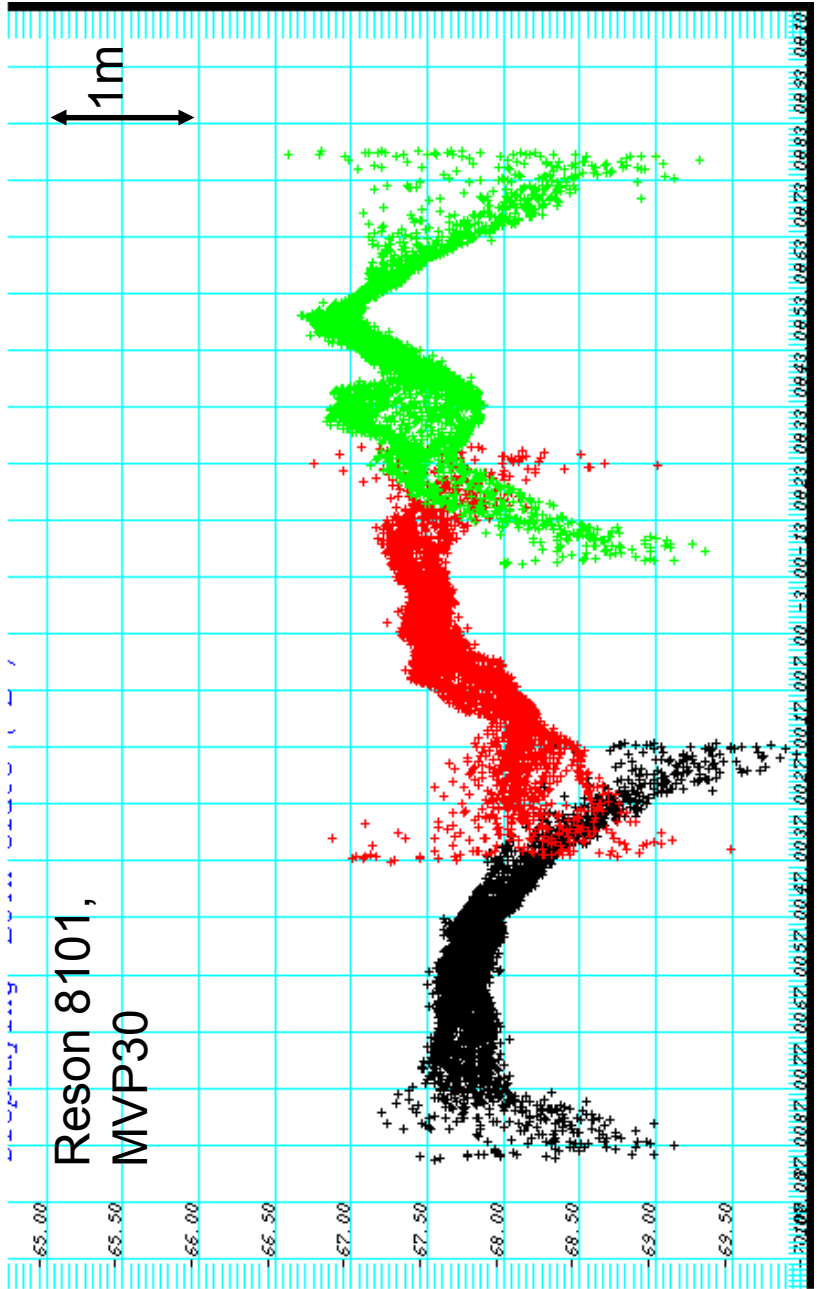


Effect of Tilted Interfaces

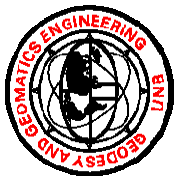




Effect of Tilted Interfaces (real example)



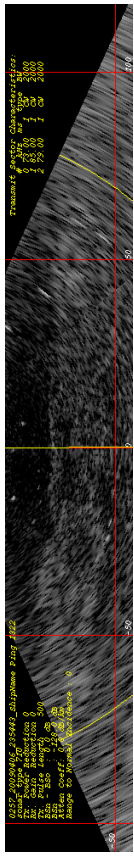
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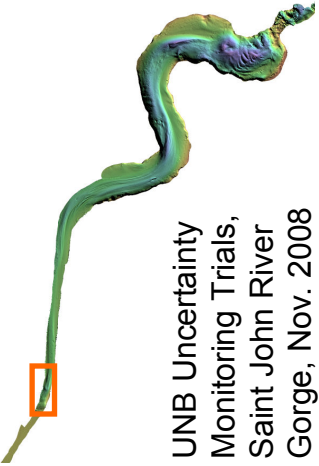
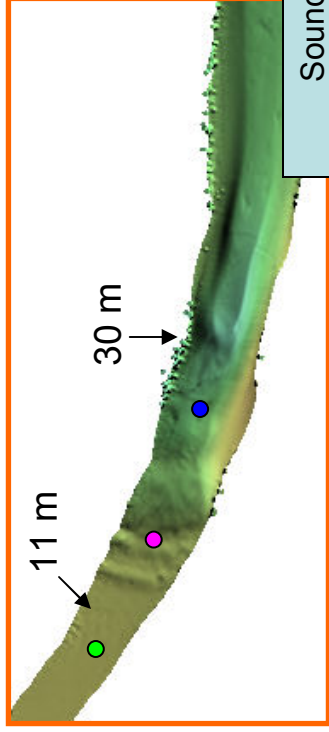
Practicalities:

How to help the Hydrographer?

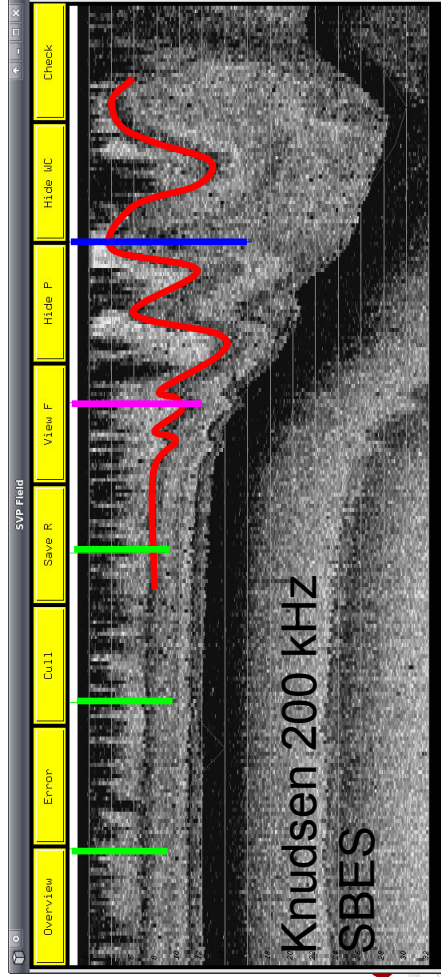
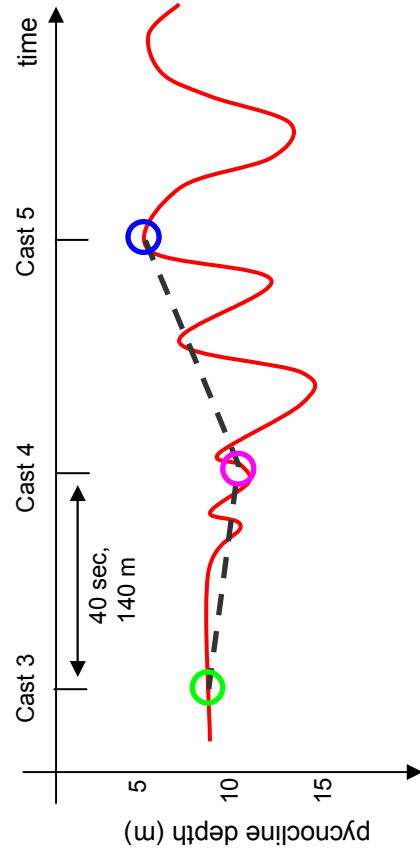
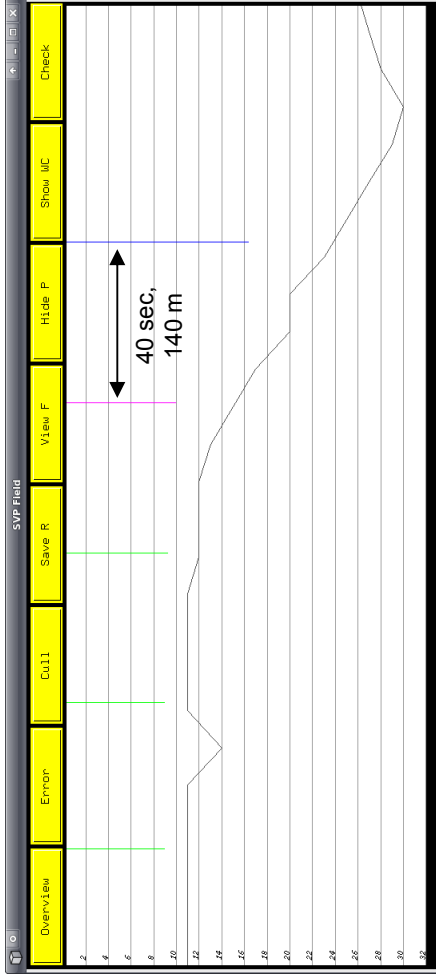
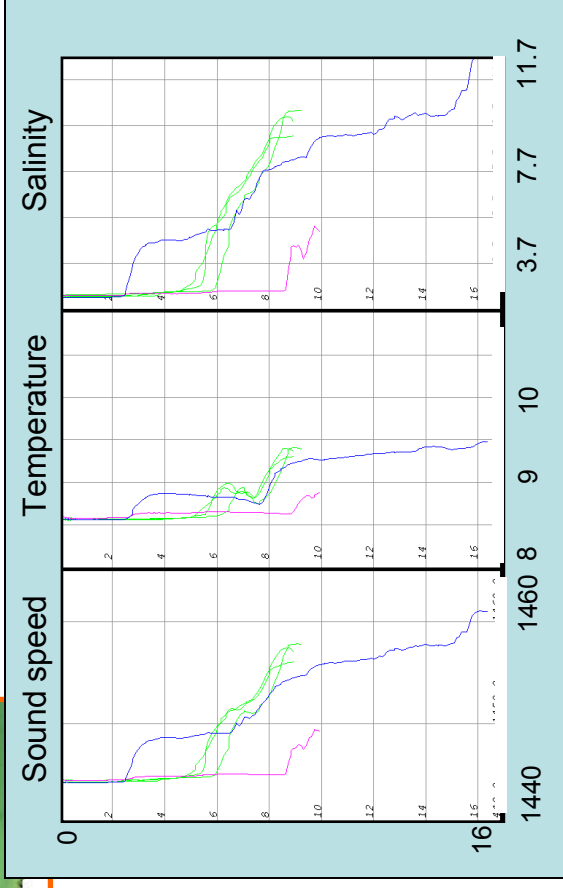
- What a mess, how can we possibly ever hope to work in such difficult areas?
- Work harder
 - Decrease line spacing
 - Collect more casts
- Work smarter
 - MVP, Acoustics and Uncertainty Wedge Analysis for REA
 - Identify favourable survey windows, take advantage of them
 - Identify poor survey conditions, work around them



Challenging Conditions



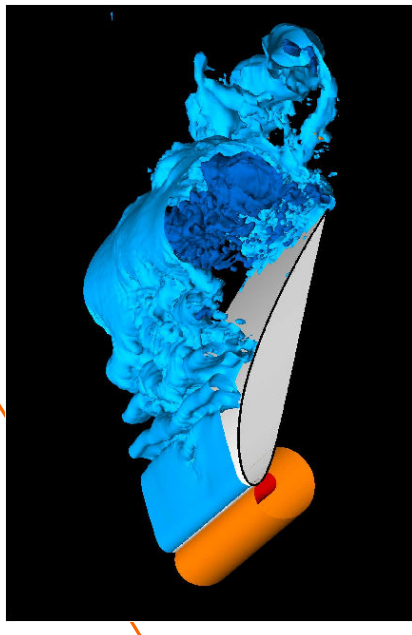
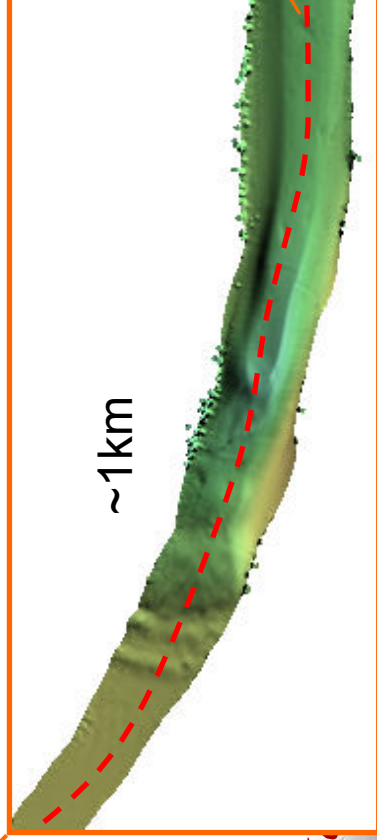
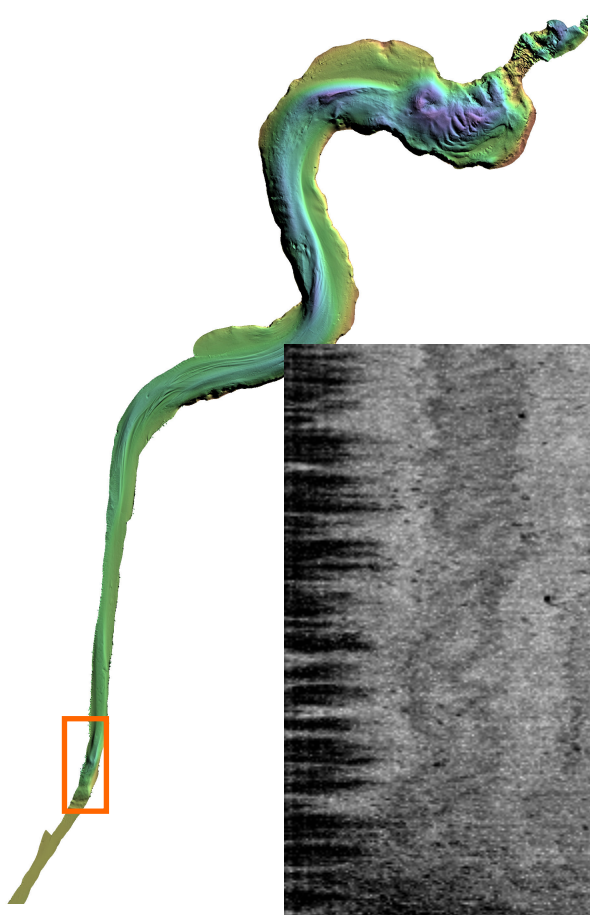
UNB Uncertainty Monitoring Trials, Saint John River Gorge, Nov. 2008



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Finding Favourable Survey Windows



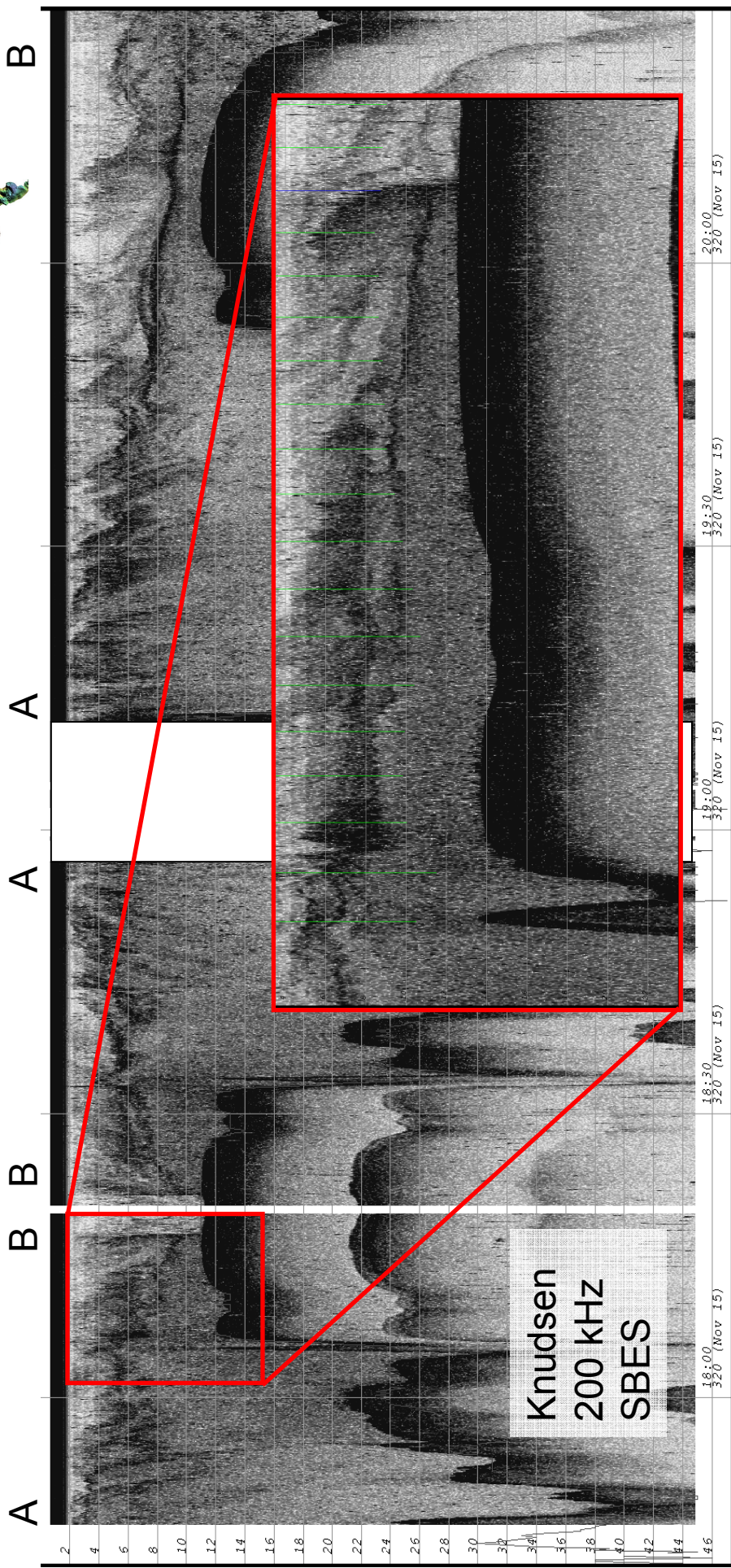
Ocean M

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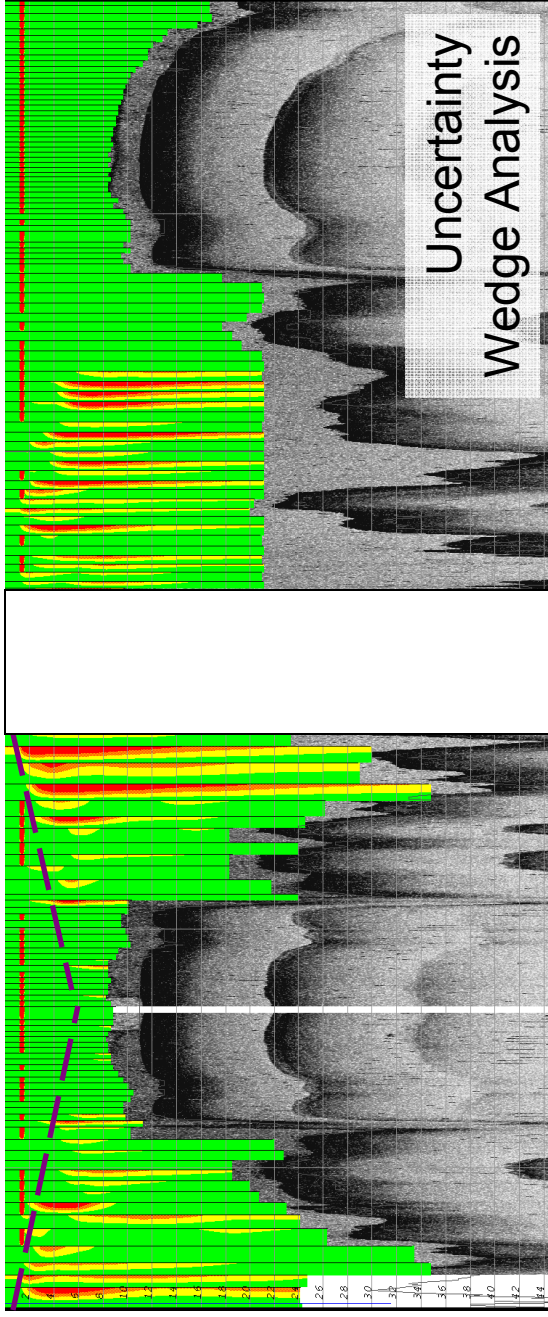
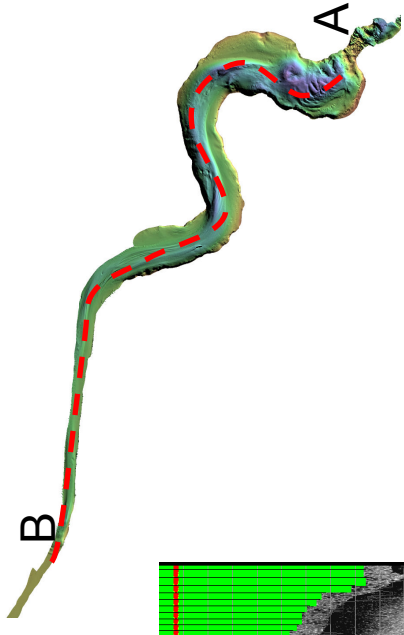
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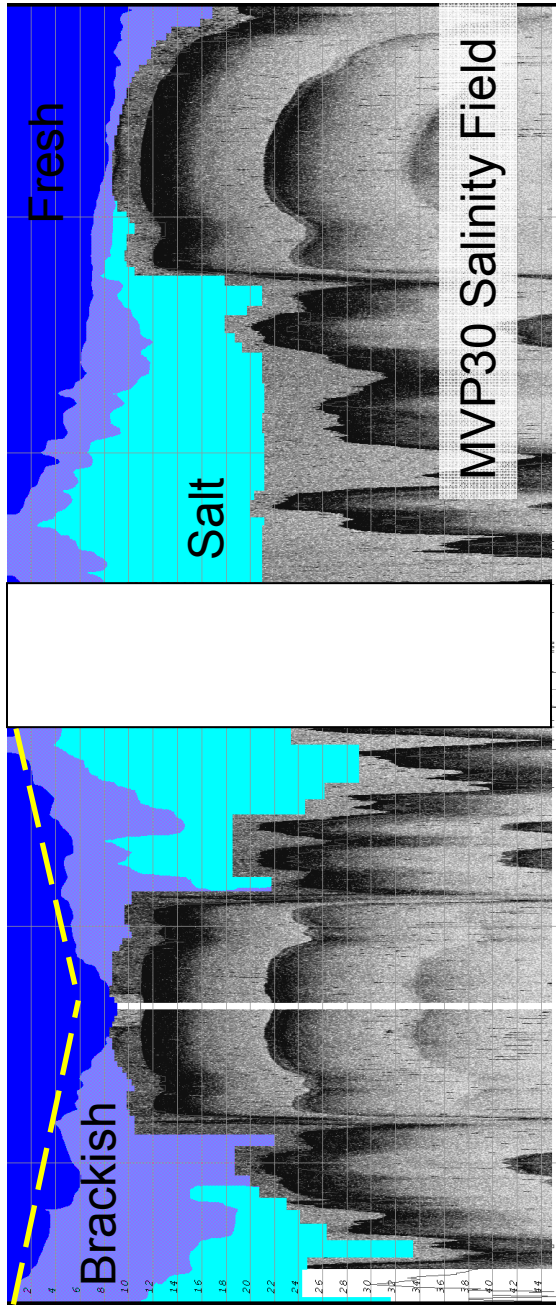
Realizing what variability affects you most



Realizing what variability affects you most

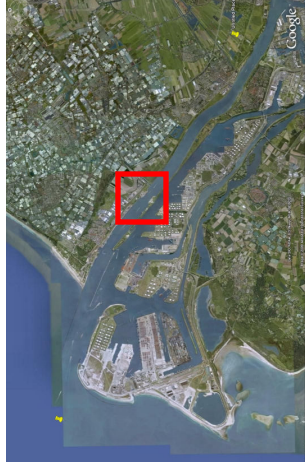


← Pass 1 → Pass 2 → Pass 3 →

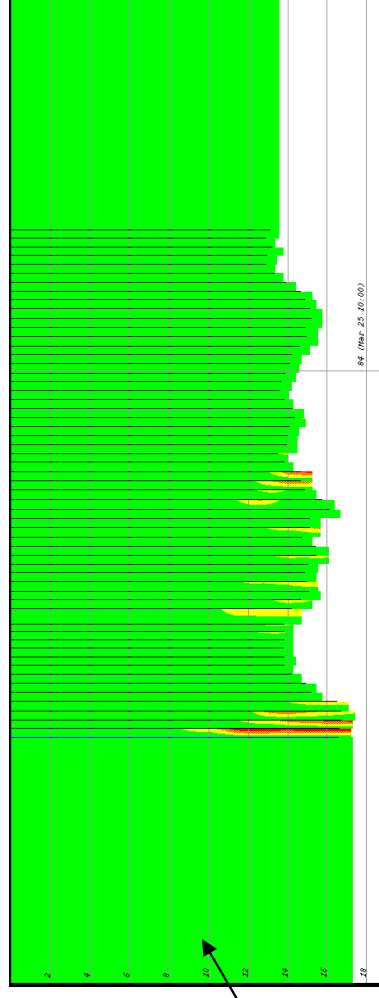
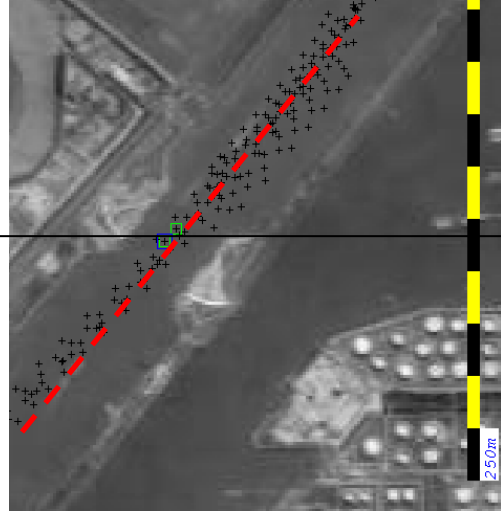
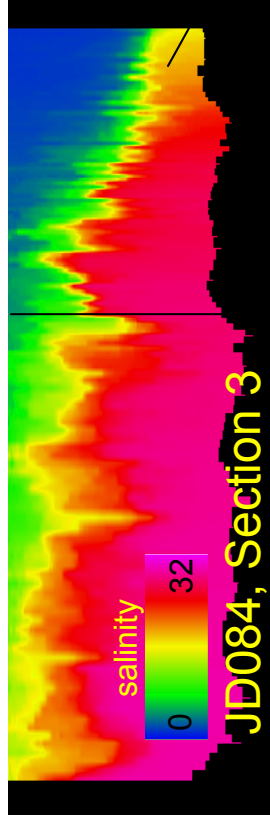


← Pass 1 → Pass 2 → Pass 3 →

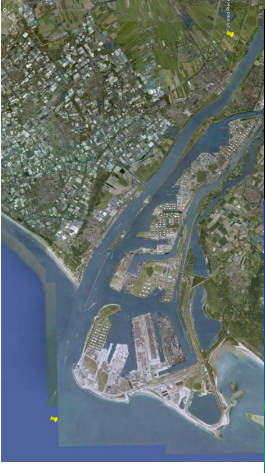
Identify low turbulence tidal survey windows



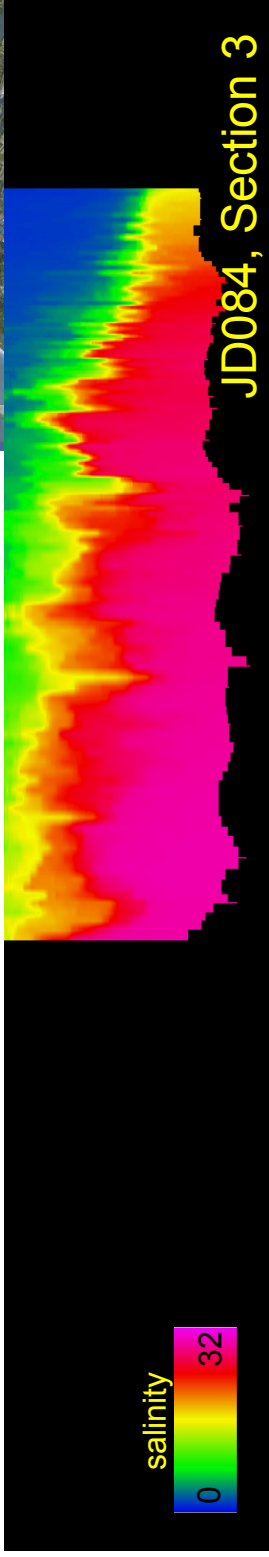
Rijkswaterstaat Rotterdam Waterway
MVP-30 Trials, March/April 2009



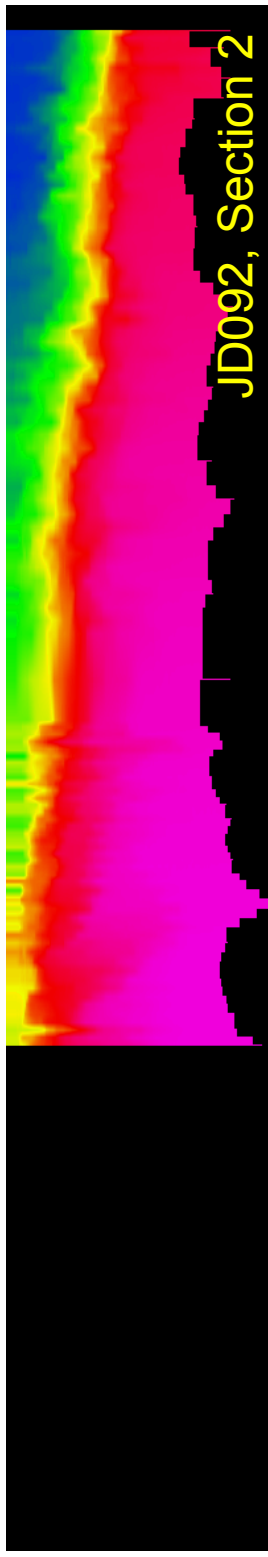
Flood vs. Ebb?



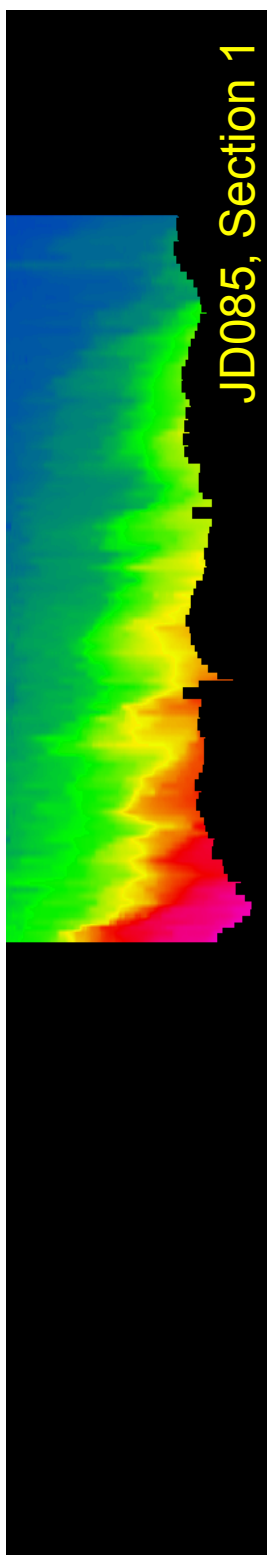
Slackening
high water



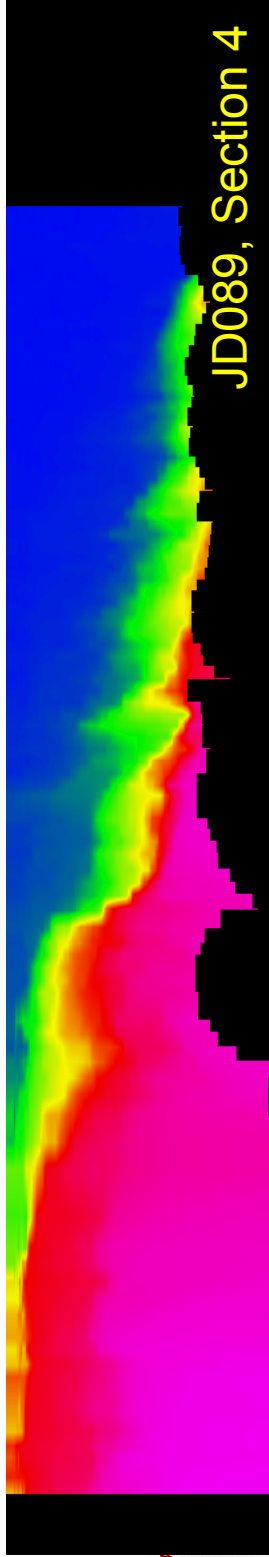
Falling tide



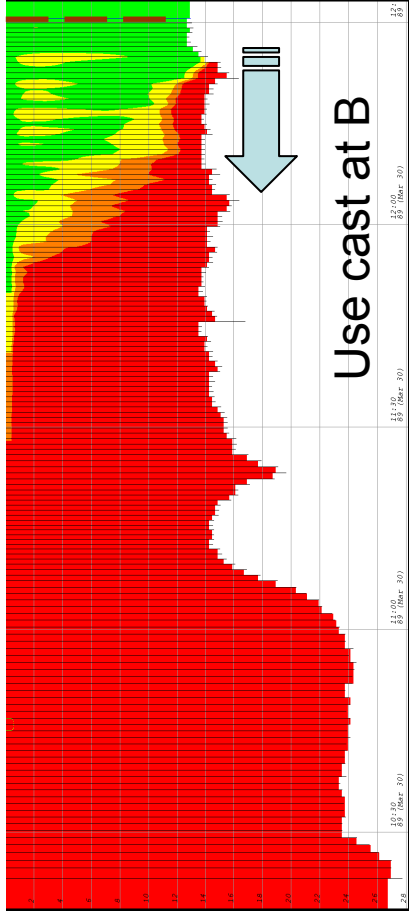
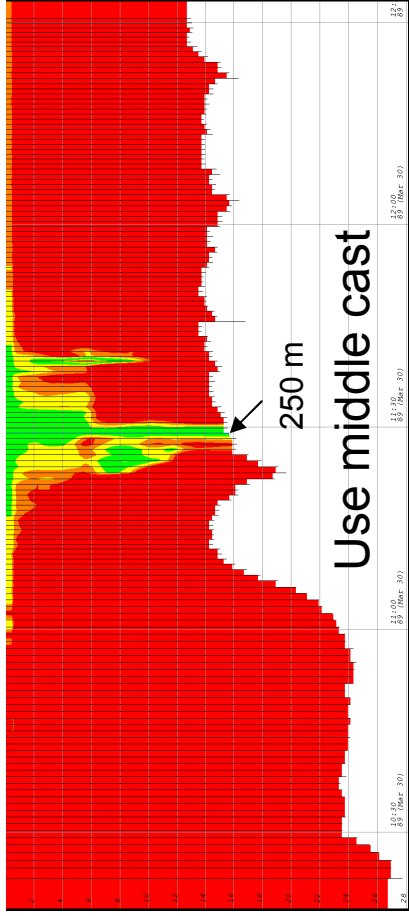
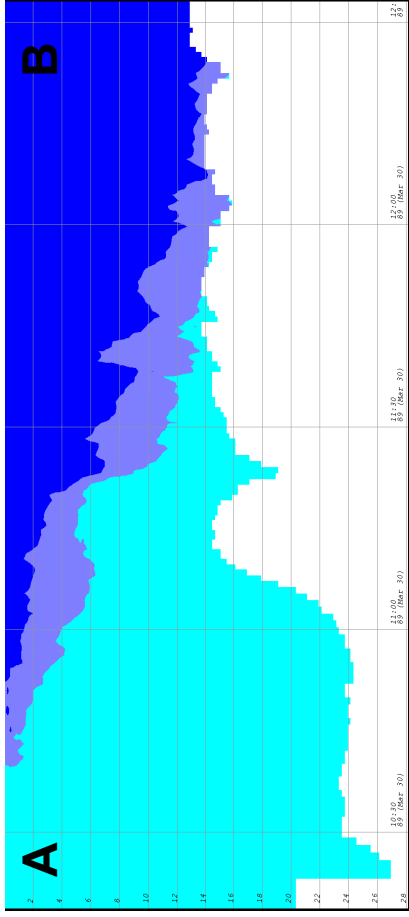
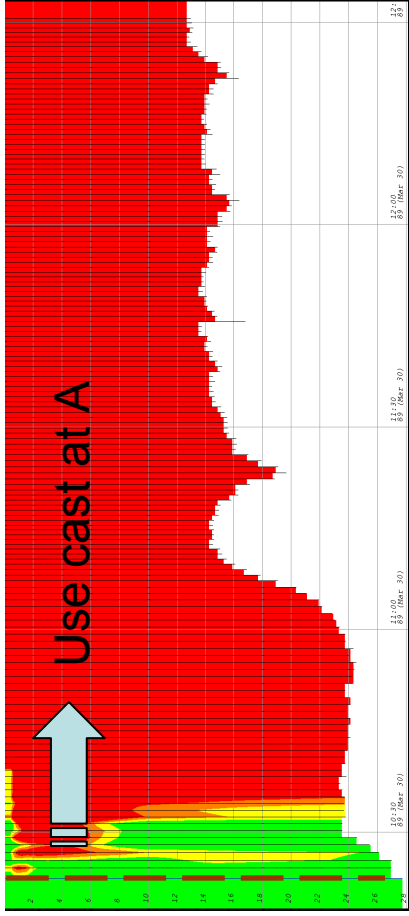
Middle of
double low
(aggrer)



Beginning
to rise

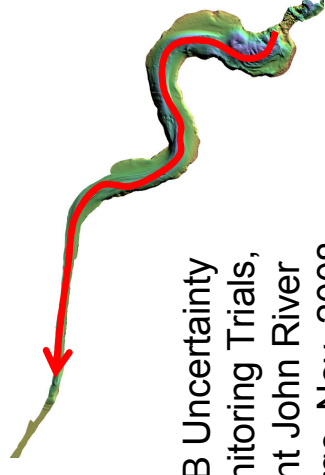
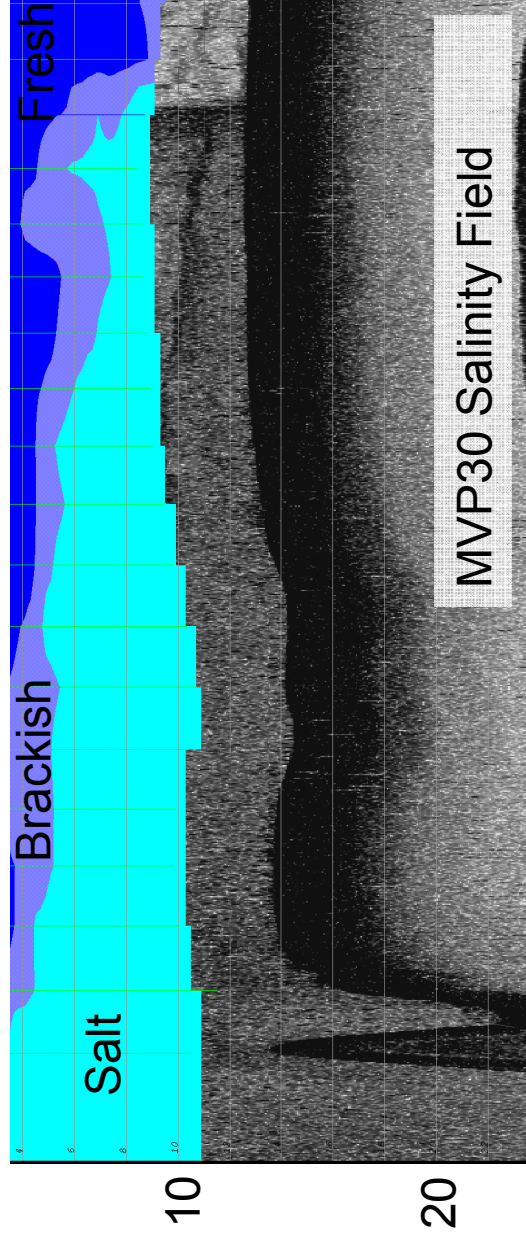
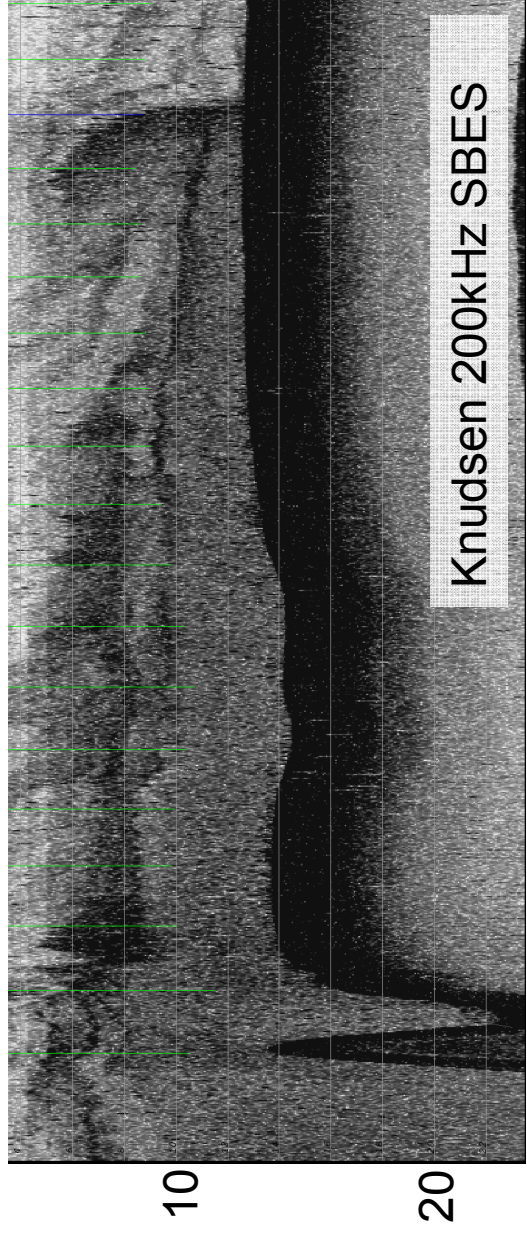


MVP for REA



Analysis for 150° angular sector, 0.3m draft with surface sound speed probe

Acoustics for REA



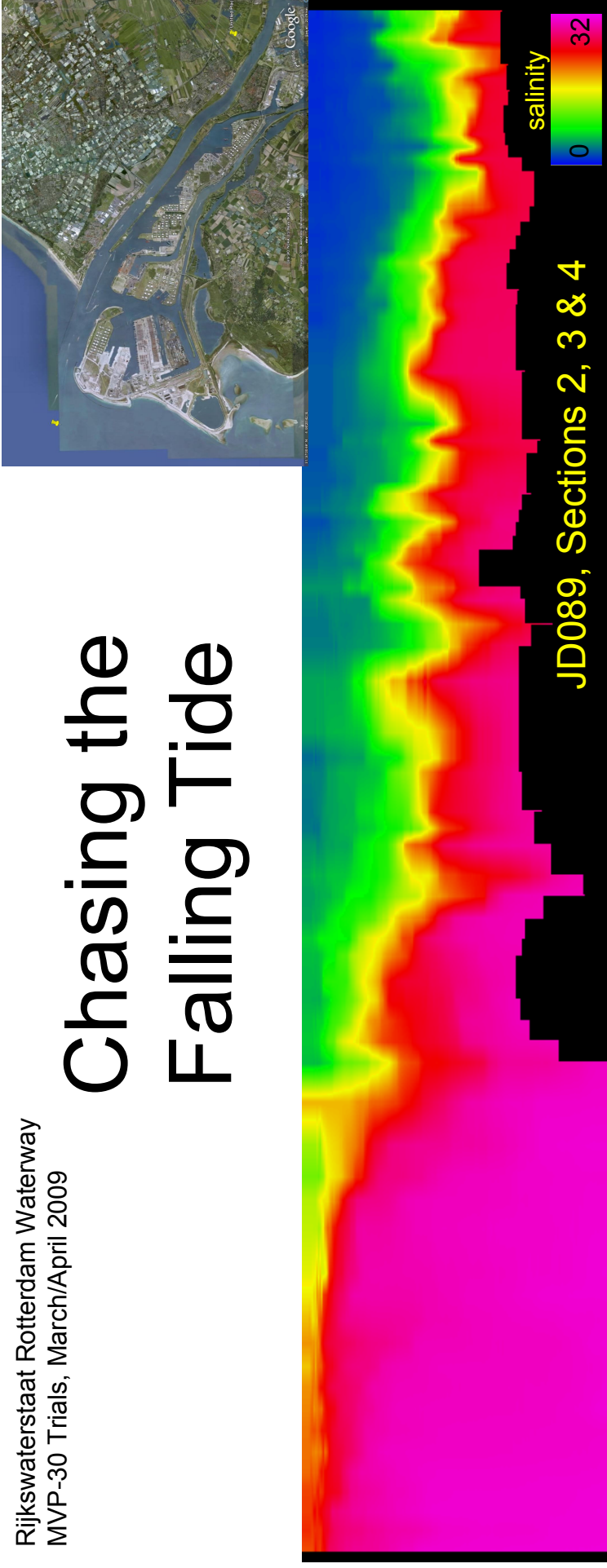
UNB Uncertainty
Monitoring Trials,
Saint John River
Gorge, Nov. 2008

Hunting for the end of the Salt Wedge

Use watercolumn
acoustics to hunt for
upstream edge of salt
wedge at high
slackwater.

Confirm with sound
speed cast.

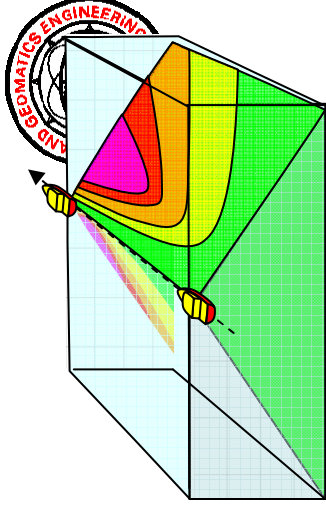
Chasing the Falling Tide



Once you find the edge of the salt wedge, work slightly upstream and chase it out to sea as the river flushes salt water out.

Extreme retreats of the wedge may preferentially occur during spring or neap tides, which could be taken advantage of.

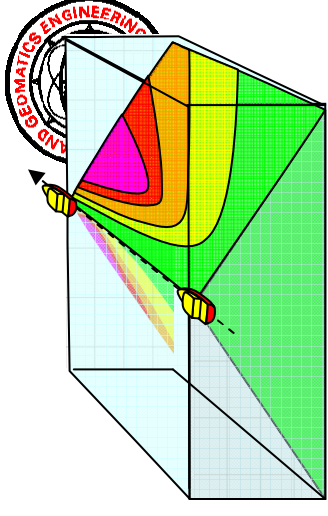
Conclusion (1)



- Ability to monitor watercolumn conditions as a source of uncertainty gives unprecedented control over refraction type biases
- Surveyors can have confidence in refraction solution *in real-time*

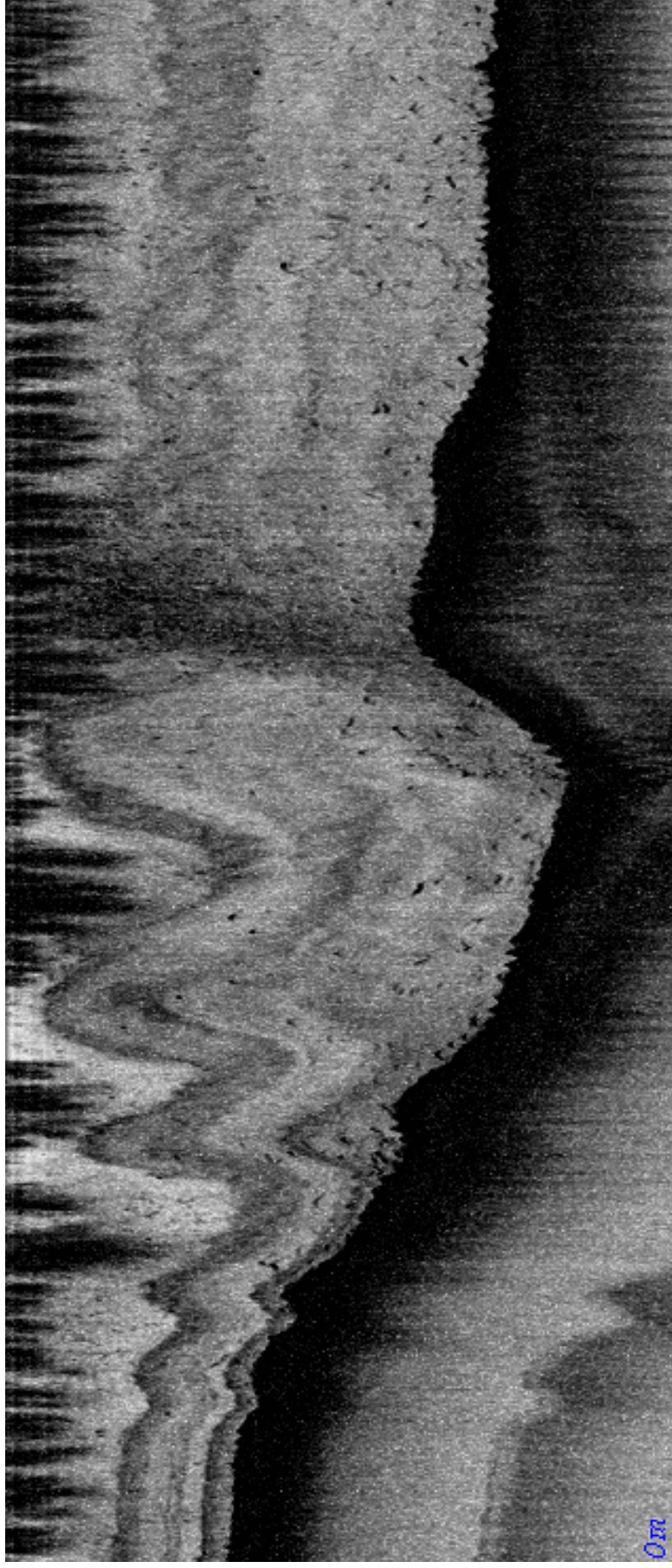
Conclusion (2)

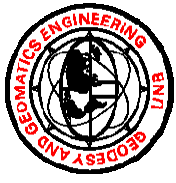
- Acoustic reconnaissance can help you pick your battles, such information allows us to understand
 - underlying causes of variability,
 - the temporal and spatial nature of that variability
 - ...and to react accordingly
- MVP, Acoustics and Uncertainty Wedge
- Analysis is a potent tool for MBES Survey REA
- This type of information can help allocate resources such as MVP more intelligently and efficiently: *work smarter, not harder*



Refraction doesn't need to be a mystery

THANK YOU!!





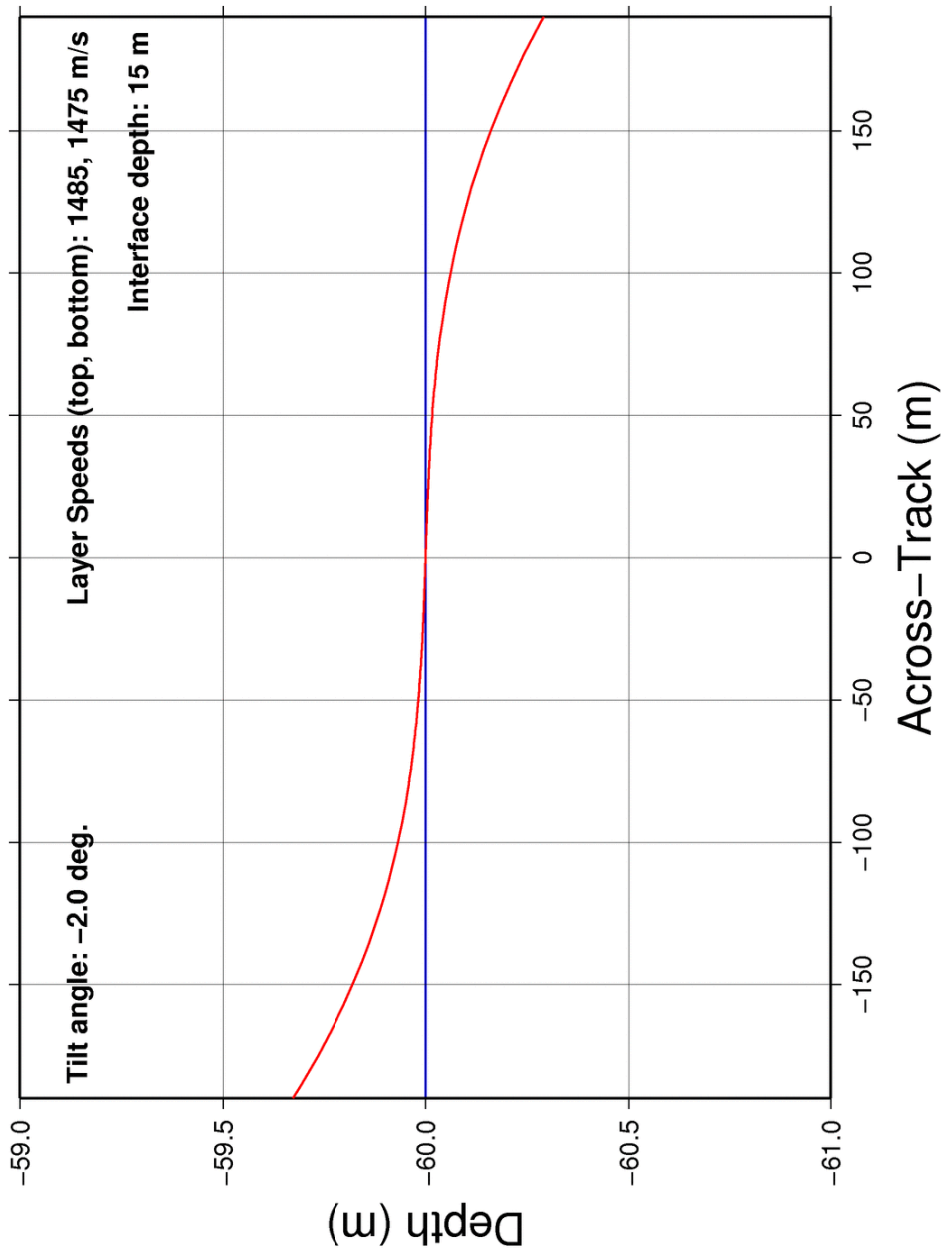
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 - Route Survey Office (Canadian Navy)
 - Royal (U.K.) Navy
 - U.S. Geological Survey



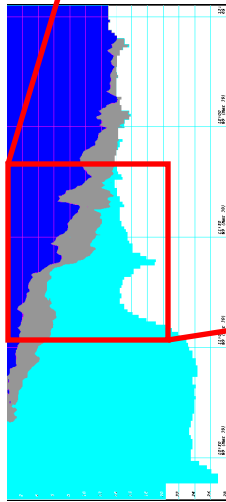


Effect of Tilted Interfaces (2)

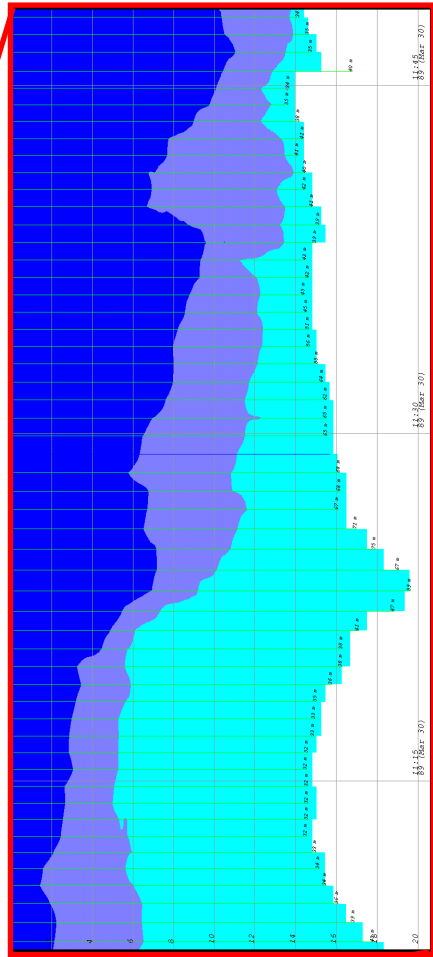




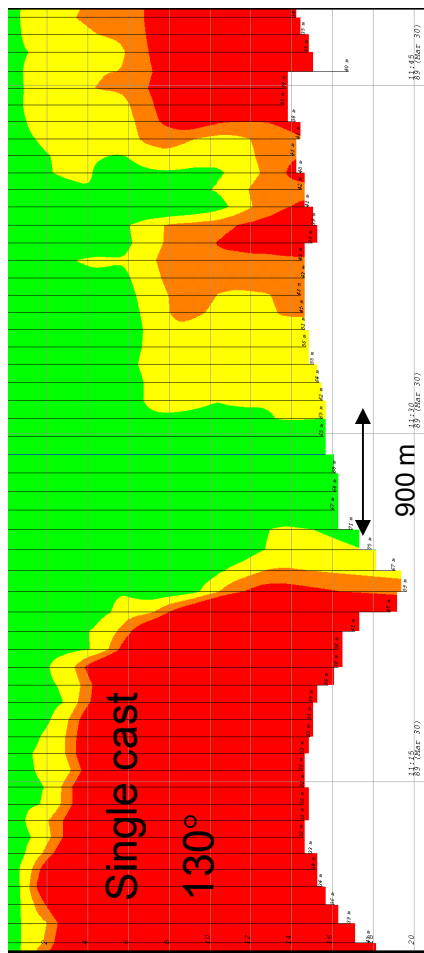
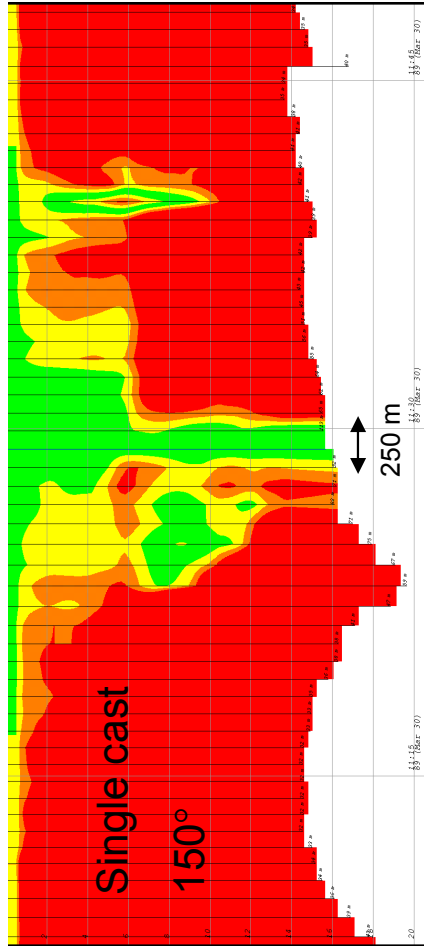
MVP for REA (2)

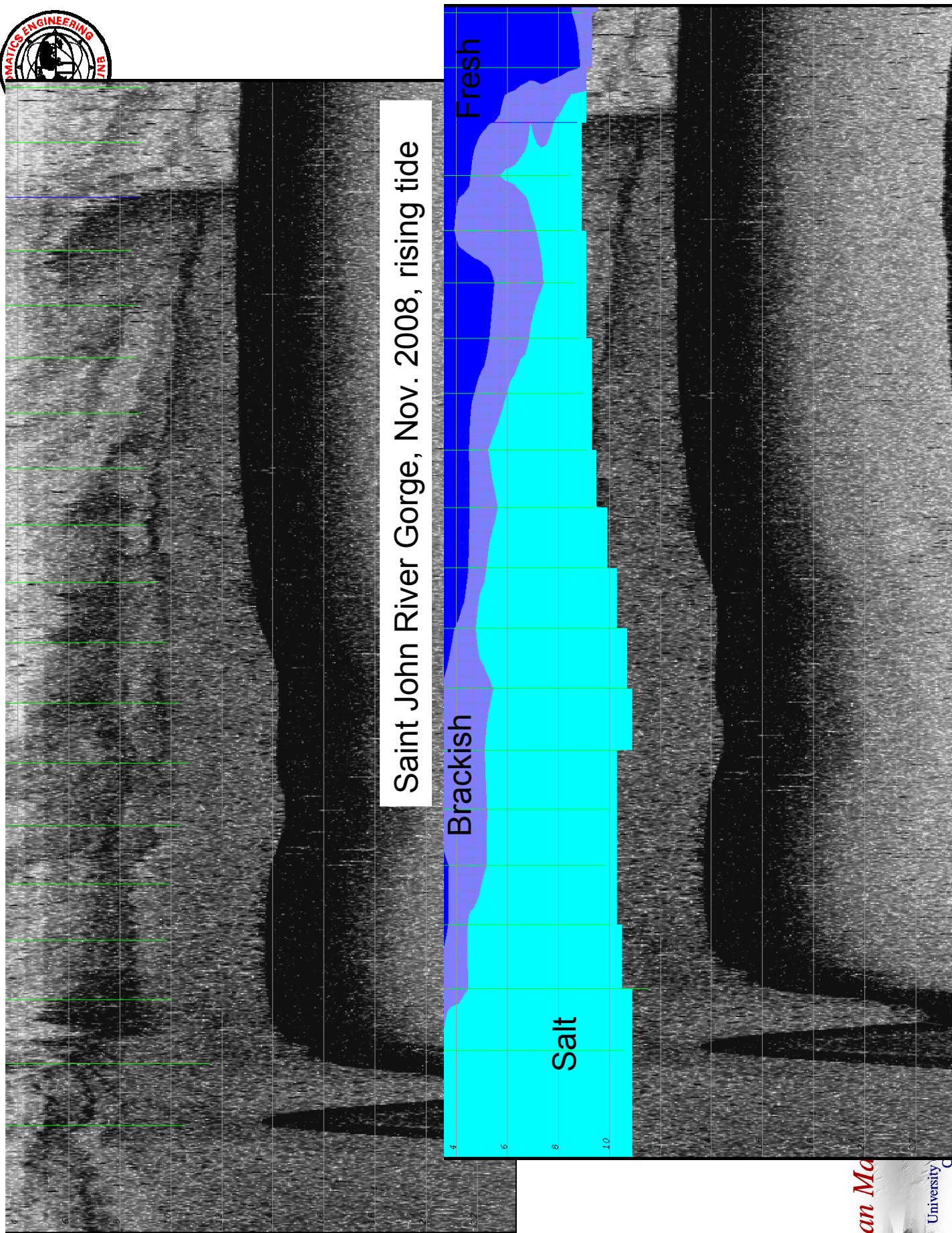


MVP 150°



84 (Nov. 25, 07:00)





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