# Is air-sea interaction inhibited in tropical upwelling systems ?


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SOPRAN
Surface Ocean Processes in the Anthropocene

SFB 754

NORDATLANTIK

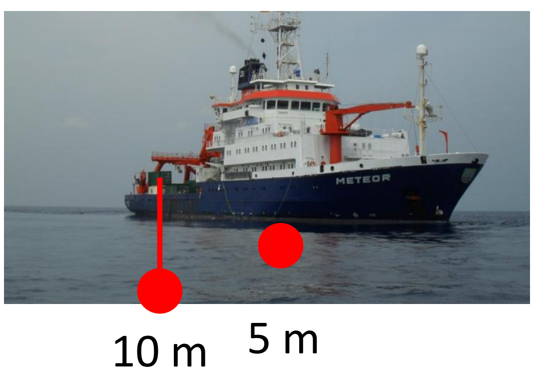
GROOM

Maybe the more precise question is:

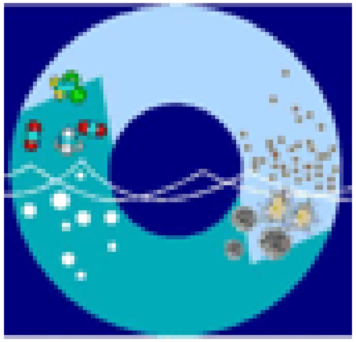
**Is air-sea gas exchange overestimated in tropical upwelling systems when using common gas exchange parametrizations?**

This question is motivated by our efforts to quantify greenhouse gas emissions from upwelling systems and oxygen minimum zones.

The usual technique is measuring mixed layer concentrations and then use bulk formulae. The results depend critically on the used parametrization for the gas transfer velocity kw.




$$\Phi = k_W \cdot \left(c \;\; - c_{100}\right)$$



Maybe the more precise question is:

**Is air-sea gas exchange overestimated in tropical upwelling systems when using common gas exchange parametrizations?**

## Outline

**Indications that air-sea gas exchange might be lower than calculated:**

1. **$N_2O$ surface layer budget in Canary upwelling system**
2. **Productivity estimates in Canary upwelling system**
3. **Observed diurnal stratification of surface layer**

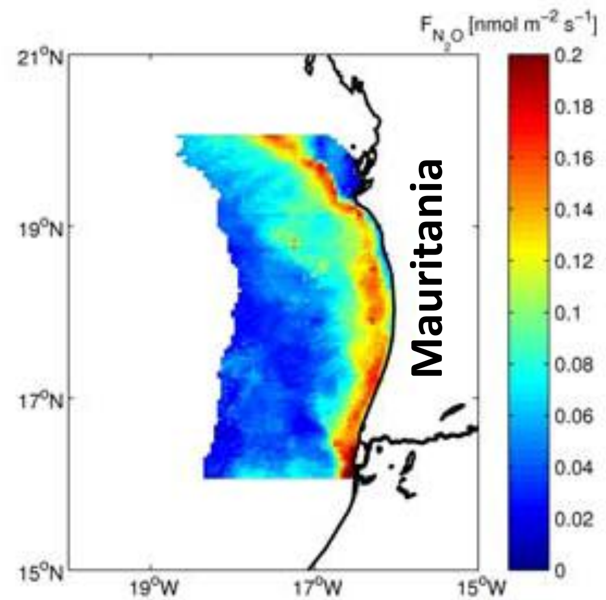
**Planned research Nov. 2012 to Feb. 2013, Meteor cruises off Peru.**

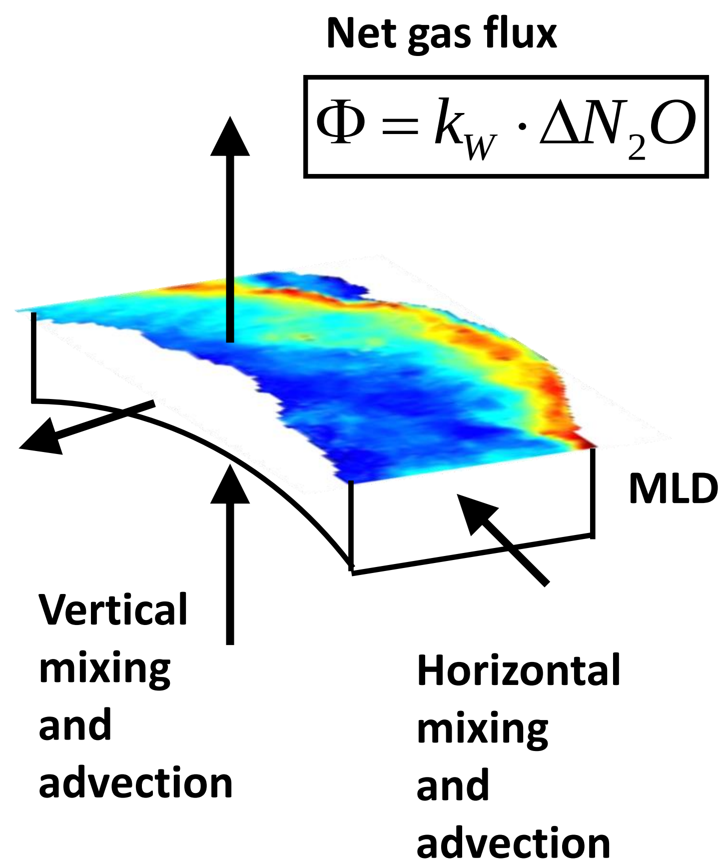
# Indication 1

# $N_2O$ budget discrepancy in Canary upwelling system

**[study of A. Kock et al. 2012]**

**After 3 campaigns in 2007/2008 measuring**
**$N_2O$ and diapycnal mixing:**
**Define a mixed layer box for an $N_2O$ budget.**
**Delta $N_2O$ parametrized from SST anomalies.**



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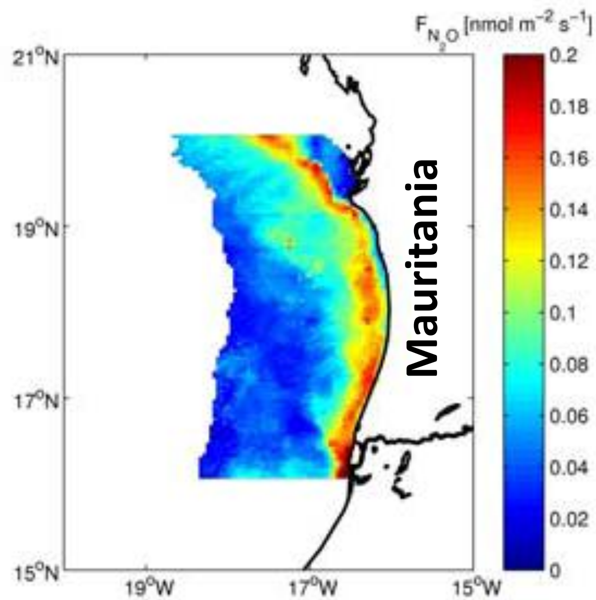


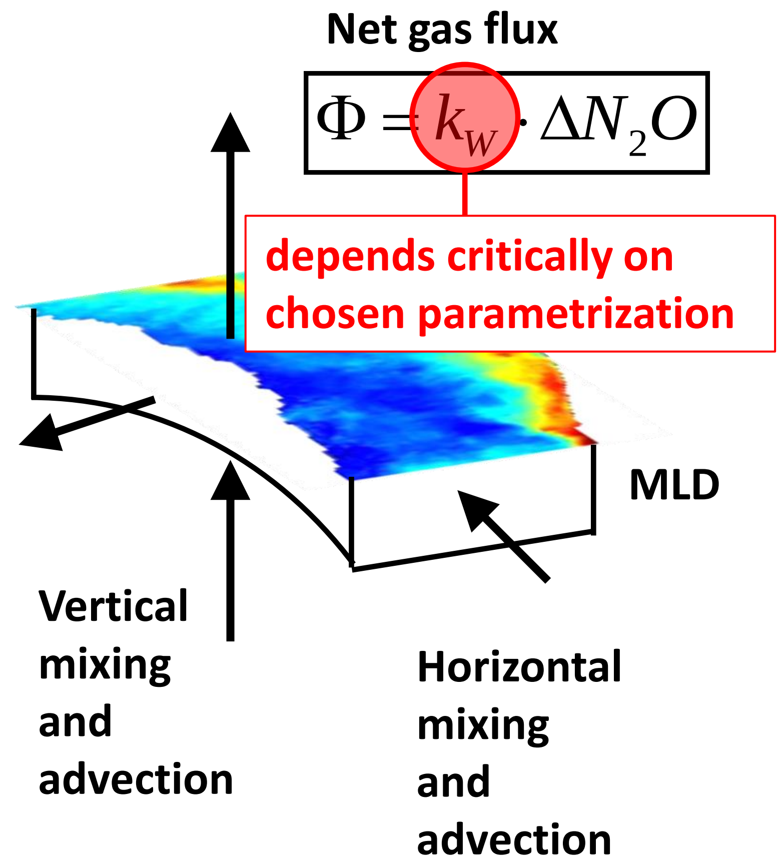

# Indication 1
# $N_2O$ budget discrepancy in Canary upwelling system
**[study of A. Kock et al. 2012]**

**Comparing different parametrizations for gas transfer velocity kw:**

| Parametrization | Outgassing : supply |
|---|---|
| Liss and Merlivat (1986) | 2.3 |
| Wanninkhof (1992) | 4 |
| Nightingale (2000) | 3.3 |

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| Liss and Merlivat (1986) | 2.3 | 33 |
| Wanninkhof (1992) | 4 | 80 |
| Nightingale (2000) | 3.3 | 61 |

**Maximum conceivable $N_2O$ production in Mauritanian mixed layer is about 10 nmol/kg/a.**

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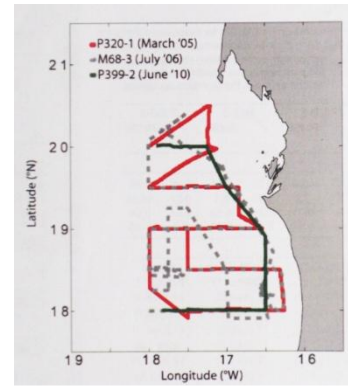
| Liss and Merlivat (1986) | 2.3 | 33 |
| Wanninkhof (1992) | 4 | 80 |
| Nightingale (2000) | 3.3 | 61 |
| Tsai and Liu (2003) | 0.9 | -1 |

**Tsai and Liu (2003) is particularly for the case of surface slicks / surfactants and takes into account their function as a gas exchange barrier.**
**The investigated area was highly biologically productive during the sampling periods, so conditions for surfactants were favourable.**

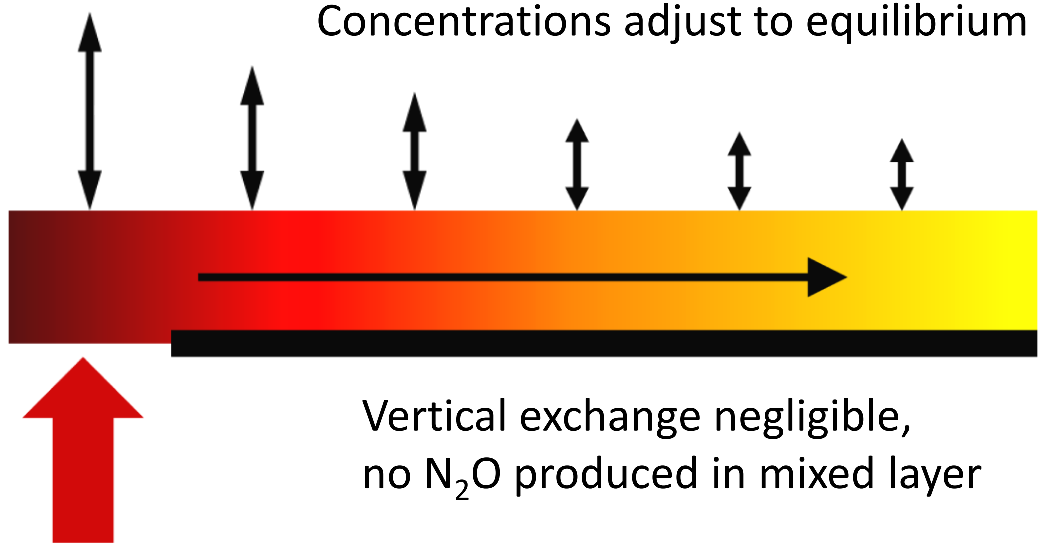
# Indication 2
# Estimating productivity with a triple gas approach
**[study by T. Steinhoff et al. 2012]**




**After 3 campaigns in 2005 to 2010 measuring $N_2O$, $CO_2$ and $O_2$ surface concentrations.**

**How is air-sea gas exchange involved ?**

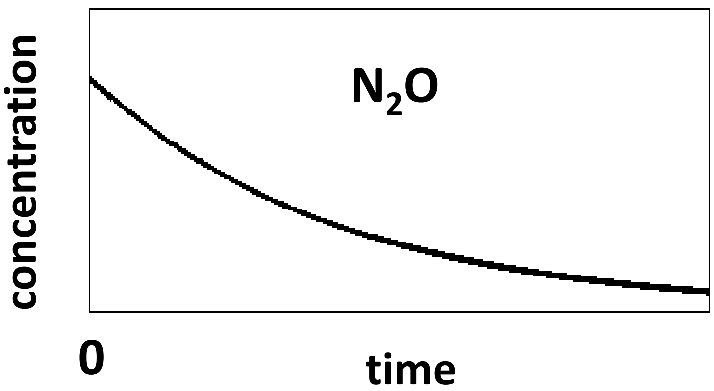
Upwelled water near coast.
$N_2O$ and $CO_2$ supersaturated.
$O_2$ undersaturated.

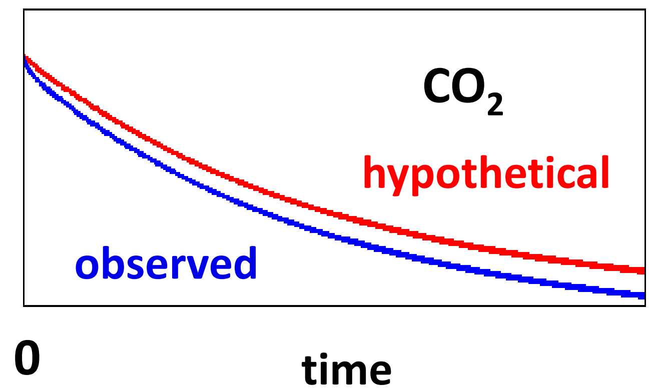


# Indication 2
# Estimating productivity with a triple gas approach
### [study by T. Steinhoff et al. 2012]

Assume a gas exchange parametrization. $N_2O$ assumed as inert now provides a time stamp for the sampled water parcels.

Using the time stamp calculate a hypothetical $CO_2$ concentration (as if $CO_2$ were inert).




The additional observed $CO_2$ loss is interpreted as caused by Net Community Production (NCP). The inferred NCP is critically dependent on the choice of gas exchange parametrization.

**Indication 2**

**Estimating productivity with a triple gas approach**

**[study by T. Steinhoff et al. 2012]**

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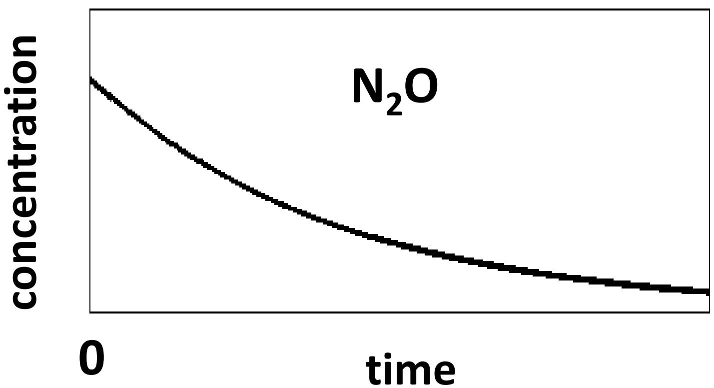
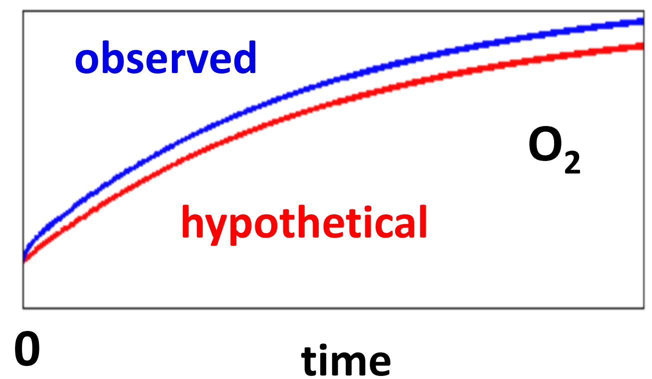
Using the time stamp calculate a hypothetical $O_2$ concentration (as if $O_2$ were inert).




NCP is further constrained by $O_2$ observations and observed nitrate uptake.

**Again the most consistent picture appears using Tsai and Liu (2003).**

# Indication 3
# Diurnal shallow stratification

## Intermezzo

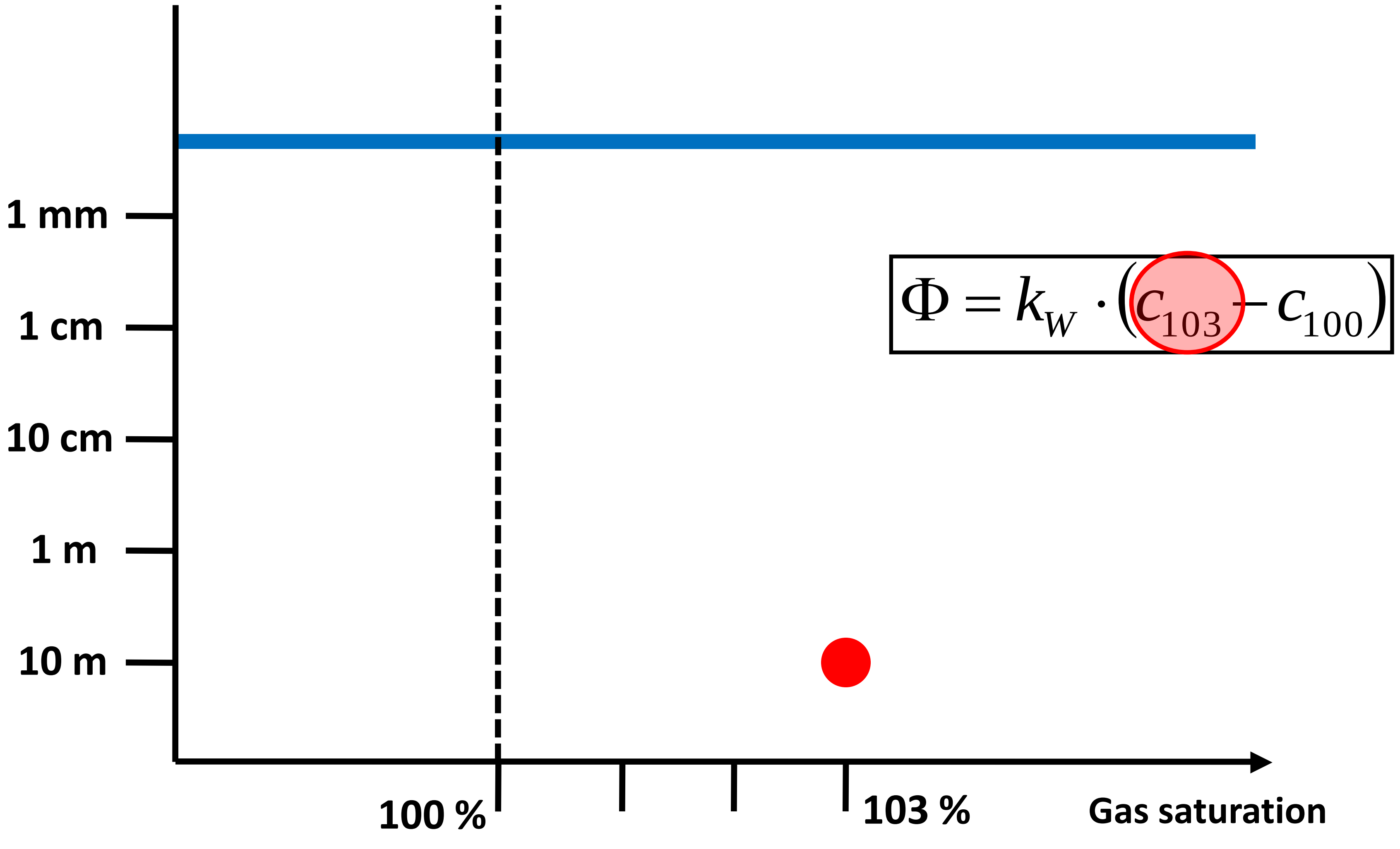
**Surfactants is one candidate to explain measurements in Canary upwelling system.**

**Another reason for reduced air-sea gas exchange could be the existence of gas concentration gradients in the „mixed layer“. We have no direct evidence for this yet.**

**But we often observe stratification in the uppermost meters of the water column in the tropics, particularly in upwelling regions. This stratification undergoes a diurnal cycle.**

**A simple model suggests that diurnal shallow stratification can lead to recognizable reductions of gas exchange.**

# 3a Concentration gradients may cause flux overestimation



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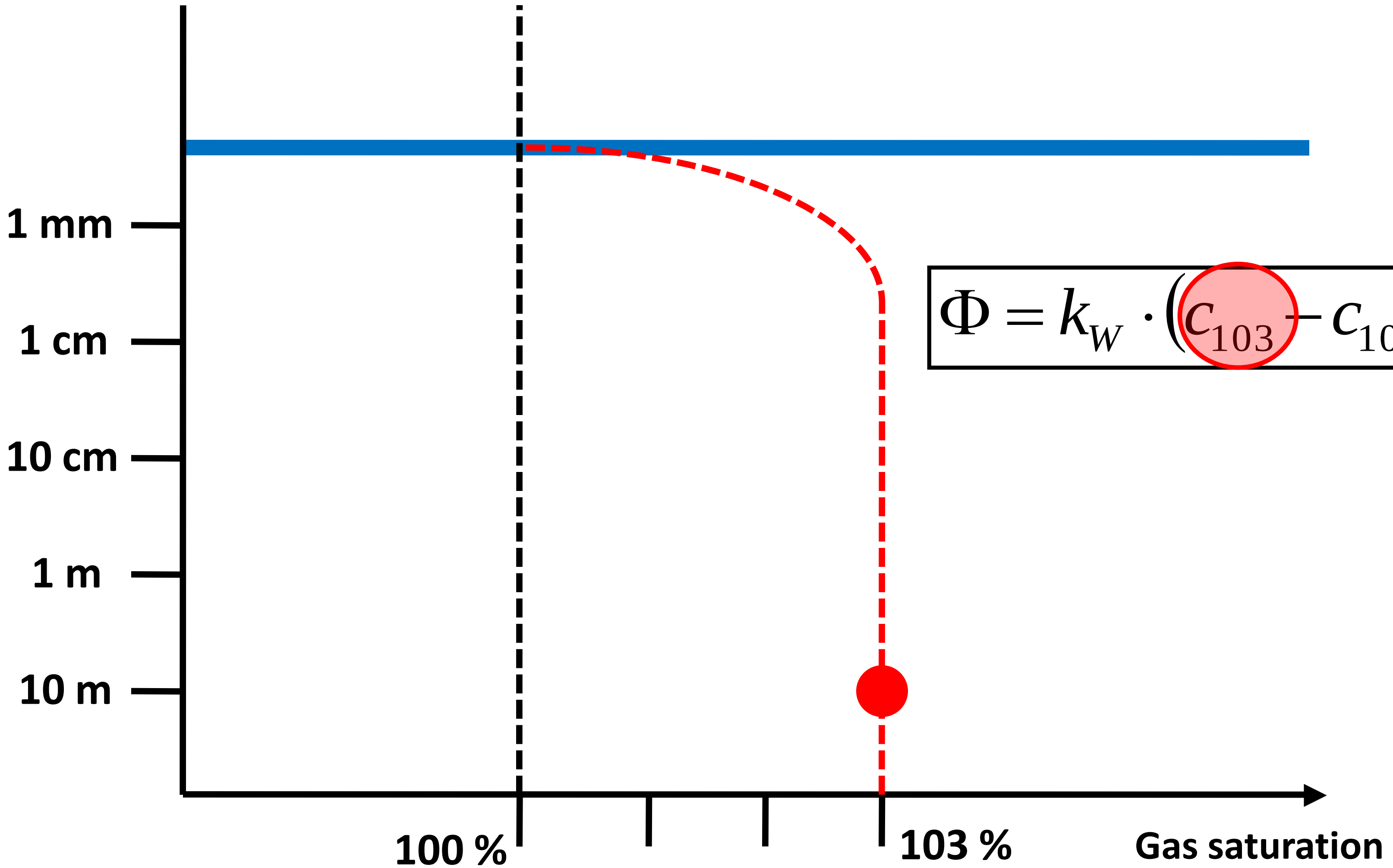

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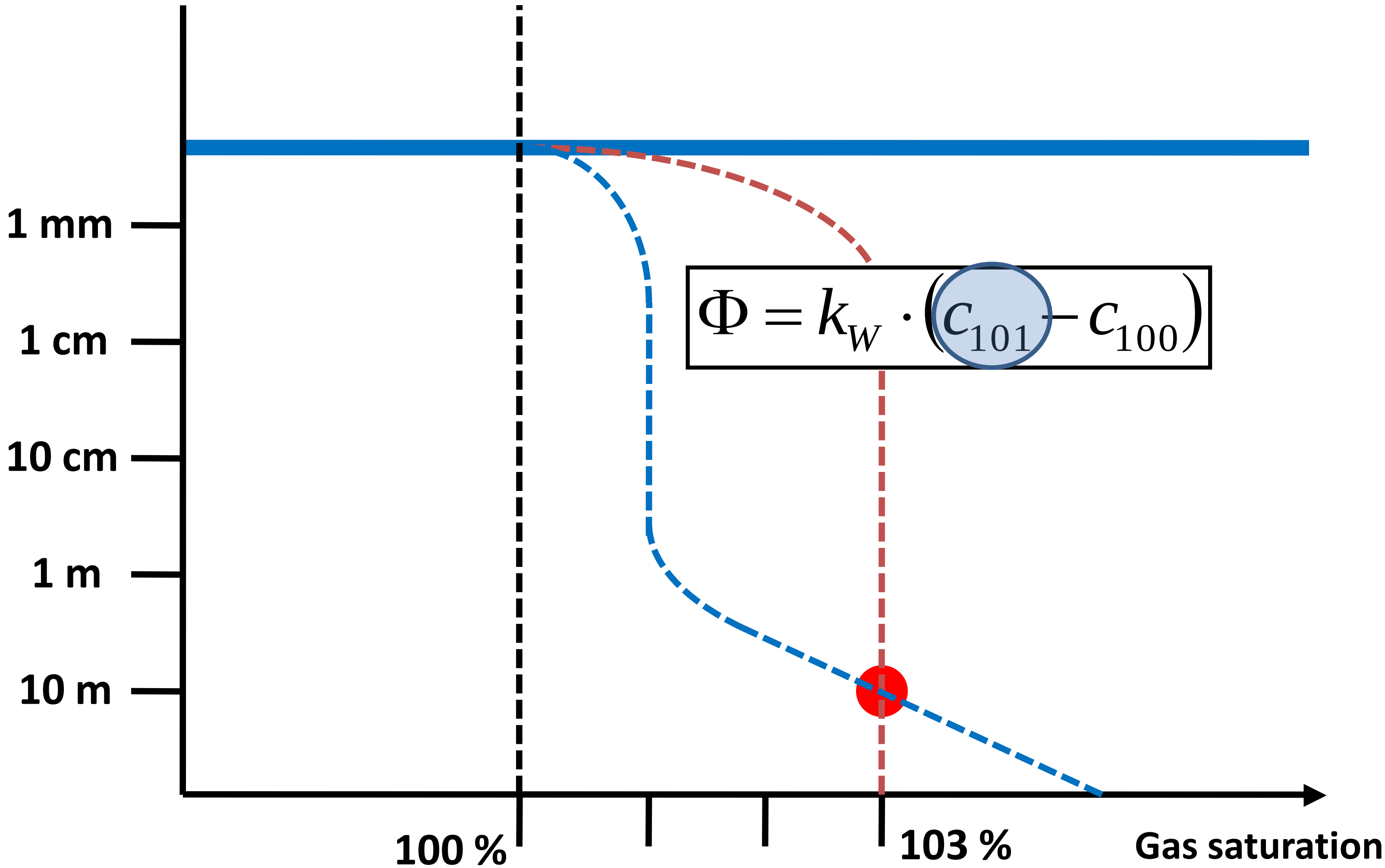
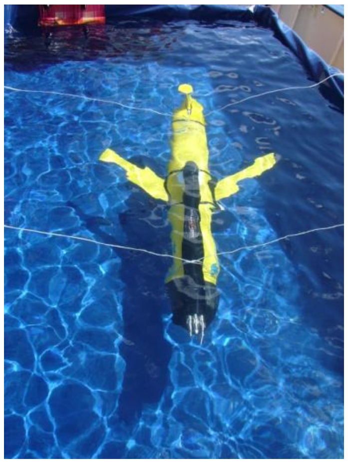
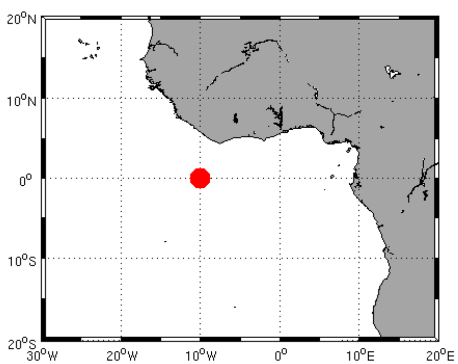
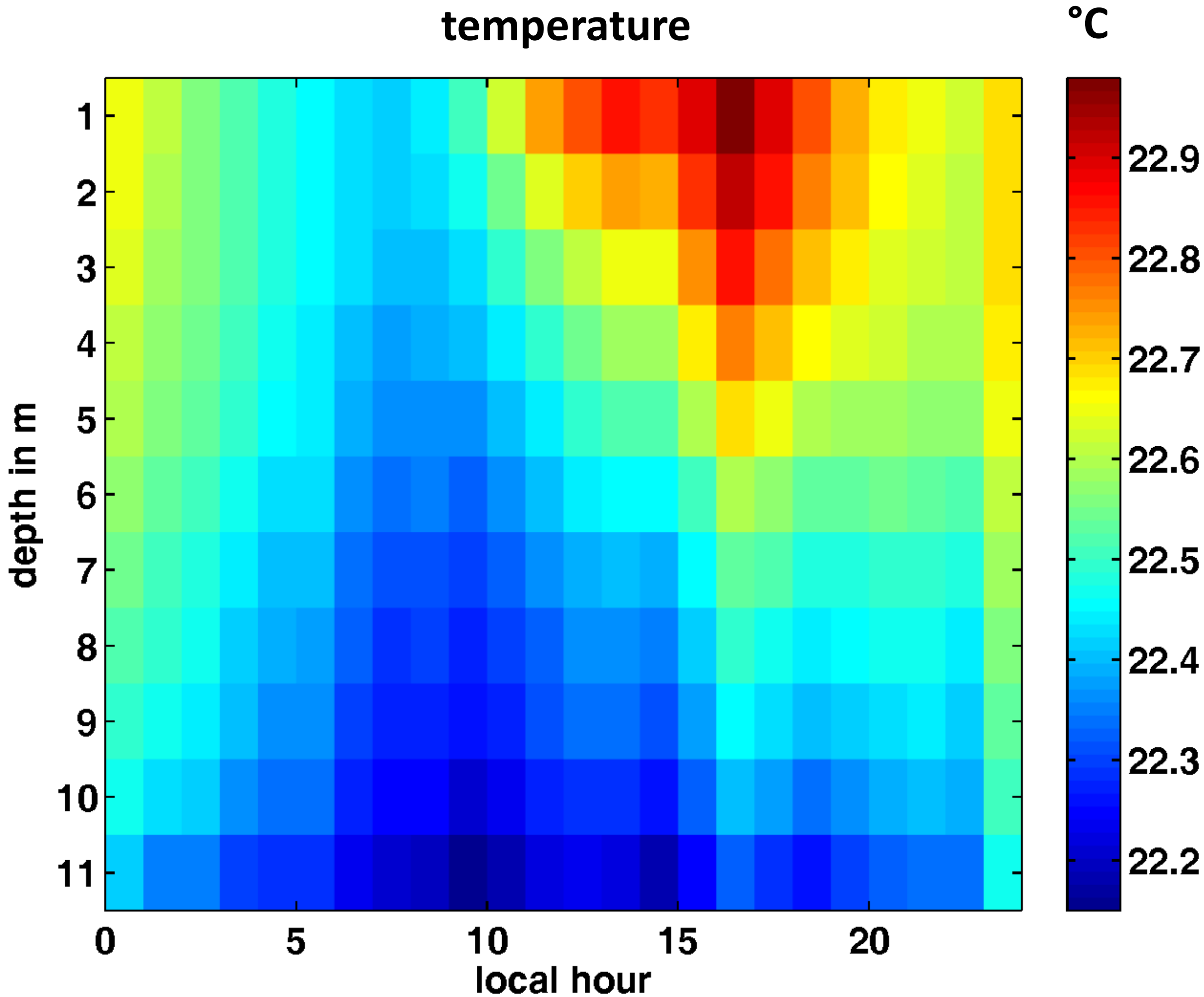


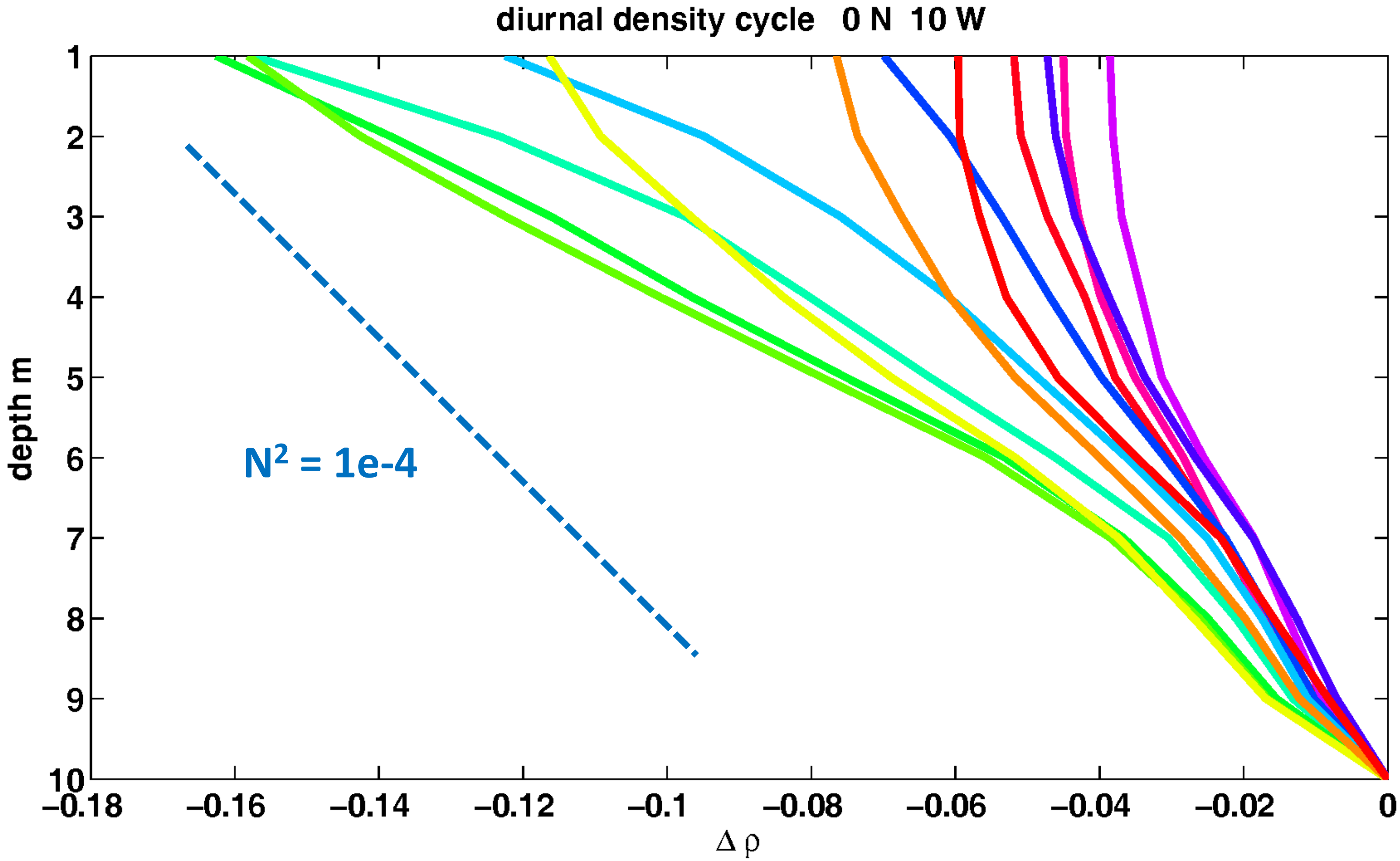
# 3b Glider data at 0 N 10 W show diurnal temperature cycle





# … which translates to a diurnal cycle in stratification



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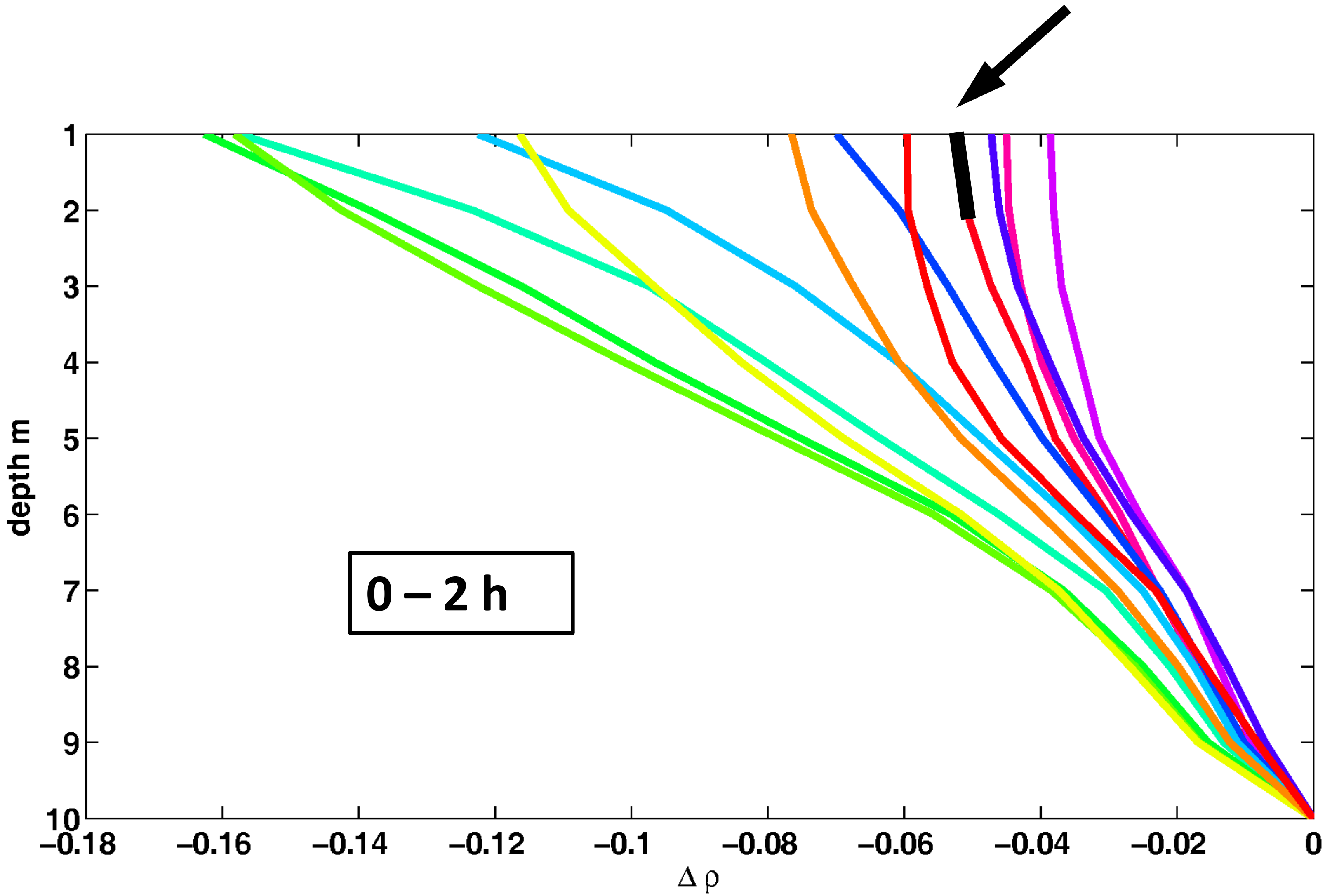

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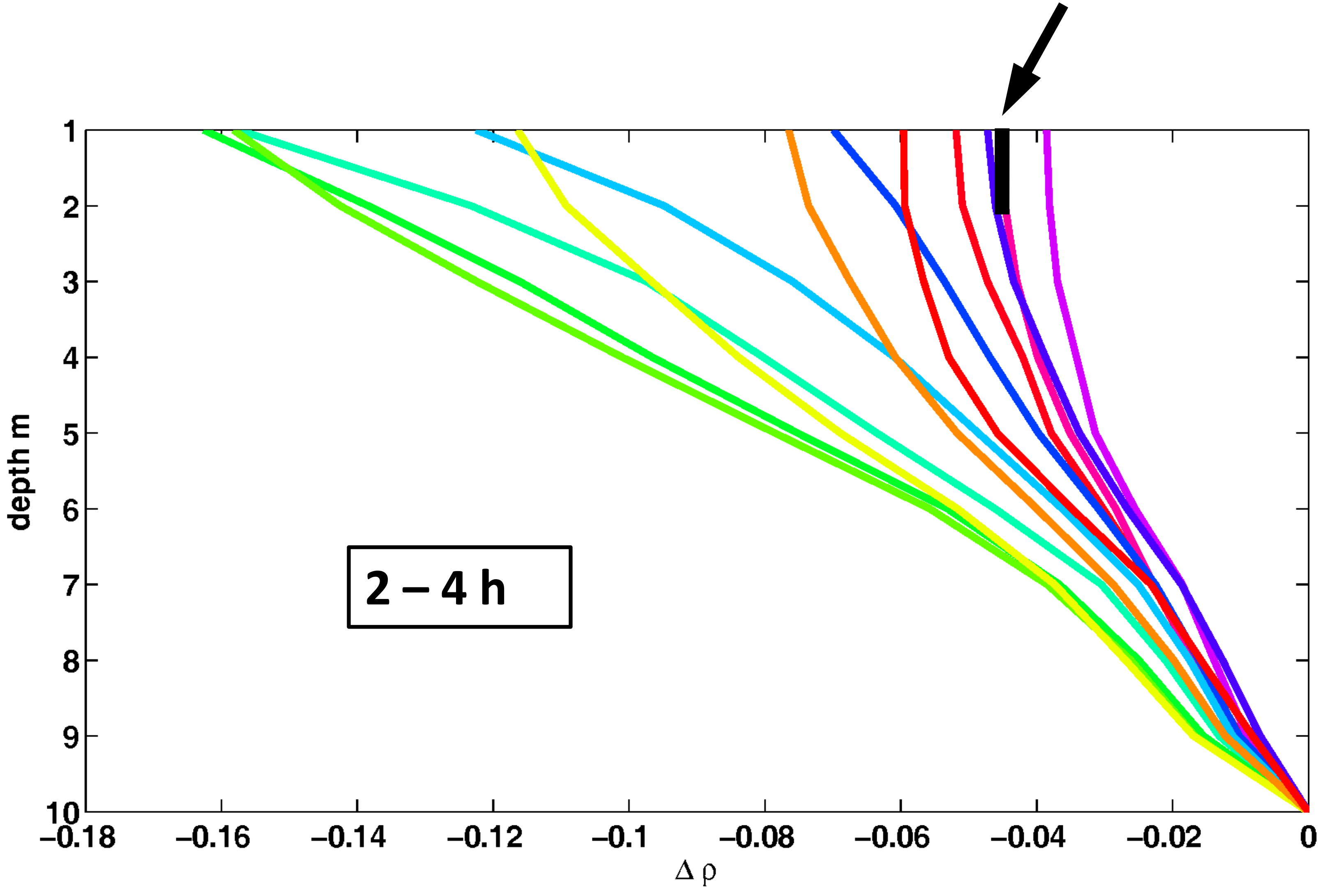

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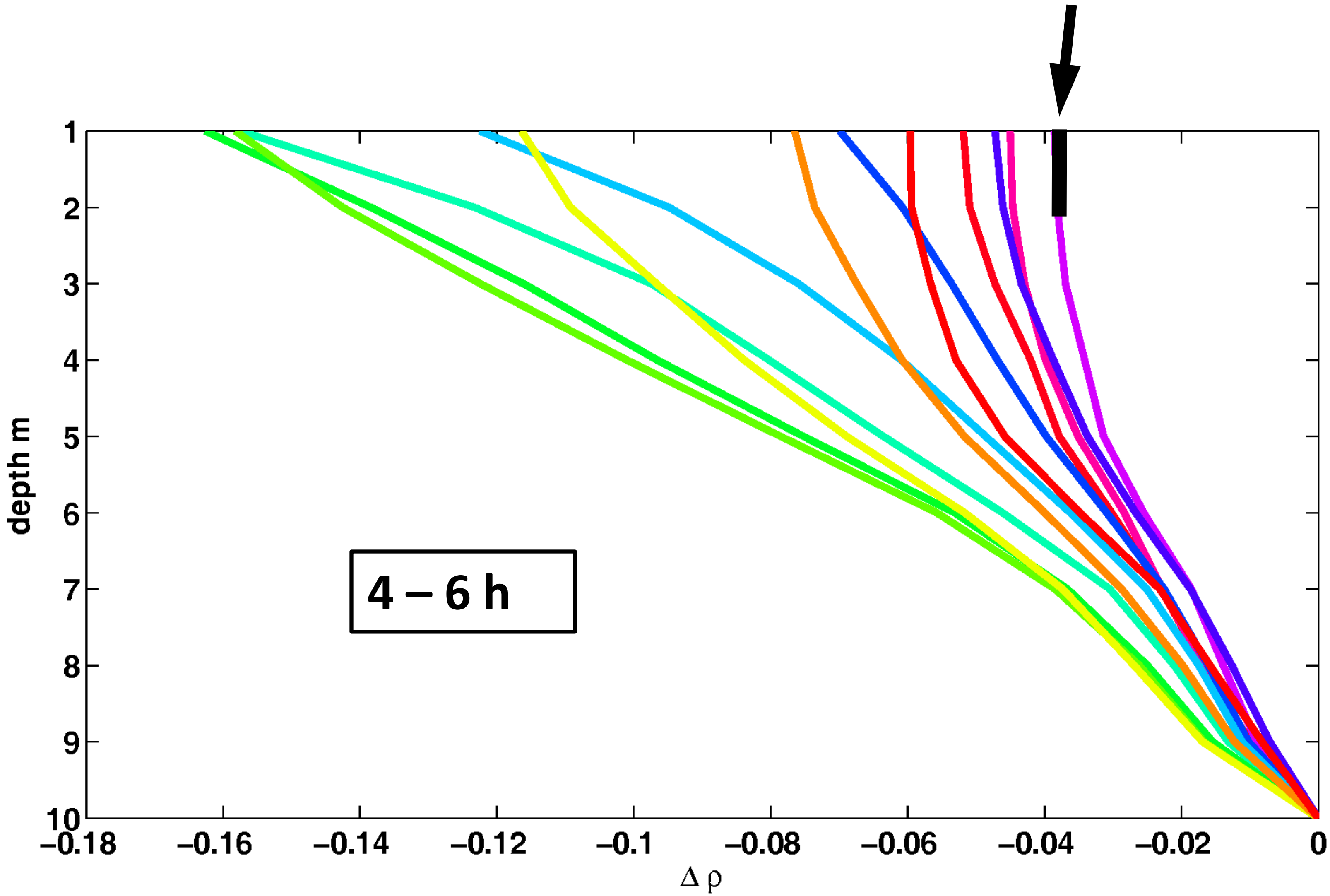

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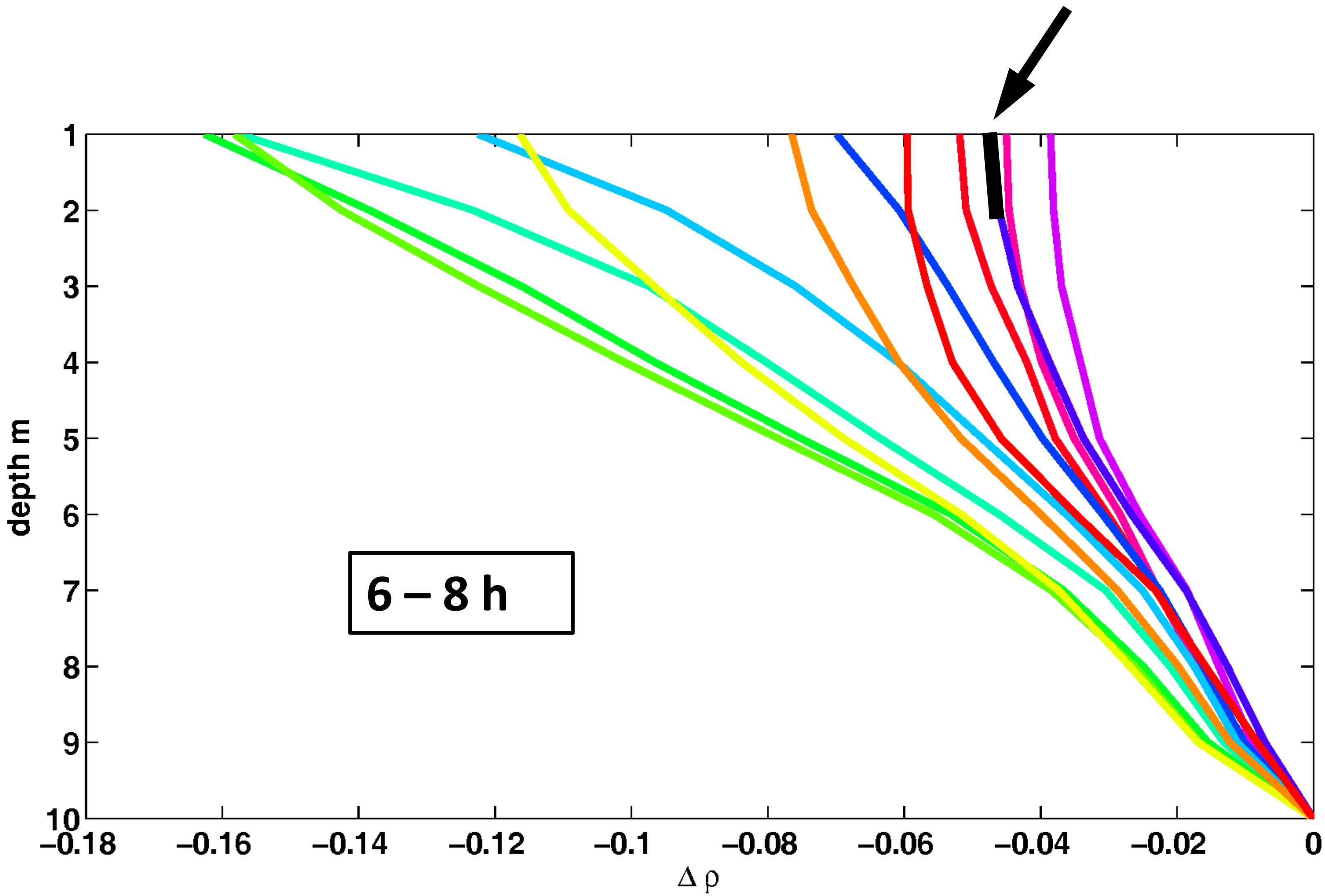

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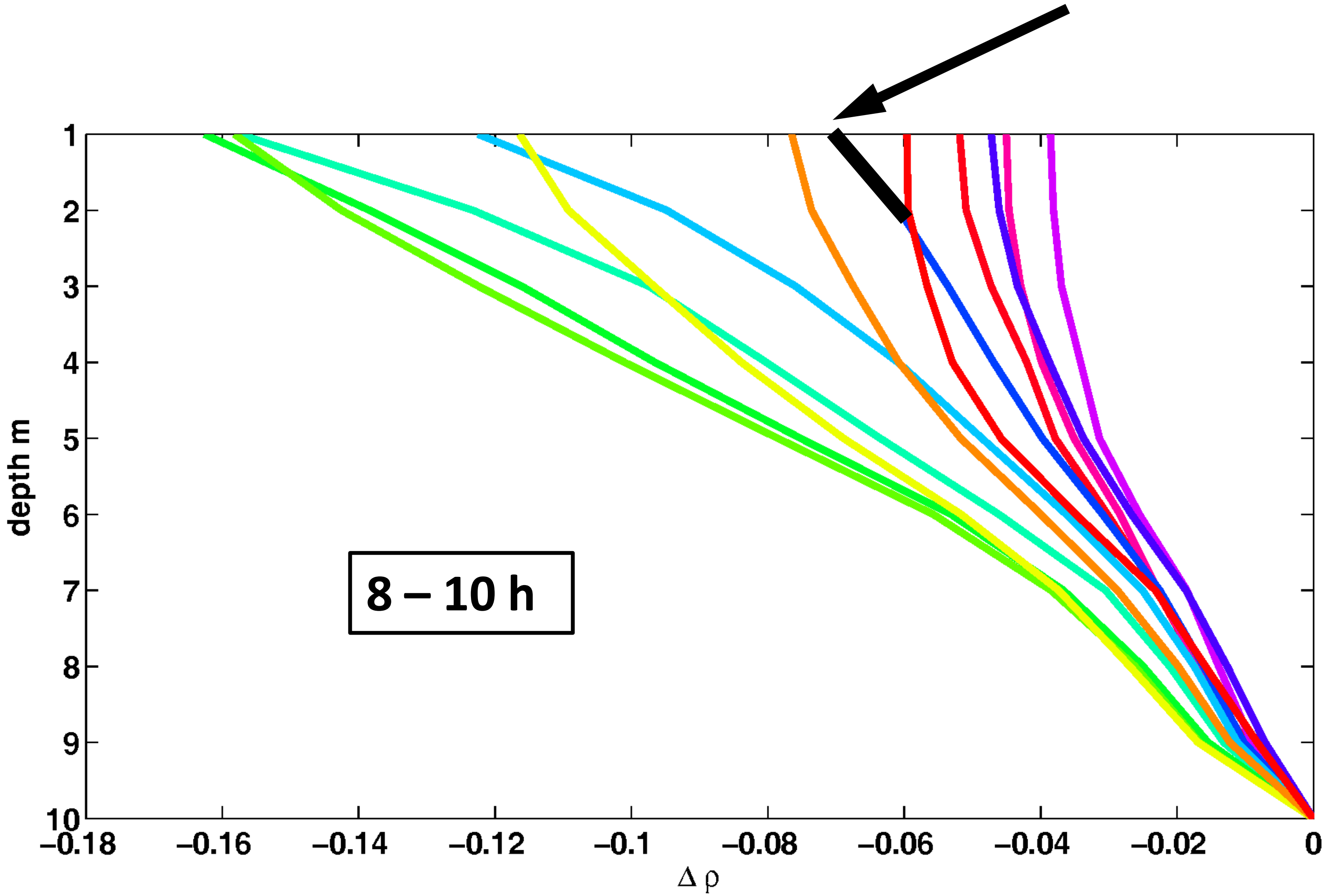

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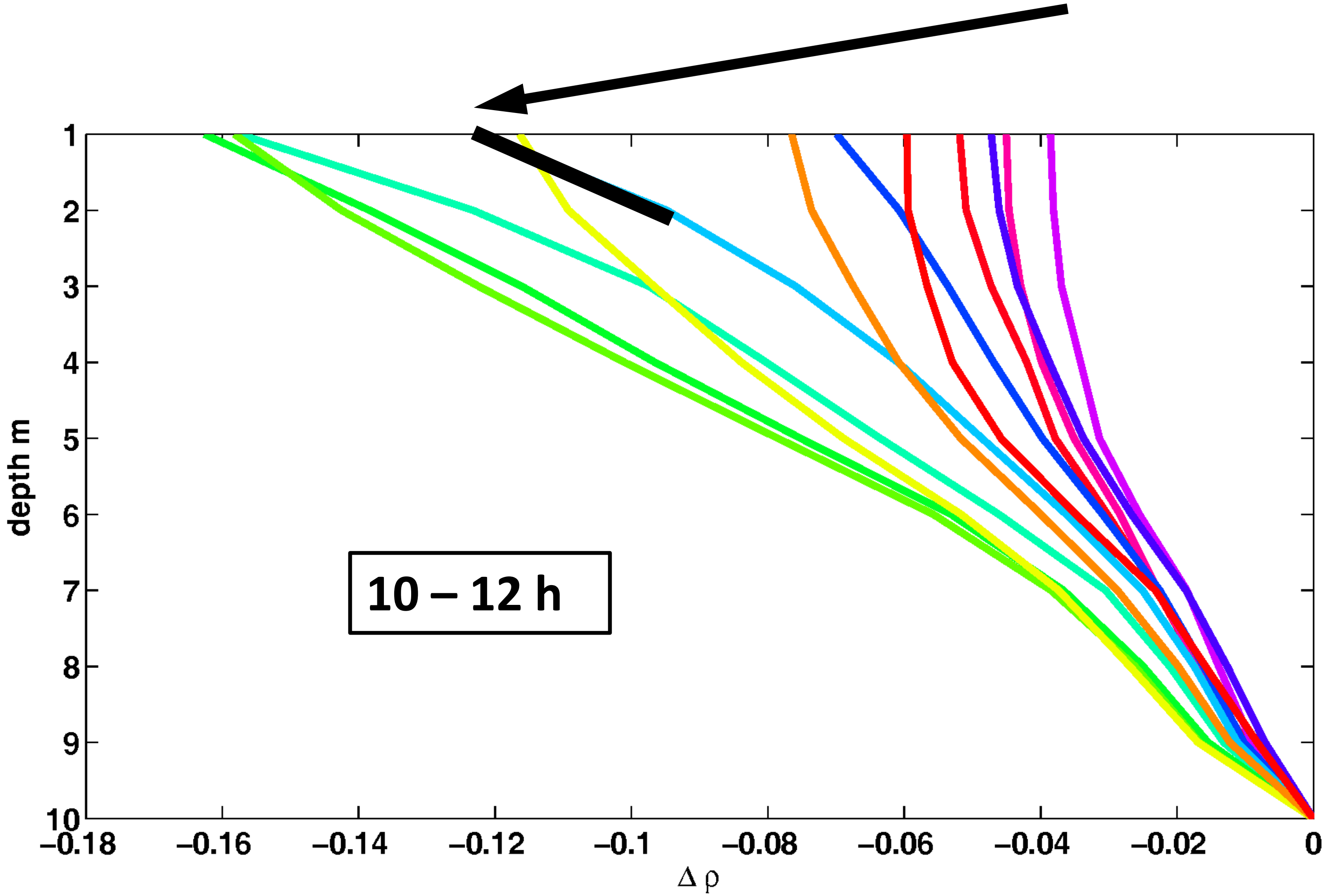

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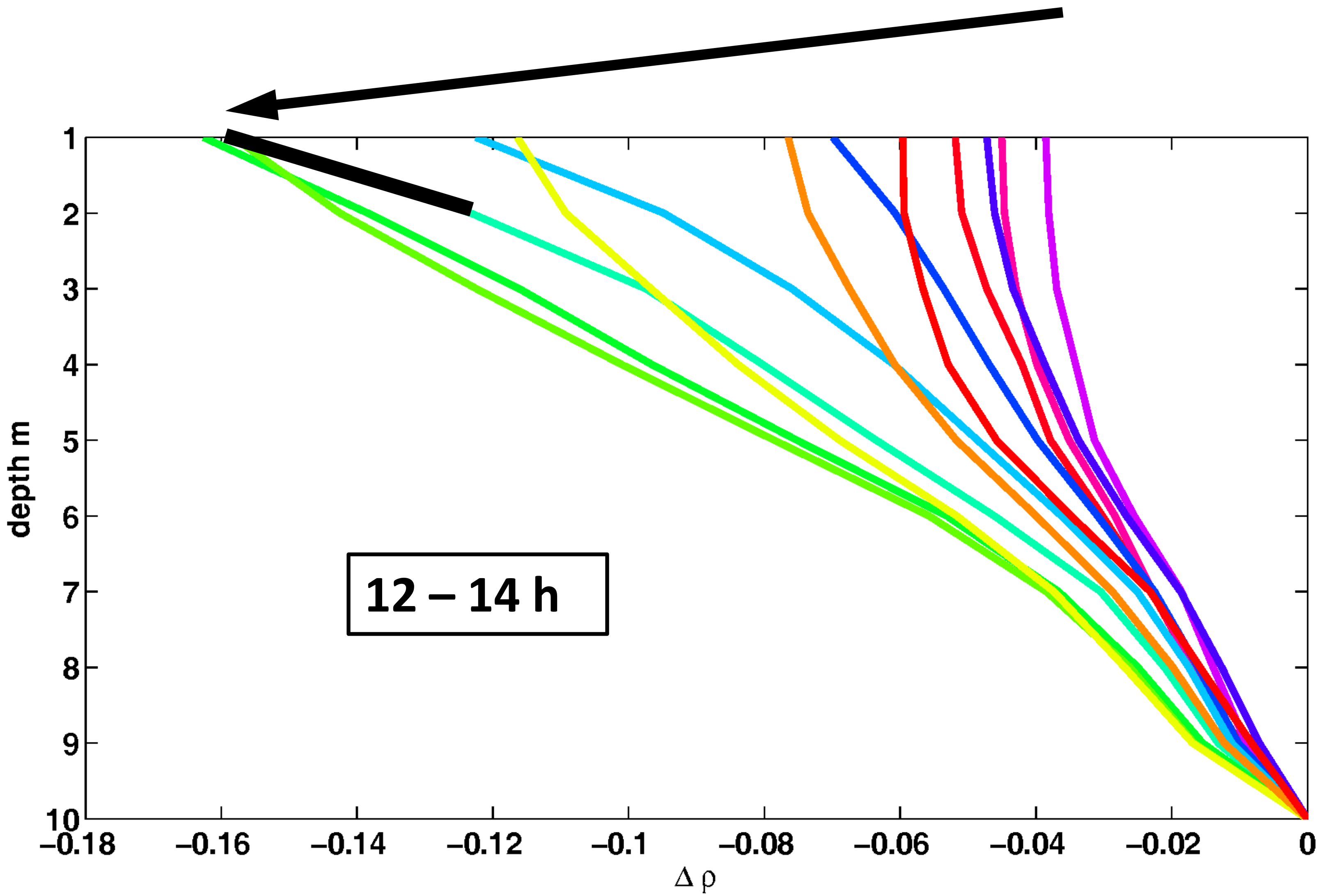

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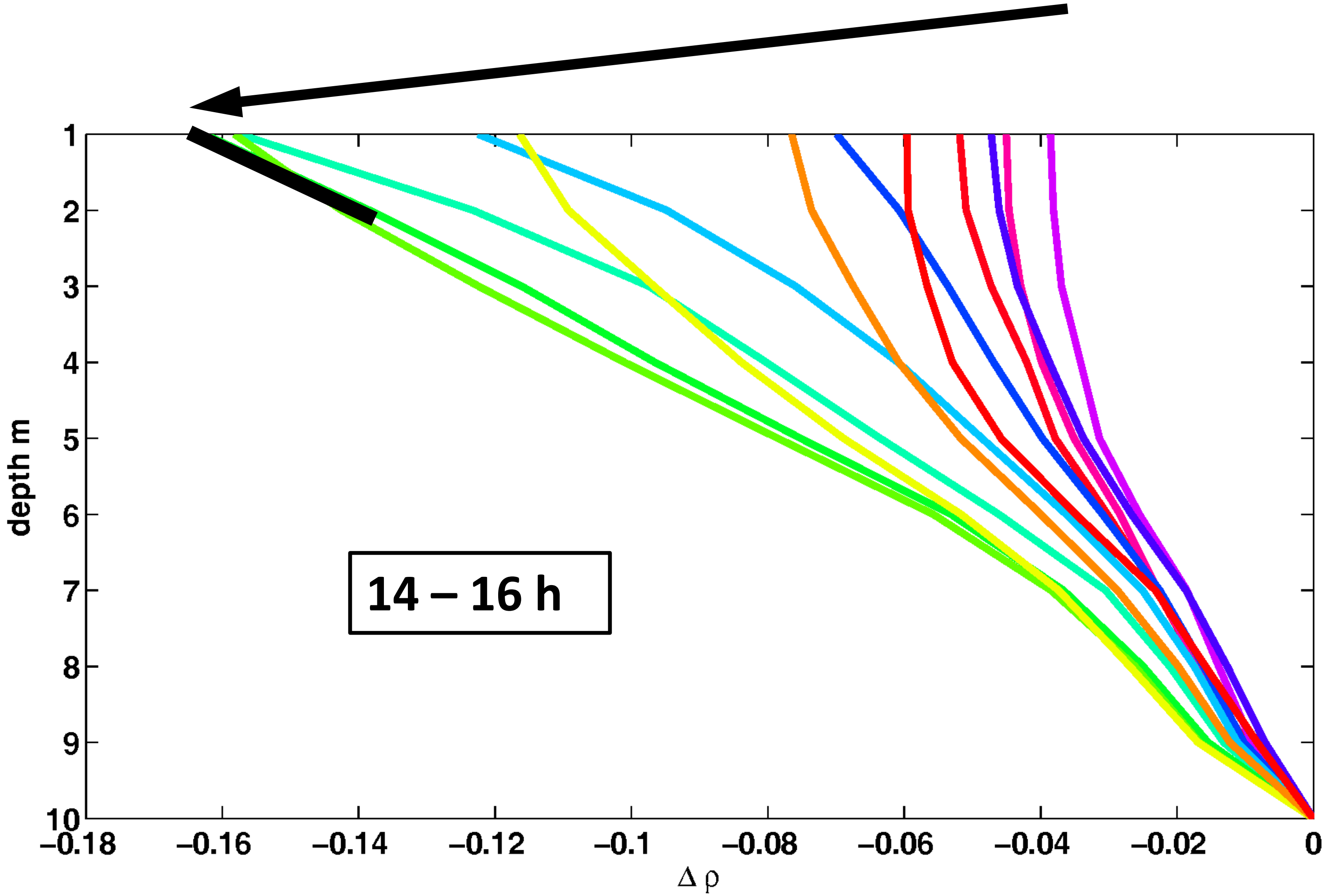

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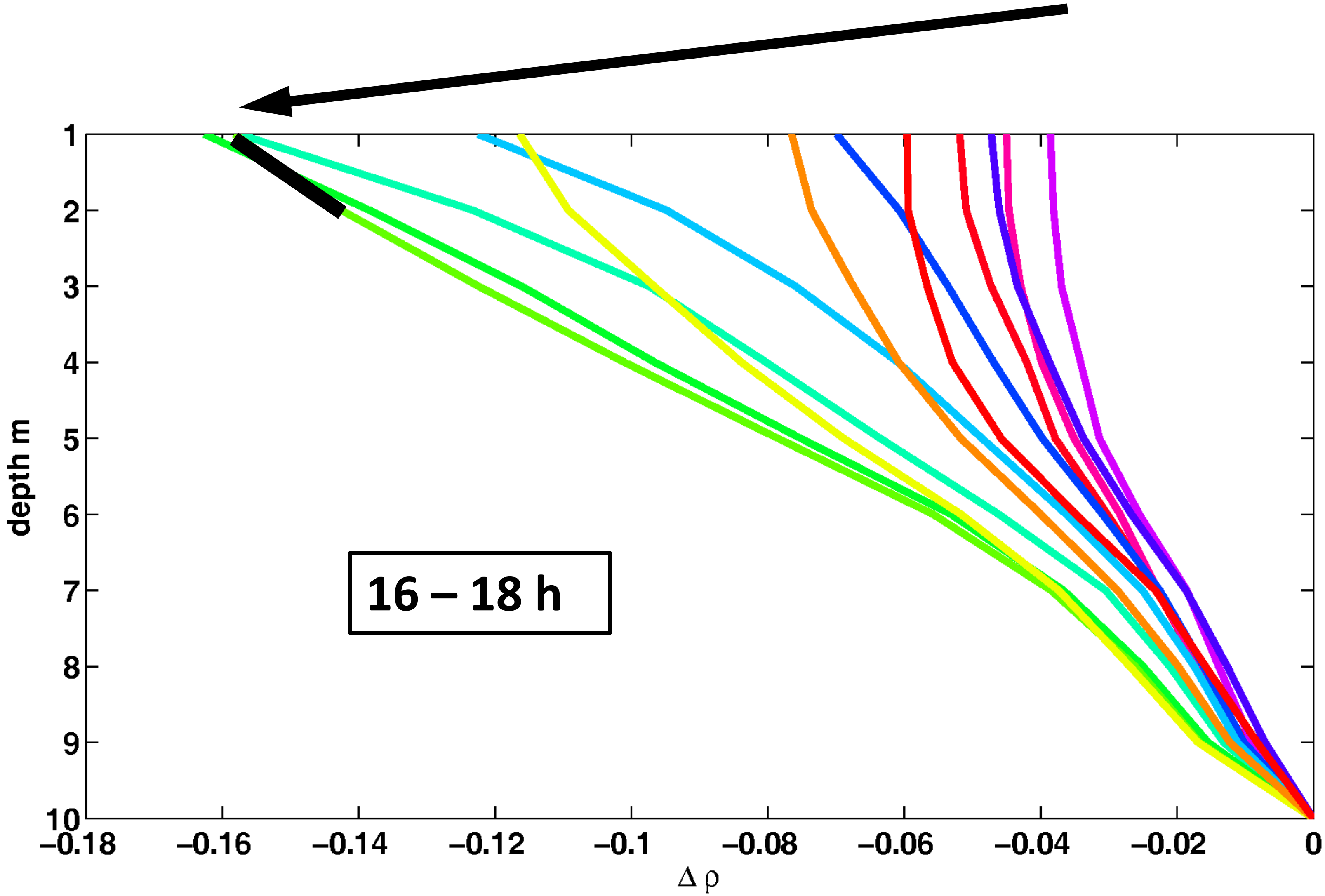

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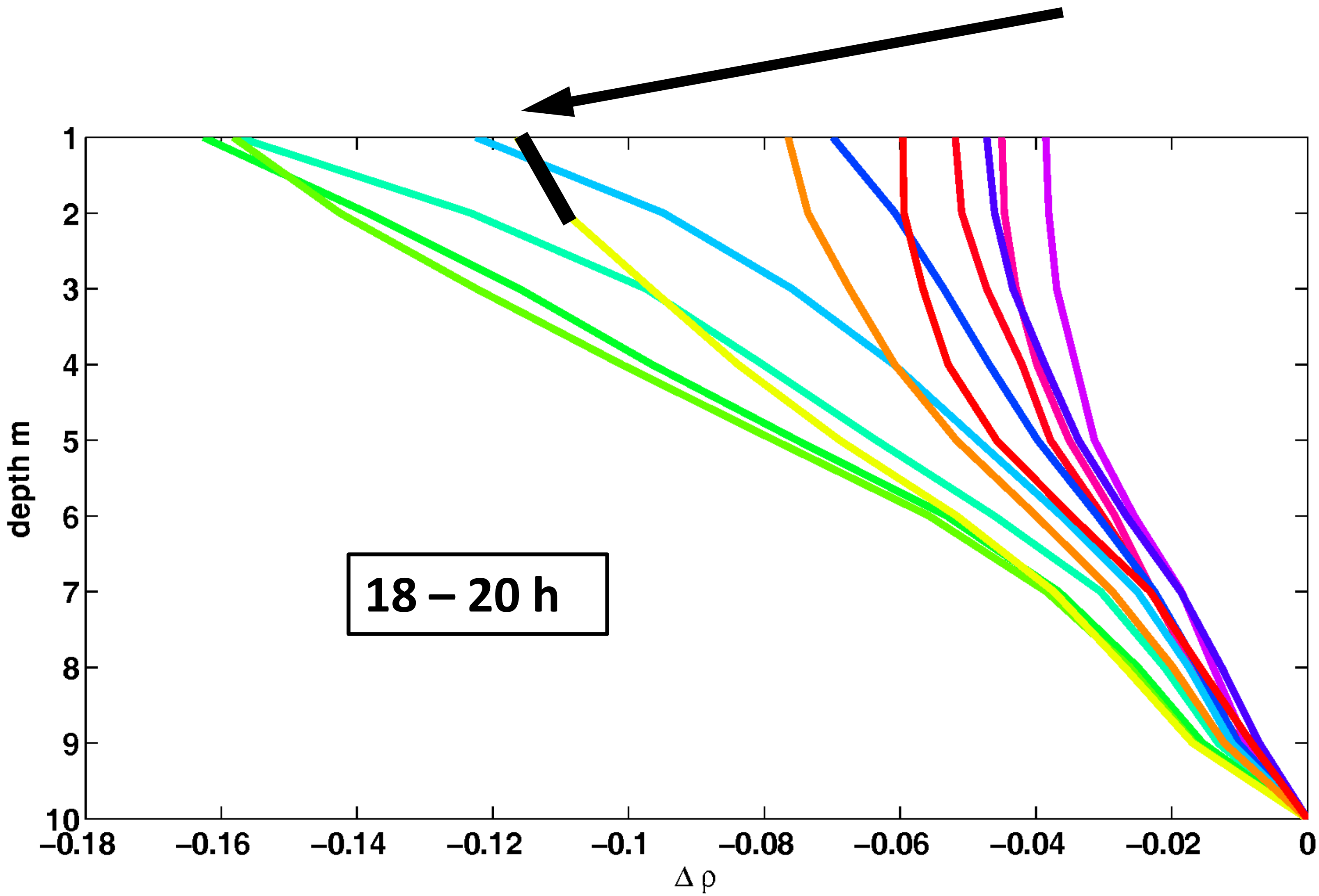

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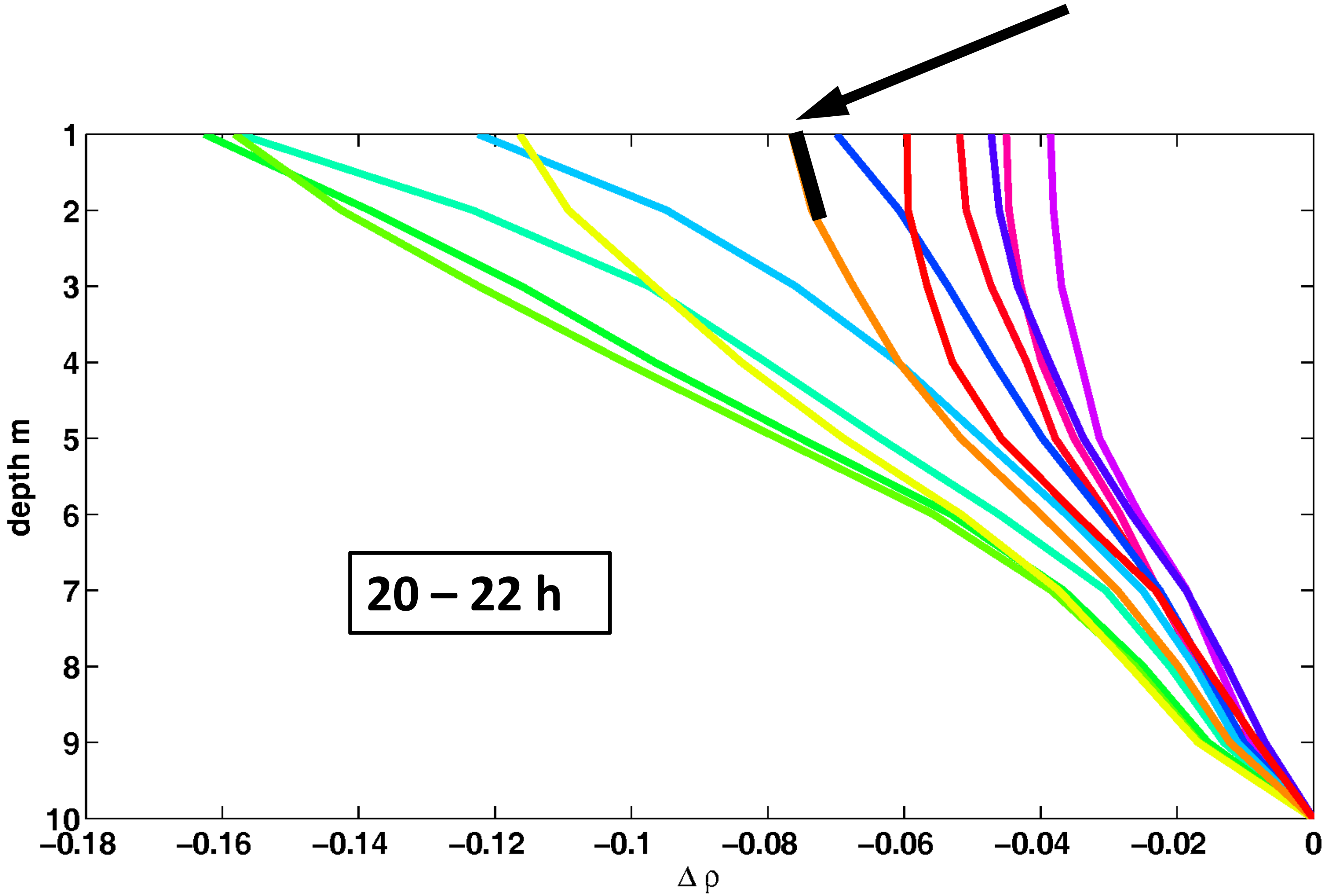

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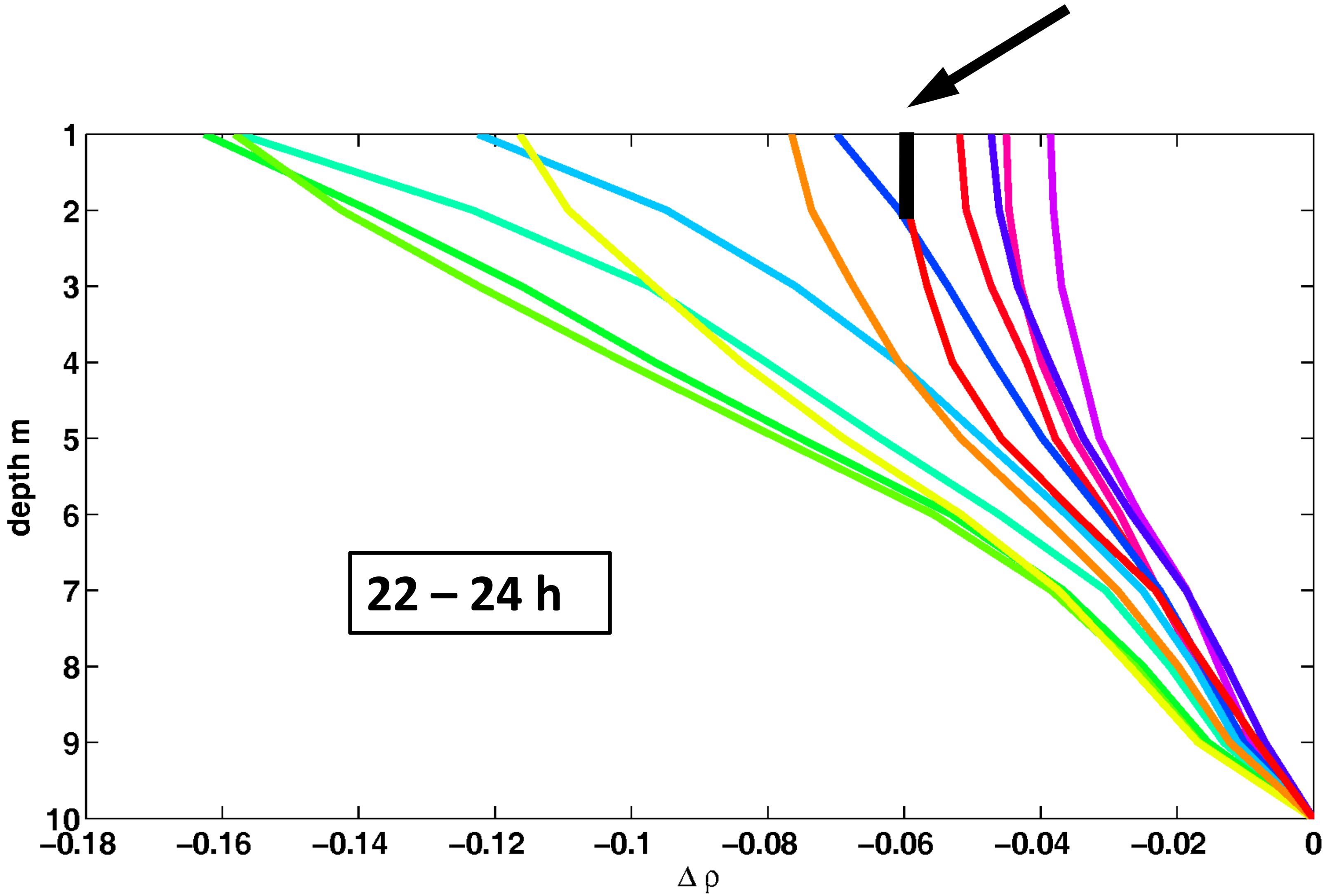
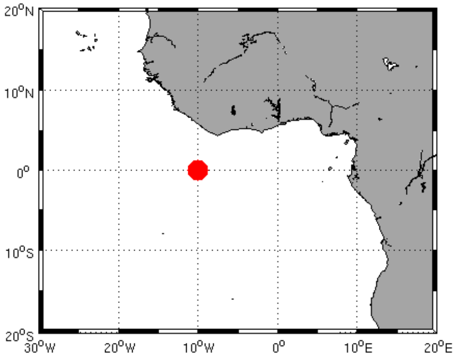
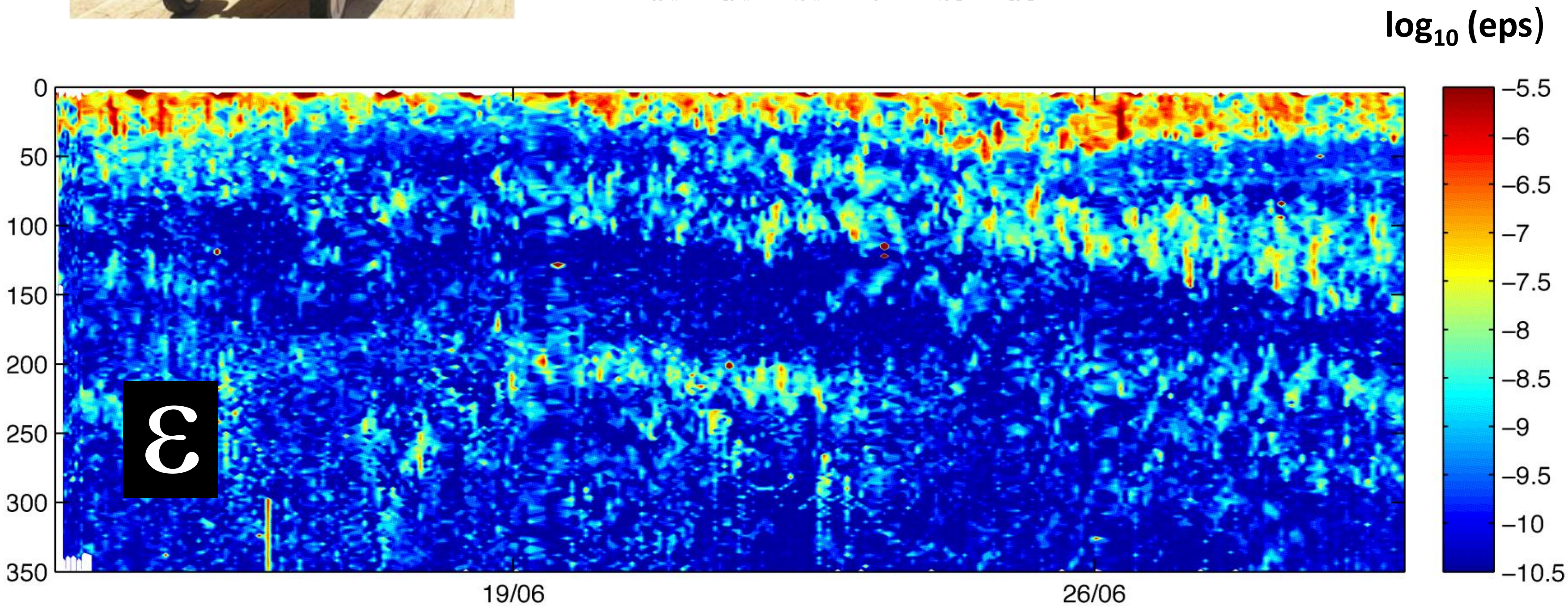


# 3b Glider based turbulence measurements




M. Dengler

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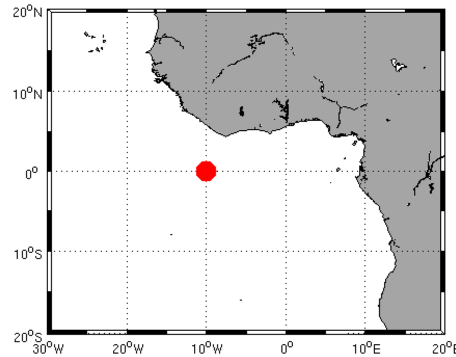
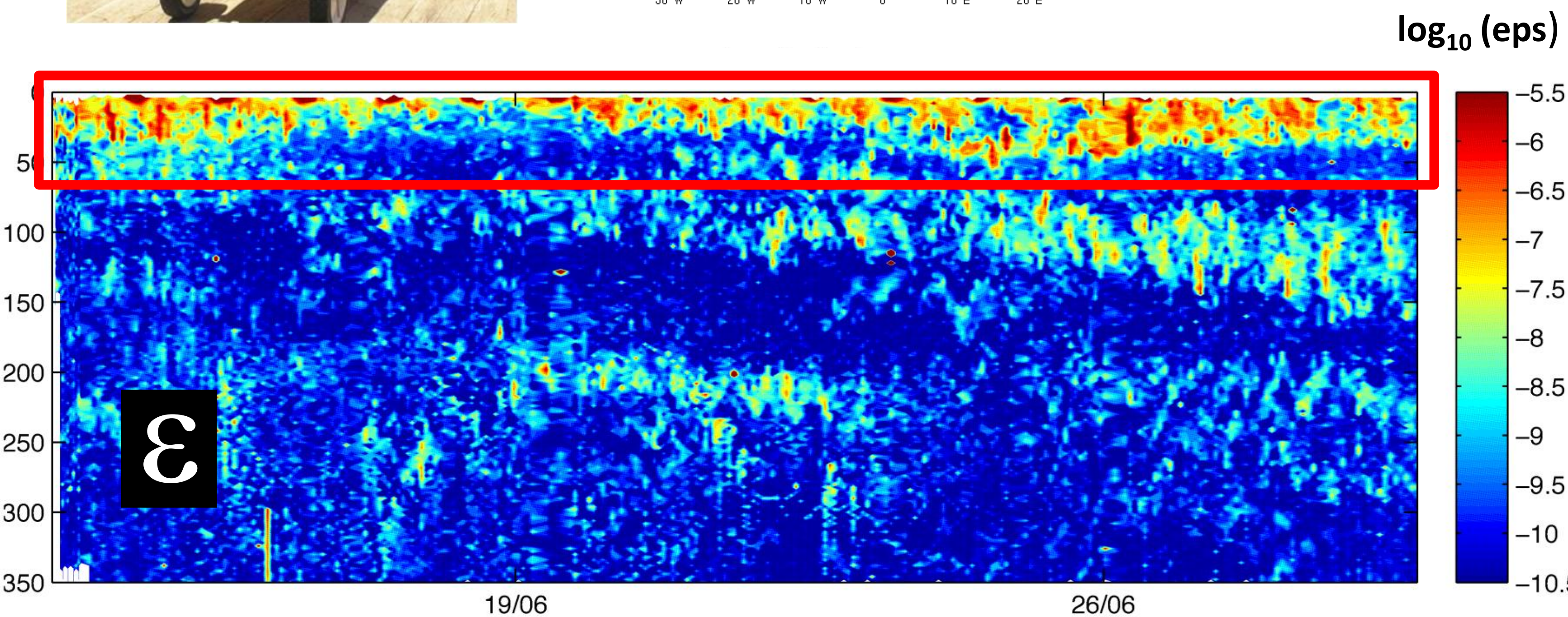
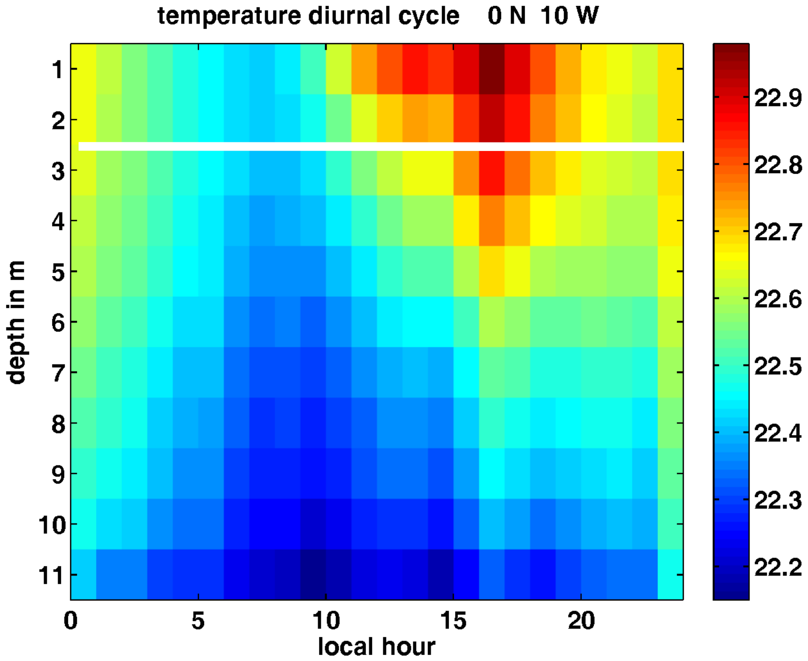


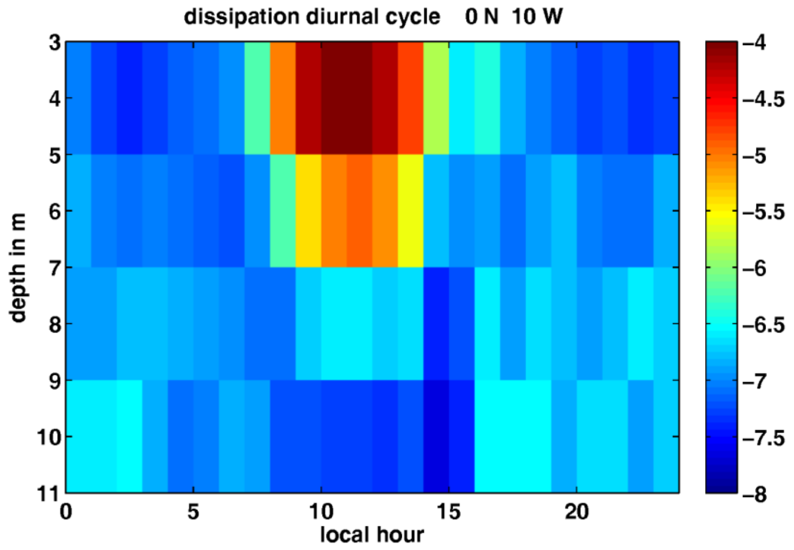

**M. Dengler**

# 3b Average diurnal cycles at 0 N 10 W

T



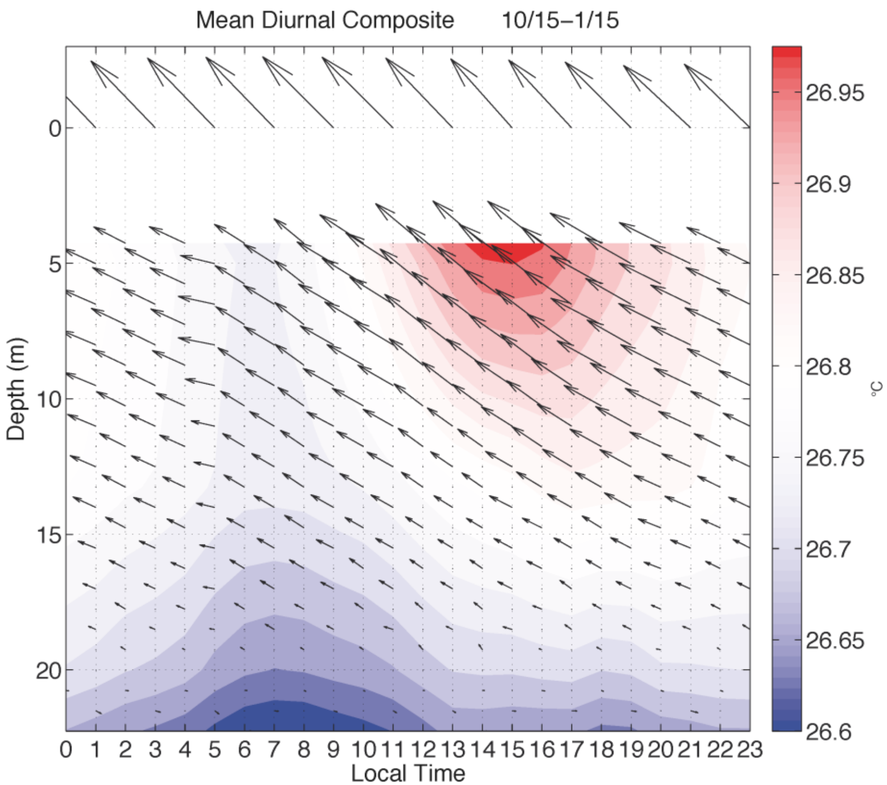

ε

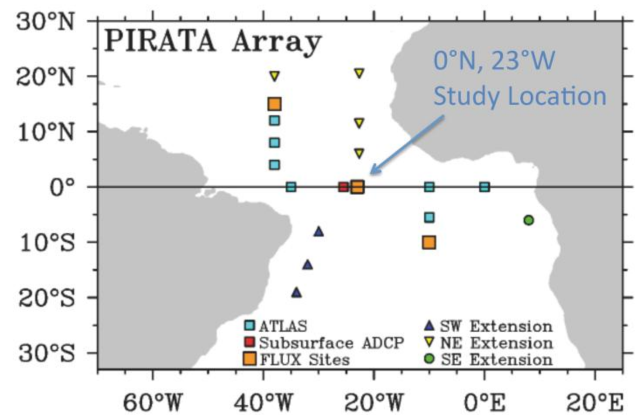


# 3b Diurnal cycle in near-surface temperature and shear

**Also seen from PIRATA mooring data (Wenegrat, McPhaden, 2012).**

2008/2009 on 0 N 23 W

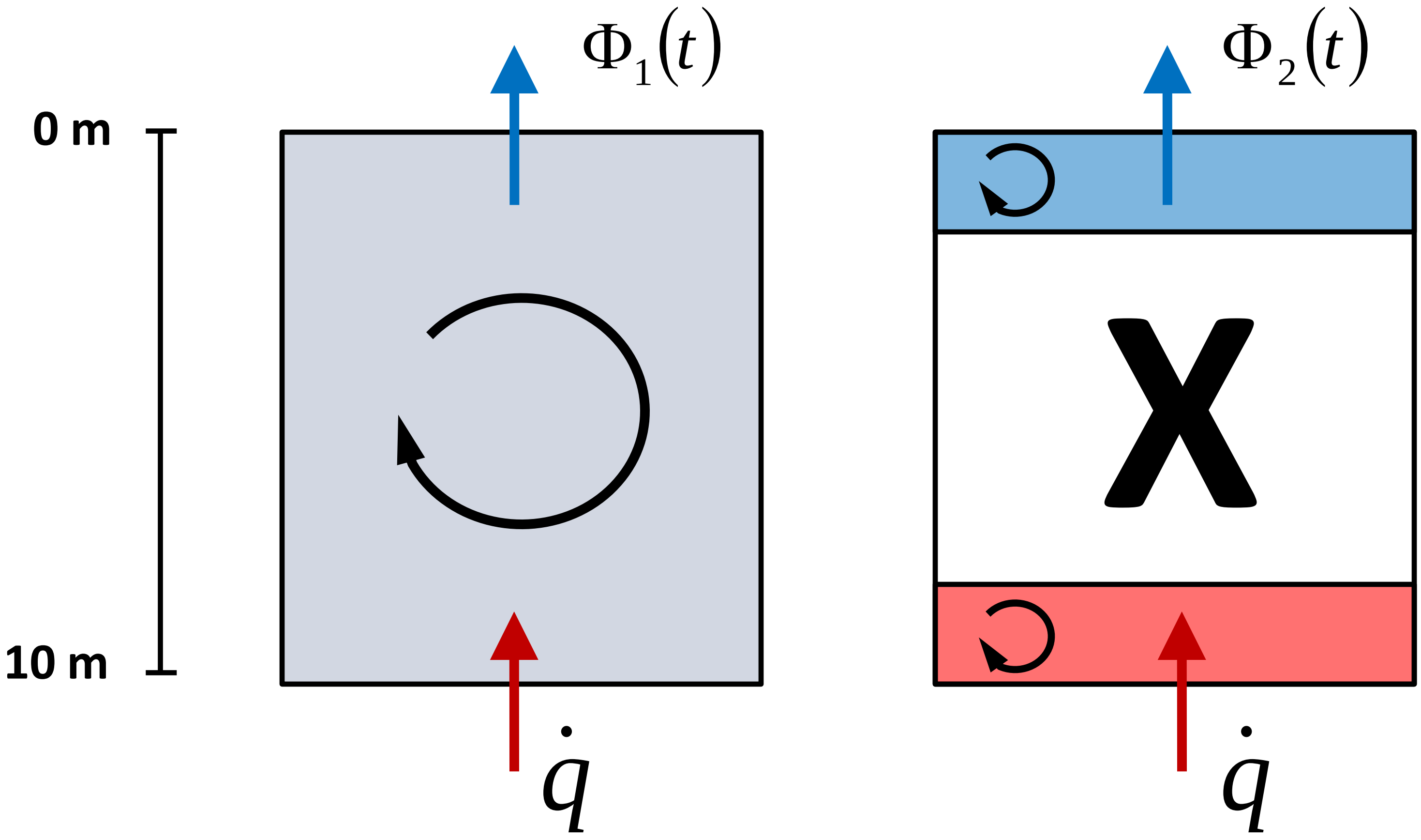



„Upper ocean thermal stratification traps wind momentum in the near-surface, creating a diurnal jet and increasing shear, introducing a diurnal cycle into the […] eddy viscosity“

**3c** **Could diurnal stratification affect gas flux calculation?**

**Simple model: inert gas from below, subsurface temporarily stagnant.**
**How much will the equilibrium concentration in the subsurface react?**



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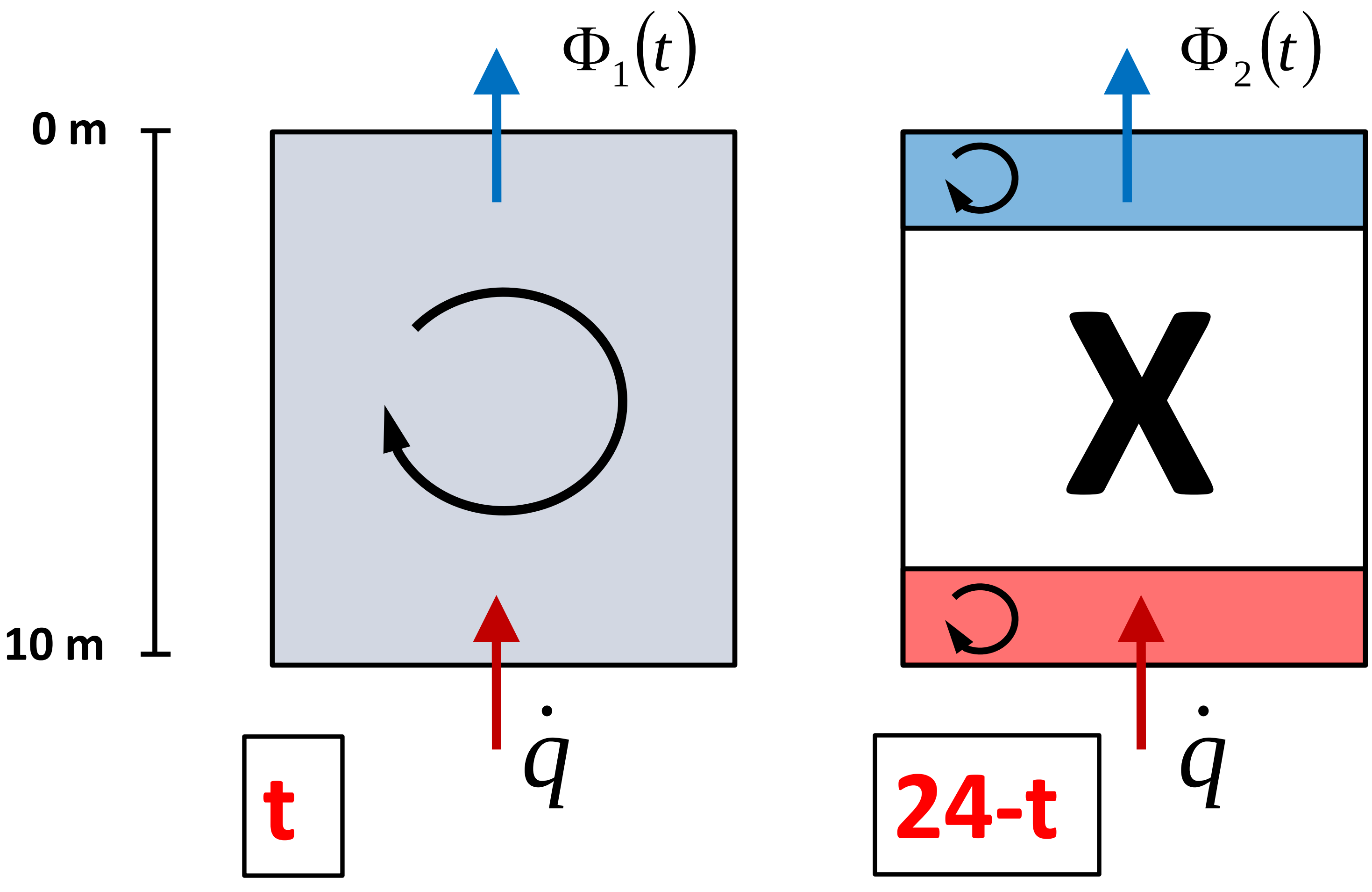

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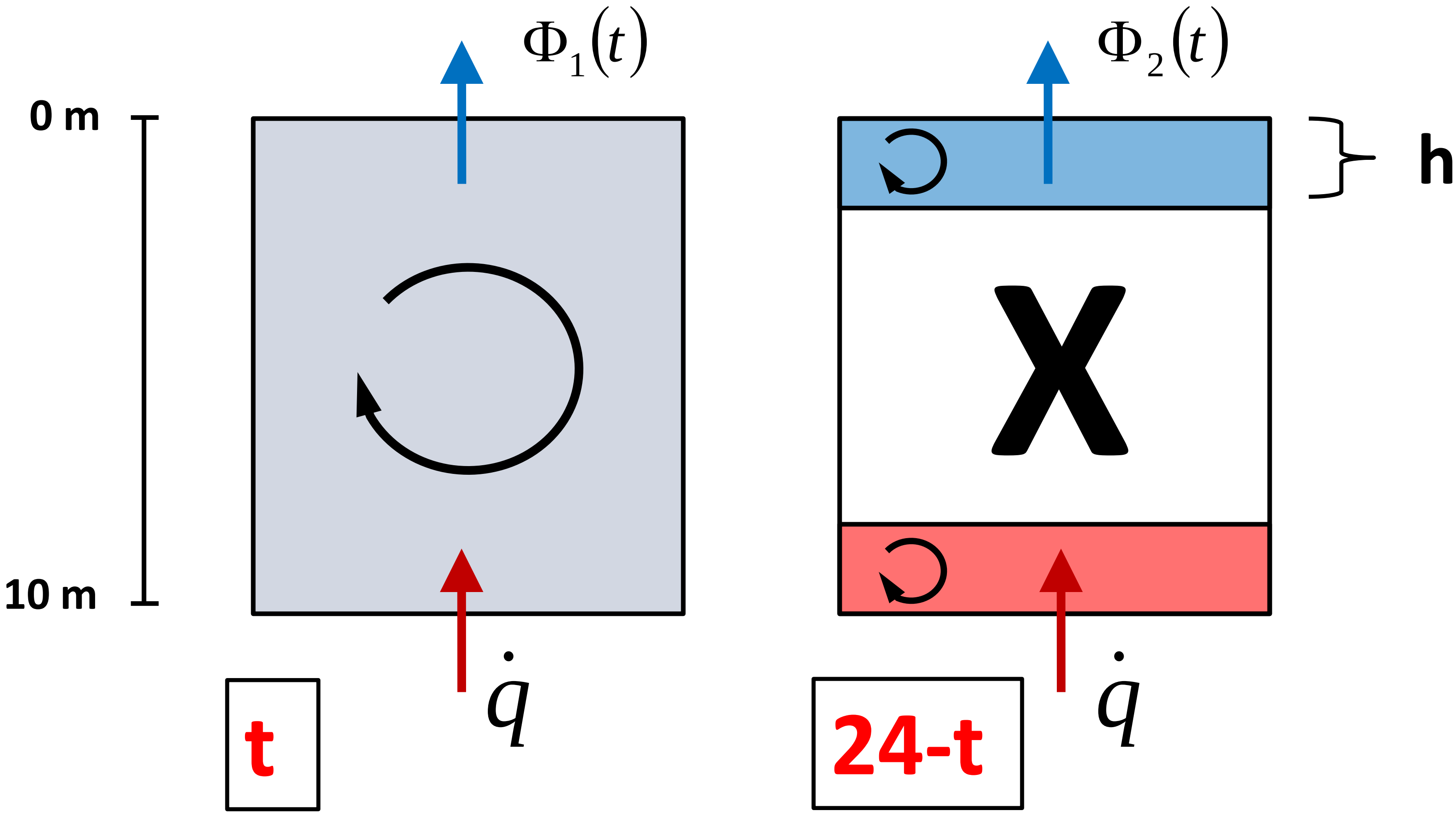
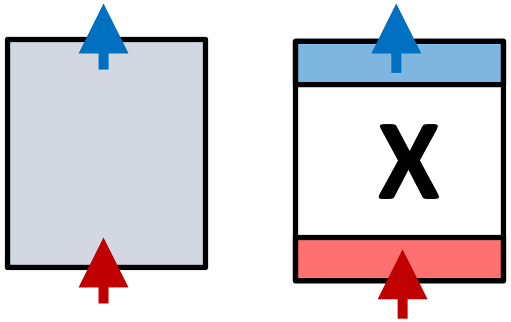
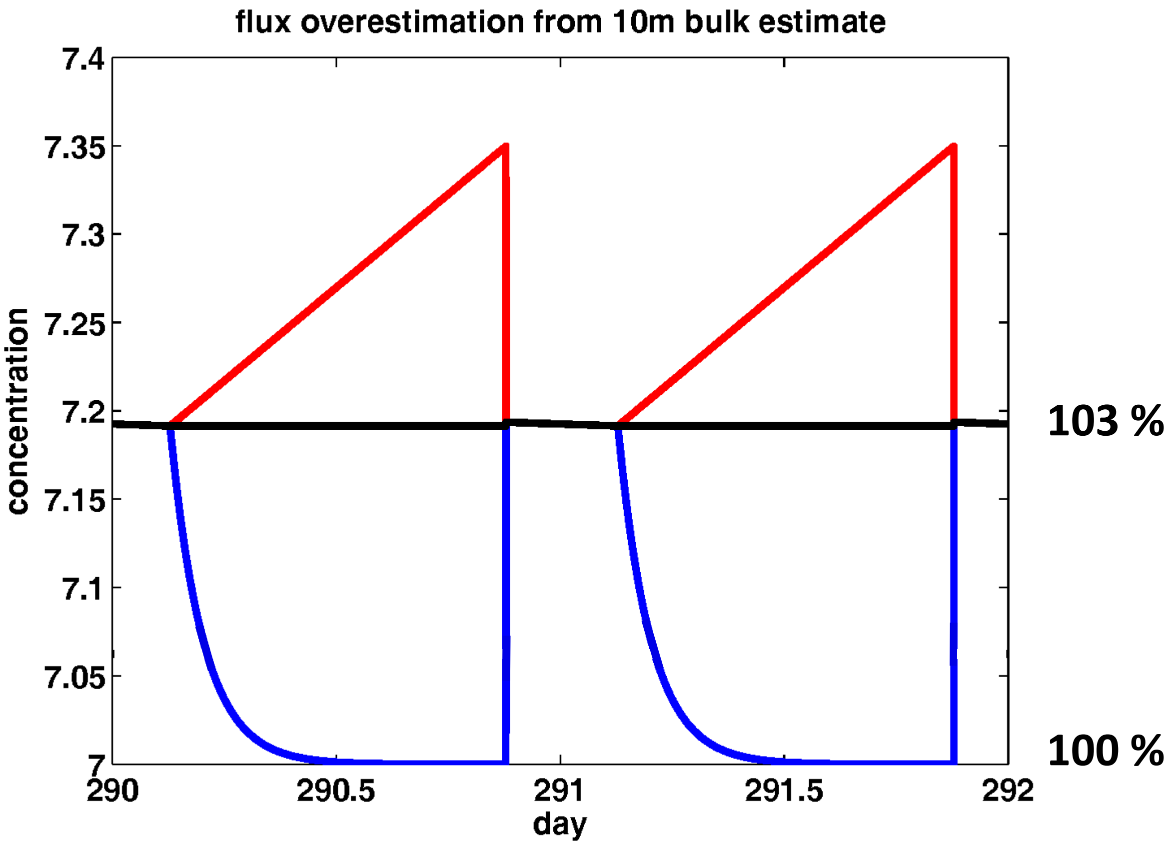


# 3c Simple model: example stationary solution

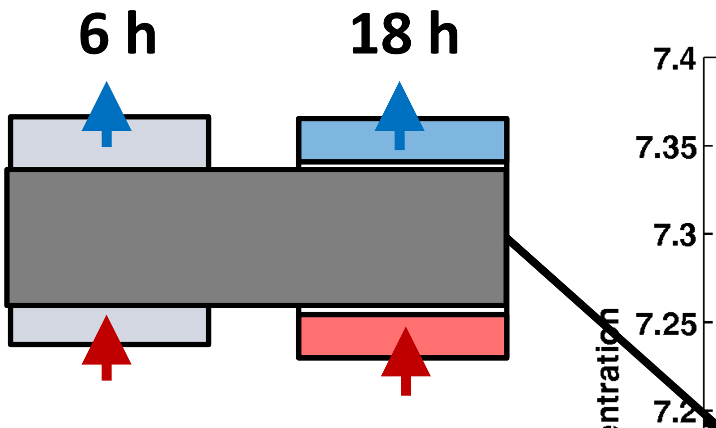
6 h 18 h

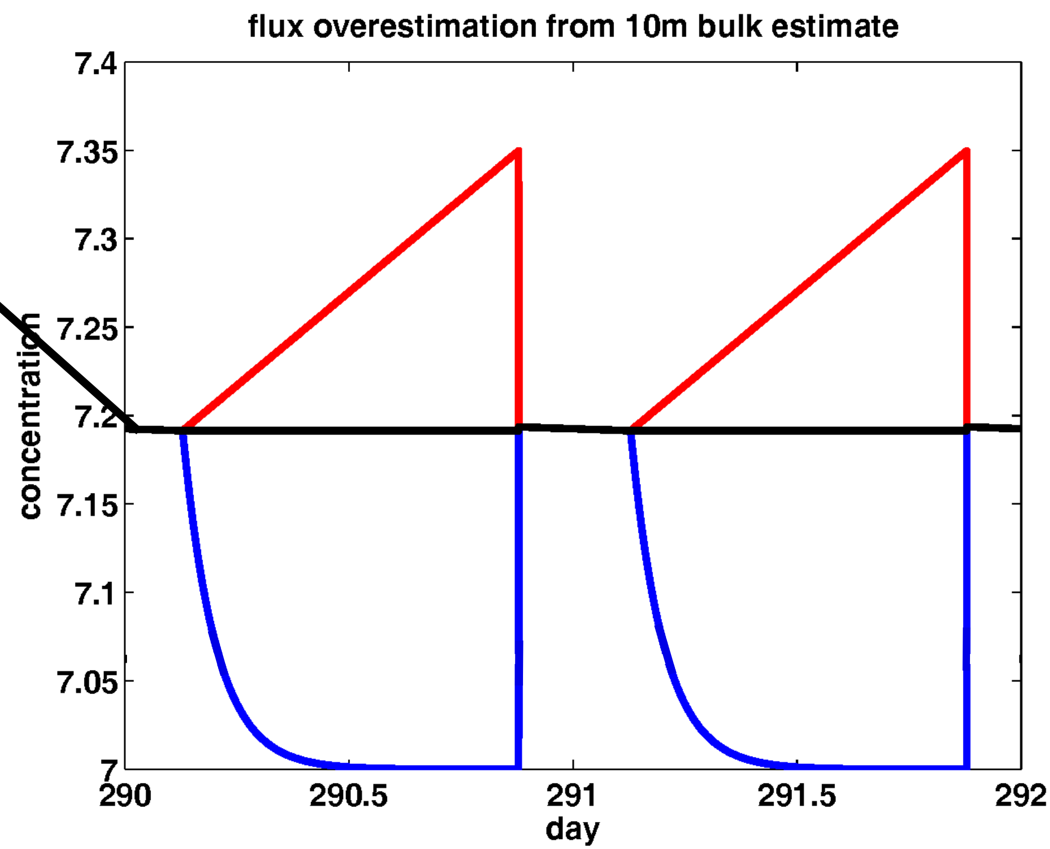



h = 0.1 m t = 6 h wind = 3 Bft

# 3c Simple model: example stationary solution




103 %

100 %

**This is the depth range we usually get our gas concentrations from. By Niskin bottles or underway sampling.**

**h = 0.1 m t = 6 h wind = 3 Bft**

## 3c Simple model: example stationary solution

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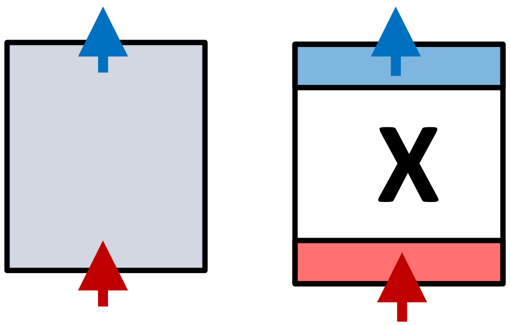
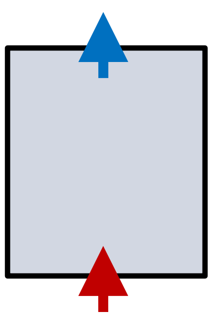
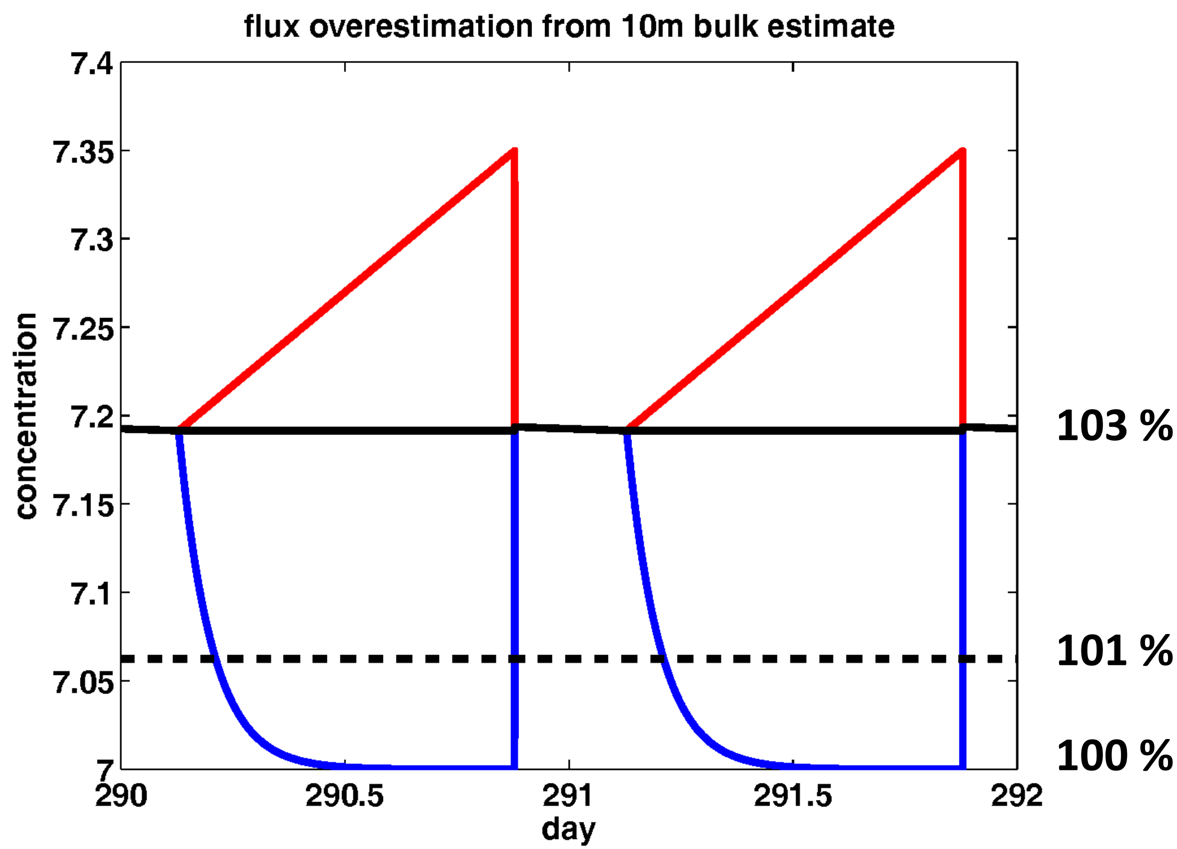



24 h

Reference:





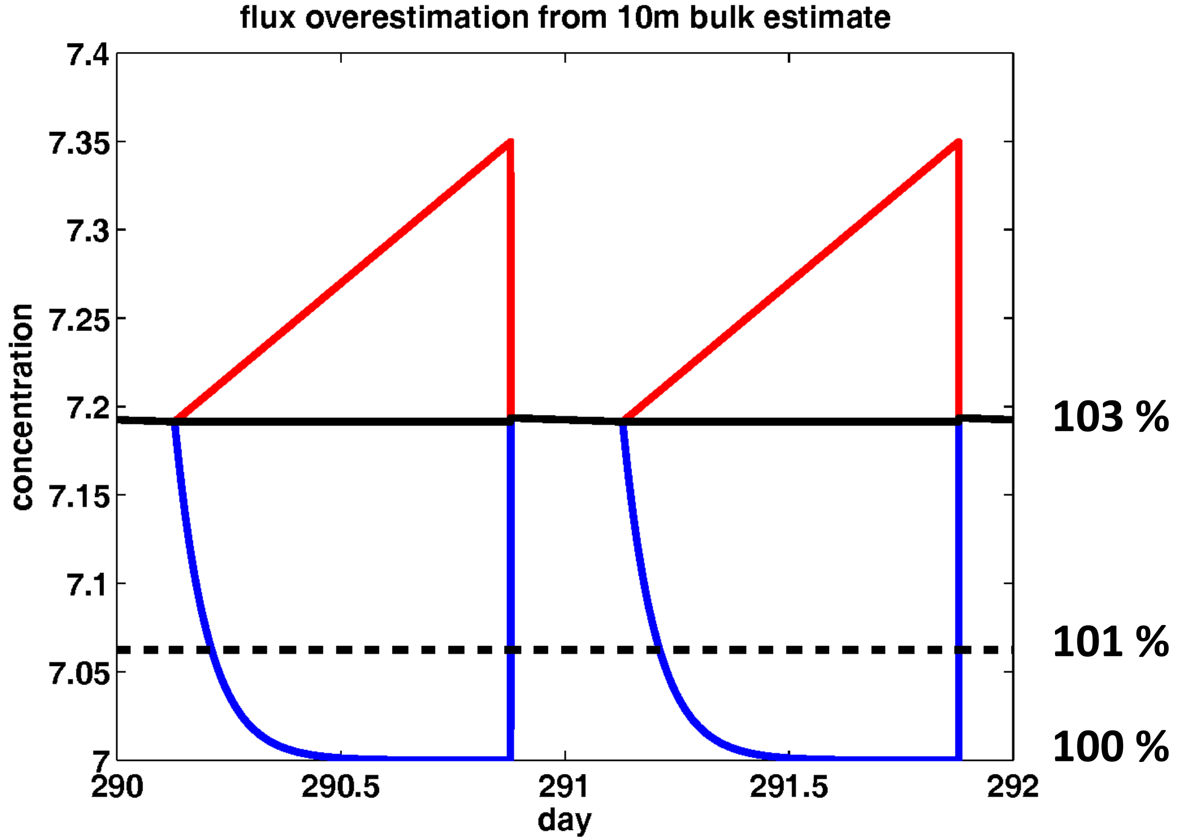

h = 0.1 m t = 6 h wind = 3 Bft

# 3c Simple model: example stationary solution

$$\Phi_{obs} = k_W \cdot \left(c_{103} - c_{100}\right)$$

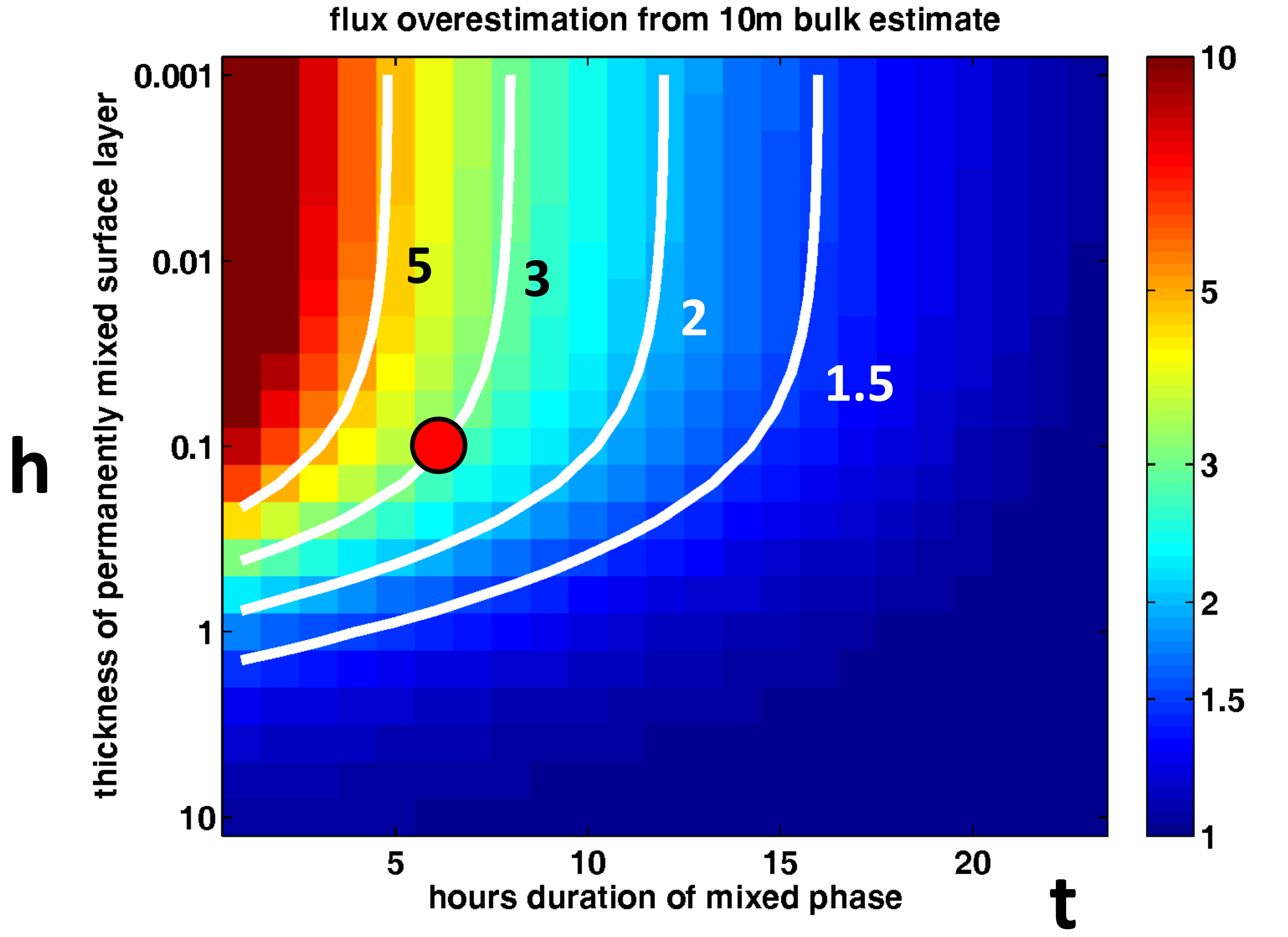
**The observed saturation would overestimate the gas flux by a factor of 3.**

$$\Phi_{ref} = k_W \cdot \left(c_{101} - c_{100}\right)$$

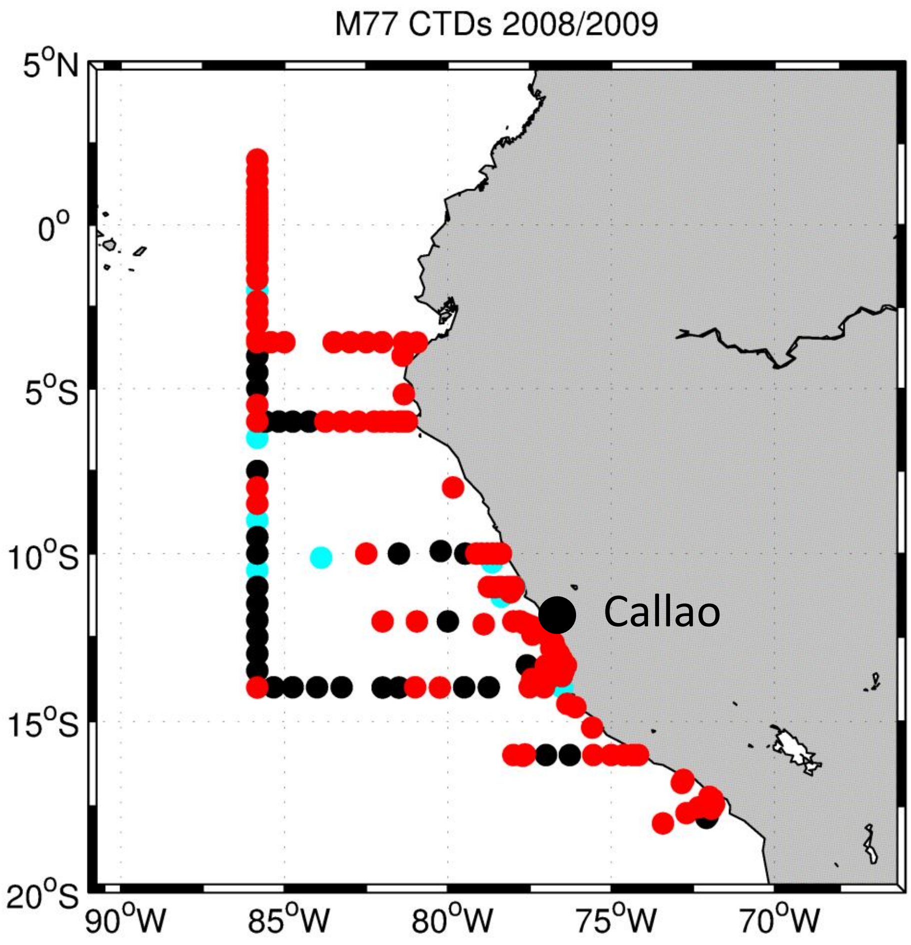



**h = 0.1 m t = 6 h wind = 3 Bft**

## 3c Model result: Flux overestimation depending on t and h



**3c** **Ship-based CTD profiles from 2008/2009 off Peru show a high percentage of stratification at 5 to 10m depth**




**$N^2$ in 5 to 10m depth:**

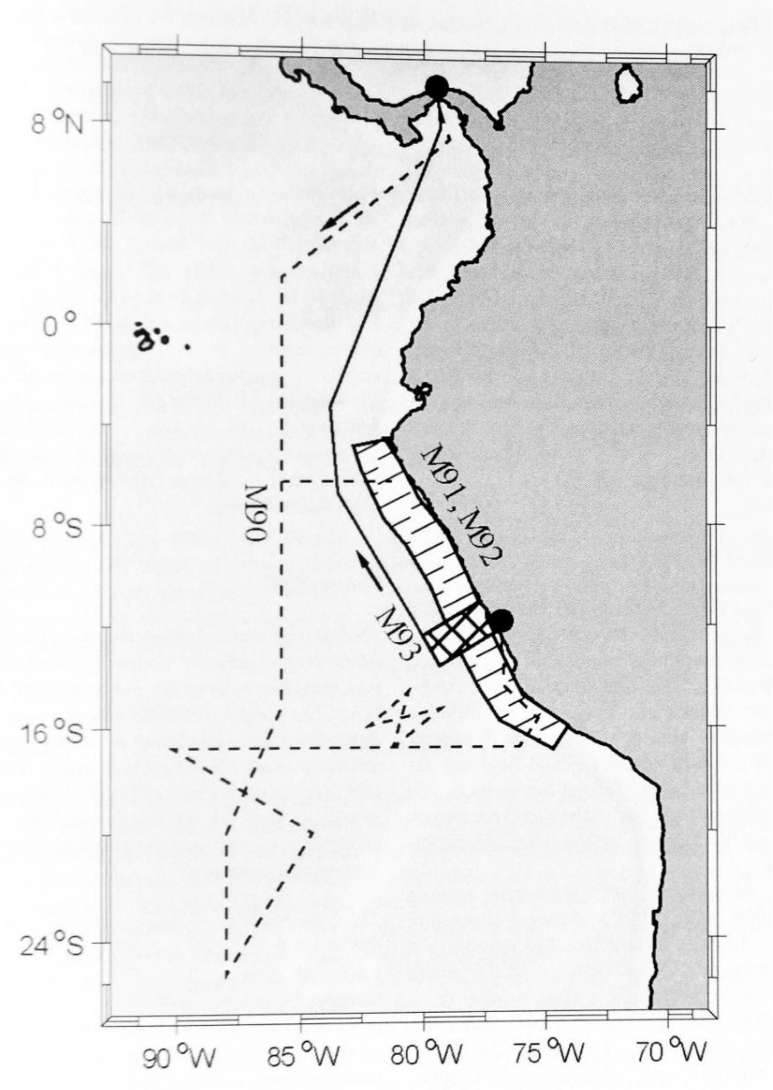
- Red: **$> 10^{-5}\ s^{-2}$ (comparable to main thermocline)**
- Black: **$< 10^{-5}\ s^{-2}$**
- Blue: **undecided**

# Planned research for 4 Meteor cruises off Peru
# Nov. 2012 to Feb. 2013

**Peru EBUS is a good place to watch out for shallow stratification, gas concentration gradients, surface slicks.**

**This will be part of the research happening through Meteor cruises M90 to M93.**

**Particularly on cruise M91 starting Nov. 28, which is a SOPRAN contribution to the SOLAS Mid-Term Strategy Initiative.**



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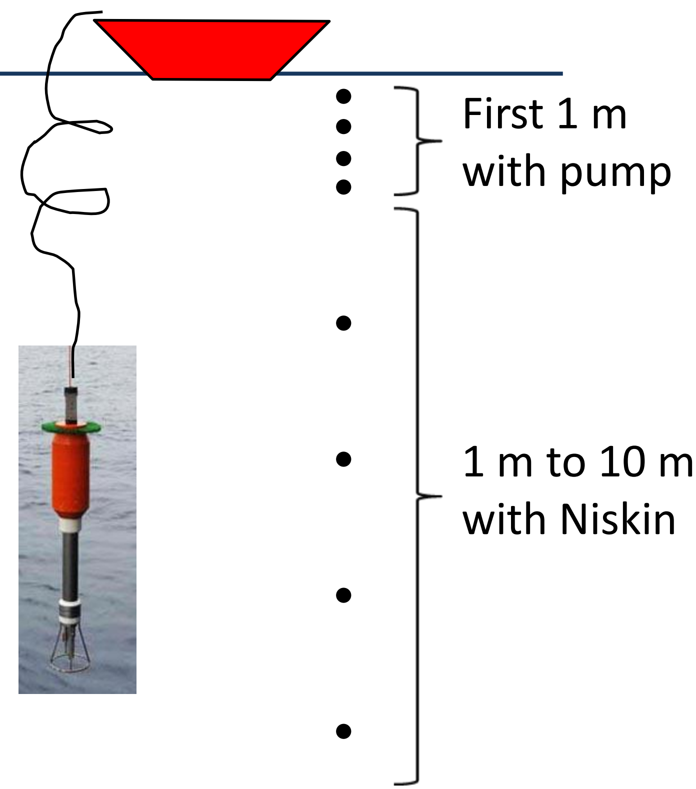
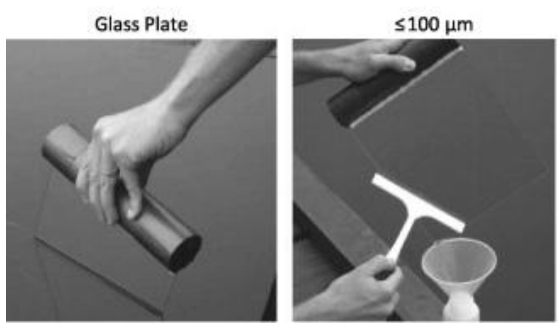
# Planned research for Meteor cruises off Peru Nov. 2012 to Feb. 2013


Sampling $N_2O$, T, S, mixing in the upper 10m




Sampling the surface microlayer
(SOPRAN, TP A. Engel)

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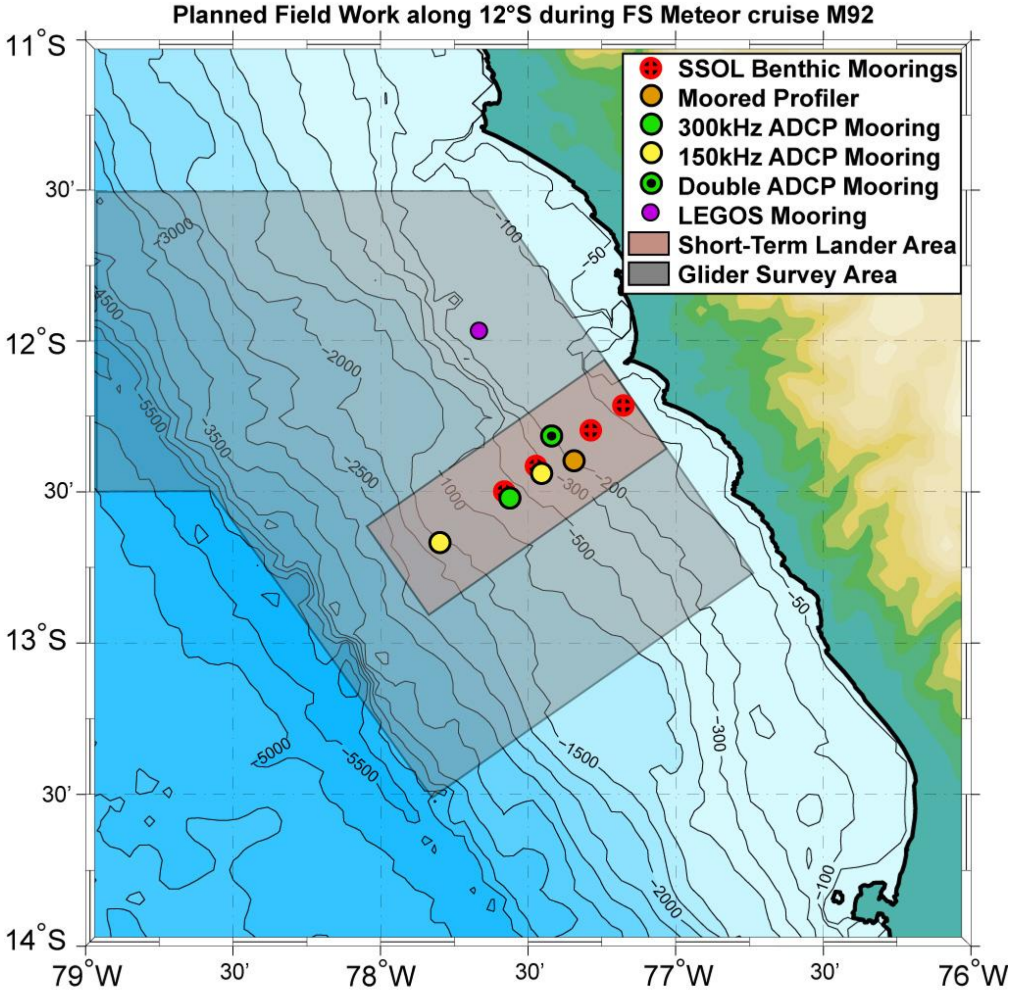
During M92 and M93

7 gliders circling in a 1x1degree area.
CTD, oxygen, chlorophyll, turbidity.

1 or 2 gliders with turbulence „MicroRider“



# Summary

**We found 2 promising candidates for causing reduced gas exchange:**

**- Surface active substances (surfactants)**

**- Diurnal stratification of the „mixed layer“**

**During cruises in the Peru upwelling in Nov. 2012 to Feb. 2013**
**we hope to obtain data that allows more insight, comprising:**

**- Shallow CTD data**
**- Shallow gas concentration profiles**
**- Shallow turbulence data**
**- Surface microlayer sampling**

References:

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