Tidally-induced dispersion of the Storfjorden overflow plume onto the West Svalbard Shelf

Fred Wobus[1]

G.I. Shapiro[1], J.M. Huthnance[2], M.A.M. Maqueda[2], Yevgeny Aksenov[3]

[1] University of Plymouth,

[2] National Oceanography Centre, Liverpool

[3] National Oceanography Centre, Southampton

RESEARCH WITH PLYMOUTH UNIVERSITY

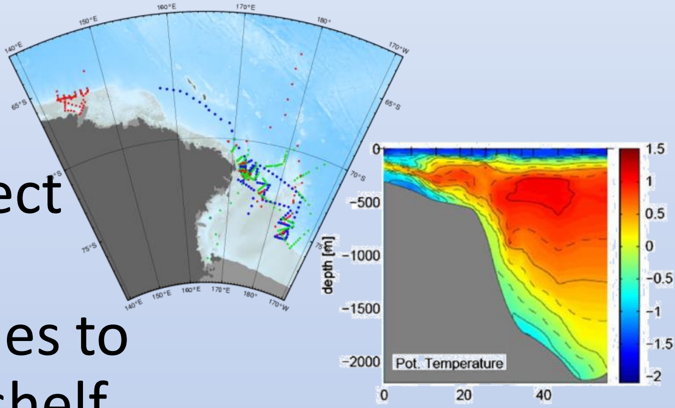
Vienna, 10th Apr 2013

EGU2013-4912

National Oceanography Centre

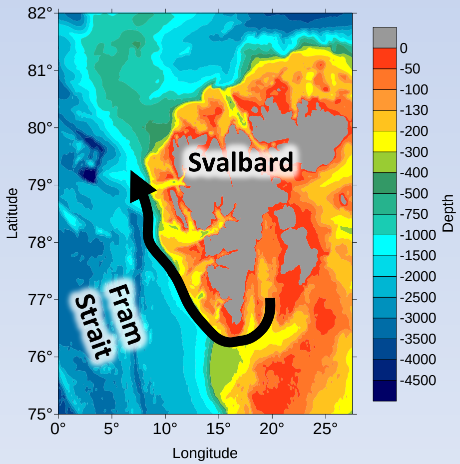
Dense water overflows and tides

- Scarce data until observations of thick dense bottom layer during **AnSlope** project (Gordon et al., 2004; Padman et al., 2009)
- Analytical & idealised models showed tides to increase plume height and augment off-shelf transport (Ou et al., 2009; Guan et al., 2009)



This study: Svalbard, Arctic Ocean

- Realistic model setup
  - Compare simulations with and without tides.
- Which phys. processes explain the differences?
- Can previous findings be applied to Svalbard?



Dense … and tides

- Scarce data … dense botto… (Gordon et al., …
- Analytical & … to increase plu… f transport (O…

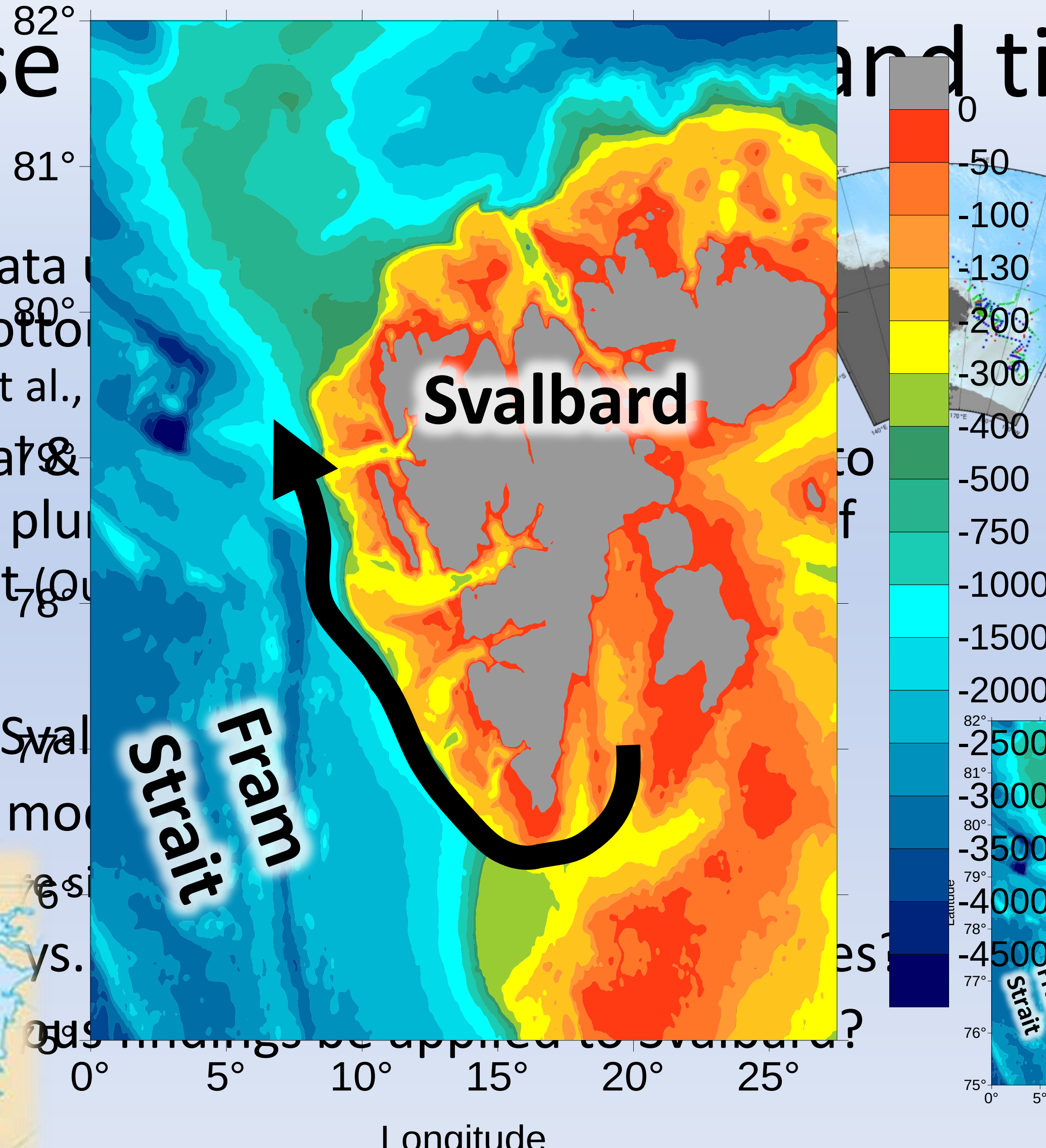
This study: Sval…

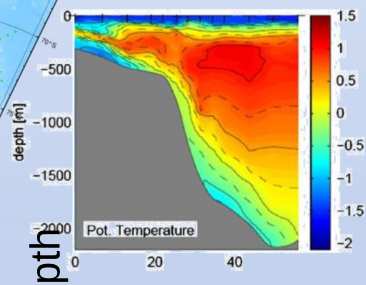
- Realistic mo…

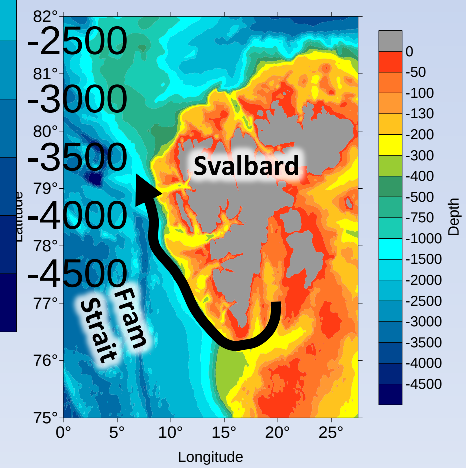
…e si…

…ys. … es?

…ous findings be applied to Svalbard?

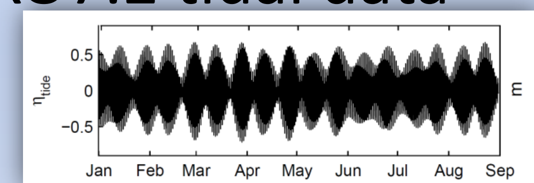




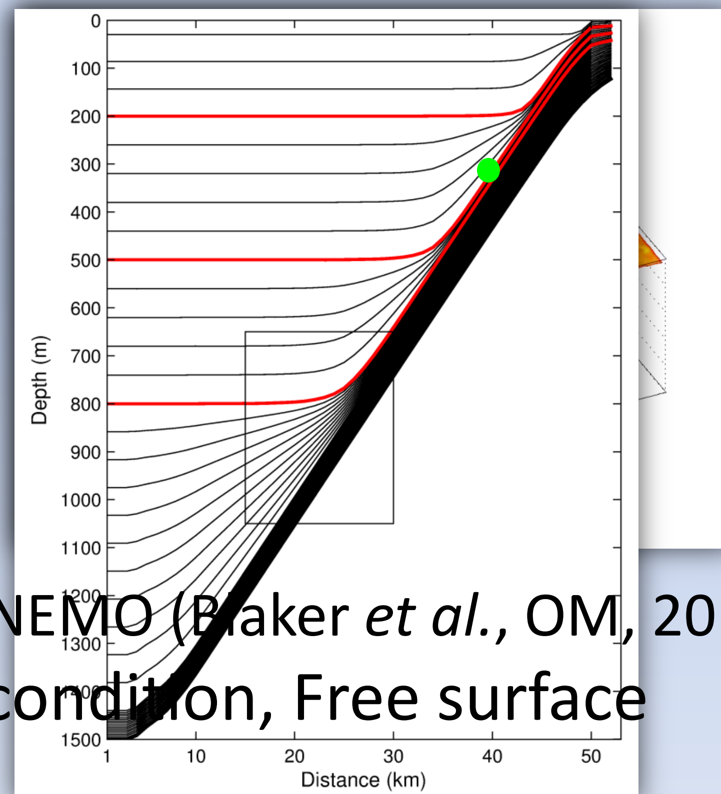


NEMO-Shelf v3.2 (O'Dea *et al.*, 2012)

- 3km horizontal resolution, 50 levels
- s_h-vertical coordinate system (Wobus *et al.*, 2013, OM)
- IBCAO v3 bathymetry
- DFS4.1 meteo forcing
- TPXO7.2 tidal data

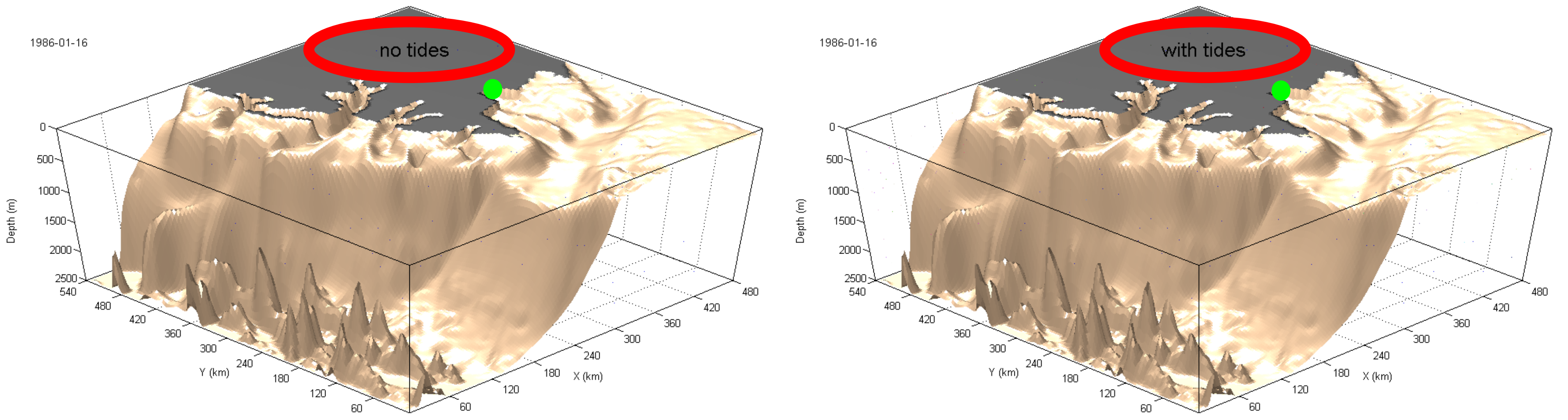


- GLS turbulence scheme
- Open boundaries
  - Forcing from 1/12° global NEMO (Blaker *et al.*, OM, 2012)
- No-slip bottom boundary condition, Free surface
- Parameterised overflow
  - Injection of dense water behind sill (●), 4 scenarios for S_{sill}



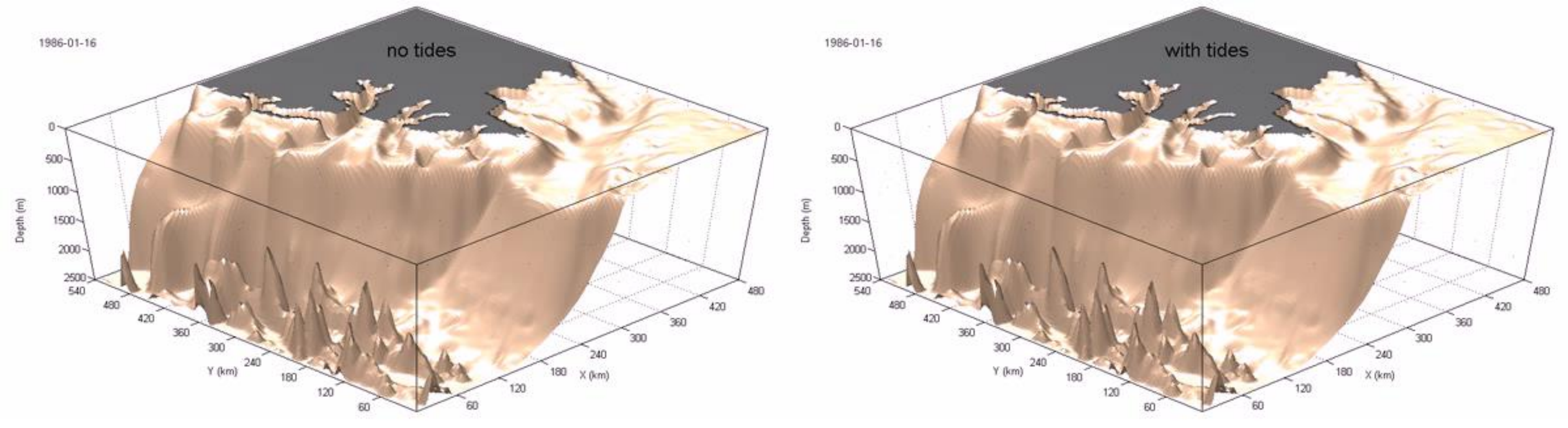
Comparison non-tidal vs tidal

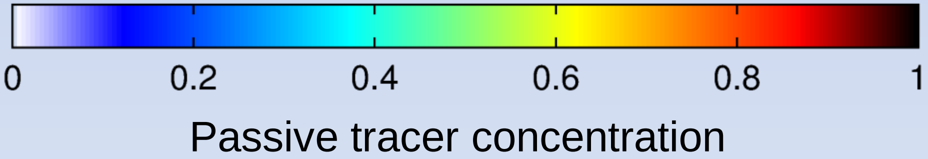
● = parameterised dense water overflow



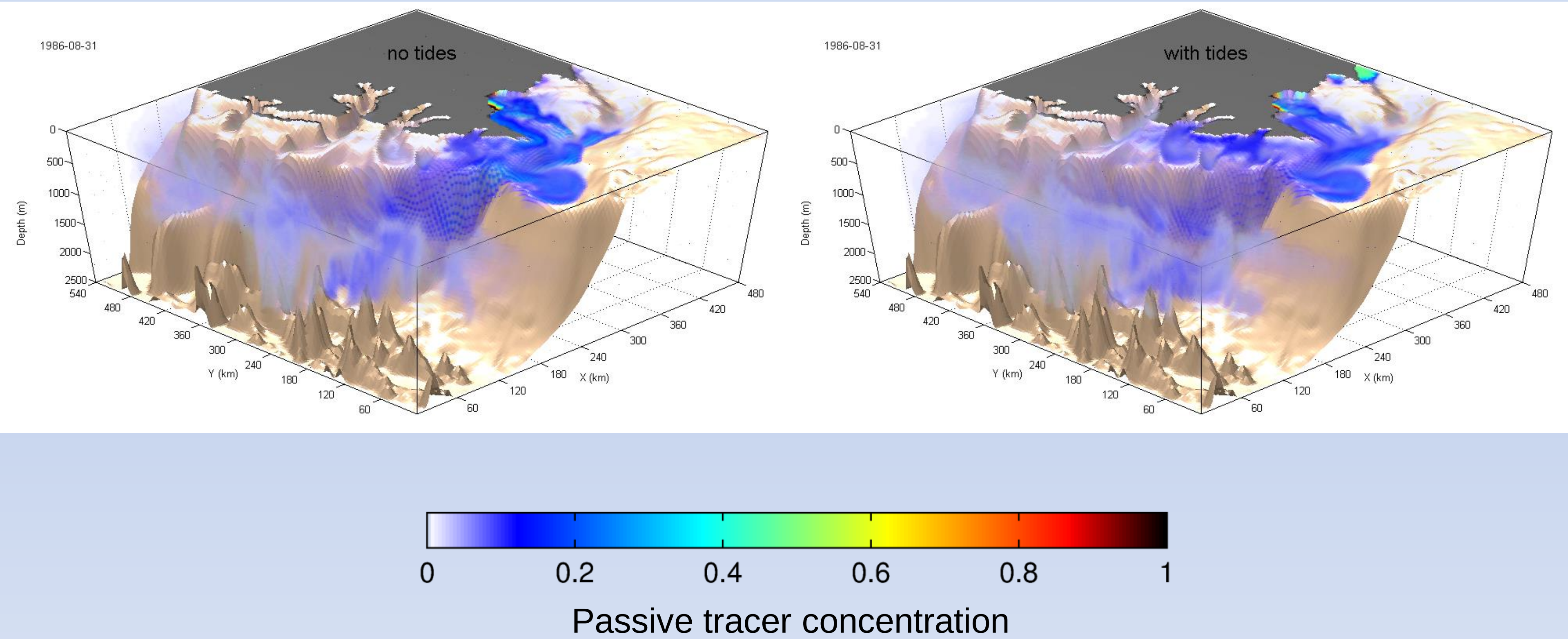
Passive tracer concentration

Comparison non-tidal vs tidal

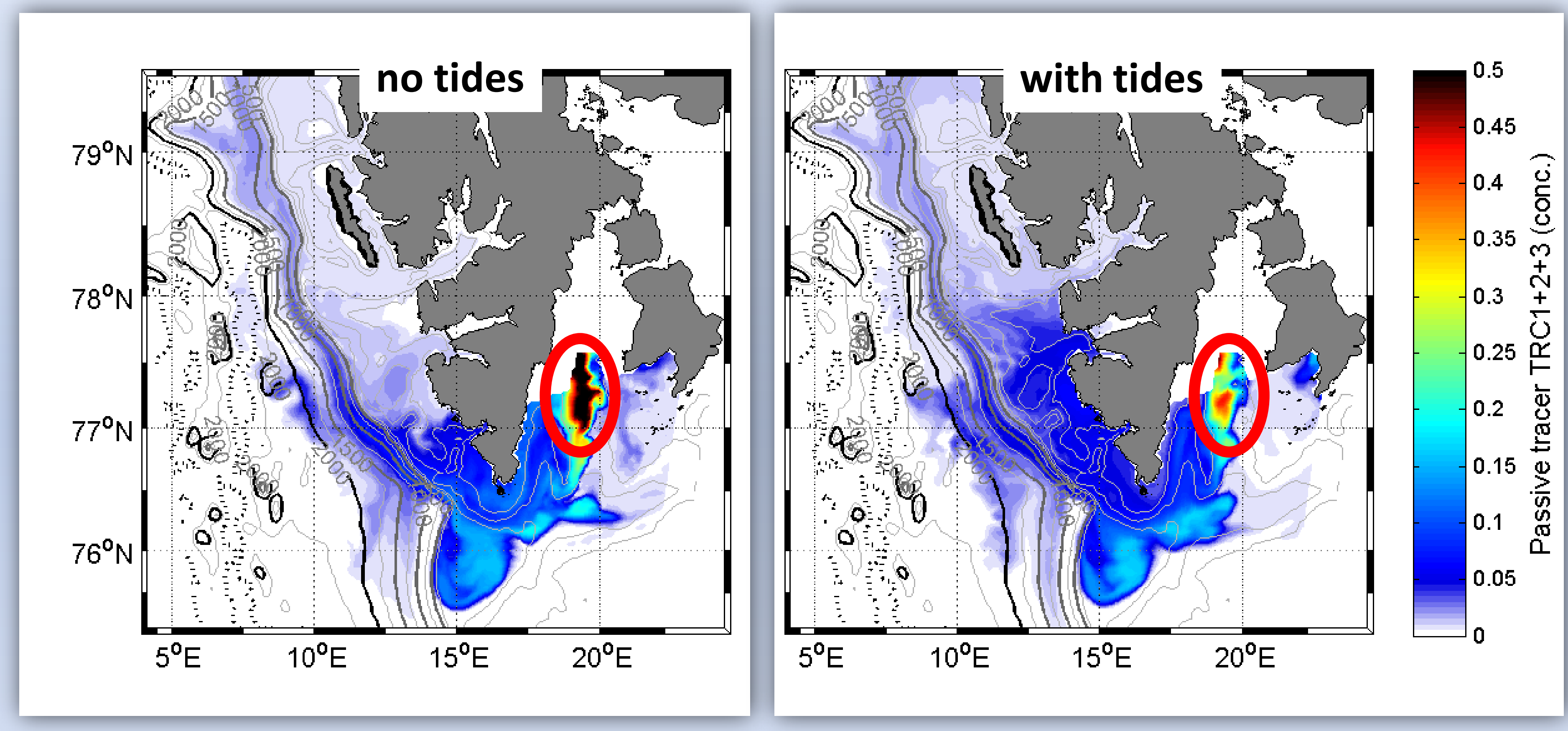




Comparison non-tidal vs tidal



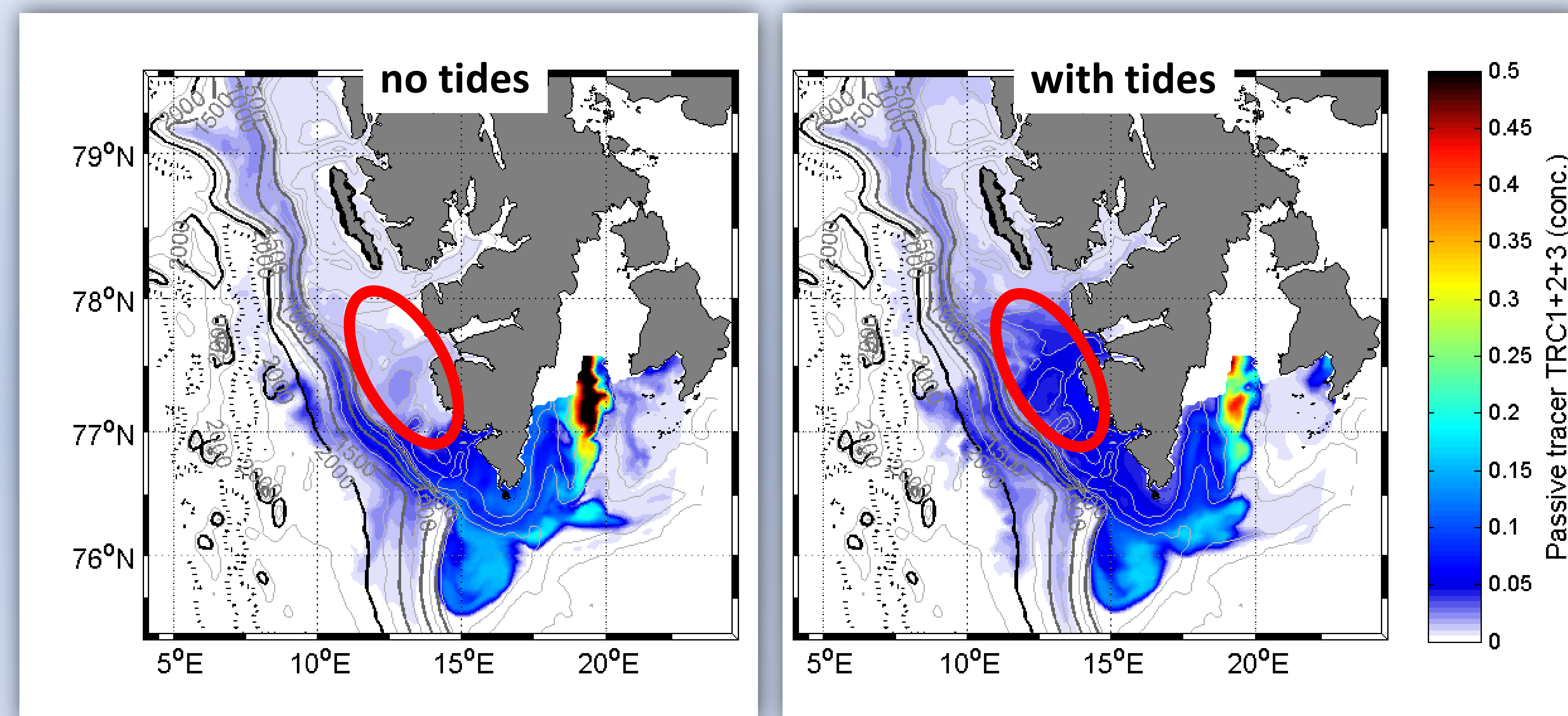
Comparison non-tidal vs tidal



- Tidal effect #1:
  Increase drainage of dense water from the fjord

Wobus *et al.* (2013) *Ocean Sci. Discuss.*, 10, 691-726

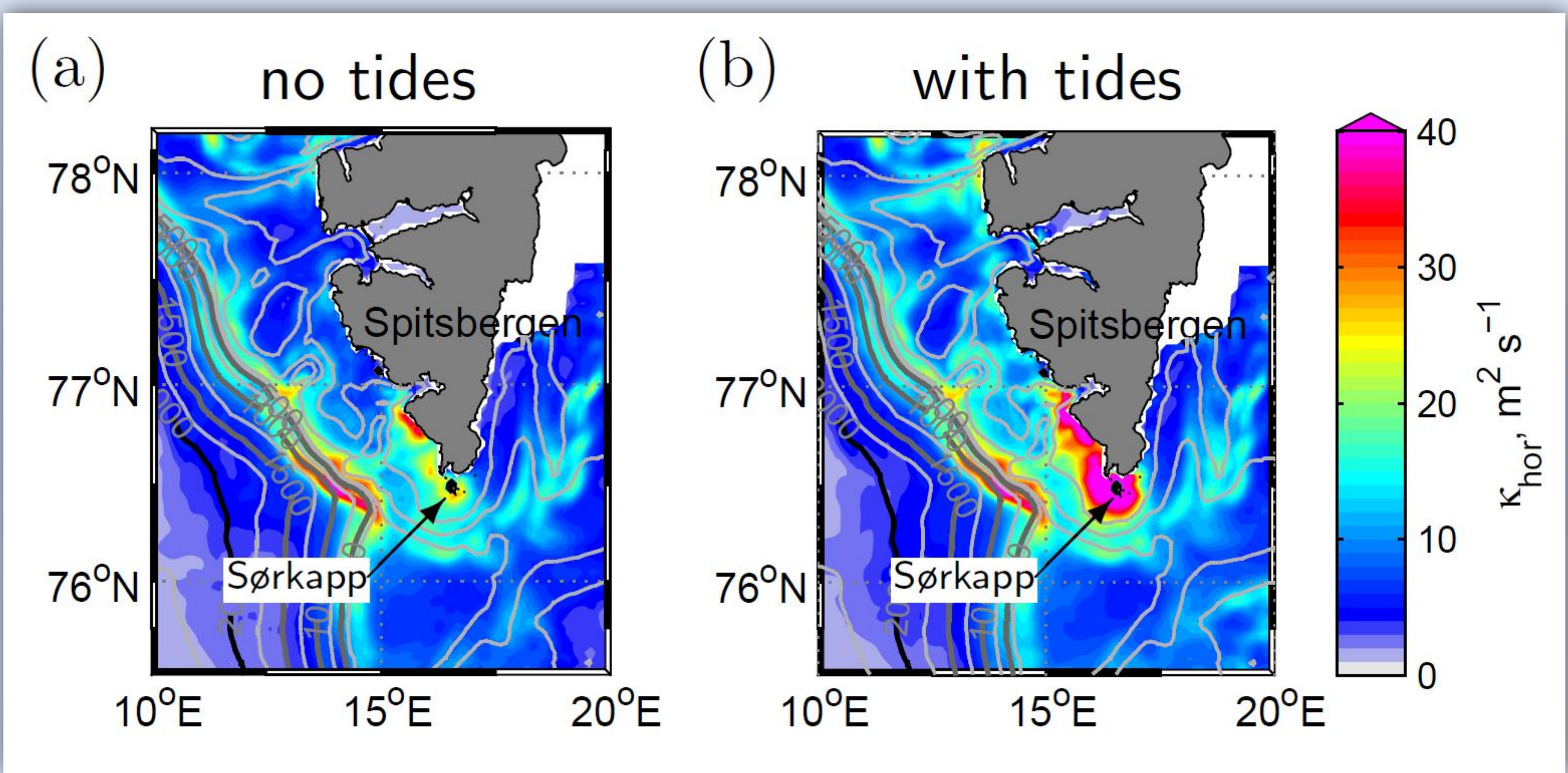
Comparison non-tidal vs tidal



- Tidal effect #2:
  Higher concentration of overflow water on shelf
  (plume is wider, flow is dispersed)

Wobus *et al.* (2013) *Ocean Sci. Discuss.*, 10, 691-726

Horizontal diffusion $D_{hor} = \nabla\cdot\left(\kappa_{hor}\,\Re\,\nabla T\right)$

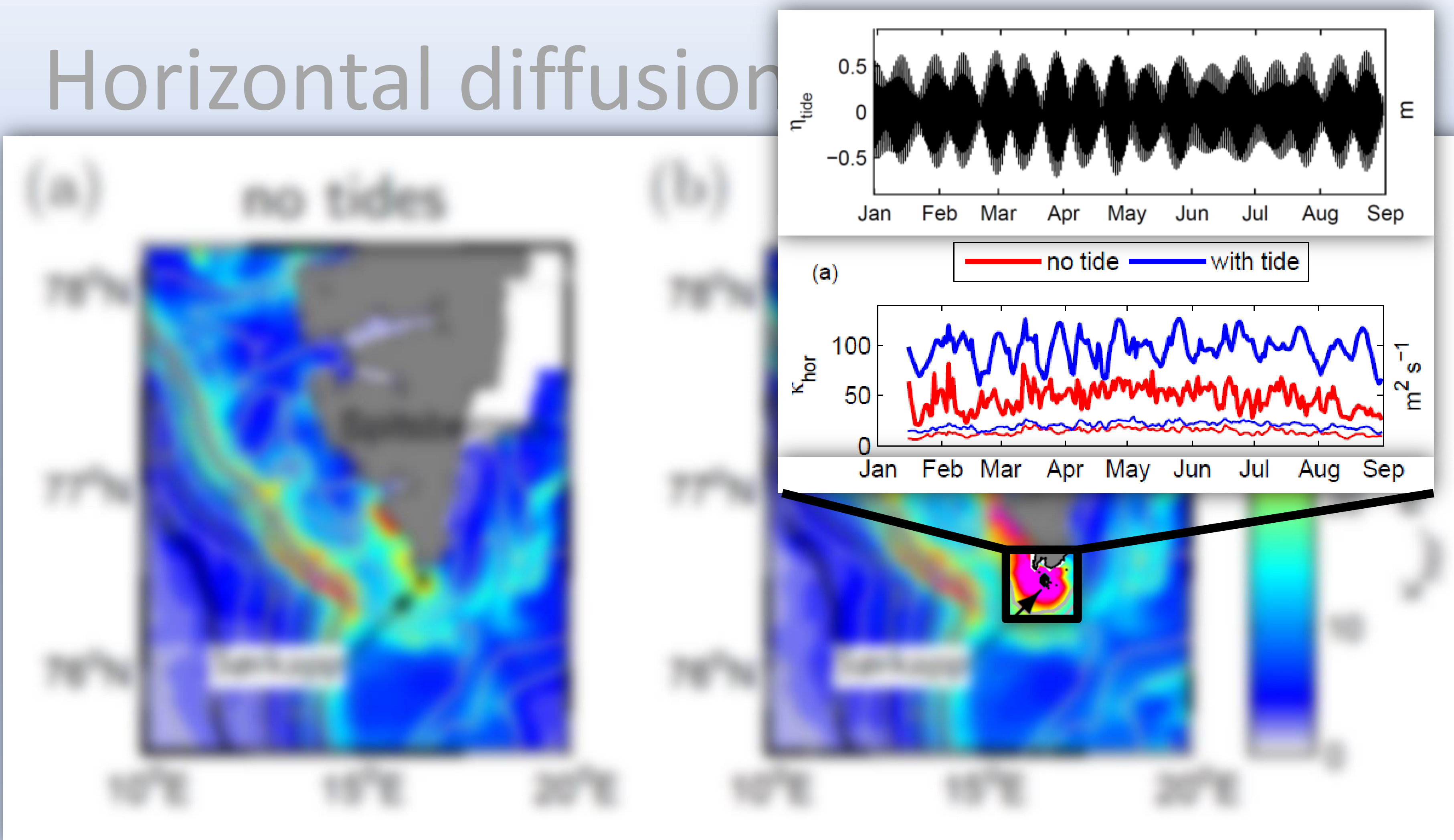


- Increased κ_{hor} around the Sørkapp
- Tracer gradient ∇T unaffected

➡ Tidally enhanced horizontal diffusion

Wobus *et al.* (2013) *Ocean Sci. Discuss.*, 10, 691-726

Horizontal diffusion

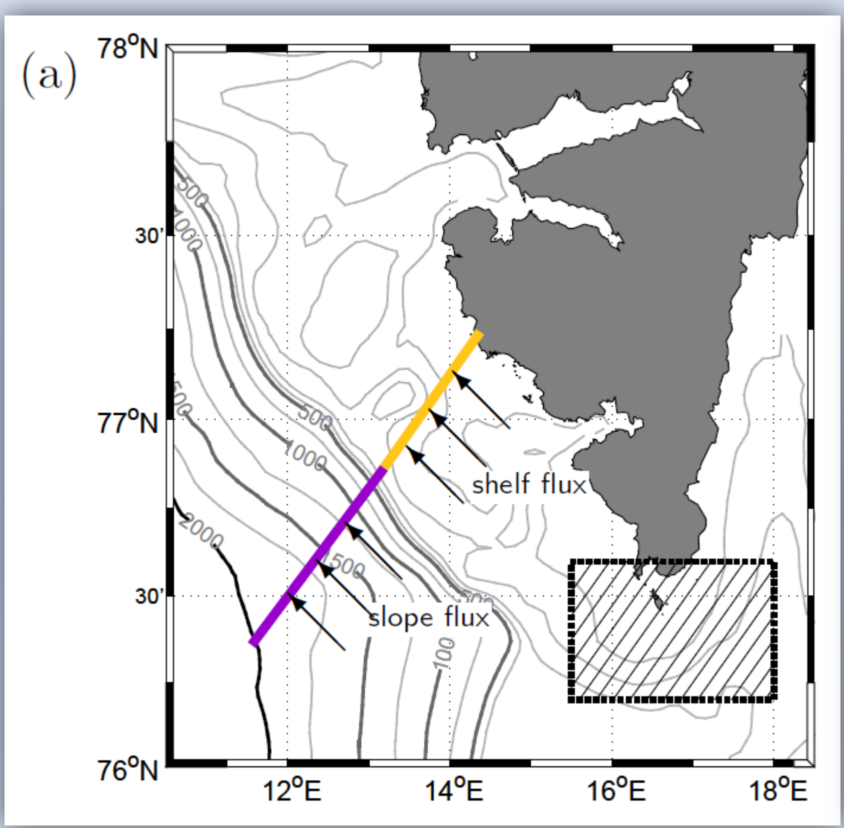


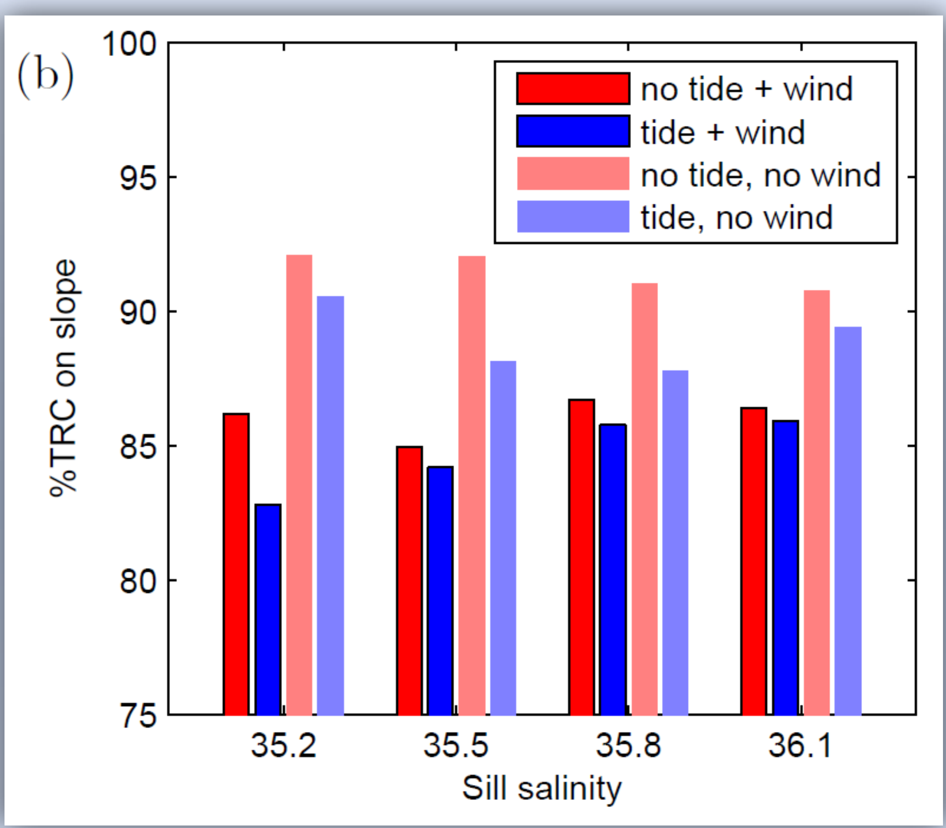
- Increased κ_{hor} around the Sørkapp
- Tracer gradient ∇T unaffected

➡ Tidally enhanced horizontal diffusion

Wobus *et al.* (2013) *Ocean Sci. Discuss.*, 10, 691-726

Downslope fluxes

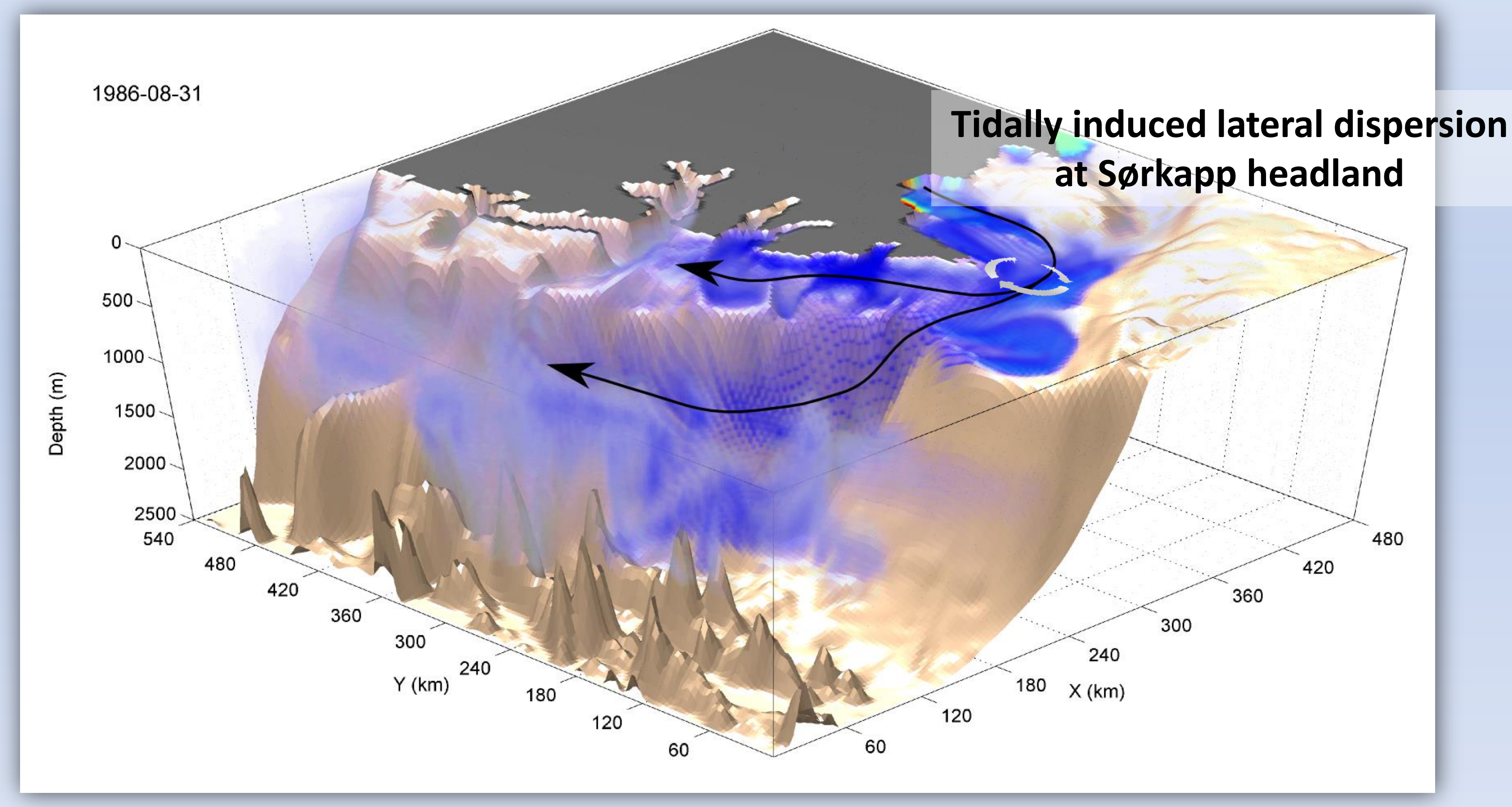




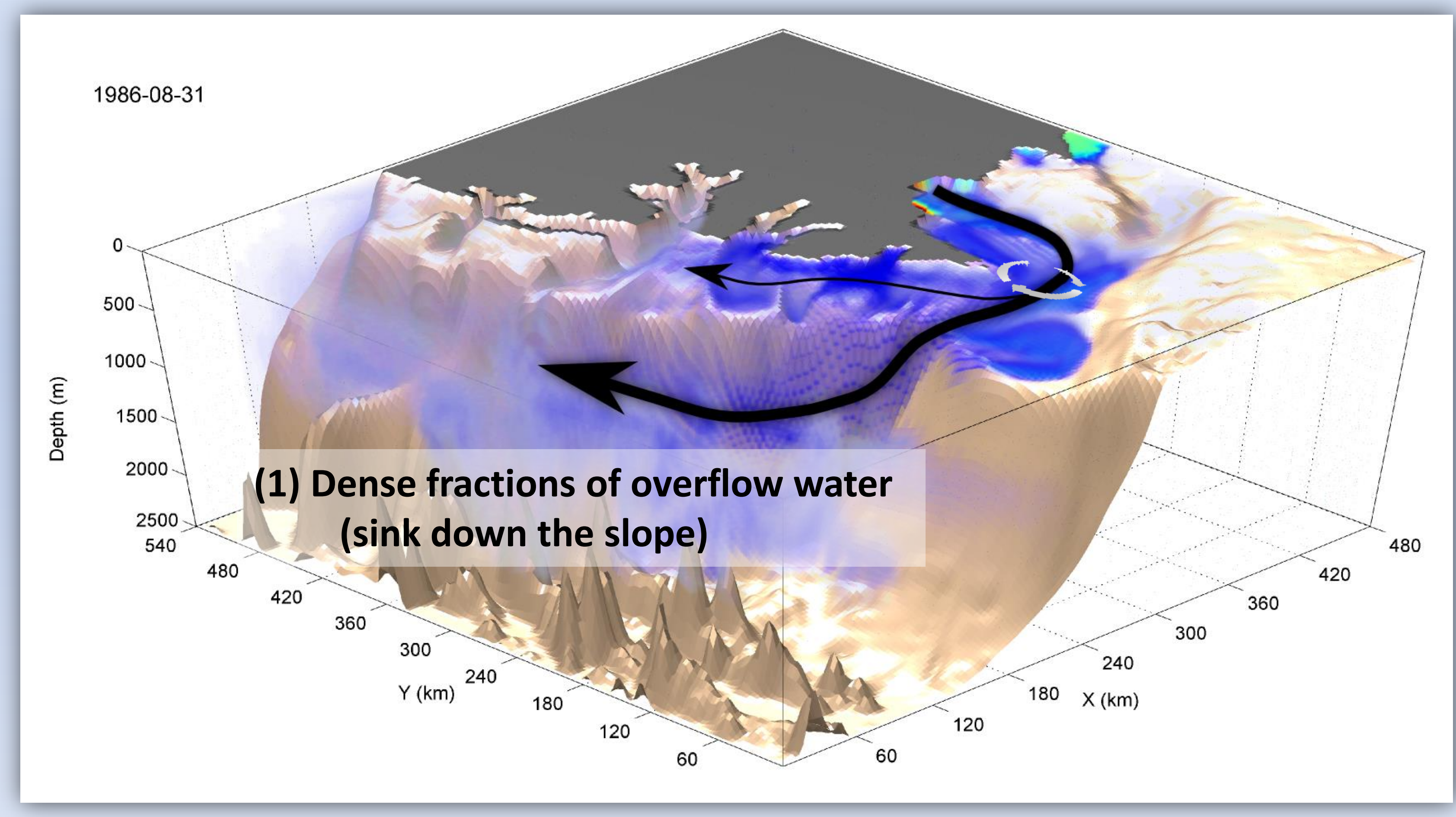
- Tides reduce downslope fluxes on deep slope (!!)
- Greater proportion of overflow water diverted onto shelf

Wobus *et al.* (2013) *Ocean Sci. Discuss.*, 10, 691-726

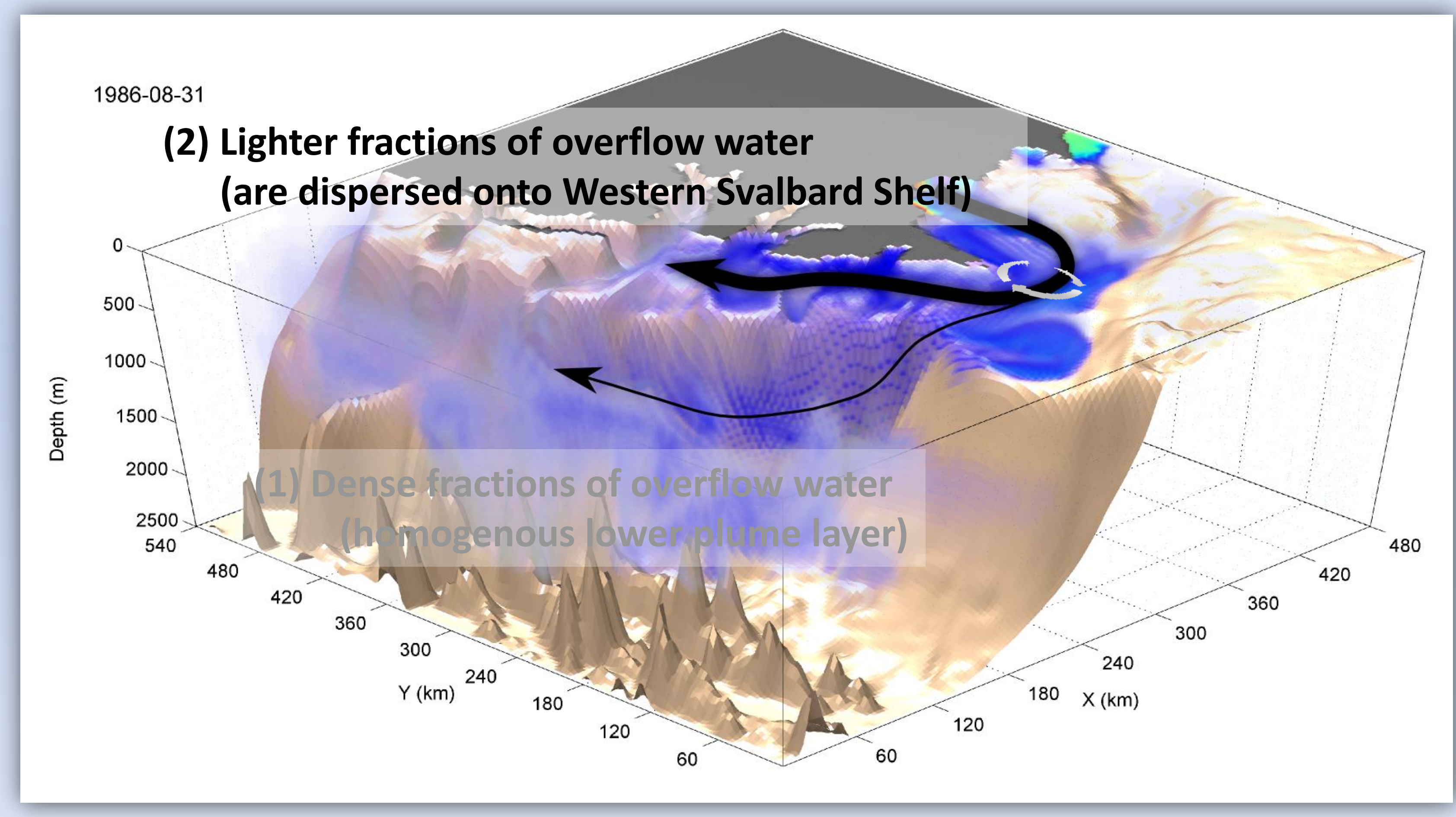
Tidally-induced branching



Tidally-induced branching



Tidally-induced branching



see also Fer *et al.* (DSR1, 2003)

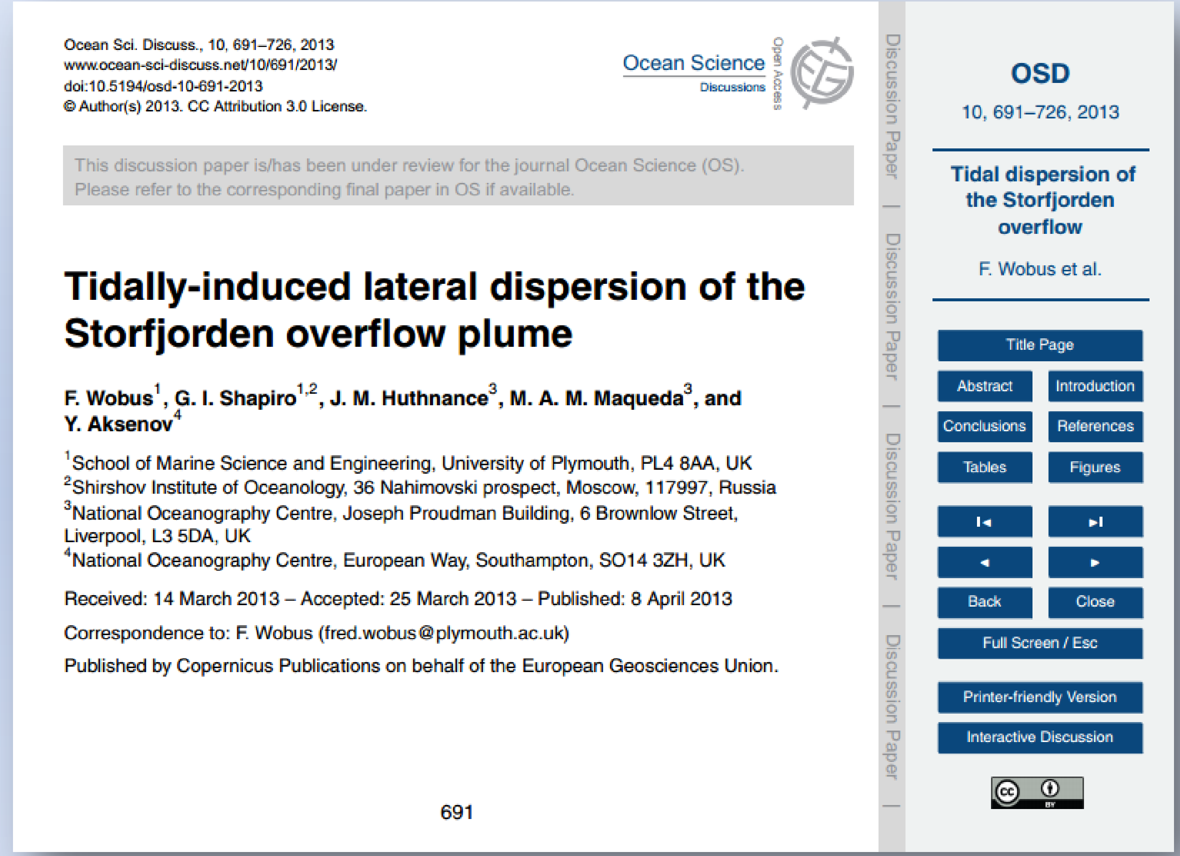
Conclusions

1. During shallow phase of flow (from sill to headland)
   - Thicker plume, increased off-shelf transport (Ou *et al.*, 2009)
   - → Findings of AnSlope models apply
2. During intermediate stage of the flow (at Sørkapp headland)
   - Tidal dispersion at the headland draws overflow waters away from main plume into Svalbard coastal current
   - → Reduction in flux of dense waters into deep Fram Strait
   - Intense overflow episodes are accompanied by increased fluxes of Storfjorden water on to the shelf and into the fjords of Western Svalbard
3. Tides are significant in models of dense water overflows
   - *see also* Postlethwaite et al. (OS, 2011) and Holloway & Proshutinsky (JGR, 2007)
4. **Where abrupt topography intersects the plume path, tidal effects around may alter downslope fluxes**

Wobus *et al.* (2013) *Ocean Sci. Discuss.*, 10, 691-726

Ocean Science Discussions

http://www.ocean-sci-discuss.net/10/691/2013/osd-10-691-2013.html



Ocean Sci. Discuss., 10, 691–726, 2013
www.ocean-sci-discuss.net/10/691/2013/
doi:10.5194/osd-10-691-2013

Ocean Science Discussions
Open Access

This discussion paper is/has been under review for the journal Ocean Science (OS). Please refer to the corresponding final paper in OS if available.

Tidally-induced lateral dispersion of the Storfjorden overflow plume

F. Wobus[1], G. I. Shapiro[1,2], J. M. Huthnance[3], M. A. M. Maqueda[3], and Y. Aksenov[4]

[1]School of Marine Science and Engineering, University of Plymouth, PL4 8AA, UK
[2]Shirshov Institute of Oceanology, 36 Nahimovski prospect, Moscow, 117997, Russia
[3]National Oceanography Centre, Joseph Proudman Building, 6 Brownlow Street, Liverpool, L3 5DA, UK
[4]National Oceanography Centre, European Way, Southampton, SO14 3ZH, UK

Received: 14 March 2013 – Accepted: 25 March 2013 – Published: 8 April 2013

Correspondence to: F. Wobus (fred.wobus@plymouth.ac.uk)

Published by Copernicus Publications on behalf of the European Geosciences Union.

OSD
10, 691–726, 2013

Tidal dispersion of the Storfjorden overflow

F. Wobus et al.

Title Page
Abstract | Introduction
Conclusions | References
Tables | Figures
◄ | ►
◄ | ►
Back | Close
Full Screen / Esc
Printer-friendly Version
Interactive Discussion

fred.wobus@plymouth.ac.uk

or Google fred plymouth university

References 1/3

Wobus, F., G. I. Shapiro, M. A. M. Maqueda, J. M. Huthnance (2011) Numerical simulations of dense water cascading on a steep slope. Journal of Marine Research, **69**, 391–415

Wobus, F., G. I. Shapiro , J. M. Huthnance, M. A. M. Maqueda (2013) The piercing of the Atlantic Layer by an Arctic shelf water cascade in an idealised study inspired by the Storfjorden overflow in Svalbard. *Ocean Modelling* (Arctic Ocean Special Issue, in press)

Ivanov, V. V., G. I. Shapiro, J. M. Huthnance, D. L. Aleynik, P. N. Golovin (2004) Cascades of dense water around the world ocean. *Progress In Oceanography*, **60**(1), 47–98.

Quadfasel, D.; Rudels, B. & Kurz, K. (1988) Outflow of dense water from a Svalbard fjord into the Fram Strait, *Deep-Sea Research A*, **35**(7), 1143-1150

R. Skogseth, P.M. Haugan, M. Jakobsson, Watermass transformations in Storfjorden (2005) *Continental Shelf Research*, **25**(5–6), 667-695

Skogseth, R., I. Fer, and P. M. Haugan (2005) Dense-water production and overflow from an arctic coastal polynya in Storfjorden, in *The Nordic Seas: An Integrated Perspective Oceanography, Climatology, Biogeochemistry, and Modeling*, Geophys. Monogr. Ser., vol. 158, edited by H. Drange et al., pp. 73–88, AGU, Washington

References 2/3

Gordon, A.L., Zambianchi, E., Orsi, A., Visbeck, M., Giulivi, C.F., Whitworth, Thomas, I., Spezie, G., 2004. Energetic plumes over the western ross sea continental slope. Geophysical Research Letters 31, L21302

Padman, L., Howard, S.L., Orsi, A.H., Muench, R.D., 2009. Tides of the northwestern ross sea and their impact on dense outflows of antarctic bottom water. Deep Sea Research Part II: Topical Studies in Oceanography 56, 818–834.

Ou, H.W., Guan, X., Chen, D., 2009. Tidal effect on the dense water discharge, part 1: Analytical model. Deep Sea Research Part II: Topical Studies in Oceanography 56, 874–883

Guan, X.; Ou, H.-W. & Chen, D., 2009. Tidal effect on the dense water discharge, Part 2: A numerical study. Deep Sea Research Part II: Topical Studies in Oceanography 56, 884-894

Geyer, W.R., Signell, R.P., 1992. A reassessment of the role of tidal dispersion in estuaries and bays. Estuaries and Coasts 15, 97–108.

McCabe, R.M., MacCready, P., Pawlak, G., 2006. Form drag due to flow separation at a headland. Journal of Physical Oceanography 36, 2136–2152.

References 3/3

Postlethwaite, C. F.; Morales Maqueda, M. A.; le Fouest, V.; Tattersall, G. R.; Holt, J. & Willmott, A. J., 2011. The effect of tides on dense water formation in Arctic shelf seas. Ocean Science 7, 203-217

Holloway, G. & Proshutinsky, A., 2007. Role of tides in Arctic ocean/ice climate. Journal of Geophysical Research: Oceans 112, C04S06

Fer, I.; Skogseth, R.; Haugan, P. M. & Jaccard, P., 2003. Observations of the Storfjorden overflow. Deep Sea Research Part I: Oceanographic Research Papers 50, 1283-1303

Blaker, A. T.; Hirschi, J. J.-M.; Sinha, B.; de Cuevas, B.; Alderson, S.; Coward, A. & Madec, G., 2012. Large near-inertial oscillations of the Atlantic meridional overturning circulation. Ocean Modelling 42, 50-56

O'Dea, E. J., J. While, R. Furner, A. Arnold, P. Hyder, D. Storkey, K. P. Edwards, J. R. Siddorn, M. J. Martin, H. Liu, J. T. Holt, 2012, An operational ocean forecast system incorporating SST data assimilation for the tidally driven European North-West European shelf. Journal of Operational Oceanography, Volume 5, Number 1, pp. 3-17(15)

Abstract EGU2013-4912

Tidally-induced dispersion of the Storfjorden overflow plume onto the West Svalbard Shelf

We investigate the flow of brine-enriched shelf water from the Storfjorden (Svalbard) into Fram Strait and onto the Western Svalbard Shelf using NEMO, a 3D numerical ocean circulation model, in a regional setup with realistic bathymetry, full meteorology, open boundary conditions and tides. The model has 3 km horizontal resolution and 50 vertical levels in the s_h-coordinate system which is specially designed to resolve bottom boundary layer processes.

In a series of experiments varying initial plume density and wind strength we focus on the influence of the tides on the propagation of the dense water plume by turning on and off the tidal forcing at the model boundaries.

Simulations including tides consistently reveal increased horizontal diffusivity around the Sørkapp, the southernmost headland of Spitsbergen, which is in close proximity to the plume path. Due to the tides and largely independent of wind effects the plume widens and laterally disperses as it spreads into Storfjordrenna, the trough steering the plume's path from the fjord towards the continental slope. On the shallow shelf the tides also increase the vertical diffusivity and thus plume height, with wind-driven turbulence contributing to this effect.

We find that a tidally augmented exchange between the Svalbard Coastal Current and lighter fractions of overflow water leads to their propagation onto the Western Svalbard Shelf where water of Storfjorden origin may enter several large fjords. Based on our results from the Storfjorden we conclude that tidal modulation during the shallow phase of the overflow could also be important for other dense water cascades originating in shallow shelf regions.