ALFRED-WEGENER-INSTITUT
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Key controls of water vapour isotopes during oceanic evaporation and their global impact

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Focus of this study

Does wind speed influence kinetic fractionation processes of $H_2{}^{18}O$ and HDO during water evaporation from ocean surface?

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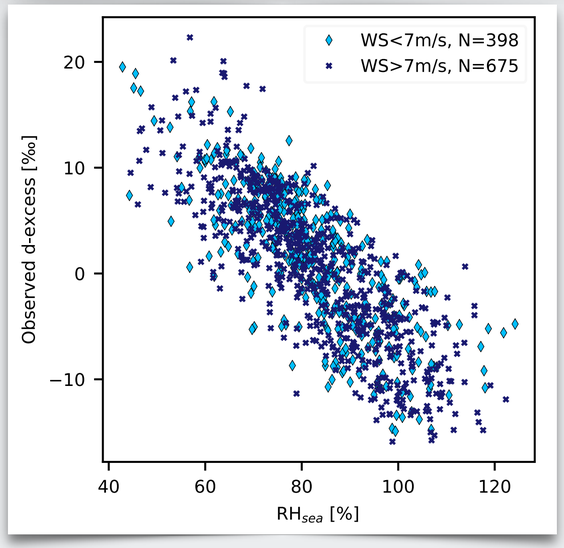
Motivation

- two years of continuous vapour isotope measurements on board of the research vessel Polarstern have not revealed any wind speed dependency of the kinetic fraction during evaporation
  - *the data challenges the pioneering model approach of Merlivat & Jouzel (1979)*
- simulation results of the isotope-enabled model ECHAM5-wiso agree better with observations if a constant fractionation factor for a rough wind regime is assumed



Hypothesis

- a constant fractionation factor for a rough wind regime also leads to better model results compared to other available vapour isotope measurements

Bonne, J. L., Behrens, M., Meyer, H., Kipfstuhl, S., Rabe, B., Schönicke, L., Steen-Larsen, H. C. and Werner, M.:
Resolving the controls of water vapour isotopes in the Atlantic sector, Nature Communications, 10(1), 1632, doi:10.1038/s41467-019-09242-6, 2019.

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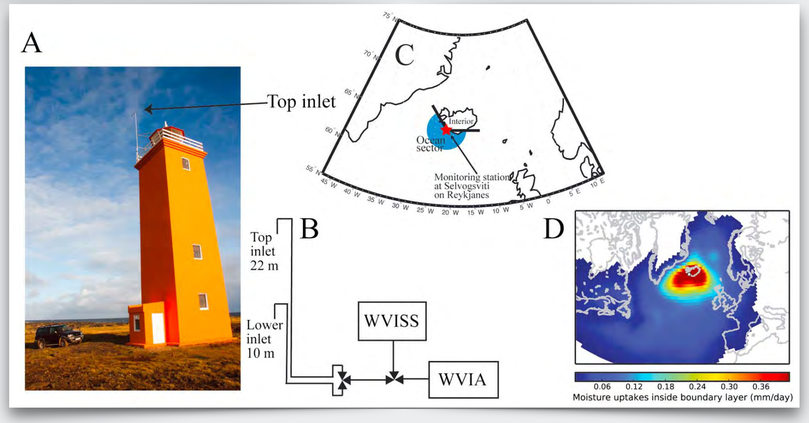
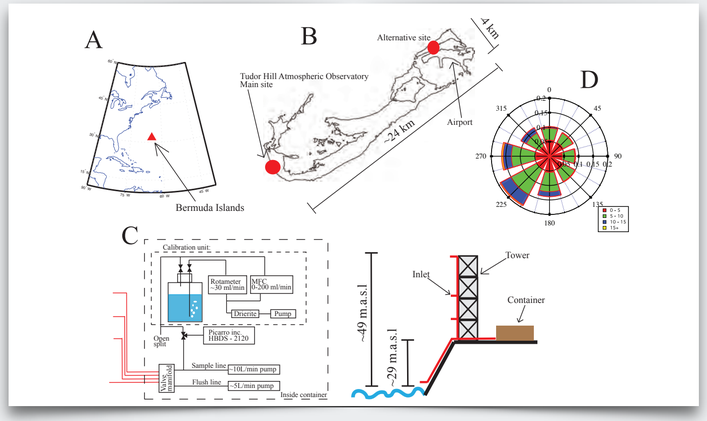
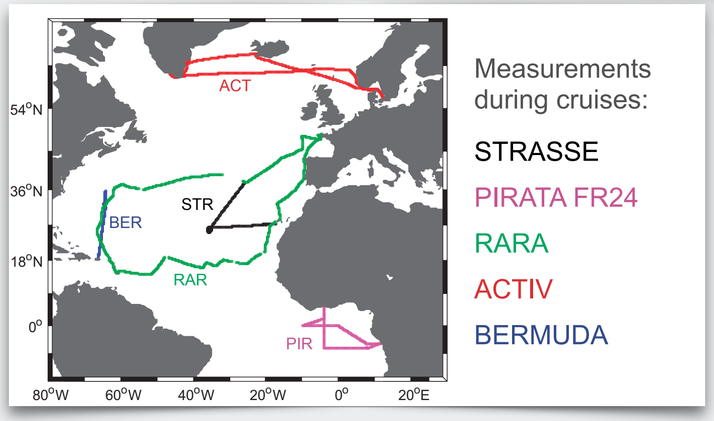
Approach

- isotopes in vapour have been continuously measured at Bermuda, Iceland and NEEM Greenland during the last years, as well as during 5 shorter ship cruises over the Atlantic
- model results come from 3 different ECHAM5-wiso simulations with a smooth/rough/wind-speed dependent fractionation coefficient plus one ECHAM6-wiso simulation (smooth regime coefficient)
- Pearson correlation coefficient *r* and root mean square error *RMSE* are calculated to evaluate the model-data agreement for both $\delta^{18}O$ and Deuterium excess (*dex*) in vapour







Benetti et al.: Stable isotopes in the atmospheric marine boundary layer water vapour over the Atlantic Ocean, 2012–2015, *Scientific Data*, 4, 160128, doi:10.1038/sdata.2016.128, 2017.
Steen-Larsen et al.: Moisture sources and synoptic to seasonal variability of North Atlantic water vapor isotopic composition, *JGR Atmosphere*, 120, 5757–5774, doi:10.1002/2015JD023234, 2015.
Steen-Larsen et al.: Climatic controls on water vapor deuterium excess in the marine boundary layer of the North Atlantic based on 500 days of in situ, continuous measurements, *ACP*, 14(15), 7741–7756, doi:10.5194/acp-14-7741-2014, 2014.
Steen-Larsen et al.: What controls the isotopic composition of Greenland surface snow? *Climate of the Past*, 10(1), 377–392, doi:10.5194/cp-10-377-2014, 2014.

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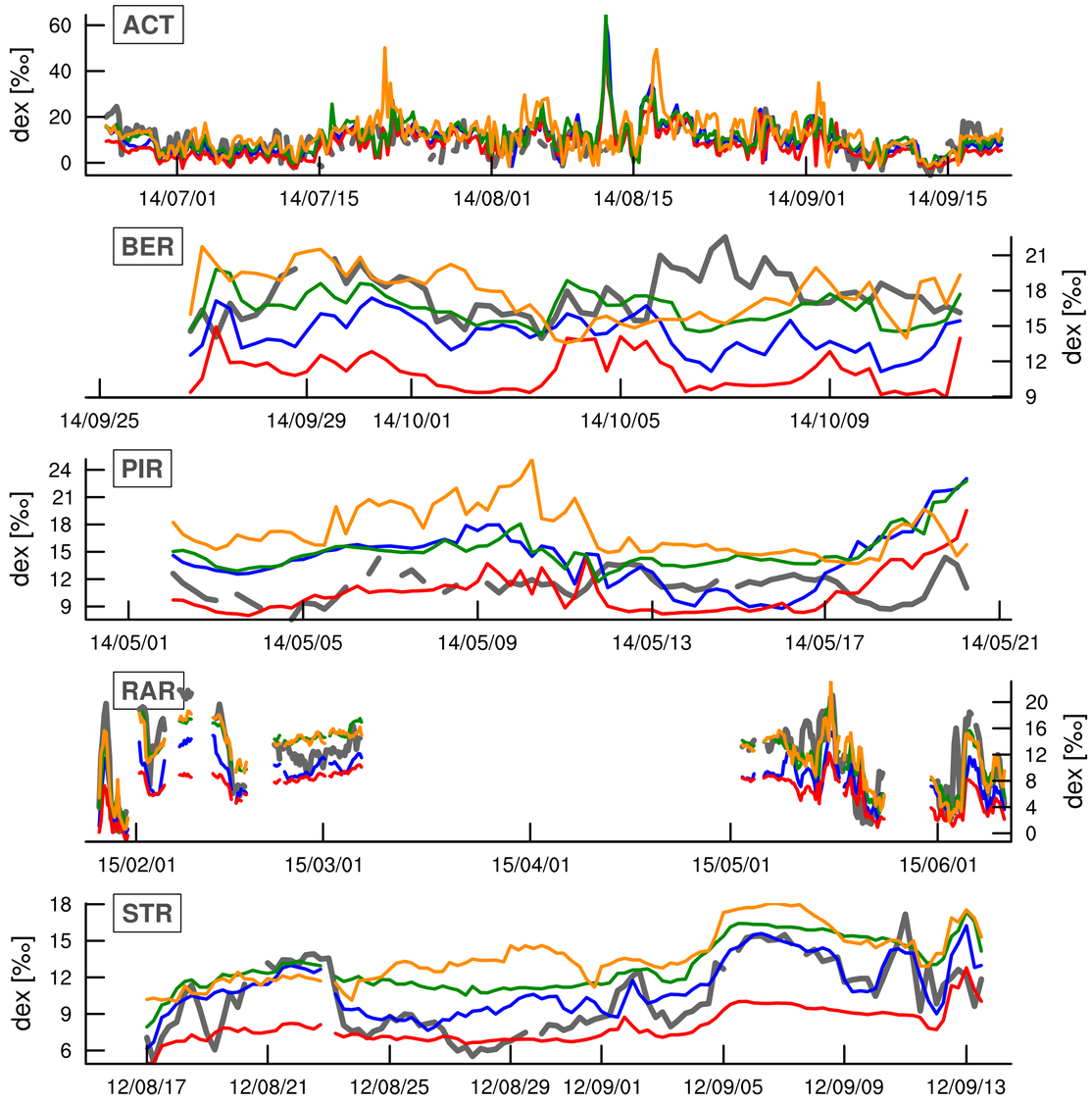
	correlation r (RMSE)	ACT	BER	PIR	RAR	STR
dex	ECHAM5-wiso smooth	0.37 (7.24)	-0.06 (2.66)	0.02 (4.69)	0.79 (3.12)	0.82 (3.09)
	ECHAM5-wiso mixed	0.31 (7.55)	-0.14 (4.28)	-0.04 (4.67)	0.78 (4.81)	0.84 (1.73)
	ECHAM5-wiso rough	0.29 (7.39)	-0.13 (7.07)	-0.01 (2.90)	0.72 (6.42)	0.75 (3.12)
	ECHAM6-wiso smooth	0.42 (7.08)	-0.08 (2.89)	0.03 (6.58)	0.78 (3.23)	0.58 (4.12)

* better model-data matches are highlighted by grey cells *

Results: ship cruise Deuterium excess data

- for ECHAM5-wiso (T106 resolution, nudged to ERAinterim), no simulation setup is clearly superior to the other ones
- *in few cases, the smooth regime setup is slightly better*
- ECHAM6-wiso (T127 resolution, nudged with ERA5 data) shows an improved agreement for the ACT cruise, only



Key controls of water vapour isotopes during oceanic evaporation

	correlation r (RMSE)	Bermuda	Iceland	NEEM
dex	**ECHAM5-wiso smooth**	0.74 (8.28)	0.73 (5.04)	0.23 (9.46)
	ECHAM5-wiso mixed	0.61 (7.29)	0.72 (5.04)	0.22 (11.62)
	ECHAM5-wiso rough	0.57 (7.39)	0.63 (6.69)	0.24 (13.07)

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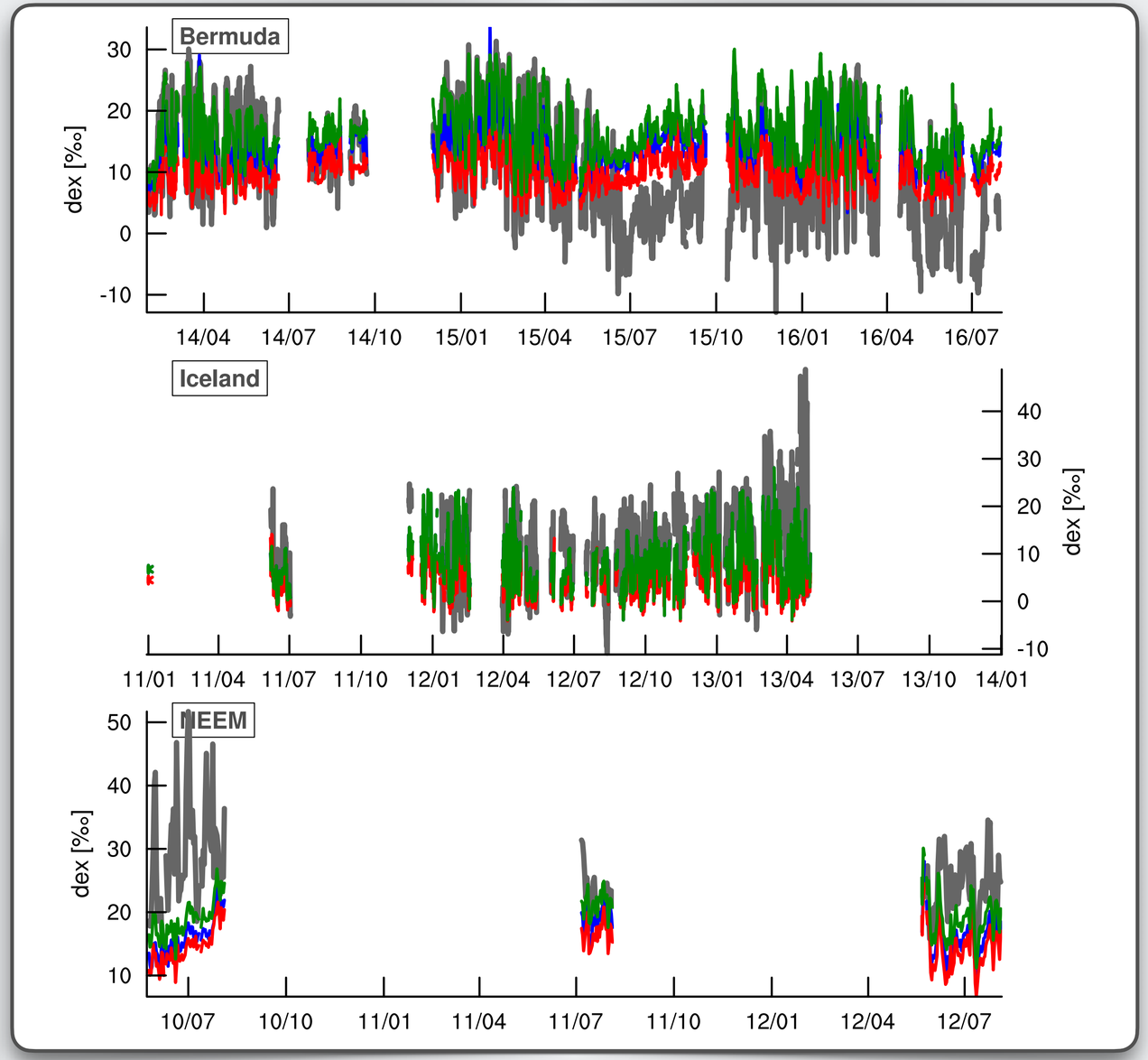

Results: land-based Deuterium excess data

- for Bemuda, ECHAM5-wiso with a smooth regime shows the best correlation but the worst RMSE
- for Iceland, the smooth regime setup has the best agreement to the observations
- for NEEM Greenland, all simulations have a large RMSE compared to the observations
- *NEEM vapour is strongly affected by isotopic vapour-snow exchange which is not considered in ECHAM5-wiso*

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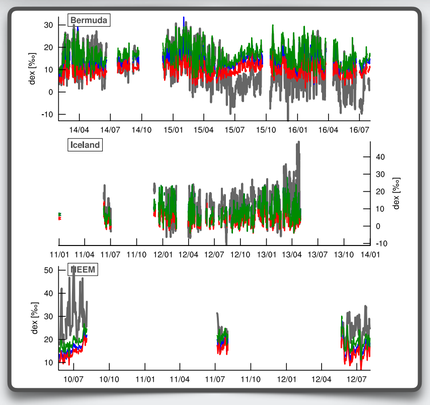
Summary

- two years of measurements on board of the research vessel Polarstern did not reveal any wind speed dependency of the kinetic fraction during evaporation
- our hypothesis was that a constant fractionation factor for a rough wind regime will also lead to model-data improvements for other available vapour isotope measurements
- **based on the performed model-data comparison we can't confirm our hypothesis**
  - ***the conducted model-data comparison does not reveal a very clear picture which kinetic fractionation coefficient should be implemented in isotope-enabled GCMs (in some cases, a slight improvement is seen for a smooth wind regime fractionation coefficient)***



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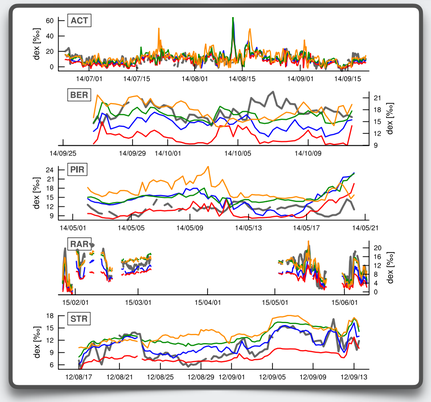

	correlation r (RMSE)	Bermuda	Iceland	NEEM
dex	ECHAM5-wiso smooth	0.74 (8.28)	0.73 (5.04)	0.23 (9.46)
	ECHAM5-wiso mixed	0.61 (7.29)	0.72 (5.04)	0.22 (11.62)
	ECHAM5-wiso rough	0.57 (7.39)	0.63 (6.69)	0.24 (13.07)

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Additional slides

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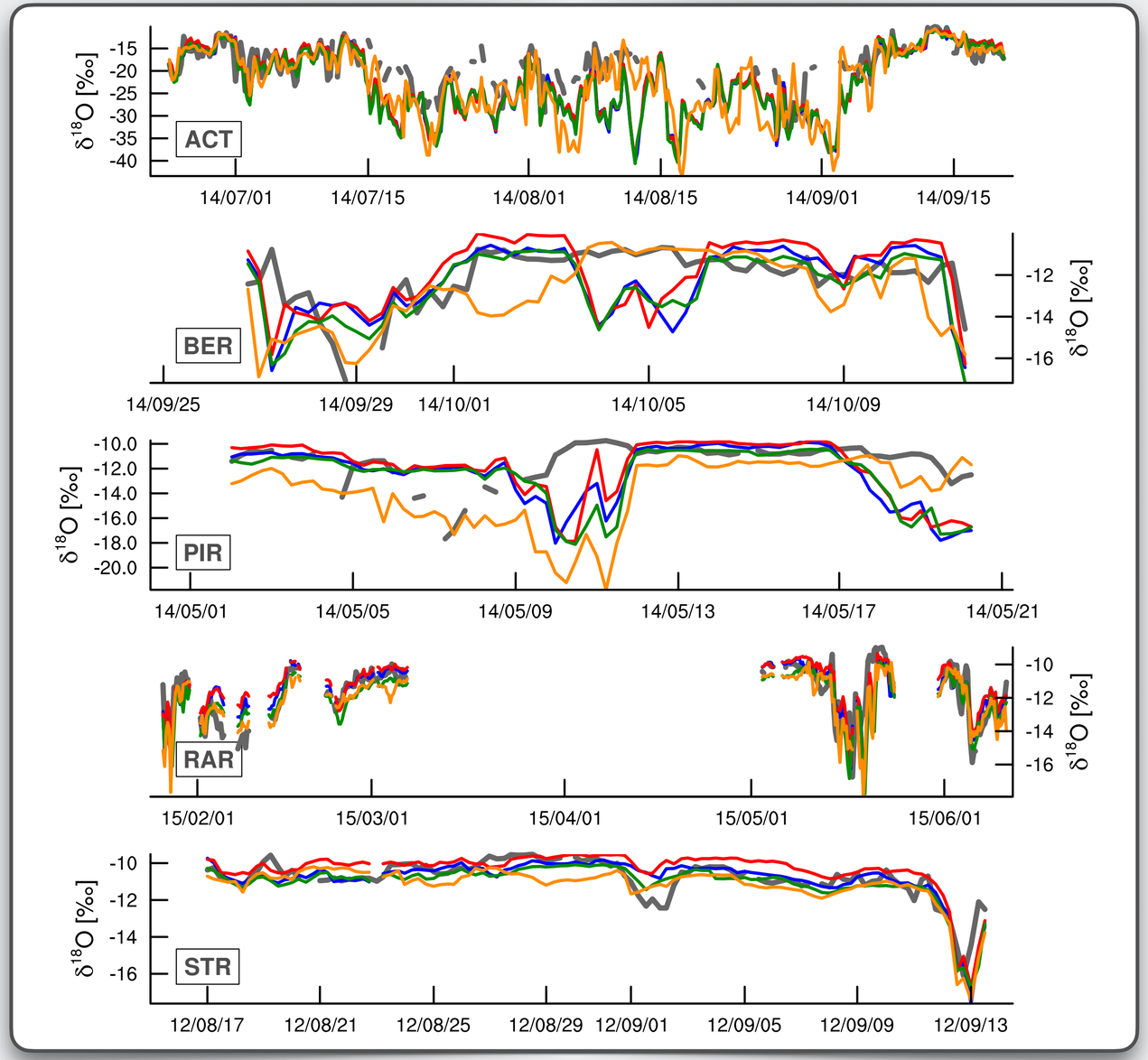
Results: ship cruise $\delta^{18}O$ data

	correlation r (RMSE)	ACT	BER	PIR	RAR	STR
$\delta^{18}O$	ECHAM5-wiso smooth	0.70 (5.66)	0.45 (1.56)	0.00 (3.14)	0.76 (1.17)	0.84 (0.68)
	ECHAM5-wiso mixed	0.69 (5.65)	0.31 (1.69)	0.11 (2.90)	0.75 (1.12)	0.81 (0.69)
	ECHAM5-wiso rough	0.69 (5.51)	0.37 (1.65)	0.09 (2.84)	0.74 (1.19)	0.81 (0.82)
	ECHAM6-wiso smooth	0.69 (5.27)	0.58 (1.54)	0.22 (3.73)	0.77 (1.16)	0.82 (0.79)

* better model-data matches are highlighted by grey cells *



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Results: land-based $\delta^{18}O$ data

	correlation r (RMSE)	Bermuda	Iceland	NEEM
$\delta^{18}O$	**ECHAM5-wiso smooth**	0.61 (1.92)	0.57 (2.96)	0.83 (4.09)
	ECHAM5-wiso mixed	0.55 (1.76)	0.56 (2.96)	0.81 (4.62)
	ECHAM5-wiso rough	0.51 (1.68)	0.56 (3.10)	0.83 (4.66)

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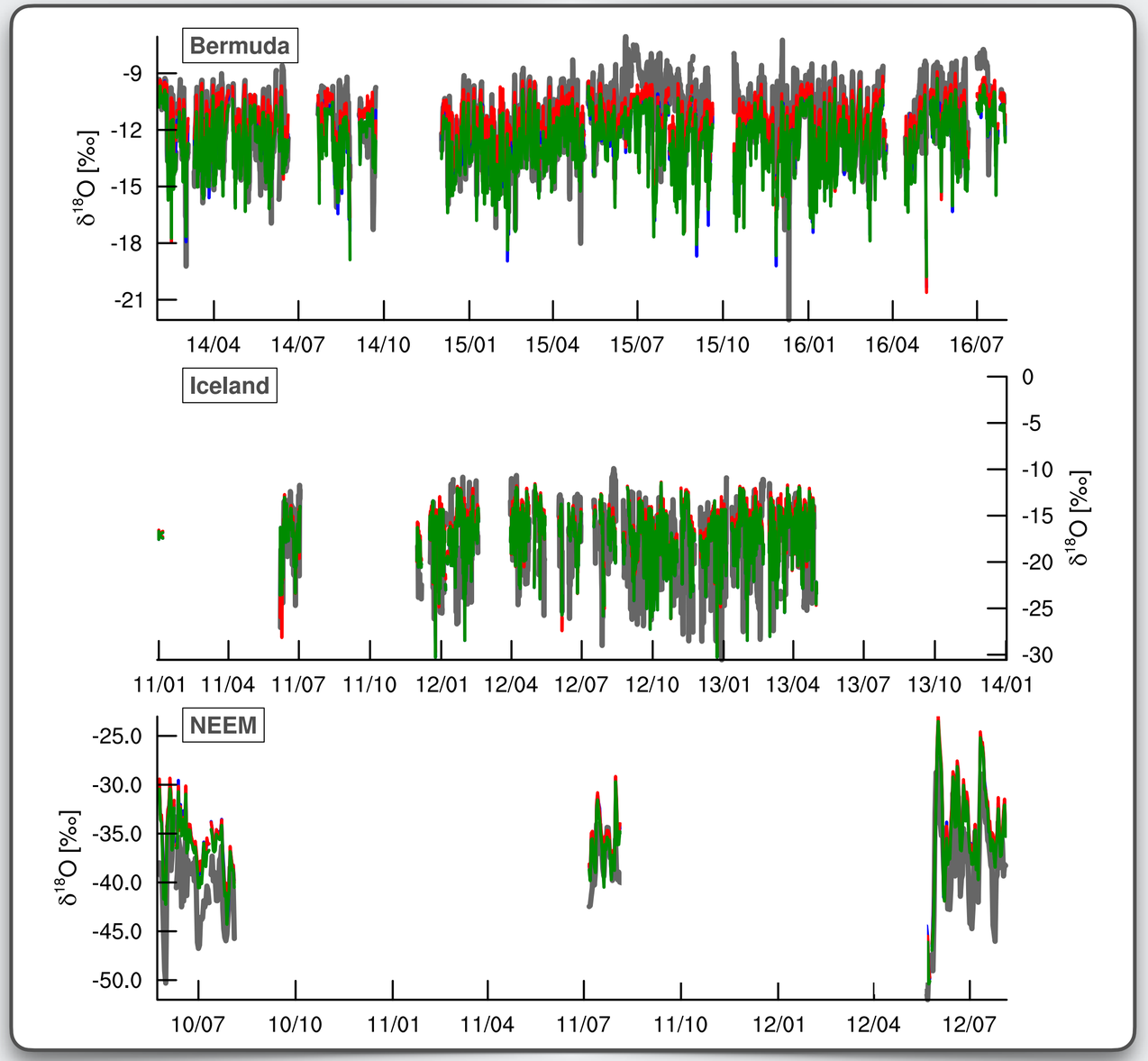

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