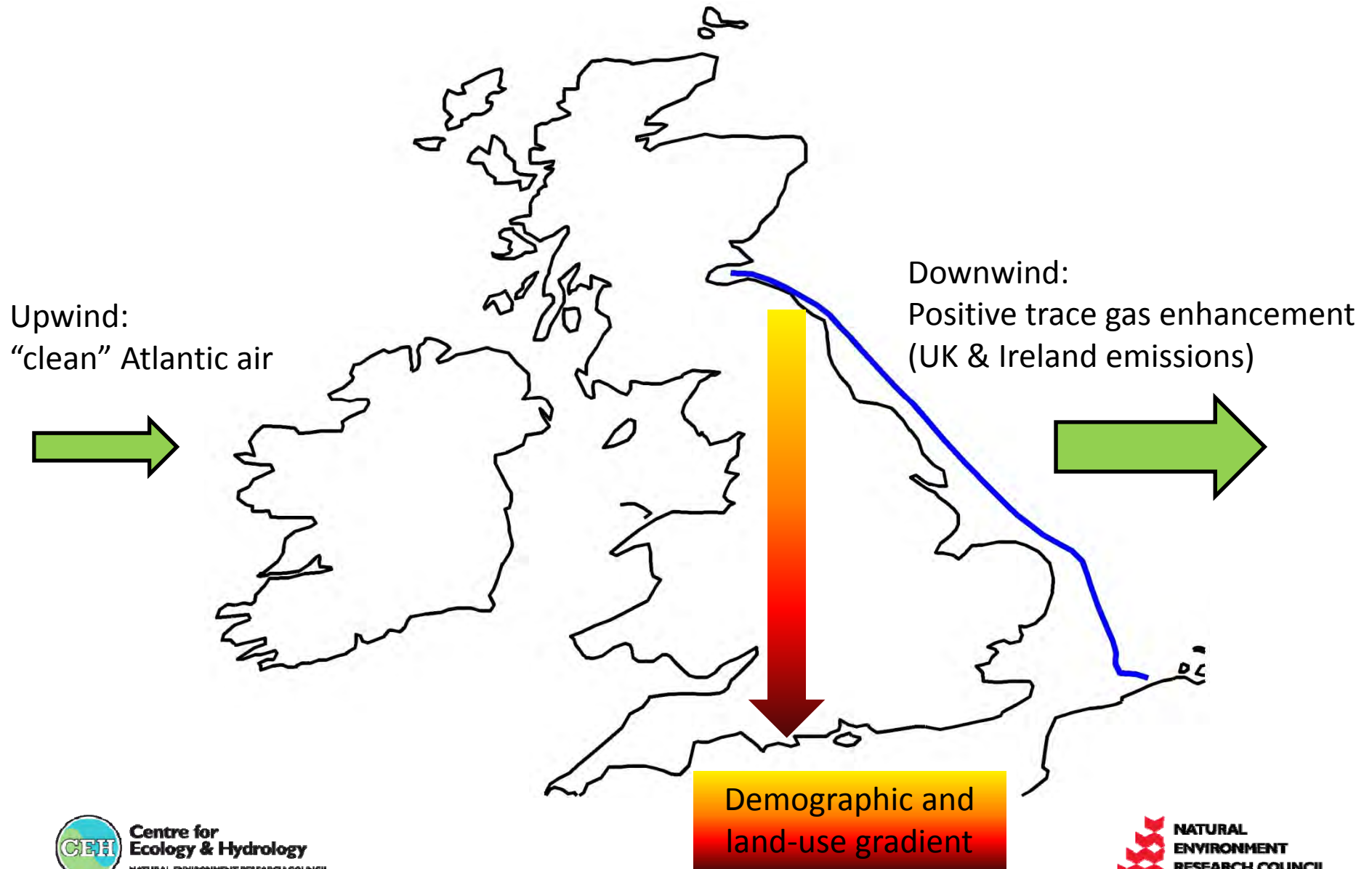# Ship-borne observations of trace gas concentrations at the UK outflow

Carole Helfter, Neil Mullinger, Massimo Vieno and Eiko Nemitz
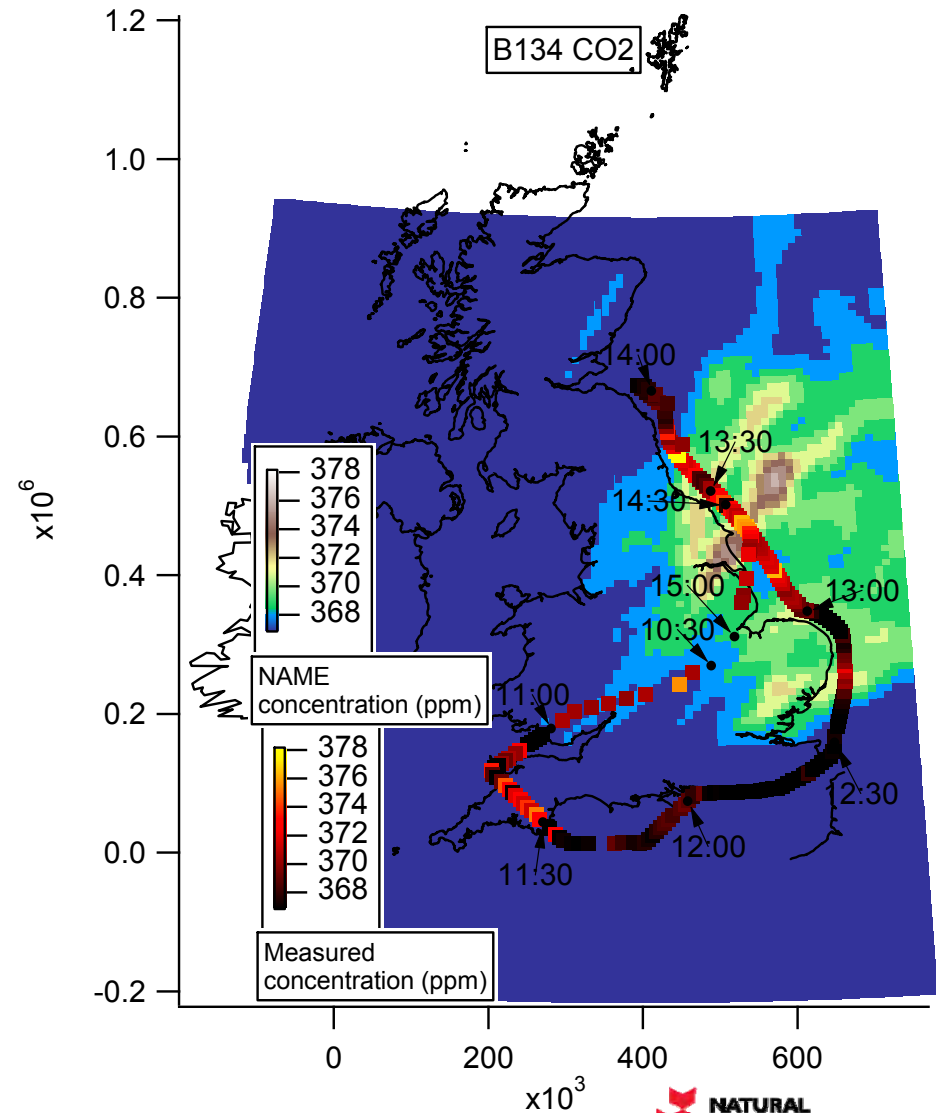*NERC Centre for Ecology and Hydrology, Edinburgh*

Rationale: estimation UK-scale emissions

Upwind:
"clean" Atlantic air

Downwind:
Positive trace gas enhancement
(UK & Ireland emissions)

Demographic and
land-use gradient

Airborne Boundary Layer Budgets

- 2005/06 – 16 flights
- Autumn only
- Real-time CO
- Bag sampling for CO_2 / CH_4

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Rationale: estimation UK-scale emissions

DFDS freight ferry route
(Rosyth, Scotland to Zeebrugge, Belgium)

- 3 return journeys per week.
- Hugs ca. 500 km UK coastline.
- Prevailing wind SW/W.

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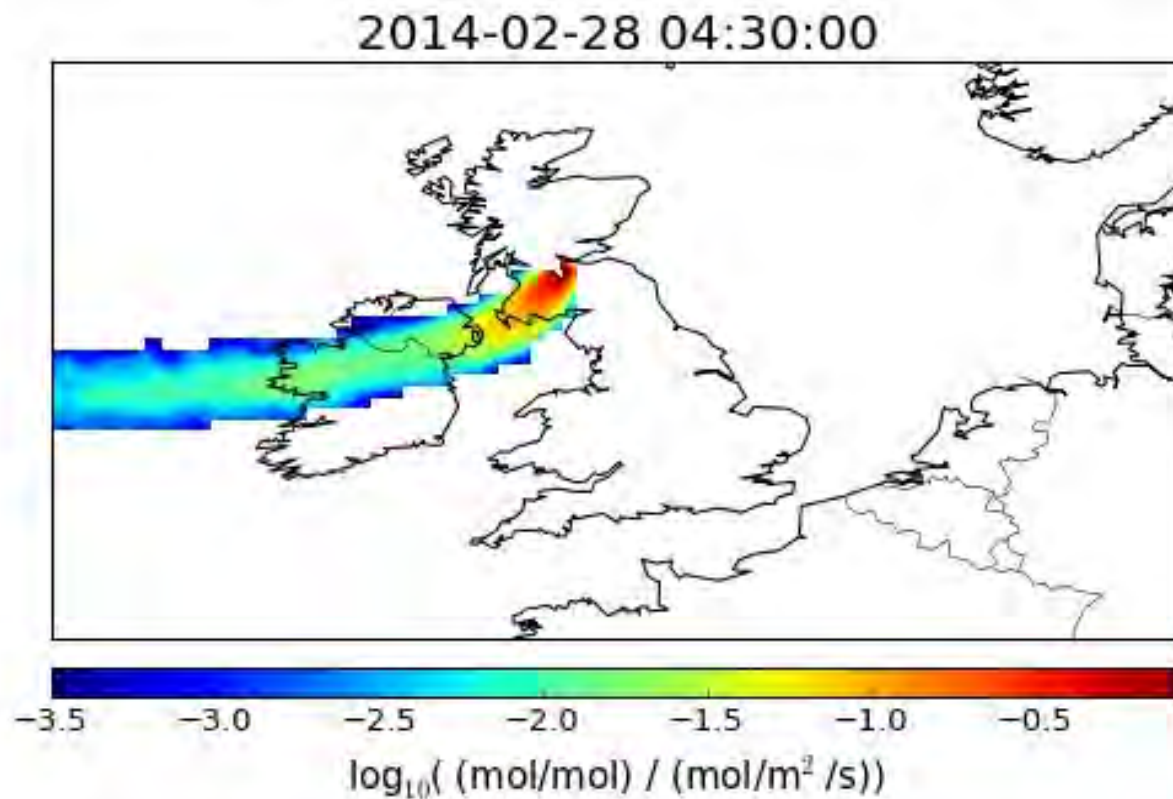# Setup: Finlandia Seaways (09/06/2014 -)

- Vaisala WXT 510 weather station (wind speed & direction, air temperature, pressure).
- Picarro 1301 (CH_4, CO_2, H_2O).
- Thermoelectron NOx monitor
- Garmin GPS (position, course, speed).
- Aerodyne QCL (N_2O, CO) campaign basis.

Footprint

2014-02-28 04:30:00

$\log_{10}(\ (mol/mol)\ /\ (mol/m^2\ /s))$
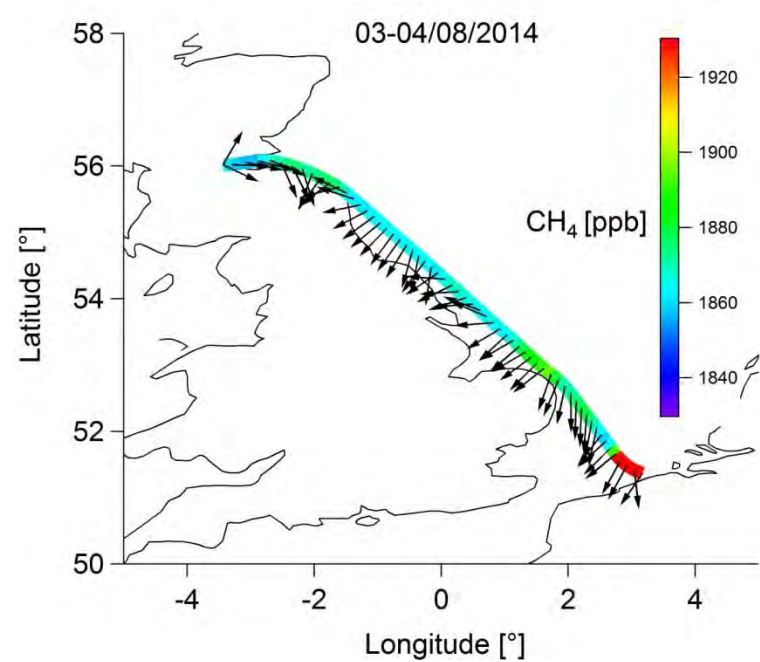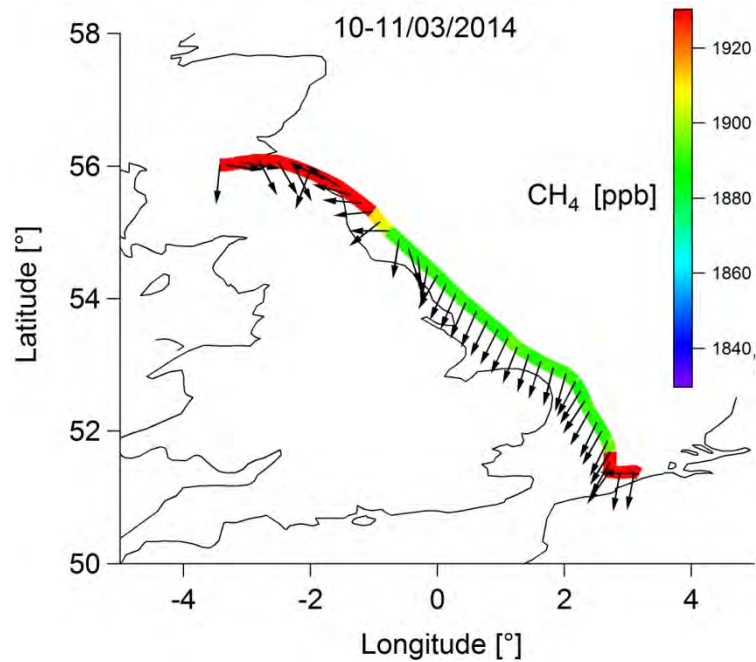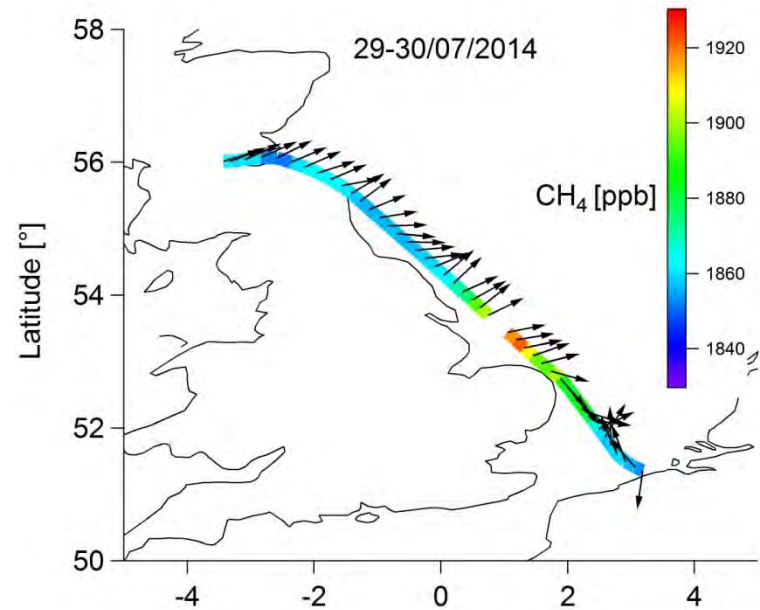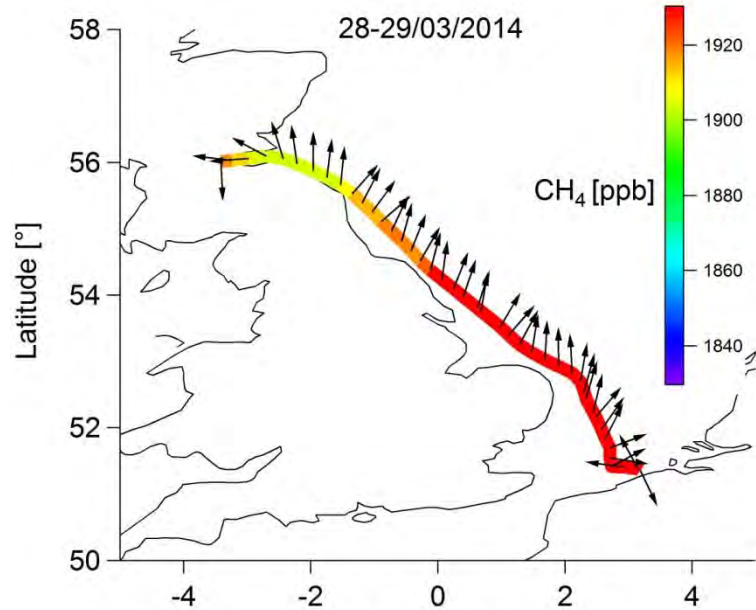
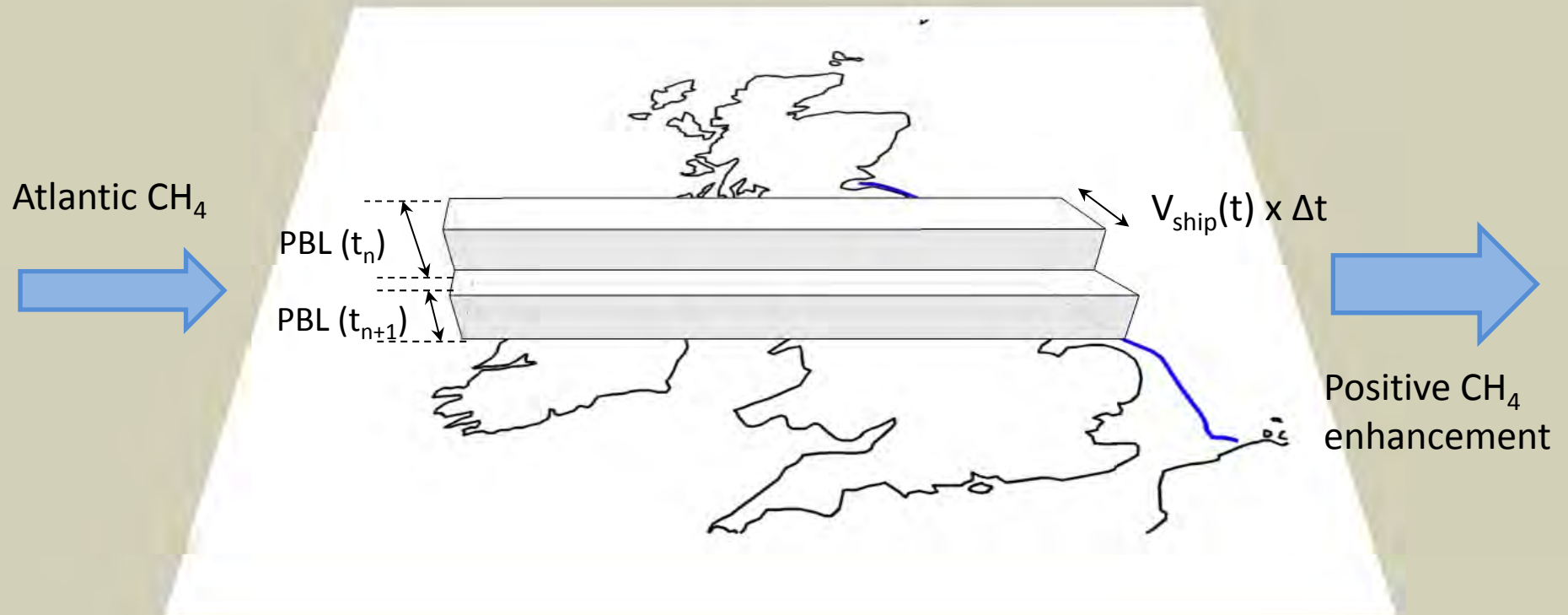*NAME footprints computed by Anita Ganesan, Matt Rigby, Angelina Wenger (University of Bristol) and Alistair Manning (UK Met Office)*

Simple mass balance

$$M_{CH4} = \sum_{wedge_0}^{wedge_N} m_{CH4}(t) \approx \int_{t0}^{tN} A(t) \cdot PBL(t) \cdot \Delta CH_4(t) \int_0^{PBL} \rho_{CH4} \cdot n_{air}(t,z)\,dz\,dt$$

Atlantic CH$_4$

PBL (t_n)

PBL (t_{n+1})

$V_{ship}(t) \times \Delta t$

Positive CH$_4$ enhancement

Assumptions:
- Steady wind speed and direction.
- Air column well-mixed when exiting volume.
- No lateral or vertical leaks.

Simple mass balance

Data sources:
- Inflow CH_4: Mace Head station (AGAGE network site).
- Outflow CH_4: ferry (also GPS and meteorological data).
- PBL height: WRF model (Massimo Vieno, CEH).

Atlantic CH_4

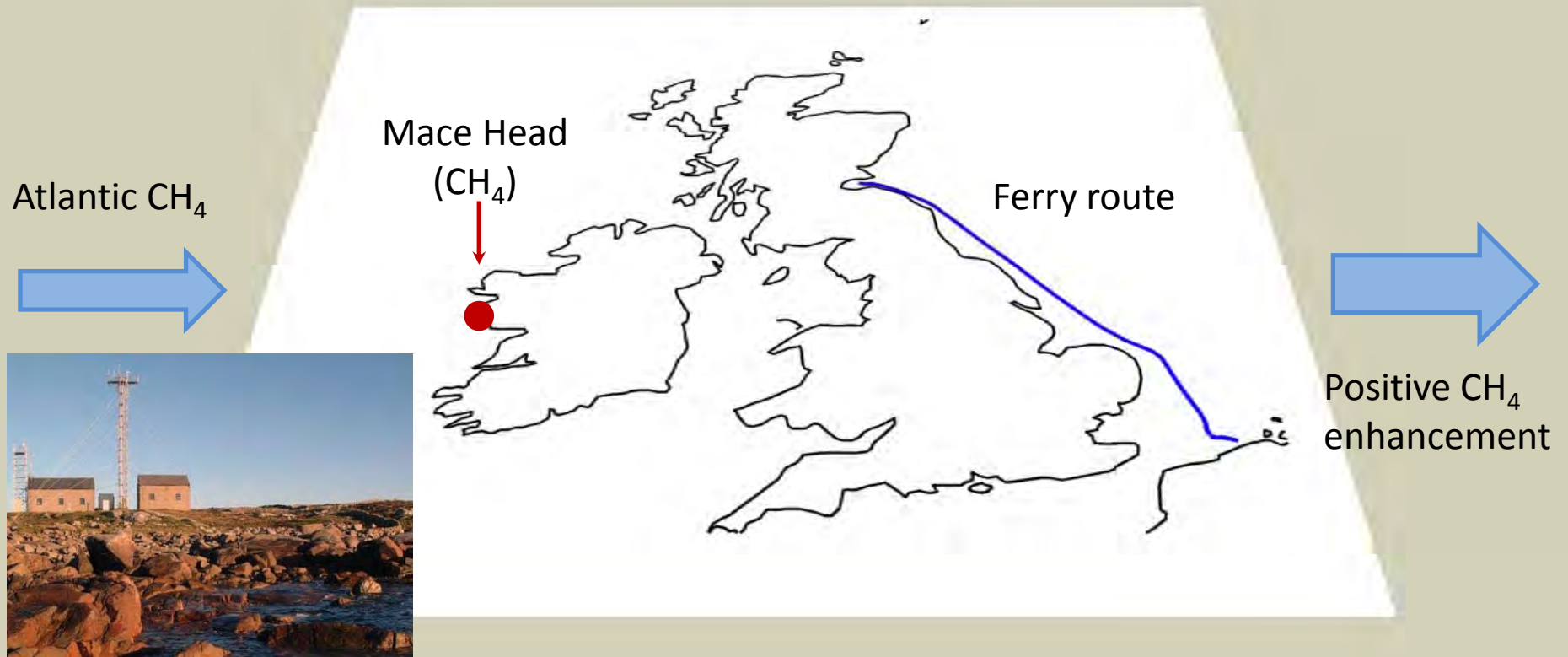Mace Head (CH_4)

Ferry route

Positive CH_4 enhancement

Assumptions:
- Steady wind speed and direction.
- Air column well-mixed when exiting volume.
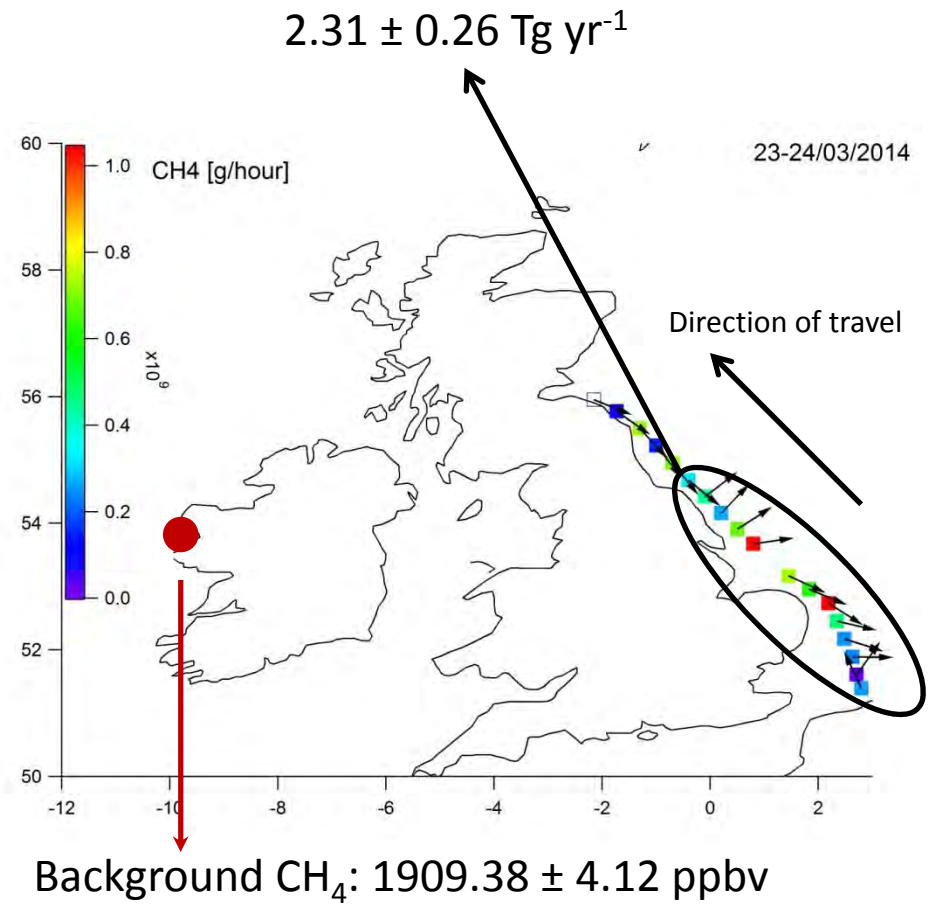- No lateral or vertical leaks.

Simple mass balance
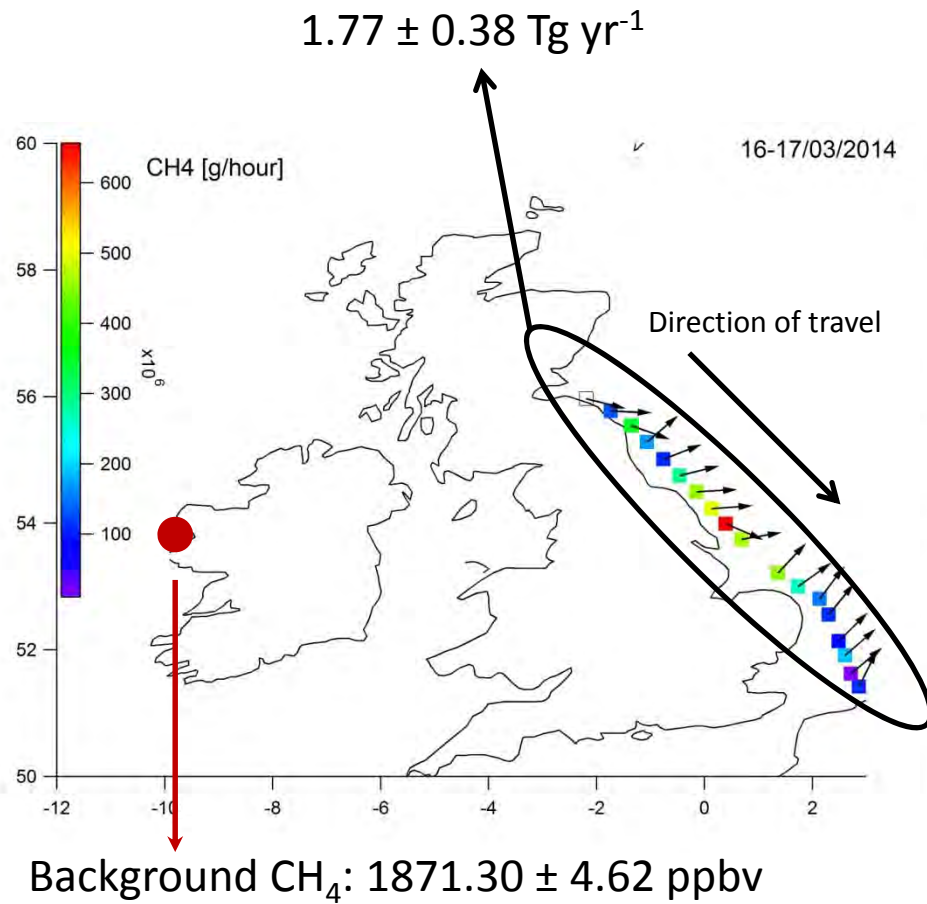

1.77 ± 0.38 Tg yr⁻¹

2.31 ± 0.26 Tg yr⁻¹

Direction of travel

Direction of travel

16-17/03/2014

23-24/03/2014

CH4 [g/hour]

CH4 [g/hour]

Background CH₄: 1871.30 ± 4.62 ppbv

Background CH₄: 1909.38 ± 4.12 ppbv

Comparison with independent estimates

CH_4 [Tg yr^{-1}]	Republic of Ireland	Scotland	UK	Total	Total excl. Scotland
Inventories	0.58 ± 0.12[1]	0.32[2]	2.42 ± 0.484[1]	3.00	2.68
Ganesan et al. (2015)[3],*				1.65 – 2.67	
This study					2.00 ± 0.32

(1) UNFCCC (United Nations Framework Convention on Climate Change).
(2) Scottish government data (2012).
(3) Ganesan A.L. et al. (2015), *Quantifying methane and nitrous oxide emissions from the UK and Ireland using a national-scale monitoring network*, Atm. Chem. Phys. 15, pp 6393-6406.

* Emissions estimates computed from tall tower measurements combined with inversion modelling using the UK Met Office NAME III model (Numerical Atmospheric dispersion Modelling Environment).

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Summary & Outlook

- Preliminary mass balance estimates of UK (excl. Scotland) & Ireland CH_4 emissions are consistent with atmospheric emissions inventory and literature values.

- 1.5 years of ferry data (CH_4 & CO_2) available to date which will be used to refine the mass balance estimates.

- Seasonality and spatial variability to be studied.

- QCL to be deployed on the ferry on a 6-months campaign basis to derive N_2O & CO budgets.

- Use of data in NAME inversions.

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Acknowledgements

Mass balance: merged datasets

CH$_4$ mass balance estimate (England, Wales, Northern Ireland & Republic of Ireland):
2.00 ± 0.32 Tg yr^{-1}

Emission hotspots consistent with spatial increments in demography and entrained land area .