MEMENTO:
Towards a New Estimate of Global CH₄ and N₂O Emissions

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Oceanic emissions of $N_2O$

- Greenhouse gas and Ozone depleting substance
- Increasing concentrations in the atmosphere:
  - 1750: ~270 ppb
  - 2015: ~328 ppb
- Microbial production:
  - Nitrification (aerobic)
  - Denitrification (anaerobic)
- Ocean: subsurface accumulation @ decreasing $O_2$. Elevated emissions in upwelling and coastal areas.

**Global $N_2O$ emissions [Tg-$N_2O$ yr$^{-1}$]**

- Anthropogenic: 6.9 (39%)
- Natural: 11 (61%)

**Global Ocean:** ~4 (1.8 - 9.4)

Figure by Arévalo-Martínez, 2015; Data from IPCC, 2014
Data from Nevison et al. 2004 (figure: Martínez-Rey et al. 2015)

$\sum \sim 4 \text{Tg N yr}^{-1}$

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Oceanic emissions of \( \text{CH}_4 \)

Different sources for \( \text{CH}_4 \): geological, biogenic

\( \text{CH}_4 \) production in sediments
\( \text{CH}_4 \) oxidation in water column

Oceanic Methane Paradox: \( \text{CH}_4 \) supersaturation in oxygenated waters @ depth of chlorophyll maximum

Large variability of emission estimates:

0.2 – 50 Tg CH\(_4\) yr\(^{-1}\)

(Rhee et al. 2009)

Kvenvolden and Rodgers (2005)
MEMENTO was initiated in 2009 to:

- collect available N$_2$O and CH$_4$ data from the global ocean in a database with open access to the scientific community.

- create a quality controlled, harmonized dataset of global N$_2$O/CH$_4$ data to

- compute a global climatology of dissolved N$_2$O/CH$_4$ concentrations and an updated global CH$_4$/N$_2$O emission estimate.

- provide a global dataset of depth profiles of N$_2$O/CH$_4$, interpolated to standard depth levels and transformed to uniform units

- keep the database alive by regularly uploading new data submissions and updating concentration and flux field calculations.
The data collection

Depth Profiles (Sampling Depth >10m)

> 100,000 data entries for \( \text{N}_2\text{O} \)
> 20,000 data entries for \( \text{CH}_4 \)

Surface Measurements (Sampling Depth <10m)

\( \text{CH}_4 \)
\( \text{N}_2\text{O} \)
\( \text{CH}_4 + \text{N}_2\text{O} \)
The data collection

Original data included in MEMENTO:
• Depth profiles
• Underway surface measurements and corresponding atmospheric measurements (if available)

Parameters included:
• $\text{N}_2\text{O}$ and/or $\text{CH}_4$, position, date & time, sampling depth (mandatory)
• Temperature, salinity, oxygen, nutrients (optional)

Planned data products:
• $1^\circ \times 1^\circ$ gridded surface concentration and emission maps
• A global dataset of depth profiles, interpolated to standard depths and transformed to uniform units.
The MEMENTO website

Homepage with database access:

https://memento.geomar.de/home

https://memento.geomar.de/database

-> login information upon request
Data processing in MEMENTO

Data Submissions

Availability, range check

Original Data

Interpolation to standard depth levels, complementation of missing (T), S data and atmospheric mole fractions, conversion to common units, calculation of saturation and $\Delta$-values

Harmonized Data
Individual measurements

\[ \Delta pN_2O \] natm
Surface data processing in MEMENTO

Data Submissions

- Availability, range check

Original Data

- Interpolation to standard depth levels,
- complementation of missing (T),S data and atmospheric mole fractions,
- conversion to common units, calculation of saturation and Δ-values

Harmonized Data

- Calculation of 5°x5° and 1°x1° fields of monthly, seasonally and annually averaged surface saturation and Δ-values

1°x1° Gridded Data
$1^\circ \times 1^\circ$ gridded surface $\Delta pN_2O$
Data processing in MEMENTO ($\text{N}_2\text{O}$)

1°x1° Gridded Data

Data Interpolation (Lana et al. 2011): calculation of global first-guess fields based on Longhurst provinces; successive correction (Barnes, 1964)

Global 1°x1° Fields of Annually and Seasonally Averaged $\Delta \text{N}_2\text{O}$ & $\Delta \text{pN}_2\text{O}$

Calculation of gas exchange using daily ERA-interim wind speed, SST and sea ice data. $k_w$ parameterized according to Nightingale (2000)

Global 1° x 1° Fields of Annually and Seasonally Averaged $\text{N}_2\text{O}$ fluxes

Updated $\text{N}_2\text{O}$ Emission Estimate
Data processing in MEMENTO (N$_2$O)

Emissions:
$\sum \sim 4 \text{Tg N yr}^{-1}$

![Map showing N$_2$O flux with color scale from 0 to 0.3 nmol m$^{-2}$ s$^{-1}$]
1°x1° gridded CH$_4$ data

$\Delta p_{\text{CH}_4}$ natm

0 1000 2000 3000 4000 5000
Data processing in MEMENTO (CH$_4$)

1°x1° Gridded Data

Data distribution not sufficient for interpolation -> parameterization

Global 1°x1° Fields of Annually Averaged $\Delta$CH$_4$ & $\Delta$pCH$_4$

Calculation of gas exchange using daily ERA-interim wind speed, SST and sea ice data. $k$ parameterized according to Nightingale (2000)

Global 1°x1° Fields of Annual CH$_4$ fluxes

First global CH$_4$ Emission Estimate
Data processing in MEMENTO (CH$_4$)

Emissions:
$\sum <2$ Tg CH$_4$ yr$^{-1}$

Other variables for CH$_4$ parameterization?
First results

$\text{N}_2\text{O}$:

- $\text{N}_2\text{O}$ mainly supersaturated in the surface ocean, elevated emissions from upwelling areas, Southern Ocean, North Pacific (consistent with Nevison et al. 2004).

- $\text{N}_2\text{O}$ emissions from Peru upwelling and West Indian shelf one order of magnitude higher than from other upwelling areas.

- Areas with undersaturation in high latitudes and subtropical gyres

$\text{CH}_4$:

Emission estimate based on bottom depth -> small overall oceanic contribution to emissions
Next steps

- Explore different methods for mapping of global N₂O/CH₄ distributions
- Explore methods to resolve seasonality of N₂O/CH₄ distribution
- New instruments -> increased number of measurements (e.g. on VOS lines)
  Intensify cooperation with SOCAT
- Cross-calibration of depth profile data
- SCOR Working Group 143: intercalibration exercise for N₂O/CH₄ measurements; of „best practices“ for measurements
  -> Implementation of data quality criteria in MEMENTO