Simulated $\delta^{13}\text{CH}_4$ from high-latitude wetlands

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Atmospheric methane is increasing but becoming isotopically “lighter” (i.e. depleted in $^{13}$CH$_4$)

Isotopic measurements help to discriminate CH$_4$ sources:
- Atmosphere: -47‰
- Oil & Gas extraction: -35‰ to -45‰
- Wetlands: -58‰ to -90‰
- Biomass burning: -25‰ to -30‰

Inverse atmospheric modelling for sources and sinks assimilate $\delta^{13}$CH$_4$
- Small variations in atmosphere
- Larger range in methane source signatures, but typically assume a single value for each source

What is the effect on the retrieved source estimates if we incorporate more realistic wetland types (flux and source signature)?
CEH Wallingford/Met Office: New estimates of wetland methane flux

- Improved parameterisation of the $Q_{10}$ temperature response using data from the tropics and high northern latitudes (CEH: Skiba Leeds: Gloor, Sheffield: Zona)

- Representation of methane from tropical forest wetlands (Open University: Gauci)

- Comparison with top-down estimates (Edinburgh: Palmer)

- Isotopic signatures from wetlands (Bristol: Ganesan)
Different wetland types have

- Varying source signatures
  - Ombotrophic (bog) ~-85‰
  - Minerotrophic (fen) ~-60‰

- Varying fluxes
  - Fens have higher fluxes than bogs
    (Turetsky et al., GCB, 20, 2014)

Hornibrook et al., 2009
JULES Wetland Methane Scheme

- JULES Wetlands Scheme based on TOPMODEL approach (Gedney and Cox, 2003)

- Predicts the distribution of sub-grid scale water table depth and wetland fraction \( f_w \) from the overall soil moisture and the sub-grid scale topography

- Methane flux from wetlands \( (F_{wCH4} ; \text{Gedney et al., GRL, 2004}) \):
  \[
  F_{wCH4} = k_{CH4} \times f_w \times C_s \times Q_{10}(T_{soil})(T_{soil} - T_0)/10
  \]

- JULES now has 3 methods to specify substrate carbon, \( C_s \): (i) soil carbon, (ii) NPP, (iii) soil respiration
- Initial focus on boreal wetlands
- Separate bogs and fens using soil pH: bogs – acidic; fens – alkaline
- Harmonized World Soil Database
- Regional differences (e.g., Alaska more fen, Scandinavia mixture)

Kaplan et al.
Methane flux from bogs ($F_{CH4}^b$)

$$F_{CH4}^b = f_w \times f_b \times A_b \times Q_{10}(T_{soil})(T_{soil} - T_0)/10$$

with equivalent expression for fen

$\delta^{13}CH_4$ source signature map based on wetland fraction, bog/fen fraction and varying sources signatures

- Regional differences

Temperature terms from JULES using measured bog/fen $Q_{10}$’s

- $Q_{10}$’s collated from 71 sites (Turetsky et al, 2014)
  - bogs = 2.6; poor fen = 1.7; rich fen = 2.0

Preliminary results

Map of boreal wetland $\delta^{13}CH_4$ signatures
Evaluation of the boreal wetland $\delta^{13}$CH$_4$ signatures

Keeling plots from aircraft measurements

Indicate regional source signature

- **Siberia regional signature**
  - -70 to -78 ‰ (France et al., 2016, Umezawa et al., 2012)

- **Scandinavia regional signature**
  - $\sim$ -70‰ (Fisher et al., 2017)

- **Alaska regional signature**
  - $\sim$ -63‰ (Umezawa et al., 2012)
Next steps and future work

- Simulate $\delta^{13}$CH$_4$ at atmospheric measurement sites using NAME Lagrangian atmospheric transport model
- Modelled $\delta^{13}$CH$_4$ at site will be flux and sensitivity weighted contribution of the source signature
- How well do the modelled compare to observed regional source signatures?
- What is the impact of including wetland types on inversions using atmospheric $\delta^{13}$CH$_4$ values?