High resolution methane flux estimate from multi-species and mass balance methods

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Challenge:

- Observations at O(1 km scales), can drive inversions
- Difficult to constrain transport (lack of wind info)
  (Use extra tracers e.g., H2O, CO ,….)
- Density of observations enable gradient detection methods.
  (Consider flux gradient and covariance methods)

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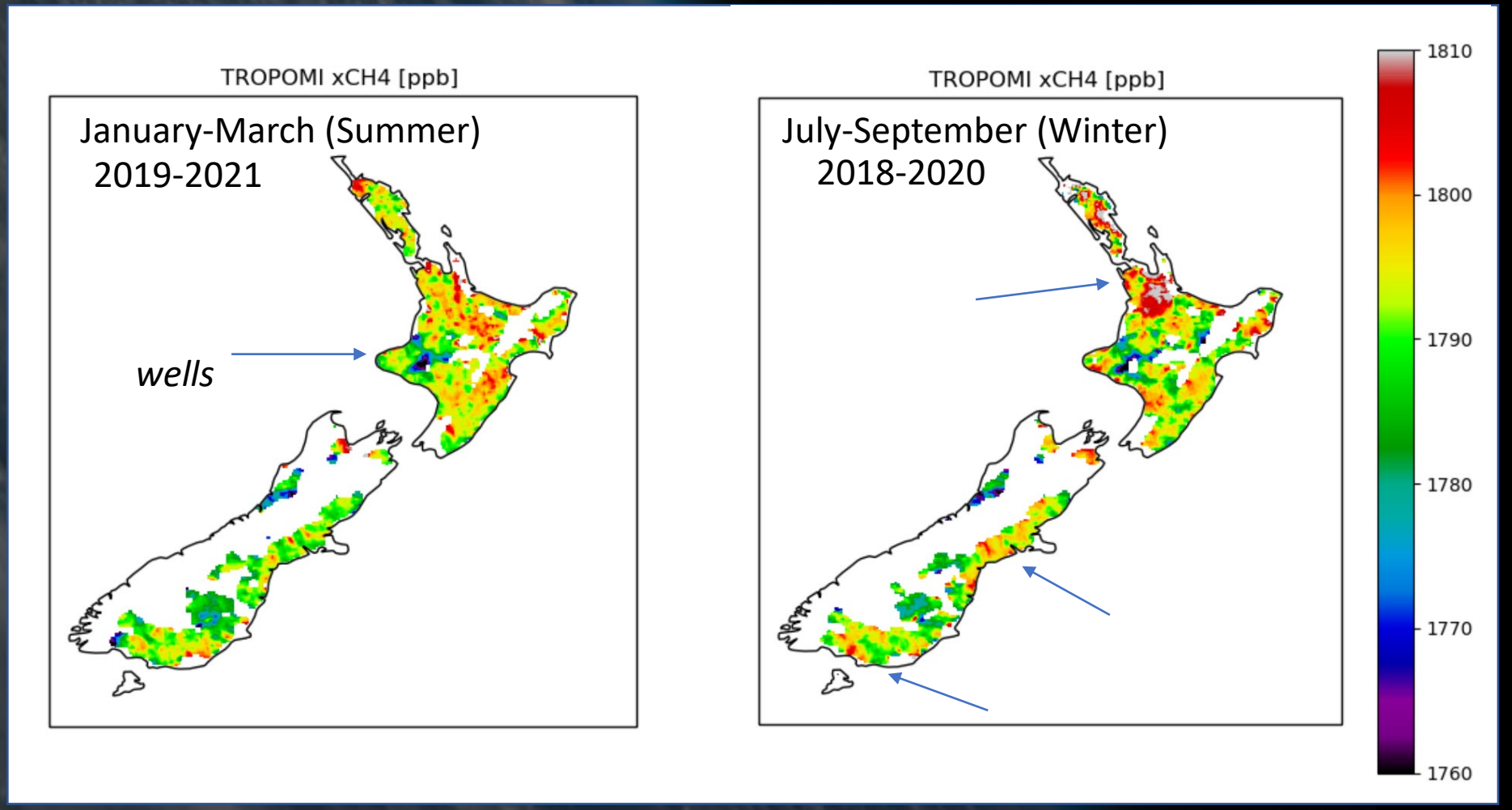
Case of Aotearoa, New Zealand: xCH4 TROPOMI



New Zealand is approximately the size of California

Mostly agricultural sources (Dairy and beef, 6.3 million – doubled since 1990 – 4x per person vs USA)
Dominates NZ GHG portfolio. (About half, CO_2 from transportation is the other half)

TROPOMI at ~5 km/observation: maps to ~ 1km oversampling under precision trade off.

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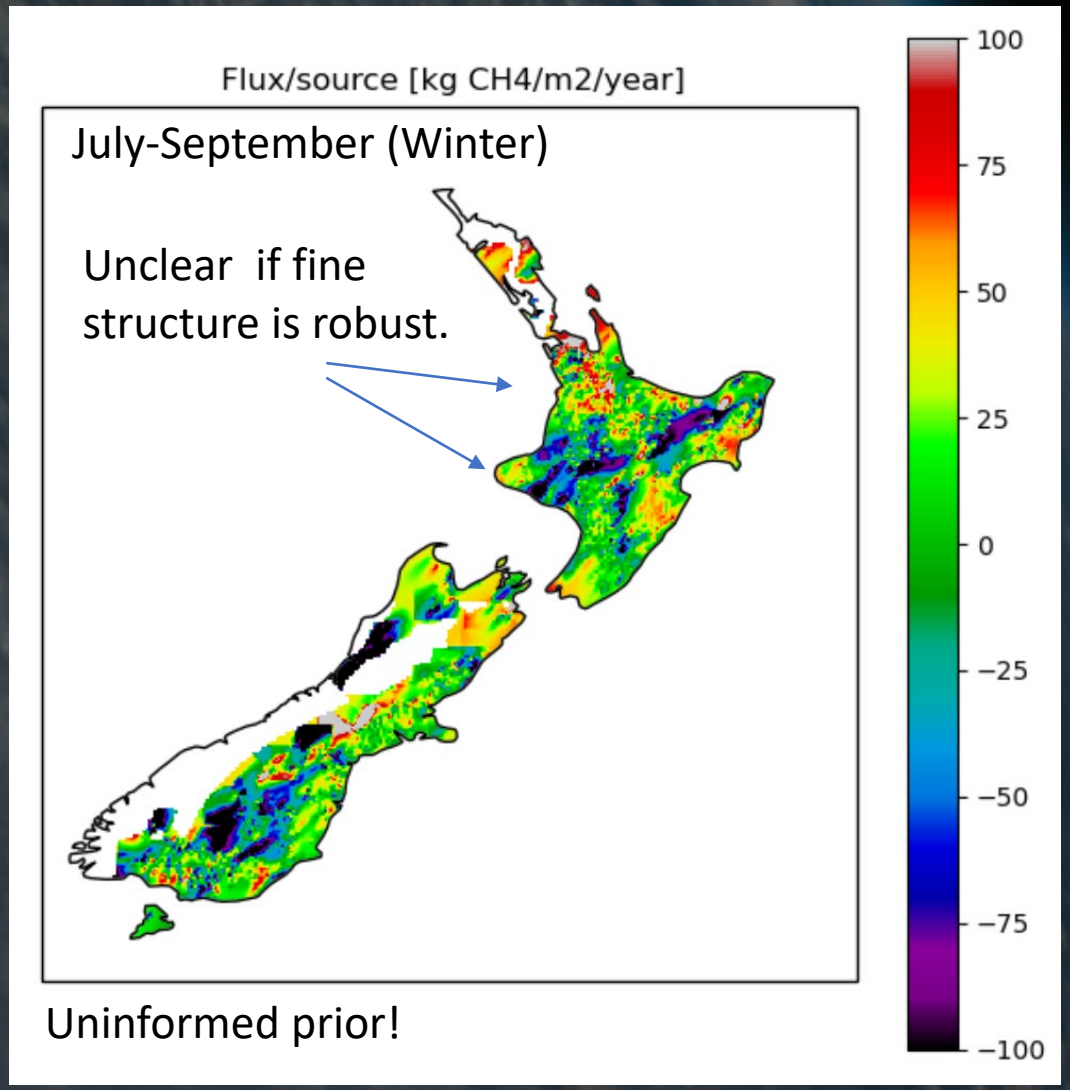
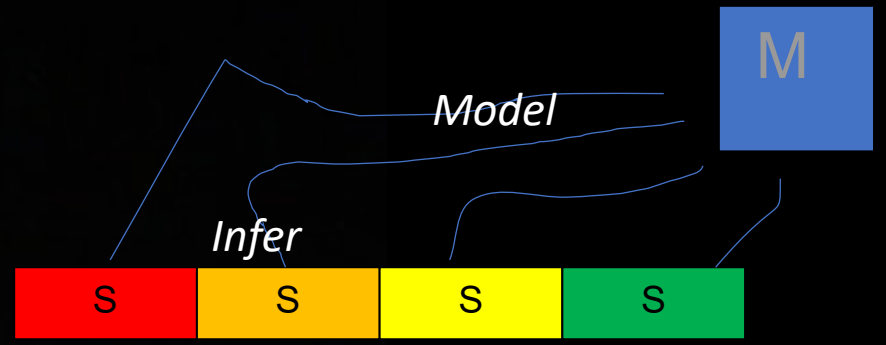
Source inversion (*linear Bayesian method*)



Uninformed prior!



$$M = M_0 + \sum_{x,t} \phi(x,t) s(x,t)$$

Methane M, composed of background M0, plus contributions from sources.

Estimate sources, s, with model for transport ϕ.

Serval simplifications
Efficient low-dimensional pseudo-adjoint for sources
Simple treatment of background

Slightly under constrained: TROPOMI sampling
number of observations ~ 1/3 number of 5x5 km grid

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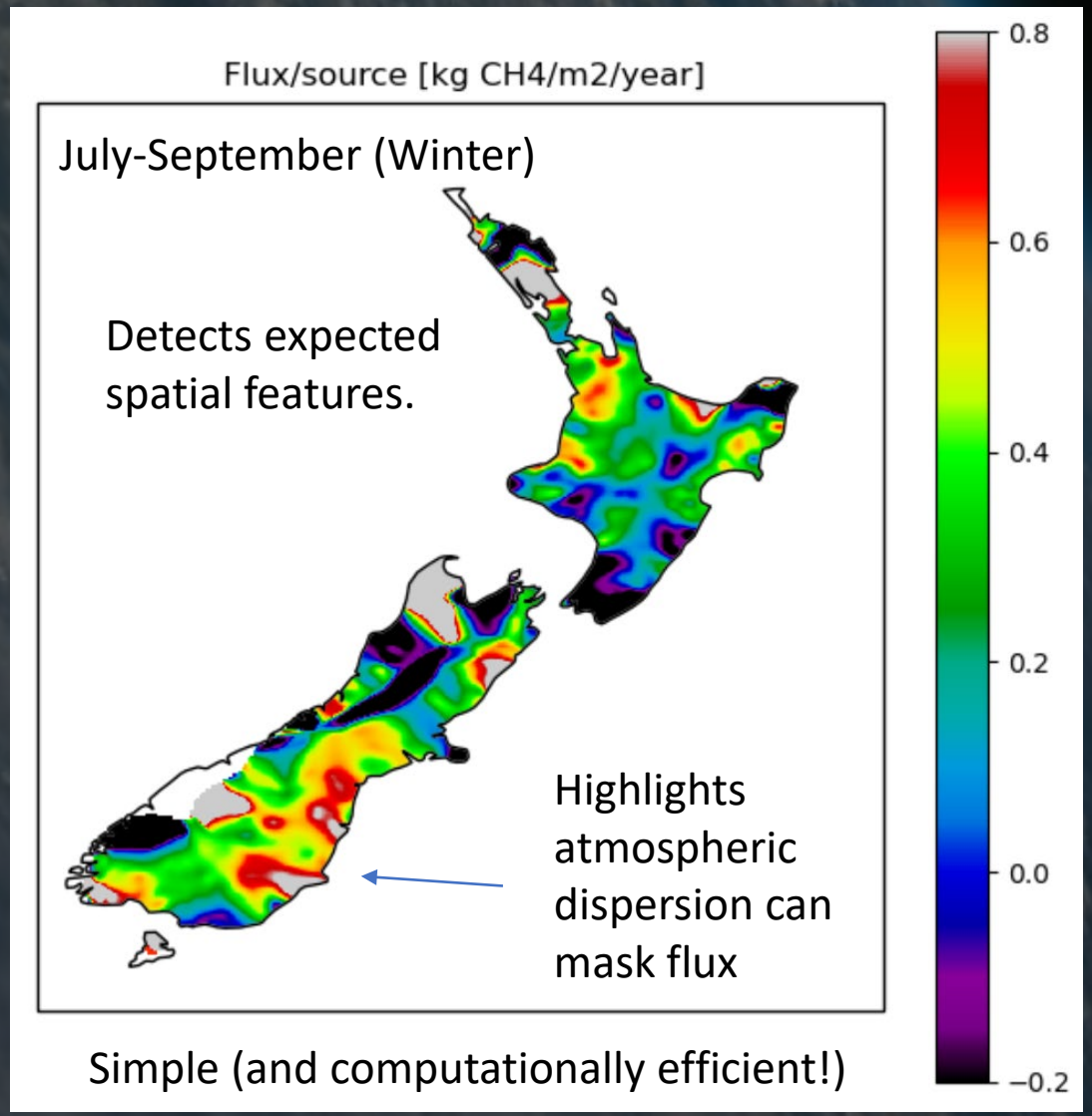
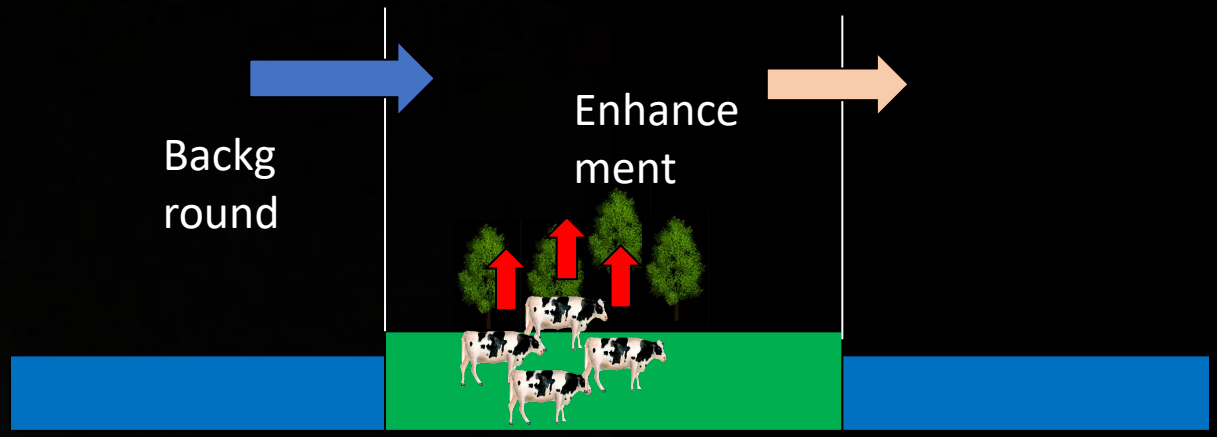
Alternate approach



Simple (and computationally efficient!)



Spatial gradients cause by sources.

$$\frac{\partial}{\partial x}(vh(M - M_0)) = S$$

V the transport velocity, h the depth of the well mixed PBL, and we assume the PBL dominates the local enhancement.

Directly evaluate S.
Require, *v*, such that

$$\frac{\partial}{\partial x}(vh) = 0$$

M_0 constructed by scaling AIRS L3

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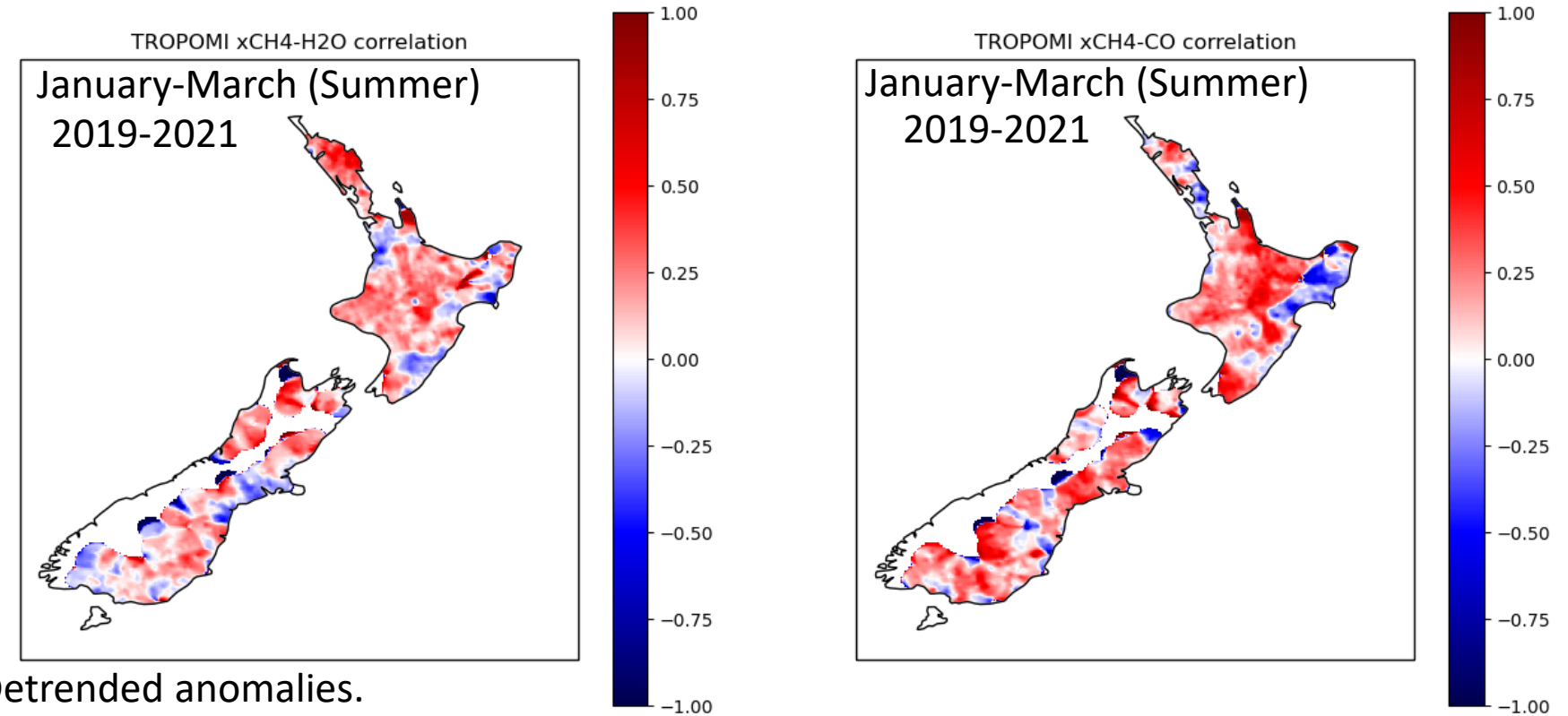
Covariation with complementary tracers



Detrended anomalies.

"Trend" from Bearing Head flasks*

e.g., H2O: Mix of local sources plus, and high higher background (high H_2O associated with tropical "atmospheric rivers", which bring positive CH4 anomies to southern latitudes.

Flask data from NOAA Global Monitoring Division public archive

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Challenges and opportunities

- Requirement for computational efficiency with high resolution, but offers new approaches.
- Rethink transport constraints relevant for remote sensing at ~ km scale.
- PBL time scale 1-6 hours for most cases – has advantages.

- New efficient methods for obtaining sources (borrowed from hydrology)
- Clear case for multi-species inversion.
- Clear need for inclusion of multiple sensors:
  SWIR over land for column enhancement, TIR over ocean (and elsewhere) for background.

- Synthesis activities required: TROPMI, GOSAT, MethaneSat, plus AIRS, CrIS, IASI, …