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GUIDING CARBON MITIGATION STRATEGIES

NIWA Taihoro Nukurangi | GNS Science Te Pū Ao | Manaaki Whenua Landcare Research | The University of Waikato Te Whare Wānanga o Waikato

Regional to National Scale Inverse Modelling of New Zealand's Carbon Balance

Beata Bukosa, Sara Mikaloff Fletcher, Gordon Brailsford, Colin Nankivell, Dan Smale, Elizabeth Keller, Jocelyn Turnbull, Kay Steinkamp, Mike Harvey, Peter Sperlich, Rowena Moss, Sally Gray, Stuart Moore, Sylvia Nichol, and Zoe Buxton

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Wind coming from over the sea

Greenhouse gases in the air affected by land uptake and emissions

Air monitoring station

KEY

Greenhouse gas emissions

Greenhouse gas uptake

Air monitoring station

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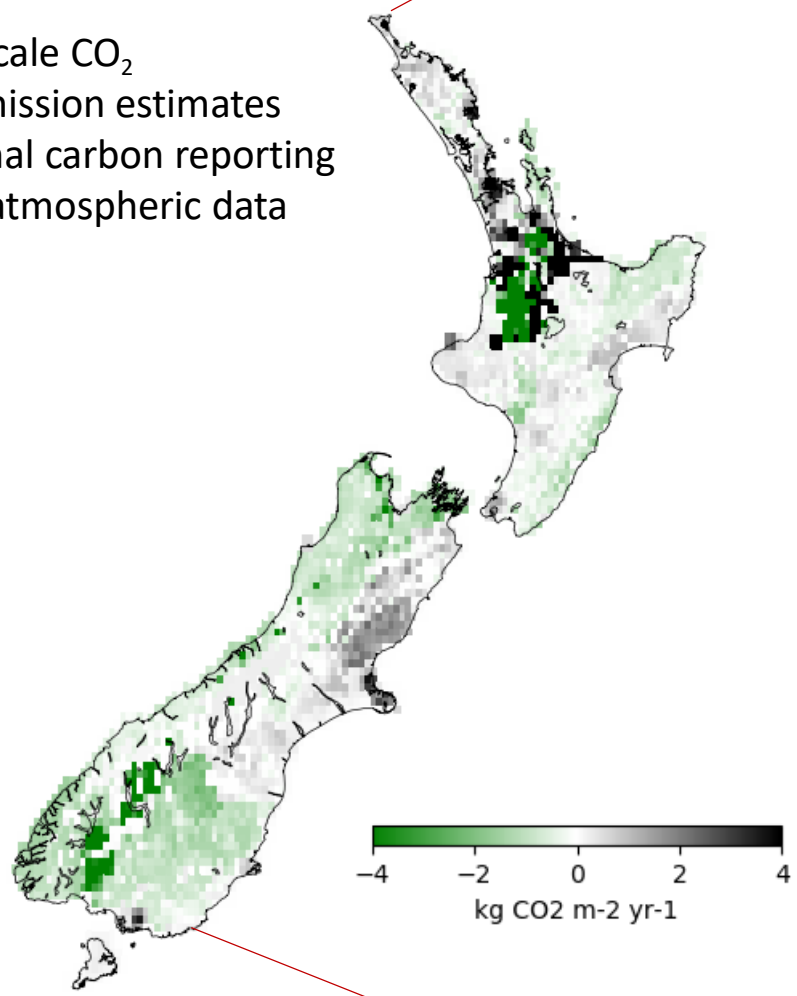
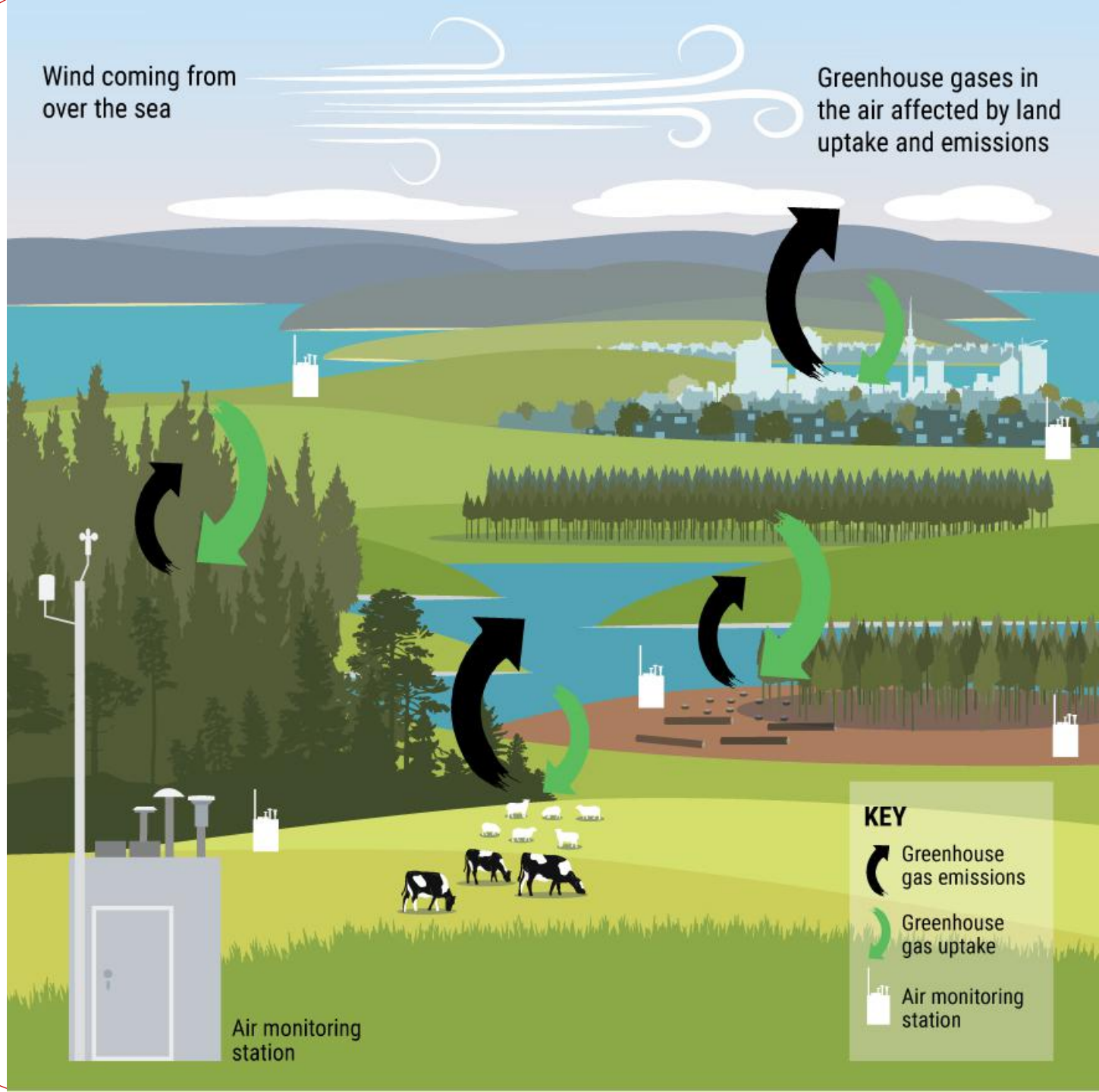
National scale CO_2 uptake/emission estimates and national carbon reporting based on atmospheric data





CarbonWatch NZ – Pilot Study

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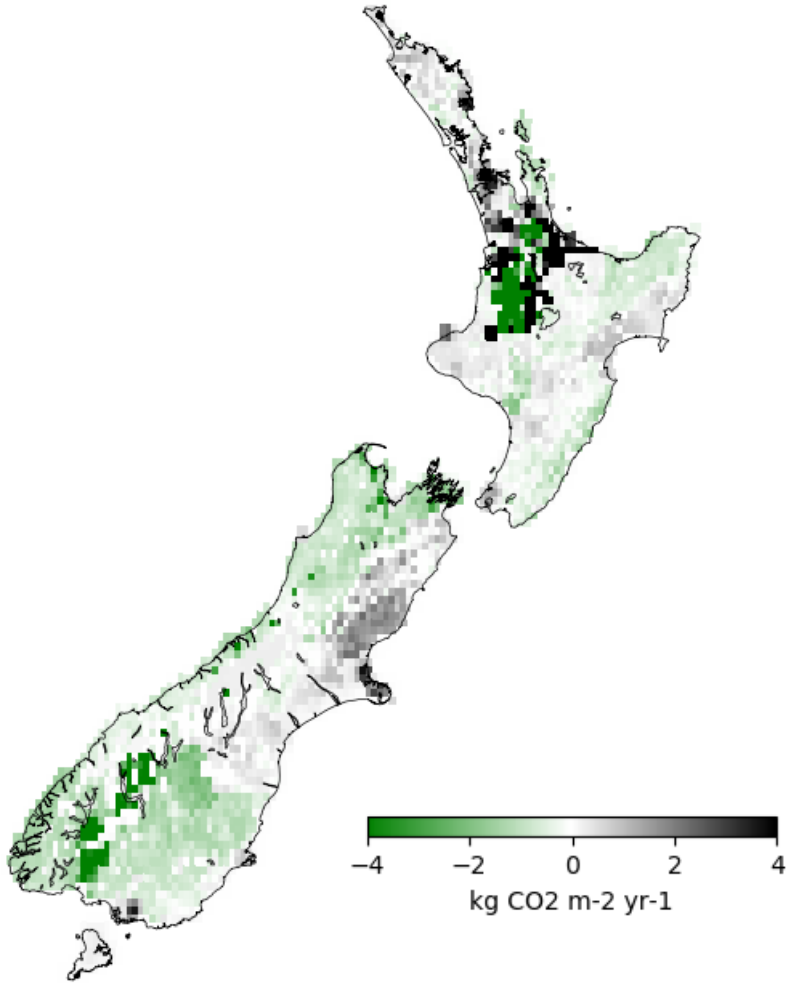
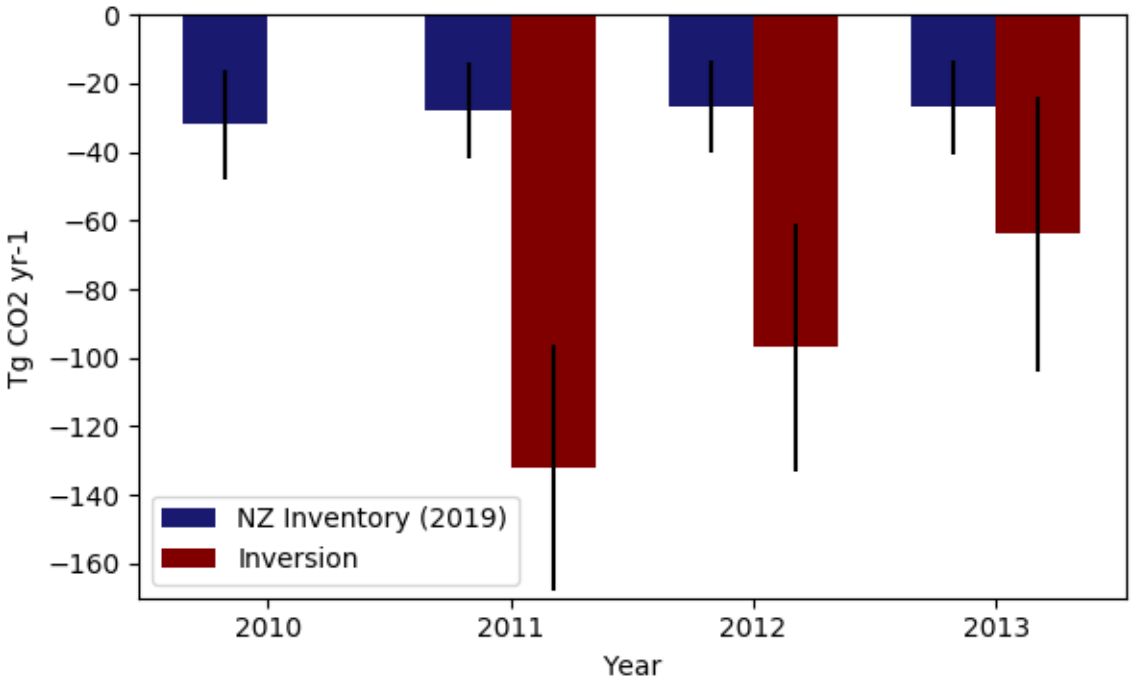


Annual mean CO_2 fluxes, Steinkamp et al. (2017)



National Inventory vs inversion results

(bottom up) (top down)

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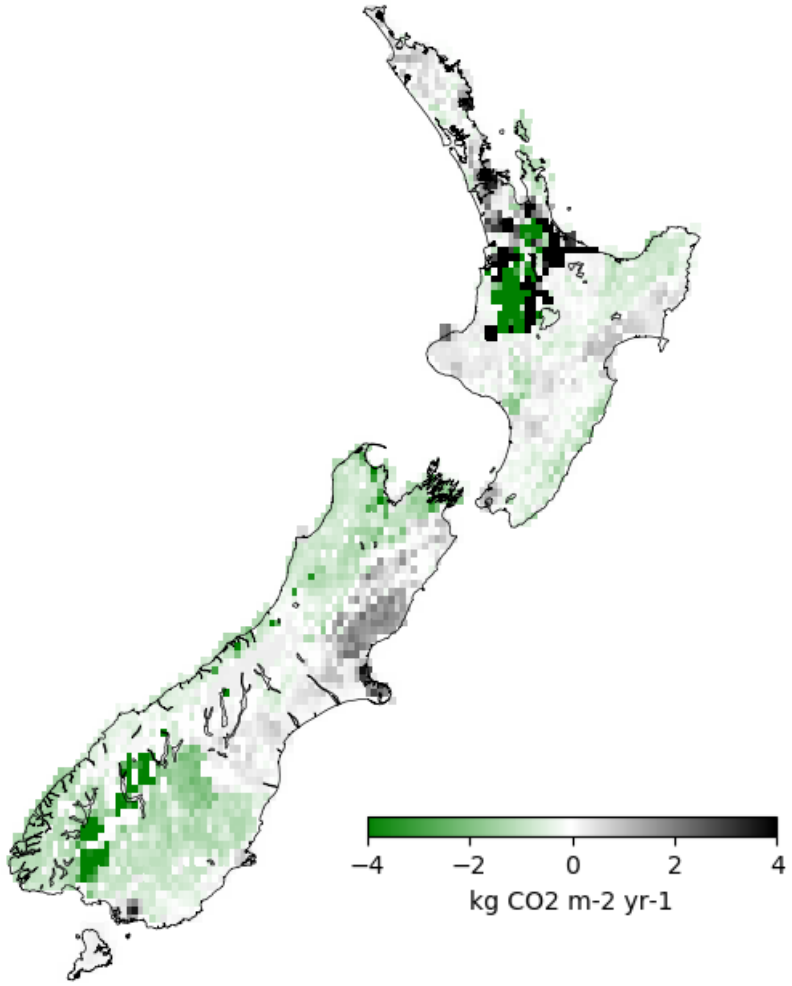

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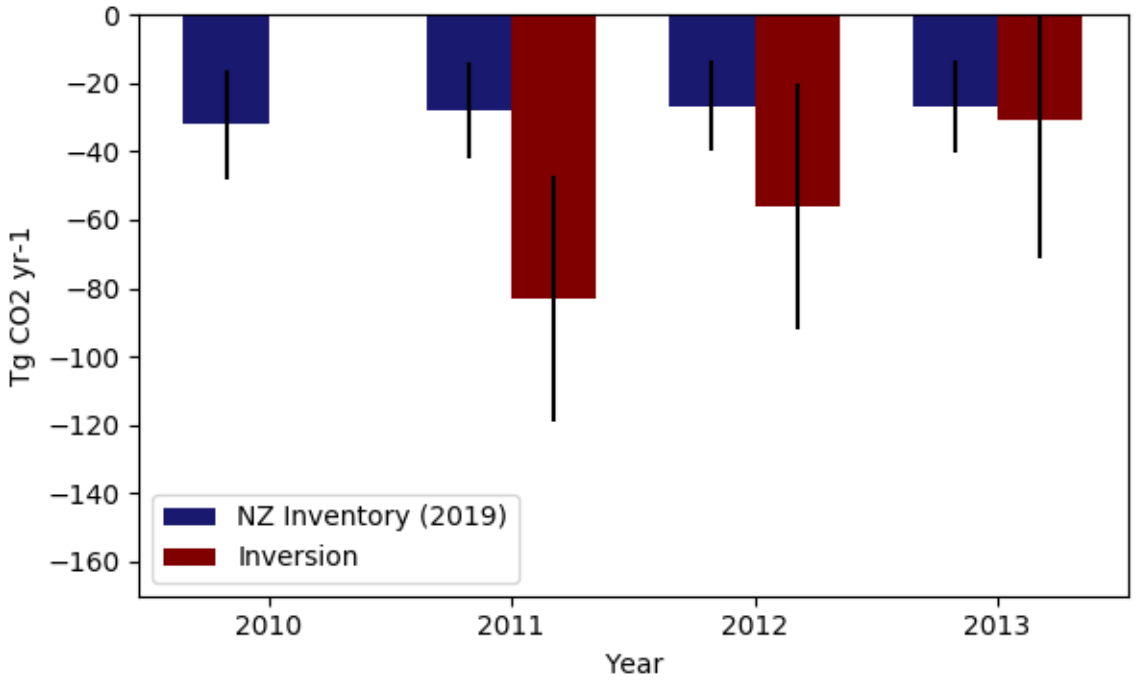

Inversion → 30-60% larger CO_2 sink

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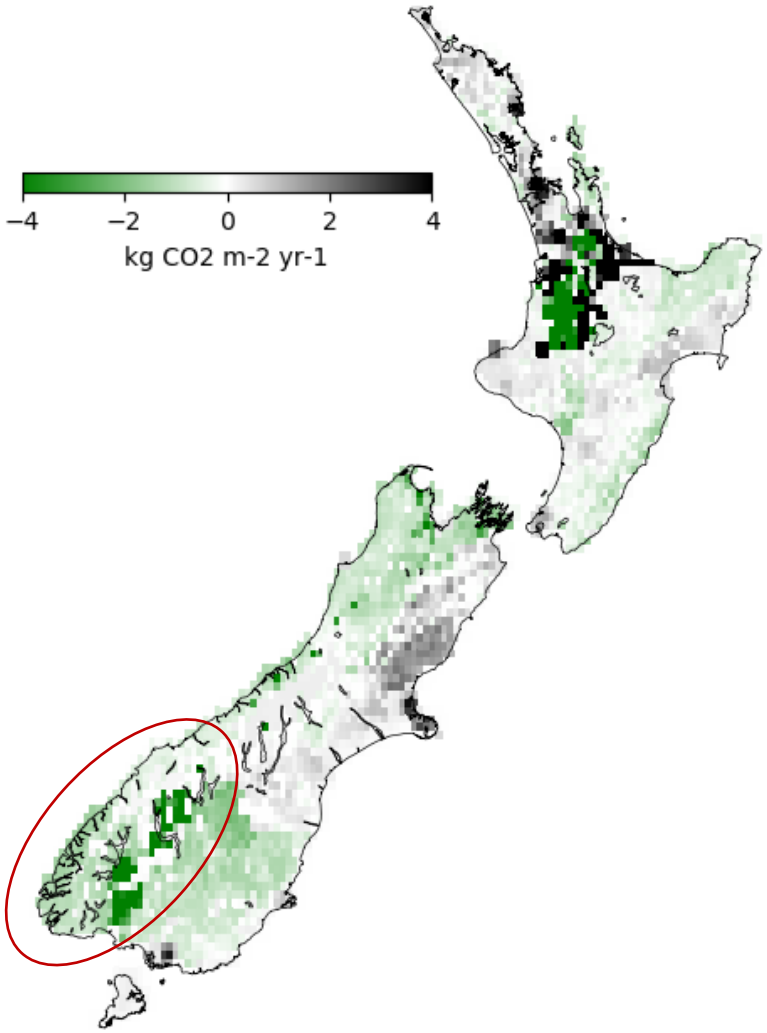
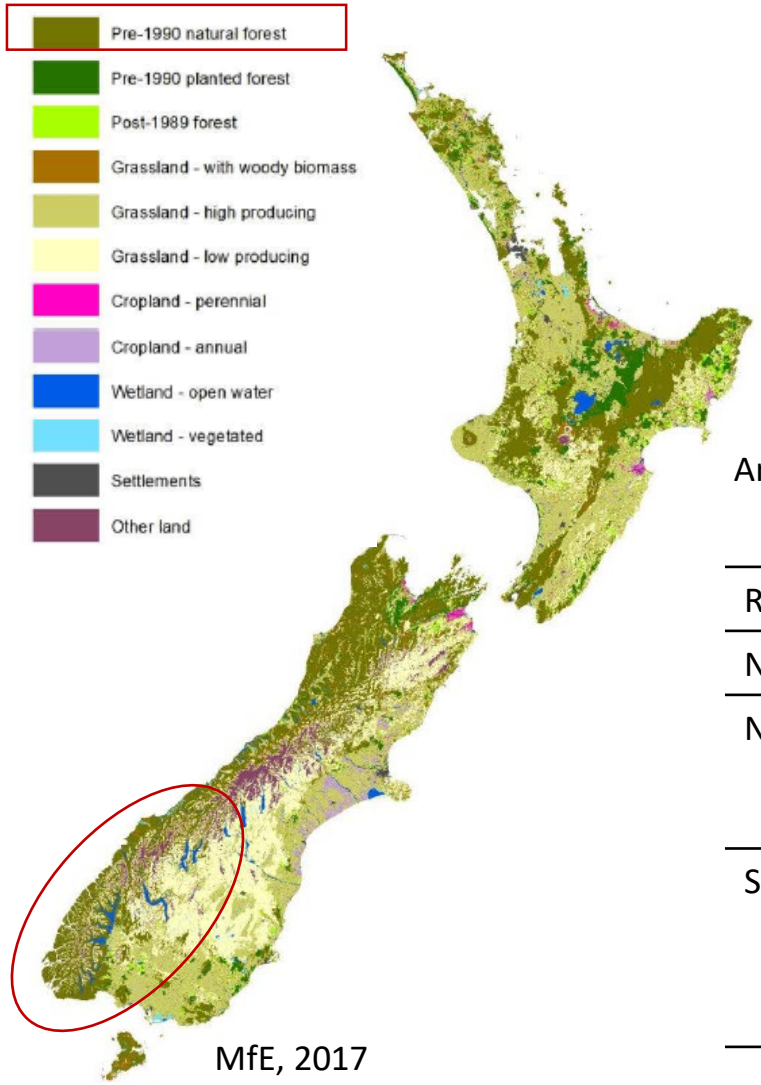
Stronger CO_2 sink





MfE, 2017

MfE – Ministry for the Environment

Annual mean CO_2 flux with uncertainty (1σ) for NZ regions
Steinkamp et al. (2017)

Region	2011	2012	2013
NZ Total	-132(36)	-97(36)	-64(40)
North Island	18(28)	-40(28)	-1(30)
North	5(25)	-10(25)	7(25)
South	13(17)	-30(17)	-8(19)
South Island	-149(22)	-56(23)	-63(28)
East	-37(17)	9(18)	-10(23)
West	-113(17)	-65(16)	-52(17)
Fiordland	-68(13)	-22(12)	-31(14)

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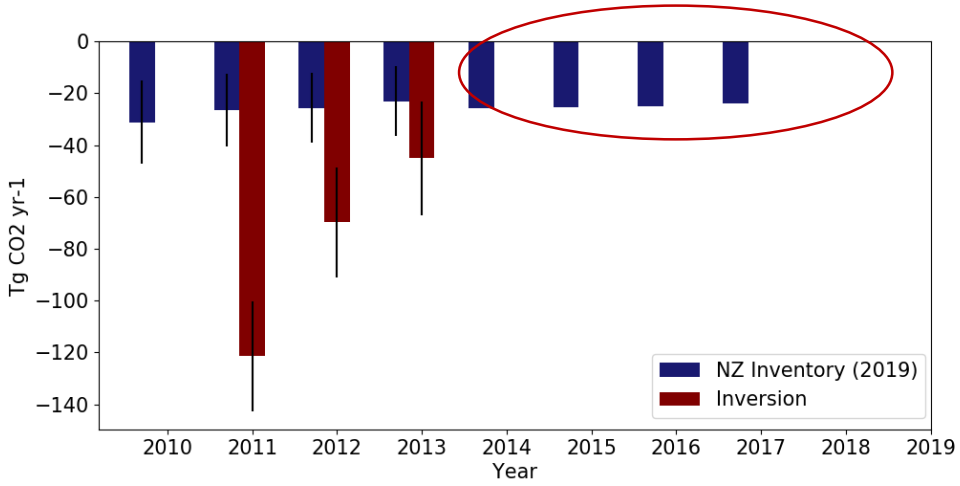
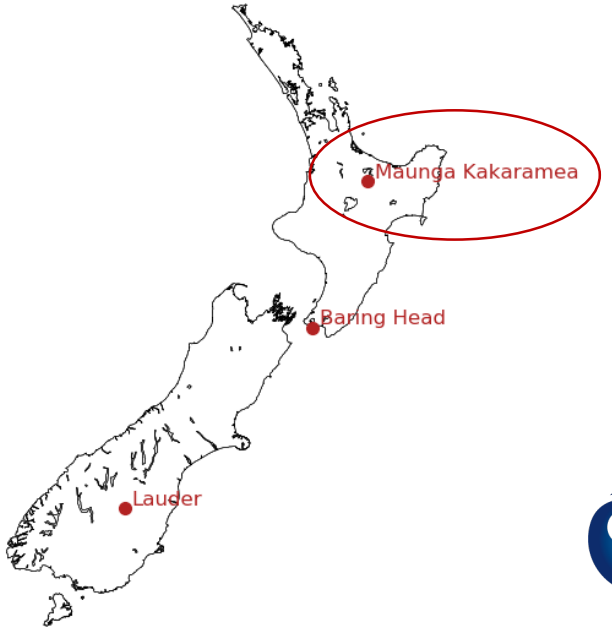
Talk Overview

- Methodology
- Inversion Setup

- Results
- Carbon exchange for recent years, still a sink?
- Inversion improvements
  - → Higher model resolution
  - → Impact of measurements from a new site





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How the inversion works

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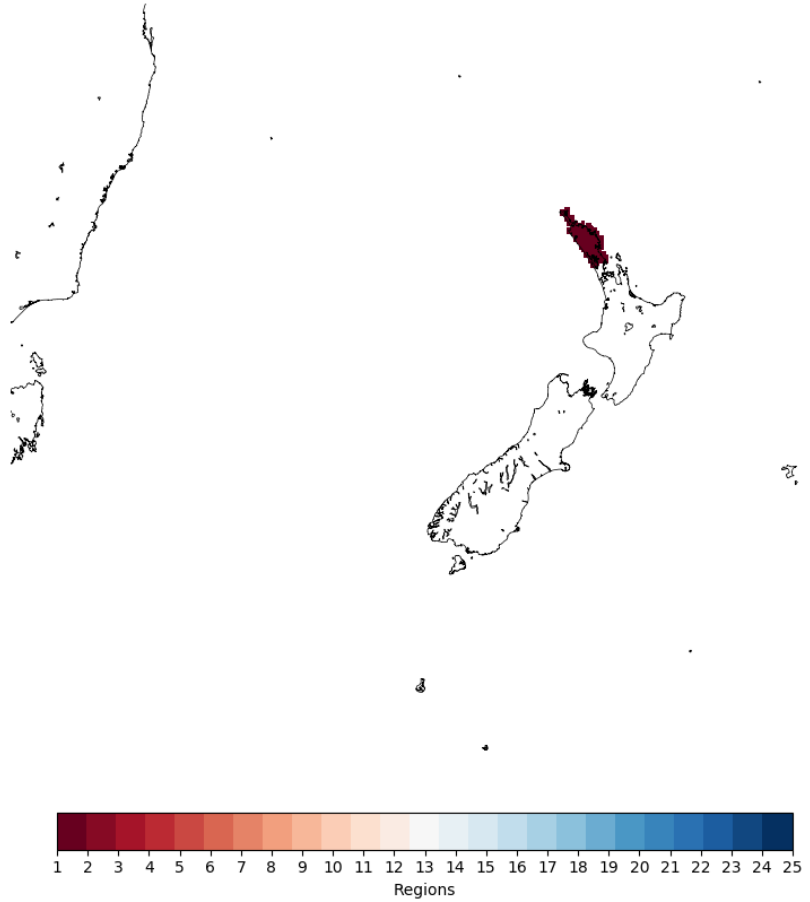
Methodology - Bayesian approach

- 25 regions



$$J = \frac{1}{2}(Tx - d)^T C_d^{-1}(Tx - d) + \frac{1}{2}(x - x_o)^T C_o^{-1}(x - x_o) + \frac{1}{2}(Sx)^T C_s^{-1}(Sx)$$

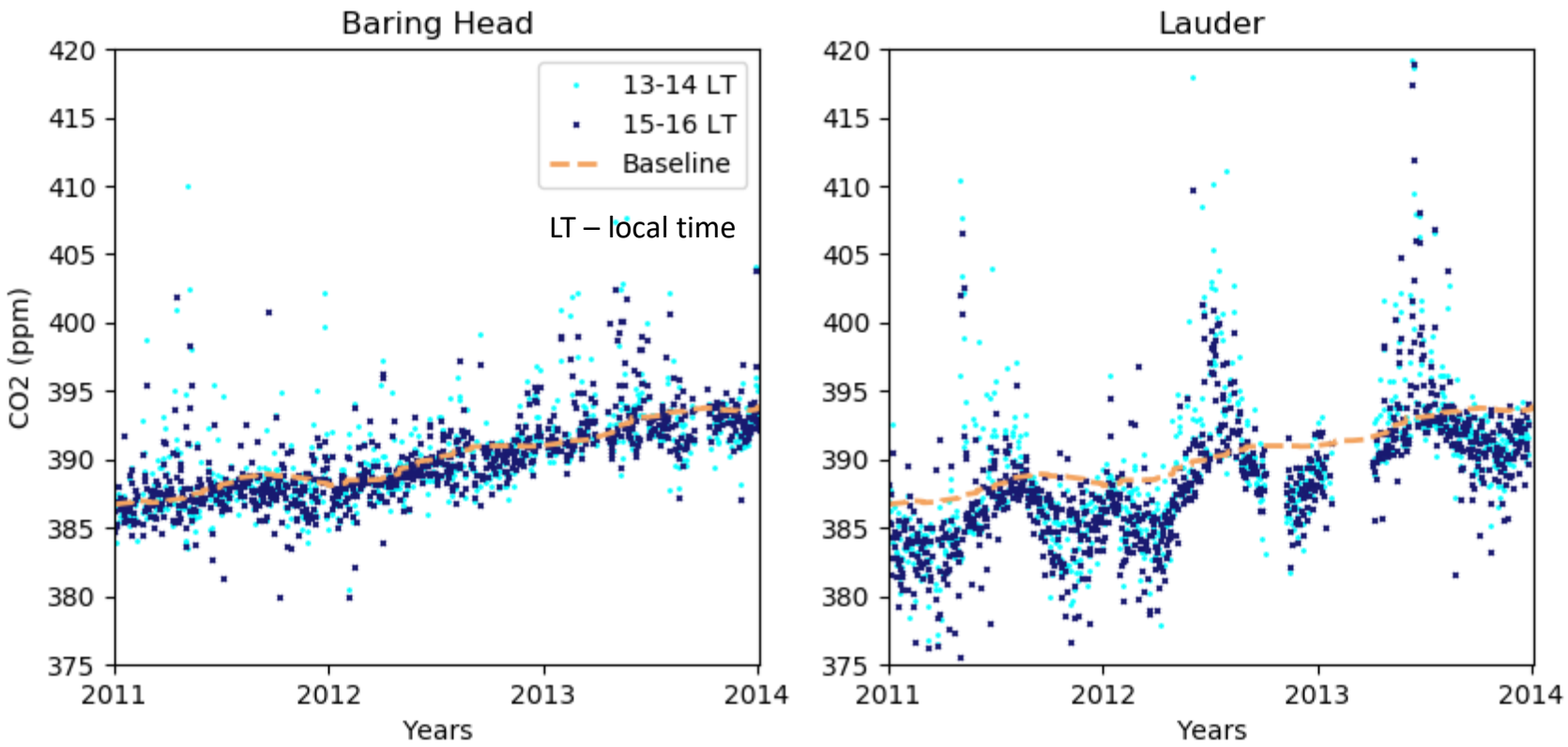
minimized analytically

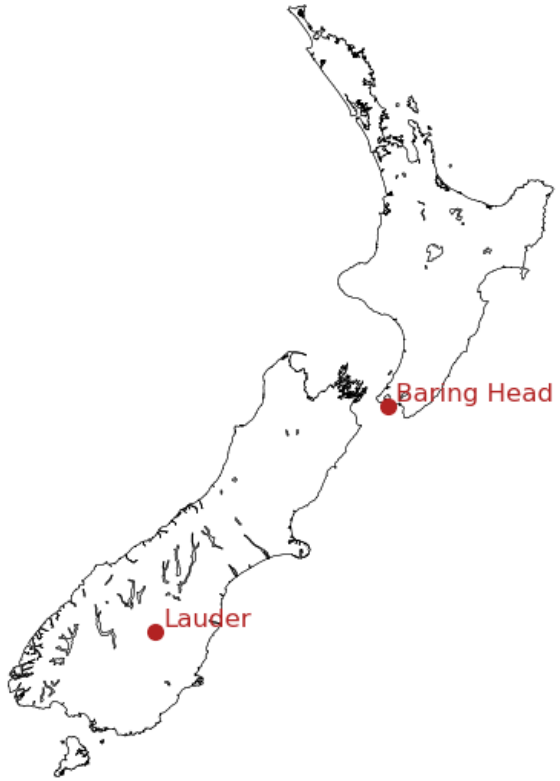
$$x = C(T^T C_d^{-1} d + C_o^{-1} x_o)$$

$$C = (T^T C_d^{-1} T + C_o^{-1})^{-1}$$

The posterior & error covariance matrix

What do we see from the measurements?



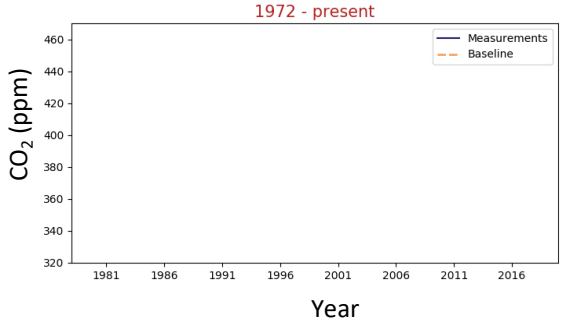


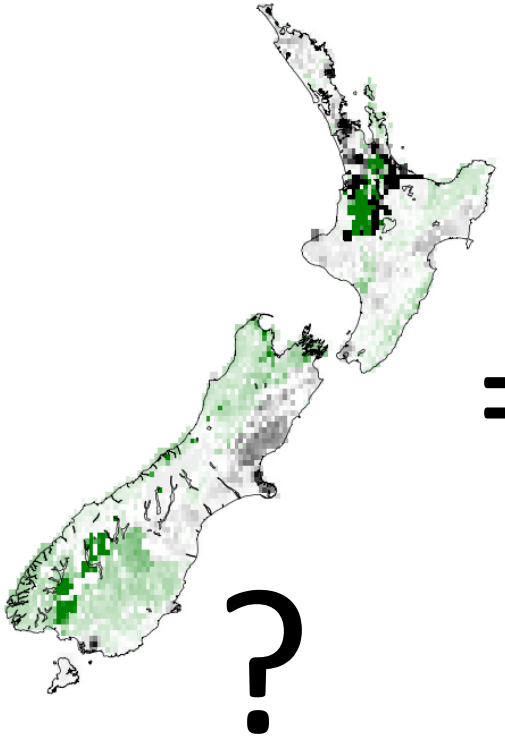
13-14, 15-16 LT – well mixed air

Baseline – predominantly oceanic air

Inversion data = measurements – baseline – anthropogenic signal

Methodology





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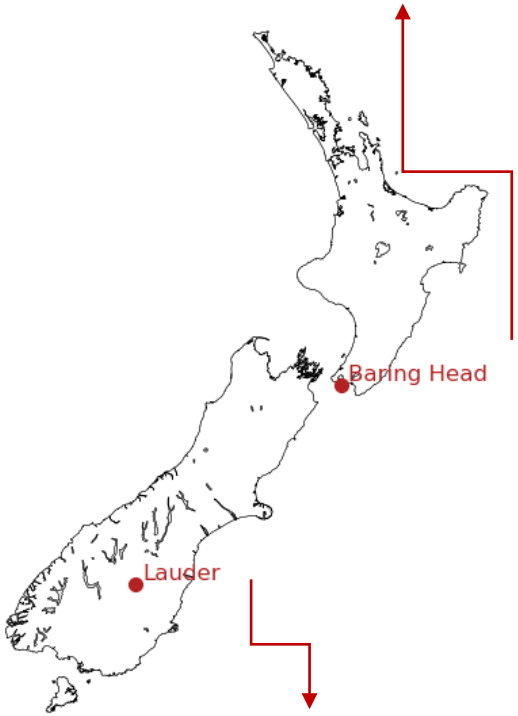

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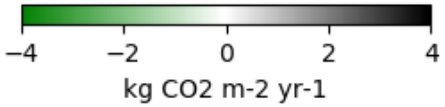

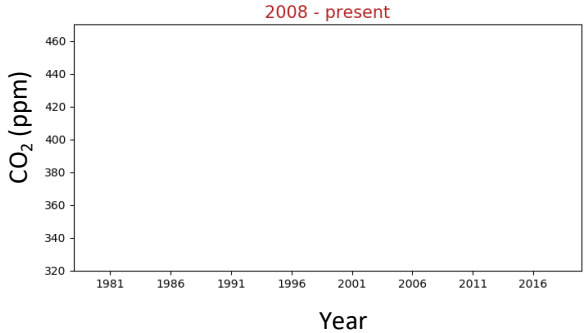

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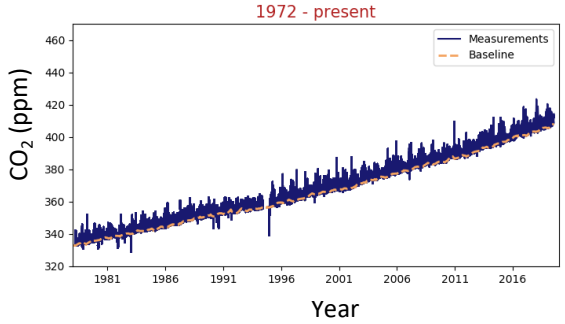
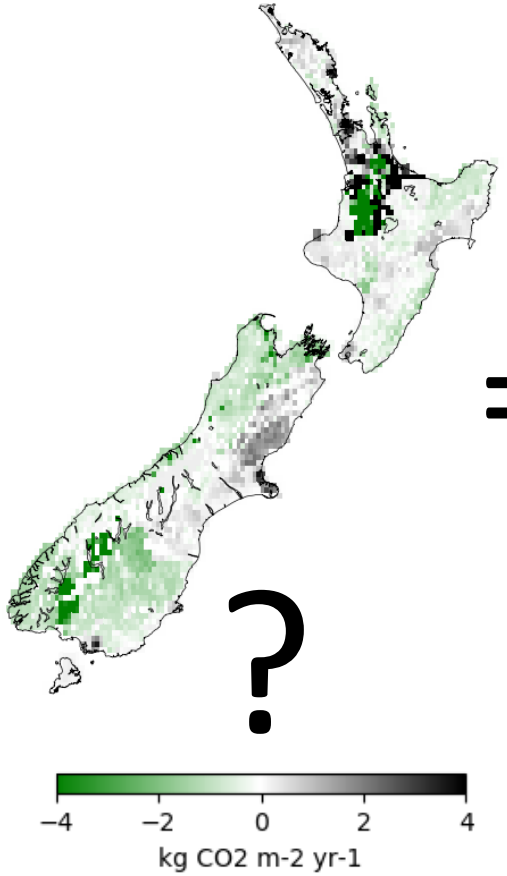
Methodology





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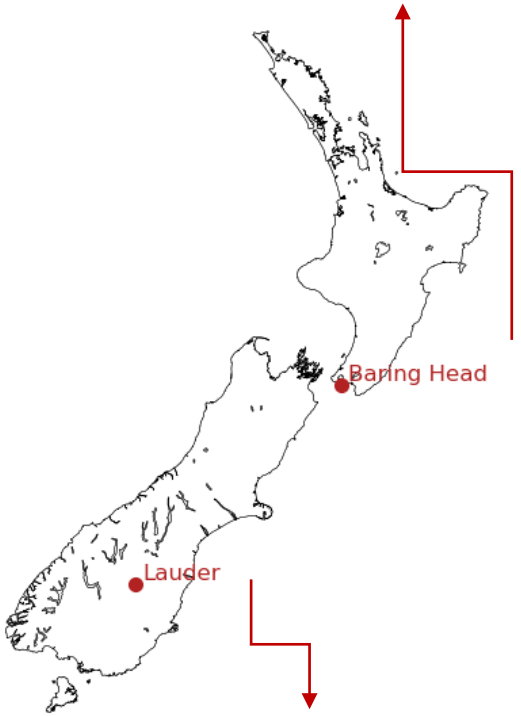

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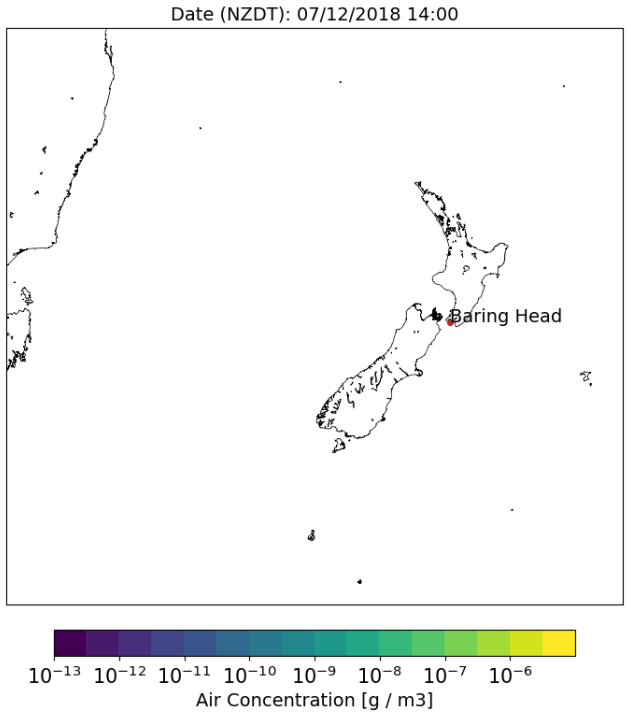

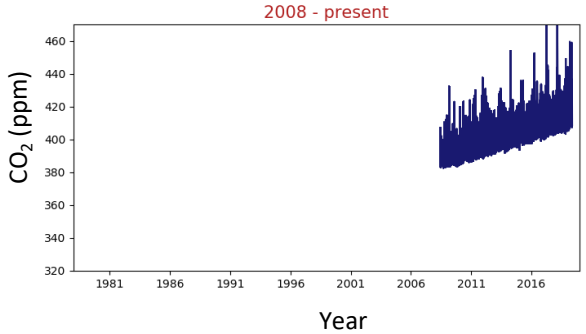

Transport model

NAME III Lagrangian dispersion model

+

NZLAM (12 km) / NZCSM (1.5 km) meteorology (Local configuration of the UK Met Office Unified Model)

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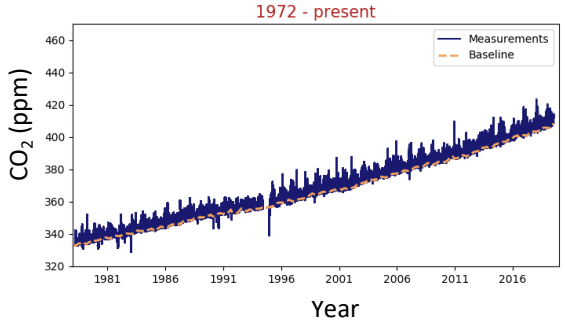
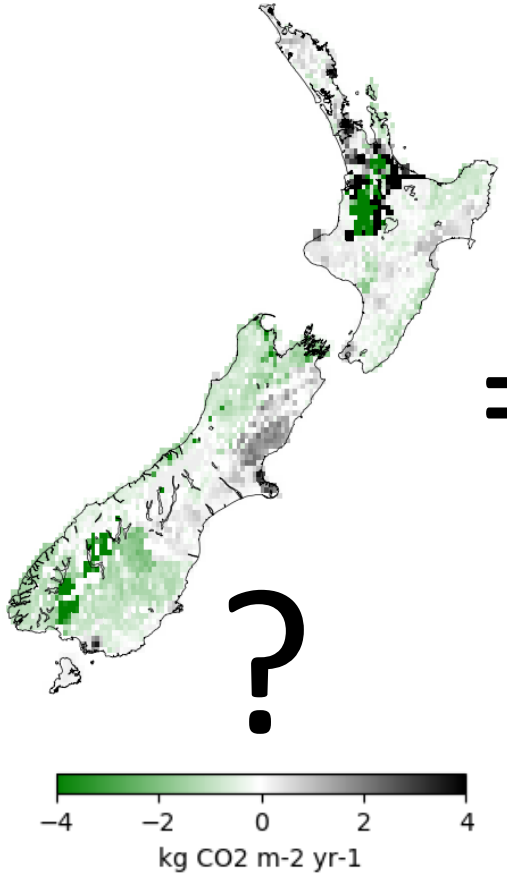
Methodology





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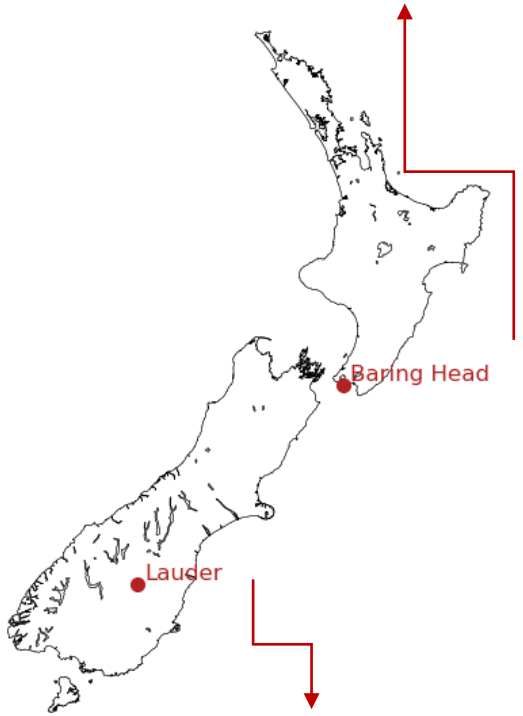

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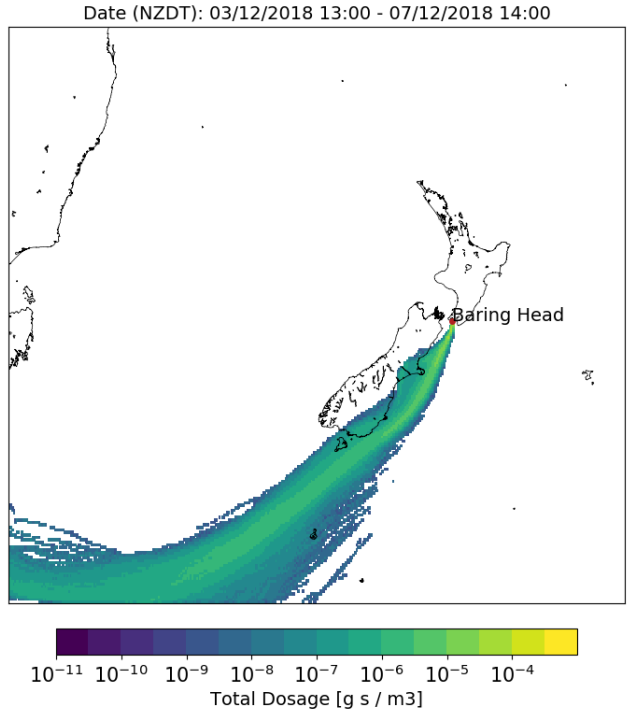

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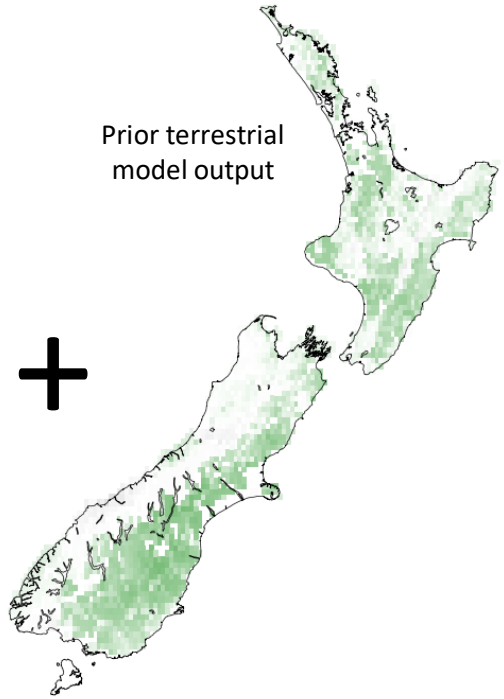

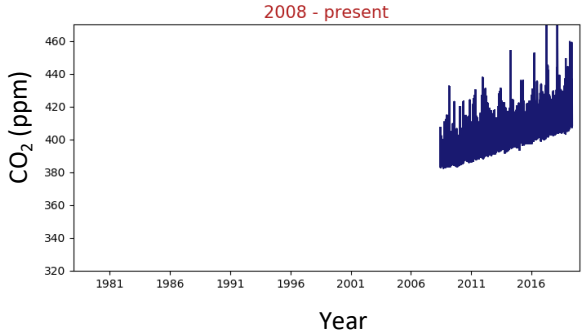

Transport model

NAME III Lagrangian dispersion model

+

NZLAM (12 km) / NZCSM (1.5 km) meteorology (Local configuration of the UK Met Office Unified Model)

Prior flux

Biosphere – BIOME-BGC v4.2

Ocean – Takahashi et al. (2009)

Anthropogenic – EDGAR v4.2

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Results

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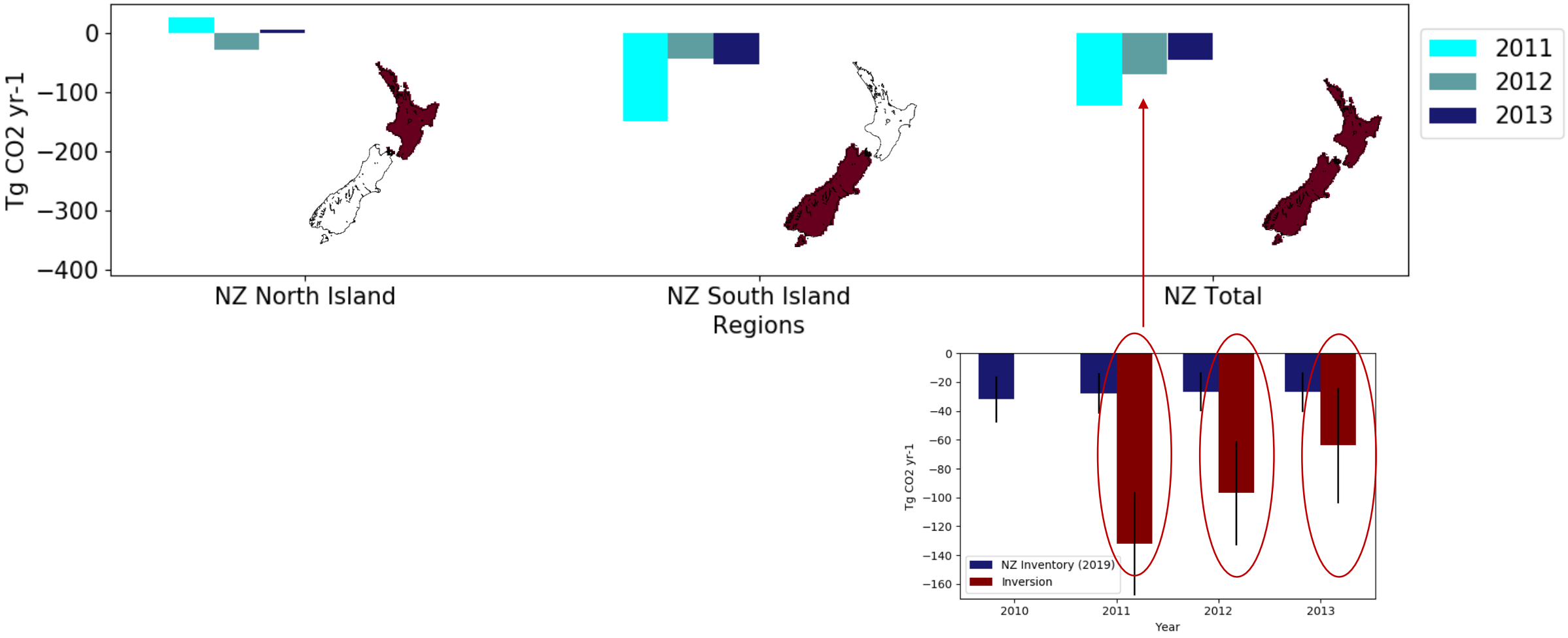
Annual fluxes



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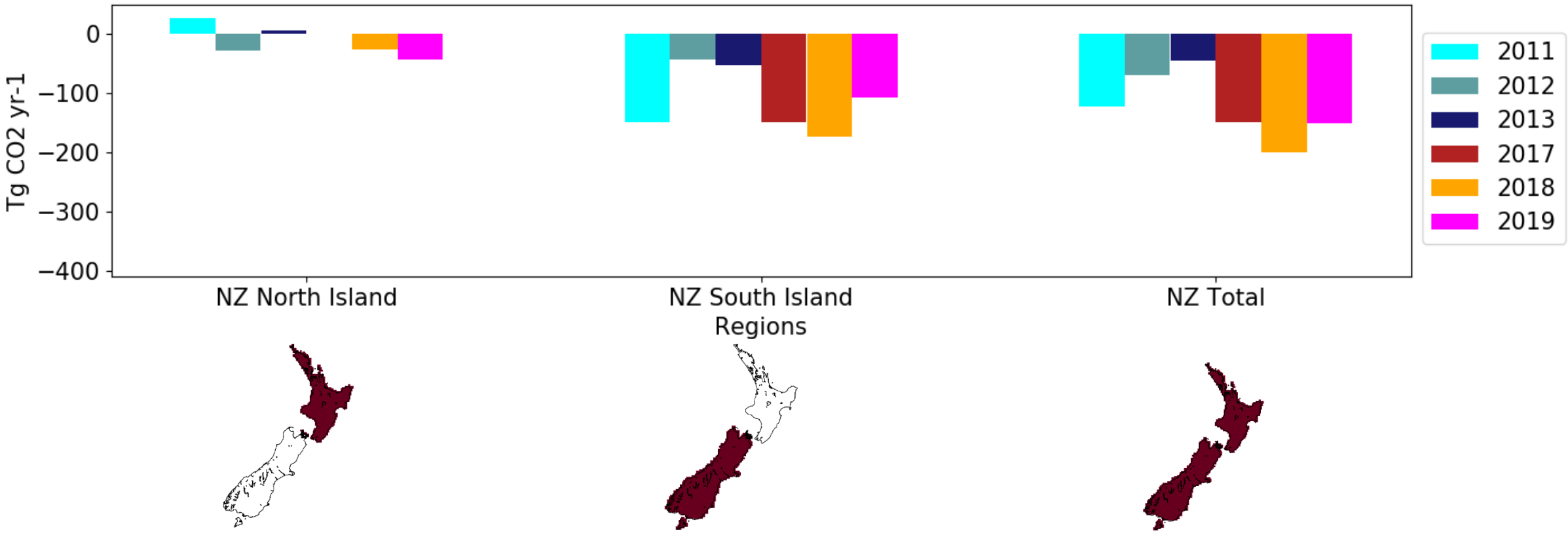
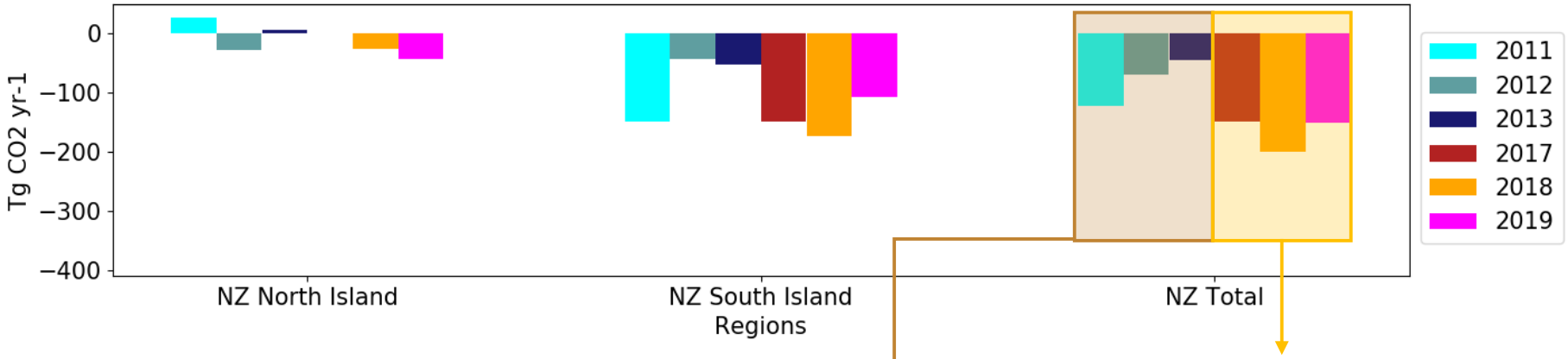
Annual fluxes



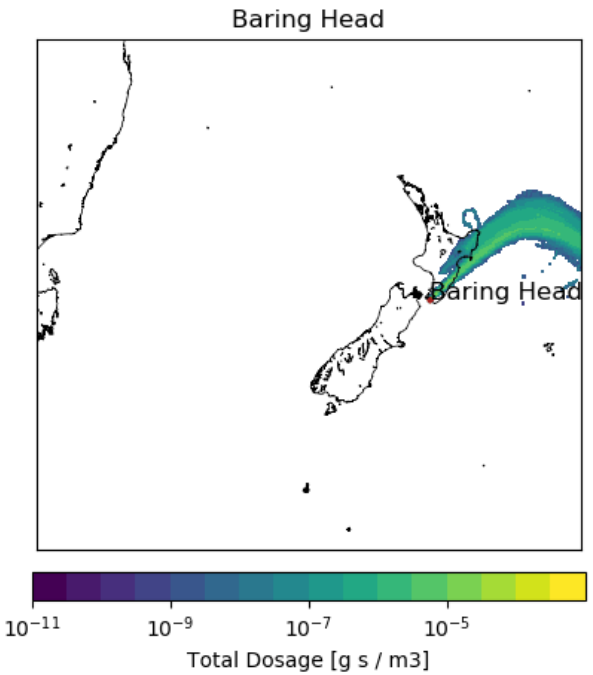
2014, 2015, 2016 work in progress

Important model improvement!

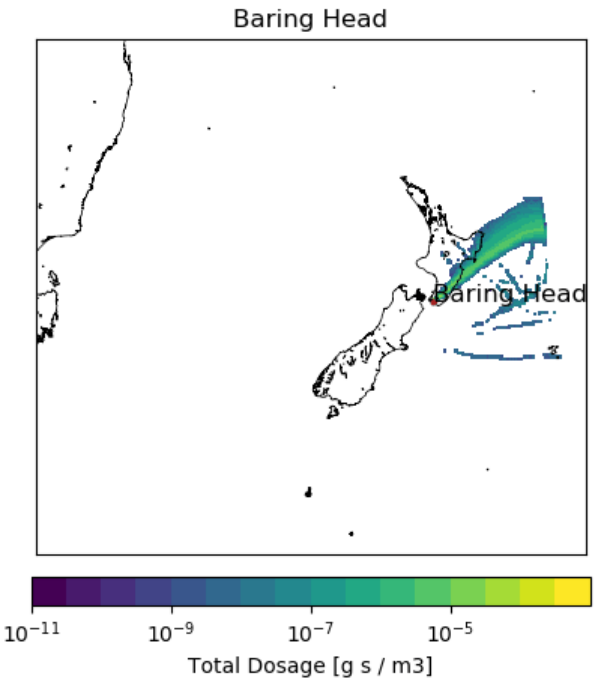


NZLAM (12 km)

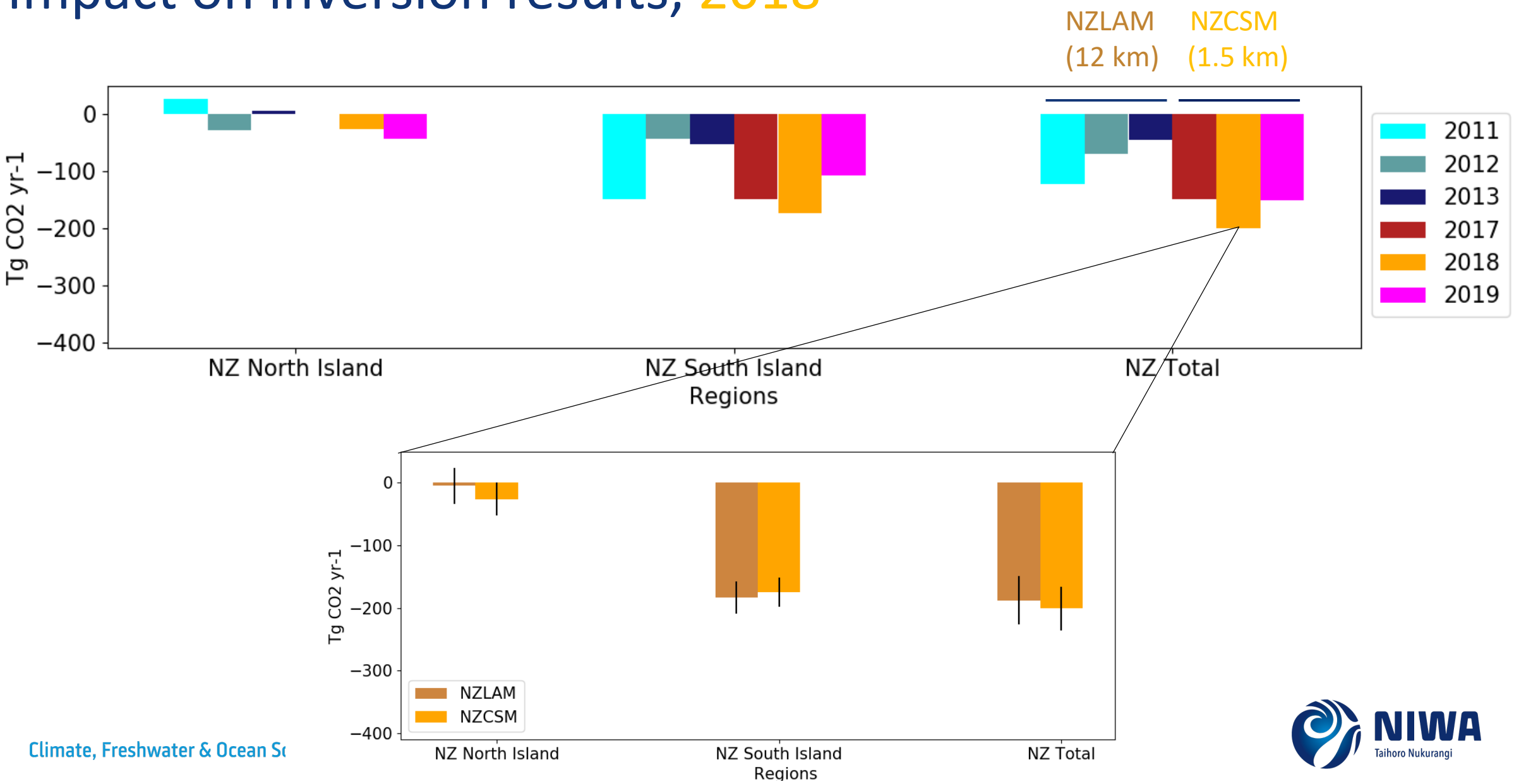
NZCSM (1.5 km)



01/12/2018



Impact on inversion results, 2018



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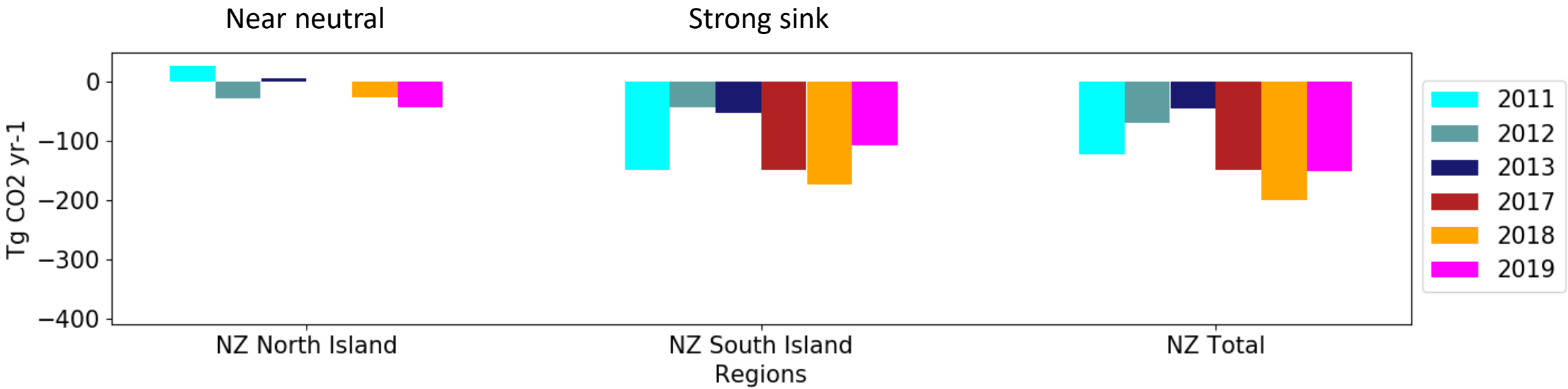
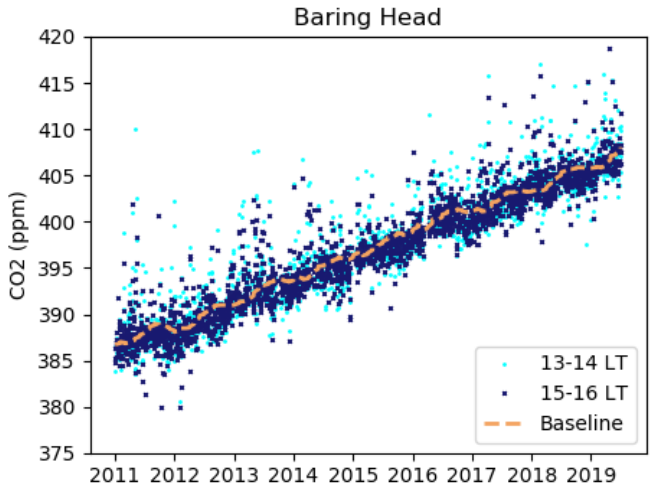
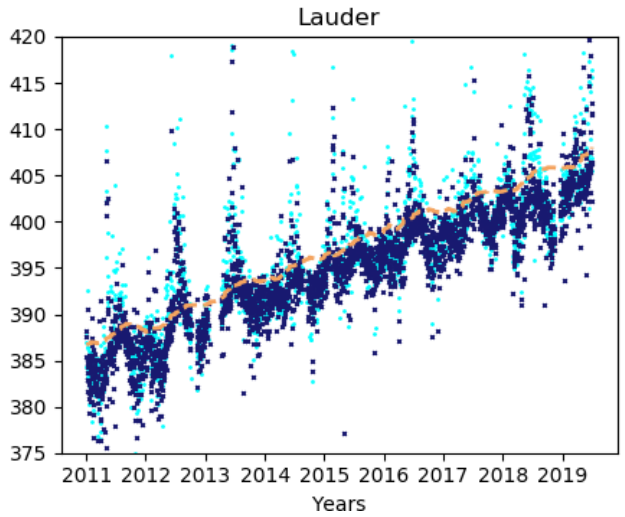
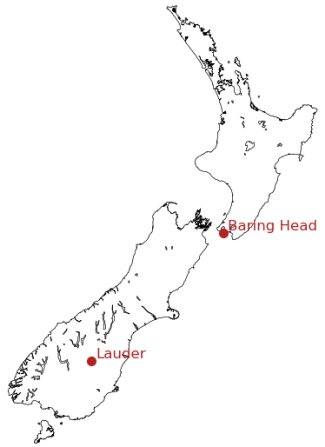
Annual fluxes – sink location









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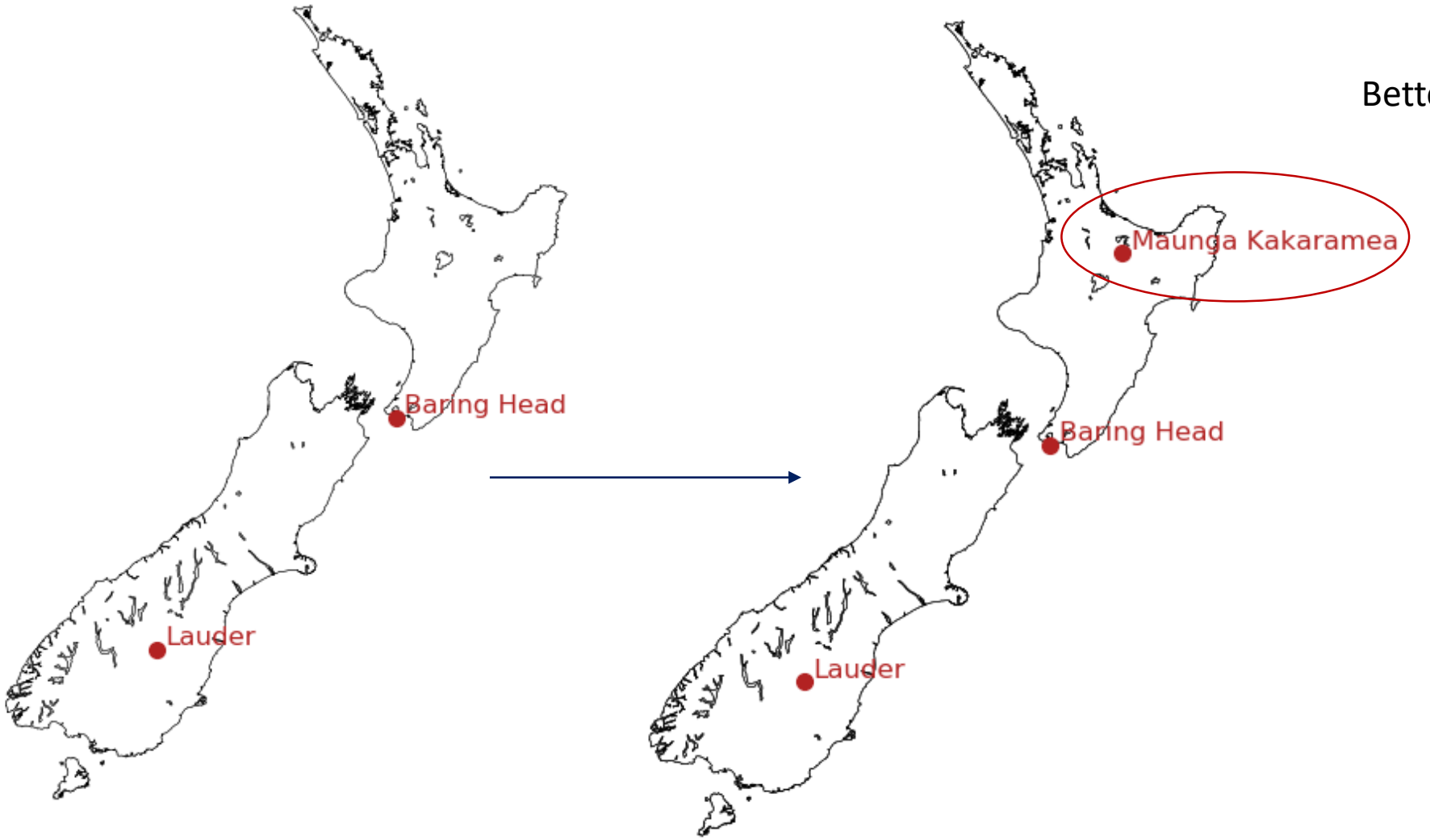
New site, Maunga Kākaramea



Better CO_2 flux estimates
&
Better understanding of the CO_2 exchange between different forest types

North Island
Indigenous & planted, exotic forests

vs

South Island
Mature, indigenous forests

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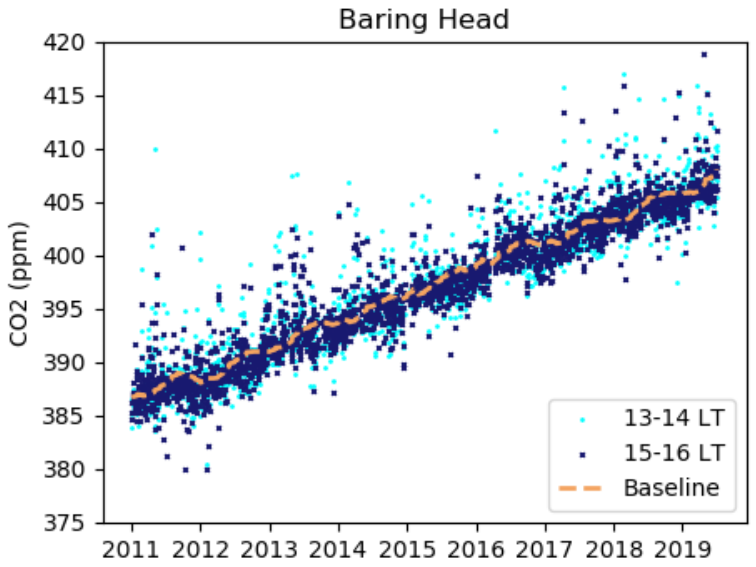
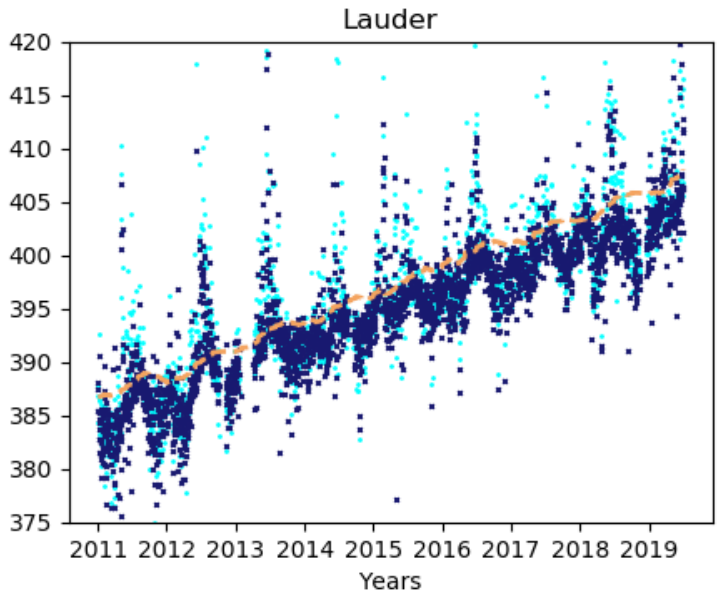
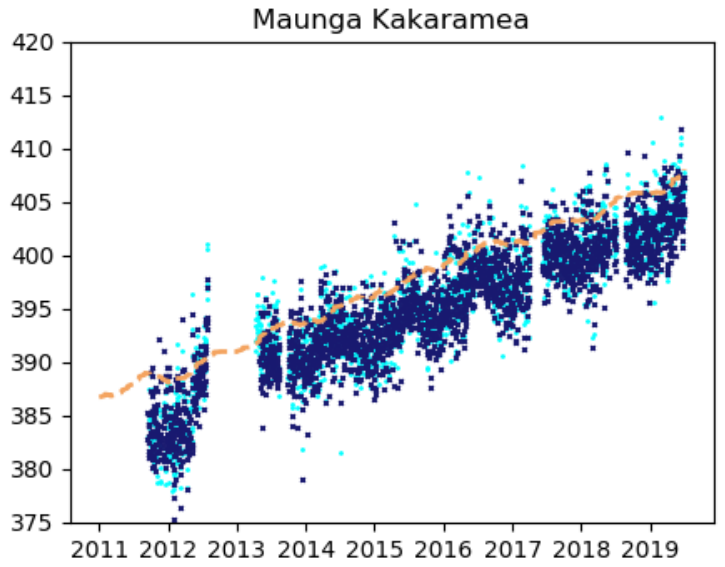
What do we expect? Even larger sink?







Additional significant CO_2 sink in the North Island**?**

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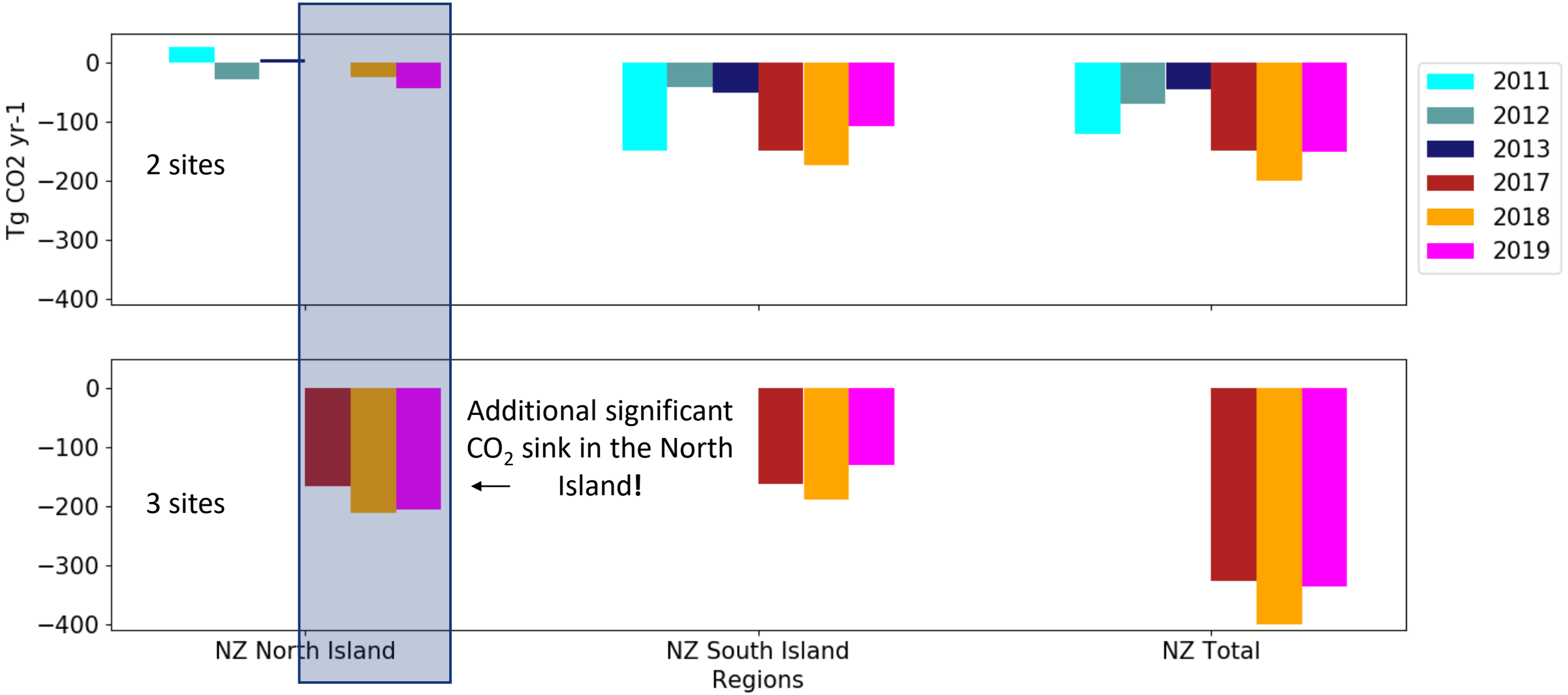
Annual fluxes with new data



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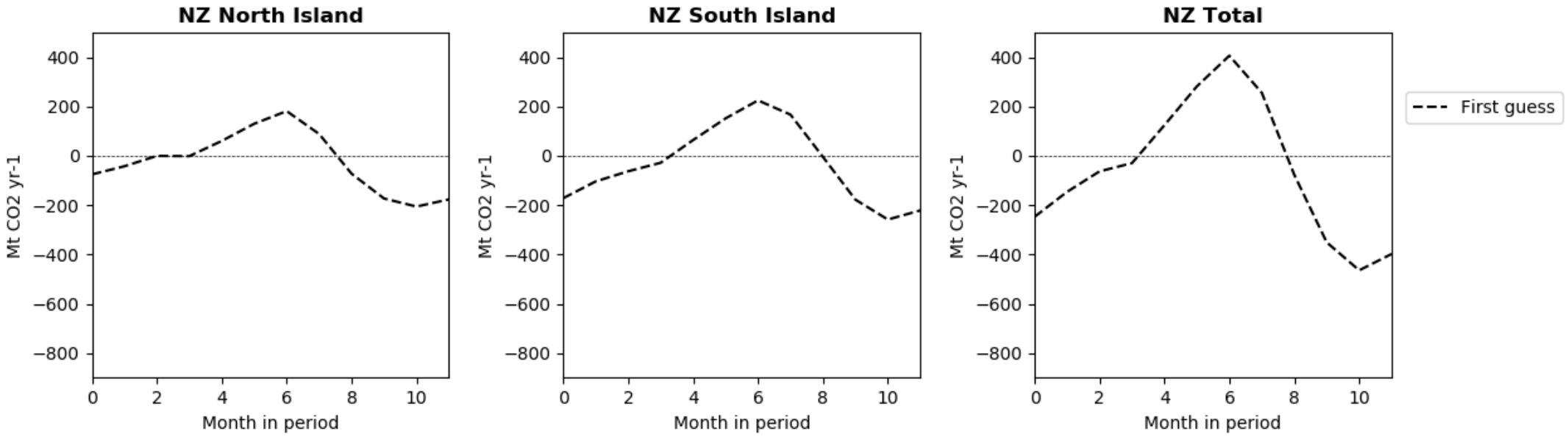
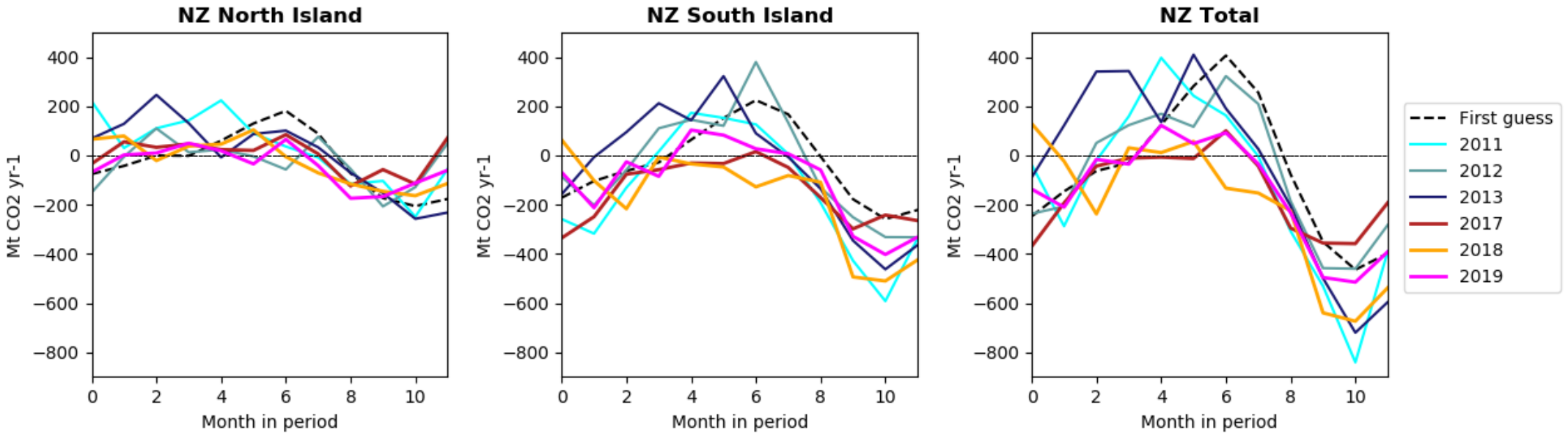
Monthly fluxes, CO_2 variability



Southern Hemisphere seasons!

Monthly fluxes, CO_2 variability



2 sites

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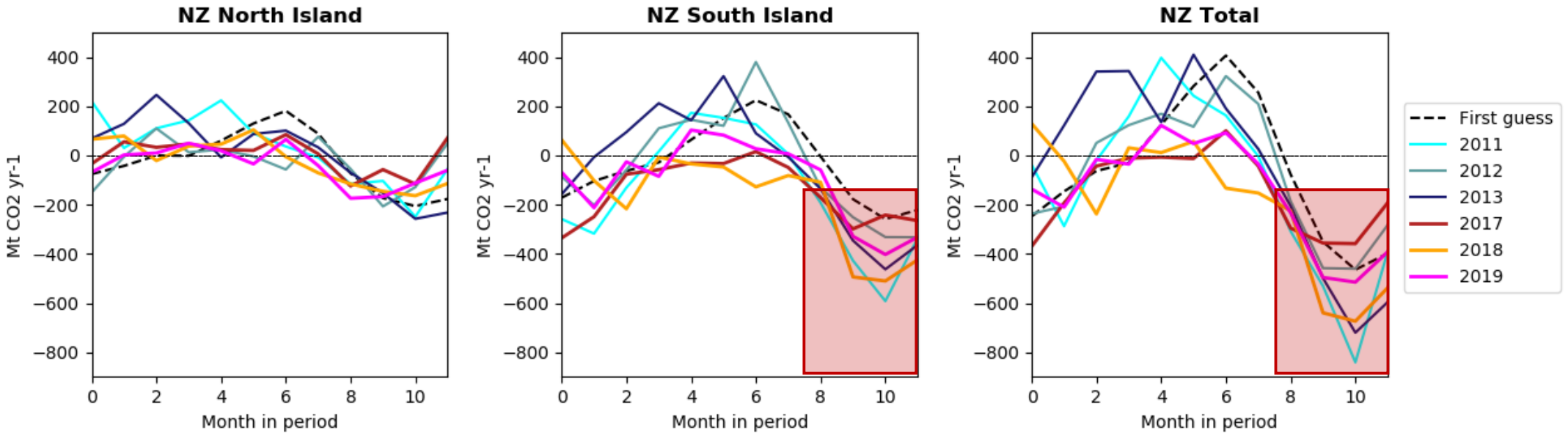
Monthly fluxes, CO_2 variability



2 sites

Stronger CO_2 uptake during summer

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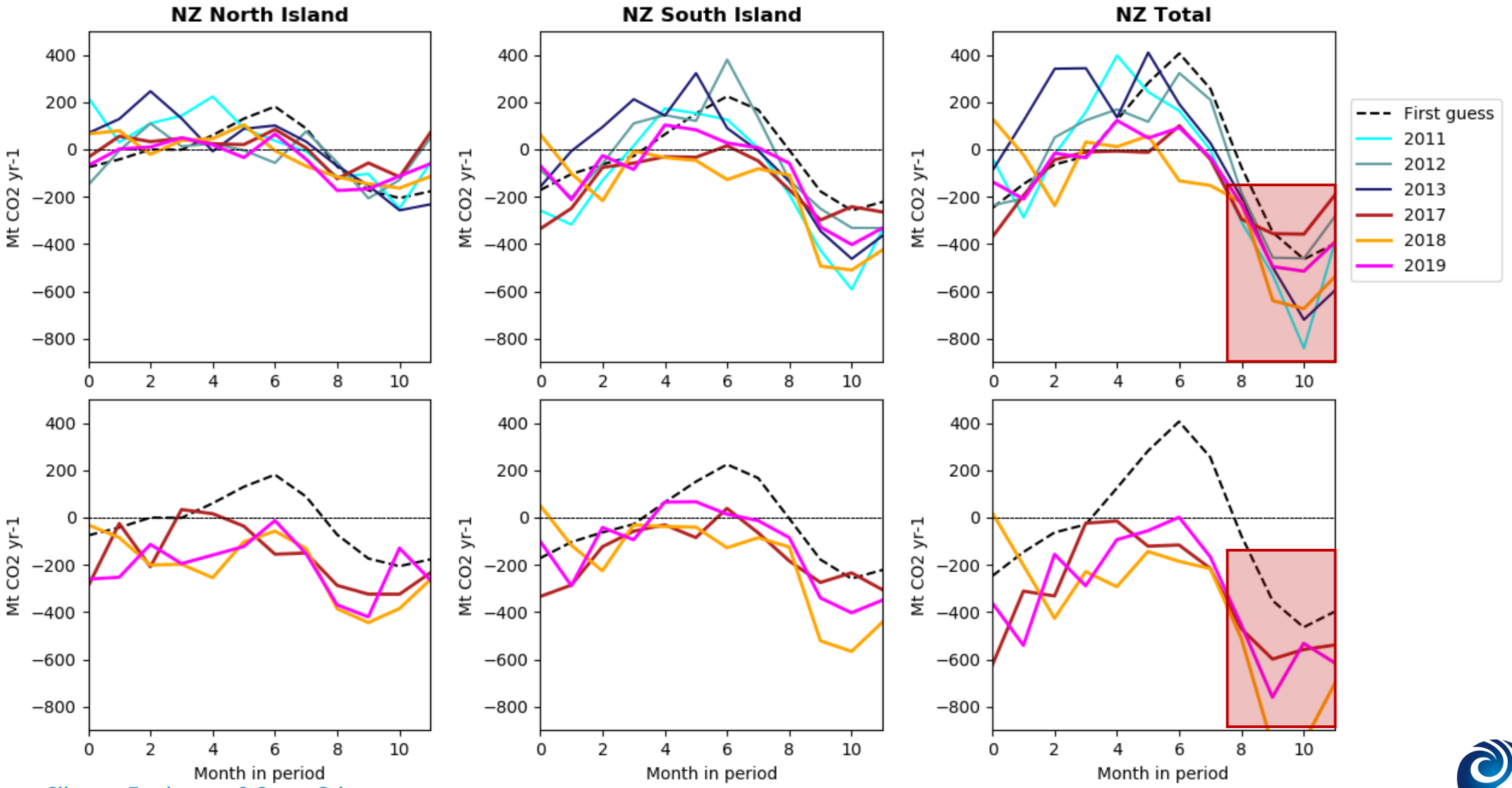
Monthly fluxes, CO_2 variability



2 sites

3 sites

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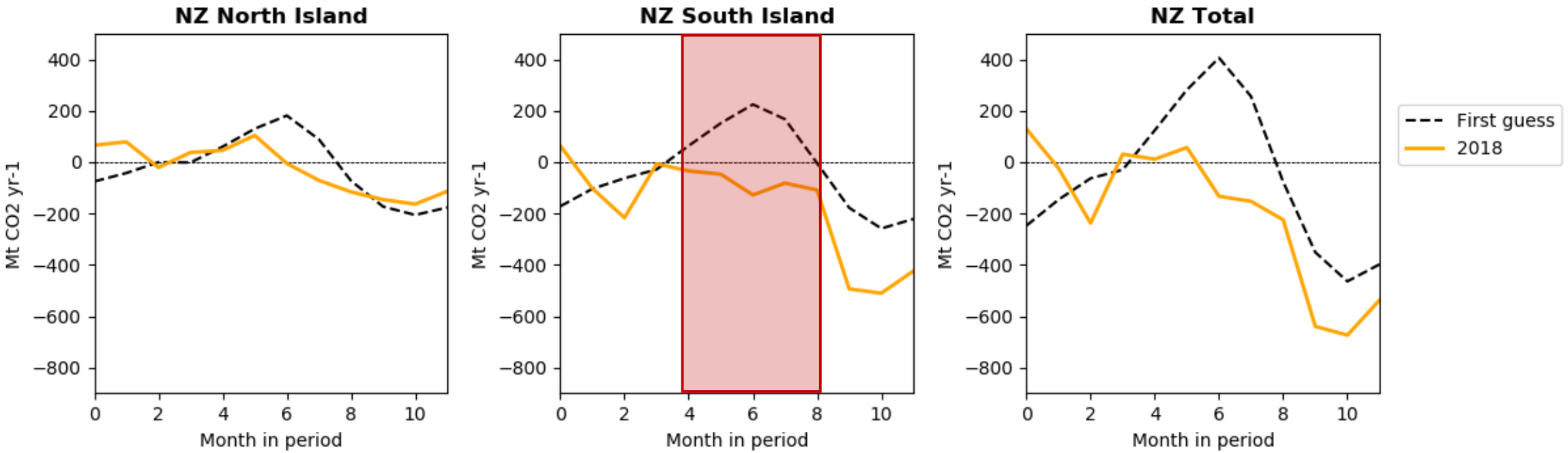
Monthly fluxes, CO_2 variability, 2018 – 2 sites



CO_2 uptake present in winter also

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CO_2 tracer measurements, Fiordland

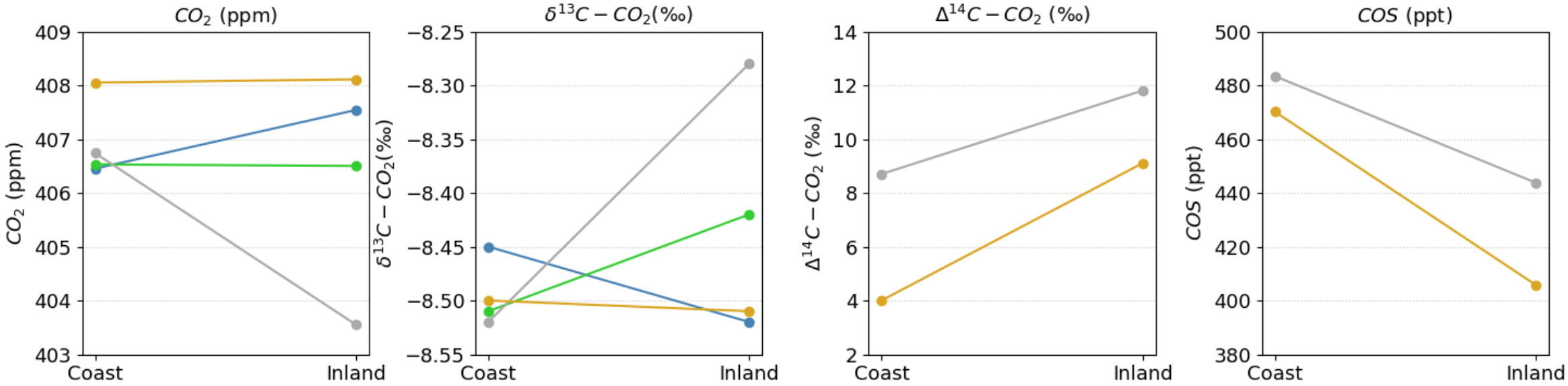
CO_2 isotopes ($\delta^{13}C$ and $\Delta^{14}C$) and Carbonyl sulphide (COS) flask measurements in Fiordland

CO_2 signal

Terrestrial biosphere signal

Respiration

Photosynthesis



CO2 (ppm)	Uptake	Respiration
Autumn	-26.4	23.4
Winter	-42.9	43.0

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Data from Peter Sperlich & Stephen Montzka

CarbonWatch NZ - Future directions

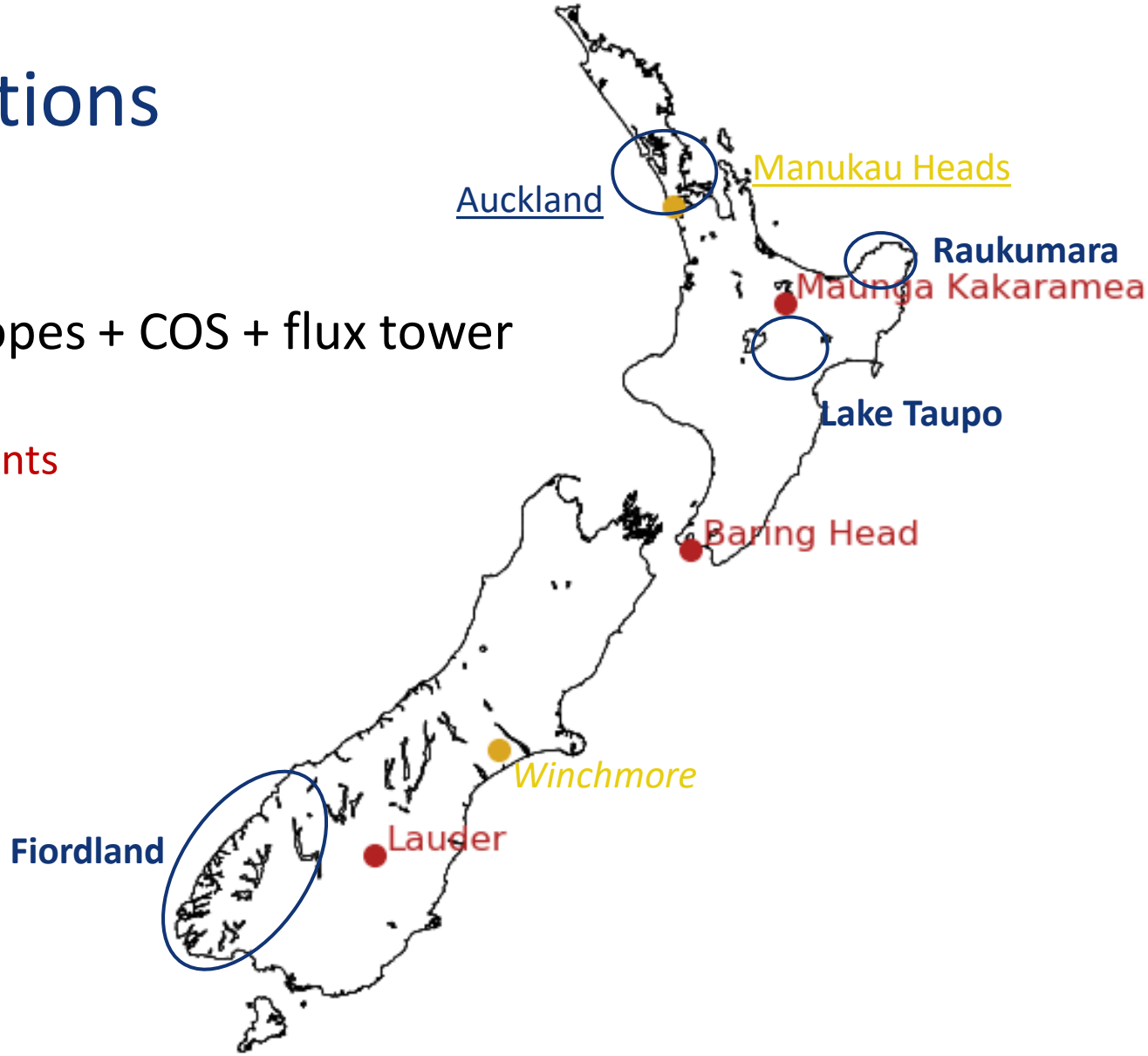
GUIDING CARBON MITIGATION STRATEGIES

13 sites in total - GHG measurements + isotopes + COS + flux tower

3 long running sites with continuous measurements
9 new sites with in situ measurements
8 new sites with discrete measurements

+ smaller scale studies:

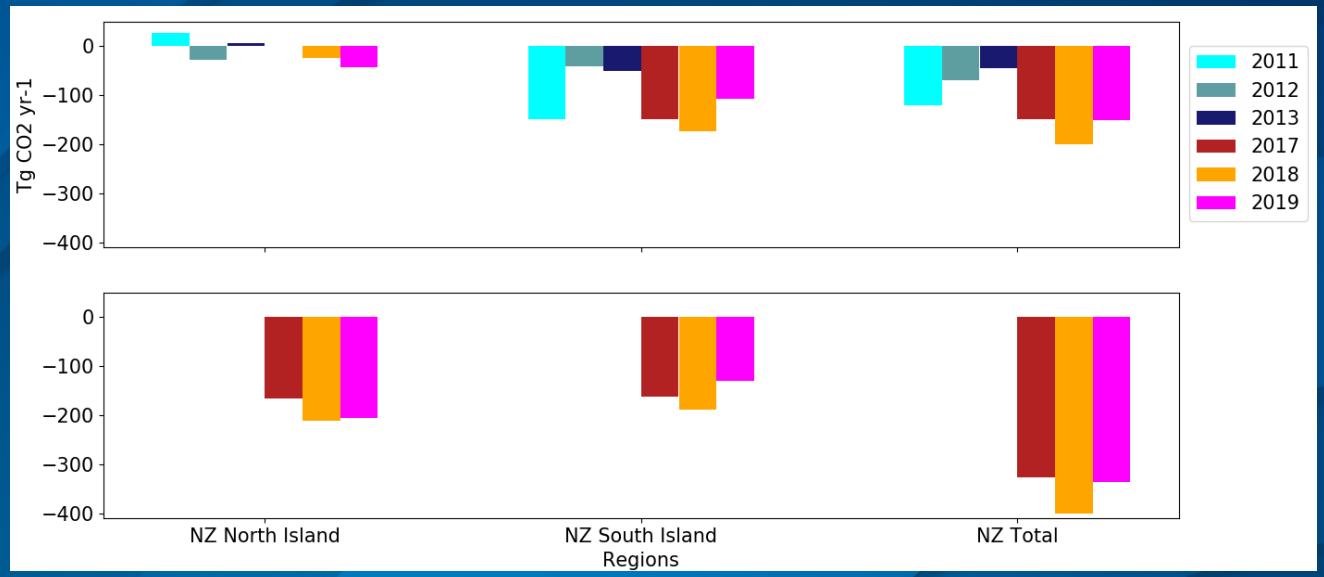
Forests
Grasslands
Urban areas



Summary

- Recent flux NZ picture: 2017-2019 CO_2 sink still present
- New measurements suggest even larger sink

  ⟶ Work in progress, sensitivity tests, uncertainty quantification



Thank you

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More Info: https://www.niwa.co.nz/climate/research-projects/carbon-watch-nz

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#CarbonWatchNZ

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- MBIE, Marsden Fund, and NIWA for funding
- NIWA in situ measurements team

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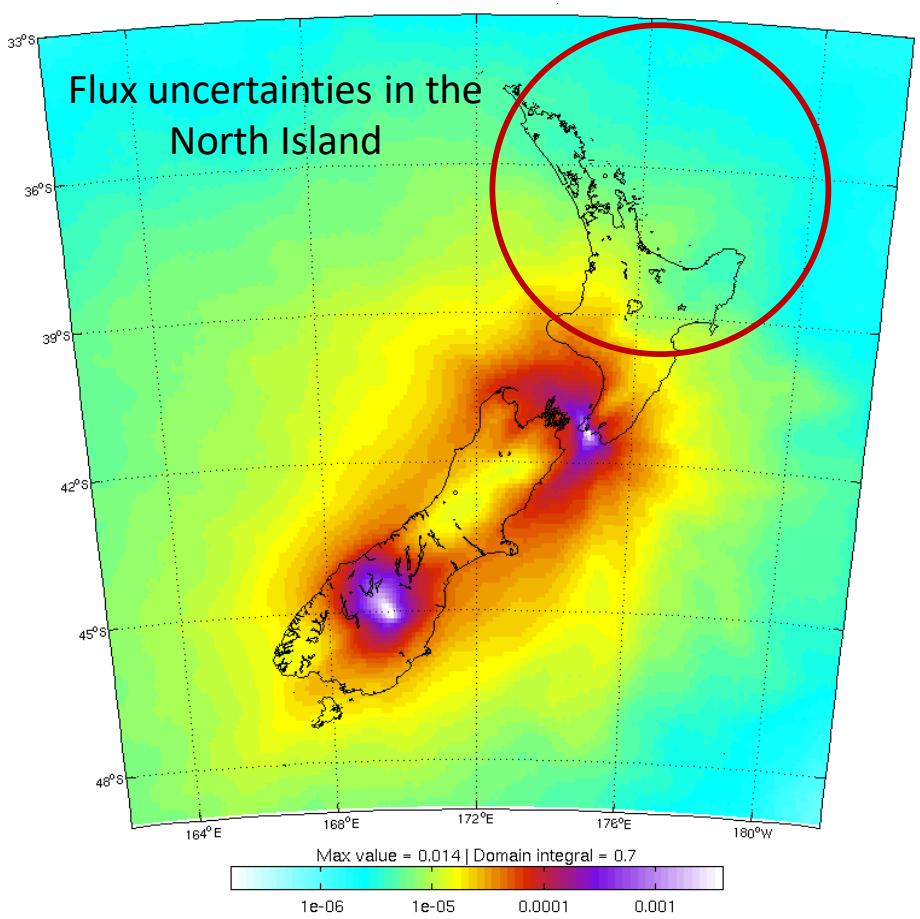
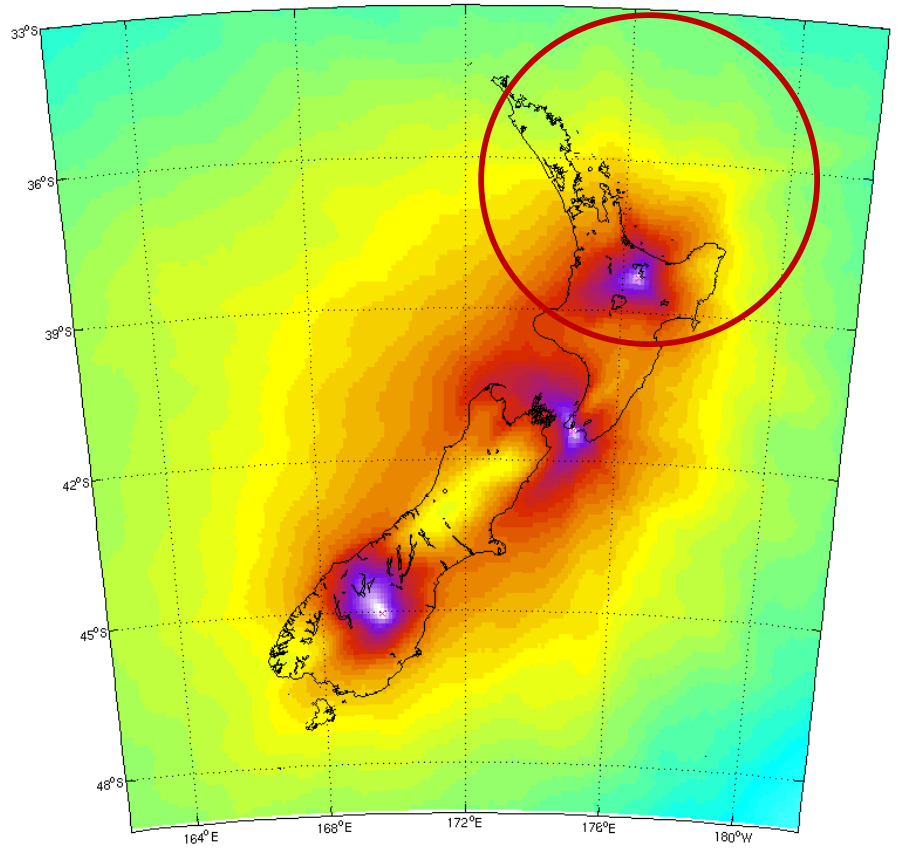
Modelled footprints

Baring Head and Lauder



Baring Head, Lauder and **Maunga Kakaramea**



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