A comparison of carbon storage and exchange in two subalpine grasslands

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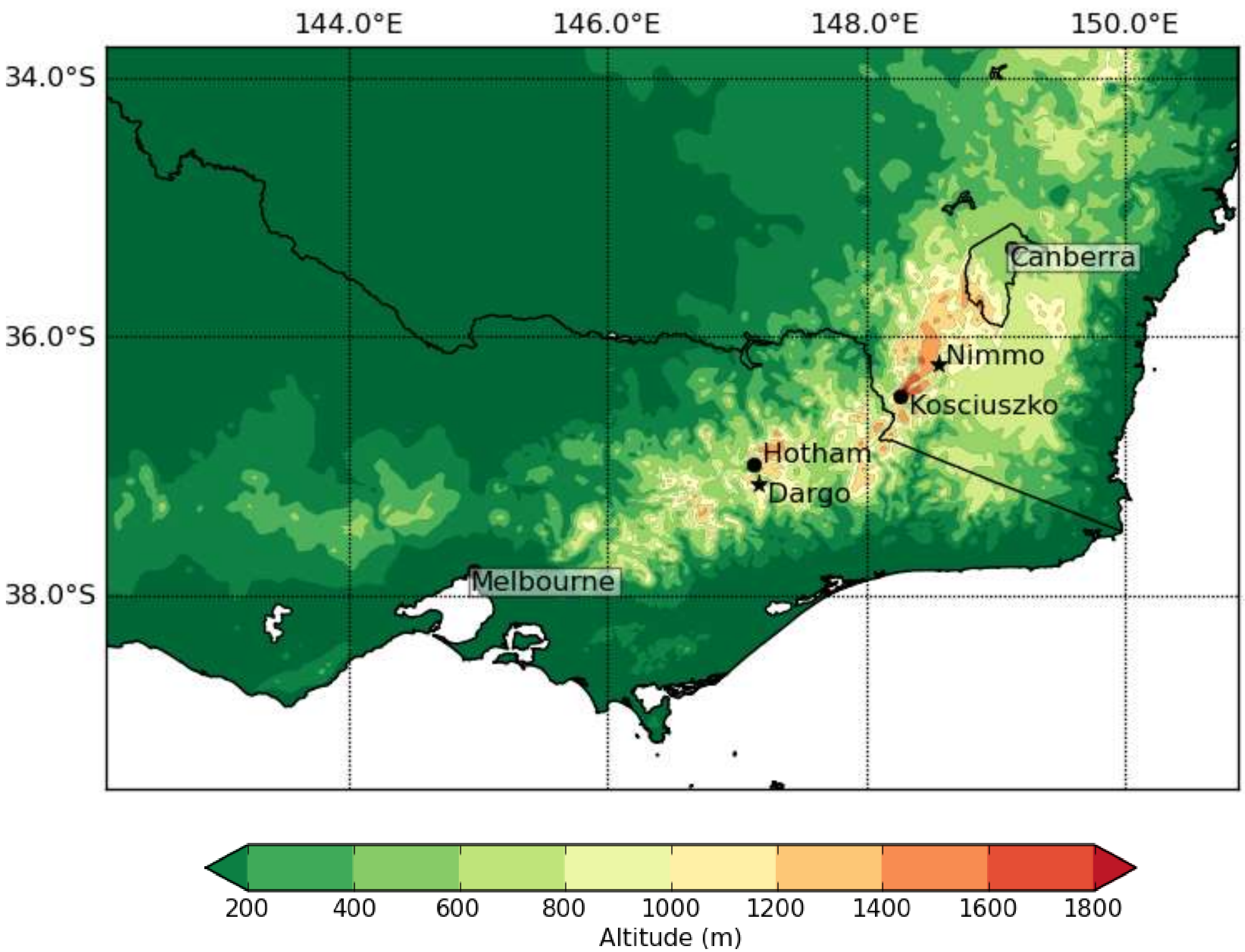
Context and objectives

- Part of HCFEF project under Bushfire CRC
- Montane / subalpine / alpine ecosystems vulnerable to climate change because of: 1) rate of climate change; 2) sensitivity to change; 3) inability to migrate ('Islands in the sky')
- How is the carbon cycle, and thus carbon storage, likely to be affected?

1. Quantify soil and vegetation carbon reservoirs
   - Field sampling / laboratory analysis of soils and vegetation
2. Quantify annual net ecosystem exchange (NEE)
   - Eddy covariance technique / auxiliary chamber measurements
3. Investigate drivers of variation in NEE between sites
   - Partition GPP and R_e and quantify biotic and abiotic factors

Location details

Two climatologically contrasting subalpine grasslands…

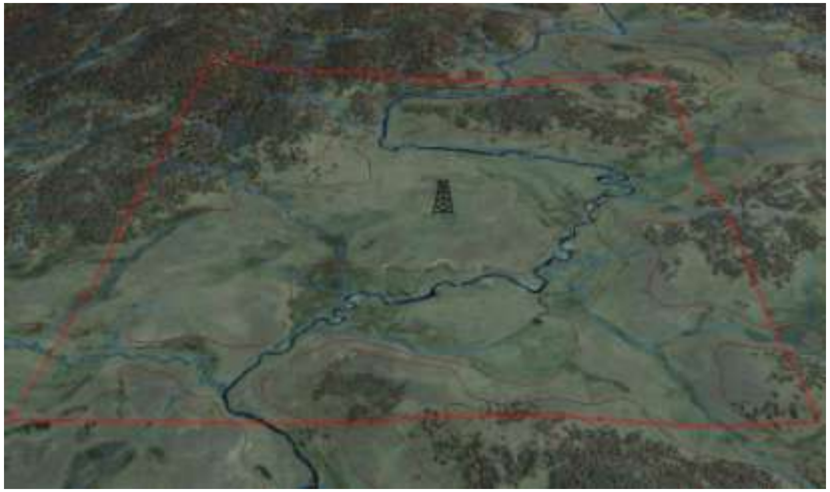


Dargo:
S37º 08.003'
E147 10.258'
1518mASL
- South-easterly aspect
- Exposed midslope

Nimmo:
S36º 12.953'
E148 33.165'
1326mASL
- South-easterly aspect
- Valley floor

Dargo

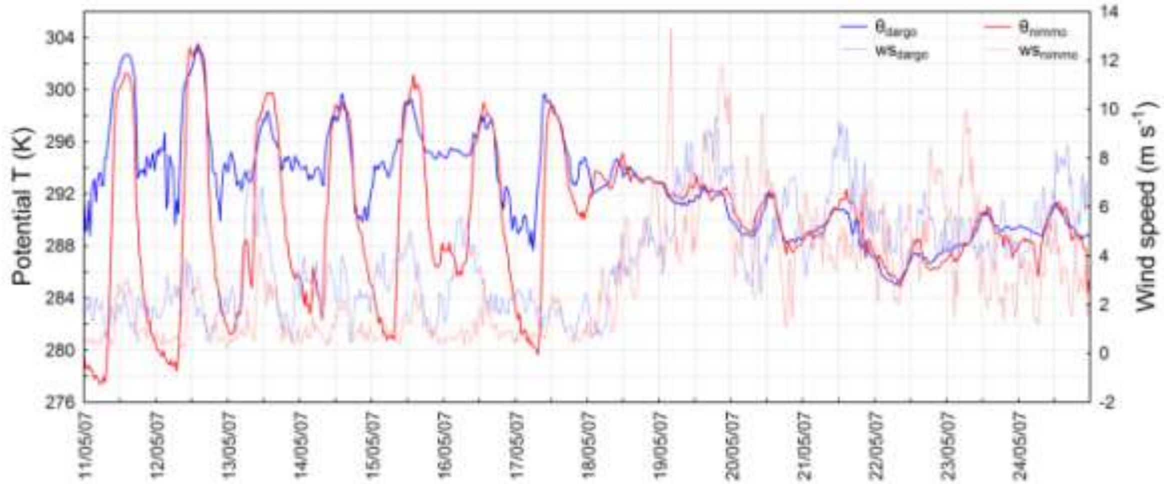
Nimmo



Climate

Temperature (°C)

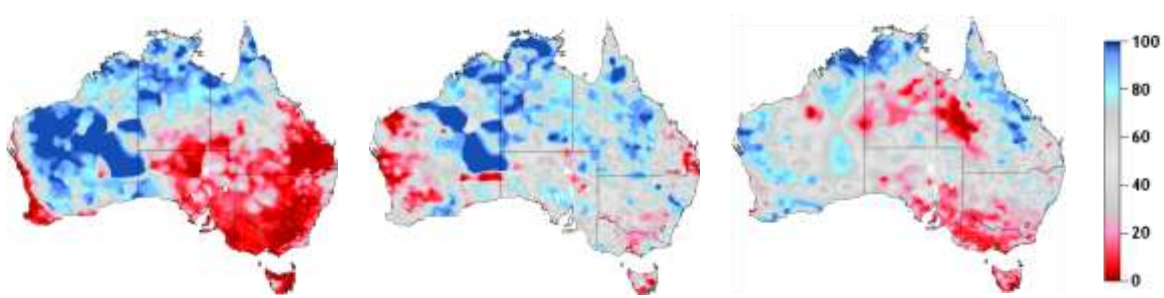
	Dargo	Nimmo
January	14.4	15.7
July	-0.5	0.3
Annual	6.8	7.7



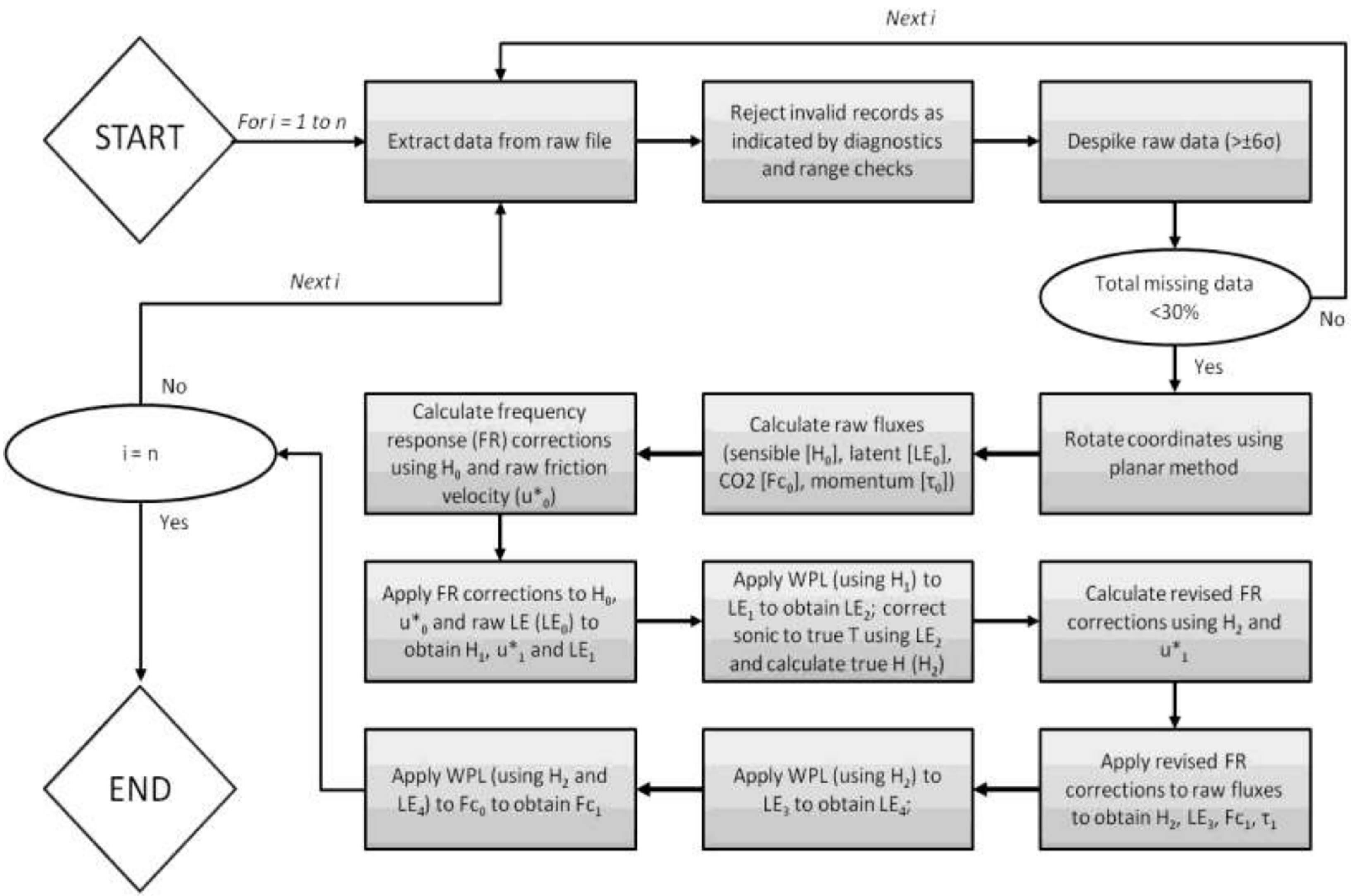
Precipitation (mm)

	Dargo	Nimmo
2007	1084	996
2008	812	970

2006 **2007** **2008**



Data processing (EdiRe)



Data quality assurance

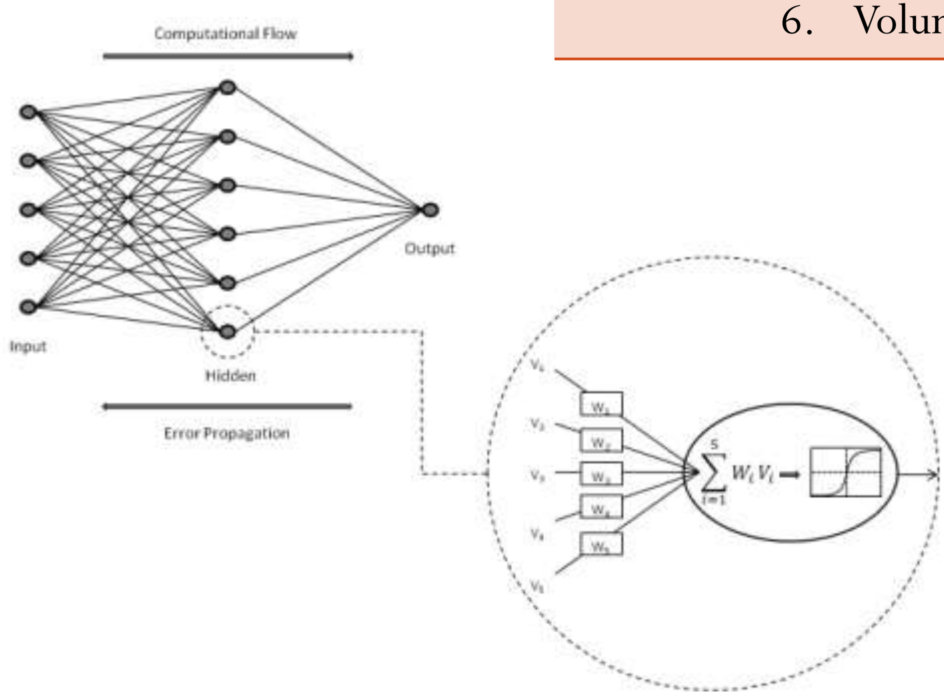
Automatic rejection	Conditional rejection	Statistical rejection
•Precipitation • Plausible range limits • Instrument diagnostics • Missing data >30% • Momentum +ve • F_c and LE if H false • F_c if LE false	Based on combined quality flags (see Foken and Wichura, 1996; Aubinet, 2000; Foken *et al.* 2004) of: 1. Time series stationarity 2. Integral turbulence 3. Wind direction Class 1-3 data highest quality (used for parameterisations); 4-6 acceptable; 6-8 conditional on other criteria; >8 rejected.	Outlier identification based on median of absolute deviation from differences between neighbouring points (see Papale, 2006); applied iteratively.

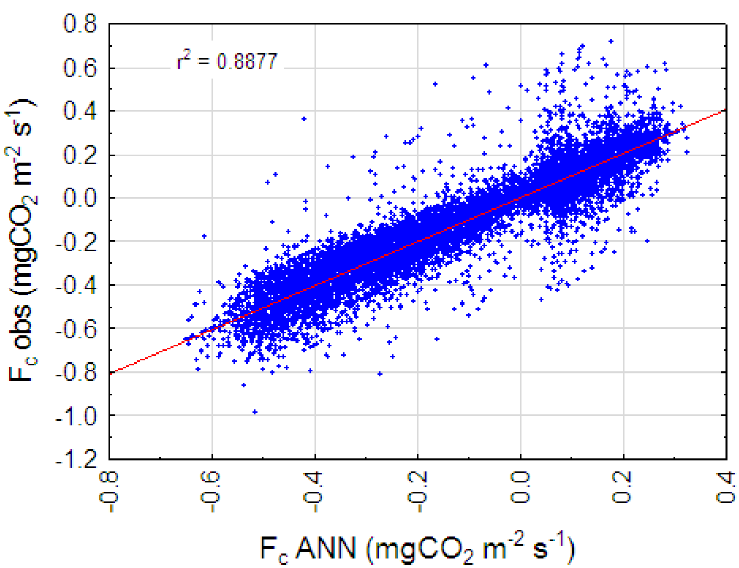
- Low u* correction with objective threshold determination technique (Reichstein *et al.*, 2005)
- Low temperature semi-empirical LI7500 correction (Burba *et al.*, 2008)

Data imputation: artificial neural nets

- Multi-layer perceptrons
- Trained annually
- SOS cost function
- Test and train datasets
- Early stopping procedure

Target	Input
NEE	1. Incoming photosynthetically active radiation (PAR) 2. Reflected PAR 3. Air temperature (2m) 4. Soil temperature (0-0.1m) 5. Vapour pressure deficit 6. Volumetric soil moisture content (0-0.1m)





CO_2 flux data partitioning

$$R_e = f(T_s) \cdot f(VWC)$$

Temperature response: Lloyd & Taylor (1994) modified Arrhenius function

$$f(T_s) = R_{ref}\, e^{E_o\left(\frac{1}{T_{ref}-T_0} - \frac{1}{T_s - T_0}\right)}$$

- R_{ref} reference respiration
- E_0 activation energy
- T_{ref} reference temperature (283.15K)
- T_0 zero R_e temperature (227.13K)

Soil moisture response: generic sigmoid function (see Richardson *et al.* 2007)

$$f(VWC) = \frac{1}{1 + e^{\theta_1 - \theta_2 VWC}}$$

- θ_1
- θ_2

} sigmoid shape parameters

GPP estimation

Light response: modified Michaelis-Menten (1913) rectangular hyperbolic function (Falge *et al.*, 2001)

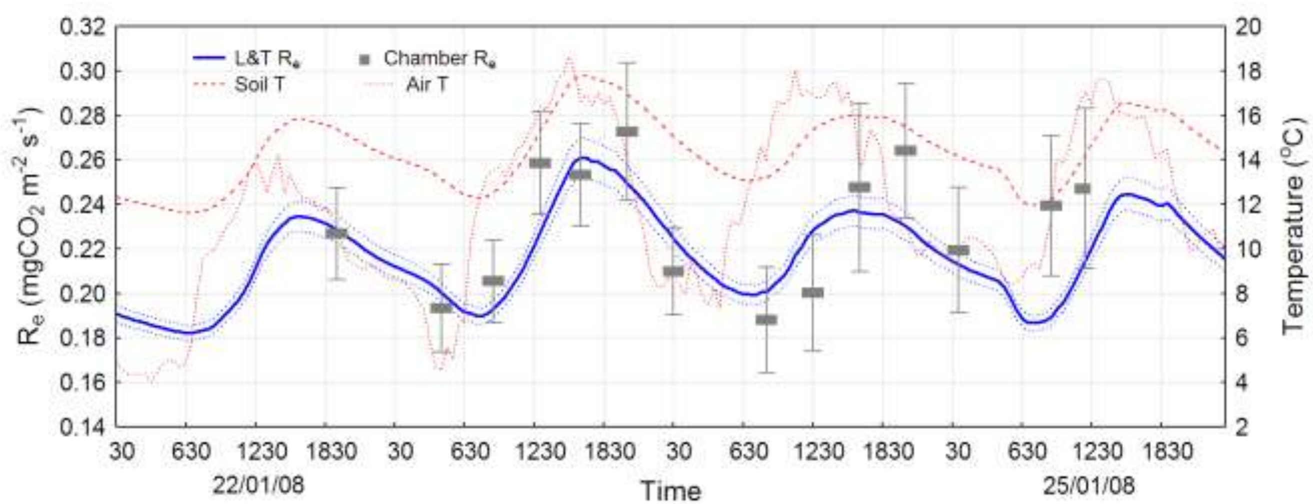
$$GPP = \frac{\alpha Q}{\left(1-\phi/2000\right) + \alpha Q/A_{opt}}$$

- α quantum efficiency (μmol CO_2 / μmol photons)
- Q photosynthetic photon flux density (μmol photons m^{-2} s^{-1})
- A_{opt} GPP @ Q = 2000μmol photons m^{-2} s^{-1}

Data validation

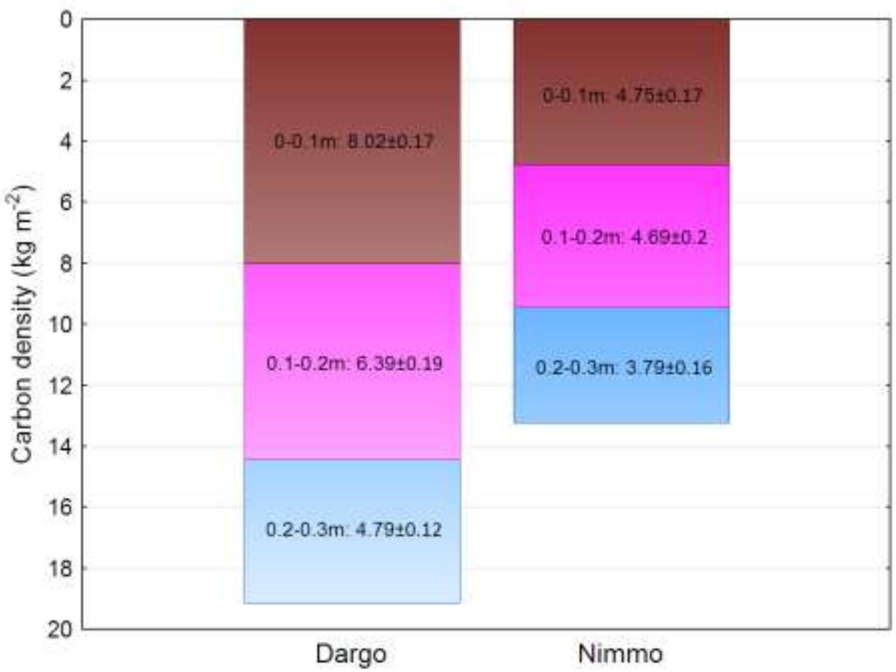
Systematic error checks:

1. Energy balance closure
2. Comparison of nocturnal and light use curve-derived R_e
3. Comparison of eddy covariance and chamber-based R_e



Results

Carbon storage

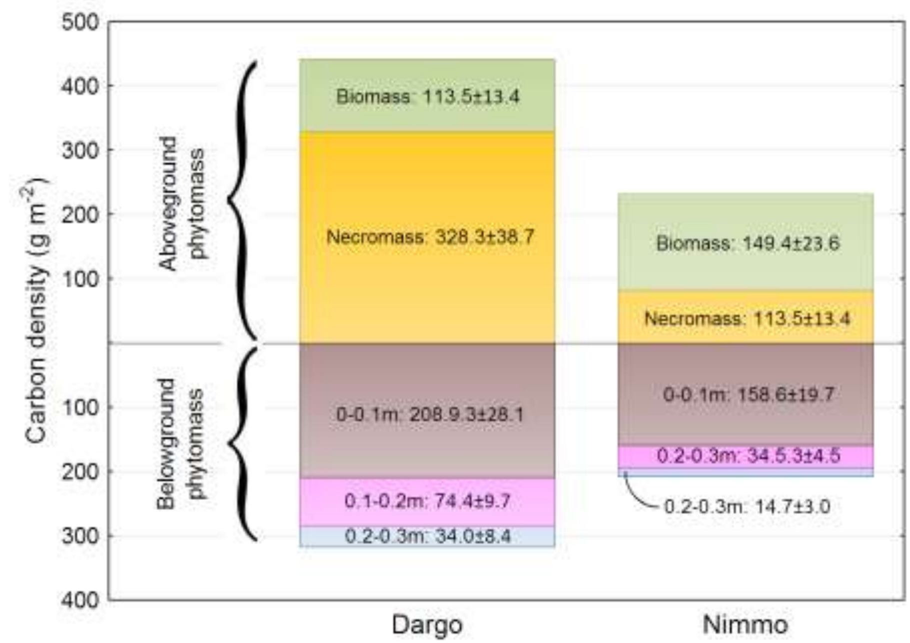


Soil organic C density ± SE (kgC m^{-2})

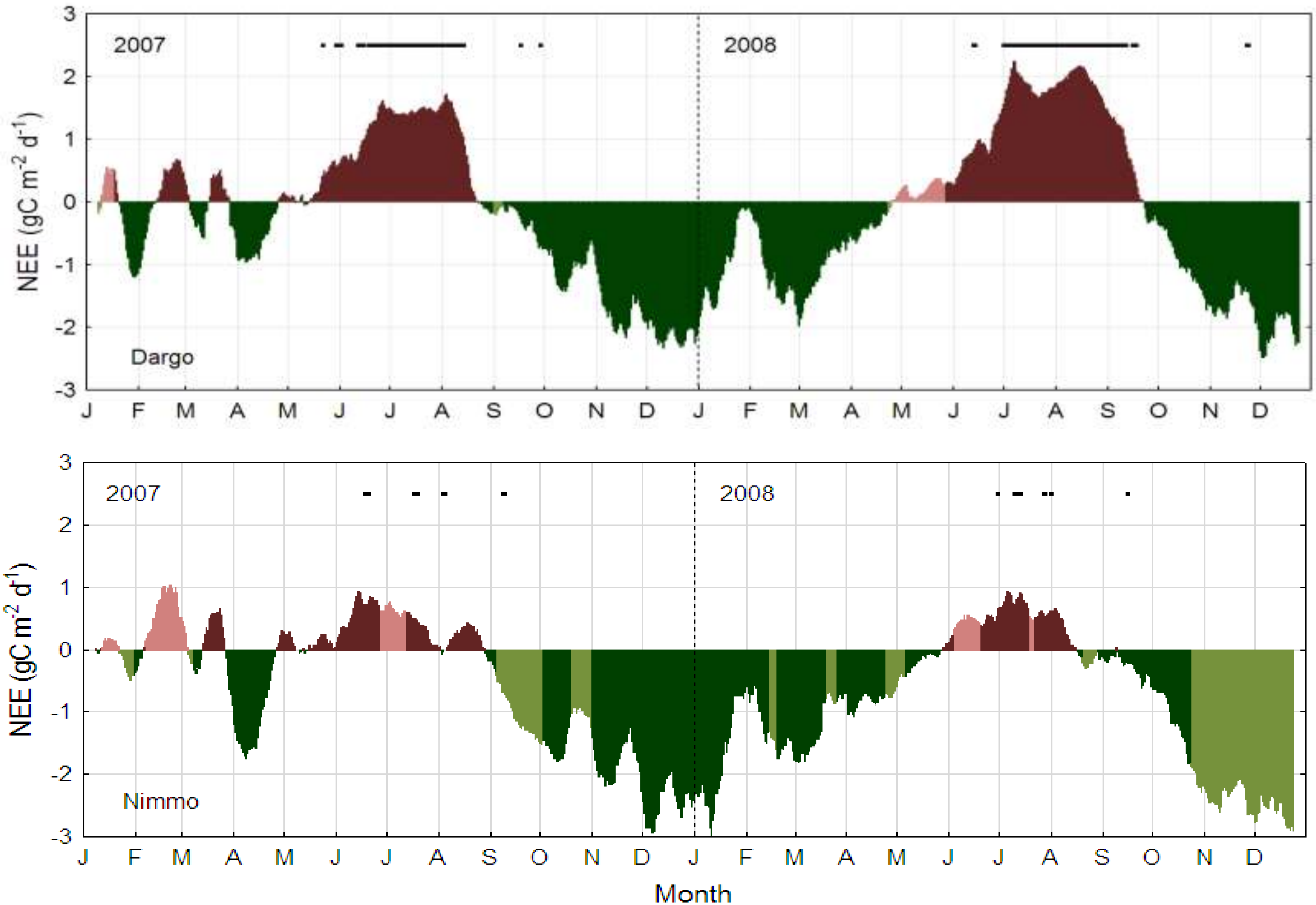
Dargo	Nimmo
19.12±0.39	13.34±0.35

Phytomass components ± SE (gC m^{-2})

	Dargo	Nimmo
AGP	441.8±52.1	231.5±36.4
BGP	317.3±35.1	207.7±19.6
Total	759.2±55.5	439.3±40.1



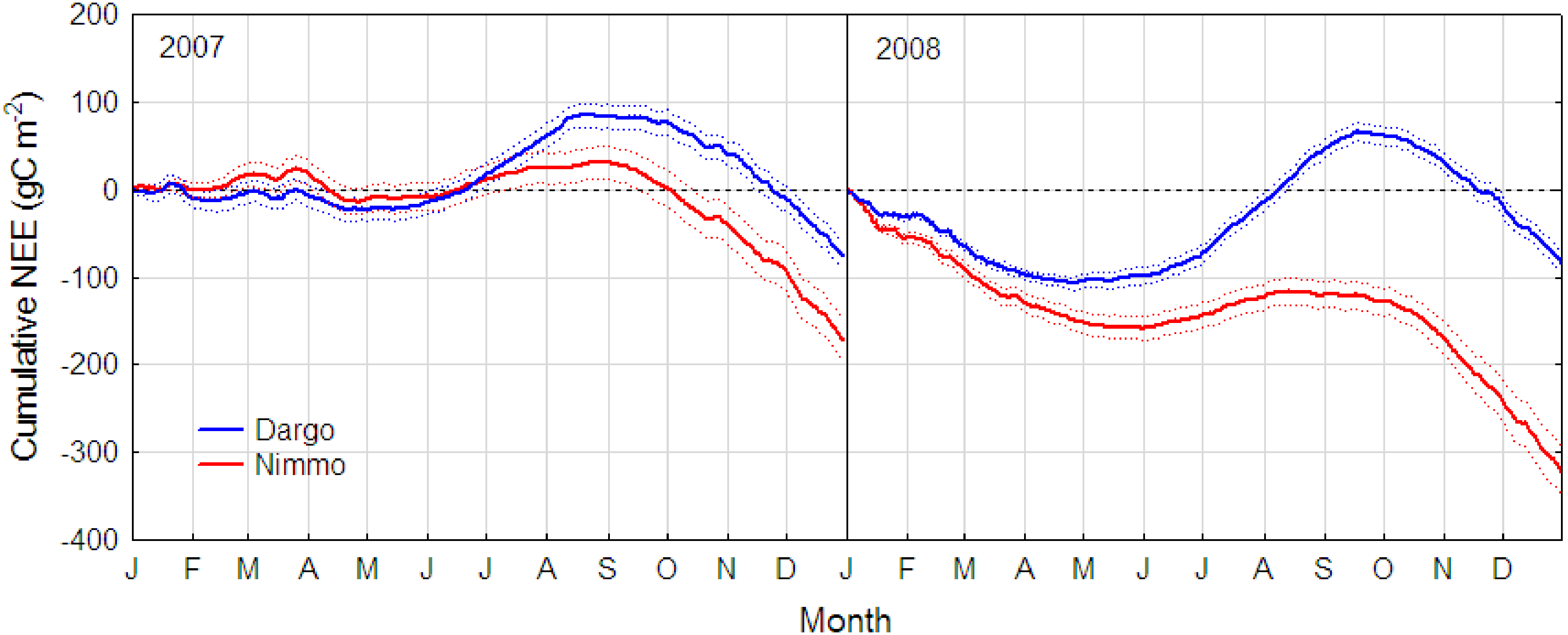
Net ecosystem exchange (NEE)



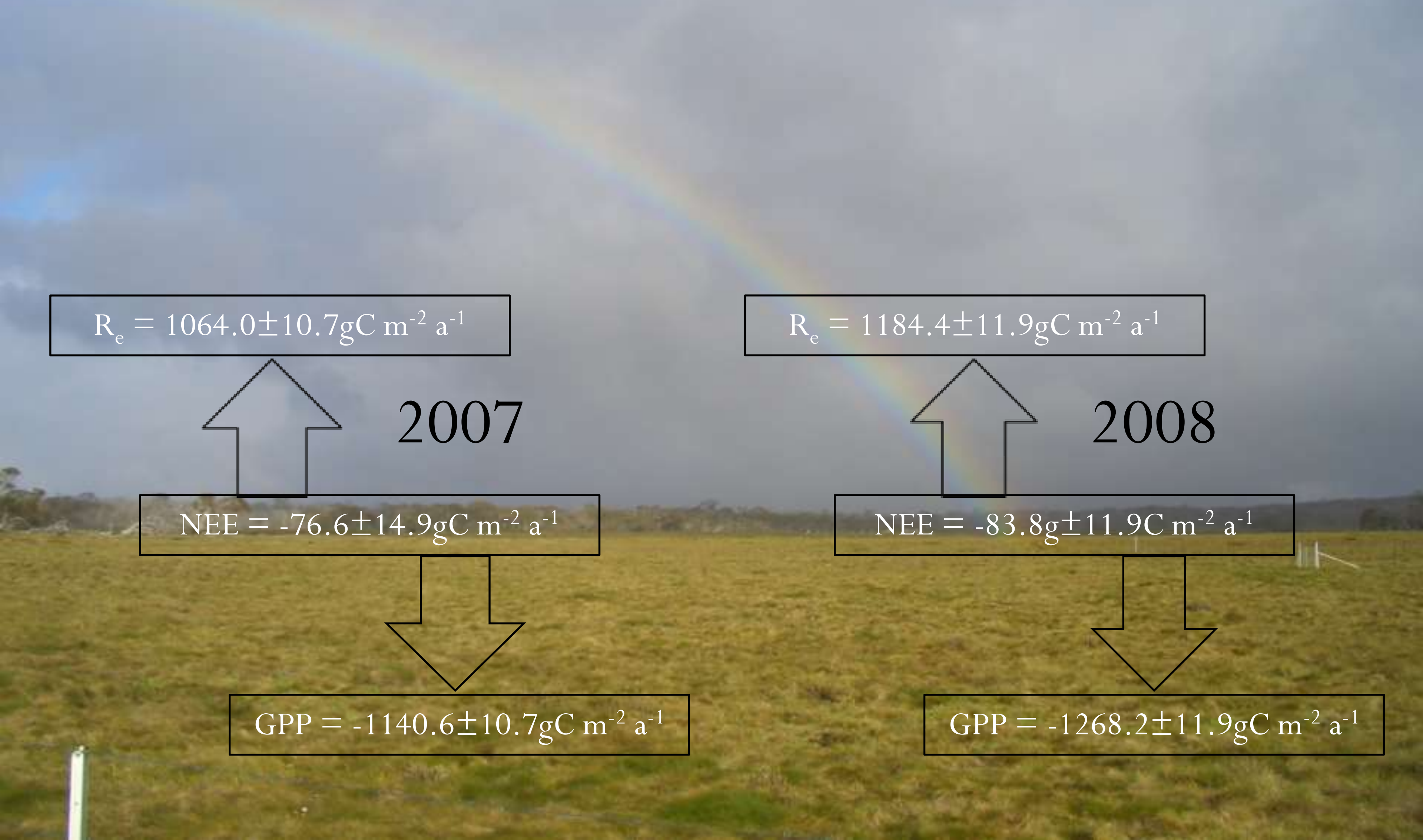
Annual NEE

NEE±95%CI (gC m^{-2})

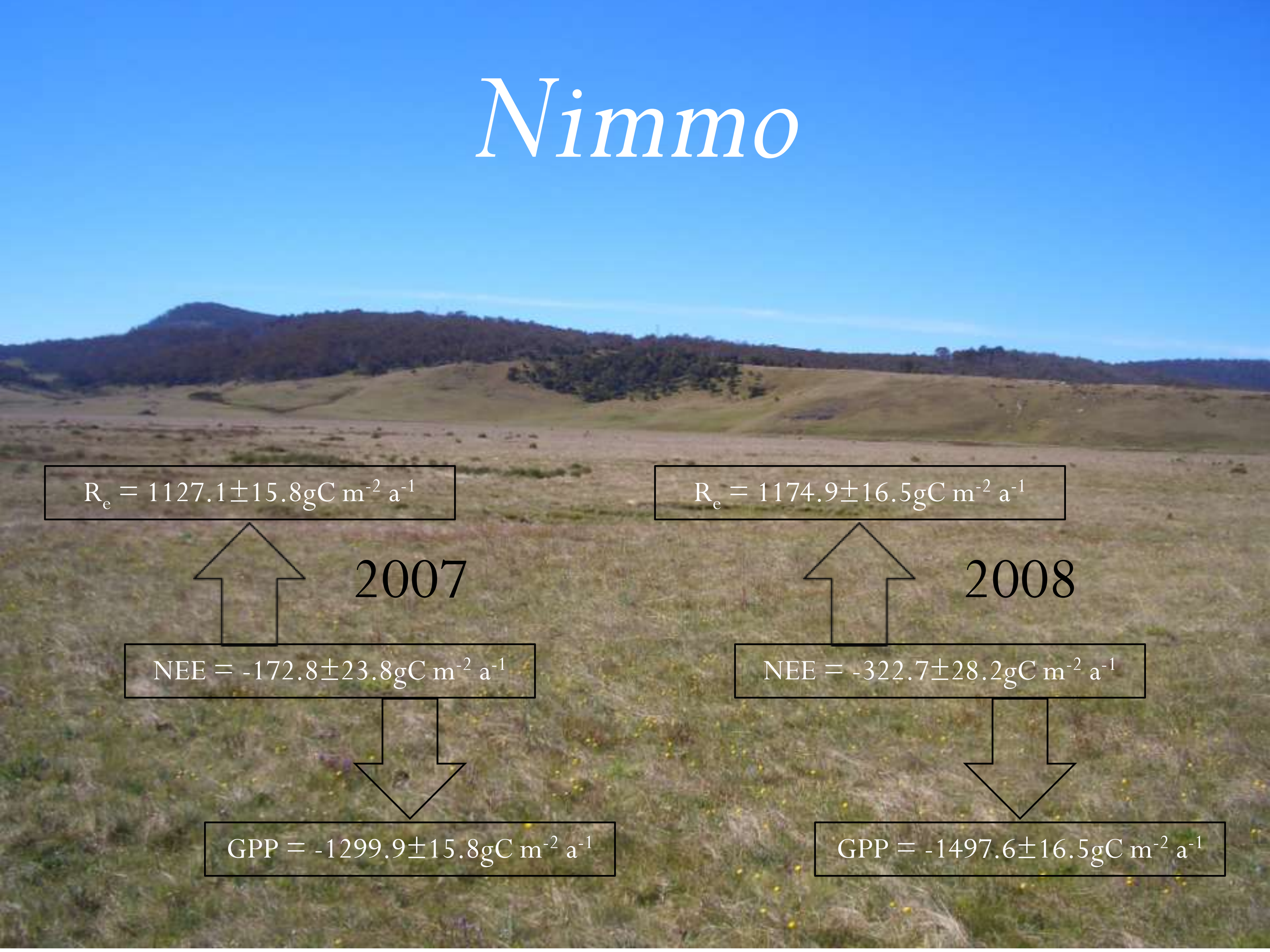
	Dargo	Nimmo
2007	-76.6±14.9	-172.8±23.8
2008	-83.8±11.9	-322.7±28.2



Dargo


2007
R_e = 1064.0±10.7gC m^{-2} a^{-1}
NEE = -76.6±14.9gC m^{-2} a^{-1}
GPP = -1140.6±10.7gC m^{-2} a^{-1}
2008
R_e = 1184.4±11.9gC m^{-2} a^{-1}
NEE = -83.8g±11.9C m^{-2} a^{-1}
GPP = -1268.2±11.9gC m^{-2} a^{-1}

Nimmo



2007

$R_e = 1127.1 \pm 15.8 gC\ m^{-2}\ a^{-1}$

$NEE = -172.8 \pm 23.8 gC\ m^{-2}\ a^{-1}$

$GPP = -1299.9 \pm 15.8 gC\ m^{-2}\ a^{-1}$

2008

$R_e = 1174.9 \pm 16.5 gC\ m^{-2}\ a^{-1}$

$NEE = -322.7 \pm 28.2 gC\ m^{-2}\ a^{-1}$

$GPP = -1497.6 \pm 16.5 gC\ m^{-2}\ a^{-1}$

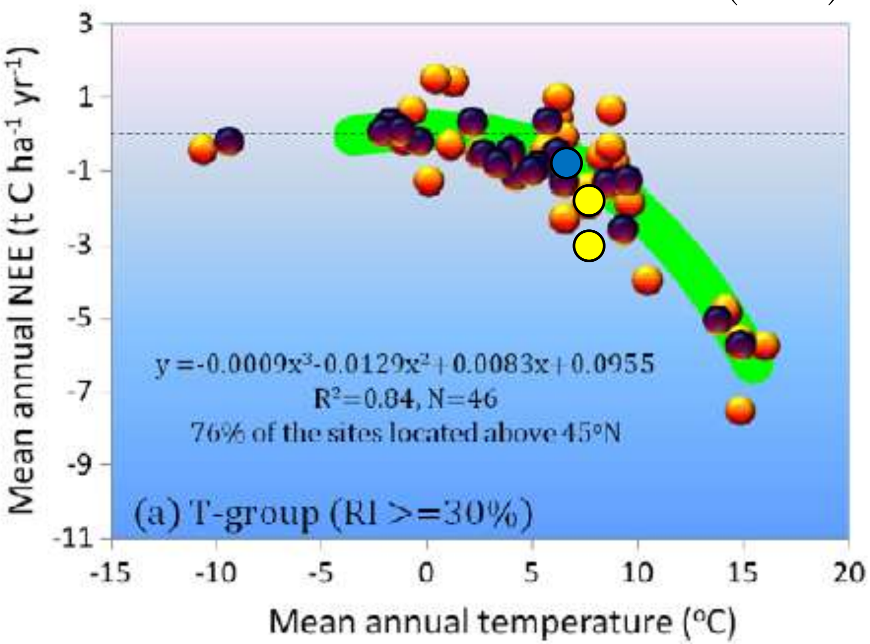
Global context

Ecosystem	Annual NEE (gC m^{-2})
Grasslands	+400 to -800
Alpine grasslands	+112 to -282

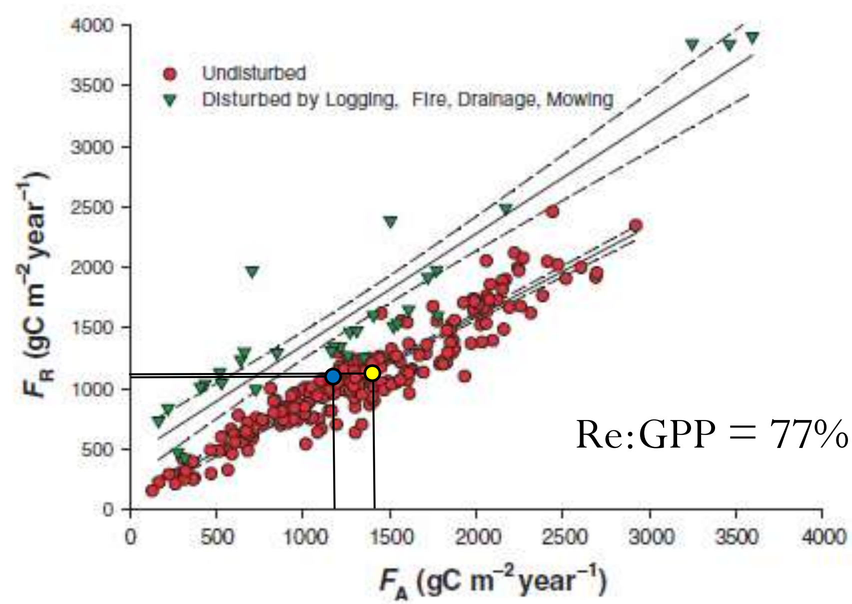
Re:GPP (%)

	Dargo	Nimmo
2007	91.5 ≤ 93.3 ≤ 95.1 (85.0)	84.5 ≤ 86.7 ≤ 89.0
2008	91.7 ≤ 93.4 ≤ 95.1 (82.3)	76.5 ≤ 78.5 ≤ 80.4

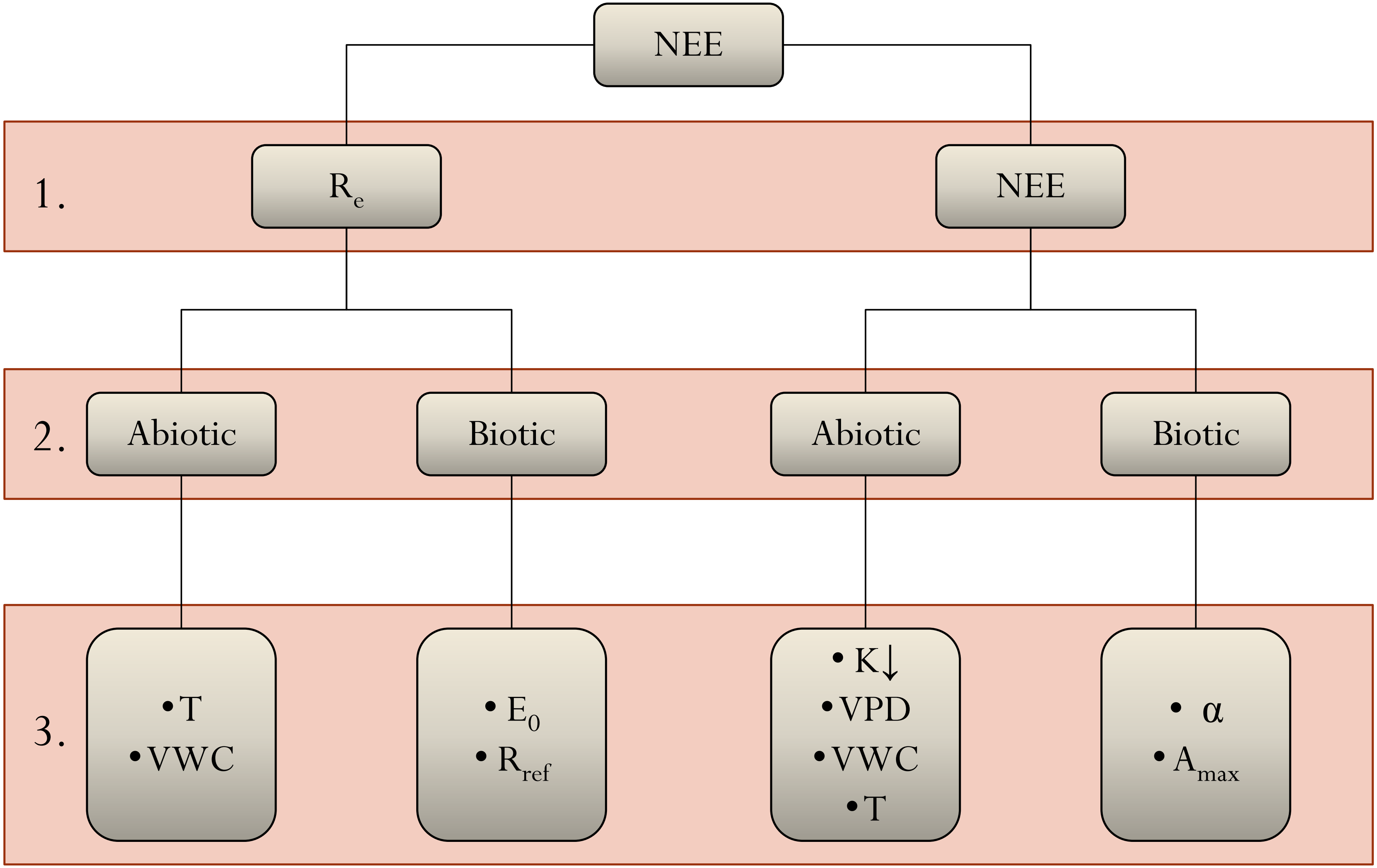
Yi *et al.* (2011)



Baldocchi (2008)

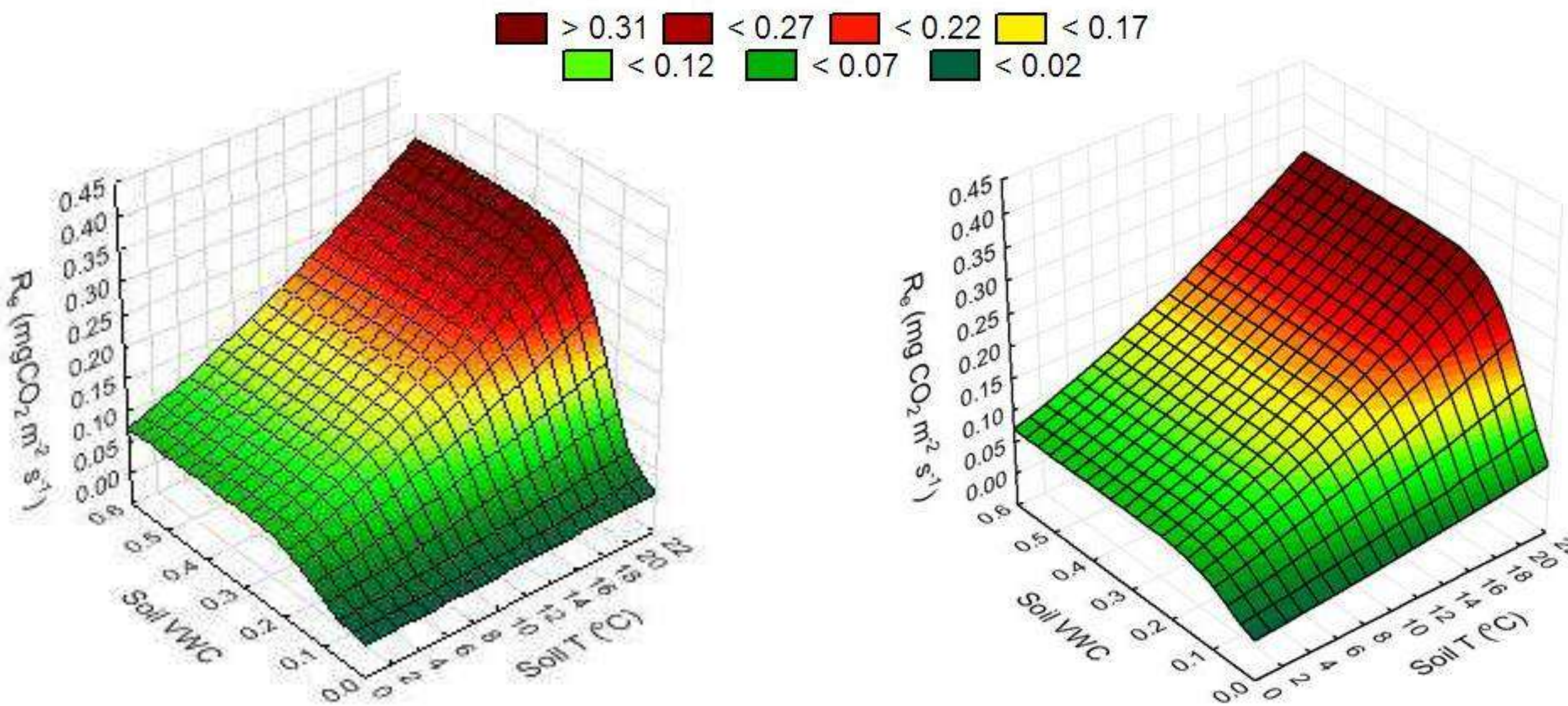


Causes of NEE differences…

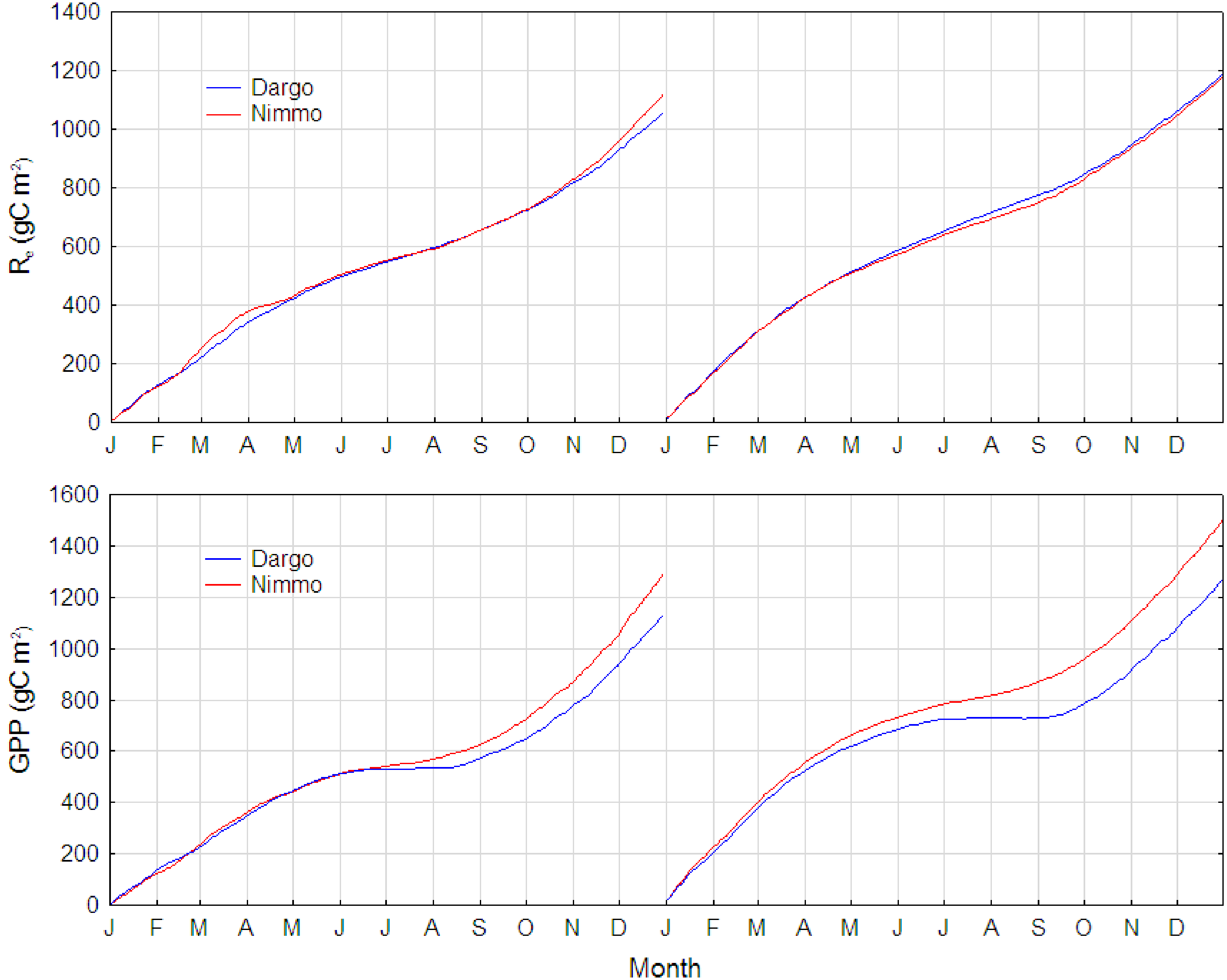


R_e response

	E_0	R_{ref}	θ_1	θ_2
Dargo	0.1581	221.01	1.595	17.94
Nimmo	0.1435	237.6	1.178	18.55



R_e and GPP



Dargo
Nimmo
R_e (gC m^{-2})
0
200
400
600
800
1000
1200
1400
J F M A M J J A S O N D J F M A M J J A S O N D
Dargo
Nimmo
GPP (gC m^{-2})
0
200
400
600
800
1000
1200
1400
1600
J F M A M J J A S O N D J F M A M J J A S O N D
Month

Summing up…

- Intersite NEE differences (Dargo<Nimmo)
  - R_e (Dargo ≈ Nimmo)
  - GPP (Dargo < Nimmo)
    - Abiotic factors (dominant)
      - 1) Snow season length (K↓); 2) air temperature
    - Biotic factors (secondary)
      - $A_{opt,Dargo} < A_{opt,Nimmo}$; $\alpha_{Dargo} \approx \alpha_{Nimmo}$
- Interannual NEE differences (2008>2007)
  - Re (2008>2007)
    - Abiotic factors (dominant)
      - 1) Soil moisture; 2) soil temperature
    - Biotic factors (secondary)
      - $R_{ref,2008} > R_{ref,2007}$; $E_{0,2008} \approx E_{0,2007}$
  - GPP (2008>2007)
    - Abiotic factors (dominant)
      - Soil moisture (Nimmo); Snow season length (K↓) and soil moisture (Dargo)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