The role of flux tower observations in water, carbon and climate information

Eva van Gorsel

OCEANS AND ATMOSPHERE FLAGSHIP
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TERN Terrestrial Ecosystem Research Network
NCRIS National Research Infrastructure for Australia
An Australian Government Initiative
CSIRO

Globally terrestrial ecosystems annually sequester about one quarter of anthropogenic emissions of CO_2.

- They provide an ecosystem service worth millions of dollars.

Carbon, water and energy cycles are linked

Globally terrestrial ecosystems annually sequester about one quarter of anthropogenic emissions of CO_2.

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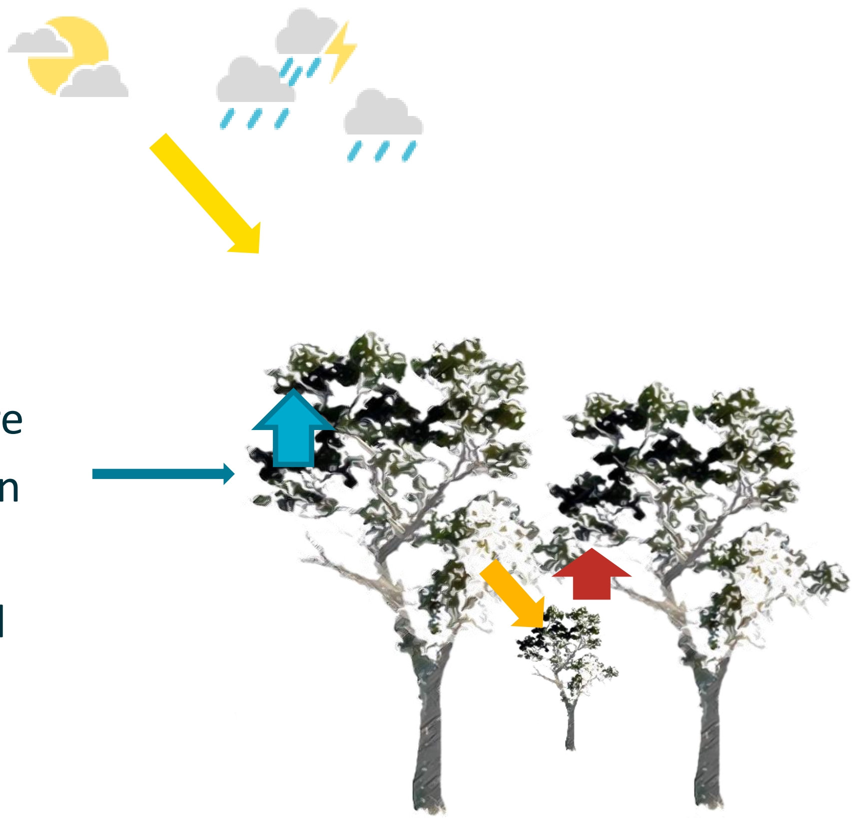
To understand the interaction between these coupled cycles we need information on

1) how climate exerts controls over vegetation
2) how plants respond to the environment.

Carbon, water and energy cycles are linked

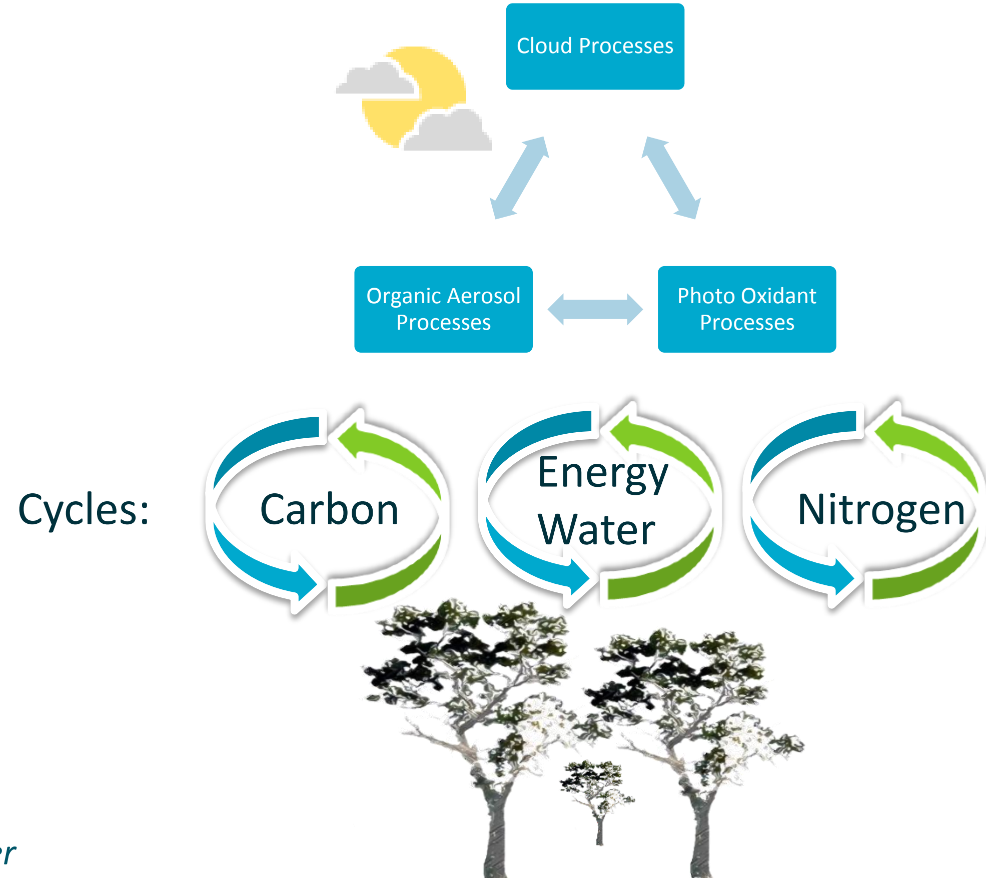
climate controls over vegetation

- Radiation
- Temperature
- Precipitation
- VPD
- Wind speed



Carbon, water and energy cycles are linked

plant responses to the environment



- Transpiration
- Photosyntesis
- Energy Balance

after A. Guenther

carbon water and energy cycles are linked

Globally terrestrial ecosystems annually sequester about one quarter of anthropogenic emissions of CO2.

- They provide an ecosystem service worth millions of dollars.

In sequestering carbon they also use water. Water use by vegetation (through evapotranspiration) is the biggest loss term in the terrestrial water budget.

- Through land management, evapotranspiration is one of the terms in the water budget that we can manage.

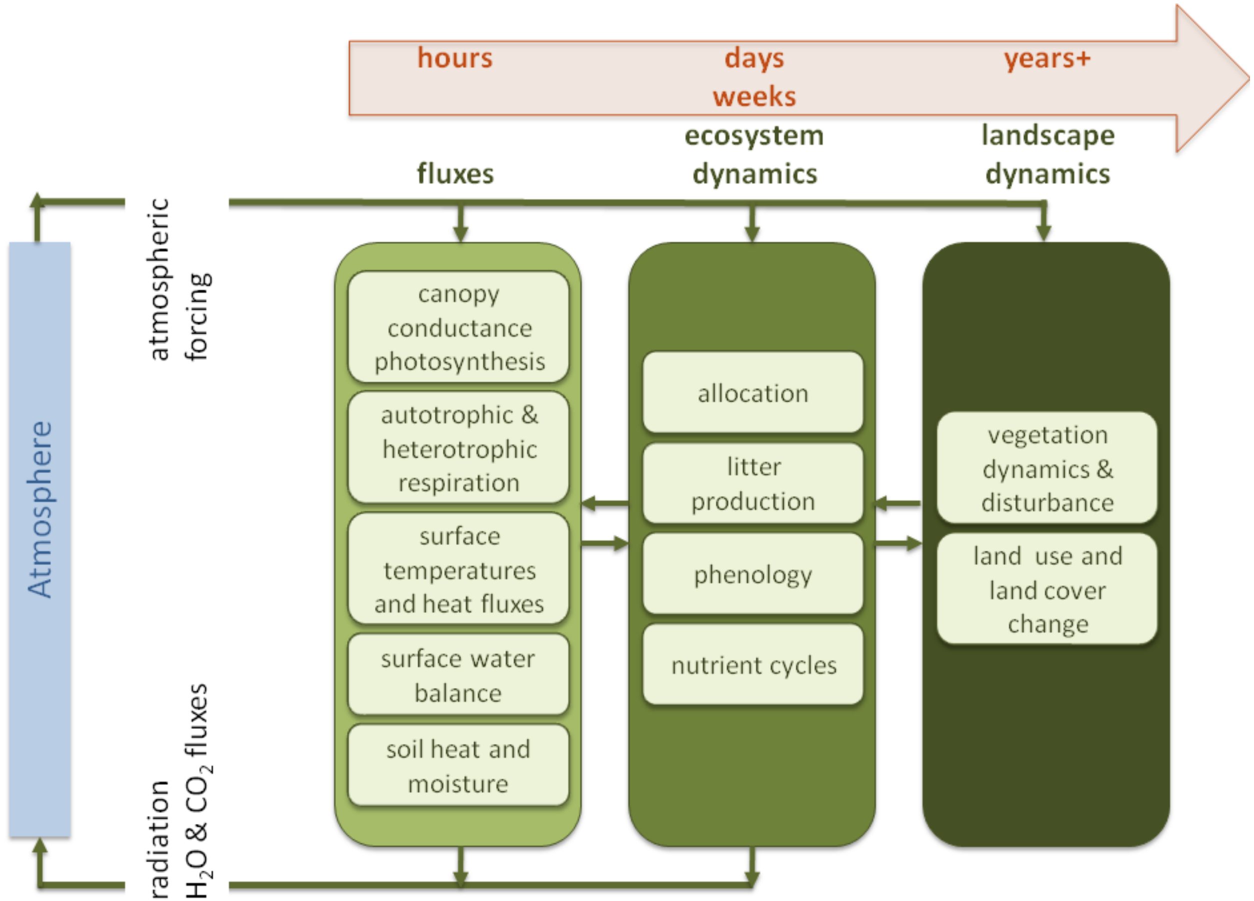
Terrestrial landscapes also affect the local and regional climate through changing the surface properties of reflectance and roughness.

- Quantification of the exchanges of carbon, water and energy in space and time provides critical information required to underpin the sound management of Australia’s landscapes to maintain key ecosystem services.

carbon water and energy cycles are linked

Despite its great importance to understand and manage the impact of land use on carbon sequestration and water availability, such knowledge has not been readily available for many of Australia's unique ecosystems.

time scales involved in the exchanges of water and carbon between plants and atmosphere

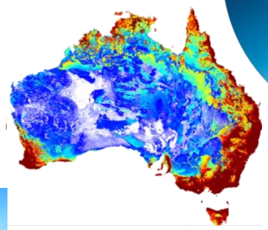


after M.Williams et al., www biogesciences.net/t/1341/2009/

spatial scales involved...

Globe: 10'000 km

Continent: 1000 km



Landscape: 1-100 km

Canopy: 100-1000 m

Plant: 1-100 m

Leaf: 0.01-0.1 m

Stomata: 10^{-5} m

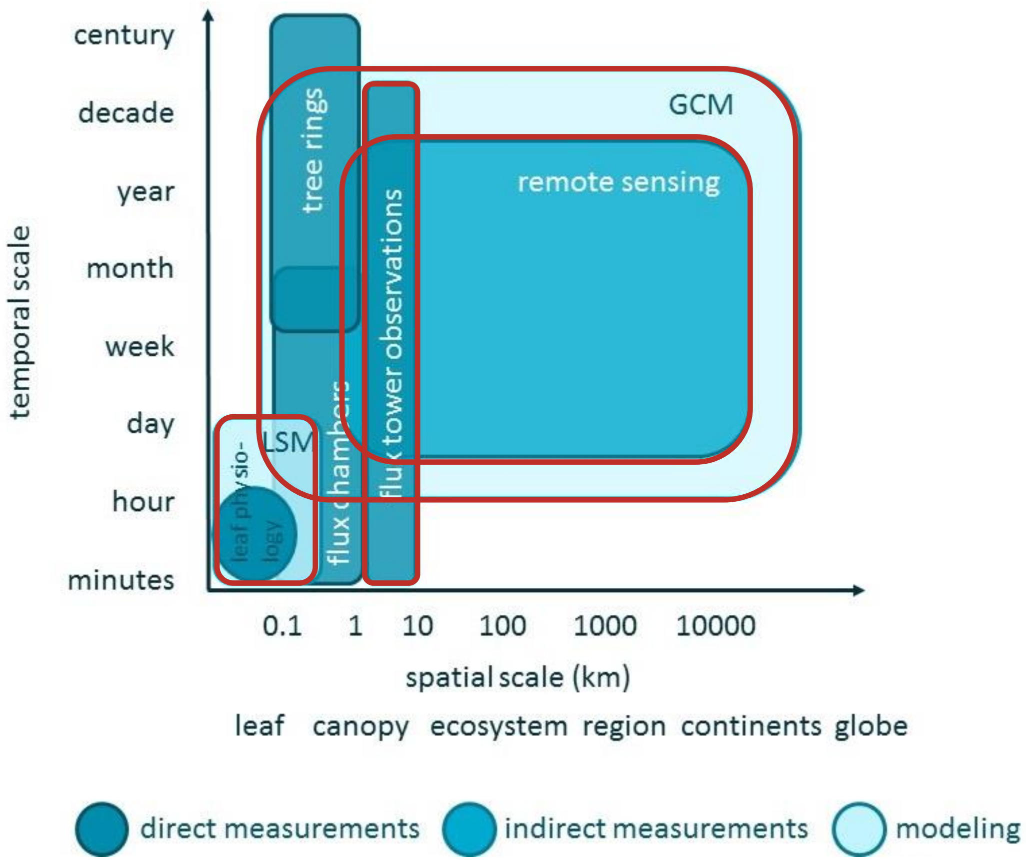
Chloroplast: 10^{-6} m

... span about 14 orders of magnitude

after D. Baldocchi, 5th annual flux course, 'Biosphere Breathing'

CSIRO

time and length scales covered by plant atmosphere interactions



after P. Isaac

Tower observations provide information on ecosystem processes for the exchanges of energy, water and carbon on all relevant time scales.

Remote sensing observations are rich in spatial information content and can be used to 'scale up' from local to larger scales.

Scaling up through modelling allows quantification through space and time and physical understanding.

Today, a new scientific revolution is emerging [...] where groups of scientists are producing global scale information on carbon and water fluxes. They are doing so by merging of information from networks of flux towers, biophysical models, ecological databases and satellite-based remote sensing to produce a new generation of flux maps.

Dennis Baldocchi, UC Berkeley

Modelling approaches

Biophysical models

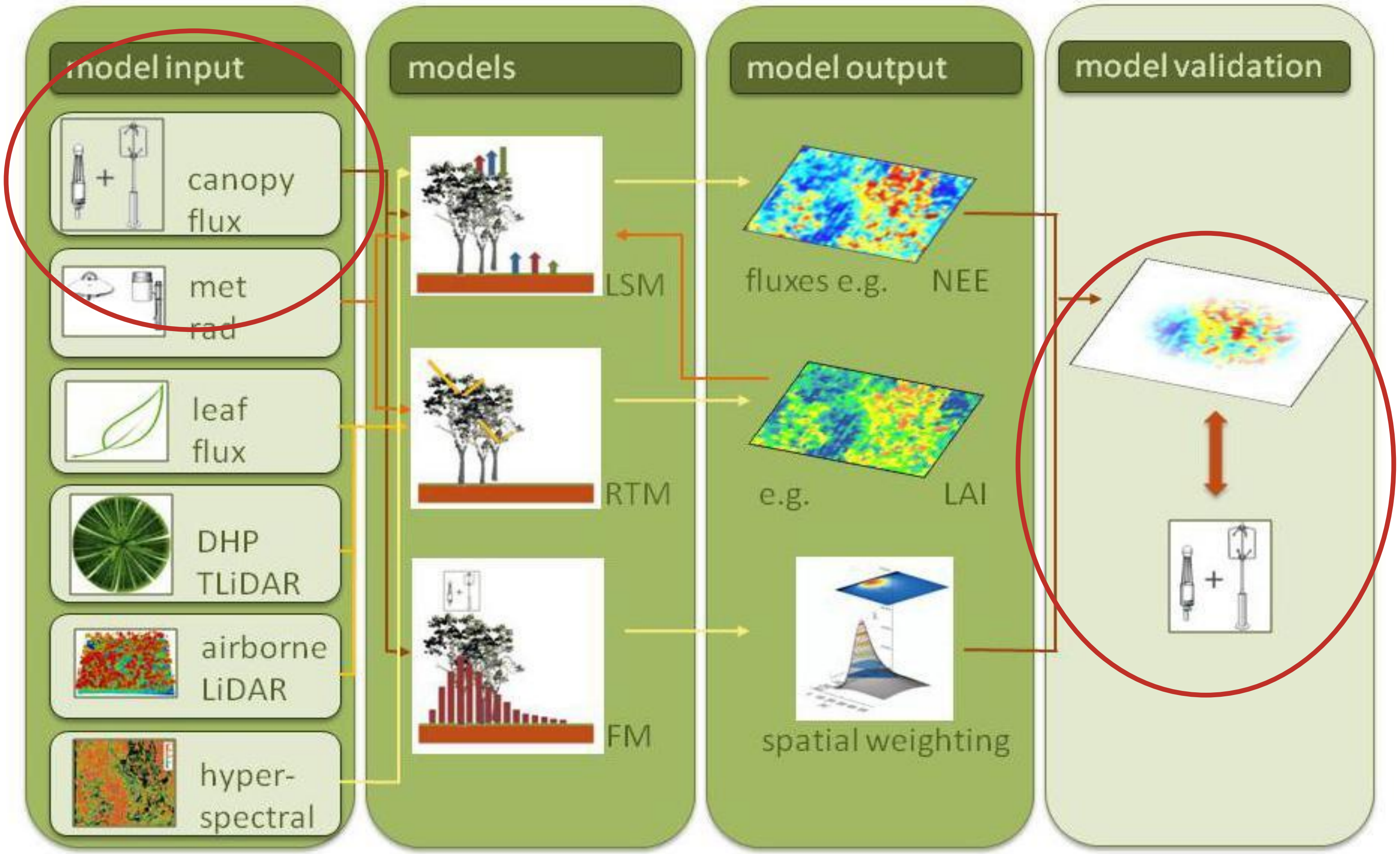
- process related information
- prognistic

Data mining and machine learning

- some process related information
- ability to accurately upscale when underlying processes change (no a priori knowledge required)

Integrated Biophysical Modelling

schematic data-model integration



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Biogeosciences Open Access

Multiple observation types reduce uncertainty in Australia's terrestrial carbon and water cycles

V. Haverd[1], M. R. Raupach[1], P. R. Briggs[1], J. G. Canadell[1], P. Isaac[1], C. Pickett-Heaps[1], S. H. Roxburgh[2], E. van Gorsel[1], R. A. Viscarra Rossel[3], and Z. Wang[1,4]

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doi:10.5194/bg-10-851-2013

Biogeosciences Open Access

The Australian terrestrial carbon budget

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Modelling Framework BIOS2

CABLE = Community Atmosphere-Biosphere-Land Exchange model

Water, energy, carbon fluxes

Wang et al. (2011)

SLI = Soil-Litter-Iso

Soil hydrology, soil evaporation

Haverd et al. (2010)

CASAcnp = Biogeochemical model

Soil and plant C, N, P dynamics

Wang et al. (2010)

AWAP = Australian Water Availability Project

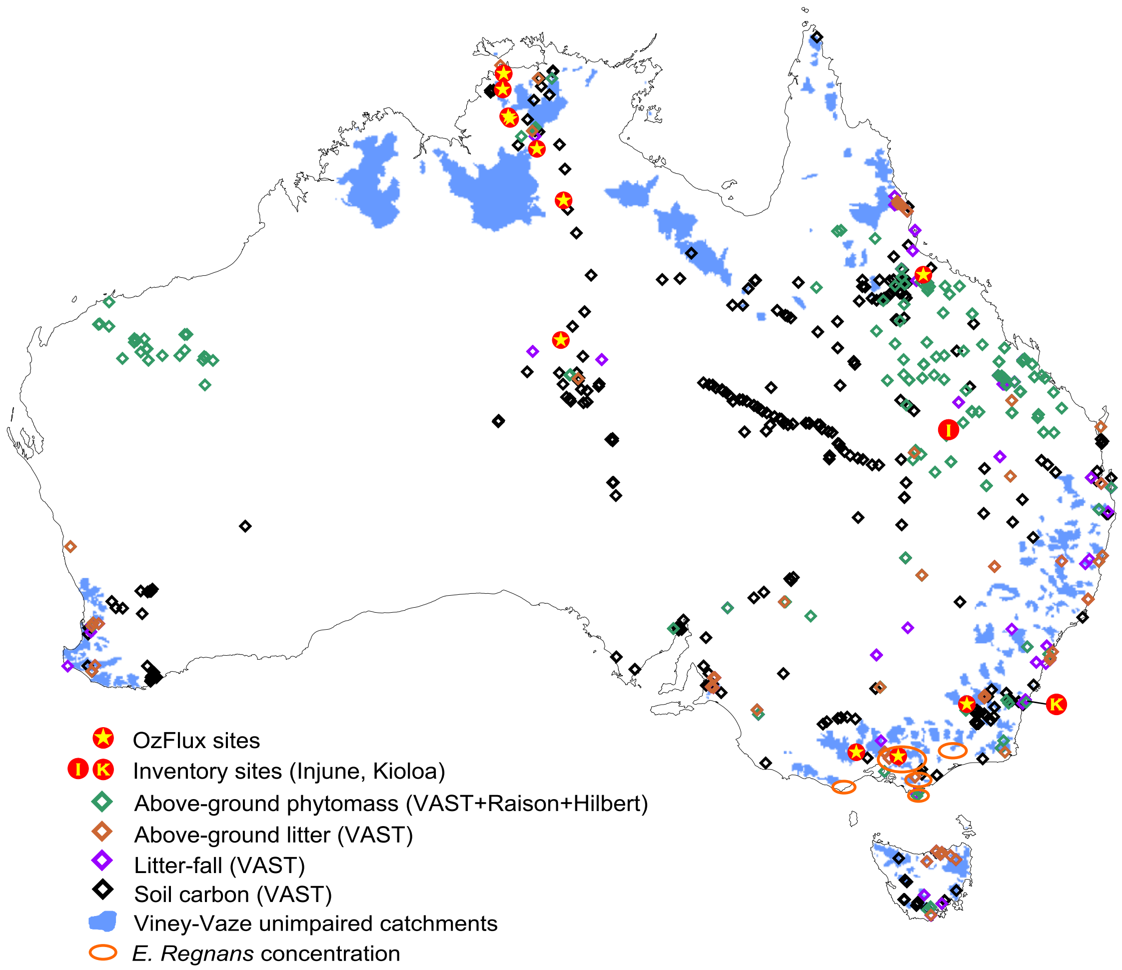
Continental processing framework

Met and soil data

Model-Data Fusion

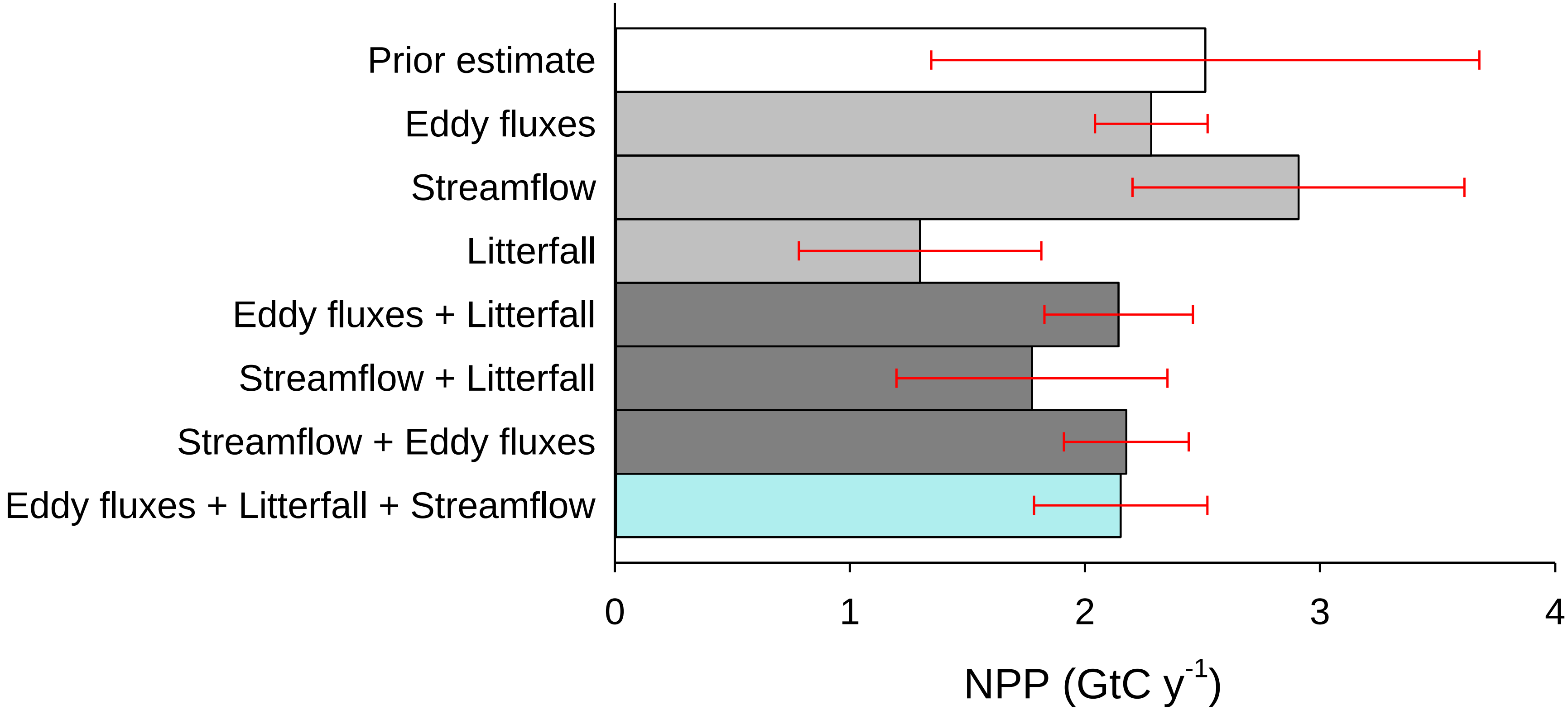
Raupach et al. (2009)

Observations for BIOS2 constraints and evaluation

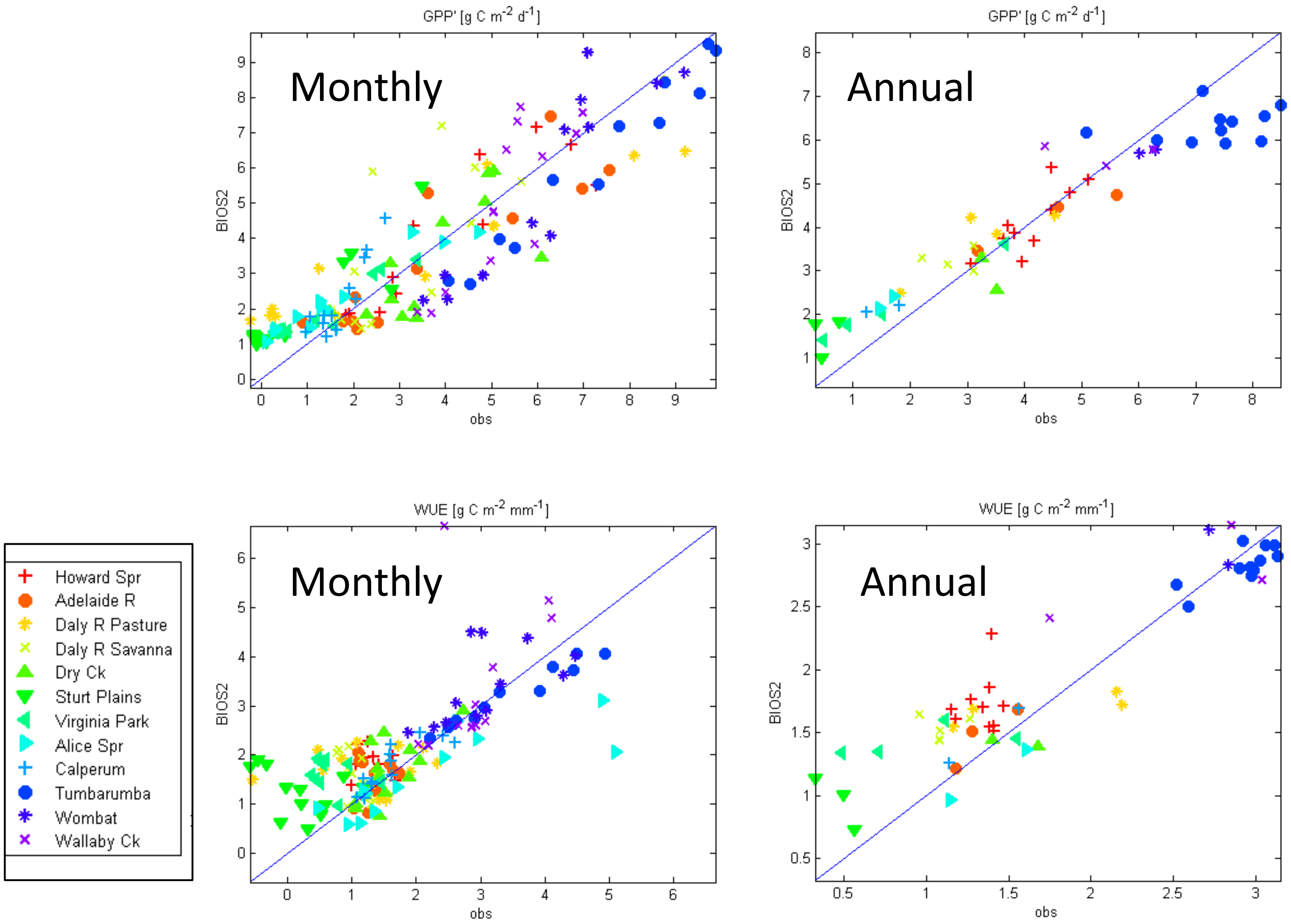


Multiple constraints on Australian terrestrial Net Primary Production : Tower observations (Eddy flux data) provide the tightest constraint

error bars = uncertainty from propagated parameter uncertatinties (1σ)



Verification - comparing OzFlux measured ET, GPP and BIOS2 simulations



Statistical Modelling
data mining and machine learning

Data driven estimate of global land ET

compiled using the observations from the global flux network, meteorological and remote sensing observations, and a machine-learning algorithm.

LETTER

doi:10.1038/nature09396

Recent decline in the global land evapotranspiration trend due to limited moisture supply

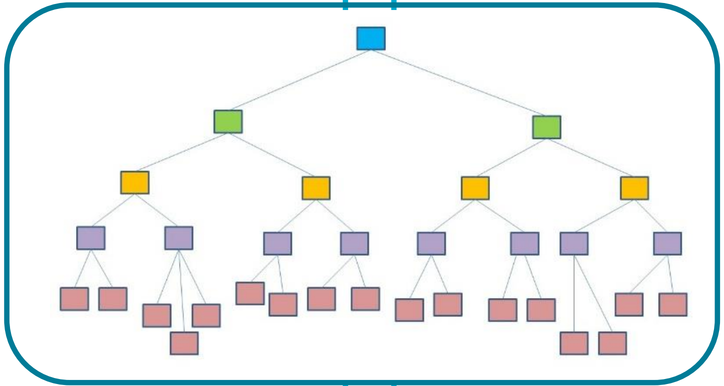
Martin Jung[1], Markus Reichstein[1], Philippe Ciais[2], Sonia I. Seneviratne[3], Justin Sheffield[4], Michael L. Goulden[5], Gordon Bonan[6], Alessandro Cescatti[7], Jiquan Chen[8], Richard de Jeu[9], A. Johannes Dolman[9], Werner Eugster[10], Dieter Gerten[11], Damiano Gianelle[12], Nadine Gobron[13], Jens Heinke[11], John Kimball[14], Beverly E. Law[15], Leonardo Montagnani[16], Qiaozhen Mu[17], Brigitte Mueller[3], Keith Oleson[6], Dario Papale[18], Andrew D. Richardson[19], Olivier Roupsard[20], Steve Running[17], Enrico Tomelleri[1], Nicolas Viovy[2], Ulrich Weber[1], Christopher Williams[21], Eric Wood[4], Sönke Zaehle[1] & Ke Zhang[14]

Data mining and machine learning

Training

Site level explanatory variables
- Meteorology
- Vegetation type
- Remote sensing indices

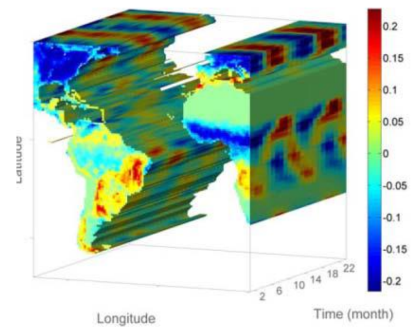
Target variable
- flux of carbon, energy, water



Prediction

Explanatory variables
- Gridded meteorology
- Gridded vegetation type
- Gridded remote sensing indices

➢ gridded target variable



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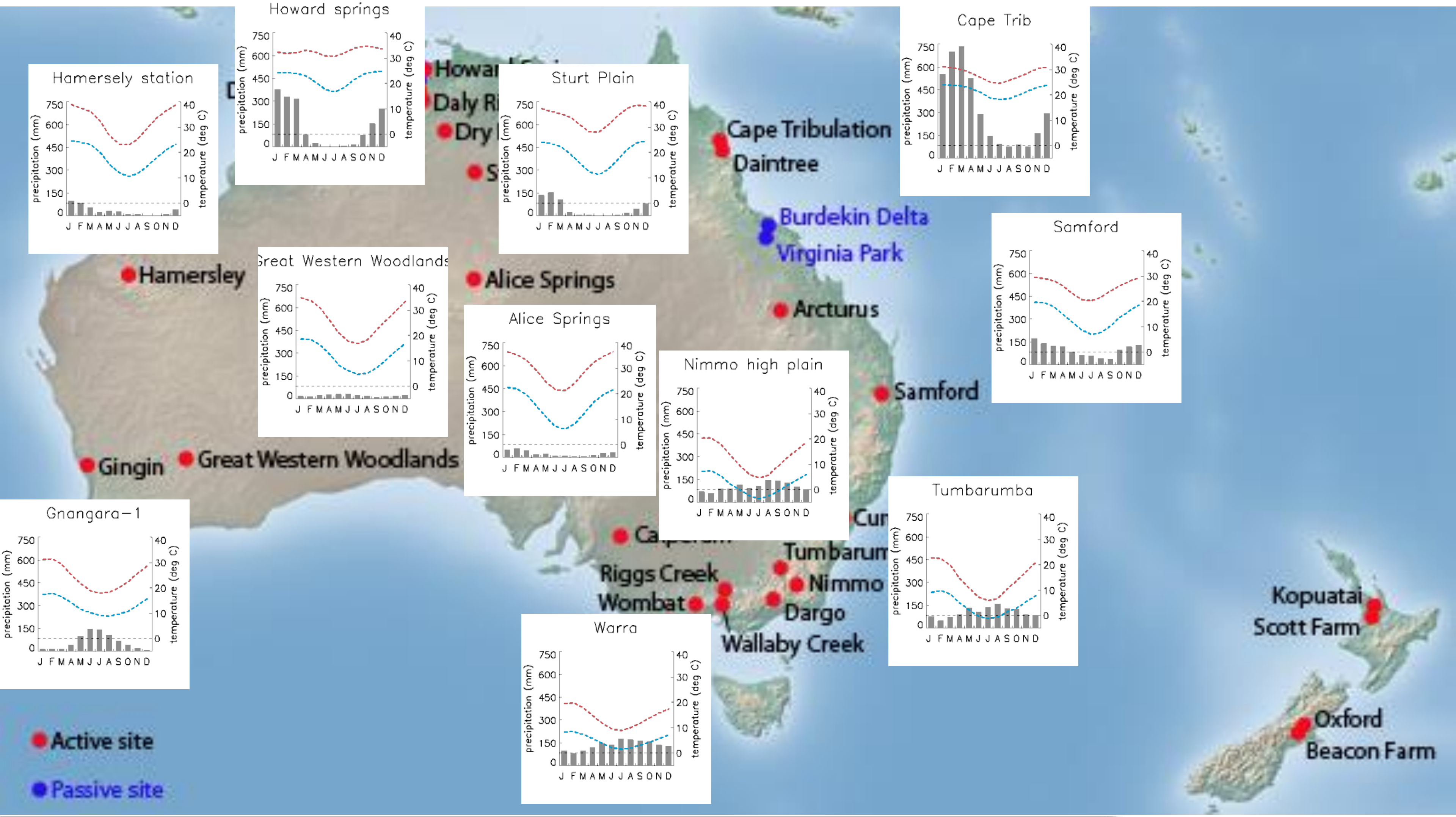
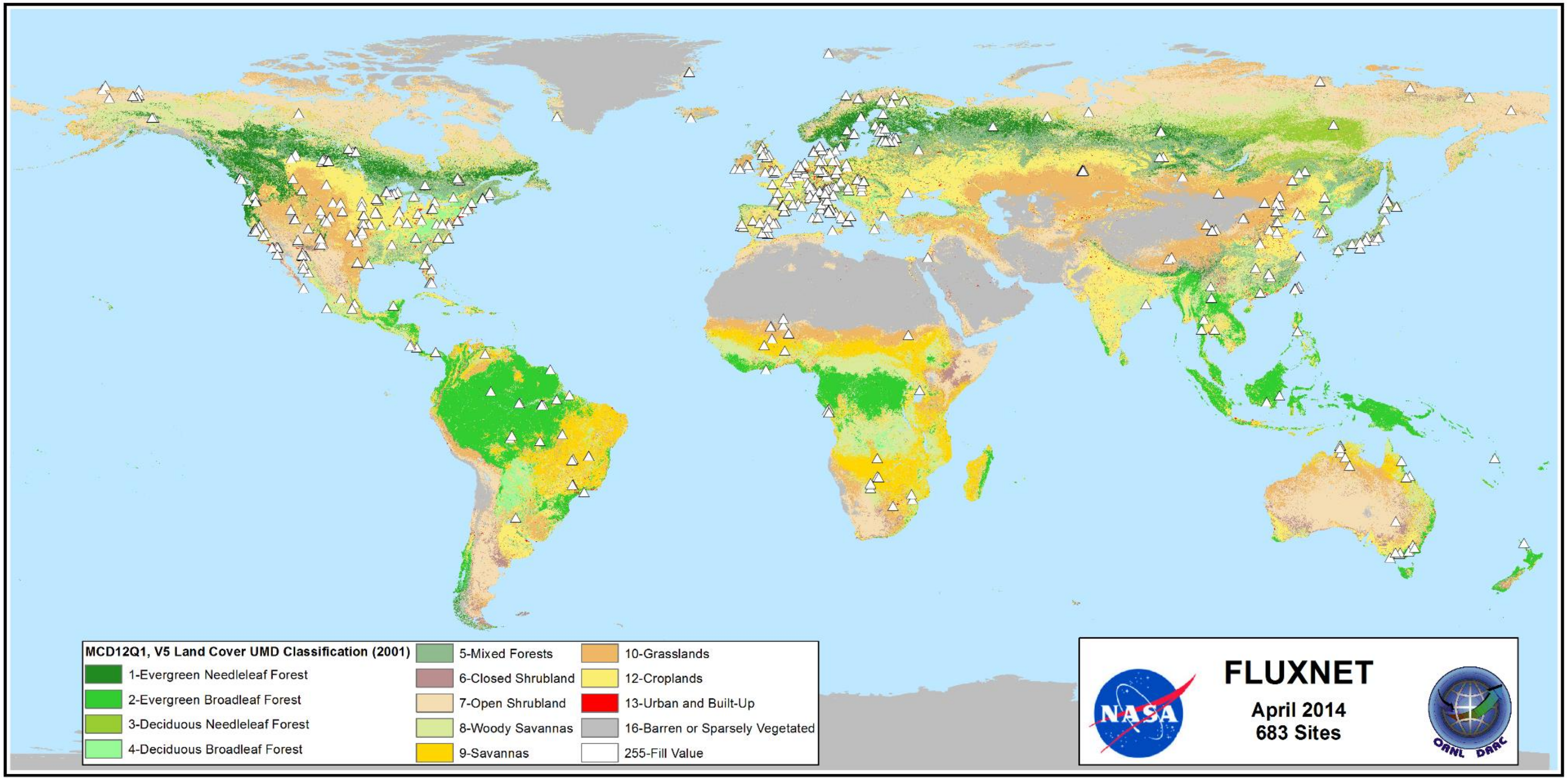
OzFlux

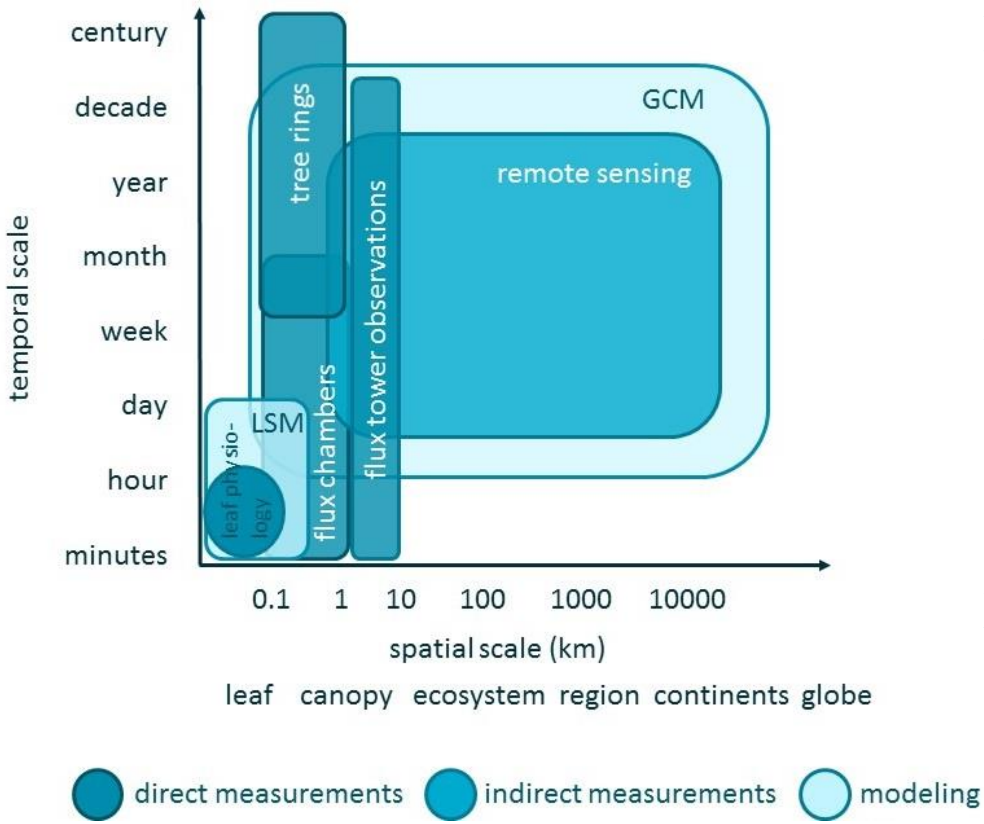


Howard springs
Hamersely station
Sturt Plain
Cape Trib
Samford
Great Western Woodlands
Alice Springs
Nimmo high plain
Tumbarumba
Gnangara−1
Warra
precipitation (mm)
temperature (deg C)
J F M A M J J A S O N D
750
600
450
300
150
0
40
30
20
10
0
Cape Tribulation
Daintree
Burdekin Delta
Virginia Park
Hamersley
Alice Springs
Arcturus
Samford
Gingin
Great Western Woodlands
Riggs Creek
Wombat
Nimmo
Dargo
Wallaby Creek
Kopuatai
Scott Farm
Oxford
Beacon Farm
Active site
Passive site

Network density



Conclusions



- flux tower observations of water, energy and carbon are critical for (cons)training models and to verify model output
- remote sensing data provide gridded spatial and temporal information that makes them ideal for upscaling
- models without observations are not constrained and their output can not be verified

Conclusions

- We need an integrated observation – modelling approach
- Satellite data can provide very useful information for upscaling but can not replace ground networks
- Ground networks in decline are bad news
- Sparse ground networks in decline are particularly bad news and are something that we can't afford if we want spatio-temporally resolved information on water, energy and carbon exchanges between the land and the atmosphere.

Thank you

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