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Inescapable variation

Effects of a non-homogeneous flux tower footprint on seasonal carbon fluxes in a temperate forest

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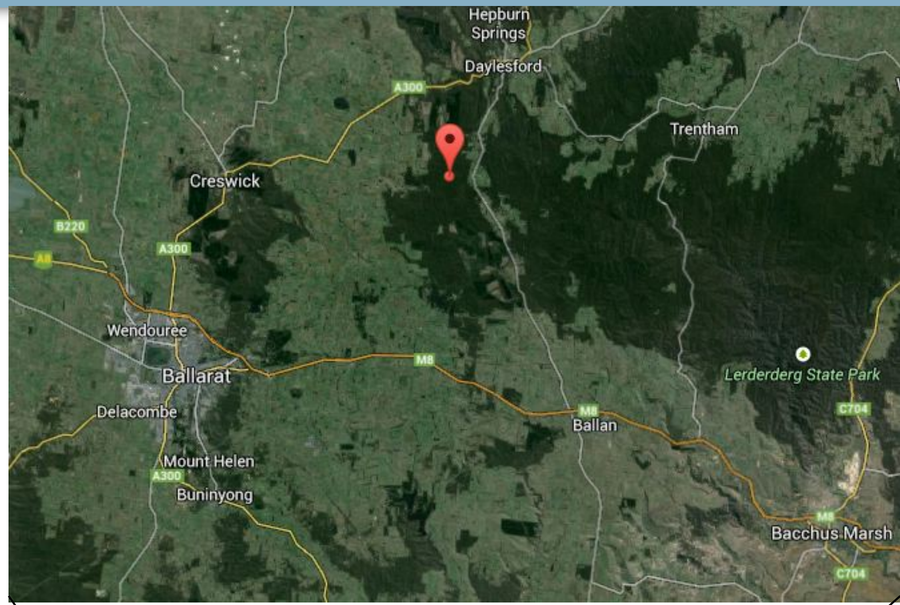
Study site location

Fig. 1: Forest distribution in Australia.
(Australia's State of the Forest Report, 2008)



Site characteristics

- Evergreen eucalypt forest
- Mixed species (*Eucalyptus rubida, E. obliqua, E. radiata*)
- History of selective harvesting, burns etc.
- Variable tree heights (South: 15 m North: 25 m)
- Patchy understorey, mainly grasses and ferns
- Flux tower instrumentation at 30 m

Observation – large variability in NEE

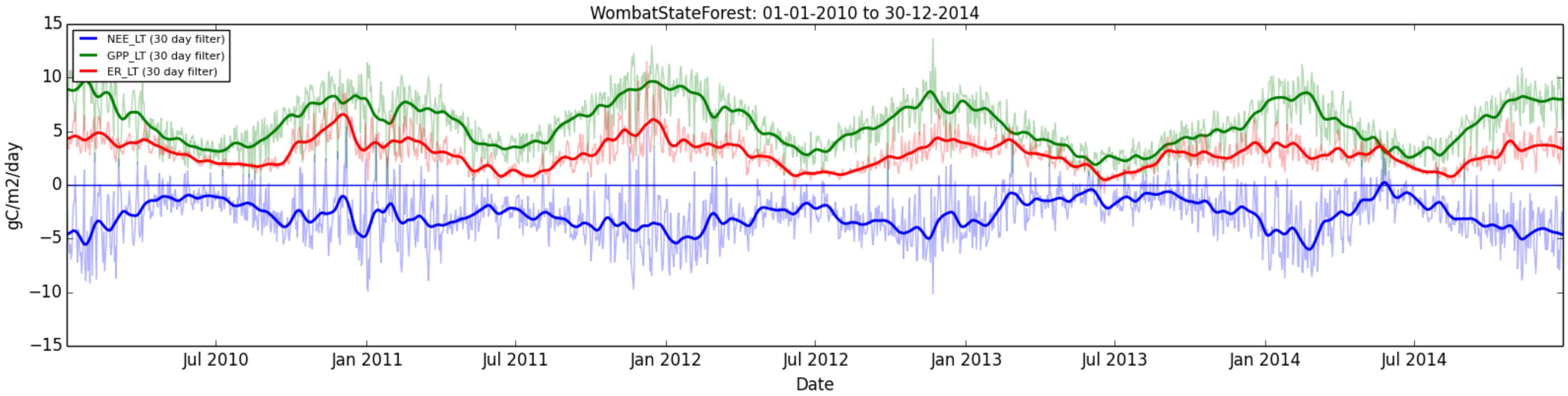


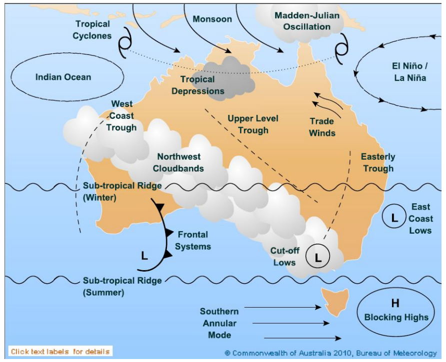
Fig. 2. Daily NEE, GPP and Respiration from 2010 to 2014.

<u>Ecosystem dynamics:</u>

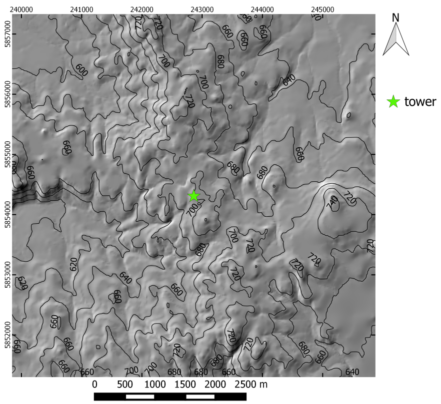
- Forest is a carbon sink in all seasons
- Large seasonal variation of NEE
- Important for annual NEE sums, also for respiration and GPP

What can cause such interannual variations in NEE?

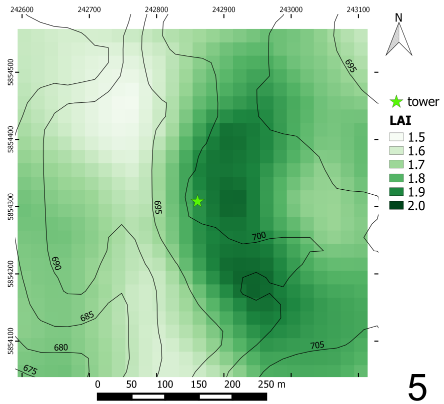
climatic drivers?



Terrain?



surface characteristics?



Terrain overview

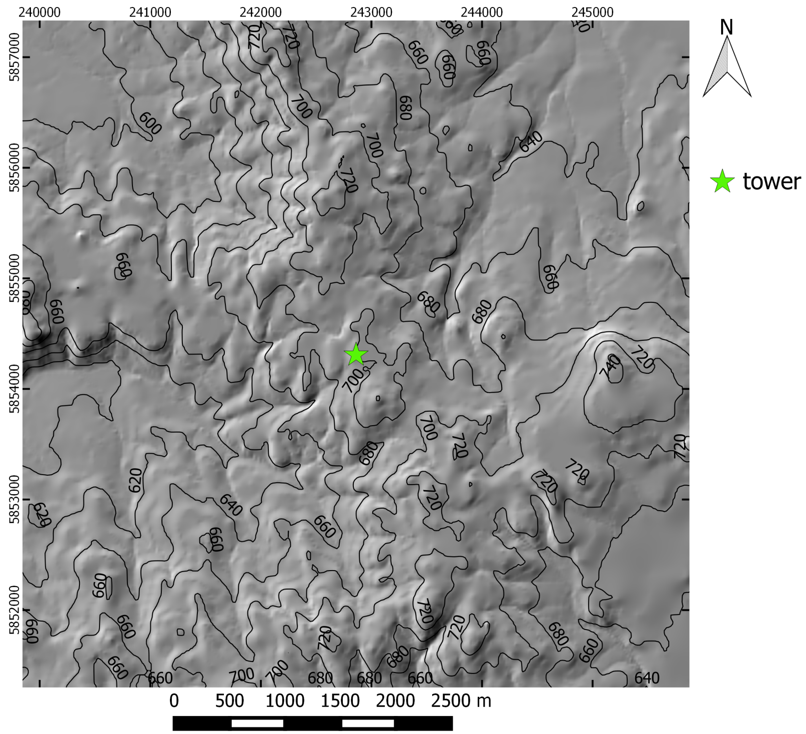


Fig. 3. Terrain overview around flux tower.

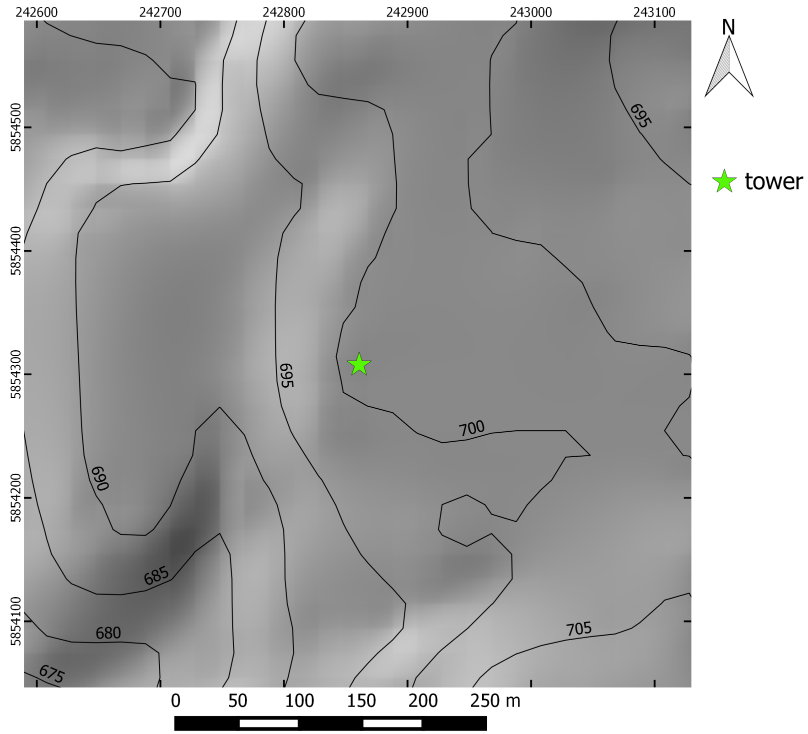


Fig. 4. Terrain close-up within core extension of flux tower footprint.

- Ridge oriented N-S
- Descending NW-SE and NE-SW
- Wind channelled along the orientation of slopes (typically NW/SE)

- Slopes are moderate
- Gullies towards NW, SW and S
- Flat terrain E of tower

Vegetation and wetness within footprint

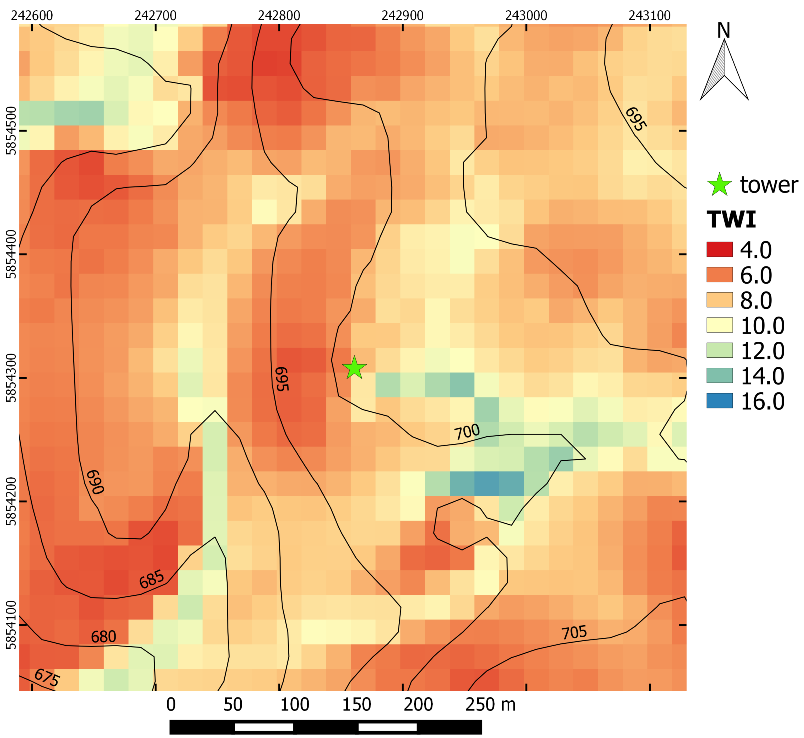


Fig. 5. Topographic wetness index (TWI) variation within flux tower footprint.

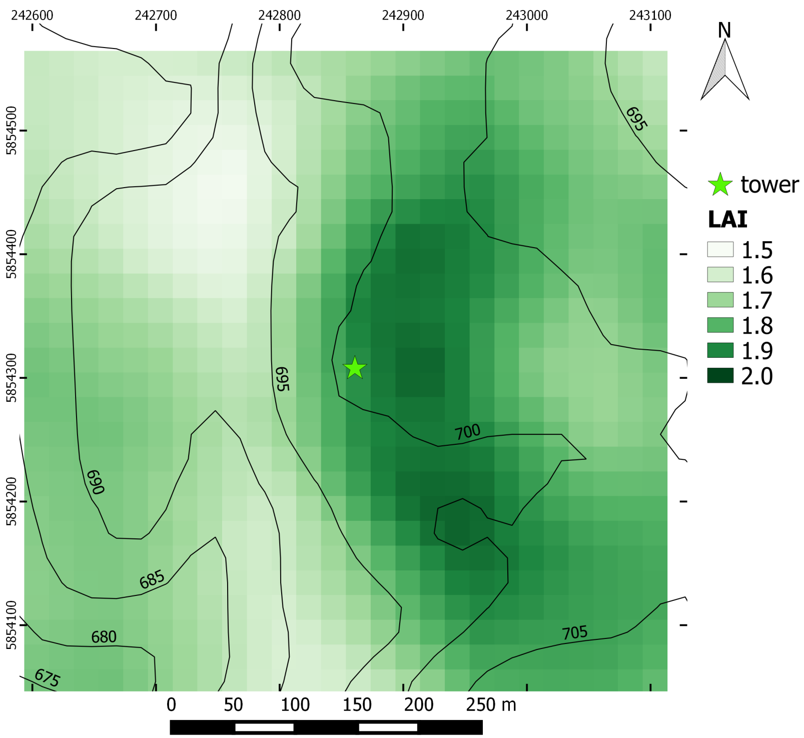


Fig. 6. Overstory leaf area index (LAI) variation within flux tower footprint.

- Topography formed drainage basins
- Large range of wetness within flux footprint → patchy understory
- Drier towards N and W & wetter towards E and SW

- LAI ranges from 1.5 to 2 m^2/m^2
- Lower LAI towards NW of tower, greater LAI towards SE of tower

Wind direction 2013 and 2014

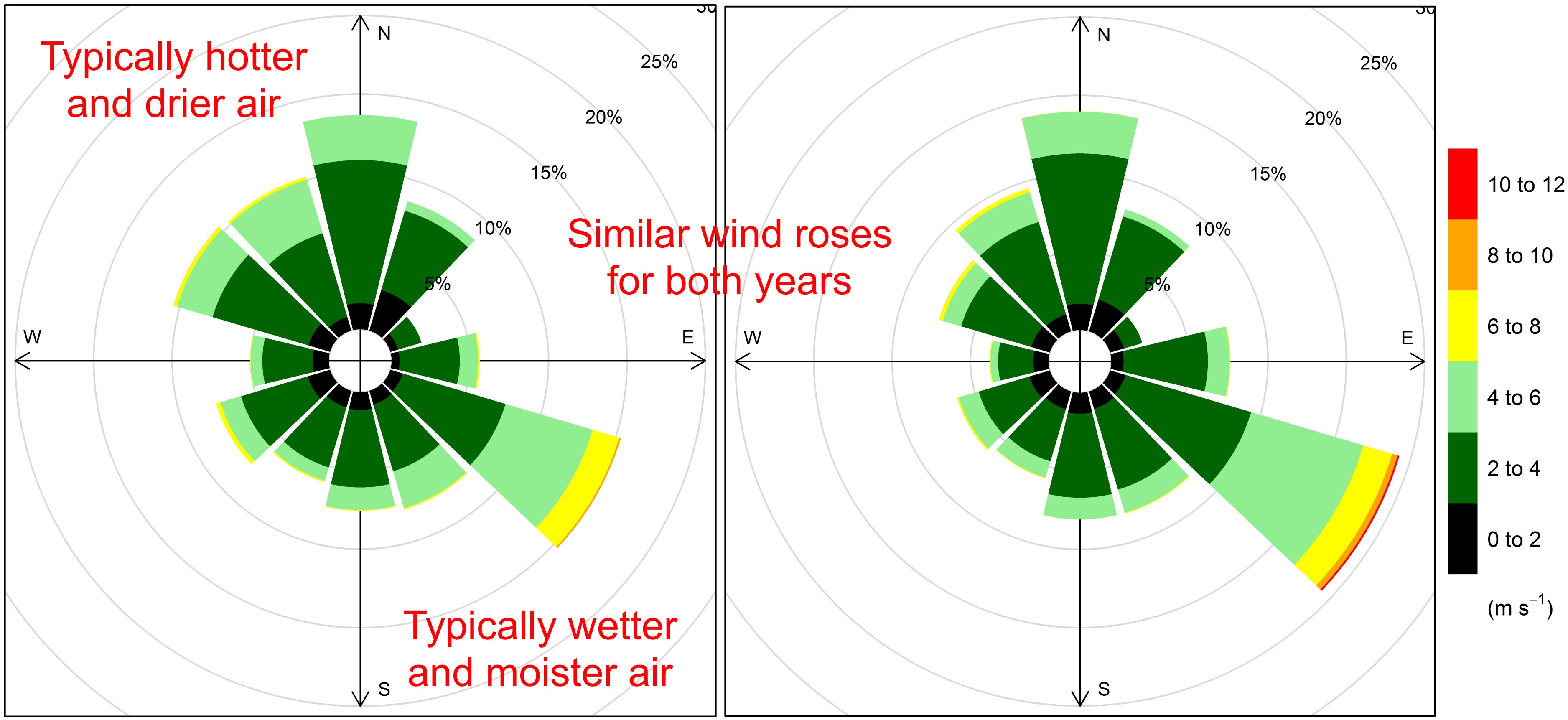


Fig. 7. Wind rose for 2013.

Fig. 8. Wind rose for 2014.

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Daytime fluxes 2013 and 2014

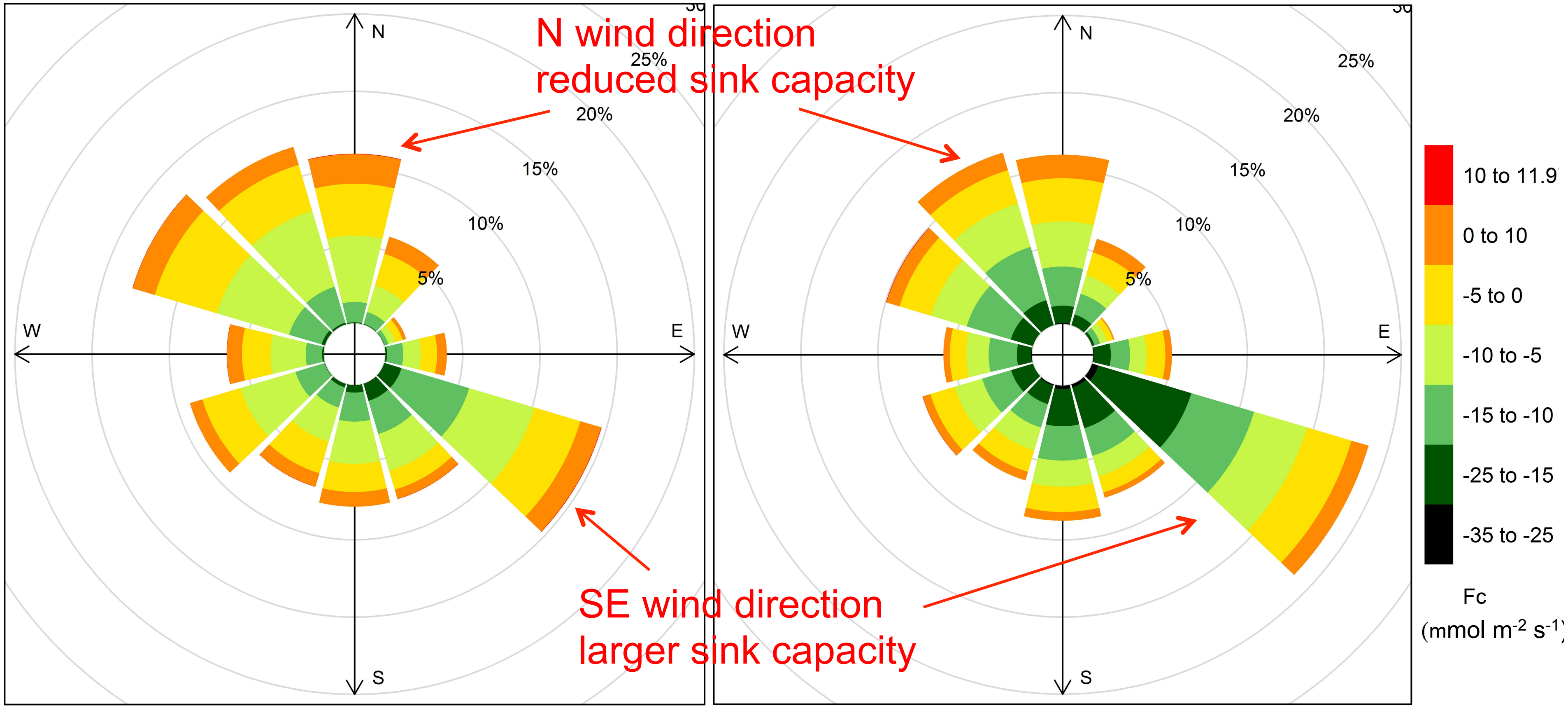


Fig. 9. Day-time carbon flux (Fc) for 2013.

Fig. 10. Day-time carbon flux (Fc) for 2014.

Summer fluxes 2013 and 2014

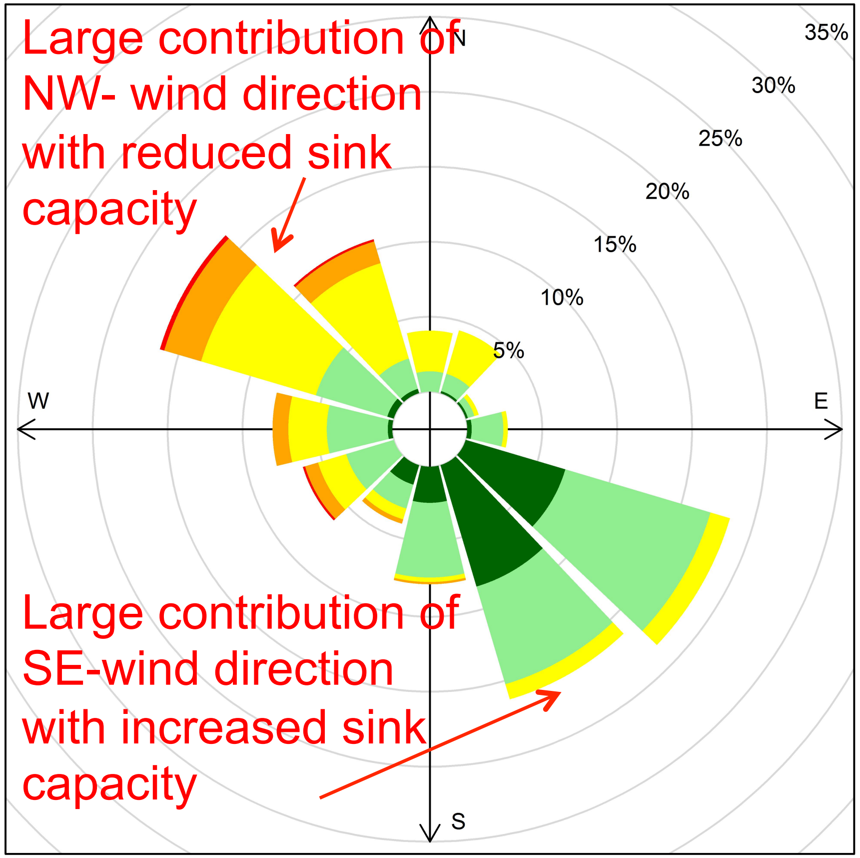


Fig. 11. Carbon flux during summer 2013 under optimal light conditions (incoming radiation >800 W m^{-2})

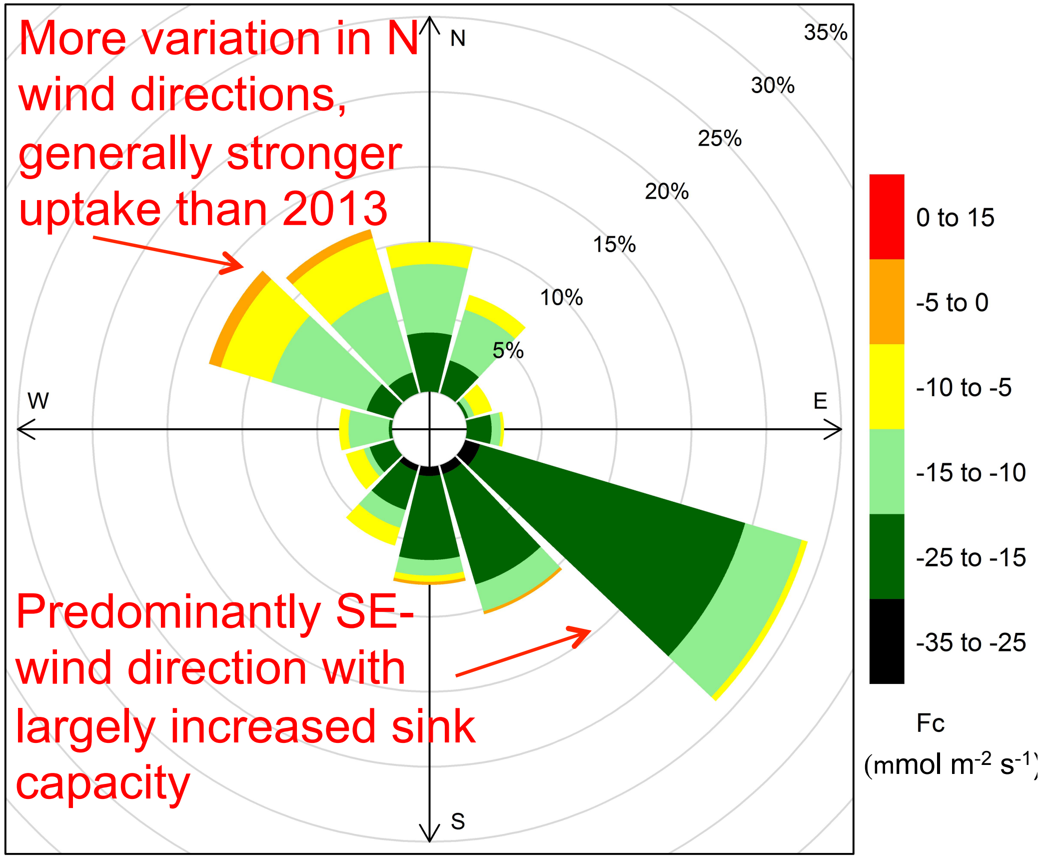
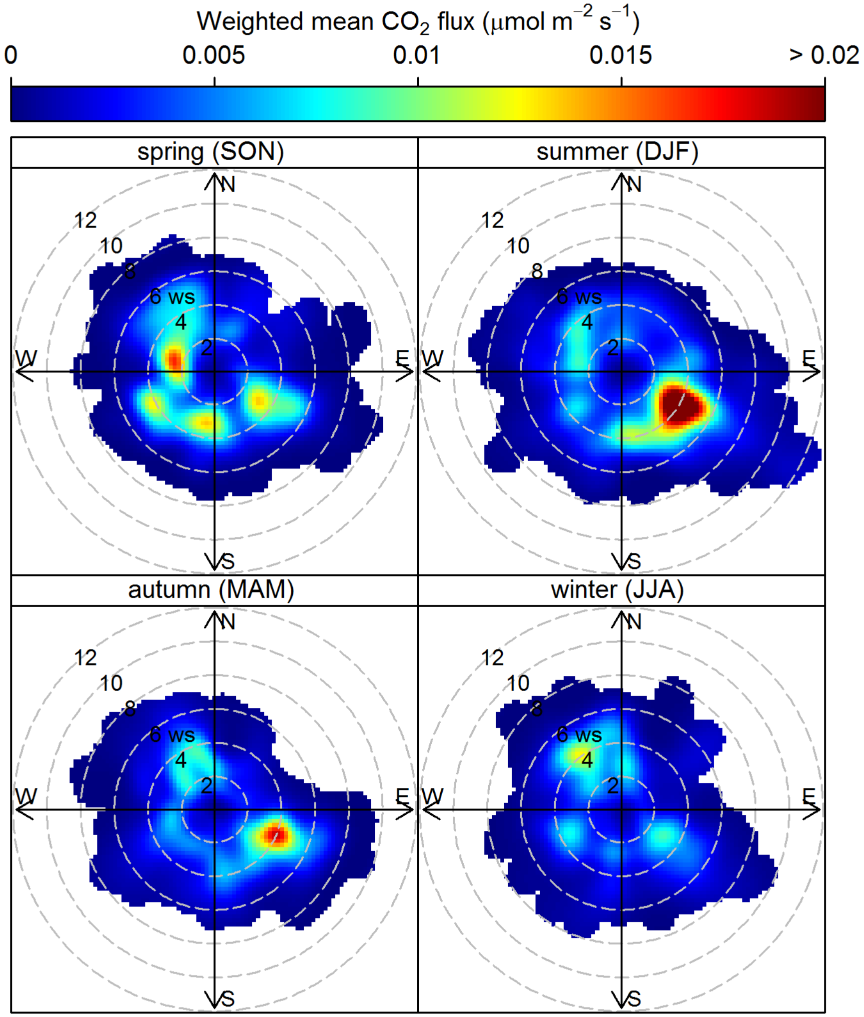


Fig. 12. Carbon flux during summer 2014 under optimal light conditions (incoming radiation >800 W m^{-2})

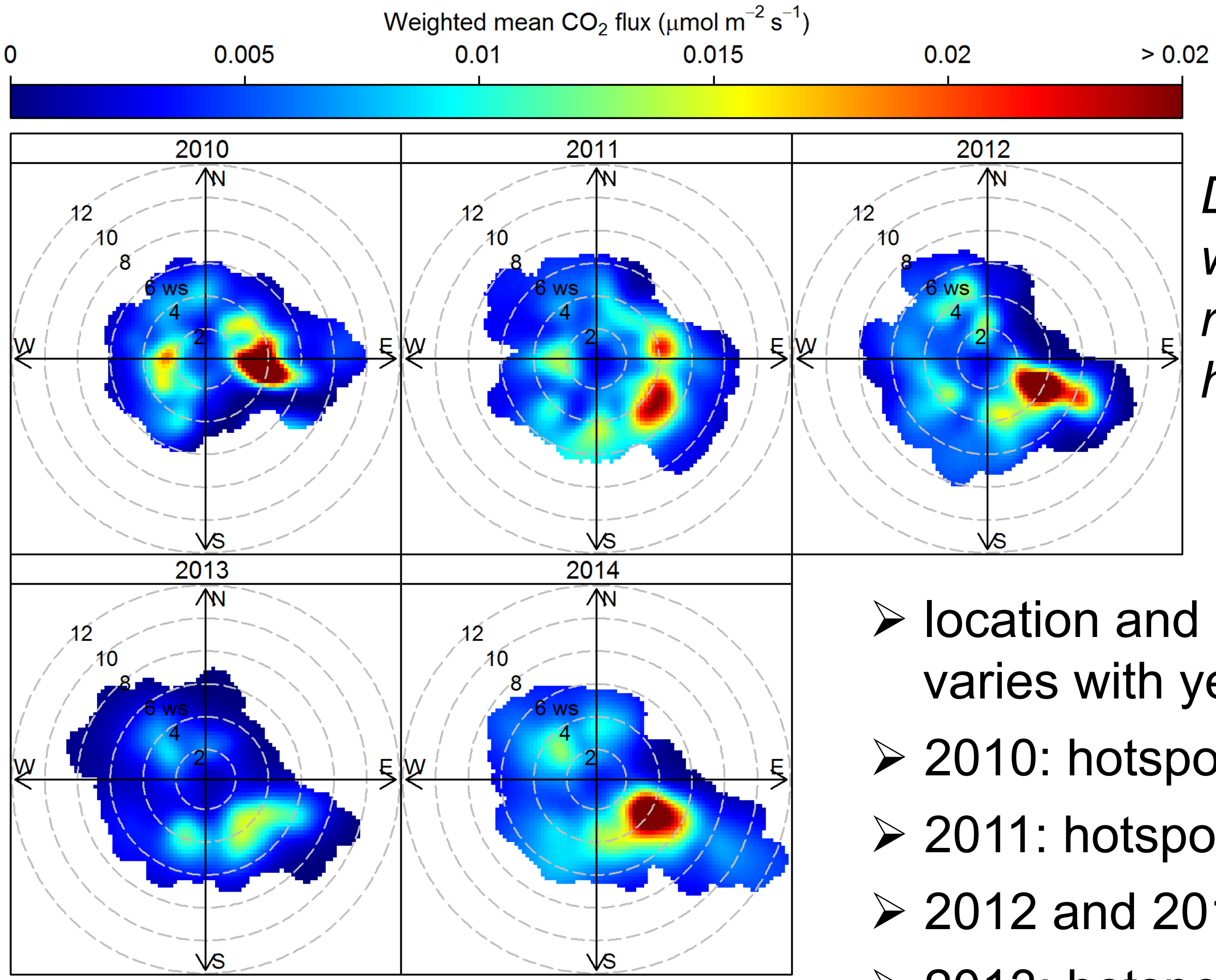
Seasonal variation of CO_2 uptake hotspots



Distinct wind speed and wind direction combinations result in CO_2 uptake hotspots

- location and intensity of hotspots varies with season
- consistencies per sector:
  - NE: very minor contribution
  - SE: hotspot noticeable in every season, strongest in summer
  - SW & NW: varying intensity with season

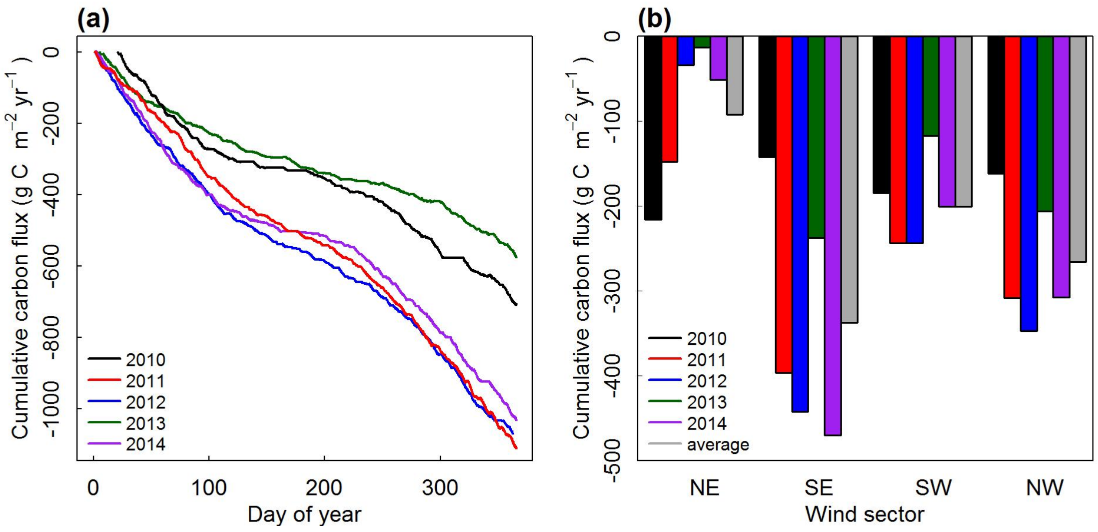
Yearly variation of summer hotspots



Distinct wind speed and wind direction combinations result in CO_2 uptake hotspots

- location and intensity of hotspots varies with year
- 2010: hotspot extends further North
- 2011: hotspot split
- 2012 and 2014: hotspot very distinct
- 2013: hotspot intensity is weak

Contribution per wind sector



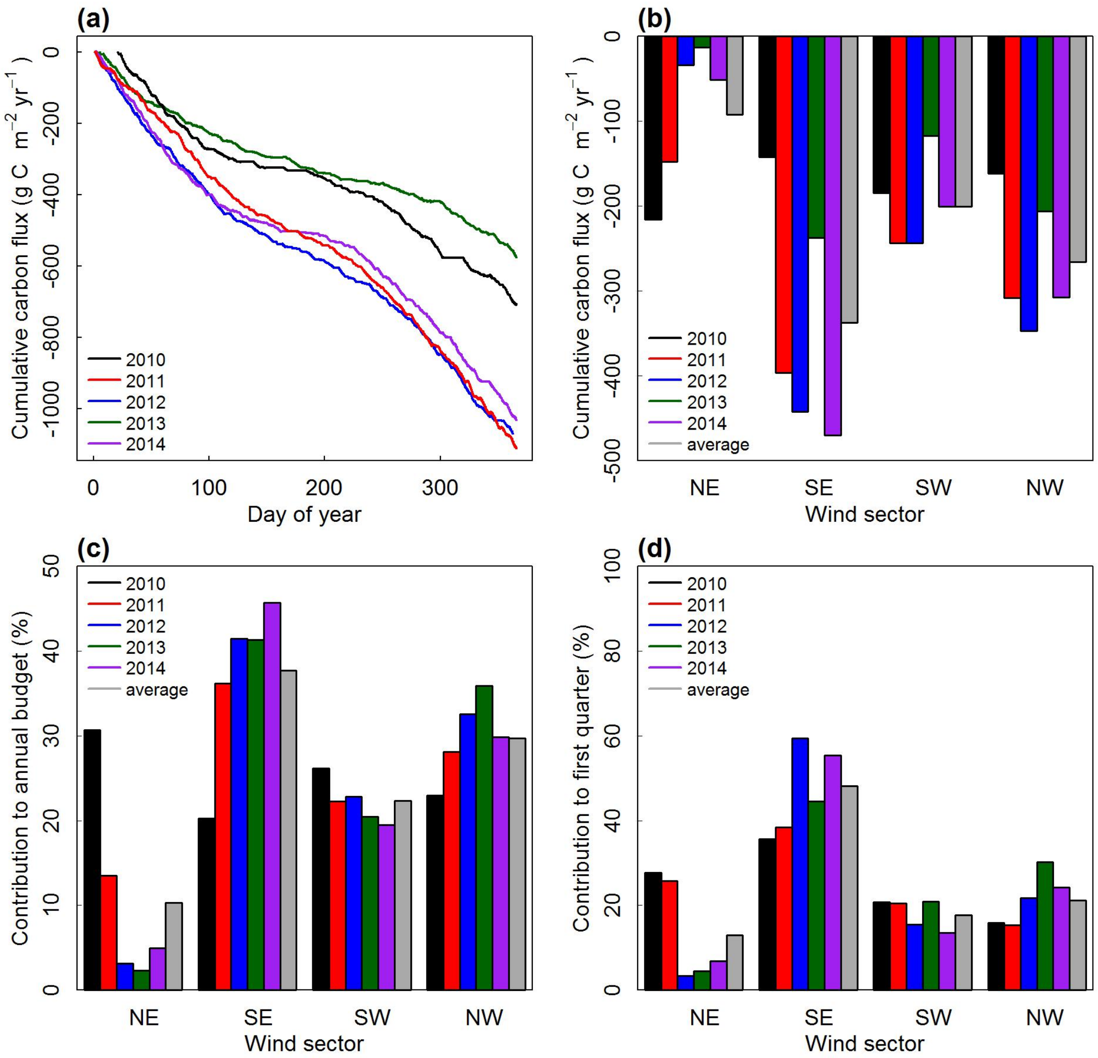
Ecosystem dynamics:

- ➢ Large seasonal variation of NEE
- ➢ Large range of annual sums

Role of footprint:

- ➢ Forest is C sink in all wind sectors
- ➢ Large range of C uptake between all sectors
- ➢ Hotspot location and extent reflected in wind sector contribution:
  - ➢ 2010 & 2011: northward shift = increased contribution of NE sector
  - ➢ 2013: weak hotspot = reduced sink
  - ➢ 2012 & 2014: strong hotspot = strong sink

Contribution per wind sector



<u>Role of footprint:</u>

- % contribution varies with sector

→ SE sector contributes ~35%

- largest differences in summer months

→ SE sector contributes ~50%

→ continental scale climate patterns largely modified sectoral contributions (La Niña in 2010-2011)

Footprint adjustment procedure

steps:

1) determine the average wind pattern from all observation years for each wind sector and sum the occurrences when fluxes originated from each sector, then divided by the number of observation years
   - *standardized frequency contribution for each sector*
2) determine the average carbon flux from each sector during each year
   - *preserves natural variability within each sector and year*
3) re-calculate the cumulative carbon uptake for each sector and each year based on the average wind patterns that were standardized over the study period, i.e. we multiplied the sector-specific results from step 1) with average fluxes from step 2)
   - *footprint coverage now equal for each year*
4) integrate across all sectors in each year
   - ***result: remaining annual variability of CO2 fluxes can be linked more accurately to variations in ecophysiological drivers***

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Footprint adjustment

	2010	2011	2012	2013	2014
Footprint adjustment (%)					
4 wind sectors	39.2	-3.2	-5.2	-5.3	-2.6
8 wind sectors	**23.1**	-3.0	-2.9	-7.5	-2.8
1st Quarter*	**17.2**	4.7	-4.8	**-18.9**	-1.4
2nd Quarter*	58.6	-3.4	-9.1	-12.4	10.7
3rd Quarter*	25.2	-13.1	6.1	11.4	-9.4
4th Quarter*	8.2	-0.6	-2.2	-5.2	-6.1
Filtered data*	48.7	3.9	-10.6	-9.7	-13.8
Footprint adjustment (g C m^{-2} yr^{-1})					
8 wind sectors	**-162.8**	32.8	30.9	42.8	29.0
1st Quarter*	-43.0	-14.6	17.5	39.5	5.1
2nd Quarter*	-48.2	7.1	17.4	14.3	-13.9
3rd Quarter*	-39.3	28.5	-11.8	-8.5	17.7
4th Quarter*	-17.8	2.3	6.8	9.2	20.3
Annual budgets (g C m^{-2} yr^{-1})					
original (non-adjusted)	-705.4	-1108.9	-1068.0	-574.9	-1030.2
adjusted based on annual period*	**-868.2**	-1076.1	-1037.1	**-532.1**	-1001.2
adjusted based on quarterly period*	-853.7	-1085.6	-1038.1	-520.5	-1000.9

Conclusion

What can cause such interannual variations in NEE?

climatic drivers?

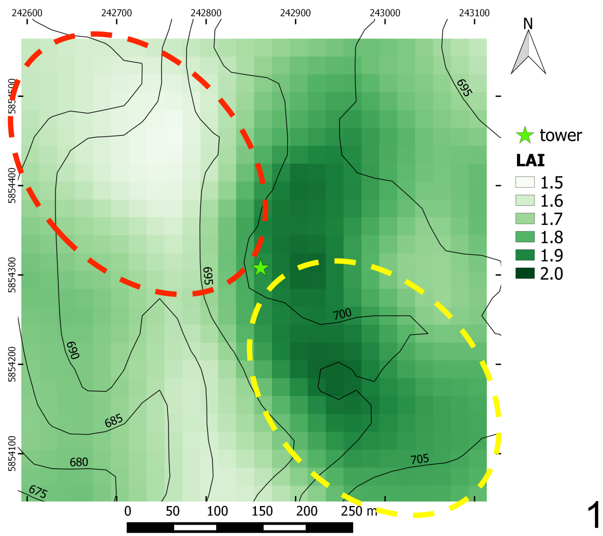
- Hot and dry air from N
- Colder and wetter air from S

surface characteristics?

- Higher LAI in the SE direction
- Lower LAI in the NW direction

Terrain?

- Channels northerly winds into NW direction
- Channels southerly winds into SE direction



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Thank you

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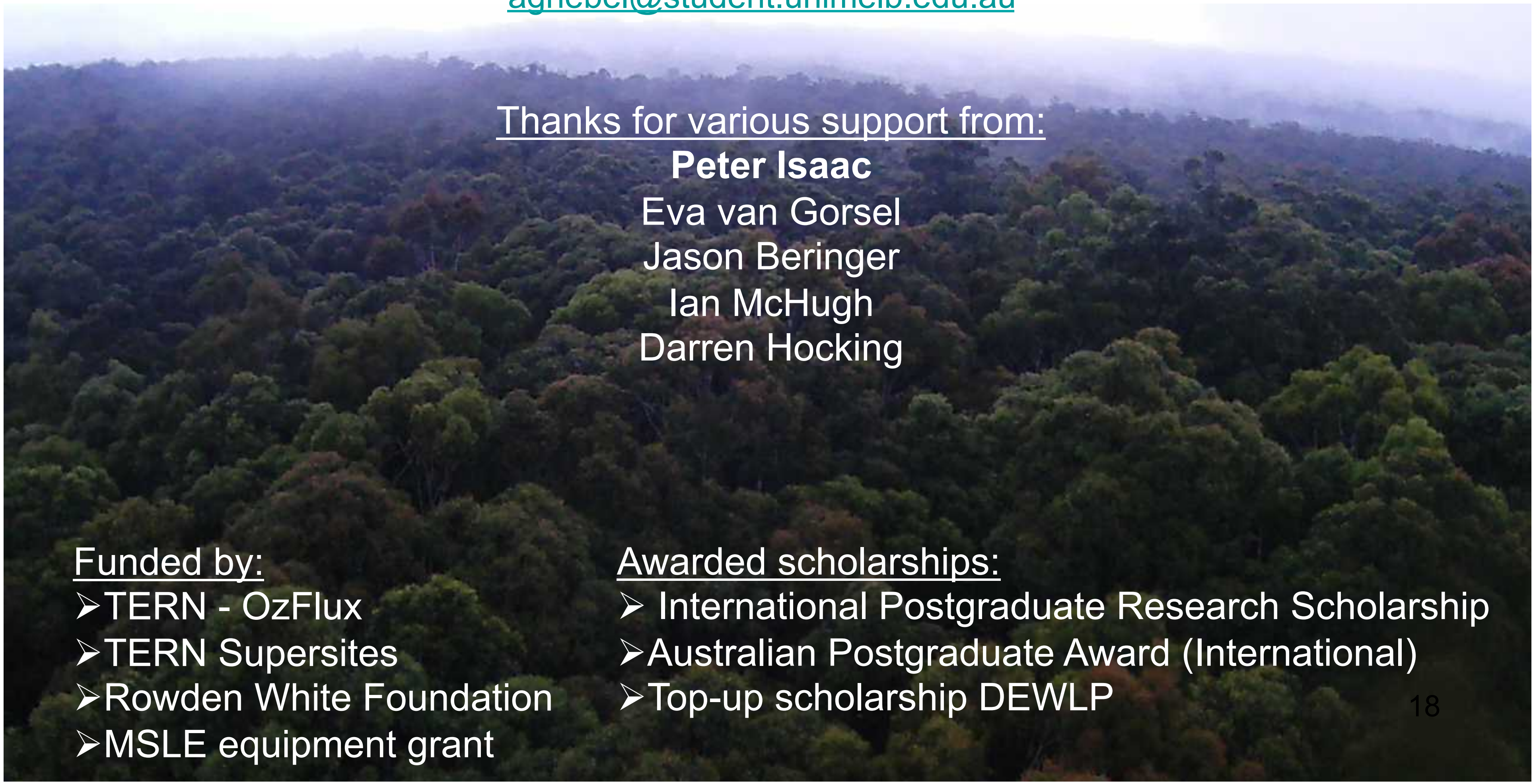

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