Satellite observations of changes in tropospheric NO_2 and CHOCHO amounts during the 2010-2012 La Niña events across Australia

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Motivation

Nitrogen dioxide (NO_2)

- is one of the most important air pollutants in the troposphere because it contributes to the formation of tropospheric ozone and photochemical smog
- is mainly released from anthropogenic activities (e.g. high temperature combustion processes)
- but is also formed naturally in the atmosphere by lightning and produced by plants, soils, and wildfires
- has an atmospheric lifetime on the order of hours

Glyoxal (CHOCHO)

- is the smallest of the alpha-dicarbonyls and one of the most prevalent carbonyls in the atmosphere
- is often used as a tracer of hydrocarbons over areas with enhanced volatile organic compound (VOC) emissions (photochemical hot spot regions)
- is mainly produced from the oxidation of isoprene, acetylene and aromatic hydrocarbons
- has an atmospheric lifetime on the order of hours

El Niño-Southern Oscillation (ENSO)

- is a cycle that is driven by changes in the Pacific Ocean and its overlying atmosphere
- El Niño (La Niña) events are associated with a warming (cooling) of the central and eastern tropical Pacific
- The 2010-2012 La Niña events were exceptionally strong (see Fig. 1) and affected the atmosphere, biosphere, and hydrosphere across Australia

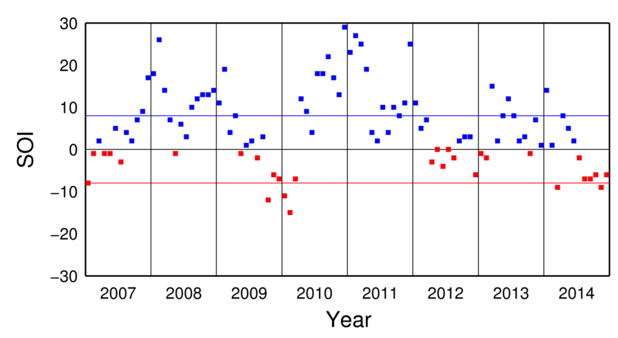
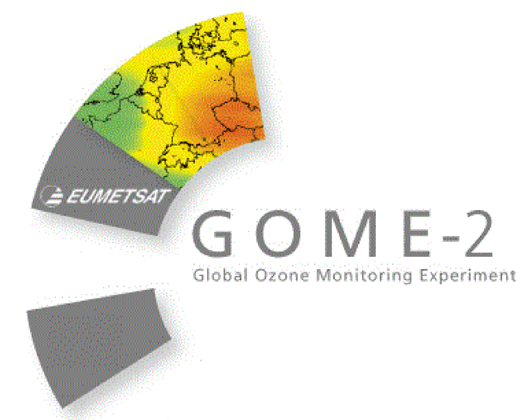


Fig. 1: Monthly Southern Oscillation Index (SOI) values for the 2007-2014 period. The threshold for La Niña (blue) and El Niño (red) events is -8 and +8, respectively.

NO_2 and CHOCHO from GOME-2



The second Global Ozone Monitoring Experiment (GOME-2)

- is located on board the MetOp-A satellite (launched in October 2006)
- is the first of a series of three identical instruments
- performs UV/visible observations of the atmosphere
- covers the spectral range between 240 and 790 nm
- has a ground pixel size of 80 x 40 km^2 in nadir view
- overpasses the Equator at 09:30 local time (LT) in the descending node
- provides near global coverage every day

- The satellite spectral measurements are analyzed using the Differential Optical Absorption Spectroscopy (DOAS) technique, applying a nonlinear least-squares fitting algorithm

			Cross-Sections						
Trace gas	Fitting window	polynomial	NO_2	CHOCHO	O_3	O_4	H_2O_{vap}	H_2O_{liq}	Ring
NO_2	425-497 nm	3 coefficients	yes	no	yes	yes	yes	yes	yes
CHOCHO	433-460 nm	4 coefficients	yes	yes	yes	yes	yes	yes	yes

- The output of the DOAS analysis – total slant column densities (SCD) of NO_2 and CHOCHO – are converted into tropospheric vertical columns (TVC) by applying airmass factors (AMFs) and a stratospheric correction
- The FRESCO+ retrieval is applied to remove data with cloud fraction > 0.2 (NO_2) and > 0.3 (CHOCHO)

NO_2 and glyoxal response to La Niña

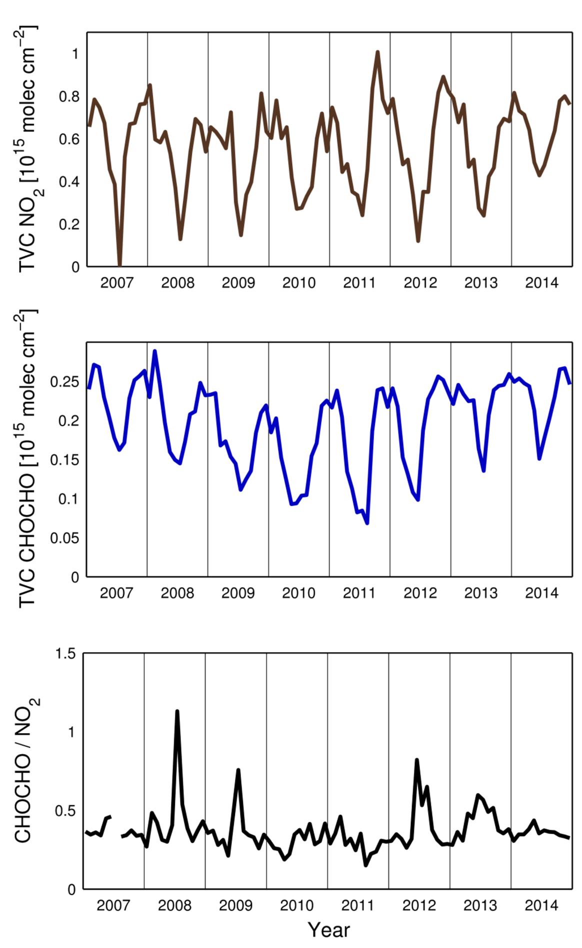


Fig. 2: Monthly NO_2 (upper) and CHOCHO (middle) values over Australia for the 2007-2014 period. The ratio of the two trace gases is shown in the lower panel.

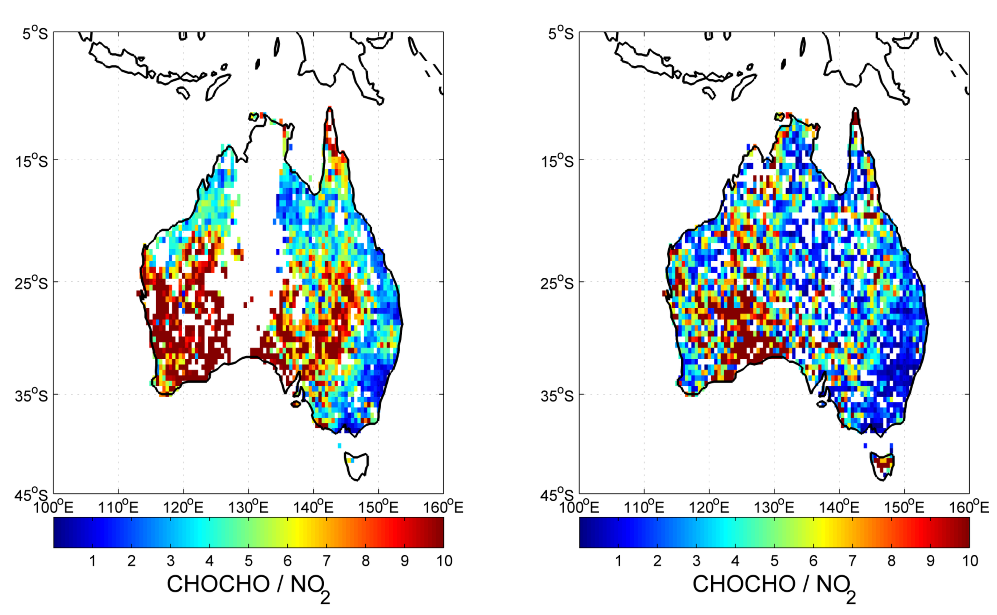


Fig. 3: Glyoxal to NO_2 ratio for austral winter months (June, July, and August), averaged over weak to moderate La Niña years 2007, 2008, 2009, 2012, 2013, 2014 (left) and averaged over strong La Niña years 2010 and 2011 (right).

- Obvious changes in tropospheric NO_2 and CHOCHO are observed during the 2010-2012 La Niña events (Fig. 2)
- Tropospheric NO_2 amounts in austral winter and summer are higher than usual, whereas tropospheric CHOCHO amounts in austral winter are lower than the years before and after
- The glyoxal to NO_2 ratio indicates decreased values during the 2010 and 2011 La Niña phase (Fig. 2 and Fig. 3)
- What are the drivers of these NO_2 and glyoxal changes?

Fire and vegetation as possible drivers

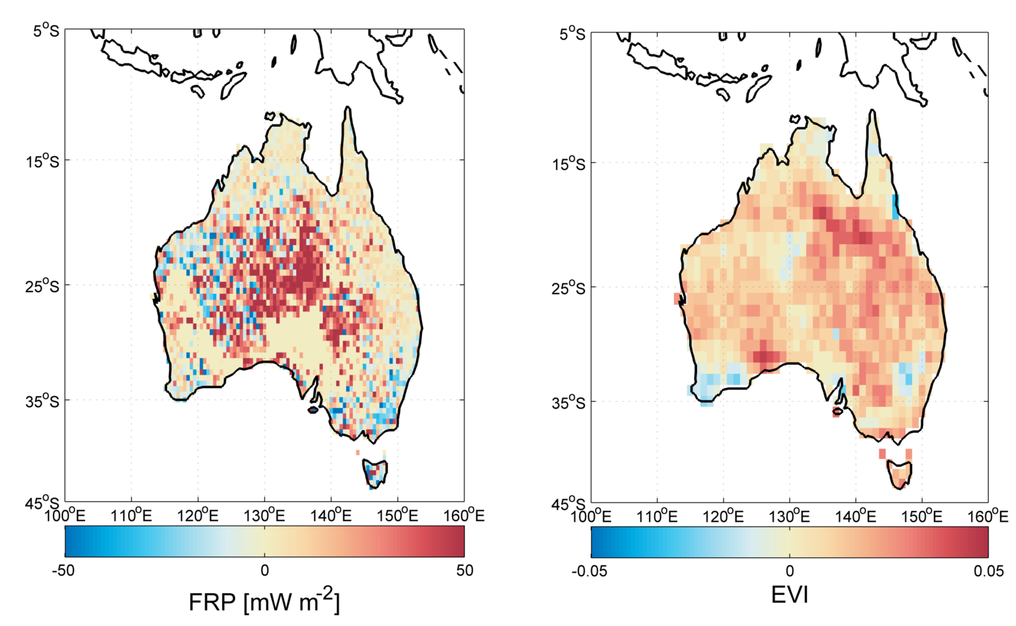


Fig. 4: Differences in FRP (left) and EVI (right), calculated by subtracting the parameters as averaged over the 2011 to 2012 period from the parameters as averaged over the years 2007, 2008, 2009, 2010, 2013, and 2014.

- Differences in fire radiative power (FRP) and enhanced vegetation index (EVI) between strong and weak to moderate La Niña years are shown in Fig. 4
- During the 2011-2012 La Niña period, fire activity was higher than usual in large parts of Australia
- During the same period, increased vegetation growth across most of Australia is also observed

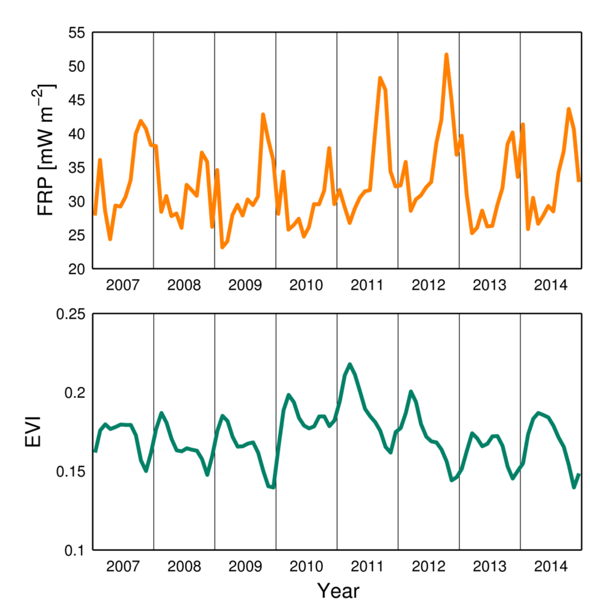


Fig. 5: Monthly FRP (upper) and EVI (lower) values over Australia for the 2007-2014 period.

- FRP and EVI follow a seasonal cycle in Australia with maxima of FRP (EVI) during the dry (wet) season (Fig. 5)
- There is a clear inter-annual variability for both FRP and EVI with maxima observed during the 2010-2012 La Niña phase
- Is the seasonal cycle of NO_2 and CHOCHO driven by these two variables?

More possible drivers …

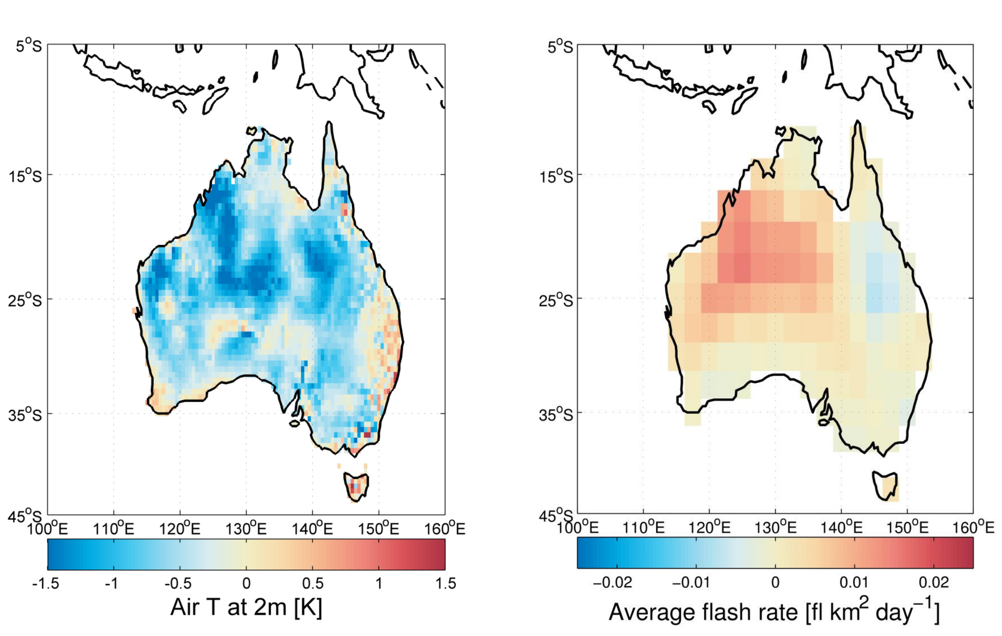


Fig. 6: Differences in air T at 2 m (left) and average flash rate (right), calculated by subtracting the parameters as averaged over the 2011 to 2012 period from the parameters as averaged over the years 2007, 2008, 2009, 2010, 2013, and 2014.

- Differences in air temperature and average flash rate between strong and weak to moderate La Niña years are shown in Fig. 6
- During the 2011-2012 La Niña period, air temperature was lower across most of Australia
- During the same period, the average flash rate increased as well, in particular over Western Australia and Northern Territory

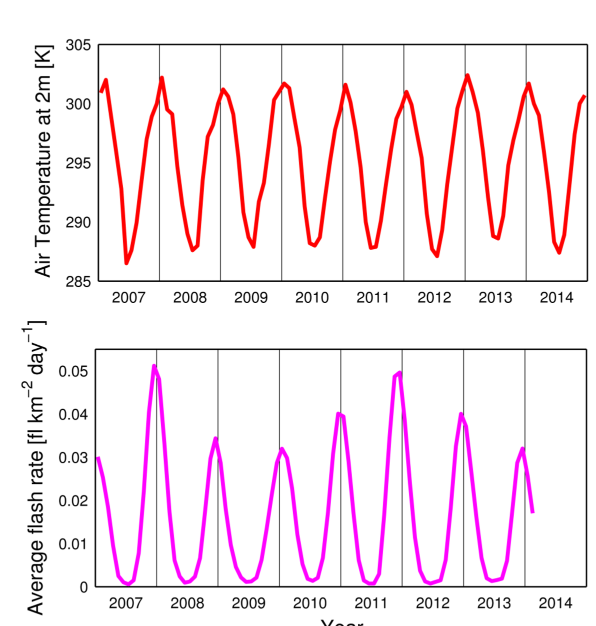


Fig. 7: Monthly air temperature at 2 m (upper) and average flash rate (lower) values over Australia for the 2007-2014 period.

- Air temperature and lightning activity follow a seasonal cycle over Australia with maxima during the austral summer
- While inter-annual changes in air temperature can hardly be seen, flash rate is correlated with SOI (Fig. 7)

Can we predict NO_2 and CHOCHO?

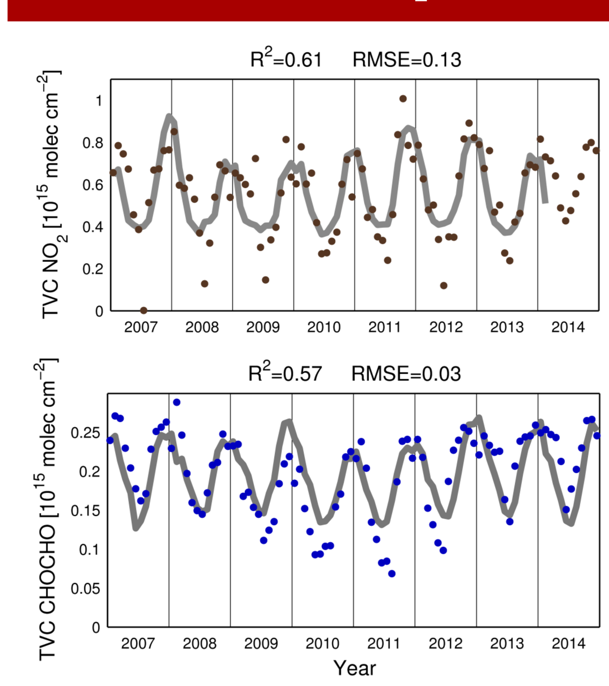


Fig. 8: Monthly measured NO_2 (brown) and CHOCHO (blue) as well as modeled NO_2 and CHOCHO (gray) values over Australia for the 2007-2014 period.

- The measured (dots) and fitted (solid line) time series for the Australian continent are shown in Fig. 8 for NO_2 and CHOCHO
- Overall, the seasonal cycle of the NO_2 and CHOCHO time series is explained by the model
- While the increased maxima of NO_2 during the 2011 and 2012 La Niña events are explained by the model, the minima of CHOCHO are not
- The agreement increases when the time series are averaged over a selected region (Fig. 9)

- A polynomial curve fitting using a polynomial of one degree is performed on the monthly and spatially averaged data
- $NO2_{model} = FRP * a1 + Lightning * a2 + b$
- $CHOCHO_{model} = FRP * a1 + EVI * a2 + AirT2m * a3 + b$

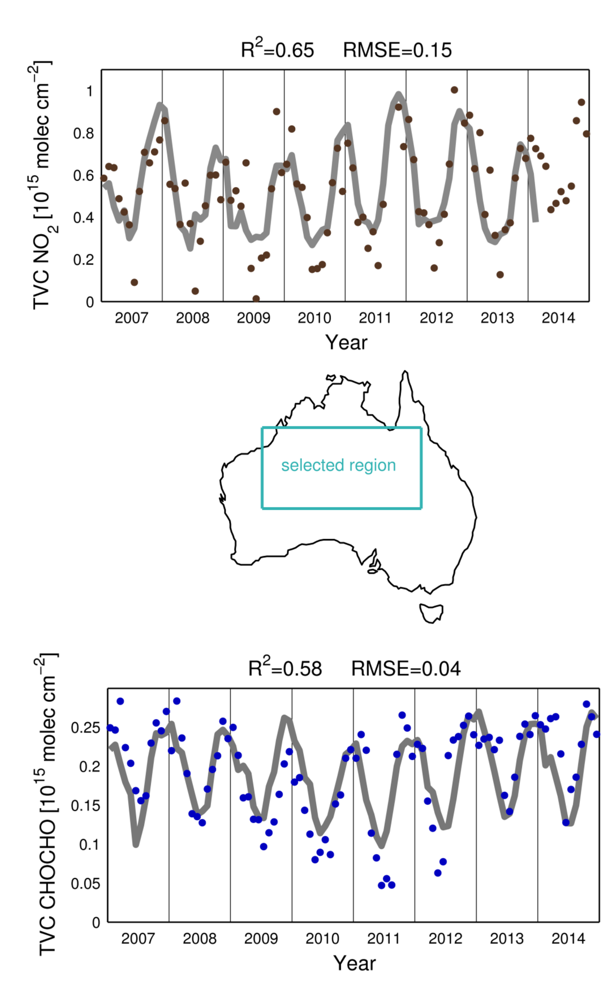


Fig. 9: Same as Fig. 8, but for the selected region.

References & Acknowledgements

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- http://www.bom.gov.au/climate/enso/

- GOME-2 lv1 data have been provided by EUMETSAT (http://www.eumetsat.int/website/home/index.html)
- SOI and Air temperature data have been provided by NOAA (http://www.noaa.gov)
- MODIS FRP and EVI as well as LIS lightning data have been provided by NASA (http://www.nasa.gov)
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Summary & Conclusions

- During the 2010-2012 period, moderate to strong La Niña events affected the atmosphere, biosphere, and hydrosphere above and across Australia
- GOME-2 observations of tropospheric nitrogen dioxide (NO_2) and glyoxal (CHOCHO) amounts indicated substantial changes during this period
- The motivation of this study was to find possible drivers for both the seasonal and inter-annual variability of NO_2 and CHOCHO over Australia
- Long-term satellite data of fire radiative power (FRP), enhanced vegetation index (EVI), air temperature at 2 m, and flash rate of lightning were analyzed
- While fire activity, vegetation growth, and lightning activity were higher during the 2010-2012 La Niña phase, a strong decrease of air temperature was observed across Australia at the same time
- A polynomial curve fitting was performed with the four independent variables to model the time series of NO_2 and CHOCHO
- The overall seasonal pattern of the two trace gases is explained by the simple model properly
- However, the reason for the decreased CHOCHO minima during the 2010-2012 La Niña events remains unclear

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