Studies of variability in fire count in Indonesia: Effects of ENSO and MJO phase

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Agenda

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- Results, Part 1
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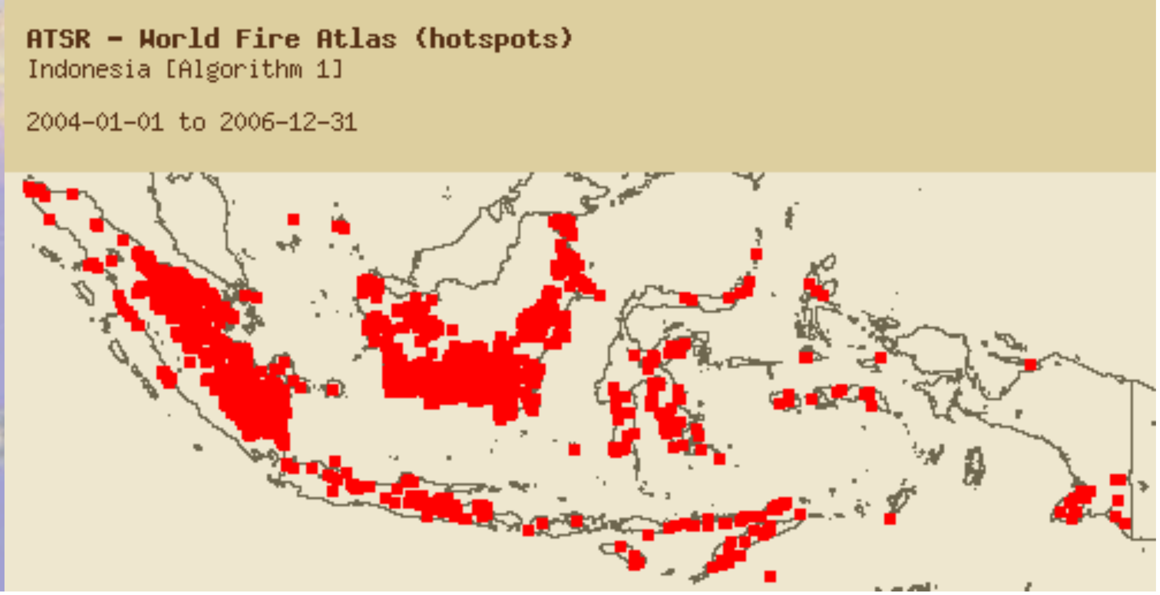
- References



ATSR - World Fire Atlas (hotspots)
Indonesia [Algorithm 1]

2004-01-01 to 2006-12-31

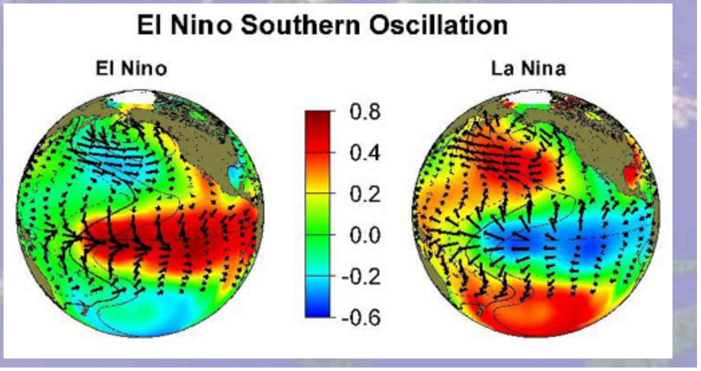
Introduction:
Impacts of Tropical Biomass Burning

- Biomass burning (BB) accounts for large annual emissions of trace gases (including radiatively-important greenhouse gases) and aerosols to the atmosphere
  - Includes naturally-occurring wildfires, as well as anthropogenic fires set for land-clearing or as part of agricultural practices
- Tropical regions have the highest annual emissions from fires, and tropical BB is believed to have been highly perturbed (increased) by human activity (Taylor, 2010)
- Studies suggest complicated feedbacks between climate and BB
  - Drought increases BB (LePage et al., 2008; Field et al., 2009)
  - But emissions from BB may in turn cause regional-scale climate changes (Zhang et al., 2008; Tosca et al., 2010)

Indonesian Biomass Burning and Climate Indicators

- It is well known that fires in Indonesia are related to climate indices such as the El Nino – Southern Oscillation, which can suppress rainfall over Indonesia [e.g., Qian et al., 2010]
    - Huge BB event in 1997-98 has been studied extensively (e.g., Fuller and Murphy, 2006) and was found to have global impacts on trace gas budgets and climate
- El Niño has been defined as the irregular development of an anomalously warm pool of surface water in the eastern tropical Pacific, which generally lasts between 12 and 18 months (standing pattern).

El Nino conditions cause a reduction in cloud formation by convection and hence also reduce rainfall → **interannual** (year-to-year) variability in rainfall / drought



http://ffden-2.phys.uaf.edu645fall2003_web.dir/Jason_Amundson/enso.htm

The Madden-Julian Oscillation

- Since we know drought affects Indonesian BB, there may be climate-related influences other than ENSO on the number of fires each year
- The Madden-Julian oscillation is an eastward-moving tropical pattern over the Indian and Pacific Oceans, with a period of 30-90 days, that is characterized by large regions of enhanced and suppressed rainfall (Wikipedia.org)
- The MJO is the largest component of the intraseasonal variability in the tropical atmosphere, and so might be expected to influence Indonesian BB with *month-to-month variability*
- 8 phases of the MJO have been identified and characterized by Wheeler and Hendon [2004]; as will be shown, some phases of the are associated with below-average rainfall in Indonesia

Problem Statement

- In this work we are seeking relationships between El Niño events and observed fire counts in Indonesia, using available multiyear data sets, to explain interannual variability in fire counts
  - Relationships can impact regional and global chemistry and climate
  - Indonesian signal is large and well-studied, so a good place to start, but findings may apply to other regions as well
- The fewest years of data are satellite-derived "hot spots" that indicate the number (not necessarily size or magnitude) of fires. These are available from 1995 – present (ATSR World Fire Atlas, http://wfaa-dat.esrin.esa.int/)
- We use two different climate indices for correlation:
  - **Multivariate ENSO Index (MEI),** NOAA ESRL: http://www.esrl.noaa.gov/psd/enso/mei/
  - **Southern Oscillation Index**, http://www.bom.gov.au/climate/current/soi2.shtml
- We also seek relationships between burning and MJO phase to explain variability in fire counts on time scales of a few months
  - We use the daily phase information available from M. Wheeler's website: http://cawcr.gov.au/staff/mwheeler/maproom/RMM/index.htm

Methods: ENSO Correlations

- The ENSO indexes are reported monthly so we used the monthly fire count data.
- For each year, we found total fire counts from July (year 1) – June (year 2), to be consistent with the ENSO cycle
- We computed the average MEI or SOI over the same July-June time period

chosen area: Indonesia

:: start date :: 1 January 1997

:: end date :: 31 December 1998

:: algorithm :: 1

output format: Chart (mths)

:: add classification ::

☐ Admin area

☐ GlobCover

☐ Biomass

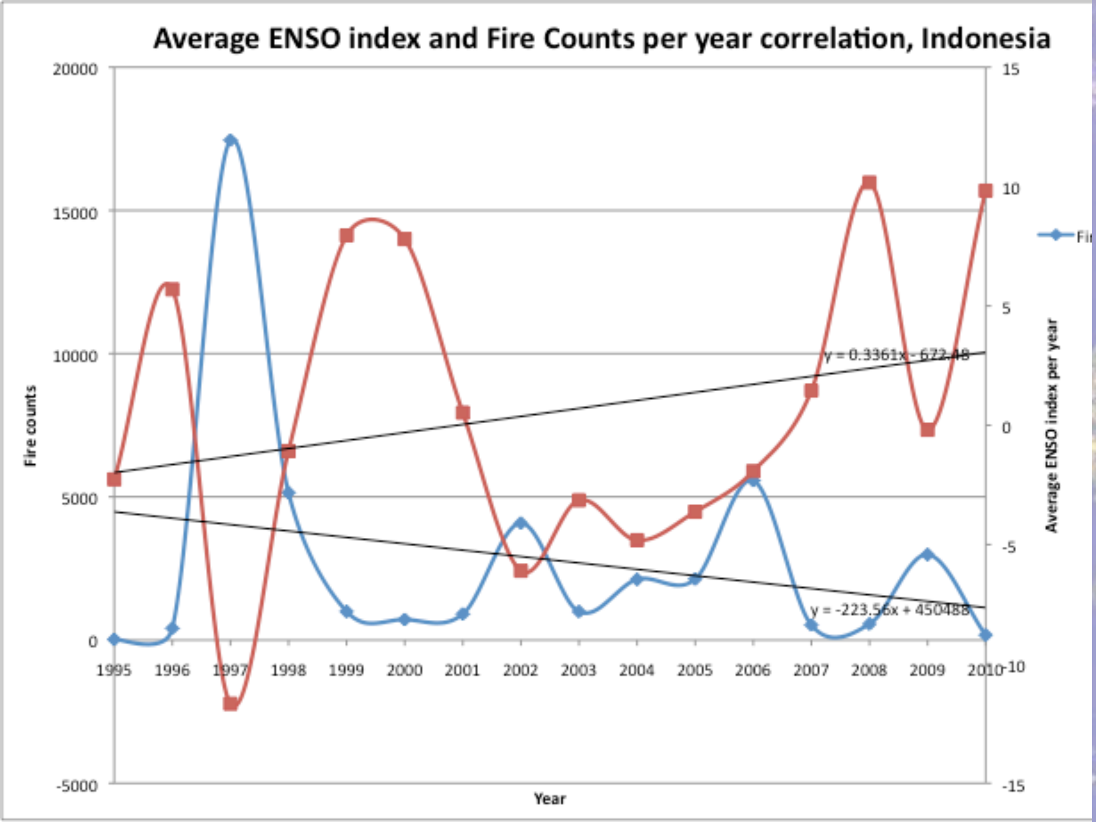
☐ Koeppen

ATSR - World Fire Atlas (monthly number of hotspots)

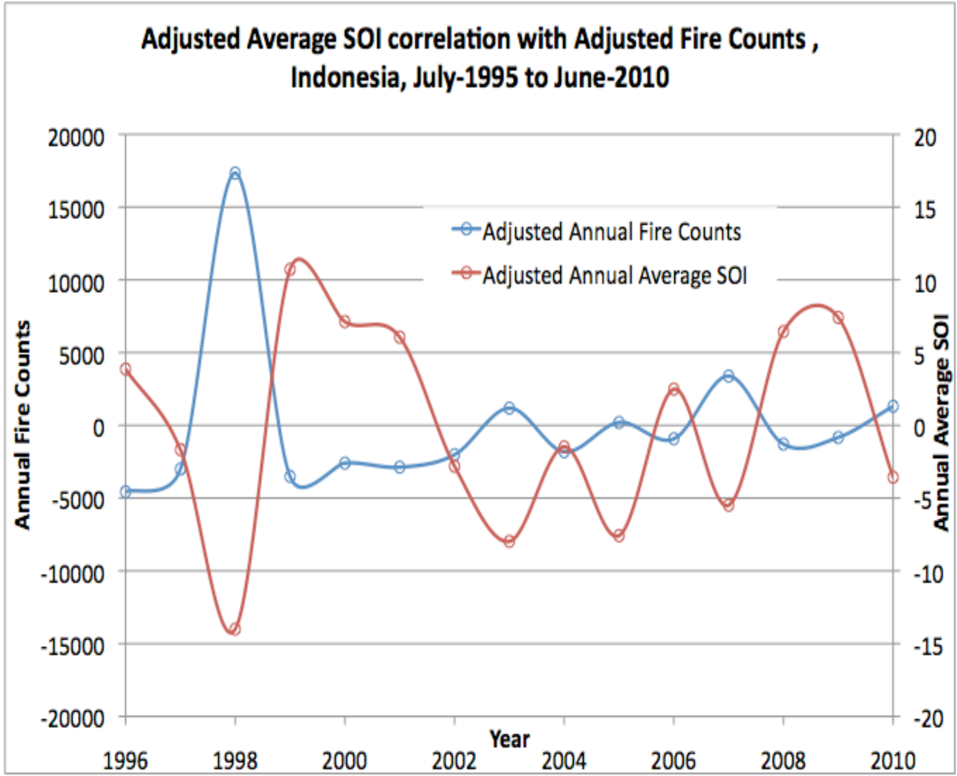
Indonesia [Algorithm 1]

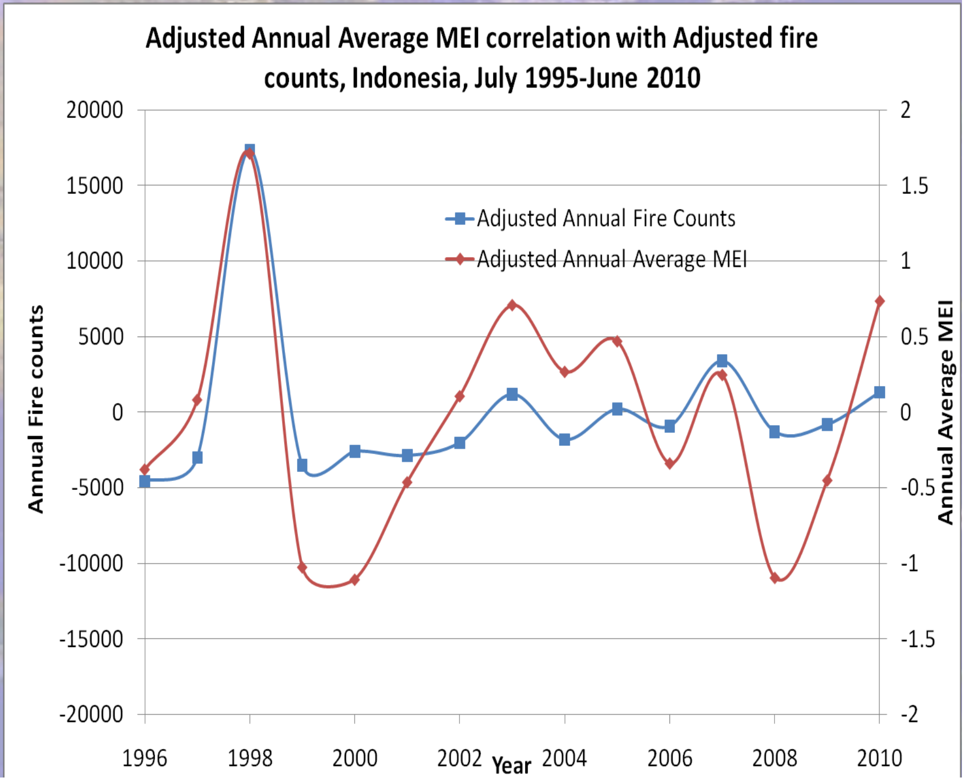
Methods, ENSO Correlations, Cont'd

- Finally, we SUBTRACTED linear trends over the years of data (1995-2010) for BOTH data sets (see example below)
  - This gives us ANOMALY ("adjusted") plots that we can use for comparison

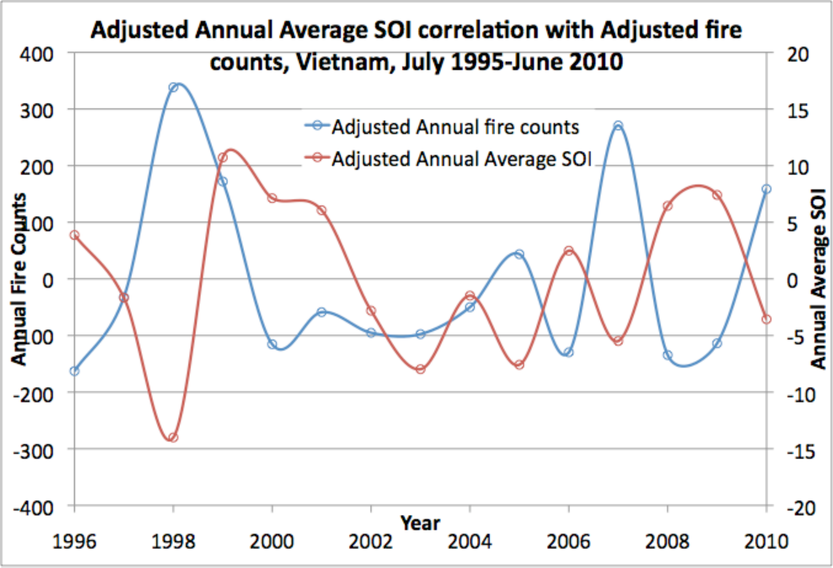


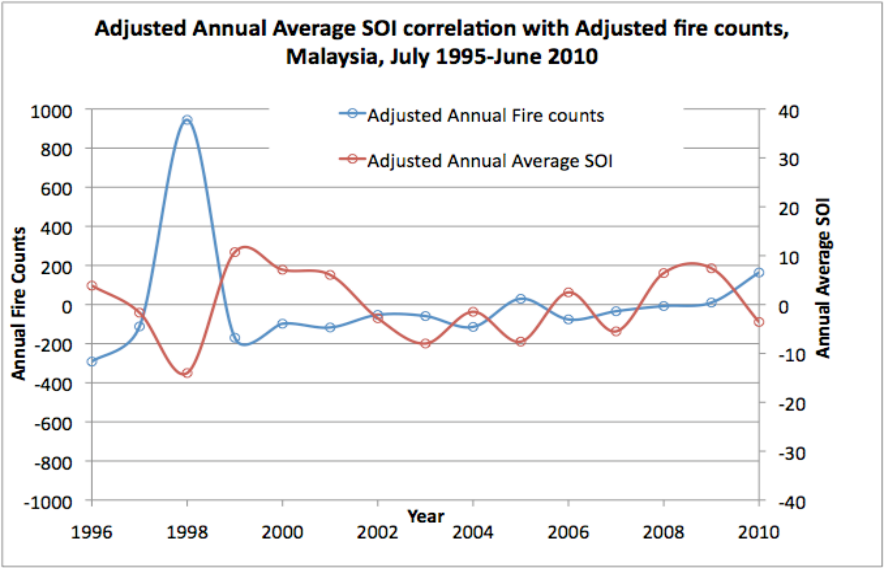
Results: SOI and MEI correlation fire counts, Indonesia

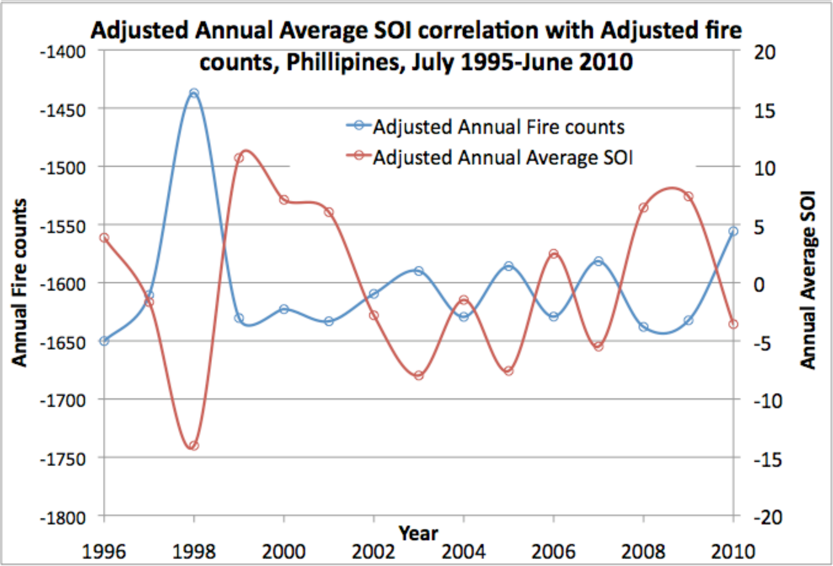




Extension to Other SE Asia Regions (SOI)

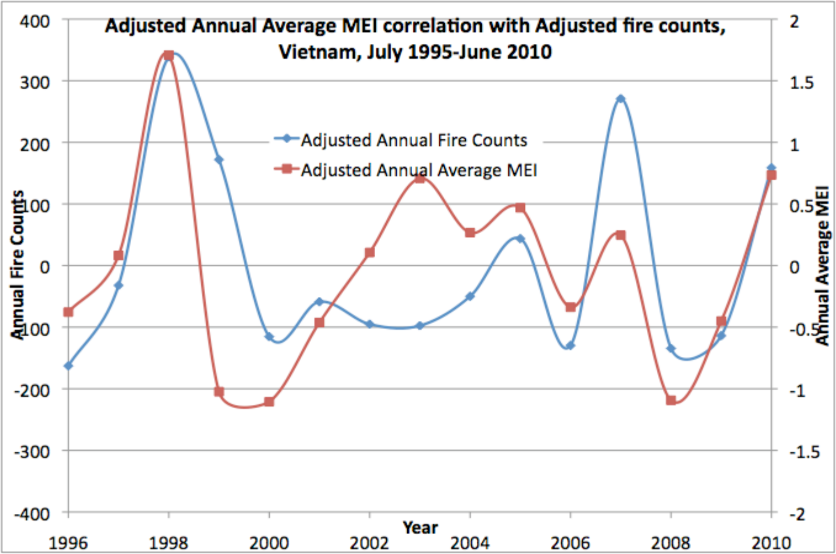

Adjusted Annual Average SOI correlation with Adjusted fire counts, Vietnam, July 1995-June 2010


Adjusted Annual Average SOI correlation with Adjusted fire counts, Malaysia, July 1995-June 2010

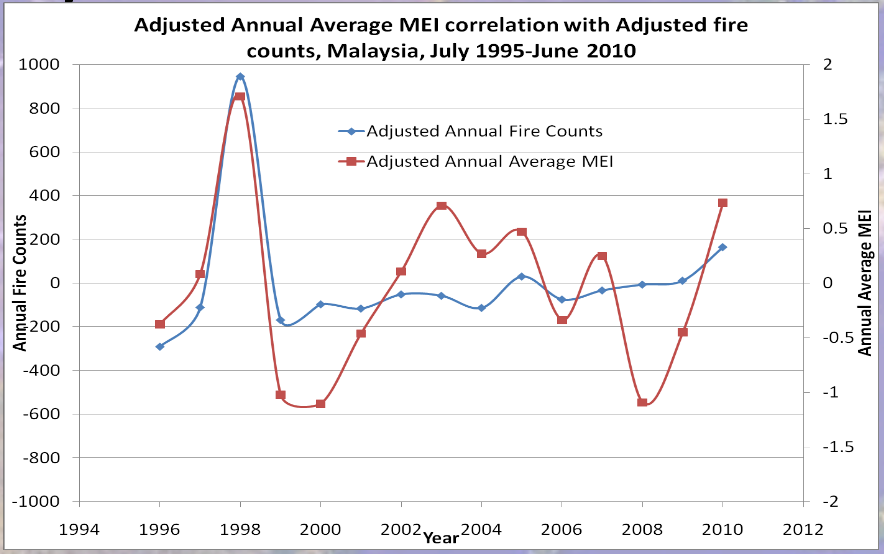

Adjusted Annual Average SOI correlation with Adjusted fire counts, Phillipines, July 1995-June 2010

Strong relationships seen between satellite "hot spot" and ENSO anomalies for all locations studied

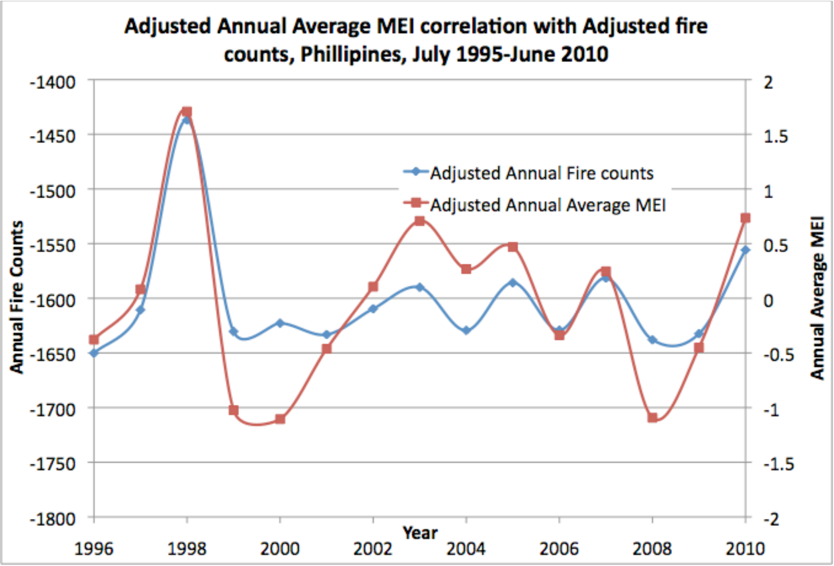
Extension to Other SE Asia Regions (MEI)



Adjusted Annual Average MEI correlation with Adjusted fire counts, Vietnam, July 1995-June 2010



Adjusted Annual Average MEI correlation with Adjusted fire counts, Malaysia, July 1995-June 2010



Adjusted Annual Average MEI correlation with Adjusted fire counts, Phillipines, July 1995-June 2010

Strong relationships seen between satellite "hot spot" and ENSO anomalies for all locations studied

Methods: MJO Correlations

- Because the MJO varies on much shorter timescales than do ENSO-related indices, we use **daily** (rather than monthly) values for this part of our work.
- The phase is related to variables defined by Wheeler and Hendon (RMM1 and RMM2) We used daily values of the phase available from http://cawcr.gov.au/staff/mwheeler/maproom/RMM/RMM1RMM2.74toRealtime.txt
- Also, discrete values of the fire counts for each region are available (time and location of each hot spot), but these data needed to be specially processed into a file of daily fire counts for each region.
- Because this processing was time-consuming, we chose seven years (2002-2008) for initial investigation, to examine whether any relationships exist between the data sets, and confined our analyses to Indonesia.

Phases of the MJO (May / June composite)

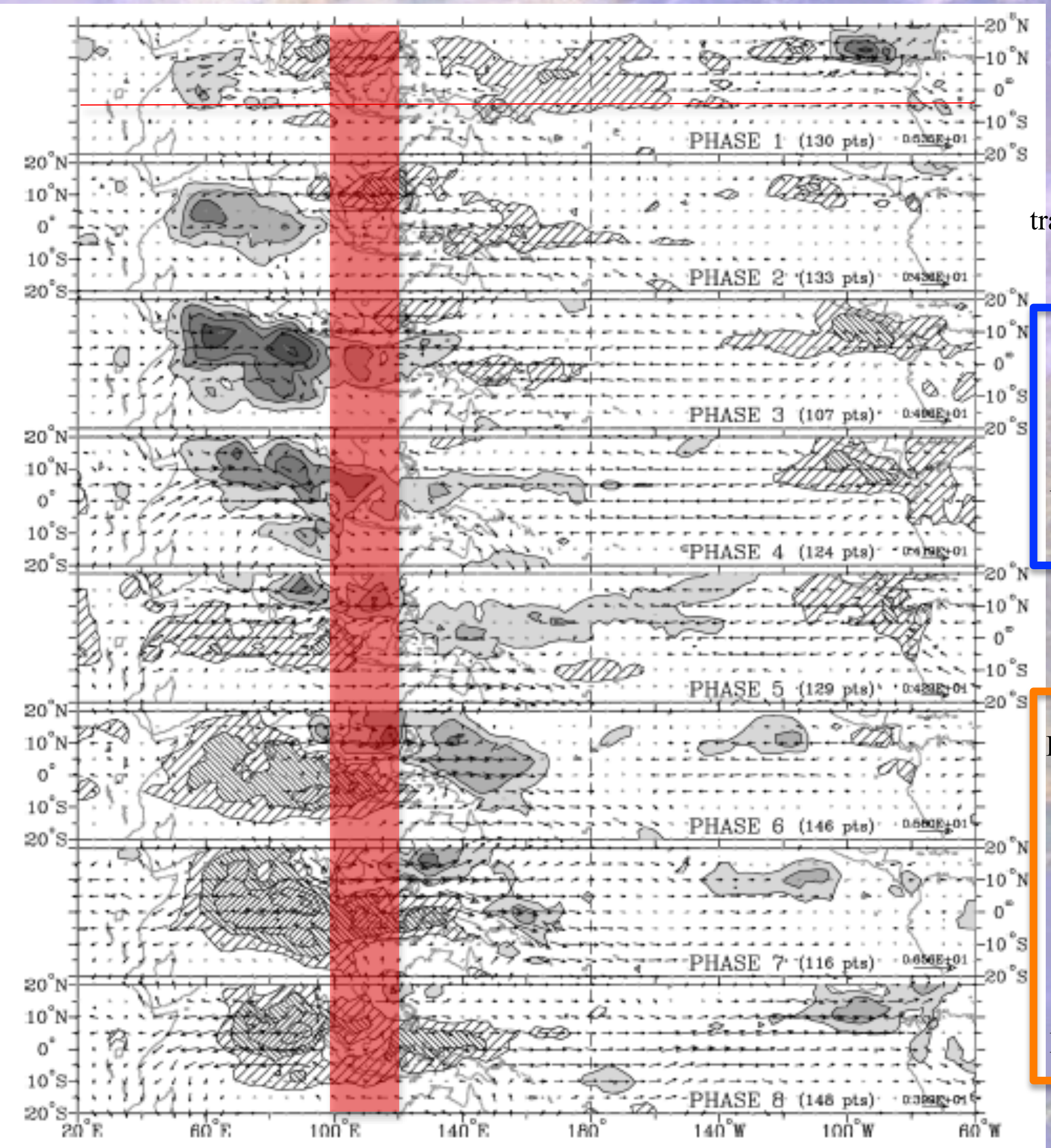


FIG. 9. As in Fig. 8, except for the MJ composite.

trans

trans

trans / WET

WET

trans / DRY

DRY

DRY

DRY

Indonesia shown in red; categories shown at right

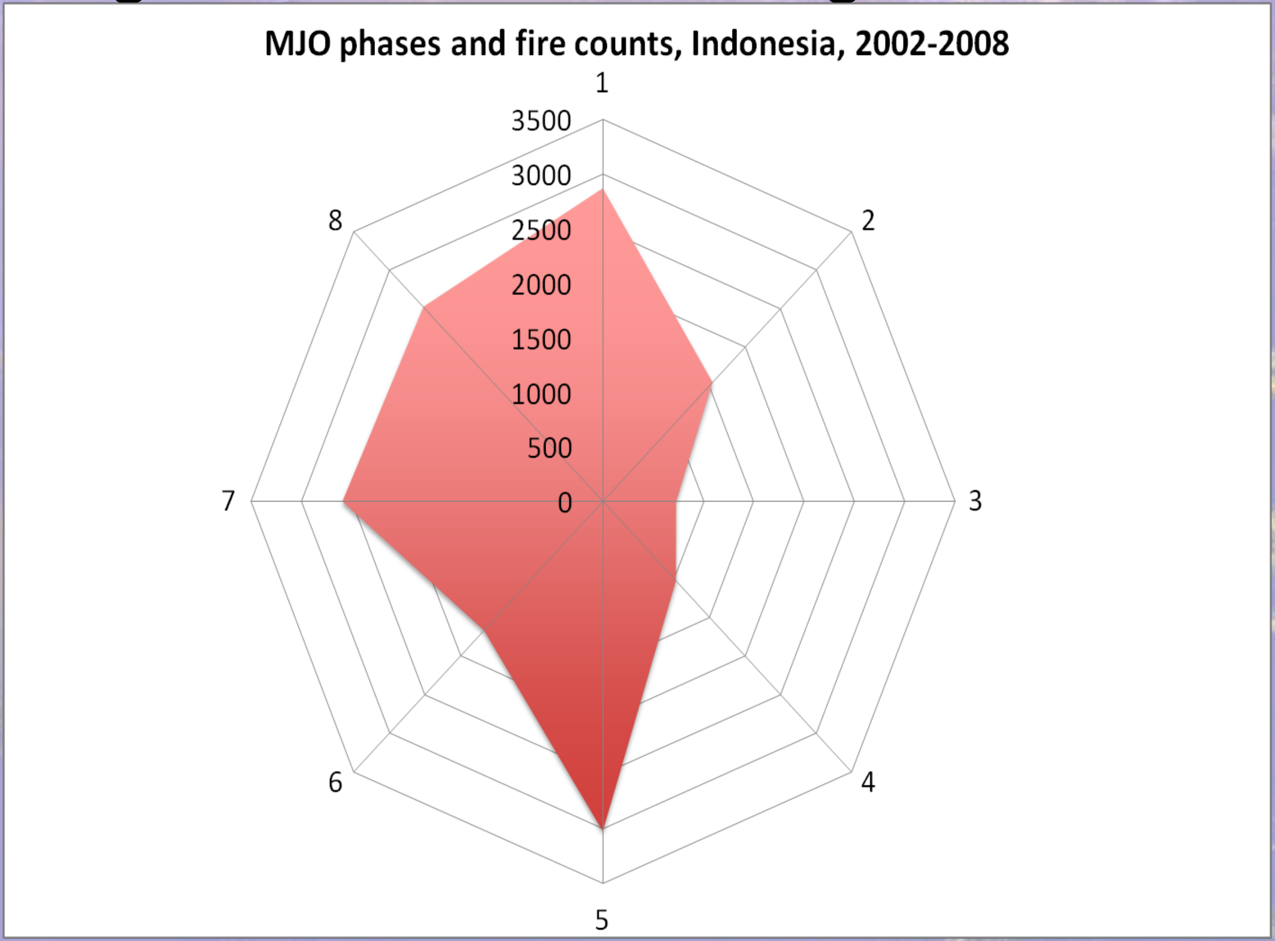
Negative OLR anomaly = enhanced convection (precipitation)

Phases 3 and 4 are "wet"

Phases 6, 7, 8 are "dry"

Results: MJO Phase and Fire Counts

- We binned all fire counts in the years 2002-2008 according to the MJO Phase assigned to that day



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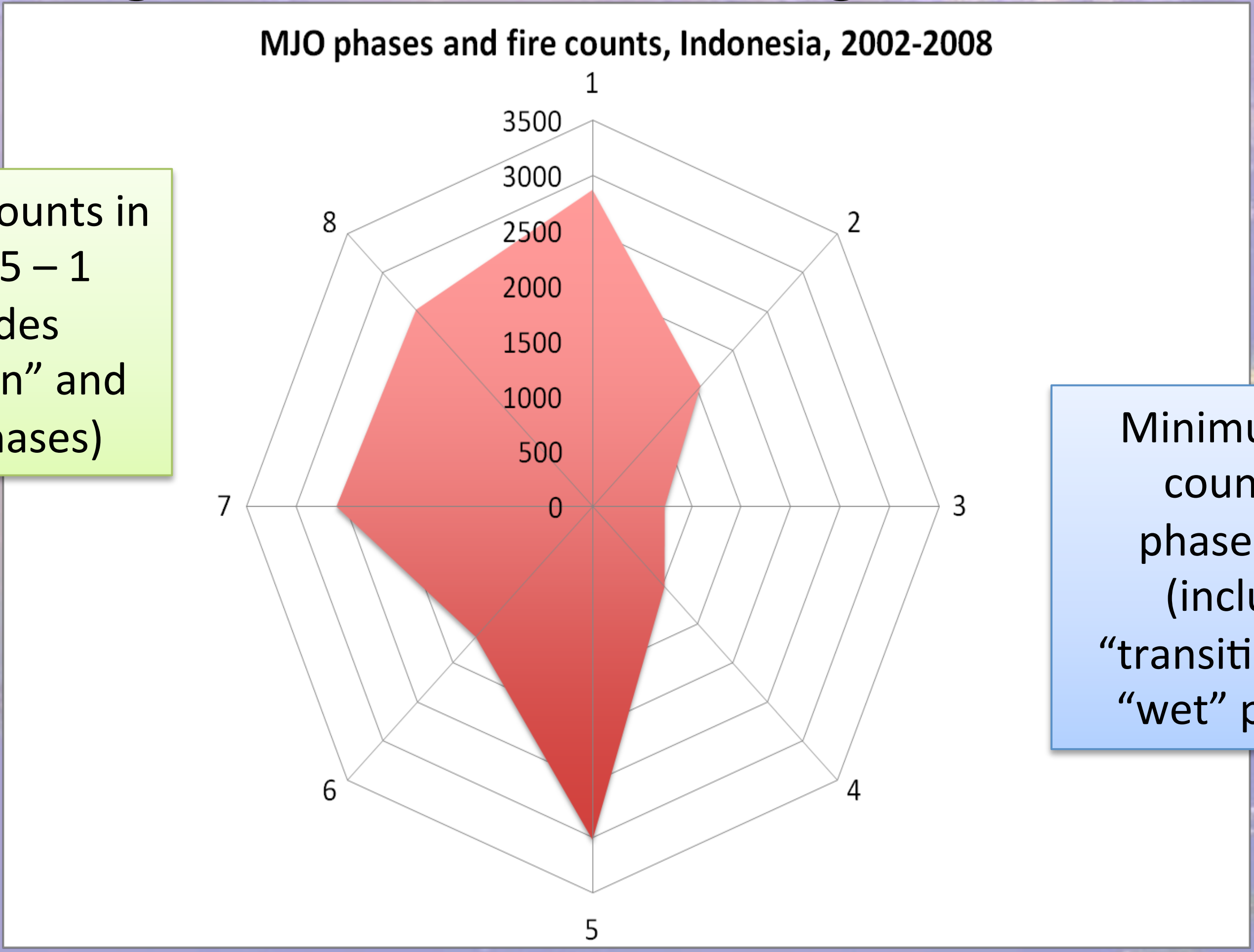

MJO phases and fire counts, Indonesia, 2002-2008

Peak fire counts in phases 5 – 1 (includes "transition" and "dry" phases)

Minimum fire counts in phases 2 – 4 (includes "transition" and "wet" phases)

Conclusions

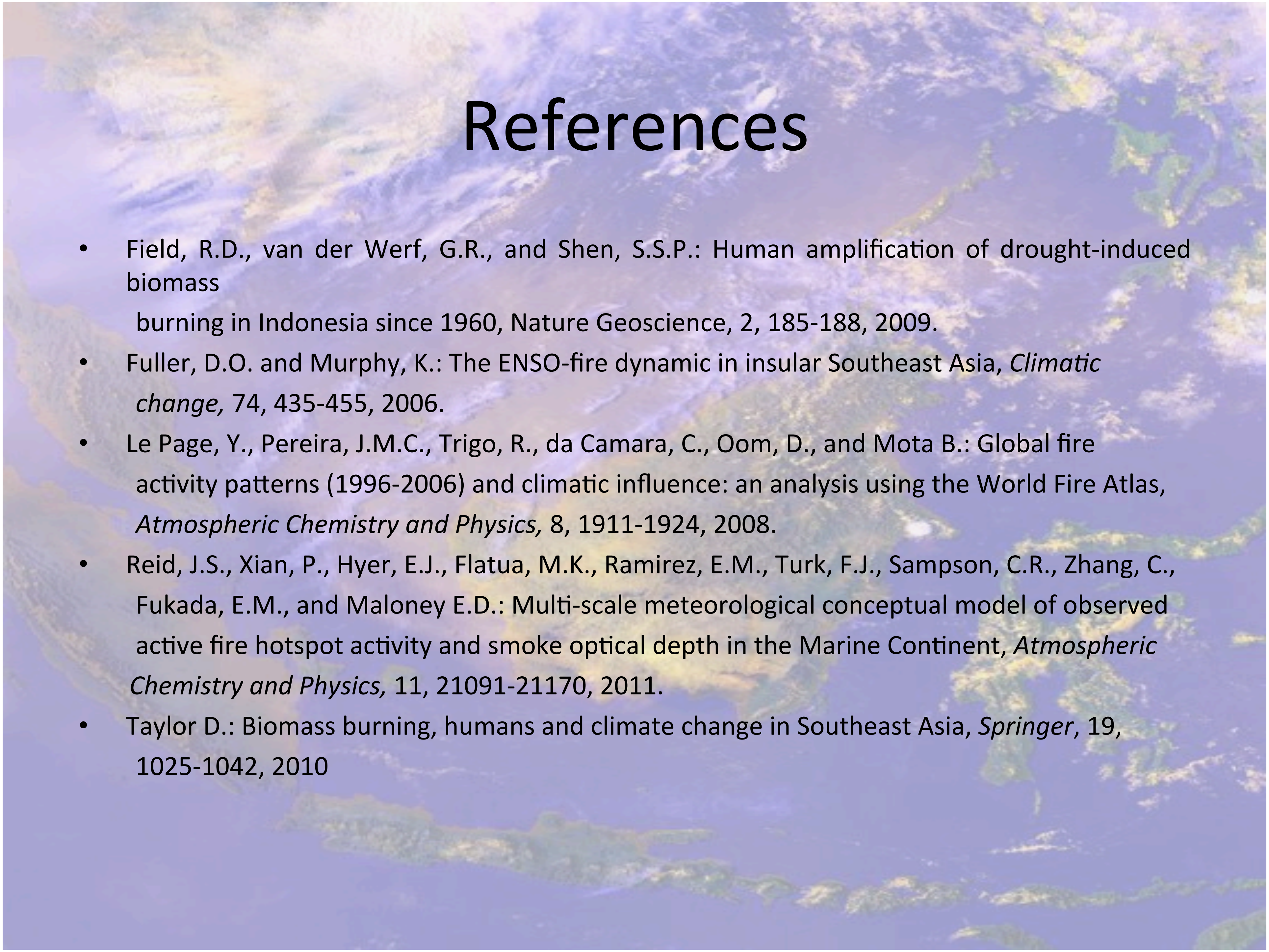
- We found a strong relationship between the SOI and satellite-derived fire counts, and MEI and satellite-derived fire counts for the SE Asia locations considered
  - Strong influence on **interannual** variability in fires
- This relationship is expected because when El Niño is present, a decrease in cloud formation over Indonesia occurs, often associated with drought
- Certain phases of the MJO are also strongly associated with decreased rainfall and dry conditions in Indonesia. Therefore, we expected to see fire counts increase during those phases, and our findings thus far are consistent with this expectation
  - Strong influence on **month-to-month variability** in fires within the "fire season"
  - MJO and ENSO not completely independent, so further relationships may exist that can be explored with these data sets
  - Should also process more years of data to ensure this signal is robust

Future work

- To improve the MJO analysis we have to increase the number of years in the study.
- Otherwise, in the ENSO index cases, we could do a quantitative analysis to know the exact correlation of the fire counts with El Niño.

Acknowledgements

- The following WebPages for their data sets:
  - http://wfaa-dat.esrin.esa.int/
  - http://cawcr.gov.au/staff/mwheeler/maproom/RMM/index.htm
  - http://www.bom.gov.au/climate/current/soihtm1.shtml
- This work has been supported by the National Science Foundation Science and Technology Center for Multi-Scale Modeling of Atmospheric Processes, managed by Colorado State University under cooperative agreement No. ATM-0425247.



References

- Field, R.D., van der Werf, G.R., and Shen, S.S.P.: Human amplification of drought-induced biomass burning in Indonesia since 1960, Nature Geoscience, 2, 185-188, 2009.
- Fuller, D.O. and Murphy, K.: The ENSO-fire dynamic in insular Southeast Asia, *Climatic change,* 74, 435-455, 2006.
- Le Page, Y., Pereira, J.M.C., Trigo, R., da Camara, C., Oom, D., and Mota B.: Global fire activity patterns (1996-2006) and climatic influence: an analysis using the World Fire Atlas, *Atmospheric Chemistry and Physics,* 8, 1911-1924, 2008.
- Reid, J.S., Xian, P., Hyer, E.J., Flatua, M.K., Ramirez, E.M., Turk, F.J., Sampson, C.R., Zhang, C., Fukada, E.M., and Maloney E.D.: Multi-scale meteorological conceptual model of observed active fire hotspot activity and smoke optical depth in the Marine Continent, *Atmospheric Chemistry and Physics,* 11, 21091-21170, 2011.
- Taylor D.: Biomass burning, humans and climate change in Southeast Asia, *Springer*, 19, 1025-1042, 2010

Questions