Inter-Annual Variability of Tropical and Subtropical Lightning Production from TRMM LIS: Locations, Magnitudes, and Mechanisms

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Key Questions

- Where and why does inter-annual lightning variability exist?
  - Relations to normal environmental cycles?
  - Why here and not there?
  - Patterns vs outliers
- Can environmental data be used to explain the observed lightning patterns?

Plan and Approach

1. Identify locations with inter-annual lightning variability using TRMM LIS
   - TRMM LIS study area ± 38° from April 1998 to March 2014
2. Describe and quantify the lightning activity at those locations
3. Compare lightning and environmental patterns

Study Data

- Low Resolution Time Series (LRTS) from the "Gridded Lightning Climatology from TRMM LIS and OTD"
  - Seasonally smoothed lightning time series
- Model reanalysis data from the NCEP/NCAR 40 Year Reanalysis Project
- Precipitation data from the TRMM Multi-Satellite Precipitation Analysis (TMPA) 3B42 dataset
- Oceanic Niño Index (ONI)

El-Niño/Southern Oscillation

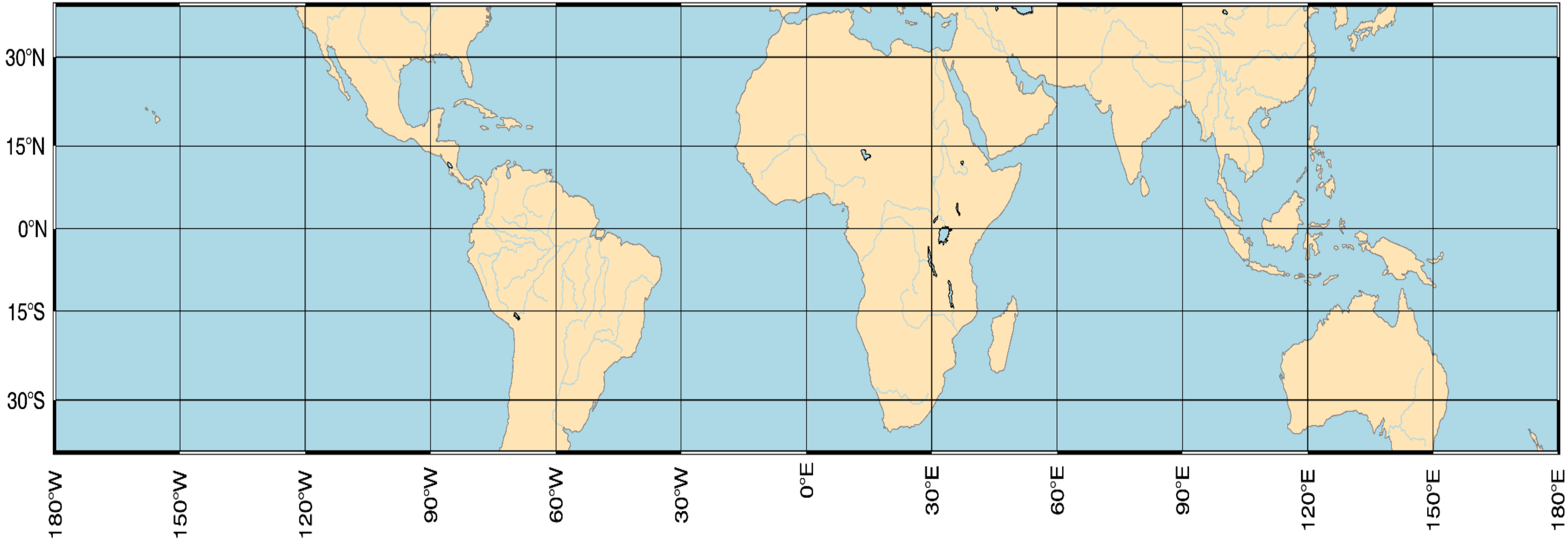
- Strongest impact on inter-annual atmospheric variability
- ONI for ENSO Phase
- Used "ENSO Years" (EYR)s to split data
- 16 EYRs split into:
  - 8 cold phase years*
  - 4 warm phase years
  - 4 neutral phase years

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
1997	-0.5	-0.4	-0.1	0.3	0.8	1.2	1.6	1.9	2.1	2.3	2.4	2.4
1998	2.2	1.9	1.4	1	0.5	-0.1	-0.8	-1.1	-1.3	-1.4	-1.5	-1.6
1999	-1.5	-1.3	-1.1	-1	-1	-1	-1.1	-1.1	-1.2	-1.3	-1.5	-1.7
2000	-1.7	-1.4	-1.1	-0.8	-0.7	-0.6	-0.6	-0.5	-0.5	-0.6	-0.7	-0.7
2001	-0.7	-0.5	-0.4	-0.3	-0.3	-0.1	-0.1	-0.1	-0.2	-0.3	-0.3	-0.3
2002	-0.1	0	0.1	0.2	0.4	0.7	0.8	0.9	1	1.2	1.3	1.1
2003	0.9	0.6	0.4	0	-0.3	-0.2	0.1	0.2	0.3	0.3	0.4	0.4
2004	0.4	0.3	0.2	0.2	0.2	0.3	0.5	0.6	0.7	0.7	0.7	0.7
2005	0.6	0.6	0.4	0.4	0.3	0.1	-0.1	-0.1	-0.1	-0.3	-0.6	-0.8
2006	-0.8	-0.7	-0.5	-0.3	0	0	0.1	0.3	0.5	0.7	0.9	0.9
2007	0.7	0.3	0	-0.2	-0.3	-0.4	-0.5	-0.8	-1.1	-1.4	-1.5	-1.6
2008	-1.6	-1.4	-1.2	-0.9	-0.8	-0.5	-0.4	-0.3	-0.3	-0.4	-0.6	-0.7
2009	-0.8	-0.7	-0.5	-0.2	0.1	0.4	0.5	0.5	0.7	1	1.3	1.6
2010	1.5	1.3	0.9	0.4	-0.1	-0.6	-1	-1.4	-1.6	-1.7	-1.7	-1.6
2011	-1.4	-1.1	-0.8	-0.6	-0.5	-0.4	-0.5	-0.7	-0.9	-1.1	-1.1	-1
2012	-0.8	-0.6	-0.5	-0.4	-0.2	0.1	0.3	0.3	0.3	0.2	0	-0.2
2013	-0.4	-0.3	-0.2	-0.2	-0.3	-0.3	-0.4	-0.4	-0.3	-0.2	-0.2	-0.3
2014	-0.4	-0.4	-0.2	0.1	0.3	0.2	0.1	0	0.2	0.4	0.6	0.7

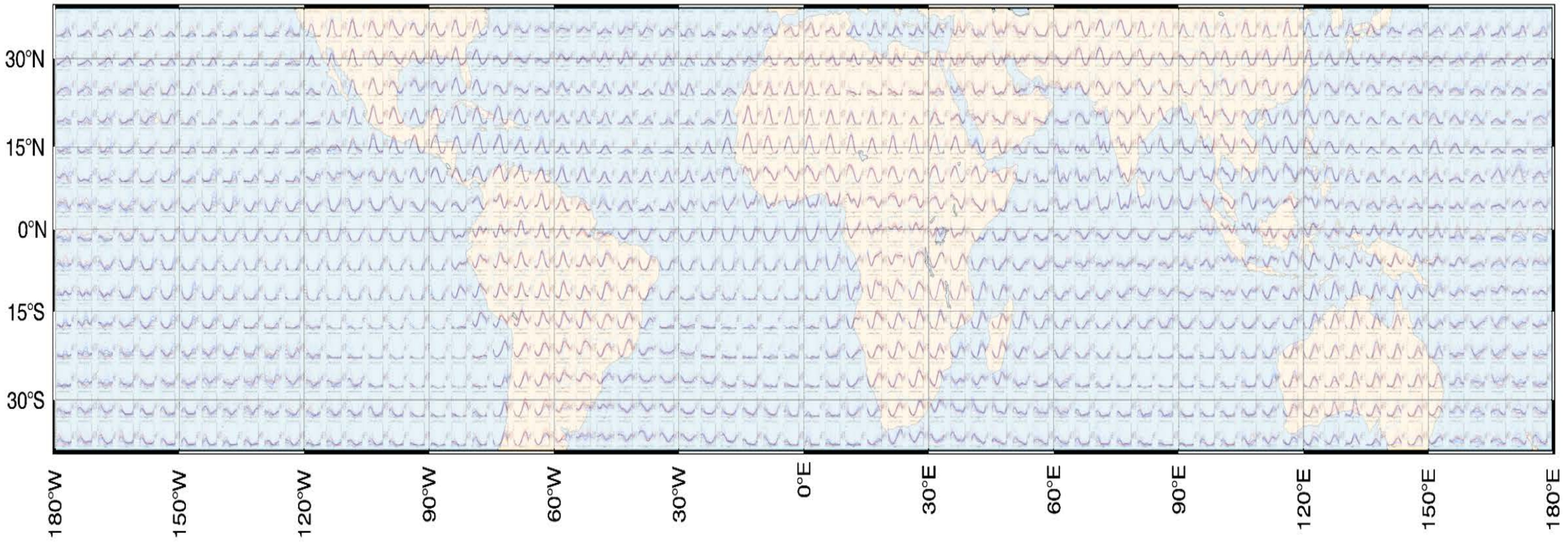
Methods

- Locations:
  - Mean Flash Density ≥ 3 Fl km^{-2} Yr^{-1}
  - Size $\geq 10° \times 10° \approx 1{,}000{,}000$ km^2
  - Spatiotemporal continuity of lightning pattern
- Describe and Quantify:
  - Anomalous years
  - Large/minimal inter-annual variability
  - ENSO phase sensitivity
  - Magnitudes
- Compare
  - Model patterns and lightning patterns over time
  - Relationship of atmospheric variables and lightning

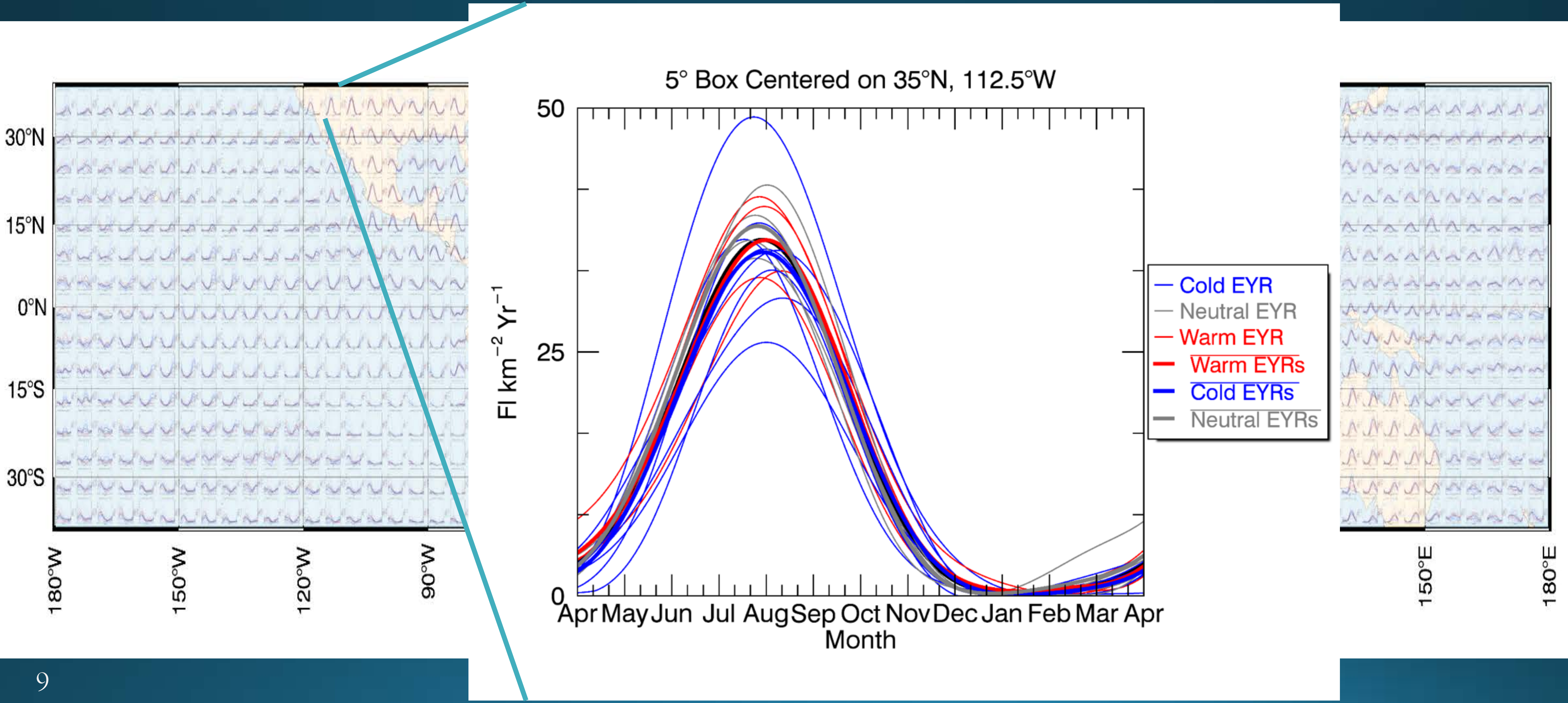
5° "Pixel" Time Series



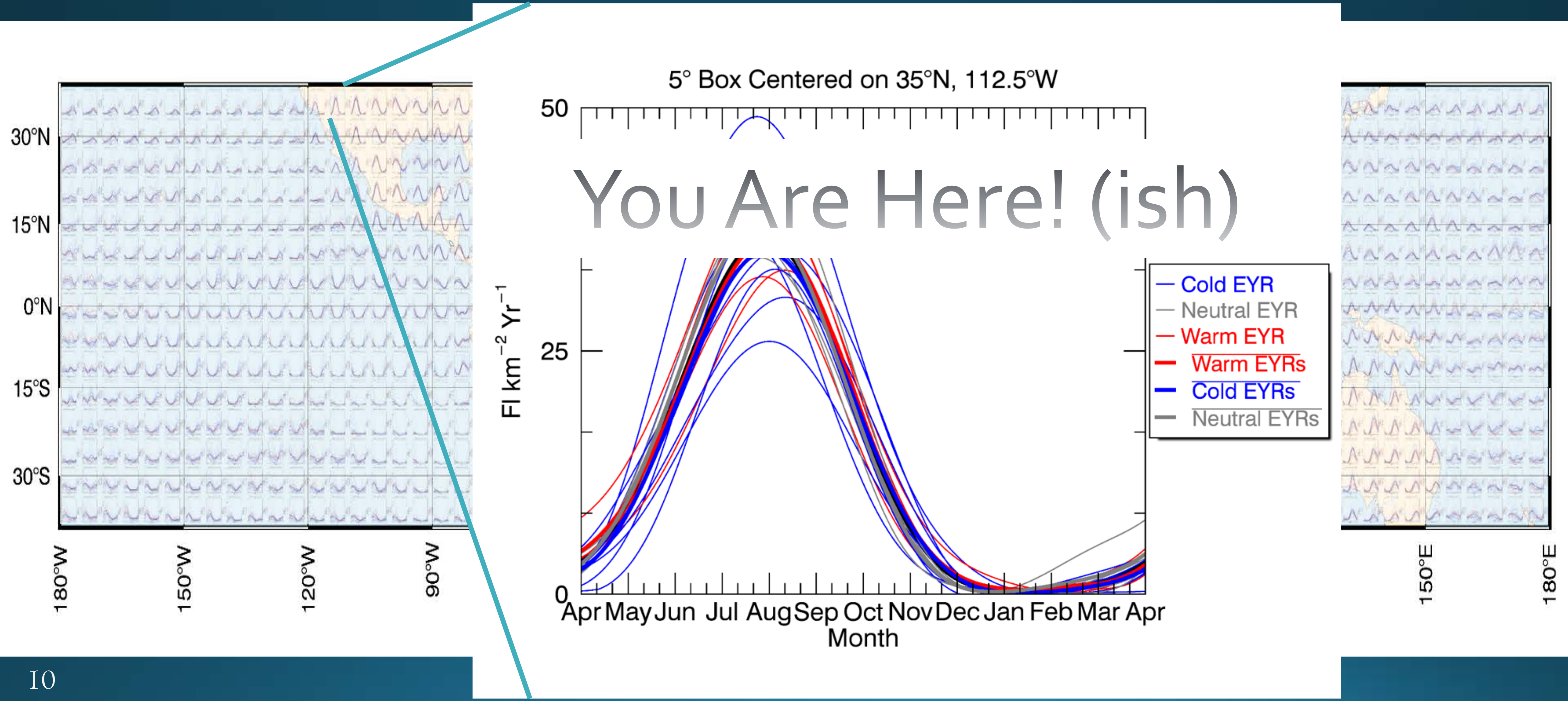
5° "Pixel" Time Series



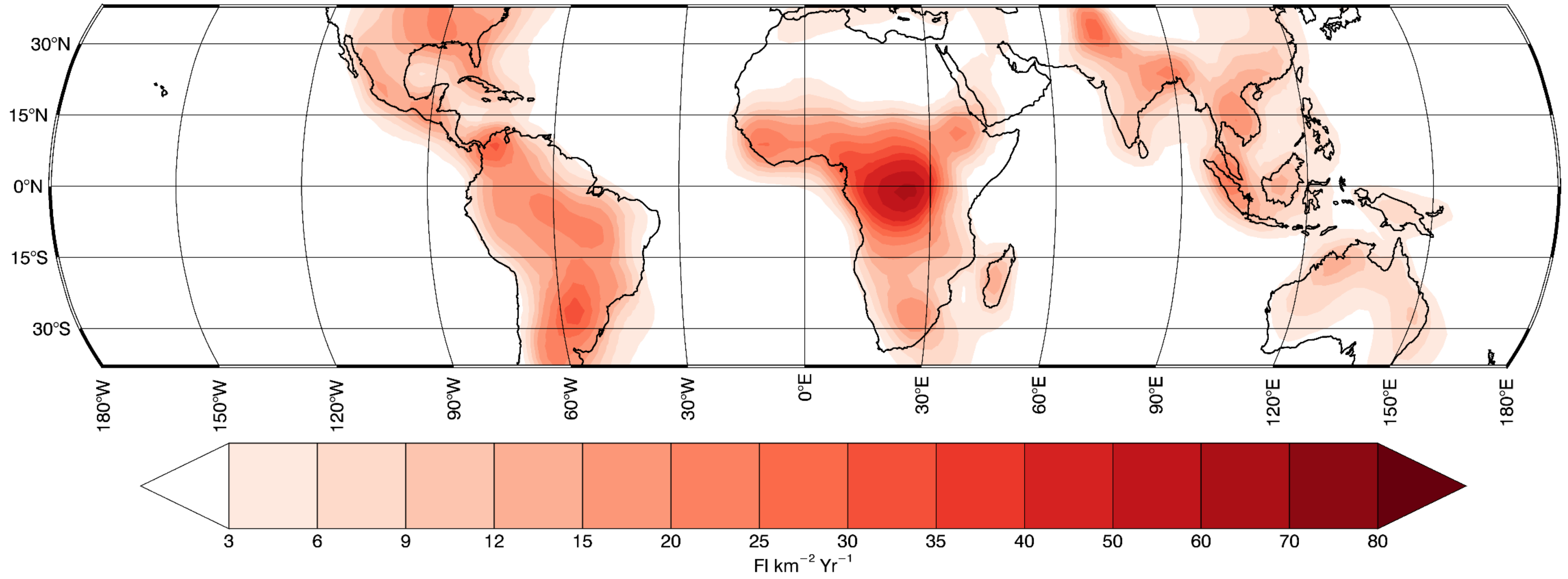
5° "Pixel" Time Series



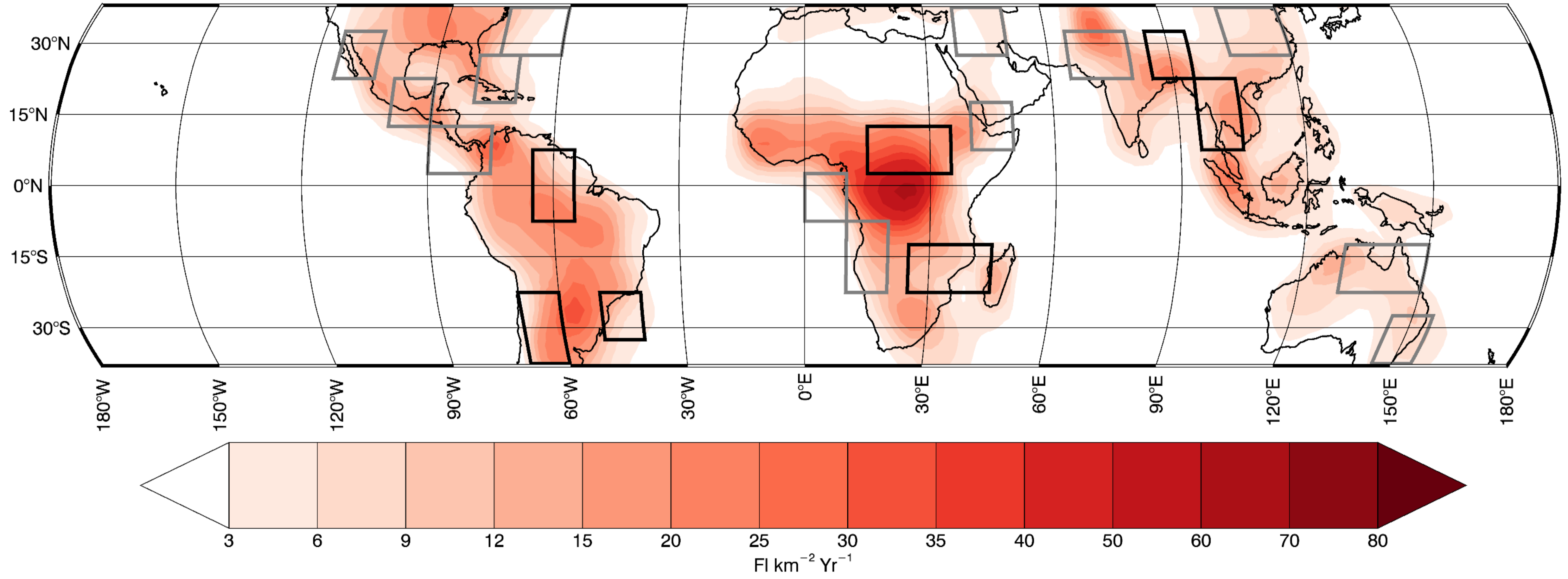
5° "Pixel" Time Series



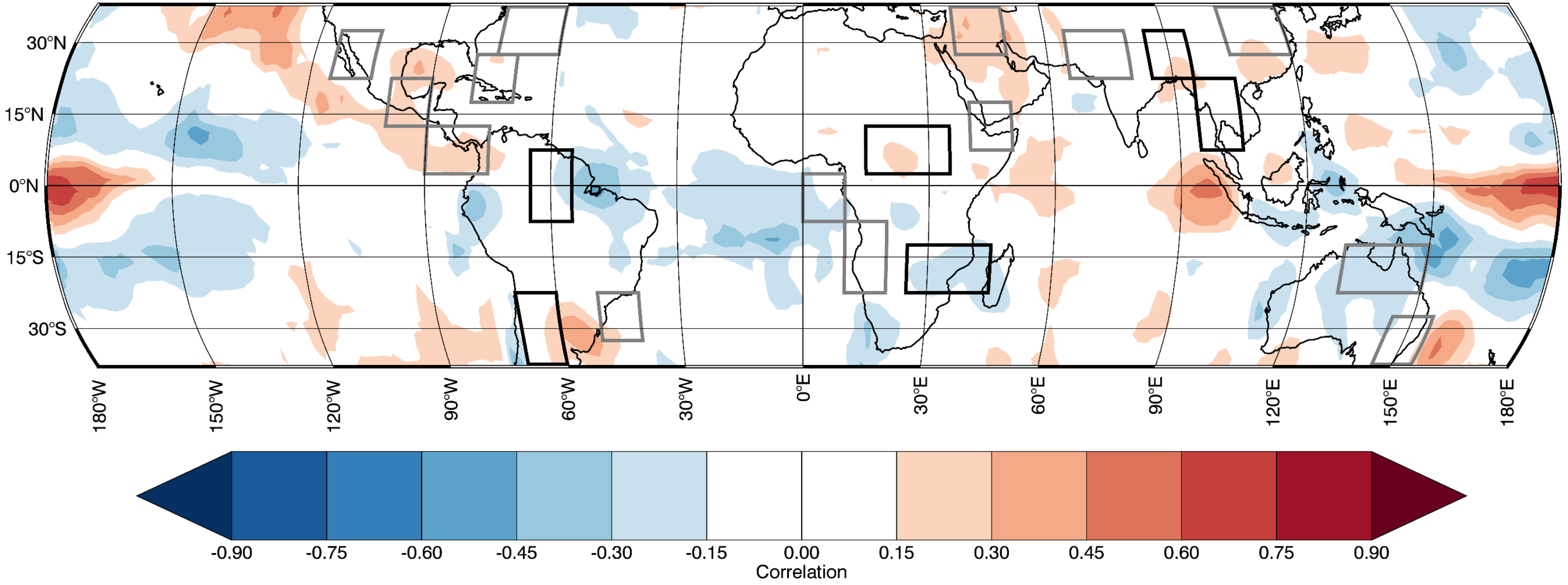
Mean Flash Climatology



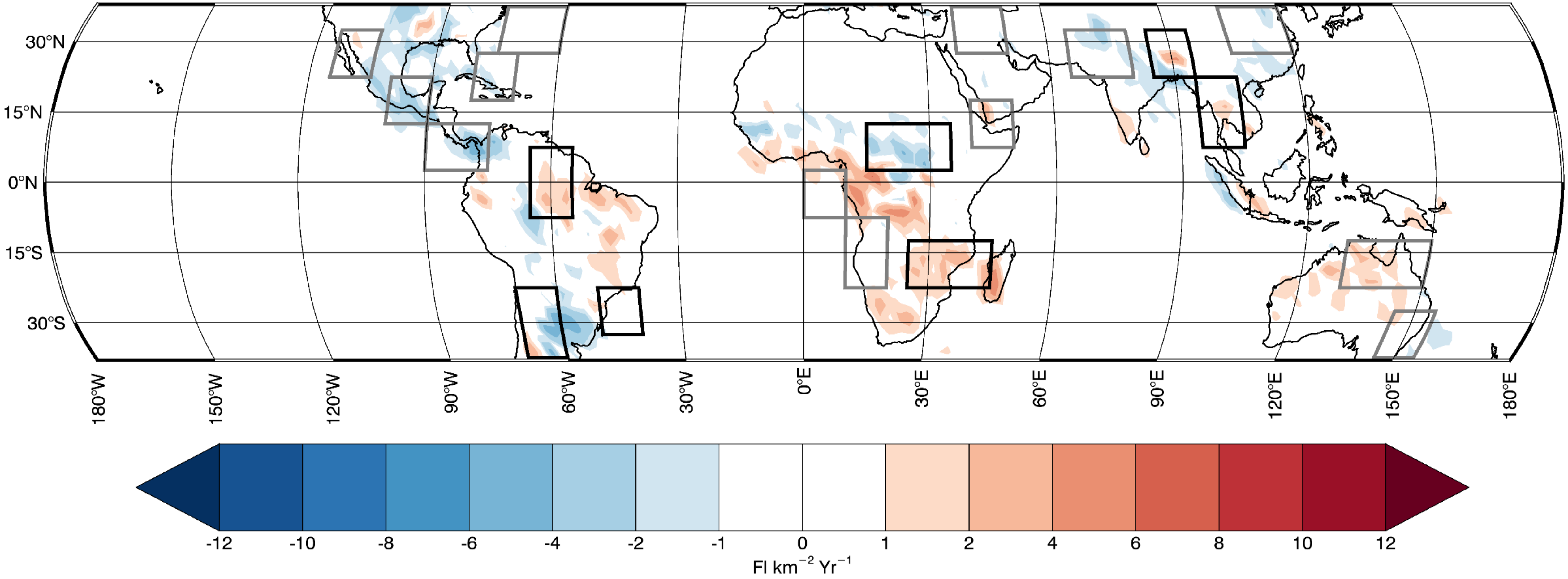
Mean Flash Climatology



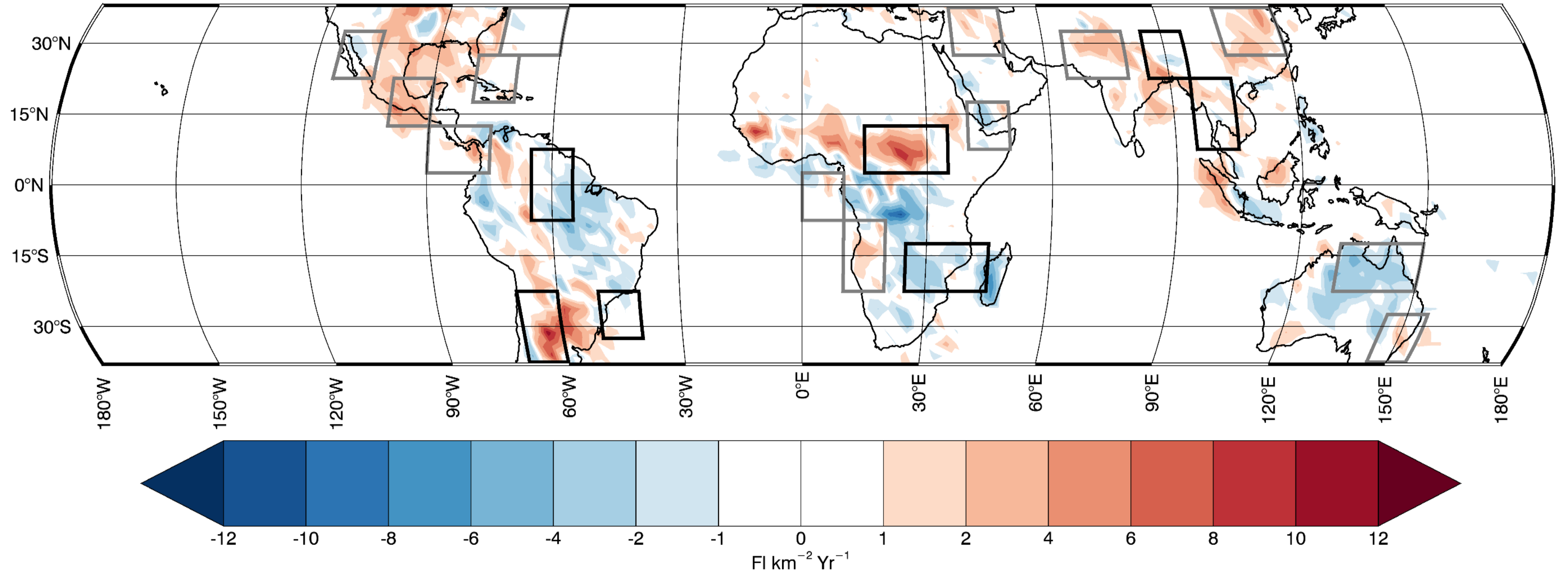
ENSO Index vs Seasonal Lightning



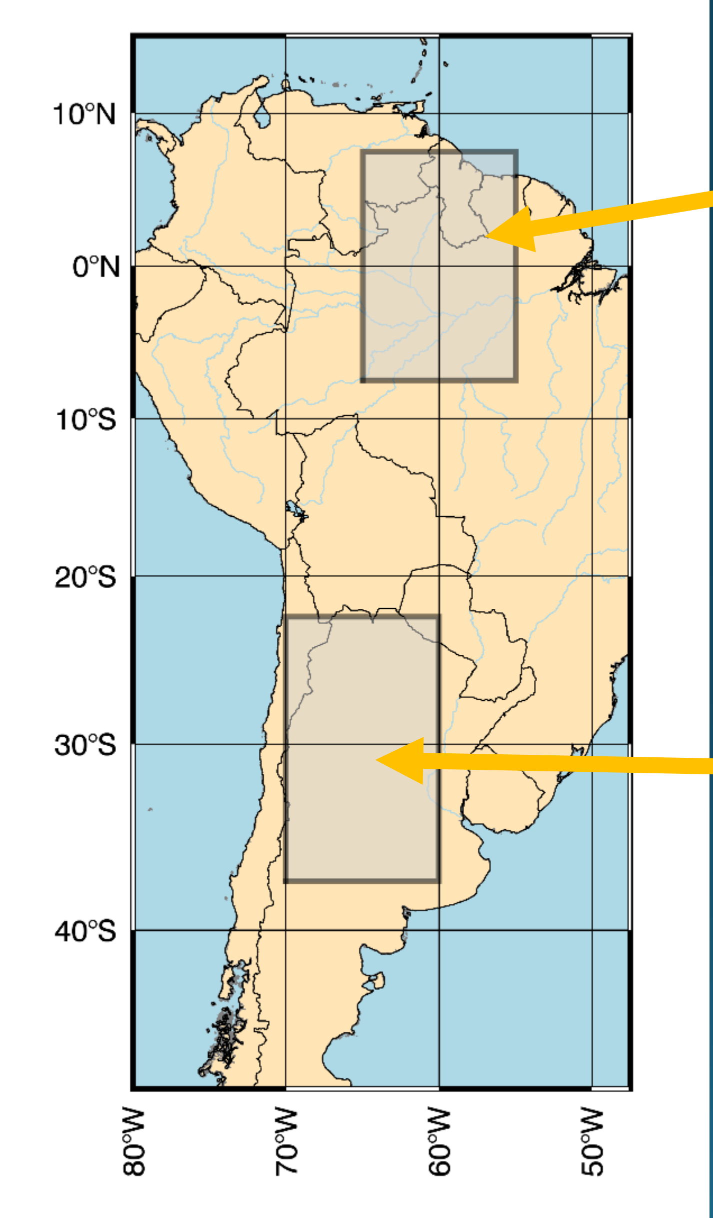
Cold Phase Flash Density Anomalies

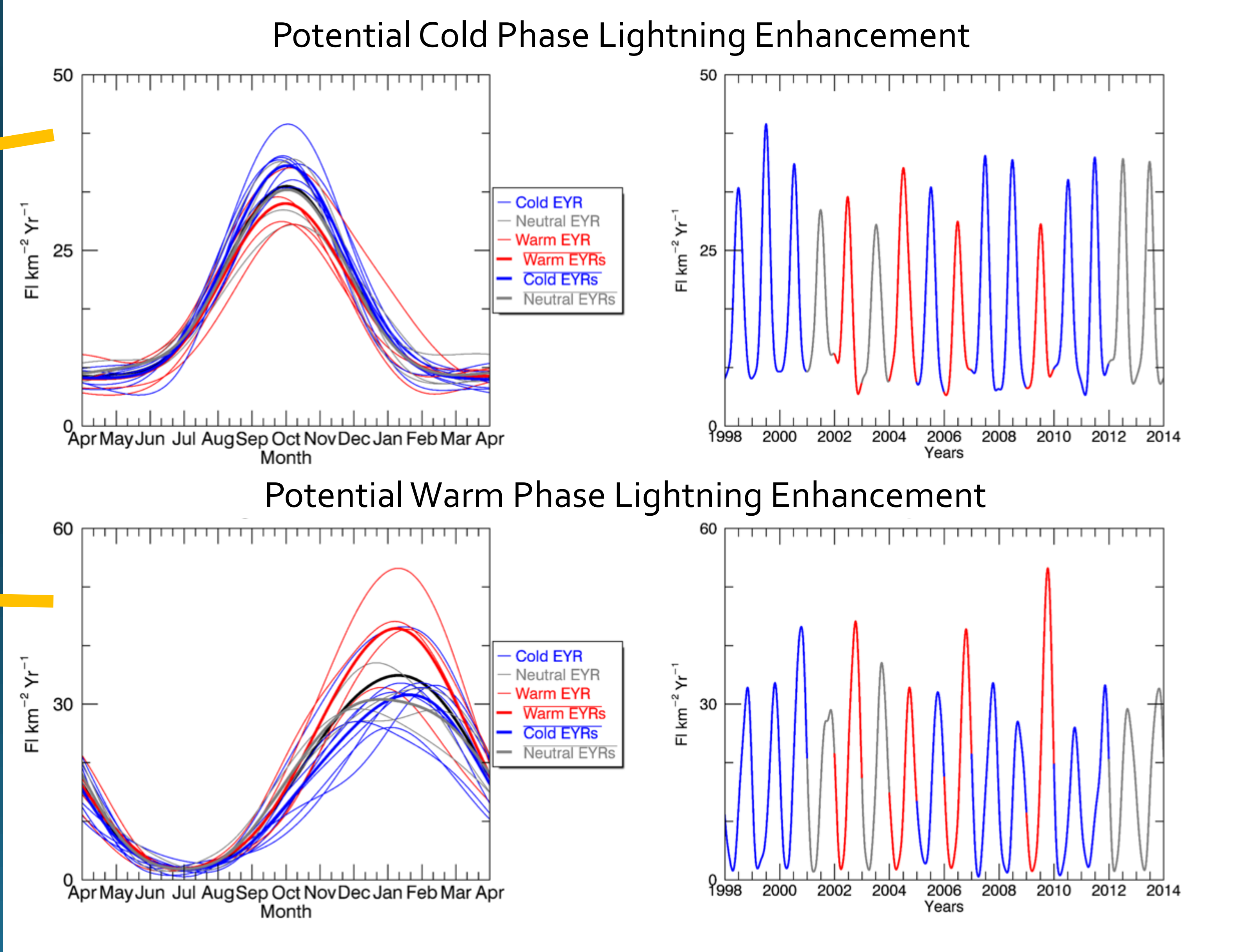


Warm Phase Flash Density Anomalies



Potential ENSO Connections





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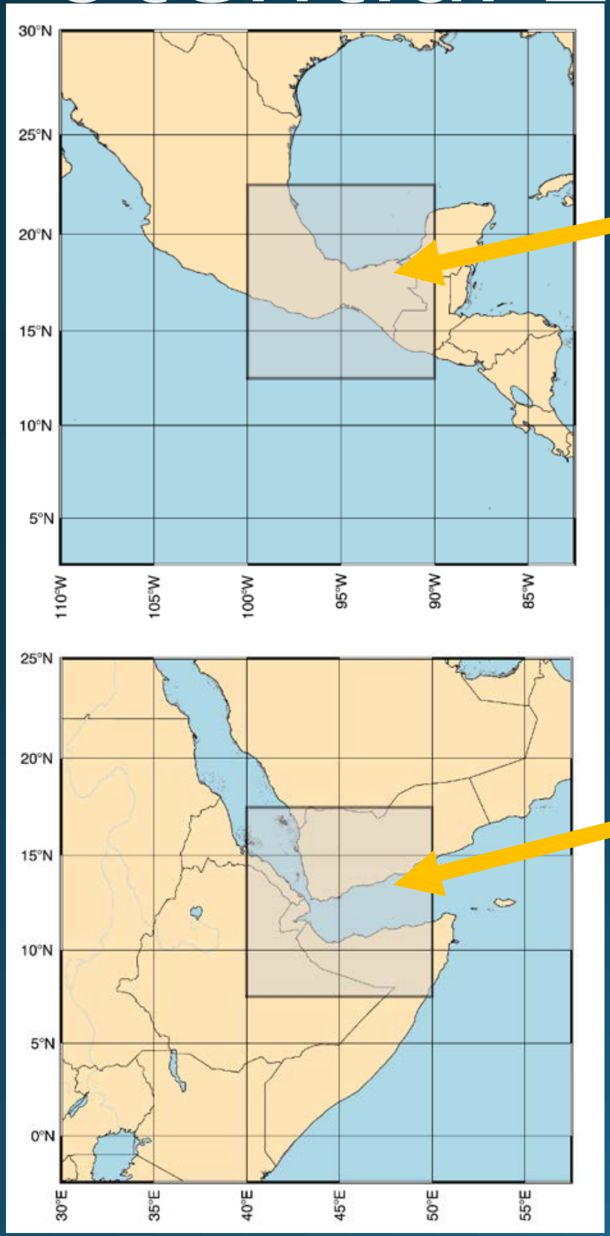
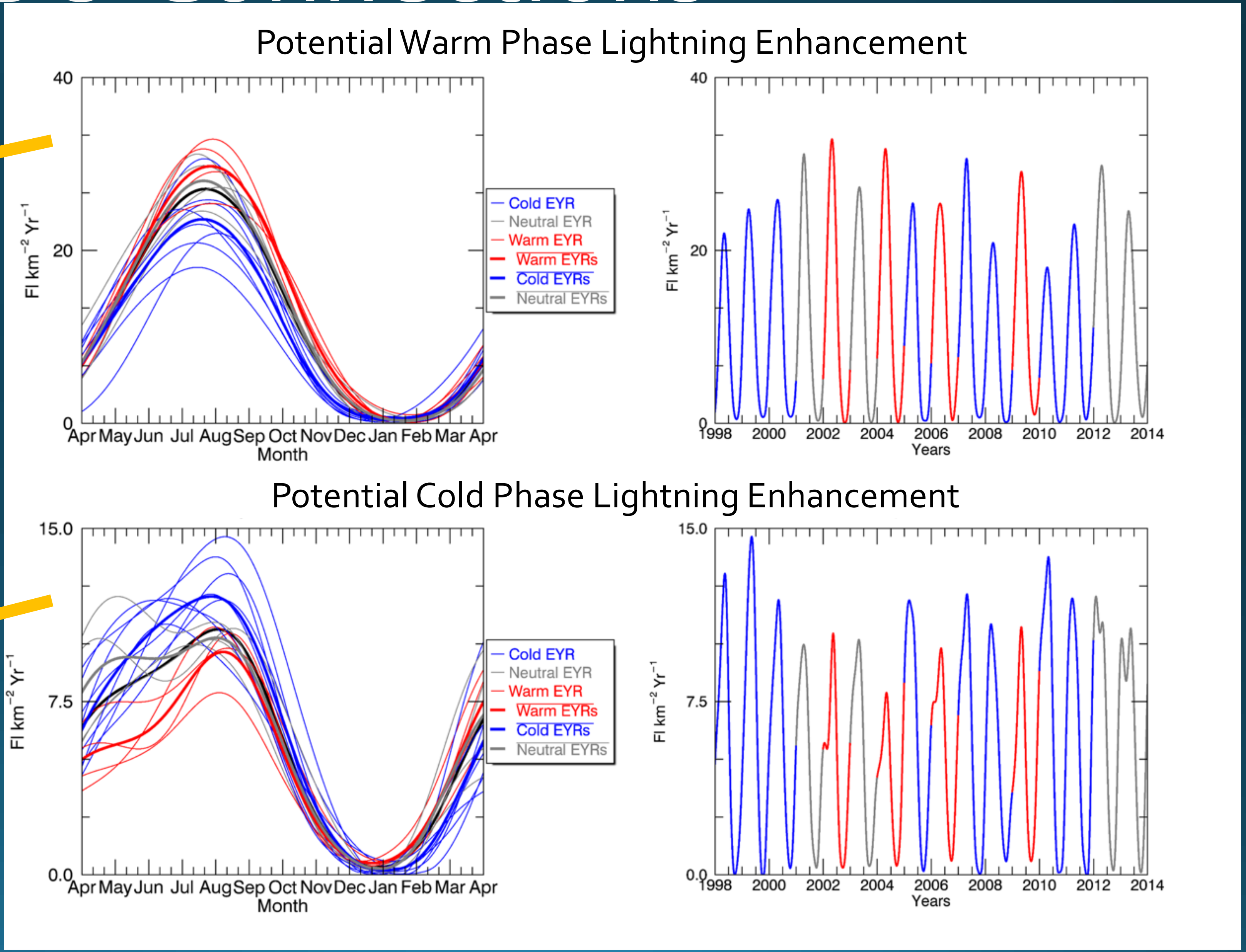
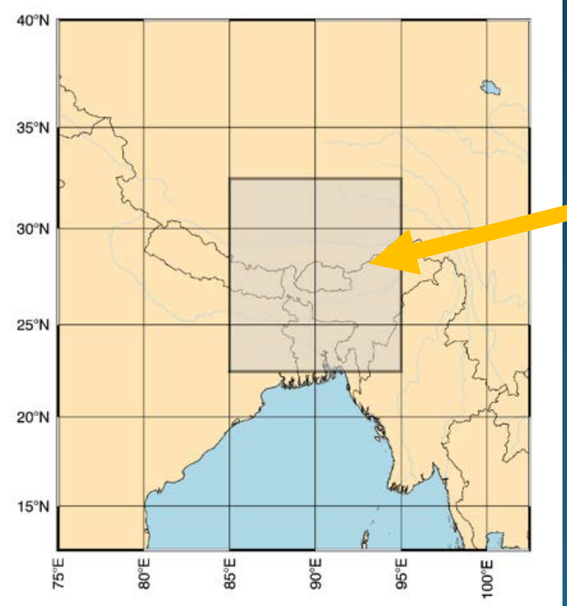
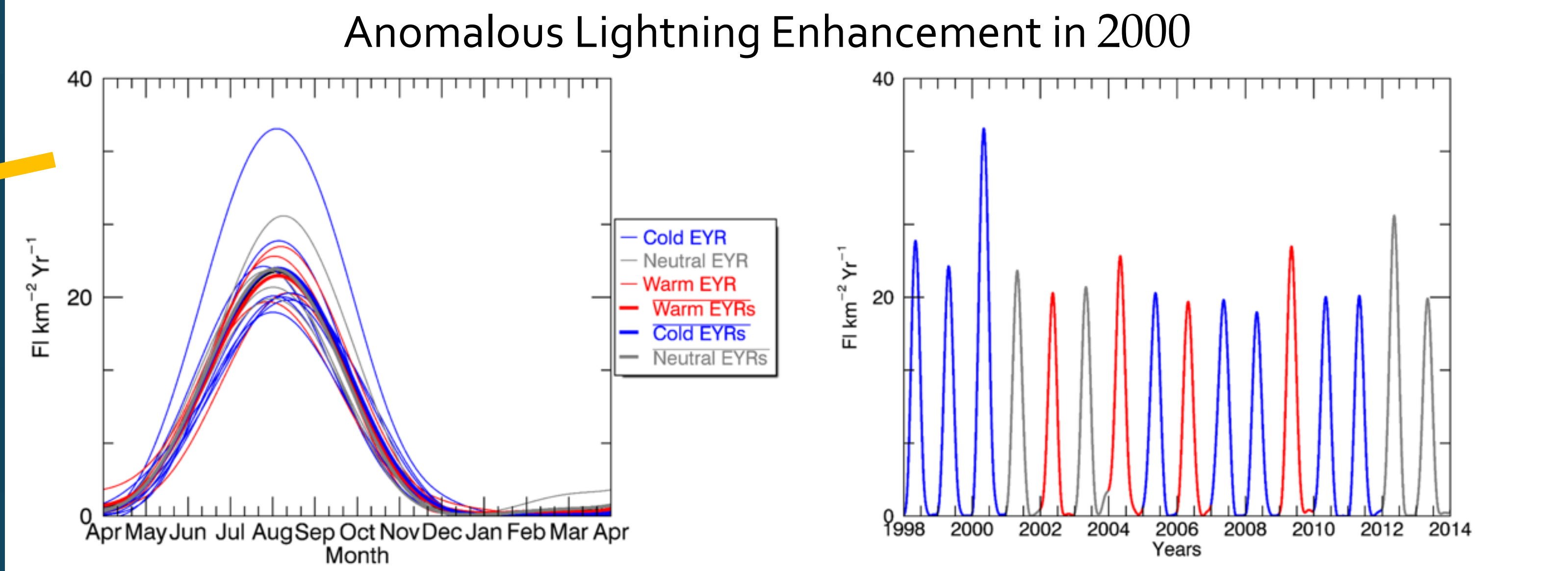
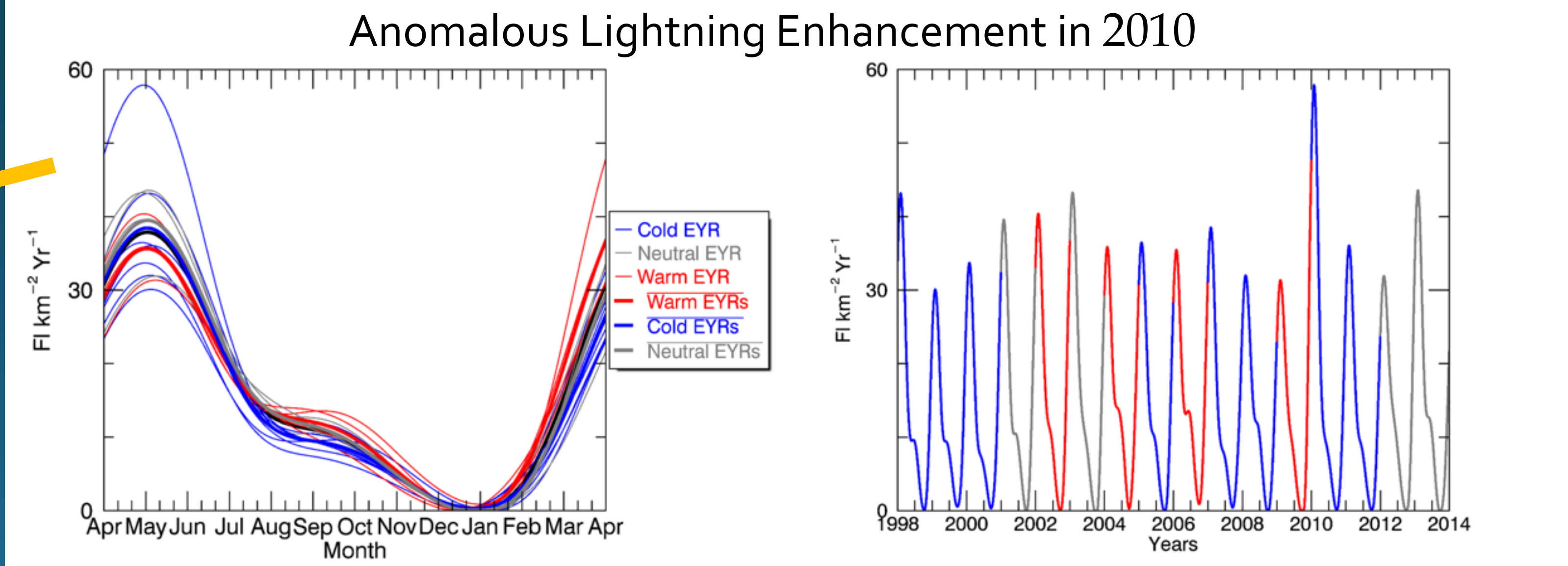




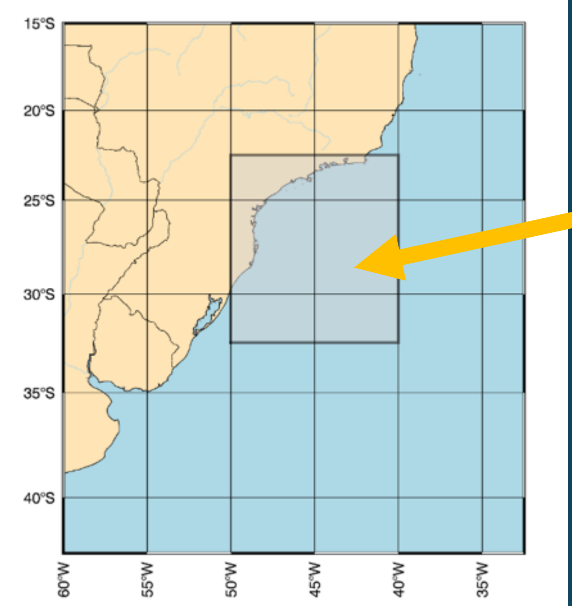
Anomalous Years

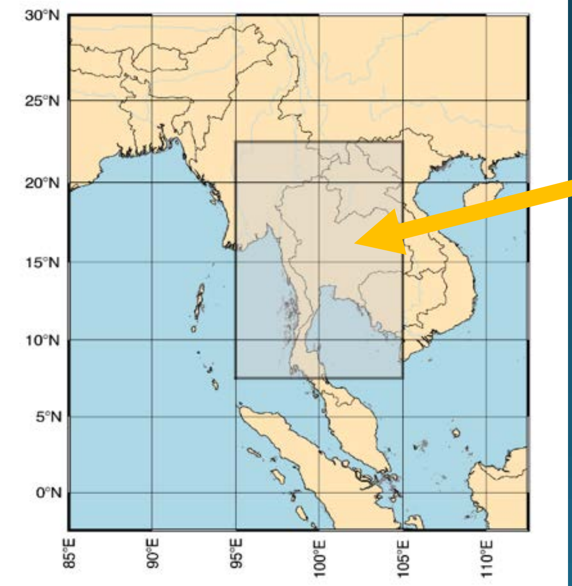


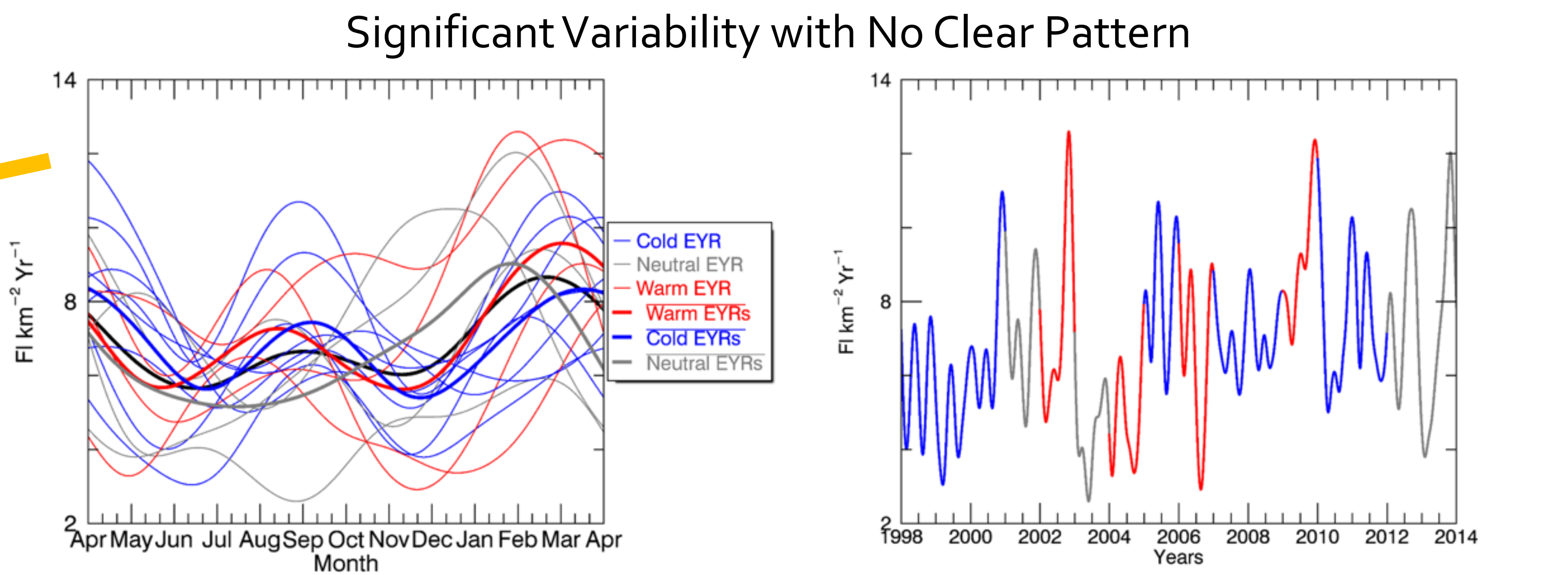


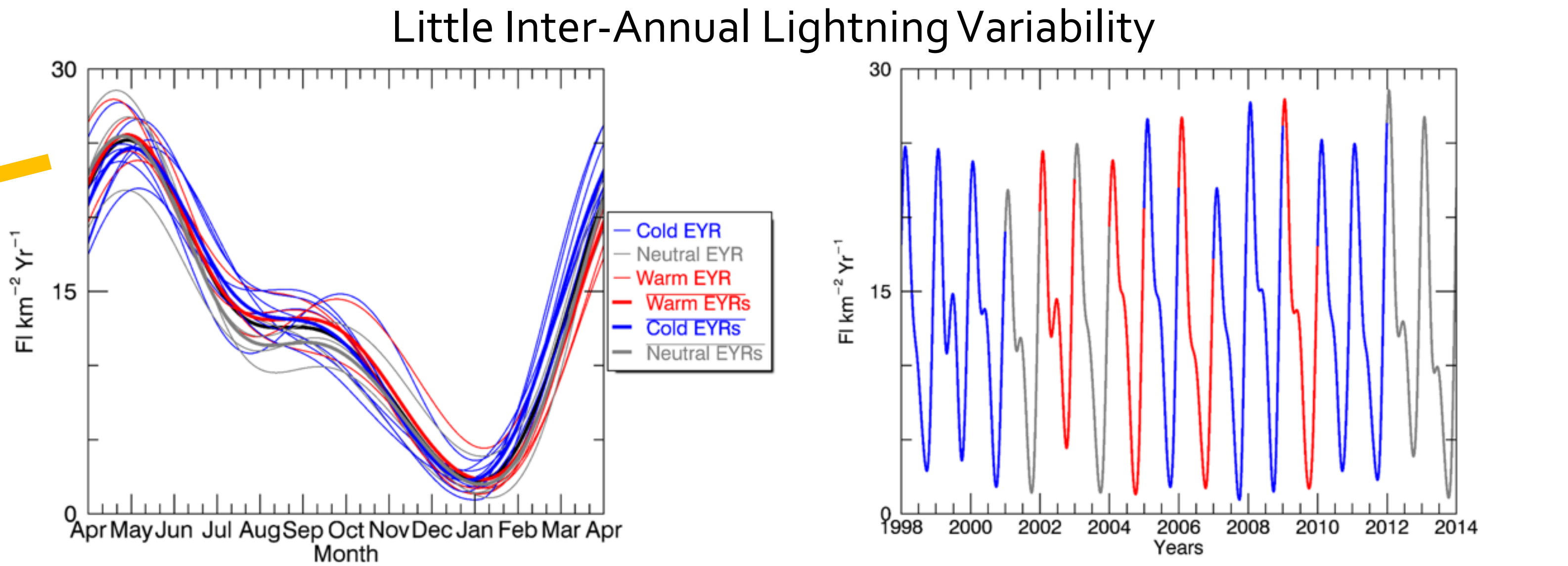


Non-ENSO Related Patterns

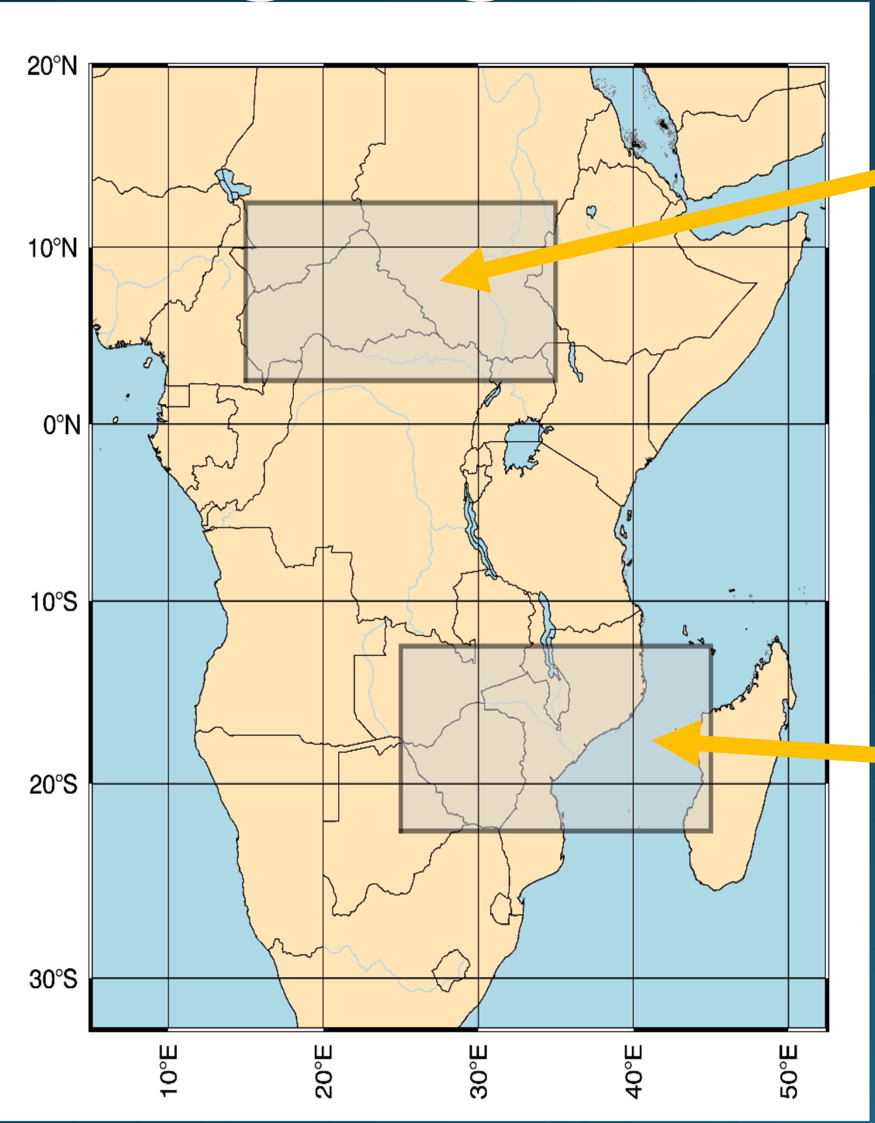


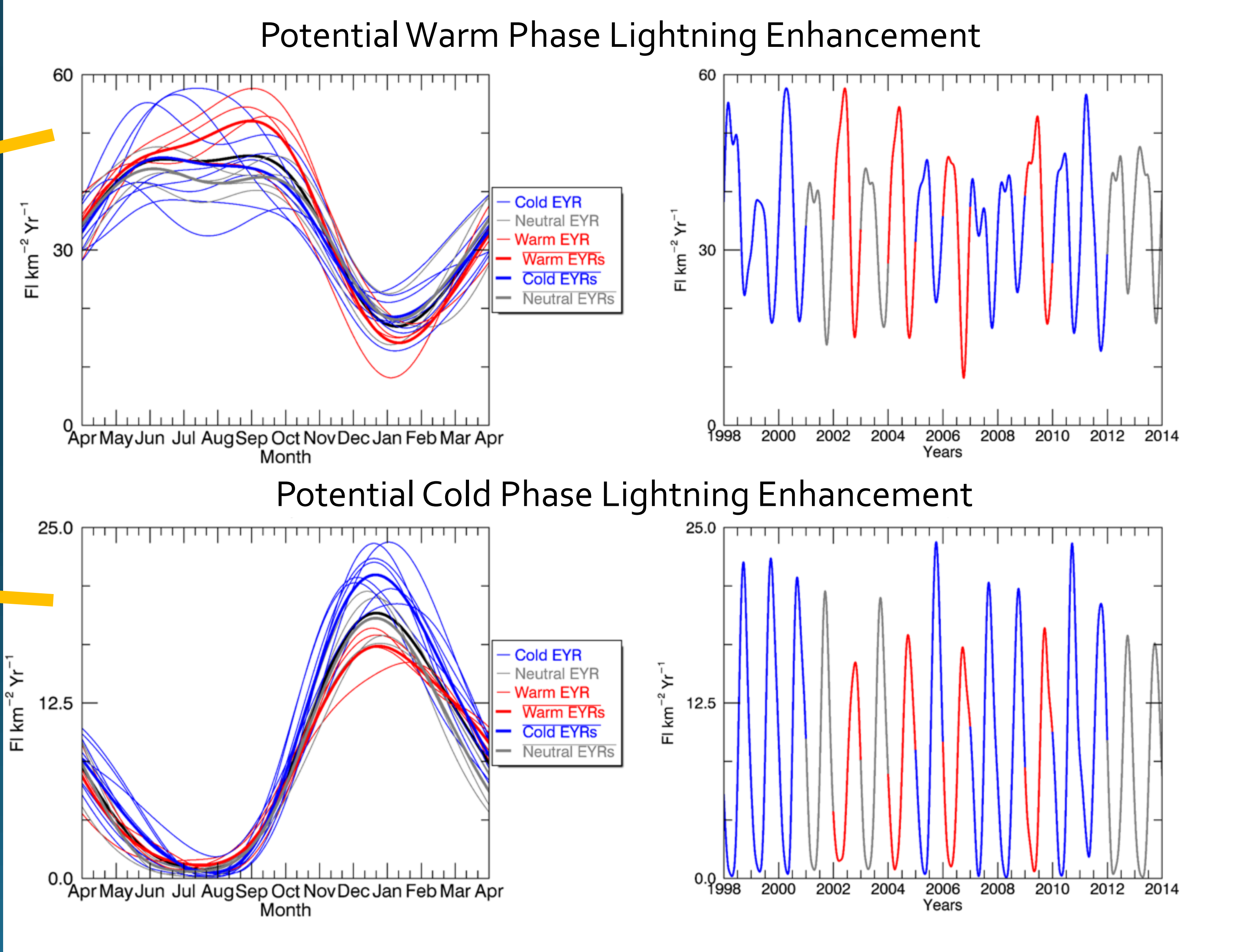






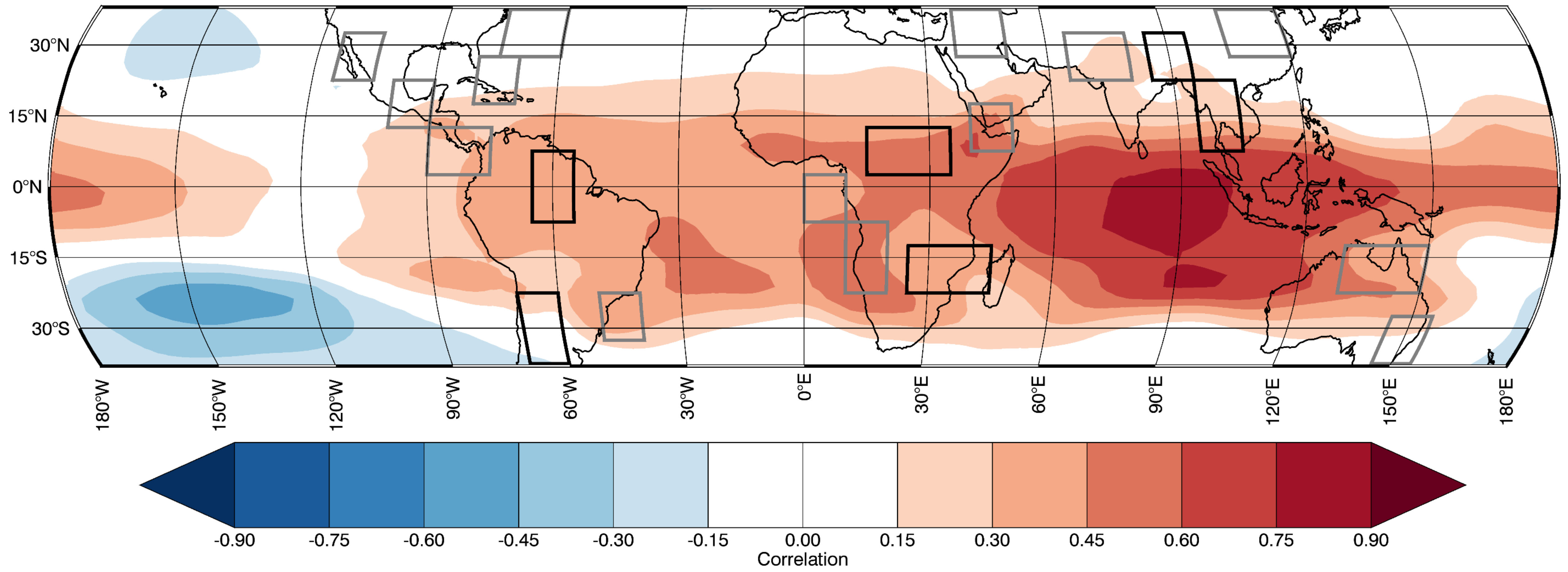
Highlighted Areas





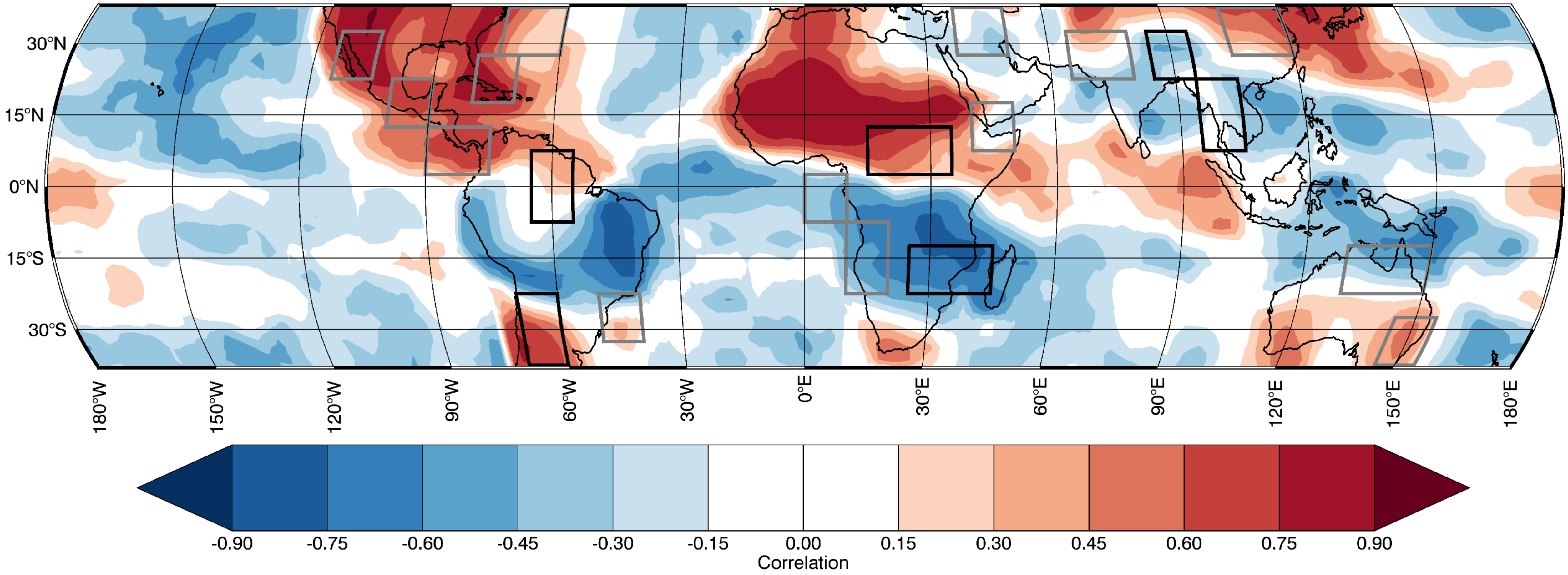
Seasonal 850hPa Height Correlations

Correlation to ENSO Index

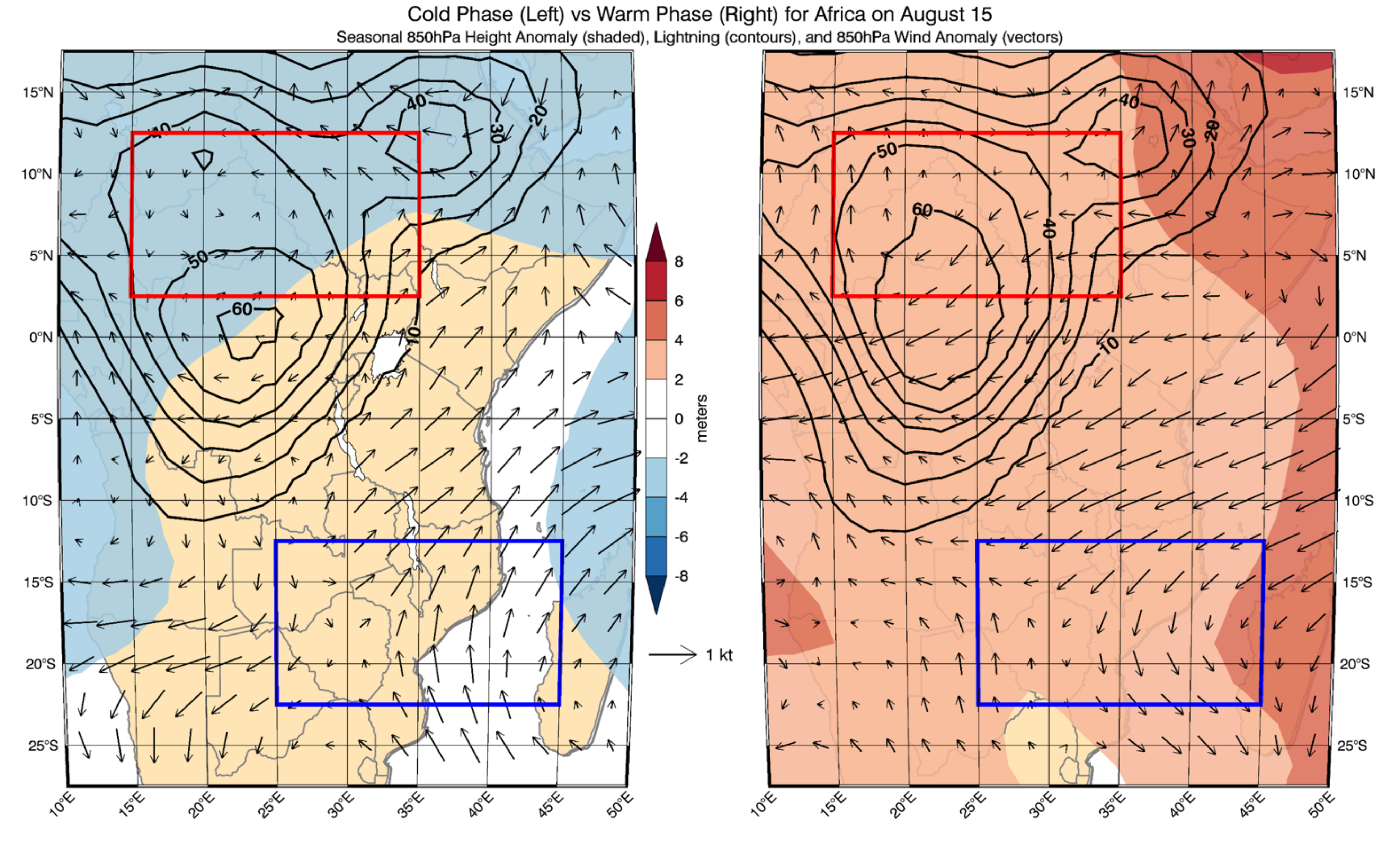


Seasonal 850hPa Height Correlations

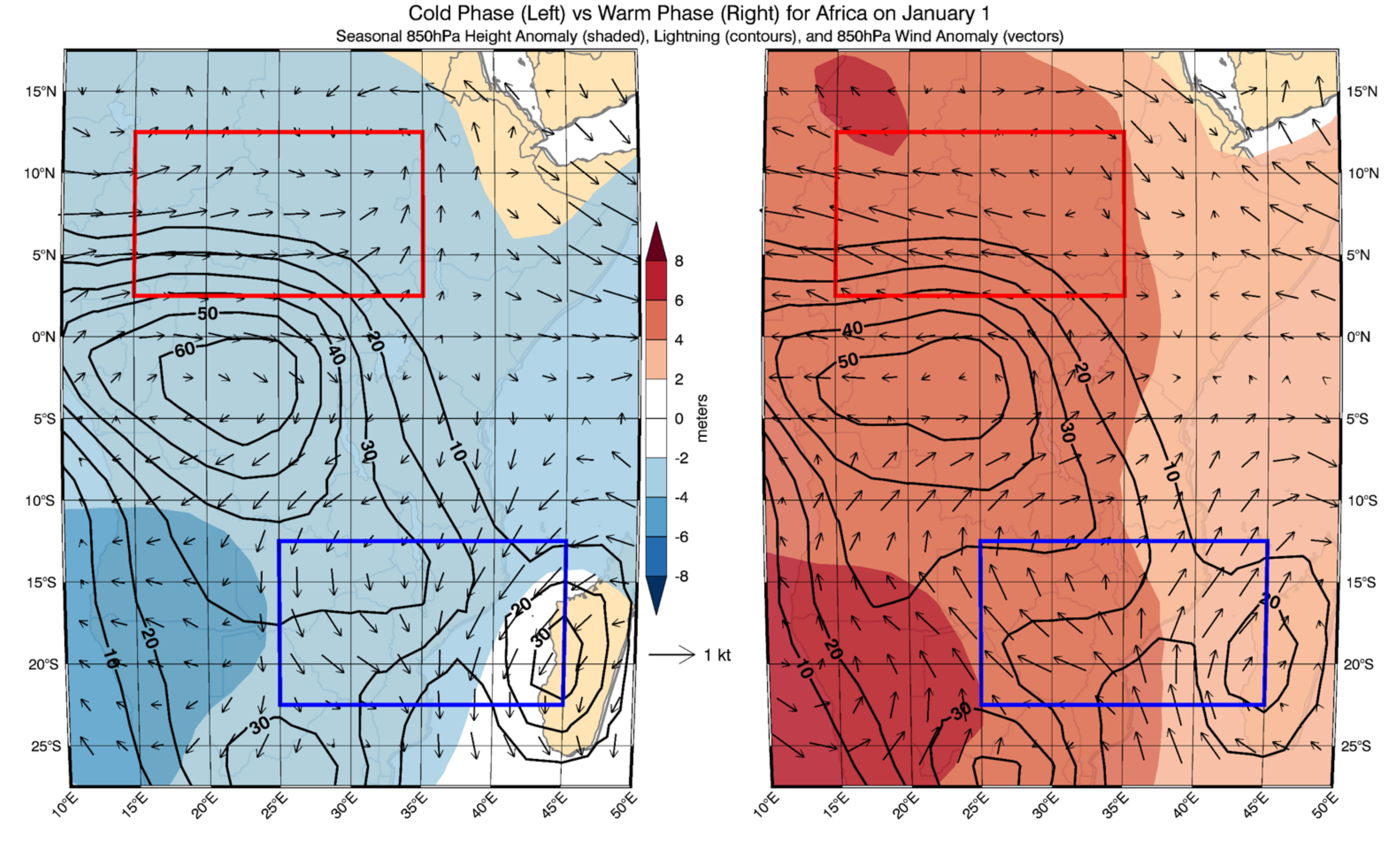
Correlation to Seasonal Lightning Activity



Mean seasonally averaged lightning pattern with seasonal wind and 850hPa height anomalies on August 15th, when lightning activity in central Africa (red box) peaks.



Mean seasonally averaged lightning pattern with seasonal wind and 850hPa height anomalies on January 1st, when lightning activity in southeastern Africa (blue box) peaks.



Conclusions

- Identified 20 locations
  - Lightning at some locations is affected by ENSO phase
  - Large variability and anomalies do exist independent of ENSO
- Largest observed seasonal lightning departures occurred with warm phase ENSO events and anomalous years*
  - Argentina and Central Africa ≥ 8 Fl km^{-2} Yr^{-1} from mean
  - All anomalous years > 8 Fl km^{-2} Yr^{-1} from mean
- ENSO phase affects the position of some large scale circulations, causing wind and pressure patterns to change
  - In Africa, this takes the form of the Indian Ocean High and the ITCZ

Future Work

- Expand study period using OTD and ISS LIS to incorporate more years and more of the subtropics
- Test the sensitivity of the ENSO patterns to ENSO Year starting month
- Produce weighted average ENSO Years based on phase magnitude
- Average cold years down to reduce bias
- Incorporate geostationary and ground network lightning records

References

Cecil, D. J., D. Buechler, and R. Blakeslee, 2014: Gridded lightning climatology from TRMM-LIS and OTD: dataset description. *Atmos. Res.,* 135-136, 404–414, doi:10.1016/j.atmosres.2012.06.028

Chronis, T. G. et al., 2008: Global lightning activity from the ENSO perspective, *Geophys. Res. Lett.*, 35, L19804, doi:10.1029/2008GL034321

Dowdy, A. J., 2016: Seasonal forecasting of lightning and thunderstorm activity in tropical and temperate regions of the world, *Sci. Rep.,* 6:20874, doi:10.1038/srep20874

Huang, B. et al., 2017: Extended Reconstructed Sea Surface Temperature, Version 5 (ERSSTv5): Upgrades, Validations, and Intercomparisons, *J. Climate.,* 30, 8179-8205, doi:10.1175/JCLI-D-16-0836.1

Jury, M. R., B. Pathack, and B. J. Sohn, 1992: Spatial structure and interannual variability of summer convection over southern Africa and the SW Indian Ocean, *S. Afr. J. Sci.,* 88, 275-280

Kalnay et al., 1996: The NCEP/NCAR 40-year reanalysis project, *Bull. Amer. Meteor. Soc.*, 77, 437-470

Liu, Z. et al., 2012: Tropical rainfall measuring mission (TRMM) precipitation data and services for research applications. *Bull. Amer. Meteor. Soc.,* Sep. 2012, 1317-1325, doi:10.1175/BAMS-D-11-00152.1

Nassor, A. and M. R. Jury, 1997: Intra-Seasonal Climate Variability of Madagascar. Part 2: Evolution of Flood Events , *Meteor. Atmos. Phys.,* 64, 243-254

Sátori, G., E. Williams, and I. Lemperger, 2009: Variability of global lightning activity on the ENSO time scale, *Atmos. Res.*, 91, 500-507, doi:10.1016/j.atmosres.2008.06.014

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Thank you! Questions?

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