Introduction

Predicting Wildfire Favorable Conditions in California at Subseasonal to Seasonal Lead Times Using Remote Predictors

Ciara Dorsay[1], Tom Murphree[2], Kellen Jones[2]

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NOAA 45th Climate Diagnostics and Prediction Workshop
Oct. 20, 2020

Problem: Devastating Wildfires at End of Dry Season in California

85	Number of deaths associated with Camp Fire in November 2018 (Penn et al. 2019)
$30 billion	Amount of money for wildfire liabilities PG&E expects to pay following Camp Fire (Penn et al. 2019)

Can be human or naturally induced (ex. broken power lines)

Camp Fire: "Butte County Sheriff Kory Honea called it 'the worst-case scenario,' saying it is what officials long feared because there was not enough time to implement an evacuation plan" (Thompson 2018).

Research Questions

What global scale conditions create offshore, fire favorable winds in California?

How well can we predict wildfire favorable conditions in California at sub-seasonal to seasonal lead times using remote predictors?

What we found:

Multiple lines of evidence indicating offshore wind events tied to variations in tropical convection in Indian Ocean and western/central Pacific

Skill at predicting offshore, wildfire favorable winds in California 1-3 months in advance

Data

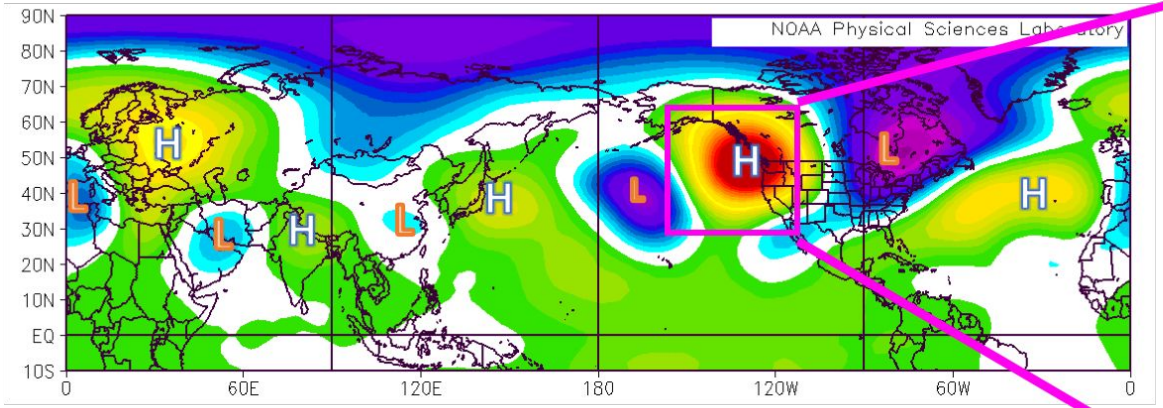
1. Monthly / daily atmospheric and oceanic NCEP/NCAR Reanalysis 1 data
2. August-November 1970-2019
3. Indices of known climate variations (e.g., Indian Ocean Dipole)

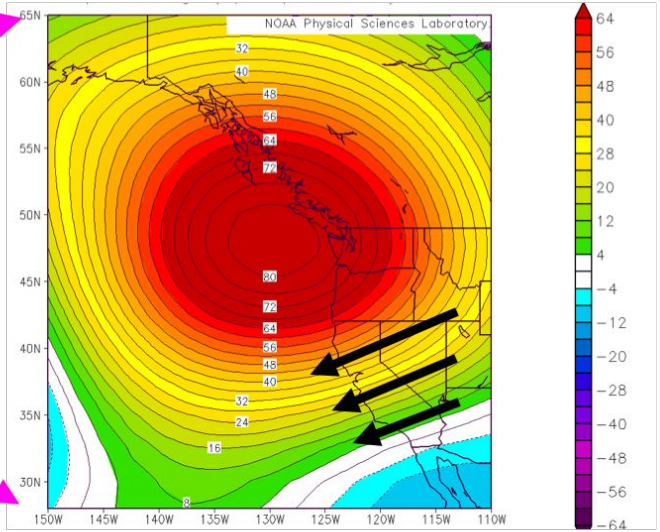
Methods

1. Statistical and dynamical analyses (e.g., conditional compositing, correlations, regressions, wave train and teleconnection analyses)
2. Experimental forecast system development and testing
3. Hindcast and forecasting, including verification and skill scores

What we found:

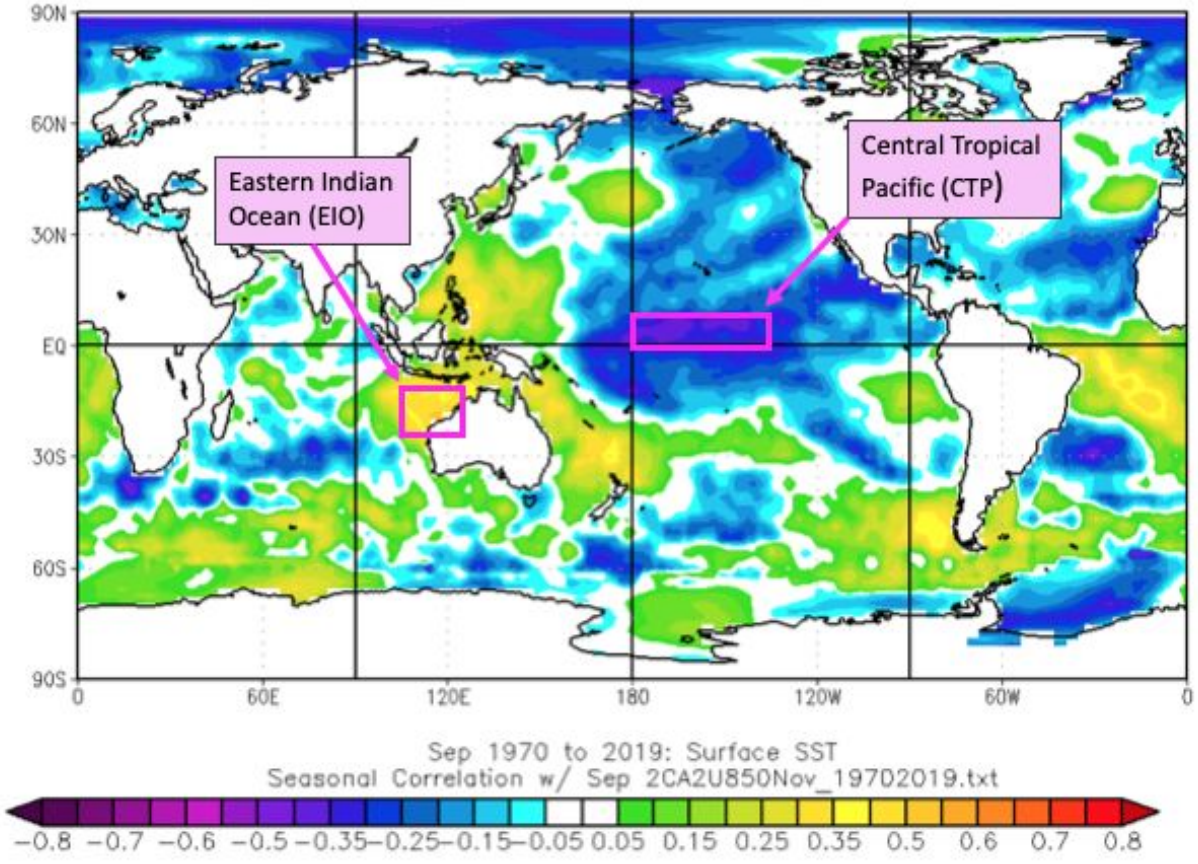
Conditional Composite of Anomalous Upper Tropospheric Heights During Fire Favorable Novembers in California





Offshore, fire favorable winds in California are associated with anomalous global wave trains.

Correlation between California winds in November and global SST in September



Identified 2 tropical SST regions as potential predictors of California winds in November

Combined together into Indo-Pacific Index (IPI)

IPI = EIO – CTP

If IPI below normal, then predict California U850 winds to be below normal and thus fire favorable.

Regression model predictions based on IPI are skillful at leads of 1-3 months (HSS = 0.26-0.49).

Nov. 2020 Prediction
monthly average zonal winds will be onshore and wildfire unfavorable

Presentation

Predicting Wildfire Favorable Conditions in California at Subseasonal to Seasonal Lead Times Using Remote Predictors

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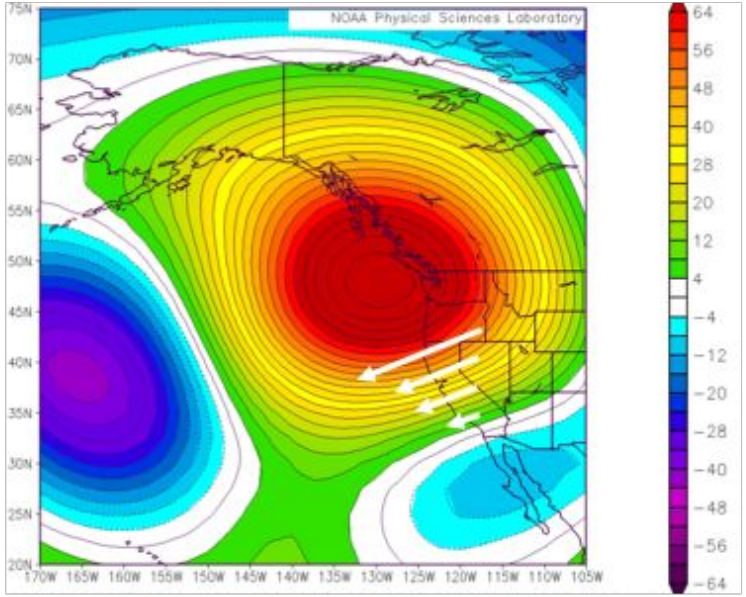
Offshore Flow: What we are trying to predict

Northern California

Southern California

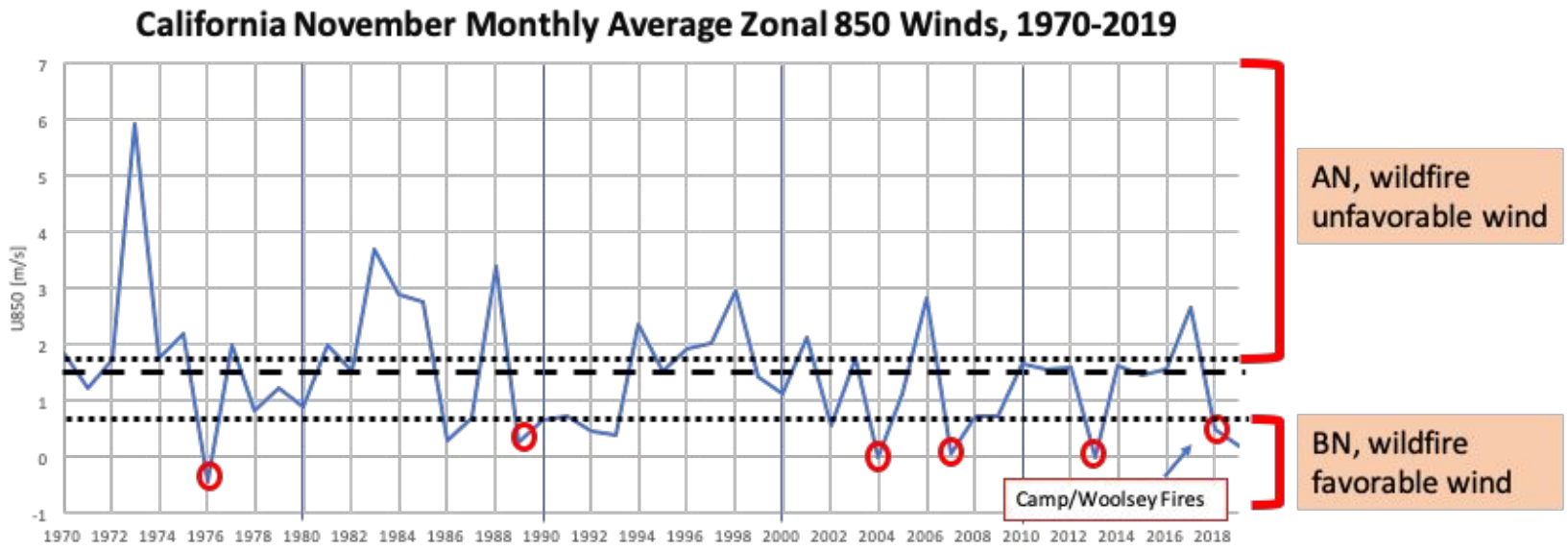
200 mb Geopotential Height Anomaly Associated with the most offshore wind Novembers in California



Strong offshore winds at end of dry season

Large potential for wildfires

Background: Fire Favorable Winds



In wildfire favorable Novembers, zonal winds less positive/more offshore than average

AN cutoff = 1.861 m/s
CA mean = 1.500 m/s
BN cutoff = 0.726 m/s

Research Process

We investigated:

(1) the dynamical relationships between these low-level, offshore winds in California and remote climate variations

(2) the potential to use these relationships to skillfully forecast these fire favorable wind events at subseasonal to seasonal (S2S) lead times

Data and Methods

Data

1.NCEP/NCAR Reanalysis 1 monthly/daily atmospheric and oceanic data

2.August-November 1970-2019

3.Climate variation index data (MEI, DMI, EMI)

Methods

1.Detrending and standardizing of atmospheric and oceanic data

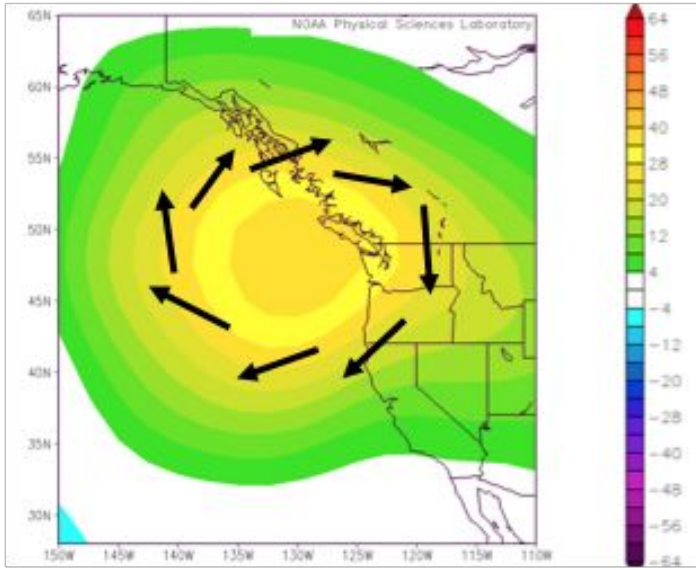
2.Conditional compositing, correlations, regressions, wave train and teleconnection analyses

3.Experimental forecast system development and testing

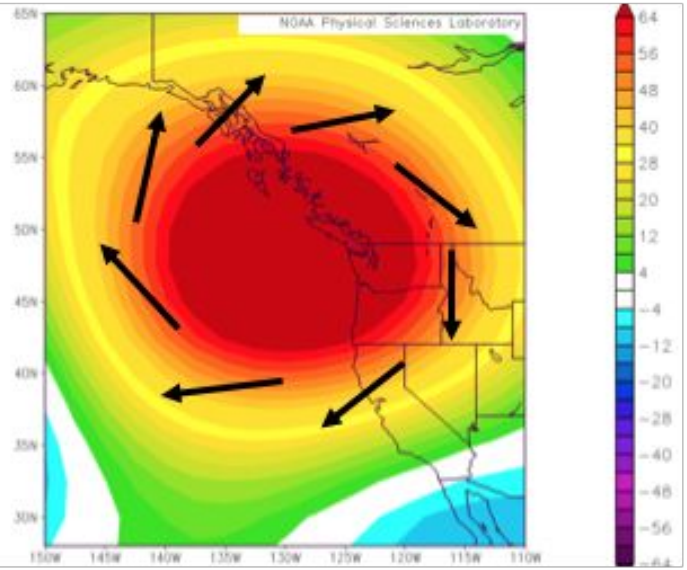
4.Hindcasting and forecasting, including verification and skill scores

What behavior do we see in the atmosphere when we look at the most offshore Novembers in California?

Conditional Composite of ZA850



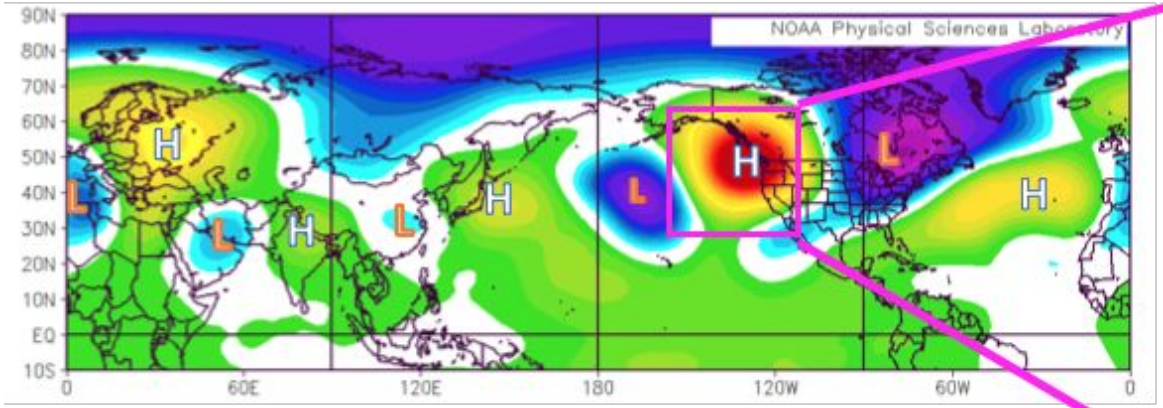
Conditional Composite of ZA200

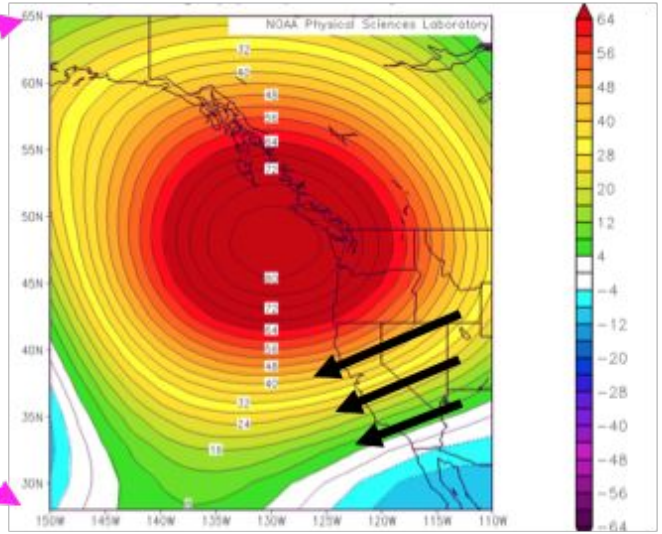


In offshore Novembers, there is a positive ZA in the lower troposphere and a positive ZA in the upper troposphere (equivalent barotropic anomaly)

What we found:

Conditional Composite of Anomalous Upper Tropospheric Heights During Fire Favorable Novembers in California

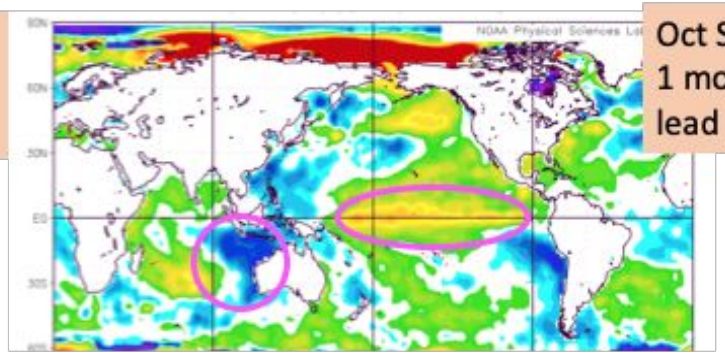




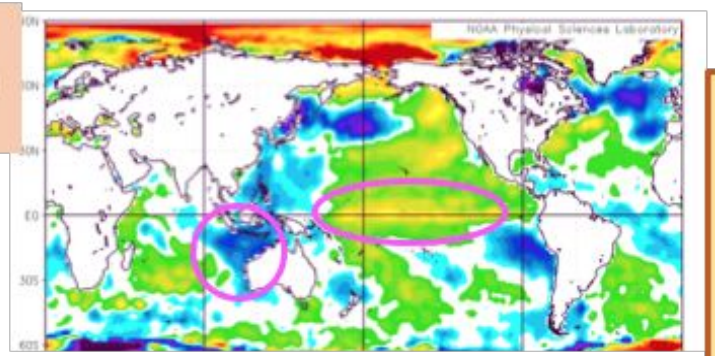
Offshore, fire favorable winds in California are associated with anomalous global wave trains.

SSTA Composites During and Prior to Novembers with Fire Favorable Winds in California

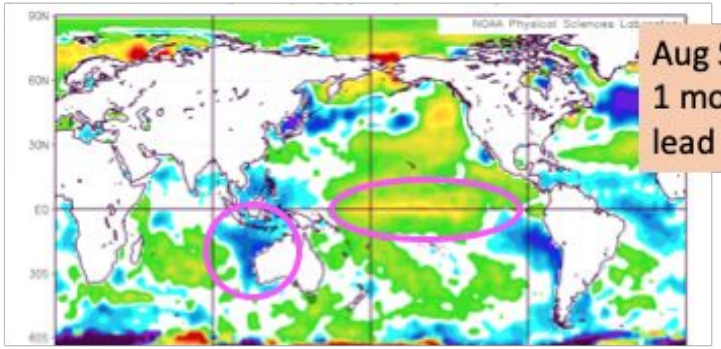
Nov SSTs
0 month
lead



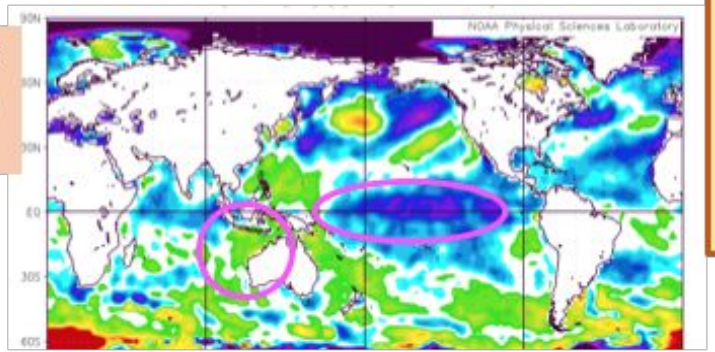
Oct SSTs
1 month
lead

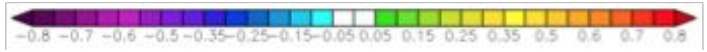


Sept SSTs
1 month
lead



Aug SSTs
1 month
lead

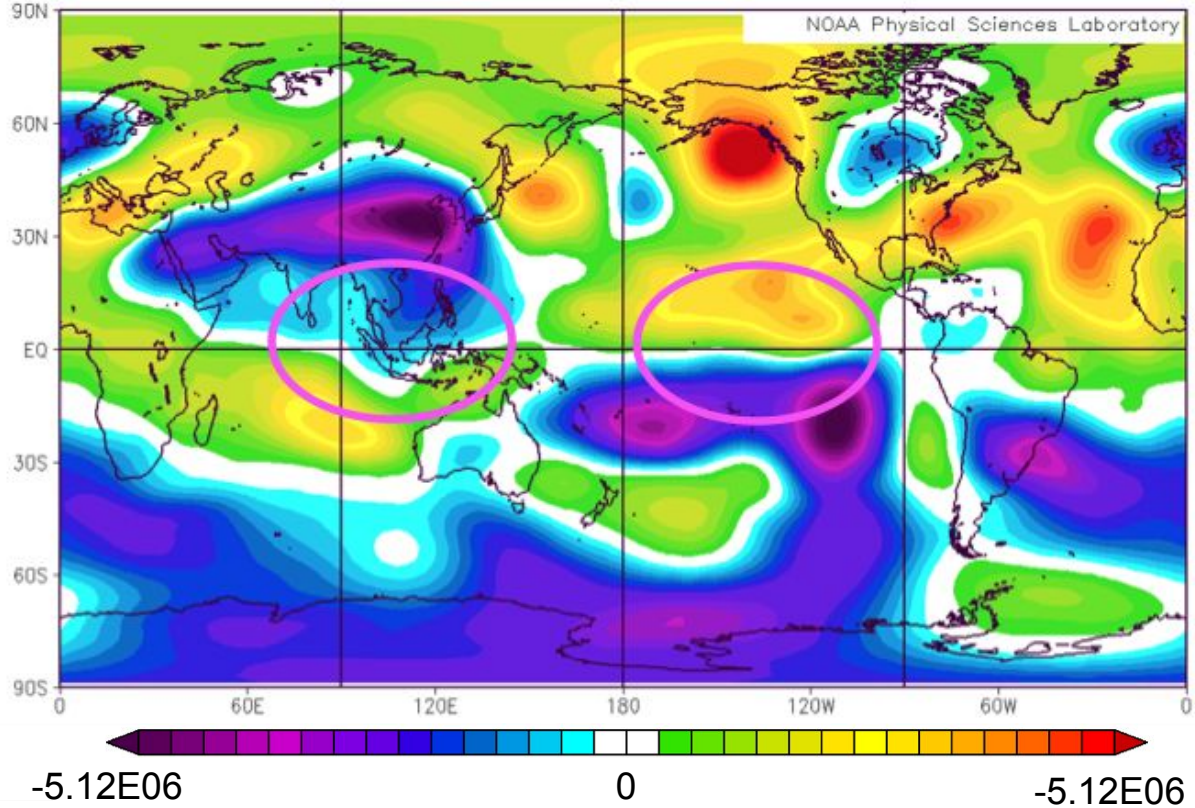


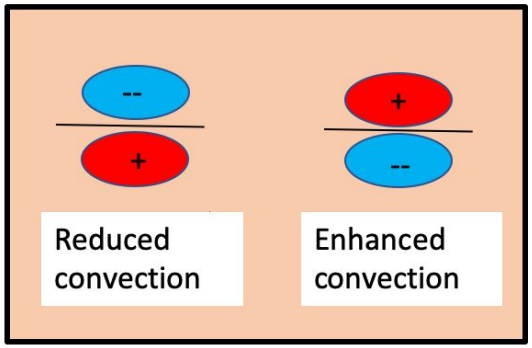


Patterns remain similar month to month

See indications of several climate variations at each lead

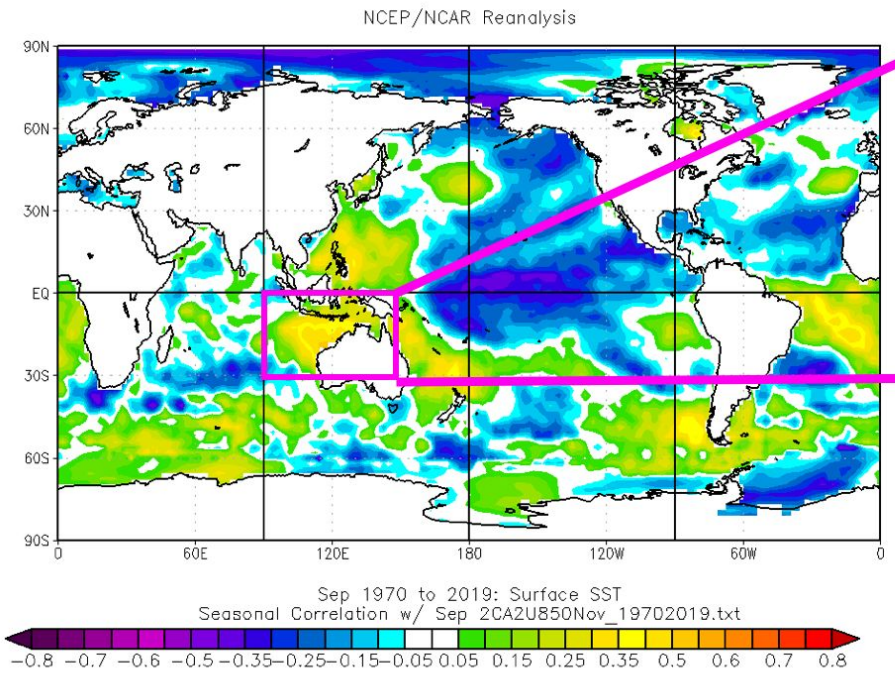
Conditional Composite of October SFA200 (stream function anomalies at 200mb) Immediately Before Fire Favorable Novembers in California

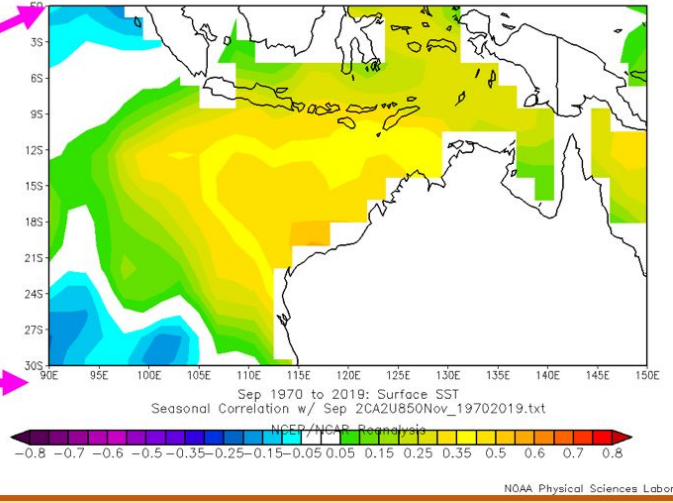




Correlation between September global SSTs and November California zonal 850 mb winds

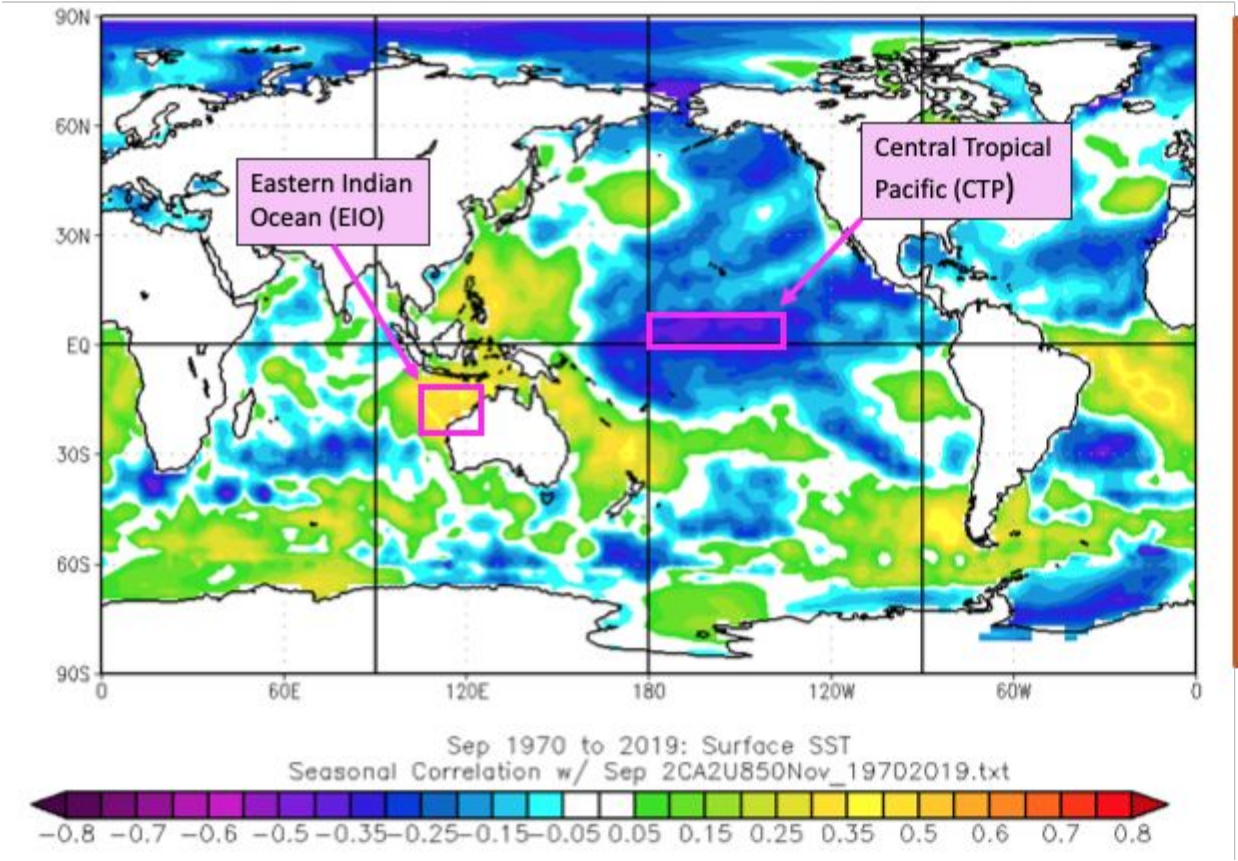
Correlations confirm composite maps





SSTs in regions extending from central Indian Ocean to central tropical Pacific Ocean are strongly correlated with CA U850 winds.

Correlation between California winds in November and global SST in September



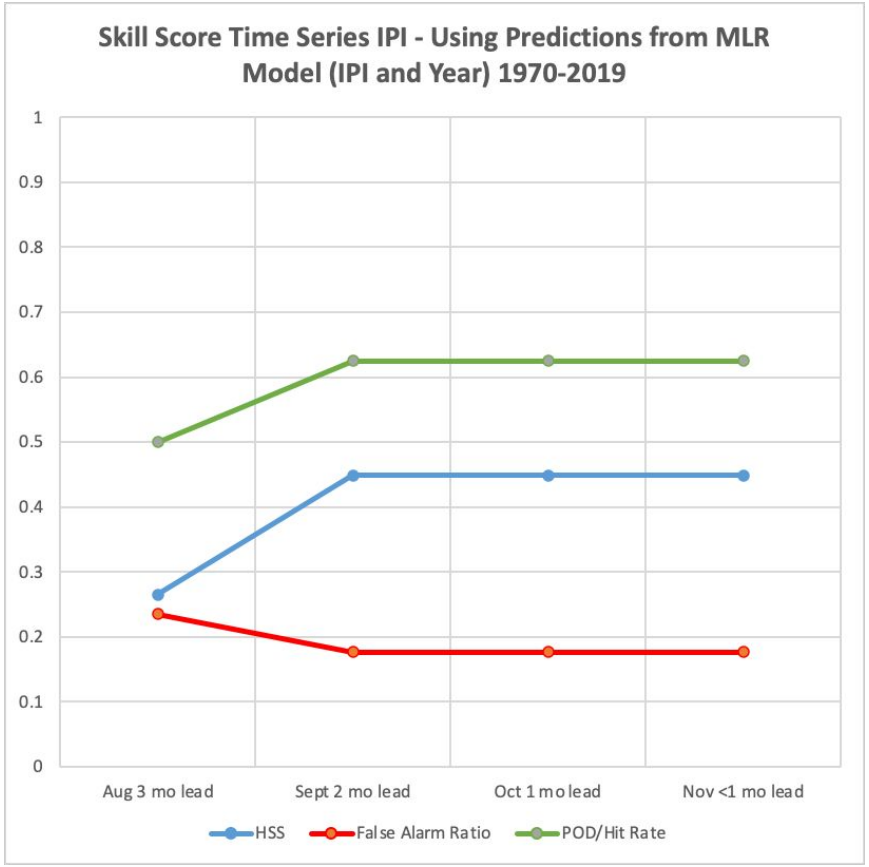
Identified 2 primary regions as potential predictors of California winds in November

Combined together into Indo-Pacific Index (IPI)

IPI = EIO – CTP

If IPI below normal, then predict California U850 winds to be below normal and thus fire favorable.

IPI and Multiple Linear Regression Results



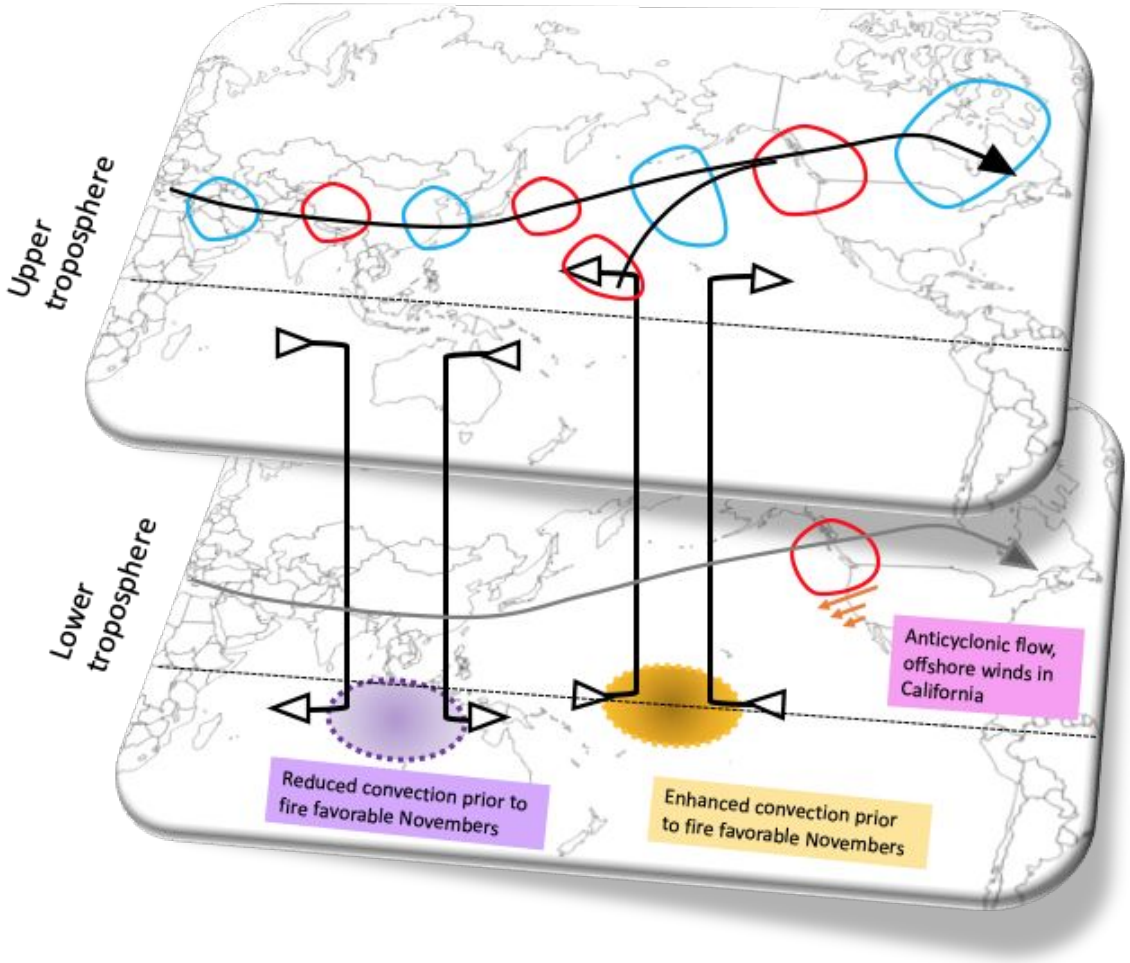
Correl. Values between IPI and Observed Nov CAU850 1970-2019

Aug IPI vs. Nov CAU850	**0.488**
Sept IPI vs. Nov CAU850	**0.476**
Oct IPI vs. Nov CAU850	**0.526**
Nov IPI vs. Nov CAU850	**0.472**

Created IPI and combined with year

Developed MLR model

Hindcast 1970-2019 using output from linear regression model



Schematic: Interpretation of Dynamical Processes

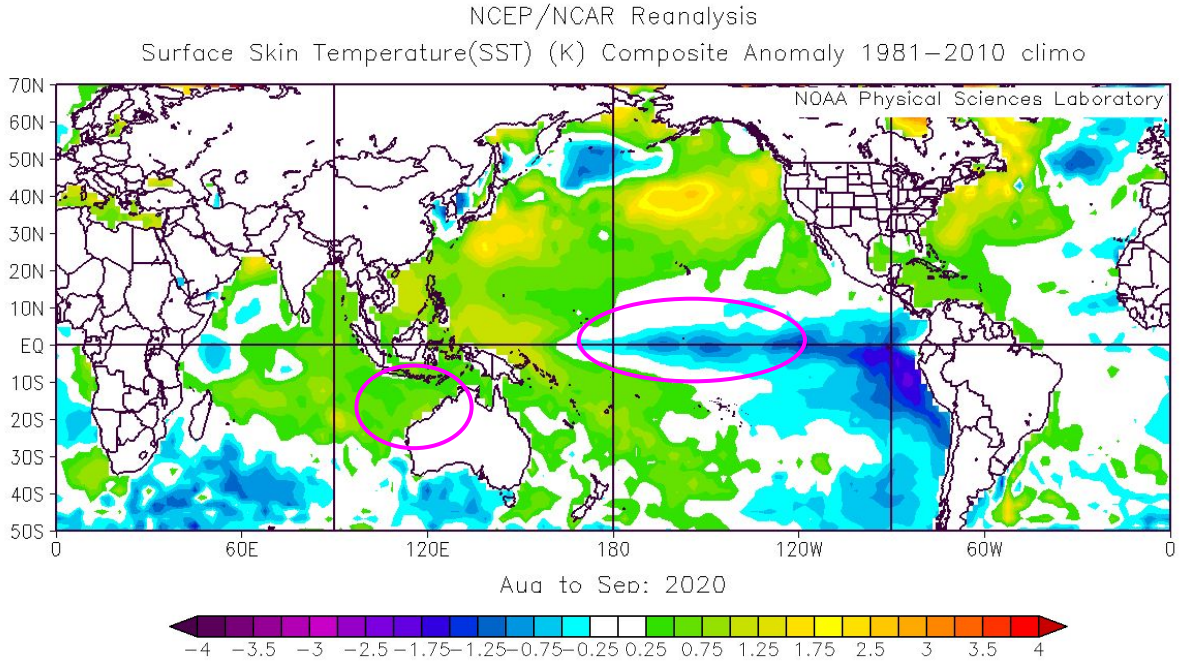
What could be causing ups/downs: positive phase of Indian Ocean Dipole, El Niño Modoki

What is most likely not causing ups/downs: negative phase of Indian Ocean Dipole, La Niña Modoki, El Niño/La Niña

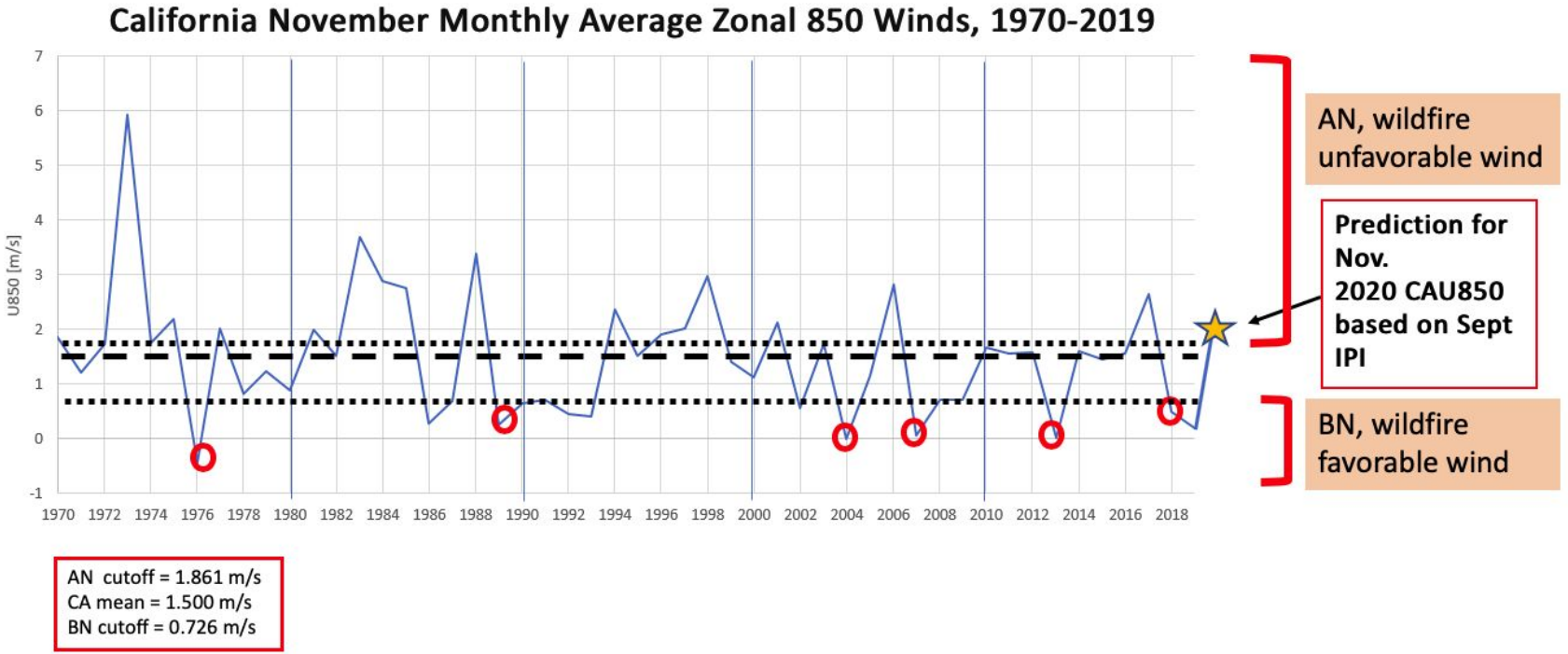
Prediction for November 2020

AN
NN
BN

	Aug	Sept
IPI/CA 2020	1.7157	2.0900
EIO/CA 2020	1.6493	2.5136



Given Aug/Sept positive SSTAs in Eastern Indian Ocean and negative SSTAs in central tropical Pacific, expect to observe wildfire unfavorable winds in California Nov. 2020


California November Monthly Average Zonal 850 Winds, 1970-2019
U850 [m/s]
7
6
5
4
3
2
1
0
-1
1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
AN, wildfire unfavorable wind
Prediction for Nov. 2020 CAU850 based on Sept IPI
BN, wildfire favorable wind
AN cutoff = 1.861 m/s
CA mean = 1.500 m/s
BN cutoff = 0.726 m/s

Summary

Findings

1. California wildfire favorable winds in November are linked to tropical climate variations and may be predictable at leads of several months
2. Longer lead predictions should contribute to improved planning and reduction of risks and losses

Future Research

1. Expand to other months
2. Incorporate V component of wind into methodology
3. Develop better understanding of role of climate variations
4. Incorporate cross validation into prediction model

Acknowledgements

Gabriel Garagiulo and Annabelle Norman at the York School in Monterey, CA.

Sources

Unless otherwise indicated, all figures provided by the NOAA/ESRL Physical Sciences Laboratory, Boulder Colorado from their website at http://psl.noaa.gov/

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Slide 2/9:

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Slide 3:

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Slide 11:

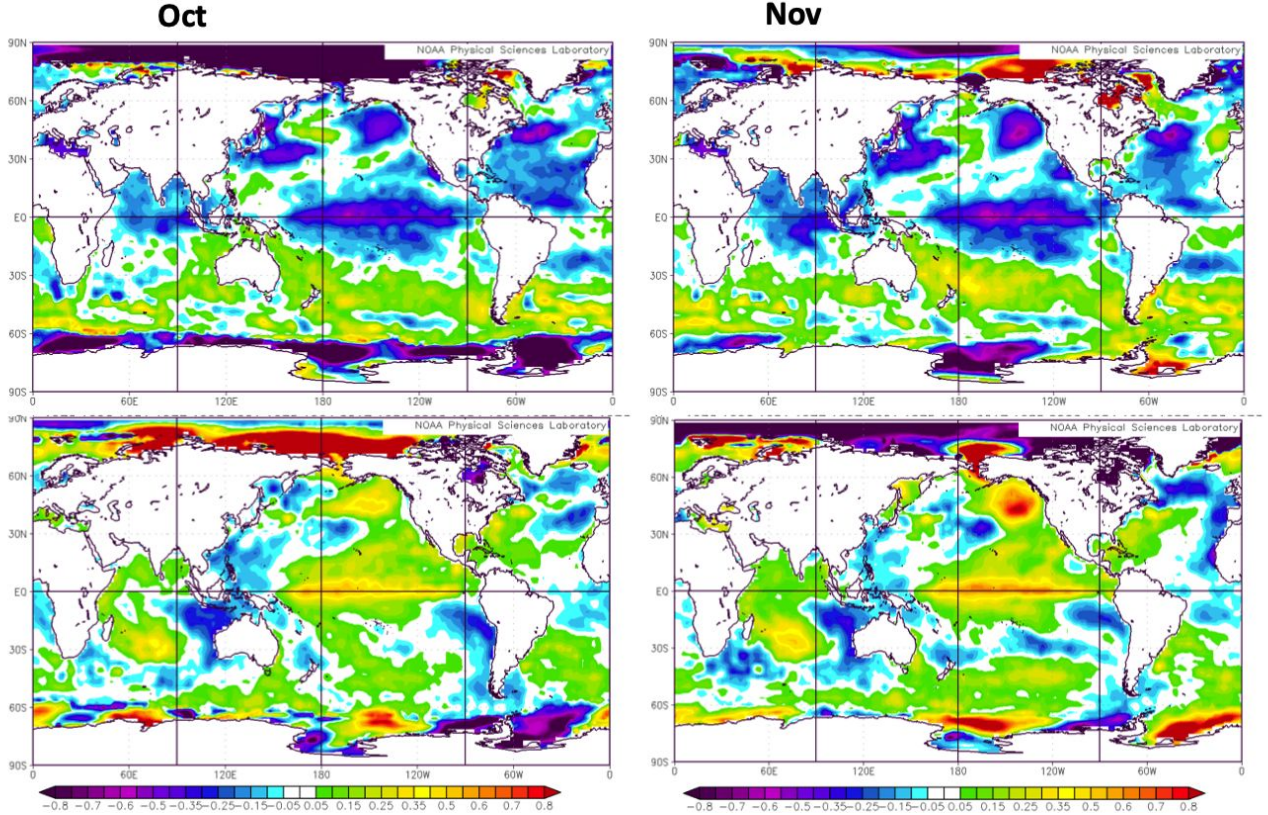
Cassidy, Emily, 2018: Here's What Smoke From California's Wildfires Looks Like From Space. Resource Watch, Accessed 4 October 2020, https://blog.resourcewatch.org/2018/11/14/heres-what-smoke-from-californias-wildfires-looks-like-from-space/.

Supplementary Slides

Conditional Composites based on BN/AN CAU850 Years: Oct and Nov SSTA

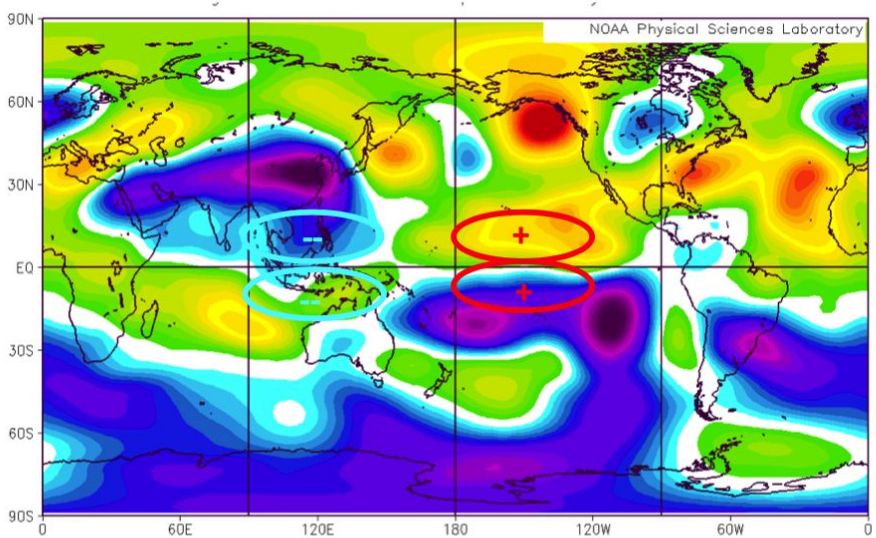
AN CAU850 Years

BN CAU850 Years

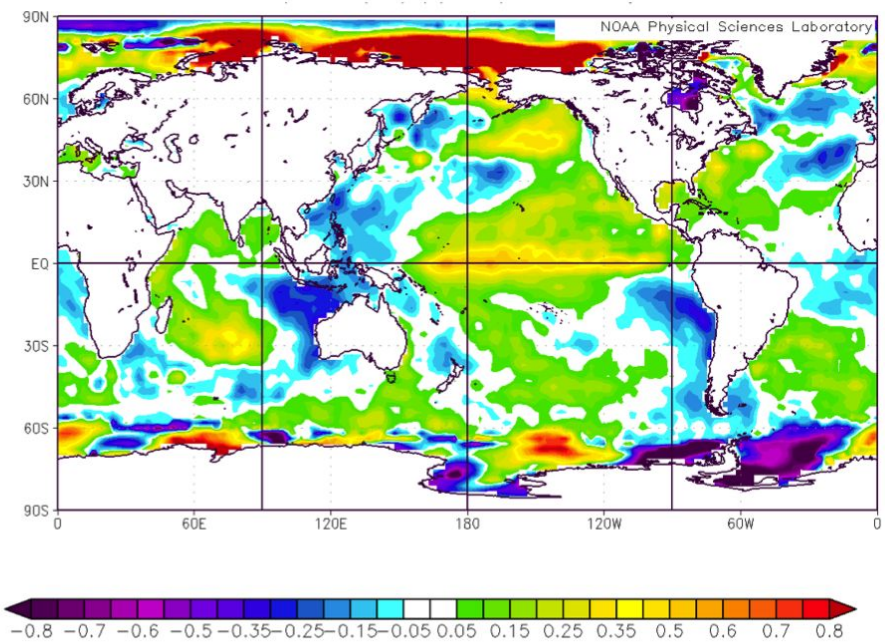


Tendency for anomalies to be opposite between AN/BN conditions in tropics

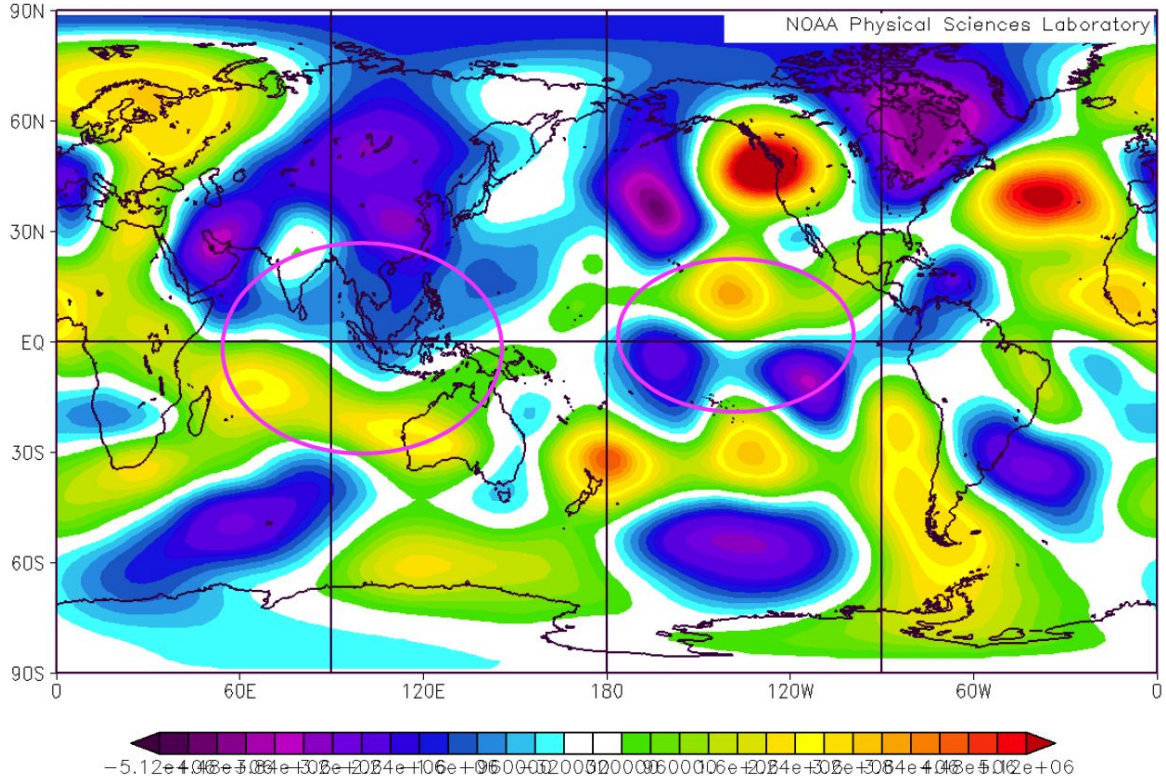
Conditional Composite of October SFA200 (stream function anomalies at 200mb) During/Immediately Before Fire Favorable Novembers in California

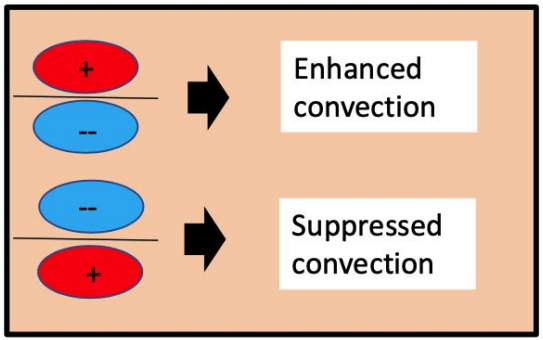


Conditional Composite of October SSTAs During/Immediately Before Fire Favorable Novembers in California



Conditional Composite of November SFA200 (stream function anomalies at 200mb) During/Immediately Before Fire Favorable Novembers in California





BN IPI Years

Aug IPI Years	Sept IPI Years	Oct IPI Years	Nov IPI Years
1986	2004	1986	1991
2018	1977	1976	1976
1987	1986	1993	2018
1997	1987	1987	1987
1972	2002	1992	2002
2019	2018	2018	1977
2004	1976	2009	2004
1977	1993	1977	1986
1994	1997	2002	2006
1976	1991	2003	1992
1993	1979	1994	2019
2012	1982	2004	1997
2002	2006	1972	1993
1982	2015	1990	2003
2006	2019	2006	2014
2015	1994	1991	2005

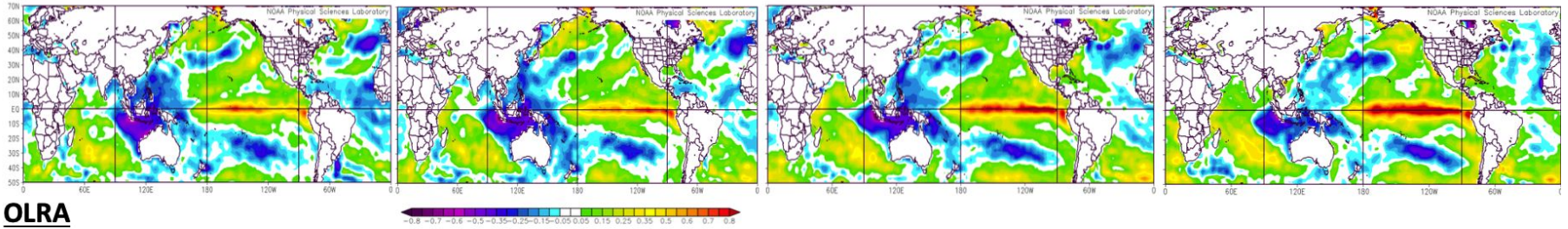
BN EIO Years

years	Aug EIO	years	Sept EIO	years	Oct EIO	years	Nov EIO
1972	23.462	1970	25.071	1971	26.436	1971	25.832
1976	23.049	1976	24.513	1972	26.508	1974	26.172
1977	23.195	1977	24.561	1975	26.441	1976	25.653
1978	23.383	1978	24.775	1976	25.626	1977	25.907
1986	22.323	1979	24.892	1977	26.275	1985	26.162
1987	23.397	1986	24.638	1978	26.473	1986	26.166
1993	23.189	1987	24.913	1985	26.043	1987	26.047
1994	23.404	1991	25.06	1986	25.474	1991	25.696
1997	23.336	1992	24.985	1987	26.29	1992	25.803
2004	23.188	1993	24.708	1992	25.951	1993	26.06
2006	23.384	1997	25.124	1993	25.804	2002	26.183
2007	23.446	2002	24.807	1995	26.378	2003	26.114
2008	23.454	2003	25.082	2002	26.573	2004	26.076
2012	23.105	2004	24.606	2003	26.376	2005	25.959
2018	22.527	2018	24.629	2005	26.531	2018	25.948
2019	22.927	2019	24.969	2011	26.494	2019	26.247

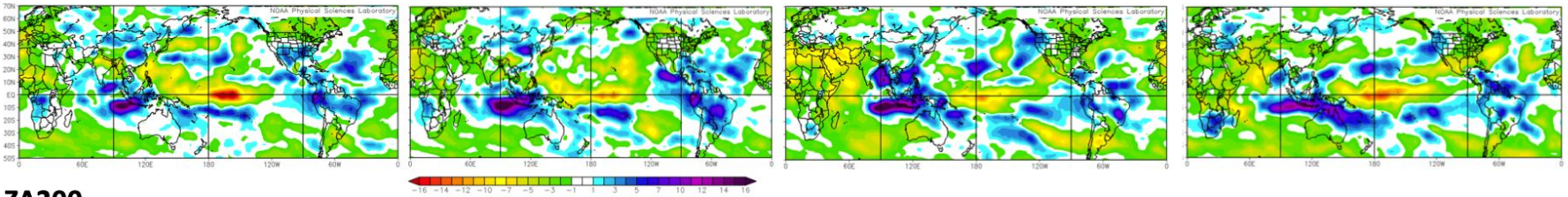
years	CA
1976	-0.443
1986	0.284
1987	0.703
1989	0.27
1990	0.654
1991	0.72
1992	0.465
1993	0.408
2002	0.557
2004	-0.006
2007	0.071
2008	0.726
2009	0.717
2013	0.012
2018	0.504
2019	0.203

Conditional Composites based on BN Aug EIO SST

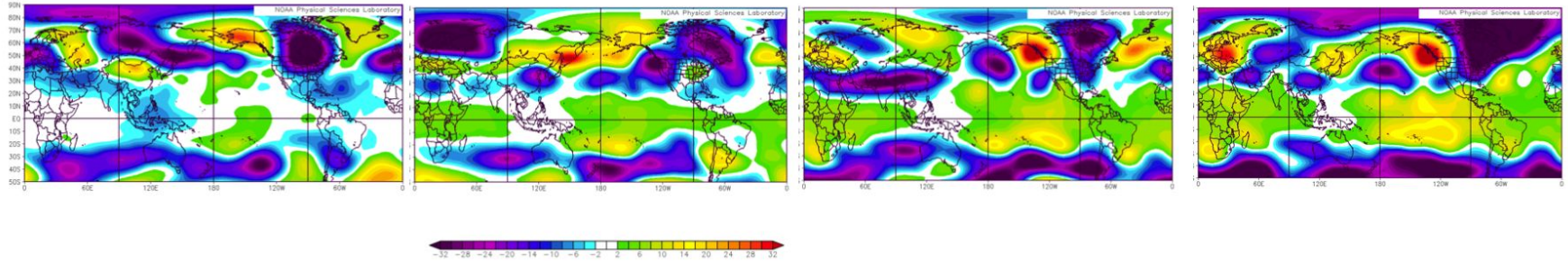
SSTA Aug Sept Oct Nov



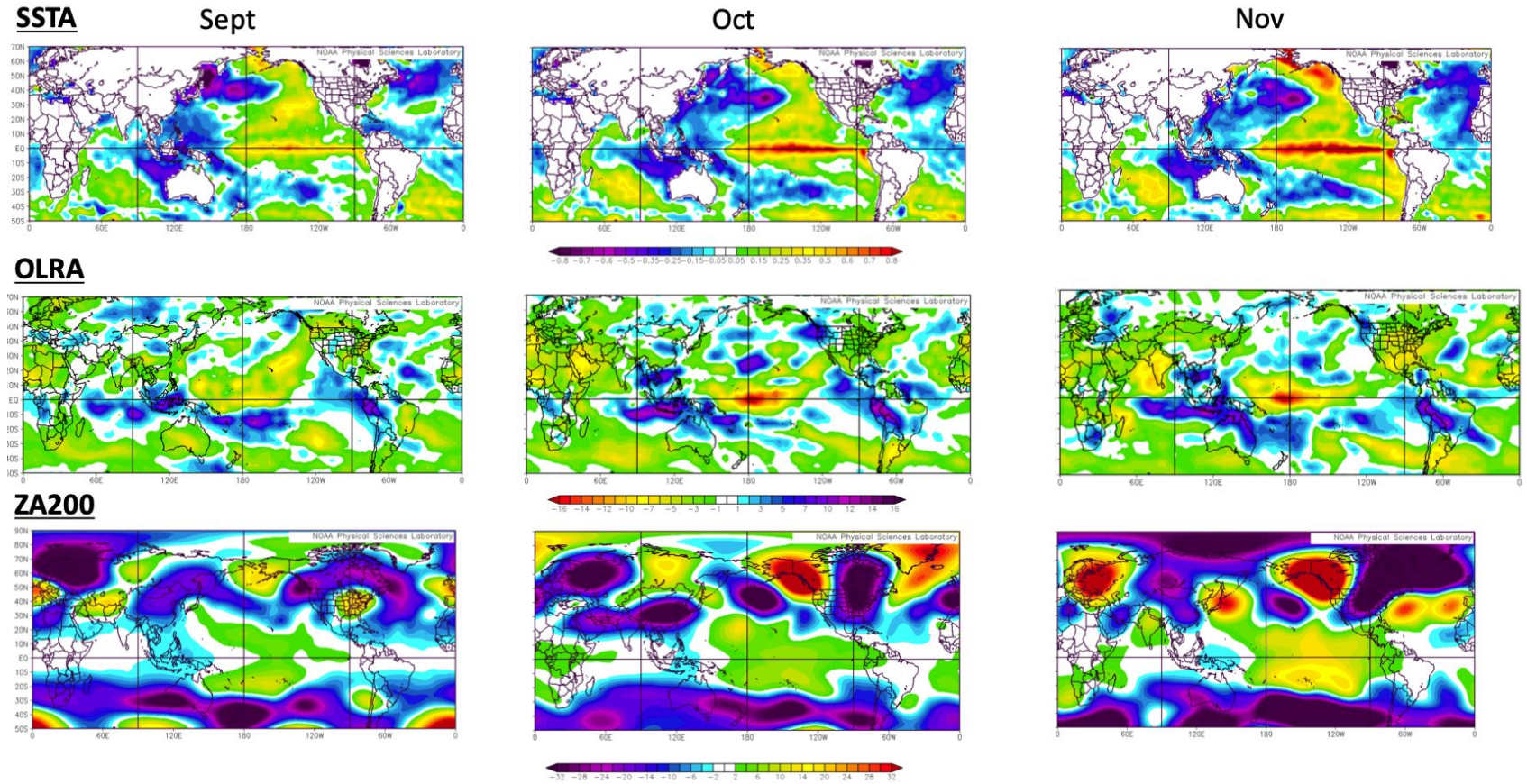
OLRA



ZA200



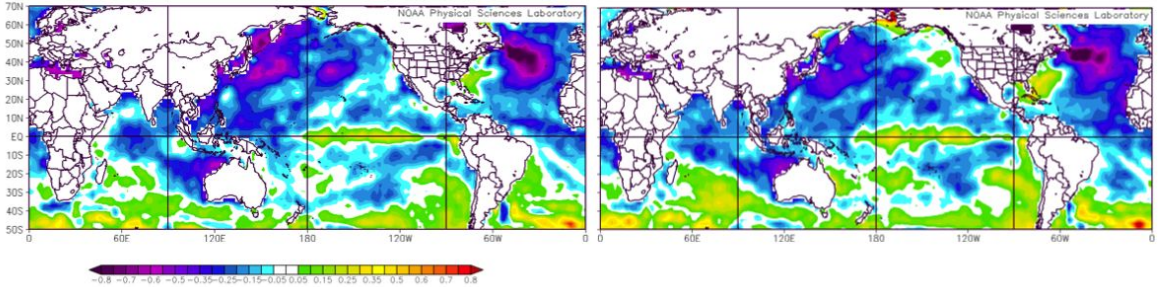
Conditional Composites based on BN Sept EIO SST



Conditional Composites based on BN Oct EIO SST

Oct Nov

SSTA



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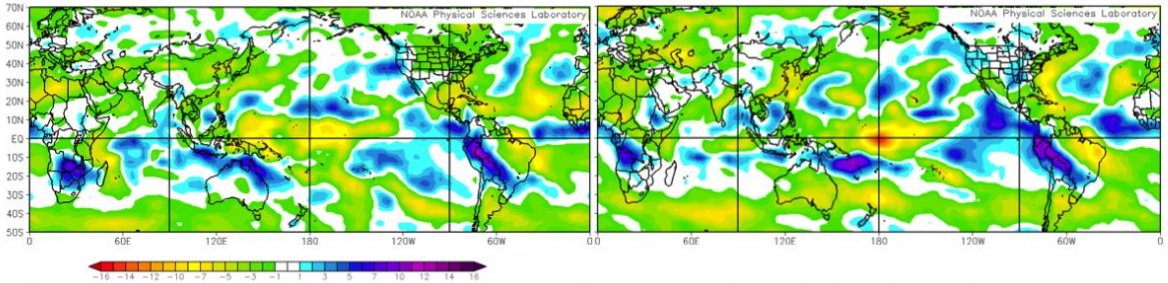
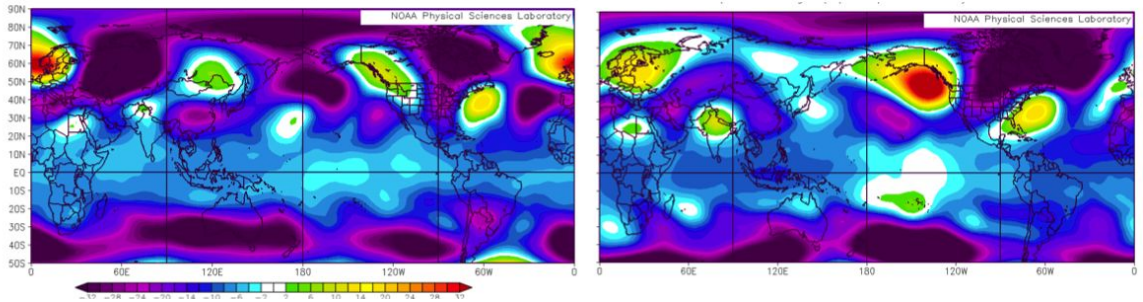


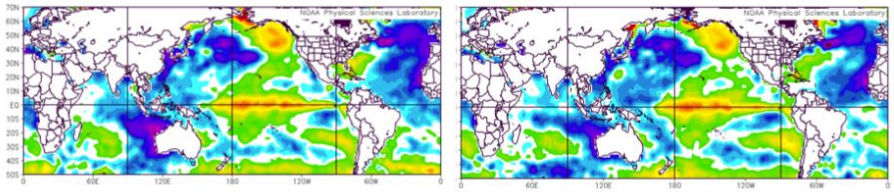
ZA200



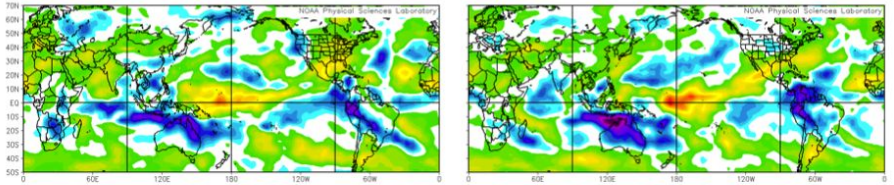
Conditional Composites based on BN Nov EIO SST

Nov Dec

SSTA



OLRA



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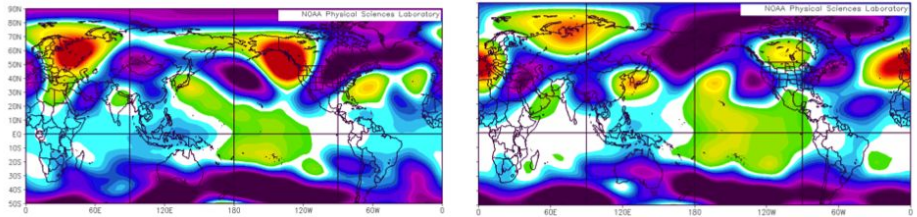
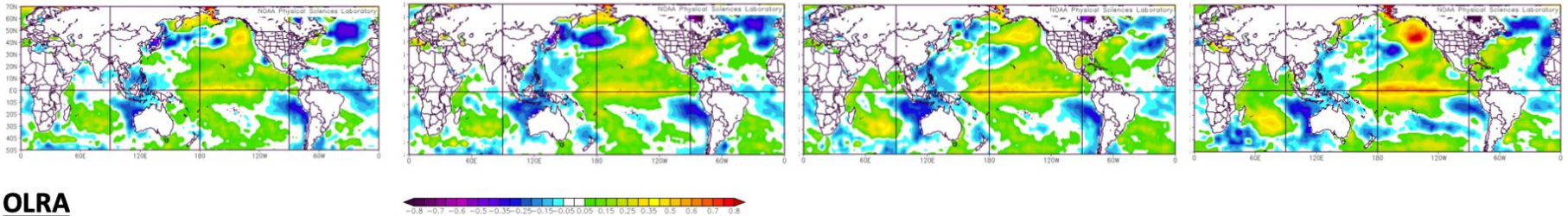


Conditional Composites based on BN Nov CAU850

SSTA Aug Sept Oct Nov



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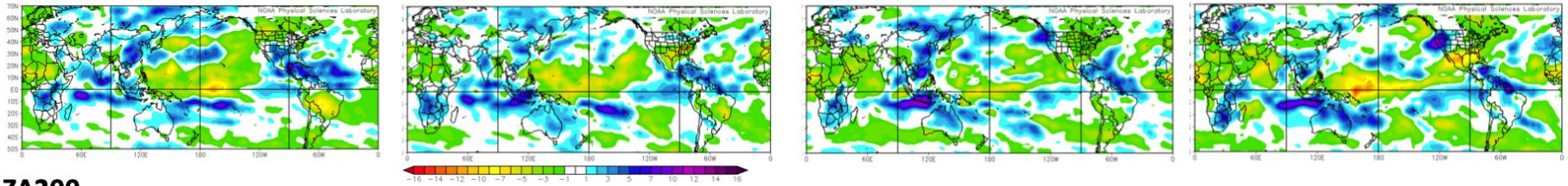

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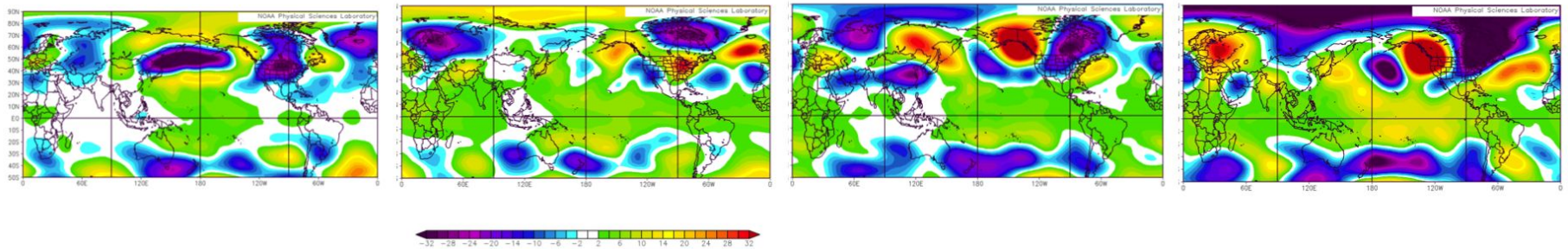
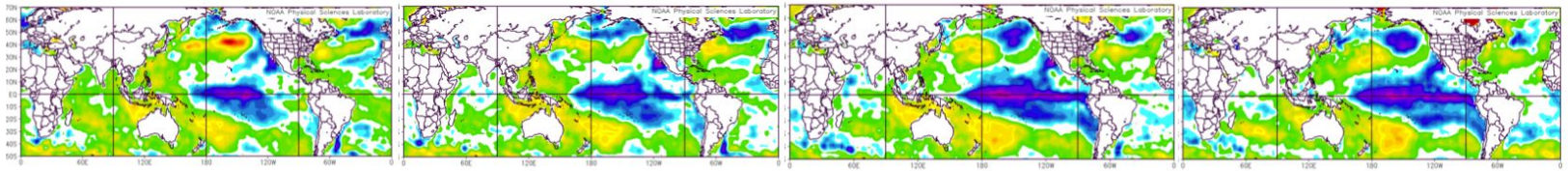


AN EIO Years for following 4 slides

years	Aug EIO	years	Sept EIO	years	Oct EIO	years	Nov EIO
1973	24.543	1973	25.75	1973	27.124	1979	27.011
1974	23.876	1974	25.643	1983	27.126	1982	27.157
1980	23.873	1975	25.601	1984	26.969	1983	26.939
1983	23.886	1980	25.568	1988	27.648	1988	26.907
1988	24.347	1981	25.677	1996	27.412	1989	26.722
1991	24.109	1983	25.524	1998	27.812	1994	26.924
1996	24.434	1988	25.64	1999	27.156	1995	26.723
1998	24.797	1989	25.502	2000	26.957	1996	27.251
1999	24.25	1995	25.531	2008	27.374	1998	27.094
2001	24.137	1996	25.682	2010	27.555	1999	26.933
2009	23.857	1998	26.297	2012	27.035	2010	27.965
2010	24.116	1999	25.63	2013	27.051	2011	26.792
2011	23.856	2008	25.594	2014	27.042	2012	27.107
2013	23.954	2013	25.602	2015	27.95	2013	26.797
2015	24.057	2015	25.577	2016	27.384	2015	27.438
2016	24.253	2017	25.69	2019	27.168	2016	27.103

Conditional Composites based on AN Aug EIO SST

SSTA Aug Sept Oct Nov



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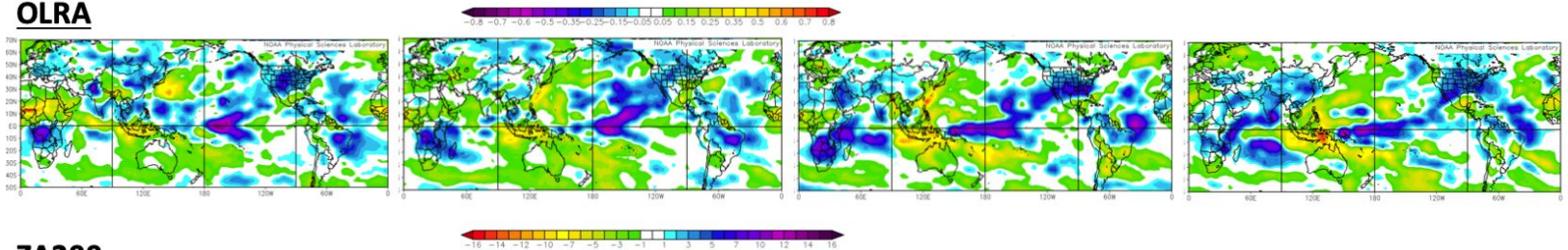

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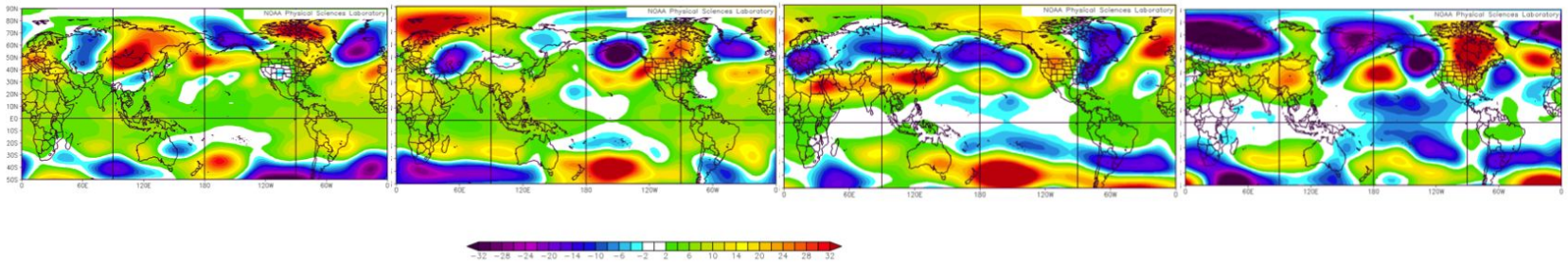
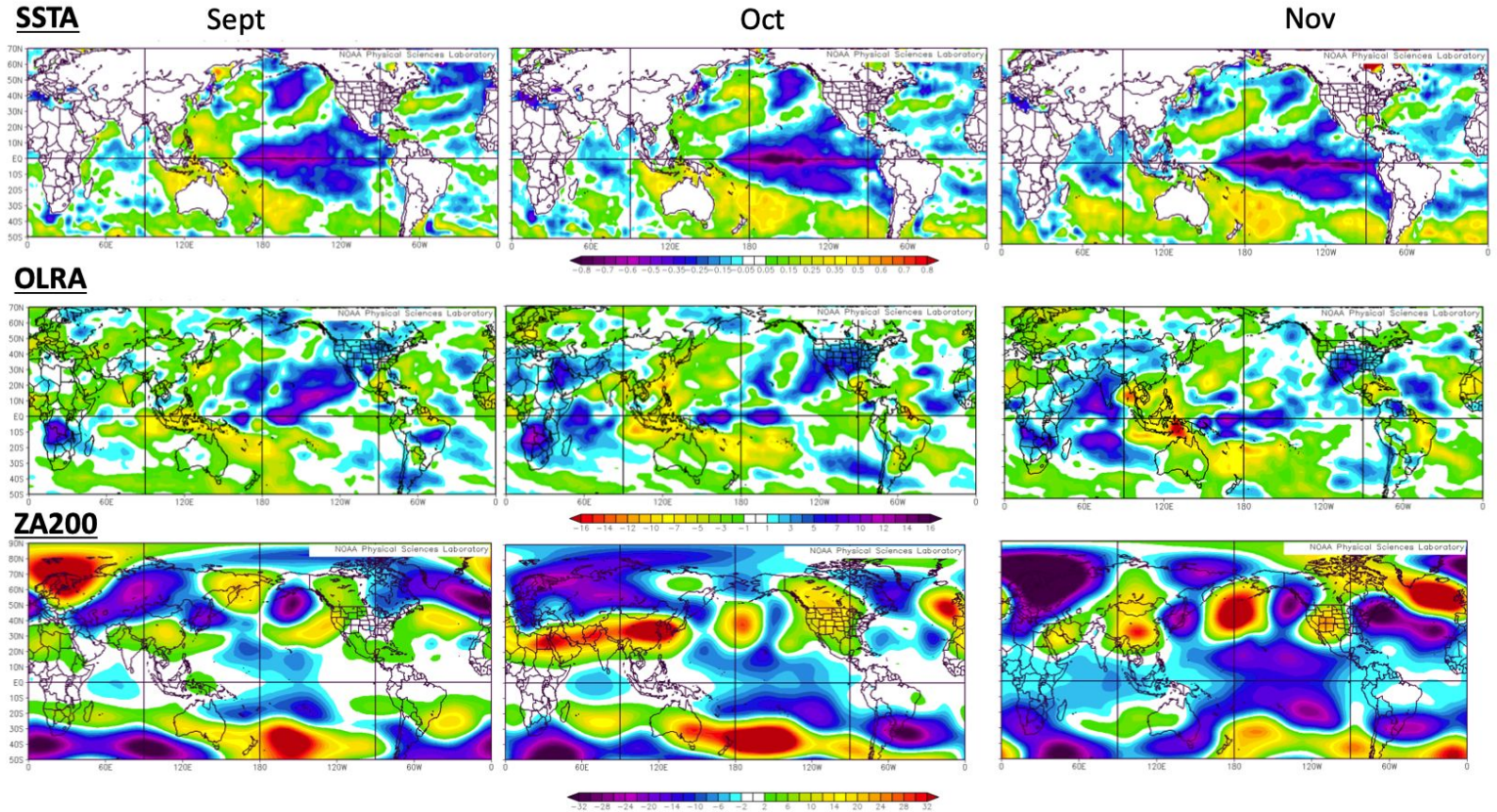
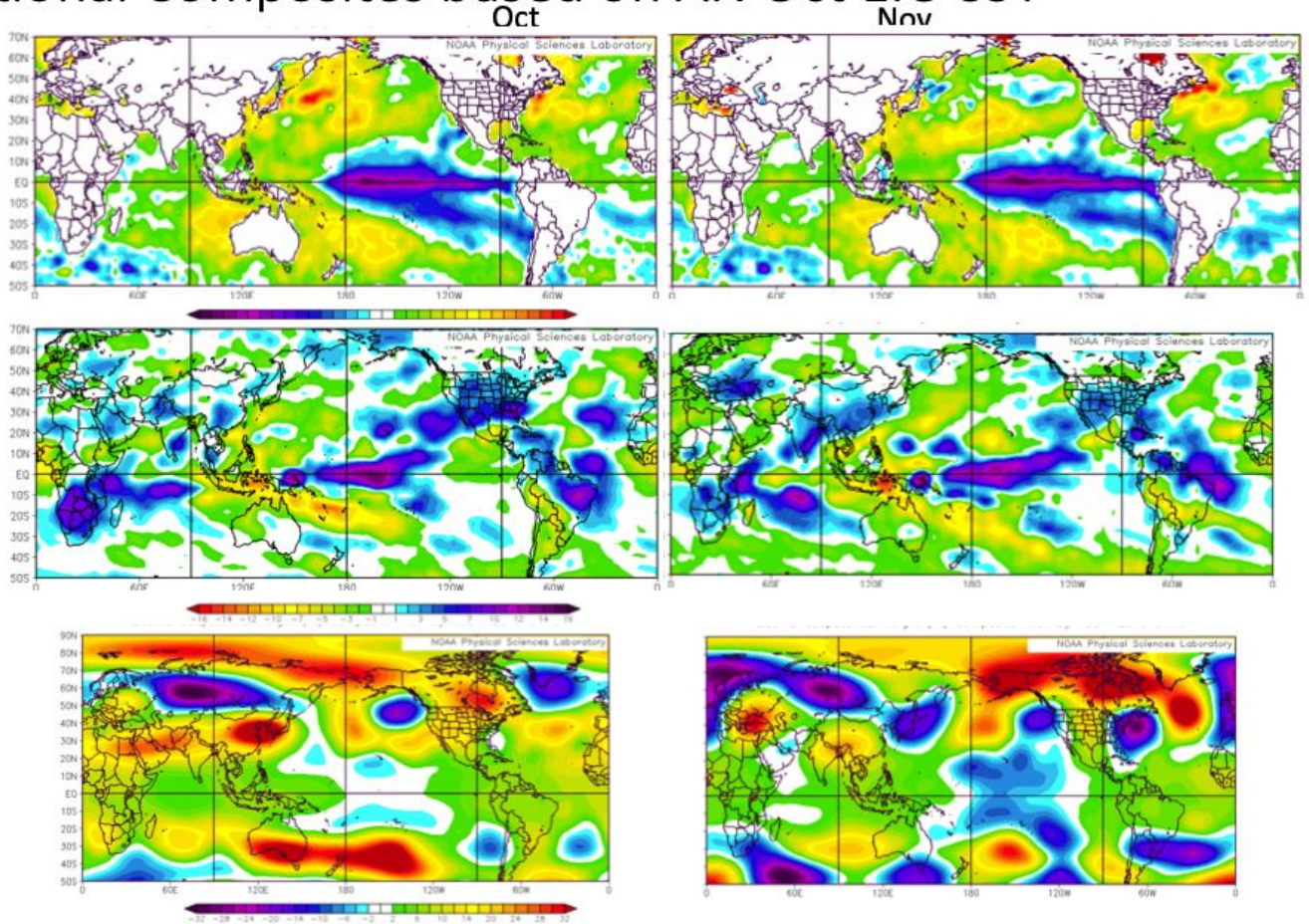


Conditional Composites based on AN Sept EIO SST



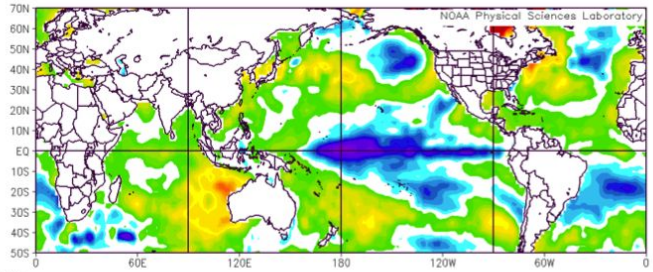
Conditional Composites based on AN Oct EIO SST



Conditional Composites based on AN Nov EIO SST

Nov

SSTA



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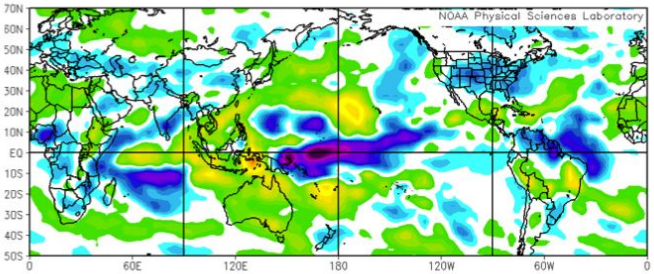

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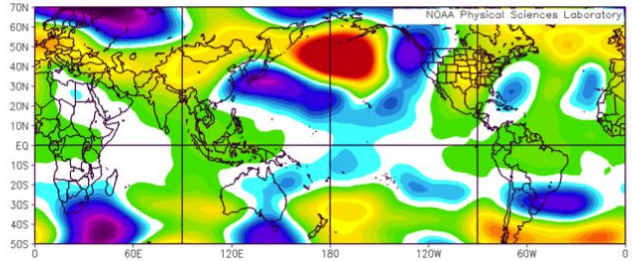


MLR Results

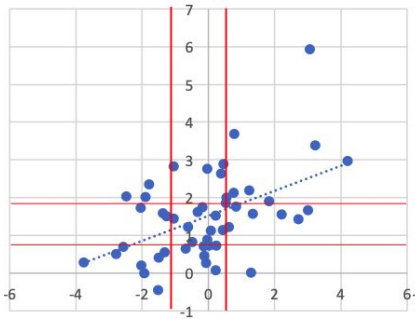
AUG SINGLE			SEPT SINGLE			OCT SINGLE			NOV SINGLE		
Multiple R	0.5003		Multiple R	0.4989		Multiple R	0.3648		Multiple R	0.3215	
R Square	0.2503		R Square	0.2489		R Square	0.1331		R Square	0.1033	
	Coefficients	*P-value*		*Coefficients*	*P-value*		*Coefficients*	*P-value*		*Coefficients*	*P-value*
Intercept	-27.4136	0.0004	Intercept	-36.8136	0.0004	Intercept	-20.4292	0.0148	Intercept	-18.8619	0.0343
Aug EIO	1.2223	0.0002	Sept EIO	1.5163	0.0002	Oct EIO	0.8194	0.0092	Nov EIO	0.7680	0.0228
AUG DETRENDED EIO, YEARS, TRENDE			SEPT DETRENDED EIO, YEARS, TRENDE			OCT DETRENDED EIO, YEARS, TRENDE			NOV DETRENDED EIO, YEARS, TRENDED WINDS		
Multiple R	0.5486		Multiple R	0.5728		Multiple R	0.5372		Multiple R	0.4592	
R Square	0.3010		R Square	0.3281		R Square	0.2886		R Square	0.2108	
	Coefficients	P-value		*Coefficients*	*P-value*		*Coefficients*	*P-value*		*Coefficients*	*P-value*
Intercept	39.0001	0.0453	Intercept	38.9990	0.0413	Intercept	48.7255	0.0150	Intercept	30.8717	0.1356
years	-0.0188	0.0543	years	-0.0188	0.0489	years	-0.0239	0.0174	years	-0.0146	0.1589
Aug EIO	1.2046	0.0002	Sept EIO	1.5841	0.0001	Oct EIO	1.1516	0.0003	Nov EIO	0.9615	0.0041
AUG TRENDED EIO, YEARS, TRENDED V			SEPT TRENDED EIO, YEARS, TRENDED V			OCT TRENDED EIO, YEARS, TRENDED W			NOV TRENDED EIO, YEARS, TRENDED WIND		
Multiple R	0.5486		Multiple R	0.5728		Multiple R	0.5372		Multiple R	0.4592	
R Square	0.3010		R Square	0.3281		R Square	0.2886		R Square	0.2108	
	Coefficients	*P-value*		*Coefficients*	*P-value*		*Coefficients*	*P-value*		*Coefficients*	*P-value*
Intercept	8.0369	0.6961	Intercept	5.3748	0.7907	Intercept	36.1756	0.0650	Intercept	28.5205	0.1696
years	-0.0176	0.0711	years	-0.0220	0.0228	years	-0.0328	0.0024	years	-0.0263	0.0148
Aug EIO	1.2046	0.0002	Sept EIO	1.5841	0.0001	Oct EIO	1.1516	0.0003	Nov EIO	0.9615	0.0041
Aug IPI, Years, Trended Wind			Sept IPI, Years, Trended Wind			Oct IPI, Years, Trended Wind			Nov IPI, Years, Trended Wind		
Multiple R	0.5443		Multiple R	0.5334		Multiple R	0.5785		Multiple R	0.5298	
R Square	0.2963		R Square	0.2845		R Square	0.3347		R Square	0.2806	
	Coefficients	*P-value*		*Coefficients*	*P-value*		*Coefficients*	*P-value*		*Coefficients*	*P-value*
Intercept	38.9997	0.0460	Intercept	38.9996	0.0478	Intercept	38.9997	0.0404	Intercept	38.9999	0.0483
years	-0.0188	0.0548	years	-0.0188	0.0564	years	-0.0188	0.0484	years	-0.0188	0.0573
Aug IPI	0.3314	0.0002	Sept IPI	0.3178	0.0003	Oct IPI	0.3716	0.0001	Nov IPI	0.3347	0.0004

IPI and Multiple Linear Regression Results

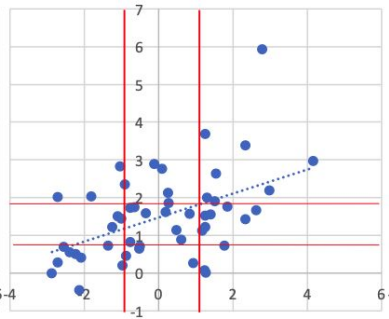
Aug IPI, Years, Trended Wind			Sept IPI, Years, Trended Wind			Oct IPI, Years, Trended Wind			Nov IPI, Years, Trended Wind		
Multiple R	0.5443		Multiple R	0.5334		Multiple R	0.5785		Multiple R	0.5298	
R Square	0.2963		R Square	0.2845		R Square	0.3347		R Square	0.2806	
	Coefficients	*P-value*		*Coefficients*	*P-value*		*Coefficients*	*P-value*		*Coefficients*	*P-value*
Intercept	38.9997	0.0460	Intercept	38.9996	0.0478	Intercept	38.9997	0.0404	Intercept	38.9999	0.0483
years	-0.0188	0.0548	years	-0.0188	0.0564	years	-0.0188	0.0484	years	-0.0188	0.0573
Aug IPI	0.3314	0.0002	Sept IPI	0.3178	0.0003	Oct IPI	0.3716	0.0001	Nov IPI	0.3347	0.0004

Scatter Plots w/ Trend Lines at Each Lead

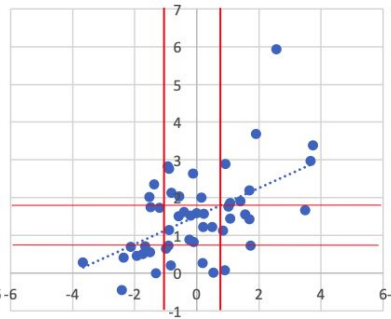
Aug. IPI vs. Nov. CAU850



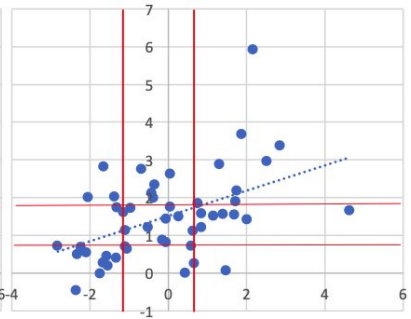
Sept. IPI vs. Nov. CAU850



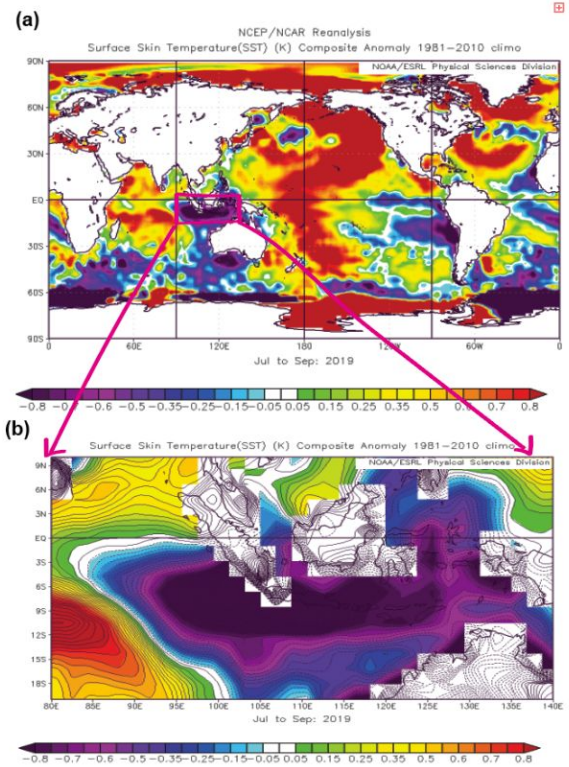
Oct. IPI vs. Nov. CAU850



Nov. IPI vs. Nov. CAU850

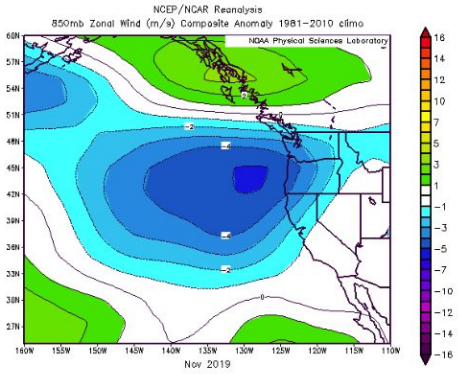


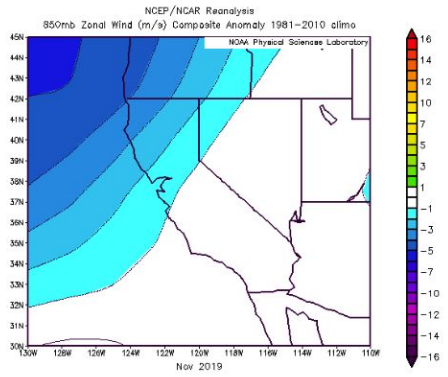
SST anomalies in summer-fall 2019 indicated increased risk of fire favorable offshore wind events in California in Oct.-Nov. 2019



Predictions

- **Summer 2019**: wanted to see how well this methodology would perform given high magnitude presence of negative SST anomalies in maritime continent during fall 2019





SSTs in 2019 correctly predicted offshore wind in California Nov 2019

Aside: Using trended vs. detrended data

Does detrending change BN CAU850 years?

trended	detrend
1976	1976
2004	1986
2013	1989
2007	2004
2019	2007
1989	2013
1986	1993
1993	1992
1992	1978
2018	1987
2002	1990
1990	1980
1987	1991
2009	2019
1991	2002
2008	1971

EIO Trends

Aug SST: y=-0.001x + 25.704
Sept SST: y=0.002x + 21.226
Oct SST: y=0.0078x + 10.898
Nov SST: y=-0.0041x + 28.466

X -> 1970, etc.

ENM Trends

Aug SST: y=0.014x + 27.582
Sept SST: y=0.0143x + 27.879
Oct SST: y=0.0152x + 28.406
Nov SST: y=-0.0159x + 27.579

X -> 1,2, etc.

NZ Trends

Aug SST: y=0.0085x + 1.846
Sept SST: y=0.0028x + 13.765
Oct SST: y=9E-05x + 18.754
Nov SST: y=-0.0041x + 28.466

X -> 1970, etc.

CAU850 Trend

Nov U850: y= -0.0188x + 39

X -> 1970, etc.

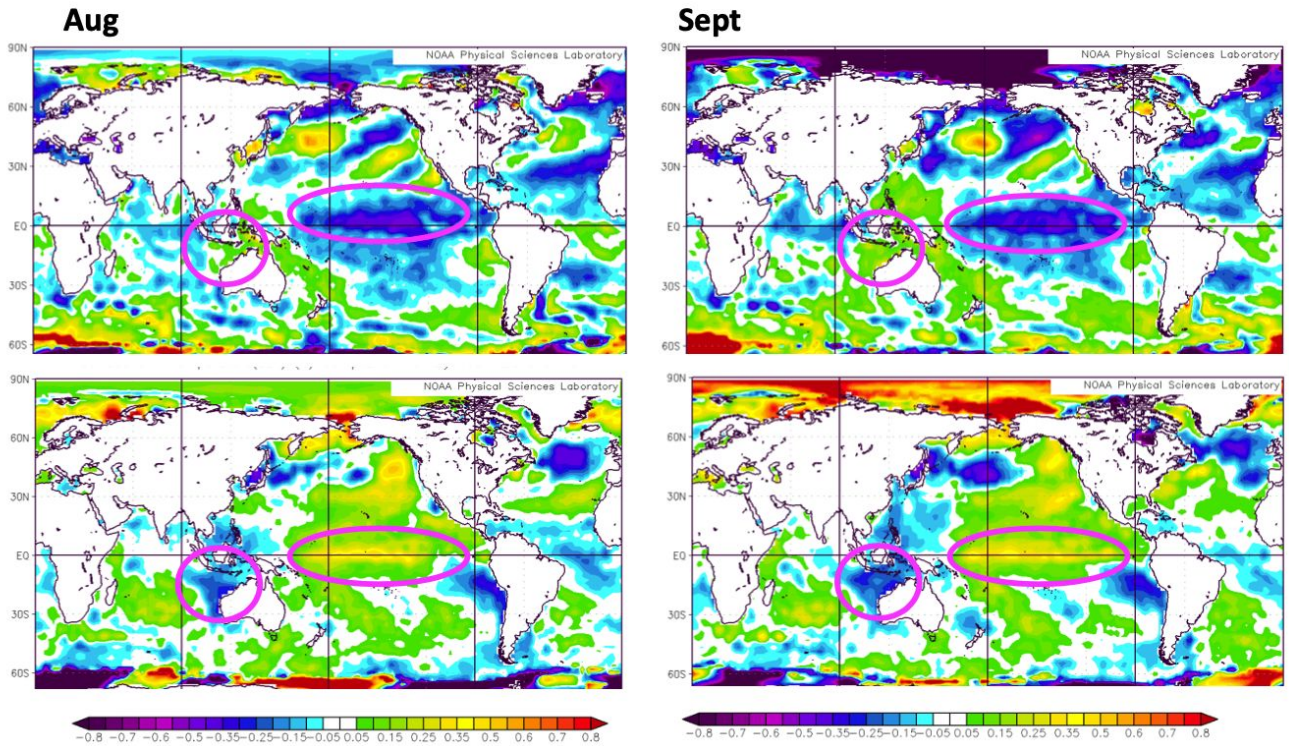
Correlation Values between different California regions

CA/NorCal	CA/CentCal	CA/SoCal
0.94	0.98	0.94
NorCal/CentCal	**NorCal/SoCal**	**SoCal/CentCal**
0.88	0.77	0.93

Conditional Composites based on BN/AN CAU850 Years: Aug and Sept SSTA

AN CAU850 Years

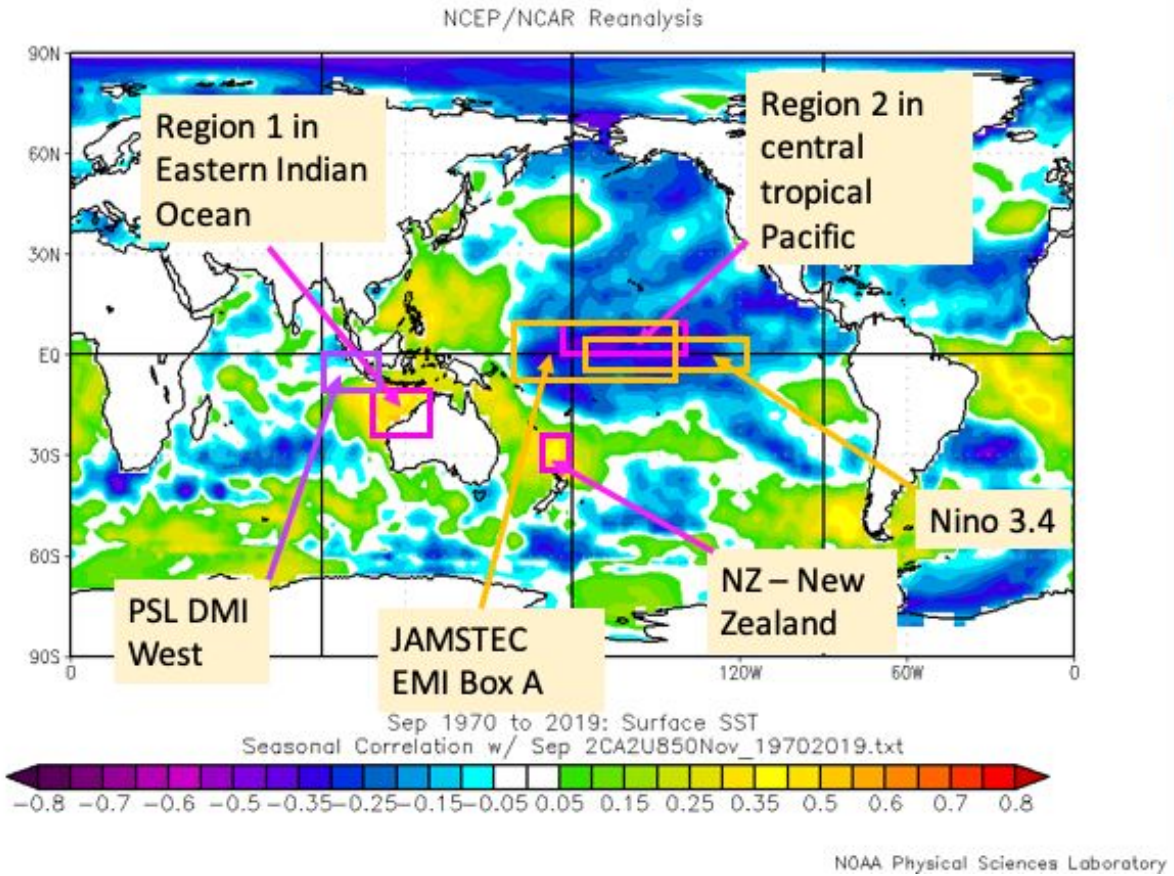
BN CAU850 Years



Tendency for anomalies to be opposite between AN/BN conditions in the tropics

Good predictors would be regions where SSTAs opposite, i.e. have strong correlation

Correlation between CA winds in November and global SST in September



Familiar climate variations seem to play a role, but standard indices not the best predictors

Prediction for November 2020

IPI Thresholds	Aug	Sept
BN threshold	1.2069	1.1753
AN threshold	1.6691	1.8122

EIO Threshold	Aug	Sept
BN threshold	1.1917	1.2848
AN threshold	1.7204	1.8125

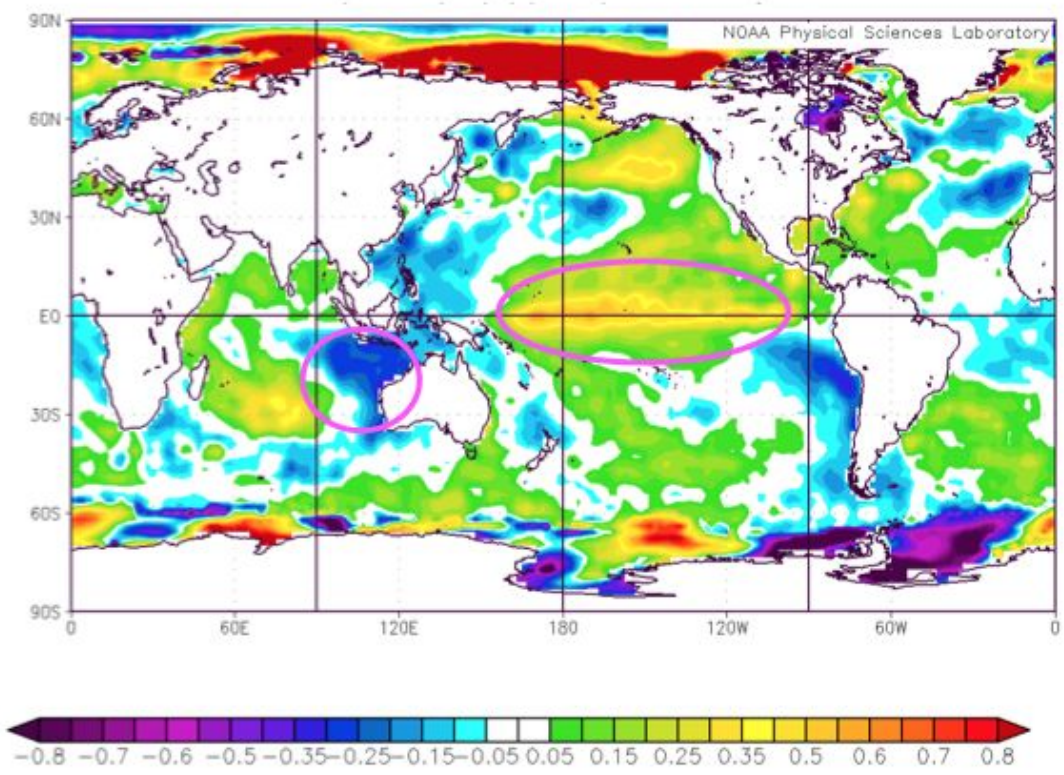
AN

NN

BN

	Aug	Sept
IPI/CA 2020	1.7157	2.0900
EIO/CA 2020	1.6493	2.5136

Conditional Composite of November SSTAs During Fire Favorable Novembers in California



Why we looked at SSTs:

Anomalous behavior easy to observe

Indications of known climate variations (Indian Ocean Dipole [IOD], El Niño Modoki [ENM], El Niño)