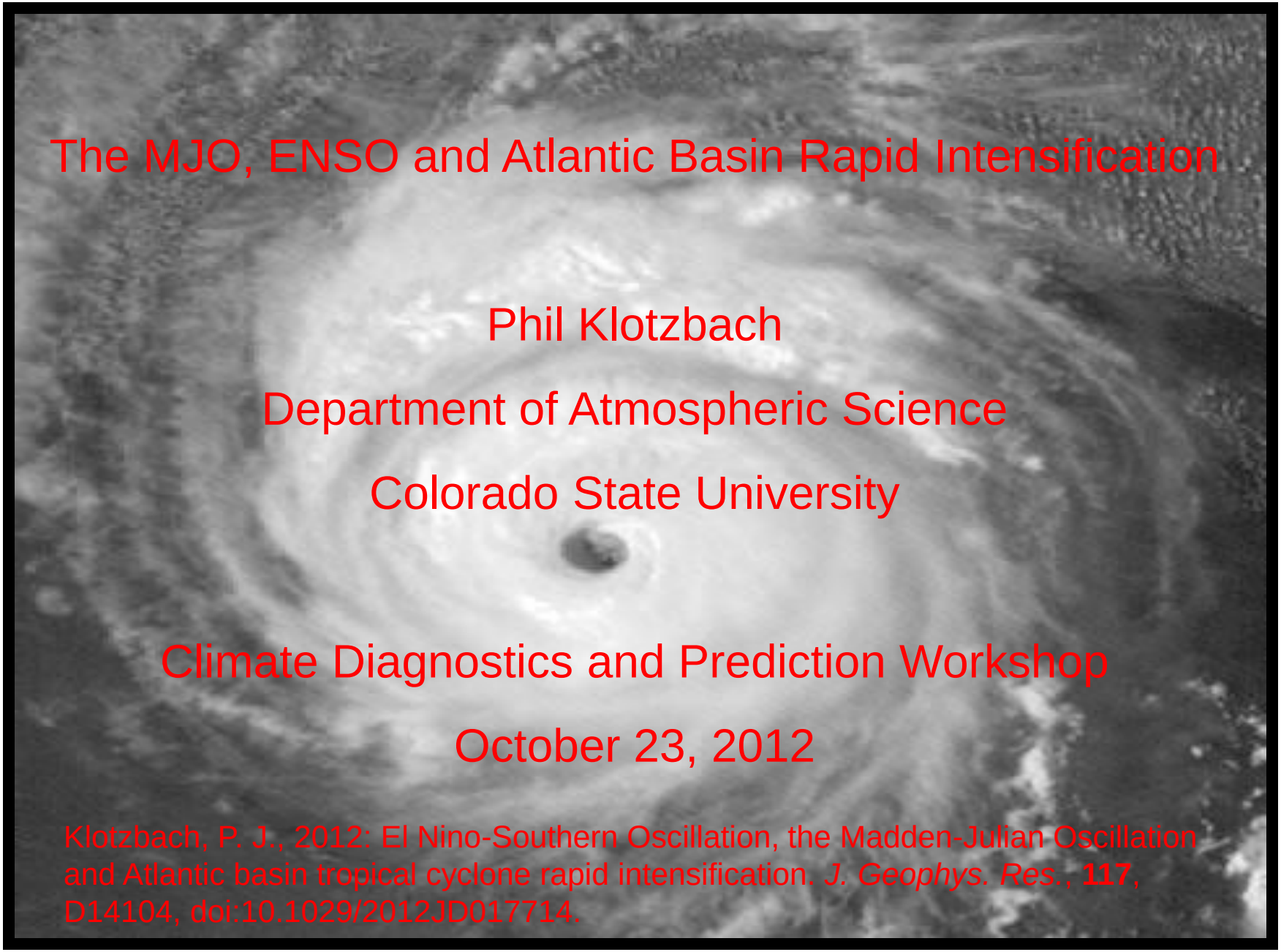


The MJO, ENSO and Atlantic Basin Rapid Intensification

Phil Klotzbach

Department of Atmospheric Science

Colorado State University

Climate Diagnostics and Prediction Workshop

October 23, 2012

Klotzbach, P. J., 2012: El Nino-Southern Oscillation, the Madden-Julian Oscillation and Atlantic basin tropical cyclone rapid intensification. *J. Geophys. Res.*, **117**, D14104, doi:10.1029/2012JD017714.

Outline

- Data
- ENSO's Impacts on Atlantic Basin TCs and RI
- MJO's Impacts on Atlantic Basin TCs and RI
- Impact of combined ENSO/MJO index on Atlantic Basin TCs and RI
- Conclusions and Future Work

Data Sources

- ENSO Index: Multivariate ENSO Index (MEI) – take August-October average – highest ten years (El Niño), middle 16 years (neutral) – lowest ten years (La Niña)

- MJO Index: Wheeler-Hendon (WH) Index – uses OLR and 200- and 850-mb zonal wind components – available since 1974, except for 1978 when OLR was unavailable (120-Day Mean and ENSO removed)

- MJO-ENSO Index: Developed by WH – Includes 120-Day Mean and ENSO

- TC Statistics – National Hurricane Center's best track

- Large-Scale Analysis – NCEP/NCAR Reanalysis I

ENSO's Impacts on Atlantic Basin TCs and RI

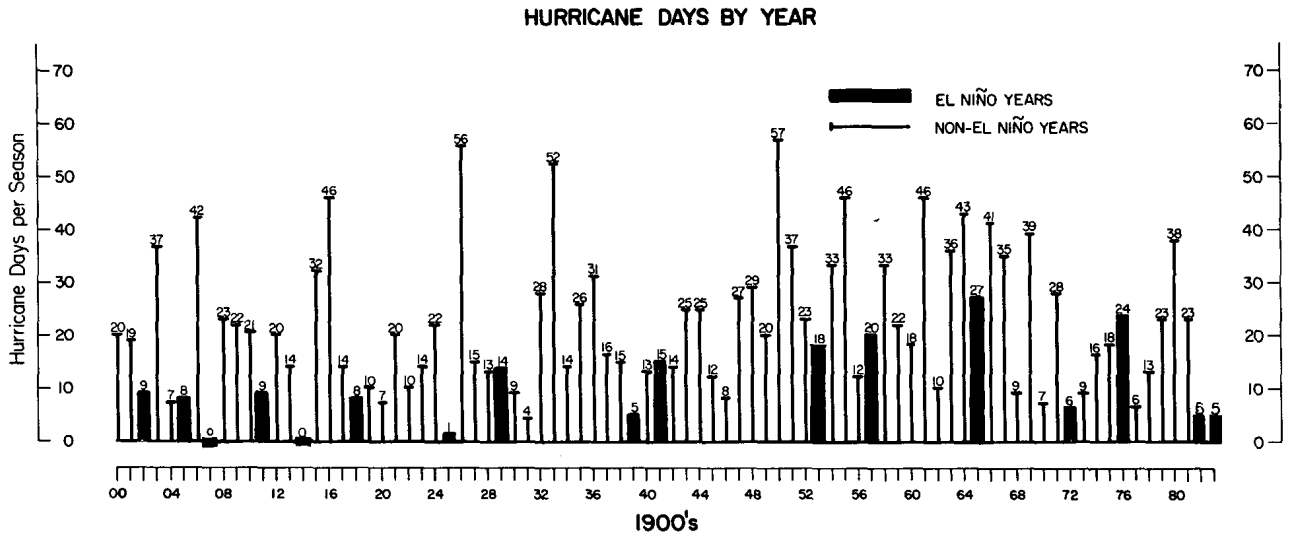


FIG. 2. Number of hurricane days (given at top of lines) in El Niño and non-El Niño years from 1900 to 1982.

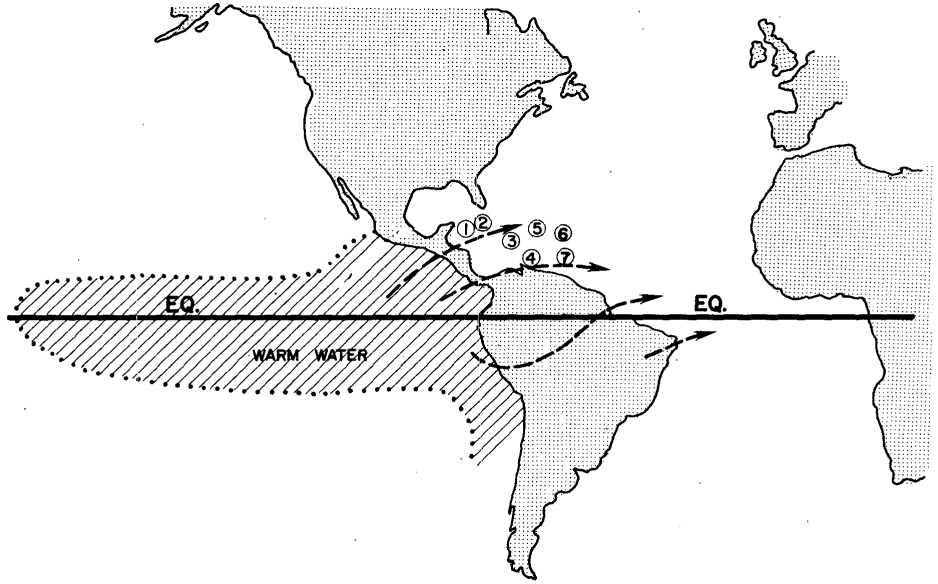
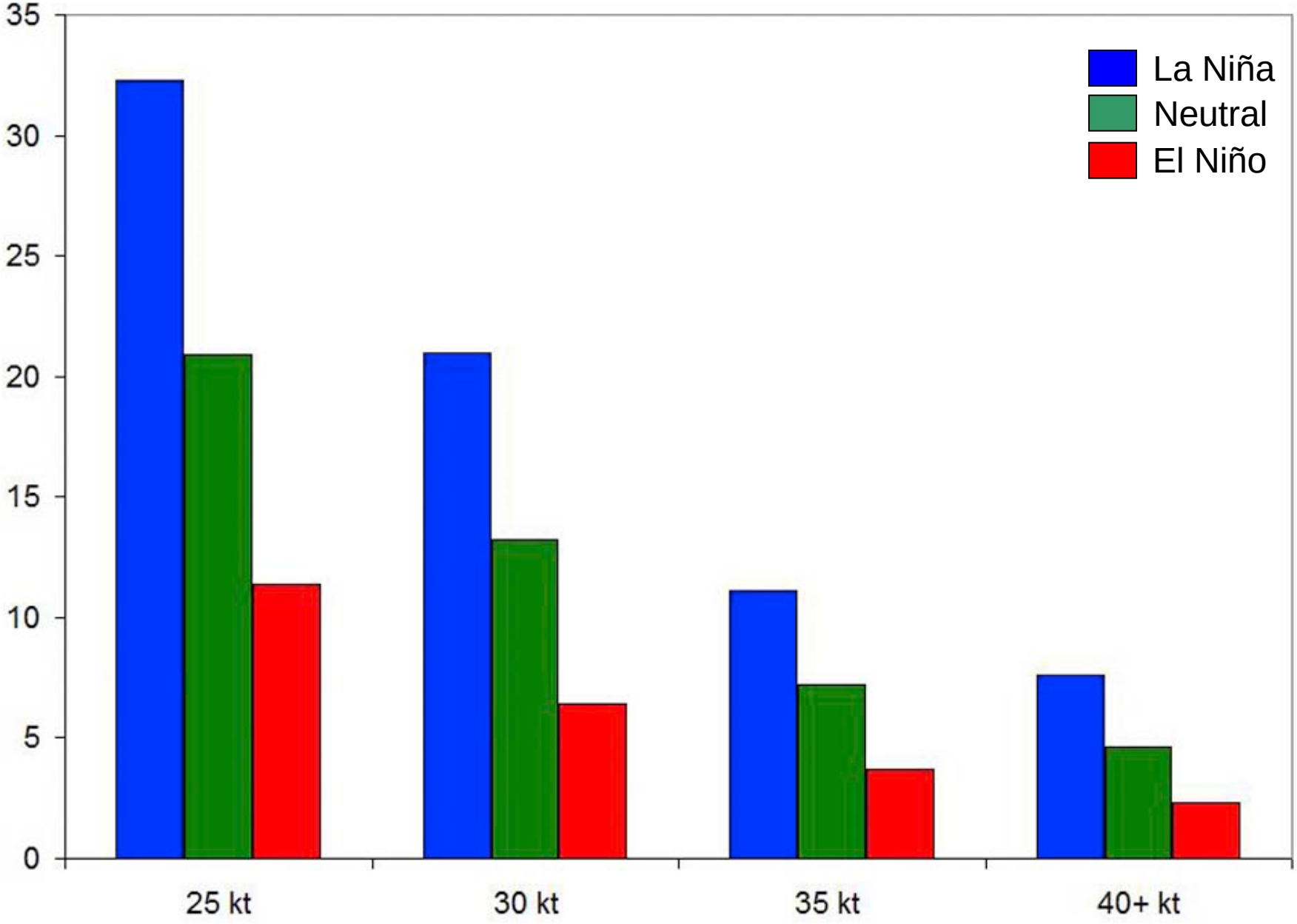


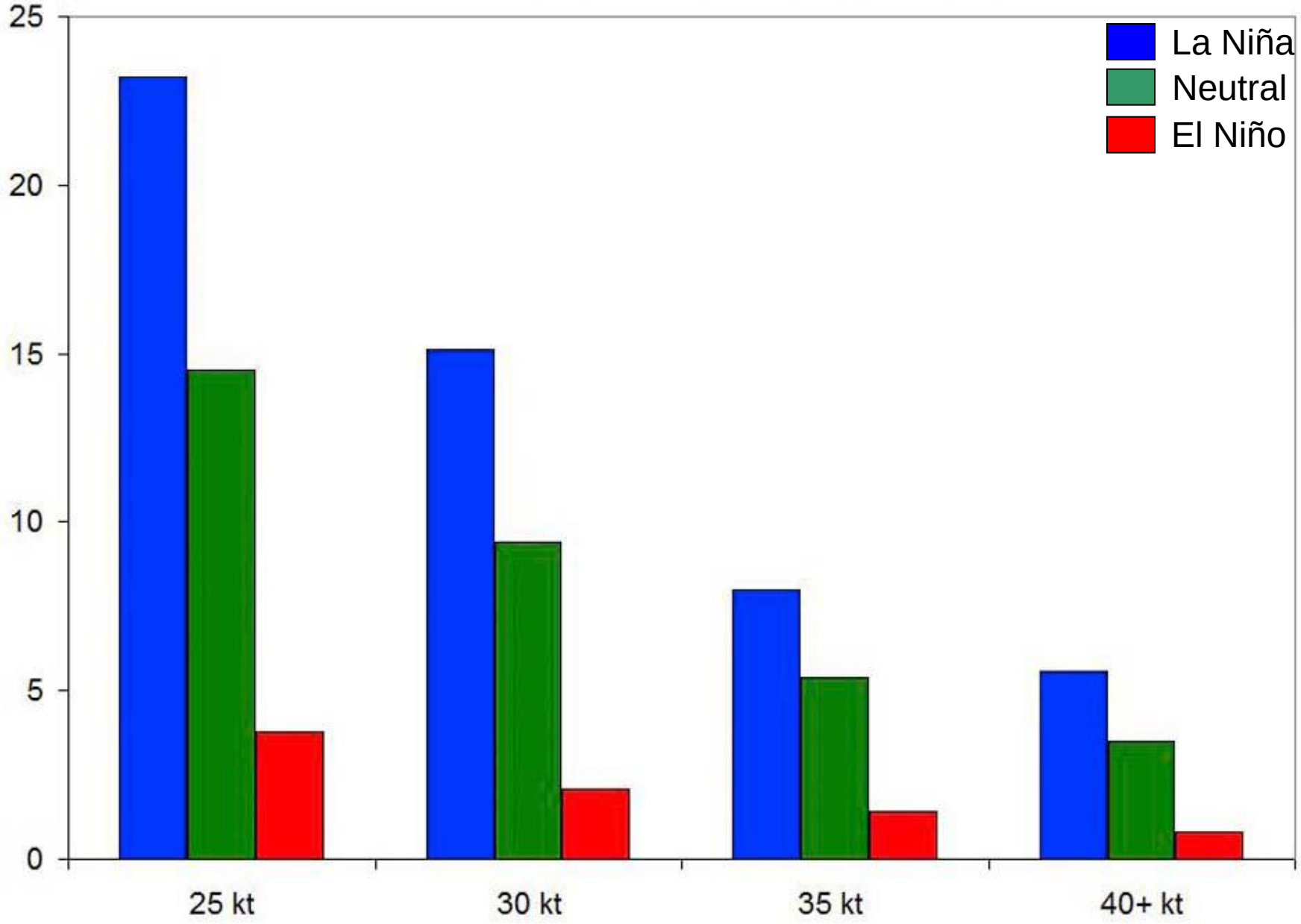
FIG. 6. Deviational upper tropospheric (~200 mb) outflow wind patterns due to enhanced deep-cumulus convection in the eastern tropical Pacific in moderate and strong El Niño years. These wind patterns are hypothesized to result from anomalously warm eastern Pacific water. [Numbers indicate upper-air stations at Swan Island (1), Grand Cayman (2), Kingston, Jamaica (3), Curaçao (4), San Juan (5), St. Maarten (6) and Barbados (7)].

Gray (1984)

Average per Year 24-Hour Periods for Systems Undergoing RI for Various Thresholds – All Atlantic Basin TCs

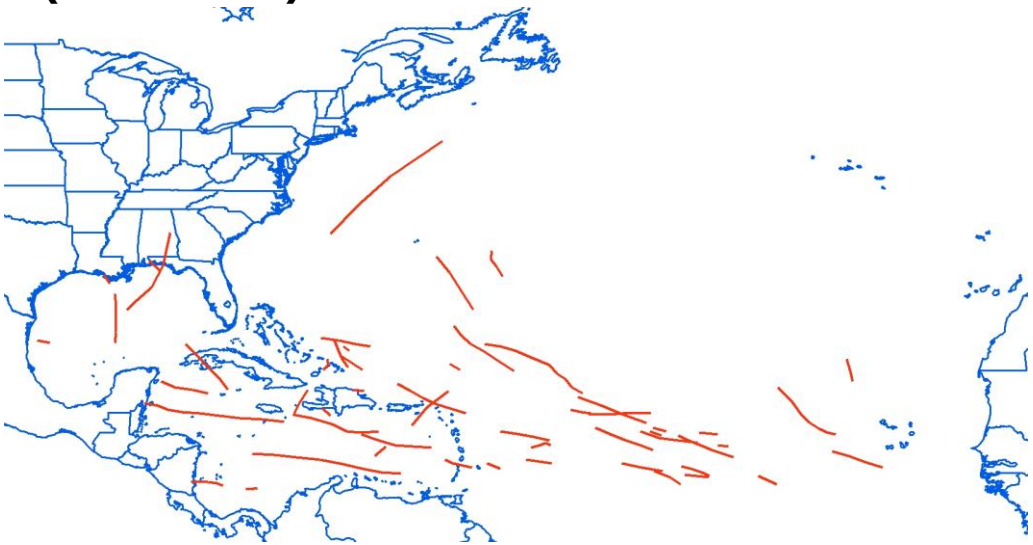


Average per Year 24-Hour Periods for Systems Undergoing RI for Various Thresholds – MDR TCs (7.5-22.5°N, 75-20°W)



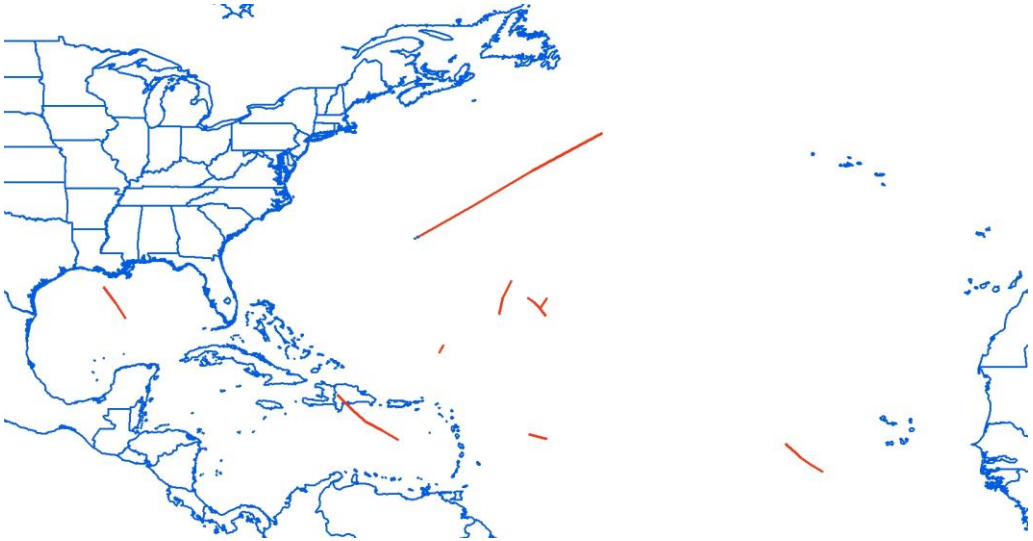
Tracks of 24-Hour RI >= 30 Knots for MDR TCs in La Niña vs. El Niño (1974-2010)

La Niña



151 24-Hour RI Events

El Niño



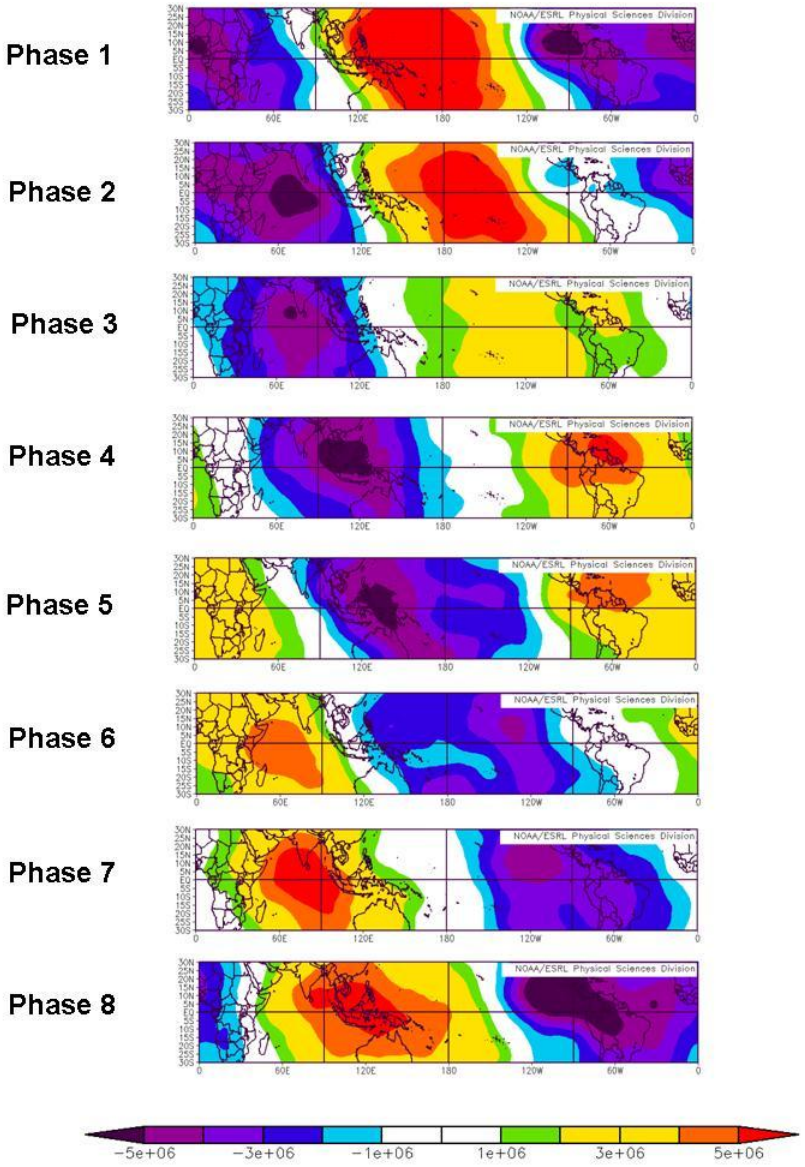
21 24-Hour RI Events

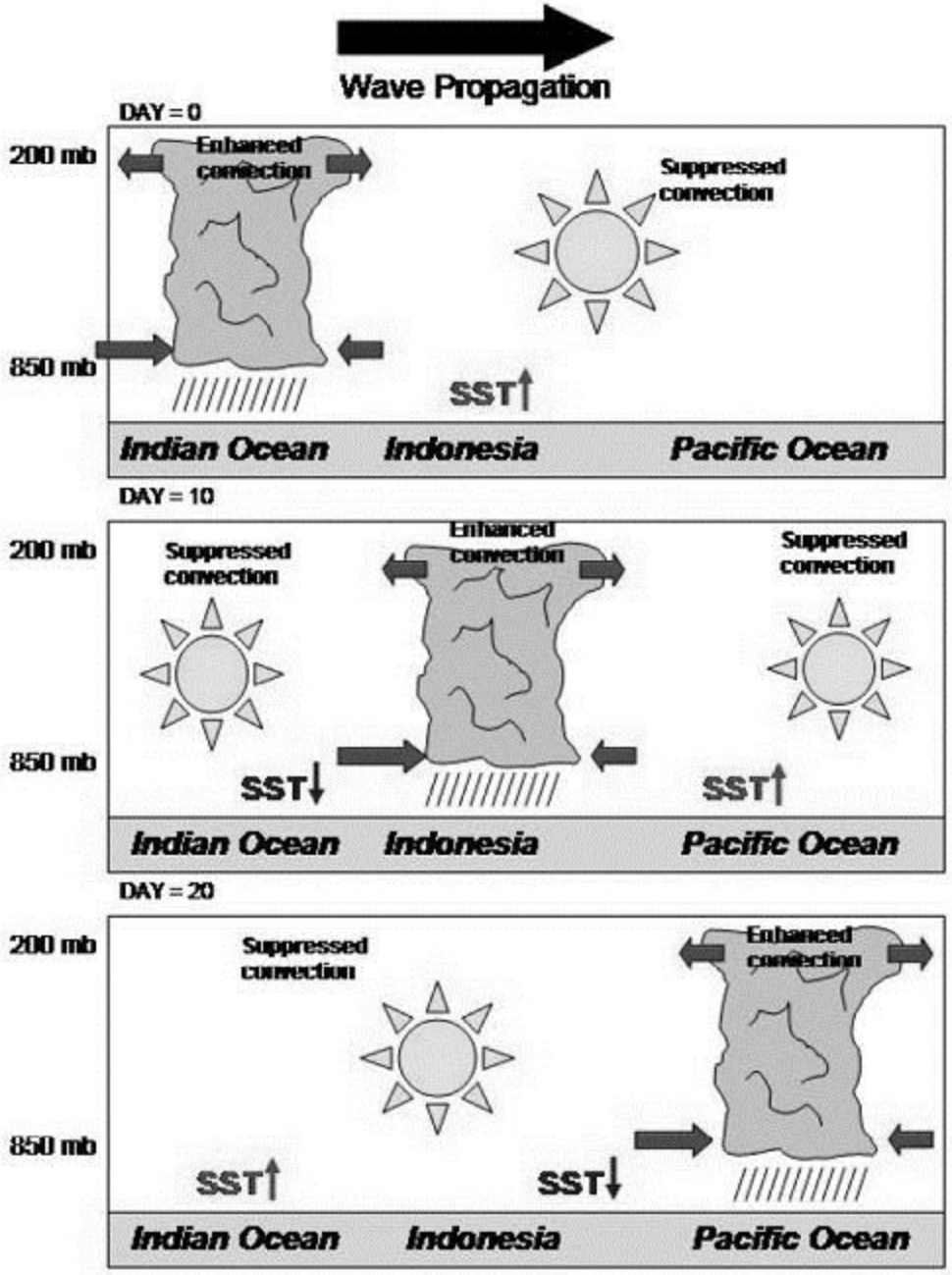
Percentage Chance of All Atlantic Basin TCs and TCs Forming in the MDR in Each Phase of ENSO Having a RI Event of 25 Knots, 30 Knots, 35 Knots and 40+ Knots Over 24 h

ENSO Phase	25 kt	30 kt	35 kt	40 kt
All TCs				
La Niña	53%	43%	29%	23%
Neutral	46%	36%	22%	14%
El Niño	39%	27%	17%	12%
MDR TCs				
La Niña	67%	58%	39%	32%
Neutral	60%	50%	35%	23%
El Niño	36%	28%	20%	12%

MJO's Impacts on Atlantic Basin TCs and RI

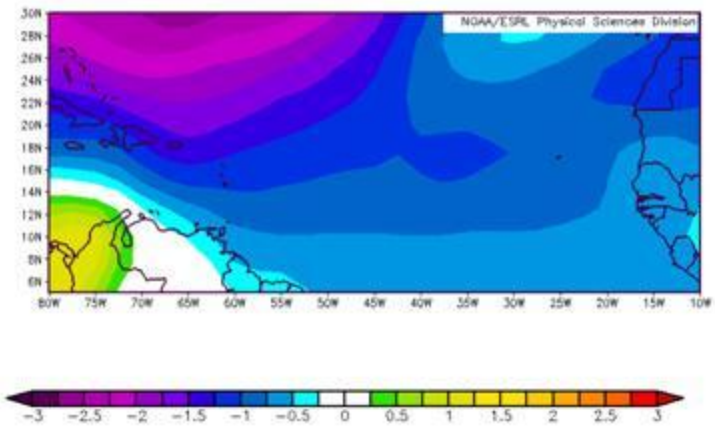
July-October 200-mb Velocity Potential Anomalies Associated with the Madden-Julian Oscillation (MJO) – as defined by the Wheeler-Hendon (WH) index



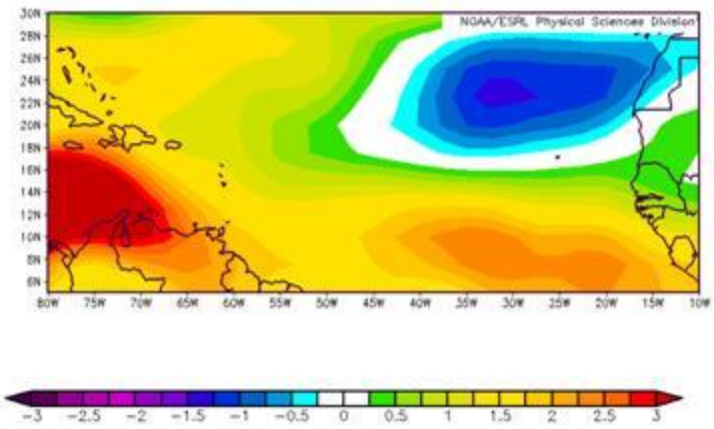

Wave Propagation
DAY = 0
200 mb
850 mb
Enhanced convection
Suppressed convection
SST↑
Indian Ocean
Indonesia
Pacific Ocean
DAY = 10
200 mb
850 mb
Suppressed convection
Enhanced convection
Suppressed convection
SST↓
SST↑
Indian Ocean
Indonesia
Pacific Ocean
DAY = 20
200 mb
850 mb
Suppressed convection
Enhanced convection
SST↑
SST↓
Indian Ocean
Indonesia
Pacific Ocean

Phase 1-2 – Phase 6-7

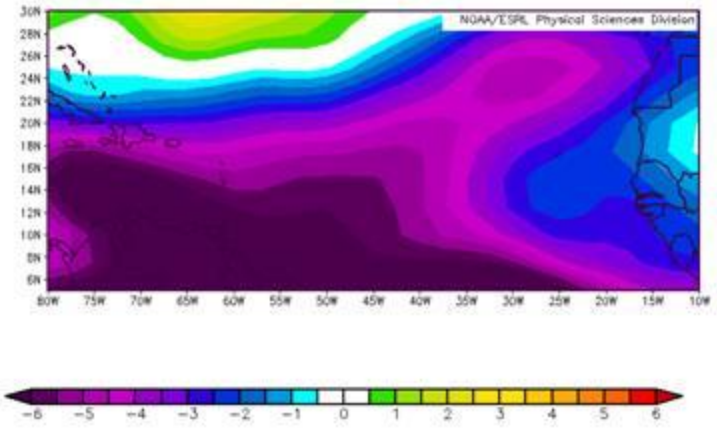
SLP



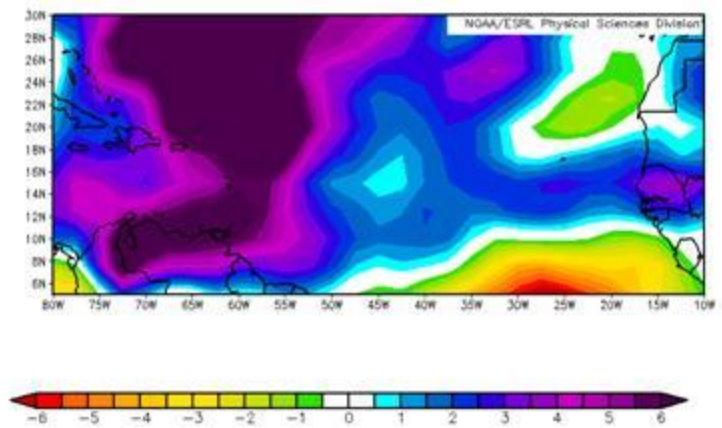
850-mb U

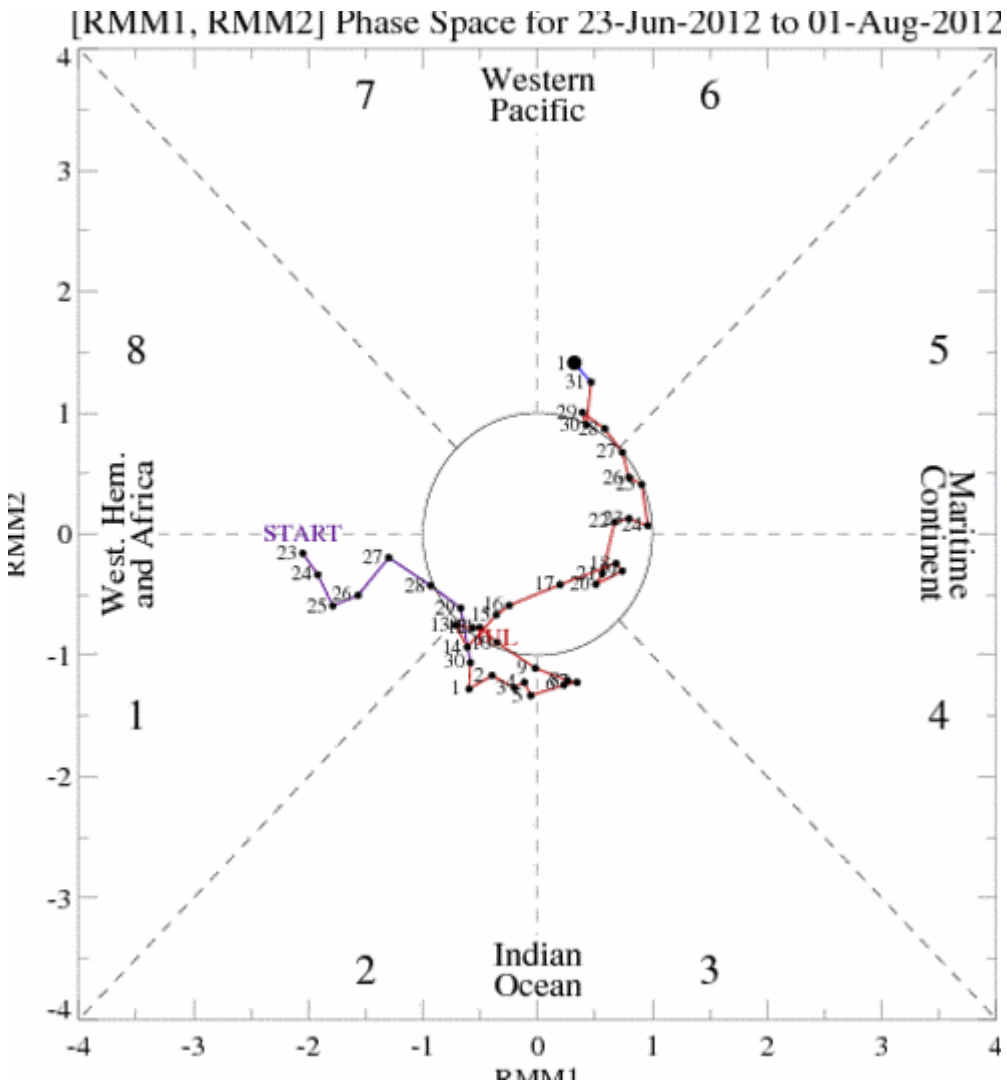


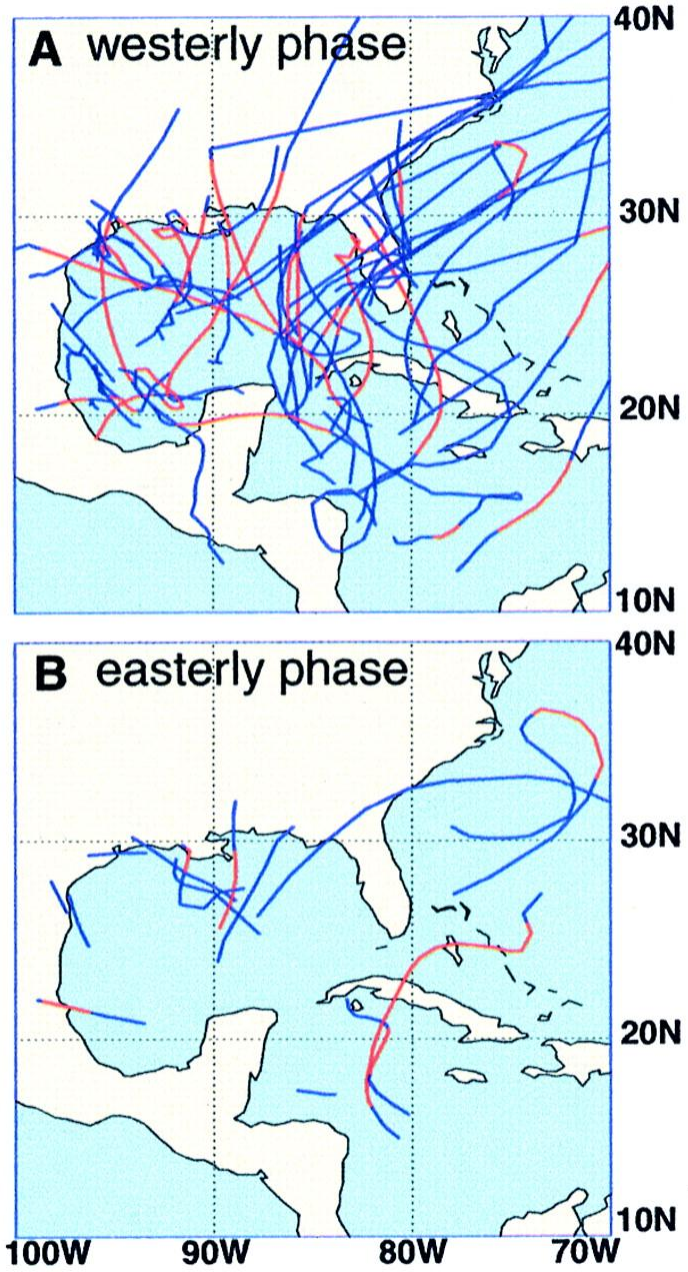
200-mb U



700-mb RH




[RMM1, RMM2] Phase Space for 23-Jun-2012 to 01-Aug-2012
Western Pacific
Maritime Continent
Indian Ocean
West. Hem. and Africa
7
6
5
8
1
4
2
3
START
RMM1
RMM2



Maloney and Hartmann (2000)

Normalized Values for Various TC Parameters in the Atlantic basin from 1974-2007 based on MJO Day of Formation

MJO Phase	NS	NSD	H	HD	MH	MHD	ACE
Phase 1	6.4	35.9	3.7	17.9	1.8	5.3	76.2
Phase 2	7.5	43.0	5.0	18.4	2.1	4.6	76.7
Phase 3	6.3	30.8	3.0	14.7	1.4	2.8	56.0
Phase 4	5.1	25.5	3.5	12.3	1.0	2.8	49.4
Phase 5	5.1	22.6	2.9	9.5	1.2	2.1	40.0
Phase 6	5.3	24.4	3.2	7.8	0.8	1.1	35.7
Phase 7	3.6	18.1	1.8	7.2	1.1	2.0	33.2
Phase 8	6.2	27.0	3.3	10.4	0.9	2.6	46.8
Phase 1-2	7.0	39.4	4.3	18.1	1.9	4.9	76.5
Phase 6-7	4.5	21.5	2.5	7.5	1.0	1.5	34.6
Phase 1-2 / Phase 6-7	1.6	1.8	1.7	2.4	2.0	3.2	2.2

Klotzbach (2010)

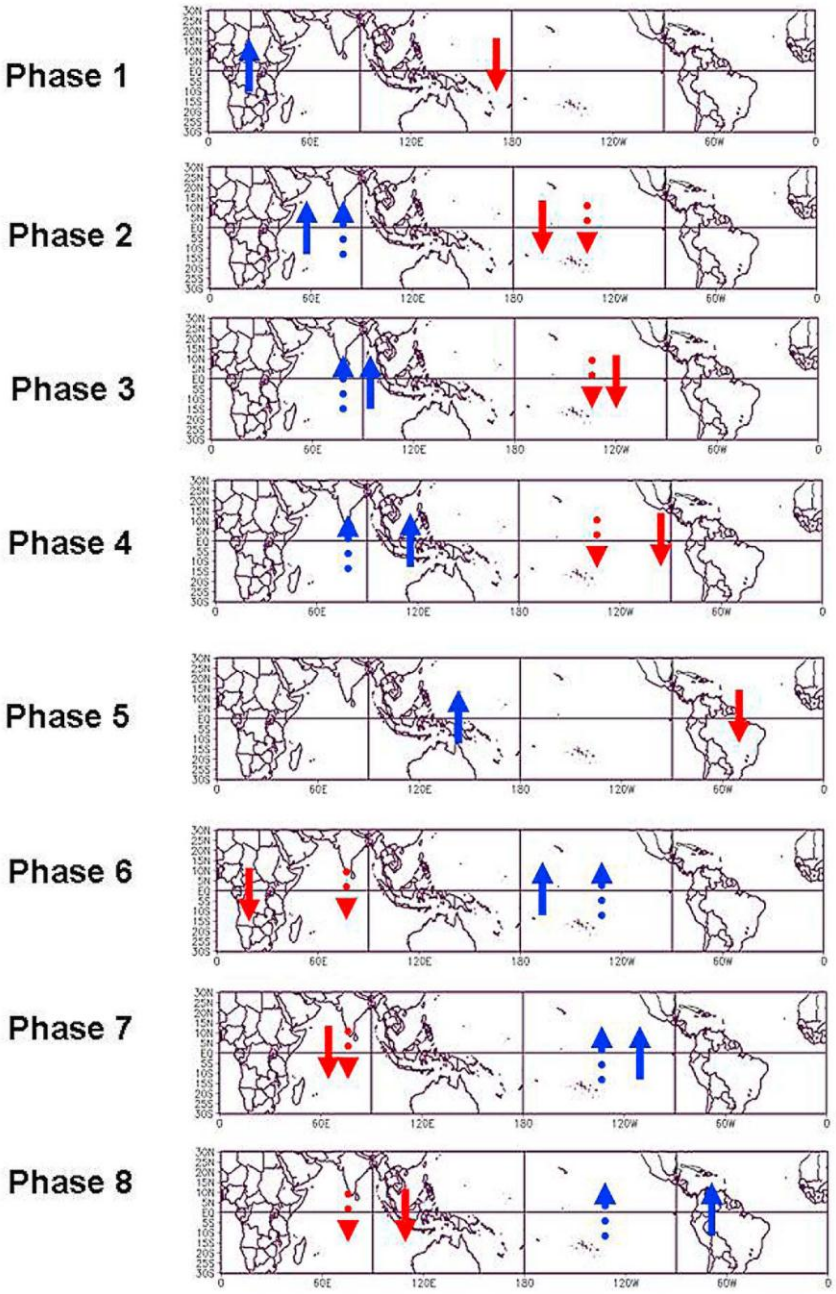
Normalized number of 24-Hour periods for TCs undergoing RI – in the MDR (1974-2010) – MJO Amplitude Greater than One

MJO Phase	25 kt	30 kt	35 kt	40+kt
Phase 1	22.0	13.7	8.1	6.1
Phase 2	22.4	14.6	9.3	6.8
Phase 3	6.9	2.8	1.4	0.9
Phase 4	14.5	9.0	4.3	2.7
Phase 5	6.8	4.8	2.4	1.8
Phase 6	6.8	3.9	1.9	0.6
Phase 7	1.5	0.5	0.5	0.0
Phase 8	5.8	4.5	2.2	0.9
Phase 1-2 / Phase 6-7	5.4	6.3	7.2	18.6

Percentage Chance of TCs Forming in the MDR in Each Phase of the MJO Having a RI Event of 25 Knots, 30 Knots, 35 Knots and 40+ Knots Over 24 h – MJO Greater than one SD

MJO Phase	25 kt	30 kt	35 kt	40+ kt
1	84%	74%	53%	42%
2	69%	62%	42%	35%
3	56%	22%	11%	11%
4	62%	54%	38%	23%
5	47%	41%	29%	12%
6	38%	23%	23%	8%
7	20%	20%	20%	0%
8	40%	40%	40%	20%
Phase 1+2	76%	67%	47%	38%
Phase 6+7	33%	22%	22%	6%

Combined ENSO/MJO Impacts on Atlantic Basin TCs and RI



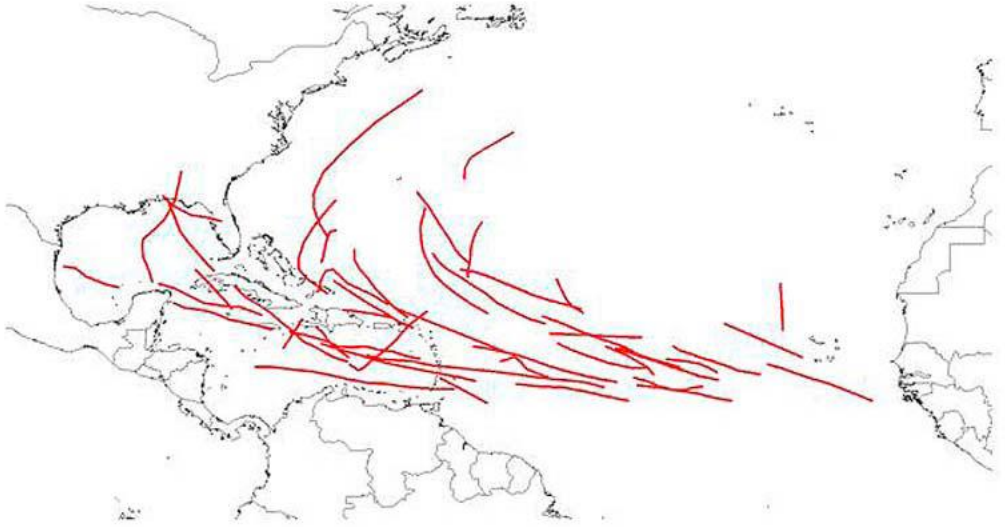
Anomalous Vertical Motion Associated with WH-Combined Index – Solid Lines represent anomalous vertical motion associated with MJO, dashed lines represent anomalous vertical motion associated with ENSO

WH-Combined Average Anomalies from July 1 – October 31 by MJO Phase (greater than 1 Standard Deviation)

MJO Phase	Days per Phase	200-mb U	850-mb U	200-850 mb U	SST	SLP	700 mb RH	300 mb ω	OLR
1	327	-1.60	0.09	-1.69	0.00	-0.25	0.49	-0.38	-0.86
2	484	-3.73	0.79	-4.53	0.08	-0.41	1.08	-1.69	-2.70
3	327	-2.49	0.60	-3.10	0.10	-0.19	0.75	-0.11	-0.06
4	370	0.80	-0.23	1.03	0.03	0.10	-0.36	-0.46	1.20
5	420	0.91	-0.29	1.20	-0.07	0.56	-1.06	2.18	3.47
6	347	1.18	-0.76	1.94	-0.13	0.55	-1.44	1.51	1.56
7	325	1.51	-0.55	2.06	-0.16	0.37	0.20	0.99	0.22
8	299	3.42	0.34	3.08	0.16	-0.73	0.34	-2.04	-2.83
Phases 2+3		-3.11	0.70	-3.81	0.09	-0.30	0.92	-0.90	-1.38
Phases 7+8		2.47	-0.10	2.57	0.00	-0.18	0.27	-0.52	-1.30
Phases 2+3 – Phases 7+8		**-5.58**	*0.80*	**-6.38**	0.09	-0.12	0.65	-0.37	-0.08

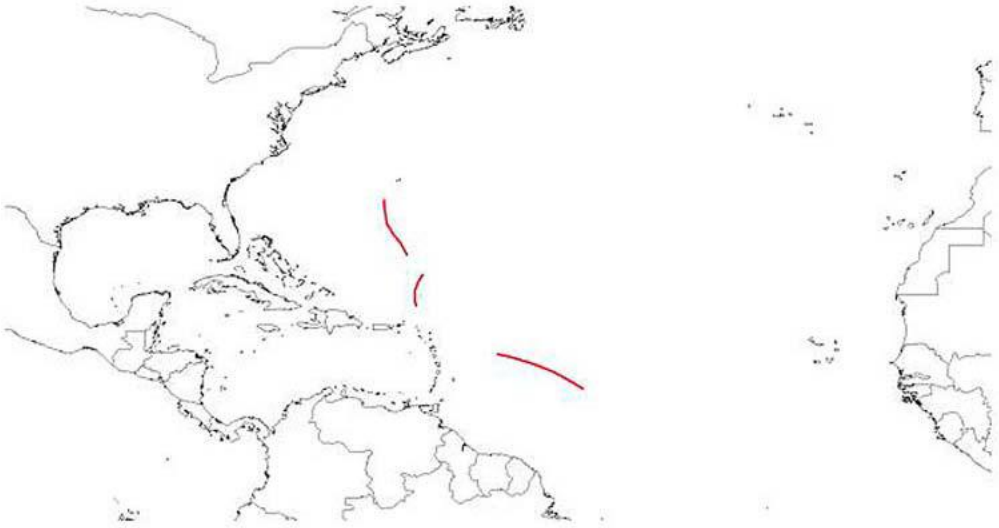
Tracks of TCs undergoing RI of at least 30 knots in 24 hours

Phases 2-3



43 TCs

Phases 7-8



3 TCs

Normalized number of 24-Hour periods for TCs undergoing RI – in the MDR (1974-2010)

WH-Combined Index	25 kt	30 kt	35 kt	40+kt
Phase 1	20.8	13.1	7.6	5.2
Phase 2	24.2	17.4	11.0	8.9
Phase 3	35.8	21.4	9.5	5.8
Phase 4	4.6	3.2	1.9	1.4
Phase 5	8.1	5.7	3.3	2.1
Phase 6	3.5	1.7	0.0	0.0
Phase 7	0.0	0.0	0.0	0.0
Phase 8	2.0	1.0	0.0	0.0
Phase 2-3 / Phase 7-8	29.0	38.2	∞	∞

Percentage Chance of TCs Forming in the MDR in Each Phase of the WH-Combined Index Having a RI Event of 25 Knots, 30 Knots, 35 Knots and 40+ Knots Over 24 h

WH-Combined	25 kt	30 kt	35 kt	40 kt
1	100%	77%	46%	38%
2	69%	66%	47%	47%
3	83%	71%	50%	33%
4	42%	33%	25%	17%
5	67%	53%	40%	20%
6	25%	17%	17%	0%
7	0%	0%	0%	0%
8	33%	33%	0%	0%
Phase 2+3	75%	68%	48%	41%
Phase 7+8	17%	17%	0%	0%

Conclusions and Future Work

- **Combining anomalies driven by ENSO (on the seasonal timescale) and the MJO (on the sub-seasonal timescale) makes for a powerful predictor for TC formation as well as RI**
- **TC alterations appear to be primarily driven by fluctuations in vertical wind shear anomalies**
- **Can the combined MJO/ENSO index aid in predictions of rapid intensification?**
- **Does the MJO/ENSO index show similar levels of skill in other tropical cyclone basins?**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