

The relationship between Easterly Waves over the Eastern Pacific and the Monsoon of North America.



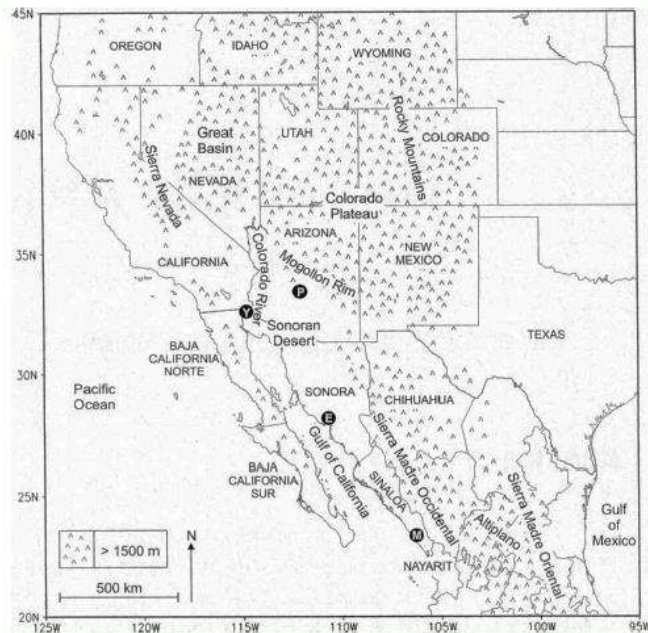
Victor M. Torres
SUNY – Albany.

Advanced School and Workshop on American Monsoons:

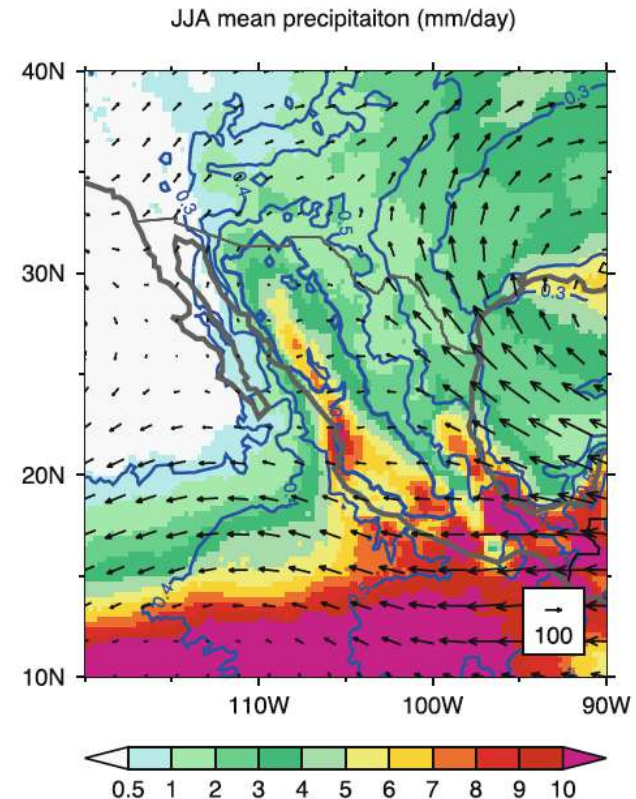
Progress and future plans

Aug 2019

The North America Monsoon region

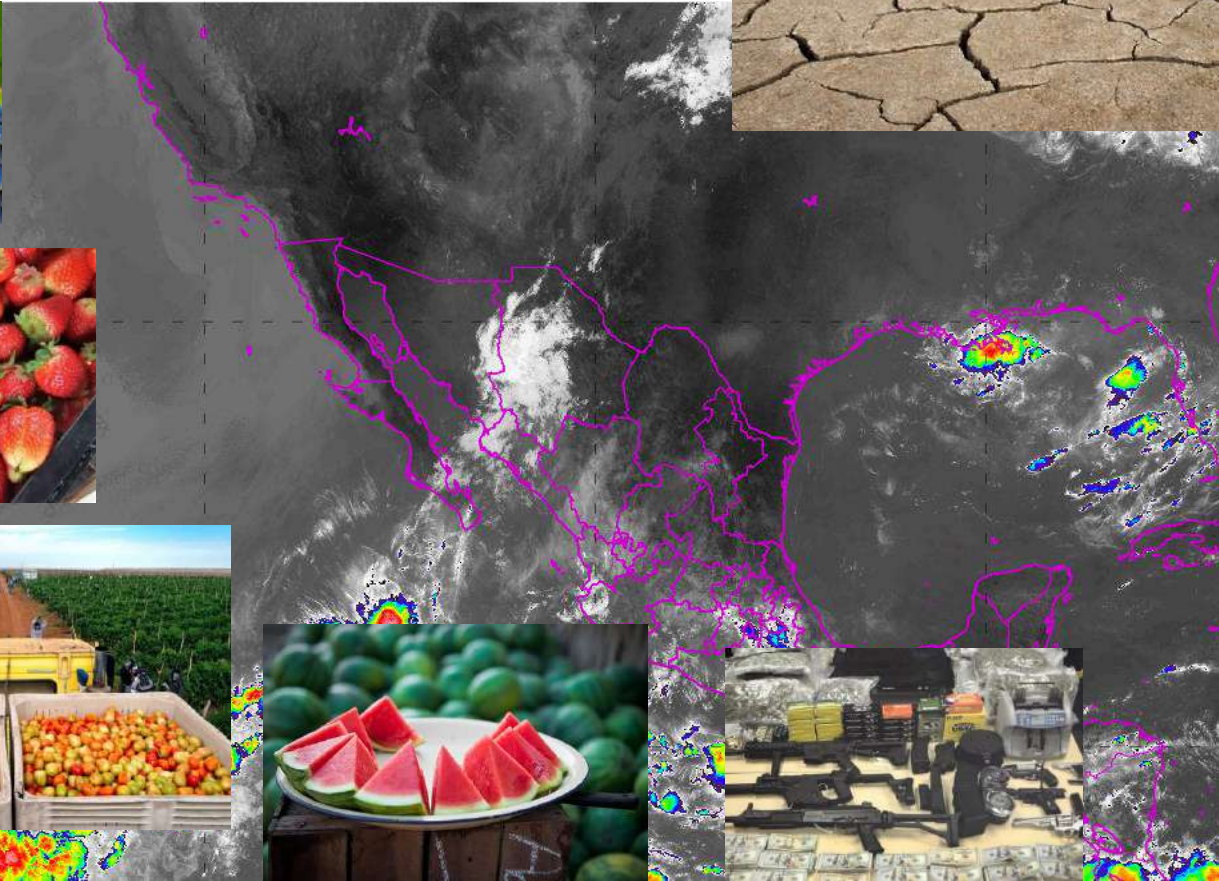


Douglas et al. 1993



Pascale et al. 2019

Importance of the NAMS



Impacts on water resources¹, food-supply, economy², social stability³

<https://droughtmonitor.unl.edu>

<http://www.sclubricants.com/california-drought/> ;

<https://www.nationalgeographic.com/news/2014/7/140715-california-drought-economic-impacts/>

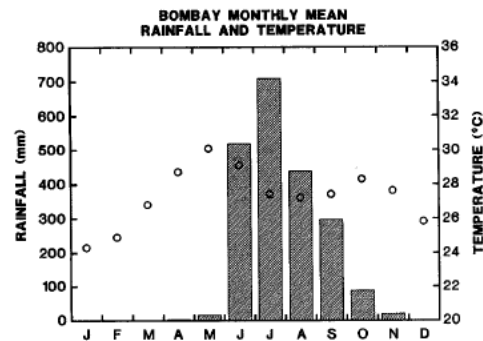
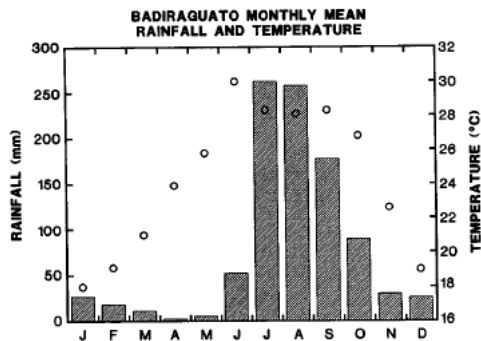
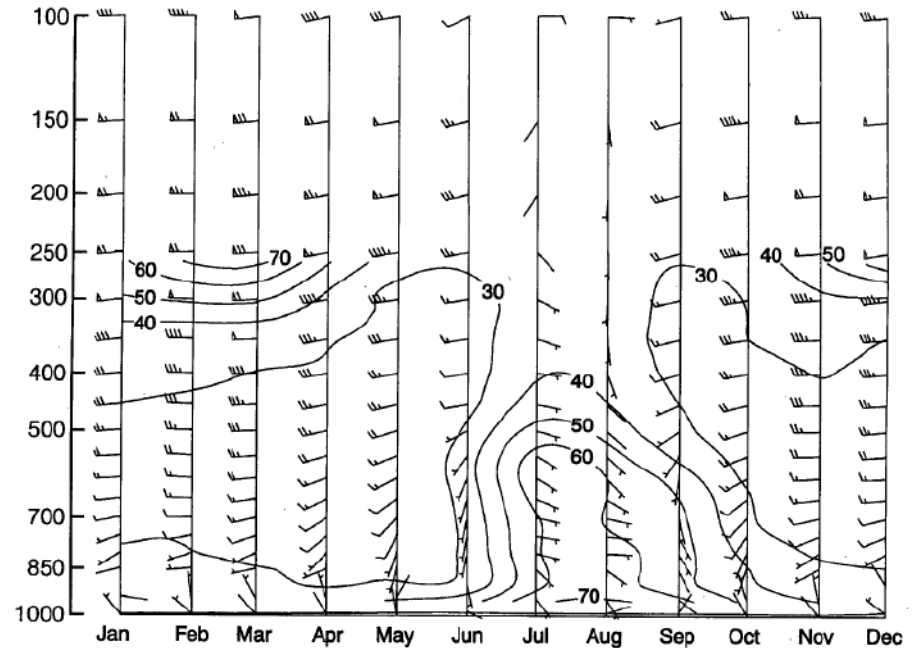
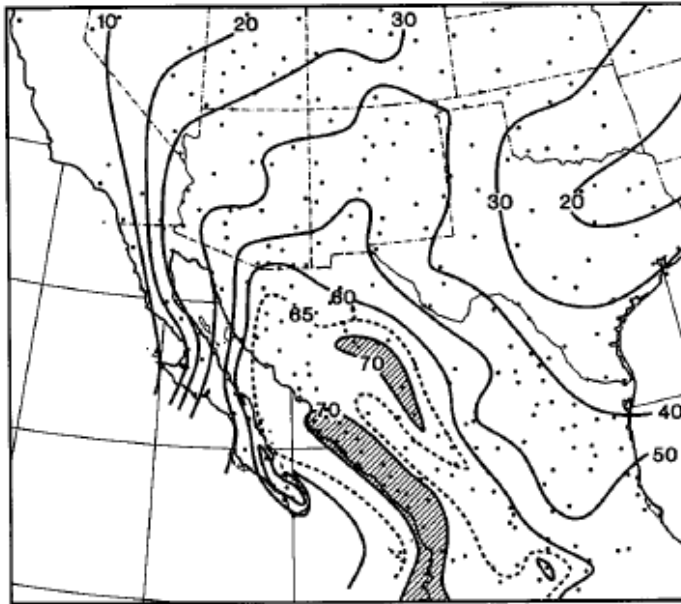
https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap12_FINAL.pdf

Is the North American Monsoon a “real” monsoon?

- **Classic definition** (Ramage 1971):
 - Prevailing winds shift 120° between January and July
 - Average frequency of prevailing wind $> 40\%$
 - Speed of mean winds exceeding 3ms^{-1}
 - Pressure patterns satisfy a steadiness criterion

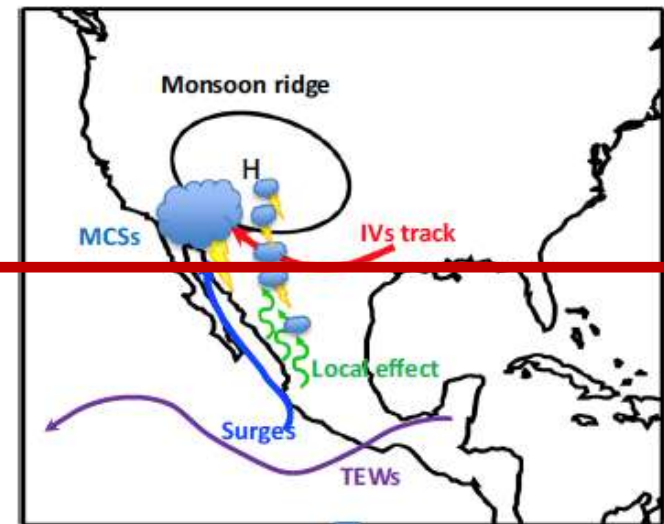
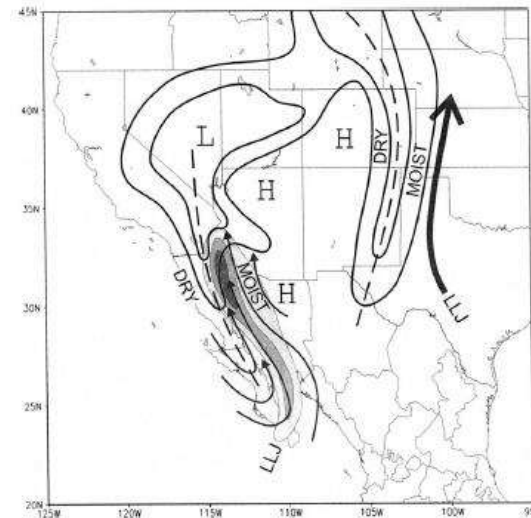
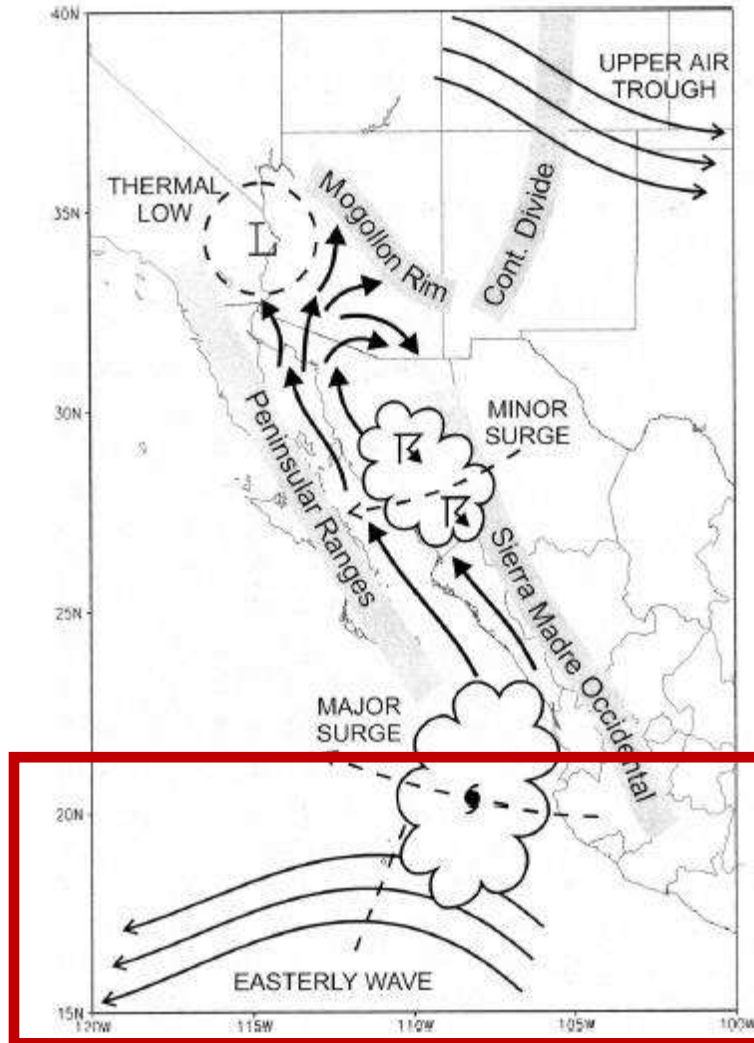
- **Current definition** (Trenberth et al. 2000):
 - Tropical overturning circulation (and associated rainfall)
 - Convective quasi-equilibrium (Emanuel 1994)

On the classic definition...



Douglas et al. 1993

Sources of moisture over the Monsoon region



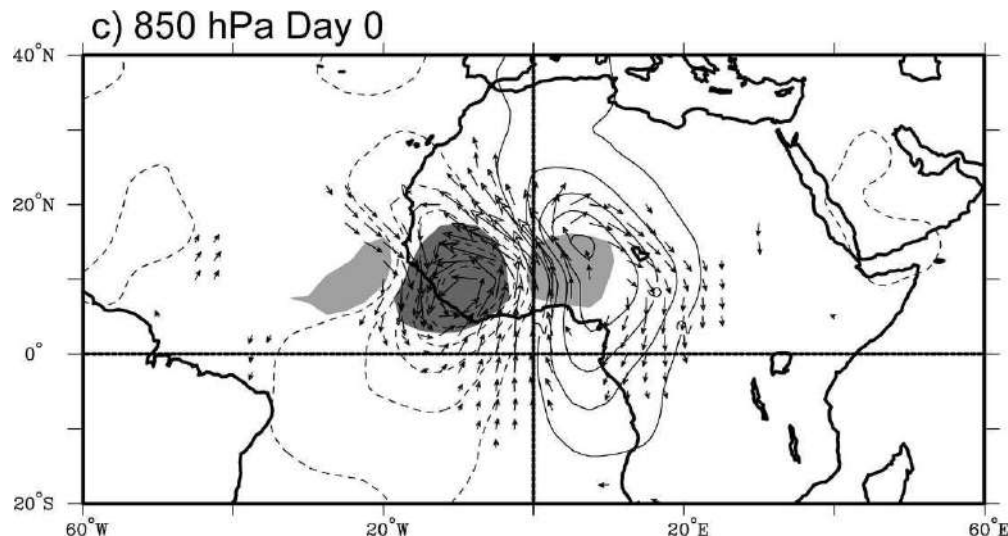
Adams and Comrie, 1997

Pascale et al. 2019

Easterly Waves

Definition

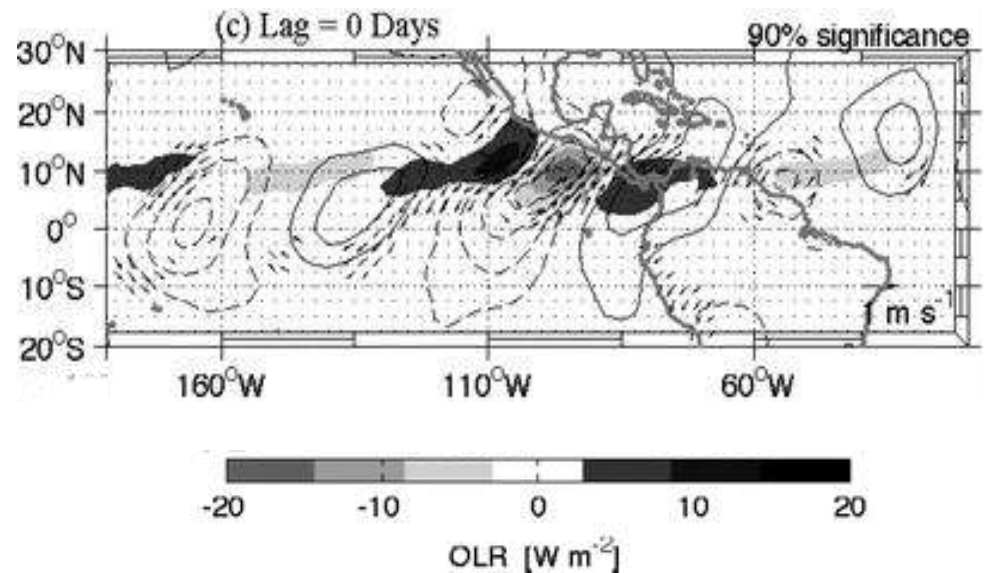
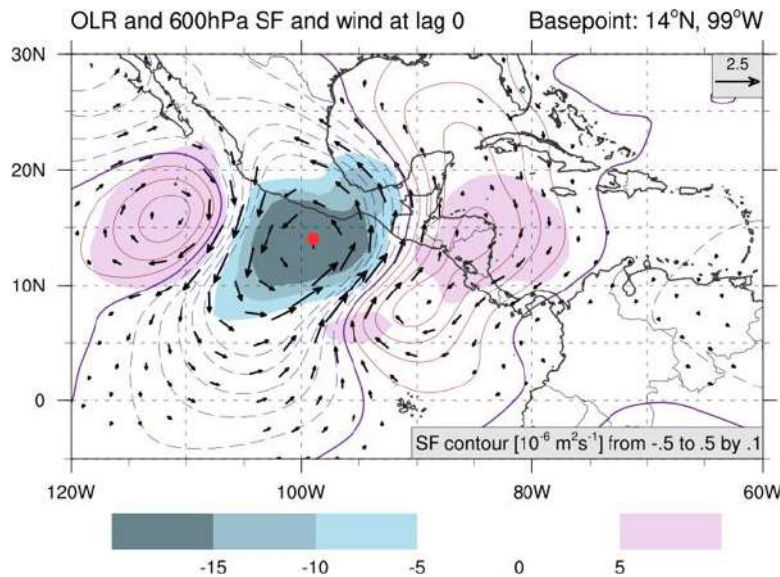
- Easterly Waves are off-equatorial convectively coupled phenomena that occur during boreal summer (Rydbeck and Maloney 2015).
- Rossby wave packets (dispersive) that in the absence of convection, they weaken and lose its structure (Molinari et al. 1997).



Importance of Easterly Waves

- Easterly Waves are associated with the 25%-40% of deep convection over the Inter-Tropical Convergence Zone (ITCZ) – (Tai and Ogura 1987; Gu and Zhang 2002)
- Easterly Waves serve as seeds of Tropical Cyclones (TCs) over the Atlantic (Kiladis et al. 2006); and over the **Pacific** (Avila and Guiney 2000; Avila et al. 2003; Pasch et al. 2009)
- Easterly Waves are present over the Caribbean*, tropical Eastern Pacific and “***even over the region of the North America Monsoon***” (Serra 2010), influencing the patterns of synoptic precipitation, as well as impacting broad regions over the American continent.

Easterly Waves over the Eastern Pacific



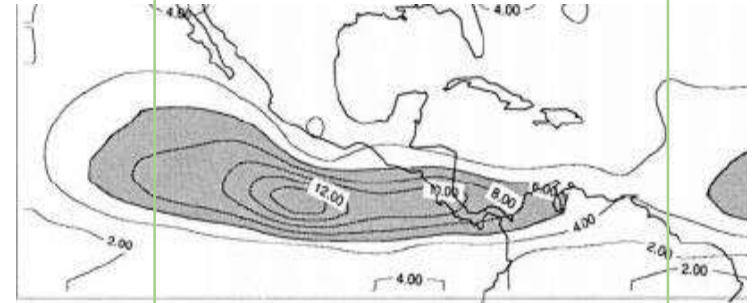
Adapted from Serra et al. 2008

- Horizontal tilting SW to NE
- Convection aligned with the center of minimal pressure.
- **Growth mechanism: barotropic mainly**

Tracking of Easterly Waves over the Eastern Pacific

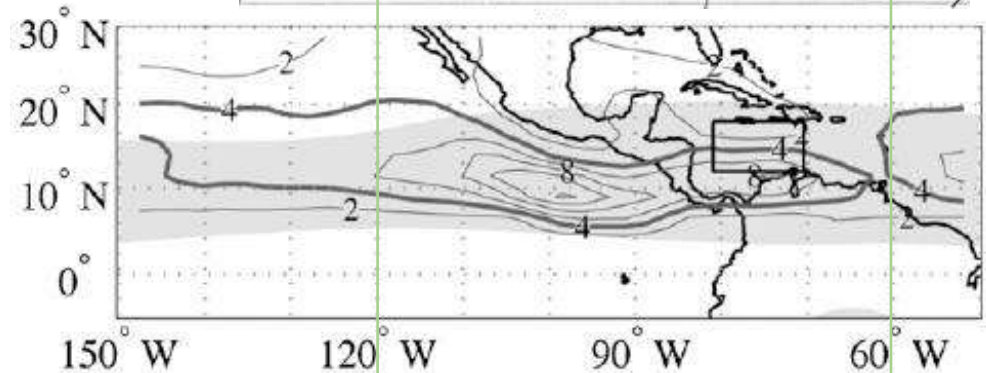
Metric: Relative vorticity at 600 hPa

Adapted from Thorncroft et al. (2001)



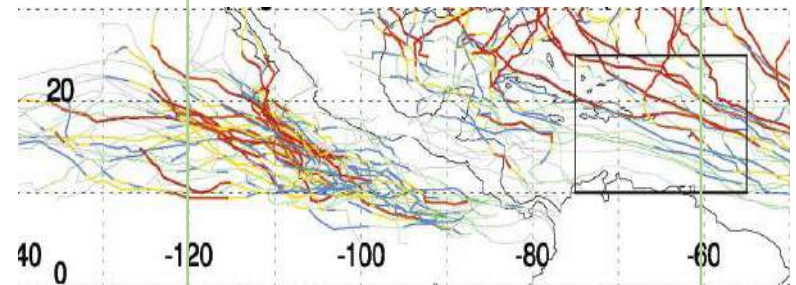
Metric: Relative vorticity averaged 850 to 600 hPa

Adapted from Serra et al. (2010)



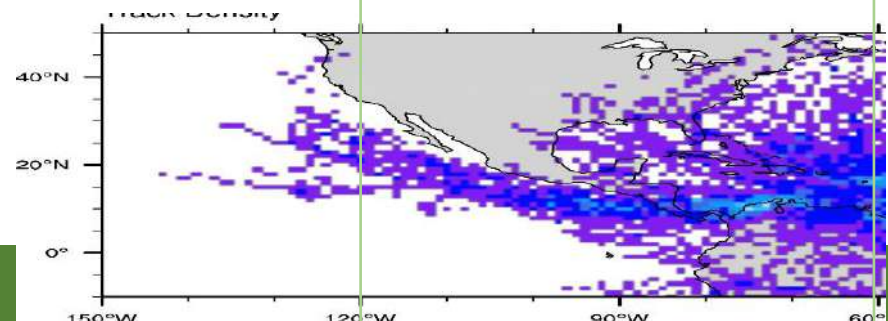
Metric: Relative vorticity averaged 925 to 850 hPa

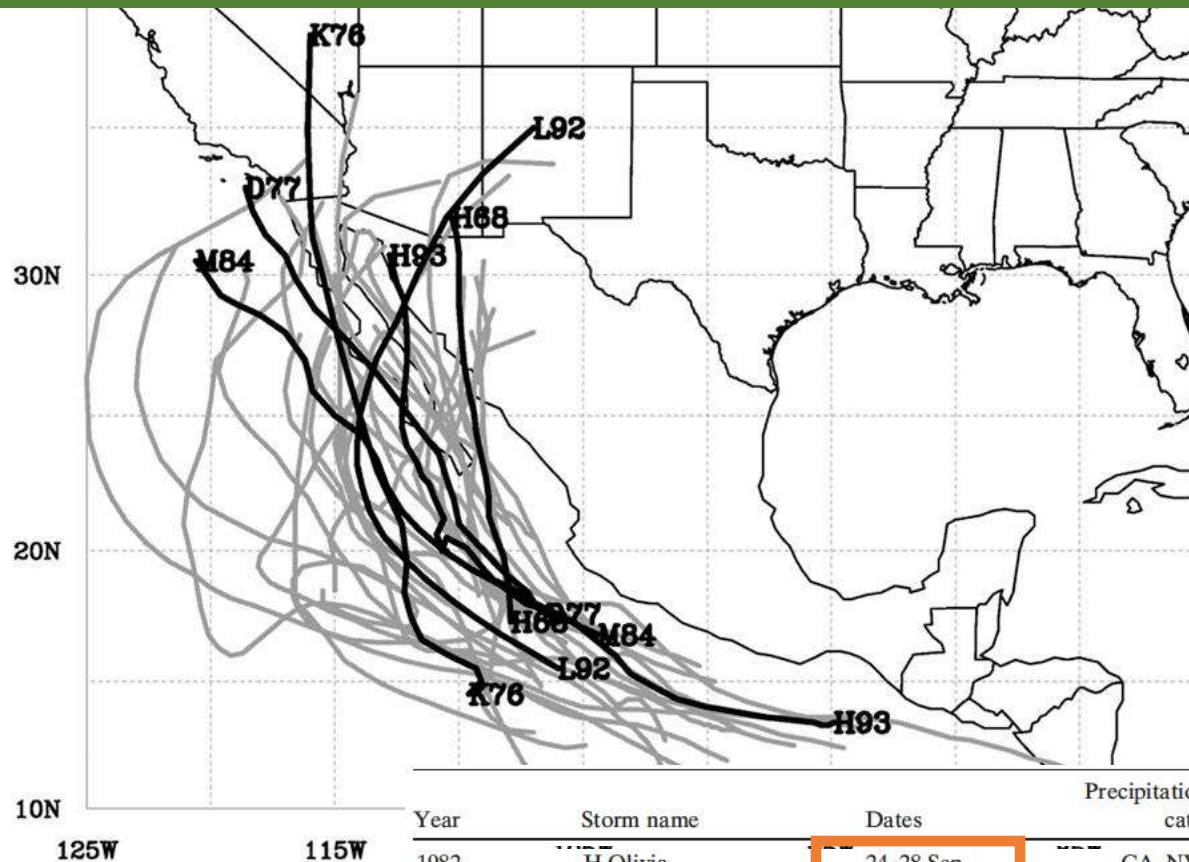
Adapted from Kerns et al. (2008)



Metric: Relative curvature vorticity 700 hPa

Adapted from Brammer and Thorncroft. (2015)

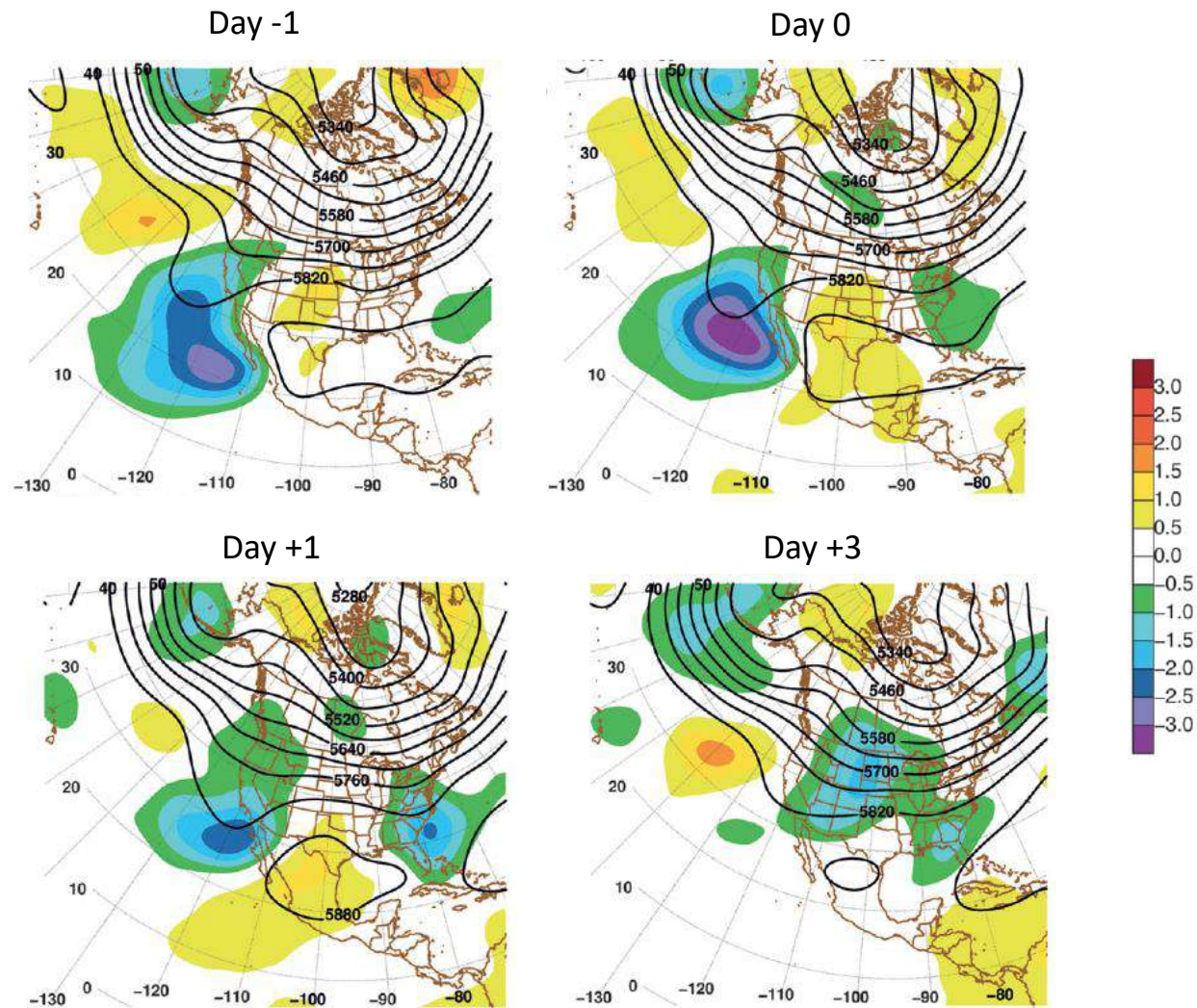




From Corbosiero et al. 2009

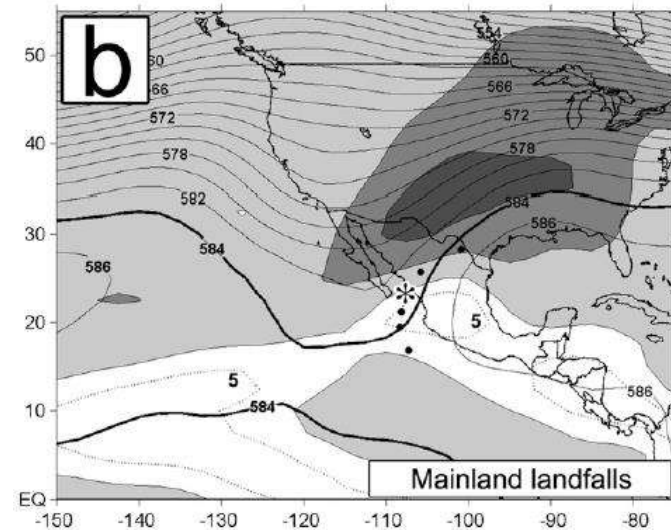
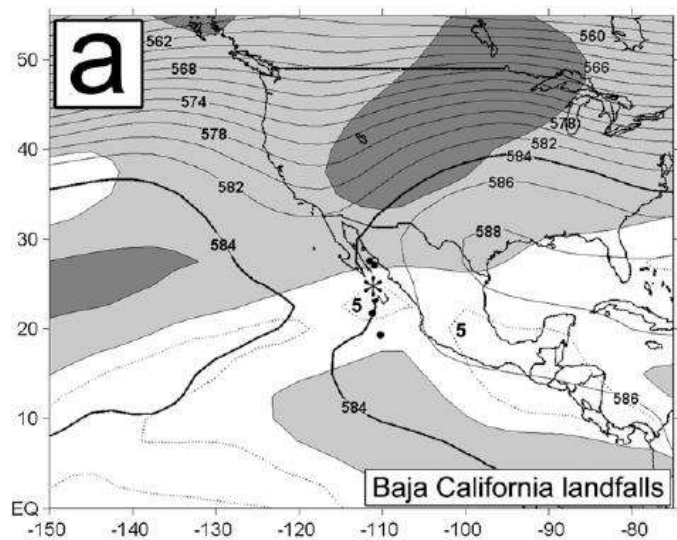
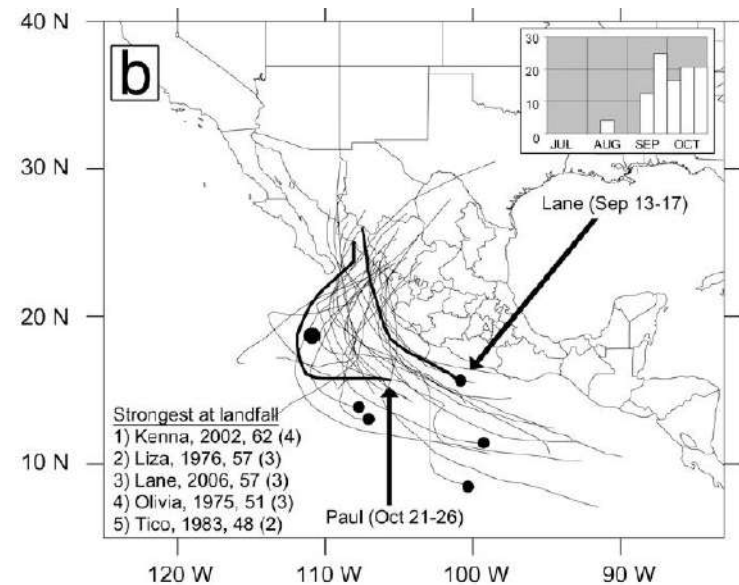
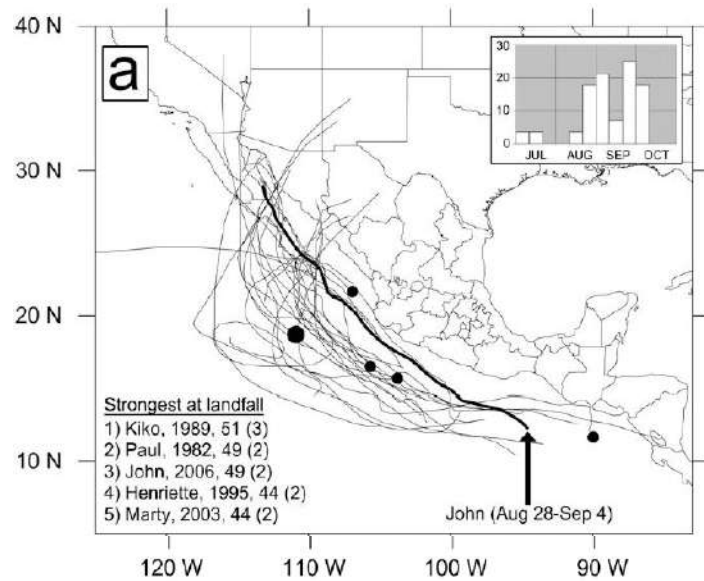
13 cases
1980-2008

Year	Storm name	Dates	Precipitation distribution category	State(s) receiving >25% of warm-season precipitation
1982	H Olivia	24-28 Sep	CA-NV track	CA NV UT
1983	H Manuel	18-20 Sep	Weakening in situ	CA
1984	H Marie	9-12 Sep	Weakening in situ	AZ CA NV
	H Norbert	25-27 Sep	SW-NE swath	—
1986	H Newton	23-26 Sep	SW-NE swath	AZ CA CO NV UT
1989	H Raymond	4-6 Oct	SW-NE swath	AZ NM
1992	H Lester	21-25 Aug	SW-NE swath	AZ CA CO NM NV UT
1993	H Hilary	26-30 Aug	SW-NE swath	AZ CA CO NM NV UT
1995	H Ismael	14-16 Sep	SW-NE swath	NM
1996	H Fausto	14-16 Sep	Weakening in situ	AZ UT
1997	H Nora	24-27 Sep	CA-NV track	AZ CA NV
1998	H Isis	3-7 Sep	CA-NV track	AZ CA NV UT
1999	H Hilary	22-24 Sep	SW-NE swath	AZ CA NV
2003	H Ignacio	26-29 Aug	Weakening in situ	AZ CA CO NM
	H Marty	24-26 Sep	Weakening in situ	AZ



500 hPa heights (m) and standardized anomalies
for 20 hurricanes 1971-1999 impacting the SW USA

Adapted from Corbosiero et al. 2009



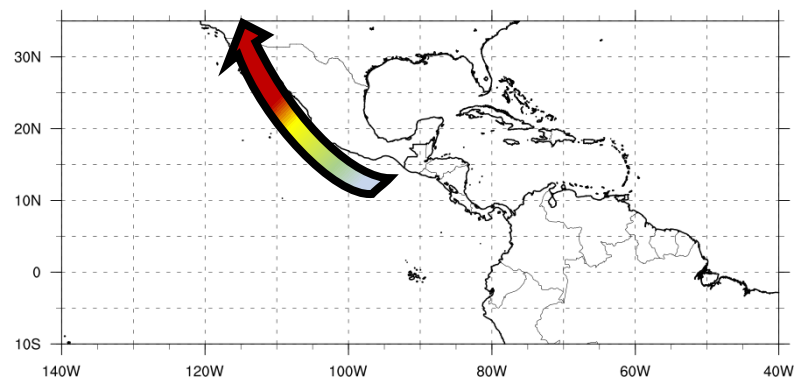
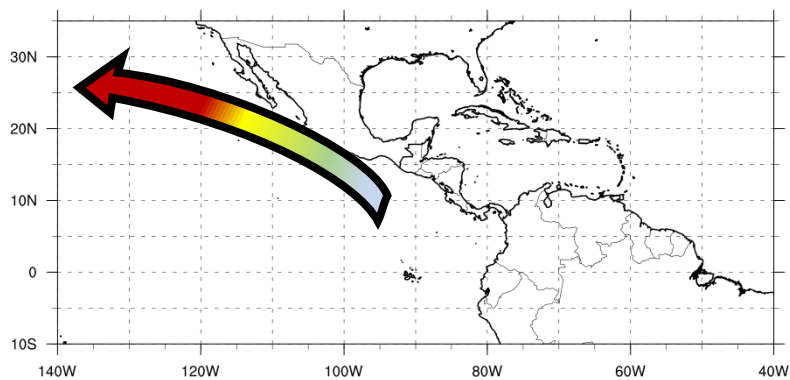
Scientific questions

- What are the mechanisms for recurving of Easterly Waves?
- Can Easterly Waves influence the moisture over the region of the North America monsoon?

Hypothesis

H_0 : No. EWs follow a track away from the continent

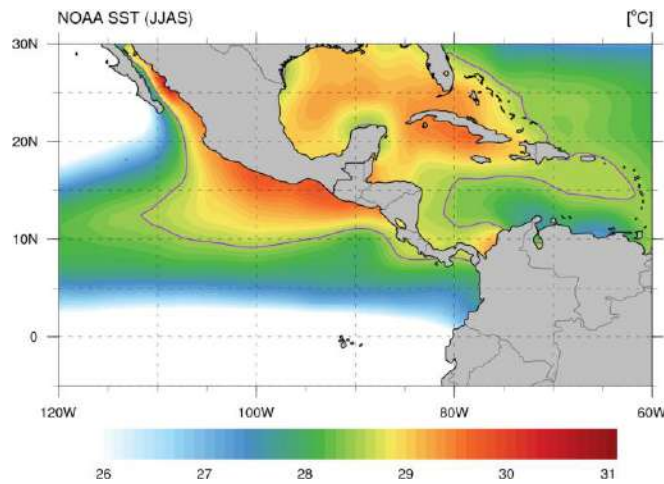
H_1 : Yes. EWs contribute only BUT when they make landfall as TCs



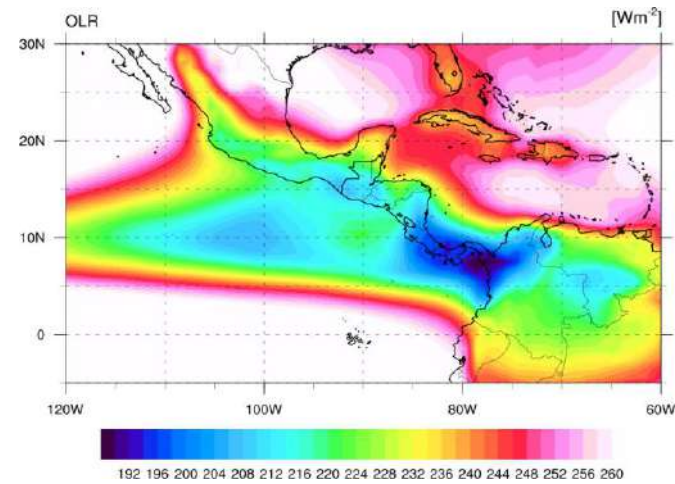
Data and Methods

- ERA Interim 0.5° JJAS 1980-2015
- Brammer and Thorncroft (2018) tracking (Lagrangian)
Curvature vorticity @ 600+700+850 hPa

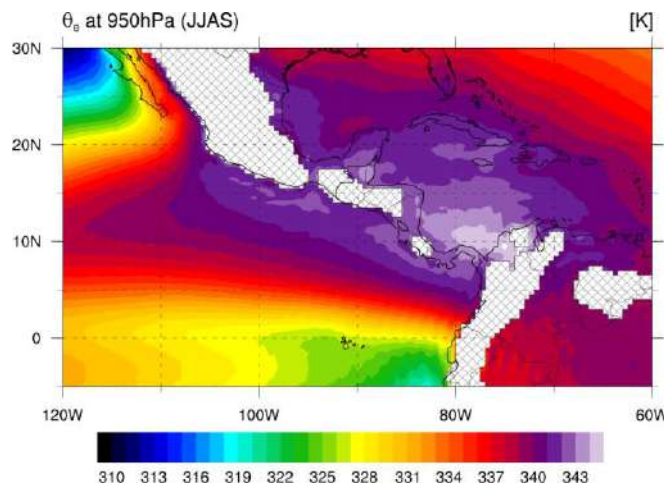
Mean state over the region: Thermodynamics



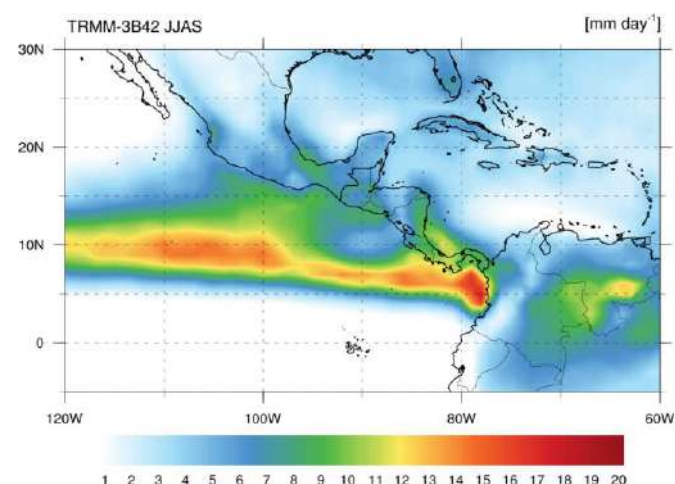
Warm pool region over the EPAC



Convective activity over the Panama region

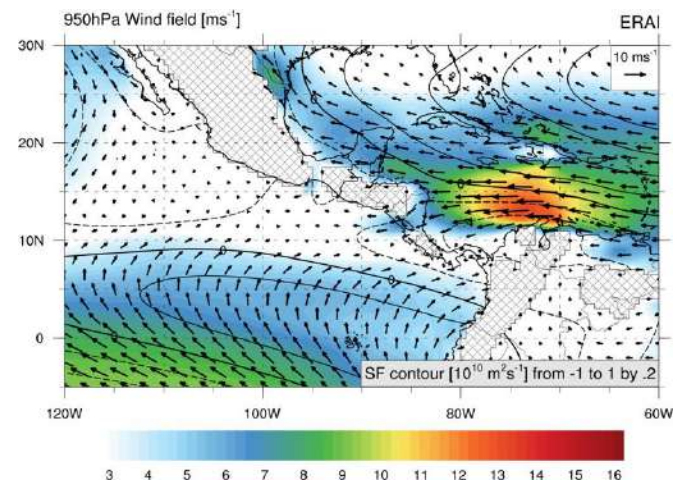
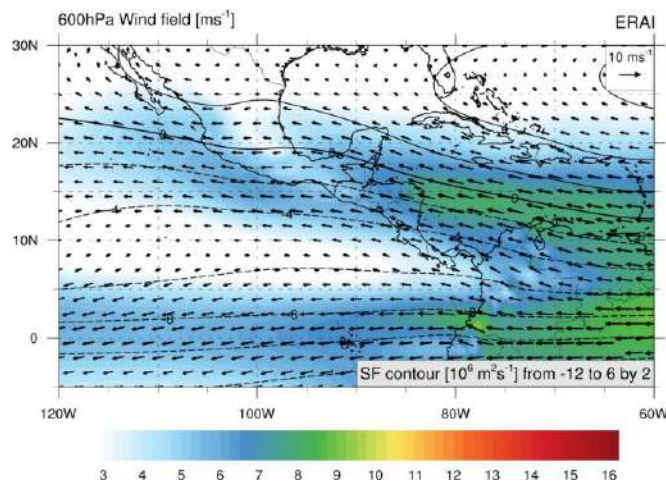
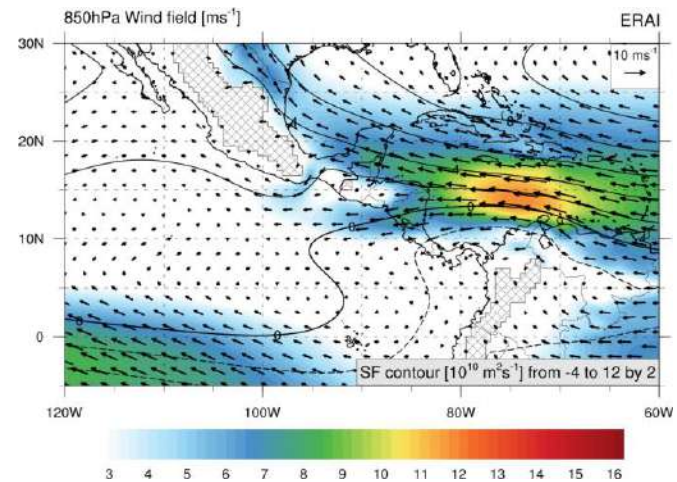
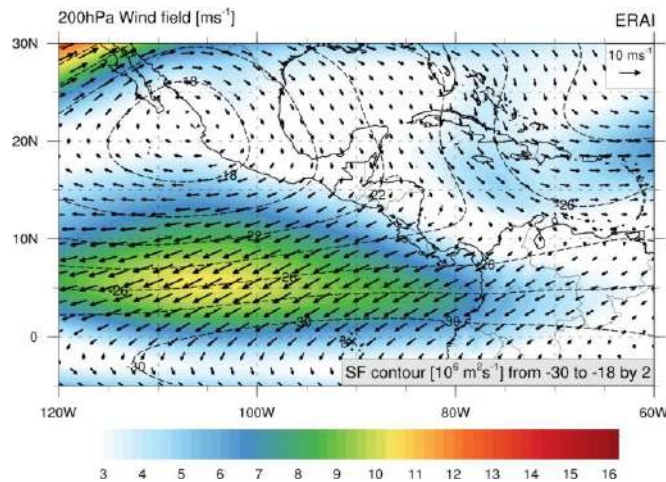


Instability over Central America



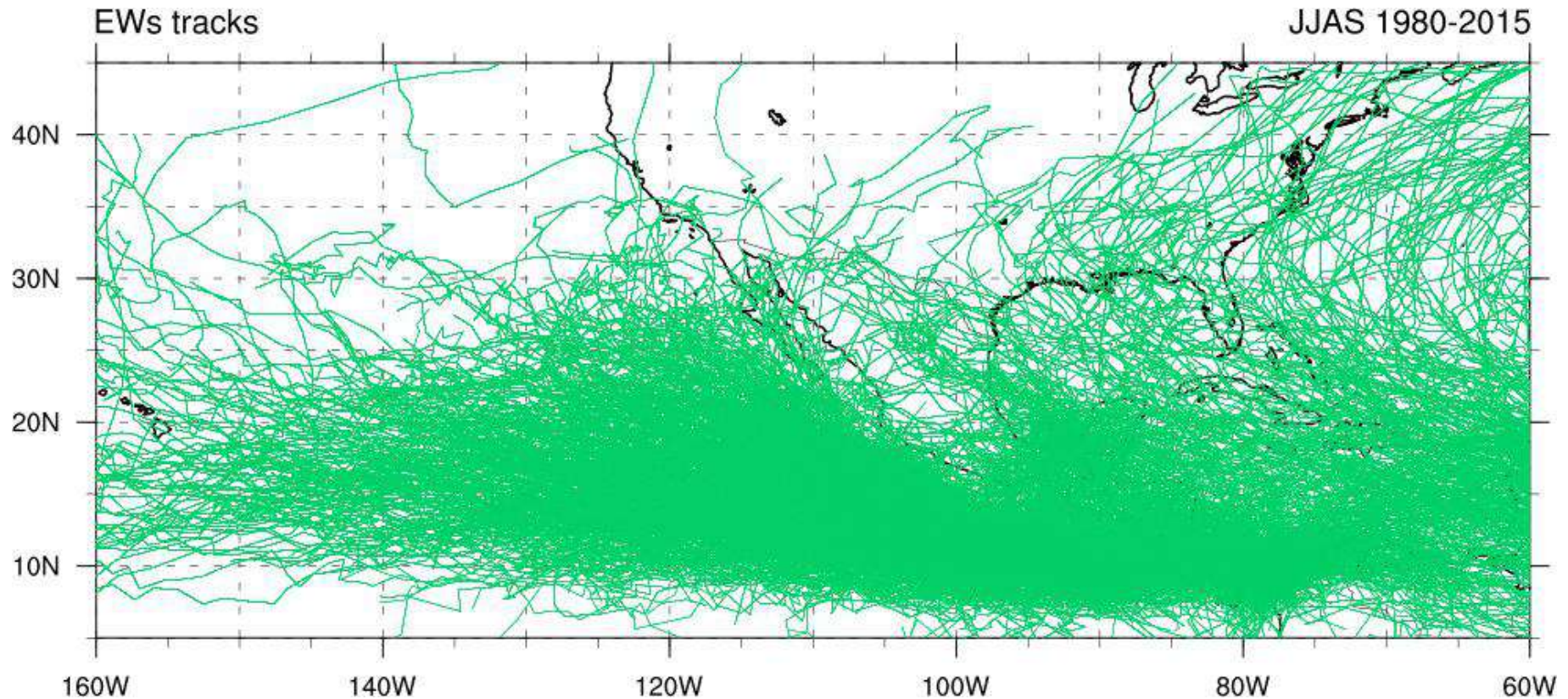
ITCZ present over the region

Mean state over the region: Winds

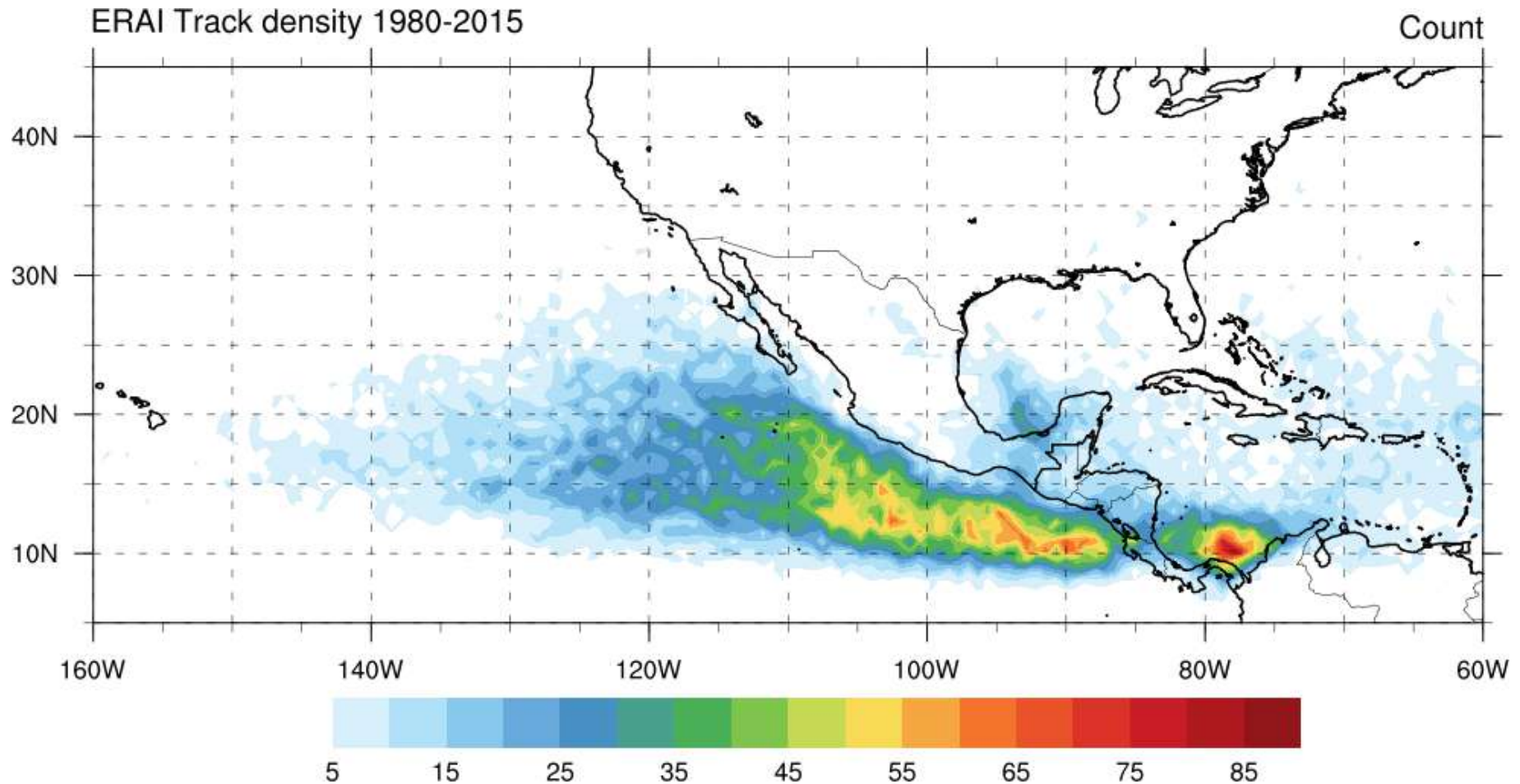


Presence of EWs over the EPAC
(track methodology)

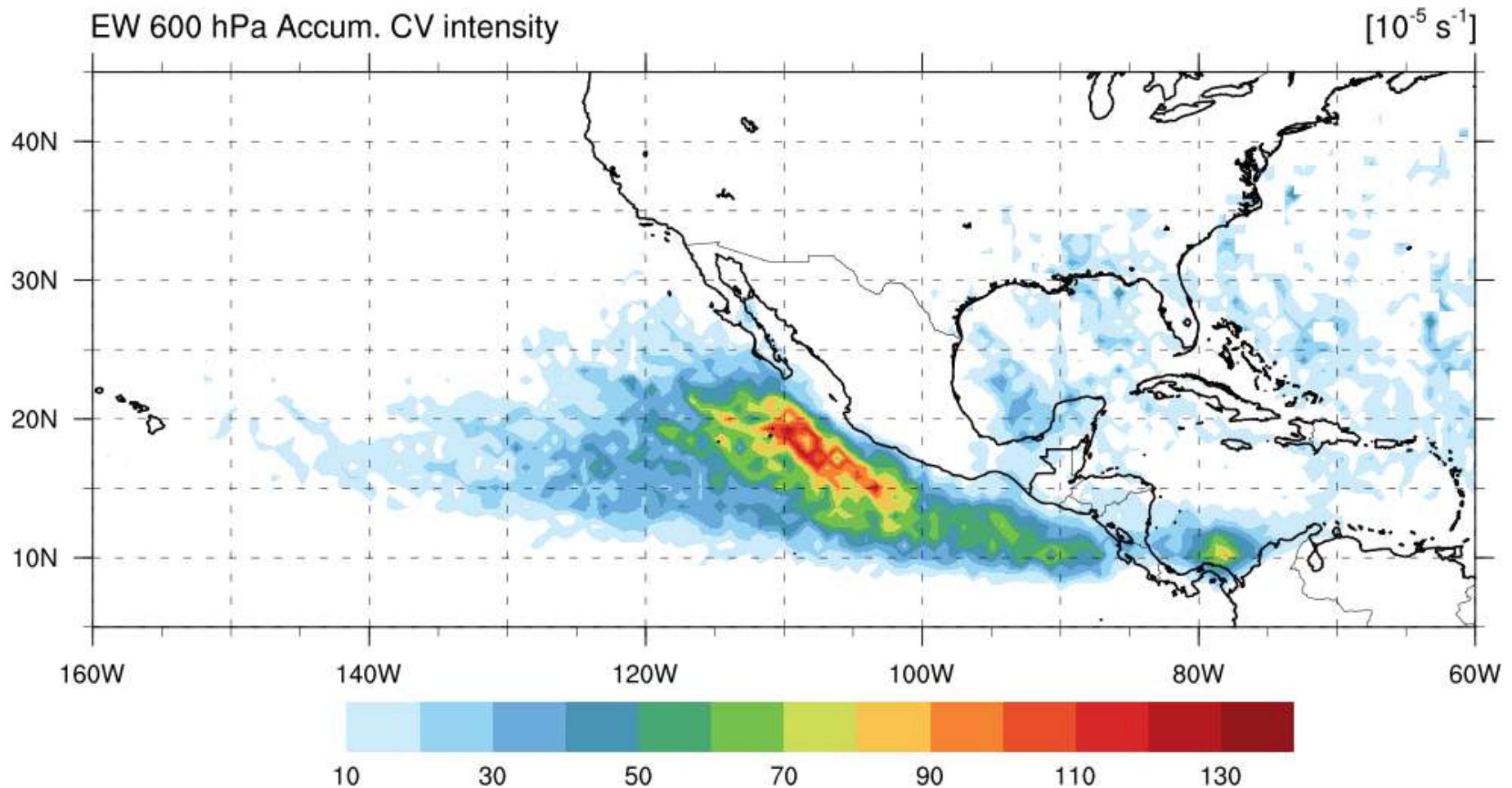
Easterly Wave tracks



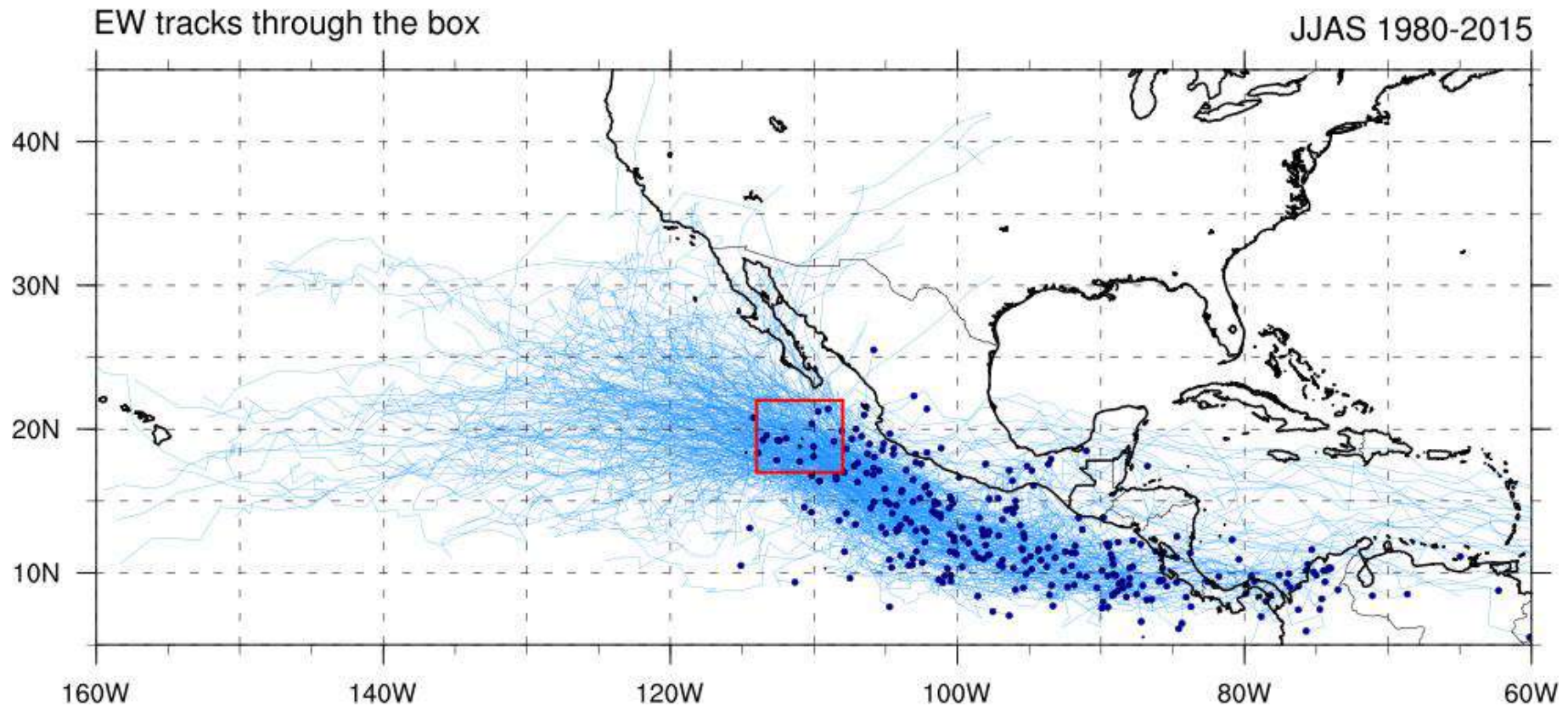
Easterly Wave density



Easterly Wave Intensity

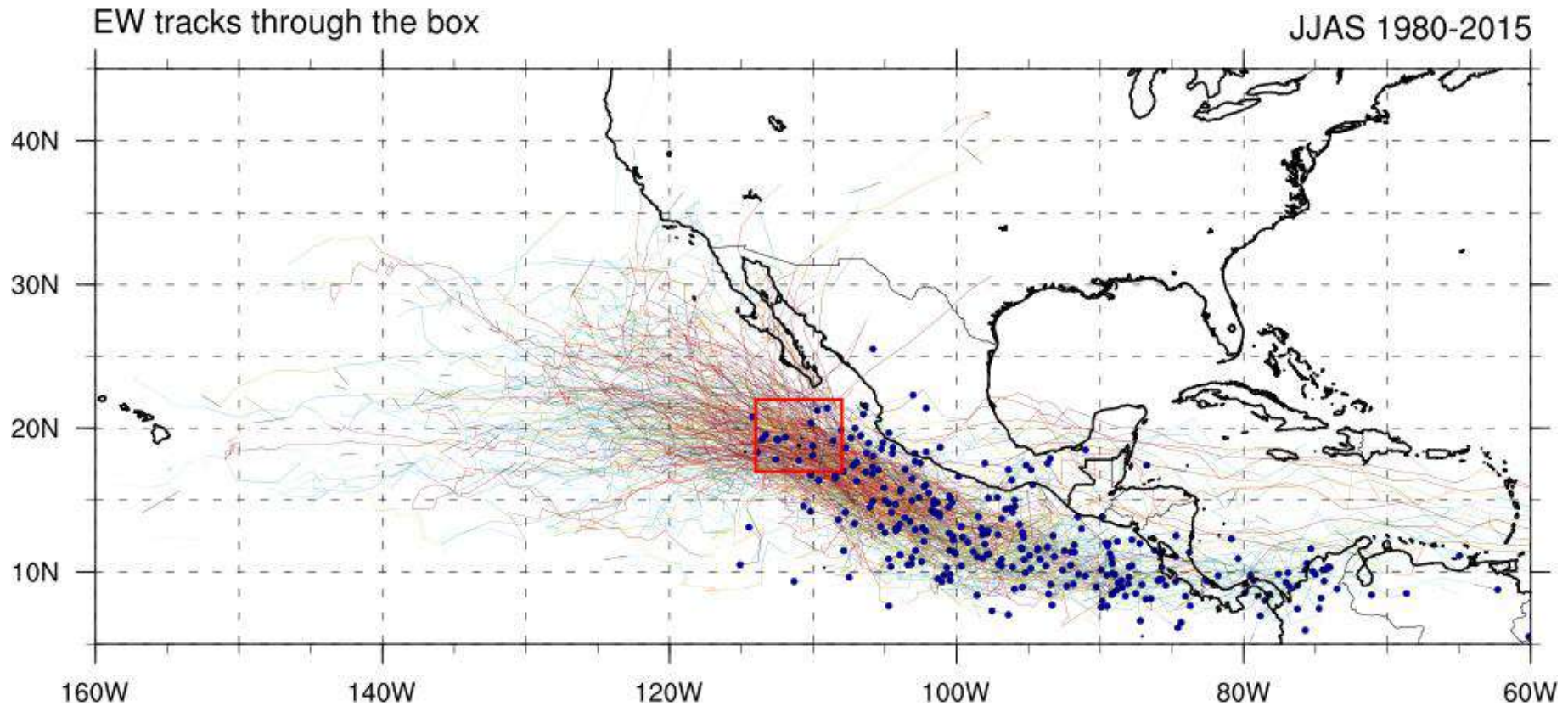


Easterly Wave track through a region



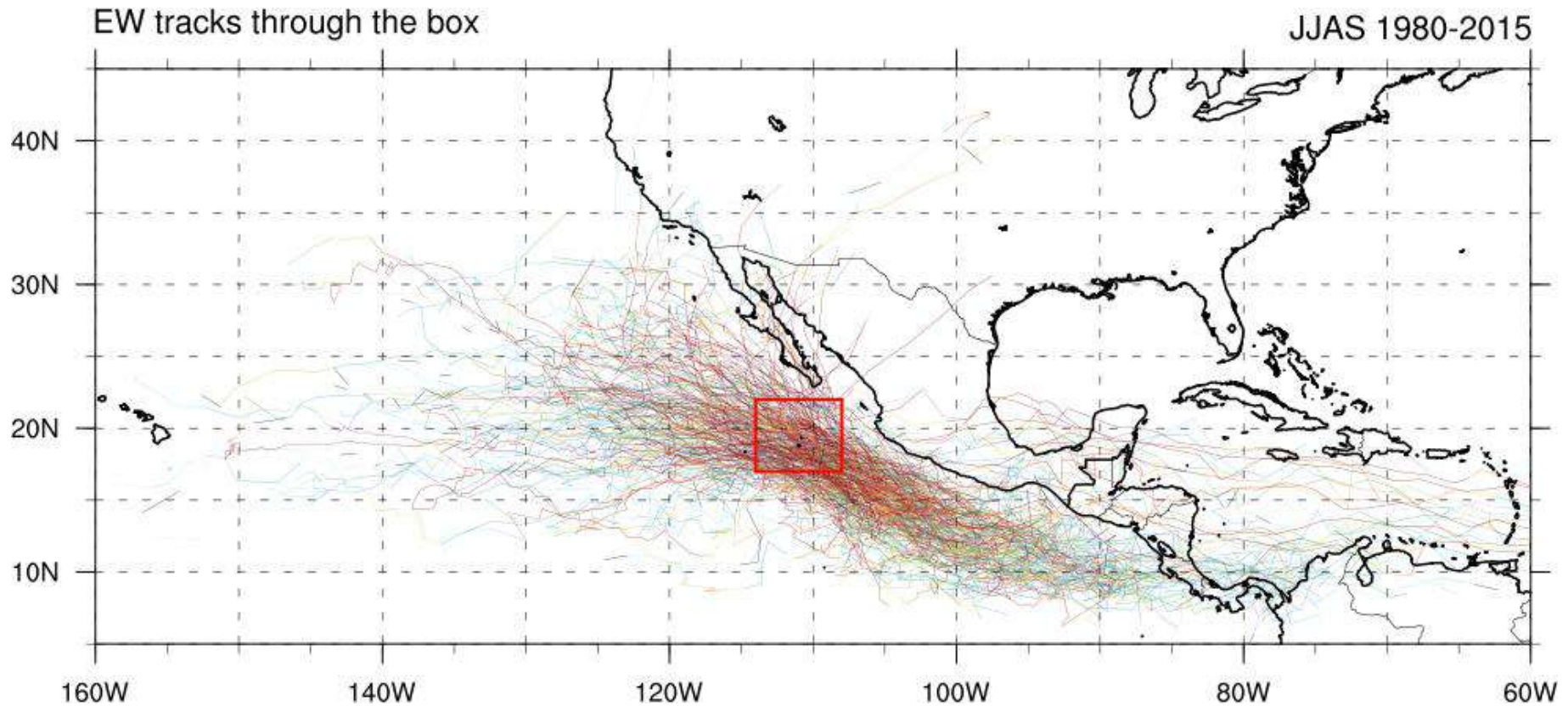
302 cases

Easterly Wave track - Intensity



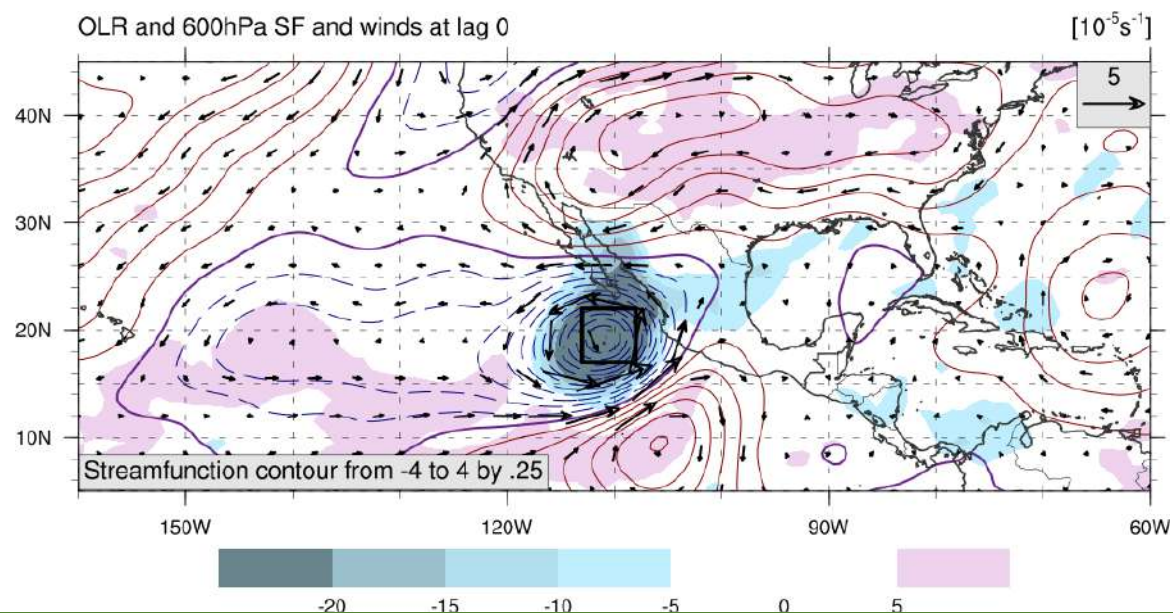
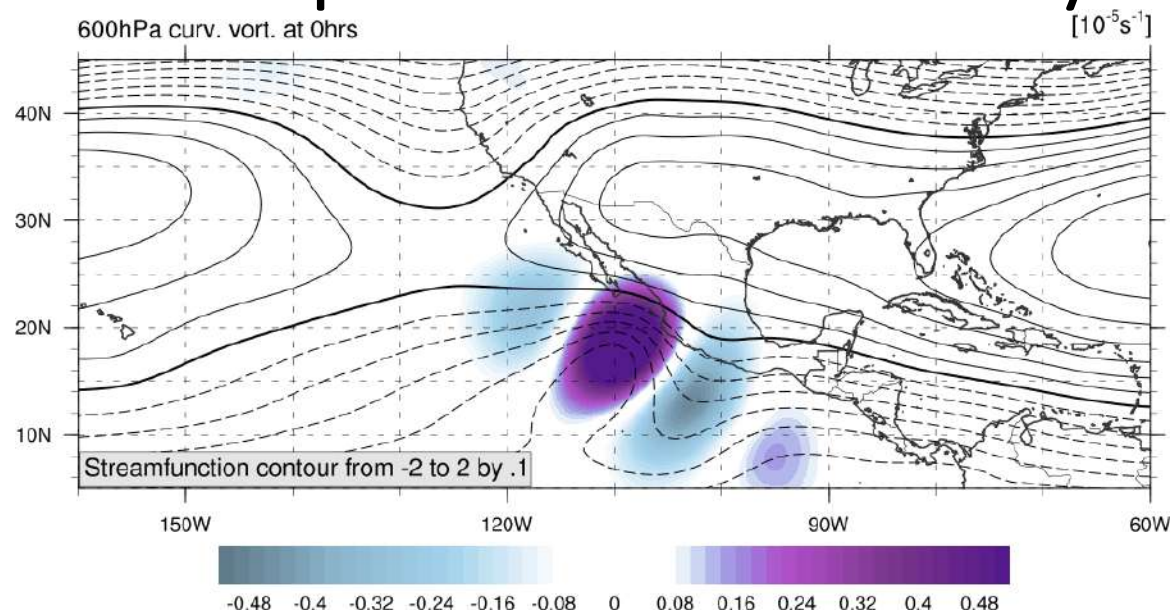
302 cases

Easterly Wave track - Intensity

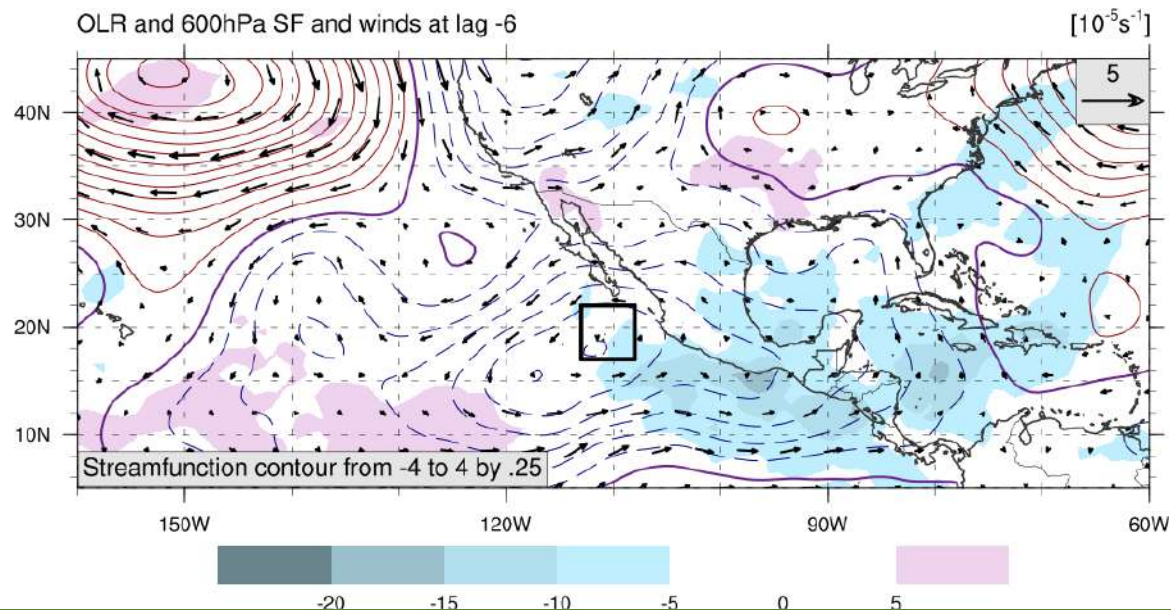
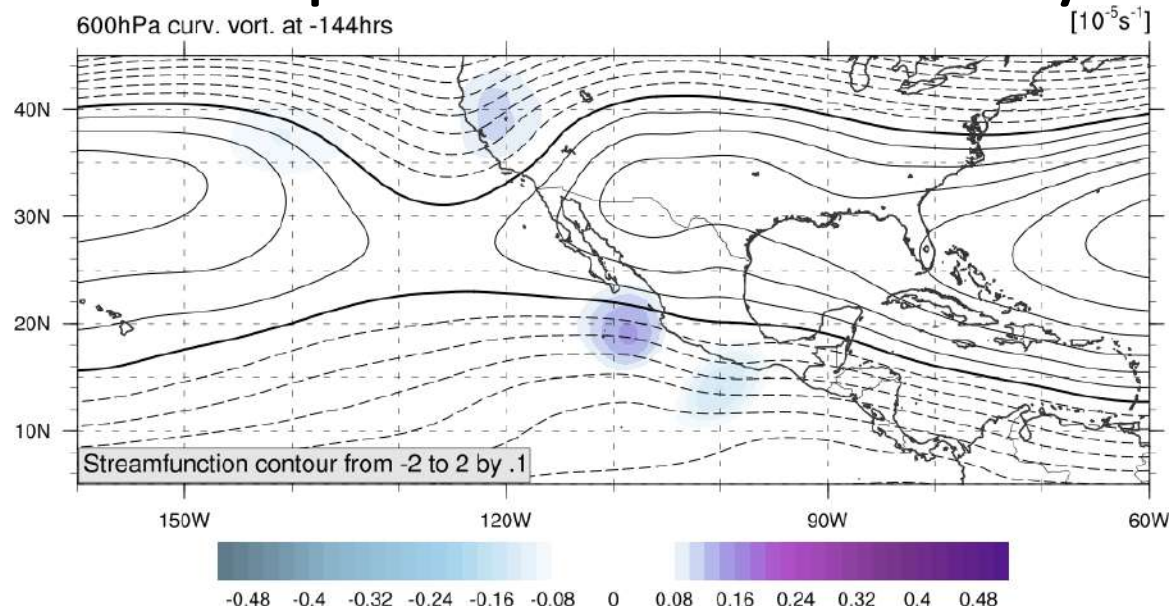


302 cases

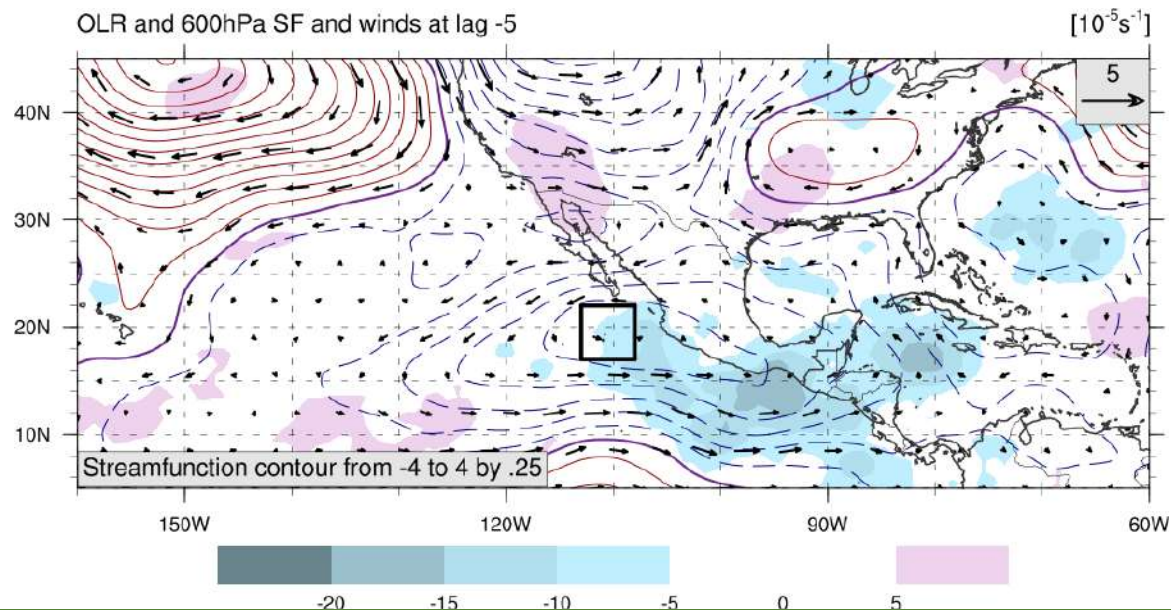
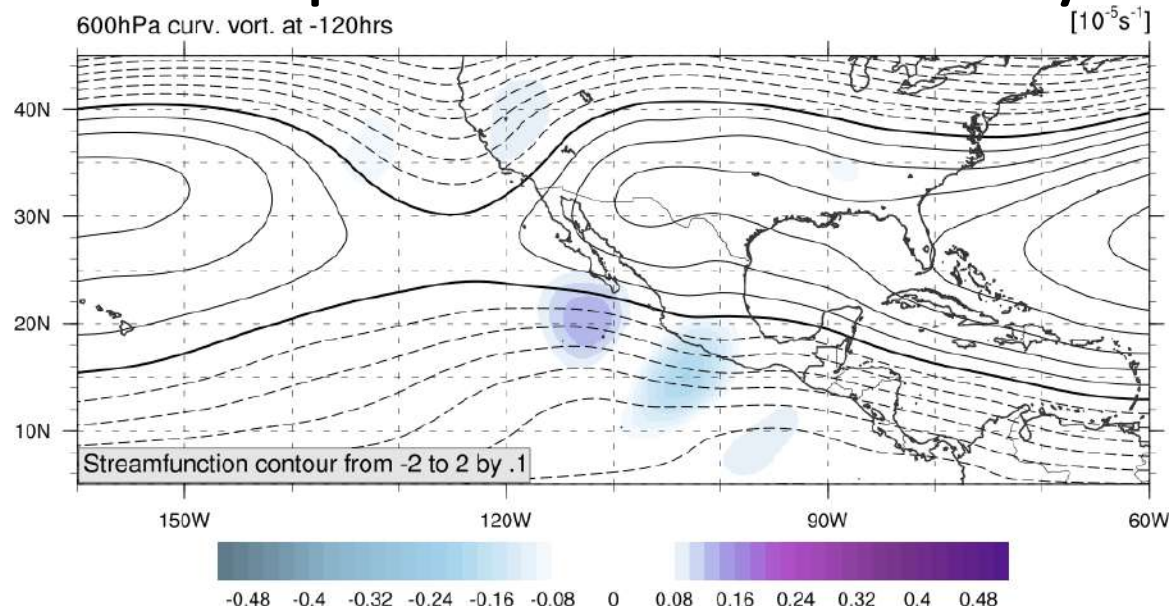
EW composited structure – Day 0



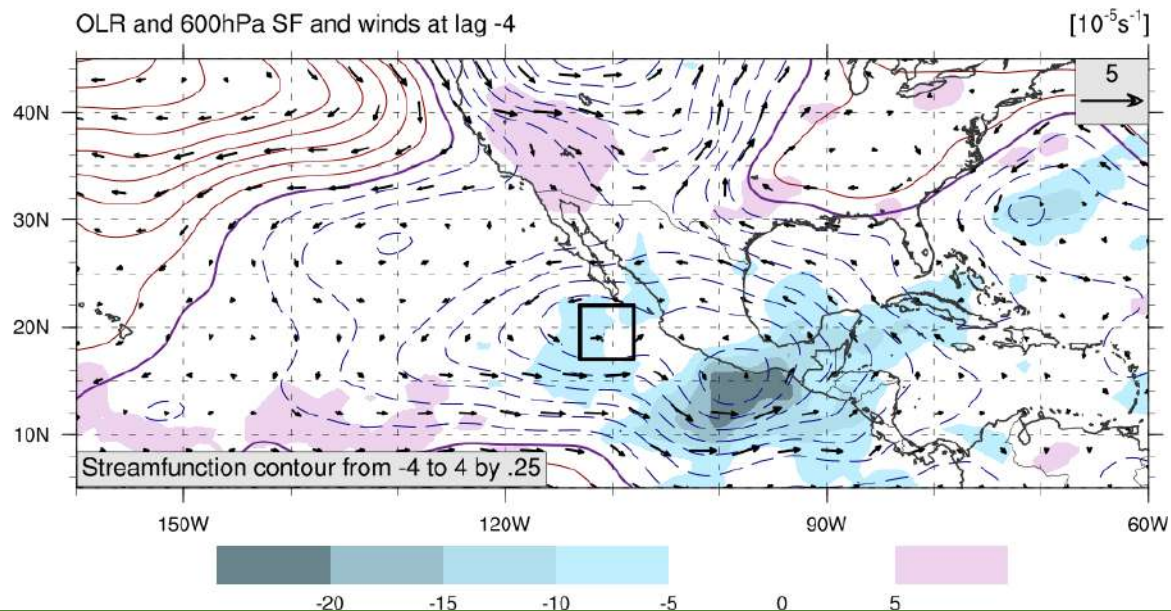
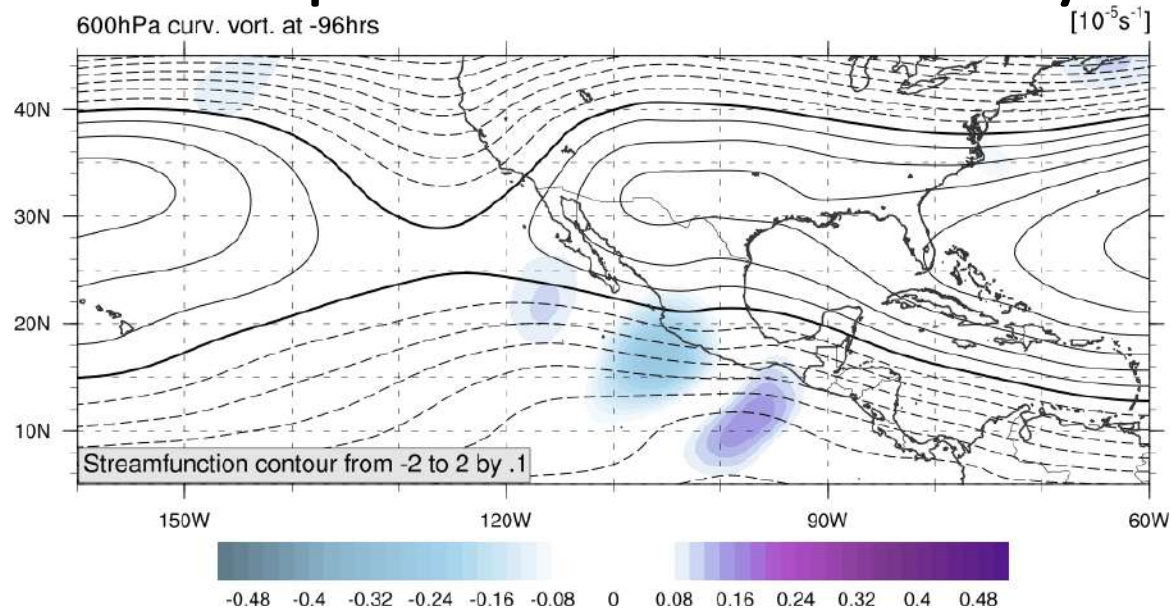
EW composited structure – Day-6



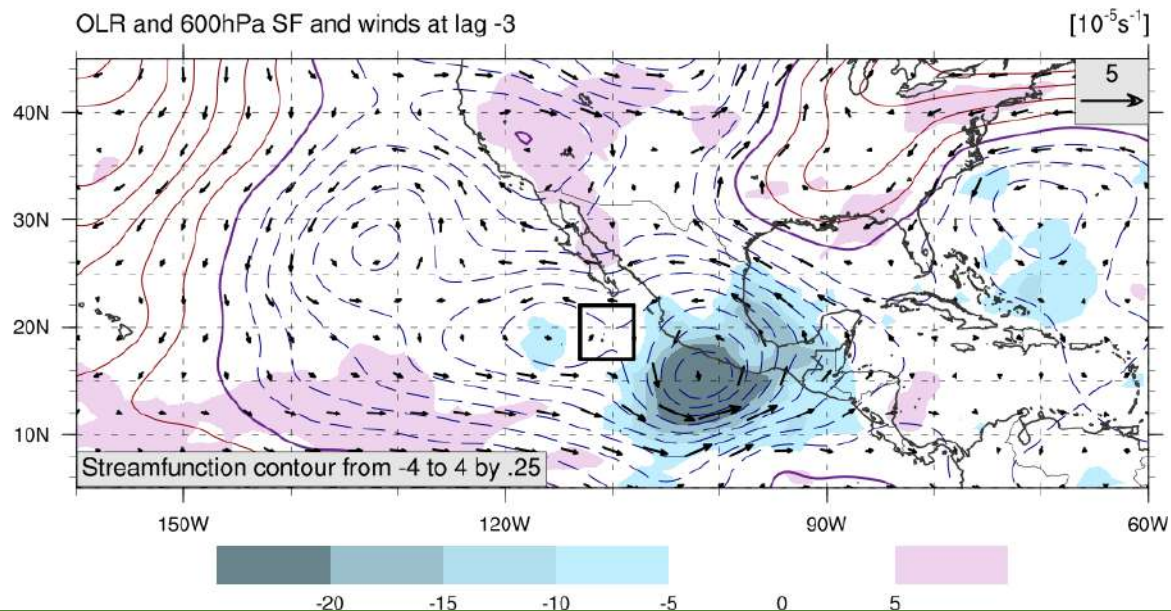
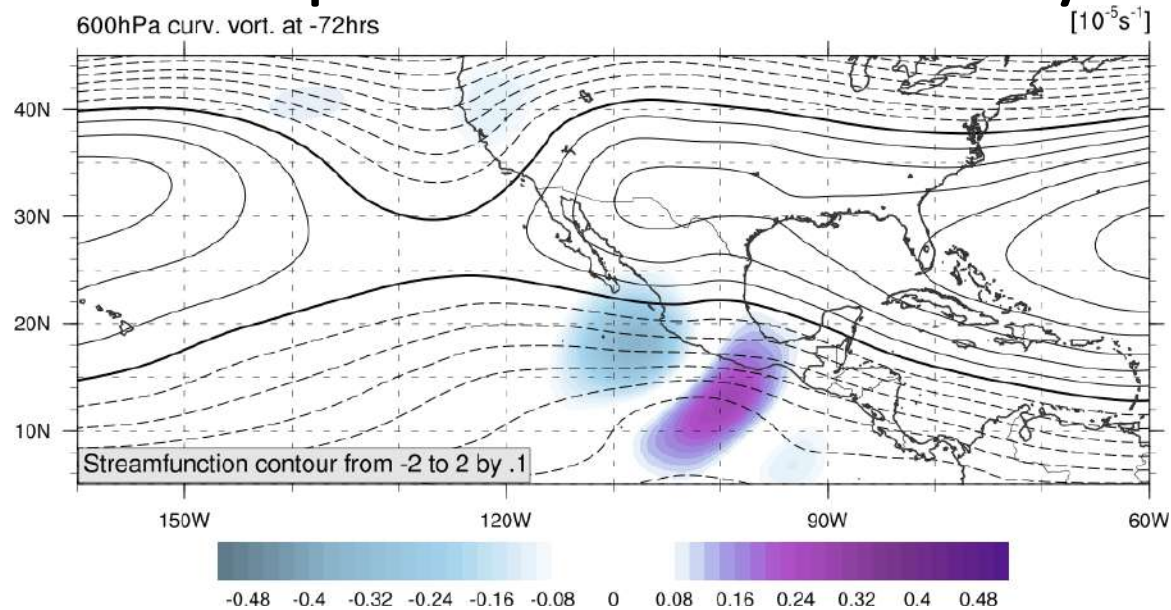
EW composited structure – Day-5



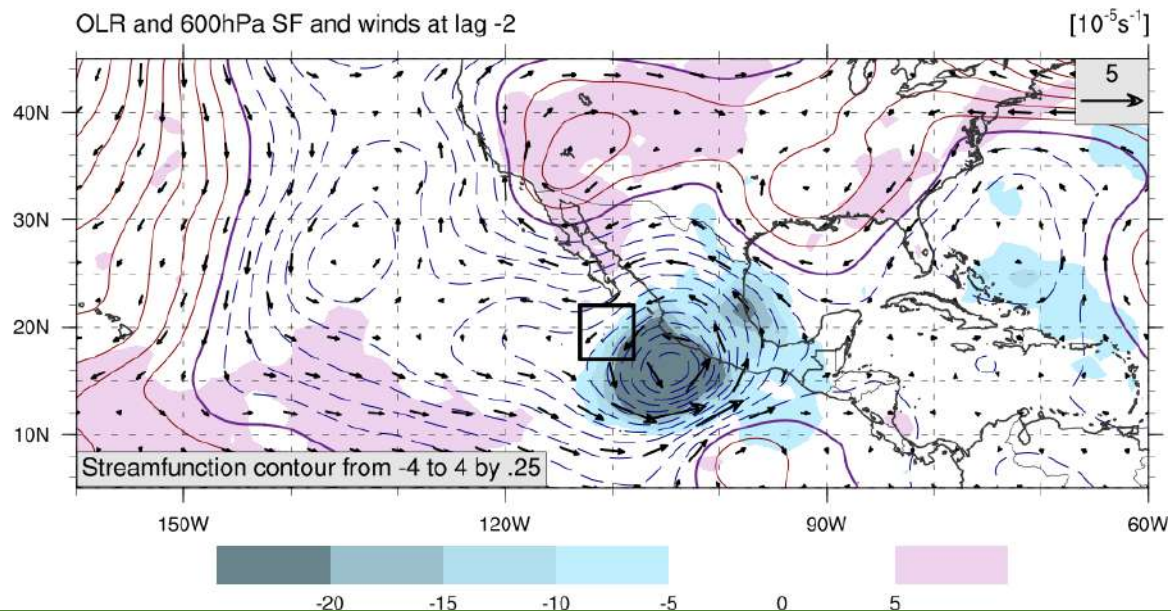
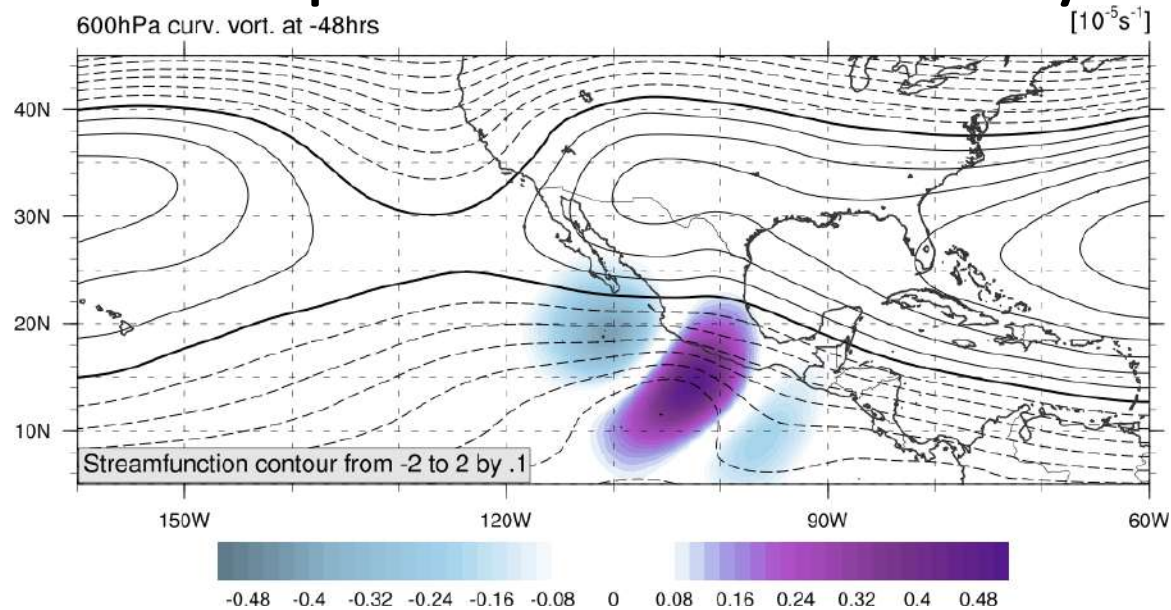
EW composited structure – Day-4



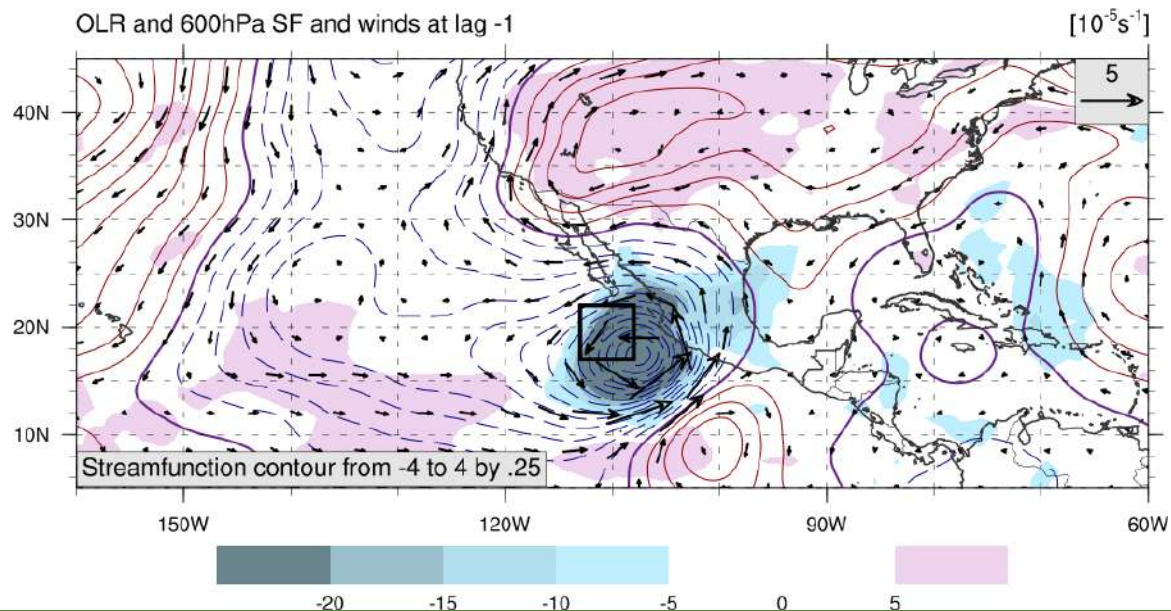
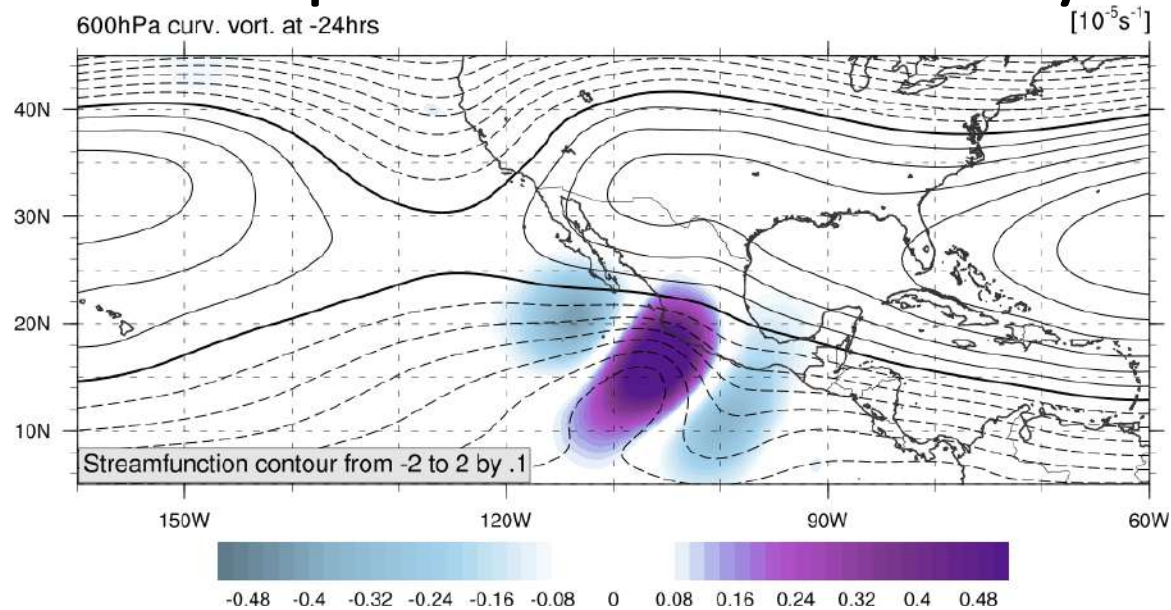
EW composited structure – Day-3



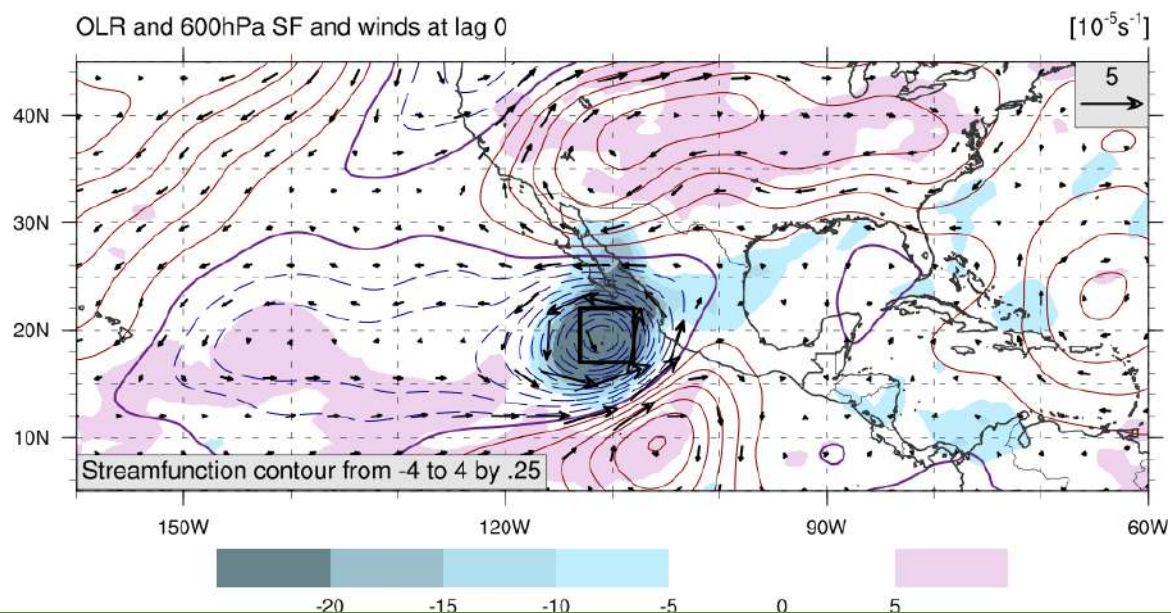
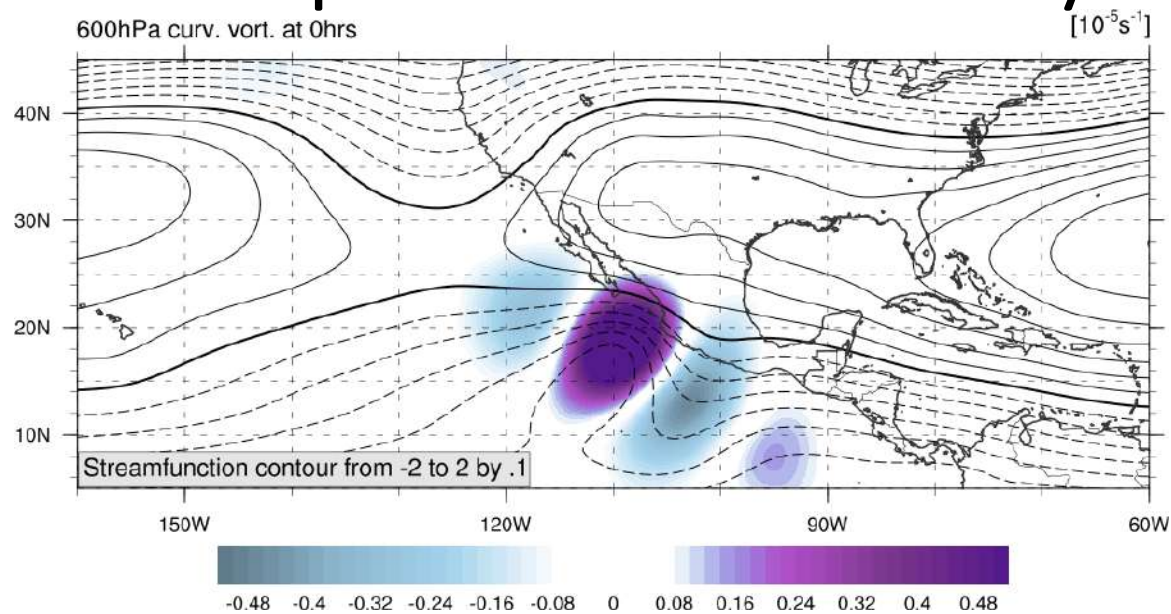
EW composited structure – Day-2



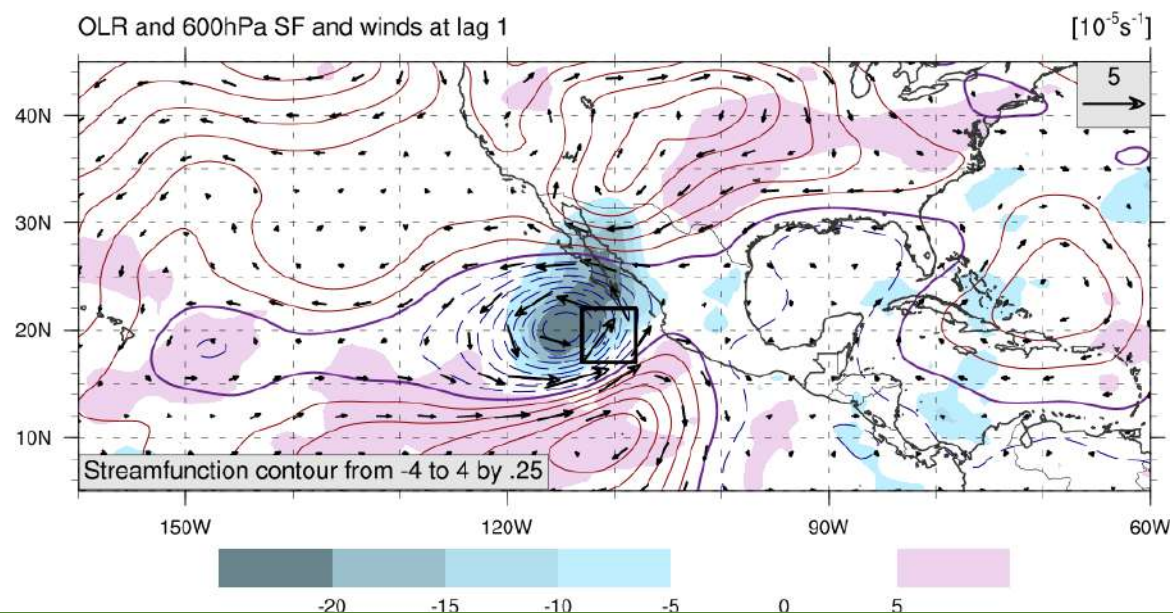
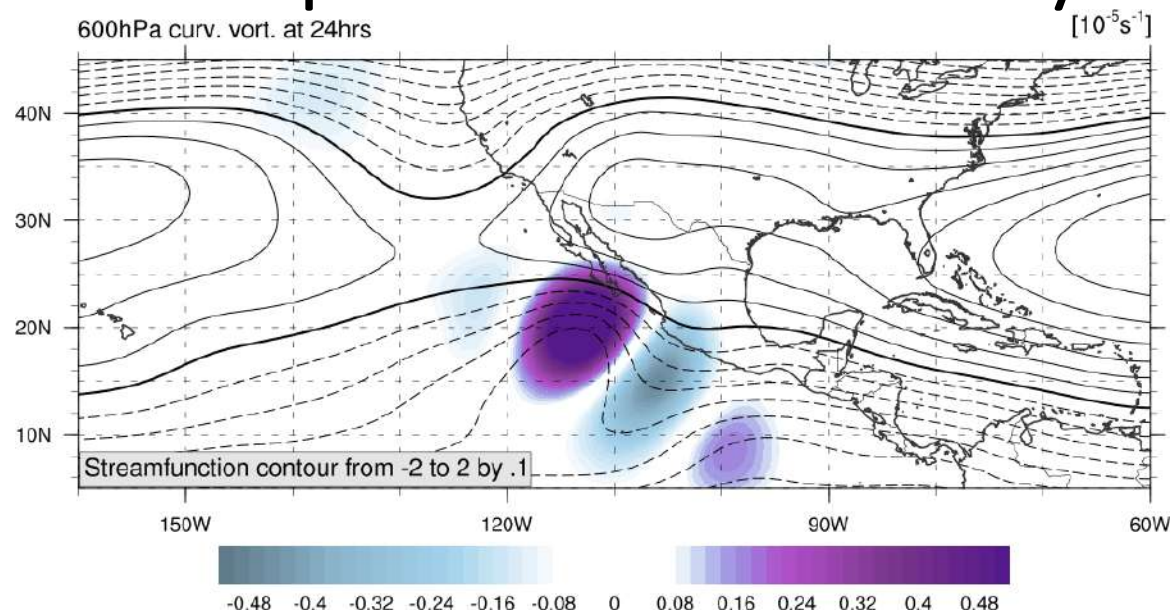
EW composited structure – Day-1



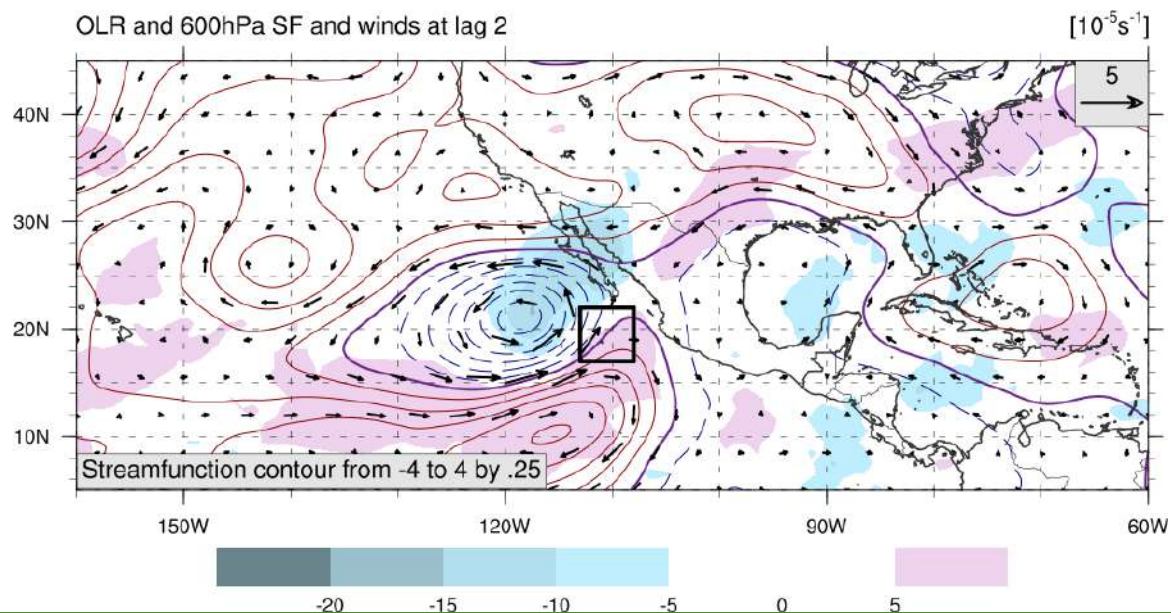
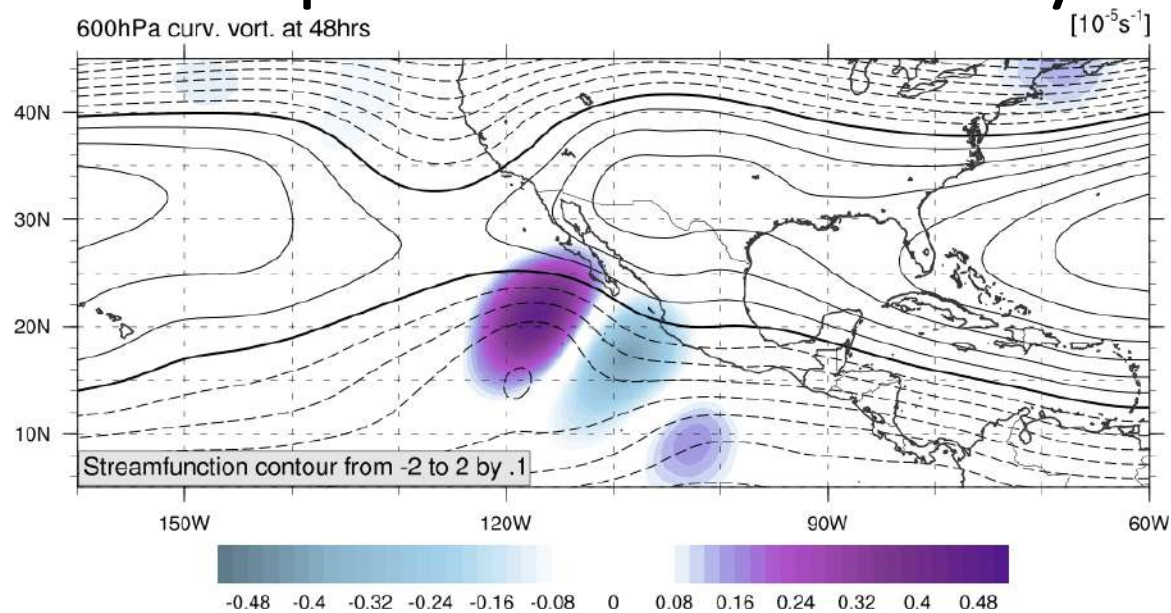
EW composited structure – Day 0



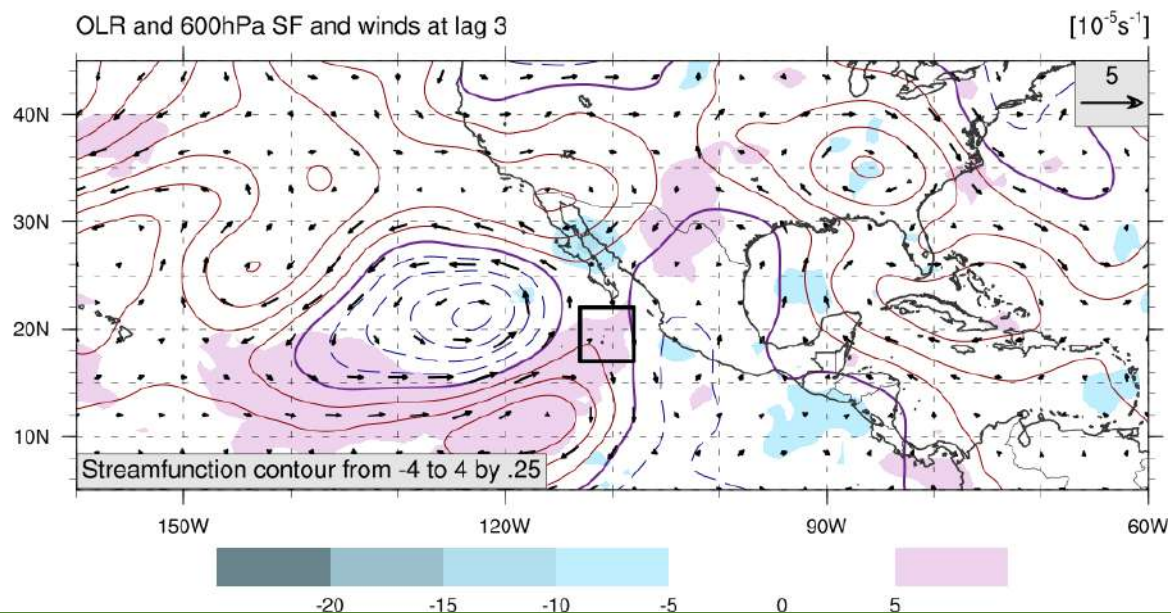
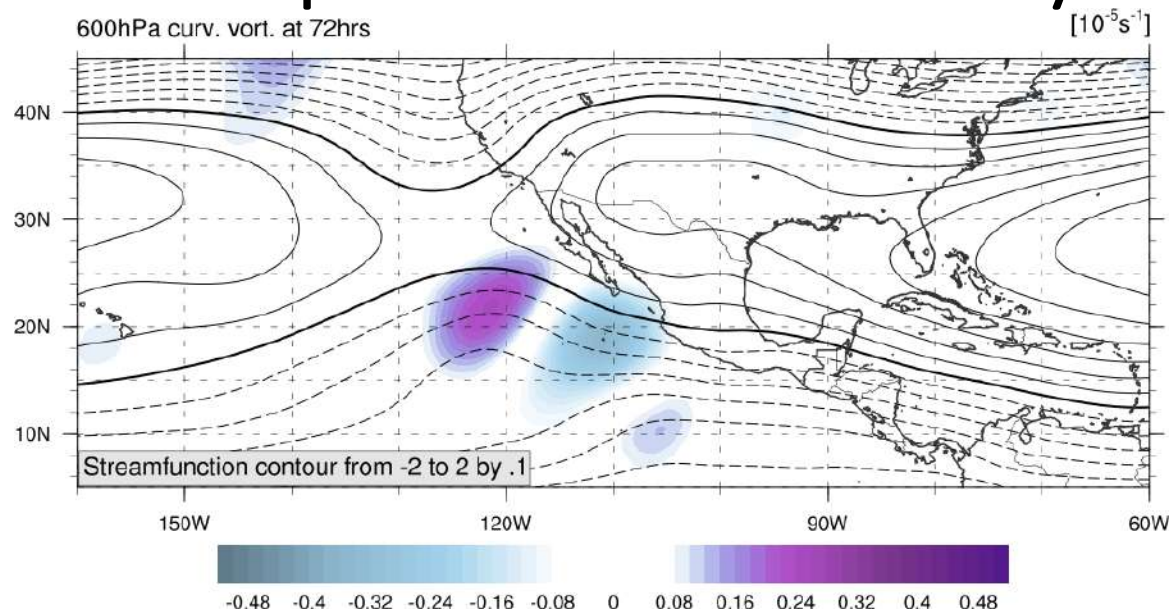
EW composited structure – Day+1



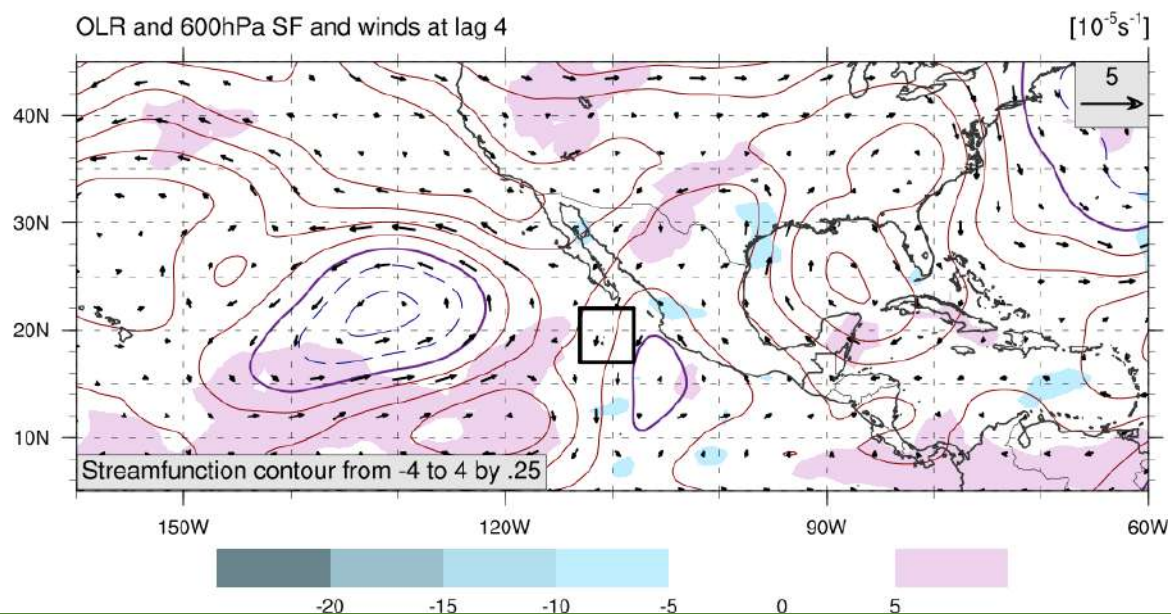
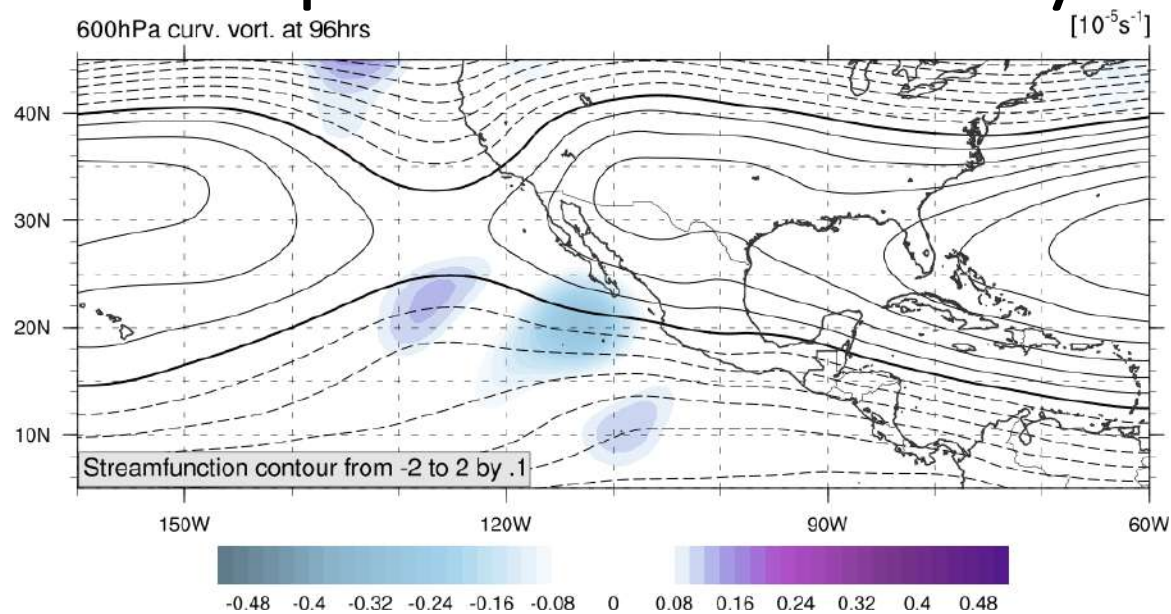
EW composited structure – Day+2



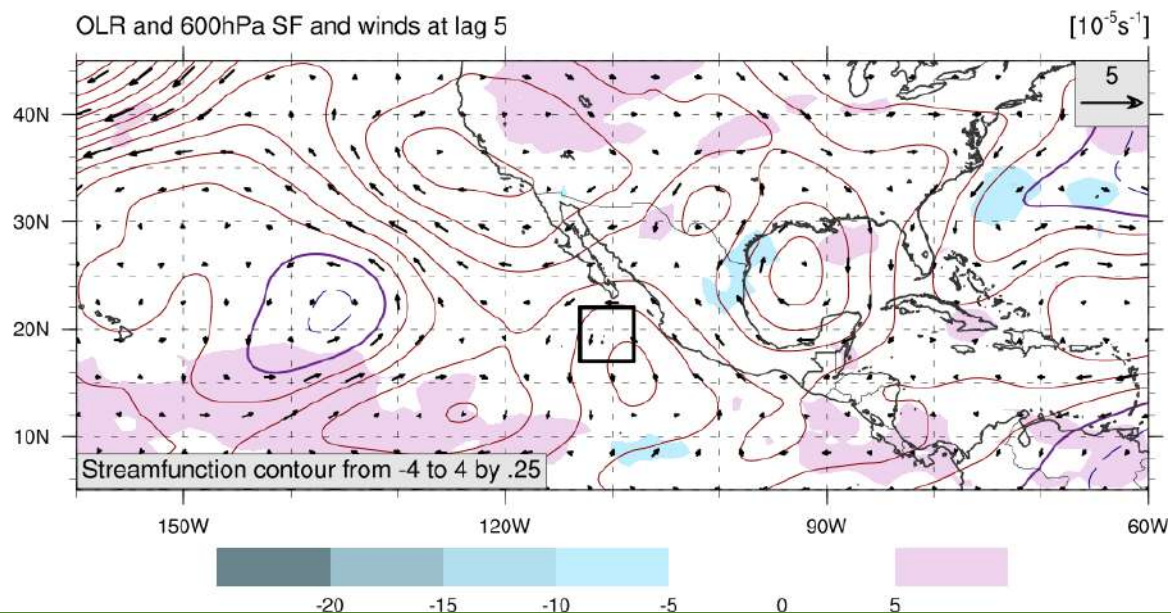
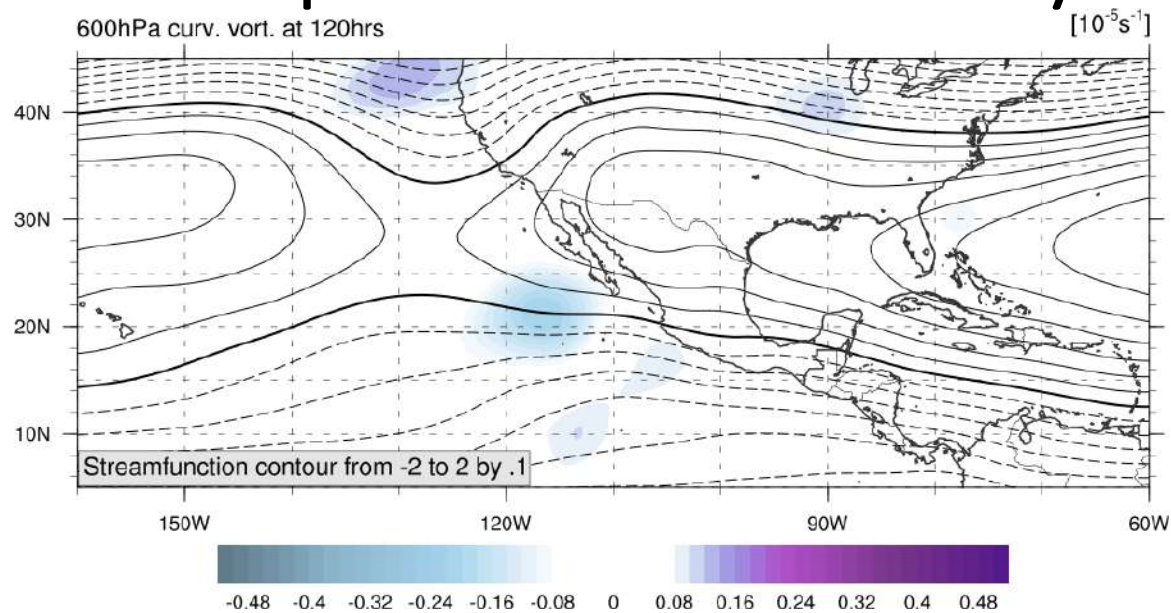
EW composited structure – Day+3



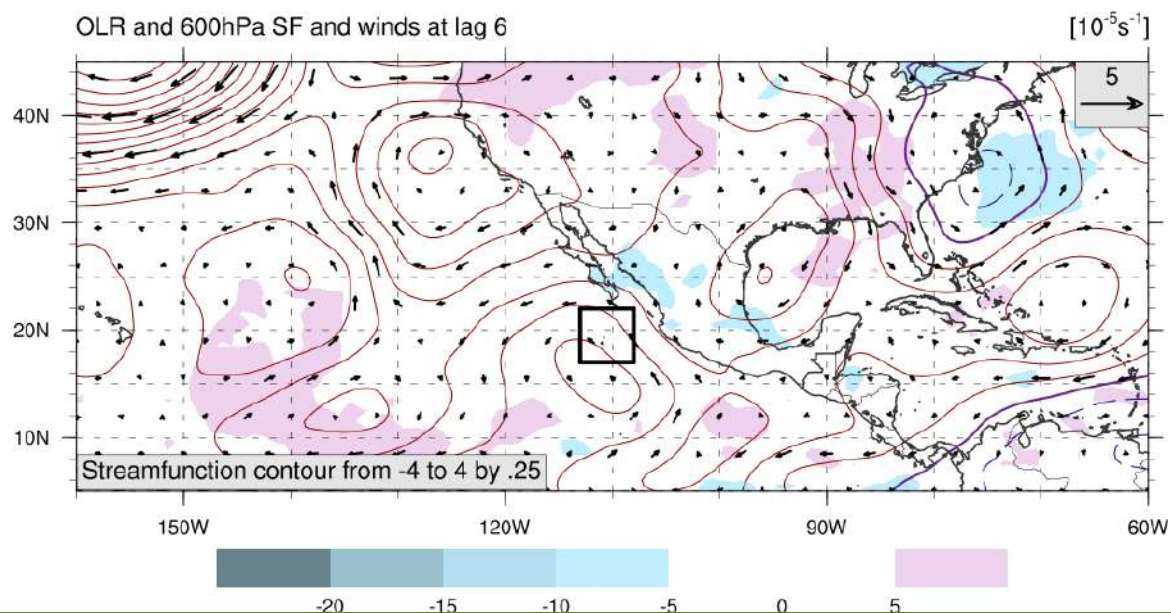
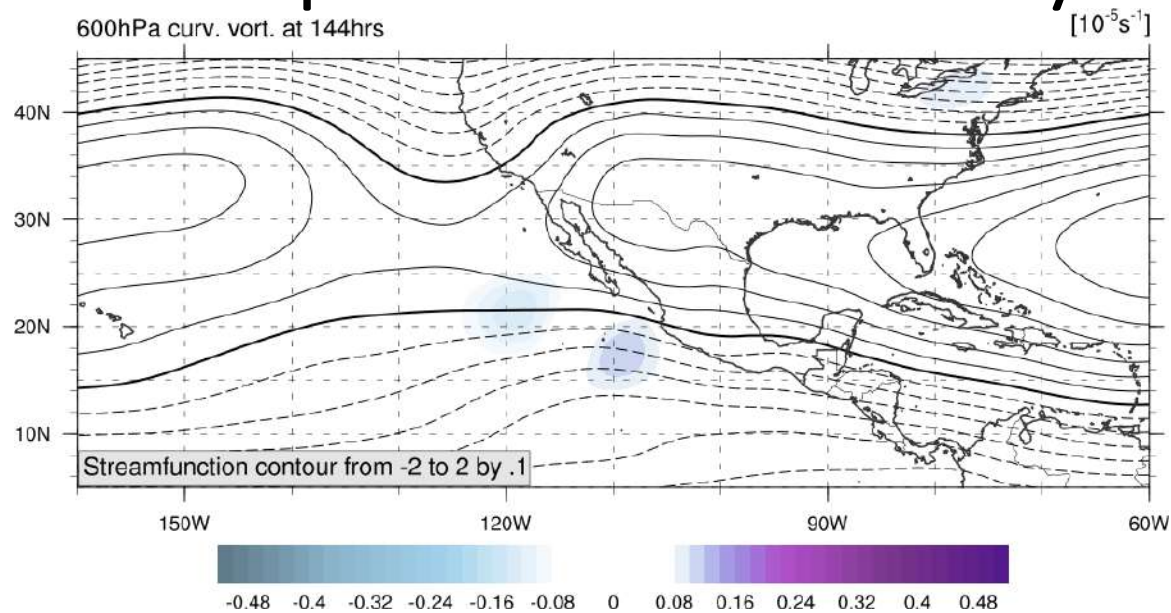
EW composited structure – Day+4



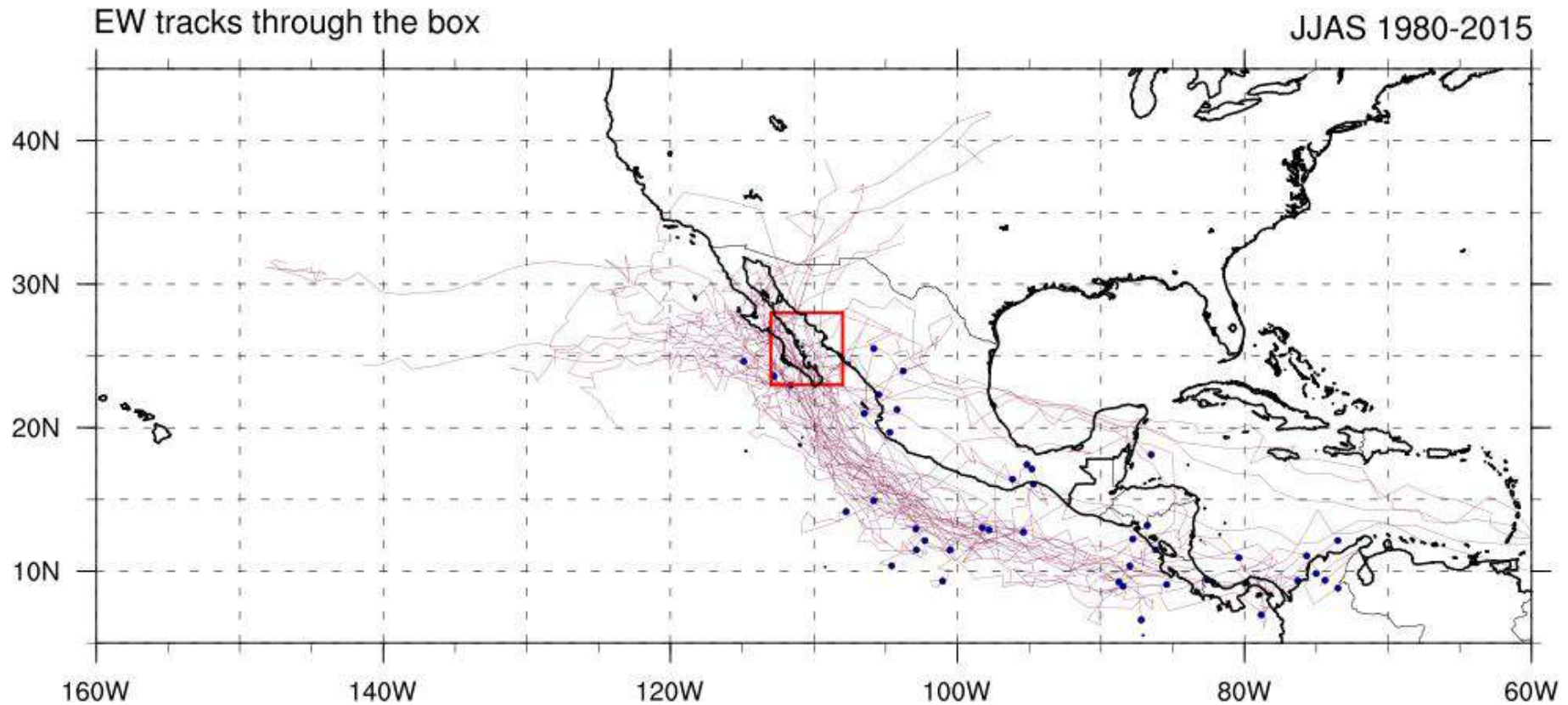
EW composited structure – Day+5



EW composited structure – Day+6

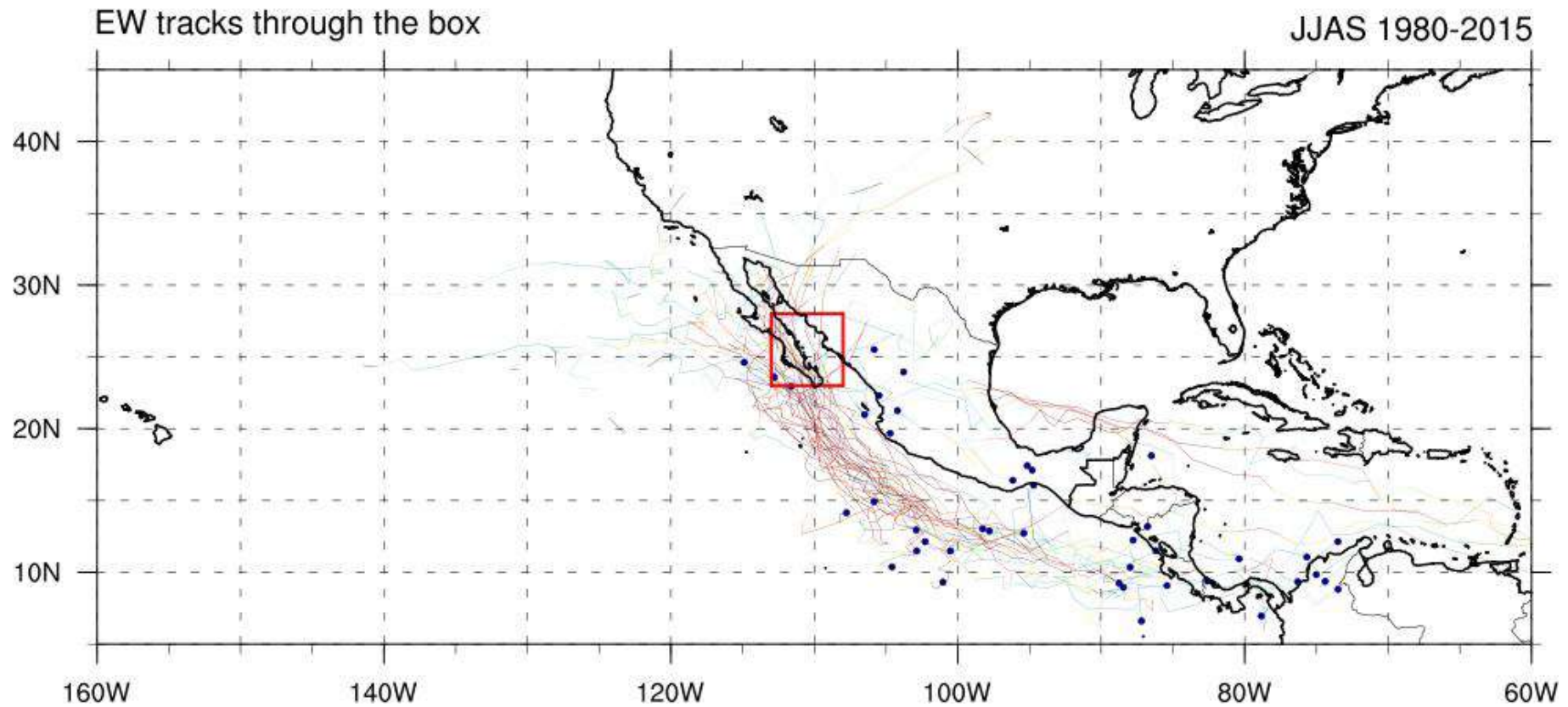


Tracks of EWs on methodology



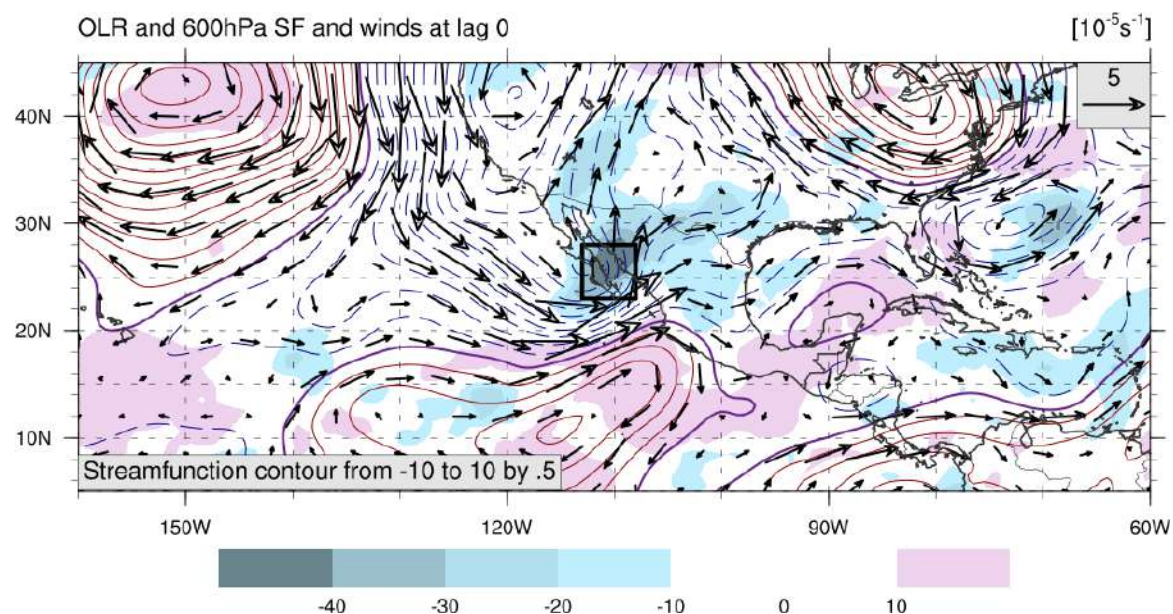
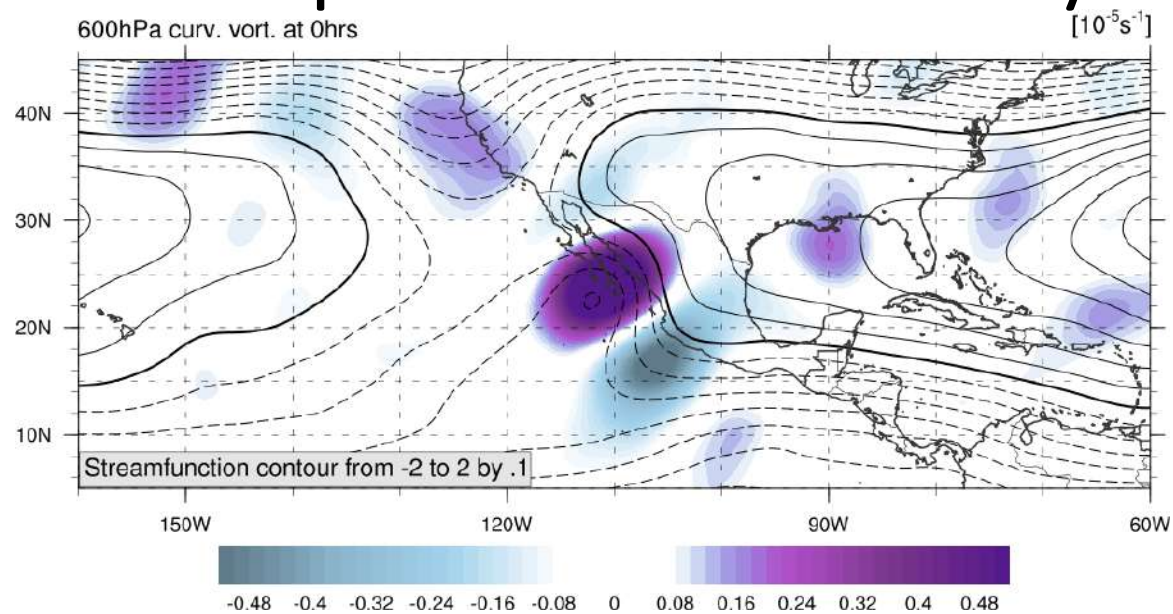
47 cases

Tracks of EWs on methodology

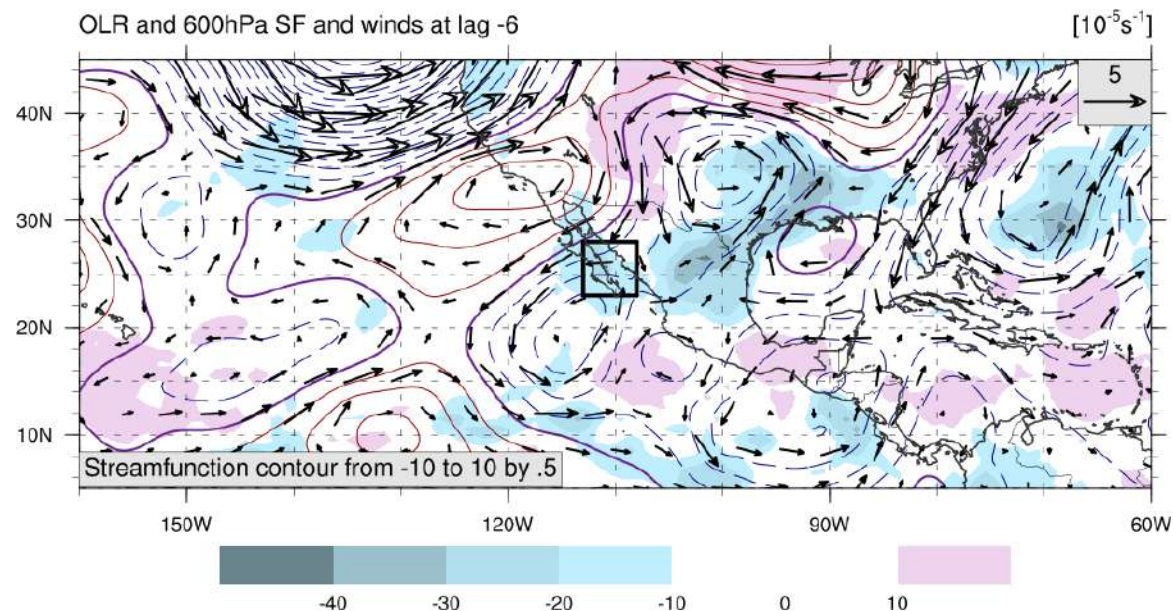
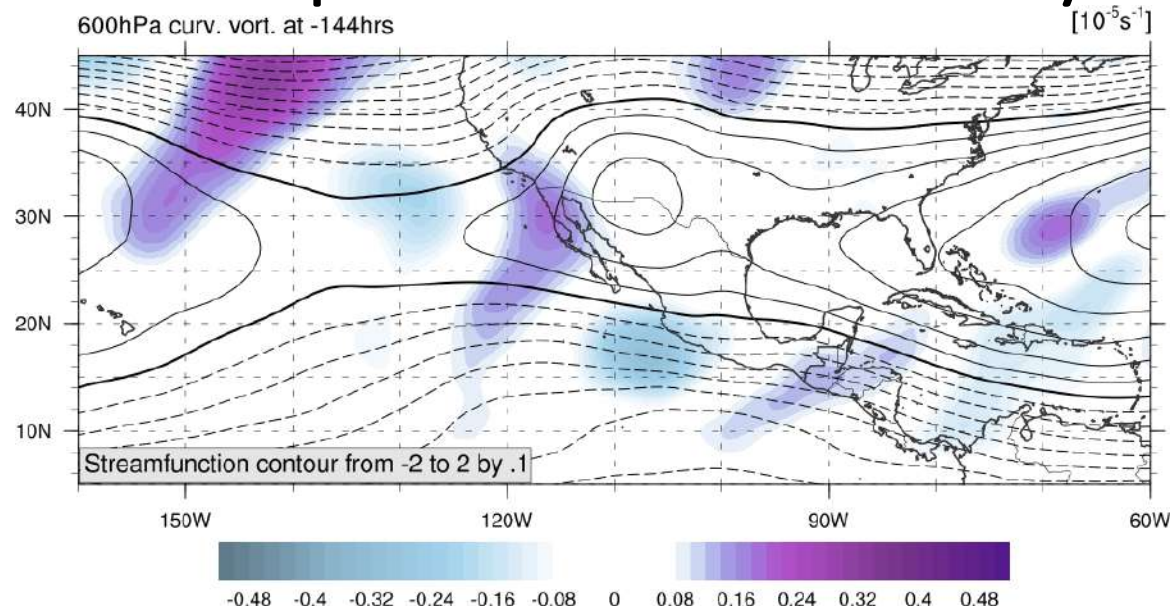


47 cases

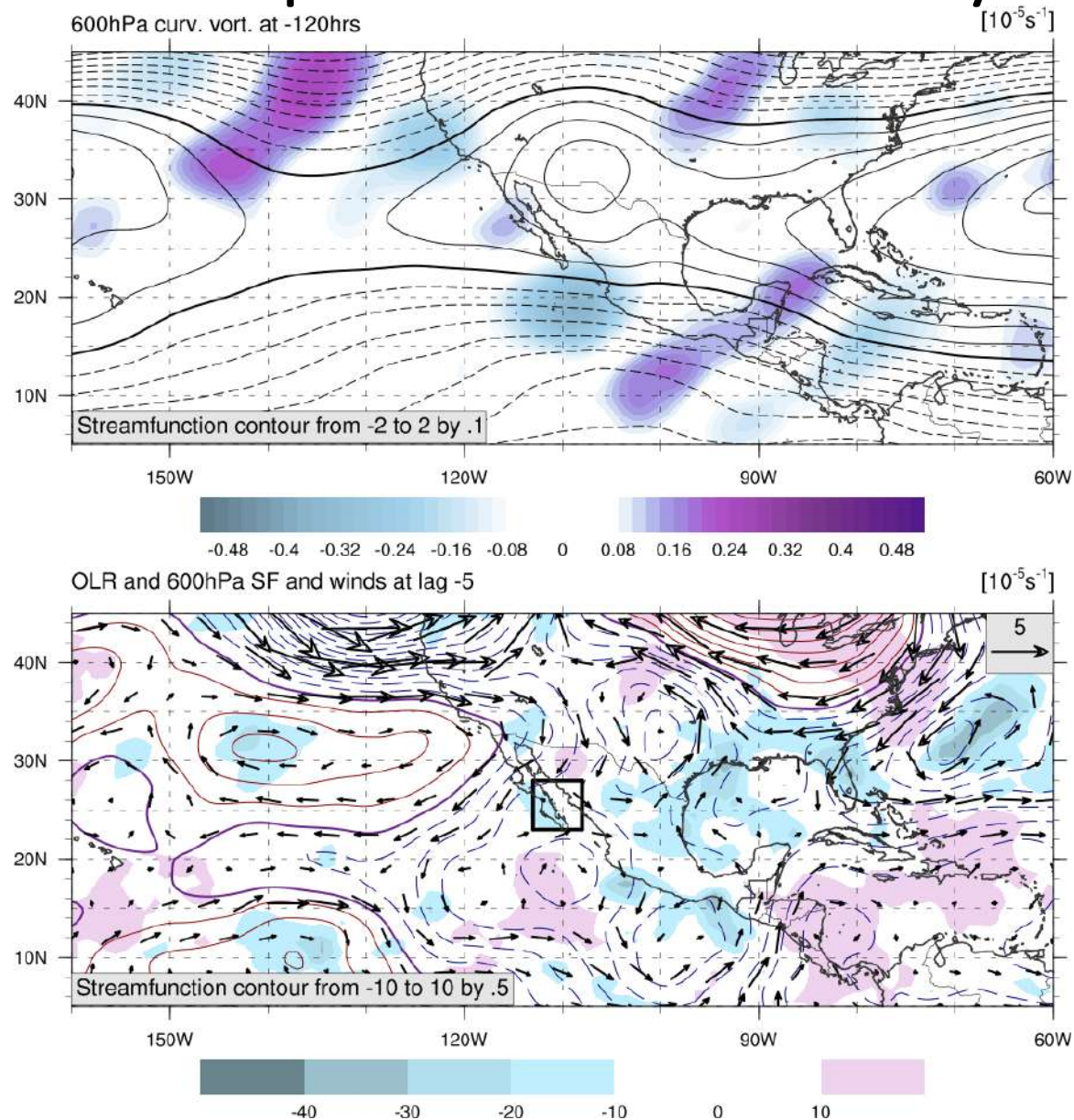
EW composited structure – Day 0



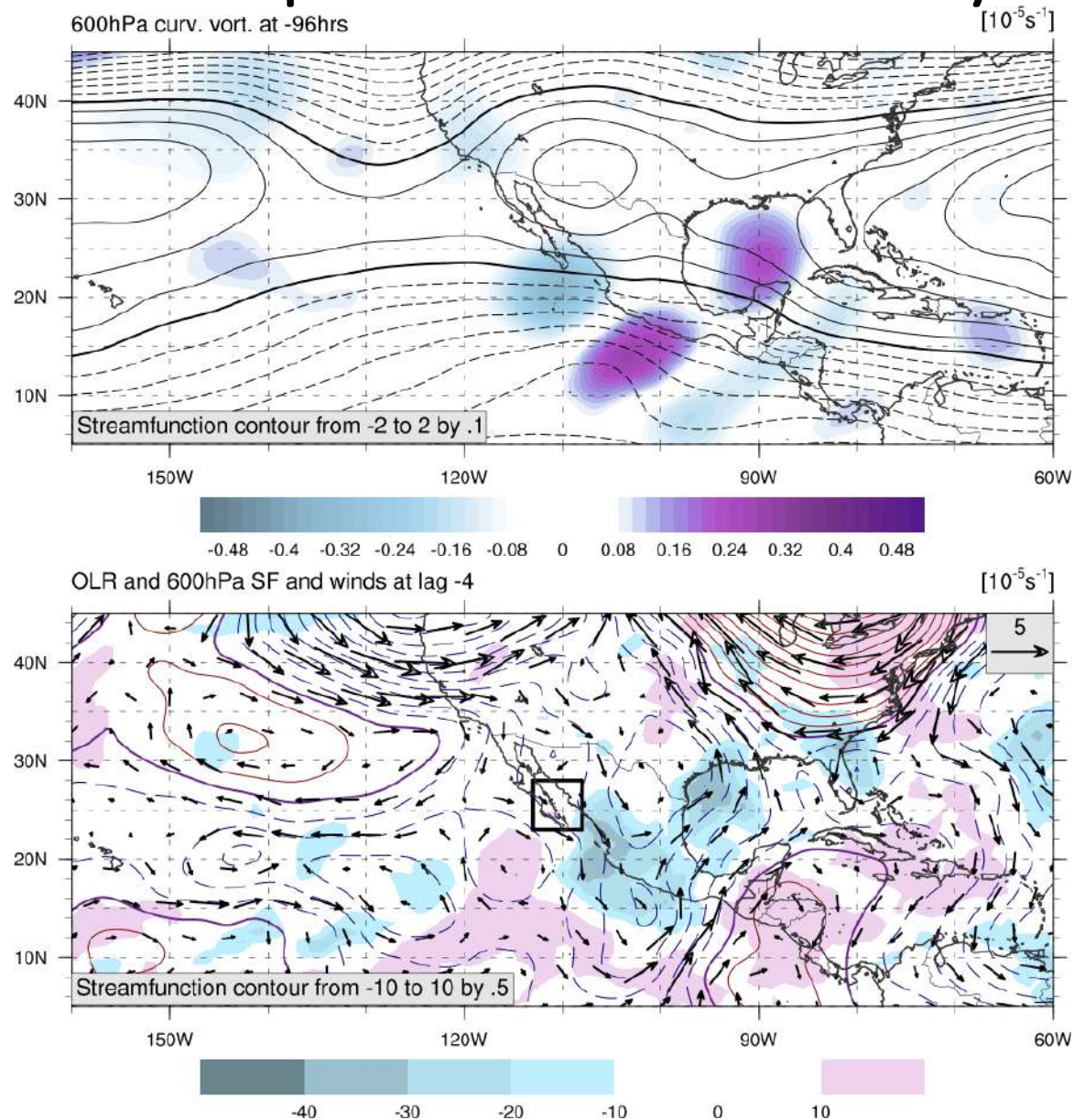
EW composited structure – Day-6



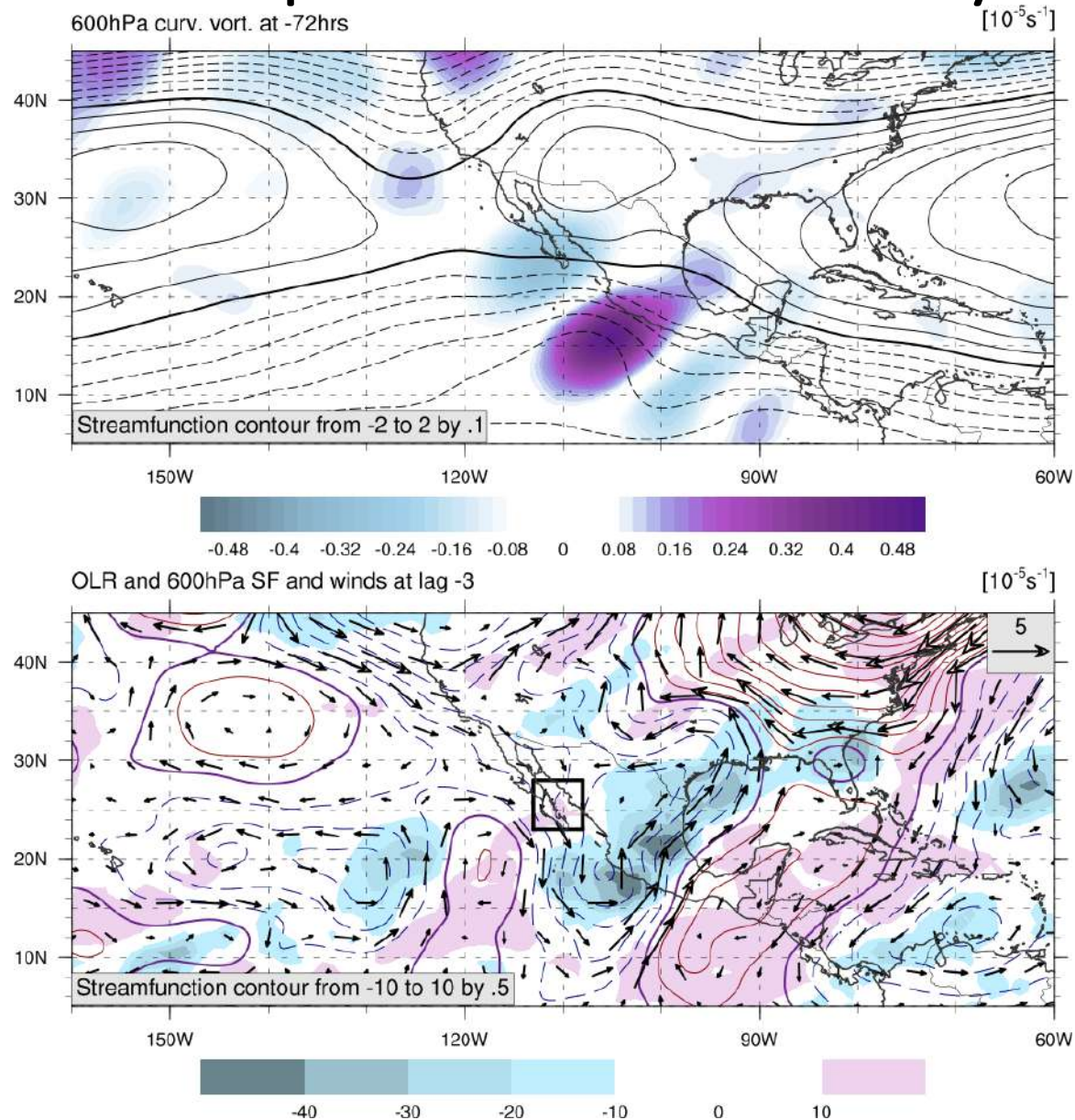
EW composited structure – Day-5



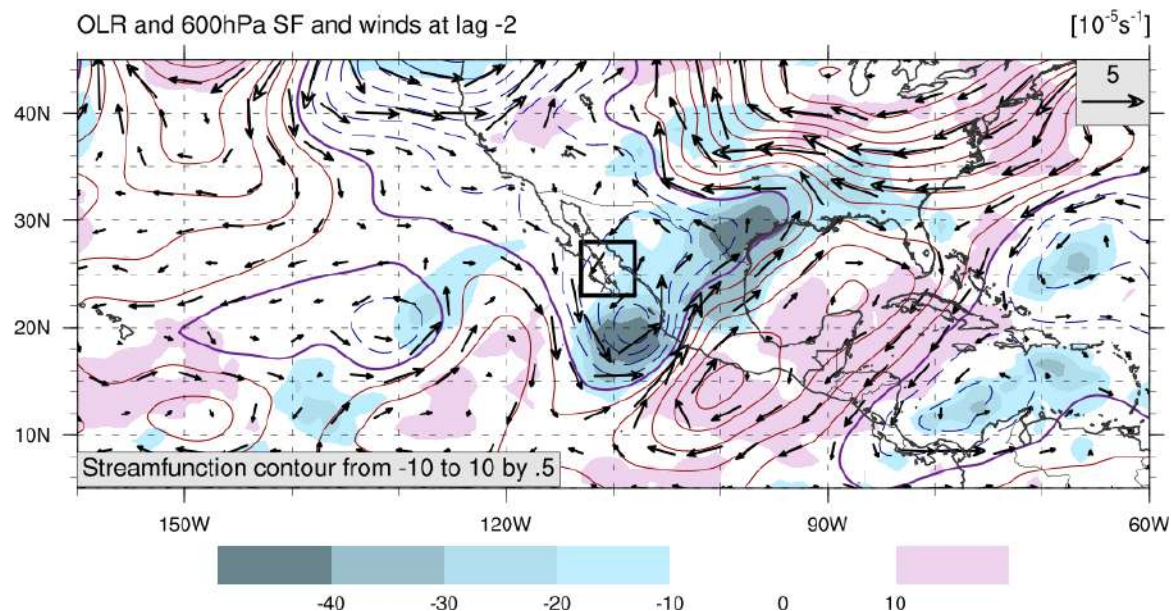
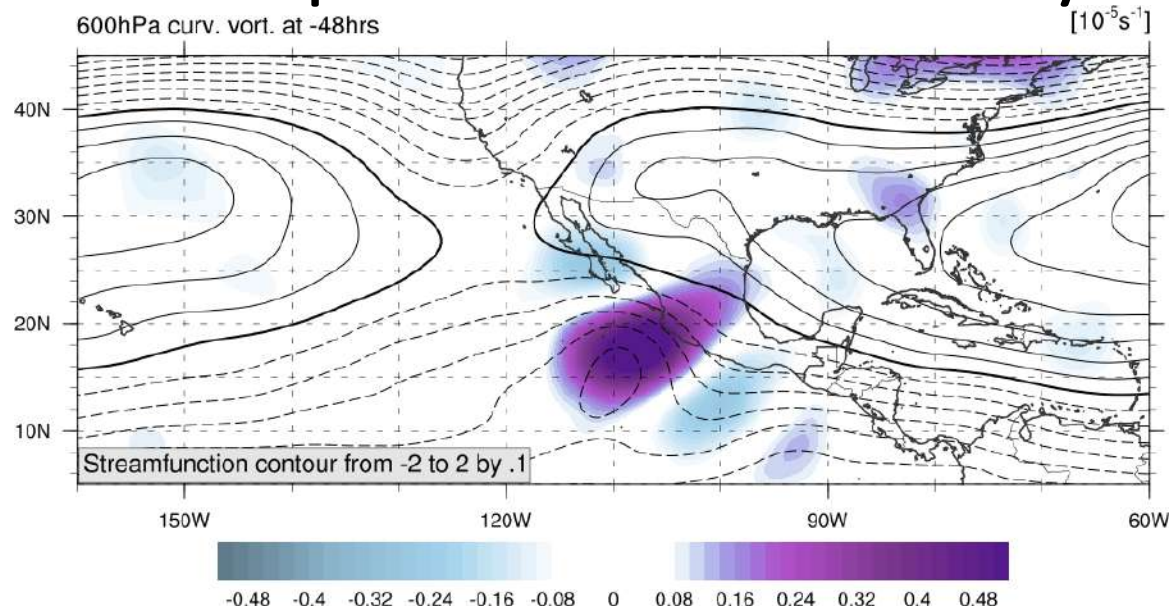
EW composited structure – Day-4



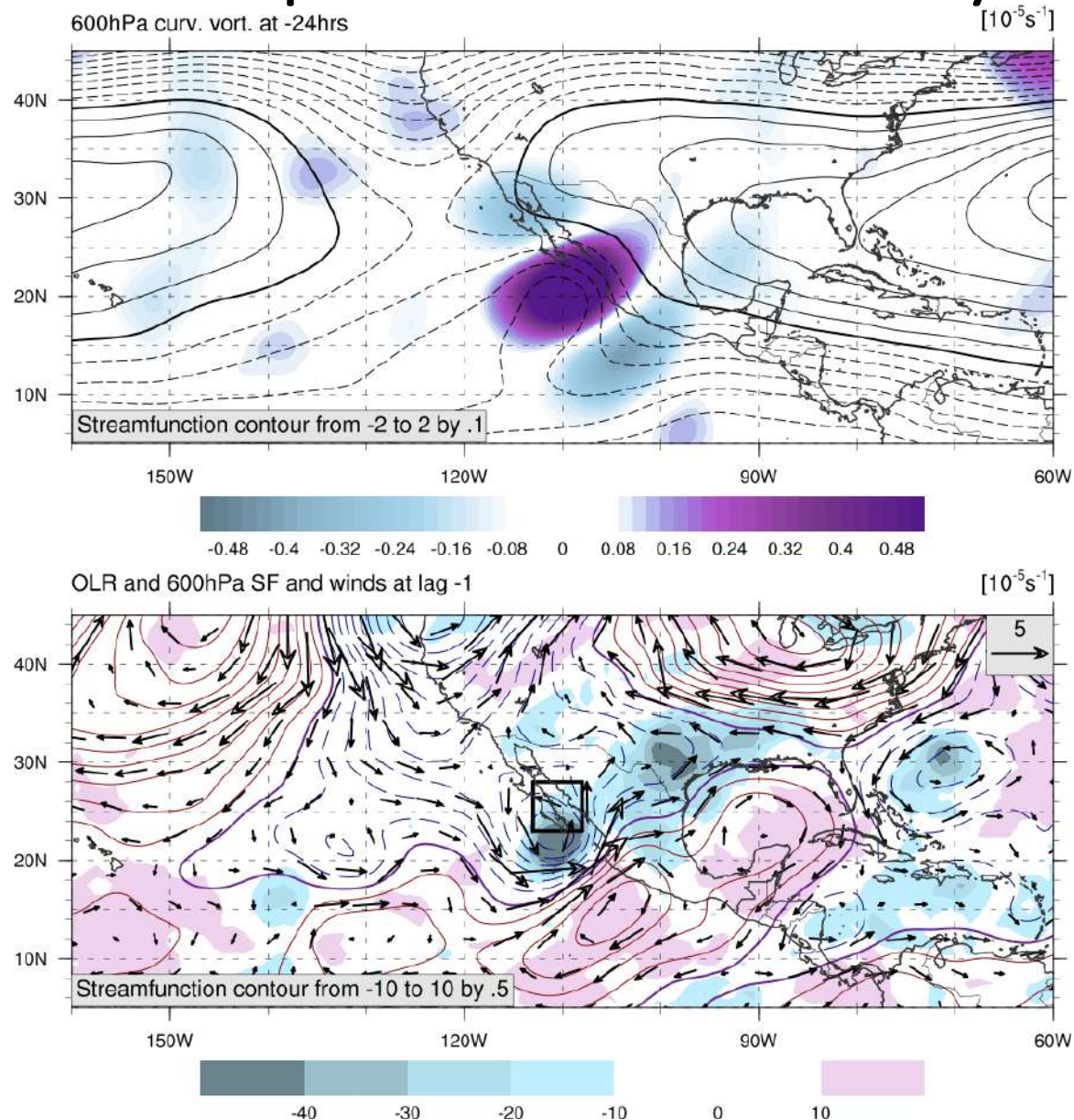
EW composited structure – Day-3



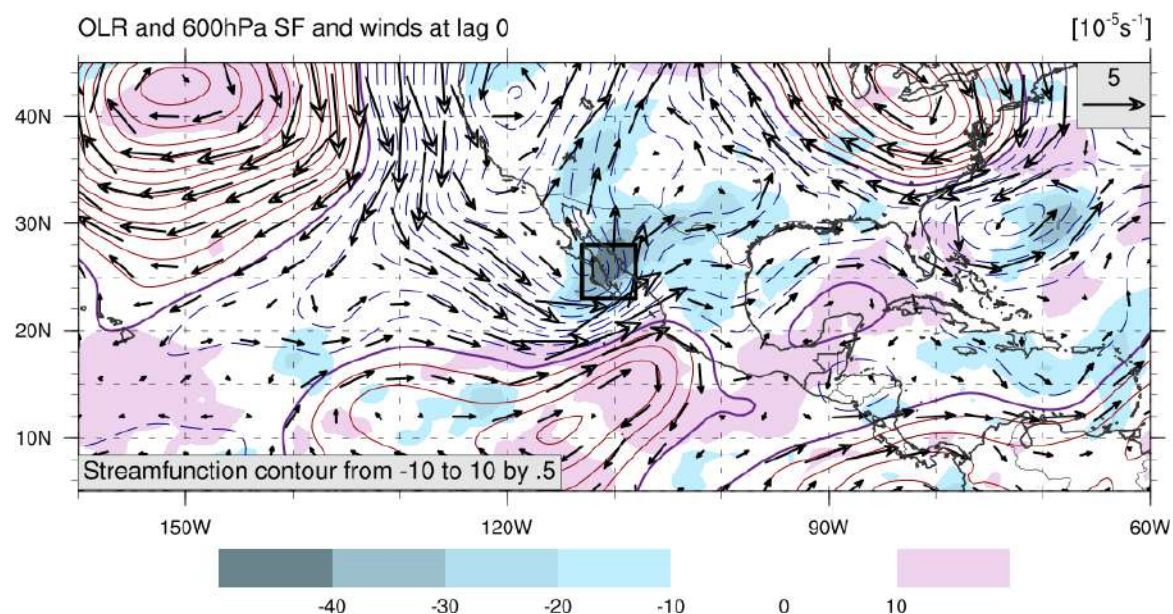
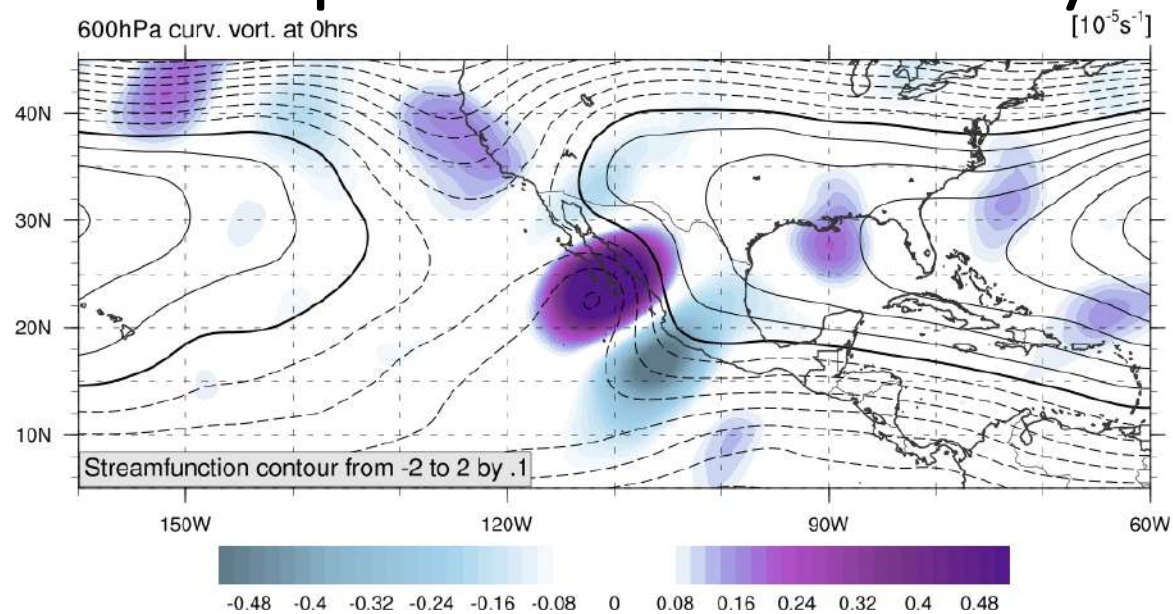
EW composited structure – Day-2



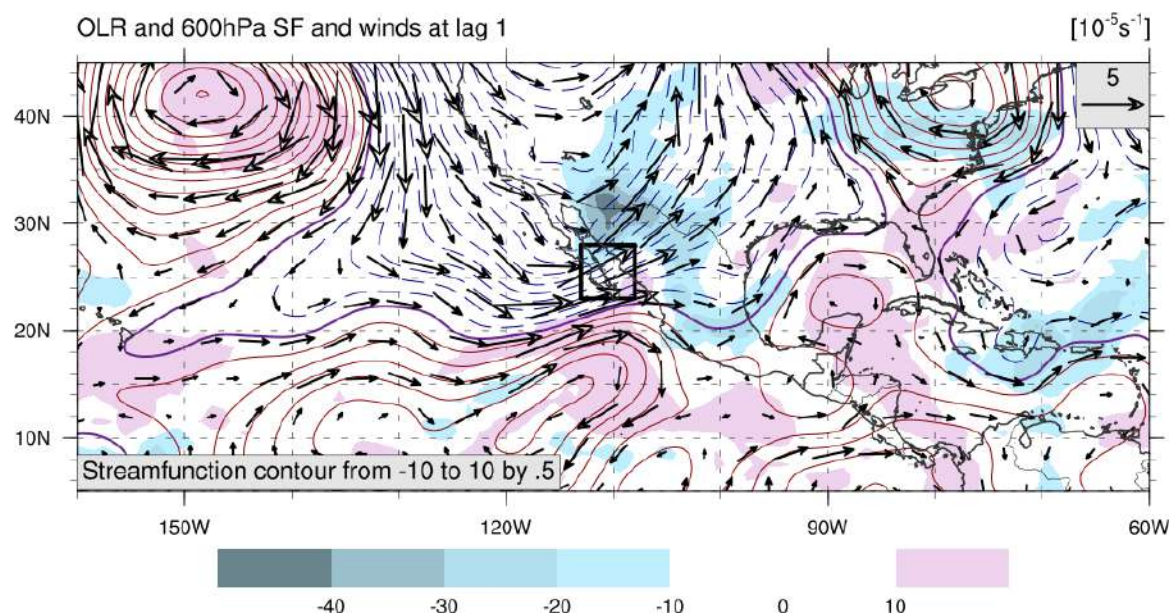
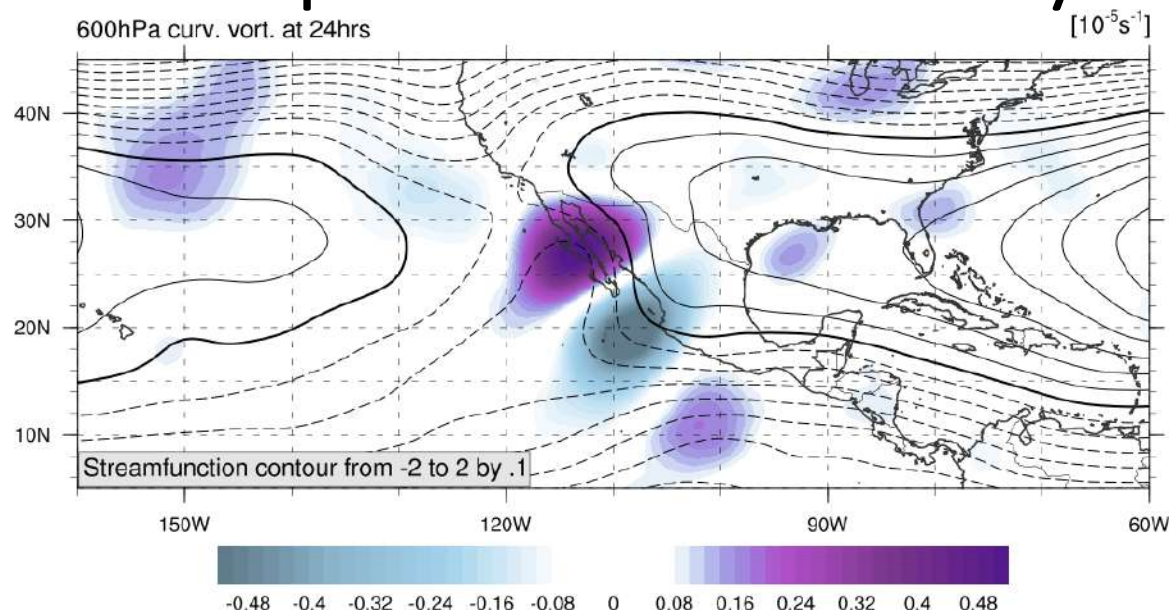
EW composited structure – Day-1



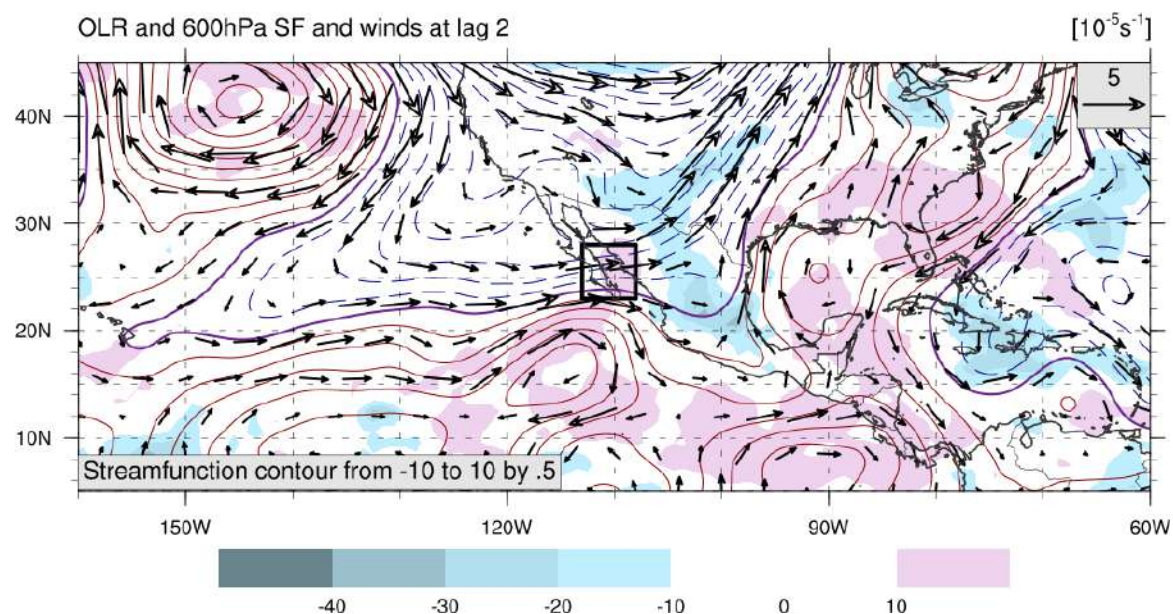
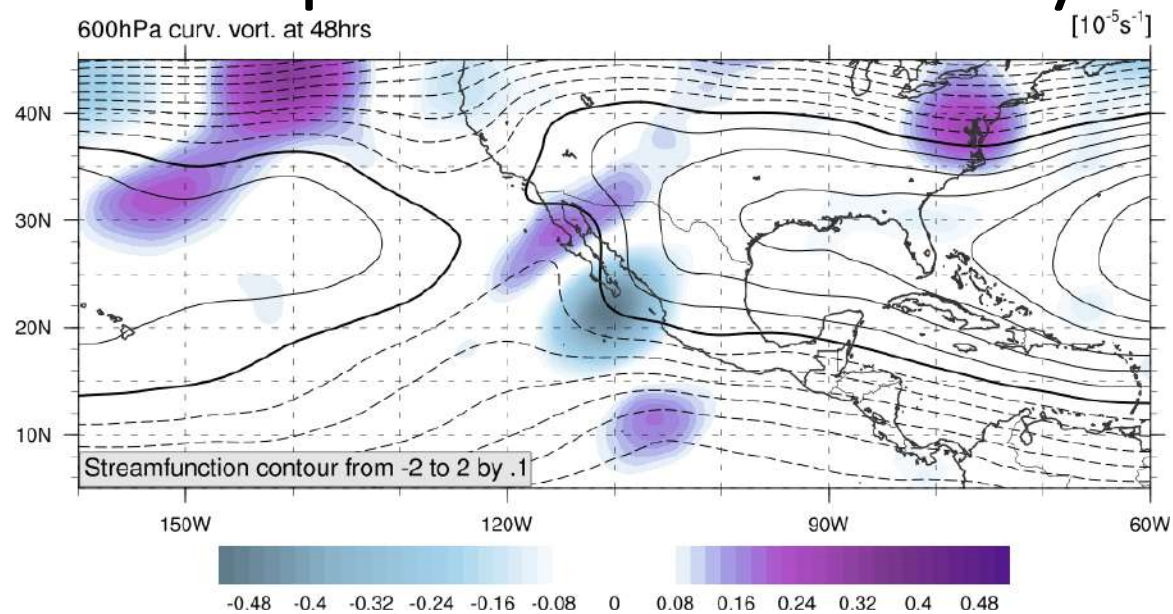
EW composited structure – Day 0



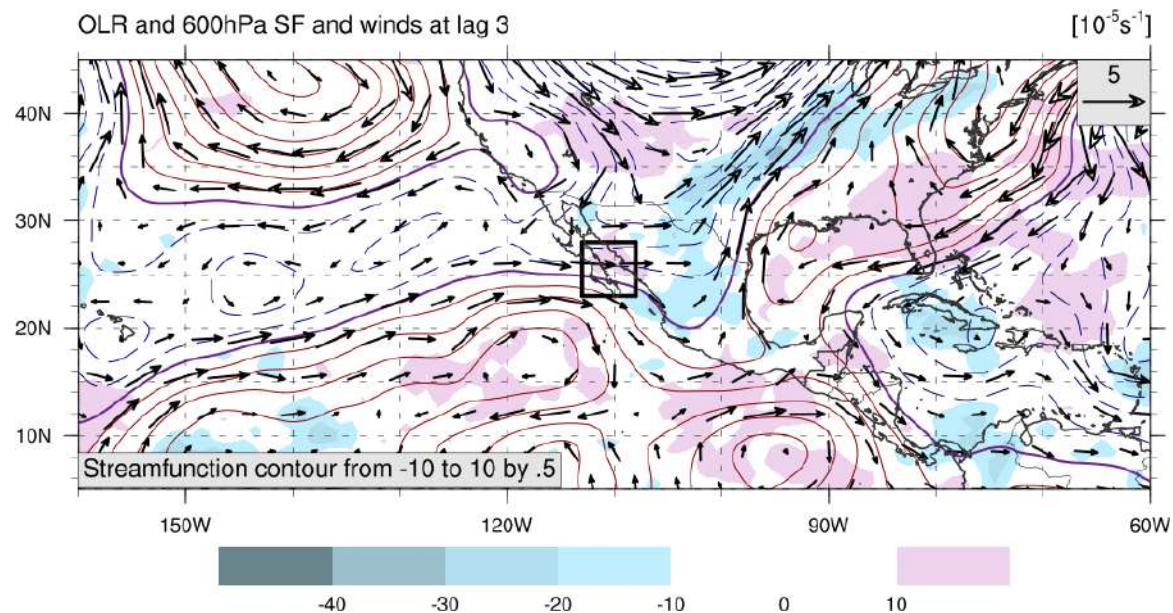
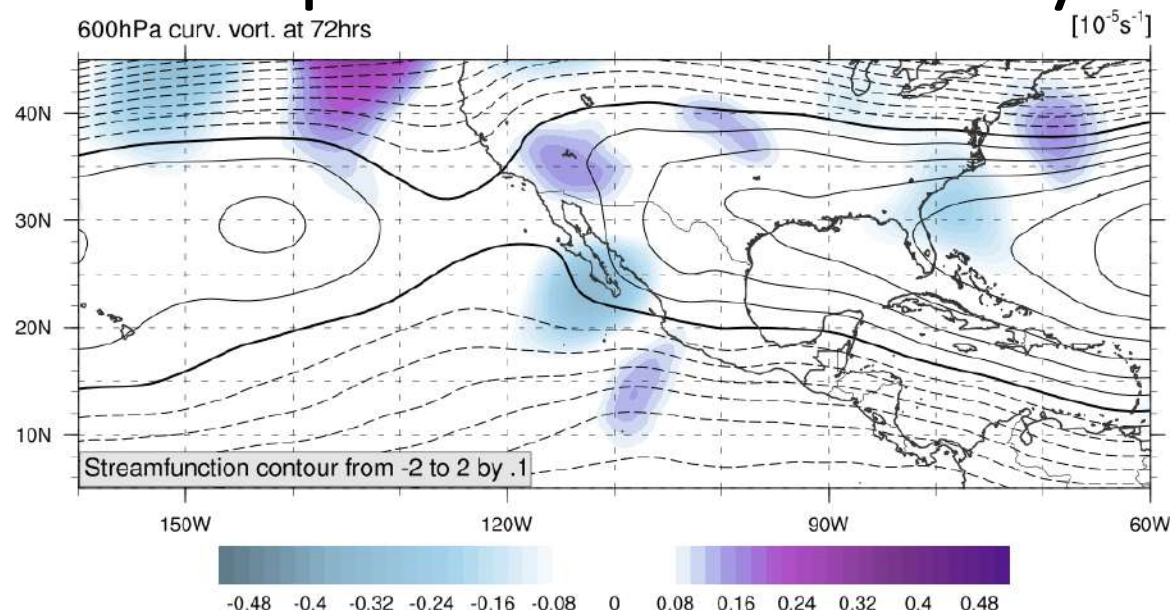
EW composited structure – Day+1



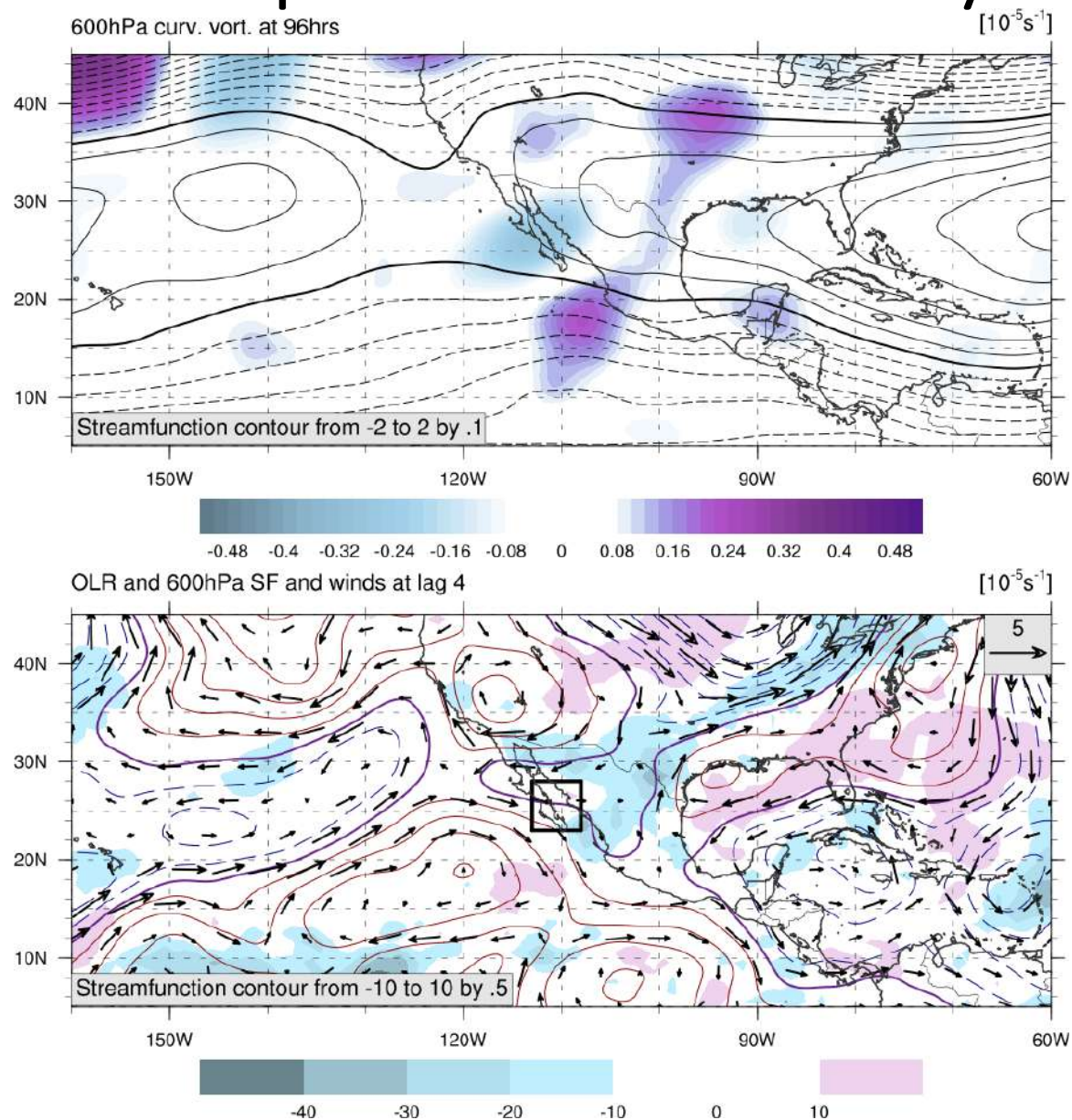
EW composited structure – Day+2



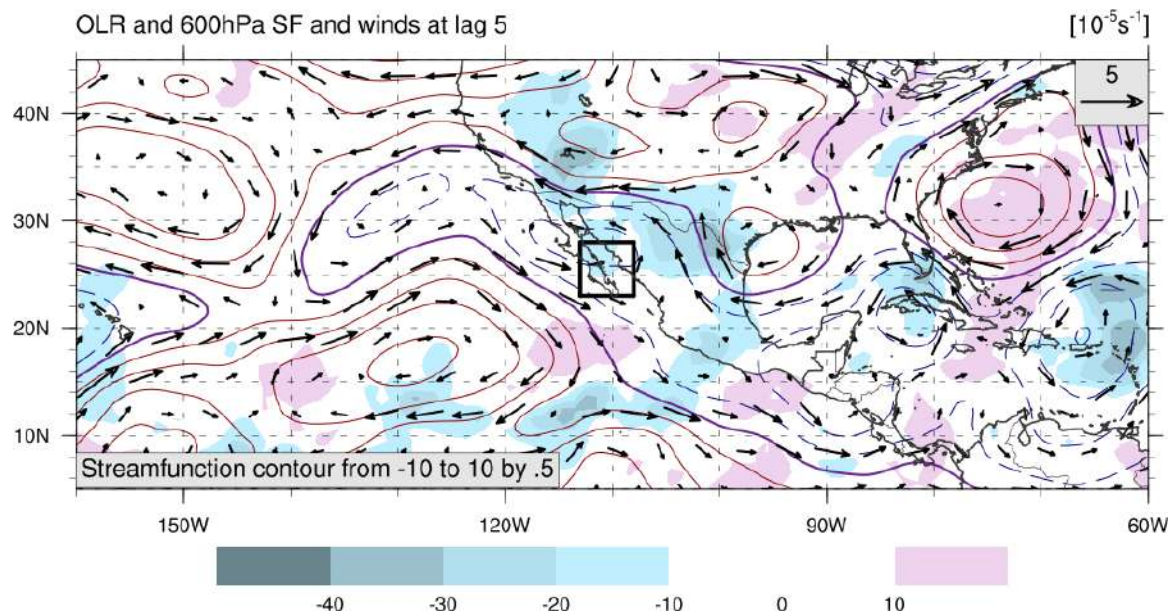
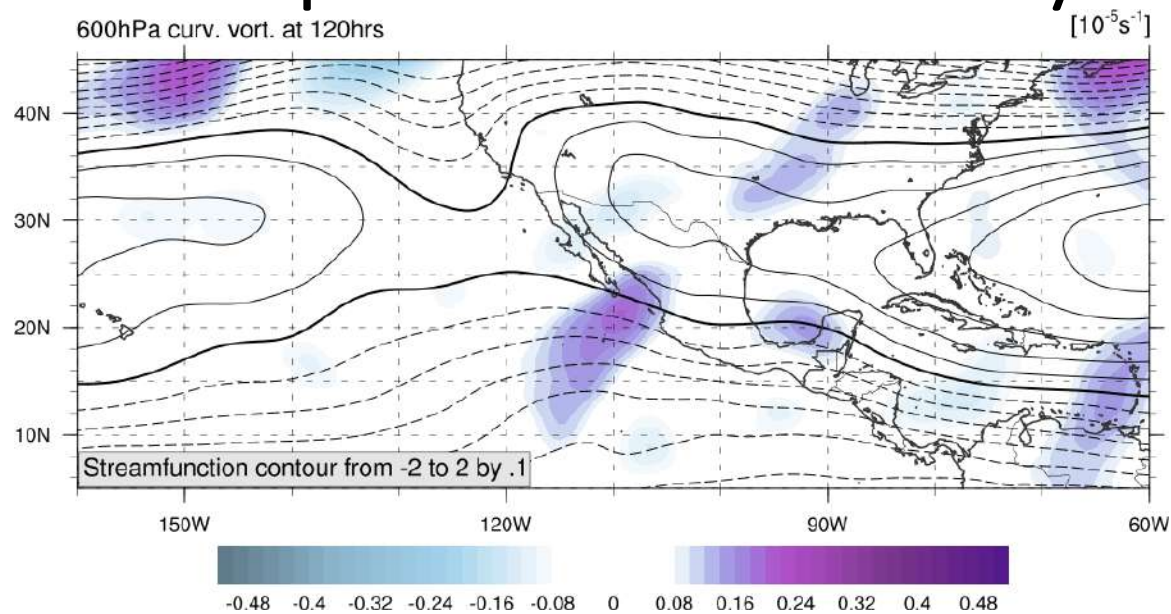
EW composited structure – Day+3



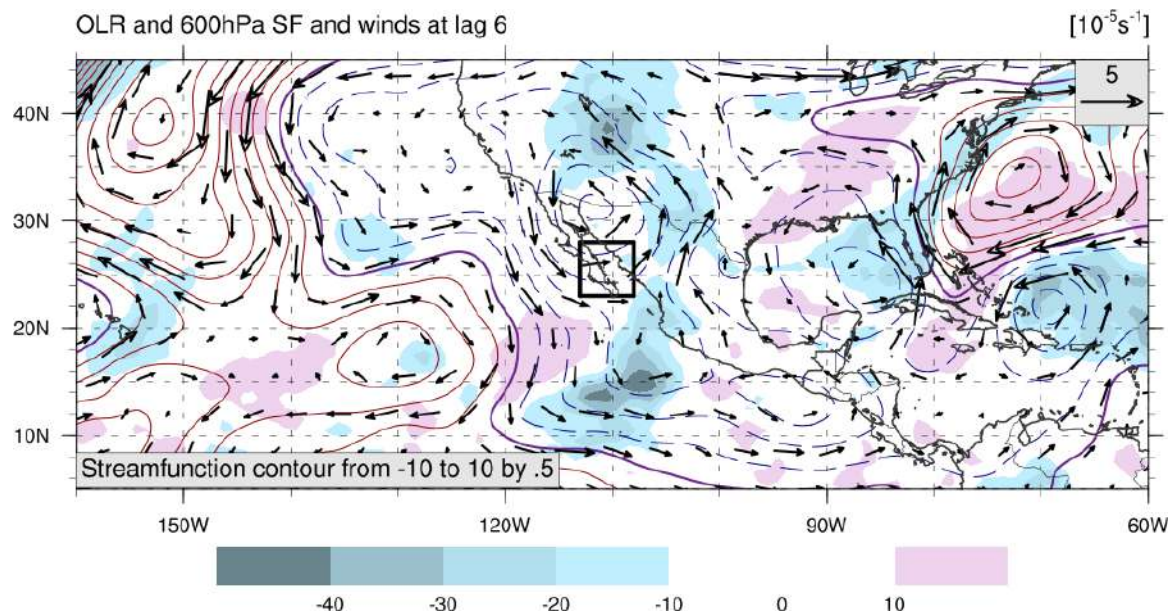
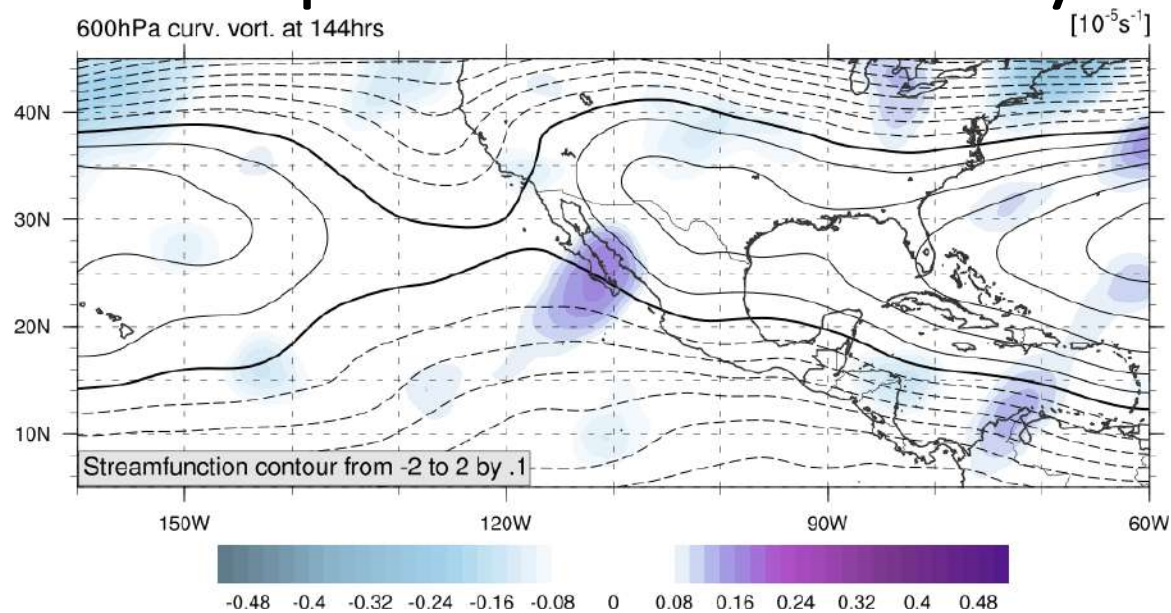
EW composited structure – Day+4

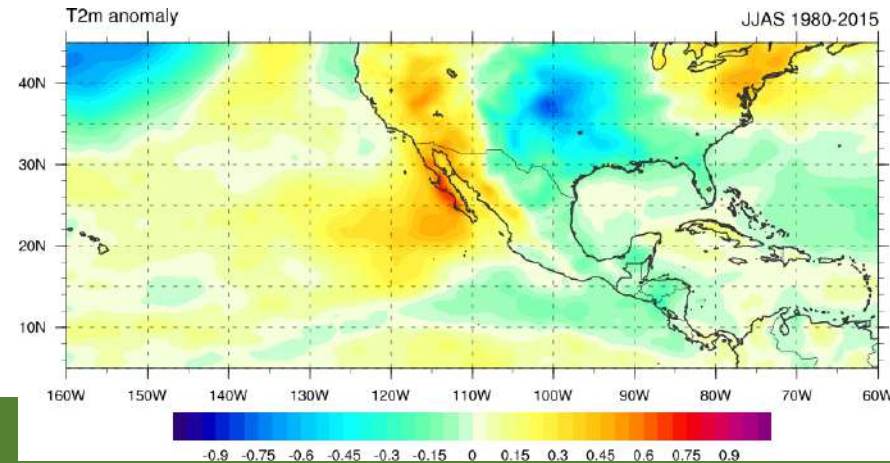
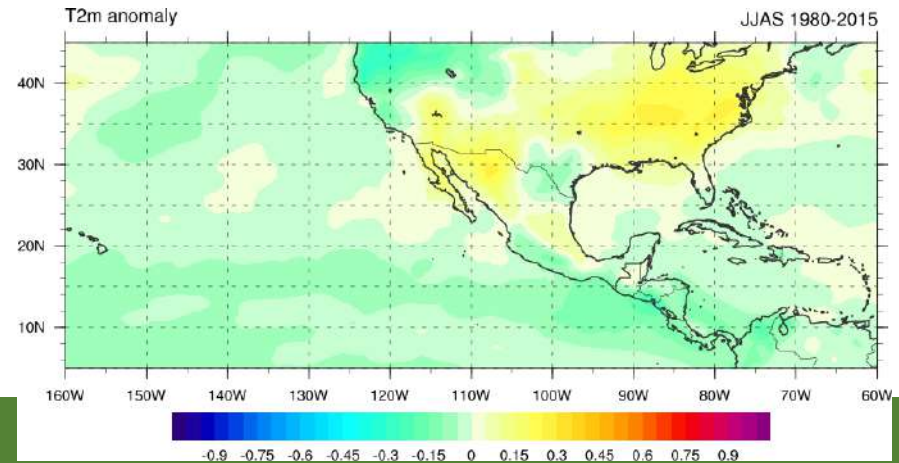
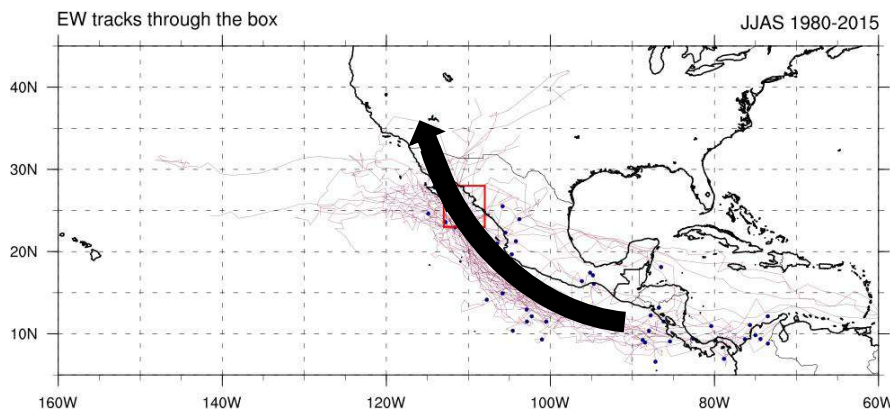
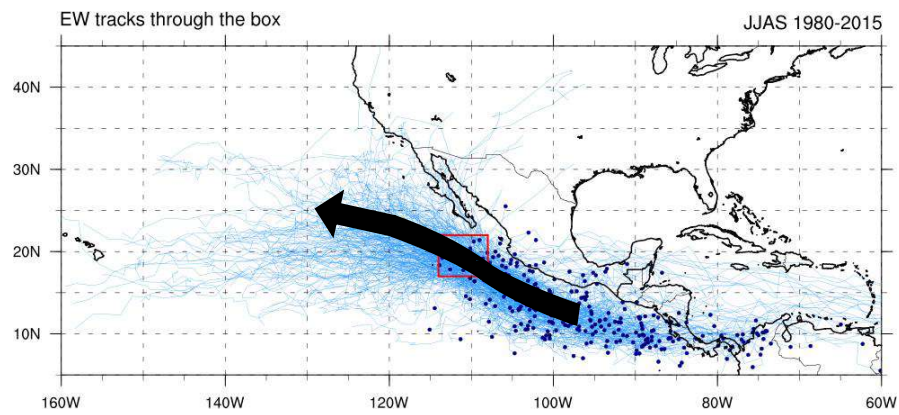
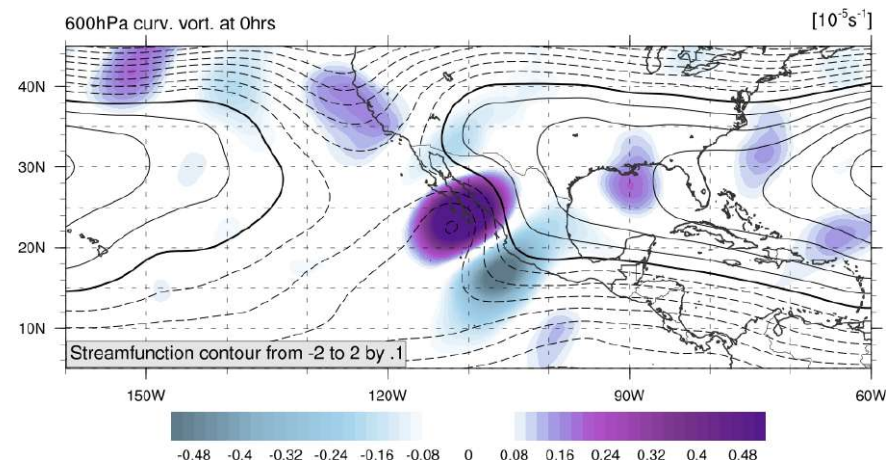
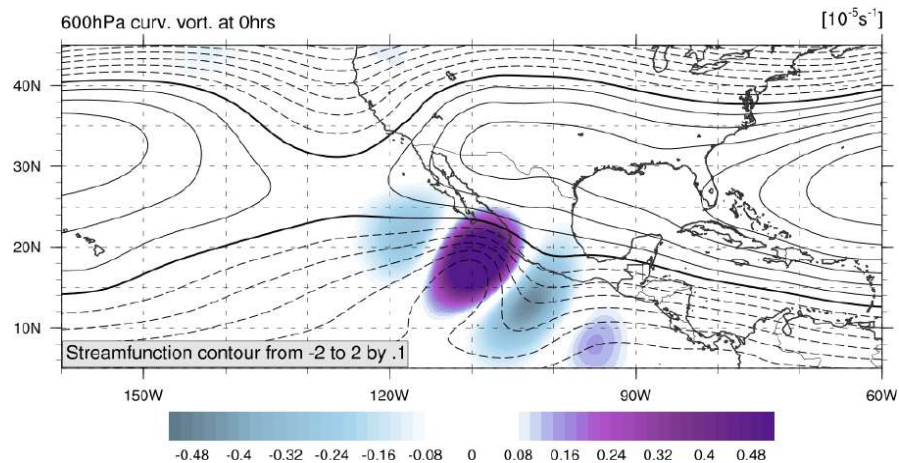


EW composited structure – Day+5

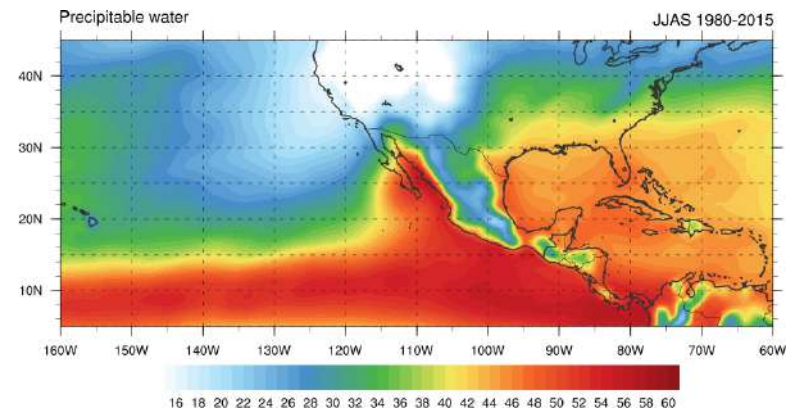
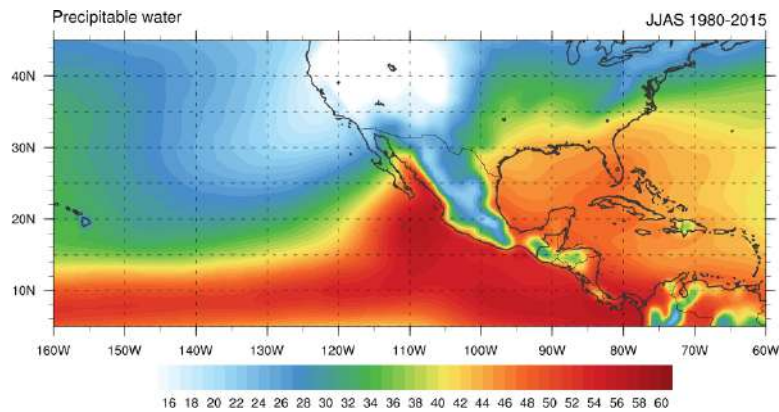
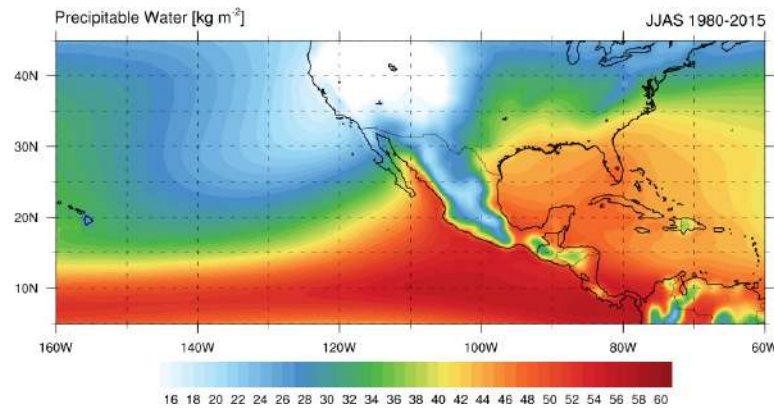


EW composited structure – Day+6





Precipitable water



Summary

- Overall, EWs track west close to the NAM region
- A small subset of EWs track towards the NAM region, mostly as TCs
- One mechanism for this is associated with mid-latitude systems
- However, increased temperature anomalies over the NAM region seems to be key for this recurving tracks also.
- Large-scale circulation suggest a role of the North Atlantic Subtropical High
- It is not evident how much these recurving systems contribute to moisture over the NAM region.

Thanks!!

Questions?

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