Advanced School and Workshop on American Monsoons: progress and future plans

ICTP-SAIFR, São Paulo, Brazil

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Contribution of tropical cyclones to Middle America's hydrological cycle

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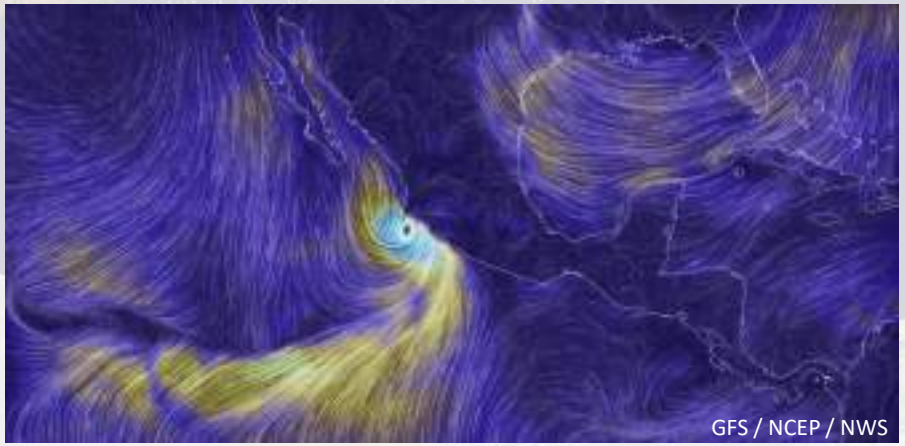
MODIS/NASA



GFS / NCEP / NWS

S. Kelly/NASA

Motivation

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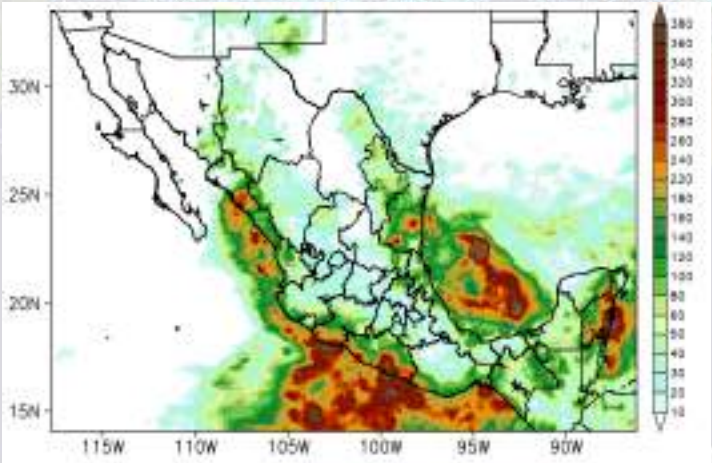
- During the warm season, Middle America is subject to **landfalling tropical cyclones (TCs)** from the Eastern Pacific and North Atlantic.

- In September 2013 **Hurricane Manuel** produced accumulated rainfall of **1107 mm,**

Hurricane Ingrid accumulated rainfall of **510.54 mm** for Sep 12-20 2013 (NOAA,2013)

PhD Question: What is the contribution of **Tropical Cyclones** to the regional hydrological cycle?



Accumulated rainfall for the 12-13 September 2013, during the occurrence of two simultaneous extreme events: hurricane Manuel (EP) and hurricane Ingrid (GoM)

Contribution of TCs to:

① **monthly rainfall**

② **extreme rainfall**

③ **moisture transport**

1. Contribution of Tropical Cyclones to rainfall over Middle America

University of Reading

Following the methodology of Guo et al. (2017, J.of Clim):

- **Rainfall estimations**:

  TMPA 3B42 satellite-derived rainfall data

  (3-hourly temporal , 0.25º x 0.25º spatial res.)

- **TC trajectories** from three sources:

1) IBTrACS (observations) , and

2) an objective feature **tracking method** (Hodges, 1999) applied to

- ERA-Interim

- JRA-55 reanalises

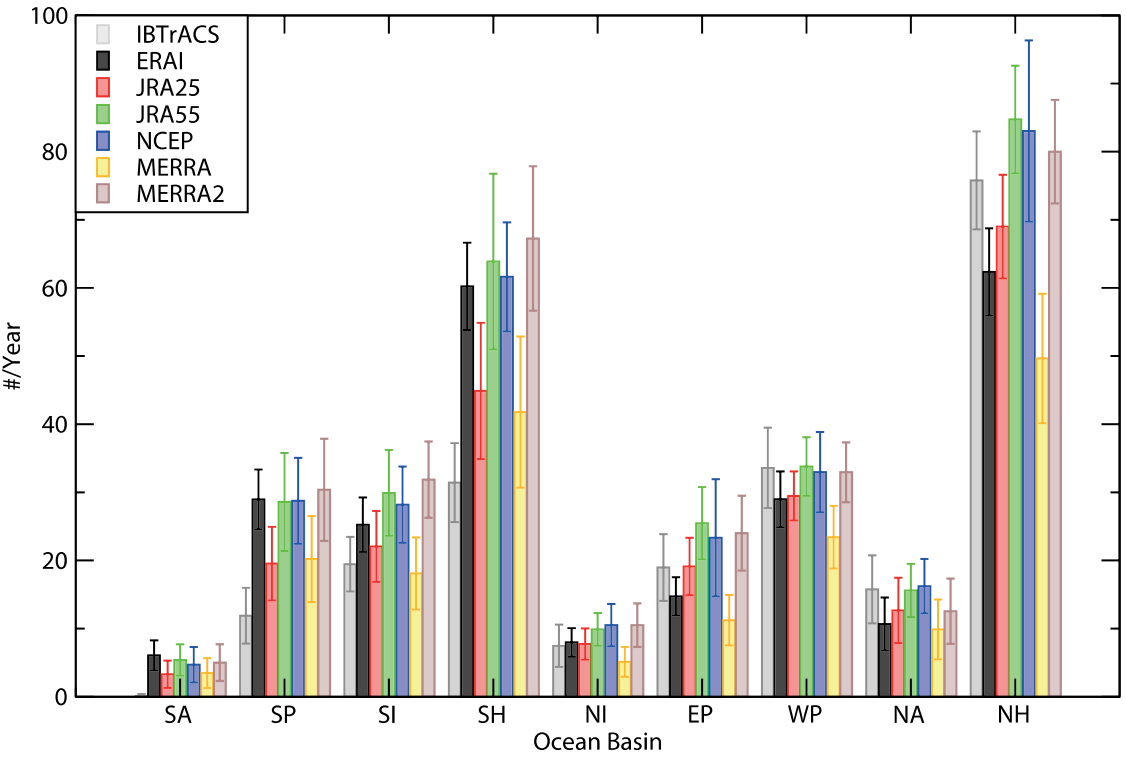


FIG. 5. The average number of TCs per year for each of the seven basins (defined in Fig. 4) for IBTrACS and identified in the reanalyses based on the objective detection method (cf. section 3b). Vertical lines at the tops of the bars indicate the standard deviation.

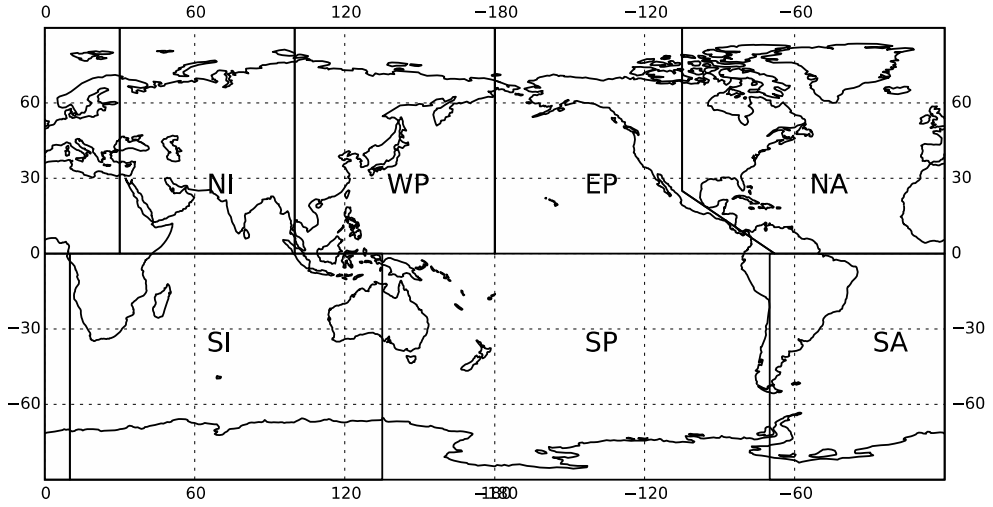


FIG. 4. The seven basins used in this study, based on the IBTrACS definition—NI: north Indian Ocean, WP: western Pacific, EP: eastern Pacific, NA: North Atlantic, SI: south Indian Ocean, SP: South Pacific, and SA: South Atlantic.

Hodges et al., 2017 . J.of Clim.

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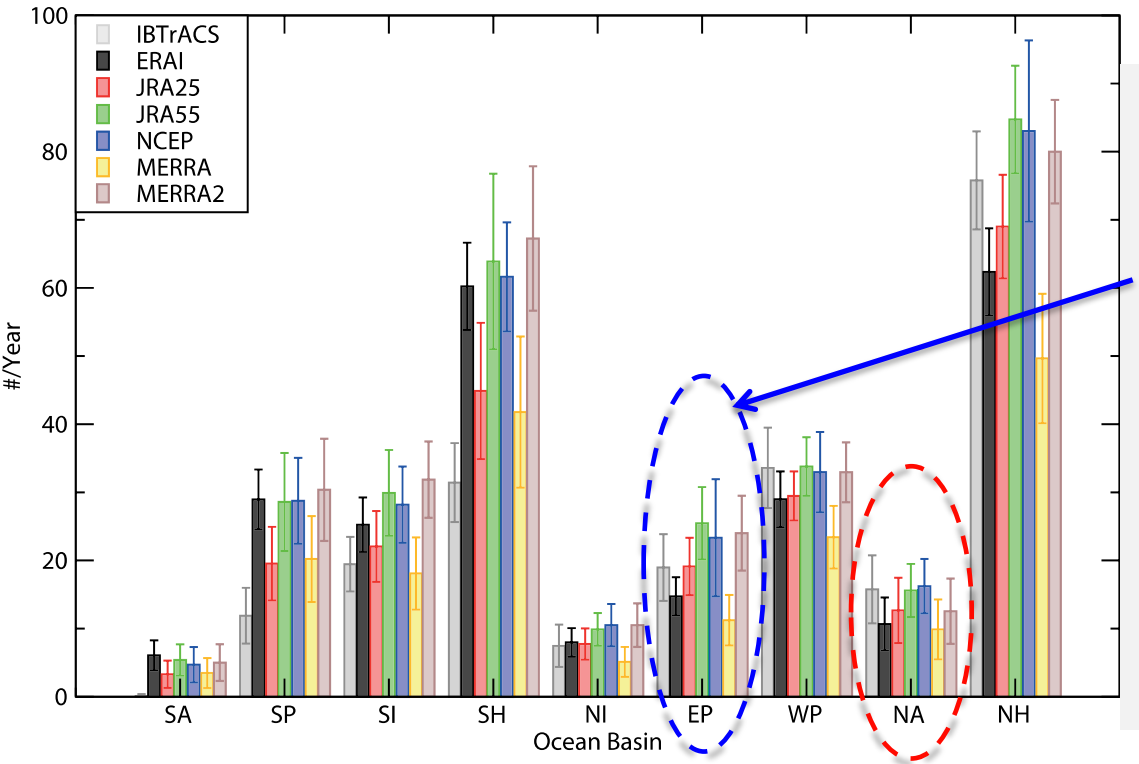

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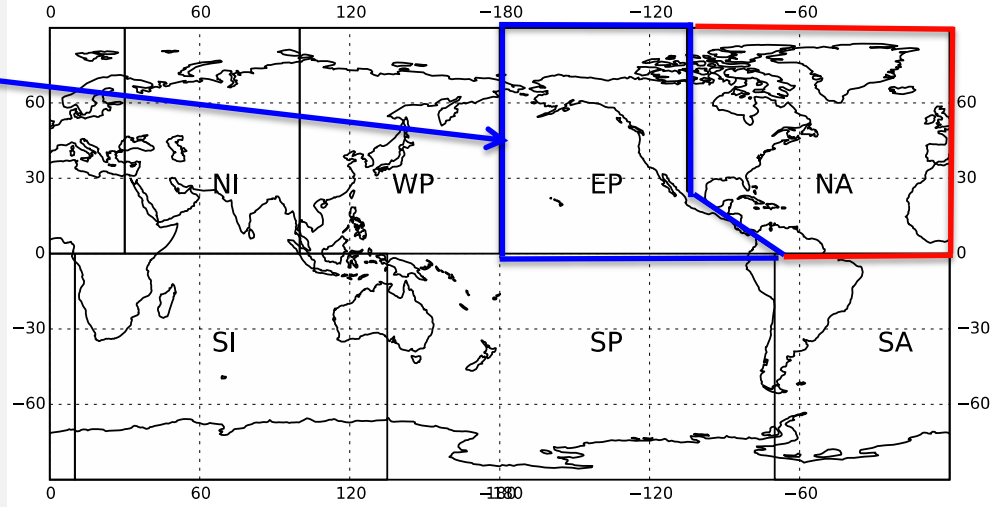
There are differences In:

- **The number of TCs**
- **Tracks**
- **TC intensities**
- **TC lifecycle**



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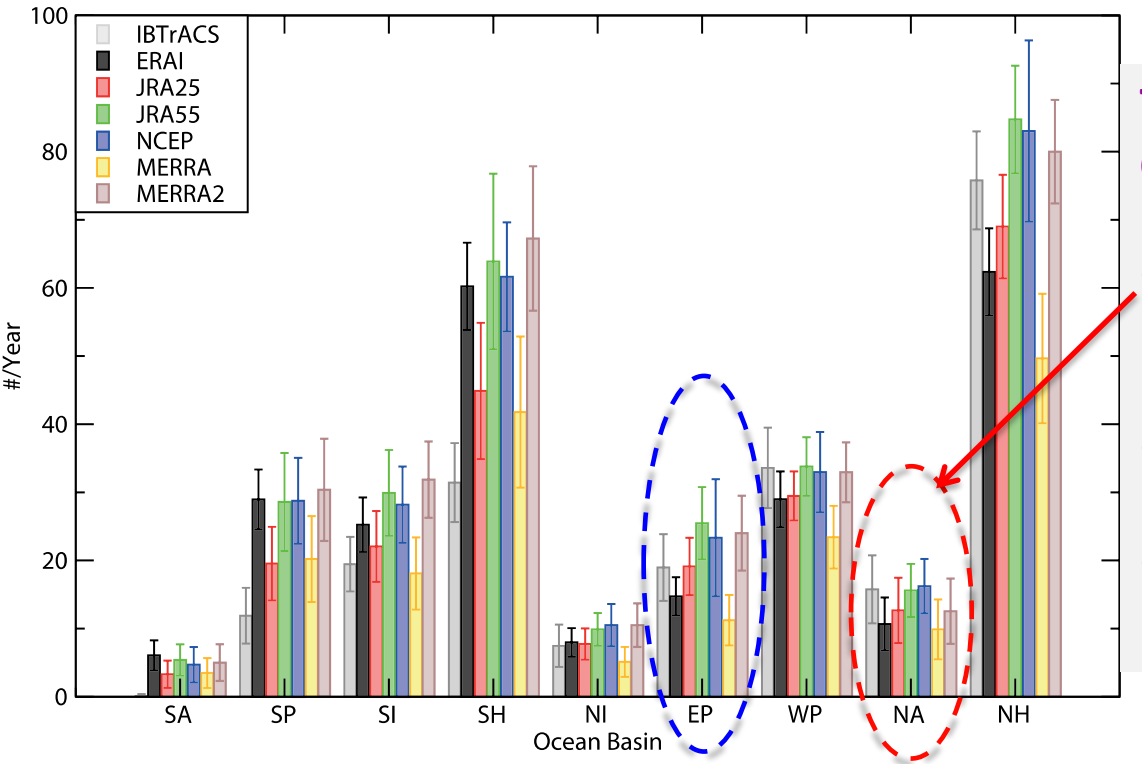

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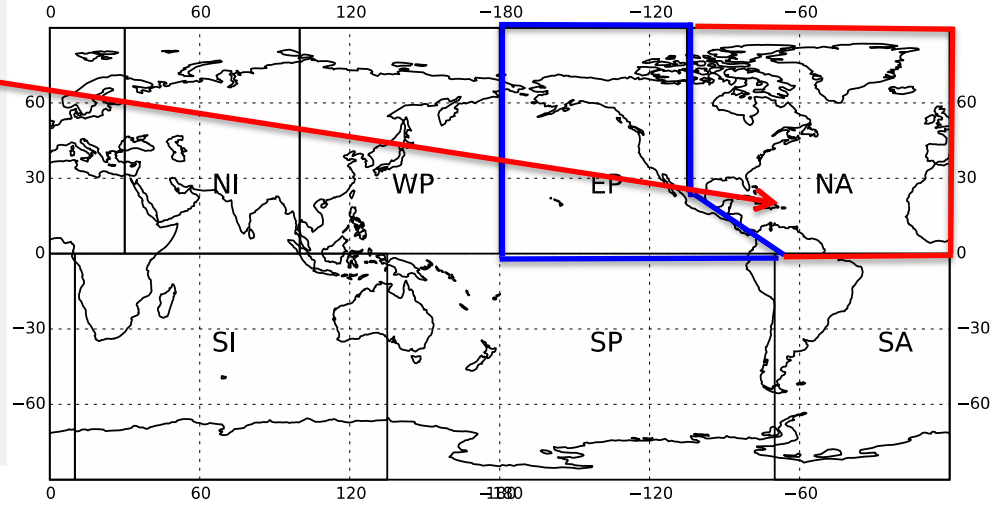

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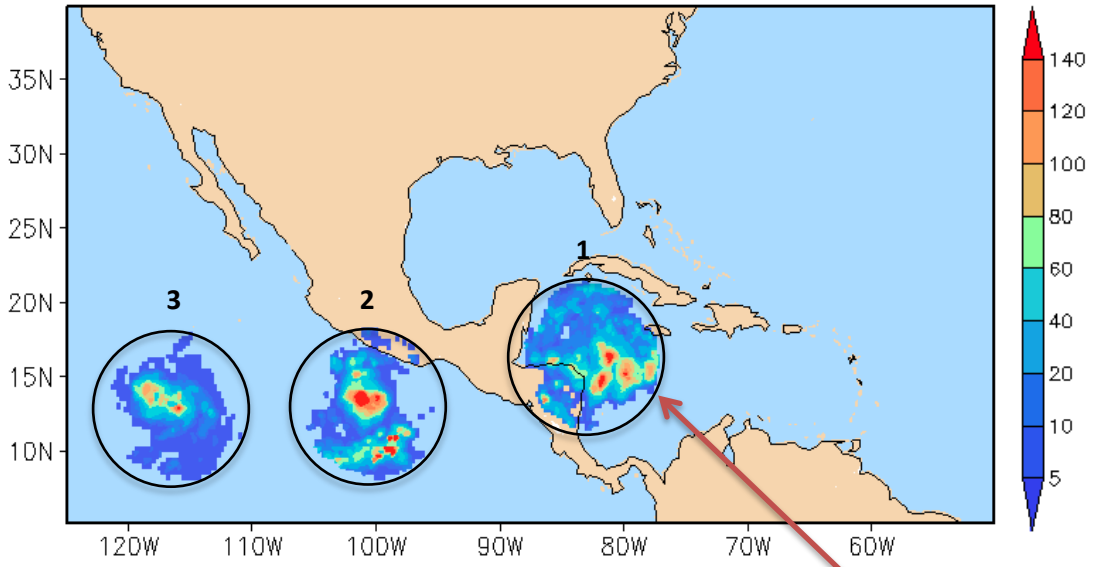
Methodology

Contribution of Tropical Cyclones to rainfall

Accumulated rainfall associated with TCs: Units (mm)
Jun 25 2010



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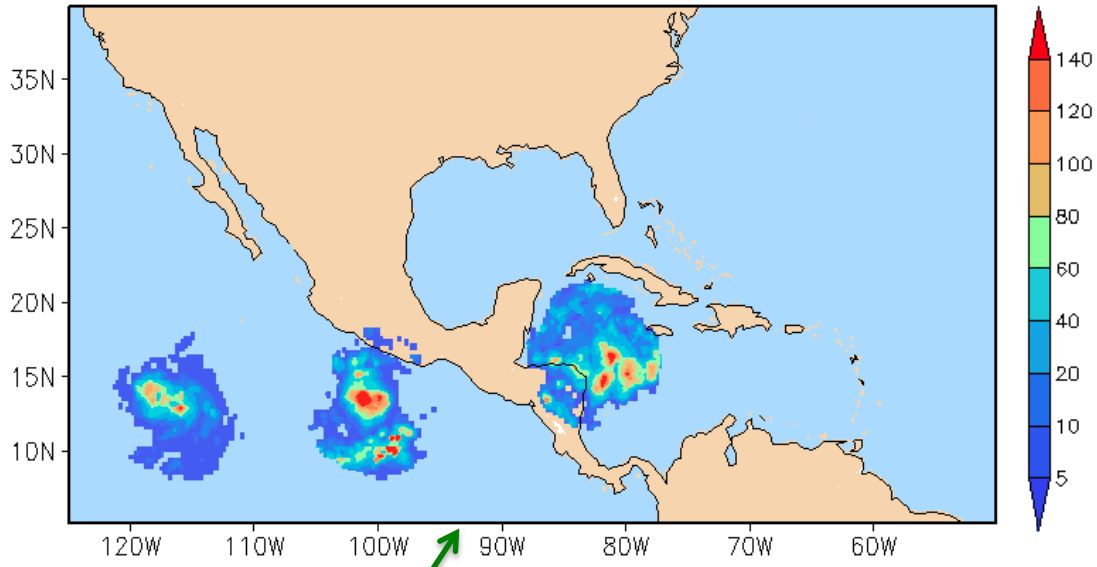


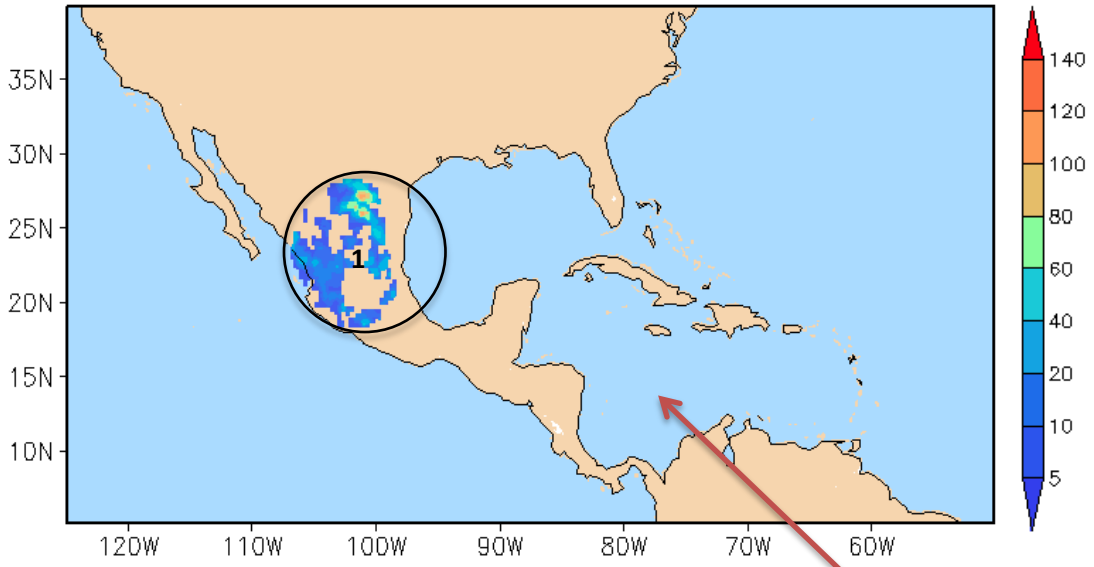
① **Hurricane Alex** **Jun 25 - Jul 02 2010**
② **Hurricane Darby** **Jun 23 - Jun 28 2010**
③ **Hurricane Celia** **Jun 18 - Jun 28 2010**

- **TC radius of 5 degrees**
- **3 hourly accumulated rainfall**

Methodology

Contribution of Tropical Cyclones to rainfall

Accumulated rainfall associated with TCs: Units (mm)
Jul 02 2010



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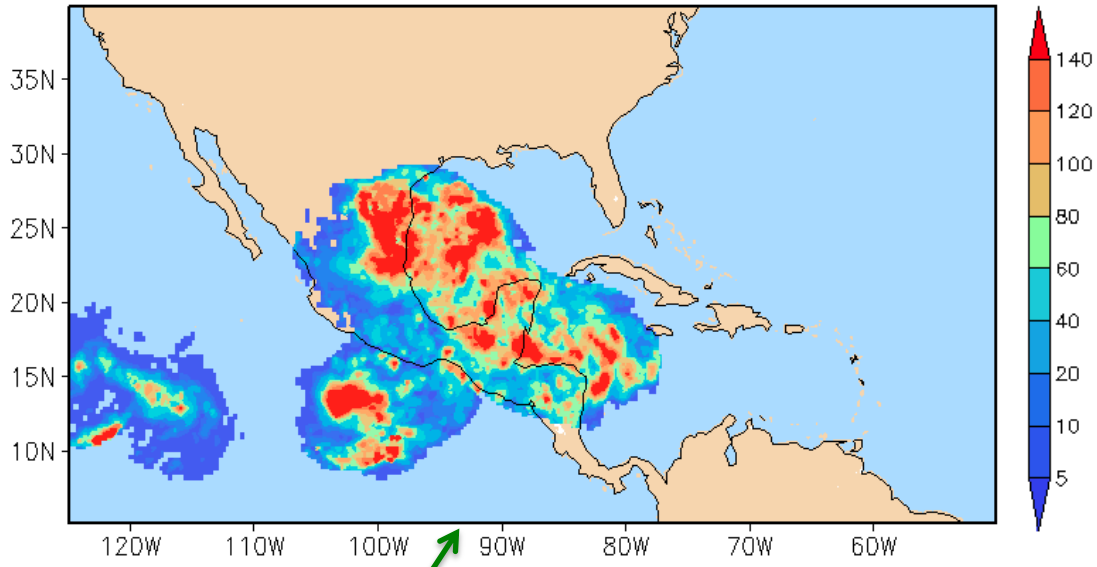

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- **TC radius of 5 degrees**
- **3 hourly accumulated rainfall**

Contribution of Tropical Cyclones to rainfall over Middle America

- Mean accumulated rainfall

1. Contribution of TCs to the mean monthly rainfall

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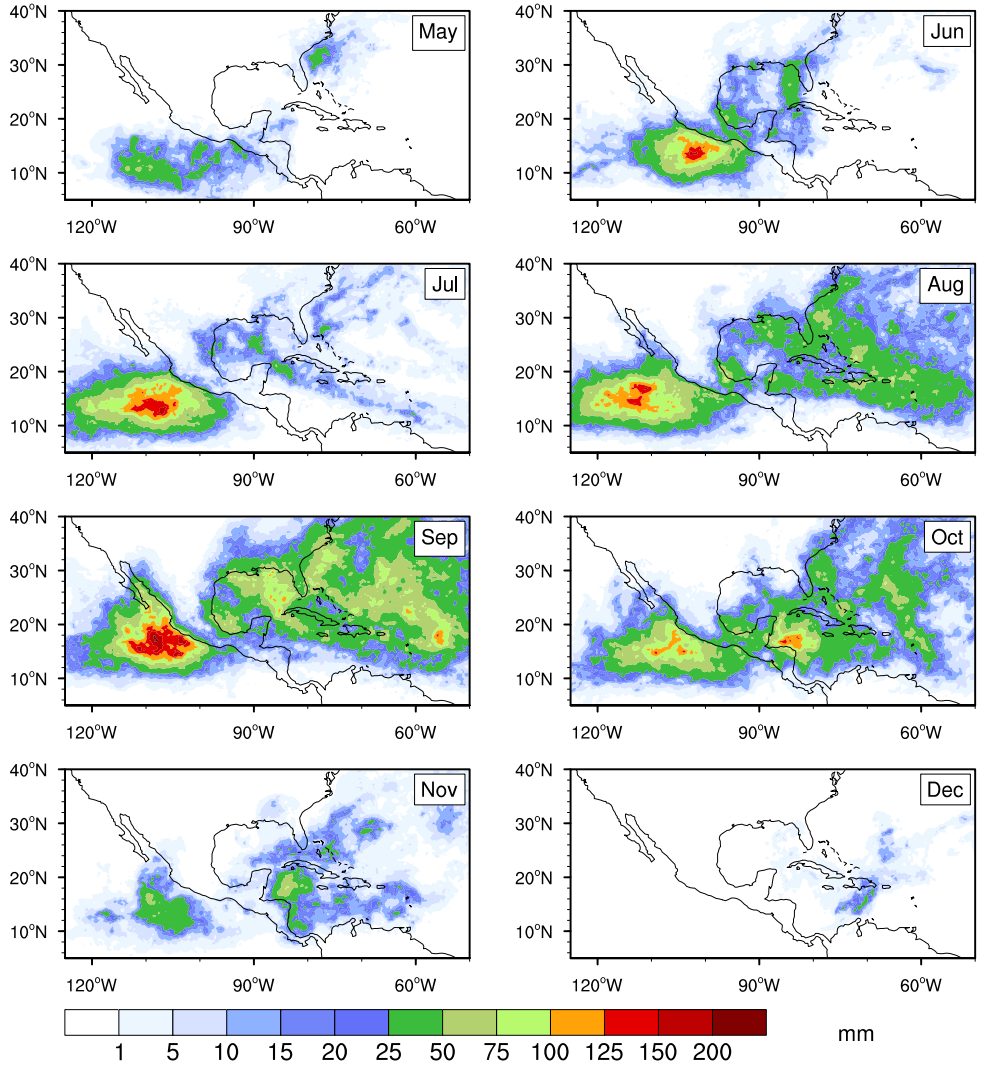
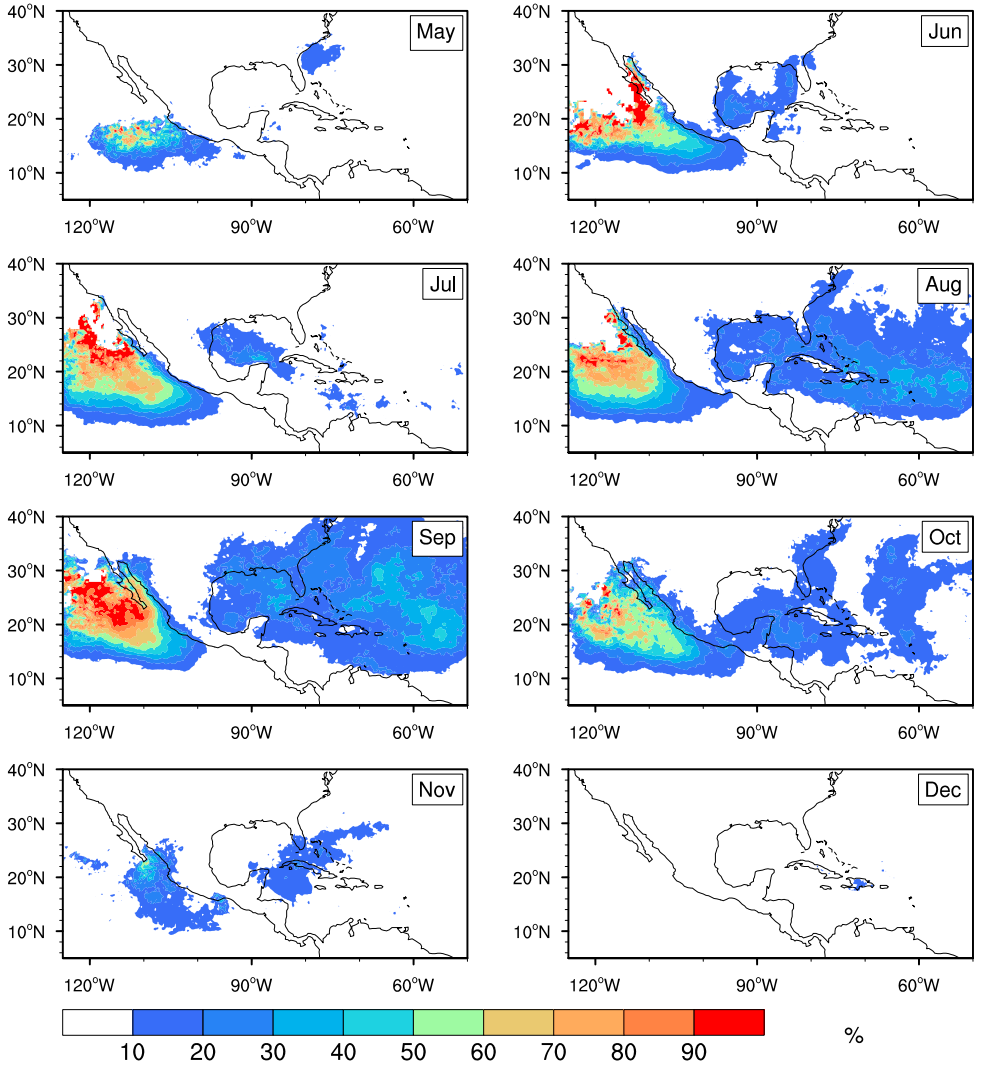
TC tracks from **IBTrACS**

Rainfall from TRMM data

Climatology for 1998-2016. Units: mm month^{-1}



Units: mm month^{-1}



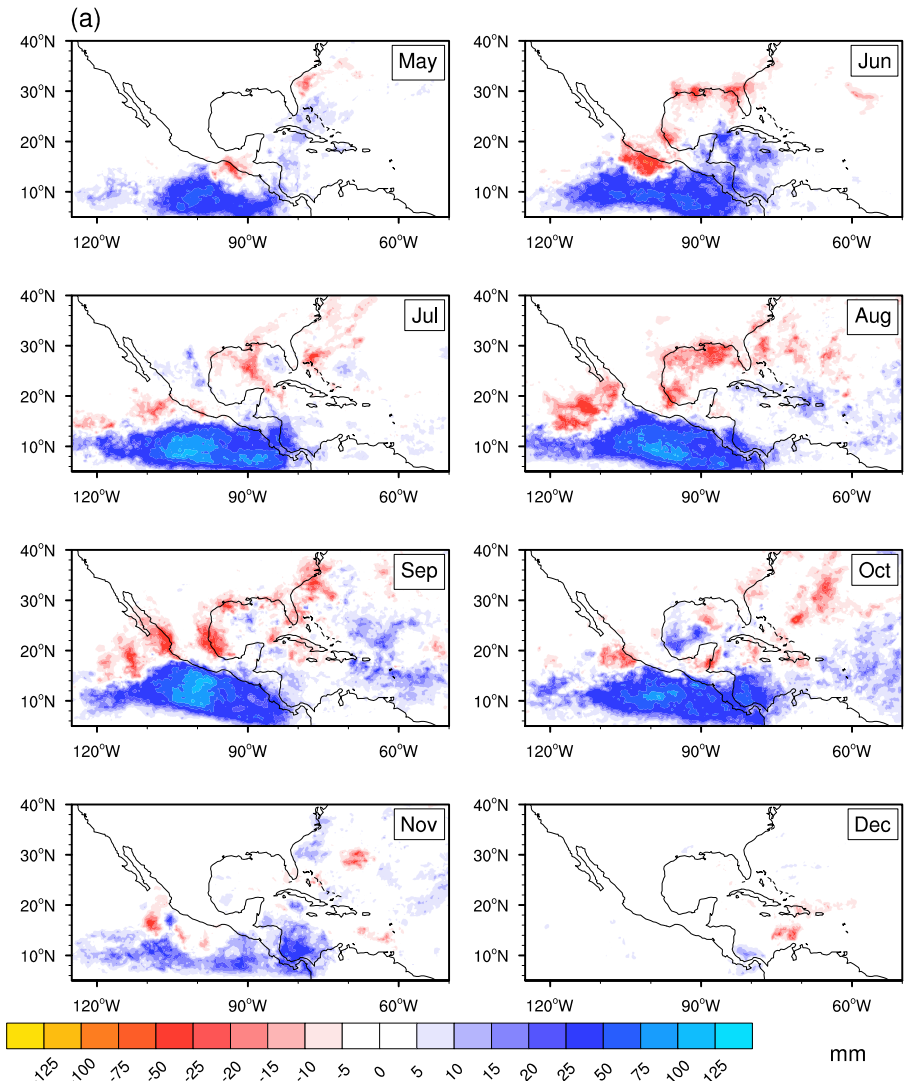
Units: %

1. Differences of the contribution of TCs to the mean monthly rainfall

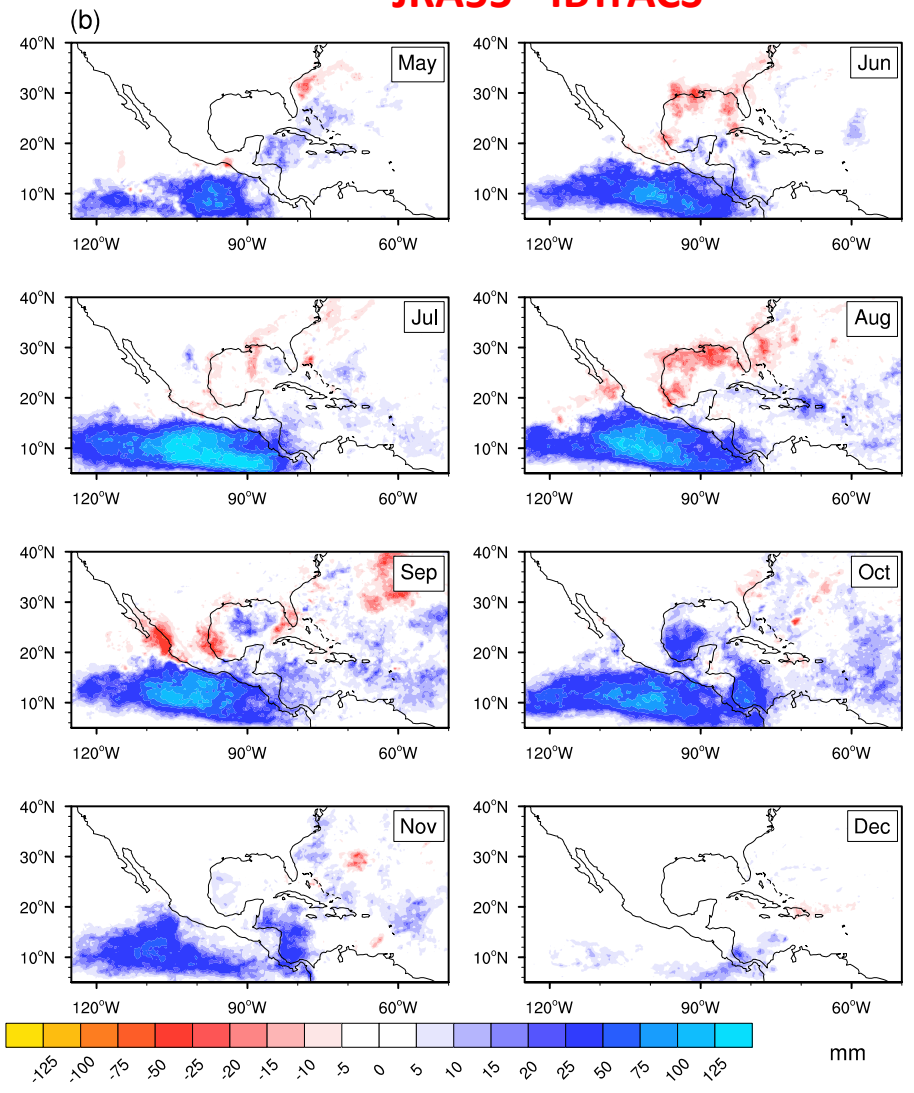
Rainfall from TMPA 3B42 dataset

Climatology for 1998-2016. Units: mm month^{-1}

ERAinterim - IBTrACS

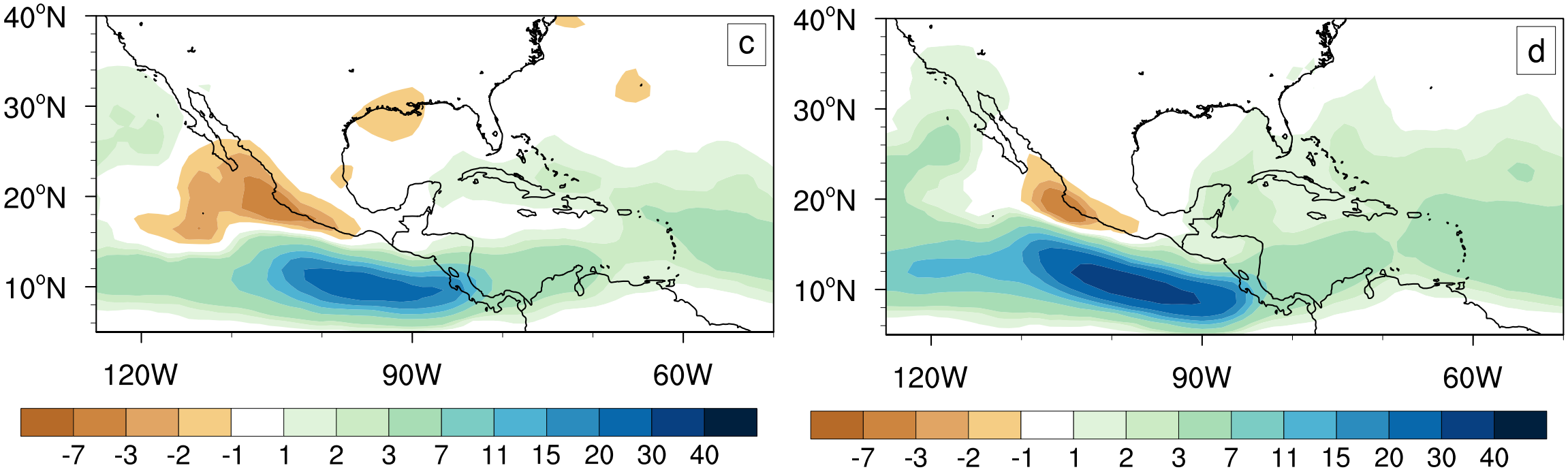


JRA55 - IBTrACS



Franco Díaz et al., 2019. Clim. Dyn.

TC track densities



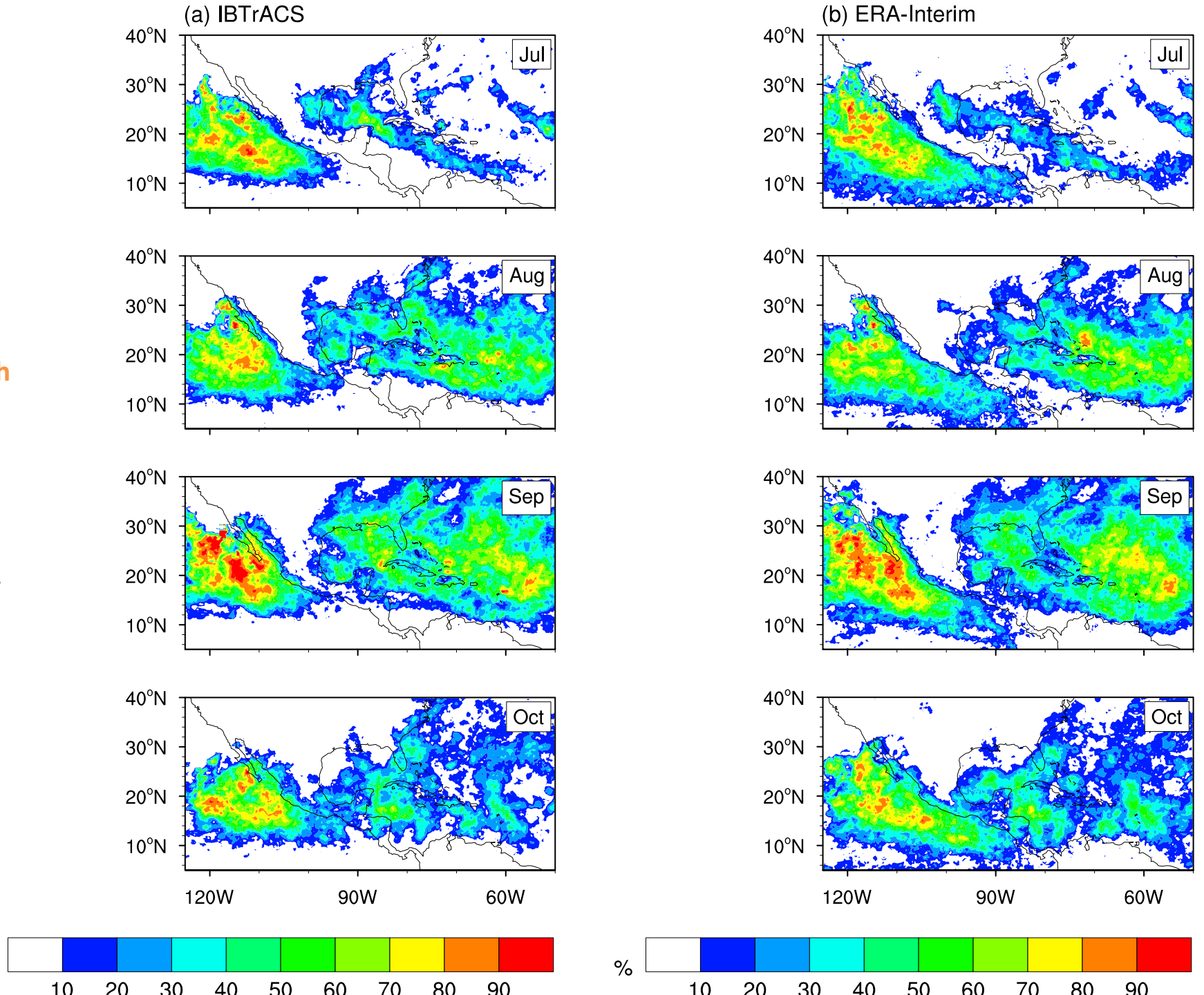
Differences between JJASO TC track densities based on (c) ERA-Interim reanalysis and IBTrACS, and (d) JRA-55 reanalysis and IBTrACS. Units: number of TCs per unit area (~ 10^6 km^2). Period 1998-2016

Contribution of Tropical Cyclones to rainfall over Middle America

- Extreme rainfall

2. Monthly-mean contribution of TCs to 95th percentile rainfall

Climatology for 1998-2016. Units: %



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Conclusions (1st part)

- From July to October, TCs contribute 10-30% of rainfall over the west and east coast of Mexico and central Mexico, with the largest monthly contribution in September over the Baja California Peninsula (up to 90%).

- TCs are associated with 40-60% of daily extreme rainfall (above the 95th percentile) over the coasts of Mexico.

- IBTrACS and reanalyses agree on TC contributions over the Atlantic Ocean but disagree over the Eastern Pacific Ocean and continent; differences over the continent are mainly attributed to discrepancies in TC tracks in proximity to the coast and TC lifecycle.

Contribution of Tropical Cyclones to moisture transport over Middle America

Decomposition of mean-flow and eddy moisture fluxes related to TCs:

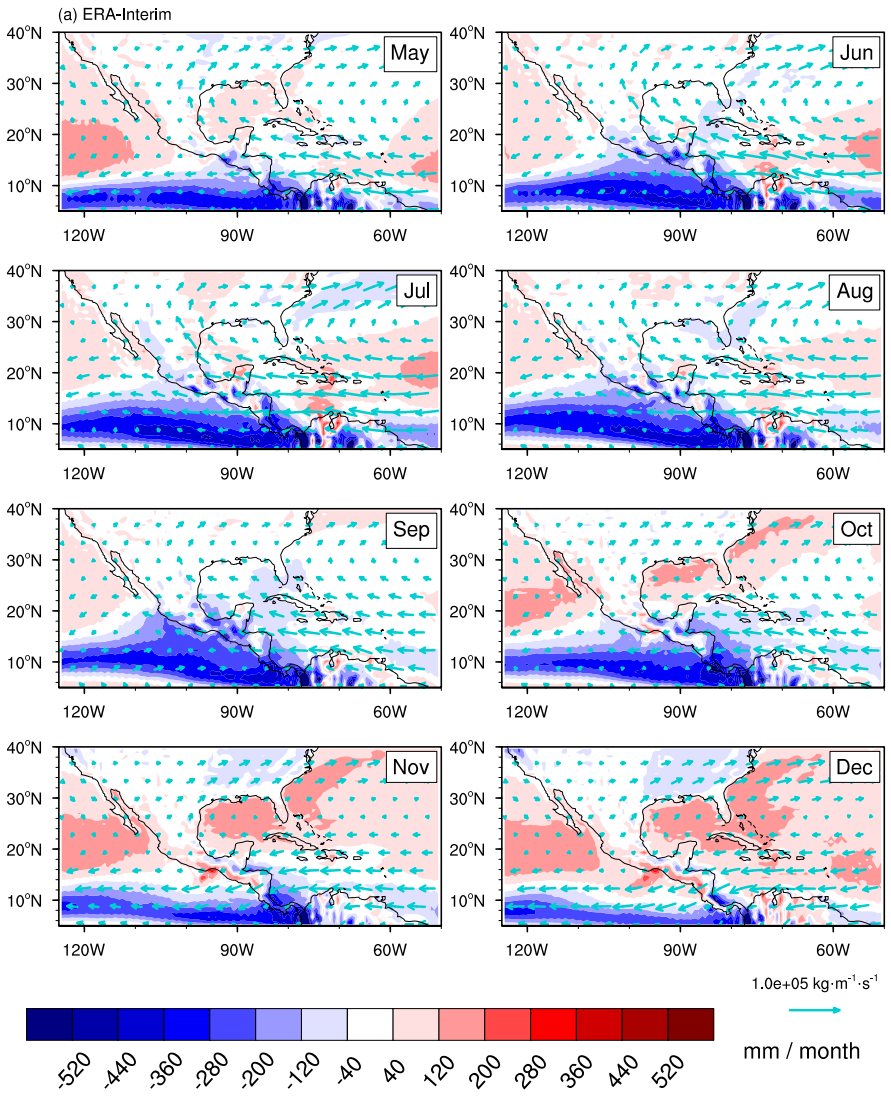
$$vq = (\bar{v} + v')(\bar{q} + q')$$

$$vq = (\bar{v} + v'_{TC} + v'_{non-TC})(\bar{q} + q'_{TC} + q'_{non-TC})$$

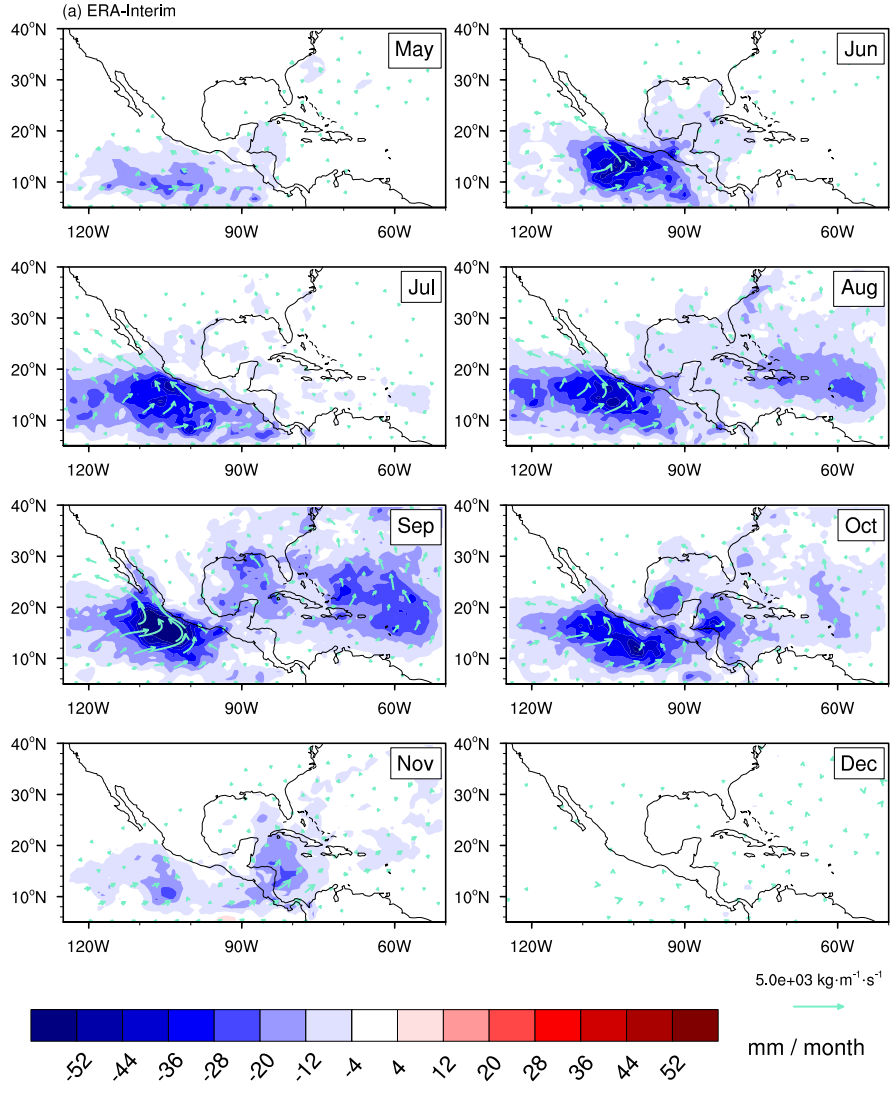
$$vq = \bar{v}\bar{q} + \bar{v}q'_{TC} + v'_{TC}\bar{q} + v'_{TC}q'_{TC}$$

$\nabla \cdot (\bar{v}\bar{q})$

Mean monthly accumulated vertically integrated moisture flux divergence Climatology for 1979–2016. Units: mm month^{-1}



$\nabla \cdot (\bar{v}q'_{TC} + v'_{TC}\bar{q} + v'_{TC}q'_{TC})$



Monthly accumulated vertically integrated moisture flux divergence for TC eddies Climatology for 1979–2016. Units: mm month^{-1}

Franco Díaz et al., 2019. Clim. Dyn.

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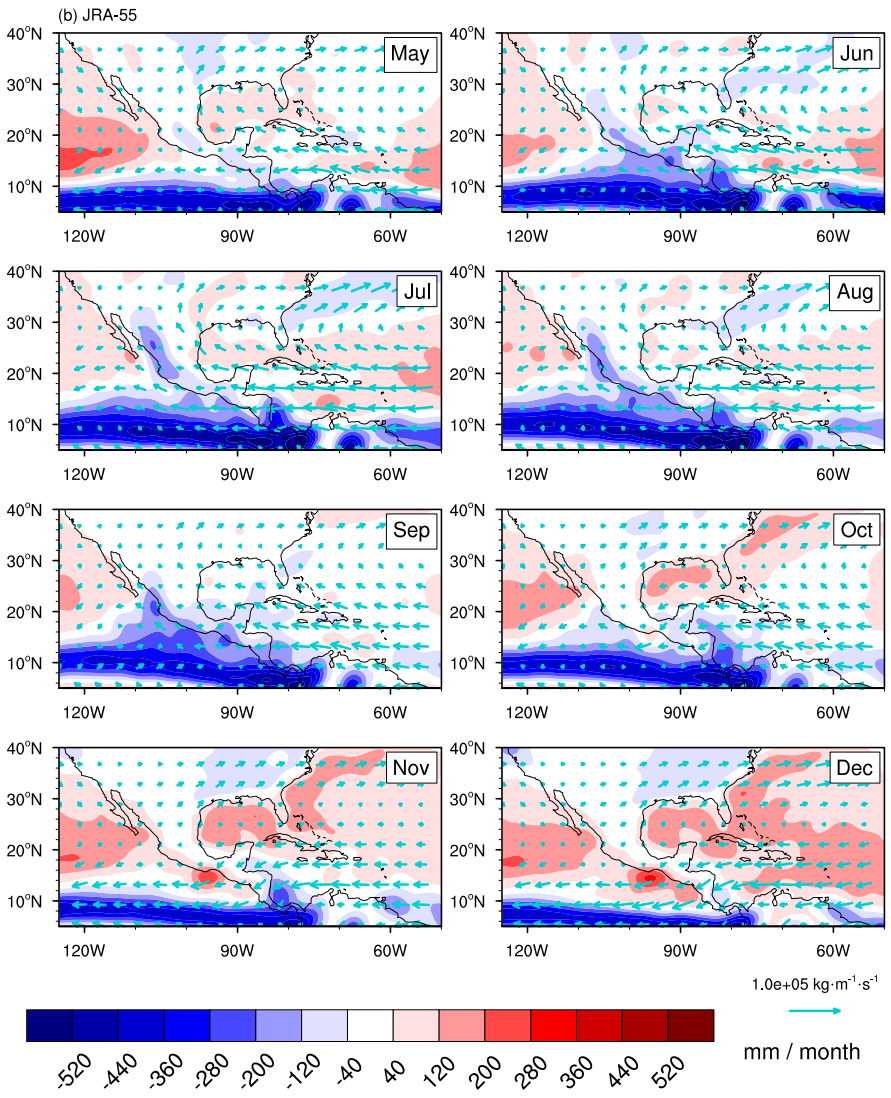

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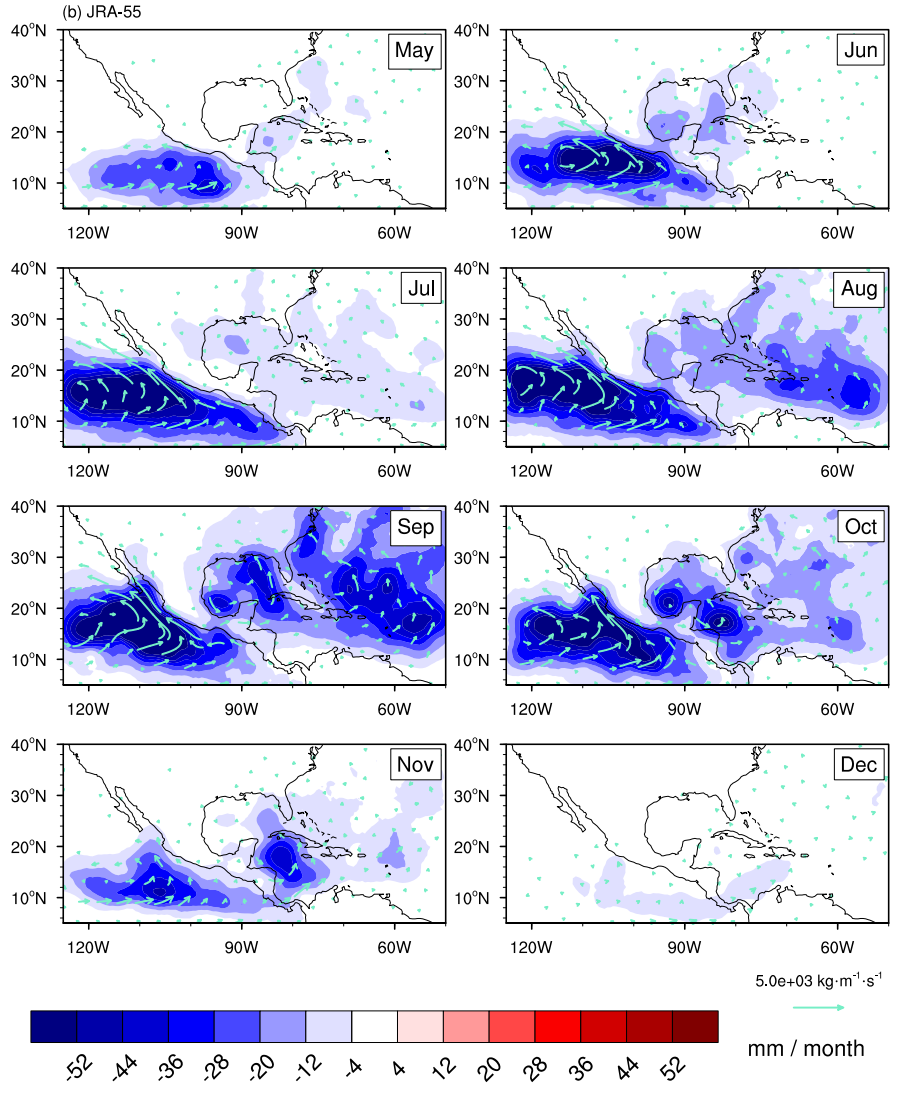
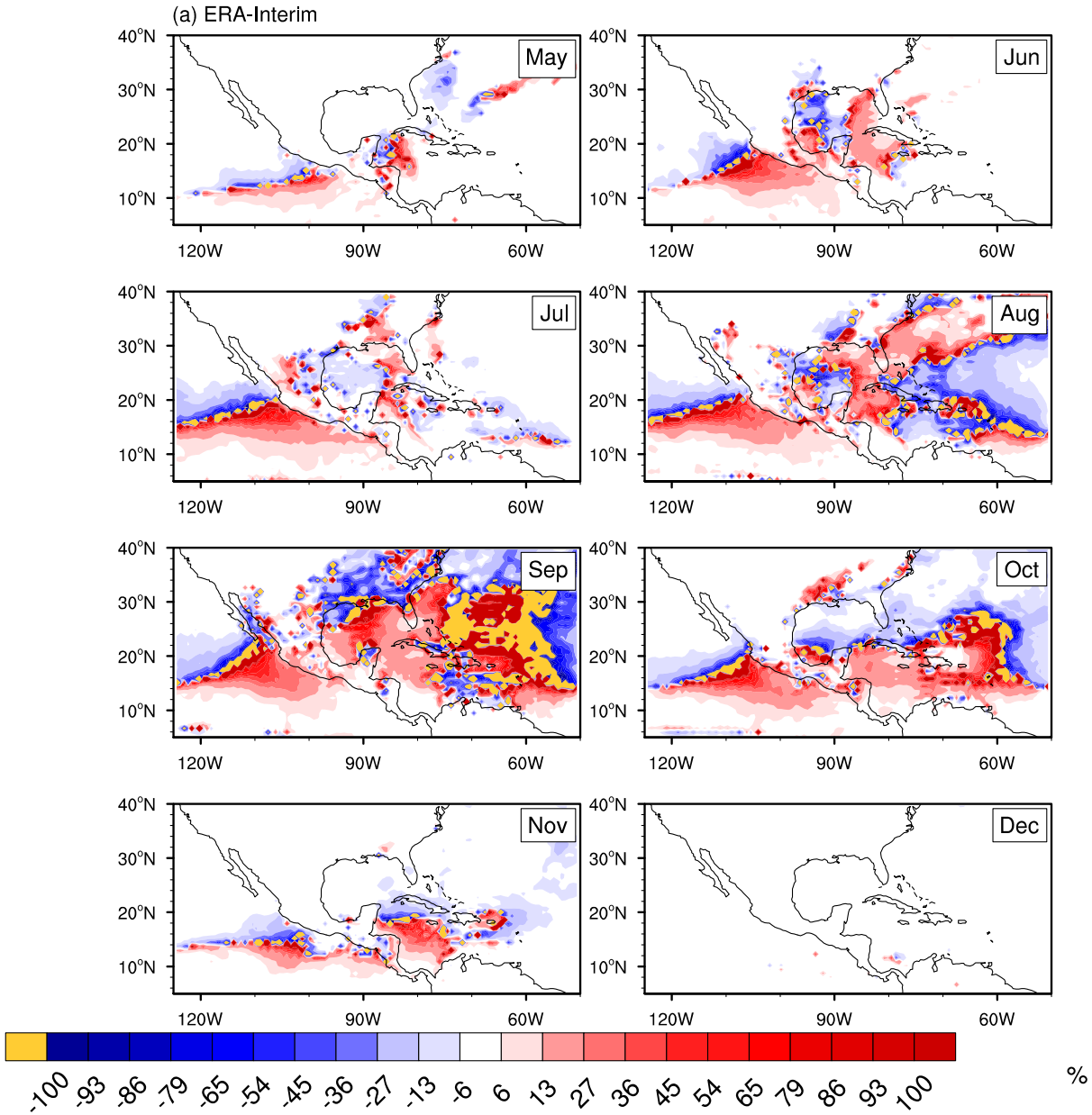


Monthly accumulated vertically integrated moisture flux divergence for TC eddies Climatology for 1979–2016. Units: mm month^{-1}

Franco Díaz et al., 2019. Clim. Dyn.

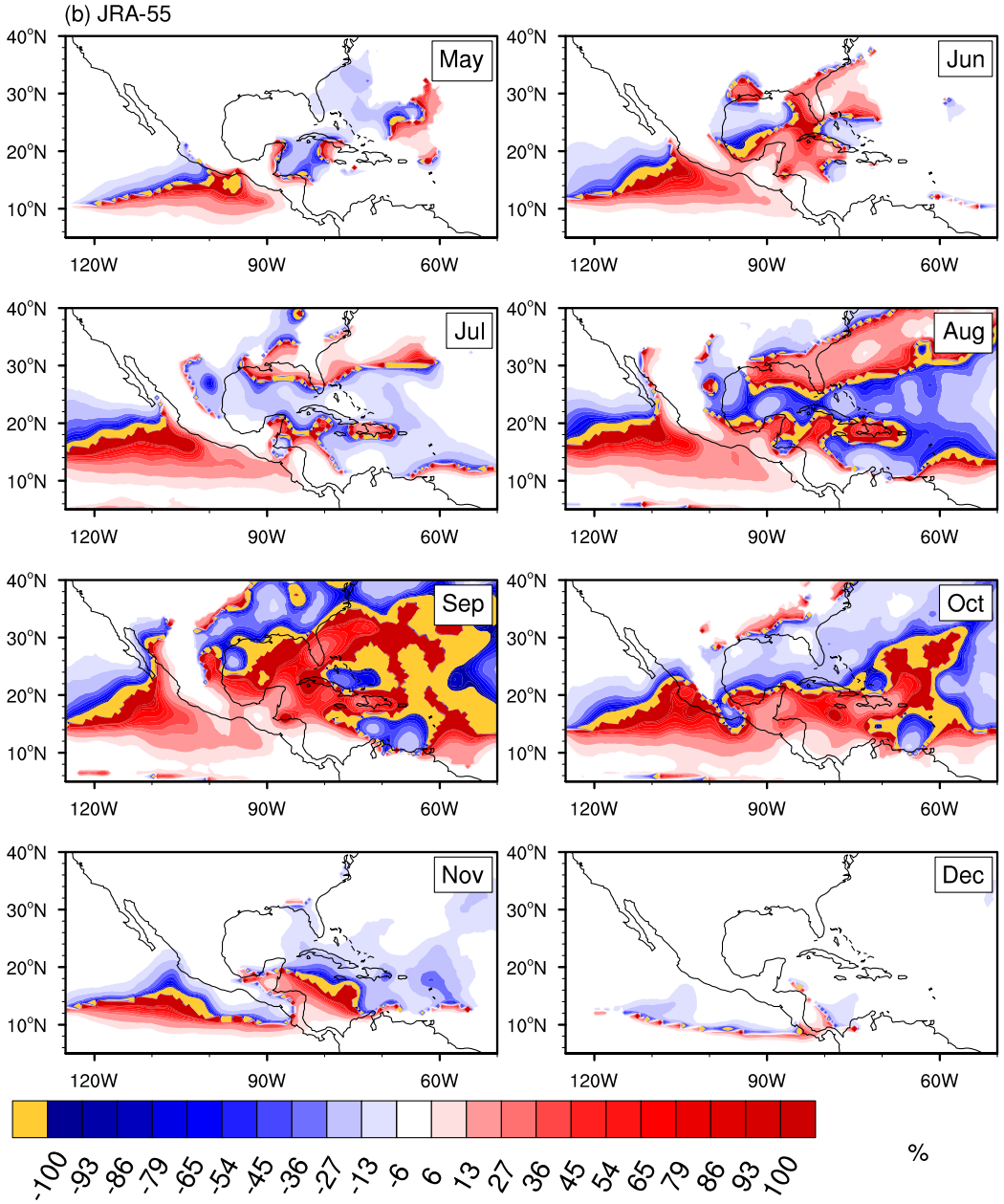
Strength of the TC-associated VIMF convergence relative to the strength of the VIMF divergence by the mean flow **(%),** estimated by using TC tracks from (a) ERA-Interim reanalysis**.**



Shaded yellow areas indicate where TC reverses the sign of the divergence by the mean circulation. Climatology for 1979-2016.

Franco Díaz et al., 2019. Clim. Dyn.

Strength of the TC-associated VIMF convergence relative to the strength of the VIMF divergence by the mean flow **(%),** estimated by using TC tracks from (b) JRA-55 reanalysis**.**



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Conclusions (2nd part)

- Reanalysis estimates of TC moisture transports show that TCs are an important moisture source for the regional water budget (coasts and farther inland areas).

- TC vertically integrated moisture flux (VIMF) convergence can turn regions of weak VIMF divergence by the mean circulation into regions of weak VIMF convergence.

¡Gracias!

Obrigada!

Tláloc, supreme God of the rain in Aztec religion