Characteristics of extreme convection over equatorial America and Africa

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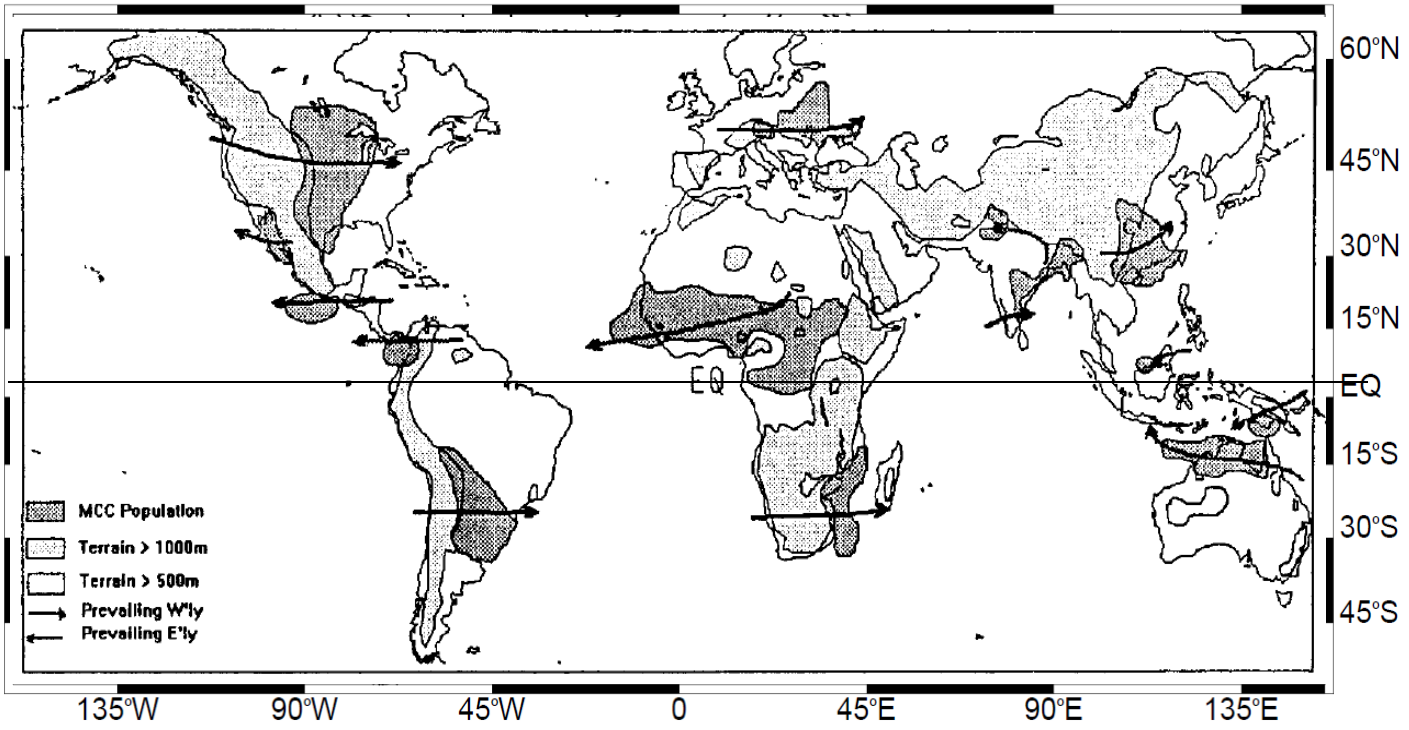
Outline

- Introduction
- Identification of extreme convection
- Climatology
- Synoptic conditions
- Diurnal Cycle
- Conclusions

Where does extreme convection occur?

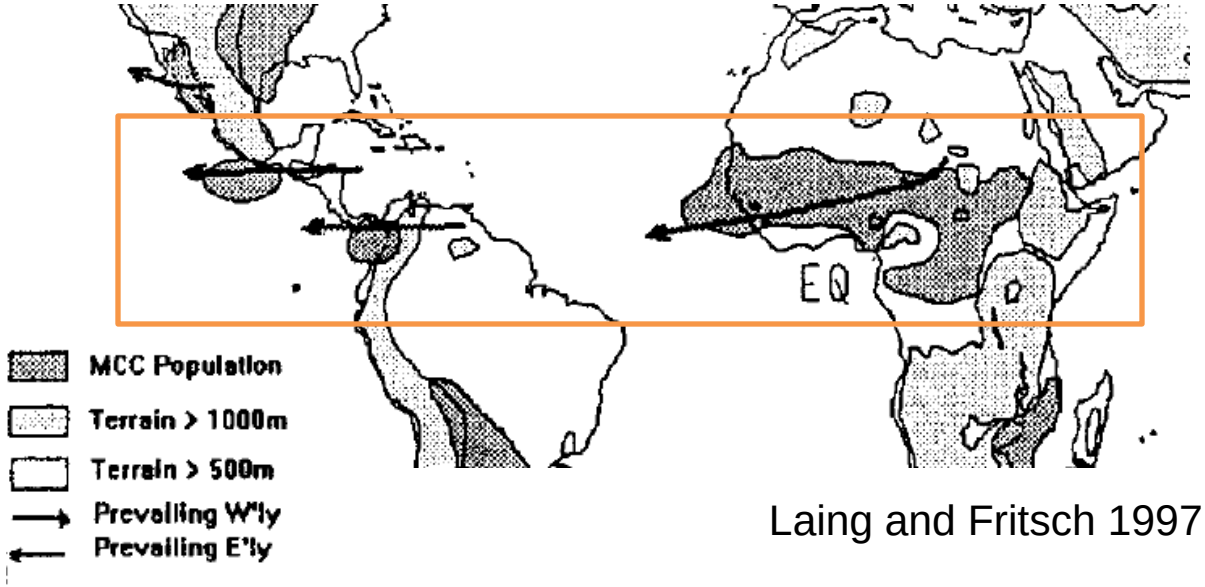
MCC population



Laing and Fritsch 1997

- Mesoscale convective complexes **"hot spots"** in specific locations around the world
- Studies have concentrated in North and South America, and the Asian Monsoon region.

Equatorial regions of America and Africa



Laing and Fritsch 1997

Extreme convection is most frequent during summer (JJA) for:

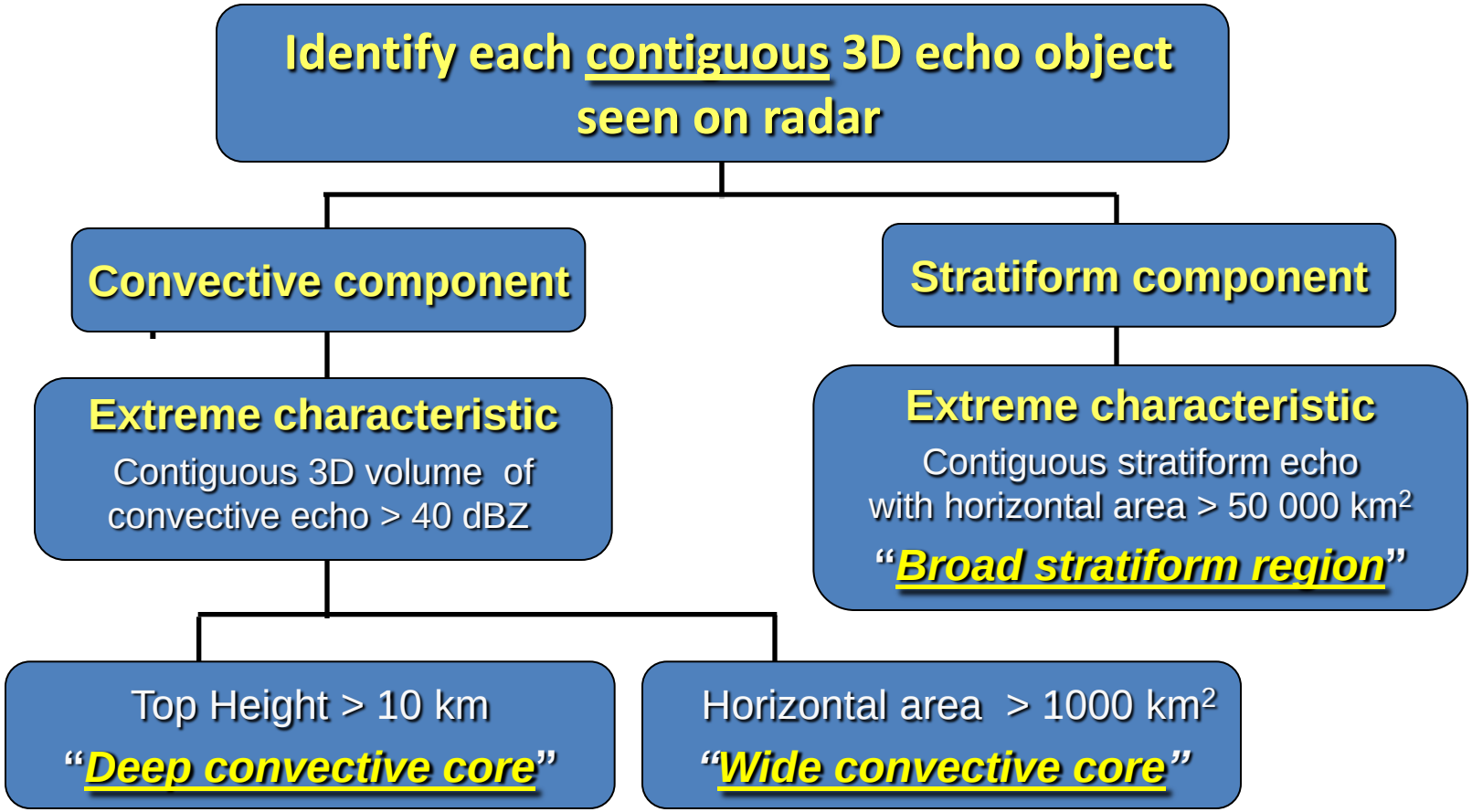
- **Africa** where there is a strong humidity and temperature gradient affected by AEW
- **America** where the ITCZ winds intersects the northernmost point of Los Andes

Identification of extreme convection

- Previous studies used IR or passive microwave measurements to determine the climatology of extreme convection.

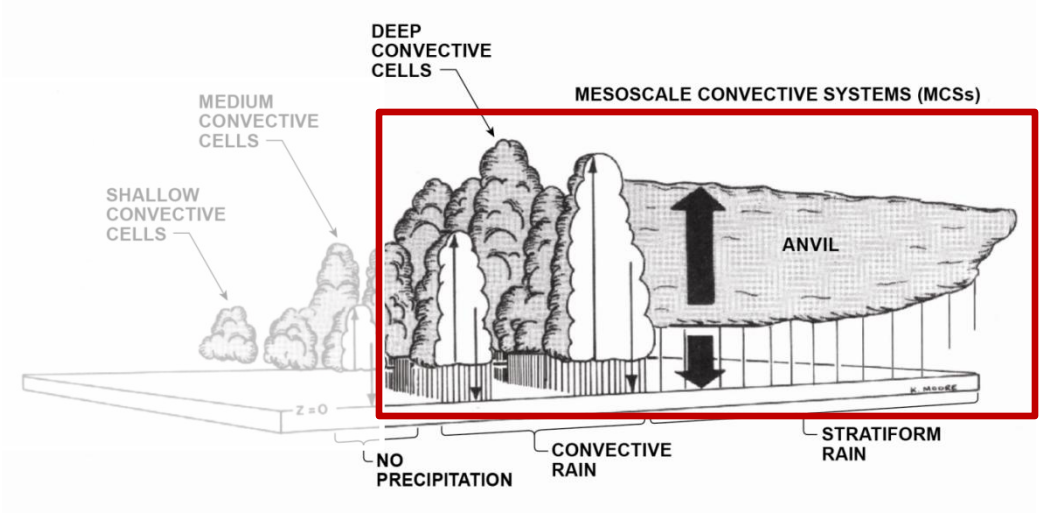
- **Deficiency**: It does not provide three-dimensional structural information

TRMM PR objective identification



Houze et al. 2007; Romatschke et al. 2010, Romatschke and Houze 2011; Barnes and Houze 2013; Zuluaga and Houze 2013

Idealized convective cloud population



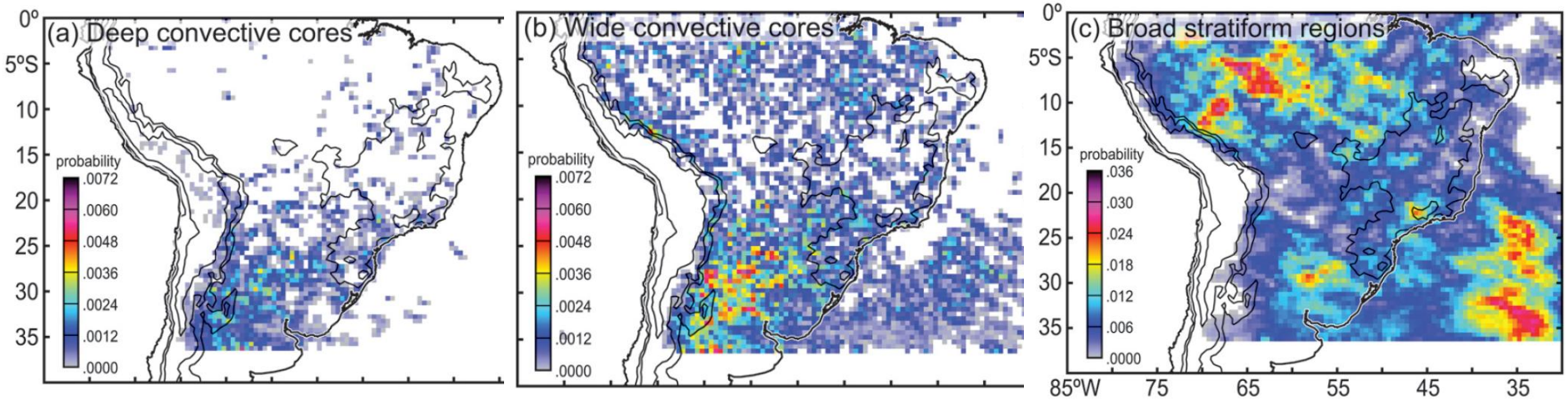
Houze et al. 1980

- **Advantage**: Associate each of the convective echo characteristics to elements within the convective cloud population

- Three important types of radar echo
  - **Deep intense convective cores** -> early stages of development
  - **Wide intense convective cores** -> middle stages of development
  - **Broad stratiform regions** -> late stages of development

Climatology of extreme convective features in South America

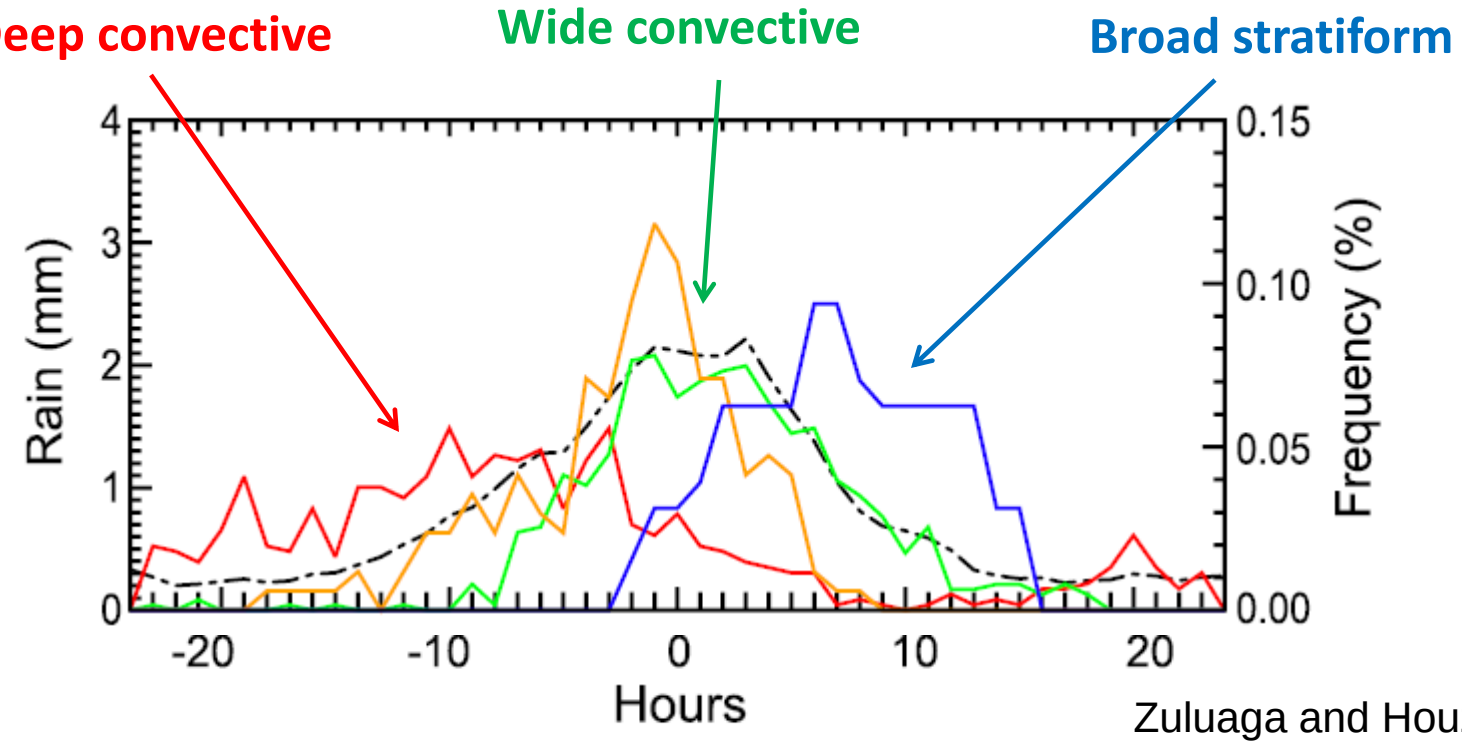
Deep Convective | **Wide Convective** | **Broad Stratiform**



Romatschke and Houze 2010

- Following the location of echo categories, it was possible to interpret that the events evolve from the slopes of Los Andes in an eastward succession of **DCC**, **WCC** and **BSR**.

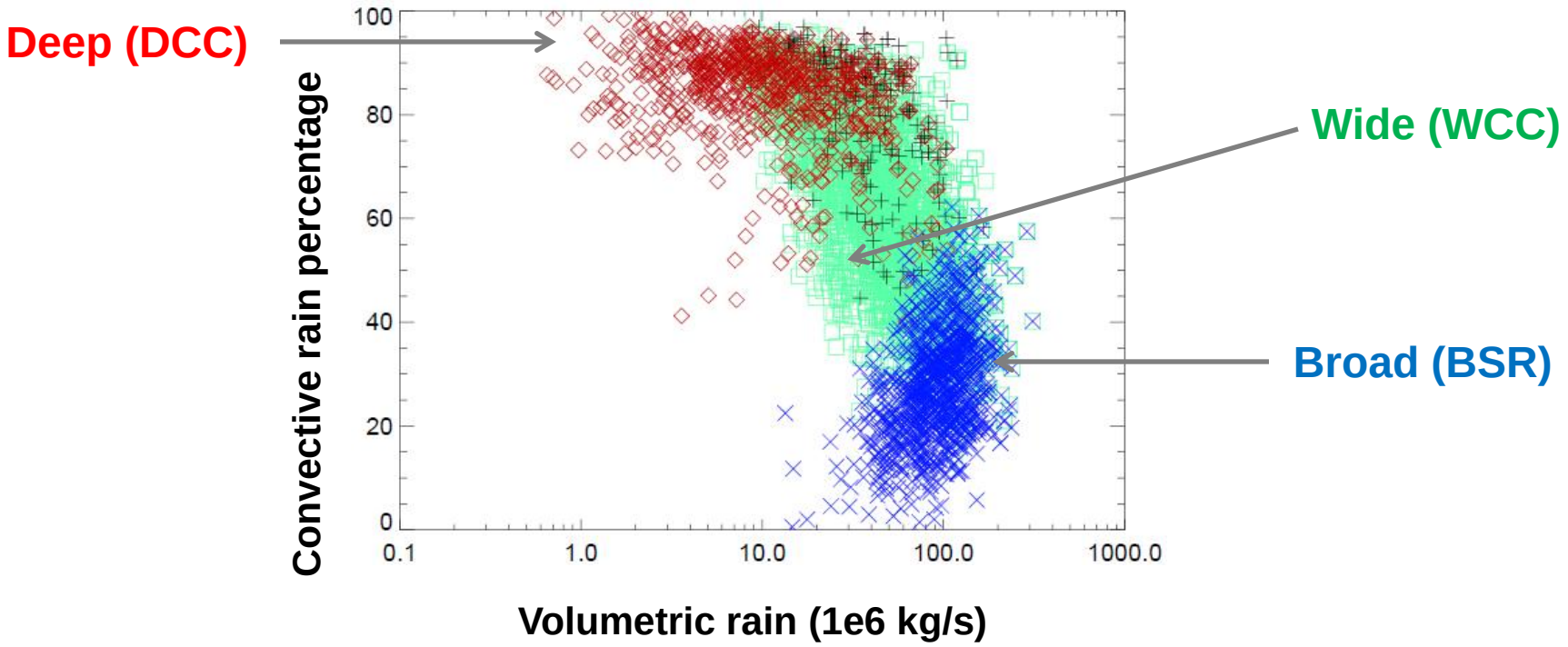
Echo type evolution relative to rainfall maximum



Zuluaga and Houze 2013

- The dominant membership of the convective population changes in sequential order with respect of the maximum in rainfall accumulation
- This change correspond to a stretched version of the life cycle of convective entities

Rainfall, % convective and echo type



- Storms containing **DC cores** have high convective rain percentage by relative low volumetric rain
- In contrast, **BS regions** have low convective rain but higher volumetric rain rates

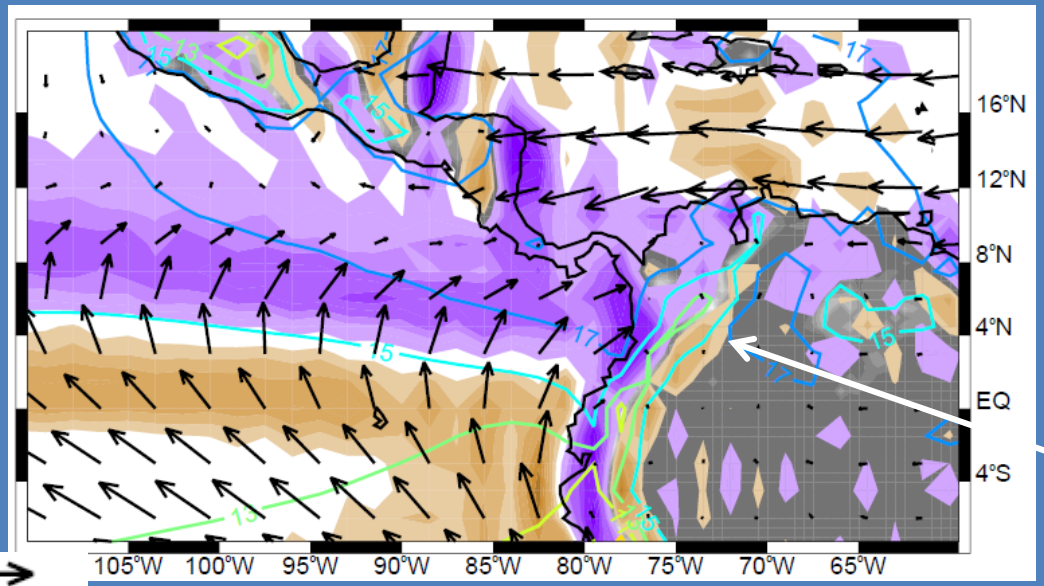
Objectives

- Compare the summer (JJA) convective cloud population between equatorial regions over **America** and **Africa** that are highly influenced by convective processes
  - Using TRMM PR radar reflectivity, rain type and rainfall intensity

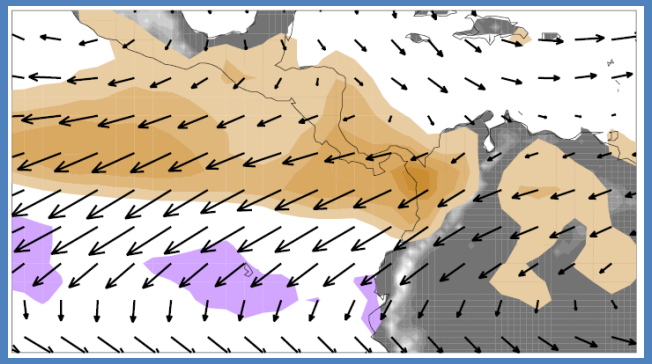
- Relate the occurrence of the cloud population to changes in large-scale environmental conditions
  - Using ERA-interim reanalysis data

Equatorial America – ERAi divergence, wind and humidity

Surface (JJA)

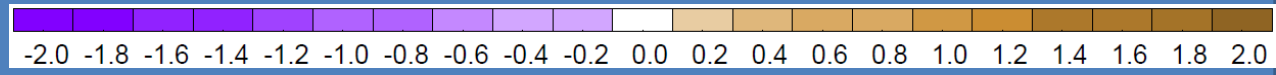


200 hPa



Contours:
Specific humidity (g/kg])

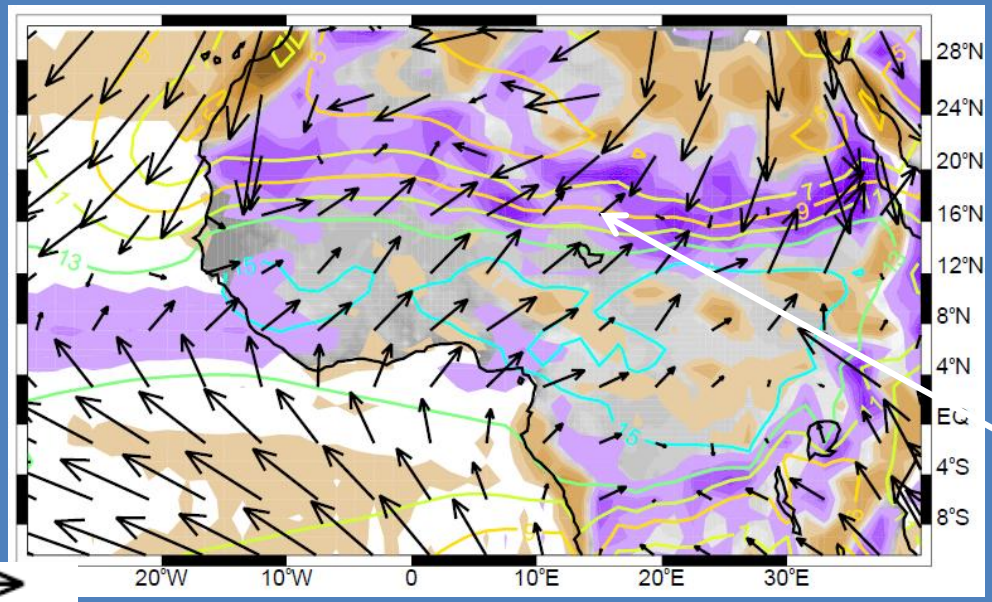
divergence ($1e^{-5}$ 1/s)



- Trade wind convergence of energy and moisture (Hadley circulation)
- Local concentration: Intra-Americas jet, and the Chocó low level jet
- Operating in regions of significant low-level moisture gradients areas

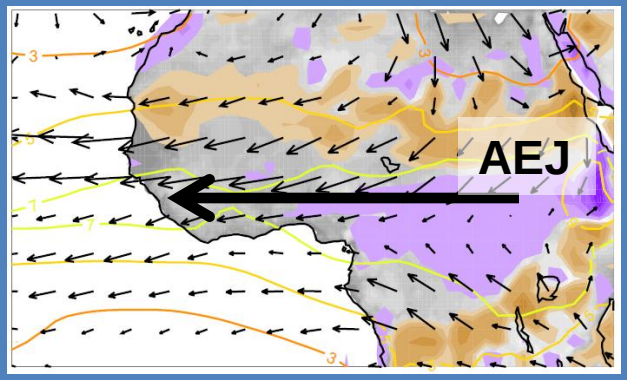
Equatorial Africa – ERAi divergence, wind and humidity

925 hPa (JJA)



10 m/s

700 hPa (JJA)



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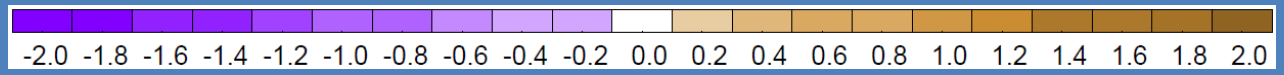


- Region of strong moisture gradient associated with the shallow, humid monsoon layer capped by the dry Sahara air layer.
- African Easterly jet generating waves and modulating convection

Frequency of occurrence

Equatorial America

Deep Convective cores (**DCC**):

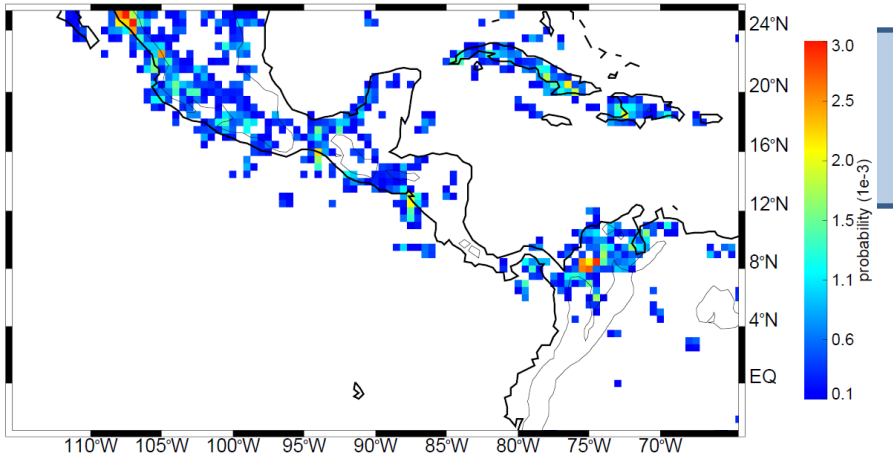
- West of Sierra Madre Sur range
- Northern fringes of the Andes
- Central America
- Caribbean Islands

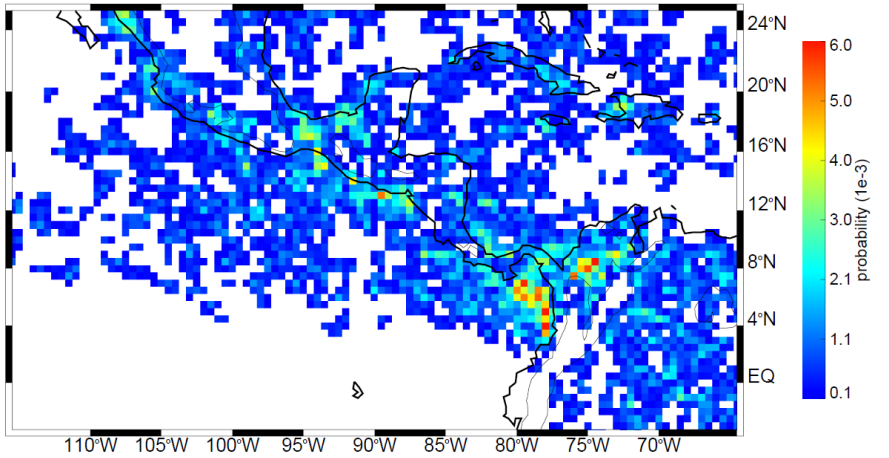
Wide Convective cores (**WCC**):

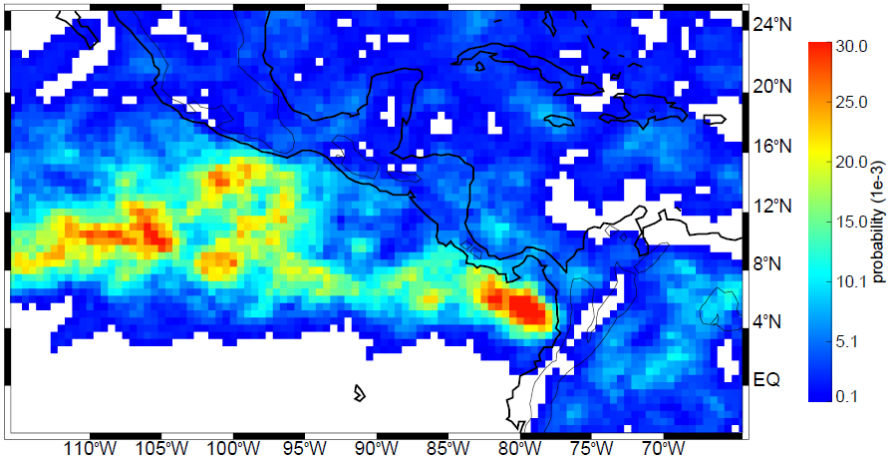
- Same regions as DCC
- Amazon region
- Pacific coast of Colombia and Panamá

Broad Stratiform regions (**BSR**):

- ITCZ over the east Pacific ocean
- Pacific coast of Colombia and Panamá







Frequency of occurrence

Equatorial Africa

Deep Convective cores:

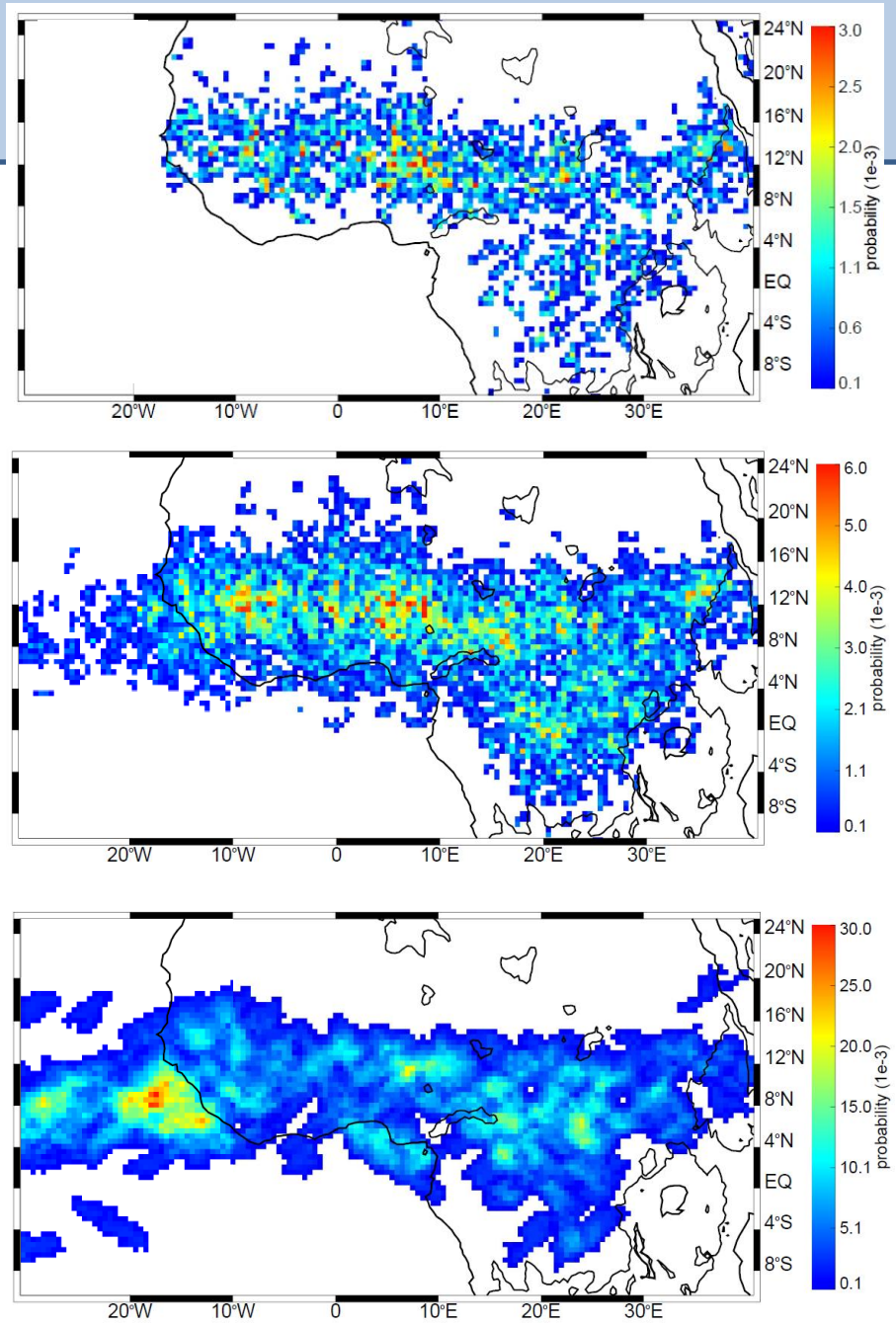
- West, Central and East Sahel
- Tropical Congo Basin
- Ethiopian Highlands

Wide Convective cores:

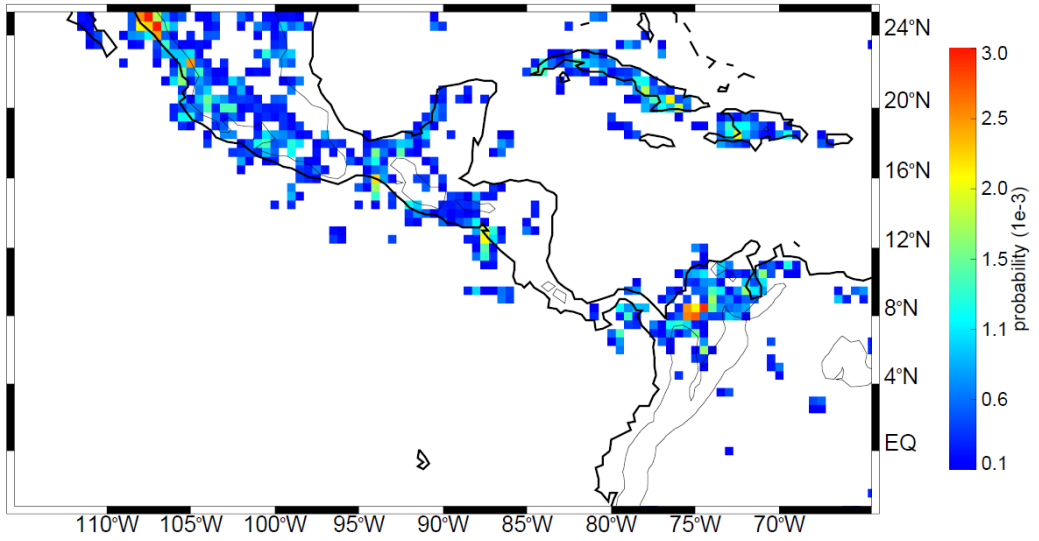
- Same regions as DC
- East Atlantic Ocean

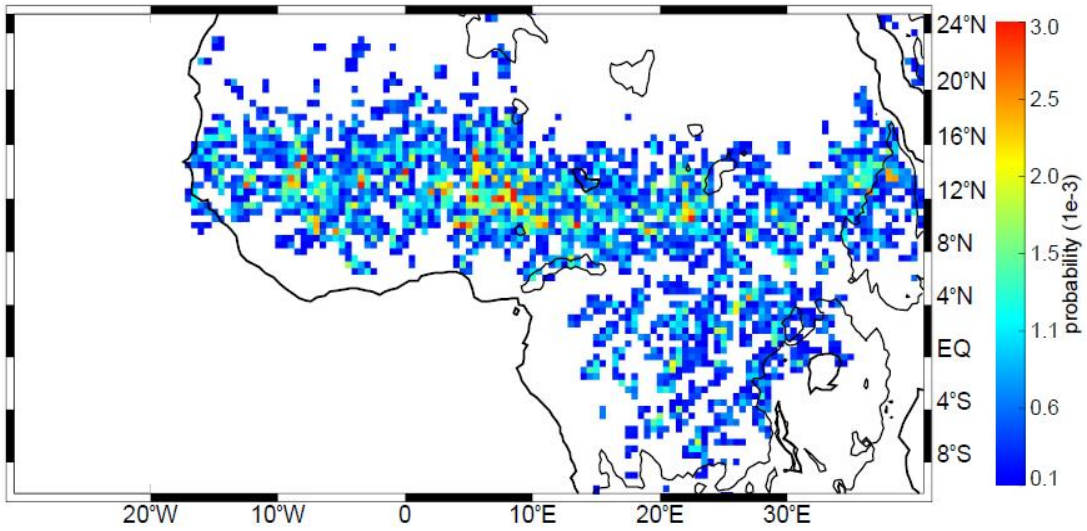
Broad Stratiform regions:

- East Sahel
- East Atlantic Ocean

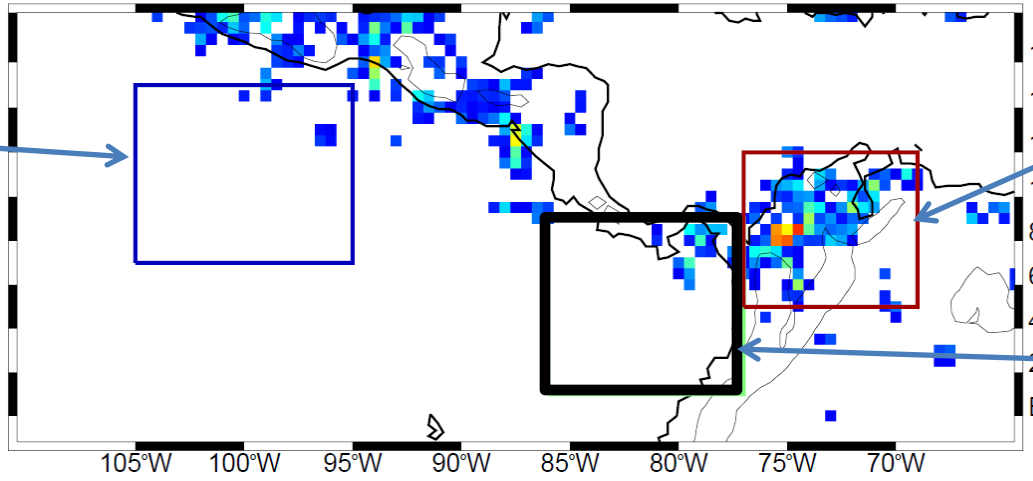


Comparison between America and Africa





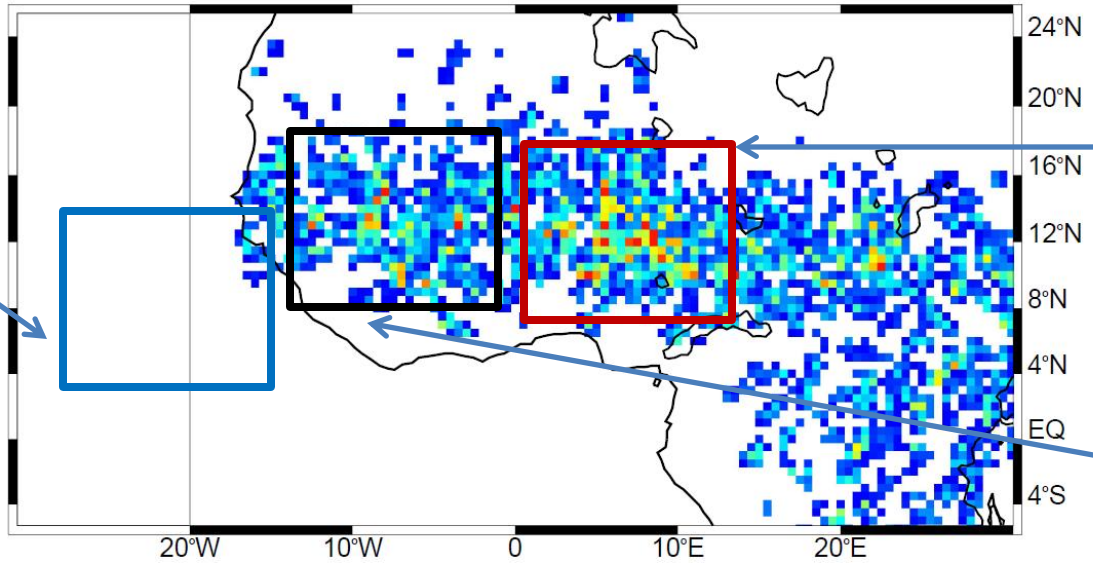
Regional analysis



East Pacific

Andes foothills

Colombian coast



East Atlantic

Central Sahel

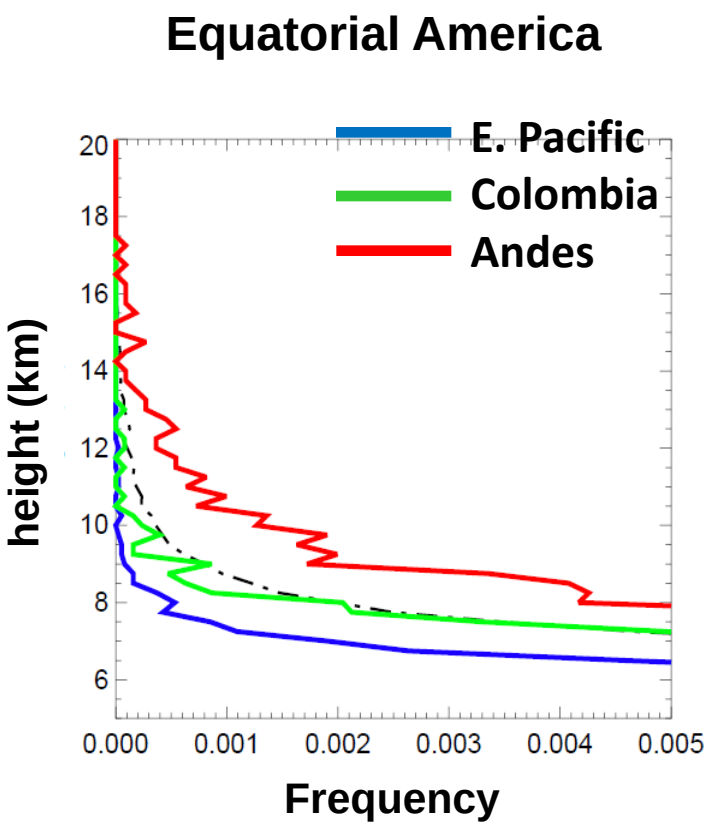
West Sahel

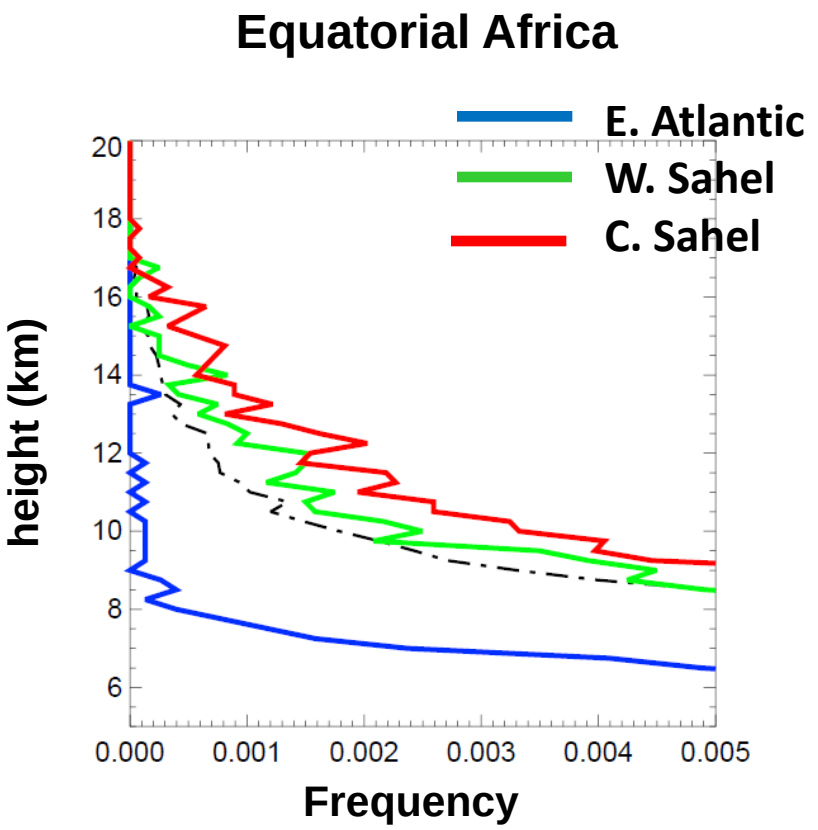
Number of elements in each region

America	DCC	WCC	BSR
East Pacific	5	232	242
Colombian coast	9	272	68
Andes foothills	111	223	17
Total (Total Region)	**125 (352)**	**727 (1926)**	**327 (670)**

Africa	DCC	WCC	BSR
East Atlantic	6	107	97
West Sahel	254	498	46
Central Sahel	399	624	55
Total (Total Region)	**659 (1456)**	**1229 (3264)**	**198 (350)**

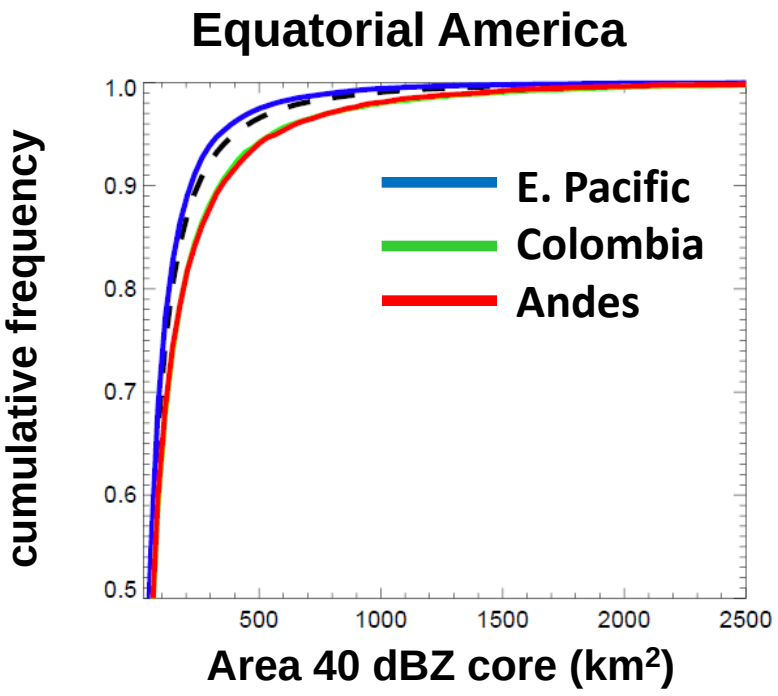
Maximum height of 40 dBZ echo

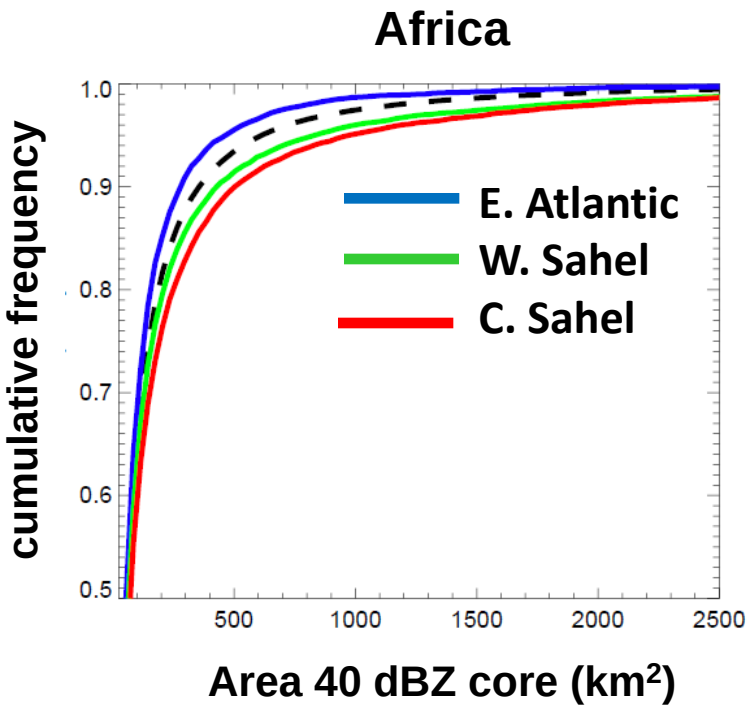




- Higher number of convective echoes reaching altitudes higher than 10 km for Equatorial Africa

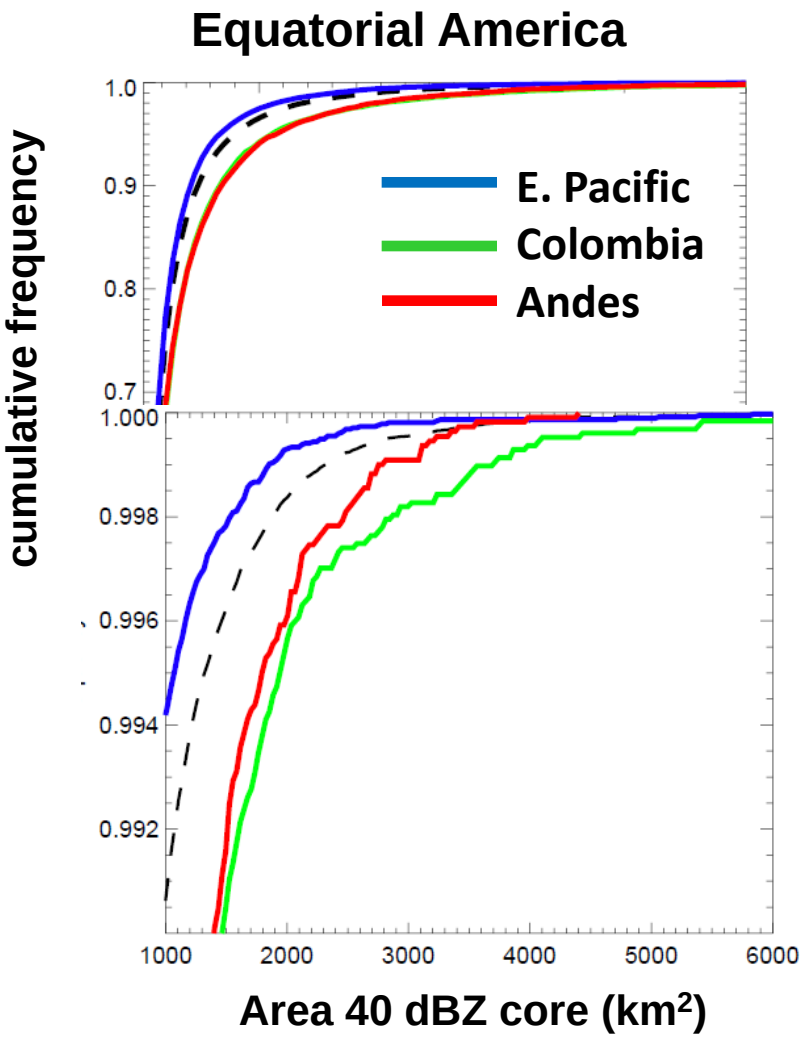
Cumulative frequency of the 40 dBZ area

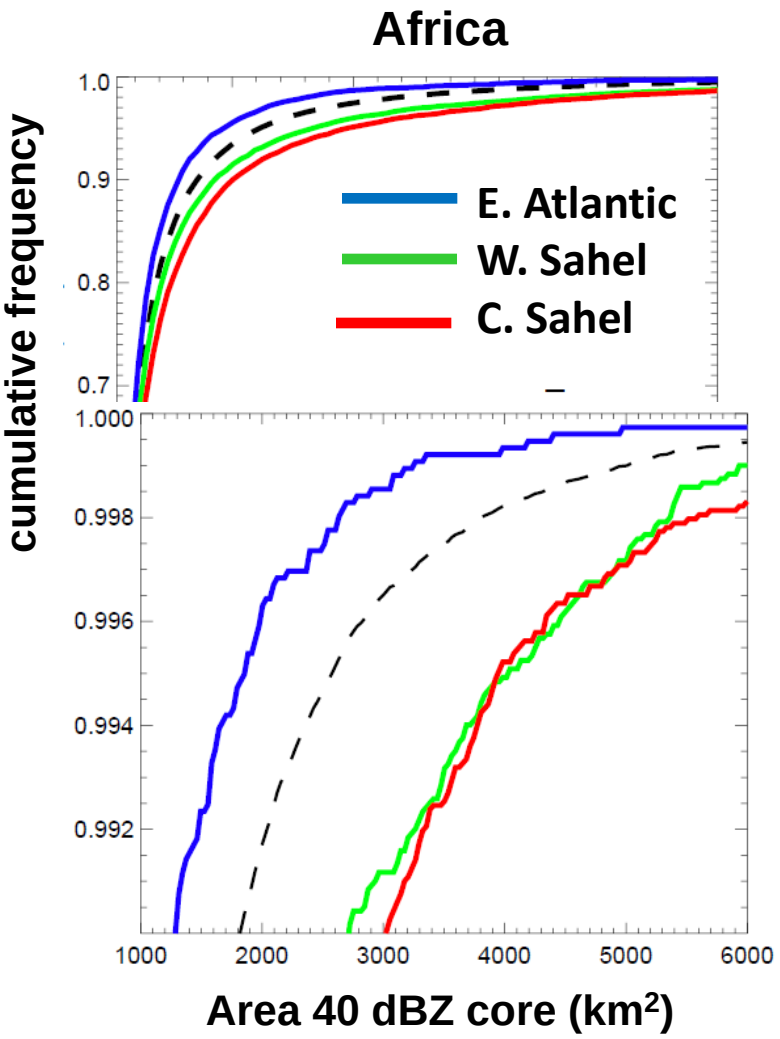




- Wider areas of extreme convection over the regions located in Africa

Cumulative frequency of the 40 dBZ area



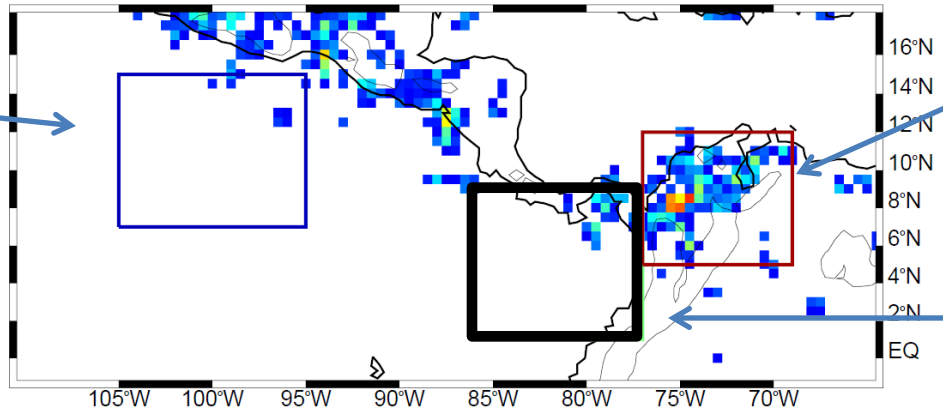


Synoptic conditions

- Composites of wind and divergence anomalies for days when:
  - **Wide convective events** in Colombian Coast, Andes foothills, and West and Central Sahel
  - **Broad stratiform regions** occurred over the East Pacific and East Atlantic

Regional analysis

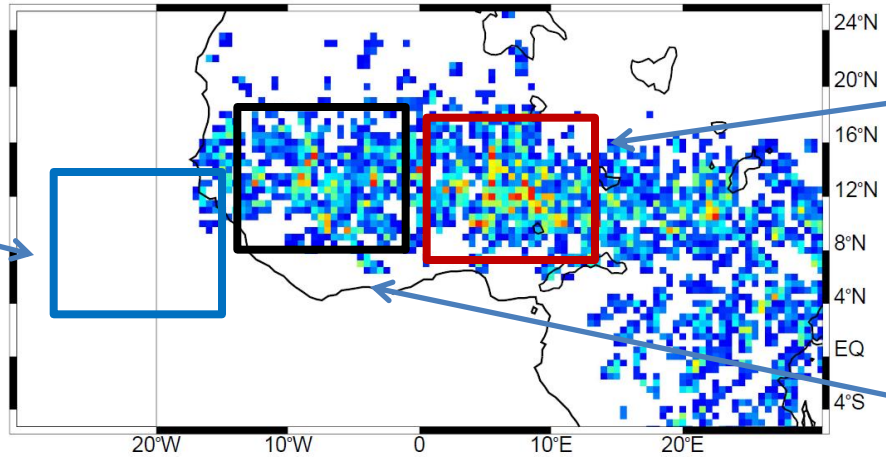
East Pacific



Andes foothills

Colombian coast

East Atlantic

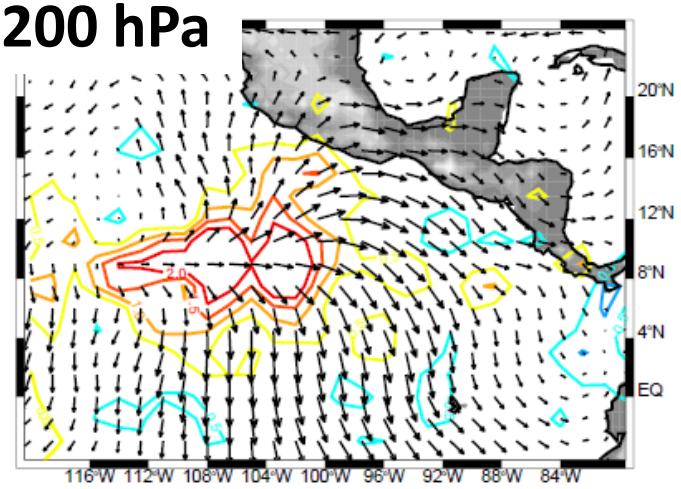


Central Sahel

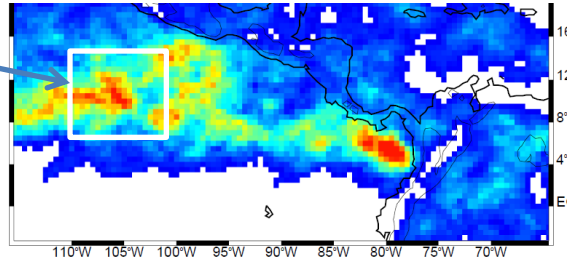
West Sahel

Broad stratiform regions over East Pacific

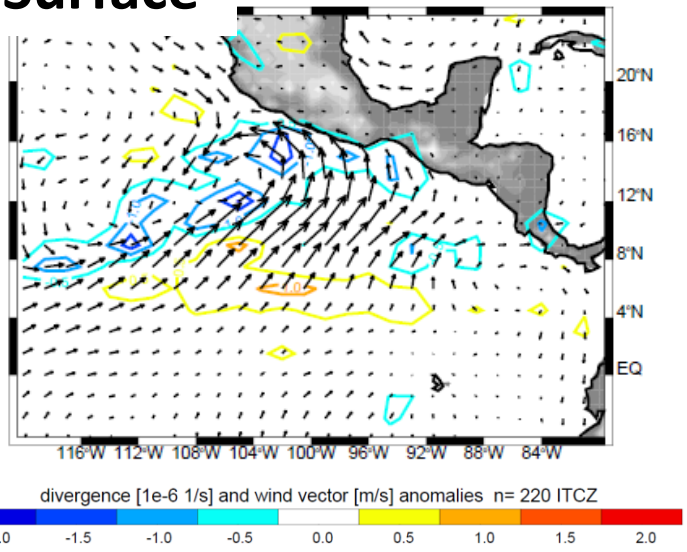
200 hPa



East Pacific



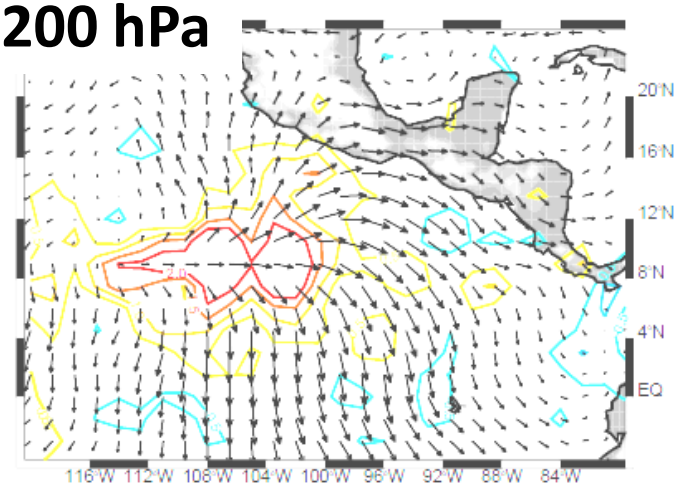
Surface



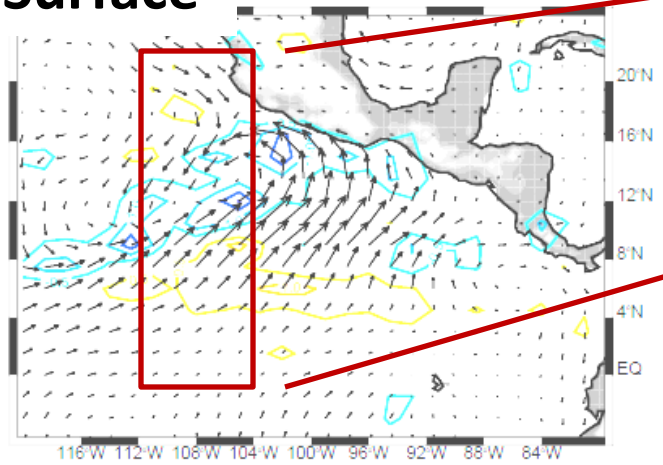
- Divergence and wind vector anomalies for days when BSR occur over East Pacific

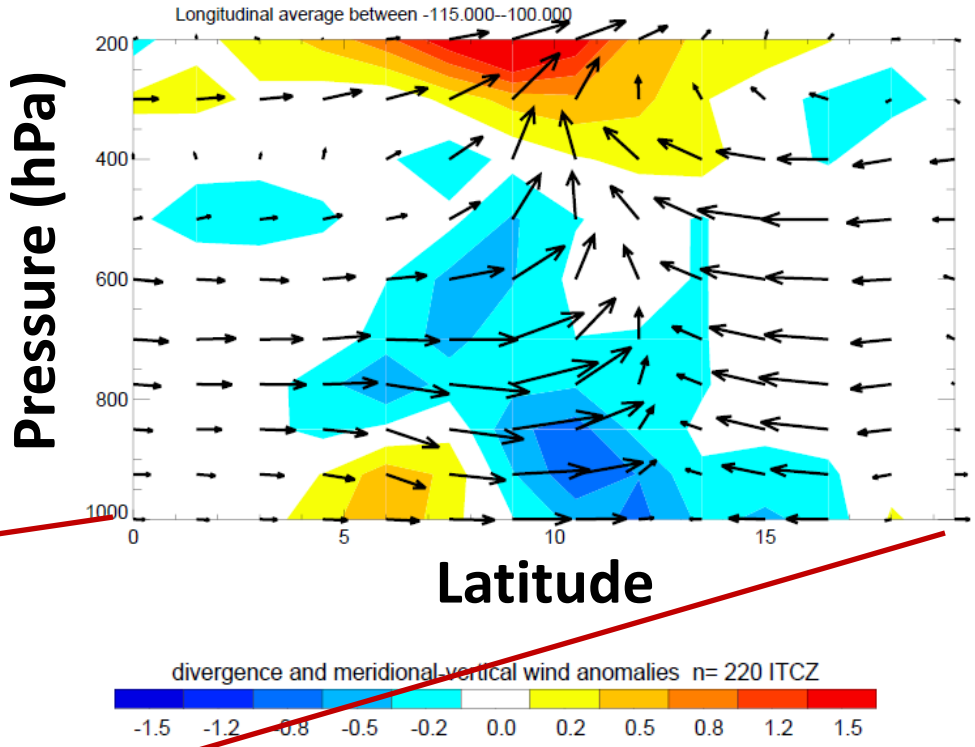
Broad stratiform regions over East Pacific

200 hPa



Surface

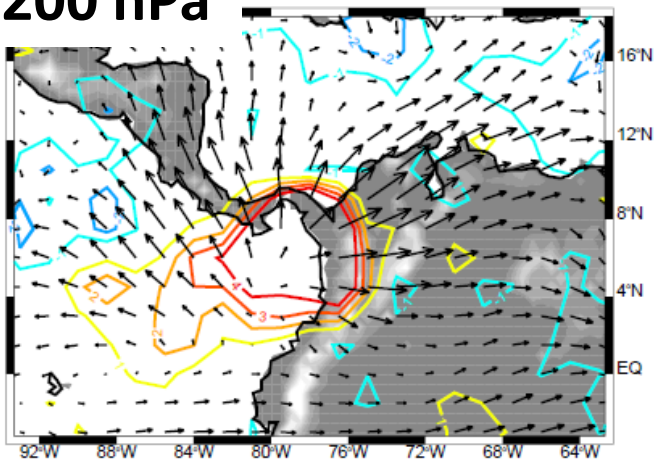




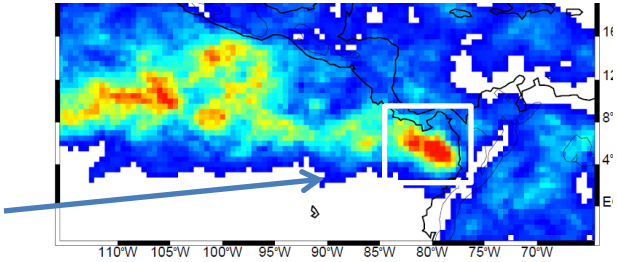
- Longitudinal average of wind and divergence anomalies

Broad stratiform over Colombian coast

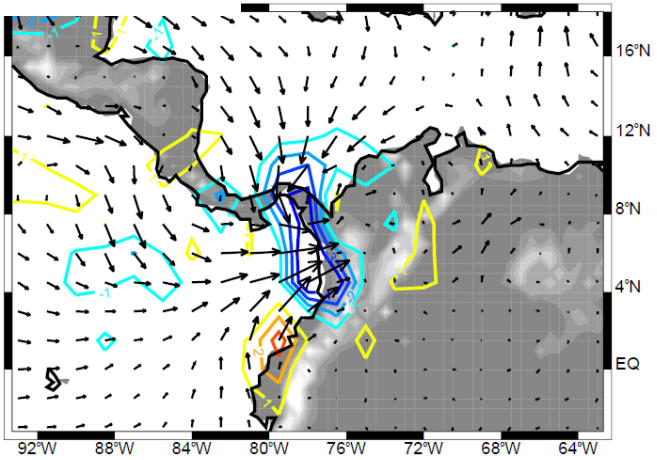
200 hPa

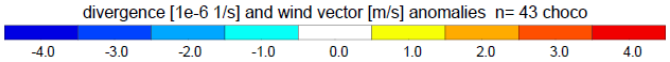


Colombian coast



Surface

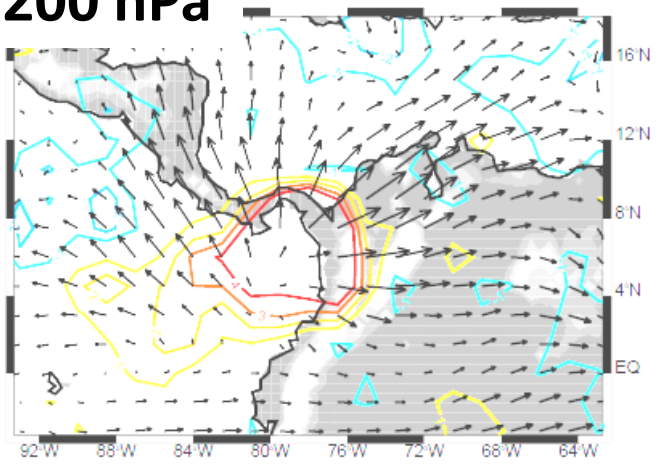




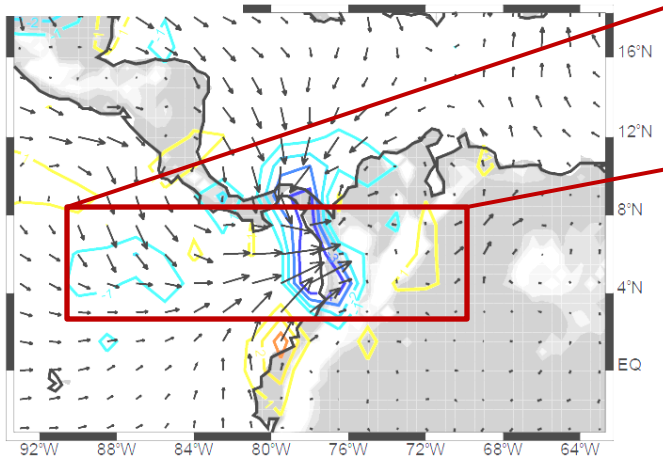
- Anomalously low-level convergence around the western foothills of Los Andes mountain range

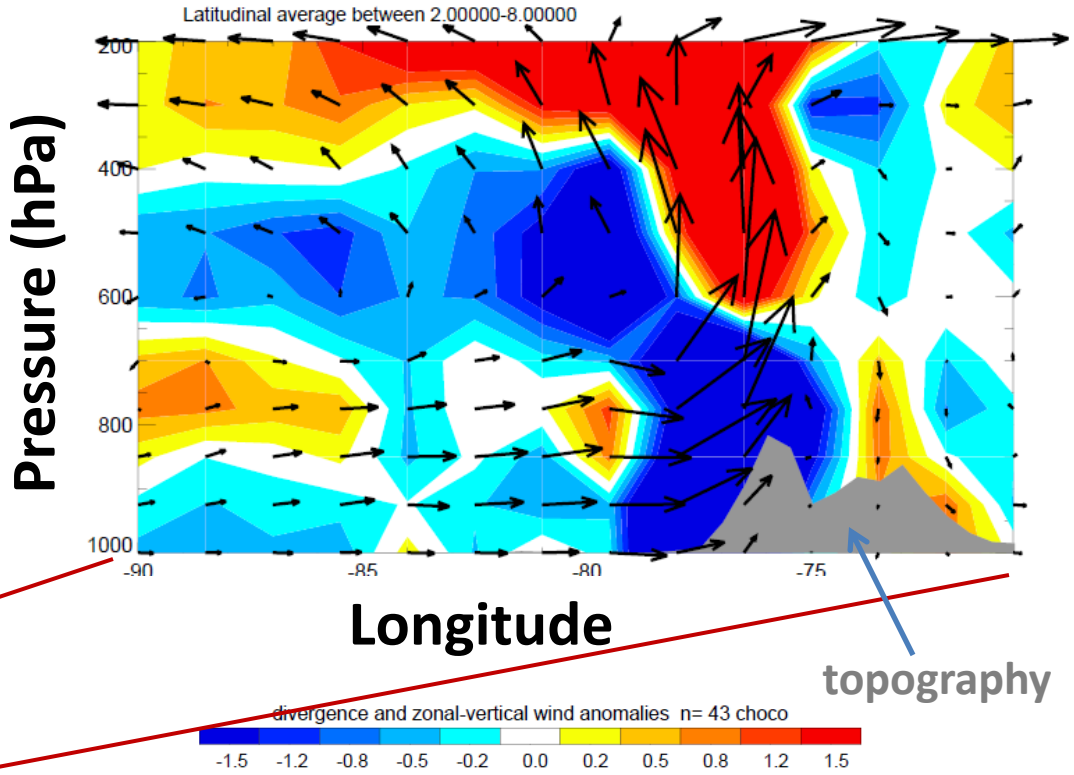
Broad stratiform over Colombian coast

200 hPa



Surface

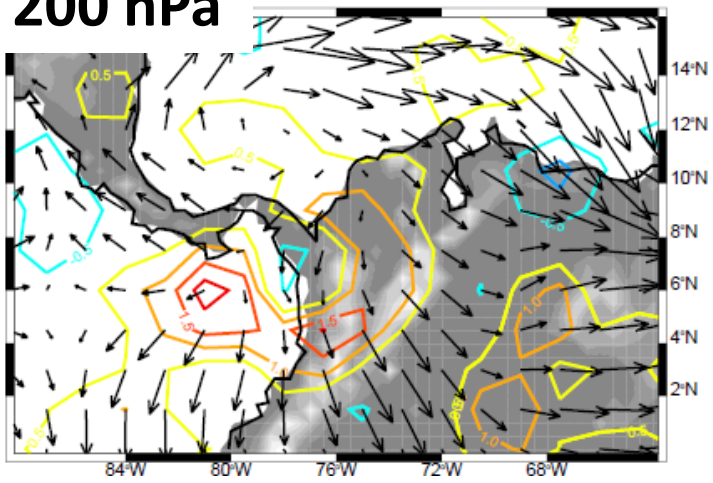




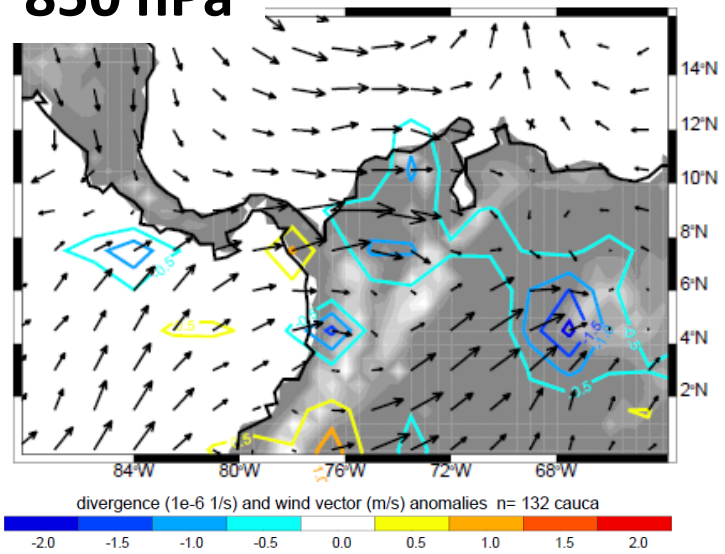
- Strong convergence that concentrates on the western foothills of Los Andes
- Similar picture for when WCC occur Colombian coast

Wide convective cores over Los Andes

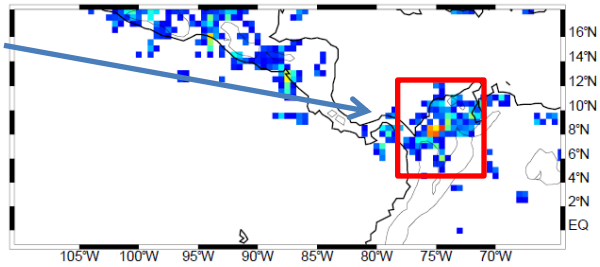
200 hPa



850 hPa



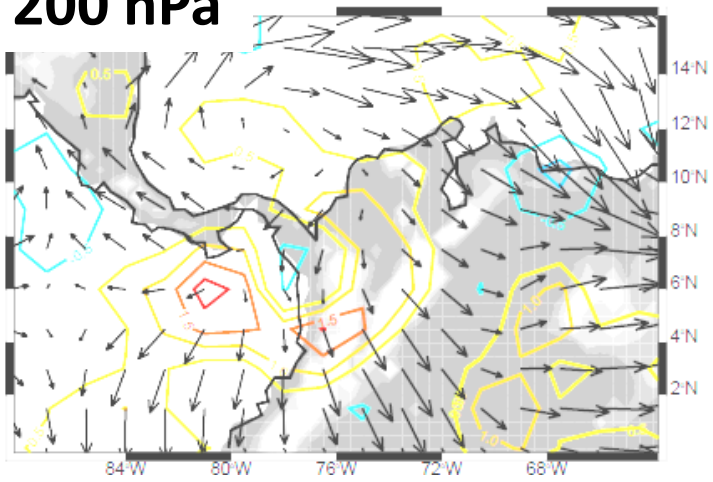
Andes foothills



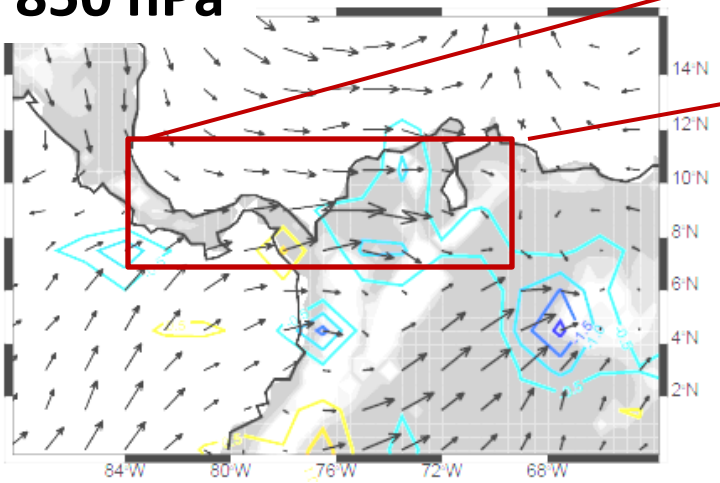
- The center of convergence now lies over the northern foothills of Los Andes

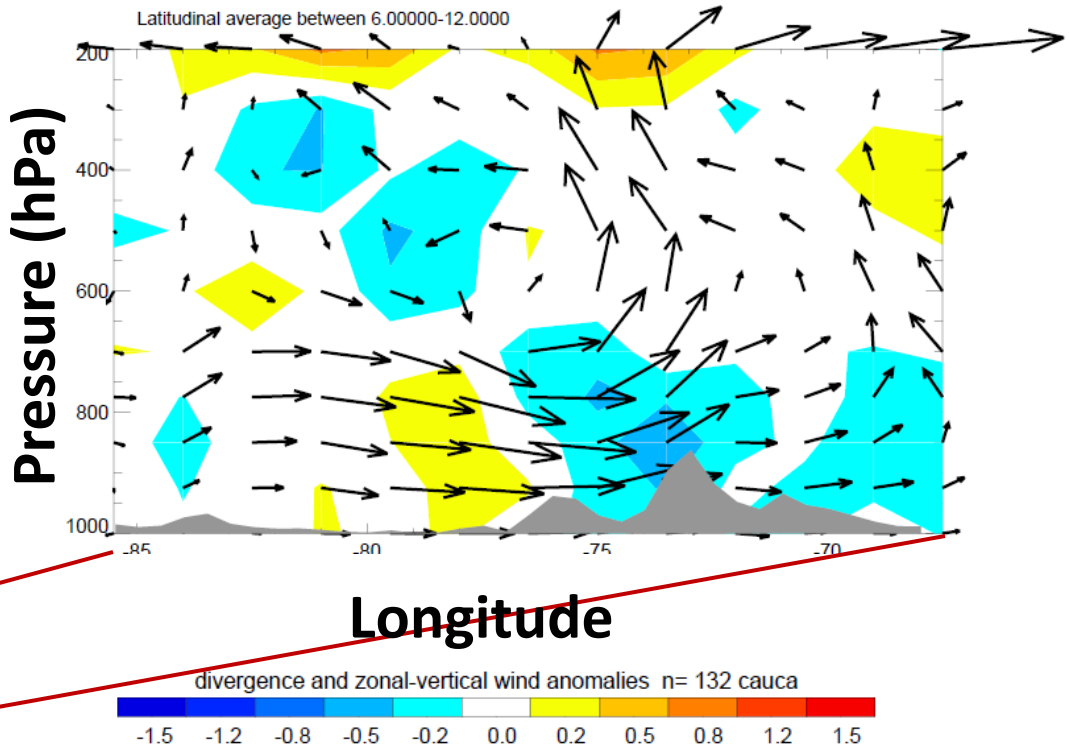
Wide convective cores over Los Andes

200 hPa



850 hPa





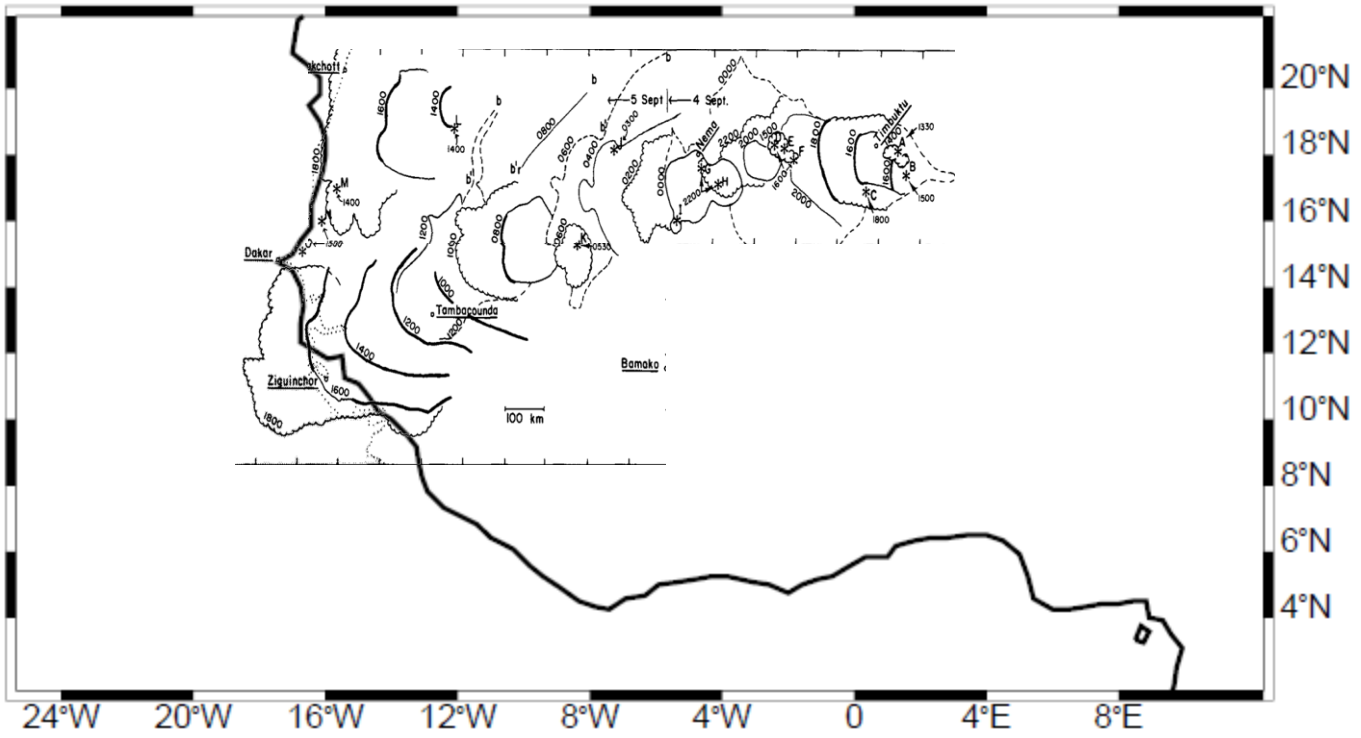
- Anomalous low-level westerly flow converging in interior Andean valleys

Summary

Extreme convection in Equatorial America:

- Local concentration
- Influenced by topographic features

Equatorial West Africa

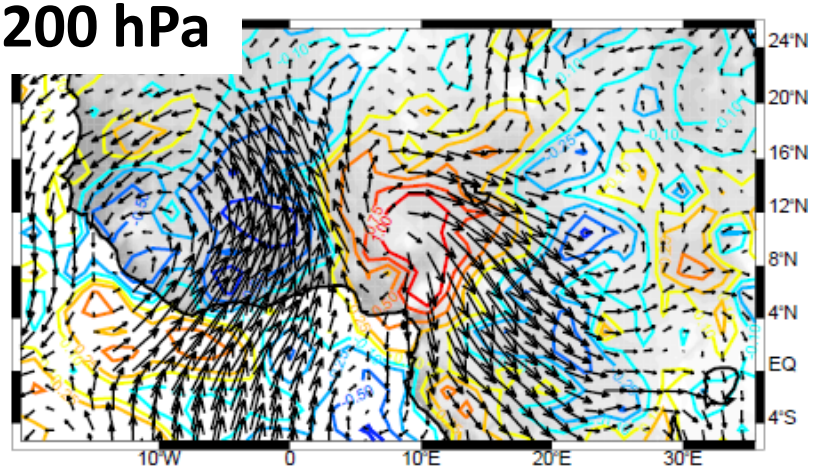


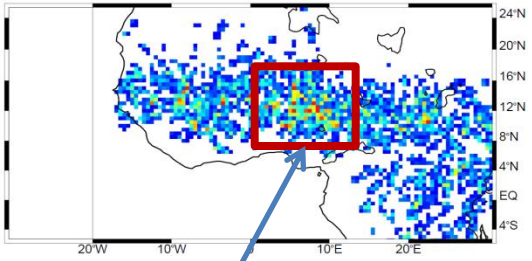
Fortune 1980

- Advance of squall-lines disturbances represent the most important rain-bearing weather systems over the region

Wide convective cores over Central Sahel

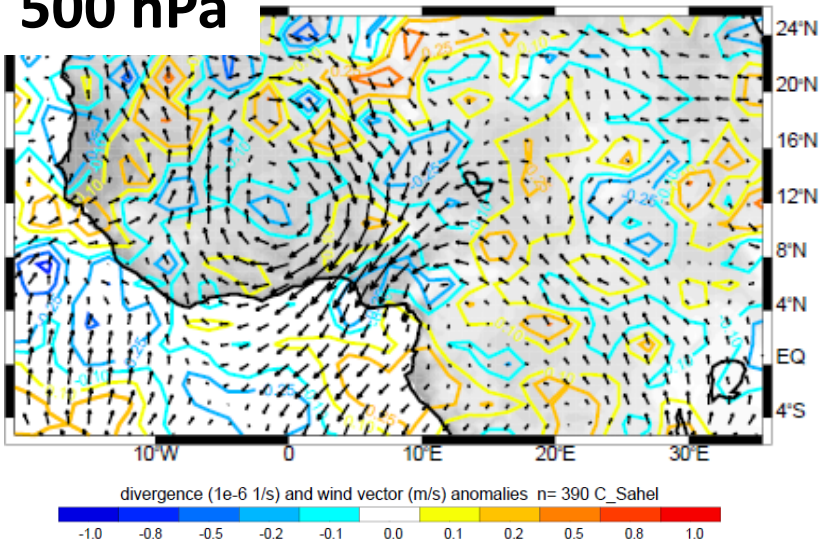
200 hPa





Central Sahel

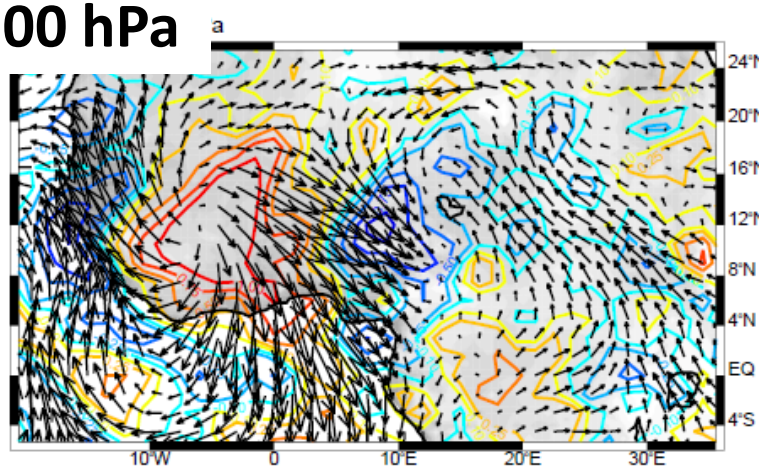
500 hPa

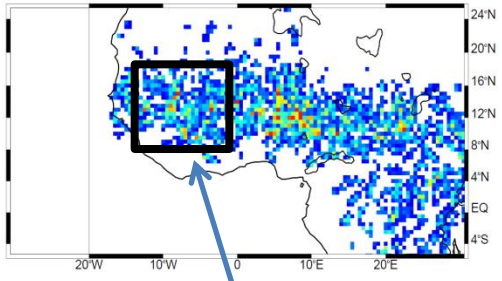


- Area west of AEW trough is favorable location for Squall-line generation (Payne and McGarry 1977)

Wide convective cores over West Sahel

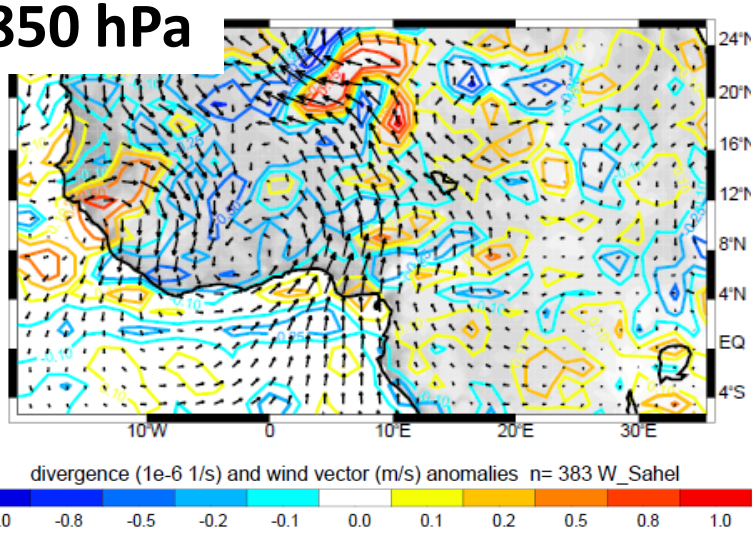
200 hPa





West Sahel

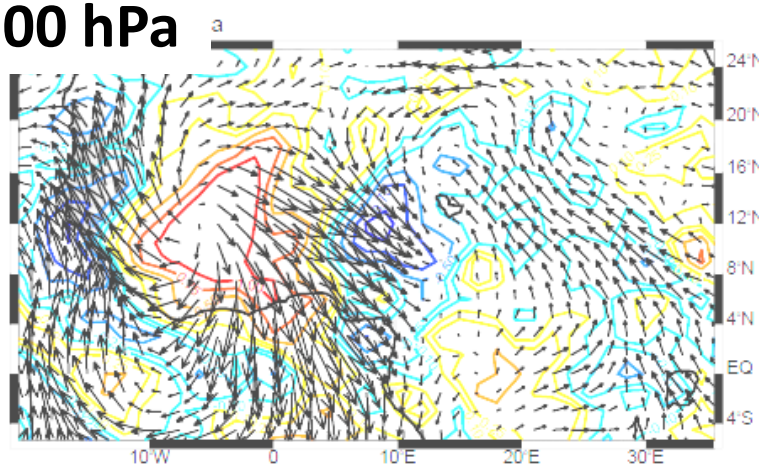
850 hPa

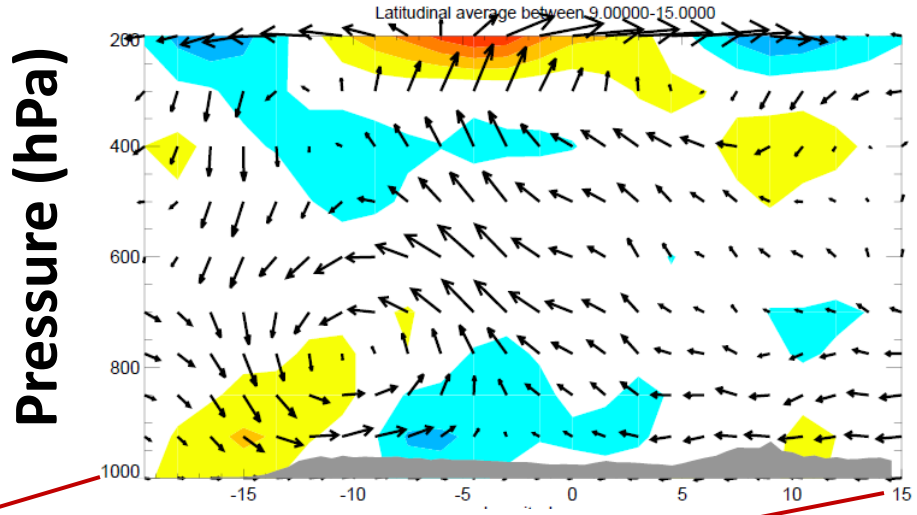


- Convergence now is located over west Sahel just west of the AEW trough with additional low level flow originating from the gulf of Guinea

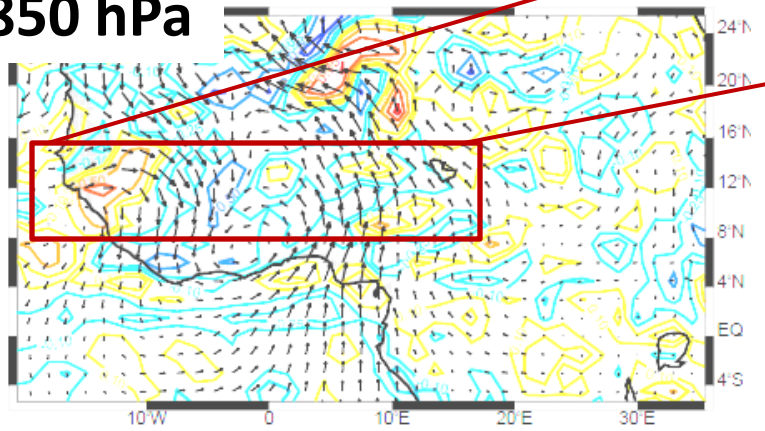
Wide convective cores over West Sahel

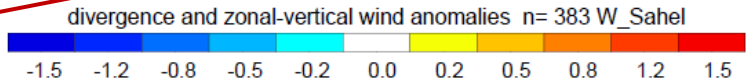
200 hPa





850 hPa

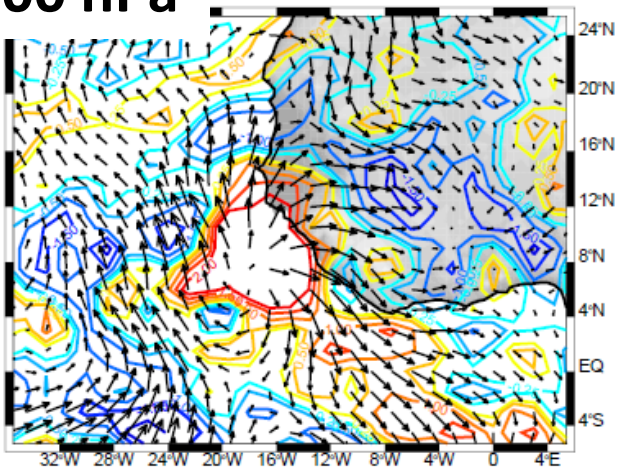




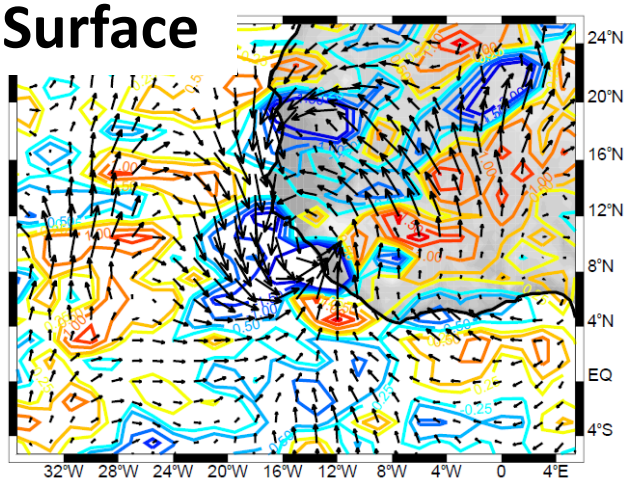
- Region on low-level convergence located over the west Sahel region

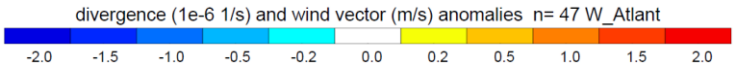
Broad stratiform over East Atlantic

200 hPa

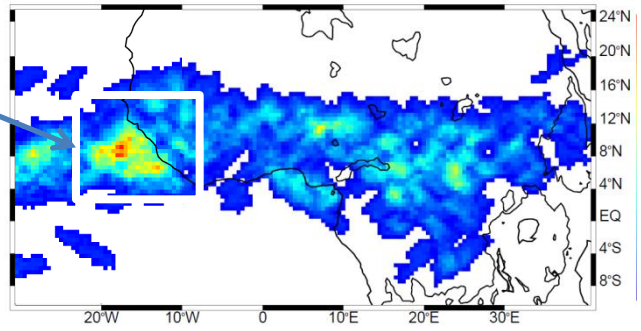


Surface





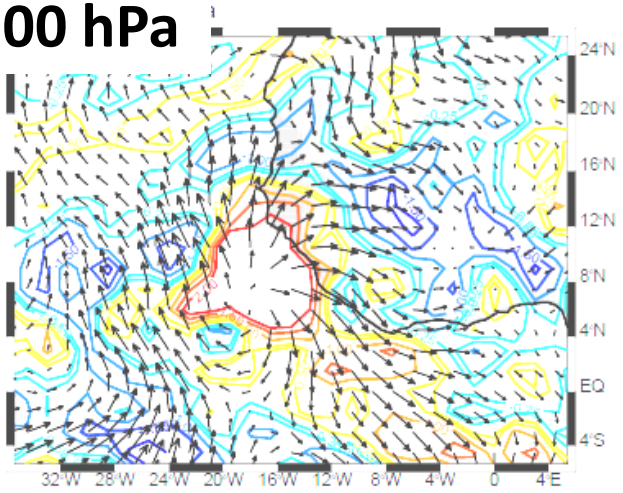
East Atlantic



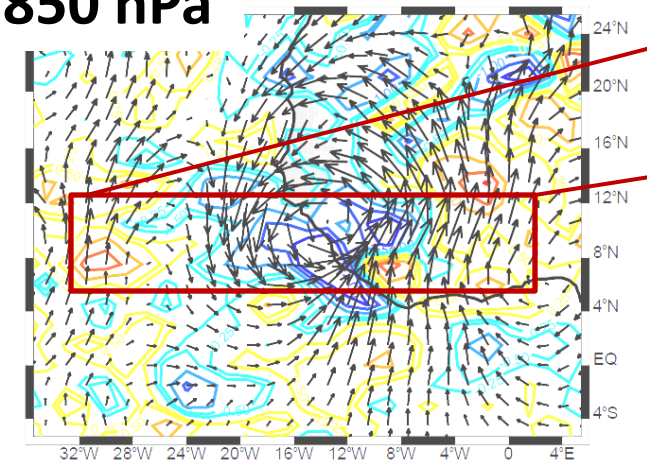
- Strong center of low-level convergence with anomalous cyclonic circulation

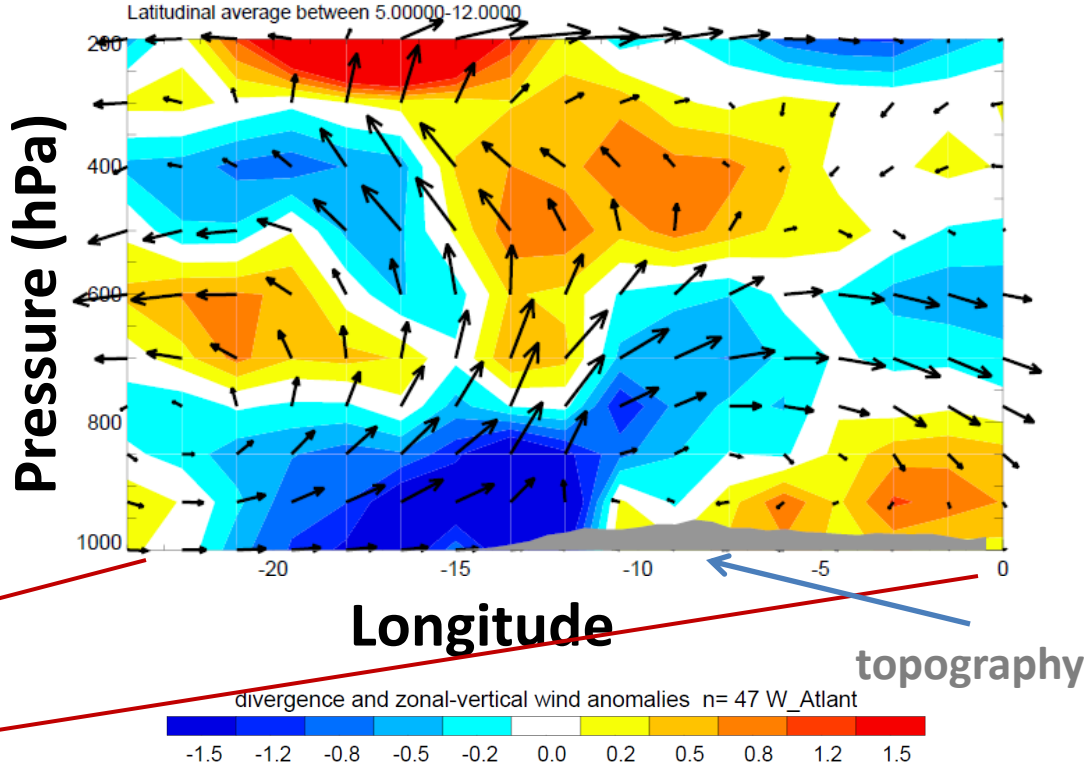
Broad stratiform over East Atlantic

200 hPa



850 hPa





- Low-level convergence over the west coast of Africa

Summary

Extreme convection in Equatorial Africa occurs:

- More widely spread across the region
- Influenced by the trough of and AEW
- Supply of moisture that can penetrate further inland

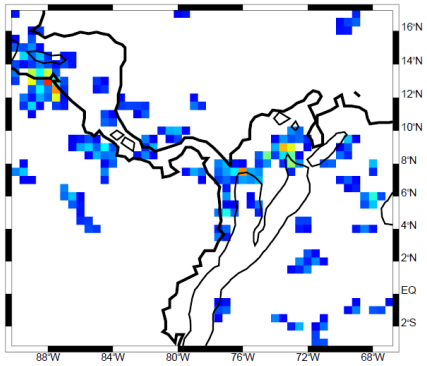
Diurnal cycle of convective categories

- Regions affected by strong monsoonal circulations created by land masses differences

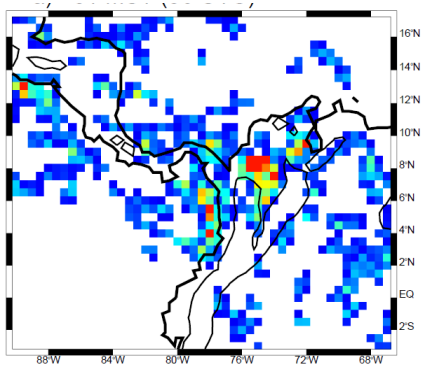
- Location of echo categories during the day for wide convective cores and broad stratiform regions over equatorial America and Africa

Diurnal cycle of wide convective and

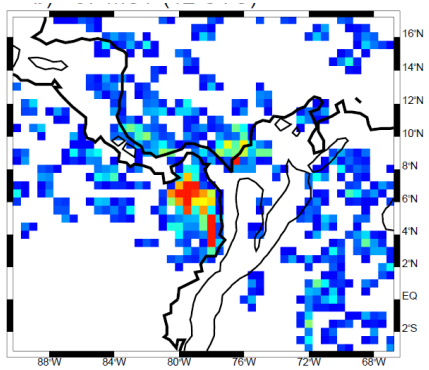
~19 MST



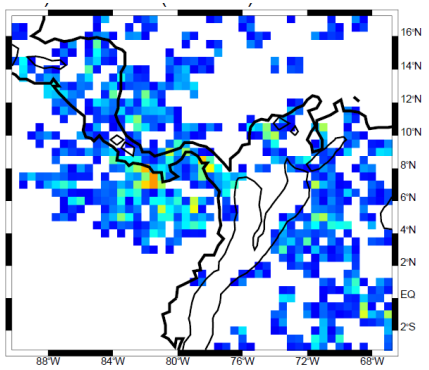
~01 MST

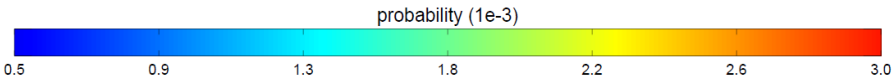


~07 MST



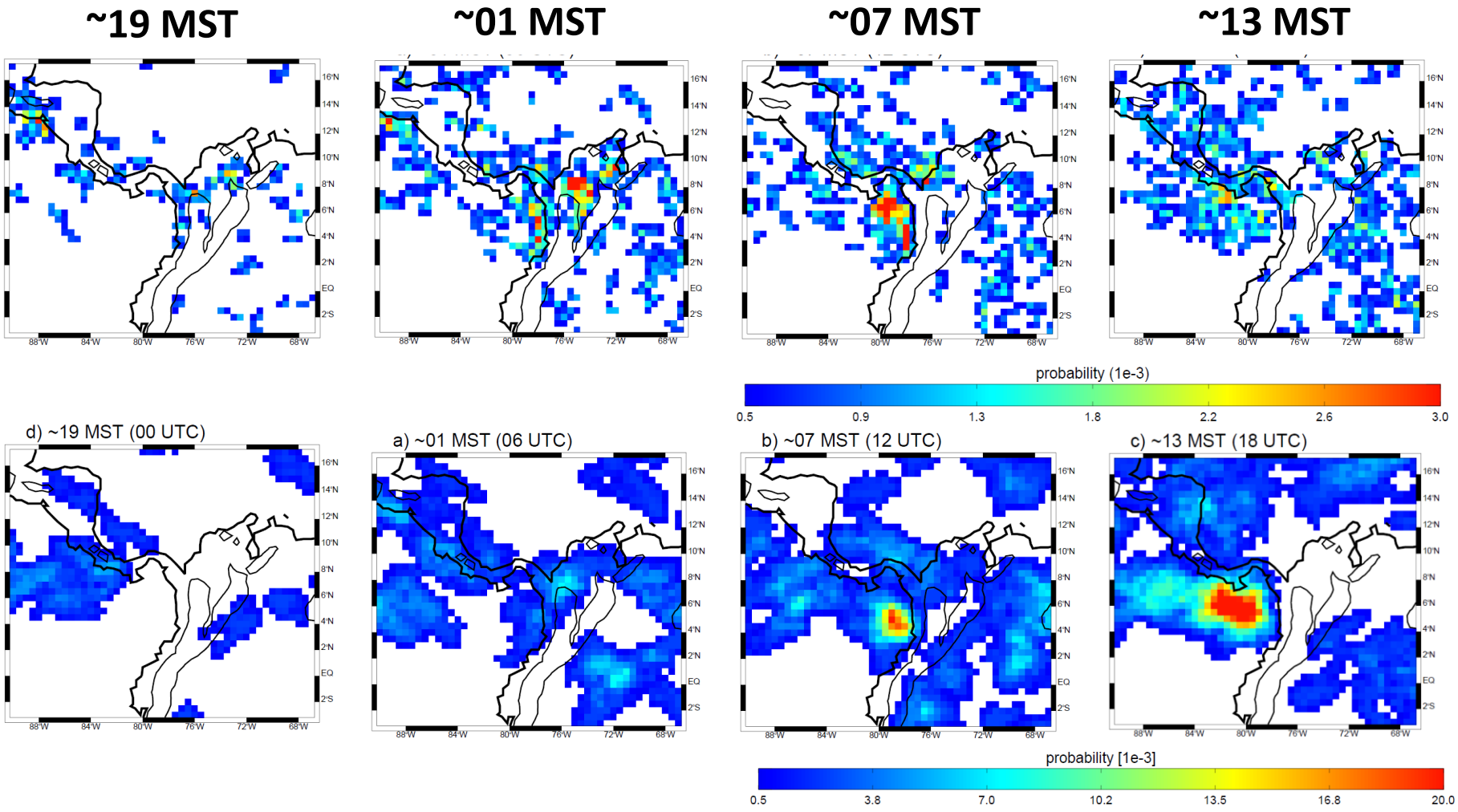
~13 MST





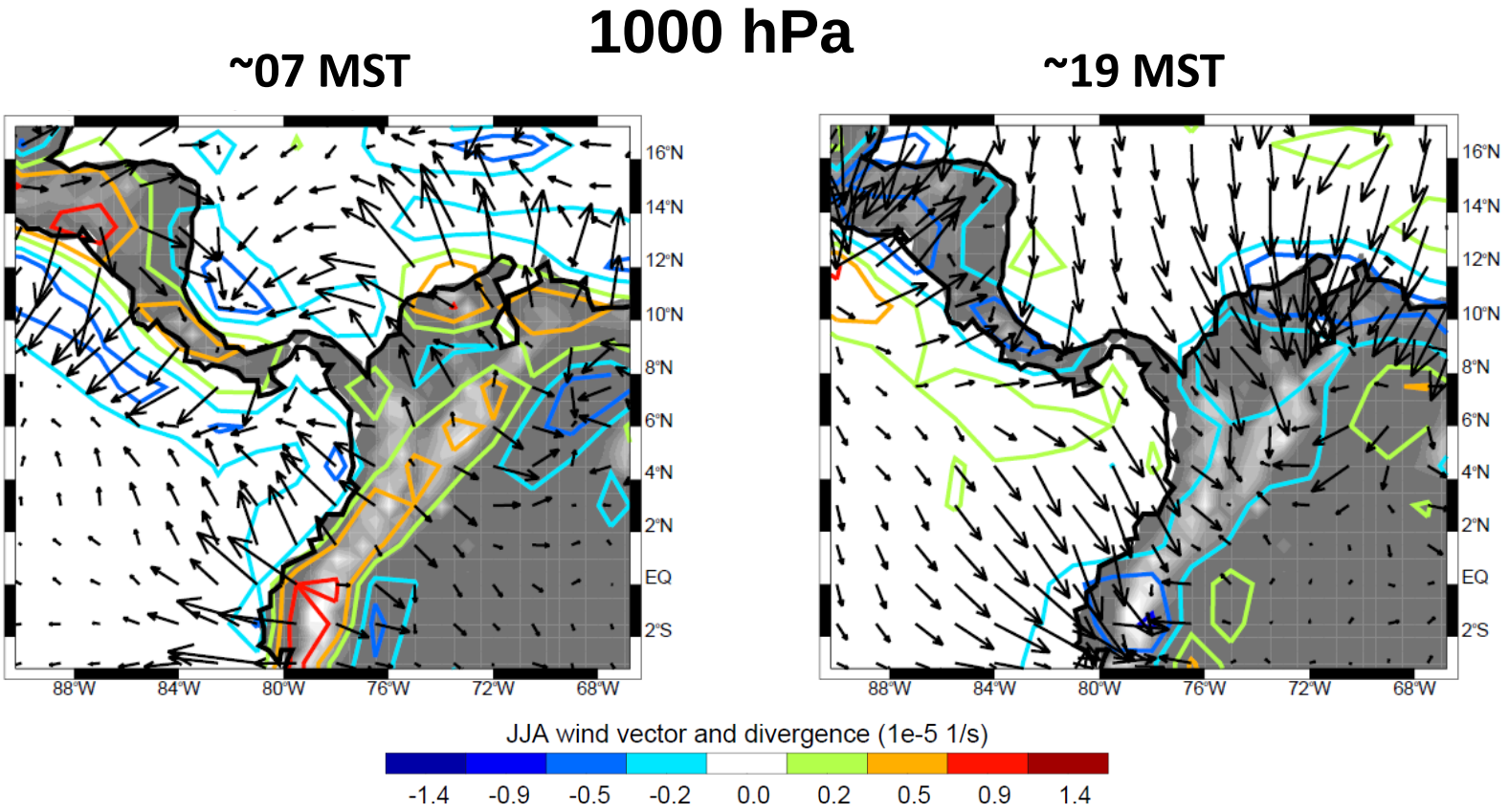
- Westward progression

Diurnal cycle of wide convective and broad stratiform regions



- Westward progression with BSR lagging WCC over Colombian coast region

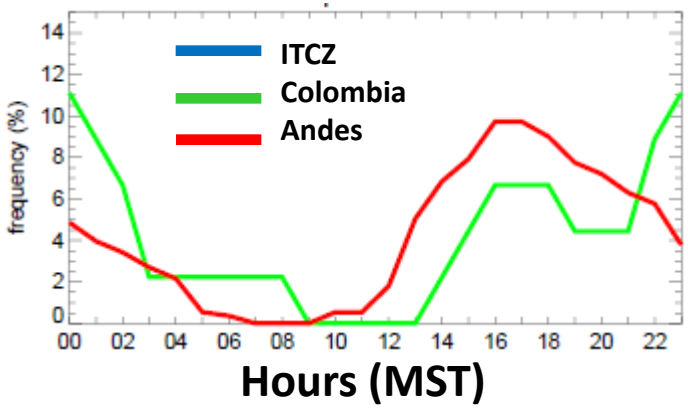
Diurnal cycle of wind and divergence



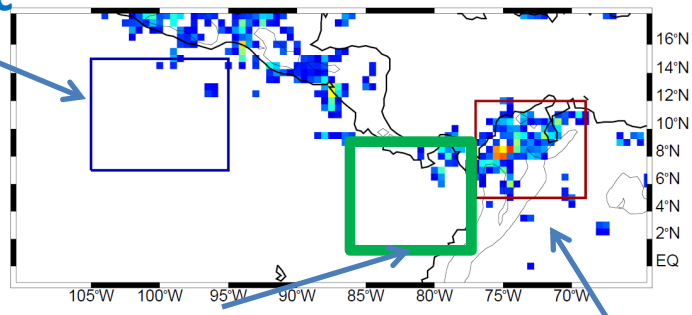
- Strong diurnal modulation, with convergence over land in the afternoon and over ocean in the early morning

Diurnal cycle for regions over equatorial America

Deep convective cores



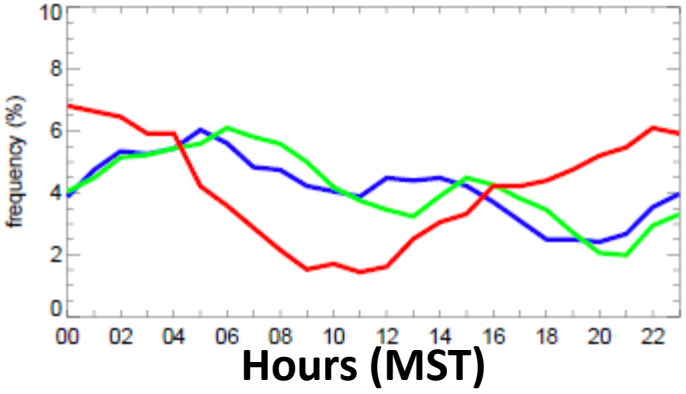
E. Pacific



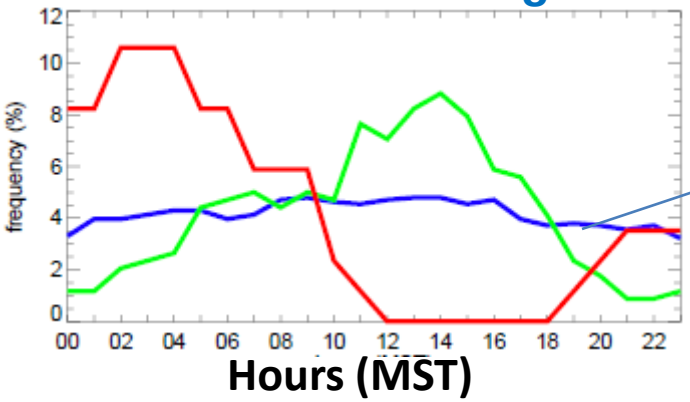
Colombian coast

Andes foothills

Wide convective cores



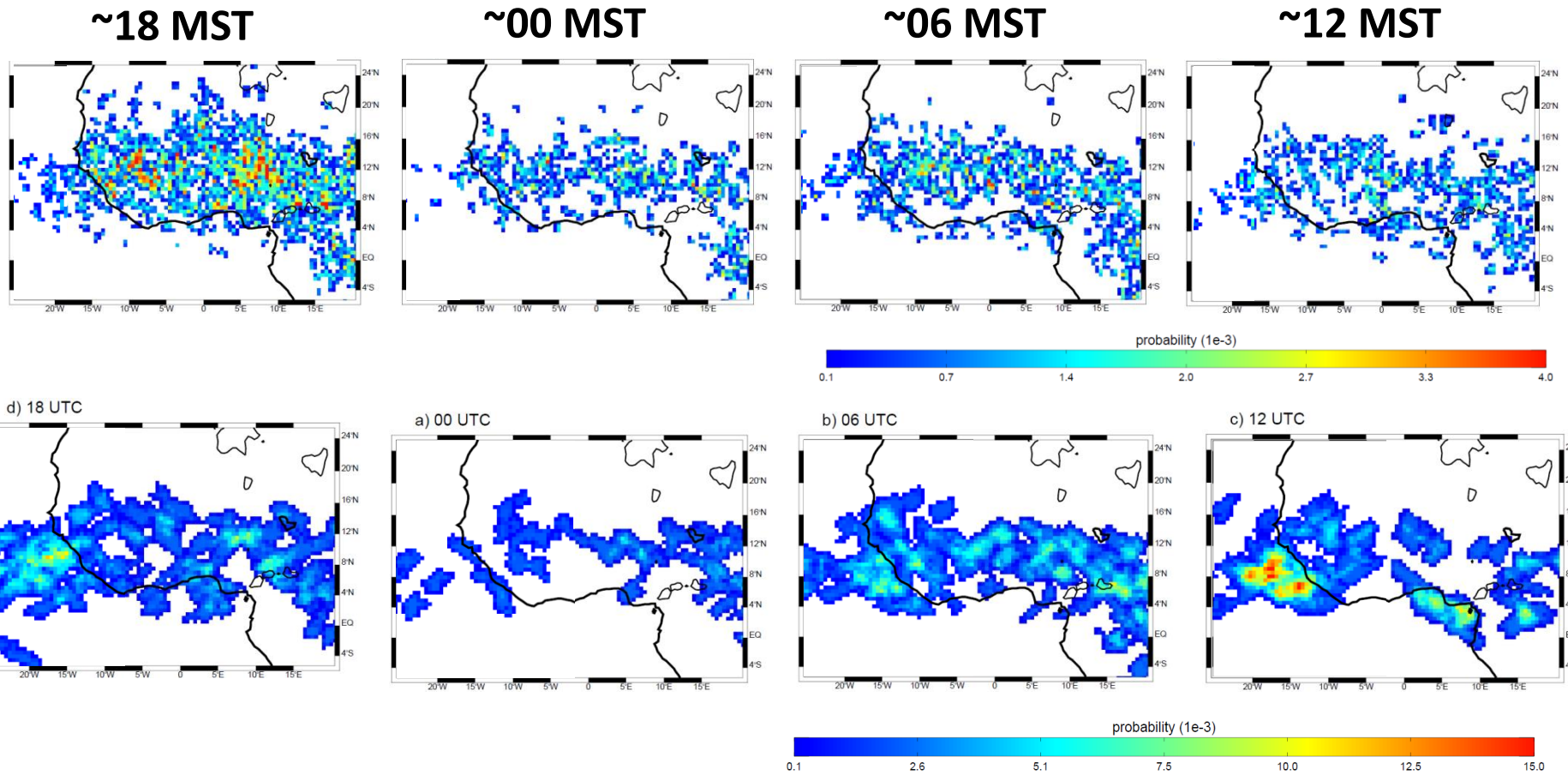
Broad stratiform regions



East Pacific

- Peak in convective categories in a succession from DCC, WCC to BSR

Diurnal cycle of wide convective and broad stratiform regions



- Not apparent diurnal cycle migration

Conclusions

- Characteristics of extreme convection in two regions that are highly influenced by day-time heating with monsoonal flow and with topographic features that permits the enhancement of convective activity

  - **Deep convective cores** are located almost exclusively over land , with a maximum concentration in the Andes foothills over equatorial America, and west and central Sahara over Africa

  - **Wide convective cores** are located in similar areas as DCC and over the coastal areas of Colombia and the East Atlantic

  - **Broad stratiform regions** coincide with the ITCZ with a maximum occurrence over the Colombian coast and the East Atlantic.

Conclusions

- Over equatorial America:
  - Extreme events tended to be concentrated in confined regions, achieved smaller sizes and reached lower altitudes
  - These systems are located in regions with significant topographic features subject to intense surface heating and strong diurnal modulation

- Over equatorial Africa:
  - Extreme events were widely zonally distributed, covered larger areas, and reached higher altitudes
  - African Easterly Waves distribute the formation, growth, and dissipation of convective events widely so that regional preferences are not pronounced

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