Diurnal and local variability of the South American Monsoon with possible effects of aerosol

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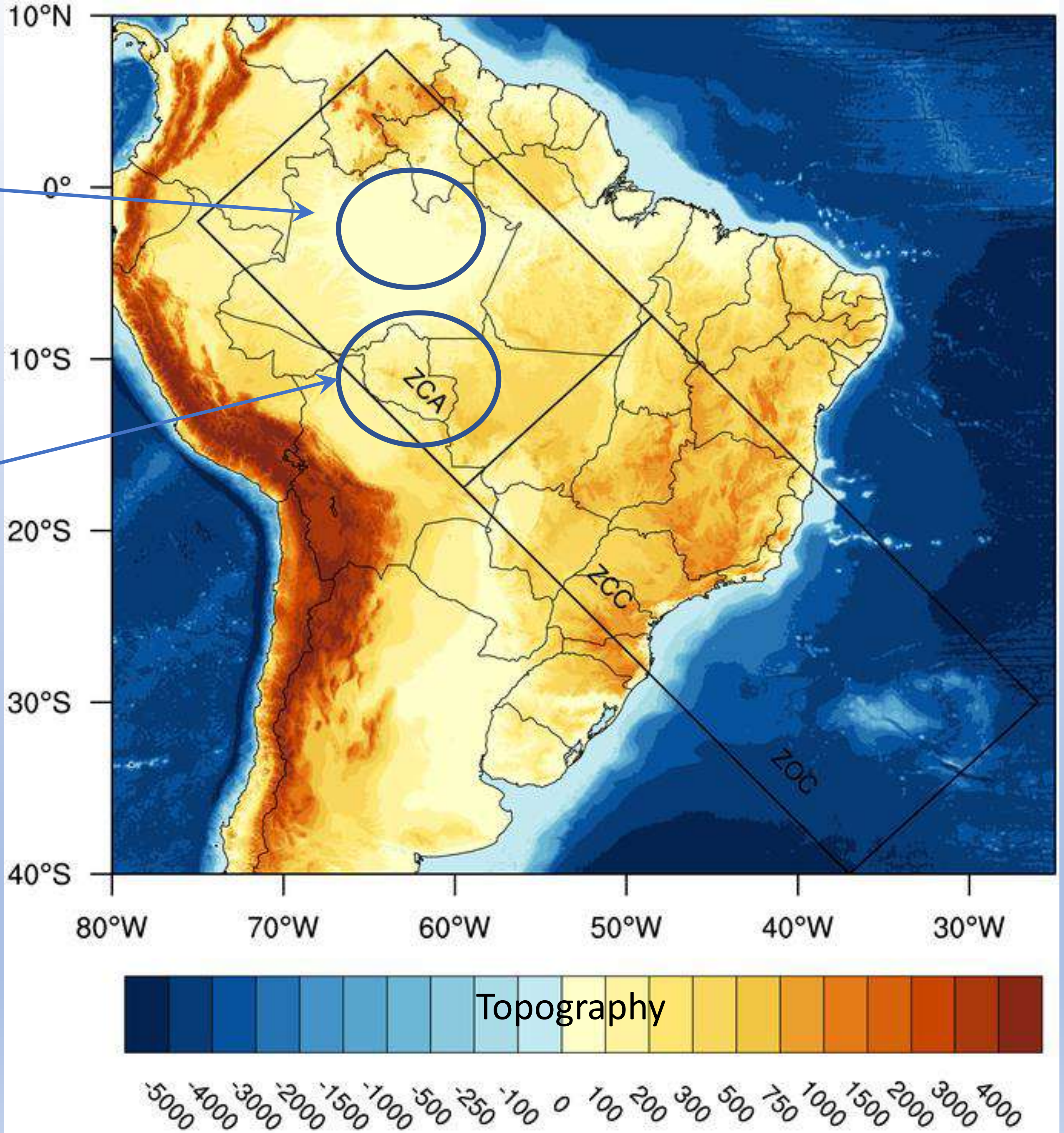
Location of GoAmazon field campaigns

Location of the state of Rondônia, SW Amazon, site of the WETAMC-TRMM/LBA and RACCI/SMOCC-LBA intensive field campaigns



ZCAS Continental Amazônica (ZCA)
SACZ Continental Amazon

ZCAS Continental Costeira (ZCC)
SACZ Continental Coastal

ZCAS Oceânica (ZOC)
SACZ Oceanic

Outline

- Diurnal variability
- Mesoscale Convective Systems and Mesoscale Cyclonic Vortices
- Aerosol effects on rainfall

Diurnal variability

- WETAMC/TRMM LBA
  - Anagnostou and Morales 2002
  - Carvalho et al 2002
  - Herdies et al 2002
  - Machado et al 2002
  - Rickenbach et al 2002
- GoAmazon
  - Giangrande et al 2017

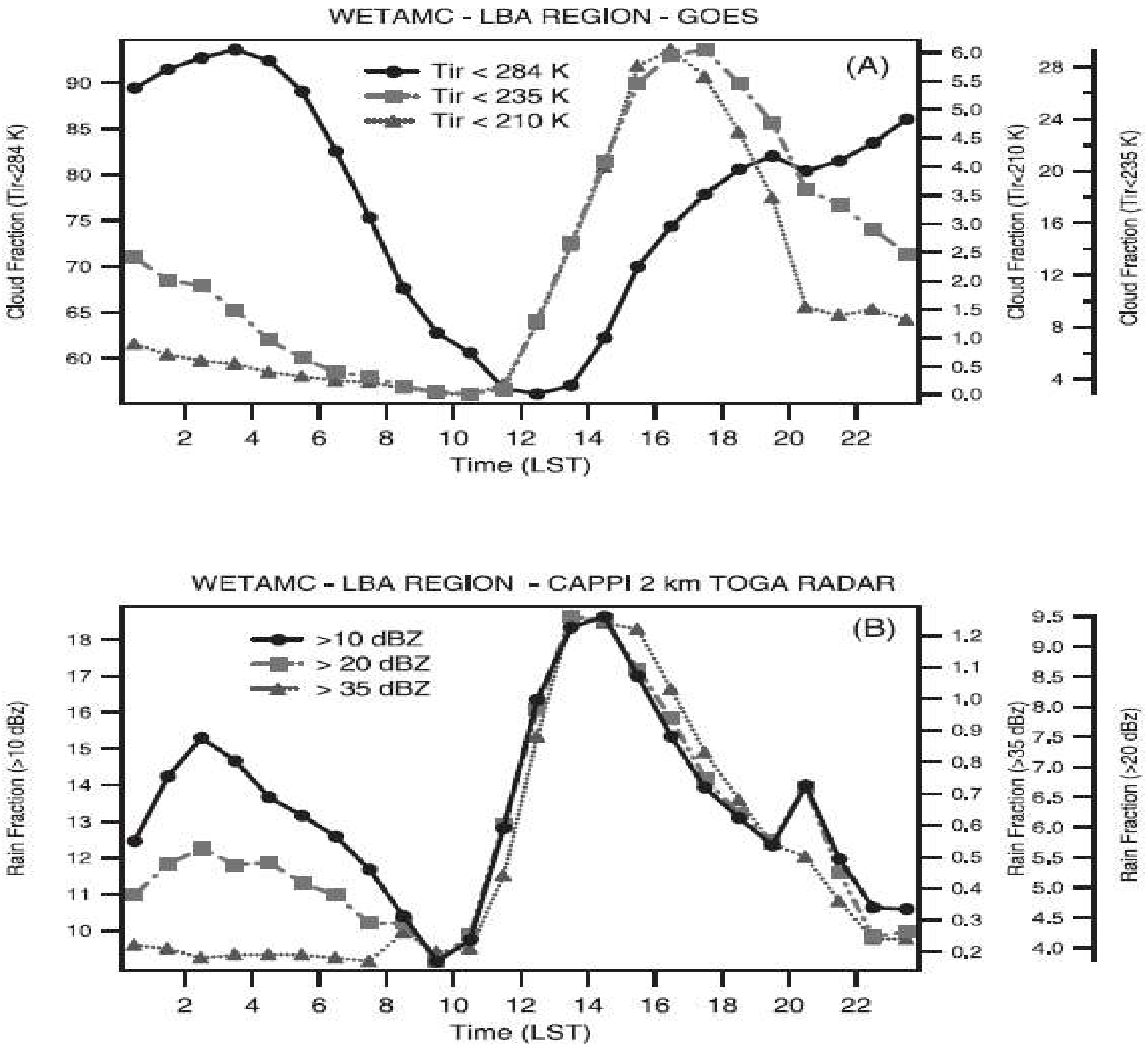


Figure 2. Hourly average cloud fraction (a) for the brightness temperature threshold of 284 K, 235 K, and 210 K, and for rain fraction (b) defined as the fraction larger than 10 dBZ, 20 dBZ, and 35 dBZ, for the period from 9 January to 27 February 1999. Each cloud fraction is presented in a specific scale.

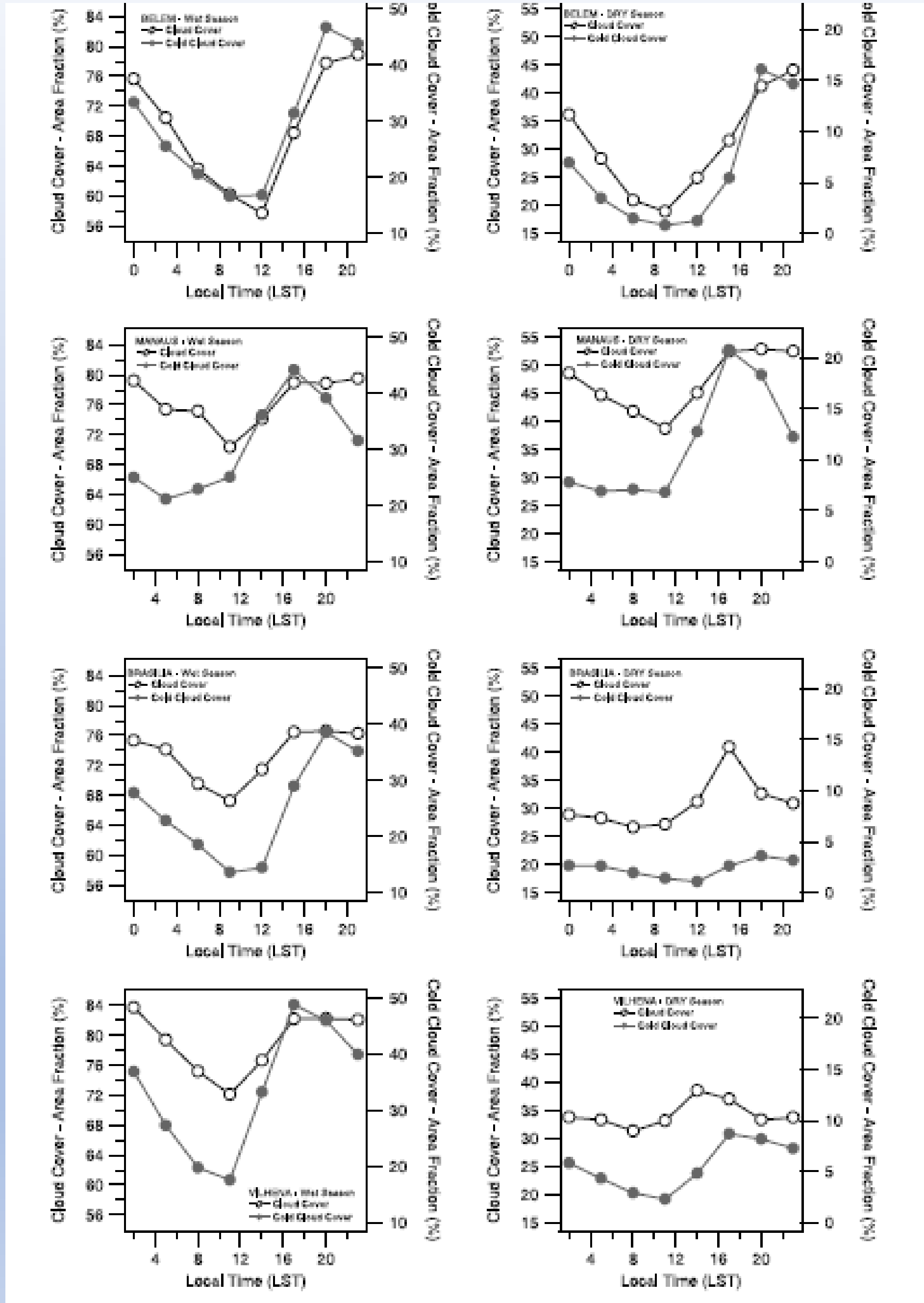
Machado et al 2002

Diurnal cycle

Cloud Cover
 Area fraction
Total (open circles)
and Cold Cloud Cover
(black circles)
from ISCCP

Machado et al 2004
Theor. Applied Climat.

Wet season | Dry season



Belem

Manaus

Brasilia

Vilhena

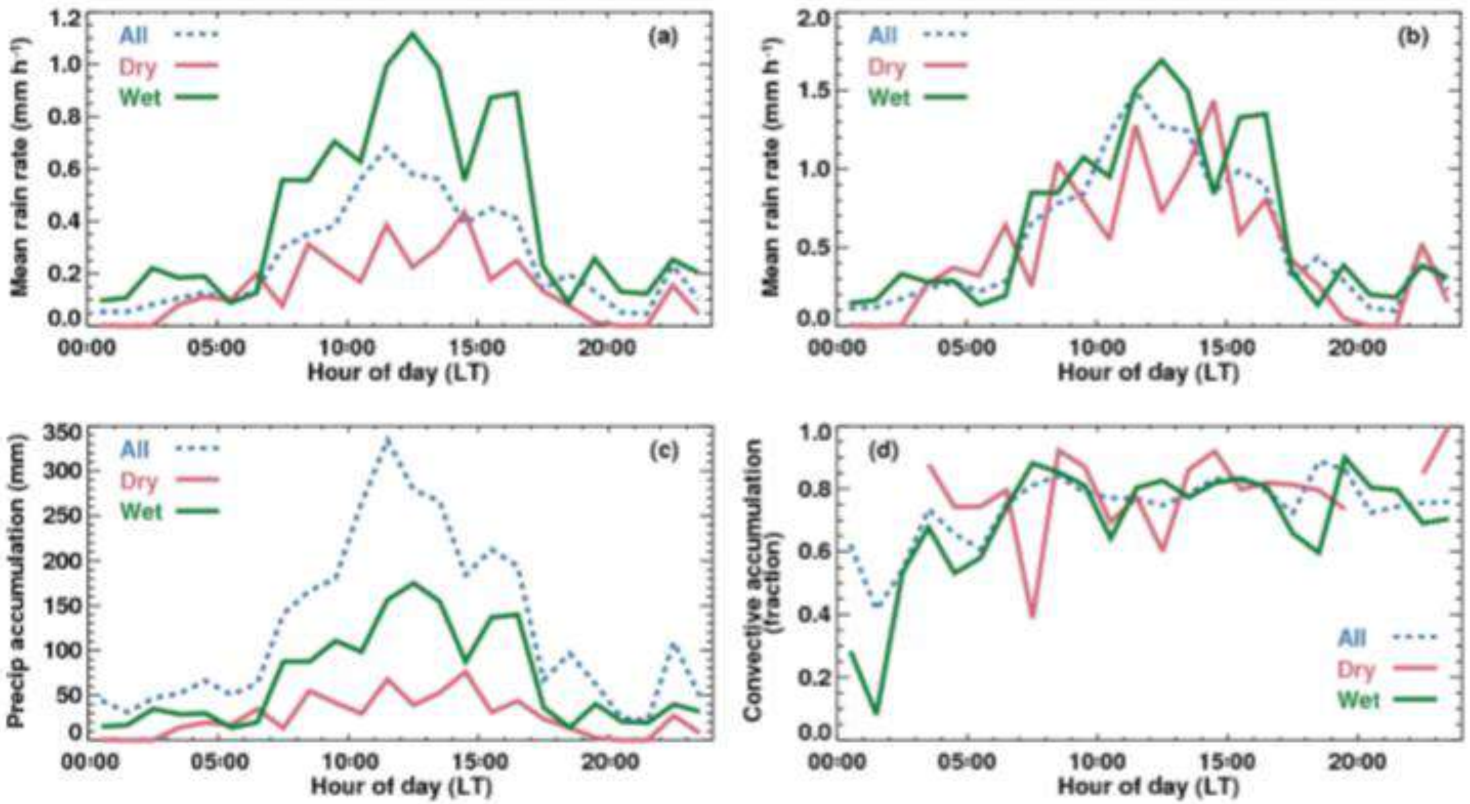
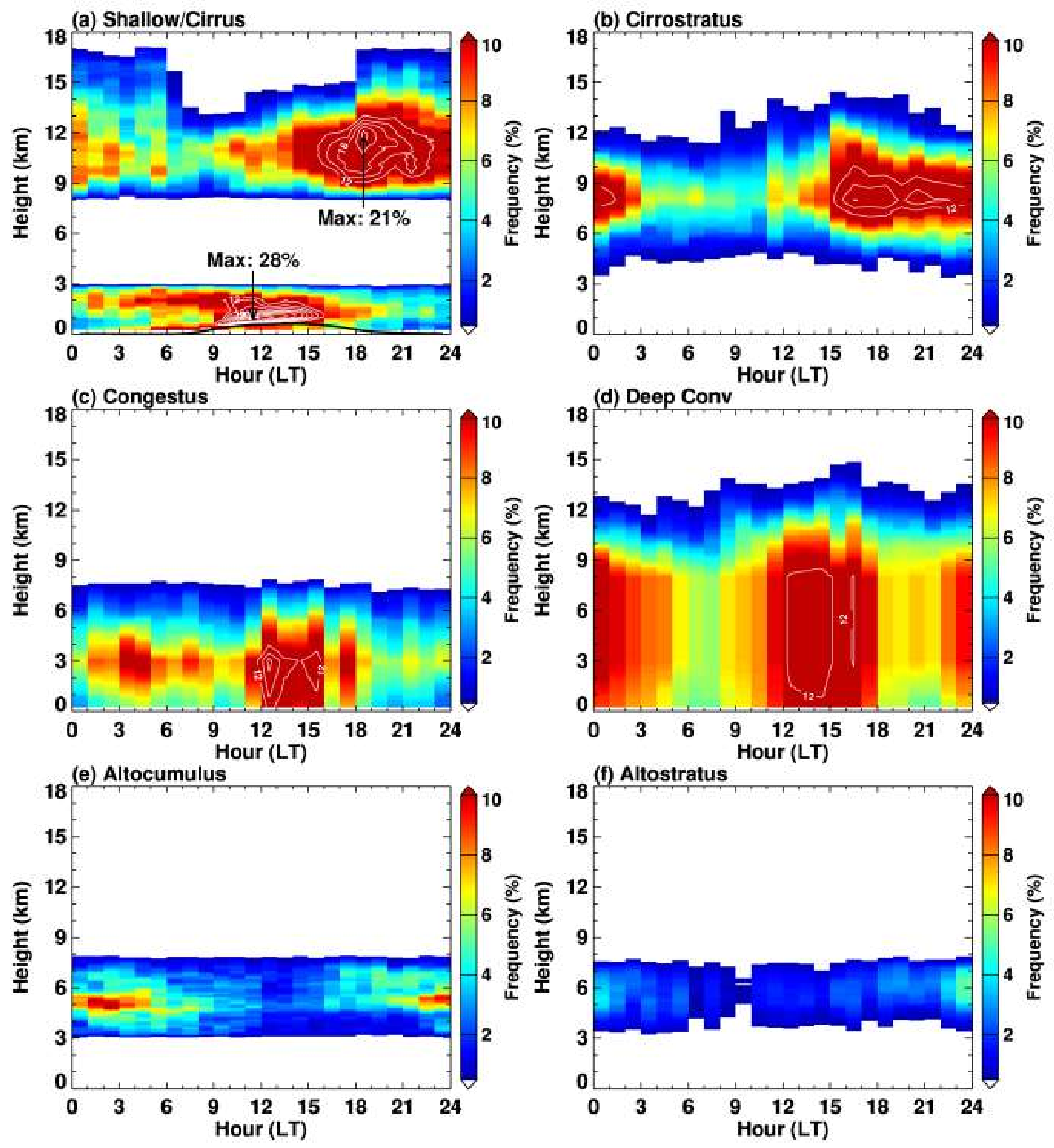


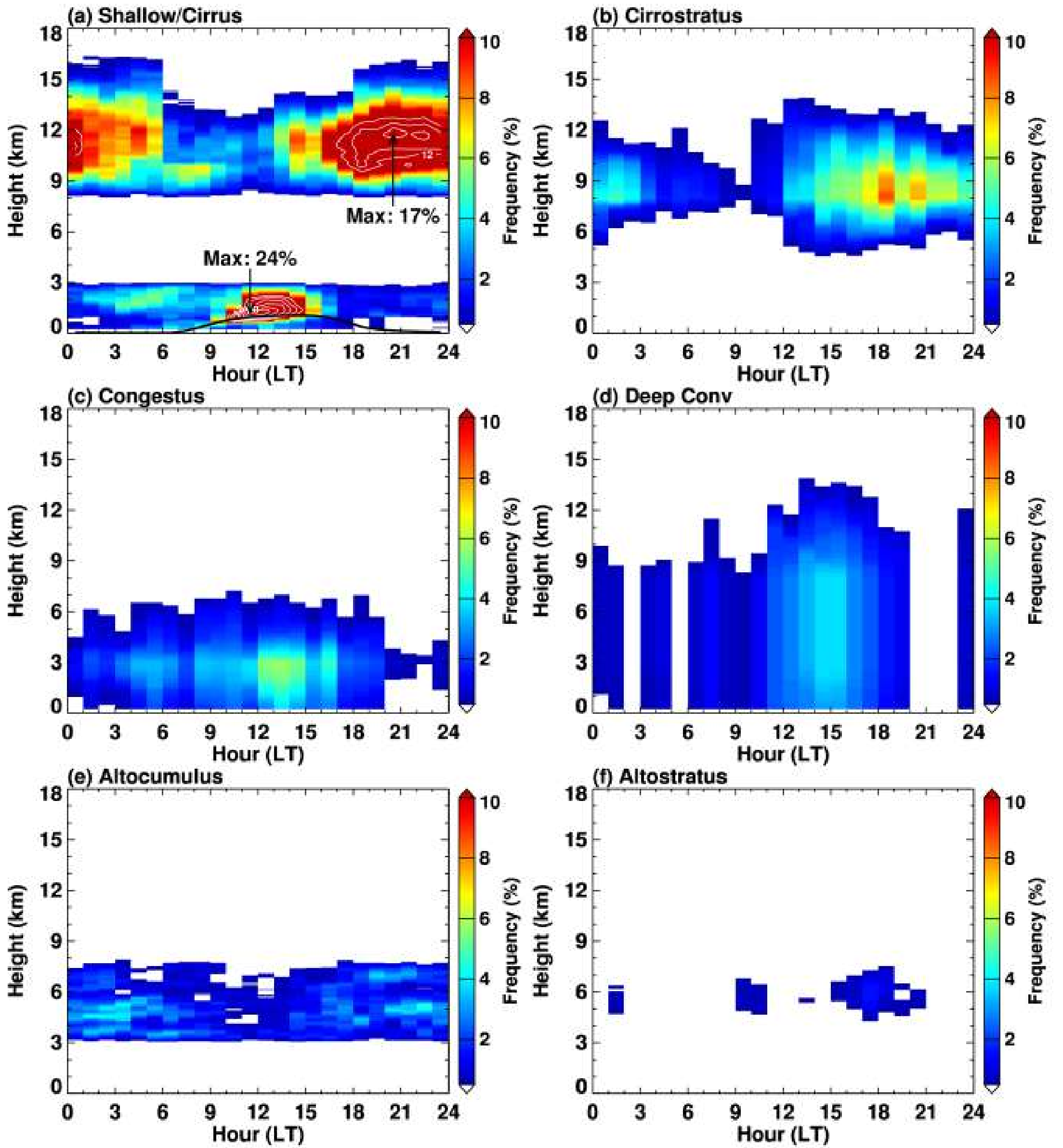
Figure 7. (**a**) Mean daily precipitation rate (mm h^{-1}) for all days and (**b**) for only the precipitating days during the campaign (> 1 mm). (**c**) The total accumulation in millimeters for the dataset and (**d**) the fractional convective accumulation as sampled by the rain gauges for the summary campaign and associated wet and dry season conditions.

WET SEASON



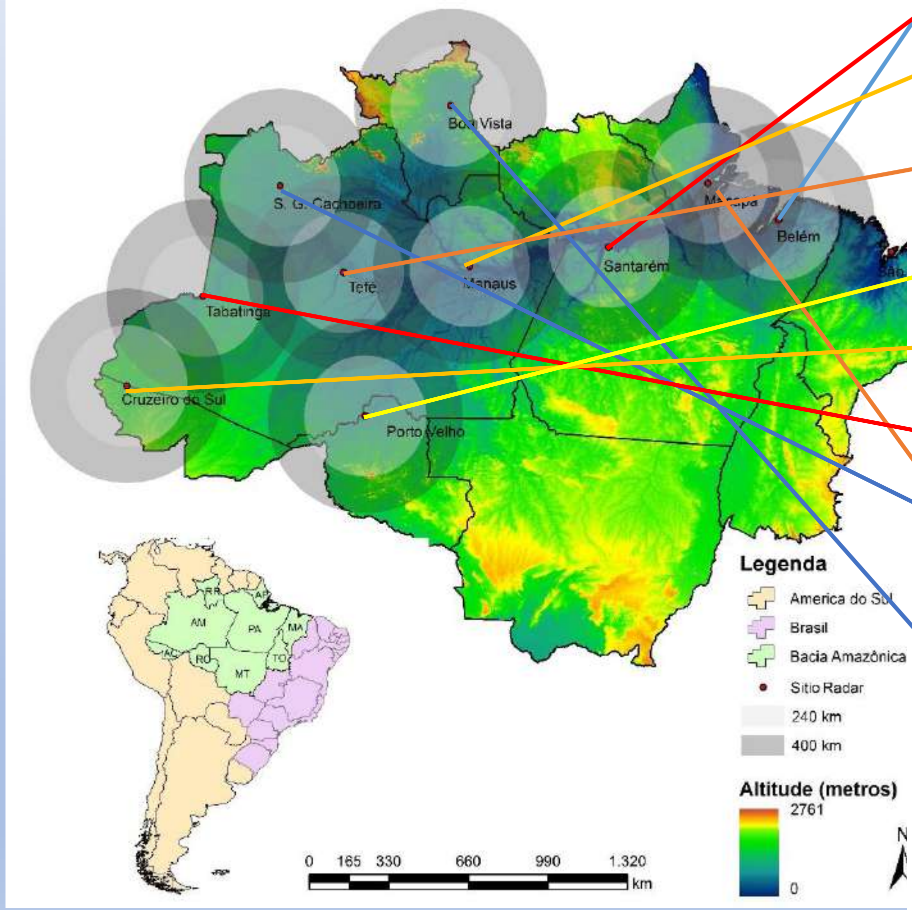
re 8: As in Fig. 6, but for wet season conditions.

DRY SEASON



9: As in Fig. 6, but for dry season conditions.

SIPAM Network of S-Band Weather Radars
5 years 2008-2012



Saraiva et al 2016

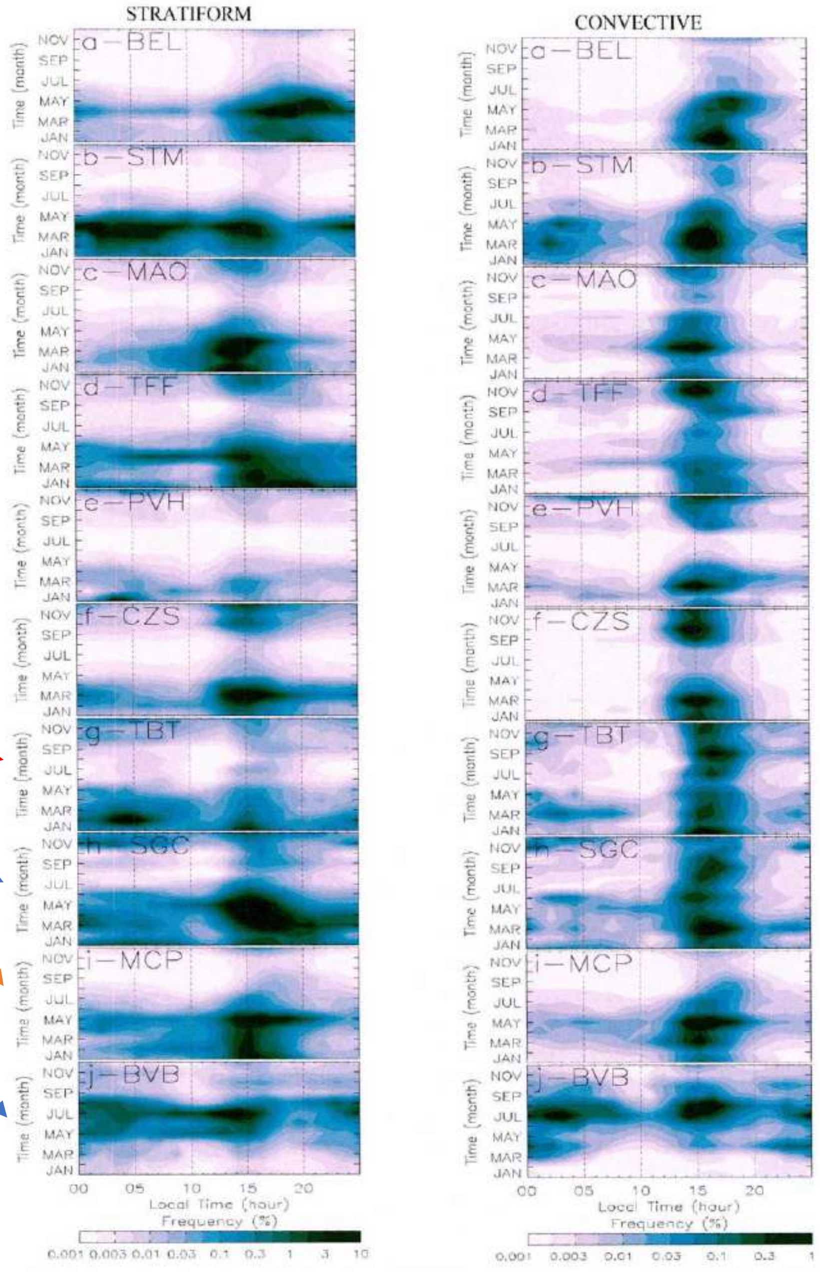


FIG. 6. Annual and diurnal cycles by binned monthly and hourly relative frequency of occurrence of (left) stratiform and (right) convective fractions for the SIPAM radars: (a) BEL; (b) STM; (c) MAO; (d) TFF; (e) PVH; (f) CZS; (g) TBT; (h) SGC; (i) MCP; (j) BVB. Vertical dashed lines correspond to local time, every 5 h.

Wind regimes: easterlies and westerlies

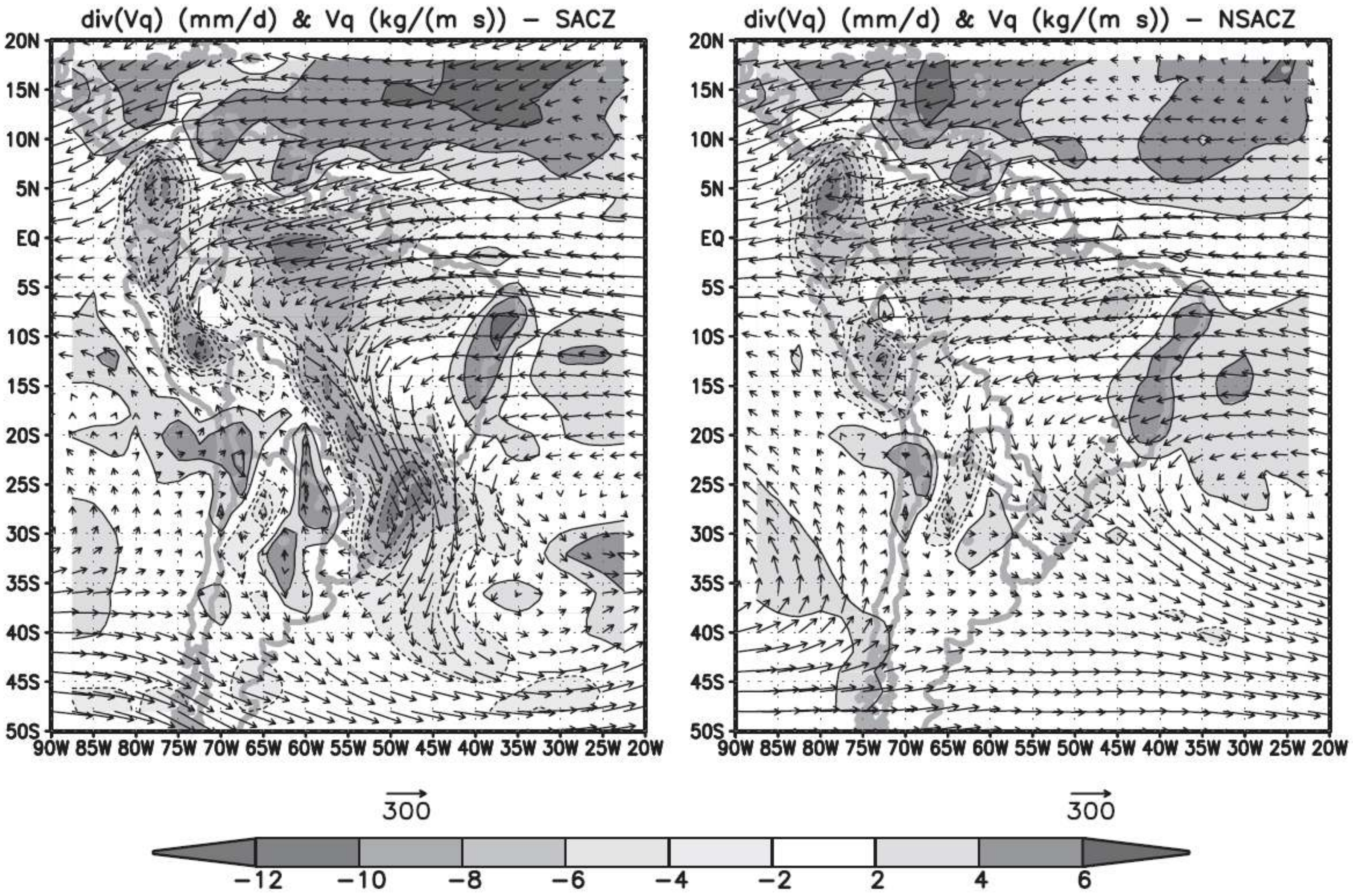
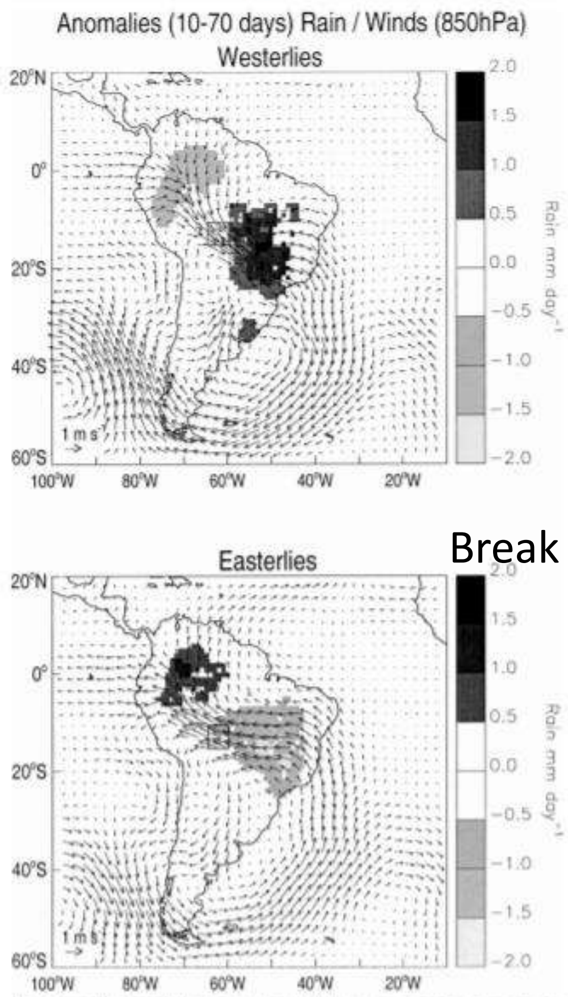


Figure 5. Vertically integrated regional moisture flux (vectors) and moisture flux divergence (shaded) for (a) SACZ period and (b) NSACZ period from GEOS-2 data set. The units for vectors is kg/(ms) and divergence in units of mm/day.



Break phase

FIG. 7. Composites of rainfall (shading) and wind (850 hPa) anomalies during (top) westerly and (bottom) easterly wind regimes. Only rainfall anomalies significant at 95% level are indicated.

Rainfall Rate (mm/hr)

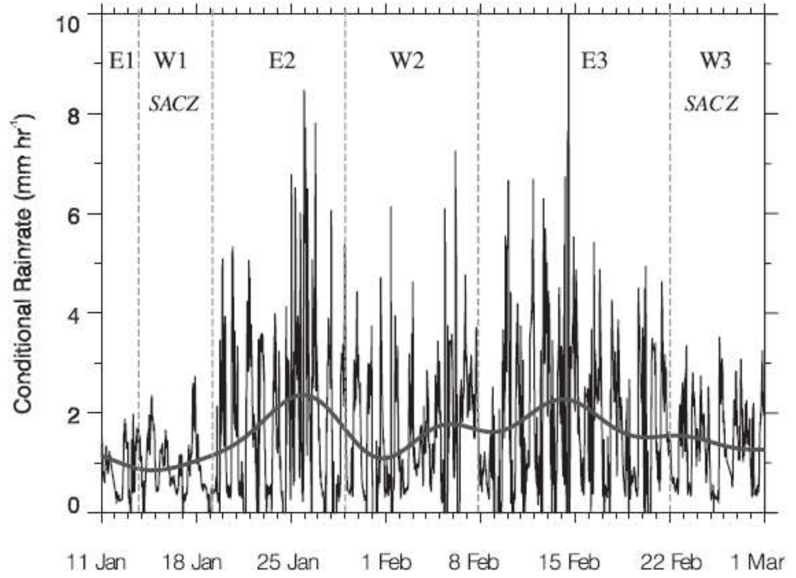


Figure 8. Time series of conditional rainfall intensity (mm hr^{-1}), from TOGA radar data. Thick line is the time series with variations of less than 8 days removed. Regime periods are shown with dashed vertical lines and labels.

Rainfall Rate (mm/hr)

Rickenbach et al 2002

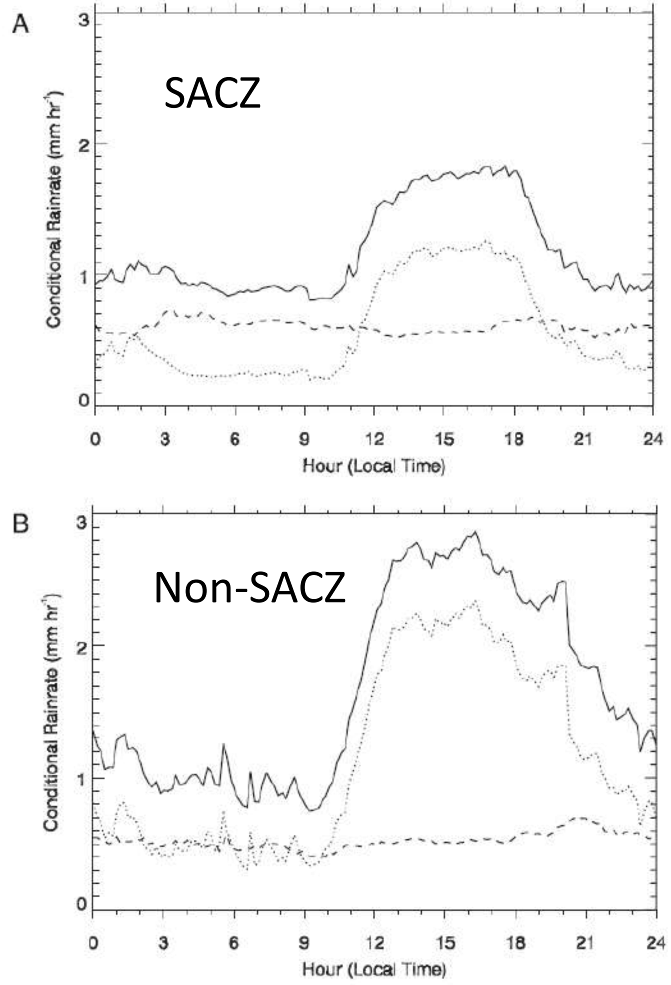


Figure 12. Diurnal variation of conditional rainfall rate (mm hr^{-1}) for (a) the SACZ regime and (b) the non-SACZ regime. Solid line is total rain, dotted line is convective rain, and dashed line is stratiform rain.

Anagnostou &Morales 2002

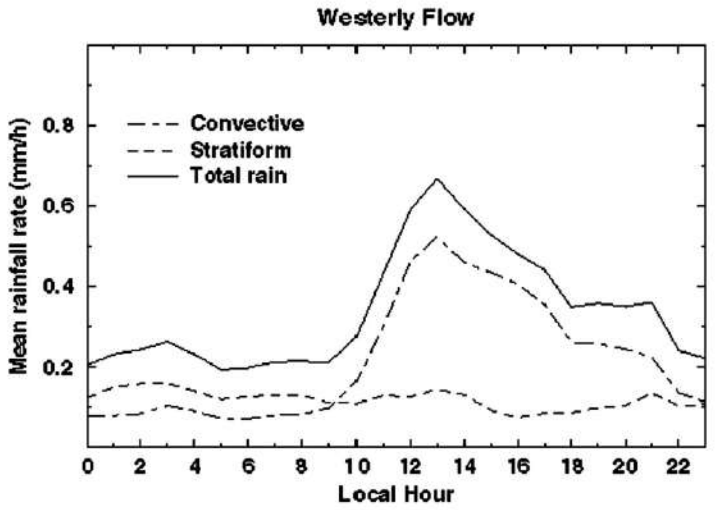
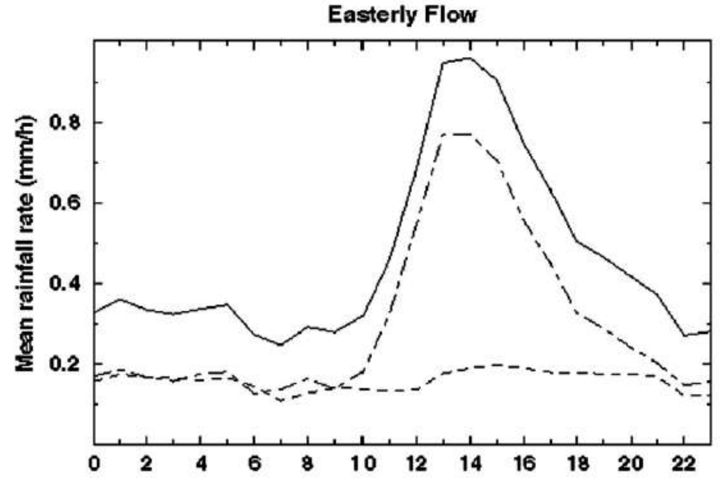


Figure 11. Mean diurnal cycle of convective, stratiform, and total rainfall for easterly (upper panel) an westerly (lower panel) regimes.



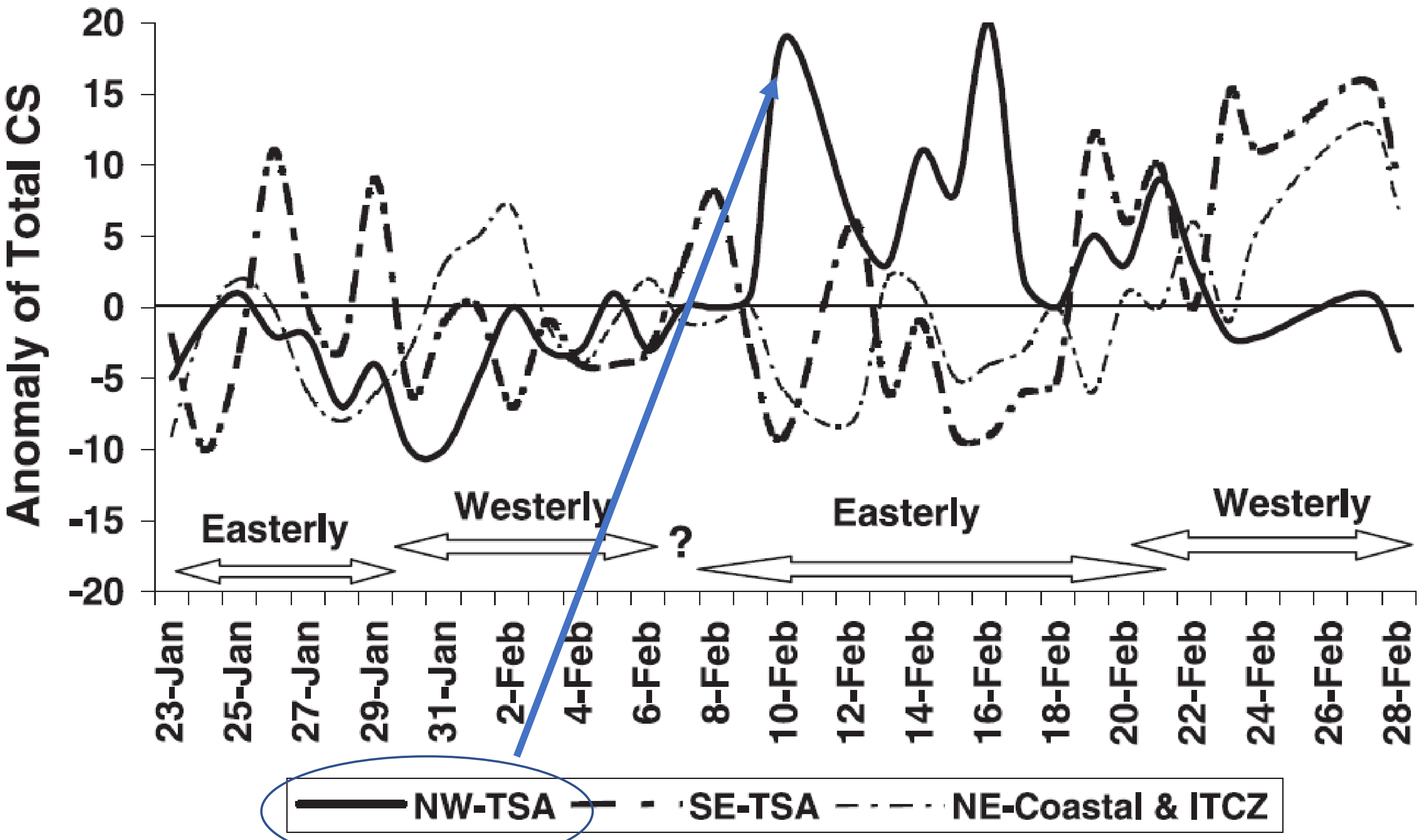
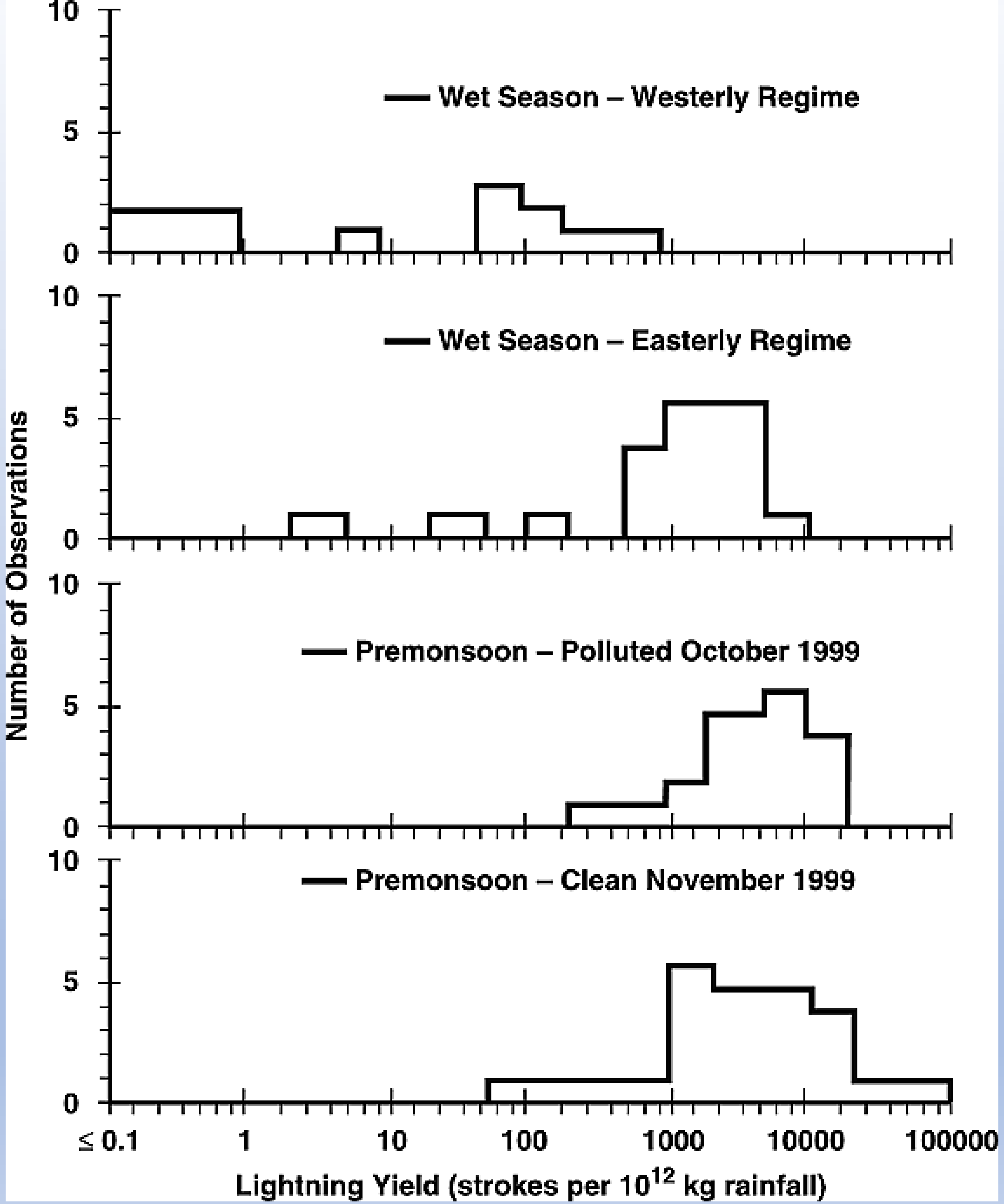


Figure 7. Daily anomaly of total CS in the TSA-Dipole and NE-Coastal and ITCZ during the TRMM-LBA campaign (from 23 January to 28 February). Periods with Easterly Westerly anomalies (10–70 days) are indicated with rows on the abscissa. The symbol ‘?’ indicates there was no anomaly in that date.

Williams et al 2002

Easterly regime has more lightning thans westerly regime:

More vigorous convection during breaks of the monsoon season

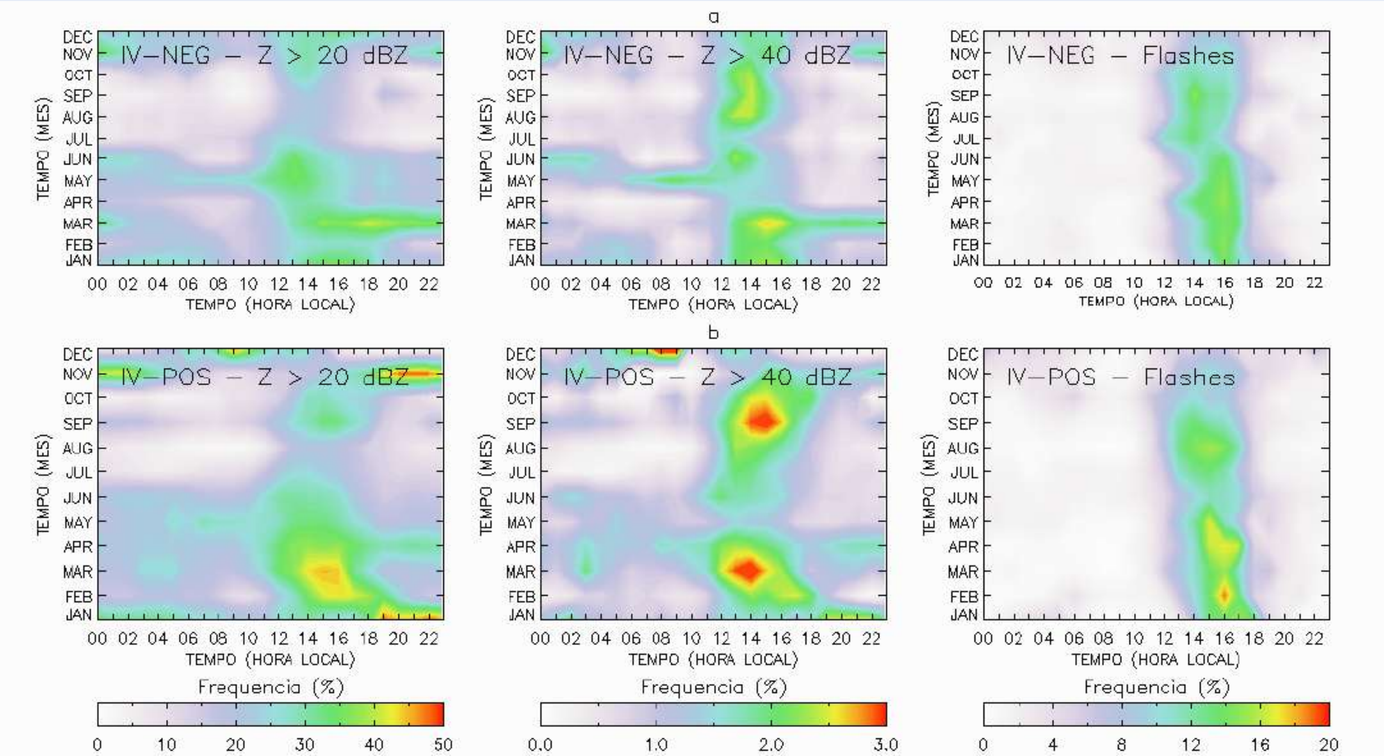


Work in progress: northerly and southerly winds impact rainfall – Saraiva et al (use V-Index from Wang and Fu 2002)

São Gabriel da Cachoeira

V-Index negative Winds from the North

V-Index positive Winds from the South



Mesoscale Convective Systems
Mesoscale Cyclonic Vortices

- Durkee and Mote 2010
- Quadro (2012)
- Quadro et al (2016)
- Laurent and Machado (2002)
- Rehbein et al 2017, 2019

Mesoscale Convective Complexes (MCC)

Velasco and Fritsch 1987

Years 1982-1983

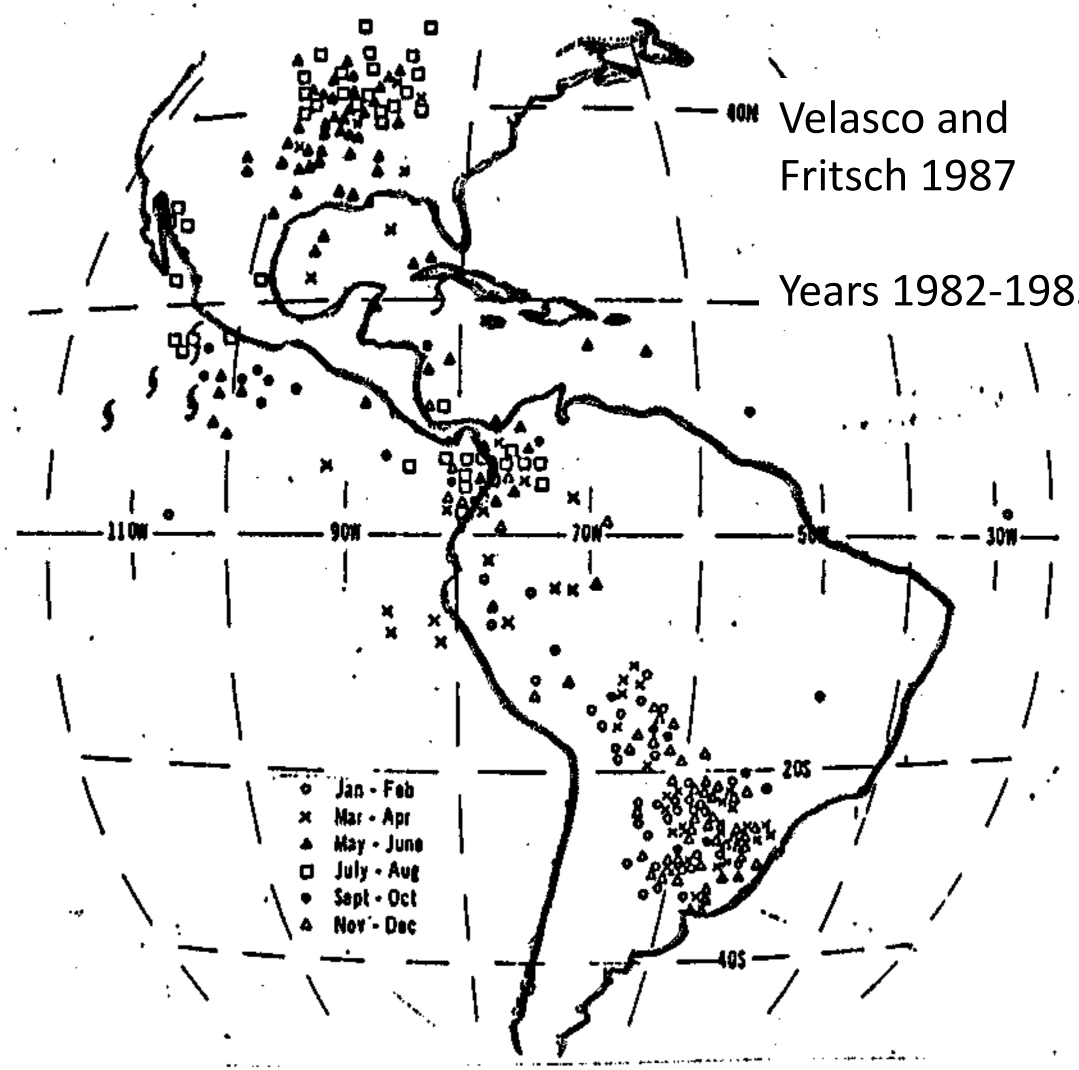
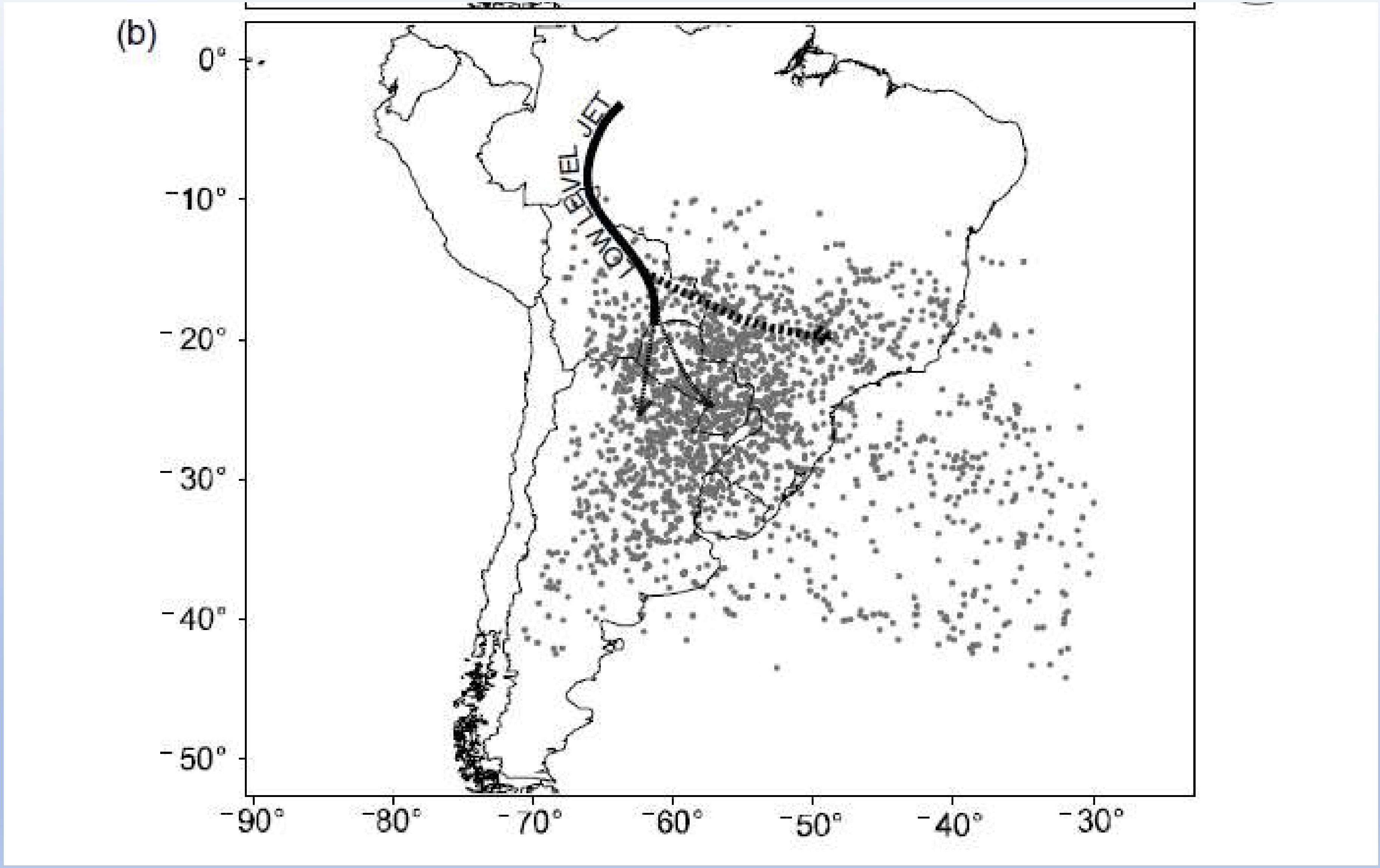
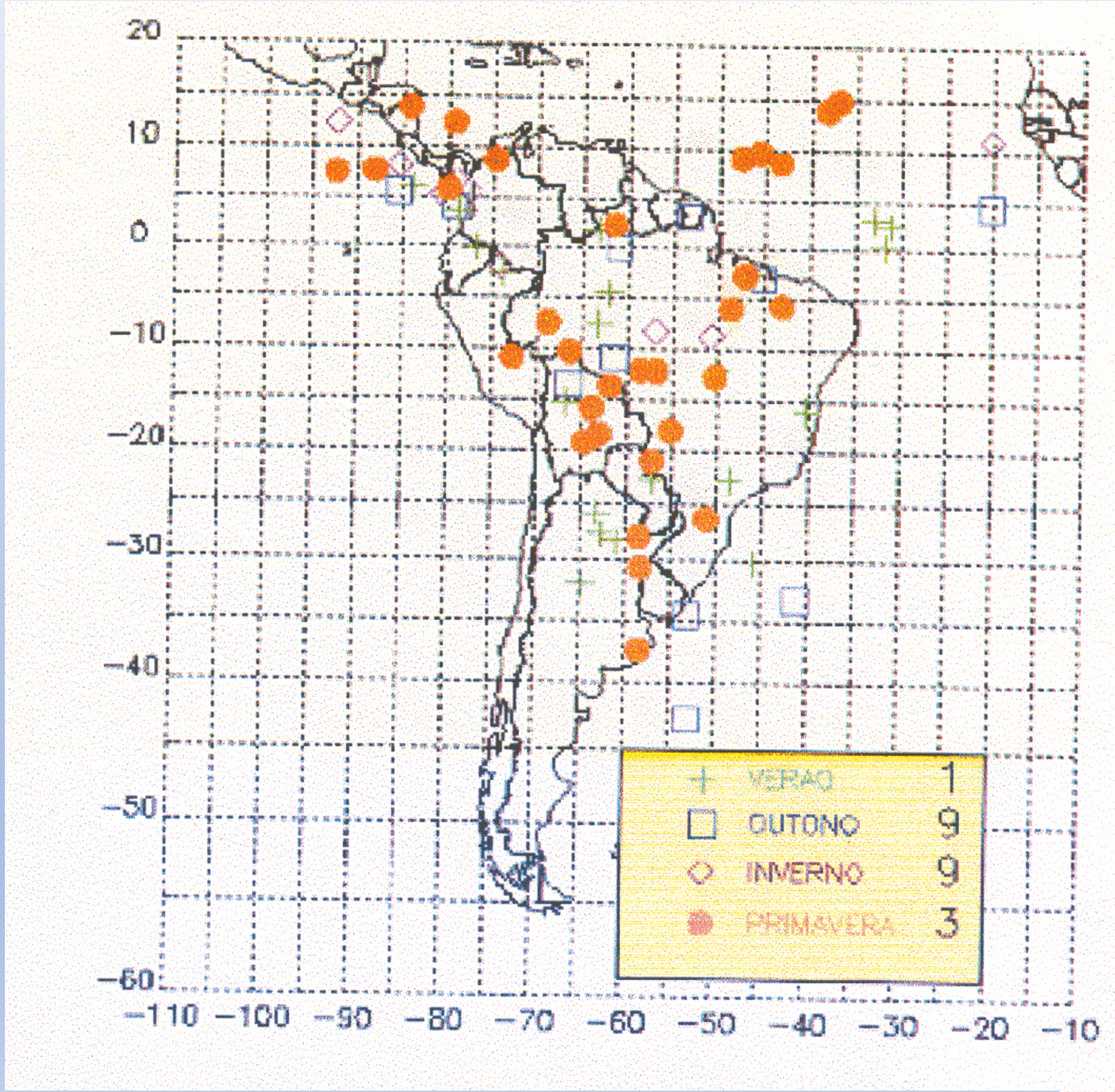


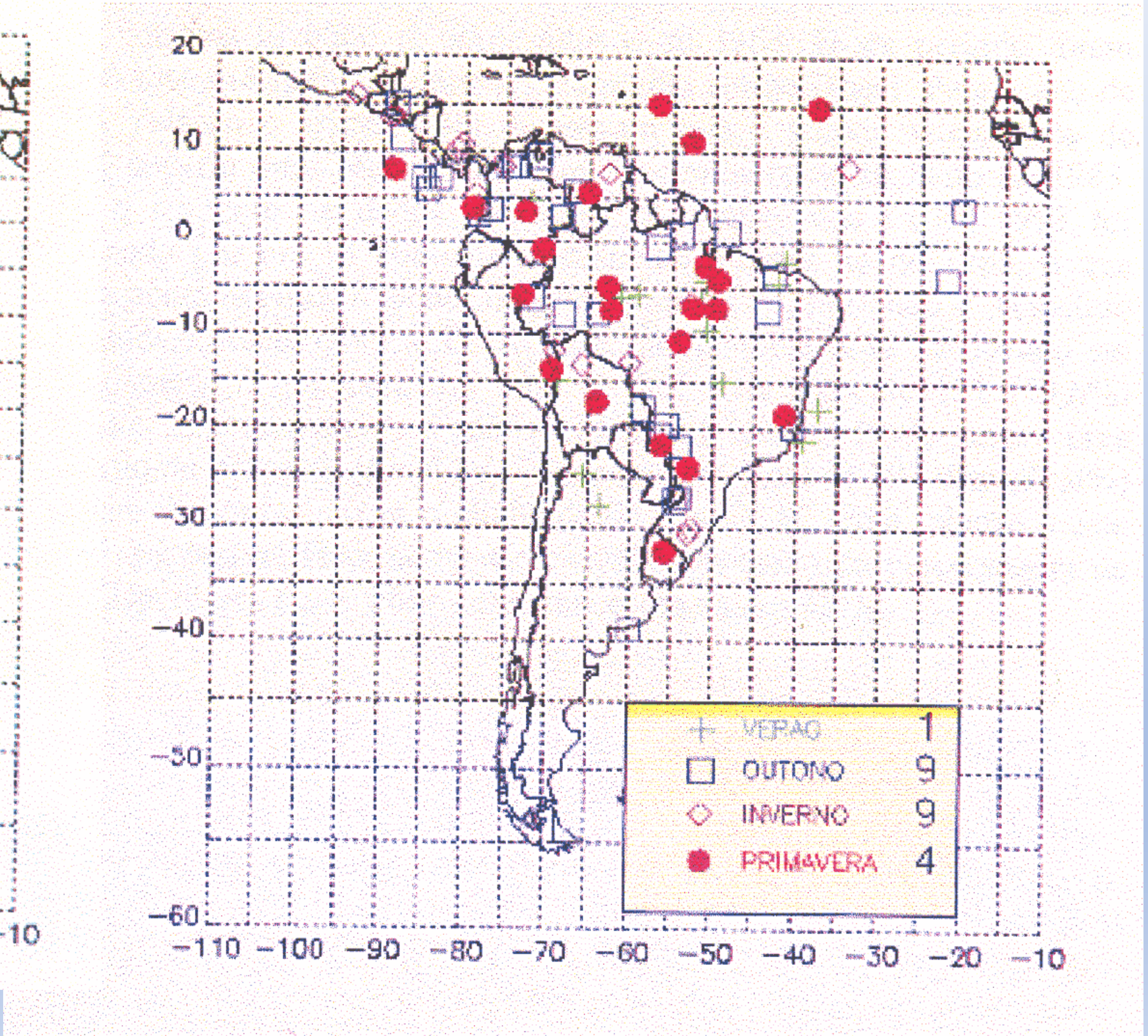
Fig. 8 Geographic and monthly distribution of MCC in and around the Americas. Locations are for the MCC cold-cloud shield at the time of maximum extent. Hurricane symbols indicate an MCC that developed into a tropical storm. Systems that were first a tropical storm and then an MCC are not shown (from Velasco and Fritsh, 1987).

Mesoscale Convective Complexes
October – May
1998-2007
Durkee and Mote 2010



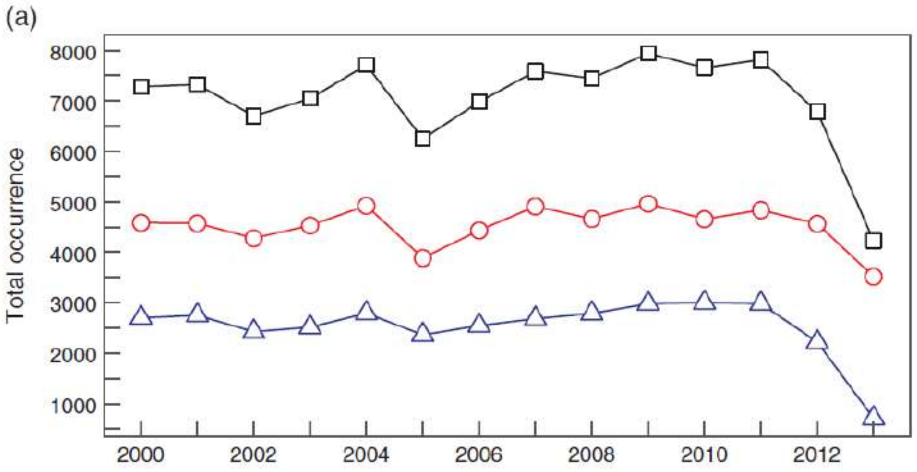
Conforte, 1997 Mesoscale Convective Complexes Years 1993-1994





Mesoscale Convective Systems - MCS

Rehbein et al 2017



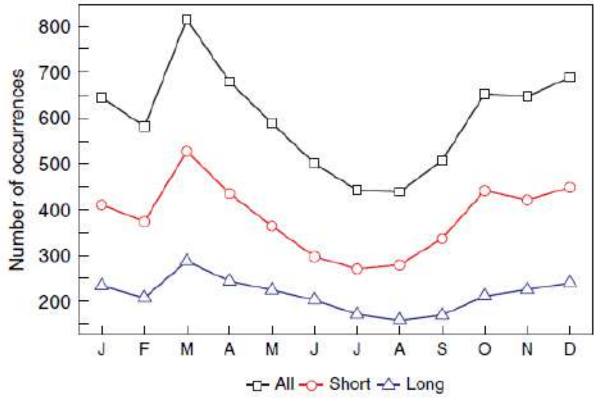


Figure 2. Monthly distribution of continental MCSs along the Amazon basin according to their lifecycles. The black colour represents MCSs with all lifespans, red with short lifespan and blue with long lifespan.

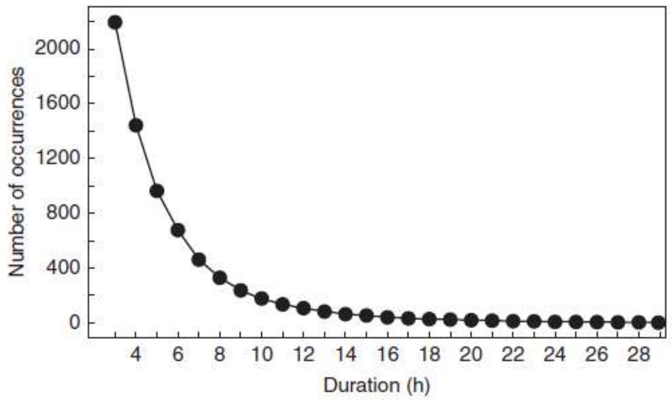


Figure 3. Occurrences of continental MCSs according to their lifecycles.

Rehbein et al 2017

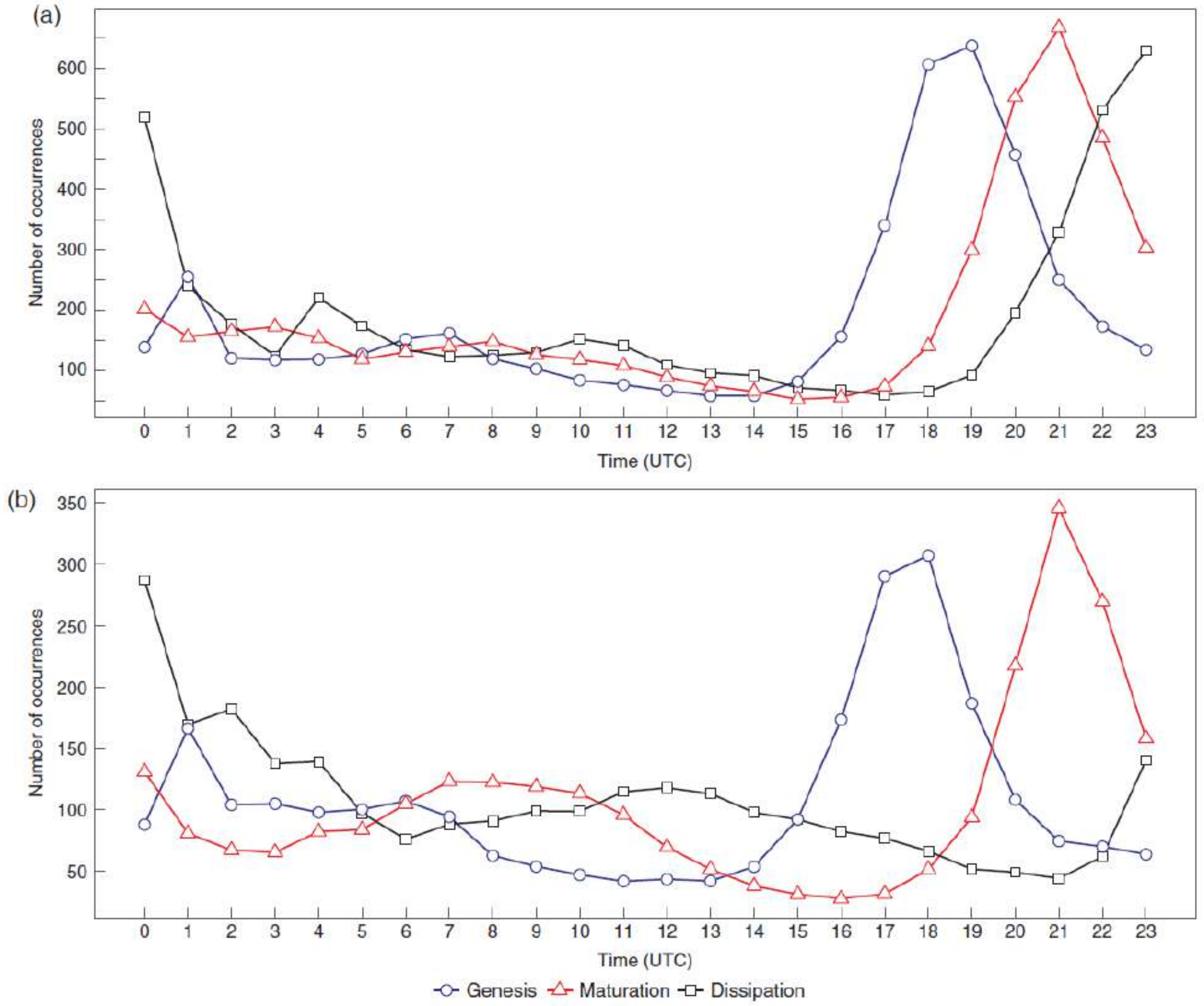
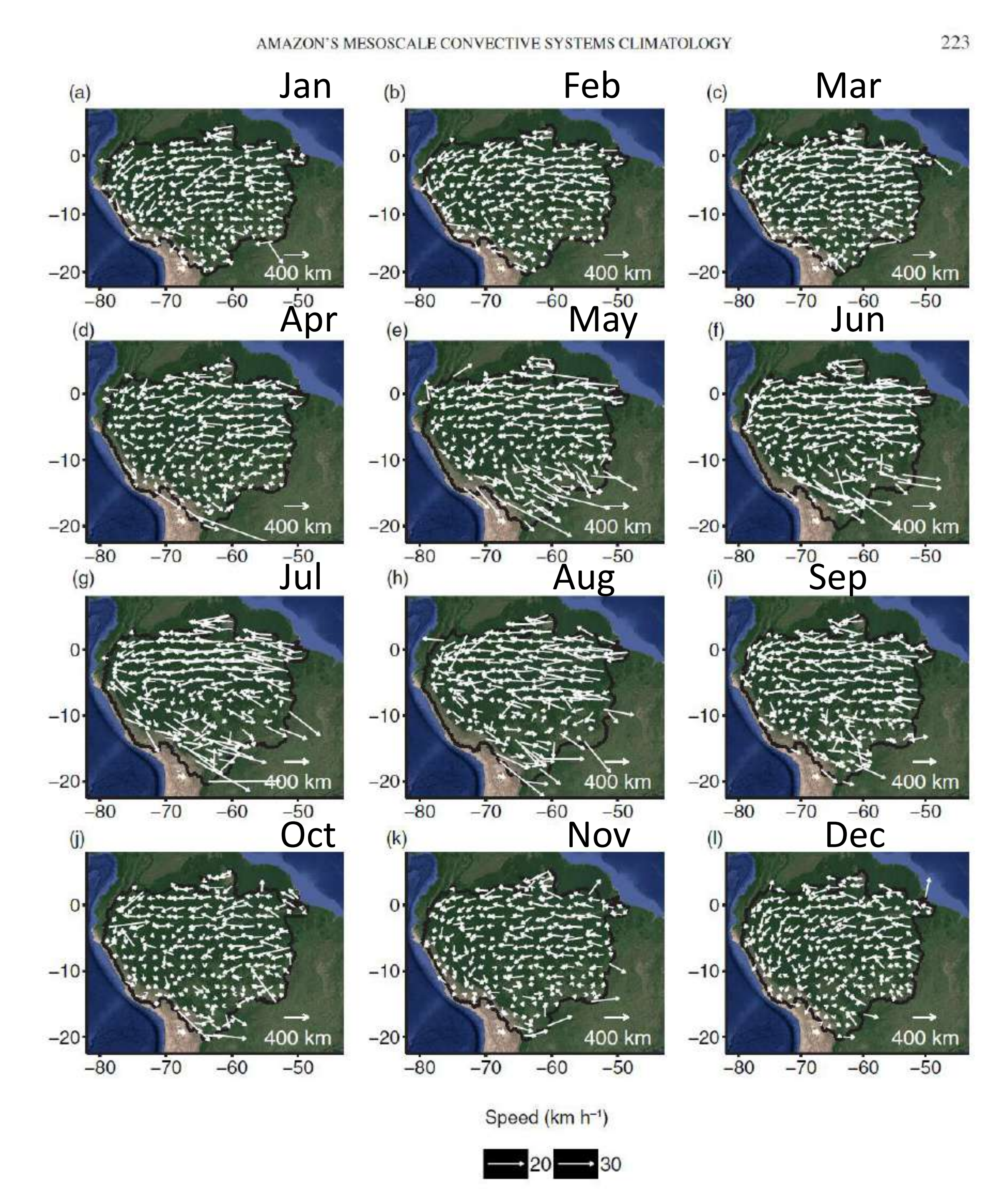


Figure 4. Time of genesis, maturation and dissipation of MCSs with (a) short lifespan and (b) long lifespan. [Colour figure can be viewed at wileyonlinelibrary.com].

Rehbein et al 2017

Long lived MCS Velocity is the thickness of the arrow, trajectory is given by the arrow length



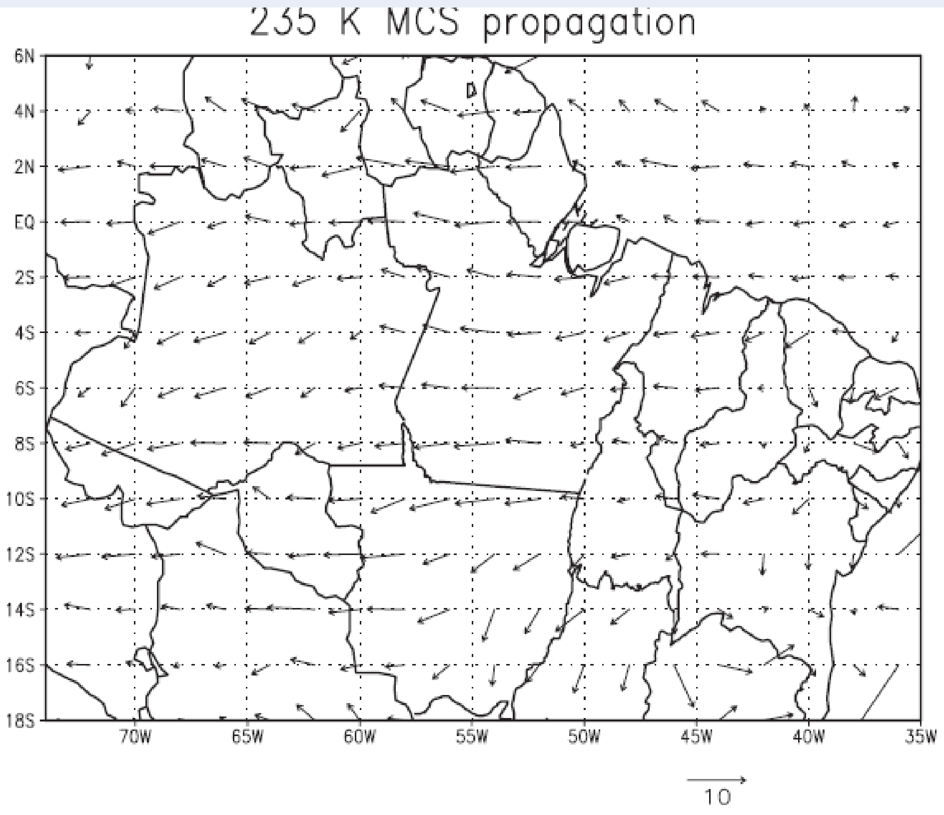


Figure 5. Mean MCS propagation (ms^{-1}) for threshold 235 K, period of 11 January–27 February 1999. Solid line indicates the state boundaries.

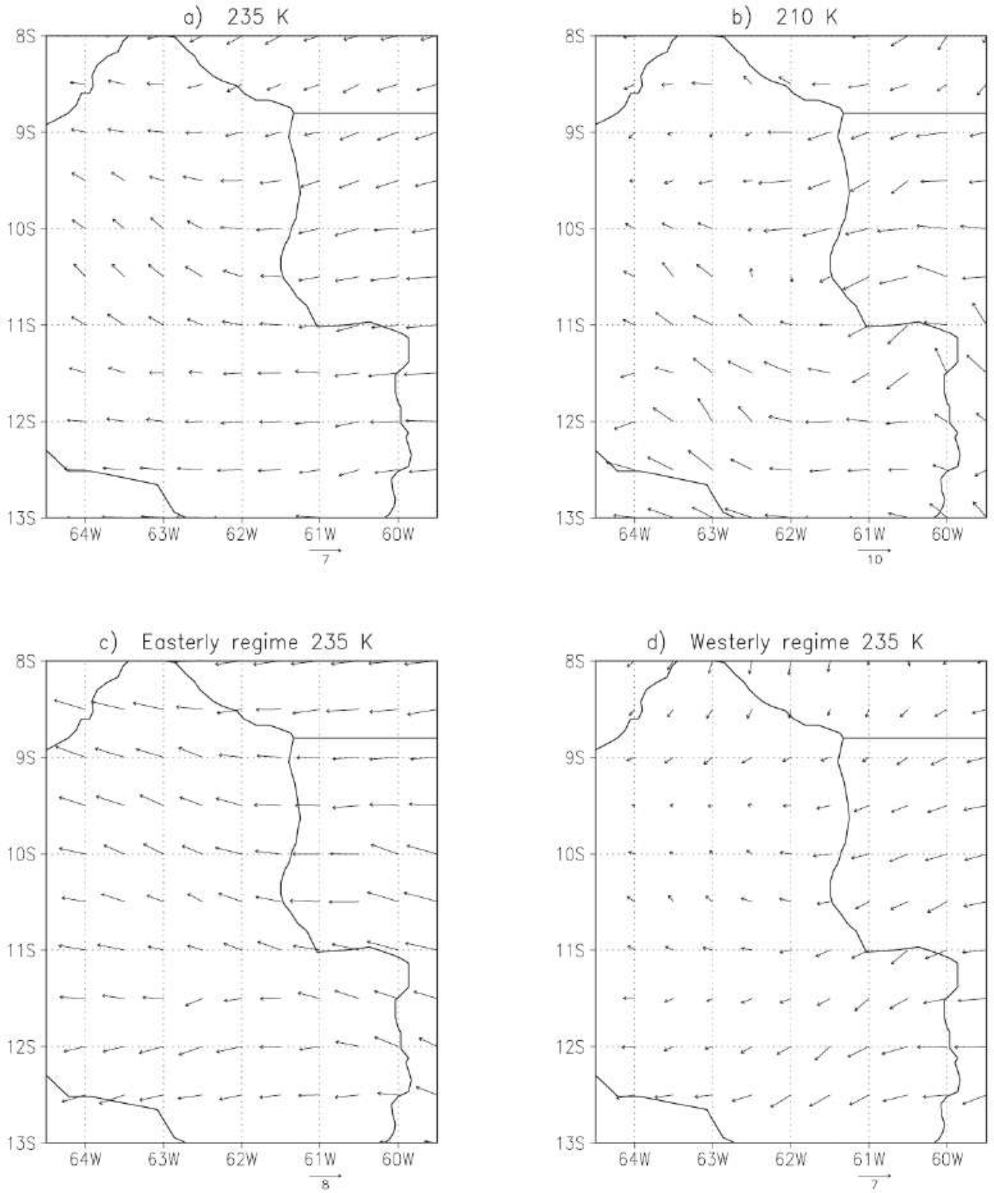


Figure 11. Mean MCS propagation (ms^{-1}) between 11 January and 27 February 1999 for a) threshold 235 K and b) threshold 210 K. c) Same as a) but for the Easterly regime. d) same as a) but for the Westerly regime. The solid line indicates the state boundaries.

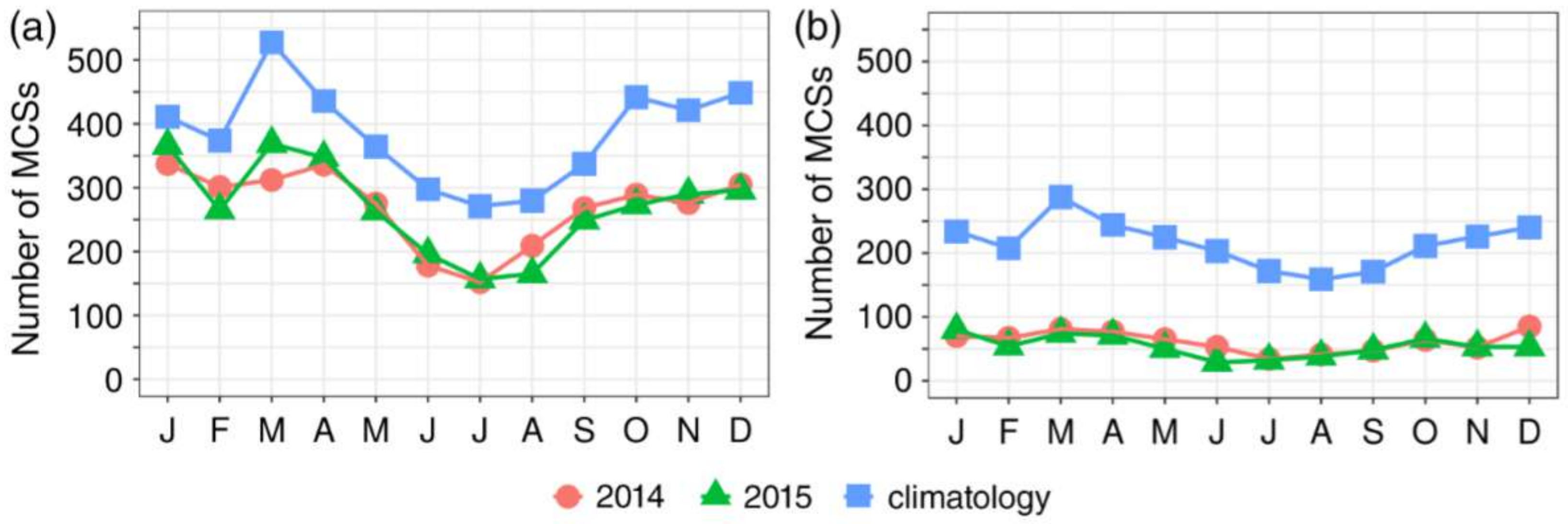


FIGURE 3 Monthly distribution of the continental MCSs occurred over the Amazon basin. In (a) MCSs with short lifespans (3 to 5.5 hr), and (b) MCSs with long lifespans (6 hr or more). The pink lines represent 2014, the green lines 2015, and the blue lines the climatological MCSs' occurrences. Climatological MCSs data from 2000 to 2013 are from Rehbein *et al*. (2017) [Colour figure can be viewed at wileyonlinelibrary.com]

Mesoscale Cyclonic Vortices

Quadro et al 2016

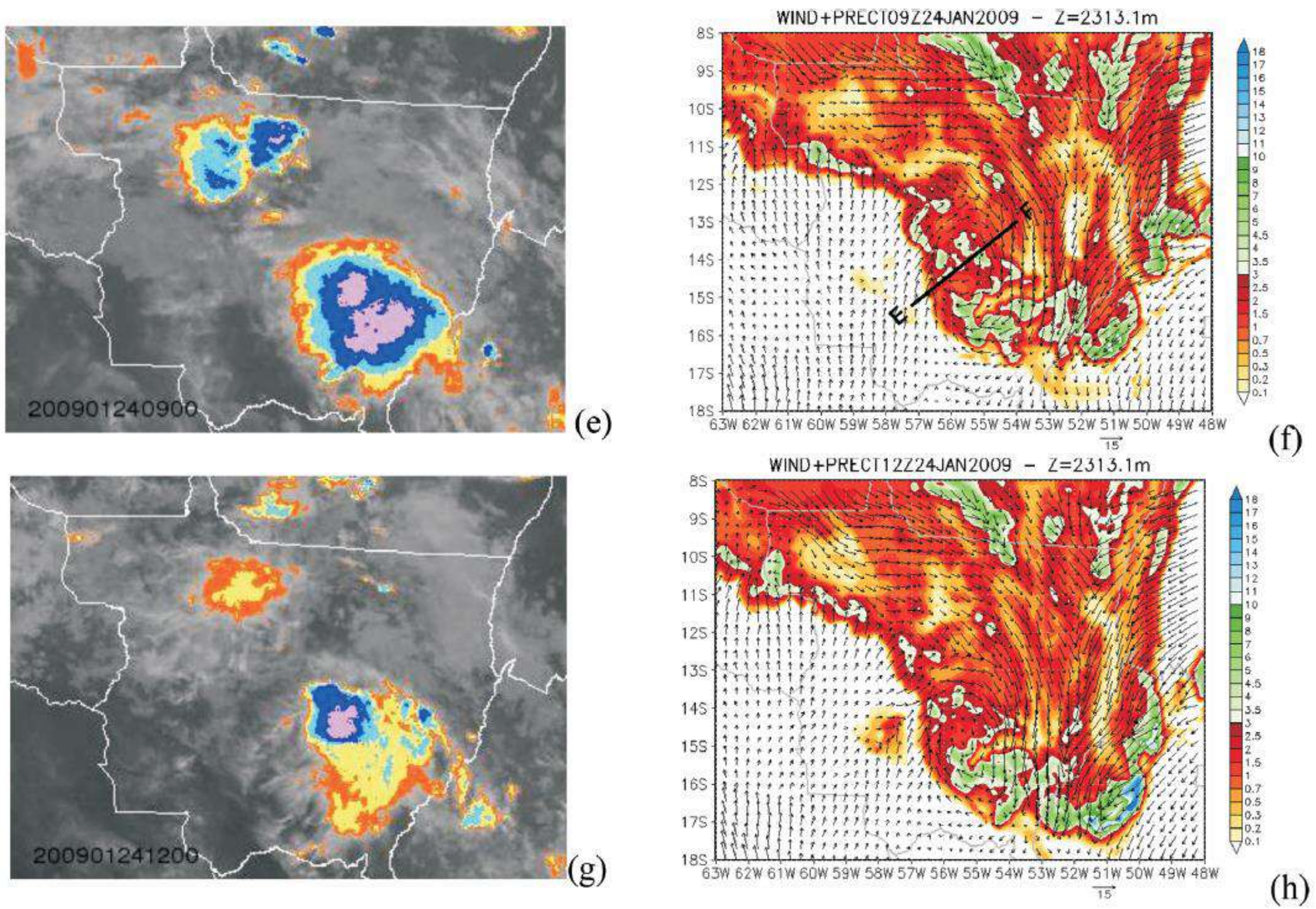


Figura 2 (cont.) - Imagem realçada do canal infravermelho do satélite GOES-10 e simulação do modelo BRAMS do campo de vento ($m.s^{-1}$) na altura de 2313,3 m e precipitação (mm) acumulada horária para 21Z do dia 23 (a e b), 03Z (c e d), 09Z (e e f) e 12Z (g e h) do dia 24 de janeiro de 2009. Os segmentos de reta nos painéis das simulações indicam setores ao longo dos quais serão feitas seções verticais na Figs. 4 e 5.

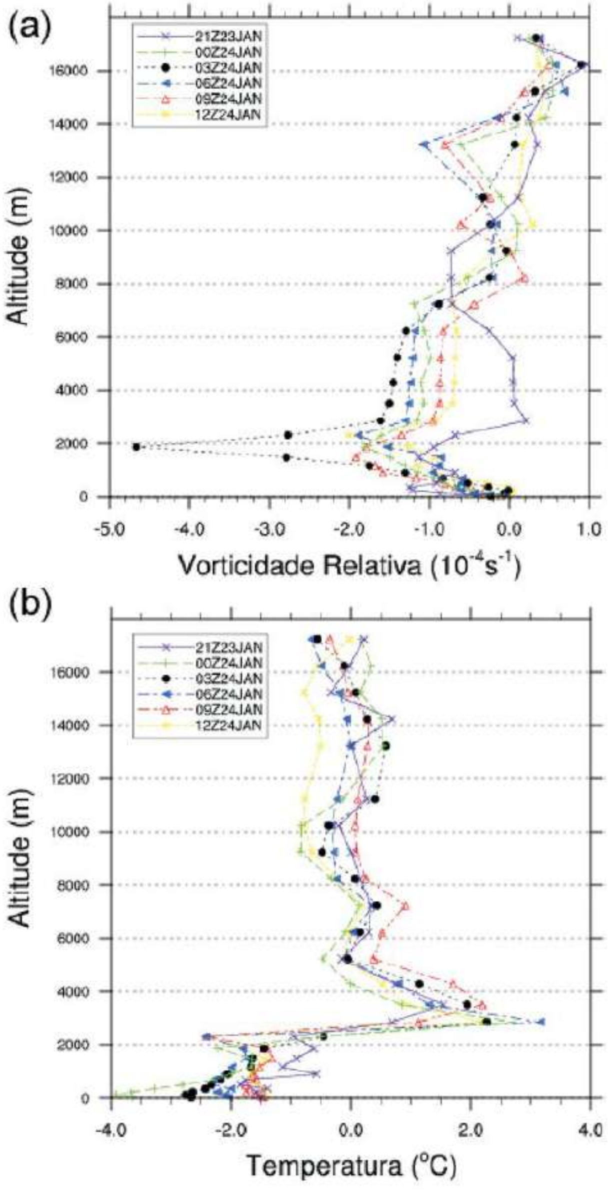


Figura 3 - Perfil vertical de (a) vorticidade relativa (10^{-4} s^{-1}) e (b) anomalia de temperatura (°C) em relação a média zonal no ponto central do mesovórtice as 21Z de 23 de janeiro, 00Z, 03Z, 06Z, 09Z e 12Z de 24 de janeiro de 2009.

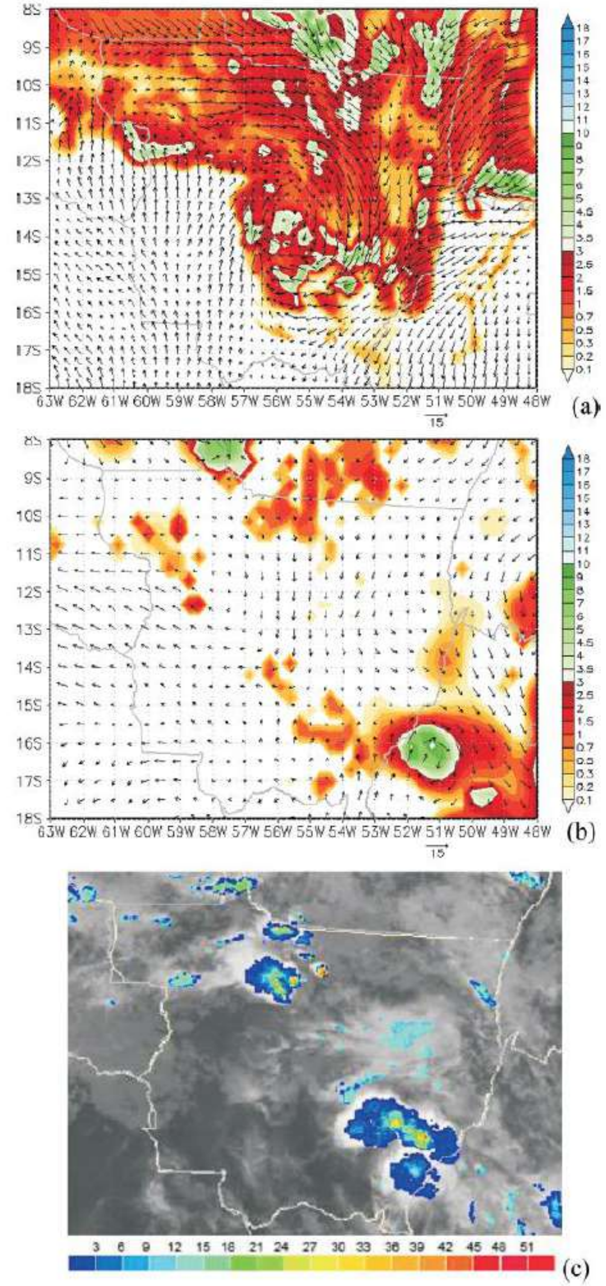
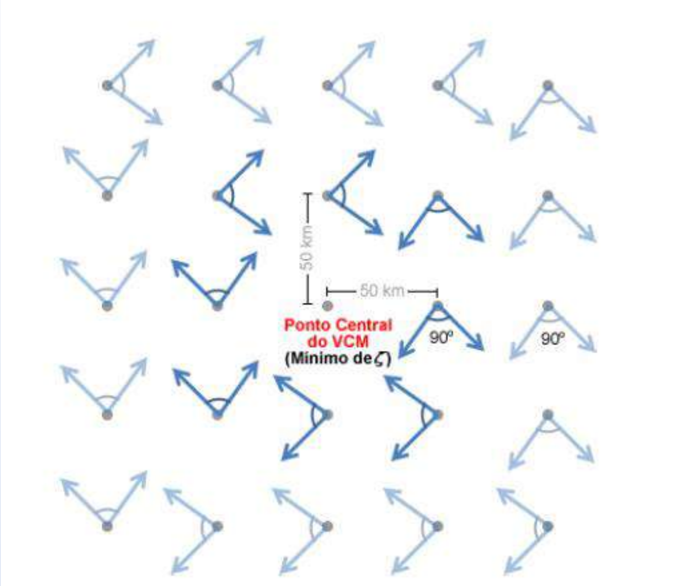


Figura 9 - Comparação entre os campos de vento ($m.s^{-1}$) e precipitação (mm) acumulada horária do modelo BRAMS na altitude de 2313 m (a), da reanálise CFSR do NCEP em 800 hPa (b) e do produto HIDROESTIMADOR (c) para as 06Z do dia 24 de janeiro de 2009.

Automatic detection algorithm using CFSR

1. Select days with SACZ
2. Within the SACZ cloudy region, and for each p-level, select grid point with minimum relative vorticity
3. Check for cyclonic circulation around selected grid point
4. Check that grid points around center are cloudy



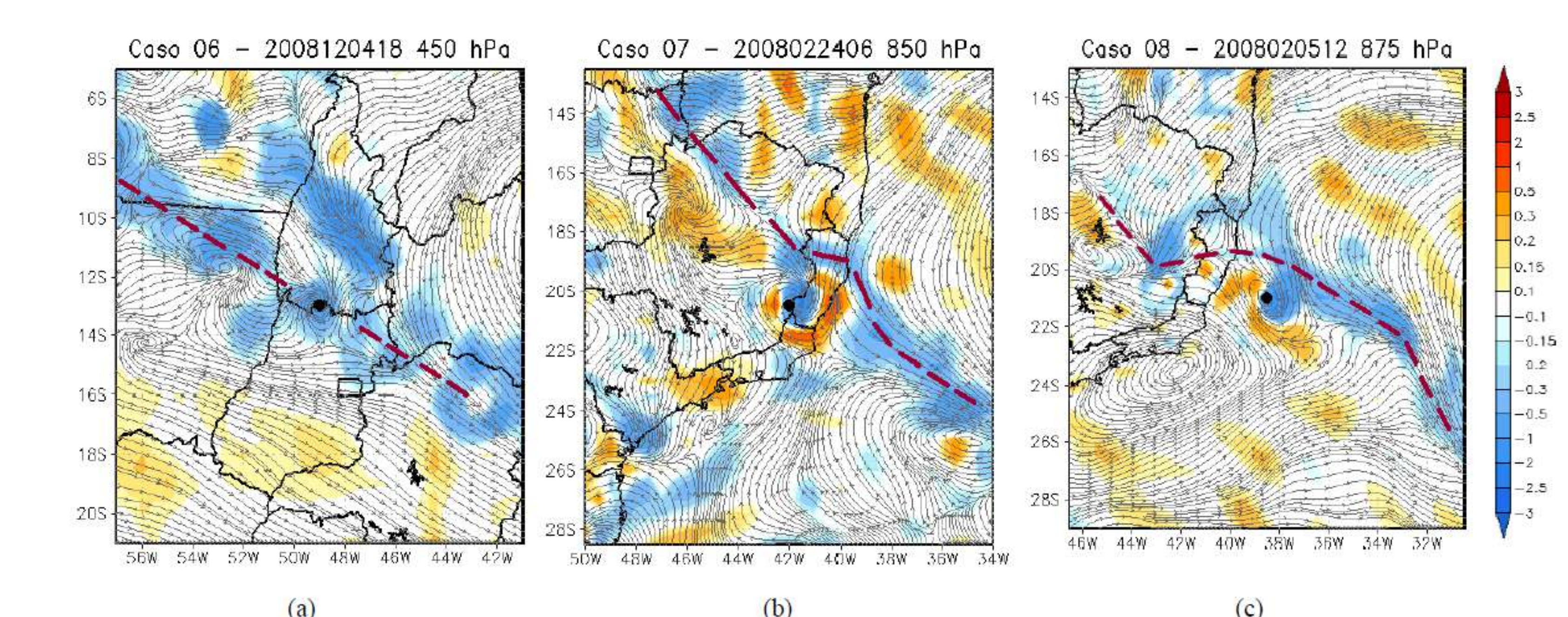
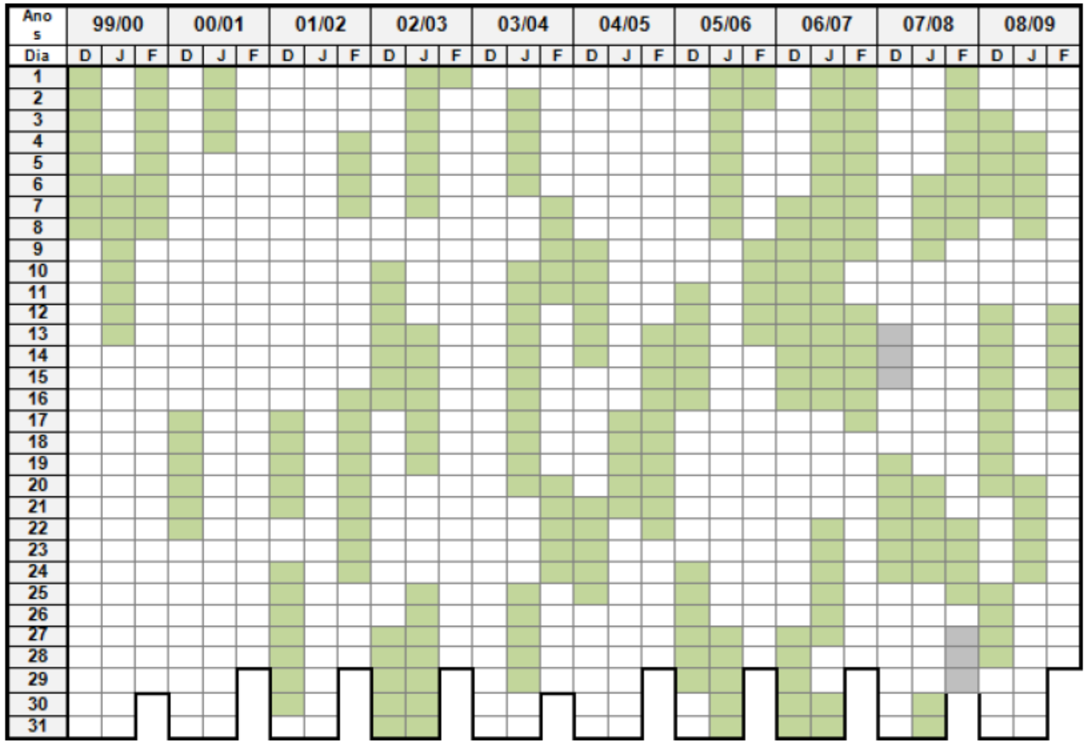


TABELA 3.2 - PERÍODOS SELECIONADOS DE EPISÓDIOS DE ZCAS NA REANÁLISE NCEP CFSR ENTRE OS ANOS DE 2000 A 2009*

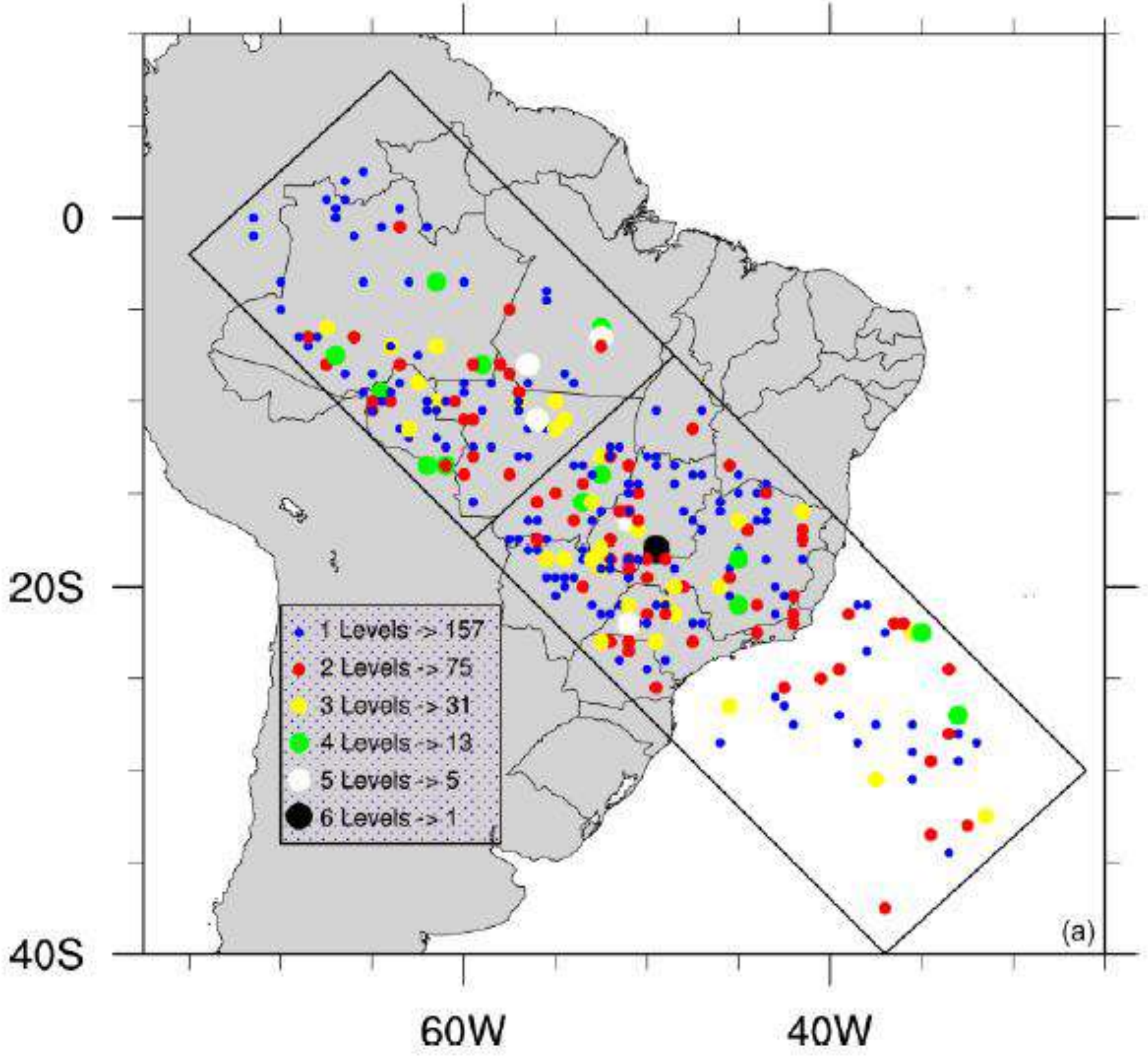


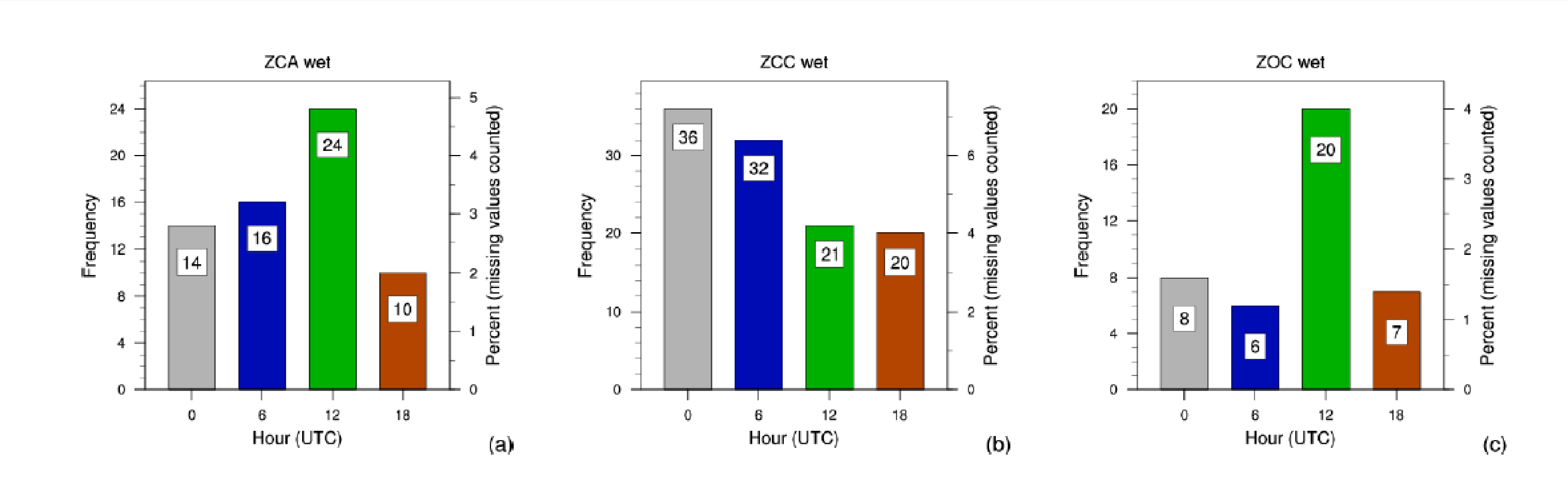
* as regiões hachuradas em verde representam episódios de ZCAS selecionados pelo Boletim Climanálise, as áreas hachuradas em cinza representam casos que não foram incluídos neste estudo em função de sua duração ser menor de 3 dias.

MCV detected for 43 SACZ cases during DJF from 2000-2009 for levels between surface and 700 hPa

Colors indicated the number of contiguous pressure leves affected by the MCV

Quadro 2012

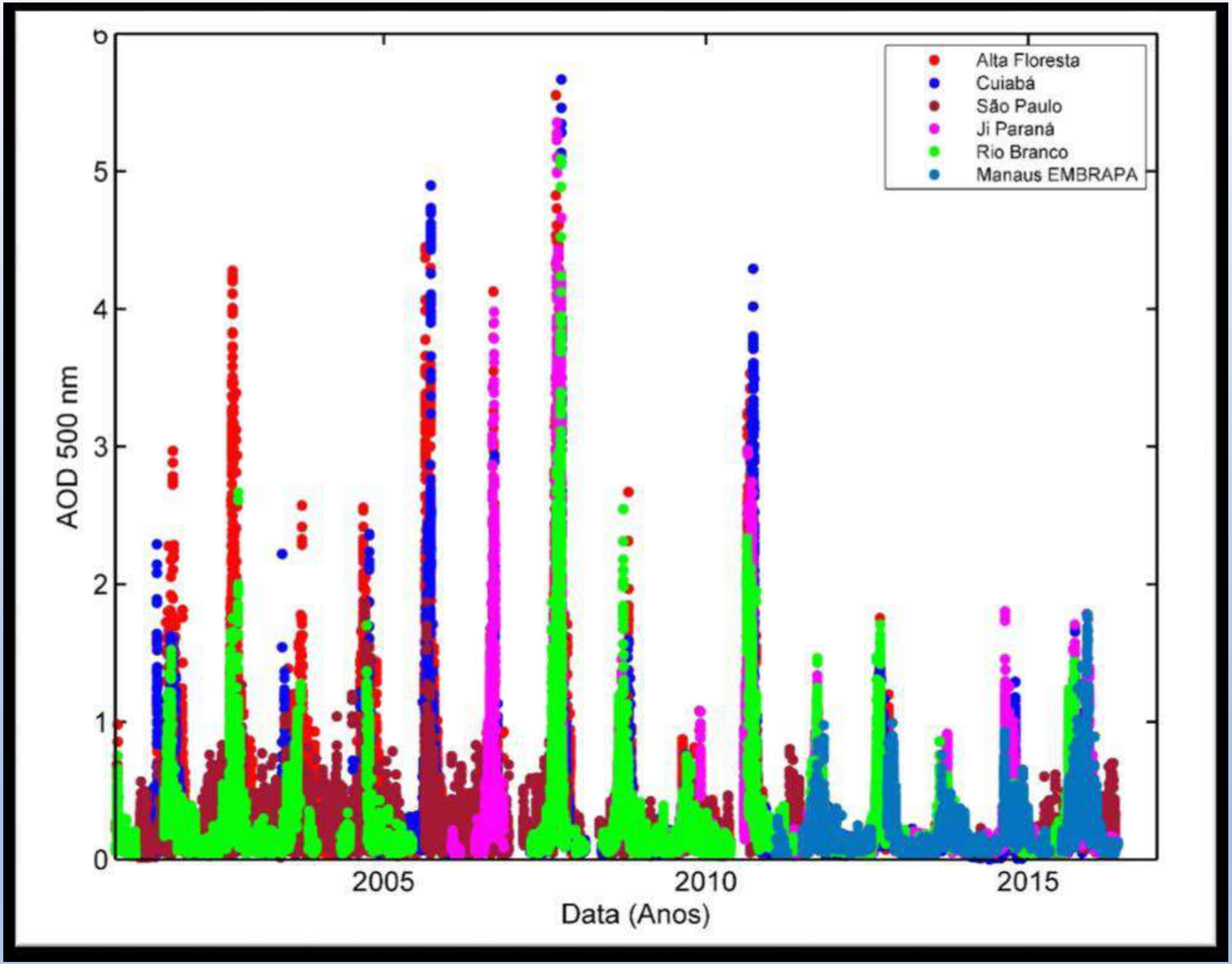




Number of Cases of detected low-level MCV during SACZ events from 2000-2009 as a function of UTC

Possible aerossol effects on rainfall

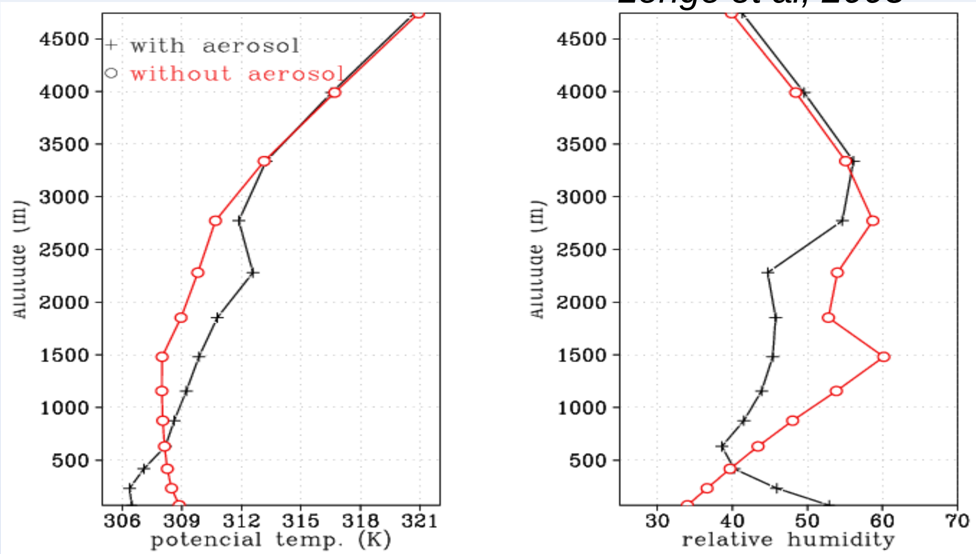
- Large scale dynamics
- Radiative effects
- Cloud microphysics effects



Time series of aerosol optical thickness measured from 2000 to 2017 using the AERONET sunphotometer network in several sites in Amazonia. AERONET Level 2 data with inversion algorithm 3.0. (Compilation done by Rafael Palácios, 2017)

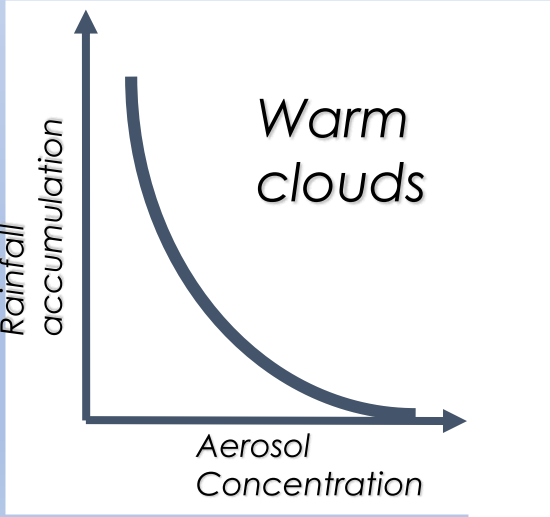
Aerosol effects

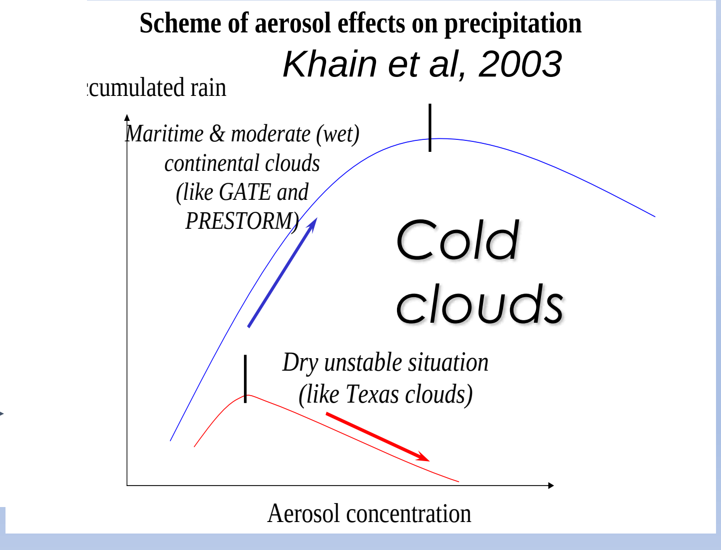
Longo et al, 2003



- Radiation
  - Radiation budget in aerosol layers
  - Colder surface, warmer lower troposphere =stabilizing effect – less clouds → less rainfall?

- Cloud microphysics
  - Cloud albedo
  - Cloud lifetime
  - Inhibit rainfall in warm clouds
  - Effect of concentration of CCN
  - Deep clouds





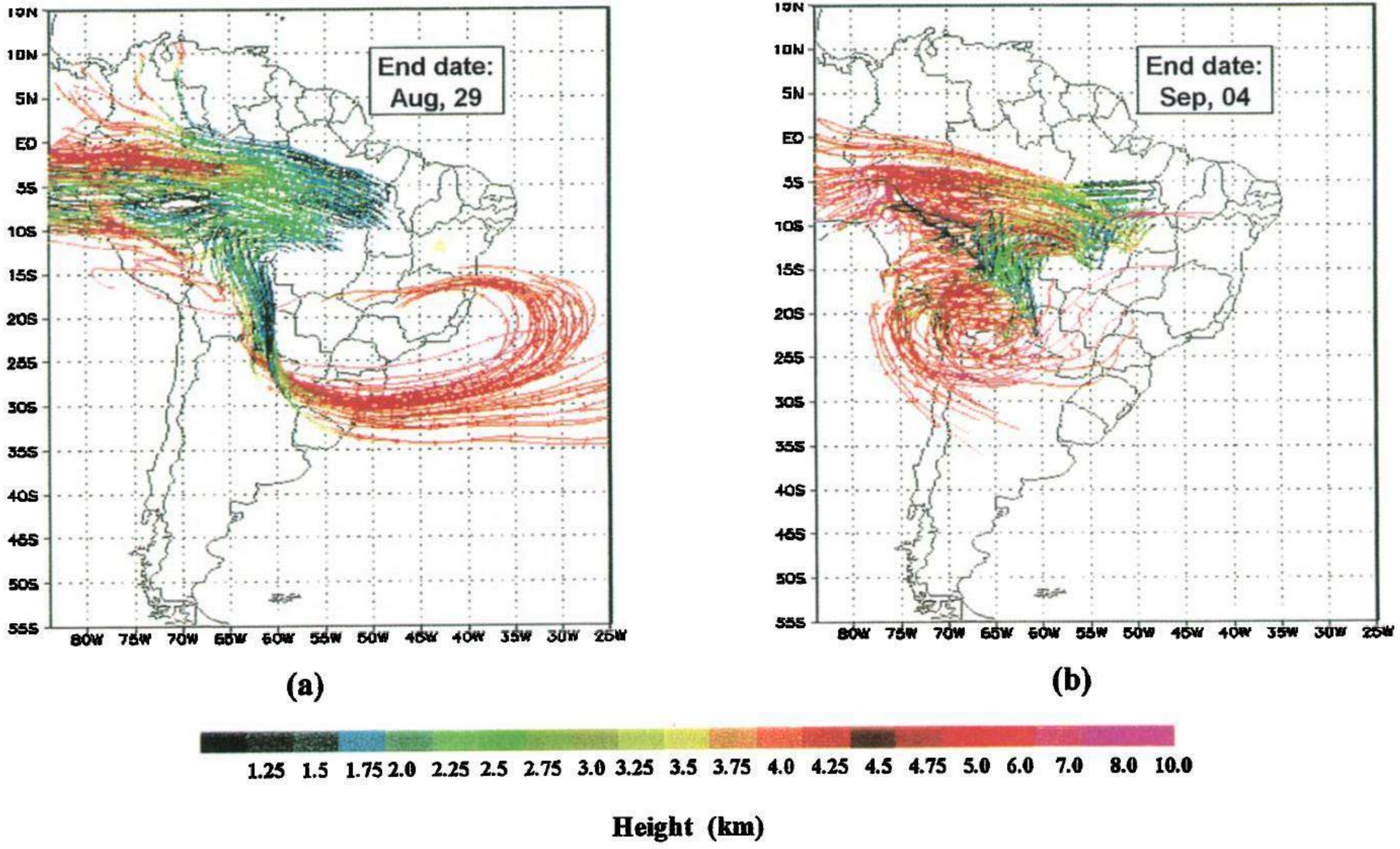
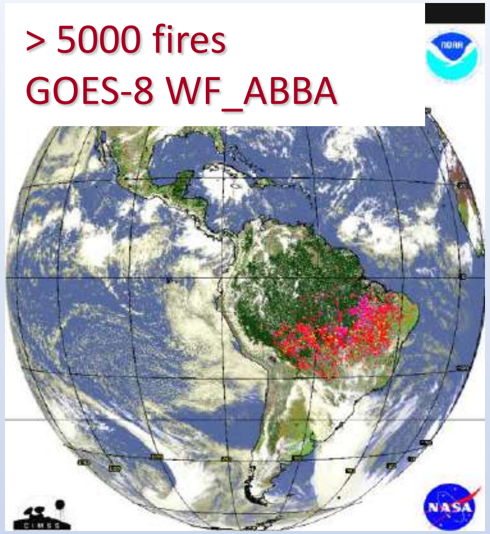


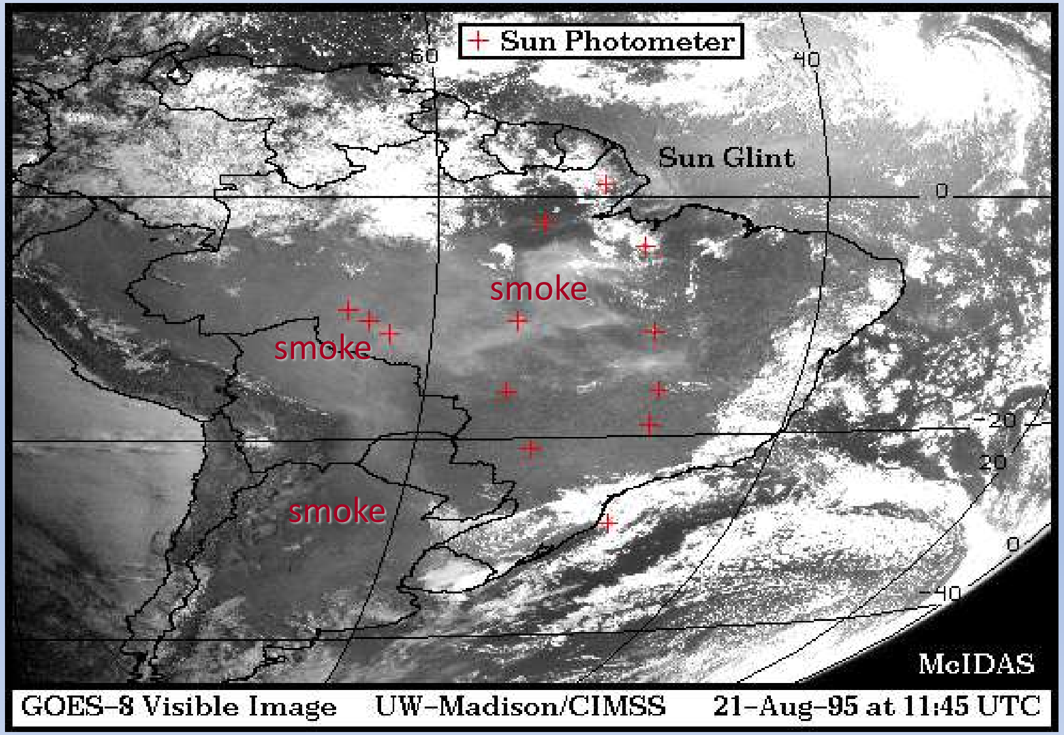
Plate 2. Clusters of 6-day forward trajectories originating from the main fire areas (described in Plate 1) at 700 hPa. Integration

Biomass Burning Emissions



Local smoke plume
(deforestation fires)

(picture from M. Andreae)



Regional smoke plume
~5 millions km^2
(Prins et al. 1998)

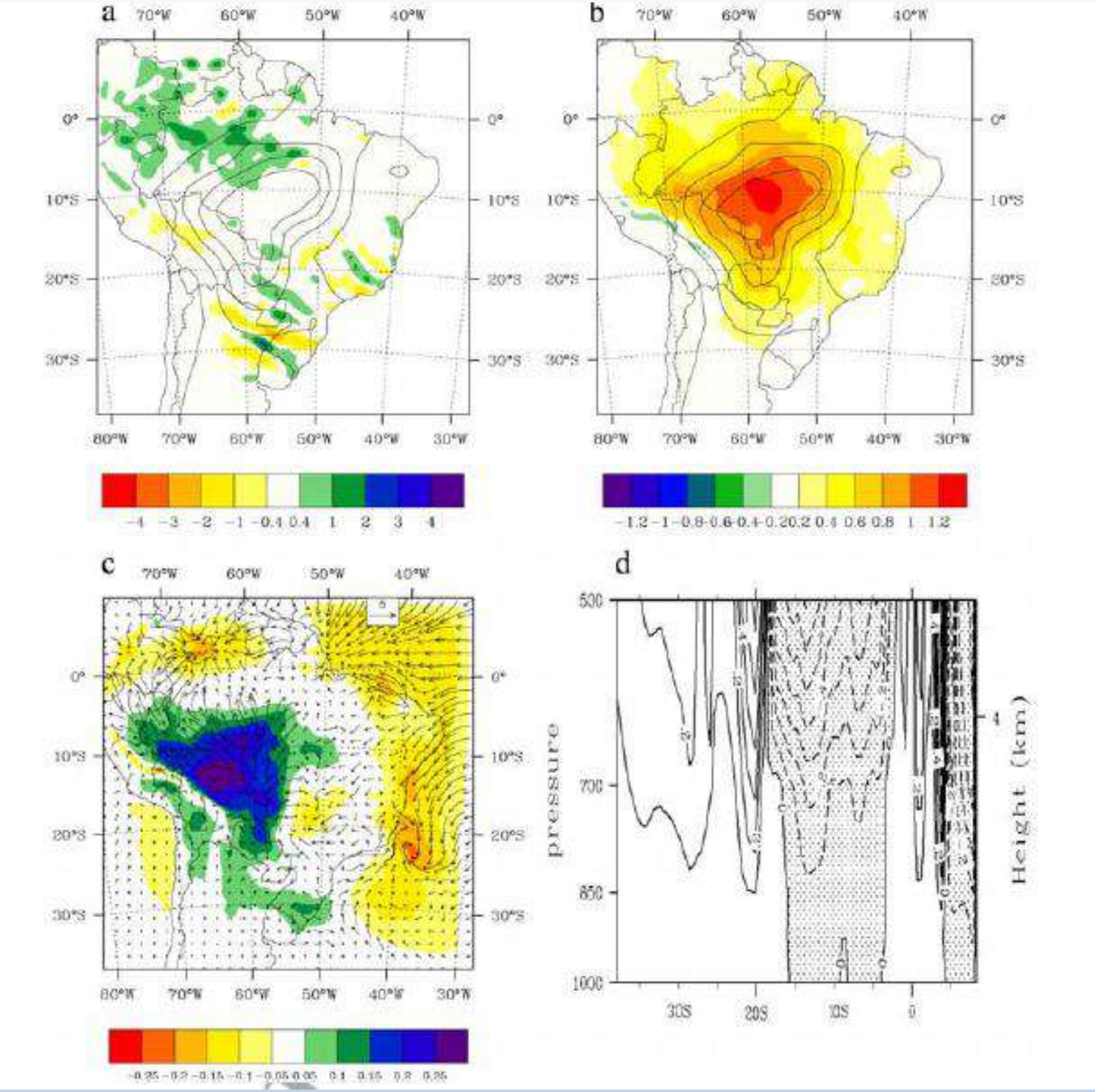
11:41

LARGE-SCALE DYNAMICS EFFECT OF BIOMASS BURNING PLUME – delay of the onset of the rainy season

Zhang et al 2009
Impact of biomass burning aerosol on the monsoon circulation transition over Amazon (GRL)

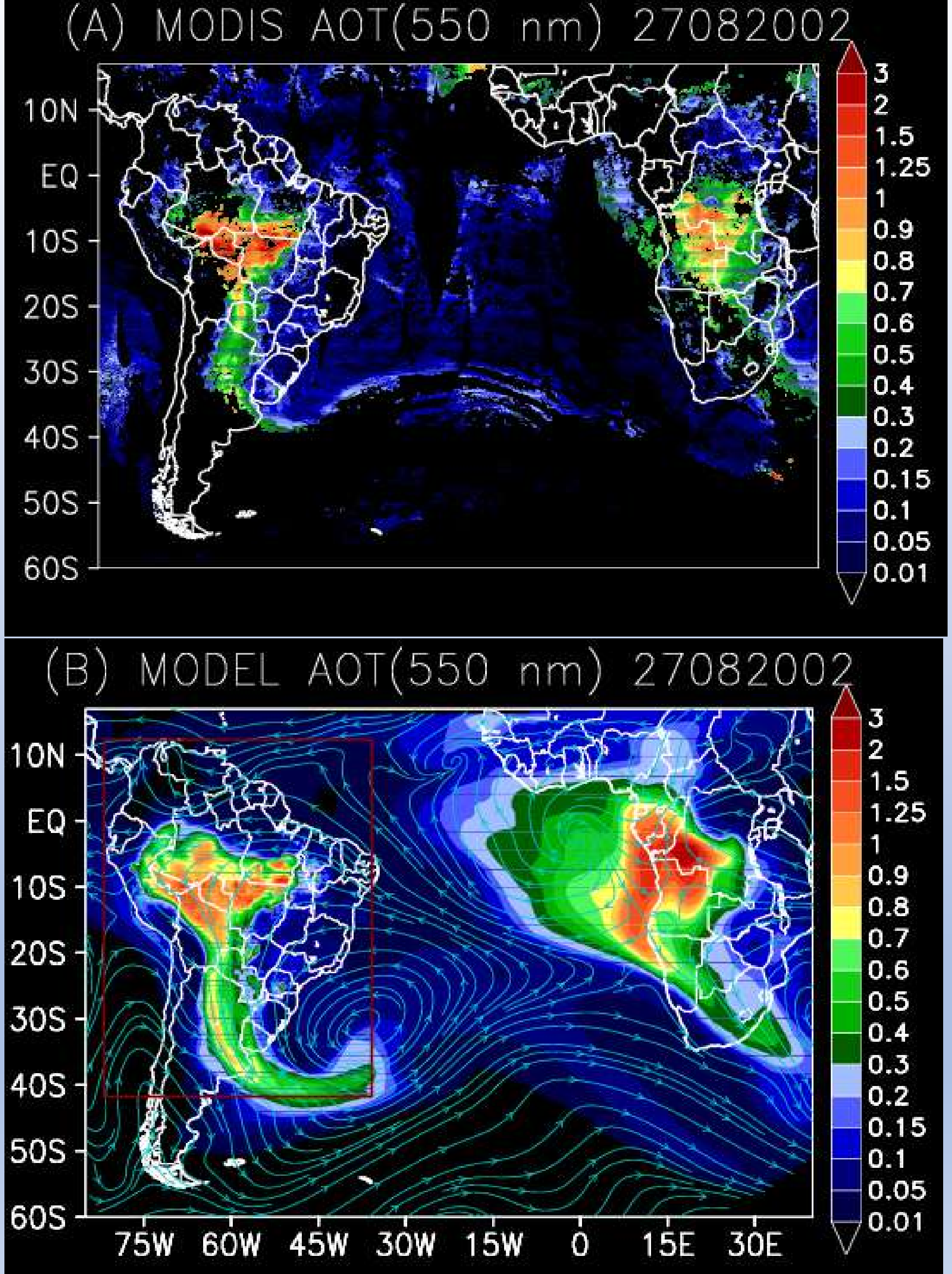
Ensemble simulation with RegCM3
September 2002
AERO radiative effects of biomass burning aerosol
CONT no aerosol
AERO-CPNT

a) Diff rainfall
b) Diff lapse pot temp lapse-rate lower atm
c) Diff surf pressure and moisture flux 925 hPa
d) Diff vertical velocity 65 W



Biomass burning emissions -> CATT – BRAMS
Coupled Aerosol and Tracer Transport to the Brazilian developments on the Regional Atmospheric Modeling System

Plume rise, regional and remote transports of biomass burning emissions
surface – boundary layer adjusted to LBA data
ABLE 2: Pickering et al (1992), Pereira et al (1991); Swap et al 1991, 1992
LBA: Longo et al 1999, Freitas et al 1996, 2000, 2005, 2007, 2009, 2017

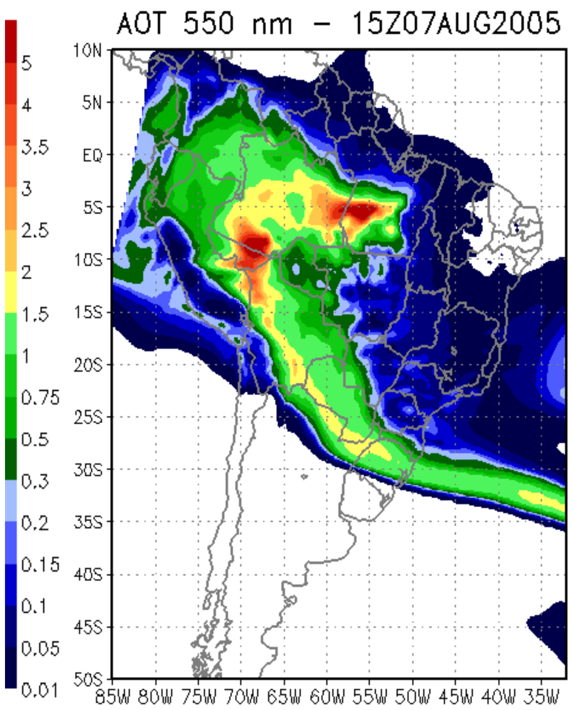


Freitas S.., Longo. Silva Dias, M. A. F., Chatfield, R., Silva Dias, P., Artaxo, P., Andreae, Grell, Rodrigues, Fazenda, Panetta, J.. 2009. (CATT-BRAMS) *Atmos. Chem. Phys.*

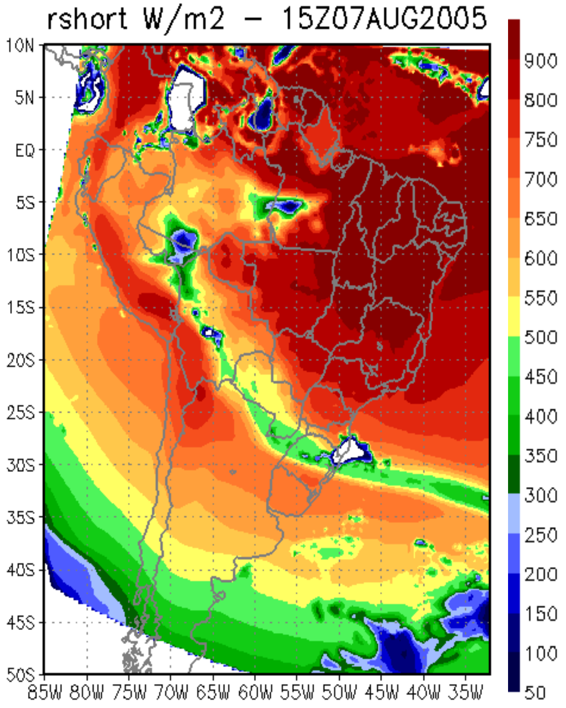
www.cptec.inpe.br/meio_ambiente

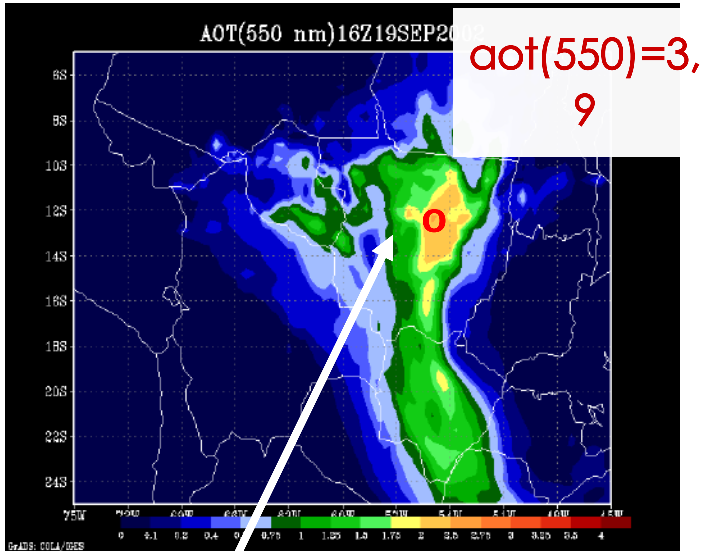
Direct radiation effect of the aerosol plume

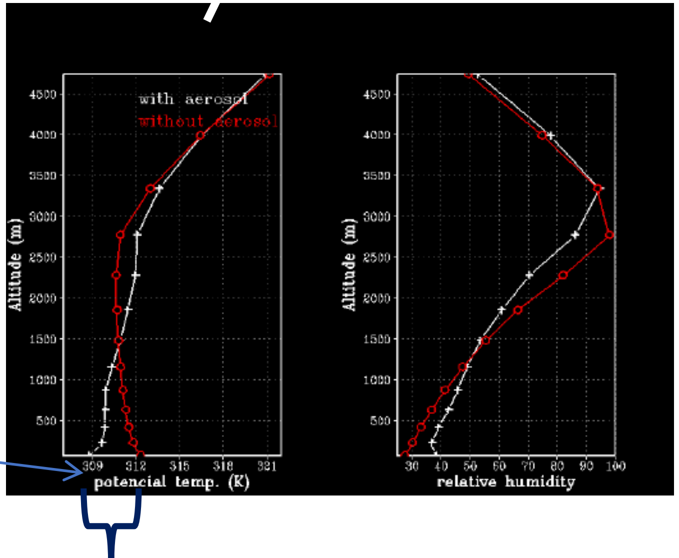
AOT 550 nm



Solar radiation at the suface



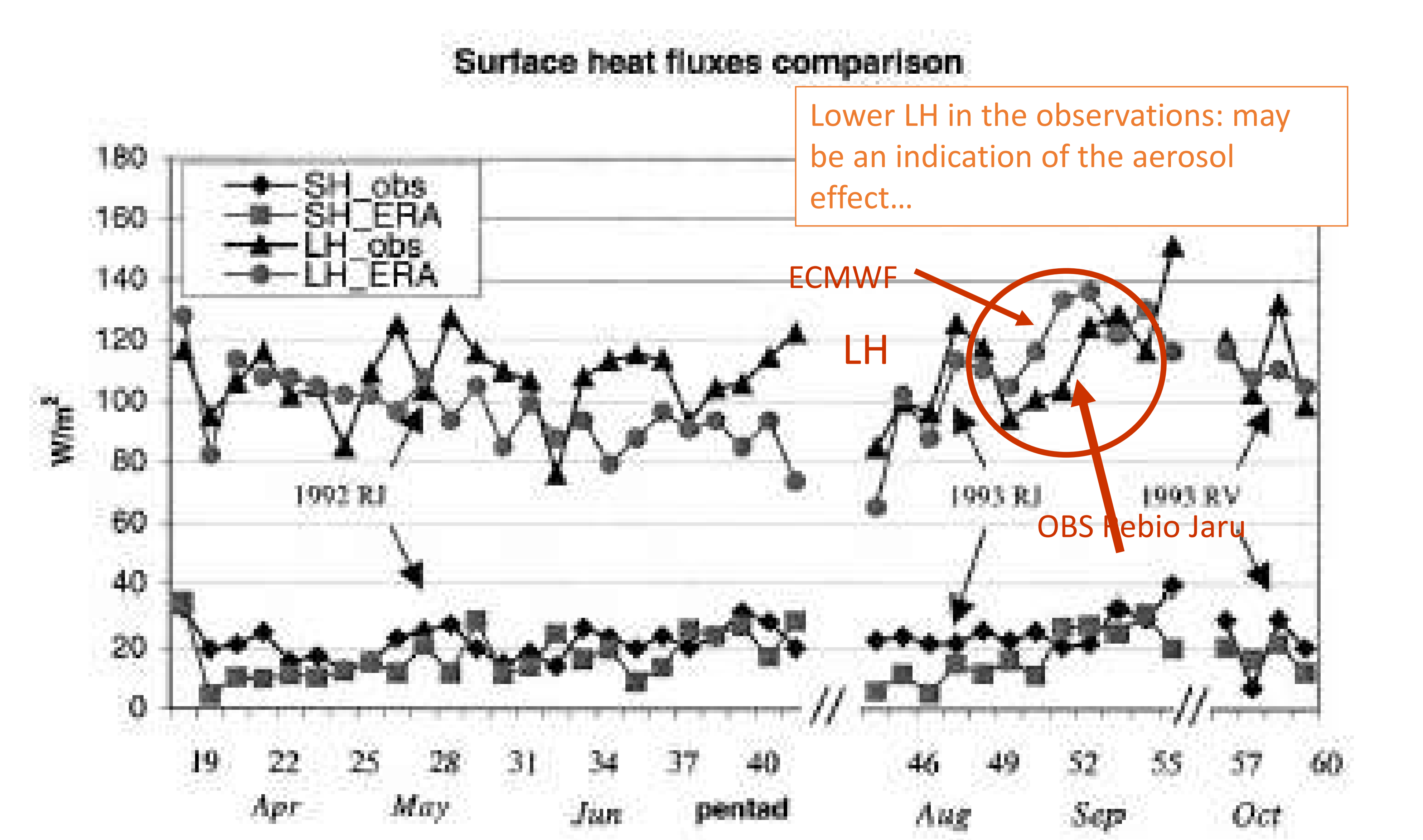




Possible effect of biomass burning delaying the onset of the rainy season

ΔT = -3.5 ºC

Li & Fu, 2004 Transition of the Large-Scale Atmospheric and Land Surface Conditions from the Dry to the Wet Season over Amazonia as Diagnosed by the ECMWF Re-Analysis. J. Climate



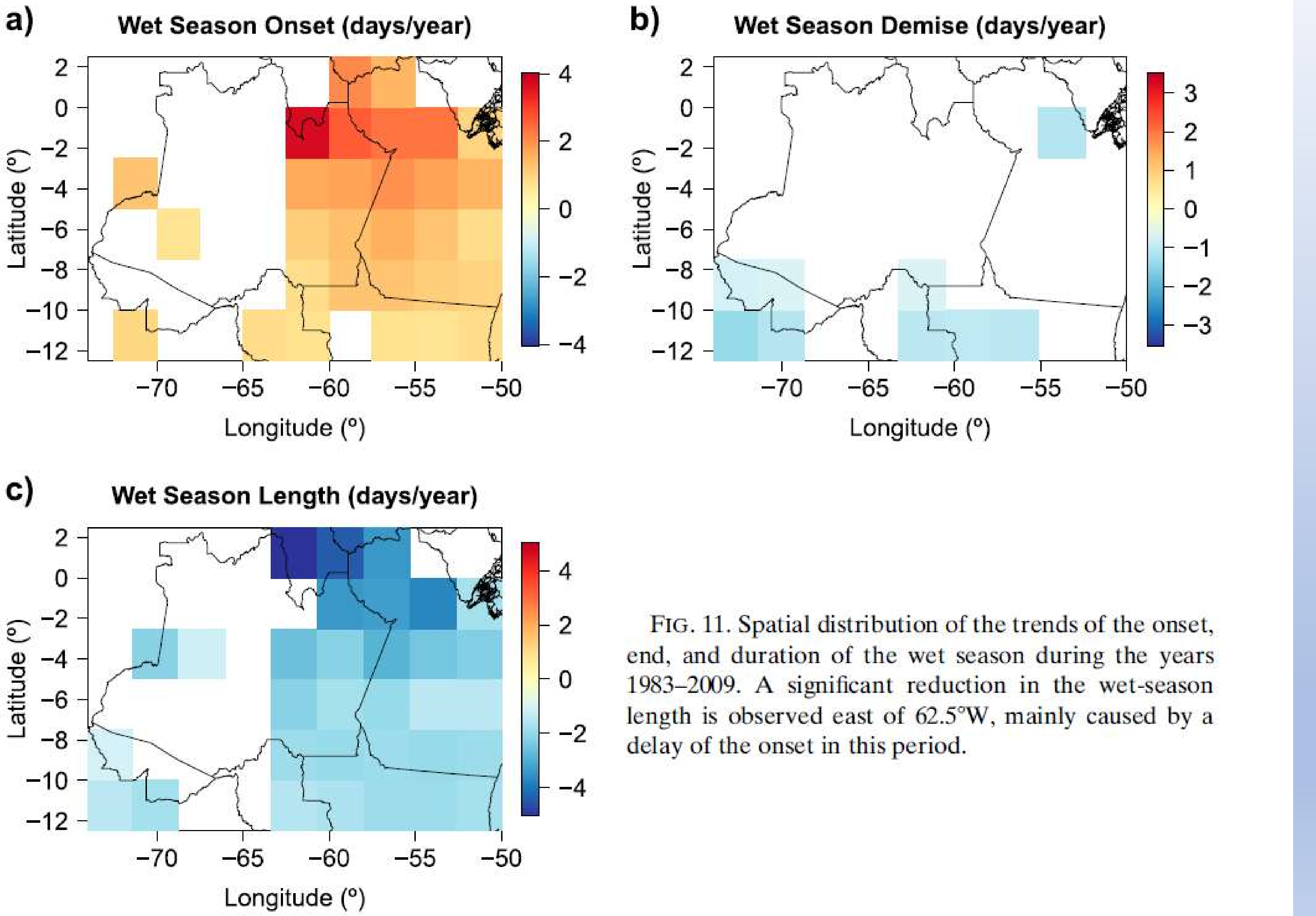
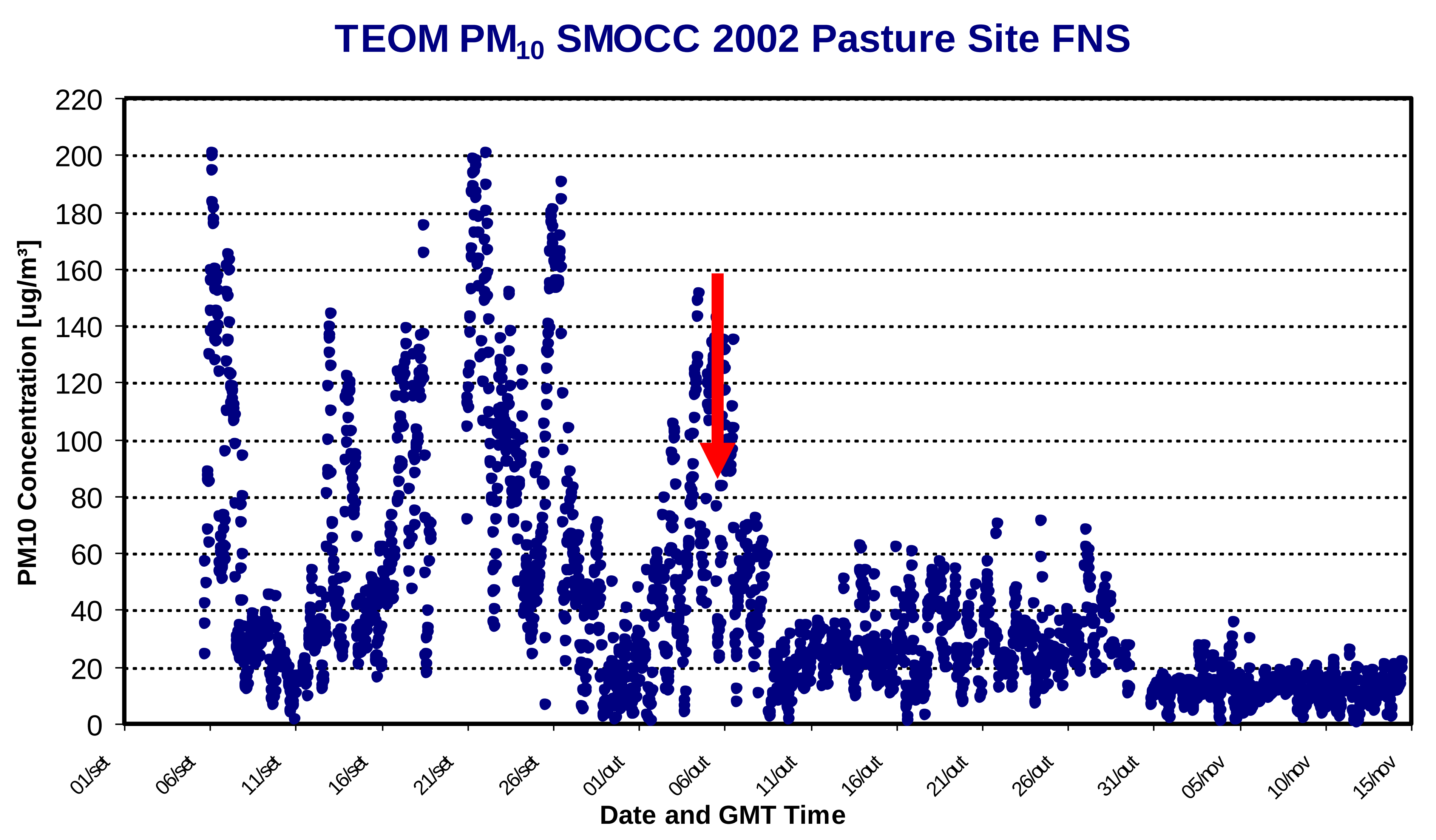


FIG. 11. Spatial distribution of the trends of the onset, end, and duration of the wet season during the years 1983–2009. A significant reduction in the wet-season length is observed east of 62.5°W, mainly caused by a delay of the onset in this period.

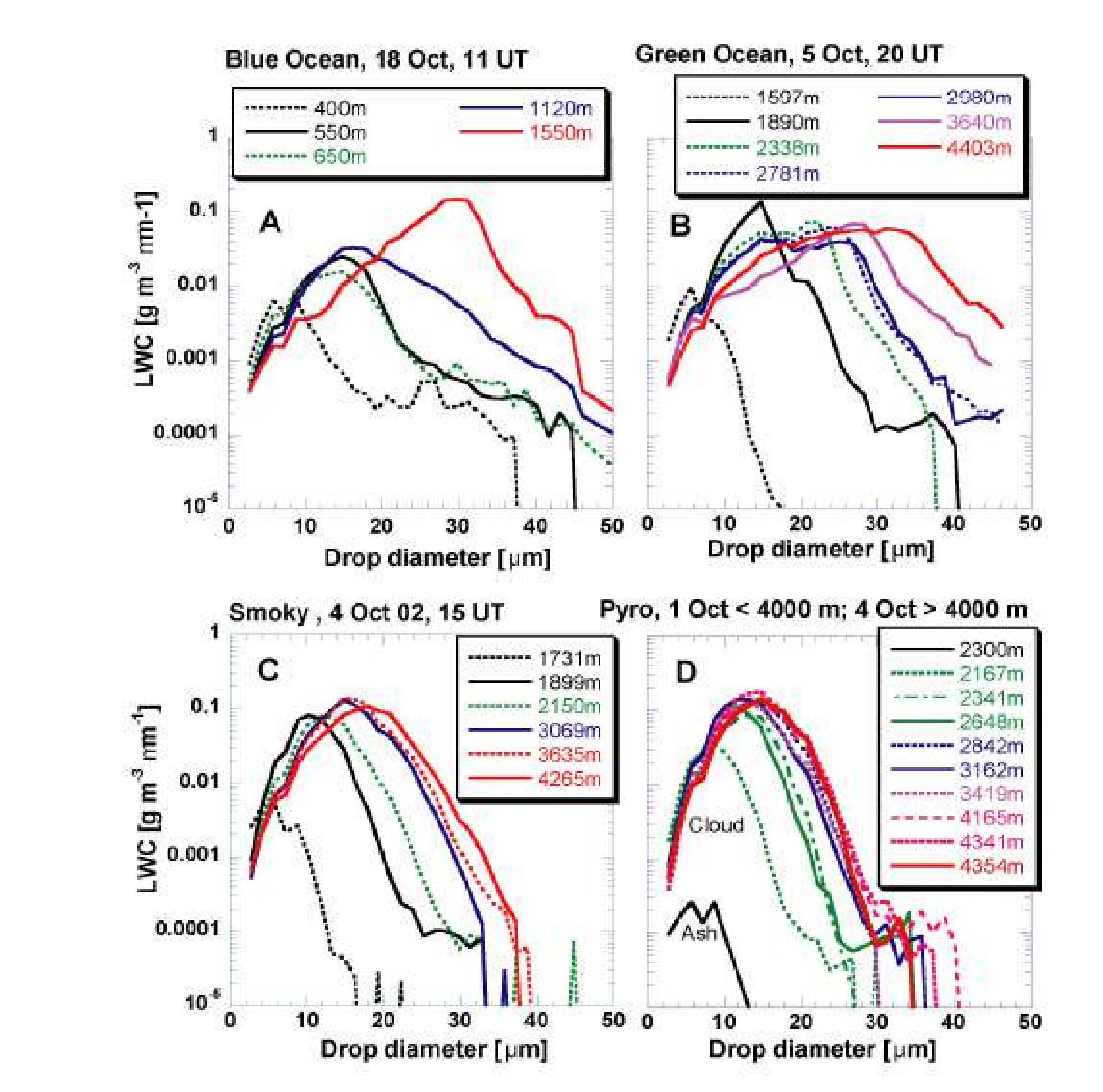
LBA-Dry to Wet Season Campaign Aerosol Concentration



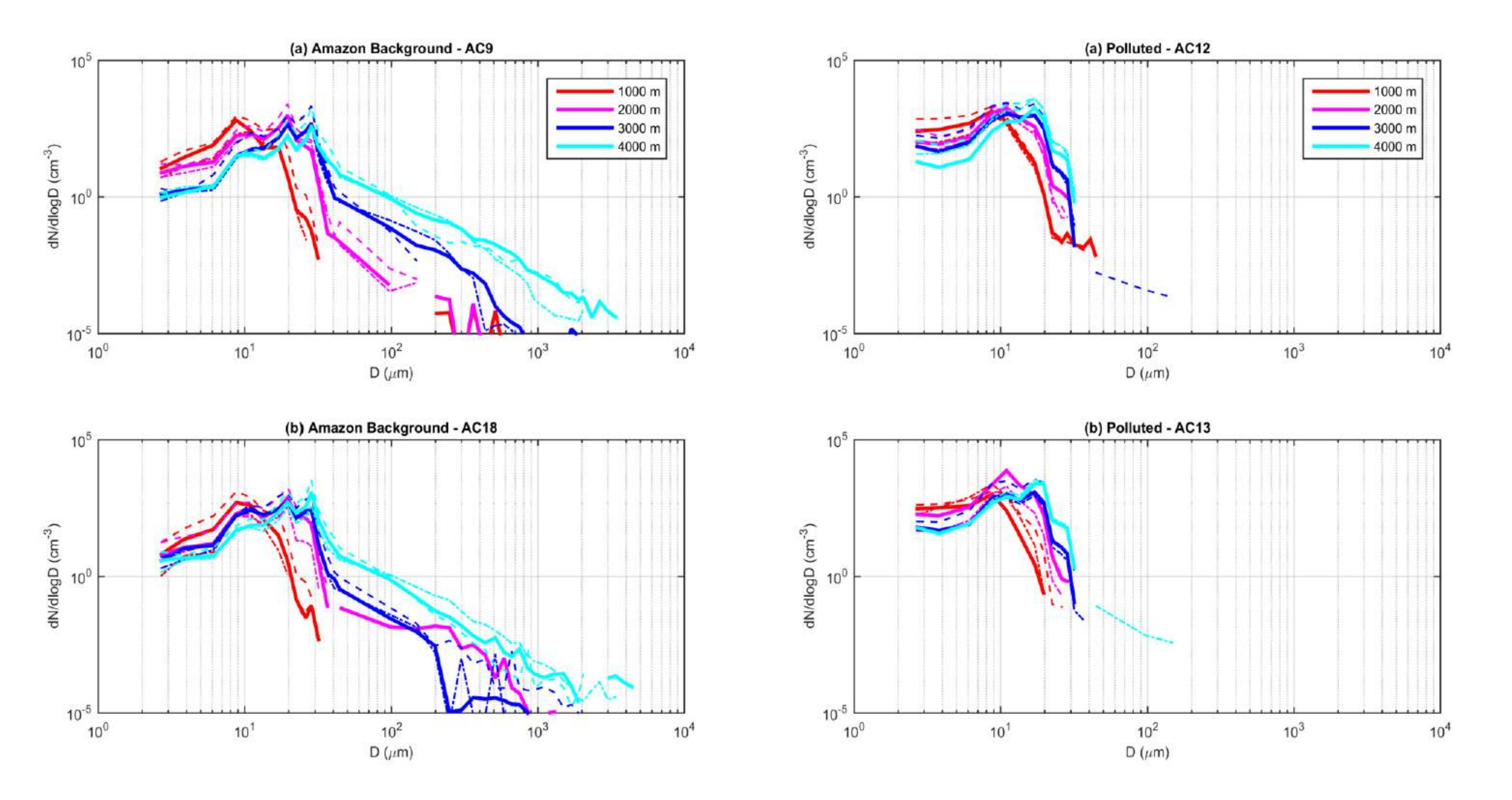

UECE
PT-SCY
26 9 2002


The islands of Trindade, Martin Vaz, Arquipelago de Fernando de Noronha, Atol das Rocas, and Penedos de São Pedro e São Paulo are not shown.
Trindade and Martin Vaz are administered by Espírito Santo; Arquipelago de Fernando de Noronha by Pernambuco.
NORTH ATLANTIC OCEAN
VENEZUELA
COLOMBIA
GUYANA
SURINAME
French Guiana (FRANCE)
TRINIDAD AND TOBAGO
PERU
BOLIVIA
AMAZONAS
PARÁ
ACRE
RONDÔNIA
RORAIMA
AMAPÁ
MARANHÃO
PIAUÍ
CEARÁ
RIO GRANDE DO NORTE
PARAÍBA
PERNAMBUCO
ALAGOAS
SERGIPE
BAHIA
TOCANTINS
MATO GROSSO
GOIÁS
DISTRITO FEDERAL
MINAS GERAIS
Caracas
Port-of-Spain
Georgetown
Paramaribo
Cayenne
Bogotá
La Paz
Brasília
Manaus
Belém
Macapá
Boa Vista
Rio Branco
Fortaleza
Natal
Recife
Salvador
Cuiabá
Palmas
Equator
Amazon

Andreae, Rosenfeld, Artaxo, Costa, Frank, Longo, Silva Dias 2004.Smoking rain clouds over the Amazon - Science

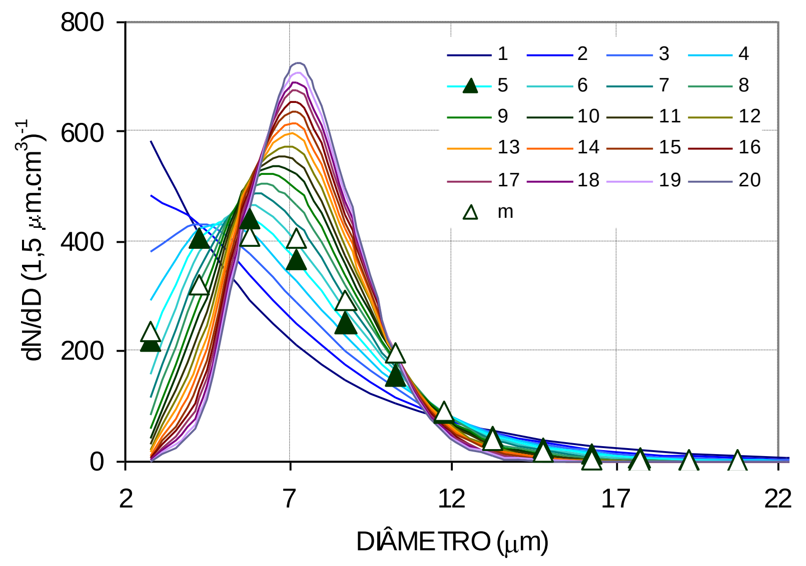


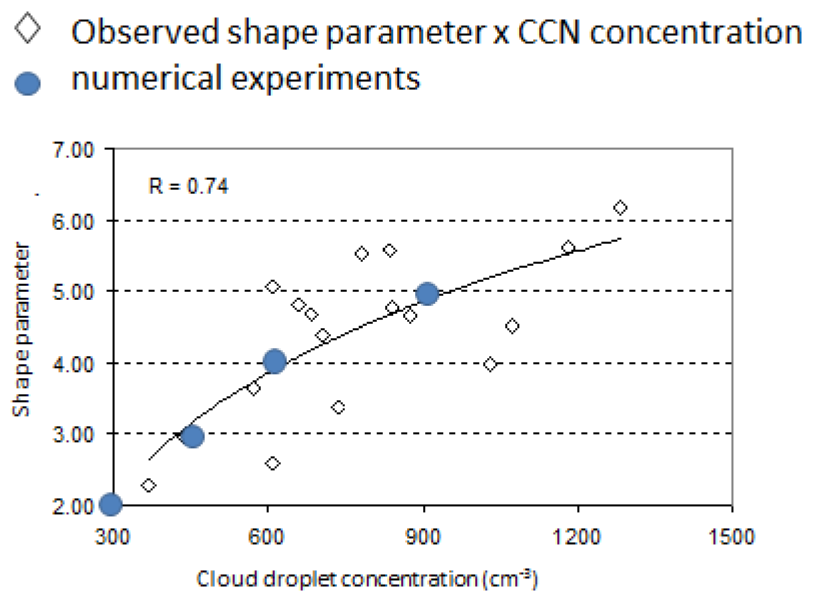
ACRDICON-CHUVA campaigns –
Machado et al 2018



Shape parameter in cloud droplet diameter distribution
Gonçalves, Martins, Silva Dias, 2008, *Atmos Research*

$$n(D) = \frac{N_t}{\Gamma(\nu)}\left(\frac{D}{D_n}\right)^{\nu-1}\frac{1}{D_n}\exp\left(-\frac{D}{D_n}\right)$$

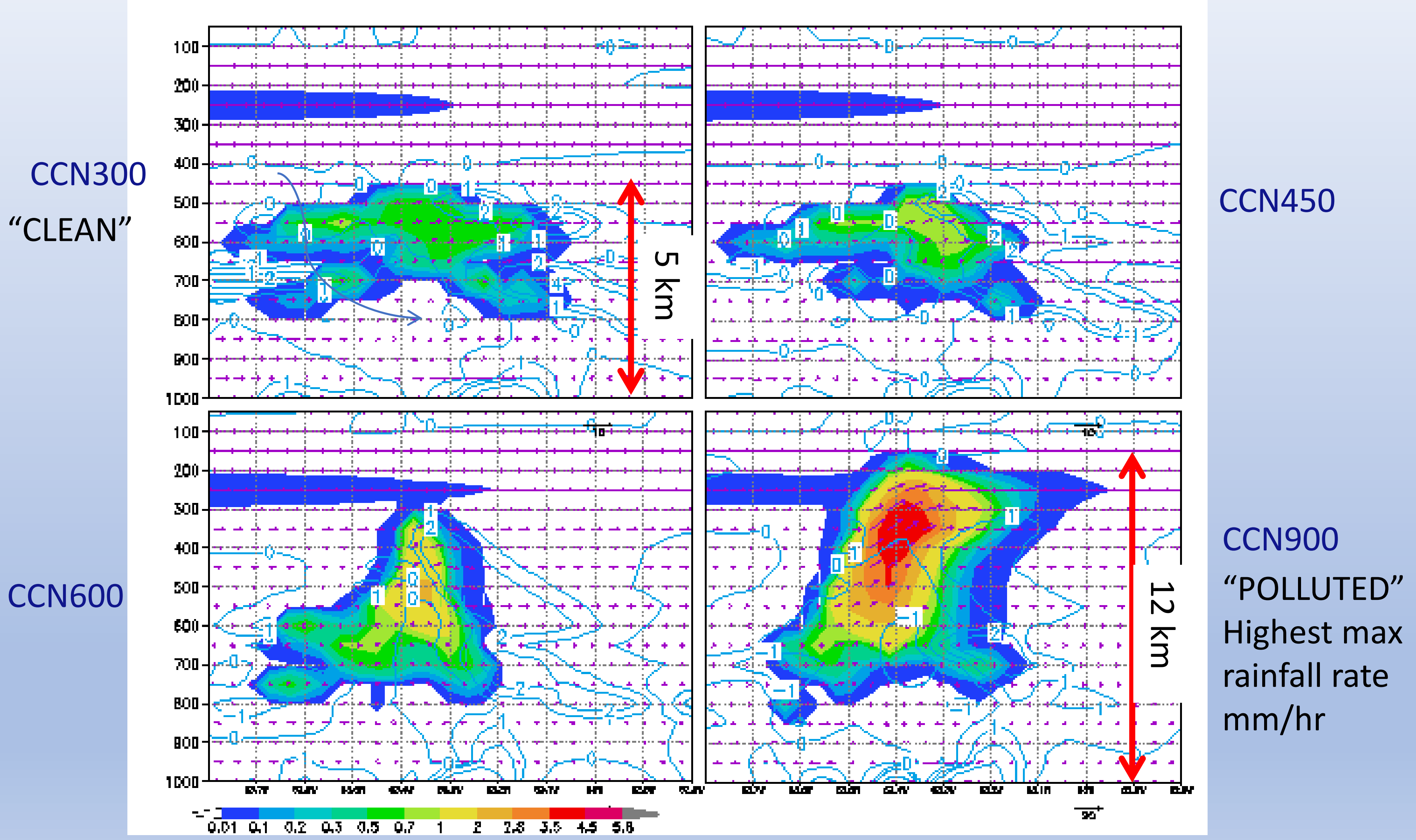




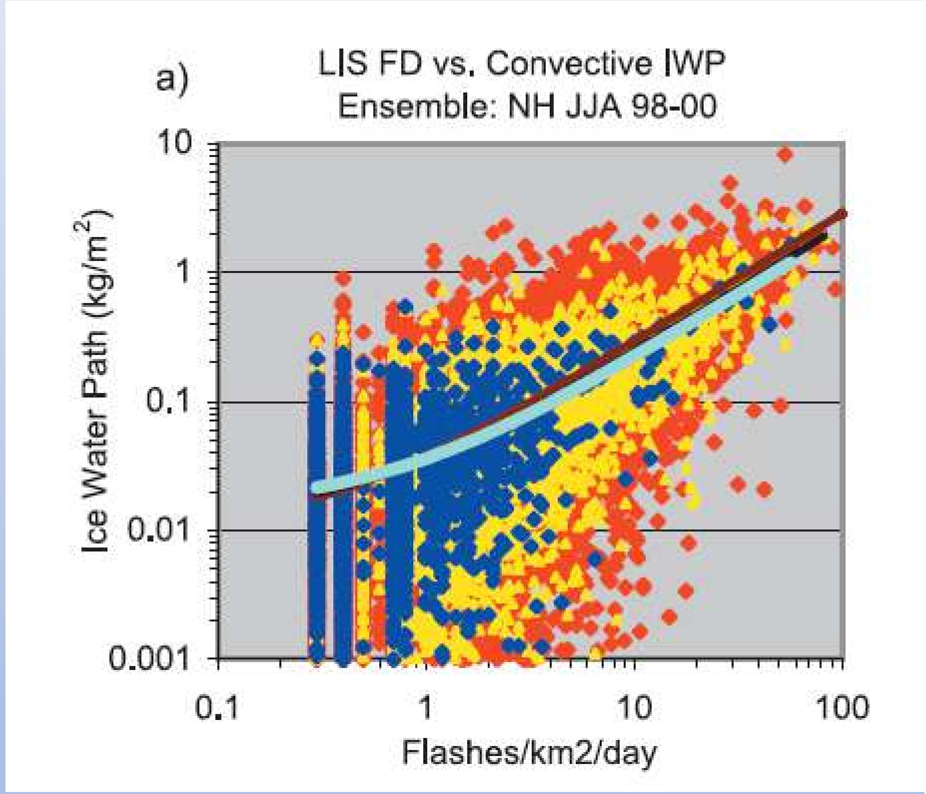
Martins, Silva Dias, Goncalves, 2009 JGR

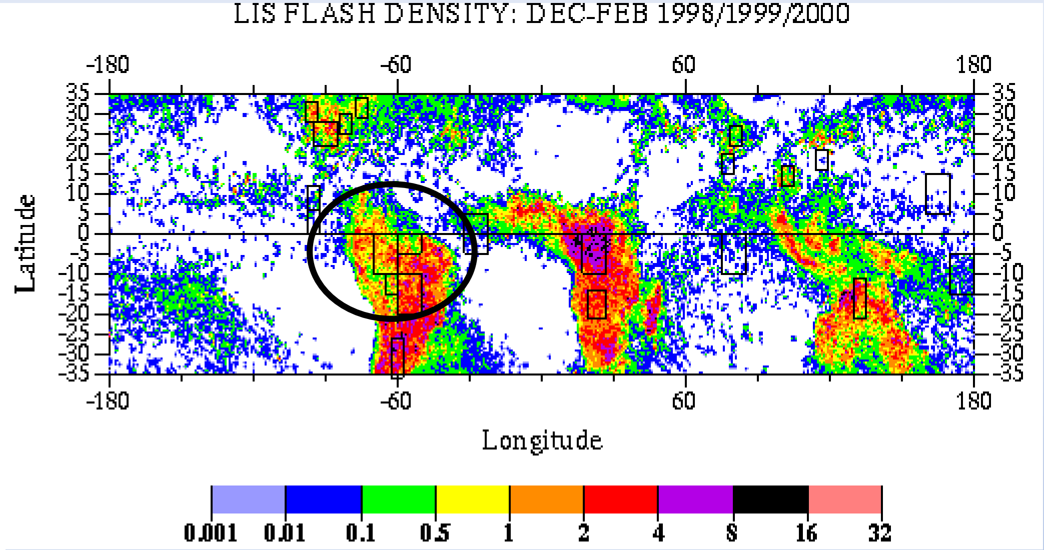
BRAMS 4 km 3D simulation - Martins, Silva Dias, Gonçalves, 2009 JGR

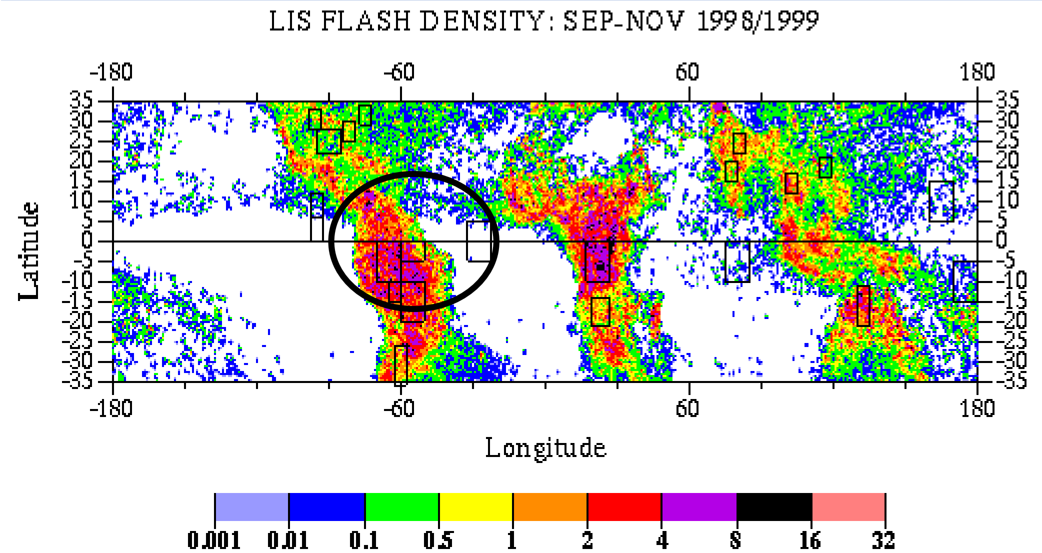
Vertical structure of cloud+ice water mixing rate at the time of maximum liquid water path



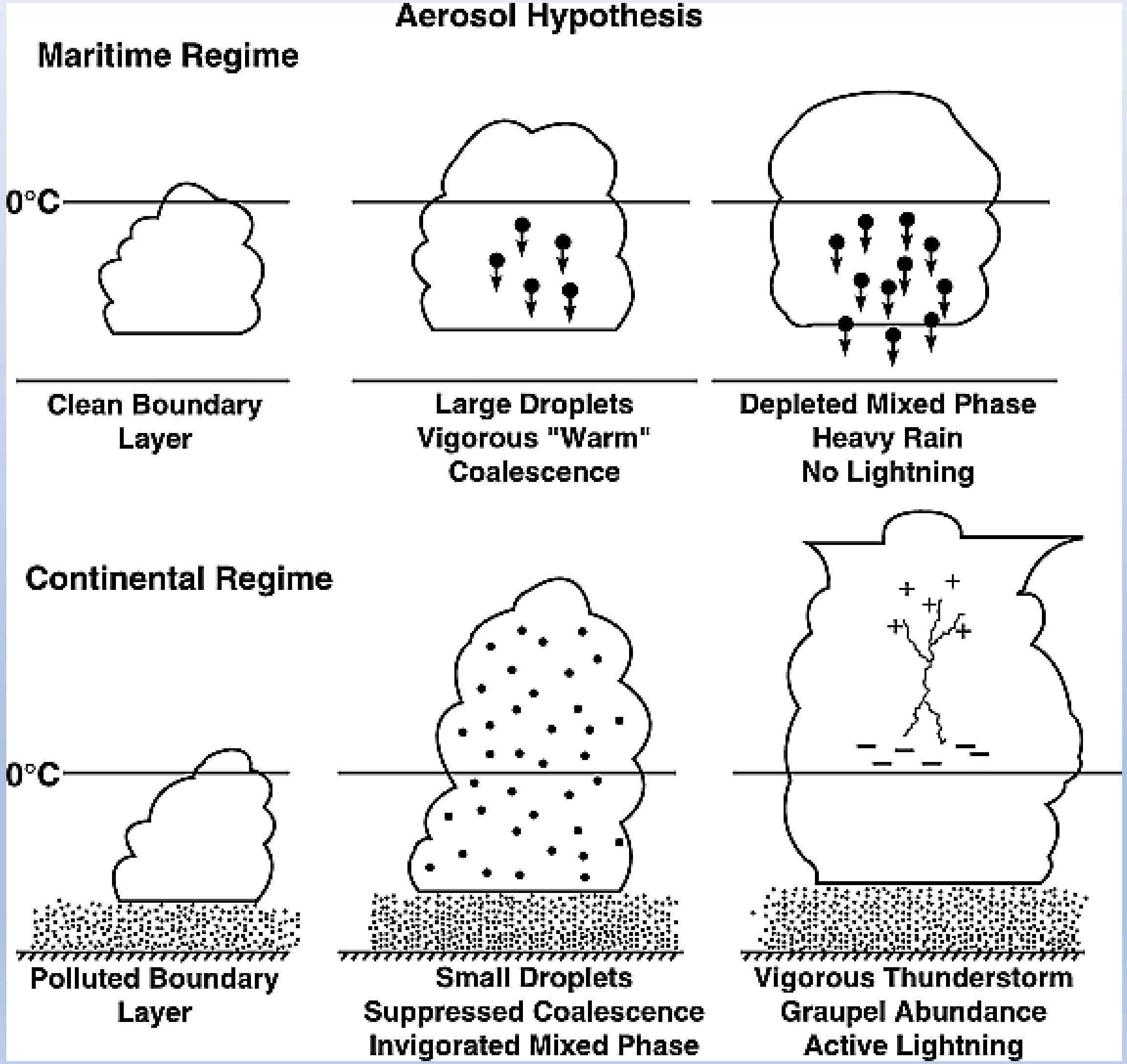
Petersen, Christian, Rutledge, 2005 TRMM observations of the global relationship between ice water
content and lightning. *GRL*

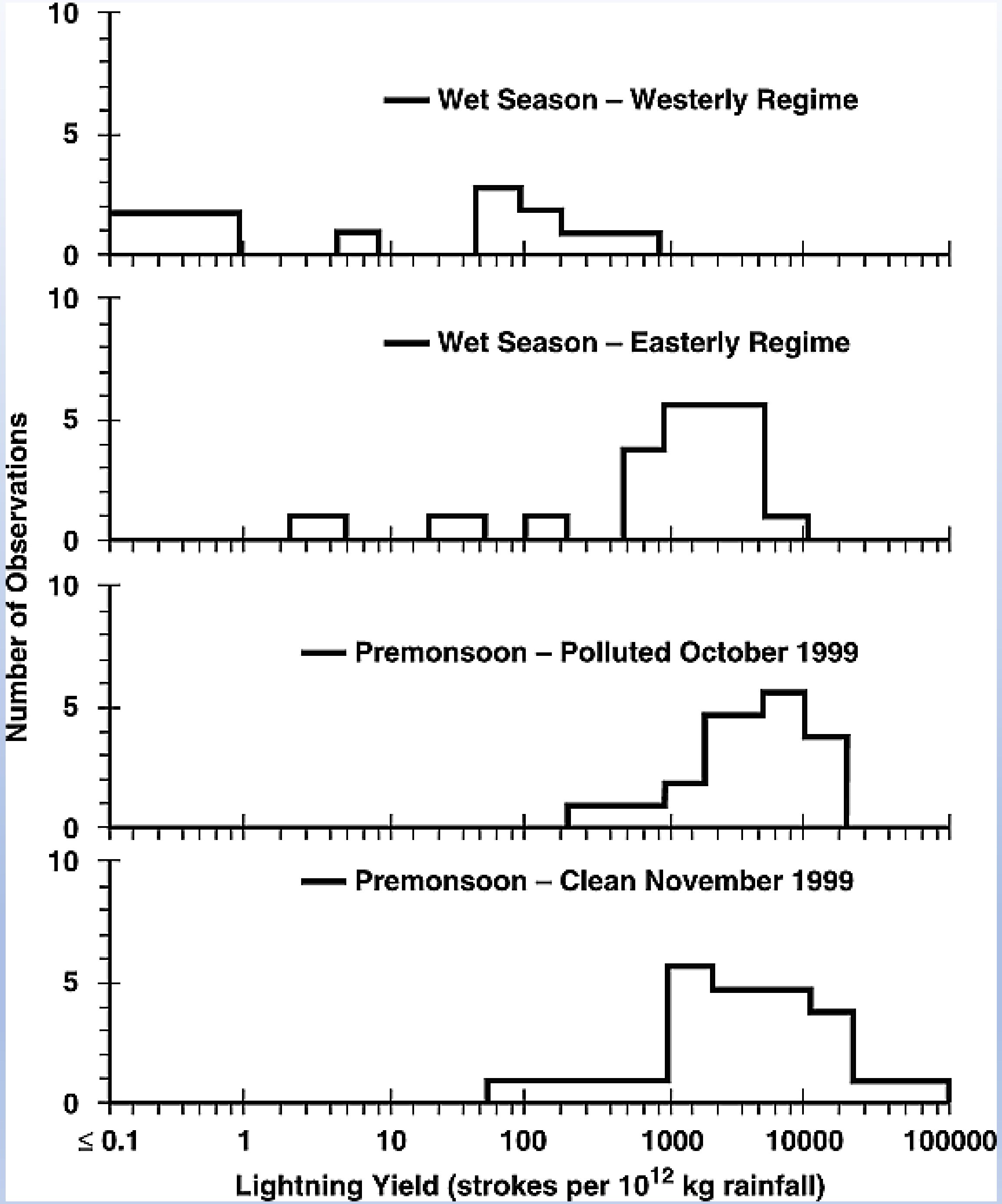






Williams et al 2002





Conclusion

- Diurnal and annual cycles vary across the region and are sensitive to wind regimes
- MCC, MCS, MCV provide local intensification of rainfall
- Aerosol from biomass burning may delay the onset of the rainy season and change behavior of deep convection from heavy rains to lightning storms

Questions

- Are models simulating/predicting correctly the rainfall diurnal and annual cycles, the occurrence of MCS, MCC, MCV, and the impact of aerosol in the South American Monsoon?
- What do we need to improve short term forecasting of rainfall in the Sotuh American Monsoon?