Efeitos dos Aerossóis na Precipitação

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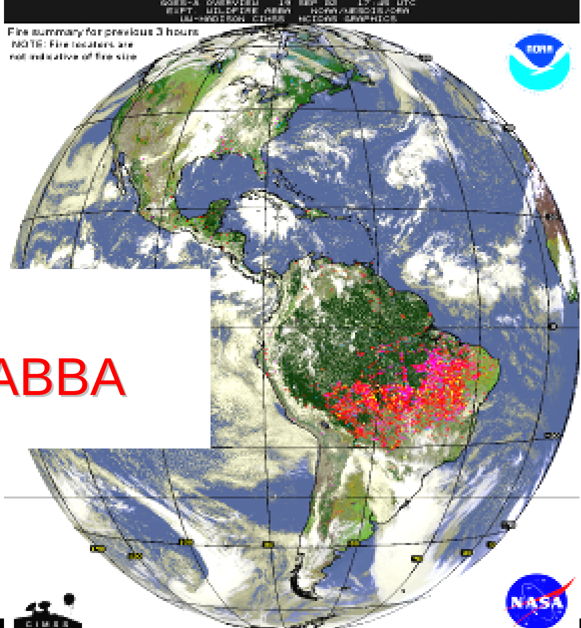
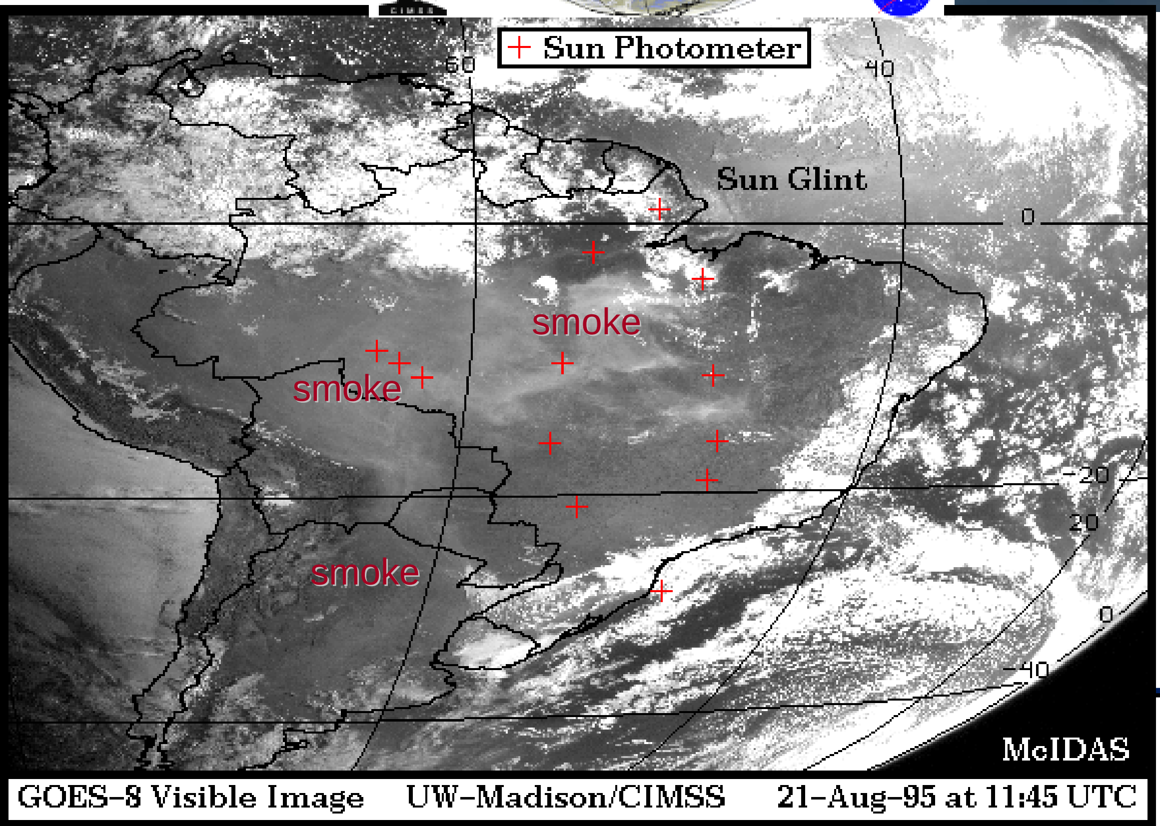
Universidade de São Paulo

III Conferencia Regional sobre Mudanças Globais: América do Sul
São Paulo, 2 de novembro de 2007

> 5000 fires
GOES-8 WF_ABBA

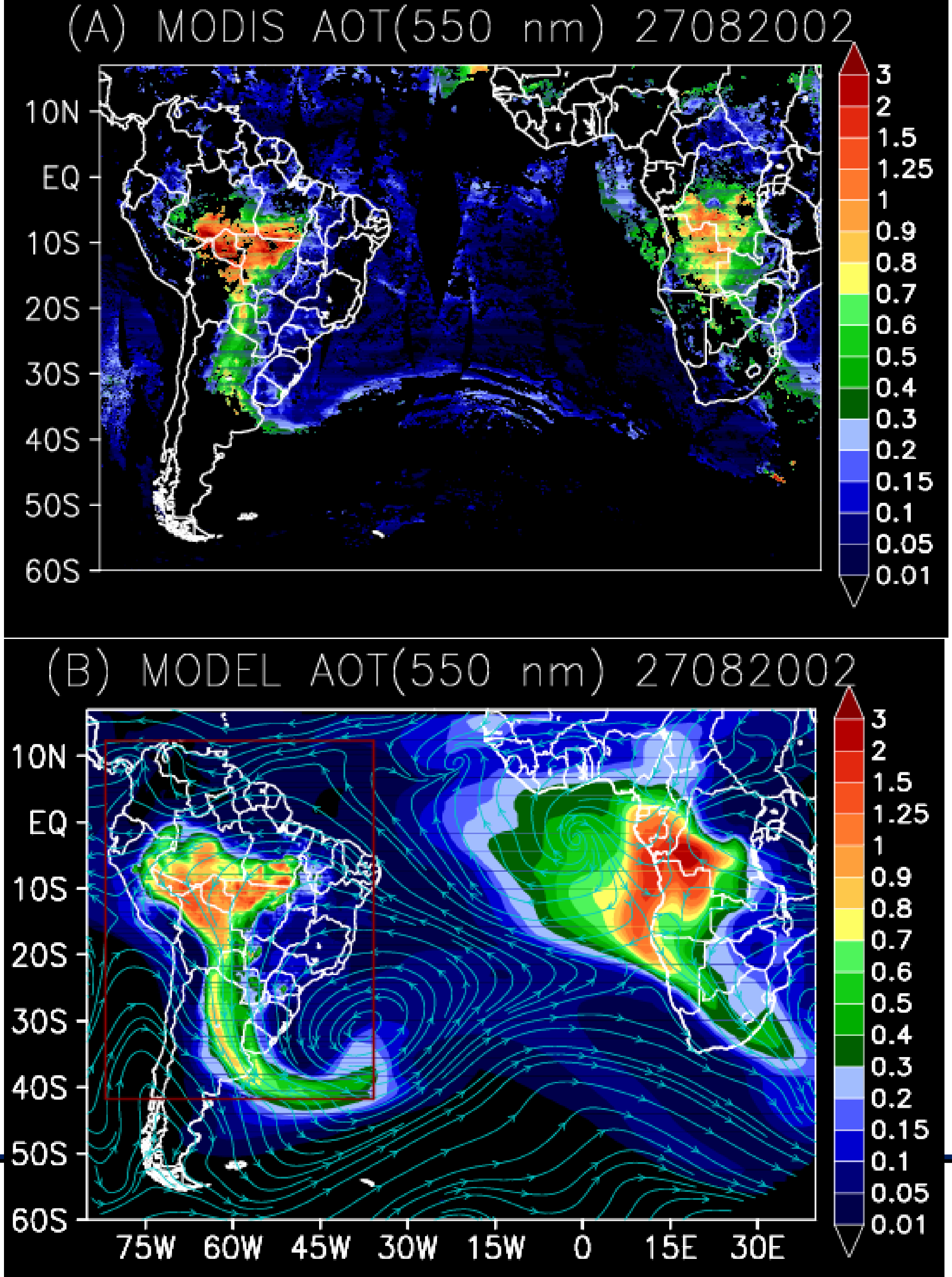


Local smoke plume
(deforestation fires)
(picture from A. Andreae)



Regional smoke plume

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



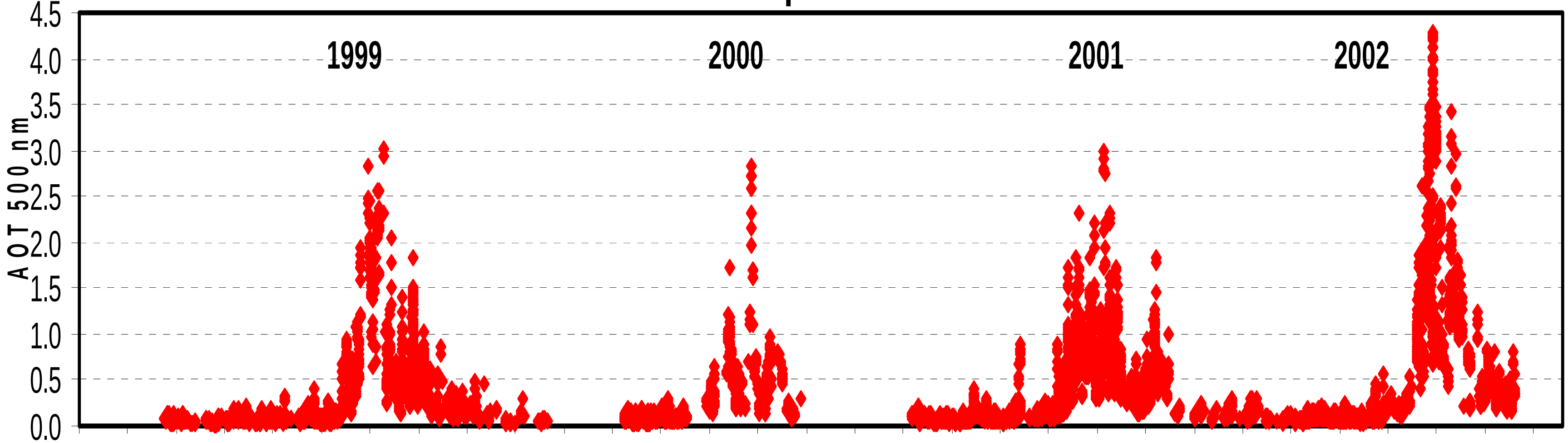
Freitas et al, 2005, 2007 Modelo de transporte dos procutos de queima de biomassa (CATT-BRAMS)

www.cptec.inpe.br/meio_ambiente

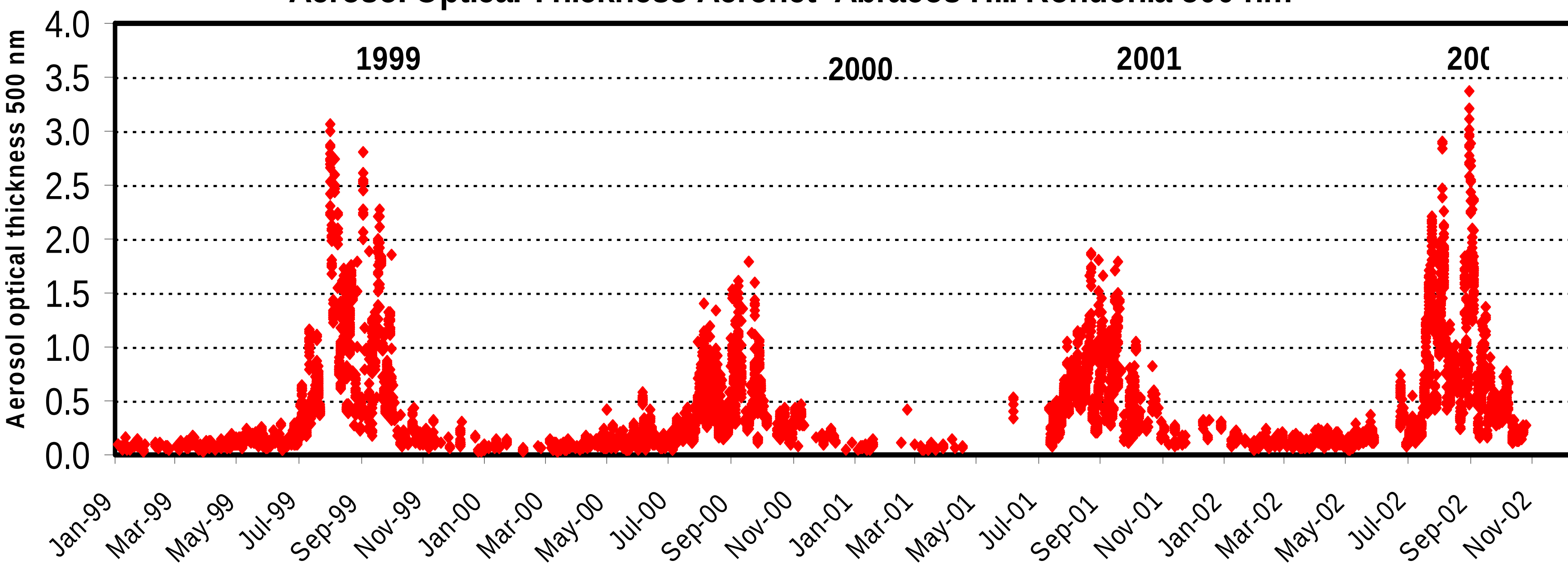
Aerosol and cloud microphysics interactions

Aeronet measurements in Alta Floresta and Rondonia 1999-2002
Artaxo et al

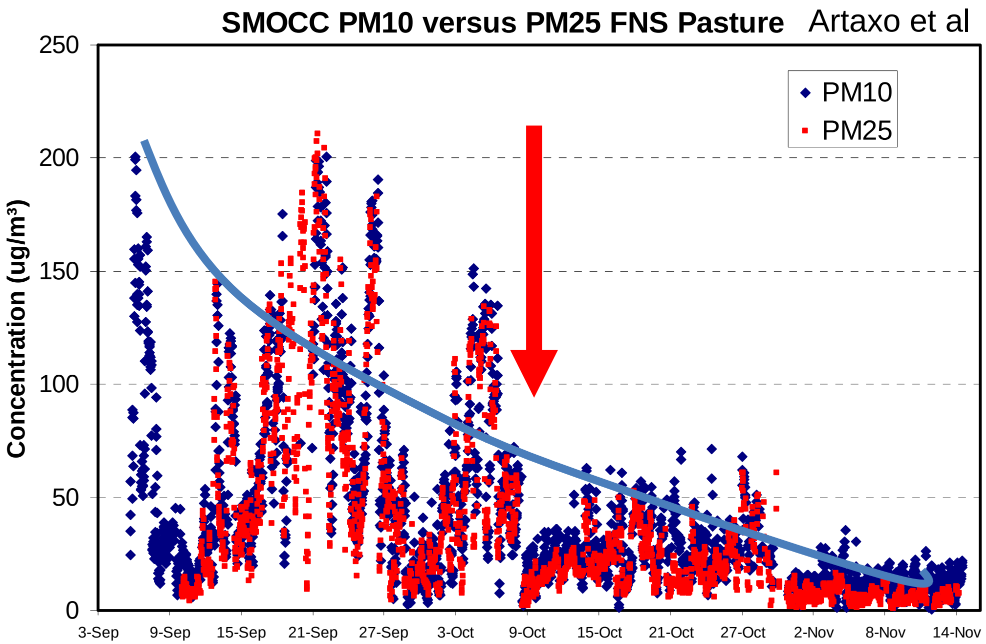
Alta Floresta AERONET Aerosol Optical Thickness Jan 99 - Nov 2002

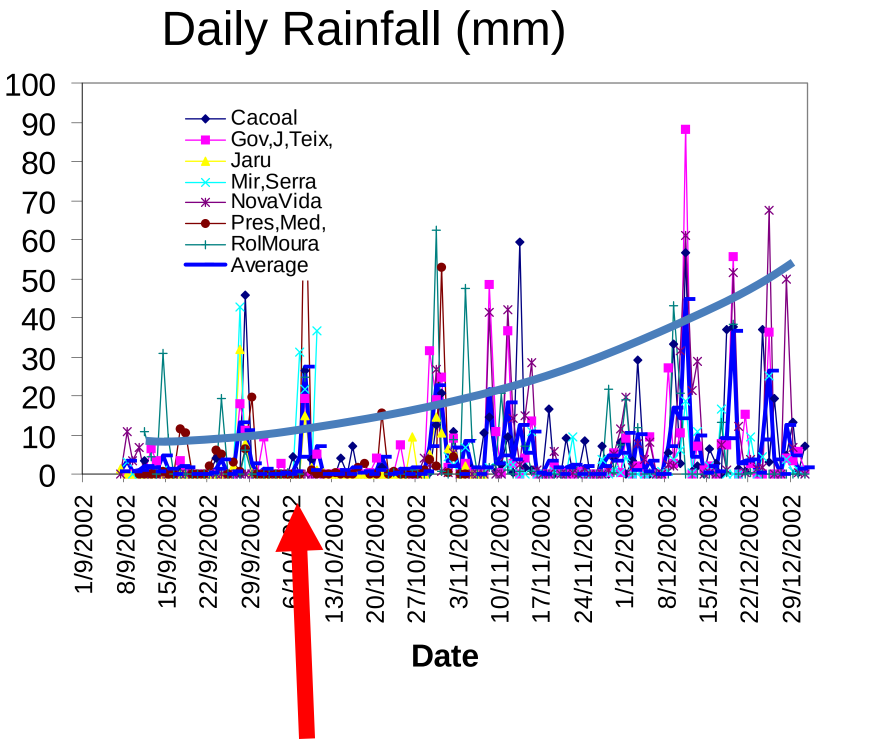


Aerosol Optical Thickness Aeronet Abracos Hill Rondonia 500 nm

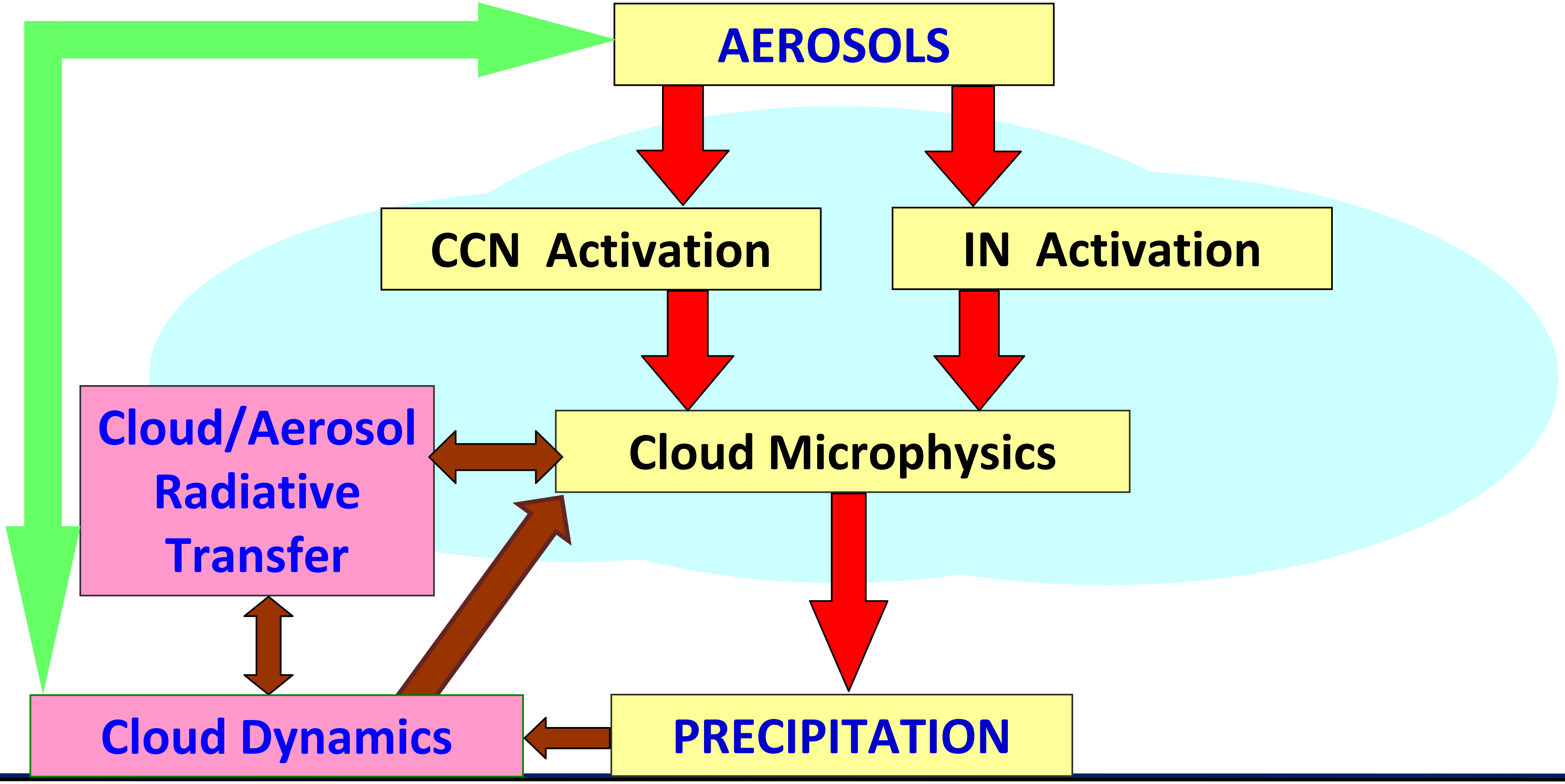


Aerossóis e Precipitação na transição da estação seca para a estação chuvosa: medidas em Rondônia Setembro a Dezembro de 2002

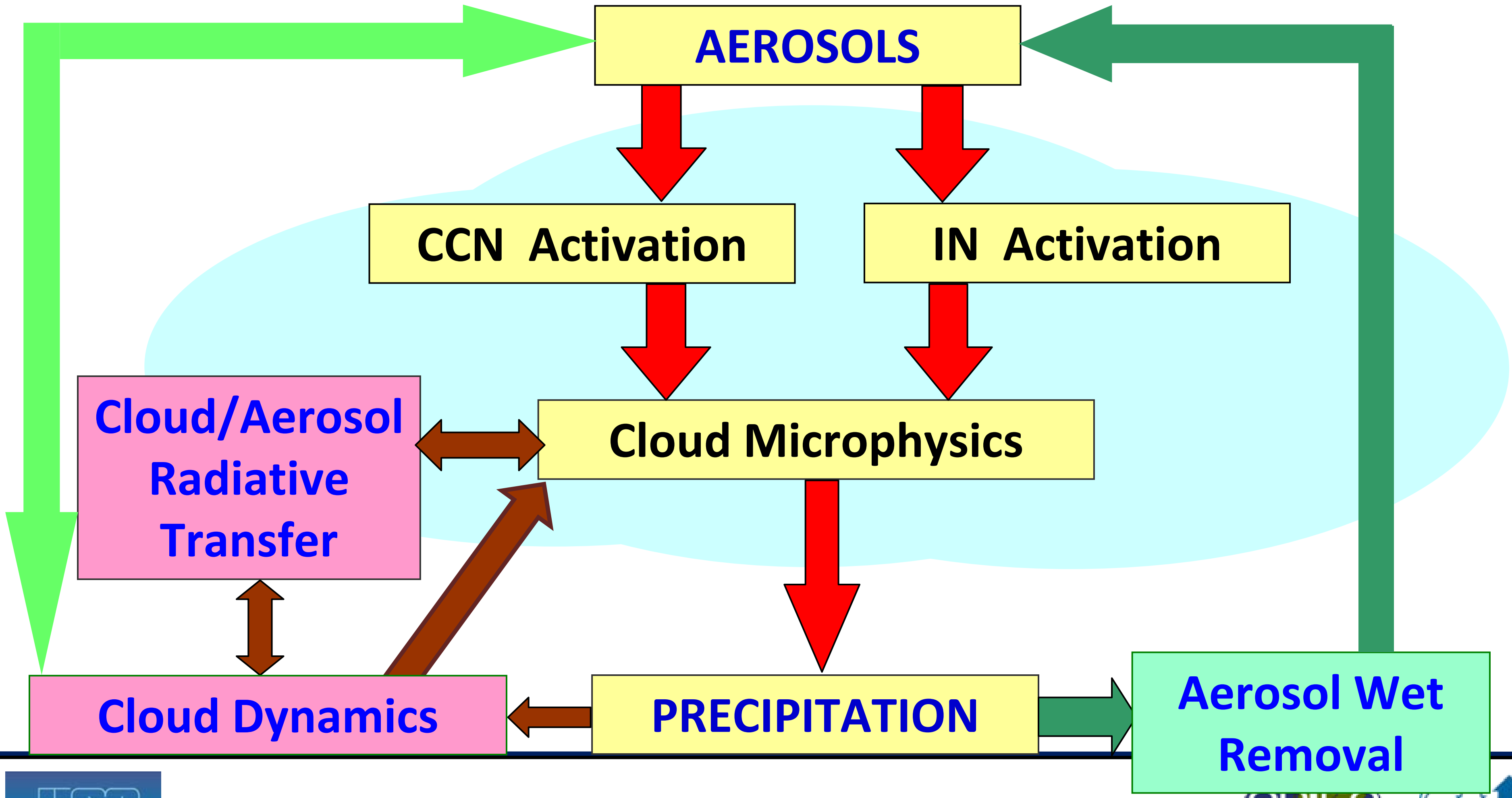




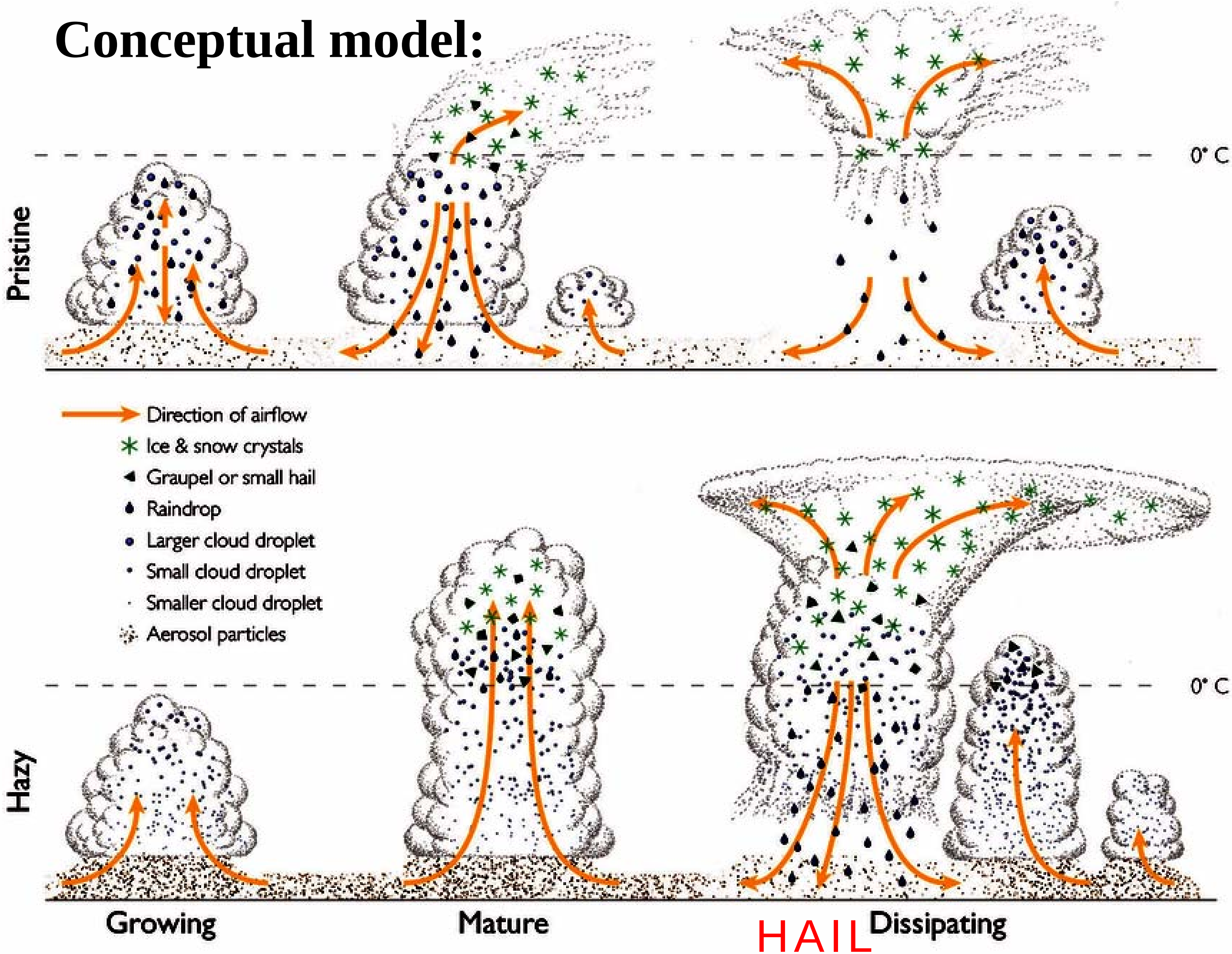
Aerosol-cloud-precipitation feedbacks



Aerosol-cloud-precipitation feedbacks



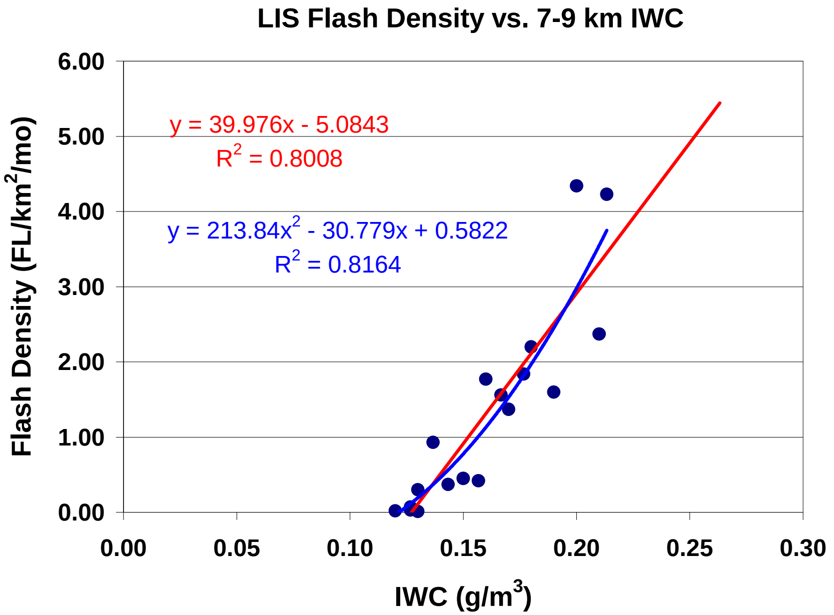
Conceptual model:

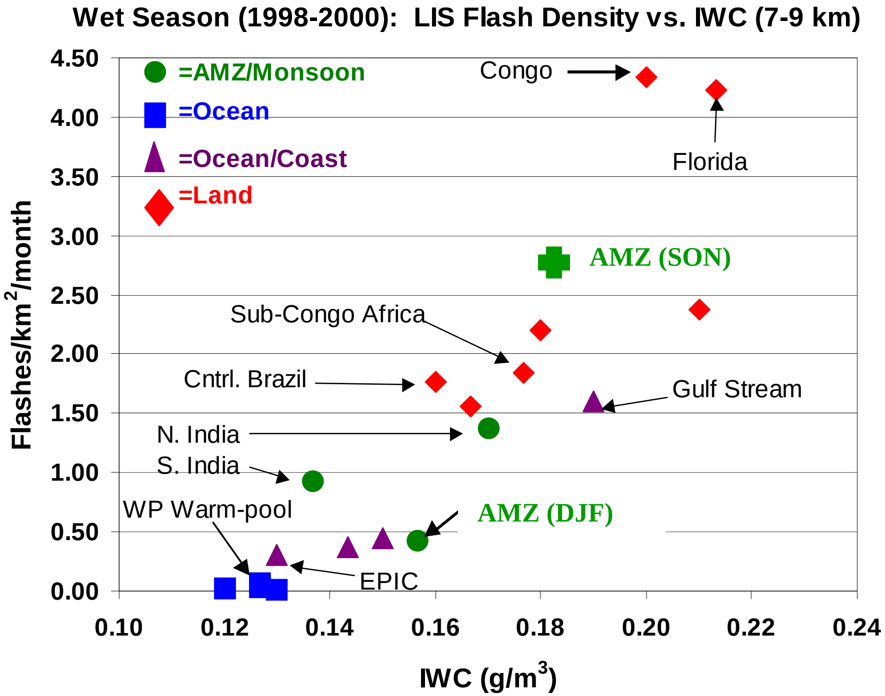


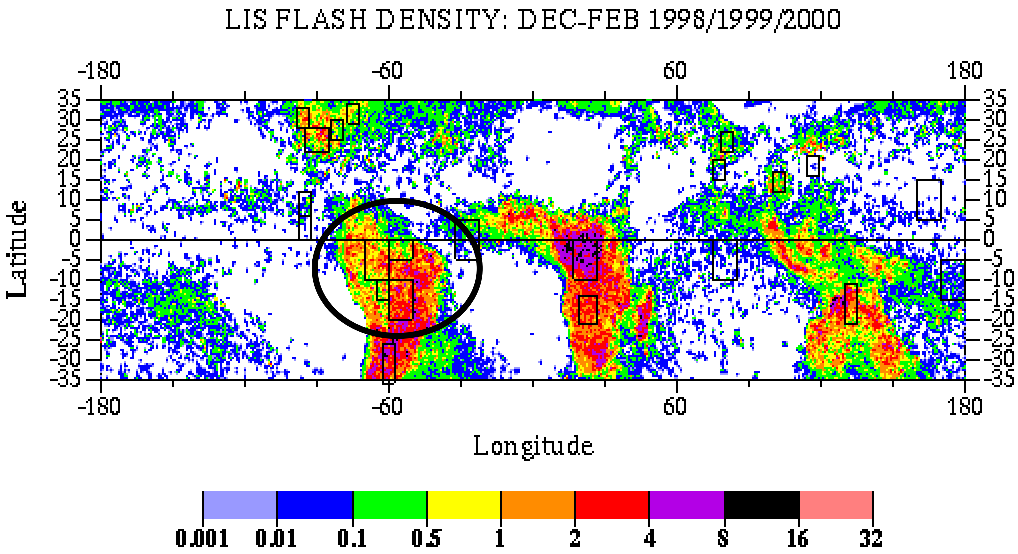
Graphics by Robert Simmon, NASA

TRMM-PR IWC (Z-M)

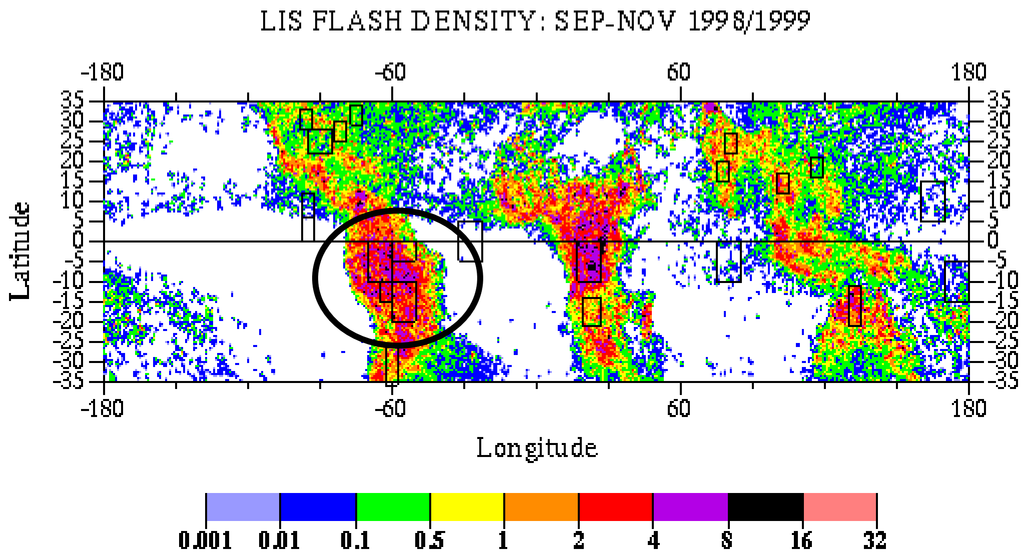
vs. LIS Flash Density







Estação chuvosa



Transição estação seca para a chuvosa

Easterlies and Westerlies are two modes of the continental scale circulation and are part of the intraseasonal oscillations

Wet Seasons

1980-1999

Jones and Carvalho, 2002

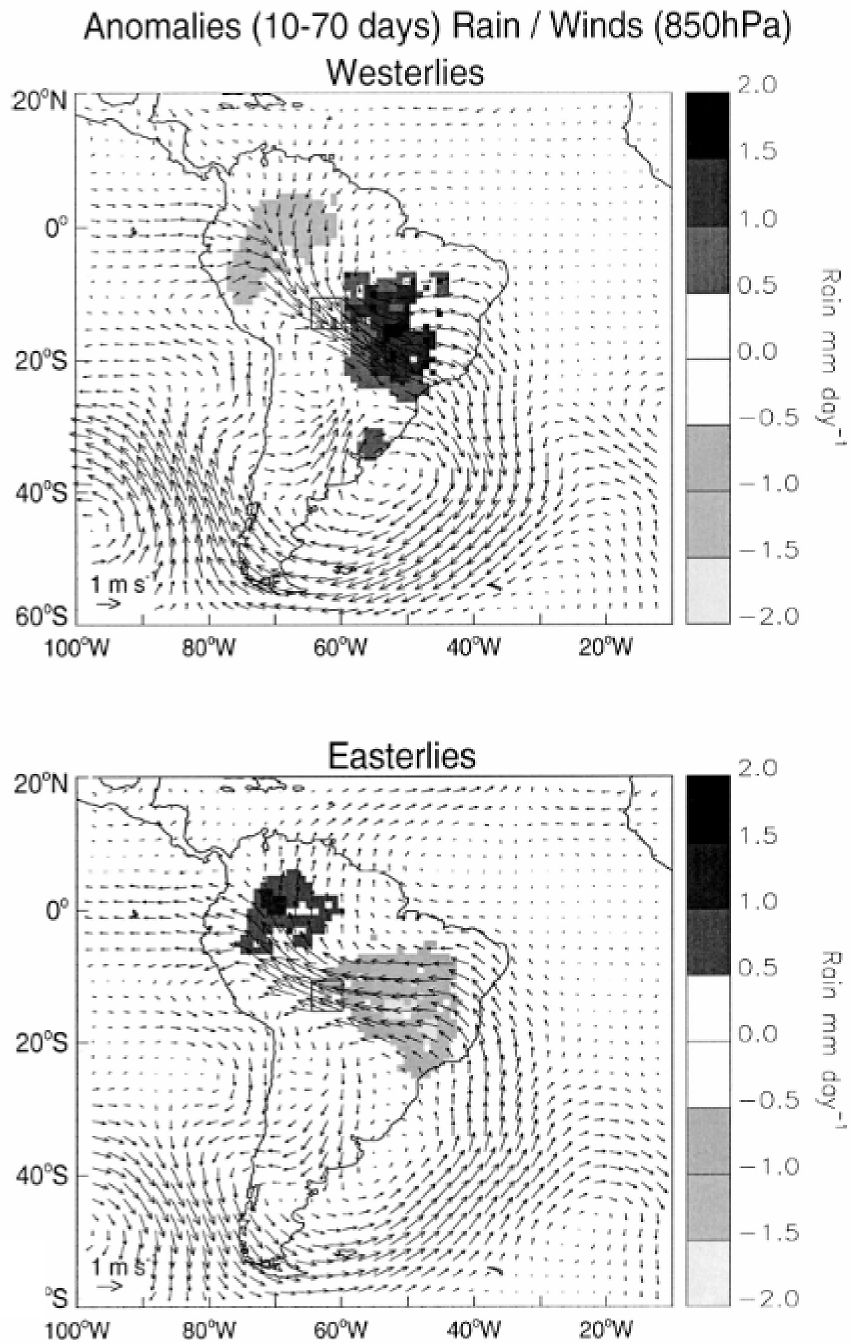
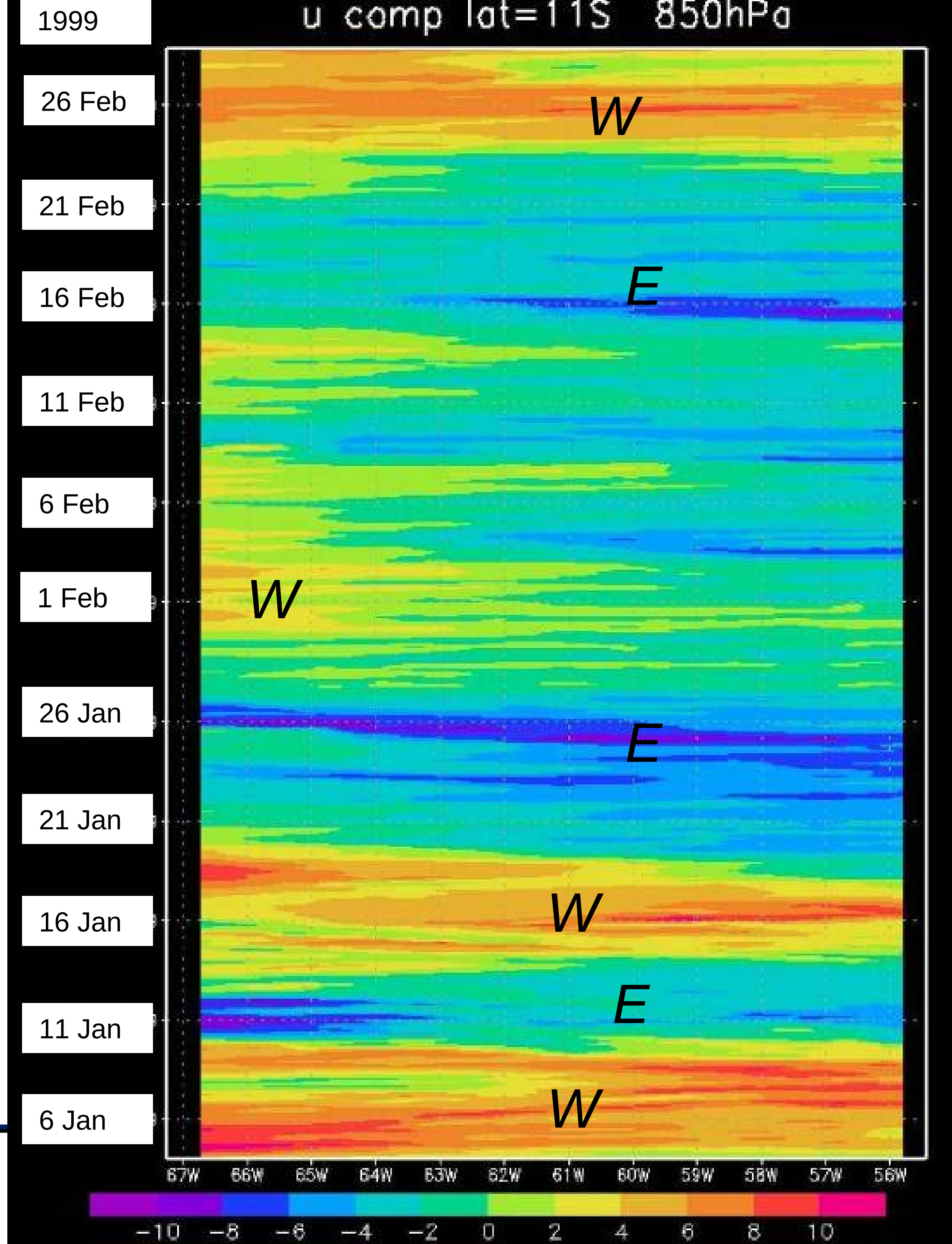


FIG. 7. Composites of rainfall (shading) and wind (850 hPa) anomalies during (top) westerly and (bottom) easterly wind regimes. Only rainfall anomalies significant at 95% level are indicated.

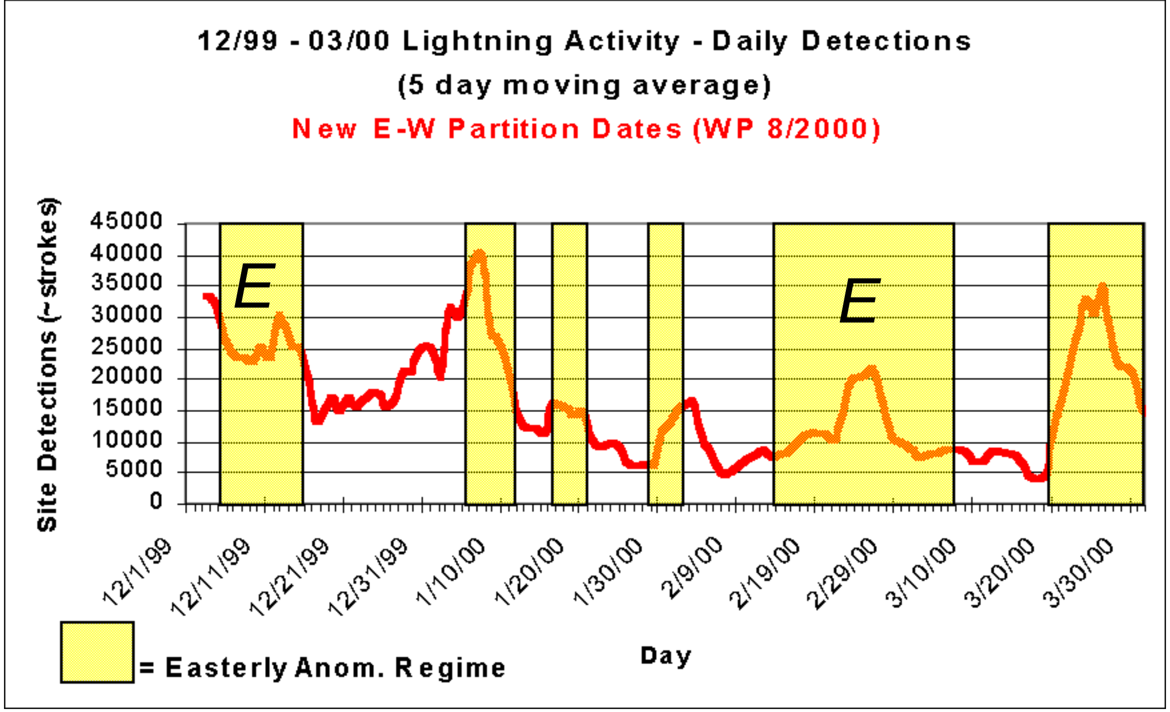
Low level wind

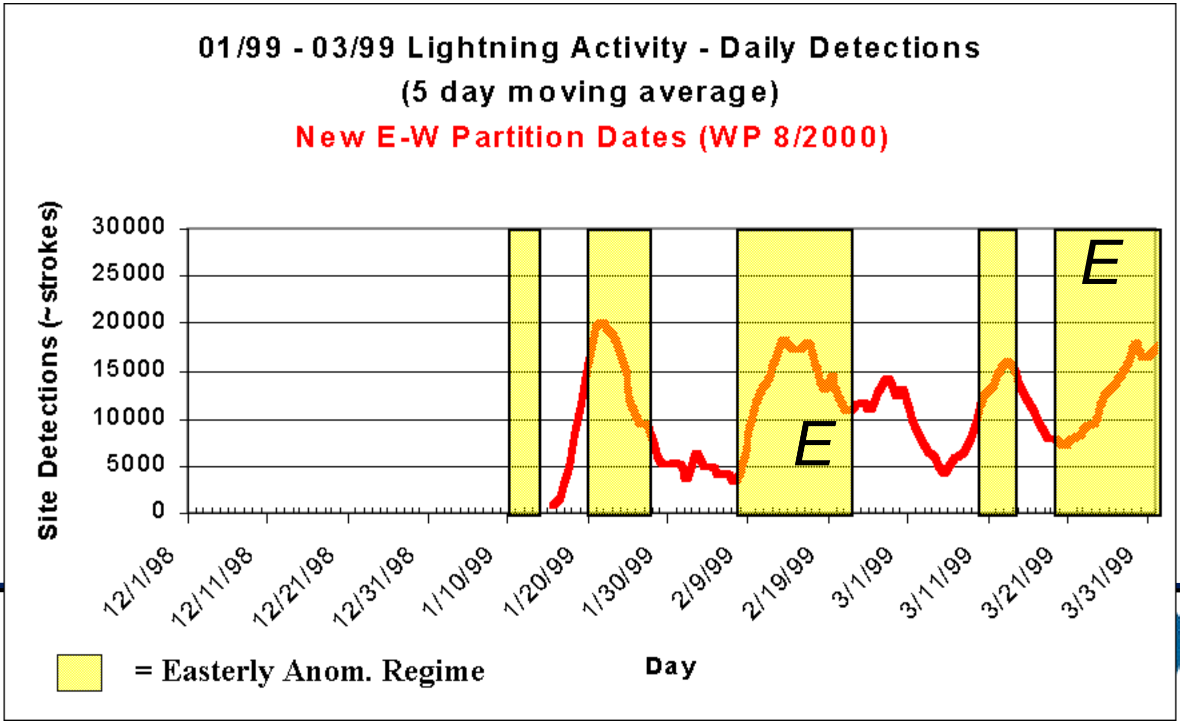


More lightning during the easterlies = deep convective systems with large Ice Water Content

Petersen & Rutledge, 2000

Blakeslee,2000



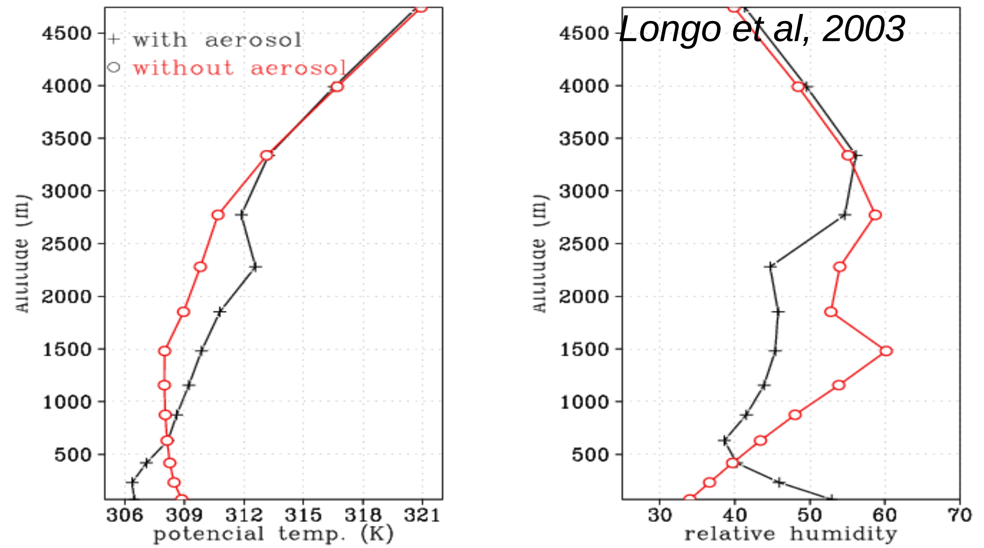


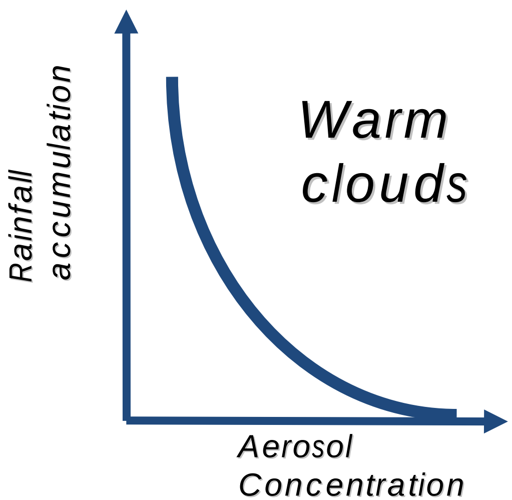
Interações Aerossóis-Precipitação

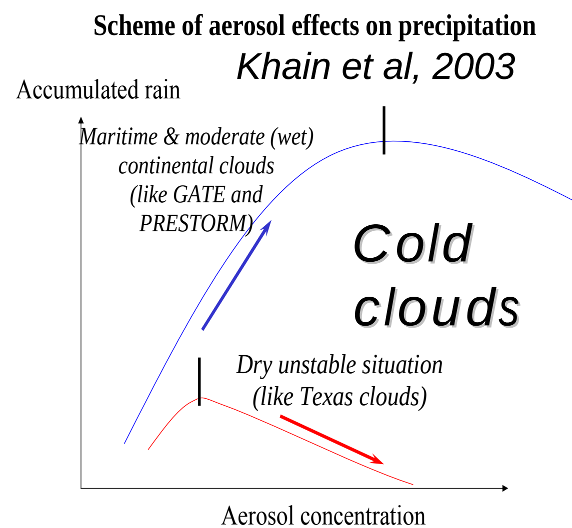
1. Efeito direto da chuva em remover aerossóis no início da estação chuvosa
2. Efeito combinado dos aerossóis na microfísica de nuvem com a mudança na dinâmica e termodinâmica da grande escala e o efeito radiativo alterando a estabilidade termodinâmica

Aerosol effects

- Radiation
  - Colder surface, warmer lower troposphere =stabilizing effect – less clouds → less rainfall?
- Cloud microphysics
  - Inhibit rainfall in warm clouds
  - Deep clouds?







Aerosol effects on precipitation

Aerosols (not including GCCN) inhibit precipitation:

Kaufman and Nakajima 1993;

Borys et al, 1998; 2000;

Rosenfeld and Lensky 1998;

Rosenfeld 1999, 2000;

Givati and Rosenfeld 2004

Tao et al (1995), Ferrier et al (1996)

Khain et al, 2001;

Khain and Pokrovsky (2004);

Khain et al (2004a,b)

Axel et al (2004); Tao et al (2004)

Teller and Levin(2006)

Margaritz et al (2006)

Lynn et al (2006)
Jirak and Cotton (2006)

Aerosols can increase precipitation:

Ohashi and Kida 2002
Shepherd and Burian 2003

Amiranashvili et al 2004

Filho et al (2004)

Khain et al (2004a,b)

Khain et al (2005-QJRMS)

Axel et al (2004);

Axel and Beheng (2004)

Tao et al (2004)

Van den Heever et al (2004)

Lynn et al (2005a,b)

Lynn et al (2006)

Khain et al (2005, 2006)

Khain and Pokrovsky (2006)

Observations in the Amazon (1)

- Koren et al (2004): scattered cumulus cloud cover decrease with increase in biomass burning derived aerosols
- Andreae et al (2004): biomass burning aerosol reduce cloud droplet size and reduce rainfall in low levels.

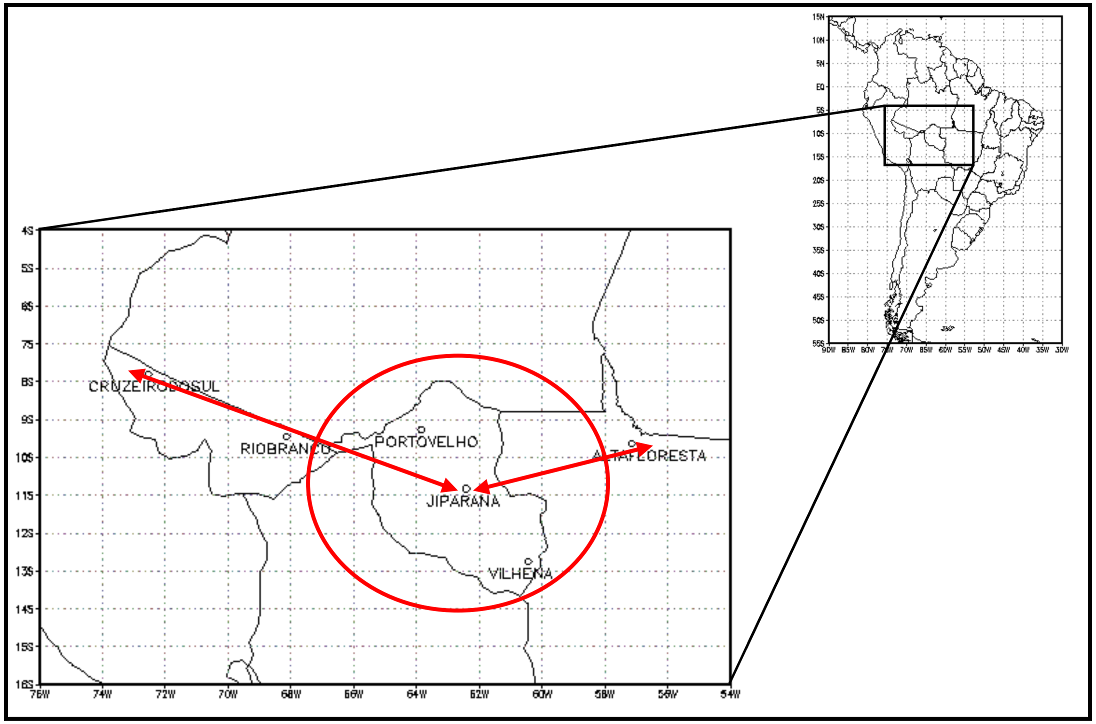

Amazonas
.CS
Acre
.RB
.PV
BRAZIL
AF.
FNS.
.JP
Rondônia
PERU
.VL
Mato Grosso
BOLIVIA


UECE
PT-SCY
26 9 2002

Flight region: SW Amazon

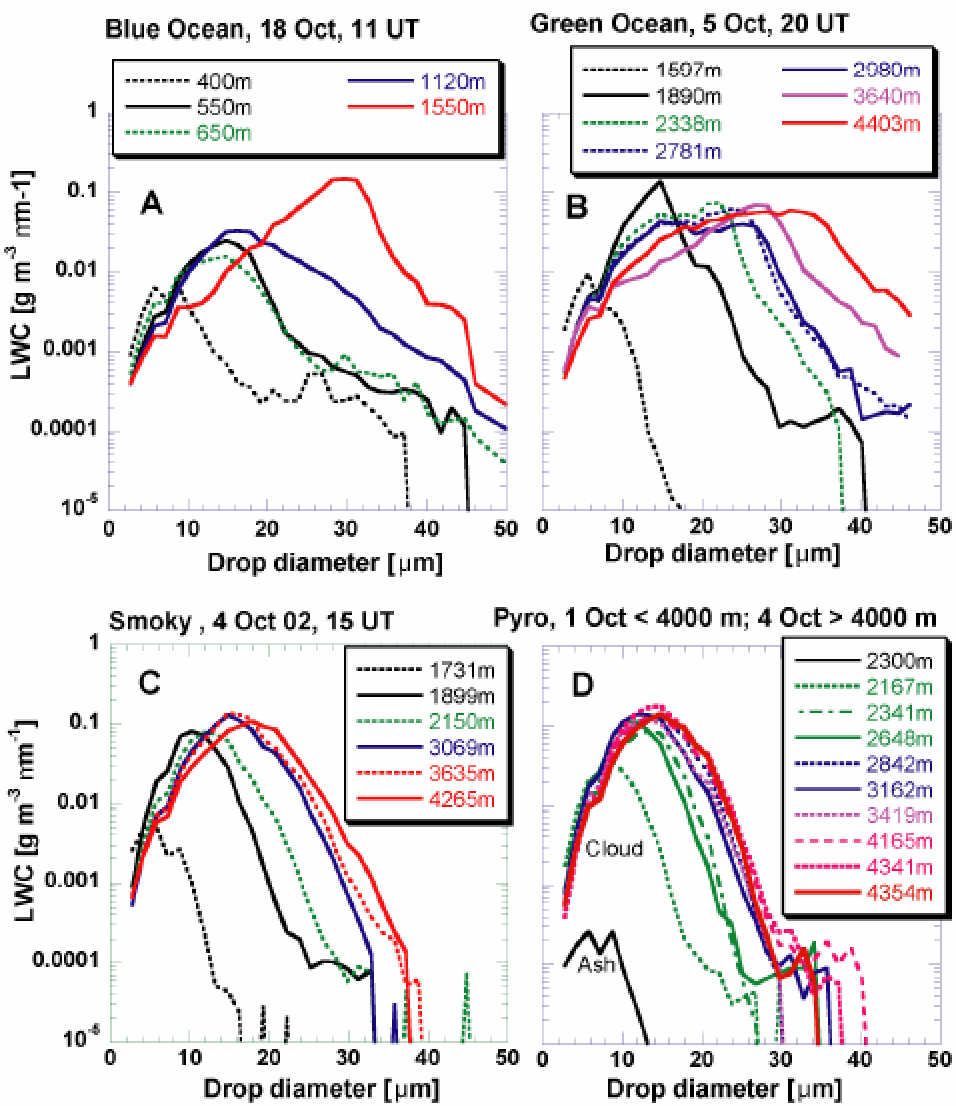
RACCI/LBA & SMOCC/LBA

- Microphysics measurements with aircraft:
  - CCN spectrum, cloud and rain drop spectra, cloud liquid water content, temperature, dew point temperature, pressure and GPS positioning.
- Flights from Sept 21 to Oct 13, 2002



Day	21	23	24	26	27	28	30a	30b	01a	01b	04a	04b
Time (LT)	13:24 15:30	14:07 16:16	14:43 17:04	14:02 16:18	14:27 16:03	13:37 15:38	11:14 12:17	13:49 16:40	10:16 12:25	16:47 17:20	11:06 12:25	13:54 15:49
Day	04c	05a	05b	06a	06b	08	09	11a	11b	12	13	
Time (LT)	16:48 18:36	12:13 14:18	15:24 17:01	11:12 13:15	14:19 16:45	14:53 16:30	13:32 15:27	10:43 12:10	13:21 14:46	11:45 13:38	13:20 15:50	

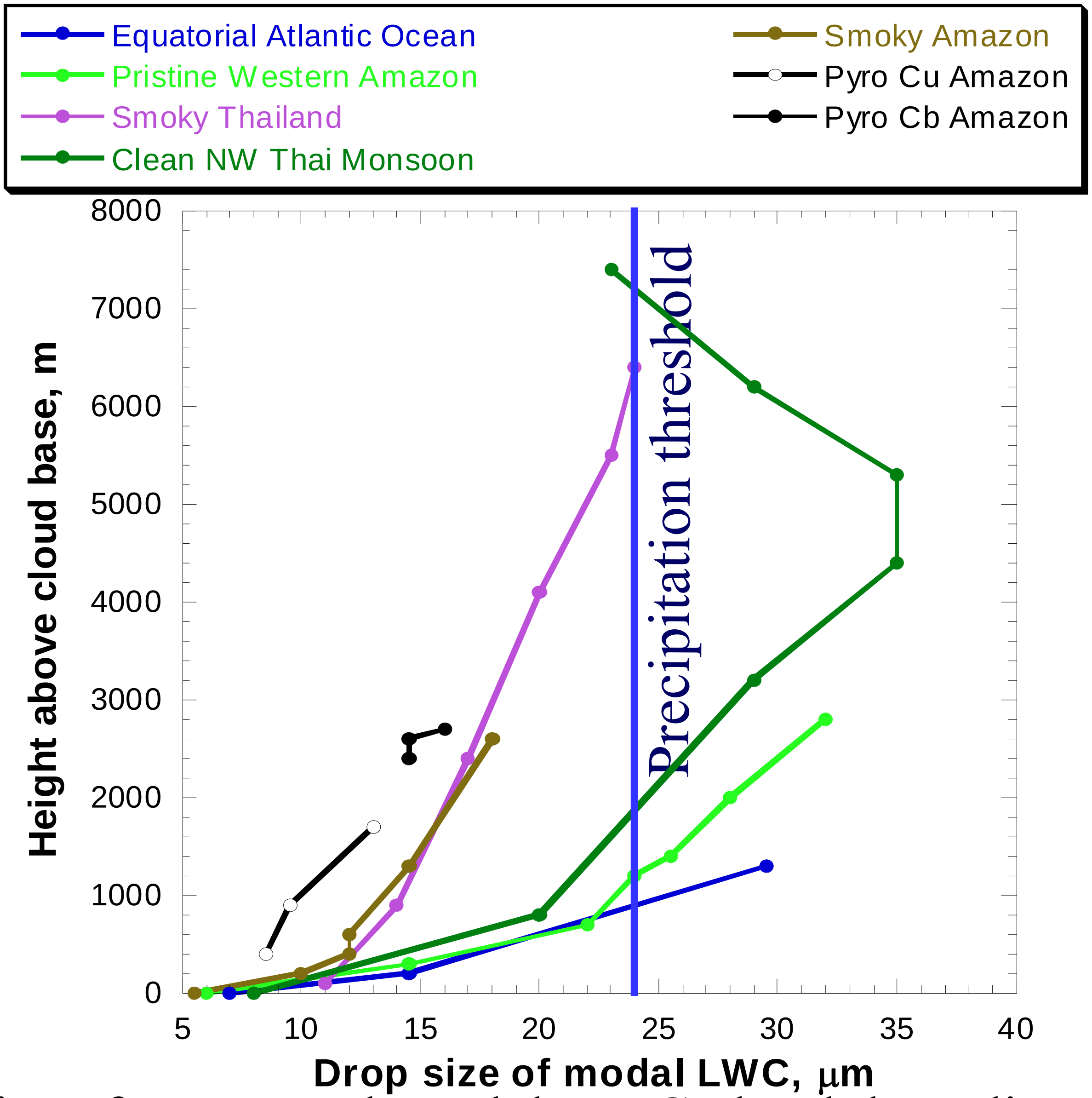
Andreae et al 2004 Smoking rain clouds over the Amazon - Science



(a)

(b)

(c)



Andreae, M. O., D. Rosenfeld, P. Artaxo et al., 2004: **Smoking rain clouds over the Amazon**. ***Science*, 303**, 1337-1342.

Aircraft measured Modal LWC cloud drop diameter as a function of height above cloud base, for the various aerosol regimes in Brazil [Thailand].

Observations in the Amazon (2)

- Lin et al (2006): high values of aerosol optical thickness in the Amazon (September-October 2000, 2003) are associated with
  - Increase in rainfall rate – change in PDF
  - Increase in Water Path (liquid + ice)
  - Increase in high level cloud cover
  - Lower values of cloud top temperatures

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 111, D19204, doi:10.1029/2005JD006884

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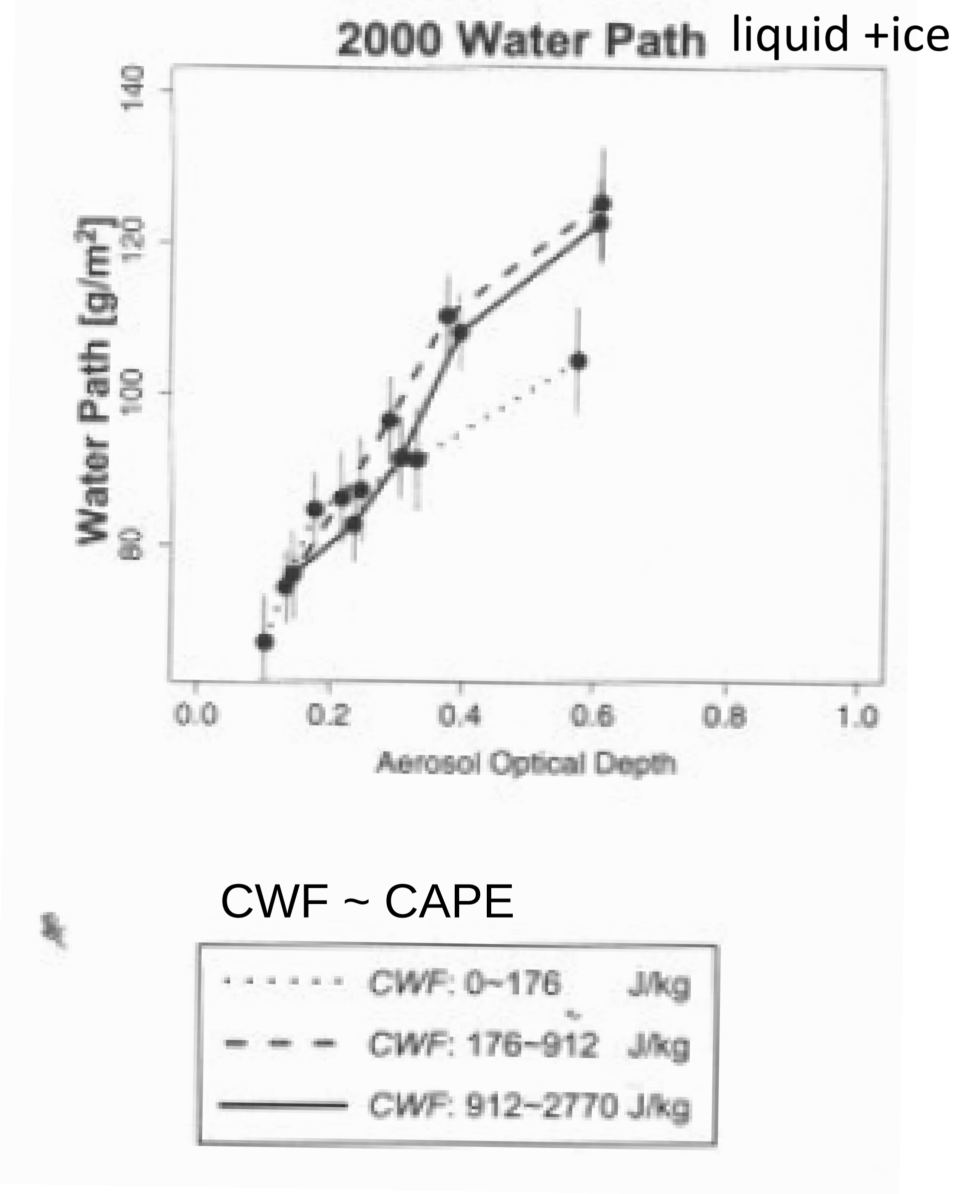
Effects of biomass-burning-derived aerosols on precipitation and clouds in the Amazon Basin: a satellite-based empirical study

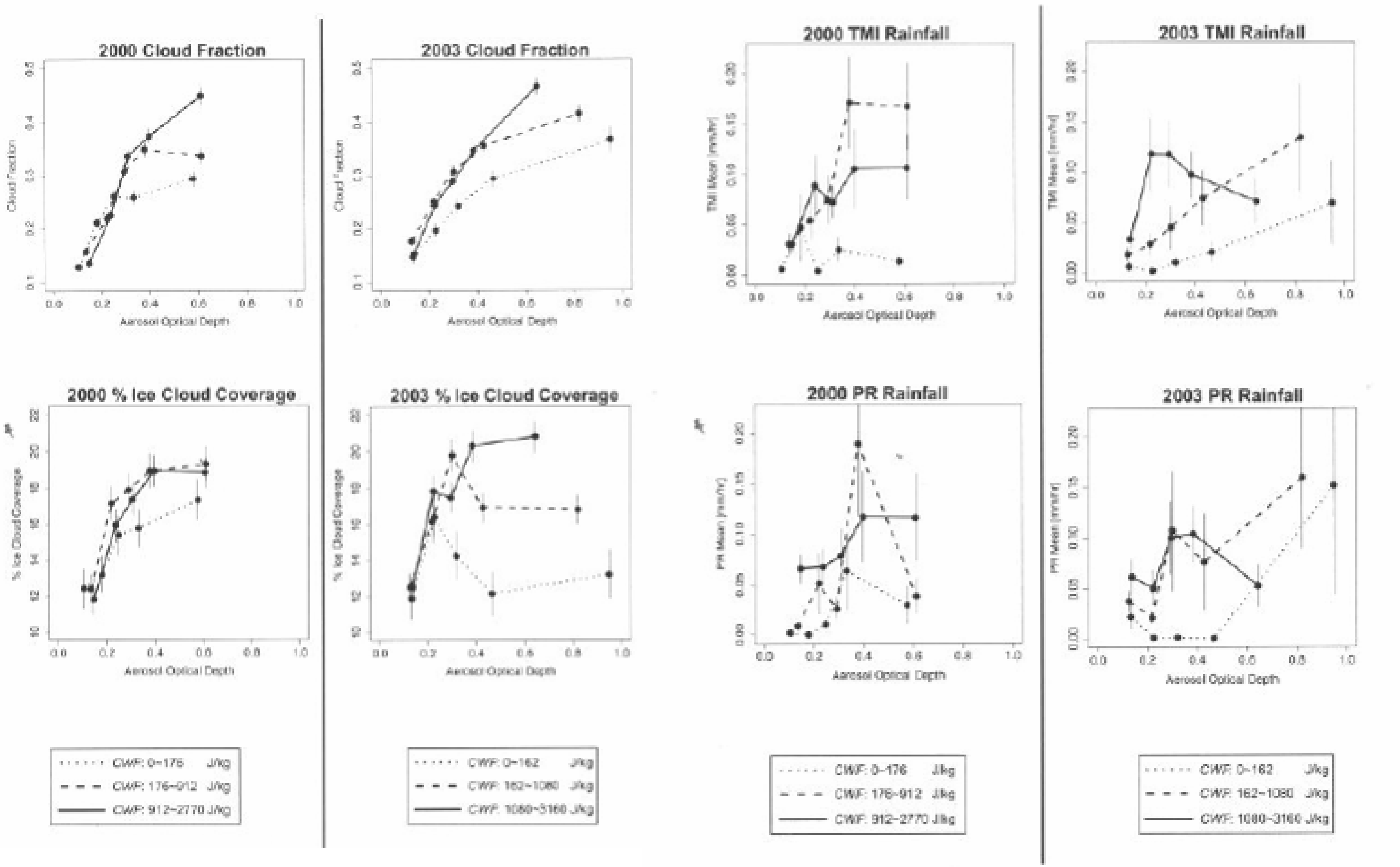
J. C. Lin,[1,2] T. Matsui,[1] R. A. Pielke Sr.,[1] and C. Kummerow[1]

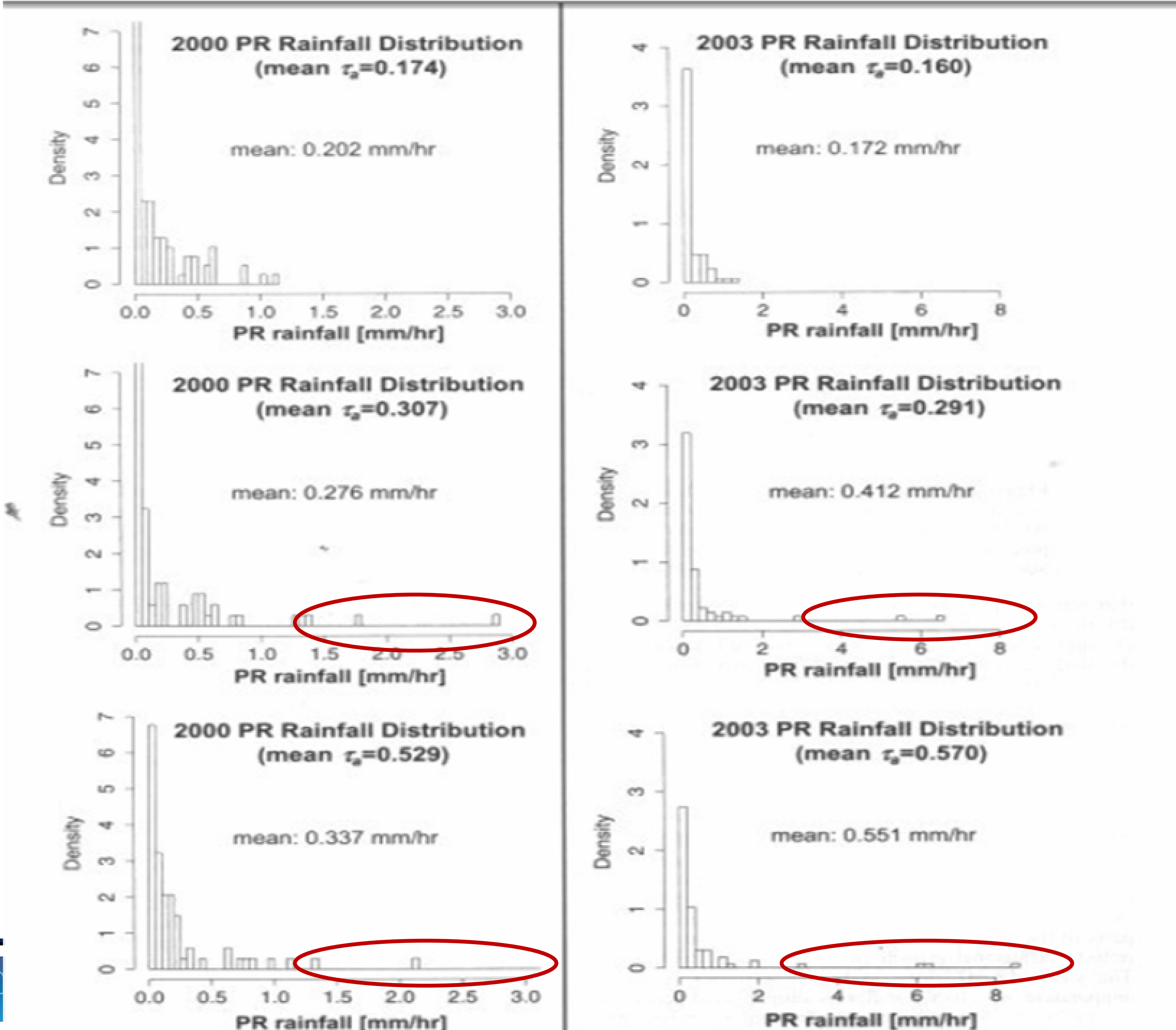
Lin et al
2006

TRMM
Precipitation
Radar
vs

MODIS AOT



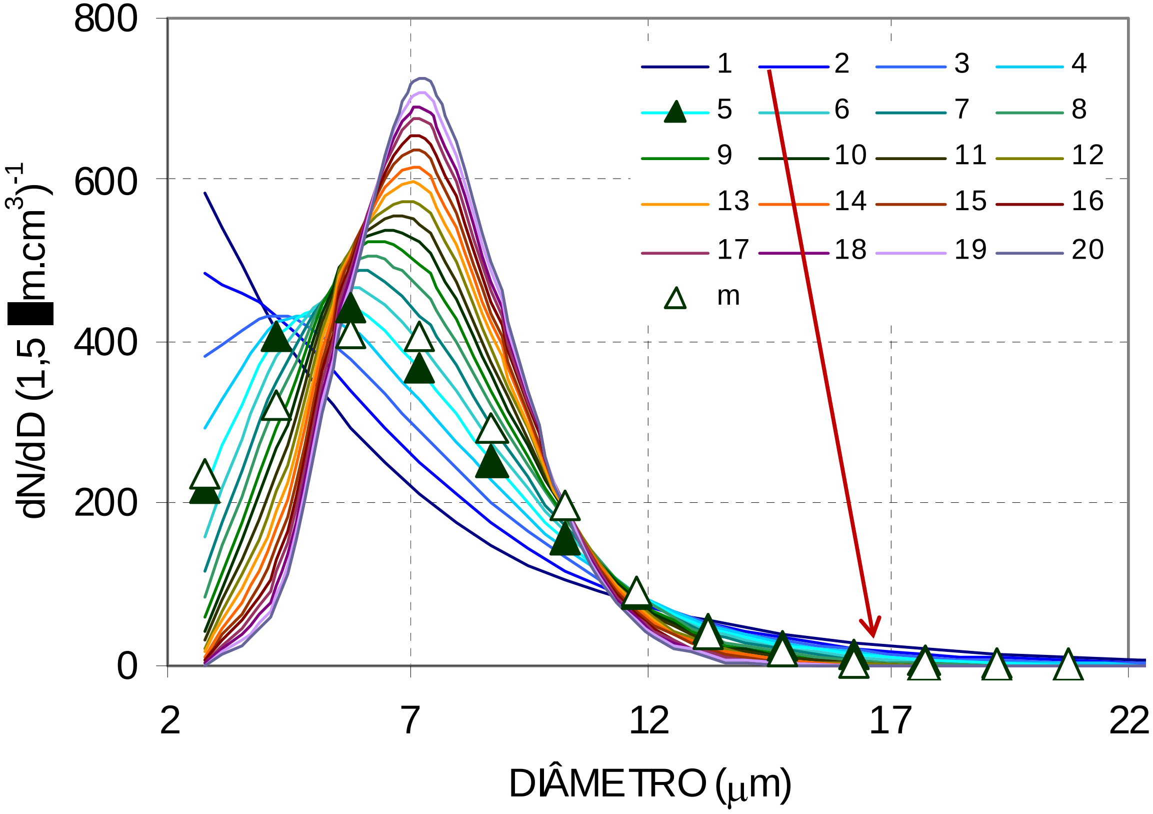

2000 Cloud Fraction
Cloud Fraction
Aerosol Optical Depth
2003 Cloud Fraction
2000 TMI Rainfall
TMI Mean [mm/hr]
2003 TMI Rainfall
2000 % Ice Cloud Coverage
% Ice Cloud Coverage
2003 % Ice Cloud Coverage
2000 PR Rainfall
PR Mean [mm/hr]
2003 PR Rainfall
CWF: 0~176 J/kg
CWF: 176~912 J/kg
CWF: 912~2770 J/kg
CWF: 0~162 J/kg
CWF: 162~1080 J/kg
CWF: 1080~3160 J/kg


2000 PR Rainfall Distribution
(mean τ_a=0.174)
mean: 0.202 mm/hr
Density
PR rainfall [mm/hr]
2003 PR Rainfall Distribution
(mean τ_a=0.160)
mean: 0.172 mm/hr
Density
PR rainfall [mm/hr]
2000 PR Rainfall Distribution
(mean τ_a=0.307)
mean: 0.276 mm/hr
Density
PR rainfall [mm/hr]
2003 PR Rainfall Distribution
(mean τ_a=0.291)
mean: 0.412 mm/hr
Density
PR rainfall [mm/hr]
2000 PR Rainfall Distribution
(mean τ_a=0.529)
mean: 0.337 mm/hr
Density
PR rainfall [mm/hr]
2003 PR Rainfall Distribution
(mean τ_a=0.570)
mean: 0.551 mm/hr
Density
PR rainfall [mm/hr]

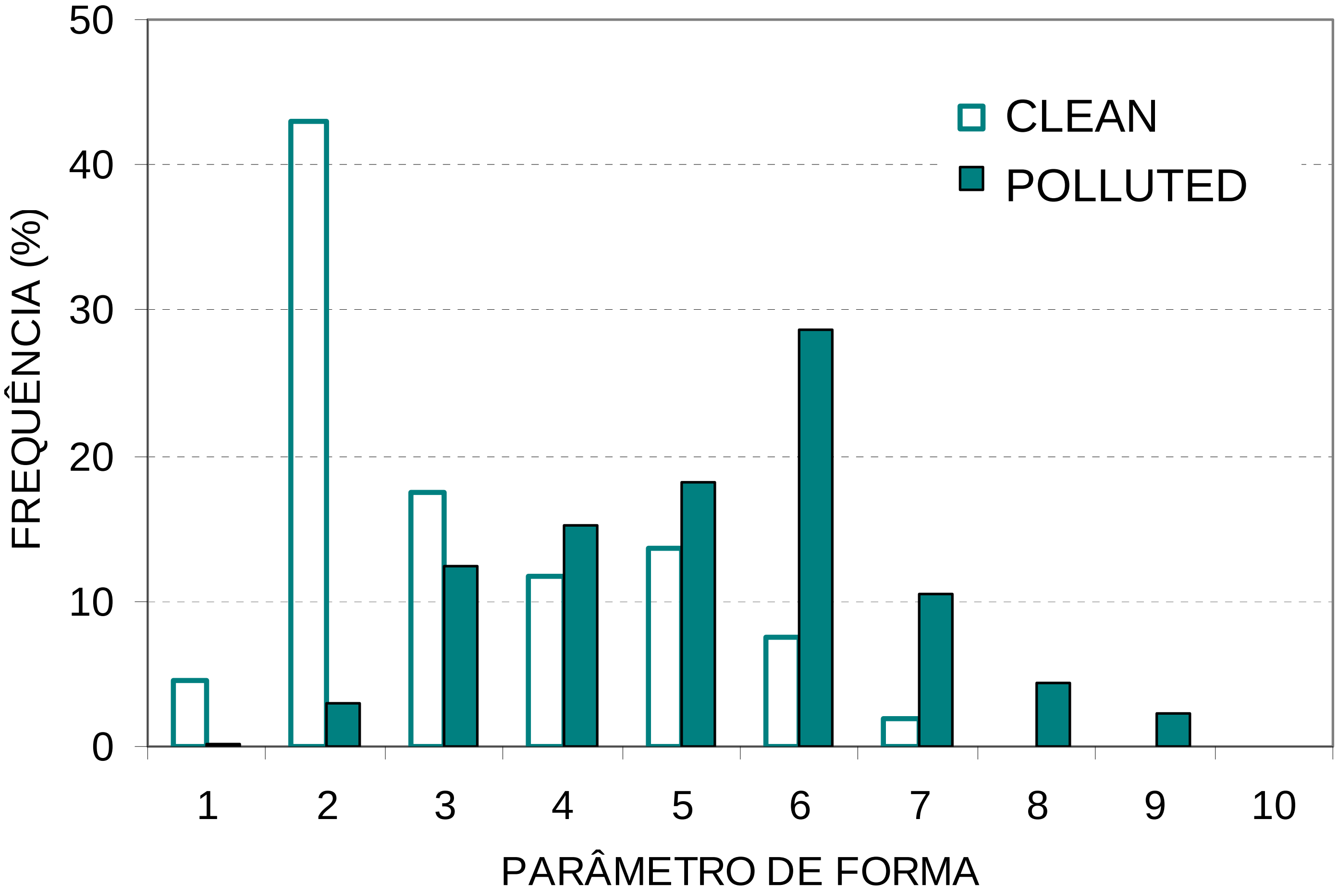
- **Martins**, Silva Dias, Gonçalves (2007):Modeling the impacts of biomass burning aerosols on precipitation in the Amazonian region using BRAMS: a case study for 23 September 2002 – To be submitted
- **Martins** et al 2007 : Cloud condensation nuclei from biomass burning during the Amazonian dry-to-wet transition season – Meteo. Atmos . Phys. (submitted)
- Gonçalves, **Martins,** Silva Dias, 2007 – Shape parameter analysis usning cloud spectra and gamma functions in numerical modelling during LBA in Amazon – accepted with minor revisions Atmos Research.

Shape parameter in cloud droplet diameter distribution

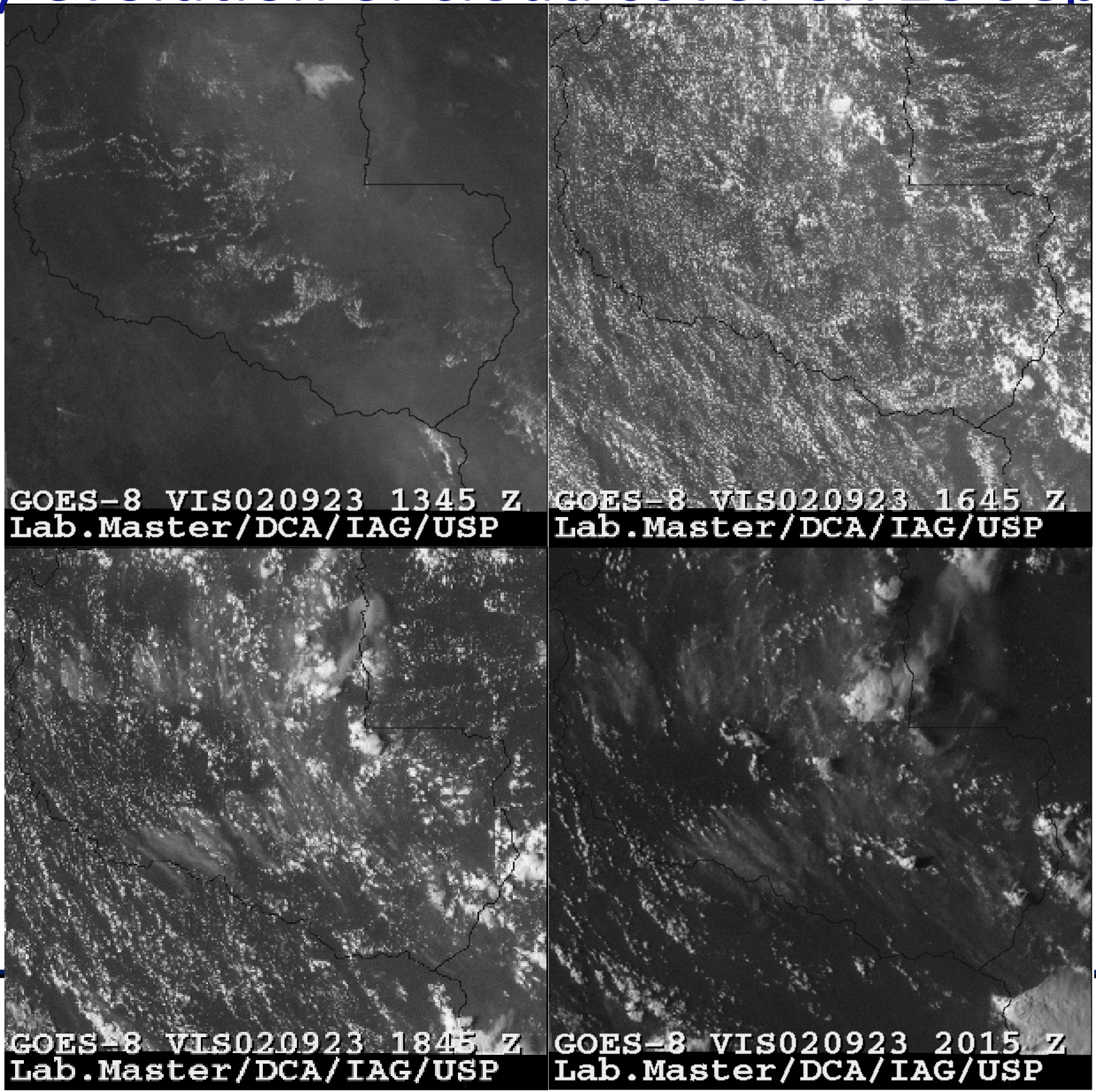
$$n(D) = \frac{N_t}{\Gamma(\nu)}\left(\frac{D}{D_n}\right)^{\nu-1}\frac{1}{D_n}\exp\left(-\frac{D}{D_n}\right)$$



Frequency of shape parameters for all flights



Visible images from GOES satellite showing the daily evolution of cloud cover on 23 September



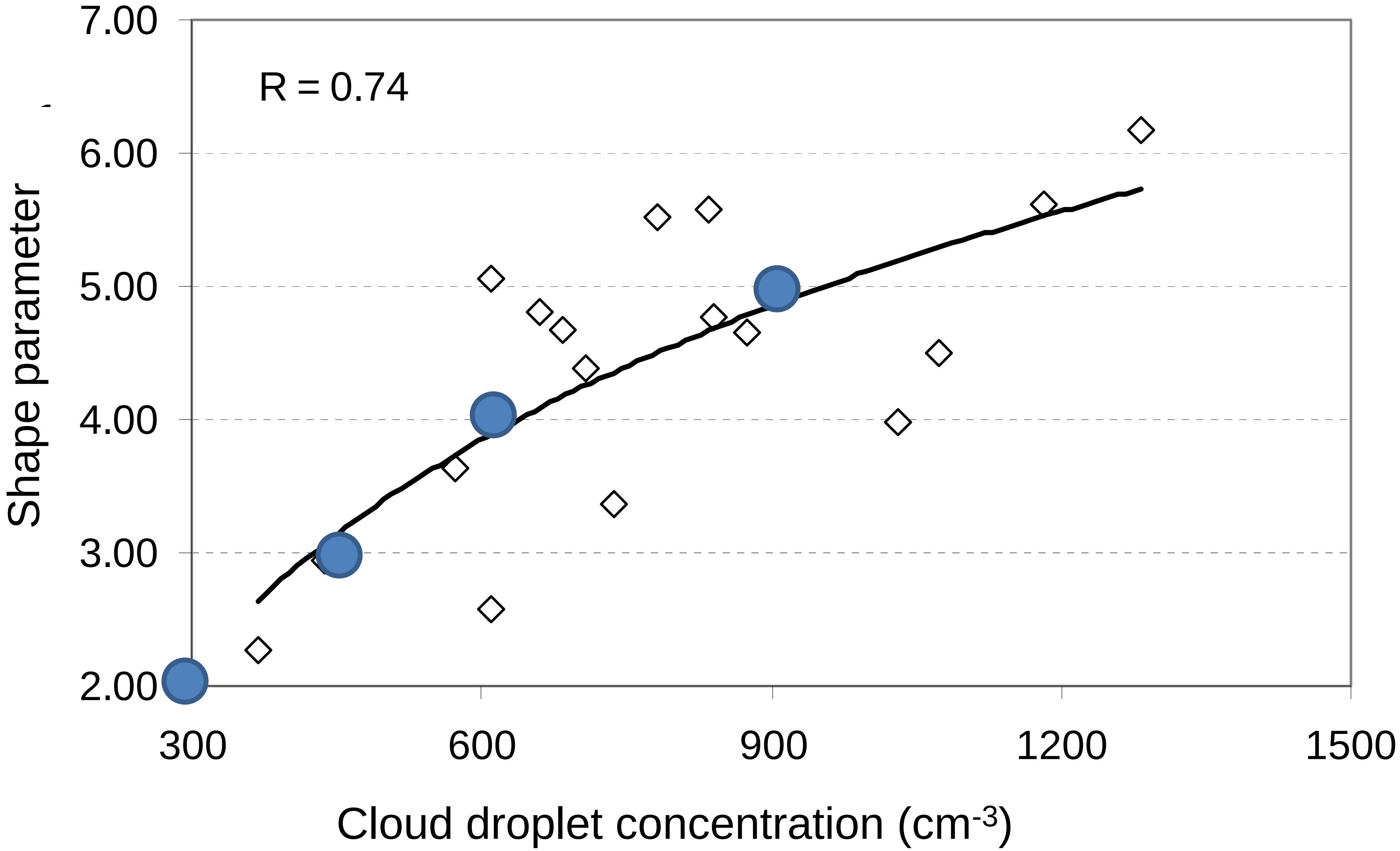
Grid specifications for the numerical experiments with BRAMS (Brazilian modifications to RAMS – Freitas et al 2007)

The Coupled Aerosol and Tracer Transport model to the Brazilian developments on the Regional Atmospheric Modeling System. 1: model description and evaluation .S. R. Freitas, K. M. Longo, M. A. F. Silva Dias, R. Chatfield, P. Silva Dias, P. Artaxo, M. O. Andreae, G. Grell, L. F. Rodrigues, A. Fazenda, J. Panetta – Accepted Atmos.Chemis. Physics.

	Grid 1	Grid 2	Grid 3	Grid 4
Starting and end time	**00Z, 23 September 2002 – 00Z, 24 September 2002**			
Number of grid points (x, y, z)	(62,62,43)	(62,62,43)	(122,122,43)	(42,42,43)
Horizontal grid spacing (x, y)	(64, 64 km)	(16, 16 km)	(4, 4 km)	(1, 1 km)
Vertical grid spacing	43 levels with variable stretching factor			
Time step	120	30	7,5	1,875
Grid center	(10,92 ºS 62,41ºW)			

◊ Observed shape parameter x CCN concentration

● numerical experiments



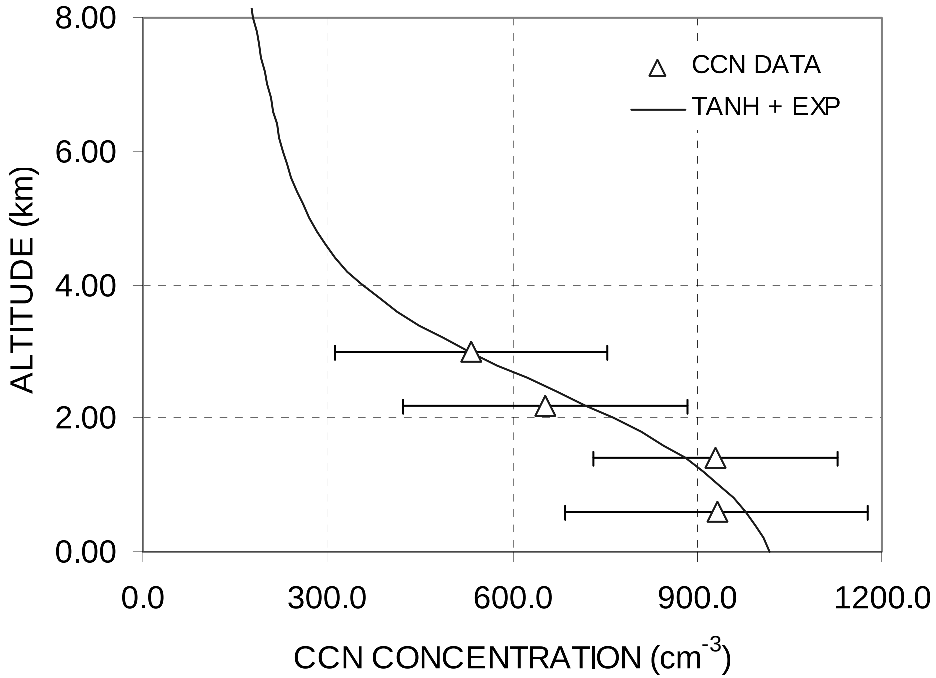
Microphysics parameters used in numerical experiments

	CCN300	CCN450	CCN600	CCN900	CCN900R
CCN concentration	300	450	600	900	900
Shape parameter – cloud droplet and pristine ice	2	3	4	5	5
Shape parameter – all remaining water categories	1	1	1	1	1
Radiative effect	None	None	None	None	Absorbing and reflecting

Parameterized radiative effect of aerosol from biomass burning in the Amazon

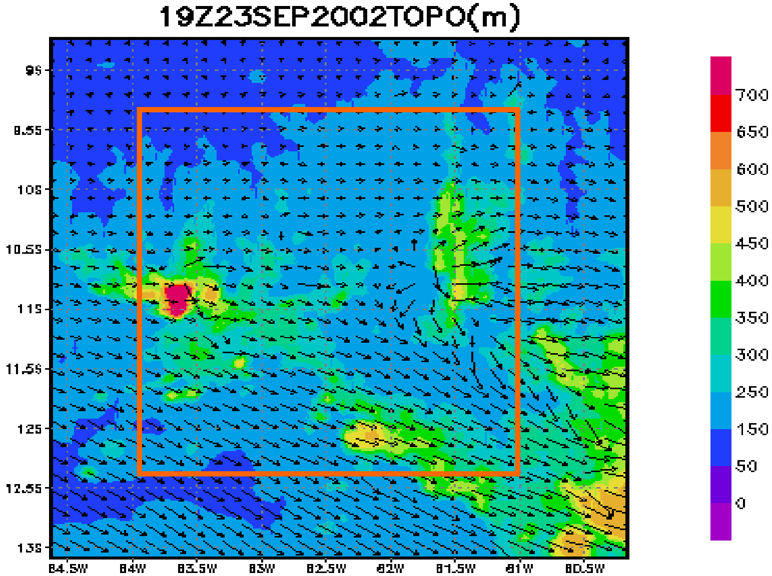
Procópio et al (2004) indicate 20% extinction of solar radiation during dry season in Amazon due to aerosol

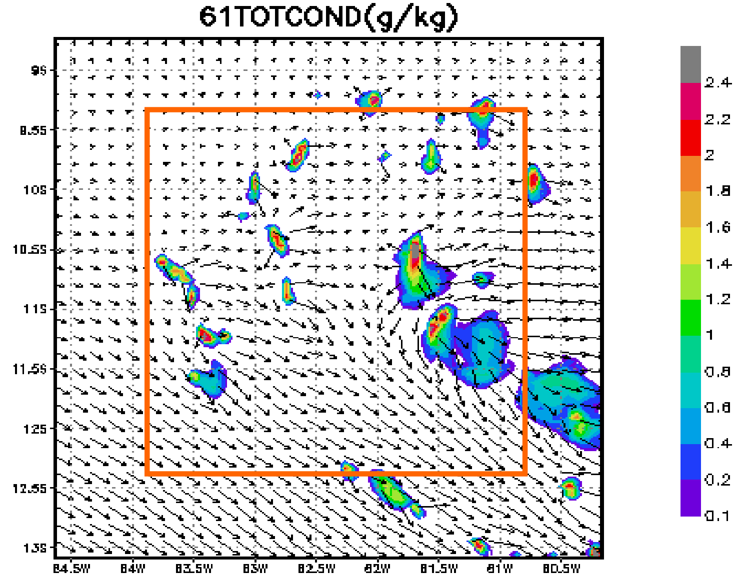
- 4% reflected
- 16% absorption in lower layers: adjusted according to observed CCN profile

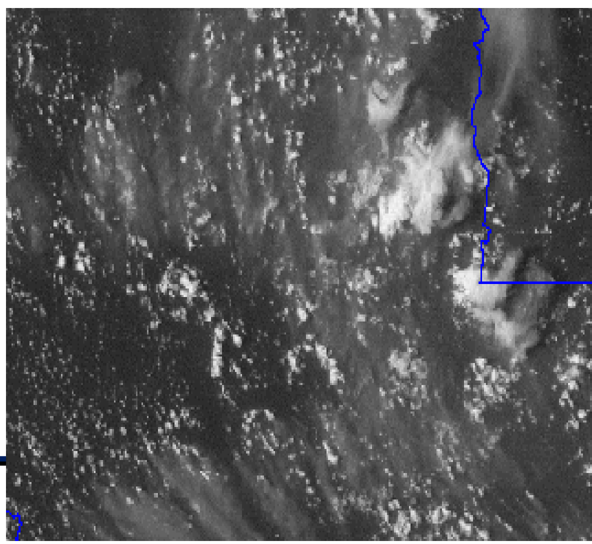


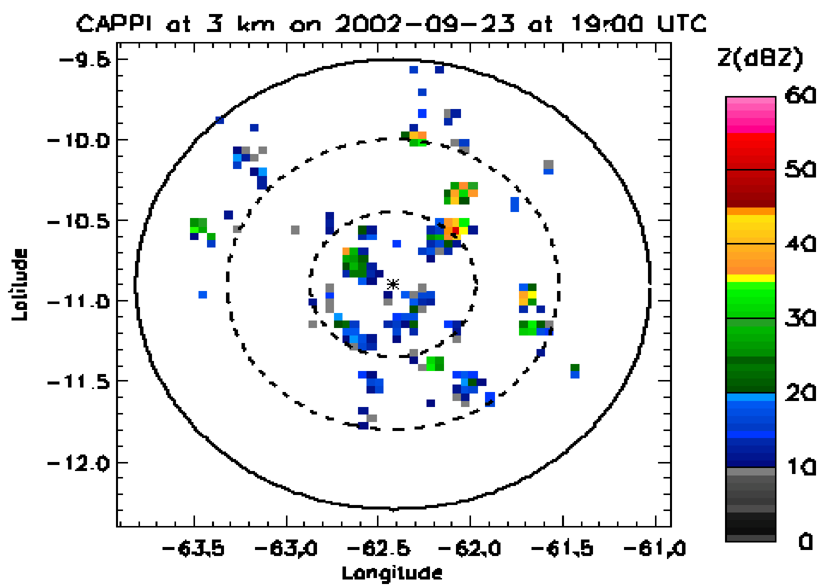
Vertical profile of CCN concentration measurements on 23 September 2003

Control simulation CCN300
Visible Satelite and Radar

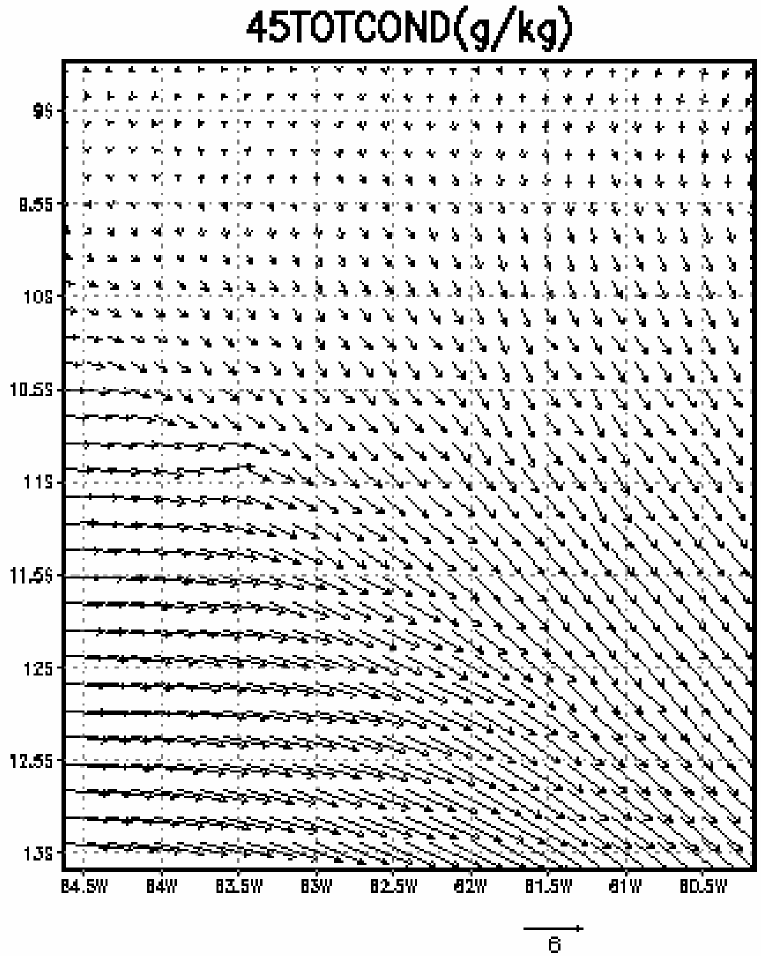








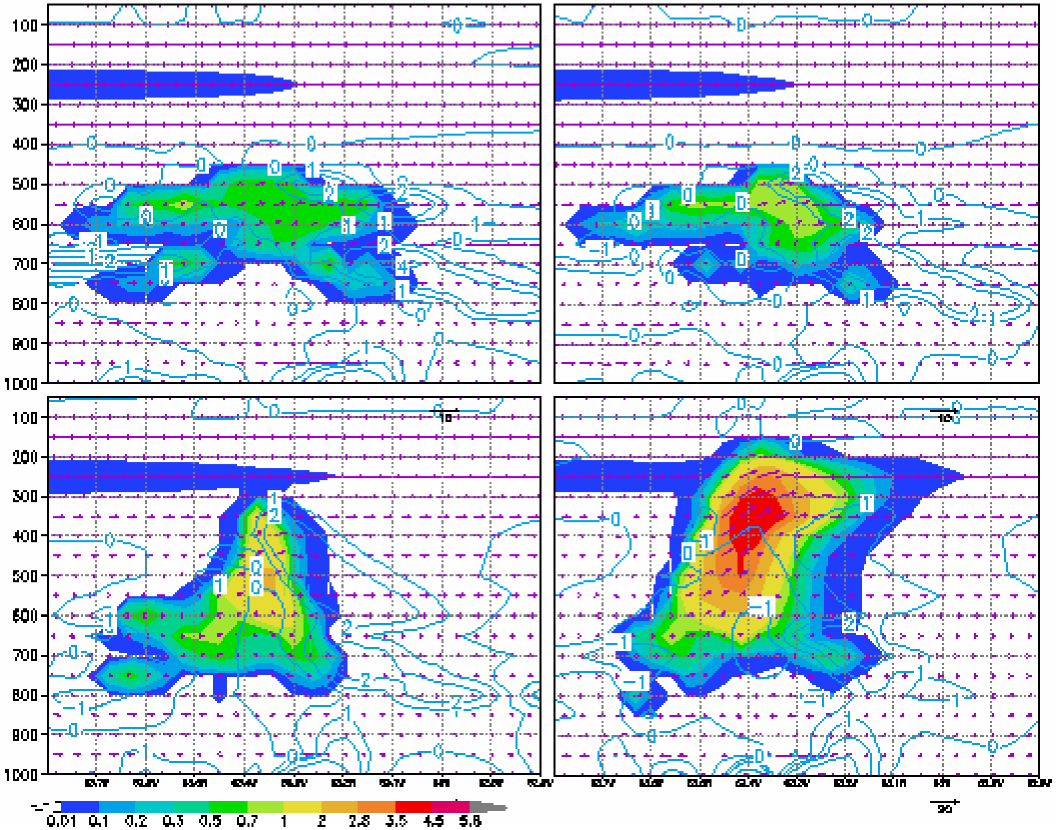
Total Condensate CCN300



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

CCN300

CCN450

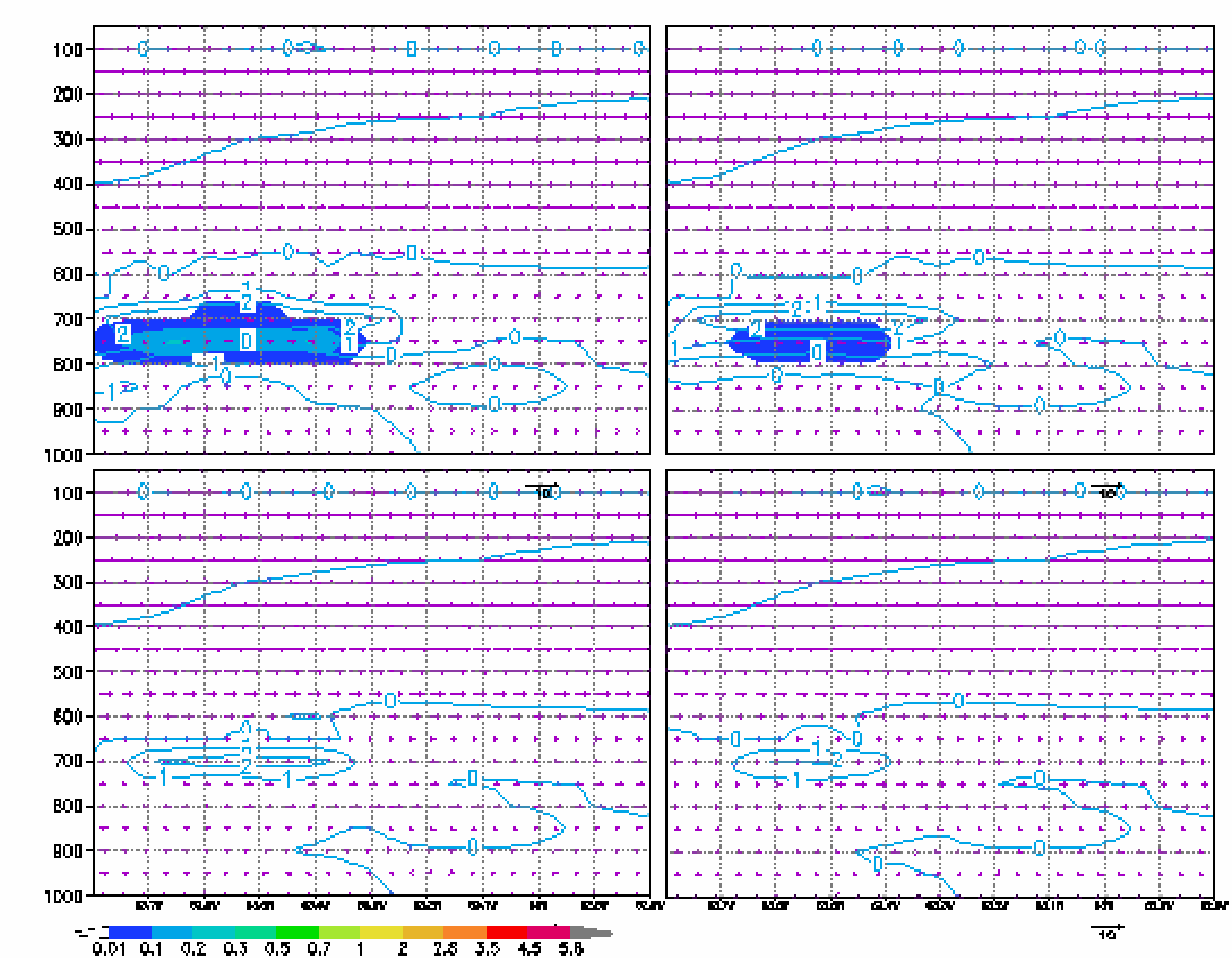


CCN600

CCN900

ccn300

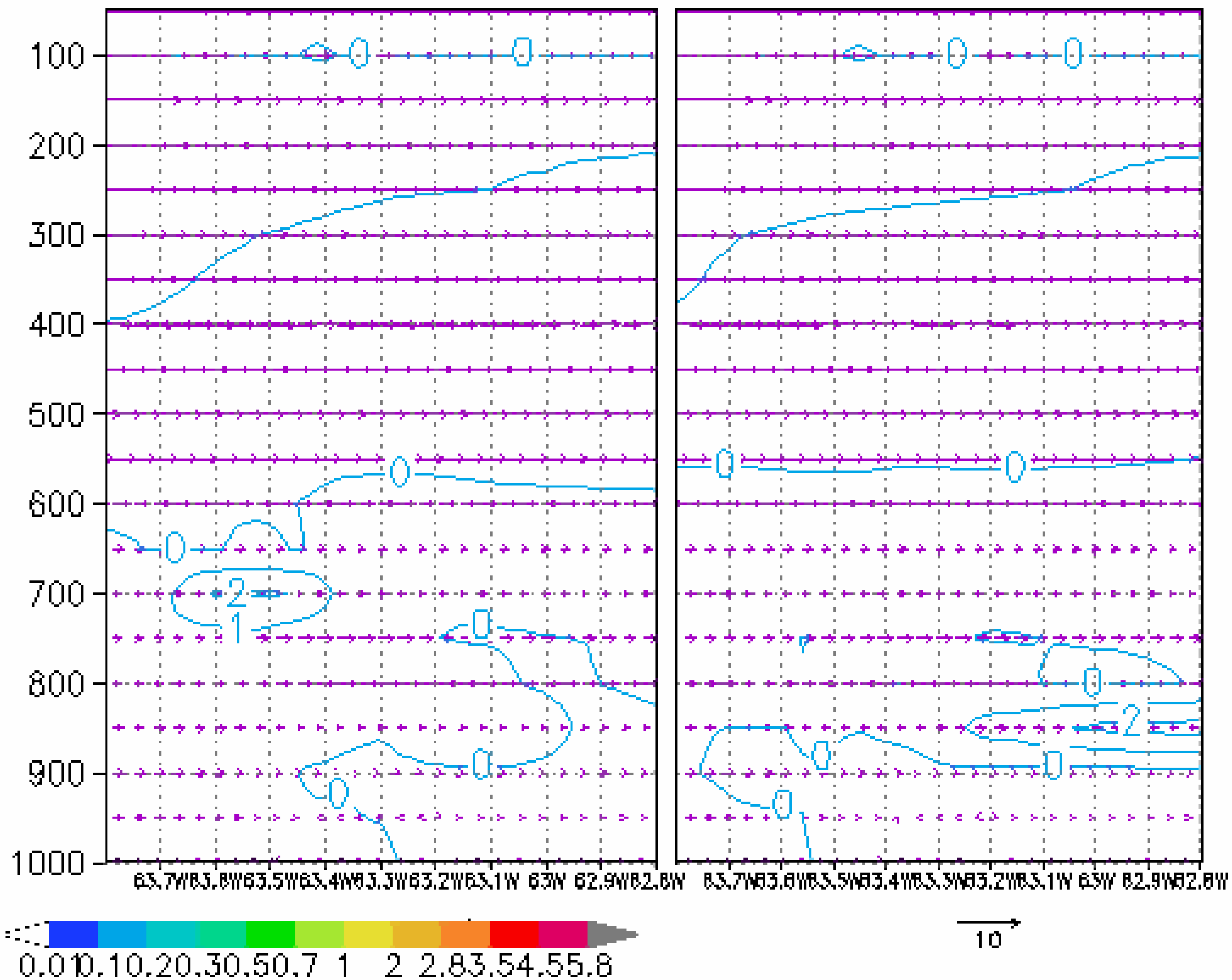
ccn450



ccn600

ccn900

CCN 900 & CCN 900R

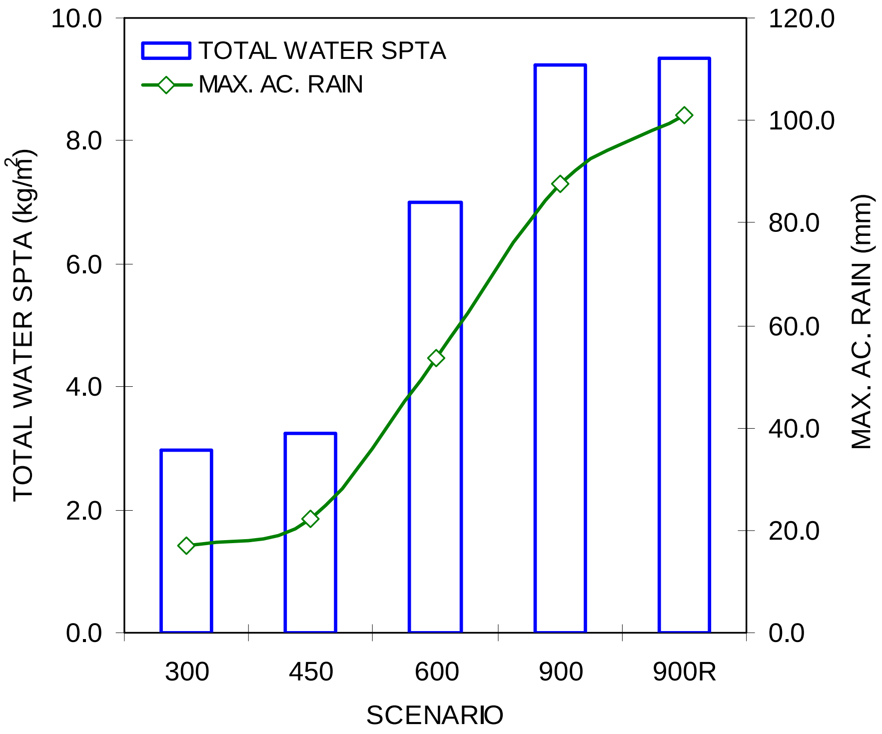


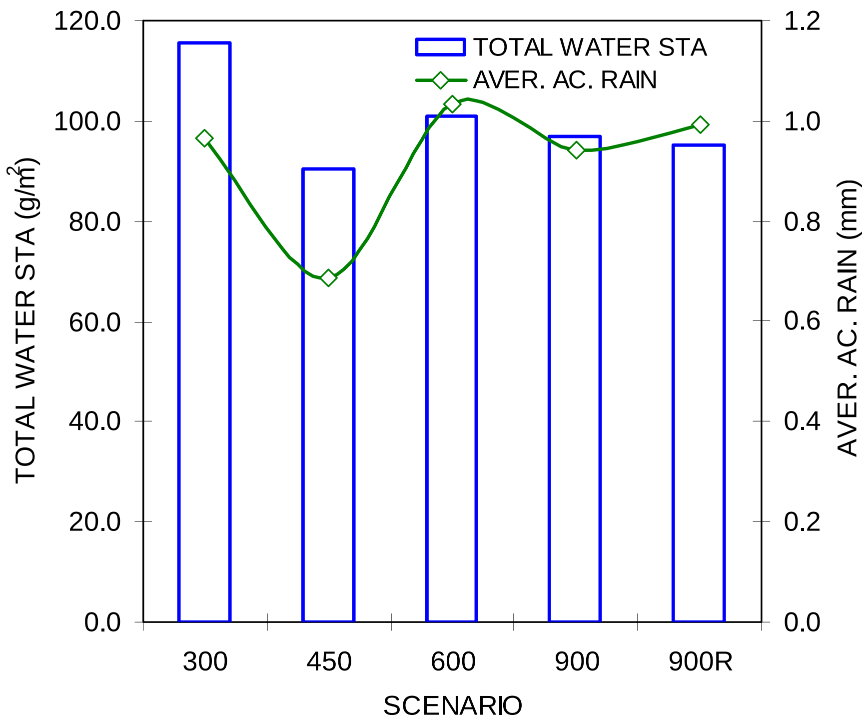
MICROPHYSICS VARIABLE	UNIT	CCN300	CCN450	CCN600	CCN900	CCN900R
MAX. CLOUD DROPLET CONC.	cm^{-3}	192.092	295.961	424.282	645.883	641.302
PRISTINE SPTA	kg/m^2	0.008	0.008	0.159	0.562	0.594
PRISTINE STA	g/m^2	0.271	0.193	0.372	2.723	2.229
SNOW SPTA	kg/m^2	0.009	0.009	0.024	0.090	0.079
SNOW STA	g/m^2	0.282	0.354	0.529	2.018	1.345
AGGREGATES SPTA	kg/m^2	0.002	0.014	0.393	1.193	1.186
AGGREGATES STA	g/m^2	0.006	0.009	0.538	7.353	6.412
GRAUPEL SPTA	kg/m^2	0.005	0.016	0.412	1.273	1.238
GRAUPEL STA	g/m^2	0.004	0.006	0.662	3.181	2.780
HAIL SPTA	kg/m^2	0.058	0.052	0.355	0.581	0.592
HAIL STA	g/m^2	0.190	0.019	0.562	1.064	1.020
TOTAL ICE SPTA	kg/m^2	0.082	0.100	1.343	3.700	3.690
TOTAL ICE STA	g/m^2	0.753	0.581	2.664	16.340	13.785
CLOUD WATER SPTA	kg/m^2	1.013	1.286	2.293	2.693	2.475
CLOUD WATER STA	g/m^2	64.600	56.273	61.452	52.061	51.359
RAIN WATER SPTA	kg/m^2	1.948	1.931	4.222	4.899	4.946
RAIN WATER STA	g/m^2	50.217	33.677	36.968	28.597	30.105
TOTAL WATER SPTA	kg/m^2	2.965	3.229	7.011	9.251	9.349
TOTAL WATER STA	g/m^2	115.569	90.532	101.083	96.998	95.249
MAX. CLOUD COVER	%	33.280	27.974	24.012	18.965	17.589
RAIN RATE SPTA	mm/h	4.972	5.441	15.571	19.340	20.169
RAIN RATE STA	mm/h	0.126	0.091	0.134	0.119	0.125
MAX. AC. PRECIPITATION	mm	16.936	22.154	53.744	87.658	100.883
AVE. AC. PRECIPITATION	mm	0.964	0.685	1.032	0.943	0.991
MAX. VERTICAL VELOCITY	m/s	2.250	2.390	5.160	7.830	8.370
SURF. ENERGY GAIN	MJ/m^2	1.38	1.57	1.63	1.75	1.52

STA – Space & Time Average

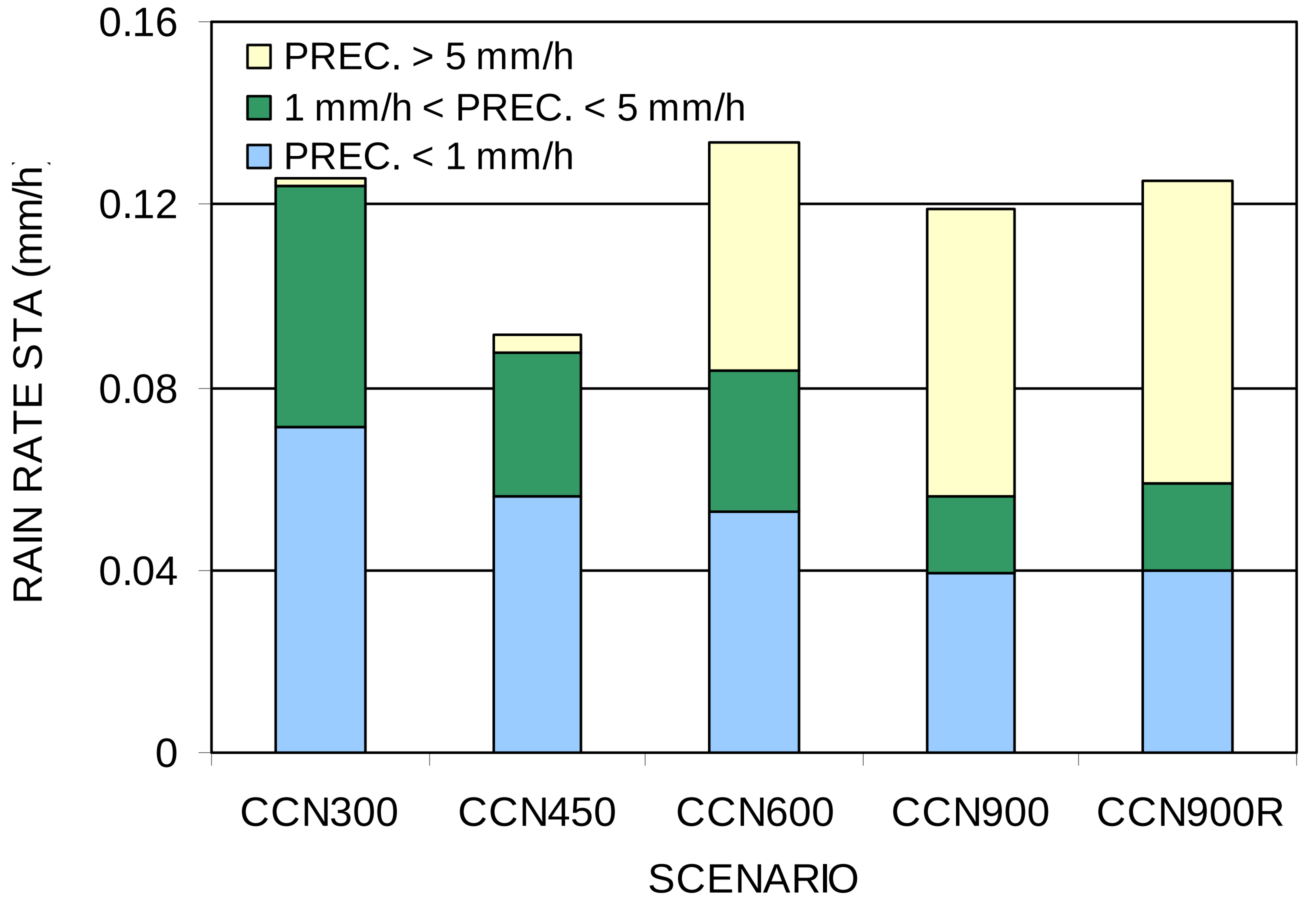
SPTA – Space Peak & Time Average

Time evolution of precipitation fields in terms of maximum and average values

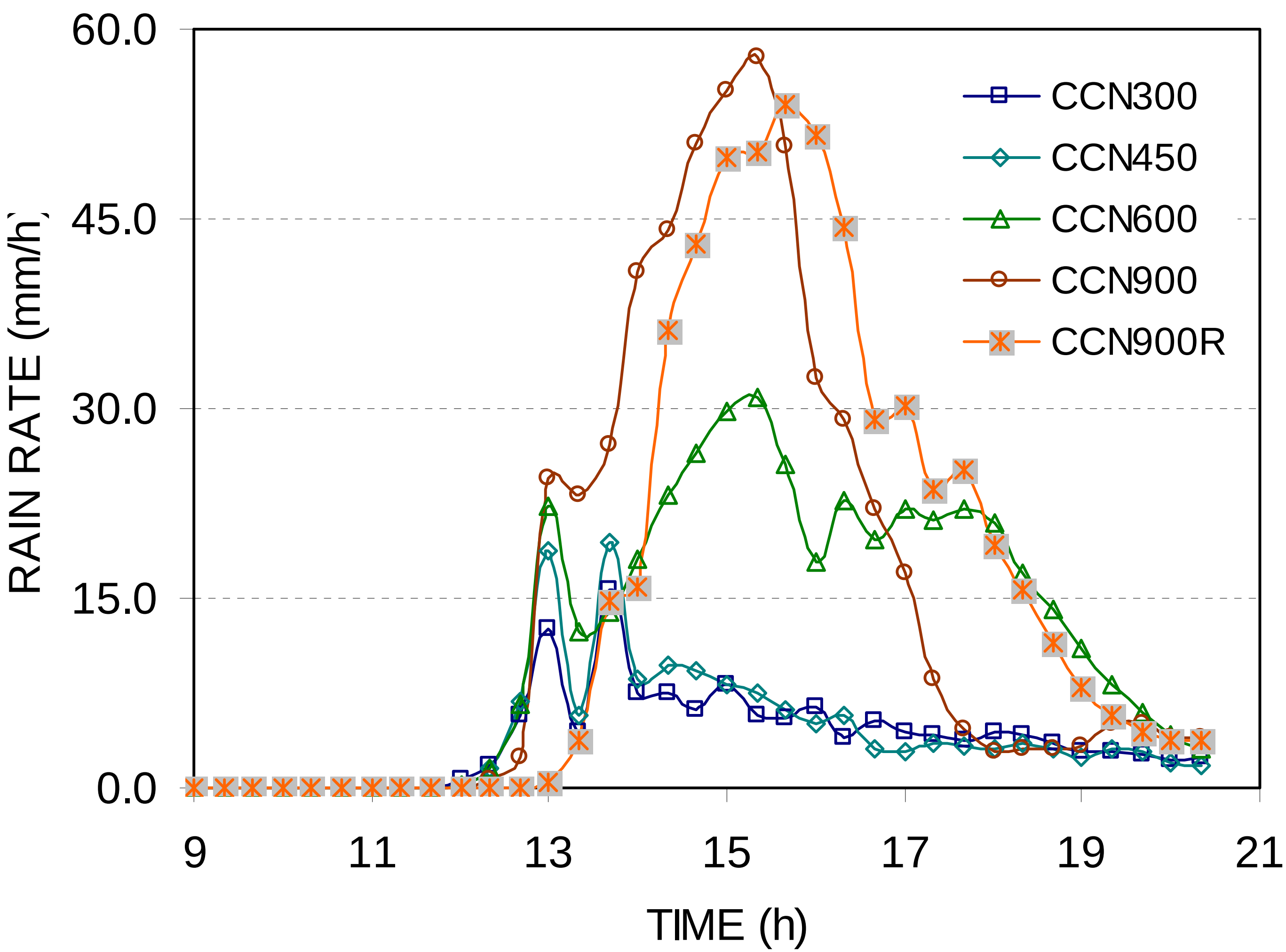




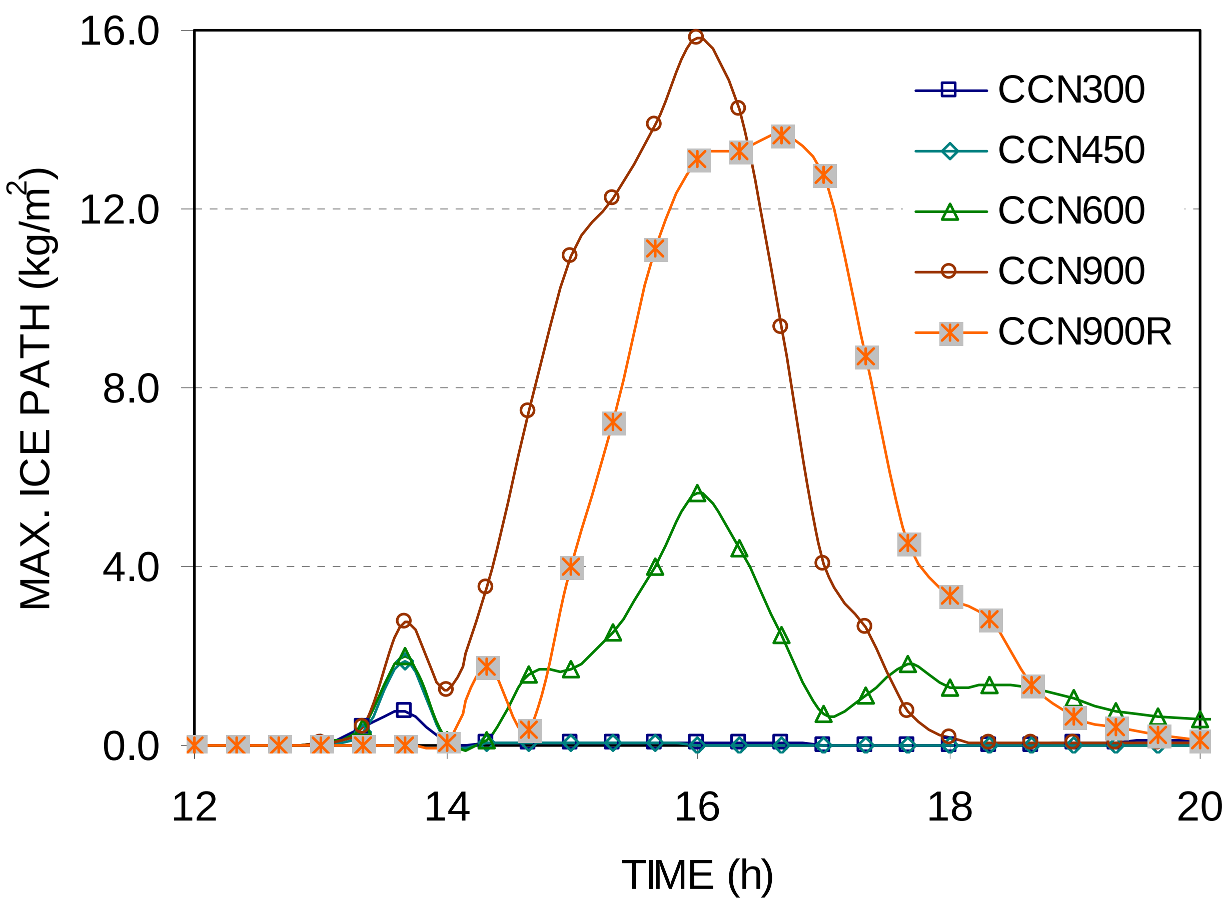
Partitioning of the precipitation according to the intensity of averaged rain rate – change in PDF



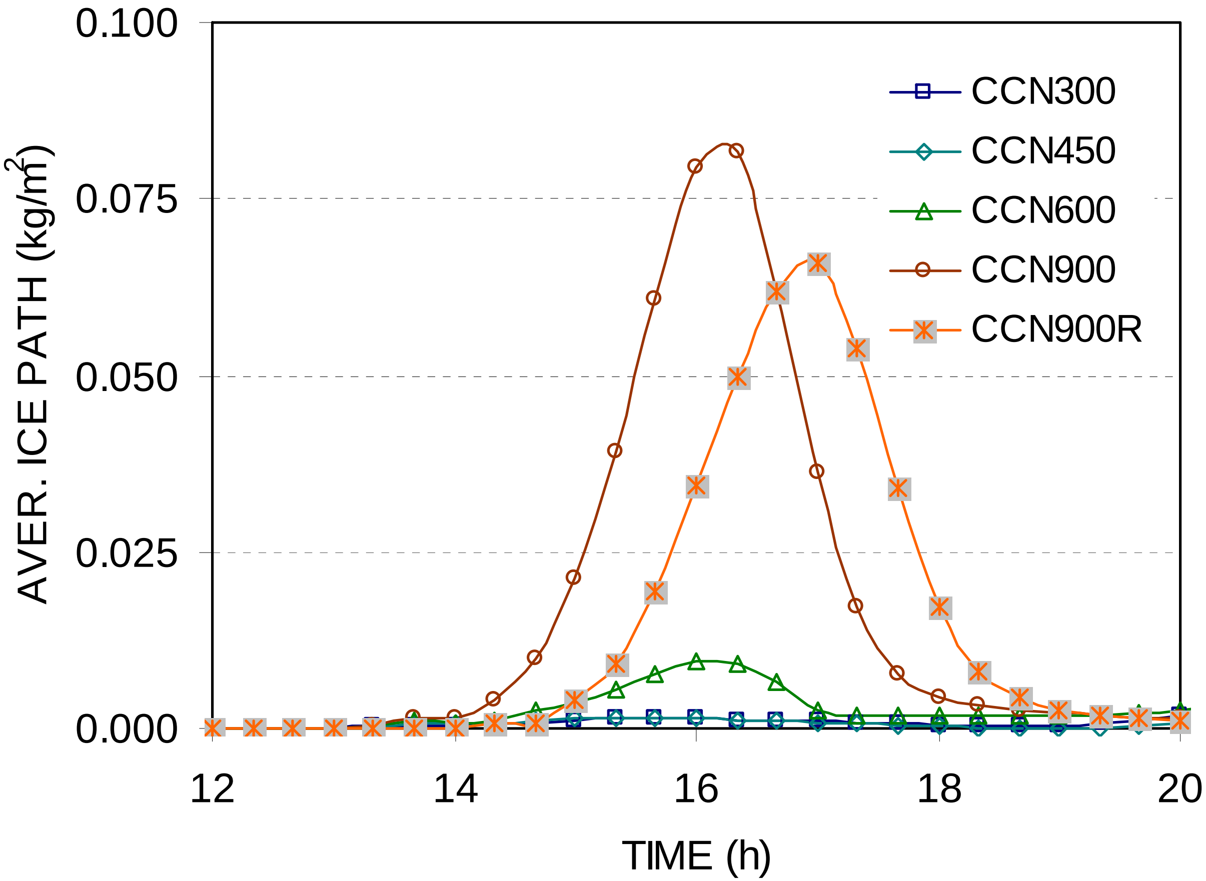
Time evolution of rain rate in terms of maximum values on grid



Time evolution of ice path in terms of maximum values on grid

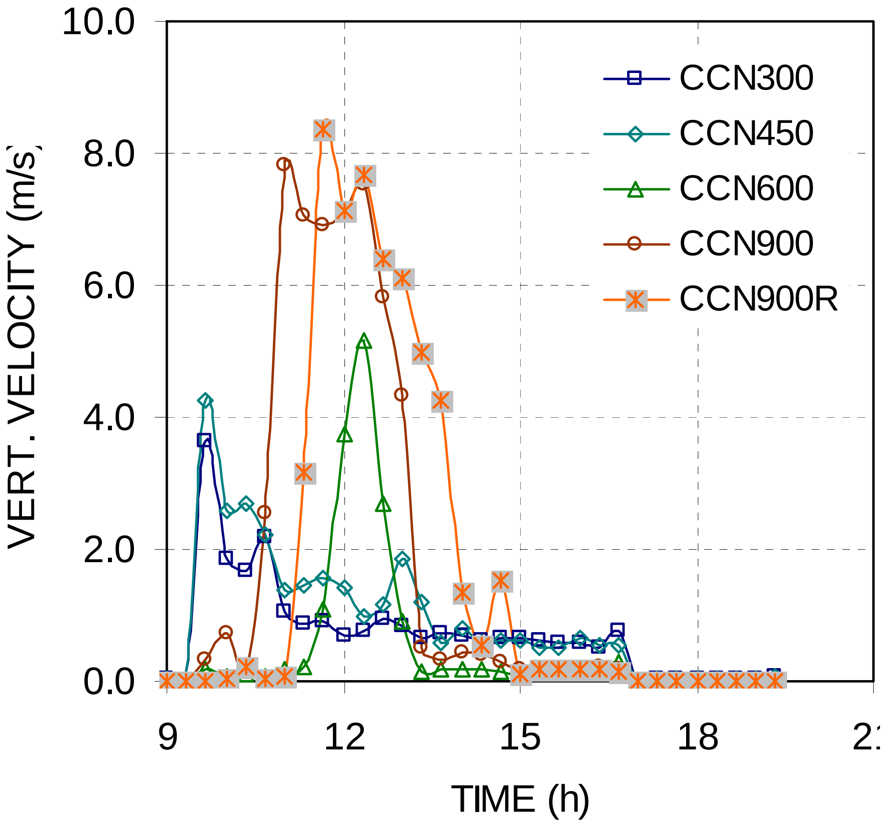


Time evolution of ice path in terms of average values on grid

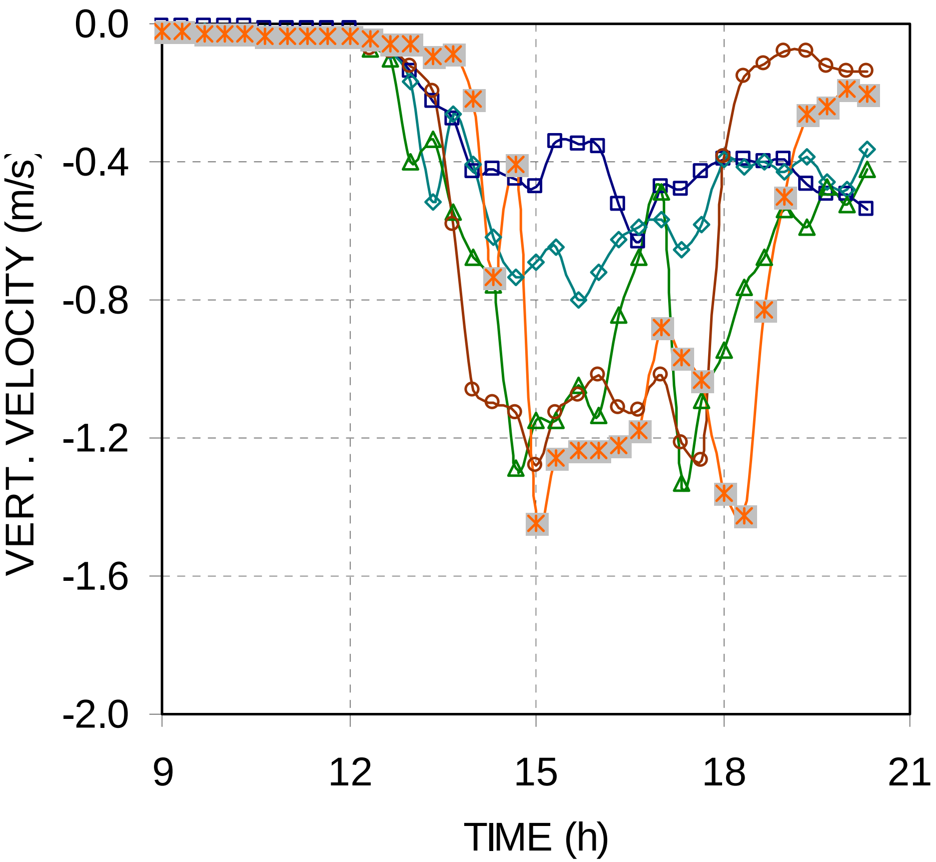


Time evolution of

(a) max updraft



(b)max downdraft

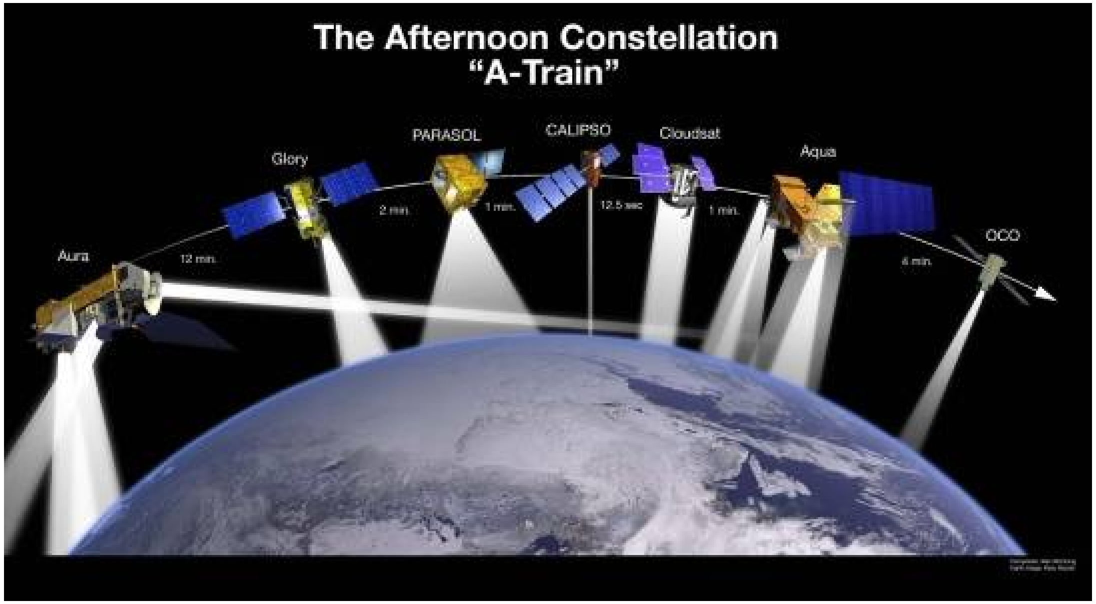


Conclusions from numerical experiments Amazon aerosol from biomass burning and rainfall interactions

- Enhanced CCN concentration increase maximum precipitation, maximum water content and maximum ice content but eventually reduce average precipitation (basically due to enhanced evaporation effects)
- Warm rain is suppressed and ice content enhanced with increased CCN
- Total cloud cover decreases with increase of CCN (dominated by shallow cumulus; increase in ice content increase high level cover
- In this particular case, radiation absorption by aerosol delay precipitation but higher rainfall amounts are obtained due to decrease in low level thermodynamic stability

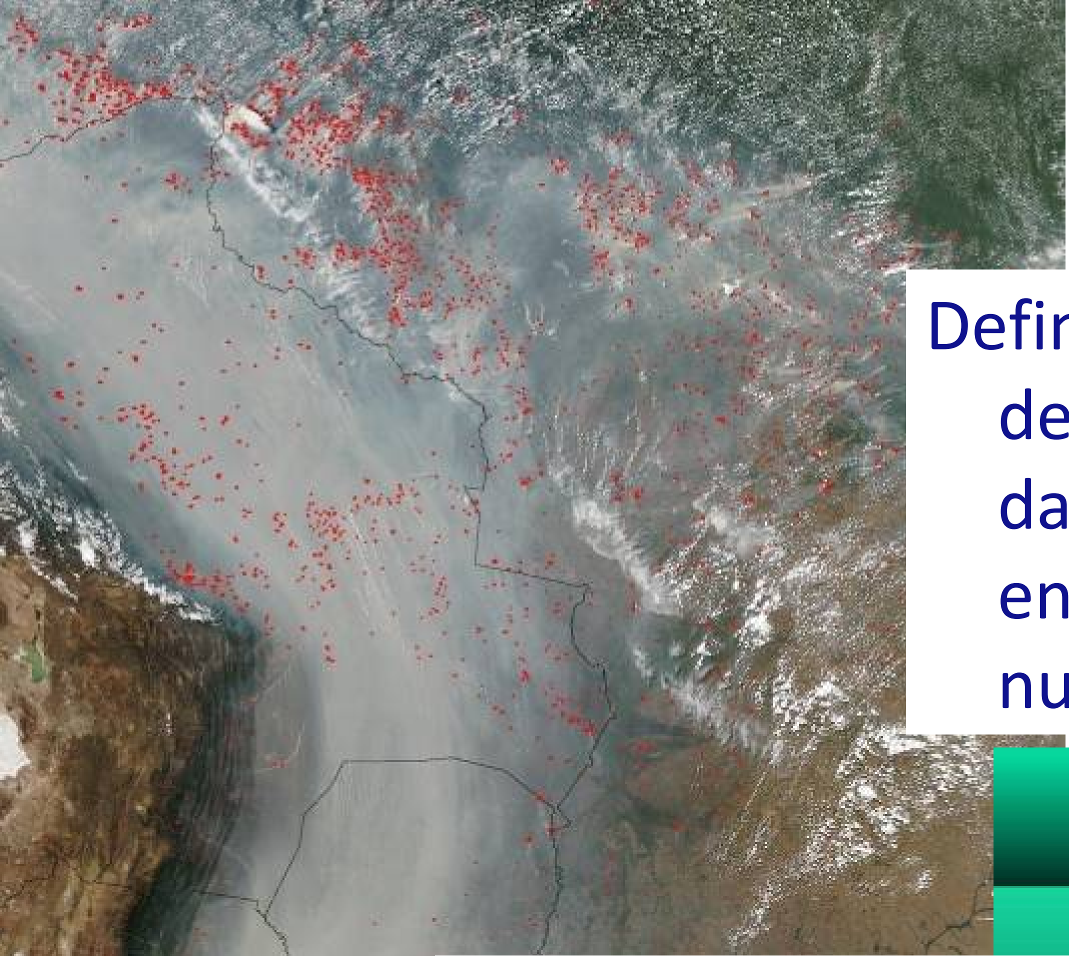
Próximos passos (1)

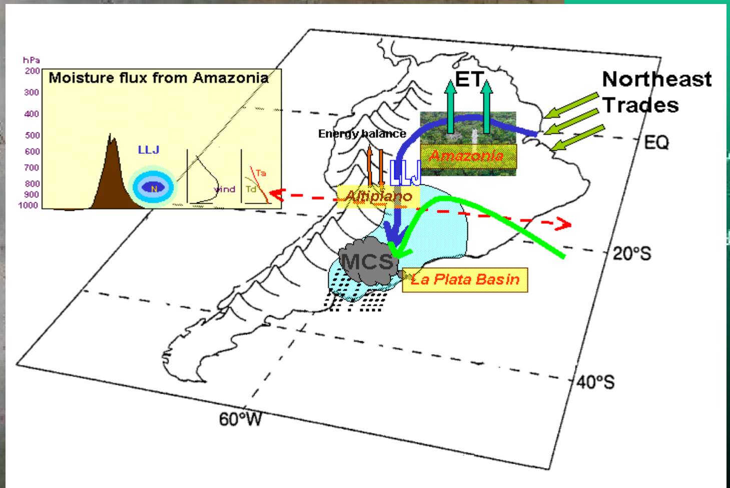
- Uso de constelações de satélites em combinações que permitem identificar relações empíricas entre aerossóis e precipitação

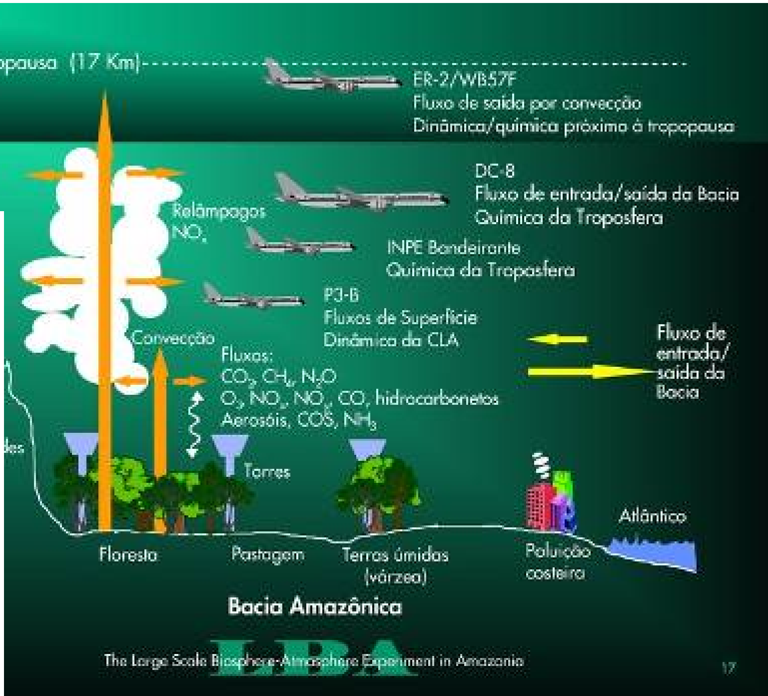


Próximos passos (2)

Definição de novas campanhas de medidas para obtenção de dados de validação com enfoque na microfísica de nuvens







Próximos passos (3)

- Modelos de alta resolução para estudo dos processos microfísicos

- Parametrizações simplificadas do efeito dos aerossóis na precipitação para uso em modelos de clima

Obrigada!