# *From RAMS to BRAMS and beyond*


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***IAG/USP***


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***RAMS origin: Colorado State University -***

***William Cotton - Greg Tripoli: end 70’s early 80’s***

- ***Cloud Microphysics***
- ***Cloud Dynamics***
- ***LES***

- ***Mesoescale Model - Roger Pielke - Virginia University***

- ***Fusion of both models => RAMS (Regional Atmospheric Modeling System)***

## *Mesoscale Modeling at IAG/USP*

- *1980's - role of sea-breeze in São Paulo - regional climate - impact of air pollution => lead to fairly complex physics - urban processes, vegetation, topography (numerical challenges)*
- *Fundamental problem: lack of computer power*
- *Theoretical studies (80's ) - instability lines - heat sources*
- *Late 80's - Elmar Reiter's PE model hydrostatic used at CPTEC and USP*
- *Semi-lagrangean models with CPTEC: remote impact of hurricanes ;*
- *Andes effect: blocking effect – eta-like coordinate, role of LLJ 's*

- *Computer power limitation -> more emphasis on observational studies;*
    - *RADASP (IPMET-UNESP/USP/INPE): July/81, Jan/Fev 82 ,Jan/89: PBL and convection - mesoscale systems; local circulations in São Paulo - Tiete River breeze – coastal breeze – heat island ….*
    - *ABLE 2a (1985) e 2b (1987) = > atmospheric chemistry - Amazon, biomass burning*
    - *ABRACOS (land use change) - FLUAMAZON ---> LBA (93)*
- *ABLE is a turning point: beginning of integrated model activities - concept of tracers (radon, CO, aerosols); Beginning of trajectory analysis, aerosol impact on radiation*
    - *ABLE lead to more observational studies on urban aerosols and urban chemistry in the late 90's (with IFUSP, IQUSP and INPE); FAPESP thematic project 97-2002….*

- *At the end of the 80 ‘s (CONVEX computer at USP - vector and 2 processors);*
- *Falling behind modeling activities….*
- *Decision:  use a complete model and work on modules:*
    - *MM5, JMA mesoscale model,…RAMS?*
- *1989: Bill Cotton visits FUNCEME, CPTEC e USP;*
- *Decision: implement RAMS.*
- ***Strong connection with observational work:  model validation (ABRACOS, LBA) and latter a strong connection with urban air quality issues;***
- *1995 - beginning of regional forecasting - 40km resolution regional domains for S/SE Brazil  (CPTEC at this time ran ETA at 80km over South America); IBM SP2 with 16 processors in 1997 - boosts operational capability - CPTEC seasonal climate downscaling in 1999.*

*•Modeling with RAMS: hurricanes, local circulation in São Paulo, São Francisco Valley, NE Brazil, Instability lines in the Amazon, intense cyclones, land use change, impact of pollution sources, convective parameterizations; vegetation (SIB)….*

*•Parallelism: end of the 90's -> FINEP project (hardware - PC cluster) - CPTEC role;*

*•Large number of students - > use of RAMS spread to several universities in Brazil (UFRJ, UFCG, FURGS, UFPA, UFSM…)*

*•FUNCEME begins operational use of RAMS for climate downscaling and weather forecasting*

*•SIMEPAR - surface data assimilation (FINEP);*

# *FINEP – BRAMS - late 90's/early 2000's*

## *(Brazilian Developments in RAMS)*

- *Version 3.0*
  - *Based on RAMS 5.04 - ASTER*
  - *Maintained by CPTEC*
  - *New Functionalities:*
    - *Shallow Cumulus*
    - *Deep Cumulus – "Grell-Ensemble"*
    - *Soil Moisture Initialization*
    - *SIB2 in addition to LEAF*
    - *Surface data assimilation with data quality control*
    - *CATT – biomass burning emission module and transport (plus urban sources).*

# Final Goal : Environmental Prediction Model - late 90/s

$$\frac{\partial X_a}{\partial t} + L_a X_a = N_a(X_a, X_o, X_v, X_c, X_s) + F_a(X_a, X_o, X_v, X_c, X_s)$$ atmosfera

$$\frac{\partial X_o}{\partial t} + L_o X_o = N_o(X_a, X_o, \;\; , X_c, X_s) + F_o(X_a, X_o, \;\; , X_c, X_s)$$ oceano

$$\frac{\partial X_s}{\partial t} + L_s X_s = N_s(X_a, \;\; , X_v, X_c, X_s) + F_s(X_a, \;\; , X_v, X_c, X_s)$$ solo

$$\frac{\partial X_v}{\partial t} + L_v X_v = N_v(X_a, \;\; , X_v, X_c, X_s) + F_v(X_a, \;\; , X_v, X_c, X_s)$$ vegetação

$$\frac{\partial X_c}{\partial t} + L_c X_c = N_c(X_a, X_o, X_v, X_c, X_s) + F_c(X_a, X_o, X_v, X_c, X_s)$$ constituintes

$$X_a = (u, v, w, T, q_v, q_l, q_r, q_i, \ldots.)$$

$$X_o = (u, v, w, T, s_v, \ldots)$$

$$X_s = (T^i{}_s, W^i{}_s, N^i{}_n, \ldots.)$$

$$X_v = (lai^i, sig^i{}_v, root^i{}_d, stom^i{}_c, VOC^i, C^i, N_i, \ldots.)$$

$$X_c = (CO_2, CH_4, O_3, NO_x, VOC's, SO_2, \ldots)$$

# *BRAMSNET*

- *Network of BRAMS users and developers*
- *Inicial partners:*
  - *UFCG*
  - *UFRJ*
  - *CPTEC*
  - *USP*
  - *SOMAR*
  - *ITAUTEC*
  - *FURG*

*GBRAMS - GRID - UFRGS, CPTEC,IAG - climate applications*

## *Other implementations:*

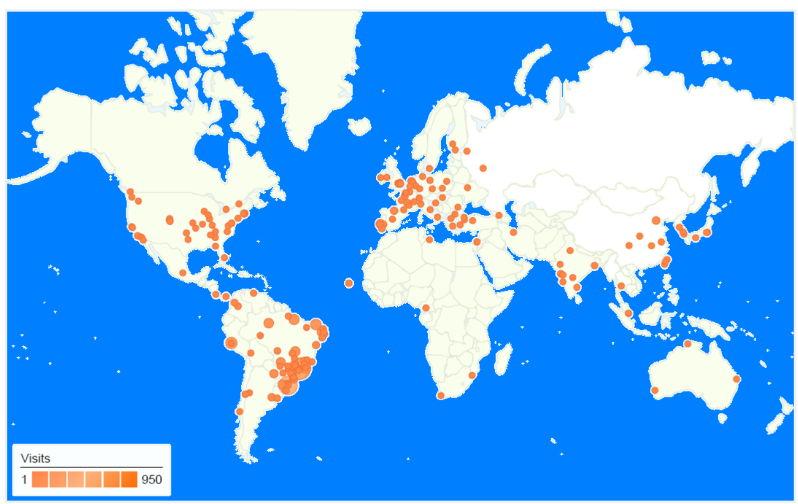
- ***Precipitation assimilation - better short range forecasts;(Bruno Biazeto…)***
- ***Urban energy balance and transfer - TEB: to improve model validation against surface observations in urban environments; (Edmilson Freitas)***
- ***Calibration of "Grell Ensemble" with precipitation data (Saulo + team);***
- ***New options for the radiative processes in the presence of gases and aerosols - space and time variation - CARMA; (Saulo, Karla presentation)***
- ***Interaction cloud/radiation - short wave - need to improve metric of validation based on fit to surface radiation measurements; (Enio,Saulo, Marcos Longo)***
- ***New options for dry turbulence; improvement of T,Td diurnal cycle) – Haroldo Velho, Saulo, Marcos Longo***
- ***New data assimilation module - based on GSI (Saulo – Eder - Glauber – com KF)***

## *Other implementations (2):*

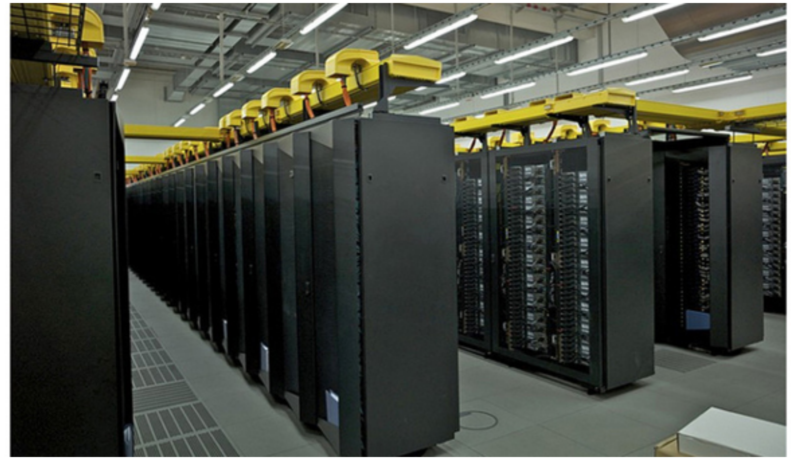
- ***New data assimilation module - based on GSI (Saulo – Eder - Glauber – with KF)***
- ***Simplified photochemistry - 2004 (product of research project with CETESB); (E. Freitas)***
- ***Full photochemistry module (CPTEC – Karla presentation)***
- ***Coupling with dynamical vegetation: 1st version with GEMTM (≈2005) now JULES (Demerval)***
- ***Coupling with ocean model (POM) and mixed layer model (R. Camargo/ Jorgetti/E.Freitas, Alexandre Costa)***
- ***Coupling with surface hydrology - Sao Francisco, Rio Grande, Uruguay – Pantanal – flooded areas and more recently in the Amazon (Daniel Dallasia / Mercel Santos)***
- ***CCN's in microphysics – Jorge Martins***
- ***Numerical methods, surface pressure (Saulo + team; Marcos Longo)***

*Code robustness (Jairo Panetta and team):*

- ***Code originally developed by researchers;***
- ***Fundamental rules of software engineering***
- ***Parallel efficiency :***
  - ***Challenge: efficiency in vector computers; massive parallelism - shared and distributed memory…***
- ***BRAMS community is significant***



- ***Challenge - Efficient use of High Performance Computing - HPC***
- *New generation of HPC machines:*
  - *architecture*
    - *Massively parallel with accelerators (GPU's etc.)*
    - *Visualization of of large data sets (3D animation)*
  - *Assistance to "poor mortal "users…*

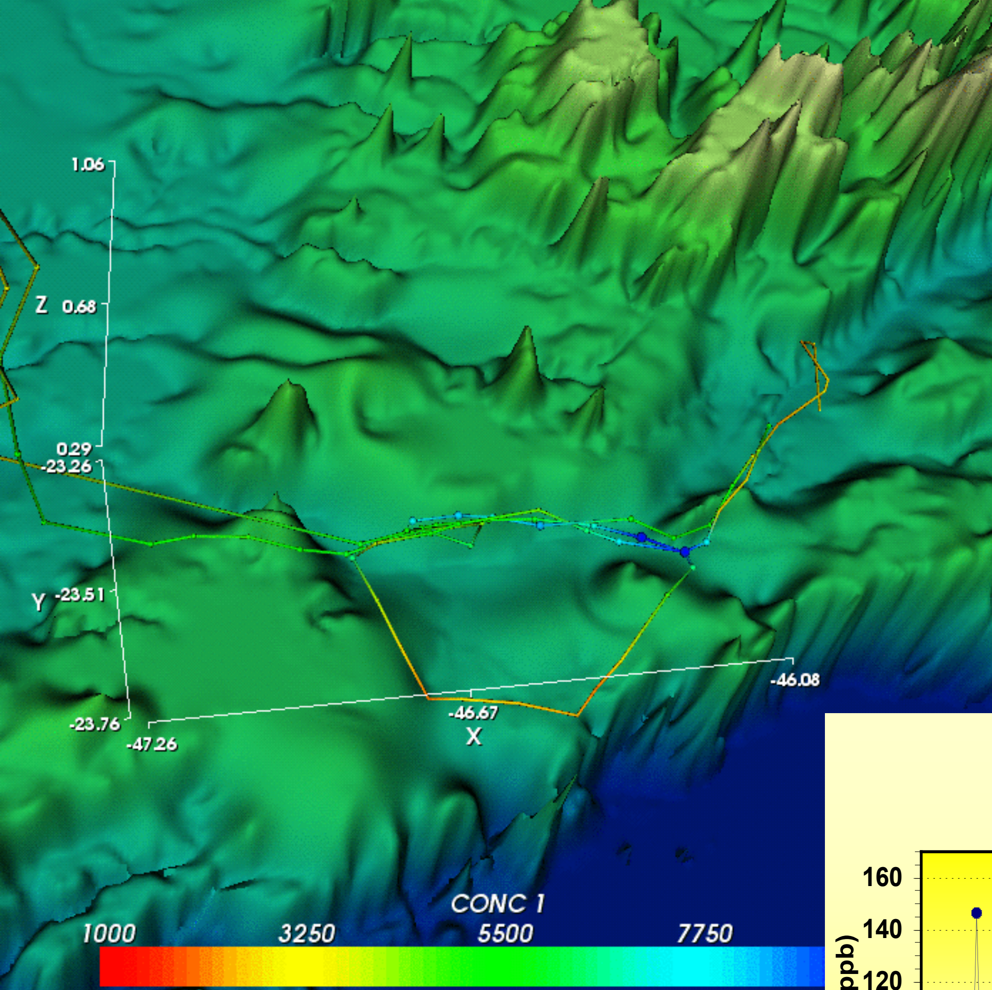


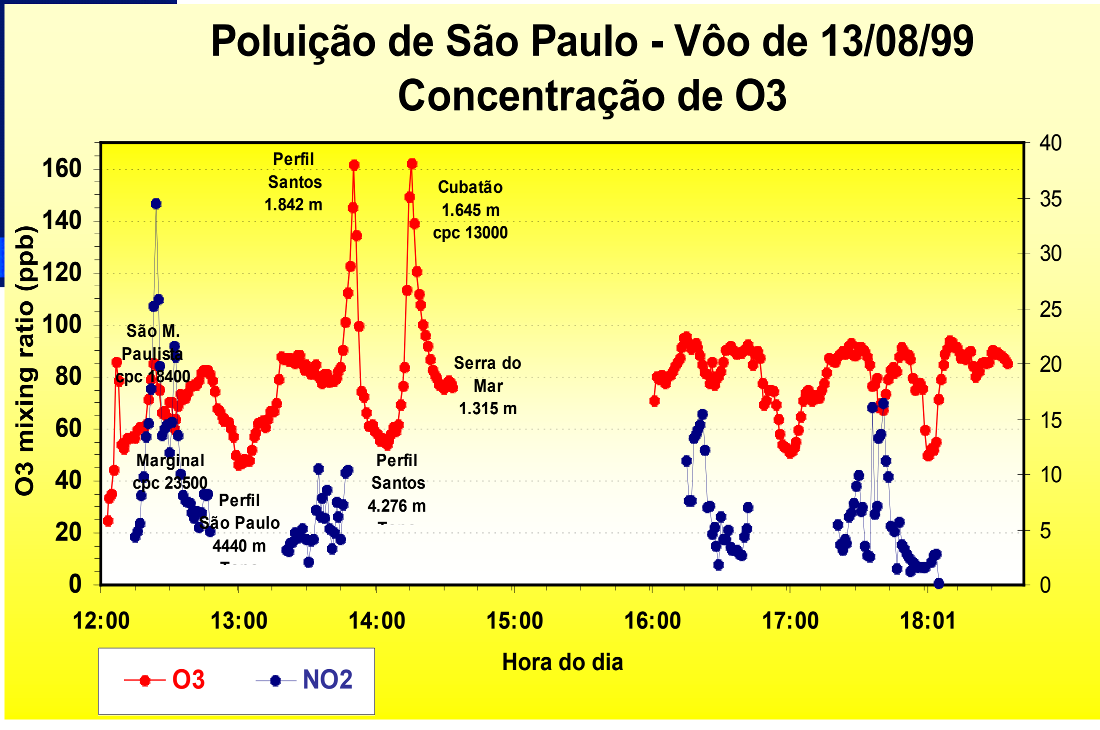
# *What is behind the success of BRAMS?*

- ***Link to observational work!!!!***
    - ***Ex. LBA, air pollution programs, micromet tower program***

- ***Operational use for regional forecasting***

# *Measurements with the INPE Bandeirantes aircraft from 11 to 13 August 1999*

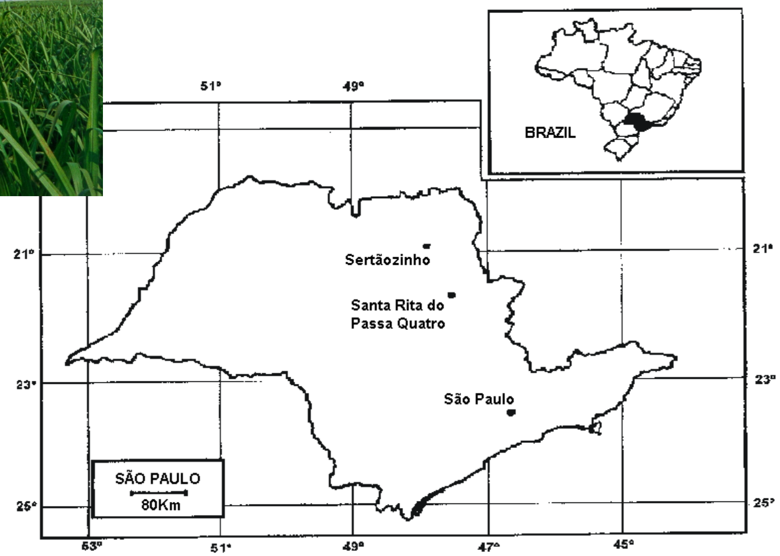



CO

$O_3$

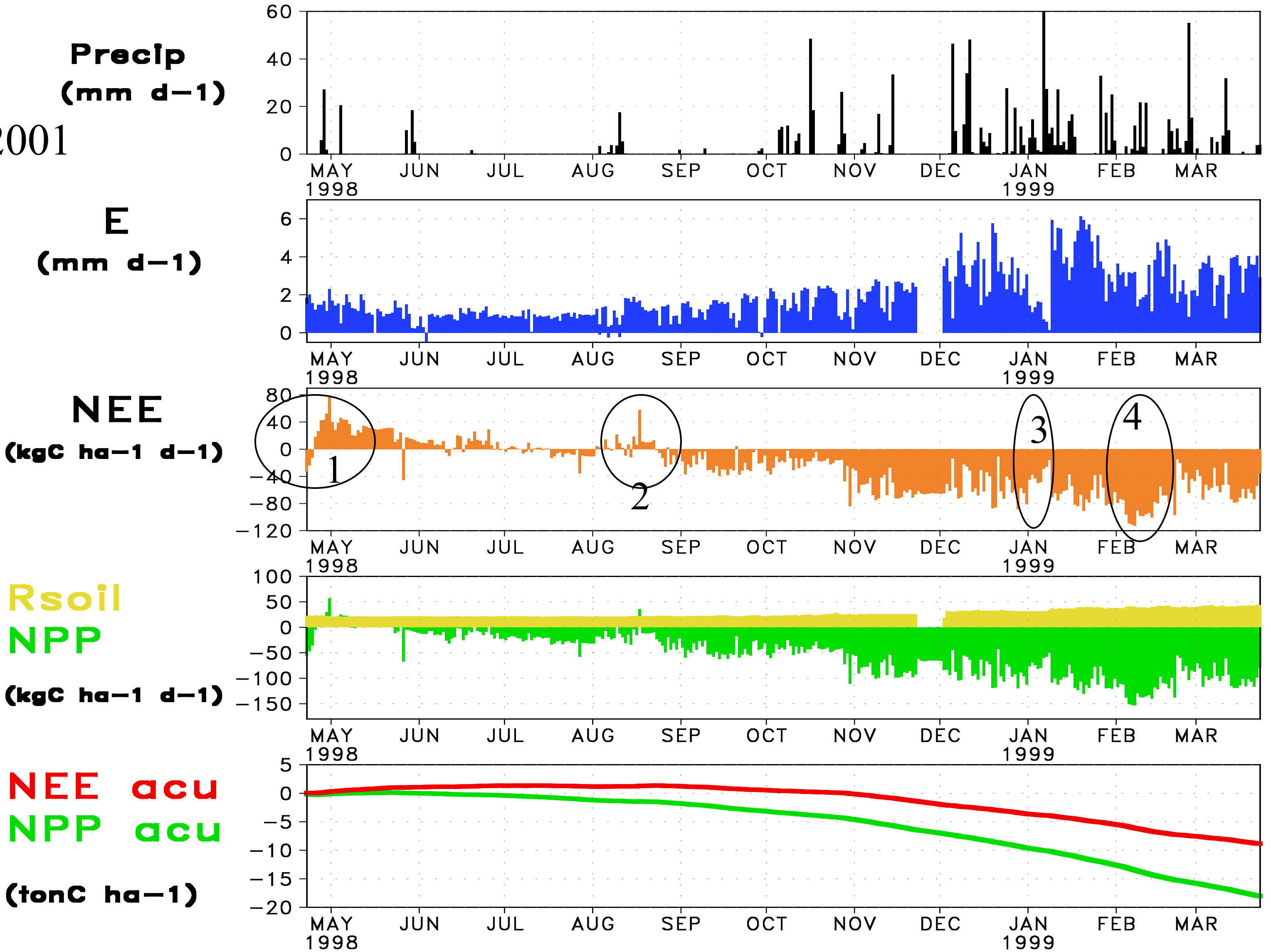
CCN

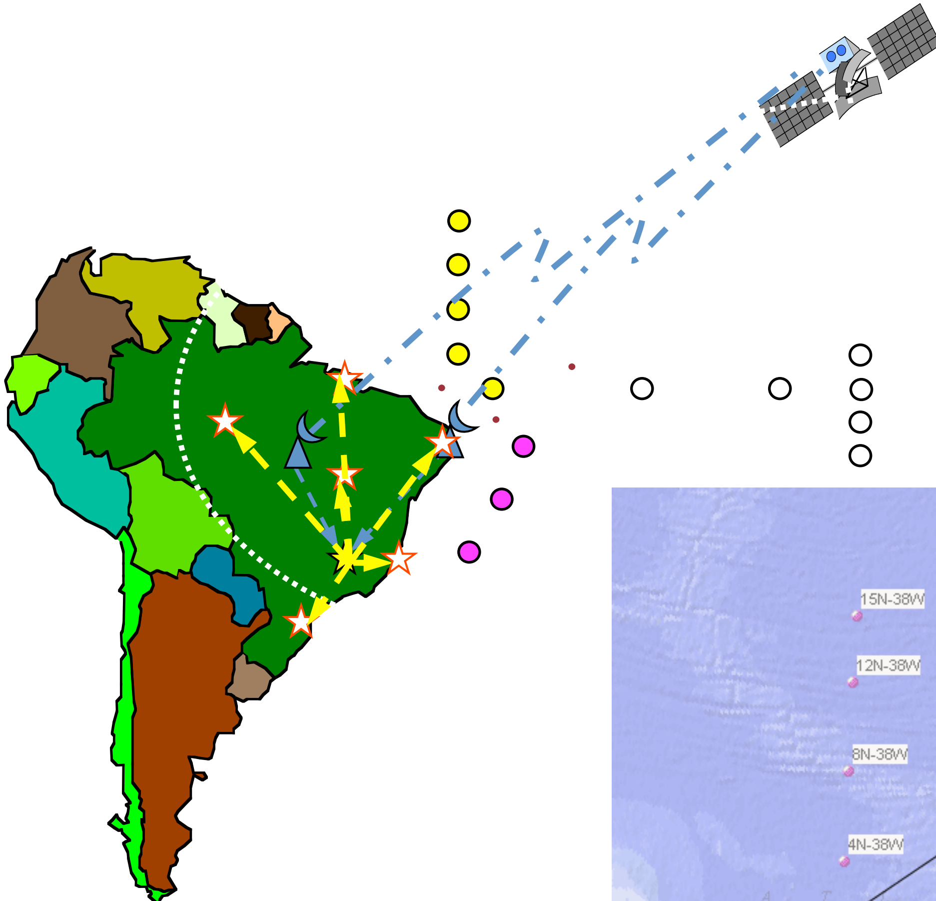

Participação: Inst. Agronômico de Campinas e UNICAMP

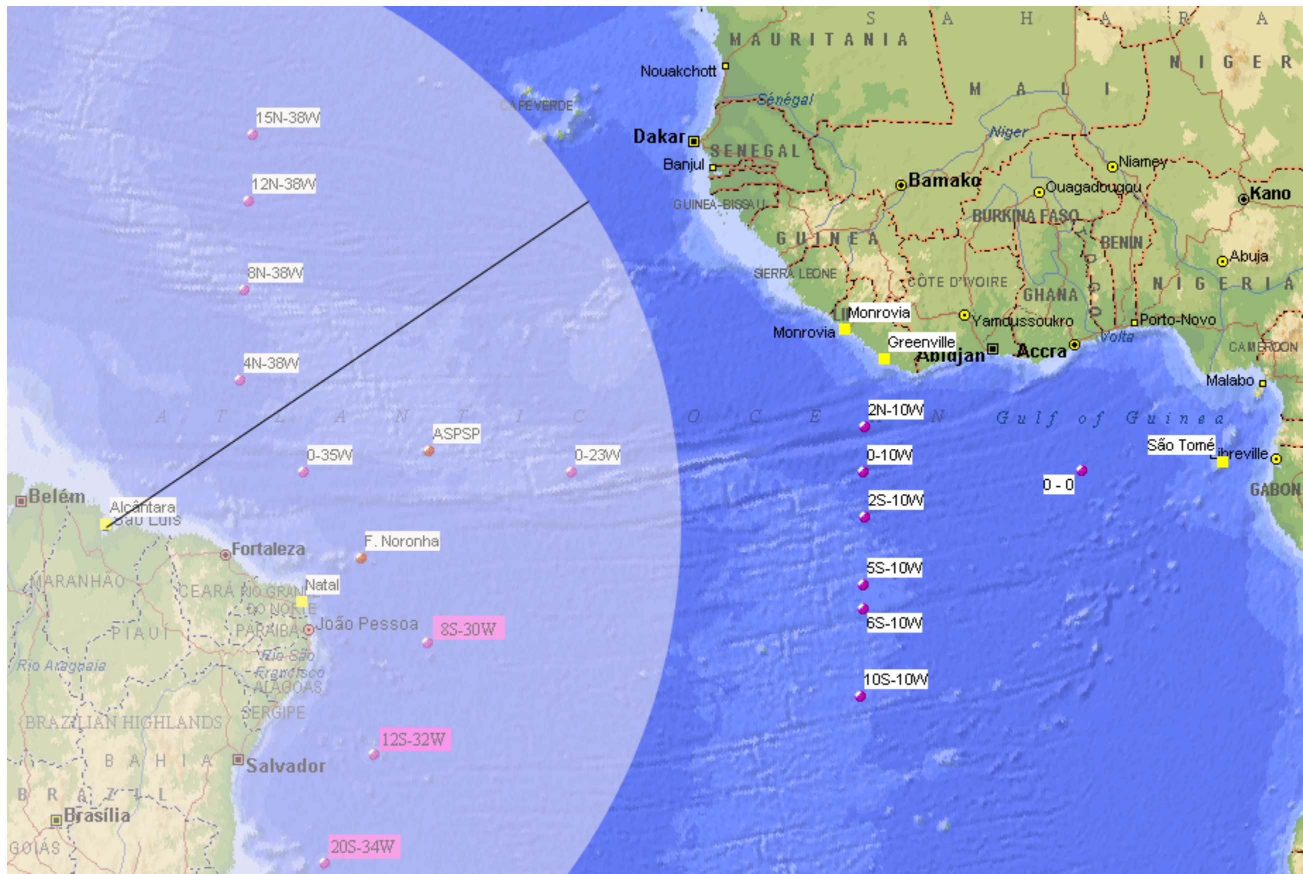
# FLUXOS CO2 E H20 @ CANA-DE-ACUCAR

Rocha 2001



# Rede PIRATA de Bóias Oceânicas & Cobertura de recepção dos satélites SCD





## *Operational use of BRAMS in regional forecasting*

# MODELOS REGIONAIS E GLOBAIS

http://www.master.iag.usp.br/num/externas/3/

- [x] **ETA (CPTEC-INPE)** - Modelo ETA - Resolução de 40km
- [ ] **ETAcr (CPTEC-INPE)** - Conjunto controle do ETA - Resolução de 40km
- [ ] **ETAm1 (CPTEC-INPE)** - Membro 1 do Conjunto do ETA - Resolução de 40km
- [ ] **ETAm2 (CPTEC-INPE)** - Membro 2 do Conjunto do ETA - Resolução de 40km
- [ ] **ETAm3 (CPTEC-INPE)** - Membro 3 do Conjunto do ETA - Resolução de 40km
- [ ] **ETAm4 (CPTEC-INPE)** - Membro 4 do Conjunto do ETA - Resolução de 40km
- [x] **ETA20 (CPTEC-INPE)** - Modelo ETA - Resolução de 20km
- [x] **RPSAS (CPTEC-INPE)** - Modelo ETA com assimilação de dados observados - Resolução de 40km
- [ ] **ETALN (CATO-LNCC)** - Modelo ETA - sudeste - Kain-Fritsch - Resolução de 17km
- [ ] **ETALN (CATO-LNCC)** - Modelo ETA - Rio - Betts-Miller - Resolução de 10km
- [ ] **ETALN (CATO-LNCC)** - Modelo ETA - Brasil - Betts-Miller - Resolução de 48km
- [ ] **ETALN (CATO-LNCC)** - Modelo ETA - Sudeste - Betts-Miller - Aninhado - Resolução de 17km
- [ ] **ETAUM_g1 (UMD-Maryland)** - Modelo ETA - Resolução de 80km
- [ ] **ETAUM_g2 (UMD-Maryland)** - Modelo ETA - Resolução de 22km
- [ ] **ETARE (SMN_ARG)** - Modelo ETA - hidrostático - com parametrização Betts-Miller-Janjic - Resolução de 30km
- [ ] **ETAAR (SMN_ARG)** - Modelo ETA - não-hidrostático - com parametrização Betts-Miller-Janjic - Resolução de 10km
- [ ] **CATTB (CPTEC-INPE)** - Modelo CATT-BRAMS iniciado com o Global do CPTEC - Resolução de 30km
- [x] **RAMSC (MASTER-USP)** - Modelo BRAMS iniciado com o Global do CPTEC - Resolução de 25km «NAMELIST»
- [ ] **RAMSV (MASTER-USP)** - Modelo BRAMS iniciado com o ETA20 - Resolução de 2km «NAMELIST»
- [ ] **TEB (MASTER-USP)** - Modelo BRAMS acoplado ao TEB iniciado com o Global do AVN - Resolução de 4km «NAMELIST»
- [ ] **RAMSB (MASTER-USP)** - Modelo BRAMS iniciado com o Global do AVN - Resolução de 10km «NAMELIST»
- [ ] **RAMSS (MASTER-USP)** - Modelo BRAMS iniciado com o Global do CPTEC - Resolução de 20km «NAMELIST»
- [ ] **RAMSM (MASTER-USP)** - Modelo BRAMS iniciado com o Global do AVN (acoplado com o Stilt) - Resolução de 12km «NAMELIST»
- [ ] **op_RJ (MASTER-USP)** - Modelo BRAMS iniciado com o Global do CPTEC - Resolução de 20km «NAMELIST»
- [ ] **opRJa (MASTER-USP)** - Modelo BRAMS iniciado com o Global do AVN - Resolução de 20km
- [ ] **GRUMA (GRUMA-UFSM)** - Modelo BRAMS - Resolução de 20km
- [ ] **UFPA_g1 (LAMAZ-UFPA)** - Modelo BRAMS - Resolução de 81km
- [ ] **UFPA_g2 (LAMAZ-UFPA)** - Modelo BRAMS - Resolução de 27km
- [ ] **LMQA (LMQA-UFRGS)** - Modelo BRAMS - Resolução de 16km
- [ ] **WRFAR (CIMA-UBA)** - Modelo WRF - Resolução de 60km
- [ ] **WRFAR (CIMA-UBA)** - Modelo WRF - Resolução de 20km
- [ ] **WRFrj (LPM-UFRJ)** - Modelo WRF - Resolução de ??km
- [ ] **HRM_g1 (CHM)** - Modelo Alemão (GME) - Resolução de 30km
- [ ] **HRM_g2 (CHM)** - Modelo Alemão (GME) - Resolução de 13km
- [ ] **GP213 (CPTEC-INPE)** - Modelo GPSAS com análise do CPTEC - Resolução de 63km
- [ ] **T299 (CPTEC-INPE)** - Modelo global T299 - Resolução de 44km
- [ ] **T213 (CPTEC-INPE)** - Modelo global T213 - Resolução de 63km
- [ ] **CPTEC (CPTEC-INPE)** - Modelo global T126 - Resolução de 100km
- [ ] **ACOPL (CPTEC-INPE)** - Modelo T126 acoplado com modelo oceânico - Experimental - Resolução de 100km
- [ ] **ACOPM (CPTEC-INPE)** - Conjunto obtido via 10 previsões consecutivas do modelo Acoplado/CPTEC - Experimental - Resolução de 100km
- [ ] **OLAMC (CPTEC-INPE)** - Modelo OLAM com microfísica de nível 1 - Resolução de 250km «NAMELIST»

# ***Future of BRAMS***

# Conclusion

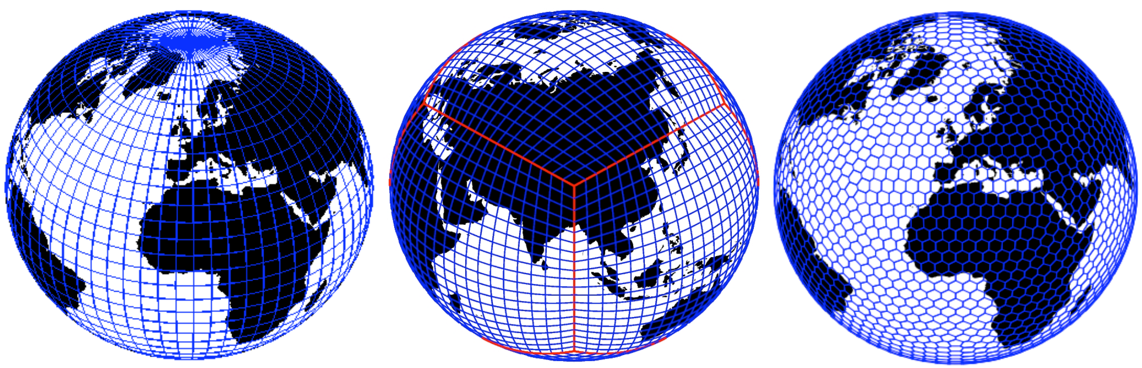
- Cooperative work of many people leading to very competitive work in integrated earth atmosphere modelling
- Creative modelling work based on observations, mainly in atmospheric field campaigns and long term surface monitoring.
- Parallelism - > accelerators

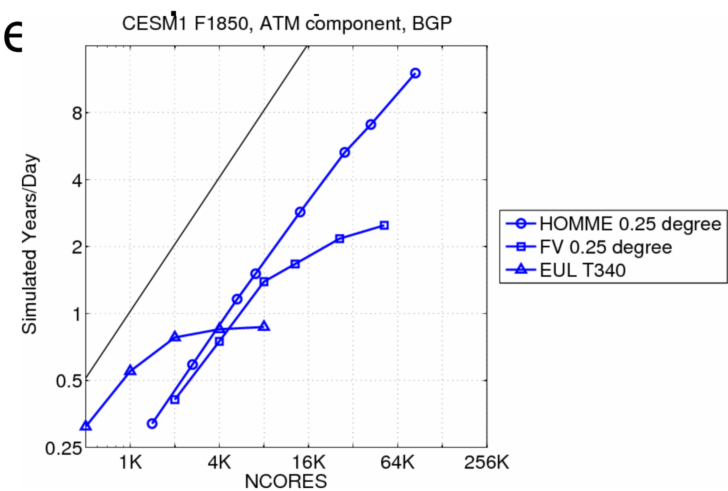
# Preparando Modelos para a Computação Exaflópica

- ✓ Substanciais recursos computacionais estão sendo usados para simulações globais de alta resolução, escala climática (p. ex. 20km ou < na atmosfera e <10km no oceano) para várias decadas.

- ✓ Resolução mais alta com refinamento regional (núcleos dinâmicos baseados em "cubed sphere, hycosaedral, hexagonal"): no nosso caso estamos investindo no OLAM – versão global do RAMS/BRAMS com resolução variável.

- ✓ Experimentos com malhas adaptativas estão e





# Conclusion - Future

- Dynamical core:
  - Challenge: avoid approximations in the equations; deal with sharp orography; deal with massive parallelization (need integrated work – new algorithms, computer architecture. OLAM is a possible choice but there are others.
- Aerosol – CCN's => cloud microphysics coupling
  - Large number of variables -> computational challenge
  - Up to what level is necessary?
- Radiation: column treatment is not OK with high resolution!!!
  - Physical processes
  - Computational challenge - horizontal communication
- Dry Turbulence:
  - Diurnal variation of T, Td, V..... (still a challenge)
- Moist convective parameterizations:
  - High resolution cloud microphysics and low resolution closure assumptions
- Data Assimilation:
  - CCN's, chemistry, vegetation, soil…
  - Needs criativity !!!!
- Many others…

# *Conclusions - final*

- *Definition of functionalities: users (research/operational);*
- *Critical to have close ties with experimental work;*
- *Friendly interface and support for users;*
- *Operational use (optimization function: computational cost, precision, evaluation against observations);*
  - *Massive Parallel efficiency is critical!*
- *Model validation - needs well defined metrics – scale dependent !*
- *Team work - need to understand users needs and priorities*
- *Persistence!!!*
  - *And human resources!!!!*

***In our case:***

- *Adjust models to our reality*
- *Human Resources: agregate groups in many areas....*
- *Products with international competitiveness (otherwise we will always be users...*


Obrigado
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