MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

PAN-AMERICAN ASSOCIATION OF COMPUTATIONAL INTERDISCIPLINARY SCIENCES

Talk to us

1st Conference of Computational Interdisciplinary Sciences (CCIS)

August 23-27, 2010, Brazil

CCIS 2010

Computational Challenges: Space and Meteorological Sciences

Haroldo de Campos Velho

LAC/INPE

E-mail: haroldo@lac.inpe.br

http://www.lac.inpe.br/~haroldo/

Scientific challenges

1. Before the XX century:

We wanted to know the nature laws (mechanics, thermodynamics, electromagnetism, life evolution, social behaviour, transfinite numbers)

2. During the XX century:

We know the laws (equations), but we want to solve them. Remarkable conquest: modern numerical weather prediction!

3. After the XX century (our century!):

Starting this new century, data science is occuping a central role in the science (genomic, data mining, background cosmic radiation in microwave, data assimilation).

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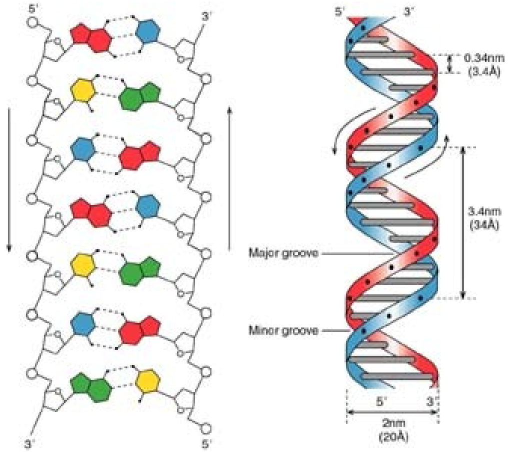
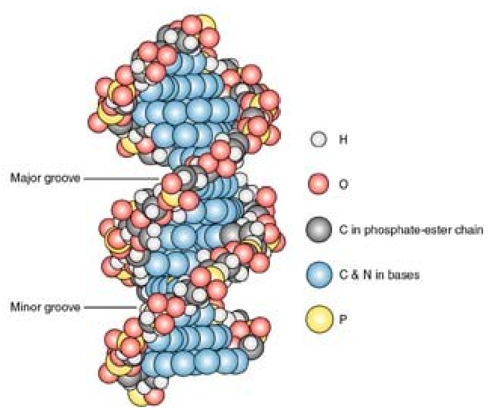
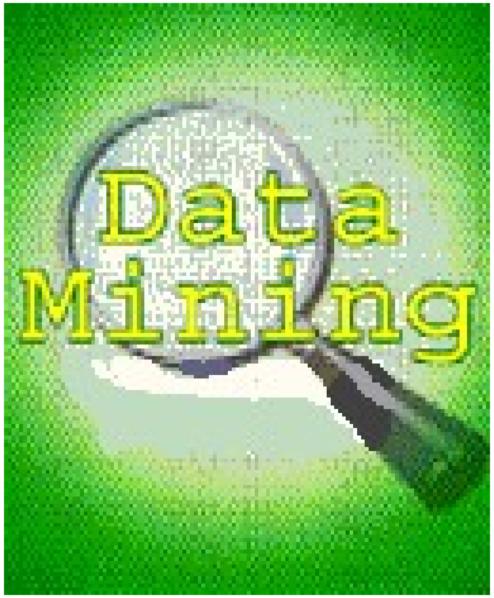
Data science

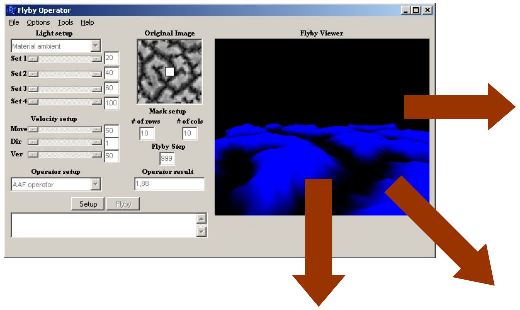
Genome projects



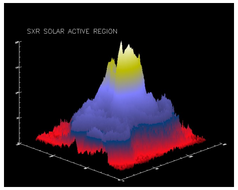




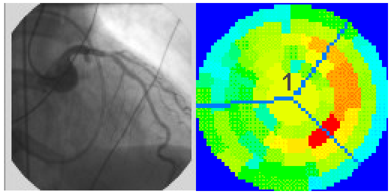
Complex system



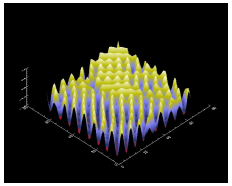
Solar physics



Heart disease



Plane waves



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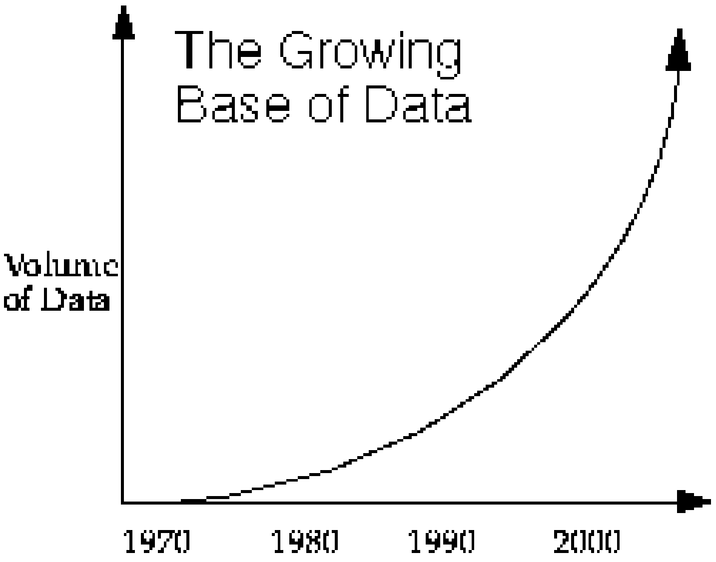
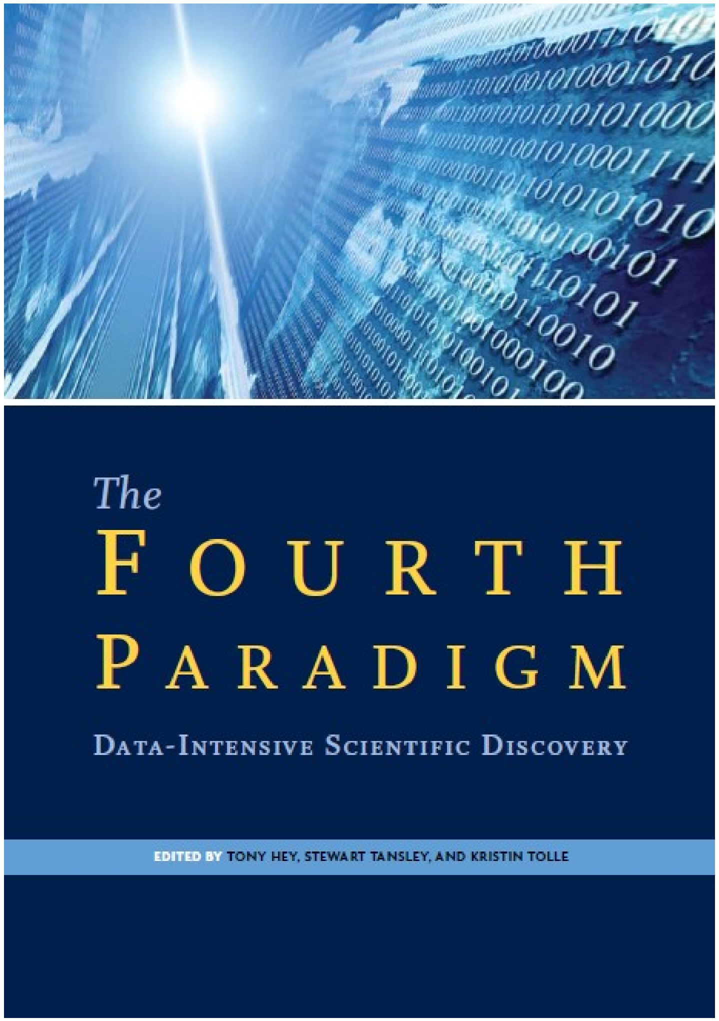
Data science – Data Mining

Techniques :

- clustering
- data summarization
- detecting anomalies
- analysing changes
- finding dependency networks
- learning classification rules

Why data mining tools?





The FOURTH PARADIGM

DATA-INTENSIVE SCIENTIFIC DISCOVERY

EDITED BY
TONY HEY, STEWART TANSLEY,
AND KRISTIN TOLLE

Data science – Data mining example

Association rules: database from Agriculture Eng. (Unicamp)

Association rules: database from Agriculture Eng. (Unicamp)

It was used DMII-CBA (Classification Based on Association) - software developed by School of Computing, National University of Singapore

http://www.comp.nus.edu.sg./~dm2/p_overview.html

Temperatura [^{0}C]	Nomenclatura	Sensação do animal
<20	T1	frio
20-23	T2	frio
23-25	T3	frio
25-27	T4	conforto
27-30	T5	conforto
30-32	T6	calor
>32	T7	calor

Níveis de ruído [dba]	Nomenclatura	Classificação
<60	RU1	ambiente tranqüilo
60-70	RU2	barulho
70-80	RU3	muito barulho
80-85	RU4	nível preocupante
>85	RU5	nível prejudicial

Umidade [%]	Nomenclatura	Sensação do animal
<60	UR1	desconforto
60-70	UR2	conforto
70-80	UR3	conforto
>80	UR4	desconforto

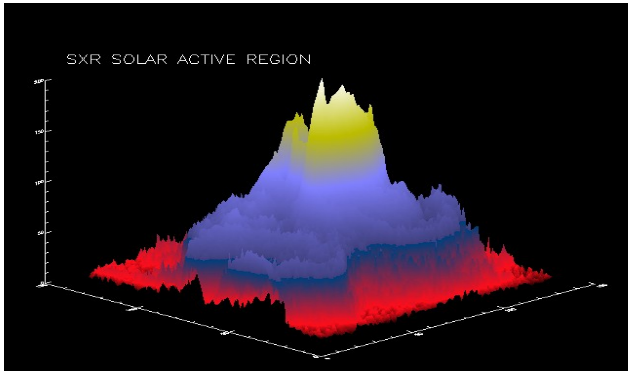
0	UR3,T4,RU5
1	UR2,T3,RU5
2	UR2,T4,RU5
3	UR2,T5,RU5
4	UR1,T5,RU5
5	UR1,T5,RU5
6	UR1,T5,RU5

Rule 28:
UR1 = Y
-> RU5 = Y
(42.857% 100.00% 3 3 42.857%)

Example of rule created by DMII-CBA software

Study of complex dynamical systems

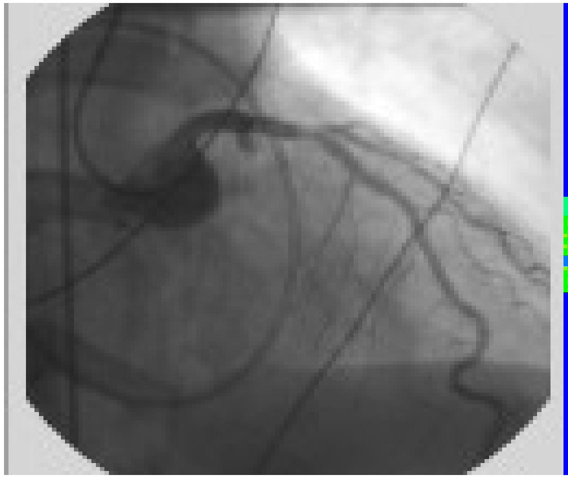
- Turbulence in solar plasma

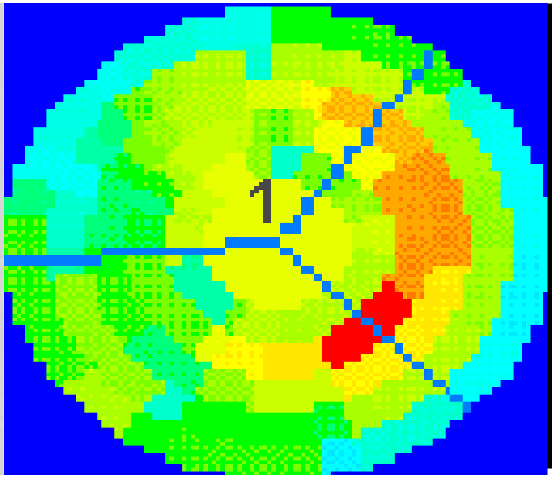


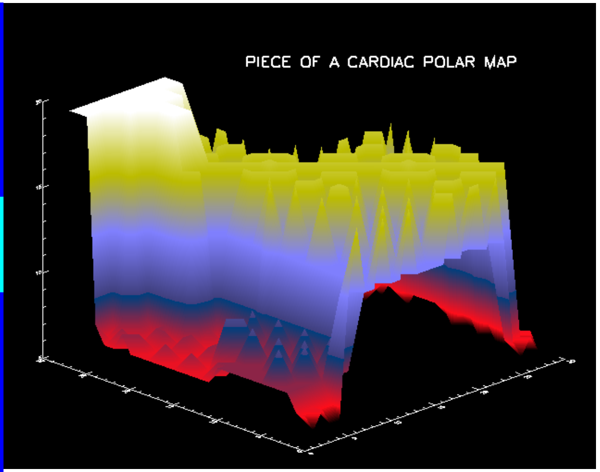
- Porous silicion analysis

- Structural Cardiology

From: R.R. Rosa (LAC/INPE)





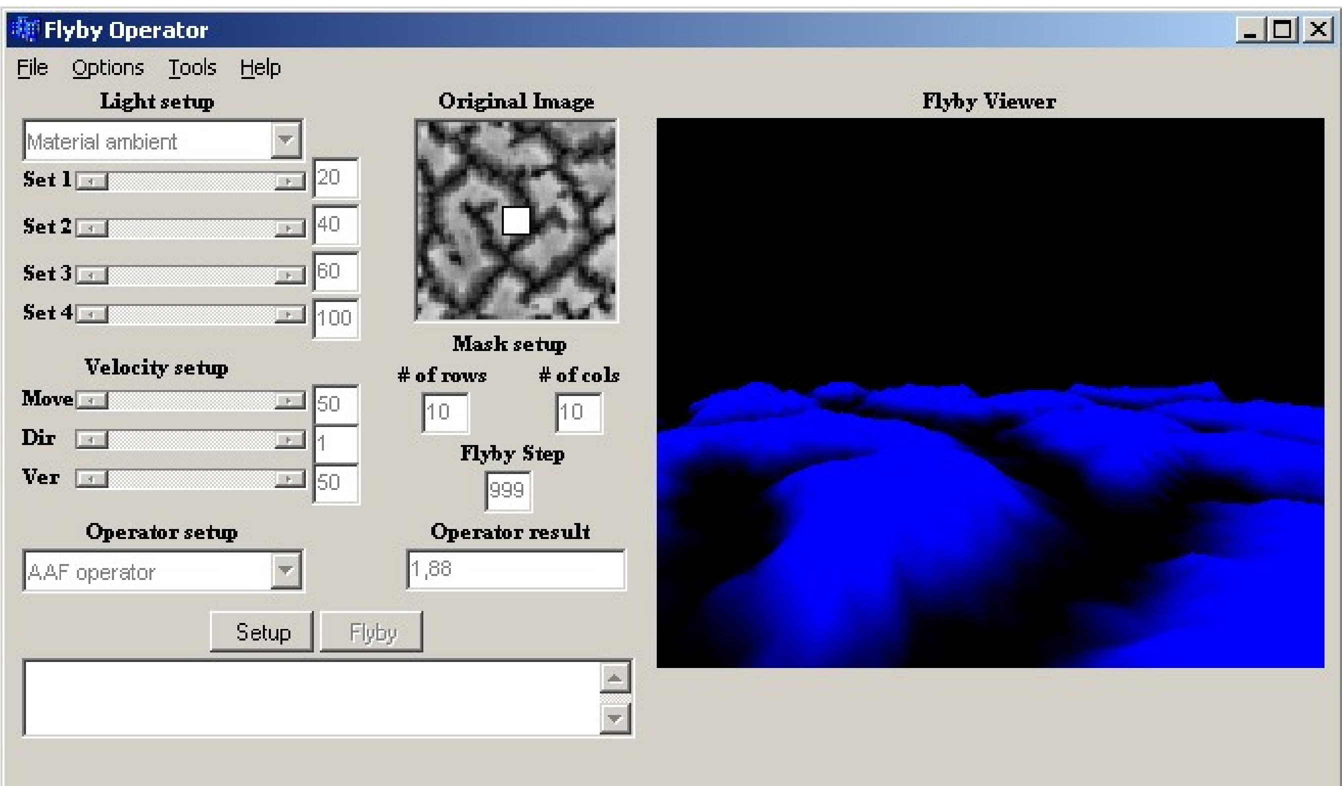


Non-linear dynamics analysis:

Visualização em 2001

Software for the GPA analysis: porous silicion.

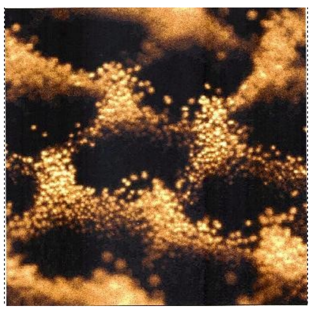
Operators: AAF (Asymmetric Amplitude Fragmentation)
CEF(Complex Entropic Form)



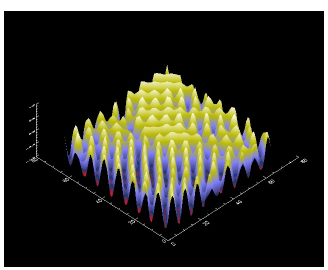
From: R.R. Rosa (LAC/INPE)

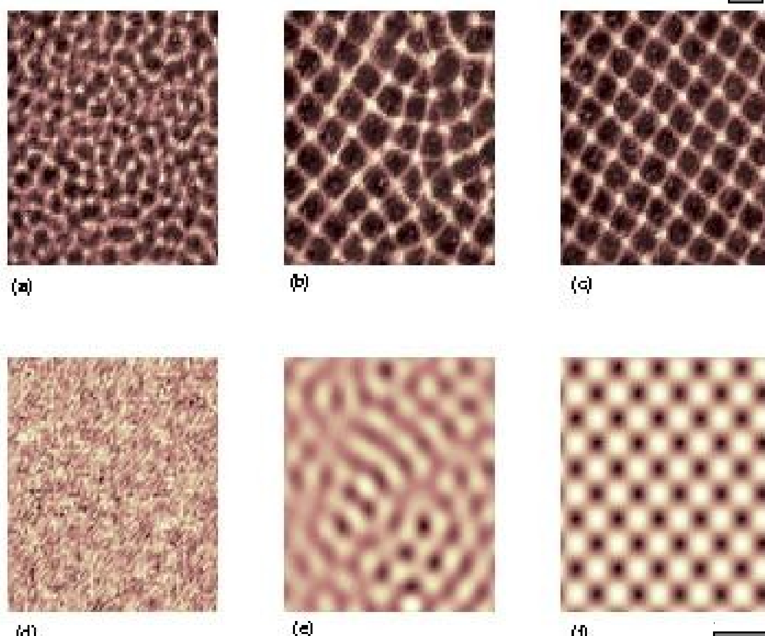
Non-linear dynamics analysis:

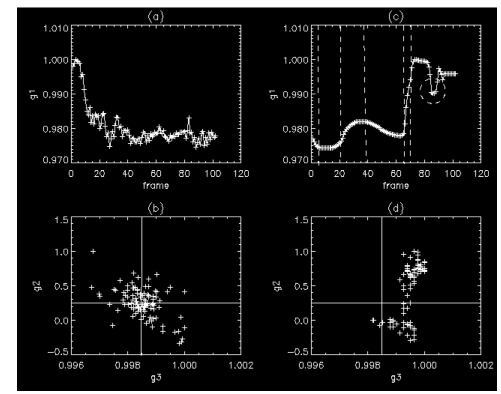
GPA analysis showing the unexpected iteration of flat waves.
Such behaviour is not verified on “oscilons” (vibrating spheres)

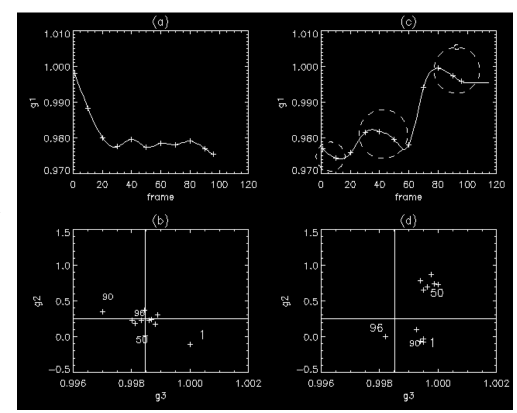


“oscilons”









“flat waves”: $\partial_t E = rE - (\nabla^2 E + 1)^2 E + \nabla . (|\nabla E|^2 \nabla E)$

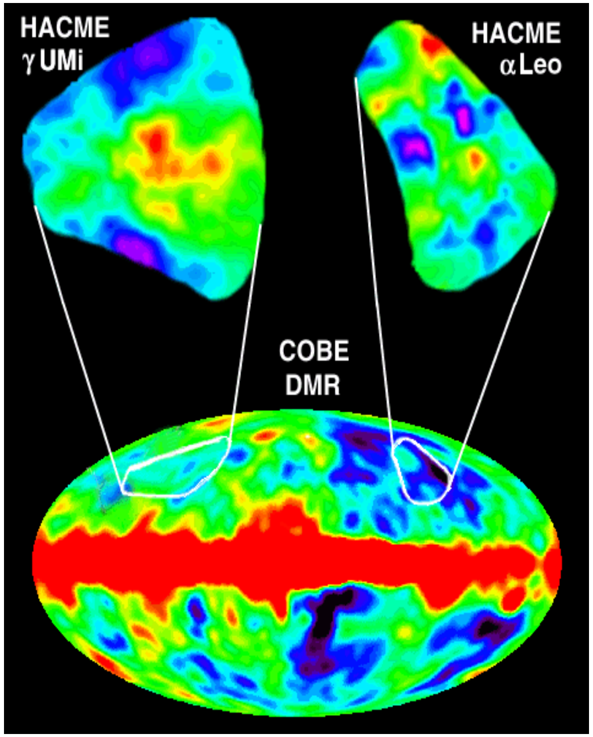
From: R.R. Rosa (LAC/INPE)

Data science in astrophysics

Representing the Background Cosmic Radiation in Microwaves (BCRM).

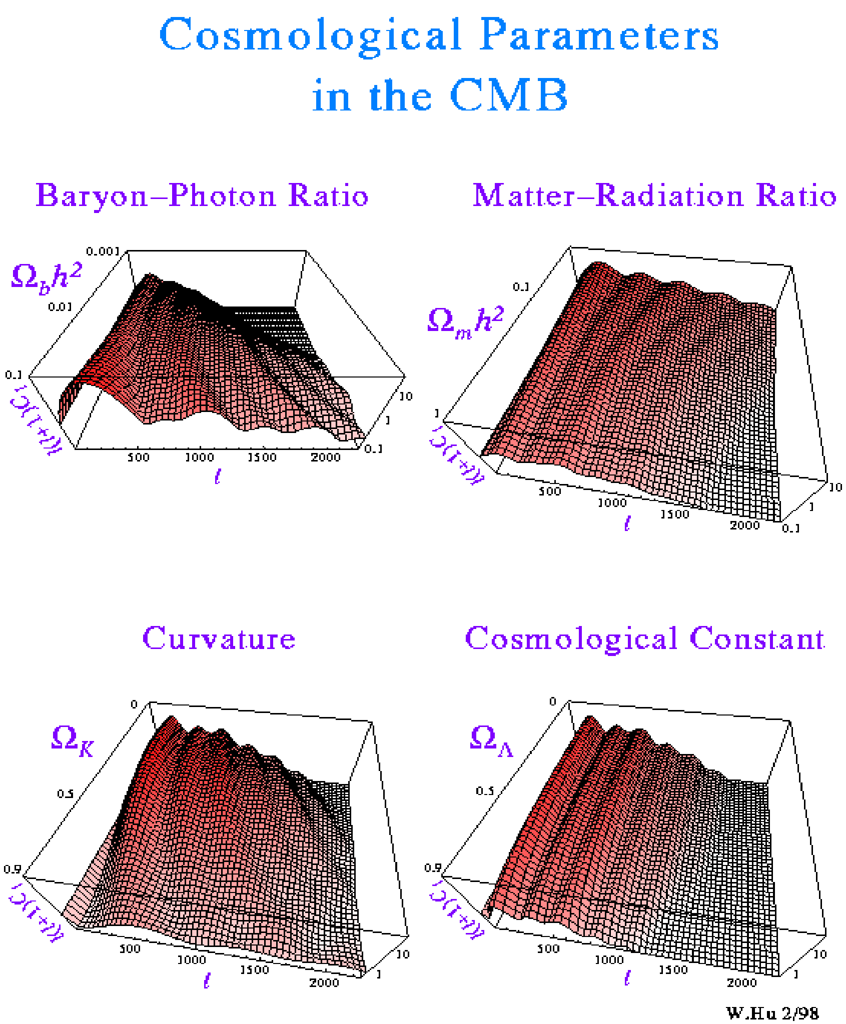
$$J(\boldsymbol{a}) = \sum_{i=1}^{N} \frac{1}{\sigma_i^2} \left[\frac{\Delta T_i}{T} - \sum_{k=1}^{M} a_k Y_{k,i} \right]$$

vector $a = [a_1 \; a_2 \; ... \; a_M]^T$ is the coefficients on spherical harmonic expansion Y_k and ΔT_i is the sky temperature.



From: cited by R.V. Correia PhD thesis (CAP/INPE), 2005

Physical interpretation of CBRM map cosmological constants:

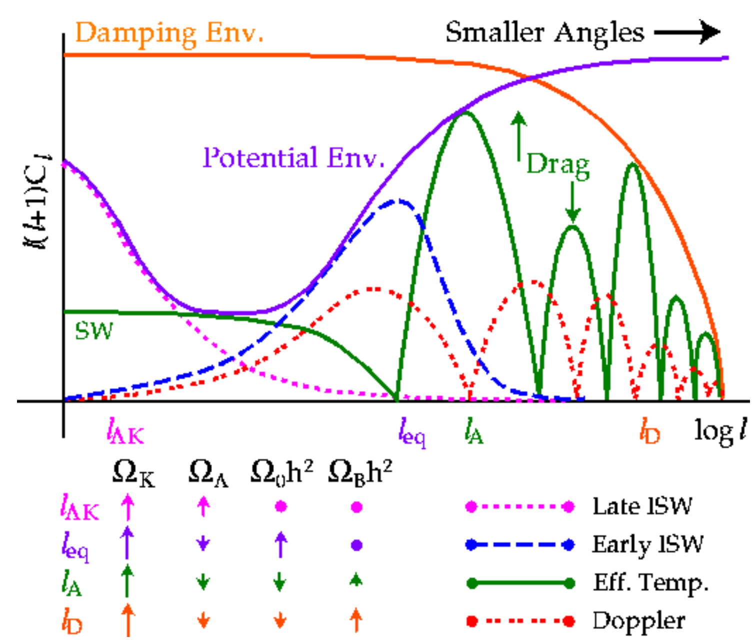


More information:

http://background.uchicago.edu/~whu/physics/physics.html

The constants are related with the peacks of the power scpetra of the BCRM maps:

$$\Omega_j = \langle a_k \rangle \qquad \text{(combining harmonics)}$$



Why is it important to study inverse problems?

➢ **Because they are economically relevant:**

- Petroleum research:

- Hubble image reconstruction:

(~ US$ 10 Billions, 10 years)

Why is it important to study inverse problems?

- Because they are politically relevant: greenhouse effect

CO_2, CO, CH_4, N_2O

Outline of the presentation – Part I

- Challenges: Astronomy and Astrophysics

  # Virtual Observatory (e-astronomy)

  # Turbulence and cosmology
  - Data: Virgo and Millenium / SDSS
  - Computing: FoF-parallel, grid environment

  # Space weather program
  - Monitoring and prediction
  - Challenges: getting initial condition

Why VO?

Traditional (old faschion) scheme in astronomy:

1. The astronomer asks a time to use a telescope
2. The astronomer colects his/her data
3. Data analysis for colected data: publishing a report (paper)

New schemes:

1. One observatory does a survey of astronomical data
2. Astronomical community can access the data
3. Which is the most efficient strategy to share data?

Astronomical survey

Sloan Digital Sky Survey

SDSS

Goal
- *Create the most detailed map of the Northern sky*
  - *"The Cosmic Genome Project"*

Two surveys in one
- *Photometric survey in 5 bands*
- *Spectroscopic redshift survey*

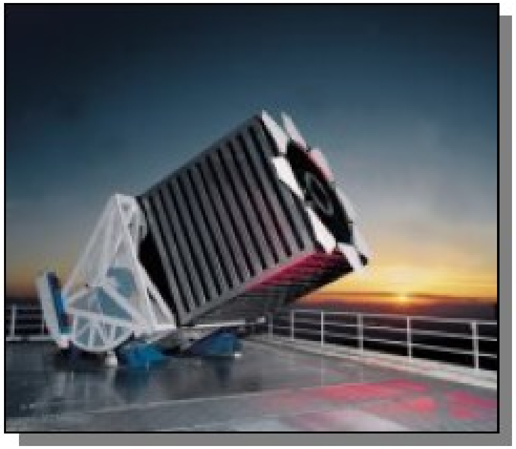
Automated data reduction
- *150 man-years of development*

High data volume
- *40 TB of raw data*
- *5 TB processed catalogs*
- *Data is public*

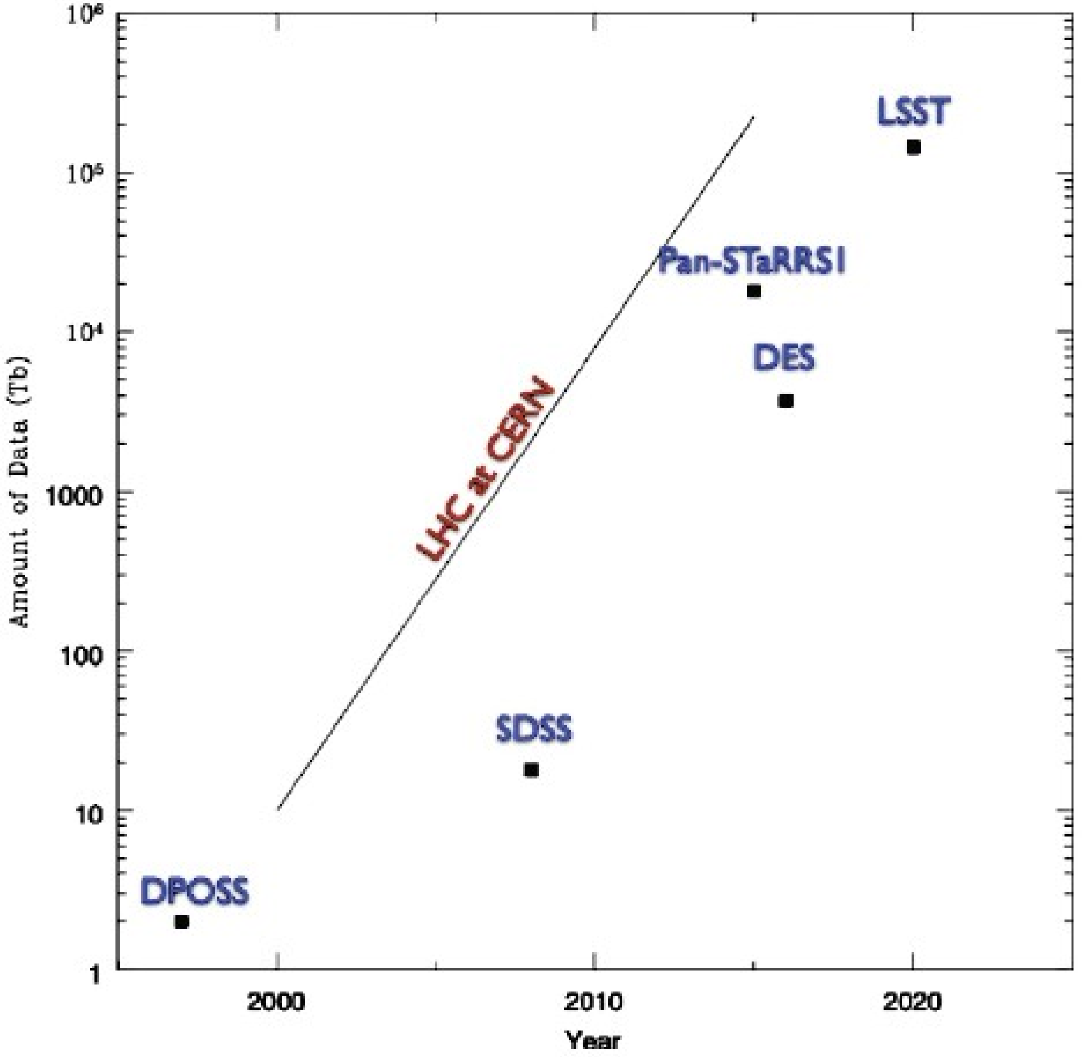
2.5 Terapixels of images

The University of Chicago
Princeton University
The Johns Hopkins University
The University of Washington
New Mexico State University
Fermi National Accelerator Laboratory
US Naval Observatory
The Japanese Participation Group
The Institute for Advanced Study
Max Planck Inst, Heidelberg

Sloan Foundation, NSF, DOE, NASA



Increase of astronomical data



What is VO?

The VO is an international astronomical community-based initiative.

It aims to allow global electronic access to the available astronomical data archives of space and ground-based observatories, sky survey databases.

It also aims to enable data analysis techniques through a coordinating entity that will provide common standards, wide-network bandwidth, and state-of-the-art analysis tools.

http://www.euro-vo.org

VO reality

The VO aims to provide the framework for global access to the various data archives by facilitating the standardisation of archiving and data-mining protocols.

The VO initiative is a global collaboration of the world's astronomical communities under the auspices of the recently formed International Virtual Observatory Alliance (IVOA).

http://www.euro-vo.org

Brazilian effort for VO: The BraVO project

http://www.lna.br/bravo

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Departamento de Astronomia

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BRAVO
Brazilian Virtual Observatory @ INPE

SOAR TELESCOPE
SOARVO
The Southern Astrophysical Research Telescope Virtual Observatory

SEAGal

Starlight
Spectral Synthesis Code

GRUPO DE ASTROFÍSICA
GAS - UFSC
BRASIL

Cyclops
Cyclotron Emission of Polars

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The BraVO project

Description

PAN-AMERICAN ASSOCIATION OF COMPUTATIONAL INTERDISCIPLINARY SCIENCES

Journal of Computational Interdisciplinary Sciences (2009) 1(3): 187-206
© 2009 Pan-American Association of Computational Interdisciplinary Sciences
ISSN 1983-8409
http://epacis.org

The Brazilian Virtual Observatory – A New Paradigm for Astronomy

R.R. de Carvalho[1], R.R. Gal[2], H.F. de Campos Velho[1], H.V. Capelato[1], F. La Barbera[3], E.C. Vasconcellos[1], R.S.R. Ruiz[1], J.L. Kohl-Moreira[4], P.A.A. Lopes[5] and M. Soares-Santos[6]

Manuscript received on September 09, 2009 / accepted on January 20, 2010

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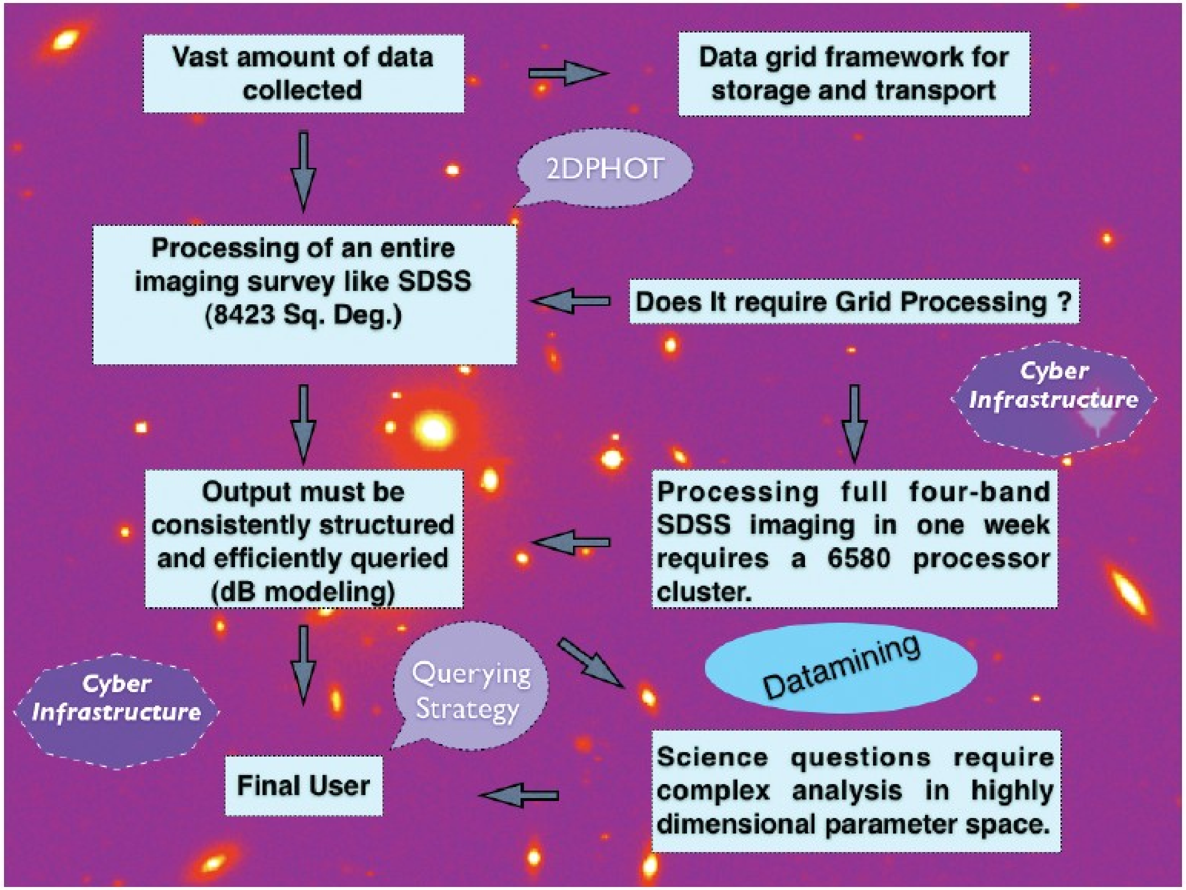
1. New tool: 2DPhot (image processing, photometry)



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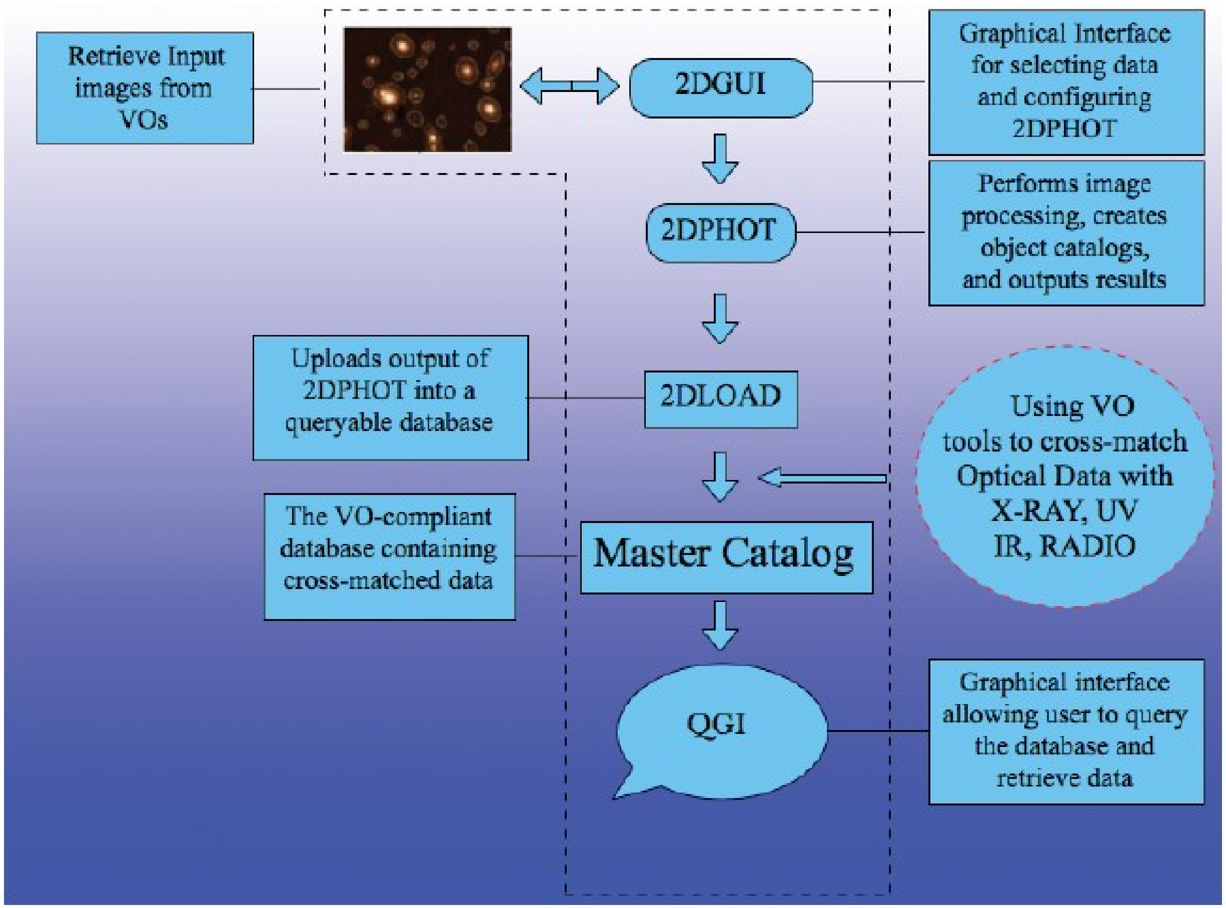
Schematic representation for 2DPhot environment



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2. Decision tree for astronomical data classification

Classification

Star/galaxy

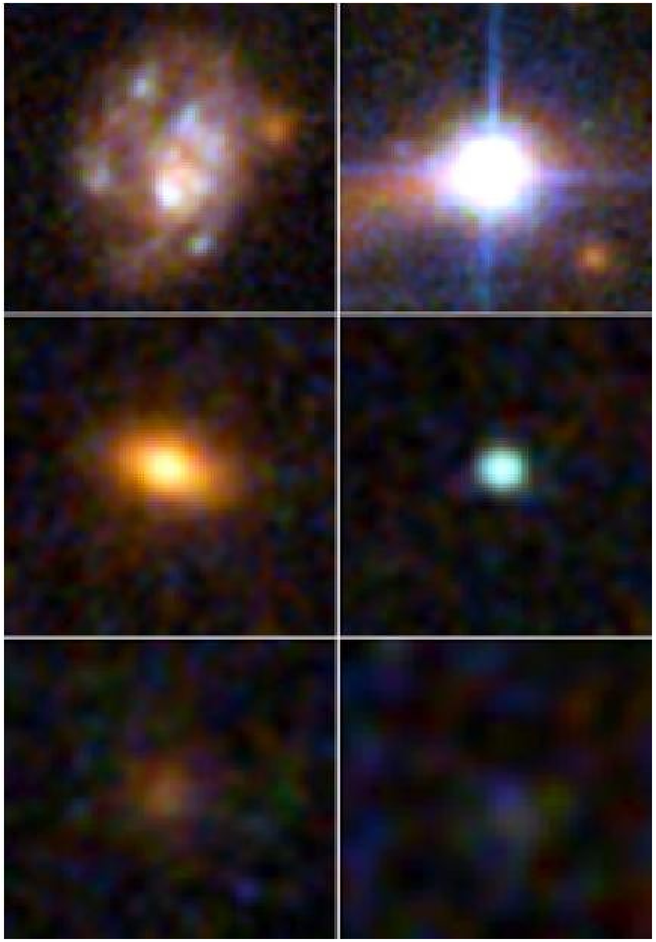
It is not easy task

See the figure:

(a)Easy

(b)More complicated

(c)How to classify?



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TEMA Tend. Mat. Apl. Comput., **10**, No. 1 (2009), 75-86.
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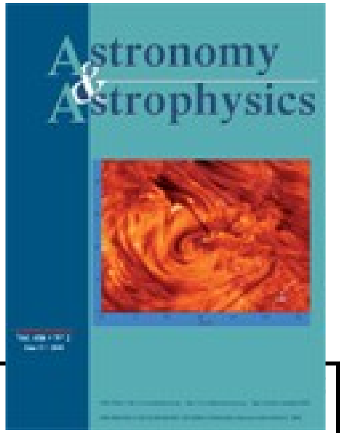
Árvores de Decisão na Classificação de Dados Astronômicos

R.S.R. RUIZ[1], H.F. DE CAMPOS VELHO [2], R.D.C. SANTOS [3], Laboratório Associado de Computação e Matemática Aplicada, LAC, INPE, 12227-010 São José dos Campos, SP, Brasil.

M. TREVISAN[4], Departamento de Astronomia, IAG, USP, 05508-900, São Paulo, SP, Brasil.

TEMA
Tendências em Matemática Aplicada e Computacional



Astronomy & Astrophysics manuscript no. Caretta08˙vResubm˙print
April 23, 2008

Evidence of Turbulence-like Universality on the Formation of Galaxy-sized Dark Matter Haloes ⋆

C. A. Caretta[1,2], R. R. Rosa[2], H. F. de Campos Velho[2], F. M. Ramos[2], and M. Makler[3]

[1] Departamento de Astronomía, Universidad de Guanajuato, Guanajuato, Gto., México
[2] Lab. Associado de Computação e Matemática Aplicada, Instituto Nacional de Pesquisas Espaciais, São José dos Campos, SP, Brazil
[3] Coordenação de Cosmologia, Relatividade e Astrofísica, Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, RJ, Brazil

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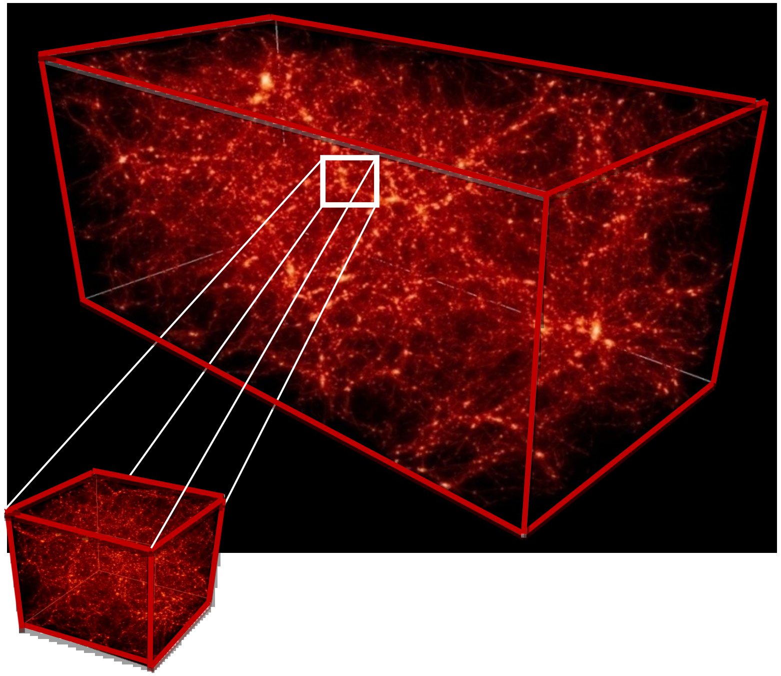
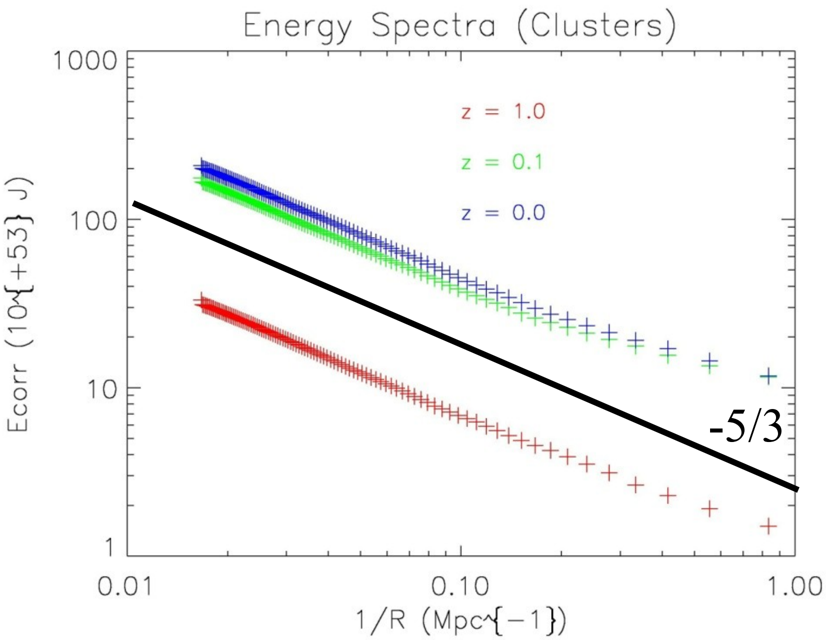
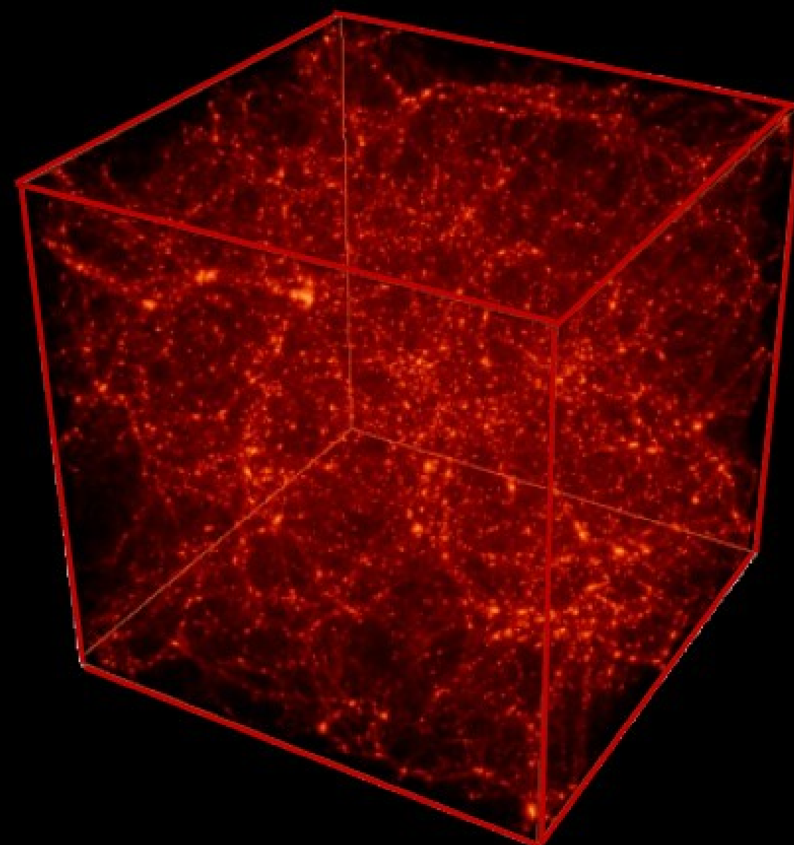
3. Parallel Friends-of-Friends (FoF)



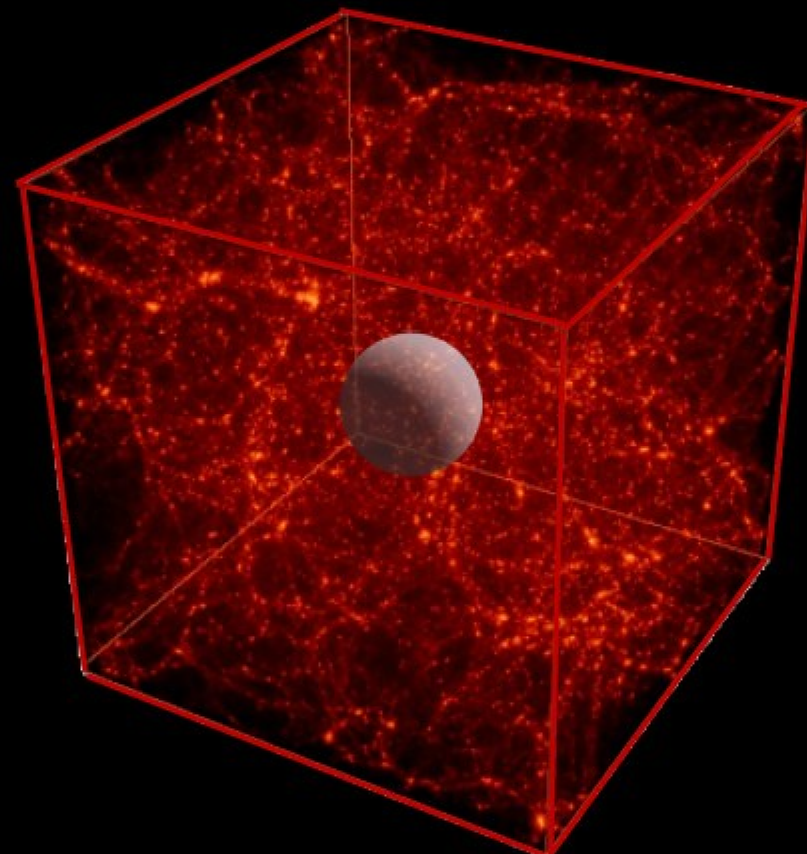


$$U_j = \frac{1}{2} G m_j \sum \frac{m_i}{r_{ij}}$$

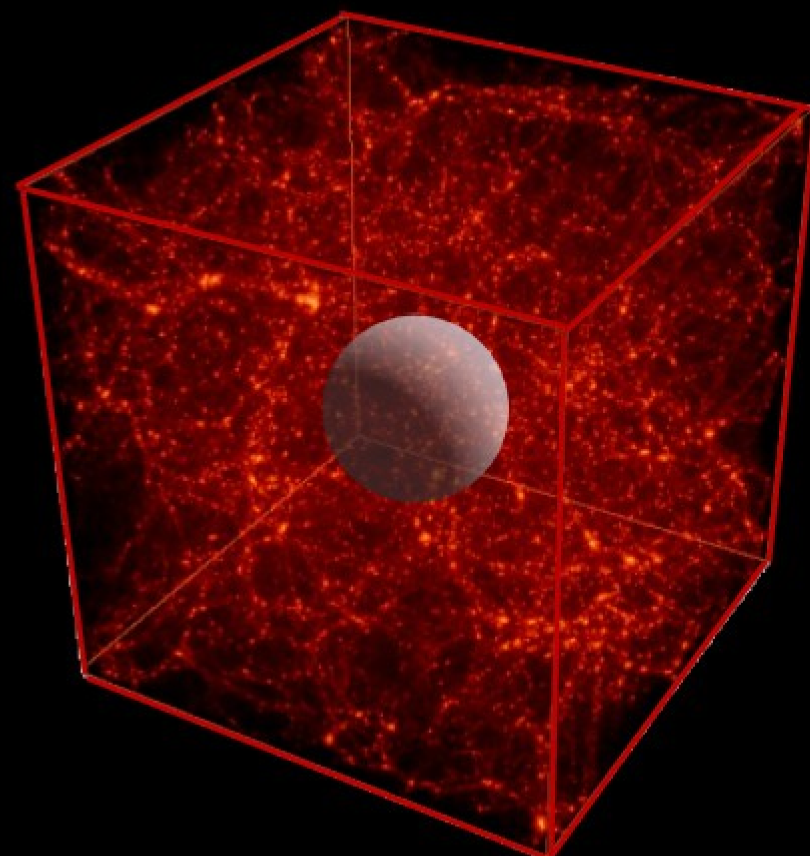


From: R.S.R. Ruiz, PhD proposal (CAP/INPE), 2009

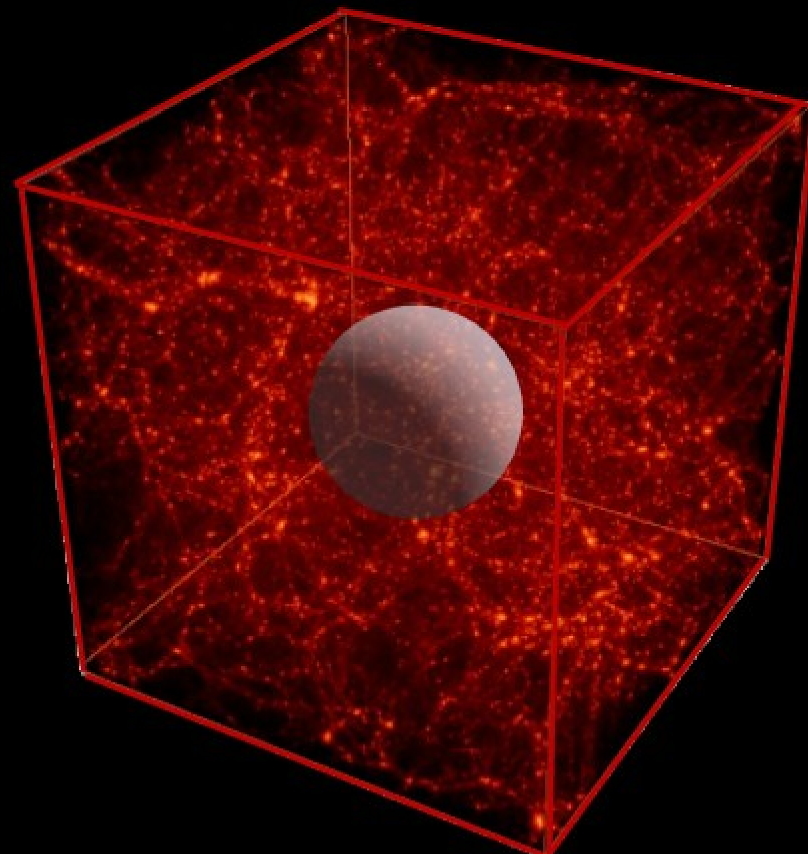
$$U_j = \frac{1}{2} G m_j \sum \frac{m_i}{r_{ij}}$$



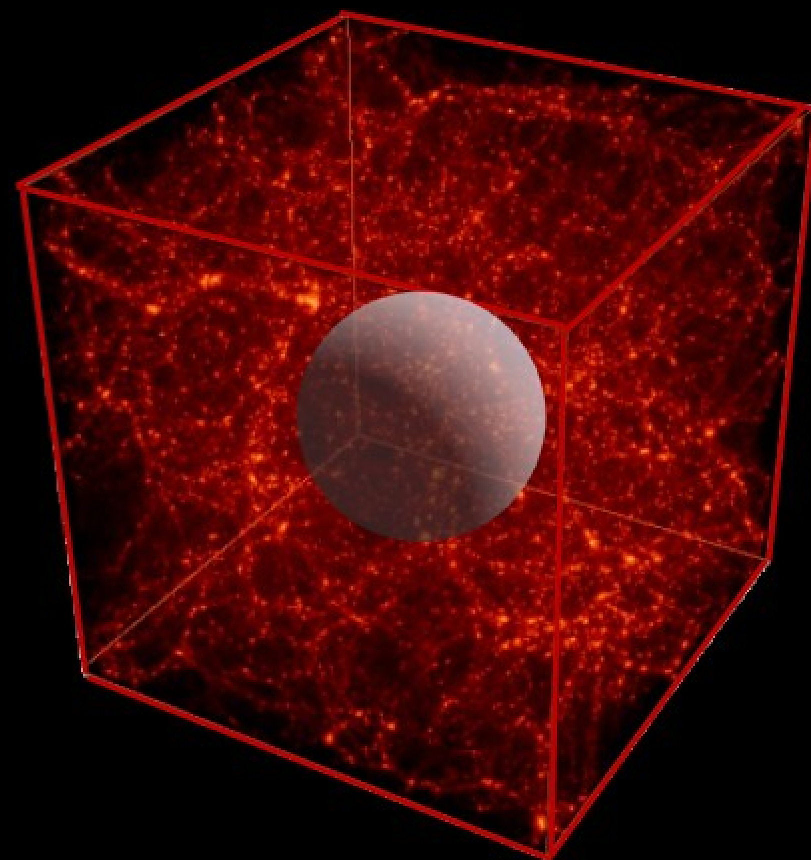
$$U_j = \frac{1}{2} G m_j \sum \frac{m_i}{r_{ij}}$$



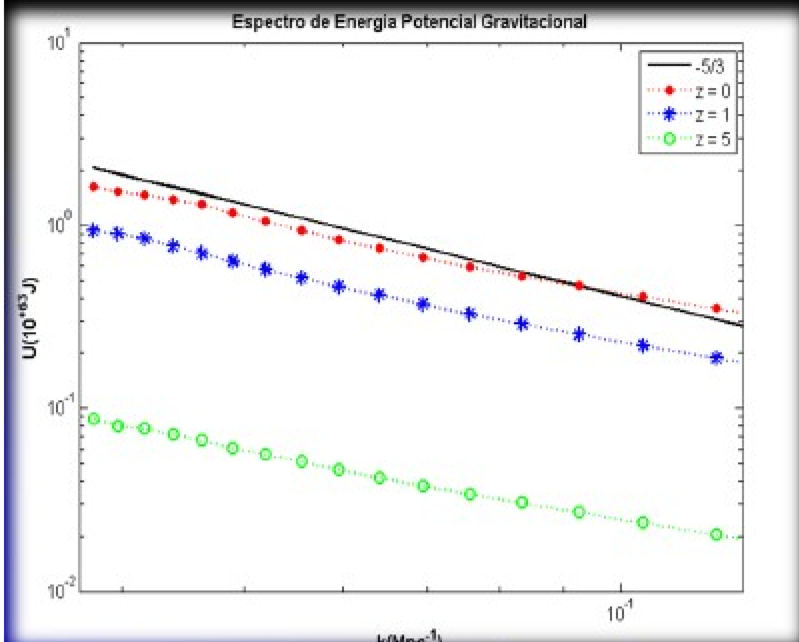
$$U_j = \frac{1}{2} G m_j \sum \frac{m_i}{r_{ij}}$$

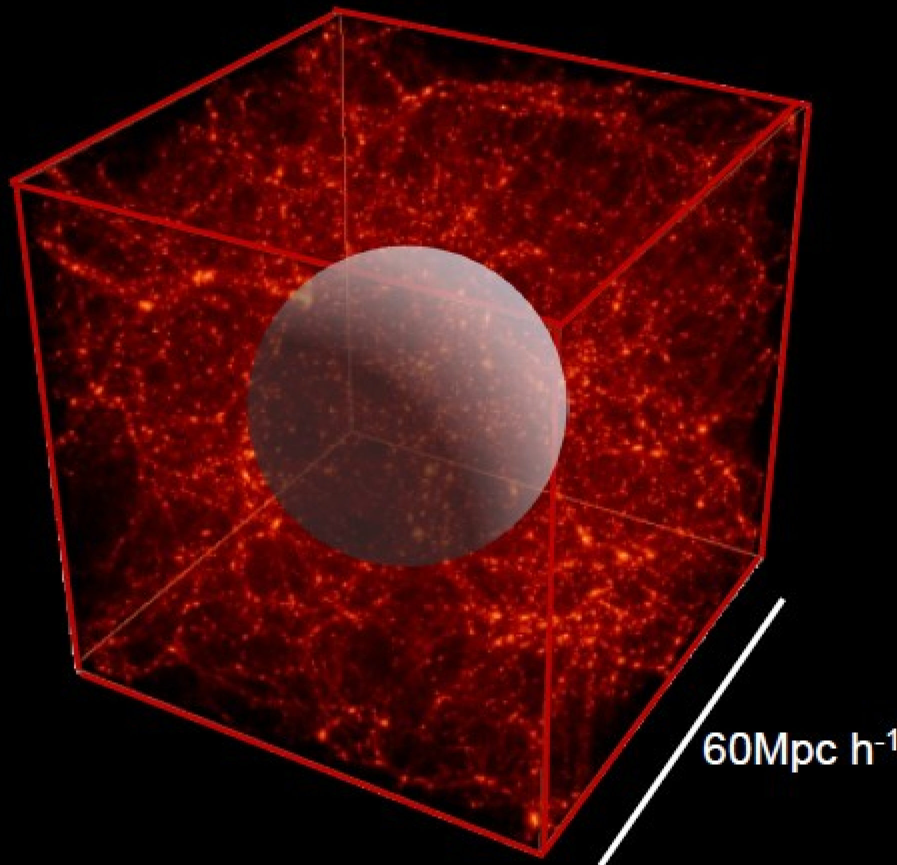


$$U_j = \frac{1}{2} G m_j \sum \frac{m_i}{r_{ij}}$$



$$U_j = \frac{1}{2} G m_j \sum \frac{m_i}{r_{ij}}$$





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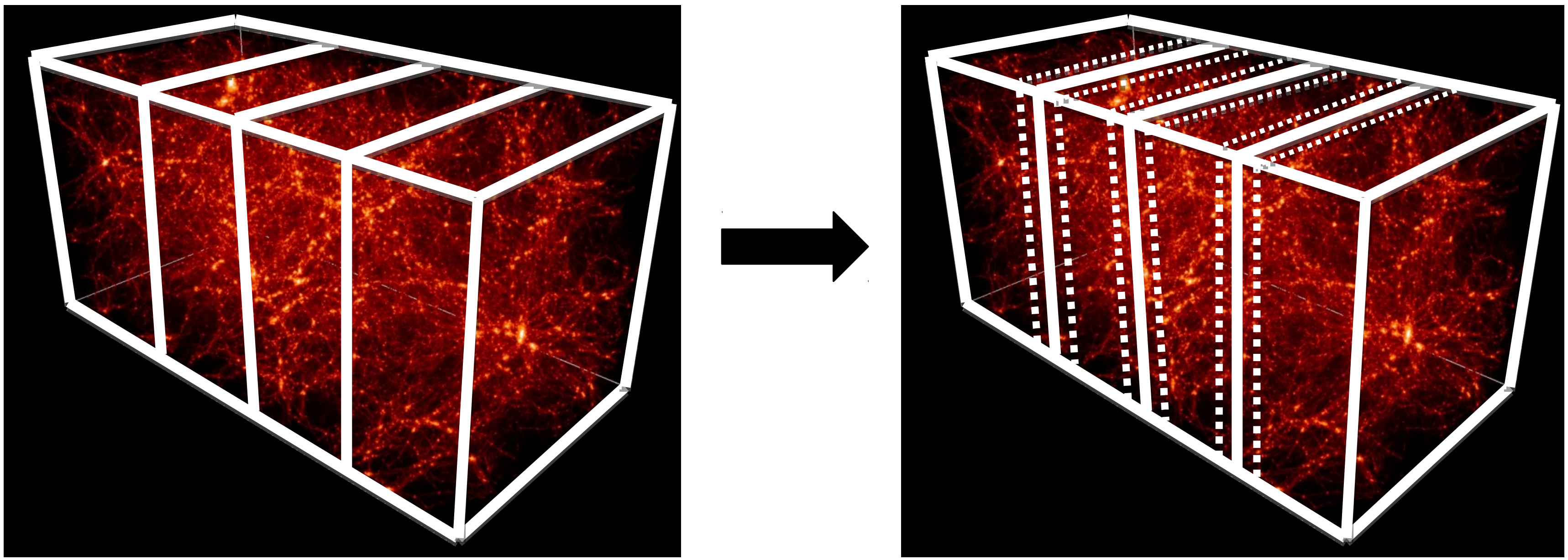
Parallel-FoF (domain decomposition)



From: R.S.R. Ruiz, C Caretta, H. F. Campos Velho (unpublished paper)

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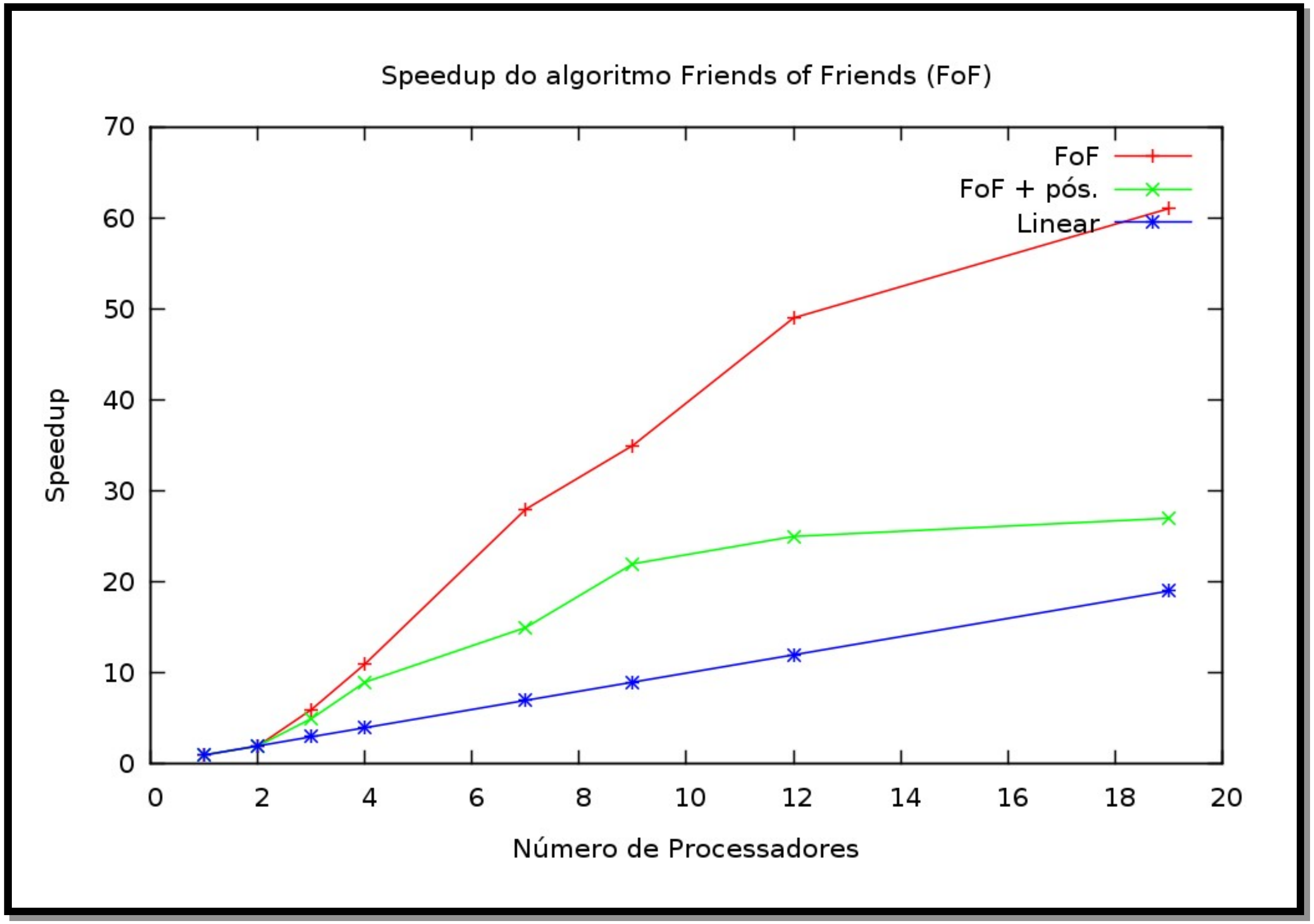
Parallel-FoF



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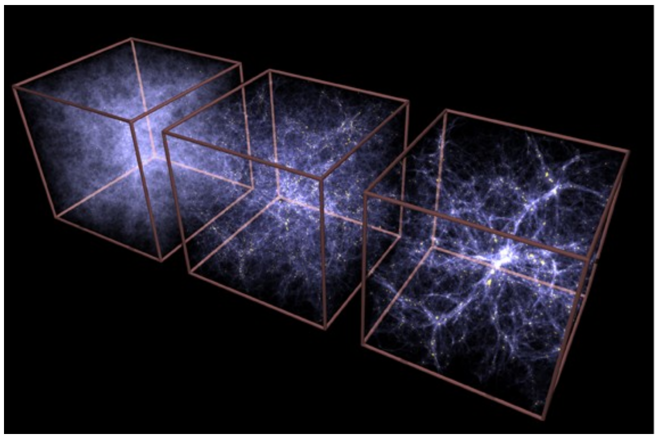
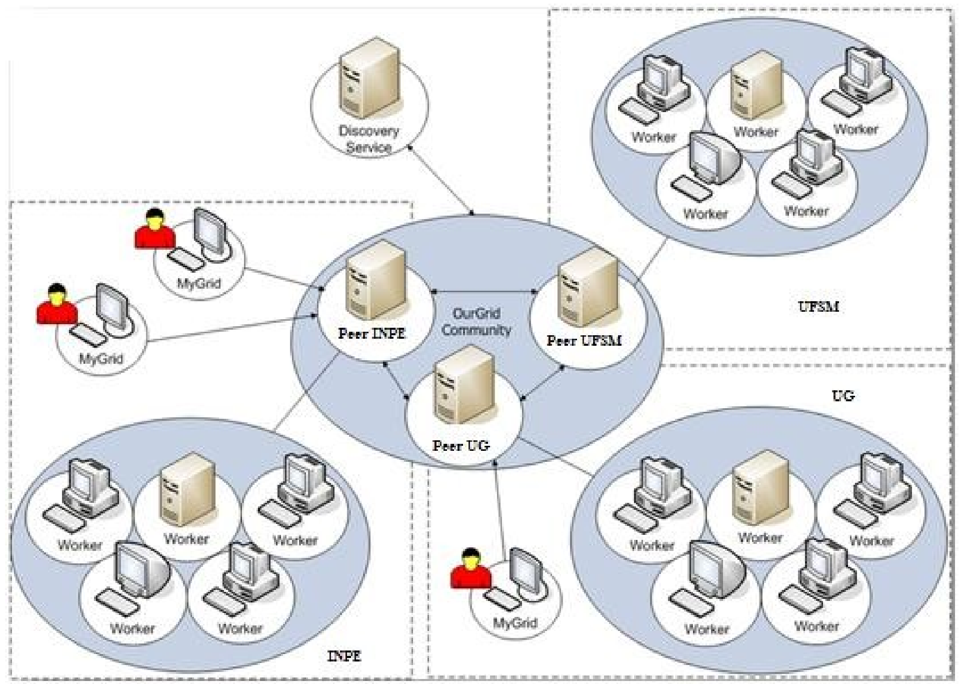
4. Grid processing (OurGrid Middleware)





From: R.S.R. Ruiz, C Caretta, H. F. Campos Velho, R.P. Souta, A.S. Charão, WorkCAP (2010)

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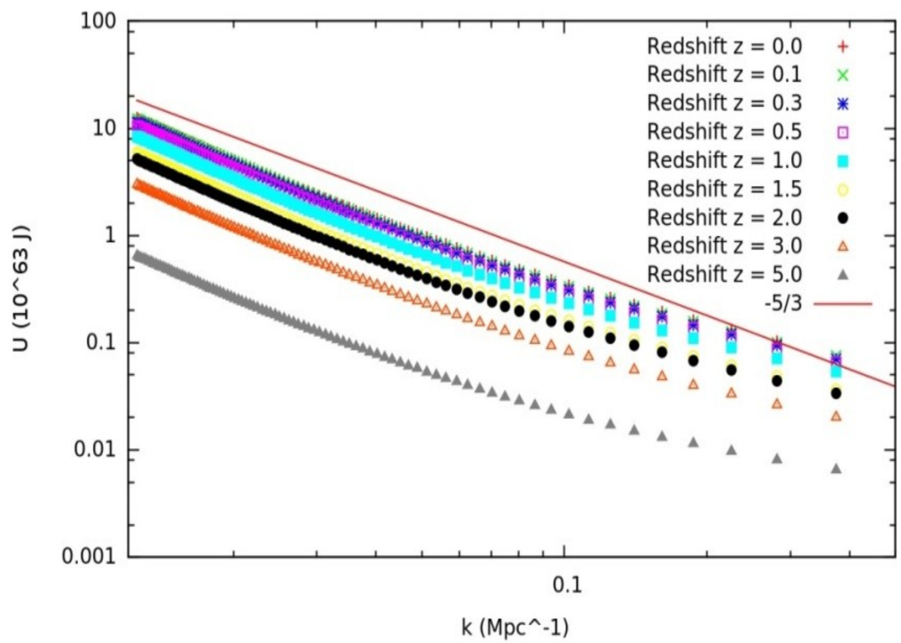
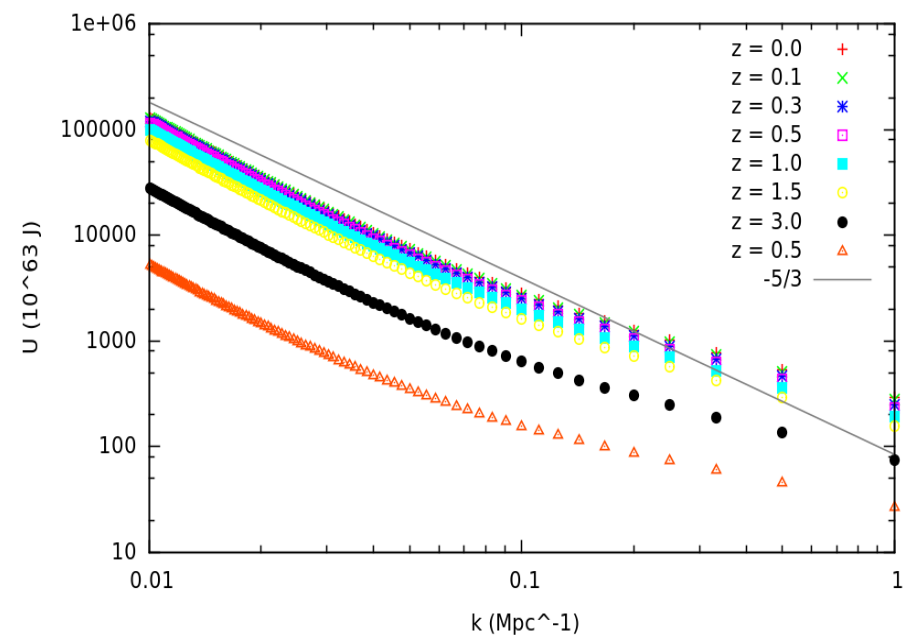
Grid processing (OurGrid Middleware)





Virgo 17x10**6

Millenium 10x10**9

From: R.S.R. Ruiz, C Caretta, H. F. Campos Velho, R.P. Souta, A.S. Charão, WorkCAP (2010)

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Grid processing (OurGrid Middleware)

Table 1: Acumulated cluster time (hours)

Cluster	Jobs	T_S (hh:mm)	T_S /Jobs (hh:mm)
C-PAD/INPE	5	14:32	02:54
LAC/INPE	3	13:57	04:39
Computação/ UFSM	1	11:57	11:57
Total	9	40:26	58,936

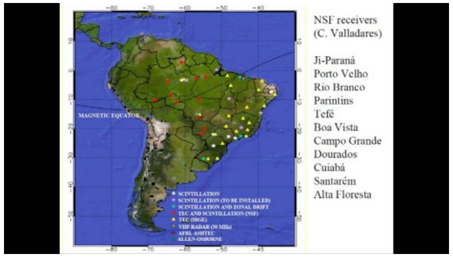
$$S = \frac{T_S}{T_G} = \frac{40.43}{14.53} = 2.78$$

From: R.S.R. Ruiz, C Caretta, H. F. Campos Velho, R.P. Souta, A.S. Charão, WorkCAP (2010)

INPE: Space Weather Program

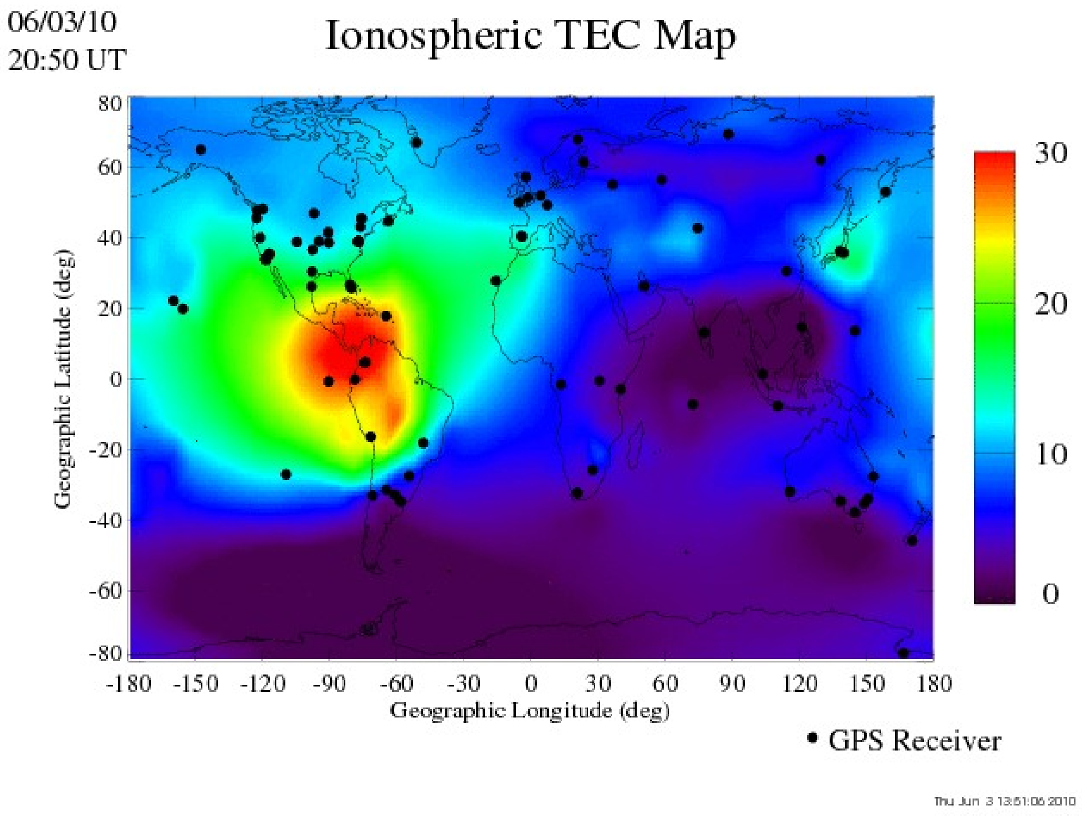
Monitoring:

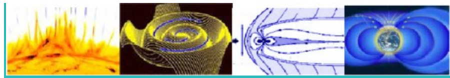
1. Network sensors (GPS, cintilation, magnetometer)
2. Networks for ionosonders (under construction)
3. Telescopes (Spua, BSS, BDA, Muons)



INPE: Space Weather Program

Prediction: our intention is to produceTEC maps

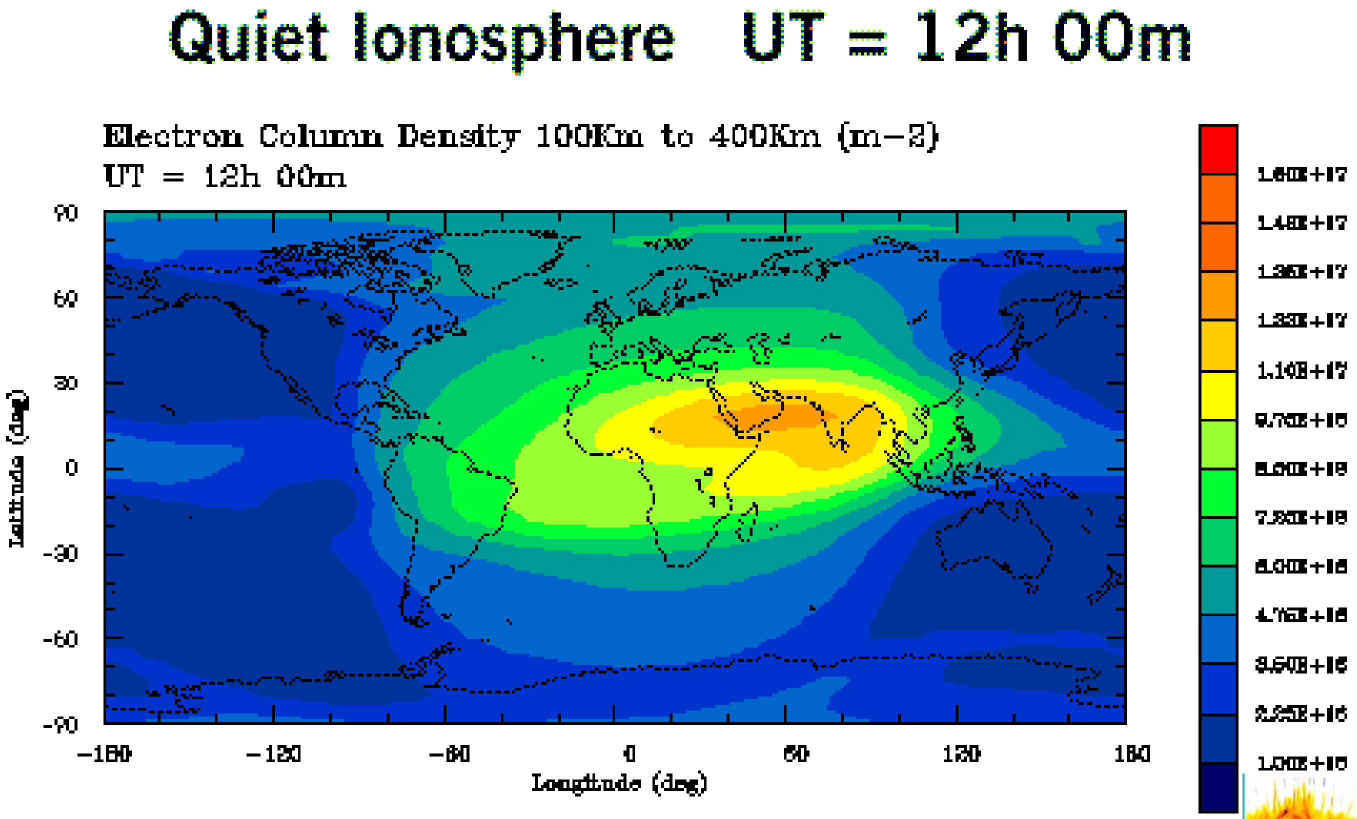


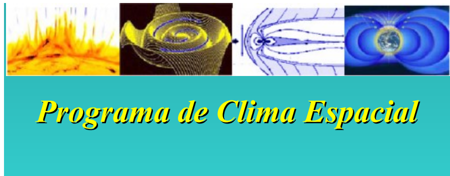


Programa de Clima Espacial

INPE: Space Weather Program

Prediction: our intention TEC maps (example)



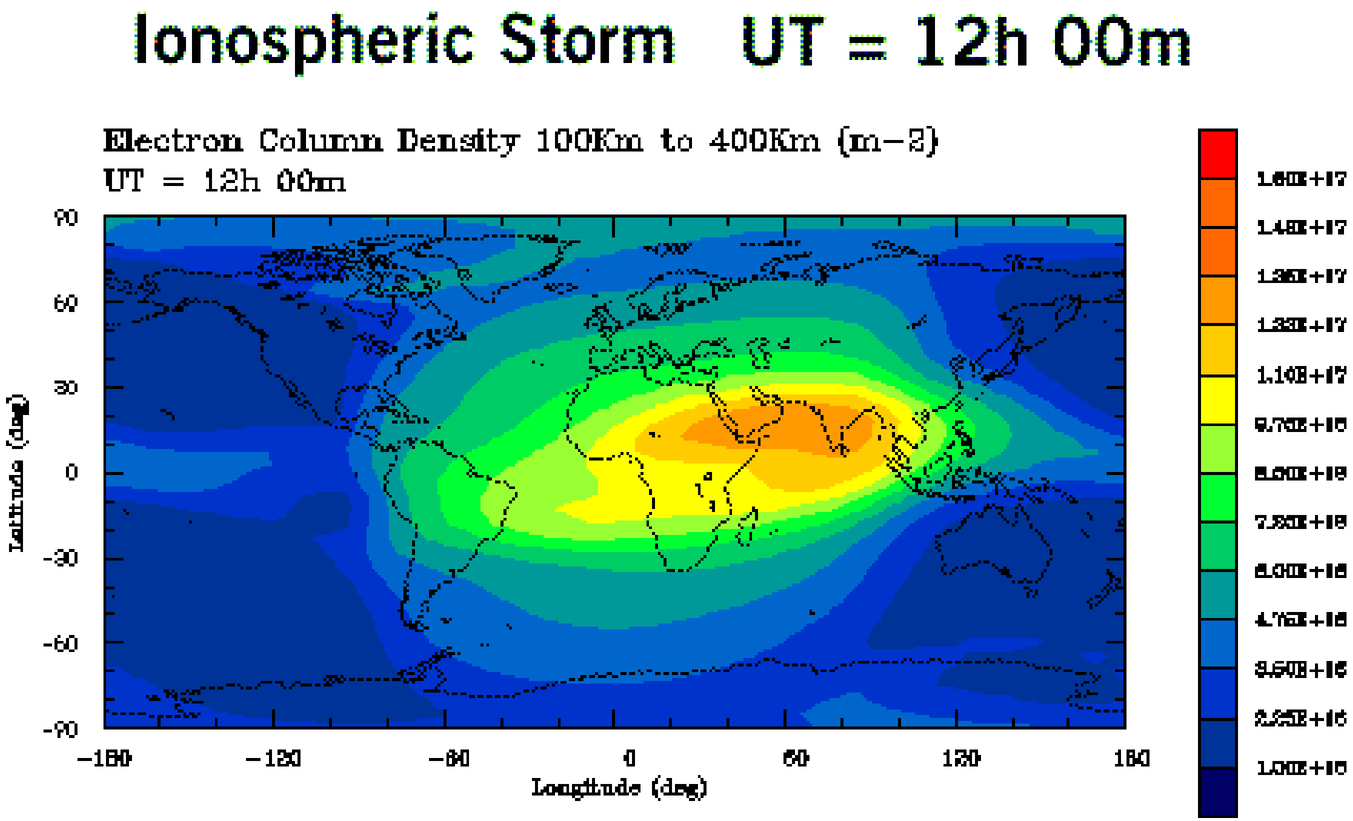


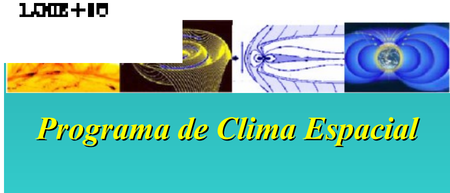
From: http://www.swpc.noaa.gov

INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

INPE: Space Weather Program

Prediction: our intention TEC maps (example)



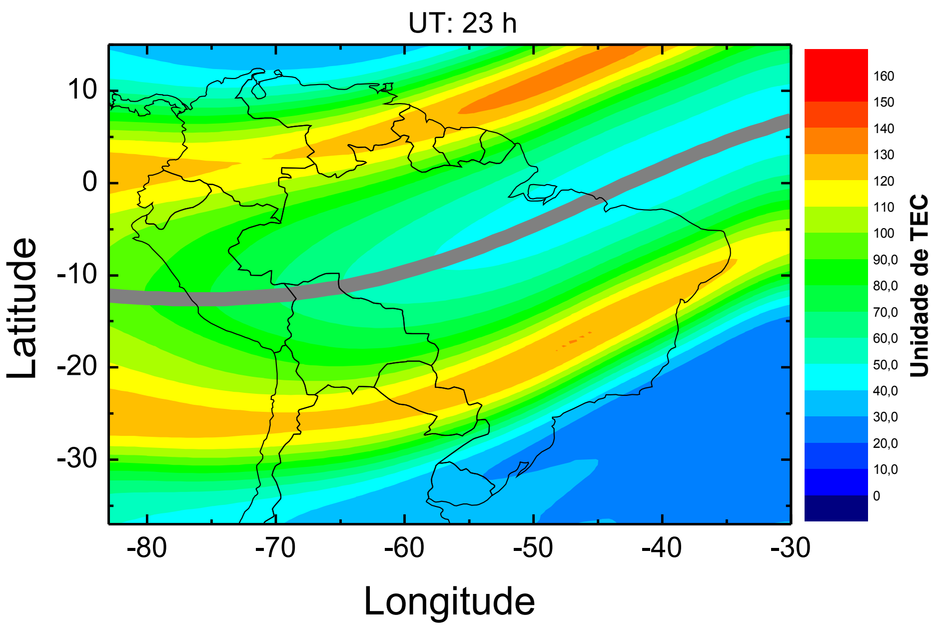


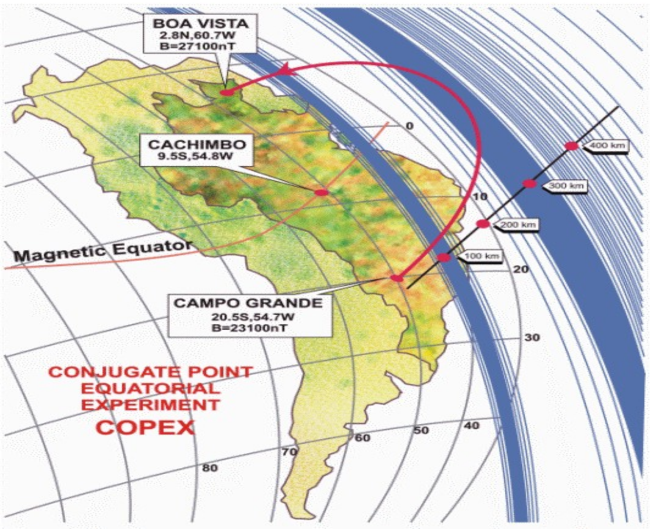
From: http://www.swpc.noaa.gov

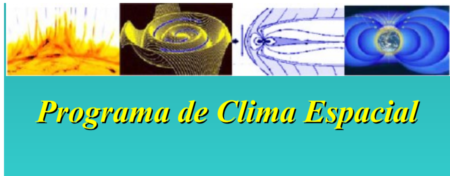
INPE: Space Weather Program

Prediction: What we have

SHEFFIELD UNIVERSITY PLASMASPHERE-IONOSPHERE MODEL (SUPIM)



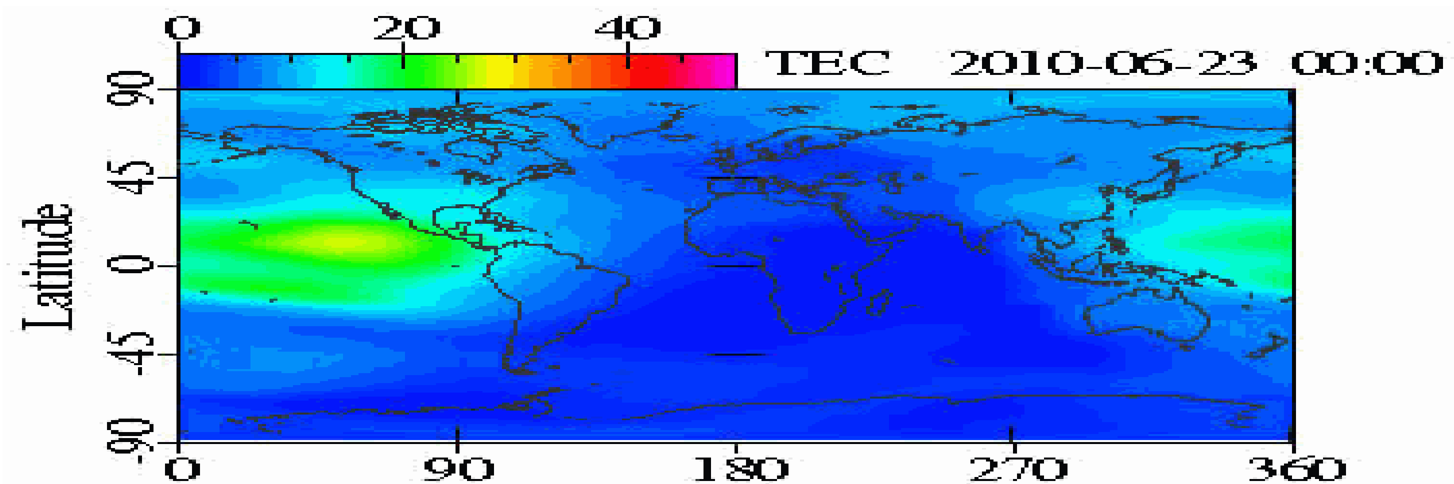


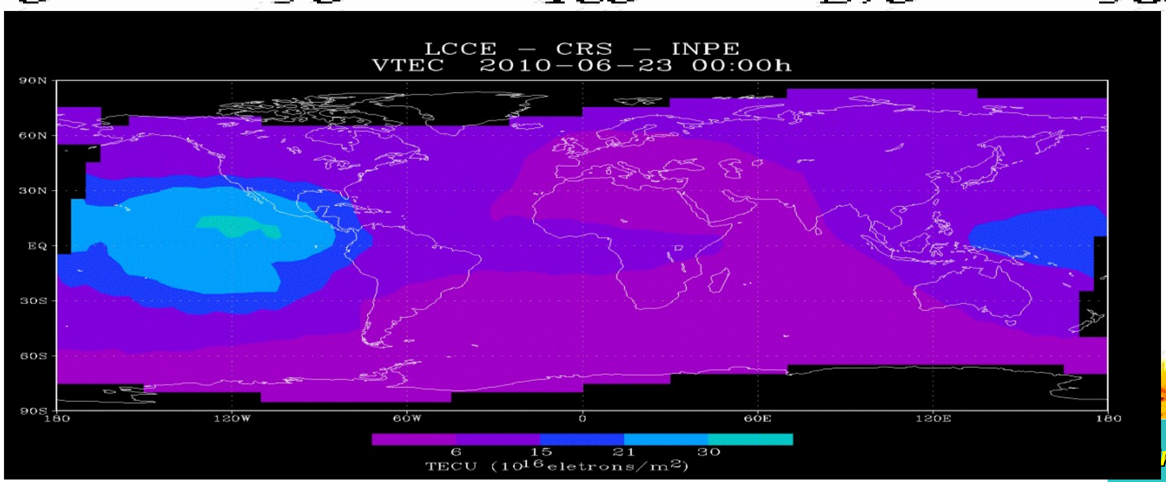


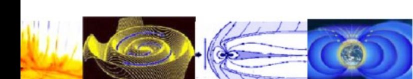
From: A. Petry (CRS/INPE)

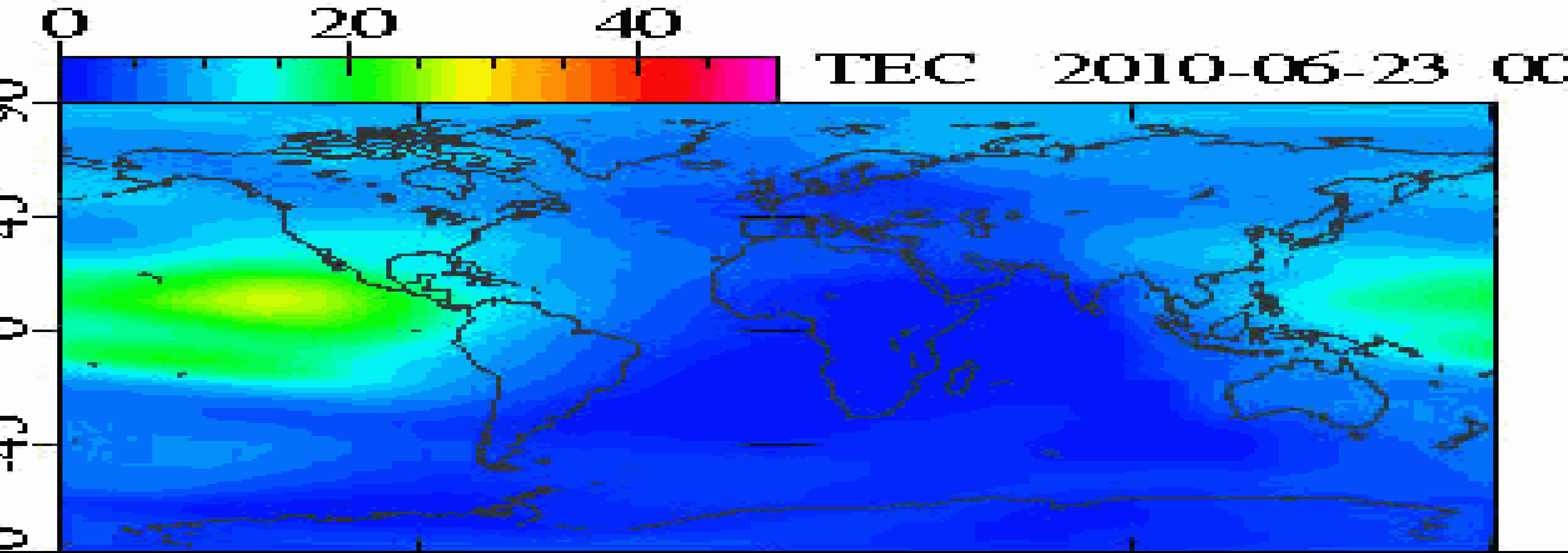
INPE: Space Weather Program

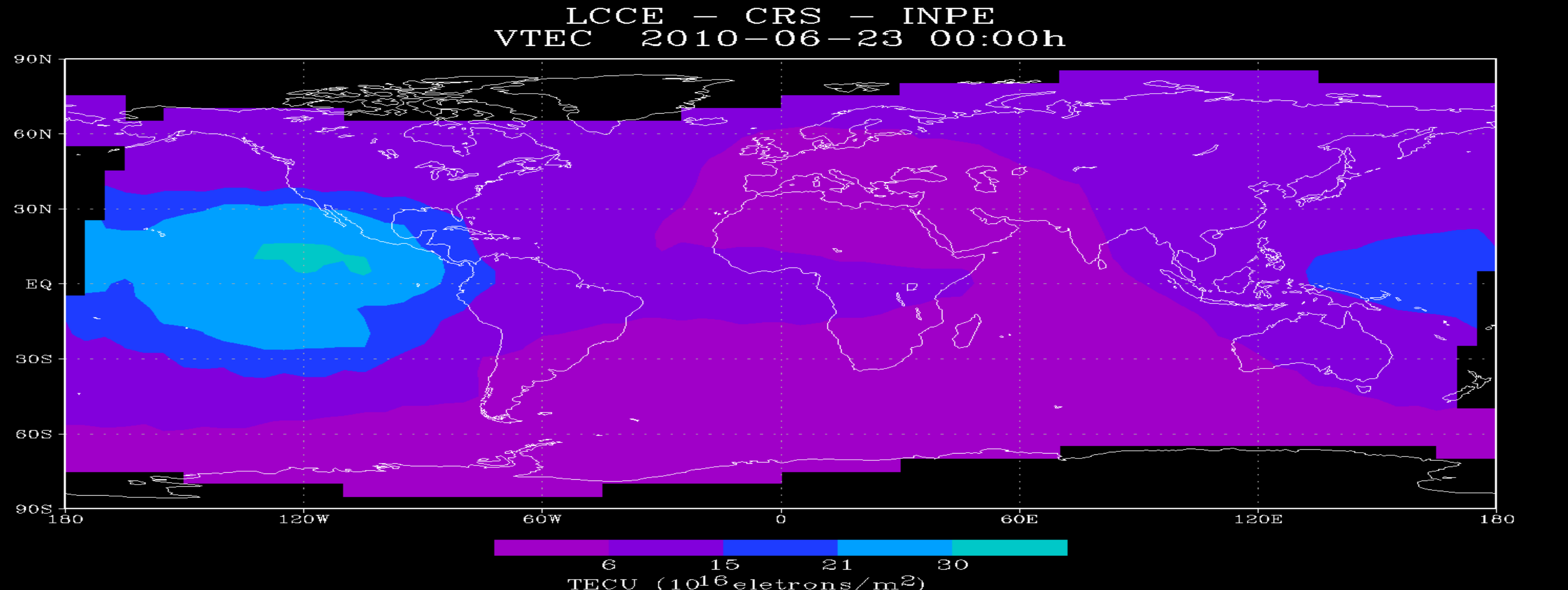
Prediction: comparison: SUPIM x GAIM (with data assimilation)








0
20
40
TEC 2010-06-23 00


LCCE – CRS – INPE
VTEC 2010-06-23 00:00h
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
180
6
15
21
30
TECU (10^{16} eletrons/m^2)

INPE: Space Weather Program

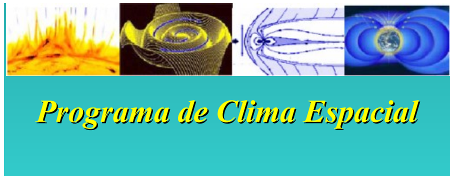
Data assimilation:

This is a multi-step procedure:

1. Data aquisition
2. Automatic verification with it is a good data
3. Data assimilation process

New research:

1. Develop a method for SUPIM (initially nudging)
2. Local ensemble Kalman filter
3. New scheme based on artificial neural networks



Outline of the presentation – Part II

- Challenges: Meteorology

  # Combining: model prediction + observations

  # Numerical methods:
  - Spectral
  - Grid point (finite volume or finite elements)

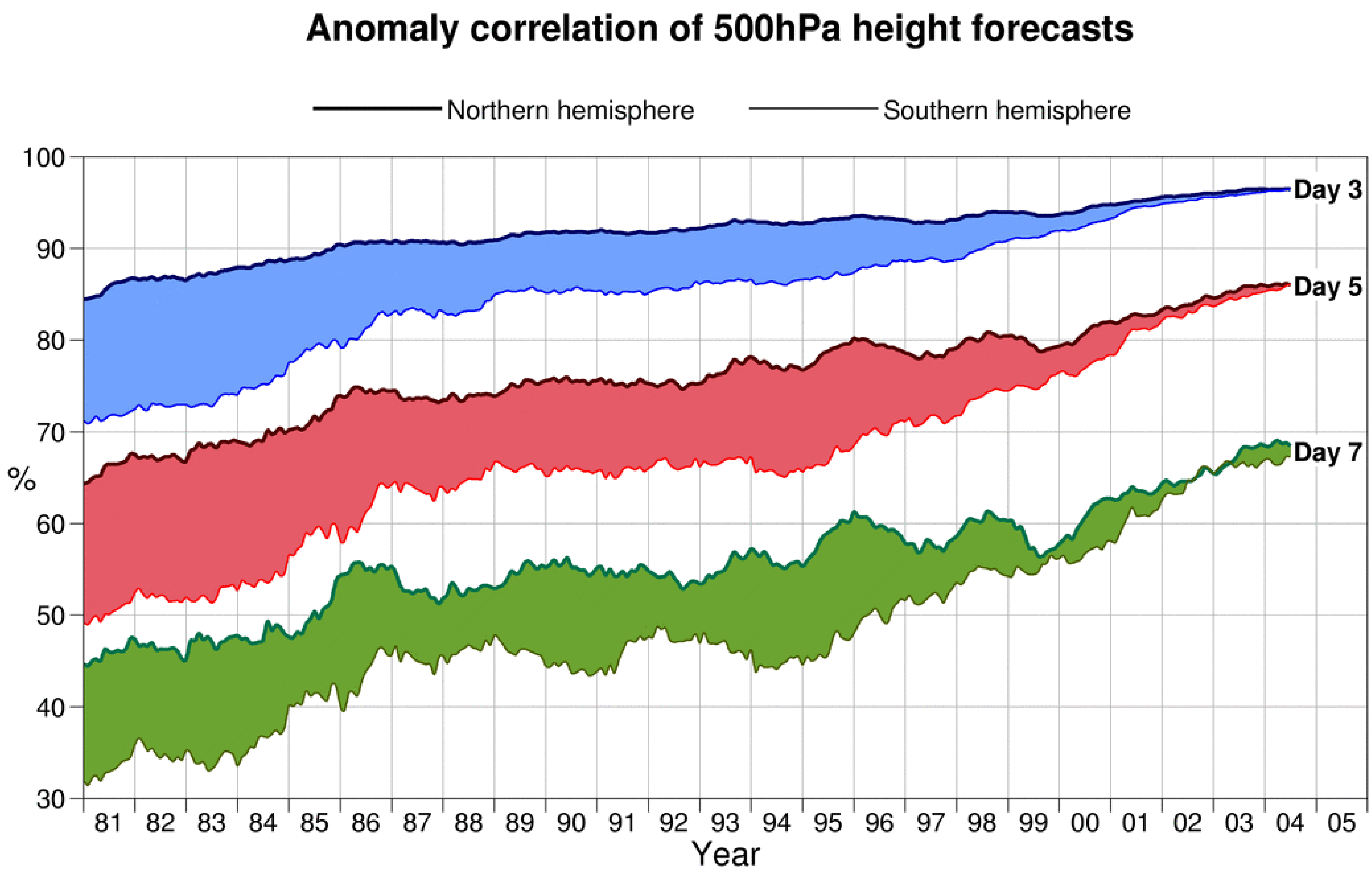
  # Computer architecture
  - Multi-core
  - Hybrid computing

Observations × weather predictions

Advanced parameterization for the water cycle has been considered in the modern models. Better numerical weather predictions have been obtained using efficient **data assimilation,** employing all information available (observational data from satellites, radars, GPS, etc). This promotes a feedback mechanism, enhancing our understanding on the atmospheric water cycle itself.

ECMWF

Forecasts Scores



Adrian Simmons

Methods for data assimilation

- Newtonian relaxation (nudging)
- Statistical ("optimal") interpolation
- Kalman filter
- Variational method: 3D and 4D
- New methods for data assimilation:

  - Ensemble Kalman filter

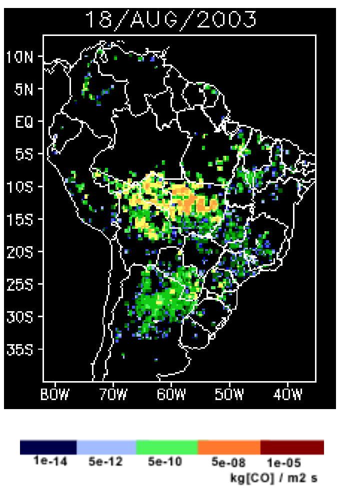
  - Particle filter

  - Artificial neural networks

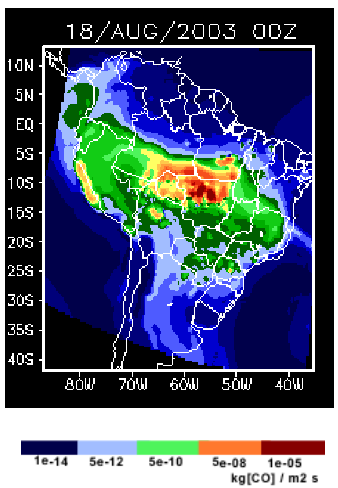
Applications: pollutant diffusion

$$\frac{\partial c}{\partial t} + \vec{v}\cdot\vec{\nabla} c = \vec{\nabla}\cdot\left[-\overline{v'c'}\right] + S^{+} + S^{-}$$

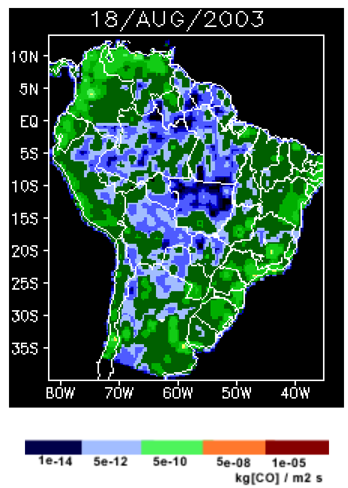
Saulo Freitas (USP/CPTEC – www.cptec.inpe.br)



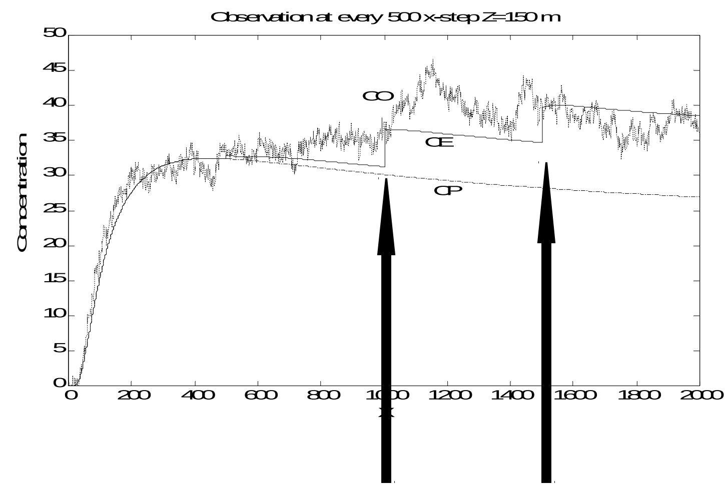
Fire emission



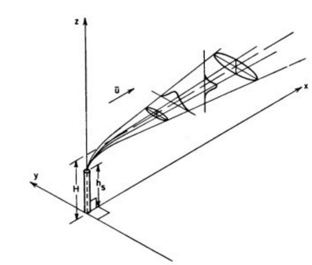
Total emission ratio



Antropogenic emission



Data insertion on numerical dispersion model

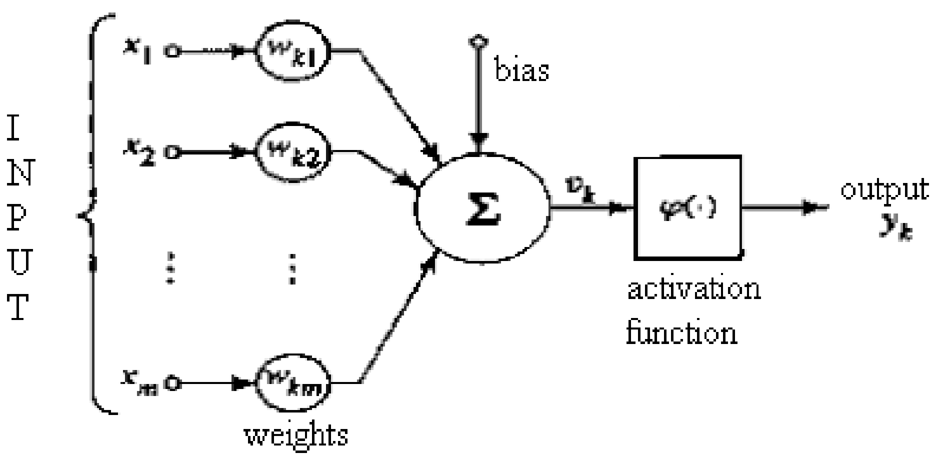


F.P. Harter, H.F. Campos Velho, *Ciência e Natura*, **17**, 177-187, 2002.

New methods: artificial neural network

For artificial neural networks (ANN), the analysis step is done by a trained ANN: multi-layer perceptron, backpropagation propagation algorithm for learning phase – emulating an extended Kalman filter

$$\boldsymbol{x}_n^a = \mathrm{f}_{NN}\left(\boldsymbol{x}_n^o, \boldsymbol{x}_n^f\right) \qquad \text{(non - linear mapping)}$$



Training phase: determination of the connection weights, bias

Activation phase: generating analized data.

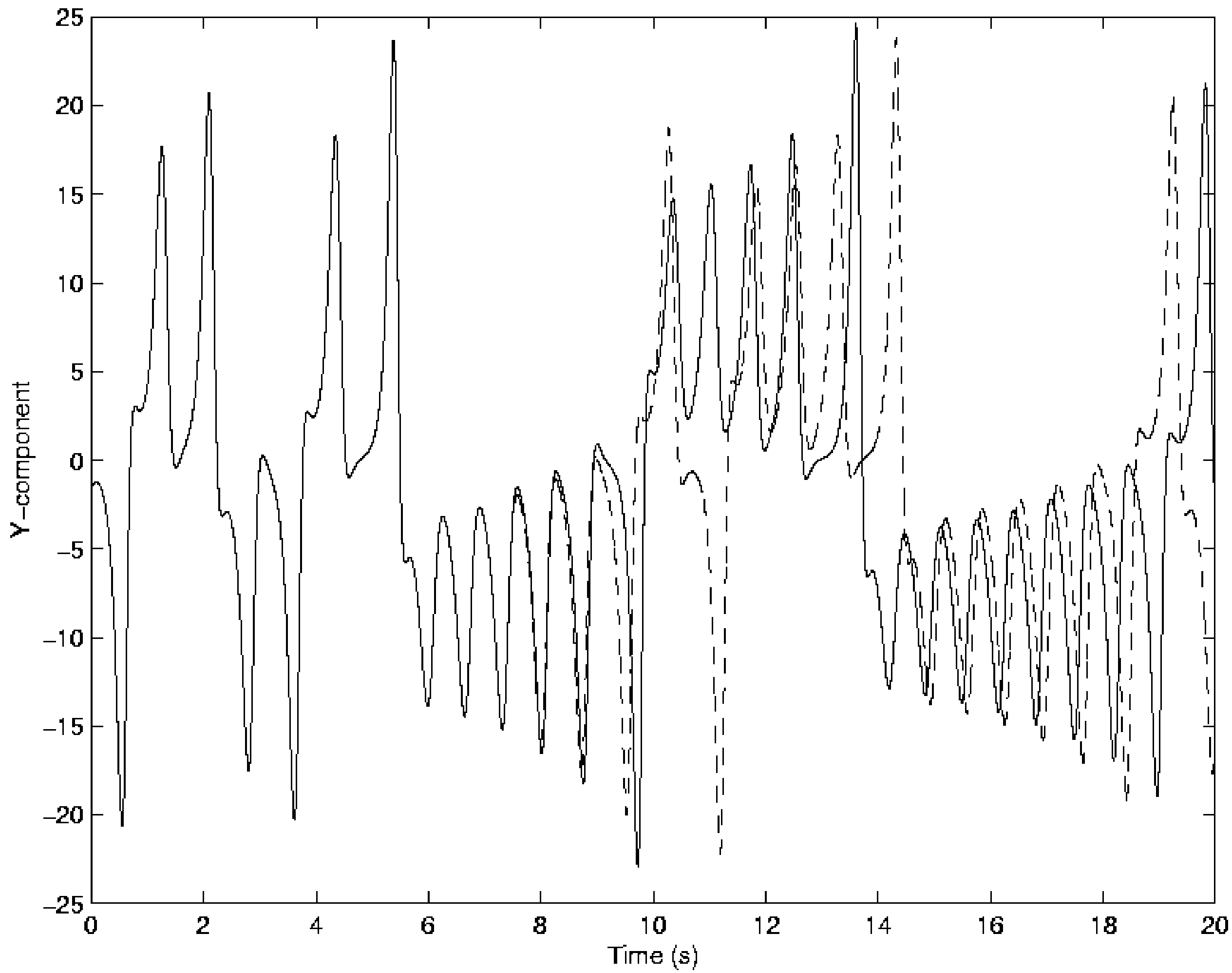
Testing model: Lorenz system

$$
\begin{aligned}
dX/dt &= -\sigma(X - Y) \\
dY/dt &= RX - Y - XZ \\
dZ/dt &= XY - bZ
\end{aligned}
$$

$$w_0 \equiv [X_0 \; Y_0 \; Z_0]^T = [1.508870 \quad -1.5312 \quad 25.46091]^T$$

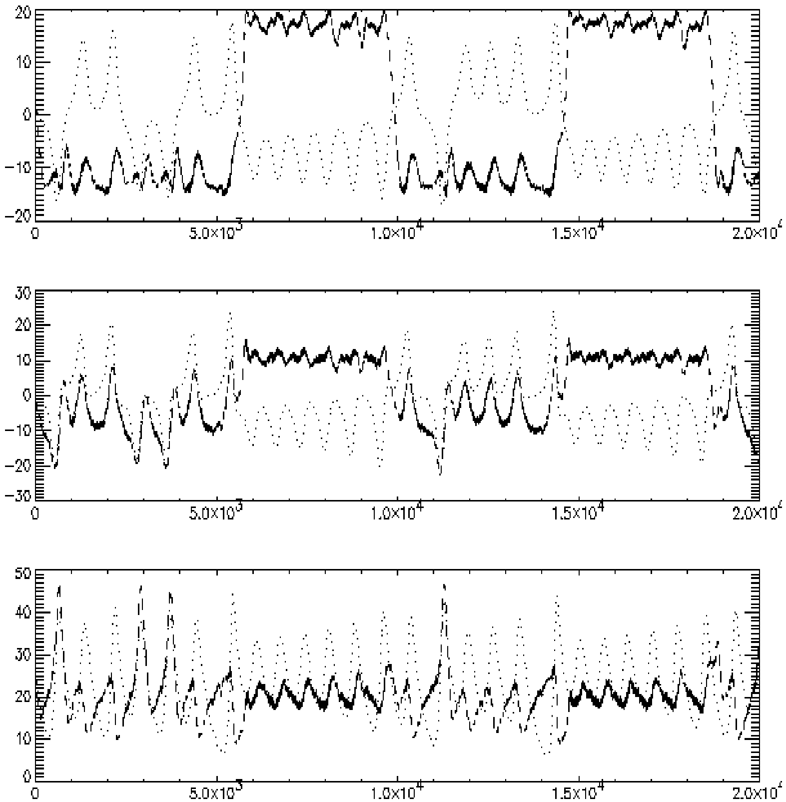
Euler predictor-corrector method adopting the following dimensionless quantities: Δt=0.001, σ=10, b=8/3, R=28, producing a chaotic dynamics.

Lorenz dynamics with 2 different conditions (Y component): w_0 and $(w_0 + \Delta w)$

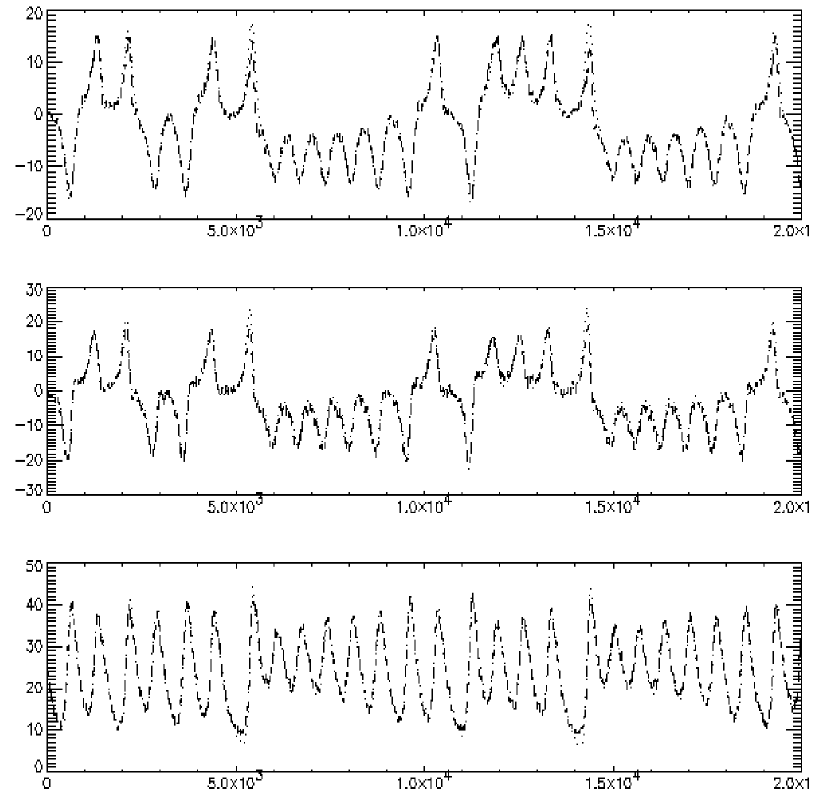


Numerical results – Lorenz system

3 neurons in the hidden layer



10 neurons in the hidden layer



Revista Brasileira de Meteorologia, **v.20**, **n.3**, 411-420, 2005

REDES NEURAIS RECORRENTES TREINADAS COM CORRELAÇÃO CRUZADA APLICADAS A ASSIMILAÇÃO DE DADOS EM DINÂMICA NÃO-LINEAR

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Recebido Março 2004 - Aceito Maio 2005

Testing model: shallow water equations

$$\frac{\partial \zeta}{\partial t} + R_o \frac{\partial (u\zeta)}{\partial x} + \delta + R_\beta v = 0$$

$$\frac{\partial \delta}{\partial t} + R_o \frac{\partial (u\delta)}{\partial x} - \zeta + R_\beta u + \frac{\partial^2 \phi}{\partial x^2} = 0$$

$$\frac{\partial \phi}{\partial t} + R_o \frac{\partial (u\phi)}{\partial x} - R_o u_0 v + R_F \delta = 0$$

- u, v zonal and meridian wind components;
- ϕ the geopotential; $\delta = \partial u/\partial x$: divergence; $\zeta = \partial v/\partial x$: vorticity;
- R_o=0.10: Rossby number; R_F=0.16: Froude number;
- R_β=10 a number associated to the β-effect
- Numerical parameters: Δt=100 s and $N_x \Delta x = L$ = 10000 Km, N_x=32
- Discretization: forward and central finite difference for time and space.

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Applied Mathematical Modelling xxx (2007) xxx–xxx

APPLIED MATHEMATICAL MODELLING

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New approach to applying neural network in nonlinear dynamic model

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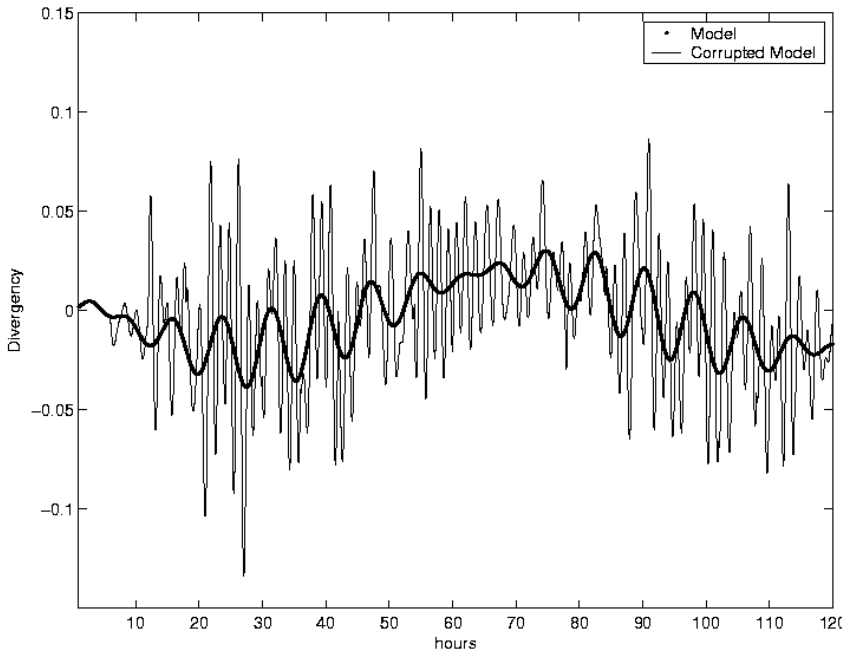
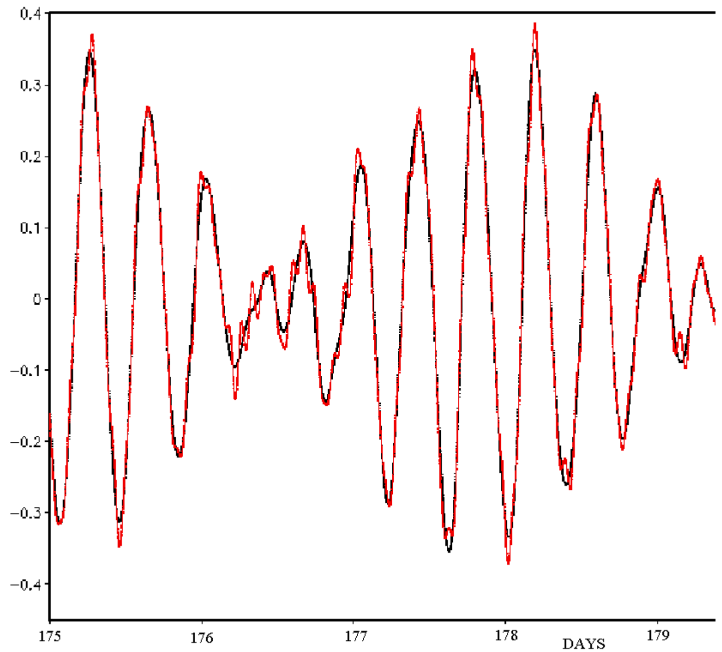
Received 2 January 2007; received in revised form 31 July 2007; accepted 17 September 2007

Atmospheric dynamics: shallow water equation 1D
Neural network: radial base function

Neural networks: new results



Without assimilation scheme



With assimilation scheme

<u>New feature:</u> the assimilation for ANN is made for each grid point, reducing the complexity of the algorithm. Example – 3 variables: 3 observations and 3 forecasts, producing 3 assimilated data for each grid point.

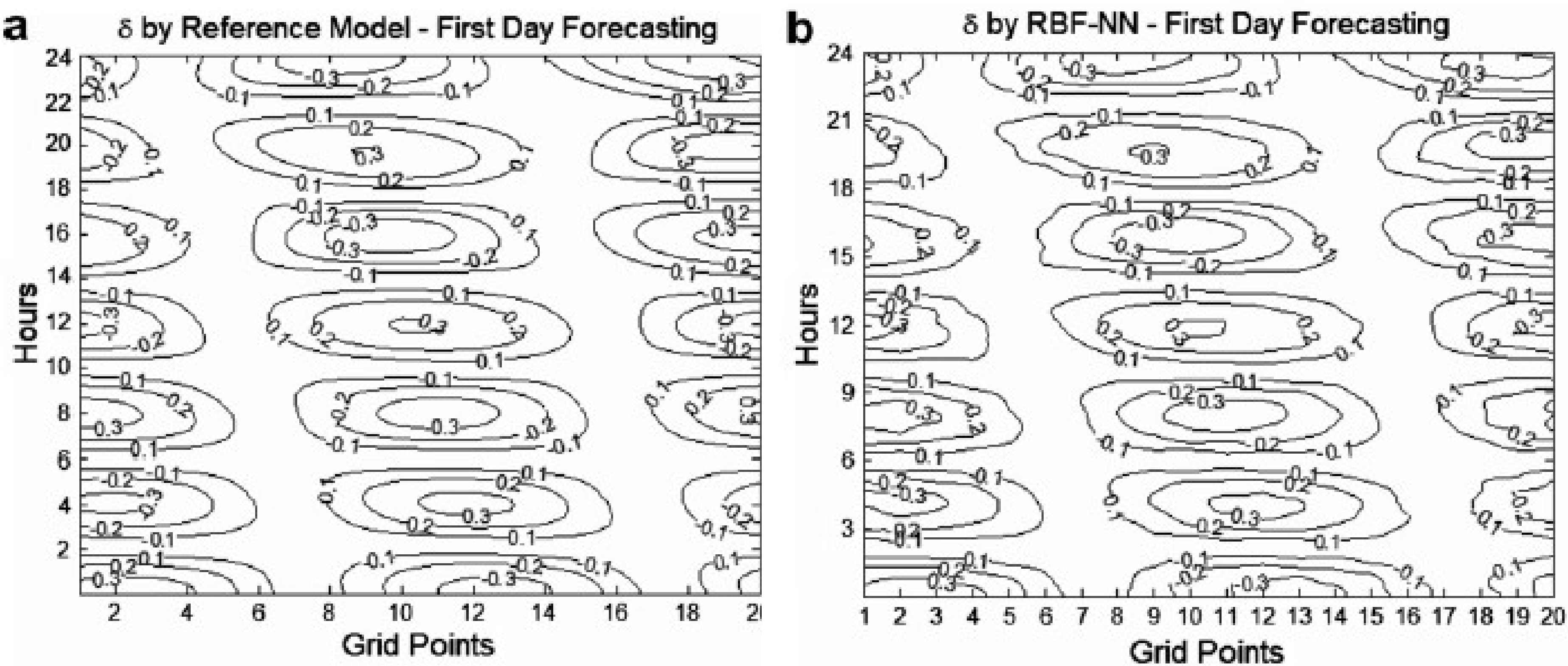
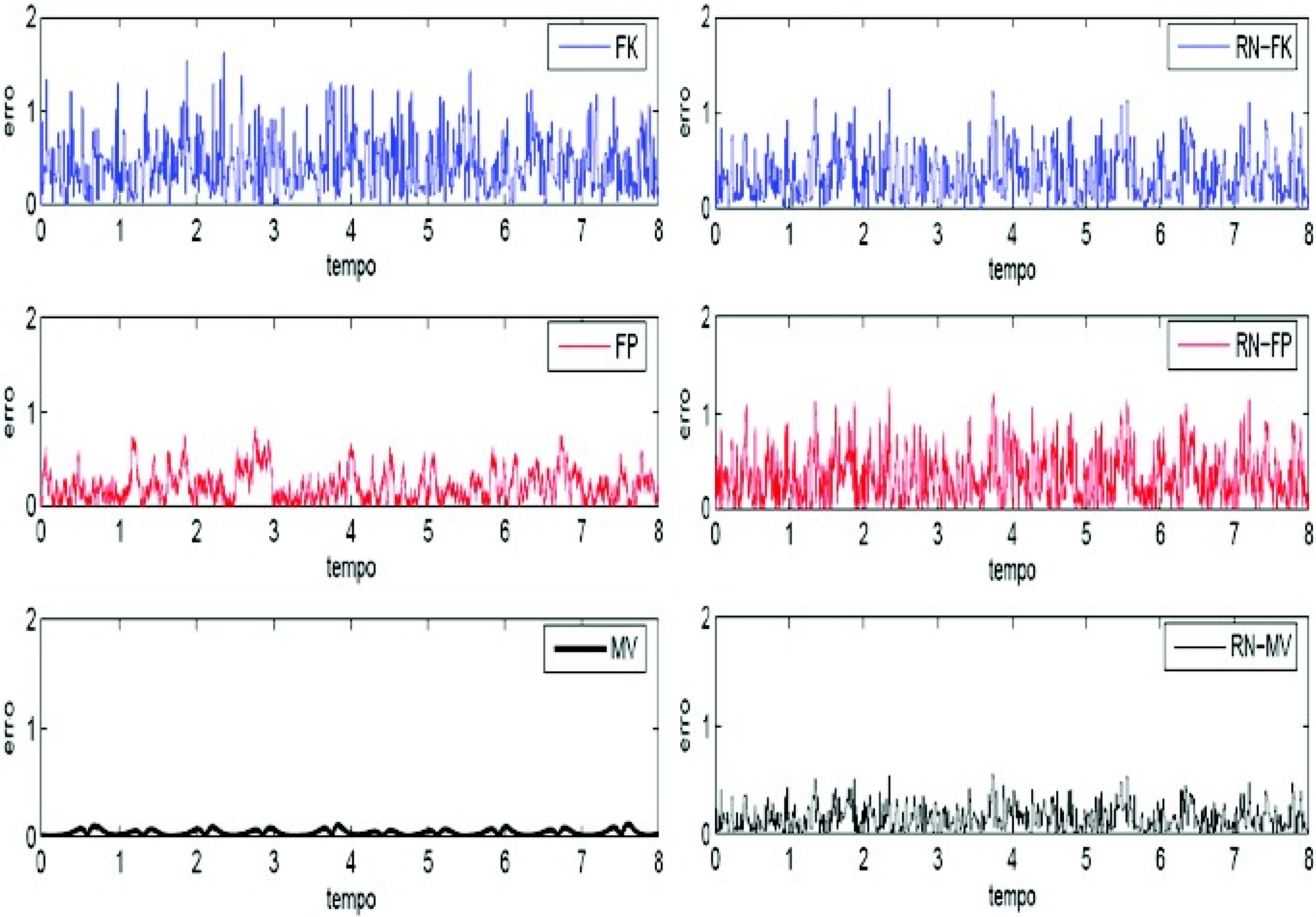


Fig. 6. Diverge field for the DYNAMO-1D model. (a) Reference model and (b) RBF-NN.

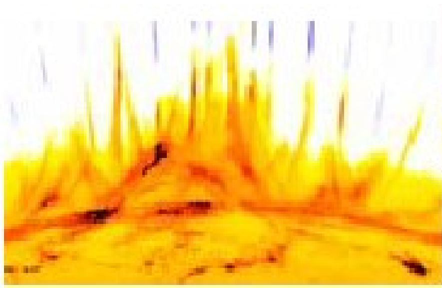
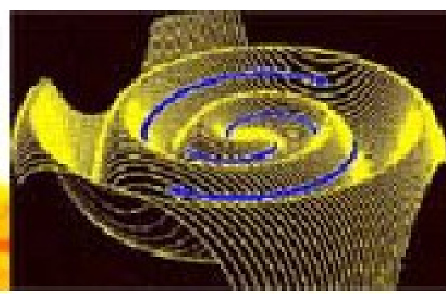
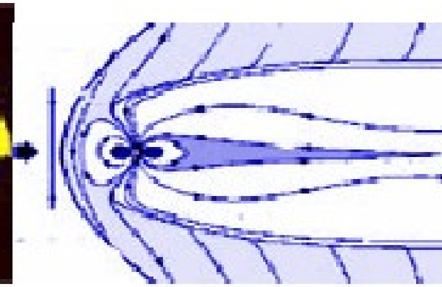
Errors: (Kalman, Particles, Variational) x Neural Networks



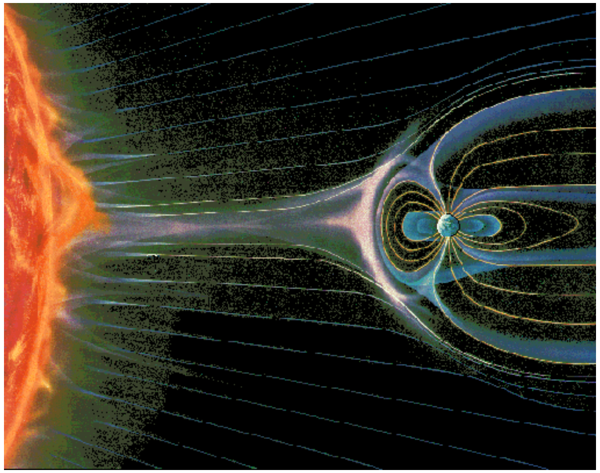
Applications: space weather

Sun-Earth interaction:

Sun activity | Propagation | Impact on magnetosphere | Perturbing ionosphere


Applications: space weather



Sun-Earth interaction:

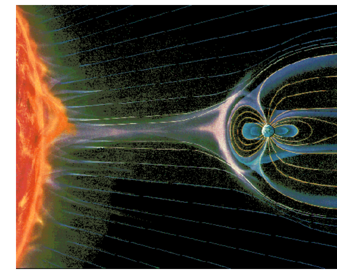
A simple model for plasma instability described by three-waves coupled:

parametric interaction of Langmuir (L), whistler (W), and Alfvén (A) waves, all propagating along the ambient magnetic field $B = B_0 \hat{z}$.

It is assumed the following phase-matching condition:

$$\omega_L \approx \omega_W + \omega_A \;\Rightarrow\; \kappa_L = \kappa_W + \kappa_A$$

Applications: space weather



Sun-Earth interaction:

Equations: three-waves coupled

$$dA_L/d\tau = \nu_L A_L + A_W A_A$$

$$dA_W/d\tau = \nu_W A_W - A_L A_A^*$$

$$dA_A/d\tau = (i\delta + \nu_A) A_A - A_L A_W^*$$

$$\nu_L = 1$$

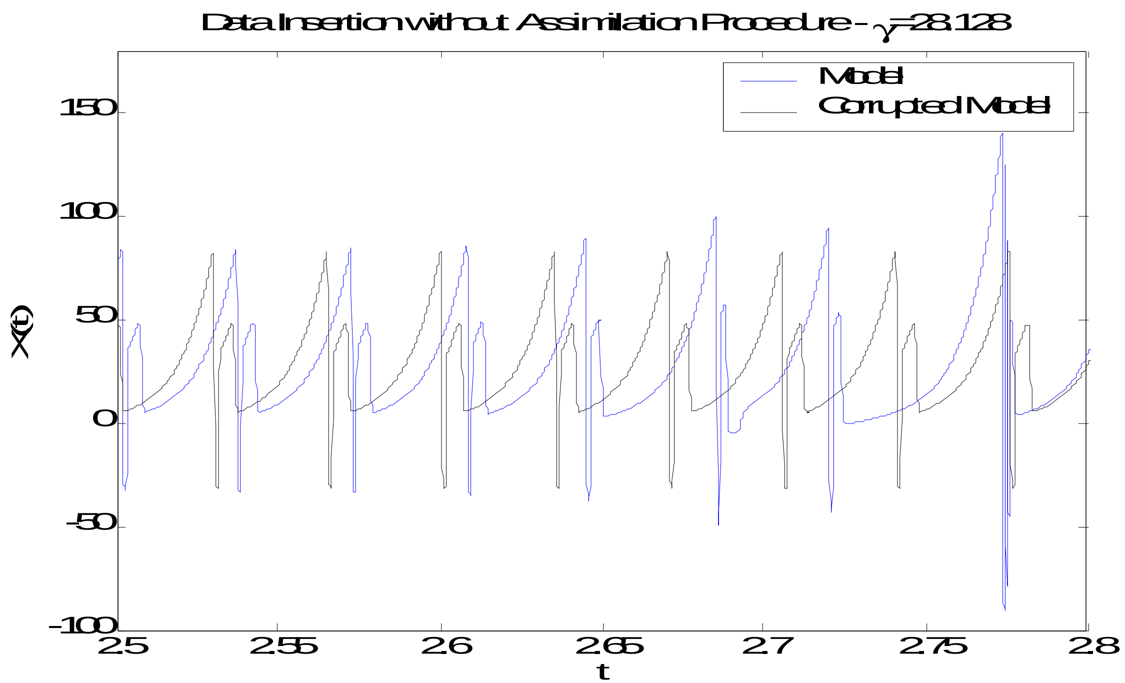
$$\nu_L = \nu_L = -\nu$$

$$\delta = 2$$

$$\tau \equiv \kappa(z - \nu t)$$

Data assimilation is performed by ANN, emulating an extended Kalman filter.

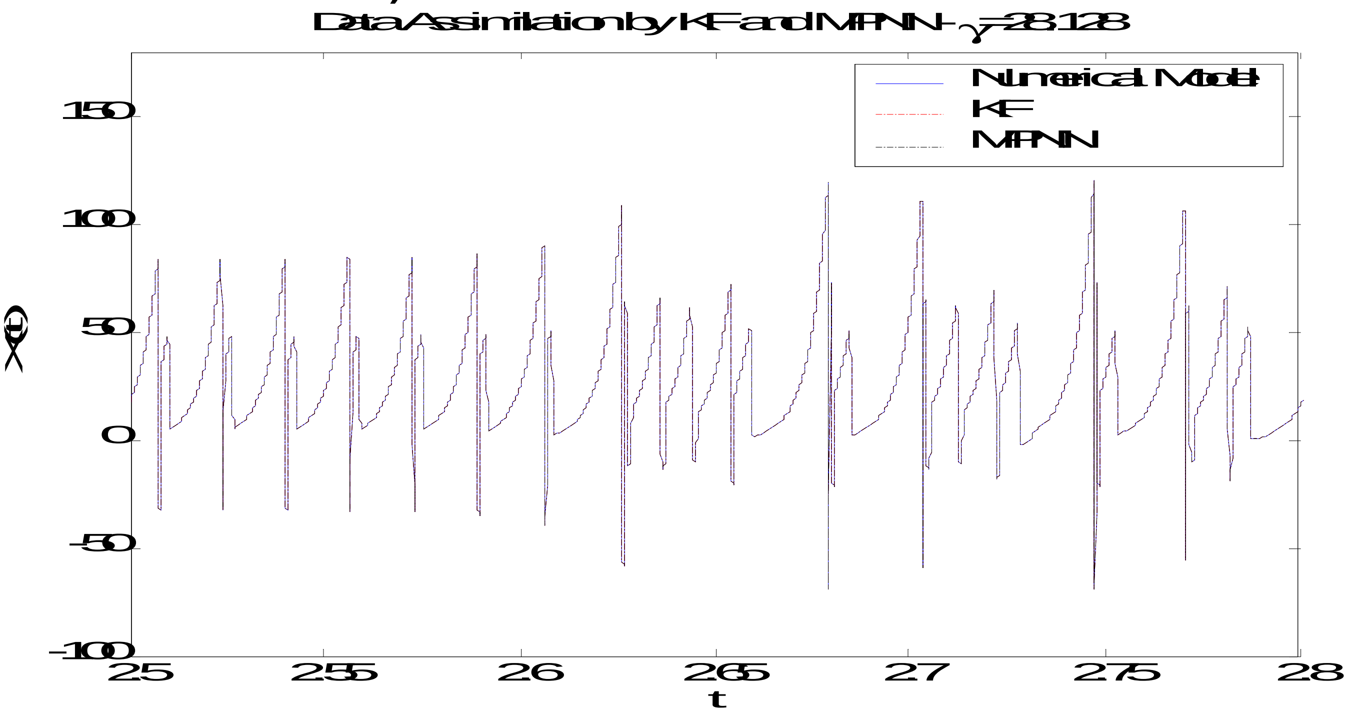
Three regimes were investigated: periodic (not shown), weak chaos (not shown), strong chaos



Without assimilation scheme.

Data assimilation is performed by ANN, emulating an extended Kalman filter.

Three regimes were investigated (only strong chaos is shown):



Assimilation scheme active

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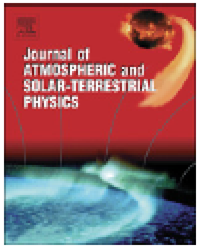

Review article

Neural networks in auroral data assimilation

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[b] National Institute for Space Research (INPE), São José dos Campos, SP, 12227-010, Brazil
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Kalman filter
Neural networks

ABSTRACT

Data assimilation is an essential step for improving space weather forecasting by means of a weighted combination between observational data and data from a mathematical model. In the present work data assimilation methods based on Kalman filter (KF) and artificial neural networks are applied to a three-wave model of auroral radio emissions. A novel data assimilation method is presented, whereby a multilayer perceptron neural network is trained to emulate a KF for data assimilation by using cross-validation. The results obtained render support for the use of neural networks as an assimilation technique for space weather prediction.

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Spectral methods vs Grid points

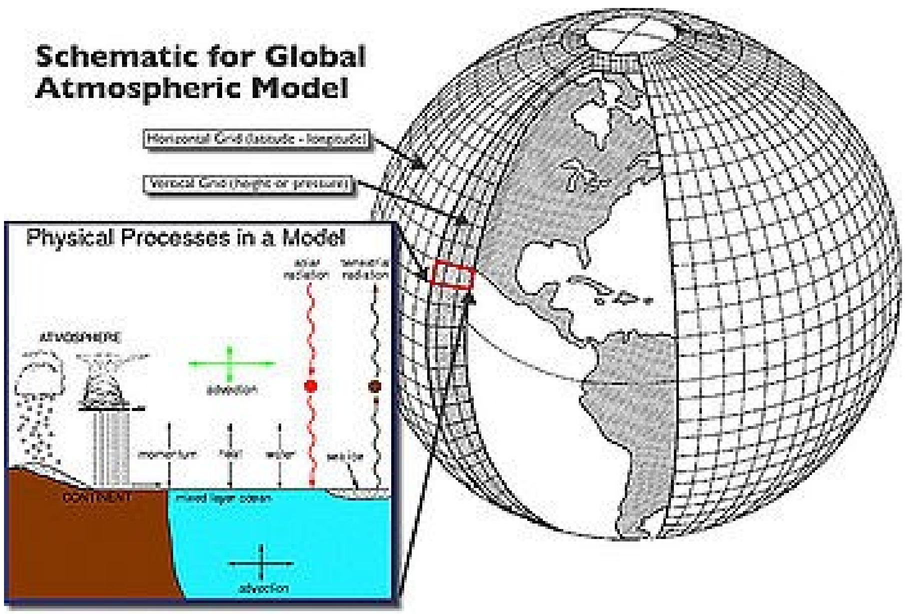
In the 70's, finite difference is a dominant method (spectral methods is computationally expensive).

Fast algorithms change everything. Most operational centers use spectral method for Global Model.

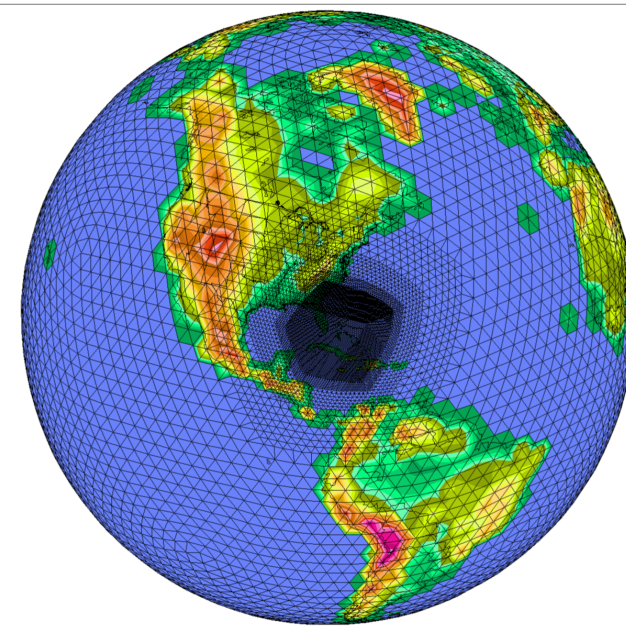
Today, new discussion: Are the spectral methods competitive under high resolution?

Spectral method vs Finite Volume

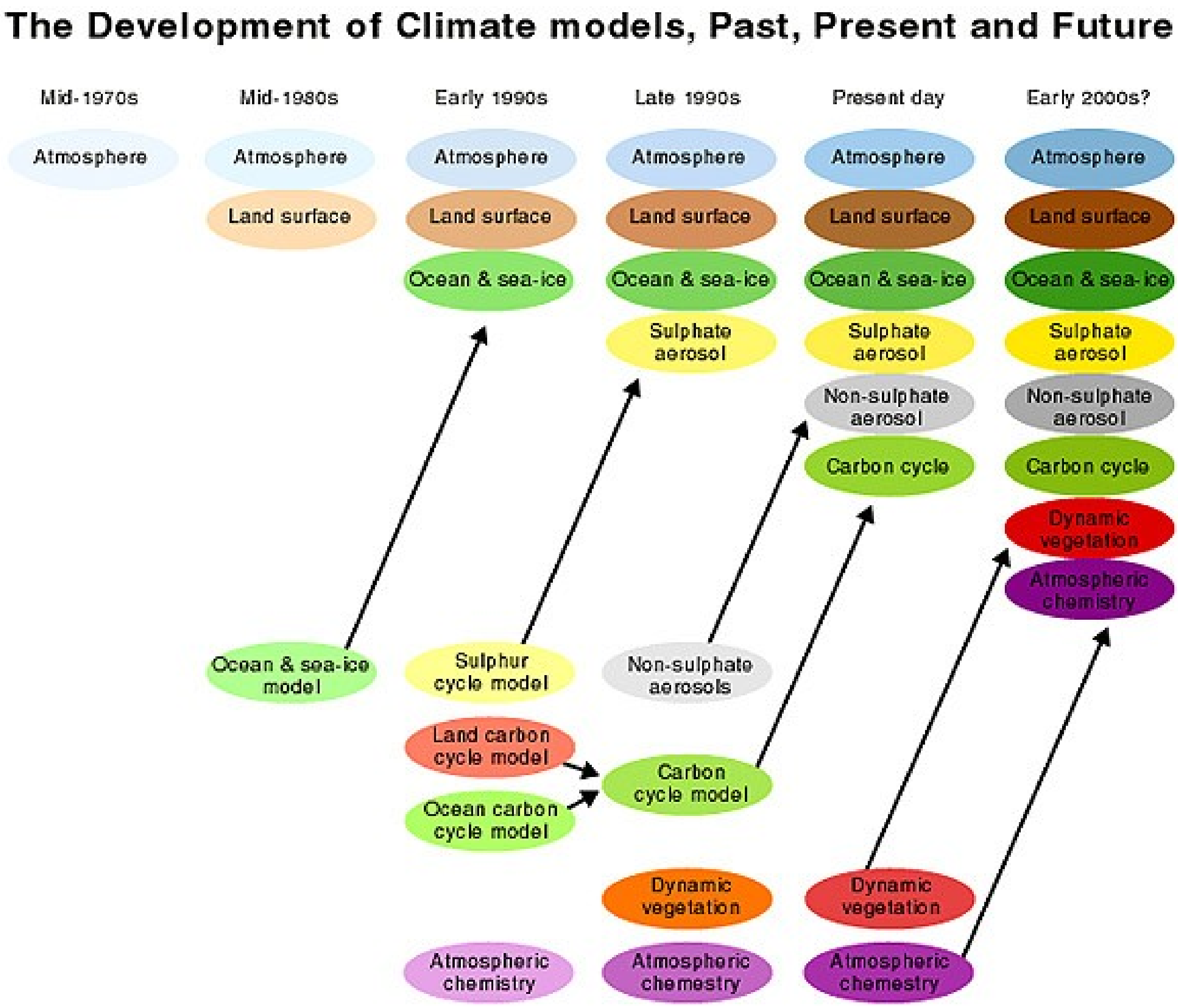
(FFT + Legendre transform)



(OLAM: unstructured grid)



Including more phenomena



Modeling the Earth Atmosphere System

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

$$\frac{\partial X_o}{\partial t}+L_o X_o = N_o(X_a,X_o,X_v,X_c,X_s)+F_o(X_a,X_o,X_v,X_c,X_s)$$ **ocean+hydrology**

$$\frac{\partial X_s}{\partial t}+L_s X_s = N_s(X_a,X_o,X_v,X_c,X_s)+F_s(X_a,X_o,X_v,X_c,X_s)$$ **soil**

$$\frac{\partial X_v}{\partial t}+L_v X_v = N_v(X_a,X_o,X_v,X_c,X_s)+F_v(X_a,X_o,X_v,X_c,X_s)$$ **vegetation**

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

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

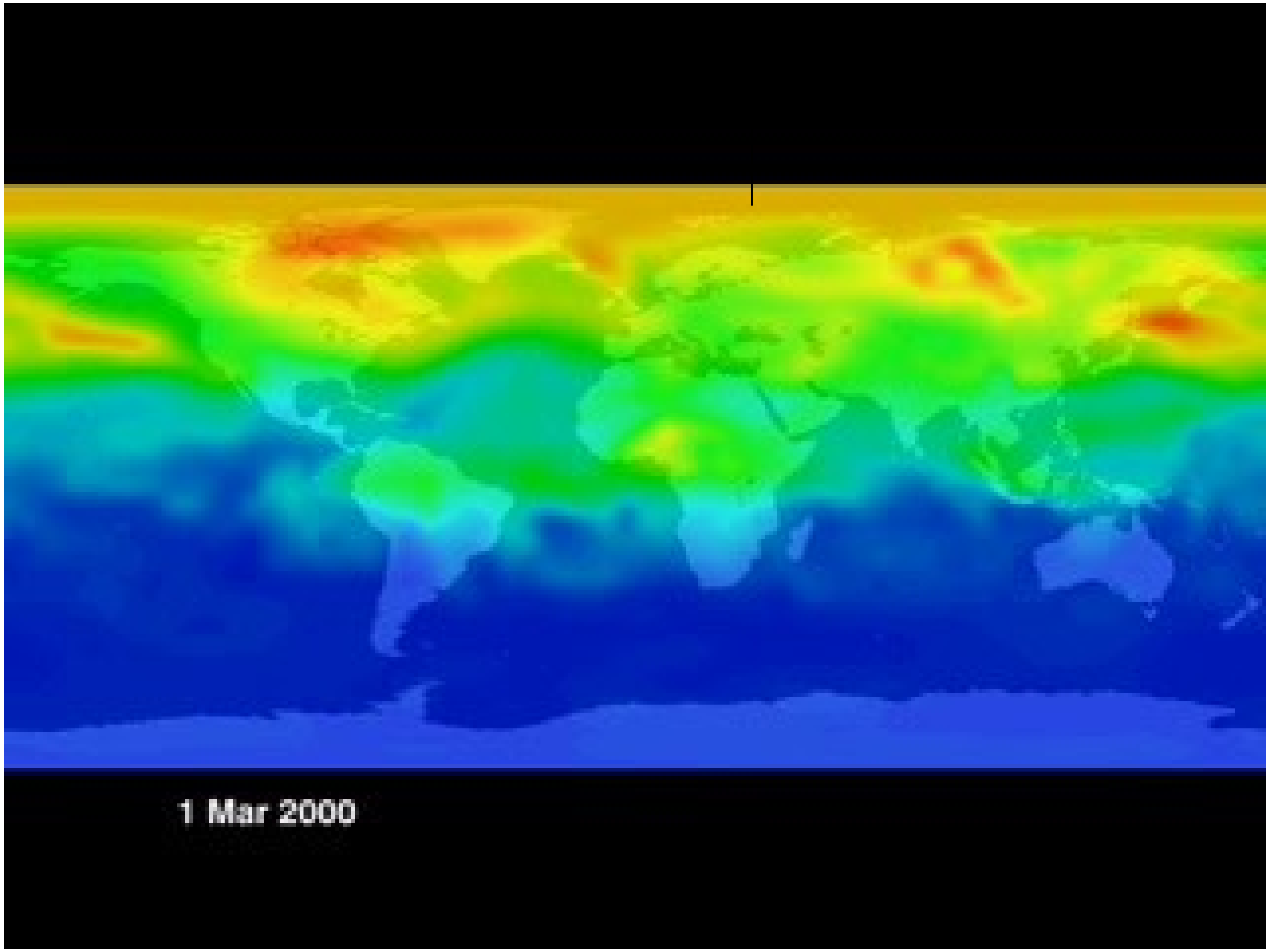
$$X_o=(u,v,w,T,s_v,\ldots)$$

$$X_s=(T^{i_s},W^{i_s},N^{i_n},\ldots.)$$

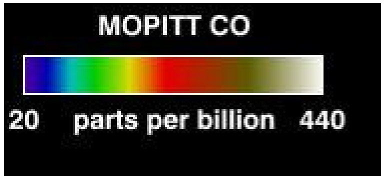
$$X_v=(lai^i,sig^{i_v},root^{i_d},stom^{i_c},VOC^i,C^i,N_i,\ldots.)$$

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

Global CO: level ~ 1500 m - year 2000



Carbon Monoxide:
- *precursor of Ozone*
- *tracer transport (residence time ≈ few months)*
- *sink of OH*



The Measurement of Pollution in the Troposphere (MOPITT)

The Coupled Aerosol Tracer Transport to the Brazilian Regional Atmospheric Modeling System – CATT-BRAMS

http://www.cptec.inpe.br/brams

- BRAMS is derived from the Regional Atmospheric Modelling System (RAMS version 5.0) from ATMET Colorado with many improvements:

✓ Numerical optimization and Standard FORTRAN 90/95

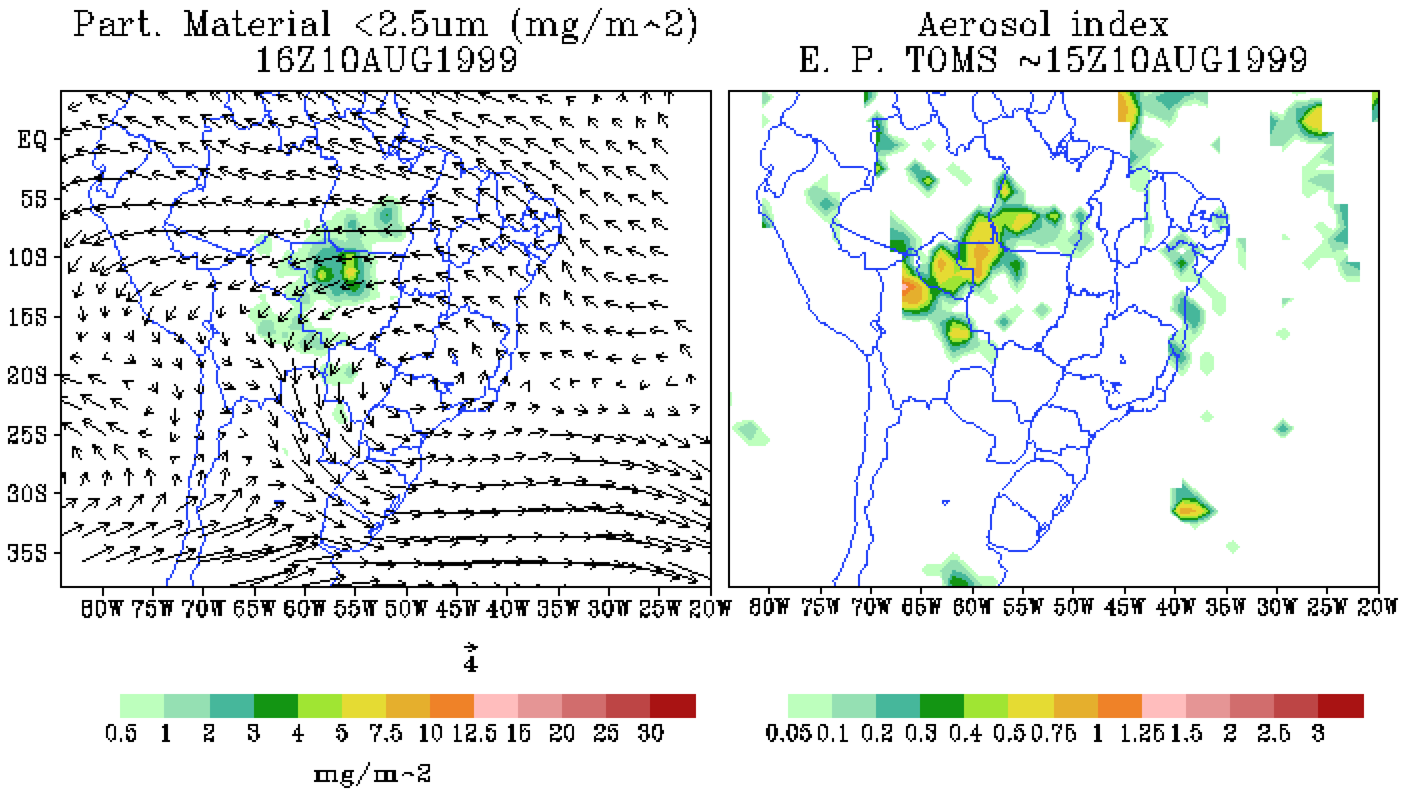
✓ New shallow cumulus scheme from Souza et al, 2000

✓ New deep and shallow cumulus scheme (Grell and Devenyi 2002)

✓ Soil moisture initialization (Gevaerd and Freitas, 2003)

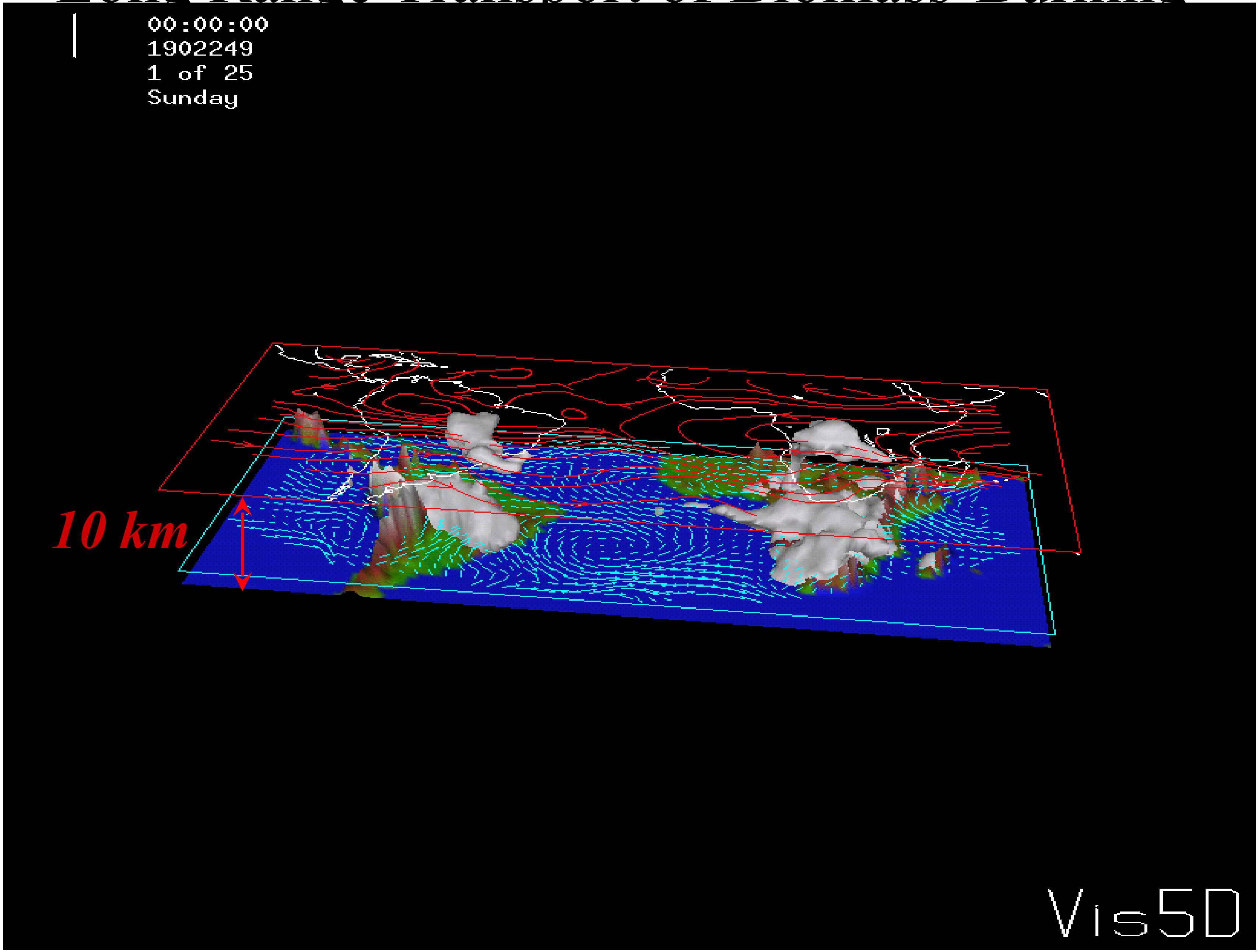
✓ SIB 2.5 (upgrading to SIB 3) land surface scheme, including CO_2 prognoses, and improvements on the tropical vegetation description

✓ Full equation for the Exner function perturbation prognostic (David et al, 2003) improving the mass conservation in the model.



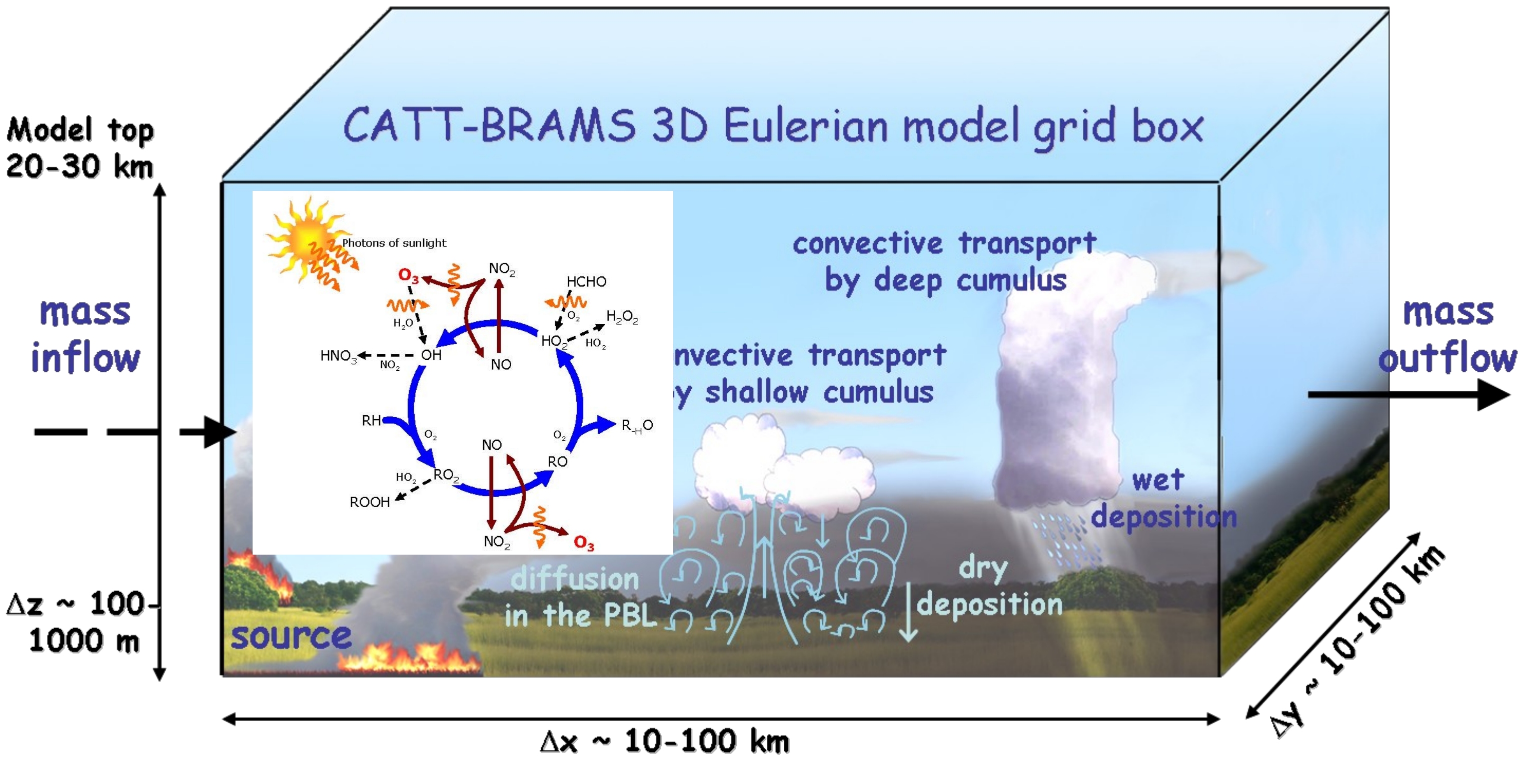
Part. Material <2.5um (mg/m^2)
16Z10AUG1999
Aerosol index
E. P. TOMS ~15Z10AUG1999
EQ
5S
10S
15S
20S
25S
30S
35S
80W 75W 70W 65W 60W 55W 50W 45W 40W 35W 30W 25W 20W
80W 75W 70W 65W 60W 55W 50W 45W 40W 35W 30W 25W 20W
4
0.5 1 2 3 4 5 7.5 10 12.5 15 20 25 30
mg/m^2
0.05 0.1 0.2 0.3 0.4 0.5 0.75 1 1.25 1.5 2 2.5 3

Long Range Transport of Biomass Burning



Coupled Chemistry-Aerosol-Tracer Transport model to the Brazilian developments on the RAMS

CATT-BRAMS + CHEM ↑ CCATT-BRAMS



Some sub-grid process involved at gases/aerosols transport and simulated by CCATT-BRAMS

Eulerian Transport Model : CCATT-BRAMS Atmospheric Model

- in-line Eulerian transport model fully coupled to the atmospheric dynamics
- suitable for feedbacks studies
- tracer mixing ratio tendency equation

$$\frac{\partial \bar{s}}{\partial t} = \left(\frac{\partial \bar{s}}{\partial t}\right)_{adv} + \left(\frac{\partial \bar{s}}{\partial t}\right)_{\substack{PBL\\turb}} + \left(\frac{\partial \bar{s}}{\partial t}\right)_{\substack{deep\\conv}} + \left(\frac{\partial \bar{s}}{\partial t}\right)_{\substack{shallow\\conv}} + W_{PM\,2.5} + R +$$

$$+ Q_{\substack{plume\\rise}} + \left(\frac{\partial \bar{s}}{\partial t}\right)_{\substack{chemical\\reactions}} + \left(\frac{\partial \bar{s}}{\partial t}\right)_{4dda}$$

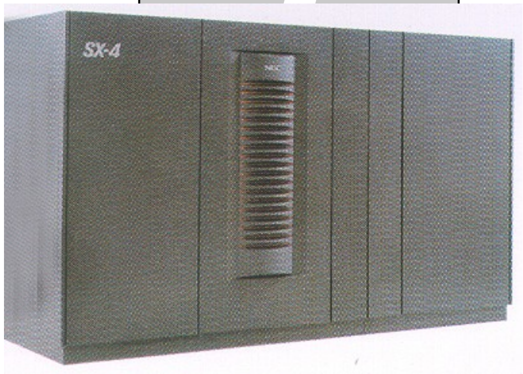
where:

- *adv* grid-scale advection
- *PBL turb* sub-grid transport in the PBL
- *deep conv* sub-grid transport associated to the deep convection including downdraft at cloud scale
- *shallow conv* sub-grid transport associated to the shallow convection
- *W* convective wet removal
- *R* sink term associated with dry deposition or chemical transformation
- *Q* source emission with plume rise sub-grid transport.
- chem. reactions
- 4dda large-scale data assimilation via Newtonian relaxation (nudging).

Evolution of supercomputing in CPTEC

	1994	1998	2002	2004
	SX3	SX4	SX6-Atual	SX6
NUMERO DE NÓS	1	1	4	12
NUMERO DE PROCESSADORES	1	8	32	96
DESEMPENHO MÁXIMO	3,2 Gflops	16 GFlops	256 GFlops	768 GFlops
MEMÓRIA	0,5 GBytes	8 GBytes	128 GBytes	768 GBytes
DISCO	60 GBytes	220 GBytes	70 TBytes	1PByte

NEC SX-4



CENAPAD Ambiental

NEC SX-6

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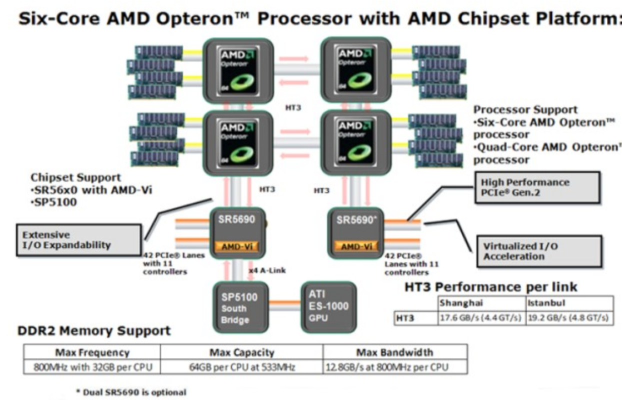
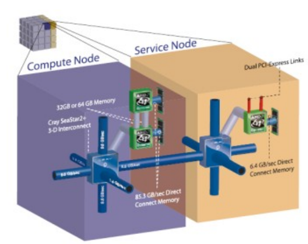
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

CPTEC/INPE supercomputer 2010





Cray XT6 supercomputer

1272 nodes, 2 six-core AMD Opteron, 192 Gflops, 32 GB, SeaStar2

Performance: 244 Tflops (storage capacity: 3,84 PB)

Sustained: 15.8 Tflops (CPTEC benchmark)

Challenging for computing

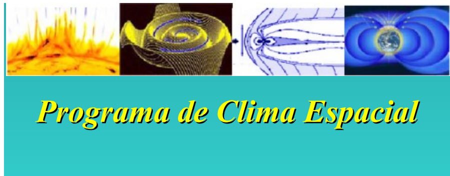
Where is the dificulty?

1. Migration to a massively parallel system (Cray XT6:1272 nodes)?
2. The multi-core archictecture (Cray XT6: six-core AMD Opteron)?
3. Software engineering (code factorization)?
4. Implement/evaluate new numerical approaches?

All of them, and MORE:

There are new tendencies.

Hybrid computing: FPGA and GPU



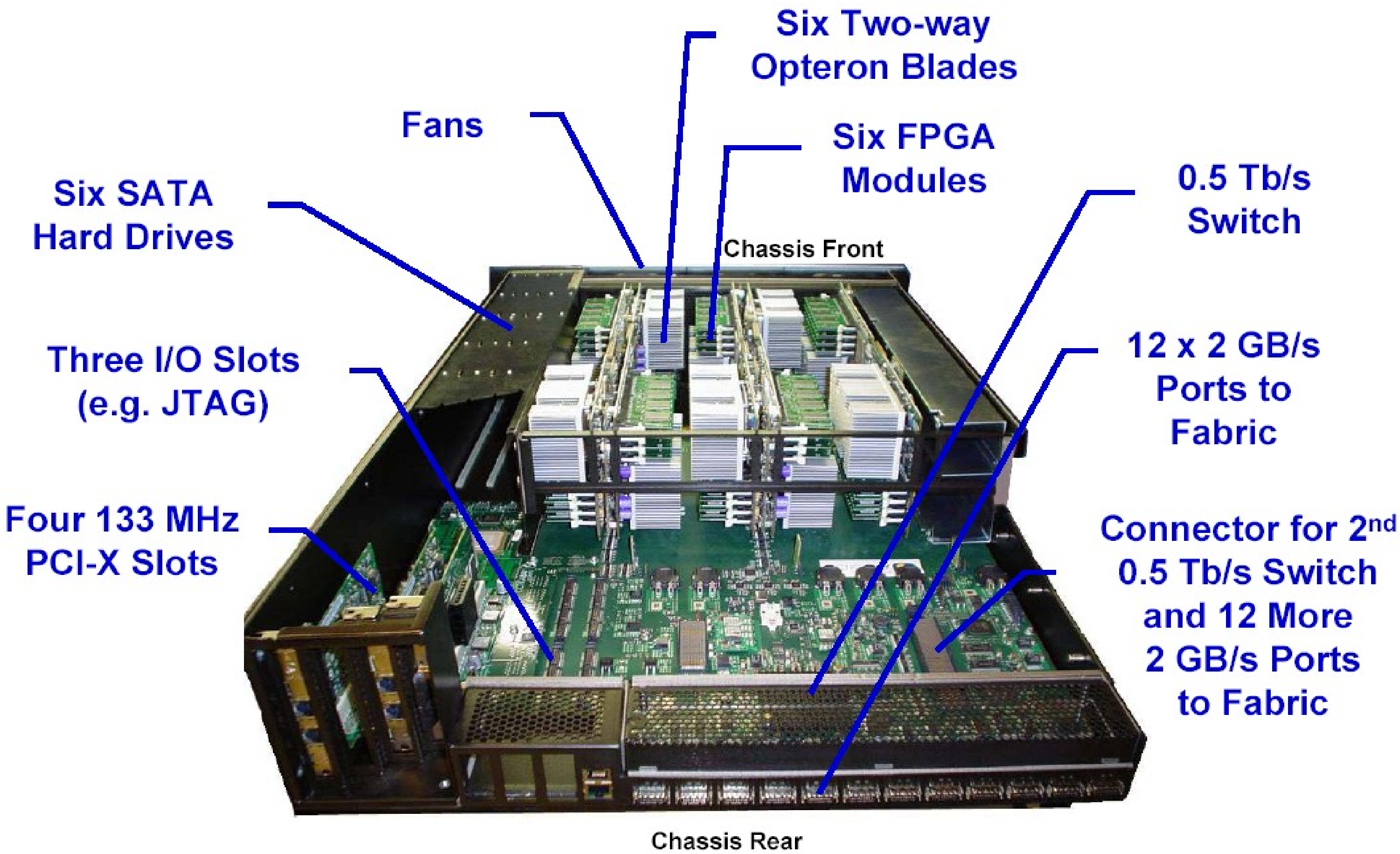
Future for the computer?

Hybrid computing:
software processing + hardware processing

The Cray XD1 -
Reconfigurable Computing

Alternative: **GP-GPU**

Cray XD1, processors + FPGA.



Thank you

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CAPES

CNPq
Conselho Nacional de Desenvolvimento Científico e Tecnológico

The British Council

FAPESP