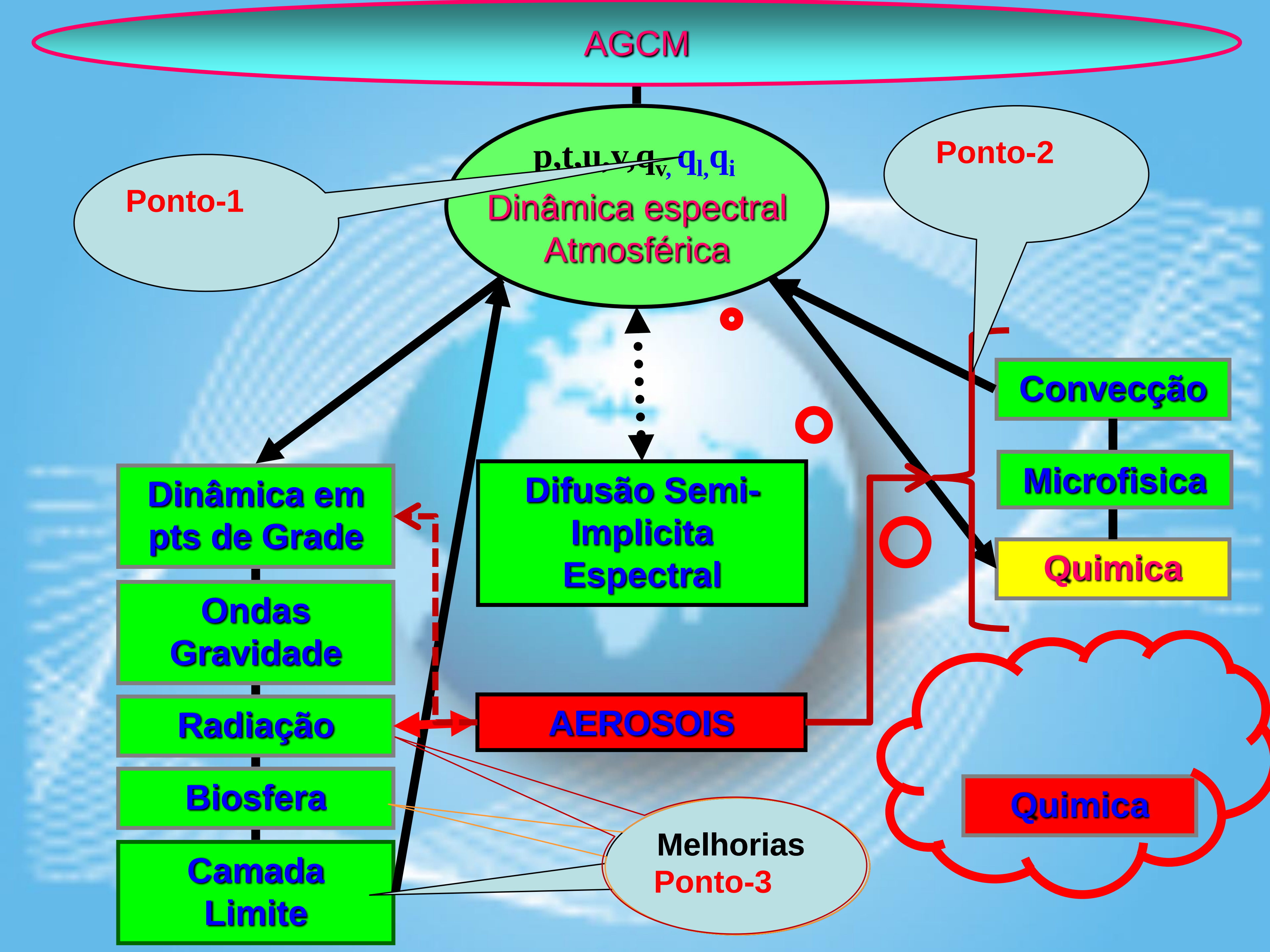
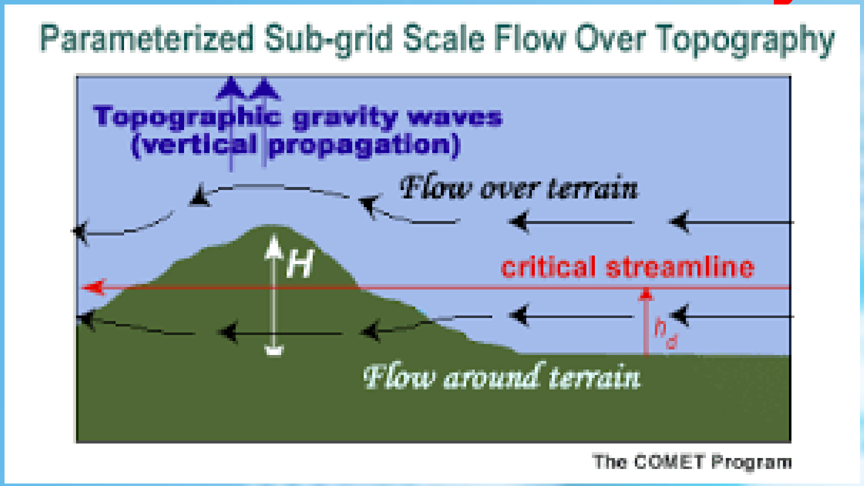
Relatório do Desenvolvimento MCGA-CPTEC/INPE

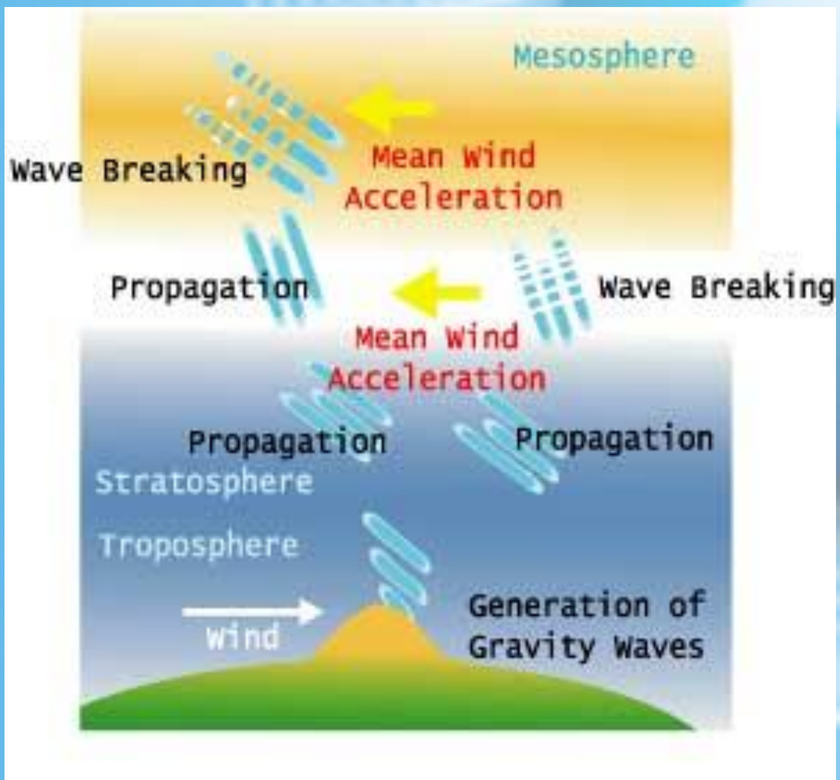
•Paulo Yoshio Kubota
•CPTEC, C. Paulista, Brasil
•17 agosto,2015

O que está em desenvolvimento no MCGA-CPTEC?


AGCM
p,t,u,v,q_v, q_l, q_i
Dinâmica espectral Atmosférica
Ponto-1
Ponto-2
Convecção
Microfisica
Quimica
Dinâmica em pts de Grade
Ondas Gravidade
Radiação
Biosfera
Camada Limite
Difusão Semi-Implicita Espectral
AEROSOIS
Quimica
Melhorias
Ponto-3

Gravity Wave Drag





Gravity Wave Drag

Utilizado Operacionalmente no CPTEC

No Blocking

Alpert, et al. 1988

Alpert, J. C., M. Kanamitsu, J. C. Sela, G. H. White, and E. Kalnay, 1988: Mountain induced gravity wave drag parameterization in the NMC medium-range model. Preprints. Eight Conf. on Numerical Weather Prediction, Amer. Meteor. Soc., 429-432.

No Blocking

Shutts, et al. 2011

Shutts, G. J. and Vosper, S. B., 2011: Stratospheric gravity waves revealed in NWP model forecasts, Article first published online: 1 MAR 2011 DOI: 10.1002/qj.763. Quarterly Journal of the Royal Meteorological Society Volume 137, Issue 655, pages 303–317, January 2011 Part B

Blocking

Kim, et al. 2005

Kim, Y.-j. and Doyle, J. D. (2005), Extension of an orographic-drag parametrization scheme to incorporate orographic anisotropy and flow blocking. Q.J.R. Meteorol. Soc., 131: 1893-1921. doi: 10.1256/qj.04.160

Gravity Wave Drag

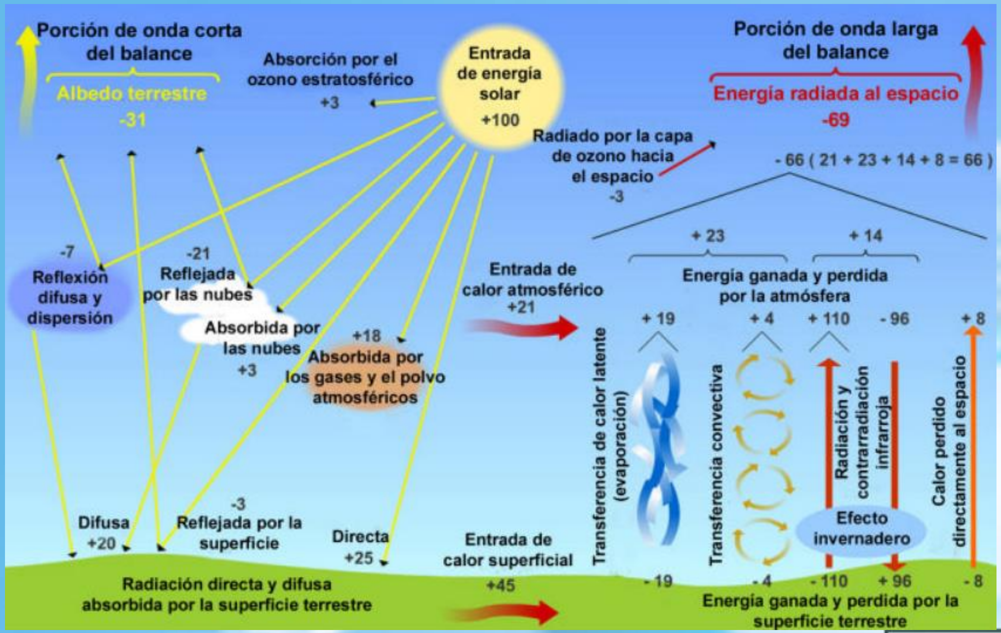
Ajuda pouco na redução da precipitação sobre topografias elevadas. Mas não resolve o problema.

Há a necessidade de realizar mais trabalhos com estes conjuntos de parametrização.

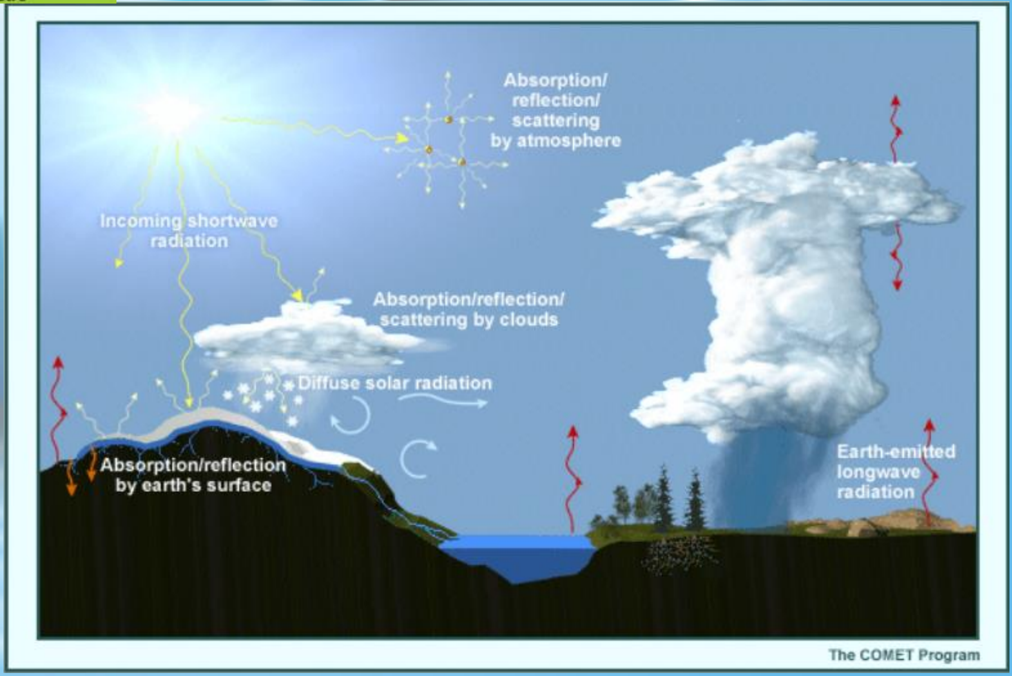
Os desenvolvimentos ainda não estão totalmente finalizados.

Prioridade de desenvolvimento baixa.

Radiation



Fonte: http://www.bioygeo.info/pdf/Balance_energetico_atmosfera.pdf



Radiation

O que está implementada no MCGA-CPTEC?

COLA

Lacis A. and J. E. Hansen, 1974: A parameterization of the absorption of solar radiation in the Earth's atmosphere. *J. Atmos. Sci.*, 31, 118-133.
Harshvardhan, R. Davis, D. A. Randall, and T. G. Corsetti, 1987: A fast radiation parameterization for general circulation models. *J. Geophys. Res.*, 92, 1009-1016.

Harshvardhan, D. A. Randall, T. G. Corsetti, and D. A. Dazlich, 1989: Earth radiation budget and cloudiness simulations with a general circulation model. *J. Atmos. Sci.*, 46, 1922-1942

CLIRAD

CLIRADT

Chou, M.-D., and M.J. Suarez. A solar radiation parameterization (CLIRAD-SW) for atmospheric studies. NASA Tech. Memo. 10460, Vol. 15, NASA Goddard Space Flight Center, Greenbelt, MD, 48 pp, 1999.

Tarasova T.A., and B.A. Fomin. Solar radiation absorption due to water vapor: Advanced broadband parameterizations. J. Appl. Meteor., 39, 1947-1951, 2000.

Tarasova, T.A., and B.A. Fomin, The use of new parameterization for gaseous absorption in the CLIRAD-SW solar radiation code for models. J. of Atm. and Oceanic Technol., v. 24, No. 6, 1157-1162, 2007

Usado Operacionalmente no CPTEC.

RRTMG

Já implementados. E estão sendo adaptado para a implementação de aerossóis atmosféricos.

UKMET

Radiation

http://rtweb.aer.com/rrtm_frame.html

RRTMG_LW

Propriedades Óticas de aerossóis

Aerossol

Iacono, M.J., J.S. Delamere, E.J. Mlawer, S.A. Clough: Evaluation of upper tropospheric water vapor in the NCAR community climate model (CCM3) using modeled and observed HIRS radiances. *J. Geophys. Res*., 108(D2), 4037, doi:10.1029/2002JD002539, 2003.

Barker, H.W., R. Pincus, and J.-J. Morcrette, The Monte-Carlo Independent Column Approximation: Application within large-scale models. *Proceedings of the GCSS/ARM Workshop on the Representation of Cloud Systems in Large-Scale Models*., May 2002, Kananaskis, Alberta, Canada, 10pp., 2003. Available on-line at: www.met.utah.edu/skrueger/gcss-2002/Extended-Abstracts.pdf.

Pincus, R., H.W. Barker, and J.-J. Morcrette: A fast, flexible, approximate technique for computing radiative transfer in inhomogeneous clouds. *J. Geophys. Res*., 108(D), 4376, doi:10.1029/2002JD003322, 2003.

Morcrette, J.-J., Impact of the radiation-transfer scheme RRTM in the ECMWF forecasting system, ECMWF Newsletter No. 91, 2001.

Iacono, M.J., E.J. Mlawer, S.A. Clough and J.-J. Morcrette: Impact of an improved longwave radiation model, RRTM. on the energy budget and thermodynamic properties of the NCAR community climate mode, CCM3. *J. Geophys. Res*., 105, 14873-14890, 2000.

Mlawer, E.J., S.J. Taubman, P.D. Brown, M.J. Iacono and S.A. Clough: RRTM, a validated correlated-k model for the longwave. *J. Geophys. Res*., 102, 16,663-16,682, 1997

Radiation

http://rtweb.aer.com/rrtm_frame.html

RRTMG_SW

↕

Propriedades Óticas de aerossóis

↕

Aerossol

Iacono, M.J., J.S. Delamere, E.J. Mlawer, M.W. Shephard, S.A. Clough, and W.D. Collins, Radiative forcing by long-lived greenhouse gases: Calculations with the AER radiative transfer models, *J. Geophys. Res.*, 113, D13103, doi:10.1029/2008JD009944, 2008.

Morcrette, J.-J., H.W. Barker, J.N.S. Cole, M.J. Iacono, and R. Pincus, Impact of a new radiation package, McRad, in the ECMWF Integrated Forecast System, *Mon. Wea. Rev.*, 136, 4773-4798, 2008.

Clough, S.A., M.W. Shephard, E.J. Mlawer, J.S. Delamere, M.J. Iacono, K. Cady-Pereira, S. Boukabara, P.D. Brown, Atmospheric radiative transfer modeling: a summary of the AER codes, *J. Quant. Spectrosc. Radiat. Transfer.*, 91, 233-244, 2005.

Barker, H.W., R. Pincus, and J.-J. Morcrette, The Monte-Carlo Independent Column Approximation: Application within large-scale models. *Proceedings of the GCSS/ARM Workshop on the Representation of Cloud Systems in Large-Scale Models.*, May 2002, Kananaskis, Alberta, Canada, 10pp., 2003. Available on-line at: www.met.utah.edu/skrueger/gcss-2002/Extended-Abstracts.pdf.

Pincus, R., H.W. Barker, and J.-J. Morcrette, A fast, flexible, approximate technique for computing radiative transfer in inhomogeneous clouds. *J. Geophys. Res.*, 108(D), 4376, doi:10.1029/2002JD003322, 2003.

Oreopoulos, L., and H.W. Barker, Accounting for subgrid-scale cloud variability in a multi-layer 1-D solar radiative transfer algorithm. *Quart. J. Roy. Meteor. Soc.*., 125, 301-330, 1999.

Mlawer, E.J., S.J. Taubman, P.D. Brown, M.J. Iacono and S.A. Clough: RRTM, a validated correlated-k model for the longwave. *J. Geophys. Res.*, 102, 16,663-16,682, 1997

Radiation

CLIRADT

Está sendo desenvolvido fora do CPTEC
(Dra. *Tatiana* A. *Tarasova*)

http://rtweb.aer.com/rrtm_frame.html

RRTMG

Está sendo desenvolvido no CPTEC
Diego Pereira Enore
Paulo Kubota

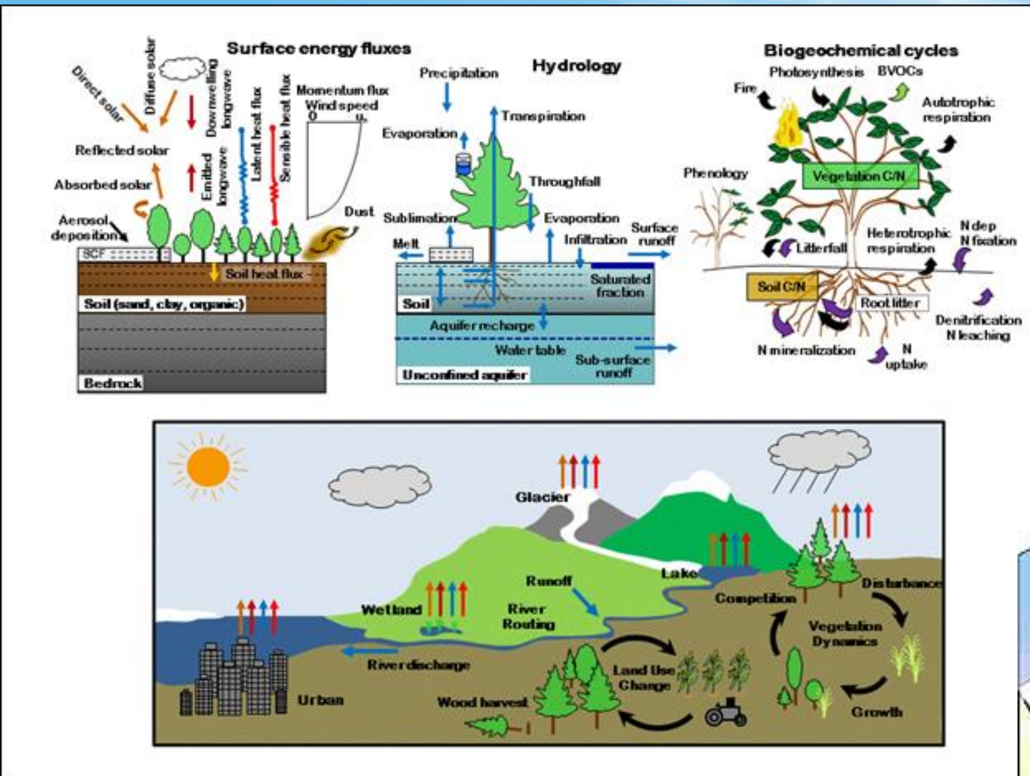
Fluxo de radiação similar ao Clirad Operacional.

Há a necessidade de realizar mais trabalhos com este conjunto de parametrização.

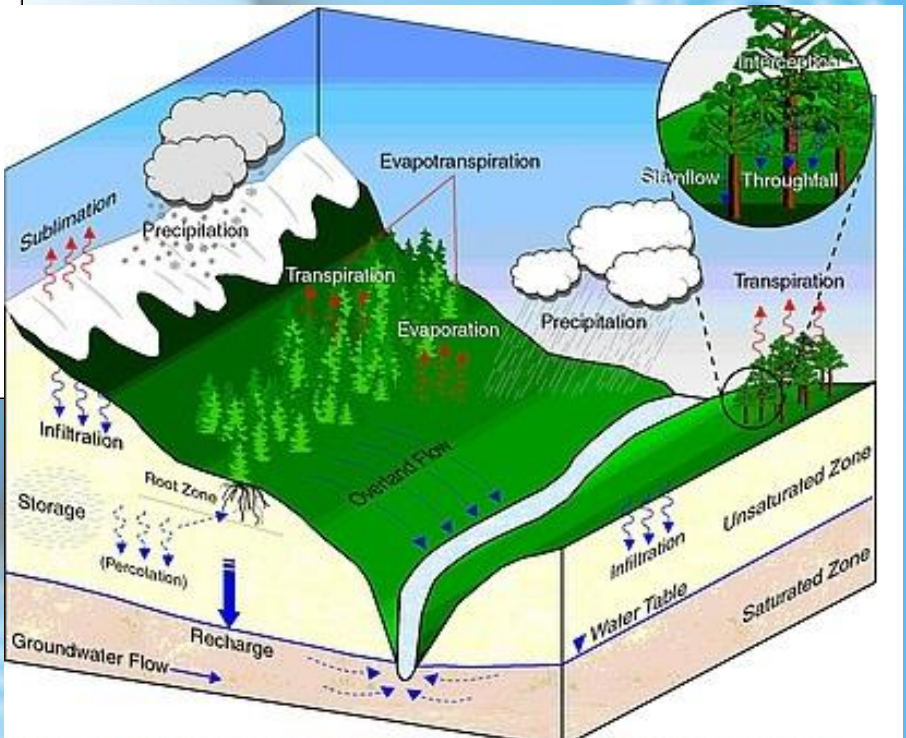
Adaptar a entrada de aerossóis. Etc..

Prioridade de desenvolvimento Alta.

Surface



http://www.cesm.ucar.edu/models/clm/



fomte: http://www.geo.uni-tuebingen.de/forschung/international-research-training-group-integrated-hydrosystem-modelling.html

Surface

O que está implementada no MCGA-CPTEC?

IBIS-2.6

Foley JA, Prentice IC, Ramankutty N et al.(1996) Na integrated biosphere Model of Land surface processes, terrestrial Carbon balance, And vegetation dynamics. Global Biogeochemical Cycles,10,603–628.
Foley JA, Levis S, Prentice IC et al. (1998) Coupling dynamic models of climate and vegetation. Global Change Biology, 4, 561–579

SSiB

Xue, Y., P. J. Sellers, J. L. Kinter And J. Shukla, 1991:A Simplified Biosphere model For global climate studes. J. Climate , 4,345-364.

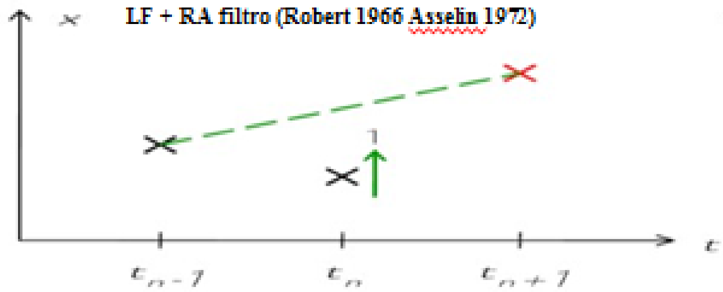
SiB-2.5

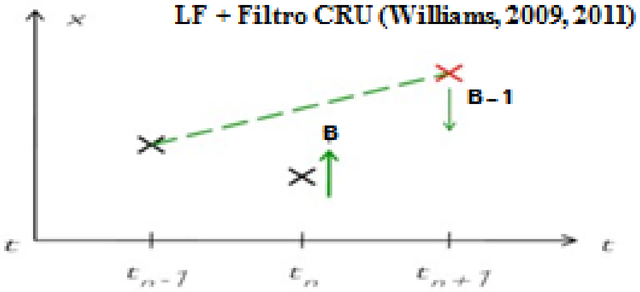
Sellers, P. J., Y. Mintz, Y. C. Sud, and A. Dalcher, A simple biosphere model (SiB) for use within general circulation models, *J. Atmos. Sci*., 43, 505-531, 1986.

Sellers, P.J., D. A. Randall, G. J. Collatz, J. A. Berry, C. B. Field, D. A. Dazlich, C. Zhang, G. D. Collelo, L. Bounoua, A revised land surface parameterization (SiB2) for atmospheric GCMs, Part 1: Model formulation. *Jour. Clim*., 9, 676-705, 1996a.

Sellers, P. J., S. O. Los, C. J. Tucker, C. O. Justice, D. A. Dazlich, G. J. Collatz, D. A. Randall, A revised land surface parameterization (SiB2) for atmospheric GCMs. Part 2: The generation of global fields of terrestrial biophysical parameters from satellite data. *Jour. Clim*., 9, 706-737, 1996b.

Surface
O que está sendo implementada IBIS-2.6?
O filtro RA vs RAW

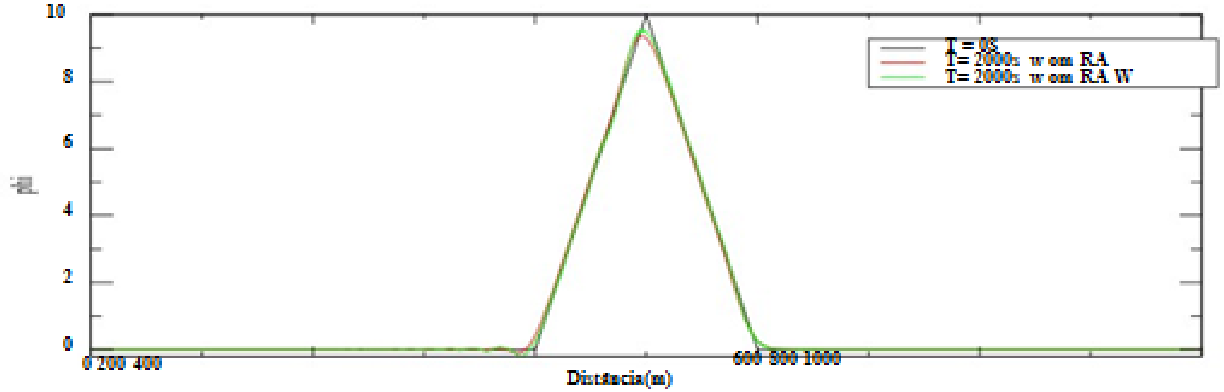




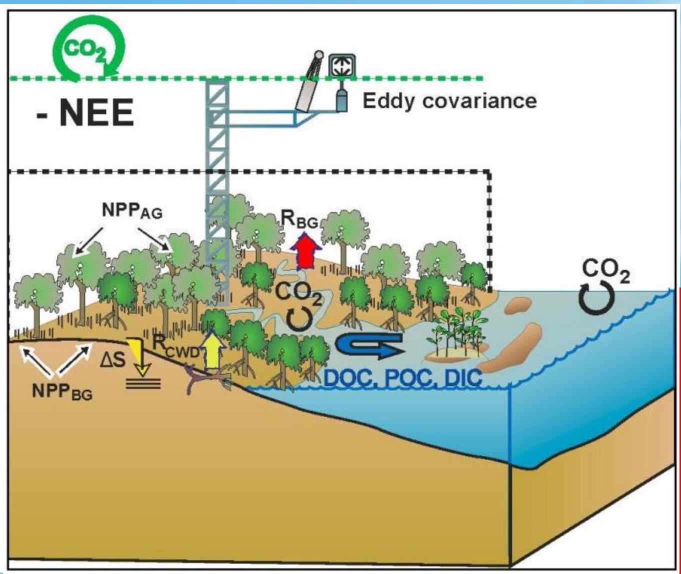
- RA filtro aplica-se em
- Reduz curvatura mas não conserva a curvatura media
- Precisão da amplitude é 1.° ordem

- Filtro-RWA aplica-se em x^n e x^{n+1}
- Reduz e ao mesmo tempo, conserva a curvatura média (para B= 1/2)
- Precisão da amplitude é ≈ 3.ª ordem

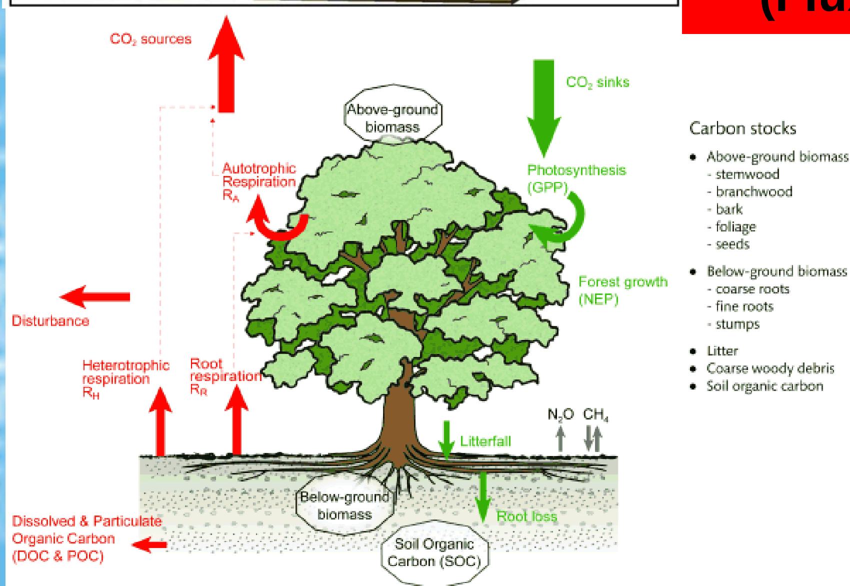
Salto com Vcto RA _and RA W _filter soc ial e dt=0,5, a alfa=0,05, beta=0,6



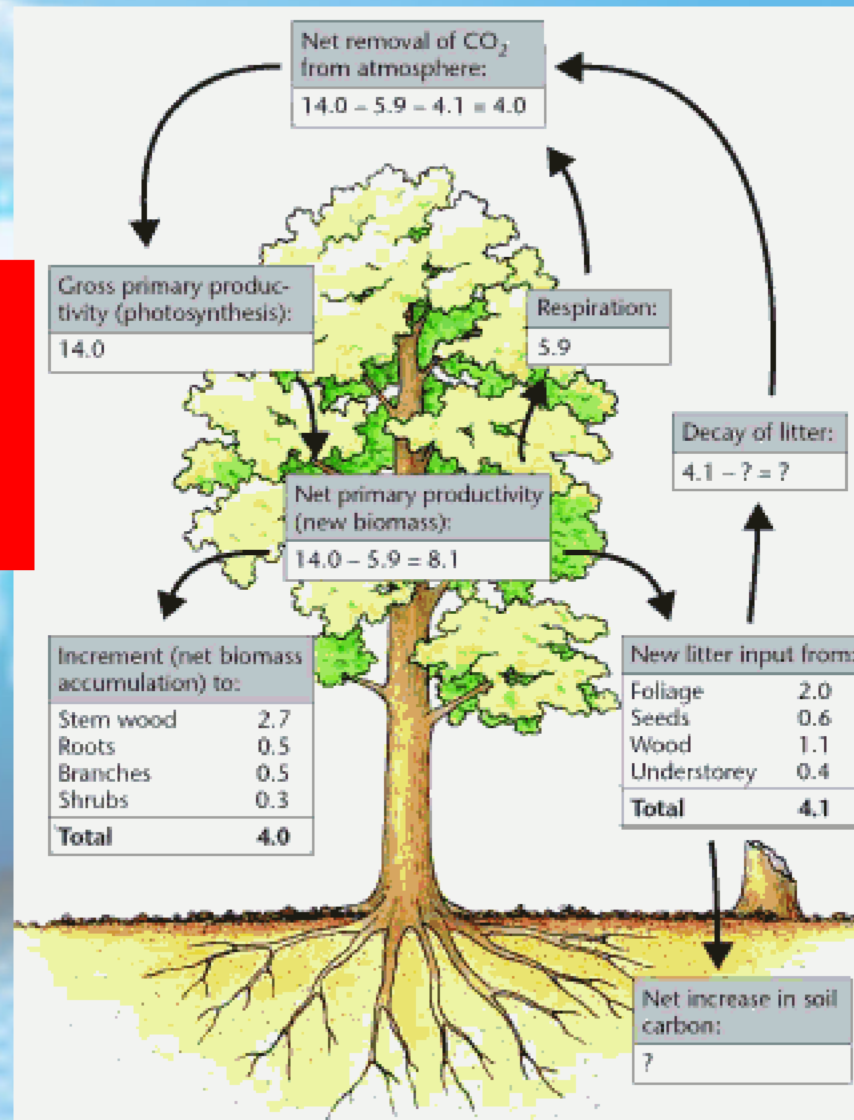
Surface
O que está sendo desenvolvido no IBIS-2.6?



Emissão Natural de CO2 para atmosfera (Fluxo)



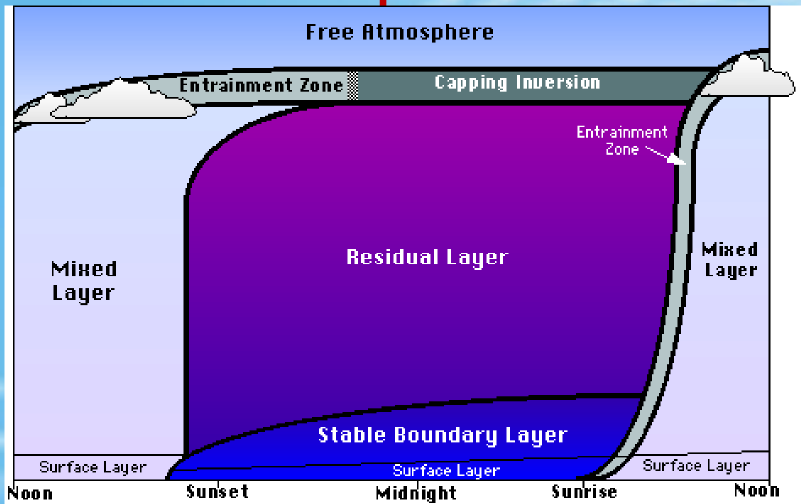
http://www.forestry.gov.uk/fr/infd-62nbuh



http://igutek.scripts.mit.edu/terrascope/?page=Forestry

Planetary Boundary Layer

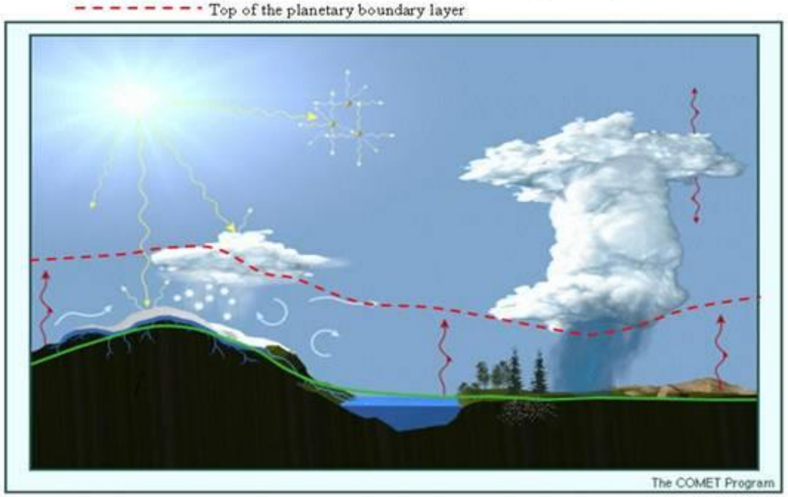
Implementation of the parameterization of moist planetary boundary layer parameterization of the Washington University.

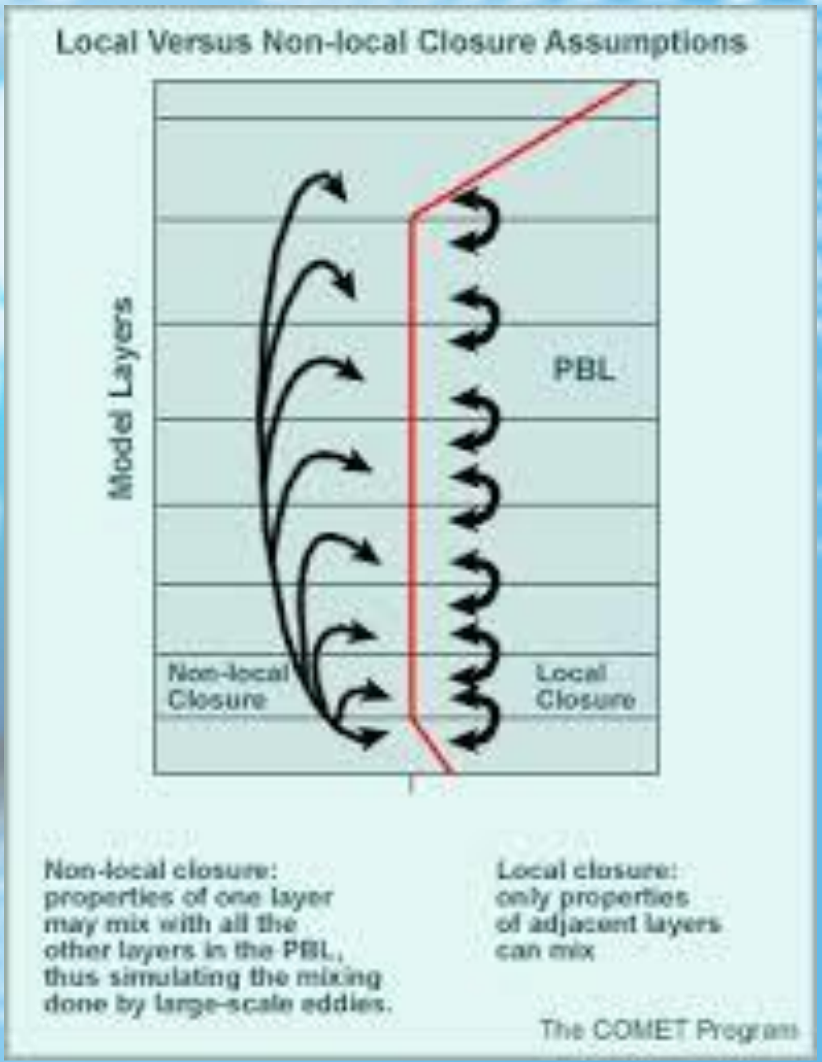


Structure of Planetary Boundary Layer
adapted from Stull, 1988

Depiction of various surfaces and PBL processes

Top of the planetary boundary layer





Planetary Boundary Layer

O que está implementada no MCGA-CPTEC?

Melor Yamada ⟷ Mellor, G. L., and T. Yamada (1982), Development of a turbulence closure model for geophysical fluid problems, Rev. Geophys.,20, 851–875, doi:10.1029/RG020i004p00851

Holtslag and Boville ⟷ A. A. M. Holtslag and B. A. Boville, 1993: Local Versus Nonlocal Boundary-Layer Diffusion in a Global Climate Model. *J. Climate*, 6, 1825–1842. doi: http://dx.doi.org/10.1175/1520-0442(1993)006<1825:LVNBLD>2.0.CO;2

Sungsu *Park* ⟷ Bretherton, C.S., and S. Park, 2009: A new moist turbulence parameterization in the Community Atmosphere Model. *Journal of Climate*, 22, 3422-3448, DOI: 10.1175/2008JCLI2556.1.

Planetary Boundary Layer

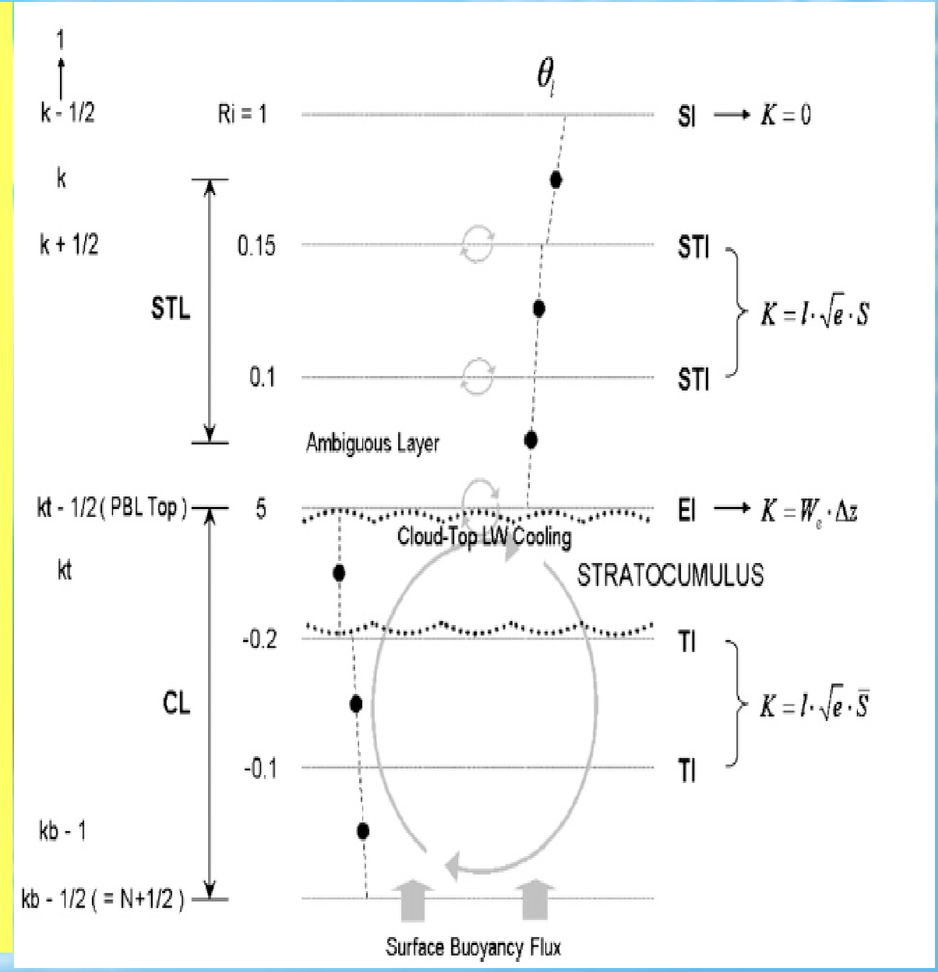
Implementation of the parameterization of moist planetary boundary layer parameterization of the Washington University.

Sungsu *Park*

As principais características do esquema incluem o uso da conservação de variáveis húmidas,

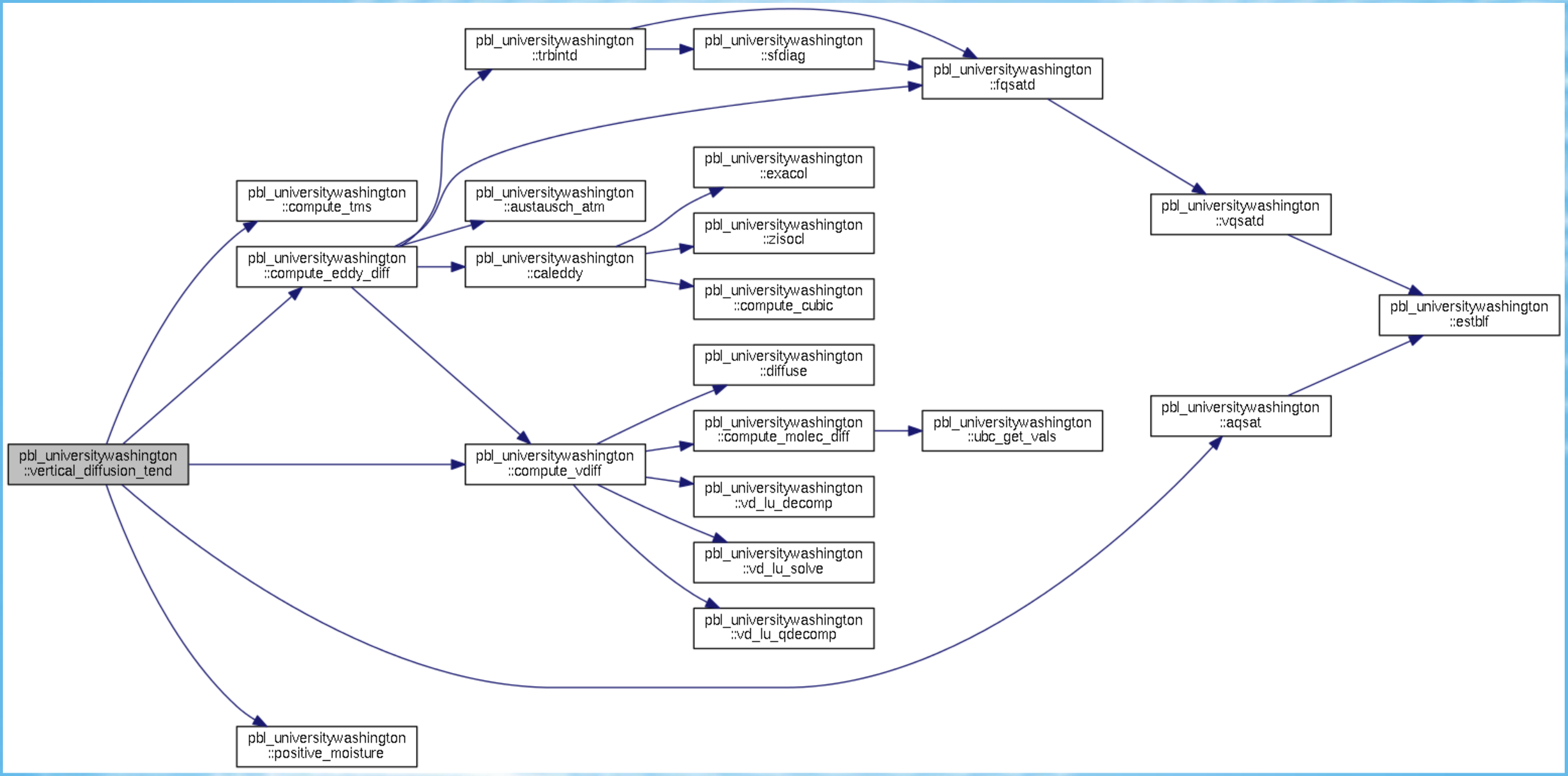
Um fechamento de entranahamento explícito para as camadas convectivas.

O diagnóstico da energia cinética turbulenta (ECT) para o cálculo dos coeficientes de difusão turbulenta. Utiliza uma nova formulação mais eficiente de transporte TKE com um relaxamento para a camada média-TKE e um tratamento unificado de todas as camadas turbulentas em cada coluna atmosférica.



Sungsu *Park*

Implementação da Parametrização da camada limite úmida da Universidade de Washington



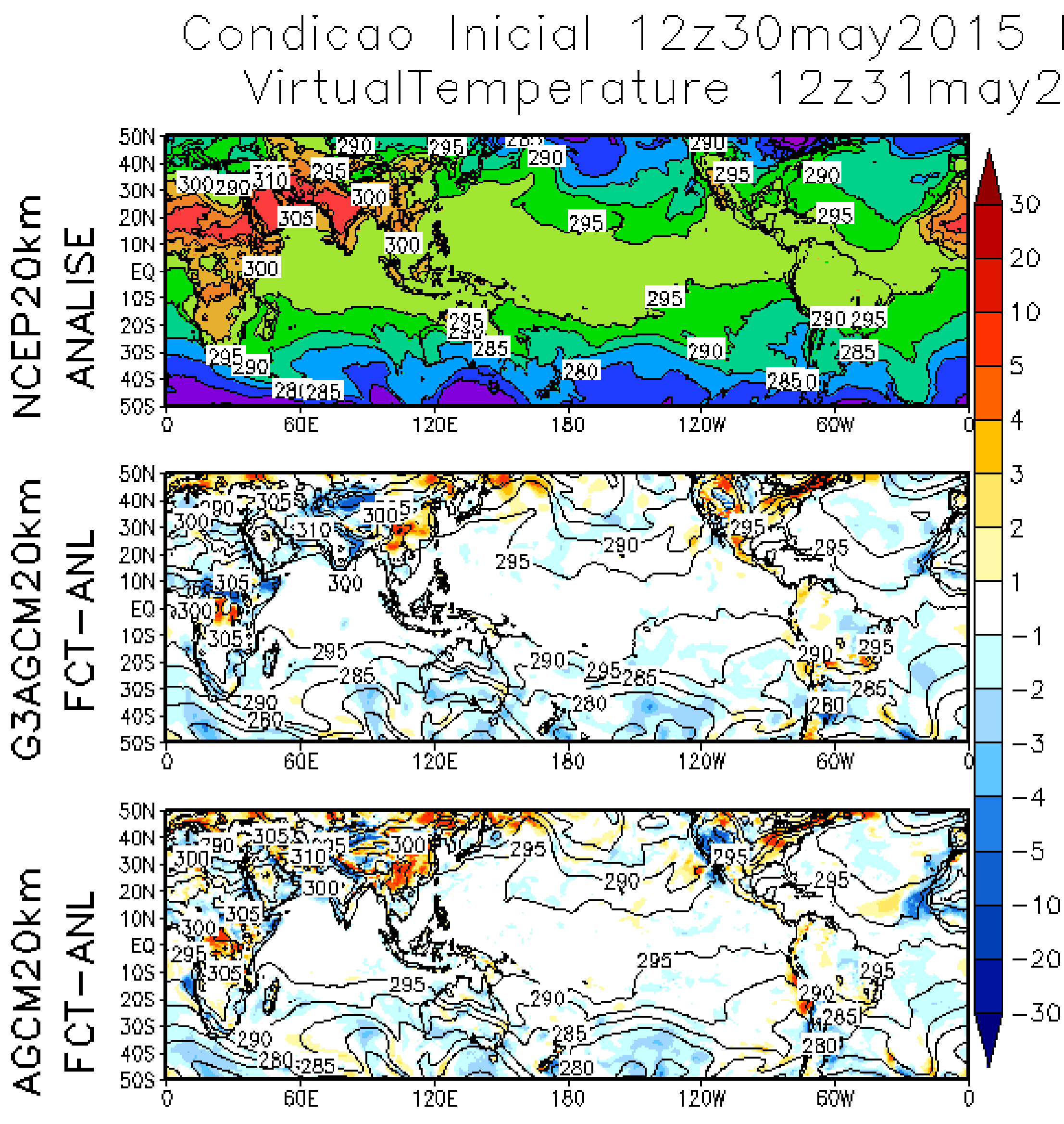
Resultado da Implementação da Parametrização da camada limite úmida da Universidade de Washington e esquema de superfície (IBIS-MOD)

IBIS-OLD

PBL-Seca

IBIS-MOD

PBL-Umida



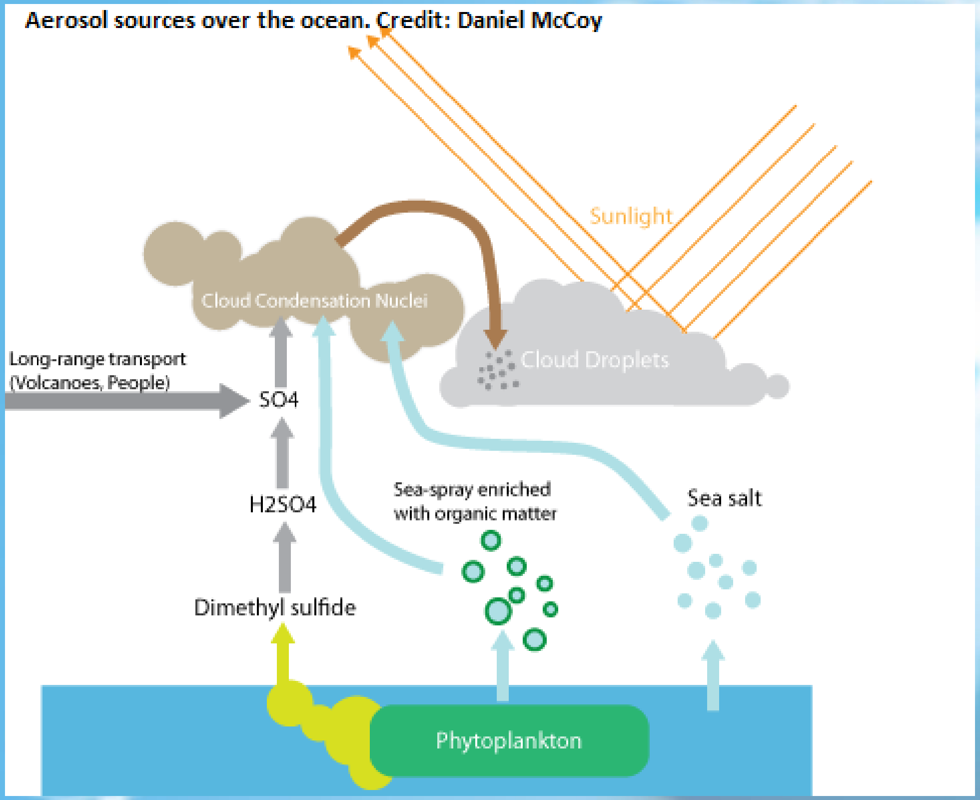
G3AGCM20KM

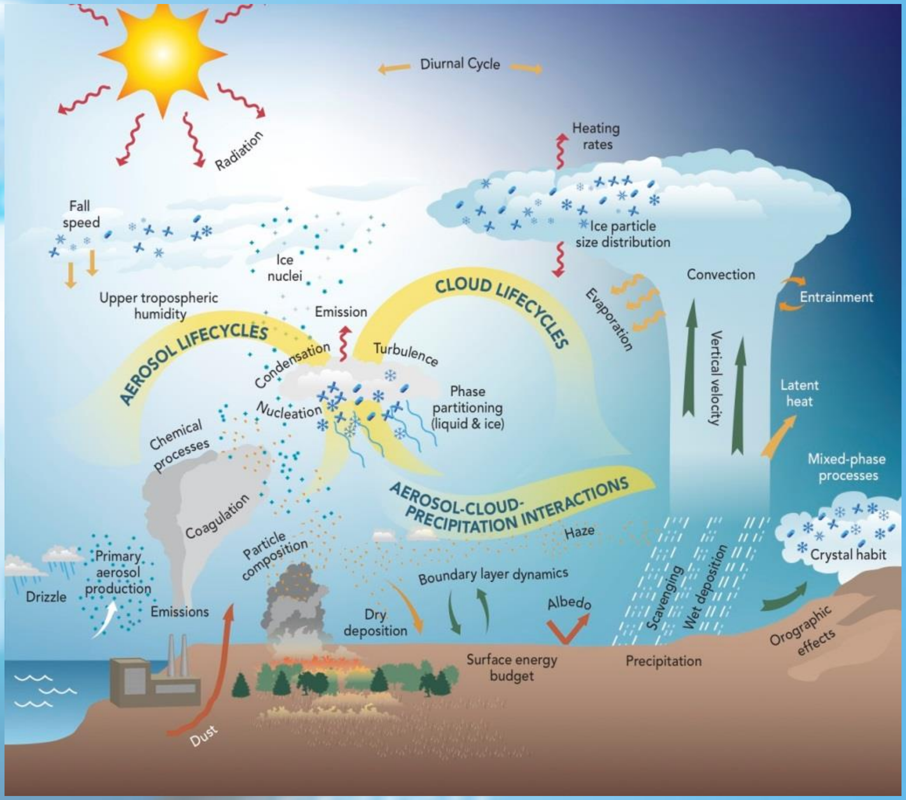
VAR	BIAS	RMSE	MSE	R
PREC	0.22	9.75	95.07	0.37
PSNM	0.19	1.48	2.20	0.98
TEMP	−0.64	1.54	2.36	0.99
UMES	−0.18	0.06	0.00	0.82
ZGEO	−9.26	13.40	179.51	0.98

AGCM20KM

VAR	BIAS	RMSE	MSE	R
PREC	−0.43	9.53	90.85	0.35
PSNM	0.26	1.50	2.25	0.98
TEMP	−0.51	1.64	2.69	0.98
UMES	−0.08	0.06	0.00	0.91
ZGEO	−12.77	15.71	246.90	0.98

Convection
Convecção Profunda





GREL

Grell, G., and D. Dévényi, Parameterized convection with ensemble closure/feedback assumptions, 9th conference on Mesoscale Processes, AMS, Ft. Lauderdale, pp 12–16, 2001.

RAS

Arakawa, A., 1972: Design of the UCLA general circulation model. Numerical Simulation of Weather and Climate, Dept. of Meteorology, University of California, Los Angeles, Tech. Rep.7, 116 pp.

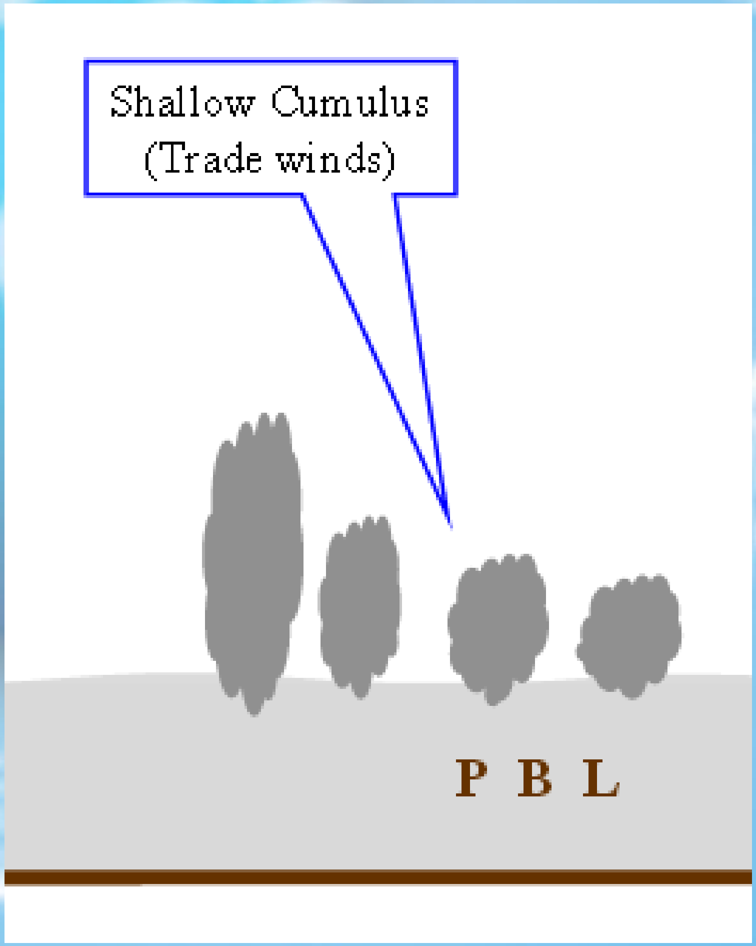
Moorthi, S., and M.J. Suarez, 1992: Relaxed Arakawa-Schubert: A parameterization of moist convection for general circulation models. Mon. Wea.Rev.,120,978-1002.

KUO

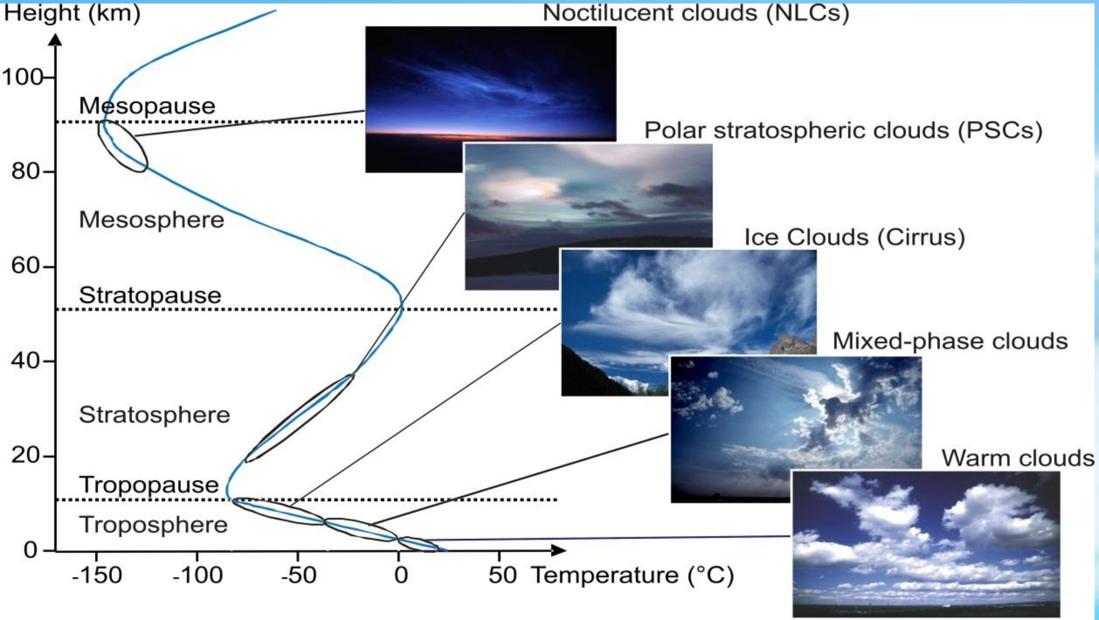
Kuo, H. L., 1974: Further studies of the parameterization of the influence of cumulus convection of large-scale flow.J. Atmos. Sci., 31, 1232–1240.

Convecção RASA

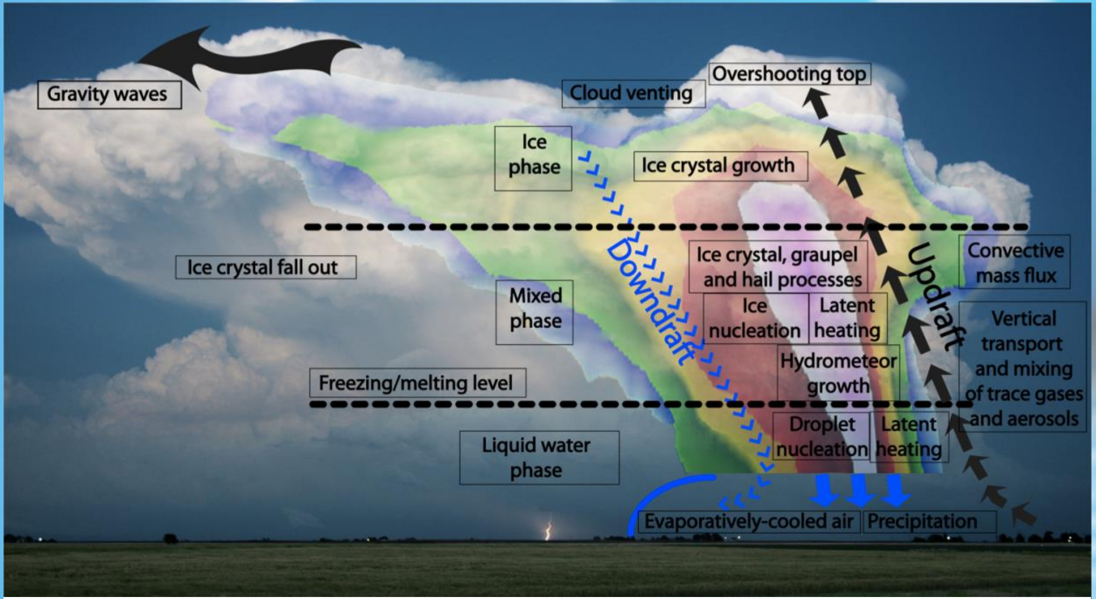
TIEDTKE, M.(1983). The sensitivity of the time-mean large-scale flow to cumulus convection in the ECMWF model. ECMWF Workshop on Convection in Large-Scale Models(pp. 297-316). Reading, England: European Centre for Medium-Range Weather Forecasts



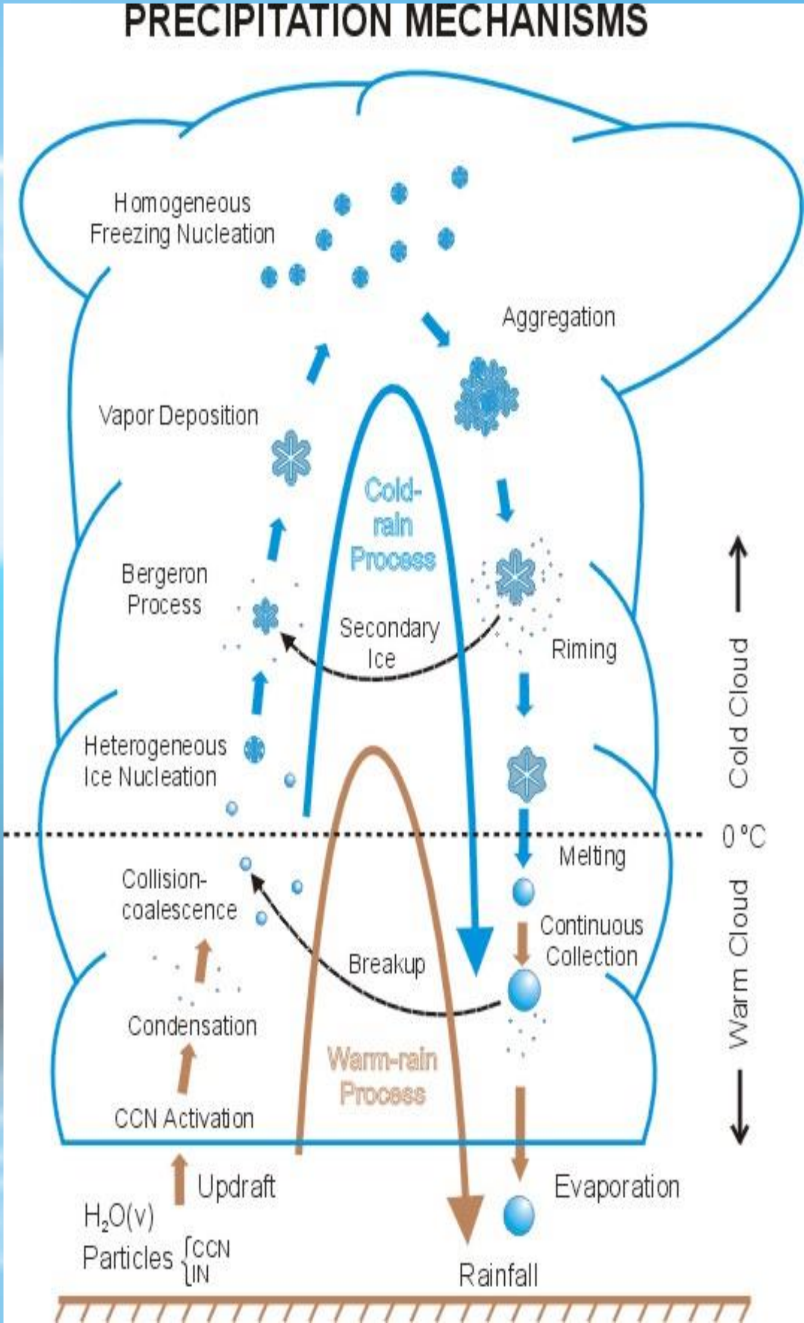
Microfisica



Fonte: https://www.imk-aaf.kit.edu/415.php



Fonte: http://reef.atmos.colostate.edu [(R. Seigel and S. van den Heever 2011)]



Microfisica

MIC

Rasch, P., and J. E. Kristjánsson, 1998: A comparison of the CCM3 model climate using diagnosed and predicted conden-sate parameterizations. J. Climate,11,1587–1614

HWRF
HGFS

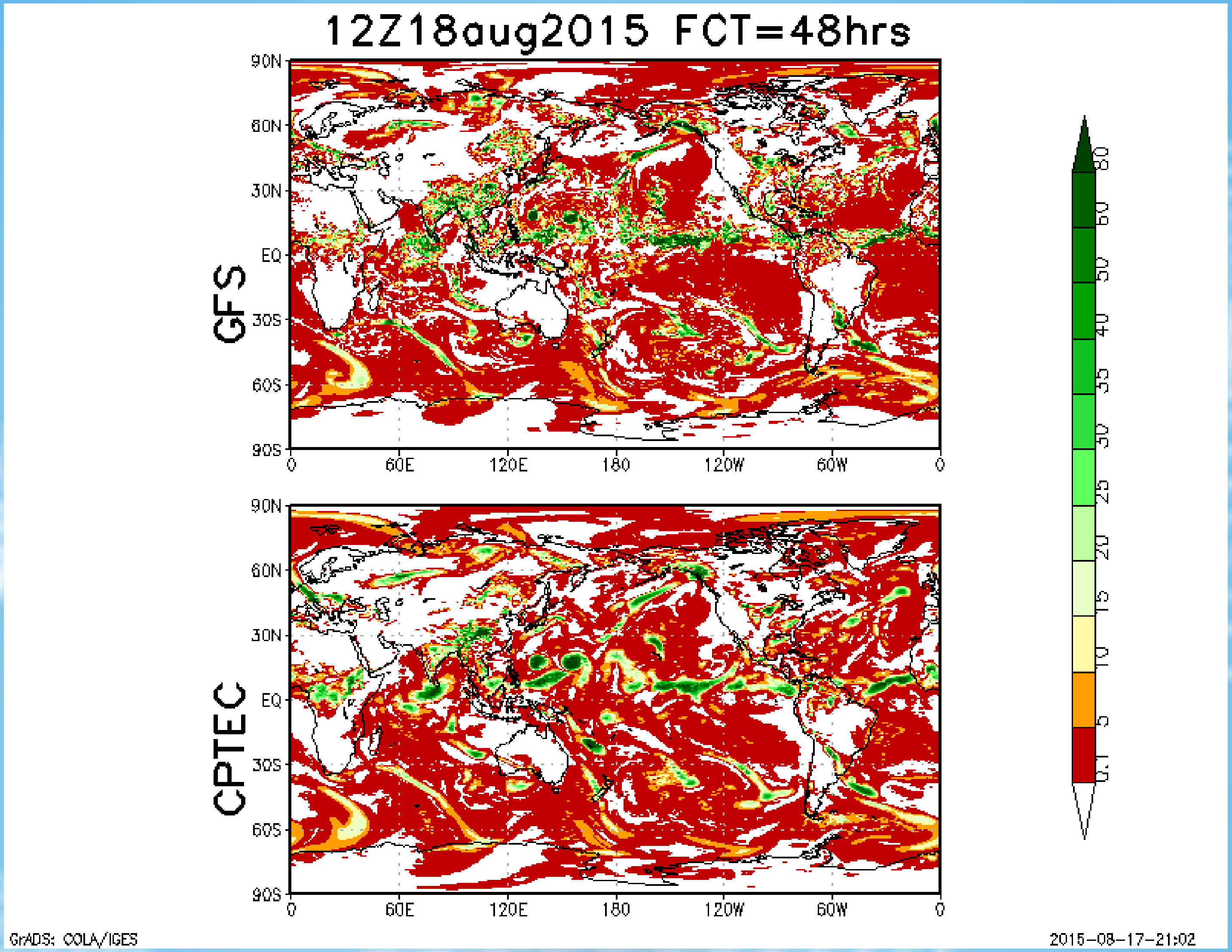
Ferrier, B. S., Tao, W. K., and Simpson, J.: A double-moment multiple-phase four-class bulk ice scheme, Part II:Simulations of convective storms in different large-scale environments and comparisons with other bulk parameterizations, J. Atmos. Sci.,52, 1001–1033, 1995.

B. S. Ferrier, Y. Lin, T. Black, E. Rogers, and G. DiMego, "Implementation of a new grid-scale cloud and precipitation scheme in the NCEP Eta model," in Proceedings of the 15th Conference on Numerical Weather Prediction, pp. 280–283, American Meteorological Society, San Antonio, Tex, USA, 2002

MORR
HUMO

Morrison, H., J. A. Curry, and V. I. Khvorostyanov, 2005: A new double-moment microphysics parameterization for application in cloud and climate models. Part I: Description. J. Atmos. Sci., 62, 1665-1677.

UKMO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GFS
CPTEC
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EQ
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10
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Dinâmica

Equação de momentum

$$\frac{\partial U}{\partial t} + \frac{1}{a\cos^2\varphi}\left(U\frac{\partial U}{\partial \lambda} + V\cos\varphi\frac{\partial U}{\partial \varphi}\right) + \dot{\sigma}\frac{\partial U}{\partial \sigma} - fV + \frac{1}{a}\left(\frac{\partial \Phi}{\partial \lambda} + RT\frac{\partial \ln ps}{\partial \lambda}\right) = F_u$$

$$\frac{\partial V}{\partial t} + \frac{1}{a\cos^2\varphi}\left(U\frac{\partial V}{\partial \lambda} + V\cos\varphi\frac{\partial V}{\partial \varphi}\right) + \dot{\sigma}\frac{\partial V}{\partial \sigma} + fU + \frac{\cos\varphi}{a}\left(\frac{\partial \Phi}{\partial \varphi} + RT\frac{\partial \ln ps}{\partial \varphi}\right) + \frac{\sin\varphi}{a\cos^2\varphi}(U^2 + V^2) = F_v$$

Equação de Termodinâmica

$$\frac{\partial T}{\partial t} + \frac{1}{a\cos^2\varphi}\left(U\frac{\partial T}{\partial \lambda} + V\cos\varphi\frac{\partial T}{\partial \varphi}\right) + \dot{\sigma}\frac{\partial T}{\partial \sigma} - \theta\dot{\sigma}\frac{\partial \Pi}{\partial \sigma} = \kappa T\left(\frac{\partial}{\partial t} + \vec{V}.\nabla\right)\ln ps + F_T$$

Equação de Umidade

$$\frac{\partial q}{\partial t} + \frac{1}{a\cos^2\varphi}\left(U\frac{\partial q}{\partial \lambda} + V\cos\varphi\frac{\partial q}{\partial \varphi}\right) + \dot{\sigma}\frac{\partial q}{\partial \sigma} = F_q$$

Equação de Pressão de Superfície

$$\frac{\partial \ln ps}{\partial t} + \int_0^1 (\vec{V}.\nabla \ln ps)d\sigma + \int_0^1 D\ d\sigma = 0$$

Equação de Hidrostática

$$\frac{\partial \phi}{\partial \sigma} + \frac{RT}{\sigma} = 0$$

Equação de Velocidade Vertical

$$\sigma\frac{\partial ps}{\partial t} + \int_0^\sigma \nabla.(ps\vec{V})d\sigma = -ps\dot{\sigma}$$

Variables:

$U = u\cos\varphi,\ V = v\cos\varphi,\ \vec{V} = (U, V)$

T - virtual temperature, θ - potential temperature, $T = \Pi\theta$
ps - surface pressure, $\sigma = p/ps$ - vertical coordinate, $\dot{\sigma}$ - vertical velocity,
f - Coriolis, q - specific humidity, D - horizontal divergence. F_U, F_V, F_T and
F_q are forcing terms due to the physical parameterization processes.

Dinâmica

As Variáveis Prognósticas

D – Campo de Divergência
ξ - Campo de Vorticidade
As velocidades U e V serão derivadas de ξ e D.
T – temperatura Virtual
Q – Umidade especifica
Ln ps – log da pressão de superfície

Será armazenado no espaço espectral . Em cada nível k, nós armazenaremos os coeficientes F_n^m de uma expansão tal como:

$$F(\lambda,\varphi) = \sum_{m=-M}^{M} \sum_{n=|m|}^{M} F_n^m P_n^m(\sin\varphi)e^{im\lambda}.$$

Onde, é utilizado um truncamento triangular para cada campo prognostico

Dinâmica

Problemas

```fortran
!VaryMWithLat: Implements Courtier-Naughton criteria for computing
!              wave number per latitude in the reduced grid.
!              Internal module procedure

SUBROUTINE VaryMWithLat(Pmn, W, mPerLat)
  REAL(KIND=r8),    INTENT(IN ) :: W(jMax)                  ! Gaussian Weights
  REAL(KIND=r8),    INTENT(IN ) :: Pmn(jMaxHalf, mnExtMax) ! AssocLegFunc
  INTEGER, INTENT(OUT) :: mPerLat(jMax)              ! Waves per latitude
  REAL(KIND=r8)    :: Partial(nExtMax, mnExtMax)
  INTEGER :: j, m, n, nPrime, mn, mnPrime
  REAL(KIND=r8)    :: erroMax, wj
  REAL(KIND=r8), PARAMETER :: acceptable=1.0e-12_r8  ! orthogonality acceptabl


  ! At a given latitude j, Partial contains the partial summations from
  ! North Pole up to j that are the contribution of this
  ! set of latitudes to the orthogonality of Associated Legendre Functions
  ! of Legendre Degree nPrime and Legendre Order m with respect to all
  ! Associated Legendre Functions with same Order. While this contribution
  ! is less than a fixed acceptable error, that particular Order is not
  ! required for that latitude. (Courier-Naughton criteria)


  Partial = 0.0_r8
  DO j = 1, jMaxHalf
     wj = w(j)
     DO m = mMax, 1, -1
        DO n = m, nExtMax
           mn = mnExtMap(m,n)
           DO nPrime = n, nExtMax
              mnPrime = mnExtMap(m,nPrime)
              Partial(nPrime,mn) = Partial(nPrime,mn) + &
                   Pmn(j,mn)*Pmn(j,mnPrime)*Wj
           END DO
        END DO
        erroMax = 0.0_r8
        DO n = m, nExtMax
           mn = mnExtMap(m,n)
           erroMax = Max(erroMax, MAXVAL(ABS(Partial(n:nExtMax,mn))))
        END DO
        IF (erroMax > acceptable) THEN
           mPerLat(j) = MIN(mMax, m+1)
           EXIT
        END IF
     END DO
  END DO
  mPerLat(jMaxHalf+1:jMax)=mPerLat(jMaxHalf:1:-1)
END SUBROUTINE VaryMWithLat
```

mMax = trunc + 1
nMax = mMax
nExtMax = mMax + 1
mnExtMax = (nExtMax+2)*(nExtMax-1)/2

```
! any MPI process has at most mnMaxLocal mn's (may
! have less) and
! at most mnExtMaxLocal mnExt's (may have less).
! mnMaxLocal and mnExtMaxLocal are used to
!dimension   arrays over all MPI processes

mnMaxLocal = MAXVAL(mnsPerProc)
mnExtMaxLocal = MAXVAL(mnsExtPerProc)

! myMNMax: scalar containing how many mn's at this
!MPI process
! myMNExtMax: scalar containing how many mnExt's
!at this MPI process

myMNMax = mnsPerProc(myId_four)
myMNExtMax = mnsExtPerProc(myId_four)
```

Problemas de Alocação de Memorias para a Configuração de grade reduzida na resolução TQ1332L64 (~10km) [Alteração no Algoritmo]

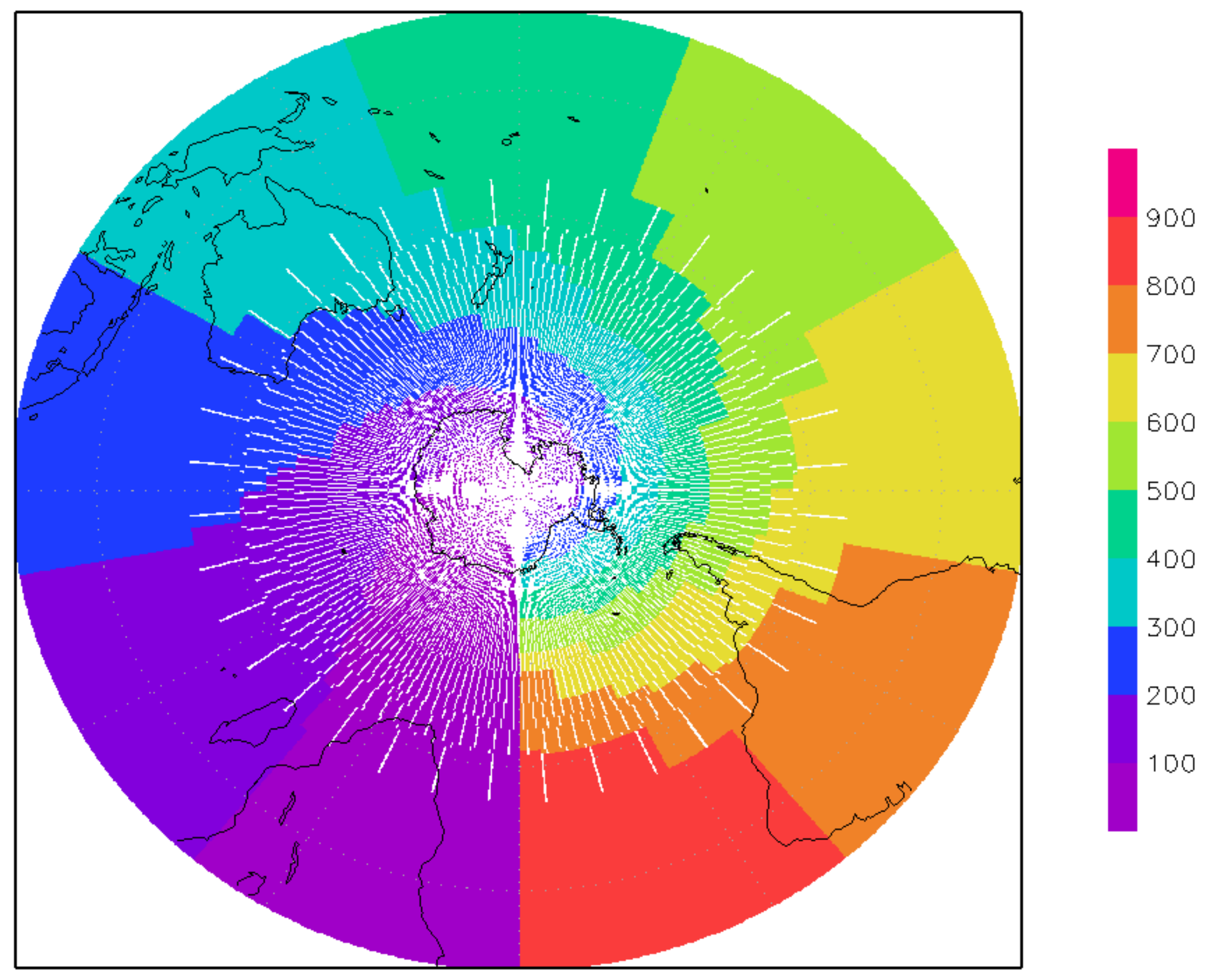
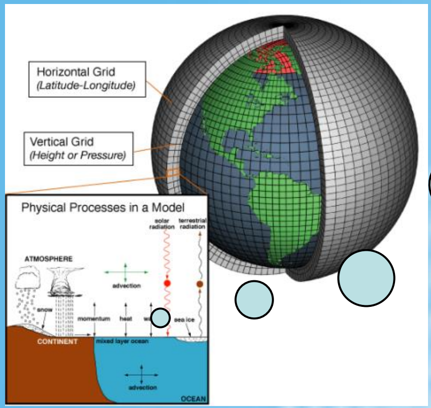


Figura 2 Distribuição dos pontos de malha em uma malha reduzida da resolução TQ0299L064.

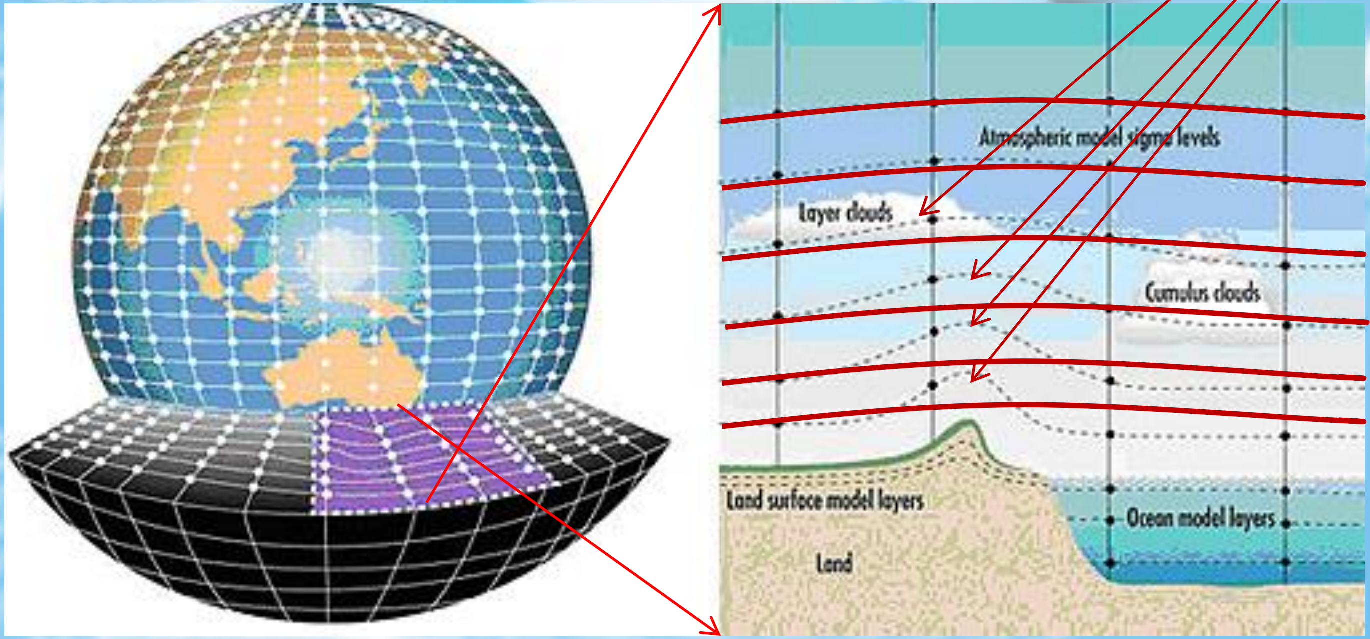
Implementação da coordenada hibrida sigma-pressão [efeito da topografia sobre a convecção]



Restruturação das parametrizações física para utilizar a coordenada hibrida

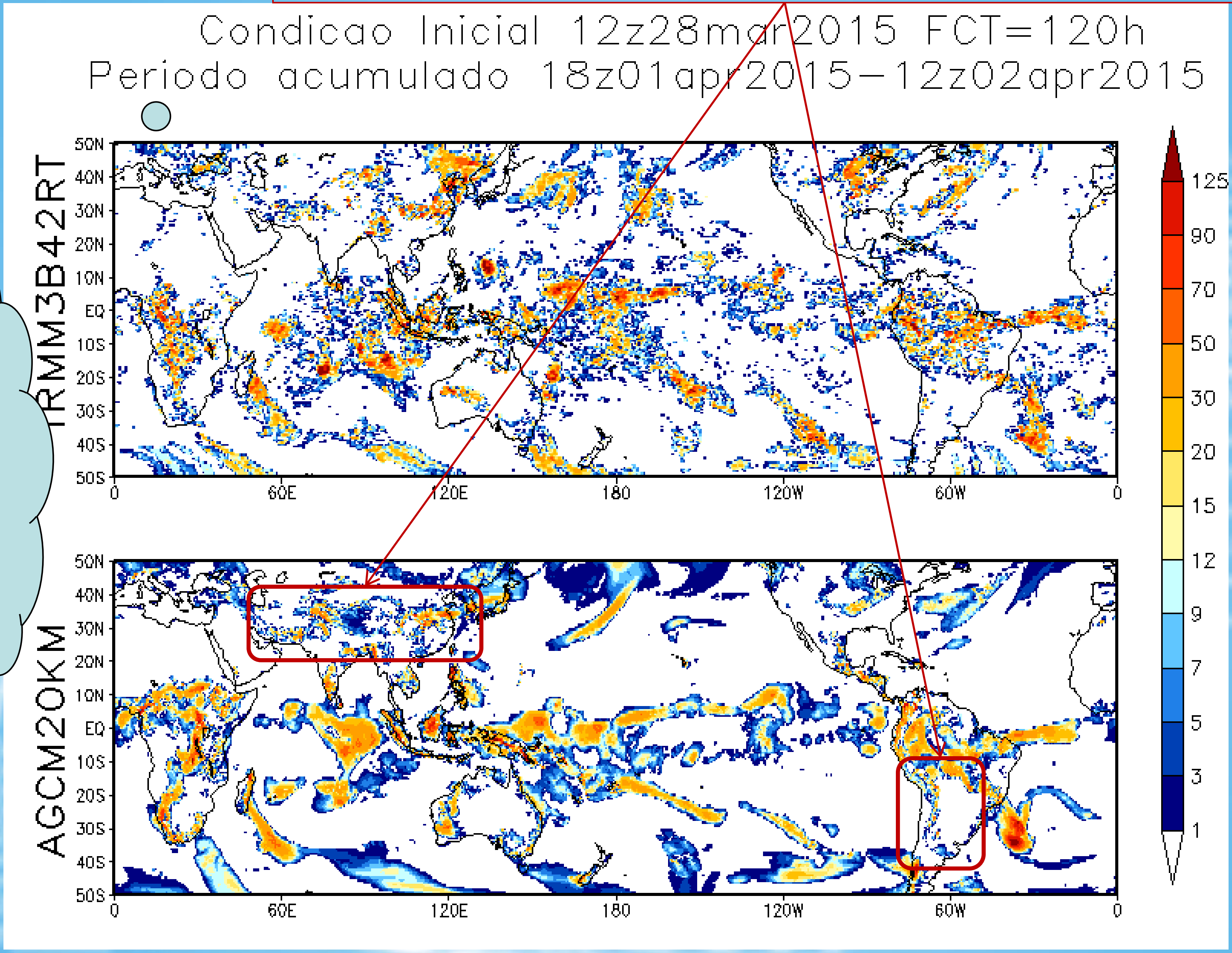
Pode gerar falsa precipitação

Fonte: http://upload.wikimedia.org/wikipedia/commons/7/73/AtmosphericModelSchematic.png



Fonte:http://www.dpi.nsw.gov.au/research/topics/climate-change/projects-modelling

Efeito da topografia e níveis sigma sobre a precipitação



Cood. Hibrida
Irá melhorar

Configuração do MCGA-CPTEC/INPE

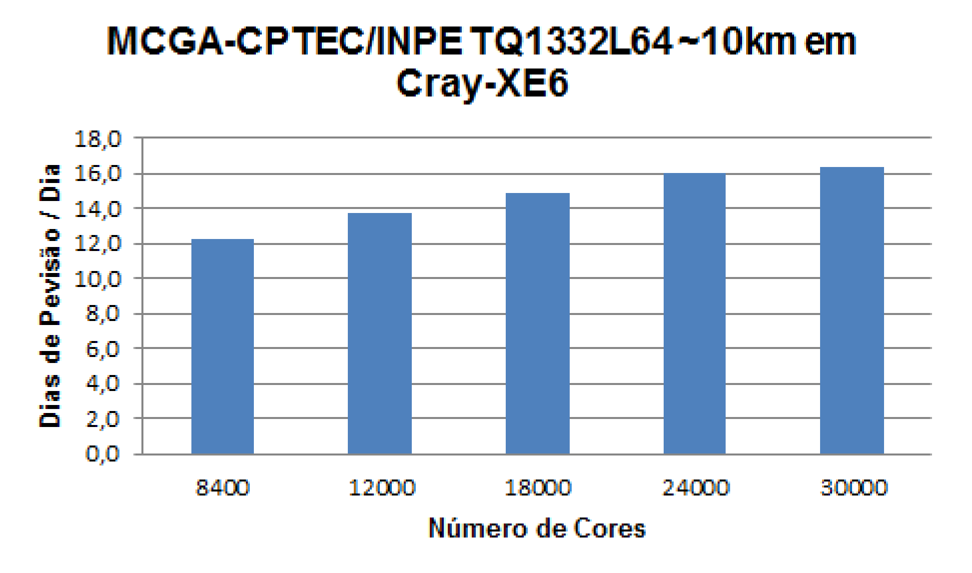
Desafios: operacionalizar o modelo TQ1332L64(~10 km)

Opcções	Descrição (OPERACIONAL TQ299L64)	Descrição (EXPERIMENTAL TQ1332L64)
Dinâmica	Euleriana com grade Reduzida	Semi-Lagrangiano com grade Reduzida
Radiação de onda Curta	CLIRAD	RRTMG
Radiação de onda Longa	HASHVANADAN(1987)	RRTMG
Camada Limite	Hostlag e Boville modificado (MY)(1992)	PBL UMIDA
Esquema de Superfície	IBIS(1996)	IBIS(1996)
Convecção Profunda	GRELL(1993)	GRELL-NILO
Convecção Rasa	TIEDKE(1983)	TIEDKE(1983)
P. de Larga escala	Microfísica (Rasch and Kristjánsson (1998))	Microfísica (Morrison)
Onda de Gravidade	ALPERT(1988)	ALPERT(1988)

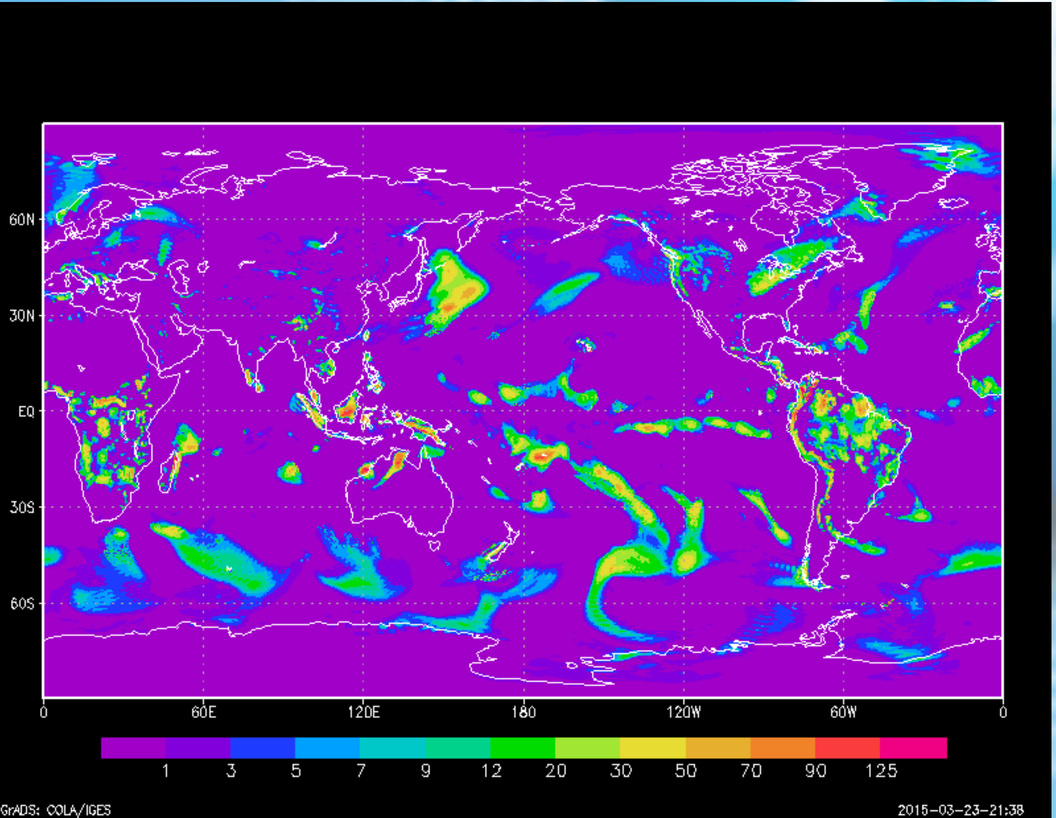
Os números do supercomputador Cray-XE6

CPUs	1280 nós, cada nó com 2 Opteron 12 núcleos de 2,1GHz, cada nó com velocidade máxima de 201,6 GFlop/s, 32 GB de memória e rede SeaStar2, totalizando 30720 cores
Desempenho	Máximo: 258 TFlop/s Efetivo: 205 TFlop/s no Linpack
Disco primário	Sistema de arquivos com 866 TB líquidos, acessíveis à 320 Gbs
Armazenamento Secundário	3,84 Petabytes (PB) em discos SATA, biblioteca de fitas com 8.000 slots com 8.000 fitas LTO4, 6 PB de fitas
Processamento Auxiliar	20 nós, cada nó com 4 Opteron 4 core de 2,7 GHz, 128 GB de memória com desempenho SPECfp_rate_base2006 agregado de 3760
Acesso Interativo	13 nós, cada nó com 4 Opteron 4 core de 2,7 GHz, 128 GB de memória com desempenho SPECfp_rate_base2006 agregado de 2444
Espaço físico, energia e refrigeração	Ocupa 100 m^2, requer 639 Kw de energia, refrigerado a ar com dissipação máxima de 550.000 Kcal/h, com portas contendo dissipadores refrigerados a água

Processos MPI	Threads OpenMP/MPI	Número de Nós	Número de Core	Período de Integração	Tempo de CPU
1400	6	350	8400	24 horas	1,962 horas
2000	6	500	12000	24 horas	1,745 horas
3000	6	750	18000	24 horas	1,613 horas
4000	6	1000	24000	24 horas	1,494 horas
5000	6	1250	30000	24 horas	1,468 horas



TQ1332L64(~10 km)



Muito Obrigado pela Atenção

Desempenho Computacional

Table 1: Profile by Function Group and Function

Time%	Time	Imb. Time	Imb. Time%	Calls	Group / Function / PE=HIDE / Thread=HIDE
100.0%	658.256547	--	--	7997569.5	Total
75.6%	497.506558	--	--	7532901.3	USER
19.4%	127.763015	4.385194	3.3%	1320.2	transform_spectofour_
19.2%	126.270011	83.010881	40.0%	661.0	modtimestep_timestep_
10.6%	69.748234	69.479808	50.3%	2856.6	rrtmg_sw_spcvmc_spcvmc_sw_
5.6%	36.960482	5.694902	13.5%	658.0	semilagrangian_semilagr_
3.1%	20.386691	4.093877	16.9%	658.0	communications_exchange_fields_
2.2%	14.293395	15.969601	53.2%	1320.0	transform_depositgrid_
1.6%	10.314310	6.480043	38.9%	17211.5	micro_morr_morr_two_moment_micro_
1.5%	9.607280	9.604971	50.4%	1320.0	transform_fourtospec_
1.0%	6.372858	6.488201	50.9%	519.2	rrtmg_sw_rad_rrtmg_sw_
0.7%	4.648023	3.265597	41.6%	2916.4	microphysics_runmicrophysics_
0.7%	4.411638	2.742619	38.7%	964.0	radsw_rad_rrtmg_sw_
0.7%	4.403092	0.139955	3.1%	38063.3	semilagrangian_interpcublin3d_
0.6%	4.034586	0.868501	17.9%	658.0	communications_exchange_winds_
0.6%	3.925277	0.078770	2.0%	1.0	cloudopticalproperty_ice_lookup_
0.5%	3.231306	0.278274	8.0%	1.0	exit
0.5%	2.967143	0.488630	14.3%	321.1	rrtmg_lw_rad_rrtmg_lw_
0.4%	2.535965	6.649031	73.0%	930629.2	micro_morr_rayleigh_soak_wetgraupel_
0.3%	2.009093	1.933843	49.5%	639869.1	rrtmg_sw_vrtqdr_vrtqdr_sw_
0.3%	1.735494	0.114465	6.2%	2910.7	physicsdriver_physcs_
0.3%	1.729219	1.507652	47.0%	519.2	mcica_subcol_gen_sw_mcica_subcol_sw_
0.3%	1.709582	1.684517	50.0%	639869.1	rrtmg_sw_reftra_reftra_sw_
0.2%	1.565776	0.072518	4.5%	321.1	radlw_rad_rrtmg_lw_
0.2%	1.468049	0.469894	24.5%	1322.0	transform_withdrawgrid_
0.2%	1.206873	0.146309	10.9%	2916.4	convection_cumulus_driver_
0.2%	1.203978	1.128092	48.8%	519.2	mcica_subcol_gen_sw_generate_stochastic_clouds_sw

Melhorar a estrutura do modelo MCGA-CPTEC/INPE

```
.
├── Assimilation
│   ├── GridDump.f90
│   ├── SpecDump.f90
│   └── SpecDump.f90.in
├── Diagnostics
│   ├── Diagnostics.f90
│   ├── GridHistory.f90
│   └── mpif.h
├── Documentation
│   ├── HISTORICO
│   ├── README_DIAGNOSTIC.txt
│   └── README_INSTALL.txt
├── DummyMPI
│   ├── include
│   │   ├── mpi.h
│   │   ├── mpif.h
│   │   ├── mpp.h
│   │   └── wtime.h
│   ├── Makefile
│   ├── Makefile.common
│   ├── Makefile.cygwin_gnu -> ../makefiles/Makefile.cygwin_gnu
│   ├── Makefile.linux_gnu -> ../makefiles/Makefile.linux_gnu
│   ├── mpi_dummy.c
│   ├── mpi_dummyc.c
│   ├── mpi_dummyf.f
│   ├── wtime.c
│   └── wtime.f
├── Dynamics
│   ├── GridDynamics.f90
│   ├── mpif.h
│   ├── SemiLagrangian.f90
│   ├── SpecDynamics.f90
│   └── TimeStep.f90
├── Fields
│   ├── FieldsDynamics.f90
│   └── FieldsPhysics.f90
├── Initialization
│   ├── Init.f90
│   ├── mpif.h
│   ├── NonLinearNMI.f90
│   └── Options.f90
├── InputOutput
│   ├── InputOutput.f90
│   └── IOLowLevel.f90
├── Main
│   ├── Atmos_Model.f90
│   ├── Model.f90
│   └── mpif.h
├── Makefile
```

```
├── Makefile.common
├── Makefile.in
├── makefiles
│   ├── CVS
│   │   ├── Entries
│   │   ├── Repository
│   │   └── Root
│   ├── Makefile.cray_cray
│   ├── Makefile.cray_cray32
│   ├── Makefile.cray_craydbg
│   ├── Makefile.cygwin_gnu
│   ├── Makefile.cygwin_gnu_dbx
│   ├── Makefile.gnu_cray
│   ├── Makefile.gnu_cray_dbx
│   ├── Makefile.gnu_cray2
│   ├── Makefile.linux_gnu
│   ├── Makefile.linux_intel
│   ├── Makefile.linux_intel_dbx
│   ├── Makefile.pgi_cray
│   ├── Makefile.pgi_cray_craydbg
│   ├── Makefile.sx6
│   ├── Makefile.tupay
│   ├── Makefile.una_gnu
│   └── Makefile.una_intel
├── mpif.h
├── Parallelism
│   ├── Communications.f90
│   ├── mpif.h
│   ├── Parallelism.f90
│   └── Sizes.f90
```

```
├── Physics
│   ├── BoundaryLayer
│   │   ├── HostlagBoville
│   │   │   └── Pbl_HostlagBoville.f90
│   │   ├── MellorYamada0
│   │   │   └── Pbl_MellorYamada0.f90
│   │   ├── MellorYamada1
│   │   │   └── Pbl_MellorYamada1.f90
│   │   ├── PBL_Entrain.f90
│   │   └── PblDriver.f90
│   ├── Convection
│   │   ├── CloudFraction
│   │   │   └── UKMET
│   │   ├── Convection.f90
│   │   ├── DeepConvection
│   │   │   ├── DeepConvection.f90
│   │   │   ├── Grel
│   │   │   │   ├── Cu_Grellens.f90
│   │   │   │   └── Cu_Grellens_CPTEC.f90
│   │   │   ├── GrellEns
│   │   │   │   └── Cu_Grellens.f90
│   │   │   ├── GrellEns_New
│   │   │   │   ├── Cu_Grellens.f90
│   │   │   │   ├── Cu_Grellens.f90-NEW-CLOSURES-17-18-19-20_JULY27-2013
│   │   │   │   └── Cu_Grellens.f90-NEW-CLOSURES-17-18-19-20_JULY27-2013_PK
│   │   │   ├── GrellEns_OLD
│   │   │   │   └── Cu_Grellens.f90
│   │   │   ├── GrellEnsCPTEC
│   │   │   │   └── Cu_Grellens_CPTEC.f90
│   │   │   ├── Kuo
│   │   │   │   └── Cu_Kuolcl.f90
│   │   │   ├── Ras
│   │   │   │   └── Cu_RAS.f90
│   │   │   └── Zhang
│   │   │       └── Cu_ZhangMcFarlane.f90
│   │   ├── LrgScl
│   │   │   └── Prec_LrgScl.f90
```

```
│   │   ├── MicroPhysics
│   │   │   ├── Ferrier
│   │   │   │   ├── Micro_Ferrier.f90
│   │   │   │   └── Micro_Ferrier.f90_ok
│   │   │   ├── Hack
│   │   │   │   └── Micro_Hack.f90
│   │   │   ├── HWRF
│   │   │   │   ├── ETAMPNEW_DATA
│   │   │   │   └── Micro_HWRF.f90
│   │   │   ├── LrgScl
│   │   │   │   └── Micro_LrgScl.f90
│   │   │   ├── MicroPhysics.f90
│   │   │   ├── MORRISON
│   │   │   │   └── Micro_MORR.f90
│   │   │   ├── MORRISON_AERO
│   │   │   │   ├── Micro_HugMorr.f90
│   │   │   │   ├── Micro_HugMorr.f90_orig
│   │   │   │   ├── Micro_HugMorr.f90~
│   │   │   │   ├── Micro_MORR.f90
│   │   │   │   ├── micro_morr.mod
│   │   │   │   └── Micro_MORR.o
│   │   │   └── UKME
│   │   │       ├── Micro_UKME.f90
│   │   │       ├── micro_ukme.mod
│   │   │       ├── Micro_UKME.x
│   │   │       └── StratCloudFraction.f90
│   │   └── ShallowConvection
│   │       ├── JHack
│   │       │   └── Shall_JHack.f90
│   │       ├── ShallowConvection.f90
│   │       ├── Souza
│   │       │   └── Shall_Souza.f90
│   │       ├── Tied
│   │       │   └── Shall_Tied.f90
│   │       └── UWShCu
│   │           └── Shall_UWShCu.f90
```

```
│   ├── GravityWaveDrag
│   │   ├── Alpert
│   │   │   └── GwddSchemeAlpert.f90
│   │   ├── CAM
│   │   │   └── GwddSchemeCAM.f90
│   │   ├── ECMWF
│   │   │   └── Gwdd_ECMWF.f90
│   │   ├── GwddDriver.f90
│   │   └── UKMET
│   │       ├── GwddSchemeCPTEC.f90
│   │       └── GwddSchemeUSSP.f90
│   ├── PhysicsDriver.f90
│   ├── Radiation
│   │   ├── Clirad
│   │   │   ├── cah.data90
│   │   │   ├── coa.data90
│   │   │   ├── mcai.data90
│   │   │   └── Rad_Clirad.f90
│   │   ├── CloudOpticalProperty.f90
│   │   ├── CloudOpticalProperty.f90~
│   │   ├── COLA
│   │   │   └── Rad_COLA.f90
│   │   ├── RadiationDriver.f90
│   │   └── UKMET
│   │       ├── Rad_UKMO.f90
│   │       ├── sp_lw_hadgem1_3
│   │       └── sp_sw_hadgem1_3r
│   └── Surface
│       ├── Land
│       │   ├── IBIS2.6
│       │   │   ├── Sfc_Ibis_BioGeoChemistry.f90
│       │   │   ├── Sfc_Ibis_BioGeoPhysics.f90
│       │   │   ├── Sfc_Ibis_Fiels.f90
│       │   │   └── Sfc_Ibis_Interface.f90
│       │   ├── SiB2.5
│       │   │   └── Sfc_SiB2.f90
│       │   └── SSiB
│       │       └── Sfc_SSiB.f90
│       └── Ocean
│           ├── SeaFlux_COLA
│           │   ├── Sfc_SeaFlux_COLA_Model.f90
│           │   └── Sfc_SeaFlux_COLA_Model.f90~
│           ├── SeaFlux_UKME
│           │   └── Sfc_SeaFlux_UKME_Model.f90
│           ├── SeaFlux_WGFS
│           │   └── Sfc_SeaFlux_WGFS_Model.f90
│           ├── SeaIceFlux_WRF
│           │   └── Sfc_SeaIceFlux_WRF_Model.f90
│           ├── Sfc_SeaFlux_Interface.f90
│           └── SLAB
│               └── SlabOceanModel.f90
```

```
├── scripts
│   ├── MODELIN
│   ├── run%)
│   ├── run_multi_SX6
│   ├── run_multi_TX7
│   ├── run_multi_UNA
│   ├── runModel
│   ├── runModel.SX6
│   └── runModel.XT6
├── Transform
│   ├── mpif.h
│   └── Transform.f90
├── tree_dir
└── Utils
    ├── Constants.f90
    ├── Constants.f90.in
    ├── mpif.h
    ├── PhysicalFunctions.f90
    ├── Utils.f90
    └── Watches.f90
```

- **Reestruturar o código do MCGA em função do código de aerossóis**
- **Otimizar alguns módulos da física para melhorar o desempenho do modelo**
- **Melhorar a Documentação do MCGA-CPTEC/INPE**
- **Adotar uma padronização de codificação e documentação do código**