

The physical parameterizations of LMDZ

LMDZ team

Laboratoire de Météorology Dynamique / IPSL / CNRS /SU

LMDZ training, December 2024

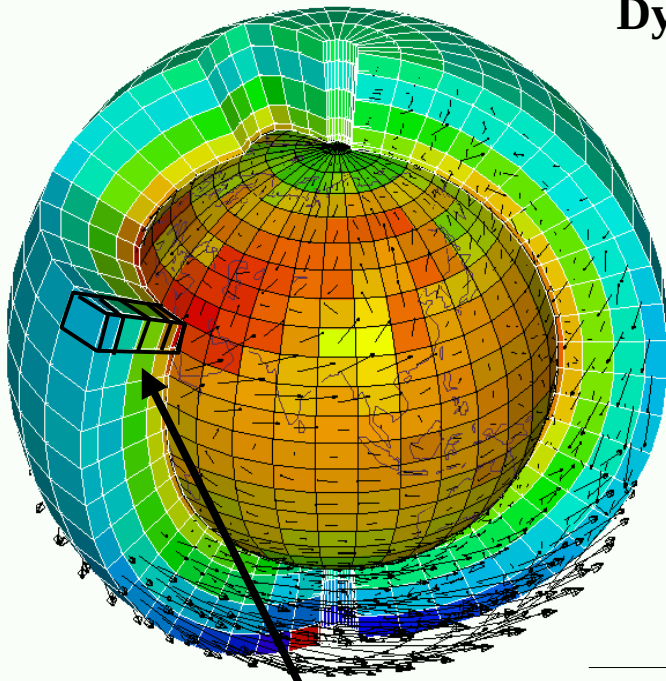
Part I : Frédéric presenting

- Principles
- Radiation (clear sky)
- Reynolds decomposition
- Turbulent diffusion
- Mass flux representation of the convective boundary layer
- Subgrid scale orography
- Practice

Part II : Jean-Baptiste presenting

- Moist convection
- Clouds

Dynamical core : primitive equations discretized on the sphere



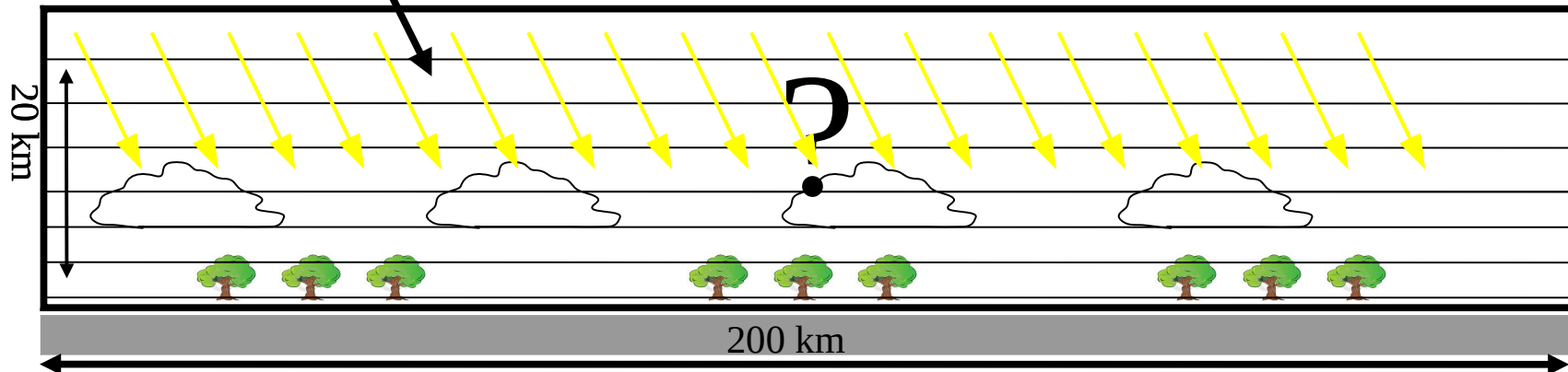
- Mass conservation

$$D\rho/Dt + \rho \operatorname{div}\underline{U} = 0$$
- Potential temperature conservation

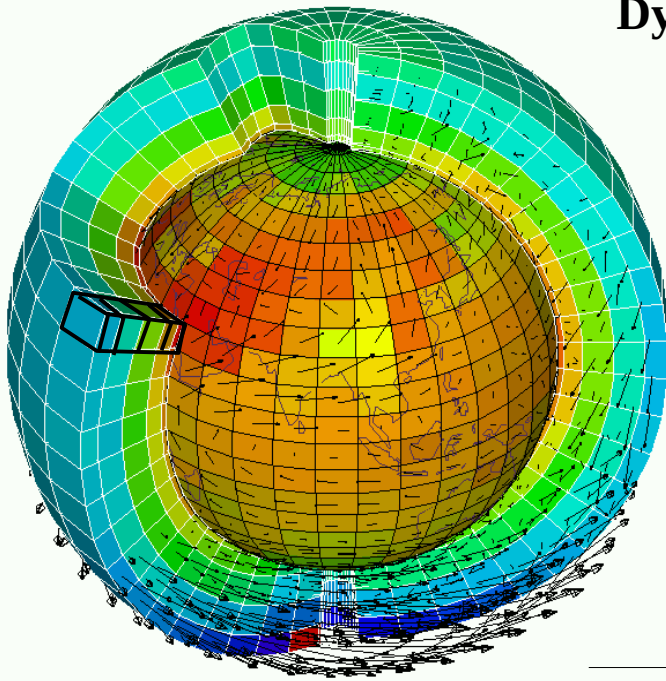
$$D\theta / Dt = Q / C_p (p_0/p)^\kappa$$
- Momentum conservation

$$D\underline{U}/Dt + (1/\rho) \operatorname{grad} p - g + 2 \underline{\Omega} \wedge \underline{U} = \underline{F}$$
- Secondary components conservation

$$Dq/Dt = Sq$$



Dynamical core : primitive equations discretized on the sphere



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$$D\rho/Dt + \rho \operatorname{div}\underline{U} = 0$$
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- Secondary components conservation
$$Dq/Dt = Sq$$

Parameterizations purpose : account for the effect of processes non resolved by the dynamical core

→ **Traditional « source » terms in the equations**

- Q : Heating by radiative exchanges, thermal conduction (neglected), condensation, sublimation, **subgrid-scale motions (turbulence, clouds, convection)**
- $\underline{F}$: Molecular viscosity (neglected), **subgrid-scale motions (turbulence, clouds, convection)**
- Sq : condensation/sublimation (q = water vapor or condensed), chemical reactions, photo-dissociation (ozone, chemical species), micro physics and scavenging (pollution aerosols, dust, ...), **subgrid-scale motions (turbulence, clouds, convection)**

Model tendencies

The integration of a given prognostic variable X ($T, \vec{v}(u, v, w), p, \rho, q_{vap}$) can be written as :

$$X_{t+\Delta t} = X_t + \left(\frac{\partial X}{\partial t} \right)_{\text{dyn}} \Delta t \text{ (dynamical core)} \quad (1)$$

$$+ \left(\frac{\partial X}{\partial t} \right)_{\text{param}} \Delta t \text{ (parameterizations)} \quad (2)$$

From model outputs

temp(t+dtphys)-temp(t)=dtdyn+dtphy

ovap(t+dtphys)-ovap(t)=dqdyn+dqphy

vit[u/v](t+dtphys)-vit[u/v](t)=dudyn+duphy

Physics time-step :

dtphys=daysec*iphysic/(day_step) , day_sec=86400

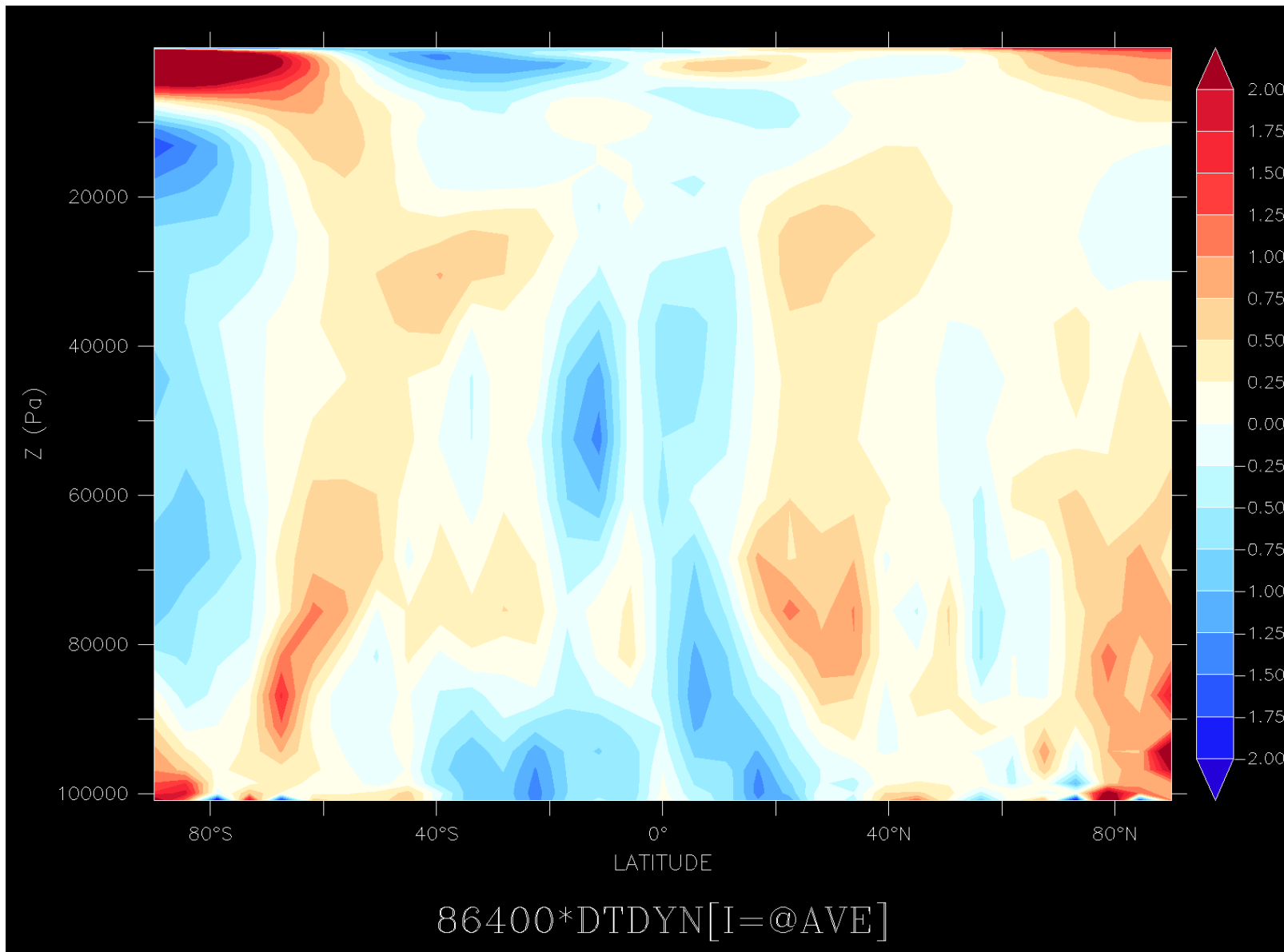
Zonal mean heating by large scale dynamics (K/day)

use histday.nc

reg/l=3

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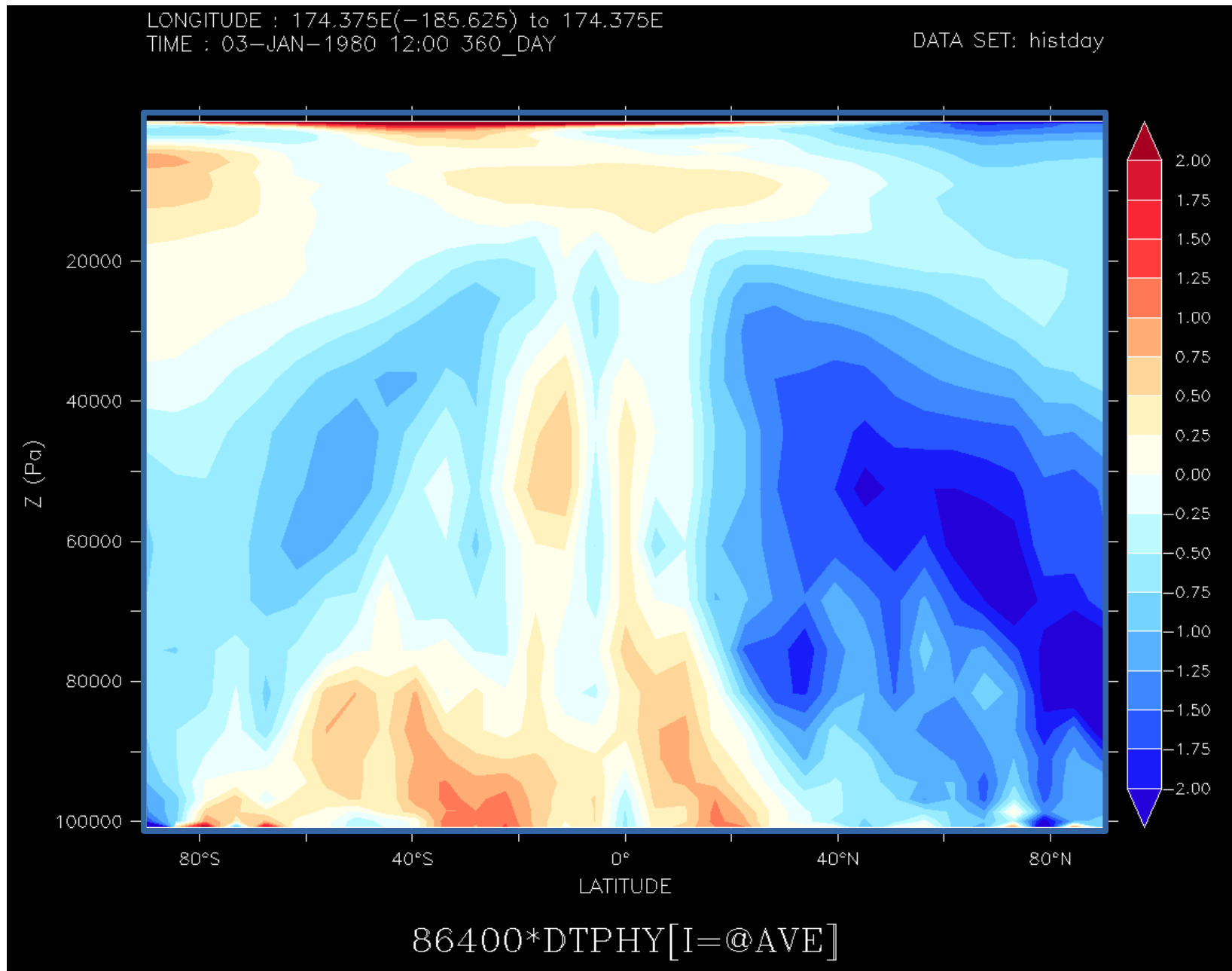
(prendre le temps d'expliquer la commande)



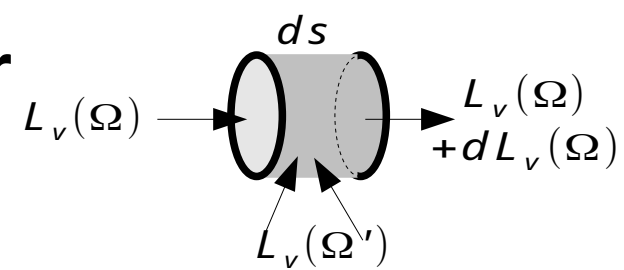
Zonal mean heating by large scale dynamics (K/day)

reg/l=3

fill/lev=(-Inf)(-2,2,0.25)(inf)/pal=blue_darkred 86400*dtphy[i=@ave]



Parameterization of radiative transfer



Radiative transfer : well known equations ...

Giving the evolution of luminance along a line of sight:

$$\frac{dL_v(\Omega)}{ds} = \underbrace{-\kappa_v L_v(\Omega)}_{\text{absorption}} + \underbrace{\kappa_v B_v(T)}_{\text{emission}} - \underbrace{\sigma_v L_v(\Omega)}_{\text{Scattered in other directions}} + \underbrace{\sigma_v \frac{1}{4\pi} \int_{4\pi} P(\Omega', \Omega) L_v(\Omega') d\Omega'}_{\text{Scattered from other directions}}$$

Computation of energy fluxes very costly

- should be integrated over all frequencies ν
- should be integrated on angles
- knowing radiative properties of scatterers and absorbers is a question by itself

Computing radiation for one full scene with reference methods for the spectral integration (line-by-line) and angular (discrete ordinates, Monte-Carlo) integrations, even for a plan parallel atmosphere without clouds, may take hours of CPU hours on super computers.

In LMDZ : using codes developed and used at ECMWF

3 codes avec des mots clé : **oldrad** / **rtrm** / **ecrad**

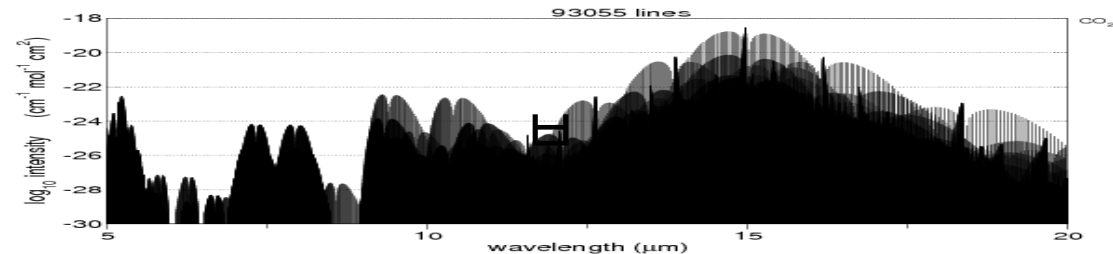
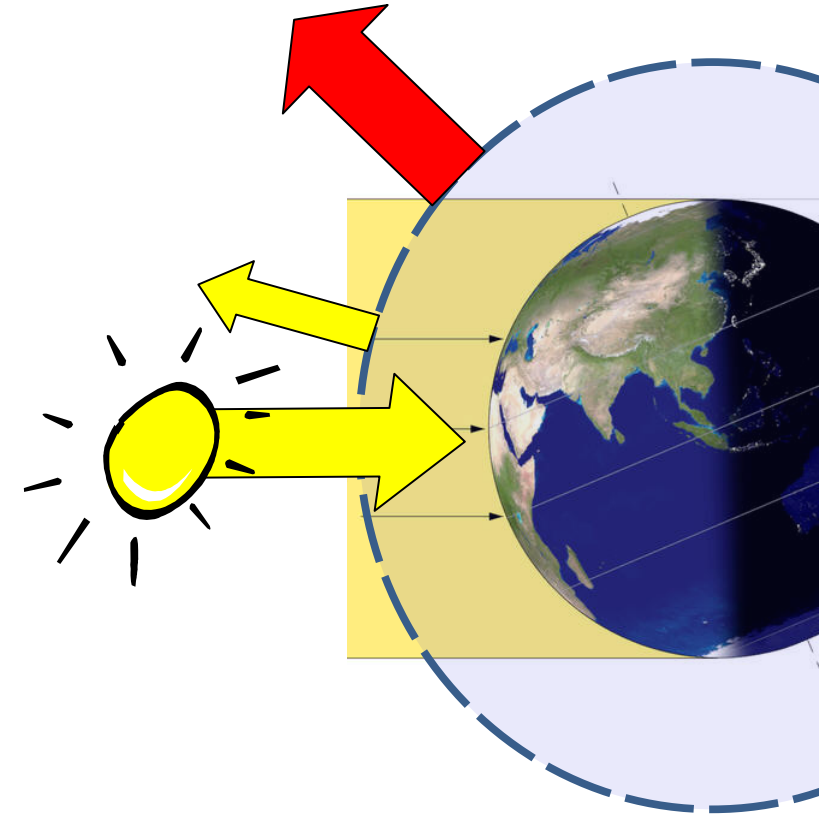
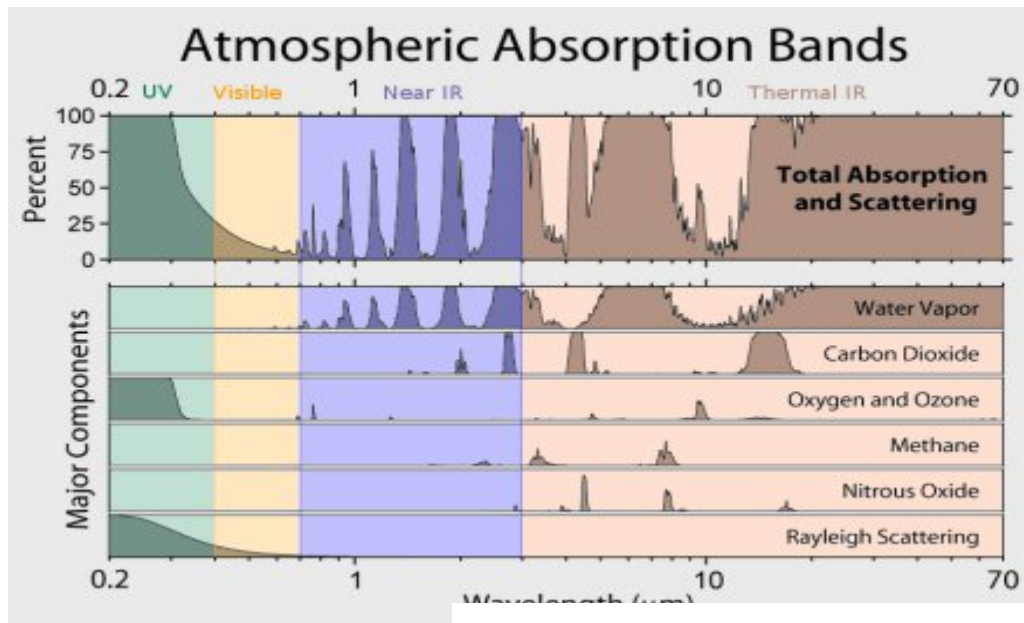
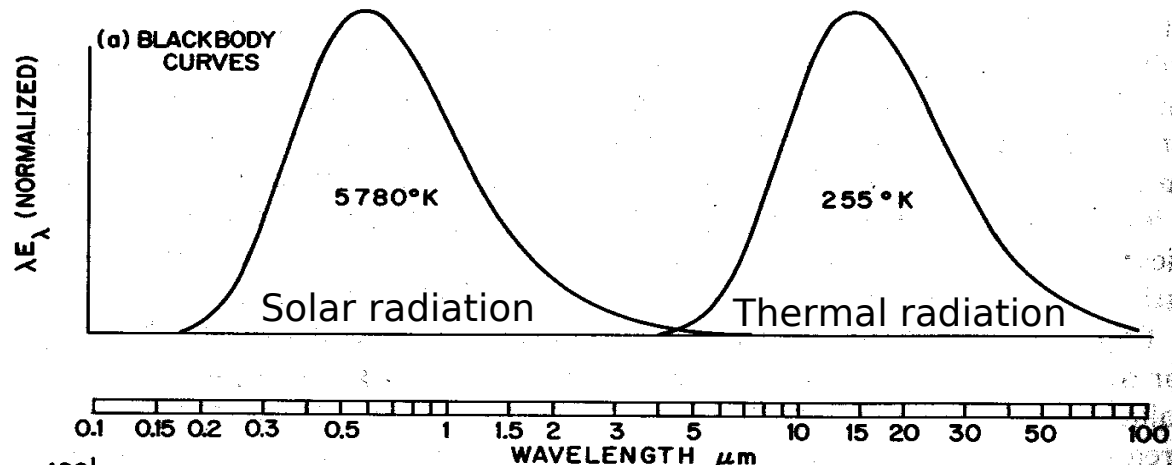
ECrad can be seen as a tool box with various options for :

Spectral integration : **S/RRTM** or **ECCKD**

Solver : **McICA**, **Tripleclouds** or **Spartacus**

Spectral : separating radiation between solar and thermal infrared

Valid thanks to the linearity of the radiative transfer equation with respect to sources



Approaches for spectral integration

Emissivity / band models (code « Fouquart Morcrette, 1980)

$$\epsilon_{\Delta\nu}(z_1, z_2) = \frac{1}{\Delta\nu} \int_{\Delta\nu} \epsilon_\nu(z_1, z_2) d\nu$$

Loosing a fundamental property : $\epsilon_{\Delta\nu}(z_1, z_2) = \epsilon_{\Delta\nu}(z_1, z) \epsilon_{\Delta\nu}(z, z_2)$

Cost in N² instead of N, where N is the number of layers

K-distribution methods

Replacing the integration on ν by an integration on k .

$k(P, T)$ differ depending on the transition considered.

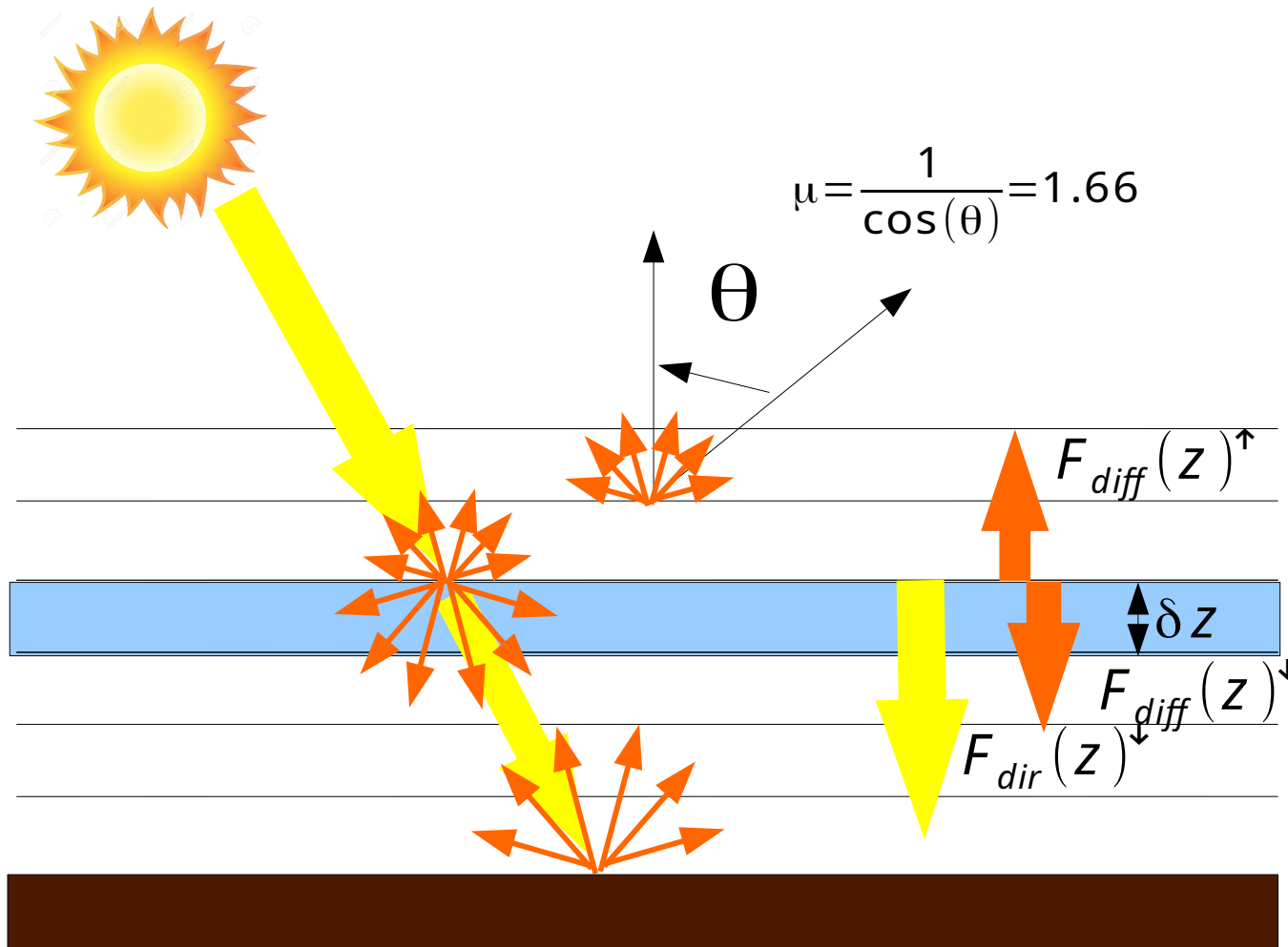
Name in .def files	SW	LW
oldrad	2 bands	6 bands
rrtm	6 bands	K-distributions (RRTM)
ecrad	K-distributions (SRTM) ECCKD	K-distributions (RRTM) ECCKD

Solar radiation : Direct radiation + 2-stream for diffuse radiation

Plane parallel approximation: homogeneous semi-infinite space

Upward and downward photons are grouped into two streams

Delta-Eddington approximation for scattering by strongly asymmetric phase functions



$$F^\uparrow = F_{diff}^\uparrow - F_{diff}^\downarrow - F_{dir}^\downarrow$$

$$F(z)^\uparrow$$
$$F(z - \delta z)^\uparrow$$

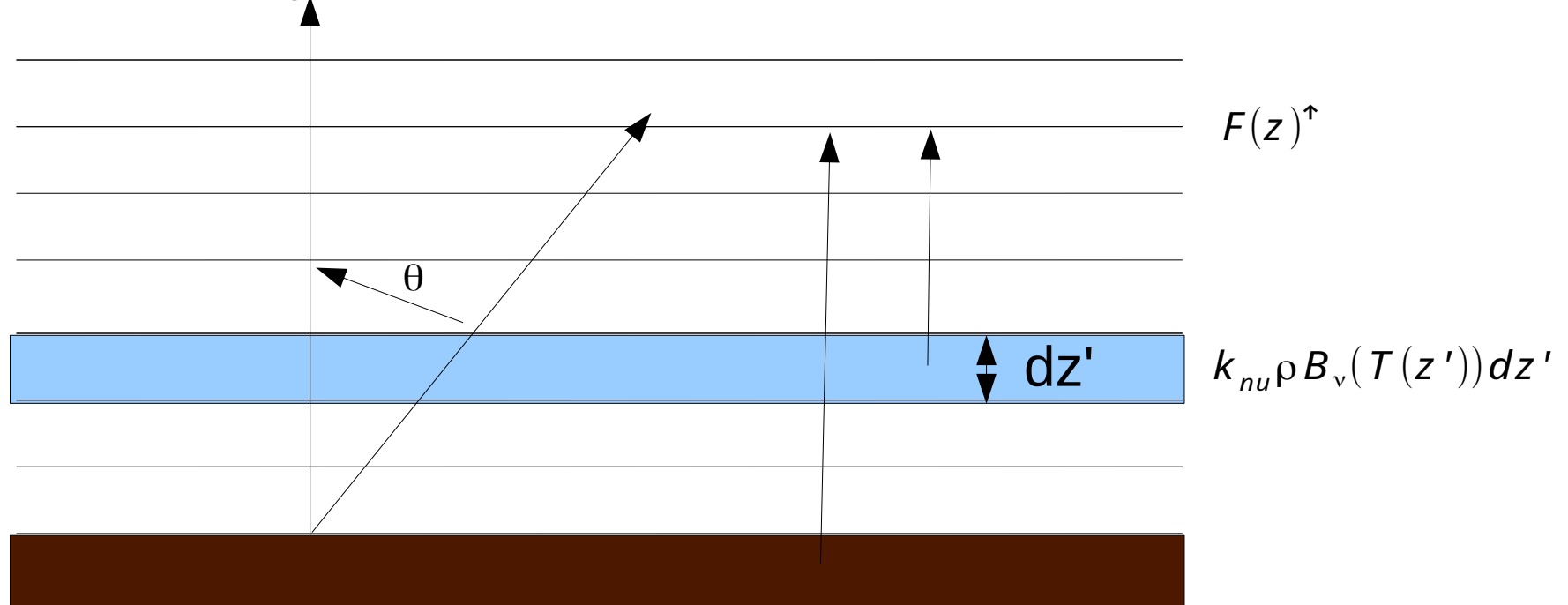
$$Q = \frac{F(z) - F(z - \delta z)}{C_p \rho \delta z}$$

Infrared, non-scattering case

Plane parallel approximation: homogeneous semi-infinite space

Diffuse" approximation

Up/down flux separation, 2-stream



$$\frac{\partial F(z)^\uparrow}{\partial z} = -k_{\nu} \rho \mu F(z)^\uparrow + k_{\nu} \rho \mu B_{\nu}(T) \quad \mu = \frac{1}{\cos(\theta)} = 1.66$$

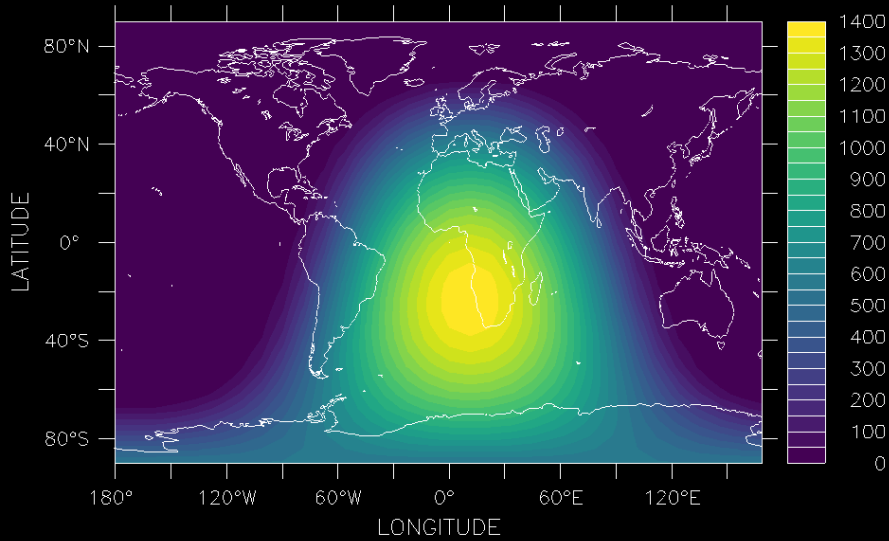
$$\epsilon_{\nu}(z_1, z_2) = \exp \left[-\mu \int_{z_1}^{z_2} k_{\nu}(P, T) \rho dz \right]$$

$$F(z)^\uparrow = B_{\nu}(T_s) \epsilon(0, z) + \int_0^z k_{\nu} \rho B_{\nu}(T(z')) \epsilon(z', z) dz'$$

$$F(z)^\uparrow = B_{\nu}(T_s) \epsilon(0, z) + \int_0^z B_{\nu}(T(z')) \frac{\partial \epsilon(z', z)}{\partial z'} dz'$$

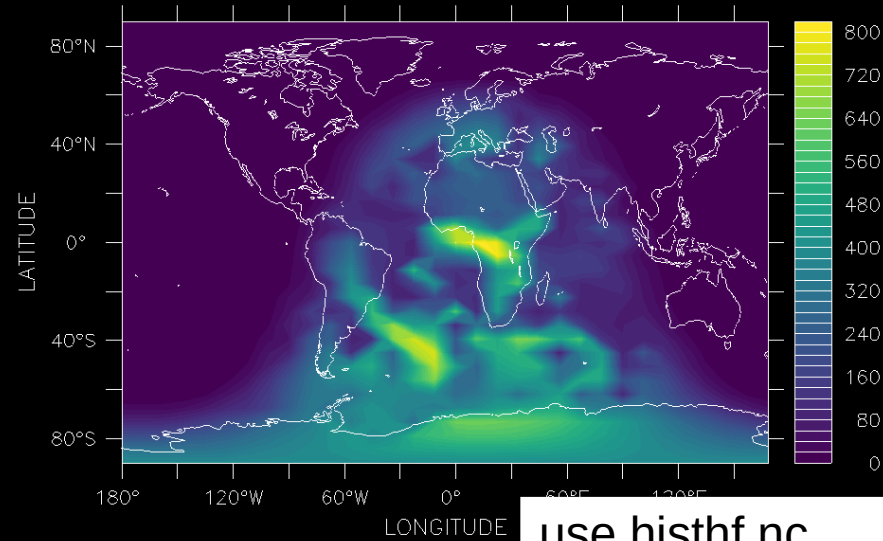
$$Q = \frac{\partial T}{\partial z} = \frac{1}{\rho C_p} \frac{\partial F(z)^\uparrow}{\partial z}$$

TIME : 03-JAN-1980 11:00 360_DAY DATA SET: histhf



SWdn at TOA (W/m2)

TIME : 03-JAN-1980 11:00 360_DAY DATA SET: histhf



SWup at TOA (W/m2)

use histhf.nc

reg/l=30

set v ul ; fill swdntoa ; go land

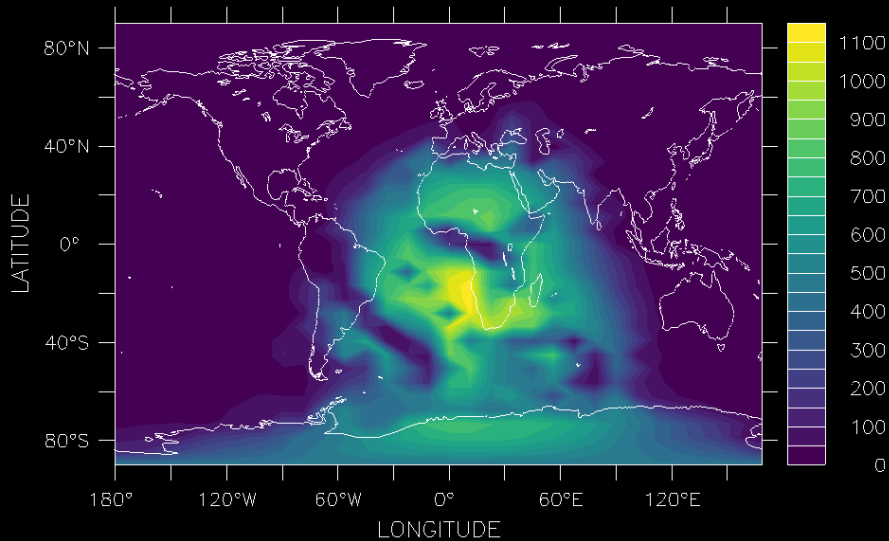
set v ur ; fill swuptoa ; go

land

set v ll ; fill swdnsfc ; go land

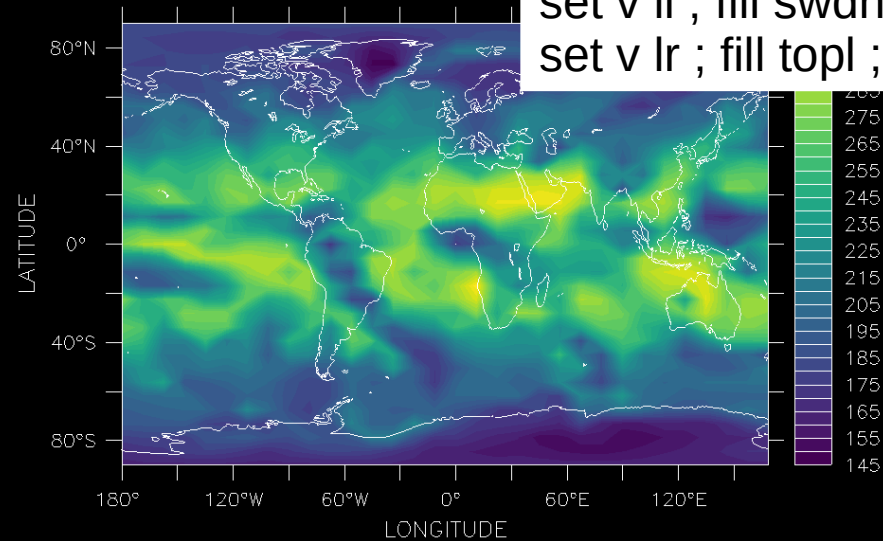
set v lr ; fill topl ; go land

TIME : 03-JAN-1980 11:00 360_DAY DATA SET: histhf

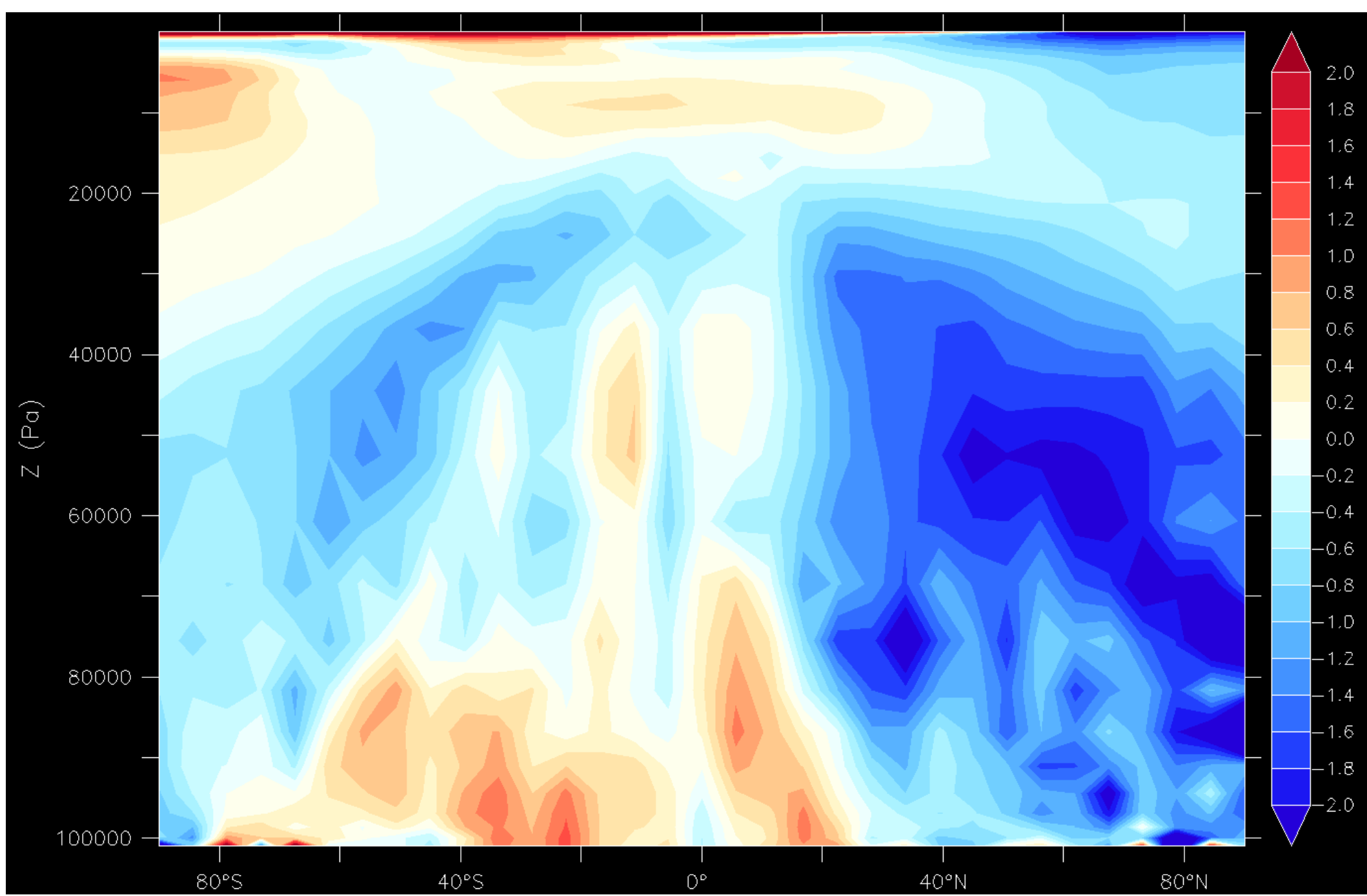


SWdn at surface (W/m2)

TIME : 03-JAN-1980 11:00 360_DAY DATA SET: histhf

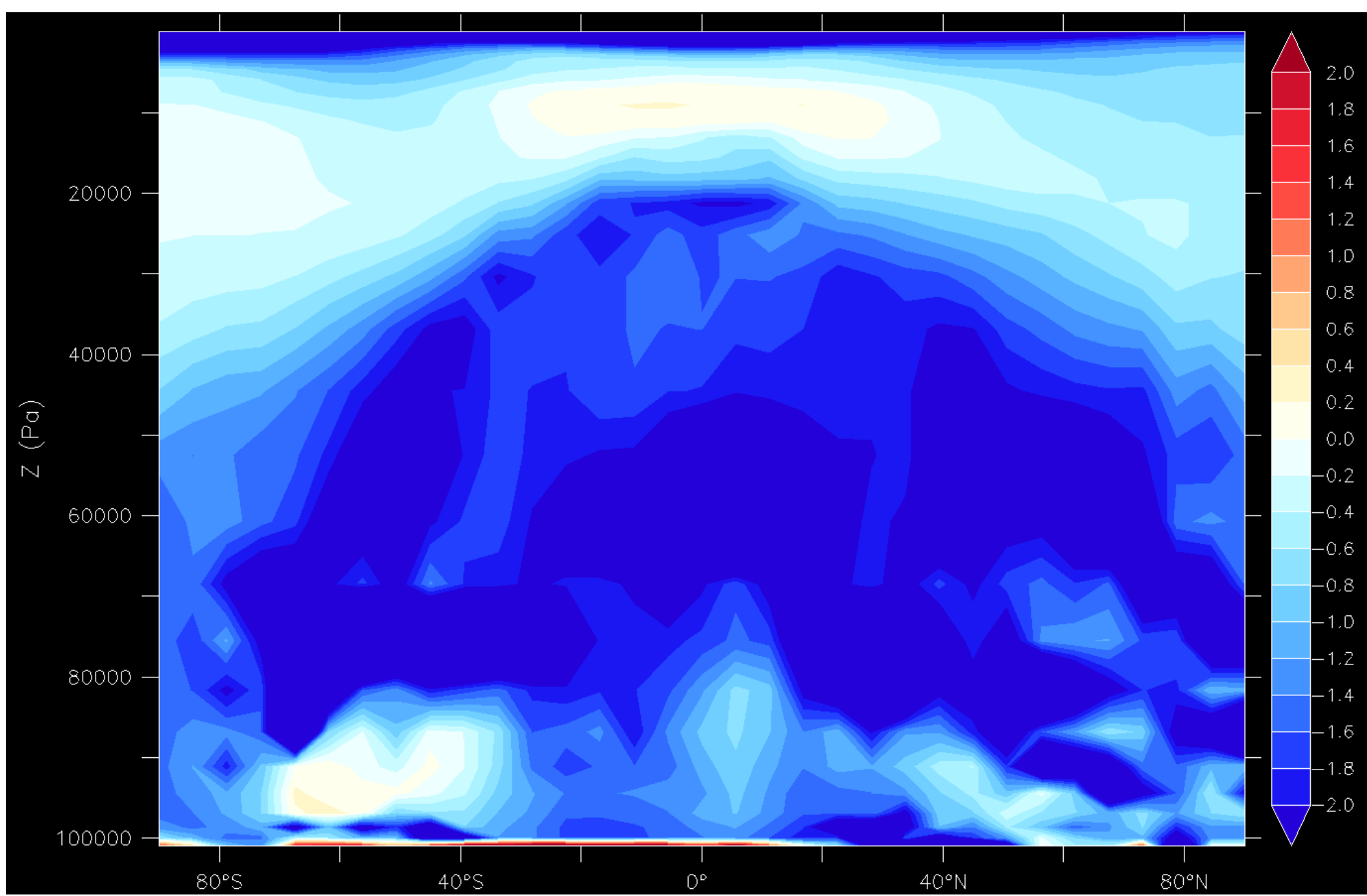


IR rad. at TOA (W/m2)



fill/lev=(-Inf)(-2,2,0.2)(Inf)/pal=blue_darkred 86400*Dtphys[l=25:36@ave,i=@ave]

86400*DTPHY[L=25:36@AVE,I=@AVE]



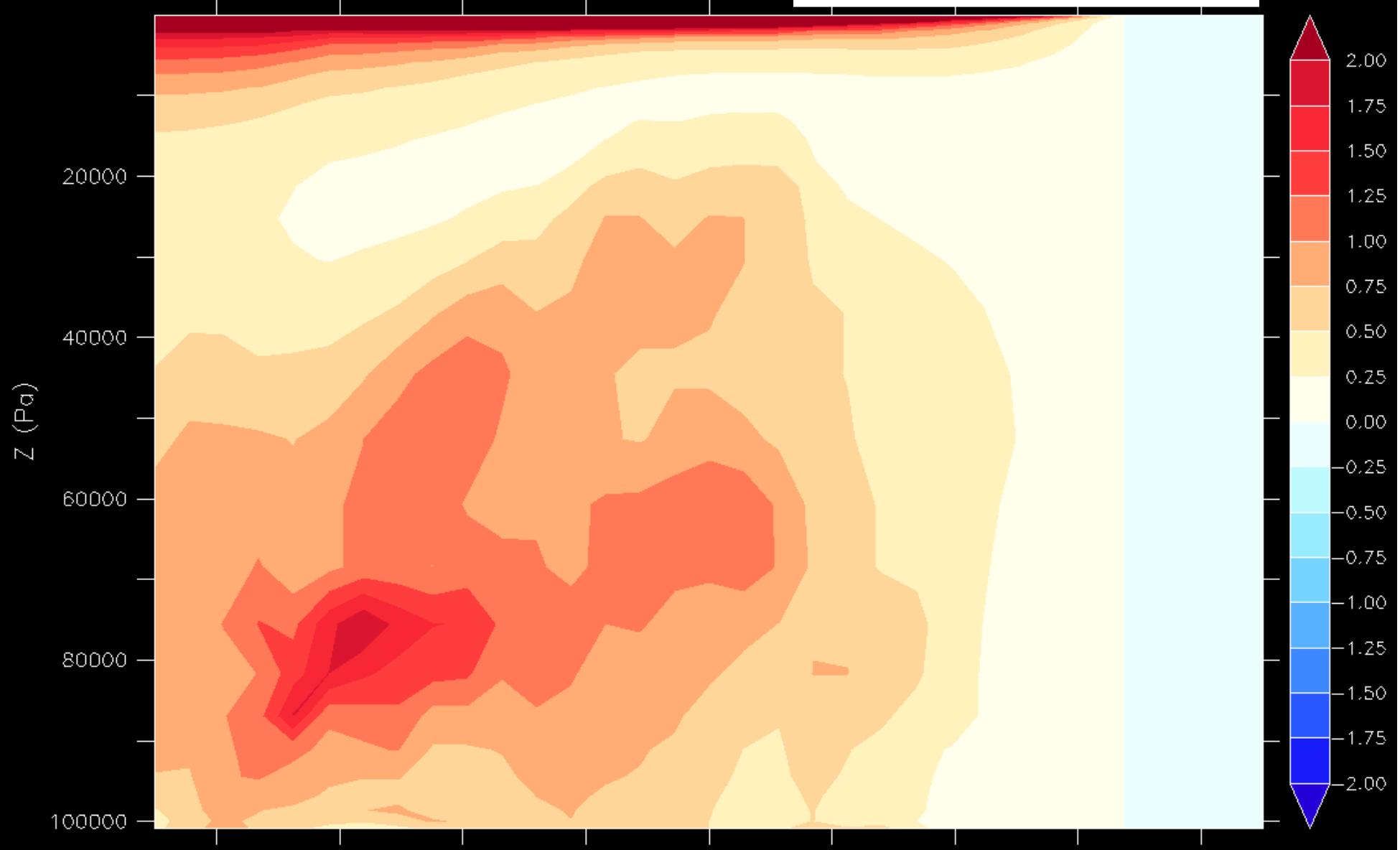
fill/lev=(-Inf)(-2,2,0.2)(Inf)/pal=blue_darkred 86400*dtlwr[l=25:36@ave,i=@ave]

86400*DTLWR[L=25:36@AVE,I=@AVE]

LONGITUDE : 174.375E(-185.625) to 174.375E
TIME : 03-JAN-1980 12:00 360_DAY

DATA SET: histday

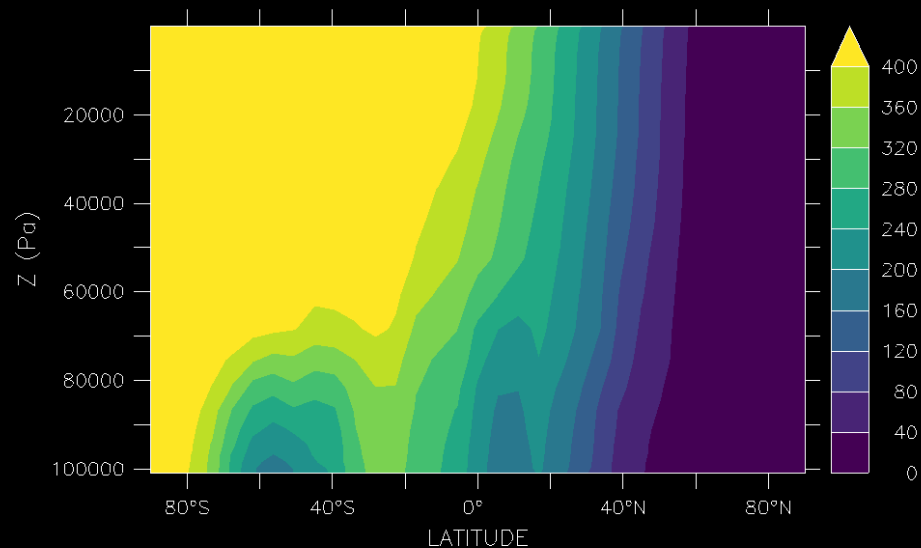
86400*dtswr[i=@ave]



fill/lev=(-Inf)(-2,2,0.2)(Inf)/pal=blue_darkred 86400*dtswr[l=25:36@ave,i=@ave]

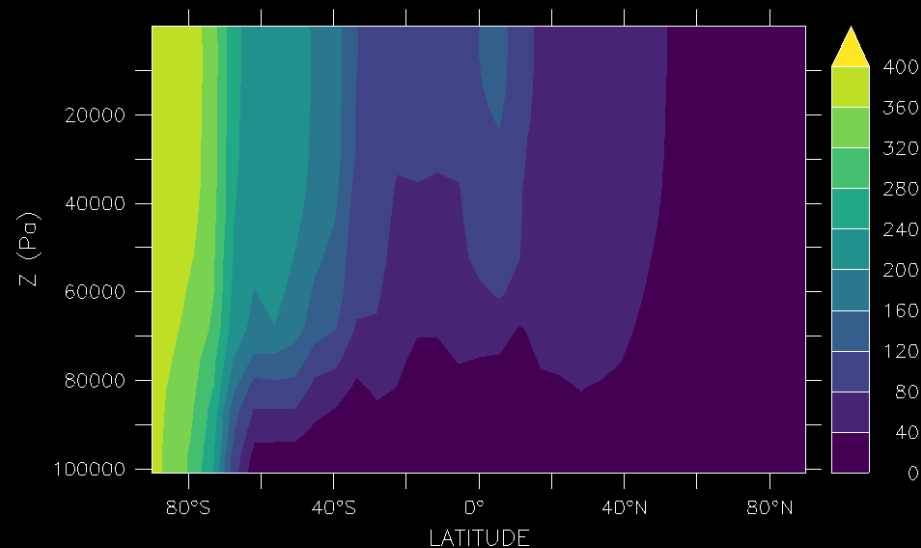
86400*DTSWR[I=@AVE]

LONGITUDE : 174.375E(-185.625) to 174.375E (averaged)
TIME : 03-JAN-1980 12:00 360_DAYDATA SET: histday



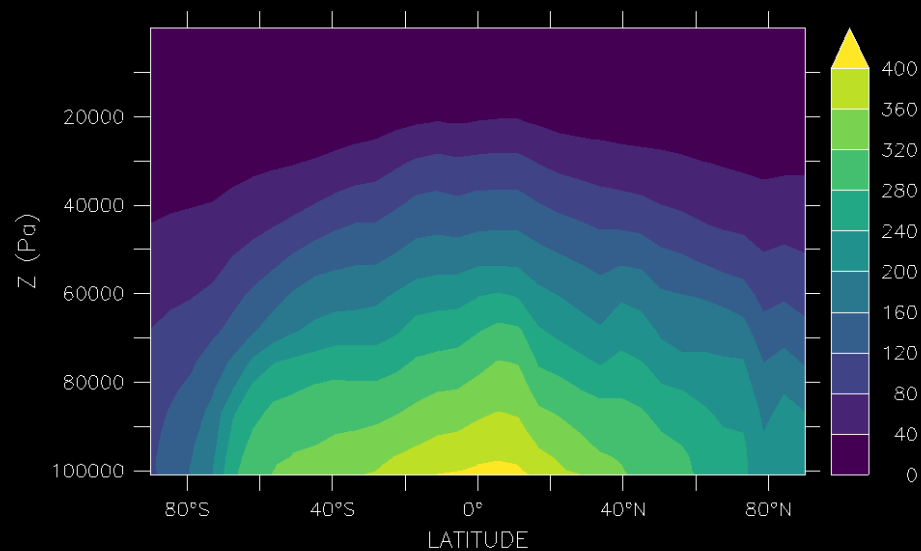
SW downward radiation (W m^{-2})

LONGITUDE : 174.375E(-185.625) to 174.375E (averaged)
TIME : 03-JAN-1980 12:00 360_DAYDATA SET: histday



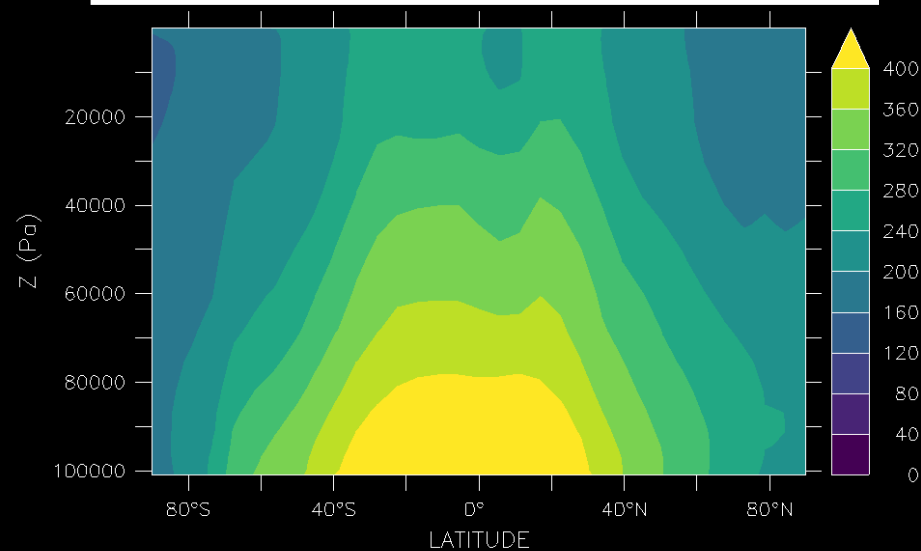
SW upward radiation (W m^{-2})

LONGITUDE : 174.375E(-185.625) to 174.375E
TIME : 03-JAN-1980 12:00 360_DAYDATA SET: histday



$-1 \times \text{RLD}[I=@\text{AVE}]$

```
set v ul ; fill/lev=(0,400,40)(Inf) rsd[i=@ave]
set v ur ; fill/lev=(0,400,40)(Inf) rsu[i=@ave]
set v ll ; fill/lev=(0,400,40)(Inf) -1*rld[i=@ave]
set v lr ; fill/lev=(0,400,40)(Inf) rlu[i=@ave]
```



LW upward radiation (W m^{-2})

Parameterization of subrid-scale motions

- Reynolds decomposition
- Turbulence
- Boundary layer convection
- Deep convection
- Subgrid-scale orography

Based on the Reynolds decomposition between

- large-scale/resolved/explicit variables (dynamical core)
- subgrid-scale/unresolved/turbulent fluctuations (parameterizations)

Reynolds decomposition

$\tilde{X}$: "average" or "large scale" variable

$\bar{X} = \tilde{\rho} \tilde{\mathbf{v}} / \tilde{\rho}$: air mass weighted "average"

$X = \tilde{X} + X'$: X' , turbulent fluctuation

$$\begin{aligned} \Rightarrow \rho \tilde{\mathbf{v}} c &= \rho (\bar{\mathbf{v}} + \widetilde{\mathbf{v}'}) (\bar{c} + c') \\ &= \tilde{\rho} \bar{\mathbf{v}} \bar{c} + \tilde{\rho} \overline{\mathbf{v}' c'} \end{aligned}$$

$$\begin{aligned} \frac{\partial \rho c}{\partial t} + \widetilde{\text{div}(\rho \mathbf{v} c)} &= 0 \quad \Rightarrow \quad \frac{\partial \tilde{\rho} \bar{c}}{\partial t} + \text{div}(\tilde{\rho} \bar{\mathbf{v}} \bar{c}) + \text{div}(\tilde{\rho} \overline{\mathbf{v}' c'}) = 0 \\ \frac{\partial \bar{c}}{\partial t} + \mathbf{\bar{v}} \cdot \mathbf{grad} \bar{c} &= -\frac{1}{\tilde{\rho}} \text{div}(\tilde{\rho} \overline{\mathbf{v}' c'}) = -\frac{1}{\tilde{\rho}} \frac{\partial \overline{\rho \mathbf{v}' c'}}{\partial z} \end{aligned}$$

Parameterization of subrid-scale motions

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$$\frac{\partial \rho c}{\partial t} + \widetilde{\text{div}(\rho \mathbf{v} c)} = 0 \quad \Rightarrow \quad \frac{\partial \tilde{\rho} \bar{c}}{\partial t} + \text{div}(\tilde{\rho} \bar{\mathbf{v}} \bar{c}) + \text{div}(\tilde{\rho} \overline{\mathbf{v}' c'}) = 0$$

$$Dq/Dt = Sq$$

$$\frac{\partial c}{\partial t} + \mathbf{v} \cdot \mathbf{grad} c = -\frac{1}{\rho} \text{div}(\rho \overline{\mathbf{v}' c'}) = -\frac{1}{\rho} \frac{\partial \overline{\rho w' c'}}{\partial z}$$

Turbulent diffusion : bases

**Boundary layer approximation (horizontal homogeneity)
+ eddy diffusion**

$$\overline{w'c'} = -K_z \frac{\partial c}{\partial z} \quad \longrightarrow \quad \frac{\partial c}{\partial t} = \frac{1}{\rho} \frac{\partial}{\partial z} \left(\rho K_z \frac{\partial c}{\partial z} \right)$$

- Analogy with molecular viscosity
(Brownian motion $\leftrightarrow$ turbulence)
- Down-gradient fluxes.
- Turbulence acts as a "mixing"

Turbulent diffusion : Mellor et Yamada

Turbulent diffusivity K_z

- Prandtl (1925) mixing length : $K_z = l|\overline{w'}|$ or $K_z = l^2 \frac{\partial ||\mathbf{v}||}{\partial z}$
- Accounting for static stability (Ex. Louis 1979)

$$K_z = f(Ri)l^2 \left| \frac{\partial \mathbf{v}}{\partial z} \right|, \text{ in } \quad \text{with } Ri = \frac{g}{\theta} \frac{\frac{\partial \theta}{\partial z}}{\left(\frac{\partial \mathbf{v}}{\partial z} \right)^2} \quad (1)$$

- Turbulent kinetic energy $\overline{w'^2} \simeq e = \frac{1}{2} \left[\overline{u'^2} + \overline{v'^2} + \overline{w'^2} \right]$

$$\frac{\partial e}{\partial t} = -\overline{w'u'} \frac{\partial u}{\partial z} - \overline{w'v'} \frac{\partial v}{\partial z} + \frac{g}{\theta} \overline{w'\theta'} - \frac{1}{\rho} \frac{\partial \overline{w'p'}}{\partial z} - \frac{\partial \overline{w'e}}{\partial z} - \epsilon$$

In LMDZ : Mellor and Yamada (Yamada 1983 version, see also Vignon et al. publications)

Turbulent diffusion : coupling with surface

$$\frac{\partial c}{\partial t} = -\frac{1}{\rho} \frac{\partial F_c(z)}{\partial z}$$

$$F_c(z > 0) = -K_z \rho \frac{\partial c}{\partial z}$$

At surface :

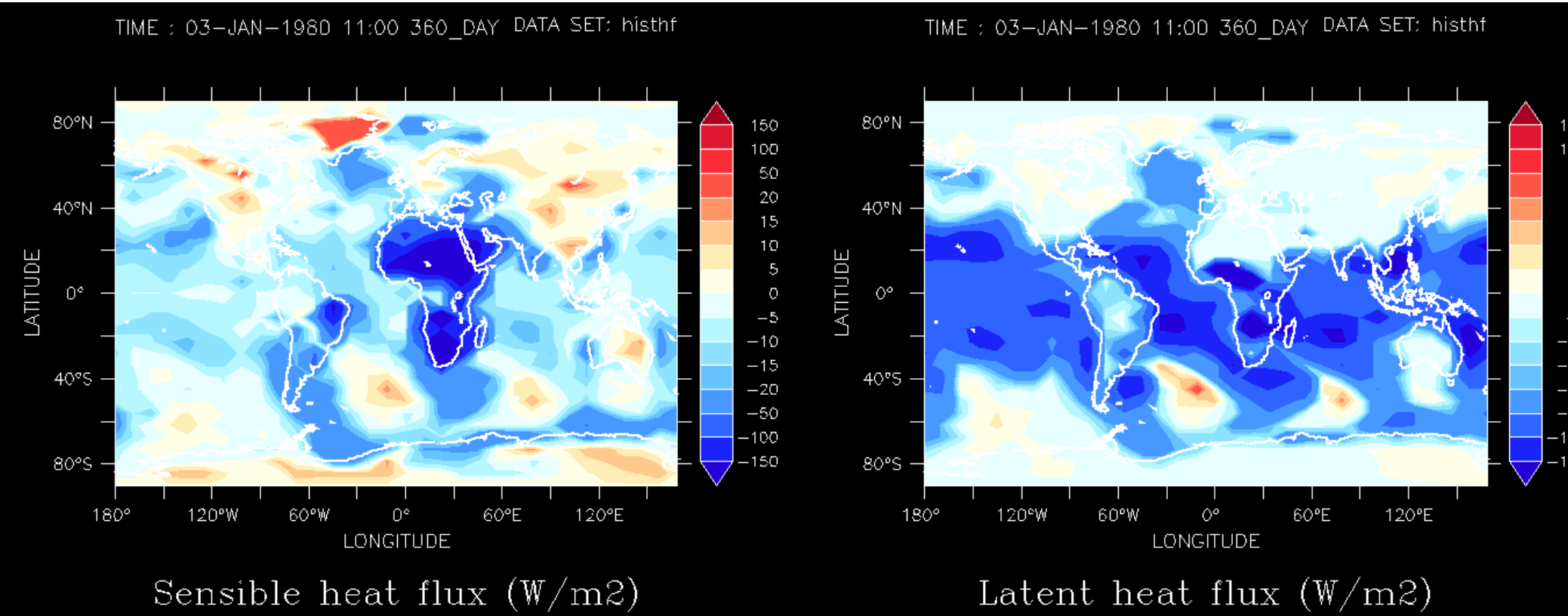
$F_c(z = 0)$: imposed or

$$F_c(z = 0) = \rho C_d ||V|| (c_s - c_1)$$

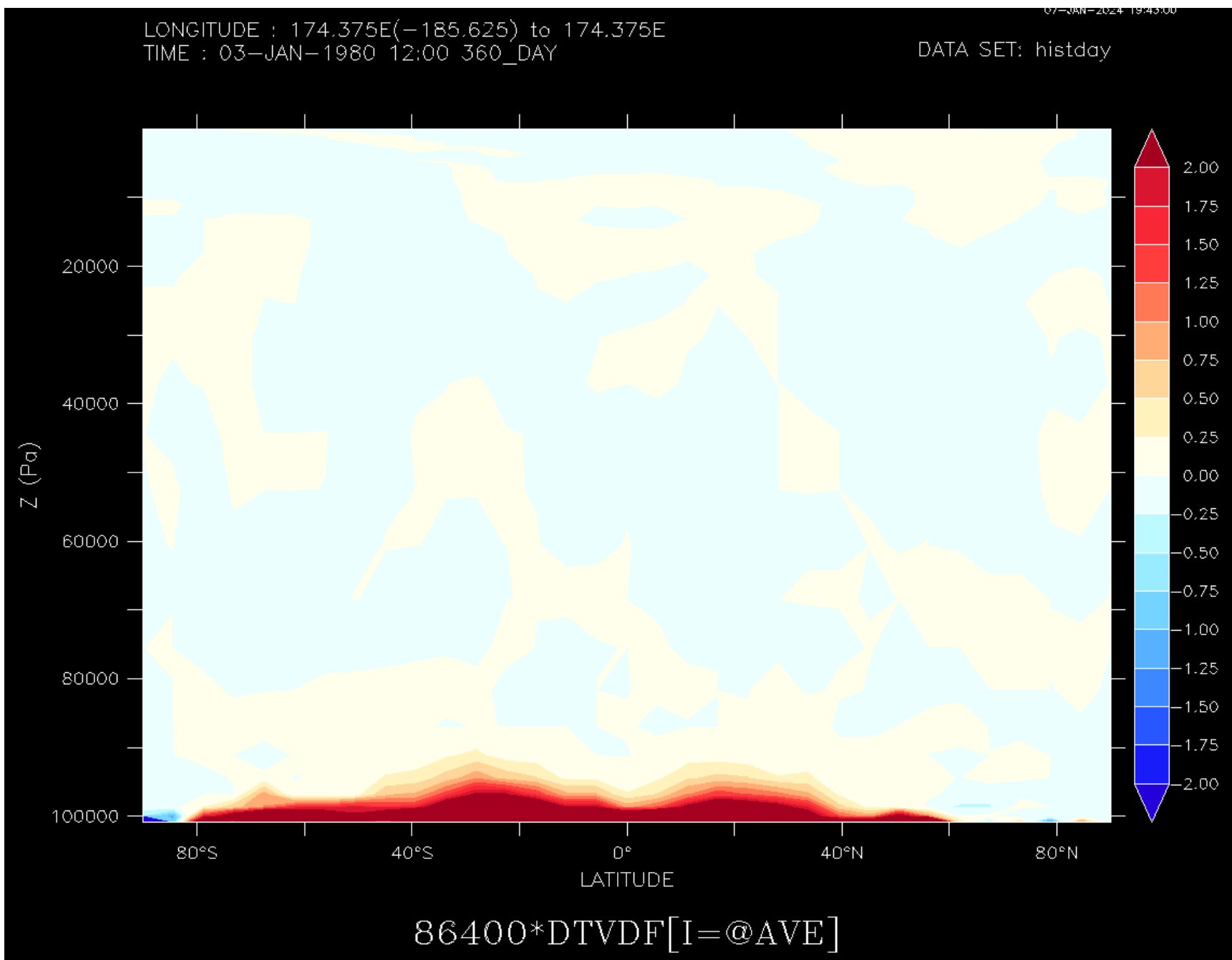
Where c_s and c_1 are values of c at the surface and in the first model layer respectively

Surface sensible heat flux : $H = \rho C_d ||V_h|| (T_s - T_1)$
Surface latent heat flux : $LE = \rho C_d ||V_h|| \beta (Q_s(T_s) - Q_1)$

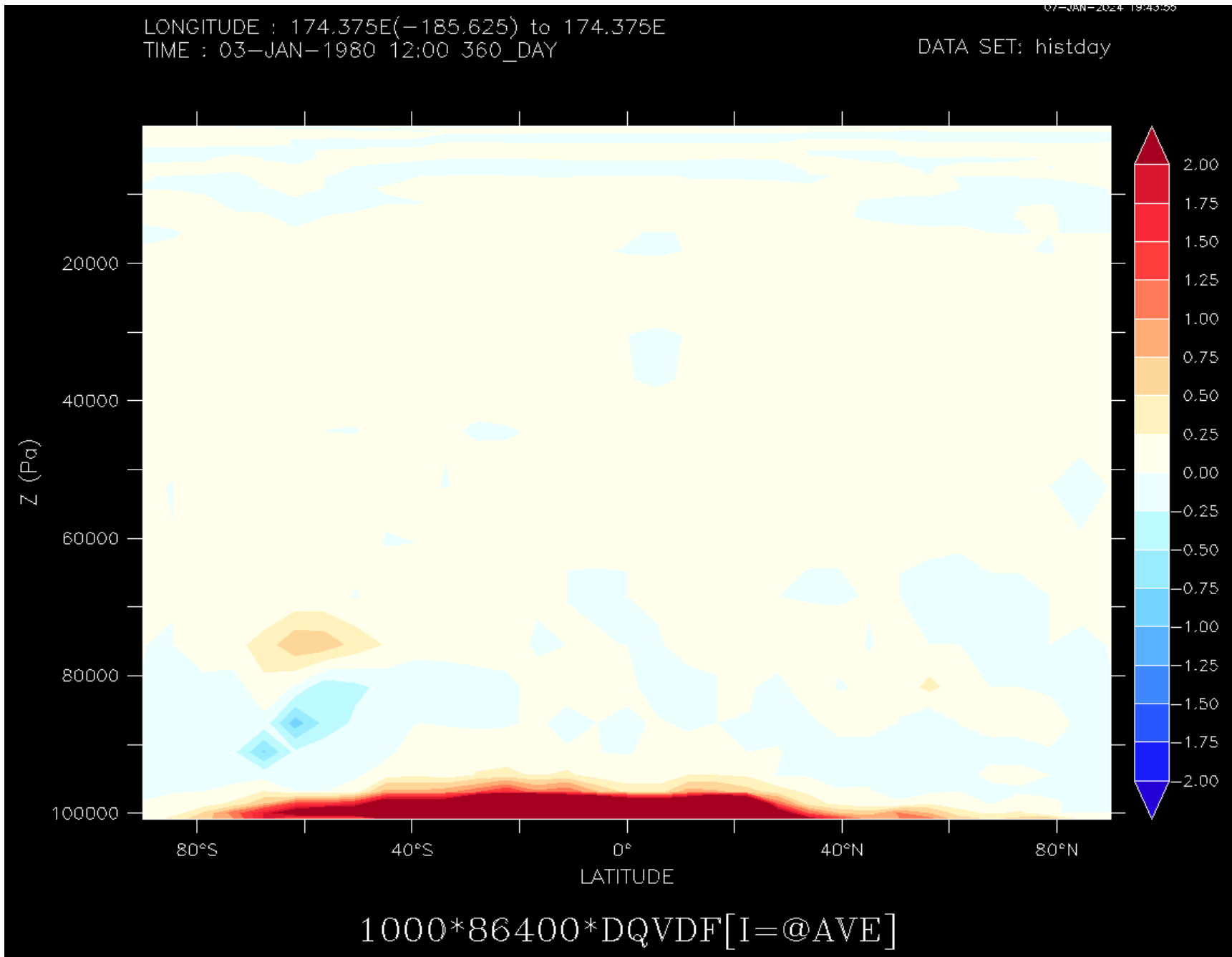
```
reg/l=30  
set v ll ; fill/lev=(-Inf)(-150,-50,50)(-20,20,5)(50,150,50)(Inf)/pal=blue_darkred sens ; go land thick  
set v lr ; fill/lev=(-Inf)(-150,-50,50)(-20,20,5)(50,150,50)(Inf)/pal=blue_darkred flat ; go land thick
```



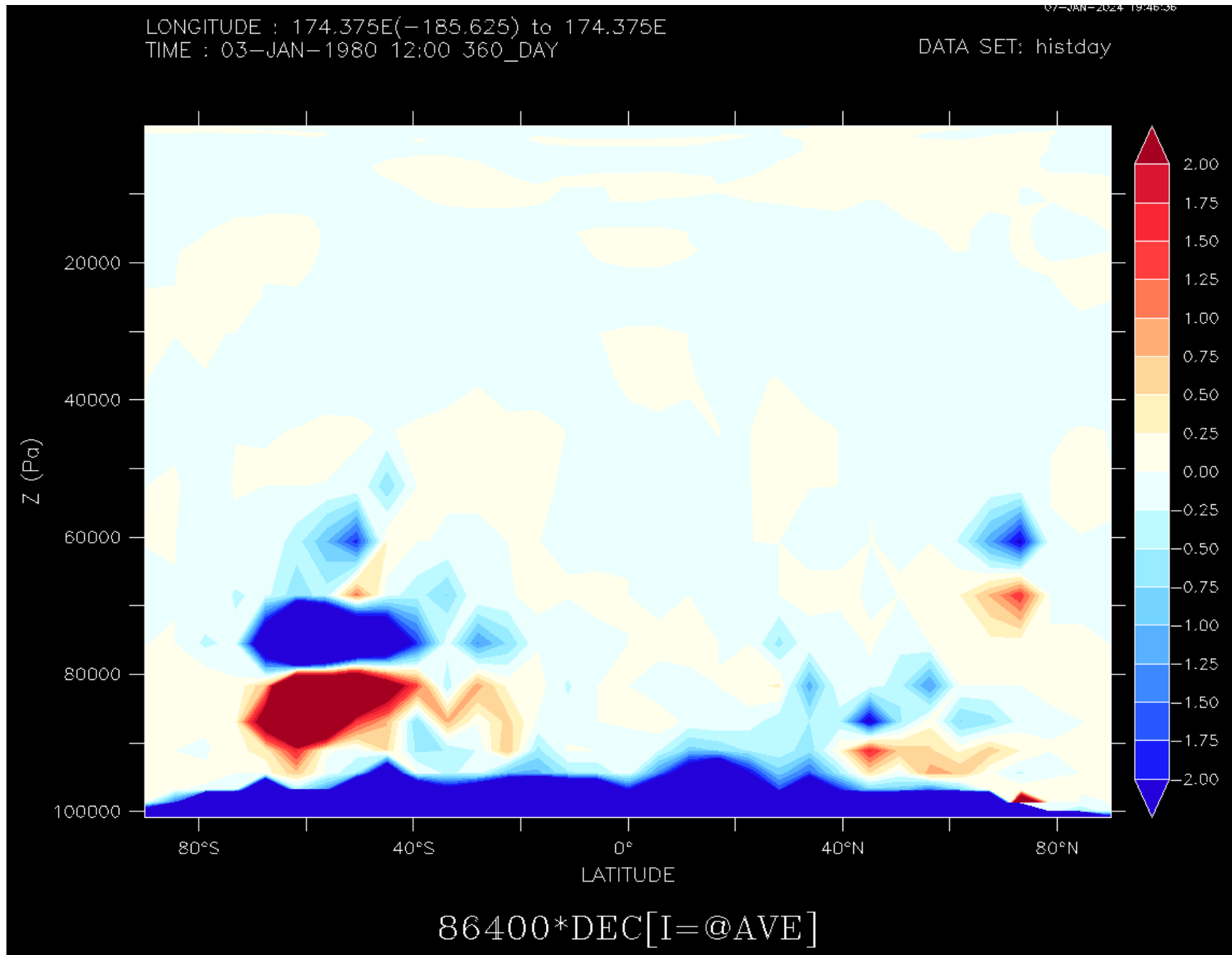
fill/lev=(-Inf)(-2,2,0.25)(inf)/pal=blue_darkred
86400*dtvdf[i=@ave]



fill/lev=(-Inf)(-2,2,0.25)(inf)/pal=blue_darkred
1000*86400*dqvdf[i=@ave]



```
let dec=vitu*duvdf+vitv*dvvdf  
yes? fill/lev=(-Inf)(-2,2,0.25)(inf)/pal=blue_darkred  
86400*dec[i=@ave]
```



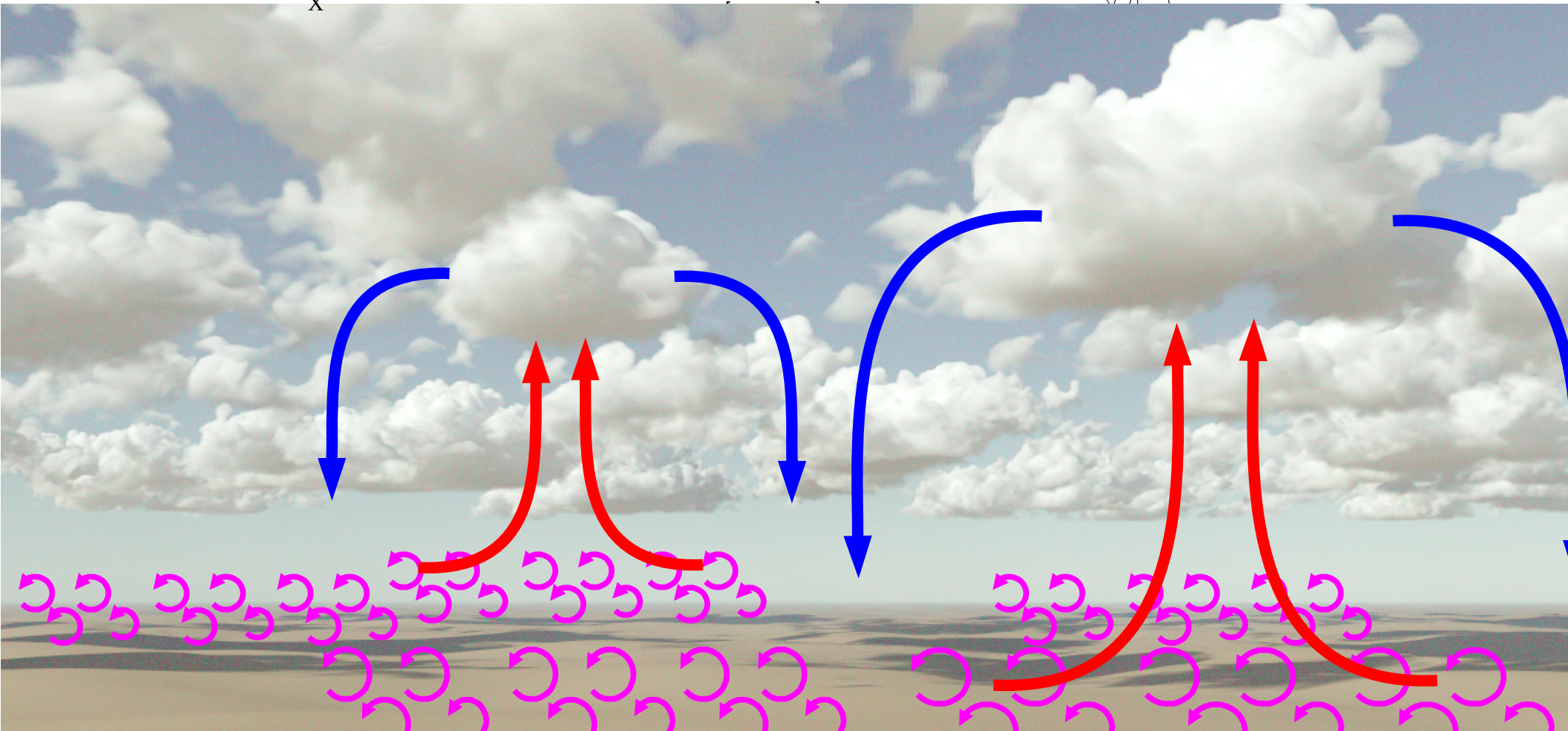
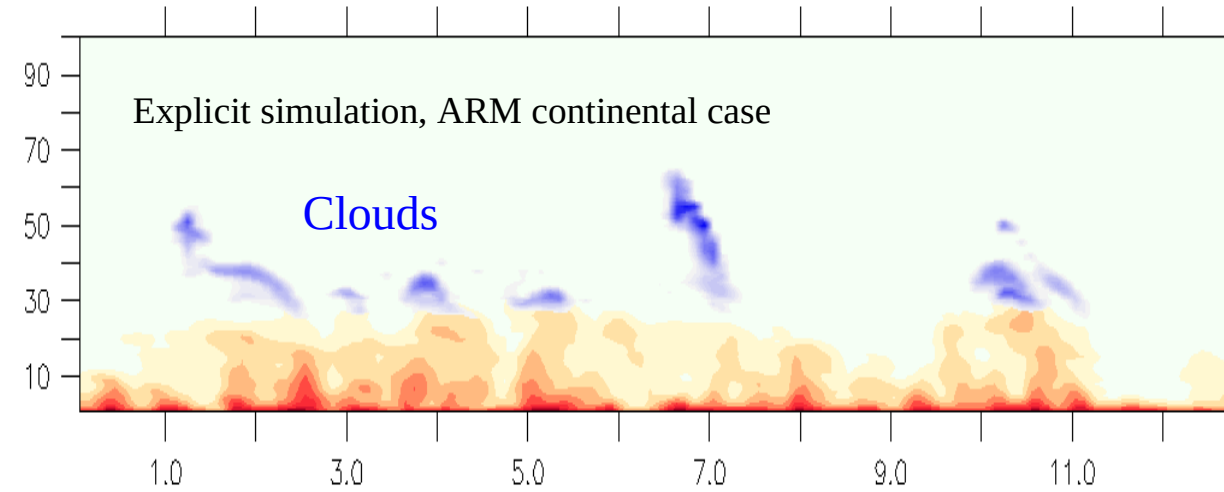
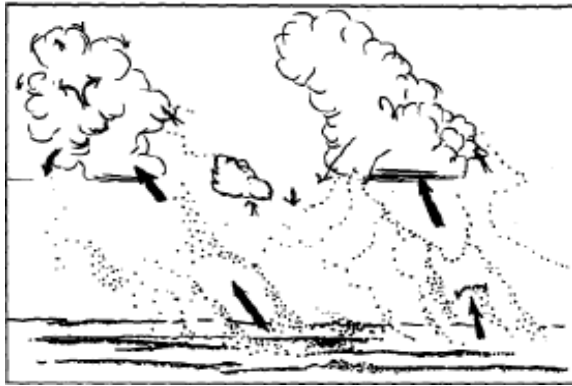
Parameterization of the convective boundary layer

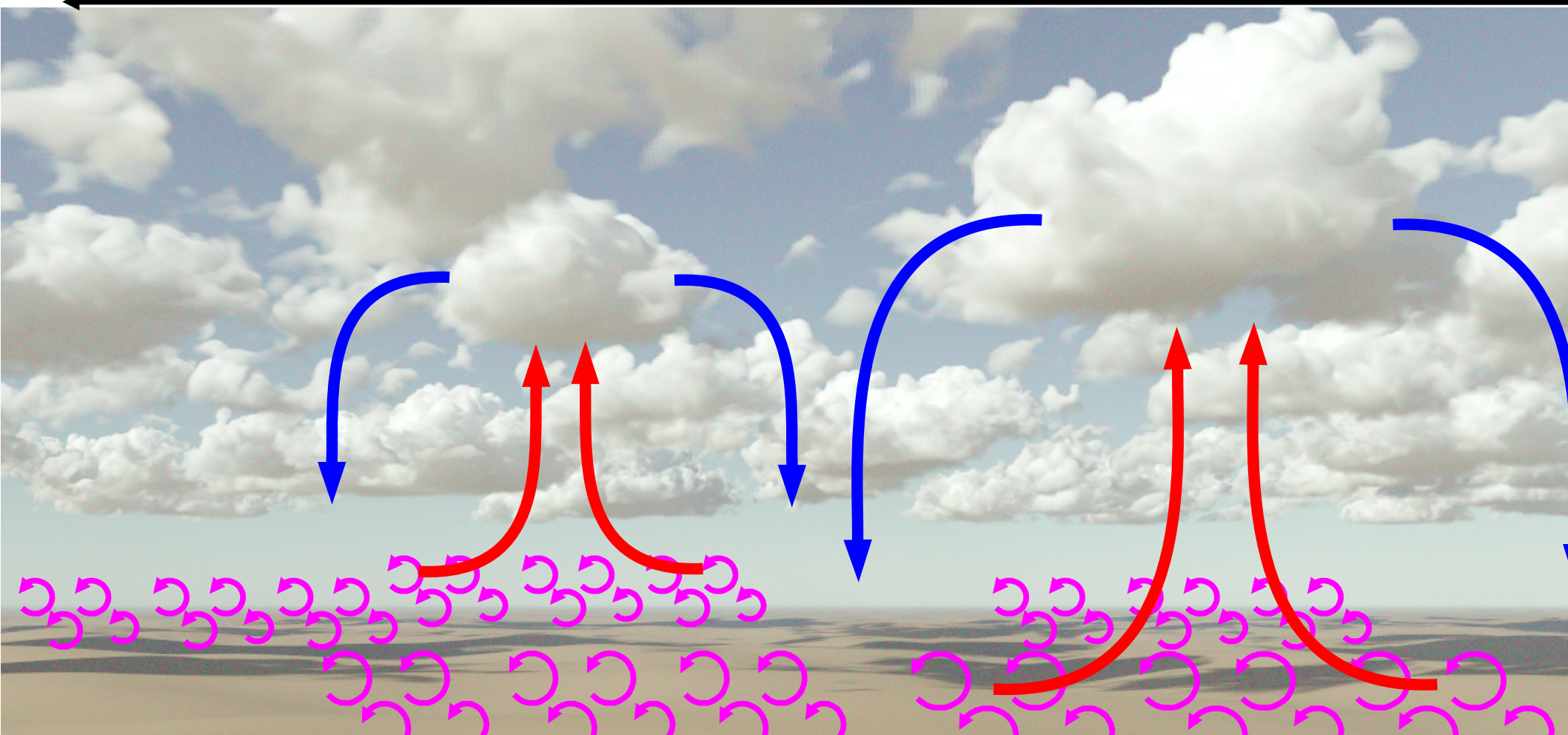
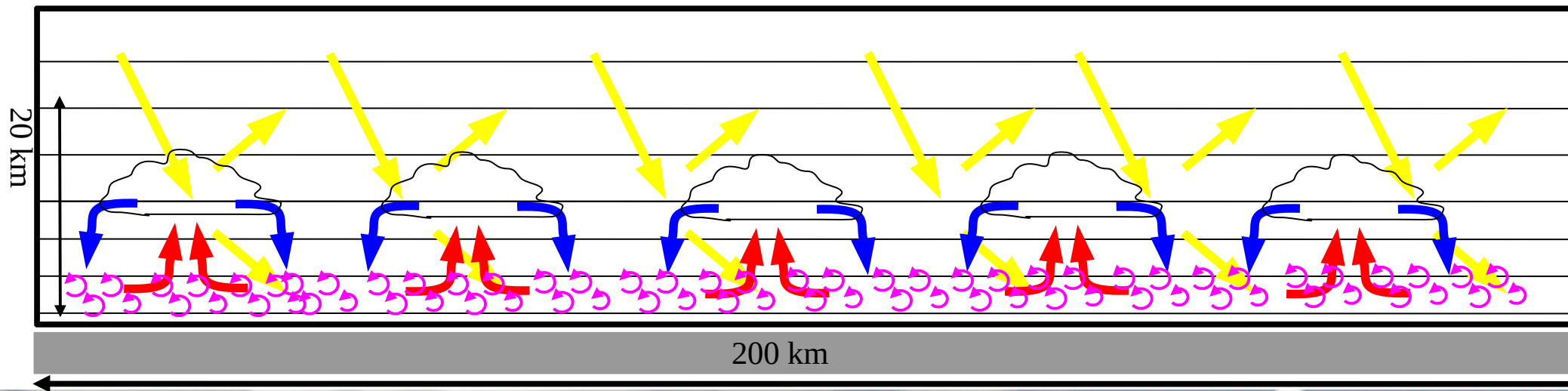
Based on high resolution explicit (LES) simulations

Movie entirely based on physics : MesoNH LES and physical rendering with htrdr (Villefranque)



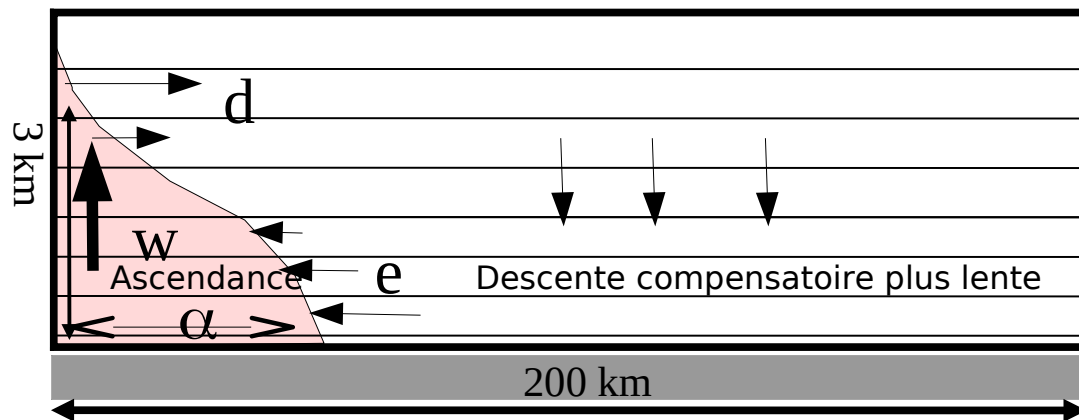
LeMone and Pennell, MWR, 1976





2. Couche limite convective

Le modèle du thermique



Variables internes de la paramétrisation :

w : vitesse moyenne des panaches ascendants

α : fraction de la surface couverte par les ascendances

e : taux d'entrée latérale d'air dans le panache (entraînement)

d : sorties d'air depuis le panache (déentraînement)

q_a : concentration du composant q dans l'ascendance

Terme source pour les équations explicites

$$S_q = -\frac{1}{\rho} \frac{\partial}{\partial z} \overline{\rho w' q'} = \frac{1}{\rho} \frac{\partial}{\partial z} \rho K_z \frac{\partial q}{\partial z} + \left(-\frac{1}{\rho} \frac{\partial}{\partial z} [\rho \alpha w (q_a - q)] \right)$$

Diffusion turbulente

Transport par le modèle de panache

4 Paramètres libres :

$$a_1 = \frac{2}{3}, \beta_1 = 0.9, b = 0.002, c = 0.012 m^{-1}, d = 0.5$$

Conservation de la masse :

$$\frac{\partial f}{\partial z} = e - d \quad \text{avec } f = \alpha \rho w$$

Conservation de la masse du composant q

$$\frac{\partial f q_a}{\partial z} = e q - d q_a$$

Equation du mouvement

$$\frac{\partial f w}{\partial z} = -d w + \alpha \rho B$$

et la poussée d'Archimède

$$B = g \frac{\theta_{va} - \theta_v}{\theta_v}$$

$$e = f \max(0, \frac{\beta_1}{1 + \beta_1} (a_1 \frac{B}{w^2} - b))$$

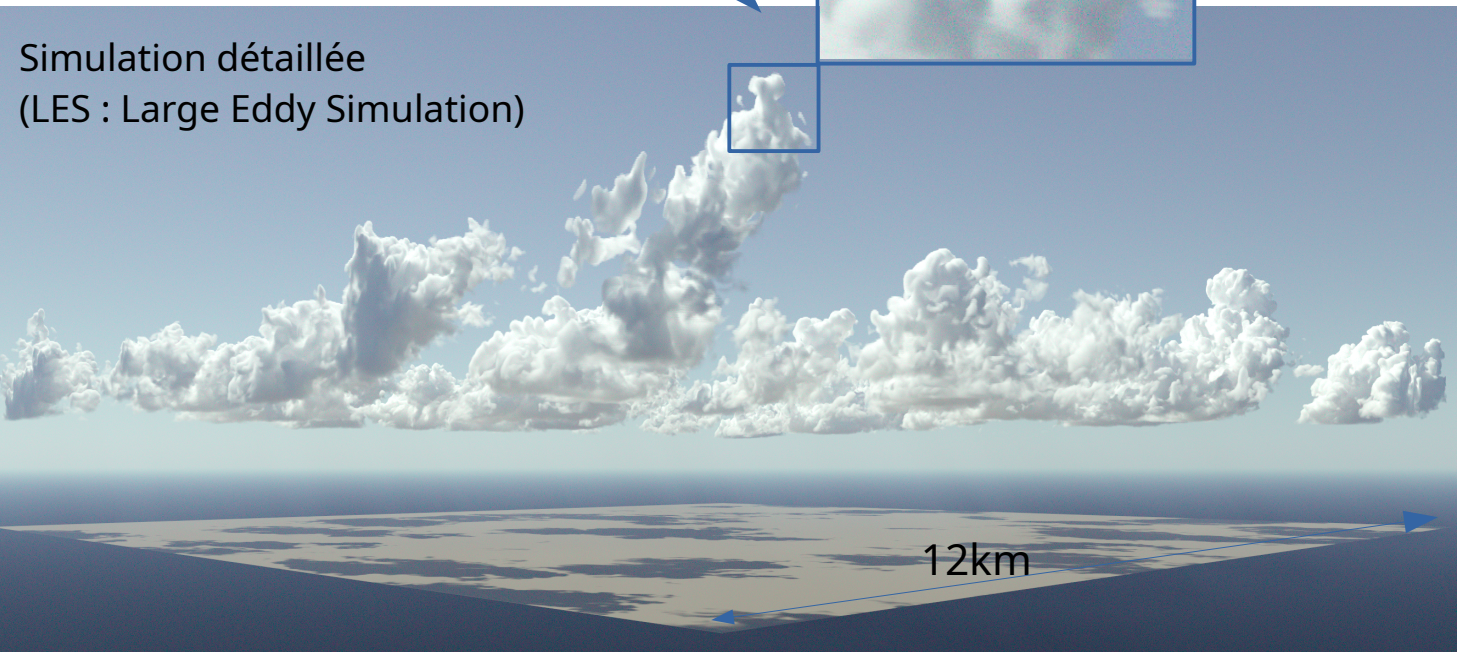
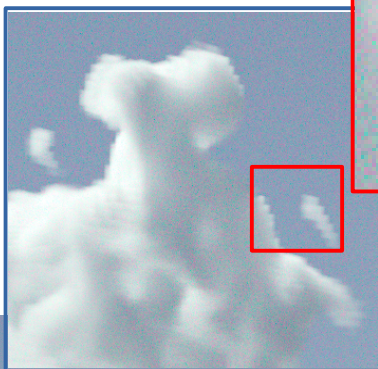
$$d = f \max(0, -\frac{a_1 \beta_1}{1 + \beta_1} \frac{B}{w^2} + c (\frac{(q_a - q)/q_a}{w^2})^d)$$

Etc ...

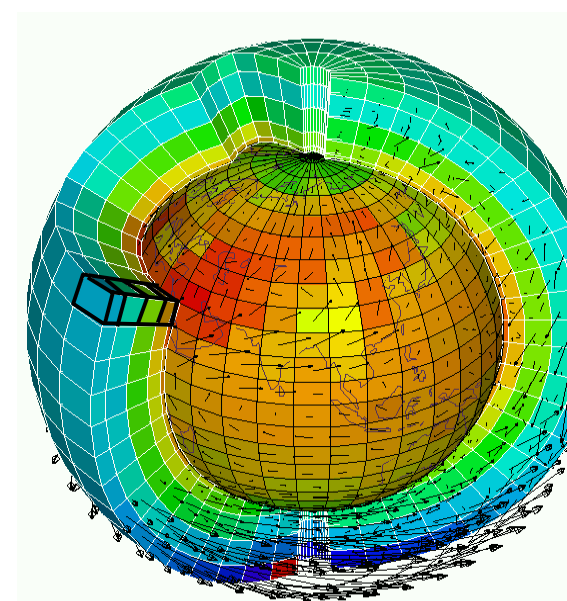


Campagne d'observation

Evaluation



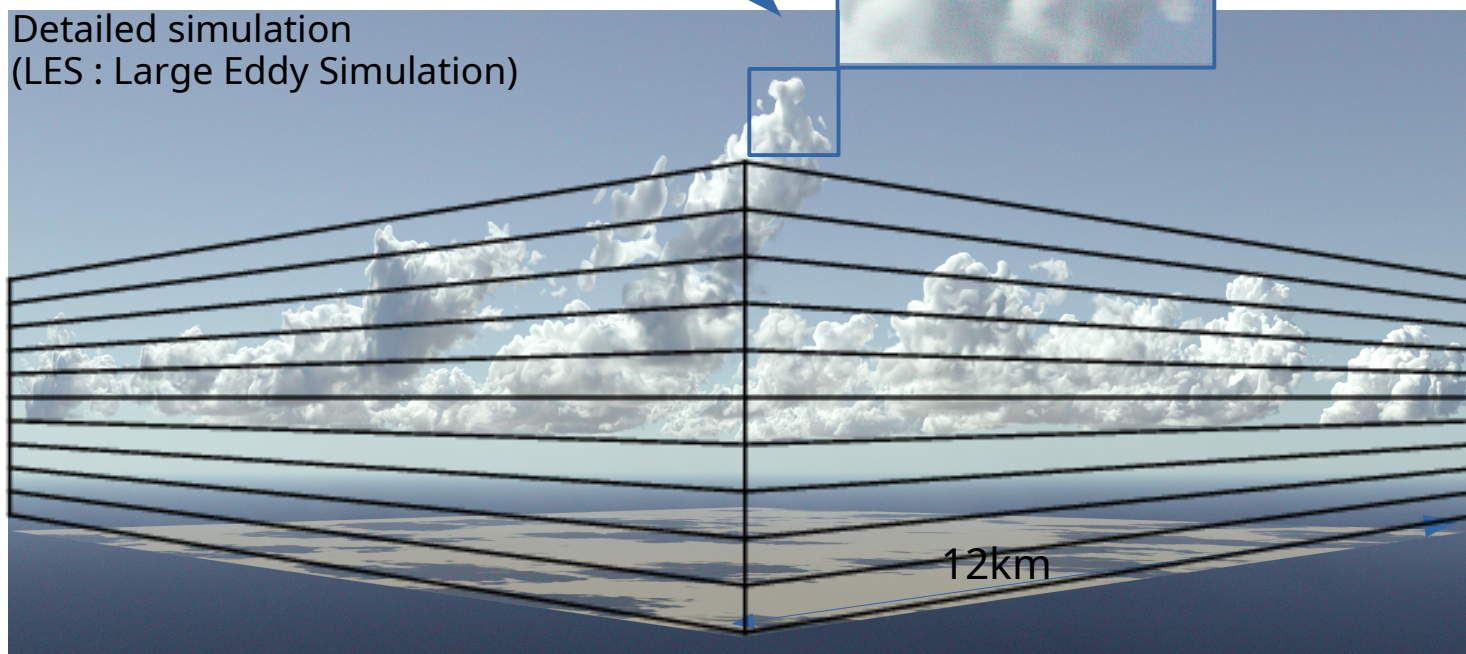
Simulation détaillée
(LES : Large Eddy Simulation)



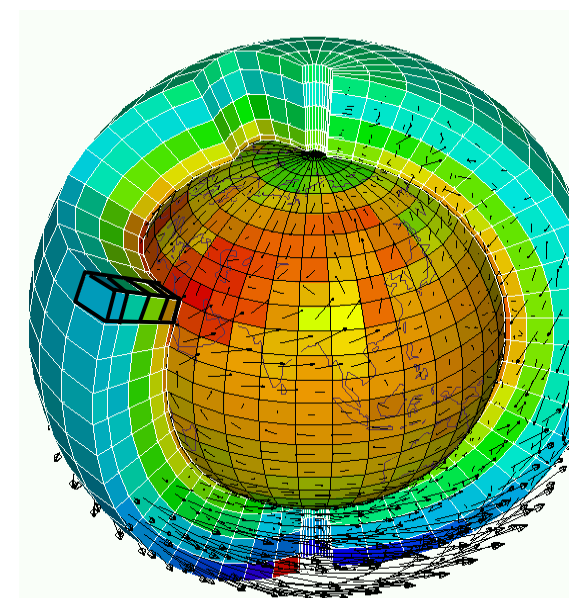
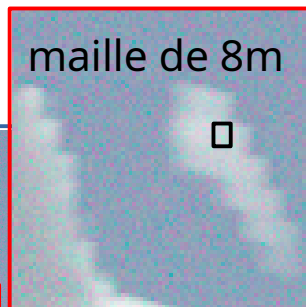
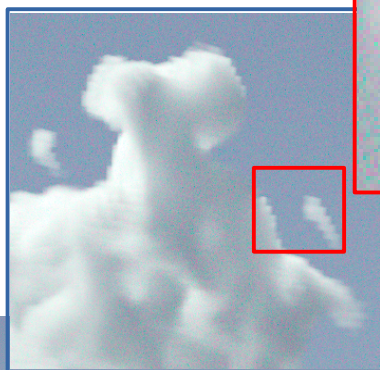


Field campaign experiment

Detailed simulation
(LES : Large Eddy Simulation)



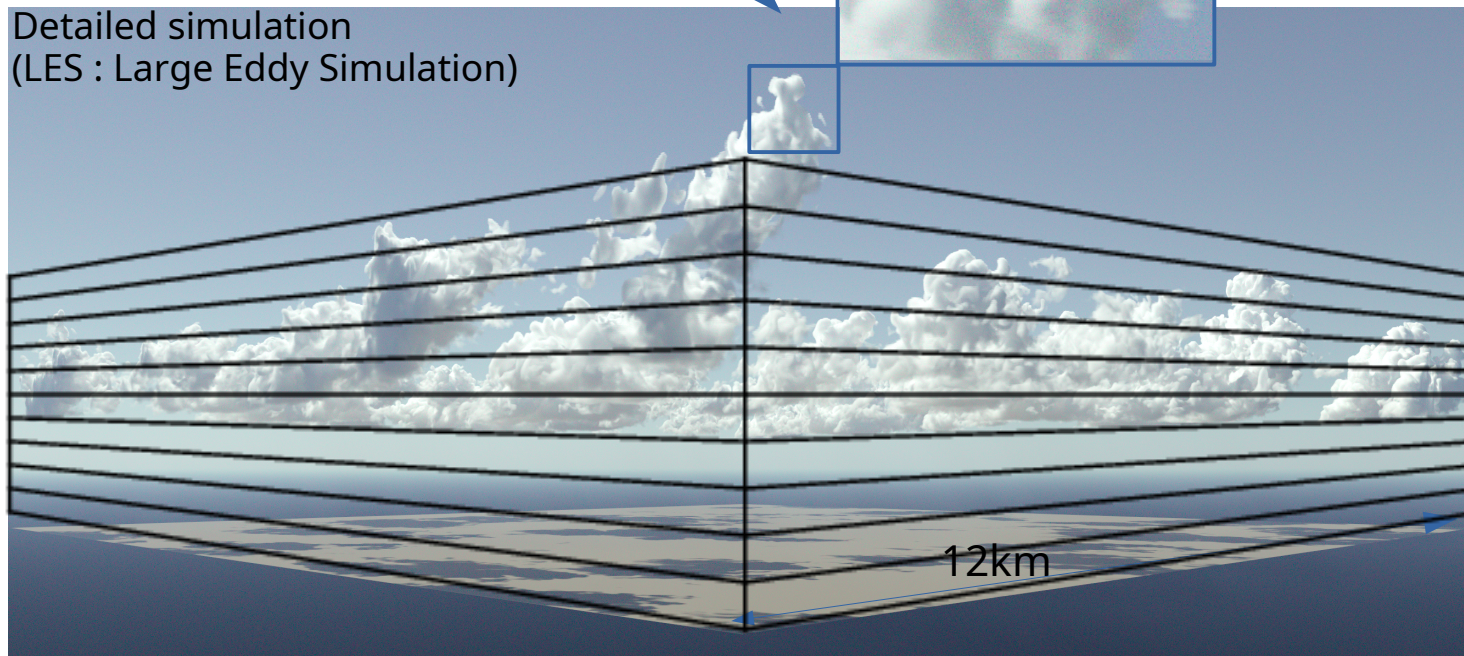
Evaluation



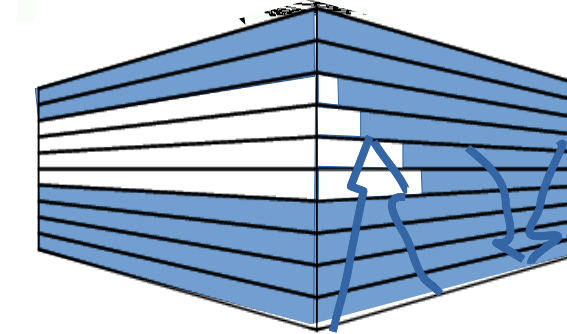
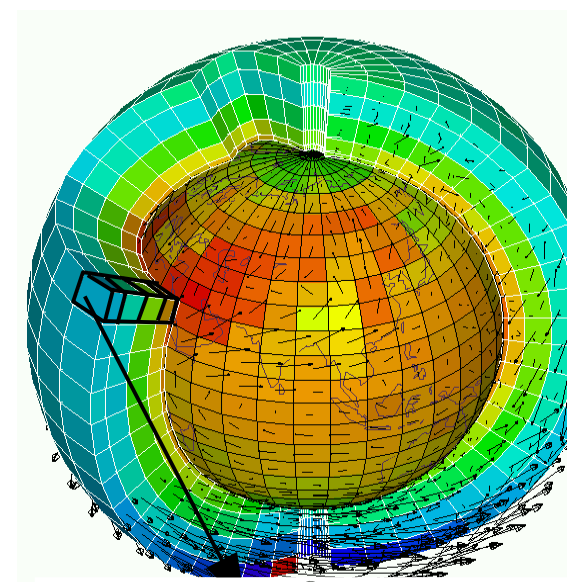
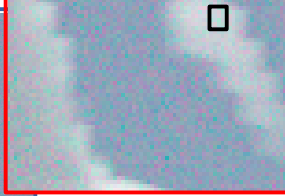


Field campaign experiment

Detailed simulation
(LES : Large Eddy Simulation)



maille de 8m

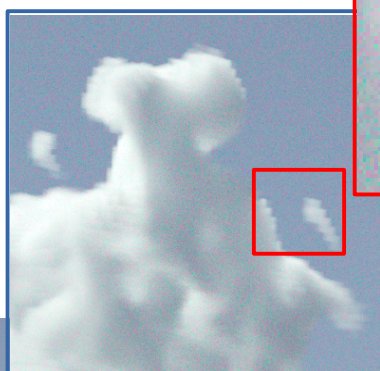


**Building a model of a
convective plume and
associated clouds.
Trying to represent an
idealized mean cloud**

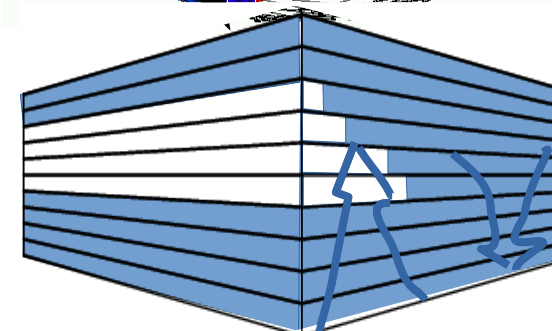
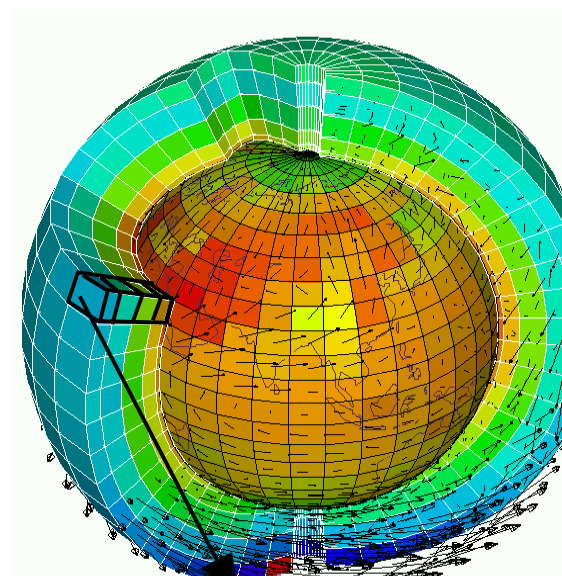
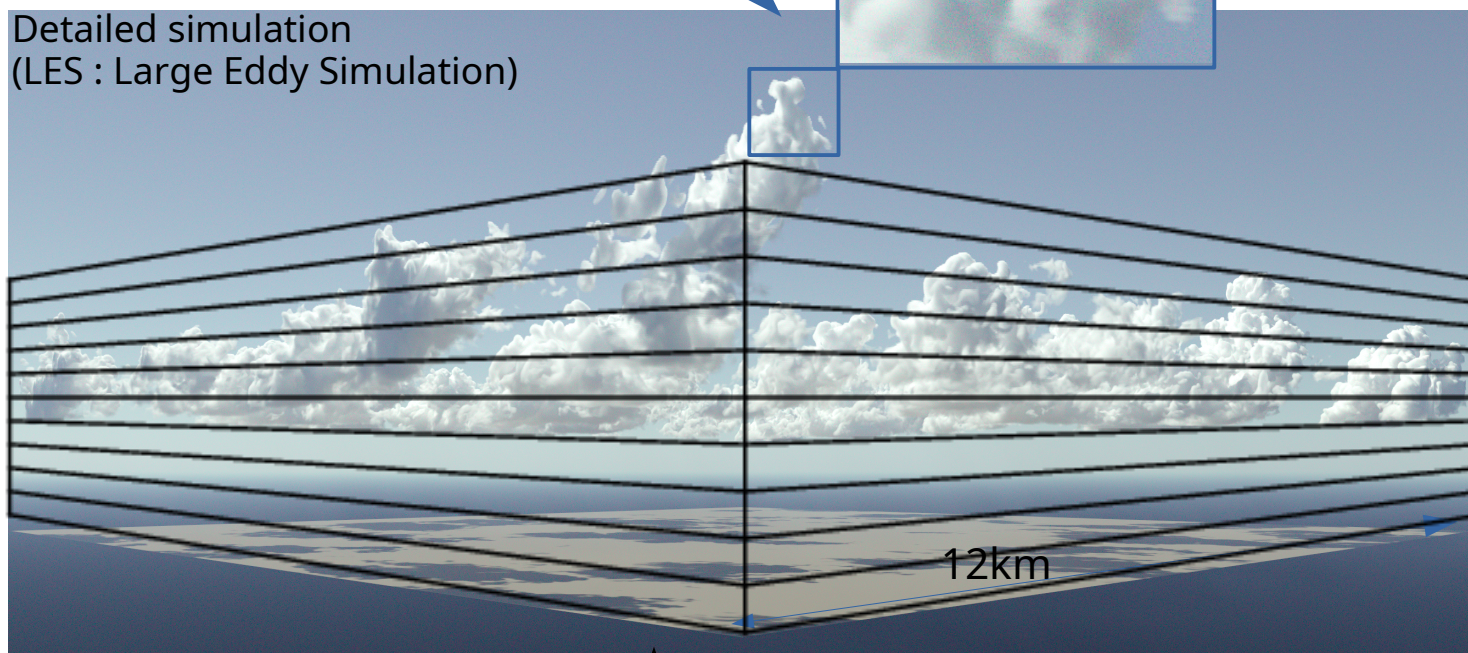


Field campaign experiment

Evaluation

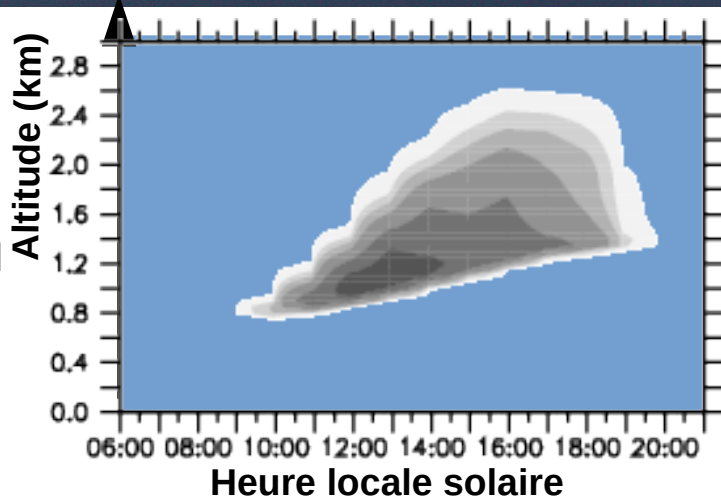


Detailed simulation
(LES : Large Eddy Simulation)

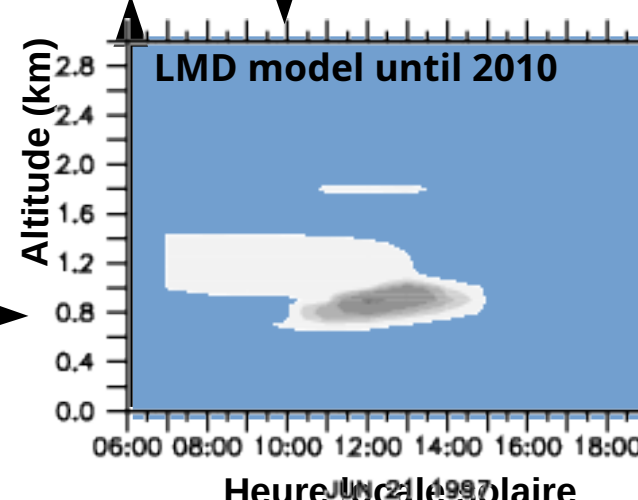


Computing the cloud fraction for each cell in one column GCM

Computing at each altitude the fraction of the horizontal domain covered by clouds.
Also called :
the cloud fraction



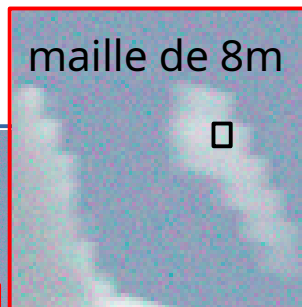
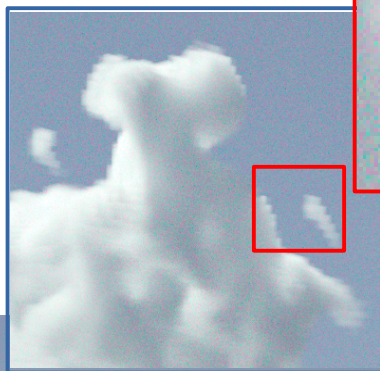
Evaluation



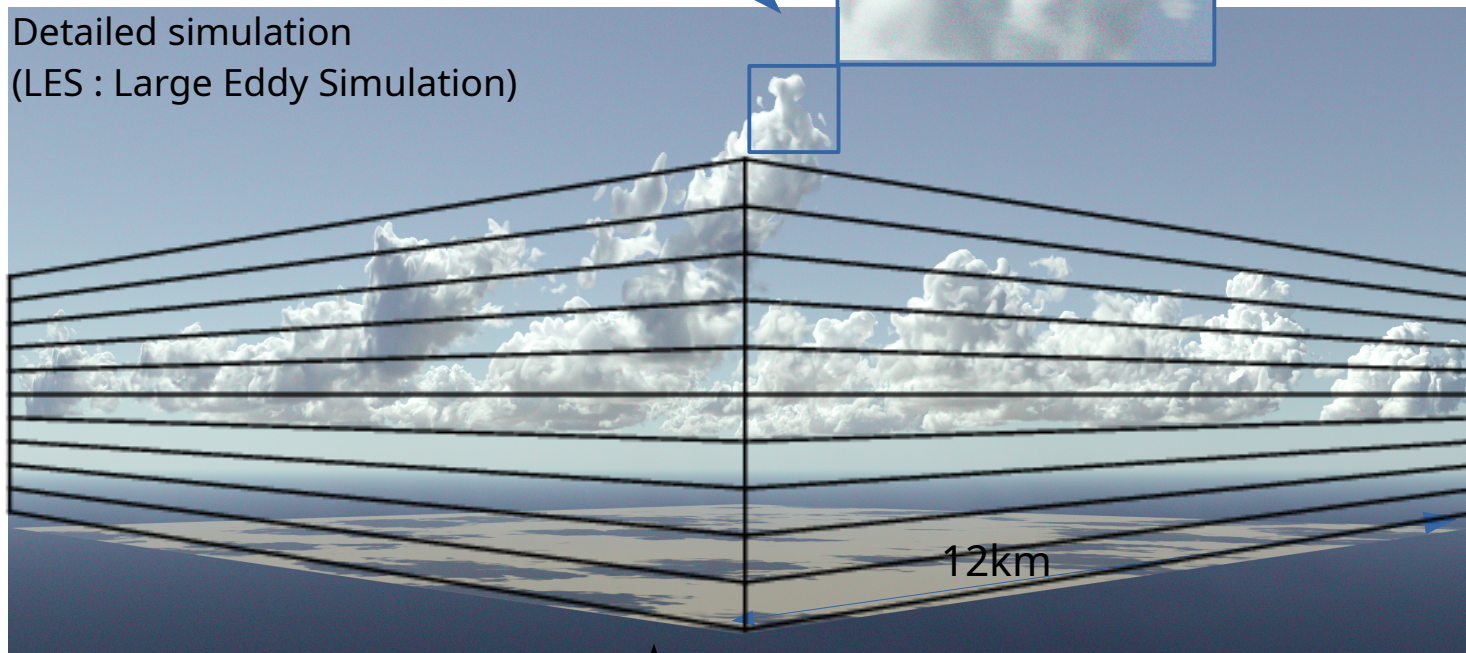
JUN 21 1997



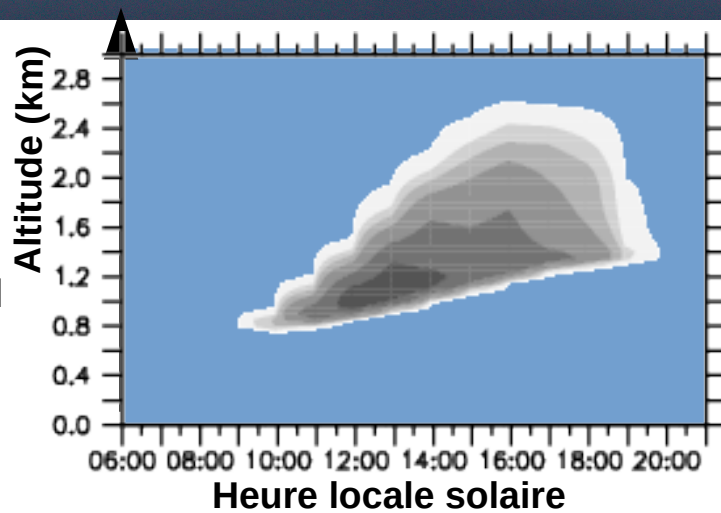
Evaluation



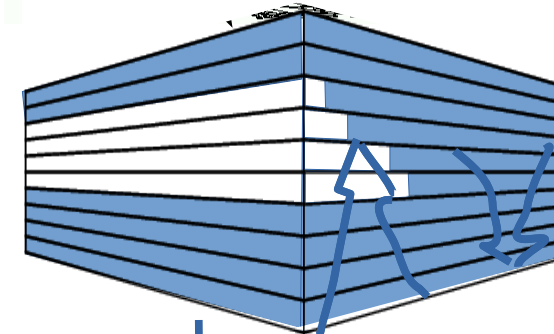
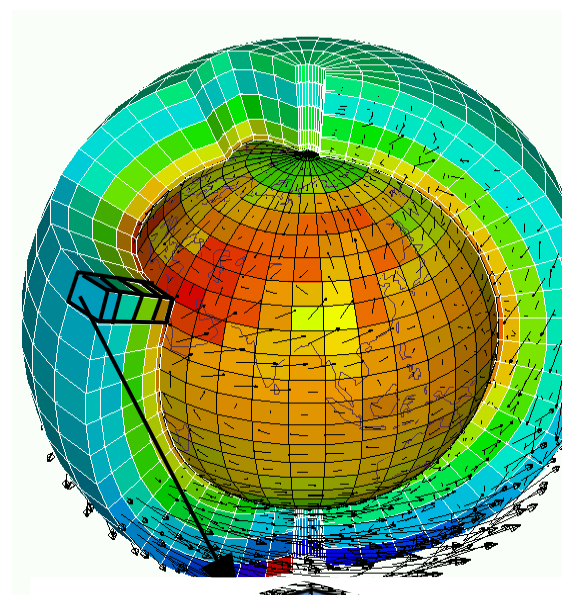
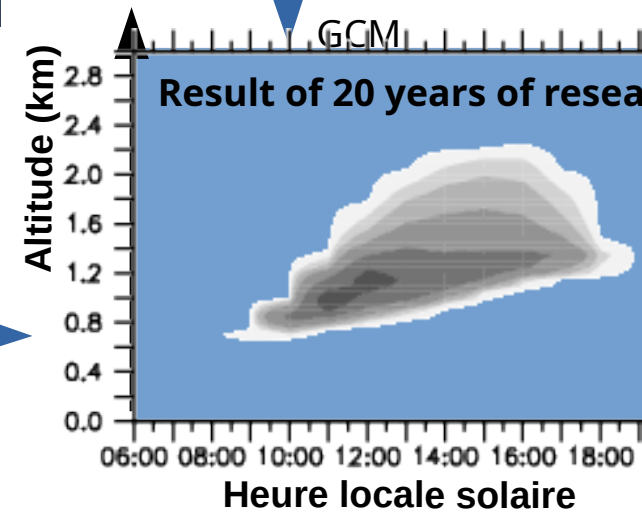
Detailed simulation
(LES : Large Eddy Simulation)



Computing at each altitude the fraction of the horizontal domain covered by clouds.
Also called :
the cloud fraction



Evaluation

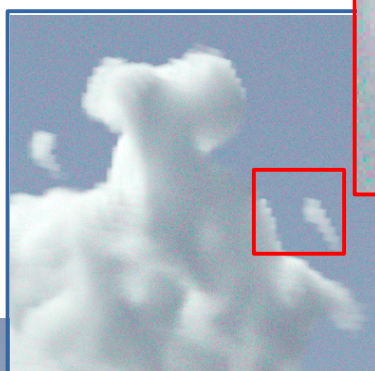


Computing the cloud fraction for each cell in one column
GCM

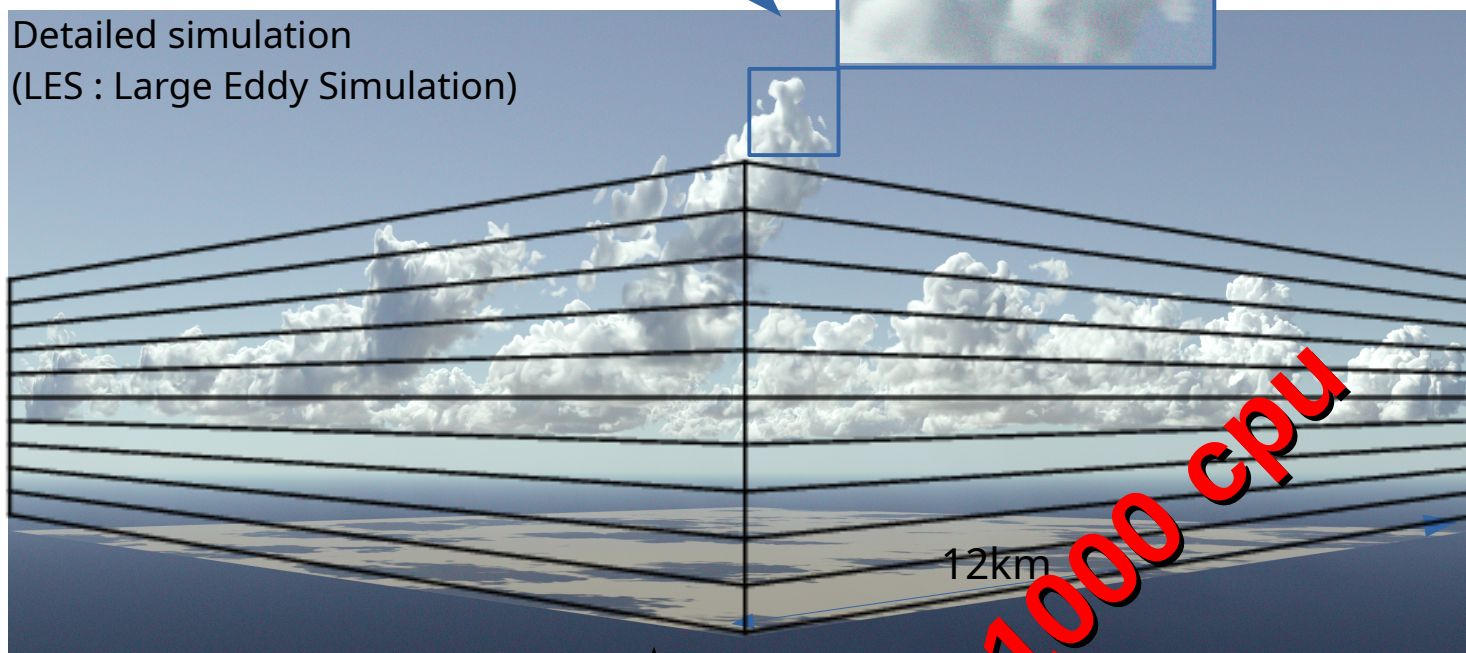


Field campaign experiment

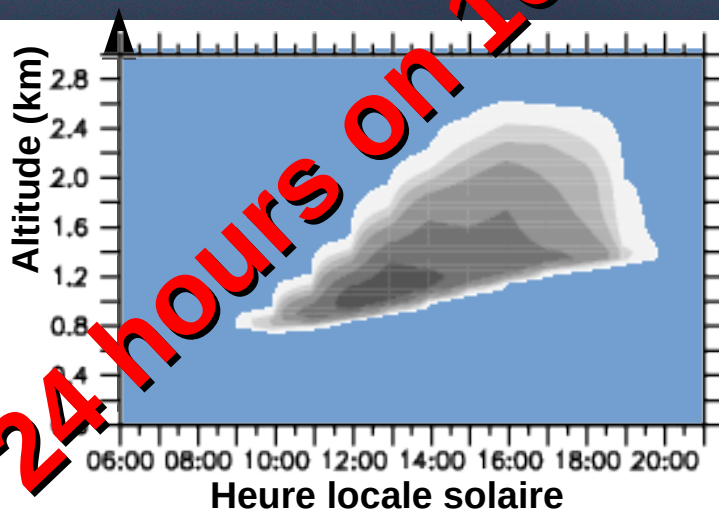
Evaluation



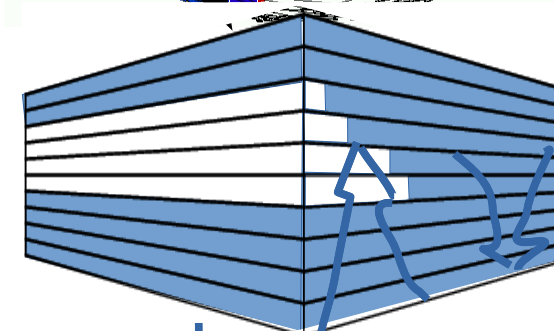
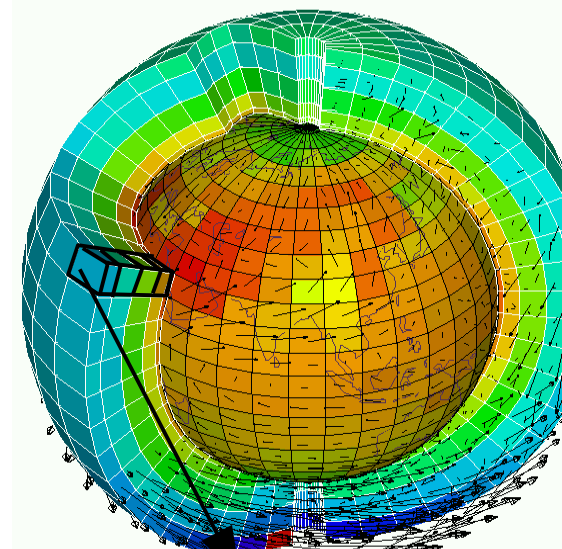
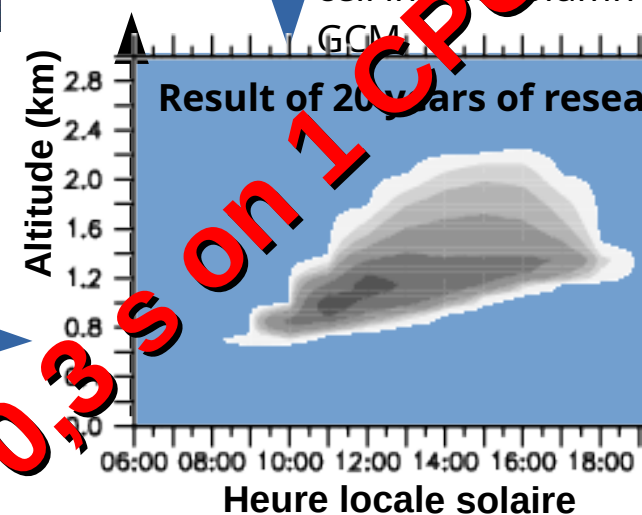
Detailed simulation
(LES : Large Eddy Simulation)



Computing at each altitude the fraction of the horizontal domain covered by clouds.
Also called :
the cloud fraction



Evaluation

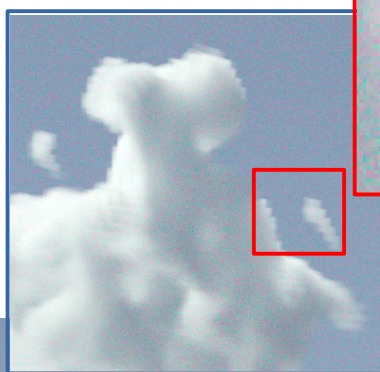


Computing the cloud fraction for each cell in one column GCM

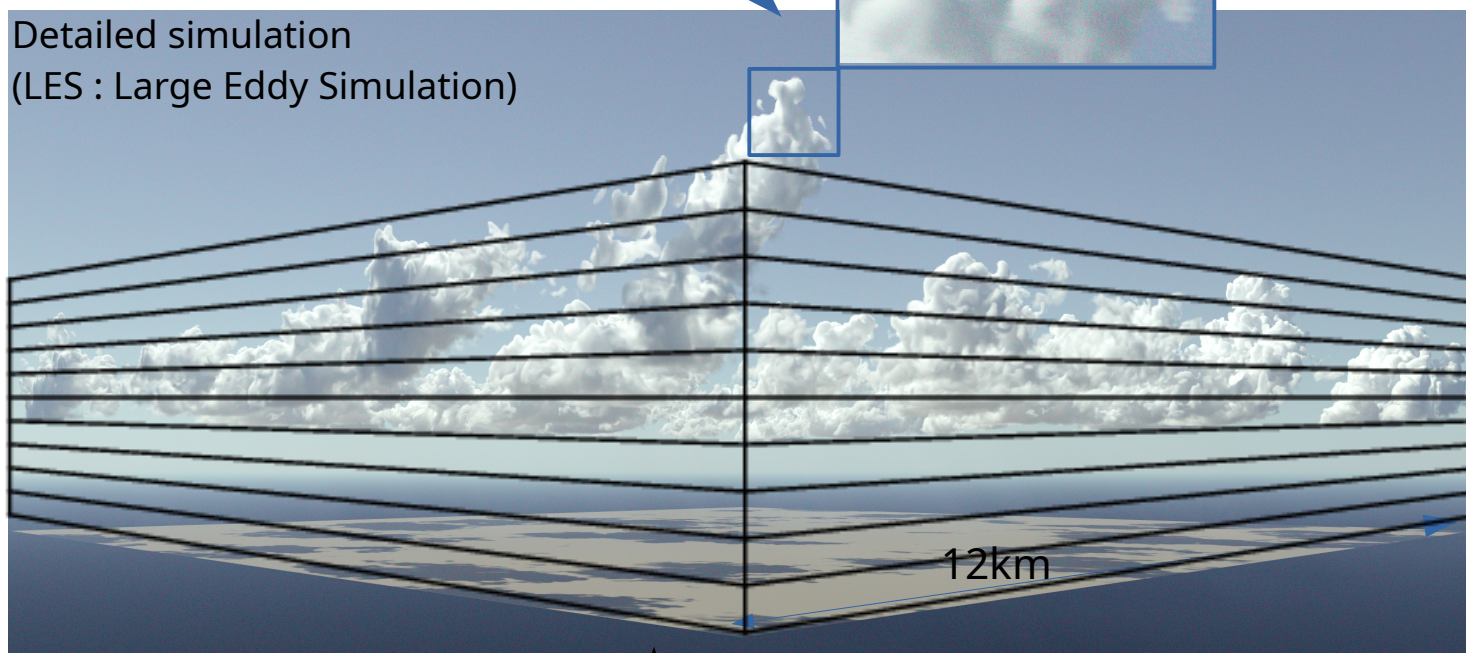


Field campaign experiment

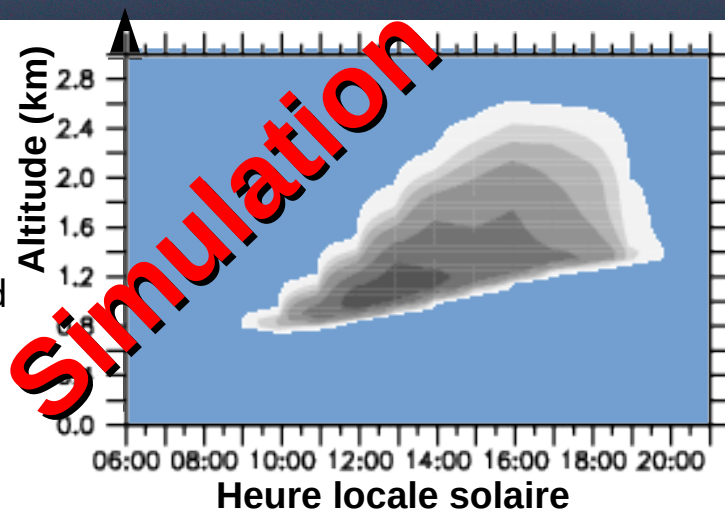
Evaluation



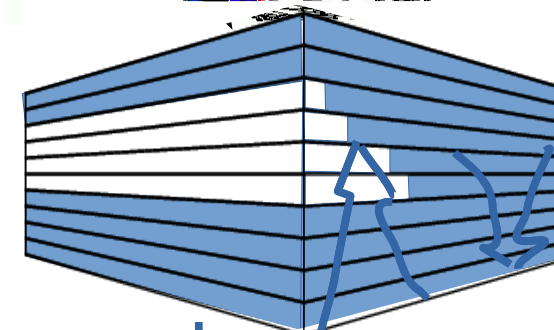
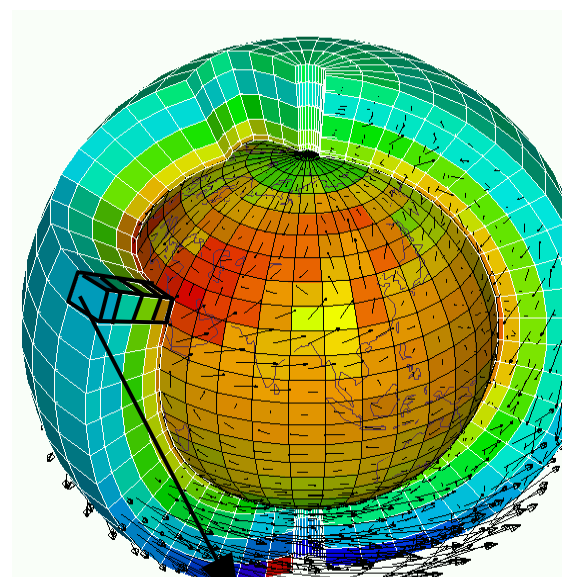
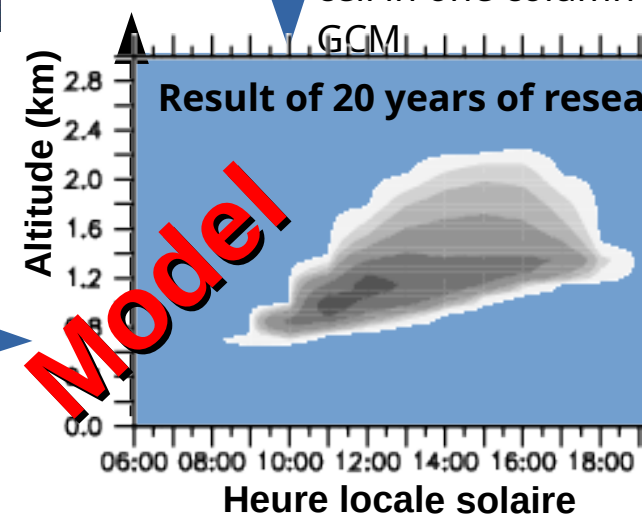
Detailed simulation
(LES : Large Eddy Simulation)



Computing at each altitude the fraction of the horizontal domain covered by clouds.
Also called :
the cloud fraction



Evaluation



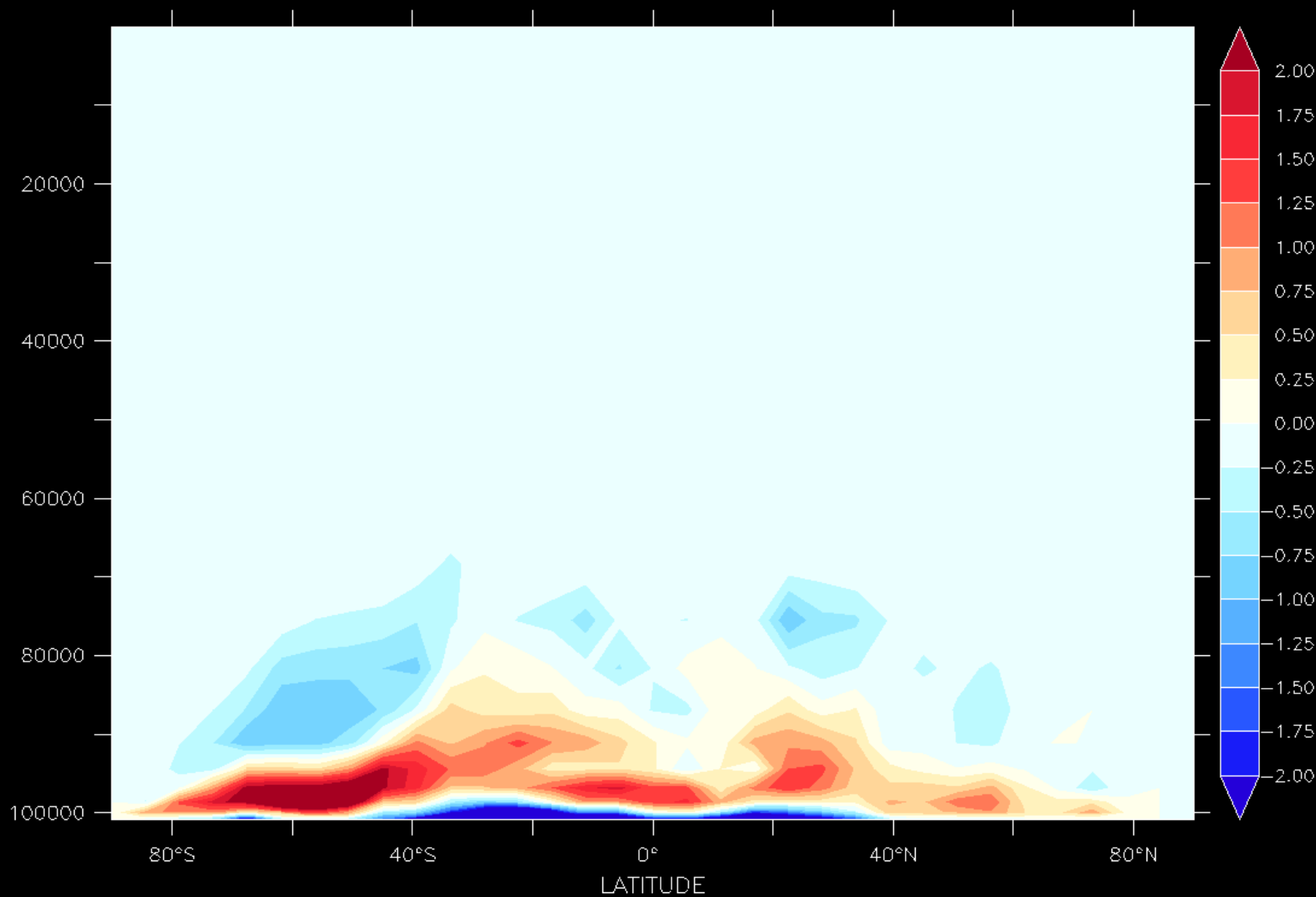
Computing the cloud fraction for each cell in one column
GCM

Result of 20 years of research

fill/lev=(-Inf)(-2,2,0.25)(inf)/pal=blue_darkred
86400*dtthe[i=@ave]

LONGITUDE : 174.375E(-185.625) to 174.375E
TIME : 03-JAN-1980 12:00 360_DAY

DATA SET: histday

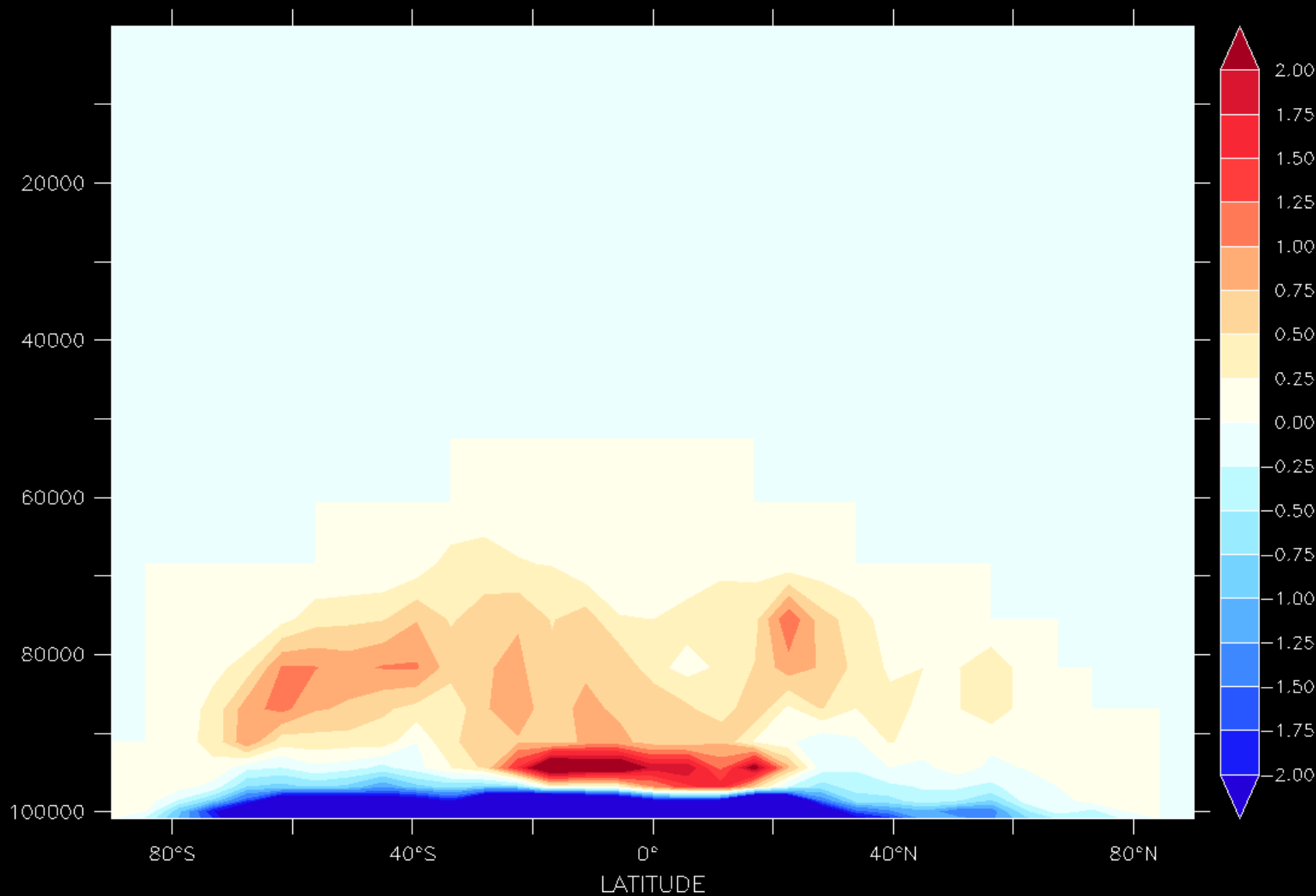


86400*DTTHE[I=@AVE]

fill/lev=(-Inf)(-2,2,0.25)(inf)/pal=blue_darkred
1000*86400*dqthe[i=@ave]

LONGITUDE : 174.375E(-185.625) to 174.375E
TIME : 03-JAN-1980 12:00 360_DAY

DATA SET: histday



1000*86400*DQTHE[I=@AVE]

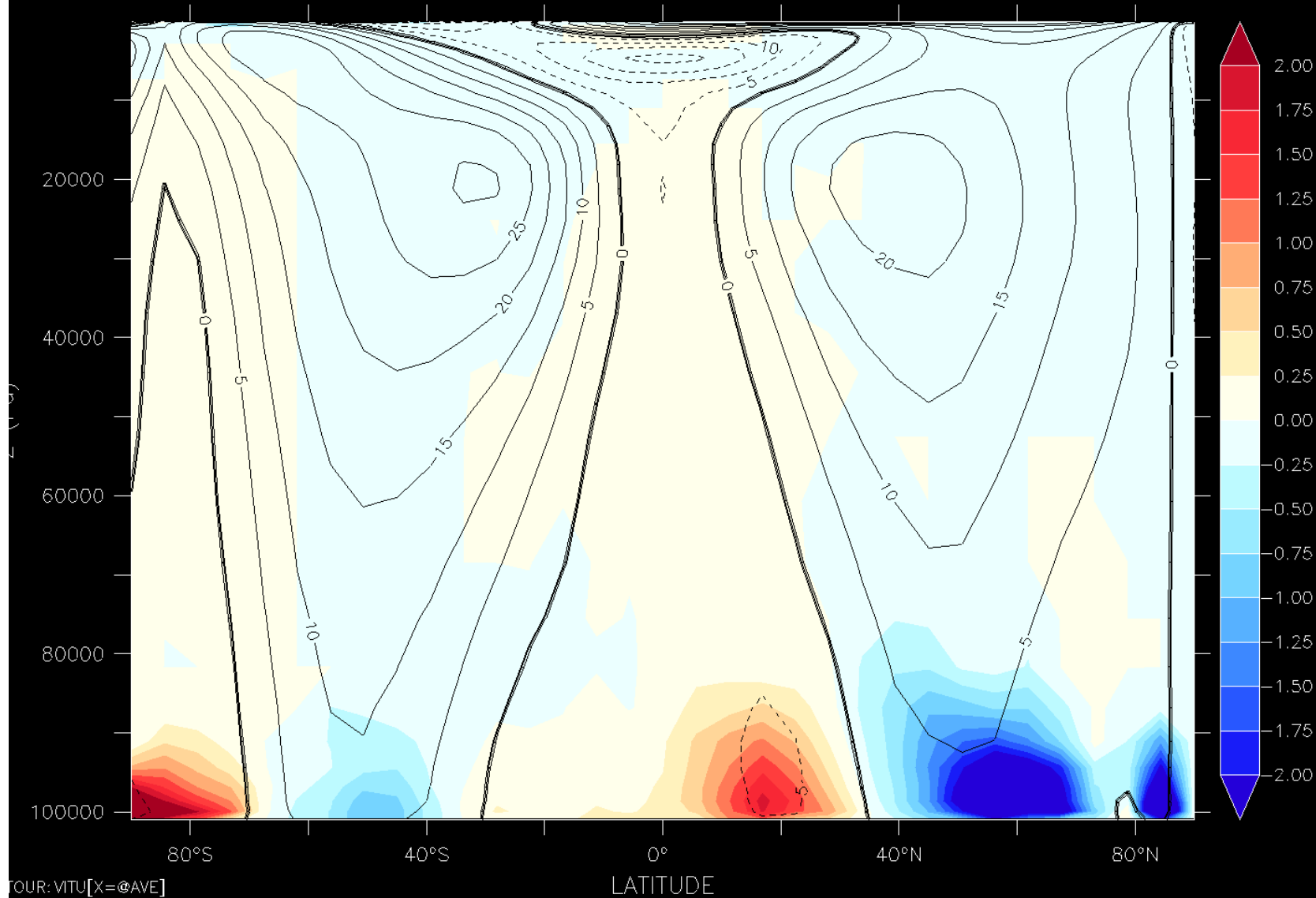
Parameterization of subgrid-scale orography

- Marine presentation


```
fill/lev=(-Inf)(-2,2,0.25)(inf)/pal=blue_darkred 86400*duoro[i=@ave
]
contour/o/color=white/lev=(-Inf)(-30,30,5) vitu[i=@ave]
```

LONGITUDE : 174.375E(-185.625) to 174.375E
TIME : 03-JAN-1980 12:00 360_DAY

DATA SET: histday



Temperature tendencies

Basic facts about parametrizations I

- Each parametrization : (1) works almost independently of the others ; (2) depends on vertical profiles of u , v , w , T , q and on some interface variables with the other parametrizations ; (3) ignores the spatial heterogeneities associated with the other processes (except for some processes in the deep convection scheme).
- The total tendency due to sub-grid processes is the sum of the tendencies due to each process :

$$\begin{aligned} S_T = (\partial_t T)_\varphi = & (\partial_t T)_{eva} + (\partial_t T)_{lsc} + (\partial_t T)_{diff\ turb} + (\partial_t T)_{conv} \\ & + (\partial_t T)_{wk} + (\partial_t T)_{Th} + (\partial_t T)_{ajs} \\ & + (\partial_t T)_{rad} + (\partial_t T)_{oro} + (\partial_t T)_{dissip} \end{aligned}$$

In the model, the total tendency of T for example is $\partial_t T_{dyn} + \partial_t T_{param} = dtdyn + dtphy$, where :

$dtphy = dteva + dtlsc + dtvdf + dtcon +$
 $dtwak + dtthe + dtajs +$
 $(dtswr + dtlwr) + (dtoro + dtlif) + (dtdis + dtec)$

Output names
→ **Not the same**
as their name in
the source code !
physiq_mod.f90

Specific humidity tendencies

Basic facts about parametrizations II

- Similarly, the total tendency of a given tracer q writes :

$$S_q = (\partial_t q)_\varphi = (\partial_t q)_{\text{eva}} + (\partial_t q)_{\text{lsc}} + (\partial_t q)_{\text{diff turb}} + (\partial_t q)_{\text{conv}} \\ + (\partial_t q)_{\text{wk}} + (\partial_t q)_{\text{Th}} + (\partial_t q)_{\text{ajs}}$$

In the model, the total tendency of q is therefore

$\partial_t q_{\text{dyn}} + \partial_t q_{\text{param}} = \text{dqdyn} + \text{dqphy}$, where :

$\text{dqphy} = \text{dqeva} + \text{dqlsc} + \text{dqvdf} + \text{dqcon} + \text{dqwak} + \text{dqthe} + \text{dqajs}$

Subroutine structure

physiq_mod.F90 structure - I

Initialization (once) : *conf_phys*, *phyetat0*,
phys_output_open

Beginning *change_srf_frac*, *solarlong*

Cloud water evap. *reevap*

Vertical diffusion (turbulent mixing) *pbl_surface*

Deep convection *conflx* (Tiedtke) or *concul* (Emanuel)

Deep convection clouds *clouds_gno*

Density currents (wakes) *calwake*

Strato-cumulus *stratocu_if*

Thermal plumes *calltherm* and *ajsec* (sec = dry)

Large scale clouds *calcratqs*

Large scale and cumulus condensation *fisrtilp*

Diagnostic clouds for Tiedtke *diagcld1*

Aerosols *readaerosol_optic*

Cloud optical parameters *newmicro* or *nuage*

Radiative processes *radlwsu*

In blue : subroutines and instructions modifying state
variables

physiq_mod.F90 structure - II

Orographic processes : drag *drag_noro_strato* or
drag_noro

Orographic processes : lift *lift_noro_strato* or
lift_noro

Orographic processes : Gravity Waves *hines_gwd* or
GWD_rando

Axial components of angular momentum and
mountain torque : *aaam_bud*

Cosp simulator *phys_cosp*

Tracers *phytrac*

Tracers off-line *phystokenc*

Water and energy transport *transp*

Outputs

Statistics

Output of final state (for restart) *phyredem*

Subroutine structure

physiq_mod.F90 structure - I

Initialization (once) : *conf_phys*, *phyetat0*,
phys_output_open

Beginning *change_srf_frac*, *solarlong*

Cloud water evap. *reevap*

Vertical diffusion (turbulent mixing) *pbl_surface*

Deep convection *conflx* (Tiedtke) or *concul* (Emanuel)

Deep convection clouds *clouds_gno*

Density currents (wakes) *calwake*

Strato-cumulus *stratocu_if*

Thermal plumes *calltherm* and *ajsec* (sec = dry)

Large scale clouds *calcratqs*

Large scale and cumulus condensation *fisrtilp*

Diagnostic clouds for Tiedtke *diagcld1*

Aerosols *readaerosol_optic*

Cloud optical parameters *newmicro* or *nuage*

Radiative processes *radlwsw*

In blue : subroutines and instructions modifying state
variables

physiq_mod.F90 structure - II

Orographic processes : drag *drag_noro_strato* or
drag_noro

Orographic processes : lift *lift_noro_strato* or
lift_noro

Orographic processes : Gravity Waves *hines_gwd* or
GWD_rando

Axial components of angular momentum and
mountain torque : *aaam_bud*

Cosp simulator *phys_cosp*

Tracers *phytrac*

Tracers off-line *phystokenc*

Water and energy transport *transp*

Outputs

Statistics

Output of final state (for restart) *phyredem*

Effect of subrid-scale transport

Coupling with surface

Clouds and radiation

Today

Tomorrow

Radiation : output variables

Radiation I

Subroutine : radlsw

Tendencies :

dtswr, dtlwr Temperature tendencies due to solar radiation (SW = short wave)
and thermal infra-red (LW = long wave)

The total radiative tendency is the sum of the SW and LW tendencies.

Other variables

- dtsw0 : clear sky SW tendency
- dtlw0 : clear sky LW tendency
- tops : net solar radiation at top of atmosphere (positive downward)
- topl : net infra-red radiation at top of atmosphere (positive upward)
- tops0, topl0 : same for clear sky
- sols : net solar radiation at surface (positive downward)
- soll : net infra-red radiation at surface (positive downward)
- sols0, soll0 : same for clear sky

New variables :

S[L]Wdn[up]TOA[SFC][clr] :

Short[Long]Wave

Downward[upward] radiative flux at

Top-Of-Atmosphere[Surface][clear-sky]

Cloud radiative effect (CRE) :

Old names : VAR - VAR0

New names : VAR - VARclr

Radiation : control parameters

In physiq.def (deepL translation)

```
#####  
#  
# Radiation  
#####  
#  
# activation of the new RRTM radiation code  
# 0: Old code and 1: RRTM (D=0)  
iflag_rrtm=1  
  
# Number of strips for SW. Set 2 if iflag_rrtm=0  
NSW=6
```

In config.def

```
#Radiative transfer code  
#*****  
# added this flag to activate/deactivate the radiation (MPL)  
# 0: no radiation. 1: radiation is activated (D=1).  
iflag_radia=1  
## Number of calls of radiation routines ( per day)  
nbapp_rad=24
```

Turbulent diffusion : output variables

Vertical diffusion

Subroutine : pbl_surface

Tendencies :

dtvdf, dqvdf, duvdf, dvvdf

Other variables

- sens : sensible heat flux at the surface (positive upward)
- evap : water vapour flux at the surface (positive upward)
- flat : latent heat flux at the surface (positive downward)
- taux, tauy : wind stress at the surface

Turbulent diffusion : control parameters

In physiq.def (deepL translation)

```
#####  
# Turbulent boundary layer  
#####  
  
# New version of Mellor and Yamada  
new_yamada4=y  
  
# Choice of numerical scheme for new_yamada4=y  
# 1 MAR diagram. Good for stable CL but destroys the stratoculus.  
# 5 MAR schema modified. Precaunise.  
yamada4_num=5  
  
# Stable boundary layer control flag  
iflag_corr_sta=4  
  
# min on the surface stability functions  
f_ri_cd_min=0.01  
  
# max of Ric for Kz. Larger decoupling for larger Ric.  
yamada4_ric=0.18  
  
# minimum mixing length for Kz  
lmixmin=0  
  
#shema of the surface layer (D:1, 1:LMD, 8:Mellor-Yamada)  
iflag_pbl=12  
  
# Thresholds for turbulent diffusion  
ksta_ter=1e-07  
ksta=1e-10
```

Radiation : input parameters

In physiq.def (deepL translation)

```
#####
```

```
# Convective boundary layer / thermal model
```

```
#####
```

```
# Dry convection (D:0, 0:dry adjustment,=>1:thermal model)
```

```
iflag_thermals=18
```

```
# no splitting time for thermals
```

```
# TURNS BUT POSES MORE PROBLEMS THAN IT SOLVES
```

```
nsplit_thermals=1
```

```
# tau_thermals to have a time constant on the thermals.
```

```
# invalid
```

```
tau_thermals=0
```

```
# Flag controlling training and practice
```

```
iflag_thermals_ed=8
```

```
# We will look for the air at  $z * (1 + \text{fact\_thermals\_ed\_dz})$  to  
compute
```

```
# training (A. Jam)
```

```
fact_thermals_ed_dz=0.07
```

Thermal plume model : output variables

Thermals and dry adjustment

Subroutine : calltherm

Tendencies :

dtthe, dqthe, duthe, dvthe

Other variables

- dtajs : temperature tendency due to the sole dry adjustment
- dqajs : humidity tendency due to the sole dry adjustment
- a_th : fractional area of thermal plumes
- d_th : detrainment
- e_th : entrainment
- f_th : mass flux
- w_th : vertical velocity in the thermal plume (m/s, positive upward)
- q_th : total water content in the thermal plume
- zmax_th : altitude of the top of the thermal plume (m)
- f0_th : Thermal closure mass flux (kg/m².s)

Practice

**Try to analyse the diurnal cycle of temperature and humidity
Choose for instance a location in Sahel : 0W, 12N**