LMDZ outputs

LMDZ Training, January 2024, Abderrahmane IDELKADI

Outline

- Introduction
- «history» files
- «restart» files
- file of control printing and error messages

LMDZ outputs

LMDZ Training, January 2024, A. Idelkadi

Introduction

LMDZ outputs include:

- «**history**» files : they gather instantaneous or averaged diagnostic variables
- «**restart**» files : used to extend or to restart a simulation
- «**output**» file : collects all control and error messages

Introduction

Netcdf / IOIPSL / XIOS libraries:

- LMDZ «history» and «restart» files are in **NetCDF** format and written using either : the NetCDF or IOIPSL/XIOS libraries.
  IOIPSL and **XIOS** were developed at *IPSL* for model I/Os using the NetCDF library.

- The output of variables consists in 2 steps :
  - definition of the variables to output (during initialisation of the run)
  - computation and writing of the variables (during the simulation)

- Note that :

➔ For «history» files, they allow variables to be « manipulated » (e.g. average/max/min) before being written out with **XIOS** providing many more possibilities than **IOIPSL**

➔ To help with the debugging of the code, there is also a mechanism which writes the variables in the **GrADS** format (using directly NetCDF).

Introduction

Dynamical and Physical modules / Parallel mode :

- The partition between the dynamical module and the physical module in the LMDZ code and the fact that one can be run without the other implies that both modules need to have their own **«restart»** and **«history»** outputs :

  ➔ **«restart.nc»** for the dynamics module and **«restartphy.nc»** for physics module

  ➔ «**history**» file for the dynamics module only consists of the variables of state (U, V, T, Q, Ps) at two frequencies : instantaneous and averaged.

- When run in parallel mode with **IOIPSL**, each process writes its own history files in its domain. The global file is reconstructed from these various files by using the rebuild utility distributed with the **IOIPSL** library.
When using the **XIOS** package, **XIOS** can provide this rebuilding mechanism automatically.

LMDZ outputs

LMDZ Training, January 2024, A. Idelkadi

«history» outputs of the physics module:

Vertical coordinate in LMDZ:

- **The hybrid coordinate system is used for the verticale in LMDZ.**

  Principle: to define it implicitly by giving the pressure in layer l as: p(l) = ap(l) + bp(l)*ps(1)
  ps: surface pressure
  - **The ap and bp coefficients are chosen so that:**
    - the model levels follow the relief near the surface (p(l)=bp(l)*ps : ap~0 and bp~1)
    - and are close to the isobaric levels at higher altitudes (ap~0 and bp~0 with ap>>bp*ps)
  - **The distribution of vertical layers is irregular, in order to have:**
    - a finer discretization for the atmospheric boundary layer
    - and a coarser discretization for higher altitudes.

- **given in appendix :**
  - **Mechanism used in LMDZ to calculate ap and bp coefficients**
  - **Example of the verticale coordinate of LMDZ standard configuration with 79 levels**

LMDZ outputs

LMDZ Training, January 2024, A. Idelkadi

«history» outputs of the physics module:

- Scheme which allows to individually control the output of the variables in 9 files :
  - ➔ 5 basic files : ***histmth.nc, histday.nc, histhf.nc, histins.nc, histLES.nc***
  - ➔ 1 specific file (data sites) : ***histstn.nc***
  - ➔ 3 files with predefined pressure levels **:** ***histmthNMC.nc, histdayNMC.nc, histhfNMC.nc***
    outputs interpolated on 17 standard levels pressures :
    1000., 925., 850., 700., .600., 500., 400., 300., 250., 200., 150., 100., 70., 50., 30., 20., 10.hPa

- There are 3 specific «history» outputs files :
  histmthCOSP.nc, histdayCOSP.nc, histhfCOSP.nc
  Outputs from the COSP simulator

- **By using XIOS, this basic scheme can be redefined totally, e.g. the CMIP6 IPSL workflow in which LMDZ outputs files containing single timeseries of requested variables**

«history» outputs of the physics module with IOIPSL

Principle:

- To each «history» file "histX.nc", an output level, **lev_histX,** is associated
  To each variable "V", an output level **flag_V** is associated

Then if
flag_V $\leq$ **lev_histX** ==> variable "V" is defined and written in the file "histX.nc"

- These control keys are defined in the files **config.def/output.def**

- Each output file can be controlled to :
  activate it
  define its name,
  define its ouput level,
  define its output frequency,
  define the mathematical operation on the output variables (average, max/min ...)
  define the whole or a limited domain to output the variables

LMDZ outputs

LMDZ Training, January 2024, A. Idelkadi

«history» outputs of the physics module with IOIPSL:

In practice :

In the **config.def** or **output.def**, file :

✓ **define the control keys of the various files :**

```
# Activate or not the output of the file :
phys_out_filekeys=       y        y        n        y           n     n    n     n              n

# Name of files :
phys_out_filenames=  histmth   histday   histhf   histins     ............................     histhfNMC.nc

# Output level of files
phys_out_filelevels=     5         2        2       4          .........................       5

# Archive operation (inst, ave, min, max)
phys_out_filetypes=    ave(X)    ave(X)   ave(X)  inst(X)      .........................     inst(X)

# Frequencie (mounths, mth, mois, day, days, jour, jours, heure, mn, TS, ... )
phys_out_filetimesteps= 1mth    1day      6hr      1TS         .........................      6hr
```

✓ **define the control keys of each variable :**

```
# Surface temperature
flag_tsol      =          2         3        7          6       .........................      10
name_tsol      =     tsol
```

«history» outputs of the physics module with IOIPSL (in practice):

In practice:

In the **config.def** or **output.def** file :

✓ output the variables on the whole or a limited domain

```
# Names of files :
phys_out_filenames =  histmth.nc     histday.nc    histhf.nc      histins.nc       ............
# Activate or note the output on a limited domain
reg_out_fkeys =             n              n             y              n            ............


# Longitude min and max of domain
phys_out_lonmin =        -180           -180            0            -180            ...........
phys_out_lonmax =        +180           +180           90            +180            ...........

# Latitude min and max of domain
phys_out_latmin =        -90             -90          -30            -90             ...........
phys_out_latmax =        +90             +90          +40            +90             ...........

#  Vertical level  min and max
phys_out_levmin=           1               1            1              1             ...........
phys_out_levmax=          39              39            3             39             ...........
```

Number of variables controled by this mechanism (approx.)

+550 2D-fields and +300 3D-fields

LMDZ outputs

LMDZ Training, January 2024, A. Idelkadi

«history» outputs of the physics module:

- **How to add a new output variable ?**

2 routines need to be modified:

- **libf/phylmd/phys_output_ctrlout.F90**:
  - declaration of name, description, unit and output level of the new variable
- **libf/phylmd/phys_output_write.F90**:
  - write the new variable in each file

Example for «t2m_min» variable :

…/libf/phylmd/phys_output_ctrlout.F90

```
 type(ctrl_out),save :: o_t2m_min   =   ctrl_out((/ 1,1,1,5,10,10,5,5,5 /), &
         't2m_min','Temp 2m min', 'K', (/ 't_min(X)','t_min(X)','t_min(X)', &
         't_min(X)','t_min(X)','t_min(X)','t_min(X)','t_min(X)','t_min(X)' /))
```

…/libf/phylmd/phys_output_write.F90

```
 CALL histwrite_phy(o_t2m_min, zt2m)
```

«history» outputs of the physics module with XIOS

XIOS library :

- **IOIPSL** is progressively replaced by **XIOS**
  in the libIGCM tools developed at IPSL to produce climate change simulations, **XIOS** has already replaced IOIPSL

- **XIOS** : XML – IO – SERVER
  Library developped at LSCE/IPSL for management of IO of climate codes

➔ Based on client – server principle : IO server manages the outputs so that the climate code does not waste time on its outputs, it just sends them to the IO server

➔ All aspects of the outputs (name, units, post-processing frequencies, operations, …) are controlled by external xml files but can be overriden from the source code.

LMDZ outputs

LMDZ Training, January 2024, A. Idelkadi

«history» outputs of the physics module with *XIOS*

XIOS library:

- Advantages of XIOS library:
  - ➔ Client – server model : code not slowed down by outputs
  - ➔ Flexible
  - ➔ No recompilation of code necessary when changing IO definitions (all done in xml files)
  - ➔ Particularly geared towards parallel code (no more rebuilding output files, asynchronous writes …)
  - Lots of functionalities : reading files, filters and transformations, on-the-fly interpolation to a particular grid, on-the-fly timeseries output

- Disadvantages:
  - ➔ Another library to install (mpi, boost, blitz)
  - ➔ Needs necessarily a mpi library

«history» outputs of the physics module with XIOS

In practice:

- **Use :**

Need to download XIOS from http://forge.ipsl.jussieu.fr/ioserver/XIOS and compile it. (see tutorial)

- **LMDZ compile :**

3 options to the makelmdz/makelmdz_fcm command :
 -io ioipsl only IOIPSL
 -io xios only XIOS
 -io mix both IOIPSL and XIOS

- **Execution :**
  - ➔ **ok_all_xml = y** in run.def file to get xml to control everything
  - ➔ Sample xml files in **DefLists** directory (../modipsl/modeles/LMDZ/DefLists)

- To add variables to the XIOS output files, you will need to :
  - ➔ add them as before to the 2 routines **phys_output_ctrlout.F90, phys_output_write.F90**
  - ➔ and add them to the **xml files**

LMDZ outputs

LMDZ Training, January 2024, A. Idelkadi

«history» outputs of the physics module with XIOS

Xml files :

One file, at least must be present (model will crash if this file is absent): **iodef.xml**

```
<?xml version="1.0"?>
<!-========================================================================== -->
<!-- iodef.xml : Configuration file for production of output files using XIOS     -->
<!--             This file contains the context XIOS.                               -->
<!-========================================================================== -->

<simulation>
  <context id="xios">
    <variable_definition>
         <variable_group id="server">
            <variable id="using_server2" type="bool">false</variable>
            ….
         </variable_group>

        <variable_group id="buffer">
            …....
         </variable_group>

        <variable_group id="parameters" >
          <variable id="using_server" type="bool">false</variable>
          <variable id="info_level" type="int">1</variable>
          ….
        </variable_group>
      ….
    </variable_definition>

  </context>

 <context id="LMDZ" src="./context_lmdz.xml"/>

</simulation>
```

«history» outputs of the physics module with XIOS

Xml files:

context_lmdz.xml :

```
<! Context LMDZ >
<!--  <calendar type="D360" start_date="1980-01-01 00:00:00" /> -->

<! Define available variables >
<field_definition src="./field_def_lmdz.xml"/>

<! Define output files
     Each file contains the list of variables and their output levels >

  <file_definition src="./file_def_histday_lmdz.xml"/>
  ...

  <! Define domains and groups of domains >
  <domain_definition>
    <domain id="dom_glo" data_dim="2" />
  </domain_definition>

  <! Define groups of vertical axes >
  <axis_definition>
    <axis id="presnivs" standard_name="Vertical levels" unit="Pa"/>
    ...
  </axis_definition>

  <! Define grids >
  <grid id="grid_glo_presnivs">
     <domain domain_ref="dom_glo" />
     <axis axis_ref="presnivs" />
  </grid>

</context>
```

«history» outputs of the physics module with XIOS

Xml files:

field_def_lmdz.xml :

```
<field_definition level="1" prec="4" operation="average" freq_op="1ts" enabled=".true."
default_value="9.96921e+36">

    <field_group id="fields_2D" domain_ref="dom_glo">
        <field id="phis"    long_name="Surface geop.height"     unit="m2/s2" />
        <field id="ffonte"    long_name="Thermal flux for snow melting"    unit="W/m2" />
        ...
    </field_group>
    <field_group id="fields_3D" domain_ref="dom_glo" axis_ref="presnivs">
        <field id="tke"    long_name="TKE"    unit="m2/s2" />
        ...
    </field_group>

    <field_group  id="fields_NMC" domain_ref="dom_glo" axis_ref="plev">
      <field id="ta" long_name="Air temperature" unit="K" />
      ...
    </field_group>
      ...
    <field_group id="fields_COSP_CALIPSO" domain_ref="dom_glo" freq_op="3h">
      <field id="cllcalipso"    long_name="Lidar Lowlevel Cloud Fraction"   unit="1" />
      ...
    </field_group>
</field_definition>
```

LMDZ outputs

LMDZ Training, January 2024, A. Idelkadi

«history» outputs of the physics module with XIOS

Xml files:

file_def_histday_lmdz.xml :

```
<file_definition>
    <file_group id="defile">
        <file id="histday" name="histday" output_freq="1d" output_level="2" enabled="TRUE"
compression_level="4">
            <! VARS 2D >
            <field_group operation="average" freq_op="1ts">
                <field field_ref="phis" level="1" />
                ...
                <field field_ref="ffonte" level="10" />
                ...
                <field_group operation="average" freq_op="1ts" detect_missing_value=".true.">
                    <field field_ref="u850" level="7" />
                    ...
                </field_group>
            </field_group>
            <! VARS 3D >
            <field_group operation="average" freq_op="1ts" axis_ref="presnivs">
                <field field_ref="cldtau" level="5" />
            </field_group>
        </file>
    </file_group>
</file_definition>
```

«history» outputs files of COSP :

- COSP : CFMIP Observation Simulator Package
  - simulator : a diagnostic code that computes pseudosatellite observations from model variables in order to compare them to real satellite observations
  - Cosp implemented in LMDZ to evaluate the representation of cloud process in the models **(https://lmdz.lmd.jussieu.fr/Members/aidelkadi/cosp)**
  - COSP has simulators for these satellite cloud products: ISCCP, CALIPSO, CLOUDSAT, PARASOL, MISR, MODIS
- 2 versions of COSP implemented in LMDZ model :
  cospv1 (used for CMIP6 exercise) ***cospv2*** (new version of cosp with more diagnostics)

  Directory : **cospv1**: *`.../phylmd/cosp`* and ***cosp*****v2:** *`.../phylmd/cospv2`*
  Outputs routines:
  - **v1**: **`cosp_output_mod.F90`** **`and`** **`cosp_output_write_mod.F90`**
  - **v2**: lmdz_**`cosp_output_mod.F90`** **`and`** **`lmdz_cosp_output_write_mod.F90`**
- To run LMDZ simulation with COSP simulator :
  - Compile LMDZ model with option : **`-cosp none/v1/v2`**
  - Activate COSP in LMDZ simulation : **`ok_cosp=y`** in config.def file

LMDZ outputs

LMDZ Training, January 2024, A. Idelkadi

«history» outputs files of COSP:

The same philosophy, as described before for *LMDZ history files*, is used with IOIPSL and XIOS:

- 3 outputs files for COSP: *histmthCOSP.nc, histdayCOSP.nc, histhfCOSP.nc*

  Lot of cloud diagnostics : low, mid, hight level, total, vertical distribution of cloud fraction, …

- The control keys of files and variables :
  - **With IOIPSL library:**

```
cosp_outfilenames = histmthCOSP.nc, histdayCOSP.nc, histhfCOSP.nc
cosp_outfilekeys =       y                y              n
cosp_ecritfiles =      1mth             1day             3h
cosp_outfiletypes =    ave(X)           ave(X)         inst(X)
cles_cllcalipso =        y                y              n
name_cllcalipso =    LowCldMth        LowCldDay       LowCldHf
```

  - **With XIOS library:**

    Variables defined in XML file: `field_def_cosp1.xml / field_def_cospv2.xml`

    Output files defined in XML files:

```
file_def_histmthCOSP_lmdz.xml / file_def_histmthCOSPv2_lmdz.xml
file_def_histdayCOSP_lmdz.xml / file_def_histmthCOSPv2_lmdz.xml
file_def_histhfCOSP_lmdz.xml / file_def_histhfCOSPv2_lmdz.xml
```

- **Number of Cosp output variables** (approx.): **+70(cospv1)   +100(cospv2)**

«Restart» files :

- The dynamical and physical modules each write their own restart file (**restart.nc** and **restartphy.nc**).
  These files save the state variables that the model needs at each time step so that :
  the model can be restarted without losing continuity (in practical terms this is known as «**1+1=2**»)

- Routines involved in this process are :

`…/libf/dyn3d/dynredem.F` for the dynamical module (the restart state being read in by **`…/libf/dyn3d/dynetat0.F`**)

`…/libf/phylmd/phyredem.F` for the physics module (corresponding routine in **`…/libf/phylmd/phyetat0.F`**)

- These routines do not use the **IOIPSL** library and are interfaced directly with the **NetCDF** library.

files of control printing and error messages:

- **Controlling output messages :**

  ➔ Most of control outputs and messages are written to standard output (the screen) by the use of commands such as: `print*, …` or `write(*,*) 'ma variable =',..`

  ➔ A cleaner mechanism exists to output these messages to a file rather than the screen.
  - ✓ to include in any new routine, the iniprint.h file : **#include iniprint.h**
    in iniprint.h are defined 2 parameters :
    - lunout : a unit number corresponding to the output file
    (if lunout ≠ 6 ==> a lmdz.out file is created and assigned to this number)
    - prt_level : an output level
    The value of these two parameters can then be modified in the **run.def** file

  - ✓ to use them in the routine you then just need to add lines such as :

    ```
    IF (prt_level>9) WRITE(lunout,*) 'pas de convection'
    ```
    While keeping small values of **prt_level** for really important messages

  ➔ To note :
  - ✓ A mechanism to write files with all the control parameters effectivly read and used for the simulation (**used_run.def, used_config.def**, ...)

  - ✓ We have introduced a routine called **prt_alerte_mod.F90** to print informative alert messages:
    see for information:
https://lmdz-forge.lmd.jussieu.fr/mediawiki/LMDZPedia/index.php/HowTo:_Print_alert_messages

Output file of control printing and error messages:

- **What use are they ?**

If the model crashes or does not seem to run properly, these output messages should give you an indication of what's going on.

➔The first thing to do is : `grep 'Houston, we have a problem ' output_file`

As the model will output this string with an indication of the problem it encountered, when the problem has been anticipated by the developers (might be a configuration problem, a temperature that's suddenly out of range, …).

➔If the string is not found and no obvious error (**`segmentation fault, memory violation, floating point exception`**) can be found in the output messages,
the best is to recompile the model with the **`-debug`** option and run it again.
It should now give you an indication of the line and the routine that is causing the crash.
Once found, you can start debugging the routine or call for help with some vital information.

LMDZ outputs

LMDZ Training, January 2024, A. Idelkadi

Appendix : verticale coordinate in LMDZ

- **Calcul of ap and bp :**
  - **we consider a distribution of sigma sig0(l) levels associated to a reference surface pressure Preff**
  - **We look for the sig(l) function such that : bp(l)= exp[1-1/(sig(l**2)] and ap(l)=pa*(sig(l)-bp(l)) so that the pressure of a layer is given by the relation : P(l)=ap(l)+bp(l)*Ps**
  - **Then : P(l)=sig0(l)*Preff**
    Then : sig0(l)*Preff = ap(l)+ bp(l)*Preff
    In which we insert ap(l) et bp(l) :
    sig0(l)*Preff=pa*(sig(l)-bp(l)) + bp(l)*Preff
    sig0(l)*Preff=pa*sig(l)+bp(l)(Preff-pa)
    sig0(l)*Preff=pa*sig(l)+(Preff-pa)*exp[1-1/(sig(l2)]**
    This allows us to determine the values of sig(l) (via iterative procedure)
  - **Once sig(l) has been determined, bp(l) and ap(l) can be calculated:**
    bp(l)=exp[1-1/(sig(l2)]**
    ap(l)=pa*(sig(l)-bp(l))
  - **In output file of control printing (listing) :**
    - **values of ap and bp ⇒ AP and BP**
    - **Values of P ⇒ PINTERF (interface pressures)**
    - **Values of presnivs ⇒ PRESNIVS (pressures at mid-layer)**

LMDZ outputs

LMDZ Training, January 2024, A. Idelkadi

Appendix :Verticale coordinate of LMDZ

- **Exemple for standard configuration with 79 levels**

layer	1	2	3	4	5	6	7	8	9	10	…
ap	0.0	80.59	170.50	270.80	382.68	507.46	646.62	801.79	974.78	1167.58	...
bp	1.0	0.997	0.993	0.989	0.985	0.980	0.974	0.968	0.961	0.954	...
P	101325	101079	100806	100805	100163	99786	99367	98902	98386	97812	...
Presnivs	101202	100942	100653	100332	99974	99577	99135	98643	98099	97494	...

...	70	71	72	73	74	75	76	77	78	79	80
…	201.90	156.17	118.27	87.19	62.05	42.10	26.73	15.39	7.63	2.97	0.0
…	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
…	201.9	156.2	118.3	87.2	62.0	42.1	26.7	15.4	7.6	3	0.0
…	179.03	137.22	102.73	74.62	52.08	34.41	21.06	11.51	5.30	1.48	

Thank you for your attention