# WRF Registry and Examples


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# Outline

- Registry Mechanics

  - - - - - - - - - - - - -

- Examples

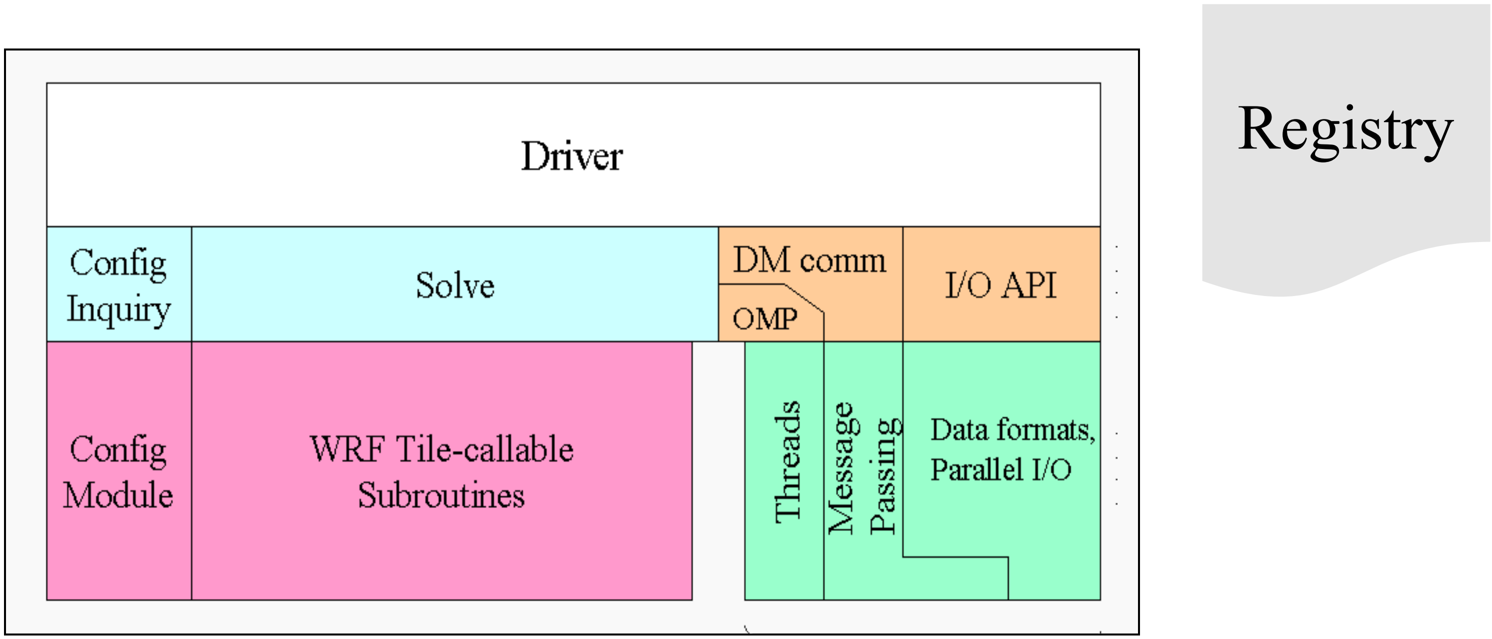
# Introduction – Intended Audience

- Intended audience for this tutorial session: scientific users and others who wish to:
  - Understand overall design concepts and motivations
  - Work with the code
  - Extend/modify the code to enable their work/research
  - Address problems as they arise
  - Adapt the code to take advantage of local computing resources

# Introduction – WRF Resources

- WRF project home page
  - http://www.wrf-model.org
- WRF users page (linked from above)
  - http://www.mmm.ucar.edu/wrf/users
- On line documentation (also from above)
  - http://www.mmm.ucar.edu/wrf/WG2/software_v2
- WRF user services and help desk
  - wrfhelp@ucar.edu

# WRF Software Architecture




- Hierarchical software architecture
  - Insulate scientists' code from parallelism and other architecture/implementation-specific details
  - Well-defined interfaces between layers, and external packages for communications, I/O, and model coupling facilitates code reuse and exploiting of community infrastructure, e.g. ESMF.

# WRF Registry

- "Active data-dictionary" for managing WRF data structures
  - Database describing attributes of model state, intermediate, and configuration data
    - Dimensionality, number of time levels, staggering
    - Association with physics
    - I/O classification (history, initial, restart, boundary)
    - Communication points and patterns
    - Configuration lists (e.g. namelists)
    - Nesting up- and down-scale interpolation

# WRF Registry

- "Active data-dictionary" for managing WRF data structures
  - Program for auto-generating sections of WRF from database:
    - 2000 - 3000 Registry entries ⇒ 300-thousand lines of automatically generated WRF code
    - Allocation statements for state data and I1 data
    - Interprocessor communications: Halo and periodic boundary updates, transposes
    - Code for defining and managing run-time configuration information
    - Code for forcing, feedback, shifting, and interpolation of nest data

# WRF Registry

- Why?
  - Automates time consuming, repetitive, error-prone programming
  - Insulates programmers and code from package dependencies
  - Allow rapid development
  - Documents the data
- A Registry file is available for each of the dynamical cores, plus special purpose packages
- Reference: Description of WRF Registry, http://www.mmm.ucar.edu/wrf/WG2/software_v2

# Registry Data Base

- Currently implemented as a text file: Registry/Registry.EM
- Types of entry:
  - *Dimspec* – Describes dimensions that are used to define arrays in the model
  - *State* – Describes state variables and arrays in the domain structure
  - *I1* – Describes local variables and arrays in solve
  - *Typedef* – Describes derived types that are subtypes of the domain structure

# Registry Data Base

- Types of entry:
  - *Rconfig* – Describes a configuration (e.g. namelist) variable or array
  - *Package* – Describes attributes of a package (e.g. physics)
  - *Halo* – Describes halo update interprocessor communications
  - *Period* – Describes communications for periodic boundary updates
  - *Xpose* – Describes communications for parallel matrix transposes
  - *Include* – Similar to a CPP #include file

# Registry State Entry

```
#       Type  Sym   Dims    Use      Tlev  Stag  IO           Dname       Descrip
state   real  u     ikjb    dyn_em    2     X     i01rhusdf    "U"     "X WIND COMPONENT"
```

- Elements
  - *Entry*: The keyword "state"
  - *Type*: The type of the state variable or array (real, double, integer, logical, character, or derived)
  - *Sym*: The symbolic name of the variable or array
  - *Dims*: A string denoting the dimensionality of the array or a hyphen (-)
  - *Use*: A string denoting association with a solver or 4D scalar array, or a hyphen
  - *NumTLev*: An integer indicating the number of time levels (for arrays) or hypen (for variables)

# Registry State Entry

```
#       Type  Sym   Dims    Use      Tlev  Stag  IO          Dname      Descrip
state   real  u     ikjb    dyn_em   2     X     i01rhusdf   "U"    "X WIND COMPONENT"
```

- Elements
  - *Stagger*: String indicating staggered dimensions of variable (X, Y, Z, or hyphen)
  - *IO*: String indicating whether and how the variable is subject to I/O and Nesting
  - *DName*: Metadata name for the variable
  - *Units*: Metadata units of the variable
  - *Descrip*: Metadata description of the variable

# Registry State Entry

```
#       Type Sym  Dims    Use    Tlev Stag     IO        Dname       Descrip
state   real  u   ikjb   dyn_em   2    X    i01rhusdf    "U"     "X WIND COMPONENT"
```

- This single entry results in over 100 lines of code automatically added to more than 40 different locations in the WRF model, the real and ideal initialization programs, and in the WRF-Var package

- Nesting code to interpolate, force, feedback, and smooth u
- Addition of u to the input, restart, history, and LBC I/O streams

# Registry State Entry

```
#      Type Sym  Dims    Use    Tlev Stag     IO       Dname       Descrip
state  real  u   ikjb   dyn_em   2    X   i01rhusdf    "U"    "X WIND COMPONENT"
```

Declaration and dynamic allocation of arrays in TYPE(domain)

Two 3D state arrays corresponding to the 2 time levels of U

u_1 ( ims:ime , kms:kme , jms:jme )

u_2 ( ims:ime , kms:kme , jms:jme )

# Registry State Entry

```
#       Type  Sym   Dims     Use     Tlev Stag      IO        Dname       Descrip
state   real   u    ikjb   dyn_em    2    X     i01rhusdf     "U"     "X WIND COMPONENT"
```

Declaration and dynamic allocation of arrays in TYPE(domain)

Eight LBC arrays for boundary and boundary tendencies (dimension example for x BC)

u_b[xy][se] ( jms:jme, kms:kme, spec_bdy_width, 4 )

u_bt[xy][se] ( jms:jme, kms:kme, spec_bdy_width, 4 )

# State Entry: Defining a variable-set for an I/O stream

- Fields are added to a variable-set on an I/O stream in the Registry

```
#       Type  Sym   Dims    Use     Tlev  Stag    IO         Dname      Descrip
state   real  u     ikjb    dyn_em  2     X      i01rhusdf   "U"   "X WIND COMPONENT"
```

***IO*** is a string that specifies if the variable is to be subject to initial, restart, history, or boundary I/O. The string may consist of '**h**' (subject to history I/O), '**i**' (initial dataset), '**r**' (restart dataset), or 'b' (lateral boundary dataset). The 'h', 'r', and 'i' specifiers may appear in any order or combination.

# State Entry: Defining a variable-set for an I/O stream

- Fields are added to a variable-set on an I/O stream in the Registry

```
#       Type  Sym   Dims    Use     Tlev   Stag     IO        Dname      Descrip
state   real   u    ikjb    dyn_em   2      X    i01rhusdf    "U"    "X WIND COMPONENT"
```

The ‘h’ and ‘i’ specifiers may be followed by an optional integer string consisting of ‘0’, ‘1’, … , ‘9’ Zero denotes that the variable is part of the principal input or history I/O stream. The characters ‘1’ through ‘9’ denote one of the auxiliary input or history I/O streams.

**usdf** refers to nesting options: **u = UP, d = DOWN, s = SMOOTH, f = FORCE**

State Entry: Defining Variable-set for an I/O stream

`irh` -- The state variable will be included in the WRF model input, restart, and history I/O streams

`irh13` -- The state variable has been added to the first and third auxiliary history output streams; it has been removed from the principal history output stream, because zero is not among the integers in the integer string that follows the character 'h'

## State Entry: Defining Variable-set for an I/O stream

**`rh01`** -- The state variable has been added to the first auxiliary history output stream; it is also retained in the principal history output

**`i205hr`** -- Now the state variable is included in the principal input stream as well as auxiliary inputs 2 and 5. Note that the order of the integers is unimportant. The variable is also in the principal history output stream

State Entry: Defining Variable-set for an I/O stream

**ir12h** -- No effect; there is only 1 restart data stream

**i01 --** Data goes into real and into WRF

**i1 --** Data goes into real only

# Rconfig Entry

```
#           Type      Sym               How set                Nentries   Default
rconfig     integer spec_bdy_width   namelist,bdy_control         1            1
```

- This defines namelist entries
- Elements
  - *Entry*: the keyword “rconfig”
  - *Type*: the type of the namelist variable (integer, real, logical, string )
  - *Sym*: the name of the namelist variable or array
  - *How set*: indicates how the variable is set: e.g. namelist or derived, and if namelist, which block of the namelist it is set in

# Rconfig Entry

```
#          Type         Sym               How set              Nentries  Default
rconfig    integer spec_bdy_width  namelist,bdy_control    1           1
```

- This defines namelist entries
- Elements
  - *Nentries*: specifies the dimensionality of the namelist variable or array. If 1 (one) it is a variable and applies to all domains; otherwise specify max_domains (which is an integer parameter defined in module_driver_constants.F).
  - *Default*: the default value of the variable to be used if none is specified in the namelist; hyphen (-) for no default

# Rconfig Entry

```
#          Type        Sym              How set              Nentries  Default
rconfig    integer spec_bdy_width  namelist,bdy_control    1          1
```

- Result of this Registry Entry:
  - Define an namelist variable "spec_bdy_width" in the bdy_control section of namelist.input
  - Type integer (others: real, logical, character)
  - If this is first entry in that section, define "bdy_control" as a new section in the namelist.input file
  - Specifies that bdy_control applies to all domains in the run

```
--- File: namelist.input ---

&bdy_control
 spec_bdy_width        = 5,
 spec_zone             = 1,
 relax_zone            = 4,
    . . .
 /
```

# Rconfig Entry

```
#          Type      Sym             How set              Nentries  Default
rconfig    integer  spec_bdy_width  namelist,bdy_control    1          1
```

- Result of this Registry Entry:
  - if Nentries is “max_domains” then the entry in the namelist.input file is a comma-separate list, each element of which applies to a separate domain
  - The single entry in the Registry file applies to each of the separate domains

```
 --- File: namelist.input ---

&bdy_control
 spec_bdy_width        = 5,
 spec_zone             = 1,
 relax_zone            = 4,
    . . .
 /
```

# Rconfig Entry

```
#          Type     Sym             How set              Nentries  Default
rconfig    integer  spec_bdy_width  namelist,bdy_control    1         1
```

- Result of this Registry Entry:
  - Specify a default value of "1" if nothing is specified in the namelist.input file
  - In the case of a multi-process run, generate code to read in the bdy_control section of the namelist.input file on one process and broadcast the value to all other processes

```
 --- File: namelist.input ---

&bdy_control
 spec_bdy_width              = 5,
 spec_zone                   = 1,
 relax_zone                  = 4,
    . . .
 /
```

# Package Entry

- Elements
  - *Entry*: the keyword “package”,
  - *Package name*: the name of the package: e.g. “kesslerscheme”
  - *Associated rconfig choice*: the name of a rconfig variable and the value of that variable that choses this package

```
# specification of microphysics options
package   passiveqv     mp_physics==0    -       moist:qv
package   kesslerscheme mp_physics==1    -       moist:qv,qc,qr
package   linscheme     mp_physics==2    -       moist:qv,qc,qr,qi,qs,qg
package   ncepcloud3    mp_physics==3    -       moist:qv,qc,qr
package   ncepcloud5    mp_physics==4    -       moist:qv,qc,qr,qi,qs

# namelist entry that controls microphysics option
rconfig   integer     mp_physics   namelist,physics     max_domains    0
```

# Package Entry

- Elements
  - *Package state vars*: unused at present; specify hyphen (-)
  - *Associated* variables: the names of 4D scalar arrays (moist, chem, scalar) and the fields within those arrays this package uses, and the state variables (state:u_gc, ...)

```
# specification of microphysics options
package    passiveqv     mp_physics==0    -       moist:qv
package    kesslerscheme mp_physics==1    -       moist:qv,qc,qr
package    linscheme     mp_physics==2    -       moist:qv,qc,qr,qi,qs,qg
package    ncepcloud3    mp_physics==3    -       moist:qv,qc,qr
package    ncepcloud5    mp_physics==4    -       moist:qv,qc,qr,qi,qs

# namelist entry that controls microphysics option
rconfig    integer     mp_physics    namelist,physics     max_domains    0
```

# Package Entry

```
USE module_state_descriptions

...

micro_select : SELECT CASE ( mp_physics )

   CASE ( KESSLERSCHEME )
      CALL kessler ( ...

   CASE ( THOMPSON )
      CALL mp_gt_driver ( ...

   ...

END SELECT micro_select
```

Packages define automatically enumerated types to avoid the usual tests ( i.e. option #17 for microphysics)

# Halo Entry

- Elements
  - *Entry*: the keyword “halo”,
  - *Communication name*: given to the particular communication, must be identical in the source code (case matters!)
  - *Associated dynamical core*: dyn_em XOR dyn_nmm are acceptable
  - *Stencil size:* 4, or (2n+1)^2-1 (i.e. 8, 24, 48; semi-colon separated)
  - *Which variables*: names of the variables (comma separated)

```
# Halo update communications
halo      HALO_EM_TKE_C dyn_em 4:ph_2,phb
```

# HALO Entry

Place communication in dyn_em/solve_em.F

```
#ifdef DM_PARALLEL
#     include "HALO_EM_TKE_C.inc"
#endif
```

```
# Halo update communications
halo      HALO_EM_TKE_C dyn_em 4:ph_2,phb
```

# PERIOD and XPOSE Entry

- Elements
  - *Entry*: the keyword "period" or "xpose" (transpose)
  - *Communication name*: given to the particular communication, must be identical in the source code (case matters!)
  - *Associated dynamical core*:  dyn_em XOR dyn_nmm are acceptable
  - *Stencil size for period:* # rows and columns to share for periodic lateral BCs
  - *Which variables for period*: names of the variables (comma separated)
  - *Which variables for xpose:* original variable (3d), x-transposed and y-transposed fields

```
# Period update communications
period  PERIOD_EM_COUPLE_A dyn_em 2:mub,mu_1,mu_2
```

```
# Transpose update communications
xpose XPOSE_POLAR_FILTER_TOPO dyn_em t_init,t_xxx,dum_yyy
```

# Registry IO: registry.io_boilerplate

- include – method to populate Registry without duplicating information which is prone to administrative mismanagement
  - *Entry*: the keyword “include”
  - *Name*: file name to include in the Registry file

```
Entry                  Name
include registry.io_boilerplate
```

# Registry IO: registry.io_boilerplate

- rconfig - namelist entries
  - *Entry*: the keyword “rconfig”,
  - *Type*: integer, logical, real
  - *Symbol*: name of variable in namelist
  - *How set:* name of the resident record *(usually)*
  - *Number of entries*: either “1” or “max_domains”
  - *Default value*: what to define if not in namelist.input file
  - *NOT REQUIRED name and description*: for self documentation purposes

```
Entry       Type         Sym                How set
rconfig   character  auxinput5_inname  namelist,time_control

Num Entries                Default
    1           "auxinput5_d<domain>_<date>”
```

<domain> expanded to 2-digit domain identifier
<date> expanded to the usual WRF “years down to seconds” date string

# Registry IO: registry.io_boilerplate

```
Entry       Type        Sym                  How set

rconfig character auxinput5_outname      namelist,time_control
rconfig character auxinput5_inname       namelist,time_control
rconfig integer   auxinput5_interval_mo  namelist,time_control
rconfig integer   auxinput5_interval_d   namelist,time_control
rconfig integer   auxinput5_interval_h   namelist,time_control
rconfig integer   auxinput5_interval_m   namelist,time_control
rconfig integer   auxinput5_interval_s   namelist,time_control
rconfig integer   auxinput5_interval     namelist,time_control
rconfig integer   auxinput5_begin_y      namelist,time_control
rconfig integer   auxinput5_begin_mo     namelist,time_control
rconfig integer   auxinput5_begin_d      namelist,time_control
rconfig integer   auxinput5_begin_h      namelist,time_control
rconfig integer   auxinput5_begin_m      namelist,time_control
rconfig integer   auxinput5_begin_s      namelist,time_control
rconfig integer   auxinput5_end_y        namelist,time_control
rconfig integer   auxinput5_end_mo       namelist,time_control
rconfig integer   auxinput5_end_d        namelist,time_control
rconfig integer   auxinput5_end_h        namelist,time_control
rconfig integer   auxinput5_end_m        namelist,time_control
rconfig integer   auxinput5_end_s        namelist,time_control
rconfig integer   io_form_auxinput5      namelist,time_control
```

# Registry IO: registry.io_boilerplate

| Entry | Type | Sym | How set |
|---|---|---|---|
| rconfig | integer | io_form_input | namelist,time_control |
| rconfig | integer | io_form_history | namelist,time_control |
| rconfig | integer | io_form_restart | namelist,time_control |
| rconfig | integer | io_form_boundary | namelist,time_control |
| rconfig | integer | io_form_auxinput1 | namelist,time_control |
| rconfig | integer | io_form_auxinput2 | namelist,time_control |
| rconfig | integer | io_form_auxinput3 | namelist,time_control |
| rconfig | integer | io_form_auxinput4 | namelist,time_control |
| rconfig | integer | io_form_auxinput5 | namelist,time_control |
| rconfig | integer | io_form_auxinput6 | namelist,time_control |
| rconfig | integer | io_form_auxinput7 | namelist,time_control |
| rconfig | integer | io_form_auxinput8 | namelist,time_control |
| rconfig | integer | io_form_auxinput9 | namelist,time_control |
| rconfig | integer | io_form_gfdda | namelist,fdda |
| rconfig | integer | io_form_auxinput11 | namelist,time_control |

For any given WRF model fcst, users have access to these input streams

# Registry IO: registry.io_boilerplate

| Entry | Type | Sym | How set |
|---|---|---|---|
| rconfig | integer | io_form_auxhist1 | namelist,time_control |
| rconfig | integer | io_form_auxhist2 | namelist,time_control |
| rconfig | integer | io_form_auxhist3 | namelist,time_control |
| rconfig | integer | io_form_auxhist4 | namelist,time_control |
| rconfig | integer | io_form_auxhist5 | namelist,time_control |
| rconfig | integer | io_form_auxhist6 | namelist,time_control |
| rconfig | integer | io_form_auxhist7 | namelist,time_control |
| rconfig | integer | io_form_auxhist8 | namelist,time_control |
| rconfig | integer | io_form_auxhist9 | namelist,time_control |
| rconfig | integer | io_form_auxhist10 | namelist,time_control |
| rconfig | integer | io_form_auxhist11 | namelist,time_control |

… and access to these output streams

# Registry Data Base - Review

- Currently implemented as a text file: Registry/Registry.EM
- Types of entry:
  - *Dimspec* – Describes dimensions that are used to define arrays in the model
  - *State* – Describes state variables and arrays in the domain structure
  - *I1* – Describes local variables and arrays in solve
  - *Typedef* – Describes derived types that are subtypes of the domain structure

# Registry Data Base - Review

- Types of entry:
  - *Rconfig* – Describes a configuration (e.g. namelist) variable or array
  - *Package* – Describes attributes of a package (e.g. physics)
  - *Halo* – Describes halo update interprocessor communications
  - *Period* – Describes communications for periodic boundary updates
  - *Xpose* – Describes communications for parallel matrix transposes
  - *include* – Similar to a CPP #include file

# Outline

- Registry Mechanics

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- Examples
  - 0) Add output without recompiling
  - 1) Add a variable to the namelist
  - 2) Add an array
  - 3) Compute a diagnostic
  - 4) Add a physics package

# Example 0: Add output without recompiling

- Edit the namelist.input file, the time_control namelist record

```
iofields_filename   = "myoutfields.txt"  (MAXDOM)
io_form_auxhist24   = 2  (choose an available stream)
auxhist24_interval = 10 (MAXDOM, every 10 minutes)
```

- Place the fields that you want in the named text file **`myoutfields.txt`**

```
+:h:24:RAINC,RAINNC
```

- Where "**+**" means ADD this variable to the output stream, "**h**" is the history stream, and "**24**" is the stream number

# Example 0: Zap output without recompiling

- Edit the namelist.input file, the time_control namelist record

```
iofields_filename = "myoutfields.txt"
```

- Place the fields that you want in the named text file `myoutfields.txt`

```
-:h:0:W,PB,P
```

- Where "`-`" means REMOVE this variable from the output stream, "`h`" is the history stream, and "`0`" is the stream number (standard WRF history file)

# Example 1: Add a variable to the namelist

- Use the examples for the rconfig section of the Registry
- Find a namelist variable similar to what you want
  - Integer *vs* real *vs* logical *vs* character
  - Single value *vs* value per domain
  - Select appropriate namelist record
- Insert your mods in all appropriate Registry files

# Example 1: Add a variable to the namelist

- Remember that ALL Registry changes require that the WRF code be cleaned and rebuilt

```
./clean -a
./configure
./compile em_real
```

# Example 1: Add a variable to the namelist

- Adding a variable to the namelist requires the inclusion of a new line in the Registry file:

```
rconfig integer my_option_1  namelist,time_control  1 0 - "my_option_1" "test namelist option”
rconfig integer my_option_2  namelist,time_control  max_domains 0
```

- Accessing the variable is through an automatically generated function:

```
USE module_configure
INTEGER :: my_option_1 , my_option_2

CALL nl_get_my_option_1( 1, my_option_1 )
CALL nl_set_my_option_2( grid%id, my_option_2 )
```

# Example 1: Add a variable to the namelist

- You also have access to the namelist variables from the grid structure …

```
SUBROUTINE foo ( grid , ... )

   USE module_domain
   TYPE(domain) :: grid

   print *,grid%my_option_1
```

# Example 1: Add a variable to the namelist

- … and you also have access to the namelist variables from config_flags

```
SUBROUTINE foo2 ( config_flags , ... )

   USE module_configure
   TYPE(grid_config_rec_type) :: config_flags

   print *,config_flags%my_option_2
```

# Example 1: Add a variable to the namelist

- What your variable looks like in the namelist.input file

```
&time_control
run_days                                    = 0,
run_hours                                   = 0,
run_minutes                                 = 40,
run_seconds                                 = 0,
start_year                                  = 2006, 2006, 2006,
my_option_1                                 = 17
my_option_2                                 = 1, 2, 3
```

# Examples

- 1) Add a variable to the namelist
- 2) Add an array to solver, and IO stream
- 3) Compute a diagnostic
- 4) Add a physics package

# Example 2: Add an Array

- Adding a state array to the solver, requires adding a single line in the Registry
- Use the previous Registry instructions for a state or l1 variable

# Example 2: Add an Array

- Select a variable similar to one that you would like to add
  - 1d, 2d, or 3d
  - Staggered (X, Y, Z, or not “-”, *do not leave blank*)
  - Associated with a package
  - Part of a 4d array
  - Input (012), output, restart
  - Nesting, lateral forcing, feedback

# Example 2: Add an Array

- Copy the “similar” field’s line and make a few edits
- Remember, no Registry change takes effect until a “clean -a” and rebuild

```
state  real  h_diabatic  ikj  misc  1  -      r                    \
       "h_diabatic"  "PREVIOUS TIMESTEP CONDENSATIONAL HEATING"

state  real  msft        ij   misc  1  -     i012rhdu=(copy_fcnm)  \
       "MAPFAC_M"    "Map scale factor on mass grid"

state  real  ht          ij   misc  1  -     i012rhdus             \
       "HGT"         "Terrain Height"

state  real  ht_input    ij   misc  1  -     -                     \
       "HGT_INPUT"   "Terrain Height from FG Input File"

state  real  TSK_SAVE    ij   misc  1  -     -                     \
       "TSK_SAVE"    "SURFACE SKIN TEMPERATURE"   "K"
```

# Example 2: Add an Array

- Always modify Registry.*core_name*, where *core_name* might be EM, for example

```
state  real  h_diabatic  ikj  misc  1  -      r                       \
       "h_diabatic"  "PREVIOUS TIMESTEP CONDENSATIONAL HEATING"

state  real  msft          ij   misc  1  -     i012rhdu=(copy_fcnm)  \
       "MAPFAC_M"    "Map scale factor on mass grid"

state  real  ht            ij   misc  1  -     i012rhdus             \
       "HGT"         "Terrain Height"

state  real  ht_input      ij   misc  1  -     -                     \
       "HGT_INPUT"   "Terrain Height from FG Input File"

state  real  TSK_SAVE      ij   misc  1  -     -                     \
       "TSK_SAVE"    "SURFACE SKIN TEMPERATURE"  "K"
```

# Example 2: Add an Array

- Add a new 3D array that is sum of all moisture species, called all_moist, in the Registry.EM
  - Type: real
  - Dimensions: 3D and ikj ordering, not staggered
  - Supposed to be output only: h
  - Name in netCDF file: all_moist

```
state    real   all_moist      ikj      \
dyn_em       1       -     h   \
"all_moist"  \
"sum of all of moisture species"     \
"kg kg-1"
```

# Example 2: Add an Array

- Registry state variables become part of the derived data structure usually called grid inside of the WRF model.
- WRF model top → integrate → solve_interface → solve
- Each step, the grid construct is carried along for the ride
- No source changes for new output variables required until below the solver routine

# Example 2: Add an Array

- Top of solve_em.F
- grid is passed in
- No need to declare any new variables, such as all_moist

```
!WRF:MEDIATION_LAYER:SOLVER

  SUBROUTINE solve_em ( grid , &

  config_flags , &
```

# Example 2: Add an Array

- In solve_em, add the new array to the call for the microphysics driver
- Syntax for variable=local_variable is a association convenience
- 0D, 1D, 2D, 3D state arrays are contained within grid, and must be de-referenced

```
CALL microphysics_driver(                  &
     QV_CURR=moist(ims,kms,jms,P_QV),  &
     QC_CURR=moist(ims,kms,jms,P_QC),  &
     QR_CURR=moist(ims,kms,jms,P_QR),  &
     QI_CURR=moist(ims,kms,jms,P_QI),  &
     QS_CURR=moist(ims,kms,jms,P_QS),  &
     QG_CURR=moist(ims,kms,jms,P_QG),  &
     QH_CURR=moist(ims,kms,jms,P_QH),  &
     all_moist=grid%all_moist       ,  &
```

# Example 2: Add an Array

- After the array is re-referenced from grid and we are inside the microphysics_driver routine, we need to
  - Pass the variable through the argument list
  - Declare our passed in 3D array

```
 ,all_moist &




REAL, DIMENSION(ims:ime ,kms:kme ,jms:jme ), &
      INTENT(OUT) ::  all_moist
```

# Example 2: Add an Array

- After the array is re-referenced from grid and we are inside the microphysics_driver routine, we need to
  - Zero out the array at each time step

```
!   Zero out moisture sum.

 DO j = jts,MIN(jde-1,jte)
 DO k = kts,kte
 DO i = its,MIN(ide-1,ite)
    all_moist(i,k,j) = 0.0
 END DO
 END DO
 END DO
```

# Example 2: Add an Array

- After the array is re-referenced from grid and we are inside the microphysics_driver routine, we need to
  - At the end of the routine, for each of the moist species that exists, add that component to all_moist

```
DO j = jts,MIN(jde-1,jte)
  DO k = kts,kte
  IF ( f_QV ) THEN
     DO i = its,MIN(ide-1,ite)
        all_moist(i,k,j) = all_moist(i,k,j) + &
                           qv_curr(i,k,j)
      END DO
  END IF
```