WRF Registry and Examples

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United Way
Valvoline
Virgin
WAL★MART
Wendy's
XEROX
Zellers
Zippo
Zantac

Outline

- Registry Mechanics

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- Examples

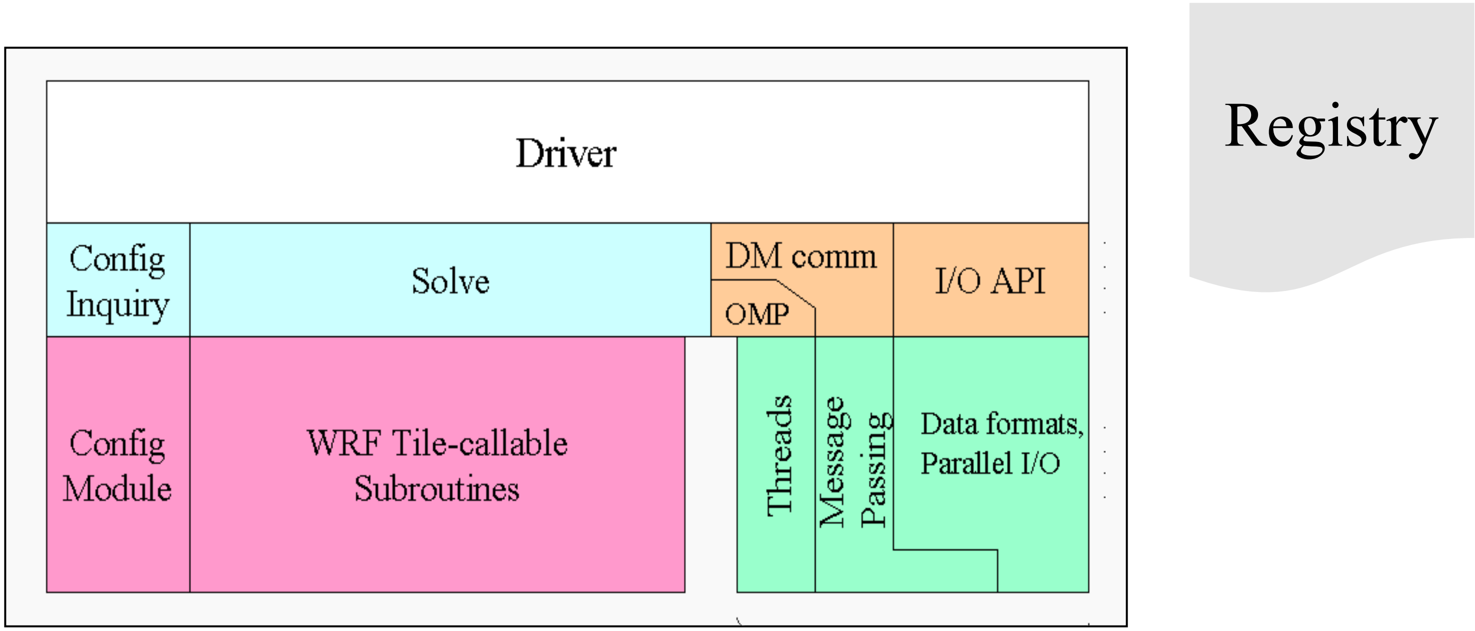
Introduction – Intended Audience

- 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:
    - <u>2000 - 3000</u> Registry entries ⇒ <u>300-thousand</u> lines of automatically generated WRF code

```
cd frame
cat *.F | wc -l
   21558
cat *.f90 | wc -l
  250653
cd ../share
cat *.F | wc -l
   34040
cat *.f90 | wc -l
  124004
```

- 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

- "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_COMMON
- 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
```

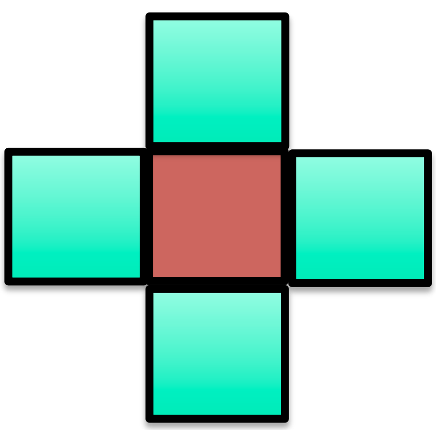
Package Entry

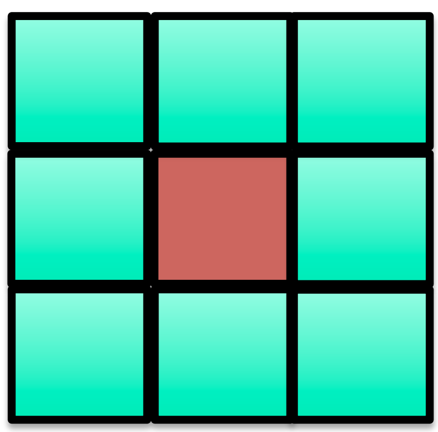
```
USE module_state_descriptions

...

Micro_select : SELECT CASE ( mp_physics )

   CASE ( KESSLERSCHEME )
      CALL kessler ( ...

   CASE ( THOMPSON )
      CALL mp_gt_driver ( ...

   ...

END SELECT micro_select
```

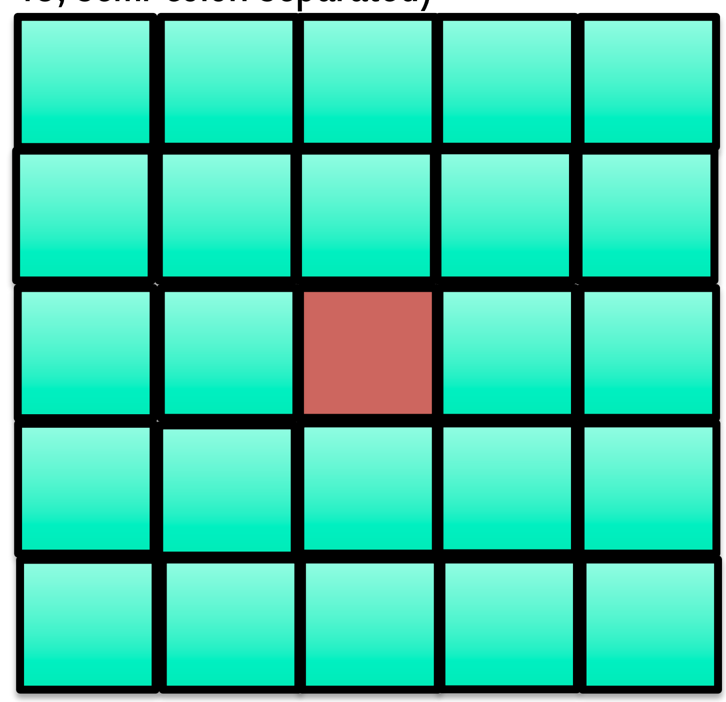
Packages define automatically enumerated types to avoid the usual tests (i.e. option #17 for microphysics)

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







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 variable

```
# 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_auxinput24	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
rconfig	integer	io_form_auxhist24	namelist,time_control

… and access to these output streams

Registry Data Base - Review

- Currently implemented as a text file: Registry/Registry.EM_COMMON
- 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 I1 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*_COMMON or Registry.*core_name*, where *core_name* might be EM

```
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_COMMON
  - 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

- The solve routine calls first_rk_step_part1
- grid is passed in
- No need to pass any variables, such as all_moist

```
!WRF:MEDIATION_LAYER:SOLVER

  CALL first_rk_step_part1( grid , &

  config_flags , &
```

Example 2: Add an Array

- Top of first_rk_step_part1.F
- grid is passed in
- No need to declare any new variables, such as all_moist

```
!WRF:MEDIATION_LAYER:SOLVER

MODULE module_first_rk_step_part1

CONTAINS

  SUBROUTINE first_rk_step_part1 ( grid , &

  config_flags , &
```

Example 2: Add an Array

- In first_rk_step_part1, add the new array to the call for the microphysics driver
- Syntax for variable=local_variable is an association convenience
- All 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
```

Examples

- 1) Add a variable to the namelist
- 2) Add an array
- 3) Compute a diagnostic
- 4) Add a physics package

Example 3: Compute a Diagnostic

- Problem: Output global average and global maximum and lat/lon location of maximum for 10 meter wind speed in WRF
- Steps:
  - Modify solve to compute wind-speed and then compute the local sum and maxima at the end of each time step
  - Use reduction operations built-in to WRF software to compute the global qualities
  - Output these on one process (process zero, the "monitor" process)

Example 3: Compute a Diagnostic

- Compute local sum and local max and the local indices of the local maximum

```
    --- File: dyn_em/solve_em.F  (near the end) ---

! Compute local maximum and sum of 10m wind-speed
    sum_ws = 0.
    max_ws = 0.
    DO j = jps, jpe
      DO i = ips, ipe
        wind_vel = sqrt( grid%u10(i,j)**2+ grid%v10(i,j)**2 )
        IF ( wind_vel .GT. max_ws ) THEN
           max_ws = wind_vel
           idex = i
           jdex = j
        ENDIF
        sum_ws = sum_ws + wind_vel
      ENDDO
    ENDDO
```

Example 3: Compute a Diagnostic

- Compute global sum, global max, and indices of the global max (WRF intrinsics)

```
! Compute global sum
   sum_ws = wrf_dm_sum_real ( sum_ws )

! Compute global maximum and associated i,j point
   CALL wrf_dm_maxval_real ( max_ws, idex, jdex )
```

Example 3: Compute a Diagnostic

- On the process that contains the maximum value, obtain the latitude and longitude of that point; on other processes set to an artificially low value.
- The use parallel reduction to store that result on every process

```
   IF ( ips .LE. idex .AND. idex .LE. ipe .AND.  &
        jps .LE. jdex .AND. jdex .LE. jpe ) THEN
      glat = grid%xlat(idex,jdex)
      glon = grid%xlong(idex,jdex)
   ELSE
      glat = -99999.
      glon = -99999.
   ENDIF

! Compute global maximum to find glat and glon
   glat = wrf_dm_max_real ( glat )
   glon = wrf_dm_max_real ( glon )
```

Example 3: Compute a Diagnostic

- Output the value on process zero, the "monitor"

```
! Print out the result on the monitor process
   IF ( wrf_dm_on_monitor() ) THEN
      WRITE(outstring,*)'Avg. ',sum_ws/((ide-ids+1)*(jde-jds+1))
      CALL wrf_message ( TRIM(outstring) )
      WRITE(outstring,*)'Max. ',max_ws,' Lat. ',glat,&
                                        ' Lon. ',glon
      CALL wrf_message ( TRIM(outstring) )
   ENDIF
```

Example 3: Compute a Diagnostic

- Output from process zero of a multi-process run

```
    --- Output file: rsl.out.0000 ---
    . . .
  Avg.    5.159380
  Max.    15.09370     Lat.    37.25022     Lon.   -67.44571
Timing for main: time 2000-01-24_12:03:00 on domain   1:    8.96500 elapsed secs.
  Avg.    5.166167
  Max.    14.97418     Lat.    37.25022     Lon.   -67.44571
Timing for main: time 2000-01-24_12:06:00 on domain   1:    4.89460 elapsed secs.
  Avg.    5.205693
  Max.    14.92687     Lat.    37.25022     Lon.   -67.44571
Timing for main: time 2000-01-24_12:09:00 on domain   1:    4.83500 elapsed secs.
   . . .
```

Examples

- 1) Add a variable to the namelist
- 2) Add an array
- 3) Compute a diagnostic
- 4) Add a physics package

Example 4: Input periodic SSTs

- Add a new physics package with time varying input source to the model
- This is how we could supply a time varying value to the model for a field that is traditionally fixed
- Example is sea surface temperature

Example 4: Input periodic SSTs

- Problem: adapt WRF to input a time-varying lower boundary condition, e.g. SSTs, from an input file for a new surface scheme
- Given: Input file in WRF I/O format containing 12-hourly SST's
- Modify WRF model to read these into a new state array and make available to WRF surface physics

Example 4: Input periodic SSTs

- Steps
  - Add a new state variable and definition of a new surface layer package (that will use the variable) to the Registry
  - Add to variable stream for an unused Auxiliary Input stream
  - Adapt physics interface to pass new state variable to physics
  - Setup namelist to input the file at desired interval

Example 4: Input periodic SSTs

- Add a new state variable to Registry/Registry.EM or Registry/Registry.NMM and put it in the variable set for input on AuxInput #4

```
#     type   symbol dims use   tl  stag   io      dname      description        units
state real   nsst   ij   misc  1   -      i4h   "NEW_SST" "Time Varying SST" "K"
```

- Also added to History and Restart
- Result:
  - 2-D variable named **nsst** defined and available in solve_em
  - Dimensions: ims:ime, jms:jme
  - Input and output on the AuxInput #4 stream will include the variable under the name NEW_SST

Example 4: Input periodic SSTs

- Pass new state variable to surface physics

```
        --- File: dyn_em/module_first_rk_step_part1.F ---

   CALL surface_driver(                                                  &
              . . .
 ! Optional
  &          ,QV_CURR=moist(ims,kms,jms,P_QV), F_QV=F_QV                 &
  &          ,QC_CURR=moist(ims,kms,jms,P_QC), F_QC=F_QC                 &
  &          ,QR_CURR=moist(ims,kms,jms,P_QR), F_QR=F_QR                 &
  &          ,QI_CURR=moist(ims,kms,jms,P_QI), F_QI=F_QI                 &
  &          ,QS_CURR=moist(ims,kms,jms,P_QS), F_QS=F_QS                 &
  &          ,QG_CURR=moist(ims,kms,jms,P_QG), F_QG=F_QG                 &
  &          ,NSST=grid%nsst                                             & ! new
  &          ,CAPG=grid%capg, EMISS=grid%emiss, HOL=hol,MOL=grid%mol     &
  &          ,RAINBL=grid%rainbl,SR=grid%em_sr                           &
  &          ,RAINNCV=grid%rainncv,REGIME=regime,T2=grid%t2,THC=grid%thc &
                . . .
```

Example 4: Input periodic SSTs

- Add new variable nsst to Physics Driver in Mediation Layer

```
     --- File: phys/module_surface_driver.F ---

SUBROUTINE surface_driver(                                       &
       . . .
          !  Other optionals (more or less em specific)
  &          ,nsst                                               &
  &          ,capg,emiss,hol,mol                                 &
  &          ,rainncv,rainbl,regime,t2,thc                       &
  &          ,qsg,qvg,qcg,soilt1,tsnav                           &
  &          ,smfr3d,keepfr3dflag                                &
      . . .
                                                                 ))
      . . .
REAL, DIMENSION( ims:ime, jms:jme ), OPTIONAL, INTENT(INOUT)::   nsst
```

- By making this an “Optional” argument, we preserve the driver’s compatibility with other cores and with versions of WRF where this variable hasn’t been added.

Example 4: Input periodic SSTs

- Add call to Model-Layer subroutine for new physics package to Surface Driver

```
        --- File: phys/module_surface_driver ---

!$OMP PARALLEL DO   &
!$OMP PRIVATE ( ij, i, j, k )
   DO ij = 1 , num_tiles
     sfclay_select: SELECT CASE(sf_sfclay_physics)

       CASE (SFCLAYSCHEME)
          . . .
       CASE (NEWSFCSCHEME)  ! <- This is defined by the Registry "package" entry

         IF (PRESENT(nsst))  THEN
            CALL NEWSFCCHEME(                                         &
                nsst,                                                 &
                ids,ide, jds,jde, kds,kde,                            &
                ims,ime, jms,jme, kms,kme,                            &
                i_start(ij),i_end(ij), j_start(ij),j_end(ij), kts,kte    )
         ELSE
           CALL wrf_error_fatal('Missing argument for NEWSCHEME in surface driver')
         ENDIF
          . . .
     END SELECT sfclay_select
   ENDDO
!$OMP END PARALLEL DO
```

- Note the PRESENT test to make sure new optional variable nsst is available

Example 4: Input periodic SSTs

- Add definition for new physics package NEWSCHEME as setting 4 for namelist variable sf_sfclay_physics

```
rconfig   integer  sf_sfclay_physics   namelist,physics   max_domains    0

package   sfclayscheme   sf_sfclay_physics==1        -            -
package   myjsfcscheme   sf_sfclay_physics==2        -            -
package   gfssfcscheme   sf_sfclay_physics==3        -            -
package   newsfcscheme   sf_sfclay_physics==4        -            -
```

- This creates a defined constant NEWSFCSCHEME and represents selection of the new scheme when the namelist variable sf_sfclay_physics is set to '4' in the namelist.input file
- `clean -a` and recompile so code and Registry changes take effect

Example 4: Input periodic SSTs

- Setup namelist to input SSTs from the file at desired interval

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

&time_control
   . . .
 auxinput4_inname       = "sst_input"
 auxinput4_interval_h   = 12
 . . .
/

   . . .
&physics
 sf_sfclay_physics   = 4, 4, 4
   . . .
/
```

- Run code with sst_input file in run-directory

Example 4: Input periodic SSTs

- A few notes…
  - The read times and the time-stamps in the input file must match exactly
  - We haven’t done anything about what happens if the file runs out of time periods (the last time period read will be used over and over again, though you’ll see some error messages in the output if you set debug_level to be 1 or greater in namelist.input)
  - We haven’t said anything about what generates sst_input

Examples

- 1) Add a variable to the namelist
- 2) Add an array
- 3) Compute a diagnostic
- 4) Add a physics package
- 5) Simple Tracer example

Tracer Example

- Add a continuous value to the lowest layers in the model at a particular grid cell to simulate a plume release.
- Use the “tracer” array with a new 3D component.
- Create a new NML option.
- Modify Registry for new fields.
- Initialize data in real.
- Set values in solver.