WRF Software 1 - Registry

John Michalakes, NCAR

Dave Gill, NCAR

WRF Software Architecture Working Group

Outline

- Registry Mechanics

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

- Examples

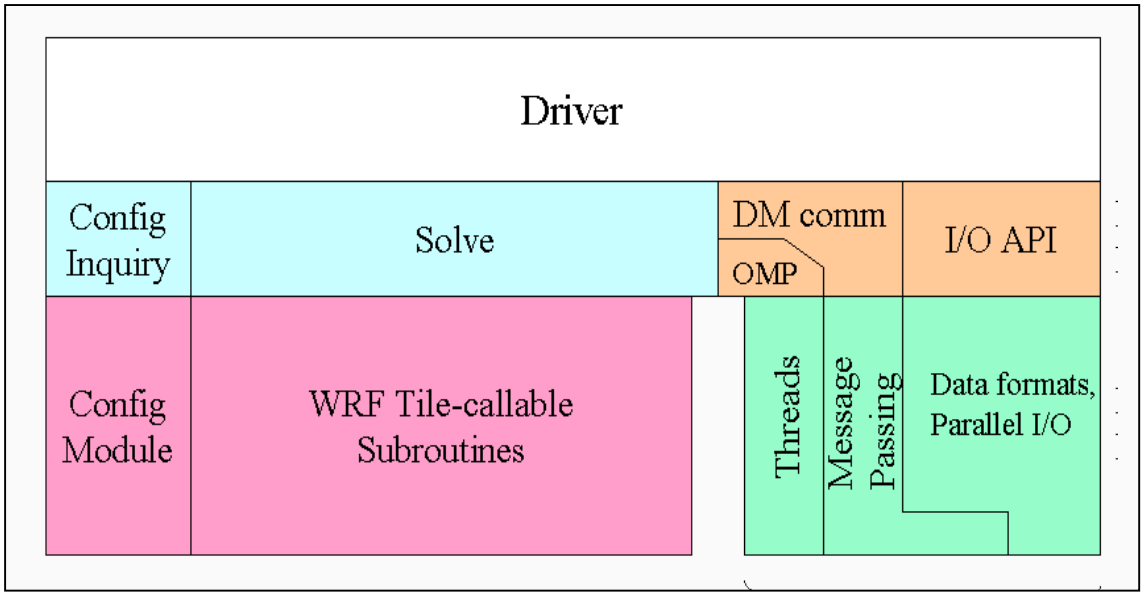
Introduction – Intended Audience

- 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



Registry

- 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
  - Program for auto-generating sections of WRF from database:
    - 2000 - 3000 Registry entries $\Longrightarrow$ 90-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** and **Registry/Registry.NMM**
- 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
  - ***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: ordinary State

- 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)
  - *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

```
#       Type Sym  Dims   Use    Tlev Stag IO          Dname      Descrip

state   real  u   ikjb   dyn_em   2   X    i01rhusdf   "U"    "X WIND COMPONENT"
```

Registry State Entry: ordinary State

```
#       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 130 lines automatically added to 43 different locations of the WRF code:
  - 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)
    - Two LBC arrays for boundary and boundary tendencies
      u_b (max(ide,jde), kms:kme, spec_bdy_width, 4)
      u_bt (max(ide,jde), kms:kme, spec_bdy_width, 4)
  - Nesting code to interpolate, force, feedback, and smooth **u**
  - Addition of **u** to the input, restart, history, and LBC I/O streams

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.

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'

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

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

- 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
  - *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

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

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
    - 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

```
 --- 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
```

- 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
  - *Package state vars*: unused at present; specify hyphen (-)
  - *Associated* 4D *scalars*: the names of 4D scalar arrays and the fields within those arrays this package uses

```
# 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,namelist_04     max_domains    0
```

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
```

Registry IO: registry.io_boilerplate

- rconfig - namelist entries
  - *Entry*: the keyword "rconfig",
  - *Type*: integer, logical, real
  - *WRF symbol*: name of variable in namelist
  - *Namelist record:* name of the resident record
  - *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
```

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
```

Outline

- Registry Mechanics

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

- Examples
  - Add a variable to the namelist
  - Add an array
  - Compute a diagnostic
  - Add a physics package

Example: 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  namelist,time_control  1 0 - "my_option" "test namelist option"
```

- Accessing the variable is through an automatically generated function:

```
USE module_configure
INTEGER :: my_option

CALL nl_get_my_option( 1, my_option )
```

Examples

- Add a variable to the namelist
- Add an array to solver, and IO stream
- Compute a diagnostic
- Add a physics package

Example: Add an Array

- Adding a state array to the solver, requires adding a single line in the Registry.

```
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"
```

Examples

- Add a variable to the namelist
- Add an array
- Compute a diagnostic
- Add a physics package

Example: 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 qualitities
  - Output these on one process (process zero, the “monitor” process)

Example: 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( u10(i,j)*u10(i,j) + v10(i,j)*v10(i,j) )
       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: Compute a Diagnostic

- Compute global sum, global max, and indices of the global max

```
! 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: 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 = xlat(idex,jdex)
      glon = 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: 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: Compute a Diagnostic

- Output from process zero of a 4 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

- Add a variable to the namelist
- Add an array
- Compute a diagnostic
- Add a physics package

Examples: working with WRF software

Add a new physics package with time varying input source to the model

Example: 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: 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: Input periodic SSTs

- Add a new state variable to Registry/Registry.EM and put it in the variable set for input on AuxInput #5

```
#      type   symbol dims use   tl stag  io      dname      description         units
state  real   nsst   ij   misc  1  -     i5rh   "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 #5 stream will include the variable under the name NEW_SST

Example: Input periodic SSTs

- Add a new state variable to Registry/Registry.NMM and put it in the variable set for input on AuxInput #5

```
#     type   symbol dims use   tl stag  io      dname      description         units
state real   nsst   ij   misc  1  -     i5rh   "NEW_SST" "Time Varying SST" "K"
```

  - Also added to History and Restart
- Result:
  - 2-D variable named **nsst** defined and available in solve_nmm
  - Dimensions: ims:ime, jms:jme
  - Input and output on the AuxInput #5 stream will include the variable under the name NEW_SST

Example: Input periodic SSTs

- Pass new state variable to surface physics

```
        --- File: dyn_em/solve_em.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: 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                                       &
          !  Other optionals (more or less nmm specific)
  &          ,potevp,snopcx,soiltb,sr                                   &
                                                                         ))
      . . .
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: 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: 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: Input periodic SSTs

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

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

&time_control
   . . .
 auxinput5_inname      = "sst_input"
 auxinput5_interval_h  = 12
 . . .
/

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

- Run code with sst_input file in run-directory

Example: 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