How to Use the WRF Registry

John Michalakes, NCEP

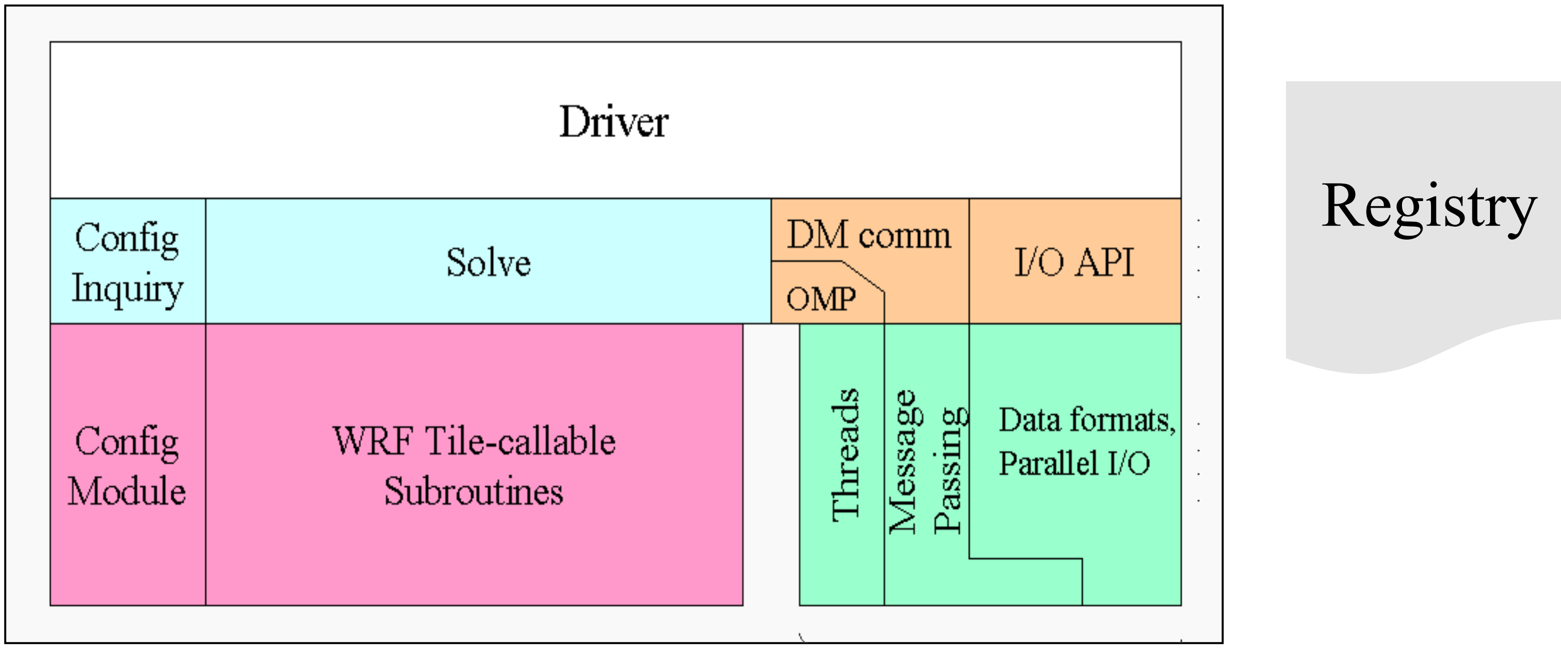
Dave Gill, NCAR

WRF Software Architecture Working Group

Outline

- What is the WRF Registry
- Keyword syntax
- The BIG Three
- Examples
  - Runtime I/O mods
  - Adding a variable to the namelist
  - Adding an array to WRF
  - Compute a diagnostic
  - New physics scheme
  - Passive tracer

WRF Software Architecture



Text based file for real and WRF
Active data dictionary
Used with cpp to auto generate source
Controls/defines
- Variables (I/O, comms, nesting)
- Communications
- namelist options

About 300k lines added to source
Easy – 3x the size since initial release
Compile-time option
- ./clean
- ./configure
- ./compile

Registry.EM_COMMON (else lost changes)

Registry Keywords

- 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 Keywords

- 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   tsk    ij    misc     1     -     i01rhusdf    "TSK"    "SKIN TEMP"
```

- 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   tsk    ij    misc     1     -     i01rhusdf   "TSK"     "SKIN TEMP"
```

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

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	tsk	ij	misc	1	-	i01rhusdf	"TSK"	"SKIN TEMP"

- ***IO*** is a string that specifies if the variable is to be available to initial, restart, or history I/O. The string may consist of '**h**' (subject to history I/O), '**i**' (initial dataset), '**r**' (restart 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  tsk    ij     misc    1      -     i01rhusdf   "TSK"    "SKIN TEMP"
```

- 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.

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	tsk	ij	misc	1	-	i01rhusdf	"TSK"	"SKIN TEMP"

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

u – at end of each set of child time steps
d – at instantiation of child domain
f – at beginning of each set of child time steps
s – after each feedback

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  tsk   ij     misc   1     -       i01rhusdf  "TSK"     "SKIN TEMP"
```

Only variables involved with I/O, communications, packages are required to be state

Local variables inside of physics packages are not controlled by the Registry

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

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
```

Outline

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

Example 1: 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 1: 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)

Outline

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

Example 2: 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 2: 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 2: 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 2: 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 2: 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 2: 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
```

Outline

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

Example 3: 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 3: 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 3: 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 3: 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 3: 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 3: 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 3: 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 3: 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 3: 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 3: 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 3: 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 3: 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 3: 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
```

Outline

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

Example 4: 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 4: 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 4: 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 4: 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 4: 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 4: 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.
    . . .
```

Outline

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

Example 5: 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 5: 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 5: 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 5: Input periodic SSTs

- Add a new state variable to Registry/Registry.EM_COMMON and put it in the variable set for input on Auxiliary Input Stream #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 grid%**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 5: 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 5: 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 5: 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 5: 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 5: 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

Outline

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

Tracer Example

Modify Registry for new fields.

- Use the "tracer" array with a new 3D component
- Use existing NML option

Initialize data in real.

- Identify (i,j) location
- Spread in "PBL"

Set values in solver.

- "Release" per time step

Tracer Example

Registry/Registry.EM add our new field “PLUME” as part of “TRACER” array.

```
#     New tracer for example
state  real  plume  ikjftb  tracer \
     1  -  irhusdf=(bdy_interp:dt) \
     "PLUME"  "Fukushima Tracer"  " "

#     4D arrays need an associated package
package  tracer_test3  tracer_opt==3  - \
     tracer:plume
```

Tracer Example

Modify the real and WRF programs to initialize and continuously re-supply the "PLUME" array

dyn_em/module_initialize_real.F (initial value from real.exe)

dyn_em/solve_em.F (continuous plume in wrf.exe)

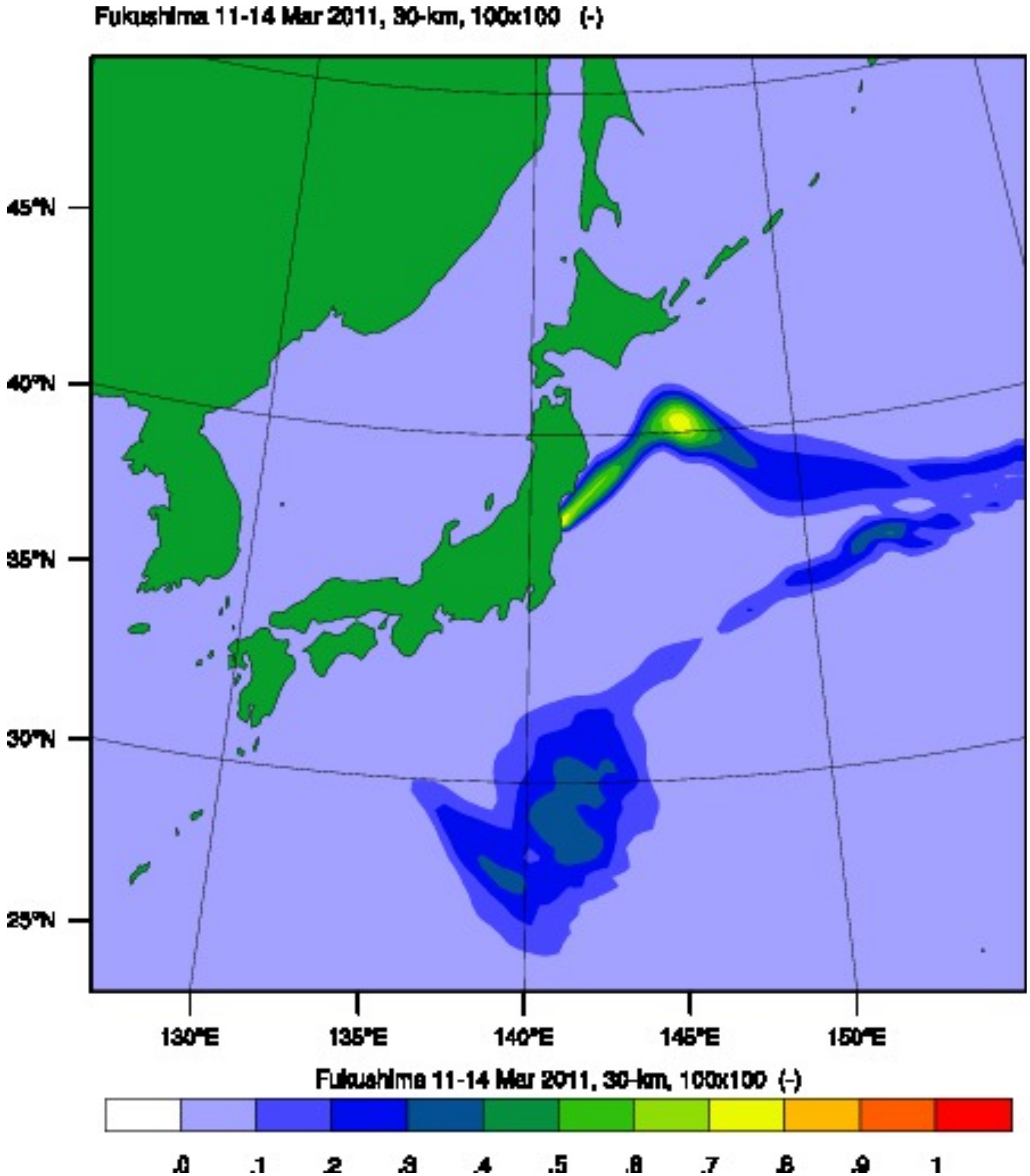
```
!   Add in the Fukushima initial venting.

    IF ( ( its .LE. 50 ) .AND. ( ite .GE. 50 ) .AND. &
         ( jts .LE. 50 ) .AND. ( jte .GE. 50 ) ) THEN
       tracer(50,1:5,50,P_plume) = 1.
    END IF
```

Tracer Example

- Modify the test/em_real/namelist.input file
- Include the new settings for the tracer option required from the Registry file

```
&dynamics
 tracer_opt  = 3, 3, 3,
```


Fukushima 11-14 Mar 2011, 30-km, 100x100 (-)
45°N
40°N
35°N
30°N
25°N
130°E
135°E
140°E
145°E
150°E
Fukushima 11-14 Mar 2011, 30-km, 100x100 (-)
.0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1

Outline

- What is the WRF Registry
- Keyword syntax
- The BIG Three
- Examples
  - Runtime I/O mods
  - Adding a variable to the namelist
  - Adding an array to WRF