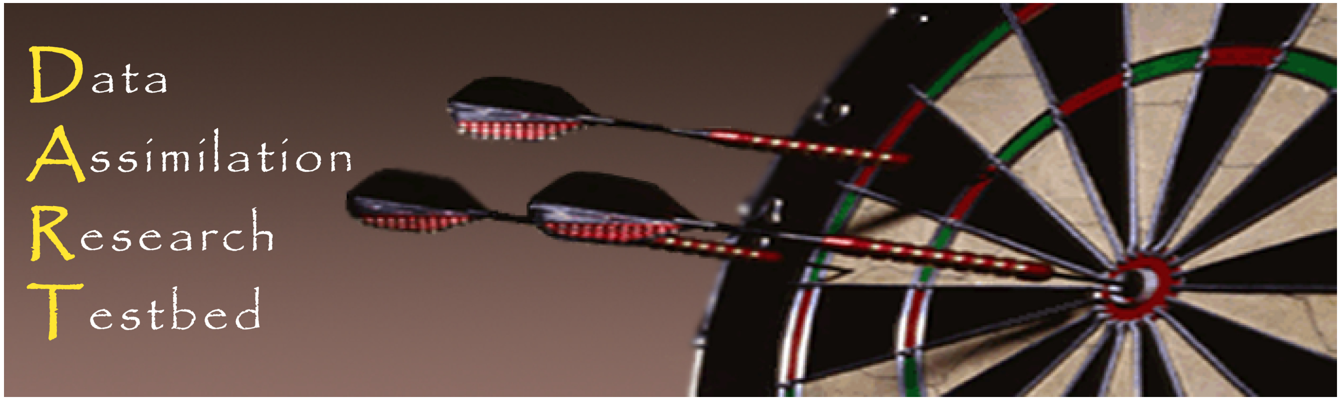
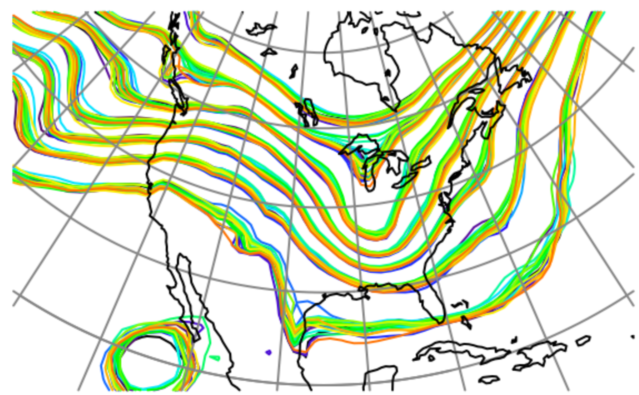


DART Tutorial Section 21:
Observation Types and Observing System Design



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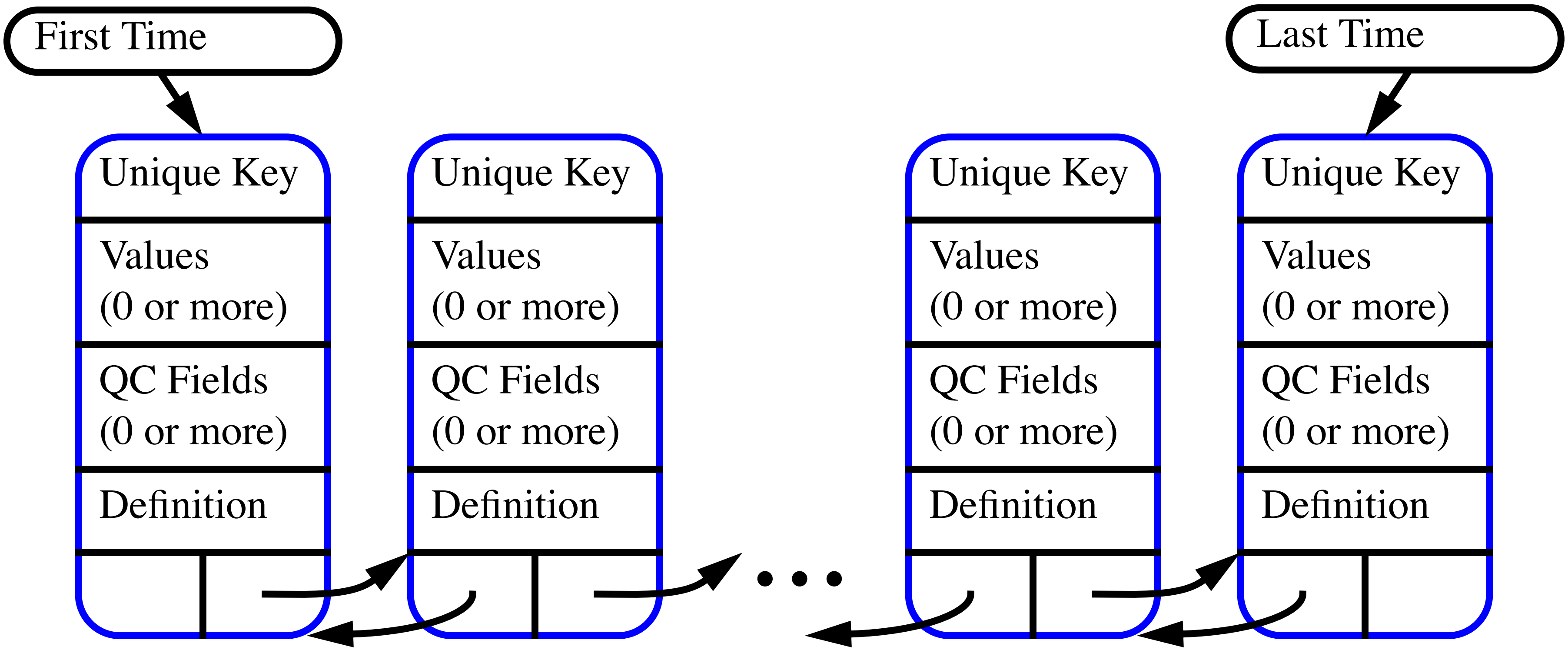
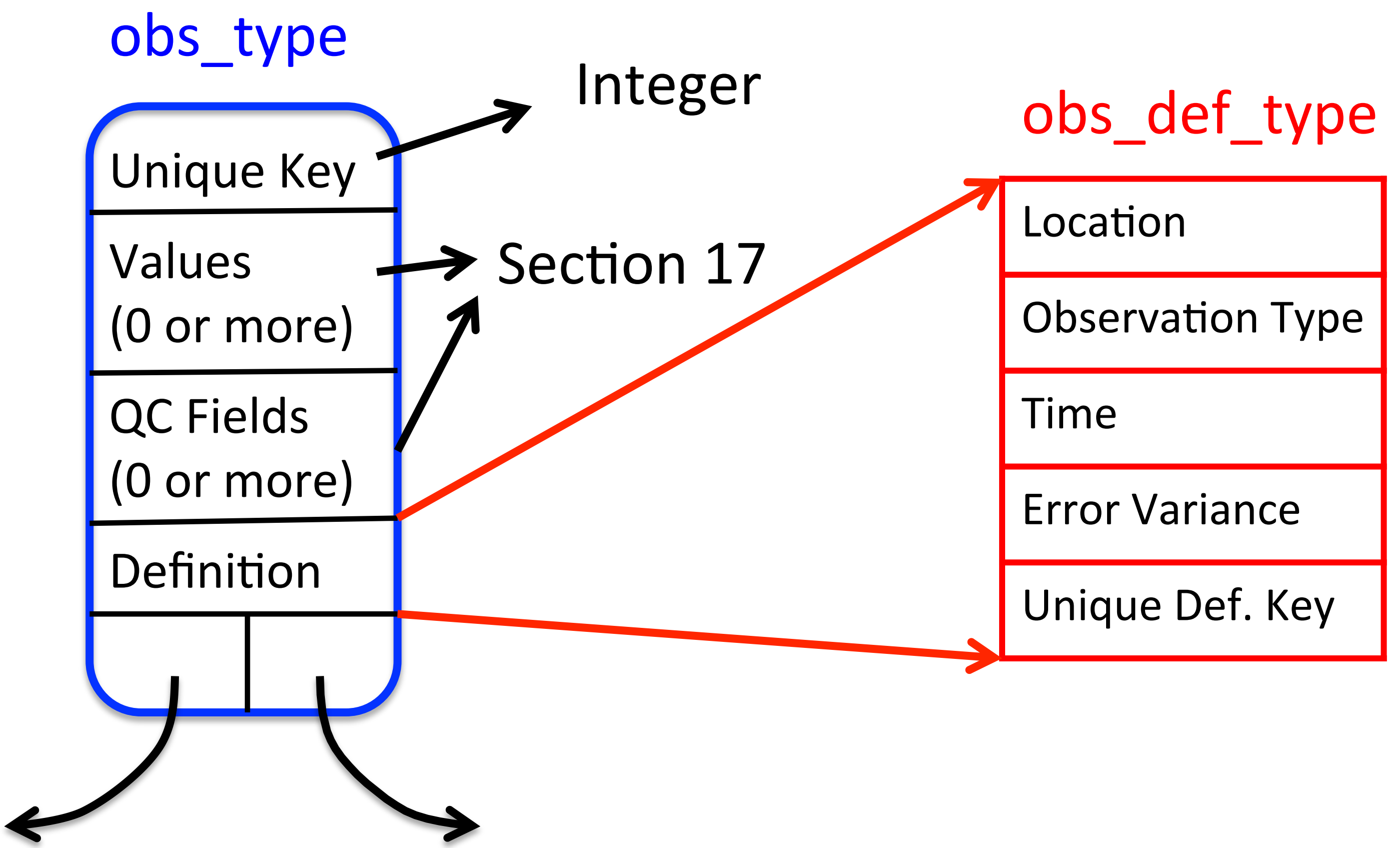
DART Assimilations controlled by Observation Sequence Files

Observation sequence files contain a time-ordered list of observations. (Stored with a ‘linked list’ of increasing times; obs do not have to be physically in time order in the file.)

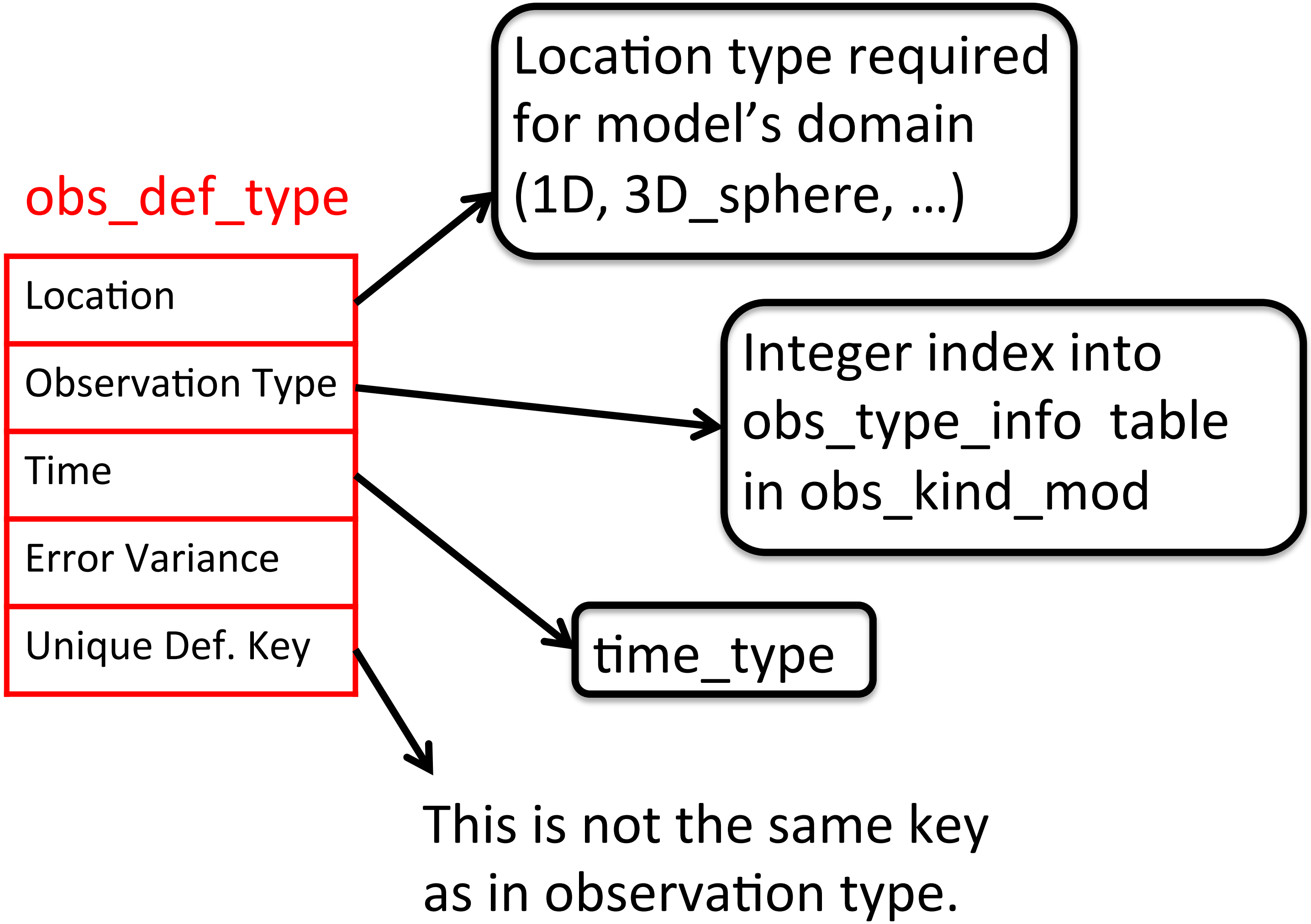


DART filter ‘assimilates’ until it runs out of observations.
Same for synthetic observation generation with ***perfect_model_obs***

Observation Type Details



Observation Type Details



Observation Definition Details

obs_type_info

Integer F90 type identifier	RADIOSONDE_ TEMPERATURE	…	ACARS_U_WIND_ COMPONENT
Name: String version of identifier	"RADIOSONDE_ TEMPERATURE"	…	"ACARS_U_WIND_ COMPONENT"
Generic Variable Quantity	QTY_ TEMPERATURE	…	QTY_U_WIND_ COMPONENT
Assimilate?	TRUE	…	FALSE
Evaluate?	FALSE	…	TRUE
Use precomputed obs?	FALSE	…	FALSE

obs_def_type

Location
Observation Type
Time
Error Variance
Unique Def. Key

Example: Observation is a radiosonde temperature

Observation Generic Kinds and Specific Types

obs_type_info table built by DART preprocess program

obs_type_info

Integer F90 type identifier	RADIOSONDE_ TEMPERATURE	…	ACARS_U_WIND_ COMPONENT
Name: String version of identifier	"RADIOSONDE_ TEMPERATURE"	…	"ACARS_U_WIND_ COMPONENT"
Generic Variable Quantity	QTY_ TEMPERATURE	…	QTY_U_WIND_ COMPONENT
Assimilate?	TRUE	…	FALSE
Evaluate?	FALSE	…	TRUE
Use precomputed obs?	FALSE	…	FALSE

Defined in special obs_def module headers

Integer parameters in global data section of obs_kind module

In obs_kind_nml. See section 17.

Radiosonde temps assimilated, forward operators only for ACARS U

Observation Generic Quantities and Specific Types

Many observation types may share a generic quantity.
Example: RADIOSONDE_TEMPERATURE, ACARS_TEMPERATURE...

obs_type_info

Integer F90 type identifier	RADIOSONDE_ TEMPERATURE	...	ACARS_U_WIND_ COMPONENT
Name: String version of identifier	“RADIOSONDE_ TEMPERATURE”	...	“ACARS_U_WIND_ COMPONENT”
Generic Variable Quantity	QTY_ TEMPERATURE	...	QTY_U_WIND_ COMPONENT
Assimilate?	TRUE	...	FALSE
Evaluate?	FALSE	...	TRUE
Use precomputed obs?	FALSE	...	FALSE

Defined in special obs_def module headers

Integer parameters in global data section of obs_kind module

In obs_kind_nml. See section 17.

Both have generic QTY_TEMPERATURE.
Model state variables are also be associated with generic quantities.

Observation Generic Quantities and Specific Types

Many observation types may share a generic quantity

Example: RADIOSONDE_TEMPERATURE, ACARS_TEMPERATURE

Both have generic QTY_TEMPERATURE.

Model state variables are also associated with generic quantities

Example: CAM/WRF interpolate in T field for all observation types with generic quantity QTY_TEMPERATURE.

Models can use the obs_kind_mod:

Have access to all generic quantities.

Also have access to all observation types if needed.

CONFUSING generic quantities and specific observation types is common.

Implementing Observation Definitions in DART

In an *observations/forward_operators/obs_def_xxx_mod.f90* file:

1. Give the observation specific type a name. This is where the name is defined.
2. Associate the observation specific type with a generic quantity, which must already exist in the DART QTY_xxx list.
3. Optionally specify a keyword to autogenerate needed routines if no specialized handling or additional metadata.

Example:

```
! BEGIN DART PREPROCESS KIND LIST
! AIRS_TEMPERATURE,          QTY_TEMPERATURE,          COMMON_CODE
! AIRS_SPECIFIC_HUMIDITY,    QTY_SPECIFIC_HUMIDITY,    COMMON_CODE
! END DART PREPROCESS KIND LIST
```

If using the autogenerated routines no additional work is needed.

Implementing Observation Definitions in DART

If the forward operator requires additional code, or if this observation specific type has additional metadata, omit the COMMON_CODE keyword and supply additional routines:

Four operations must be supported for each observation type:

1. Compute forward operator given (extended) state vector
2. Read any extra information not in obs_def_type from file (For instance, location and beam angle for radar).
3. Write any extra information not in obs_def_type to file
4. Get any extra information via interactive read of standard in

If additional metadata, suggest two additional routines:

1. get_metadata()
2. set_metadata()

Implementing Observation Definitions in DART

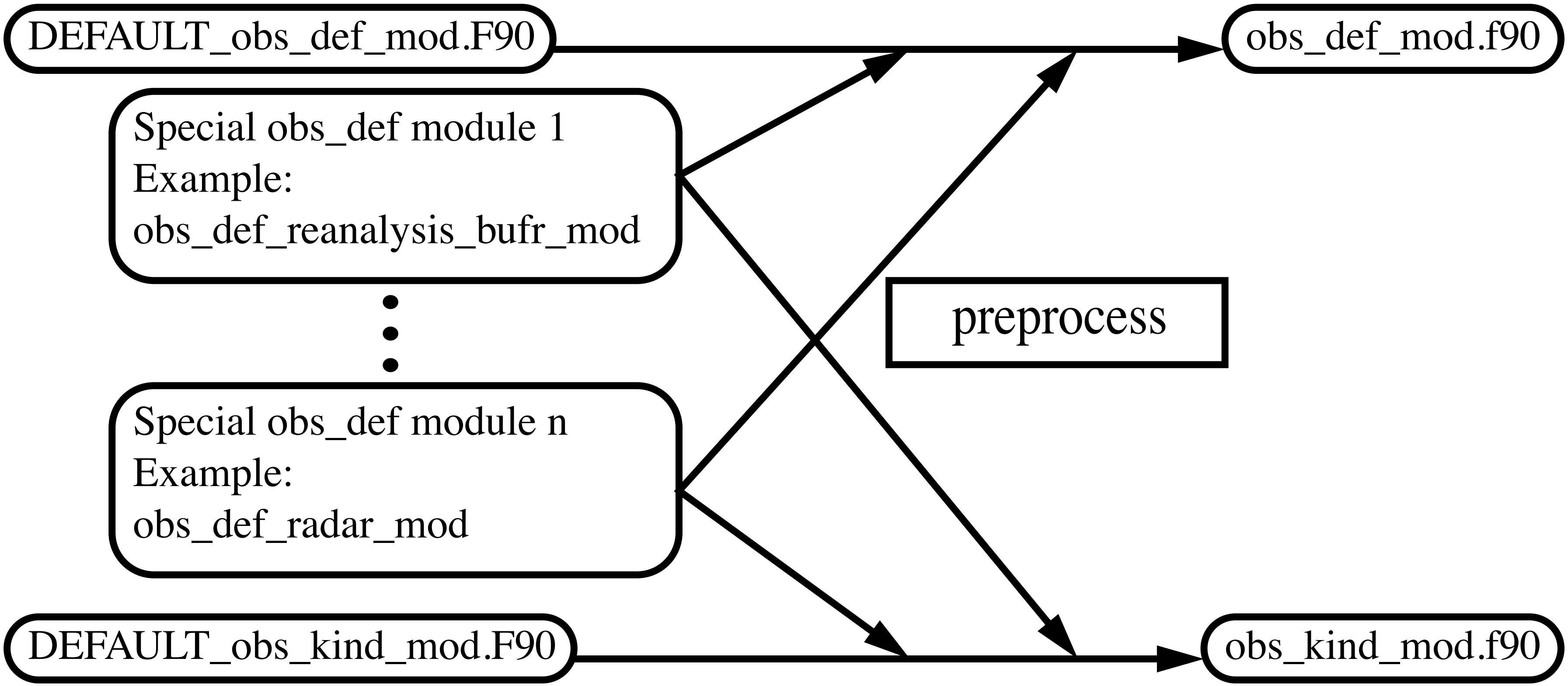
obs_def_xxx_mod.f90 files and *DEFAULT_obs_def_mod.F90* are normal Fortran 90 files with additional specially formatted comments that guide the ***preprocess*** program.

See the detailed documentation in:

- *observations/forward_operators/DEFAULT_obs_def_mod.html*
- *observations/forward_operators/obs_def_mod.html*
- *assimilation_code/modules/observations/DEFAULT_obs_kind_mod.html*
- *assimilation_code/modules/observations/obs_kind_mod.html*

Implementing Observation Definitions in DART

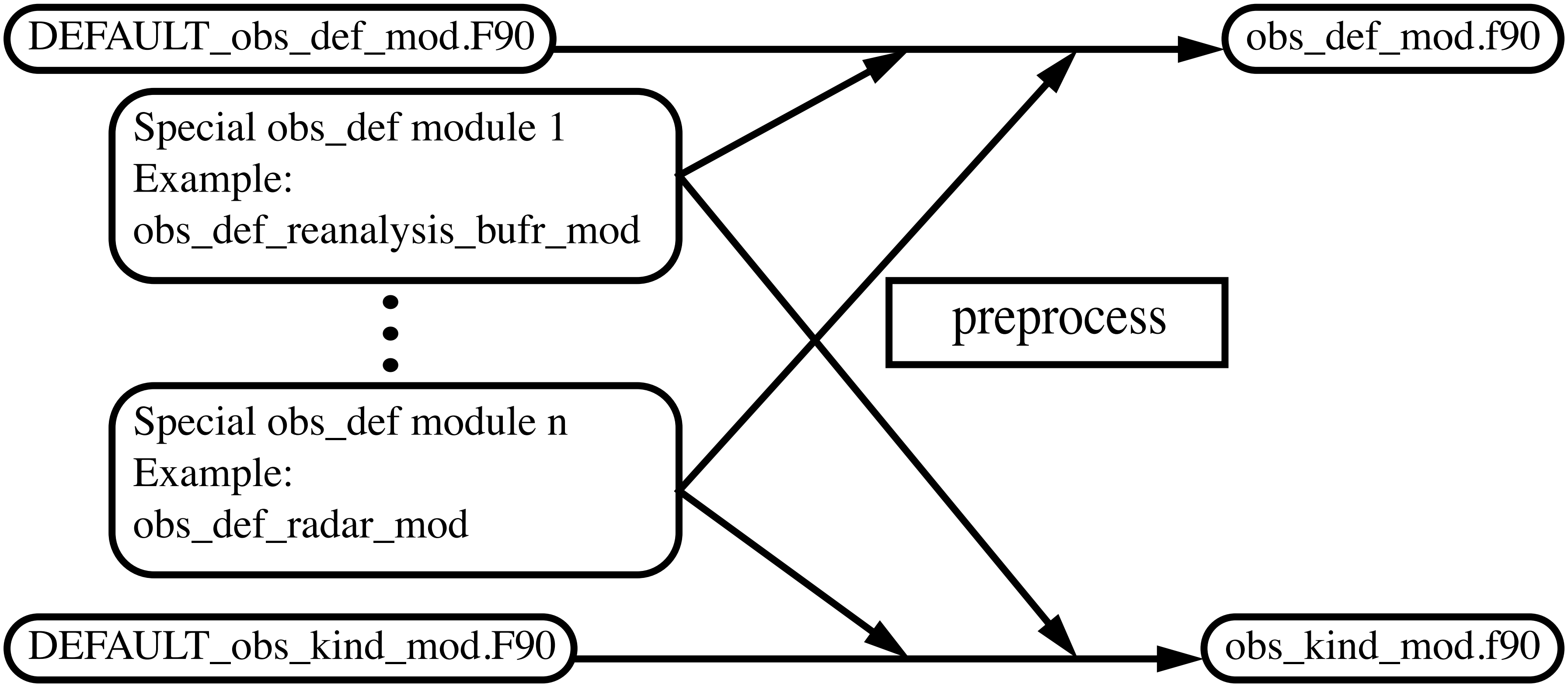
DART ***preprocess*** program creates obs_def_mod, obs_kind_mod



Namelist `&preprocess_nml` lists all special obs_def modules to be used.
(Names of DEFAULT F90s and preprocessed f90s can be changed, too)

Implementing Observation Definitions in DART

DART preprocess program creates obs_def_mod, obs_kind_mod



If no special obs_def modules are selected, can do identity obs. only.
DEFAULT modules have special comment lines to help preprocess.

Implementing Basic Observation Definitions in DART

Basic: New observation type with no specialized forward operator code and no extra observation information.

Will call the model interpolate routine to compute the forward operator for each observation type listed.
Needs no extra info in the read/write or interactive create routines.

Requires adding 1 section to one or more obs_def_mod files.

Defines the mapping between each specific observation type and generic observation quantity, plus a keyword.

A REQUIRED comment string starts and ends the section.
All lines in the special section must start with F90 comment: !

Implementing Basic Observation Definitions in DART

Define the observation types and associated generic quantities:

```
! BEGIN DART PREPROCESS KIND LIST
! RAW_STATE_VARIABLE, QTY_STATE_VARIABLE, COMMON_CODE
! END DART PREPROCESS KIND LIST
```

First column is specific type, second is generic quantity.

The keyword COMMON_CODE tells DART to automatically generate all required interface code for this new type.

Multiple types can be defined between the special comment lines.

This is all the file needs to contain.

The list of generic quantities is found in:

assimilation_code/modules/observations/DEFAULT_obs_kind_mod.F90

If not already there, the generic quantity must be added to the list.

See *obs_def_AIRS_mod.f90* for another example.

Implementing Customized Observation Definitions in DART

Customized: Either the observation type cannot simply be interpolated in a model state vector, and/or there is extra information associated with each observation which must be read, written, and interactively prompted for when creating new observations of this type.

Basic observations require only 1 section in the specialized obs_def. Customized ones require 6.

Can have mix of Basic observations (with autogenerated code) and Customized observations (with user-supplied code) in the same file.

REQUIRED comment strings start and end each section.
All lines in special sections must start with F90 comment: !
See *obs_def_1d_state_mod.f90* as an example.

Implementing Customized Observation Definitions in DART

Six special sections are required in a special obs_def_mod.

1. Define the observation types and associated generic kinds:

```
! BEGIN DART PREPROCESS KIND LIST
! RAW_STATE_VARIABLE, QTY_STATE_VARIABLE, COMMON_CODE
! RAW_STATE_1D_INTEGRAL, QTY_1D_INTEGRAL
! END DART PREPROCESS KIND LIST
```

Two observation types defined:

a. RAW_STATE_VARIABLE: generic quantity QTY_STATE_VARIABLE
   All interface code autogenerated by DART
b. RAW_STATE_1D_INTEGRAL: generic quantity QTY_1D_INTEGRAL
   User must supply 4 additional interfaces.
   Even if nothing to do, must supply a case statement for each

Implementing Customized Observation Definitions in DART

Six special sections are required in a special obs_def_mod.

2. Use statements required for use of obs_def_1d_state_mod

```
! BEGIN DART PREPROCESS USE OF SPECIAL OBS_DEF MODULE
!! Comments can be included by having a second ! at
!! the start of the line
! use obs_def_1d_state_mod, only : write_1d_integral,   &
!             read_1d_integral, interactive_1d_integral, &
!             get_expected_1d_integral
! END DART PREPROCESS USE OF SPECIAL OBS_DEF MODULE
```

This special obs_def module has 4 subroutines which do work.

A special obs_def module can also have its own namelist if needed.

Implementing Customized Observation Definitions in DART

Six special sections are required in a special obs_def_mod.

3. Case statements required to compute expected observation

```
! BEGIN DART PREPROCESS GET_EXPECTED_OBS_FROM_DEF
! case(RAW_STATE_1D_INTEGRAL)
!   call get_expected_1d_integral(state, location, &
!                         obs_def%key, obs_val, istatus)
! END DART PREPROCESS GET_EXPECTED_OBS_FROM_DEF
```

Each observation type being defined that does not have the COMMON_CODE keyword must appear in a case.

The autogenerated code calls *interpolate()* from assim_model.
The RAW_STATE_1D_INTEGRAL is more complicated and calls the *get_expected_1d_integral* in the special obs_def module.

Implementing Customized Observation Definitions in DART

Six special sections are required in a special obs_def_mod.

4. Case statements read extra info from an obs_sequence file.

```
! BEGIN DART PREPROCESS READ_OBS_DEF
! case(RAW_STATE_1D_INTEGRAL)
!   call read_1d_integral(obs_def%key, ifile, fileformat)
! END DART PREPROCESS READ_OBS_DEF
```

The autogenerated code has a case statement and continue.

`RAW_STATE_1D_INTEGRAL` observations requires extra information.

This is read with read_1d_integral subroutine.

Extra info stored in obs_def_1d_state_mod, indexed by unique DEFINITION key.

All obs types must have a case statement, even if no extra info.

Six special sections are required in a special obs_def_mod.

5. Case statements write extra info to an obs_sequence file.

```
! BEGIN DART PREPROCESS WRITE_OBS_DEF
! case(RAW_STATE_1D_INTEGRAL)
!   call write_1d_integral(obs_def%key, ifile, fileformat)
! END DART PREPROCESS WRITE_OBS_DEF
```

Same situation as `READ_OBS_DEF`

obs_def_1d_state can read and write whatever it wants
to describe the `RAW_STATE_1D_INTEGRAL` observation.

Only requirement is that it can read what it writes!

Implementing Customized Observation Definitions in DART

Six special sections are required in a special obs_def_mod.

6. Case statements to interactively create extra info.

```
! BEGIN DART PREPROCESS INTERACTIVE_OBS_DEF
! case(RAW_STATE_1D_INTEGRAL)
!   call interactive_1d_integral(obs_def%key,ifile,fileformat)
! END DART PREPROCESS INTERACTIVE_OBS_DEF
```

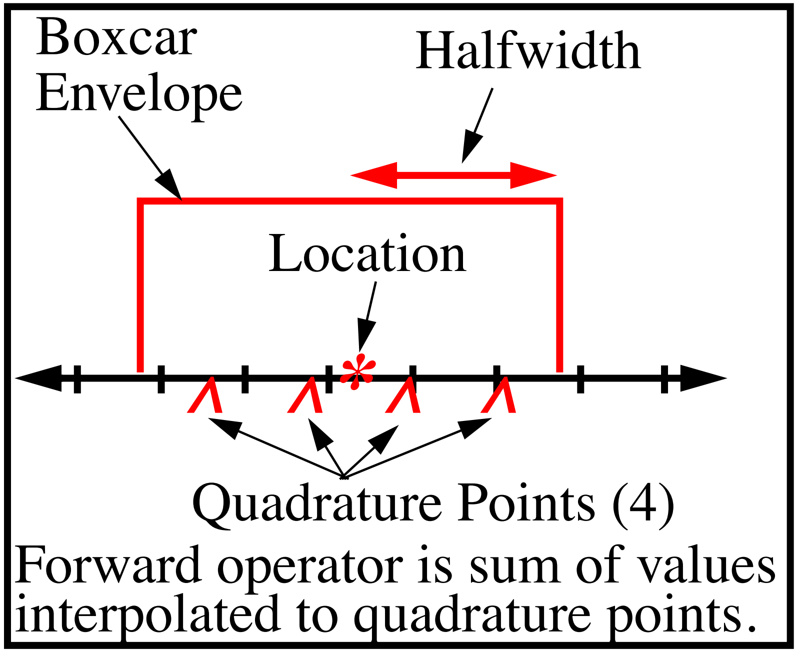
DART uses interactive input from standard in to create
type-specific information in a user-extensible form.

It's nice to be able to do a keyboard create for testing

Standard procedure: construct a text file that drives creation
(see section 17)

Implementing Customized Observation Definitions in DART

What is the observation definition ‘extra information’?
obs_def_1d_state_mod example.



raw_state_1d integral forward operator has 3 parameters:

1. Half-width of envelope,
2. Shape of envelope,
3. Number of quadrature pts.

Interactive creation asks for these 3, stores them with definition key.

Additional values written with each obs separately.

Available obs_def modules in DART

obs_def_1d_state_mod.f90
obs_def_AIRS_mod.f90
obs_def_AOD_mod.f90
obs_def_AURA_mod.f90
obs_def_CO_Nadir_mod.f90
obs_def_COSMOS_mod.f90
obs_def_GWD_mod.f90
obs_def_QuikSCAT_mod.f90
obs_def_SABER_mod.f90
obs_def_TES_nadir_mod.f90
obs_def_altimeter_mod.f90
obs_def_cice_mod.f90
obs_def_cloud_mod.f90
obs_def_cwp_mod.f90
obs_def_dew_point_mod.f90
obs_def_dwl_mod.f90
obs_def_eval_mod.f90
obs_def_goes_mod.f90

obs_def_gps_mod.f90
obs_def_gts_mod.f90
obs_def_metar_mod.f90
obs_def_ocean_mod.f90
obs_def_pe2lyr_mod.f90
obs_def_radar_mod.f90
obs_def_radiance_mod.f90
obs_def_reanalysis_bufr_mod.f90
obs_def_rel_humidity_mod.f90
obs_def_simple_advection_mod.f90
obs_def_sqg_mod.f90
obs_def_surface_mod.f90
obs_def_tower_mod.f90
obs_def_tpw_mod.f90
obs_def_upper_atm_mod.f90
obs_def_vortex_mod.f90
obs_def_wind_speed_mod.f90

Available obs_def modules in DART

Examples of frequently used obs_def modules in large models:

obs_def_reanalysis_bufr_mod.f90
Defines all obs likely to be found in BUFR files.

obs_def_ocean_mod.f90
All obs types from the World Ocean Database

obs_def_radar_mod.f90
Forward operator code for reflectivity and radial velocity

obs_def_gps_mod.f90
Simple and integrated forward operators for refractivity obs

obs_def_tower_mod.f90
Land obs types and forward operators

Using Custom Observation Definitions in DART

1. Compile and run preprocess: specify absolute or relative paths for all required special obs_def modules in `&preprocess_nml`: *input_files*.

2. Compile all other required program units, including *obs_def_mod.f90* (only) in the *path_names_?* files. preprocess will add any specialized obs_def code to the *obs_def_mod.f90* source file.

3. Select observation types to be assimilated or evaluated in `&obs_kind_nml`.

How and Where to Compute Forward Operators

Keeping models and observation definitions modular is hard.

DART recommendation: models should be able to spatially interpolate their state variables.

Forward observation operators in special obs_def modules should not expect more than this from models.

This may be too idealistic:

1. Models could do complicated forward operators for efficiency.
2. This makes it difficult to link models to DART in F90.

Different version of assim_model could help to buffer this.
Area for ongoing research.

DART Tutorial Index to Sections