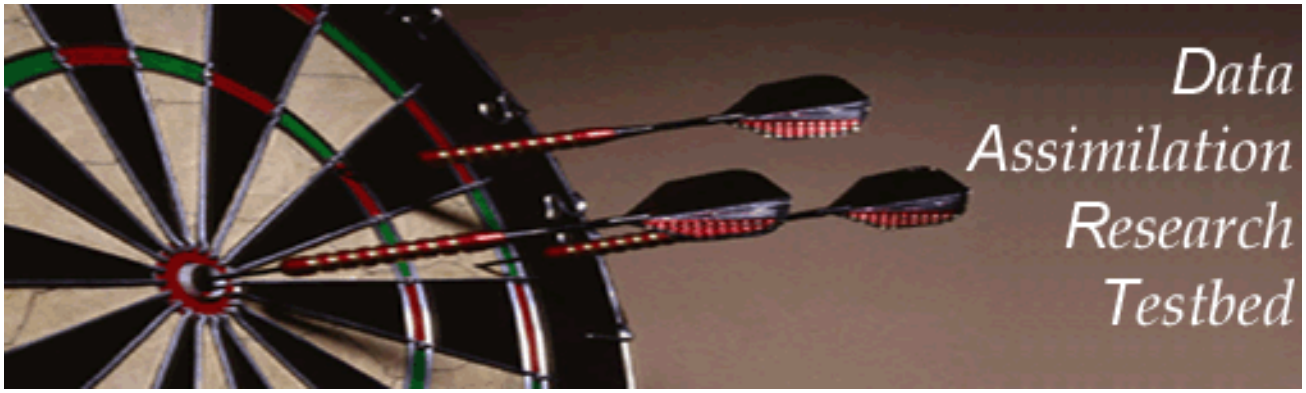
Data Assimilation Research Testbed Tutorial

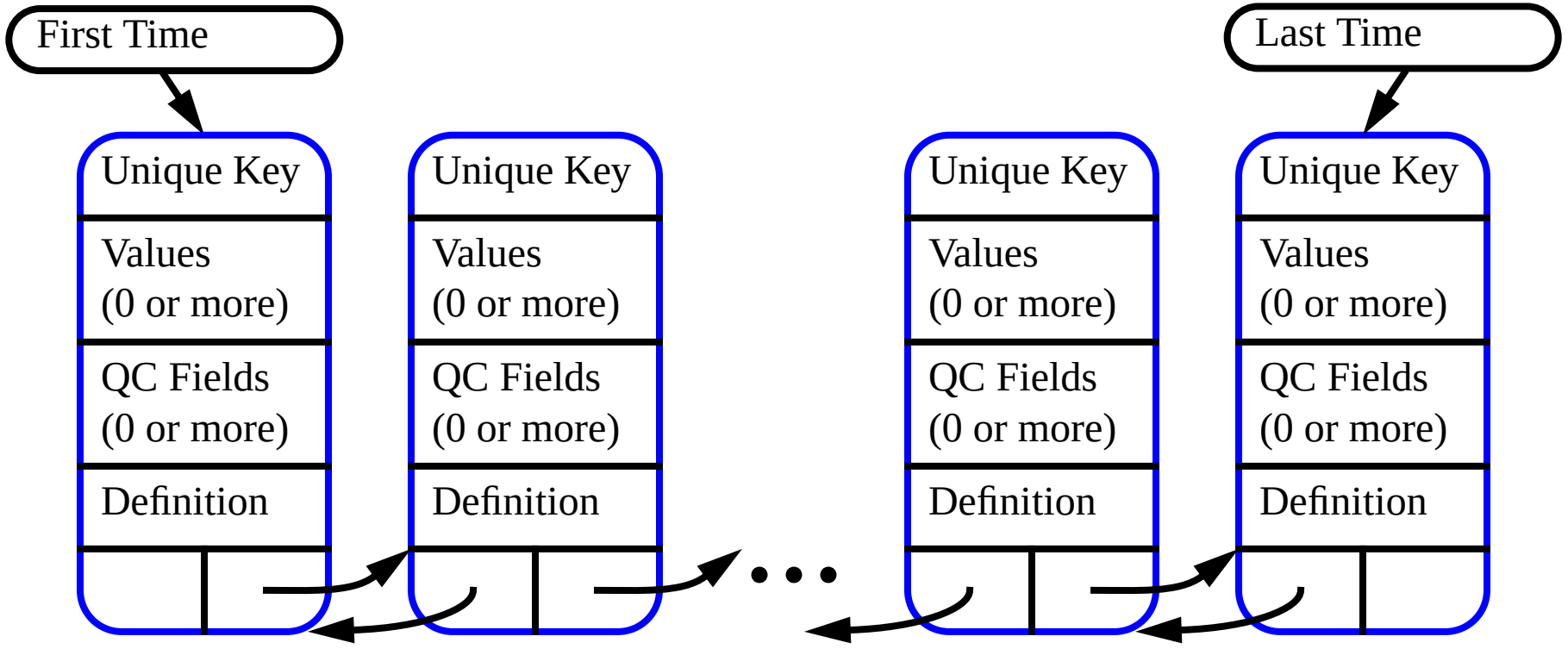


Section 21: Observation Types and Observing System Design

Version 2.0: September, 2006

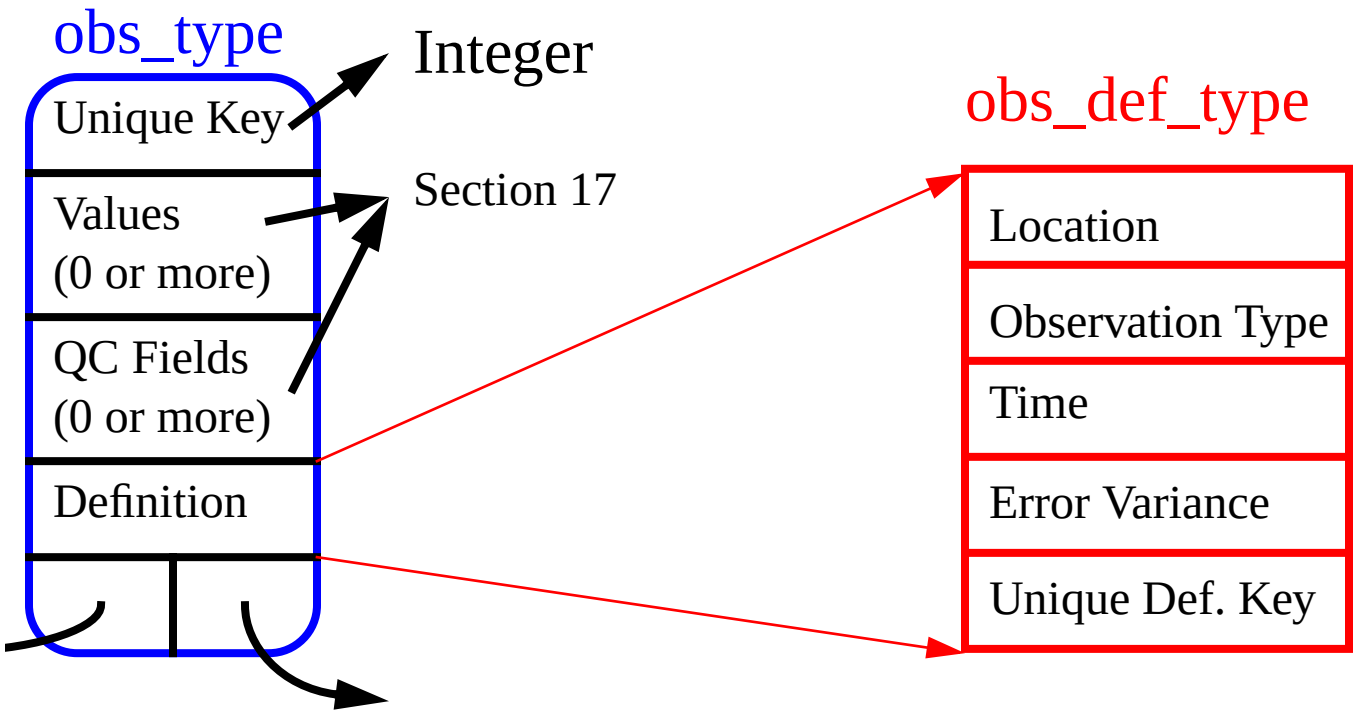
Dart assimilations are controlled by observation sequence files:

Observation sequence files contain a time-ordered list of observations.
Stored as a ‘linked list’ of observations.

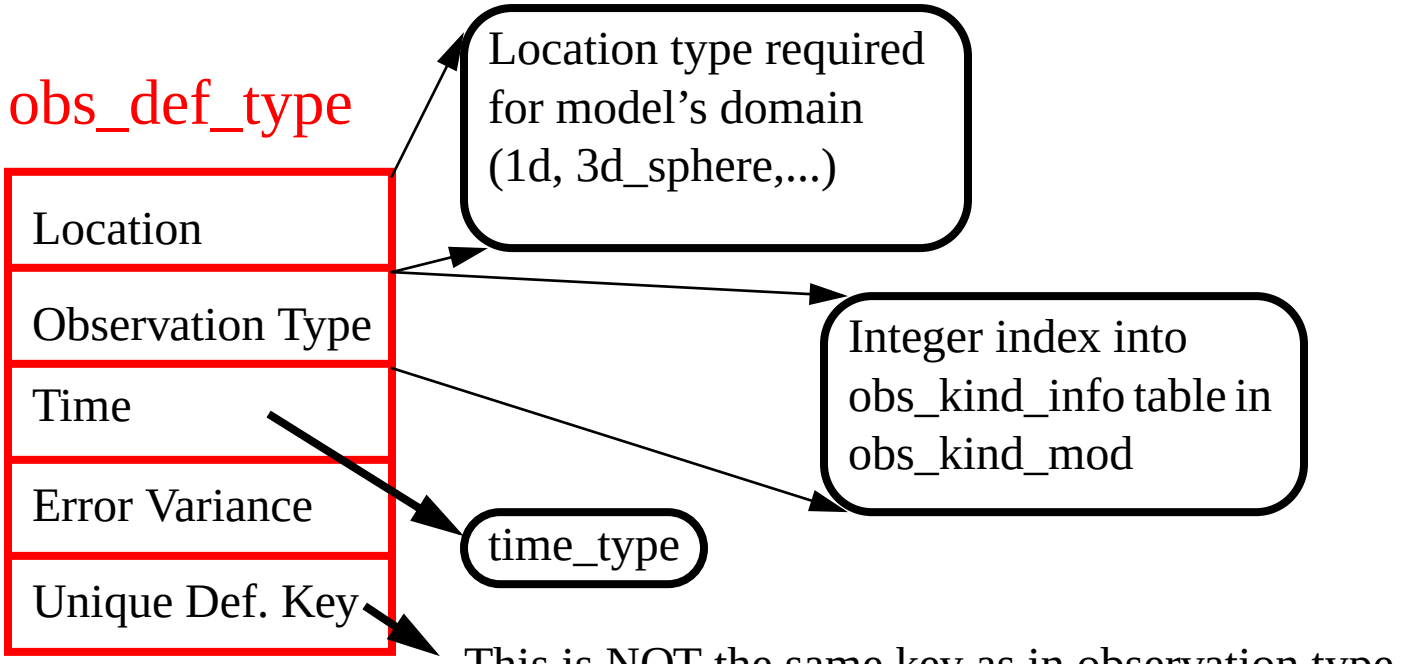


DART filter ‘assimilates’ until it runs out of observations.
Same for synthetic observation generation with perfect_model_obs.

Details of an observation type (type obs_type in obs_sequence_mod)



Details of observation definition (type obs_def_type in obs_def_mod)



Details of observation definition (type obs_def_type in obs_def_mod)

Description of obs_kind_info table.

obs_def_type

Location
Observation Type
Time
Error Variance
Unique Def. Key

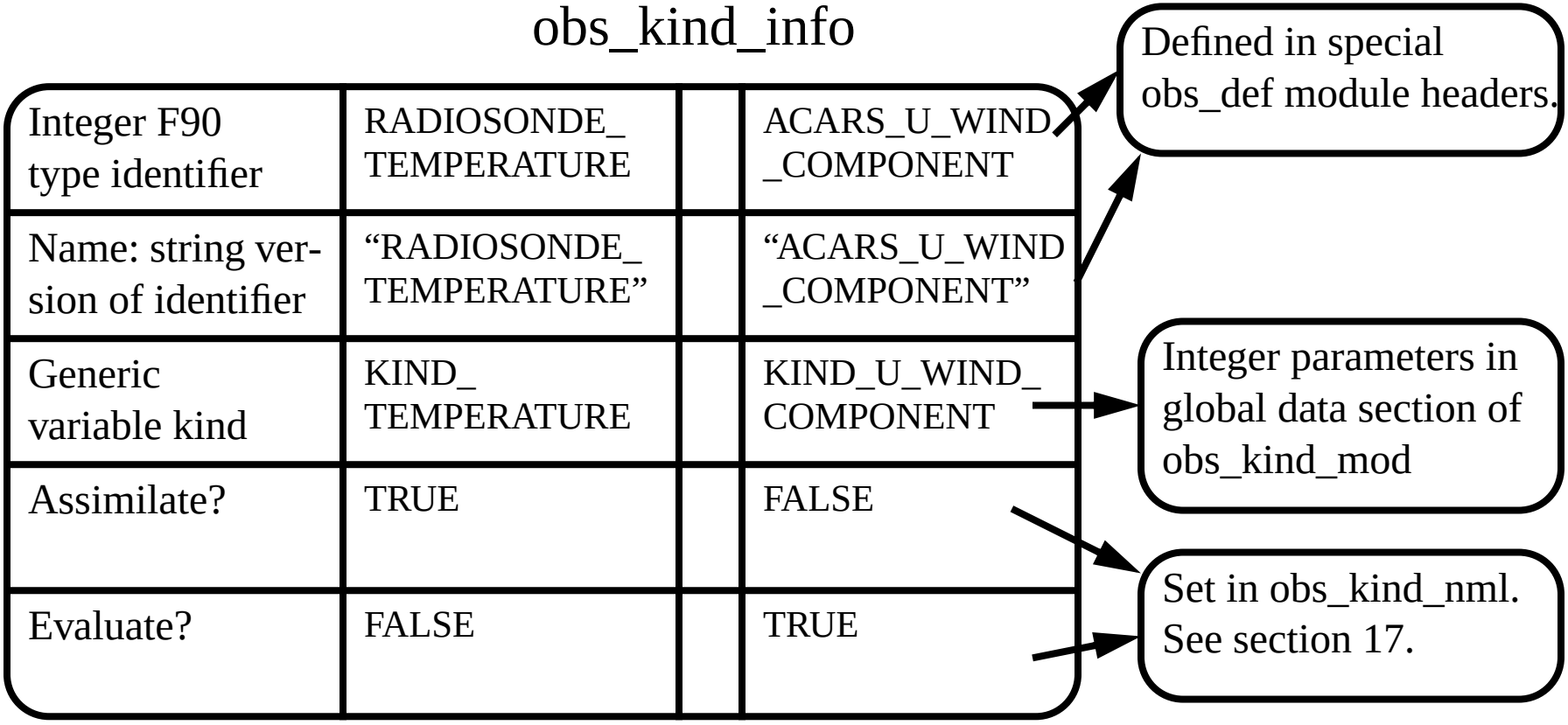
obs_kind_info

Integer F90 type identifier	RADIOSONDE_ TEMPERATURE		ACARS_U_WIND _COMPONENT
Name: string ver- sion of identifier	“RADIOSONDE_ TEMPERATURE”		“ACARS_U_WIND _COMPONENT”
Generic variable kind	KIND_ TEMPERATURE		KIND_U_WIND_ COMPONENT
Assimilate?	TRUE		FALSE
Evaluate?	FALSE		TRUE

Example: Observation is a radiosonde temperature.

The obs_kind_info table, generic kinds, and observation types:

obs_kind_info table built by DART preprocess program.



Radiosonde temps assimilated, forward operators only for ACARS U.

The obs_kind_info table, generic kinds, and observation types:

Many observation types may share a generic kind.

Example: RADIOSONDE_TEMPERATURE, ACARS_TEMPERATURE...

obs_kind_info

Integer F90 type identifier	RADIOSONDE_ TEMPERATURE		ACARS_U_WIND _COMPONENT
Name: string ver- sion of identifier	“RADIOSONDE_ TEMPERATURE”		“ACARS_U_WIND _COMPONENT”
Generic variable kind	KIND_ TEMPERATURE		KIND_U_WIND_ COMPONENT
Assimilate?	TRUE		FALSE
Evaluate?	FALSE		TRUE

Defined in special obs_def module headers.

Integer parameters in global data section of obs_kind_mod

Set in obs_kind_nml. See section 17.

Both have generic KIND_TEMPERATURE.

Model state variables can also be associated with generic kinds.

The obs_kind_info table, generic kinds, and observation types:

Many observation types may share a generic kind.
Example: RADIOSONDE_TEMPERATURE, ACARS_TEMPERATURE...
Both have generic KIND_TEMPERATURE.
Model state variables can also be associated with generic kinds.

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

Models can use the obs_kind_mod:
Have access to all generic kinds.
Also have access to all observation types if needed.

<u>CONFUSING generic kinds and specific observation types is common.</u>

Implementing observation definitions in DART

Give the observation type a name.
Associate the observation type with a generic kind.

Four operations must be supported for each observation type:

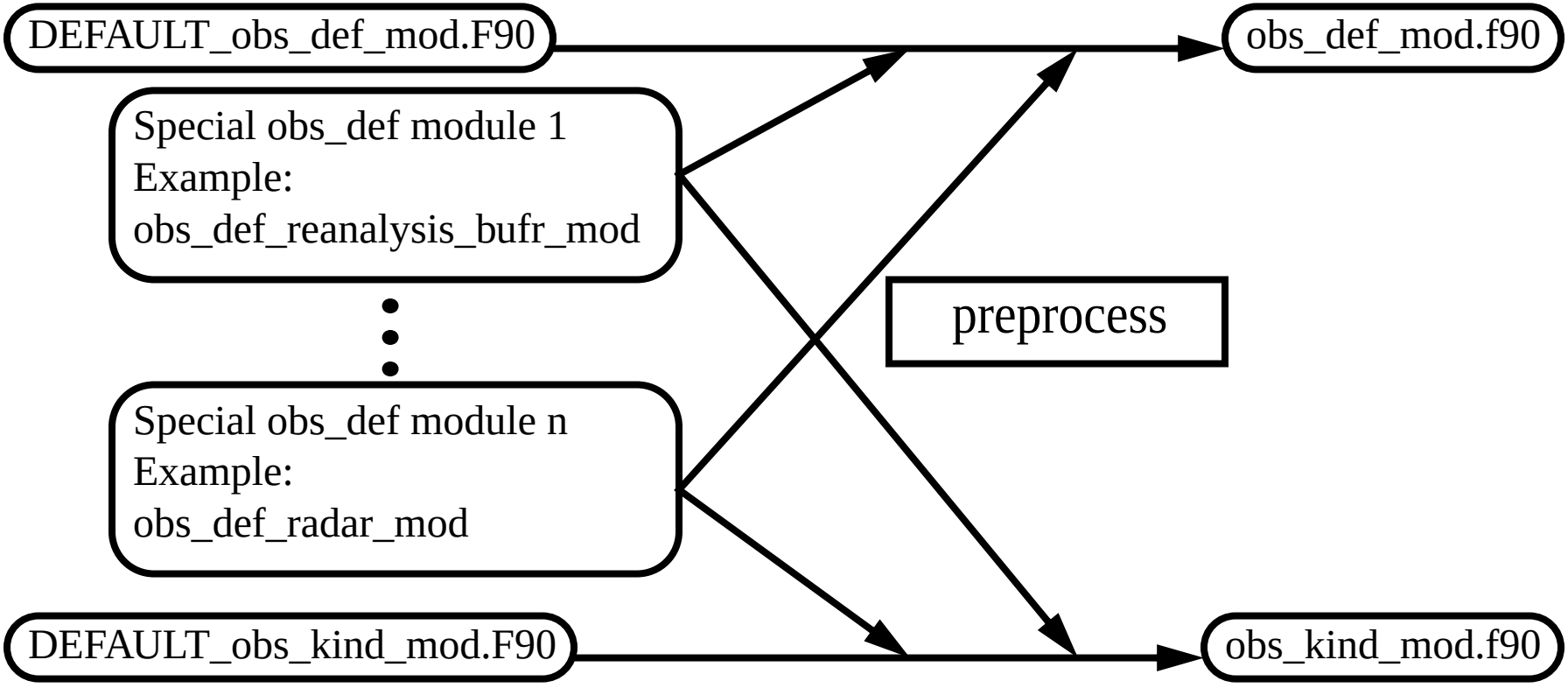
1. Compute forward operator given (extended) state vector.
2. Read any extra information not in obs_def_type from file.
   (For instance, location and beam angle for radar).
3. Write any extra information not in obs_def_type to file.
4. Get any extra information via interactive read of standard in.

This is done in a special obs_def_mod.
Code can be autogenerated if no special interpolation or extra data.

A special obs_def_mod is extended F90.
Contains special comments that guide the DART preprocess program.

Implementing observation definitions in DART

DART preprocess program creates obs_def_mod, obs_kind_mod

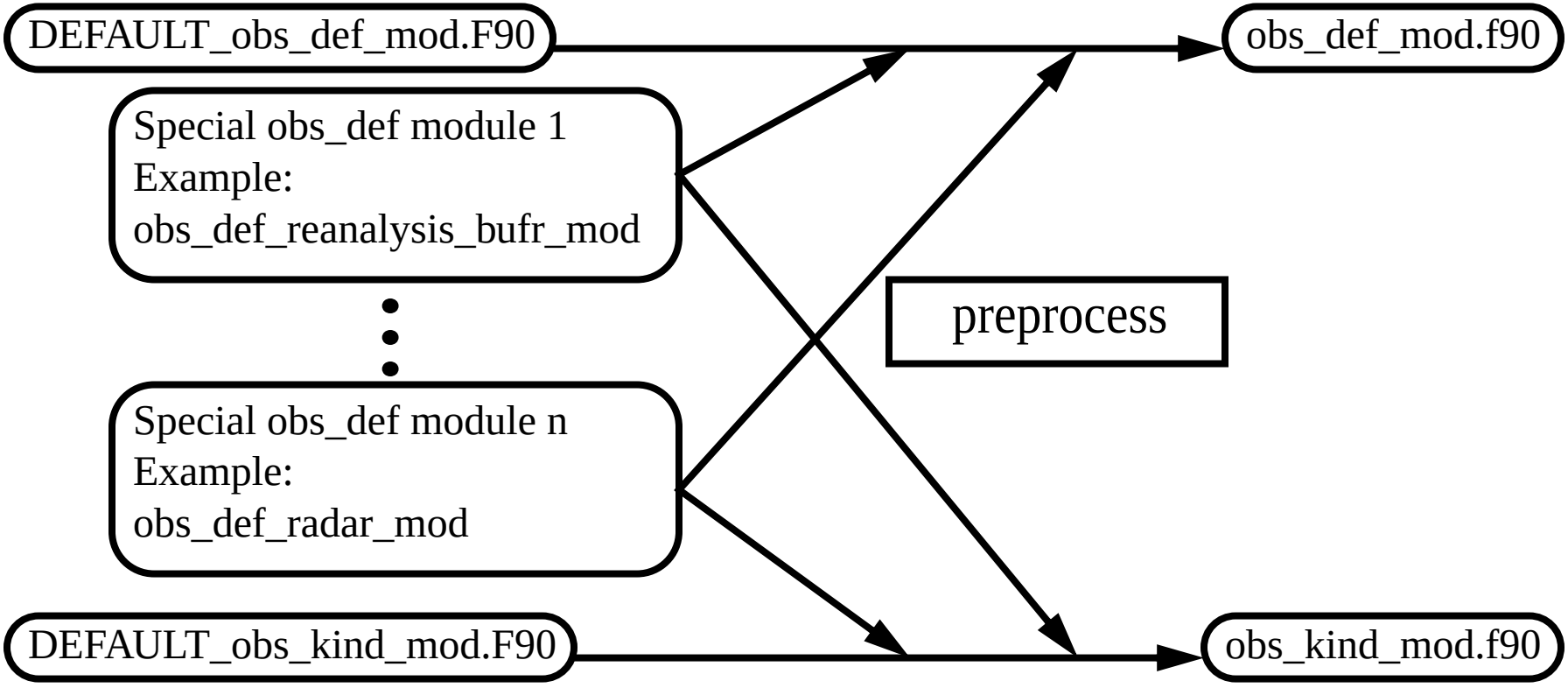


Namelist preprocess_nml lists all special obs_def modules to be used.

(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 interpolation 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 kind, 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

1. Define the observation types and associated generic kinds:

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

First column is specific type, second is generic kind.
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 kinds is found in DEFAULT_obs_kind_mod.F90.
If not already there, the generic kind must be added to the list.

See obs_def_1d_state_mod.f90 for an 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, !
Use obs_def_1d_state_mod.f90 as an example here:

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, KIND_RAW_STATE_VARIABLE, COMMON_CODE
! RAW_STATE_1D_INTEGRAL, KIND_1D_INTEGRAL
! END DART PREPROCESS KIND LIST

Two observation types defined:

a. RAW_STATE_VARIABLE: generic kind KIND_RAW_STATE_VARIABLE
   All interface code autogenerated by DART

b. RAW_STATE_1D_INTEGRAL: generic kind KIND_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 need to be used.

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 required to read extra info from 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 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.

Implementing Customized observation definitions in DART

Six special sections are required in a special obs_def_mod.

5. Case statements required to write extra info from 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 deal as for read

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 required to interactively create extra info.

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

DART uses interactive input from standard in to implement OO stuff.

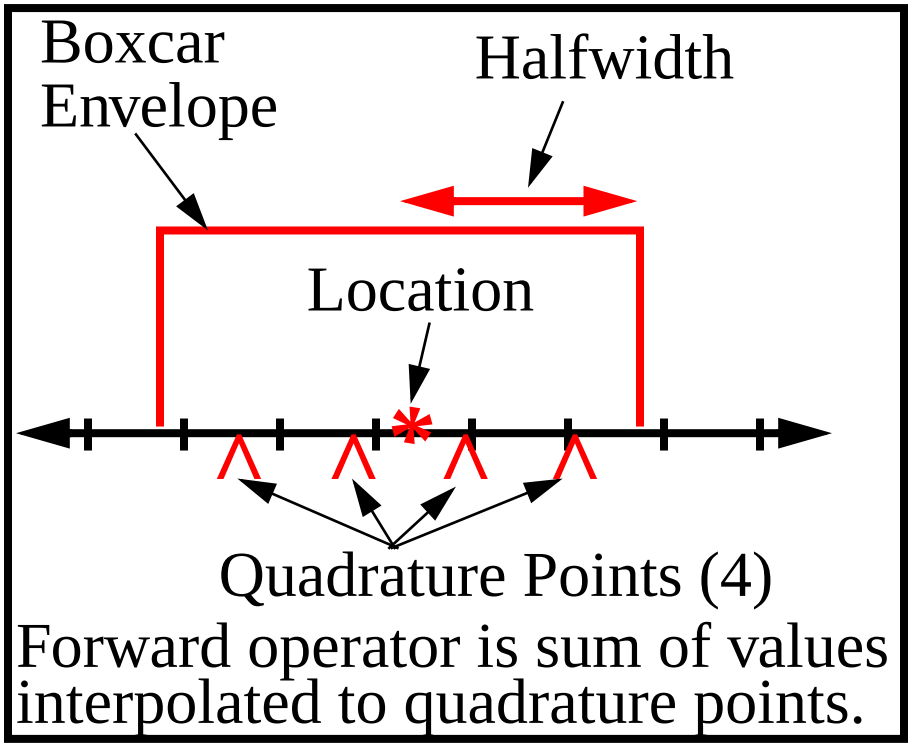
It’s nice to be able to do a keyboard create for testing.

Standard procedure: make file that drives creation (see section 17)

Implementing 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 points.

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

First write outputs total number of these obs plus params for ALL.

First read gets number, params for ALL, stores with definition key.

(Could also write information for each obs separately).

Available special obs_def modules:

1. obs_def_1d_state_mod: interpolations and integrals for models with one-dimensional domain, single state vector type.

2. obs_def_reanalysis_bufr_mod: All types of observations available in NCEP reanalysis bufr files. Most types from operational bufr files.

3. obs_def_metar_mod: 10 meter surface winds, 2 meter surface temperature and specific humidity, surface pressure.

4. obs_def_dew_point_mod: dew point temperature, free atmosphere or 2 meter surface.

5. obs_def_radar_mod: doppler radial velocity and reflectivity.

6. obs_def_gps_mod: GPS radio occultation refractivity.

General procedure for DART filtering with special obs_def modules

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_file* 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 observation 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.