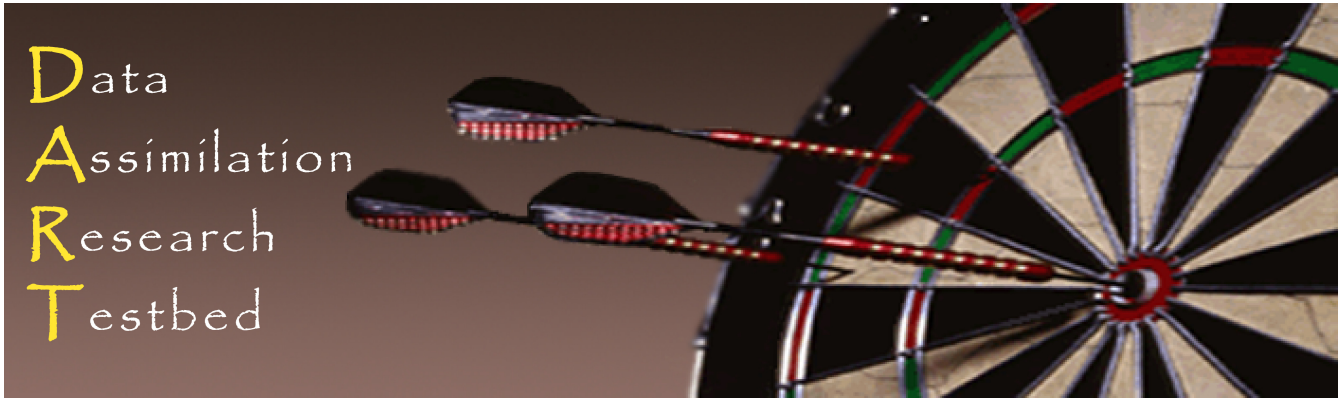
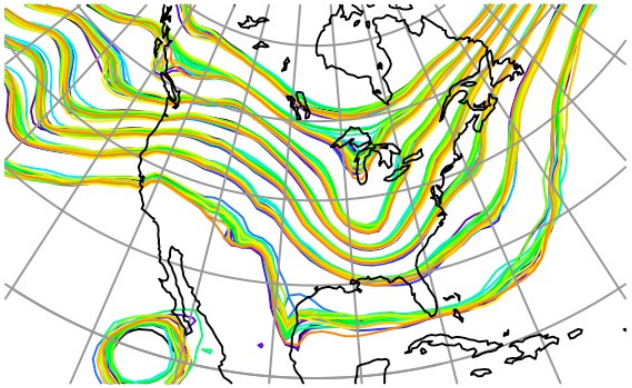


DART Tutorial Section 17: Creating Observation Sequences



The National Center for Atmospheric Research is sponsored by the National Science Foundation. Any opinions, findings and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

NCAR | National Center for
UCAR | Atmospheric Research

Types of Observations used in DART

A large number of geophysical observations are already being assimilated into models using DART.

They include:

Atmospheric Observations,

Ocean Observations,

Solar, Space Weather, Extraterrestrial Observations,

Land Observations

Sea ice observations

DART Atmospheric Observations (1)

U,V,T,Q	NCEP: Radiosonde, AIRCRAFT (commercial), ACARS
U,V	NCEP: Cloud Drift Winds from satellite
U,V (ocean surface)	QUIKSCAT, including L2B (JPL)
T,Q,refractivity of the atmosphere	COSMIC Global Positioning Satellite radio occultation
T,Q,Tsurface	AIRS from Aqua/A-train satellite
U,V,T,Q,Tsurface, pressure,altimeter	MADIS: ACARS, Marine and MESONET surface, METAR, radiosonde, satellite wind
Radar reflectivity, radial velocity	NCEP

DART Atmospheric Observations (2)

U,V	MADIS; Wind Profilers, Atmospheric Motion Vectors (AMVs)
U,V,T,Q,altimeter	OK mesonet (U. OK)
Cloud Liquid Water Path, Cloud Top and Base Pressures	GOES satellite, CIMSS
U,V	SSEC (U Wisconsin): Cloud Drift Winds from satellite
CO (carbon monoxide)	MOPITT
U,V	GOES CIMSS (U. WI); rapid-scan AMVs (Atmospheric Motion Vectors), satellite cloud winds

DART Atmospheric Observations (3)

T,Q,Total Precipitable Water	GOES CIMSS hyperspectral AIRS IR
Total Precipitable Water	AMSR, MODIS Microwave
U,V	Operational typhoon bogus winds, Taiwan Central Weather Bureau
U,V (at wind turbine hub height)	Seimens(?)
Electron density	COSMIC/FORMOSAT-3
U,V,T	GTS
Chemical concentrations	IASI on EUMETSAT Polar System MetOp satellite
Aerosol optical depth (AOD)	TERA and AQUA

DART Solar, Space Weather, Extraterrestrial Obs

Radiances, Occultation on Mars	TES, limb sounder on Mars
Density, ion concentrations	CHAMP
Thermospheric Mass Densities	CHAMP, GRACE
Electron densities	COSMIC
Total Electron Density	Garner GPS Archive
Orbital element information	NORAD
Solar Magnetic Fields	Wilcox, Mt Wilson, National Solar Observatories
Rotational, Meridional Circulation	Mt Wilson, SoHO, SDO, HMI

DART Ocean Observations

T, Salinity	World Ocean Database: Argo floats, CTD(ships), XBT, moored thermistors, drifting buoys(GT-SPP)
Surface U, V currents	CODAR

DART Land Observations

Snow cover	MODIS
Leaf area index	MODIS
Total water storage	GRACE
Brightness temperature	AMSR-E
Heat Flux, Net Carbon	Ameriflux tower network
Soil Moisture	COSMOS (neutron counter)

Building Real Observation Sequences

In the DART distribution, *observations/obs_converters* contains a collection of conversion programs from a variety of formats to DART obs_seq format.

See the observation converter overview in:

observations/obs_converters/observations.html

To create new converters for your data*:*

File format	*A good file to use as a starting point*
netCDF	Start with *MADIS/convert_madis_profiler.f90*
Comma separated text	Start with *Ameriflux*
Generic text	Start with *text*
HDF-EOS	Start with *AIRS*
BUFR or prepBUFR	Start with *NCEP*
Dense data, e.g. Satellite Swaths	Start with *quikscat*
Ray-path integrated data	Start with *gps*
World Ocean Database packed ASCII	Start with *WOD*

Observation Sequence Tools

These programs are found in directory *assimilation_code/programs.*
Each program has its own directory that includes source code (*f90*), a default namelist (*nml*, if required), and documentation (*html*).

obs_diag	Primary tool for evaluating obs space performance.
obs_seq_to_netcdf	Converts an obs_seq file to netCDF format. Cannot propagate per-obs-type metadata.
obs_sequence_tool	General tool with powerful capabilities
obs_common_subset	Select same obs from multiple files
obs_seq_coverage	Identify the same obs locations through a time series
obs_seq_verify	Creates a netCDF file for use in verification studies
obs_selection	Select a subset of observations based on another obs_seq file or the output of the coverage tool
obs_loop	Template that is a good starting point to write your own obs_sequence modifying programs.

Structure of an Obs Sequence File

See the online documentation:
https://docs.dart.ucar.edu/en/latest/guide/detailed-structure-obs-seq.html

Can contain multiple data values per observation, and multiple quality control values.

Can contain additional metadata per observation type; e.g. Radar observations, GPS obs. The forward operator code can use it when computing expected values. Must write your own read/write routines which are called by DART code to handle the metadata.

Entries DO NOT have to be physically listed in time order; DART read routines return the next observation, by time, automatically. Saves reordering the entries in the file when inserting new observations.

Structure of an Obs Sequence File (cont)

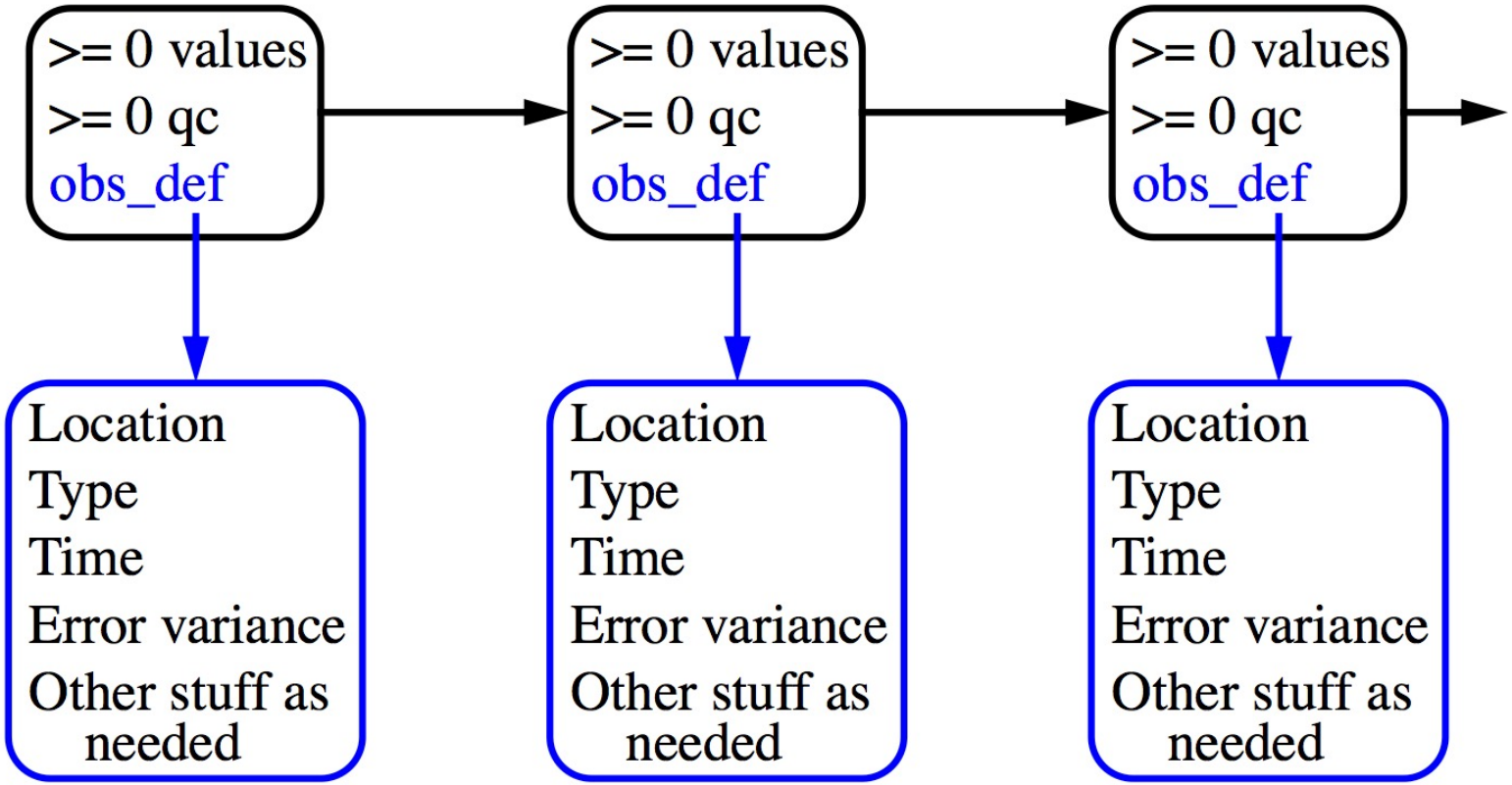
Contains a 'table of contents' of observation types at the start:

```
  obs_sequence
obs_kind_definitions                    (note: these are really a list of obs types)
           8
          25 LAND_SFC_U_WIND_COMPONENT
          26 LAND_SFC_V_WIND_COMPONENT
          27 LAND_SFC_TEMPERATURE
          35 DOPPLER_RADIAL_VELOCITY
          36 RADAR_REFLECTIVITY
          37 RADAR_CLEARAIR_REFLECTIVITY
          61 LAND_SFC_DEWPOINT
          73 LAND_SFC_ALTIMETER
```

The observations are identified by number in the rest of this file, but the numbers DO NOT have to be the same from file to file. The processing is done by matching the string name of the observation.

Structure of an Obs Sequence File (cont)

Sequence contains non-decreasing times in definitions.



Building Real Observation Sequences

Building Real observation sequences:

1. Interactive direct construction: program ***create_obs_sequence***

   - Queries for information for each observation in turn.
   - Enter type, location, time, error variance, value, qc value(s).
   - Often convenient to create an input file via an editor or a script.
   - Then redirect this file to standard input for ***create_obs_sequence***.

2. Use an existing converter

3. Create your own program
   - The obs_sequence module provides full set of Fortran 90 routines to read, write, query, create new, and alter existing observations.
   - (see directory *assimilation_code/modules/observations*)

Creating Synthetic Observation Sequences

Synthetic Observation Sequences are often used for Observing System Simulation Experiment (OSSEs)

Step 1: Create an observation sequence with no values.

A. Direct use of ***create_obs_sequence***: no need to specify value for obs.

OR...

B. Synthetic observing network fixed in time:
   1. First, use ***create_obs_sequence*** to specify observations in fixed network, all with time 0 days, 0 seconds.
   2. Use ***create_fixed_network_seq*** to specify times at which fixed network is observed.
   3. Times can be regularly or irregularly spaced.

Creating Synthetic Observation Sequences

Creating Synthetic Observation Sequences (cont)

Step 2: Use program ***perfect_model_obs*** to add observed values.

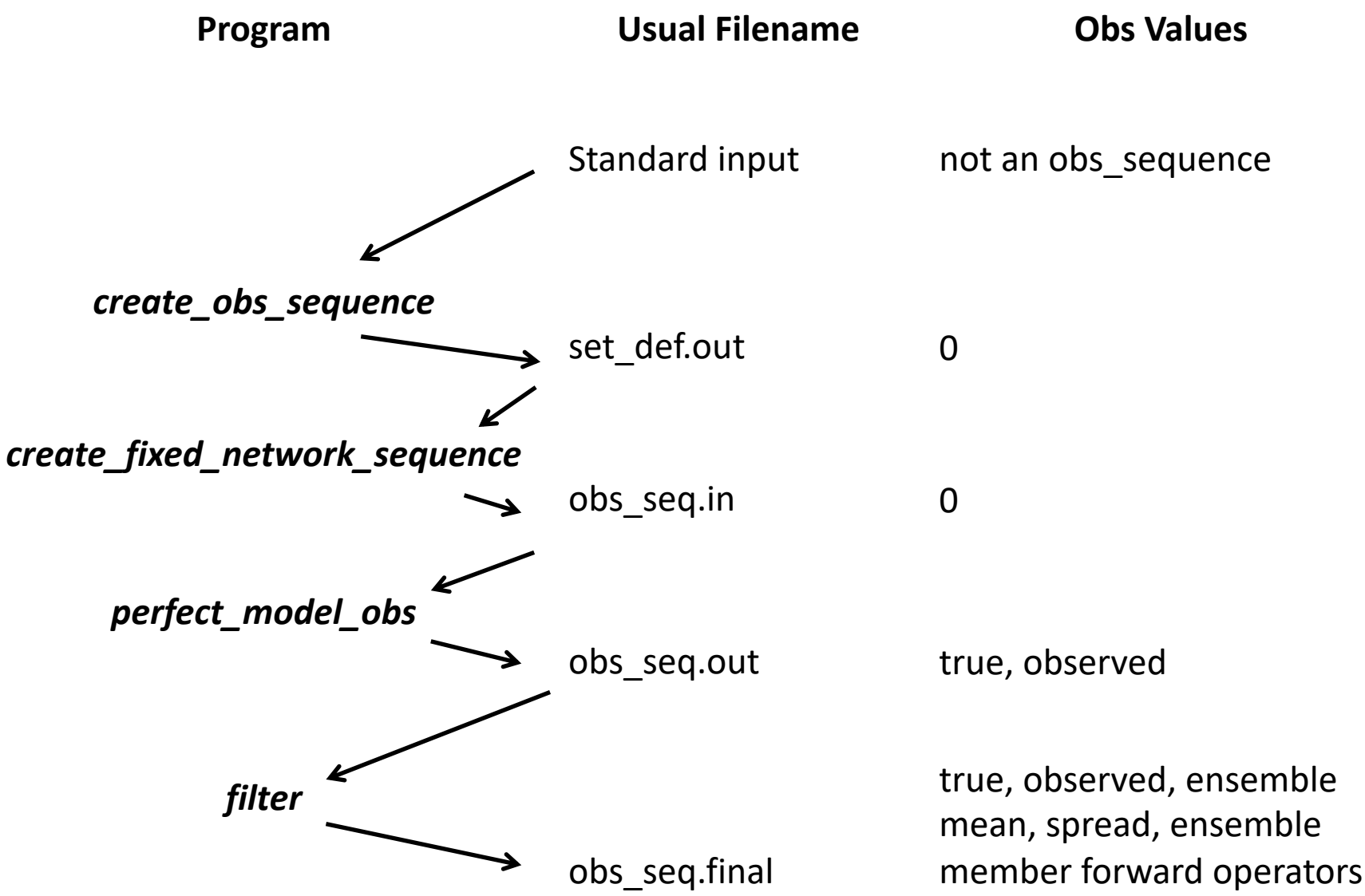
1. Integrates model.
2. Applies forward operators to get 'true' observed values.
3. Adds sample from observational error to get observed value. (Output obs_sequence has 2 values for each observation; with and without the added error sample).

Step 3: Run the ***filter***.

Ensemble mean, spread, (and individual ensemble members if requested using *num_output_obs_members* in `&filter_nml`) are added as values in the obs_sequence.

This 3 step process was done for all low-order examples so far in the tutorial.

Creating Synthetic Observation Sequences



Example: Localized Obs Set for Lorenz 96

models/lorenz_96/work/

1. Run ***create_obs_sequence*** in the *models/lorenz_96/work* directory.

   - Select 5 observations as upper bound
   - Select 0 copies of data (we'll let ***perfect_model_obs*** fill these in)
   - Also 0 quality control fields
   - Never input a -1 to terminate (we'll do all 5)
   - Select raw state variable for each observation
   - Pick a location (try grouping them close to 0.5)
   - Select time as 0 days, 0 seconds
   - Error variance of 1.0 for first try
   - Repeat for all 5 observations just varying location
   - Enter *set_def.out* for file name

Example: Localized Obs Set, Lorenz 96 (cont)

2. Run ***create_fixed_network_seq*** to observe these 5 obs. repeatedly
   - File is *set_def.out*
   - Select a regularly repeating sequence
   - Select 1000 times
   - Initial time as 0 days, 0 seconds
   - Observation period as 1 hour (0 days, 3600 seconds)
   - Resulting *obs_seq.in* observes once an hour for 1000 hours

3. Run ***perfect_model_obs*** to generate synthetic observations (OSSE)

4. Run ***filter*** with some adaptive inflation, and 80 members
   (divide these into 4 groups if you have worked with the group filter)

Use Matlab diagnostics to examine results
   Try ***plot_ens_time_series***
   Select a variable close to the observations and one far away.

Designing Localized Observations for bgrid

1. Run ***create_obs_sequence***
   - Enter only 1 observation, 0 values and qc fields
   - Select Radiosonde temperature
   - Vertical coordinate Pressure, 500 hPa
   - Try longitude and latitude 270, 45
   - Time is 0 days, 0 seconds
   - Error variance is 1.0
2. Run ***create_fixed_network_seq***
   - Select regularly repeating, 2 times
   - 0 days 0 seconds for initial time
   - 0 days 3600 seconds for period
3. Run ***perfect_model_obs***
4. Run ***filter***
5. Create innovations:
   `ncdiff analysis.nc preassim.nc Innov.nc`

1. Use ***ncview*** to look at the mean and spread (*_sd) for fields in the *Innov.nc* file. Interesting to see how Radiosonde temperature obs impact u, v, surface pressure (ps) as well as t.

Selecting Observation Types to Process

Need to specify via name (character string) in namelist:

Type of all observations to be assimilated;

Type of all observations to be evaluated but not assimilated.

(Forward operators are computed and stored in obs_sequence file).

List of available observation types found in:

assimilation_code/modules/observations/obs_kind_mod.f90

(see declaration for *obs_type_info*).

Specify in `&obs_kind_nml` using names:

```
&obs_kind_nml
   assimilate_these_obs_types = 'RAW_STATE_VARIABLE'
   evaluate_these_obs_types   = 'RAW_STATE_1D_INTEGRAL'
  /
```

Selecting a Set of Observation Definitions

Compile and run the program ***preprocess*** first!

assimilation_code/modules/observations/DEFAULT_obs_kind_mod.F90 and *observations/forward_operators/DEFAULT_obs_def_mod.F90* are merged with additional special observation definition files (in *observations/forward_operators*) to create *assimilation_code/modules/observations/obs_def_mod.f90* and *observations/forward_operators/obs_kind_mod.f90*

See section 21 for more details.

This means to change anything in *obs_def_mod.f90* or *obs_kind_mod.f90*, you have to change the DEFAULT files or your changes will be lost the next time ***preprocess*** is run.

DART Tutorial Index to Sections