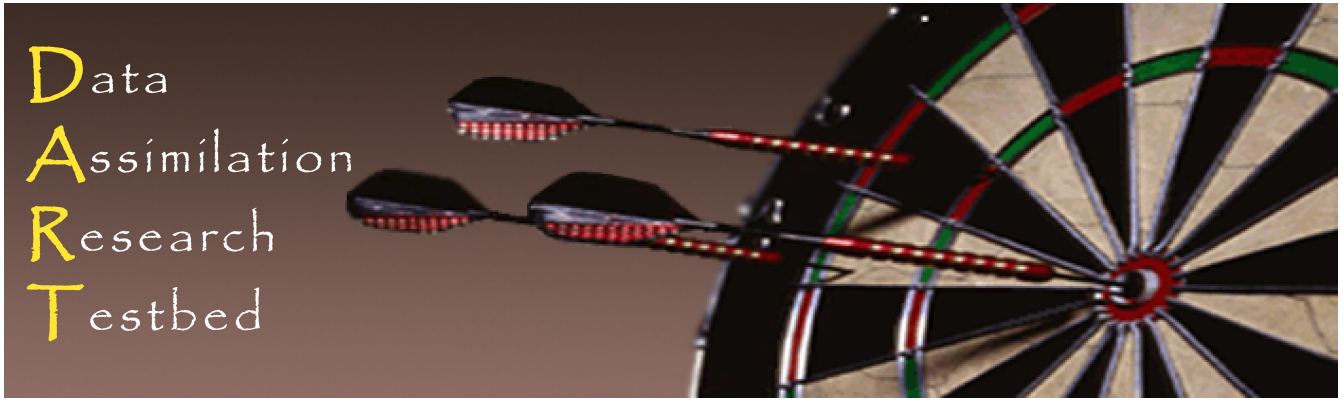
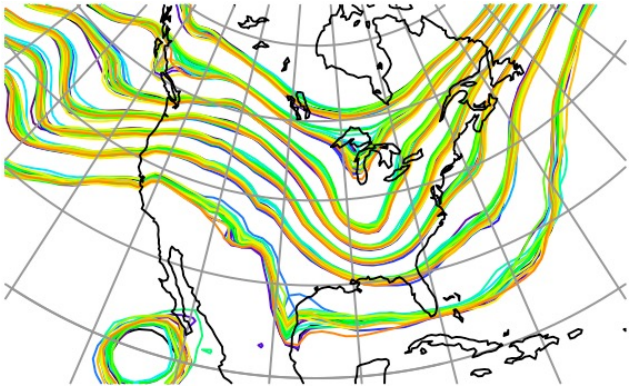


DART Tutorial Section 18: Lost in Phase Space: The Challenge of Not Knowing the Truth.



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Reality Strikes

In real applications, **the truth is unknown**.

All that we have are observations.

Having the truth available has been convenient,
but also misleading.

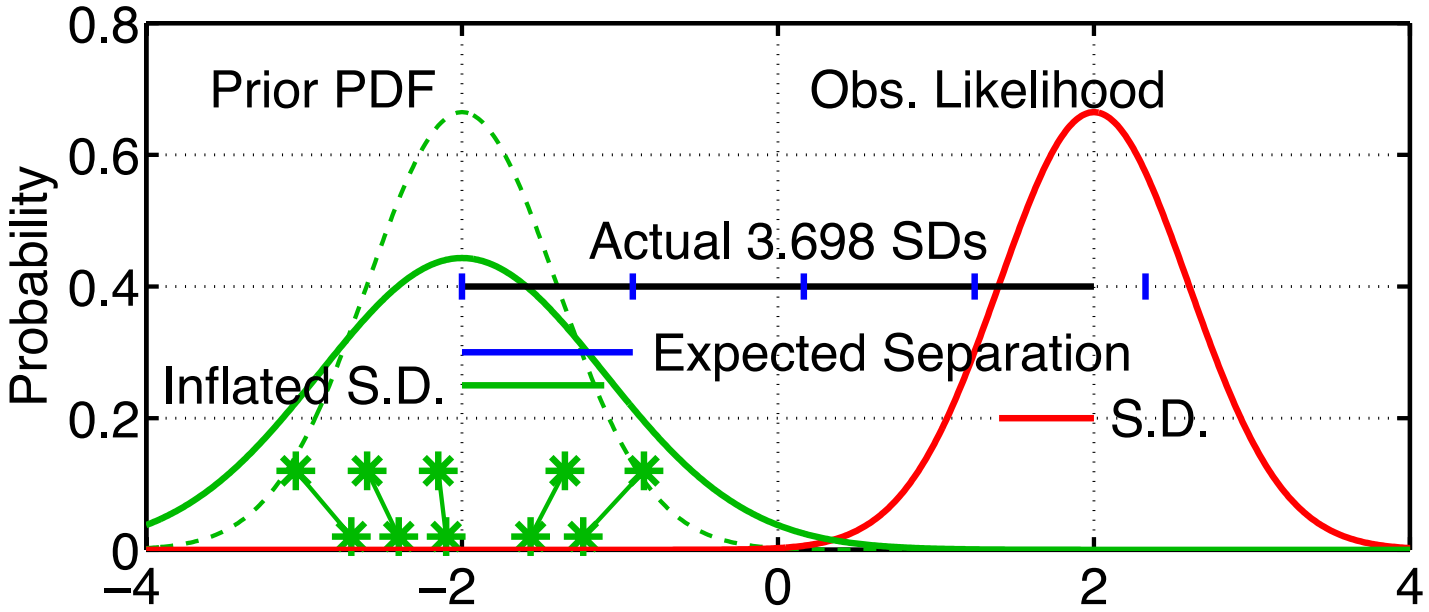
Much less information is available from the observations.

- They are generally functions of the state variables.
- They are always contaminated with observational errors.

What to expect …

Recall that

Expected(prior_mean – observation) = $\sqrt{\sigma_{prior}^2 + \sigma_{obs}^2}$



Error is dominated by observational noise if $\sigma_{obs}^2 \gg \sigma_{prior}^2$

Suppose $\sigma_{obs} = 1.0, \sigma_{prior} = 0.1$, then $\mathrm{E(RMS)} = 1.005$.

Halving σ_{prior} to 0.05 => $\mathrm{E(RMS)} = 1.001$; only a 0.4% reduction!

First Observation-space diagnostics:

Whether or not to assimilate or reject observations based on their Expected Separation is controlled during ***filter*** based on namelist settings in *input.nml*.

If $\left|\overline{y^p} - y^o\right| \Big/ \sqrt{\sigma^2_{prior} + \sigma^2_{obs}} > \text{outlier\_threshold}$ ⇒ Observation rejected! (DART QC ==7)

```
&quality_control_nml
   input_qc_threshold       = 3.0
   outlier_threshold        = -1.0
 /
```

Negative value means USE ALL

The program ***obs_diag*** post-processes *obs_seq.final*, calculates metrics like RMSE, bias, ensemble spread, totalspread, # of observations used or rejected … Start with the *lorenz_96* model.

Observation-space diagnostics

The observation sequence file is not in a particularly user-friendly format.
To aid in the evaluation and interpretation, a program named ***obs_diag*** must be run to produce a netCDF file with results that can be plotted in a manner of your choosing. DART has Matlab functions/scripts that create high-quality graphics.
For up-to-date information on the latest, greatest diagnostics, go to:
http://www.image.ucar.edu/DAReS/DART/DART2_Diagnostics.php#obs_diagnostics

```
&obs_diag_nml
   obs_sequence_name     = 'obs_seq.final',
   bin_width_days        = -1,
   bin_width_seconds     = -1,
   init_skip_days        = 0,
   init_skip_seconds     = 0,
   Nregions              = 3,
   trusted_obs           = 'null',
   lonlim1               = 0.00, 0.00, 0.50, -1.0
   lonlim2               = 1.01, 0.50, 1.01, -1.0
   reg_names             = 'whole', 'yin', 'yang', 'bogus,
   create_rank_histogram = .true.,
   outliers_in_histogram = .true.,
   use_zero_error_obs    = .false.,
   verbose               = .false.
   /
```

(Slightly different for 3D models.)

Observation-space diagnostics

The observation sequence file is not in a particularly user-friendly format.
To aid in the evaluation and interpretation, a program named ***obs_diag*** must be run to produce a netCDF file with results that can be plotted in a manner of your choosing. DART has Matlab functions/scripts that create high-quality graphics.
For up-to-date information on the latest, greatest diagnostics, go to:
http://www.image.ucar.edu/DAReS/DART/DART2_Diagnostics.php#obs_diagnostics

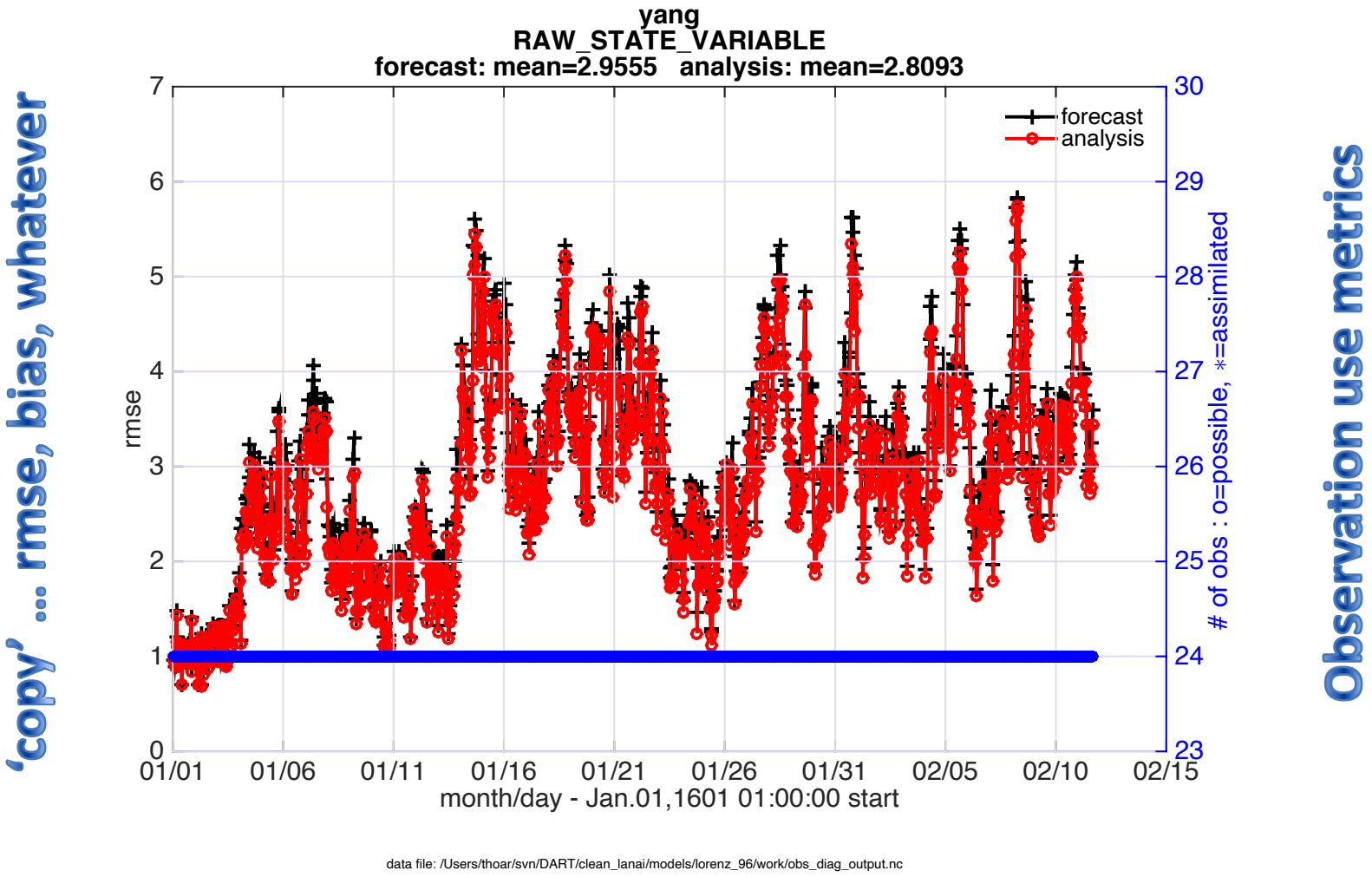
Here are a few of the Matlab functions available in *diagnostics/matlab*

- **plot_rank_histogram.m**
- **plot_evolution.m**
- **plot_rmse_xxx_evolution.m**
- **two_experiments_evolution.m**
- **plot_profile.m**
- **plot_bias_xxx_profile.m**
- **plot_rmse_xxx_profile.m**
- **two_experiments_profile.m**

These work with ANY *obs_seq.final* from ANY experiment with ANY model!

Lorenz 96 observation diagnostic example

outlier_threshold = -1.0



First Observation-space diagnostics:

Try setting the rejection threshold to a small positive number and rerunning ***filter***, and then rerunning ***obs_diag*** on the new output file.

```
&filter_nml
   …
   obs_sequence_in_name      = "obs_seq.out"
   obs_sequence_out_name     = "obs_seq.final"
   …
  /

&quality_control_nml
   input_qc_threshold        = 3.0,
   outlier_threshold         = -1.0,
   /
```

Change to what-ever you like.

Change to 3.0

Don't forget to rerun ***filter***!

Don't forget to rerun ***obs_diag***!

Don't forget to use the right filename in *obs_diag_nml*!

This is potentially **DANGEROUS**, but useful.

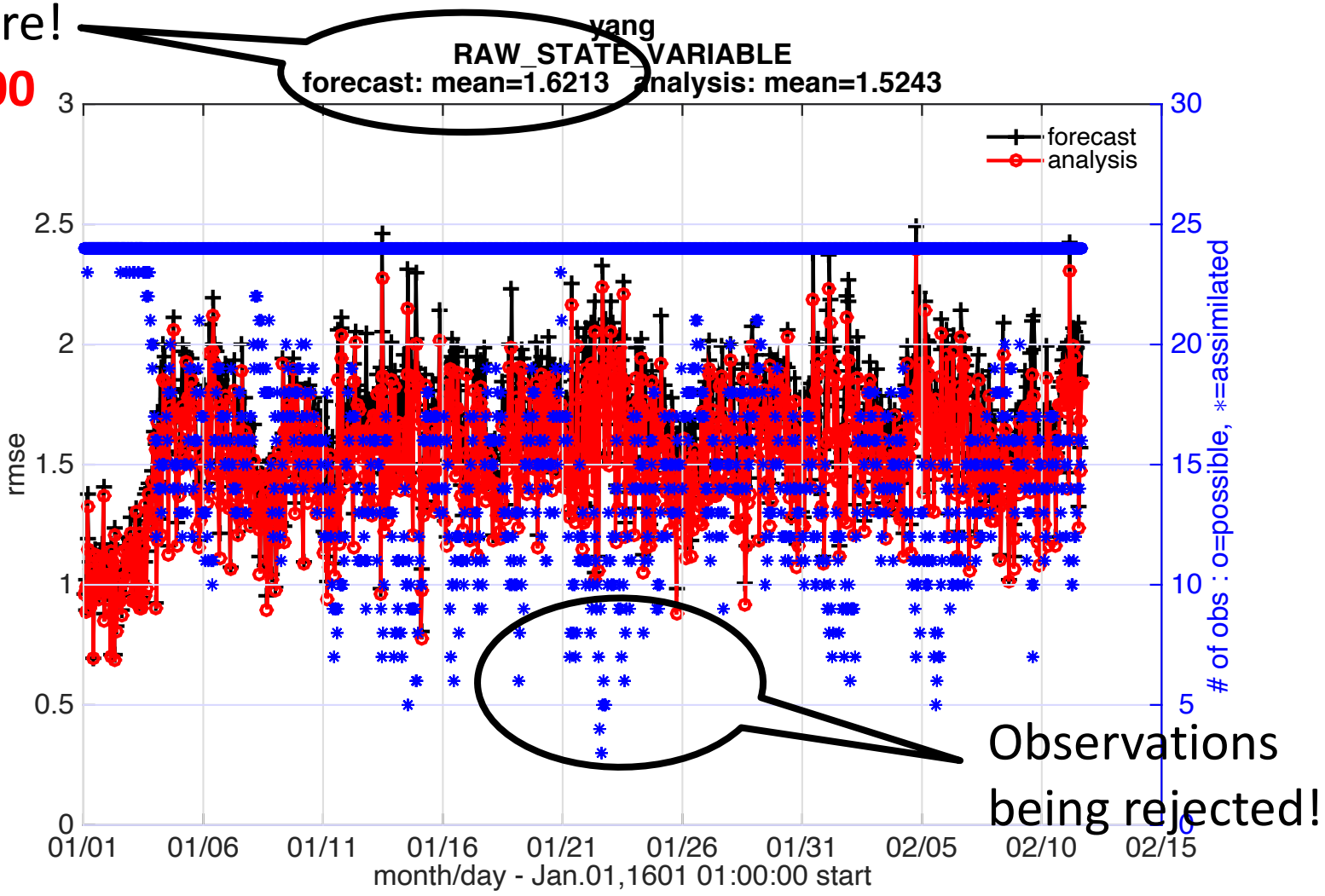
Rejecting 'good' observations can lead to inflated estimate of quality.

First Observation-space diagnostics:

Lower RMSE than before!

$1,000,000 question: Why?

outlier_threshold = 3.0



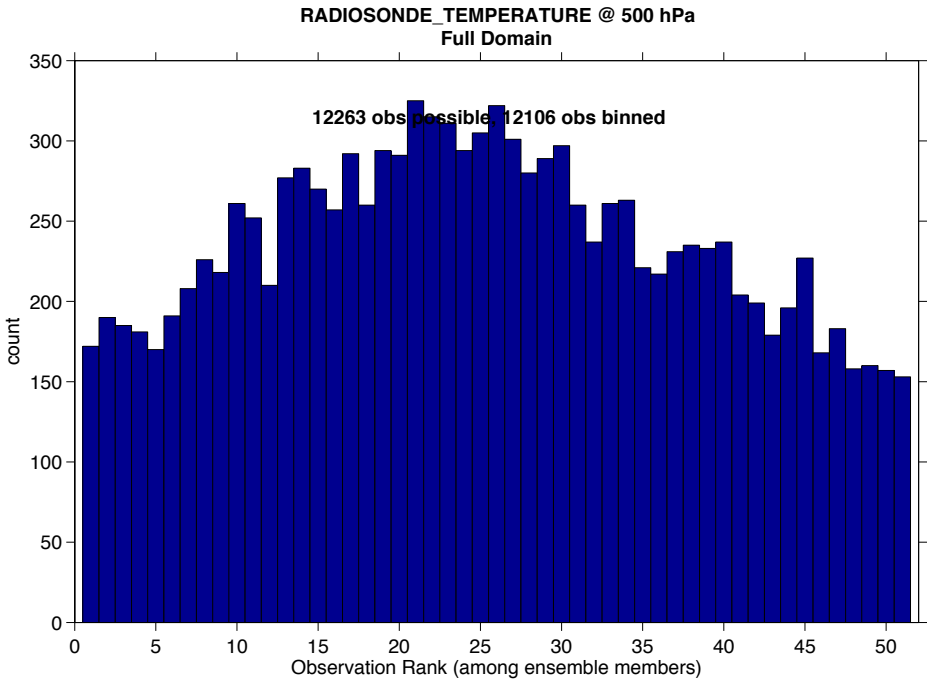
data file: /Users/thoar/svn/DART/clean_lanai/models/lorenz_96/work/obs_diag_output.nc

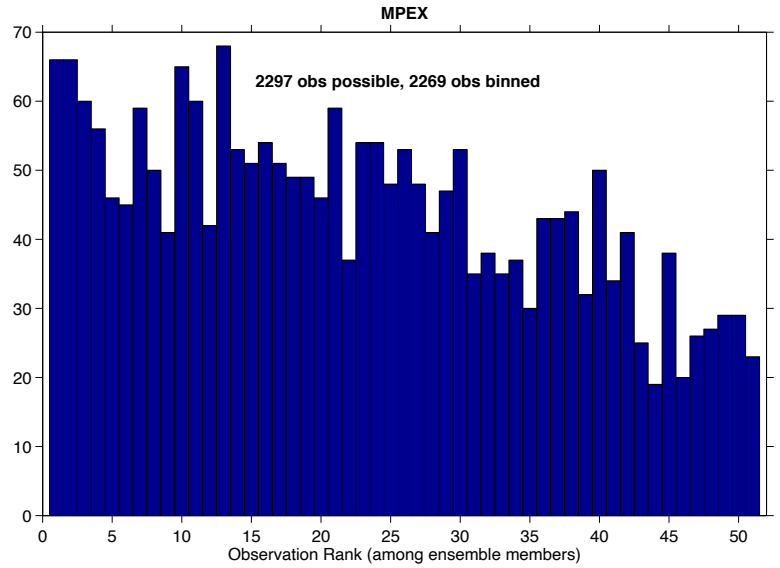
Lorenz_96 exercises:

- Pick a case that works relatively well and look at observation-space diagnostics.
- Pick a case that is similar, but clearly different, with physical-space diagnostics.
- See if you can detect the difference with observation-space diagnostics.
- Rerun ***obs_diag*** with different *bin_widths*.

Observation-space diagnostics: rank histograms

```
>> fname = 'obs_diag_output.nc';
>> timeindex = -1;
>> varname = 'RADIOSONDE_TEMPERATURE';
>> plot_rank_histogram(fname, timeindex, varname);
```



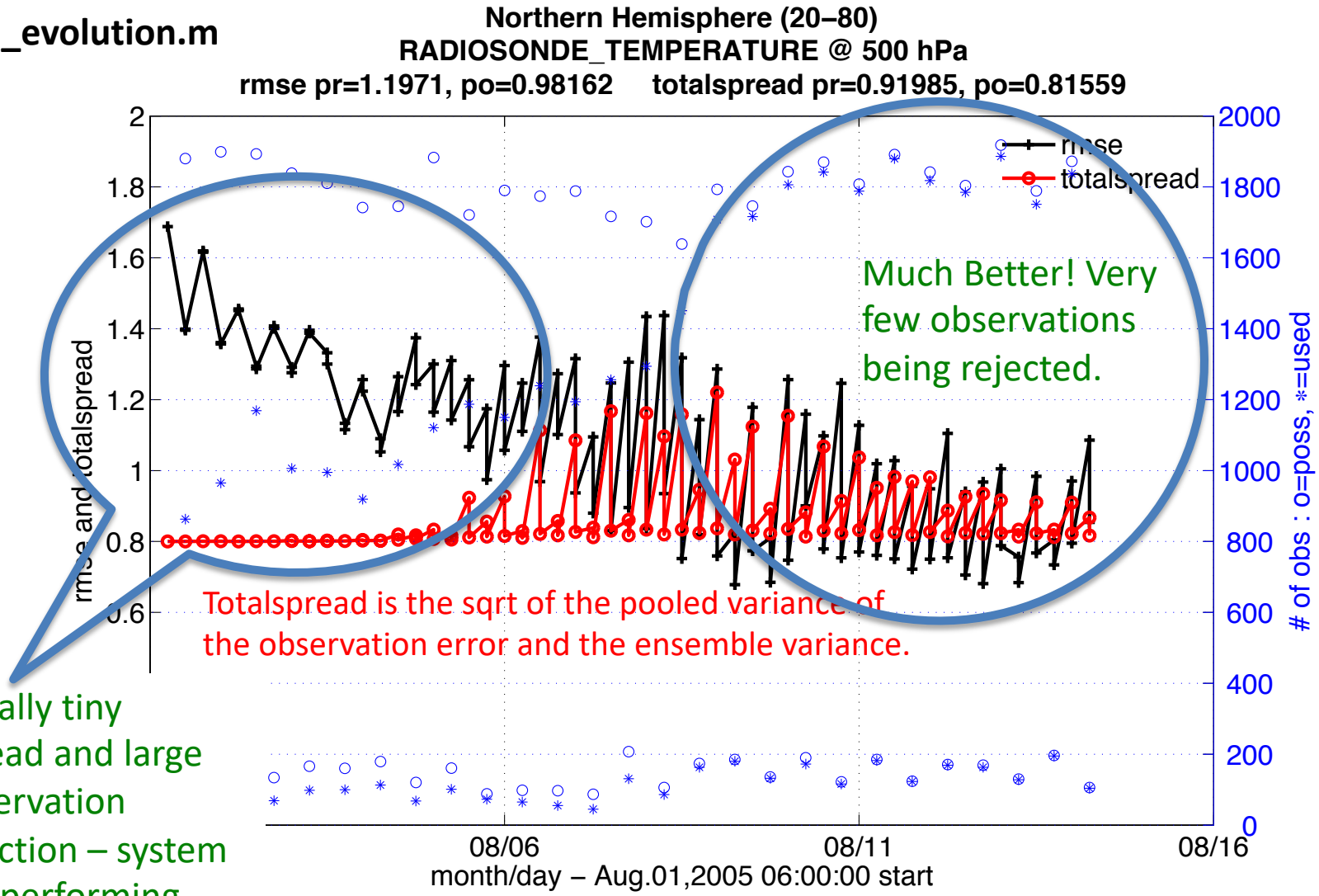


Results from WRF real-time forecasting.

Observation-space diagnostics: time evolution (by level)

plot_rmse_xxx_evolution.m

plot_evolution.m

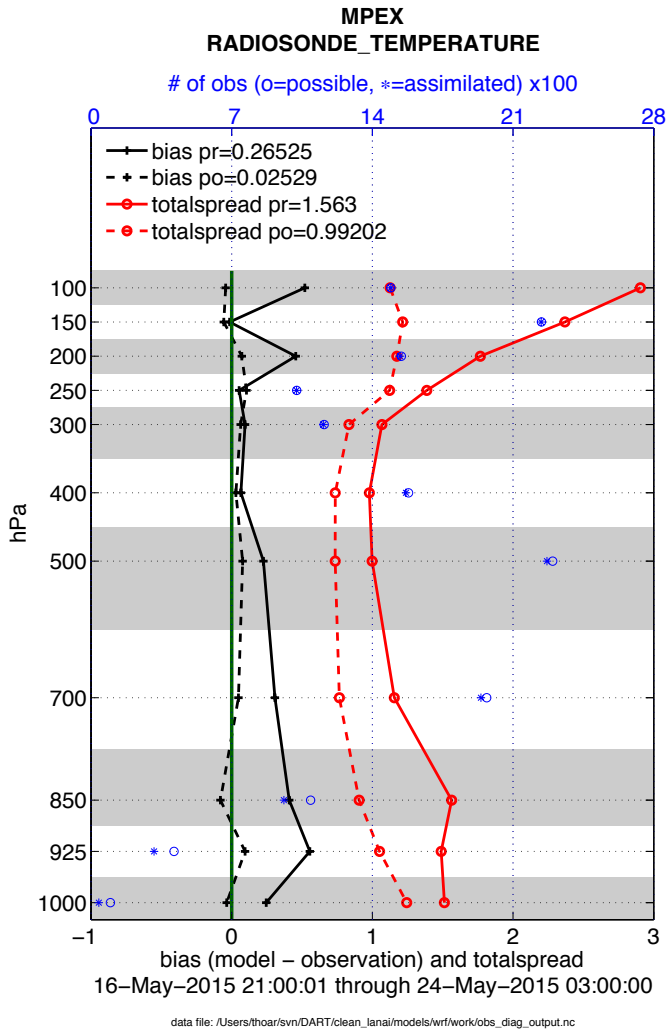


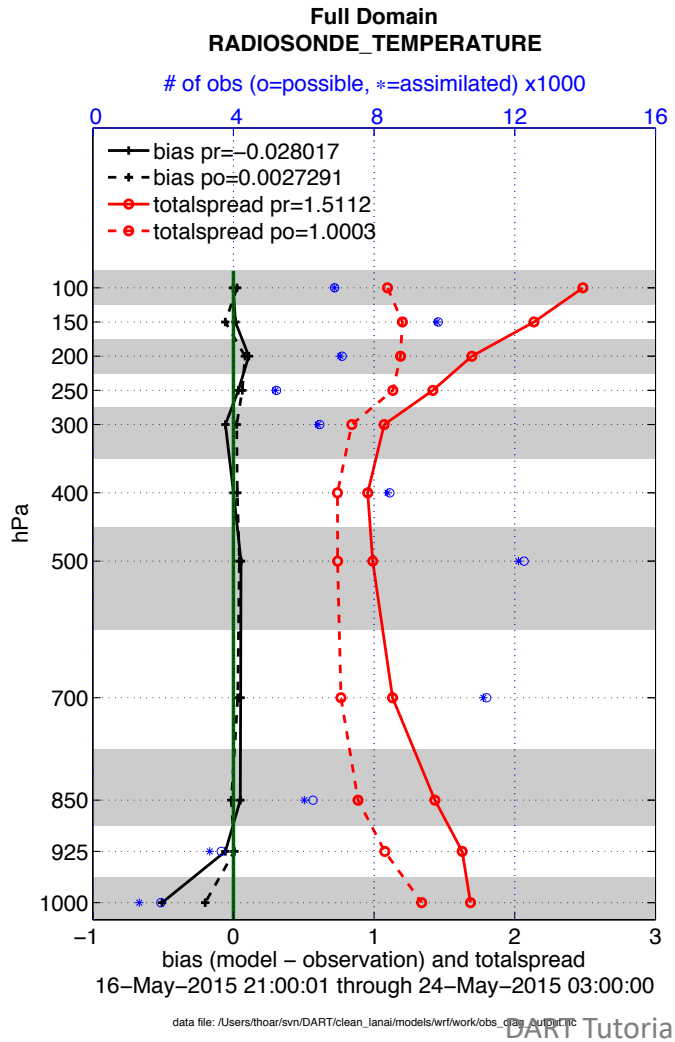
Initially tiny spread and large observation rejection – system not performing well – yet!

Observation-space diagnostics: time-averaged profiles

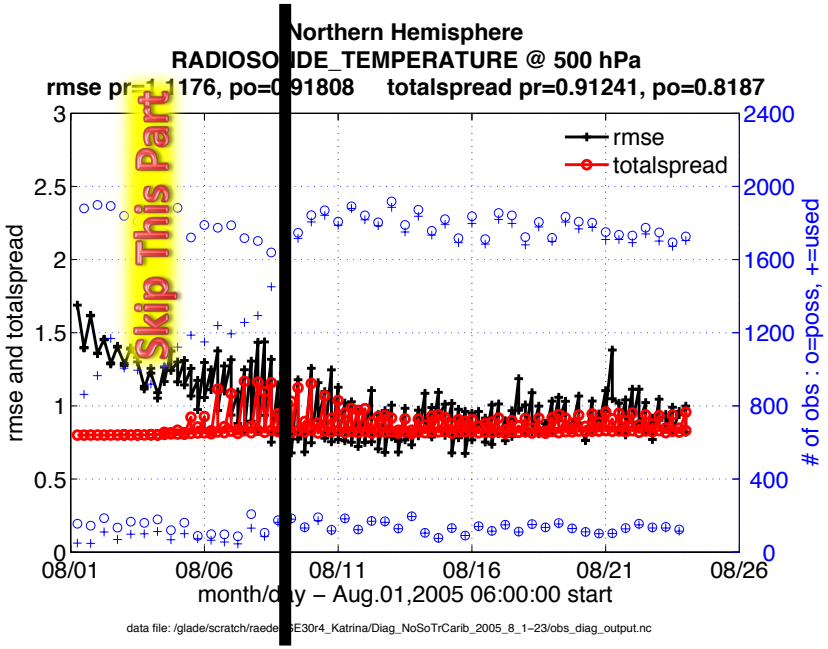
plot_profile.m plot_bias_xxx_profile.mplot_rmse_xxx_profile.m

Note: These are much more informative for models with levels! (i.e. the 1D models are not very interesting this way)





A word of warning …



NOTE: The `&obs_diag_nml` is different for low-order models and realistic models. Check carefully when using.

```
&obs_diag_nml
   obs_sequence_name = ''
   obs_sequence_list = 'file_list.txt'
   first_bin_center =  2005, 8, 1, 6, 0, 0
   last_bin_center  =  2005, 8,26, 0, 0, 0
   bin_separation   =     0, 0, 0, 6, 0, 0
   bin_width        =     0, 0, 0, 6, 0, 0
   time_to_skip     =     0, 0,10, 0, 0, 0
   max_num_bins     = 1000
   trusted_obs      = 'null'
   …
/
```

obs_diag '*time_to_skip*' setting will allow you to ignore the spinup before starting the time-averaging for the vertical profiles while still calculating metrics for the entire period of record for the time-evolution products.

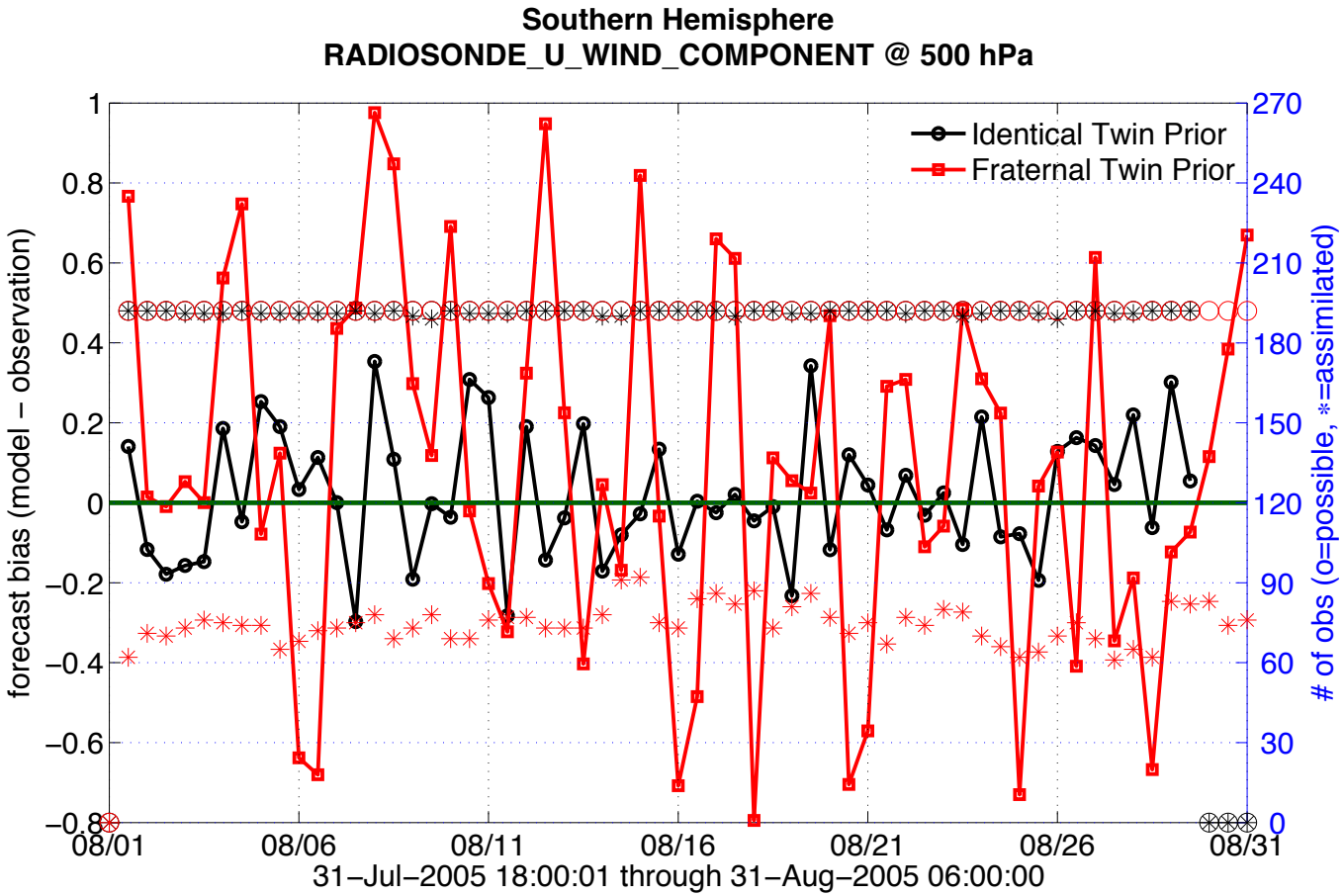
Observation-space diagnostics: comparing experiments

two_experiments_evolution.m

two_experiments_profile.m

This is useful for quick comparisons. Really 'fair' comparisons require more processing to compare the same set of observations across experiments.

assimilation_code/programs
obs_common_subset.html
obs_seq_coverage.html
obs_selection.html
obs_seq_verify.html



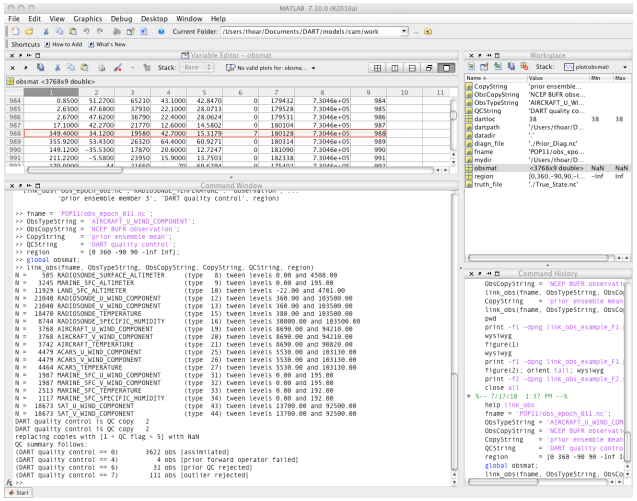
FYI:
'Identical' means the model that was used to generate the observations is also used for the assimilation.
'Fraternal' means the observations came from a different model.

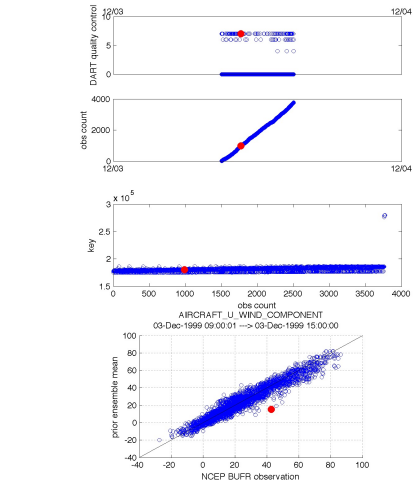
Observation-space diagnostics: netCDF

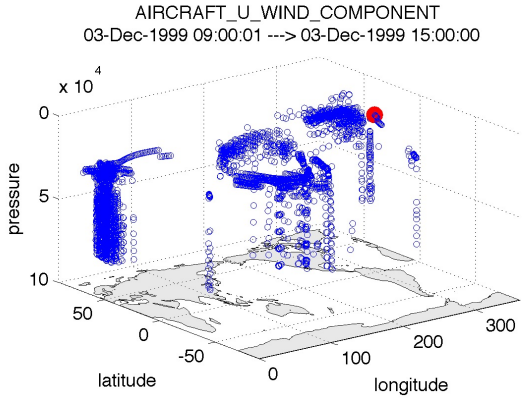
SOME of the information in the observation sequence files can be converted to netCDF and easily plotted. A program named ***obs_seq_to_netcdf*** must be run to produce the netCDF.

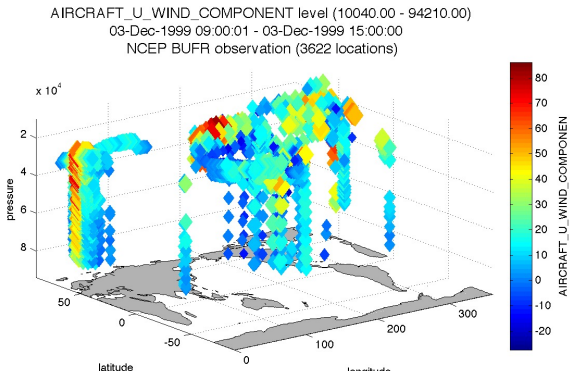
Here are a few of the Matlab functions available in *diagnostics/matlab*.

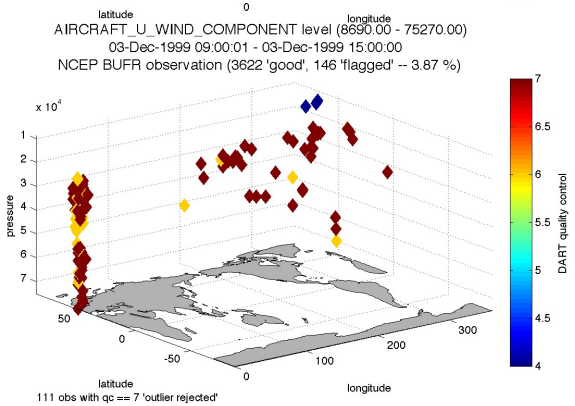
- **link_obs.m**
- **plot_obs_netcdf.m**
- **plot_obs_netcdf_diffs.m**
- **plot_coverage.m**











Complicated observation-space diagnostics.

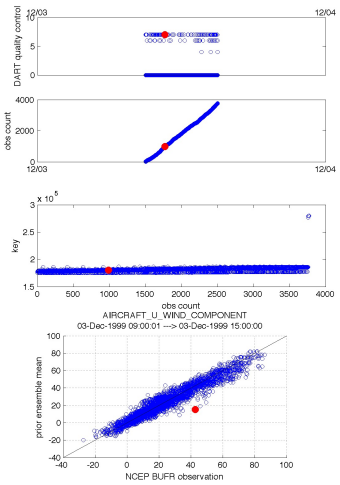
The program ***obs_seq_to_netcdf*** converts much of the information in an observation sequence file to a netCDF file. For now, we're going to explore a pre-computed file available at:

www.image.ucar.edu/pub/DART/Tutorial_Datasets/obs_epoch_SE30r4_Katrina.nc

It was generated with the following input:

```
&schedule_nml
    calendar           = 'Gregorian'
    first_bin_start    = 2005, 8, 13, 21, 0, 0
    first_bin_end      = 2005, 8, 14, 03, 0, 0
    last_bin_end       = 2005, 8, 14, 03, 0, 0
    bin_interval_days    = 10000
    bin_interval_seconds = 0
    max_num_bins         = 1000
    print_table          = .true.
  /
&obs_seq_to_netcdf_nml
    obs_sequence_name = 'cam_obs_seq.2005-08-14-00000.final'
    obs_sequence_list = ''
     lonlim1 = 160.
     lonlim2 = 40.
     latlim1 = 10.
     latlim2 = 65.
  /
```

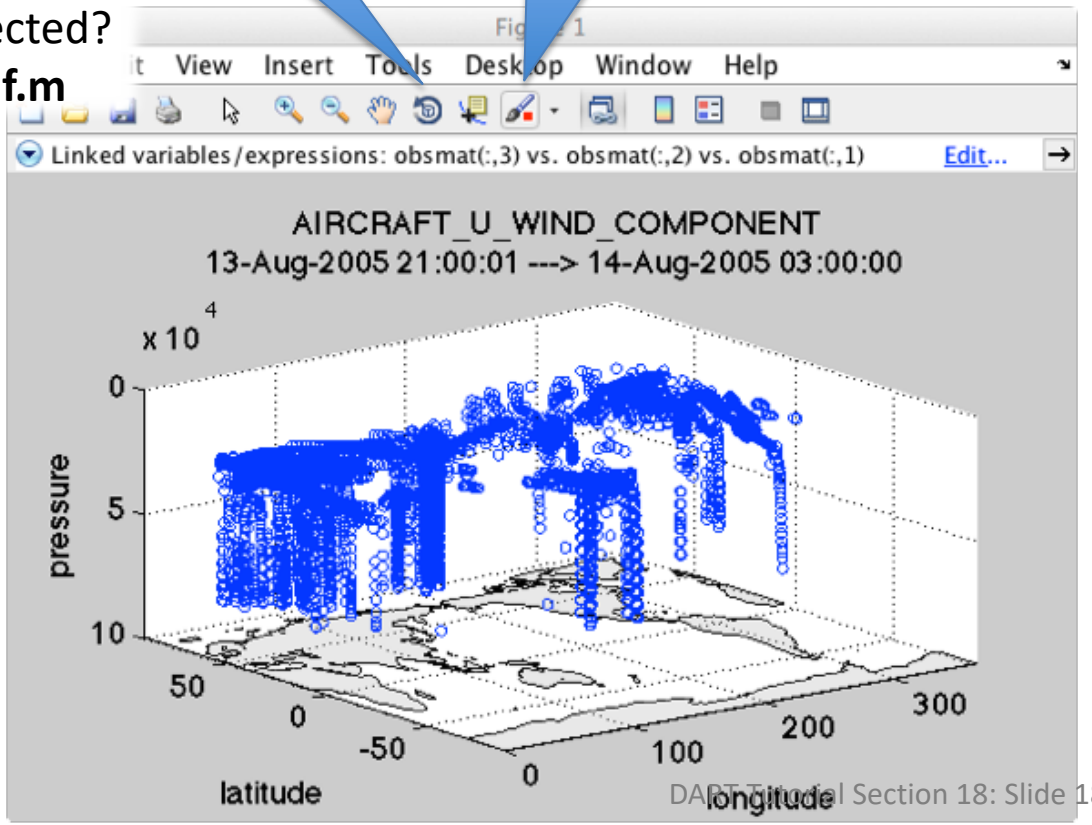
Matlab Hands-On: **link_obs** exploring observations

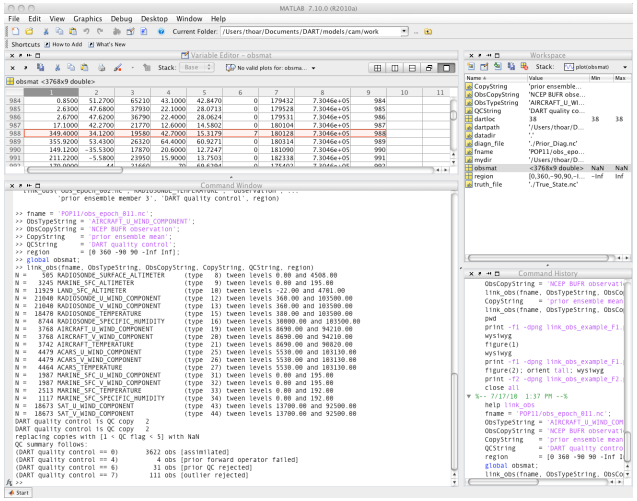


This enables rotation with the mouse.

'paintbrush' allows you to select observations for 'brushing'

Try different obs types,
Try to locate rejected obs,
Why were they rejected?
Try **plot_obs_netcdf.m**





DART Tutorial Index to Sections