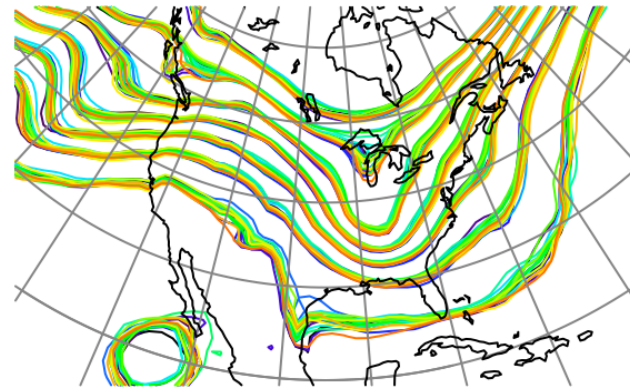


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DART Tutorial Section 18: Lost in Phase Space: The Challenge of Not Knowing the Truth.



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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.

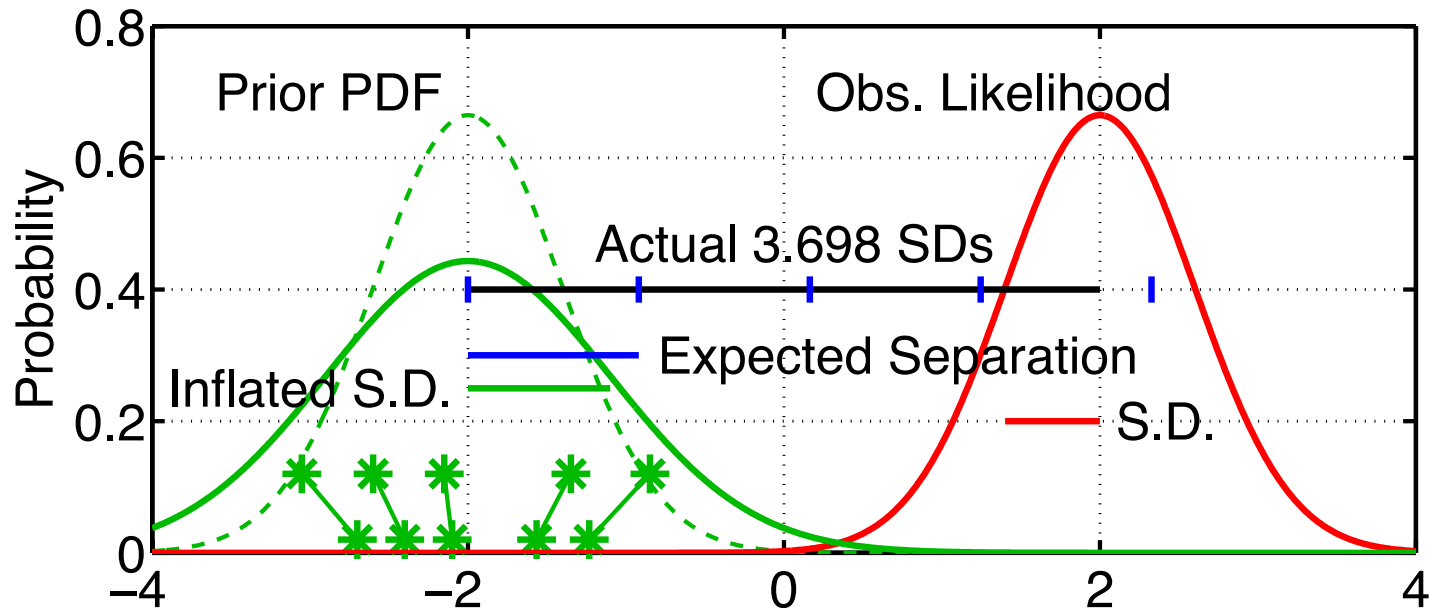
They are generally functions of the state variables.

They are always contaminated with observational errors.

What to expect ...

Recall that

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



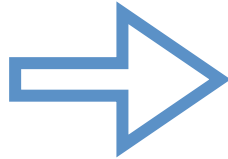
Error is dominated by observational noise if $\sigma_{\text{obs}}^2 \gg \sigma_{\text{prior}}^2$

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

Halving σ_{prior} to 0.05 $\Rightarrow E(\text{RMS}) = 1.001$; 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 $\left| \overline{y^p} - y^o \right| / \sqrt{\sigma_{prior}^2 + \sigma_{obs}^2} > \text{outlier_threshold}$  Observation rejected!
(DART QC ==7)

```
&filter_nml
```

```
...
```

```
ens_size = 20
```

```
obs_sequence_in_name = "obs_seq.out"
```

```
obs_sequence_out_name = "obs_seq.final"
```

```
num_output_state_members = 20
```

```
num_output_obs_members = 20
```

```
input_qc_threshold = 3.0
```

```
outlier_threshold = -1.0
```

```
...
```

```
/
```

 **Output filename**

 **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/DART_Documentation.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               = 1,
  trusted_obs           = 'null',
  lonlim1                = 0.00
  lonlim2                = 1.01
  reg_names              = 'whole'
  create_rank_histogram = .true.,
  outliers_in_histogram = .true.,
  use_zero_error_obs    = .false.,
  verbose                = .false.
```

(Slightly different for 3D models.)

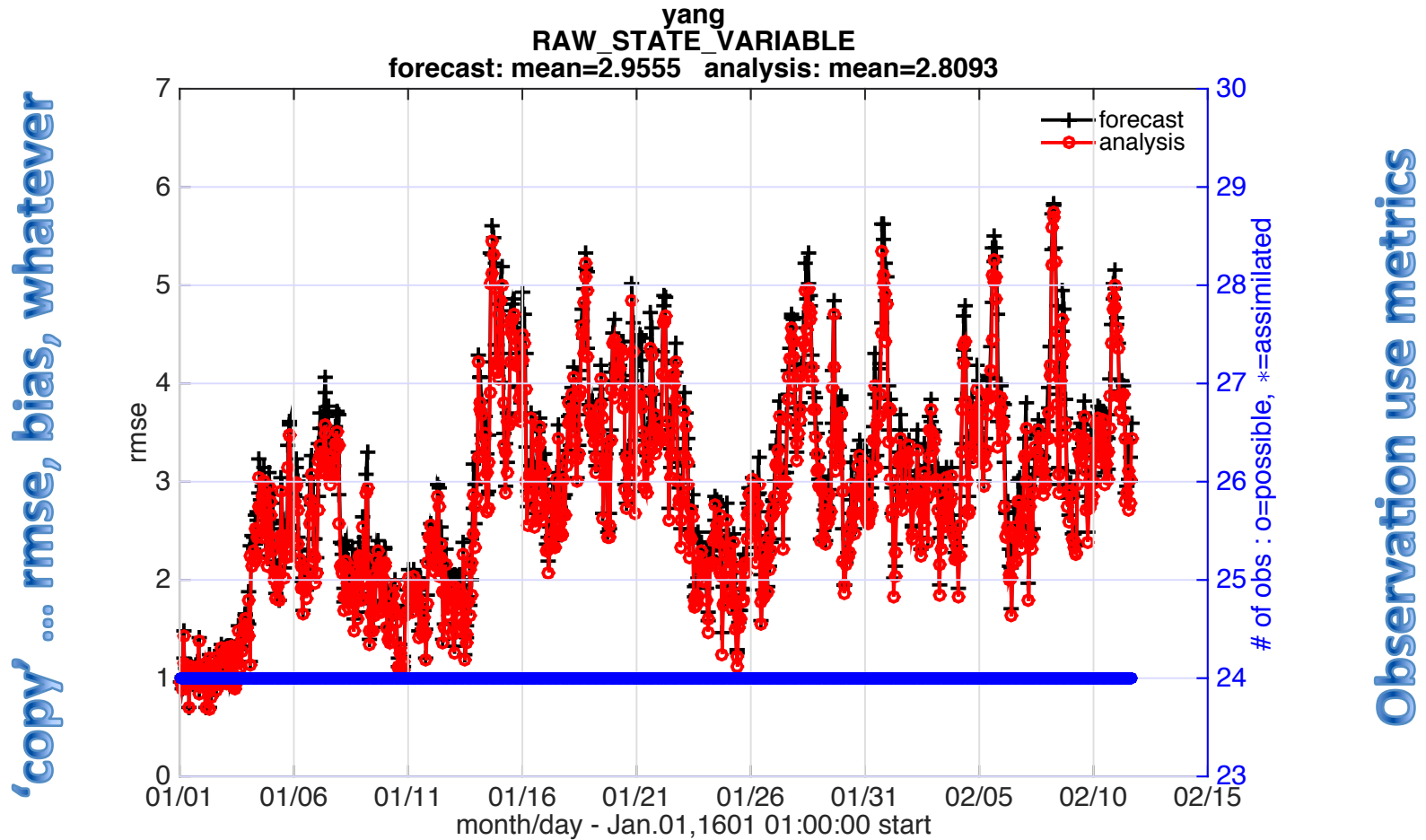
Here are a few of the Matlab functions available in `<dart>/diagnostics/matlab`

- **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



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

Time (aka 'evolution')

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
...
ens_size                = 20
obs_sequence_in_name    = "obs_seq.out"
obs_sequence_out_name   = "obs_seq.final"
num_output_state_members = 20
num_output_obs_members  = 20
input_gc_threshold      = 3.0
outlier_threshold       = -1.0
...
/
```

Change to whatever 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.

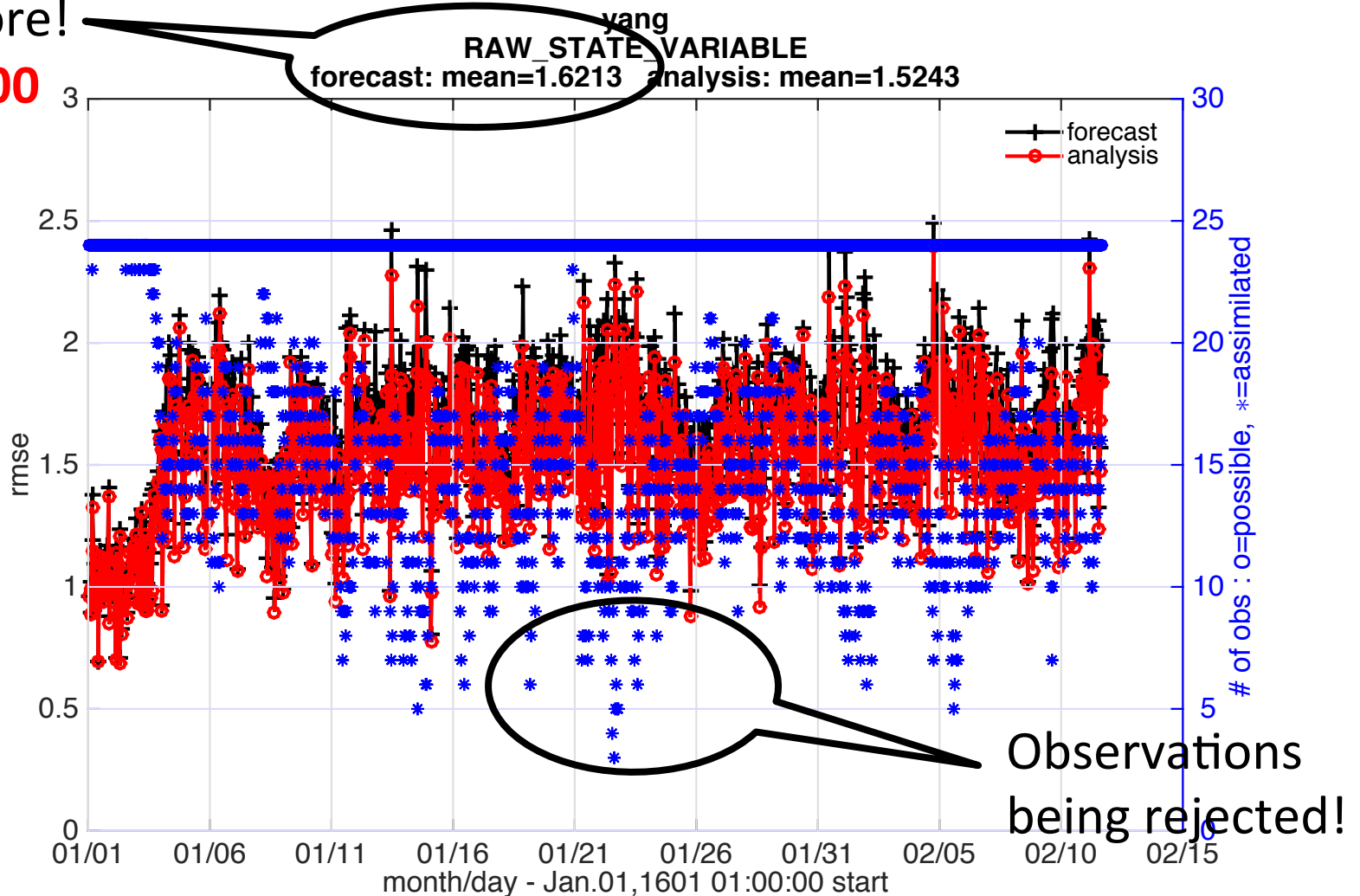
First Observation-space diagnostics:

Lower RMSE
than before!

\$1,000,000

Why?

outlier_threshold = 3.0

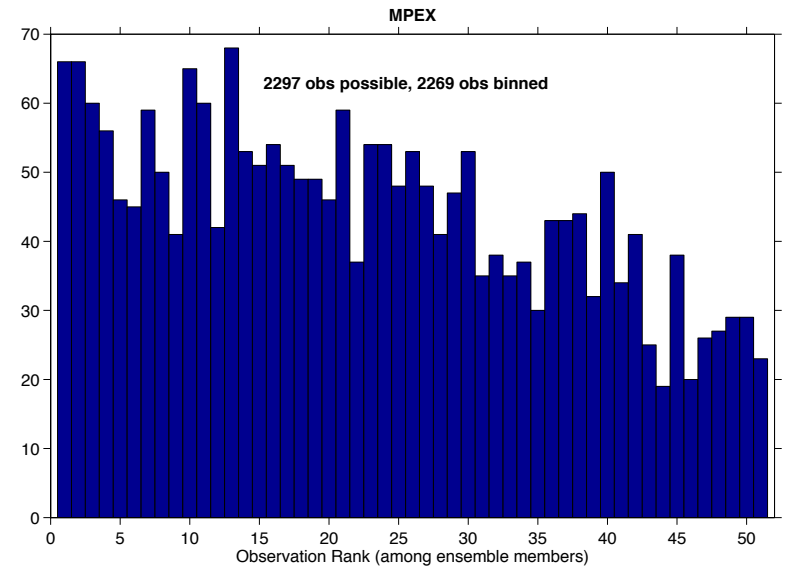
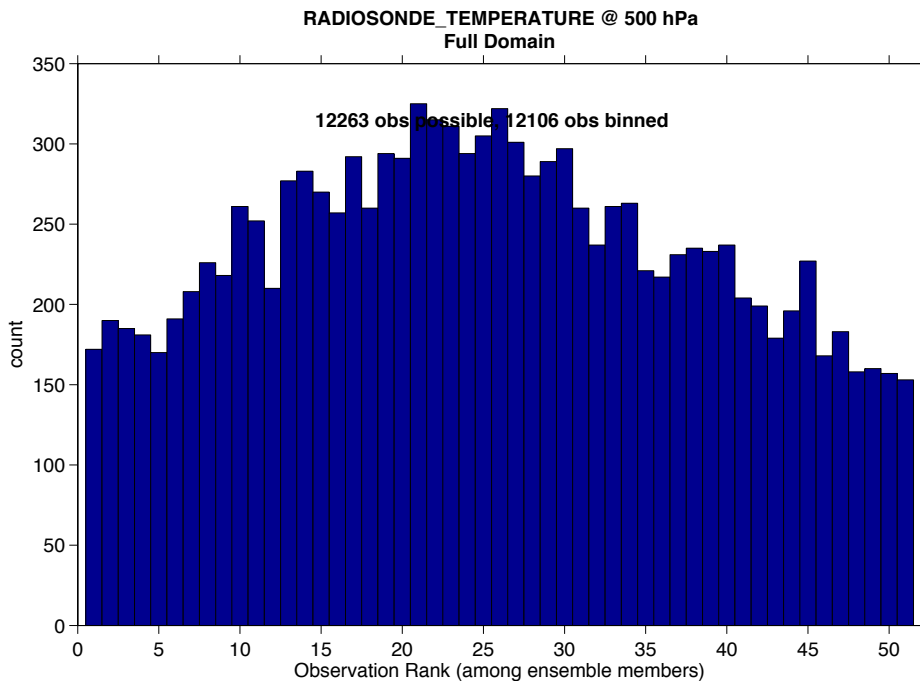


Lorenz_96 exercises:

- 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.

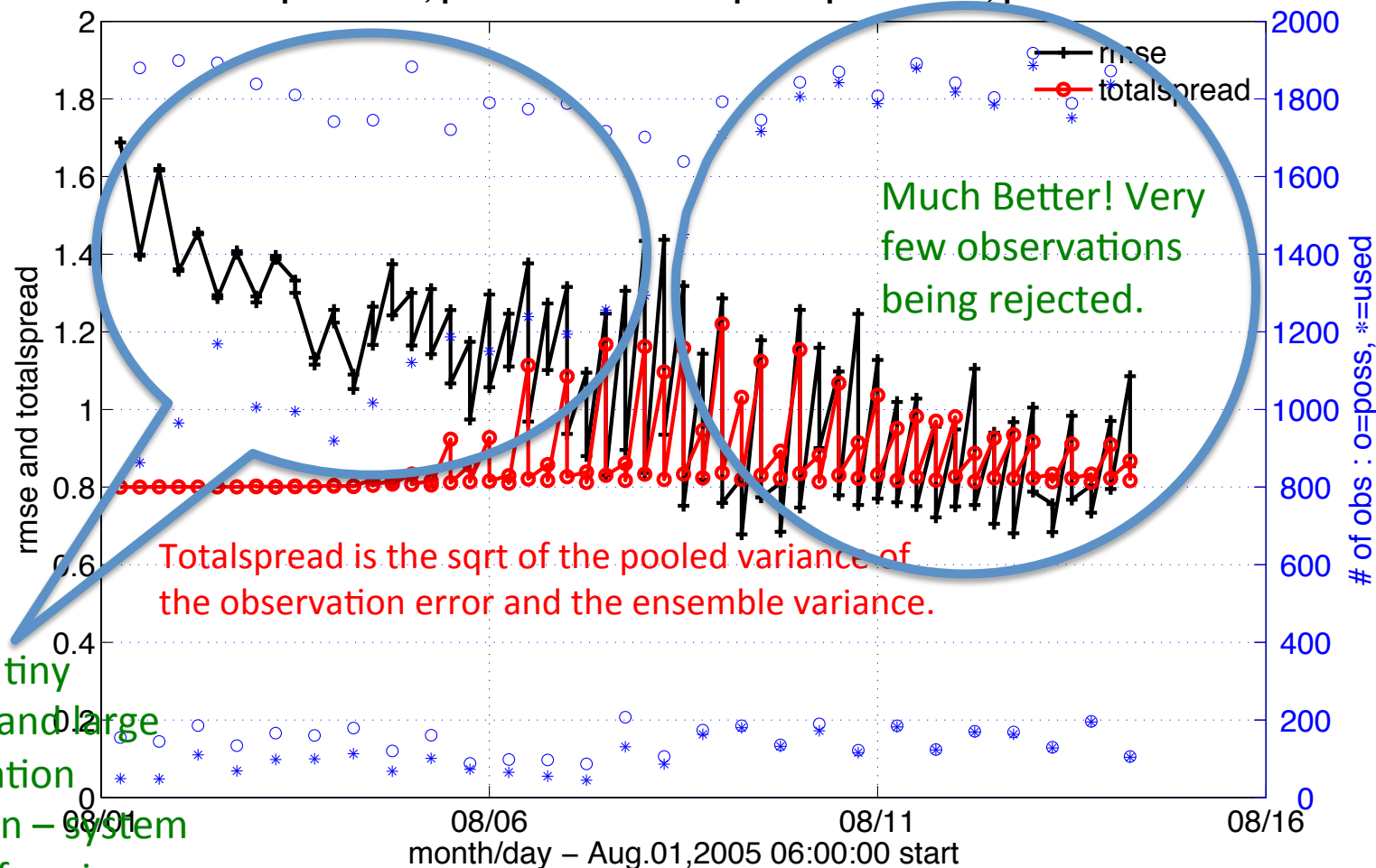
Observation-space diagnostics: time evolution (by level)

plot_rmse_xxx_evolution.m

plot_evolution.m

Northern Hemisphere (20–80)
RADIOSONDE TEMPERATURE @ 500 hPa

rmse pr=1.1971, po=0.98162 totalspread pr=0.91985, po=0.81559



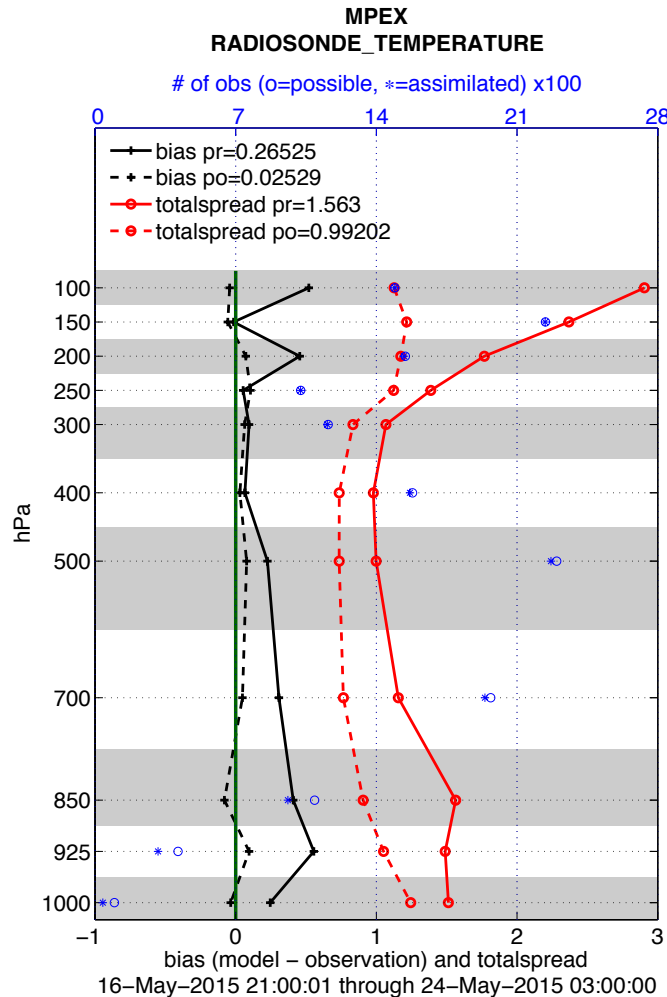
Observation-space diagnostics: time-averaged profiles

plot_profile.m

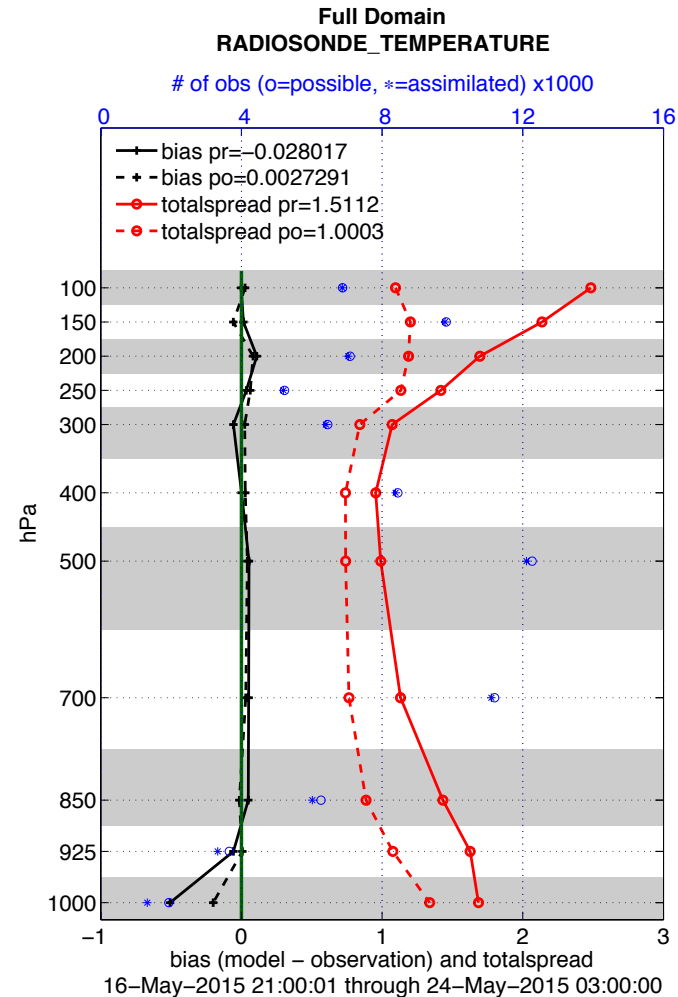
plot_bias_xxx_profile.m

plot_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)

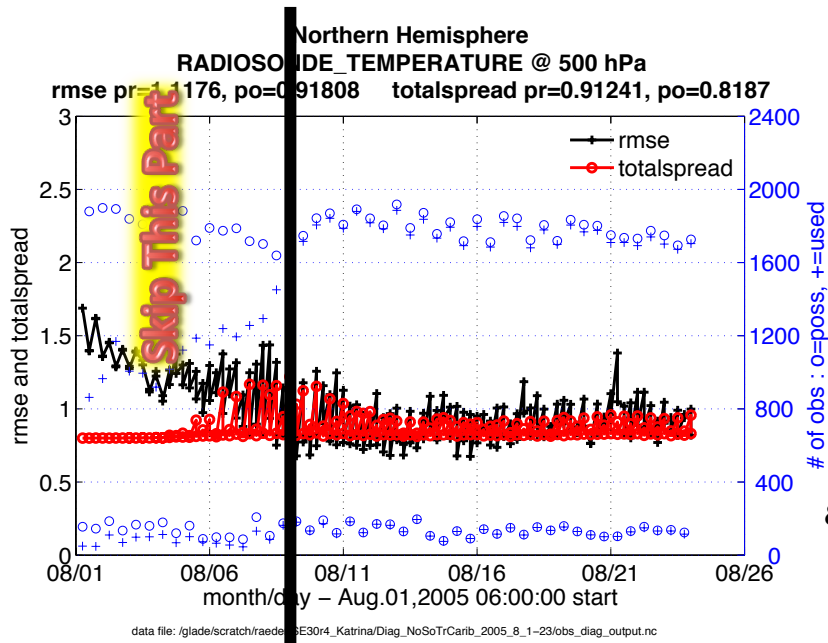


data file: /Users/thoar/svn/DART/clean_lanai/models/wrf/work/obs_diag_output.nc



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

A word of warning ...



```
&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 for the vertical profiles while still calculating metrics for the entire period of record for the time-evolution products.

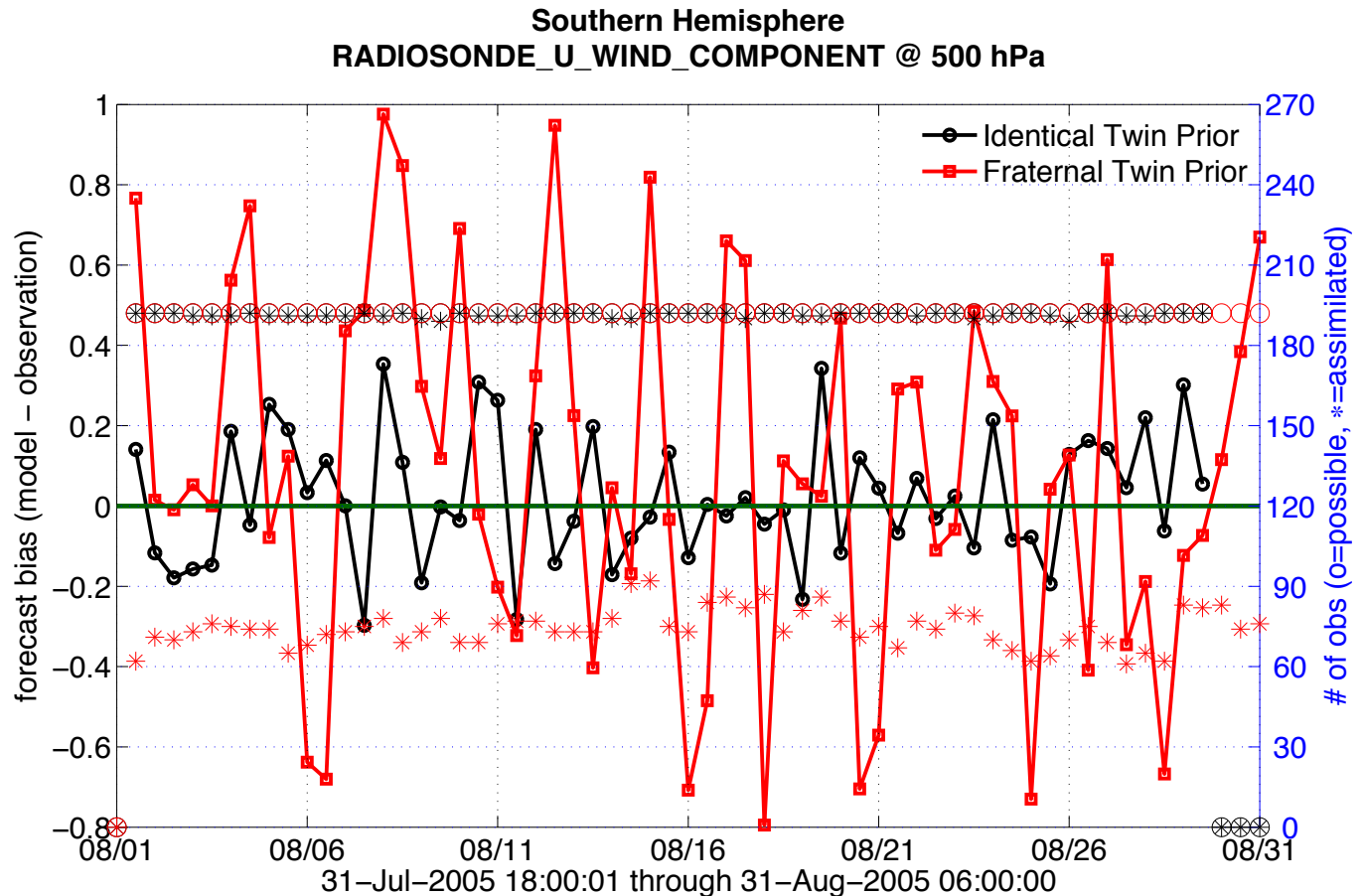
Observation-space diagnostics: comparing experiments

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.

[obs_sequence/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.

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.
/
```


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