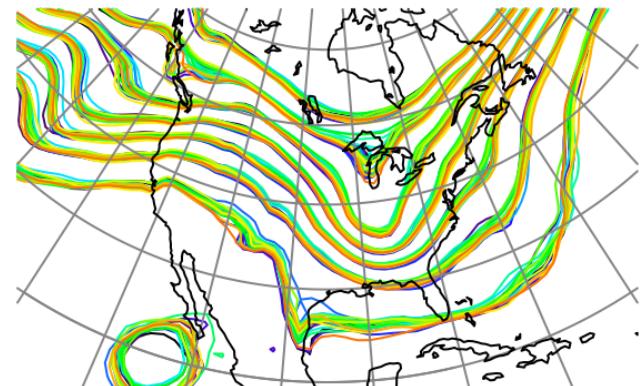


D  
a  
t  
a  
  
A  
ss  
im  
il  
at  
ion  
  
R  
es  
ear  
ch  
  
T  
est  
bed



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



©UCAR

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  
Atmospheric Research



# 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.

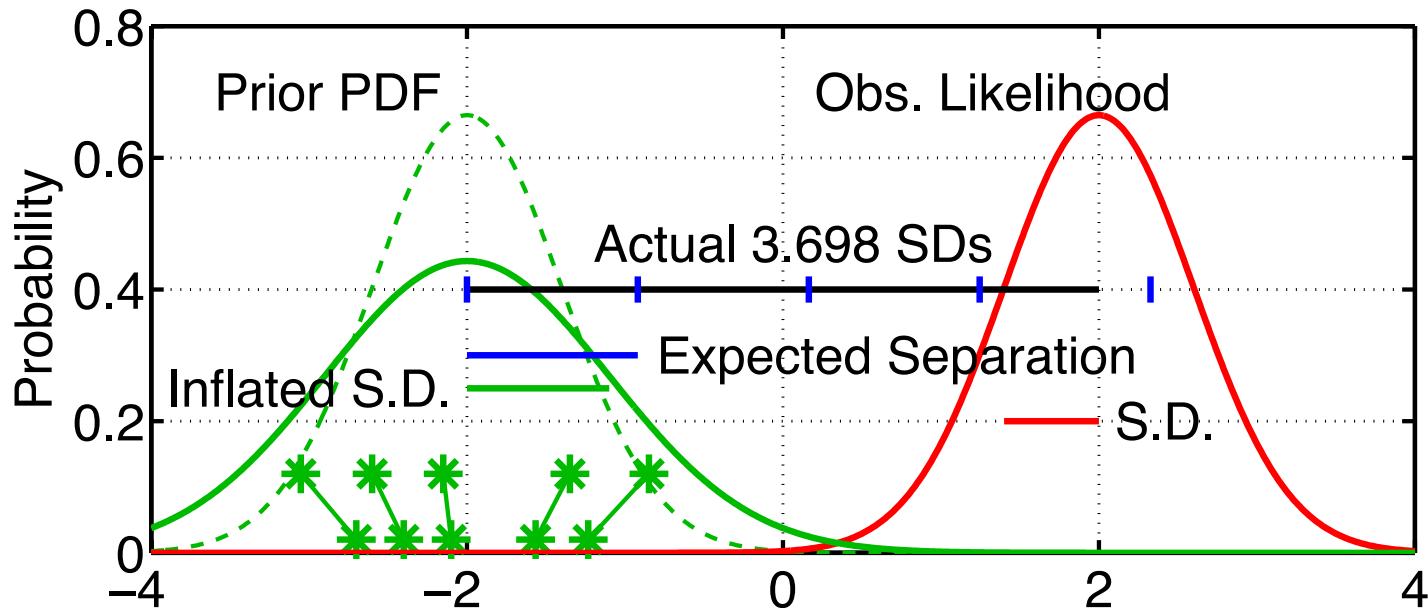
They are generally functions of the state variables.

They are always contaminated with observational errors.

# What to expect ...

Recall that

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



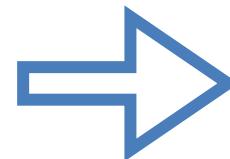
Error is dominated by observational noise if  $\sigma_{\text{obs}}^2 \gg \sigma_{\text{prior}}^2$

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

Halving  $\sigma_{\text{prior}}$  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  $\left| \bar{y}^p - y^o \right| / \sqrt{\sigma_{prior}^2 + \sigma_{obs}^2} > \text{outlier\_threshold}$   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](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,          (Slightly different for 3D models.)
  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.
/
```

# 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](http://www.image.ucar.edu/DARes/DART/DART2_Diagnostics.php#obs_diagnostics)

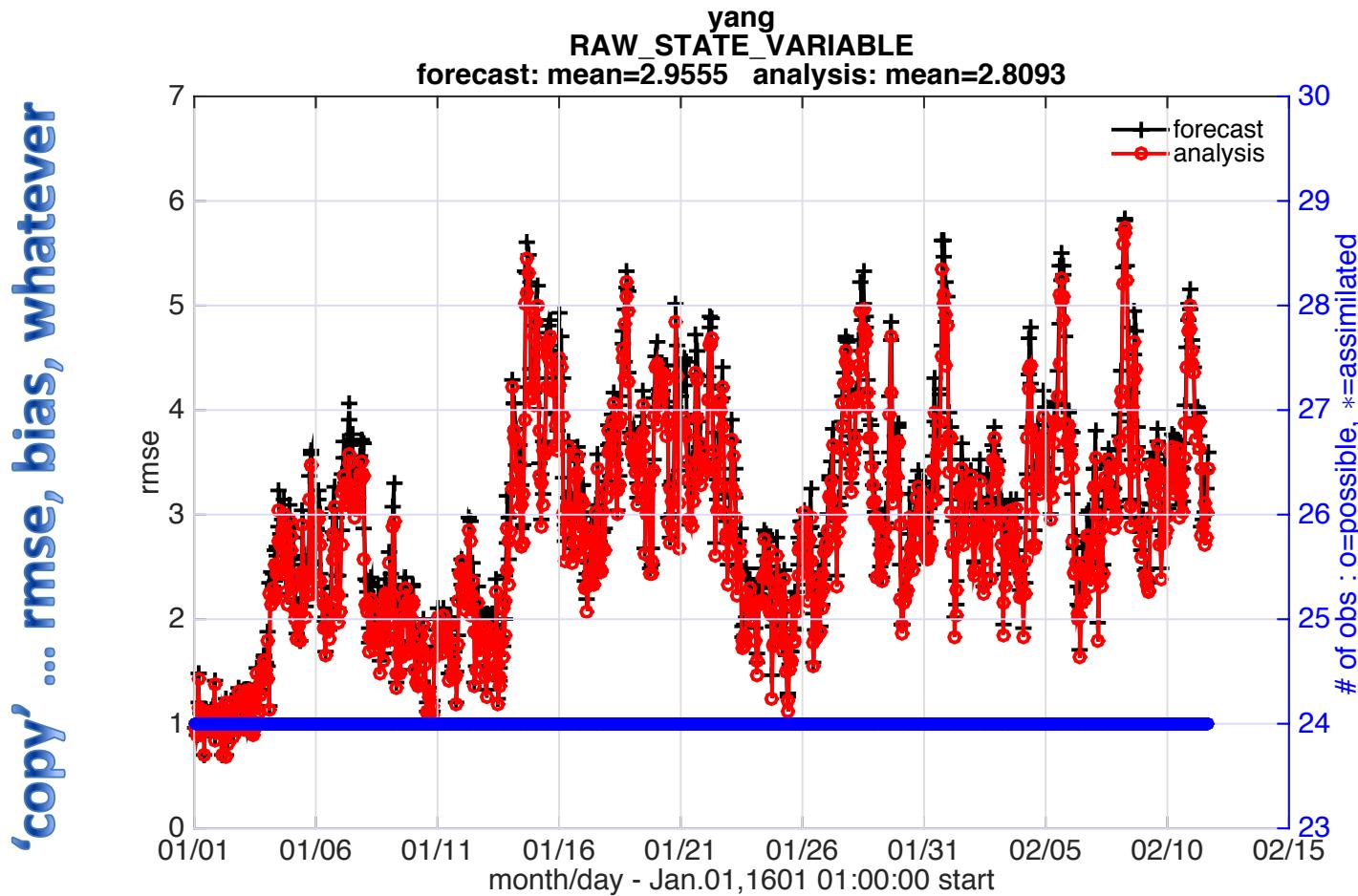
Here are a few of the Matlab functions available in *diagnostics/matlab*

- **`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



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
...
obs_sequence_in_name      = "obs_seq.out"
obs_sequence_out_name     = "obs_seq.final" ← Change to whatever you like.
...
/
&quality_control_nml
    input_qc_threshold   = 3.0,
    outlier_threshold    = -1.0, ← 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*!

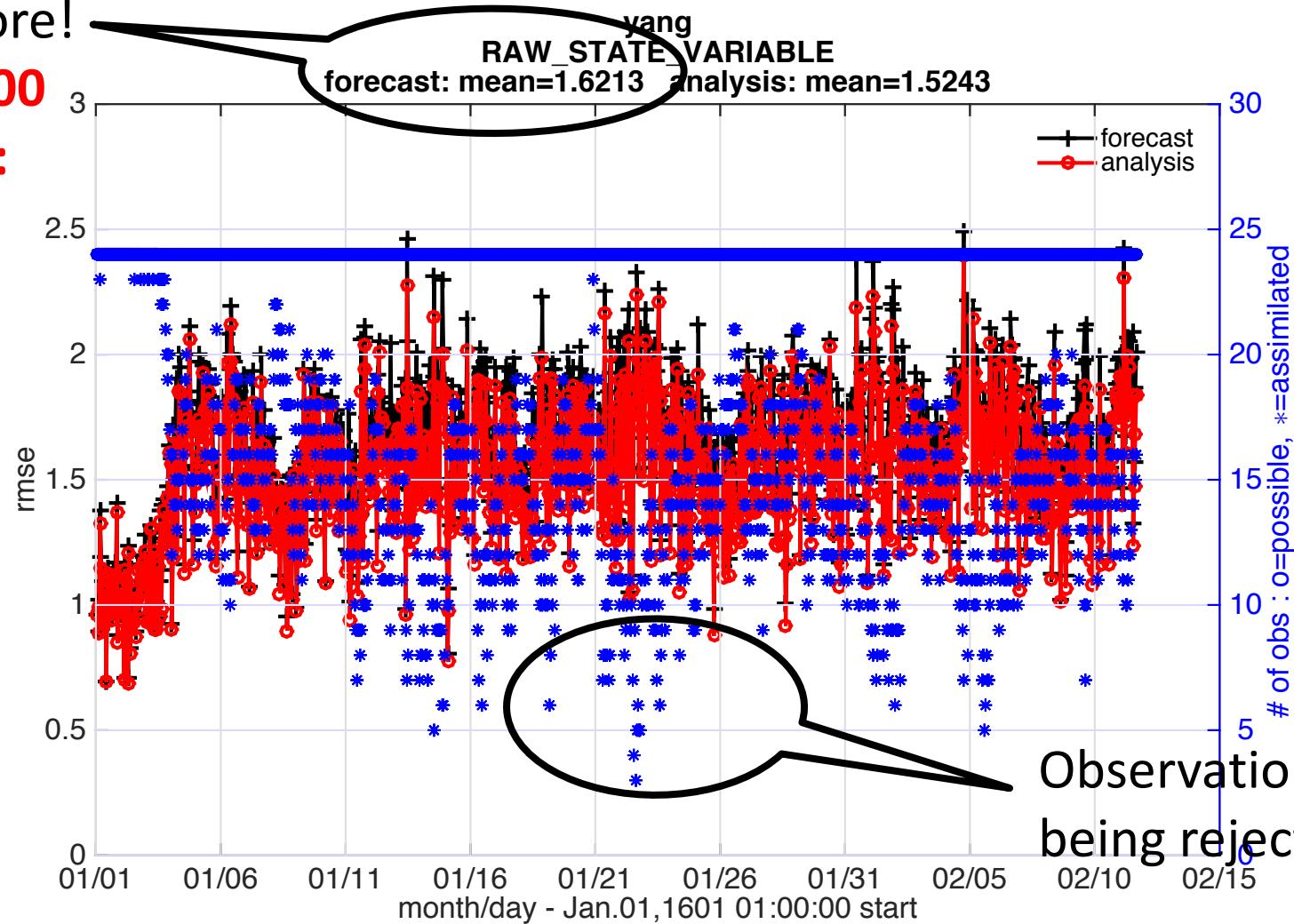
This is potentially **DANGEROUS**, but useful.

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

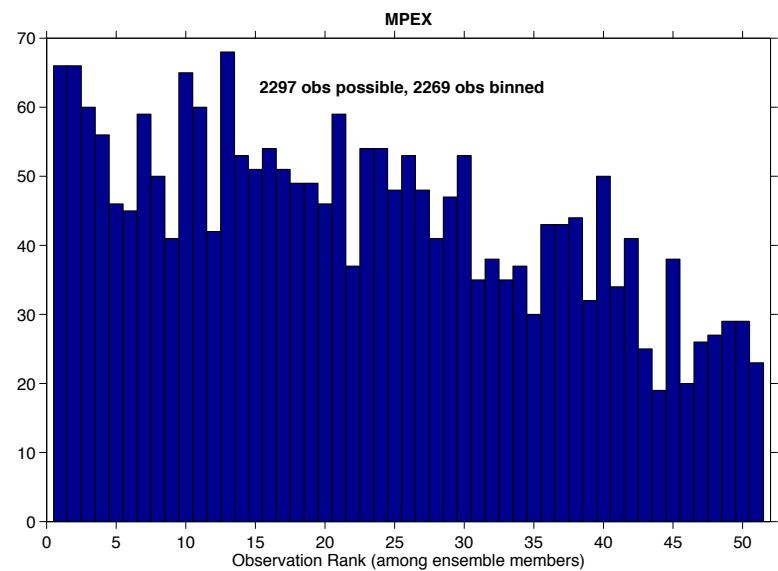
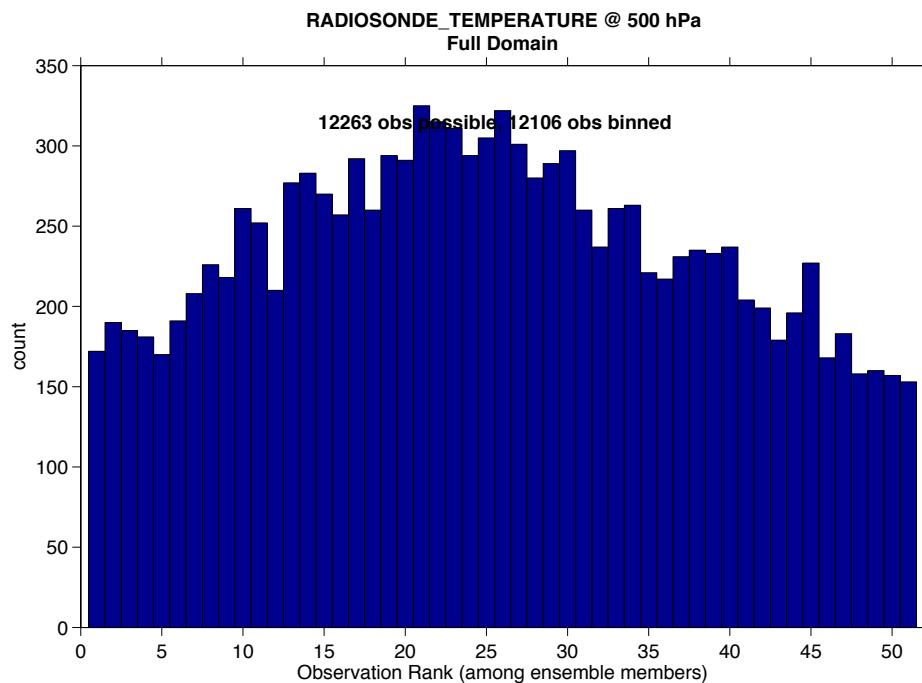


# Lorenz\_96 exercises:

- 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);
```

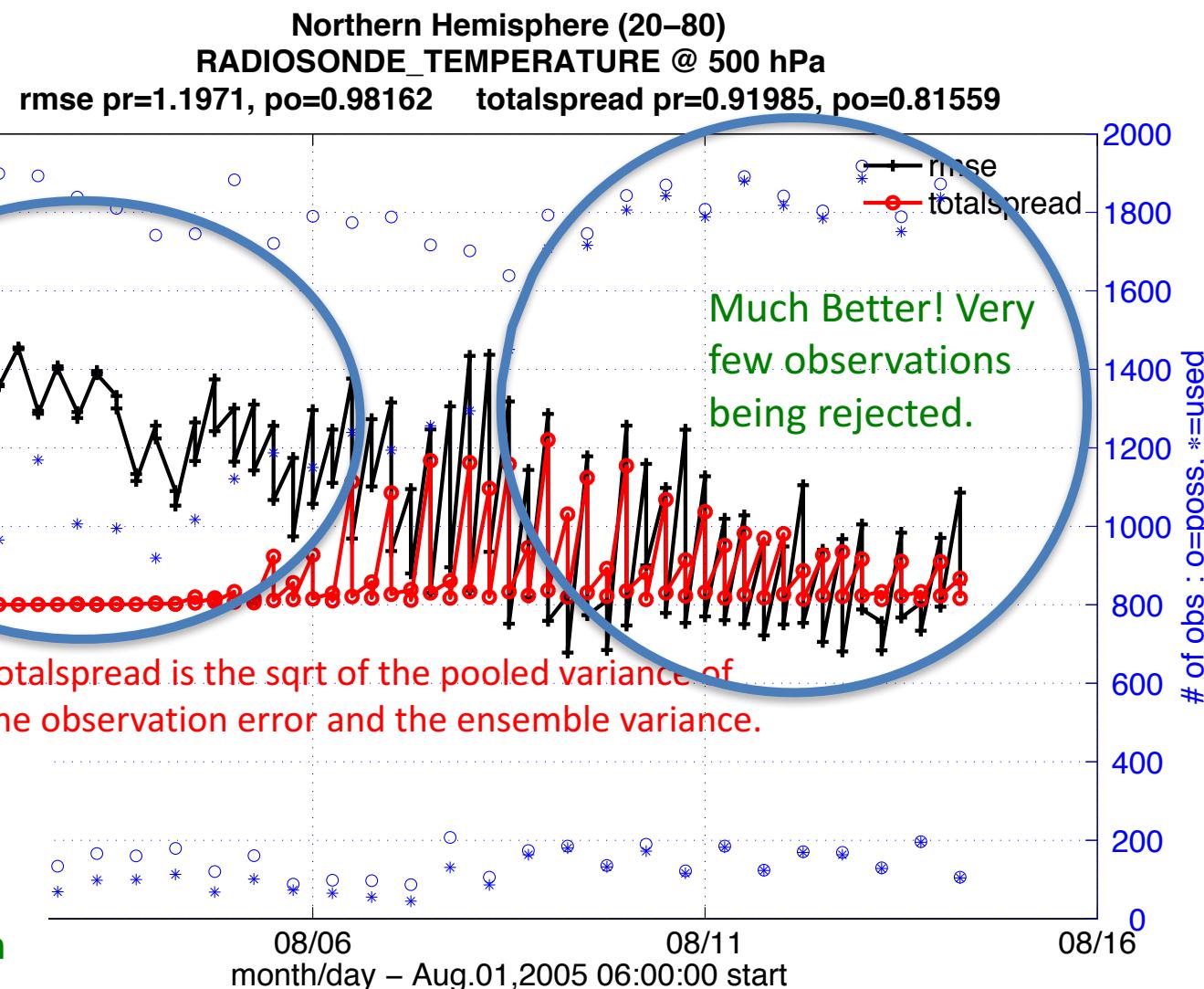


Results from WRF real-time forecasting.

# Observation-space diagnostics: time evolution (by level)

`plot_rmse_xxx_evolution.m`

`plot_evolution.m`

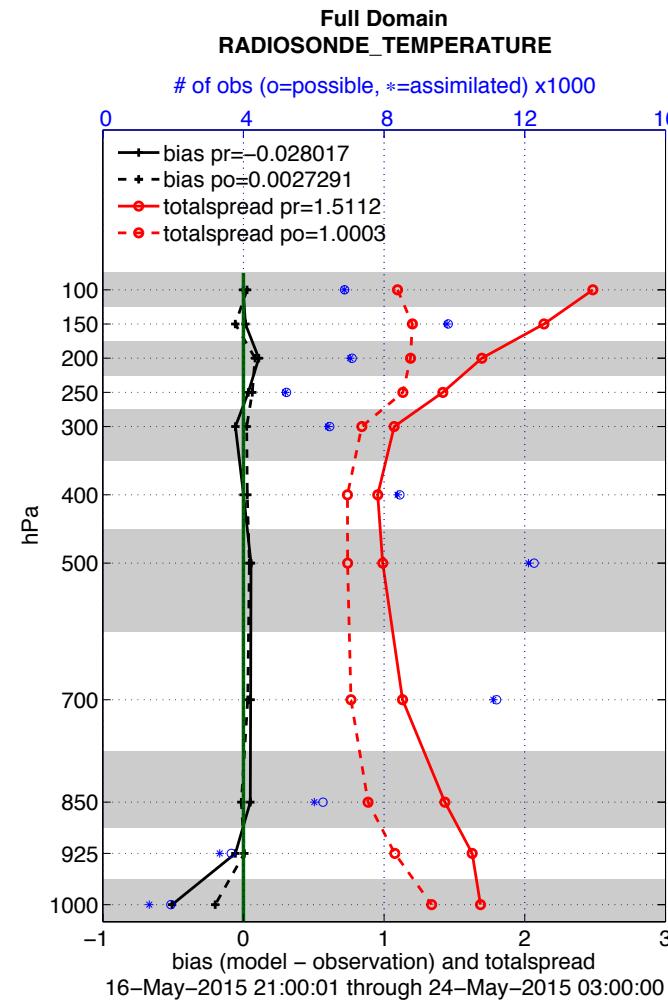
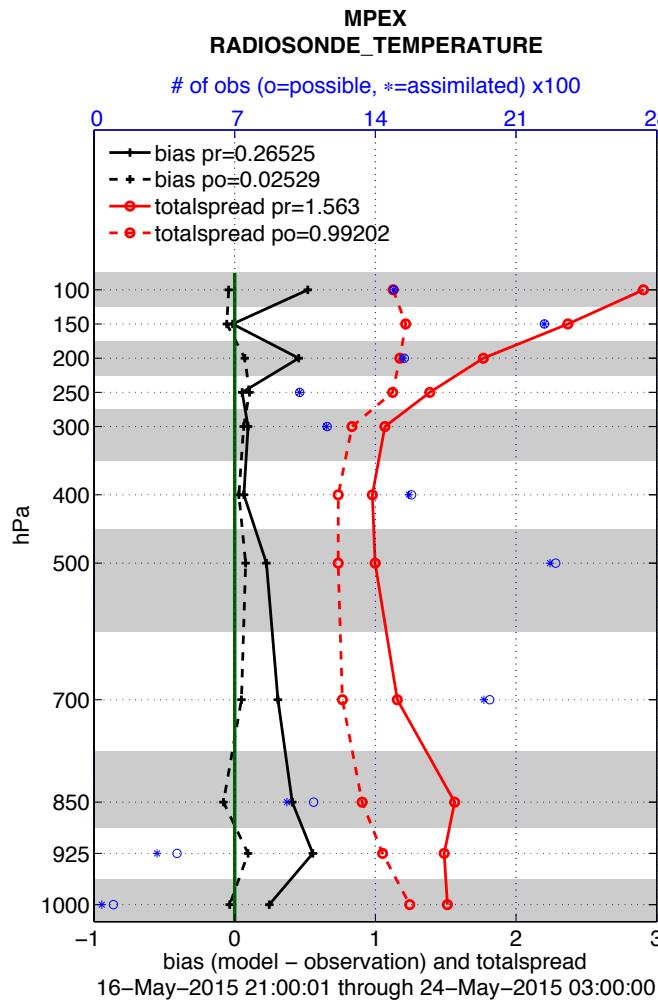


# Observation-space diagnostics: time-averaged profiles

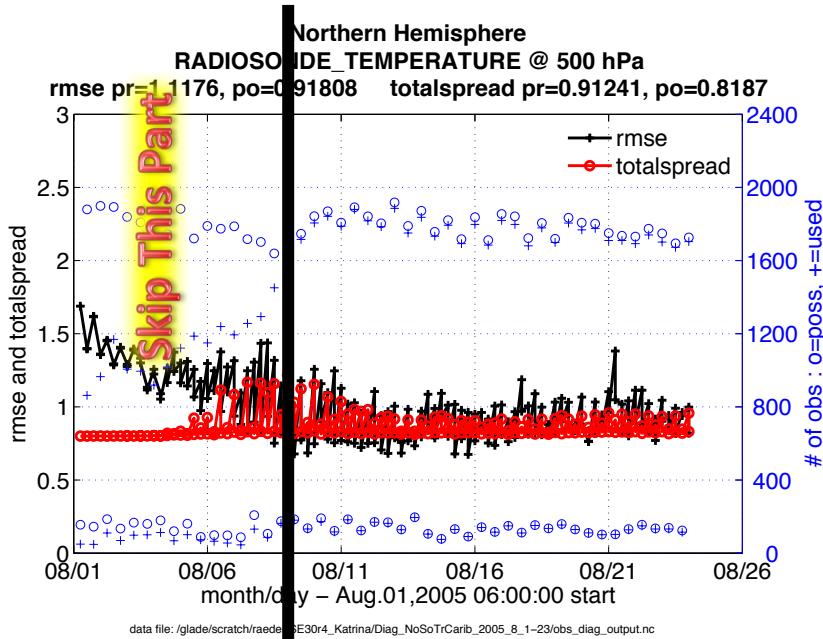
`plot_profile.m`

`plot_bias_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.

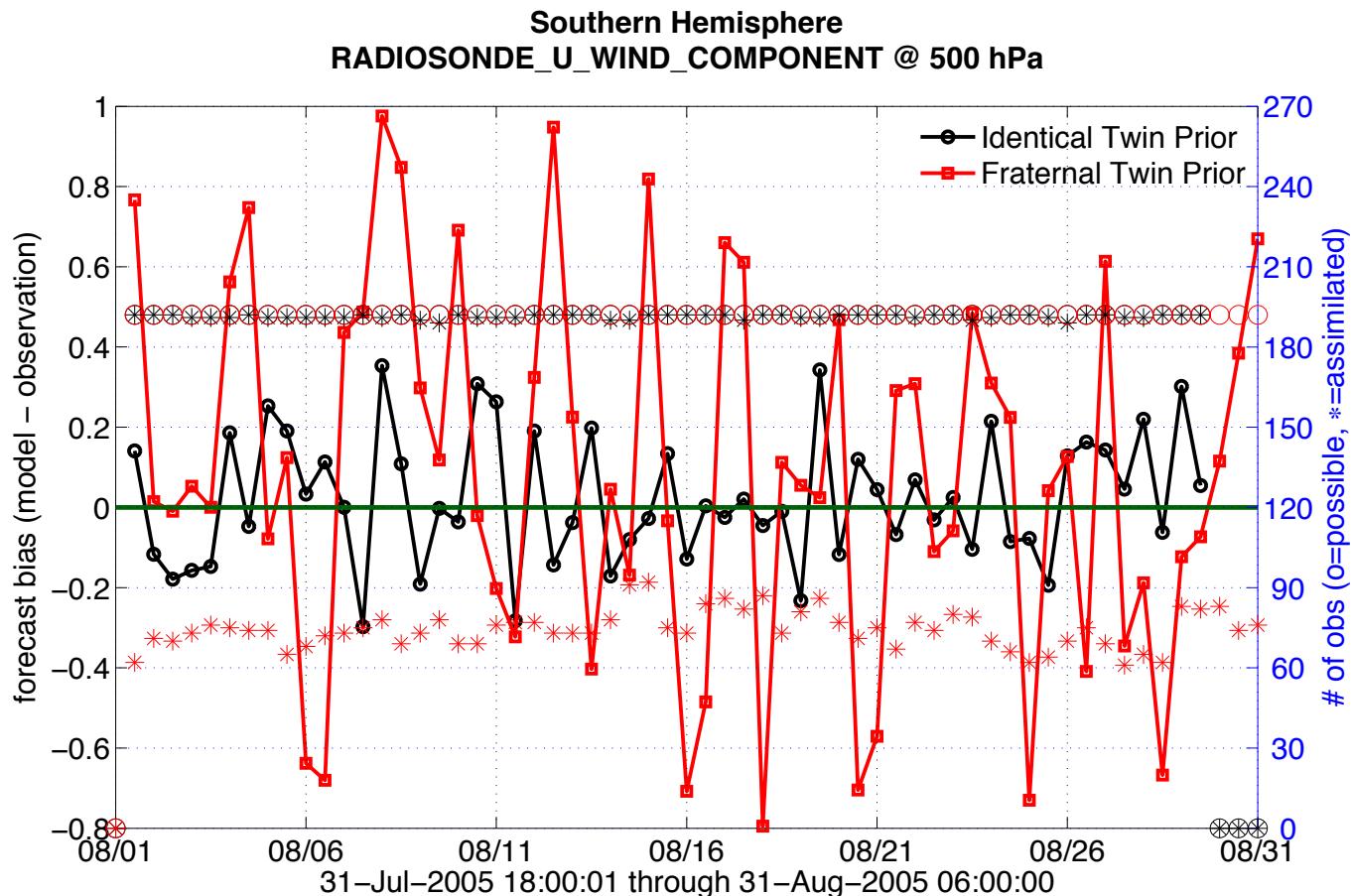
# Observation-space diagnostics: comparing experiments

`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:

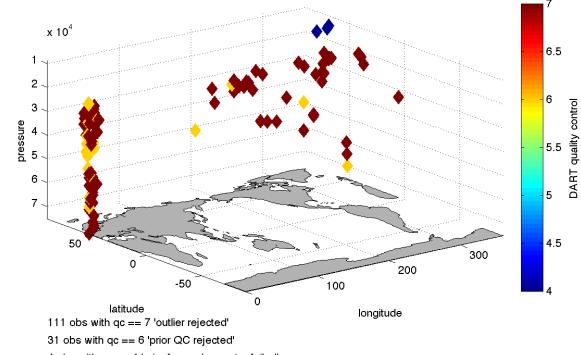
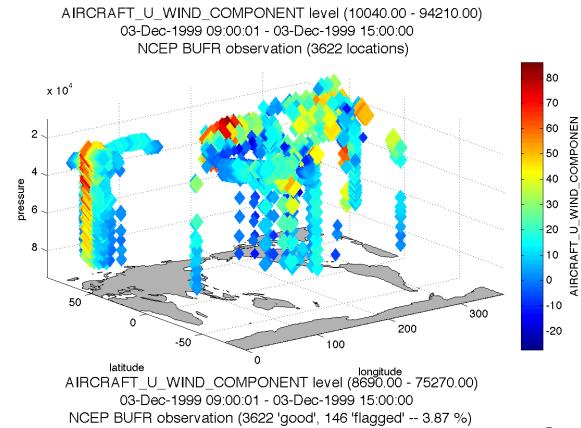
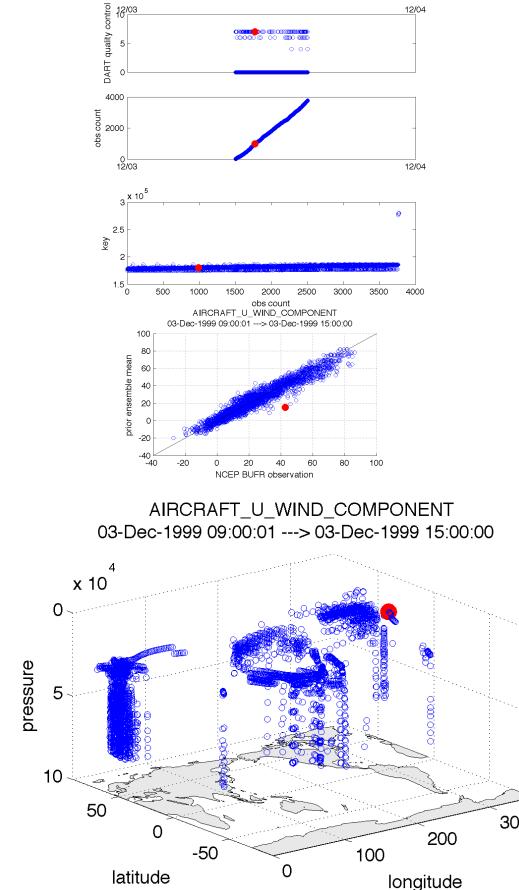
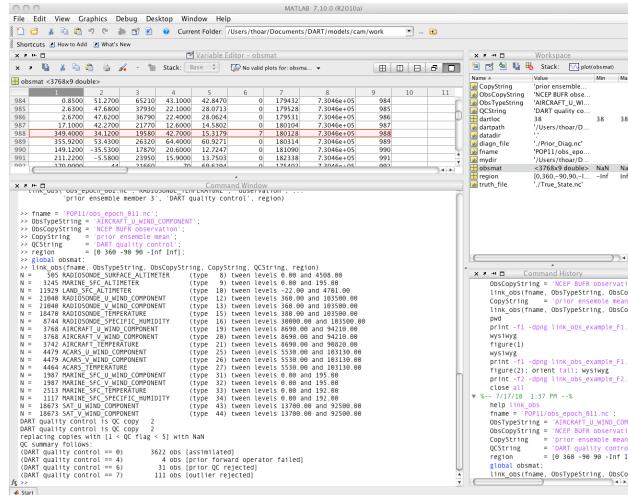
‘Identical’ means the model that was used to generate the observations is also used for the assimilation.  
‘Fraternal’ means the observations came from a different model.

# 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](http://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.
/
```

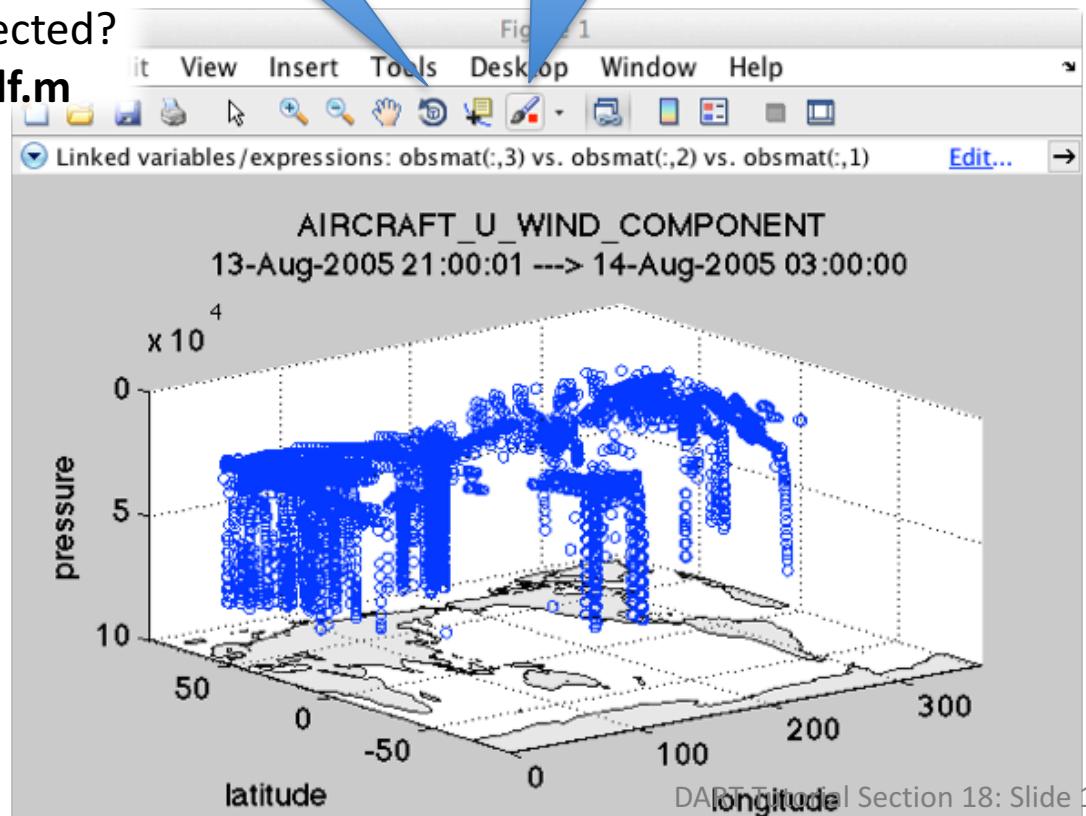
# Matlab Hands-On: link\_obs

## 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

1. Filtering For a One Variable System
2. The DART Directory Tree
3. DART Runtime Control and Documentation
4. How should observations of a state variable impact an unobserved state variable?  
Multivariate assimilation.
5. Comprehensive Filtering Theory: Non-Identity Observations and the Joint Phase Space
6. Other Updates for An Observed Variable
7. Some Additional Low-Order Models
8. Dealing with Sampling Error
9. More on Dealing with Error; Inflation
10. Regression and Nonlinear Effects
11. Creating DART Executables
12. Adaptive Inflation
13. Hierarchical Group Filters and Localization
14. Quality Control
15. DART Experiments: Control and Design
16. Diagnostic Output
17. Creating Observation Sequences
18. Lost in Phase Space: The Challenge of Not Knowing the Truth
19. **DART-Compliant Models and Making Models Compliant**
20. **Model Parameter Estimation**
21. **Observation Types and Observing System Design**
22. **Parallel Algorithm Implementation**
23. Location module design (not available)
24. Fixed lag smoother (not available)
25. **A simple 1D advection model: Tracer Data Assimilation**