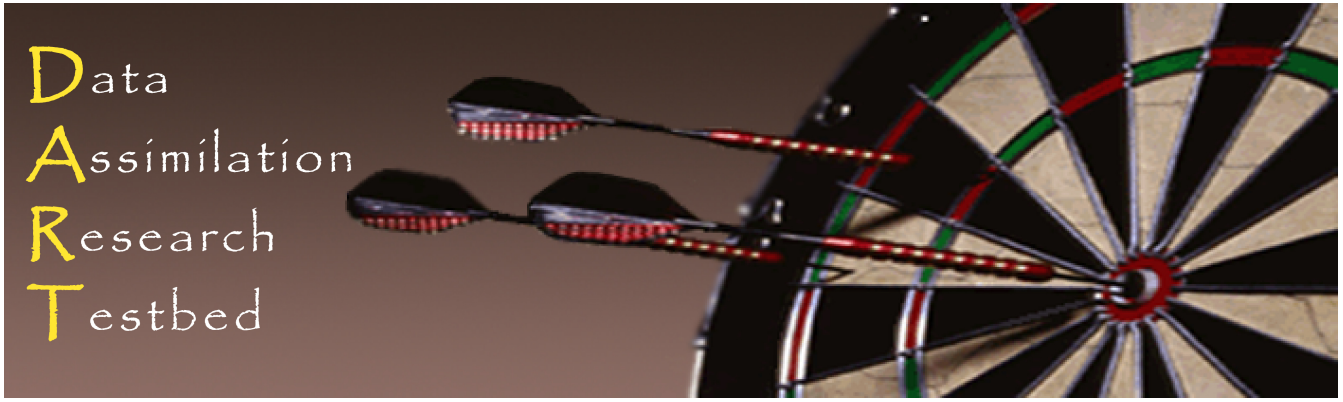
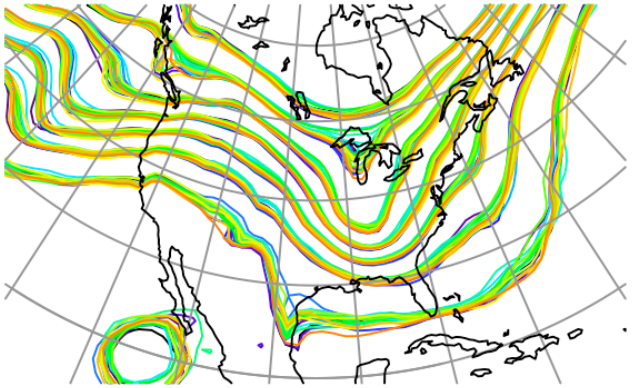


DART Tutorial Section 16: Diagnostic Output



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

DART Diagnostic Output Categories:

- State-Space:
  Values of model's state vector and inflation.
  Output using netCDF format.

- Observation-Space:
  Values of the observations.
  DART-specific *obs_sequence* format for now.

- Regression confidence factor:
  Values for state vector / observation pairs.
  Output as flat ASCII (soon to be netCDF).

- Program diagnostic output:
  Identification for source code version and namelist values.
  Error, warning, message output from modules.

State-Space Diagnostic Files:

Available in netCDF (a common data format)
http://www.unidata.ucar.edu/software/netcdf

DART outputs up to four state space diagnostic files.

These files are selected by listing their names for the *stages_to_write* entry in the `&filter_nml`.

The *stages_to_write* namelist entry and resulting netCDF file names are:

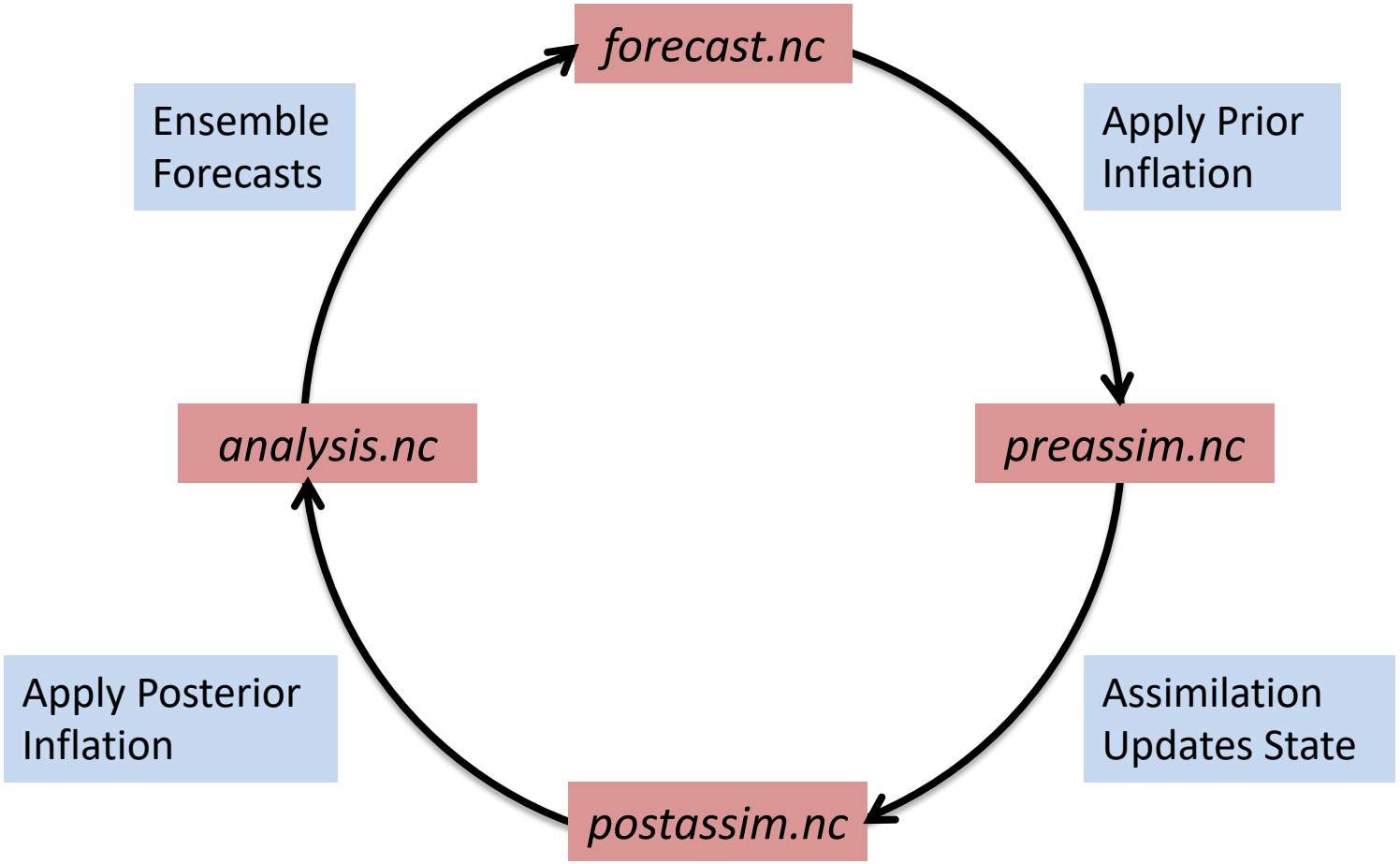
'forecast'	*forecast.nc*
'preassim'	*preassim.nc*
'postassim'	*postassim.nc*
'analysis'	*analysis.nc*

In addition, *stages_to_write* can also include:

'input'	*input.nc*	Copy of initial conditions, same format as *output.nc*
'output'	*output.nc*	Output file for restart of subsequent filter steps.

State-Space Diagnostic Files:

Location of each diagnostic file in the filter cycle.



State-Space Diagnostic Files:

Contents of state space diagnostic files are controlled by `&filter_nml`:

```
&filter_nml
   …
   output_mean                = .true.    (include ensemble mean)
   output_sd                  = .true.    (include ensemble spread)
   num_output_state_members   = ##        (include this many individual ensemble members)
   output_interval            = N         (only output every N^th assimilation time)
   …
```

Note: output_interval for *true_state.nc* is in the `&perfect_model_obs_nml` namelist.

In *input.nml* for lorenz_96, make sure all diagnostic files are listed as *stages_to_write*.
Run the filter to generate all files.
Try some Matlab diagnostics.
You can change the diagnostic file for a single plot by typing the file at the prompt, or…
You can change the file for all subsequent plots by setting Matlab variable *diagn_file*.
For instance, *diagn_file = 'postassim.nc';*

State-Space Diagnostic Files:

Trying out different diagnostic files:

In *input.nml* for lorenz_96, the default has been to output the *preassim.nc* and *analysis.nc* diagnostic files.
You could also add '*postassim*' and '*forecast*' to the list in *stages_to_write*.

So far, have only looked at diagnostics for *preassim.nc*

Two ways to change the diagnostic file in Matlab tools like *plot_total_err*:
1). Change for a single plot by entering diagnostic filename at Matlab prompt:

```
>> plot_total_err
Input name of ensemble trajectory file:
<cr> for preassim.nc
analysis.nc
Comparing true_state.nc and
          analysis.nc
```

2).You can change the file for all subsequent plots by setting Matlab variable *diagn_file*.

```
>> diagn_file = 'analysis.nc';
```

Try looking at diagnostics for *analysis.nc*, *forecast.nc,* and *postassim.nc*
Some of these will be the same unless you have both prior and posterior inflation on.

DART State-Space Diagnostic functions

See the DART website section titled: “Configuring Matlab to work with DART”

https://dart.ucar.edu/pages/Getting_Started.html#matlab

ALL the DART Matlab state-space diagnostic functions are in *diagnostics/matlab*

This **must** be in your *matlabpath*.

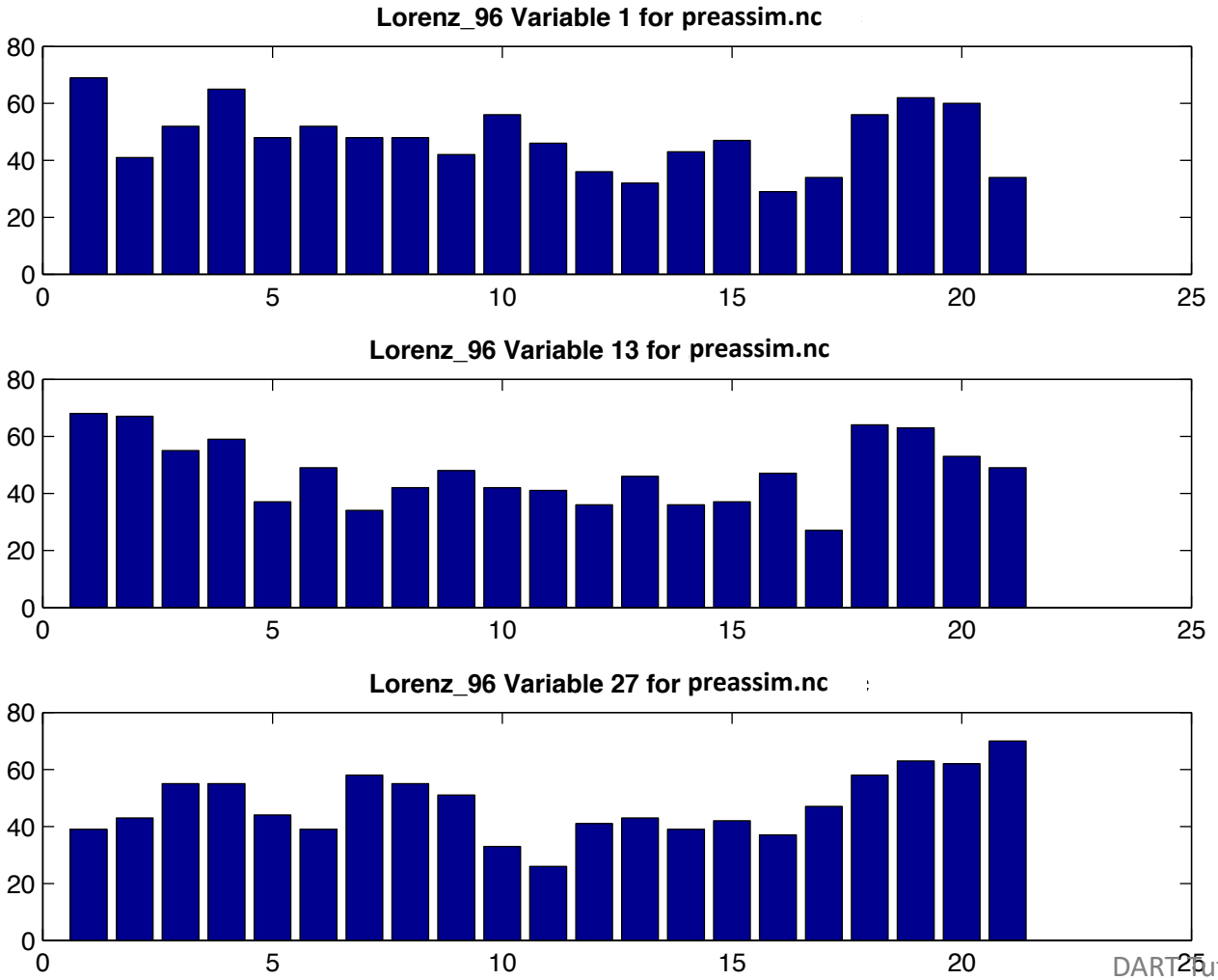
Only focus on the files that start with *plot_*

- plot_bins.m
- plot_correl.m
- plot_ens_err_spread.m
- plot_ens_mean_time_series.m
- plot_ens_time_series.m
- plot_phase_space.m
- plot_reg_factor.m
- plot_sawtooth.m
- plot_smoother_err.m
- plot_total_err.m
- plot_var_var_correl.m
- …

Some, but not all, described here.
All functions have a ‘help’ section available in the standard Matlab way.

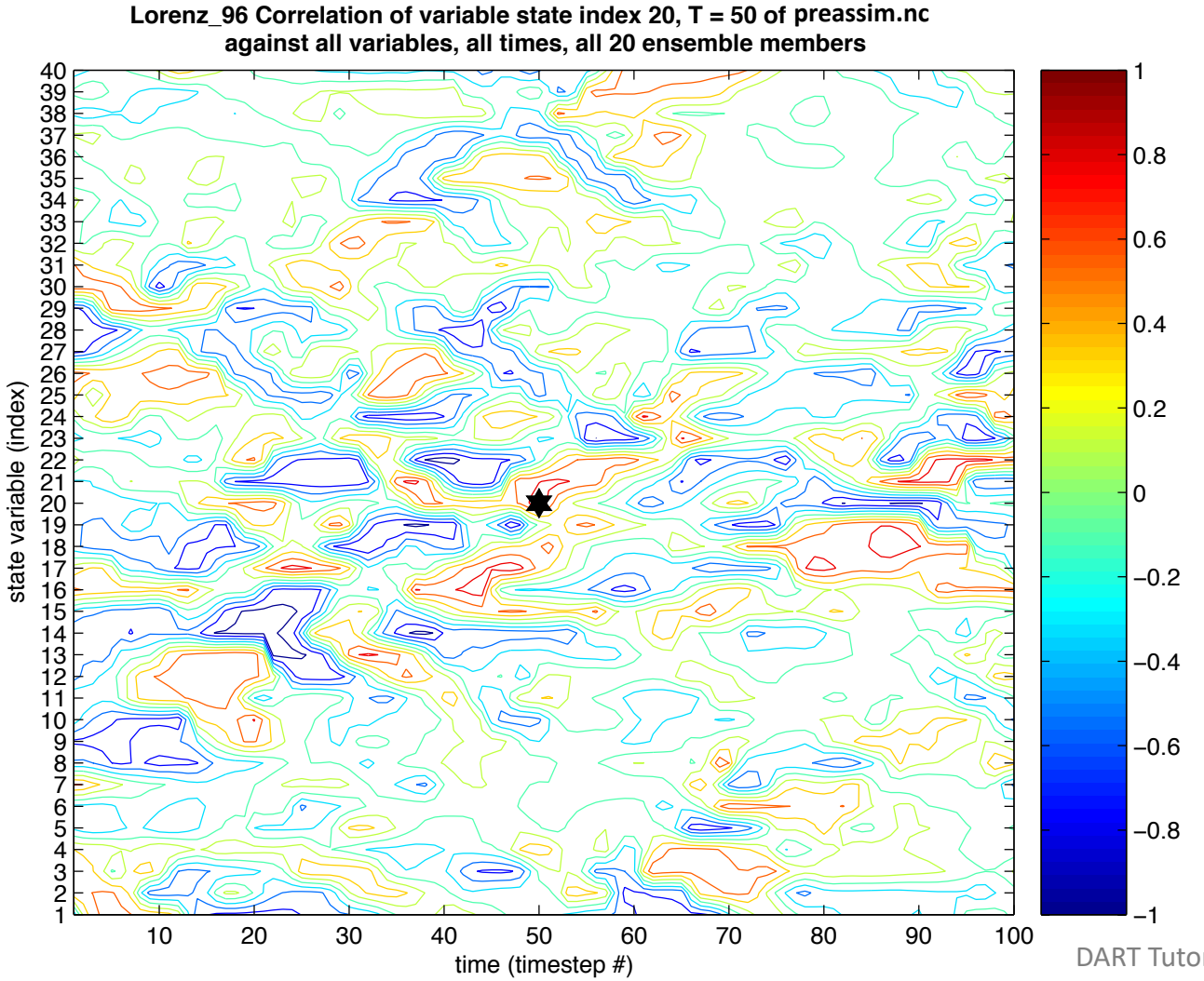
Viewing the State-Space netCDF files:

1. Standard DART matlab diagnostics:
   a. plot_bins: rank histograms,



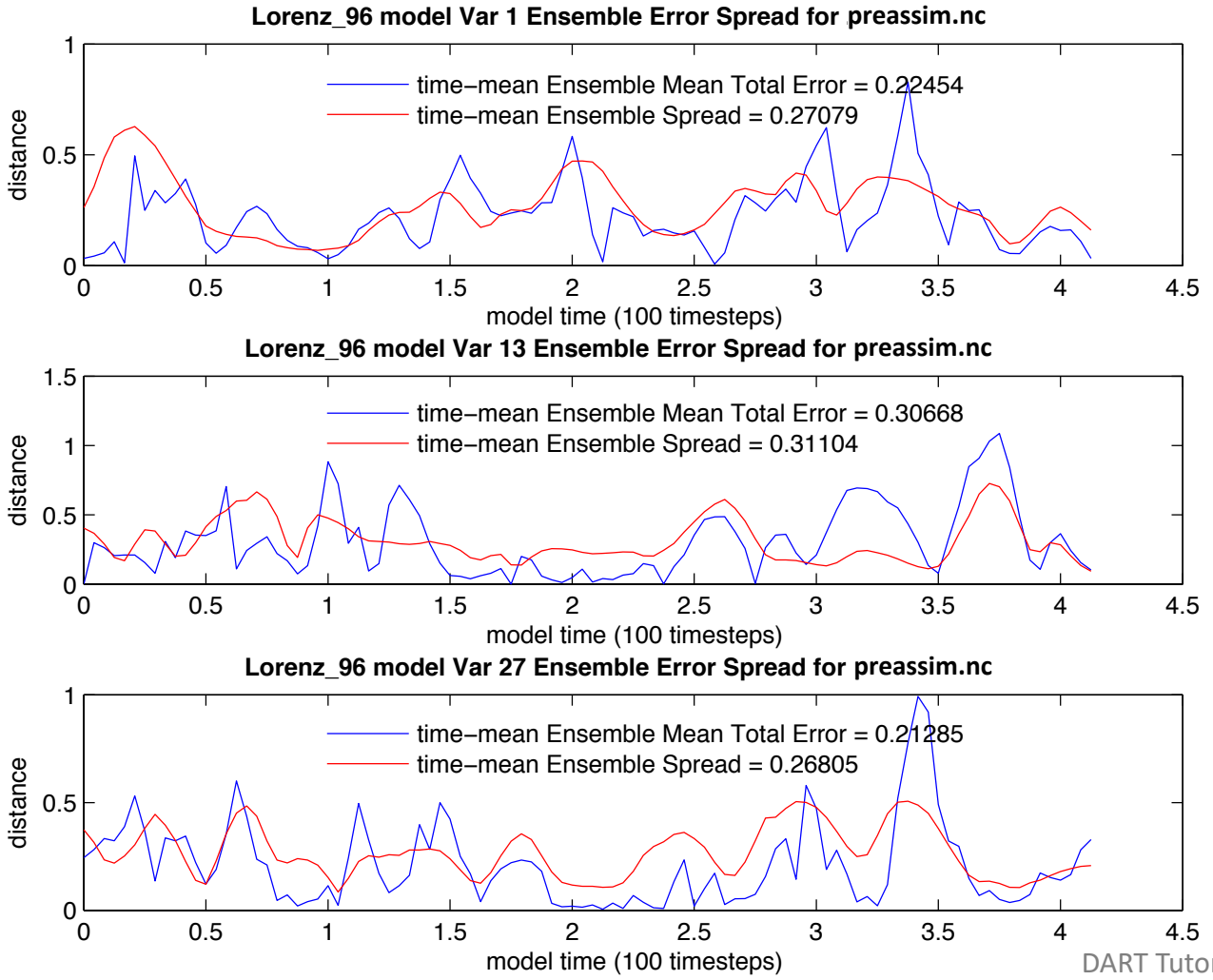
Viewing the State-Space netCDF files:

1. Standard DART matlab diagnostics:
   b. plot_correl: correlation x(t) with all other state vars at all times,



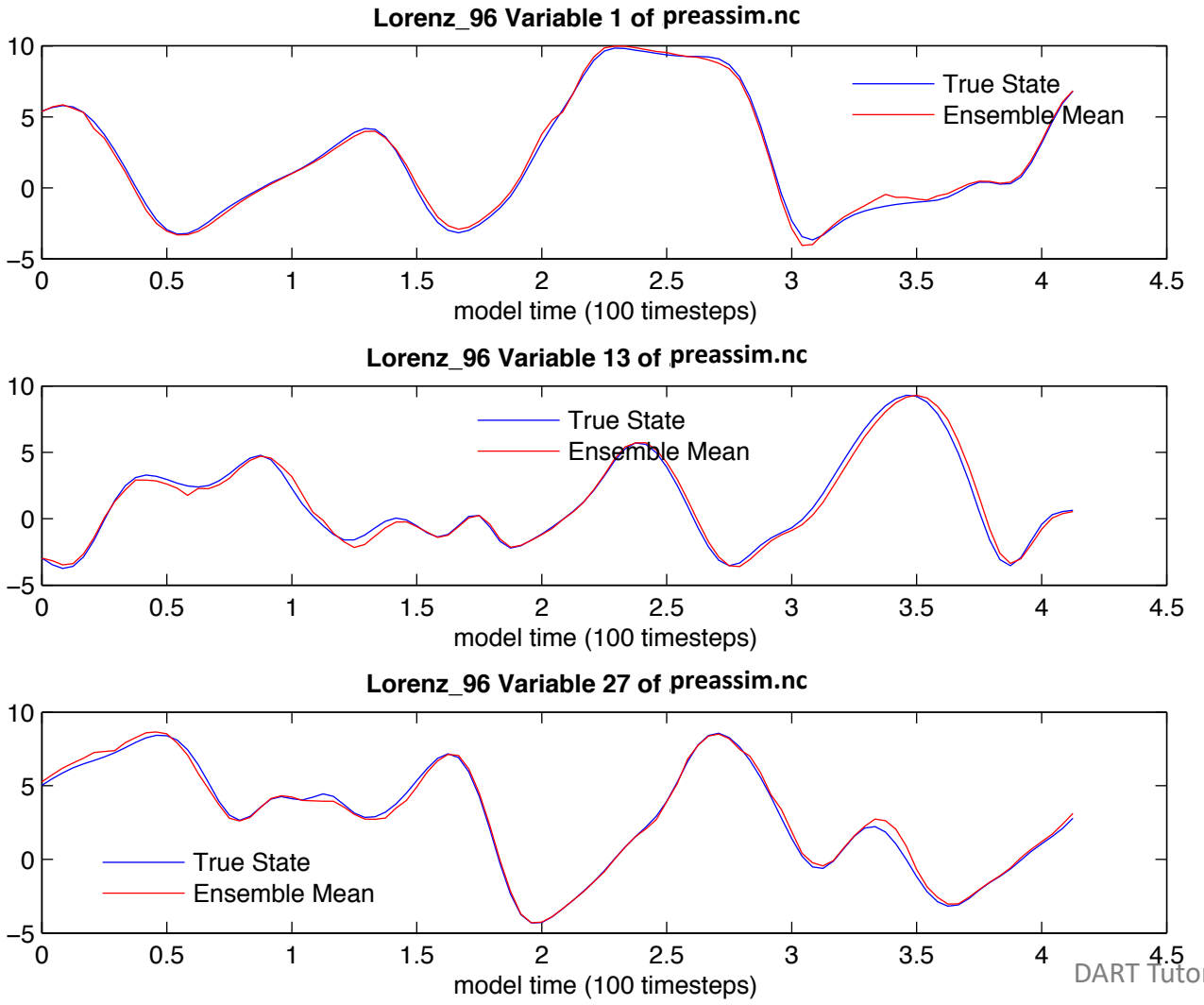
Viewing the State-Space netCDF files:

1. Standard DART matlab diagnostics:
   c. plot_ens_err_spread: rms error and spread,



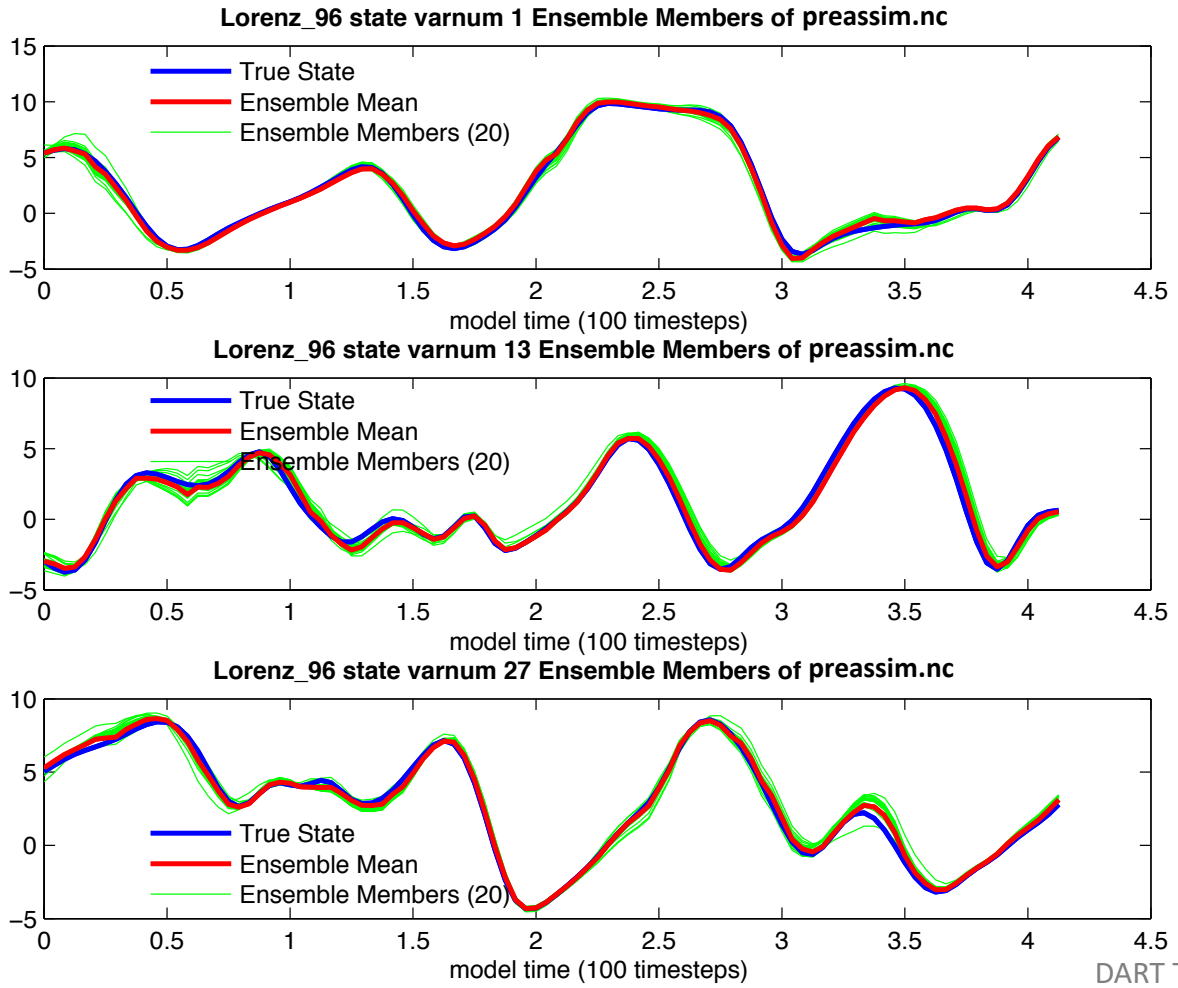
Viewing the State-Space netCDF files:

1. Standard DART matlab diagnostics:
   d. plot_ens_mean_time_series: just like the name says,



Viewing the State-Space netCDF files:

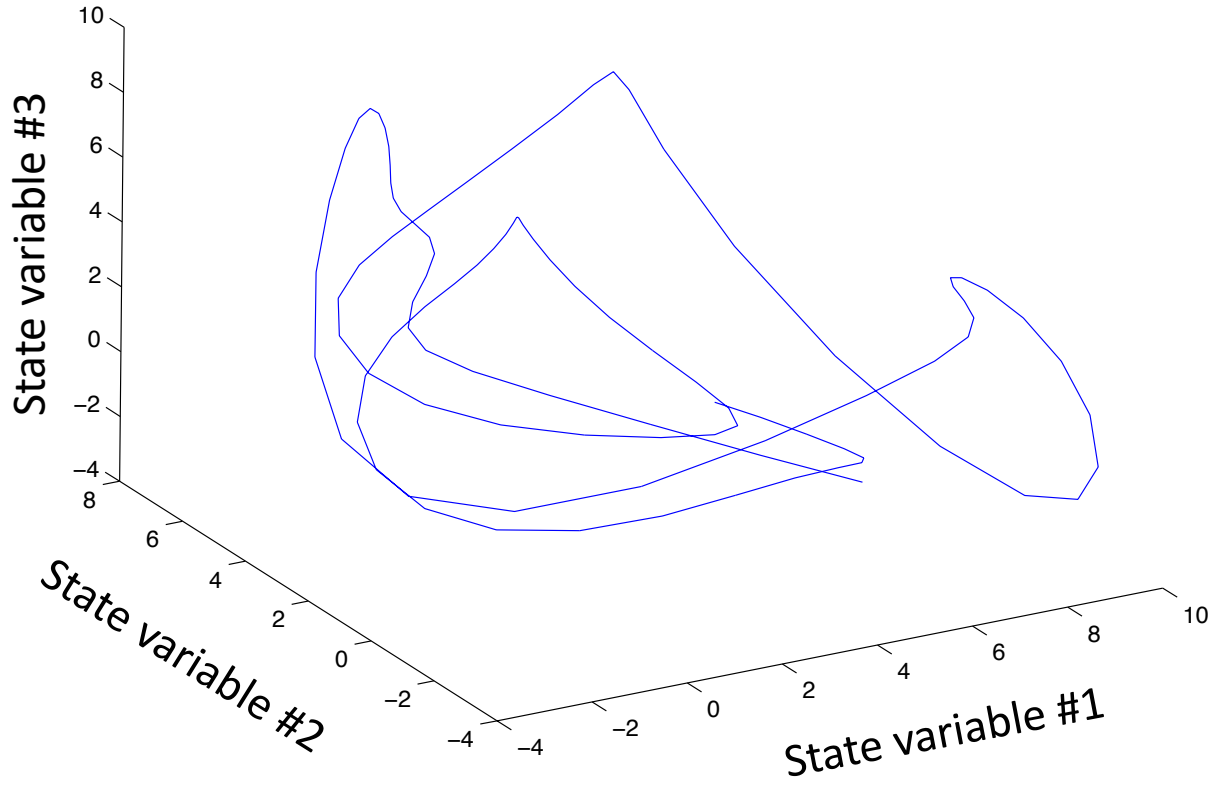
1. Standard DART matlab diagnostics:
   e. plot_ens_time_series: plots the ensemble (as available from *num_output_state_members*) ,



Viewing the State-Space netCDF files:

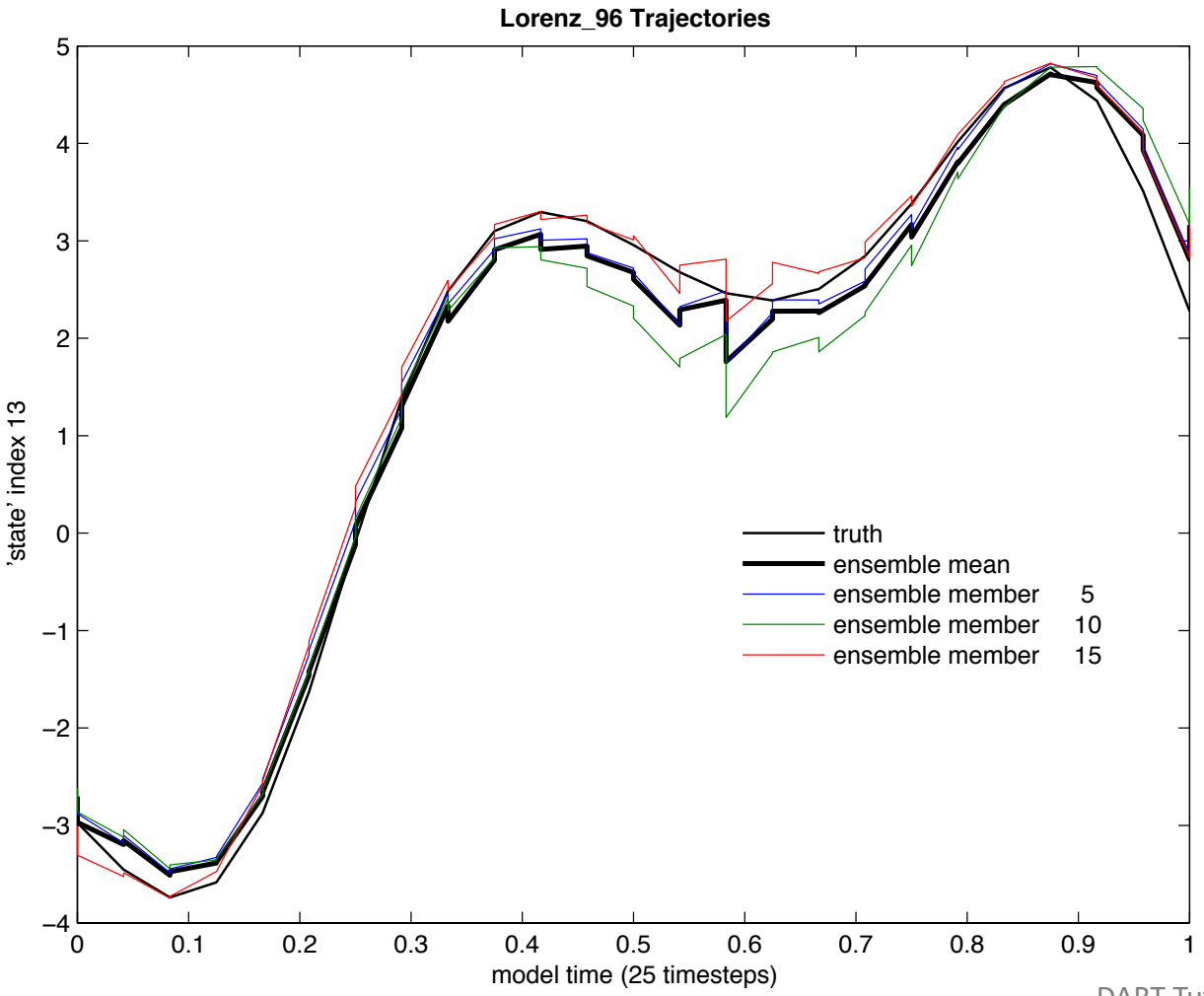
1. Standard DART matlab diagnostics:
   f. plot_phase_space: 3D phase space time evolution.

true_state.nc Lorenz_96 true_state



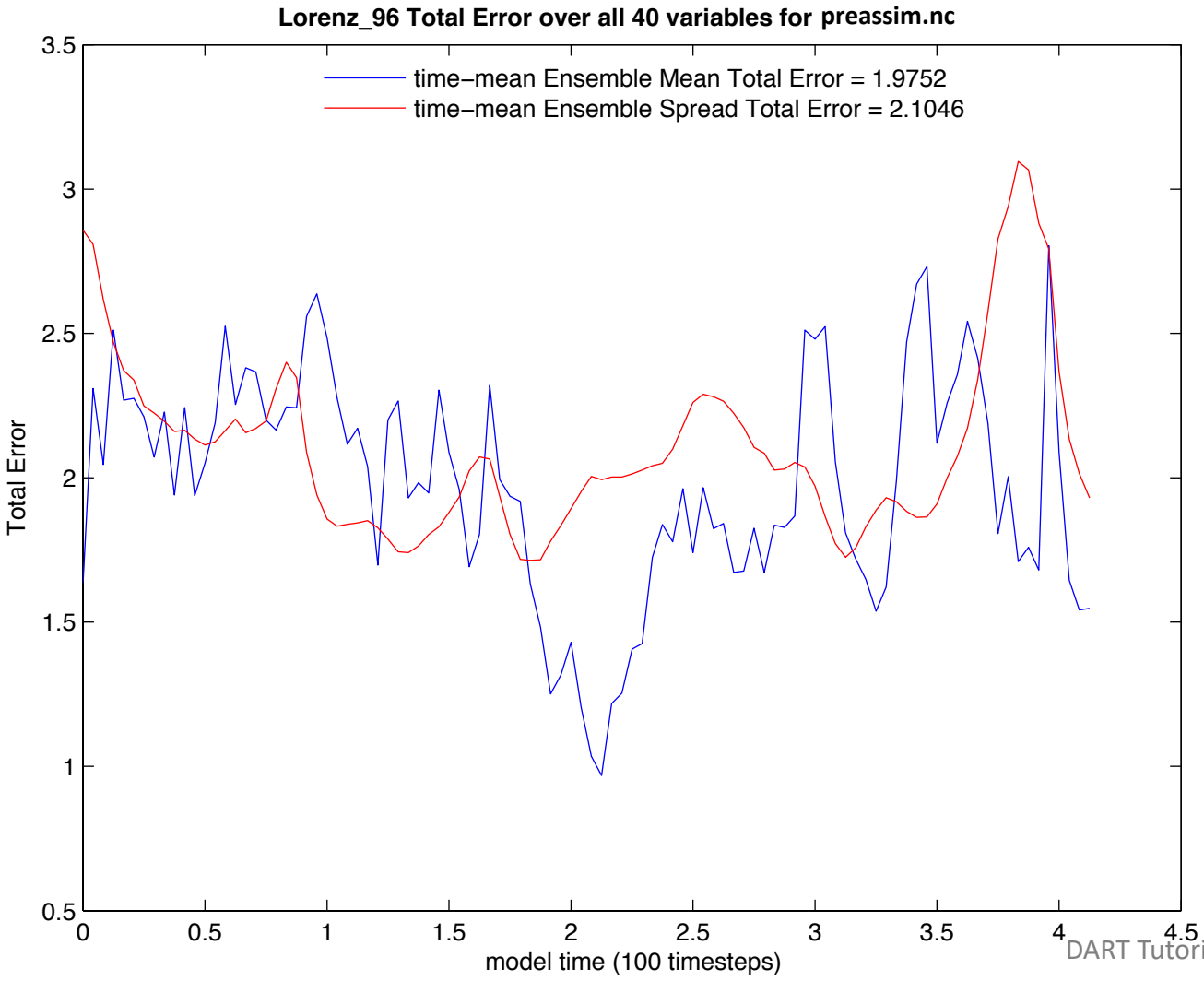
Viewing the State-Space netCDF files:

1. Standard DART matlab diagnostics:
   g. plot_sawtooth: truth, prior and posterior time series.



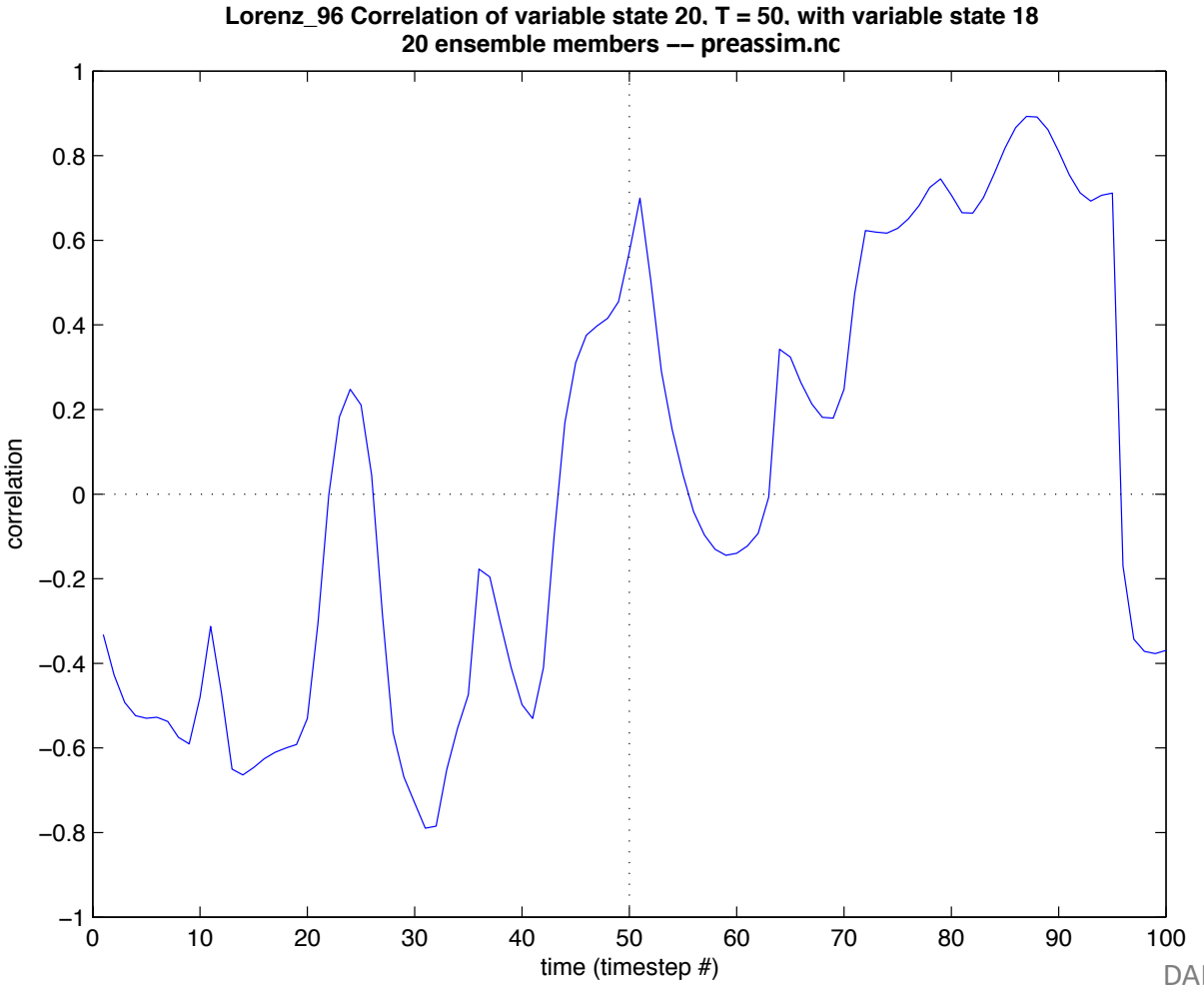
Viewing the State-Space netCDF files:

1. Standard DART matlab diagnostics:
   h. plot_total_err: total error for different fields,



Viewing the State-Space netCDF files:

1. Standard DART matlab diagnostics:
   i. plot_var_var_correl: x(t) correlation to single variable, all times.

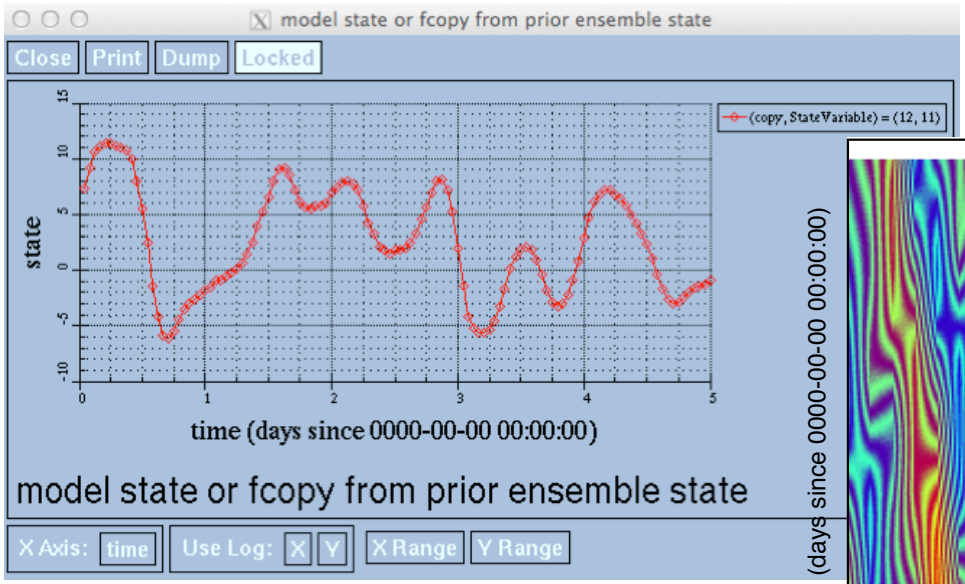


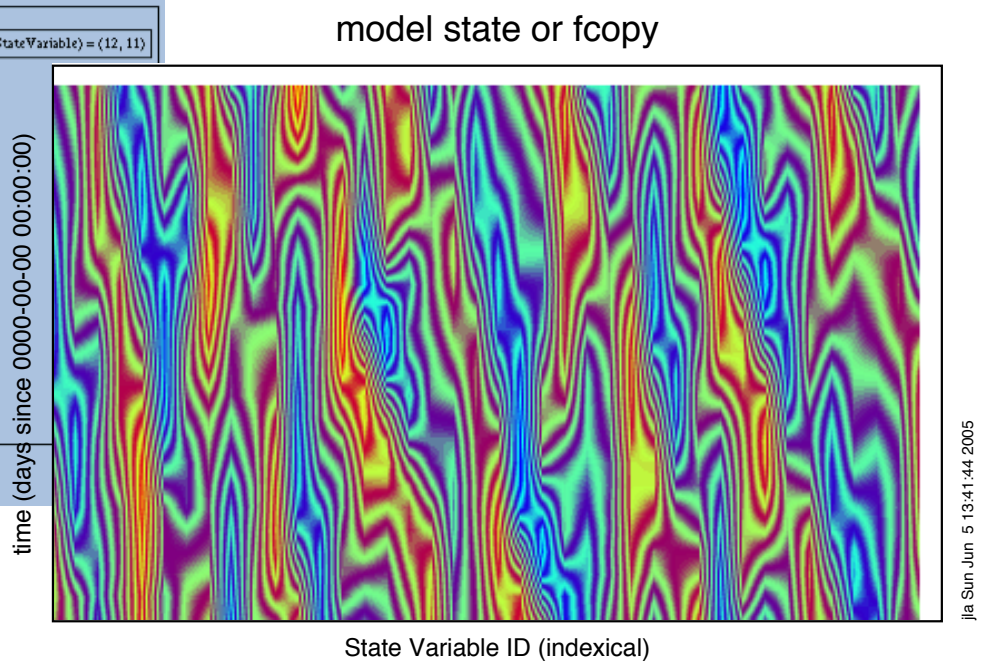
Viewing the State-Space netCDF files:

2. ncview: a quick and surprisingly useful netCDF viewer.

   http://meteora.ucsd.edu/~pierce/ncview_home_page.html

   Displays spatial slices, animations, time series …



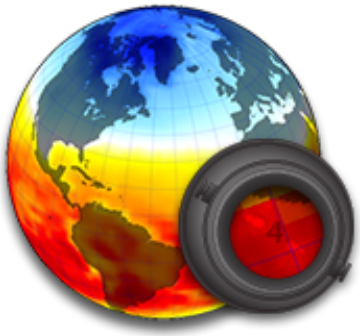


prior ensemble state
Range of model state or fcopy: -6.18328 to 11.6954 (null)
Range of State Variable ID: 1 to 40 indexical
Range of time: 0 to 1 days since 0000-00-00 00:00:00
Current ensemble member or copy: 1 nondimensional
Frame 1 in File preassim.nc

Viewing the State-Space netCDF files:

3. Many other graphical/analysis programs can read netCDF.
   (Note that we use *udunits* metadata convention.)

4. netCDF Operator (NCO) tools allow operations on netCDF files:
   (http://nco.sourceforge.net)
   Selecting hyperslices of fields,
   Differencing netCDF file,
   Averaging, etc.



NASA GISS: Panoply

netCDF Operators (NCO) Software Stack

Inflation Diagnostics in State-Space netCDF files:

The subroutine-callable models ***usually*** have a single netCDF file (*filter_output.nc*) that contains the the entire ensemble as well as the inflation values. The variables with the inflation have names like:

- *state_priorinf_mean,*
- *state_priorinf_sd,*
- *state_postinf_mean*, and
- *state_postinf_sd*

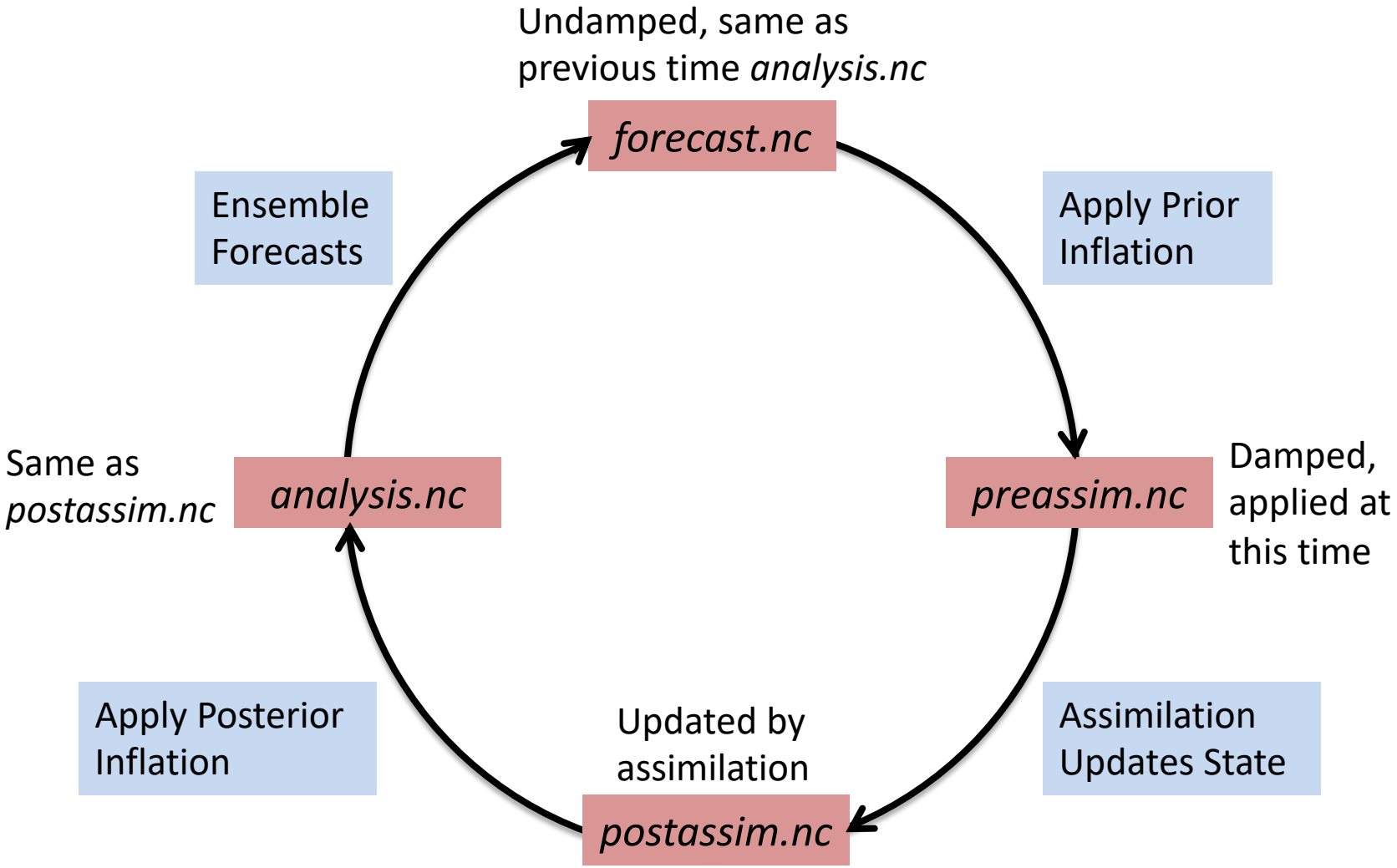
The state-space inflation values for other models are stored in netCDF files:

- *input_priorinf_mean.nc*
- *input_priorinf_sd.nc*
- *input_postinf_mean.nc*
- *input_postinf_sd.nc*

with variable names that are identical to the variables in the DART state. These files only have a single timestep in them and must be managed during a cycling experiment that uses adaptive inflation.

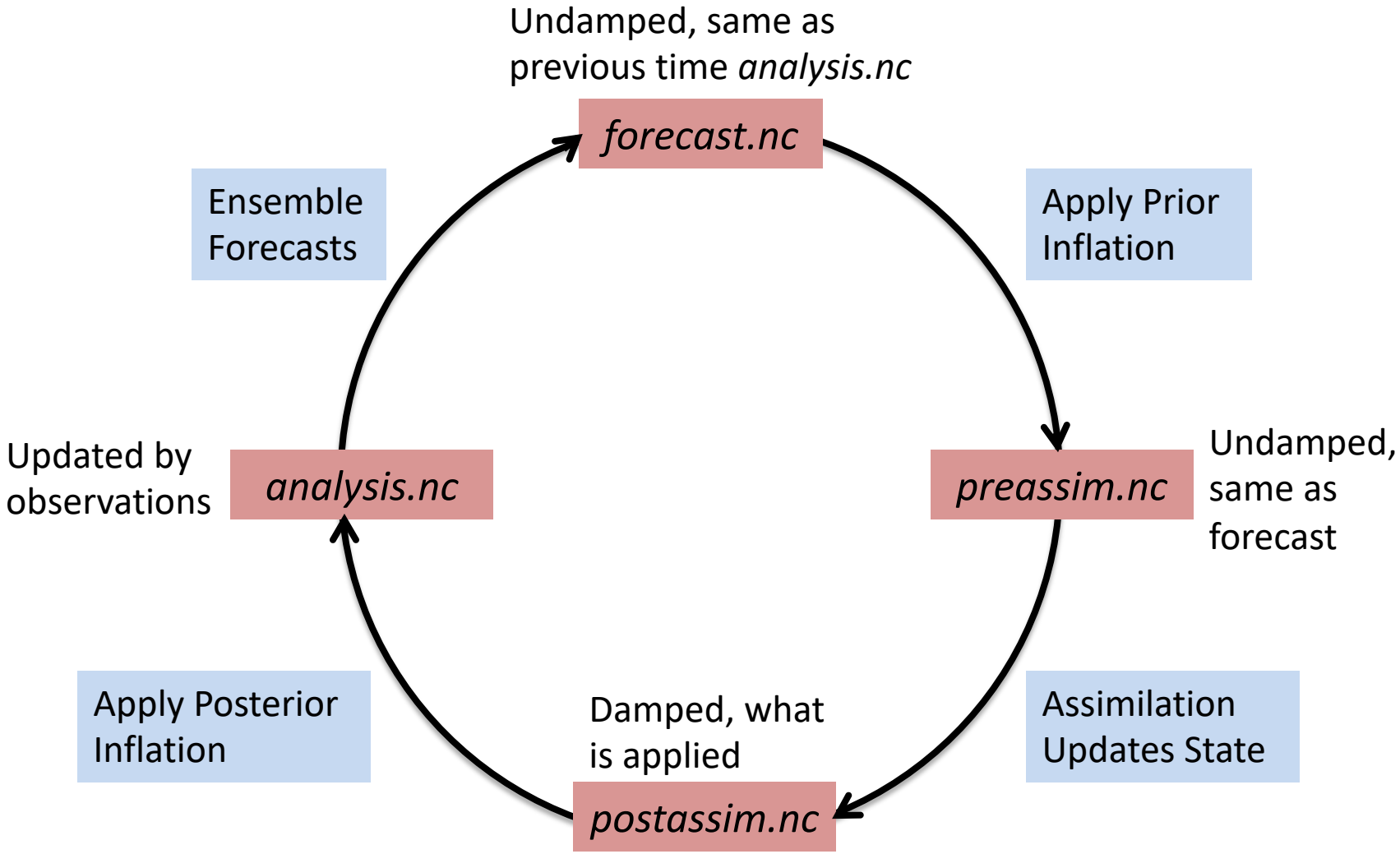
Prior Inflation State-Space Diagnostic Files:

Contents of prior inflation fields for each diagnostic file in the filter cycle.



Posterior Inflation State-Space Diagnostic Files:

Contents of posterior inflation fields for each diagnostic file in the filter cycle.



Observation-space files:

Quick recap of 'standard' observation sequence file names
(all names are actually specified in namelists):

- *obs_seq.in* input to ***perfect_model_obs***
- *obs_seq.out* **output** from ***perfect_model_obs***, also **input** to ***filter***
- *obs_seq.final* output from ***filter***

Observation sequence files output by ***filter*** have prior, posterior, observed value (and truth for OSSEs). For an overview, check out the DART section:

https://dart.ucar.edu/pages/Observations.html

Contents of *obs_seq.final* controlled by `&filter_nml`:

```
&filter_nml
   obs_sequence_in_name    = 'obs_seq.out'
   obs_sequence_out_name   = 'obs_seq.final'
   num_output_obs_members  = ##
   …
```

Name of input observation sequence file.
Name of output observation sequence file.
Output this many individual ensemble estimates.

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.

See tutorial section 18 for full coverage of viewing, diagnosing obs sequences.

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

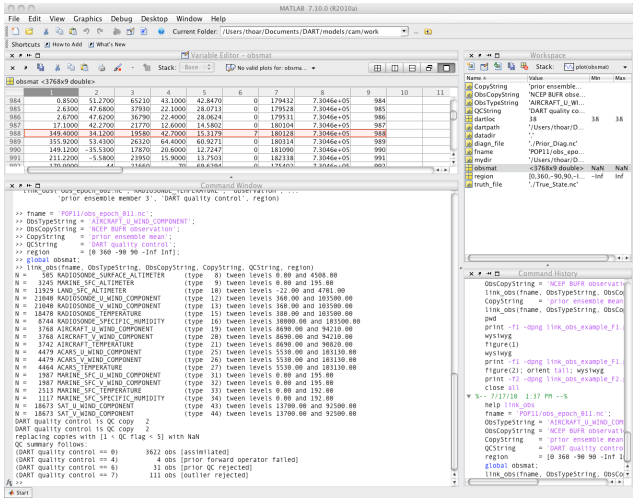
- plot_rank_histogram.m
- plot_evolution.m
- plot_rmse_xxx_evolution.m
- two_experiments_evolution.m (works with more than two, actually)
- plot_profile.m
- plot_bias_xxx_profile.m
- plot_rmse_xxx_profile.m
- two_experiments_profile.m (works with more than two, actually)

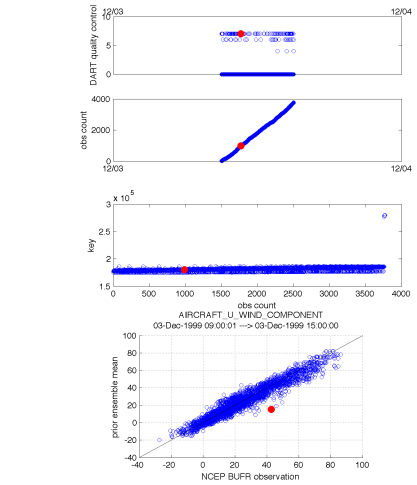
Observation-space diagnostics:

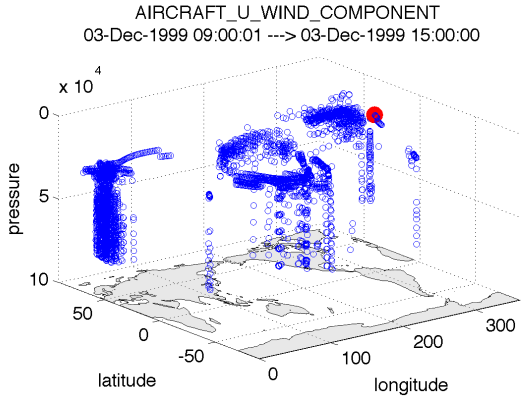
SOME of the information in the observation sequence files can be converted to netCDF and easily plotted. A program named ***obs_seq_to_netcdf*** must be run to produce the netCDF.

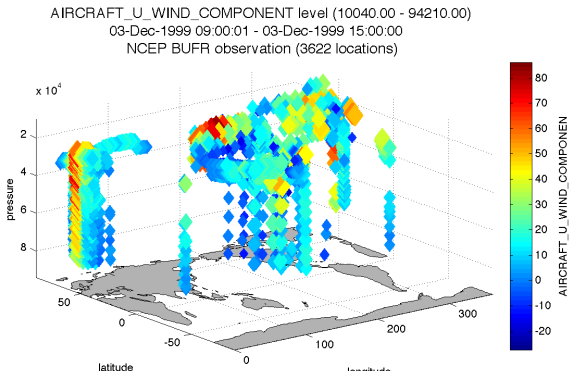
Here are a few of the Matlab functions available in *diagnostics/matlab*.

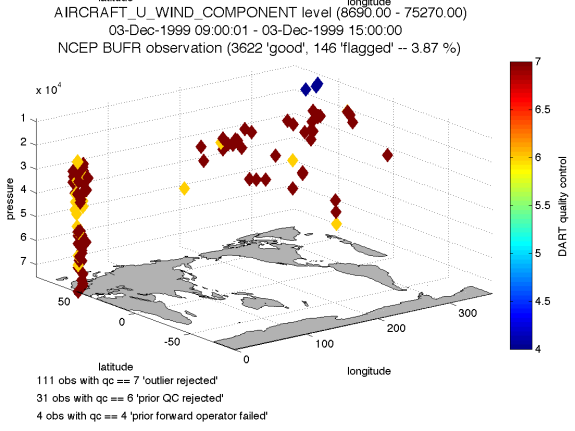
- link_obs.m
- plot_obs_netcdf.m
- plot_obs_netcdf_diffs.m











Regression confidence factor output:

Reminder: reg_factor α introduced in Tutorial Section 13 – when running the group filter (with more than 1 group!).

Controlled by `&reg_factor_nml`:

```
&reg_factor_nml
   save_reg_diagnostics = .true.
   reg_diagnostics_file = 'reg_diagnostics'
   …
```

Should file be output?

Name of output file.

File size could be (model size) X (number of obs.) X (number of assim times).

Very big, even for small models (only first 4 obs output default).

Normally, modify code in *reg_factor_mod.f90* to control:

Output is at end of select_regression = 1 code block.

Format is ASCII:

time in days, time in seconds, obs_index, state_index, α

Plot with Matlab *plot_reg_factor*.

Program Diagnostic Output:

File *dart_log.out*

All DART executables ***append*** to this file!

Contains:

- registration information
- Program start time,
- version of code for each module used
- Namelist values for each module*
- Names of output files,
- Diagnostic output for modules (through error_handler()),
- Warnings and fatal errors from DART code.

Fair Warning: This file is ***not*** cleared by DART. Can get very longgggggg …
You should feel free to delete/rename it before starting the next experiment.

*may be in a separate file, depending on `&utilities_nml` setting

DART Tutorial Index to Sections