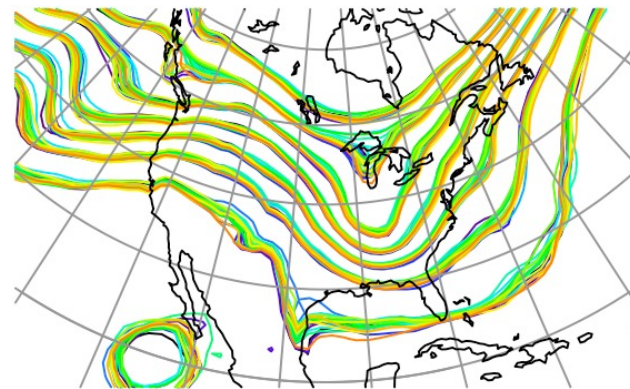


Data
Assimilation
Research
Testbed



DART Tutorial Section 7: Some Additional Low-Order Models



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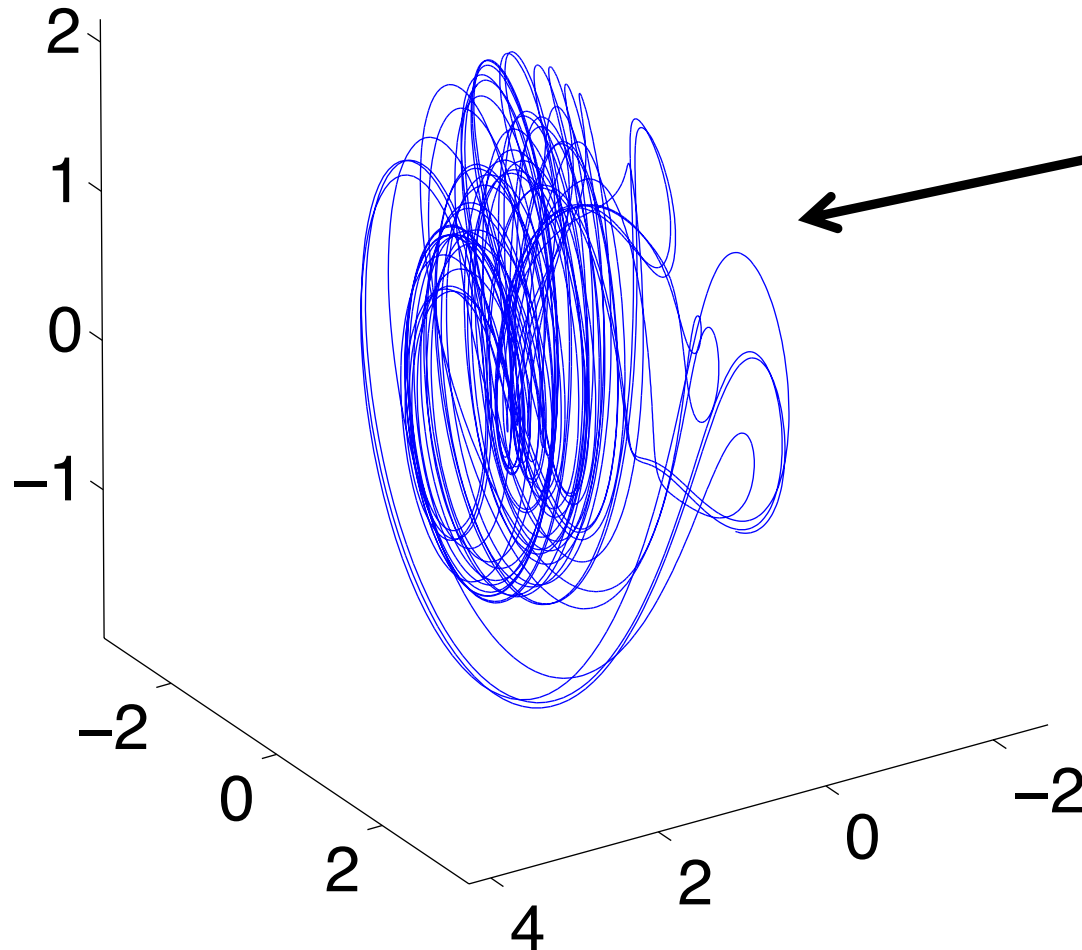
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Low Order Models in DART

Model	Size	Features
lorenz_63	3	Chaotic, nearly integral attractor, bifurcations
lorenz_84	3	More complex attractor, not as periodic
9var	9	Transient off-attractor dynamics
lorenz_96	40 (variable)	Higher dimensional system. Attractor dimension 13 with 40 variables and standard forcing.
forced_lorenz_96	80 (variable)	Allows assimilation of model parameter (see Section 20)
lorenz_96_2scale	396 (variable)	Two primary interacting spatial/temporal scales
lorenz_04	variable	Multiscale dynamics

Lorenz 84 Model

models/lorenz_84/work/



Attractor not sheet-like.

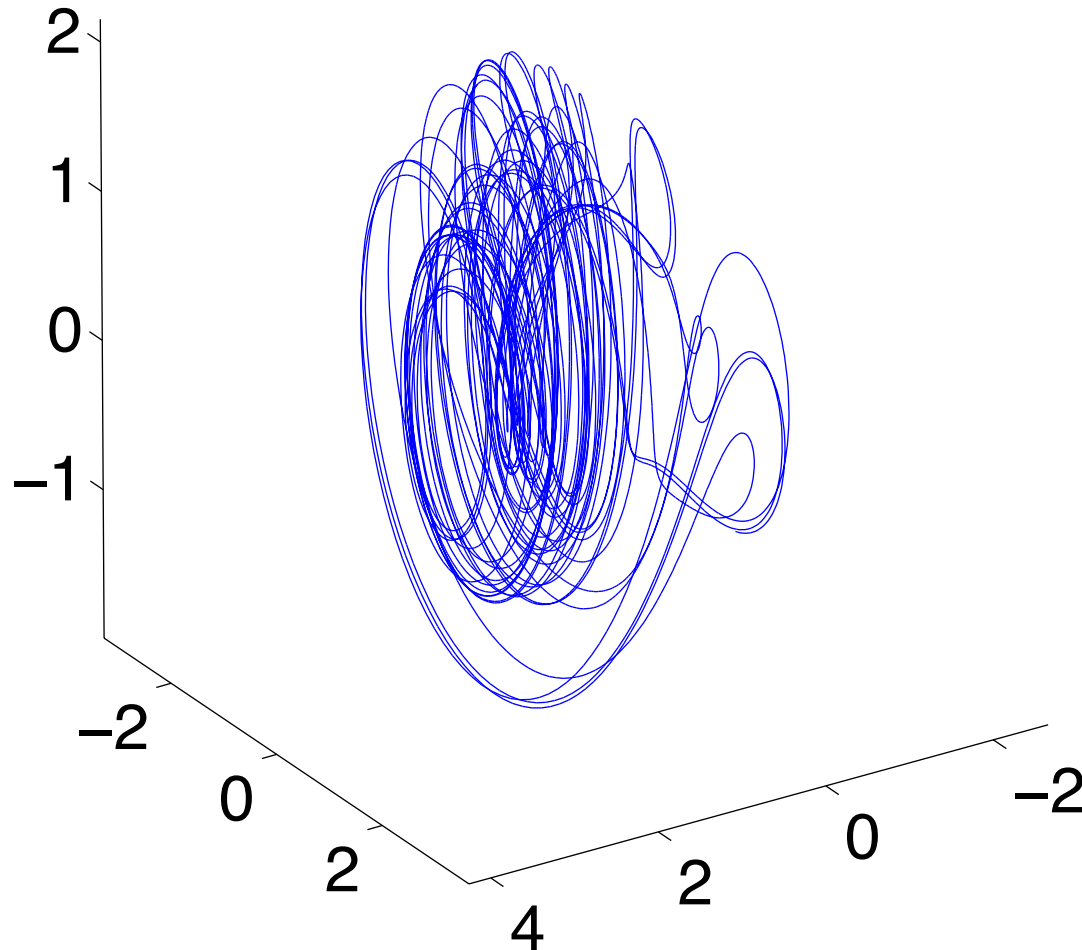
Rare significant deviations.

Trajectories along deviations don't 'mesh' back up with the rest of the attractor.

This behavior can be challenging for certain filter variants.

Lorenz 84 Model

models/lorenz_84/work/



3-variables:

$$\frac{dx_1}{dt} = -x_2^2 - x_3^2 - ax_1 + af$$

$$\frac{dx_2}{dt} = x_1x_2 - bx_1x_3 - x_2 + g$$

$$\frac{dx_3}{dt} = bx_1x_2 + x_1x_3 - x_3$$

Parameters

$$a = 0.25,$$

$$b = 4,$$

$$f = 8,$$

$$g = 1.25$$

can set from model_nml

Lorenz 84 Model

Exercise:

```
cd models/lorenz_84/work  
./workshop_setup.sh
```

Each state variable is observed every once every hour.
Observational error variance is 1.

Use Matlab to examine the output.

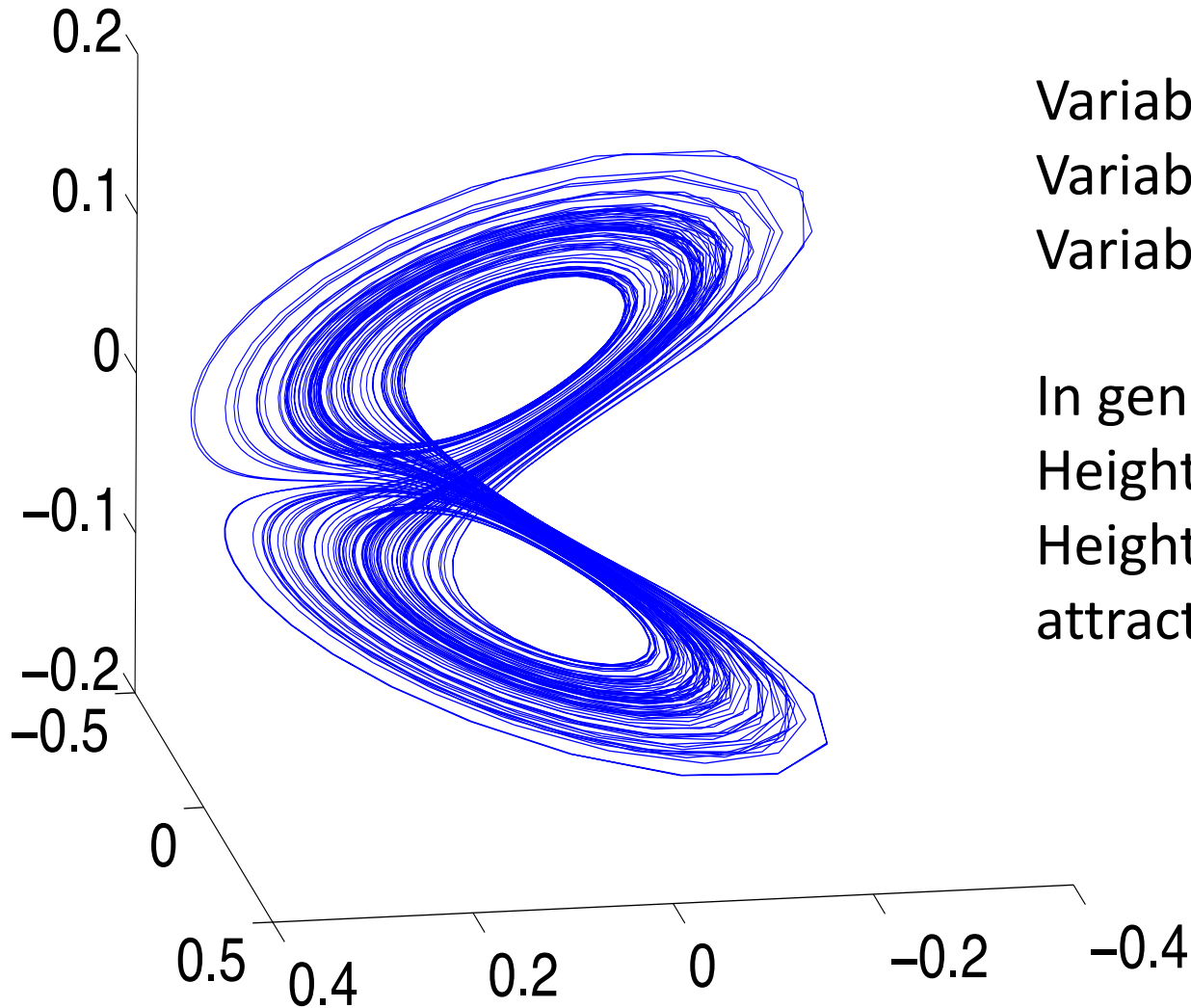
There's a new type of filter challenge represented here.

Can you identify it?

Can you propose ways to address it with techniques learned to date?

9 Variable Model

models/9var/work/



Three groups of variables

Variables 1-3: Divergence

Variables 4-6: Vorticity.

Variables 7-9: Height.

In general, divergence is small.

Height and pressure similar.

Height and pressure have attractor similar to Lorenz 63.

9 Variable Model

$$\dot{X}_i = U_j U_k + V_j V_k - v_0 a_i X_i + Y_i + a_i z_i$$

$$\dot{Y}_i = U_j Y_k + Y_j V_k - X_i - v_0 a_i Y_i$$

$$\dot{z}_i = U_j (z_k - h_k) + (z_j - h_j) V_k - g_0 X_i - K_0 a_i z_i + F_i$$

$$U_i = -b_j x_i + c y_i$$

$$V_i = -b_k x_i - c y_i$$

$$X_i = -a_i x_i$$

$$Y_i = -a_i y_i \quad i = 1, 2, 3 \quad j = \text{mod}(i, 3) + 1 \quad k = \text{mod}(i + 1, 3) + 1$$

X is divergence, Y is vorticity, Z is height

All parameters can be adjusted from model_mod.nml

9 Variable Model

When perturbed off the attractor, mimics 'gravity waves'.
Transient, high frequency oscillations dominate divergence variables.
Can also appear in height and pressure variables.

```
cd models/9var/work  
./workshop_setup.sh
```

Y1, Y2, Y3 (the 'vorticity' variables) are observed once every 6 hours
Observational error variance is 0.4.

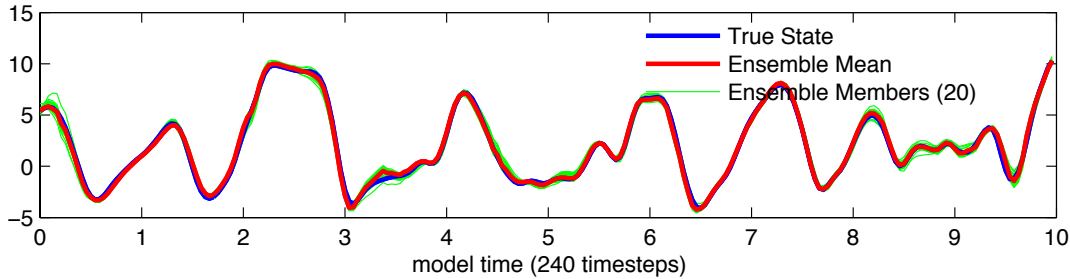
Use Matlab to examine the output.

How do different filter kinds interact with 'gravity' waves?

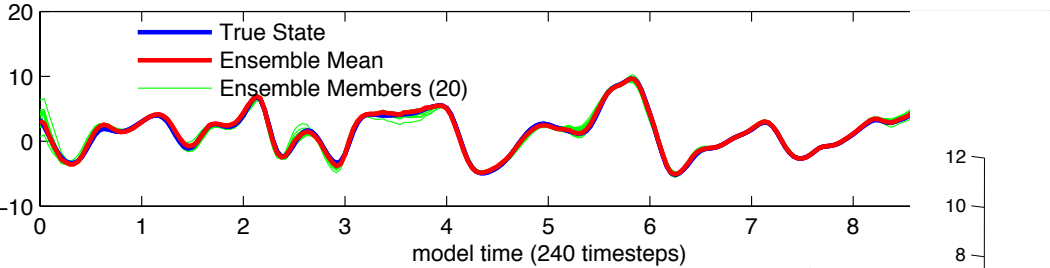
Lorenz 96 (40-variable) Model

models/lorenz_96/work/

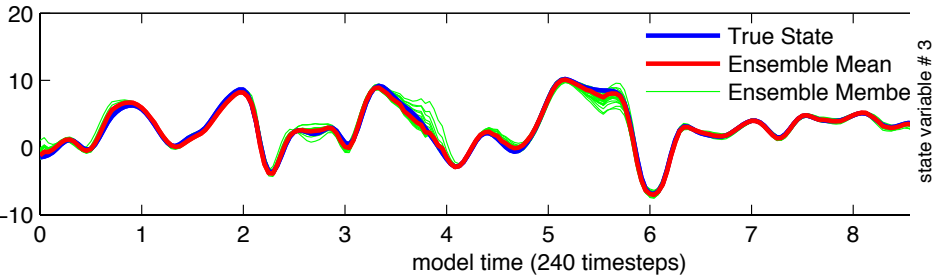
Lorenz_96 state varnum 1 Ensemble Members of preassim.nc



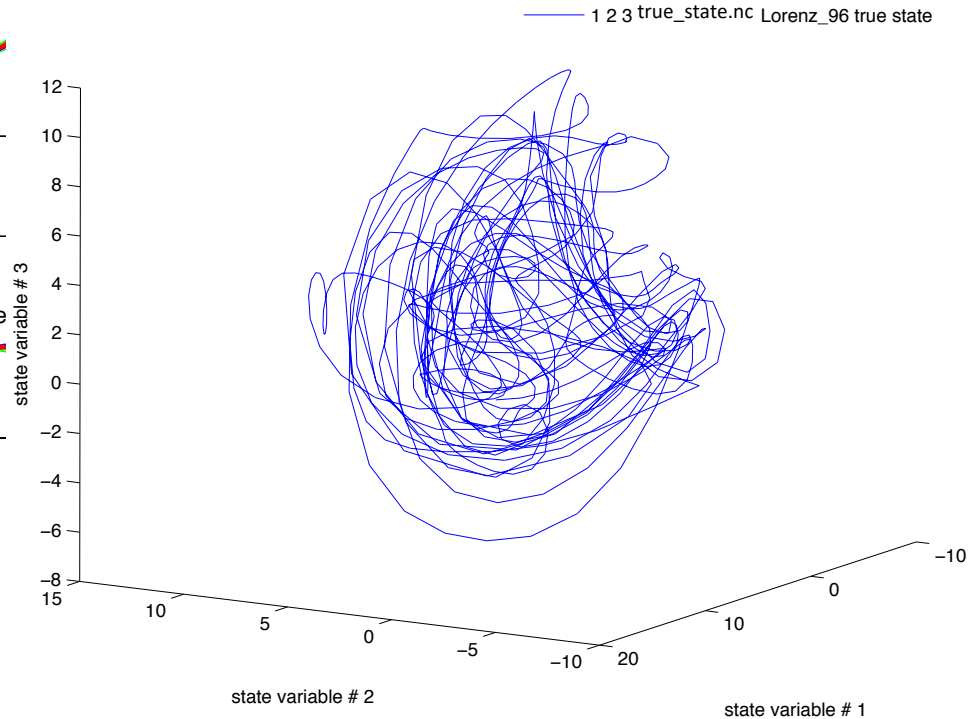
Lorenz_96 state varnum 2 Ensemble Members of preassim.nc



Lorenz_96 state varnum 3 Ensemble Members of preassim.nc



The Attractor



Lorenz 96 (40-variable) Model

Attractor dimension 13 by some measures with 40 variables and standard forcing (*forcing* = 8.00 in `&model_nm1`).

Start to explore model sizes closer to ensemble size.

Can examine possible degeneracy issues with sample covariance.

Naive application of small ensembles diverges in many cases.

Lorenz 96 (40-variable) Model

```
cd models/lorenz_96/work  
./workshop_setup.sh
```

40 observations, randomly located in space, equally spaced in time.
Observed once an hour; observational error variance is 1.0.

Use Matlab to examine the output.

Need new techniques to fix problem seen here.

For *plot_ens_time_series*, *plot_ens_mean_time_series*:

Can select subset of variables to plot,

Default selection of variables 1, 13, and 27 are approximately
equally spaced around the cyclic domain.

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**