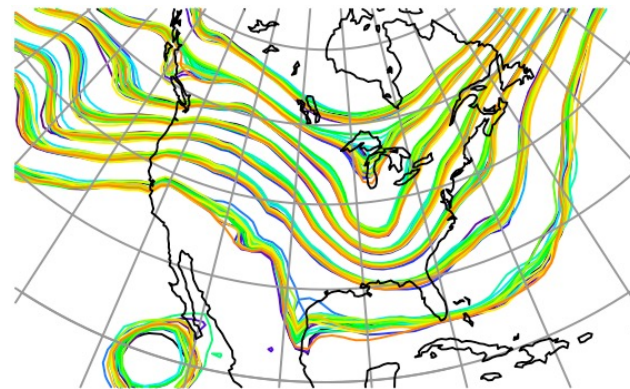


Data  
Assimilation  
Research  
Testbed



## DART Tutorial Section 9: More on Dealing with Error: Inflation



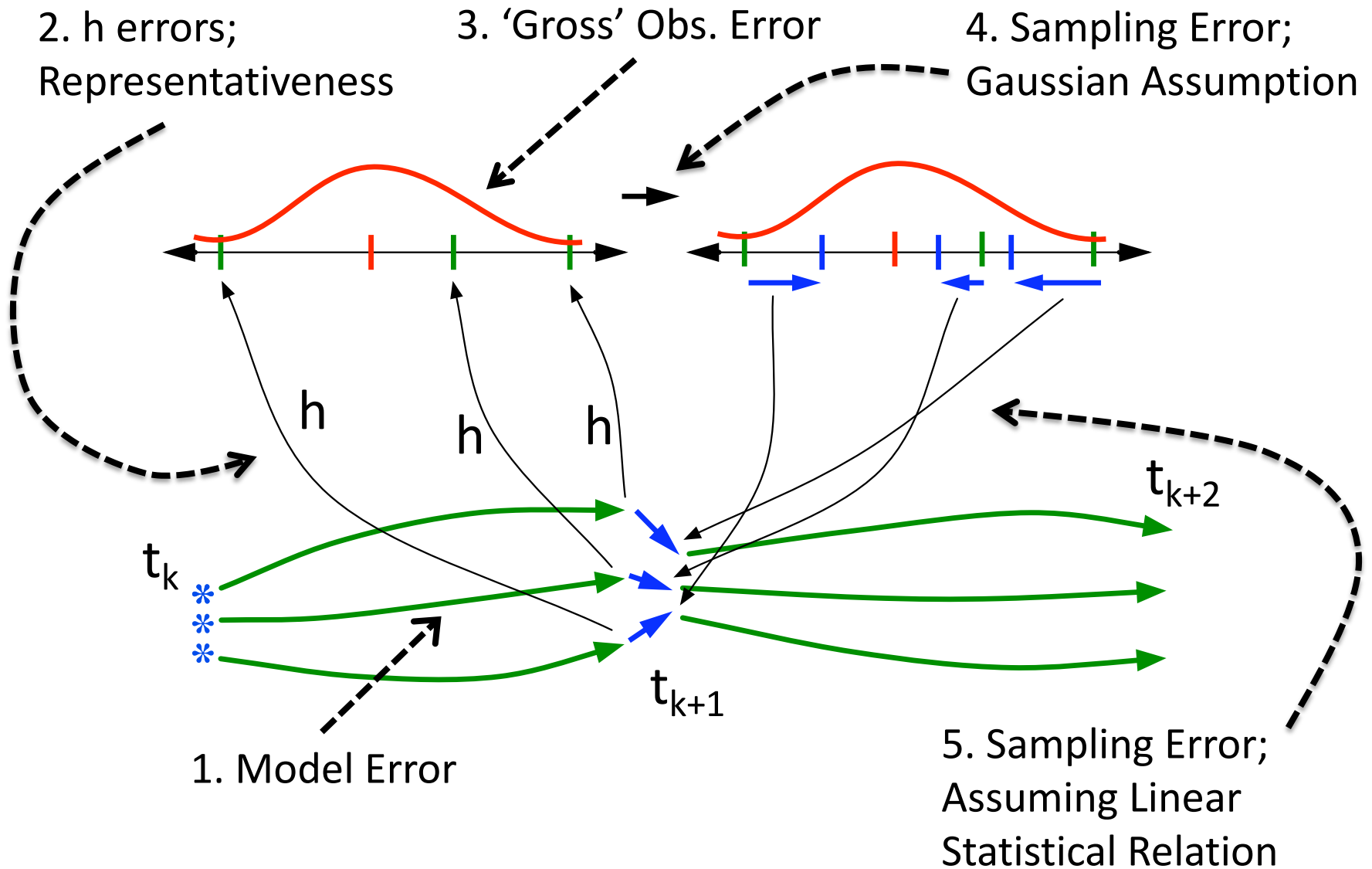
©UCAR



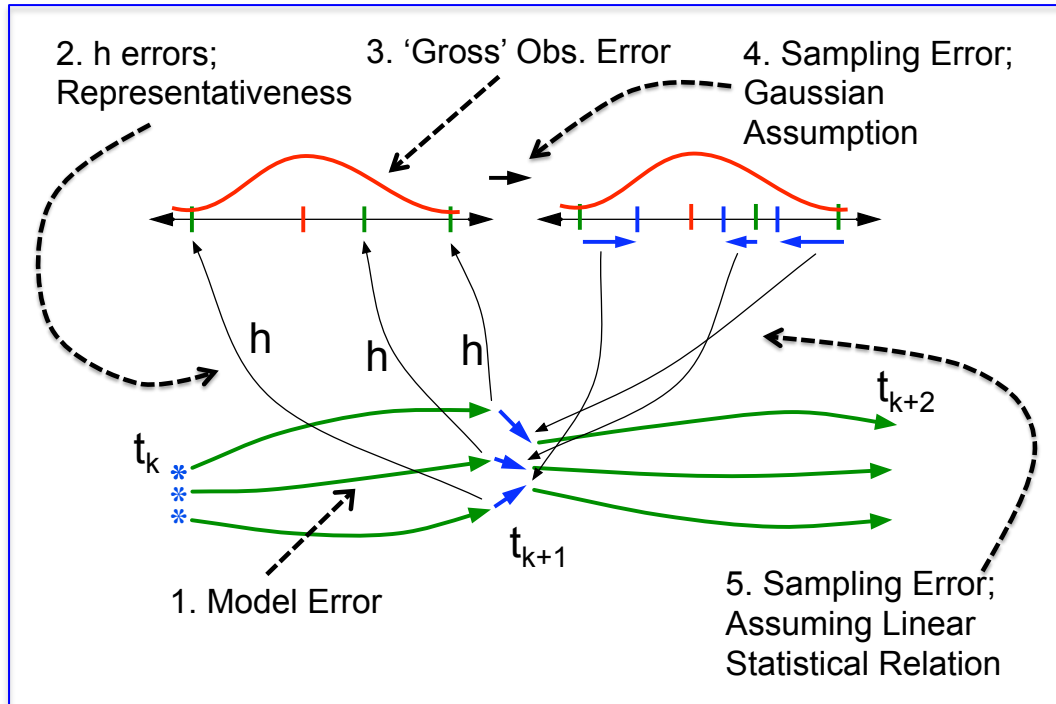
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# Some Error Sources in Ensemble Filters



# Dealing with Ensemble Filter Errors



Fix 1, 2, 3 independently,  
HARD but ongoing.

Often, ensemble filters...

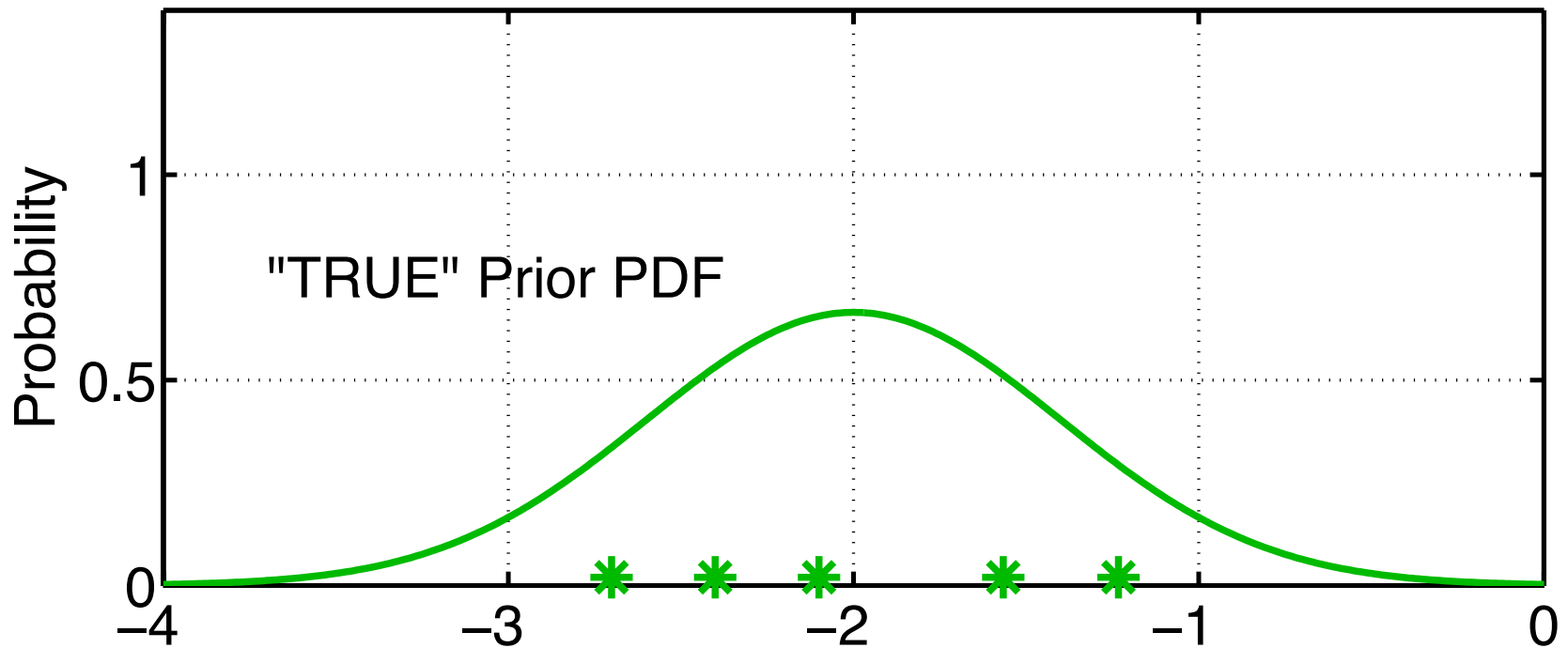
1-4: Variance inflation,  
Increase prior uncertainty  
to give obs more impact.

5. 'Localization': only let  
obs. impact a set of  
'nearby' state variables.

Often smoothly decrease  
impact to 0 as function of  
distance.

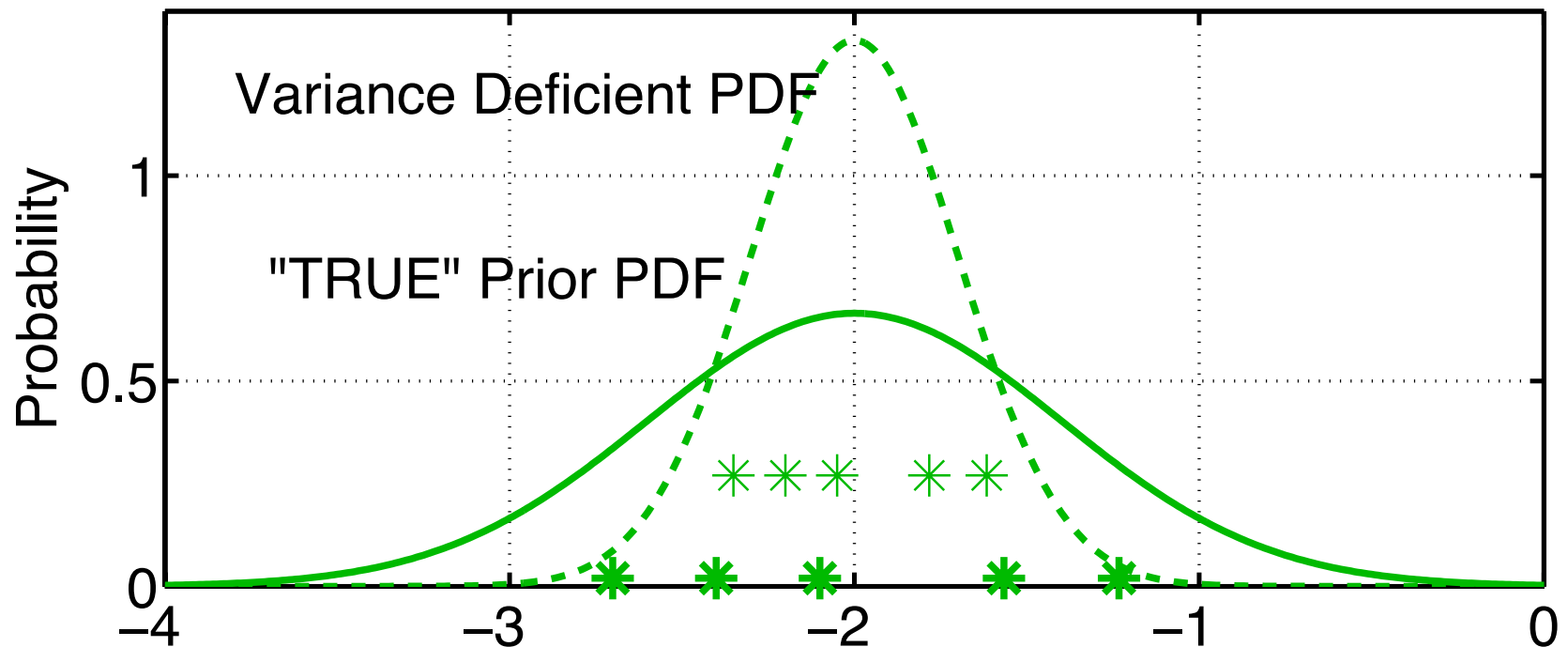
# Model/Filter Error: Filter Divergence and Variance Inflation

1. History of observations and physical system => 'true' distribution.



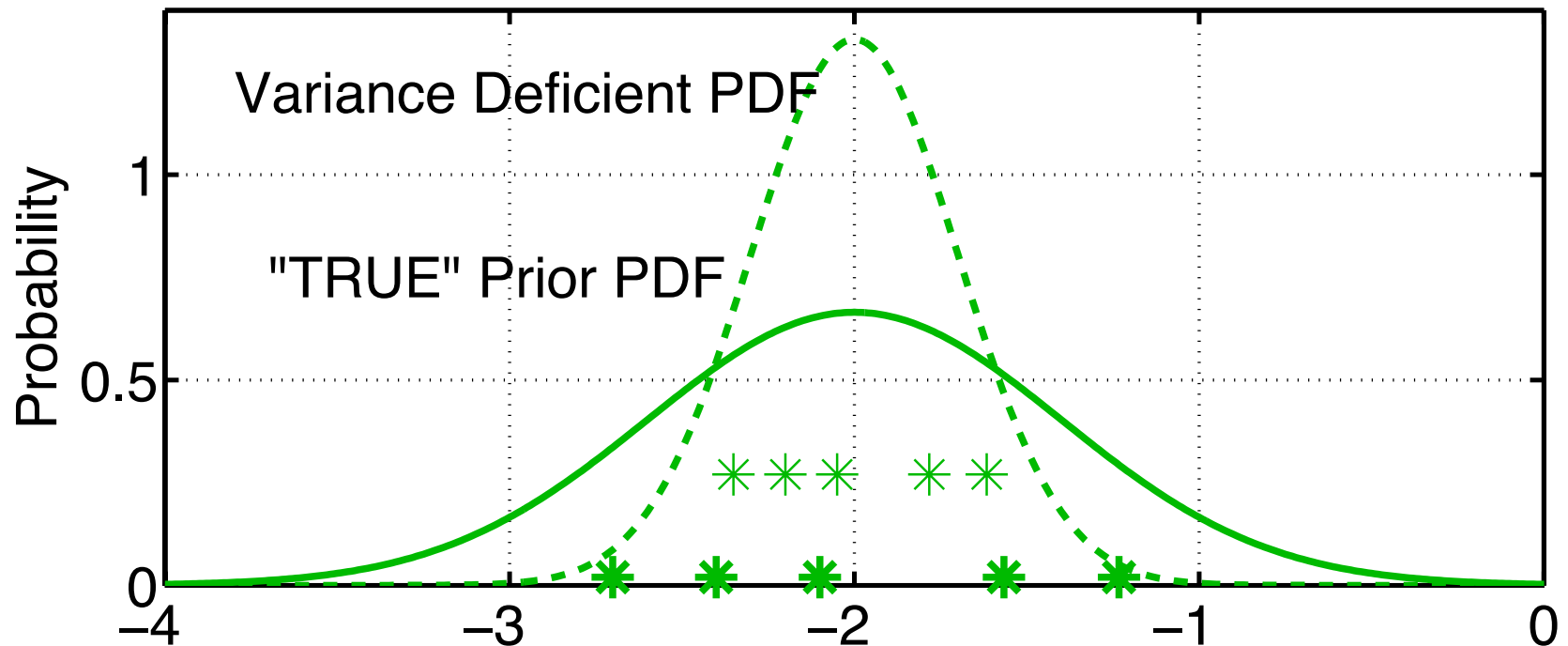
# Model/Filter Error: Filter Divergence and Variance Inflation

1. History of observations and physical system => 'true' distribution.
2. Sampling error, some model errors lead to insufficient prior variance.
3. Can lead to 'filter divergence': prior is too confident, obs. Ignored.



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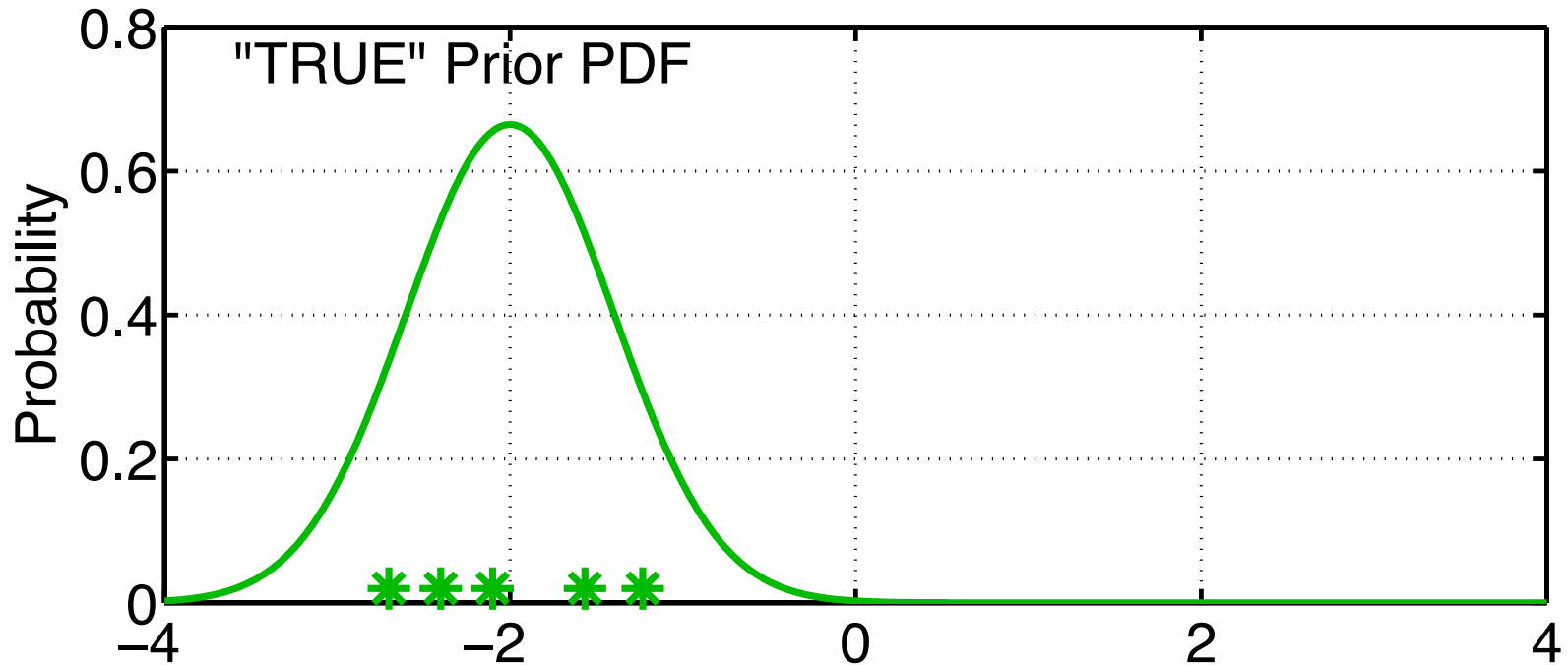


Naïve solution is variance inflation: just increase spread of prior.

For ensemble member  $i$ ,  $inflate(x_i) = \sqrt{\lambda}(x_i - \bar{x}) + \bar{x}$

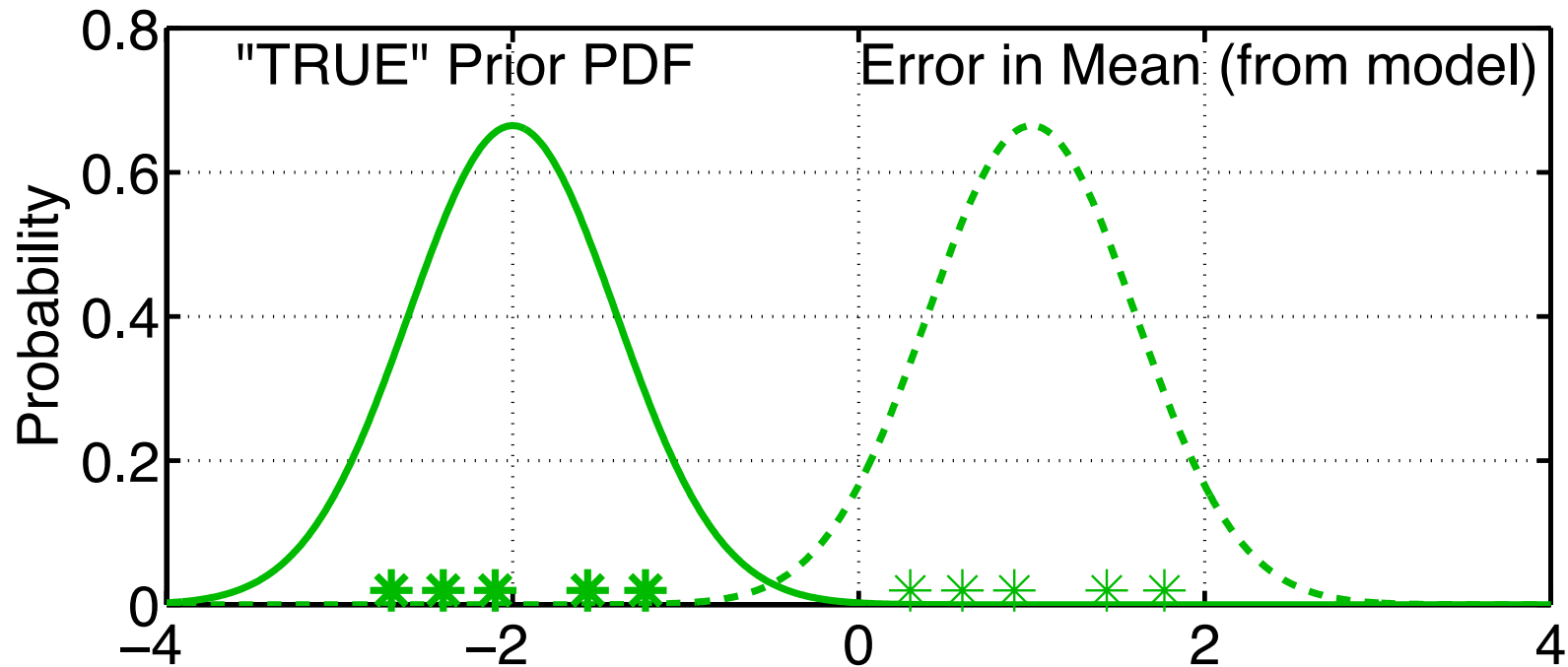
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# Model/Filter Error: Filter Divergence and Variance Inflation

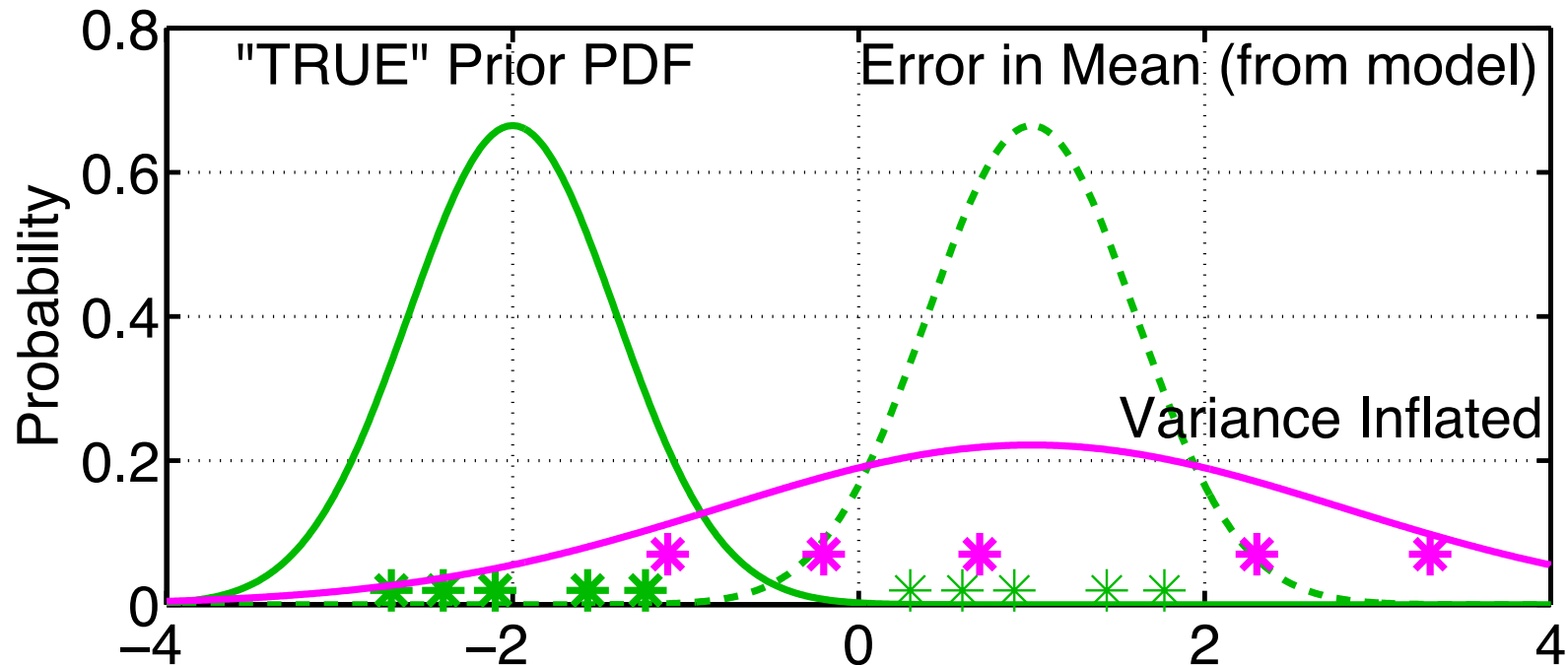
1. History of observations and physical system => 'true' distribution.
2. Most model errors also lead to erroneous shift in entire distribution.
3. Again, prior can be viewed as being TOO CERTAIN.





# Model/Filter Error: Filter Divergence and Variance Inflation

1. History of observations and physical system => 'true' distribution.
2. Most model errors also lead to erroneous shift in entire distribution.
3. Again, prior can be viewed as being TOO CERTAIN.



Inflating can ameliorate this.

Obviously, if we knew  $E(\text{error})$ , we'd correct for it directly.

# Physical Space Variance Inflation

Inflate all state variables by same amount before assimilation.

## Capabilities:

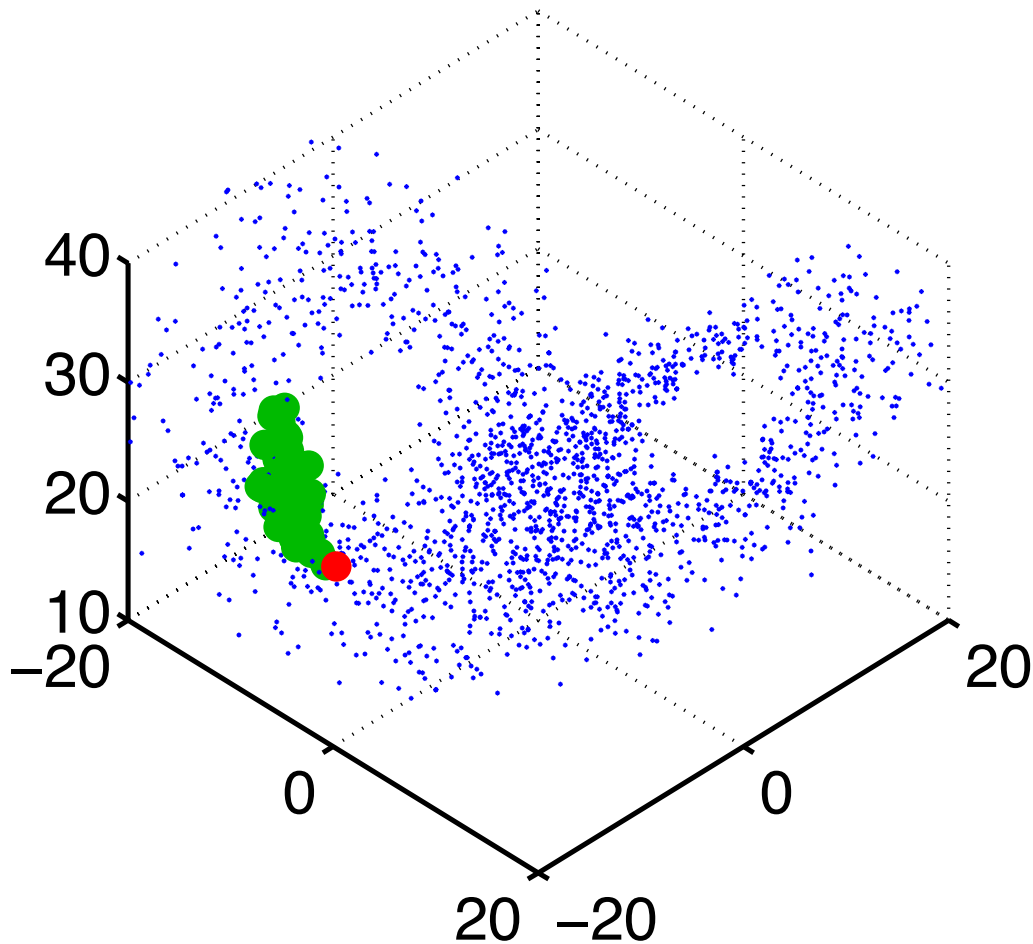
1. Can be effective for a variety of models.
2. Can maintain linear balances.
3. Stays on local flat manifolds.
4. Simple and cheap.

## Liabilities:

1. State variables not constrained by observations can 'blow up'.  
For instance unobserved regions near the top of AGCMs.
2. Magnitude of  $\lambda$  normally selected by trial and error.

# Physical Space Variance Inflation in Lorenz 63

Observation outside prior: danger of filter divergence.

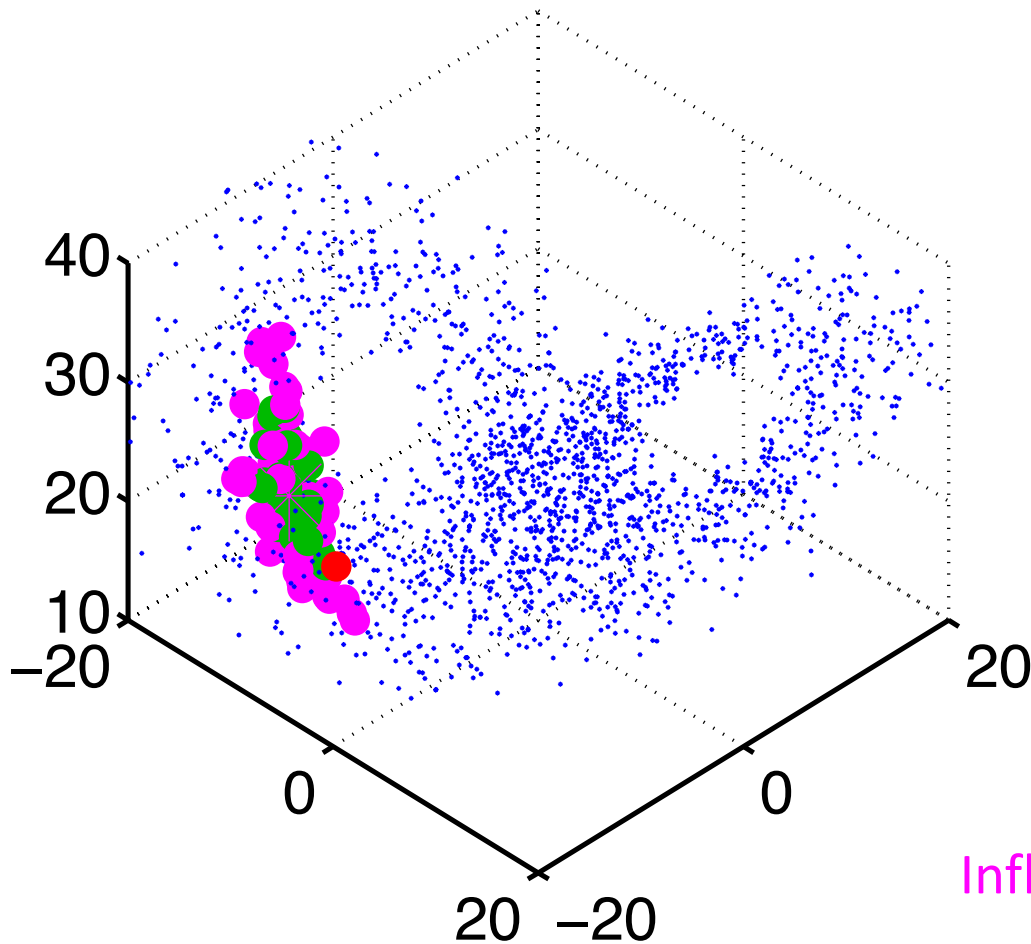


Observation in red.

Prior ensemble in green.

# Physical Space Variance Inflation in Lorenz 63

After inflating, observation is in prior cloud: filter divergence avoided.



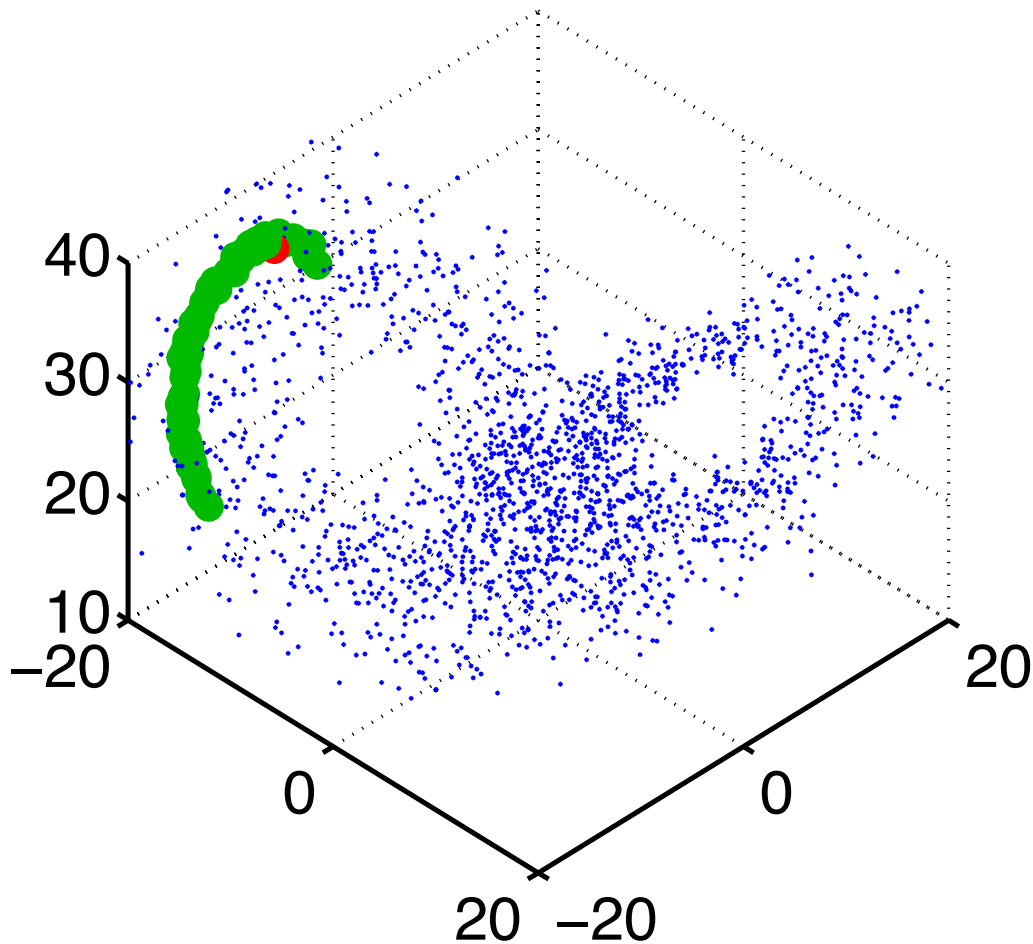
Observation in red.

Prior ensemble in green.

Inflated ensemble in magenta.

# Physical Space Variance Inflation in Lorenz 63

Prior distribution is significantly 'curved'.

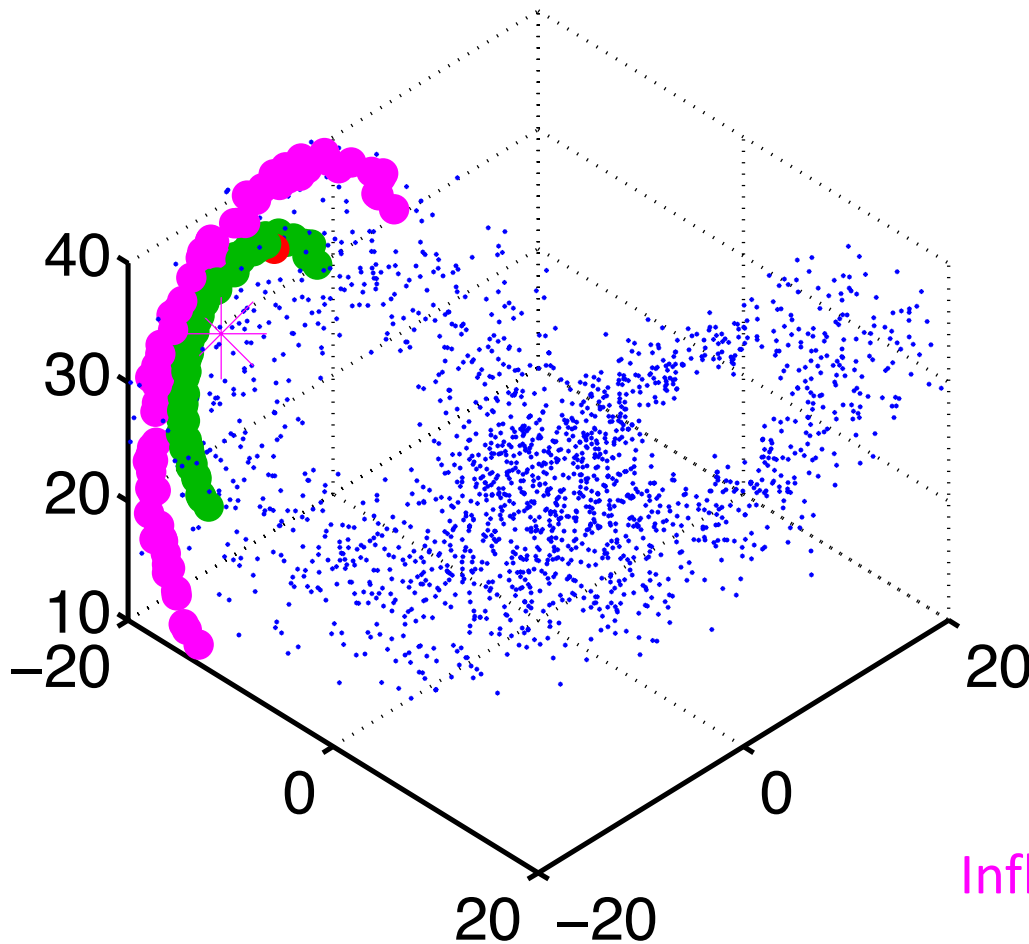


Observation in red.

Prior ensemble in green.

# Physical Space Variance Inflation in Lorenz 63

Inflated prior outside attractor. Posterior will also be off attractor.



Can lead to transient  
off-attractor behavior or...

Model 'blow-up'.

Observation in red.

Prior ensemble in green.

Inflated ensemble in magenta.

# Basic control of inflation in DART is in `&filter_nml`

	Before Assimilation	After Assimilation	
<code>inf_flavor</code>	= 0,	0,	<b>Flavor:</b> 0 => NONE 1 => deprecated 2,3 => physical
<code>inf_initial_from_restart</code>	= .false.,	.false.,	
<code>inf_sd_initial_from_restart</code>	= .false.,	.false.,	space
<code>inf_deterministic</code>	= .true.,	.true.,	
<code>inf_initial</code>	= 1.0,	1.0,	<b>Inflation Value</b>
<code>inf_sd_initial</code>	= 0.0,	0.0,	
<code>inf_damping</code>	= 1.0,	1.0,	
<code>inf_lower_bound</code>	= 1.0,	1.0,	
<code>inf_upper_bound</code>	= 1000000.0,	1000000.0,	
<code>inf_sd_lower_bound</code>	= 0.0,	0.0,	
	prior inflation column	posterior inflation column	

Initially, we'll change *inf\_flavor* and *inf\_initial* in first column.

# Physical space variance inflation in Lorenz 96

models/lorenz\_96/work/

Try some values and see what happens to assimilations with Lorenz 96.

Set *inf\_flavor* to 3 to use state space inflation.

In the first column, set *inf\_initial* to values like 1.05, 1.08, 1.10

```
&assim_tools_nml
  filter_kind           = 1
  cutoff                = 1000000.0
  spread_restoration    = .false.
  sampling_error_correction = .false.
...
&filter_nml
  ens_size = 20
  perturb_from_single_instance = .false.
...
  inf_flavor           = 3,           0
  inf_initial_from_restart = .false., .false.
  inf_sd_initial_from_restart = .false., .false.
  inf_initial          = 1.0,         1.0
  inf_sd_initial       = 0.0,         0.0
  inf_damping          = 1.0,         1.0
  inf_lower_bound      = 1.0,         1.0
  inf_upper_bound      = 1000000.0,   1000000.0
  inf_sd_lower_bound   = 0.0,         0.0
```

These were the settings that diverged without inflation.

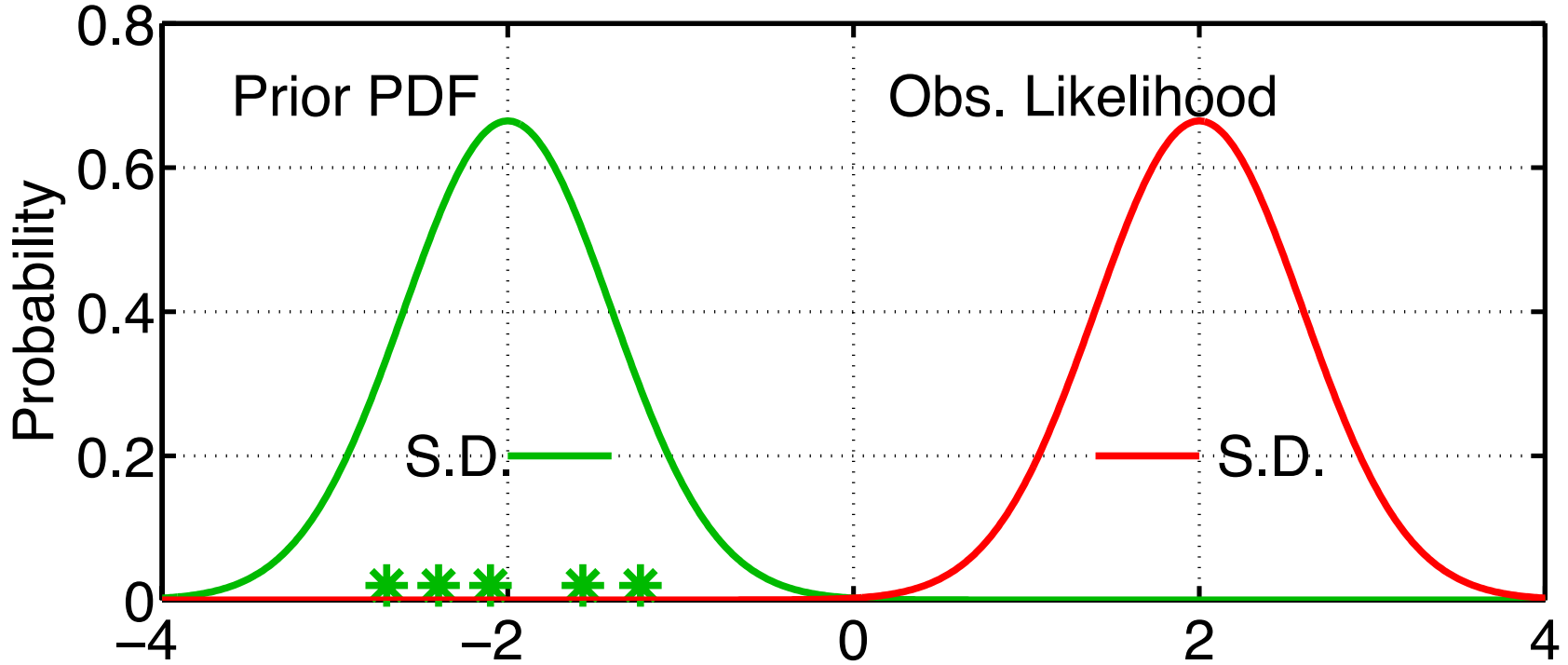
3 = state space inflation

Explore with this!



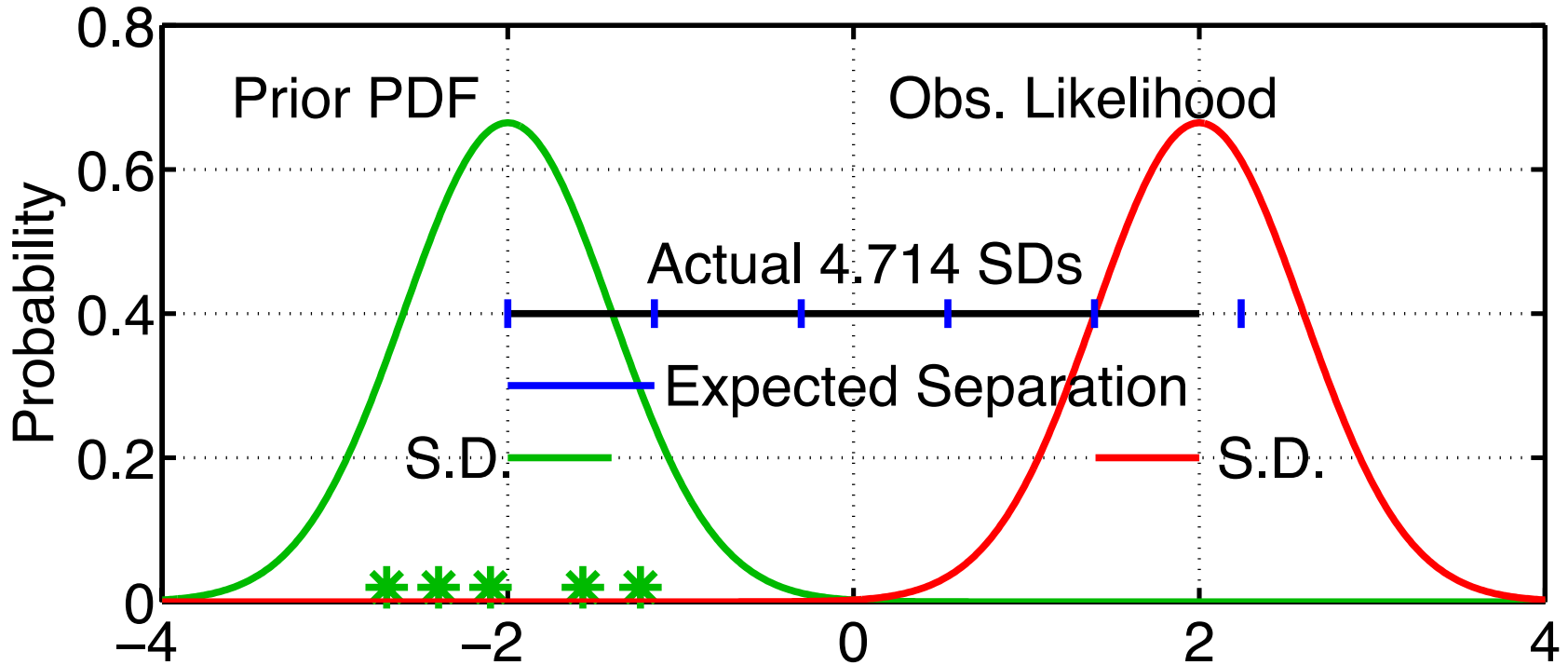
# Variance inflation in observation space

Not currently supported in DART Manhattan.



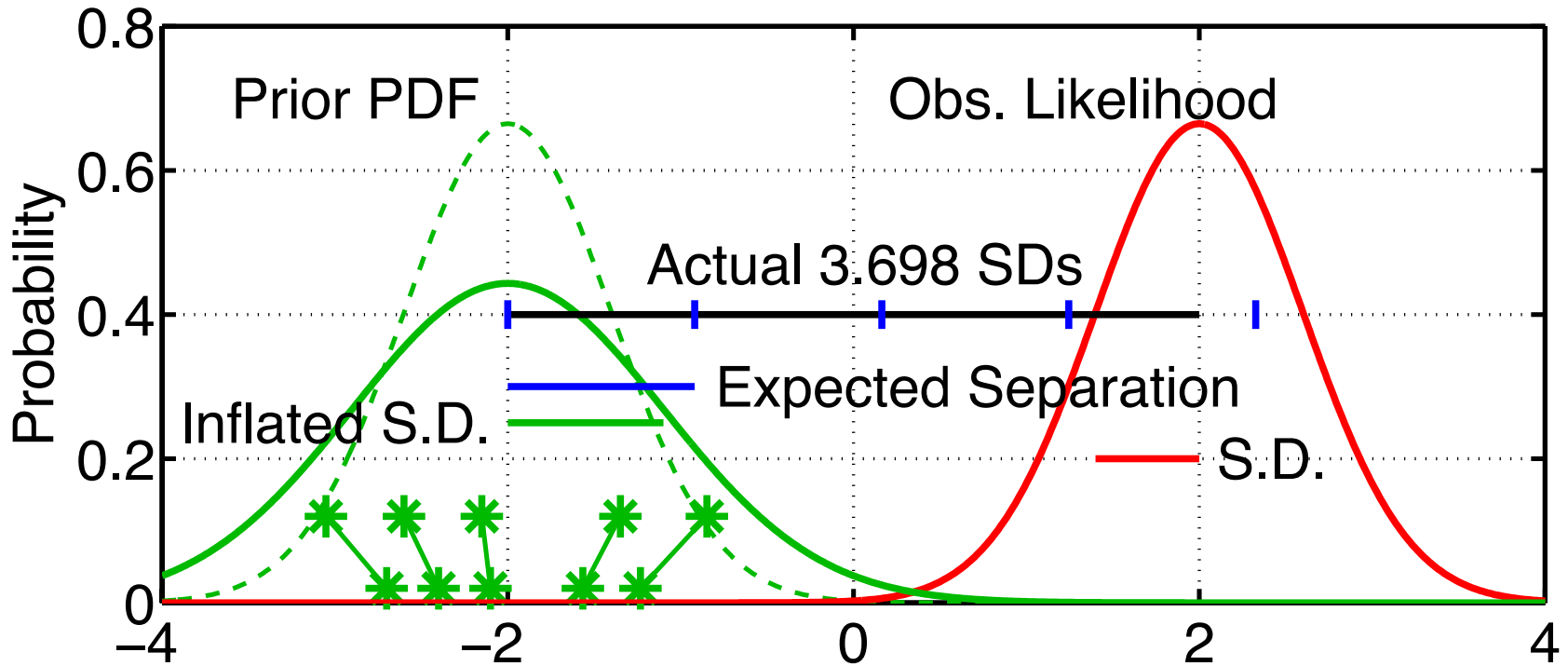
1. For observed variable, have estimate of prior-observed inconsistency.

# Variance inflation in observation space



1. For observed variable, have estimate of prior-observed inconsistency.
2. Expected (prior\_mean – observation) =  $\sqrt{\sigma_{prior}^2 + \sigma_{obs}^2}$   
Assumes that prior and observation are supposed to be unbiased.  
Is it model error or random chance?

# Variance inflation in observation space



1. For observed variable, have estimate of prior-observed inconsistency.
2. Expected (prior\_mean – observation) =  $\sqrt{\sigma_{prior}^2 + \sigma_{obs}^2}$
3. Inflating increases expected separation.  
Increases 'apparent' consistency between prior and observation.

# 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**