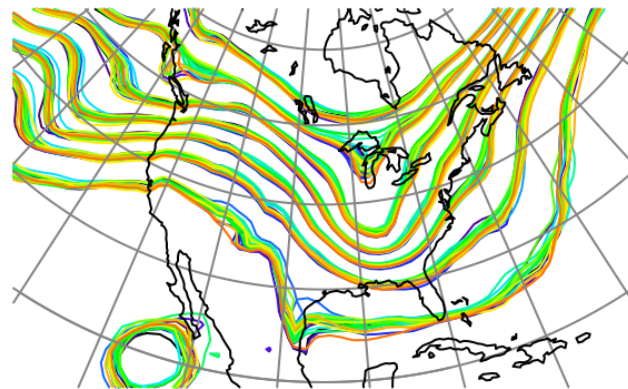


Data  
Assimilation  
Research  
Testbed



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



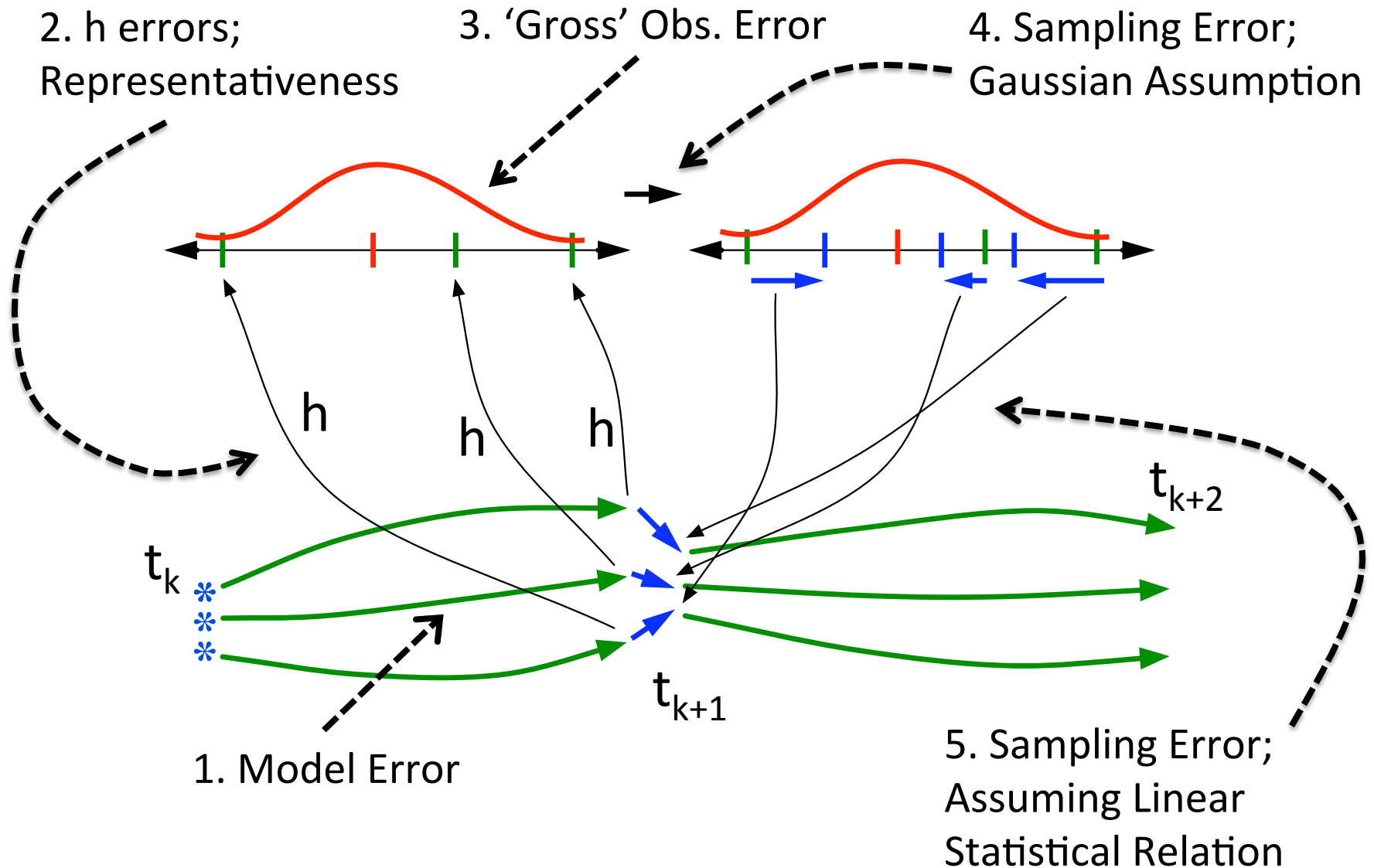
©UCAR 2014



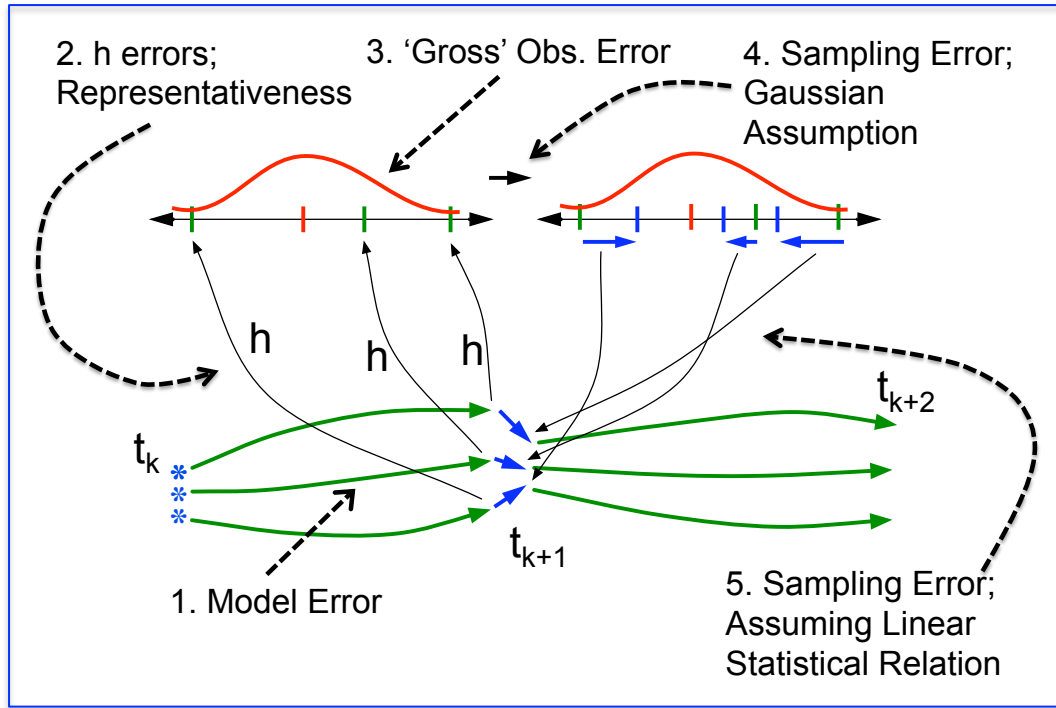
The National Center for Atmospheric Research is sponsored by the National Science Foundation. Any opinions, findings and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

NCAR | National Center for  
UCAR | Atmospheric Research

# Some Error Sources in Ensemble Filters



# Dealing with Ensemble Filter Errors



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

Often, ensemble filters...

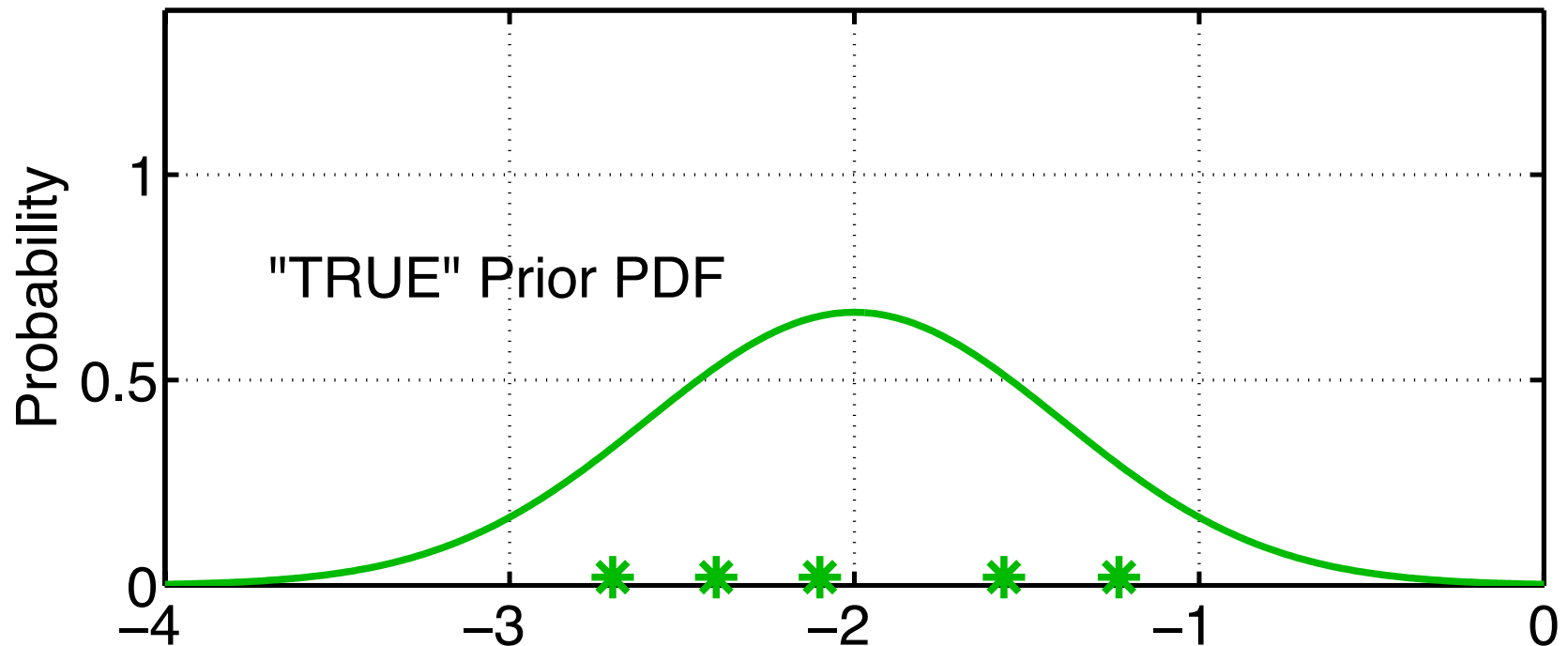
1-4: Variance inflation,  
Increase prior uncertainty  
to give obs more impact.

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

Often smoothly decrease  
impact to 0 as function of  
distance.

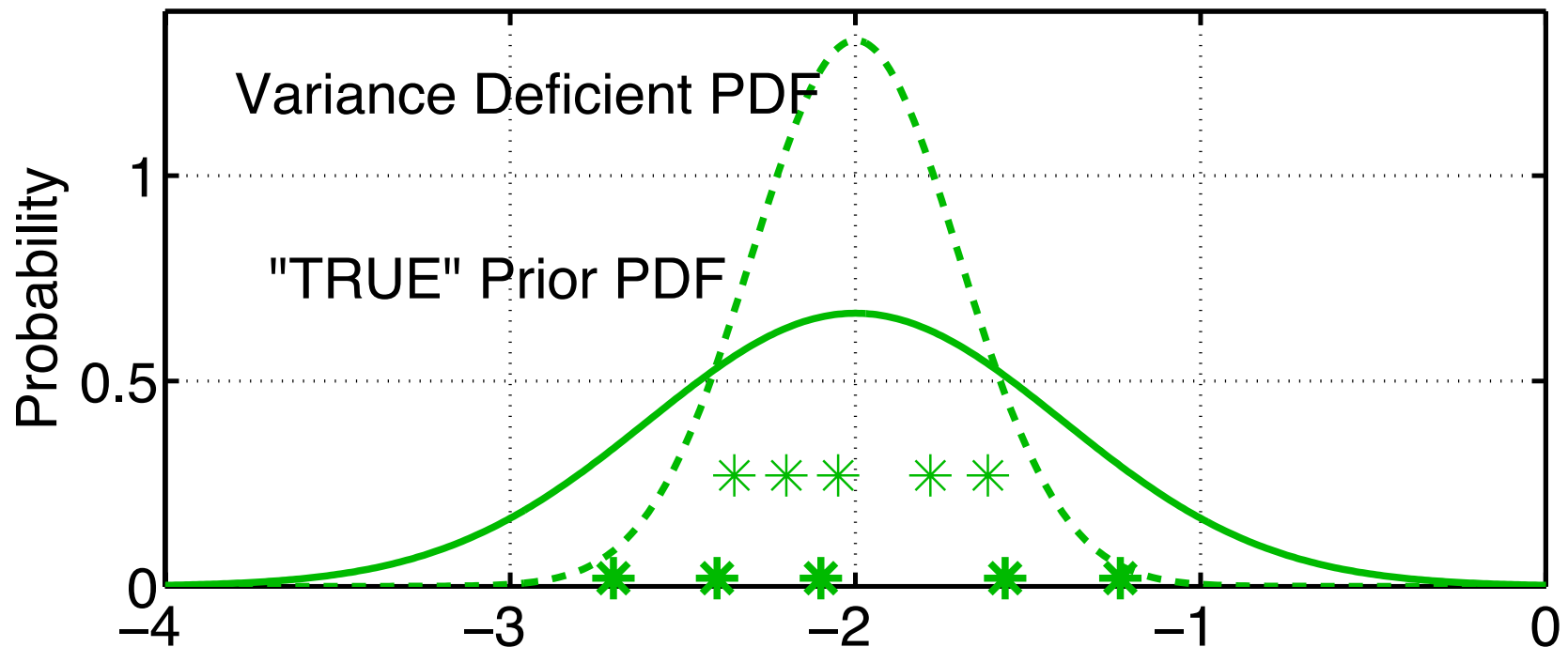
# Model/Filter Error: Filter Divergence and Variance Inflation

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



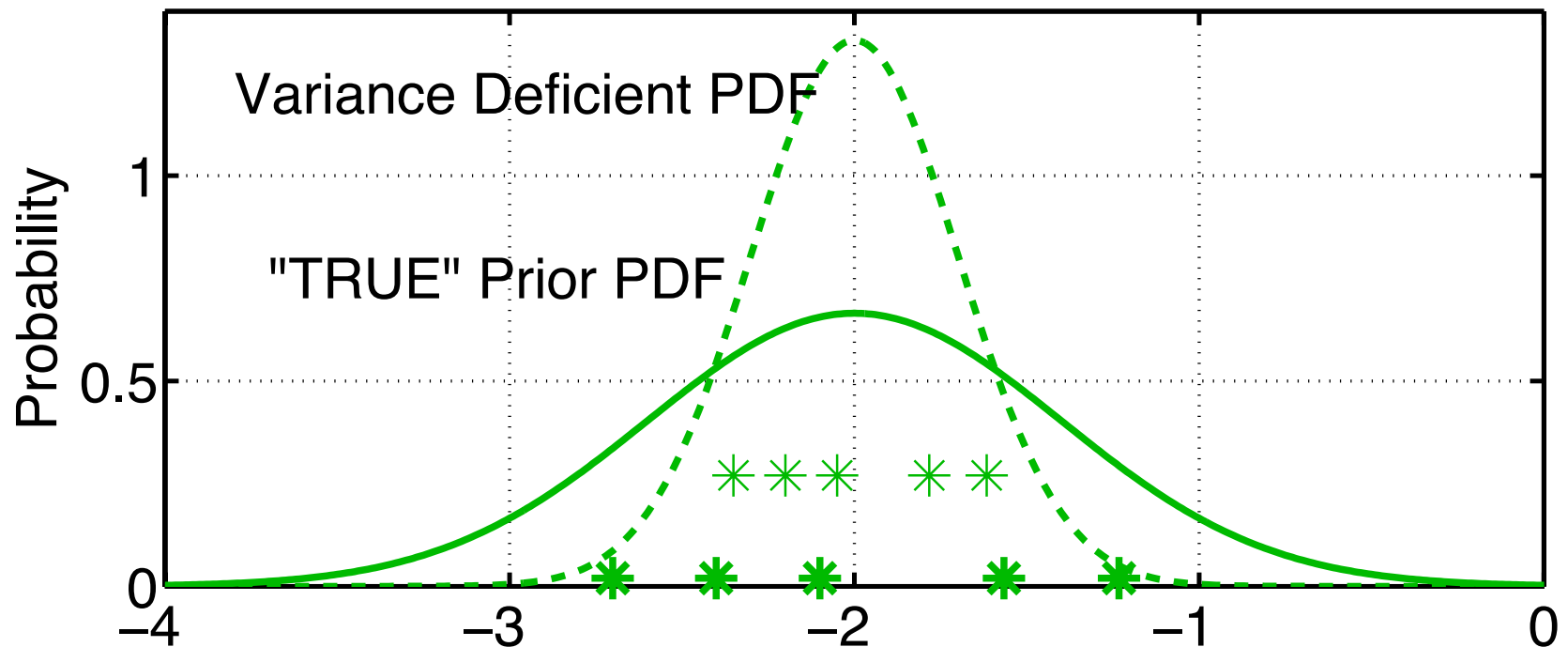
# Model/Filter Error: Filter Divergence and Variance Inflation

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.



# 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.

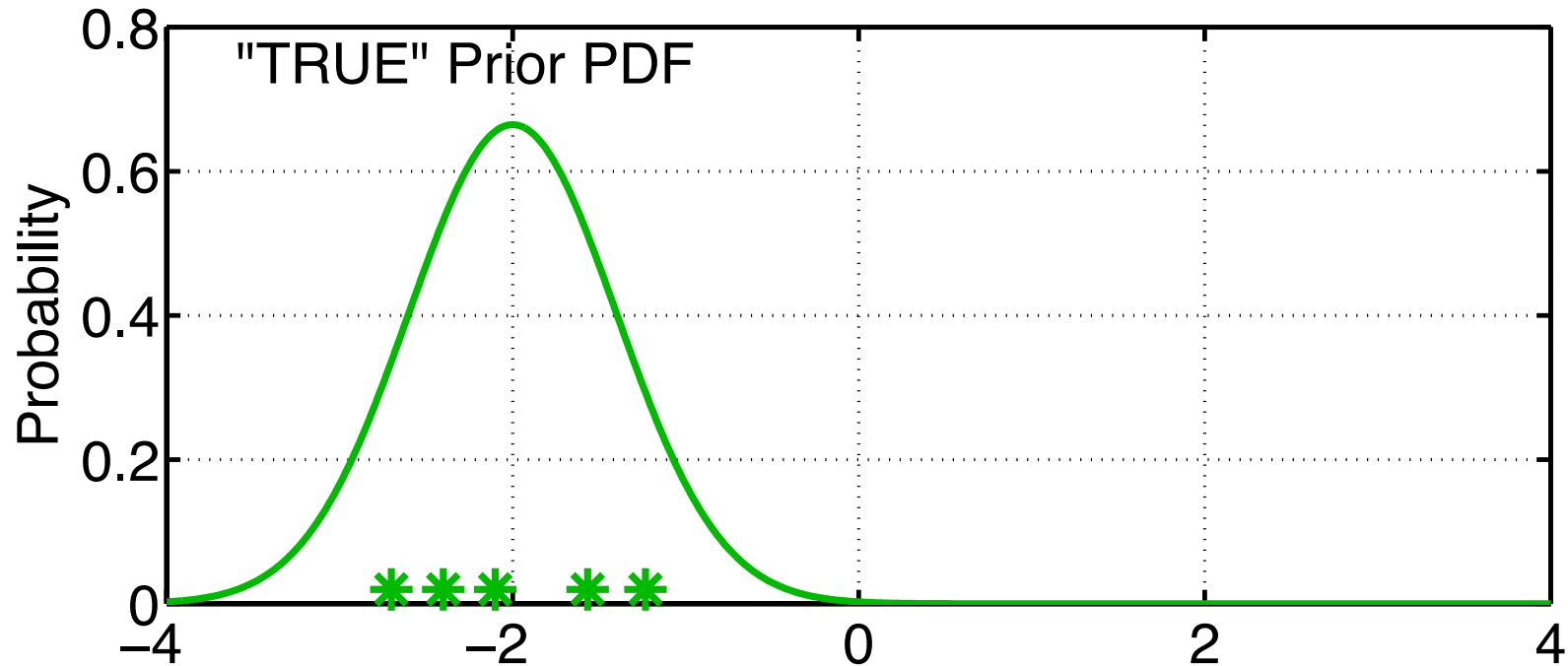


Naïve solution is variance inflation: just increase spread of prior.

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

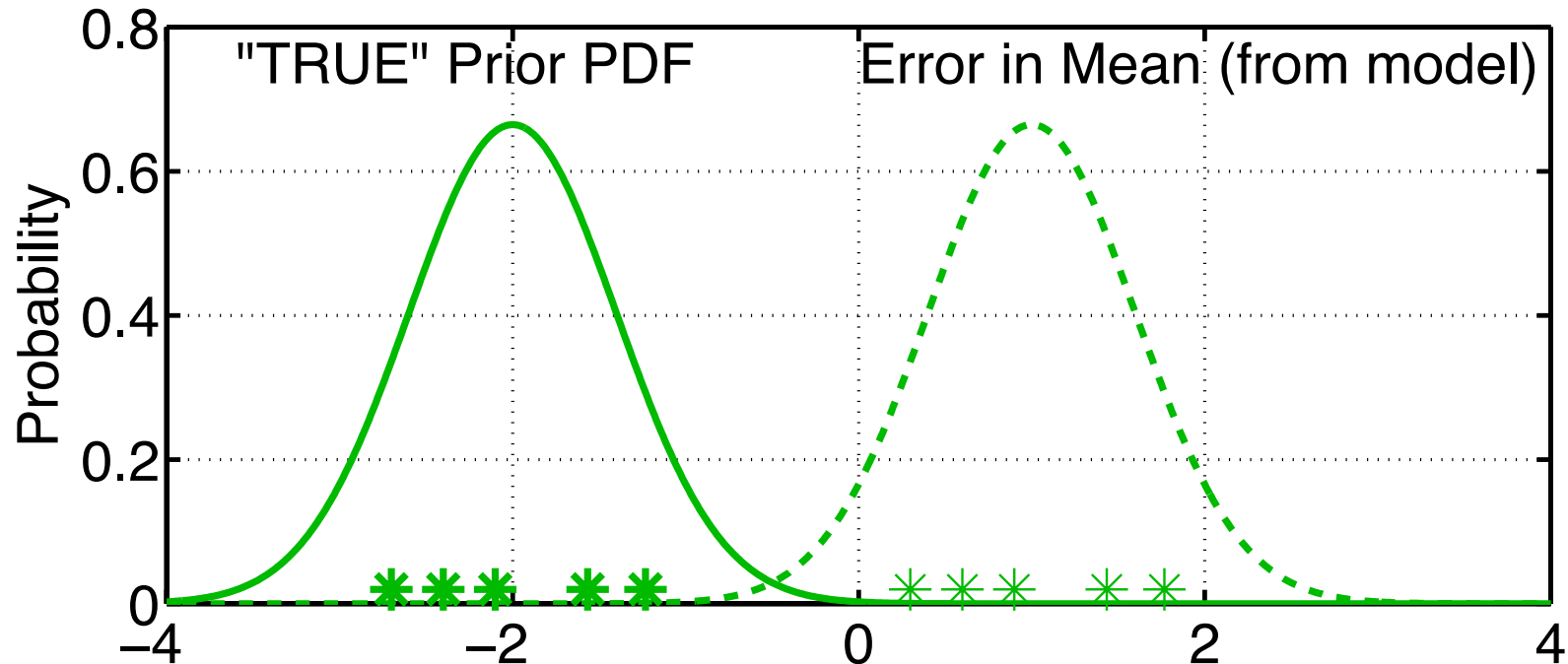
# Model/Filter Error: Filter Divergence and Variance Inflation

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



# Model/Filter Error: Filter Divergence and Variance Inflation

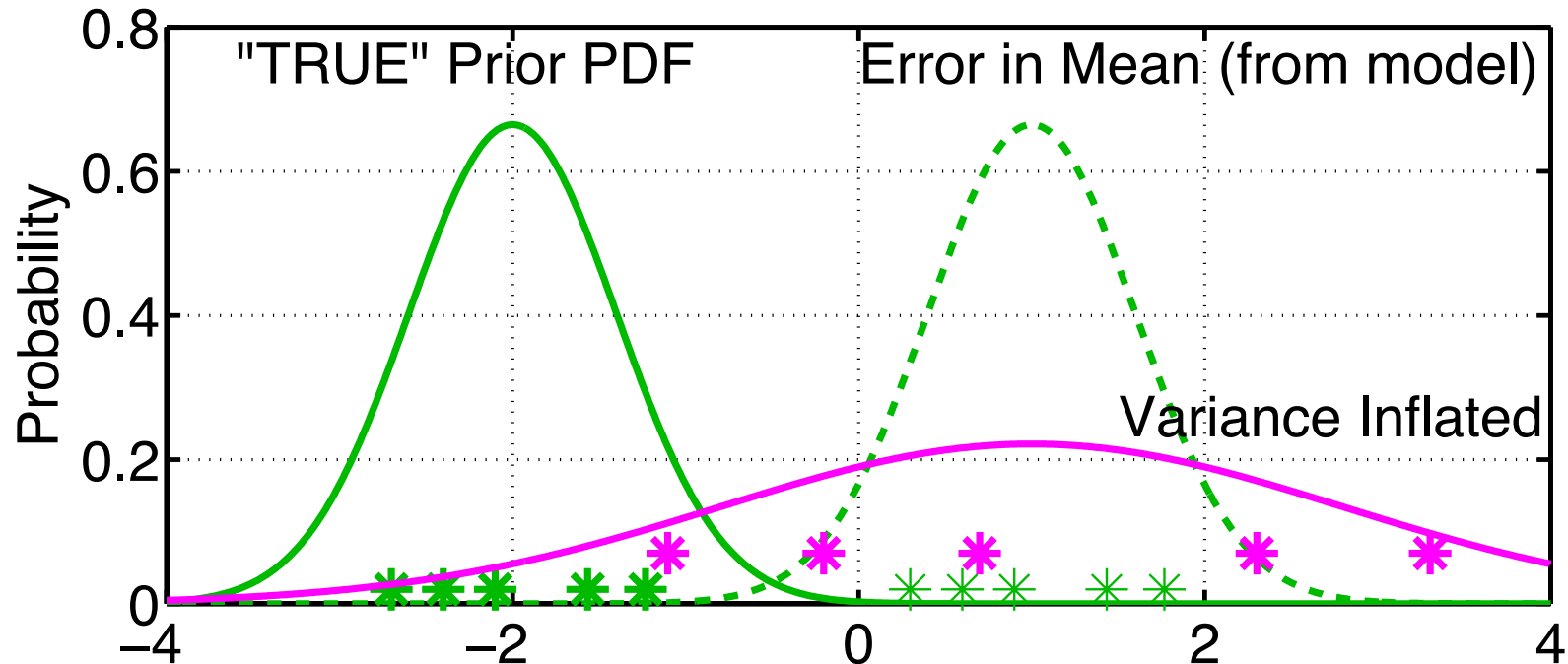
1. History of observations and physical system => 'true' distribution.
2. Most model errors also lead to erroneous shift in entire distribution.
3. Again, prior can be viewed as being TOO CERTAIN.





# 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:

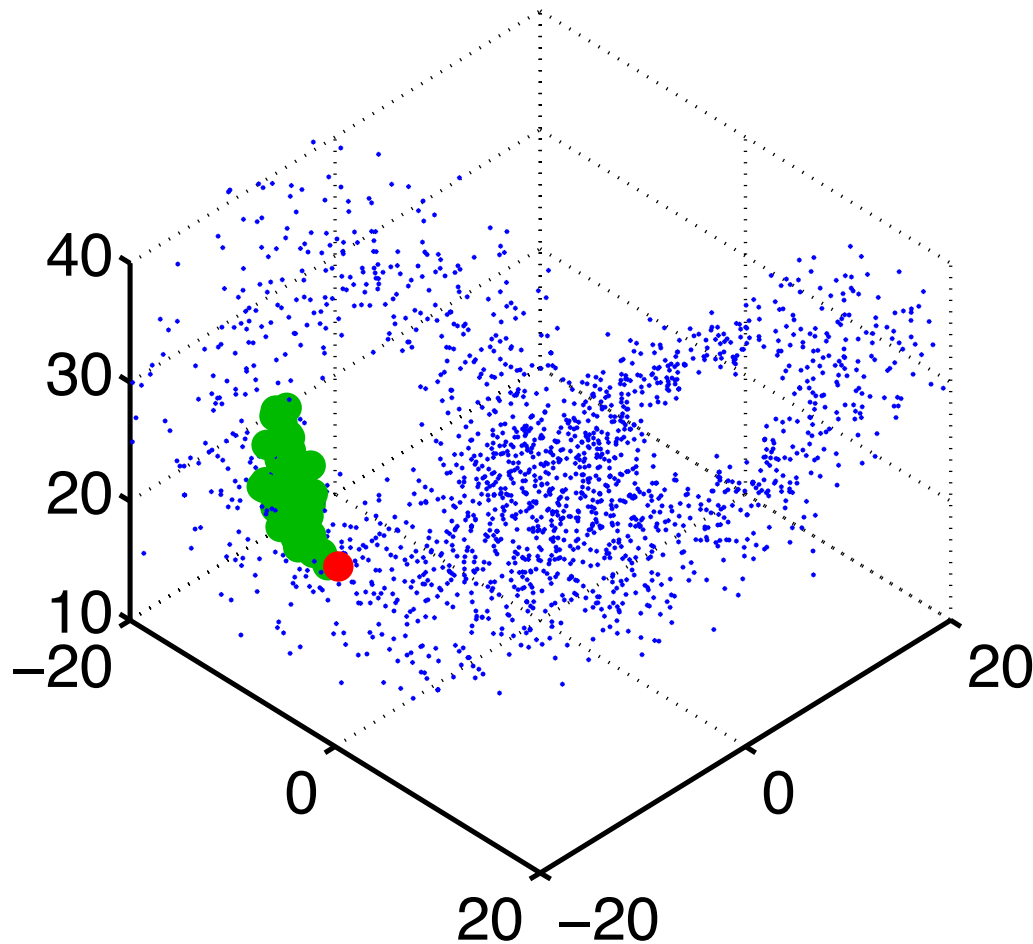
1. Can be effective for a variety of models.
2. Can maintain linear balances.
3. Stays on local flat manifolds.
4. Simple and cheap.

## 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.

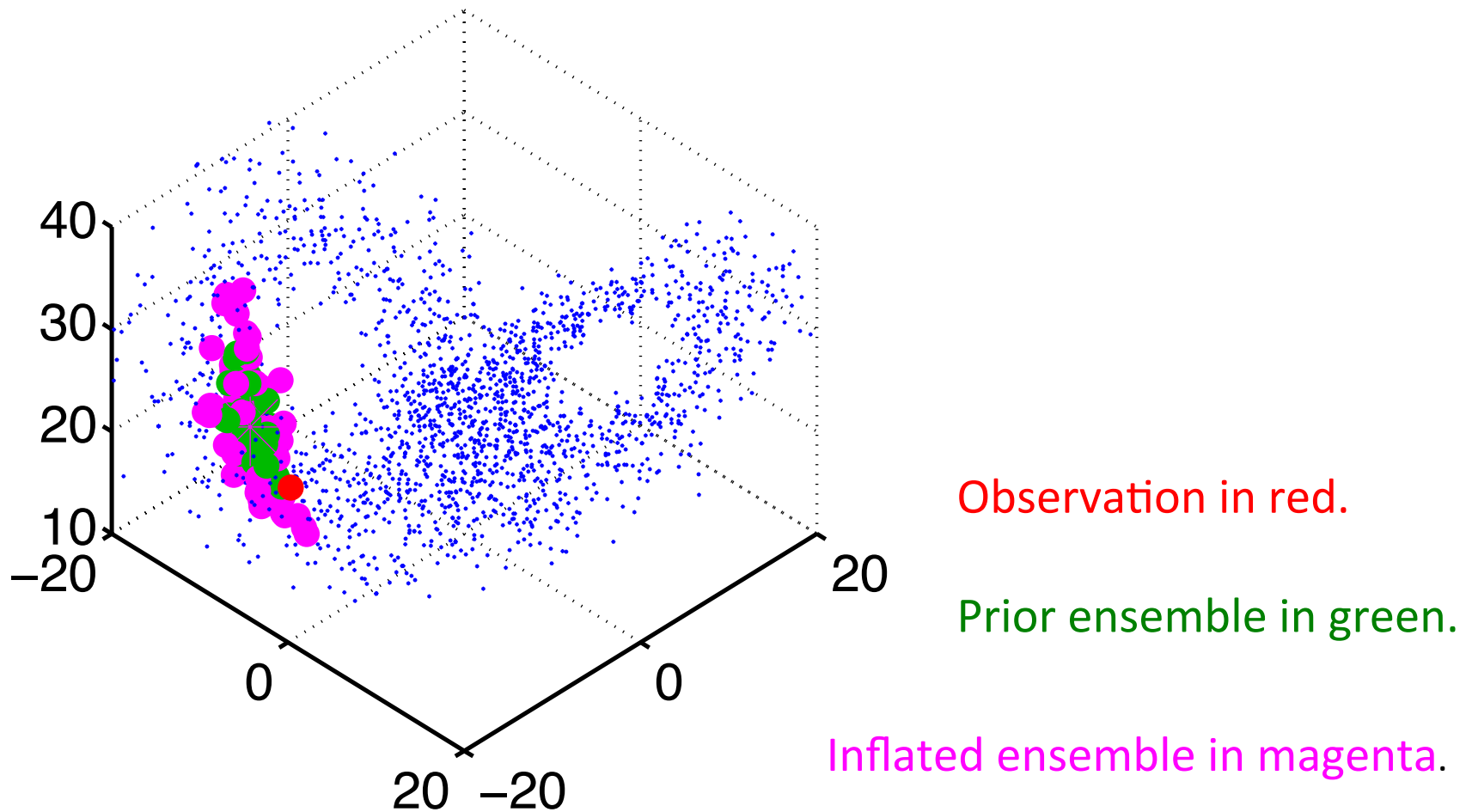


Observation in red.

Prior ensemble in green.

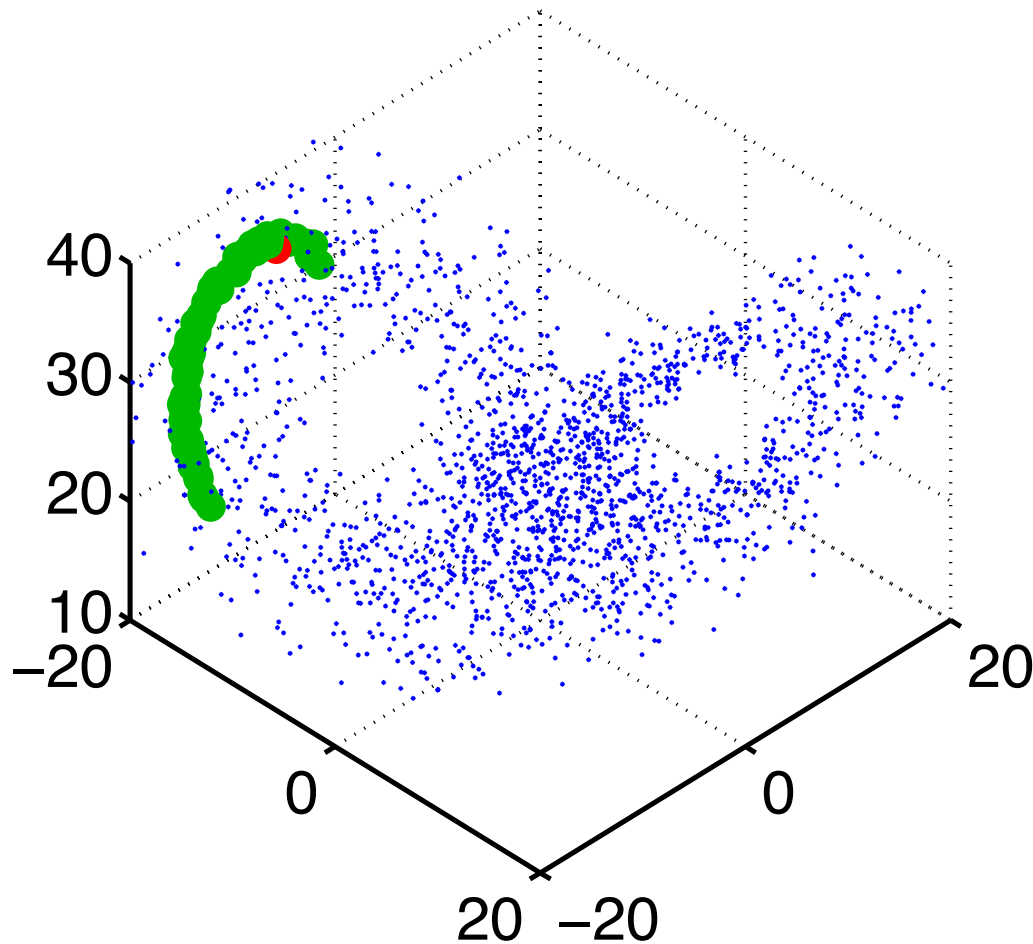
# Physical Space Variance Inflation in Lorenz 63

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



# Physical Space Variance Inflation in Lorenz 63

Prior distribution is significantly 'curved'.

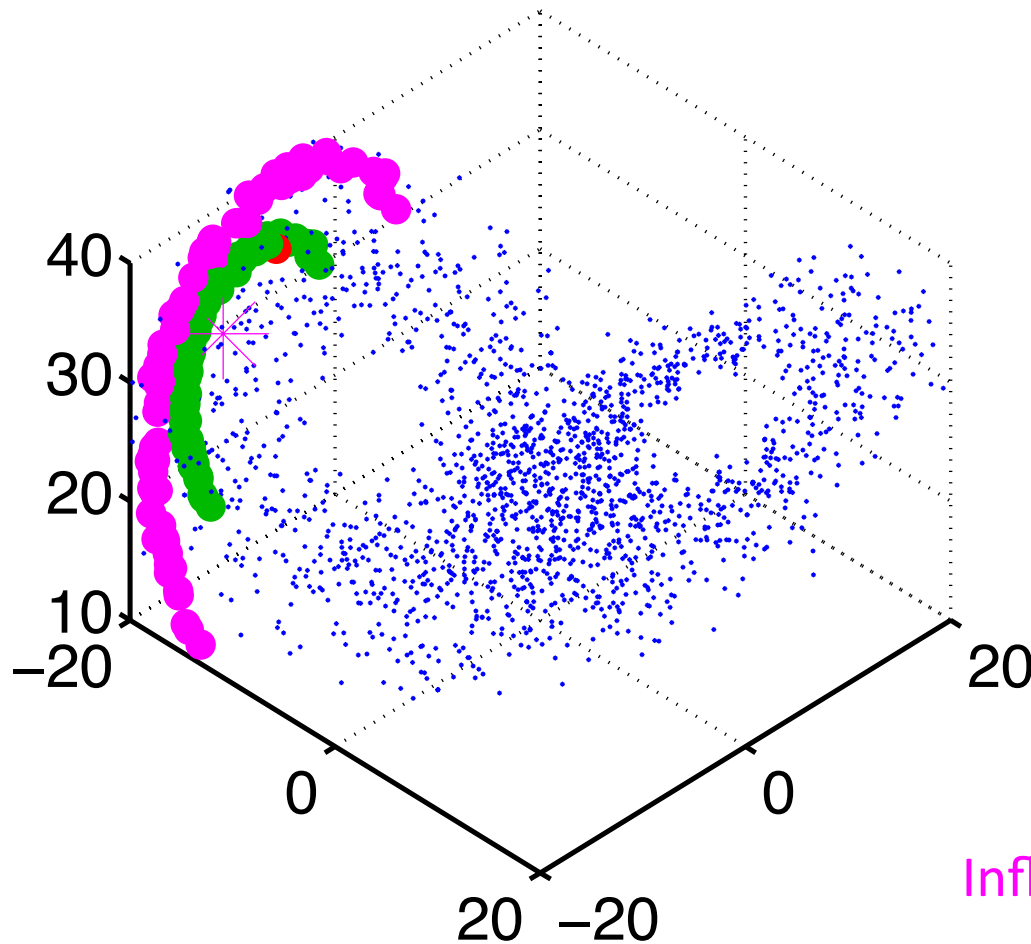


Observation in red.

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	
inf_flavor	= 0,	0,	<b>Flavor:</b> 1 => Deprecated 2,3 => physical space 0 => NONE
inf_initial_from_restart	= .false.,	.false.,	
inf_sd_initial_from_restart	= .false.,	.false.,	
inf_deterministic	= .true.,	.true.,	
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,	<b>Inflation Value</b>
inf_sd_lower_bound	= 0.0,	0.0,	

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

# Physical space variance inflation in Lorenz 96

Set *inf\_flavor=3*, state space inflation, in the first column.

Try some values and see what happens to L96 assimilation.

Set *inf\_initial* to values like 1.05, 1.08, 1.10 in the first column.

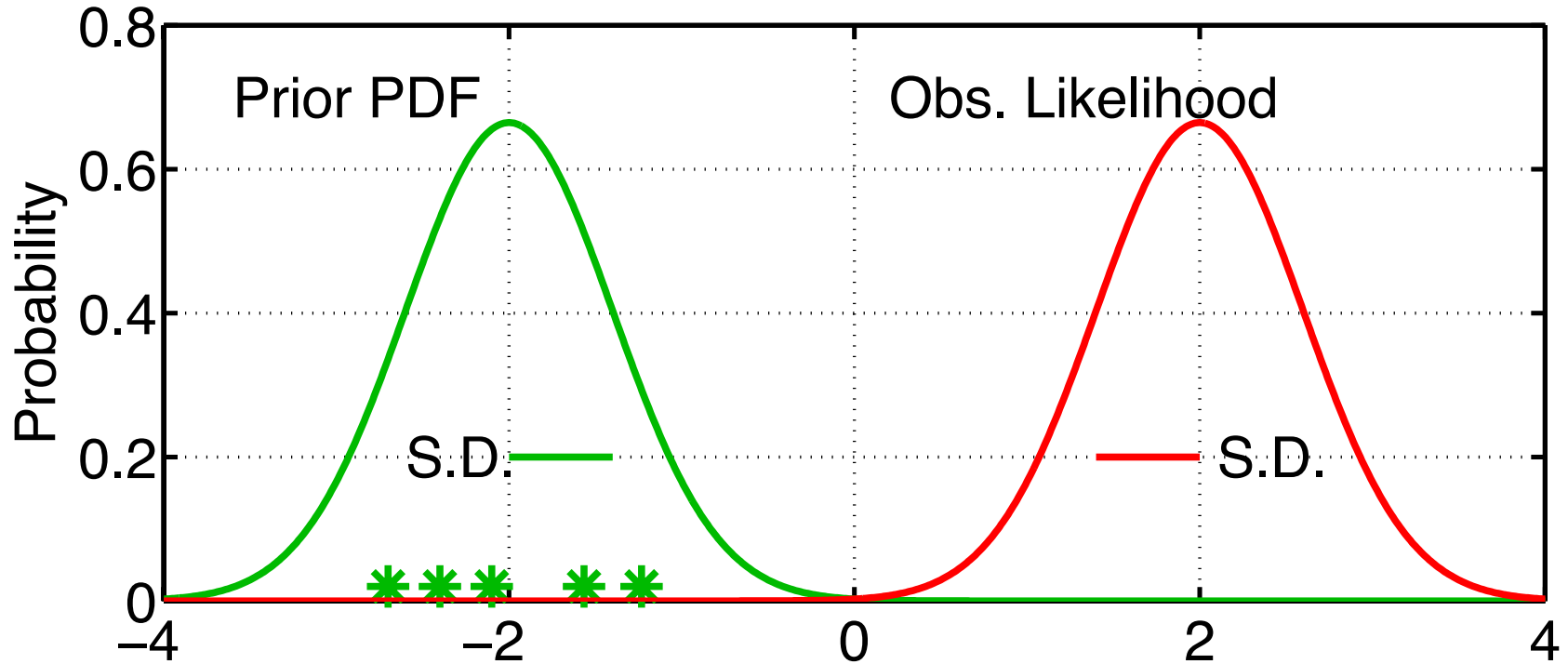
Make sure that *cutoff=1000000* and *ens\_size=20*

(These were settings that diverged without inflation)

Also that *spread\_restoration* is set to *false*.

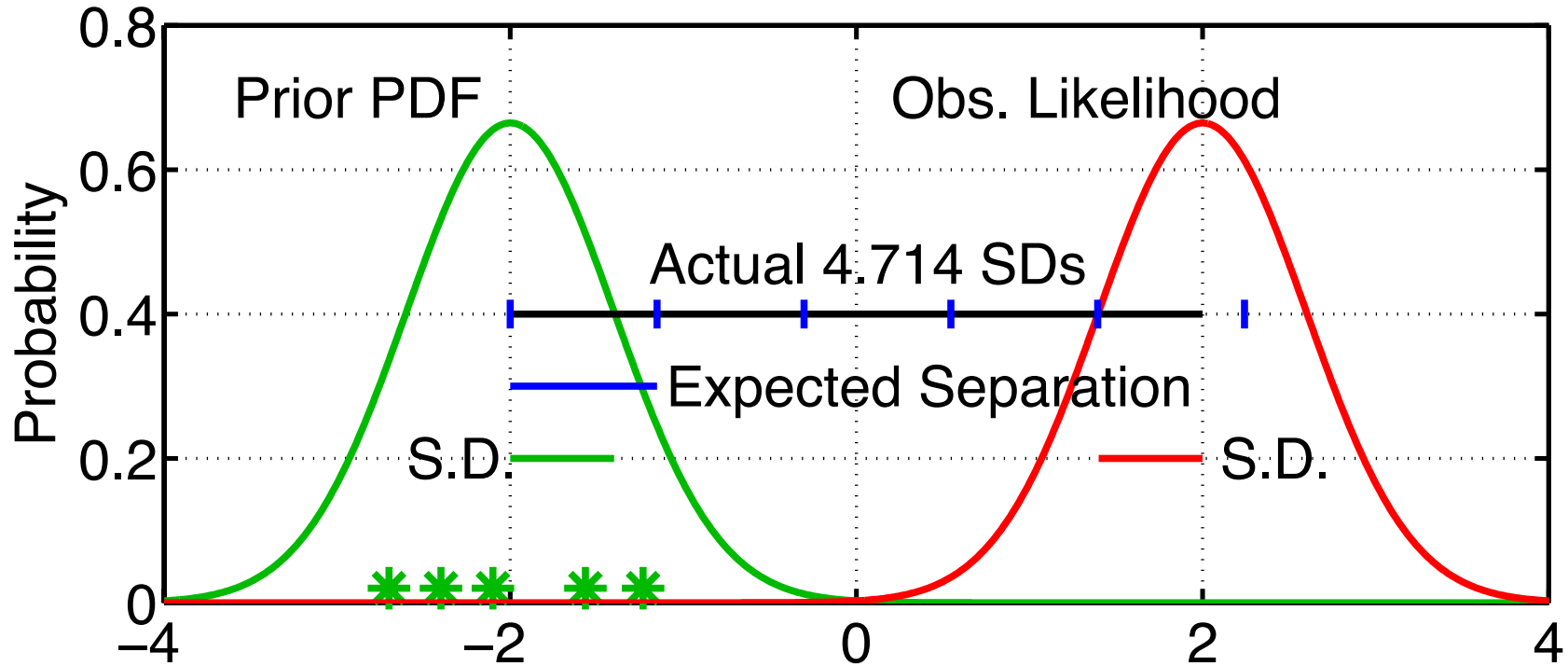


# Variance inflation in observation space



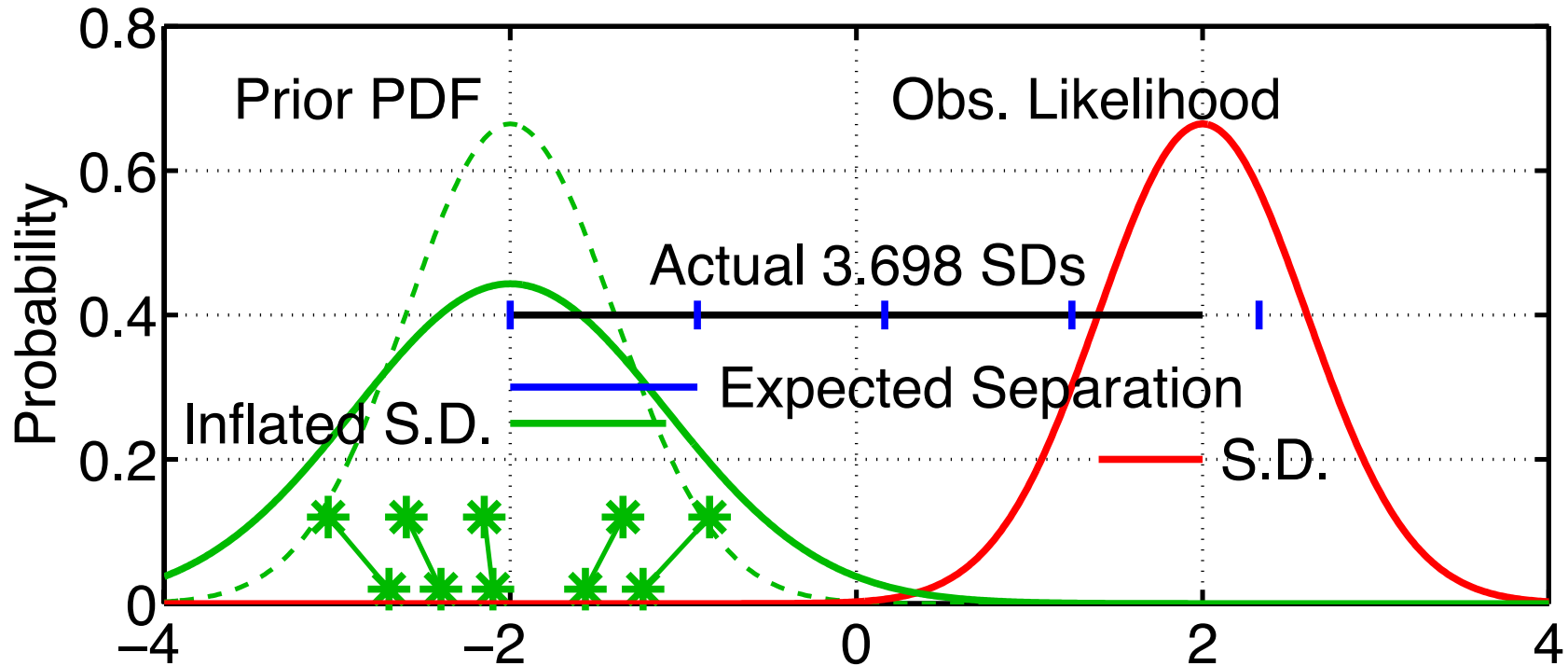
1. For observed variable, have estimate of prior-observed inconsistency.

# 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.

# Variance inflation in observation space: Lorenz 96

## Variance inflation in observation space not currently supported.

Try some values and see what happens to L96 assimilation.

Set *inf\_flavor=1*, observation space inflation in first column.

Try some values and see what happens to L96 assimilation.

Set *inf\_initial* to values like 1.05, 1.08, 1.10 in first column.

Make sure that *cutoff=10000000* and *ens\_size=20*.

(These were settings that diverged without inflation)

# 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)