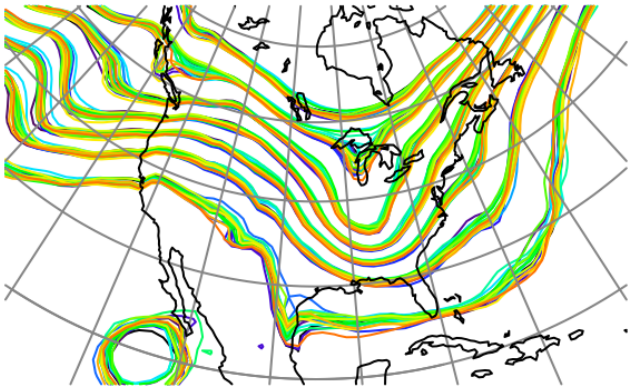
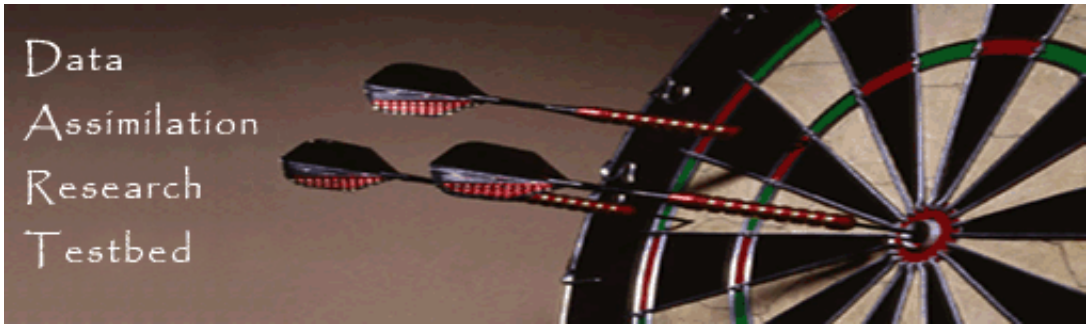


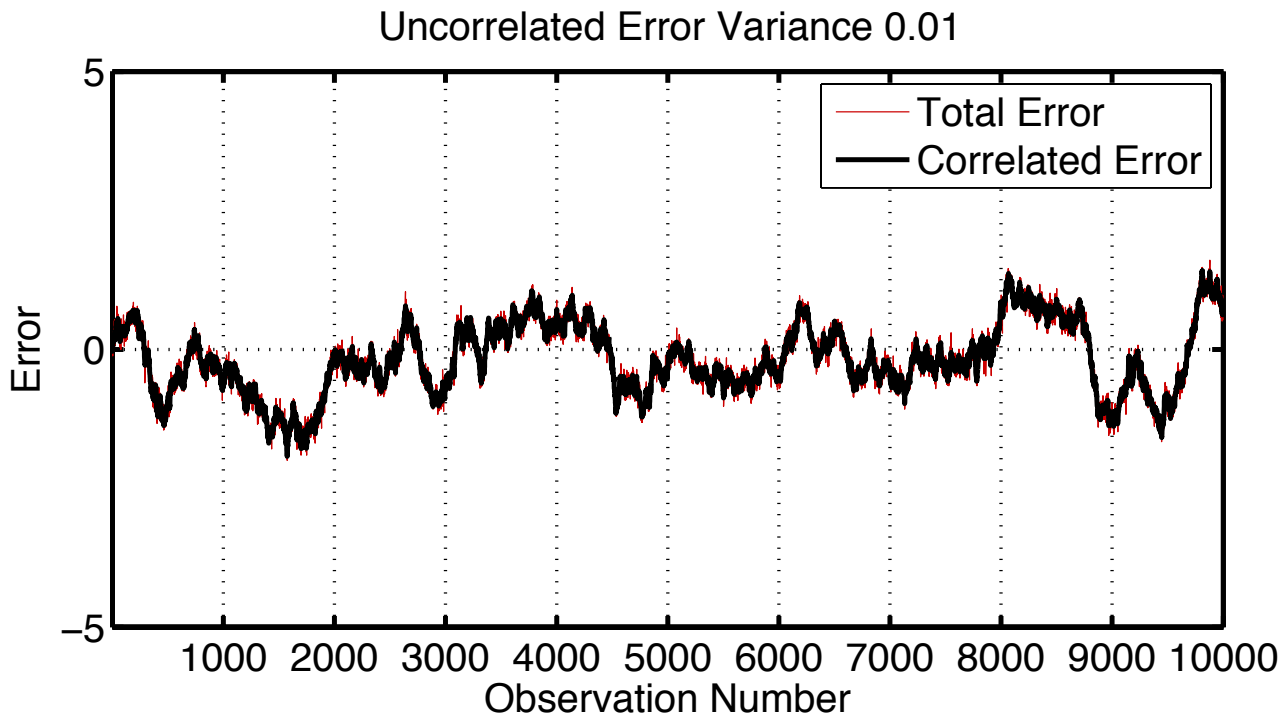
Assimilating Observations with Spatially and Temporally Correlated Errors in a Global Atmospheric Model

Jeffrey Anderson, NCAR Data Assimilation Research Section



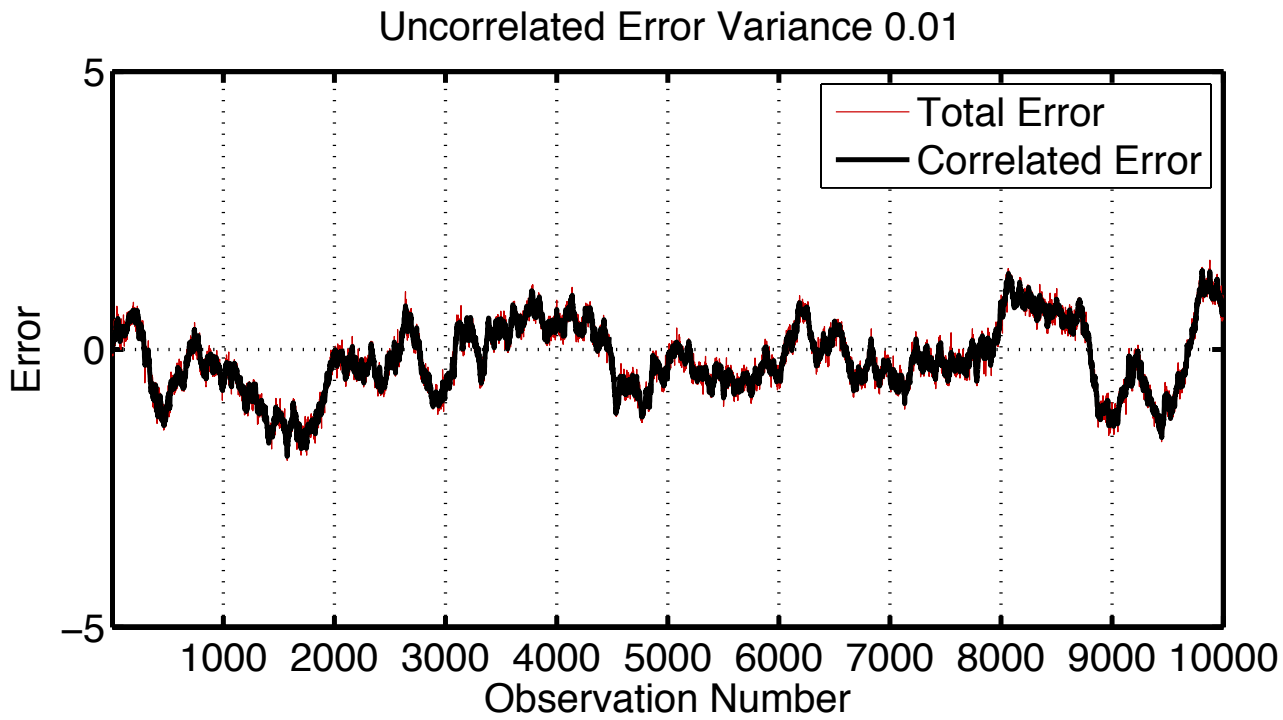
Observation Error Time Series

Example: Correlated Error AR1 with Variance 1.
Single Step Cov 0.999. Fixed for all cases.



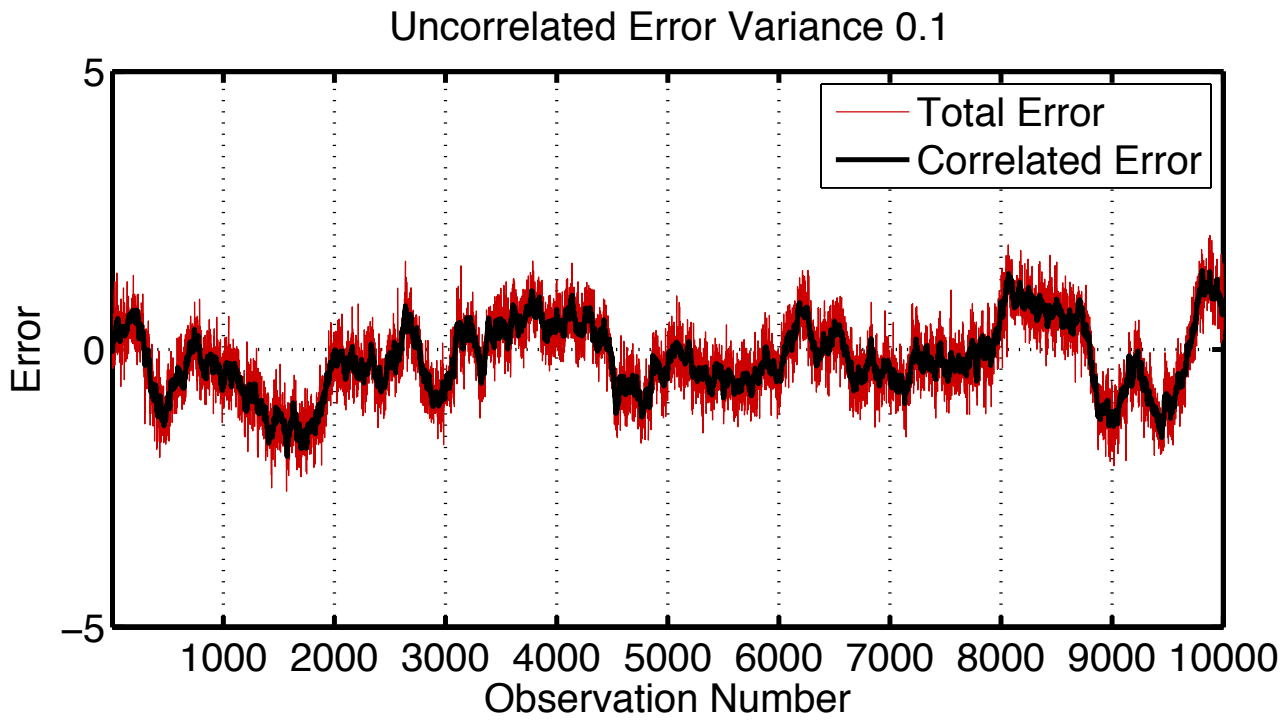
Observation Error Time Series

Example: Correlated Error AR1 with Variance 1.
Single Step Cov 0.999. Fixed for all cases.
Vary uncorrelated error variance, 0.01



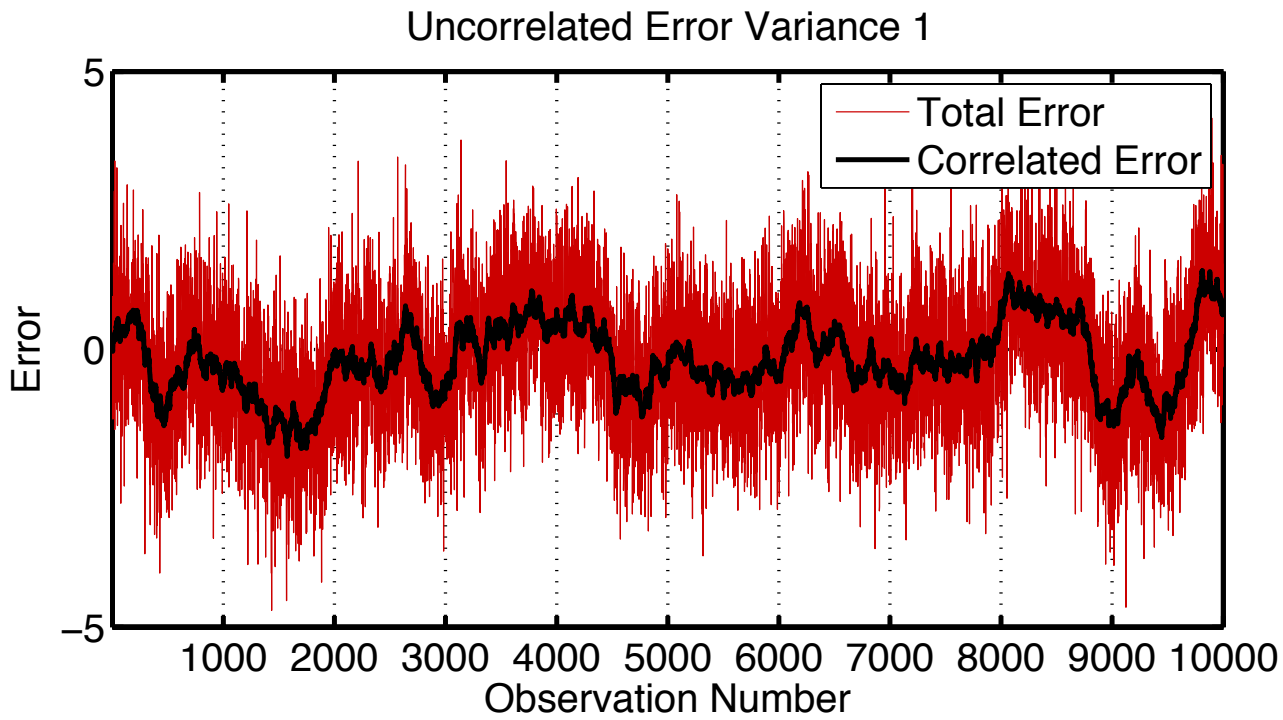
Observation Error Time Series

Example: Correlated Error AR1 with Variance 1.
Single Step Cov 0.999. Fixed for all cases.
Vary uncorrelated error variance, 0.1



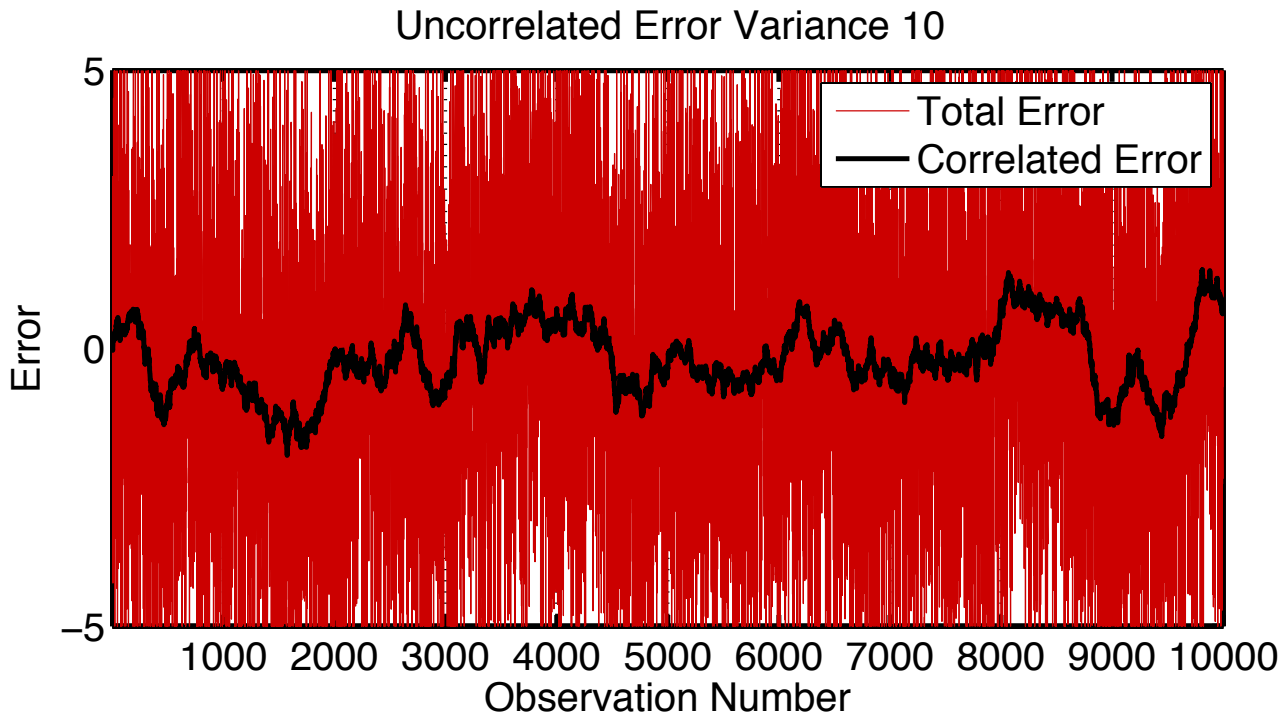
Observation Error Time Series

Example: Correlated Error AR1 with Variance 1.
Single Step Cov 0.999. Fixed for all cases.
Vary uncorrelated error variance, 1.0



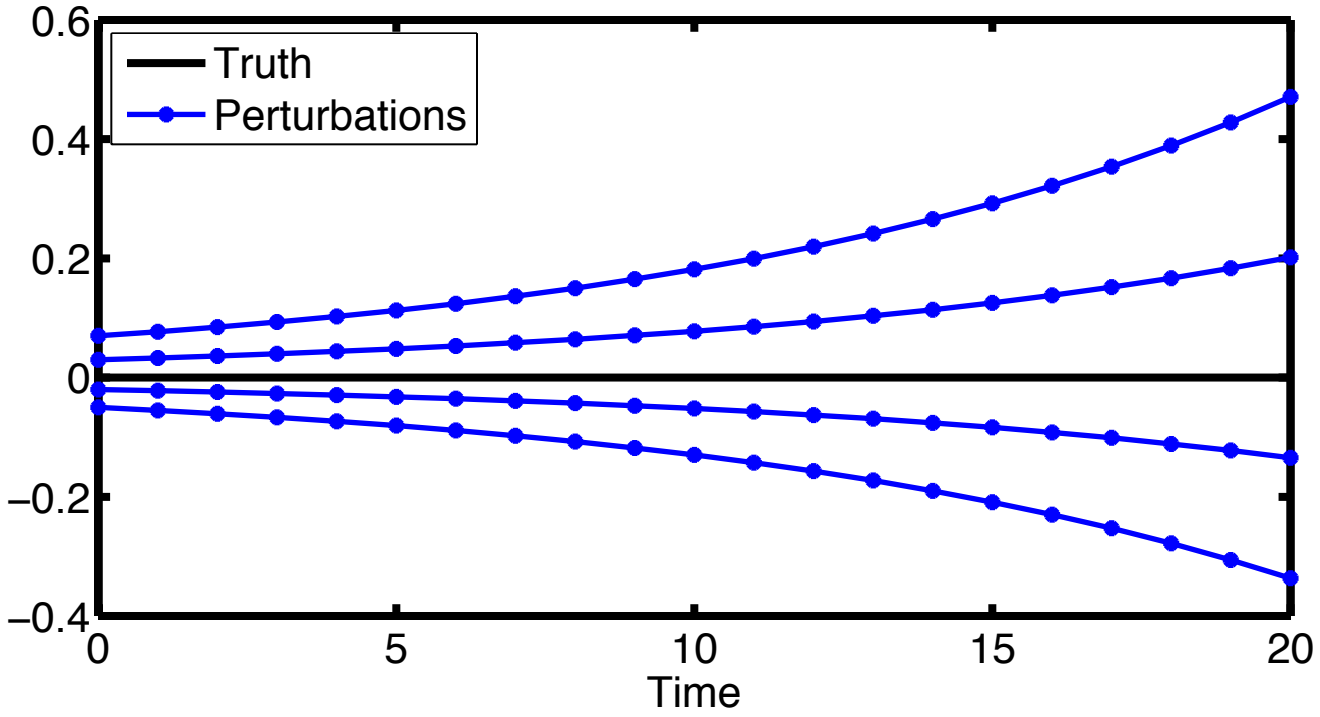
Observation Error Time Series

Example: Correlated Error AR1 with Variance 1.
Single Step Cov 0.999. Fixed for all cases.
Vary uncorrelated error variance, 10.0



1D Linear Exponential Growth Model

True trajectory is always 0.
Evolution is $x_{t+1} = 1.1x_t$
Perturbations grow exponentially in time.

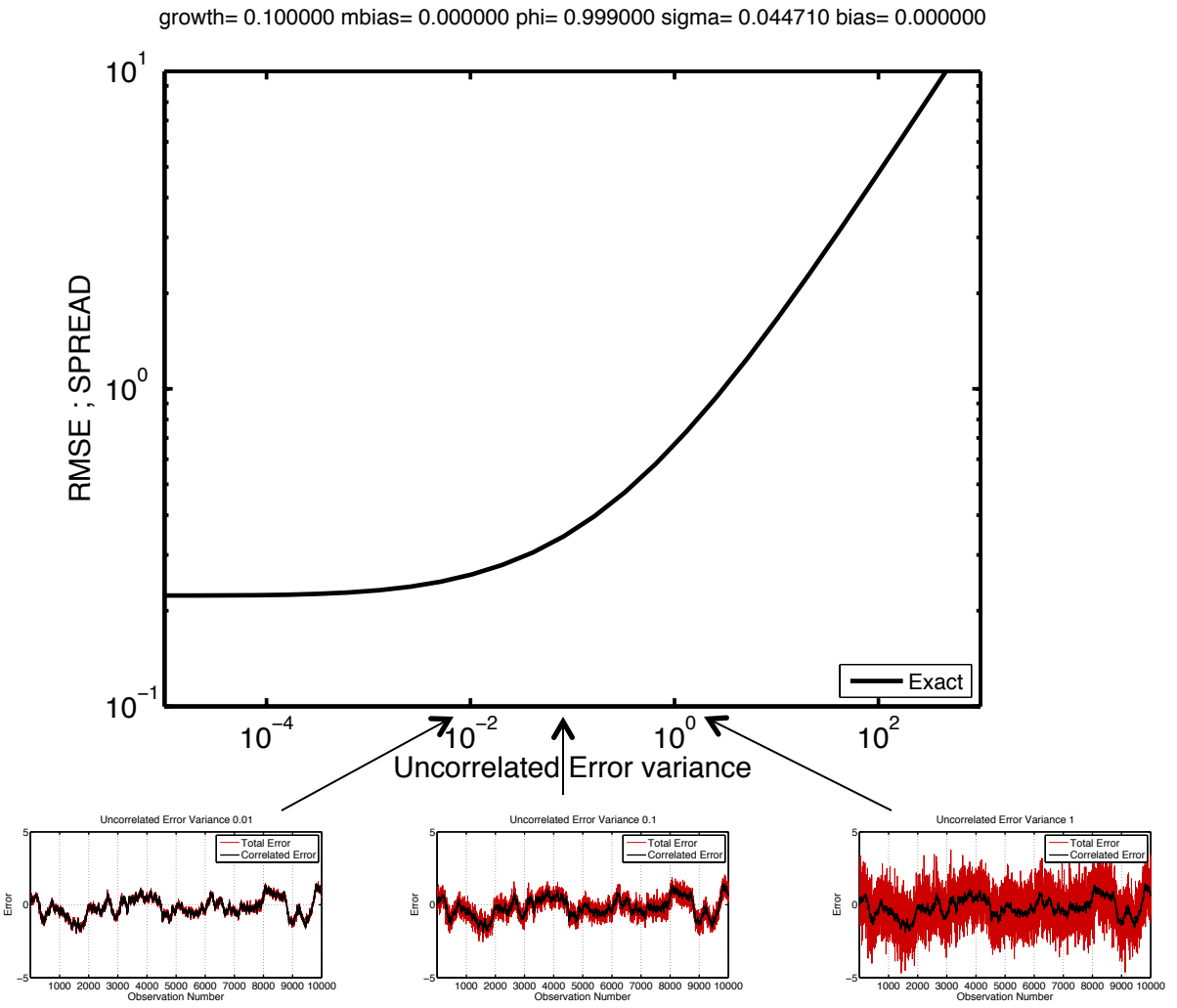


Assimilating Correlated Observations

Obs1 Obs2 Obs3 Obs4 Obs5 Obs6

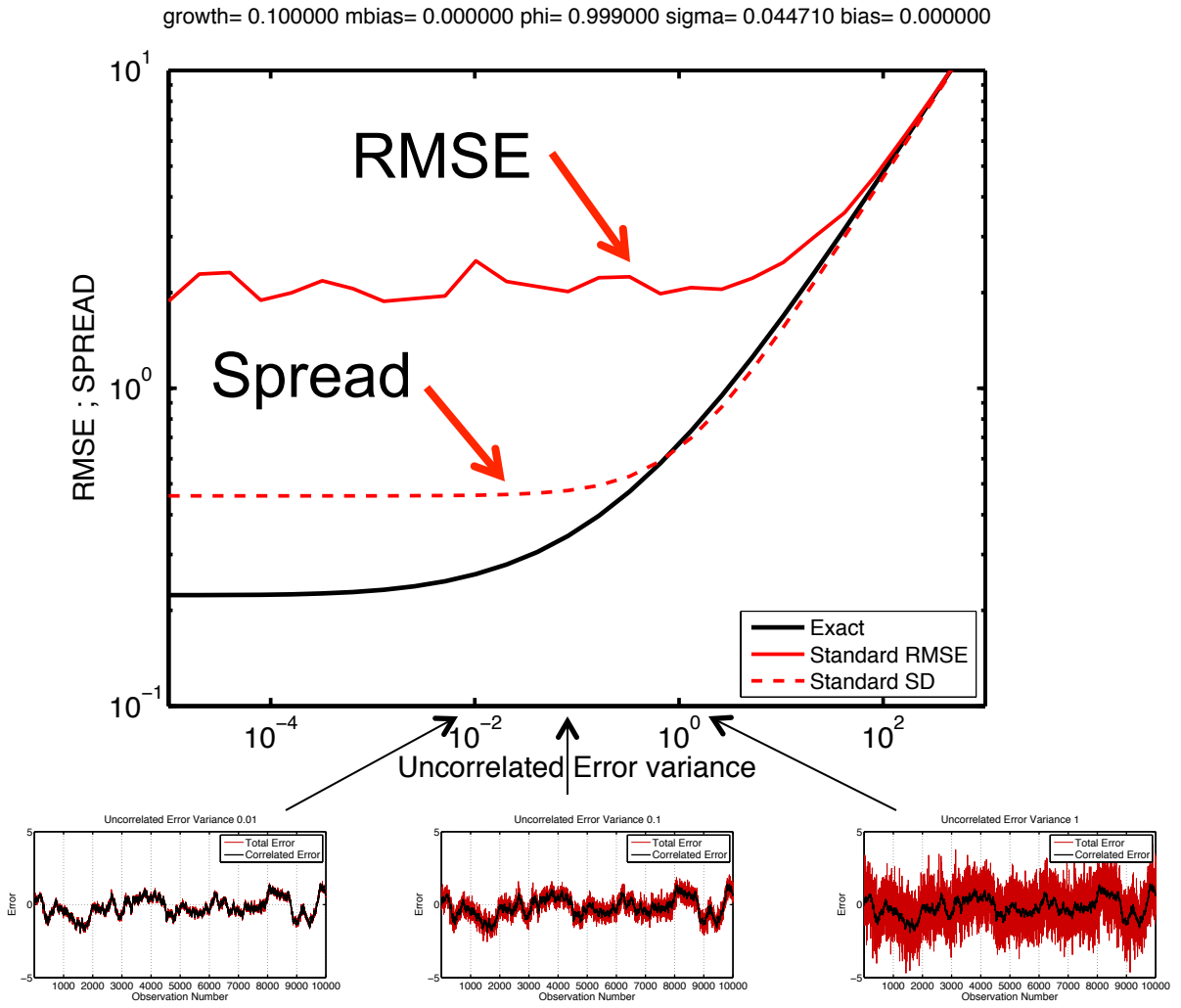
1D Exponential Growth Model Results

Exact Smoother Result. Can't do better than this.



1D Exponential Growth Model Results

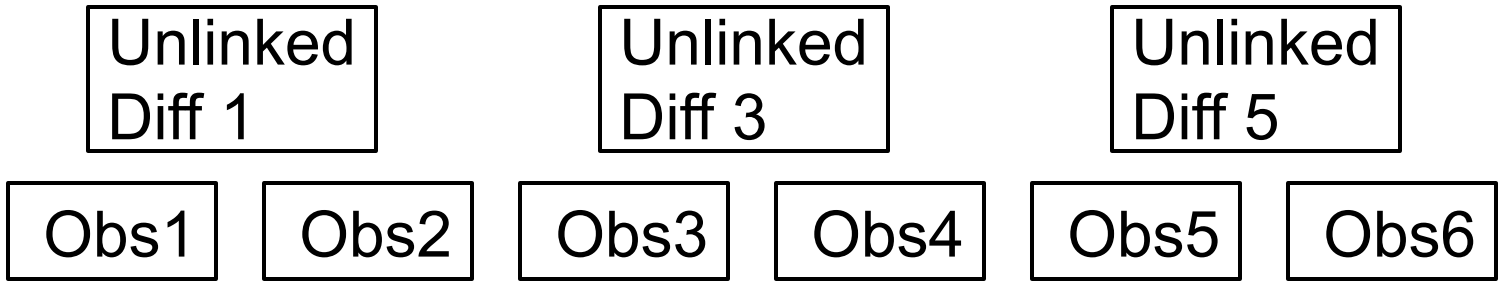
EAKF Poor Unless Uncorrelated Error Dominates



Two Types of Difference Observations

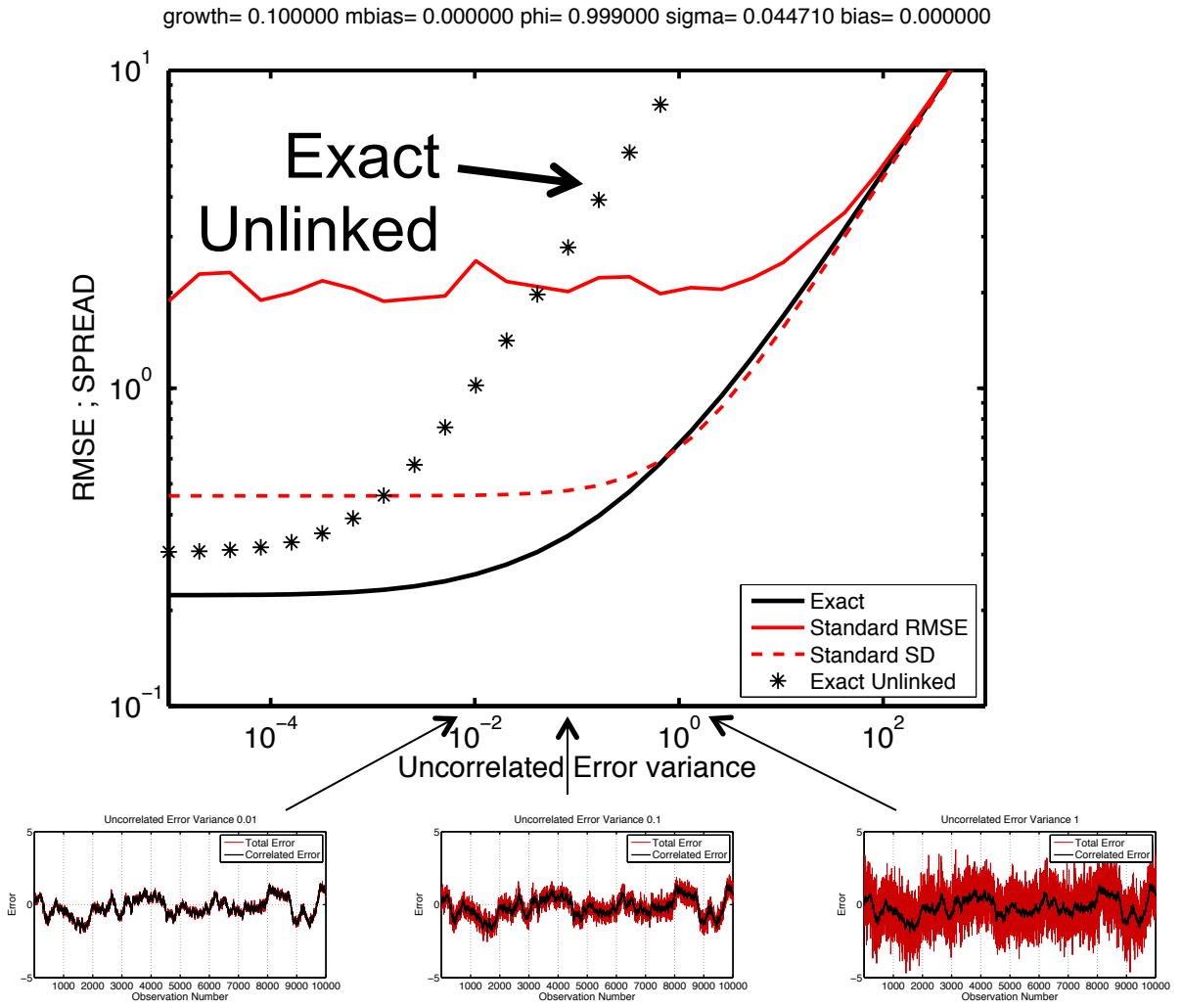
Obs1	Obs2	Obs3	Obs4	Obs5	Obs6

Unlinked Difference Observations



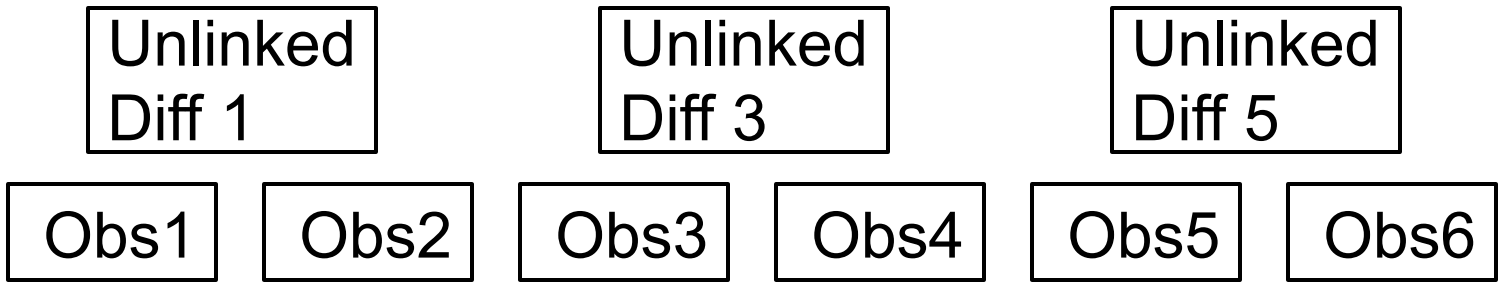
1D Exponential Growth Model Results

Exact Unlinked Difference Obs Much worse.



Uninked Difference Observations

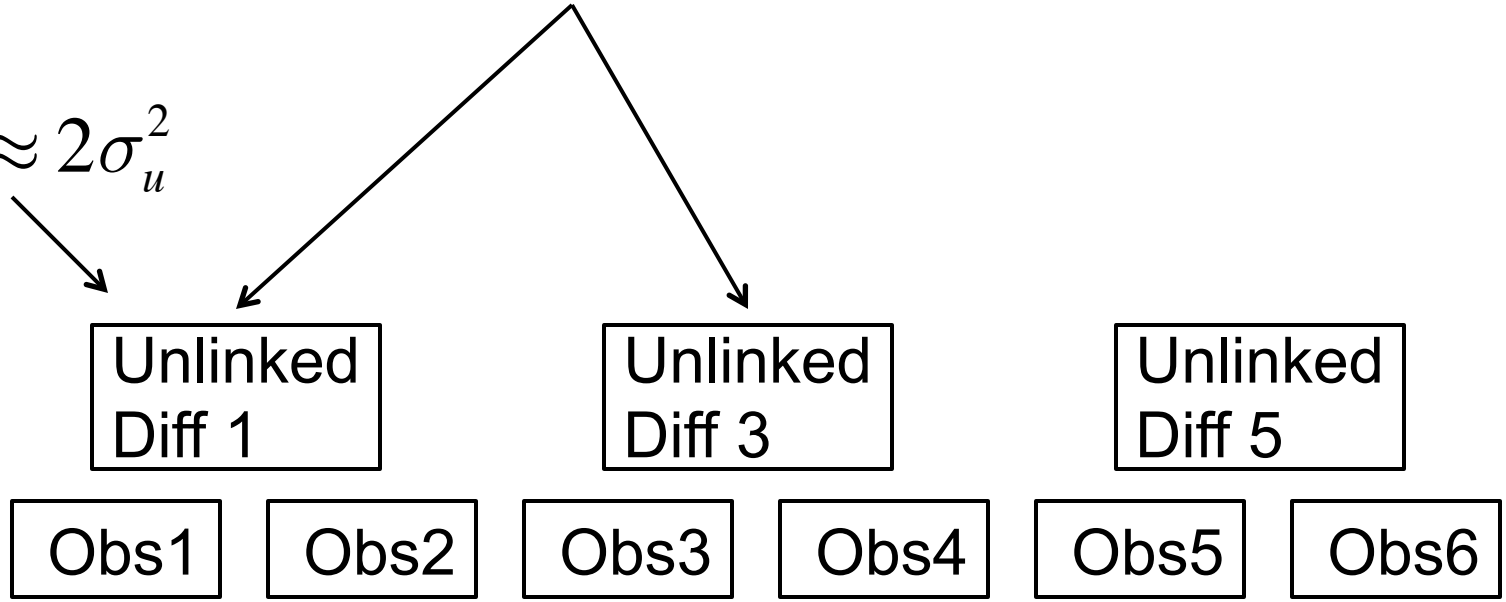
$$Var \approx 2\sigma_u^2$$



Uninked Difference Observations

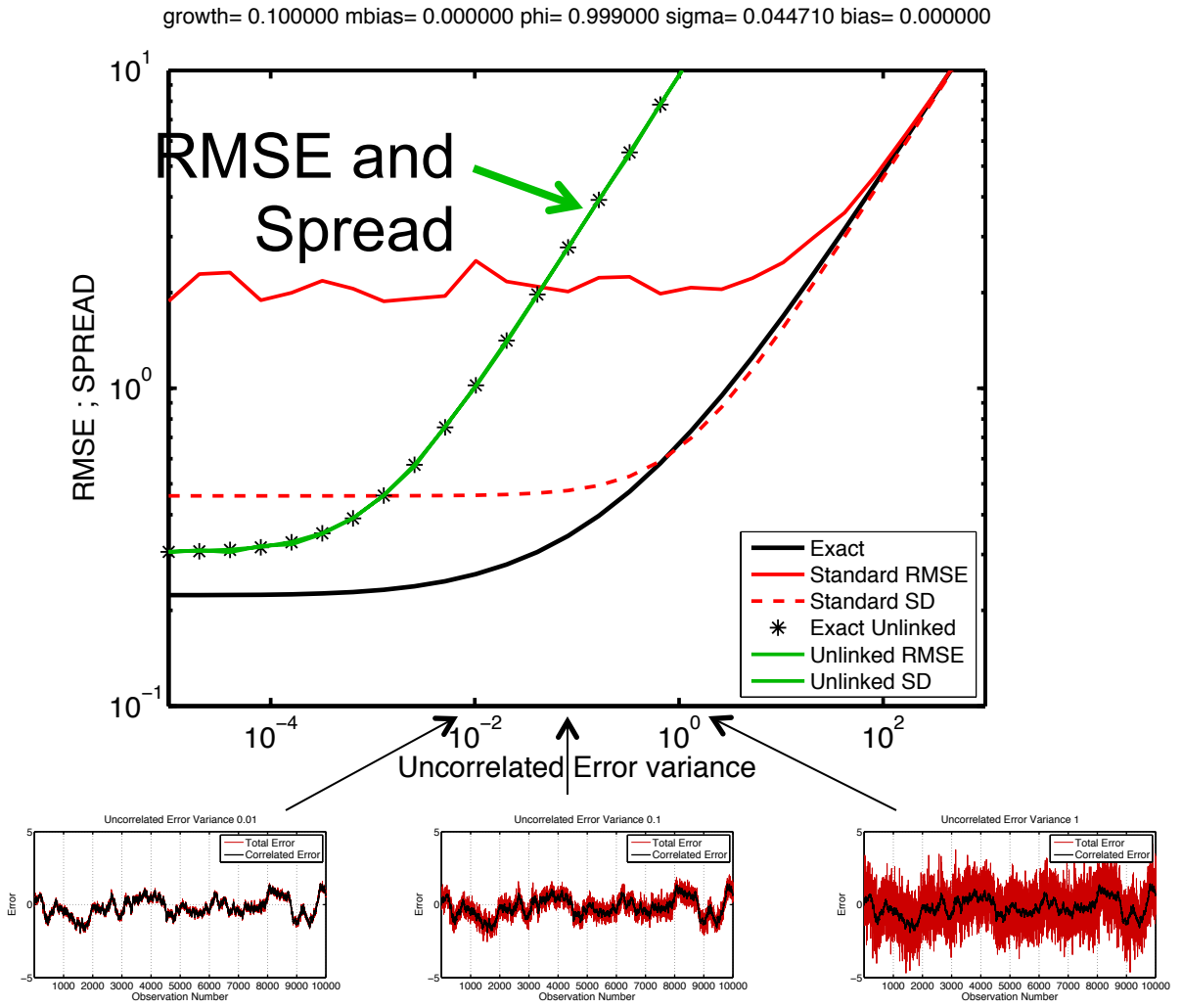
$$Cov(t, t+\Delta) \approx 0$$

$$Var \approx 2\sigma_u^2$$

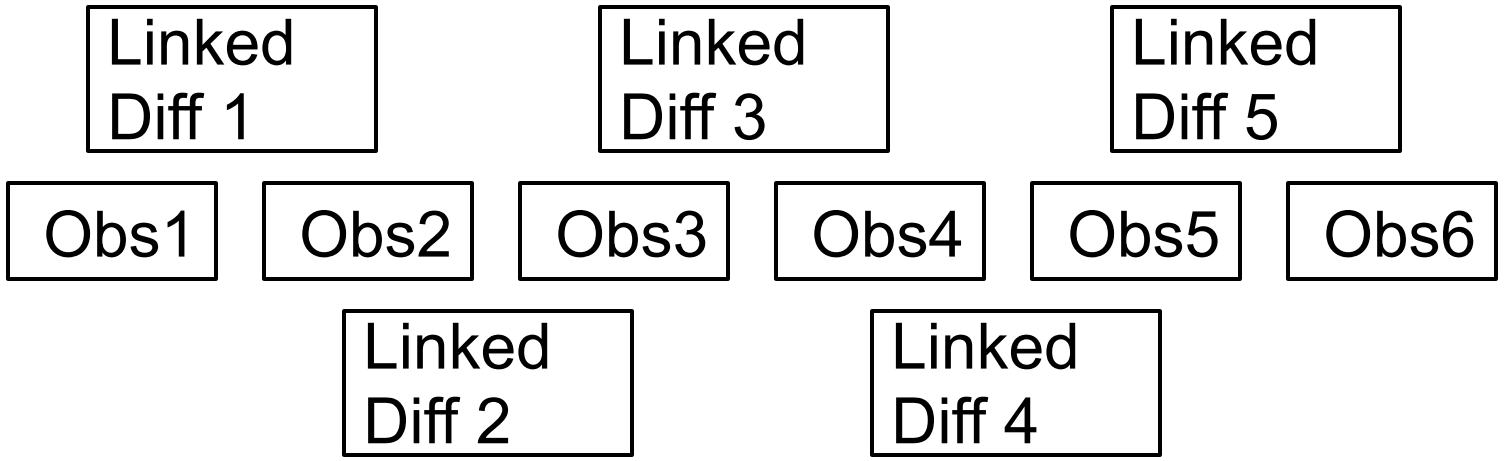


1D Exponential Growth Model Results

EAKF is nearly exact for Unlinked Difference Obs.

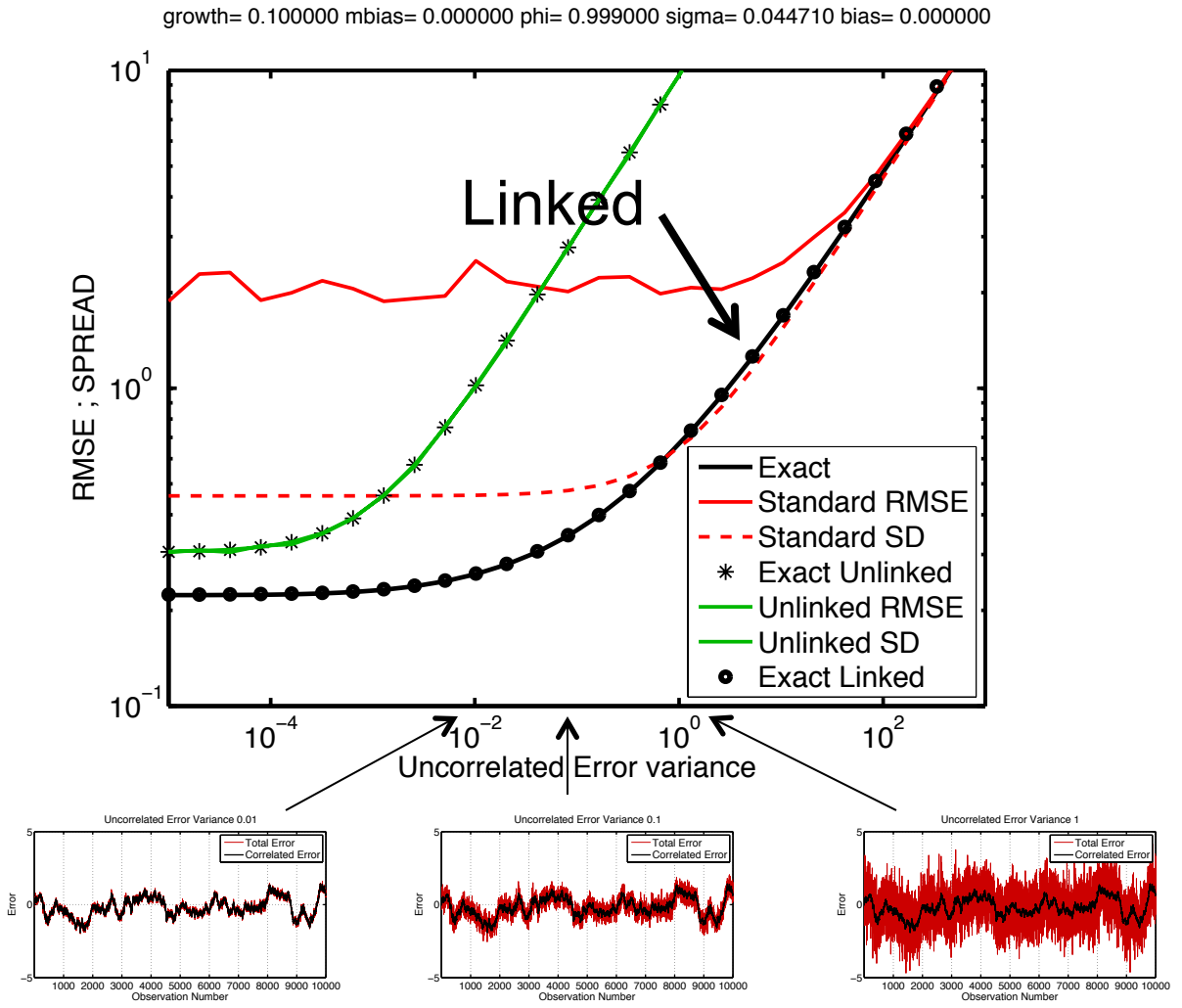


Linked Difference Observations



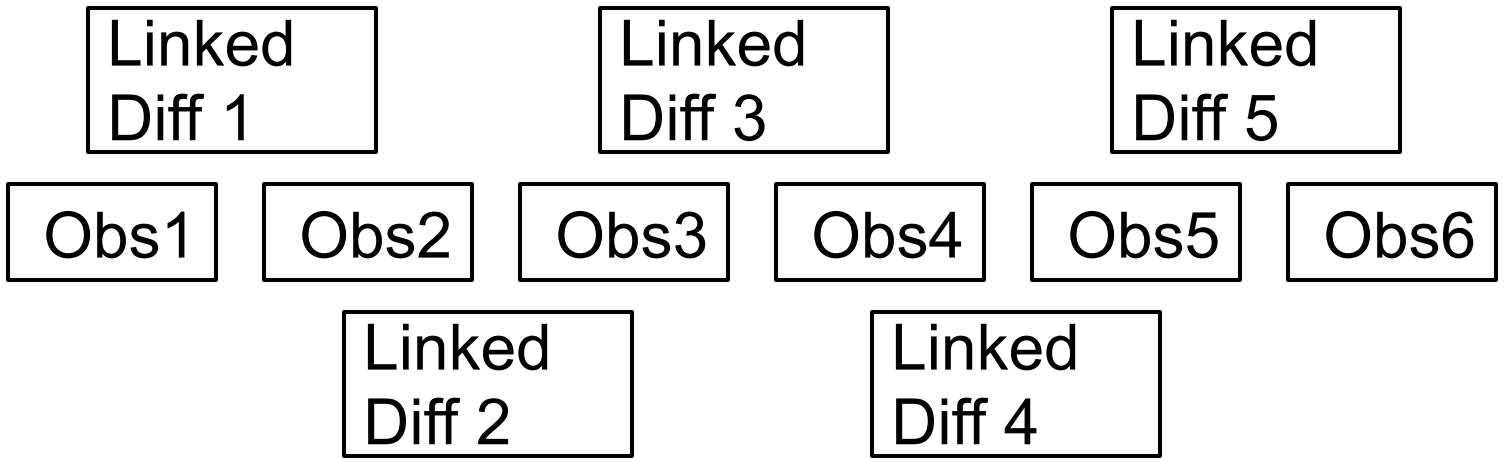
1D Exponential Growth Model Results

Exact linked Difference Obs Nearly Identical to Analytic.



Linked Difference Observations

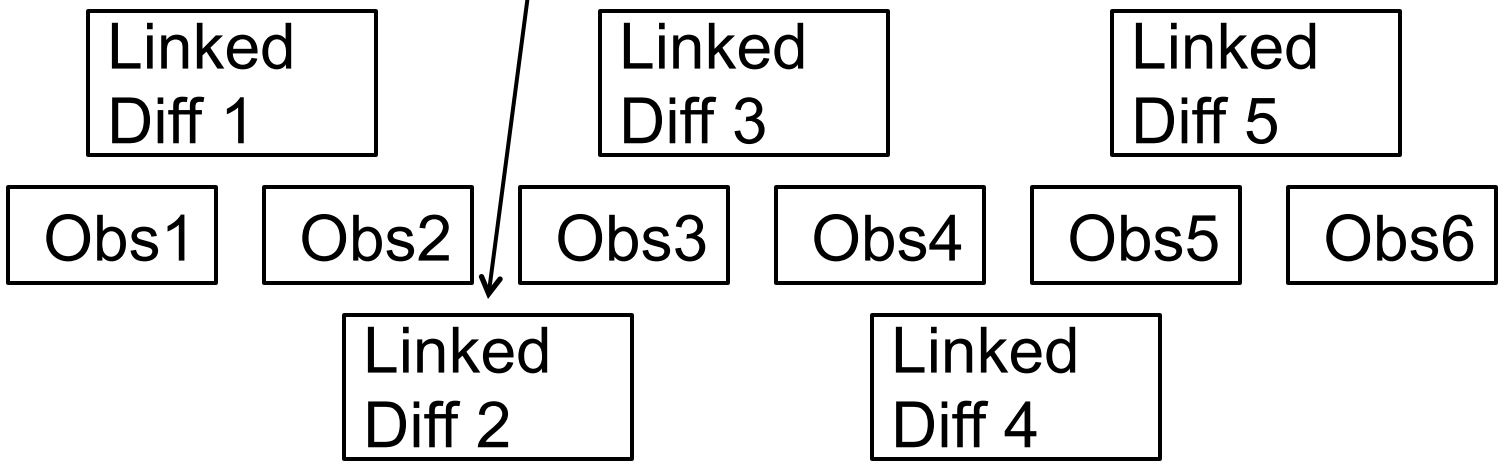
$$Var \approx 2\sigma_u^2$$



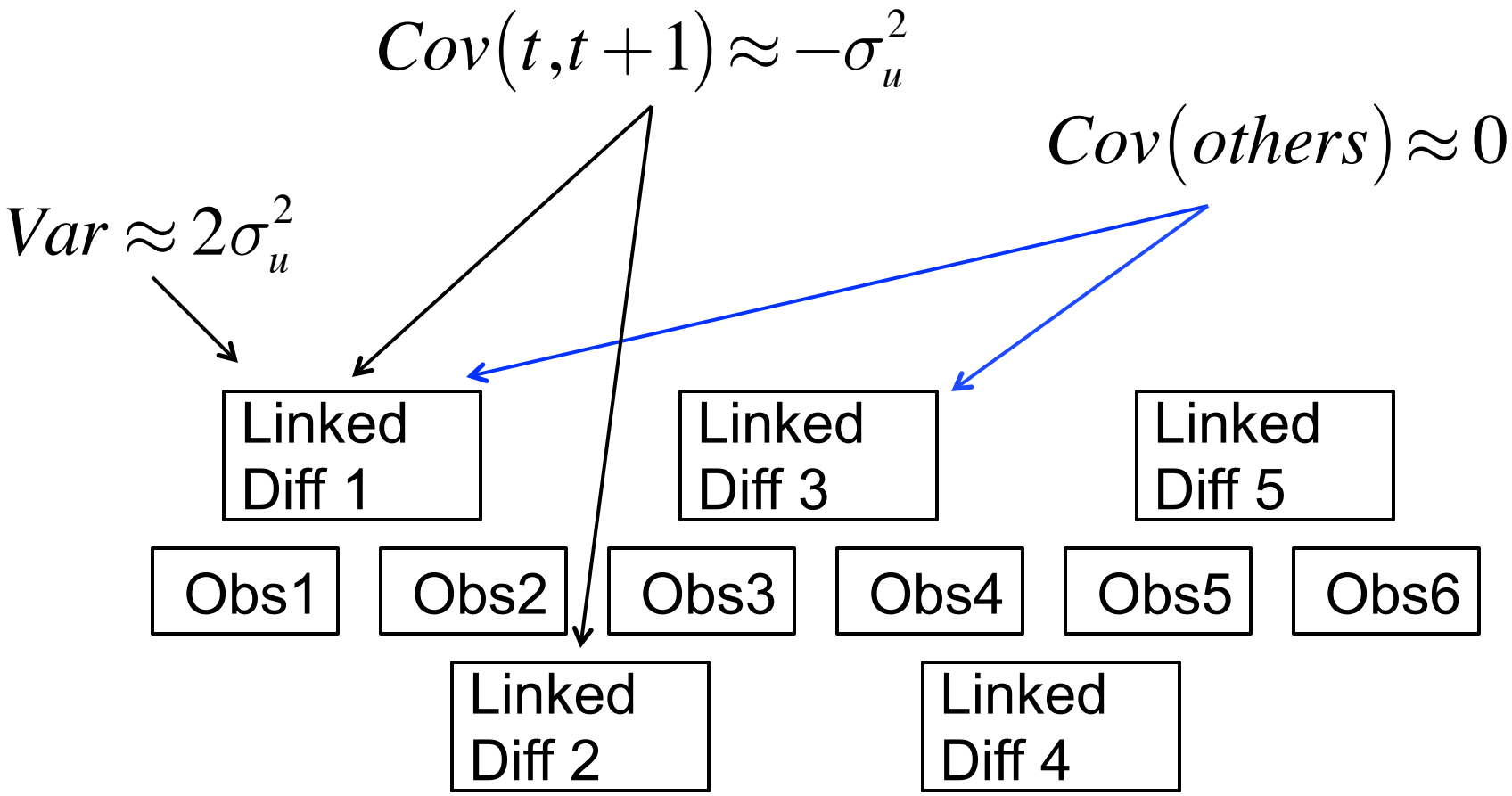
Linked Difference Observations

$$Cov(t, t+1) \approx -\sigma_u^2$$

$$Var \approx 2\sigma_u^2$$

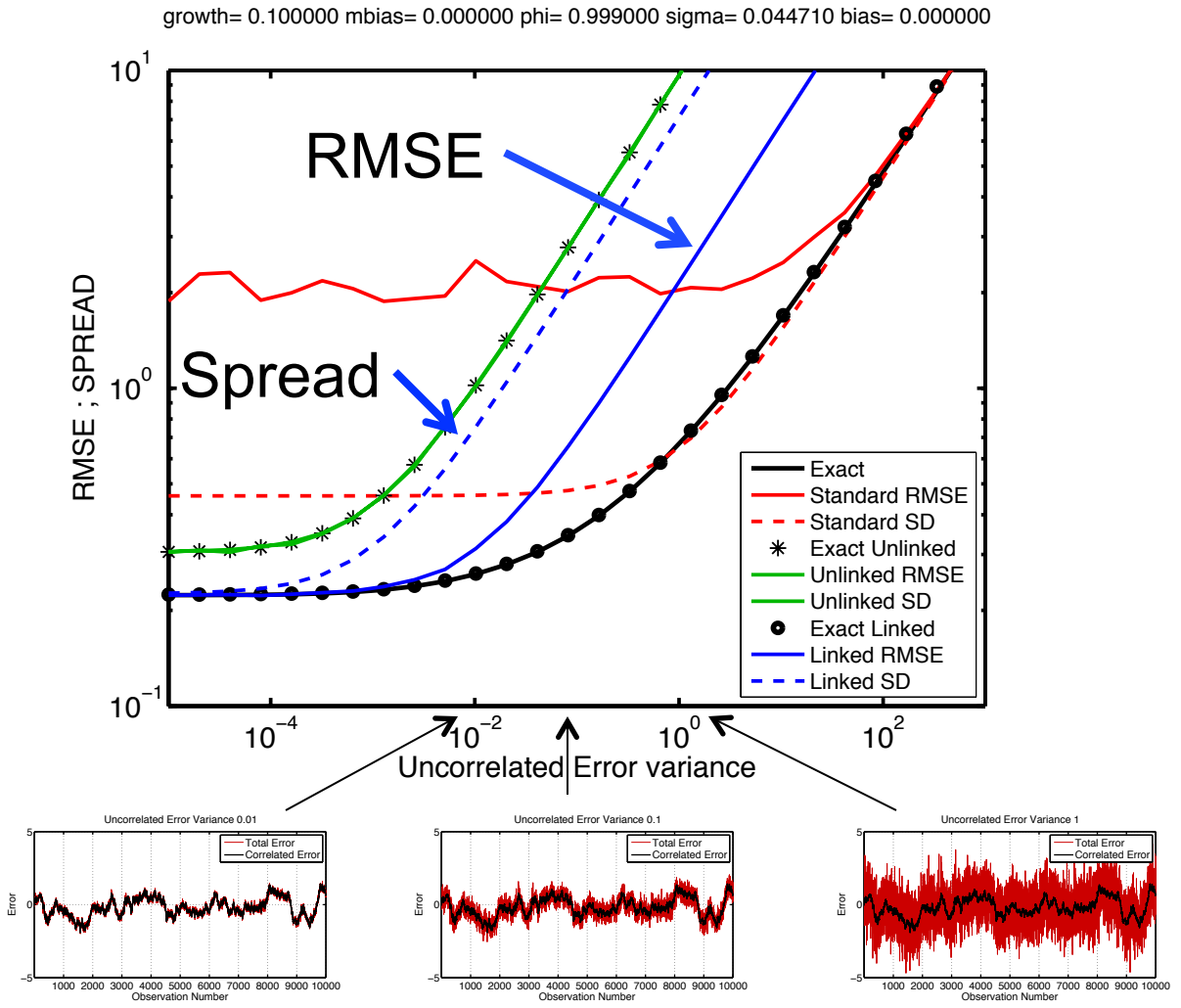


Linked Difference Observations



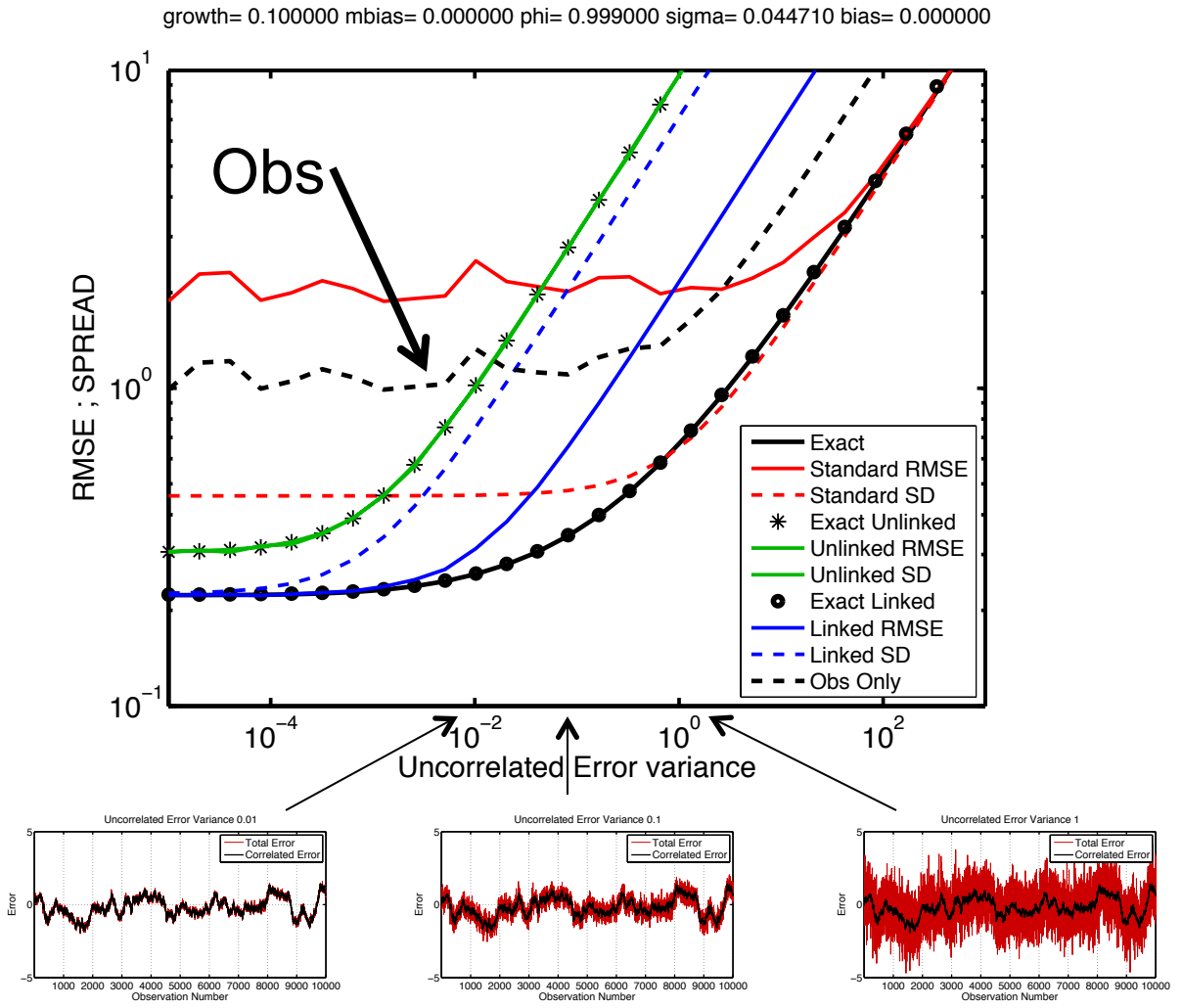
1D Exponential Growth Model Results

EAKF Linked Diff. Obs. Good when correlated error dominates.

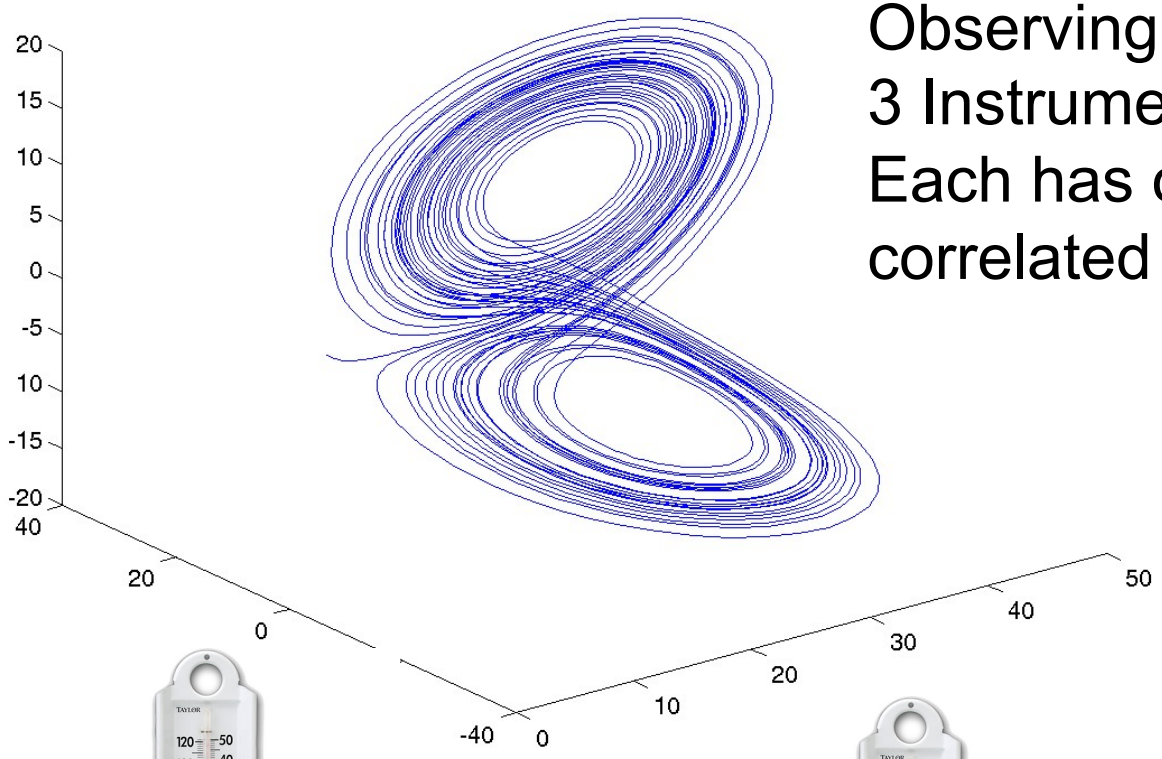


1D Exponential Growth Model Results

Comparison to Just Using Raw Observations

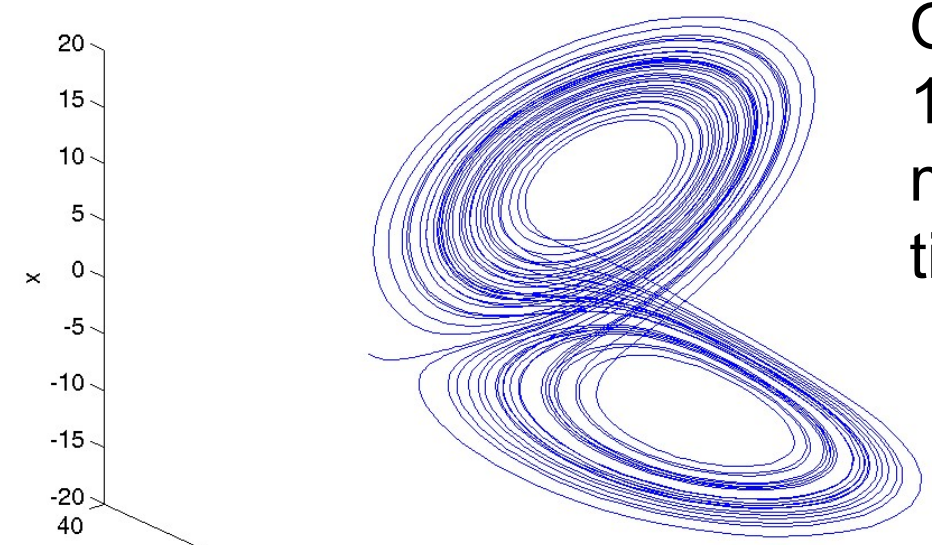


Lorenz 63 Model

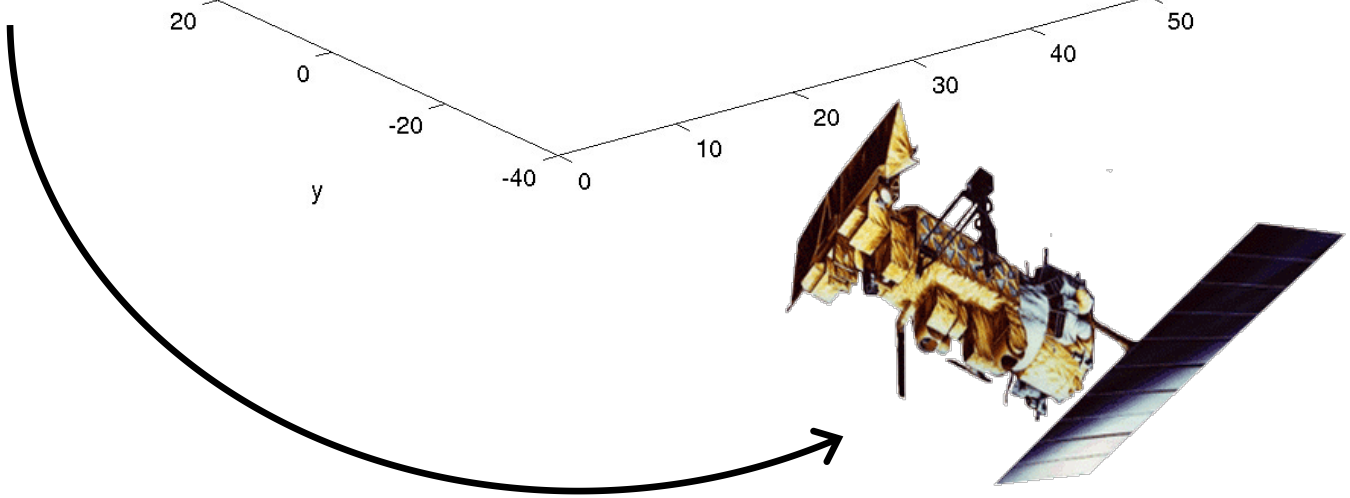


Observing System 1
3 Instruments.
Each has own
correlated error.

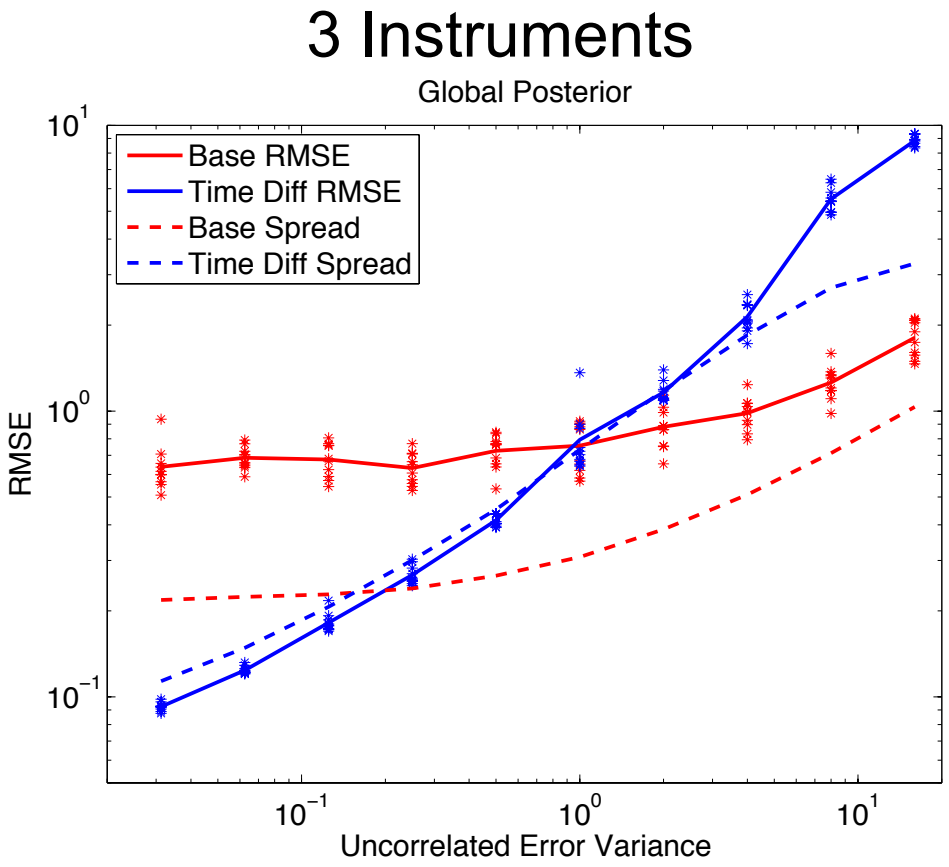
Lorenz 63 Model



Observing System 2
1 Instrument measures x,y,z each time.

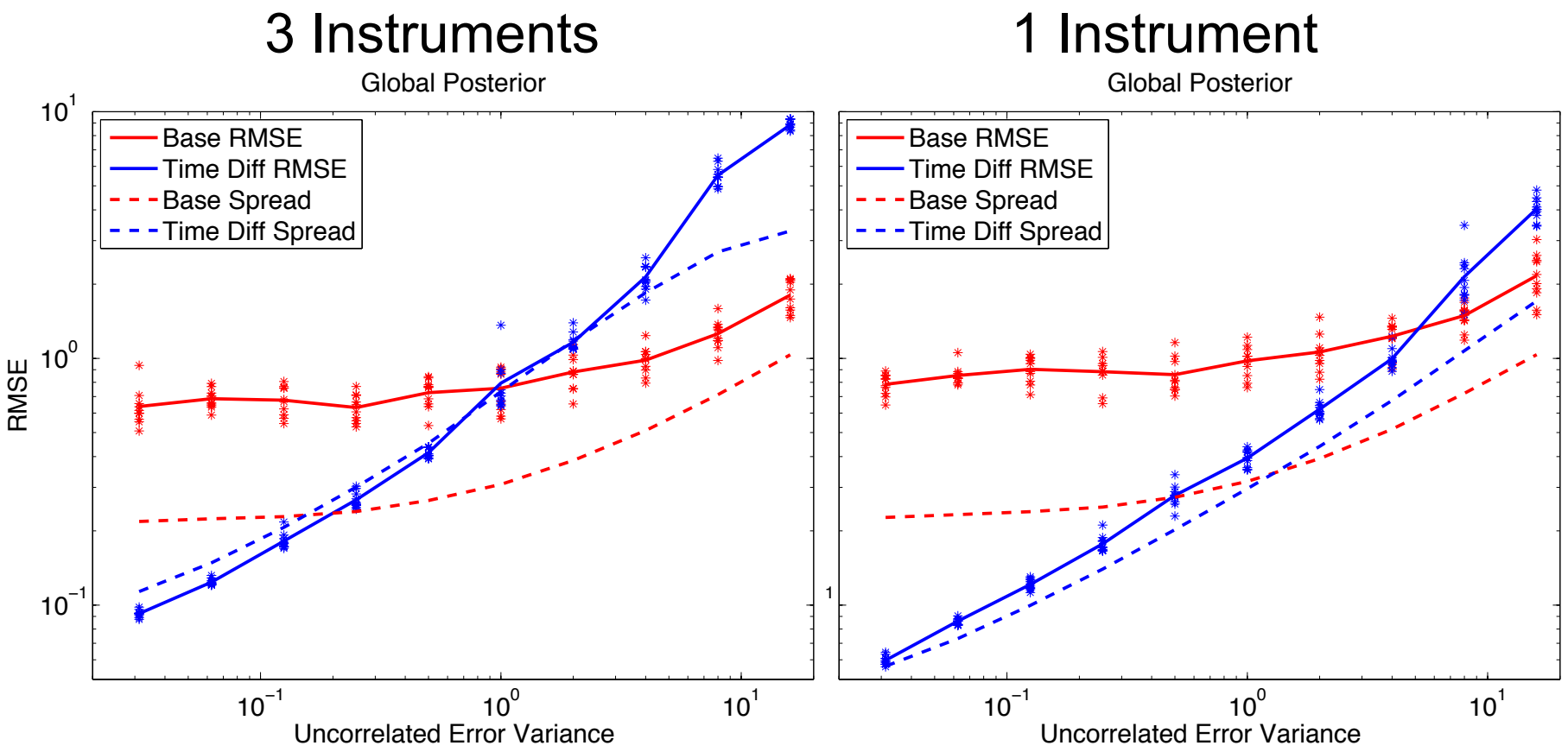


L63 Results, Linked Difference Obs



5 ensemble members.
Adaptive inflation.
Observations every 6 model timesteps.

L63 Results, Linked Difference Obs

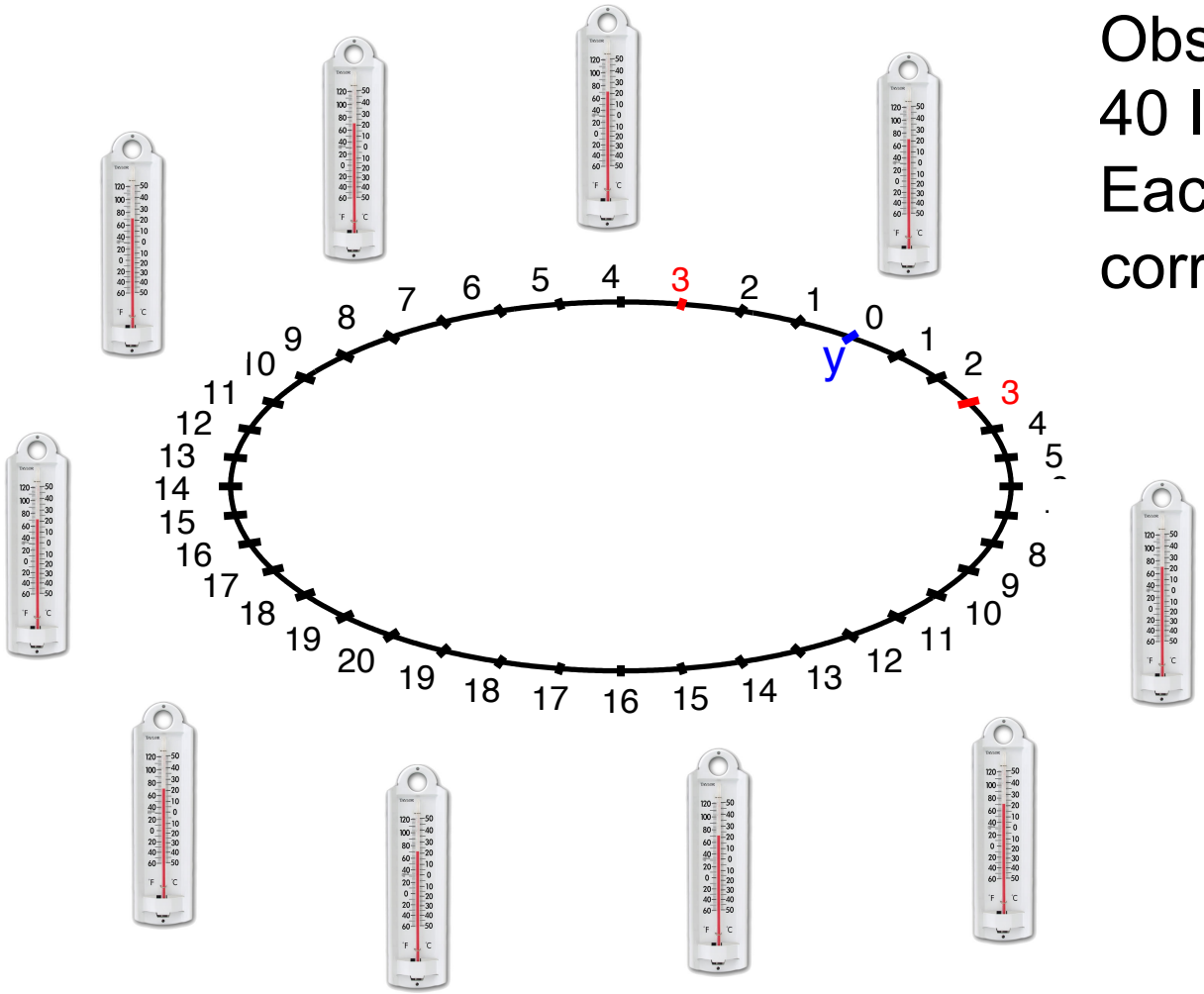


5 ensemble members.
Adaptive inflation.
Observations every 6 model timesteps.

L63 Summary

- Difference obs better unless uncorrelated error variance dominates.
- Improvement greater for single instrument.
- Ensembles often under-dispersive (what a surprise!).

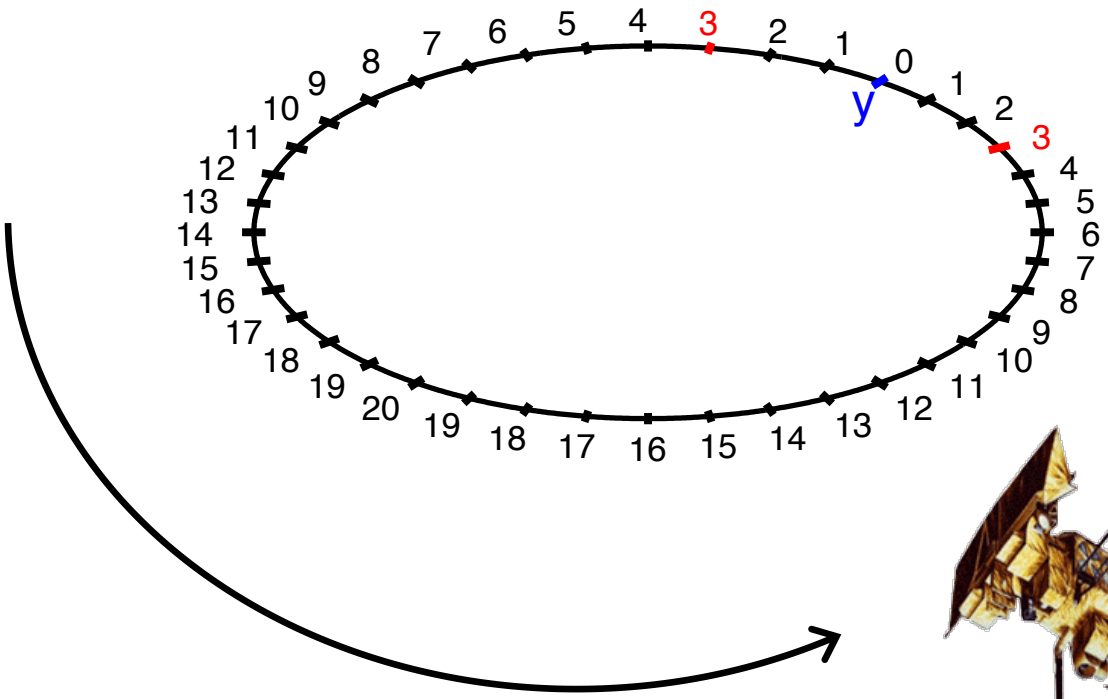
Lorenz 96 Model, 40-variables

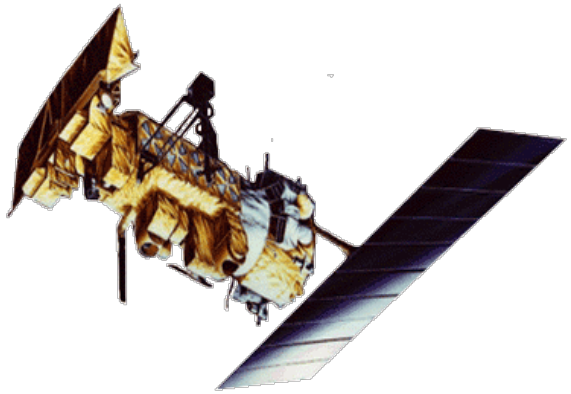


Observing System 1
40 Instruments.
Each has own
correlated error.

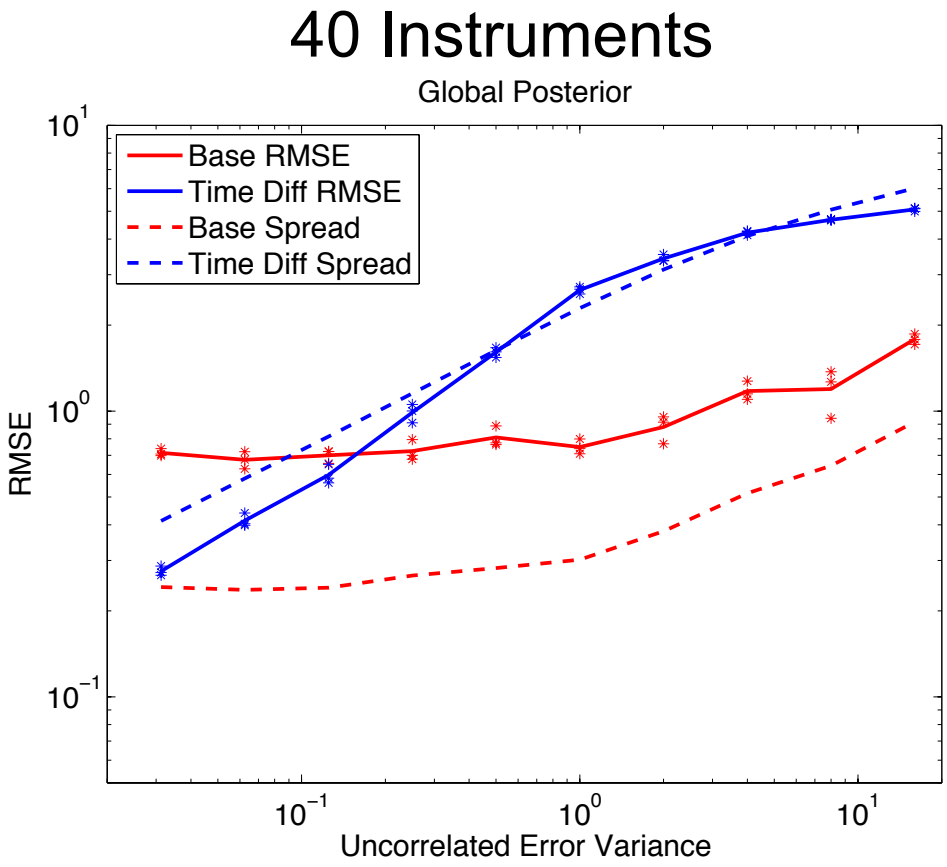
Lorenz 96 Model, 40-variables

Observing System 2
1 instrument
measures all 40
variables each time.



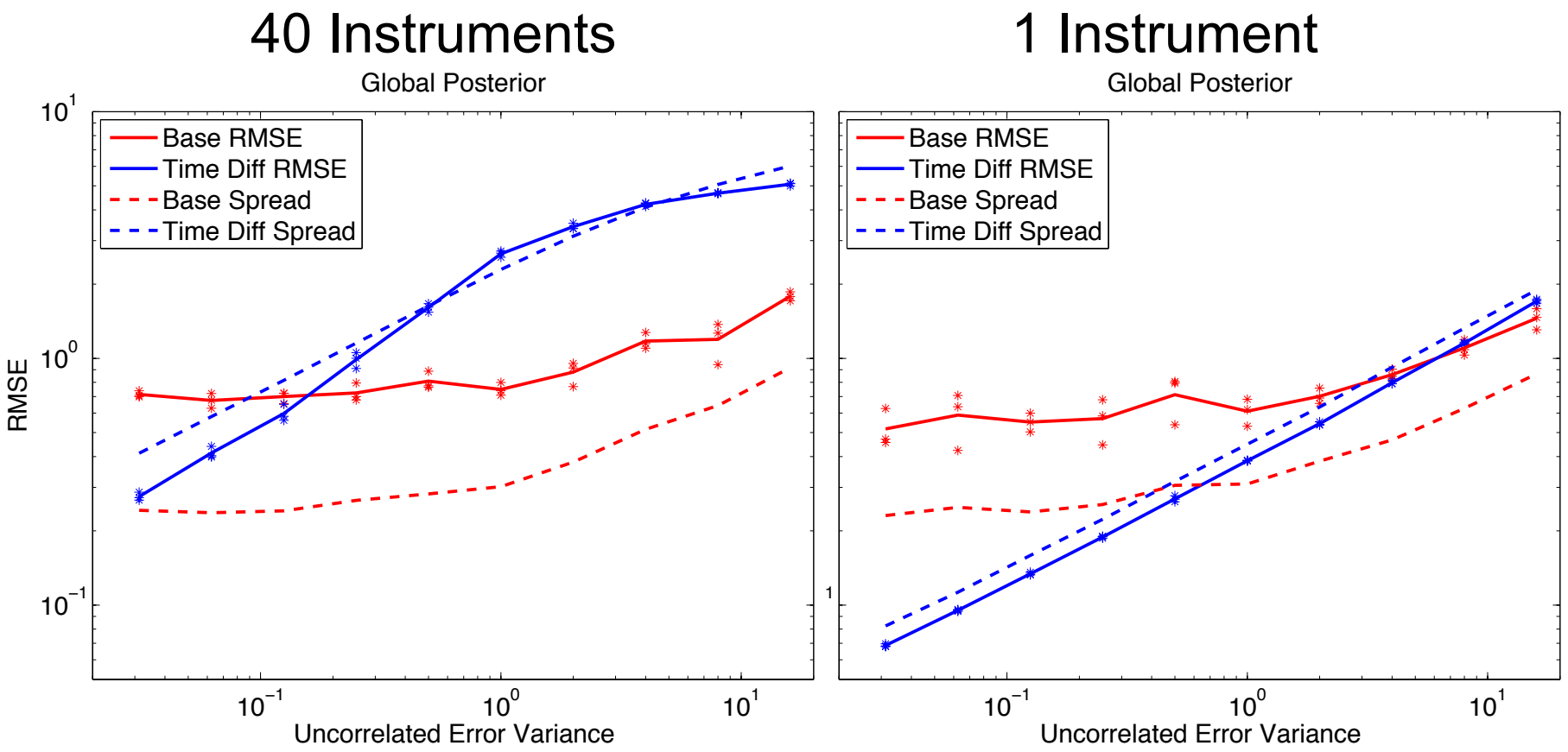


L96 Results, Linked Difference Obs



10 ensemble members.
Adaptive inflation, 0.2 halfwidth localization.
Observations every model timestep.

L96 Results, Linked Difference Obs

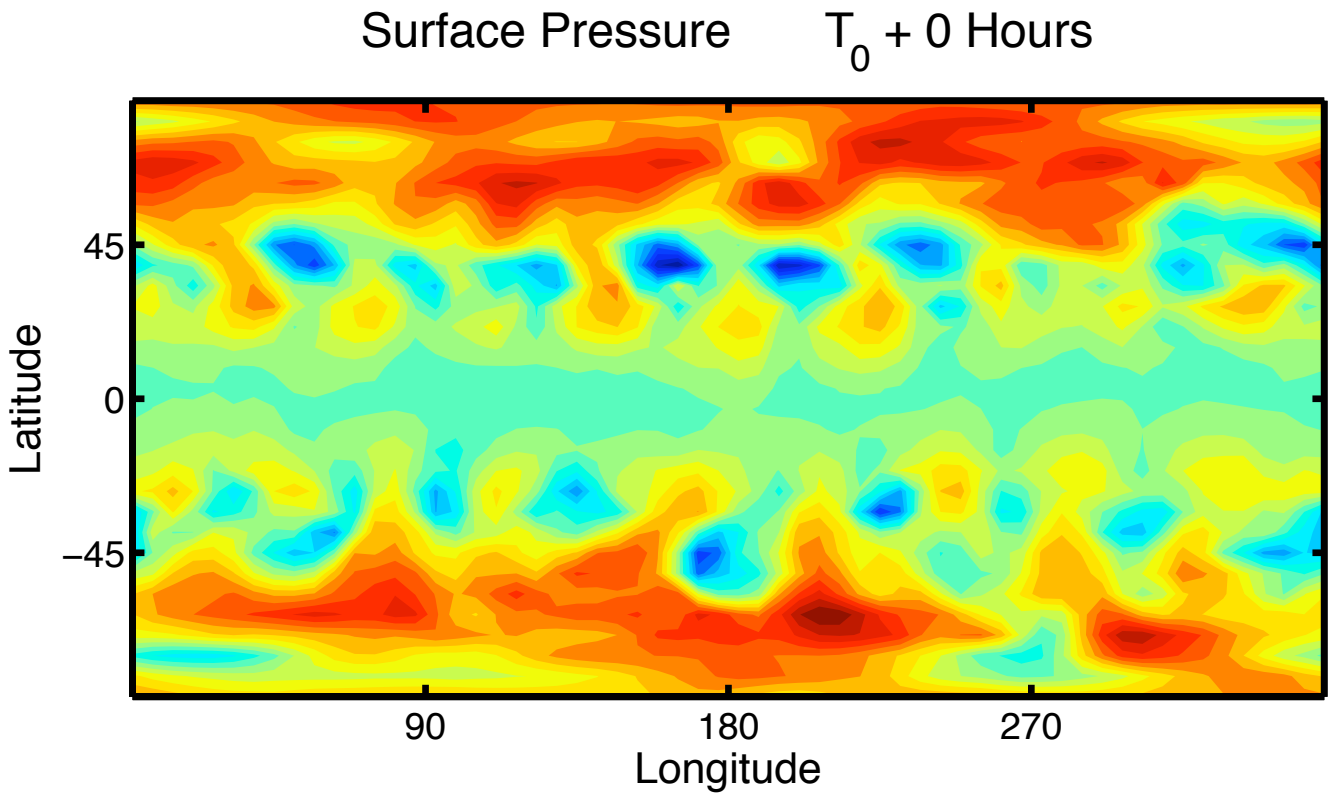


10 ensemble members.
Adaptive inflation, 0.2 halfwidth localization.
Observations every model timestep.

L96 Results, Linked Difference Obs

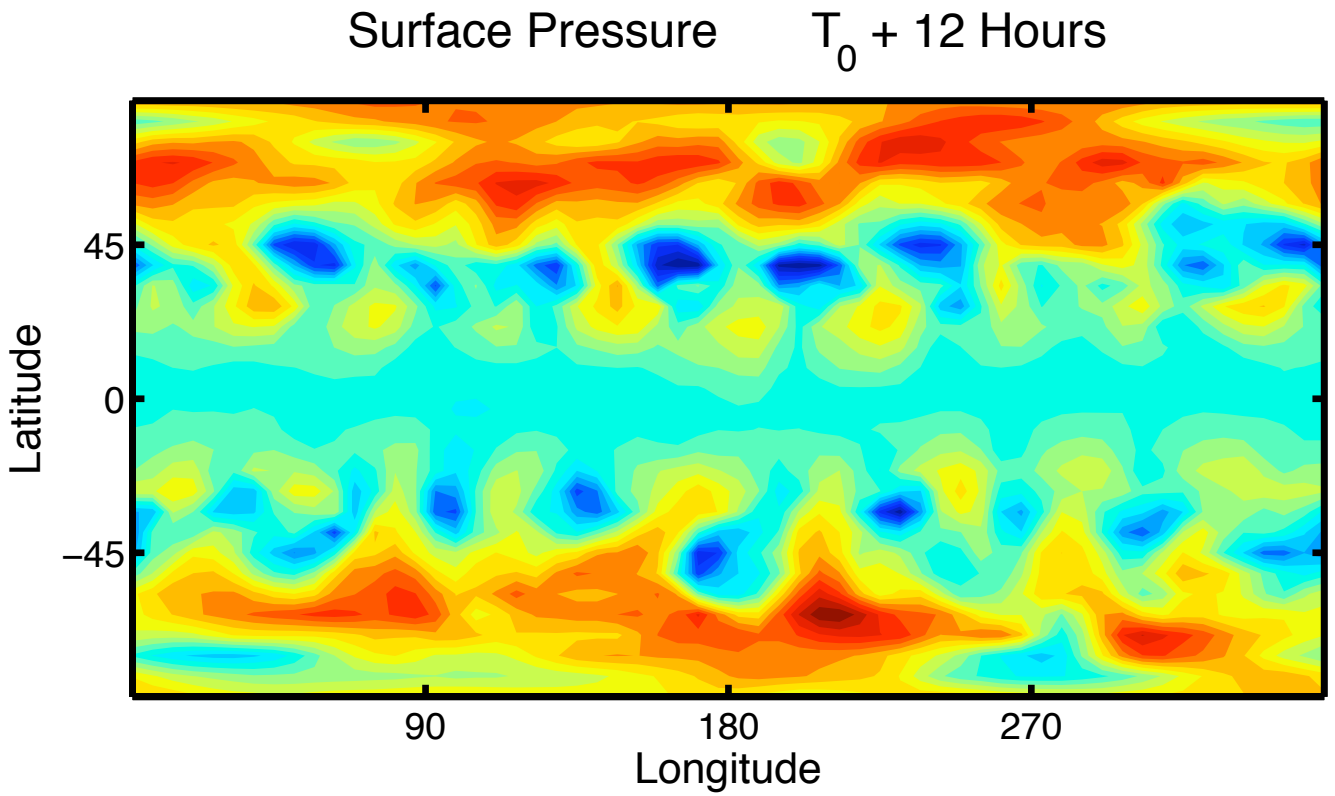
- Difference obs better unless uncorrelated error variance dominates.
- Improvement much greater for single instrument.
- Ensembles often over-dispersive.
- Dealing with time correlation harder than space correlation.

Low-Order Dry Dynamical Core



Evolution of surface pressure field every 12 hours.
Has baroclinic instability: storms move east in midlatitudes.

Low-Order Dry Dynamical Core



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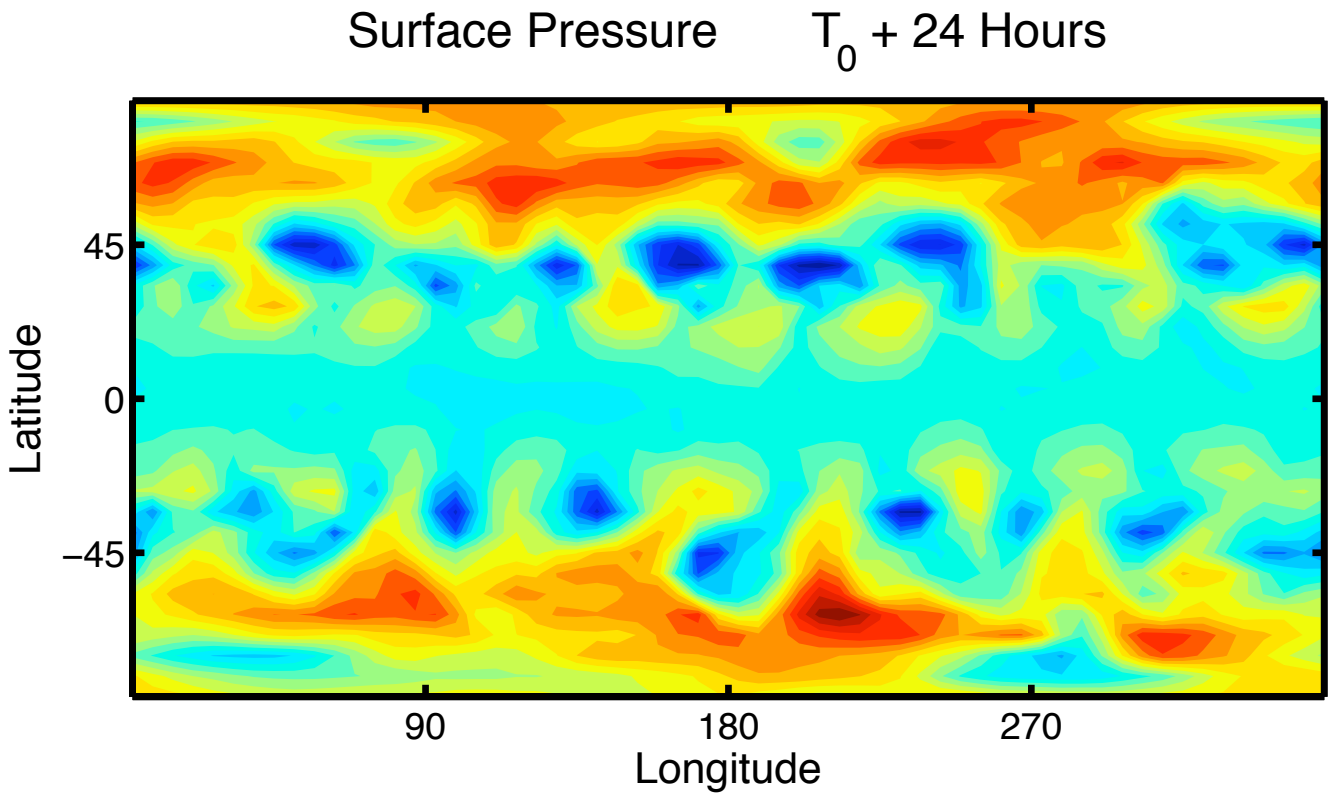

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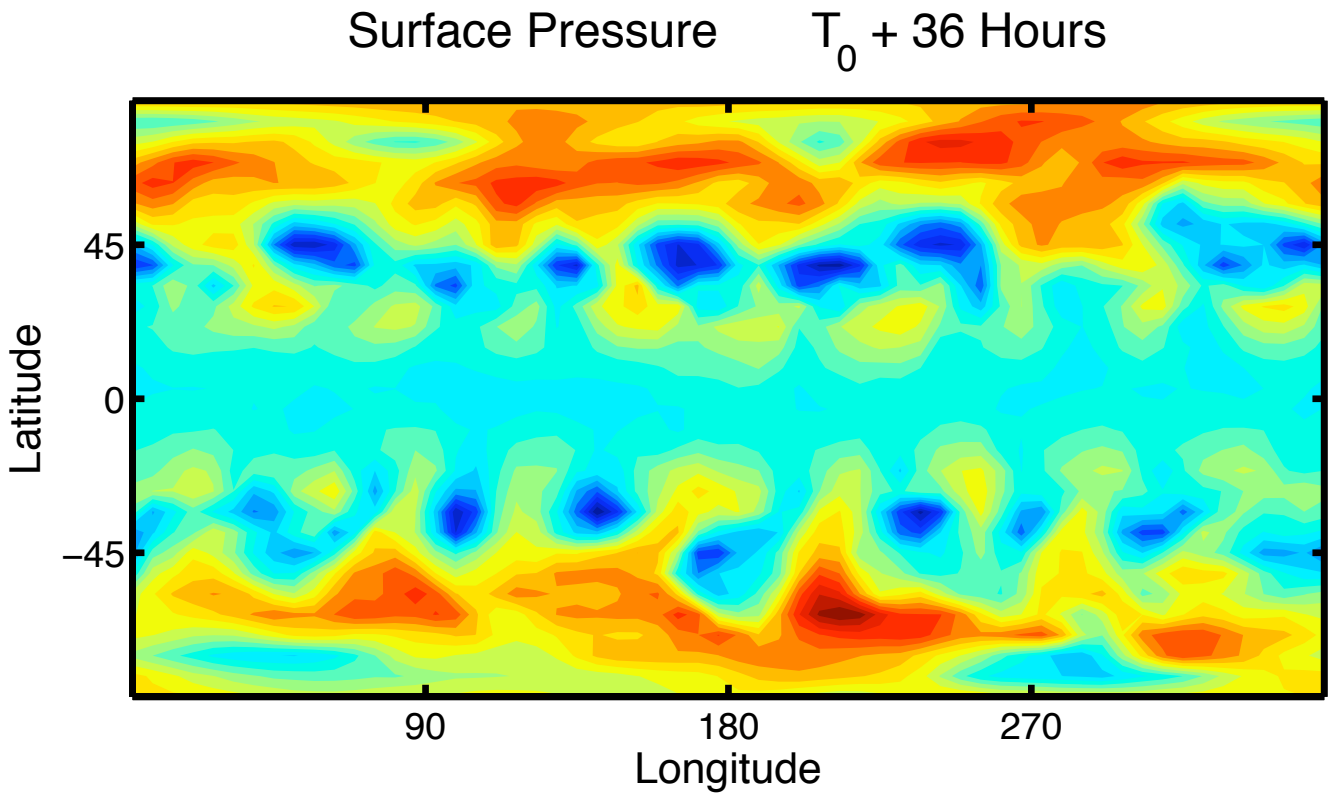

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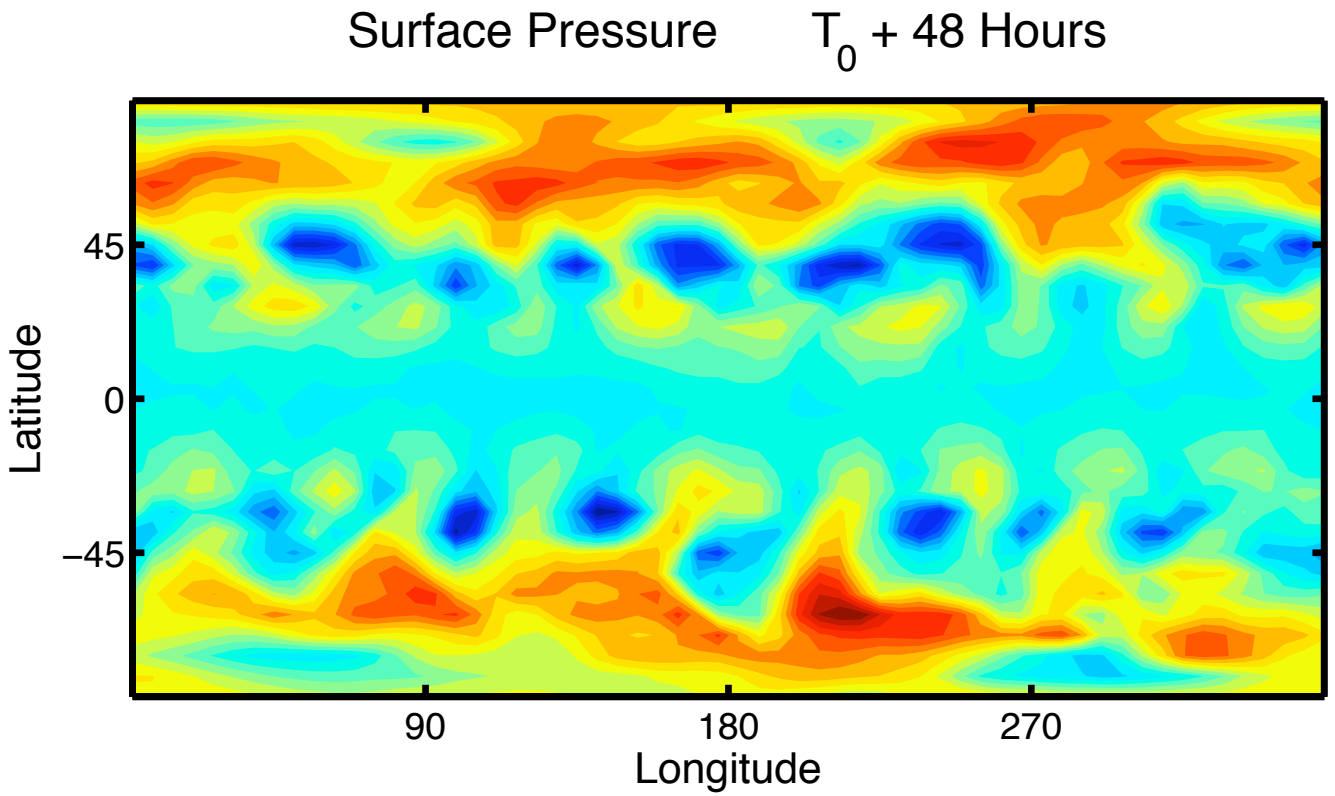
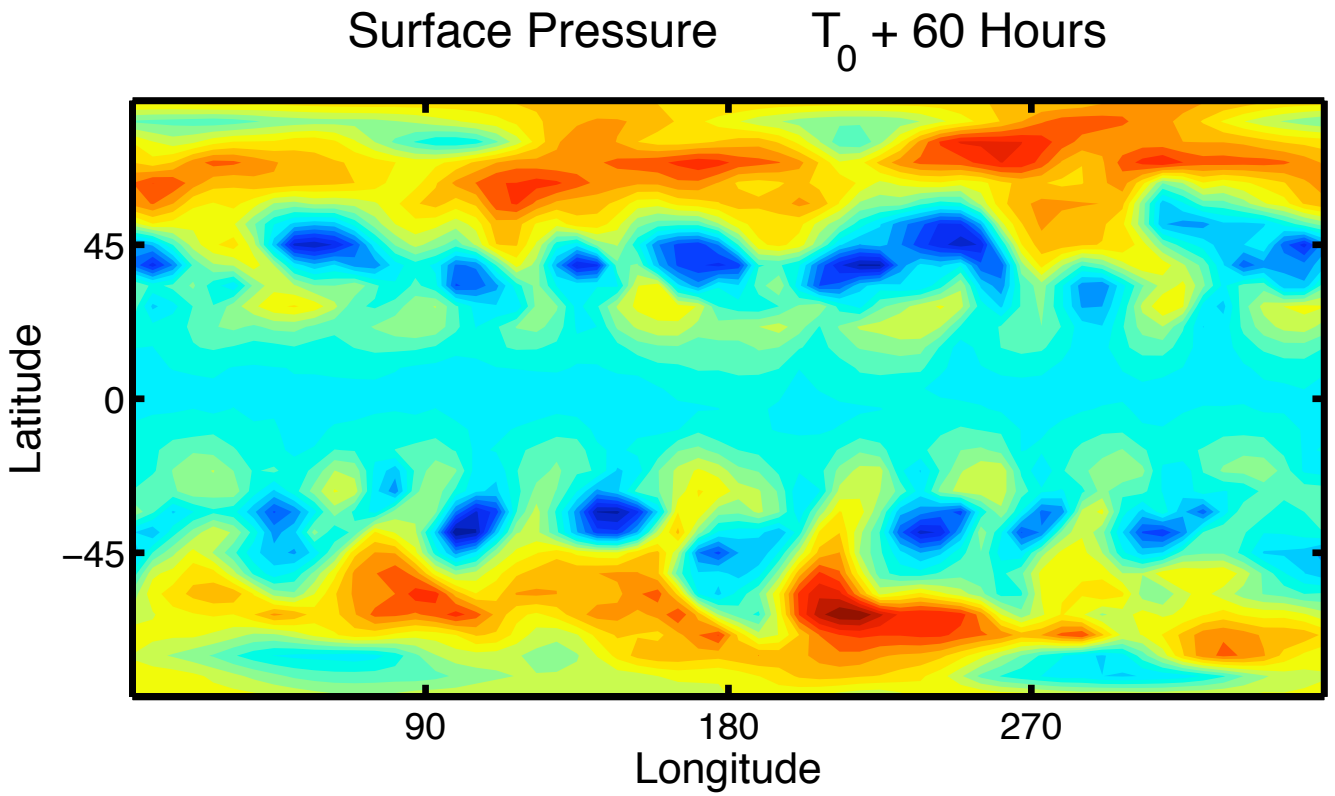
Low-Order Dry Dynamical Core



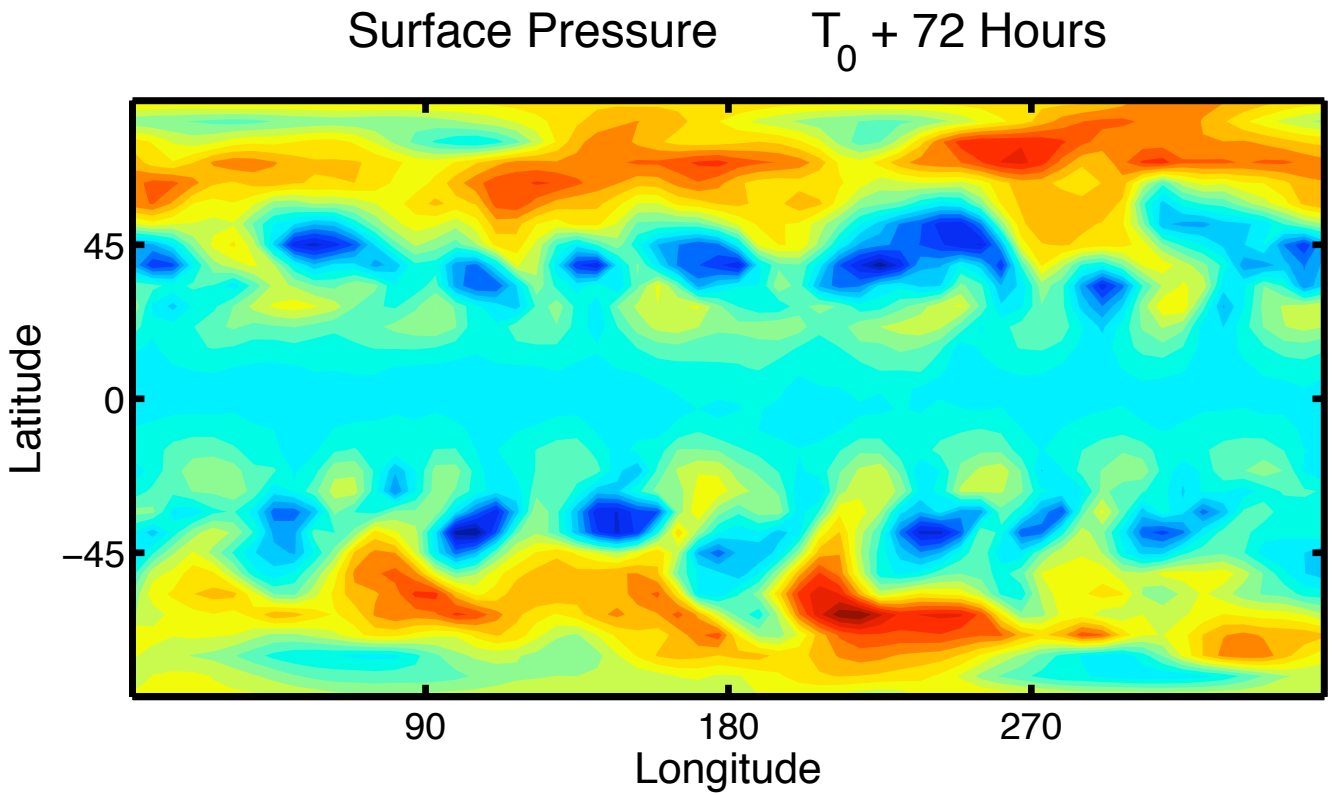
Evolution of surface pressure field every 12 hours.
Has baroclinic instability: storms move east in midlatitudes.

Low-Order Dry Dynamical Core



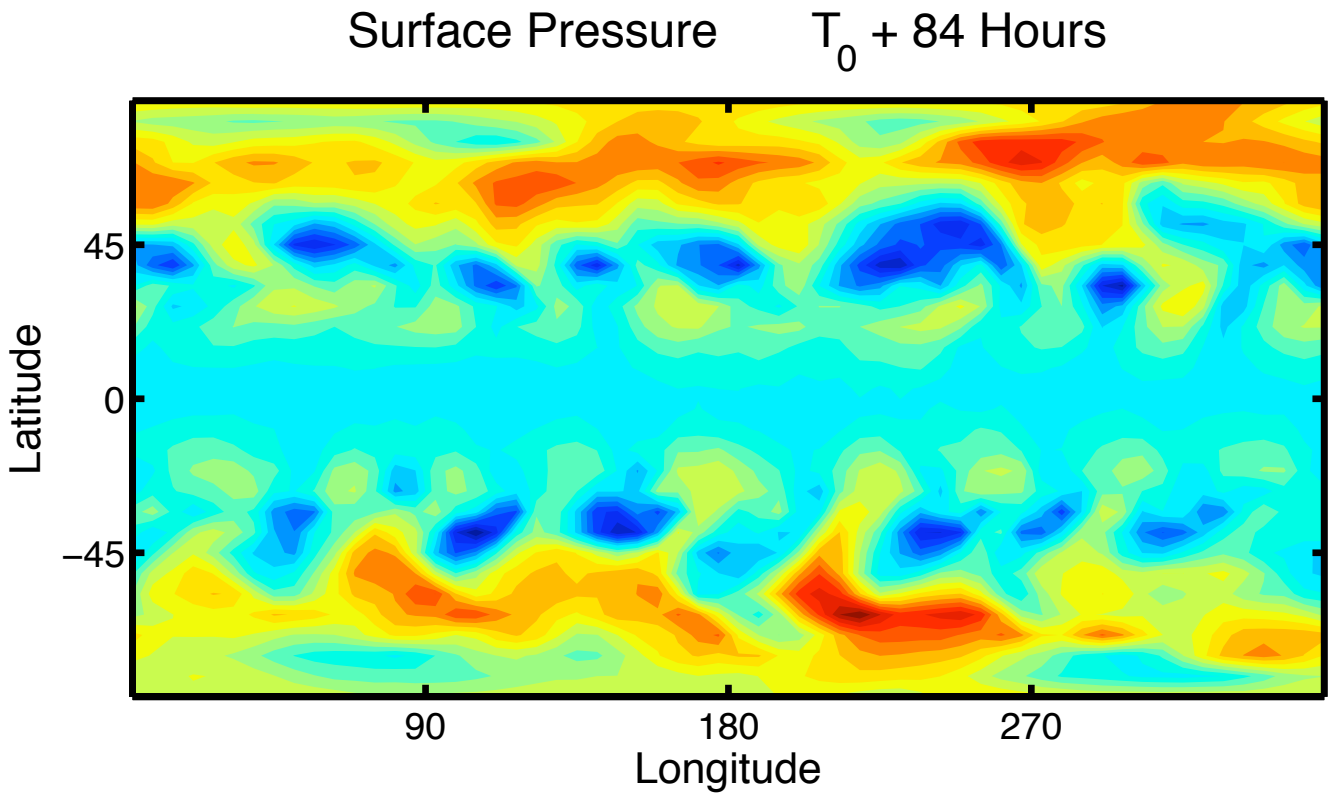
Evolution of surface pressure field every 12 hours.
Has baroclinic instability: storms move east in midlatitudes.

Low-Order Dry Dynamical Core



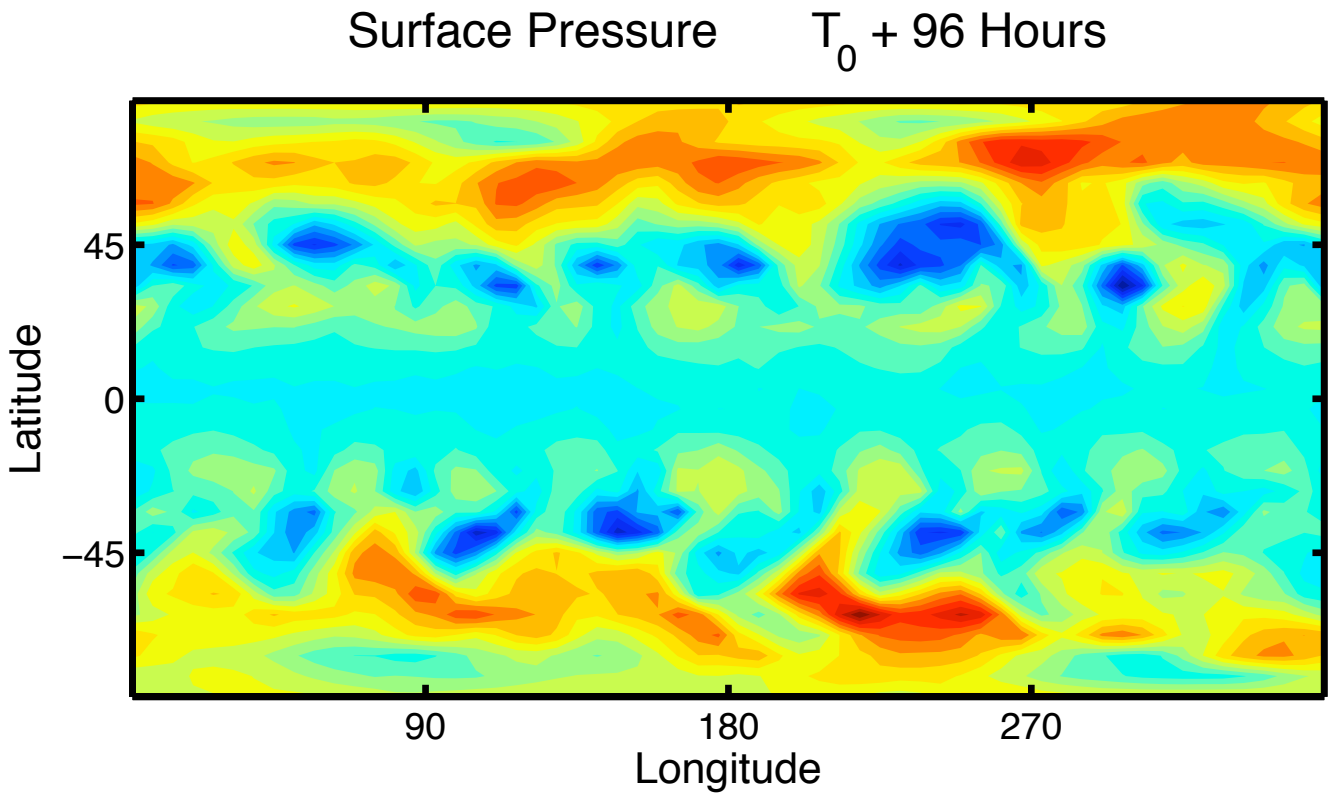
Evolution of surface pressure field every 12 hours.
Has baroclinic instability: storms move east in midlatitudes.

Low-Order Dry Dynamical Core



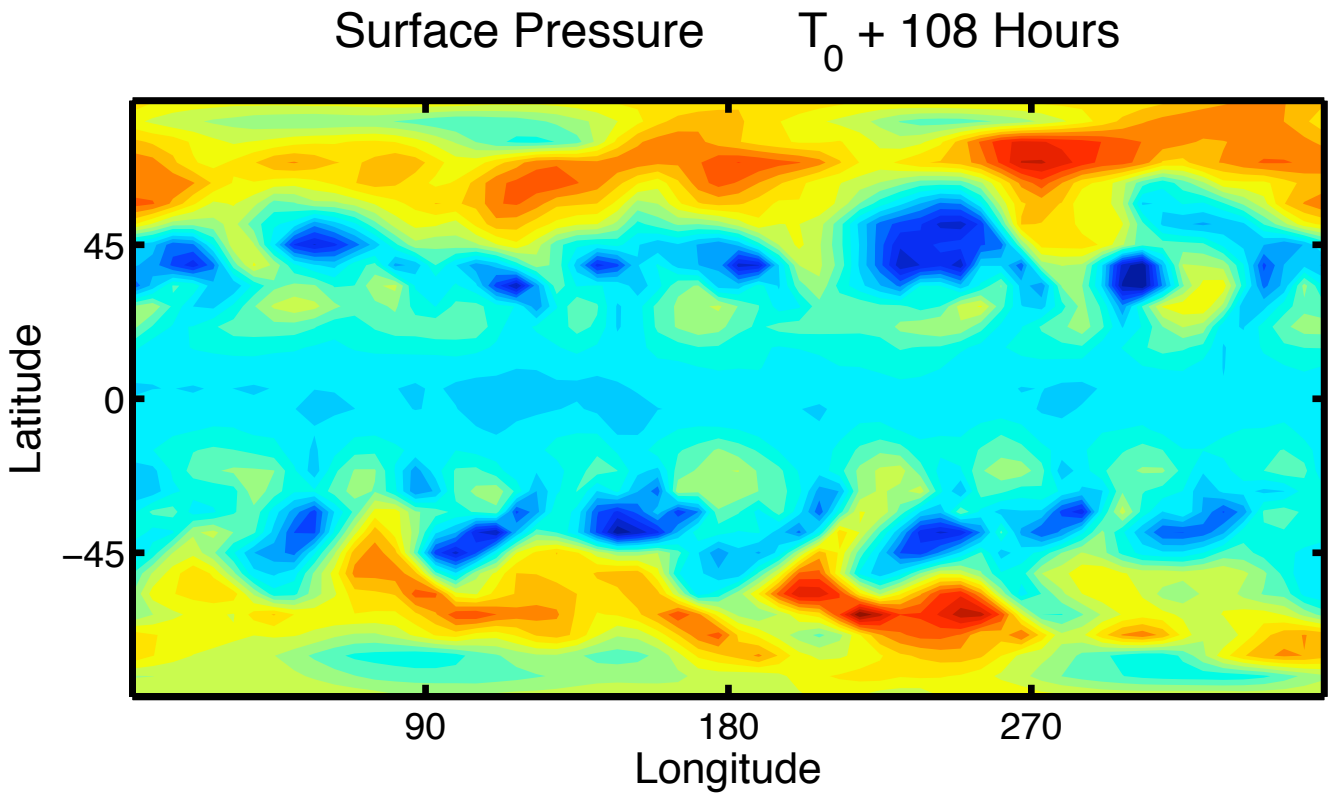
Evolution of surface pressure field every 12 hours.
Has baroclinic instability: storms move east in midlatitudes.

Low-Order Dry Dynamical Core



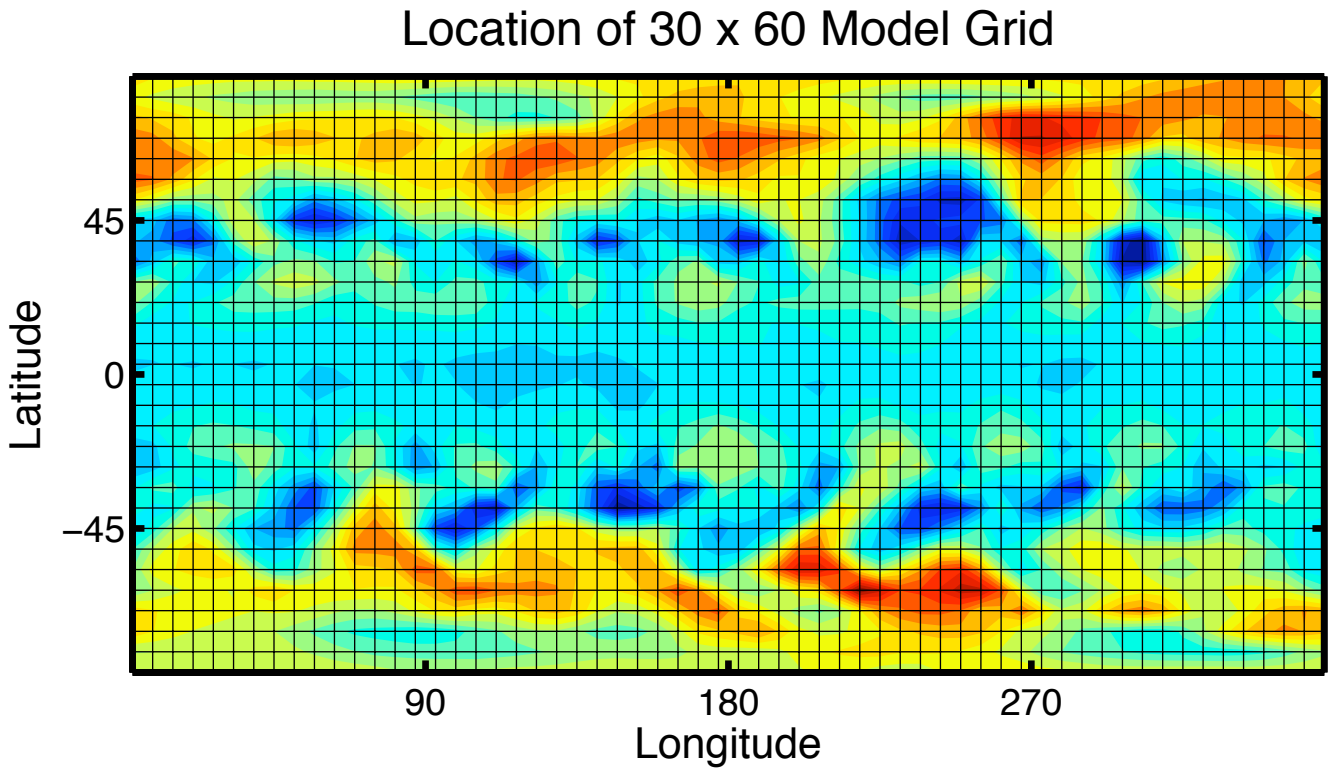
Evolution of surface pressure field every 12 hours.
Has baroclinic instability: storms move east in midlatitudes.

Low-Order Dry Dynamical Core



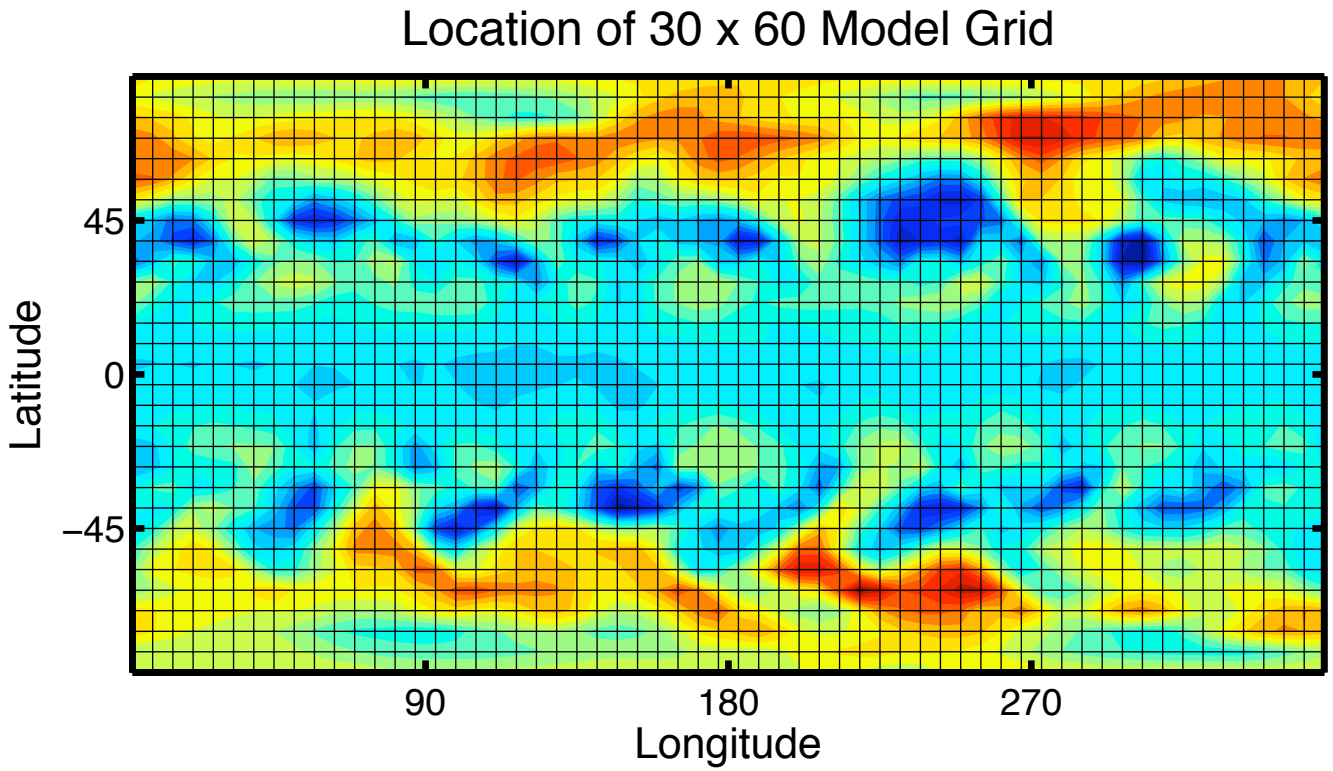
Evolution of surface pressure field every 12 hours.
Has baroclinic instability: storms move east in midlatitudes.

Low-Order Dry Dynamical Core: Grid



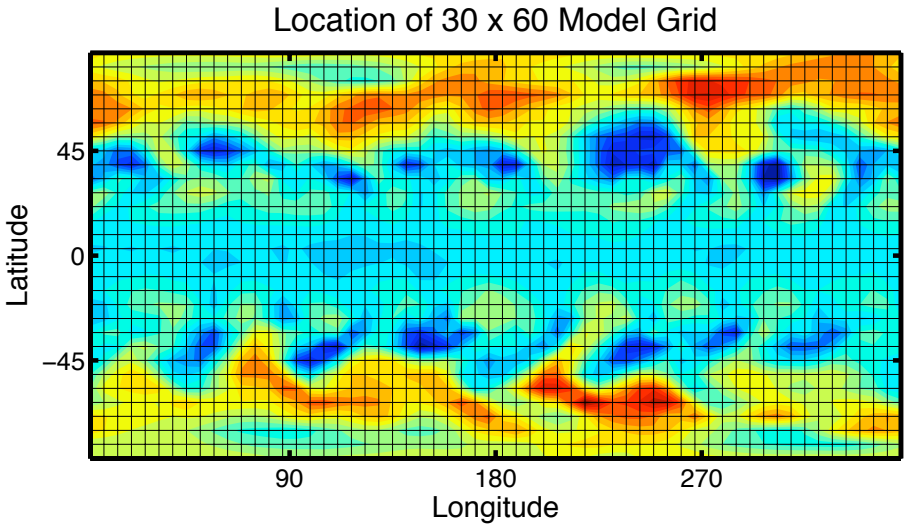
30x60 horizontal grid, 5 levels.
Surface pressure, temperature, wind components.
28,800 variables.

Low-Order Dry Dynamical Core: Observations



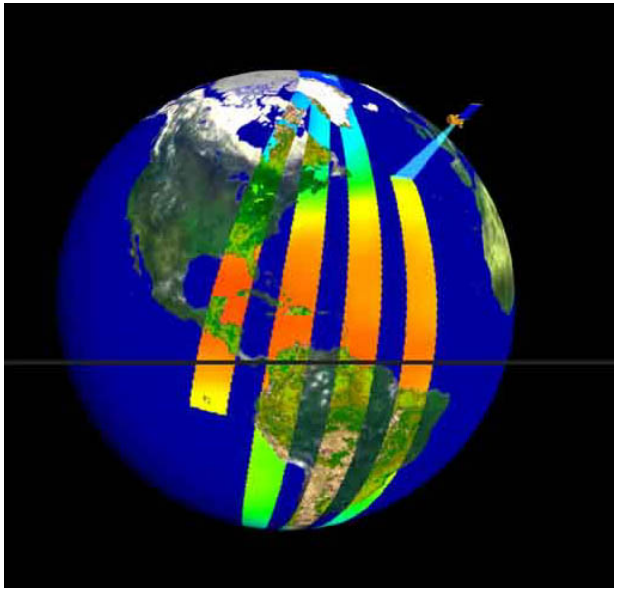
Assimilate once per day. 0.2 radian localization.
Observe each surface pressure grid point.
Uncorrelated obs error variance 100 Pa.

Low-Order Dry Dynamical Core: Observations



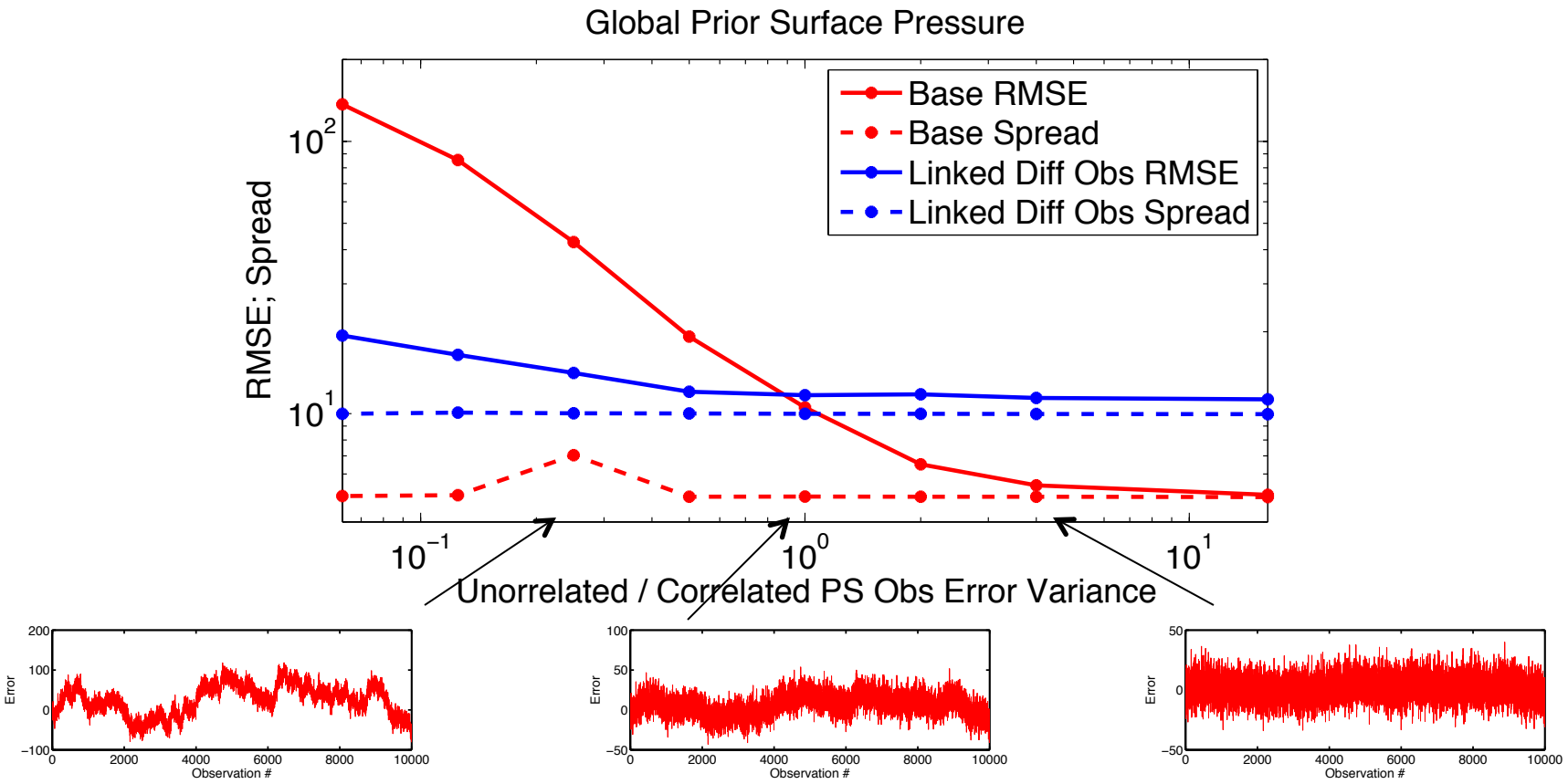
76.jpg 510×490 pixels

1/5/16, 10:53 AM



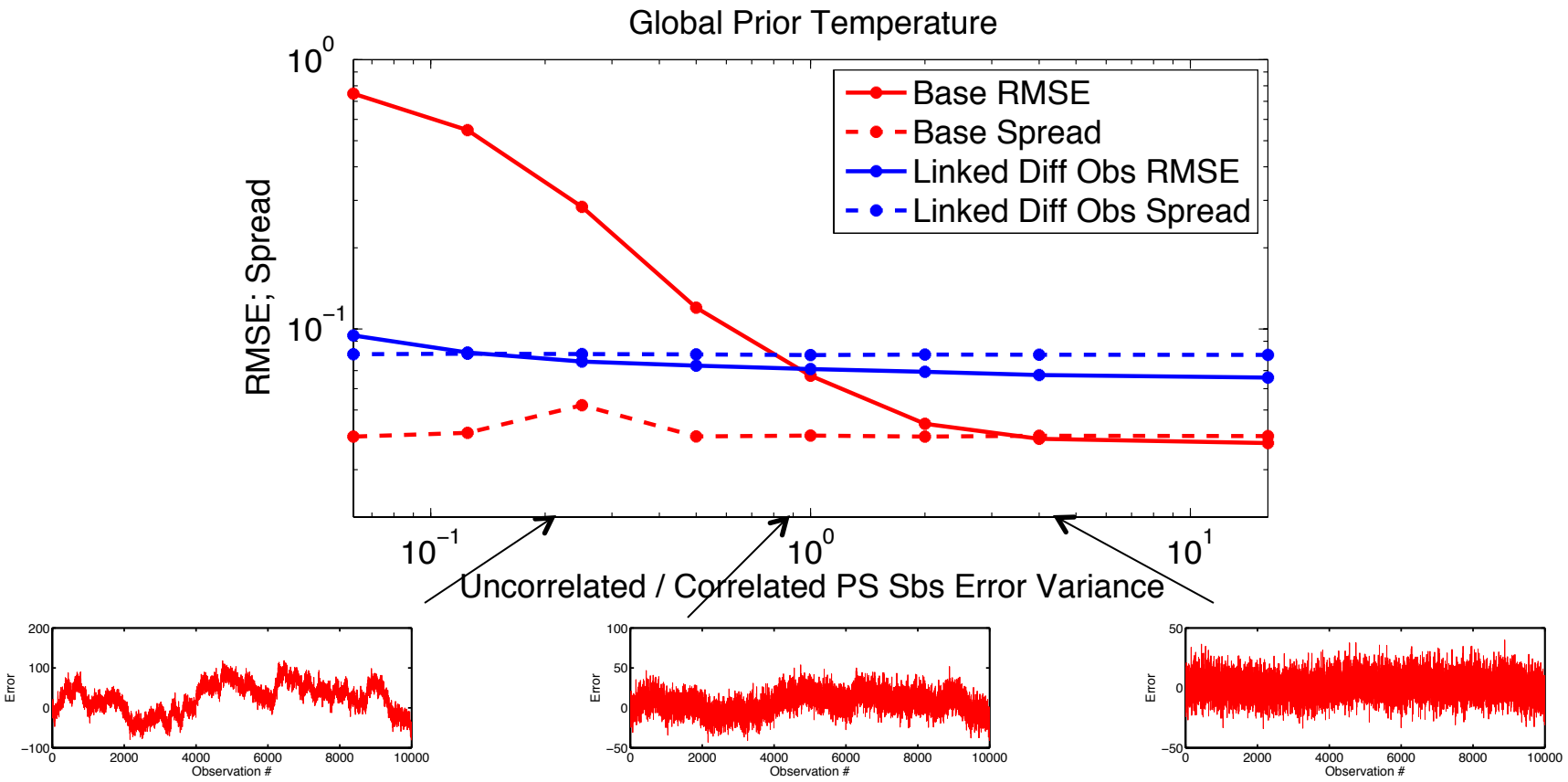
Uncorrelated obs error variance 100 Pa.
Correlated obs error along ‘simulated polar orbiter track’.
Vary ratio of correlated to uncorrelated obs error variance.

Low-Order Dry Dynamical Core: PS Results



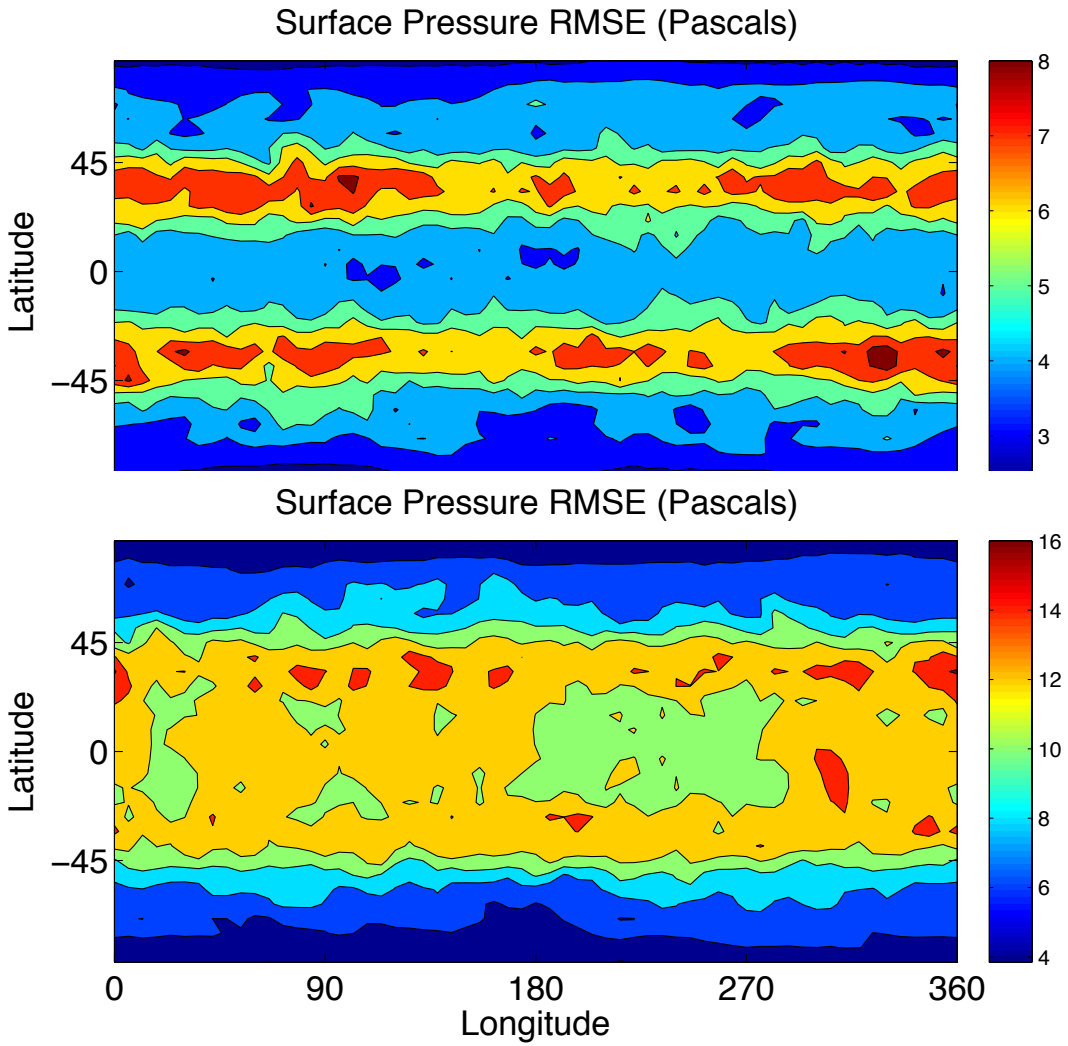
Linked difference better for large correlated error.
Standard better for small correlated error.

Low-Order Dry Dynamical Core: T Results



Linked difference better for large correlated error.
Standard better for small correlated error.

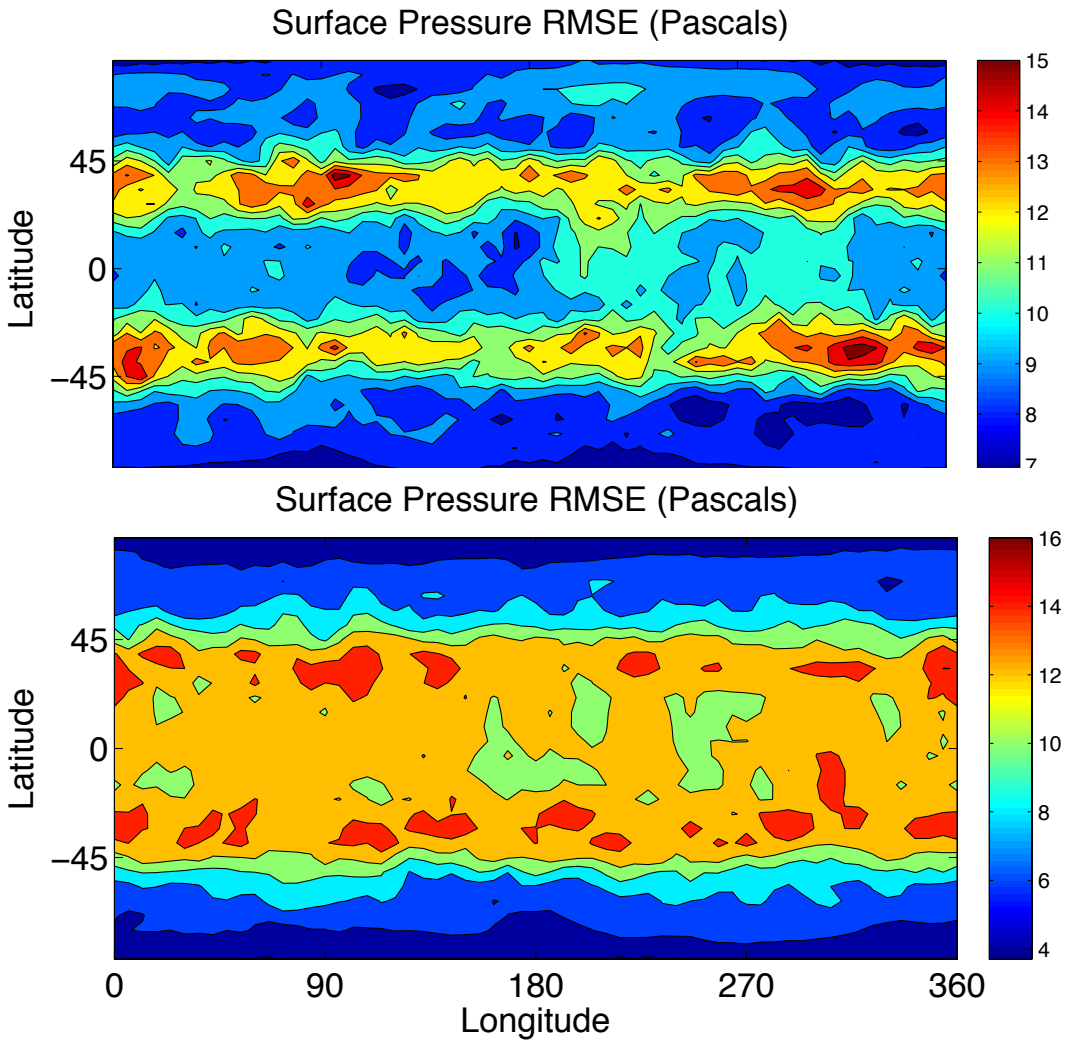
PS RMSE Structure: Large Uncorrelated Error, Ratio 4



Base errors largest in storm tracks.

Linked difference errors largest in broad tropical band.

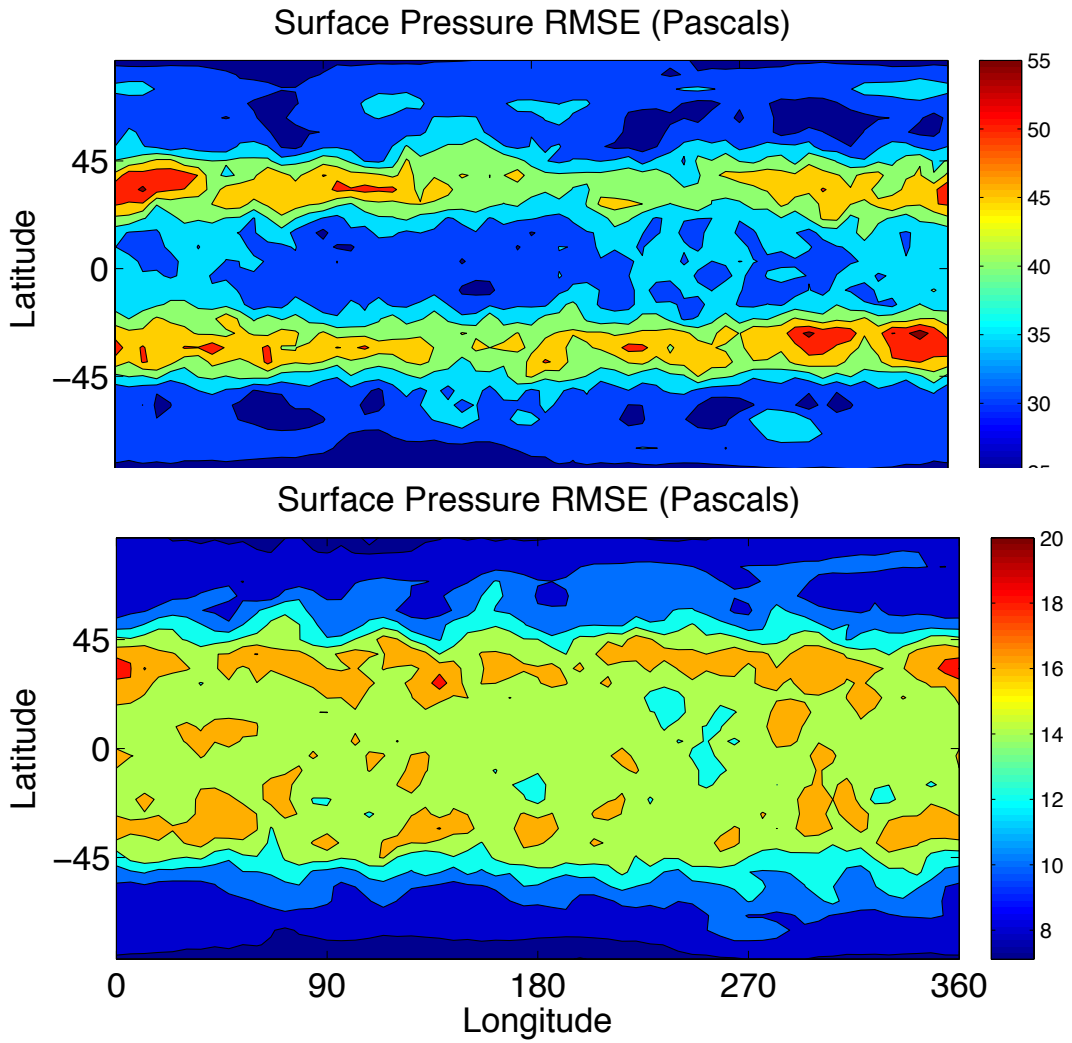
PS RMSE Structure: Moderate Uncorrelated Error, Ratio 1



Base errors largest in storm tracks.

Linked difference errors largest in broad tropical band.

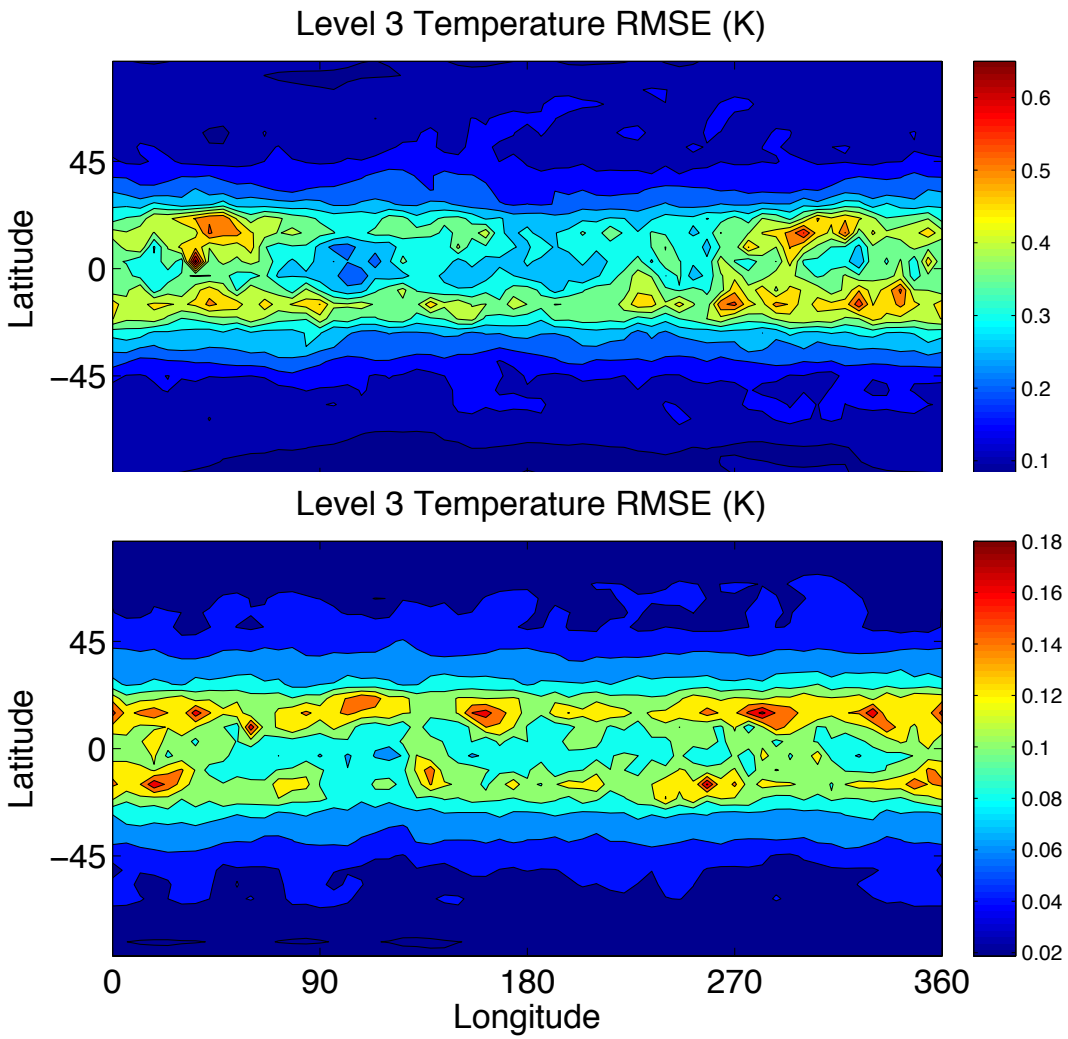
PS RMSE Structure: Small Uncorrelated Error, Ratio 1/4



Base errors largest in storm tracks.

Linked difference errors largest in broad tropical band.

T RMSE Structure: Small Uncorrelated Error, Ratio 1/4



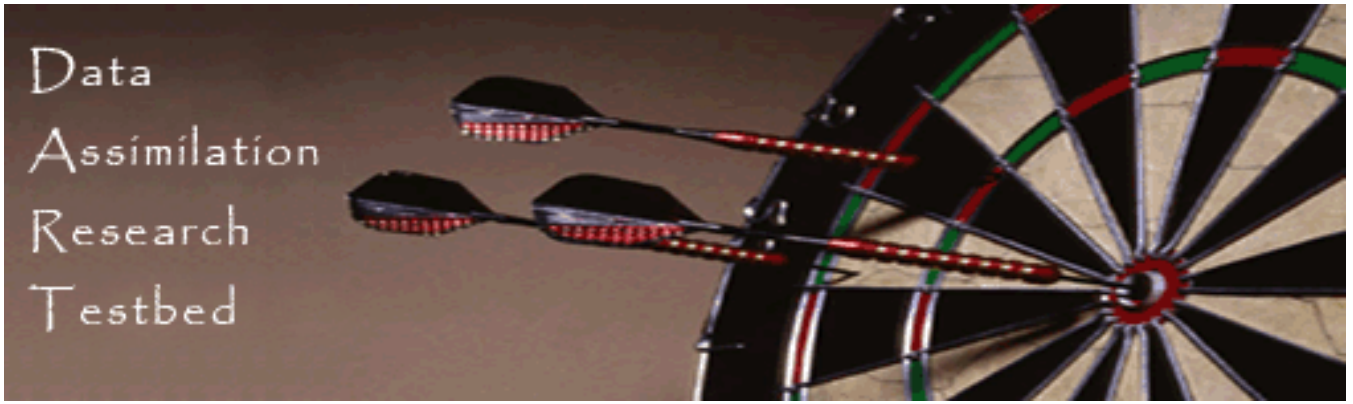
Base errors largest in tropics.

Linked difference errors have similar pattern.

Low-Order Dry Dynamical Core Summary

- Linked difference obs better for large correlated error.
- Linked difference not sensitive to correlated error size.
- Adaptive inflation struggles with large correlated error.
- Could use base approach for uncorrelated obs, difference for correlated error obs.
- For example, base for sondes, difference for radiances.
- Difference obs allows assimilating before knowing correlated error characteristics.

Learn more about DART at:



www.image.ucar.edu/DAReS/DART

Anderson, J., Hoar, T., Raeder, K., Liu, H., Collins, N., Torn, R., Arellano, A., 2009: *The Data Assimilation Research Testbed: A community facility.* BAMS, **90**, 1283—1296, doi: 10.1175/2009BAMS2618.1