Ensemble filtering using a 3d chemical-dynamical middle atmosphere model

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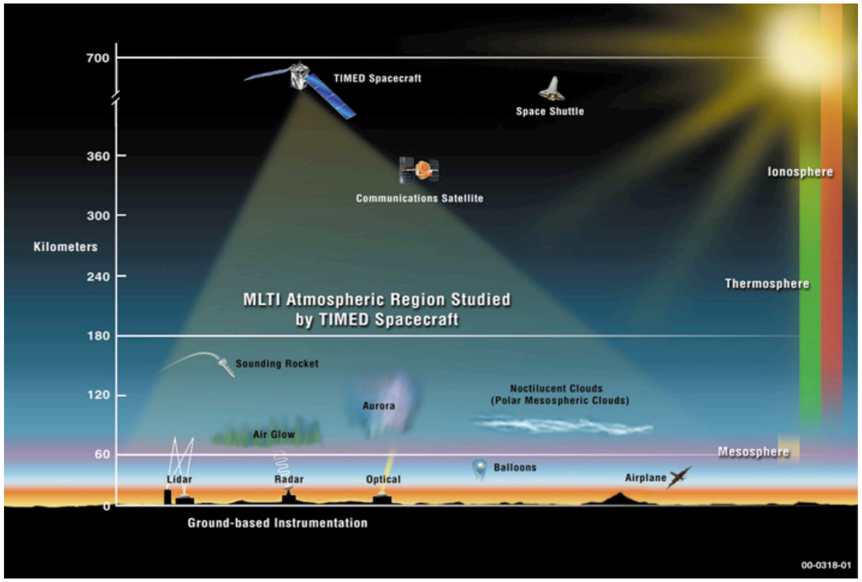
Goal and Motivation



http://www.timed.jhuapl.edu

- Chemical and dynamical timescales are the same.
- The chemistry has been a primary diagnostic of the MLT region.

- Understand the climatology of global structure of temperature, density, and wind structure.
  - impact of wave forcing variability
- Evaluate the value of observations and the design of observing system.
- Provide insights into model physics from model-observations discrepancy. (e.g., rate coefficients, diffusion, forcing, etc…)

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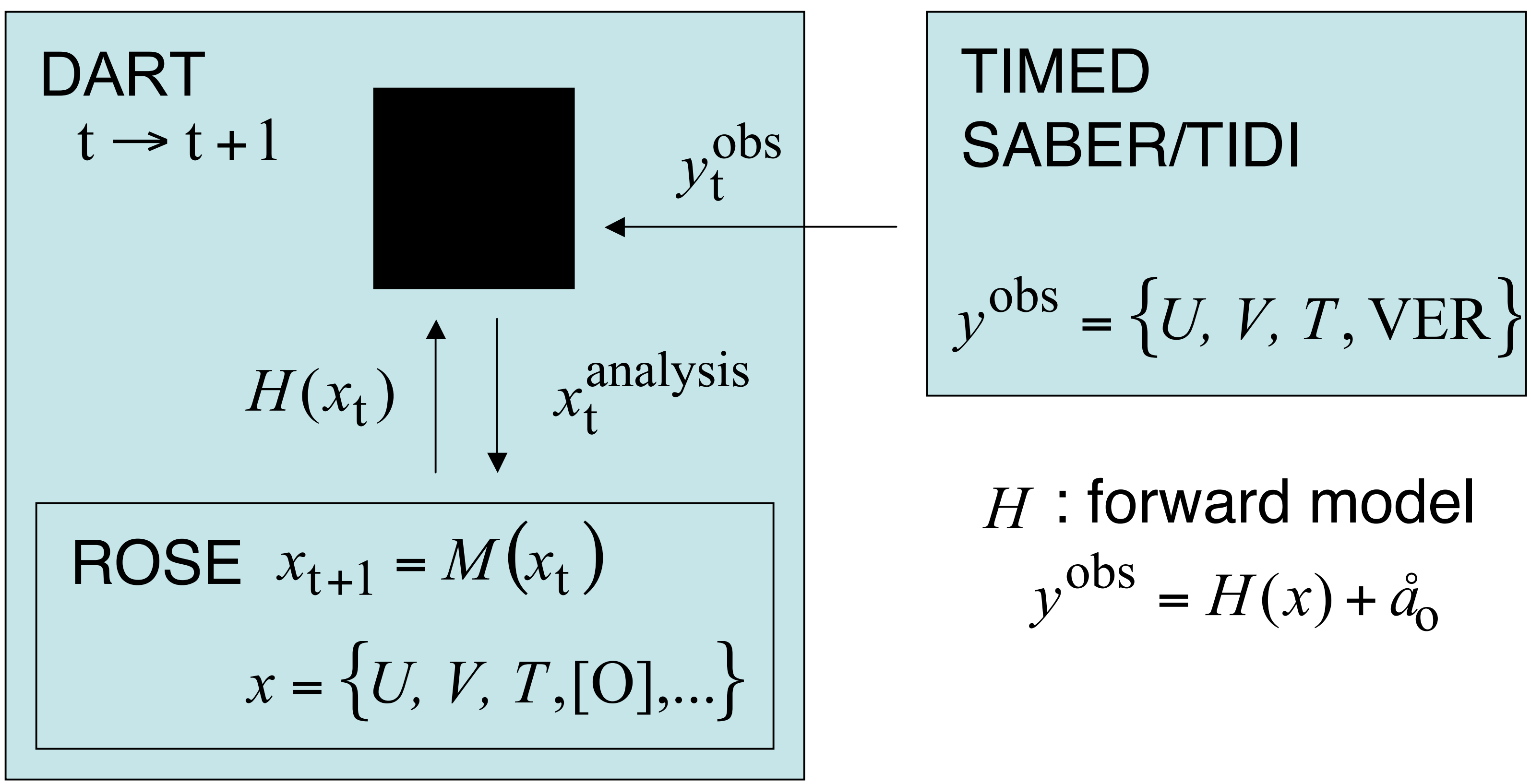
Overview



Data Assimilation Research Testbed

http://www.image.ucar.edu/DARes/DART/

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Data Assimilation Research Testbed

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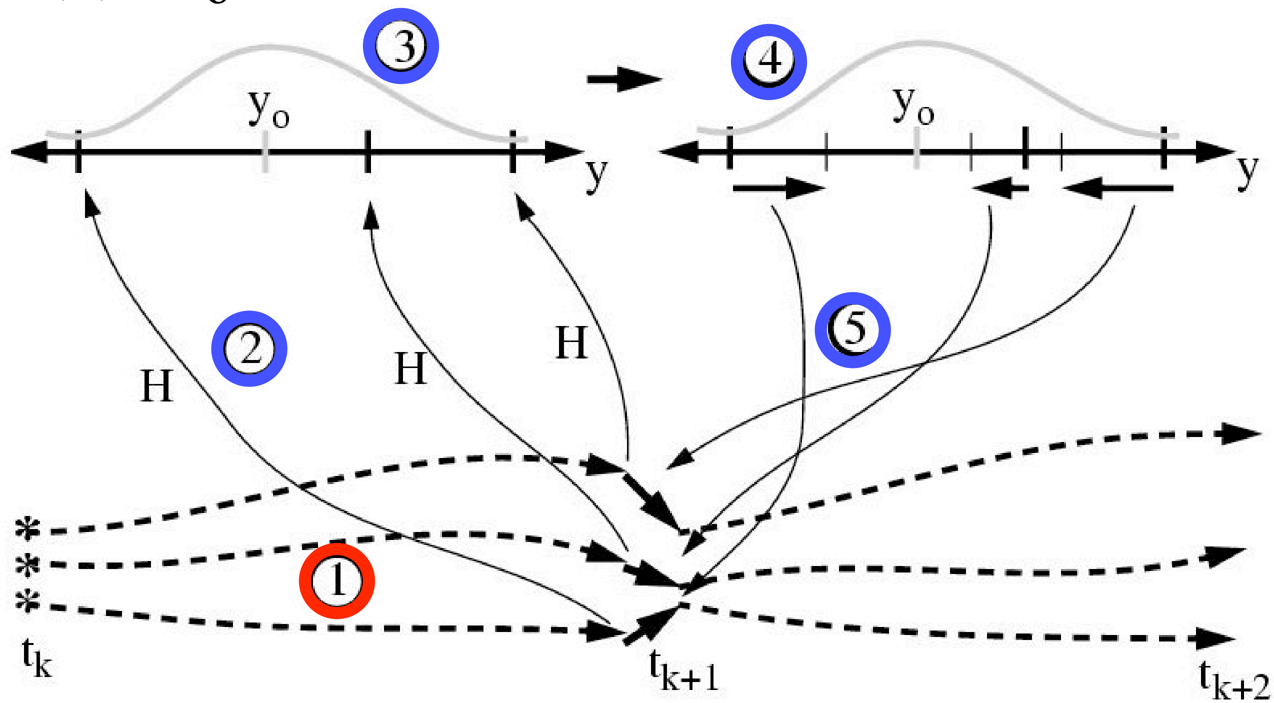
Framework has been successfully implemented for CAM, WRF,…

$$y^{obs} = H(x) + å_o$$



forecast step

$$x_{t+1,i} = M_t(x_{t,i})$$

update step

$$x^{analysis}$$

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ROSE 3-D chemical dynamical model

[Rose and Brasseur, 1983; 1989; Marsh et al., 2003]

Model Resolution

- 38 levels (pressure coordinate)
  17.5 to 110 km by 2.5 km
- 5º latitude x 11.25º longitude
- 7.5 min time step

Chemistry

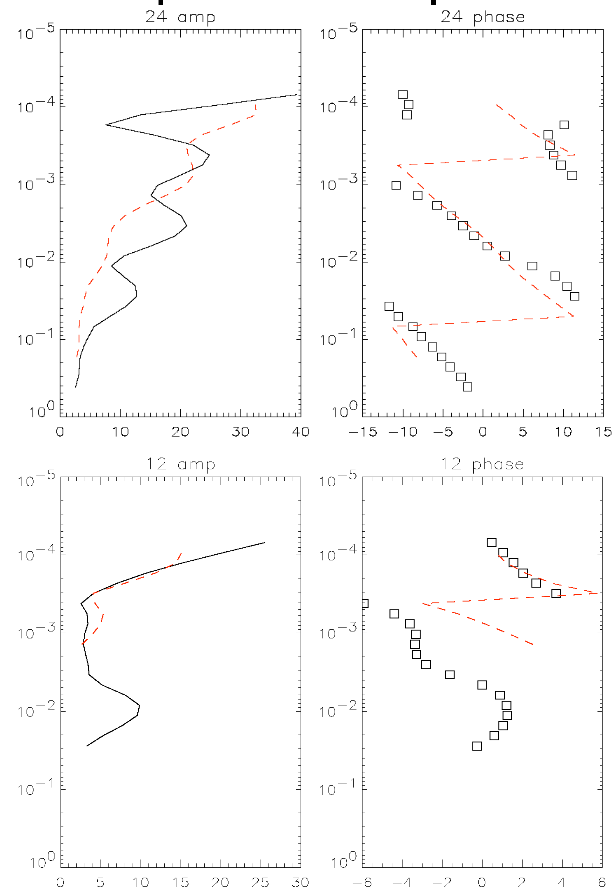
- 27 species, 101 gas-phase reactions (JPL-2000)
- Semi-lagrangian transport scheme
- Airglow package
- Offline D-region ion chemistry
- Photolysis rates based on *T U V*

Dynamics

- Primitive equations
- Hines gravity wave parameterization
- NCEP and GSWM forcing at lower boundary

Used for DA projects at Deutsches Zentrum fur Luftund Raumfahrt (DLR) and Finish Meteorological Institute

Tidal amplitude comparisons



[Marsh and Smith, 2004]

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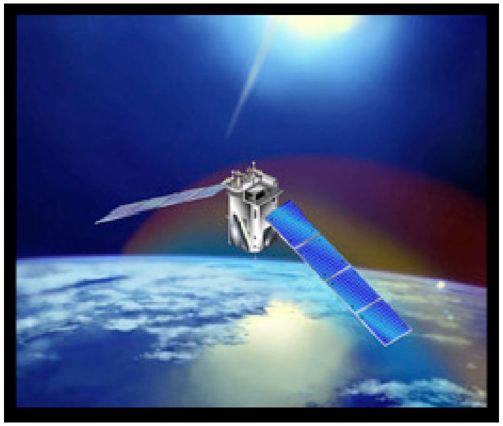

TIMED-SABER/TIDI

TIDI Dayside Measurements

Vector Wind	O_2 (0-0) P15	60 - 100 km
	O_2 (0-0) P9	70 - 115 km
	OI 557.7 nm	100 - 180 km

TIDI Nightside Measurements

Vector Wind	O_2 (0-0) P9	80 - 105 km
	OI 557.7 nm	90 - 110 km

SABER Measurements and Applications

Parameter	Wavelength (μm)	Application	Altitude Range (km)
CO_2	14.9 & 15.2	T, density, IR cooling rates, P(z), non-LTE	10–130
O_3	9.6	O_3 conc., cooling rates, solar heating, chemistry and dynamics studies	15–100
$O_2(^1\Delta)$	1.27	O_3 conc. (day), inferred [O] at night, energy loss for solar heating efficiency	50–105
CO_2	4.3	CO_2 conc., mesosphere solar heating, tracer	85–150
OH (v)	2.0 & 1.6	HO_y chem., chemical heat source, dynamics, inference of [O] and [H], PMC studies	80–100
NO	5.3	Thermosphere cooling, NO_x chemistry	90–180
H_2O	6.9	HO_y source gas, dynamical tracer	15–80

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Orbital characteristics of observations

Apr 21, 2002

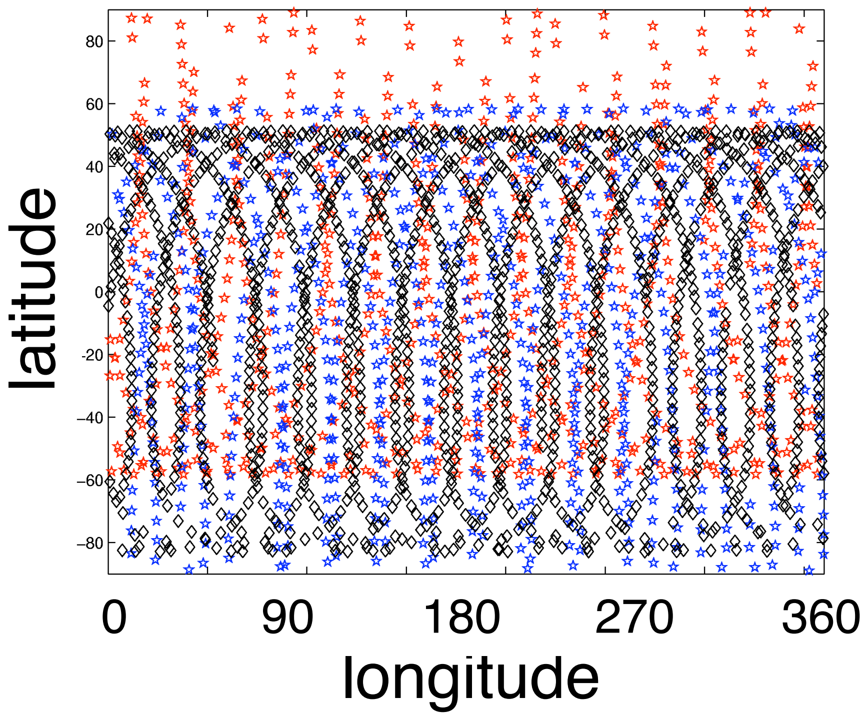
TIDI(day mode)

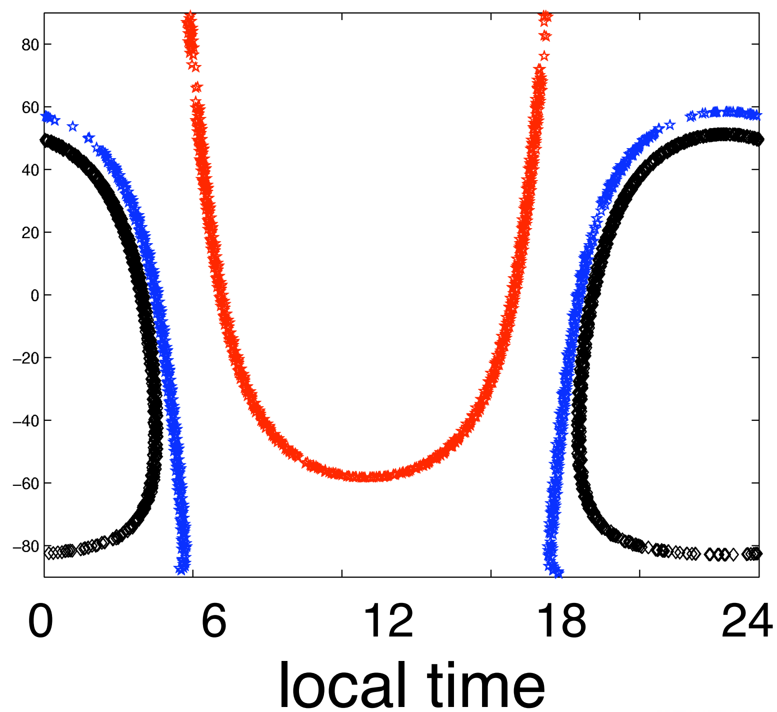
TIDI(night)

SABER

Precession rate of TIMED:

60days to precess 12-h in local time!!





Challenge

How to formulate an ensemble data assimilation problem when the model does not exhibit natural error growth.

MLT region is unique

strongly forced and dissipative system

Deterministic model: $x_{t+1,i} = M_{\mathrm{t}}\left(x_{t,\ i}, F_t\right)$

Stochastically forced model: $x_{t+1,i} = M_{\mathrm{t}}\left(x_{t,i},\ F_t + \varepsilon_{t,i}^{F}\right)$

$$\mathring{a}_{t,i}^{F} \overset{iid}{\sim} N(0,\Sigma)$$

NCEP reanalysis fields at 100mb

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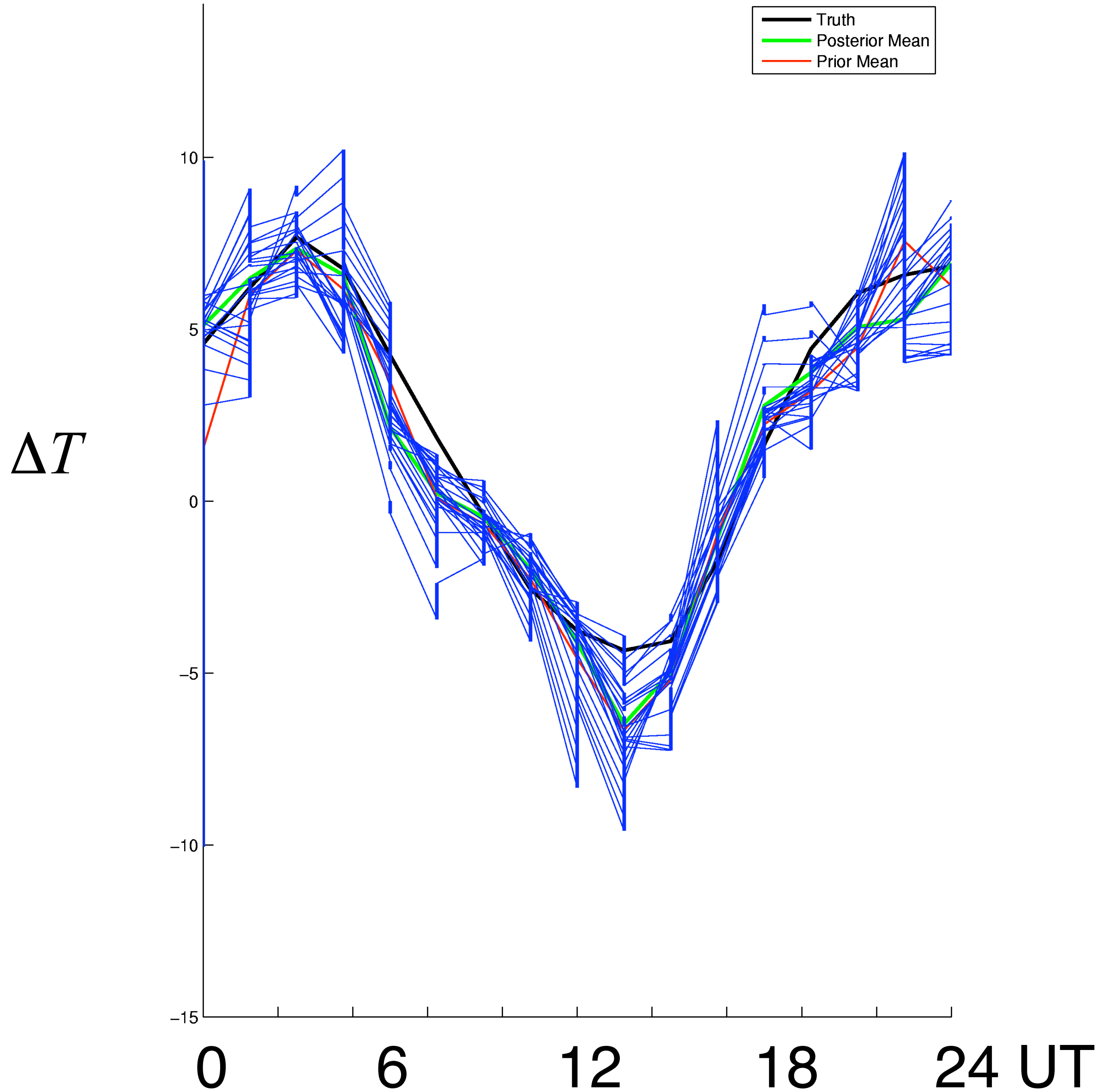
Observing System Simulation Experiments

Temperature at 85km, -2.5 lat, 225 lon



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Summary

- With the DART facility, a prototype ensemble filter assimilation system for synthetic observations with ROSE model has been constructed.

- Future Work and Potential Applications:
  – Assimilation of the ground-based and satellite observations
  – Estimation of forcing and model parameters

- Challenges and Open Questions:
  – Large uncertainty in forcing
  – Model Error v.s. Observation Error: Observed day-to-day variability is significantly higher than the variability reproduced by numerical models.
  – Representativeness error estimation

$$y^{\mathrm{obs}} = H(x) + \varepsilon_{\mathrm{o}}$$

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Future data sources

– Ground based (T,U,V, airglow).

– Other satellites: ODIN/OSIRIS, ENVISAT, Aura/MLS-2 …

– MORE?

Potential Applications

– Observing system design analysis.

– Using forecasted forcing

Adaptive observation? (scan rate, direction of telescope)

e.g., Forecast of mesospheric responses to stratospheric heating

– Identification of new sciences using SABER/TIDE.

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