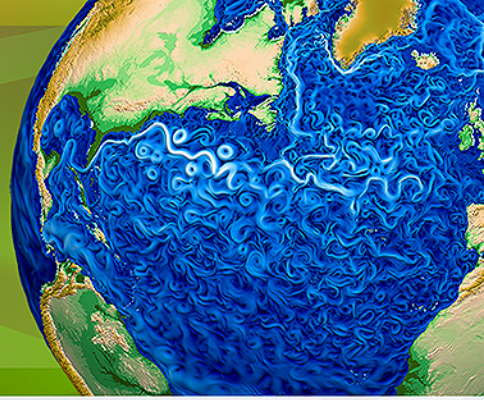
ACME
Accelerated Climate Modeling for Energy



Non-BFB Solution Reproducibility:
A New Test Based on Time Step Convergence

Hui Wan, Kai Zhang, Phil Rasch, Balwinder Singh,
Xingyuan Chen (PNNL), and Jim Edwards (NCAR)

U.S. DEPARTMENT OF ENERGY

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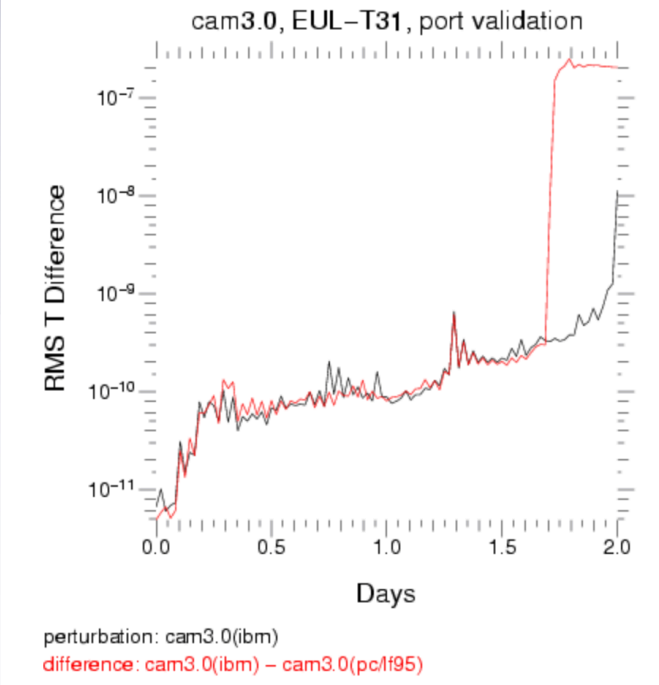

http://www.cesm.ucar.edu/models/atm-cam/port/

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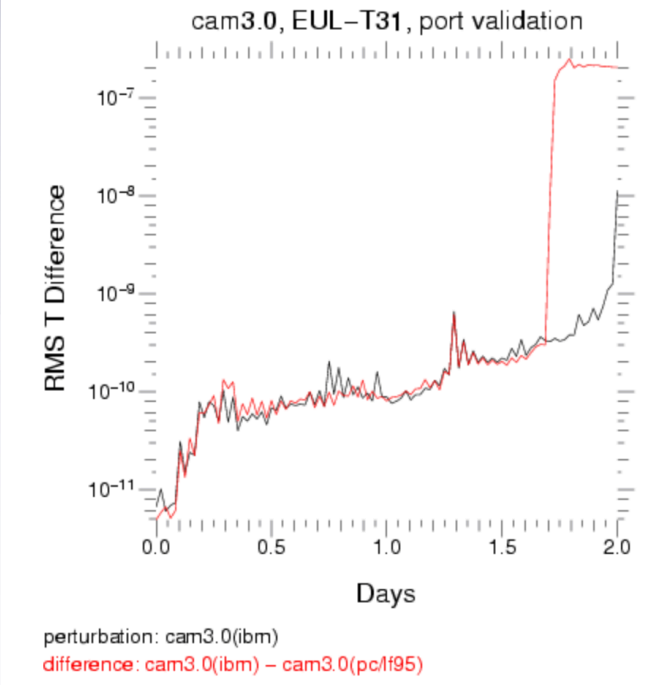

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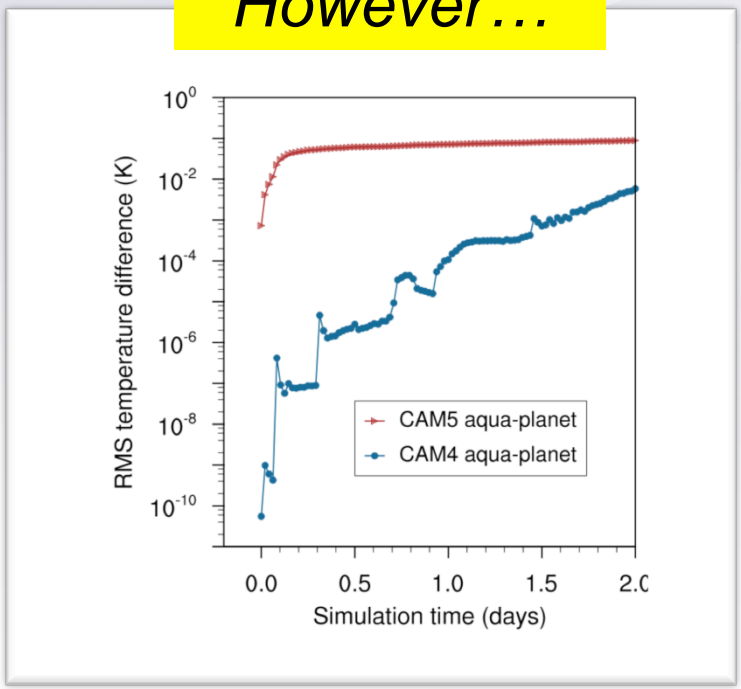

Wan et al. (2016, submitted)

NCAR's New Climate Consistency Test (Baker et al., 2015, GMD)

- Test ensemble contains 3 one-year simulations
- Reference ensemble contains 151 one-year simulations
- Analysis uses global and annual mean values of h0 output

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- Expensive
- Can miss differences in small-scale features

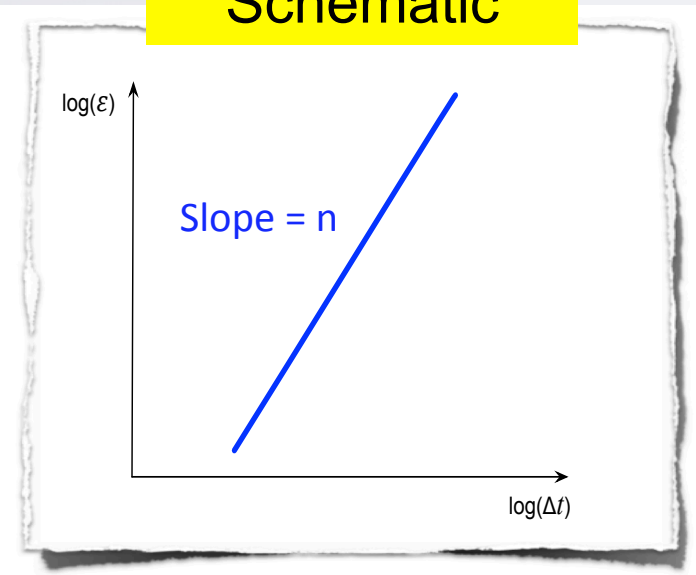
- Can we find a less expensive and more sensitive method?

Introduction to Convergence

- Differential equation $\frac{dy}{dt} = F(y,t)$
- Discretization: time step Δt , total simulation length τ
- Numerical error $\mathcal{E} = C\left(\frac{\Delta t}{\tau}\right)^{n} + \cdots$

order of accuracy
a.k.a. **convergence rate**

Schematic



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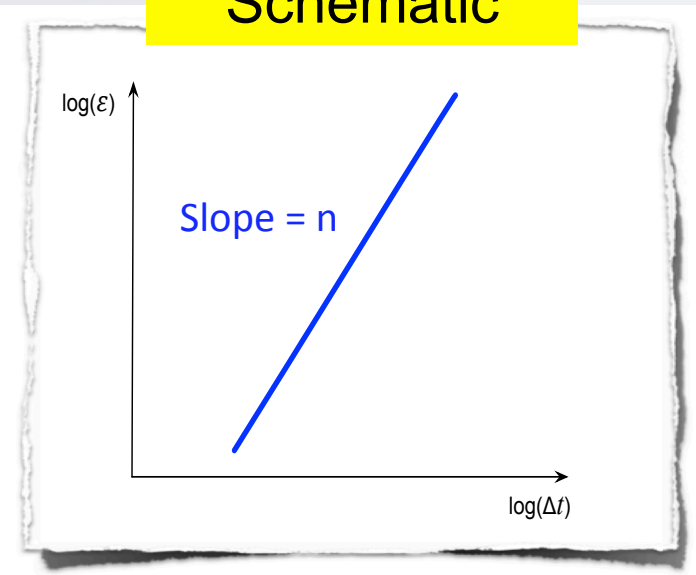
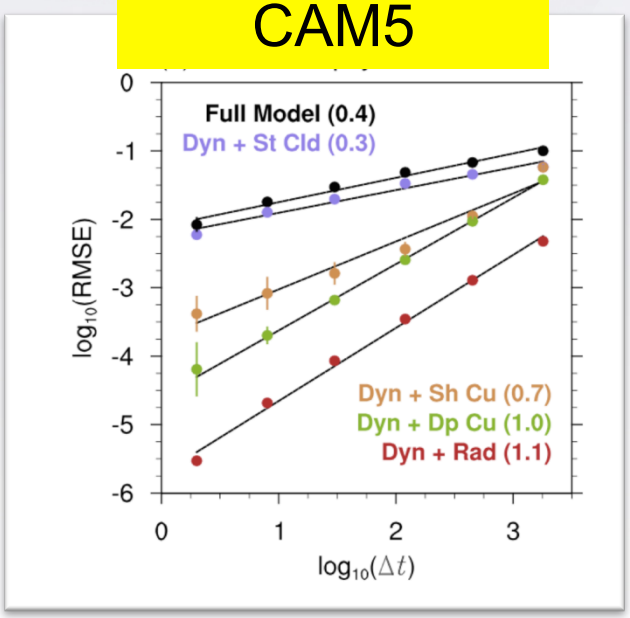


CAM5



Wan et al. (2015, JAMES)

An Important Note

- When assessing convergence, the numerical error should be calculated against the "true" solution that the discrete model is trying to solve for!

- dy/dt = F(y,t) => true solution is y = A(t)
- dx/dt = G(x,t) => true solution is x = B(t)

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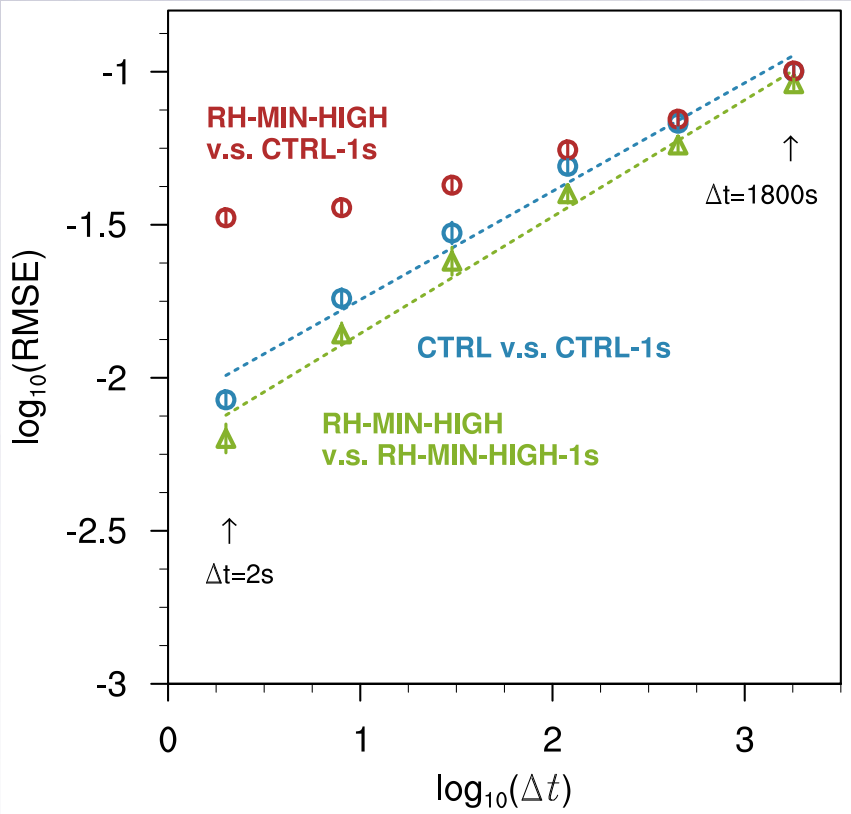
- A change in model parameter, a new parameterization scheme, or the introduction of a bug, will result in a new "true solution" in the mathematical sense.

A Real Example from CAM5.3



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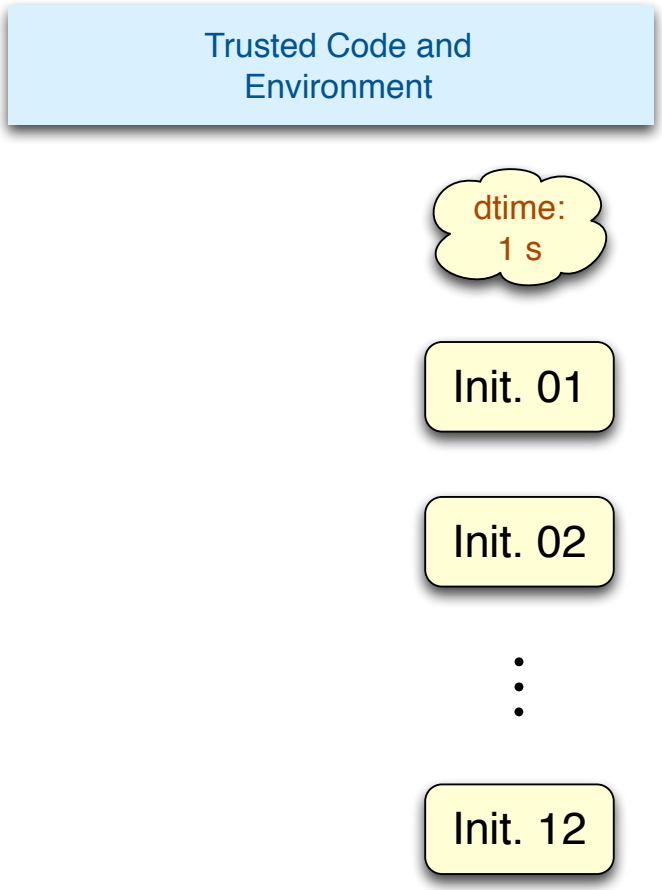
The New Test Method (TSC1.0)



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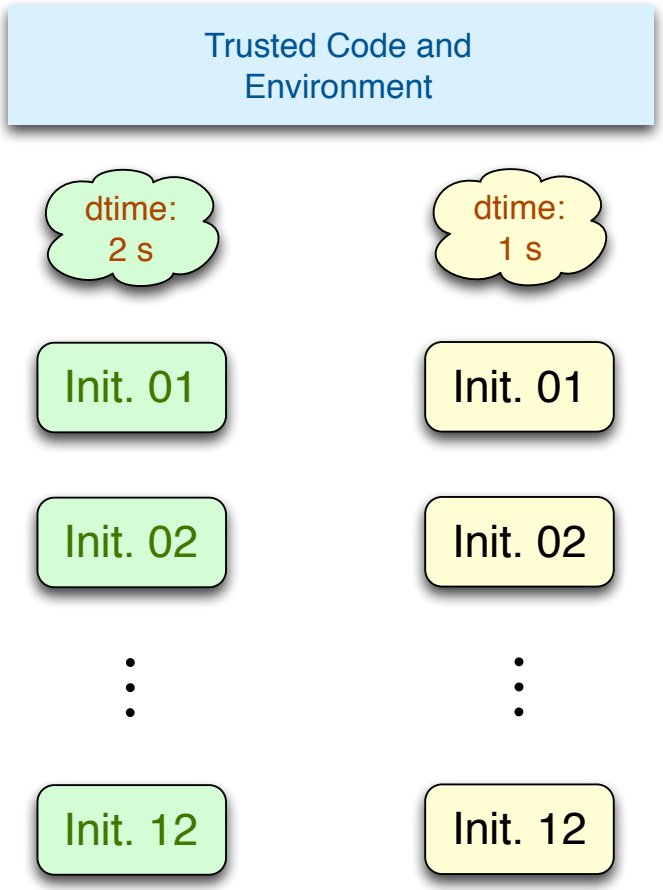

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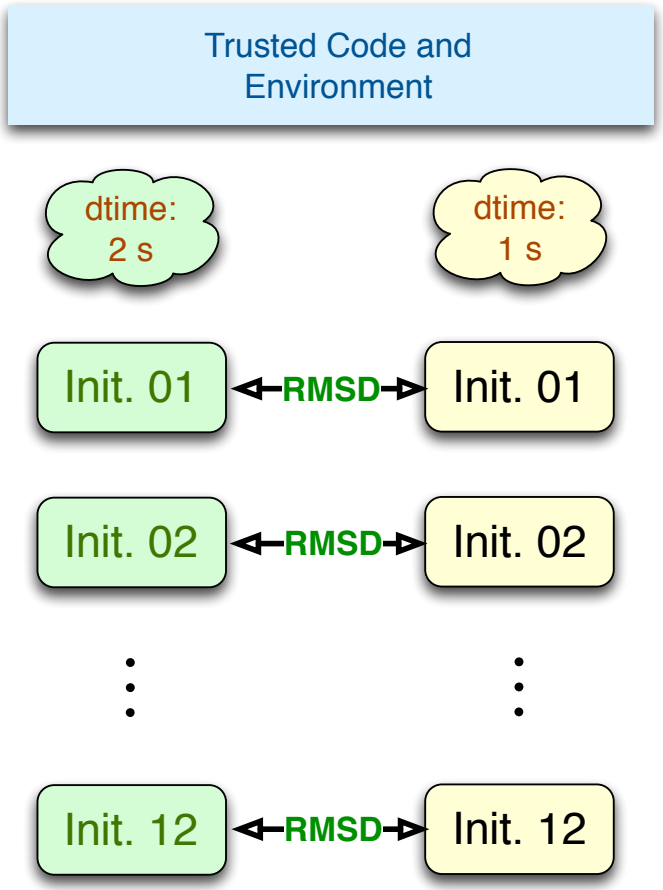

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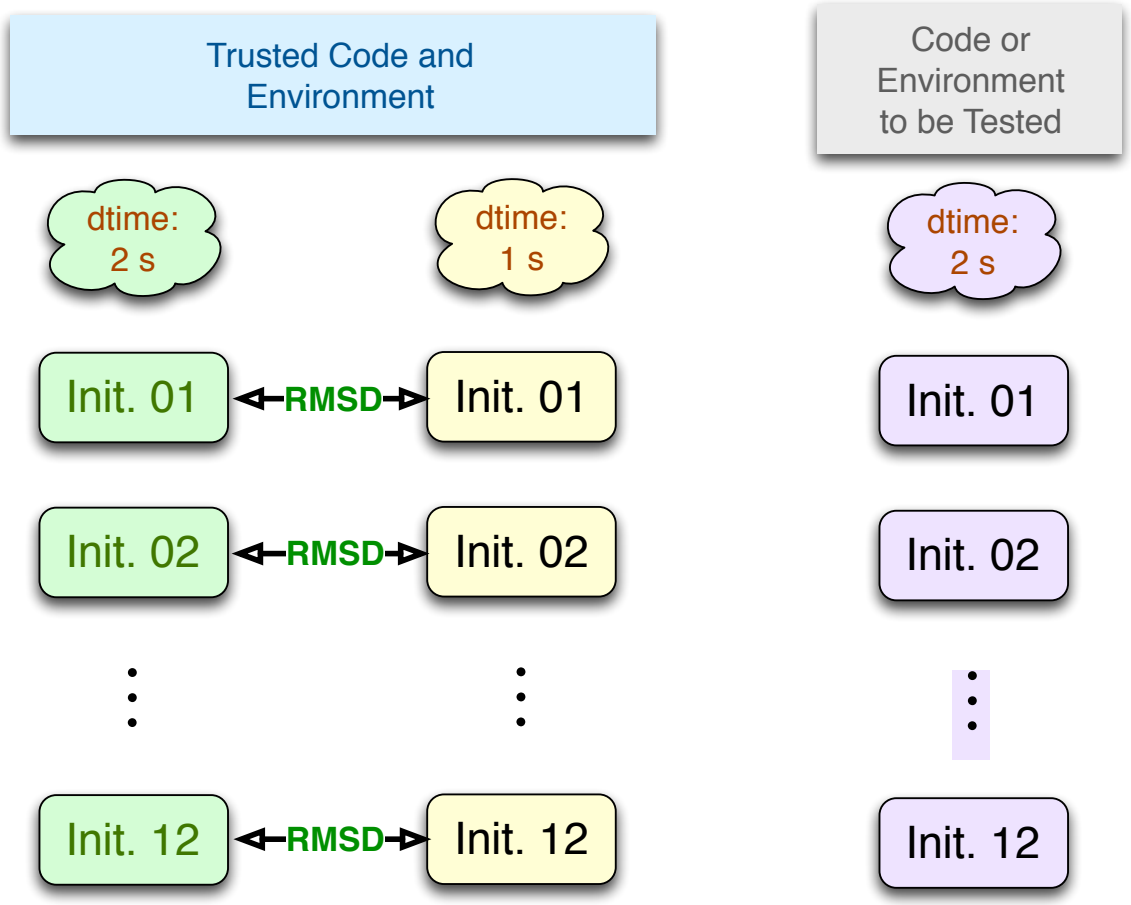

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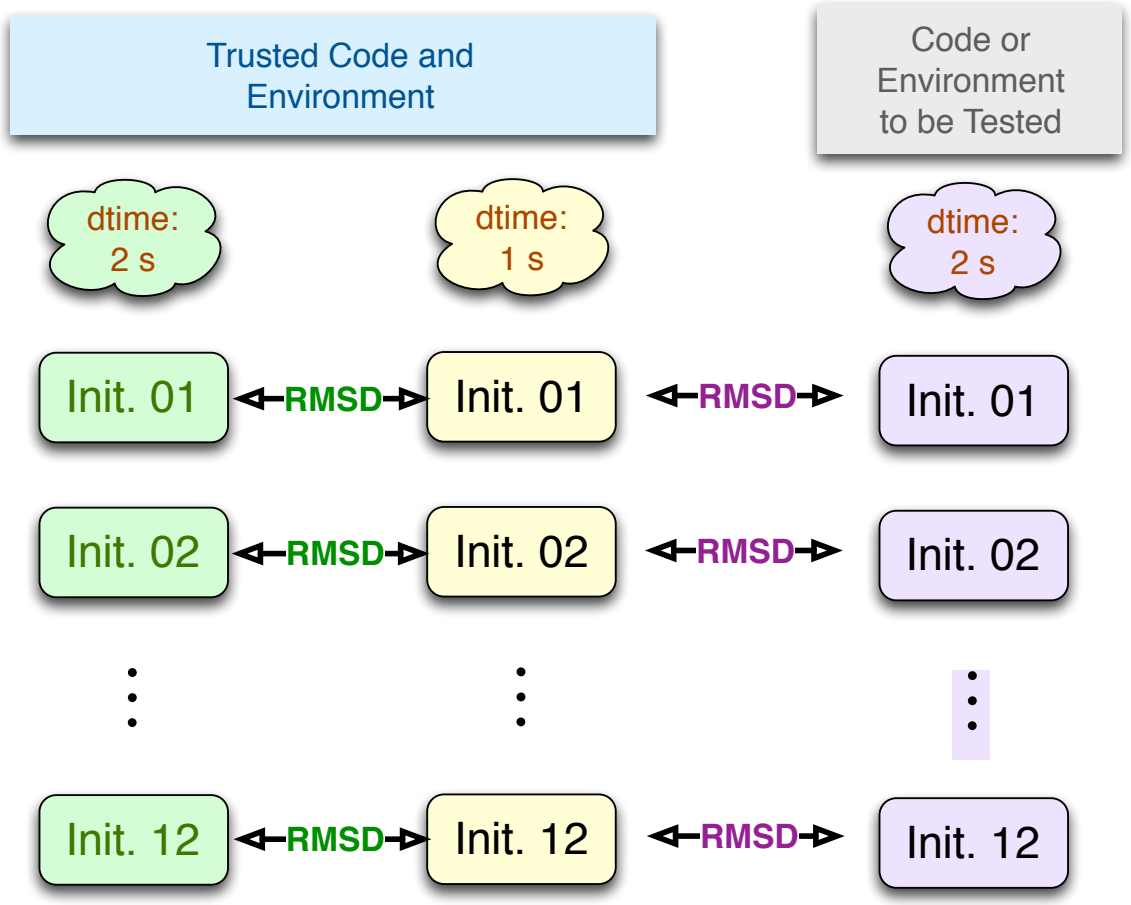

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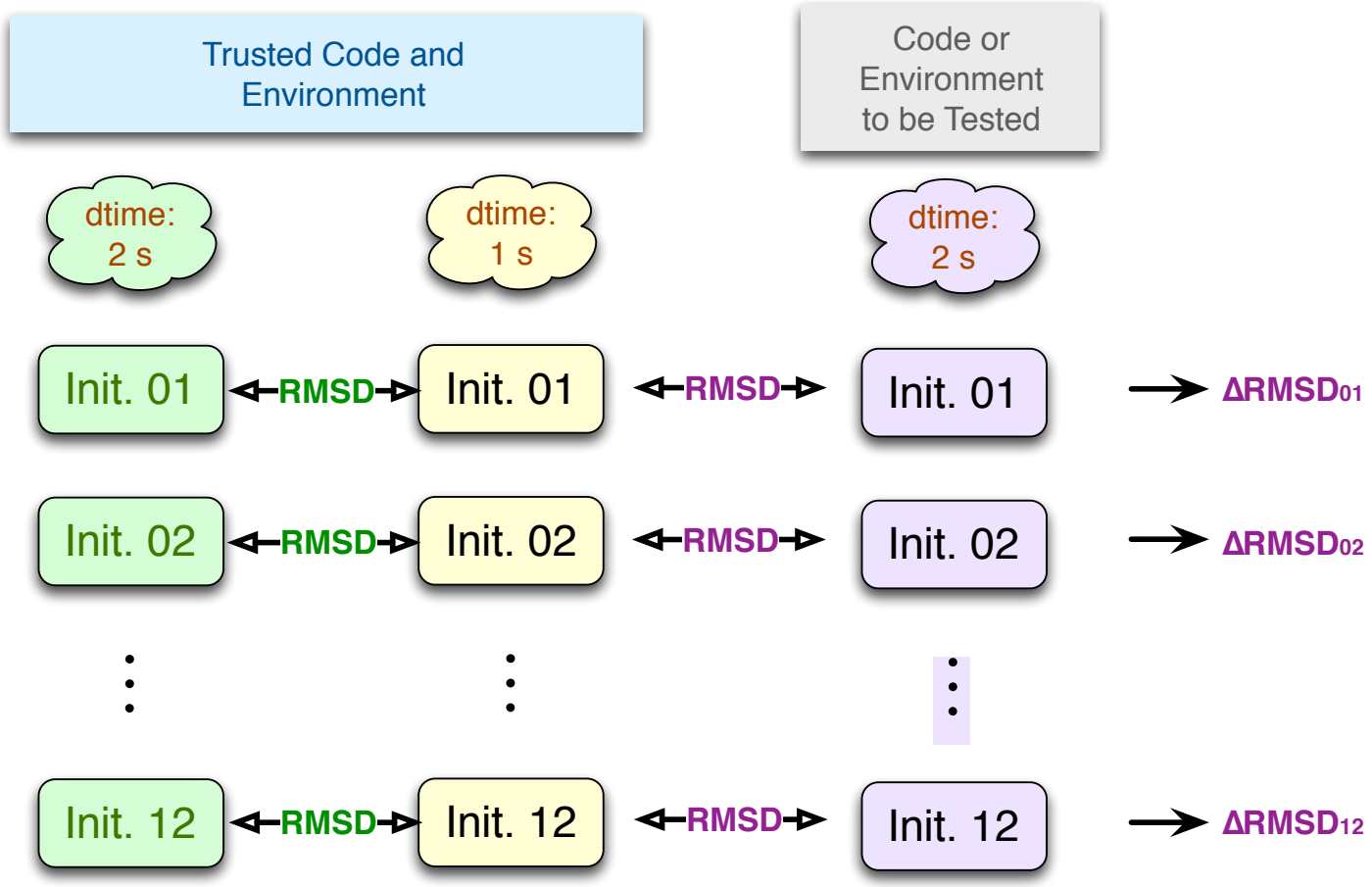

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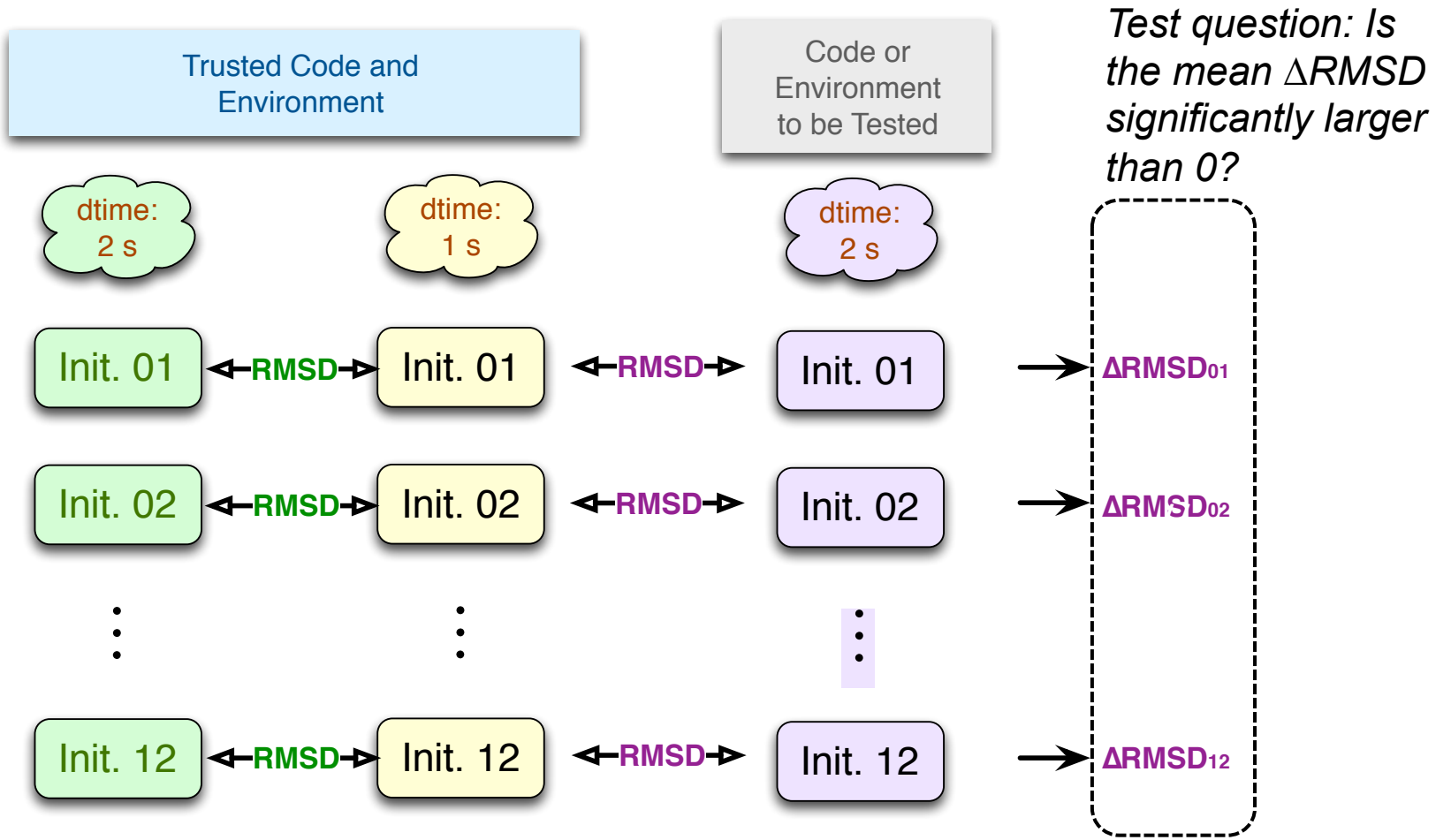
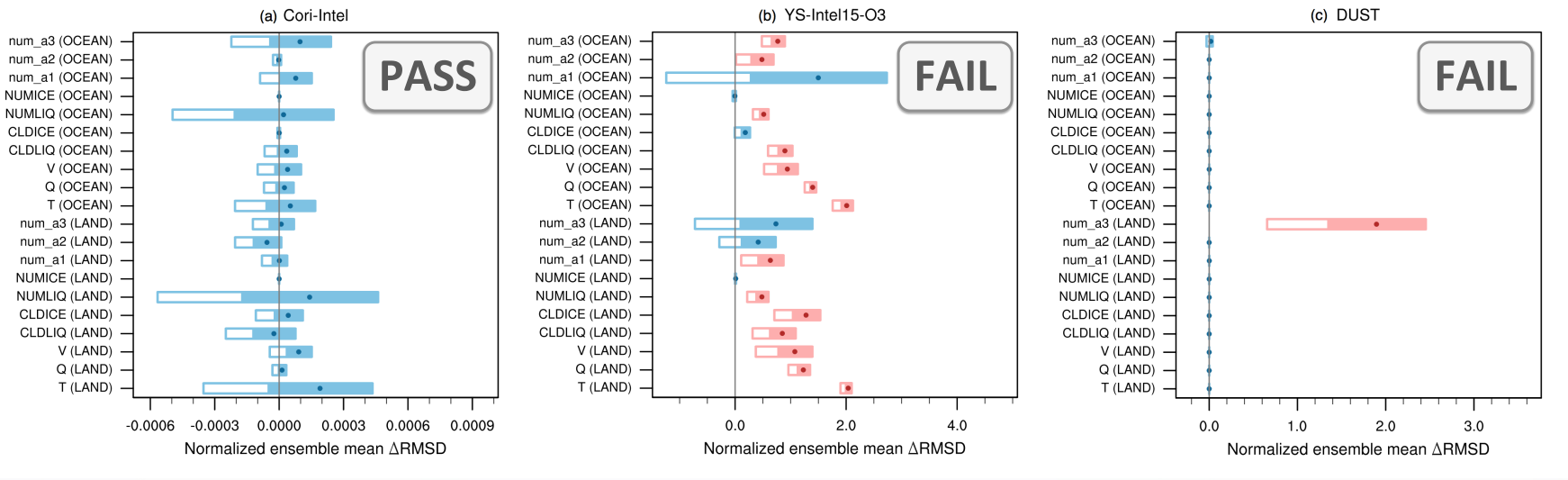


The New Test Method (TSC1.0)

- ΔRMSD is calculated for 10 prognostic variables and for land and ocean separately.
- If the probability of the ΔRMSD being zero is smaller than 0.05% for any of the 20 variables/domains, the test result is a “fail”



But How is This Related to the "Climate-Changing or Non-Climate-Changing" Question?

Category	Experiment	Expected Results	TSC Results
E	Titan-PGI	Pass	Pass
E	Constance-Intel	Pass	Pass
E	Cori-Intel	Pass	Pass
E	Yellowstone O2	Pass	Pass
E	Yellowstone O3	Fail	Fail
P	DUST	Fail	Fail
P	FACTB	Fail	Fail
P	FACTIC	Fail	Fail
P	RH-MIN-LOW	Fail	Fail
P	RH-MIN-HIGH	Fail	Fail
P	CLDFRC-DP	Fail	Fail
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Our New Method

- Is objective
- Is easy to implement (does not require any code change)
- Is much cheaper than NCAR's climate consistency test
- Can be used for debugging

What's Next

- Try it with the V1 model
- Evaluate the method using more scenarios (e.g. code bugs)
- Further optimization (ensemble size, statistical testing)

We believe the method is applicable to other model components - as long as they have appreciably positive convergence rates.