SILHS: A Monte Carlo interface between clouds and microphysics

Vincent E. Larson, Carsten Harlass, Jan Hoft

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Outline

1. How can we include subgrid variability in the many microphysics options in WRF?

2. One possible way: Use the SILHS Monte Carlo integrator.

3. Evaluation of SILHS via simulations of marine low clouds

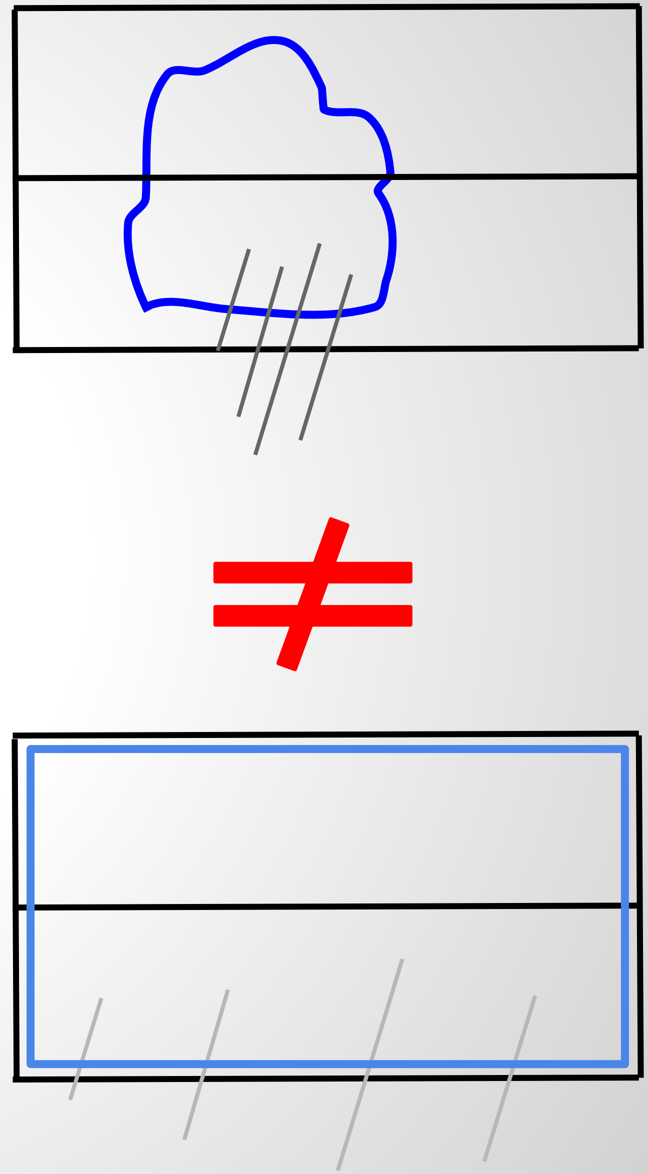
4. Conclusions and future outlook

The problem

We'd like to drive microphysical processes using subgrid-scale variability.

For instance, we'd like to account for the effects of partial cloudiness on drizzle rate. We'd also like to account for within-cloud variability.

What one would prefer to do:



What WRF does for many micro schemes:

A compounding problem

WRF contains many microphysical schemes, and we'd like to include subgrid variability in all of them.

Implementing, e.g., cloud fraction in all of WRF's microphysics schemes would be time consuming.

The root of the problem is that introducing cloud fraction into code that calculates local microphysical rates is too intrusive.

Our approach to address these problems*

1. Estimate subgrid variability related to clouds

2. Sample the subgrid variability using Monte Carlo sampling.

3. Feed the sample columns one by one into a microphysics scheme.

4. Average the resulting microphysics tendencies to form grid means.

* This approach is similar to the McICA approach for radiation, but here it is applied to microphysics.

We have created a Monte Carlo sampler called "SILHS"

1. SILHS = Subgrid Importance Latin Hypercube Sampler

2. From where does SILHS draw sample points? From subgrid probability density functions (PDFs) generated by a parameterization called "CLUBB."

3. We have implemented SILHS and CLUBB in a private copy of WRF.

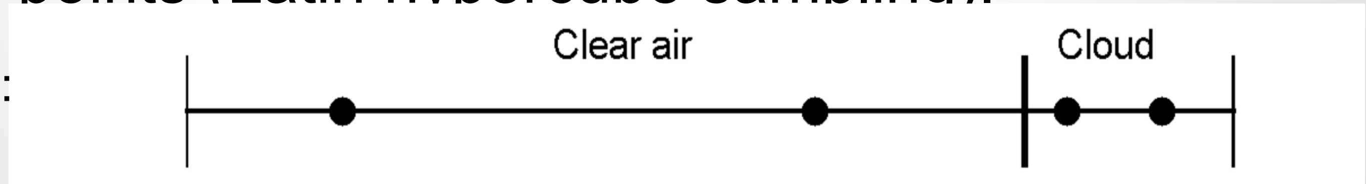
What are some *disadvantages* of SILHS?

Disadvantage 1 of SILHS: It introduces sampling noise

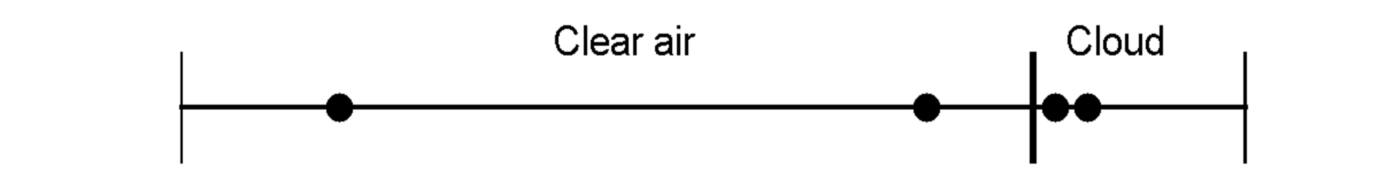
Because we can afford to use only a few sample points, SILHS introduces statistical sampling noise into simulations.

To reduce noise, SILHS draws points preferentially from cloud (importance sampling) and tries to prevent clumping of sample points (Latin hypercube sampling).

SILHS does this:



Not this:



Disadvantage 2 of SILHS: It has a large computational cost

SILHS generates random numbers and transforms them to a Gaussian or lognormal shape. Because of this, SILHS is expensive. In addition, when using SILHS, the microphysics may be called multiple times per grid box and time step.

However, optimization or parallelization of the code might reduce the runtime.

What are some potential *advantages* of SILHS over other methods?

Advantage 1 of SILHS: It's non-intrusive

SILHS separates the calculation of subgrid variability from local microphysical process rates. Hence, SILHS does not require that the microphysics code be altered.

Therefore, in principle, SILHS could be applied generally and conveniently to all microphysics schemes in WRF.

SILHS may be thought of as a general *interface* between subgrid parameterization and microphysics:

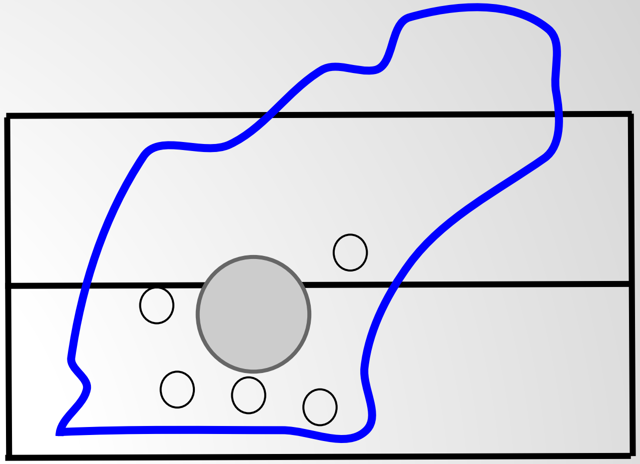
subgrid variability | SILHS | microphysics

Advantage 2 of SILHS: It's multivariate

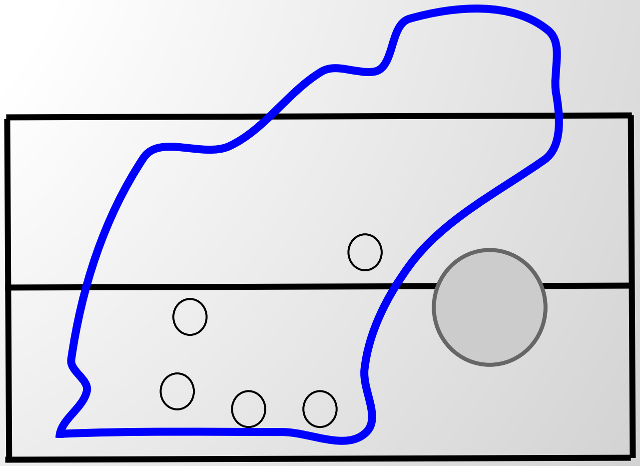
Some microphysical processes involve two or more hydrometeor species. An example is accretion of cloud droplets onto rain drops.

Such processes depend on the correlation of multiple species. SILHS can incorporate given correlations into the sampling.

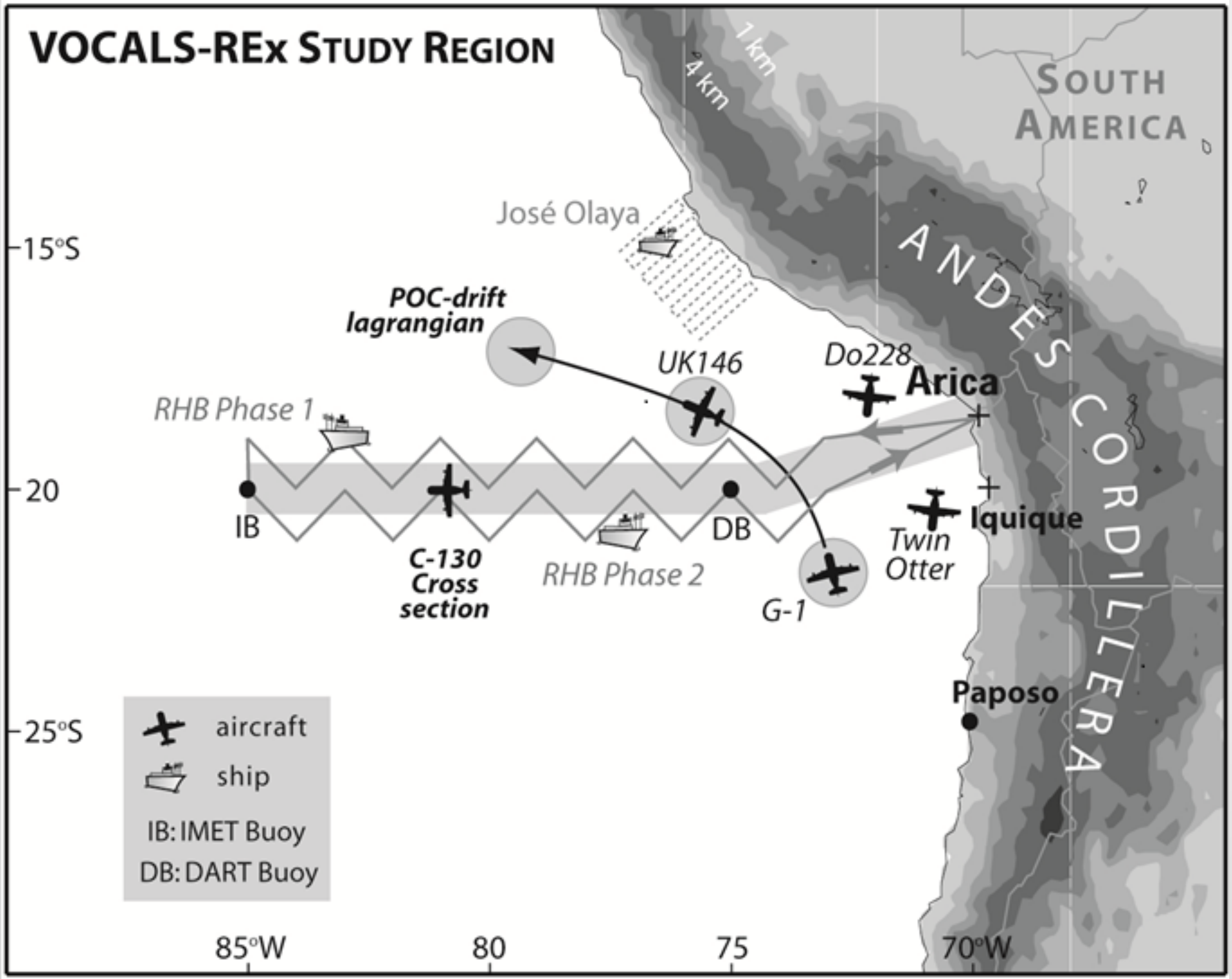
This rain drop will collect many cloud drops:



This rain drop will not:



A test case for evaluation of SILHS: The VOCALS experiment studied marine low clouds



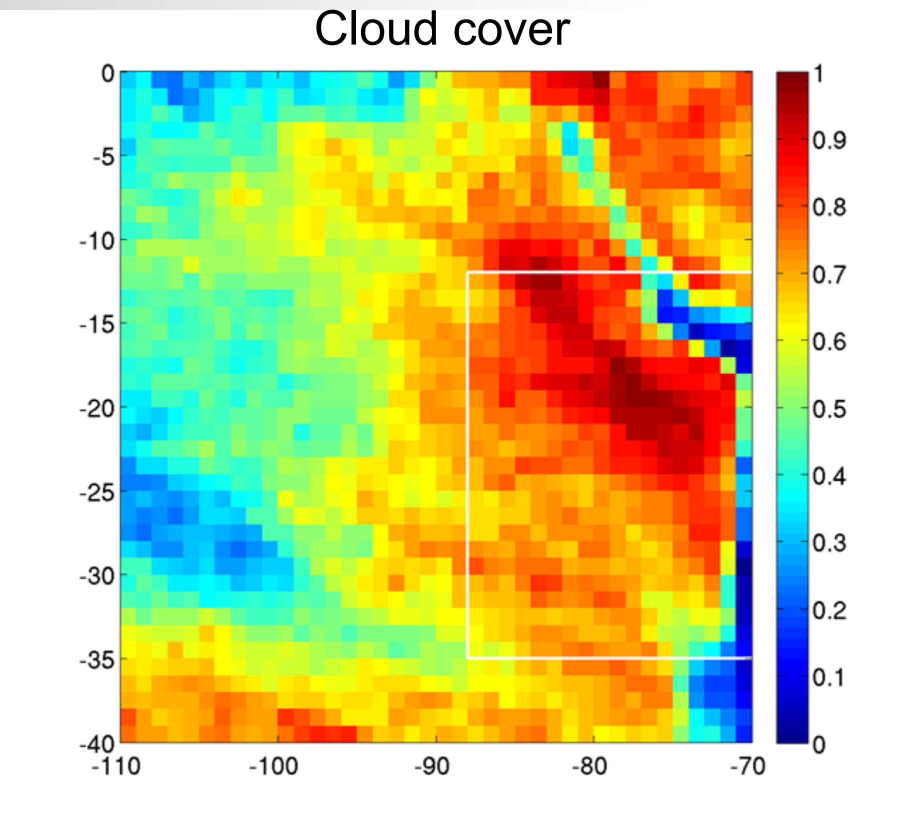
Courtesy
Rob Wood

WRF-CLUBB-SILHS has been used to simulate VOCALS clouds

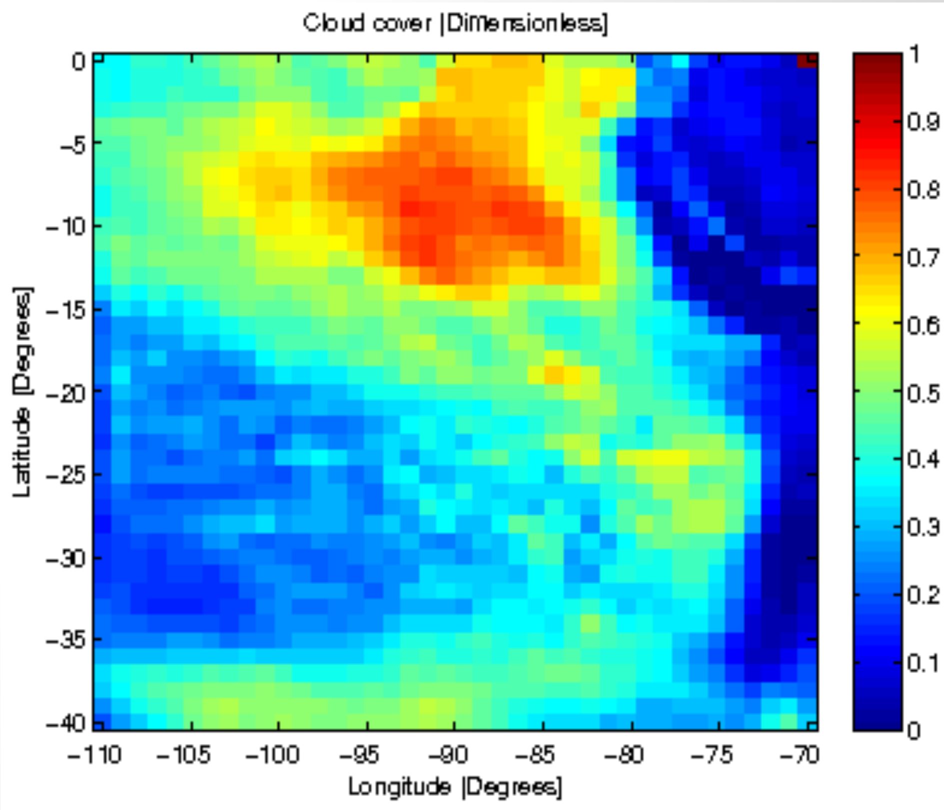
- We simulate a month-long period during Oct/Nov 2008 based on a simulation specification by Matt Wyant.
- In the plots that follow, we use the Morrison microphysics and a one-minute timestep.

WRF-CLUBB without SILHS underestimates time-averaged cloud cover (and places the cloud maximum too far north)

MODIS satellite obs



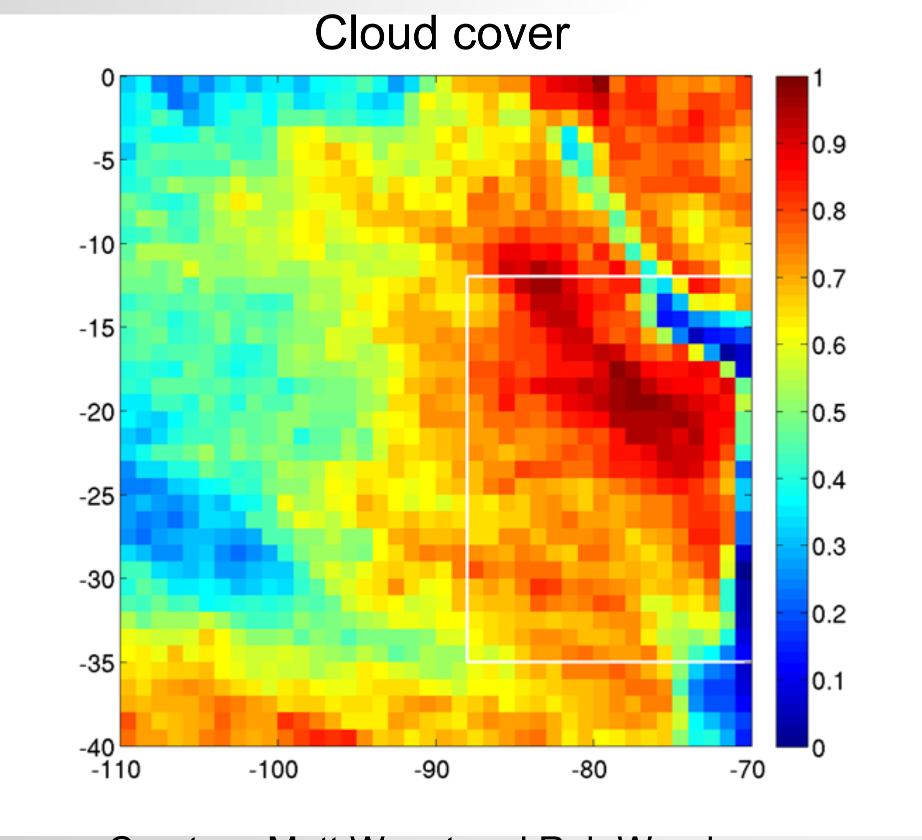
100-km WRF-CLUBB, no SILHS



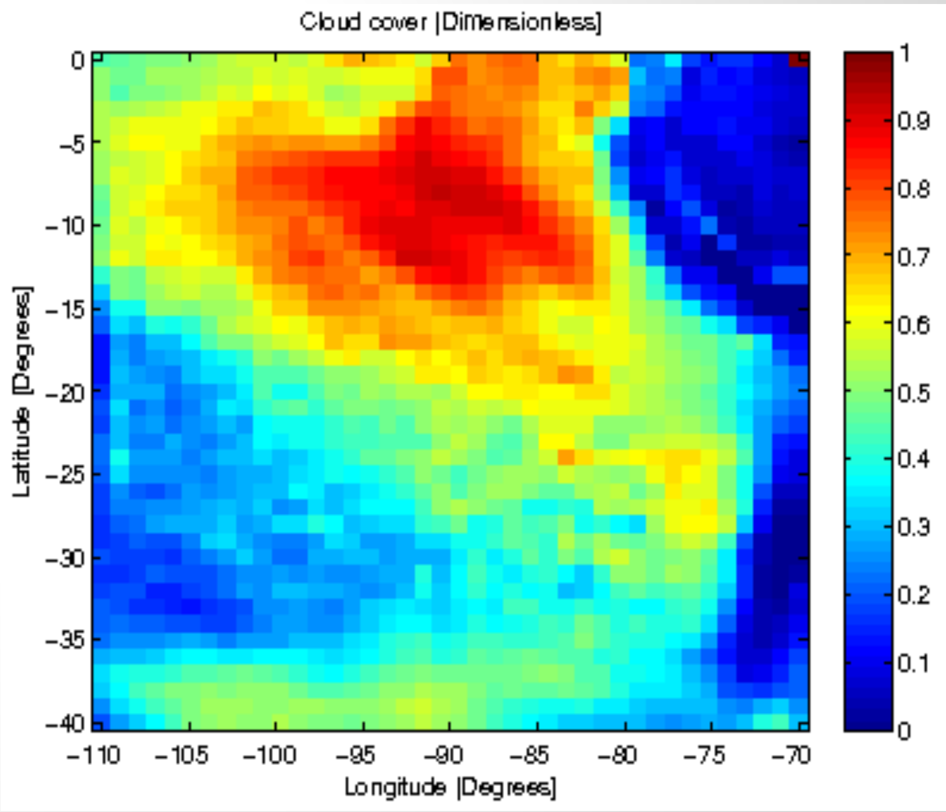
Courtesy Matt Wyant and Rob Wood

SILHS increases cloud cover by preventing Cu from evaporating during saturation adjustment

MODIS satellite obs



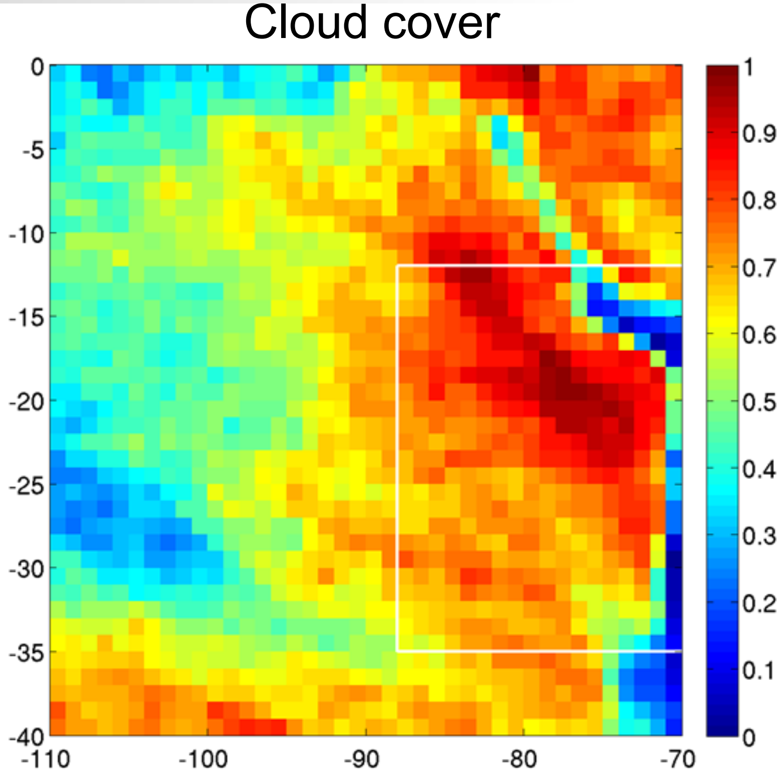
100-km WRF-CLUBB, with 2 SILHS points



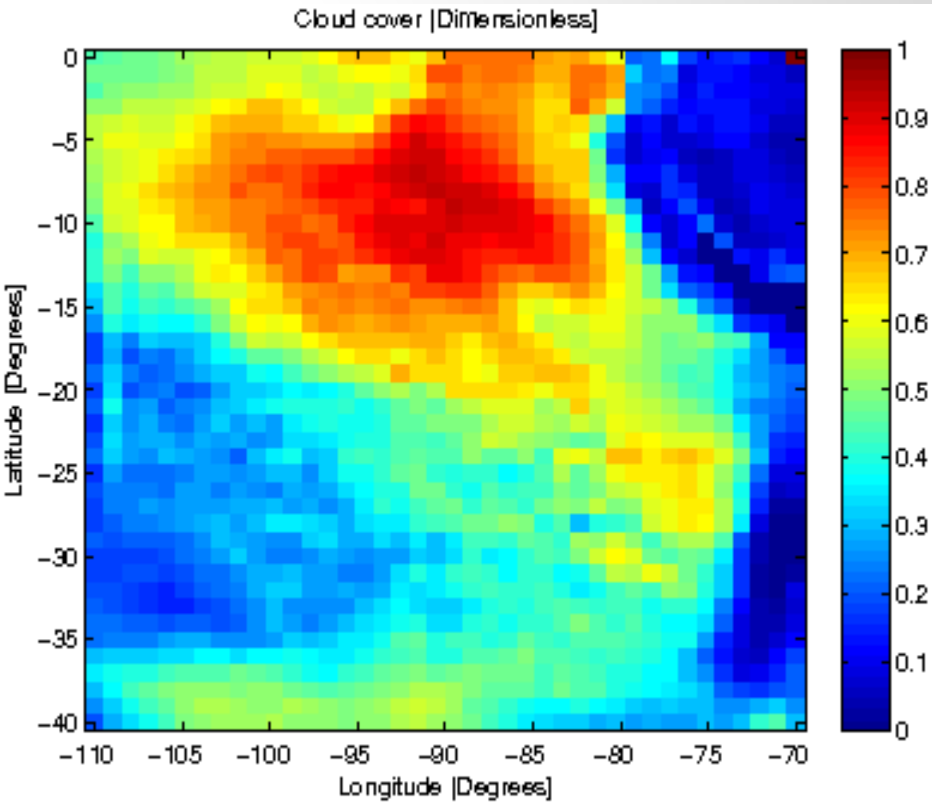
Courtesy Matt Wyant and Rob Wood

The solutions do not change much if we use 16 SILHS sample points instead of 2

MODIS satellite obs



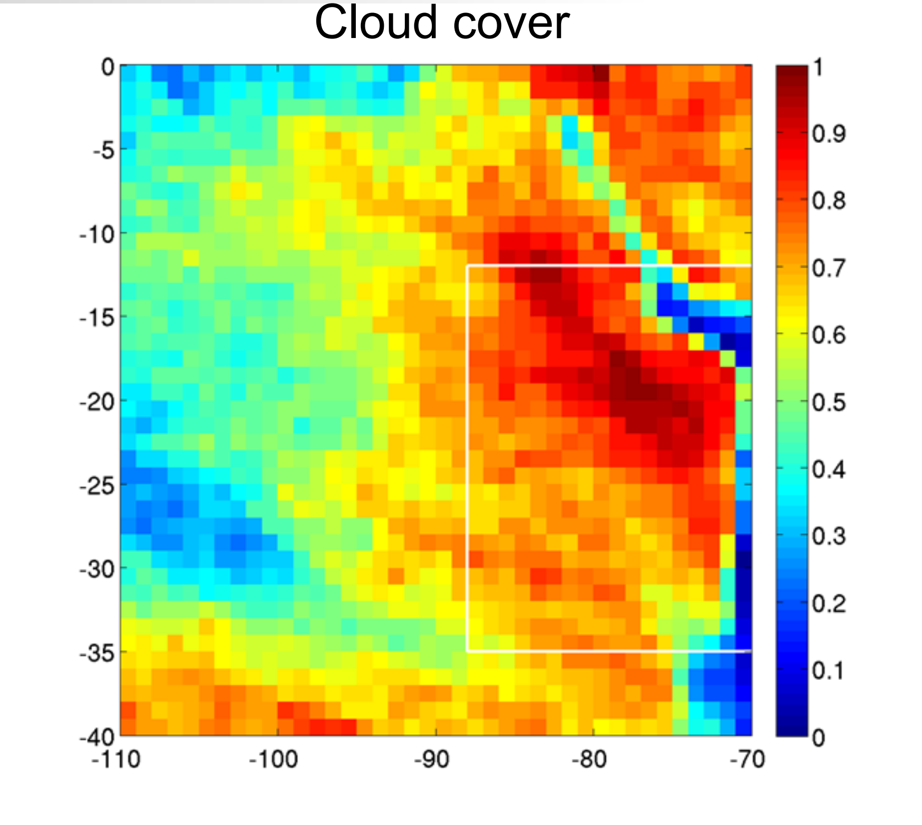
100-km WRF-CLUBB, with 16 SILHS points



Courtesy Matt Wyant and Rob Wood

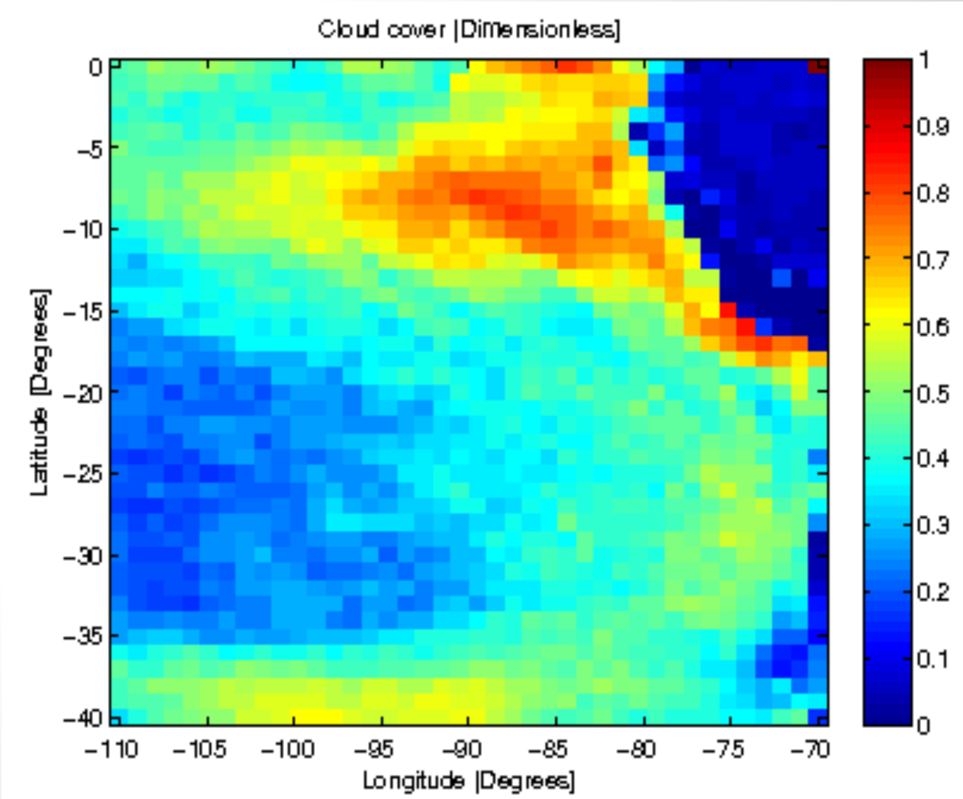
At 25-km grid spacing, WRF-CLUBB without SILHS produces near-coastal clouds but underestimates time-averaged cloud cover

MODIS satellite obs



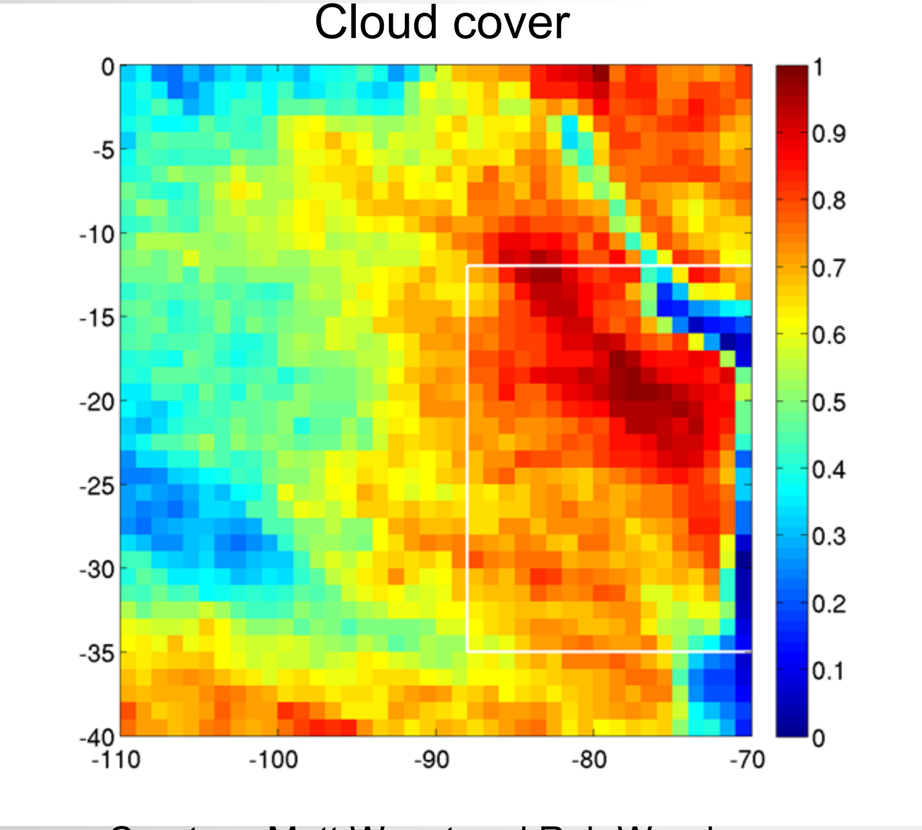
Courtesy Matt Wyant and Rob Wood

25-km WRF-CLUBB, no SILHS

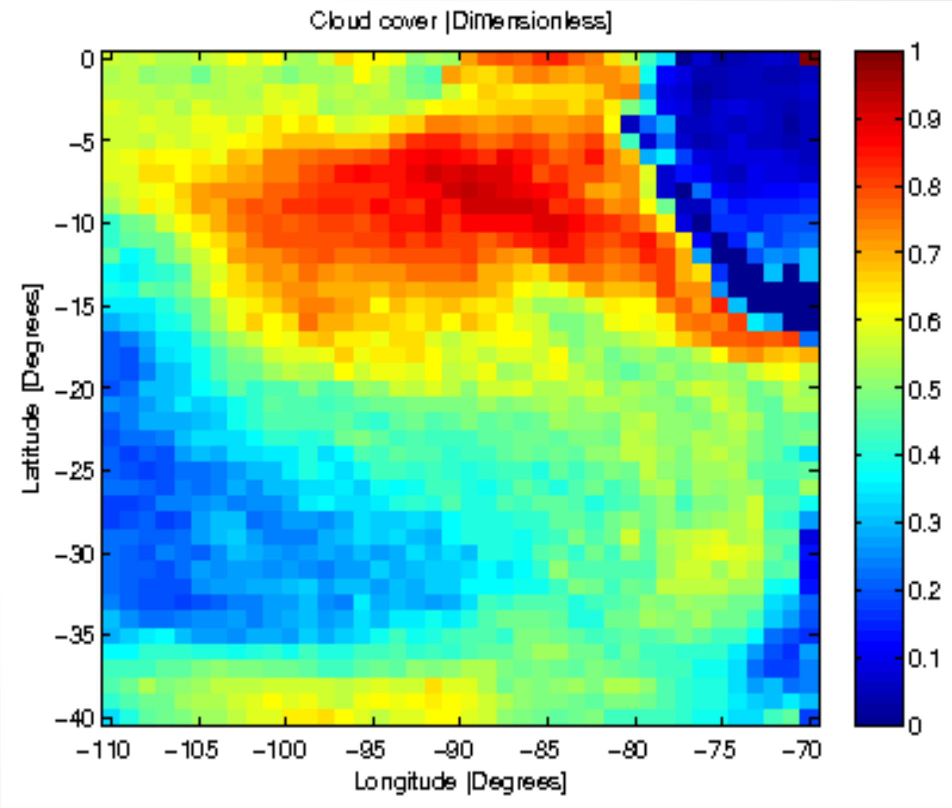


Even at 25-km grid spacing, use of SILHS still increases cloud cover

MODIS satellite obs



25-km WRF-CLUBB, with 2 SILHS points



Courtesy Matt Wyant and Rob Wood

Computational cost

Configuration	Relative computational cost
WRF-CLUBB, no SILHS	1.0
WRF-CLUBB, 2 SILHS points	1.2
WRF-CLUBB, 16 SILHS points	3.1

Conclusions and future outlook

- We've implemented a Monte-Carlo integrator ("SILHS") in WRF. Its purpose is to feed information about subgrid variability into microphysics schemes.

- We've tested SILHS for marine low clouds. It tends to increase cloudiness because it avoids evaporating cloud in grid boxes that are subsaturated in the mean.

- In the future, perhaps SILHS could be used to drive microphysics, radiation, and chemistry in a consistent way.

Thanks for your time!