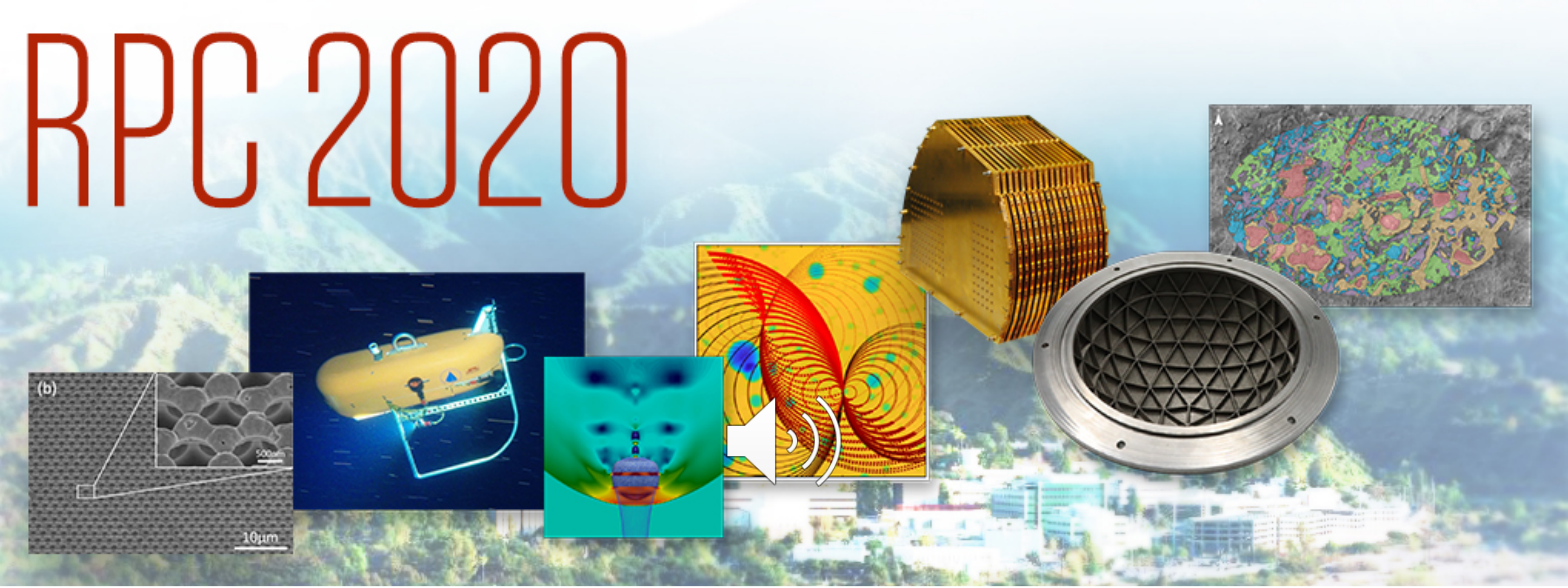

Virtual Research Presentation Conference

Observational system for constraining clouds and precipitation in atmospheric models

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Program: Topic

RPC 044

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Tutorial Introduction

Problem statement:

- Atmospheric numerical models are the primary tools for weather prediction and climate change simulation.
- Representations of subgrid-scale physical processes are the most uncertain part of the models and are responsible for the bulk of the uncertainty of climate change simulations and weather forecasts.
- Global observations combined with models are needed for improving understanding and representation of these uncertain processes.
- The important questions are:
    1. What variable should we measure to most improve process understanding and reduce model bias?
    2. What are the requirements for such measurements? (vertical resolution, error)

Project achievements & significance for JPL:

- Develop and validate objective methodology that informs questions 1 and 2.
- We propose for JPL to use this methodology when developing new instruments and mission priorities.

Methodology

Developed methodology answers the following questions:

a) Which processes in atmospheric models are responsible for the bulk of the model result uncertainty?

b) Which physical variables should be observed to successfully constrain these influential processes?

c) What are the required vertical resolution and error of measurements to meaningfully constrain influential processes?

Ingredients:

a) Numerical model: JPL Eddy-Diffusivity/Mass-Flux (JPL-EDMF) model

b) Proxy for observations: results of turbulence-resolving model

c) Studied processes: clouds, convection and turbulence for the the subtropical marine clouds

d) Studied case: shallow convection and stratocumulus clouds (here only shallow convection results are shown)

Details:

Suselj, K., D. Posselt, M. Smalley, M. Lebsock, J. Teixeira, 2020: A new methodology for observation-based parameterization development. Mon. Weather Rev. (Early Online Release), doi: 10.1175/MWR-D-20-0114.1

Which processes in atmospheric models are responsible for the bulk of the model result uncertainty?

Methodology:

a) JPL – EDMF model (Suselj et al., 2013,2019,2019a):

- Subgrid scale dynamics represented with convective plumes and locally-driven turbulence
- Subgrid scale dynamics coupled with cloud and rain physics

b) Consider only parametric uncertainty of the model – identification of 14 parameters that could lead to model result uncertainty

c) Computationally-efficient Morris-one-at-the-time (MOAT) parameter screening method to identify influential parameters

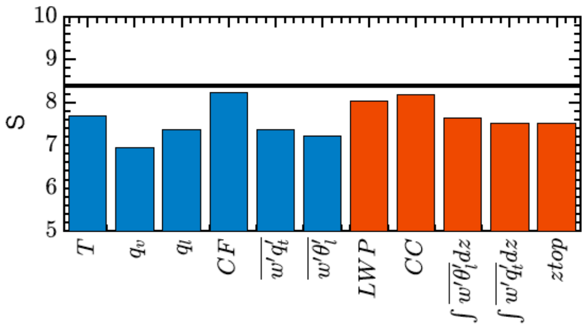
Results:

a) Essentially all model results are sensitive to only 4 model parameters:

- Two parameters describing interaction of convective plumes with the environment
- Parameter for subplume vertical-velocity variability and its contribution to the mean vertical velocity
- Parameter in small-scale turbulence mixing

Which physical variables should be observed to successfully constrain the influential model parameters?

- Bayesian estimation of posterior probability function (PDF) of model parameter values constrained by different observations
- Shannon information entropy: quantify how well different observations constrain influential model parameters



Shannon information entropy of PDF constrained by different observations (lower value = more constrained parameters). Blue bars – profile observations, Red bars - vertically integrated observations.

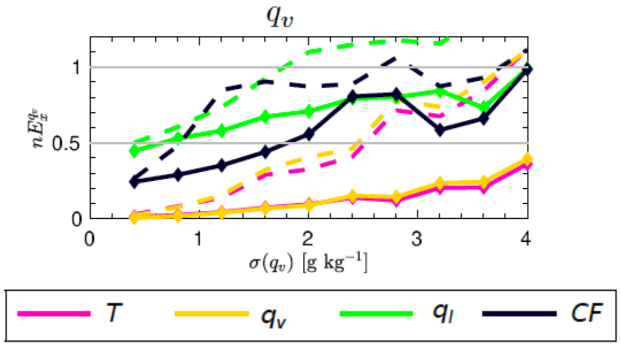
Key results:

- Observations of water vapor profile (q_v) best constrain influential model parameters.
- The most constraining observables don't necessarily have to be related to the model processes that need to be constrained.

What are the required vertical resolution and error of measurements to meaningfully constrain influential parameters?

a) Repeat Bayesian parameter estimation but constraining observations are with degraded vertical resolution and introduction of random error

b) Evaluate how well the JPL-EDMF model constrained with degraded observations represents important model results (i.e. by estimating the error of modeled results).



Expected normalized error of JPL-EDMF model results (y-axis) for model parameters constrained with water vapor profile observations with certain measurement error (indicated by x-axis) with vertical resolution of 40 m (solid lines with diamonds) and 200 m (dashed lines). The modeled results include profiles of temperature, water vapor mixing ratio, liquid water mixing ratio and cloud fraction.

Key results:

- There is a balance between the vertical resolution and acceptable error of measurements.
- Defining the acceptable error, one can use the plot to infer the measurement requirements.

Relevance for JPL

- The developed methodology can be applied to different physical processes/geographical locations and atmospheric models
- We propose the newly developed methodology to be used for designing new instruments and mission concepts

Publications and References

JPL-EDMF model description:

- Suselj, K., J. Teixeira and D. Chung, 2013: A unified model for moist convective boundary layers based on a stochastic eddy-diffusivity/mass-flux parameterization. J. Atmos. Sci., 70, 1929–1953, doi: 10.1175/JAS-D-12-0106.1.
- Suselj, K., M. J. Kurowski, and J. Teixeira, 2019: A Unified Eddy-Diffusivity / Mass-Flux Approach for Modeling Atmospheric Convection. J. Atmos. Sci., 76 (8), 2505–2537, doi:10.1175/JAS-D-18-0239.1.
- Suselj, K., M. J. Kurowski, and J. Teixeira, 2019b: On the Factors Controlling the Development of Shallow Convection in Eddy-Diffusivity / Mass-Flux Models. J. Atmos. Sci., 76 (2), 433–456, doi:10.1175/JAS-D-18-0121.1.

The details of this work:

- *Suselj, K., D. Posselt, M. Smalley, M. Lebsock, J. Teixeira, 2020: A new methodology for observation-based parameterization development. Mon. Weather Rev. (Early Online Release), doi: 10.1175/MWR-D-20-0114.1*