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The role of Large-Eddy Simulation in PBL Observing System Simulation Experiments

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2017 National Academy of Sciences Earth Science Decadal Survey

TARGETED OBSERVABLE	SCIENCE & APPLICATIONS SUMMARY	SCI/APPS PRIORITIES (MI, VI, I)	RELATED ESAS 2007 and POR	IDENTIFIED NEED/GAP	CANDIDATE MEASUREMENT APPROACH	ESAS 2017 DISPOSITION
TO-13 Planetary Boundary Layer	• Temperature • Water vapor • PBL height	- H-2a - W-1a, 2a, 3a, 10a - - - C-2b, 4a, 7a, 7b, 7c, 7d, 7e	*ESAS 2007:* PATH *POR:* AMSU/Aqua, AIRS/Aqua, CrIS/JPSS, ISAI/MetOp, AMSU/ MetOp, COSMIC, MHS/MetOp, CALIPSO, GOES-R, AMSR	POR lacks sufficient horizontal and temporal resolution	*Similar to:* AIRS, AMSU, COSMIC • Microwave & hyperspectral IR sounders; lidar for PBL height • Sampling with 3-20km horizontal, 0.2-1km vertical, 1-4hr temporal resolution	INCUBATION PROGRAM ELEMENT Consider opportunistic use of data from recommended TO-12 investment for PBL height

- ***Incubating concepts*** to observe the **planetary boundary layer** (PBL) as one of its areas of emphasis for the next decade (PBL mentioned > 100 times)
- **PBL is High Priority**: Cuts across panels (Weather and AQ, Climate, Water Resources, Ecosystems) and Integrating Themes
- **PBL was the most important objective for Weather and AQ panel**

PBL Measurement Approaches: GNSS RO, Hyperspectral IR and MW sounding, SW, Lidar/DIAL, Radar/DAR → complementary approaches

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A key challenge is to develop a framework to assess different measuring technologies and to determine the best architectures to optimally address the PBL requirements.

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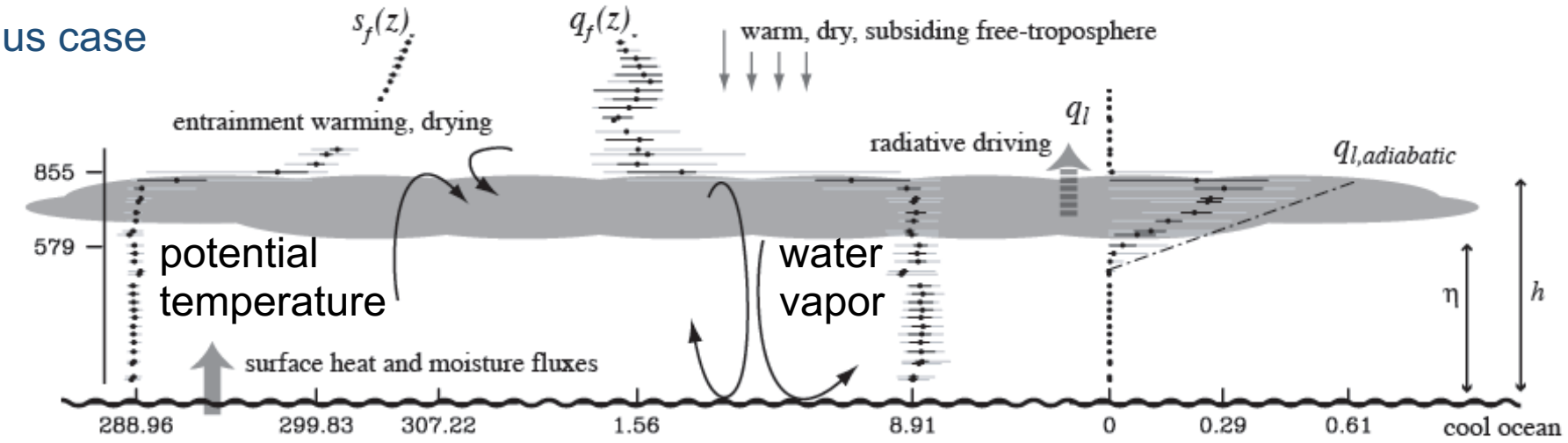
Planetary Boundary Layer

Stratocumulus case



Stevens et al. 2005

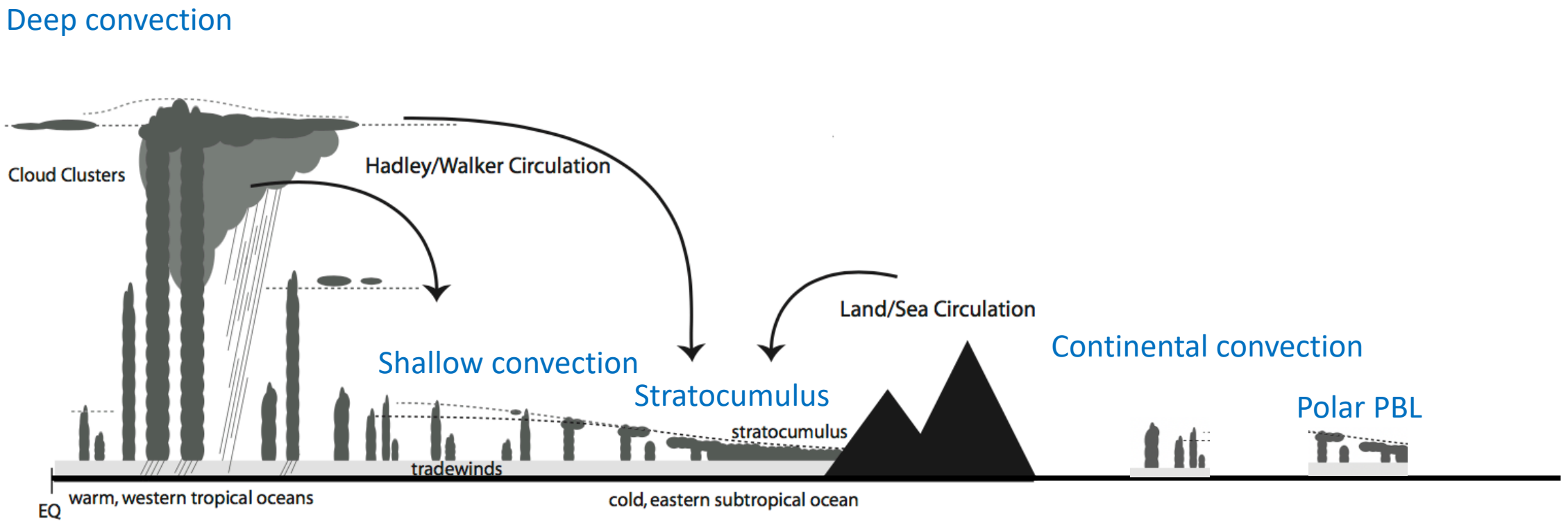
Essential role of temperature and water vapor:

- Dominate the buoyancy in the PBL
- Set the stage for clouds and control PBL mixing
- Determine the structure of other PBL constituents

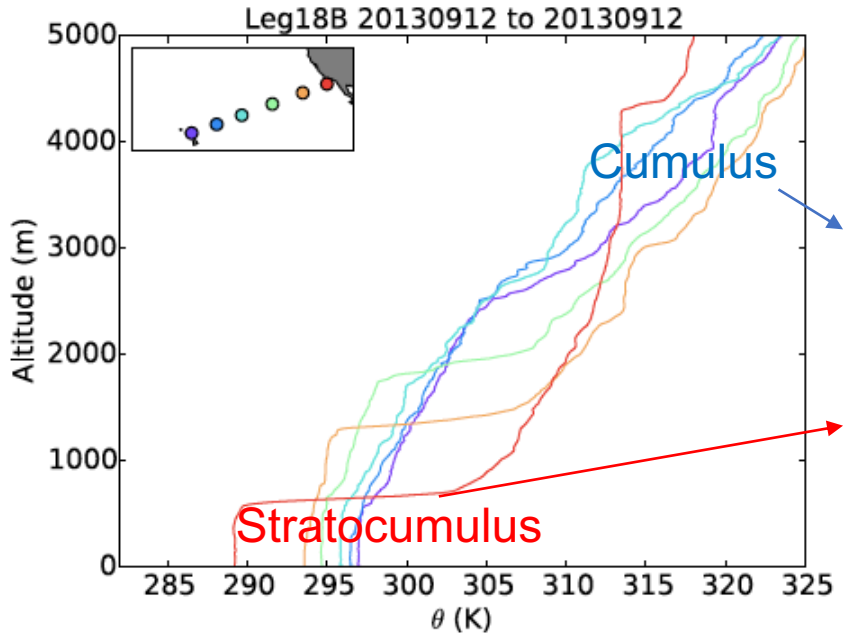
Key observational and modeling challenges:

- Strong vertical gradients
- Small-scale turbulent mixing

Planetary Boundary Layer

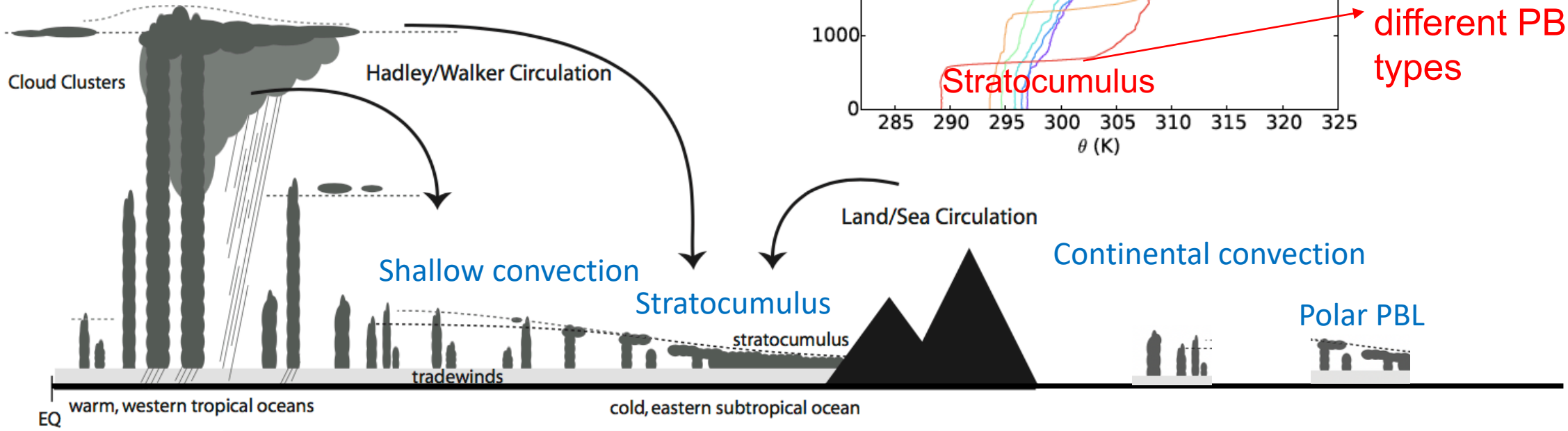


Planetary Boundary Layer



Different resolution requirements for different PBL types

Deep convection



EQUATOR

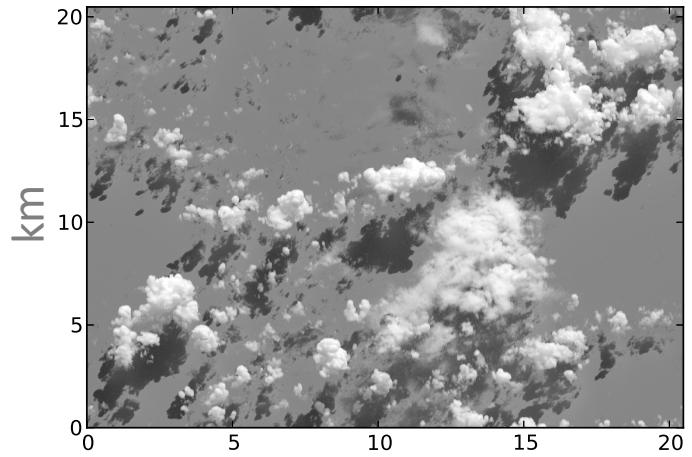
NORTH POLE

water vapor (g/kg)	17	15	10	14	1.5
Temperature (C)	30	25	18	24	-5

→ Different sensitivity requirements

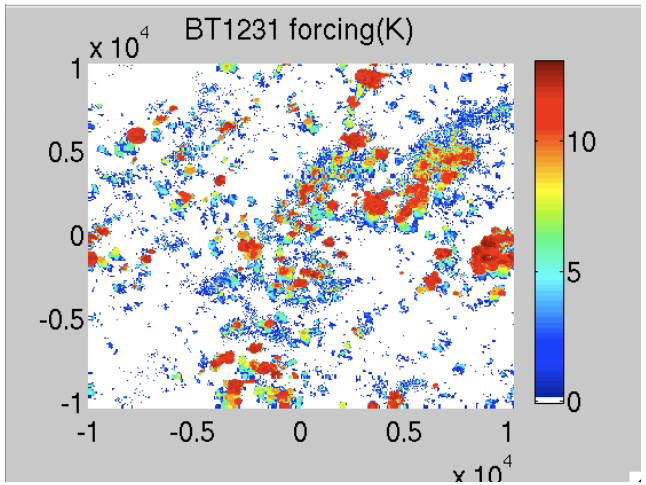
PBL Observing System Simulation Experiment (OSSE) framework

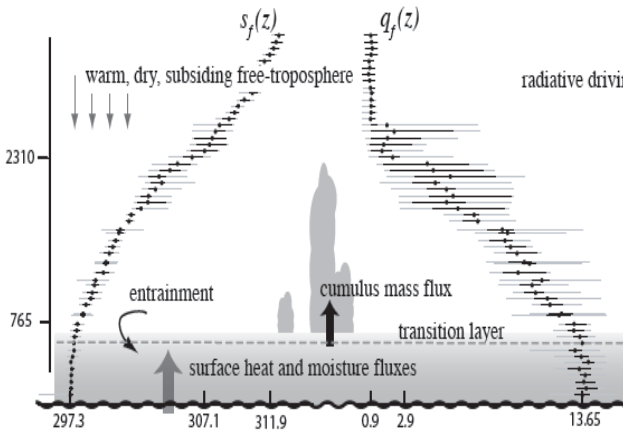
Strategy: LES, Forward models, Retrievals



Matheou and Chung 2014

Radiative forward model +
instrument characteristics

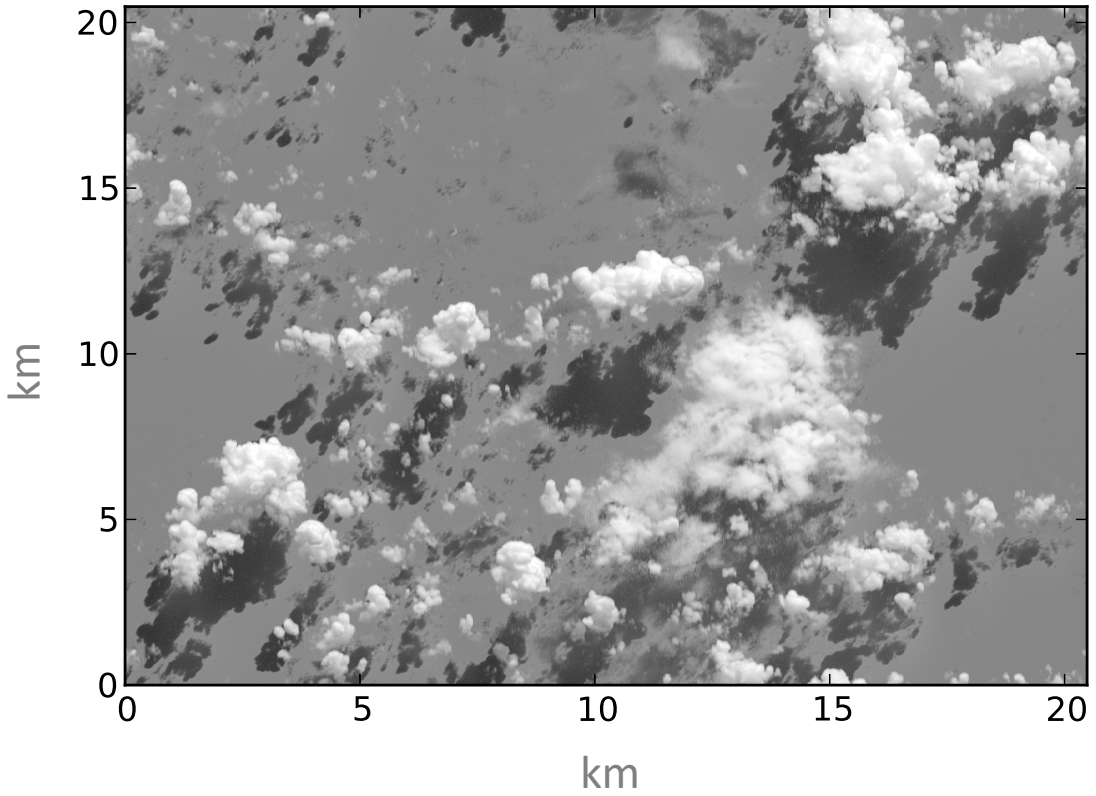




Retrieval of geophysical variables
(and/or data assimilation)

Large-eddy simulation

- LES models solve filtered Navier-Stokes equations
- High-resolutions (~10-100 m) in all 3 dimensions
- LES models resolve most of the essential turbulence/convection
- LES is known for its fidelity in representing different types of PBL



Matheou and Chung 2014

Building the library of LES cases

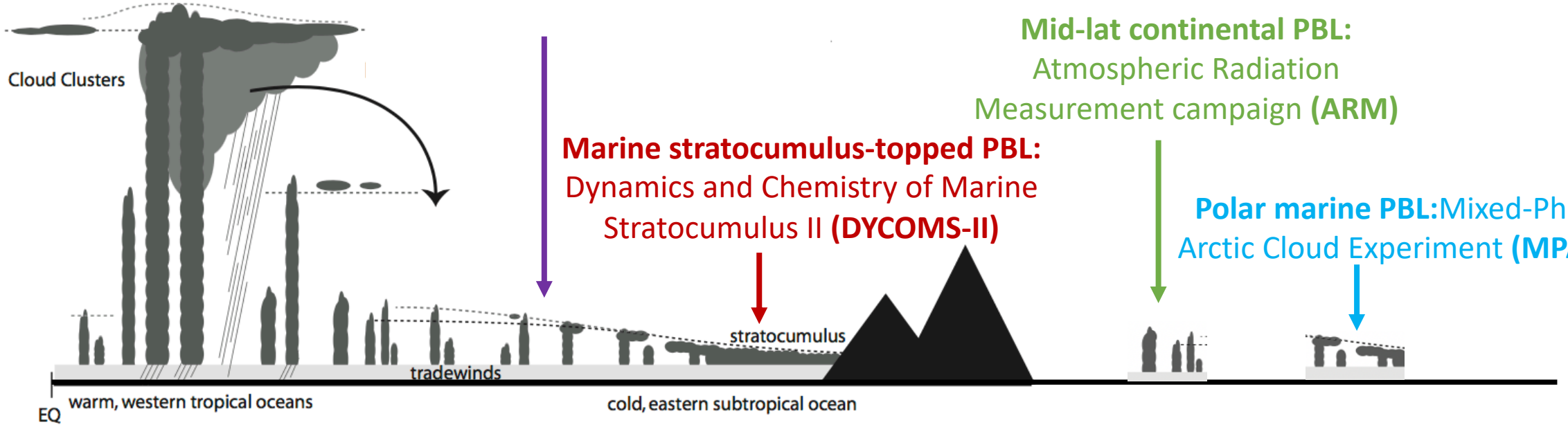
Tropical continental PBL :
Large- Scale Biosphere–Atmosphere experiment **(LBA)**

Cumulus marine PBL:
Barbados Oceanographic and Meteorological Experiment **(BOMEX)**

Marine stratocumulus-topped PBL:
Dynamics and Chemistry of Marine Stratocumulus II **(DYCOMS-II)**

Mid-lat continental PBL:
Atmospheric Radiation Measurement campaign **(ARM)**

Polar marine PBL: Mixed-Phase Arctic Cloud Experiment **(MPACE)**



EQUATOR

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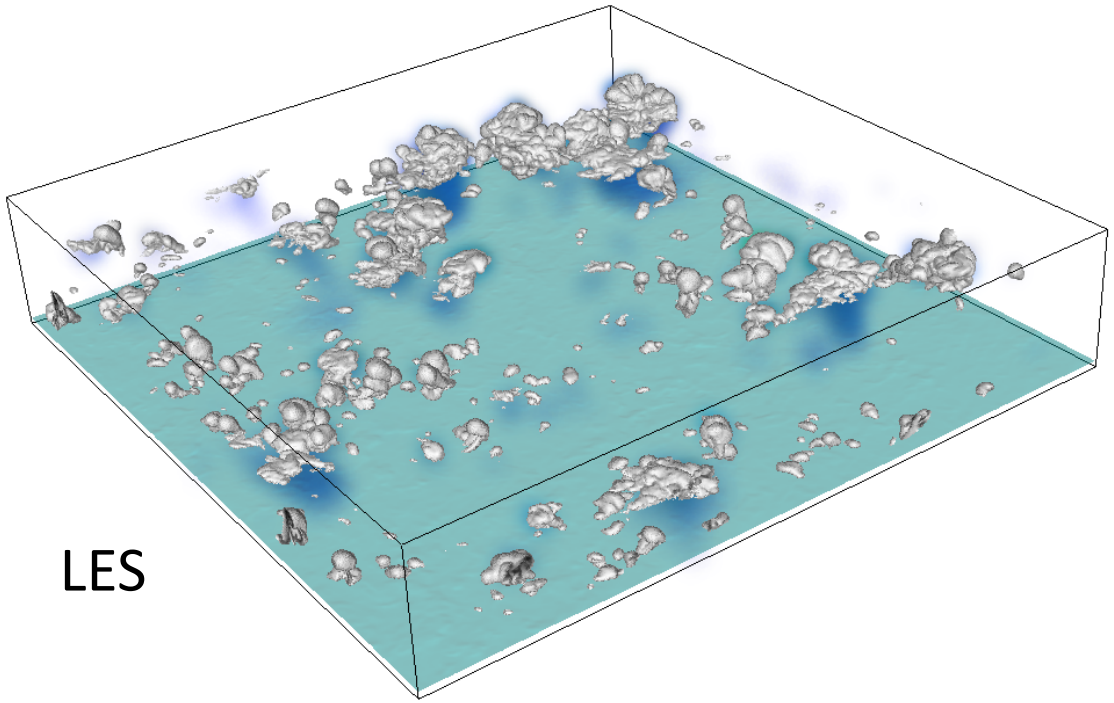
Example of forward modeling

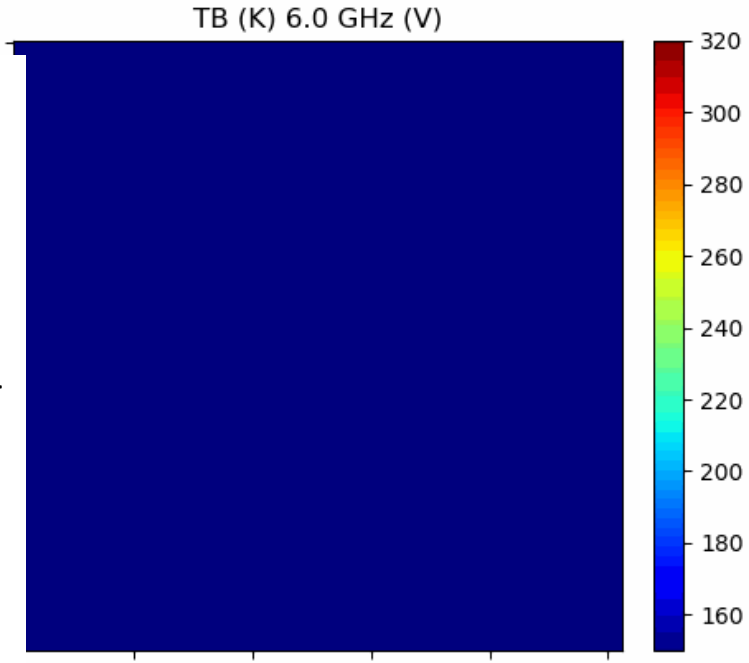


LES

Hyperspectral Microwave Simulation

Passive MW forward model integrated with LES simulations

Produces broad-spectrum, multi-angle simulated brightness temperatures



Ongoing work

- Updating the LES database with more PBL types
- Determining information content for each of the instruments for different PBL types
- Determining sensitivity/resolution capabilities and trade-offs of precision vs. spatial averaging of the next-generation instruments; Performing uncertainty and bias analysis
- Looking for a synergy of different measurement techniques to strengthen their mutual capabilities in retrieving the PBL structure (T, q, PBL height)