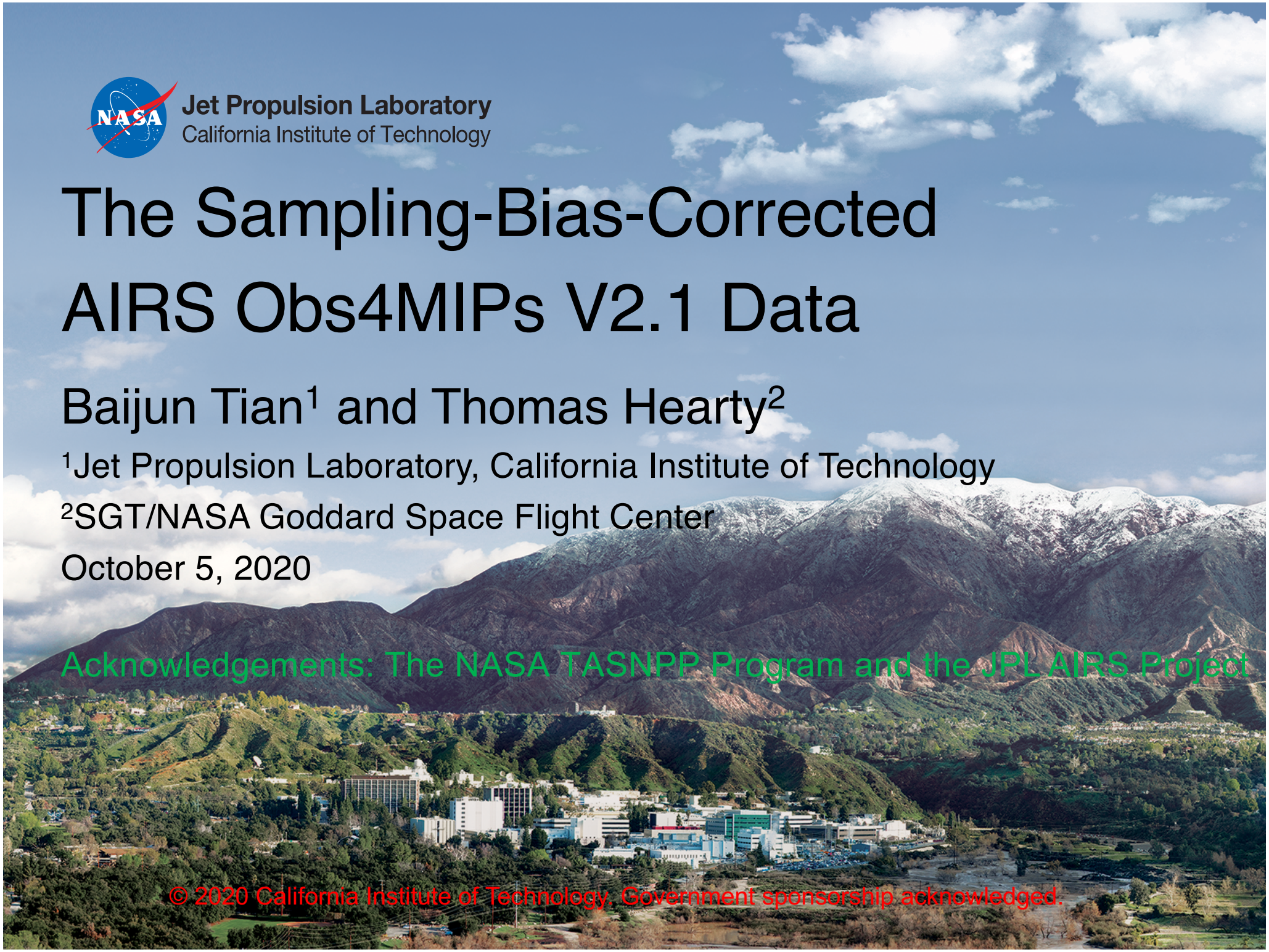

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The Sampling-Bias-Corrected AIRS Obs4MIPs V2.1 Data

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Outline

1. Introduction
2. Estimating the Sampling Biases
3. Removing the Sampling Biases
4. CMIP6 Model Evaluation
5. Summary

CMIP

- The Coupled Model Intercomparison Project (CMIP) is an international project that collects and archives multiple climate model outputs in a standardized format to make them publicly available by the wider climate community and users.
- The CMIP has evolved over five phases and become a central element of national and international assessments of climate change. For example, the CMIP Phase 3 (CMIP3) and Phase 5 (CMIP5) multi-model data sets have played an essential role for the Intergovernmental Panel on Climate Change (IPCC) Fourth and Fifth Assessment Reports (AR4 and AR5), respectively.
- The latest state-of-the-art climate model outputs from the CMIP Phase 6 (CMIP6) will be the foundation for the upcoming IPCC Sixth Assessment Report (AR6), scheduled for publication ~2021.
- To increase confidence in future climate projections and the fidelity of IPCC AR6, CMIP6 model experiments need rigorous evaluation.

Obs4MIPs

- To help CMIP model evaluation, the “Observations for Model Intercomparison Projects” (Obs4MIPs) was initiated by the NASA JPL and the DOE PCMDI to collect well-established and well-documented satellite datasets, organize them according to the CMIP model output requirements, and publish them on the Earth System Grid Federation (ESGF).
- The Obs4MIPs products are:
  - Directly comparable to a model output field in CMIP experiments,
  - Open to contributions from all data producers that meet the Obs4MIPs requirements,
  - Well documented, with traceability of product version changes, and
  - Served through ESGF.

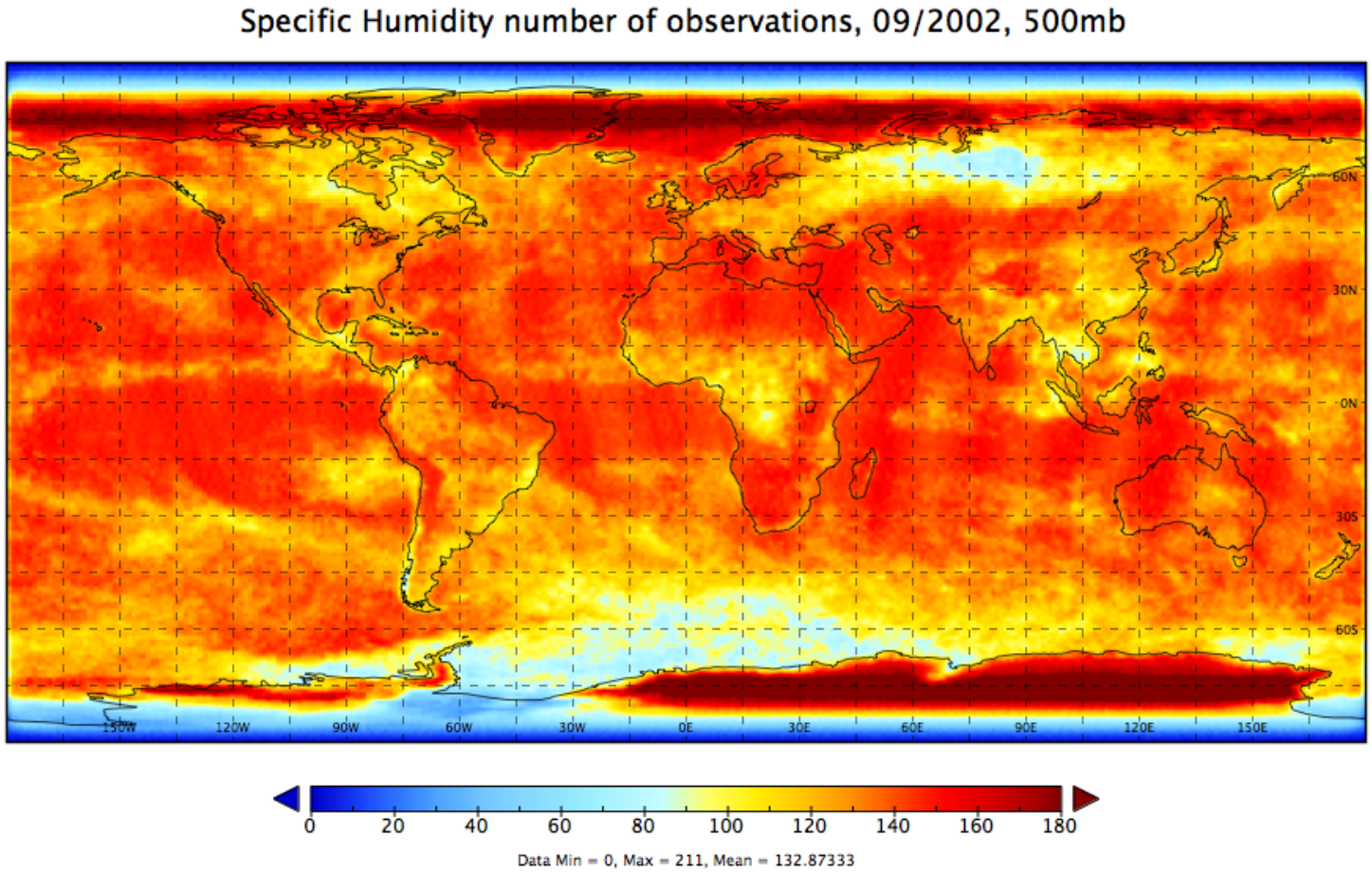
AIRS Obs4MIPs V2.0 Dataset

- Monthly mean tropospheric **air temperature (ta), specific humidity (hus), and relative humidity (hur)** profiles from Sep 2002 to Sep 2016 on a global 1ºx1º spatial grid and on the CMIP mandatory vertical pressure levels from 1000 to 300 hPa.
- For each physical variable (ta, hus, and hur), there are corresponding standard error (Stderr) and number of observations (Nobs) for a rough estimate of AIRS data retrieval error and sampling uncertainty.
- Publicly available on the ESGF website since Apr 2018.
- The major improvements from the V1 dataset are:
  - Based on the AIRS V6 L3 standard monthly products in the “TqJoint” grids from the AIRS/AMSU-A combined retrievals;
  - Covers from Sep 2002 to Sep 2016;
  - Includes monthly mean tropospheric relative humidity (hur) data.

Tian, B., Fetzer, E. J., & Manning, E. M. (2019), The Atmospheric Infrared Sounder Obs4MIPs Version 2 Data Set, *Earth Space Sci.*, *6*(2), 324-333, https://doi.org/10.1029/2018ea000508

Different Samplings between AIRS Observations and Climate Model Outputs

Climate model outputs are sampled on regular spatial and temporal grids while AIRS observations are not.



Objectives

- To estimate, validate, and remove the sampling biases of the AIRS Obs4MIPs V2.0 data and produce the sampling-bias-corrected AIRS Obs4MIPs V2.1 data.
- To assist the climate community to better use the AIRS Obs4MIPs V2 data for CMIP6 model evaluation.

Sampling Bias Estimate Methodology

Hearty et al. (2014)

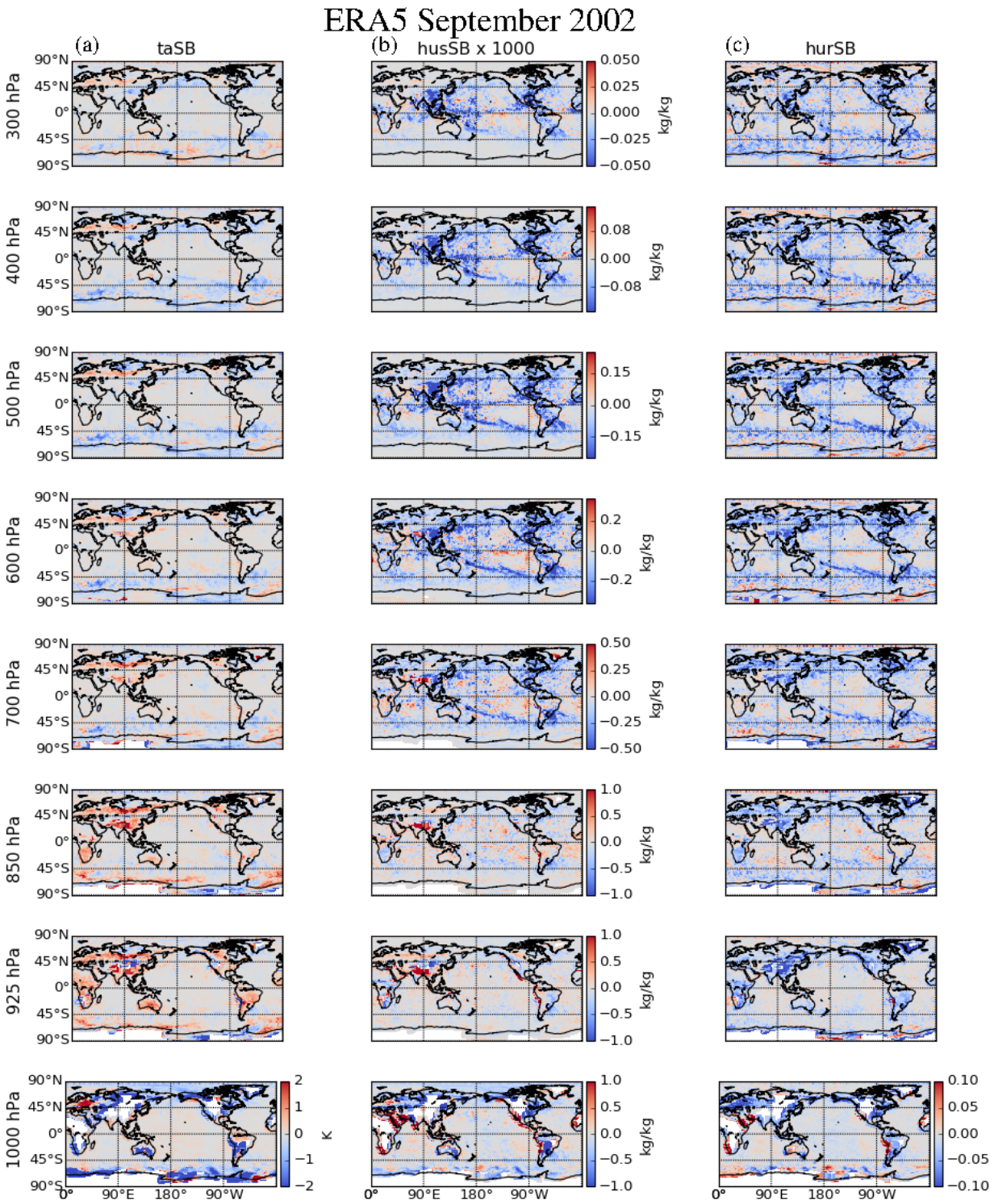
Component	Definition	Calculation
Total Sampling Bias (SB)	The under-sampling of temporal (especially diurnal) and spatial variations of the atmosphere due to all reasons.	M2SAQC − M2M E5SAQC − E5M
Orbital Sampling Bias (SB)	Caused by the Aqua spacecraft's Sun-synchronous low Earth orbit and the limited swath width of the AIRS instrument suite.	M2SA − M2M E5SA − E5M
Instrumental Sampling Bias (SB)	Caused by the AIRS quality control (QC) imposed in regions where the AIRS retrieval algorithm cannot successfully perform retrievals.	M2SAQC − M2SA E5SAQC − E5SA
Measurement Error (ME)	Difference of AIRS and reanalysis independent of sampling and caused by the AIRS retrieval algorithm or reanalysis model assimilation.	AIRS − M2SAQC AIRS − E5SAQC

MERRA-2/ERA5 Terminology	Definition
M2SAQC/E5SAQC	**M**ERRA-**2**/**E**RA**5** **S**ampled like **A**IRS with the AIRS **Q**uality **C**ontrol
M2SA/E5SA	**M**ERRA-**2**/**E**RA**5** **S**ampled like **A**IRS without the AIRS **Q**uality **C**ontrol
M2M/E5M	**M**ERRA-**2**/**E**RA**5** **M**onthly Mean or sampled like a climate model

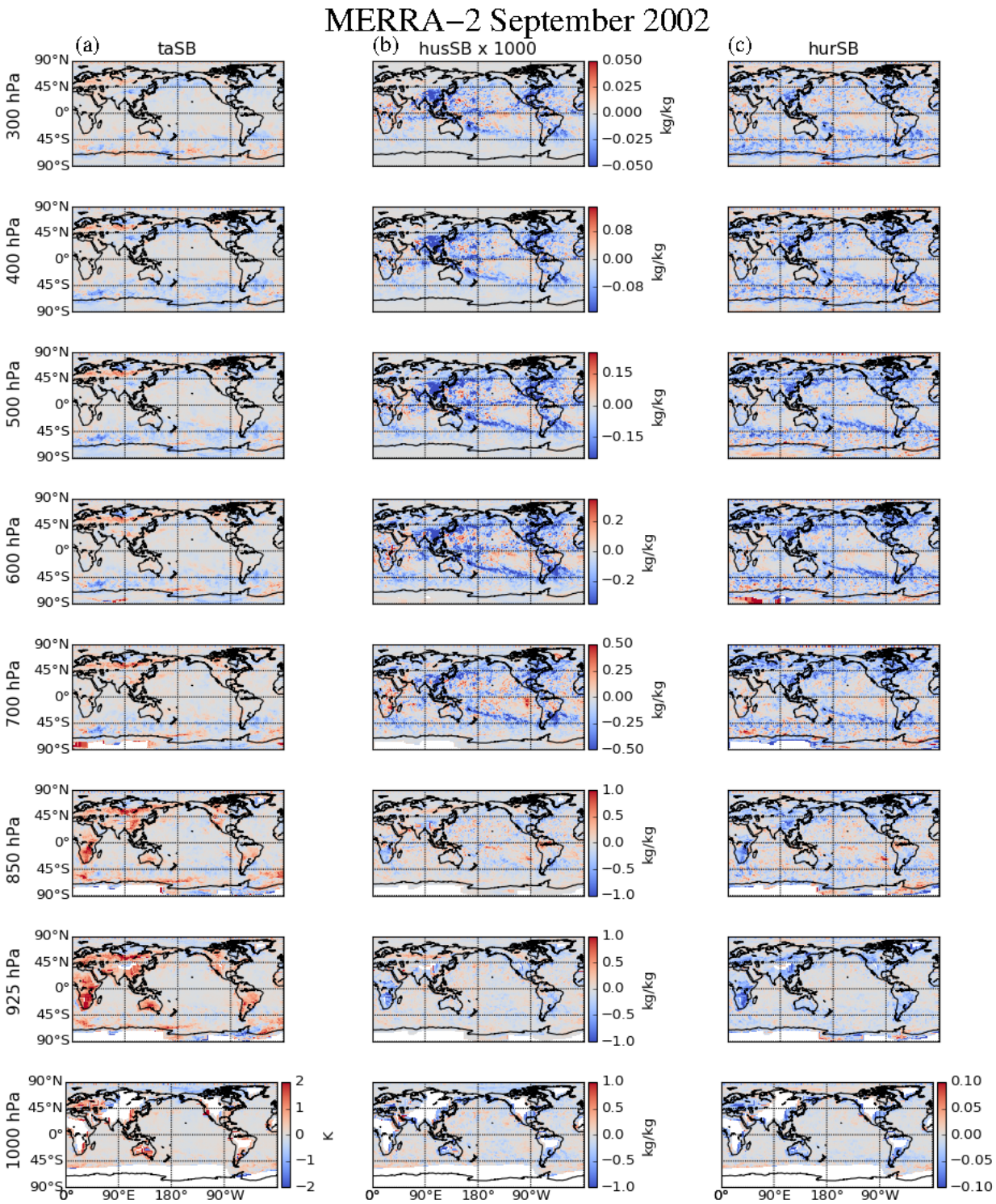
MERRA-2 vs ERA5

Reanalysis Data	MERRA-2: inst3_3d_asm_Np	ERA5
Spatial Resolution (lat x lon)	0.5° x 0.625°	0.25° x 0.25°
Vertical Resolution	42 levels from 1000 hPa to 0.1 hPa	37 levels from 1000 hPa to 1 hPa
Temporal Resolution	3-hourly	Hourly

Pressure levels:
1000/975/950/**925**/900/875/**850**/825/800/775/750/**700**/650/**600**/550/**500**/450/**400**/350/**300**/250/225/200/175/150/125/100/70/50/30/20/10/7/5/3/2/1



The monthly mean air temperature sampling bias (taSB, a), specific humidity sampling bias (husSB, b), and relative humidity sampling bias (hurSB, c) of the AIRS Obs4MIPs V2.0 data based on the ERA5 reanalysis for September 2002.

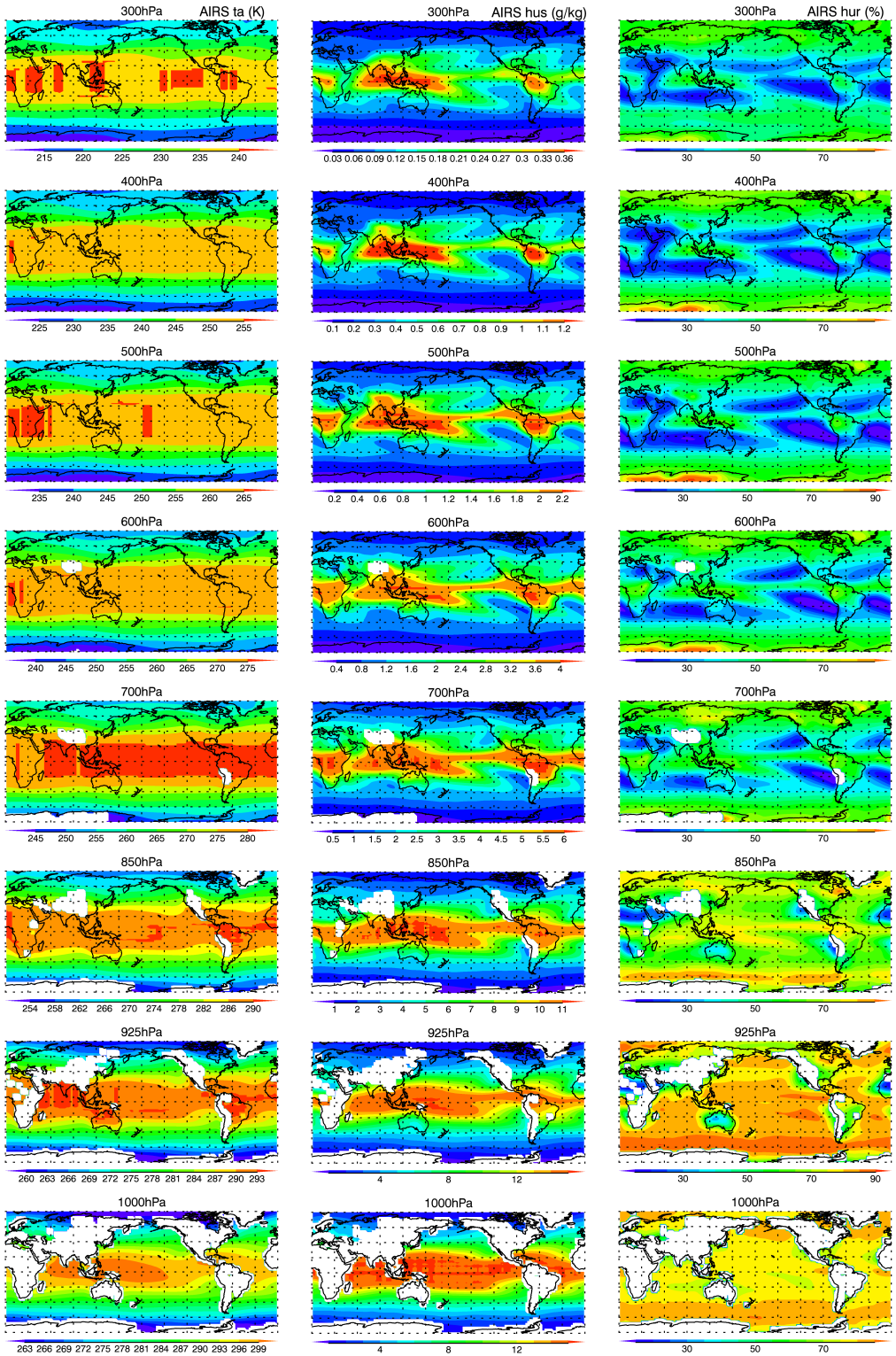


The monthly mean air temperature sampling bias (taSB, a), specific humidity sampling bias (husSB, b), and relative humidity sampling bias (hurSB, c) of the AIRS Obs4MIPs V2.0 data based on the MERRA-2 reanalysis for September 2002.

AIRS Obs4MIPs V2.1 Dataset

- We then remove the sampling biases of the AIRS Obs4MIPs V2.0 data estimated based on ERA5 from the AIRS Obs4MIPs V2.0 data to produce the sampling-bias-corrected AIRS Obs4MIPs V2.1 dataset.
- The AIRS Obs4MIPs V2.1 dataset has accounted for the sampling difference between the AIRS and climate model data and should be used in the future for climate model evaluation.
- Monthly mean sampling-bias-corrected tropospheric **air temperature (ta), specific humidity (hus), and relative humidity (hur) profiles** from Sep 2002 to Sep 2016 on a global spatial grid at 1ºx1º resolution and on the CMIP mandatory vertical pressure levels from 1000 to 300 hPa.
- The standard error (Stderr) and number of observations (Nobs) are the same as the AIRS Obs4MIPs V2.0 dataset.

Tian, B., & Hearty, T. J. (2020), Estimating and removing the sampling biases of the AIRS Obs4MIPs V2 data, *Earth Space Sci.*, submitted.

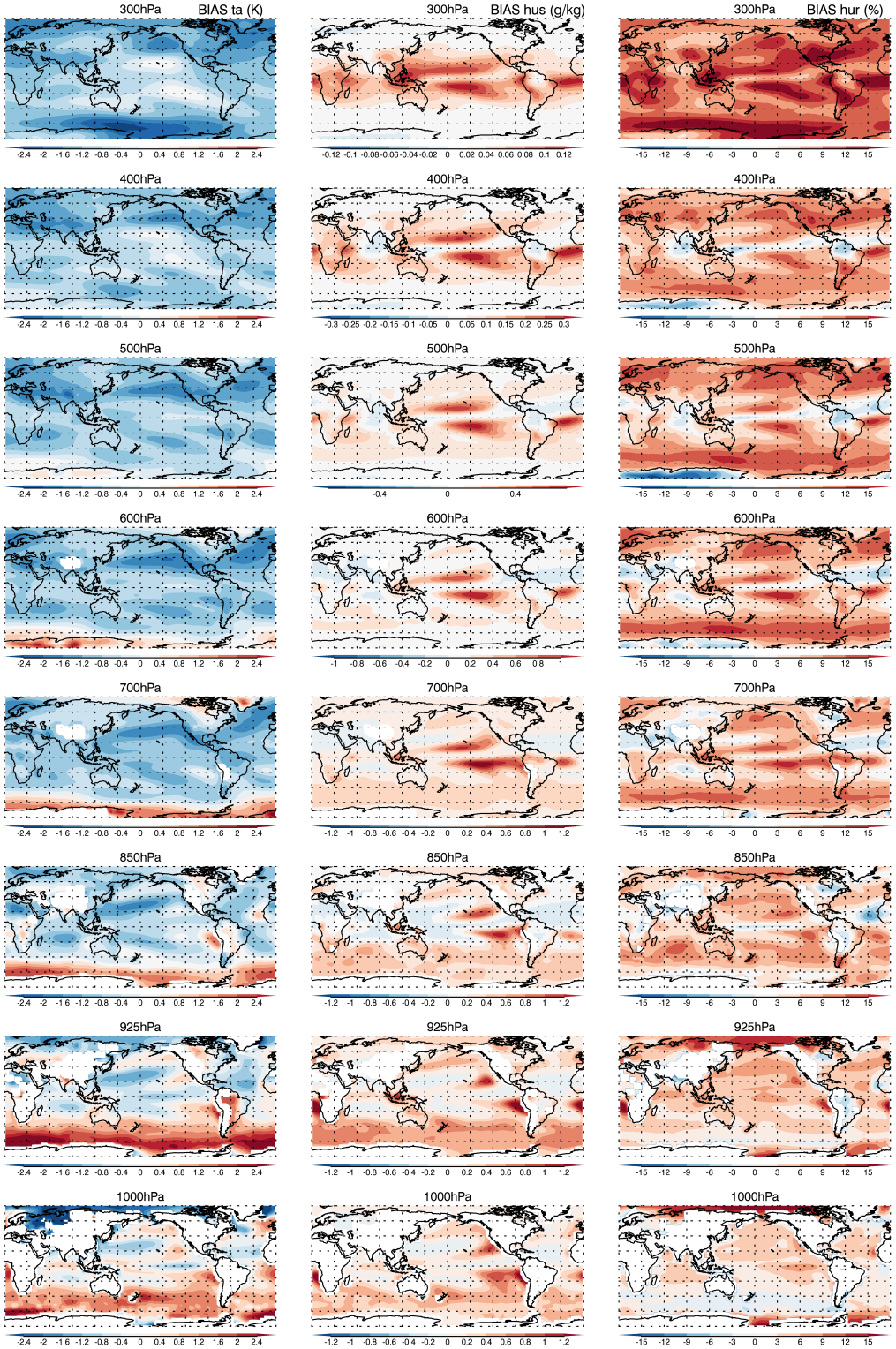


The annual mean climatologies of air temperature (ta), specific humidity (hus), and relative humidity (hur) from the AIRS Obs4MIPs V2.1 data

.1

Table 1: 34 CMIP6 Models

Model Number	Model Name (Model ID)	Modeling Center (Institution ID), Country	Atmospheric Model Spatial Resolution (Lon x Lat)
1	AWI-CM1-1-1-MR	AWI, Germany	0.9375° x 0.9375°
2	BCC-CSM2-MR	BCC, China	1.125° x 1.125°
3	BCC-ESM1	BCC, China	2.8125° x 2.8125°
4	CanESM5	CCCma, Canada	2.8125° x 2.8125°
5	CESM2	NCAR, USA	1.25° x 0.9375°
6	CESM2-WACCM	NCAR, USA	1.25° x 0.9375°
7	CIESM	THU, China	1.25° x 0.9375°
8	CNRM-CM6-1	CNRM-CERFACS, France	1.4° x 1.4°
9	CNRM-ESM2-1	CNRM-CERFACS, France	1.4° x 1.4°
10	E3SM-1-0	E3SM-Project, DOE, USA	1.0° x 1.0°
11	E3SM-1-1	E3SM-Project, DOE, USA	1.0° x 1.0°
12	E3SM-1-1-ECA	E3SM-Project, DOE, USA	1.0° x 1.0°
13	EC-Earth3	EC-Earth-Consortium, Sweden	0.7° x 0.7°
14	EC-Earth3-Veg	EC-Earth-Consortium, Sweden	0.7° x 0.7°
15	FGOALS-f3-L	CAS, China	1.25° x 1.0°
16	FGOALS-g3	CAS, China	1.25° x 1.0°
17	GFDL-ESM4	NOAA-GFDL, USA	1.25° x 1.0°
18	GISS-E2-1-G	NASA-GISS, USA	2.5° x 2.0°
19	GISS-E2-1-H	NASA-GISS, USA	2.5° x 2.0°
20	HadGEM3-GC31-LL	MOHC, UK	1.875° x 1.25°
21	HadGEM3-GC31-MM	MOHC, UK	1.875° x 1.25°
22	INM-CM4-8	INM, Russia	2.0° x 1.5°
23	INM-CM5-0	INM, Russia	2.0° x 1.5°
24	IPSL-CM6A-LR	IPSL, France	2.5° x 1.259°
25	MCM-UA-1-0	UA, USA	3.75° x 2.25°
26	MIROC6	MIROC, Japan	1.4° x 1.4°
27	MIROC-ES2L	MIROC, Japan	2.8° x 2.8°
28	MPI-ESM1-2-HR	MIROC, Japan	2.8° x 2.8°
29	MRI-ESM2-0	MRI, Japan	1.125° x 1.125°
30	NESM3	NUIST, China	1.875° x 1.875°
31	NorESM2-LM	NCC, Norway	2.5° x 1.875°
32	SAM0-UNICON	SNU, Korea	1.25° x 0.9375°
33	TaiESM	AS-RCEC, Taiwan	1.25° x 0.9375°
34	UKESM1-0-LL	MOHC, UK	1.875° x 1.25°



The annual mean climatologies of air temperature (ta), specific humidity (hus), and relative humidity (hur) biases of the 34 ensemble mean CMIP6 models based on the AIRS Obs4MIPs V2.1 data

Summary

- The sampling biases of the AIRS Obs4MIPs V2.0 data are estimated based on ERA5 reanalysis and validated based on MERRA-2 reanalysis.
- The sampling-bias-corrected AIRS Obs4MIPs V2.1 data are produced by removing the sampling bias estimates based on ERA5.
- The new AIRS Obs4MIPs V2.1 data will be published on ESGF and should be used in the future for climate model evaluation.
- CMIP6 model evaluation using the AIRS Obs4MIPs 2.1 data is under way.