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Pacific Northwest NATIONAL LABORATORY

Diagnosing Mesoscale Convective Systems in DYAMOND Models: A Feature Tracking Intercomparison

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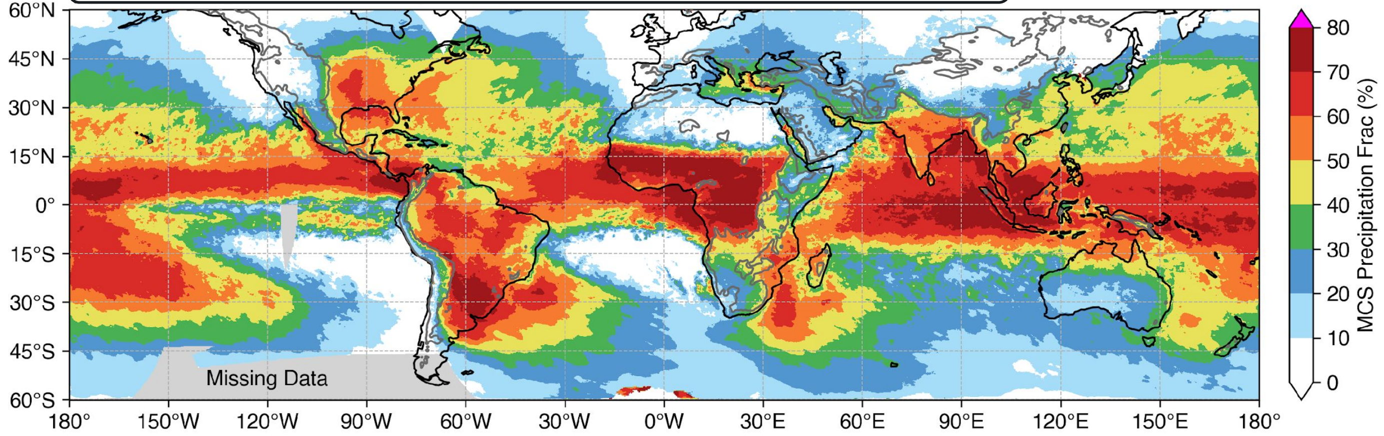
WACCEM WATER CYCLE AND CLIMATE EXTREMES MODELING

Motivation

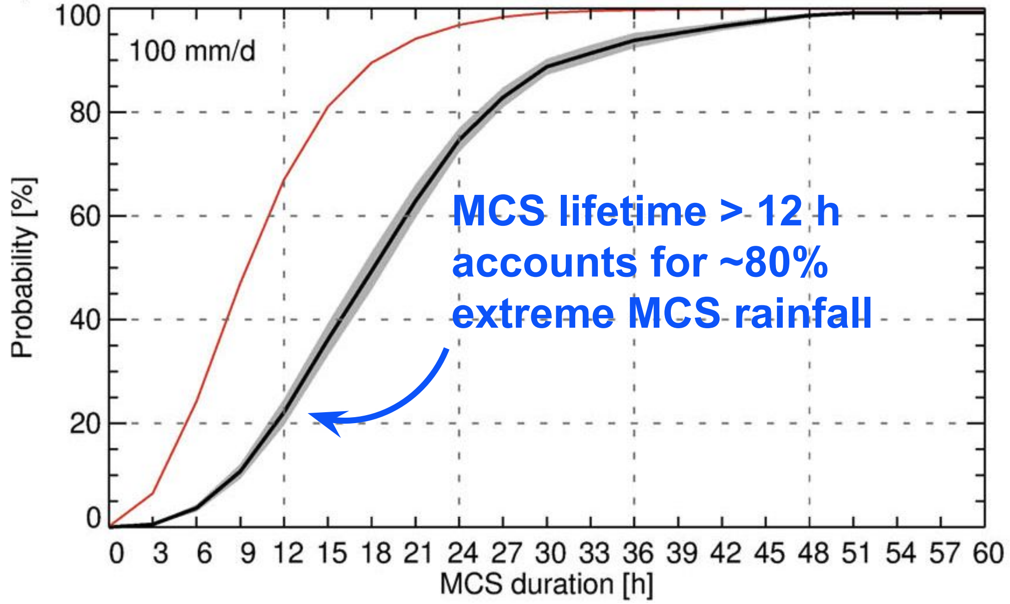
- Mesoscale convective systems (MCS) produce most of the tropical **precipitation** (Nesbitt et al. 2006; Feng et al. 2021)
- MCS disproportionally contribute to **extreme precipitation** (Roca and T. Fiolleau 2020)
- Typical global models cannot simulate MCS, convection-permitting (**km-scale**) models (**CPM**) offer new opportunities to examine how MCSs and extreme precipitation may **change in future climate** (Prein et al. 2017; 2023)

MCS Contribution to Total Precipitation



Feng et al. (2021) JGR

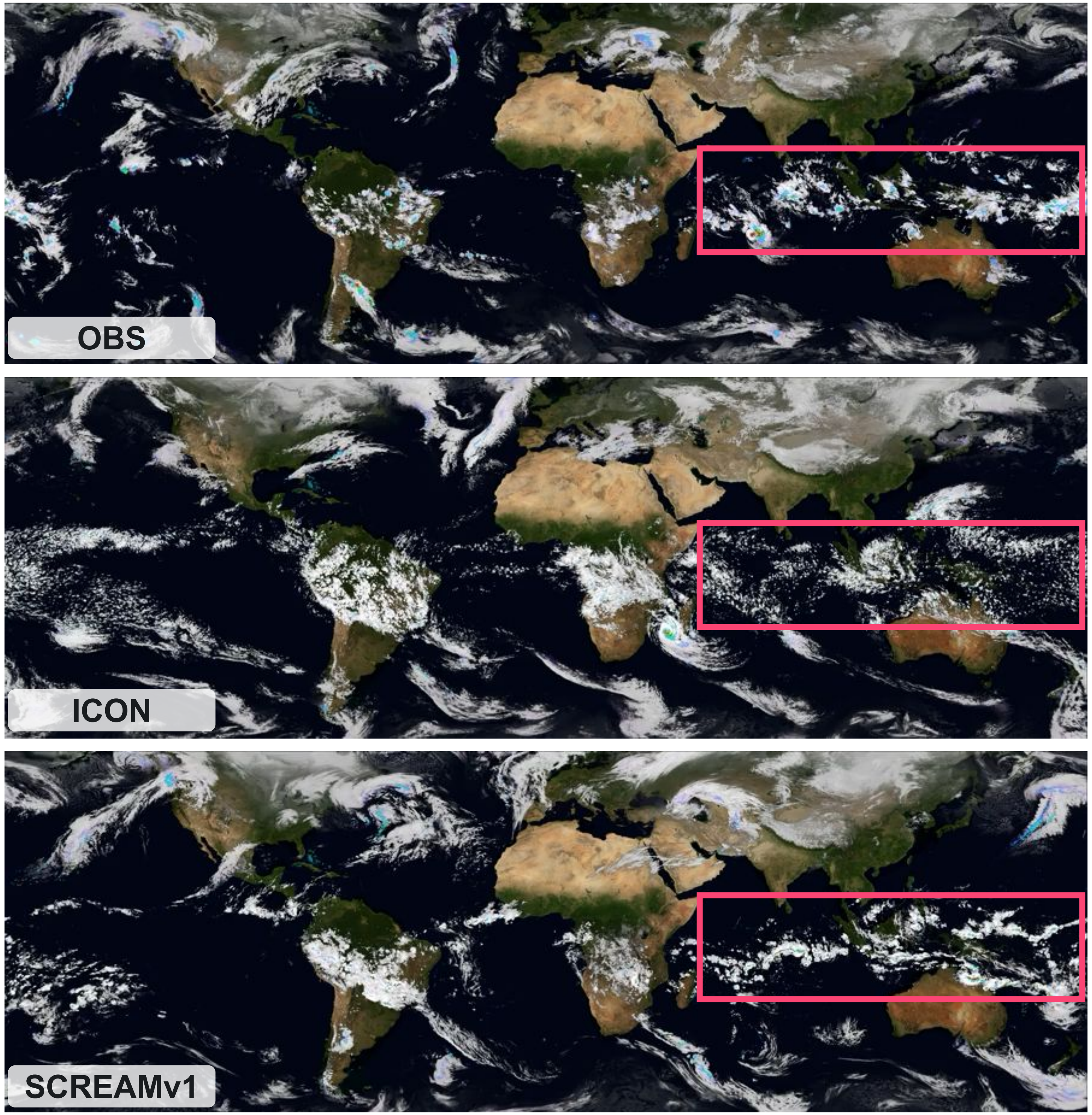
Probability of Extreme Precipitation vs. MCS Lifetime



Roca & Fiolleau (2020) CEE

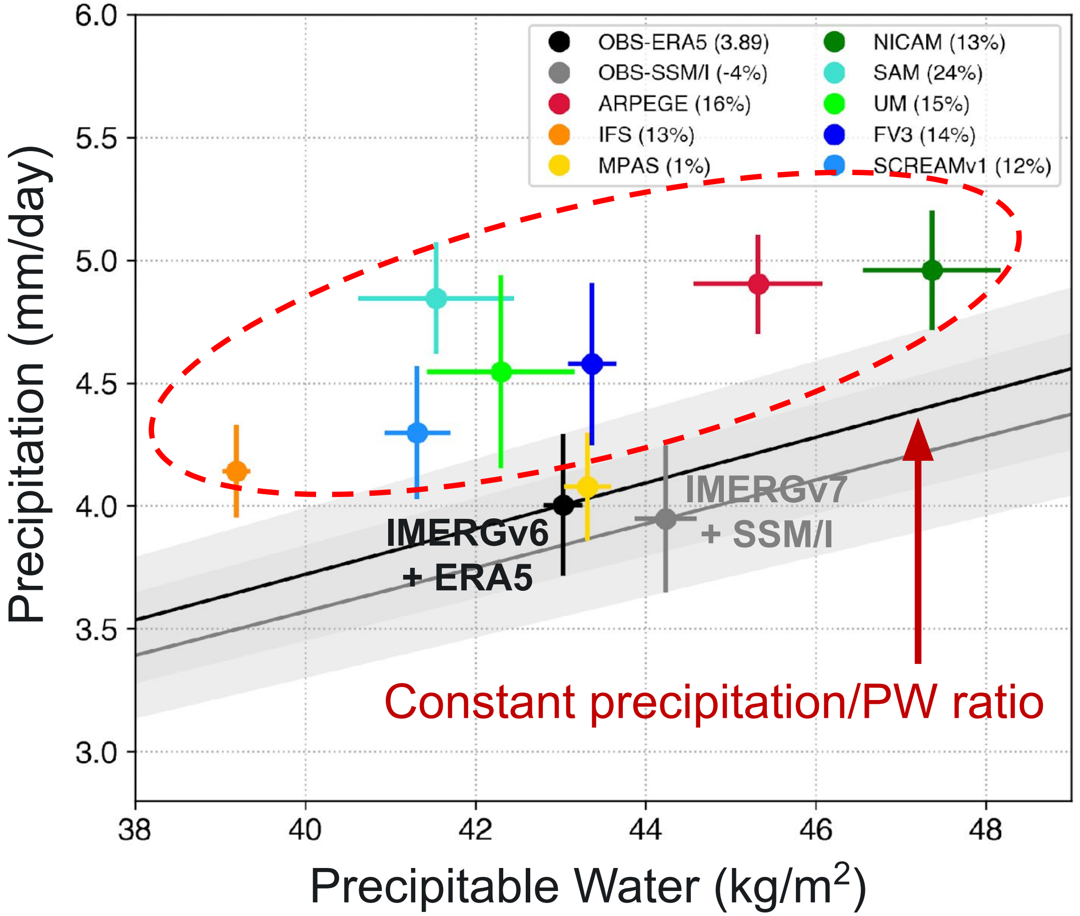
MCSMIP (MCS tracking method intercomparison)

- Substantial **differences** in the simulated characteristics of deep convection among models (Feng et al. 2023 GRL)
- **Science Questions**:
  - How sensitive are the DYAMOND simulated MCS characteristics to different tracker formulations?
  - What km-scale model biases are robust among trackers and how do the biases relate to environmental moisture?
- **Approach**
  - Evaluate model MCS characteristics from **eight different MCS trackers**

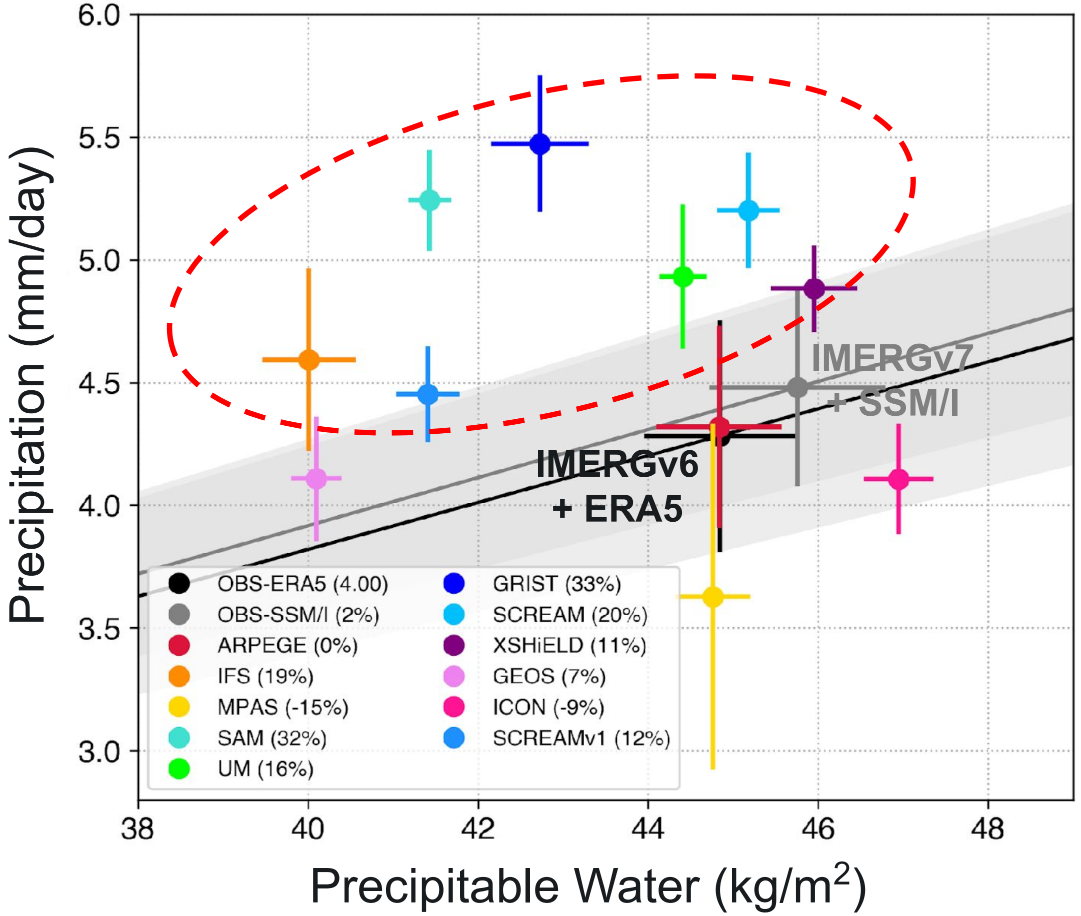


Models overestimate sensitivity of tropical precipitation to moisture

Summer



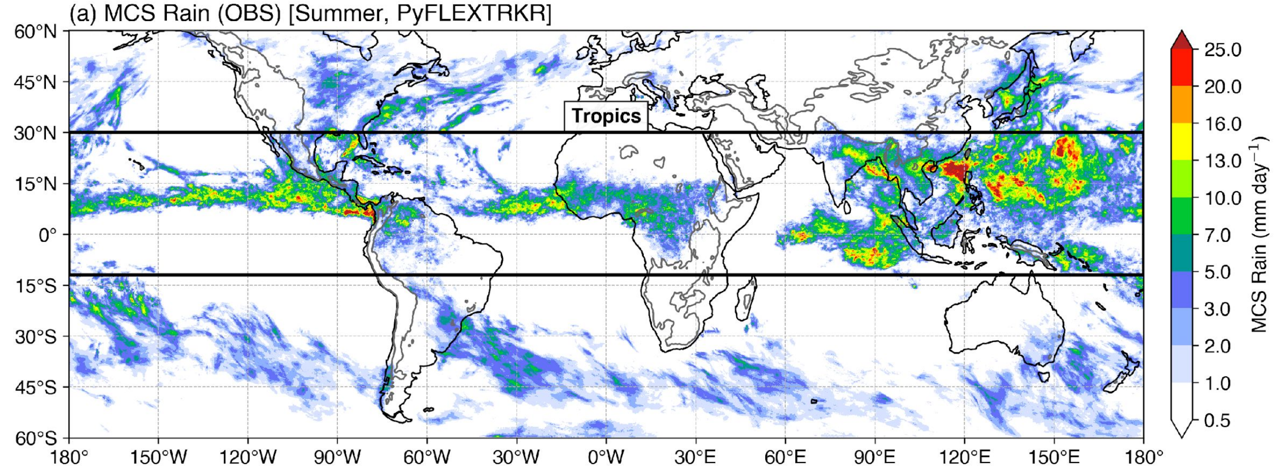
Winter



- Both phases have large inter-model spread in **PW** and **precipitation**
- Most models overestimate **precipitation/PW ratio** by up to **33%**, suggesting models may have higher sensitivity to moisture than OBS

Models underestimate MCS precipitation amount

Summer



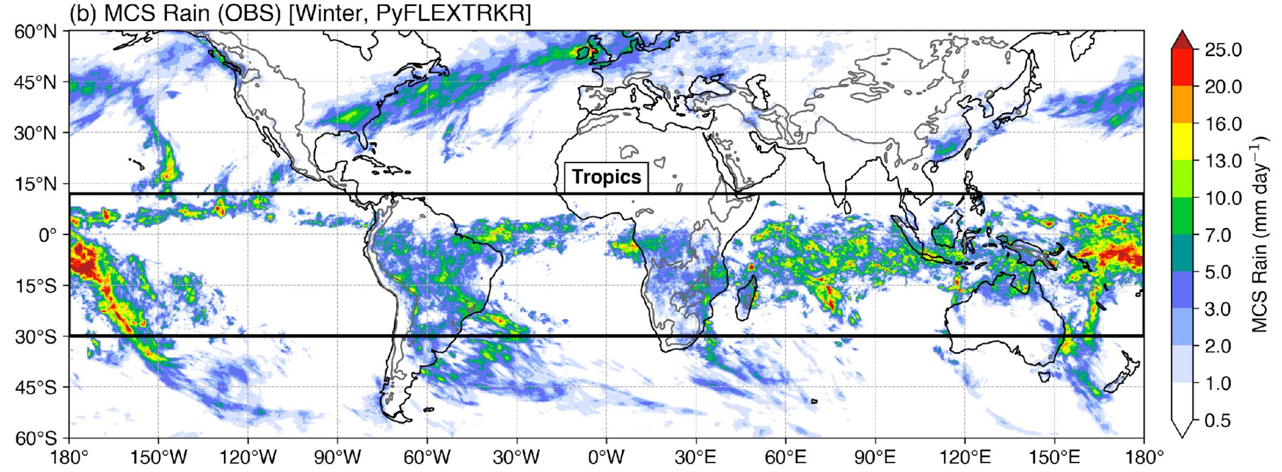
(c) Model Relative Mean Difference in MCS Rain [Summer]

	L (PyFLEXTRKR)	L (MOAAP)	L (TOOCAN)	L (tobac)	L (TAMS)	L (simpleTrack)	L (DL)	L (KFyAO)	O (PyFLEXTRKR)	O (MOAAP)	O (TOOCAN)	O (tobac)	O (TAMS)	O (simpleTrack)	O (DL)	O (KFyAO)
All Models	**-0%**	**-17%**	**-20%**	**-18%**	**-9%**	**-23%**	**-13%**	**-16%**	**-17%**	**-32%**	**-39%**	**-31%**	**-23%**	**-31%**	**-23%**	**-28%**
SCREAMv1	30%	35%	32%	12%	23%	6%	19%	22%	-8%	-8%	-9%	-22%	-15%	-14%	-10%	-11%
FV3	-8%	-12%	-15%	-10%	-14%	-20%	-19%	-19%	-9%	-16%	-19%	-16%	-13%	-19%	-18%	-18%
UM	13%	-17%	-35%	-13%	-3%	-9%	-6%	-6%	-11%	-19%	-44%	-14%	-14%	-16%	-15%	-18%
SAM	18%	-12%	-20%	-12%	-5%	-18%	-9%	-16%	-7%	-38%	-54%	-37%	-27%	-34%	-26%	-35%
NICAM	5%	-20%	9%	5%	-9%	-10%	-16%	-7%	15%	-15%	-9%	2%	4%	-1%	3%	1%
MPAS	-31%	-22%	-54%	-53%	-3%	-58%	-17%	-27%	-49%	-46%	-64%	-63%	-23%	-63%	-33%	-42%
IFS	21%	2%	17%	15%	5%	-1%	3%	3%	-14%	-29%	-23%	-17%	-27%	-25%	-22%	-26%
ARPEGE	-48%	-92%	-93%	-86%	-69%	-76%	-61%	-78%	-53%	-84%	-87%	-82%	-68%	-75%	-63%	-77%

Relative Difference (%): 100, 80, 60, 40, 20, −20, −40, −60, −80, −100

Land **Ocean**

Winter



(d) Model Relative Mean Difference in MCS Rain [Winter]

	L (PyFLEXTRKR)	L (MOAAP)	L (TOOCAN)	L (tobac)	L (TAMS)	L (simpleTrack)	L (DL)	L (KFyAO)	O (PyFLEXTRKR)	O (MOAAP)	O (TOOCAN)	O (tobac)	O (TAMS)	O (simpleTrack)	O (DL)	O (KFyAO)
All Models	**4%**	**-17%**	**-21%**	**-6%**	**-9%**	**-18%**	**-13%**	**-21%**	**-27%**	**-40%**	**-45%**	**-36%**	**-32%**	**-43%**	**-30%**	**-40%**
SCREAMv1	46%	51%	59%	18%	28%	18%	24%	34%	-19%	-23%	-31%	-30%	-26%	-39%	-19%	-26%
ICON	51%	18%	-81%	19%	51%	27%	25%	-75%	-48%	-62%	-82%	-53%	-42%	-52%	-47%	-91%
GEOS	27%	-6%	1%	19%	8%	5%	5%	14%	-44%	-52%	-47%	-41%	-47%	-46%	-43%	-47%
XSHiELD	-19%	-33%	-27%	-15%	-18%	-36%	-27%	-20%	-18%	-29%	-32%	-25%	-12%	-36%	-16%	-20%
SCREAM	-31%	-56%	-49%	-31%	-44%	-41%	-40%	-43%	-49%	-65%	-67%	-53%	-56%	-56%	-51%	-58%
GRIST	-40%	-91%	-87%	-68%	-65%	-63%	-61%	-68%	-45%	-87%	-82%	-65%	-61%	-65%	-59%	-70%
UM	27%	-6%	-30%	17%	2%	1%	4%	5%	-15%	-20%	-44%	-11%	-17%	-19%	-19%	-23%
SAM	-17%	-45%	-54%	-42%	-39%	-51%	-40%	-47%	-22%	-50%	-64%	-48%	-39%	-53%	-37%	-48%
MPAS	-50%	-46%	-40%	-48%	-46%	-72%	-54%	-49%	9%	20%	33%	-18%	14%	-37%	10%	11%
IFS	32%	33%	63%	49%	8%	10%	10%	16%	-19%	-28%	-28%	-21%	-32%	-29%	-26%	-34%
ARPEGE	21%	-4%	10%	19%	12%	-2%	8%	6%	-25%	-41%	-49%	-34%	-31%	-36%	-27%	-38%

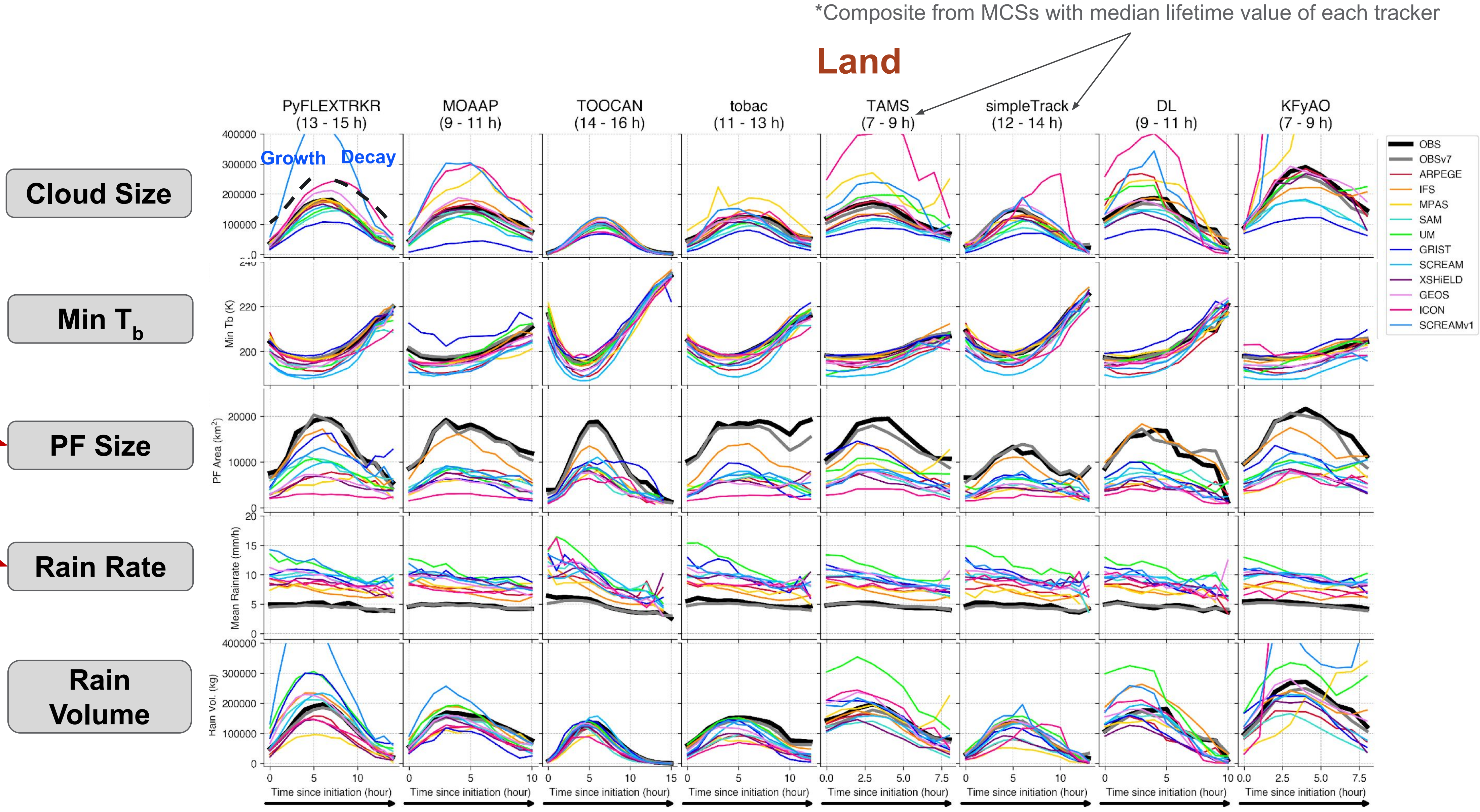
Relative Difference (%): 100, 80, 60, 40, 20, −20, −40, −60, −80, −100

Land **Ocean**

- Models generally underestimate MCS **precipitation** over **tropical ocean** by **32%**
- Biases over **tropical land** are slightly **smaller 14%**

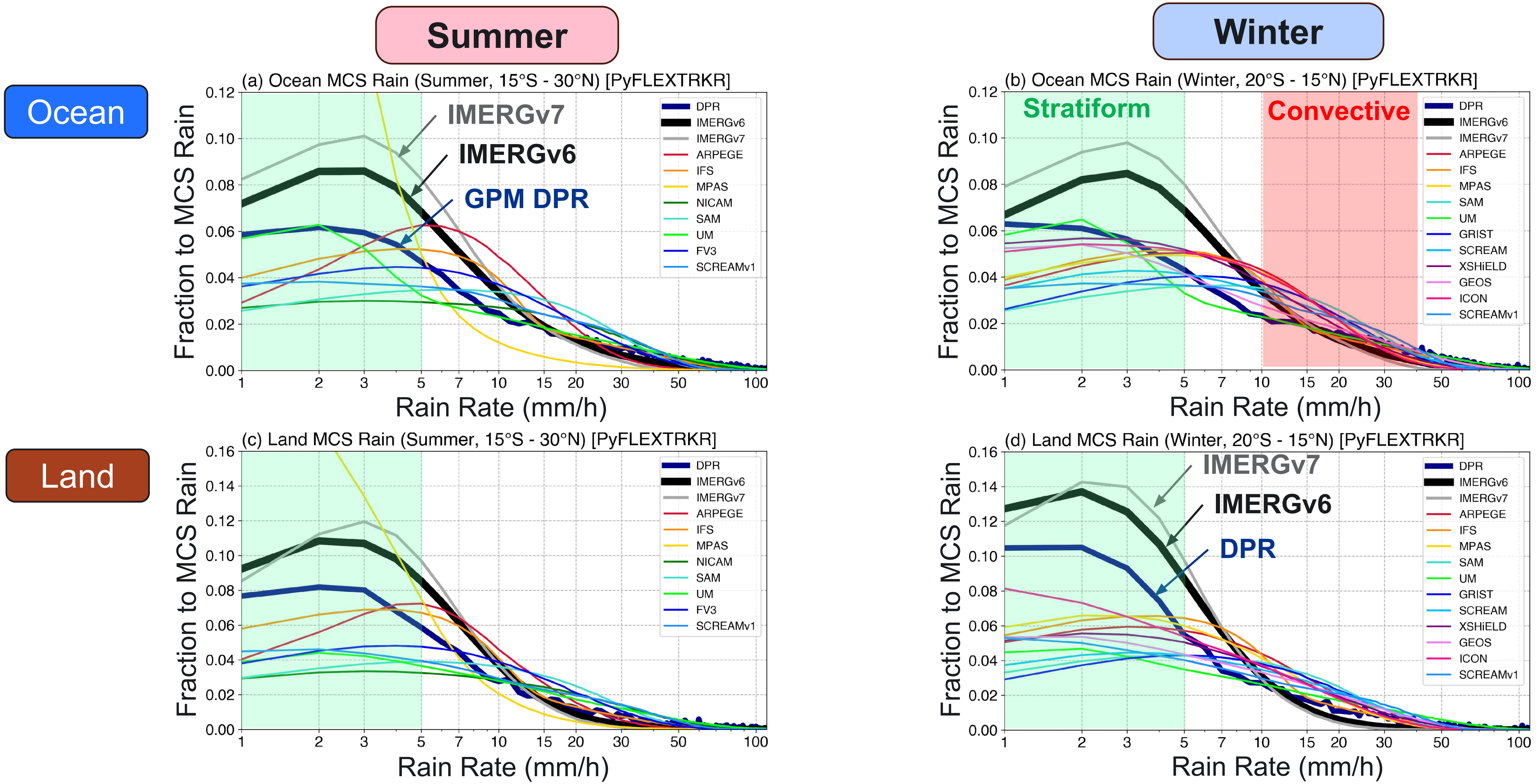
Biases in MCS precipitation characteristics are more consistent among trackers than clouds

- Models generally capture cloud shield evolution, though the magnitudes differ among the trackers
- Almost all models underestimate PF area and overestimate PF mean rain rate throughout the lifecycle, compensating the errors more comparable **rain volume**



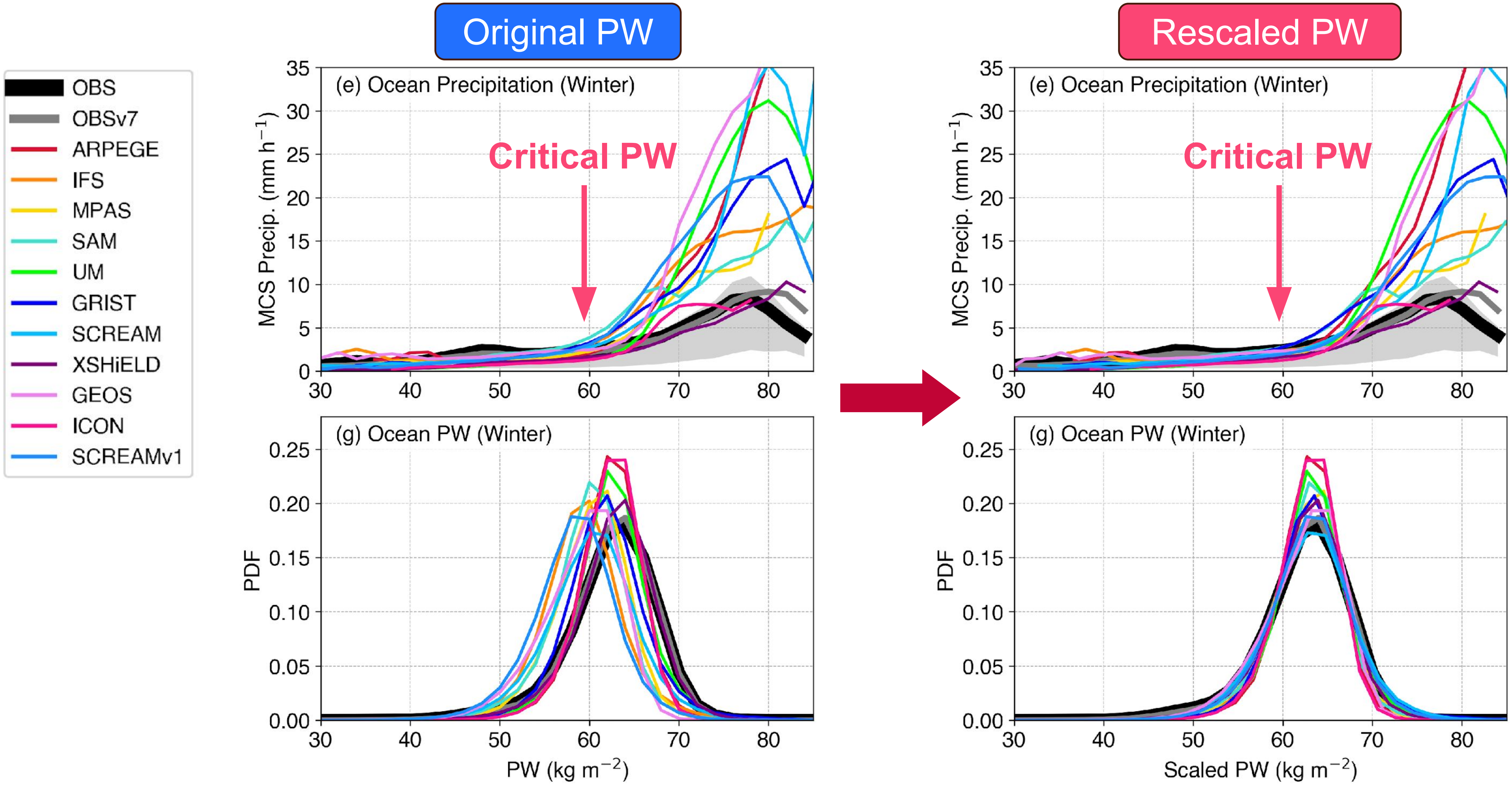
*Exclude tracks with max CCS area during first & last 10% of their lifetime (split or merge)

Models underestimate stratiform rain contribution to MCS precipitation



- Most models underestimate stratiform rain (< 5 mm/h) **contribution** to MCS rainfall compared to both IMERG & **DPR**, vice versa for convective rain **contribution** (> 10 mm/h)
- Biases are larger over land than ocean

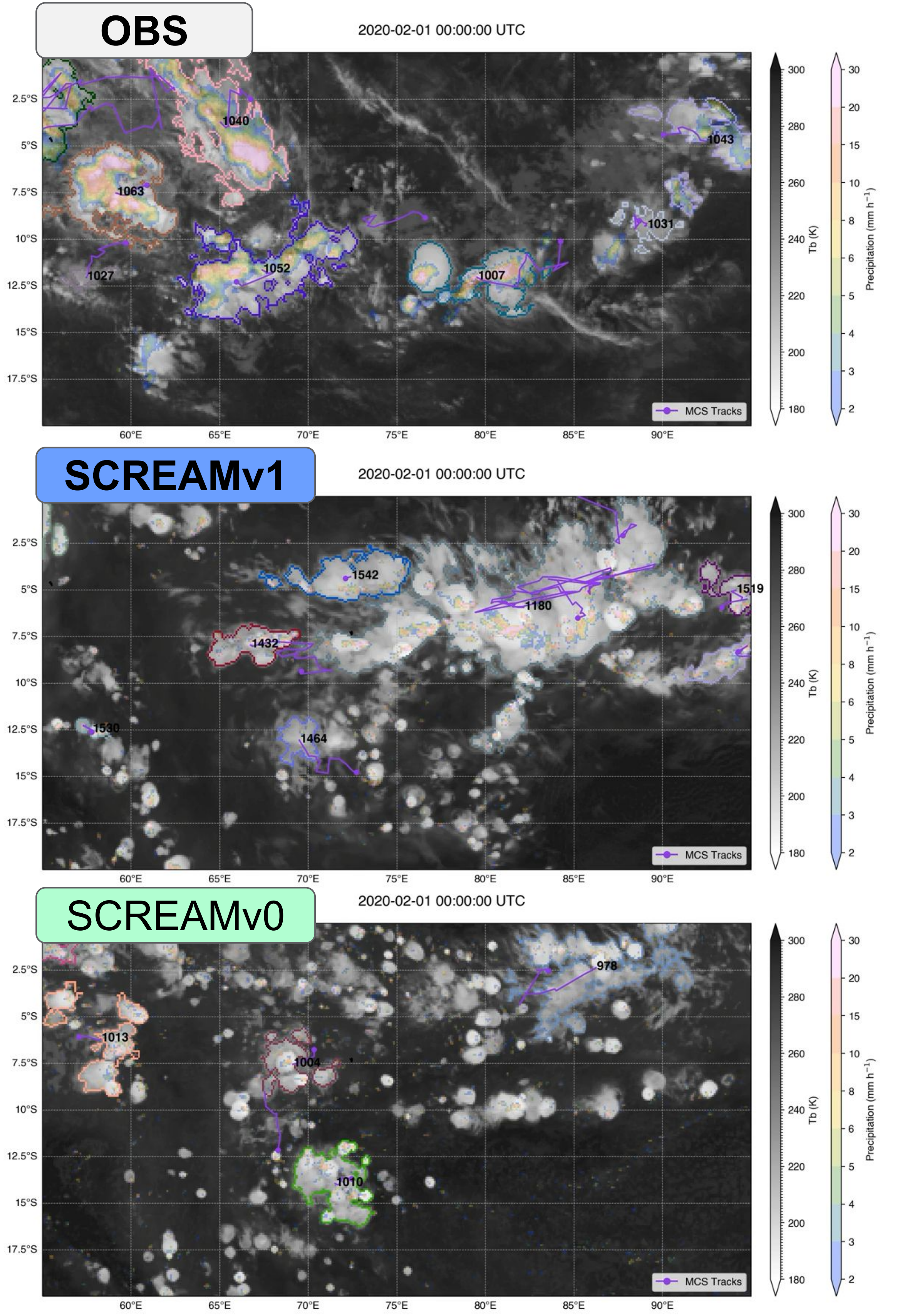
Models overestimate sensitivity of MCS precipitation intensity to moisture



- Most models show **higher** MCS precipitation intensity sensitivity to PW than ERA5
- After rescaling PW, some biases at high PW remain, but precipitation pick-up near critical PW compares better

Discussions

- **Grand challenges:**
  - How well do km-scale models simulate key processes controlling organized convection & precipitation? How do we evaluate them?
- **Gaps:**
  - **Coordination** between model development and process-oriented analysis, and better use of collocated observations to improve model diagnostics
  - **Huge data volume** hinders analysis
- **Opportunities**
  - Community effort to build model testbeds, collect and format all available observations and standardize model outputs to facilitate analysis
  - Hackathon on global km-scale model analysis



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Thank you

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