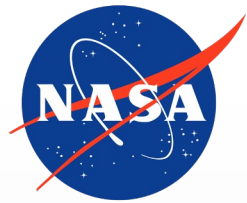


CONSTRAINING ARCTIC CLIMATE PROJECTIONS OF WINTERTIME WARMING WITH SURFACE TURBULENT FLUX OBSERVATIONS AND REPRESENTATION OF SURFACE-ATMOSPHERE COUPLING

LINETTE BOISVERT, ROBYN BOEKE, PATRICK TAYLOR AND CHELSEA PARKER

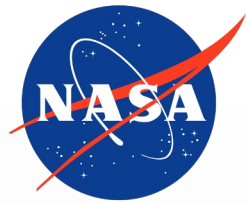
AGCI ARCTIC CLIMATE AND WEATHER EXTREMES: DETECTION, ATTRIBUTION, AND FUTURE PROJECTIONS
WORKSHOP

ASPEN, CO MAY 16-20



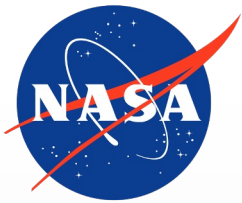
BACKGROUND

- **ALTHOUGH THE ARCTIC SEA ICE ALBEDO FEEDBACK IS LARGEST IN THE SUMMER MONTHS, THE STRONGEST WARMING HAS OCCURRED IN FALL & WINTER (*DESER ET AL.*, 2010).**
- **THIS WINTERTIME WARMING MAXIMUM HAS BEEN LINKED TO SEA ICE LOSS USING OBSERVATIONS, METEOROLOGICAL REANALYSIS, AND CLIMATE MODEL SIMULATIONS (*BOEKE AND TAYLOR*, 2018; *SCREEN AND SIMMONDS*, 2010; *SCREEN ET AL.*, 2012; *SERREZE ET AL.*, 2009).**
- **ONE WAY IN WHICH SEA ICE INFLUENCES THE WINTER WARMING MAXIMUM IS THAT REDUCED SEA ICE COVER PROMOTES INCREASED TURBULENT FLUXES FROM THE OCEAN SURFACE TO THE LOWER ATMOSPHERE AND DRIVES ATMOSPHERIC WARMING (*SCREEN AND SIMMONDS*, 2010).**
- **THE LARGE DISPARITIES BETWEEN MODELED AND OBSERVED TURBULENT FLUXES ARE CAUSED BY MULTIPLE FACTORS:**
 - 1) **THE SPECIFIC PARAMETERIZATIONS AND ASSUMPTIONS USED IN THE BULK FORMULA**
 - 2) **DISCREPANCIES IN SEA ICE PROPERTIES, WHICH DRIVE THE SURFACE TEMPERATURE AND HUMIDITY, AND DRAG COEFFICIENTS**
 - 3) **THE REPRESENTATION OF NEAR SURFACE-AIR TEMPERATURE AND HUMIDITY GRADIENTS AND INVERSIONS**
 - 4) **THE SPATIAL, VERTICAL AND TEMPORAL RESOLUTION**



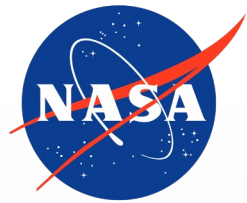
HYPOTHESIS

- **INCREASED SENSIBLE (SHF) AND LATENT (LHF) HEAT FLUXES PLAY AN IMPORTANT ROLE IN THE ARCTIC AMPLIFICATION PROCESS.**
- **DURING THE WINTER MONTHS, MODELS THAT PRODUCE A STRONGER INCREASE IN SHF AND LHF FOR THE SAME SEA ICE LOSS ARE HYPOTHESIZED TO WARM MORE OVER THE ARCTIC.**
- **WE ADDRESS THIS HYPOTHESIS BY**
 - 1) **EVALUATING THE SHF AND LHF CLIMATOLOGICAL DISTRIBUTION IN CMIP6 MODELS AGAINST OBSERVATIONS,**
 - 2) **COMPARING OBSERVED AND SIMULATED SHF AND LHF TRENDS WITHIN SEA ICE RETREAT REGIMES,**
 - 3) **ANALYZING SHF AND LHF SENSITIVITIES TO CONTROLLING FACTORS,**
 - 4) **ANALYZING RELATIONSHIPS WITH PROJECTED ARCTIC WARMING.**



OBSERVATIONAL ARCTIC TURBULENT FLUX DATA

- DATA FROM: OCTOBER-JANUARY 2002-2020
- NASA'S ATMOSPHERIC INFRARED SOUNDER (AIRS) –
 - 2,378 INFRARED CHANNELS AND A 13.5 KM SPATIAL RESOLUTION.
 - DESIGNED TO PRODUCE HIGHLY ACCURATE TEMPERATURE AND HUMIDITY PROFILES GLOBALLY ([SUSSKIND ET AL., 2014](#)), WHICH IS IMPORTANT IN THE ARCTIC WHERE DATA IS SPARSE AND CLOUDS ARE PREVALENT.
- DAILY LEVEL 3, VERSION 7 AIRS-ONLY
 - SKIN TEMPERATURE,
 - 1000HPA, 925 HPA: TEMPERATURE, RELATIVE HUMIDITY AND GEOPOTENTIAL HEIGHTS
- UNCERTAINTY IN SKIN TEMPERATURE (± 2.3 K), 2-M AIR TEMPERATURE (± 3.41 K) AND SPECIFIC HUMIDITY (± 0.54 G KG⁻¹) ([BOISVERT ET AL., 2015A](#); [TAYLOR ET AL., 2018](#))
- NASA'S MERRA-2 REANALYSIS: DAILY 10M WIND SPEEDS
- PMW SSMI: DAILY SEA ICE CONCENTRATIONS

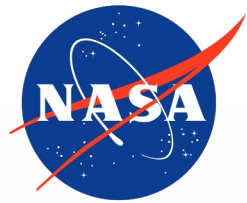


AIRS-DERIVED ARCTIC SEA ICE TURBULENT FLUXES

- TURBULENT FLUXES BASED ON THE METHODS FROM *BOISVERT ET AL.*, 2013; 2015; *TAYLOR ET AL.*, 2018
- SENSIBLE (SH) AND LATENT (LH) HEAT FLUX IS CALCULATED USING THE MONIN-OBUKHOV SIMILARITY THEORY & AN ITERATIVE CALCULATION FROM *LAUNIAINEN AND VIHMA* [1990].
- **SEA ICE SPECIFIC CHANGES:** PARAMETERIZATIONS PRODUCED USING IN SITU SHEBA OBSERVATIONS.
 - 1.) STABLE BOUNDARY LAYER FROM *GRACHEV ET AL.* [2007].
 - 2.) ROUGHNESS LENGTHS ESTIMATES OF SEA ICE IN DIFFERENT SEASONS FROM *ANDREAS ET AL.* [2010A,B].
 - 3.) EFFECTIVE WIND SPEED (S_r) WITH A PARAMETER FOR GUSTINESS, DIFFERENT IN STABLE & UNSTABLE CONDITIONS.
- **COMPARED WITH IN SITU DATA FROM THE N-ICE2015 CAMPAIGN**
 - AIRS-DERIVED LHF HAD A RMSE OF 0.74 W M^{-2}
 - AIRS-DERIVED SHF HAD A RMSE OF 5.32 W M^{-2}
 - THESE COMPARISONS INDICATE AN UNCERTAINTY OF $\sim 20\%$

$$SH = c_p S_r [C_{Hz,i} I_c (T_{s,i} - T_z) + C_{Hz,w} (1 - I_c) (T_{s,w} - T_z)]$$

$$LH = \rho S_r [C_{Ez,i} L_i I_c (q_{s,i} - q_z) + C_{Ez,w} L_w (1 - I_c) (q_{s,w} - q_z)]$$



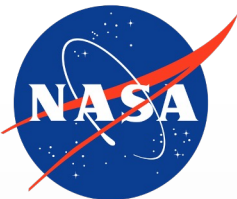
COUPLED MODEL INTERCOMPARISON PROJECT 6 (CMIP6)

- 18 CMIP6 MODELS PARTICIPATING IN THE HISTORICAL AND SSP5-8.5 (SHARED SOCIOECONOMIC PATHWAY) SCENARIOS ([EYRING ET AL., 2016](#)).
 - MONTHLY DATA FROM THE HISTORICAL SIMULATIONS FOR THE PERIOD 2002–2015 IS MERGED WITH THE FIRST 5 YEARS OF THE SSP5-8.5 FUTURE SCENARIO (2015–2020).
 - ONE ENSEMBLE MEMBER PER MODEL IS USED.
- MODEL-SIMULATED SURFACE TURBULENT FLUX DIFFERENCES ARE POORLY UNDERSTOOD DUE TO INSUFFICIENT OBSERVATIONAL DATASETS
- SUBSTANTIAL ACROSS-MODEL SPREAD IN TURBULENT FLUXES HAS REMAINED CONSISTENT FROM CMIP5 TO CMIP6 ([WILD, 2020](#)).
- MODELS LACK THE COMPLEXITY REQUIRED TO REPRESENT THE PROCESSES AFFECTING THE SIMULATION OF SURFACE TURBULENT FLUXES (E.G. EVAPORATION/PRECIPITATION, SEA ICE/SNOW COVER, WIND SPEED) ([WILD, 2020](#)).

Model

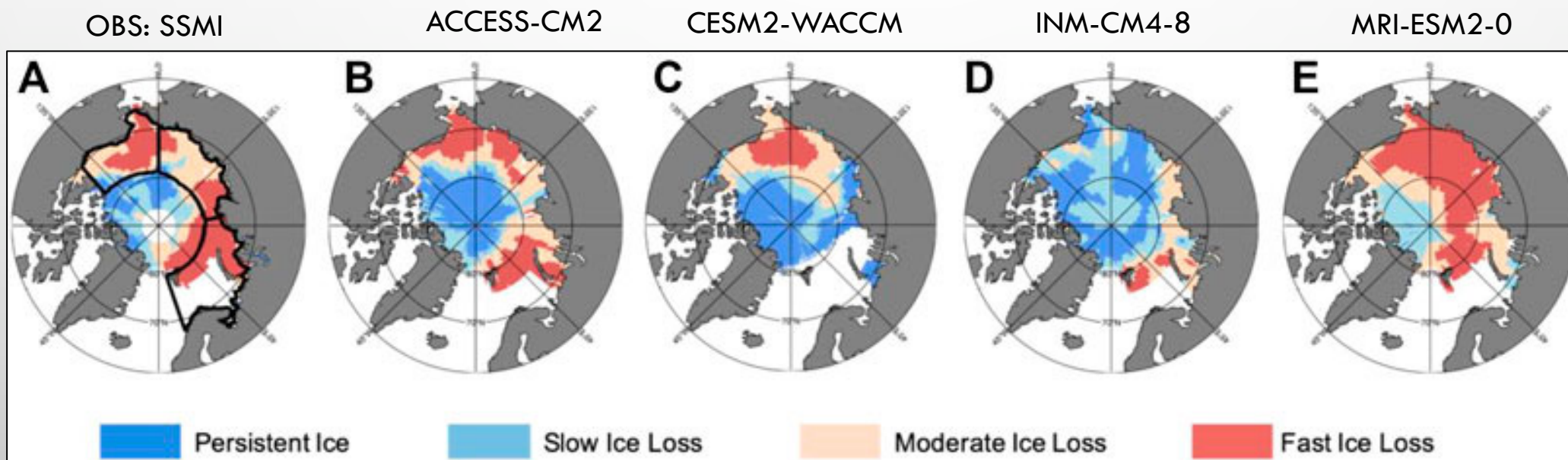
ACCESS-CM2
ACCESS-ESM1-5
BCC.CSM2-MR
CanESM5
CESM2
CESM2-WACCM
FIO-ESM-2-0
FGOALS-f3-L
FGOALS-g3
GFDL-ESM4
INM-CM4-8
INM-CM5-0
IPSL-CM6A-LR
MIROC6

MPI-ESM1-2-HR
MPI-ESM1-2-LR
MRI-ESM2-0
NESM3

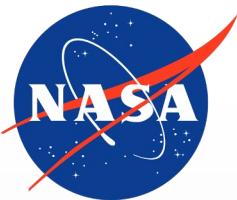


METHODOLOGY – SEA ICE REGIMES

- COUPLED, FREE RUNNING ATMOSPHERE-OCEAN MODELS USED TO SIMULATE THE RECENT CLIMATE PRODUCE THEIR OWN NATURAL VARIABILITY THAT IS NOT SYNCED WITH OBSERVED VARIABILITY.
 - A SUBSTANTIAL CHALLENGE IN THE ARCTIC WHERE NATURAL VARIABILITY IS ESPECIALLY LARGE (E.G., [KAY ET AL., 2012](#)) SO A SEA ICE REGIME COMPOSITING APPROACH IS USED TO CONTROL FOR THE EFFECTS OF ARCTIC SEA ICE VARIABILITY



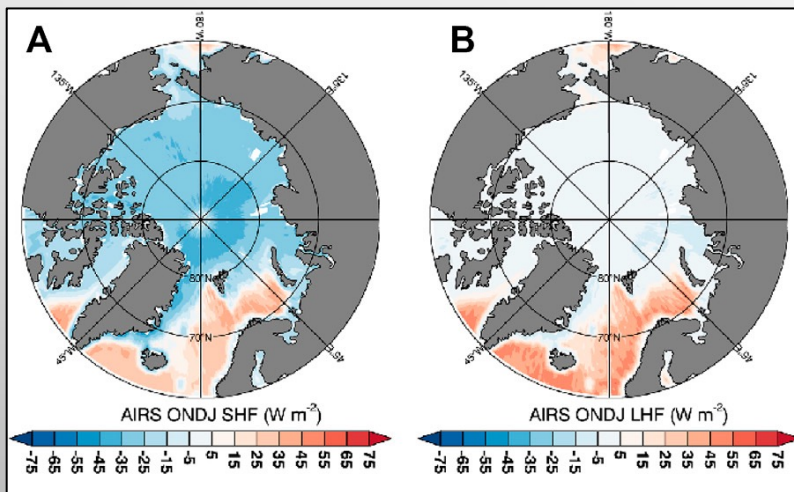
- **Persistent regime:**
 $I_C \text{ trends} > -0.27\% \text{ decade}^{-1}$
- **Slow sea ice loss:**
 $-0.27\% \text{ decade}^{-1} > I_C \text{ trends} > -2.4\% \text{ decade}^{-1}$
- **Moderate sea ice loss:**
 $-2.4\% \text{ decade}^{-1} > I_C \text{ trends} > -7.5\% \text{ decade}^{-1}$
- **Fast sea ice loss:**
 $I_C \text{ trends} < -7.5\% \text{ decade}^{-1}$



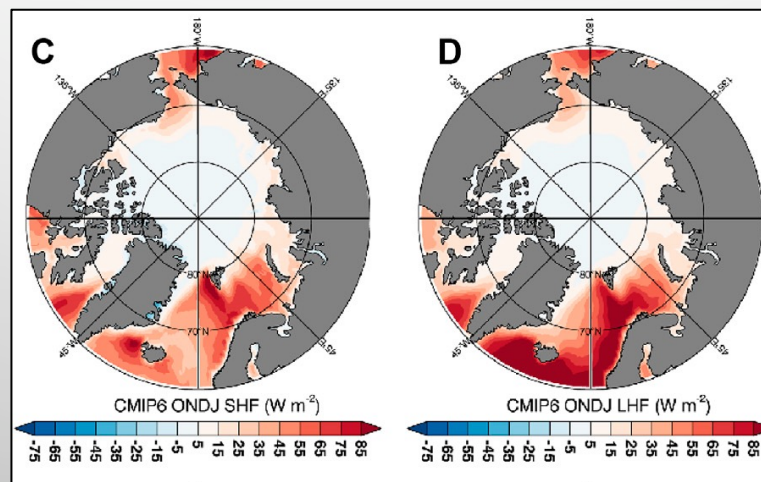
RESULTS - ARCTIC WINTER TURBULENT FLUXES

- ARCTIC SURFACE IS A NET HEAT SINK TO THE ARCTIC ATMOSPHERE DURING WINTER WITH THE STRONGEST SINK IN THE CENTRAL ARCTIC AND A HEAT SOURCE IN THE BARENTS-KARA (B-K) SEAS REGION
- THE MAGNITUDE OF THE HEAT SINK IS REDUCED BY THE POSITIVE SHF AND LHF FLUXES IN THE B-K SEAS, PROVIDING A NARROW AREA OF SURFACE HEAT SOURCE TO THE ATMOSPHERE.

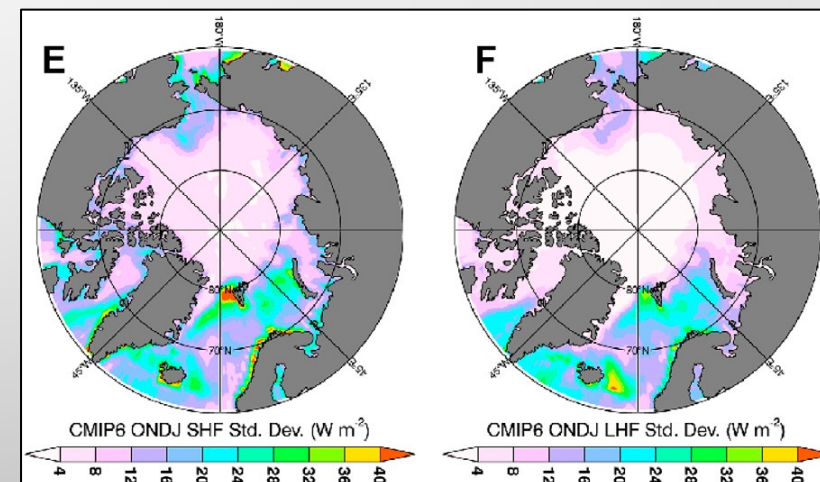
Observations

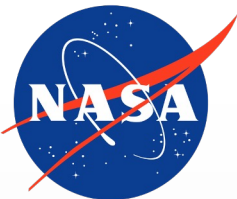


CMIP6



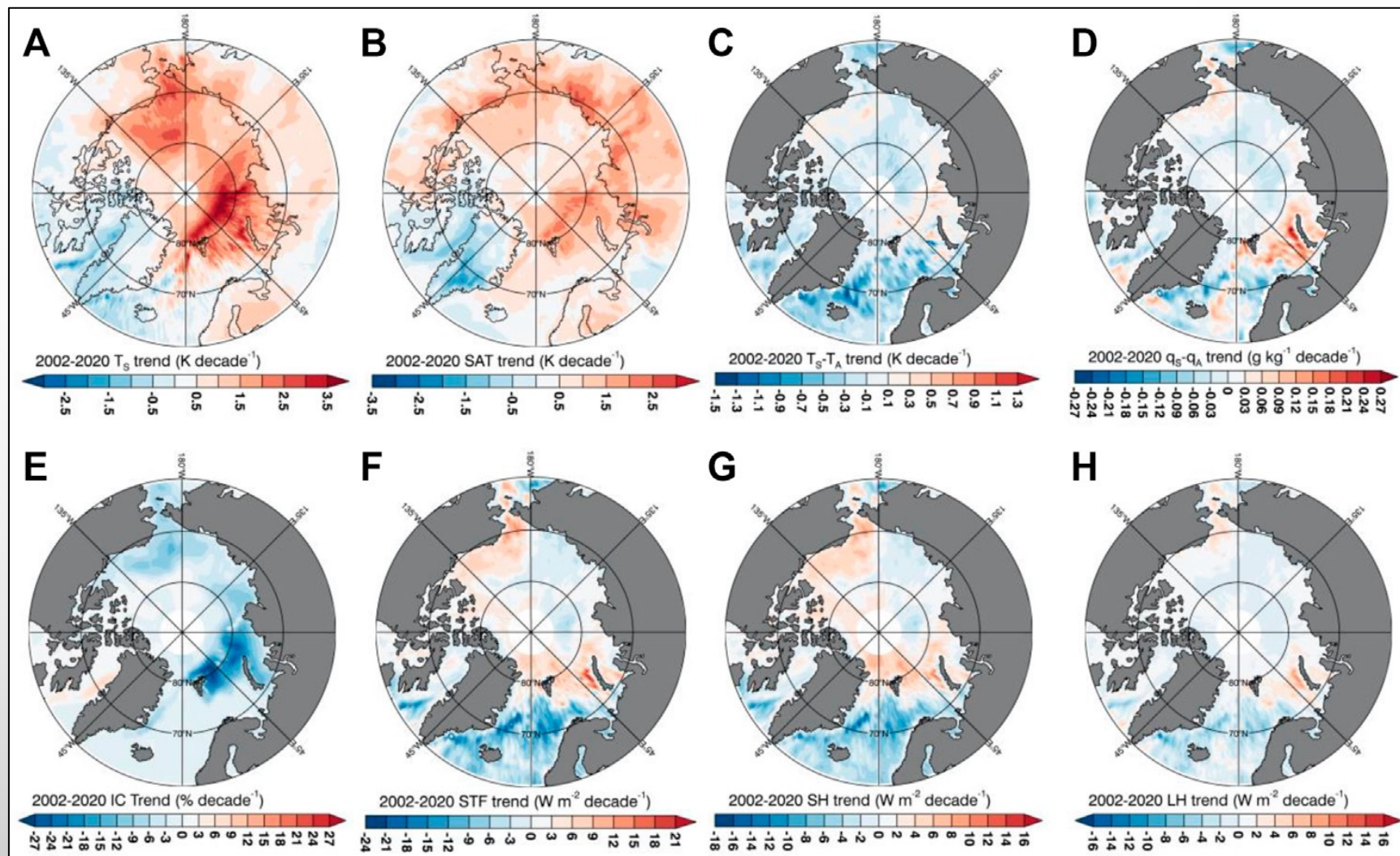
CMIP6 Std. Dev.

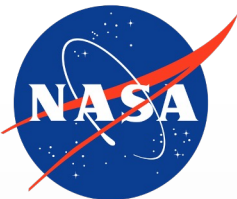




RESULTS – OBSERVED TRENDS

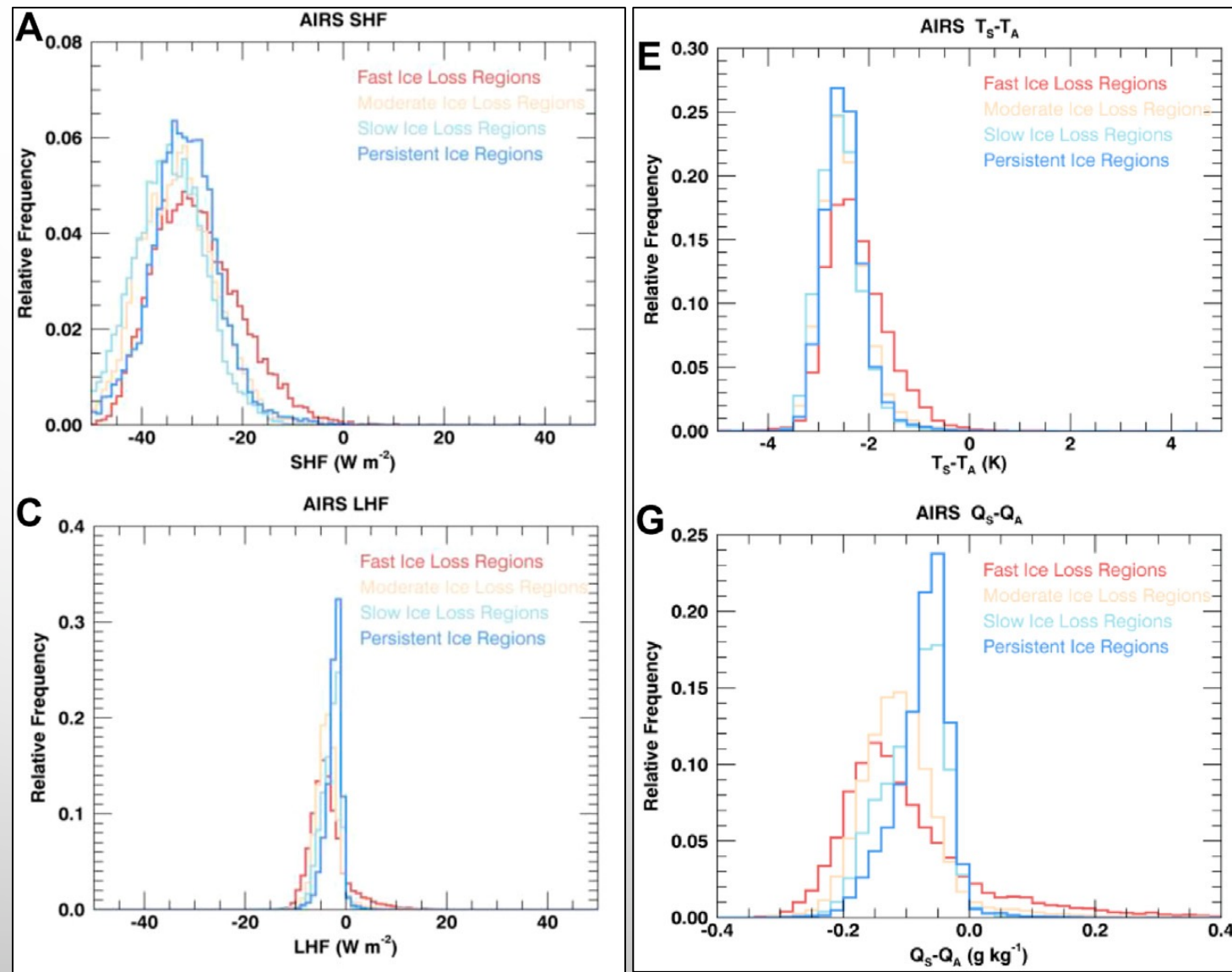
- OBSERVED FLUX TRENDS SUGGEST THAT THE CHANGING ARCTIC SURFACE IS ALTERING THE CHARACTER OF THE ATMOSPHERE'S HEAT SINK IN THE WINTER
- TRENDS SHOW INCREASES ACROSS MUCH OF THE CENTRAL ARCTIC, WEAKENING THE HEAT SINK.
- SHF TRENDS, RATHER THAN LHF, ACCOUNT FOR MOST OF THIS WEAKENING & IS DRIVEN BY:
 - THINNING OF THE MULTI-YEAR SEA ICE ([KWOK, 2018](#)), WHICH ALLOWS FOR MORE CONDUCTION THROUGH THE SEA ICE FROM THE OCEAN
 - WARMING T_S , ALONG WITH A POTENTIAL WEAKENING OF THE SURFACE-BASED TEMPERATURE INVERSION.
- TRENDS ARE CONSISTENT WITH THE AIRS-OBSERVED CHANGES IN $T_S - T_A$ AND $Q_S - Q_A$, AND ARE LARGEST IN REGIONS OF SUBSTANTIAL SEA ICE LOSS





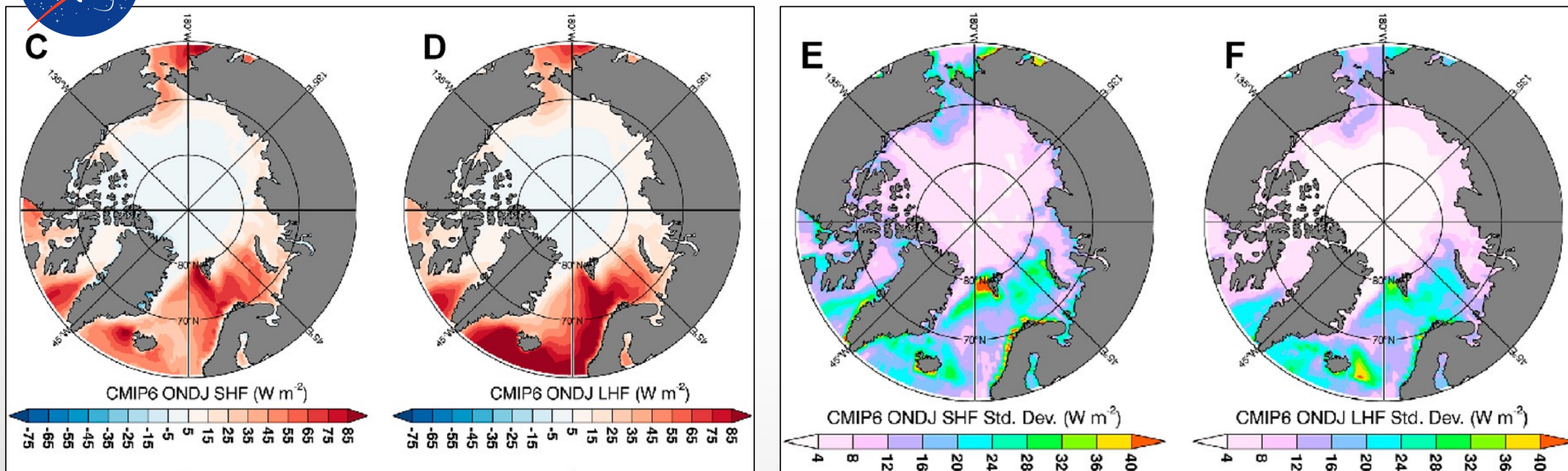
RESULTS – OBSERVATIONAL DISTRIBUTIONS

- PRESENCE OF SEA ICE MODIFIES THE SHF AND LHF FREQUENCY DISTRIBUTIONS
- CHANGES IN THE SHF AND LHF DISTRIBUTIONS BY SEA ICE REGIME CORRESPOND TO DIFFERENCES IN THE $T_S - T_A$ AND $Q_S - Q_A$ DISTRIBUTIONS.
- THUS, FASTER WINTERTIME SEA ICE LOSS CORRESPONDS WITH LARGER $T_S - T_A$ AND $Q_S - Q_A$ GRADIENTS AND POSITIVE SHF AND LHF TRENDS.

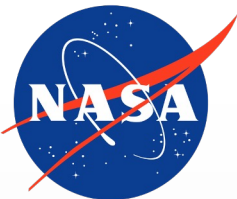




RESULTS – CMIP6 TURBULENT FLUXES

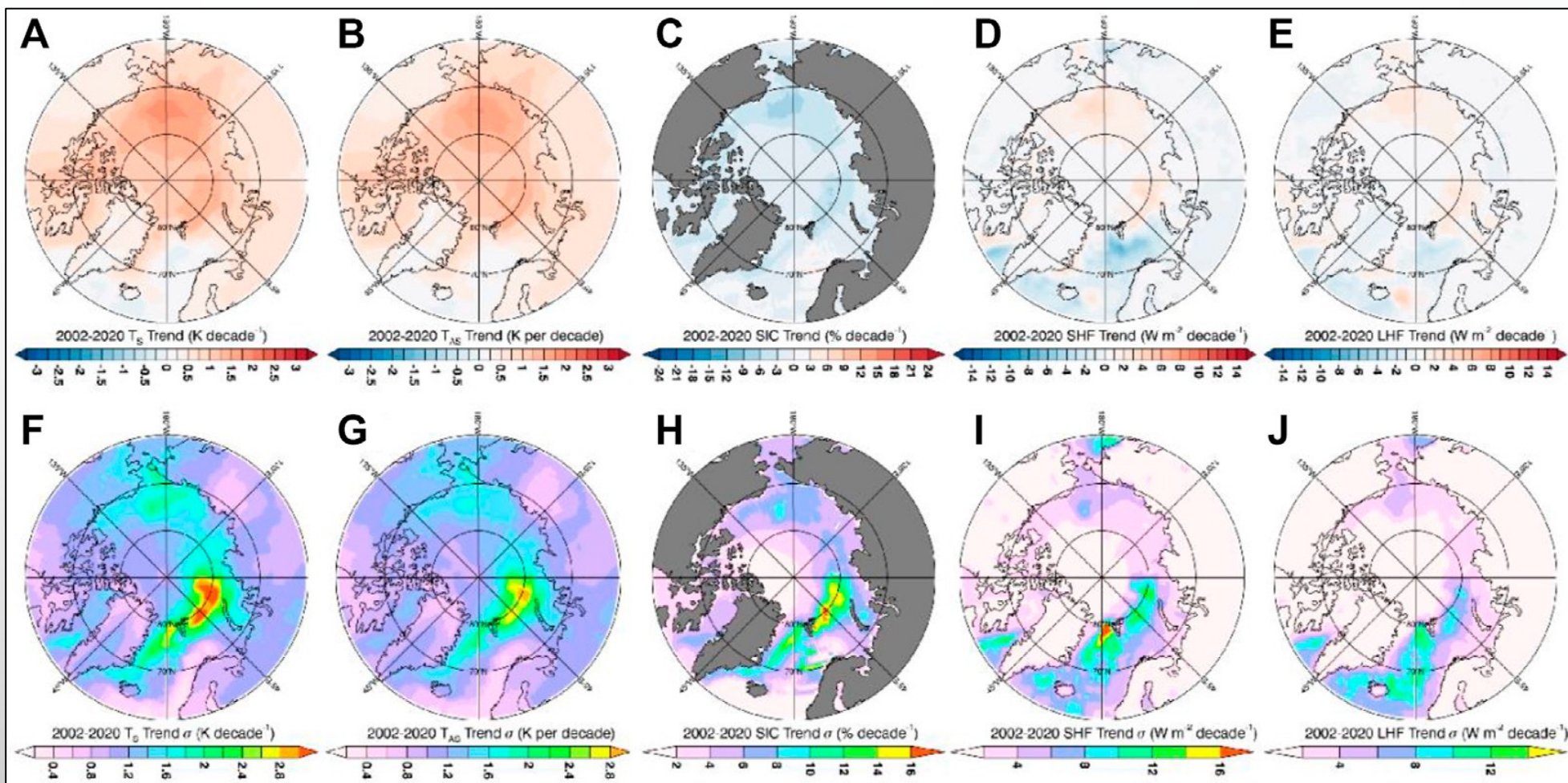


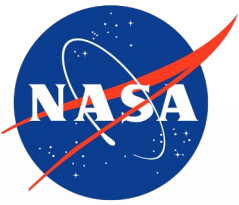
- MODELS CAPTURE KEY FEATURES OF THE OBSERVED SPATIAL VARIATIONS IN FLUXES BUT MODELS REPRESENT THE ARCTIC SURFACE AS A **HEAT SOURCE**, NOT A HEAT SINK.
- THE MODEL ENSEMBLE SHOWS WEAK NEGATIVE FLUXES ACROSS MUCH OF THE CENTRAL ARCTIC & STRONG POSITIVE FLUXES IN THE B-K SEAS REGION.
- THE ENSEMBLE MEAN ALSO SHOWS SIMILAR MAGNITUDES OF THE FLUXES SUGGESTING THAT THEY ARE OF EQUAL IMPORTANCE TO THE CENTRAL ARCTIC SURFACE ENERGY BUDGET, DIFFERENT FROM OBSERVATIONS.
- THE B-K SEAS REGION HEAT SOURCE IS APPROXIMATELY 34 TIMES STRONGER THAN IN OBSERVATIONS (
 - CMIP6 ENSEMBLE AVERAGE SHF + LHF: 70.1 W M^{-2} ; AIRS-DERIVED SHF + LHF: 2.1 W M^{-2}).)



RESULTS – CMIP6 TRENDS IN TURBULENT FLUXES

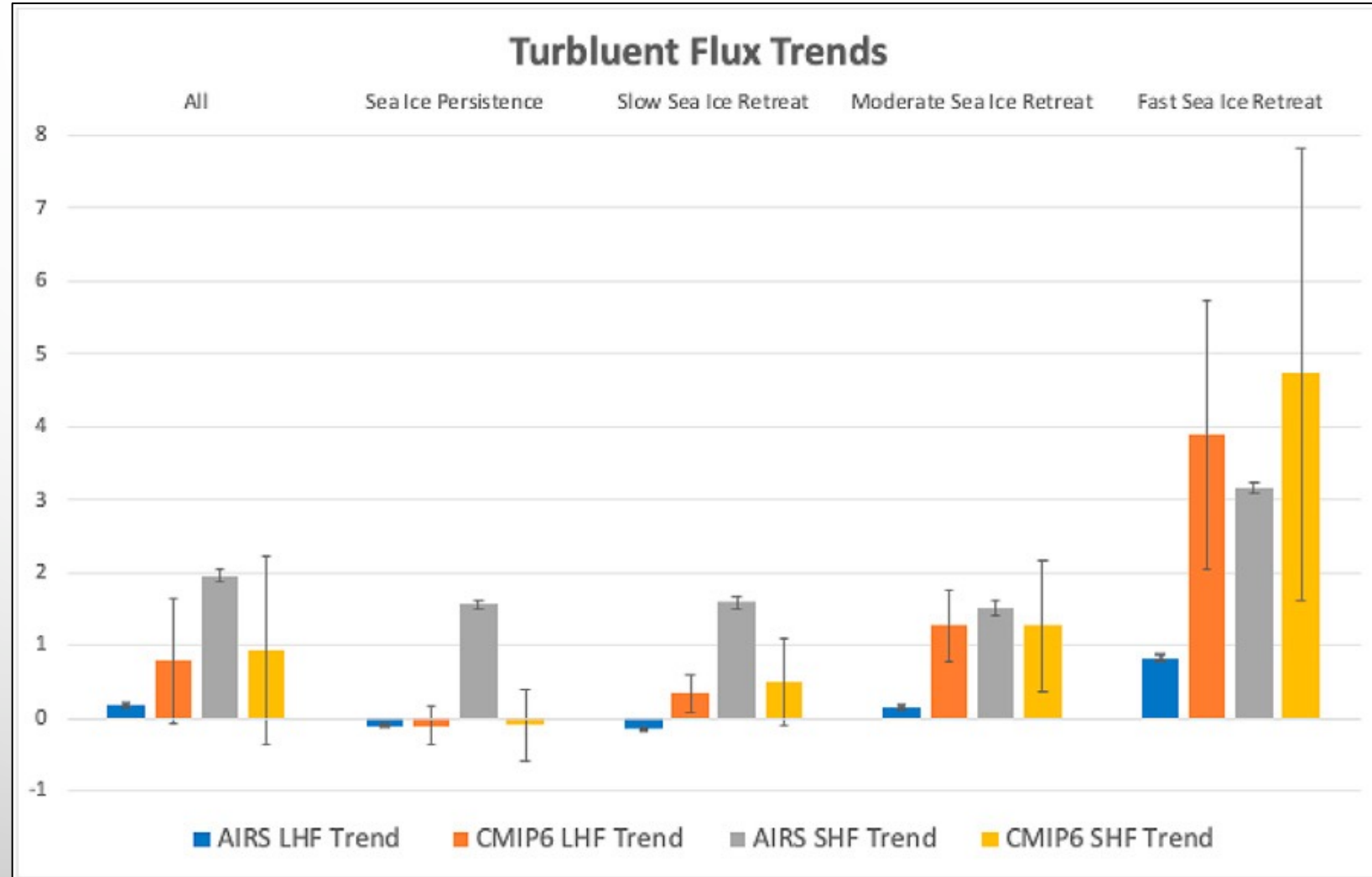
- CMIP6 FLUX TRENDS INDICATE A NARROWING AREA OF THE SURFACE ATMOSPHERIC HEAT SINK & A BROADENING OF THE HEAT SOURCE, IN CONCERT WITH THE DECLINING SEA ICE COVER
- THE INTER-MODEL SPREAD OF THESE TRENDS IS SUBSTANTIAL & IS ALSO STRONGEST IN THE REGIONS OF THE LARGEST SEA ICE LOSS.
- THE DEGREE OF SEA ICE LOSS & THE RESULTING SEB CHANGES MAY SERVE AS A USEFUL OBSERVATIONAL CONSTRAINT

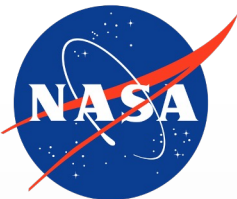




RESULTS – SEA ICE REGIME TRENDS

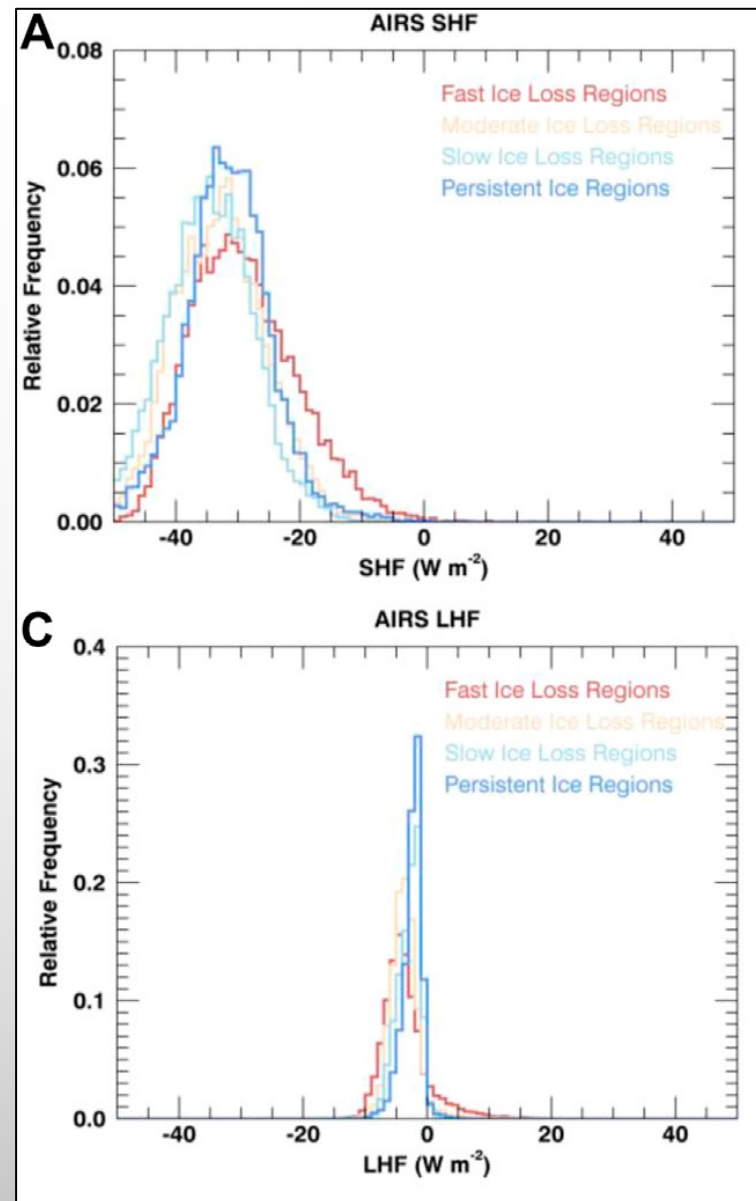
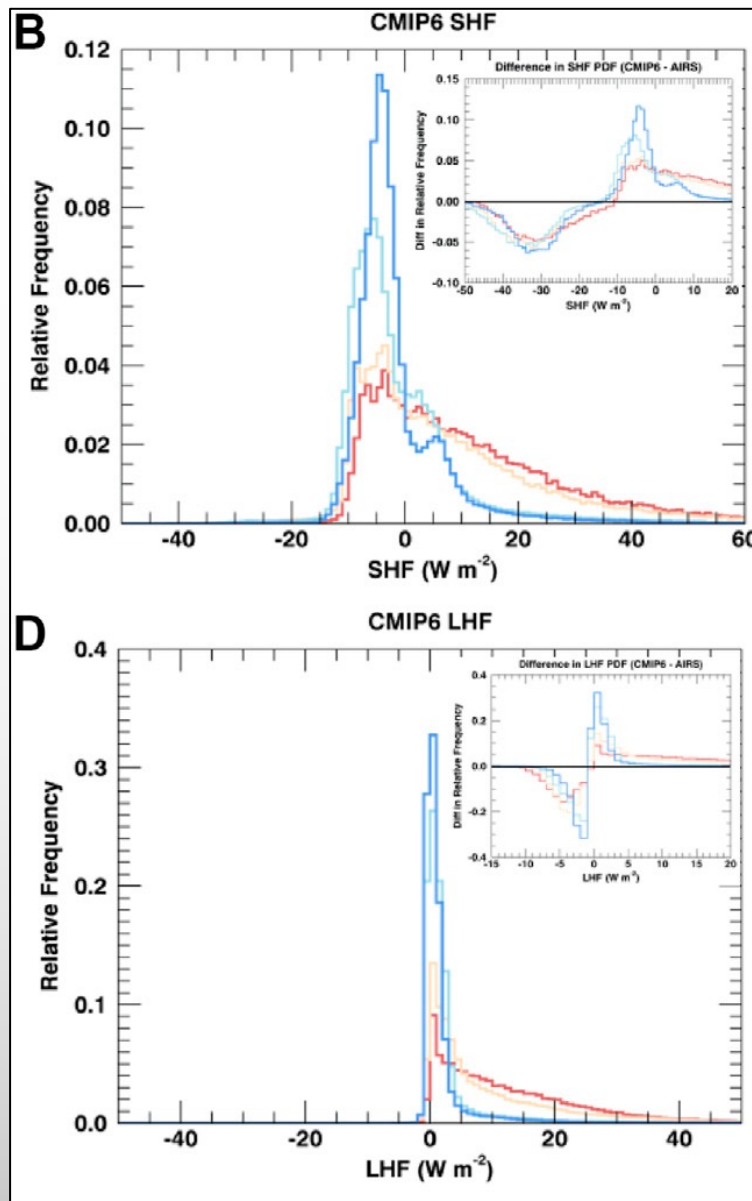
- LHF TRENDS INCREASE FROM THE SLOW TO FAST SEA ICE LOSS REGIME
- FAST SEA ICE LOSS REGIME EXHIBITS THE LARGEST TRENDS, FURTHER HIGHLIGHTING THE RELATIONSHIP BETWEEN SEA ICE & FLUXES.
- MODEL FLUX TRENDS WITHIN SEA ICE LOSS REGIMES TELL A STORY CONSISTENT WITH OBSERVATIONS, HIGHLIGHTING THE SEA ICE INFLUENCE ON THE INTER-MODEL TREND DIFFERENCES
- FOR ALL REGIMES, THE MODEL ENSEMBLE LHF TRENDS ARE ALWAYS GREATER & MORE THAN DOUBLE THE OBSERVED VALUE.
- LARGEST DISCREPANCIES BETWEEN MODELS & OBSERVATIONS OCCUR IN THE FAST SEA ICE LOSS REGIME





RESULTS – MODEL OBSERVATIONAL DIFFERENCES

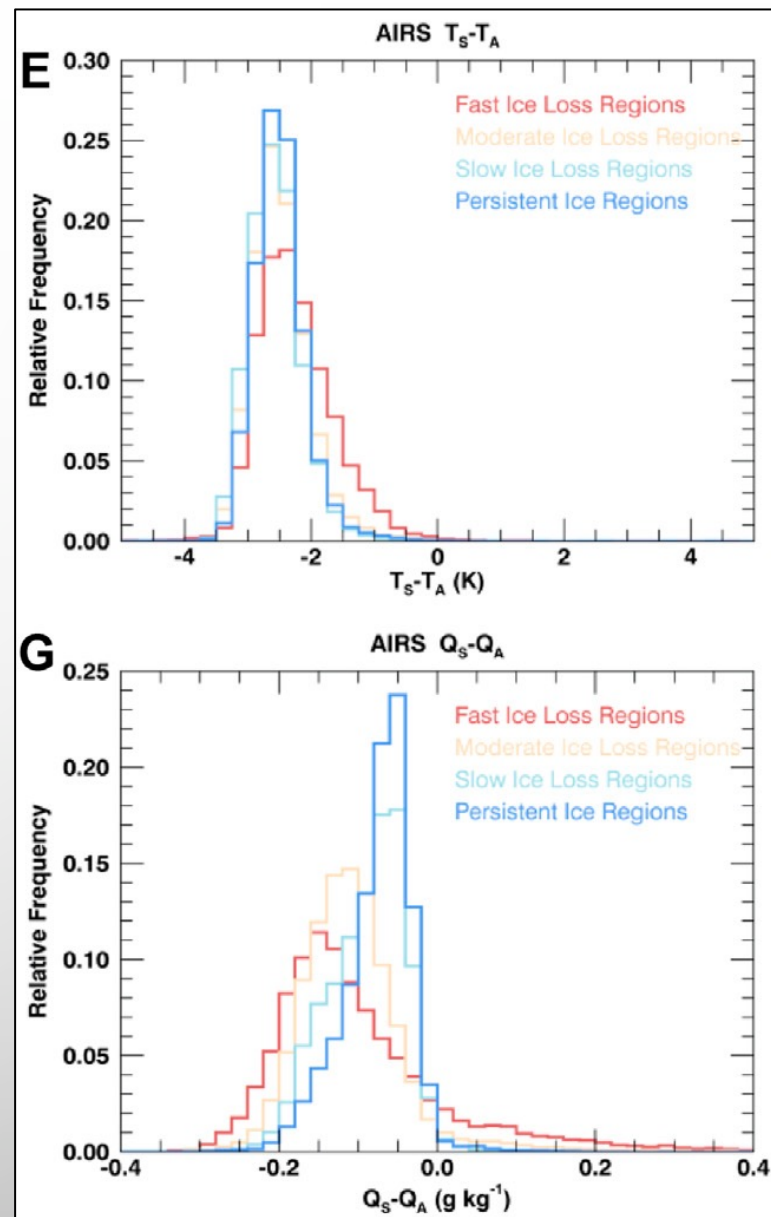
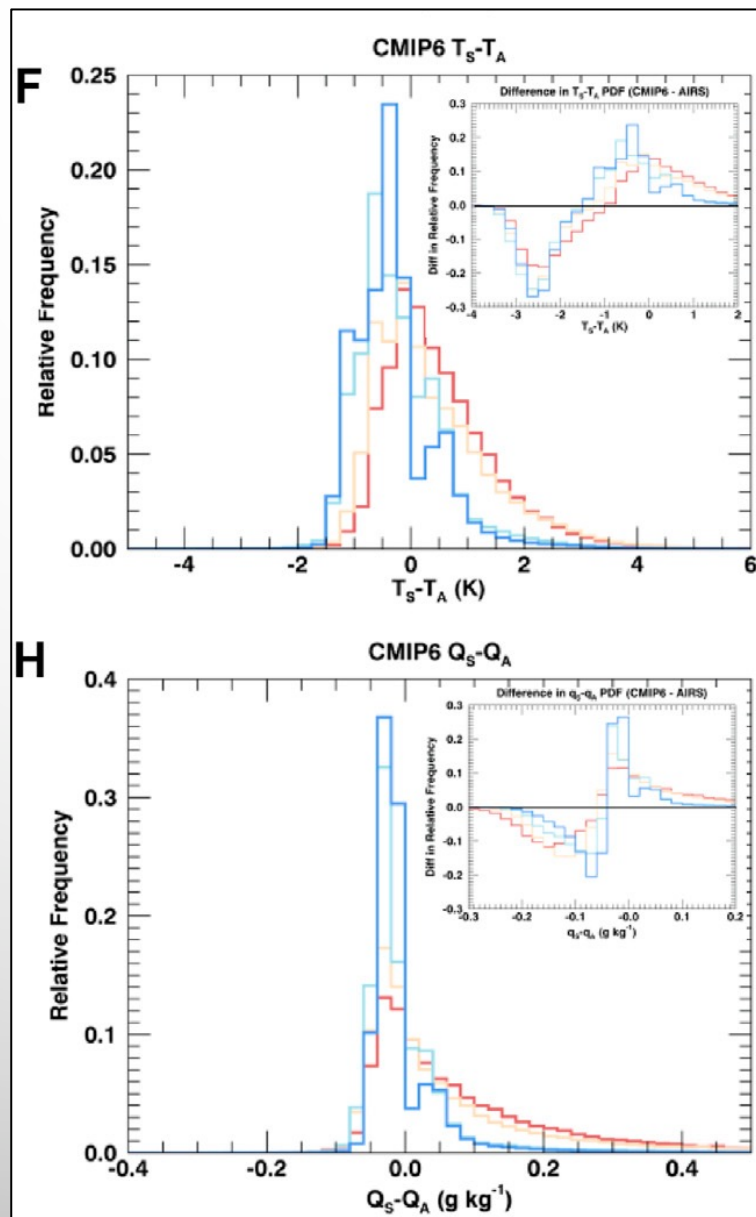
- MODEL SIMULATED FLUX DISTRIBUTIONS SHOW SIMILAR HIGH FREQUENCIES OF SLIGHTLY NEGATIVE SHF VALUES & NEAR ZERO LHF VALUES AS OBSERVATIONS
- MODELS DO NOT CAPTURE THE FREQUENCY OF NEGATIVE SHF OR LHF VALUES.





RESULTS – MODEL OBSERVATIONAL DIFFERENCES

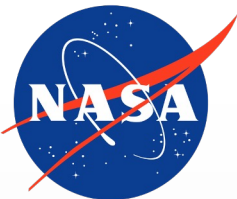
- CHARACTER OF MODEL-OBS. DIFFERENCES STEMS IN PART FROM DIFFERENT DISTRIBUTIONS OF $T_S - T_A$ & $Q_S - Q_A$
- MODEL-OBSERVATION DIFFERENCES IN THE LHF DISTRIBUTION ARE DRIVEN BY THE DIFFERENCES IN THE $Q_S - Q_A$ DISTRIBUTIONS
- THESE DIFFERENCES STEM FROM MODELS NOT SIMULATING AS STRONGLY NEGATIVE $T_S - T_A$ VALUES.





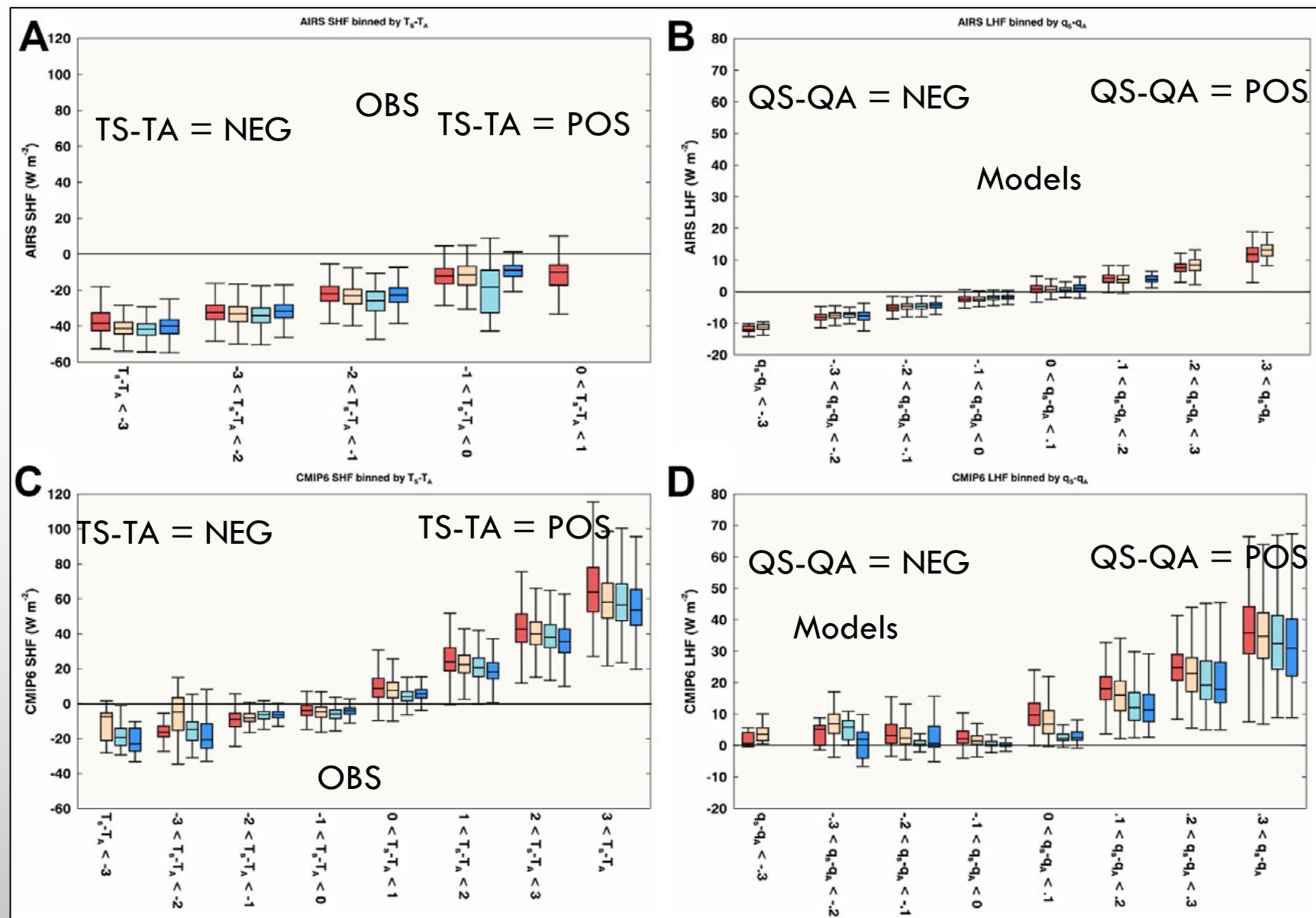
PLEASE NOTE

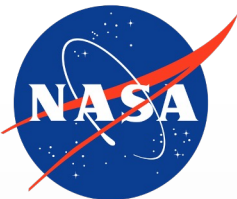
- THE UNDERLYING MODEL-OBSERVATIONS DIFFERENCES IN THE SHF & LHF VALUES ARE RELATED TO THE DIFFERENCES IN $T_S - T_A$ & $Q_S - Q_A$ DISTRIBUTIONS
- RADIOSONDES TAKEN DURING THE SHEBA CAMPAIGN SHOWED THAT Q & T CONSISTENTLY INCREASED WITH HEIGHT NEAR THE SURFACE DUE TO FREQUENT WINTERTIME INVERSIONS ([YU., 2019](#); [YU ET AL., 2019](#))
- $Q_S - Q_A$ MEASUREMENTS TAKEN DURING THE TARA DRIFTING STATION IN SPRING & SUMMER 2007 SHOWED SLIGHT NEGATIVE DIFFERENCES ([BOISVERT ET AL., 2015A](#)) EVEN WHEN SURFACE-BASED INVERSIONS ARE WEAKER THAN THE WINTER.
- THESE NEGATIVE GRADIENTS IN SATELLITE-DERIVED (OBS) $Q_S - Q_A$ APPEAR REALISTIC & ARE NOT CAPTURED IN CMIP6 MODELS.



RESULTS – TURBULENT FLUX SENSITIVITY

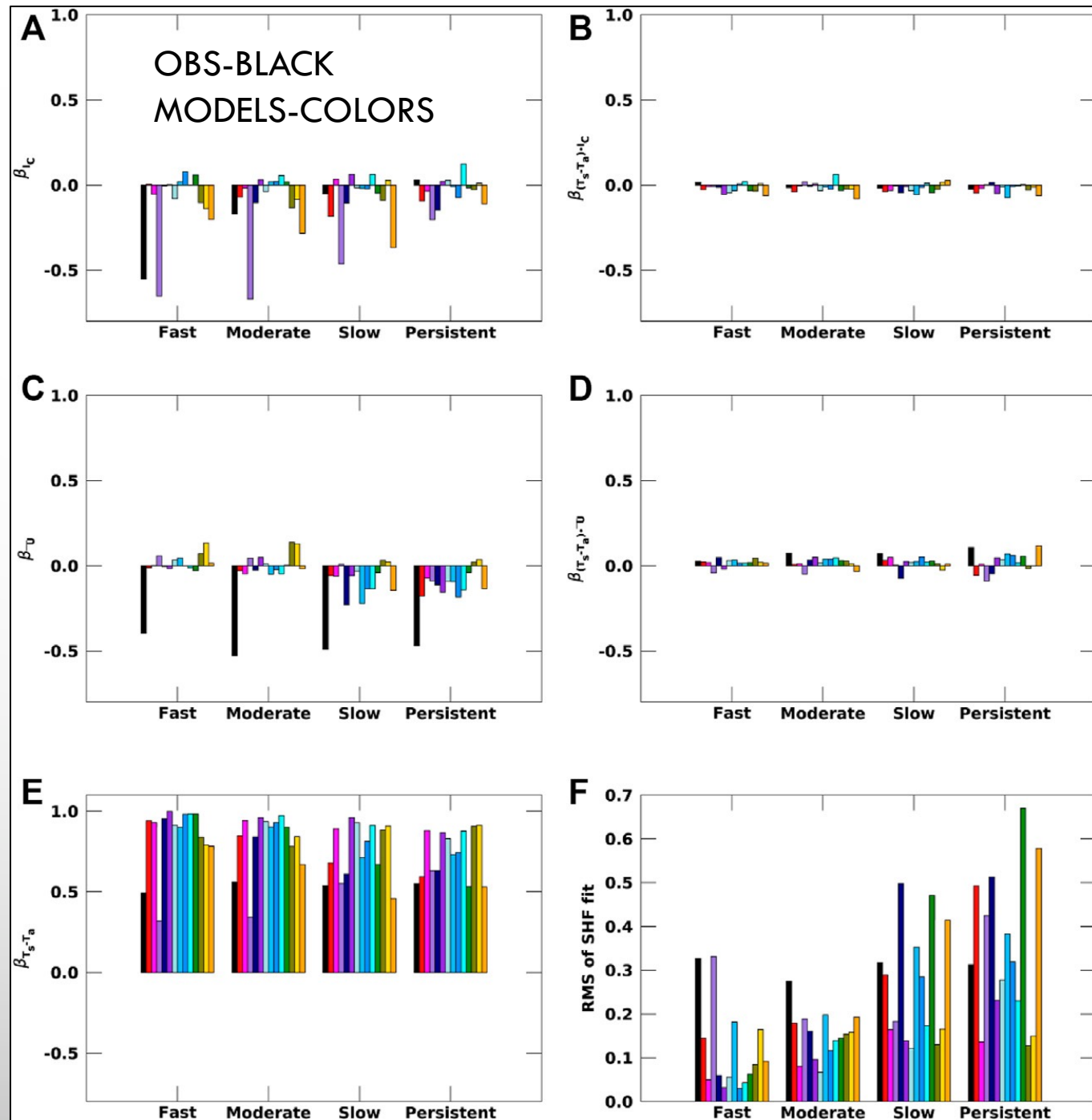
- DEPENDENCE OF THE MEAN SHF & LHF STRATIFIED BY $T_S - T_A$ & $Q_S - Q_A$ IS SIMILAR BETWEEN MODELS & OBS.
 - MODELS SHOW LARGER SHF VALUES FOR THE SAME $T_S - T_A$ & MUCH LARGER VALUES FOR LHF FOR THE SAME $Q_S - Q_A$
- MODELS SUBSTANTIALLY DIFFER FROM OBSERVED FLUX VALUES WHEN THE $T_S - T_A$ & $Q_S - Q_A$ VALUES ARE THE SAME
- MODELS ARE LARGELY UNABLE TO PRODUCE NEGATIVE $Q_S - Q_A$ GRADIENTS, & HENCE LHF





RESULTS – SENSITIVITY OF SHF

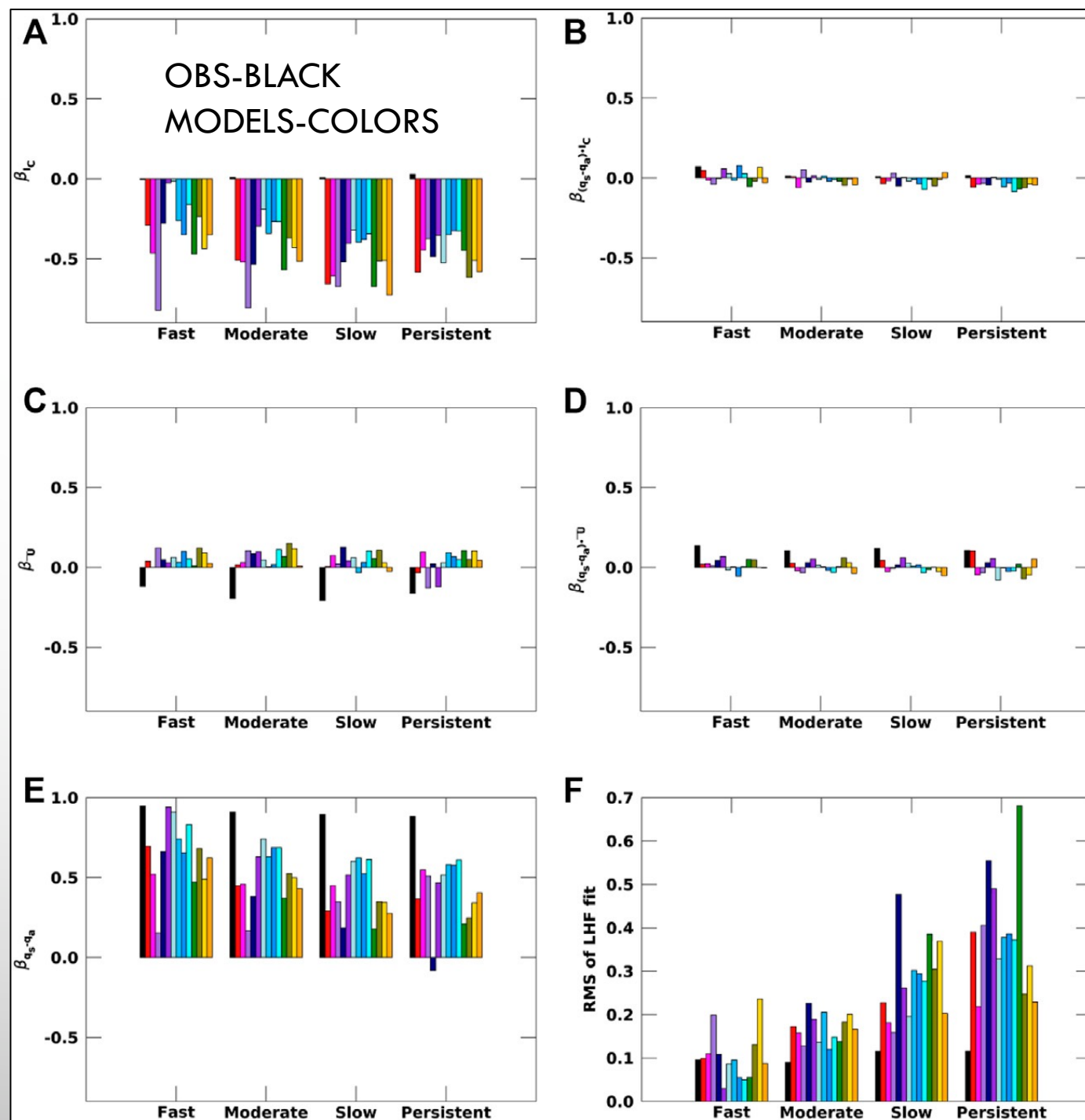
- REGRESSION APPROACH YIELDS SOME EXPECTED FEATURES
 - IMPORTANCE OF $T_S - T_A$
- AND SOME UNEXPECTED FEATURES,
 - STRONG NEGATIVE SIGN OF THE WIND TERM FOR OBSERVATIONS
- B_{TS-TA} IS AN IMPORTANT TERM FOR OBSERVED & MODELED SHF VARIABILITY; HOWEVER, MOST CLIMATE MODELS POSSESS A B_{TS-TA} NEARLY DOUBLE THE OBSERVATIONAL VALUE.
- FOR B_{IC} : LARGE SPREAD IN VALUES SUGGESTS THAT SEA ICE SURFACE PROPERTIES THAT INFLUENCE SHF (E.G., SURFACE ROUGHNESS, ATMOSPHERIC STABILITY, SEA ICE TOPOGRAPHY, ETC.) ARE EITHER REPRESENTED DIFFERENTLY BY MODELS AND/OR THEIR EFFECTS ON SHFS ARE PARAMETERIZED DIFFERENTLY.
- THE IMPORTANCE OF B_{IC} IN PRODUCING SHF VARIABILITY IS MUCH LARGER IN OBSERVATIONS THAN IN MOST MODELS





RESULTS – SENSITIVITY OF LHF

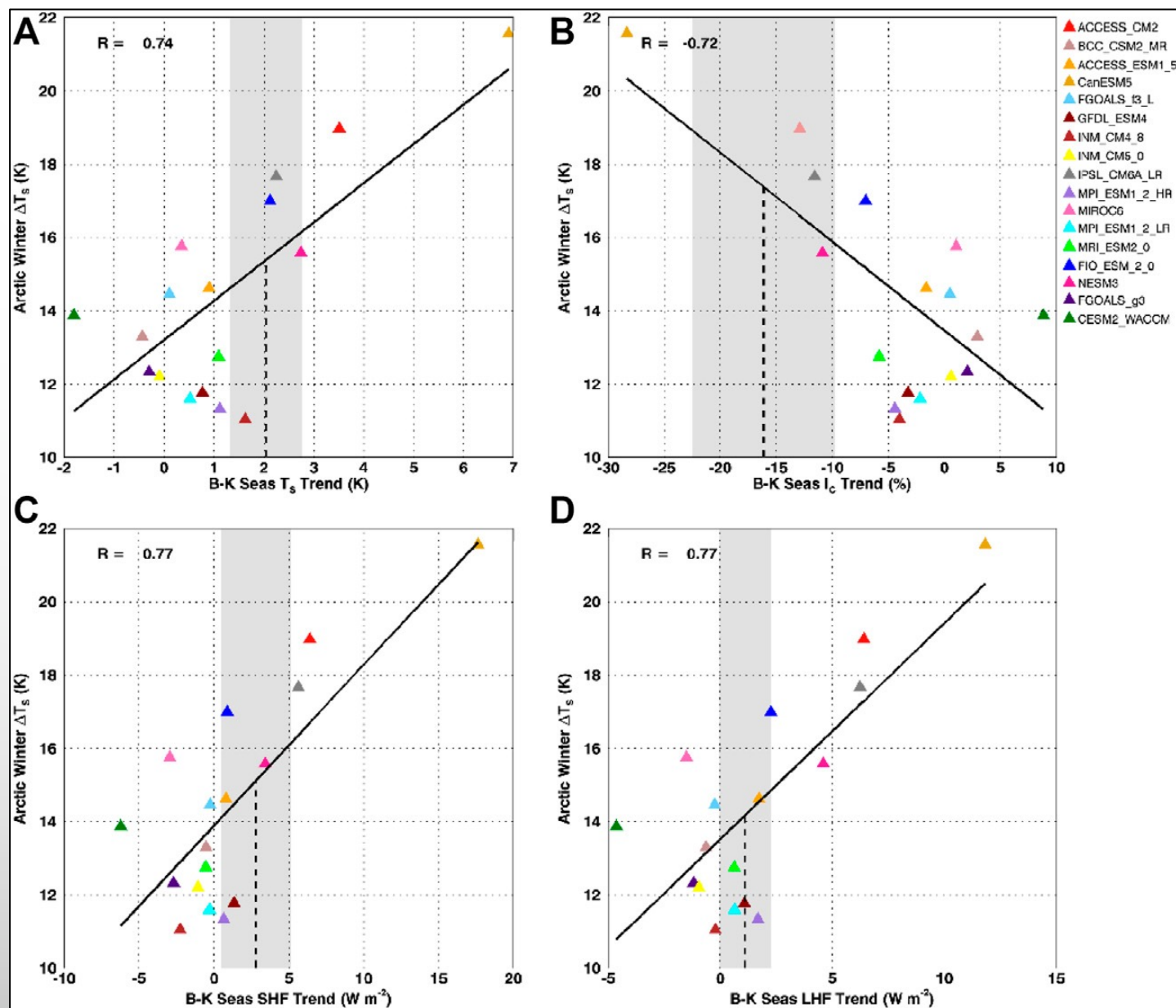
- OBSERVED VARIABILITY OF LHF IS DOMINATED BY A SINGLE TERM, B_{QS-QA} .
- ALL MODELS SHOW A CONSISTENT SIGN OF B_{QS-QA} , IN LINE WITH OBSERVATIONS, WITH A SUBSTANTIAL INTER-MODEL SPREAD IN THE MAGNITUDE.
- B_{IC} & $B_{\bar{U}}$ ARE SUBSTANTIALLY WEAKER THAN B_{QS-QA} IN OBSERVATIONS; SPECIFICALLY, OBSERVED B_{IC} IS NEAR ZERO.
- HOWEVER, B_{IC} IS OF EQUAL IMPORTANCE AS B_{QS-QA} TO EXPLAINING VARIABILITY OF LHF IN MODELS.

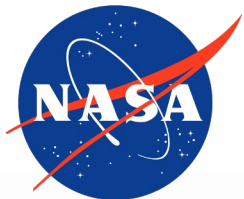




RESULTS – CONSTRAINING CLIMATE PROJECTIONS

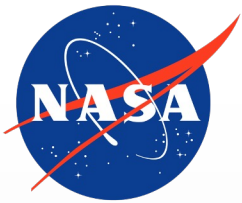
- BOEKE & TAYLOR (2018) FOUND THAT SEASONAL ENERGY EXCHANGES IN SEA ICE RETREAT REGIONS CONTRIBUTE SIGNIFICANTLY TO THE SPREAD IN MODEL PROJECTIONS OF AA
 - MODELS THAT MORE EFFICIENTLY DISPERSE THE ENERGY STORED IN THE OCEAN FROM SUMMER VIA STF WARM MORE.
- SHF (LHF) REGRESSION SLOPES FROM OBS. ARE TESTED AS A POSSIBLE EMERGENT CONSTRAINT (EC)—
 - APPROACH THAT USES AN ENSEMBLE OF MODELS TO CONNECT AN OBSERVABLE PROCESS FROM PRESENT-DAY TO FUTURE CLIMATE PROJECTIONS TO NARROW THE UNCERTAINTY
- PRESENT-DAY TRENDS IN STF, I_c AND T_s IN ICE-RETREAT REGIONS CORRELATE STRONGLY WITH PROJECTED WINTER WARMING AND COULD SERVE AS A USEFUL EC
- **CONSTRAINED ARCTIC WINTER WARMING RANGE OF ~14–17 K, SUBSTANTIALLY SMALLER THAN THE 10–21 K INTER-MODEL RANGE IN WARMING**





DISCUSSION

- UNREALISTICALLY WEAK HEAT SINK PERSISTS IN THE CURRENT GENERATION OF CMIP6 MODELS & COULD IN PART BE DRIVEN BY THE POOR REPRESENTATION OF THE STABLE BOUNDARY LAYER OVER ICE IN WINTER, WHICH CAN UNDERESTIMATE THE MAGNITUDE OF THE FLUXES ([GRACHEV ET AL., 2007](#); [BOISVERT ET AL., 2015A](#))
- MODELS HAVE A POSITIVE BIAS IN $T_S - T_A$ & $Q_S - Q_A$ WHEN COMPARED TO OBSERVATIONS
 - MAY BE RELATED TO THE MODEL REPRESENTATION OF THE STRONG WINTERTIME SURFACE-BASED INVERSIONS OVER SEA ICE
 - INFLUENCED BY HOW THEY SIMULATE THE STABLE BOUNDARY LAYER TURBULENCE, SURFACE ENERGY BUDGET, CLOUDS, RADIATIVE TRANSFER, AND THEIR VERTICAL RESOLUTION
- SEA ICE COVER ALSO INFLUENCES THE THERMODYNAMIC STRUCTURE OF THE ARCTIC ATMOSPHERE BY PROMOTING MORE FREQUENT TEMPERATURE INVERSIONS
- CLIMATE MODELS CONTINUE TO STRUGGLE TO REPRESENT SEA ICE COVER EXTENT AND RECENT DECLINE COMPARED TO OBSERVATIONS



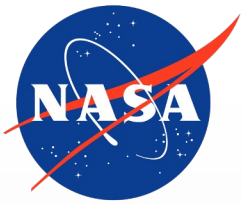
DISCUSSION

- OBSERVATIONS MIGHT ALSO BE BIASED
- CURRENT LIMITATIONS OF SATELLITE RETRIEVALS MIGHT CONTRIBUTE TO THE APPARENT MODEL BIASES.
 - FOR EXAMPLE, THE VERTICAL RESOLUTION OF AIRS IS 1 KM AND THE INSTRUMENT IS THEREFORE NOT ABLE TO RESOLVE NEAR SURFACE VARIABLES
- OBSERVATIONS MIGHT BE BIASED TOWARDS CLEAR SKY OR HETEROGENEOUS CLOUD COVER CONDITIONS.
- FUTURE SATELLITE MISSIONS, AS PART OF THE DECADAL SURVEY PLANETARY BOUNDARY LAYER, WILL WORK ON HAVING BETTER RESOLUTION NEAR THE SURFACE ([TEIXEIRA ET AL., 2021](#))



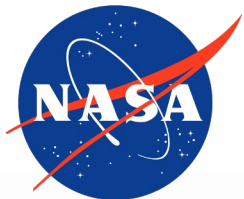
CONCLUSIONS

- RECENT WORKS HAVE ATTRIBUTED THIS SURFACE-BASED WARMING TO A LOSS IN SEA ICE COVER AND AN INCREASE IN SURFACE TURBULENT FLUXES
- CURRENTLY, THERE ARE LARGE INTER-MODEL SPREADS IN PRESENT DAY SEA ICE LOSS, TURBULENT FLUXES AND WINTERTIME WARMING
 - THIS UNCERTAINTY HINDERS OUR ABILITY TO PREDICT THE MAGNITUDE OF FUTURE WINTERTIME WARMING
- RESULTS SHOW THAT CMIP6 MODELS REPRESENT THE SURFACE TURBULENT FLUXES IN THE CENTRAL ARCTIC DIFFERENTLY FROM OBSERVATIONS, AS A HEAT SOURCE RATHER THAN A HEAT SINK TO THE WINTER ARCTIC ATMOSPHERE LIKE OBSERVATIONS
- THESE BIASES ARE LIKELY DRIVEN BY THE MODELS' INABILITY TO REPRODUCE THE STRONG SURFACE-BASED INVERSIONS OVER THE SEA ICE IN THE WINTER
- BOTH OBSERVATIONS AND MODELS SHOW THAT THE TURBULENT FLUXES HAVE INCREASED THE MOST IN AREAS OF FAST ICE LOSS



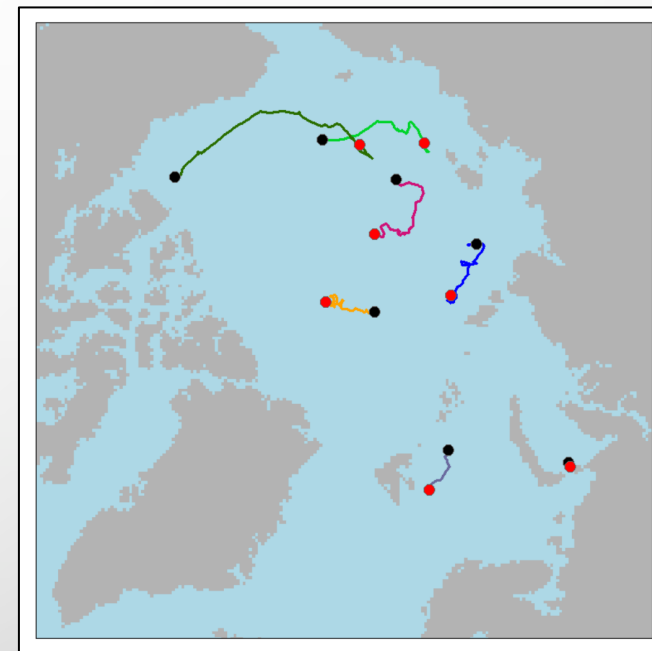
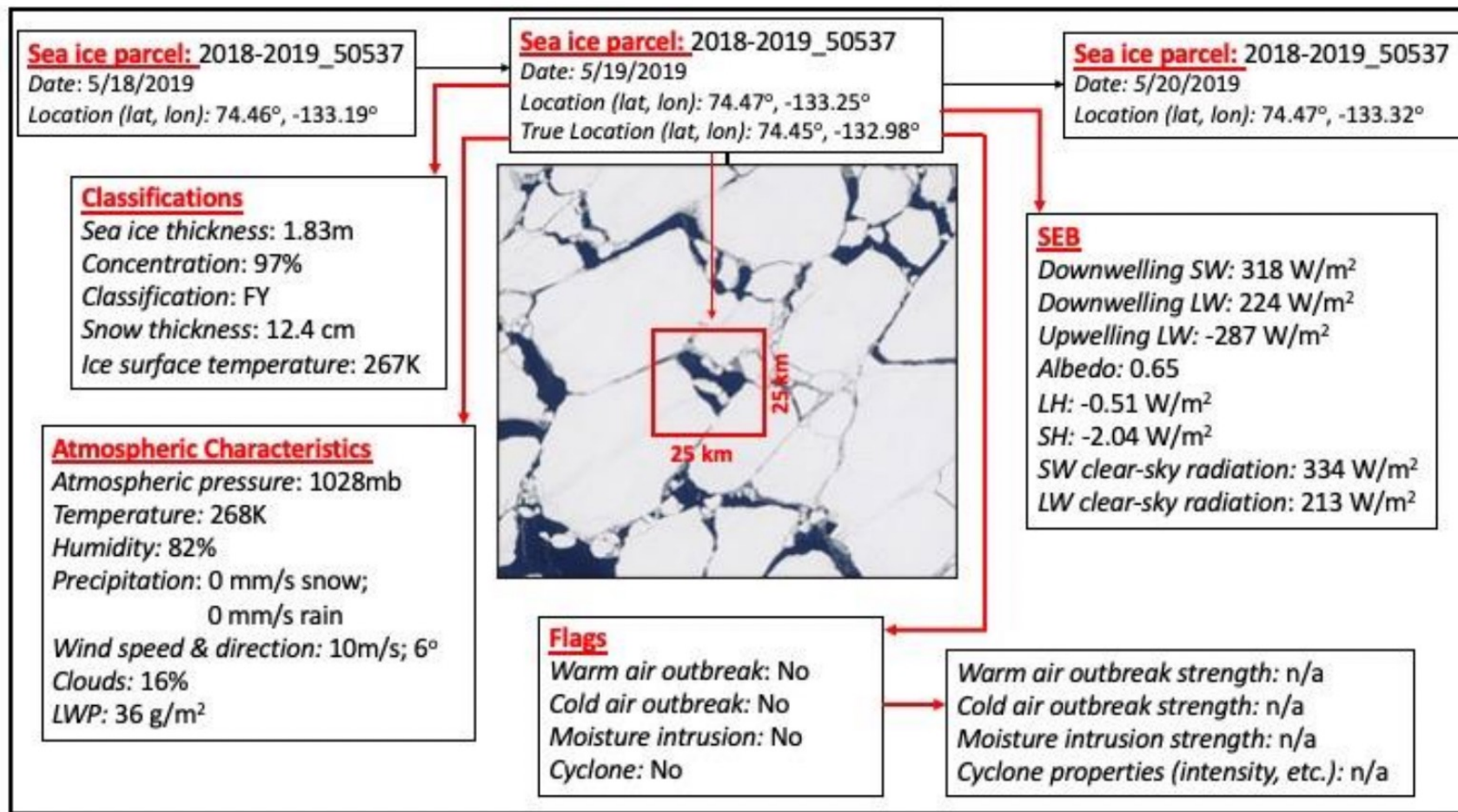
FUTURE NEEDS FOR ARCTIC TURBULENT FLUXES

- 1) FLUX SCHEMES NEED TO USE MORE PARAMETERIZATIONS THAT ARE 'ARCTIC SPECIFIC' IN ORDER TO REPRESENT THE VERY STABLE BOUNDARY LAYER CONDITIONS OVER SEA ICE
- 2) REPRESENTATION OF SEA ICE/SNOW PROPERTIES & CHARACTERISTICS (E.G. SNOW AND ICE THICKNESS, ROUGHNESS, CONCENTRATION, FLOE SIZE DISTRIBUTION) NEED TO BE IMPROVED SO THAT THE SURFACE DRAG COEFFICIENTS & ROUGHNESS LENGTHS CAN BE ACCURATELY ASSESSED & SURFACE & NEAR SURFACE VARIABLES CAN MORE CLOSELY MATCH OBSERVED VALUES
- 3) SPATIAL & VERTICAL RESOLUTION OF CLIMATE MODELS & SATELLITE OBSERVATIONS NEED TO INCREASE SO THAT THE BOUNDARY LAYER & SUB-GRID SCALE PROCESSES THAT ARE NOT CURRENTLY RESOLVED CAN BE SIMULATED
- 4) **BETTER COLLABORATION BETWEEN THOSE TAKING THE MEASUREMENTS AND THOSE WHO PRODUCE THE MODELS**



A LAGRANGIAN SEA ICE PARCEL DATABASE TO UNDERSTAND THE FATE OF SEA ICE IN THE NEW ARCTIC

Horvath, S., **L. Boisvert**, C. Parker, *et al.* 2021. "Fate of sea ice in the 'New Arctic': A database of daily Lagrangian Arctic sea ice parcel drift tracks with coincident ice and atmospheric conditions." *The Cryosphere*, (Under Review) [[10.5194/tc-2021-297](#)]



Example of some sea ice
parcel tracks
Dataset soon to be hosted by
NSIDC.org



Lagrangian Sea Ice Parcel Database to understand the fate of sea ice in the New Arctic

- Survivability of sea ice parcels. a) % of first year (FYI) and multiyear (MYI) sea ice parcels that melt/survive (red/blue) the summer melt season. b) Daily averaged net SEB for June-August, grouped by region where ice parcels end. Sea ice parcels that melted out are in red, sea ice parcels that survived the melt season are in blue.
- Parcels that melt out in the summer receiving a higher amount of energy (SEB) into the surface than those who do not melt out.**

