

# Detecting Changes in the Arctic Freshwater Budget



Chukchi Sea, Barrow, AK, July 2016, Photo: R. Laiho

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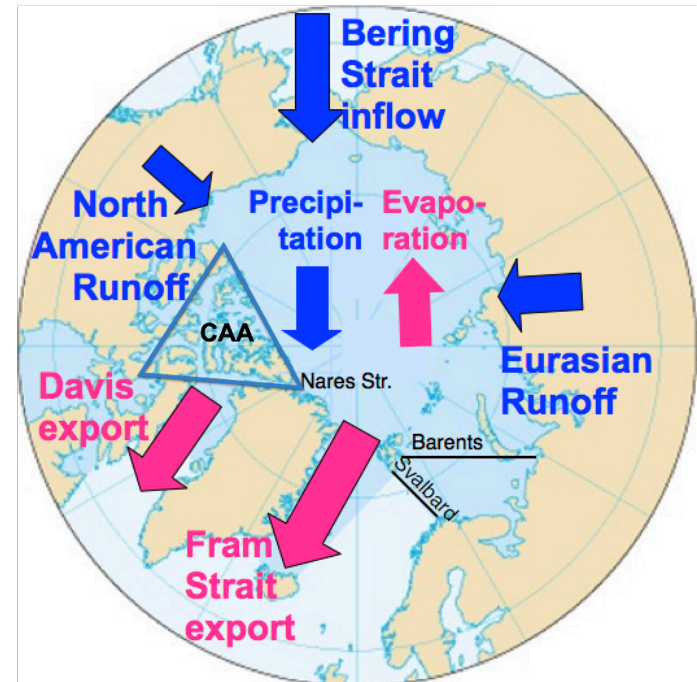


# PROJECT GOALS

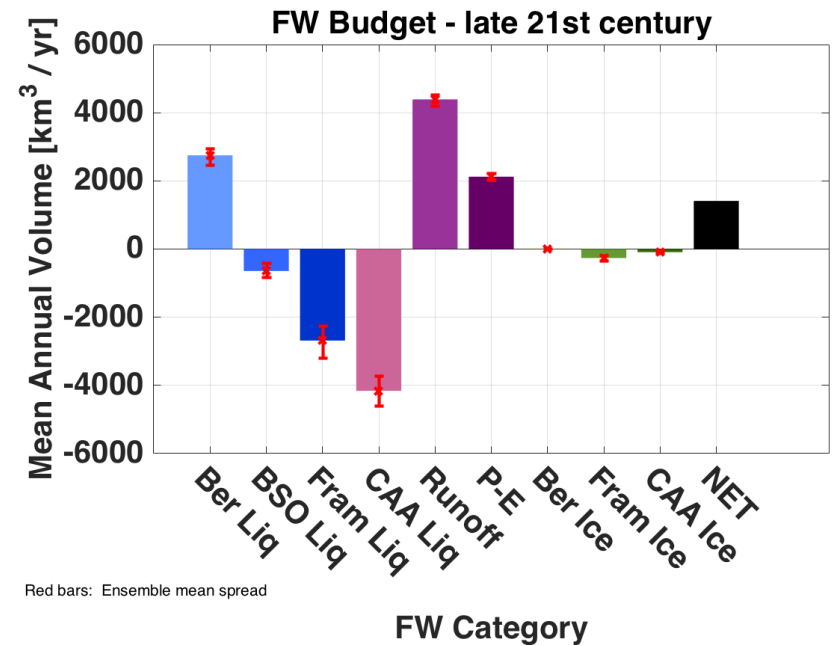
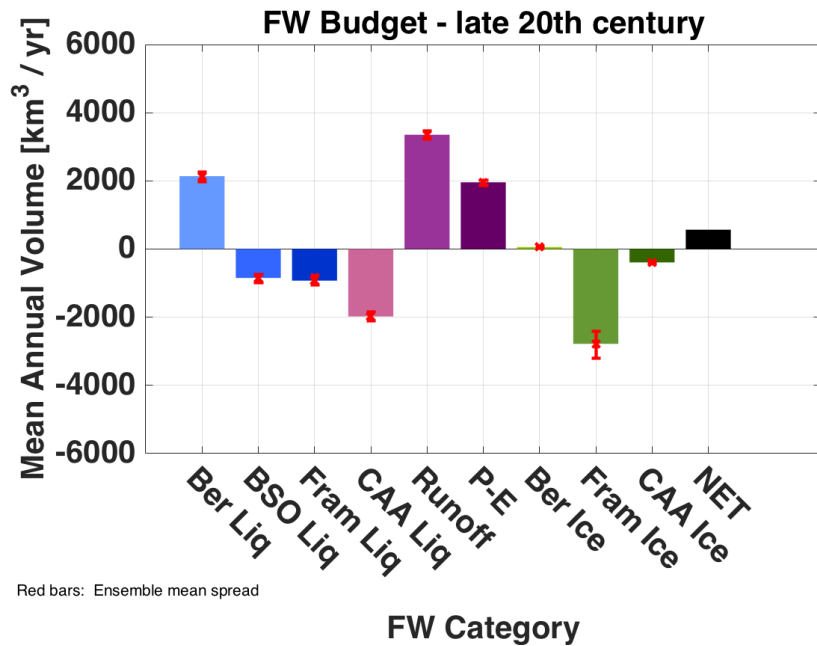
- 1) Investigate **internal variability** of Arctic FW flux budget terms
- 2) Identify the timing of **shifts** of simulated Arctic FW fluxes in **20 – 21<sup>st</sup> century simulations** under **RCP 8.5 forcing** compared to 1850 conditions:
  - How and how much will they change?
  - When can we expect to see these changes?

## ARCTIC FW FLUXES

- Solid (Sea Ice & Snow)
- Liquid
- Surface: Runoff & P-E



# Arctic Freshwater (FW) budget from CESM LE



- BERING STRAIT LIQUID
- BARENTS (BSO) LIQUID
- FRAM STRAIT LIQUID
- CAA CANADIAN ARCTIC ARCHIPELAGO LIQUID

Note: CAA =

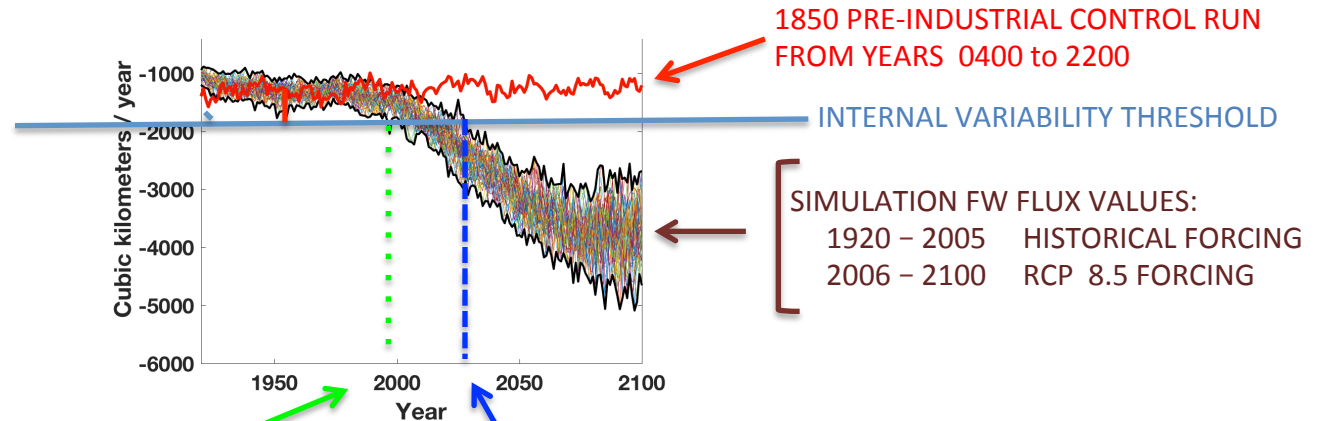
Nares Strait + Northwest Passage

- RUNOFF
- P minus E
- BERING STRAIT SOLID
- FRAM STRAIT SOLID
- CAA SOLID
- NET

# KEY CONCEPTS

## INTERNAL VARIABILITY THRESHOLD

- Internal variability threshold determined by range of pre-industrial control run values during years 0400 – 2200 (characterizes background climate state)



### SHIFT YEAR:

For a FW flux variable in an ensemble run, the first year that the FW flux annual volume is outside the internal variability threshold

### EMERGENCE YEAR:

For a FW flux variable in an ensemble run, the first year the FW flux annual volume is outside the internal variability threshold & does NOT return to background state

NOTE: Each ensemble run will have its own SHIFT and EMERGENCE years if the above threshold crossing criteria are met.

# KEY CONCEPTS

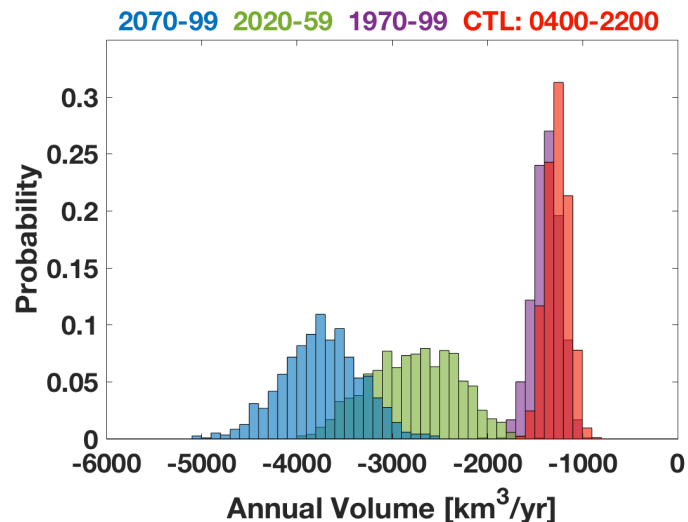
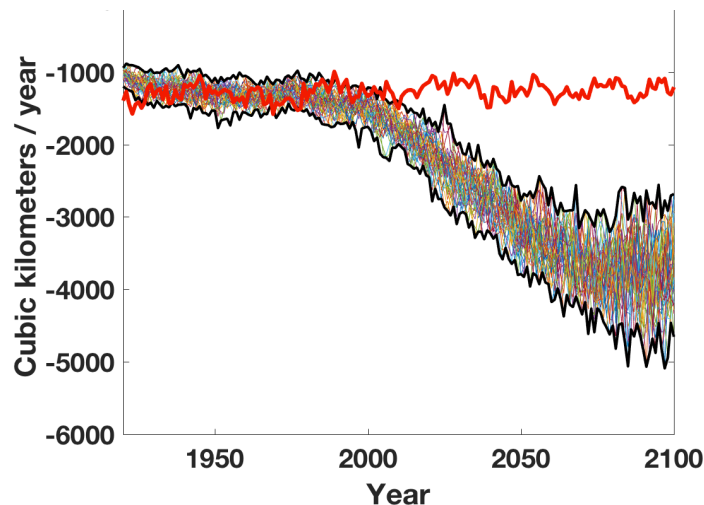
## PROBABILITY DENSITY FUNCTION (PDF) of FW FLUX VALUES

- Investigated PDFs for several time periods

1850 control run    1970-1999    2020-2059    2070-2099

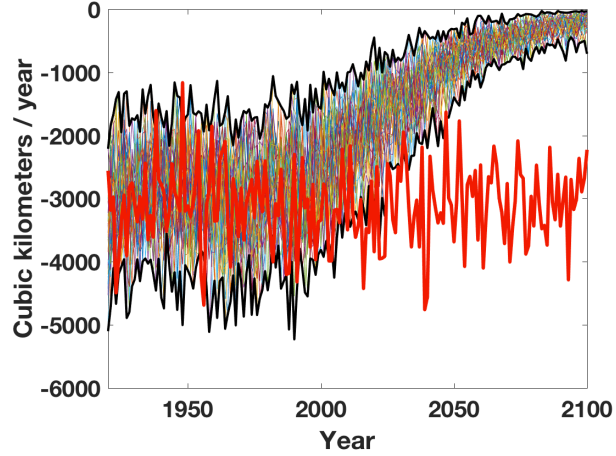
- Examined shifts over time of FW flux annual means and standard deviations and compared FW flux variables

- Sample of time-series FW flux plot and corresponding PDF plot:

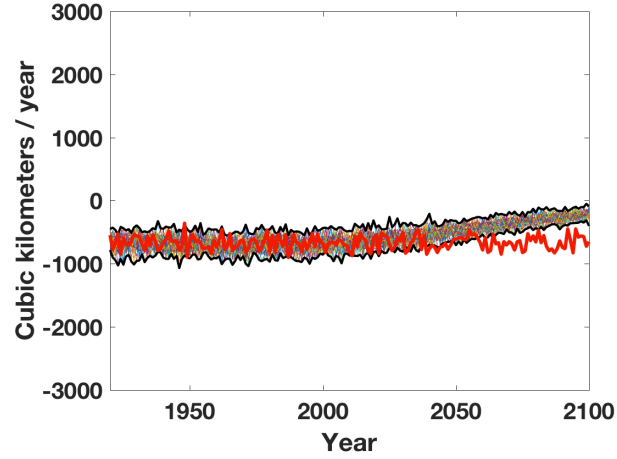


# ARCTIC SOLID FW FLUXES

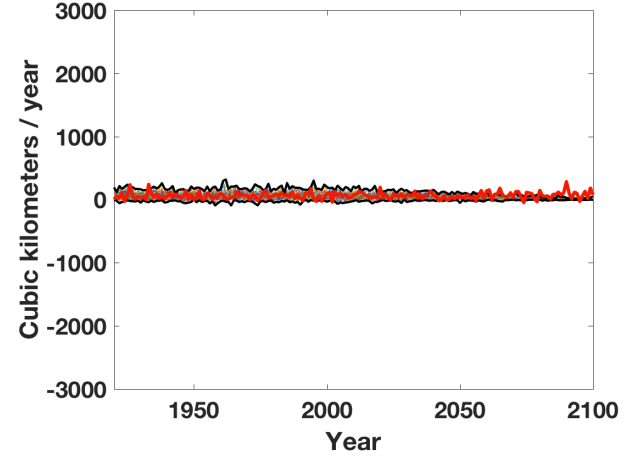
## FRAM STRAIT



## DAVIS STRAIT

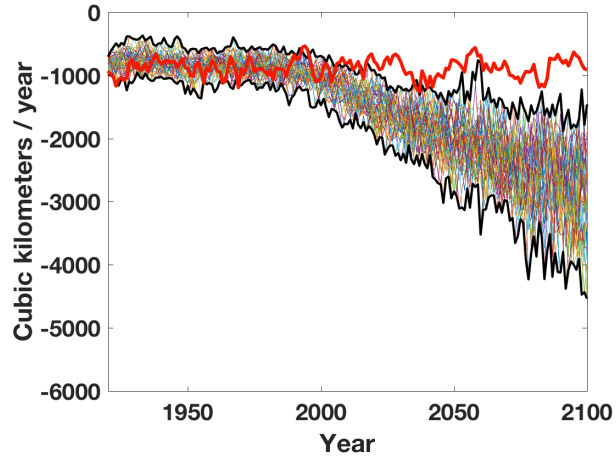


## BERING STRAIT

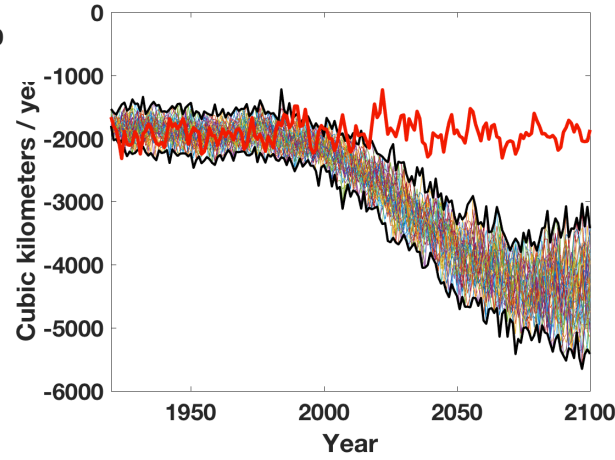


# ARCTIC LIQUID NET FW FLUXES

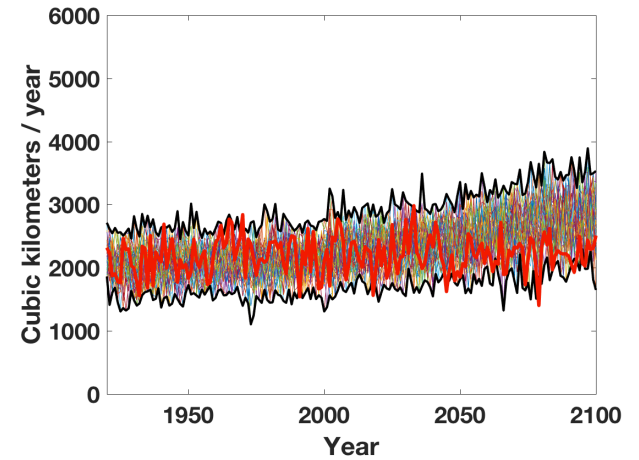
## FRAM STRAIT



## DAVIS STRAIT

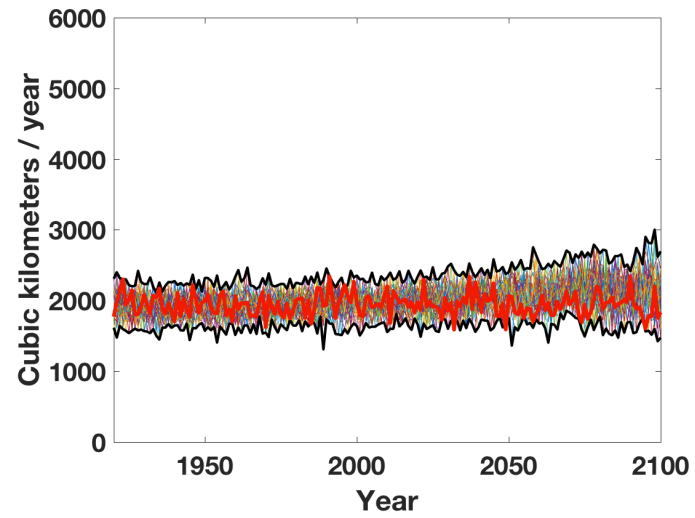


## BERING STRAIT

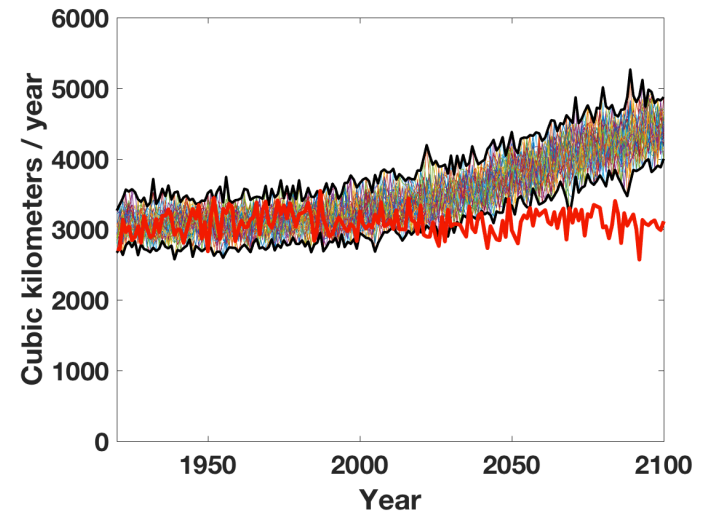


# ARCTIC SURFACE FW FLUXES

## P minus E



## RUNOFF





# FRAM STRAIT -- SOLID FW FLUX

## CESM LE Runs

SHIFT YEARS:

1945 → 2031

SHIFT RANGE:

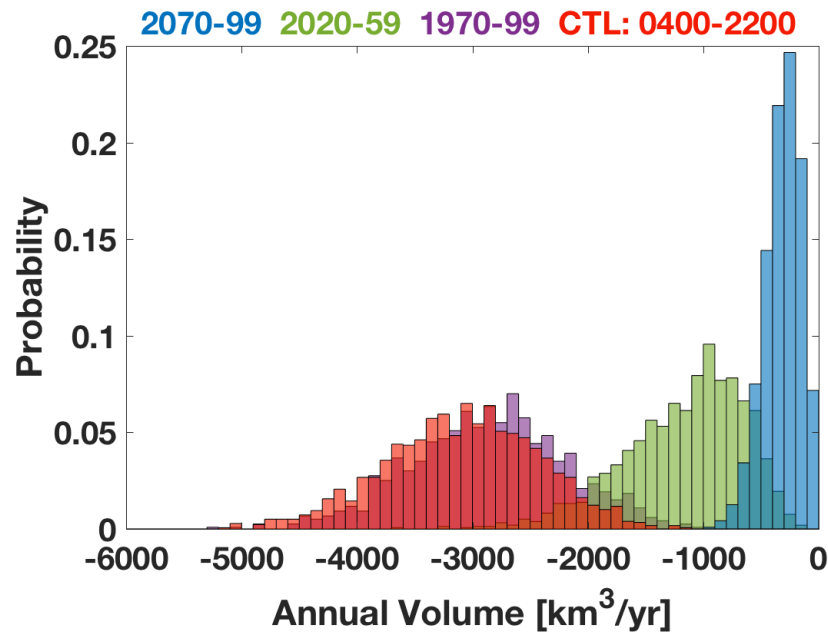
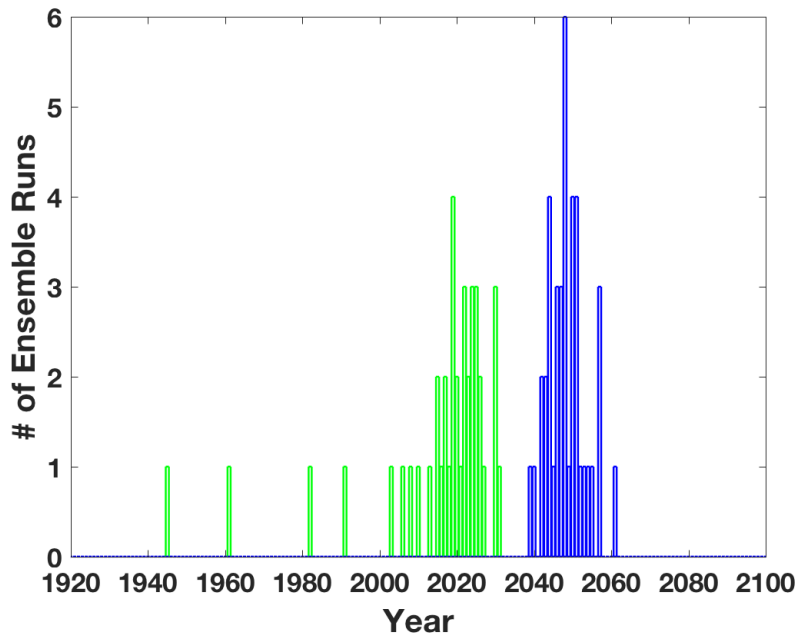
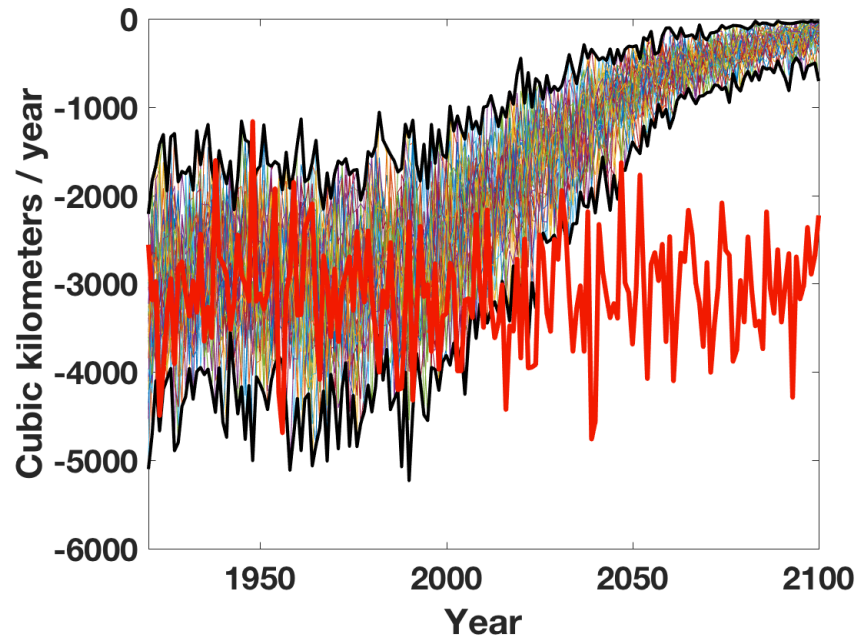
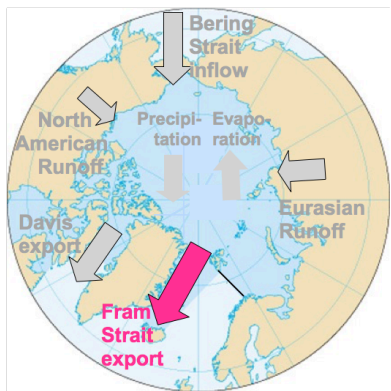
87 years (all 40 runs)

EMERGENCE YEARS:

2038 → 2060

EMERGENCE RANGE:

23 years (all 40 runs)



# FRAM STRAIT -- LIQUID NET FW FLUX

## CESM LE Runs

SHIFT YEARS:

2003 → 2027

SHIFT RANGE:

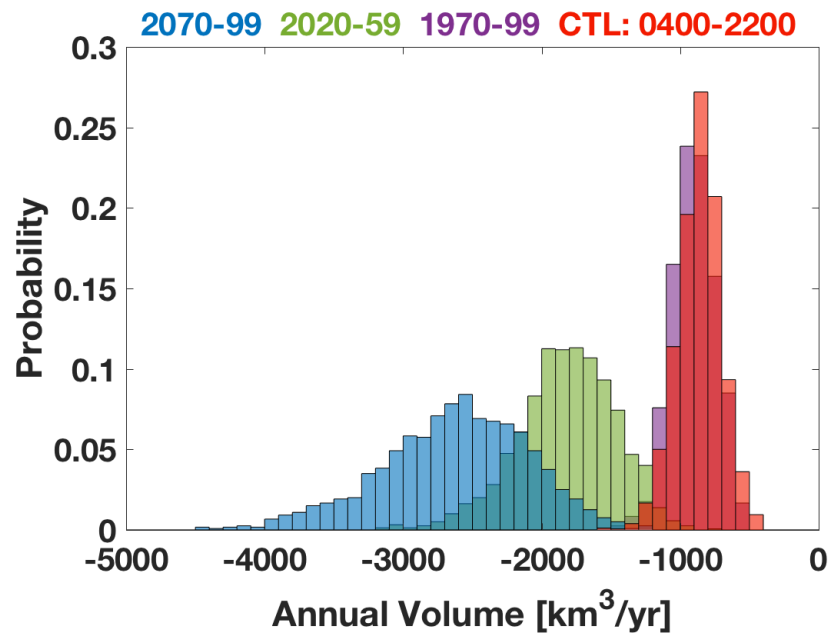
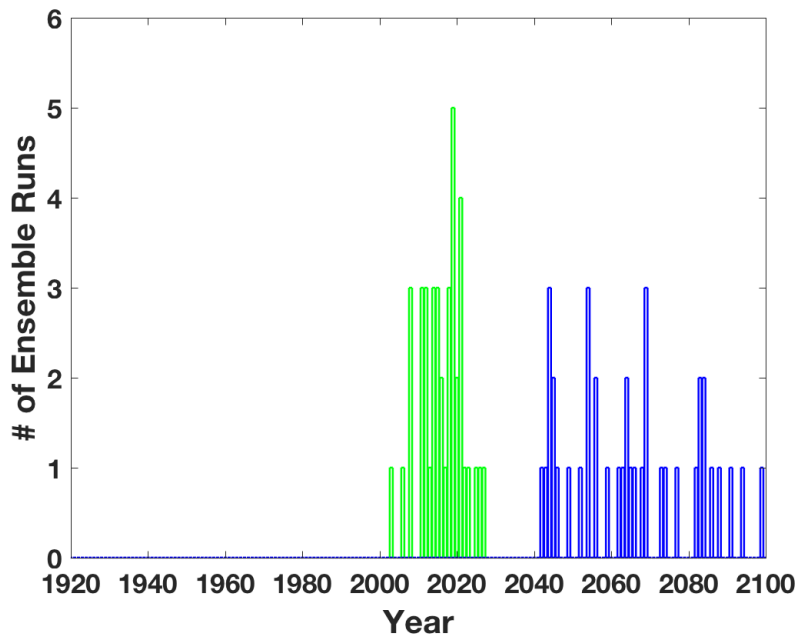
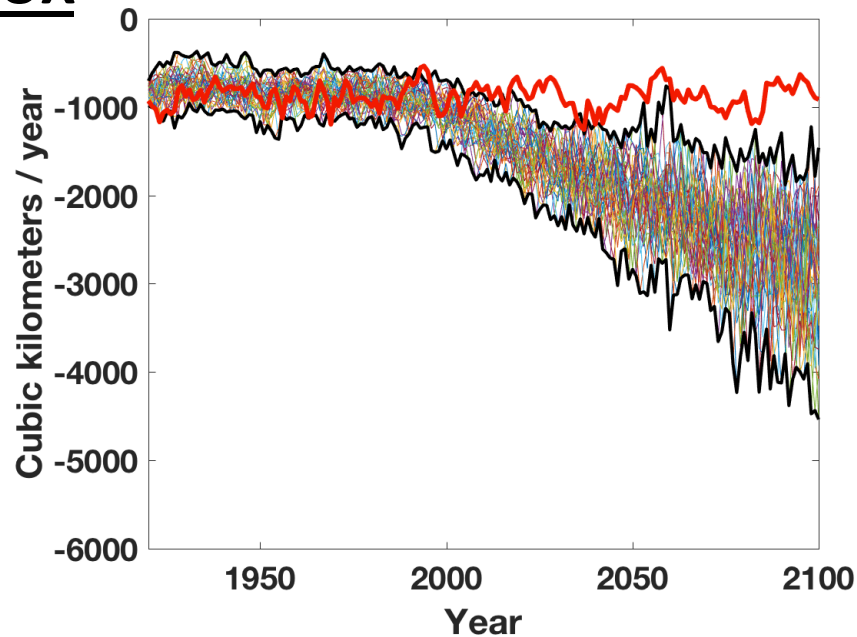
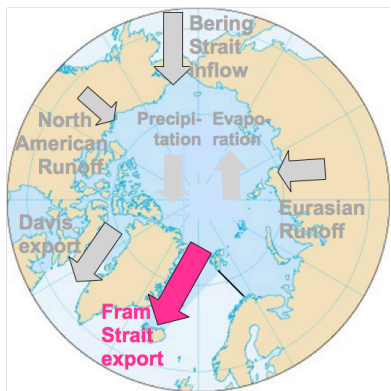
25 years (all 40 runs)

EMERGENCE YEARS:

2041 → 2100

EMERGENCE RANGE:

60 years (39/40 runs)



# DAVIS STRAIT -- SOLID FW FLUX

## CESM LE Runs

SHIFT YEARS:

2025 → 2079

SHIFT RANGE:

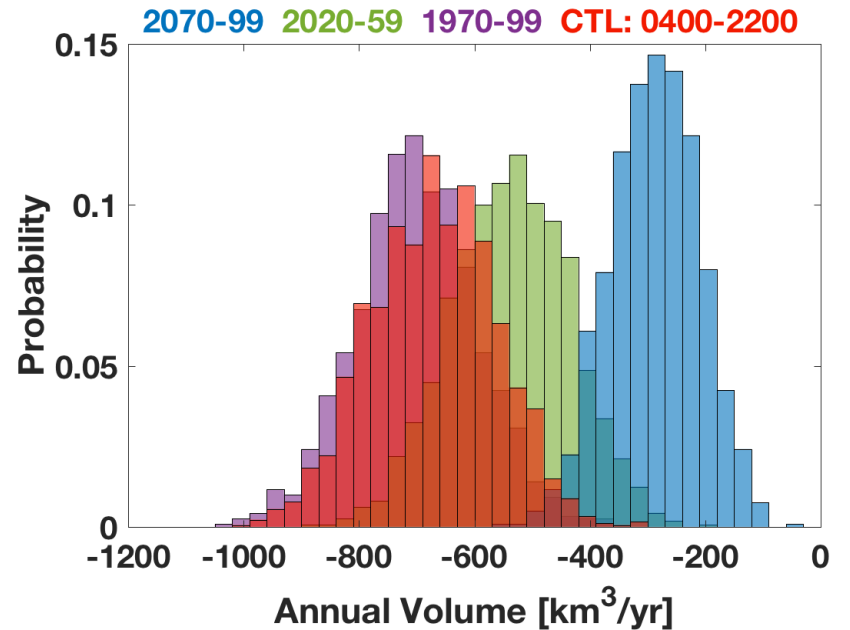
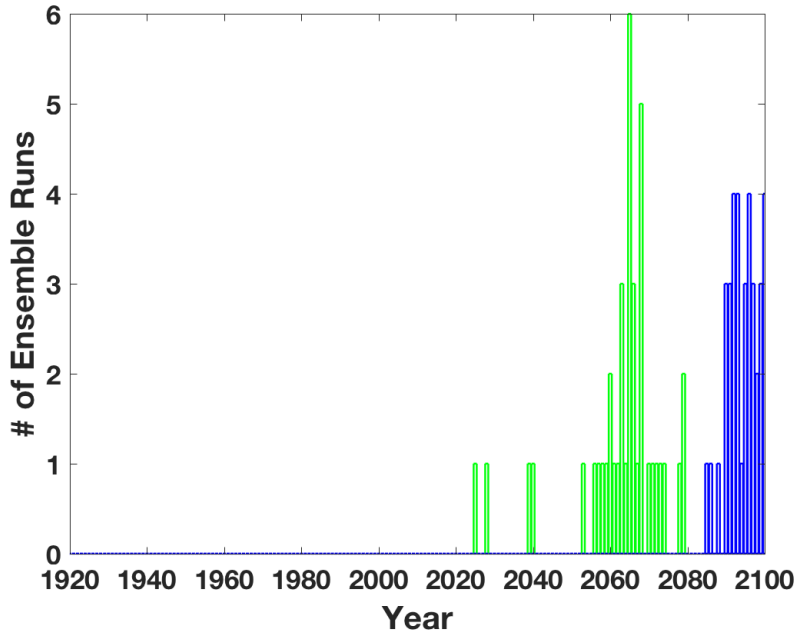
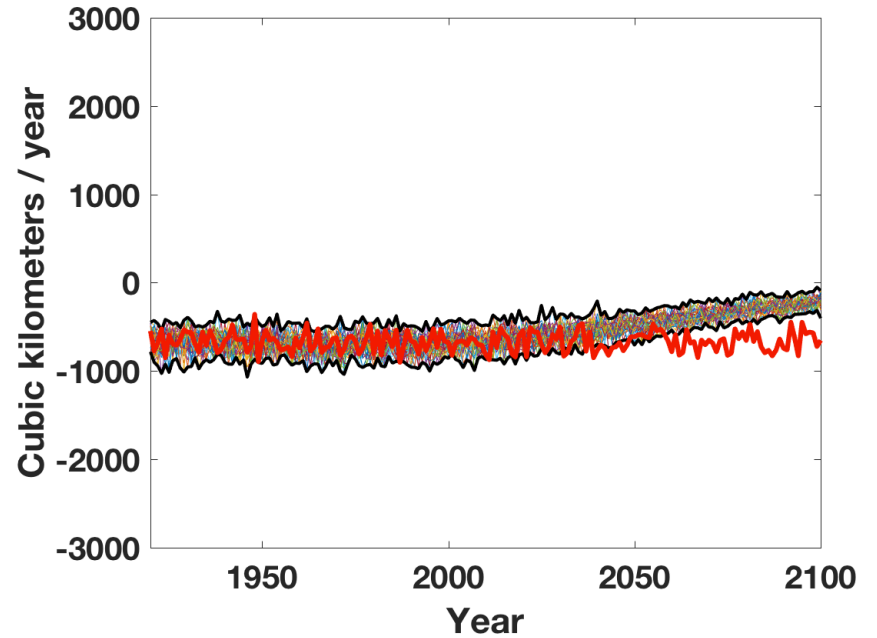
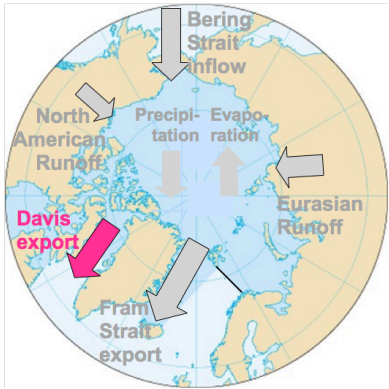
55 years (all 40 runs)

EMERGENCE YEARS:

2084 → 2100

EMERGENCE RANGE:

17 years (37/40 runs)



# DAVIS STRAIT -- LIQUID NET FW FLUX

## CESM LE Runs

SHIFT YEARS:

1989 -> 2018

SHIFT RANGE:

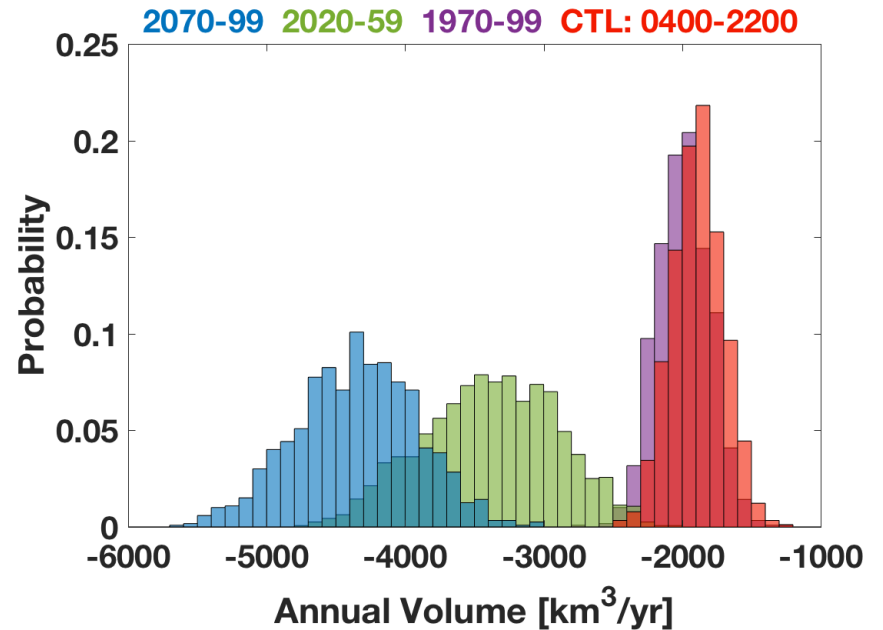
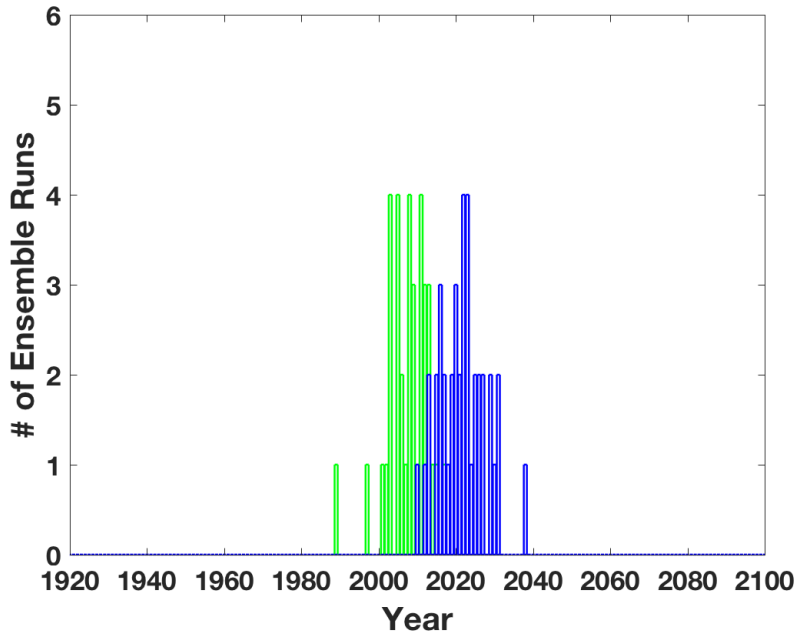
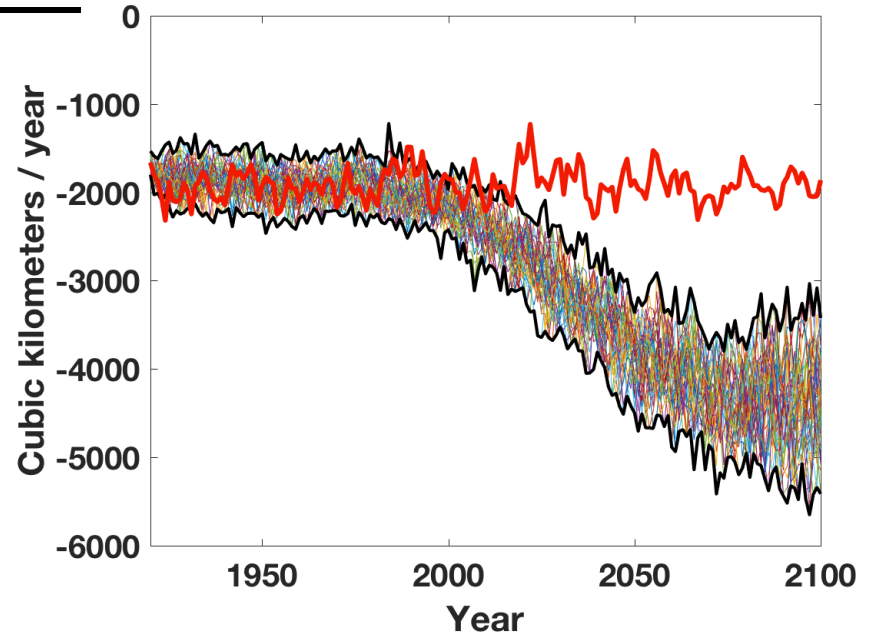
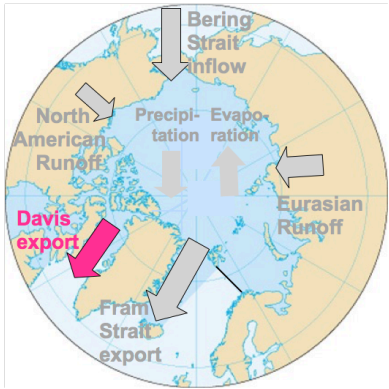
30 years (all 40 runs)

EMERGENCE YEARS:

2009 -> 2037

EMERGENCE RANGE:

29 years (all 40 runs)



# BERING STRAIT -- LIQUID NET FW FLUX

## CESM LE Runs

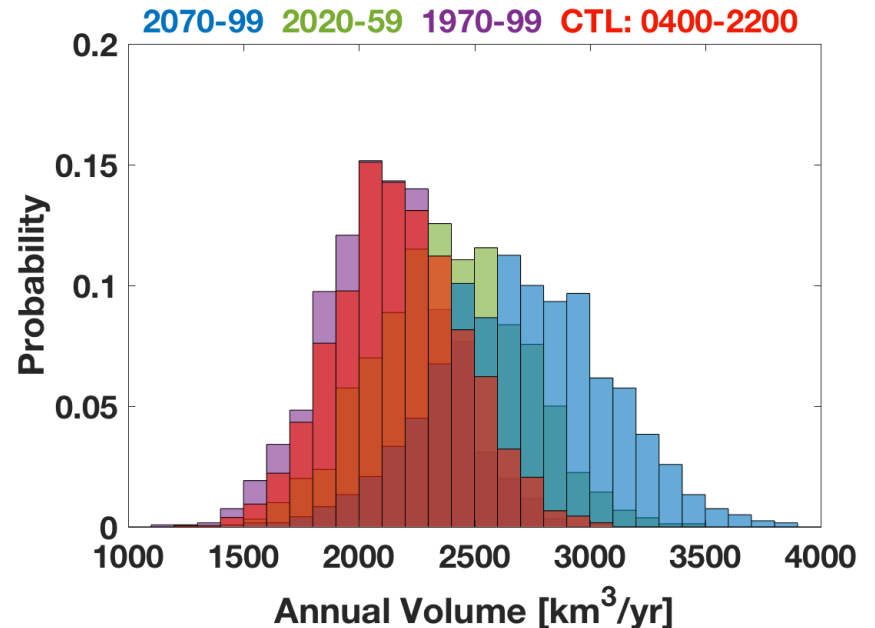
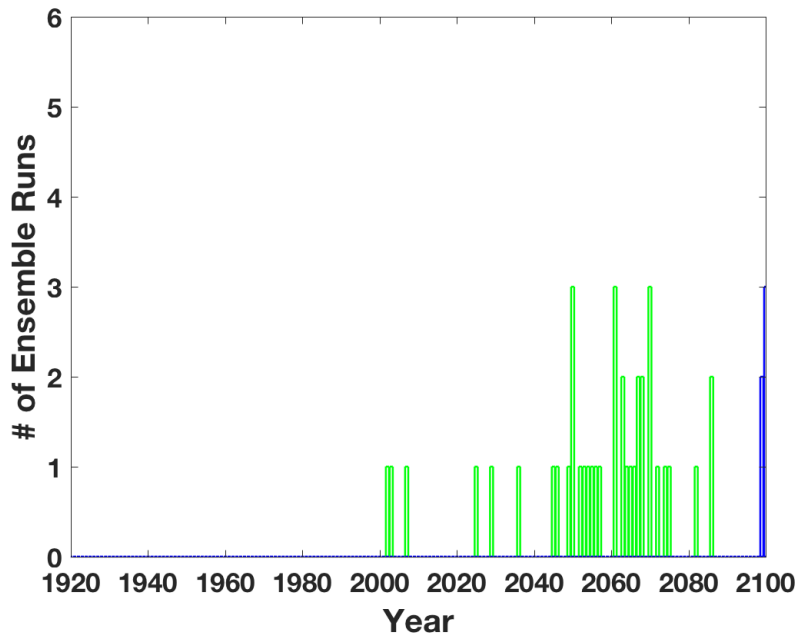
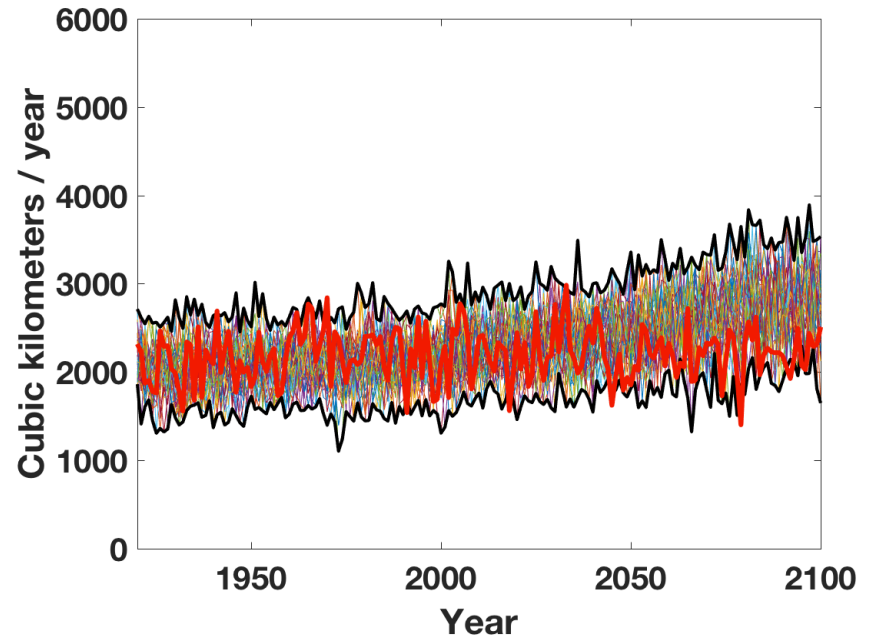
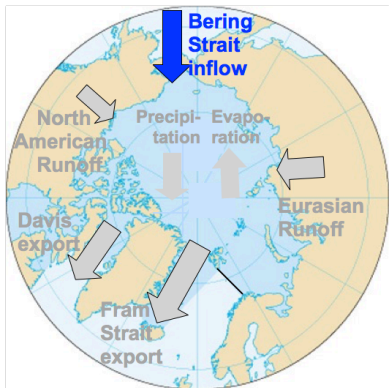
**SHIFT YEARS:**

2002 -> 2086+

**SHIFT RANGE:**

85+ years (39/40 runs)

**EMERGENCE:** MIGHT BE NEAR BEGINNING OF EMERGENCE; NEED 22<sup>nd</sup> CENTURY SIMULATION FOR FURTHER ANALYSIS



# RUNOFF FW FLUX

## CESM LE Runs

SHIFT YEARS:

2008 → 2051

SHIFT RANGE:

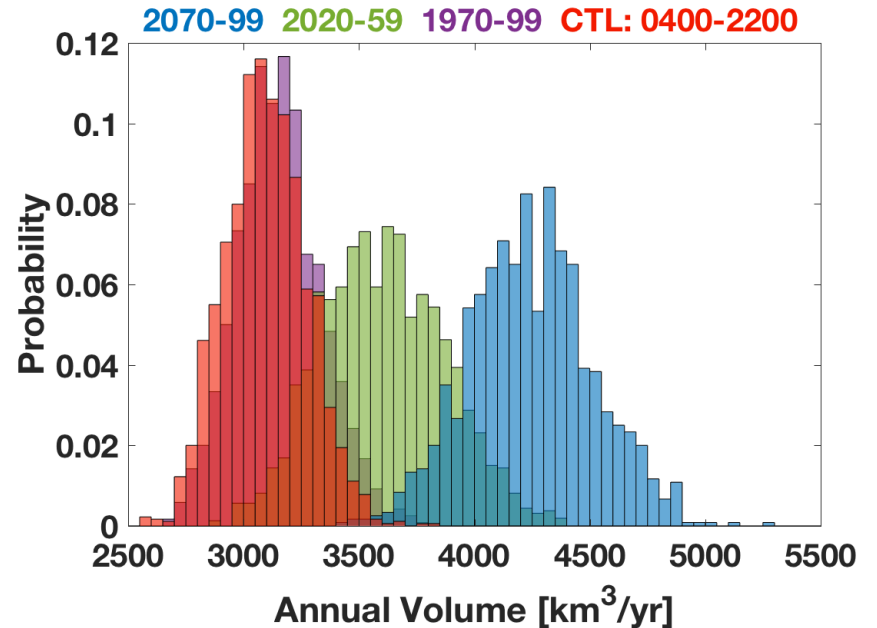
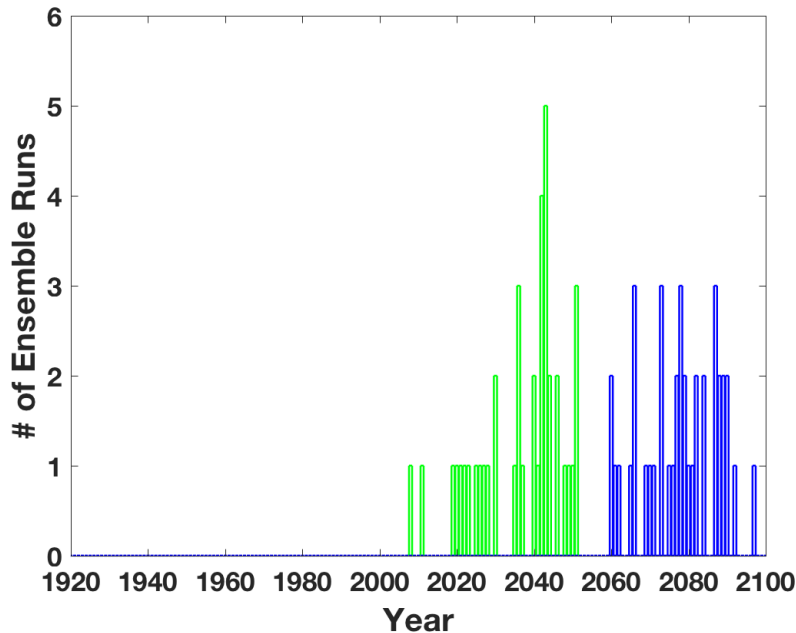
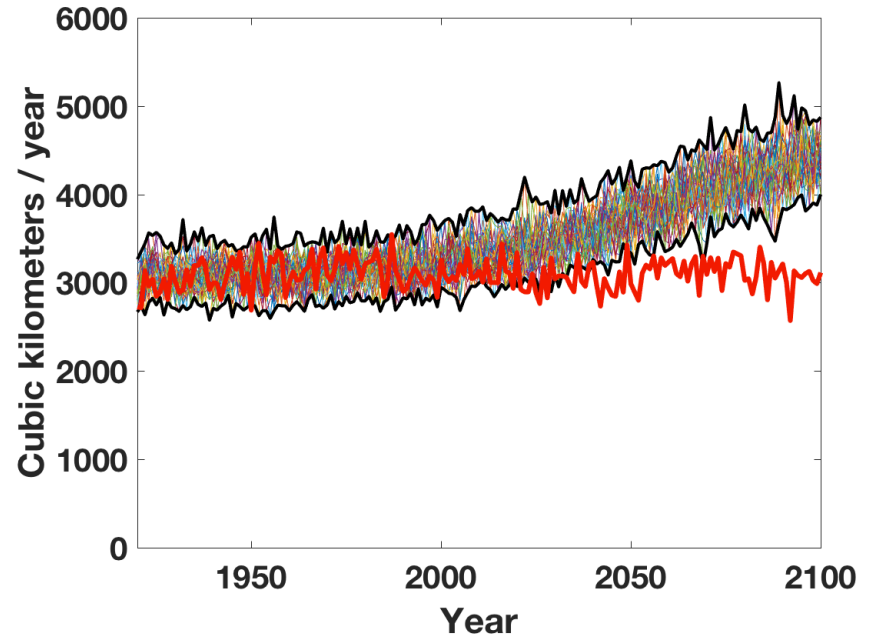
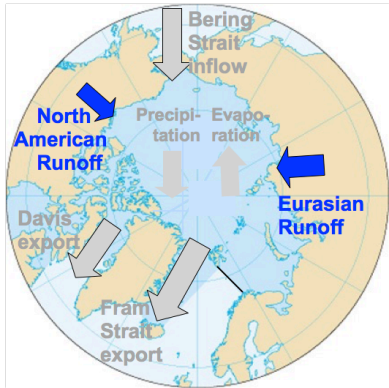
44 years (all 40 runs)

EMERGENCE YEARS:

2059 → 2096

EMERGENCE RANGE:

38 years (all 40 runs)



# P minus E FW FLUX

## CESM LE Runs

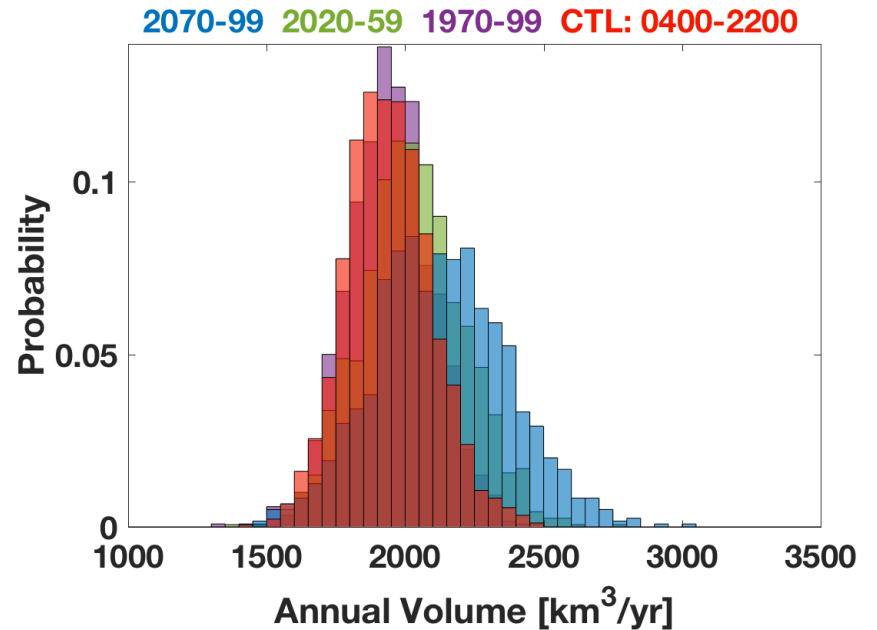
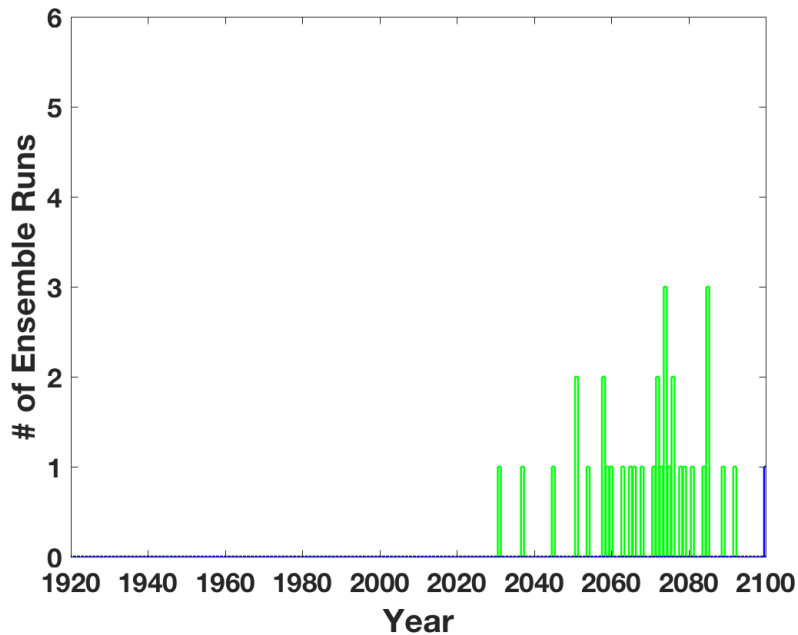
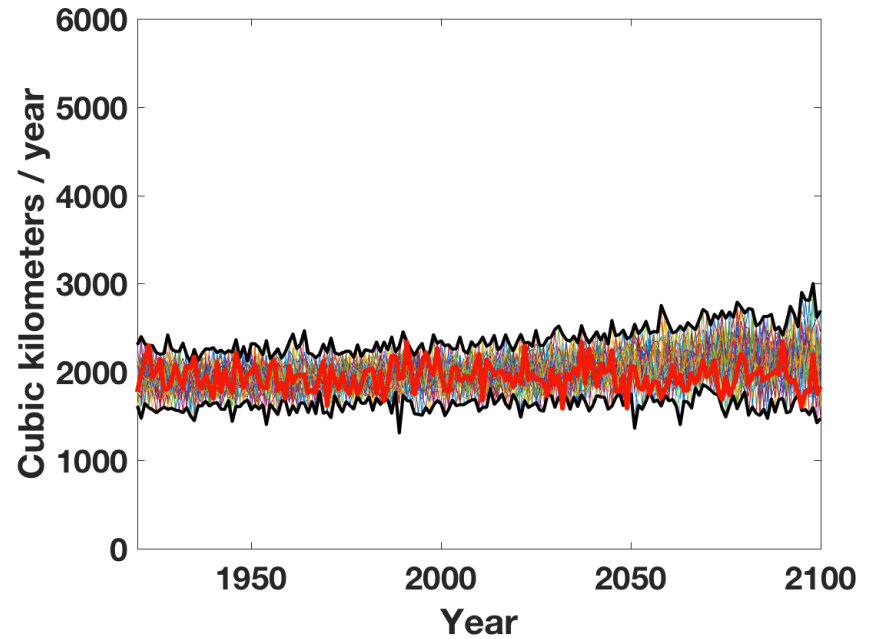
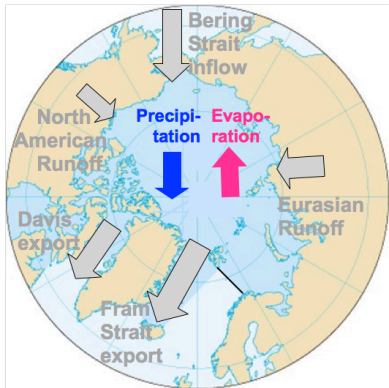
SHIFT YEARS:

2030 → 2091

SHIFT RANGE:

62 years (33/40 runs)

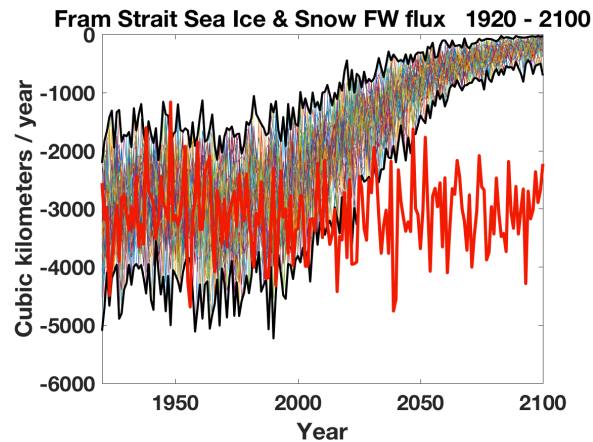
**EMERGENCE:** NEED 22<sup>nd</sup>  
CENTURY SIMULATION  
FOR FURTHER ANALYSIS



# CONCLUSIONS

## INTERNAL VARIABILITY

1) Internal variability, based on the 1850 pre-industrial control run, varies strongly for different Arctic FW budget terms. It is especially large for the Fram Strait Solid (Sea Ice & Snow) term:

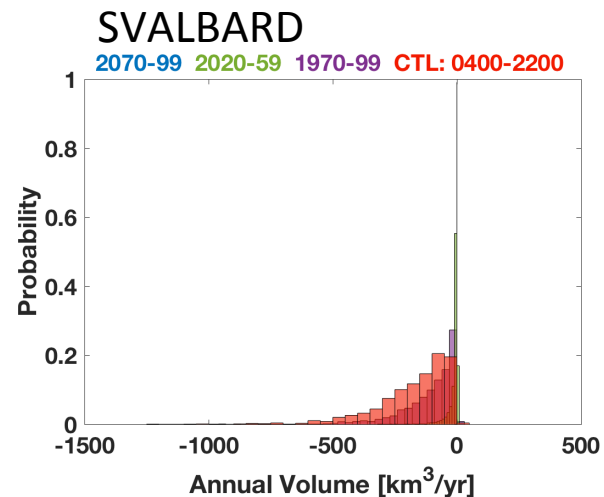
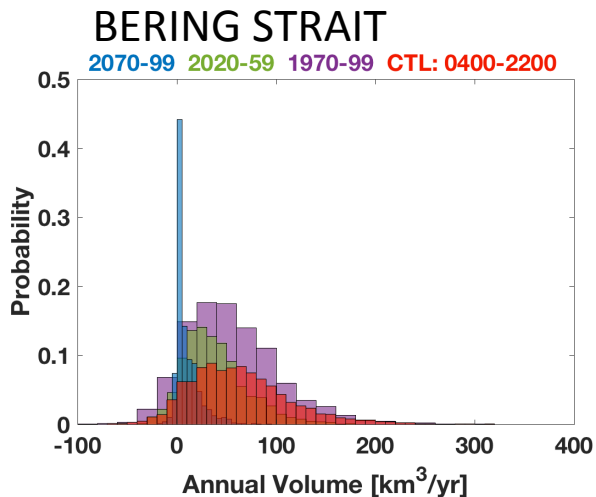
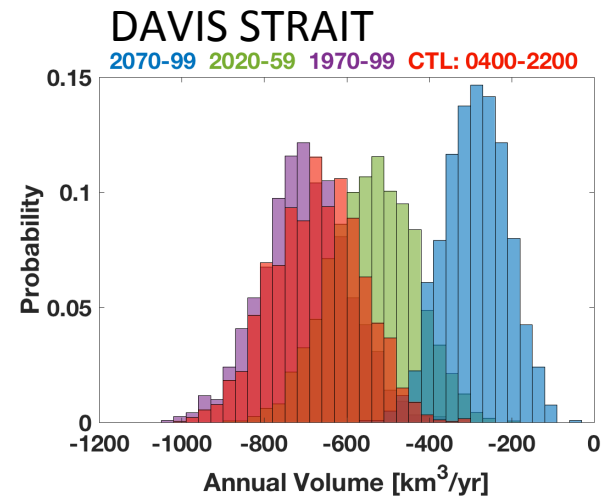
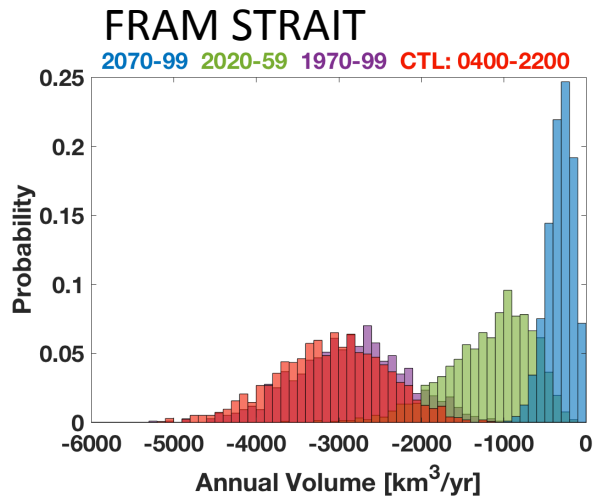




# CONCLUSIONS

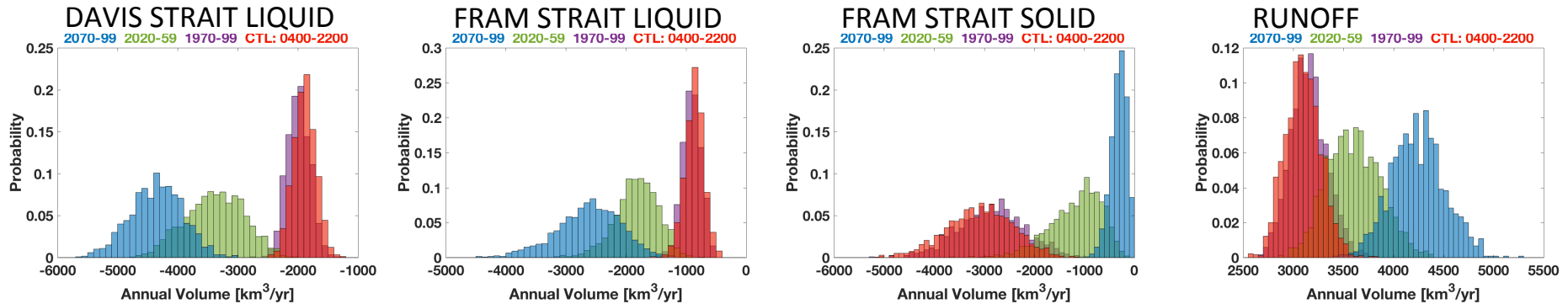
## ARCTIC FW BUDGET 20<sup>th</sup> to 21<sup>st</sup> CENTURIES

2) SOLID (sea ice & snow) FW terms decreased:



# CONCLUSIONS: ARCTIC FW BUDGET 20<sup>th</sup> to 21<sup>st</sup> CENTURIES

3) Only a subset of the Arctic FW budget terms achieved emergence outside the internal variability threshold. Some examples:



4) The SHIFT & EMERGENCE year ranges showed sizable ensemble spread:

