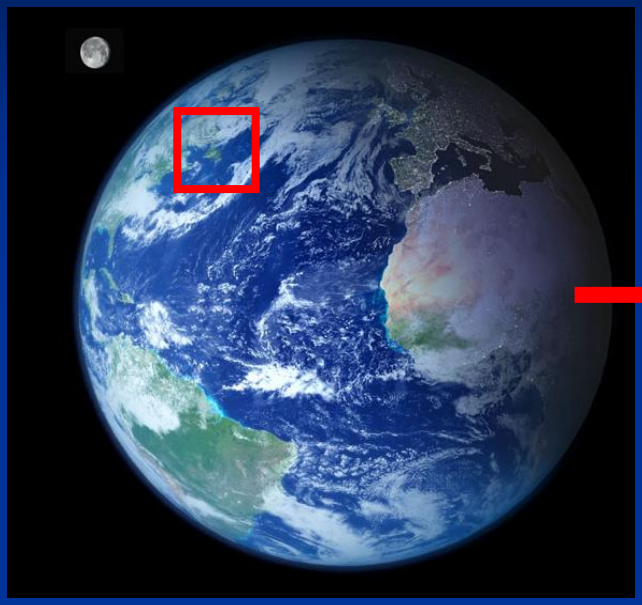
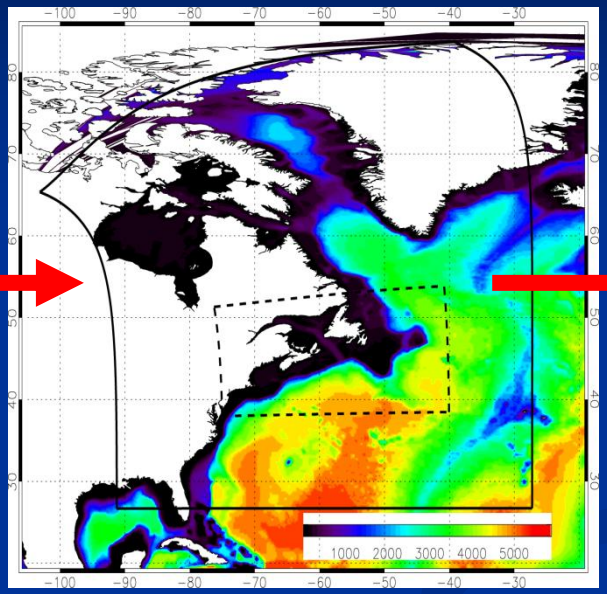
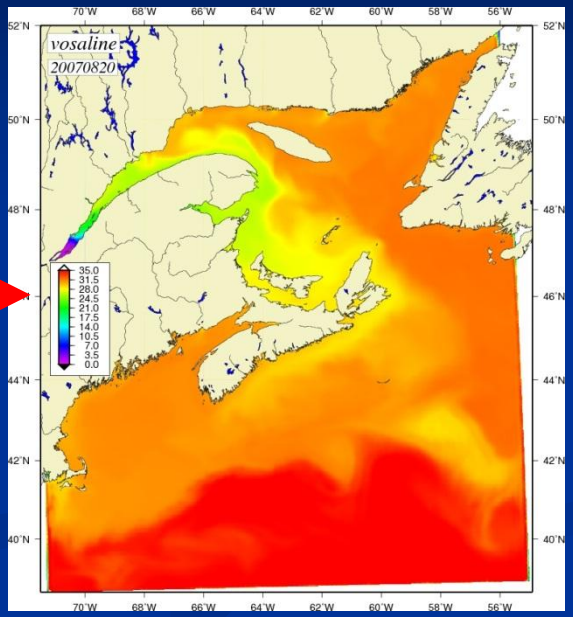
Regional simulation ensemble of the Gulf of St. Lawrence, Scotian Shelf and Gulf of Maine future ocean climate



http://luzerne.free.fr/





Joël Chassé, Will Perrie, Zhenxia Long,
Dave Brickman, Lanli Guo and Nicolas Lambert

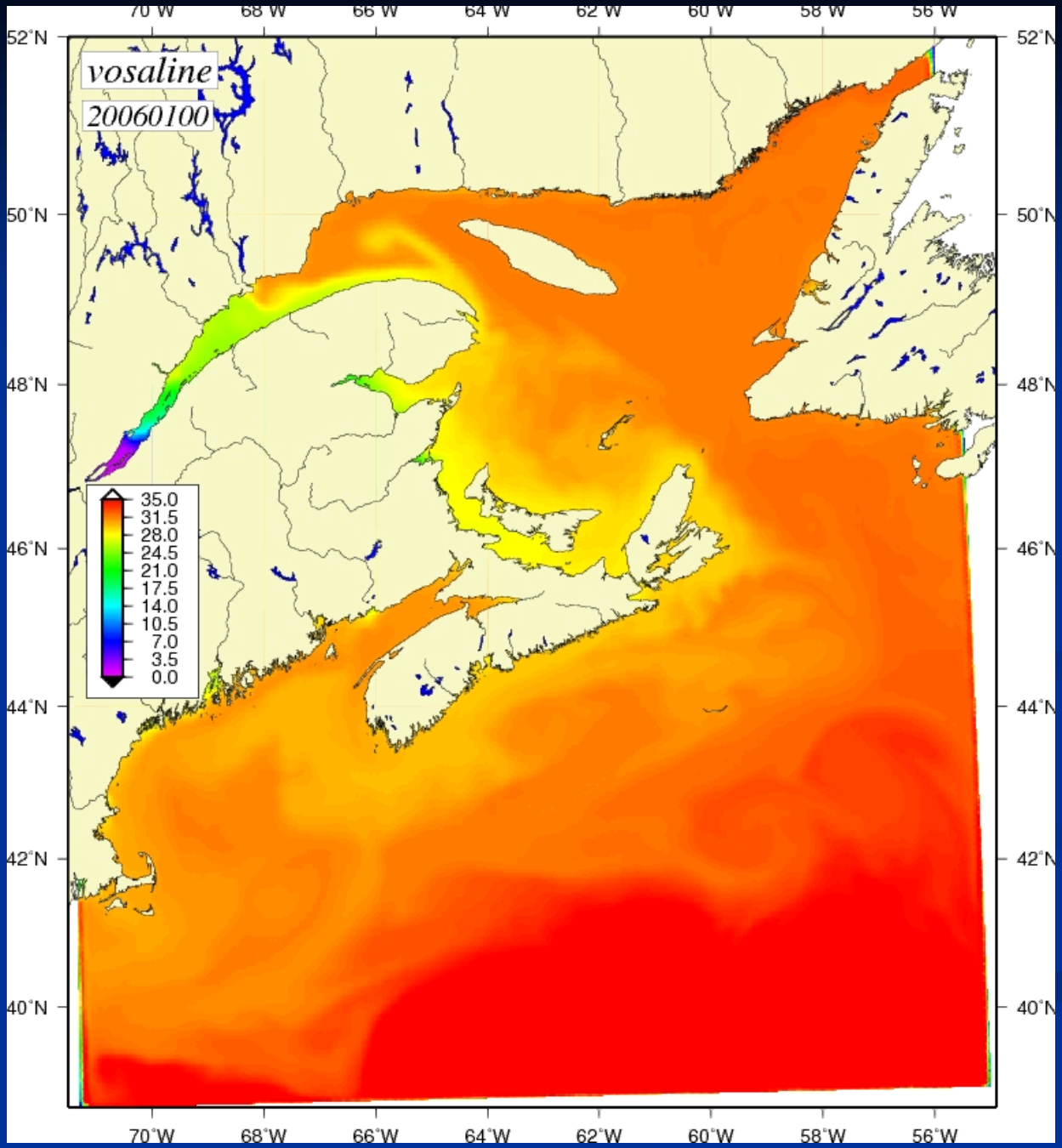
DFO – Aquatic Climate Change Adaptation Services Program (ACCASP)

ACCASP Thematic area:	Trends and Projections
DFO regions:	Maritimes, Gulf and Quebec
Institutions:	BIO, GFC and IML

Outline

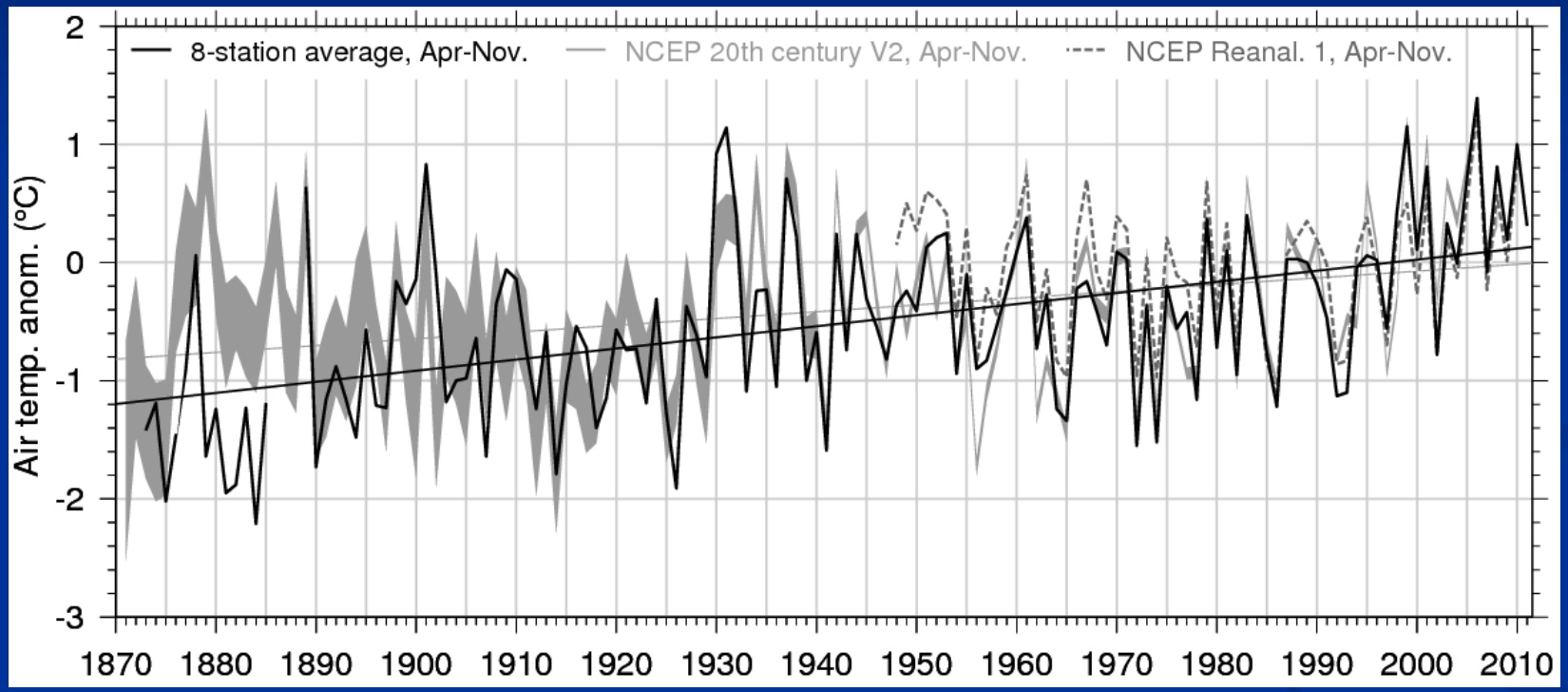
- Introduction
- Modelling System Setup and forcing
- Simulations
- Some results
  - Runoff
  - Temperature
  - Salinity
  - Stratification
  - Transport (estuarine circulation)
- Summary

Surface salinity



Galbraith, Larouche, Chassé and Petrie, Deep Sea Res. II, 2012

Coupling between Air Temperature and SST

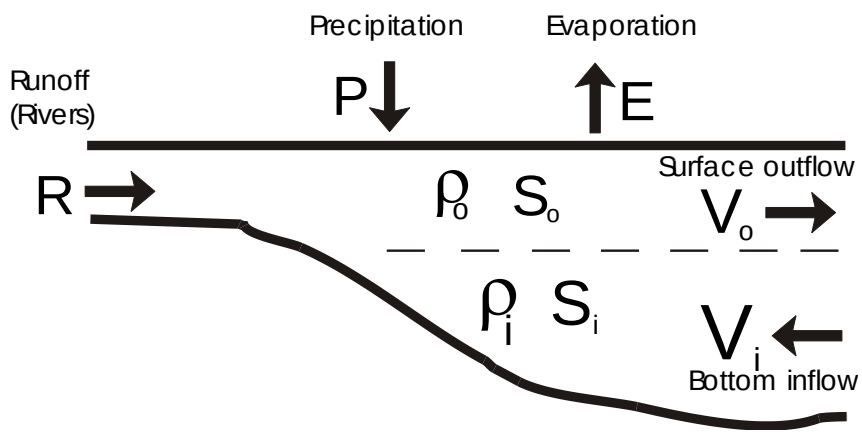


Trend : 0,9 °C per century.

From P. Galbraith, IML

Freshwater is important for coastal/shelf processes

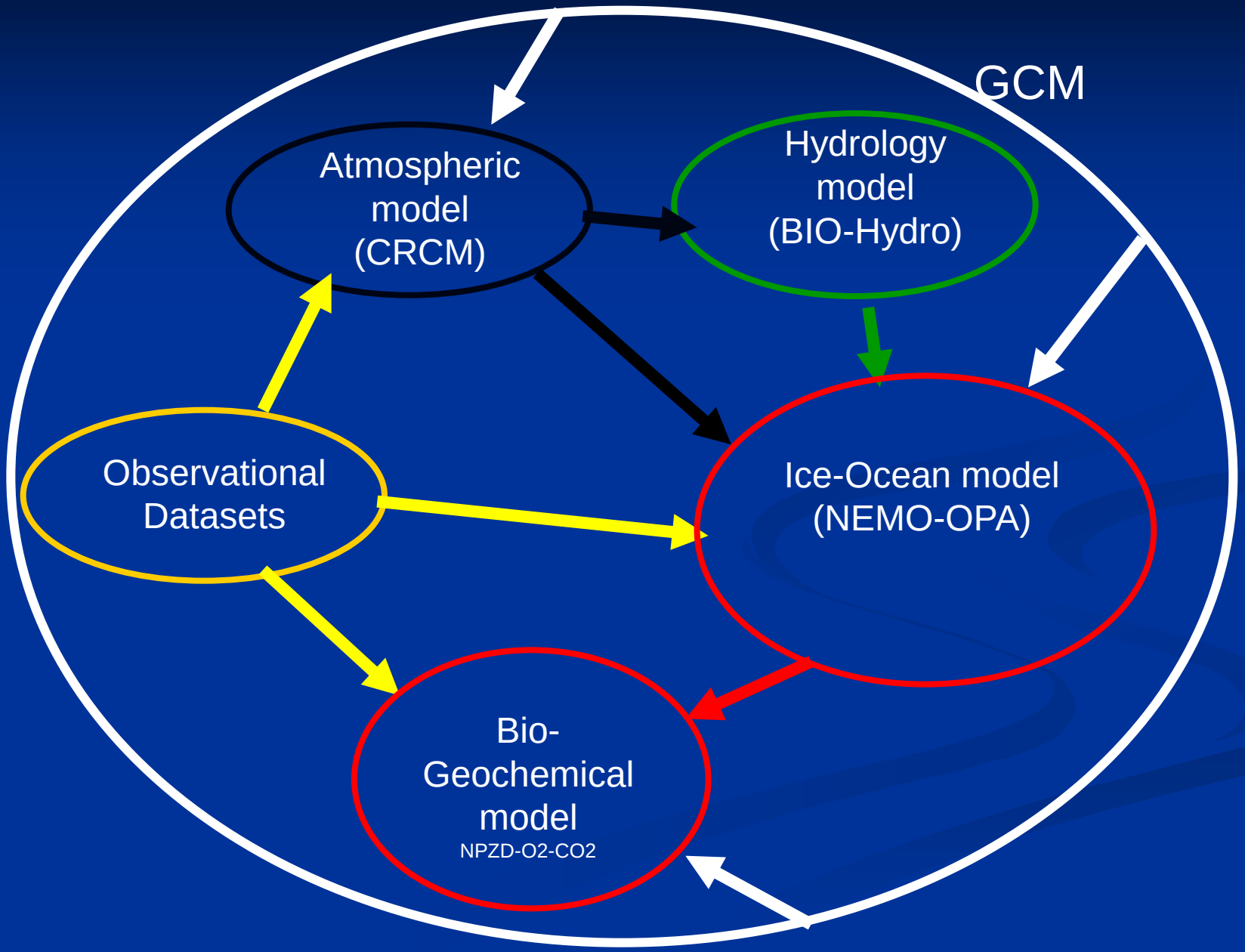
- Freshwater establishes and maintains estuarine circulation
- Activate exchange rate with the ocean
- Affect stratification
- Affect mixing
- Affect Ice formation



$$V_i = R\frac{S_o}{S_i - S_o} \quad , \quad V_o = R\frac{S_i}{S_i - S_o}$$

$Amp_r = V_o/R$

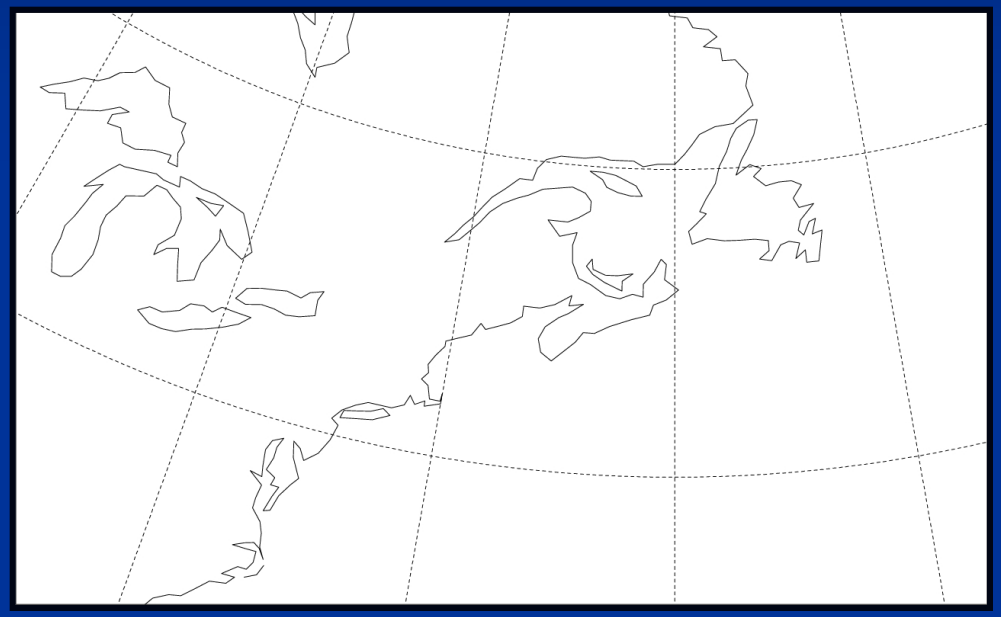
DFO Regional Ocean Climate Dowscalling System: Gulf of Saint-Lawrence, Scotian Shelf and Gulf of Maine



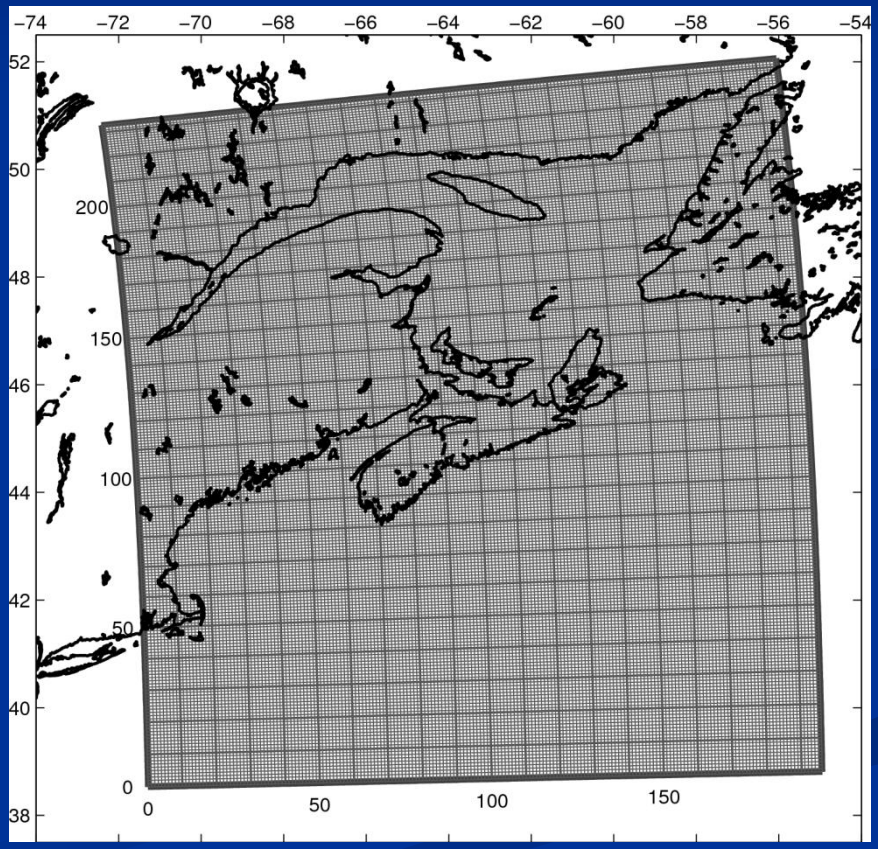
- Seven 130 year long simulations (1970-2100) done
  - CGCM3 A1B (M3, M4 and M5)
  - CCSM3 A1B
  - CCSM4 RCP8.5
  - HADLEY RCP8.5
  - CANESM2 RCP 8.5
- Crunching soon: MPI RCP4.5, MPI RCP 8.5

Atmospheric and oceanic regional domains

Atmospheric domain

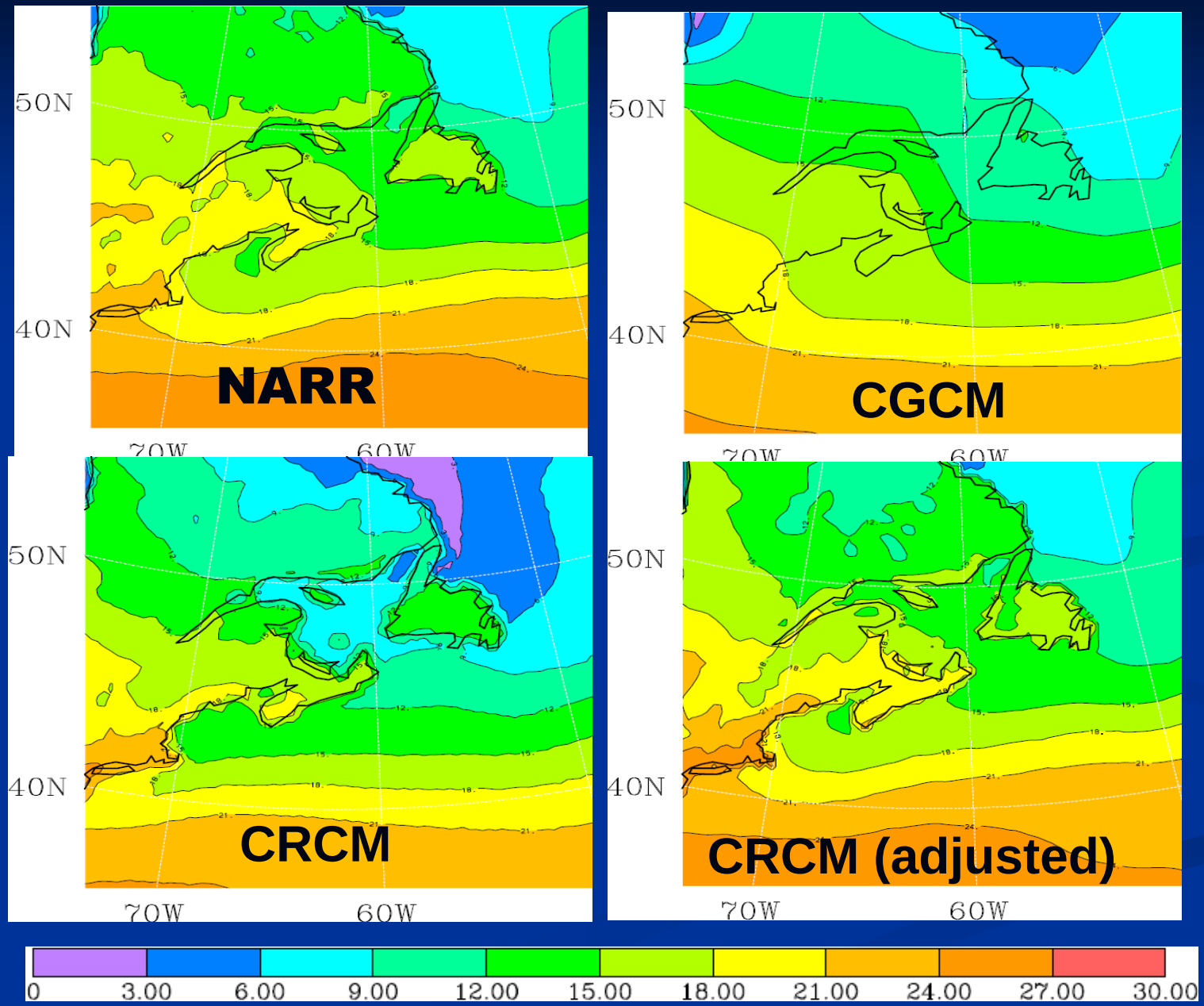


Ocean domain



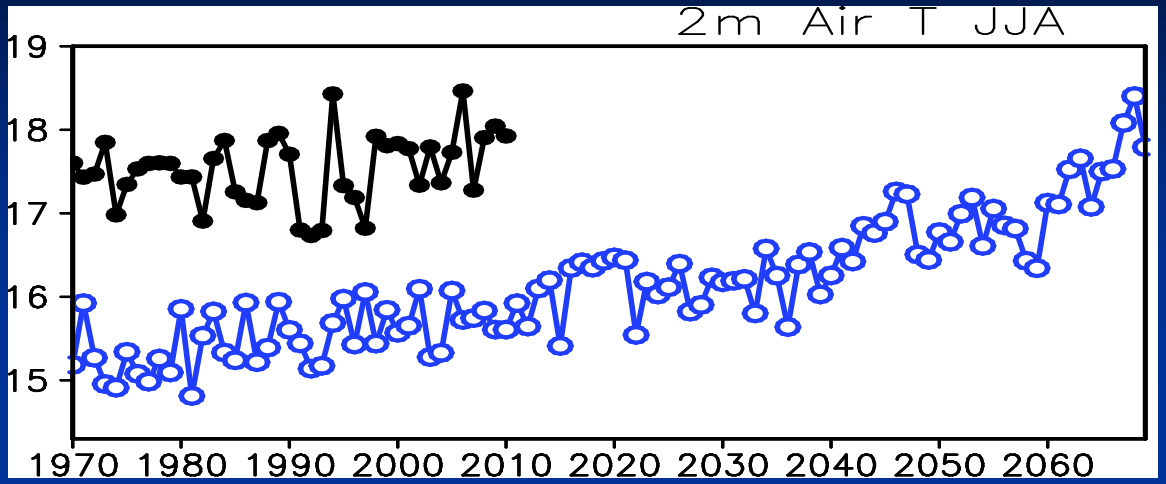
Atmospheric model improvement (Guo et al., 2013)

JULY 2m air temperature Tair (units: ° C)

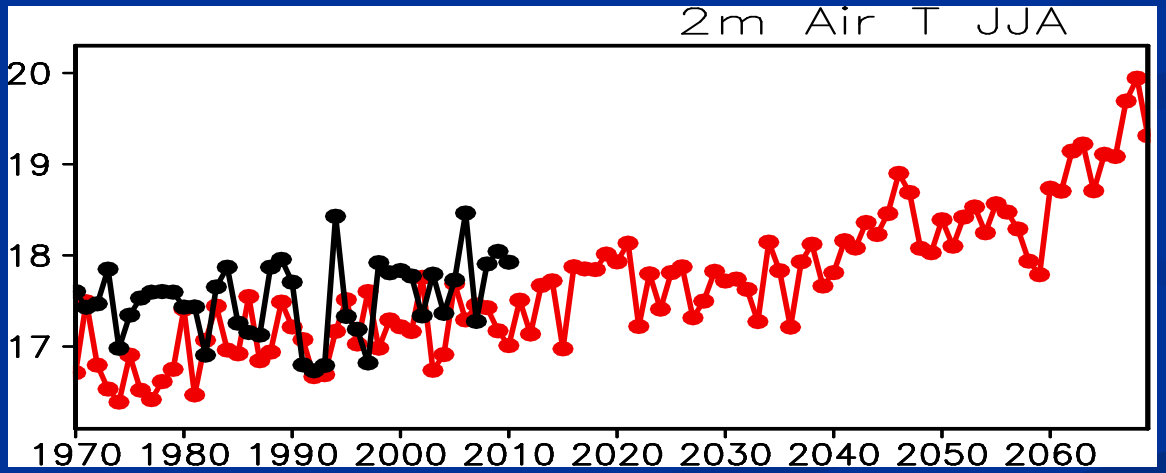


Air temperature at 2 m in summer over the middle GSL

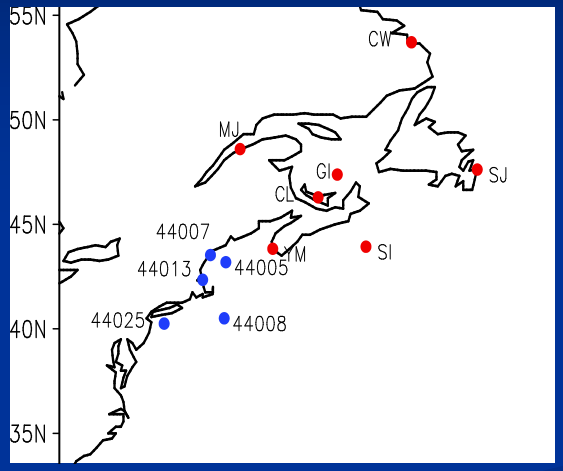
CGCM

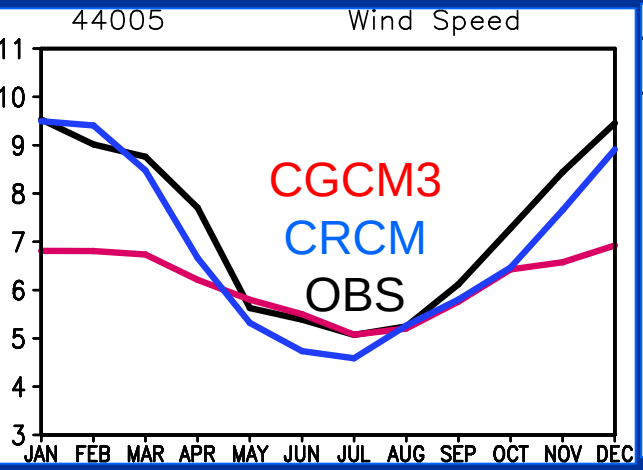


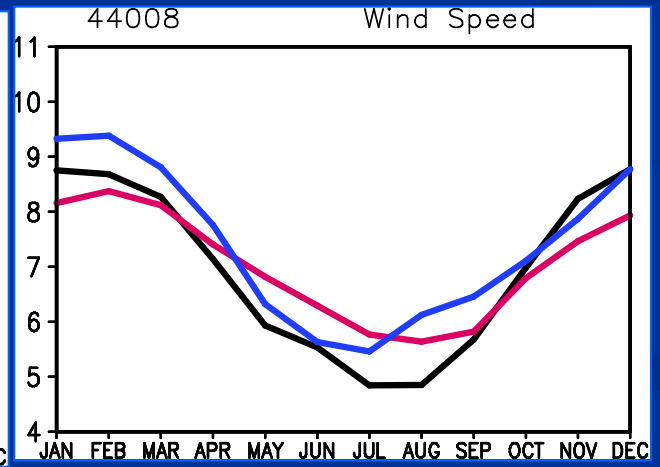
CRCM (with climatolgy Ajusted with NARR)

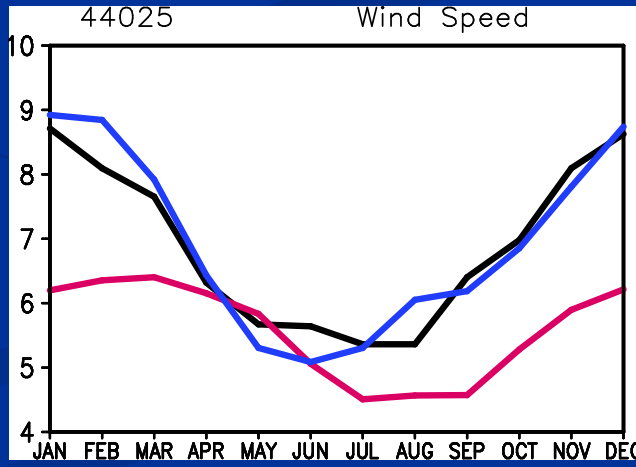


Wind speed comparison

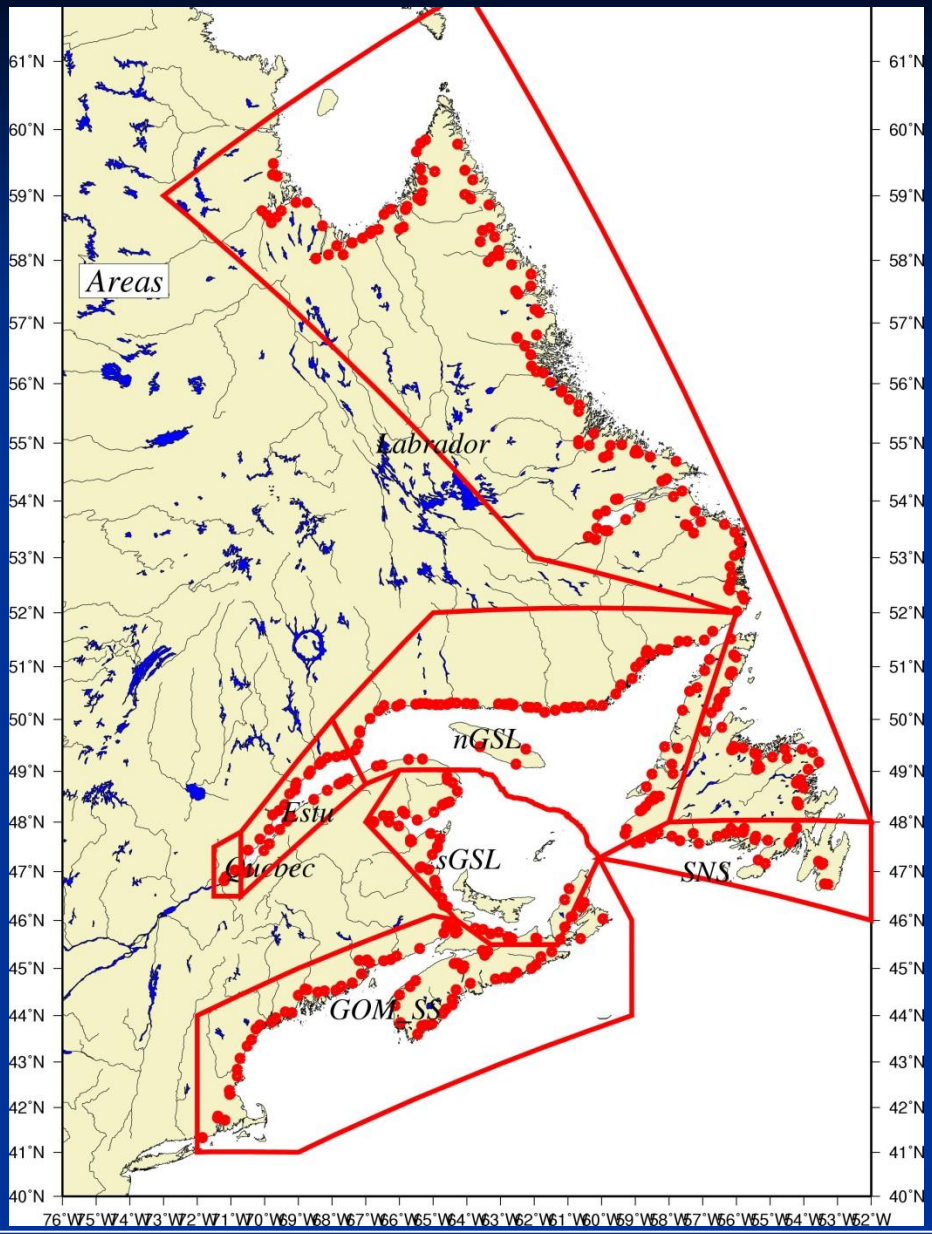


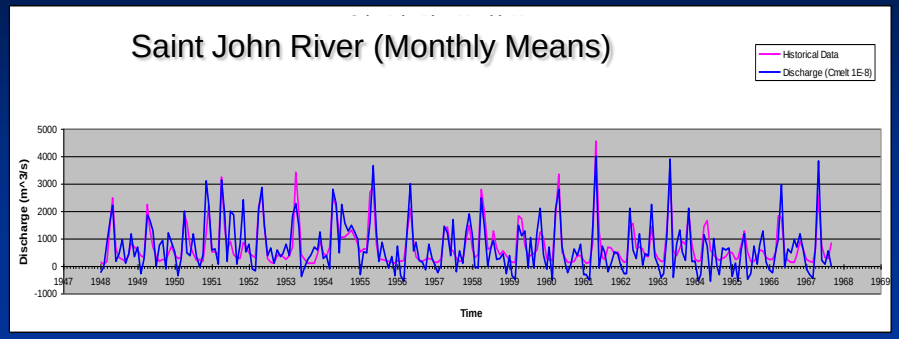




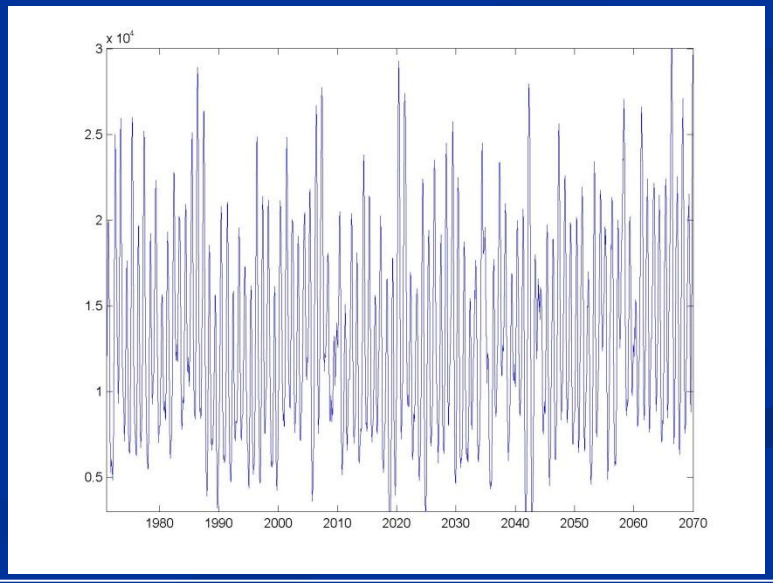


Hydrology model gives the Freshwater Runoff at river outlets



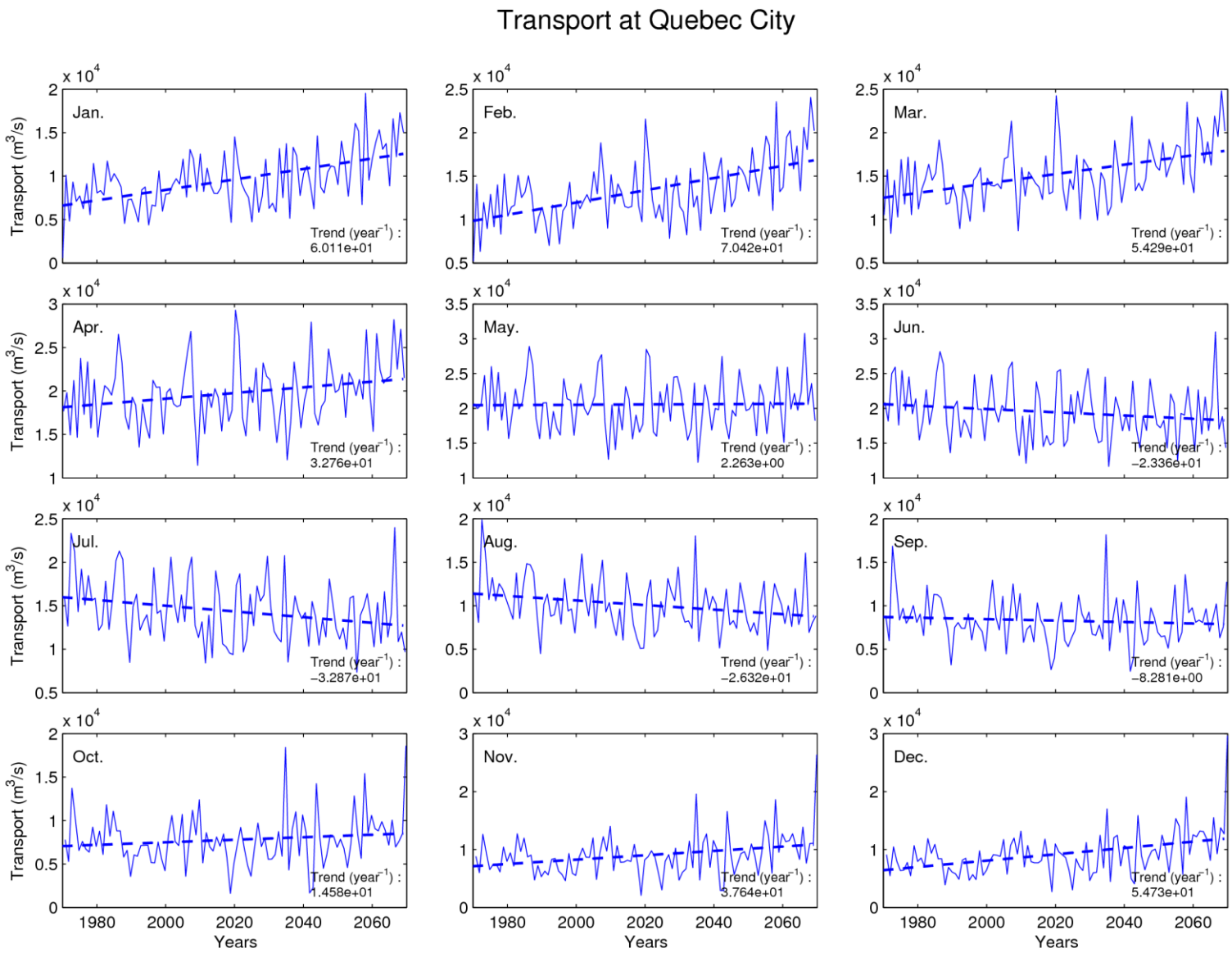


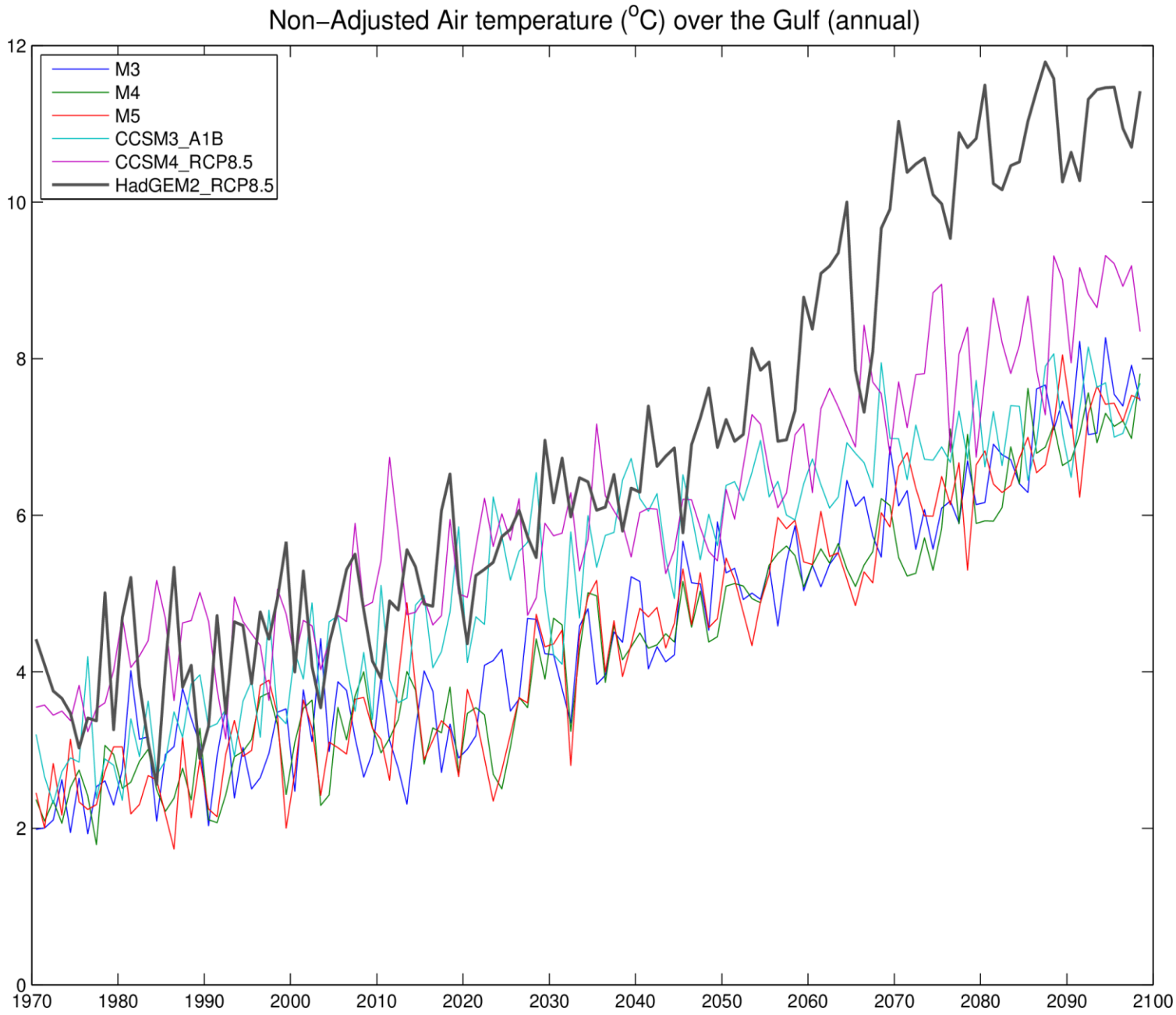
Freshwater Runoff of St. Lawrence River

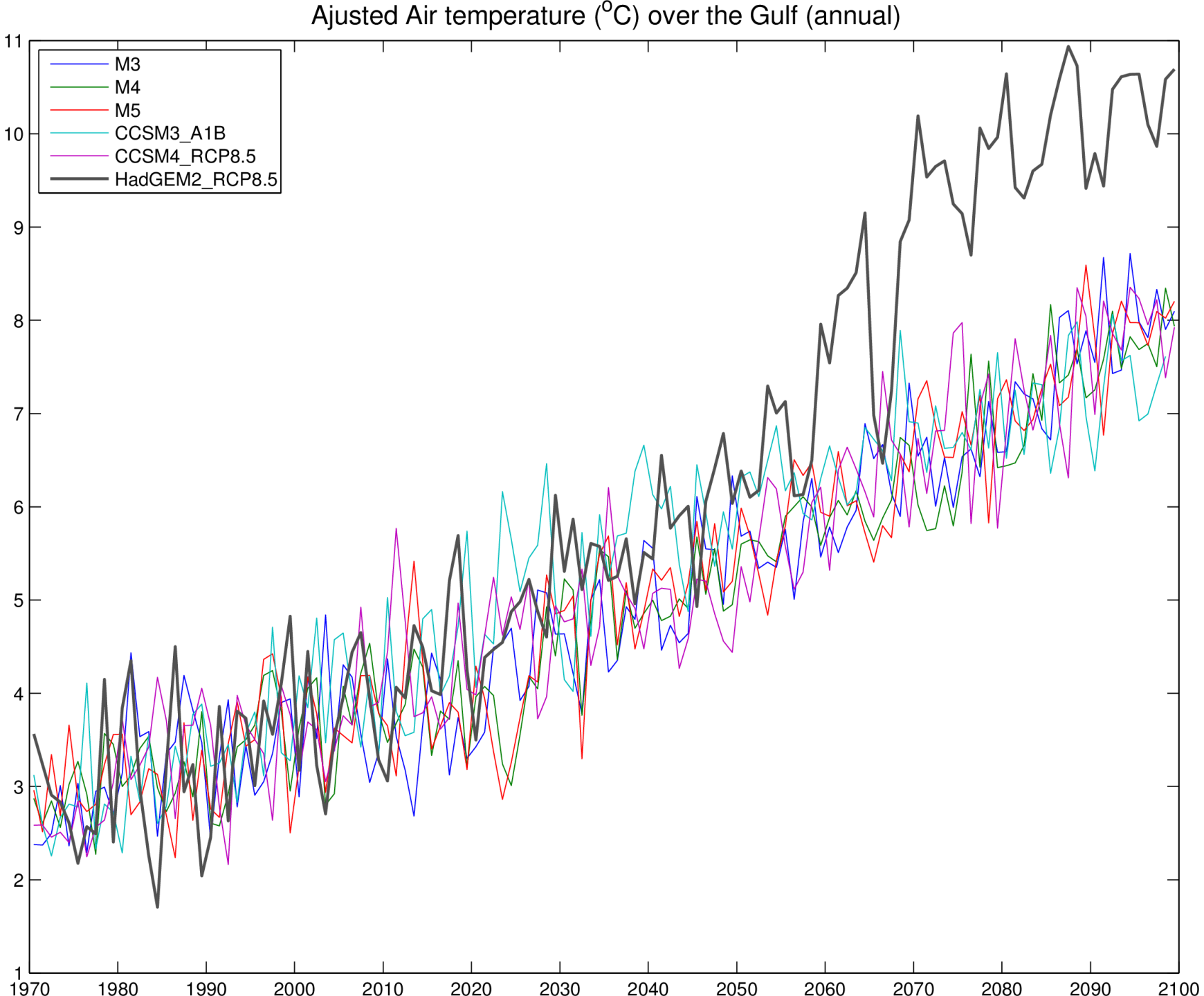


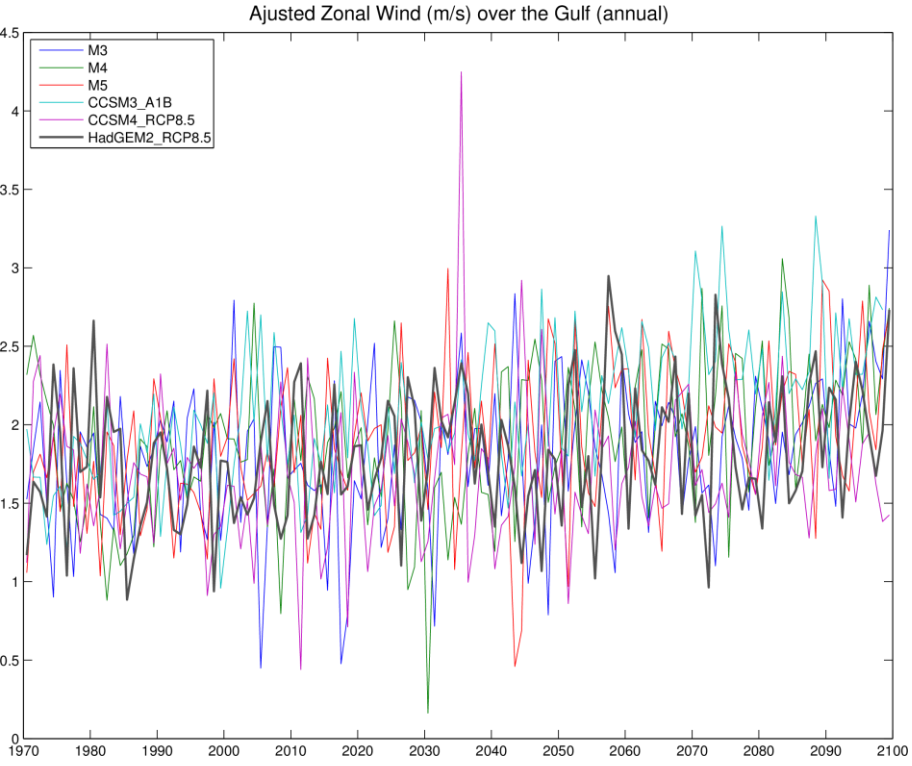
The Delta Method is also applied to freshwater runoff:
i.e. that Modeled climatologies were adjusted to observed 1971-2000 climatologies.

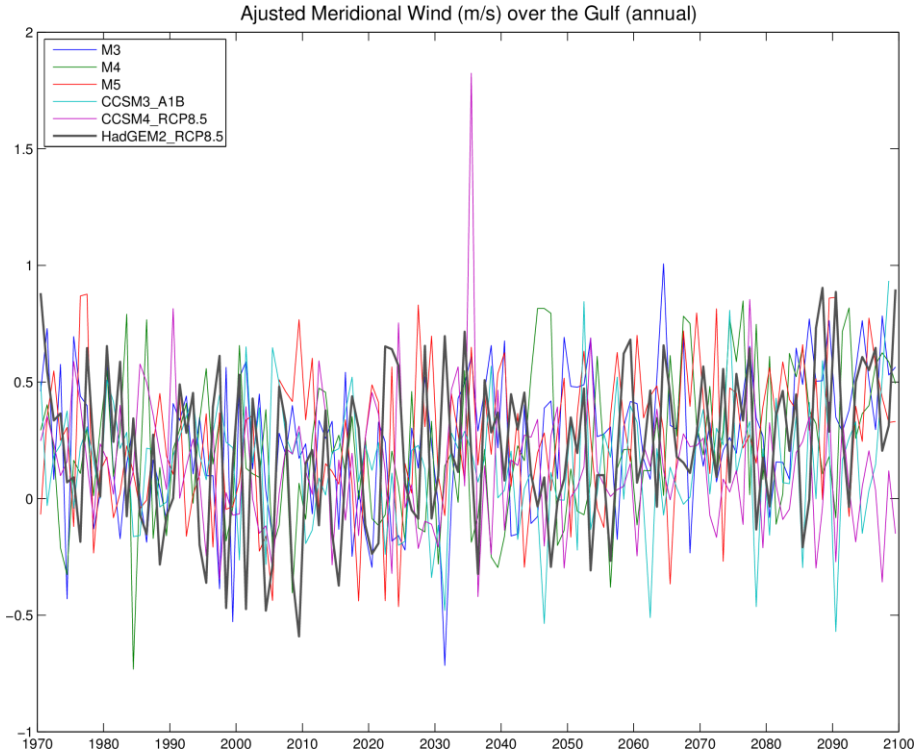
Runoff at Quebec city (M4)

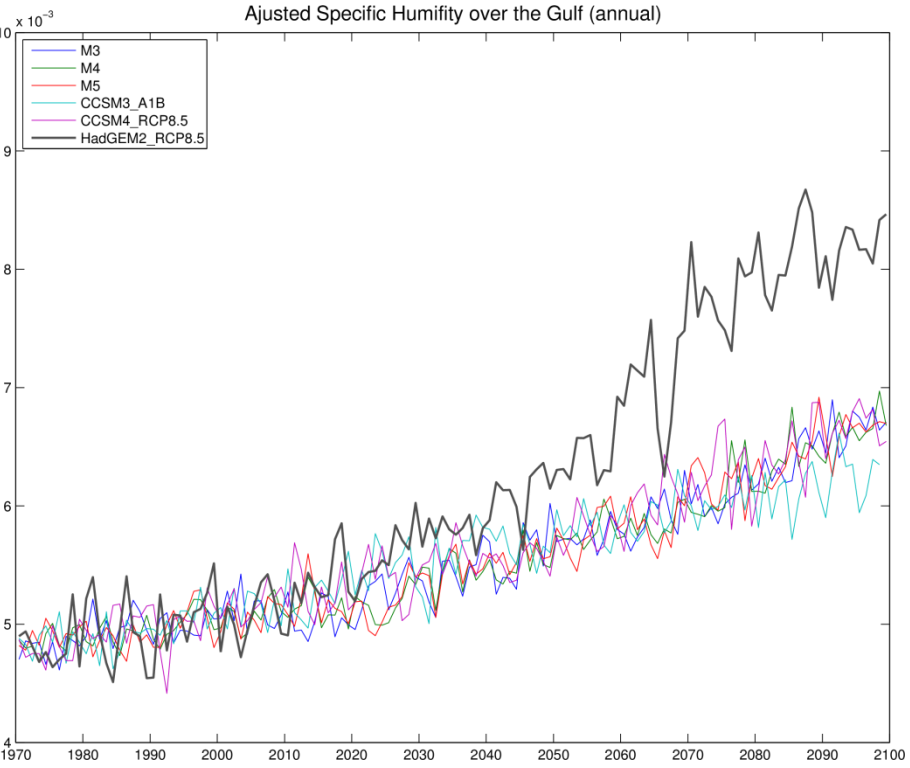


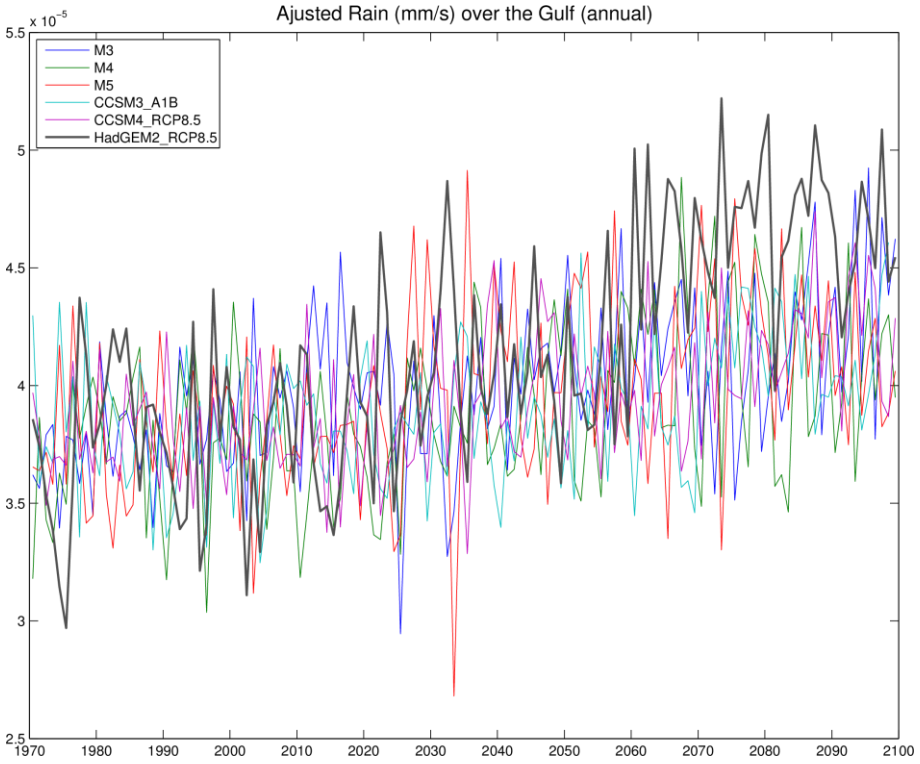

Non−Adjusted Air temperature (°C) over the Gulf (annual)
M3
M4
M5
CCSM3_A1B
CCSM4_RCP8.5
HadGEM2_RCP8.5
0
2
4
6
8
10
12
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100

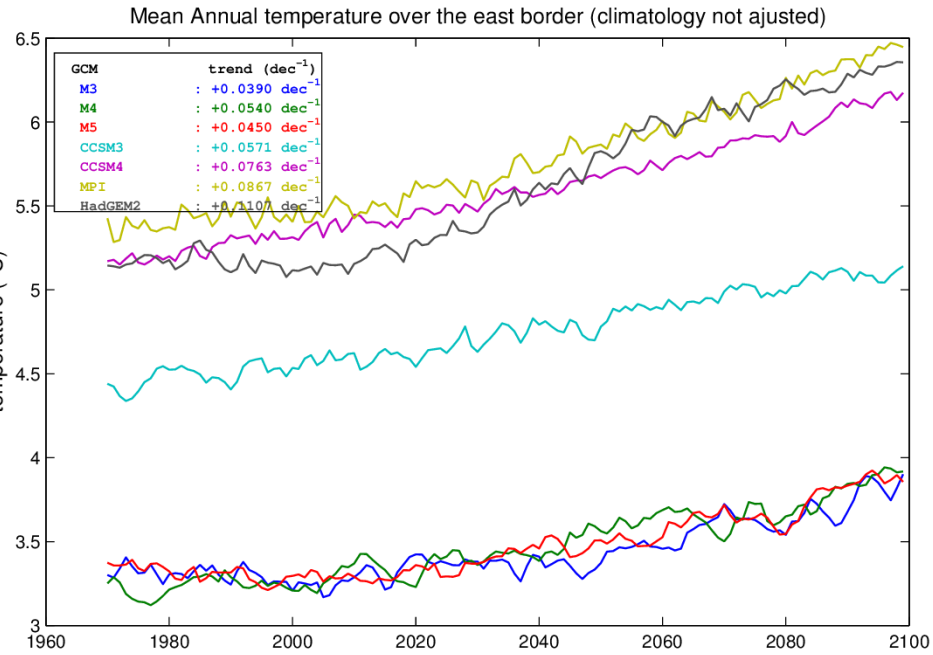

Ajusted Air temperature (°C) over the Gulf (annual)
M3
M4
M5
CCSM3_A1B
CCSM4_RCP8.5
HadGEM2_RCP8.5
11
10
9
8
7
6
5
4
3
2
1
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100

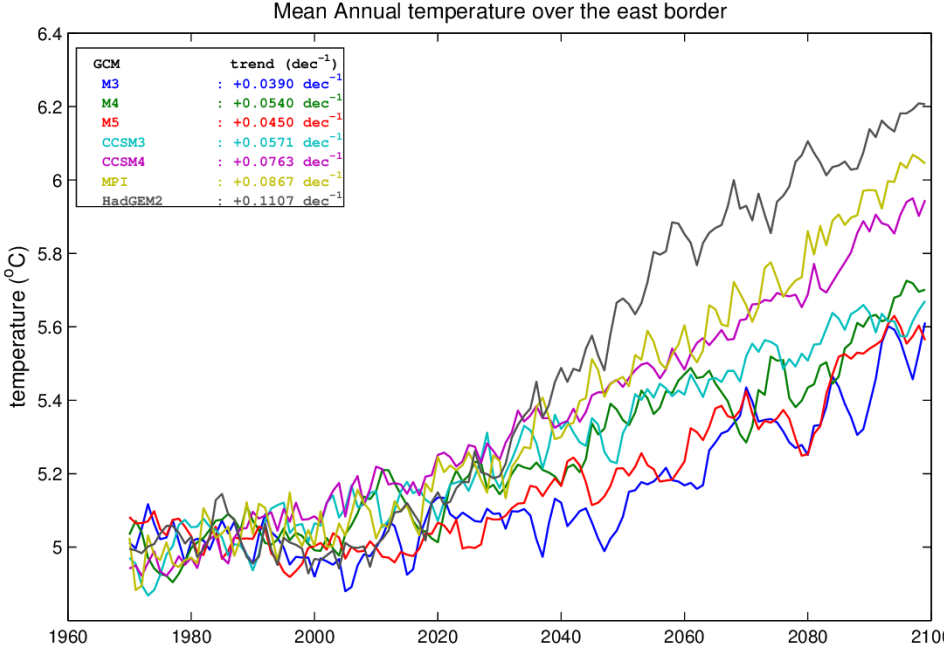

Ajusted Zonal Wind (m/s) over the Gulf (annual)
M3
M4
M5
CCSM3_A1B
CCSM4_RCP8.5
HadGEM2_RCP8.5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100


Ajusted Meridional Wind (m/s) over the Gulf (annual)
M3
M4
M5
CCSM3_A1B
CCSM4_RCP8.5
HadGEM2_RCP8.5
2
1.5
1
0.5
0
−0.5
−1
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100


Ajusted Specific Humifity over the Gulf (annual)
x 10^-3
M3
M4
M5
CCSM3_A1B
CCSM4_RCP8.5
HadGEM2_RCP8.5
10
9
8
7
6
5
4
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100


Ajusted Rain (mm/s) over the Gulf (annual)
x 10^-5
M3
M4
M5
CCSM3_A1B
CCSM4_RCP8.5
HadGEM2_RCP8.5
5.5
5
4.5
4
3.5
3
2.5
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100


Mean Annual temperature over the east border (climatology not ajusted)
GCM trend (dec^{-1})
M3 : +0.0390 dec^{-1}
M4 : +0.0540 dec^{-1}
M5 : +0.0450 dec^{-1}
CCSM3 : +0.0571 dec^{-1}
CCSM4 : +0.0763 dec^{-1}
MPI : +0.0867 dec^{-1}
HadGEM2 : +0.1107 dec^{-1}
temperature (°C)


Mean Annual temperature over the east border
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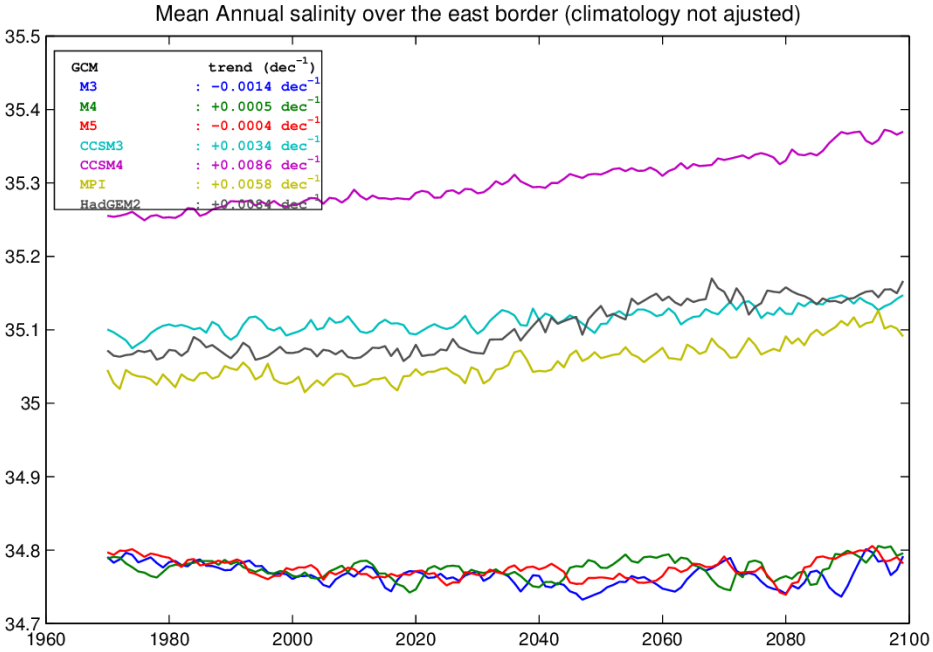
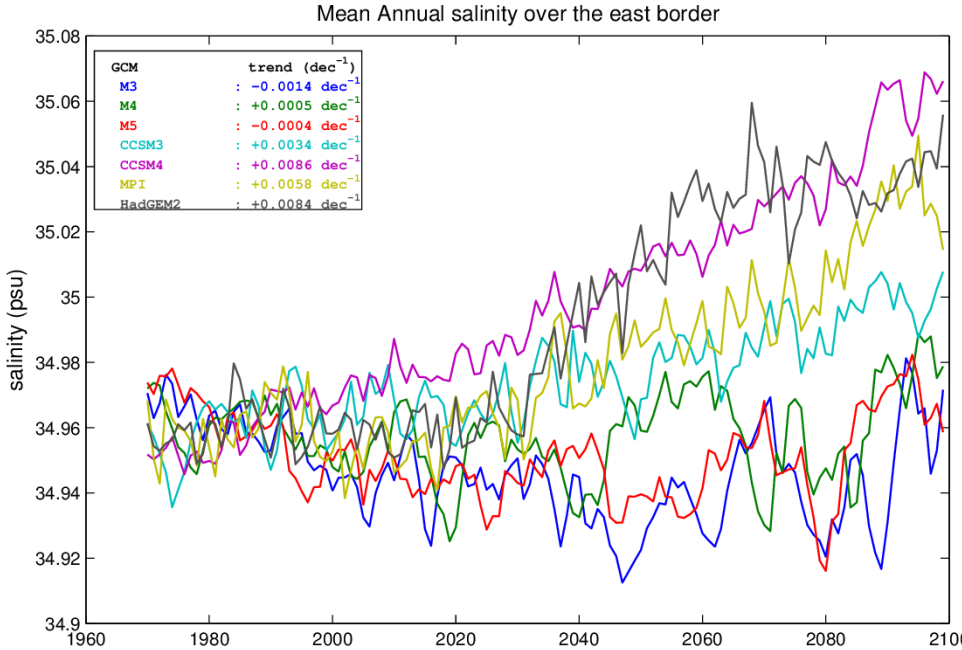
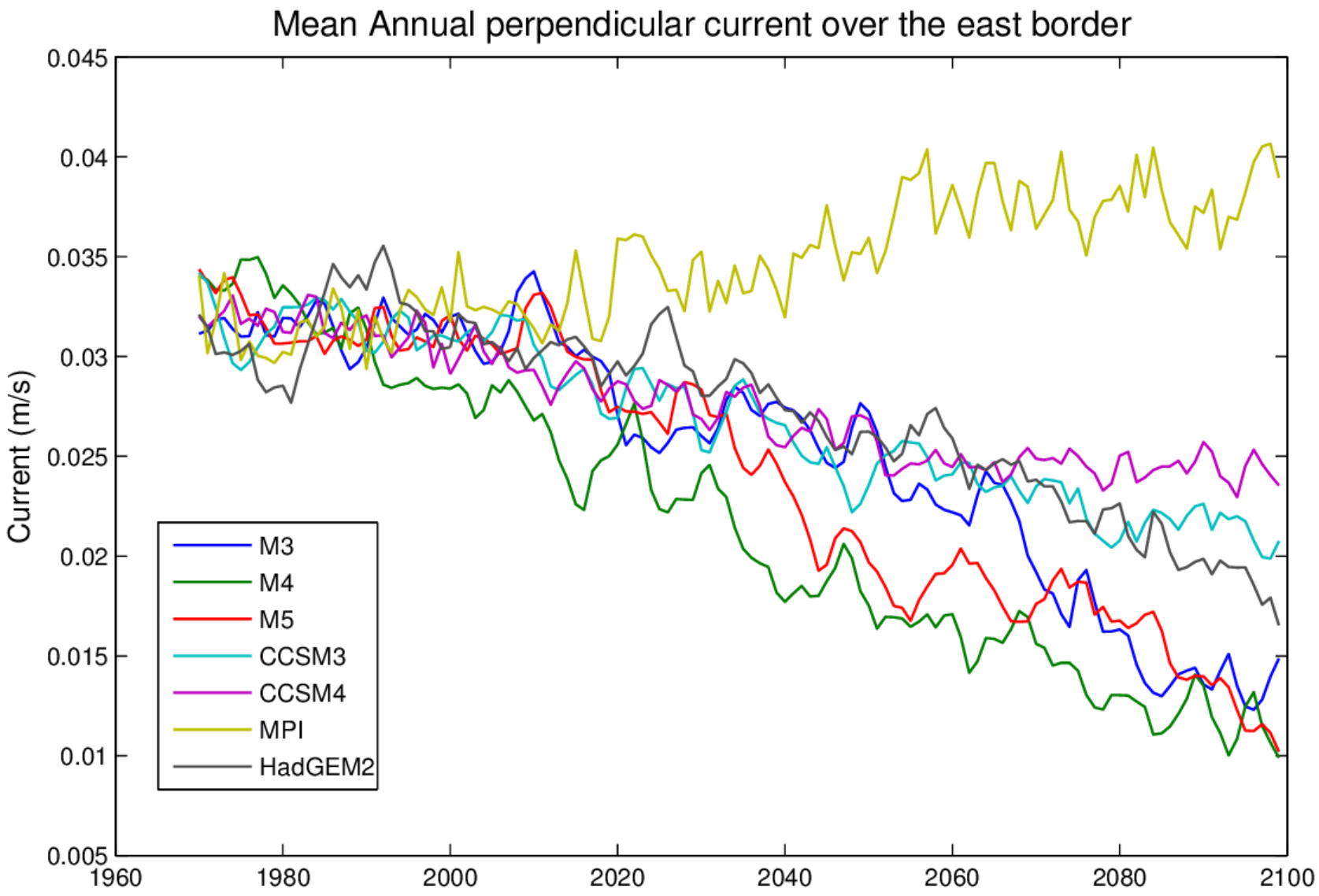
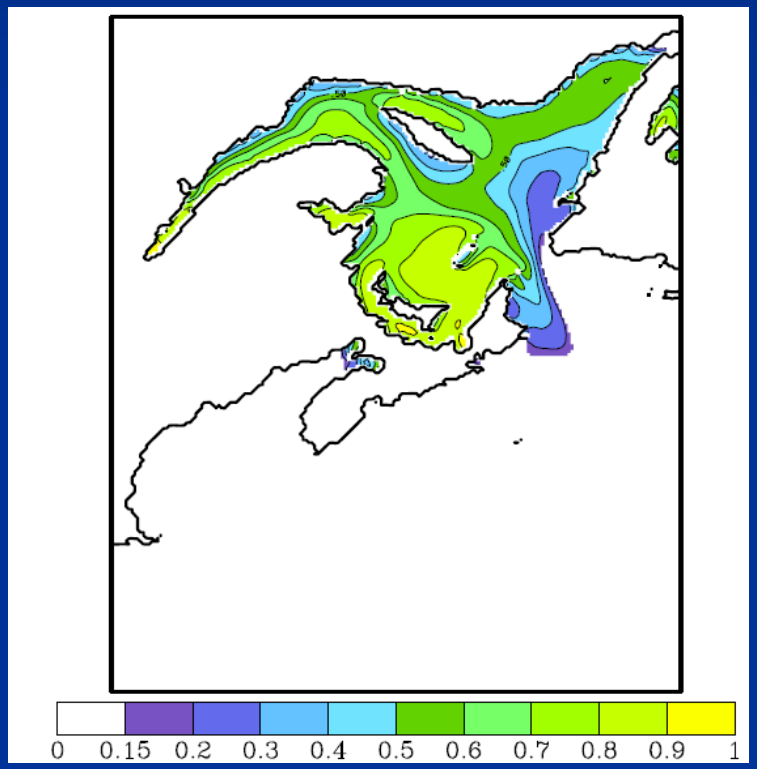
M3 : +0.0390 dec^{-1}
M4 : +0.0540 dec^{-1}
M5 : +0.0450 dec^{-1}
CCSM3 : +0.0571 dec^{-1}
CCSM4 : +0.0763 dec^{-1}
MPI : +0.0867 dec^{-1}
HadGEM2 : +0.1107 dec^{-1}
temperature (°C)


Mean Annual salinity over the east border (climatology not ajusted)
GCM trend (dec^{-1})
M3 : -0.0014 dec^{-1}
M4 : +0.0005 dec^{-1}
M5 : -0.0004 dec^{-1}
CCSM3 : +0.0034 dec^{-1}
CCSM4 : +0.0086 dec^{-1}
MPI : +0.0058 dec^{-1}
HadGEM2 : +0.0084 dec^{-1}

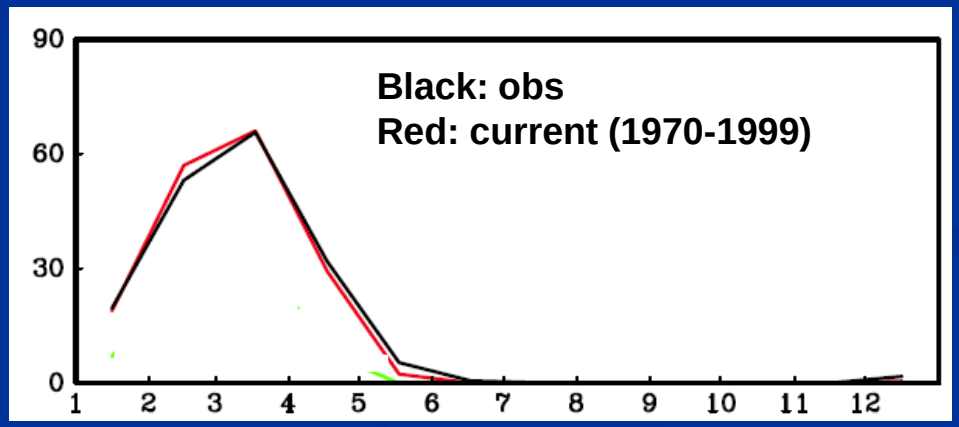

Mean Annual salinity over the east border
GCM trend (dec^{-1})
M3 : -0.0014 dec^{-1}
M4 : +0.0005 dec^{-1}
M5 : -0.0004 dec^{-1}
CCSM3 : +0.0034 dec^{-1}
CCSM4 : +0.0086 dec^{-1}
MPI : +0.0058 dec^{-1}
HadGEM2 : +0.0084 dec^{-1}
salinity (psu)


Mean Annual perpendicular current over the east border
Current (m/s)
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
1960
1980
2000
2020
2040
2060
2080
2100
M3
M4
M5
CCSM3
CCSM4
MPI
HadGEM2

Average
Ice concentration in March
(1970-1999)



Average
Ice volume
seasonal cycle

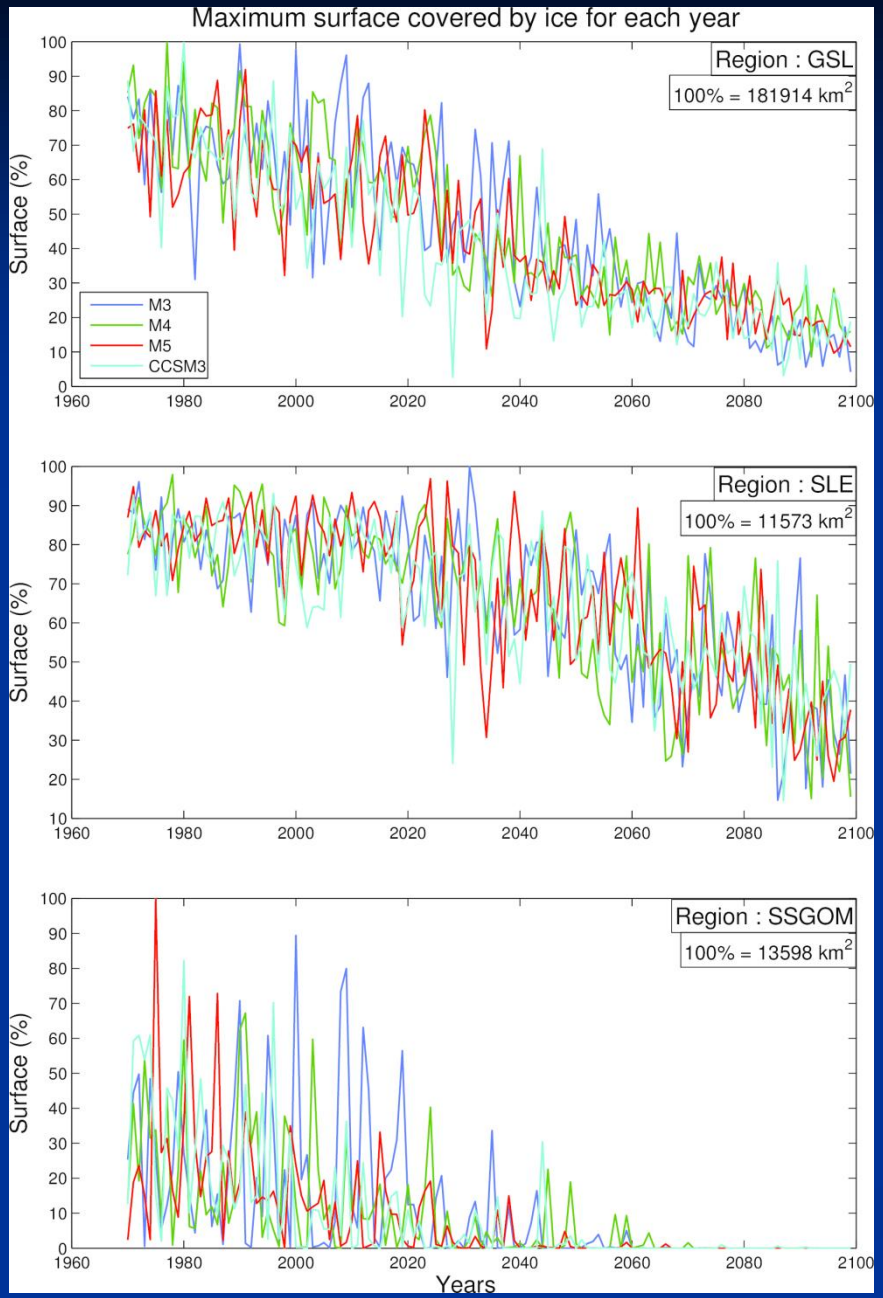


Long et al. 2015

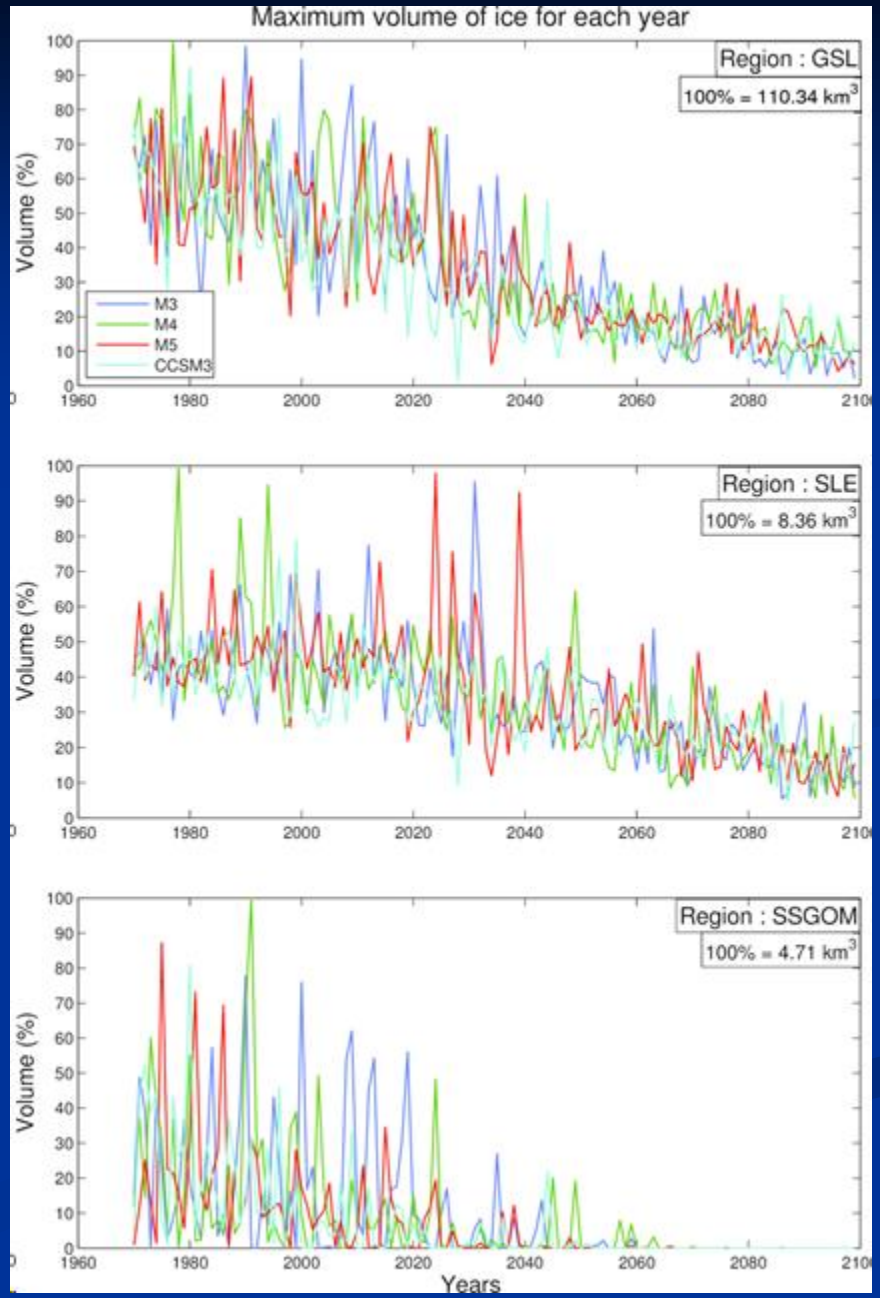
Results

- Information by bidecadal period
- Compare with contemporary period (1986-2005)
- Timeseries
- Calculation of "Emergence Times" relative to contemporary period.

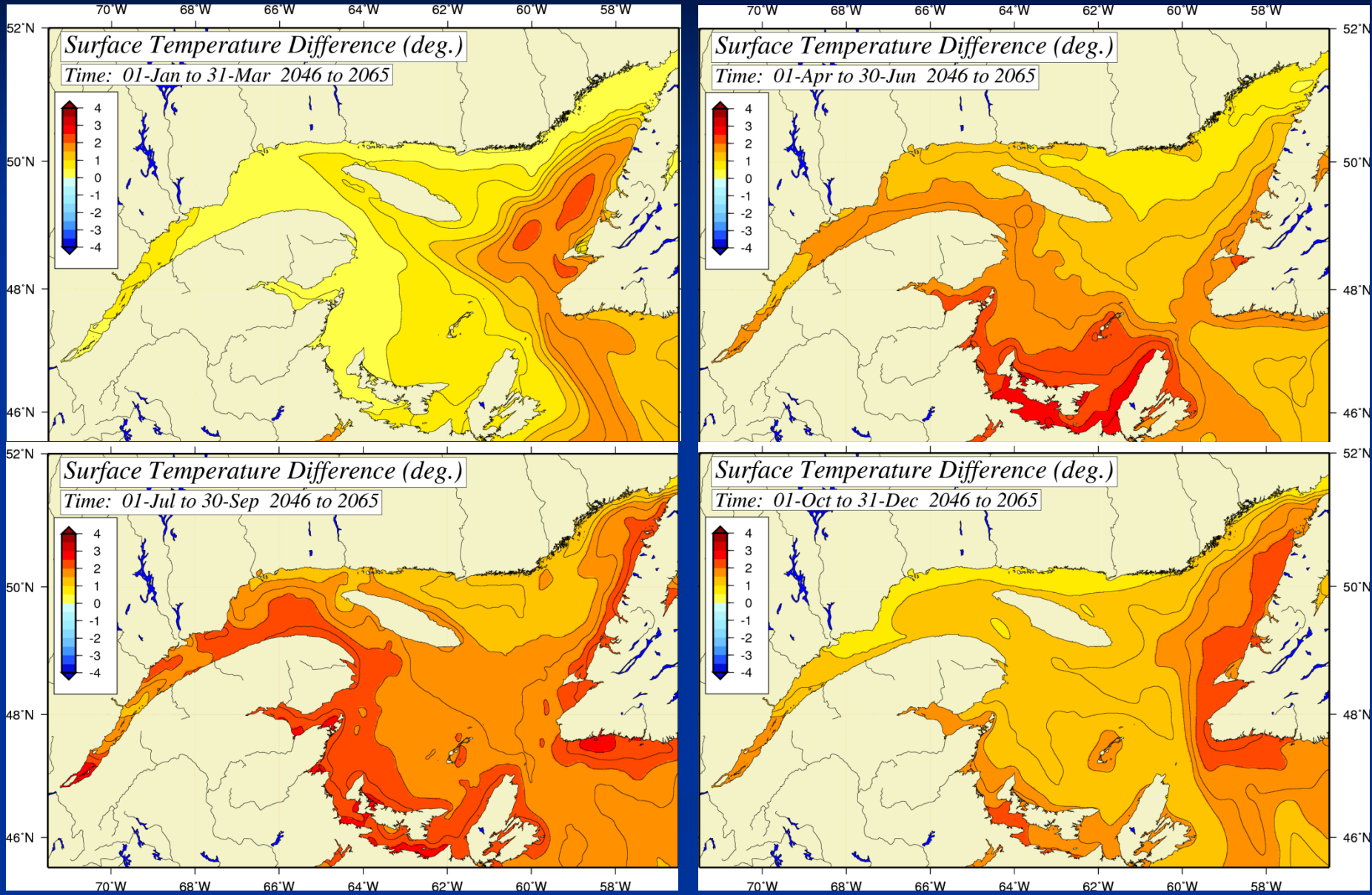
Maximum ice area



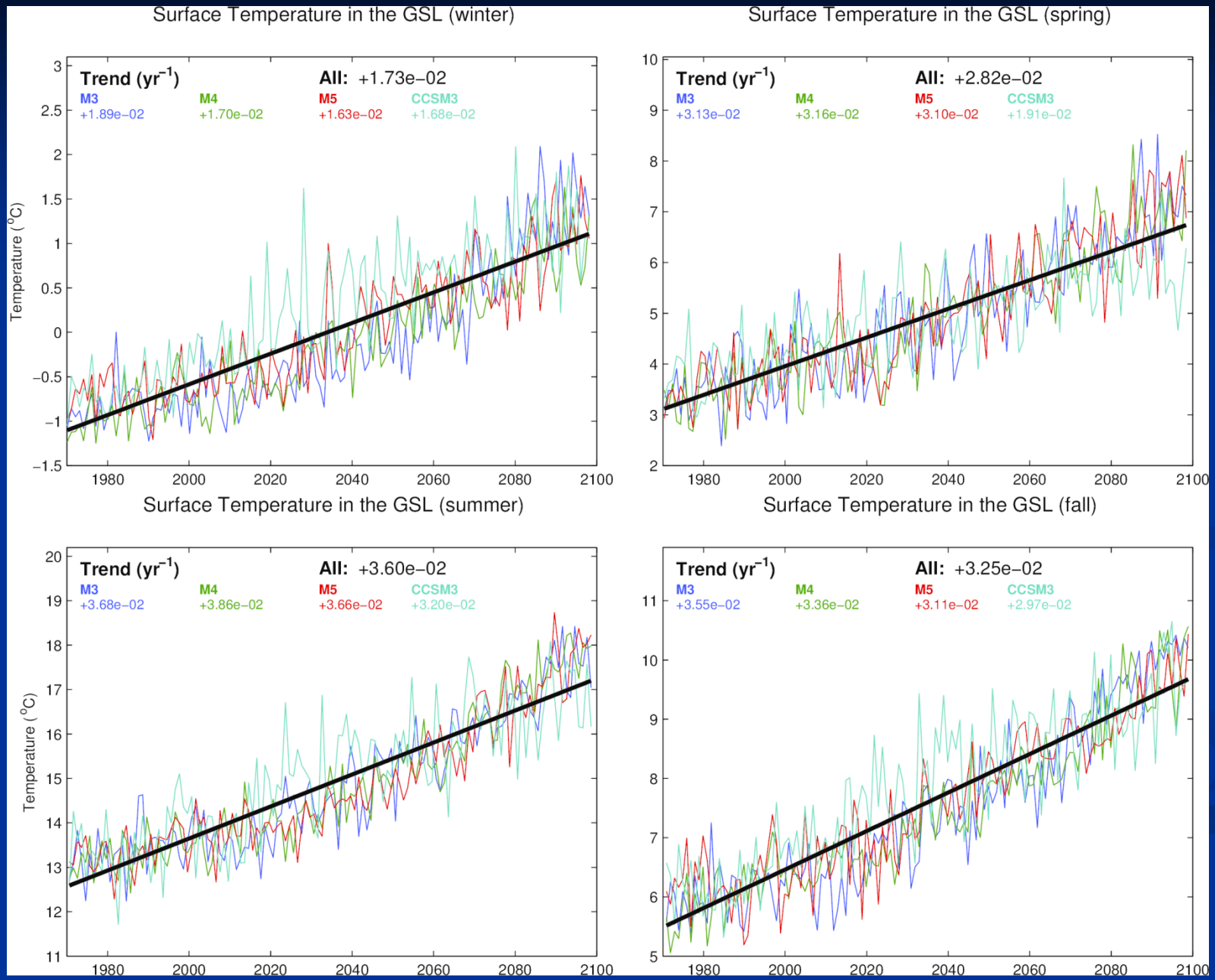
Maximum ice volume



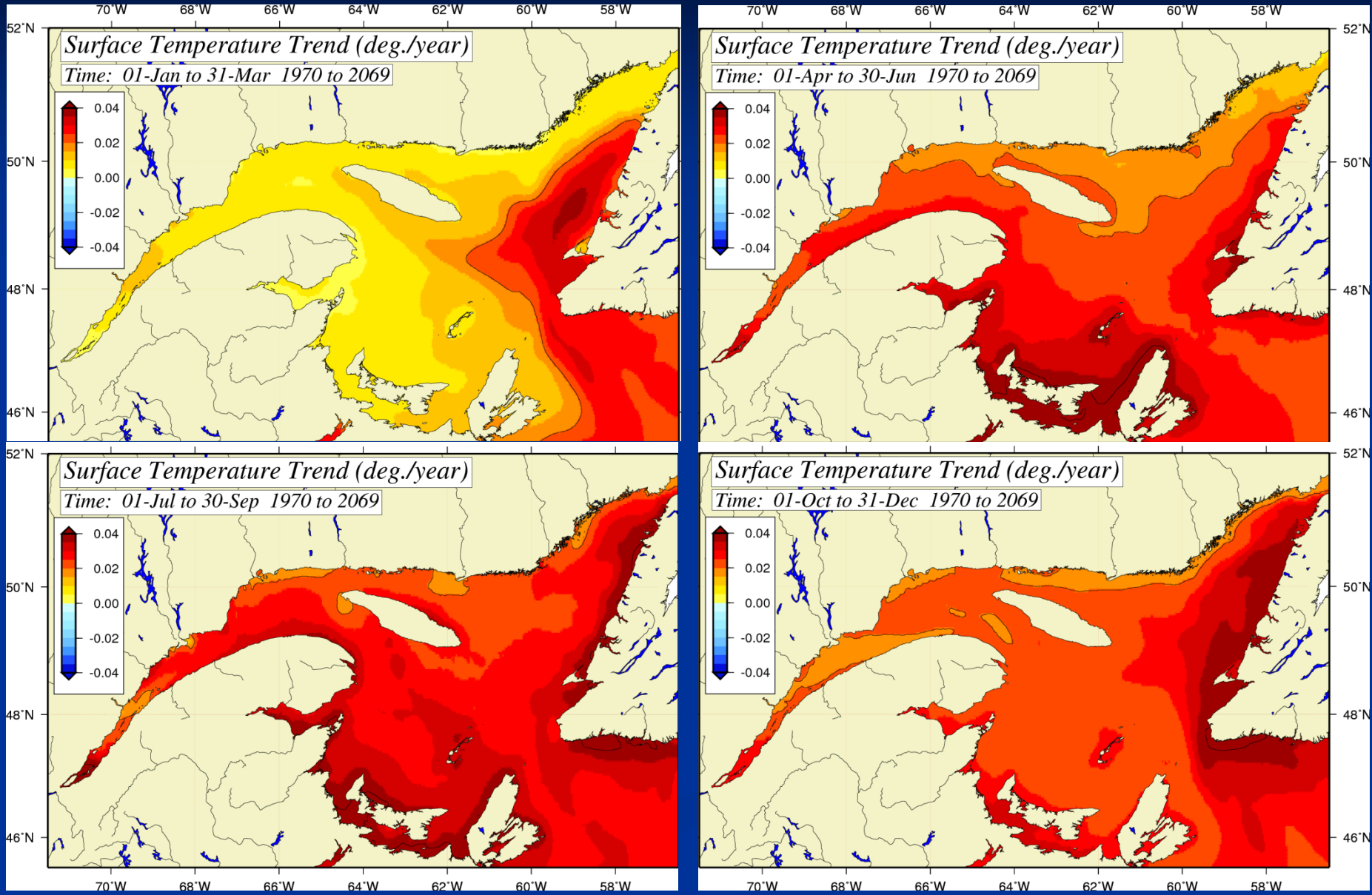
Sea Surface Temperature change by season (2046-2065) – (1985-2005)



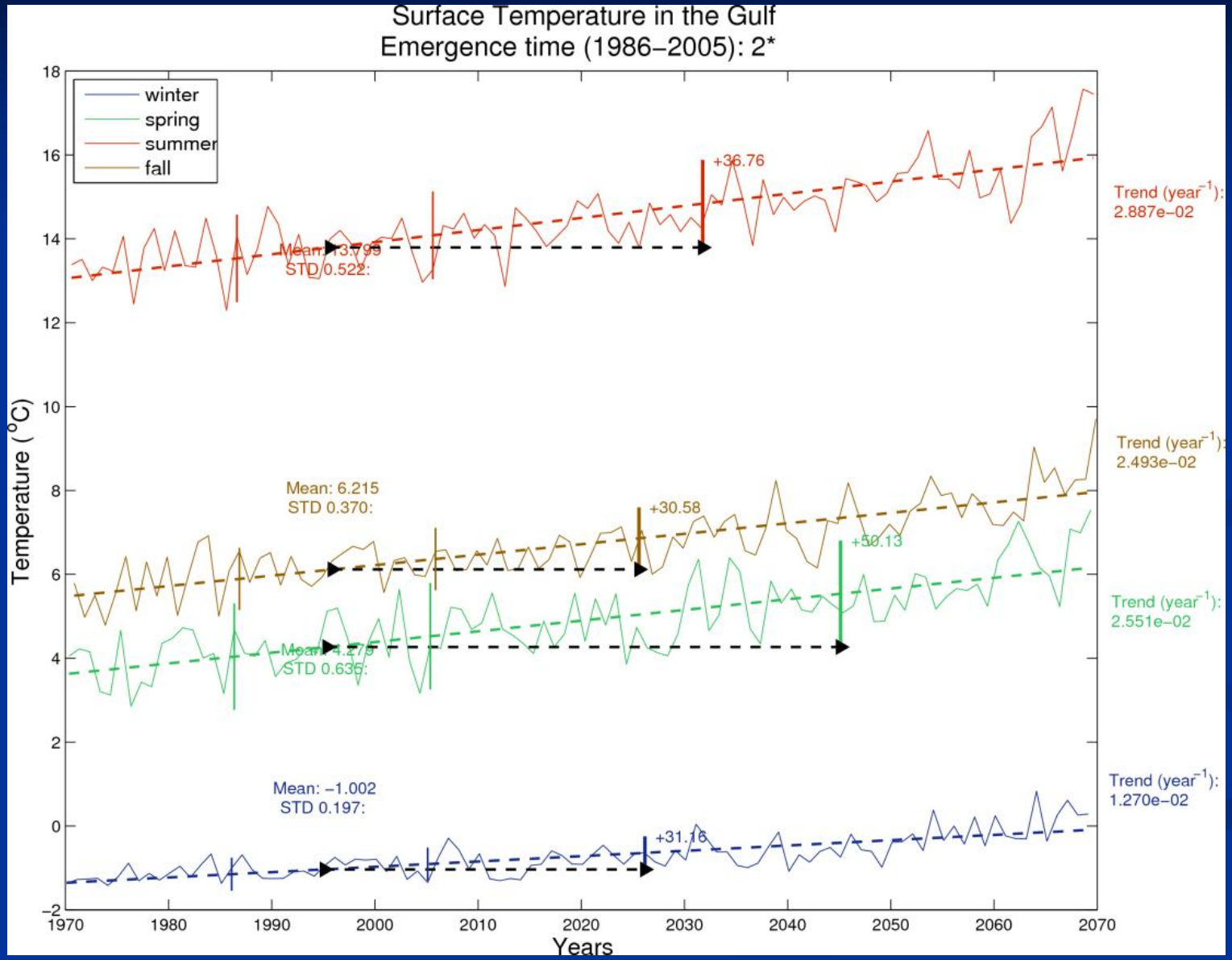
SST trends


Surface Temperature in the GSL (winter)
Trend (yr^{-1})
All: +1.73e−02
M3 +1.89e−02
M4 +1.70e−02
M5 +1.63e−02
CCSM3 +1.68e−02
Temperature (°C)
Surface Temperature in the GSL (spring)
Trend (yr^{-1})
All: +2.82e−02
M3 +3.13e−02
M4 +3.16e−02
M5 +3.10e−02
CCSM3 +1.91e−02
Surface Temperature in the GSL (summer)
Trend (yr^{-1})
All: +3.60e−02
M3 +3.68e−02
M4 +3.86e−02
M5 +3.66e−02
CCSM3 +3.20e−02
Temperature (°C)
Surface Temperature in the GSL (fall)
Trend (yr^{-1})
All: +3.25e−02
M3 +3.55e−02
M4 +3.36e−02
M5 +3.11e−02
CCSM3 +2.97e−02

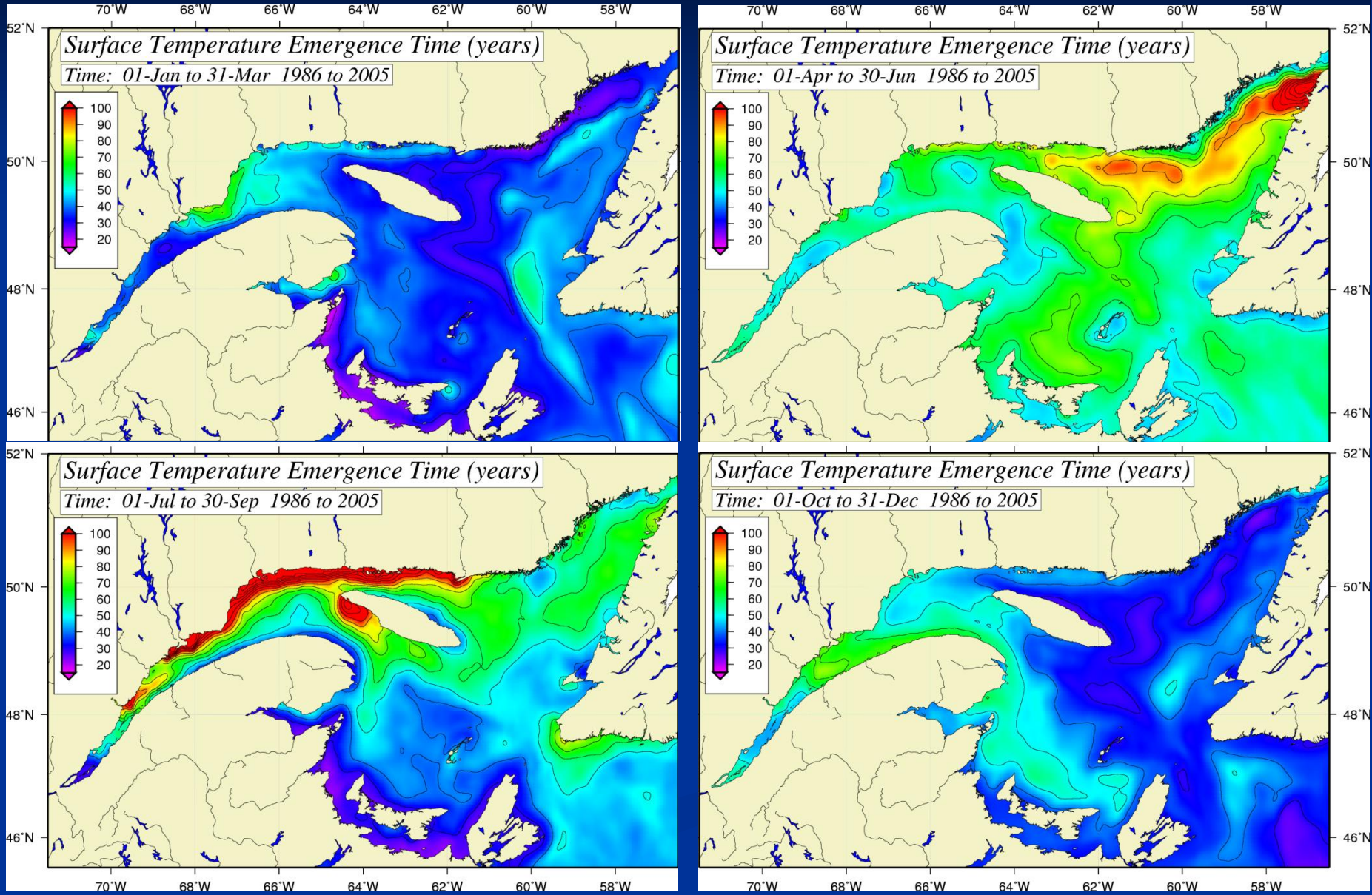
Sea Surface Temperature Trend (1970-2069)



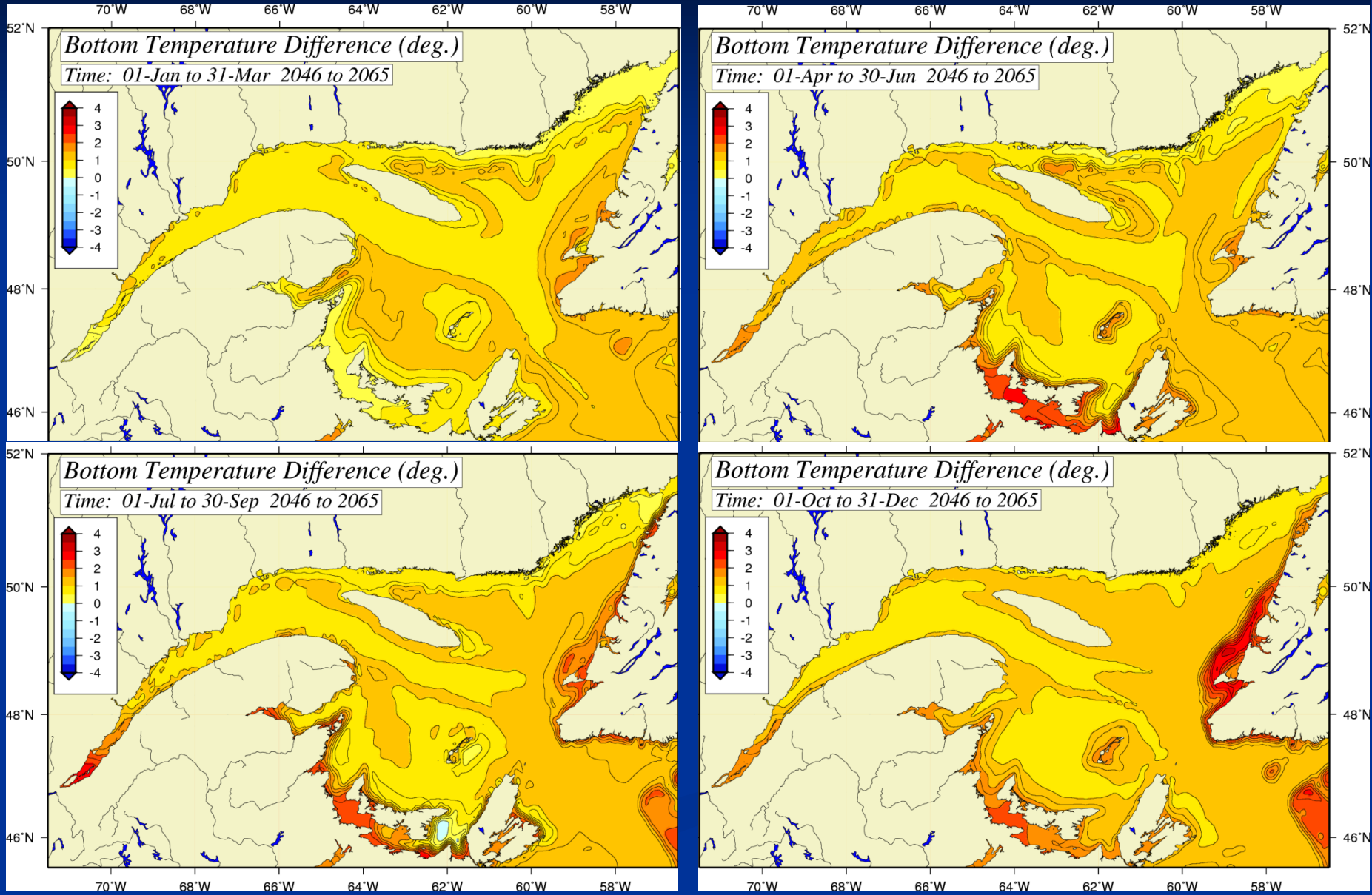
SST emergence times



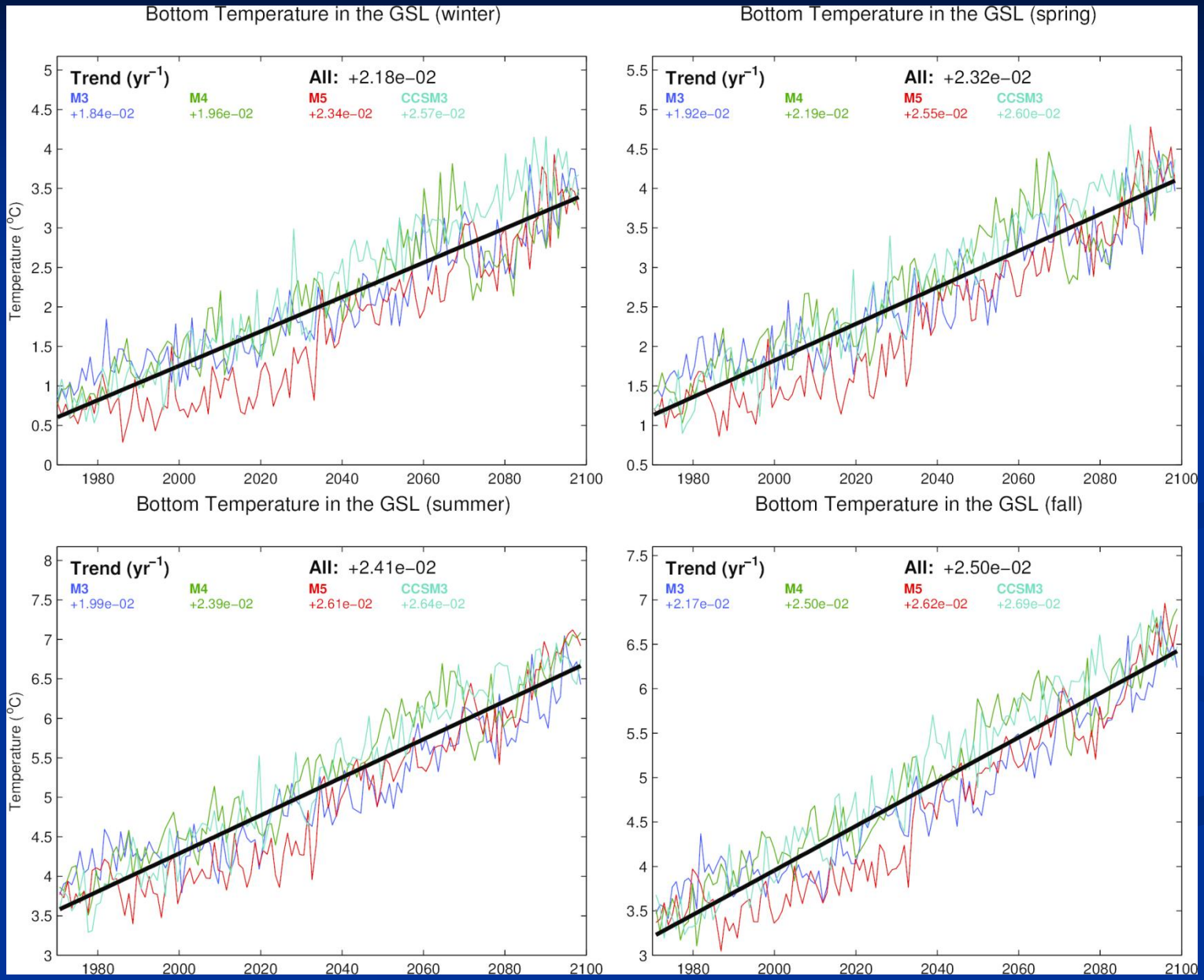
Sea Surface Temperature emergence times per season (Relative to 1986-2005 variability)



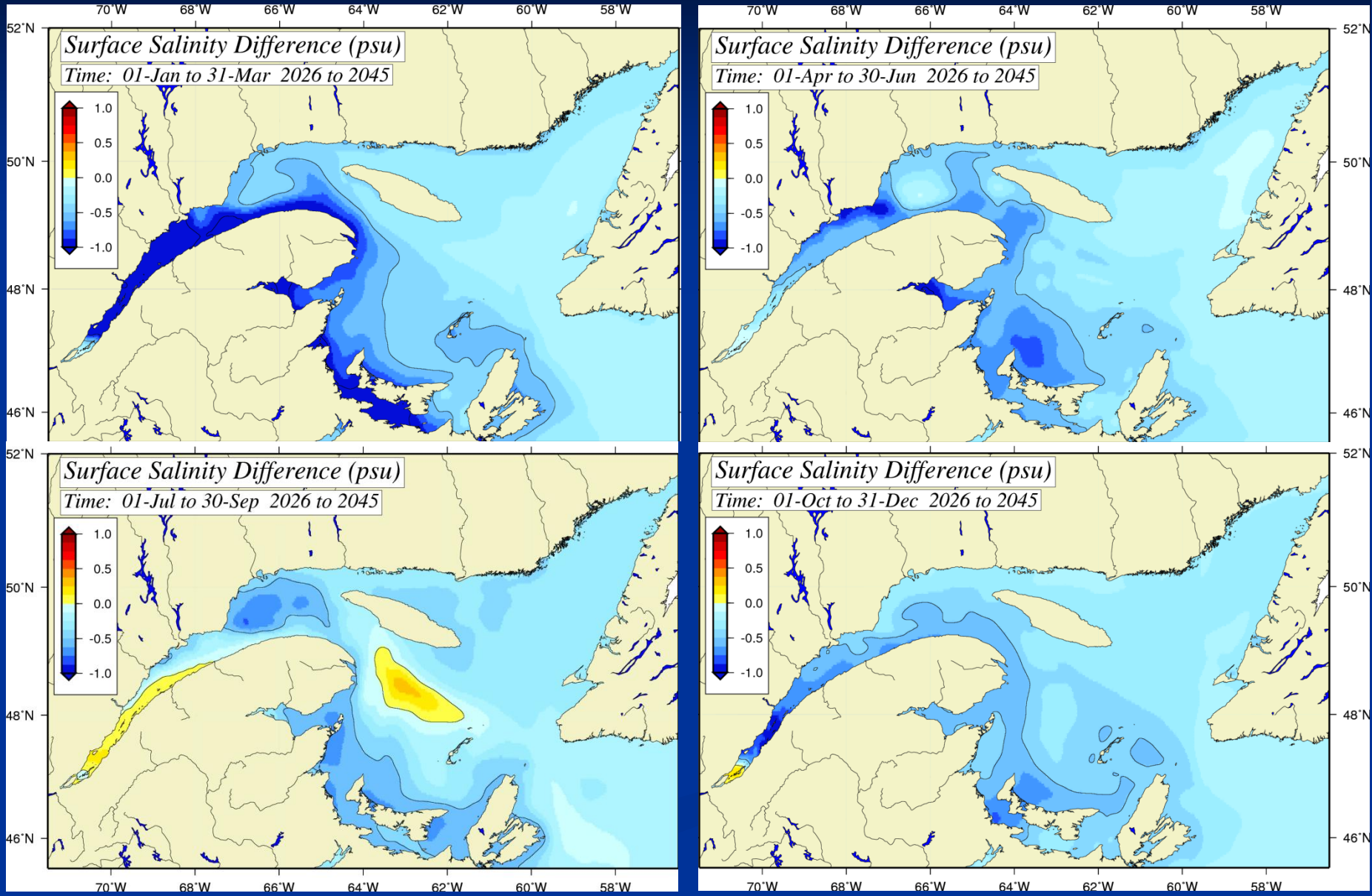
Bottom Temperature change by season (2046-2065) – (1985-2005)



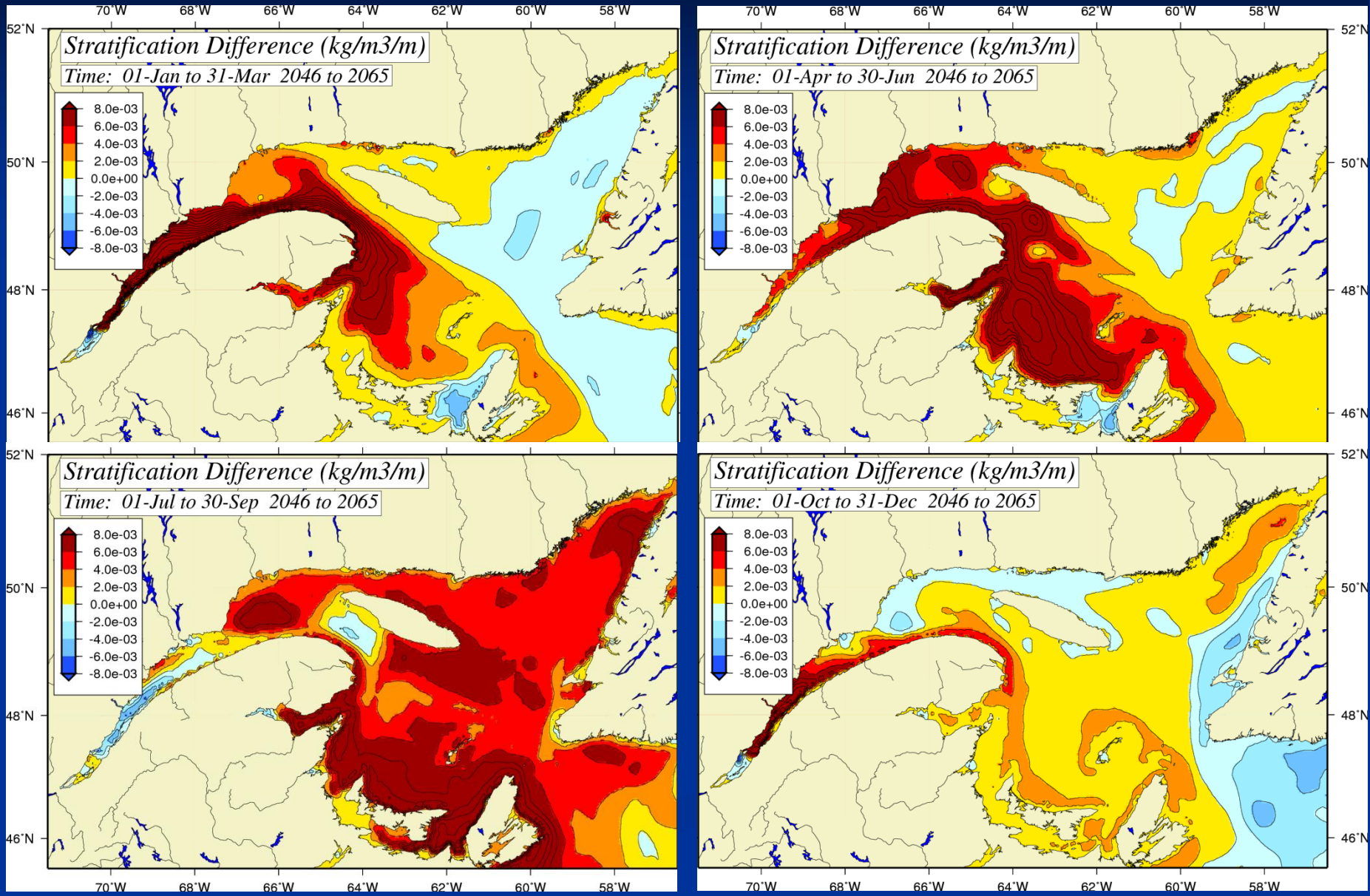
Bottom temperature trends



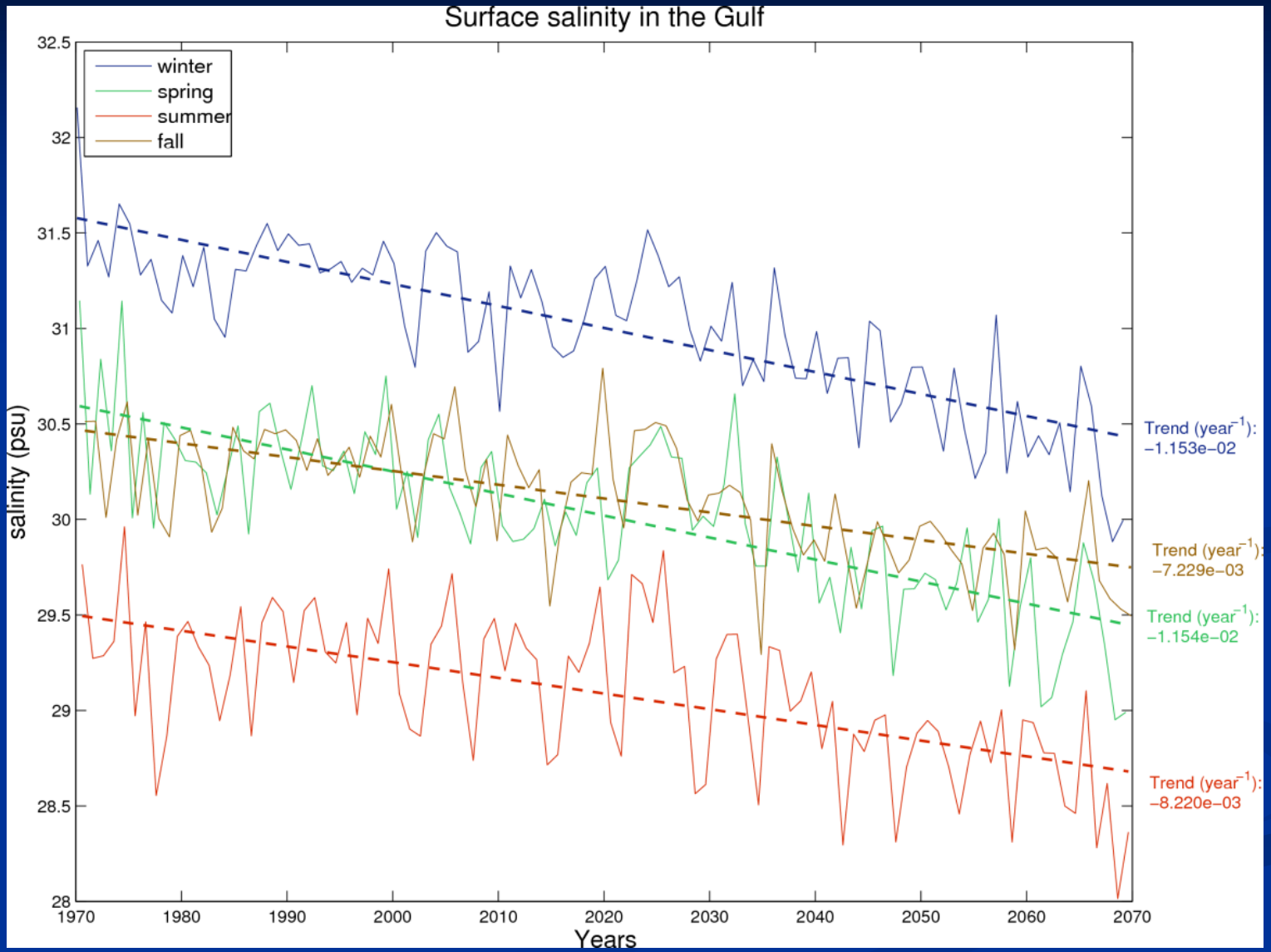
Surface Salinity change by season (2026-2045) – (1985-2005)



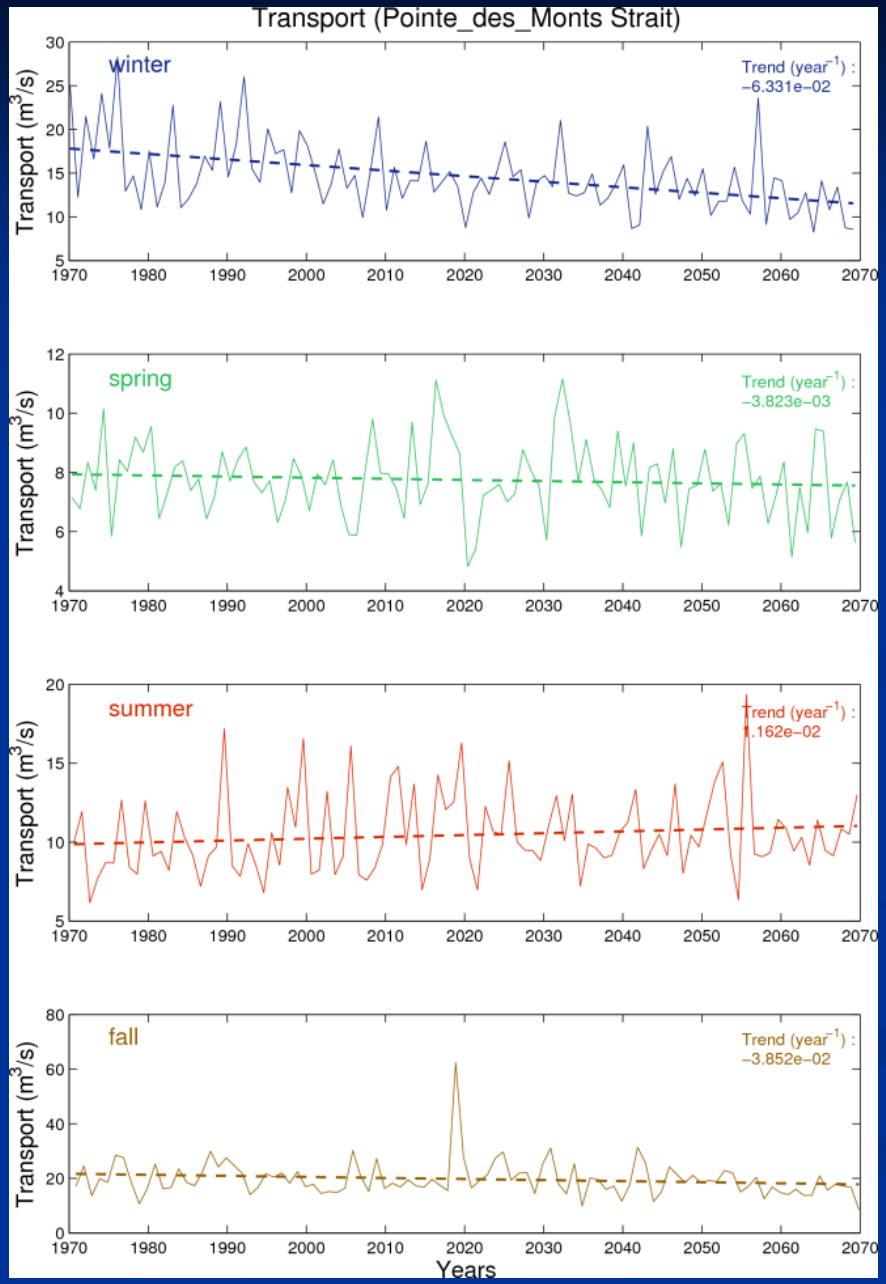
Stratification change by season (2046-2065) – (1985-2005)

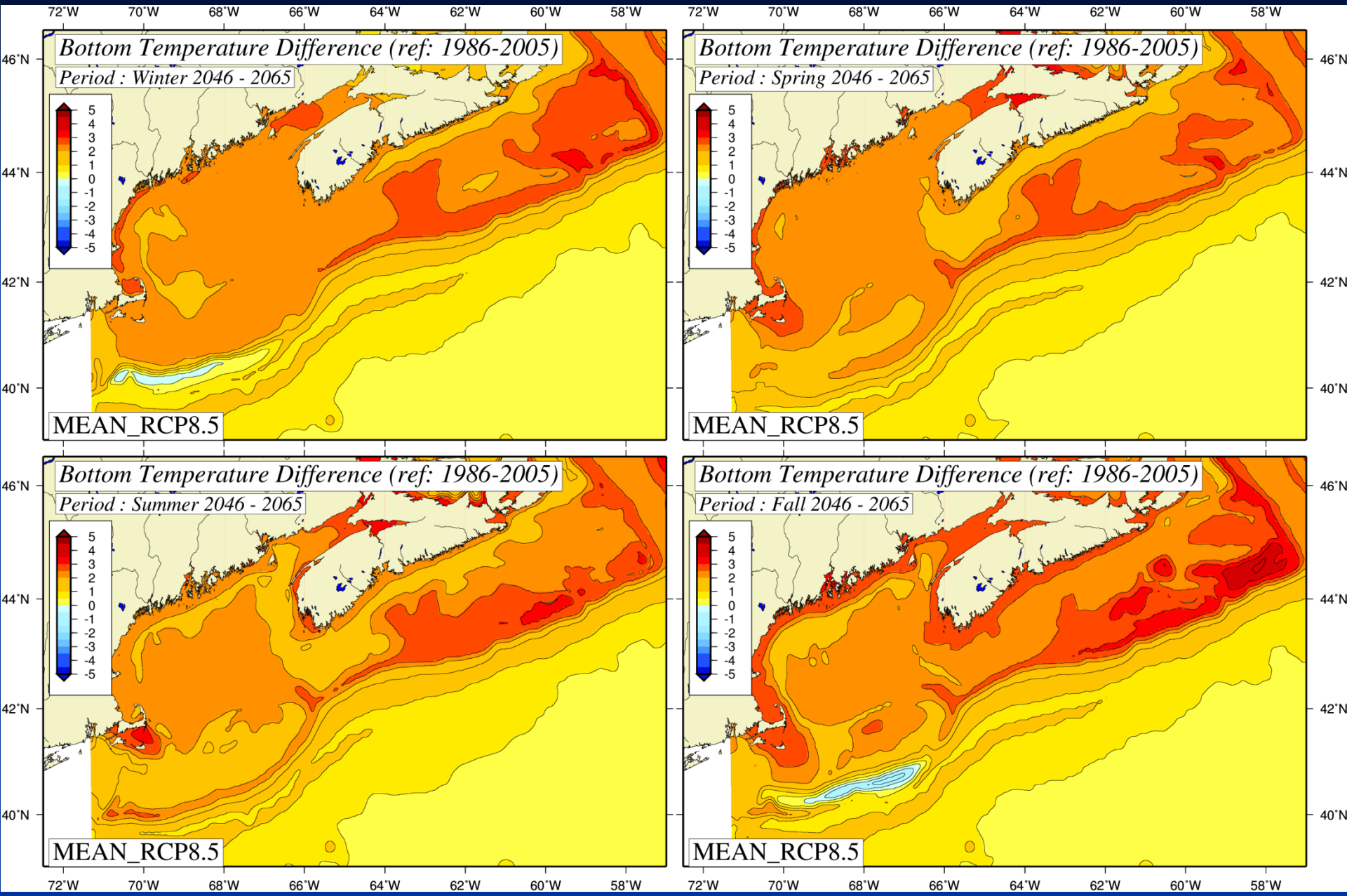


Surface Salinity trends



Estuarine Ratio




Bottom Temperature Difference (ref: 1986-2005)
Period : Winter 2046 - 2065
MEAN_RCP8.5
Bottom Temperature Difference (ref: 1986-2005)
Period : Spring 2046 - 2065
MEAN_RCP8.5
Bottom Temperature Difference (ref: 1986-2005)
Period : Summer 2046 - 2065
MEAN_RCP8.5
Bottom Temperature Difference (ref: 1986-2005)
Period : Fall 2046 - 2065
MEAN_RCP8.5
5 4 3 2 1 0 -1 -2 -3 -4 -5
72°W 70°W 68°W 66°W 64°W 62°W 60°W 58°W
46°N 44°N 42°N 40°N

A few summary bullets

- Significant spatial variability at the scale of the Gulf of St. Lawrence.

- Long term decrease of maximum ice coverage.

- SST is increasing for each season. The southern Gulf of St. Lawrence will be warming up at a faster rate than the rest of the GSL.

- The SST warming rate is bigger (double) in summer than in winter.

- The SST Emergence Times (ET) are between 31 years in summer and 58 years in the spring.

- Overall, salinity will be be decreasing in the Gulf except in summer. The decrease in salinities will be particularly marked in the estuary in winter.

- The stratification (0-50m) will be increasing.

Considerations for future work

- Continue to improve ice-ocean models including improved forcing

- Continue developing techniques for improved regional ocean downscaling. While dynamic regional downscaling yields higher spatial resolution information, the regional climate models are strongly dependent on the lateral boundary conditions obtained from the GCMs. Large-scale climate errors in the global models need to be filtered out as much as possible using, for example, the delta method to adjust the forcing of the regional models

- Small domains lead to poor gain with the downscaling approaches; downcalling over larger domains would be desirable

- Or greatly improve GCM resolution to better resolve shelf and coastal processes.

- Data assimilation what is the way ahead?