Relationship between changes in the AMOC and North Atlantic Sea Surface temperature

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AMOC → Ocean heat content (Robson et al., 2012)
SST → Impacts (Sutton et al., 2017)
AMOC → Ocean heat content in MIXED LAYER→ SST → AMV

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Rapid Climate Change

BLUE ACTION

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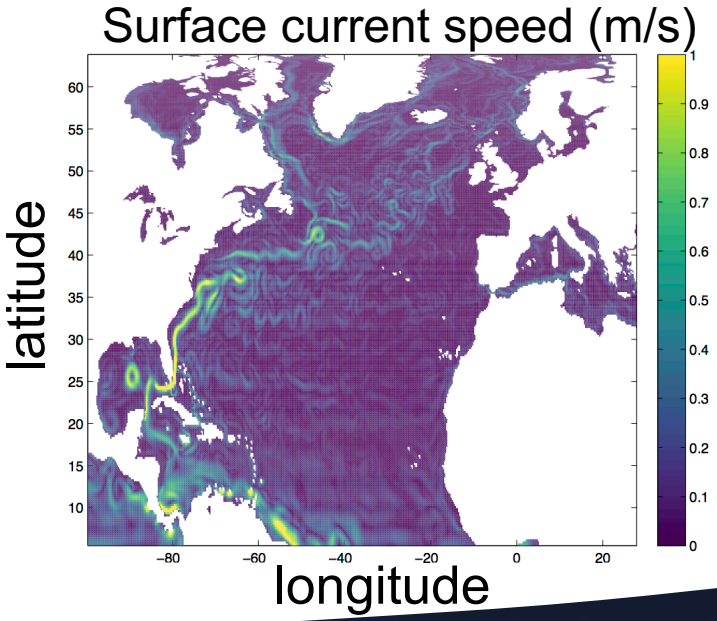
NERC SCIENCE OF THE ENVIRONMENT

HADGEM3-GC2 CONTROL

Williams et al., (2015)

- NEMO ocean circulation/sea ice model (CICE)
- 1/4 degree NEMO GO5 ocean with 75 levels in the vertical.
- Atmosphere GA6: N216 (65km)
  85 levels in the vertical
- Eddy permitting ocean
- Run for 300 years
- Pre-Industrial forcing

Run by the Met Office, UK.

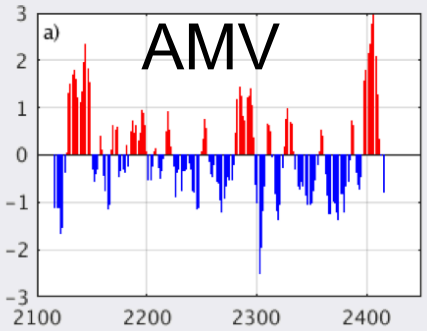


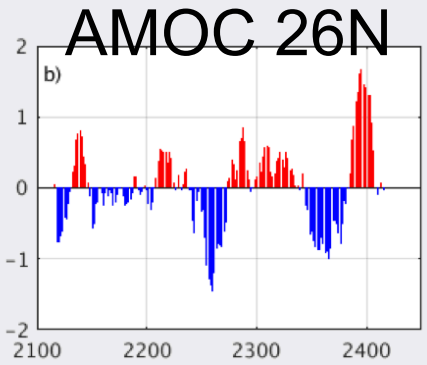
Model Evaluation

AMV period
Model: ~50 years
Obs: (30-70 years)

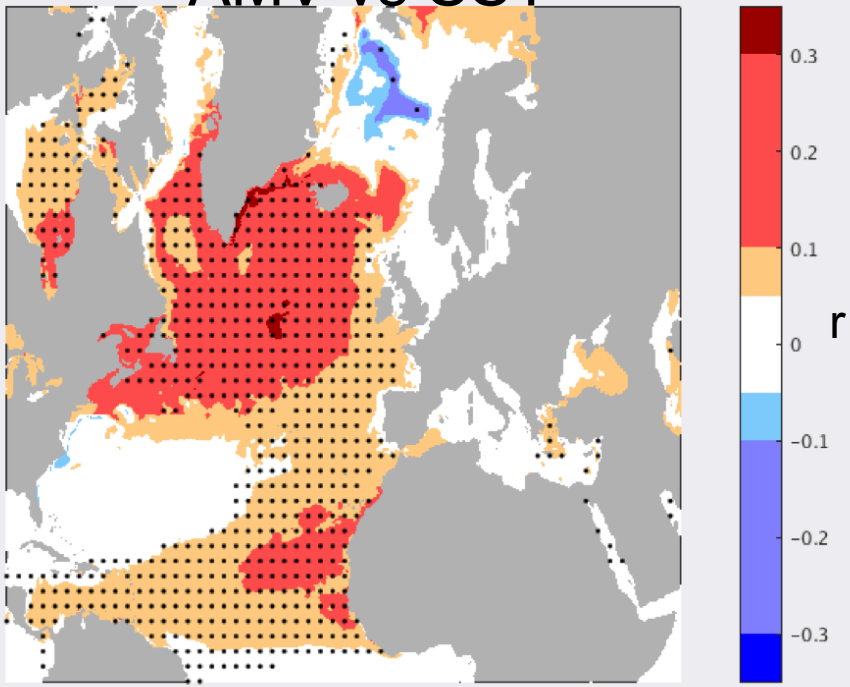
AMOC period:
~60 Years

GC2 26N AMOC:
14.7 ± 1.0 Sv
Observation:
17.1 ± 3.6 Sv





AMV vs SST



Dots indicate 95 % significance

OHC changes in the **mixed layer**

Annual averages from monthly data in the mixed layer (ML)

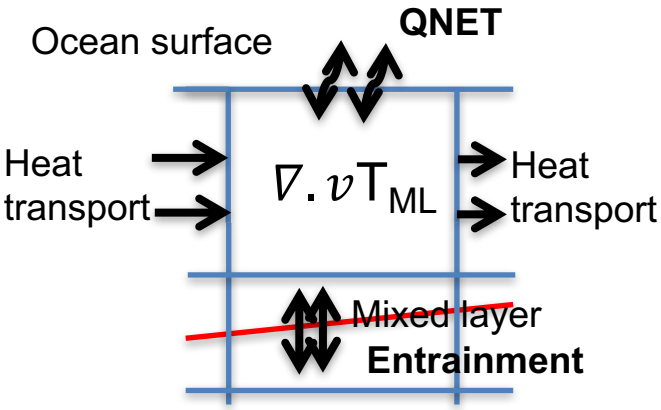
$$\frac{dOHC_{ML}}{dt} = Entrainment + Qnet + \nabla . vT_{ML}$$

Diagnosed from model temperature

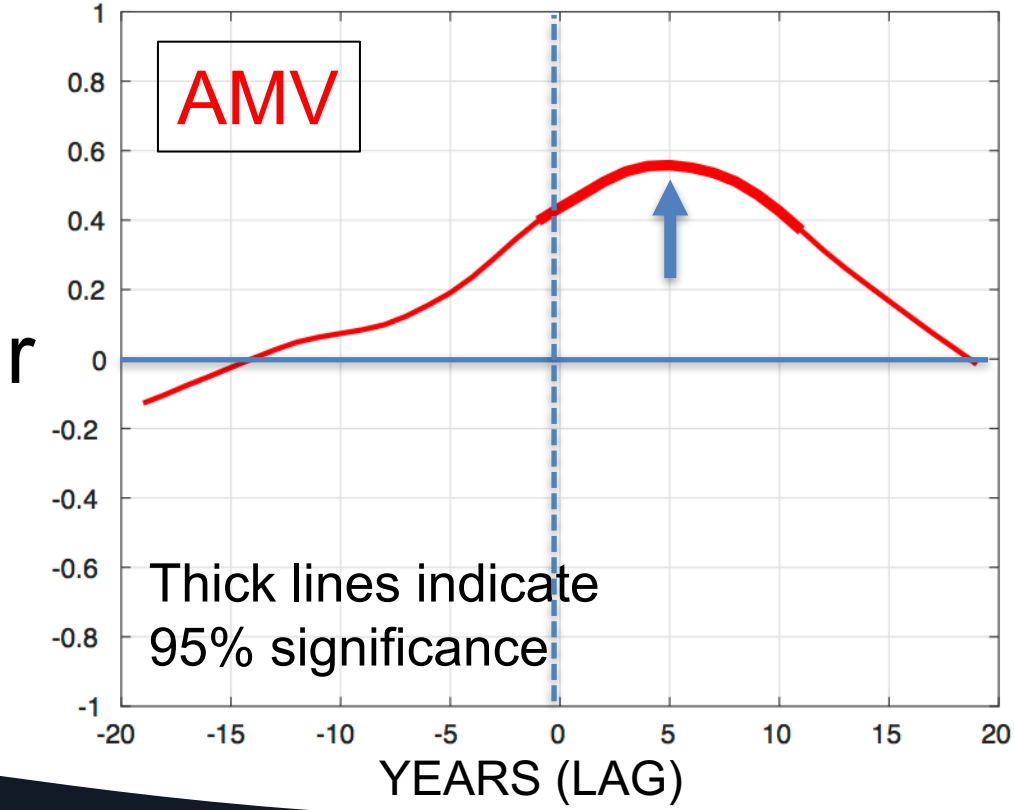
Diagnosed model mixed layer depth and temp

Diagnosed from model surface heat flux

residual



Relationship between AMOC and AMV

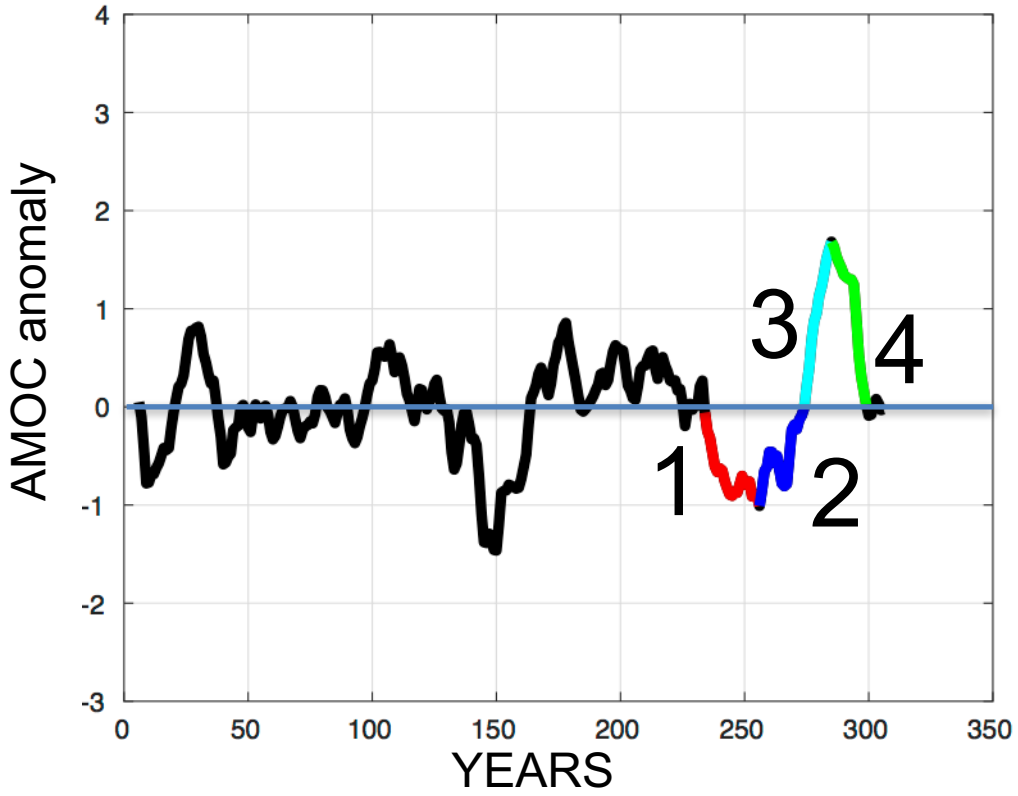


AMOC leads the AMV by 5 years

What is causing this delay?

300 years of model data

AMOC 26N



Analyze one cycle of the AMOC in terms of:

dSST/dt

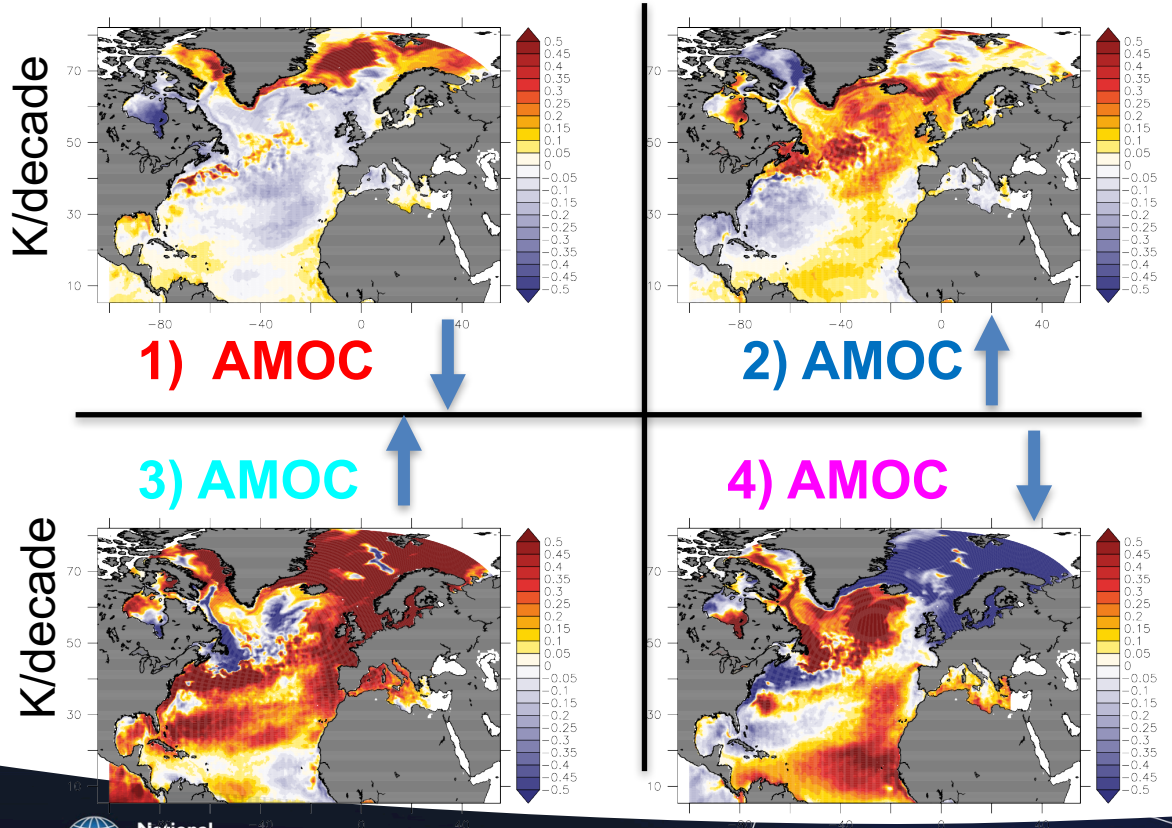
and its components related to:

ENT , $\nabla.v\mathbf{T}$ and **Qnet**

75 year cycle

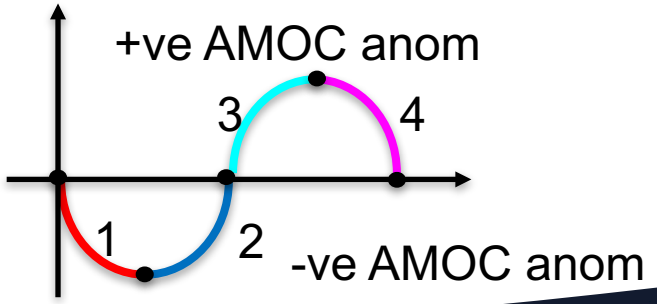
~20 years per phase

dSST/dt composite



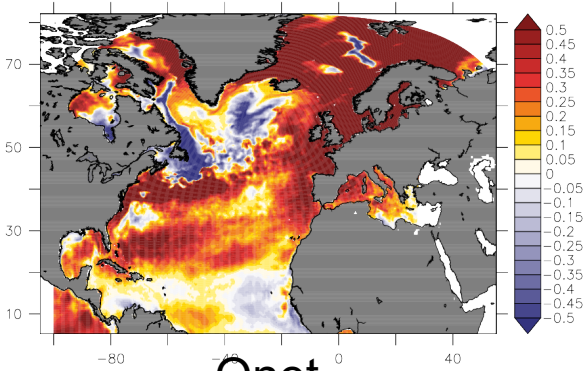
On multi decadal time scales large scale pattern varies with AMOC phase

Phase 4) SST increase in AMV region even though AMOC decreasing

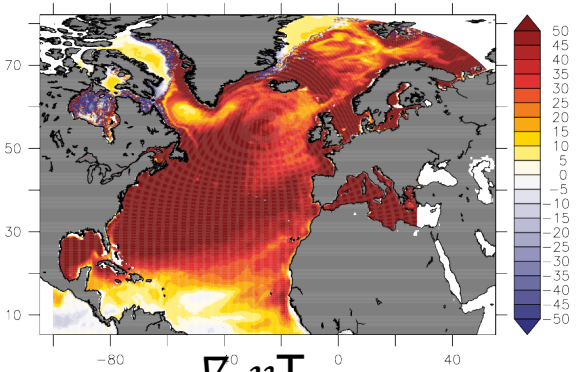


SST changes (PHASE3)

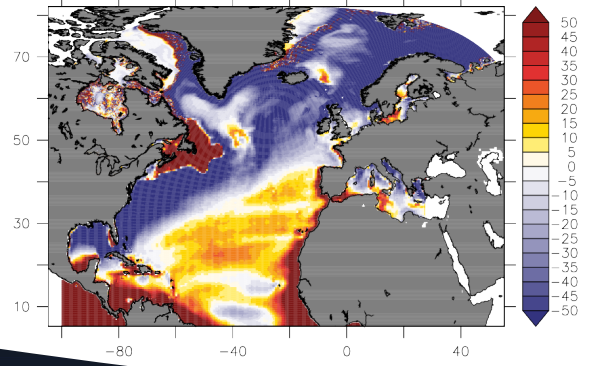
dSST/dt



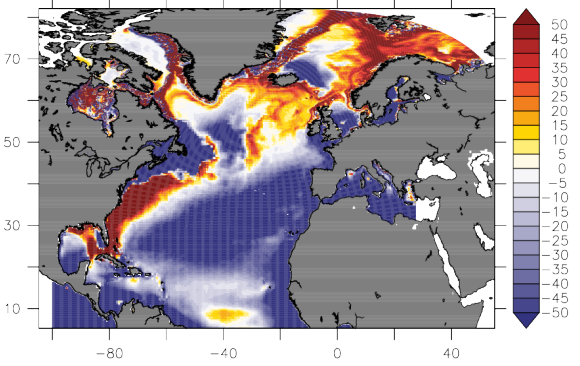
Entrainment



Qnet



$\nabla . v$T



ENT: **Entrainment always positive (for all phases)**

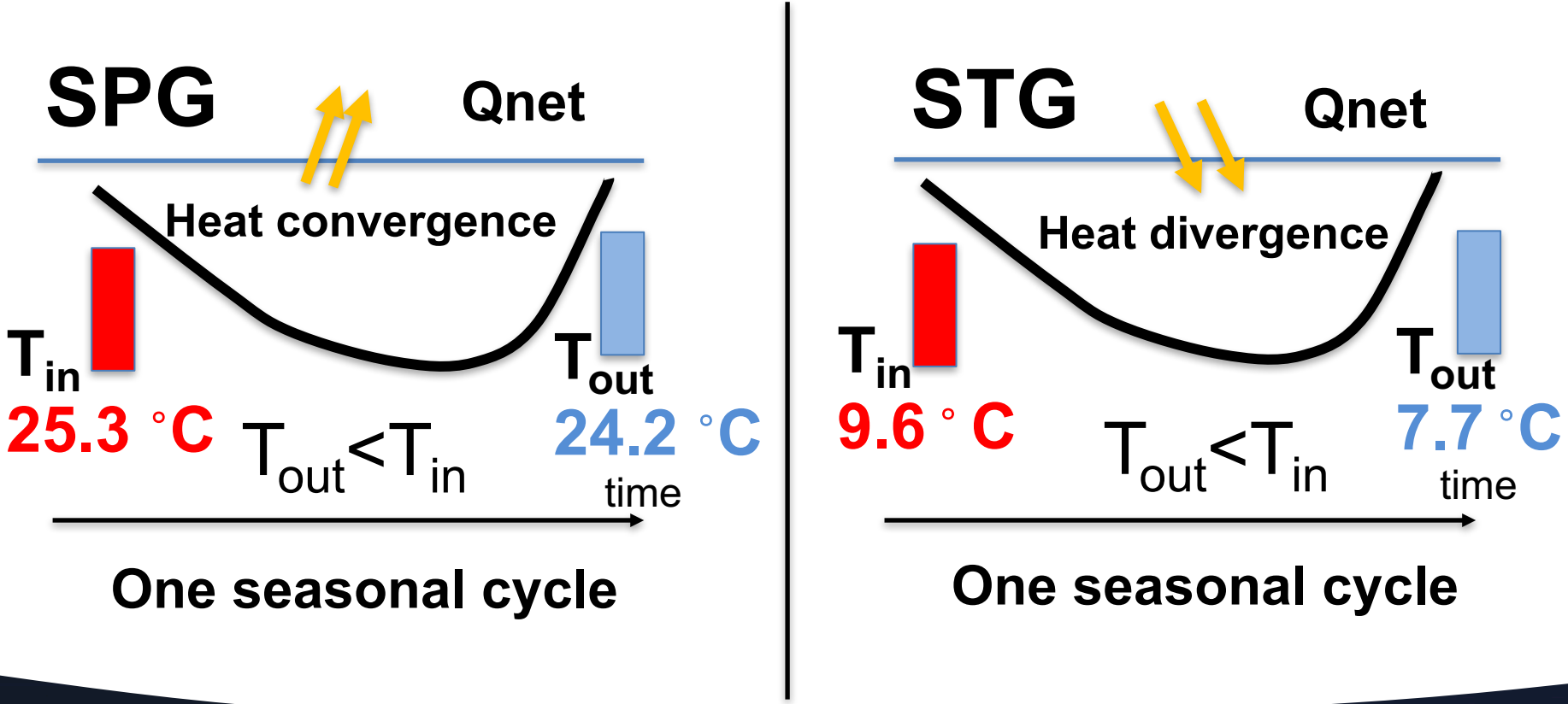
QNET: heat loss in SPG and Gulf stream.
Heat gain in STG

$\nabla . v$T: opposite to Qnet

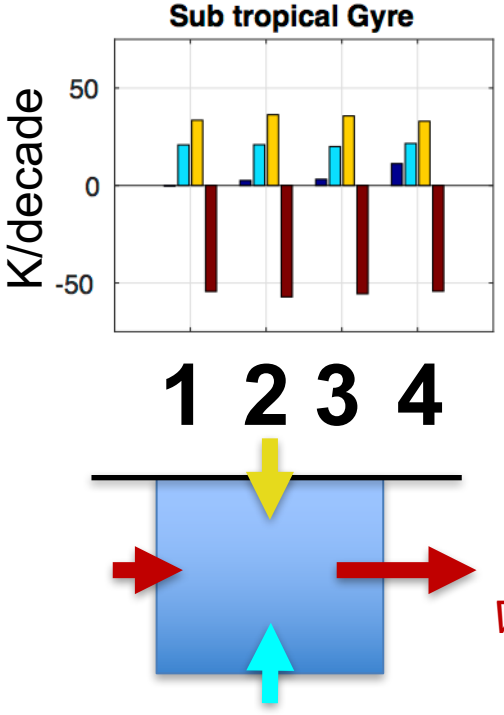
MIXED LAYER HEAT PUMP

As a result of the seasonal cycle the entrained water (T_{in}) is always warmer than the detrained water (T_{out})

MIXED LAYER HEAT PUMP

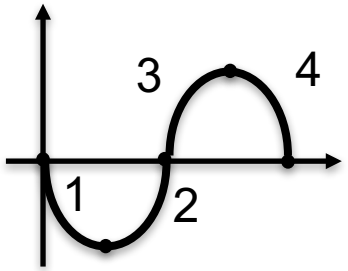


Multi-decadal SST changes

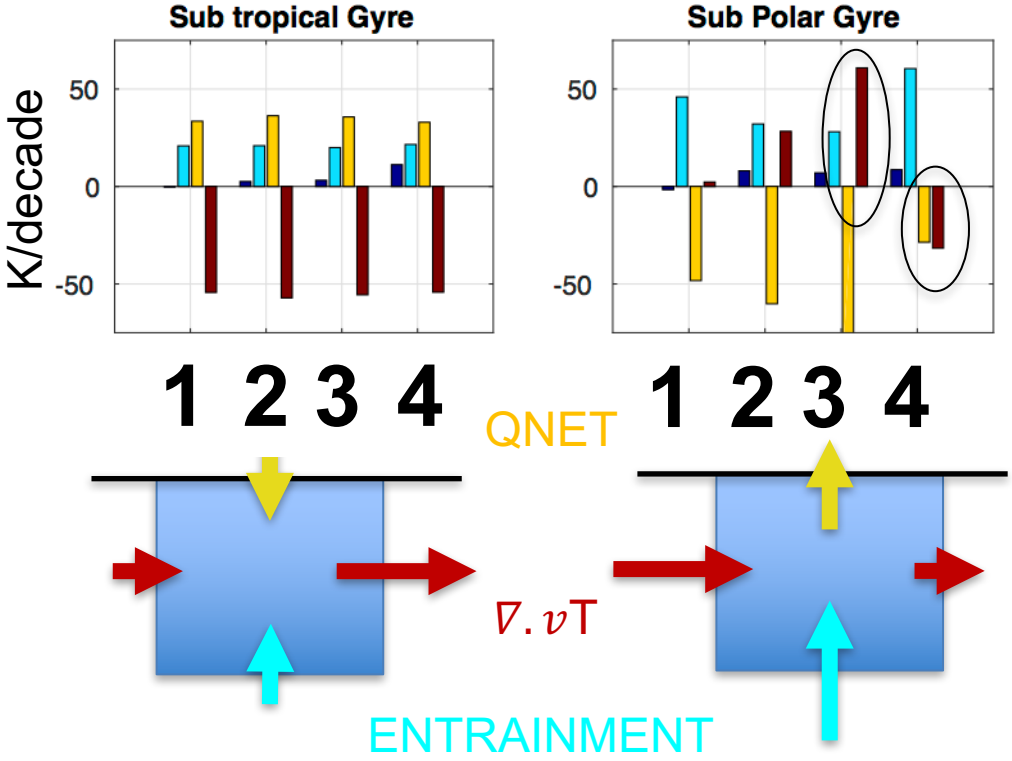


STG: dSST/dt increasing through cycle QNET and ENT warming mixed layer.

$\nabla.vT$ is always cooling the mixed layer.

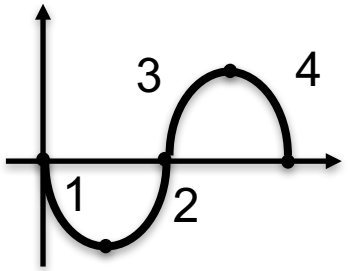


Multi-decadal SST changes

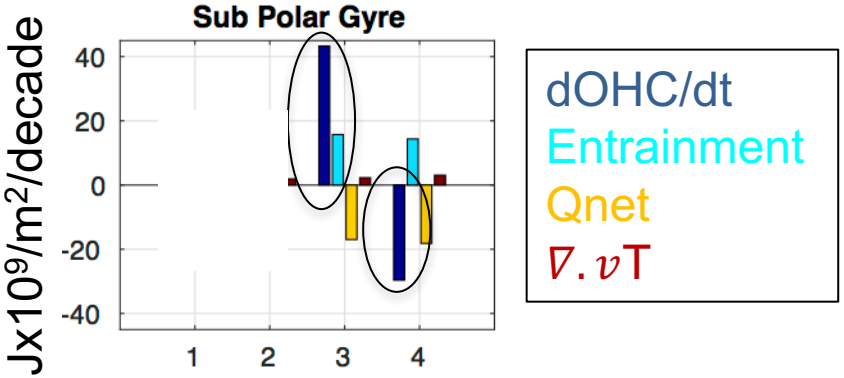


SPG behaves differently to STG.

Phase 3 to 4 $\nabla.v$T changes sign, but SST continues to warm. This Is due to increased ENT and reduced QNET



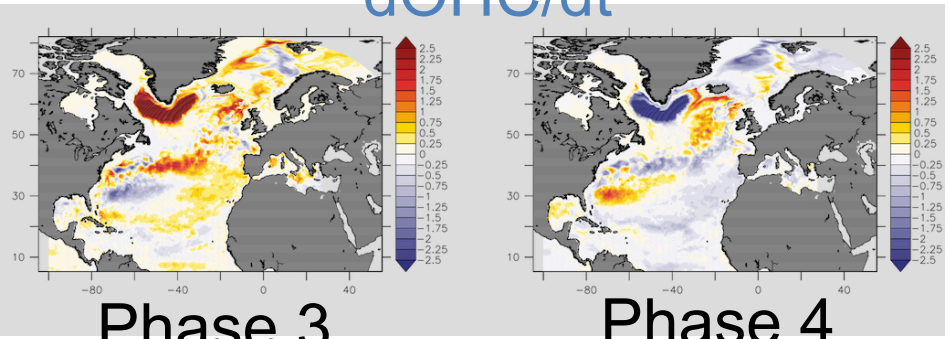
SPG OHC changes



dOHC/dt
Entrainment
Qnet
$\nabla . v\mathrm{T}$

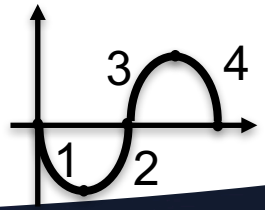
In phase 4 OHC change in the SPG is reducing, while the SST is increasing!

dOHC/dt

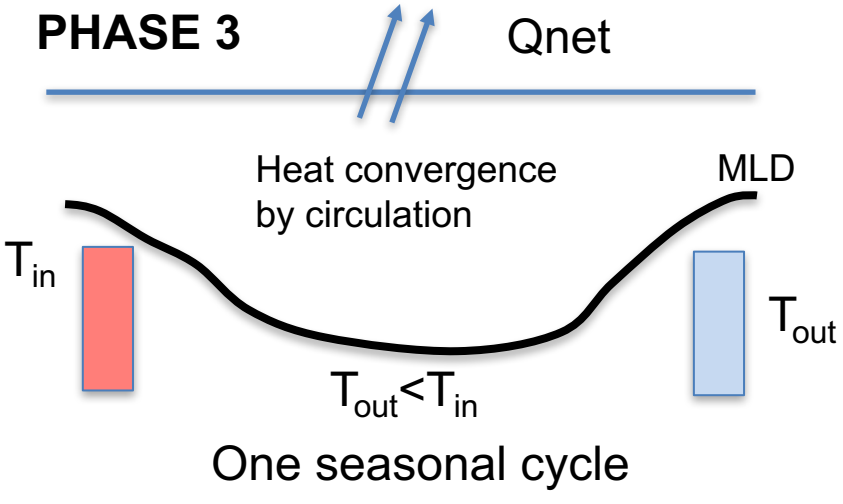


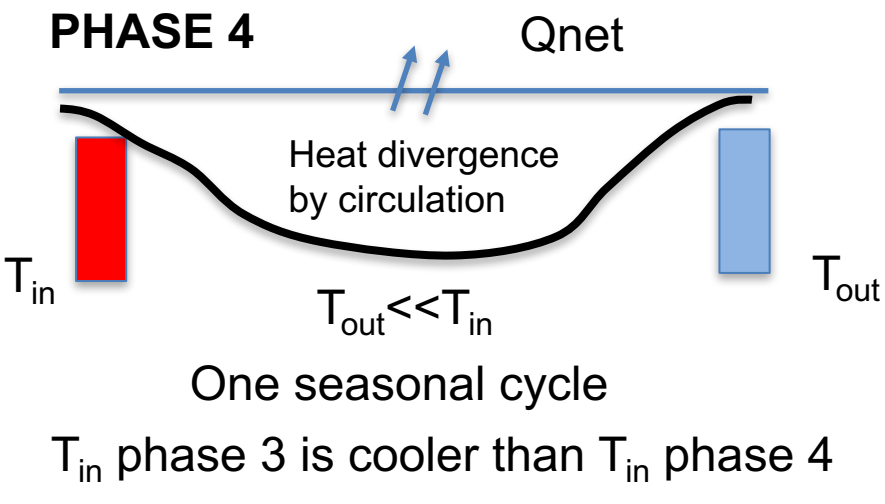
Phase 3 Phase 4

Changes in OHC are related to changes in deep convection



SPG mixed layer SST heat pump





Mixed layer is shallower in phase 4 due to reduced convection
This process explains why the SST is increasing even though OHC and AMOC are reducing.

Conclusions

- New approach based on diagnosing mixed layer budget

- Model suggest that the entrainment over a seasonal cycle is a key component and is always positive

- Changes in entrainment and Qnet explain the lag between AMOC and AMV

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