

Relationship between changes in the AMOC, North Atlantic heat content and SST

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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

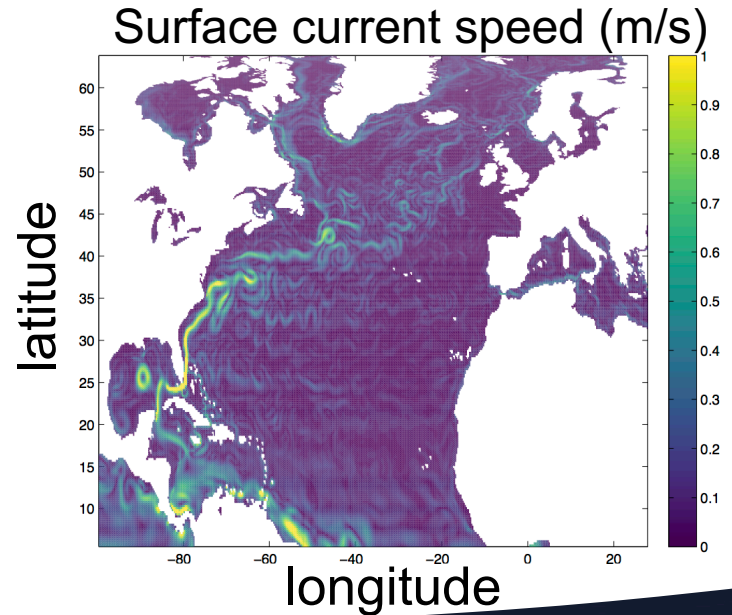


HADGEM2-GC2 CONTROL

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.

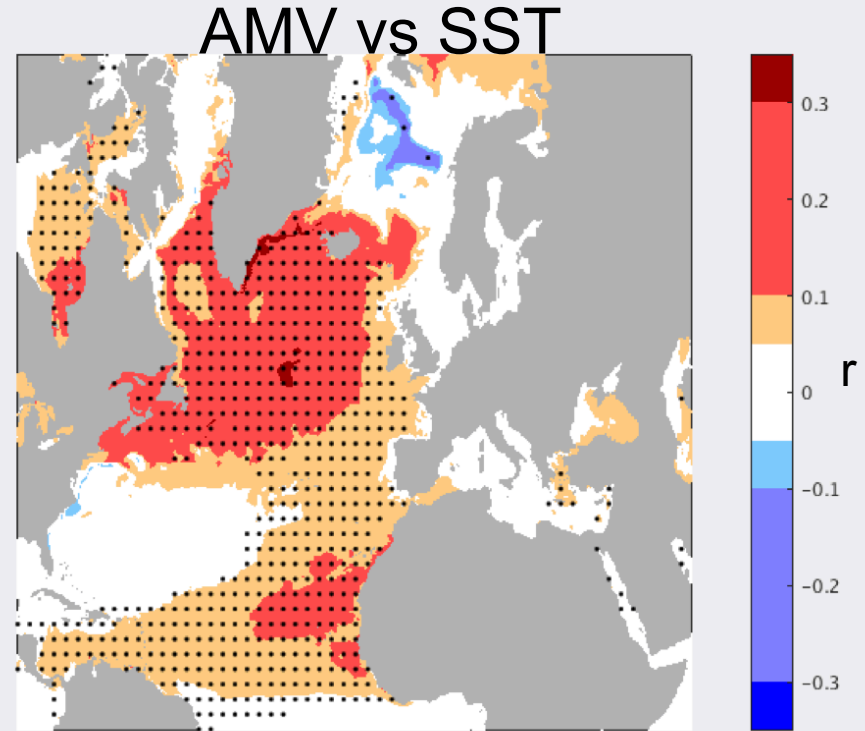
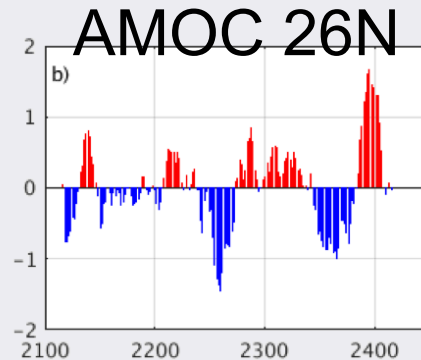
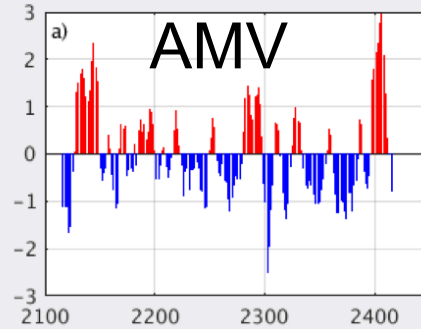


Model Evaluation

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

AMOC period:
~60 Years

GC2 26N AMOC:
 14.7 ± 1.0 Sv
Observation:
 17.2 ± 4.6 Sv



Dots indicate 95 % significance

OHC changes in the mixed layer

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

$$\frac{dOHC_{ML}}{dt} = \textit{Entrainment} + Q_{net} + \nabla \cdot vT_{ML}$$

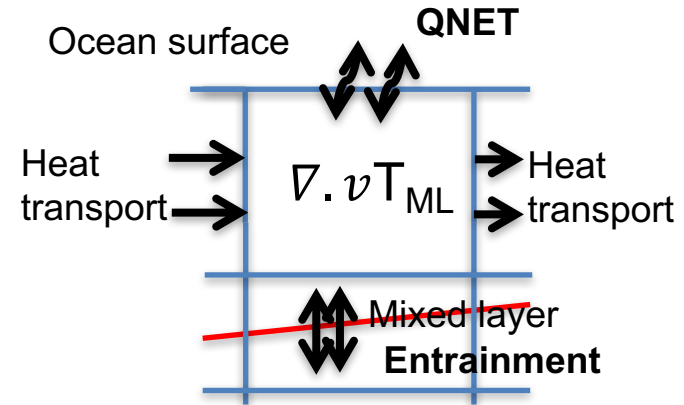
Similar equation relating $dSST/dt$ to changes due to ENT, Q_{net} and $\nabla \cdot vT$

Diagnosed from model temperature

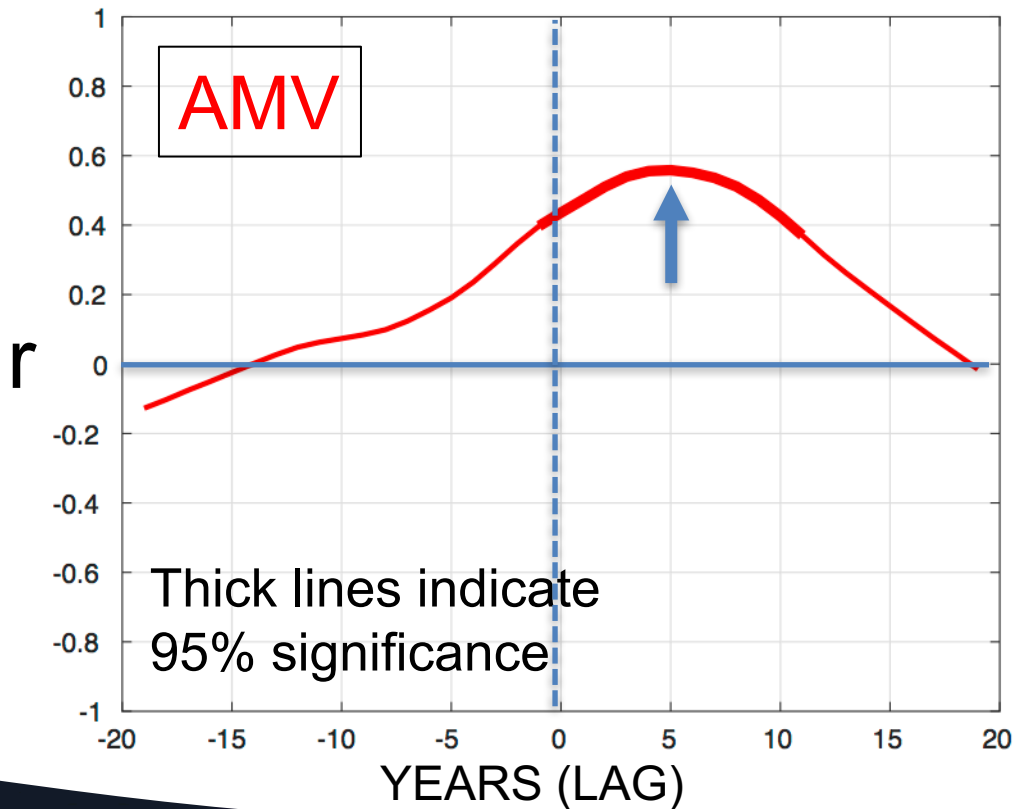
Diagnosed model mixed layer depth and temp

Diagnosed from model surface heat flux

residual



Relationship between AMOC and AMV

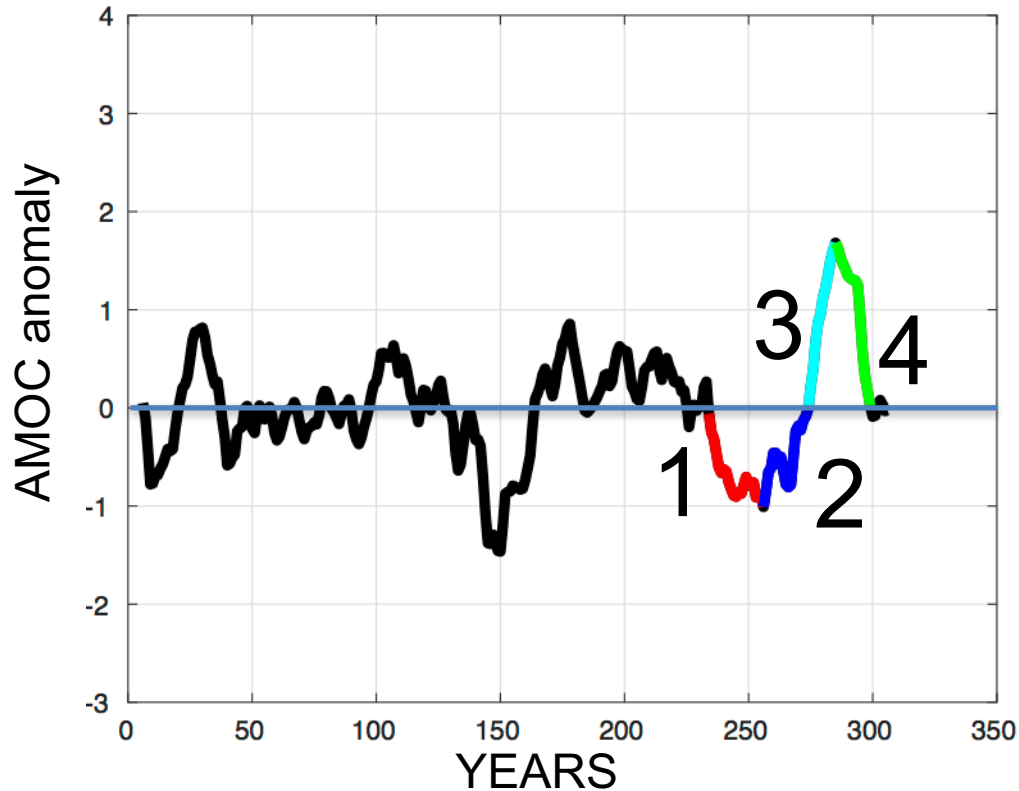


**AMOC leads the AMV
by 5 years**

**What is causing this
delay?**

300 years of model data

AMOC 26N



Analyze one cycle of the AMOC in terms of:

$dSST/dt$

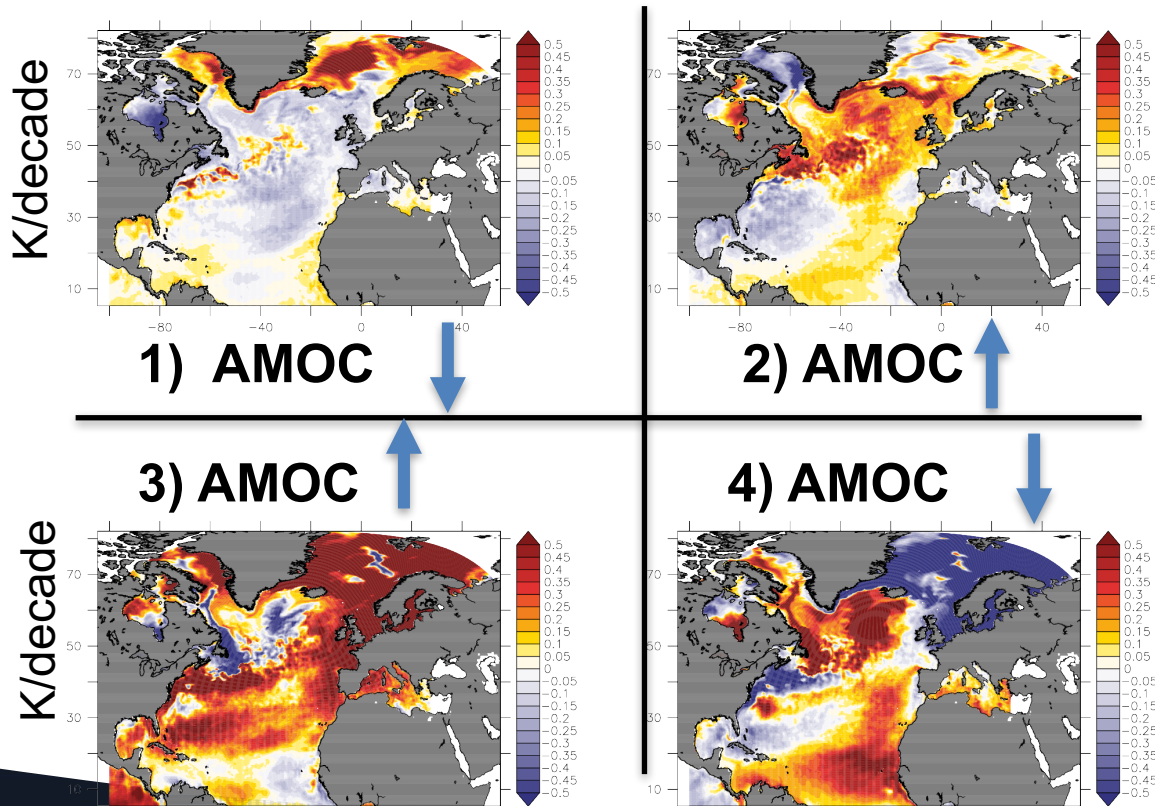
and its components related to:

ENT , $\nabla \cdot vT$ and Q_{net}

75 year cycle

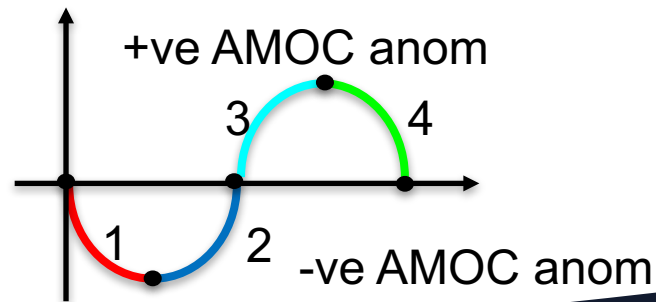
~20 years per phase

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

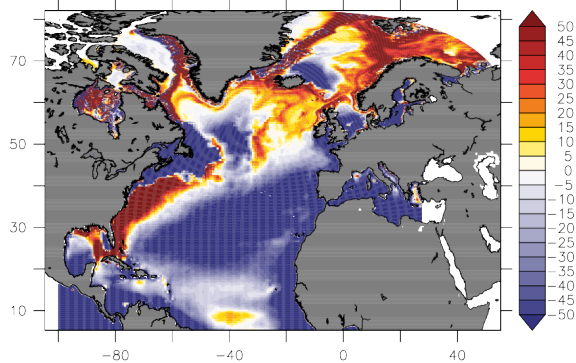
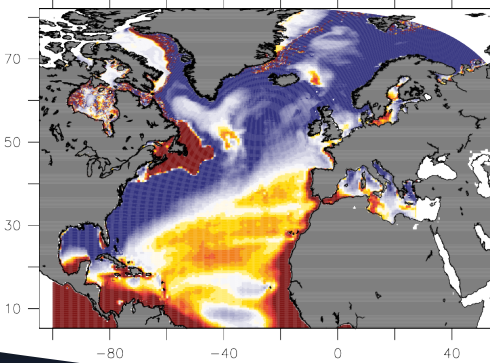
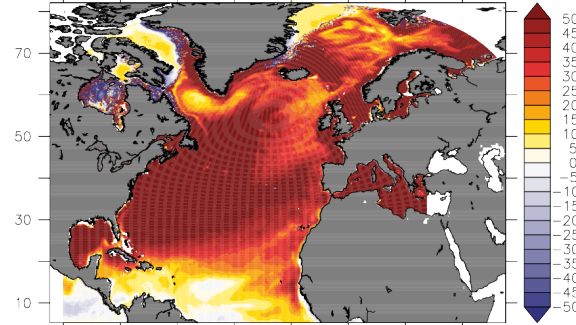
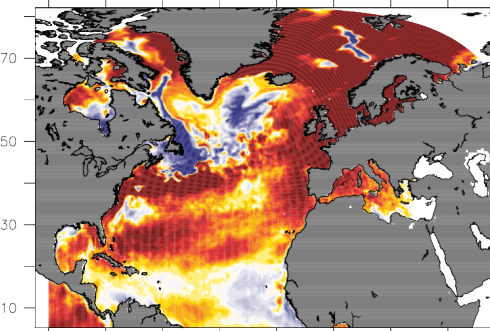
ENT: Entrainment always positive (for all phases)

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

$\nabla \cdot vT$: opposite to Qnet

Qnet

$\nabla \cdot vT$



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

SPG

Q_{net}

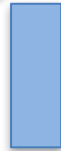


Heat convergence

T_{in}



T_{out}



$T_{out} < T_{in}$

time

One seasonal cycle

STG

Q_{net}



Heat divergence

T_{in}



T_{out}



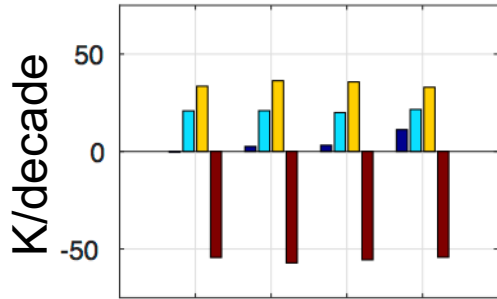
$T_{out} < T_{in}$

time

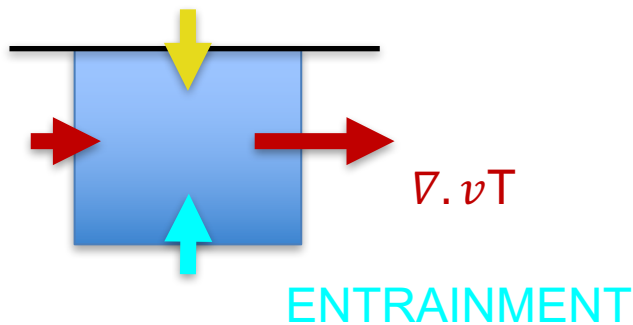
One seasonal cycle

Multi-decadal SST changes

Sub tropical Gyre

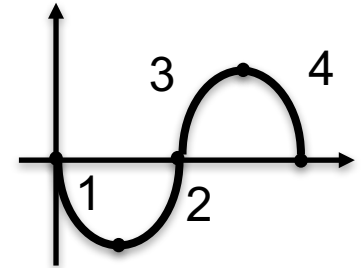


1 2 3 4



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

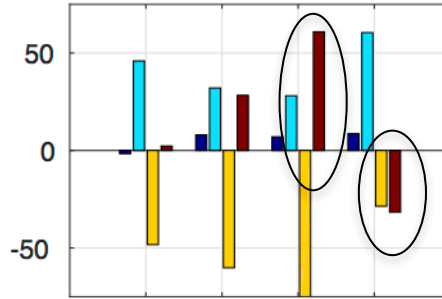
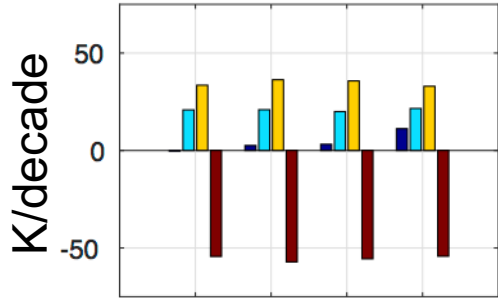
$\nabla \cdot vT$ is always cooling the mixed layer.



Multi-decadal SST changes

Sub tropical Gyre

Sub Polar Gyre



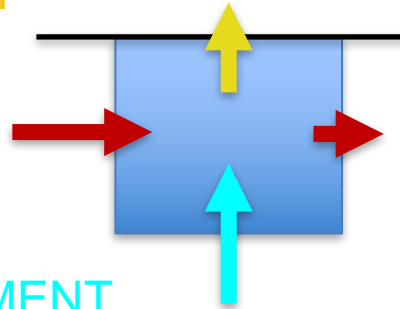
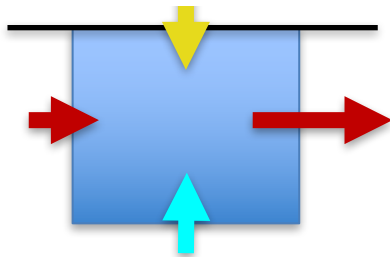
SPG behaves differently to STG.

Phase 3 to 4 $\nabla \cdot vT$ changes sign, but SST continues to warm. This is due to increased ENT and reduced QNET

1 2 3 4

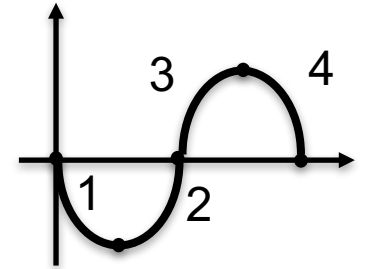
1 2 3 4

QNET

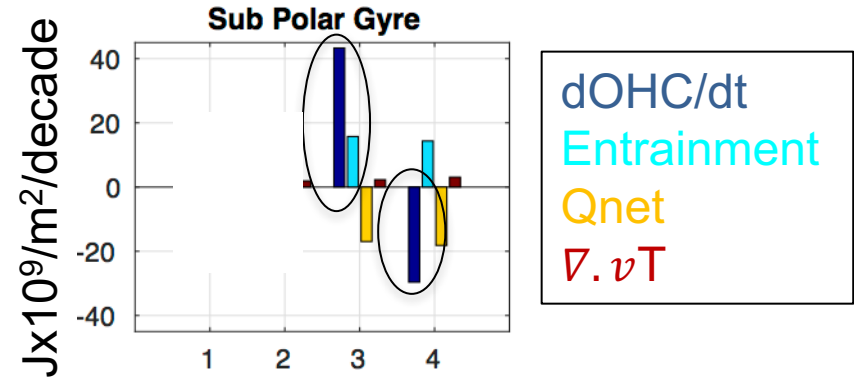


$\nabla \cdot vT$

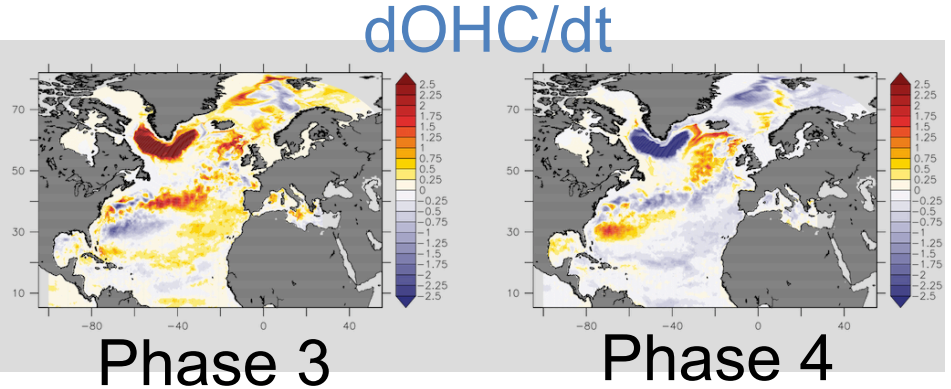
ENTRAINMENT



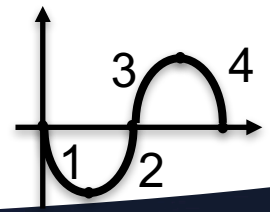
SPG OHC changes



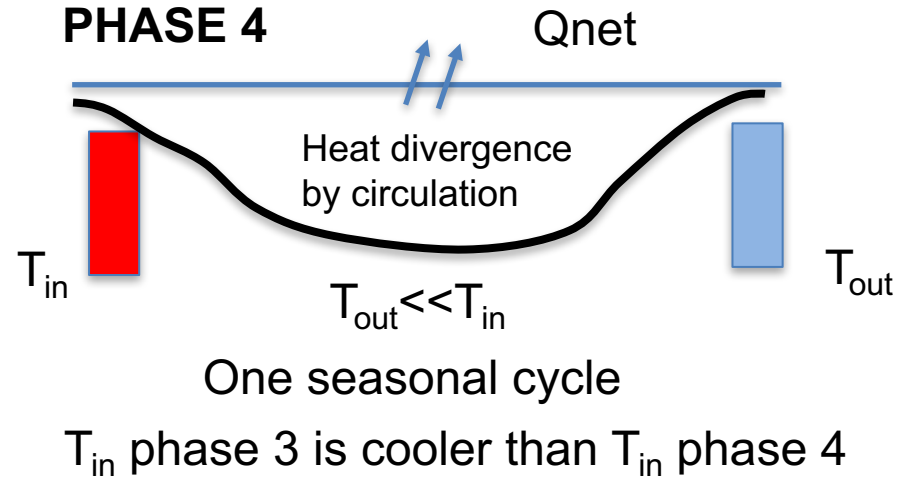
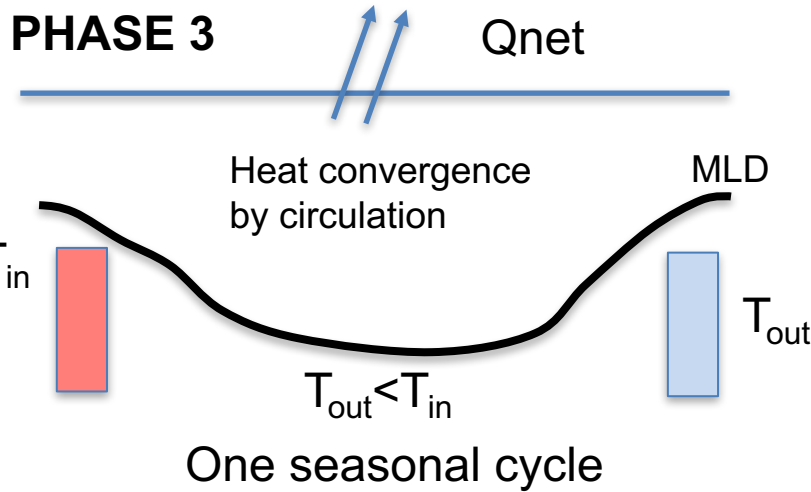
In phase 4 OHC change in the SPG is reducing, while the SST is increasing!



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 Q_{net} explain the lag between AMOC and AMV



The Blue-Action project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727852