Ocean component of CERA-20C: heat content, fluxes and sea-ice

Eric de Boisséson

ERA-CLIM2 General Assembly, Universität Wien 16-18 January 2017

Introduction

- CERA20C production was divided 14 streams starting every 8 years

- IC are taken from uncoupled reanalyses: ERA-20C for the atmosphere, ORA-20C for the ocean

- ORA-20C is a ten-member ensemble of 20th century ocean reanalyses forced by ERA-20C

- CERA-20C ocean ensemble members restart every 8 years from ORA-20C ICs.

- ORA-20C also serves as reference for CERA-20C ocean

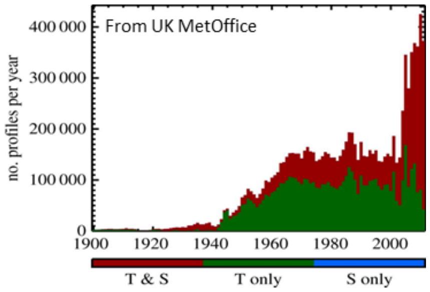
ORA-20C vs CERA-20C

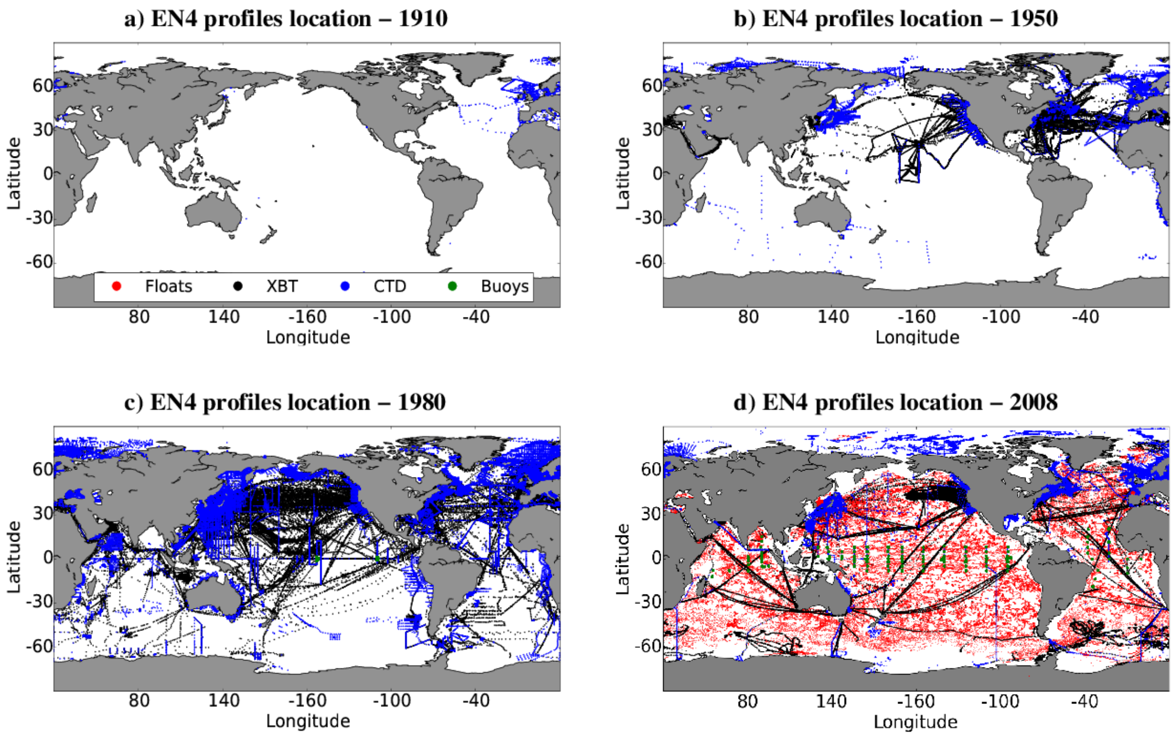
- ORA-20C and CERA-20C are based on the same NEMO configuration:
  - 10 members, ORCA1Z42 resolution
  - Active LIM2 sea-ice model (no sea-ice DA)
  - SST relaxation towards HadISST2 monthly analysis (~2-3-day timescale)
  - 3D relaxation to subsurface T/S climatology (20-year timescale)
  - Assimilate the same EN4 T/S profiles

- The main differences are:
  - ORA-20C is forced by ERA-20C
  - CERA-20C: ocean-atmosphere interactions through the coupled model
  - DA window: 1 month in ORA-20C, 24h in CERA-20C
  - ORA-20C is continuous, while CERA-20C restart every 8-years from ORA-20C ICs.

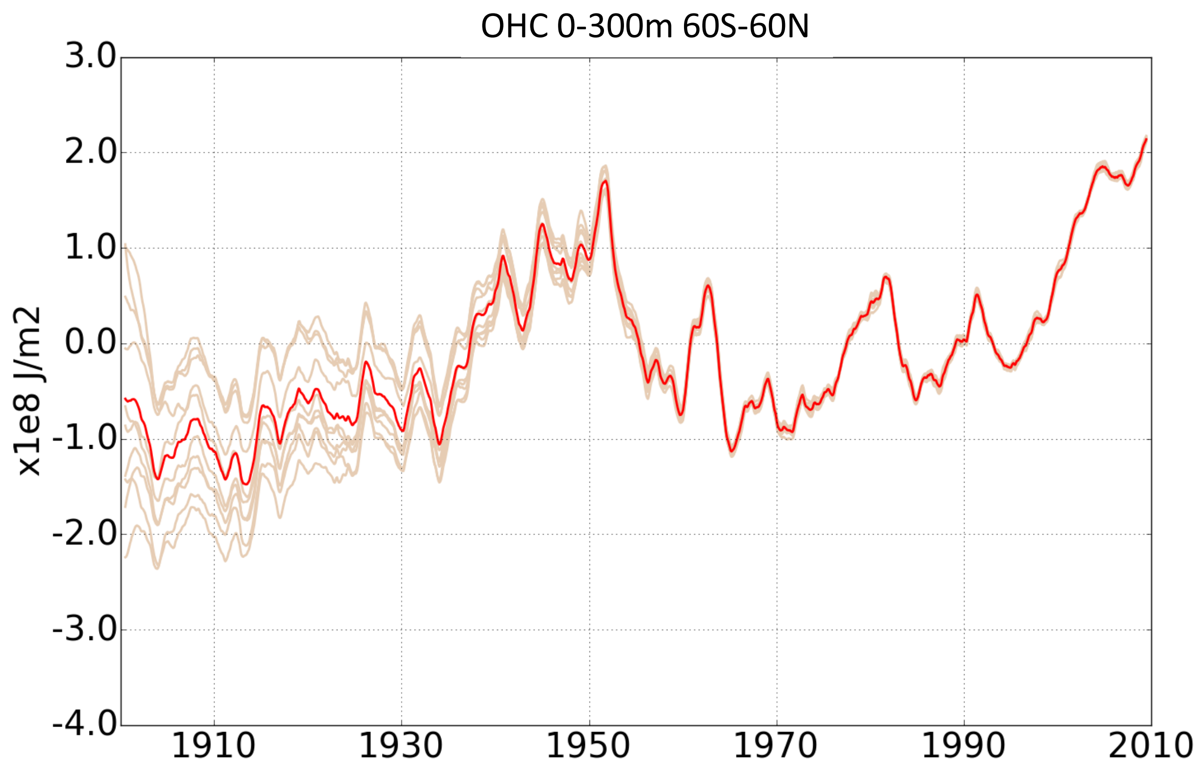
Evolution of ocean observing sytem

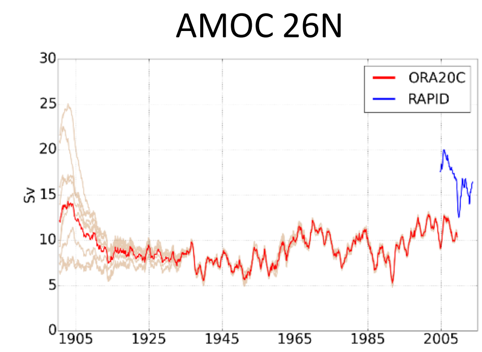
- ORA-20C and CERA-20C both assimilate EN4 T/S profiles
- Observing system grows rapidly in the 2nd half of the century

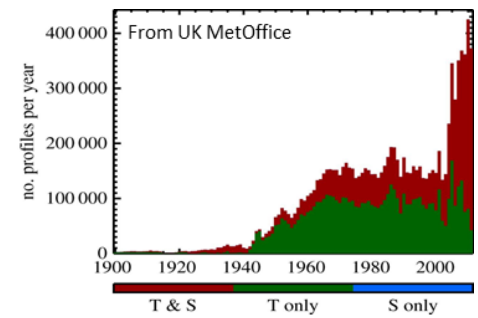




Ocean Heat Content – ORA-20C

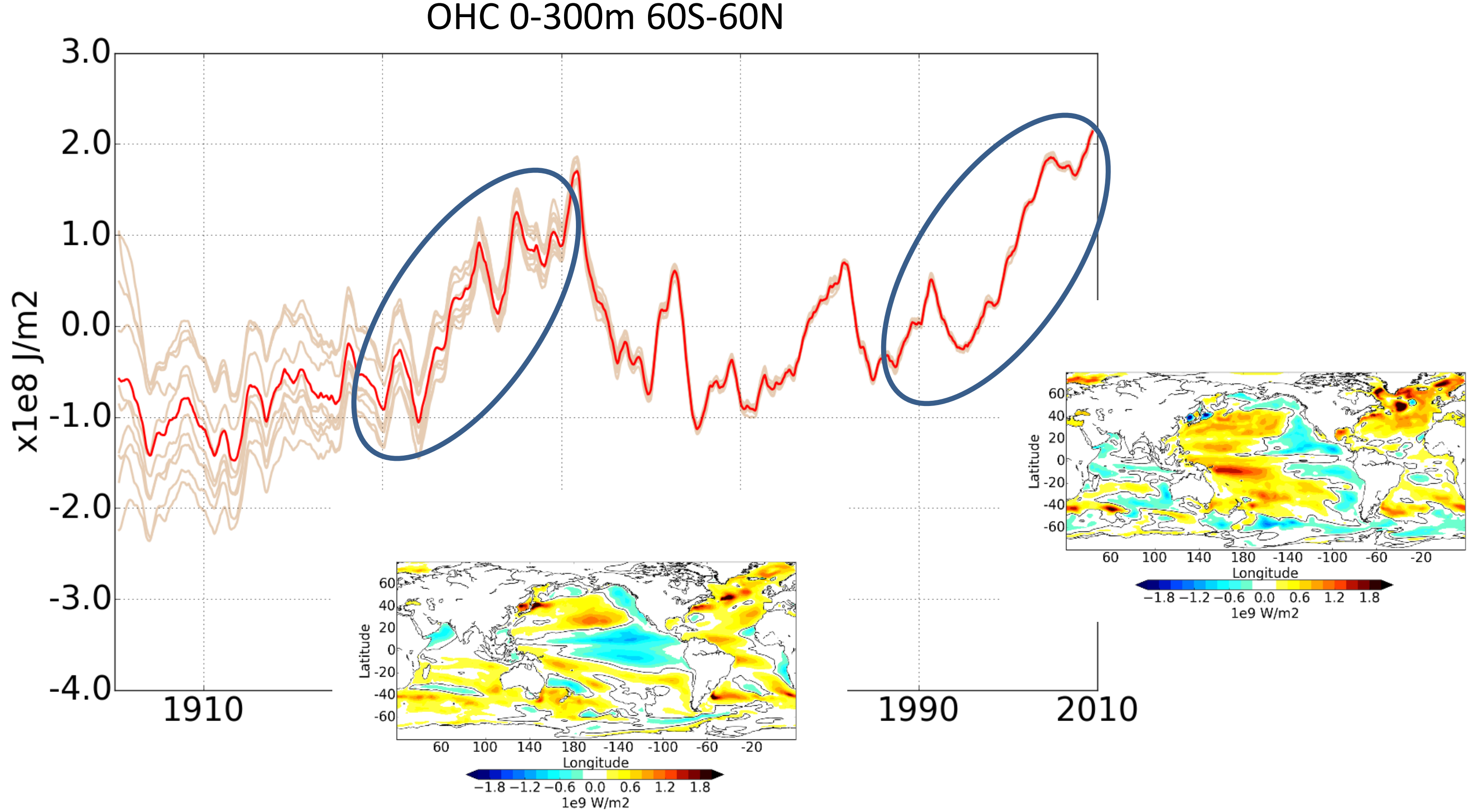






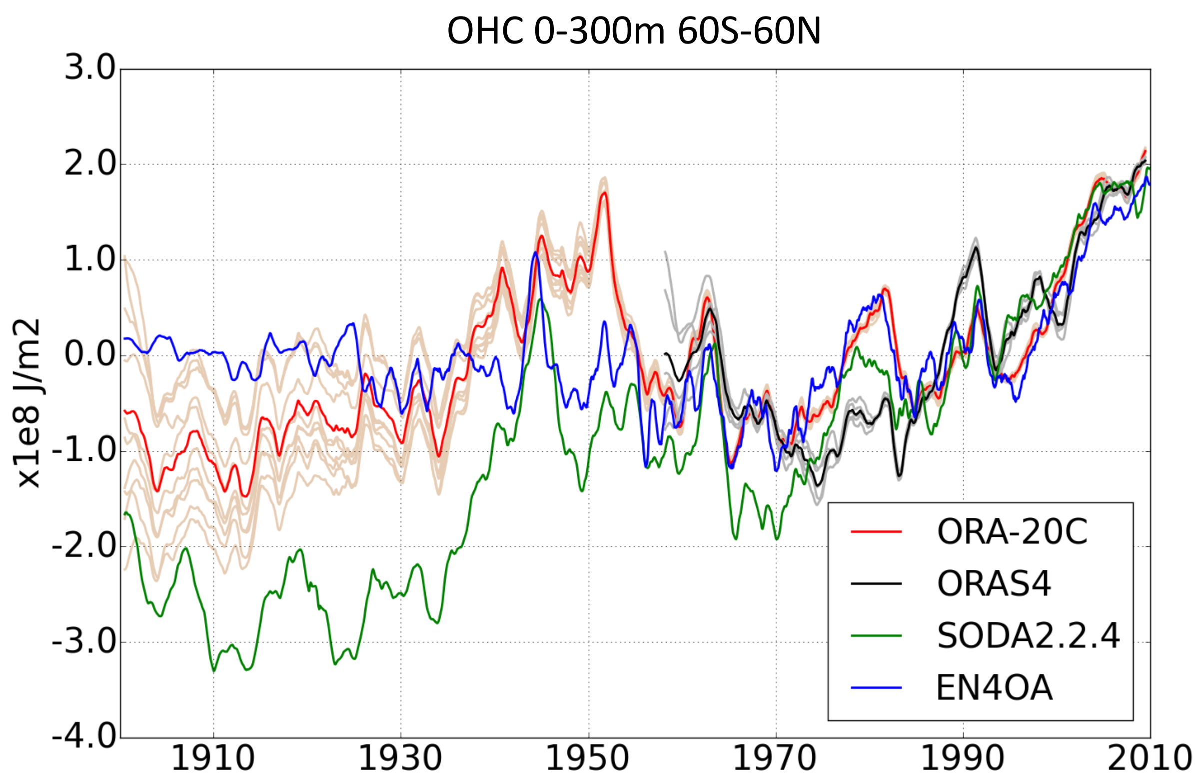
- ORA-20C has large spread in the first half of the century
- The spread decreases as the memory of the IC vanishes and the model drifts towards a warmer state and a weak AMOC. Further decrease as the number of observations increases
- Spurious cooling at the transition from poorly to well-observed period

Ocean Heat Content – ORA-20C



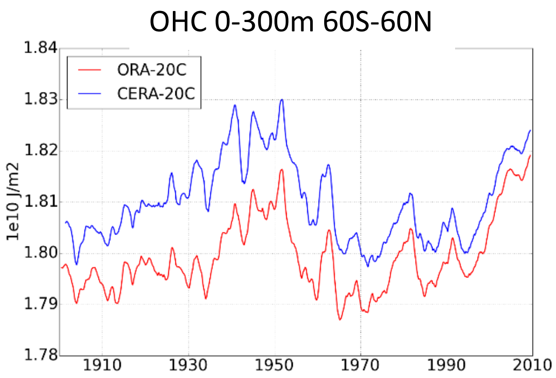
- Two periods of accelerated warming corresponding to change of phases of PDO (-) and AMO (+)

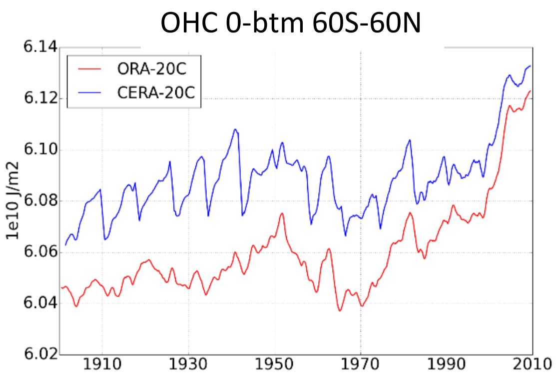
Ocean Heat Content – ORA-20C

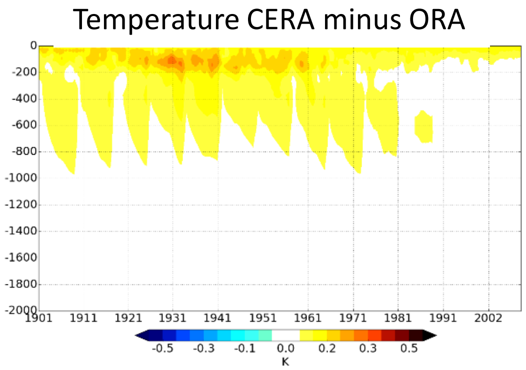


- ORA-20C shows good agreements with other products in the well-observed period

Ocean Heat Content – ORA-20C vs CERA-20C

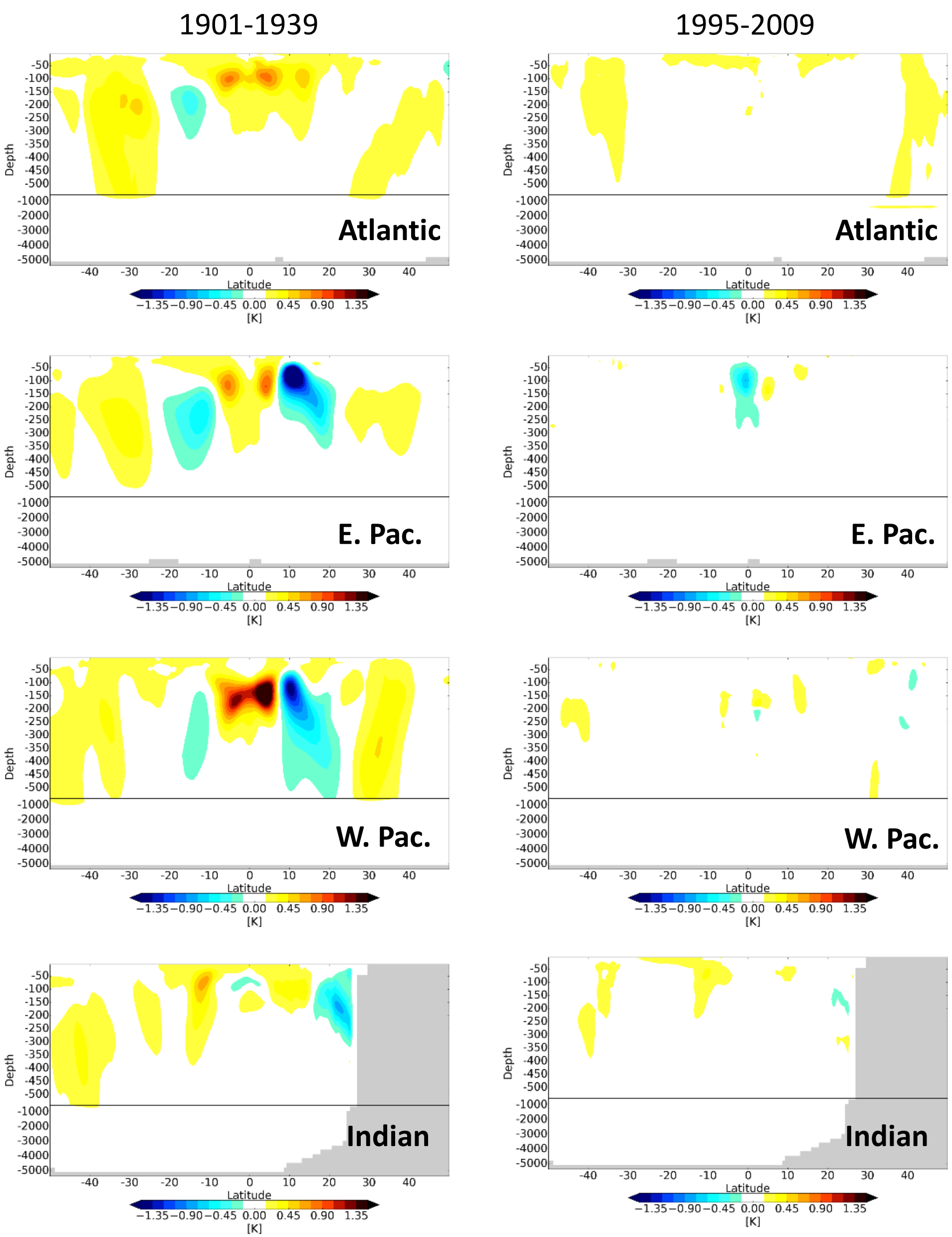






- CERA-20C shows similar variability in the upper-ocean. Relatively good consistency of the record in spite of the use of streams
- Strong discontinuities when considering the whole column that vanish in the last decades
- CERA-20C warmer than ORA-20C
- Initialization shock at the beginning of each stream. Differences in surface fluxes transferred at depth after a few months. Reduced in well observed period
- Would need a much longer overlap to get rid of the discontinuities. Not feasible in that context.

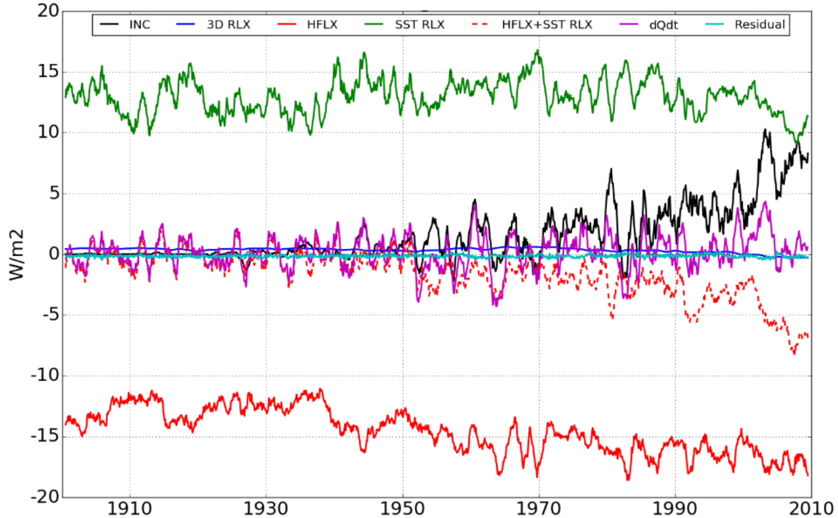
Temperature differences – ORA-20C vs CERA-20C



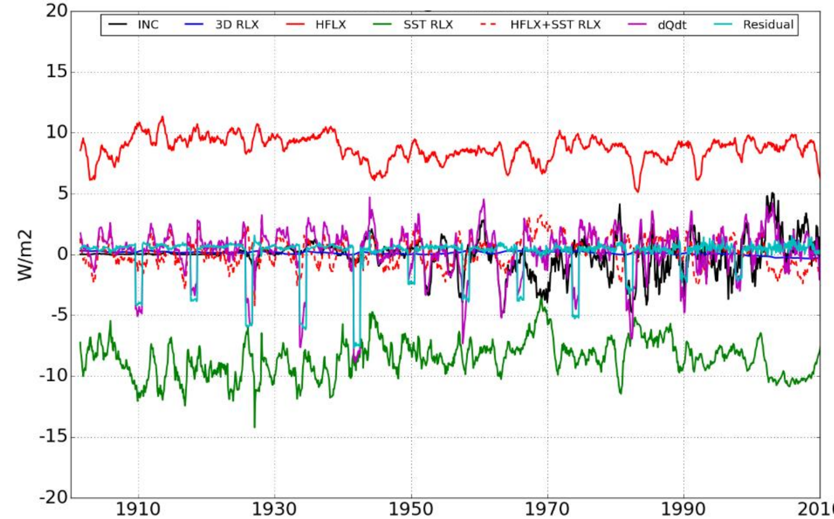
- The near-surface in CERA-20C gets warmer in the Tropics and Subtropics. The warming is trapped below the thermocline
- The warming is transferred below 300m in the Subtropics: mode water subduction?
- The differences vanish in the latest years as the observational constraint is higher
- Origin of the difference: coupled model dynamics, fluxes

Heat budget – ORA-20C vs CERA-20C

Heat Budget ORA-20C



Heat Budget CERA-20C

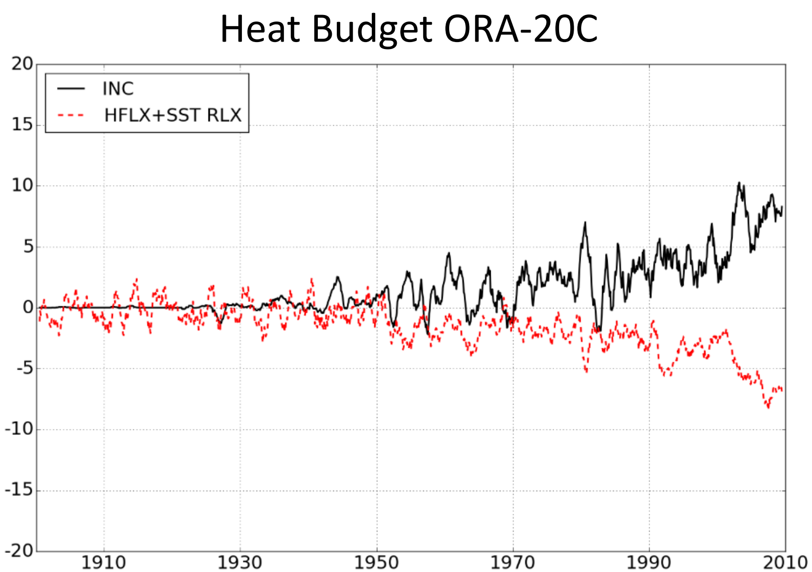


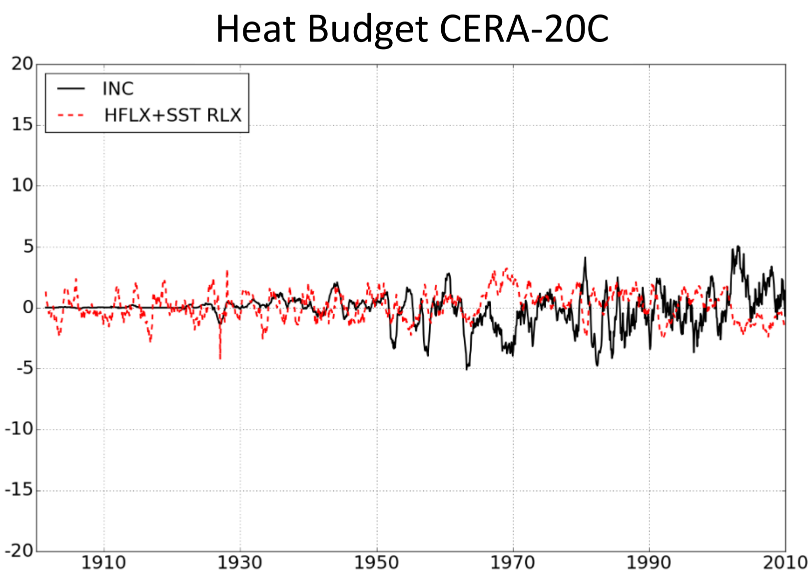
dQdt = Net HFlx + SST RLX + INC + 3DRLX + Resid

-- Net HFlx+Corr

- Both atmospheric heat fluxes and SST relaxation terms have opposite signs in ORA-20C and CERA-20C.
- Flux control the OHC variations in the early decades. Increments gain importance later on.
- The increment is controlling the changes in heat content in the last decade of both ORA-20C and CERA-20C. Large impact of the Argo data.

Heat budget – ORA-20C vs CERA-20C





- INC -- Net HFlx+Corr

- Heat fluxes in ORA-20C show a negative trend in ORA-20C from 1950s onwards.
- The trend is compensated by increasingly positive increments. Inconsistency at the air-sea interface.
- CERA-20C show fluxes and increments oscillating around 0W/m2. Better consistency in coupled mode.

Surface flux differences – ORA-20C vs CERA-20C

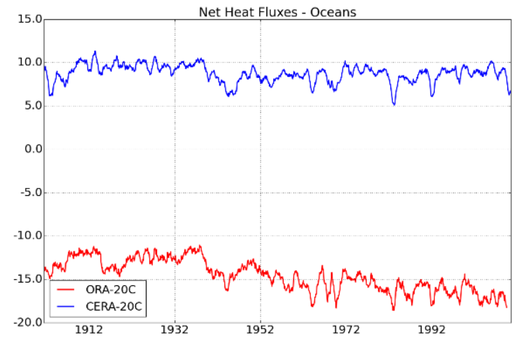
Different ways of estimating surface heat fluxes at the air-sea interface

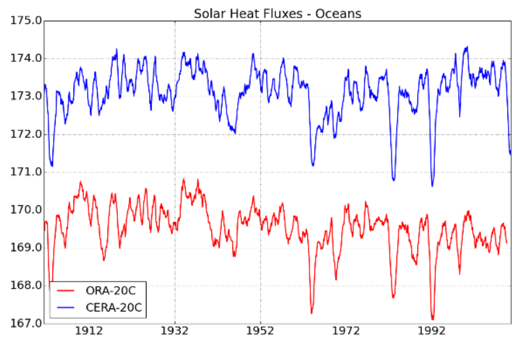
- ERA-20C: IFS bulk formula using SST and sea-ice from HadISST2 (no ocean dynamics involved).

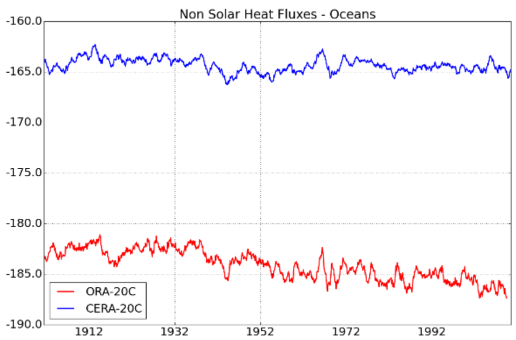
- ORA-20C: CORE bulk formula within NEMO using atmospheric surface variable from ERA-20C (Incoming solar radiation, T2m, Qsurf, U10, V10). The ocean dynamics impacts the surface forcing.

- CERA-20C: IFS bulk formula within the coupled system. Interaction between atmospheric and ocean components

Surface flux differences – ORA-20C vs CERA-20C

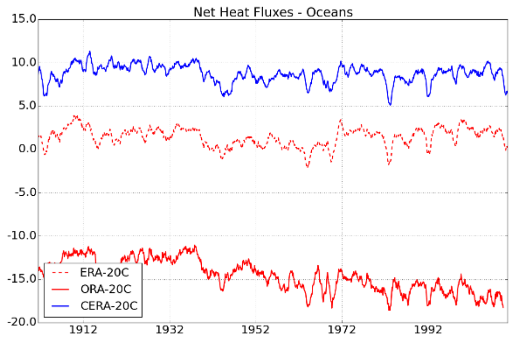


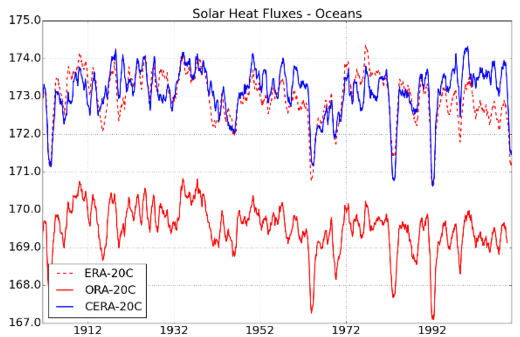


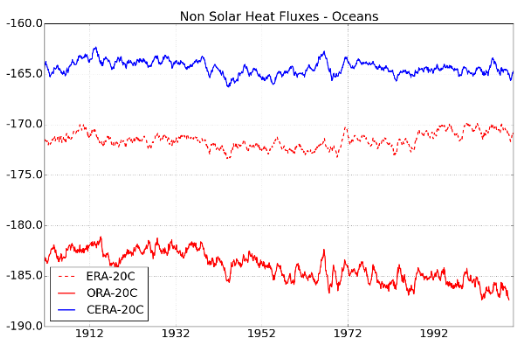


- Large difference in net heat fluxes ~25 W/m2. Compensated by SST relaxation and increments
- Solar heat fluxes differences ~4W/m2
- Non solar heat fluxes differences ~20W/m2 that come mainly from the turbulent heat fluxes. Responsible for the negative trend from the 1950s onwards in ORA-20C
- The differences in heat content may come from differences in fluxes received by the ocean at the change of stream (initialization shock)

Surface flux differences – ORA-20C vs CERA-20C





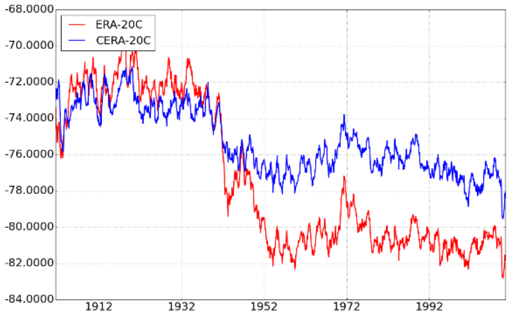


- Such large differences are due to the use of bulk formulation in ORA-20C
- Flux computed within ERA-20C not so far from CERA-20C
- The decreasing trend in heat flux is not seen in ERA-20C. Impact of the ocean increment in ORA-20C
- CERA-20C suffers from initialization shock but the coupling brings consistency at the air-sea interface

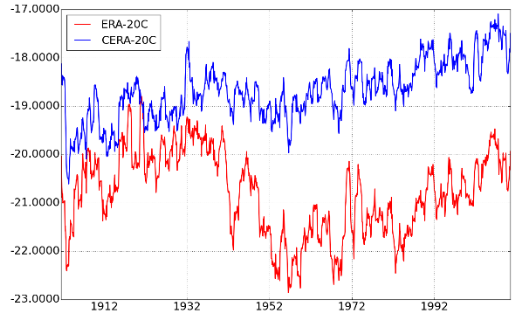
Surface flux differences – ERA-20C vs CERA-20C

Improvements in the data assimilation make CERA-20C less sensitive to change in the observing system

Surface latent Heat flux – 30N-70N

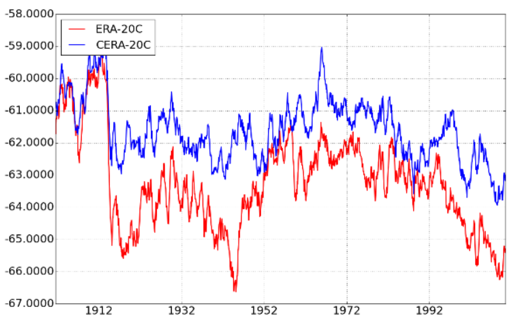


Surface sensible Heat flux – 30N-70N

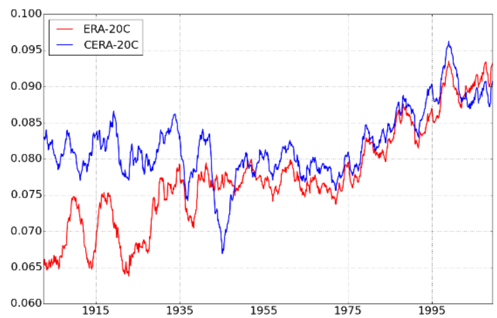


- Jump in turbulent fluxes in the N. extratropics due to changes in wind speed observations reduced

Surface latent Heat flux – 70S-30S

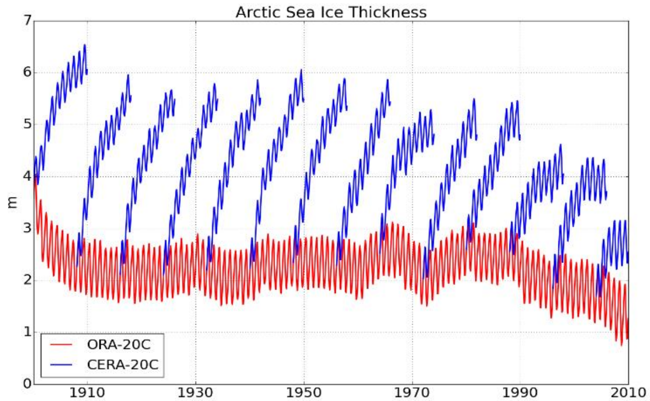


Zonal wind stress – 70S-30S

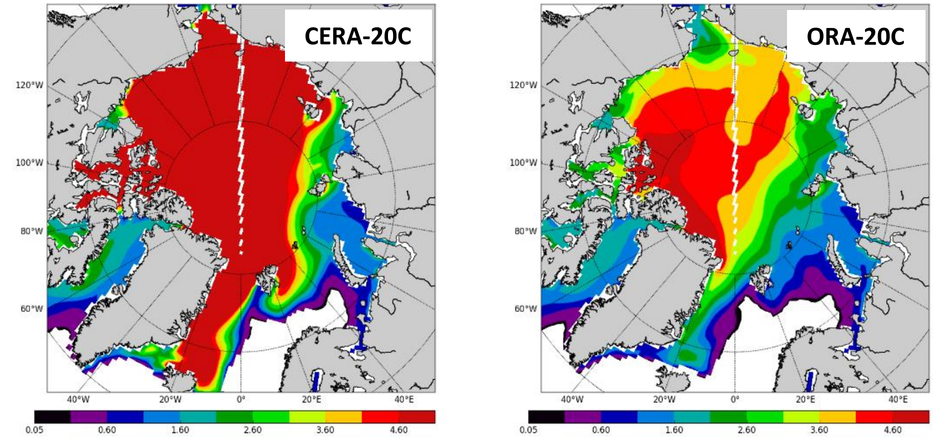


- Less sensitivity to observations in poorly-observed regions like the Southern ocean. Records more consistent.

Sea-ice – ORA-20C vs CERA-20C

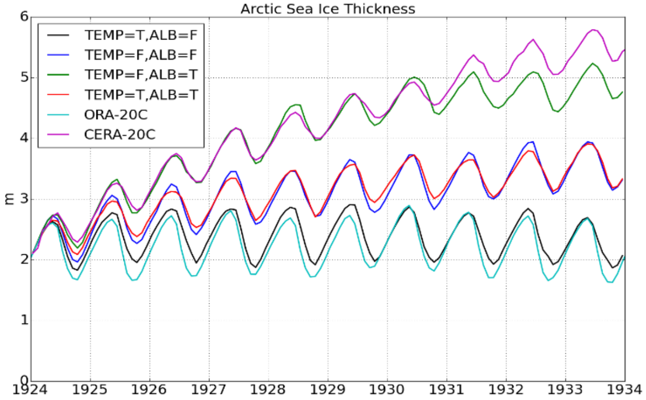


Sea ice thickness March 1932

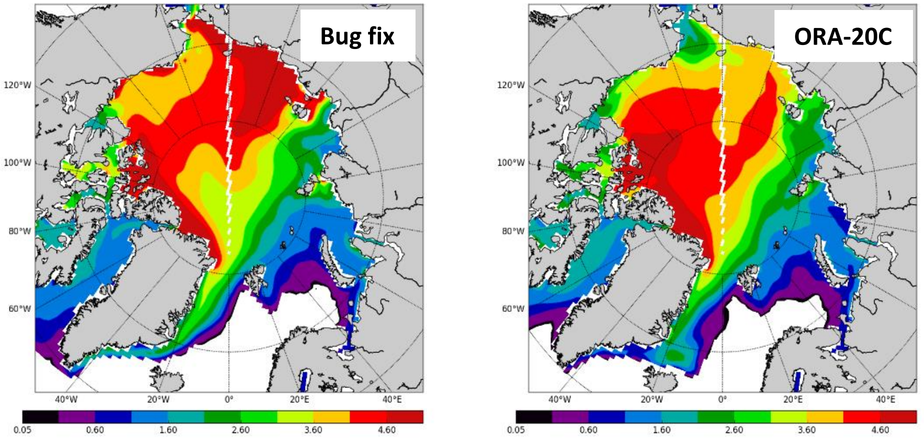


- Sea Ice accumulation in the Arctic in CERA-20C
- Not enough melting in the summer period
- The impact on the sea-ice extent is limited by the SST relaxation

Sea-ice – ORA-20C vs CERA-20C



Sea ice thickness March 1932



- Coupled experiments showed that the coupled settings for LIM chosen for CERA-20C were not suitable (problem with temperature and albedo coupling) + bug conductivity

- New settings (temperature coupled/albedo uncoupled) + bug fix for CERA-SAT sea-ice should get rid of sea-ice accumulation

Conclusion

- CERA20C upper ocean shows similar variability to ORA-20C. Large impact of the ODA in the second half of the century
- Initialization shock at the beginning of each stream leads to a warming that is transferred at depth and create discontinuities in the ocean interior
- Heat budget and flux analysis show the limits of uncoupled approach for the treatment of the air-sea interface. CERA-20C shows more consistency than ORA-20C/ERA-20C
- DA improvements provides more consistent records of air-sea fluxes in CERA-20C than in ERA-20C
- Sea-ice issues in the CERA-20C record. Sea-ice accumulation in the Arctic. Corrected for CERA-SAT