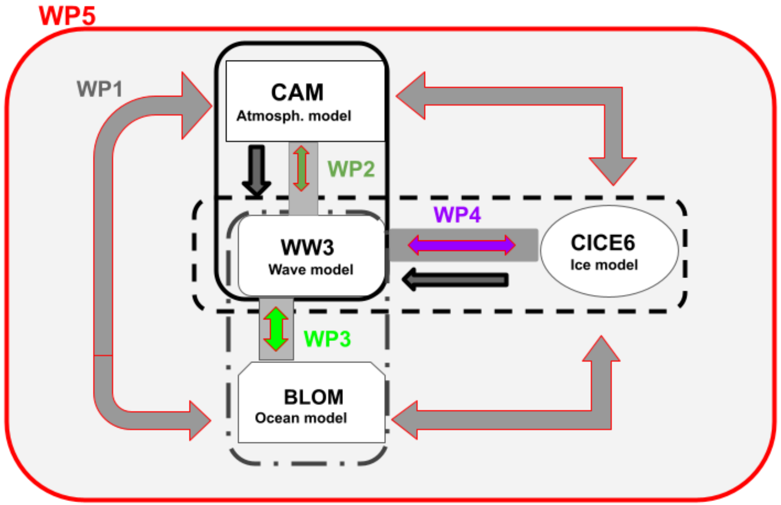
Effects of atmosphere-surface ocean waves two-way coupling on the simulated climatology of the North Atlantic

Thomas Toniazzo (NORCE and Bjerknes Centre, Bergen, Norway)

Fifth workshop on waves and wave-coupled Processes
ECMWF, Reading, 10 April 2024

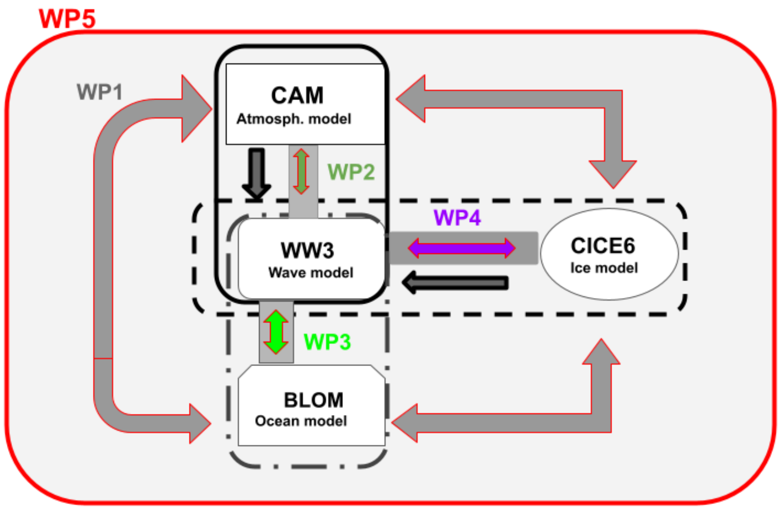
The “Making Waves” collaboration

***Ana Carrasco**, Ali Alfatih, Mats Bentsen, Øyvind Breivik, Kai Christensen,*
Jens Debernard, Thea Ellevold, Alexi Nummelin, Thomas Toniazzo
(ackn. Mariana Vertenstein)



- Drawing from different experience in
  - Operational forecasting
  - Climate simulations
- Combining existing expertise on waves, ocean, sea-ice, and atmosphere
- Include wave effects in climate simulations
  - Air-sea fluxes
  - Ocean mixing and mechanical forcing
  - Sea-ice growth and break-up

Ocean waves and **climate**



- Operational use of surface wave models mature in weather forecasting
- Main documented effect is the enhanced barometric filling of strong depressions due to increased surface friction

➔ climate simulations aimed to understand ***potential*** effects associated with

- ➔ Persistent changes in dsitribution of air-sea fluxes and diabatic heating of atmosphere
- ➔ Ocean stirring and mixed-layer deepening
- ➔ WRS on and break-up of marginal ice

➔ Coupling might amplify individual effects

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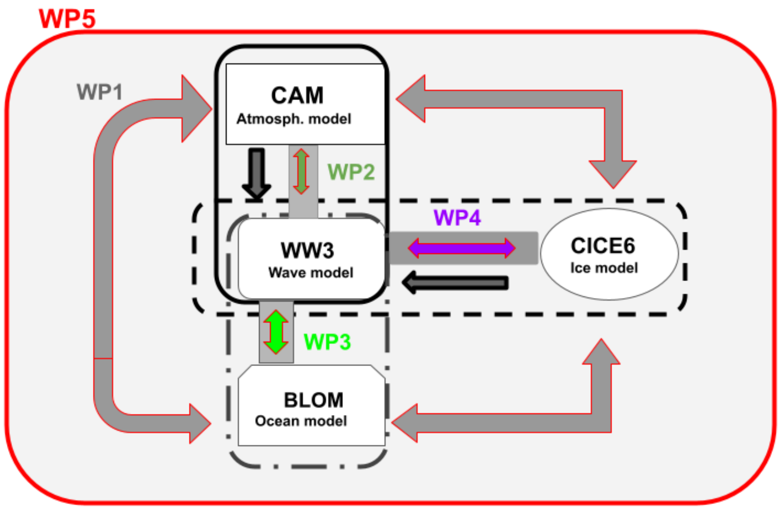

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This talk

- Coupling might amplify individual effects

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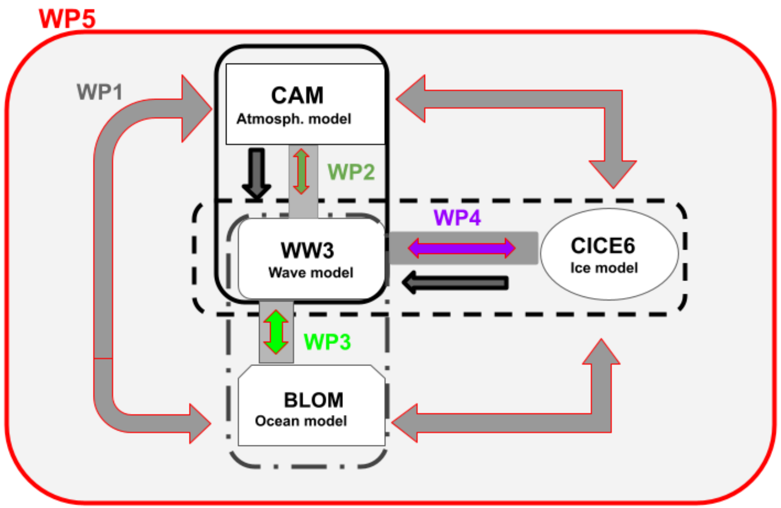

Also in this workshop:

Øyvind Breivik (MET Norway), Thu 9am

Alfatih Ali (MET Norway), poster

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COARE 3 (Fairall et al. 2013) + Drennan et al. (2005)

$$\begin{cases} {u_*}^2 = C_D \left[U(z) - U_s \right]^2 \\ C_D = \dfrac{\kappa^2}{\left[\Psi(z + z_0) - \Psi(z_0) \right]^2} \\ z_0 = a \dfrac{u_*^2}{g} + b \dfrac{\nu}{u_*} \end{cases}$$

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"Charnock parameter"

QL theory of Janssen (1989, 1991); Varlas et al. (2018)

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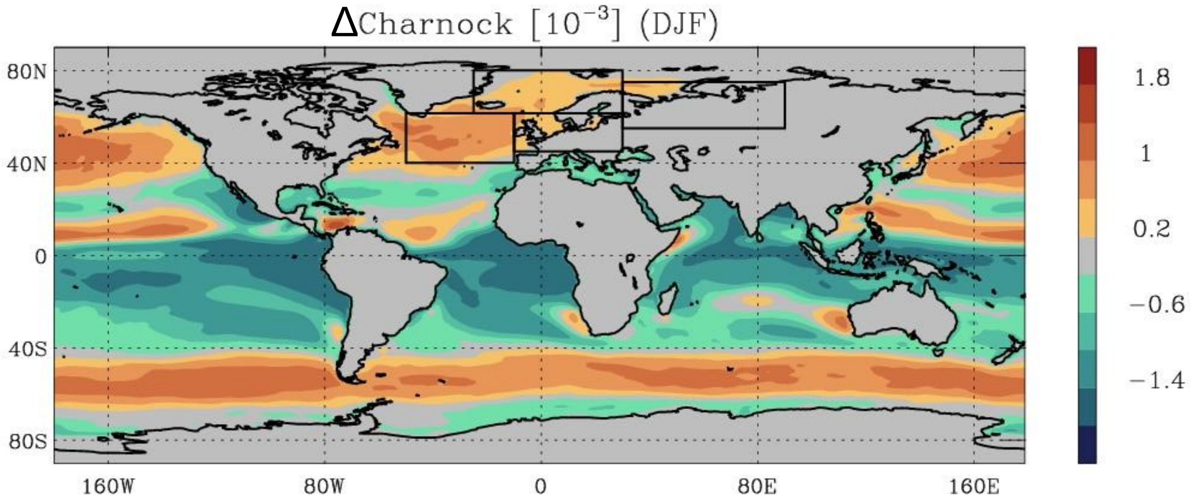
Configuration of the numerical experiments

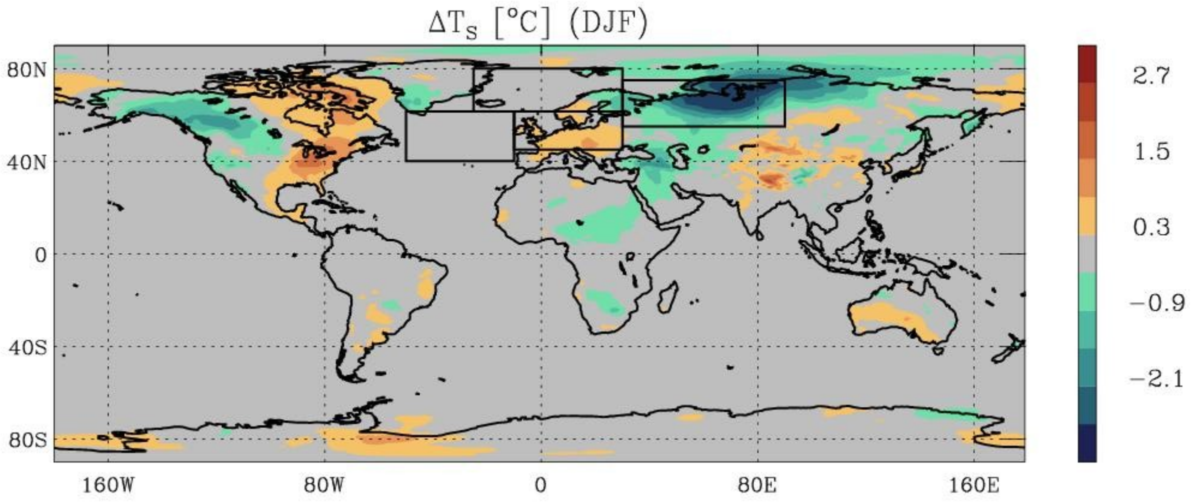
- development version of CAM-CLUBB (based on tag cam6_3_41), FV dycore, 32 levels
- WW3 dev (tag dev/unified_0.0.2) on tn066 grid
- prescribed
  - SSTs
  - sea-ice concentration
  - atmospheric composition
- Repeating annual cycle from observed monthly climatology of the decade around year 2000
- 10 years after first year spin-up
- 6 experiments from 3 control simulations (f09, f09 de-tuned, f19)

Effect of two-way (wave-Charnock) coupling on the simulated DJF climatology

"Δ" = two-way minus one-way coupling

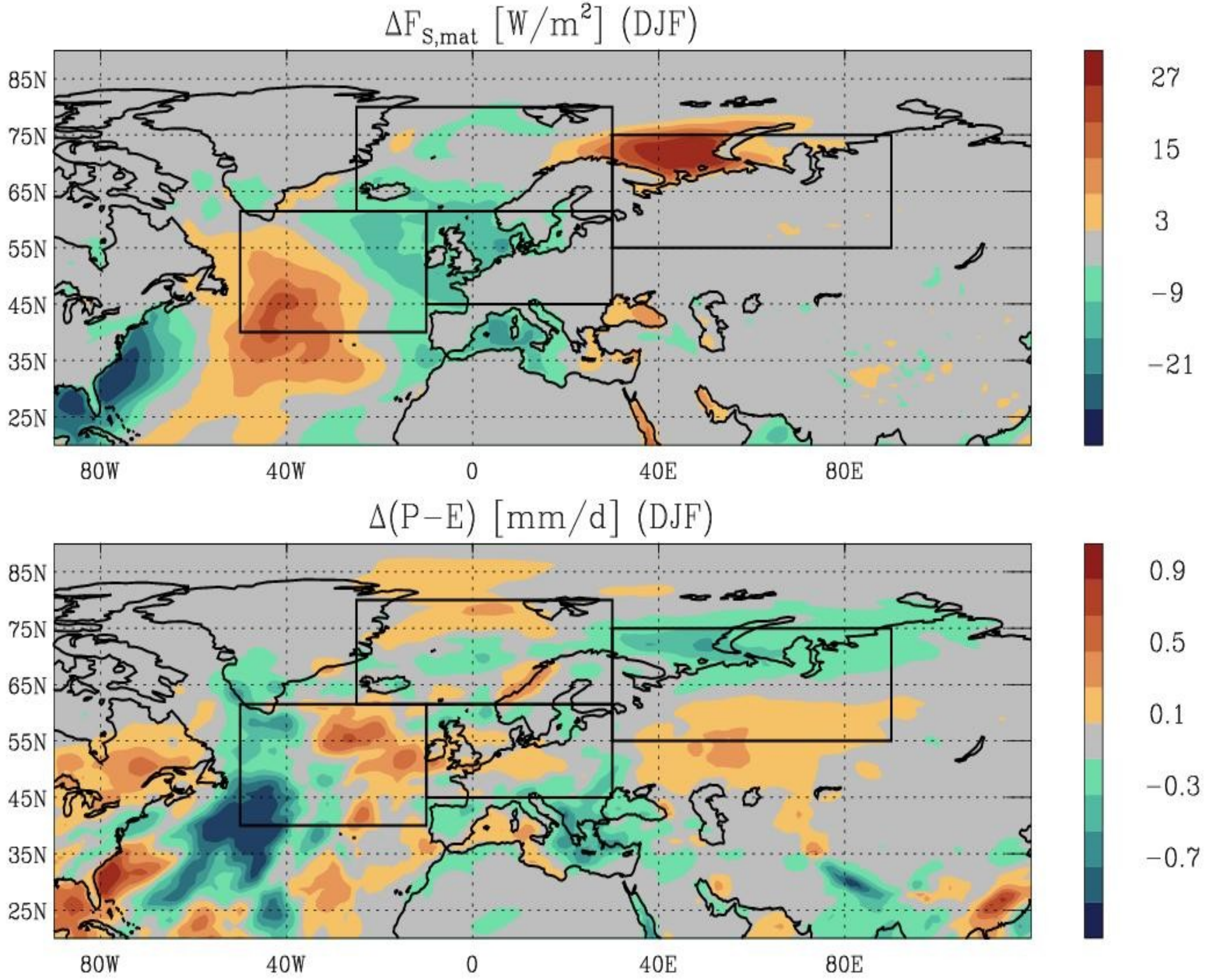
- Warmer in Europe
- Colder over Barents and Kara seas





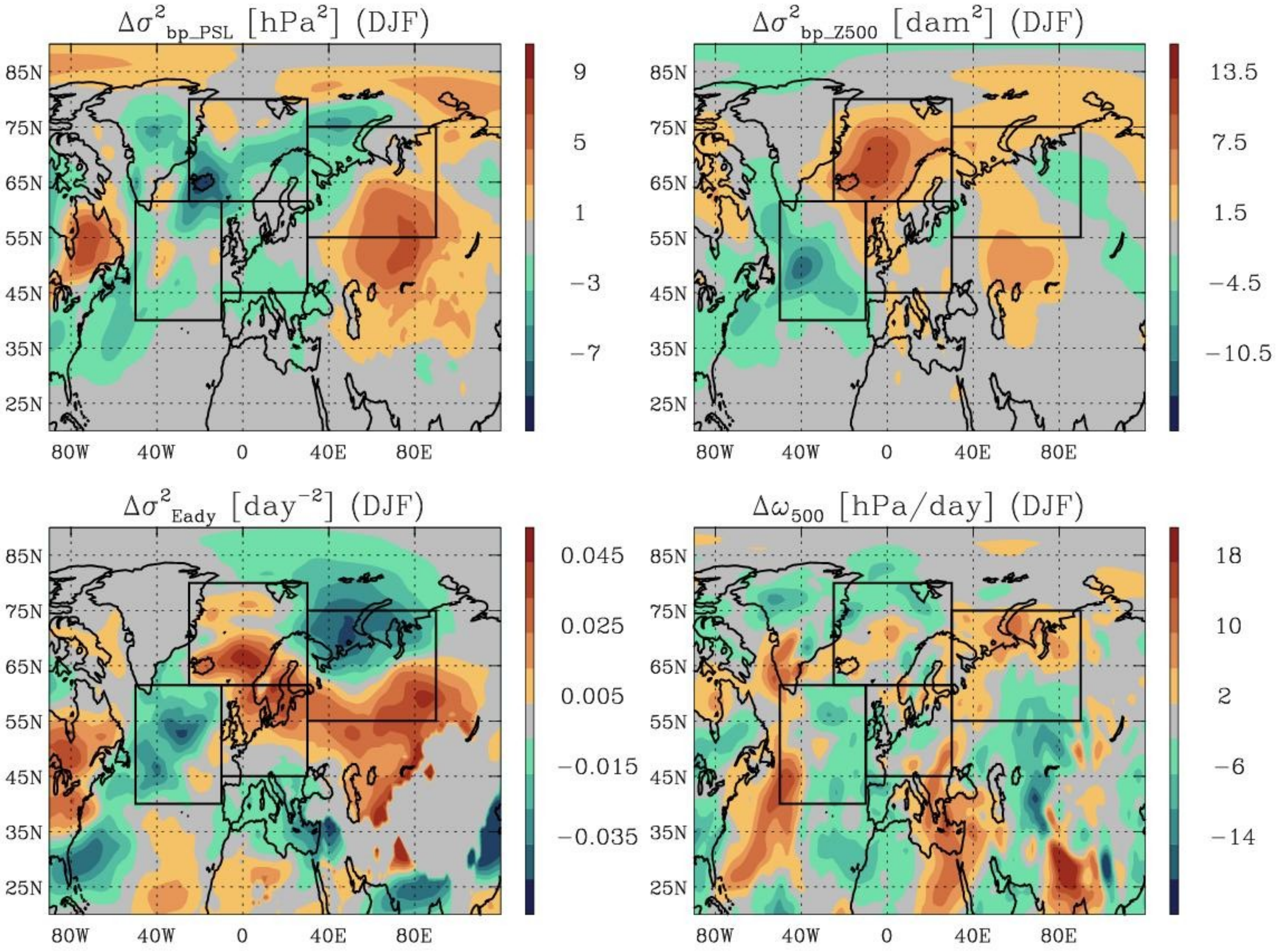
Wave-Charnock and simulated DJF climatology

- Increased evaporation over North Atlantic
- Increased precipitation downstream



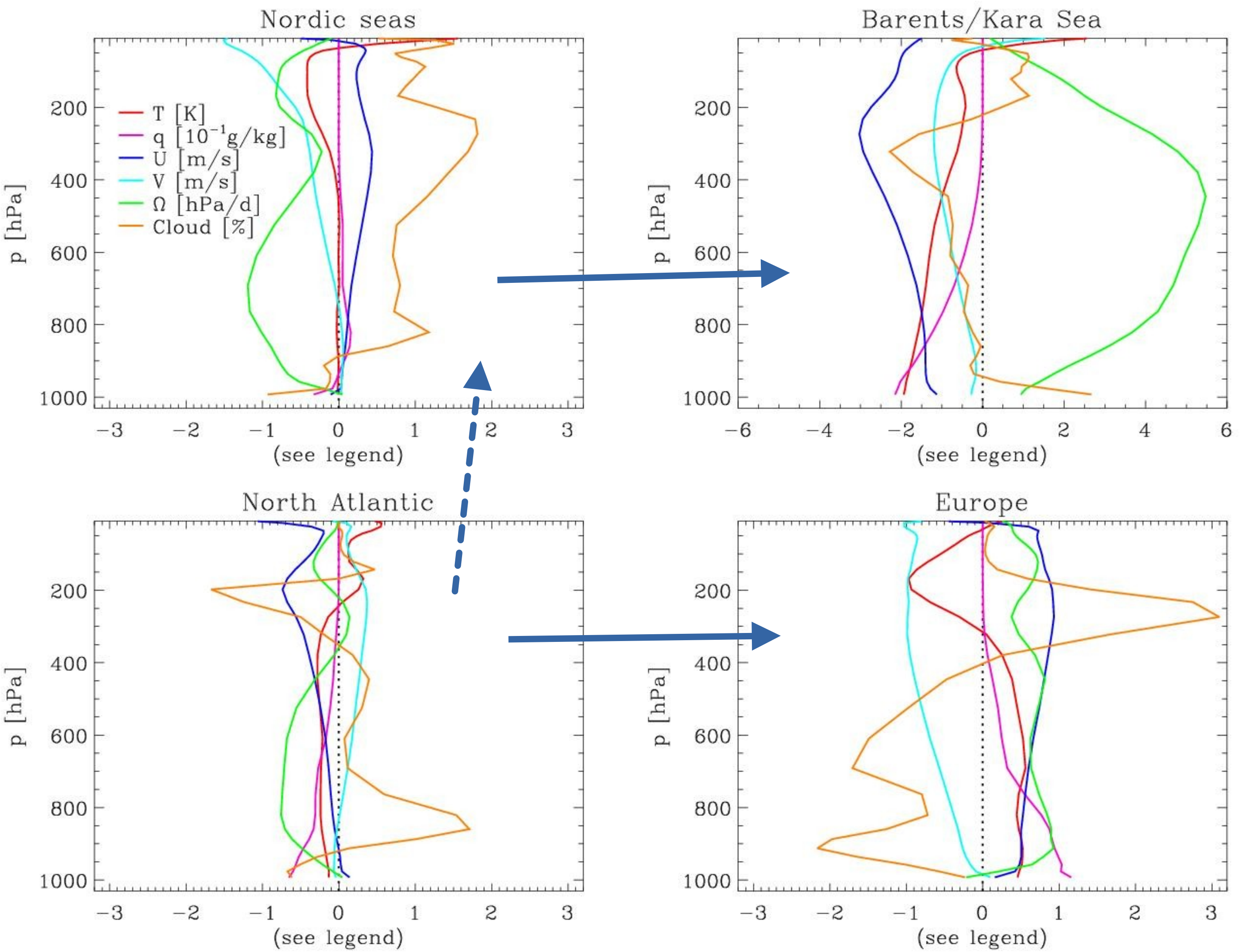
Wave-Charnock and simulated DJF climatology

- 2-6 day PSL variance decreases over ocean
- But overall baroclinic activity increases downstream of central North Atlantic
- mid-tropospheric descent over Barents and Kara seas



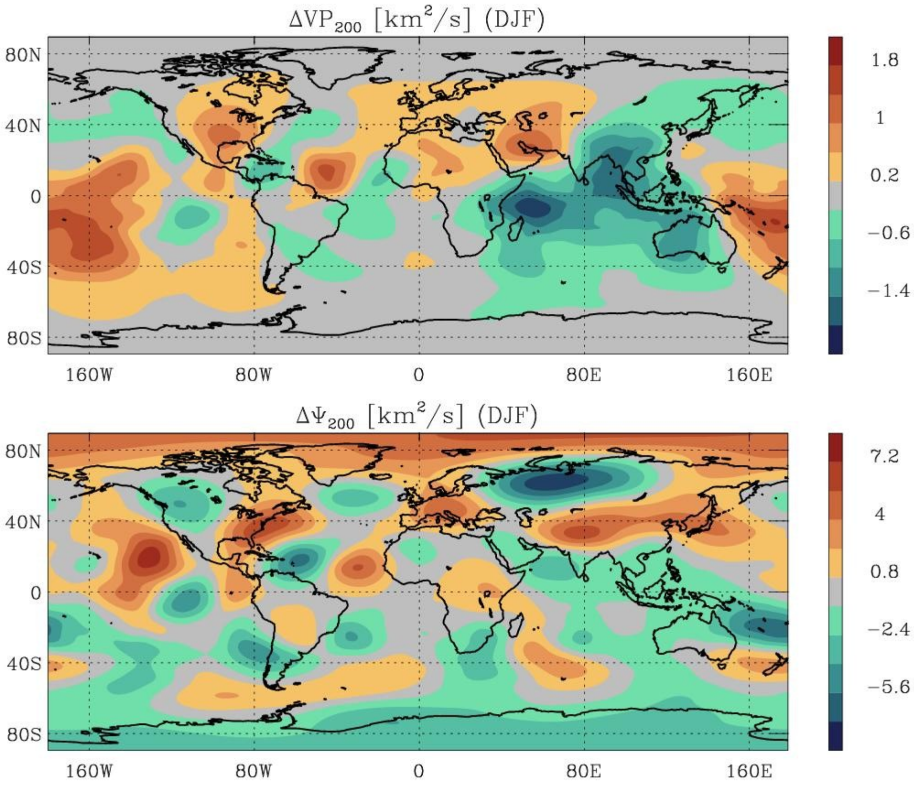
The state changes in Europe and Barents/Kara Seas consistent with downstream effects of diabatic warming over ocean

- **Westerlies and moistening over Europe**
- **Descent-drying and radiative cooling over Barents/Kara region**

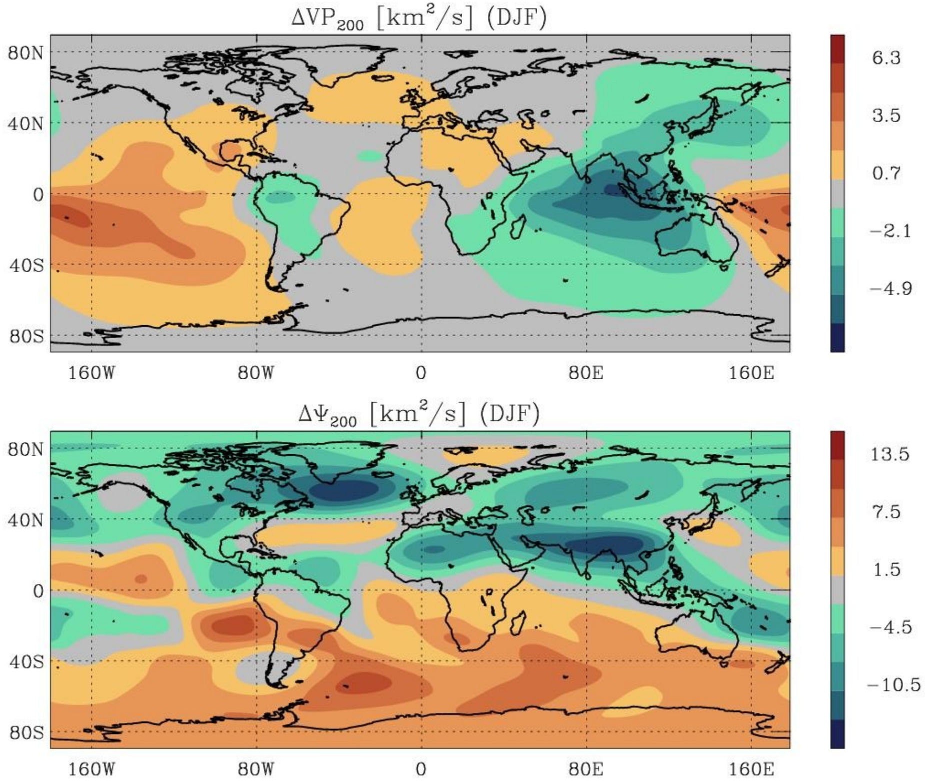


Teleconnections!

Effect of wave-Charnock

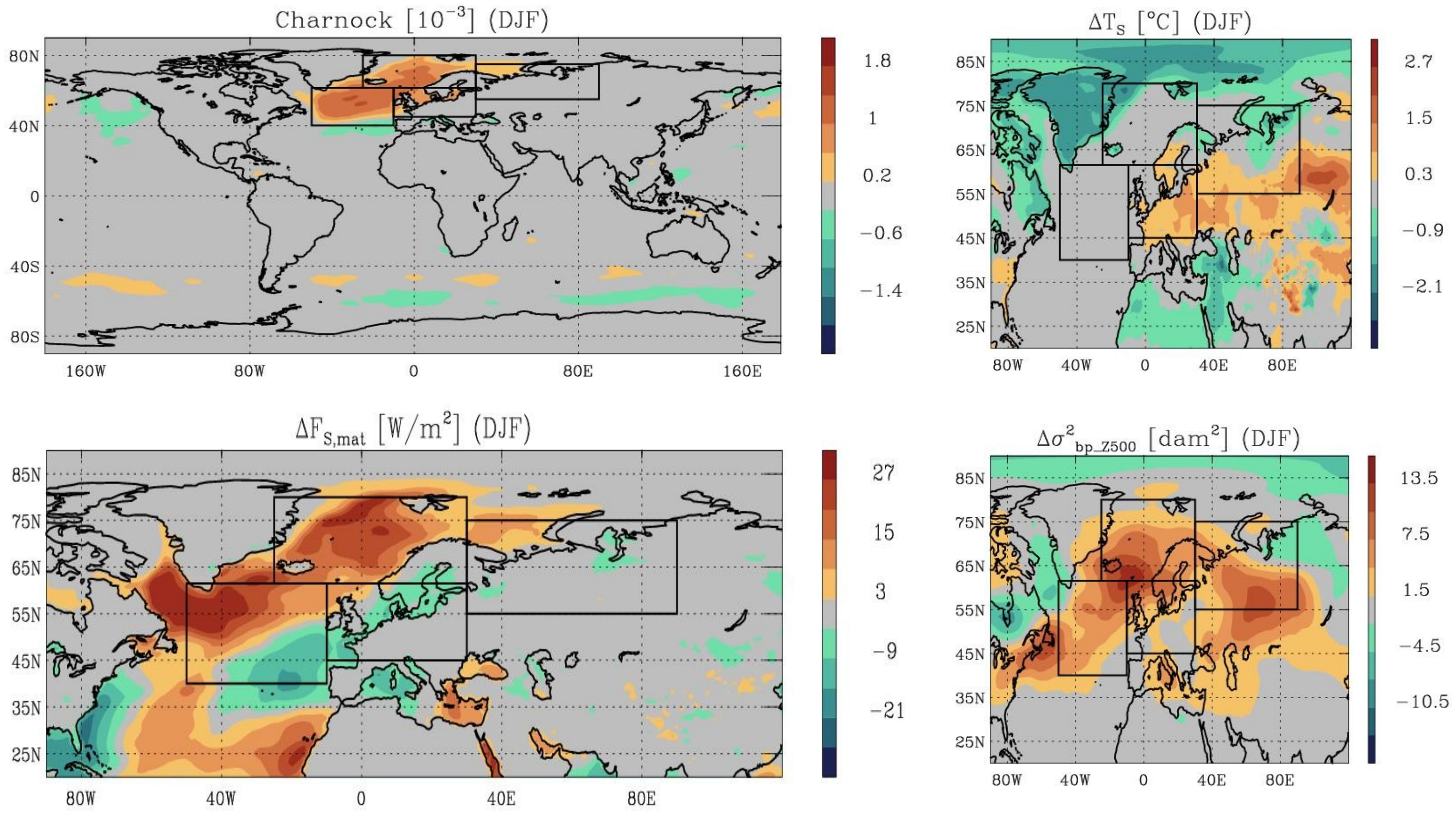


Effect of parameter (de-)tuning



Regional two-way coupling experiment (NA and Nordic Seas only)

Impacts over the NA, Nordic Seas and Europe are qualitatively similar, and larger

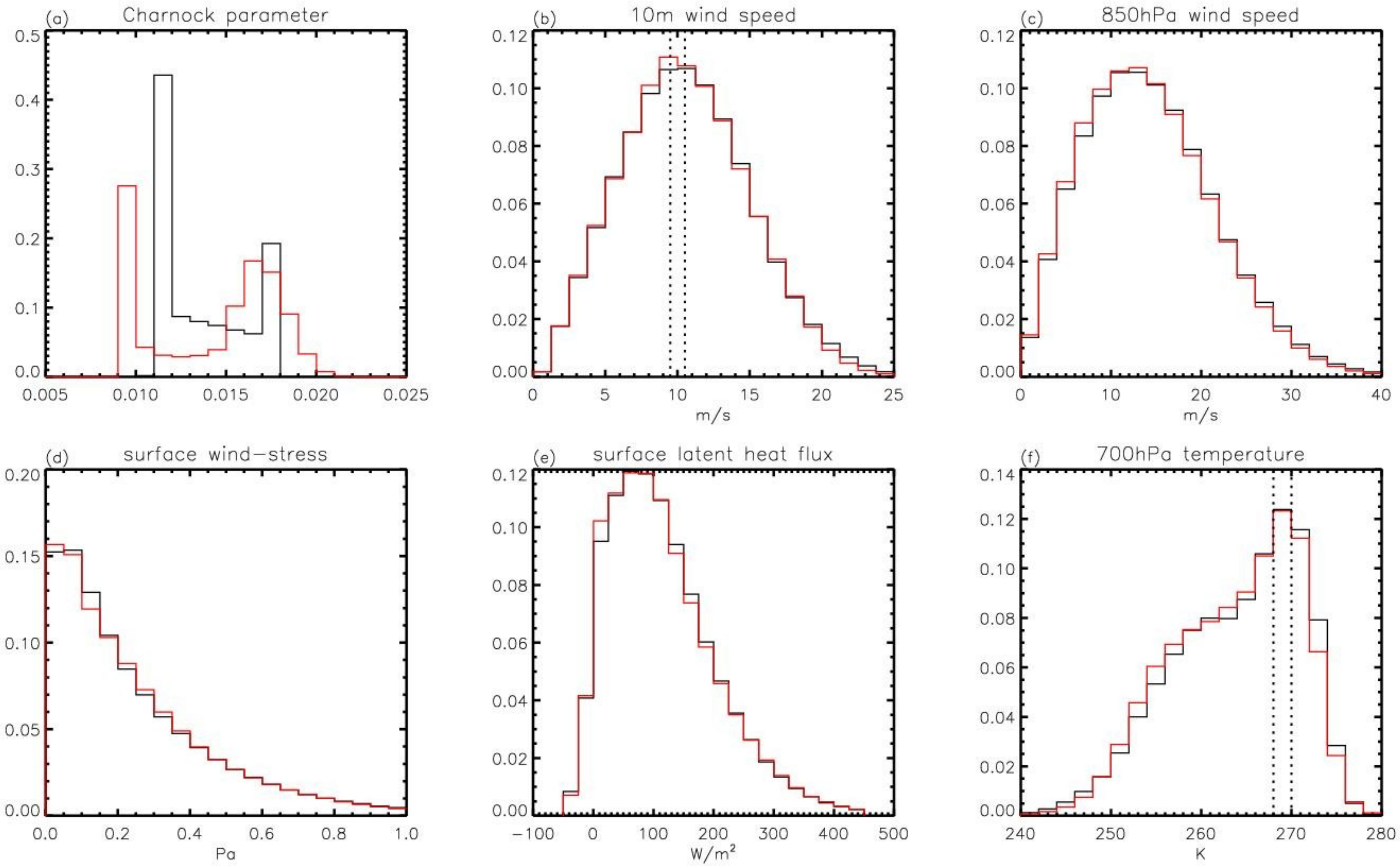


Sub-synoptic scales in the North Altantic

Control
wave-Charnock

FDs of atmospheric PBL and surface layer variables.

Generally weaker surface wind.



Sub-synoptic scales in the North Altantic

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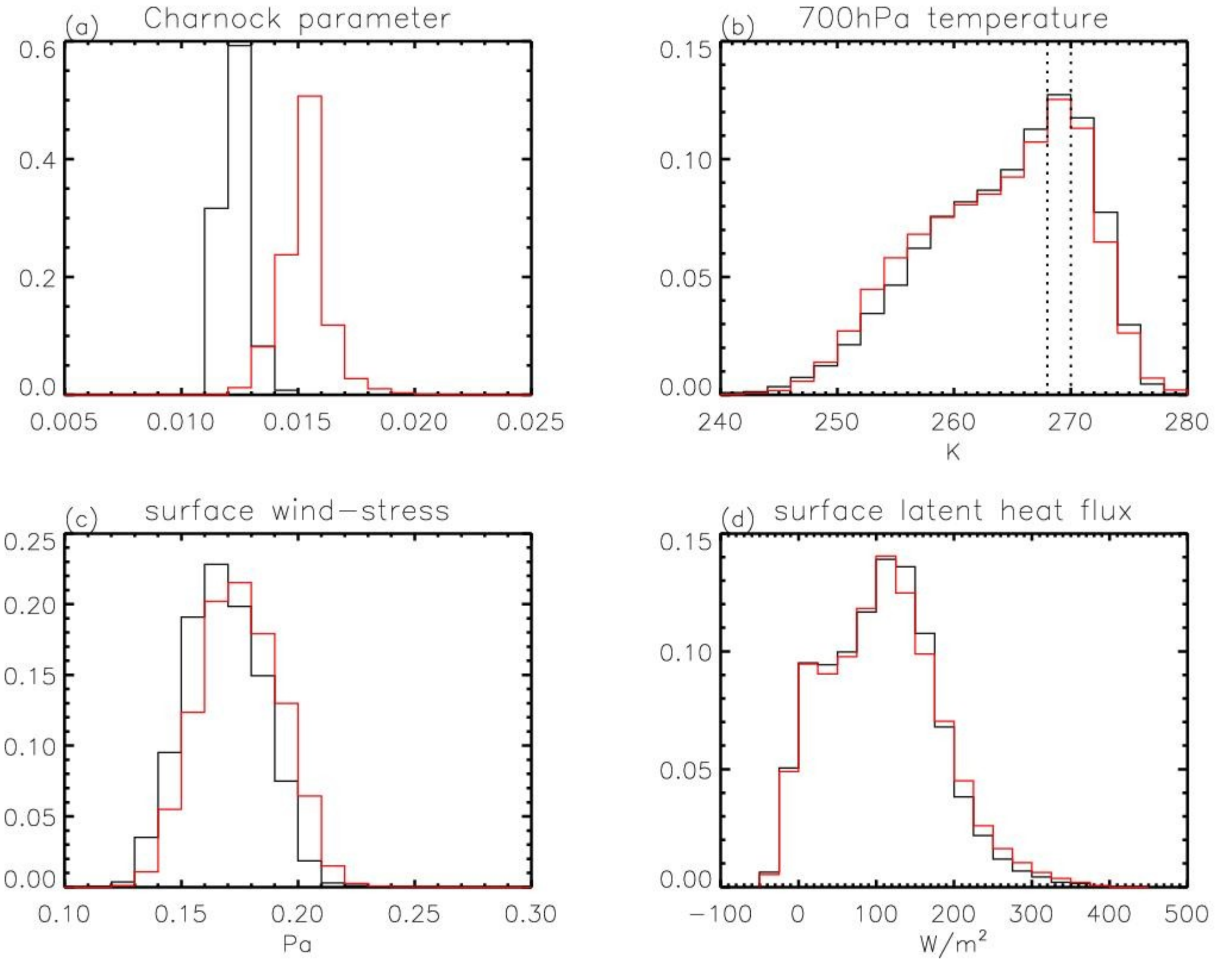
Under same wind, larger wind-stress and latent-heat flux.



Sub-synoptic scales in the North Altantic

Control

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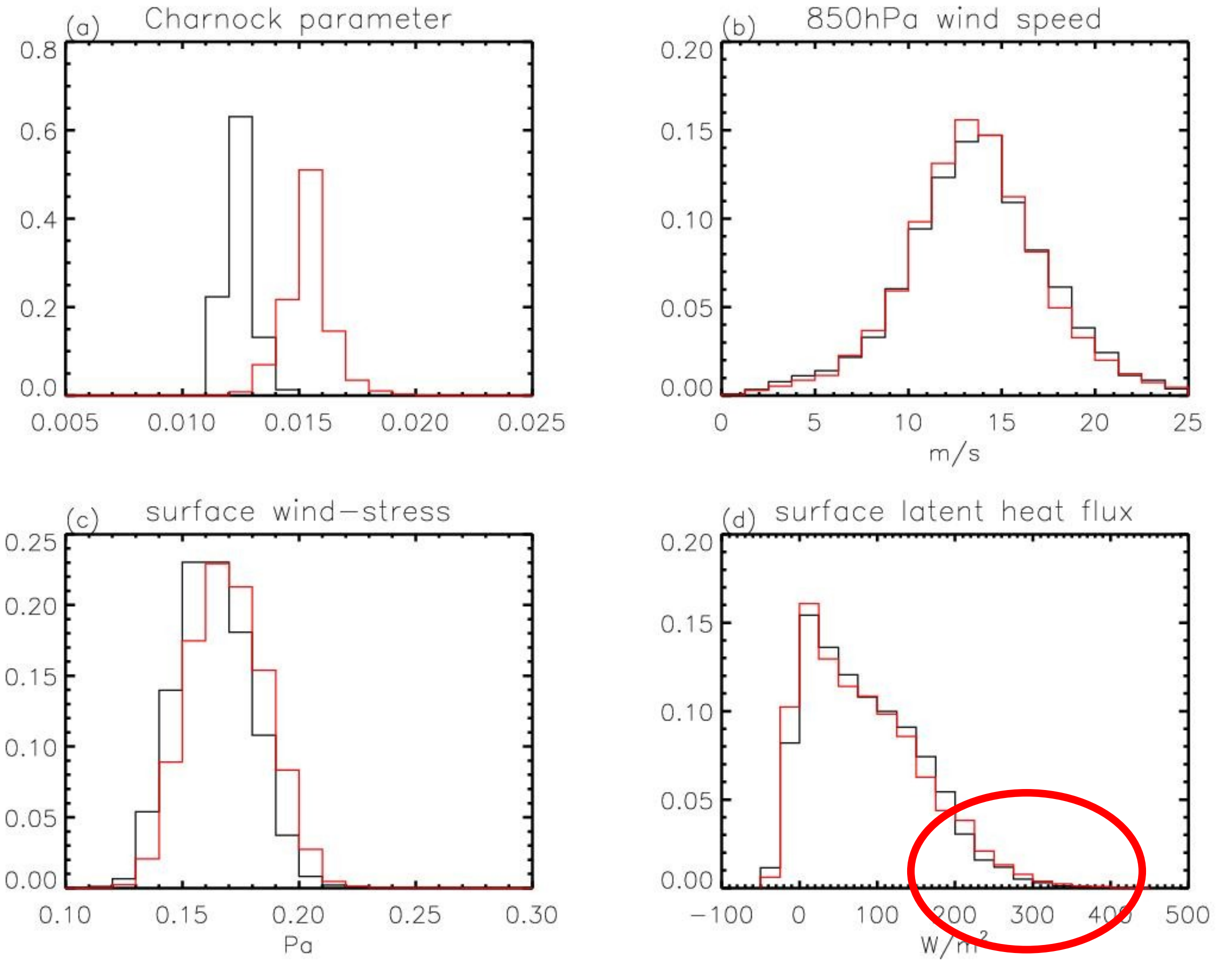
U_{10}=10m/s

T_{700}=269K

Given similar PBL conditions, wind-stress is larger and latent-heat flux still has a long “tail”.



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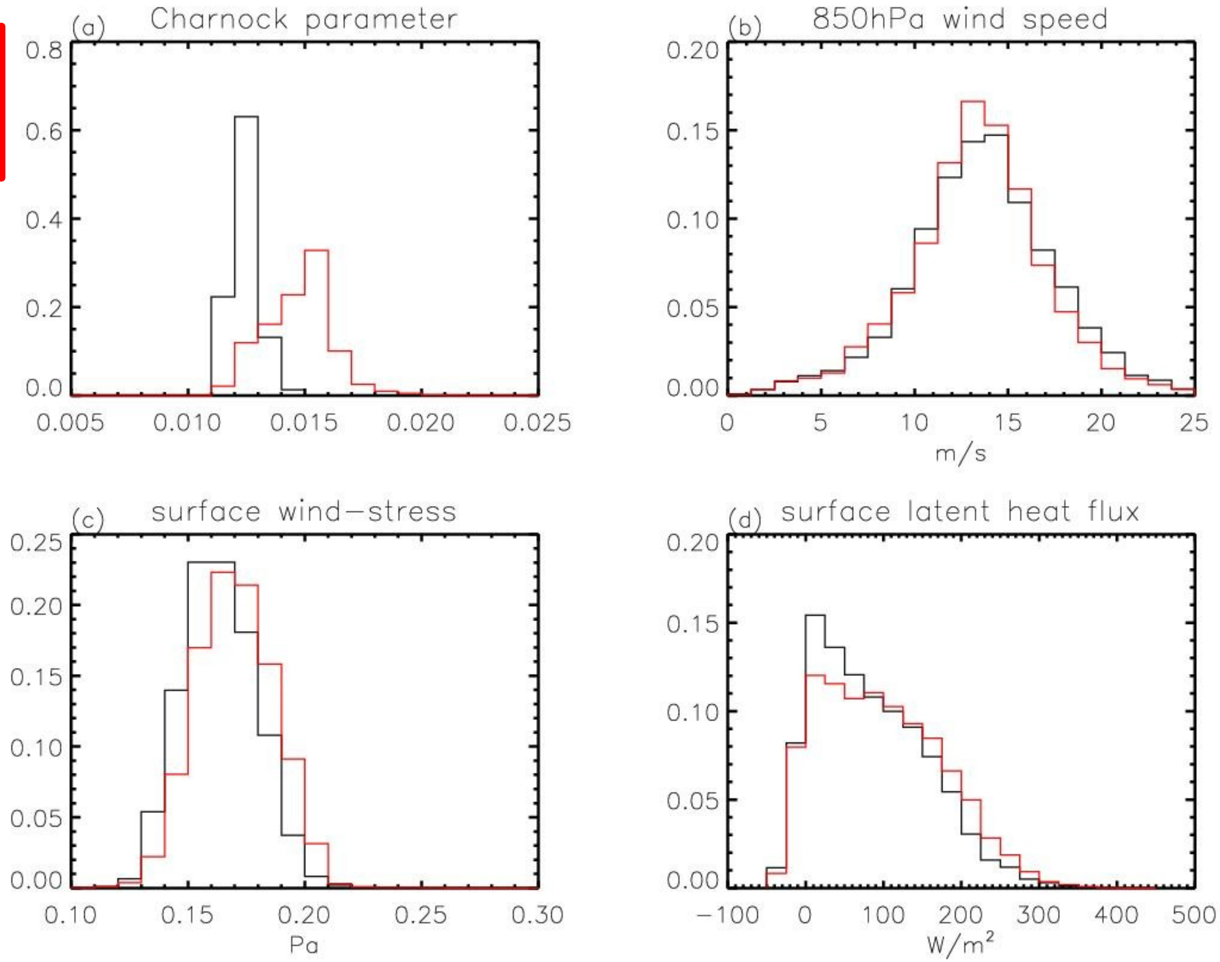
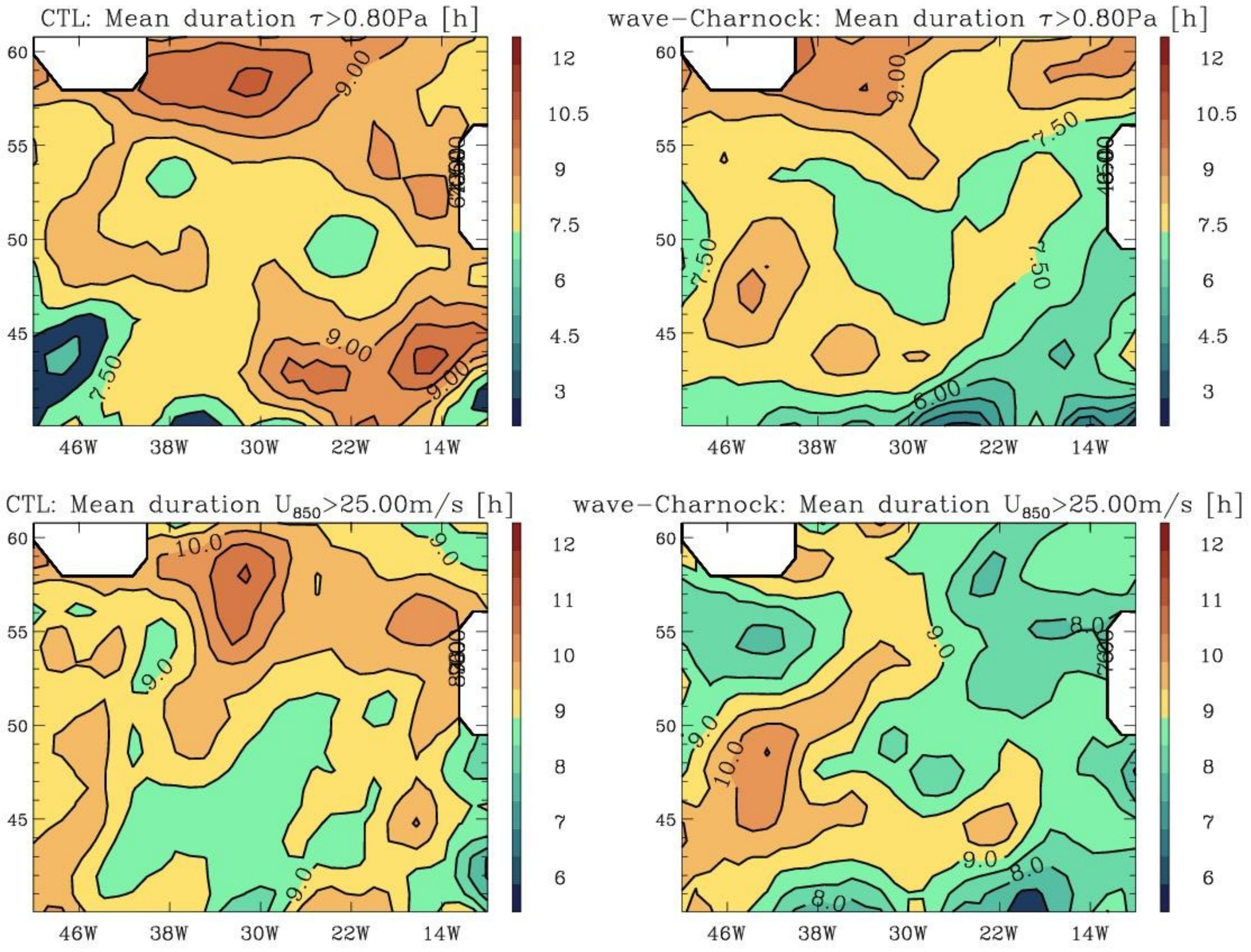
The regional wave-Charnock experiment shows a much larger effect.



Sub-synoptic scales in the North Atlantic

There is some compensation between increased wind-stress and “storm” duration.



conclusions

- Two-way atmosphere-wave coupling result in robust winter warming in Europe, enhanced storminess in the Nordic Seas, and cold conditions over the Barents/Kara Seas
- These effects appear to be attributable to increased diabatic enhancement of storminess in the North Atlantic
- Downstream effect (central Asia, Siberia and Arctic) are less robust, e.g. dependent on background model climatology
- Super-imposed are tropical-mid-latitude teleconnections dependent on remote changes in wind-stress distribution, which tend to warm the Arctic; this is climate-dependent and in low-resolution simulations it can be the dominant effect