Department of Meteorology

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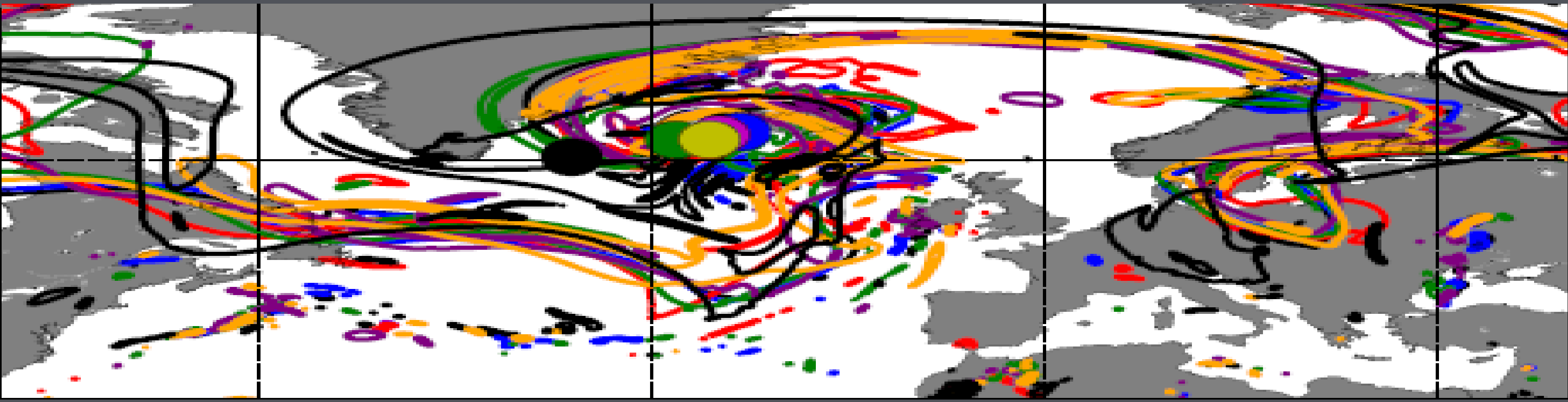
Impact of model upgrades on diabatic processes in extratropical cyclones and downstream forecast evolution



Jacob Maddison*, Suzanne Gray, Oscar Martínez-Alvarado and Keith Williams (Met Office)

*Now at Universidad Complutense de Madrid

Sources of forecast error

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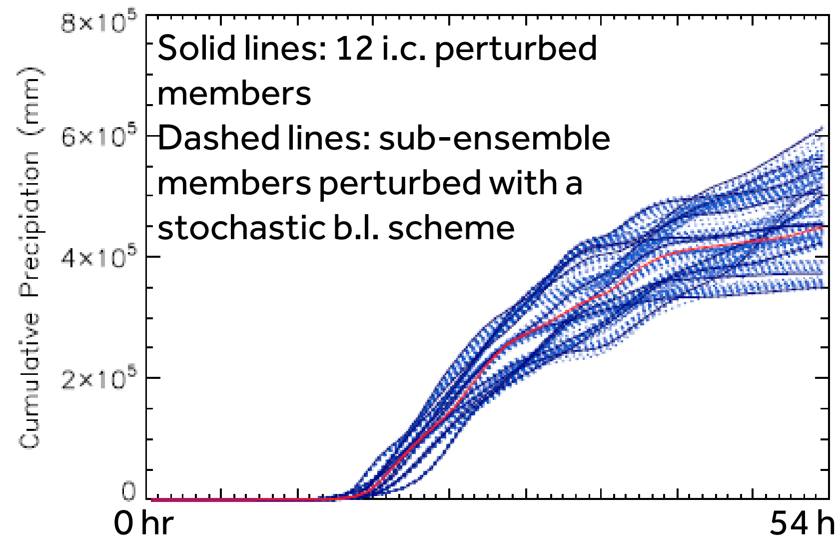
- Sources are (i) initial conditions, (2) boundary conditions, (3) model configuration: resolution, dynamical core, physics parametrizations.
- Initial condition error tends to dominate over model error although model error cannot be ignored and may be particularly important when considering weather systems with strong diabatic processes.
- Sensitivity to model parametrization schemes is typically considered by performing sensitivity experiments with large changes to schemes (either a totally different formulation or a, often unphysically, changed parameter within the scheme).
- Here instead we consider small changes to various parameterisation schemes that constitute (or could constitute) an operational upgrade to the scheme.



Cumulative precipitation for a MCS flooding case over the UK. (Flack et. al. submitted)

Blocking and warm conveyor belts

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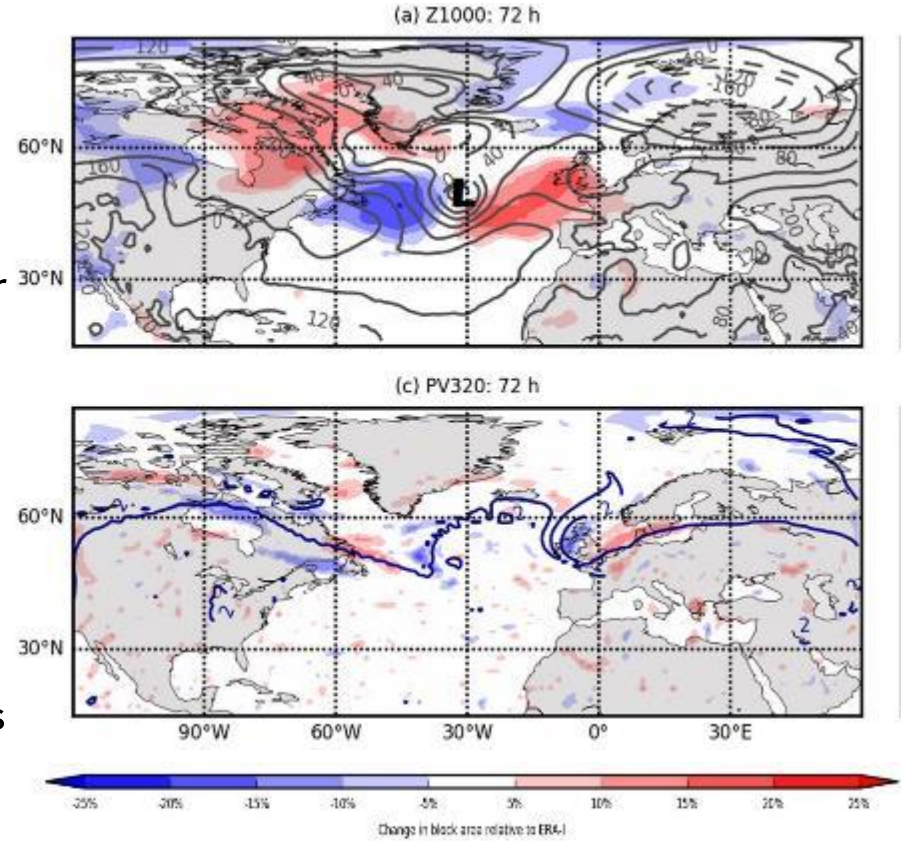
- Atmospheric blocks are notoriously difficult to forecast in NWP models and are the cause of some of the worst forecasts produced at operational NWP centres.
- Poor blocking forecasts have been linked to poor forecasts of **warm conveyor belts** in upstream cyclones e.g. Grams et al. (2018).
- We have previously shown that most of the forecasts of the 20 most uncertain block onset cases in recent years are strongly influenced by the representation of upstream extratropical cyclones (location and/or intensity).
- Here we investigate the impact of model physics uncertainty on the representation of upper-tropospheric ridge amplification and atmospheric blocking.



Sensitivity of blocking index at 144 hrs to 1000-hPa Z and 320K-PV at 72 hrs. Uses ECMWF EPS from TIGGE.
(Maddison et al. 2019)

Research questions

1. Do model upgrades to physical parameterisations or ocean-coupling have a systematic effect on forecasts of upper-tropospheric Rossby wave development and blocking?
2. How do the effects on the forecast evolution from model changes compare to those from initial condition uncertainty?
3. Does the previously found error in block forecasts associated with upstream cyclone representation and WCB structure originate from uncertainty in the representation of diabatic processes in extratropical cyclones?

Experimental setup

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- UK Met Office Model (MetUM GA6.1 N768) 20 September – 16 October 2016
- **NAWDEX period:** 20 September – 16 October 2016
- **Case study: NAWDEX IOP6**
  - Block onset 4 October 2016
  - Cyclone development 1 - 4 October 2016
  - Focus on forecast initiated 1200 UTC 27 September 2016 (7 days before block onset)
- Forecasts run for 12 days

SST-update experiment

- Sea surface temperatures and sea ice fraction updated to OSTIA analysis every 24 hours into forecast = cheap "coupled" forecast

Parametrization experiments (Prog-ent,GA7Mp, GA7Cl, GA7Bl)

- Operational improvements (MetUM Global Atmosphere GA6 -> GA7) to parametrizations of convection (convective memory), cloud, microphysics and boundary layer.

Systematic effects

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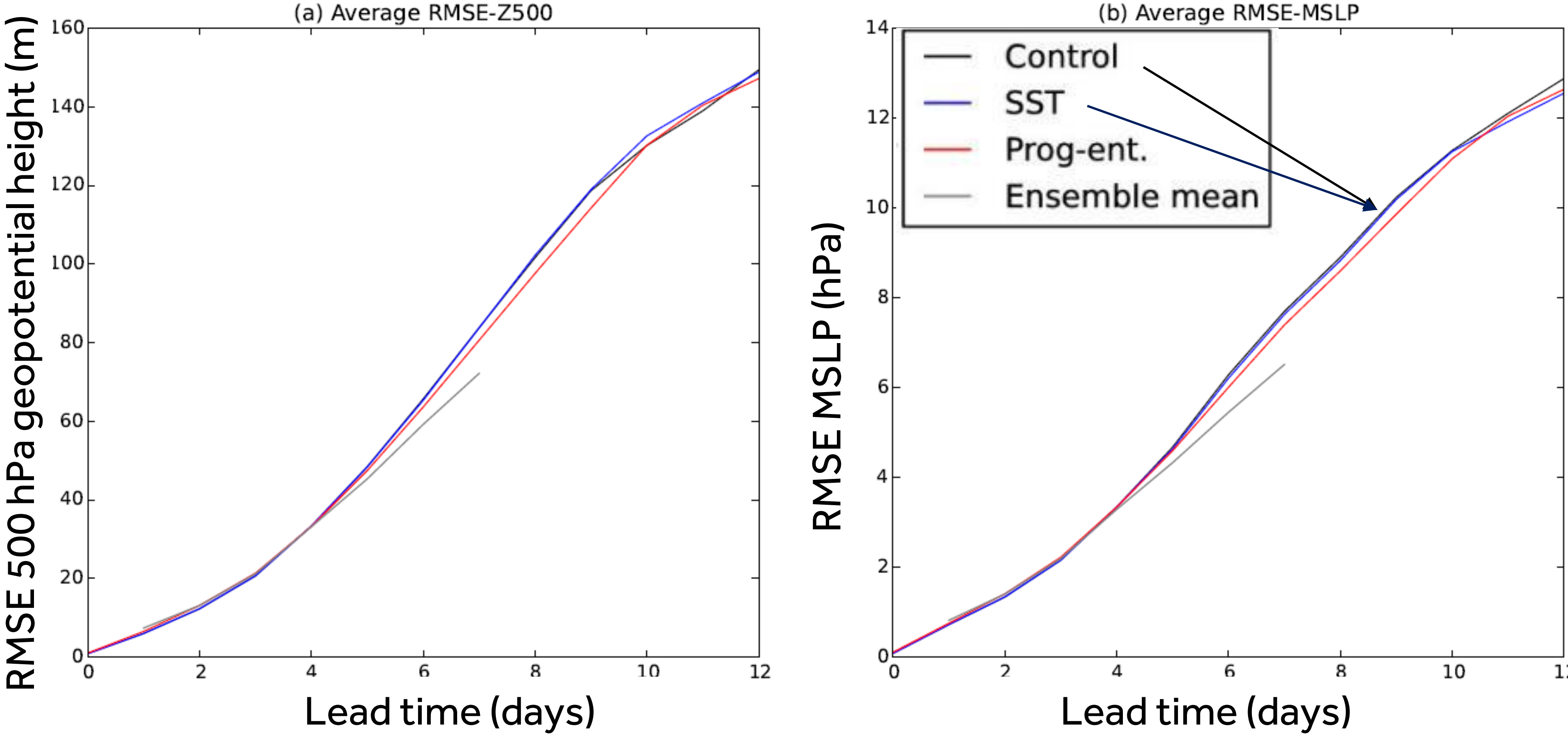
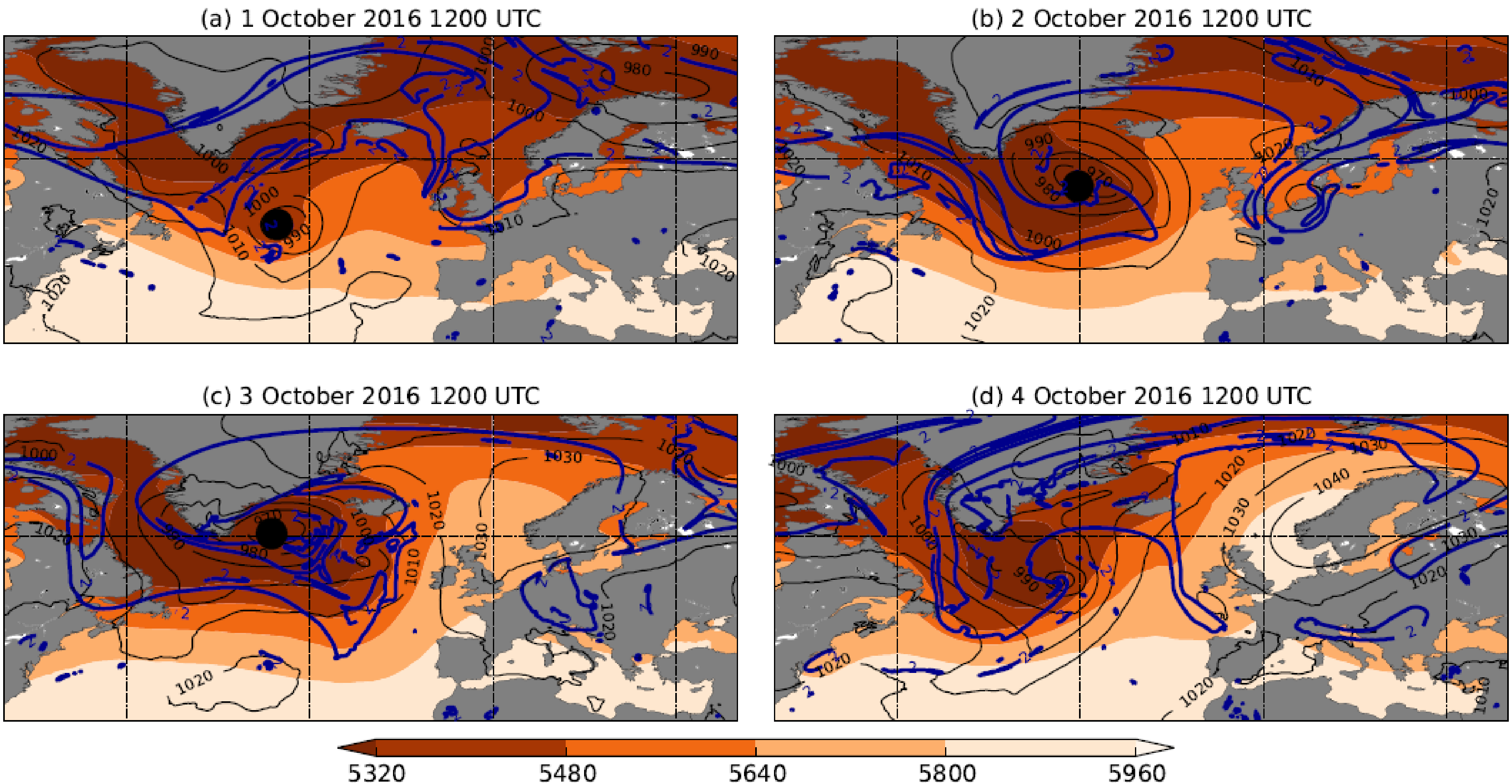


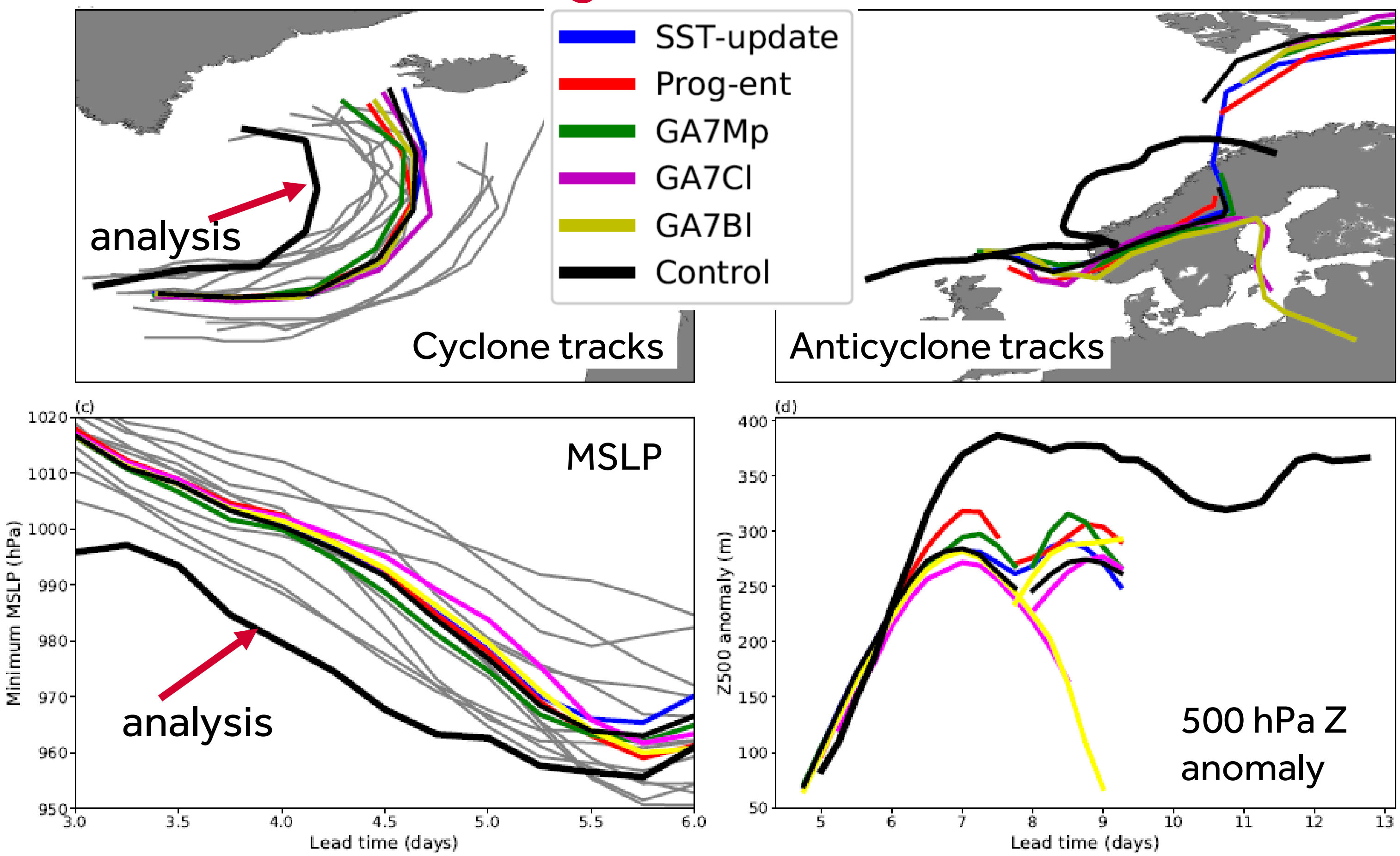
- Forecasts produced from the “coupled” system have, on average over the NAWDEX period, indistinguishable skill from the control forecasts => small benefits of coupled atmosphere-ocean NWP systems?
- In contrast, 4% reduction in forecast error using an upgraded convection scheme.

Case study: synoptic overview



Met Office analyses: 500-hPa geopotential height (colours), MSLP and 315-K tropopause. Circle is Stalactite cyclone

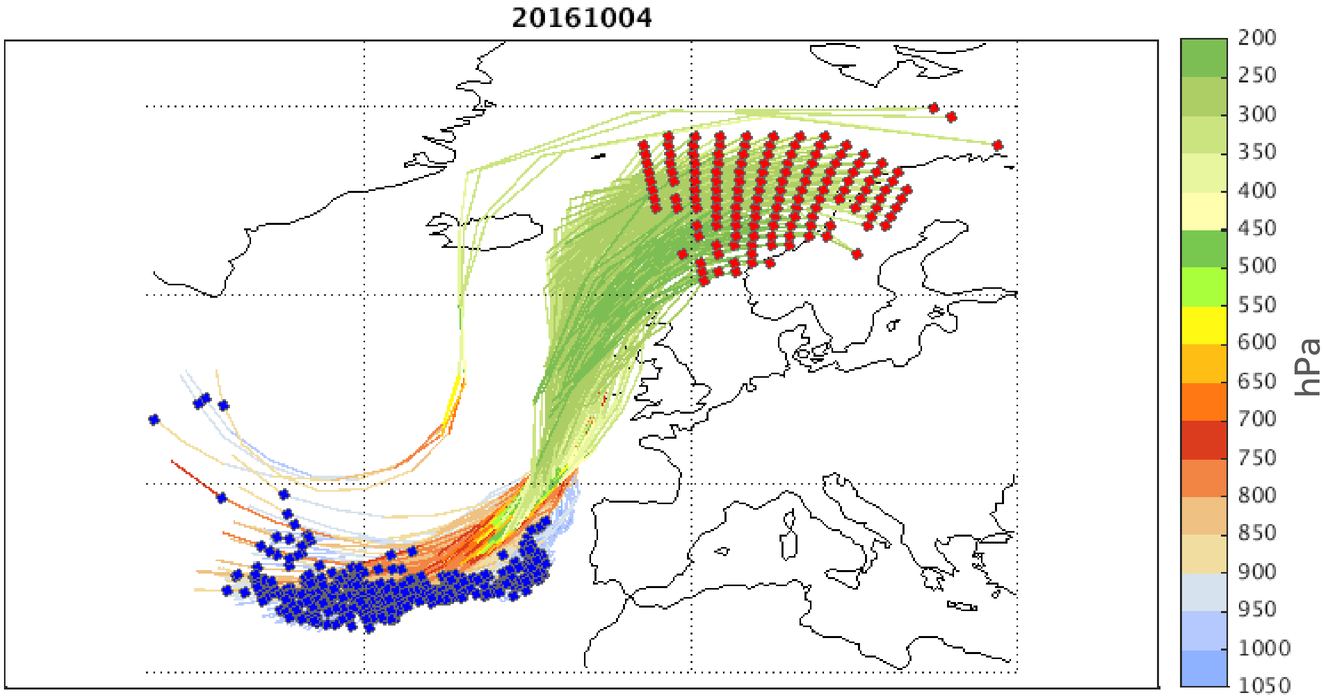
Forecast tracks of cyclone and block



- All forecasts, both operational ensemble (grey) and experiments (colours), poorly predict cyclone and block track and intensity.
- But some divergence among the experiments past 6 days forecast lead time.
- Is this divergence related to changes in diabatic heating in the WCB? Compare control with experiments

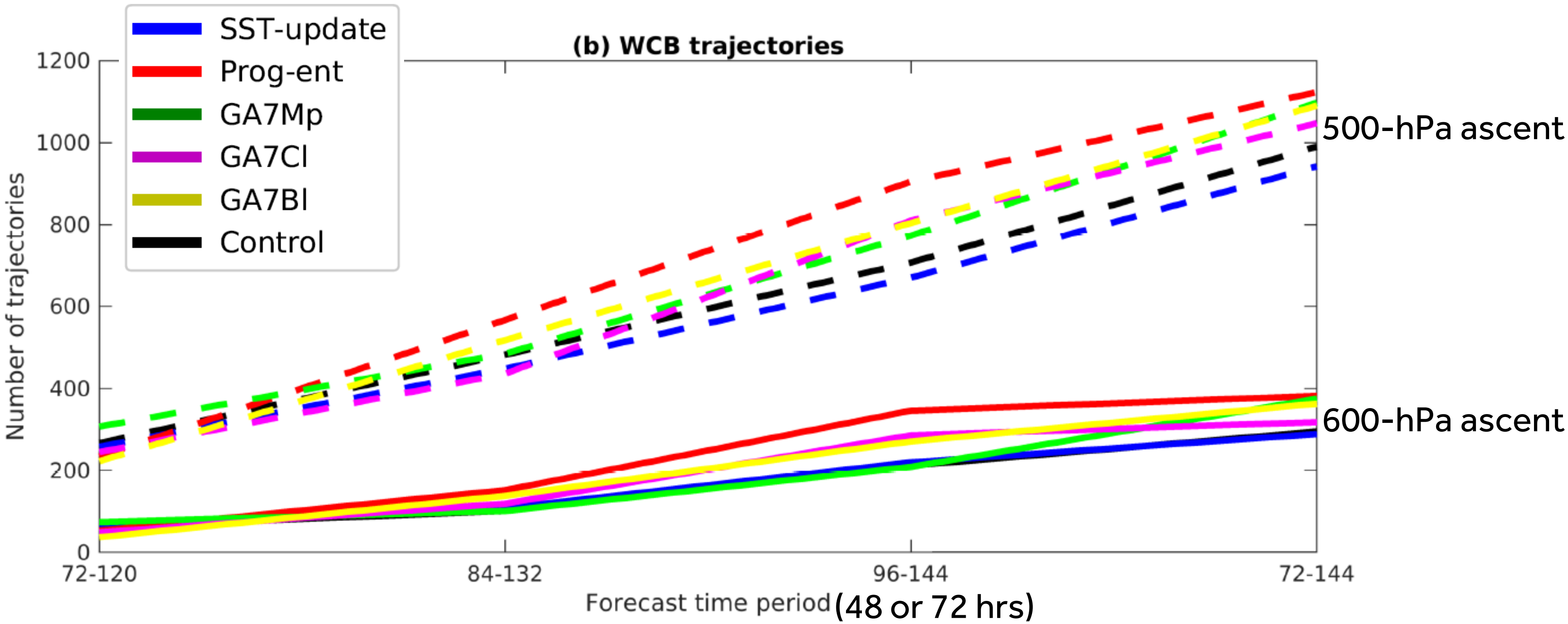
Warm conveyor belt

- Is the Stalactite cyclone a source of uncertainty in the block forecast?



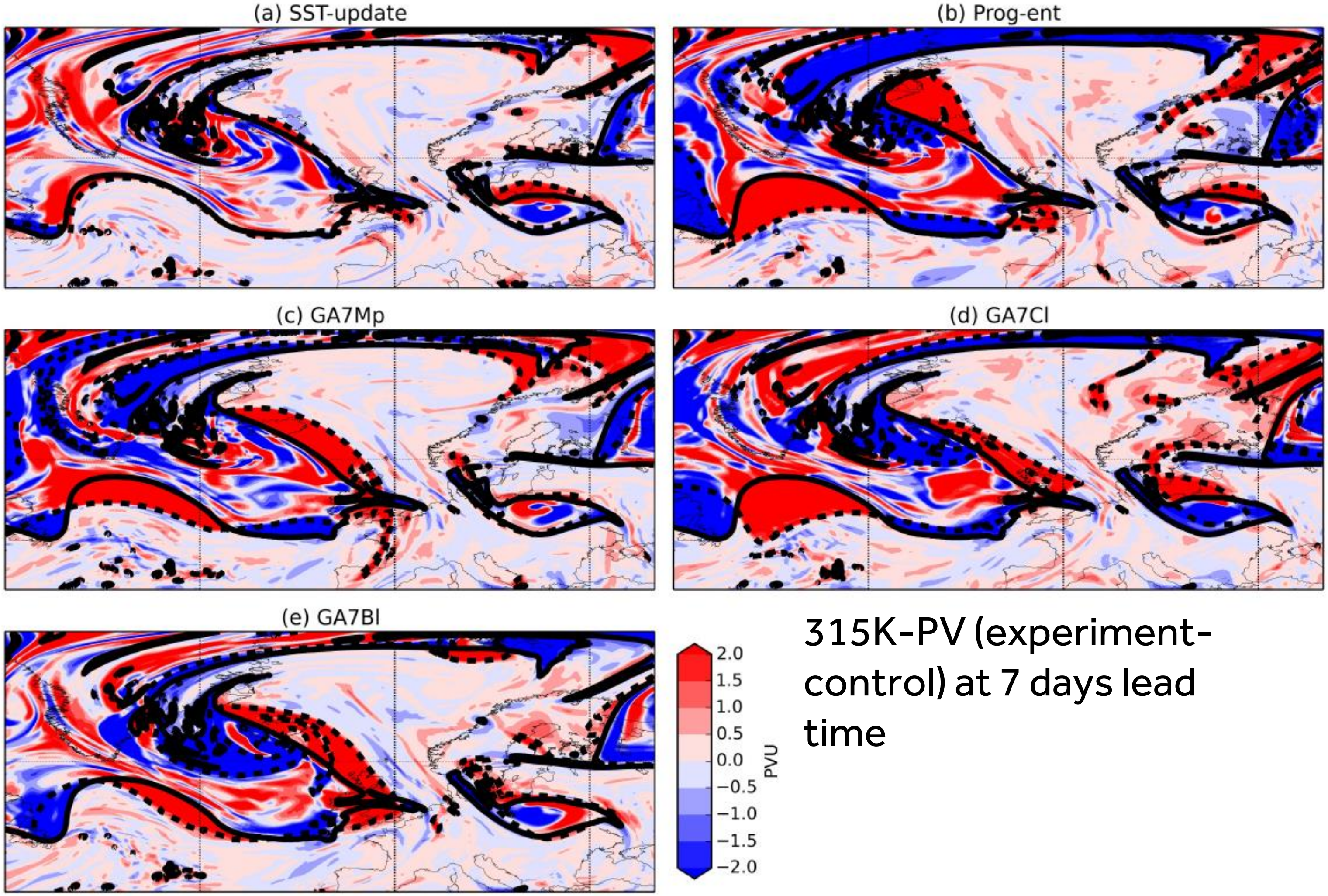
- Back trajectories using LAGRANTO from 4 October 2016
- Large mass of air arriving in block from WCB of Stalactite cyclone

Warm conveyor belt



- Some change in number of warm conveyor belt trajectories in experiments.
- Control forecast and SST-update experiment have the least while the convection parametrization experiment (prog-ent) have the most.

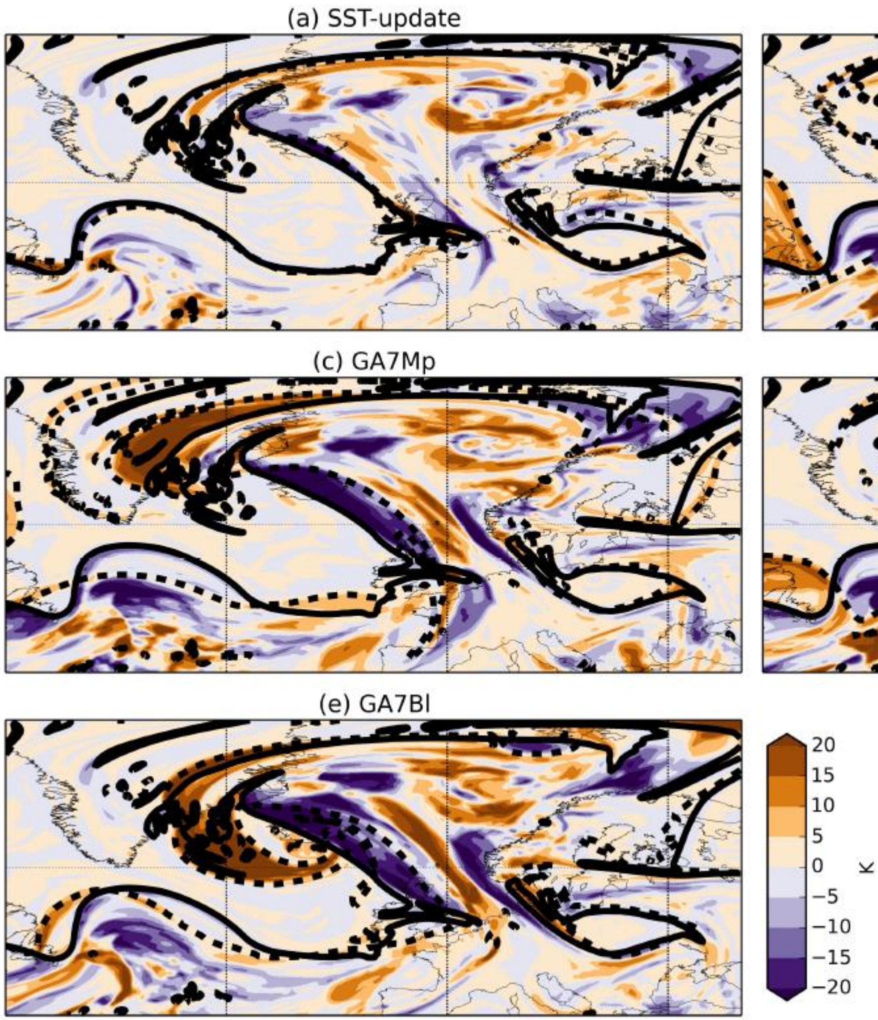
Tropopause-level potential vorticity



315K-PV (experiment-control) at 7 days lead time

- Difference in amplitude and phase of blocking ridge in experiments
- Convection (prog-ent) and cloud and microphysics experiments have larger ridges

Diabatic heating in the ridge



$(\theta - \theta_0)_{expt} - (\theta - \theta_0)_{control}$

on 315K and at 7-days lead time

- Difference in total diabatic heating within blocking ridge in experiments
- Convection (prog-ent) and cloud experiments have stronger heating

Integrated heating metric

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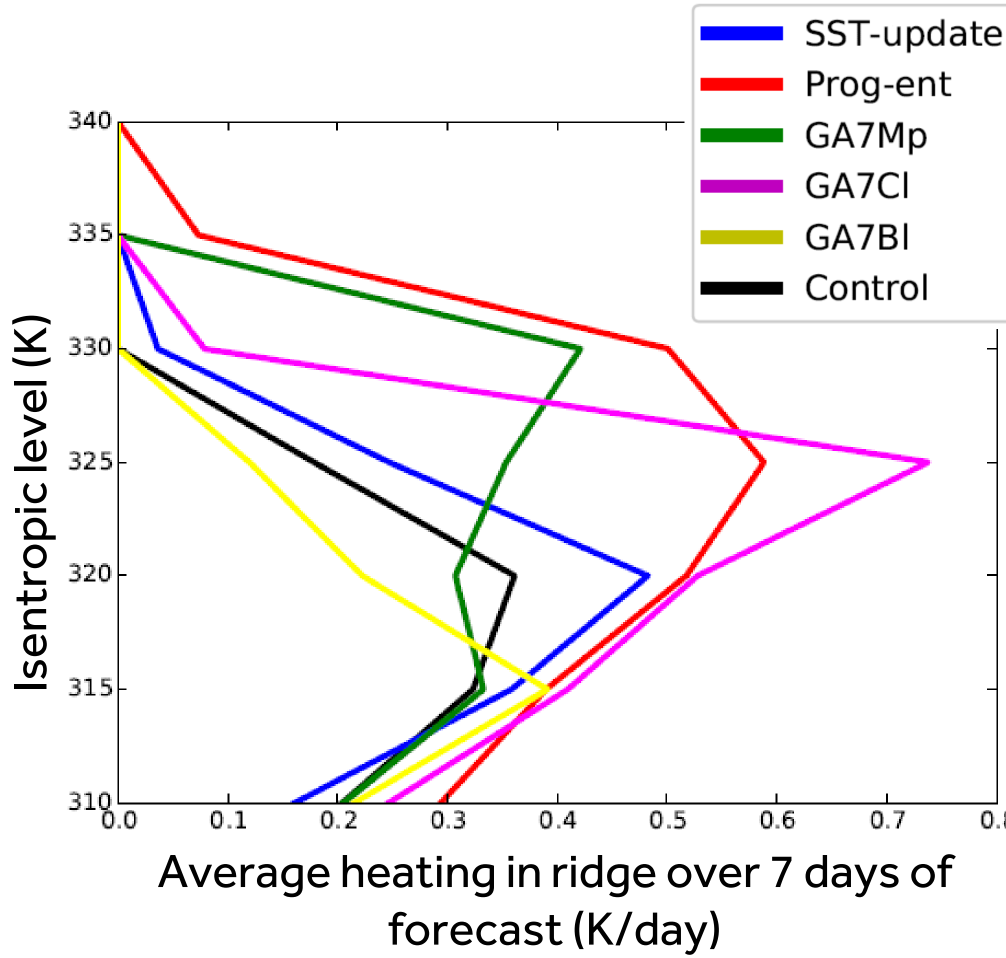
- Integrate total diabatic heating along trajectories that arrive in the upper-level blocking ridge.
- Only select those that have ascended in the WCB of the cyclone i.e. have experienced heating in the days preceding their arrival into the block.
- Convection and cloud experiments have strongest total diabatic heating throughout upper troposphere.



Stronger WCB → Stronger total diabatic heating → Larger upper-level ridge

Conclusions

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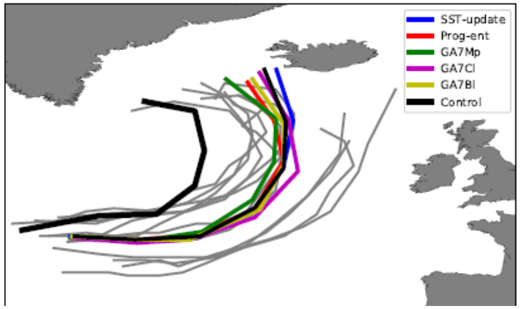
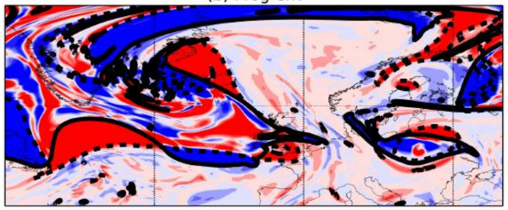


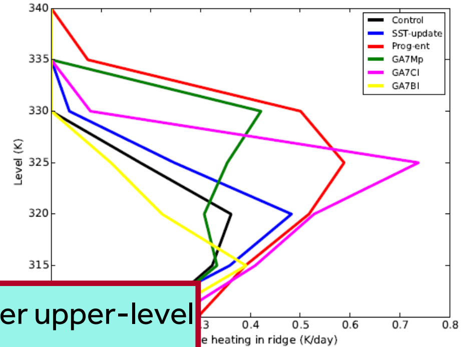
- Block onset forecast during NAWDEX unpredictable.
- Operational ensemble forecasts from the Met Office missed the block development.
- Forecasts with evolving SSTs and small parametrization changes did not improve the forecast in this case; however, systematic improvement occurs from modified convection scheme over NAWDEX period

(b) Prog-ent



BUT

- Parametrization changes caused considerable forecast evolution differences after 6-days lead time.
- Amplitude and phase of blocking ridge changed in experiments.
- Ridge amplification differences driven by changes to the total diabatic heating in the WCB of the Stalactite cyclone.
- More intense total diabatic heating (arising from amplified heating in all the parametrizations as diagnosed using diabatic tracers) results in larger ridges developing.



Stronger WCB → Stronger total diabatic heating → Larger upper-level ridge

Maddison et al. (2020). Impact of model upgrades on diabatic processes in extratropical cyclones and downstream forecast evolution. *In press QJRMS.*