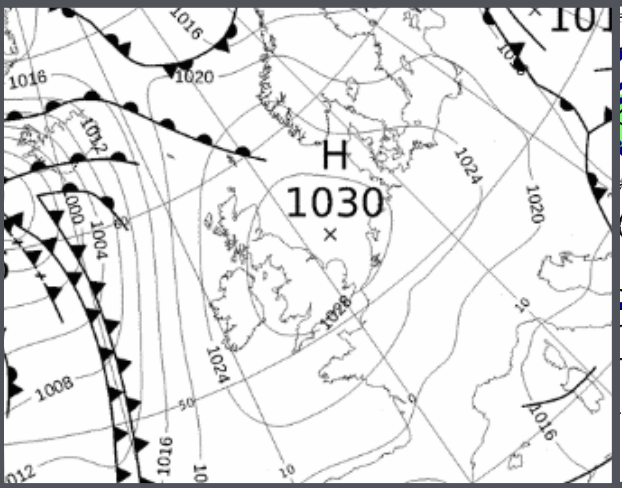
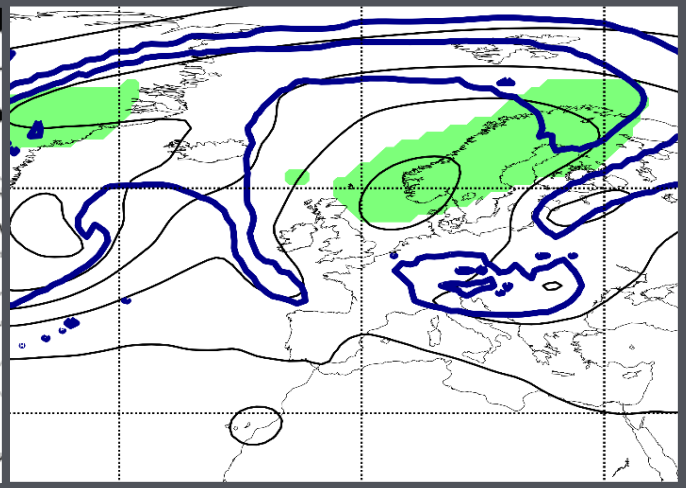
Impact of operational and potential model upgrades on block forecasts during NAWDEX





Jacob Maddison

Suzanne Gray, Oscar Martínez-Alvarado, Keith Williams (Met Office)

NAWDEX workshop. 27 March 2019

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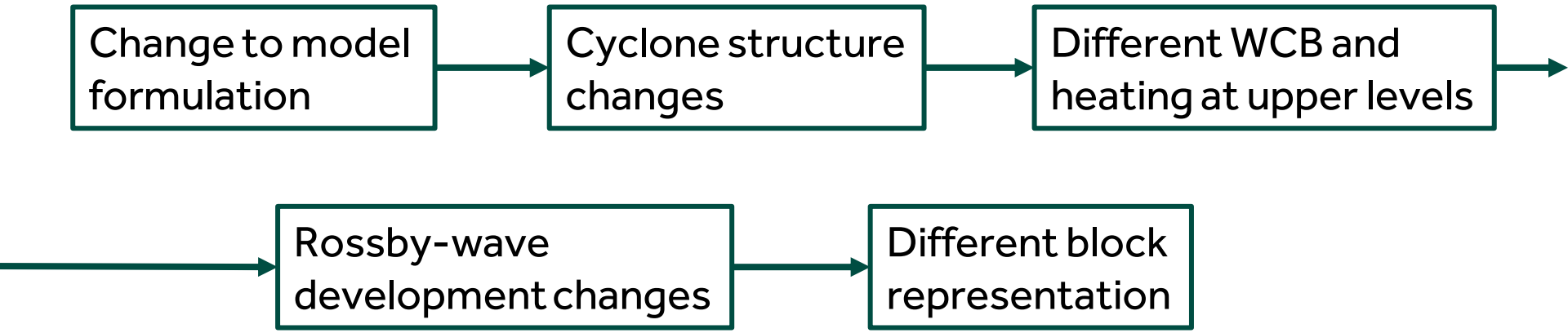
Aims and research questions

- Quantify the impact of model physics uncertainty on medium-range forecasts of atmospheric blocking during NAWDEX. Do planned operational model developments to physical parameterisations in the MetUM have an effect on block forecasts?
- What might the potential impact of coupling the atmosphere to the ocean be for block forecasts?
- How do these compare to initial condition uncertainty?



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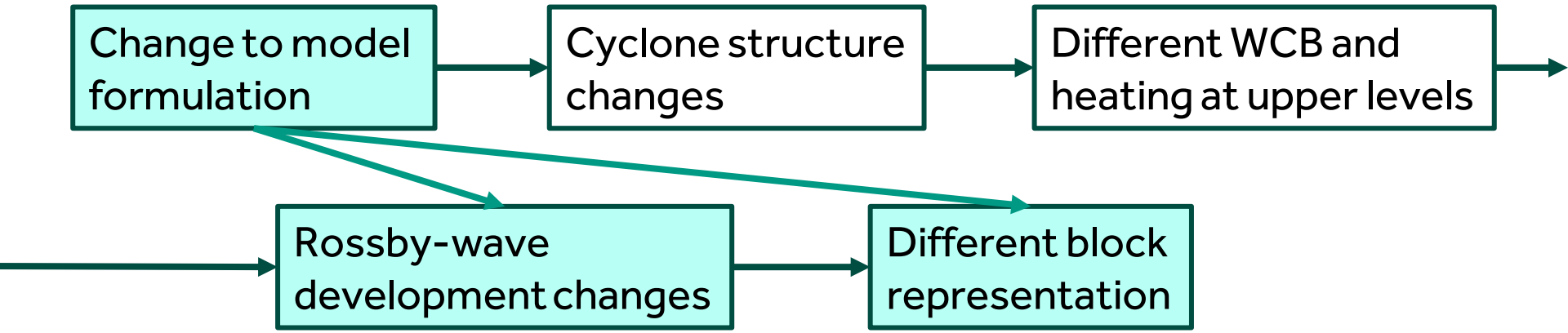
****Martínez-Alvarado et al. (2018) Atmospheric blocking and upper-level Rossby wave forecast skill dependence on model configuration. *QJRMS***



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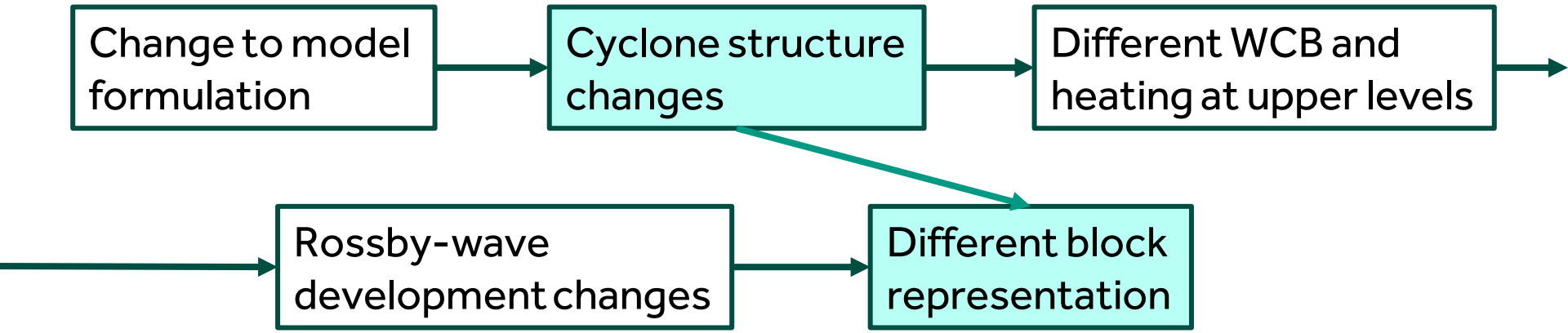
****Maddison et al. (2019) Upstream cyclone influence on the predictability of block onsets over the Euro-Atlantic region. *Monthly Weather Review***



Methods

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- Control: MetUM, Global Atmosphere (GA) 6.1 (vn10.4), N768, with PV and θ tracers. 20 Sep 2016 – 16 October 2016. 12 day forecasts.

Experiments:

- SST-update: every 24 h update SSTs and sea ice to OSTIA analysis. "Poor man's coupling"
- Prognostic-entrainment: convection scheme with measure of recent convective activity an additional prognostic variable
- GA7-microphysics: changes to sub-grid cloud water content variability, new warm rain scheme, turbulent production of liquid water in mixed phase clouds
- GA7-cloud: convective core treatment, variable critical RH profile
- GA7-boundarylayer: revised cloud top entrainments (surface driven), forced convective clouds, shear thresholds
- GA7-combinations: various combinations of GA7 experiments to test how they interact

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Run forecasts everyday at 00, 12 hours during NAWDEX period (54 forecasts)

Run for case studies of block onsets showing large sensitivity to SSTs/convection scheme

Diabatic processes

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- Are the parameterization of diabatic processes important for block onset downstream?

θ-tracers

- Isolate effects of parameterised physical processes changing θ
- Integrate θ along trajectories over a forecast of time T:

$$\theta(x,t) = \theta_0(x,t) + S(x,t), \qquad S = source$$

$$\theta(x,t) = \theta_0(x,t) + \left(\sum \Delta\theta_i(x,t)\right) + R_\theta(x,t)$$

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← Tracer error

Initial theta: advected by the flow

θ-tracer for each parameterised process

8

θ tracer error

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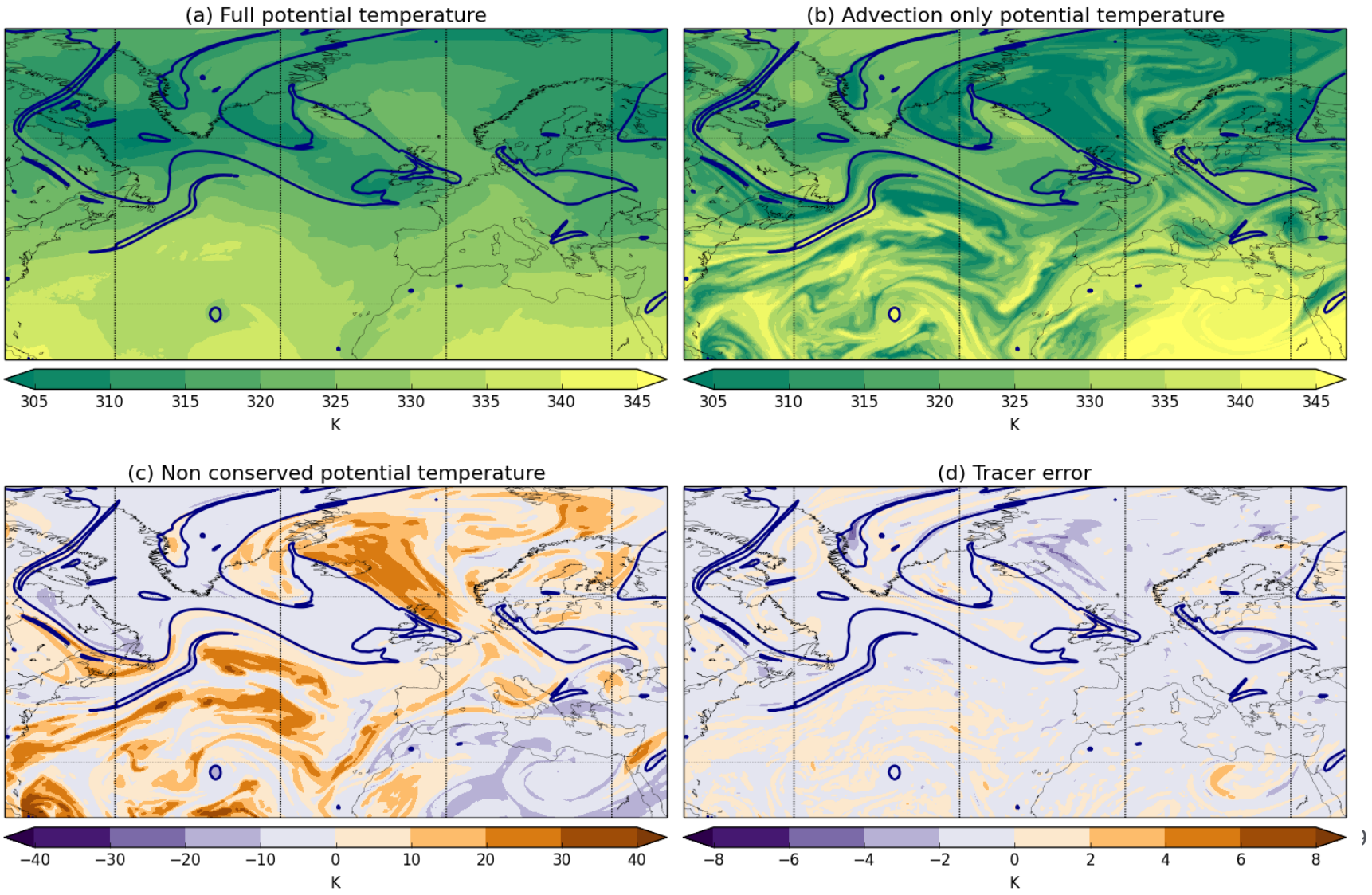

Stalactite cyclone and downstream block development

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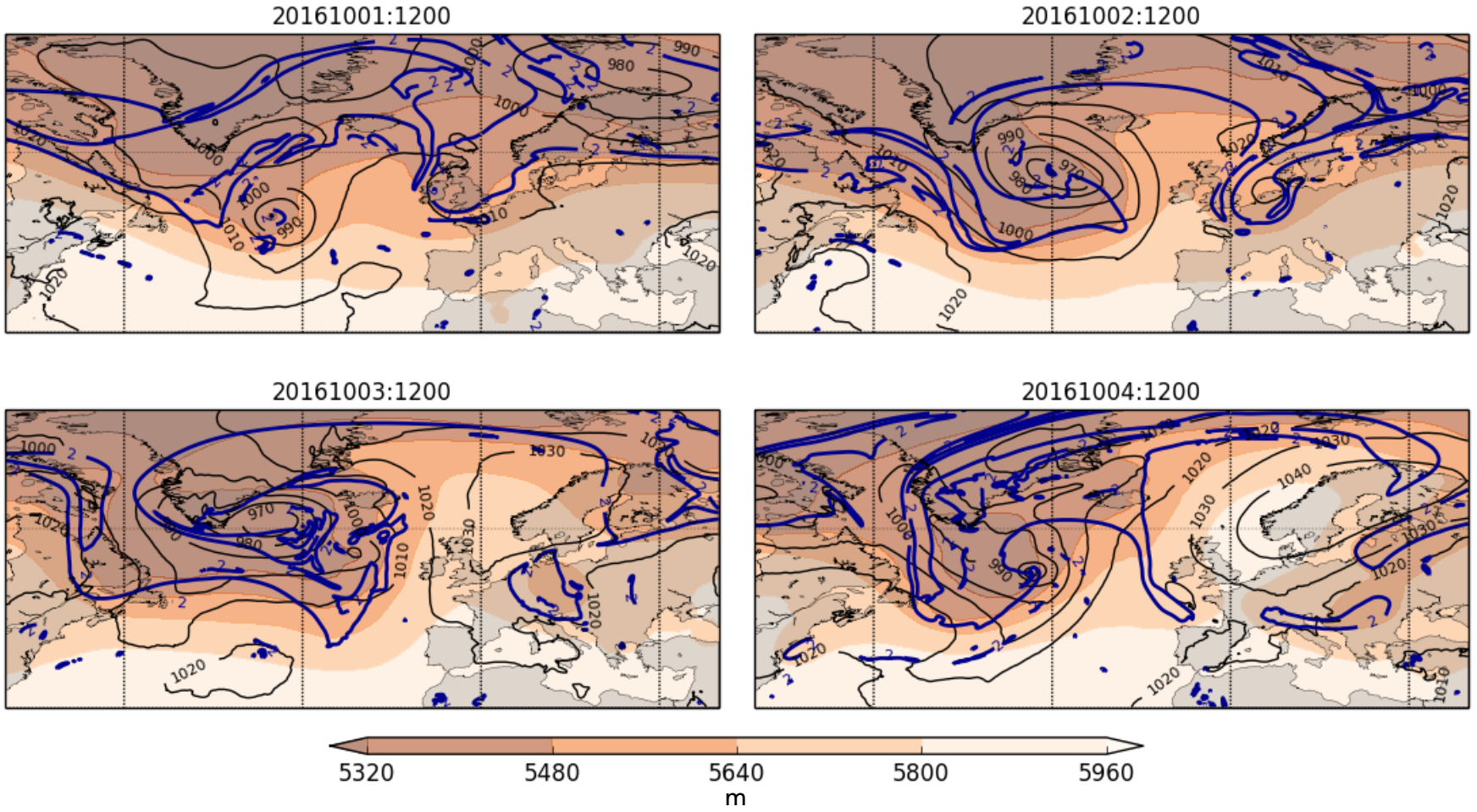

Forecast from 29 September

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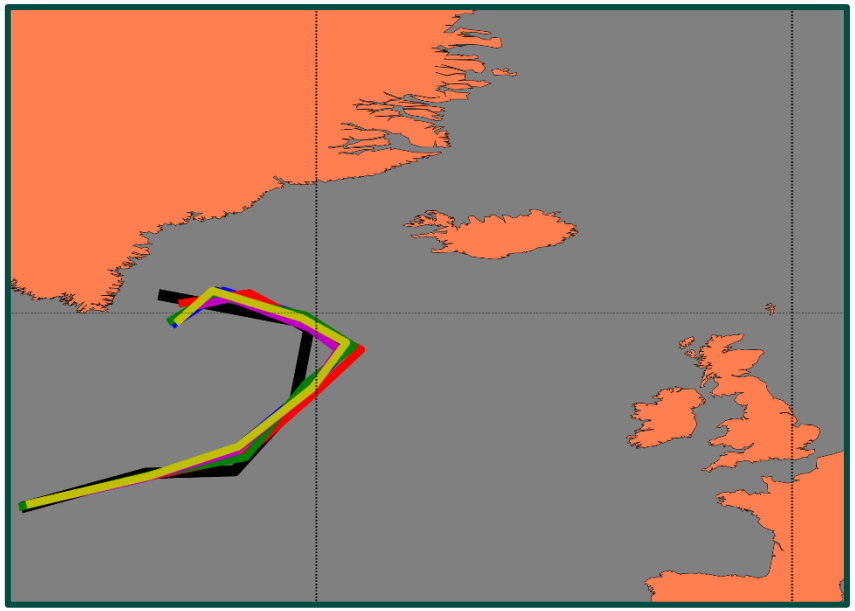
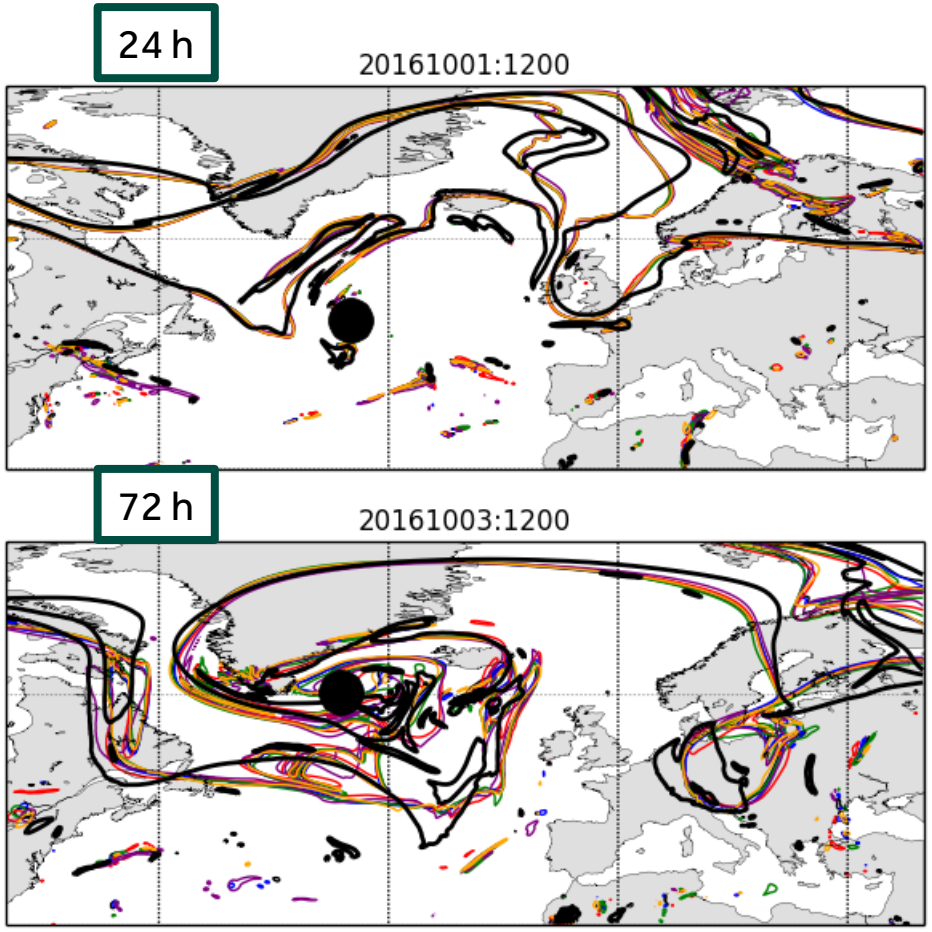
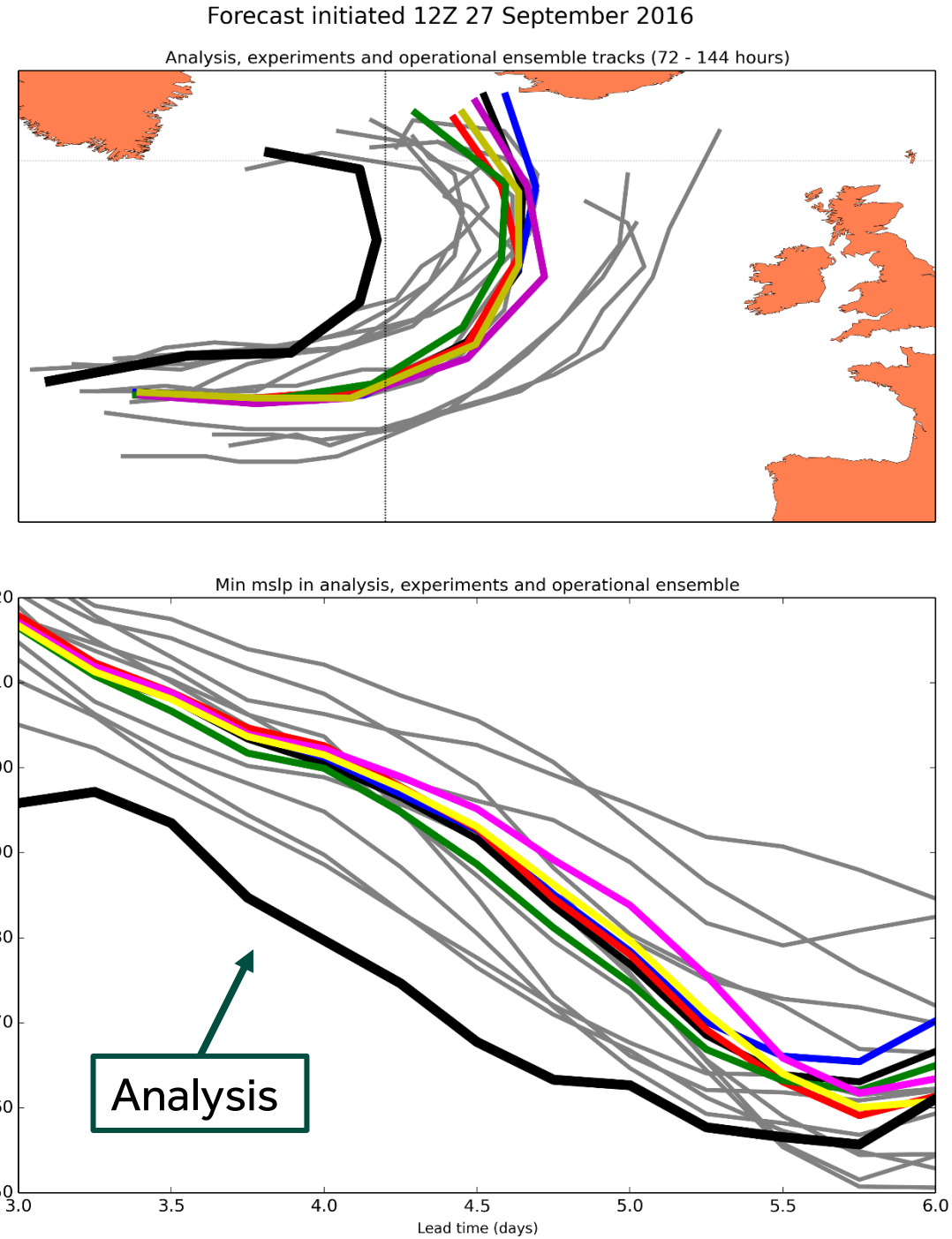




Forecast 27 September

- Correct development of the Stalactite cyclone missed in all experiments and ensemble members

- Larger spread in operational ensemble than physics ensemble at this short lead time



Ridge forecasts

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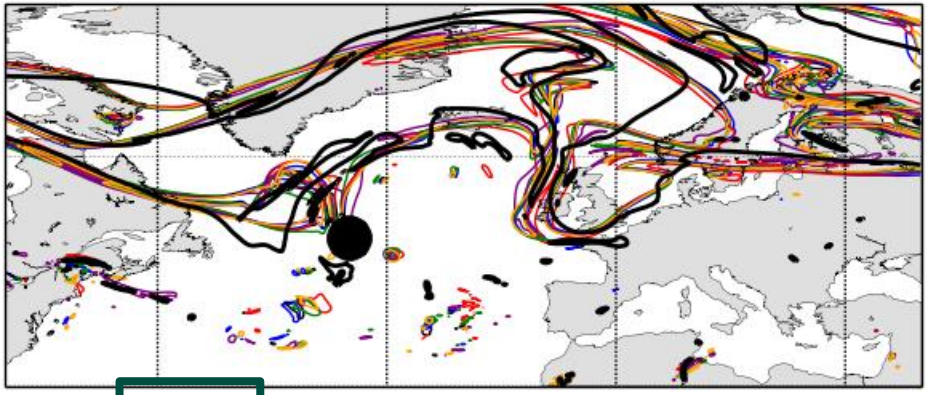
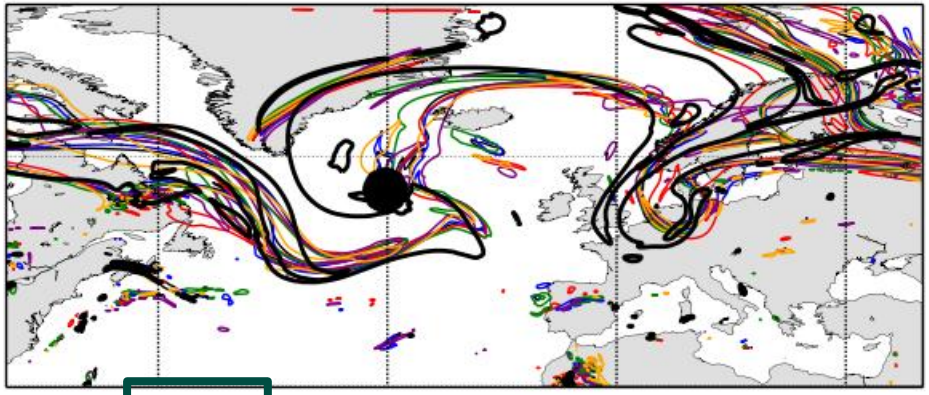
72 h

20161001:1200



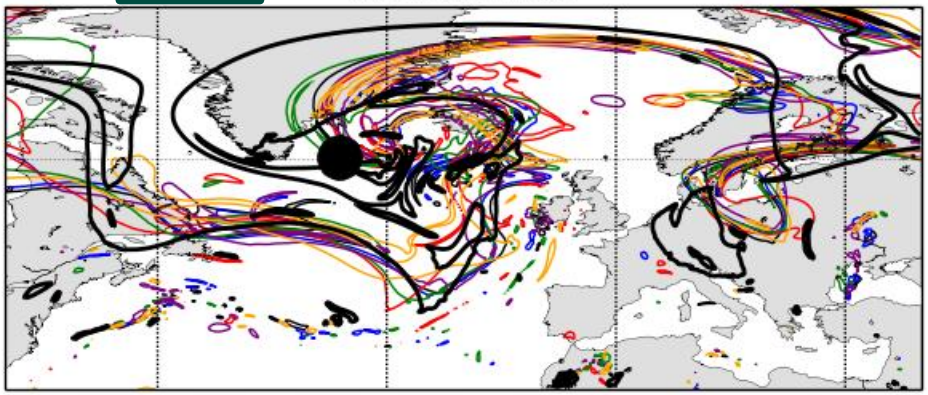
96 h

20161002:1200



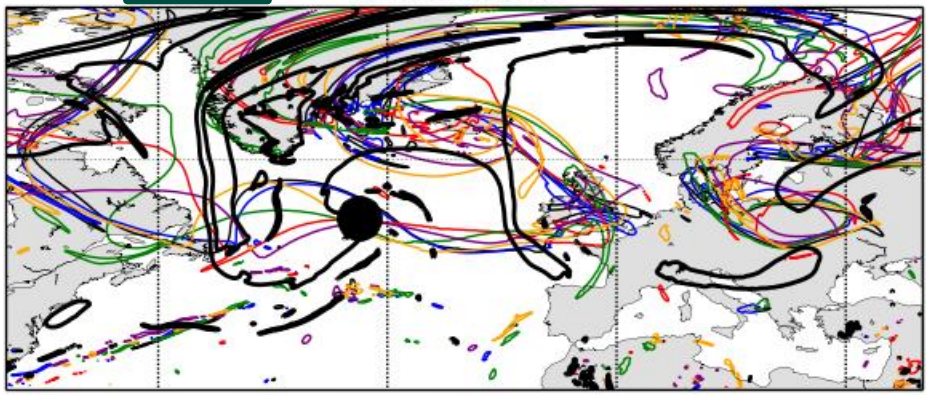
120 h

20161003:1200



144 h

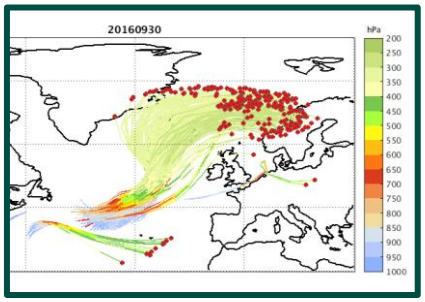
20161004:1200



Forecast initiated 27 09 2016

WCBs

- Physics changes have an impact on the intensity of the WCB
- Experiments with deeper cyclone tend to have stronger WCB



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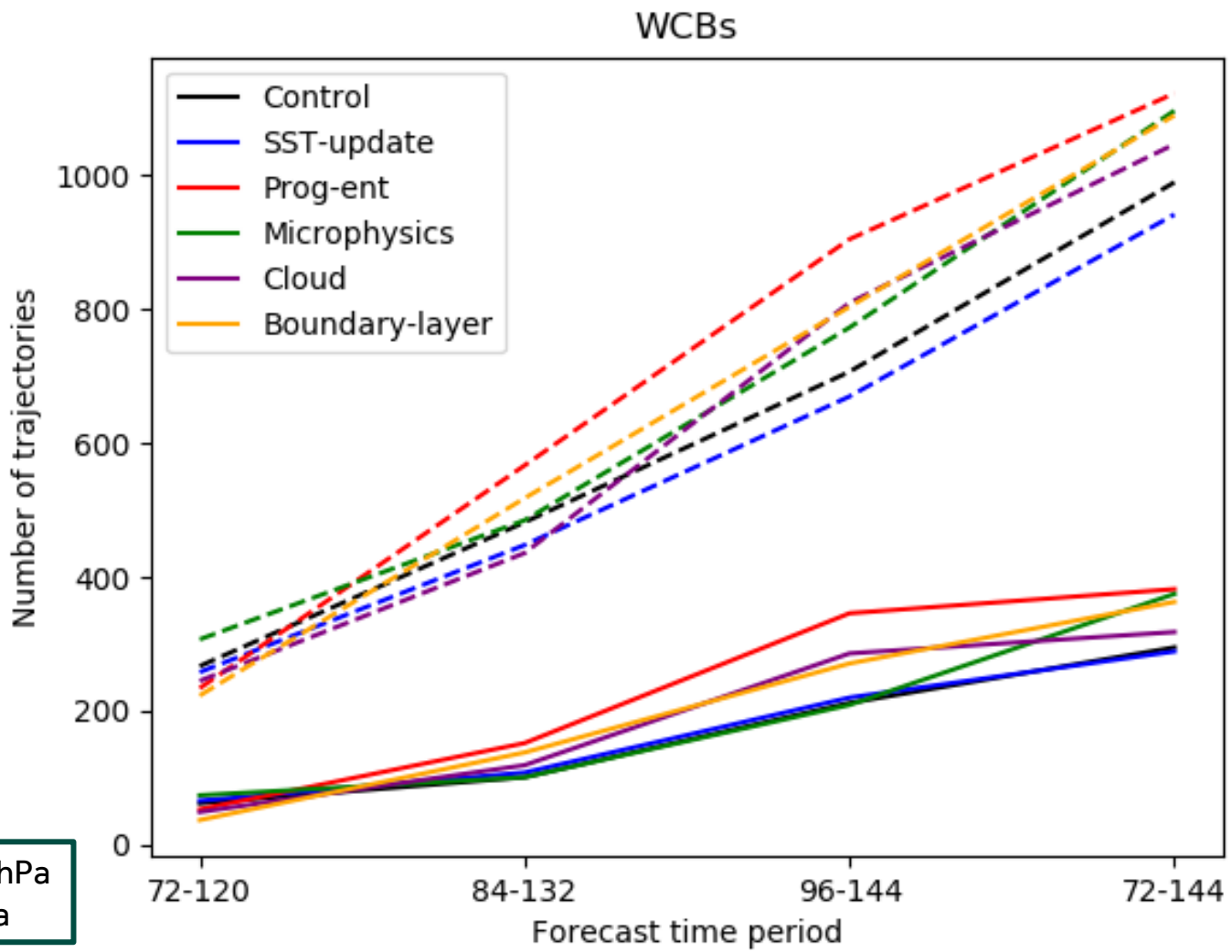
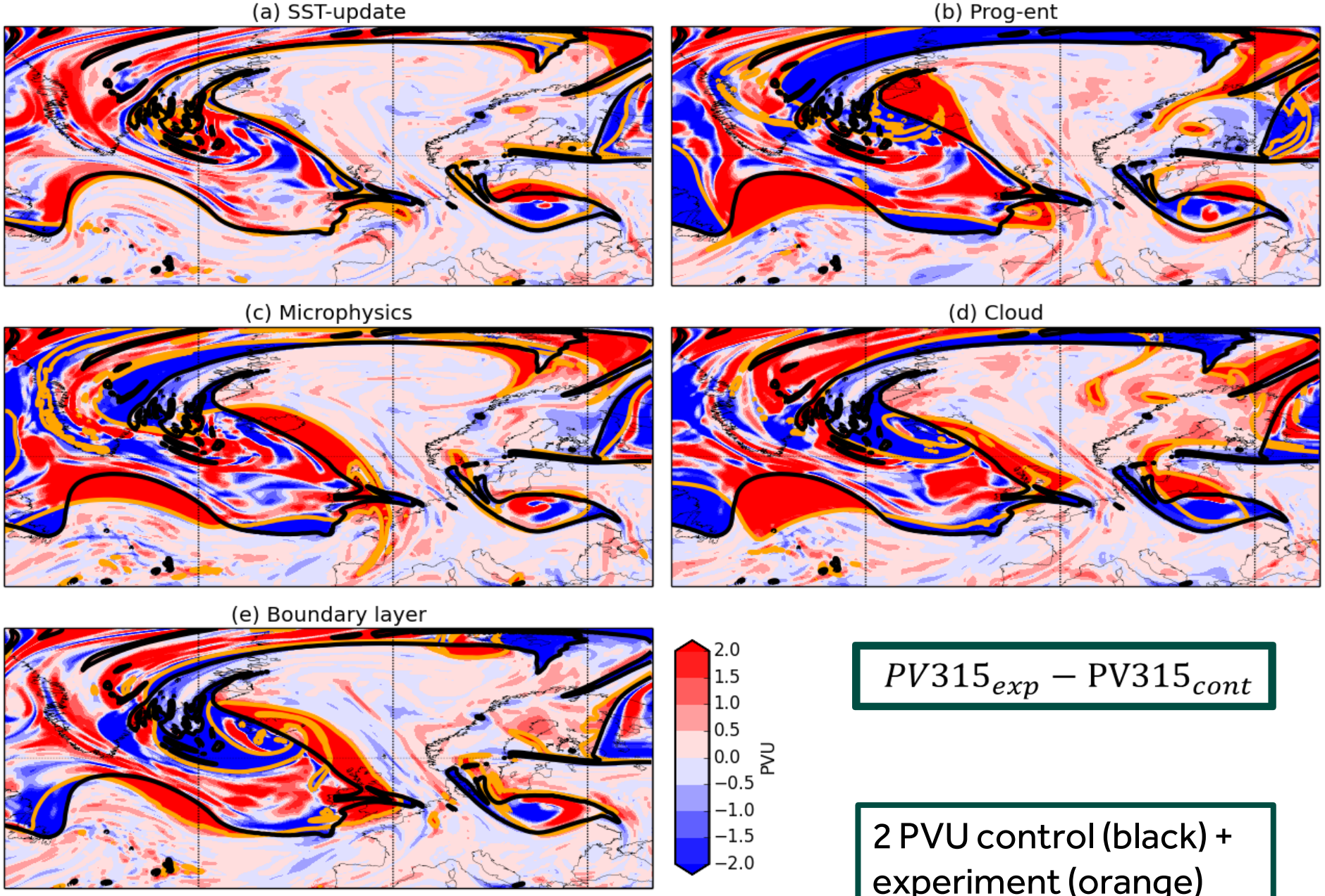
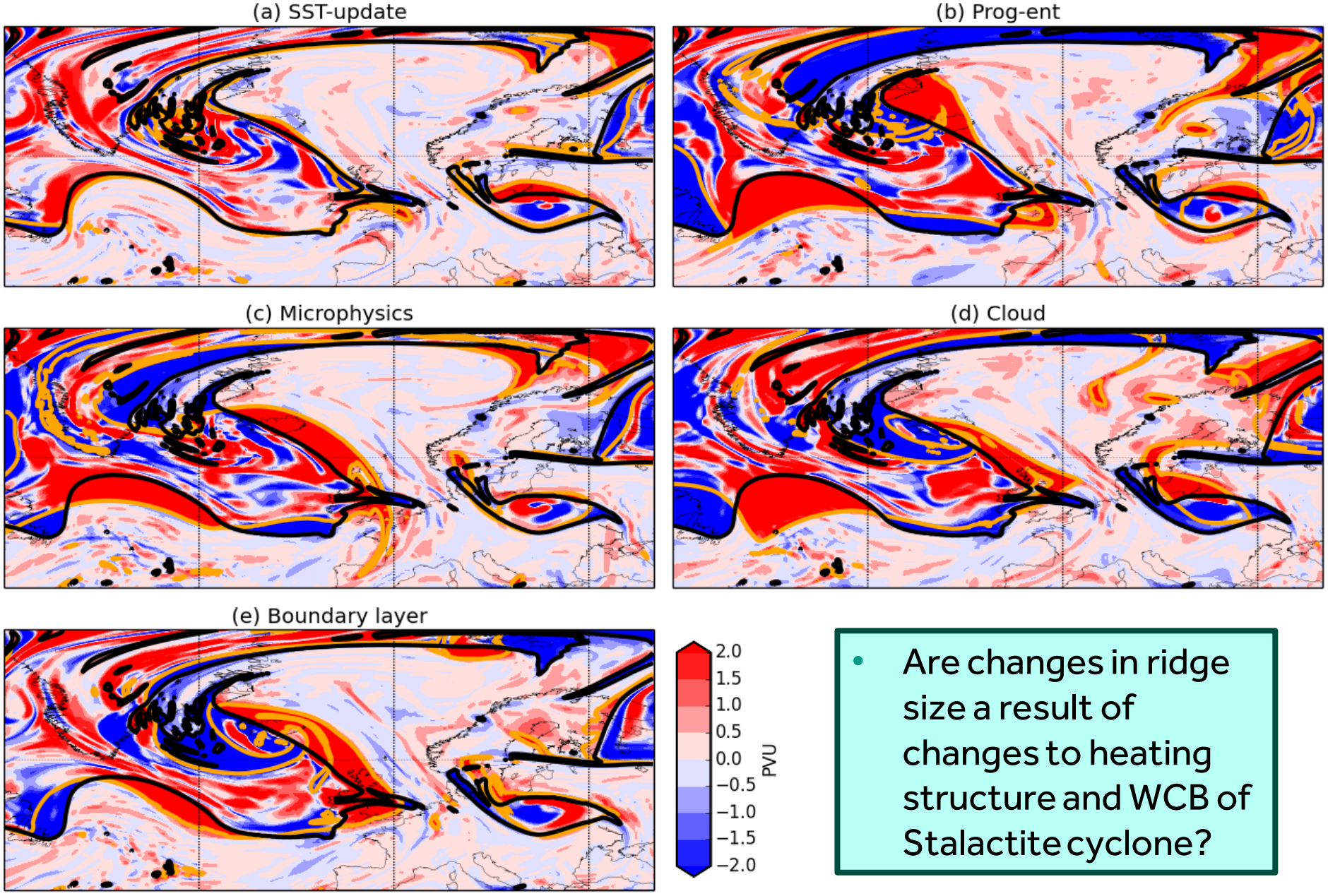


Dashed = WCB ascent > 500 hPa
Solid = WCB ascent > 600 hPa

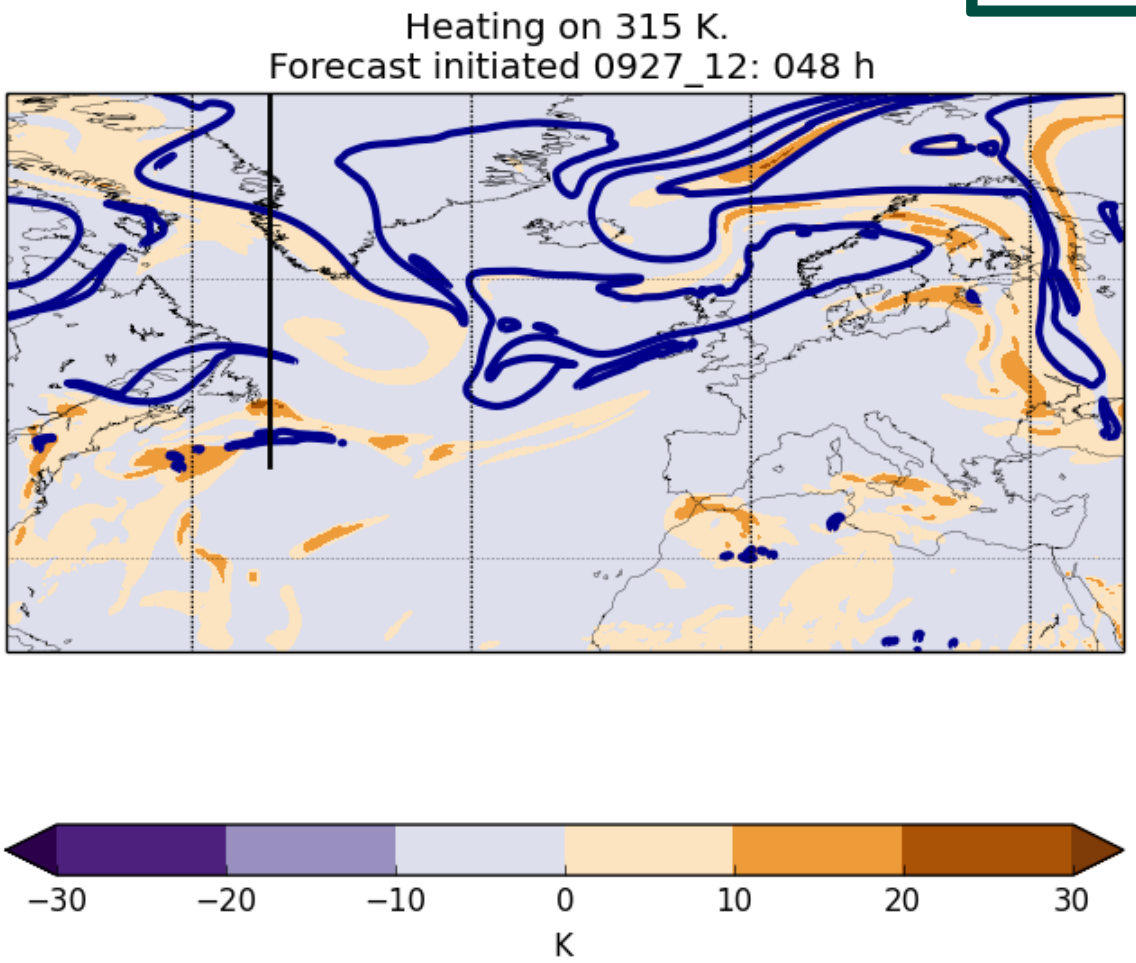

(a) SST-update
(b) Prog-ent
(c) Microphysics
(d) Cloud
(e) Boundary layer
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
PVU
$PV315_{exp} - \mathrm{PV315}_{cont}$
2 PVU control (black) + experiment (orange)

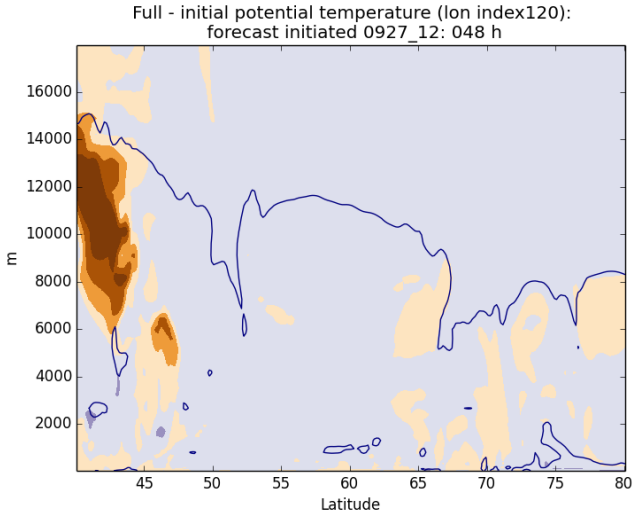


- Are changes in ridge size a result of changes to heating structure and WCB of Stalactite cyclone?

Heating in ridge

$$Heating = \theta(x,t) - \theta_0(x,t)$$





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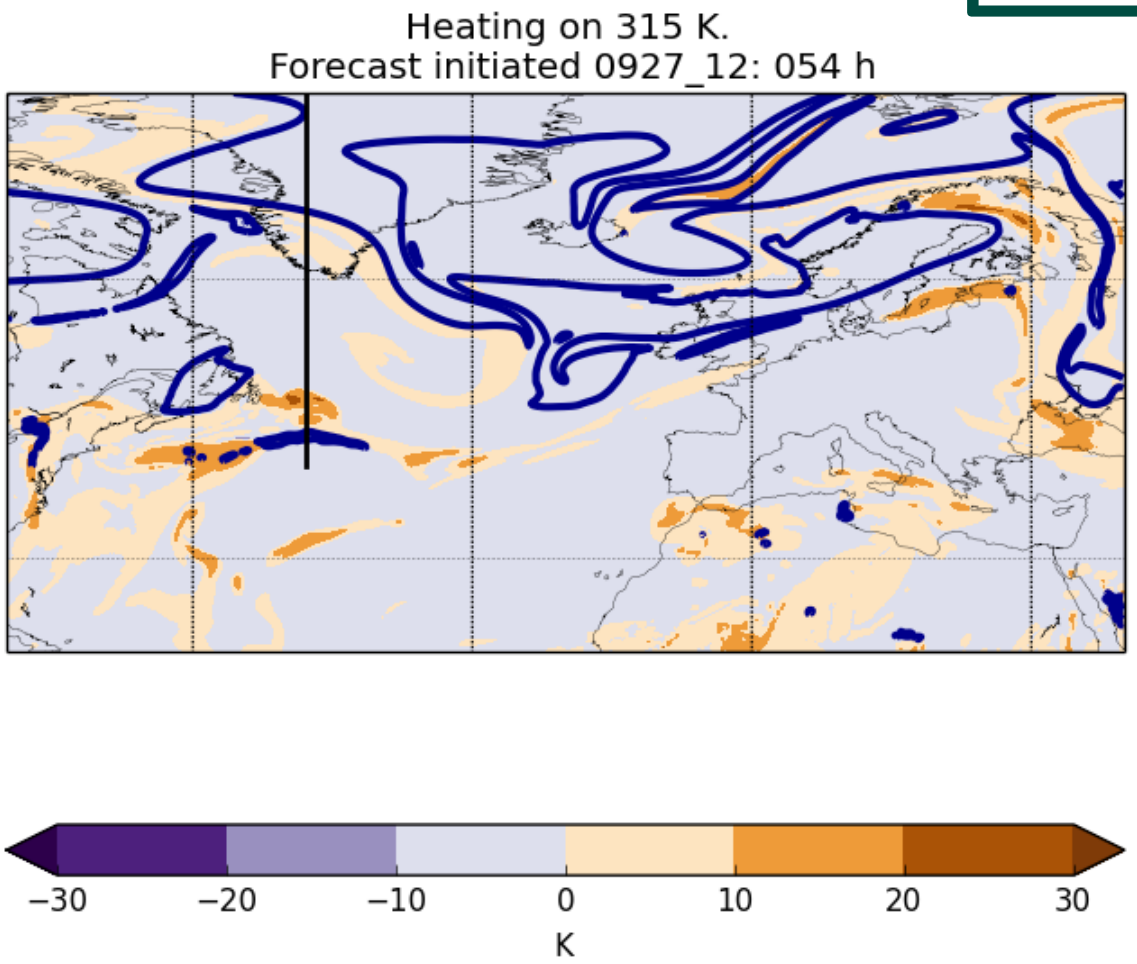

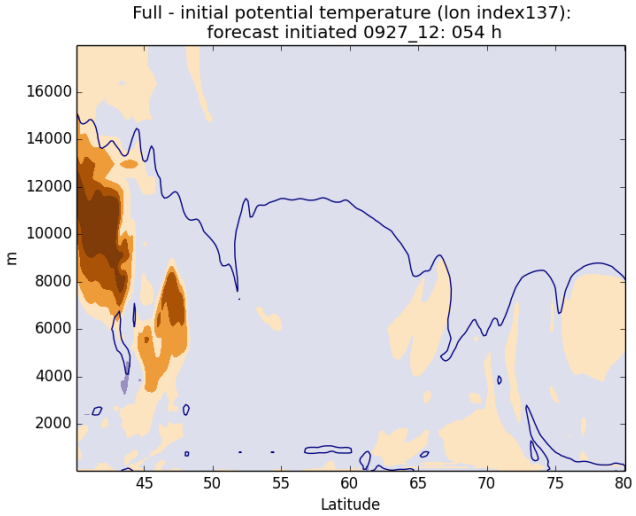

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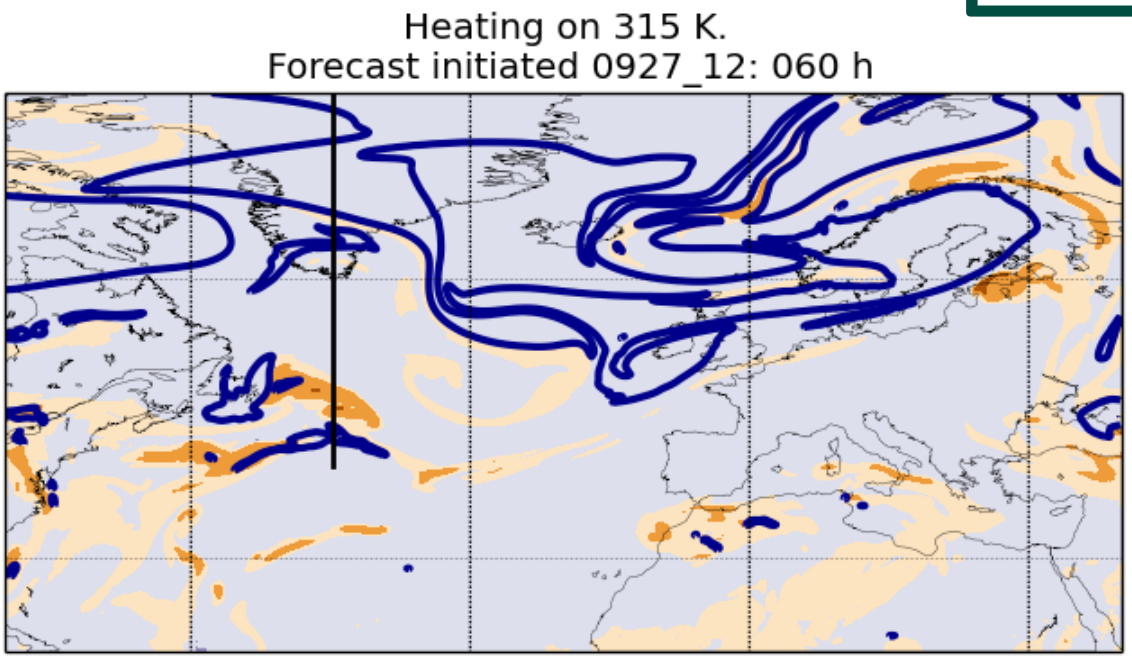

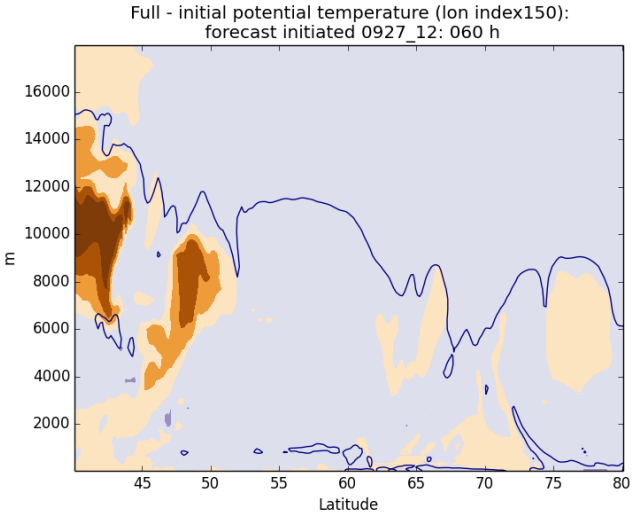

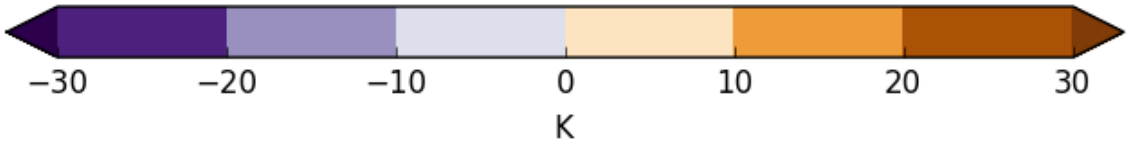

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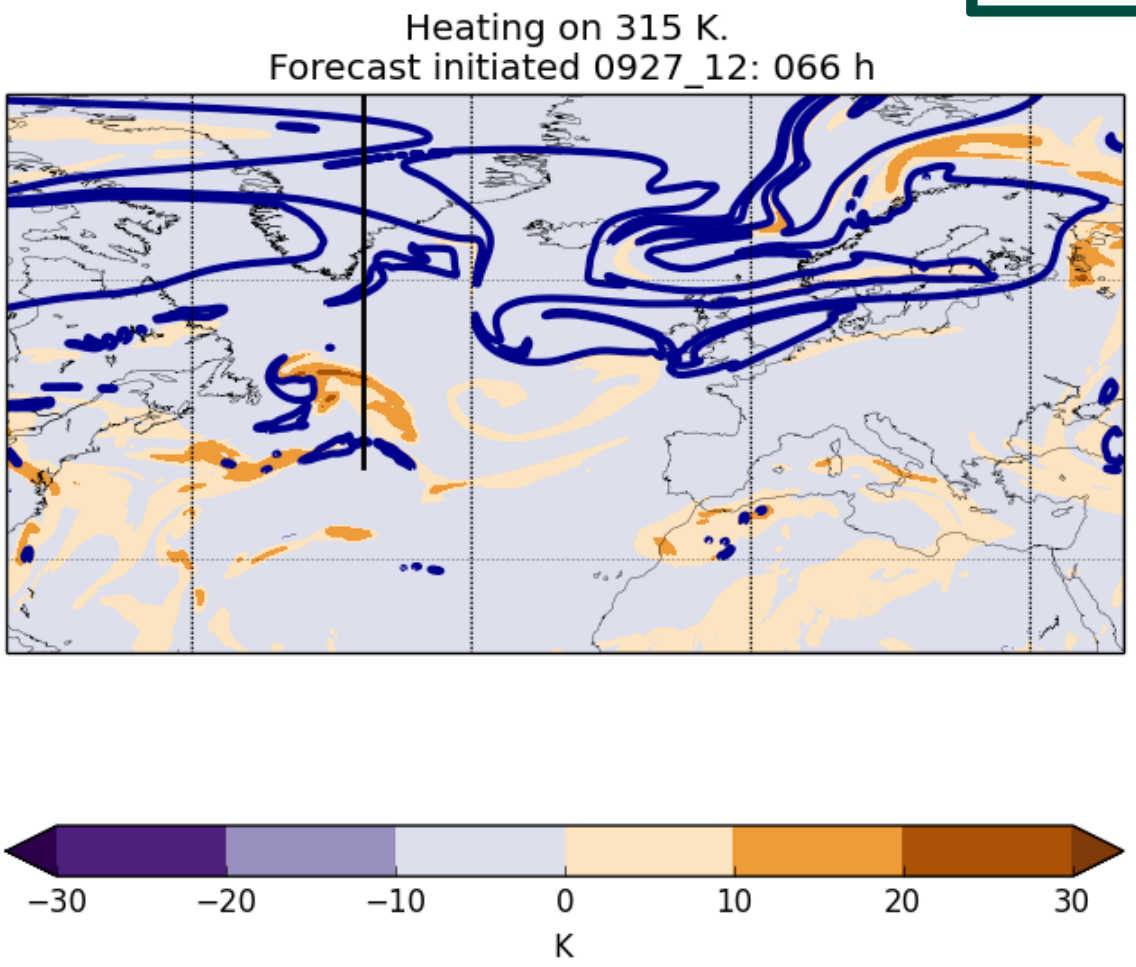

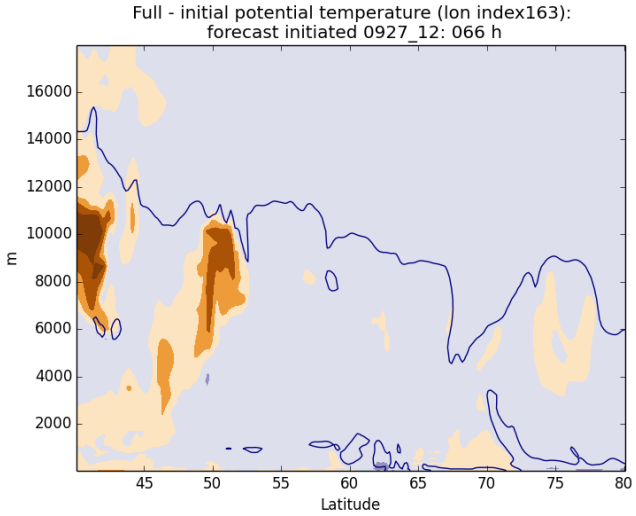

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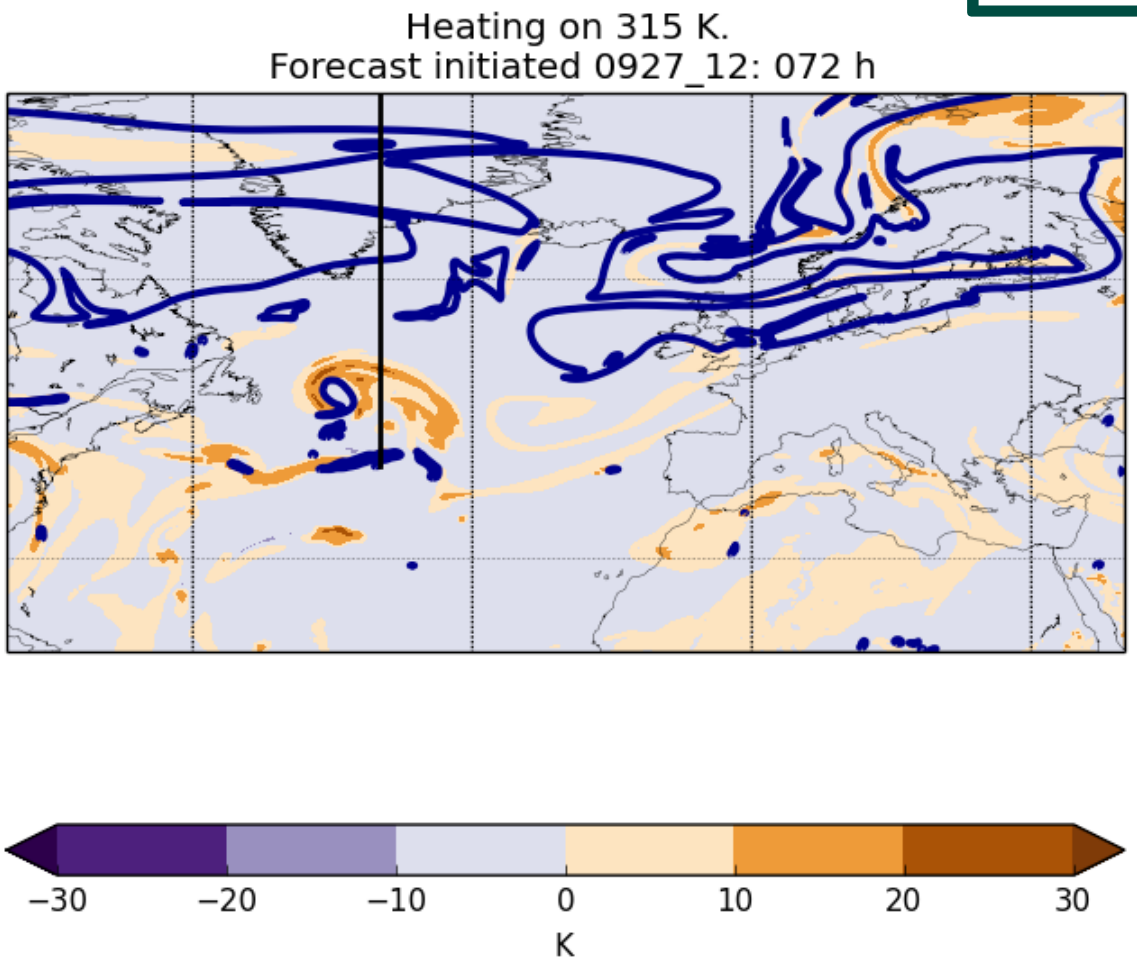

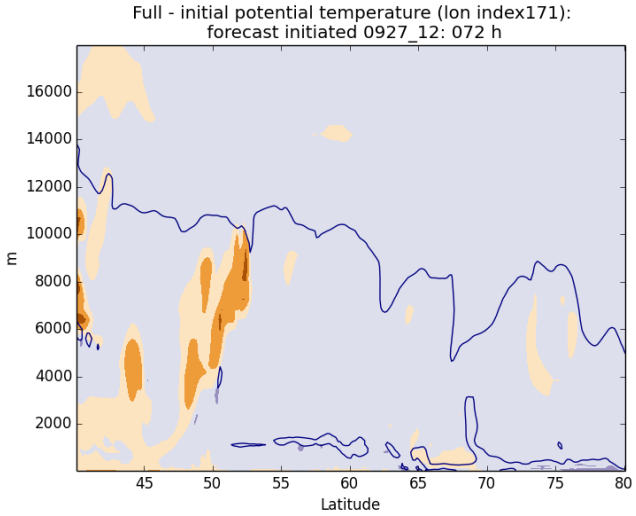

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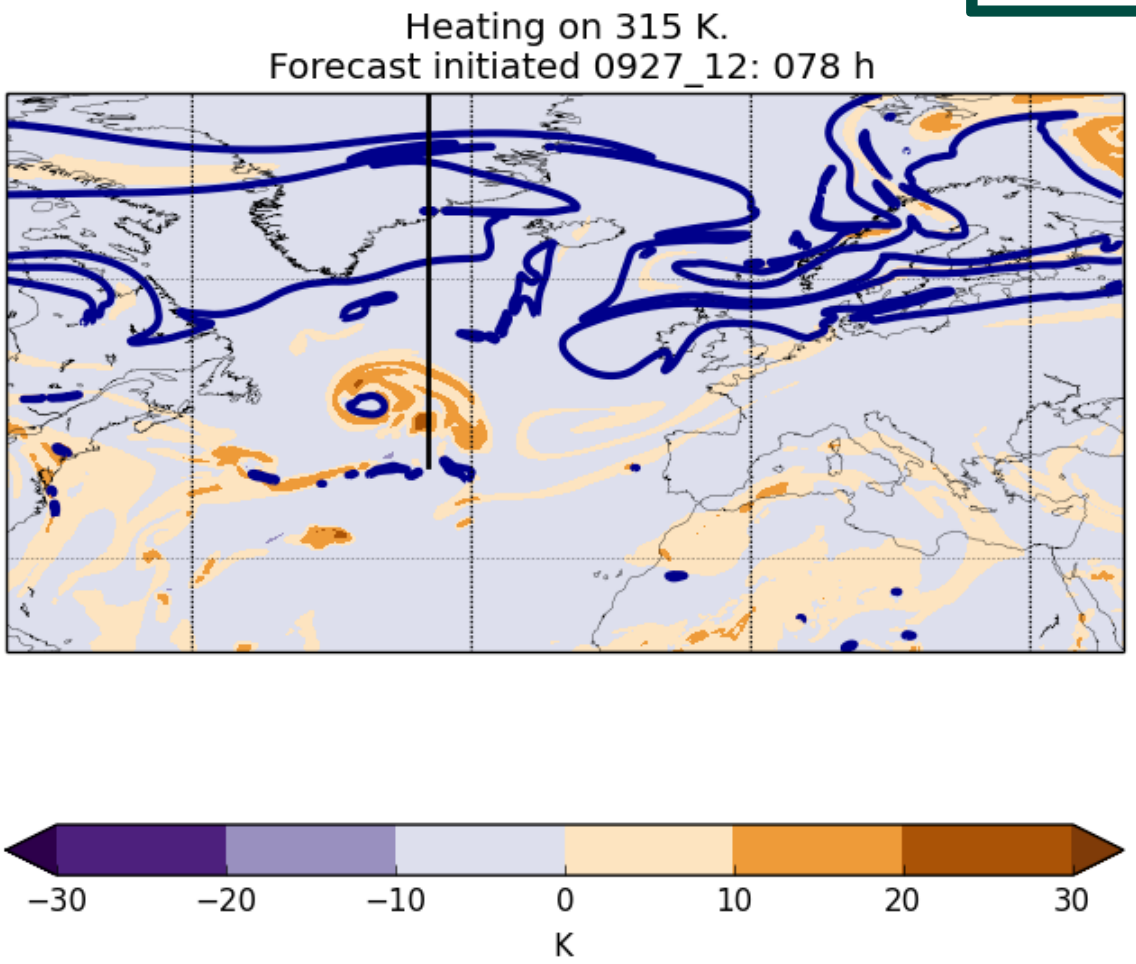
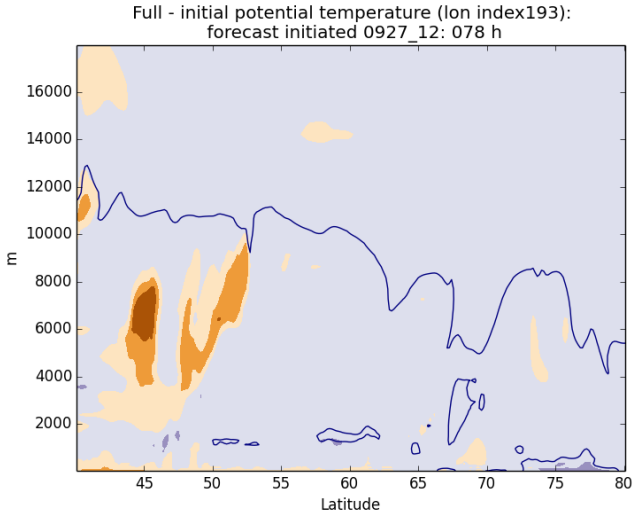
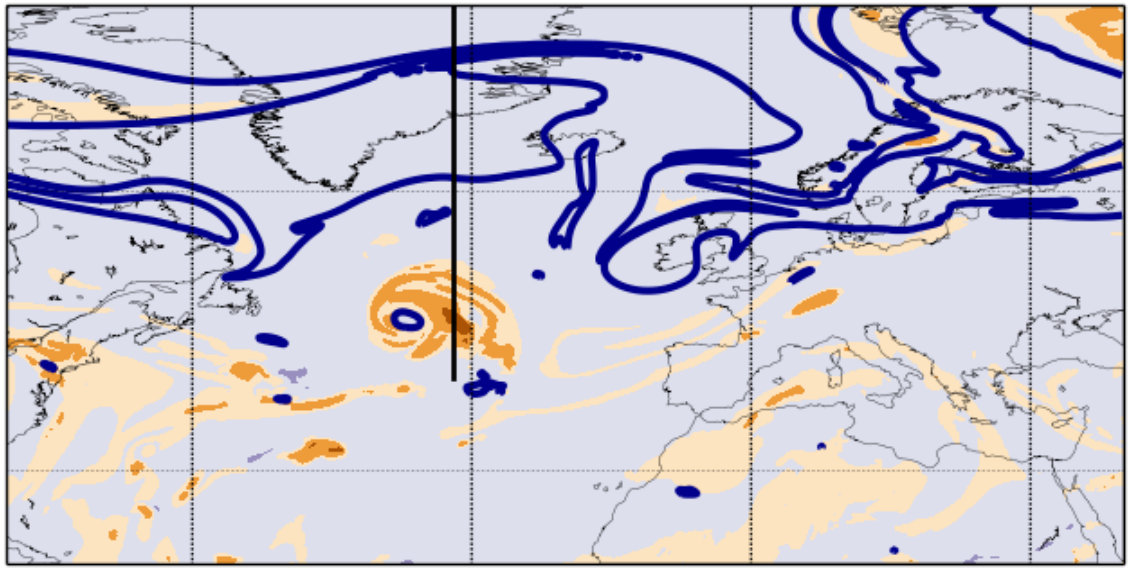
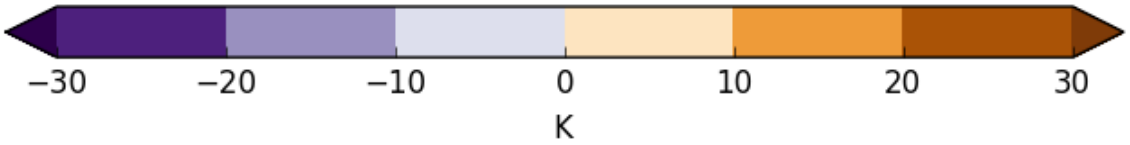


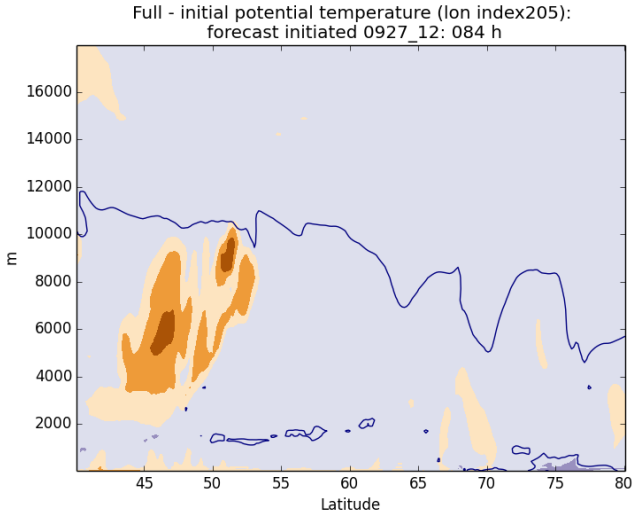


$$Heating = \theta(x,t) - \theta_0(x,t)$$

Heating on 315 K.
Forecast initiated 0927_12: 084 h







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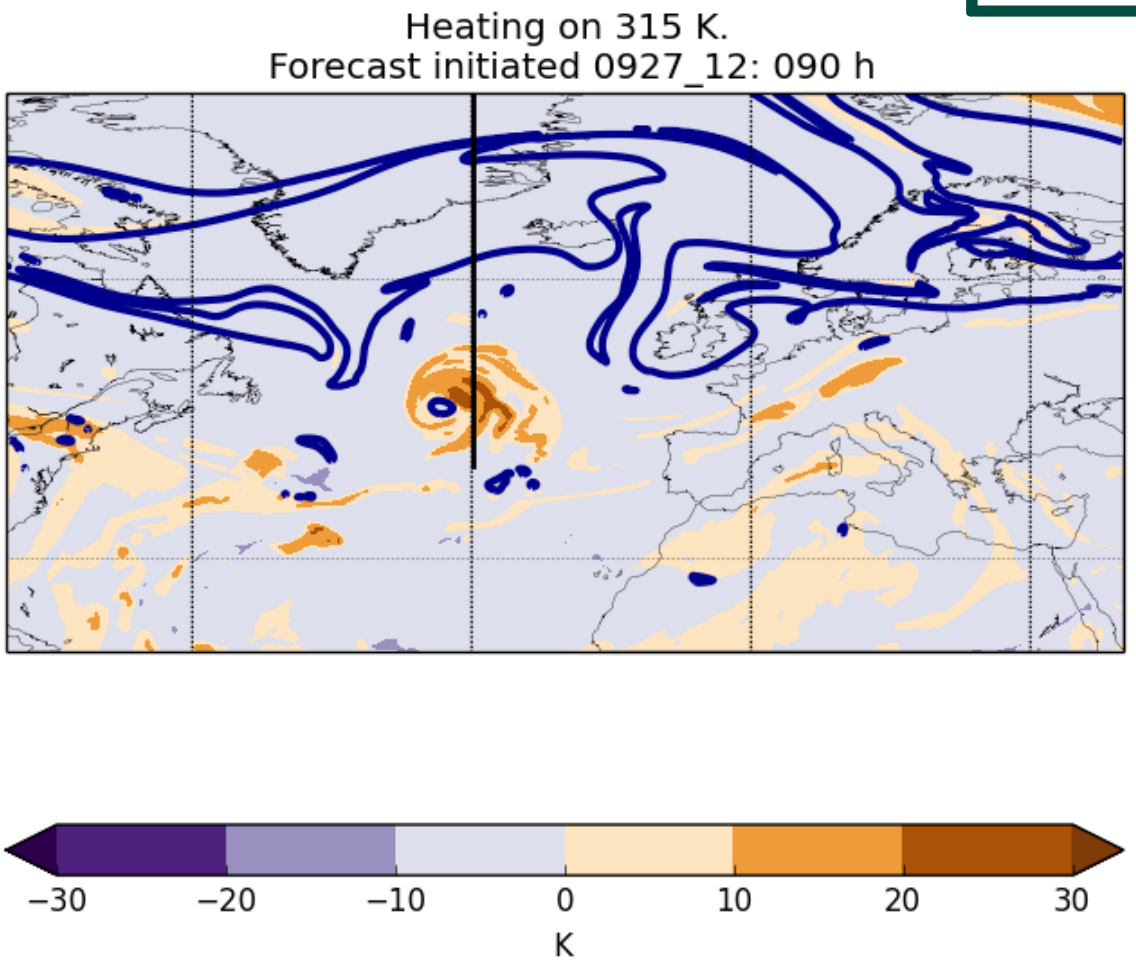

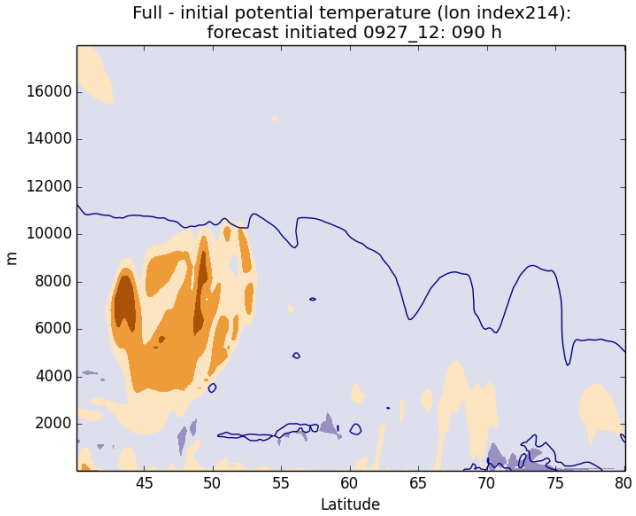

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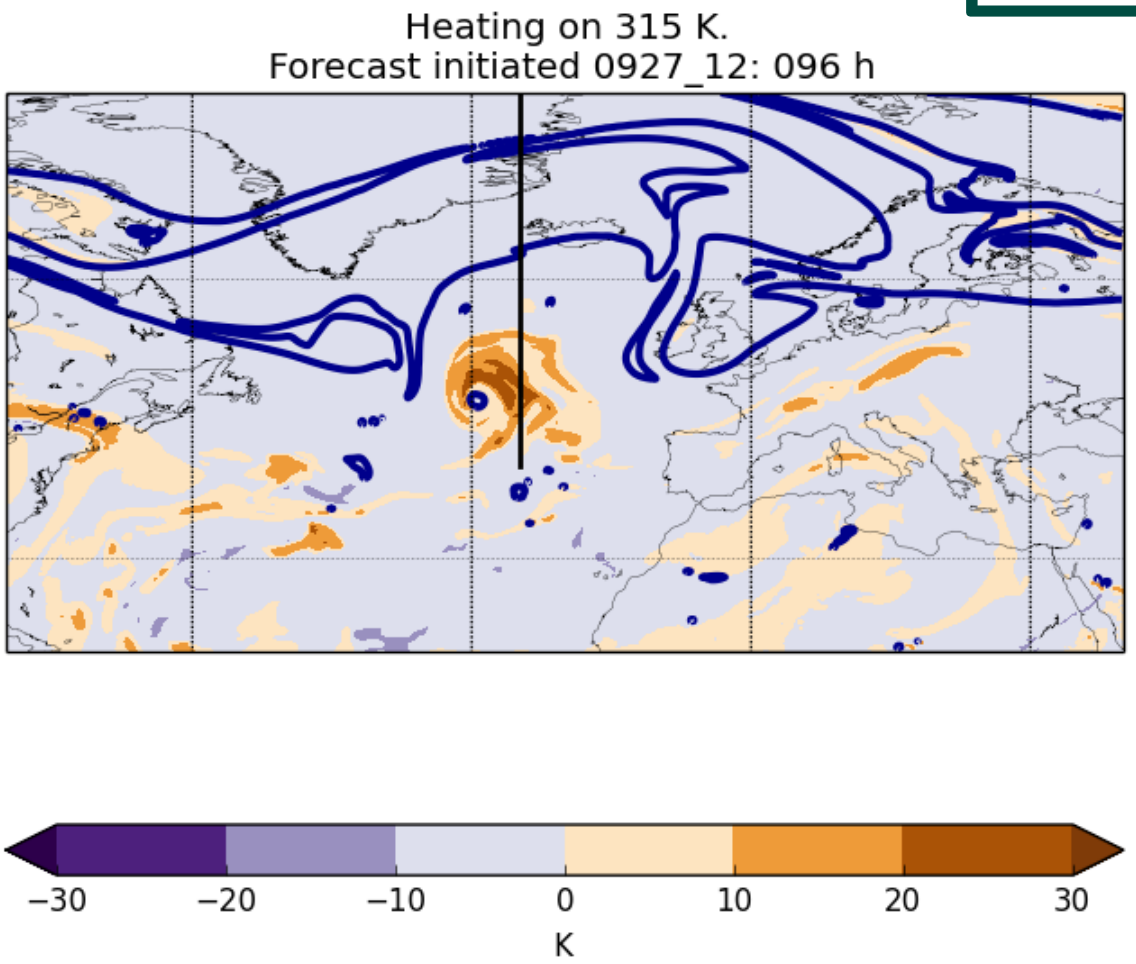

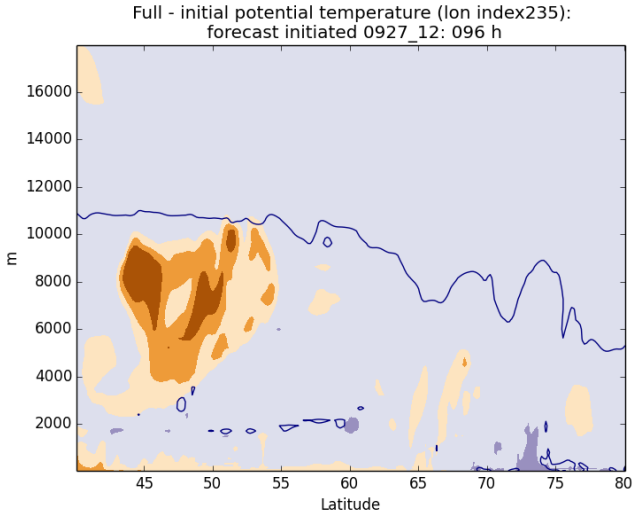

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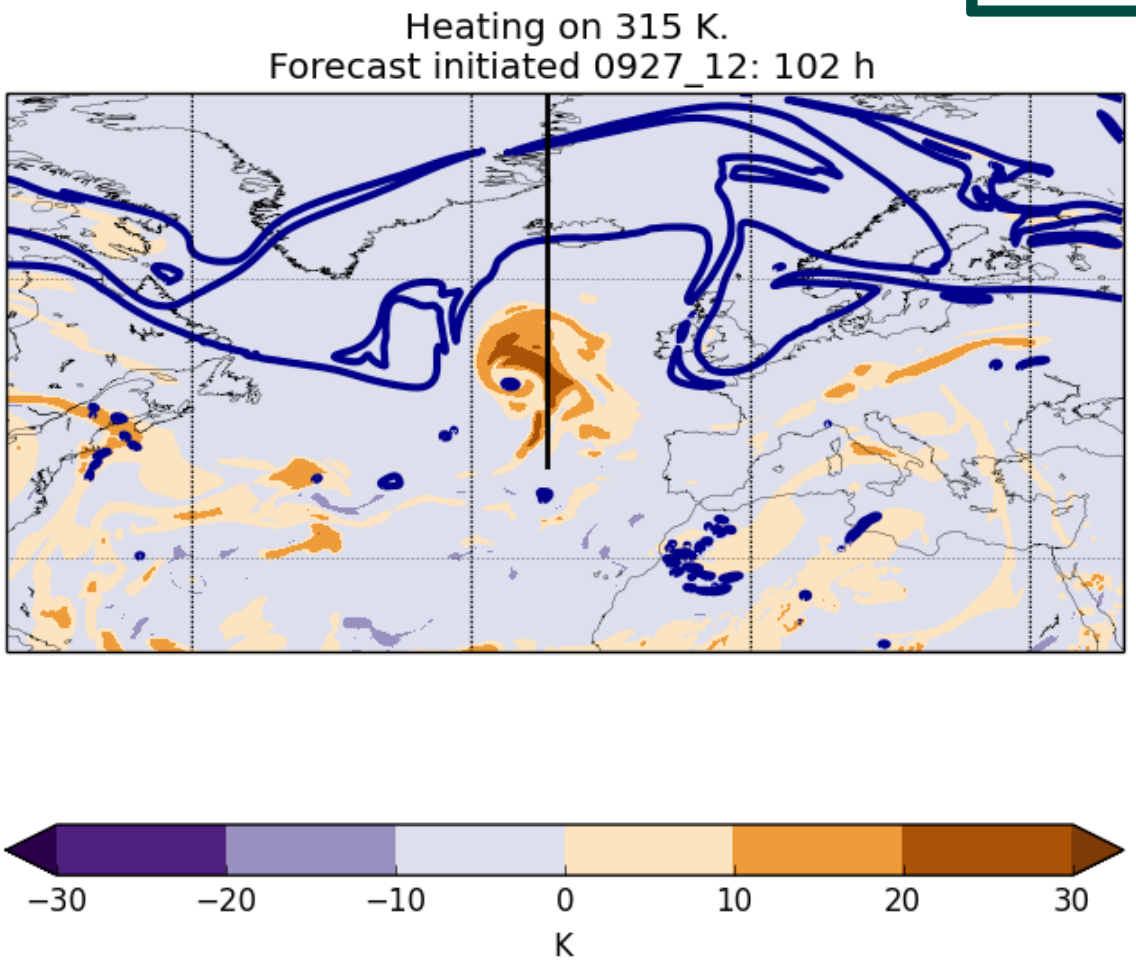

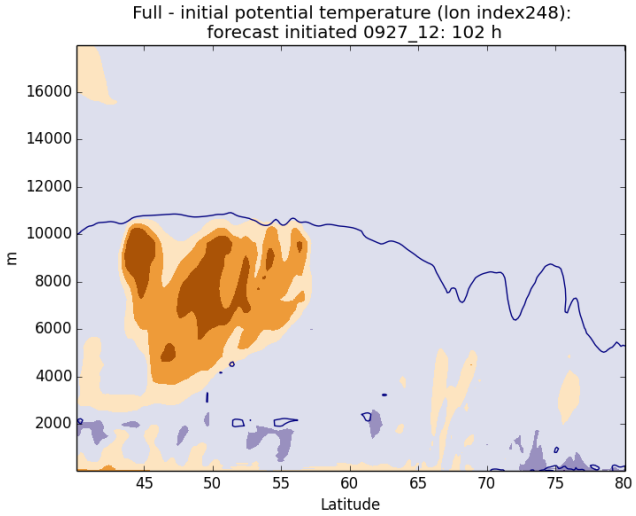

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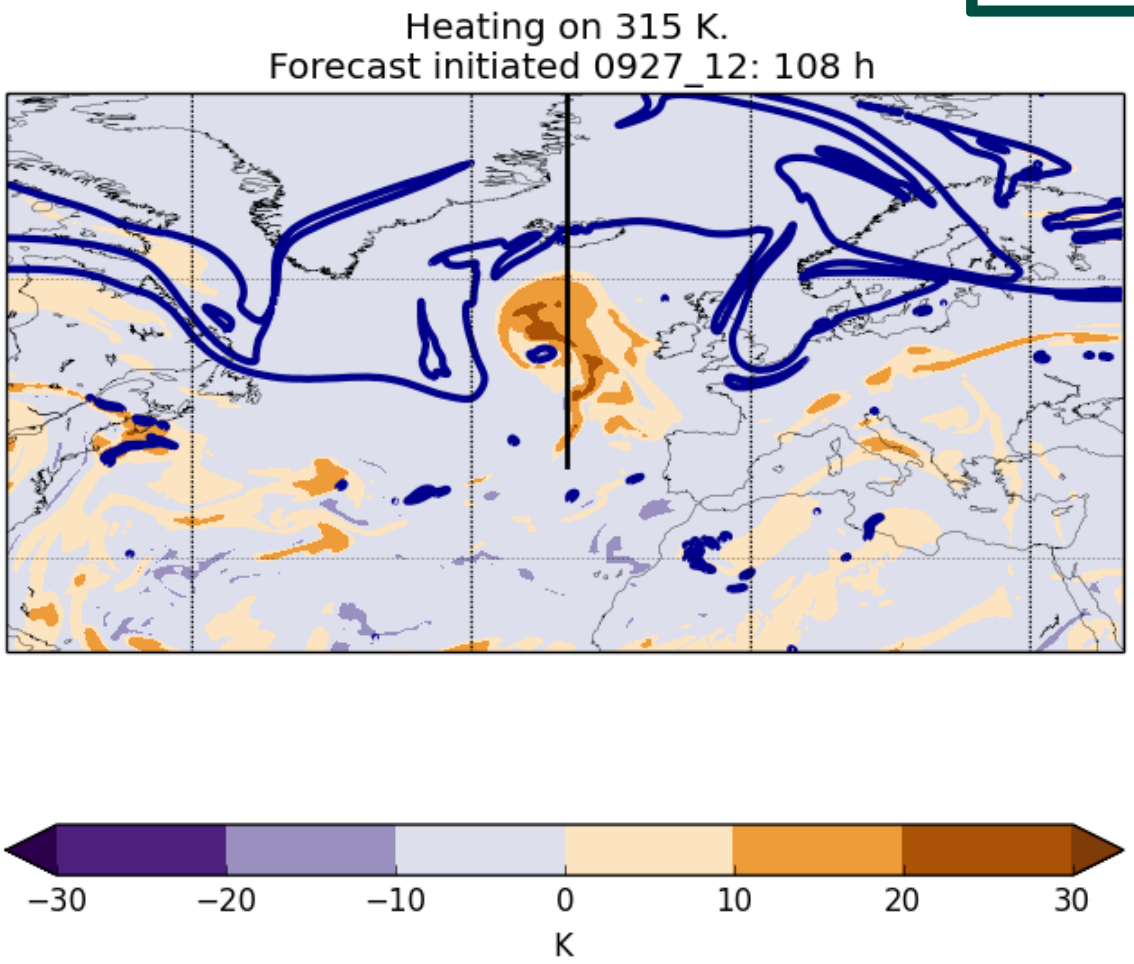

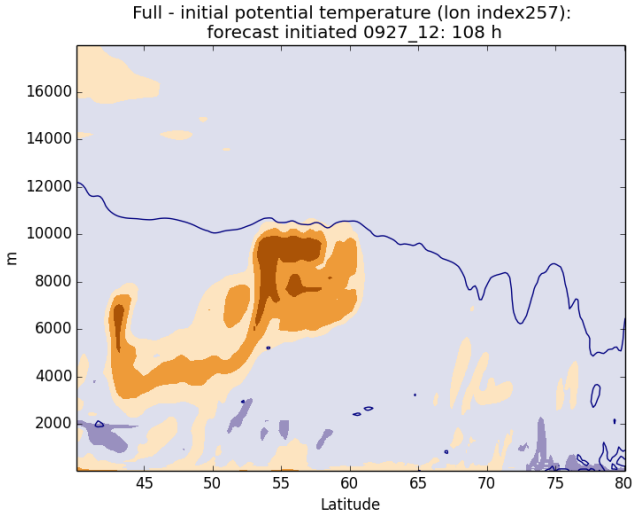

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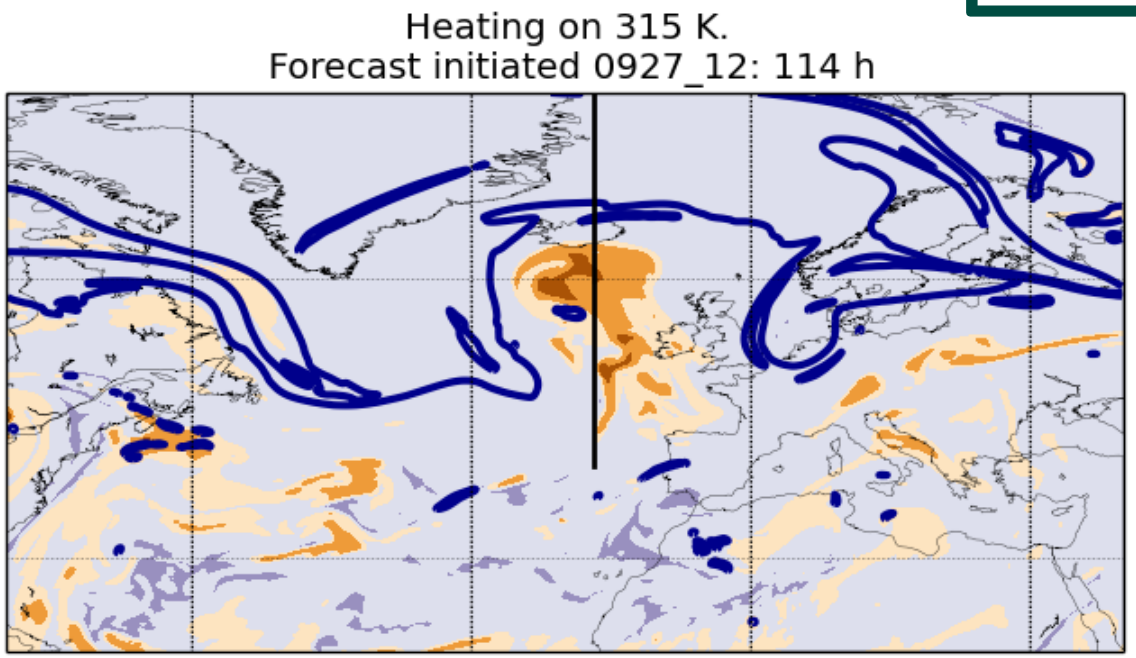

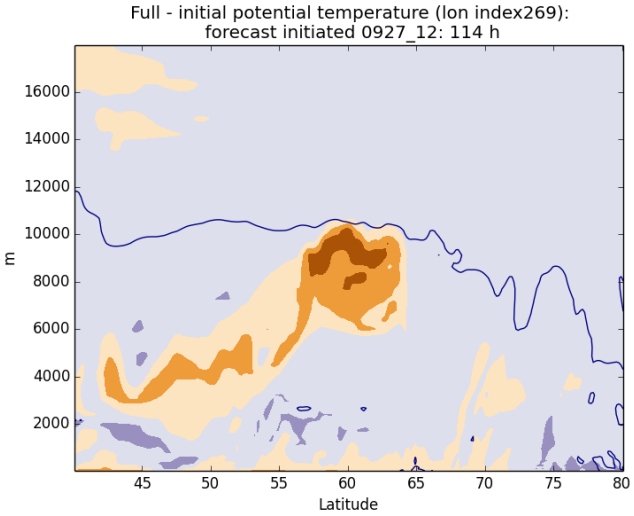

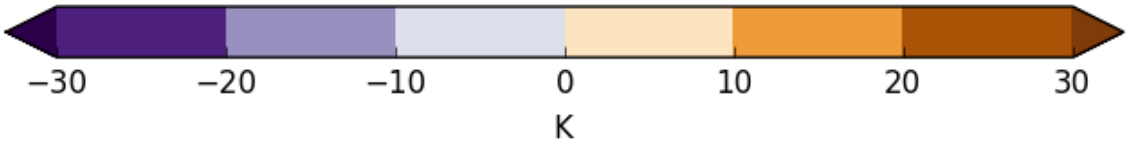

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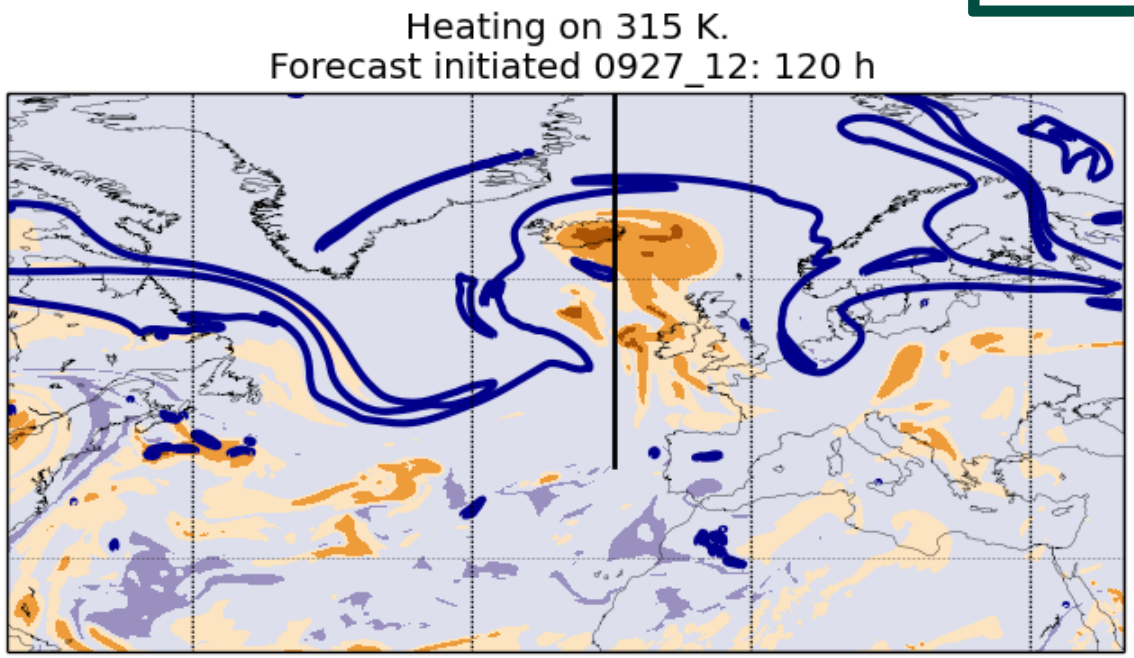
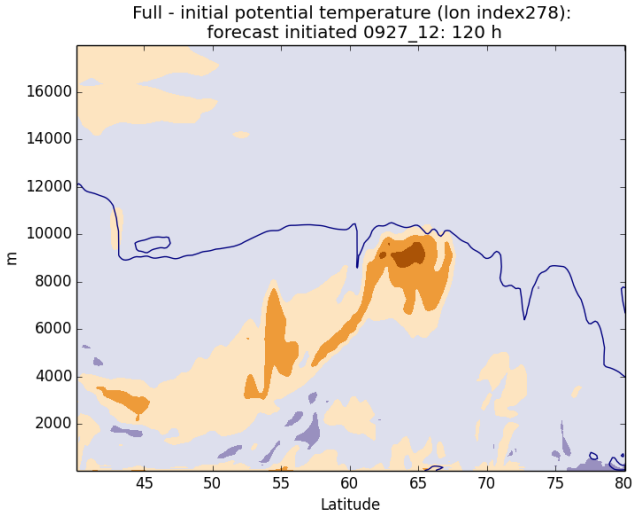
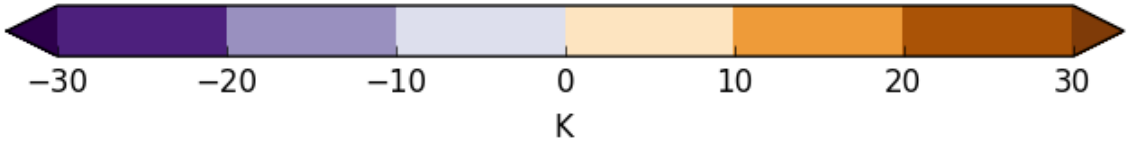
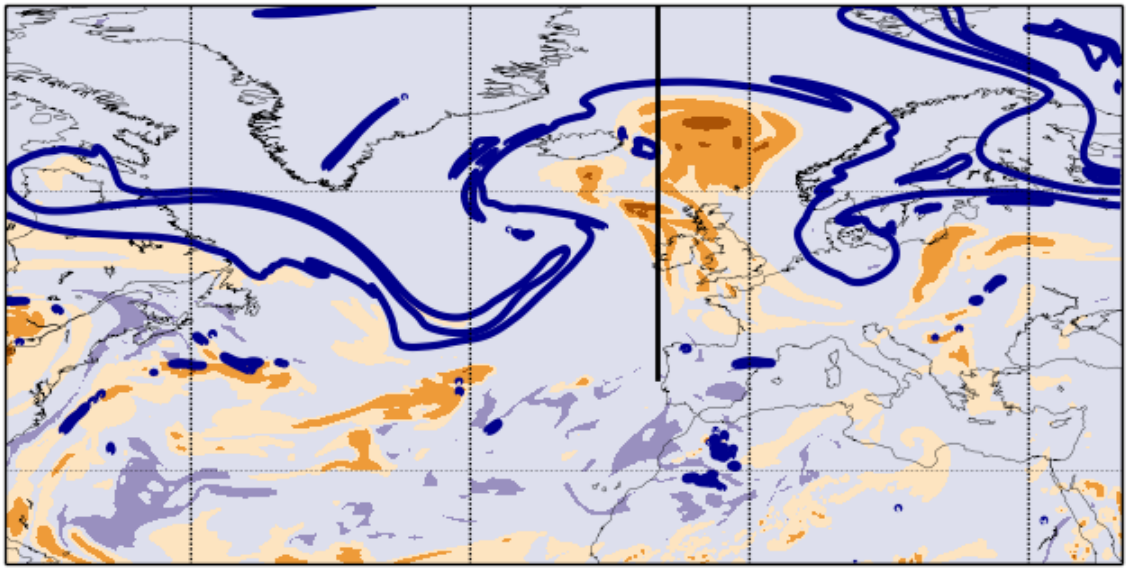


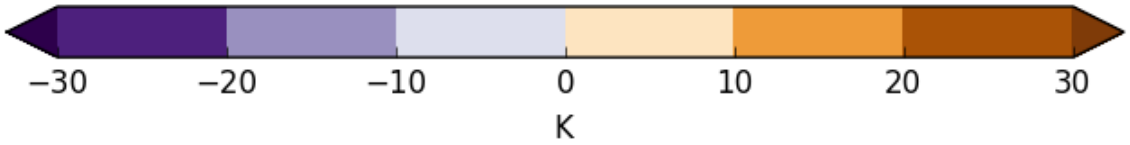


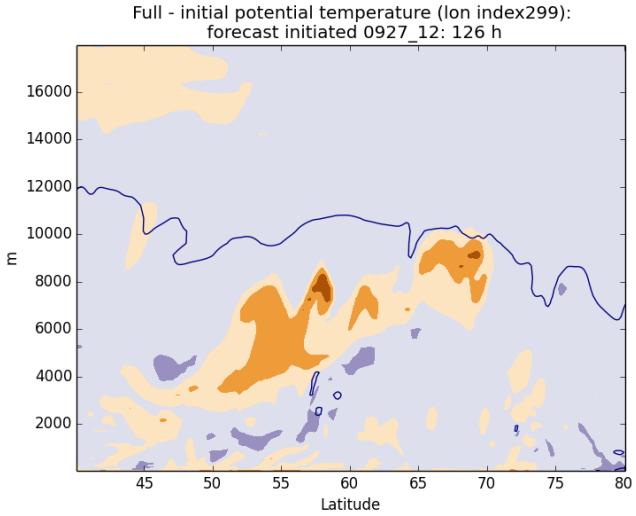


$$Heating = \theta(x,t) - \theta_0(x,t)$$

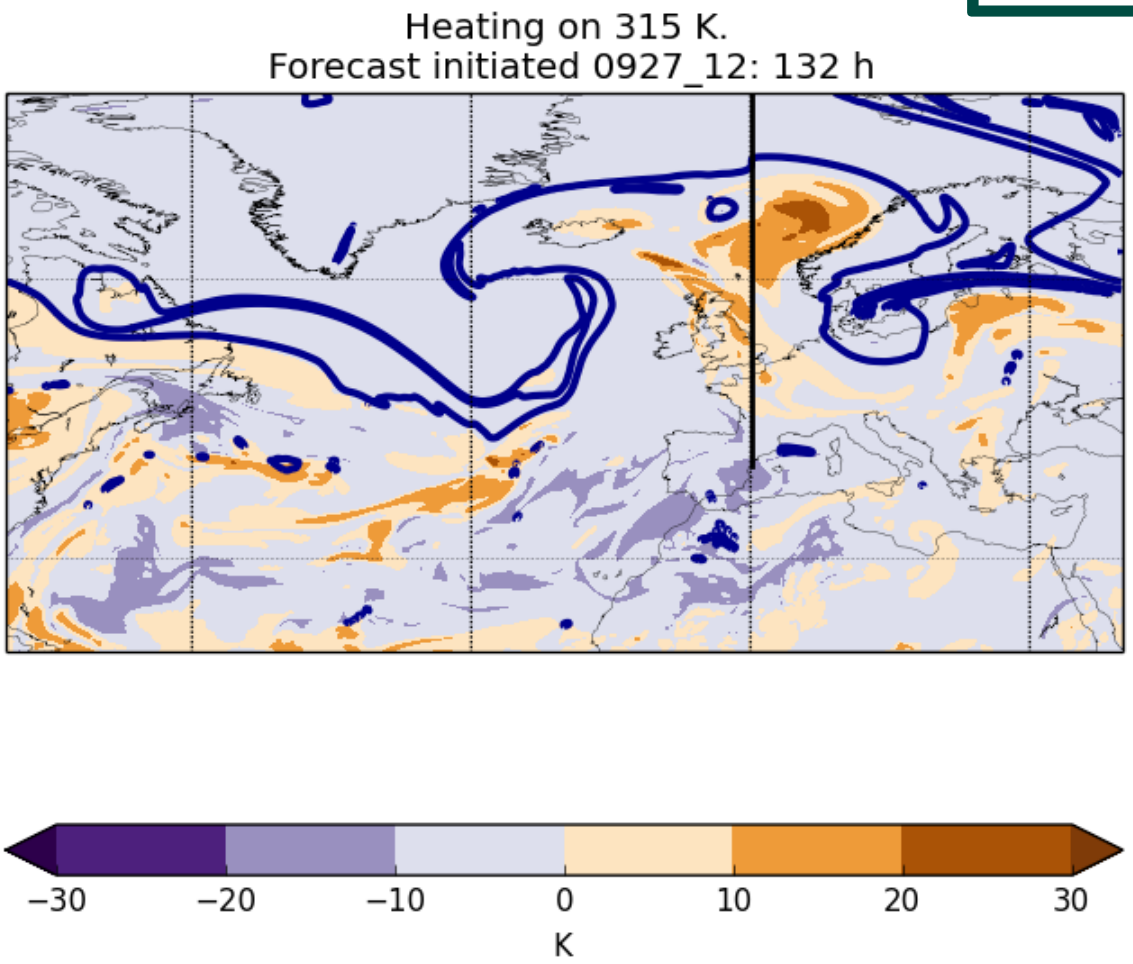
Heating on 315 K.
Forecast initiated 0927_12: 126 h

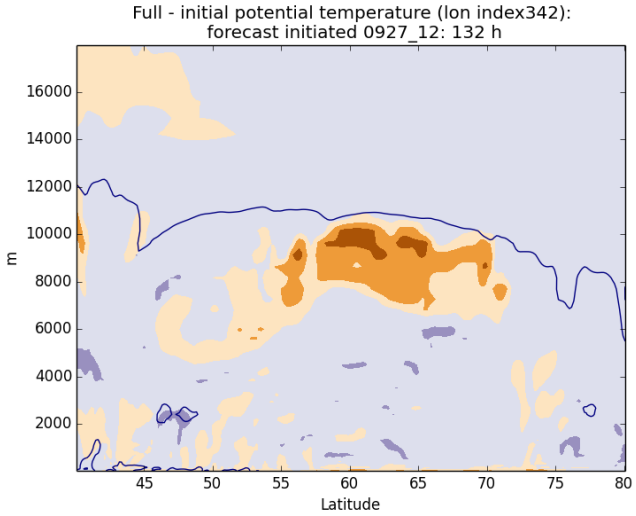




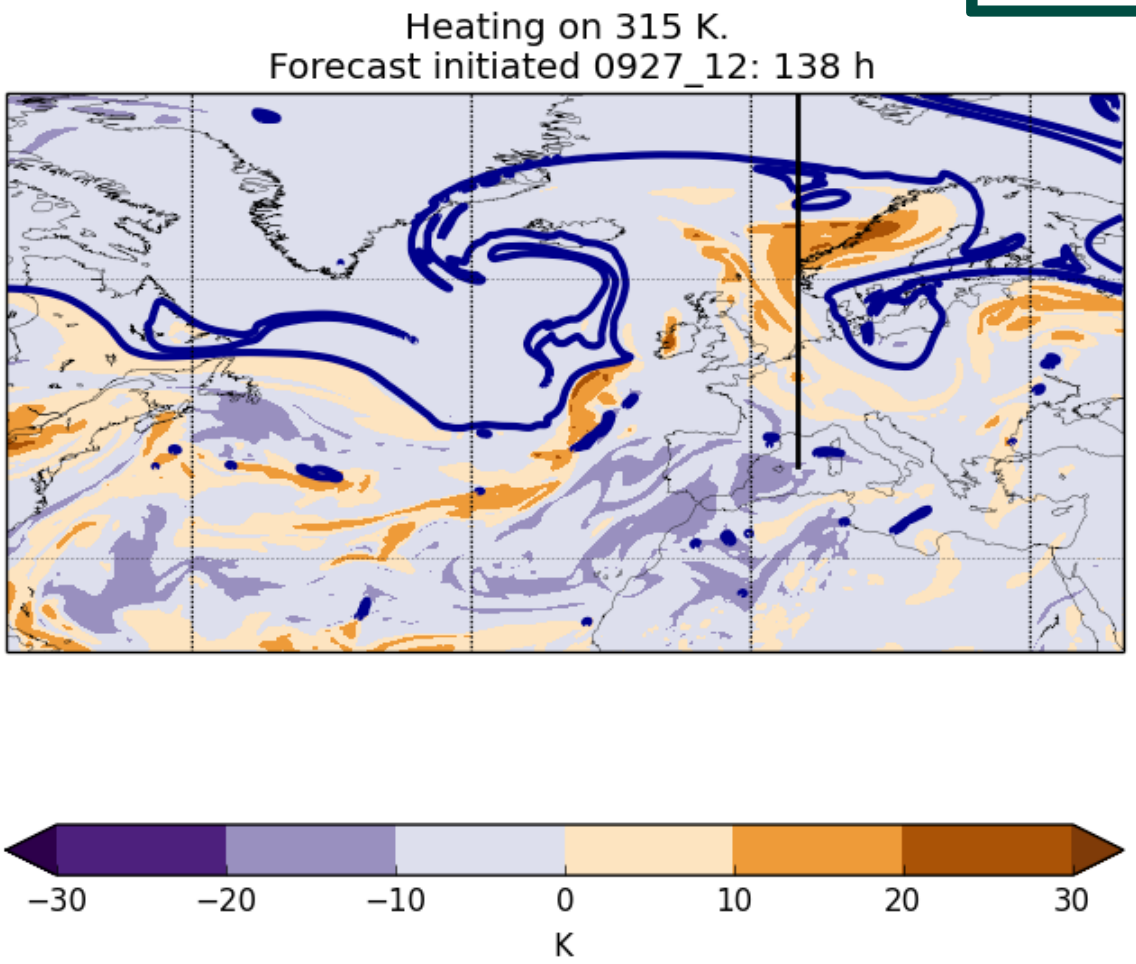


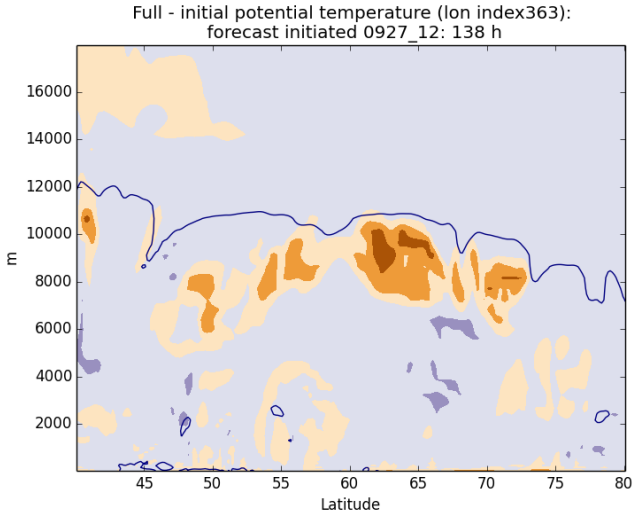
$$Heating = \theta(x,t) - \theta_0(x,t)$$





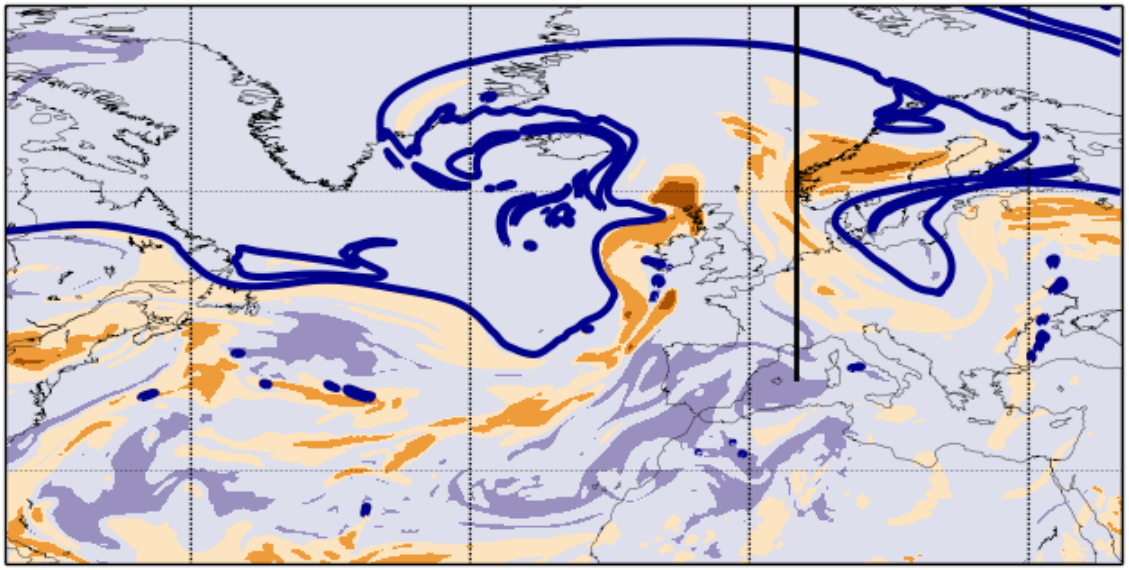
$$Heating = \theta(x,t) - \theta_0(x,t)$$

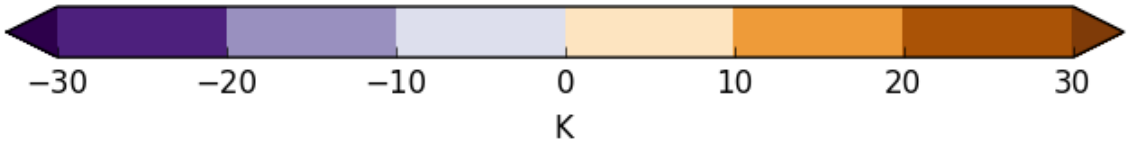


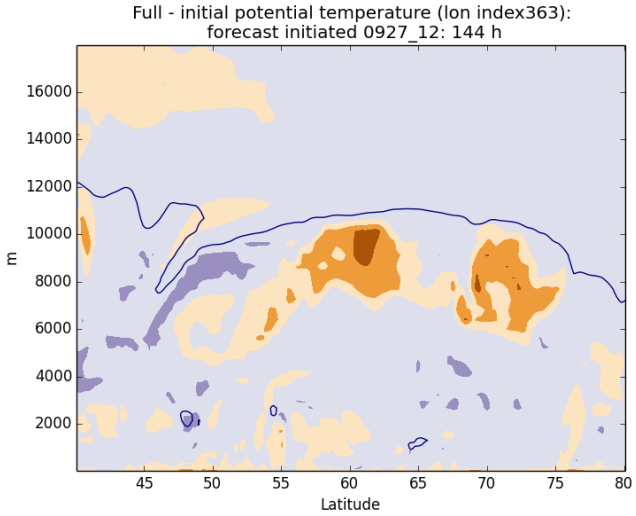


$$Heating = \theta(x,t) - \theta_0(x,t)$$

Heating on 315 K.
Forecast initiated 0927_12: 144 h







Heating in experiments

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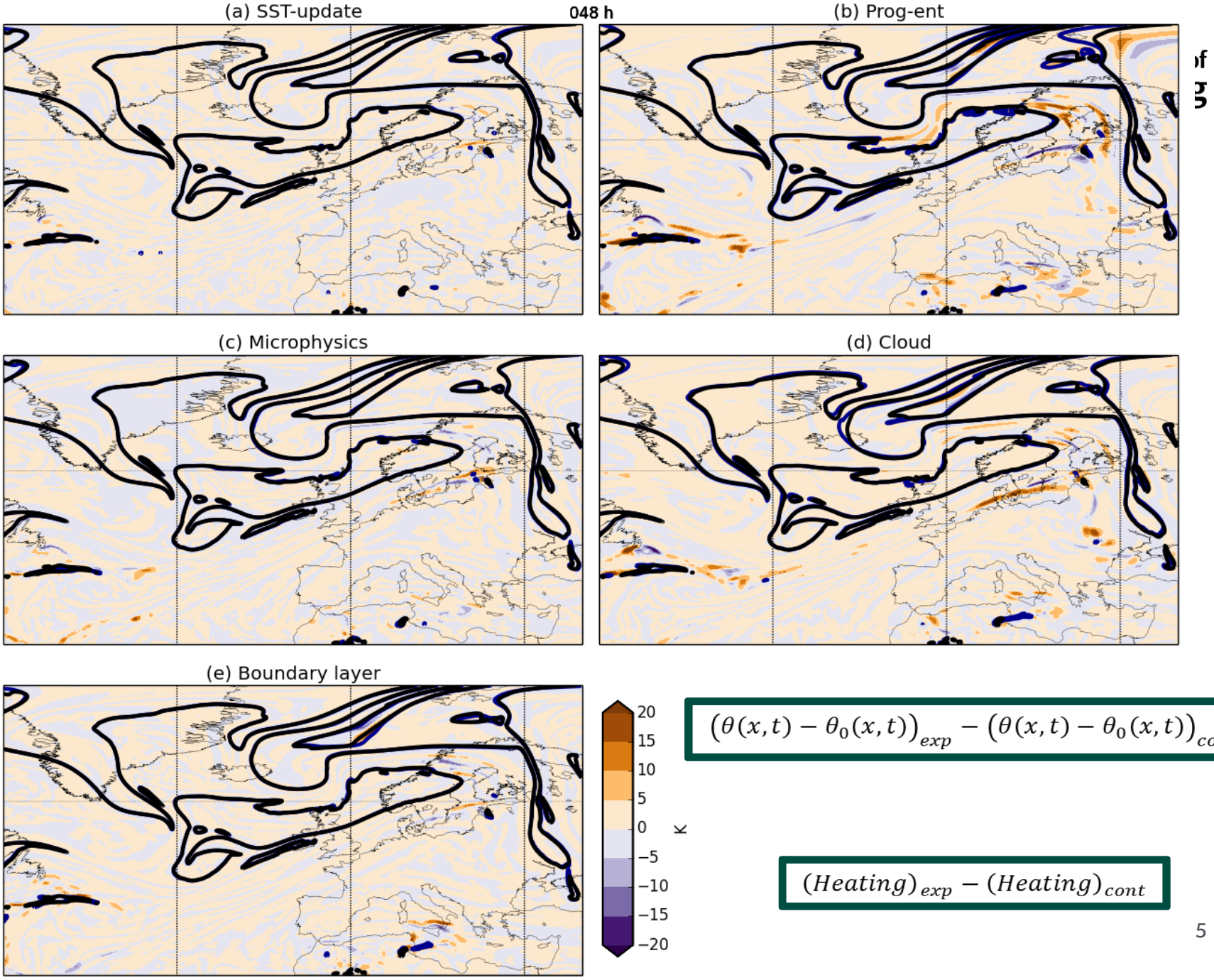
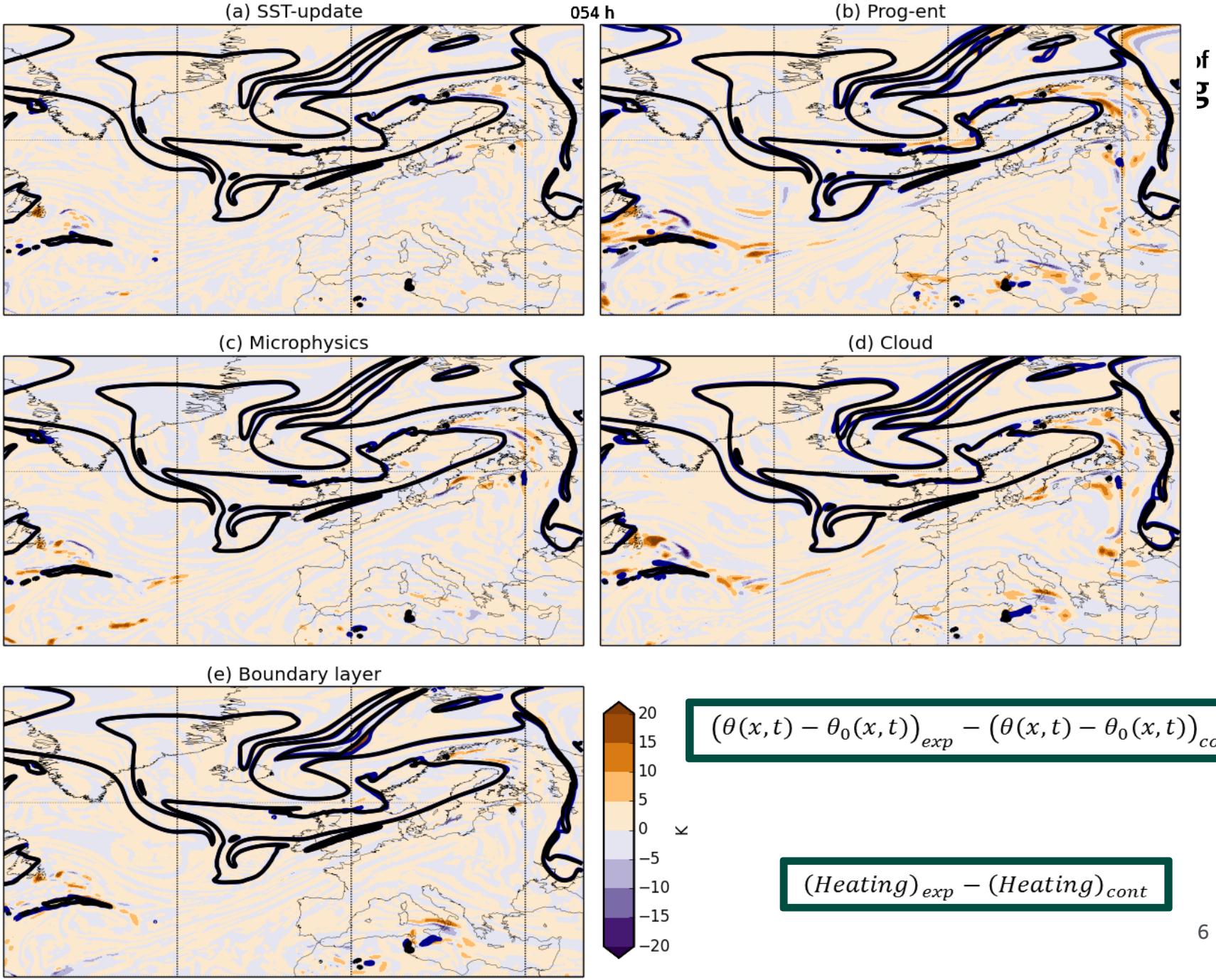
- Do we see changes to the heating structure in the Stalactite cyclone in the physics experiments?
- Are the changes contributing to change in evolution of the upper-level ridge via changes to the WCB structure?



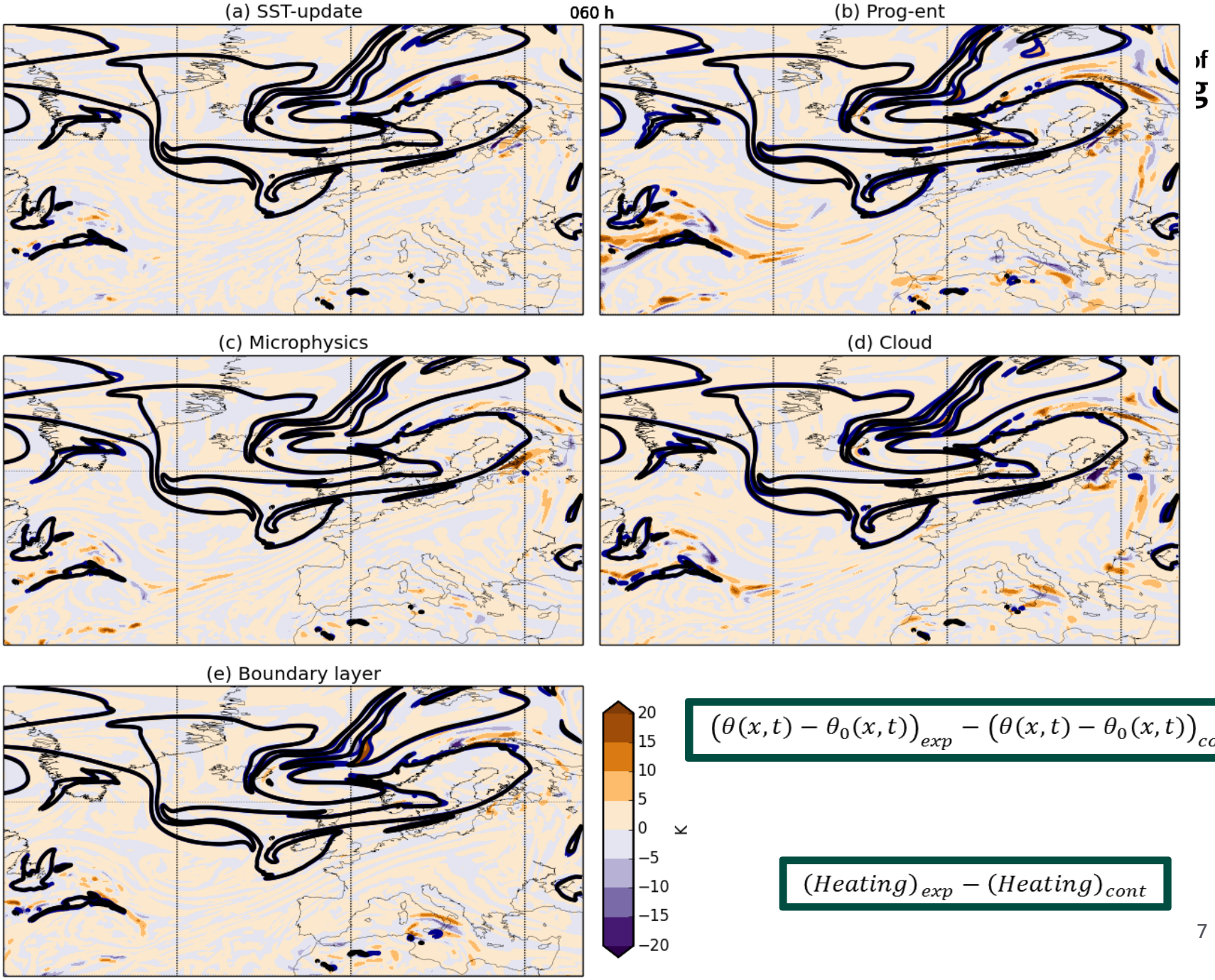
$$\left(\theta(x,t)-\theta_0(x,t)\right)_{exp}-\left(\theta(x,t)-\theta_0(x,t)\right)_{cont}$$

$$(Heating)_{exp}-(Heating)_{cont}$$



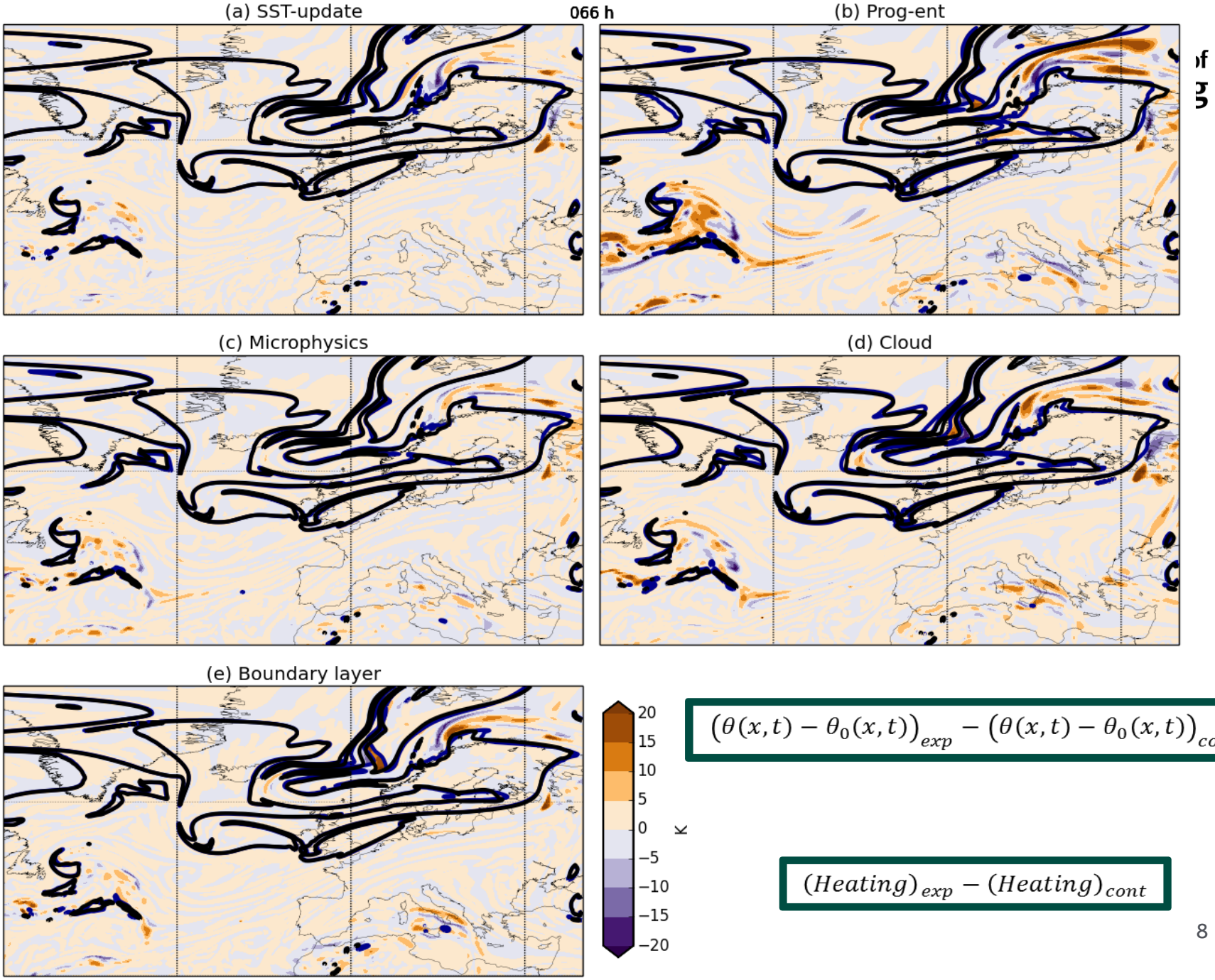
$$\left(\theta(x,t) - \theta_0(x,t)\right)_{exp} - \left(\theta(x,t) - \theta_0(x,t)\right)_{cont}$$

$$(Heating)_{exp} - (Heating)_{cont}$$



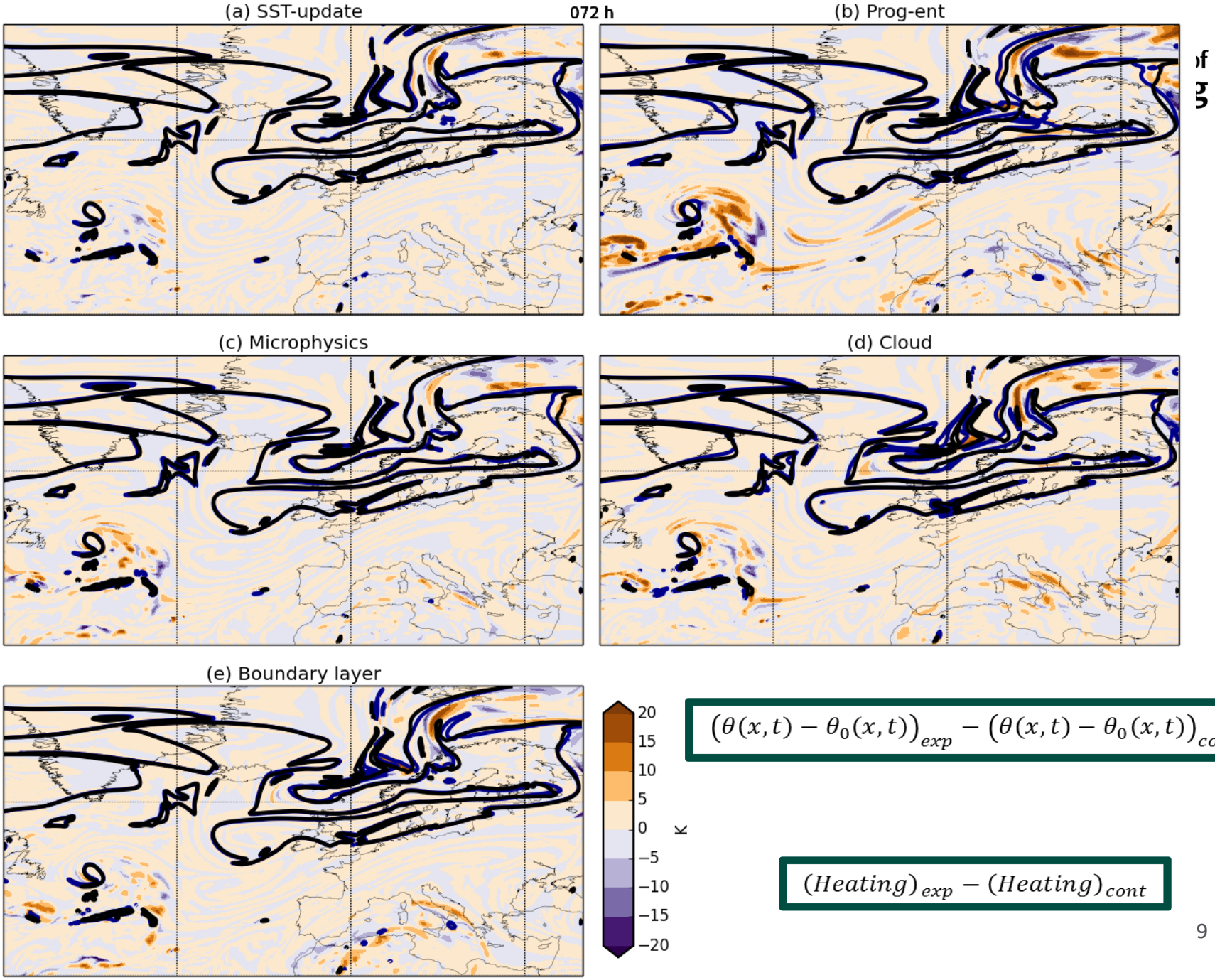
$$\left(\theta(x,t) - \theta_0(x,t)\right)_{exp} - \left(\theta(x,t) - \theta_0(x,t)\right)_{cont}$$

$$(Heating)_{exp} - (Heating)_{cont}$$



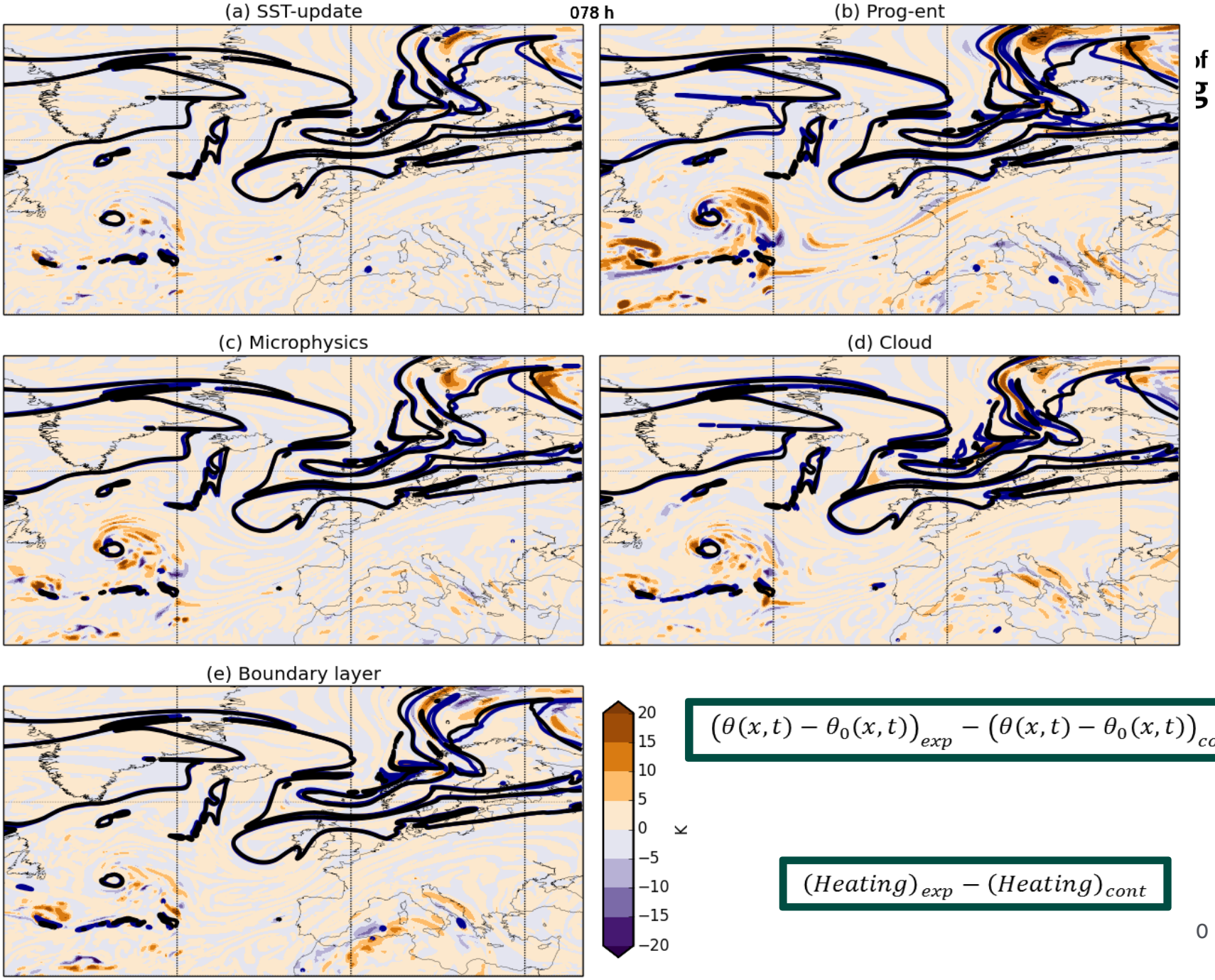
$$\left(\theta(x,t) - \theta_0(x,t)\right)_{exp} - \left(\theta(x,t) - \theta_0(x,t)\right)_{cont}$$

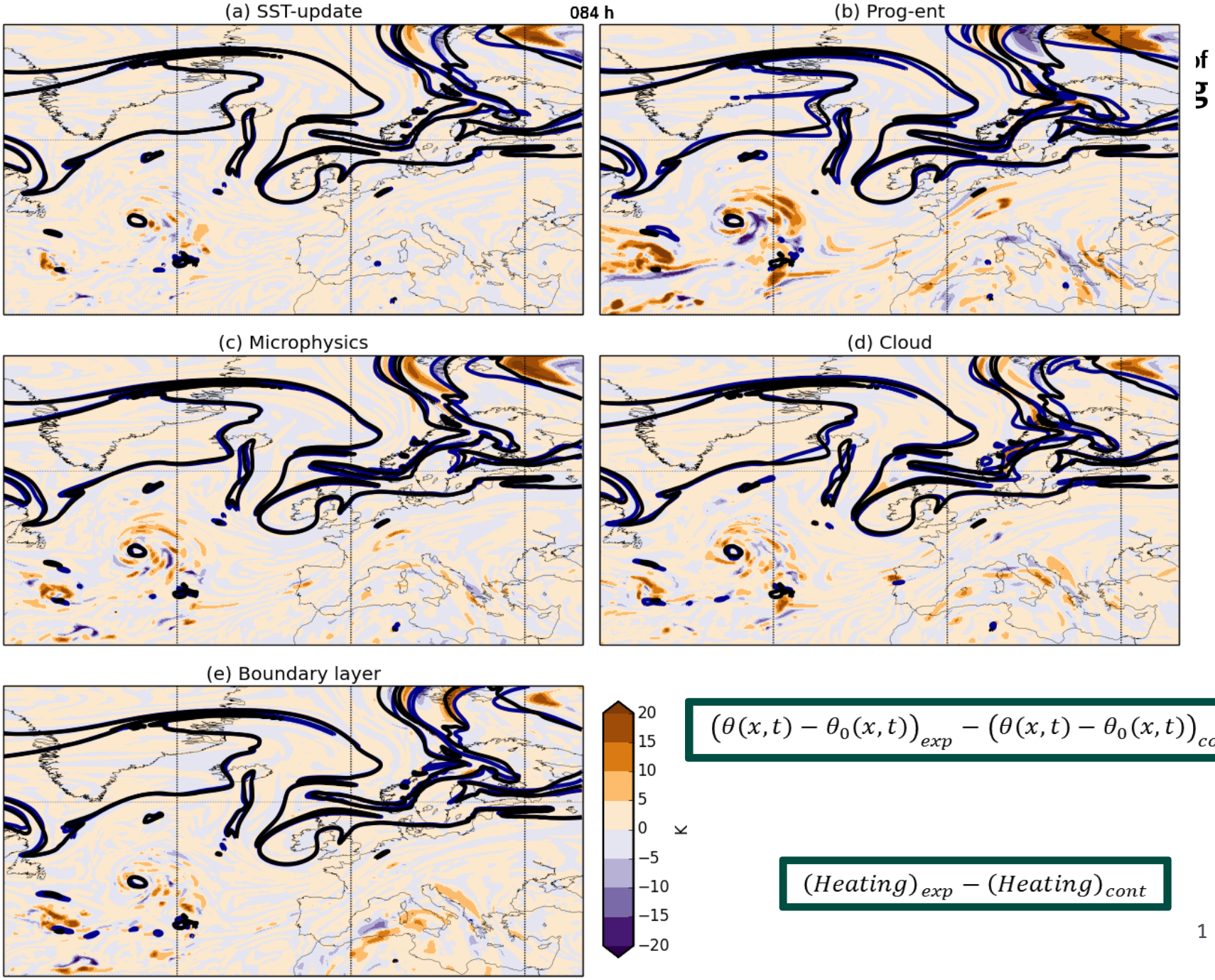
$$(Heating)_{exp} - (Heating)_{cont}$$



$$\left(\theta(x,t)-\theta_0(x,t)\right)_{exp}-\left(\theta(x,t)-\theta_0(x,t)\right)_{cont}$$

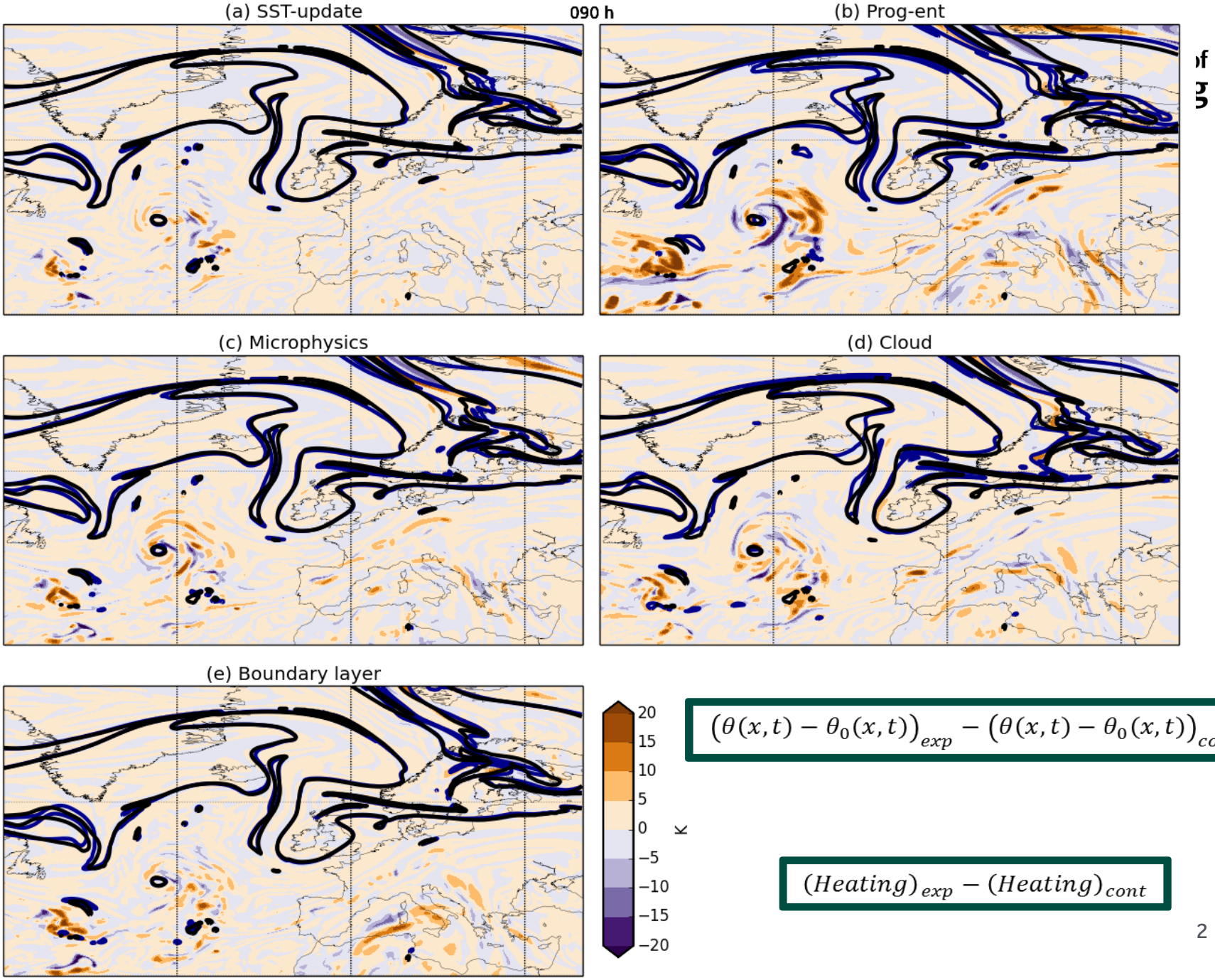
$$(Heating)_{exp}-(Heating)_{cont}$$


(a) SST-update
078 h
(b) Prog-ent
(c) Microphysics
(d) Cloud
(e) Boundary layer
20
15
10
5
0
−5
−10
−15
−20
K
$\left(\theta(x,t)-\theta_0(x,t)\right)_{exp}-\left(\theta(x,t)-\theta_0(x,t)\right)_{cont}$
$(Heating)_{exp}-(Heating)_{cont}$



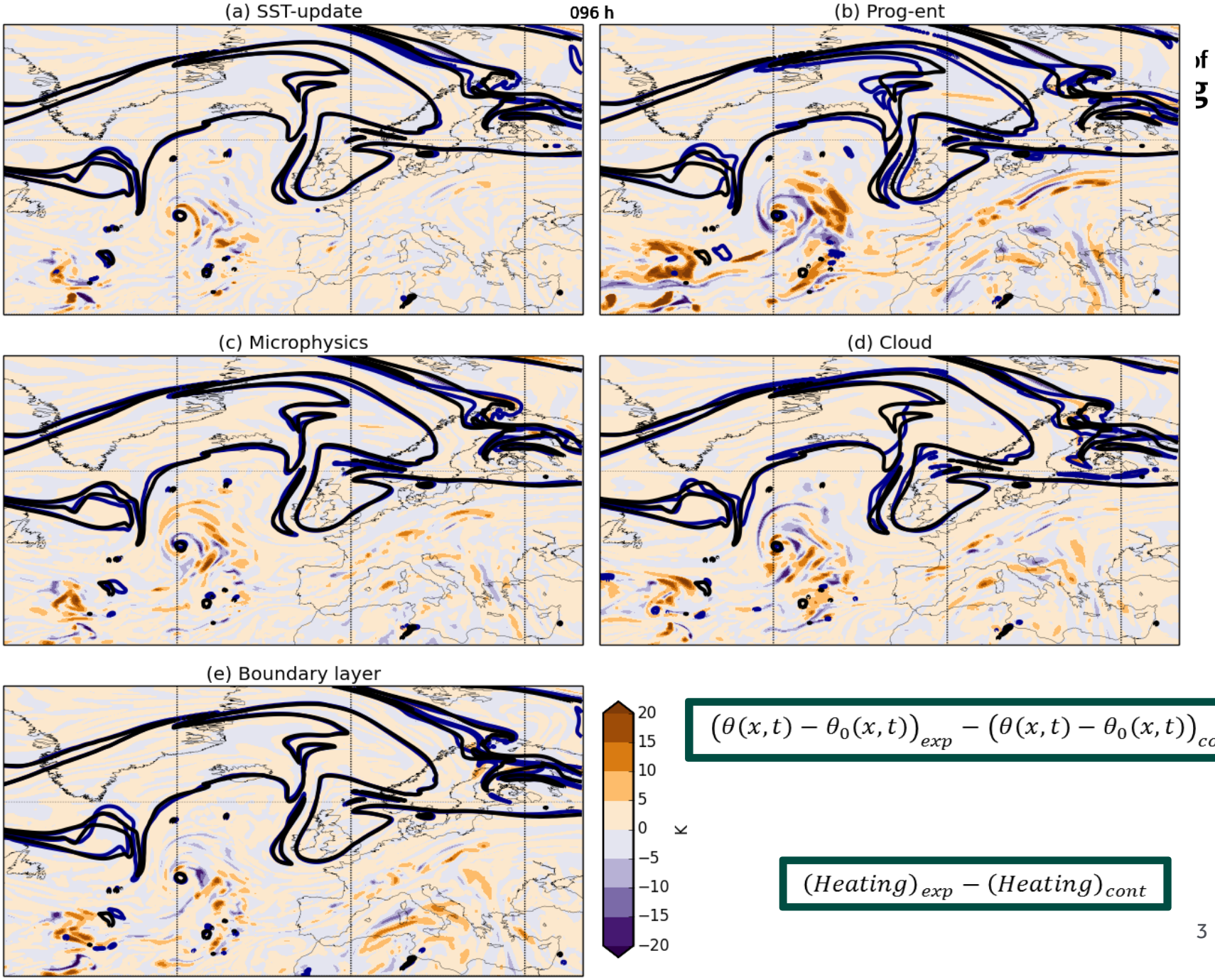
$$\left(\theta(x,t) - \theta_0(x,t)\right)_{exp} - \left(\theta(x,t) - \theta_0(x,t)\right)_{cont}$$

$$(Heating)_{exp} - (Heating)_{cont}$$



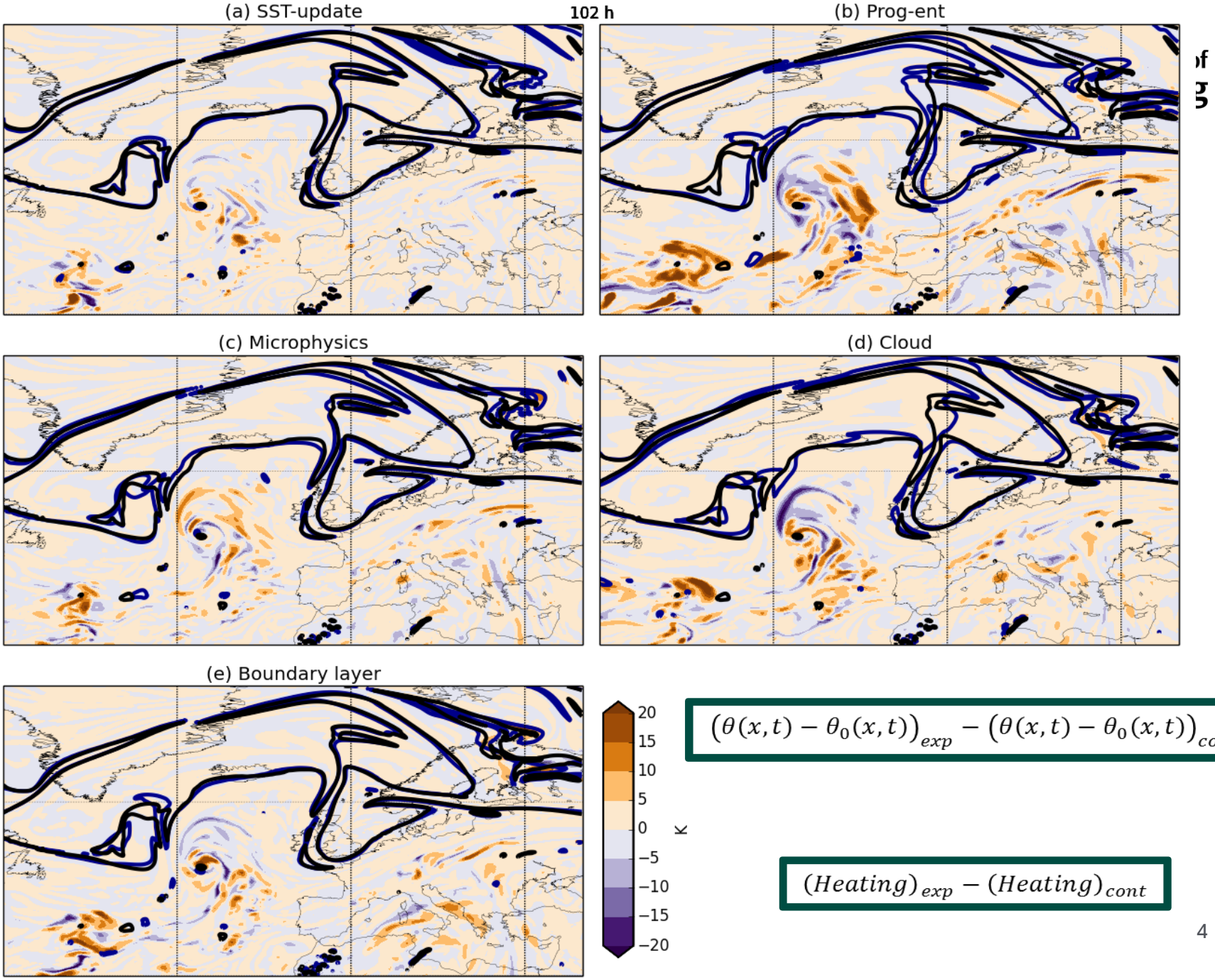
$$\left(\theta(x,t) - \theta_0(x,t)\right)_{exp} - \left(\theta(x,t) - \theta_0(x,t)\right)_{cont}$$

$$(Heating)_{exp} - (Heating)_{cont}$$



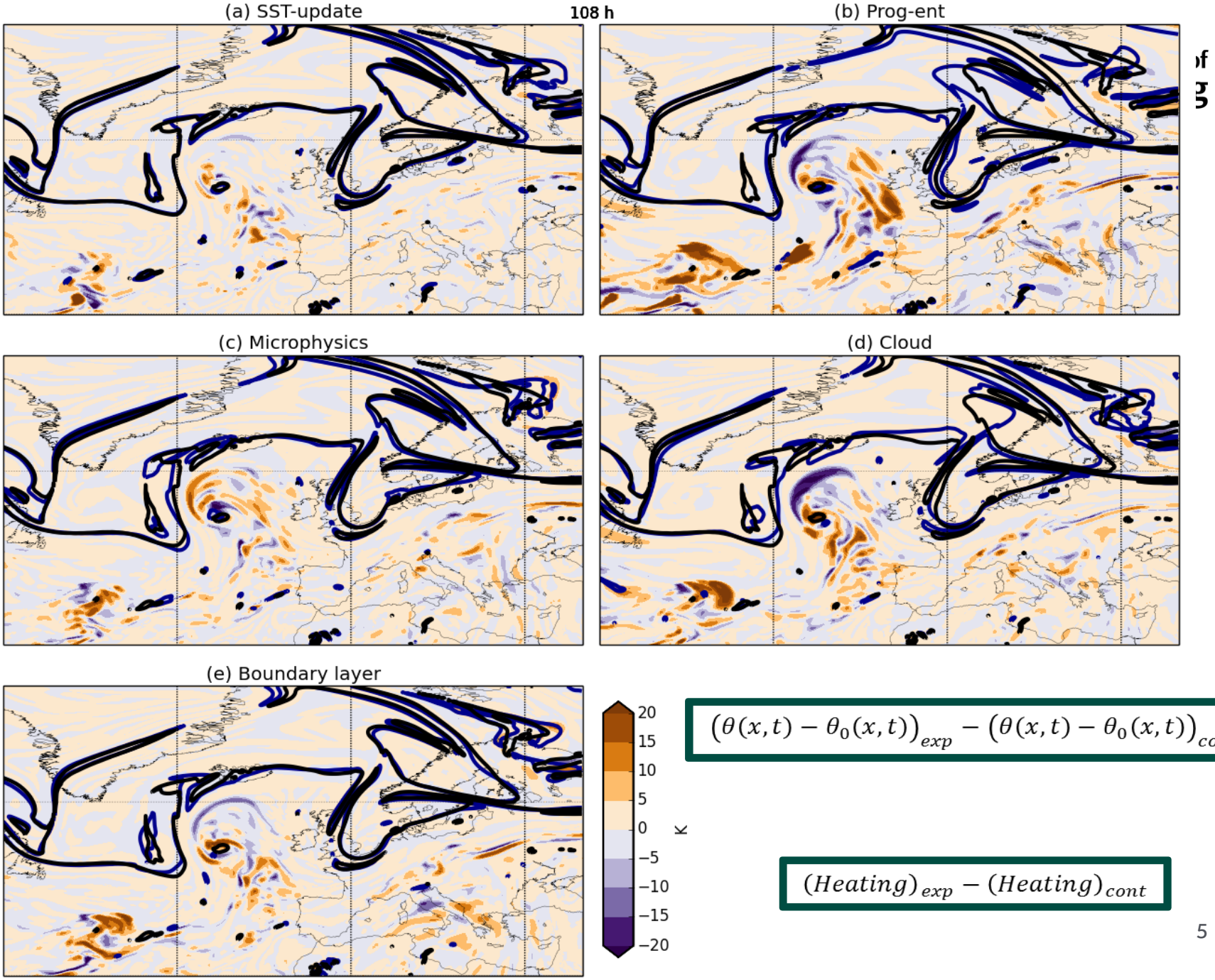
$$\left(\theta(x,t)-\theta_0(x,t)\right)_{exp}-\left(\theta(x,t)-\theta_0(x,t)\right)_{cont}$$

$$(Heating)_{exp}-(Heating)_{cont}$$



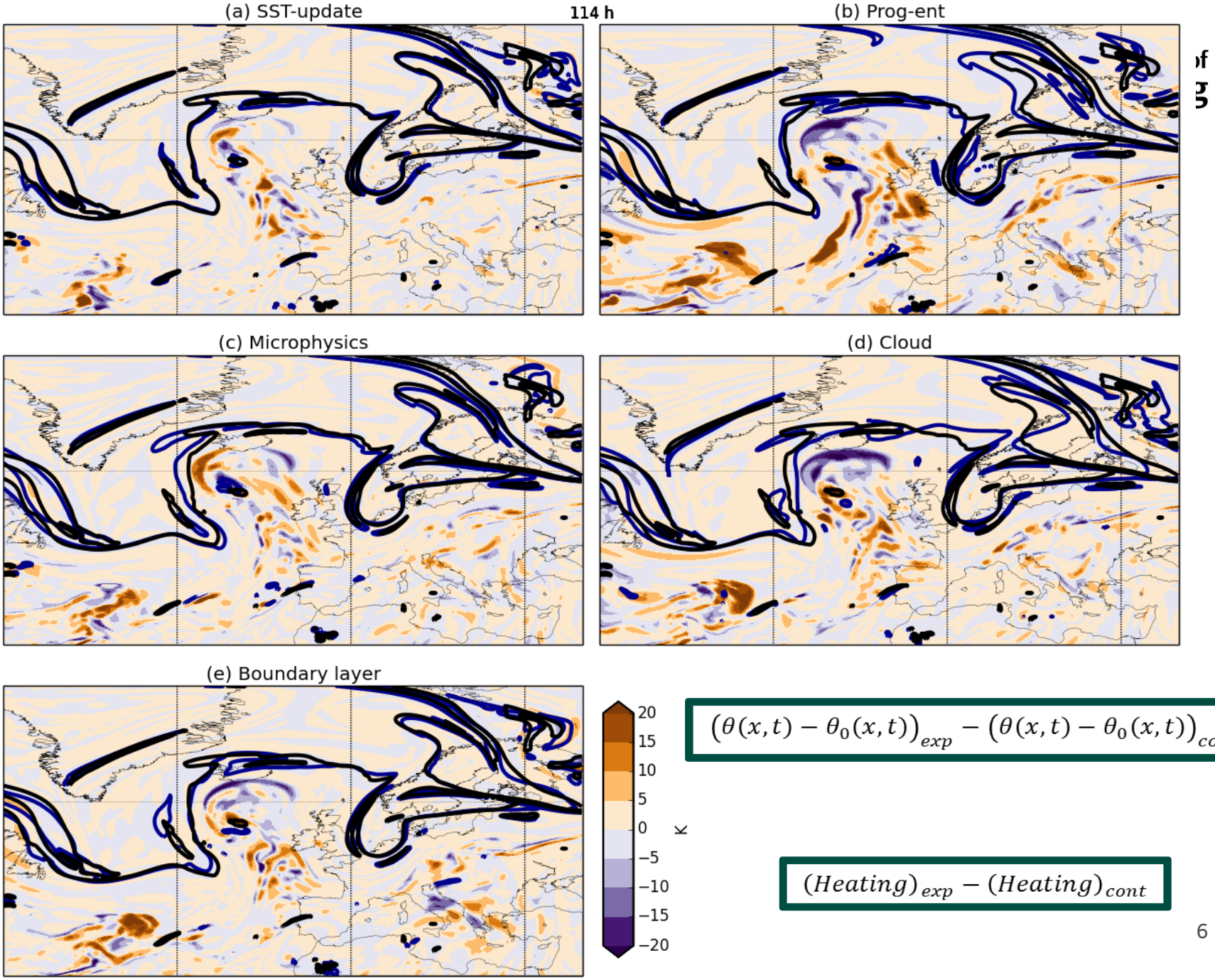
$$\left(\theta(x,t) - \theta_0(x,t)\right)_{exp} - \left(\theta(x,t) - \theta_0(x,t)\right)_{cont}$$

$$(Heating)_{exp} - (Heating)_{cont}$$



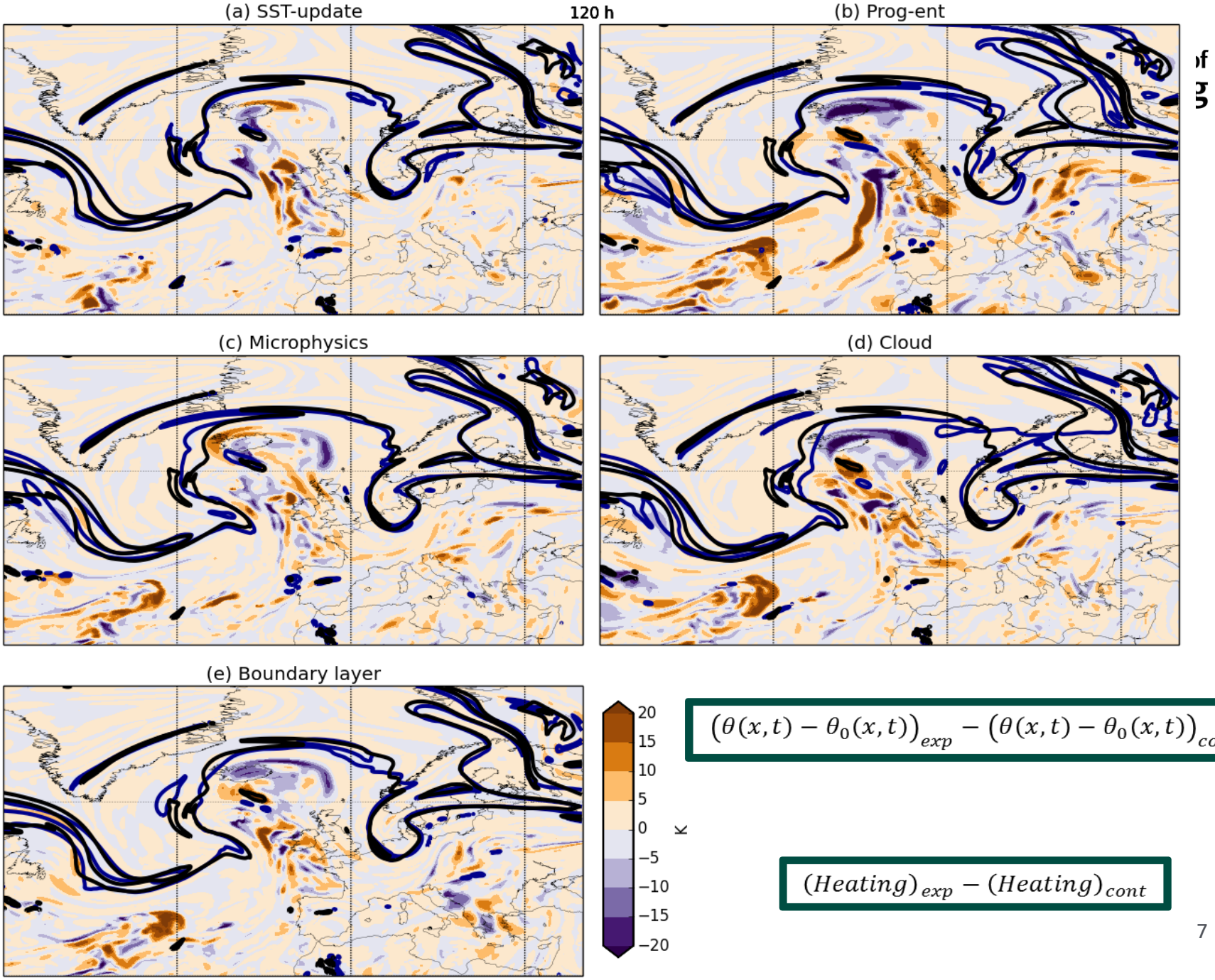
$$\left(\theta(x,t) - \theta_0(x,t)\right)_{exp} - \left(\theta(x,t) - \theta_0(x,t)\right)_{cont}$$

$$(Heating)_{exp} - (Heating)_{cont}$$



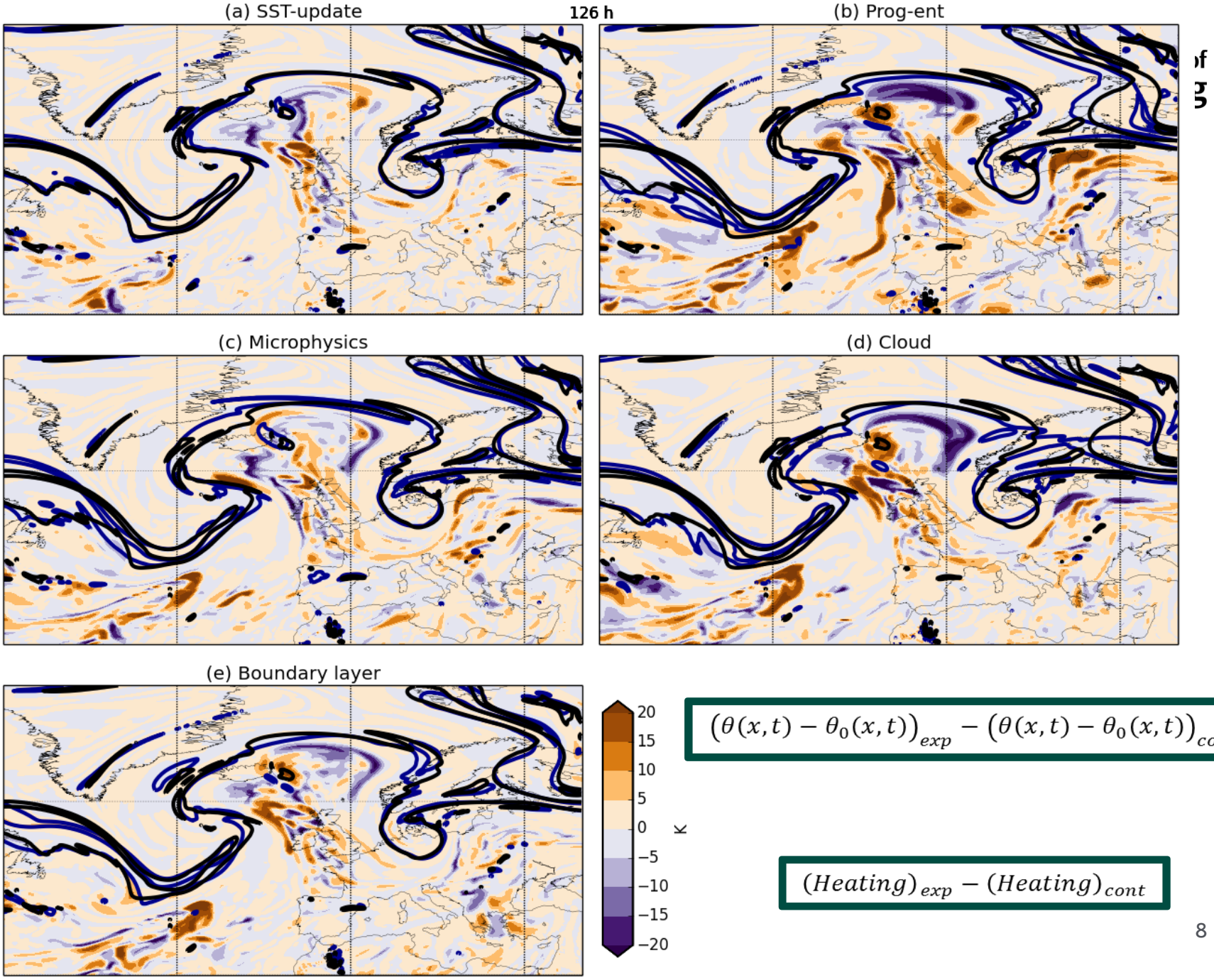
$$\left(\theta(x,t) - \theta_0(x,t)\right)_{exp} - \left(\theta(x,t) - \theta_0(x,t)\right)_{cont}$$

$$(Heating)_{exp} - (Heating)_{cont}$$



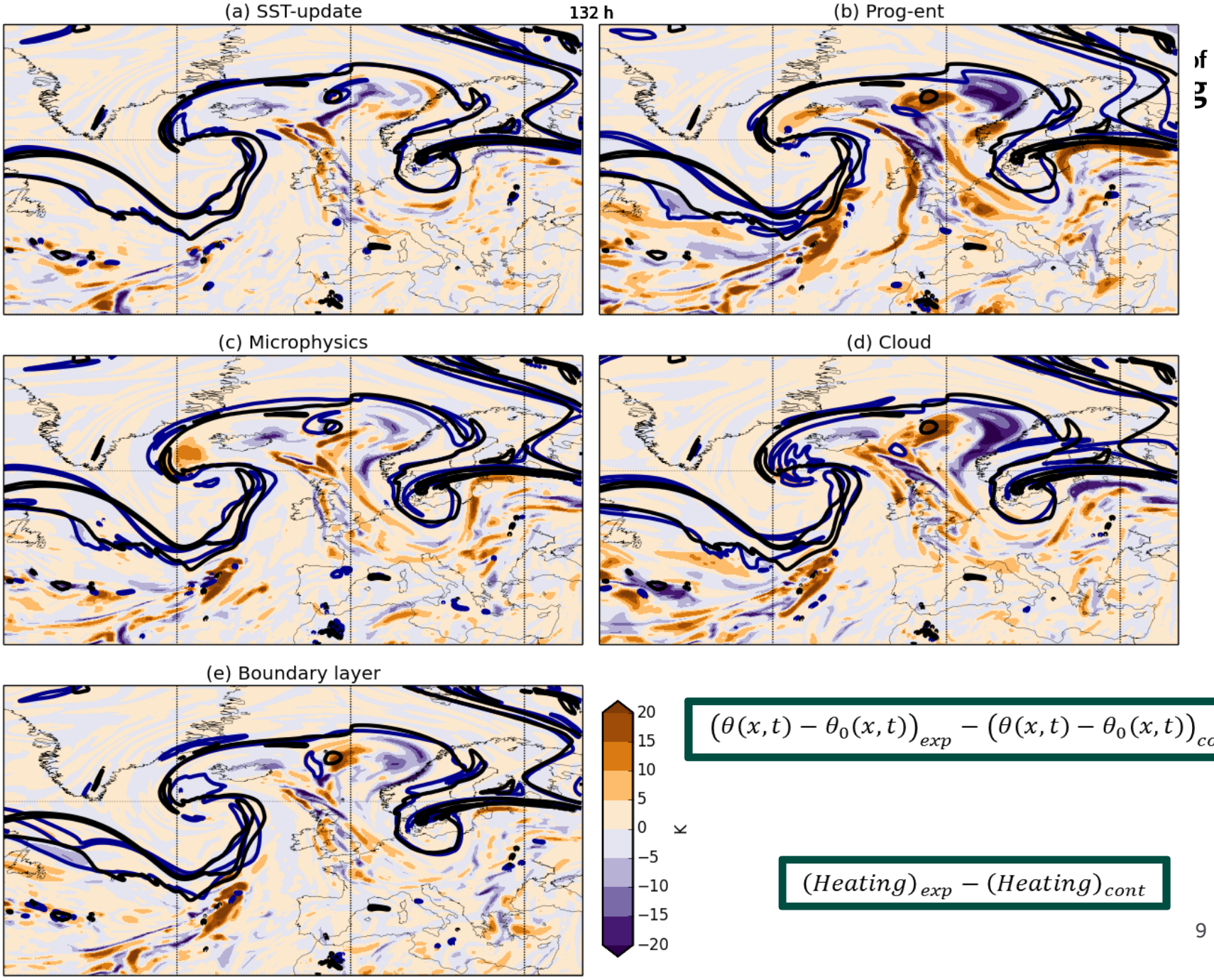
$$\left(\theta(x,t) - \theta_0(x,t)\right)_{exp} - \left(\theta(x,t) - \theta_0(x,t)\right)_{cont}$$

$$(Heating)_{exp} - (Heating)_{cont}$$



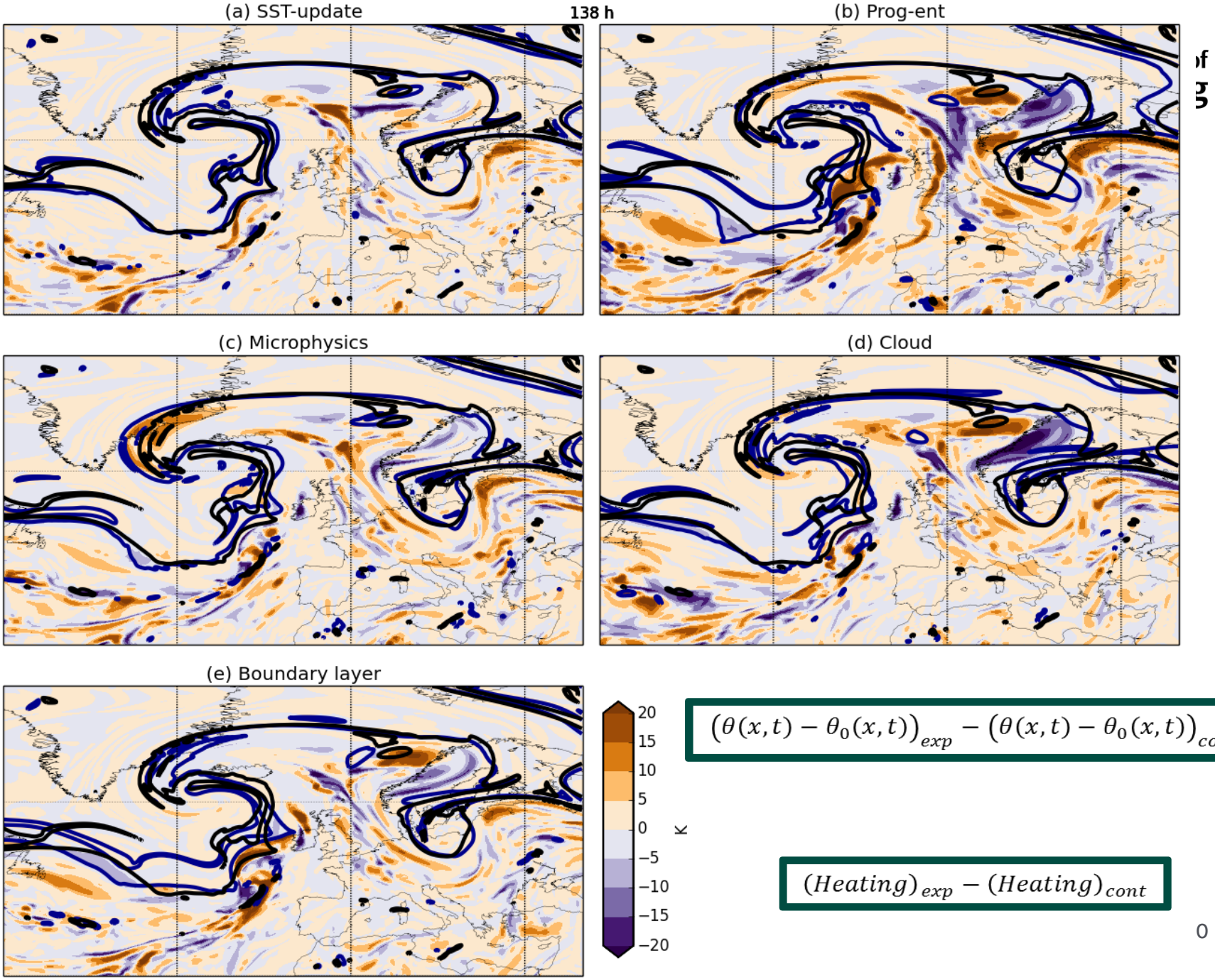
$$\left(\theta(x,t) - \theta_0(x,t)\right)_{exp} - \left(\theta(x,t) - \theta_0(x,t)\right)_{cont}$$

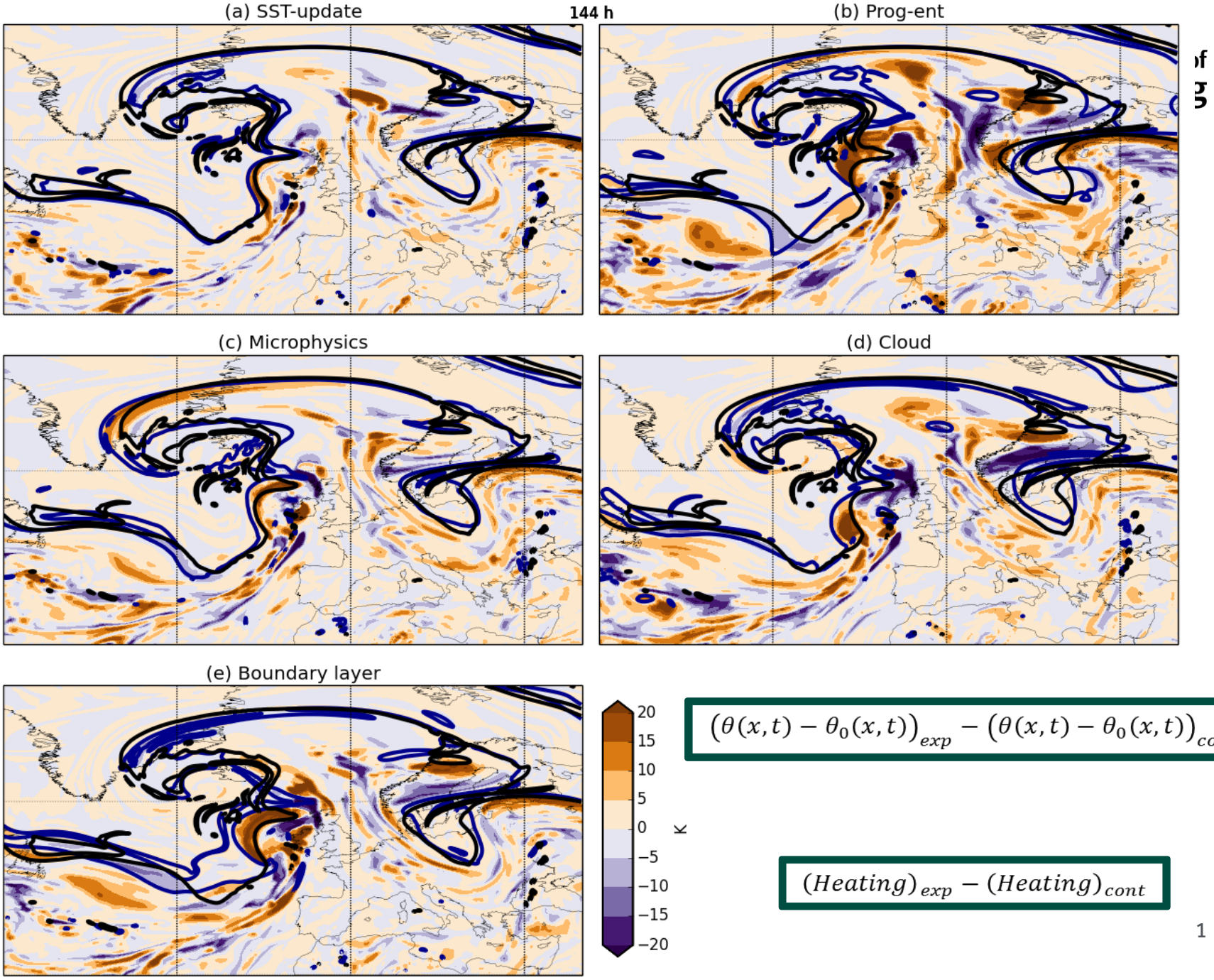
$$(Heating)_{exp} - (Heating)_{cont}$$

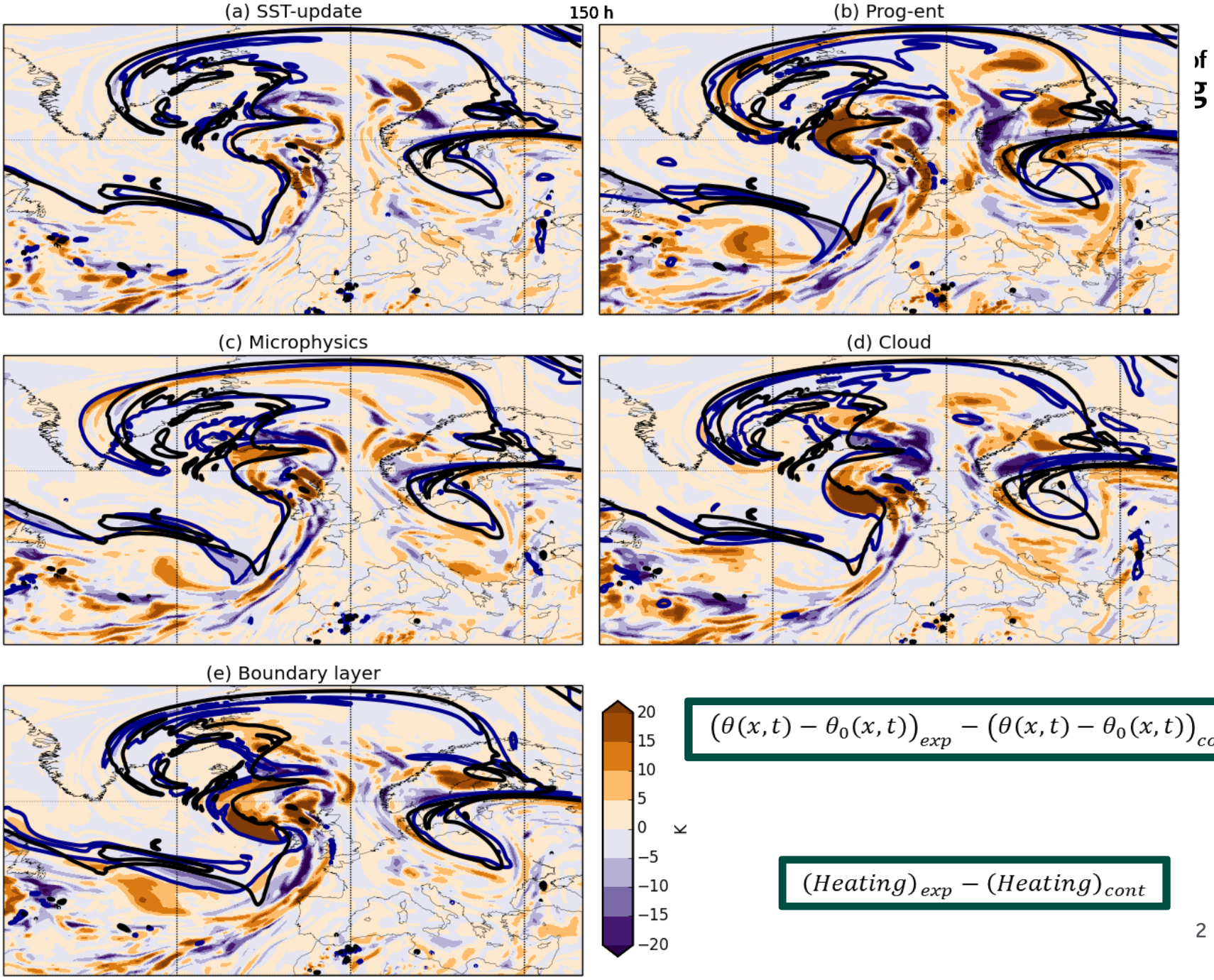


$$\left(\theta(x,t) - \theta_0(x,t)\right)_{exp} - \left(\theta(x,t) - \theta_0(x,t)\right)_{cont}$$

$$(Heating)_{exp} - (Heating)_{cont}$$

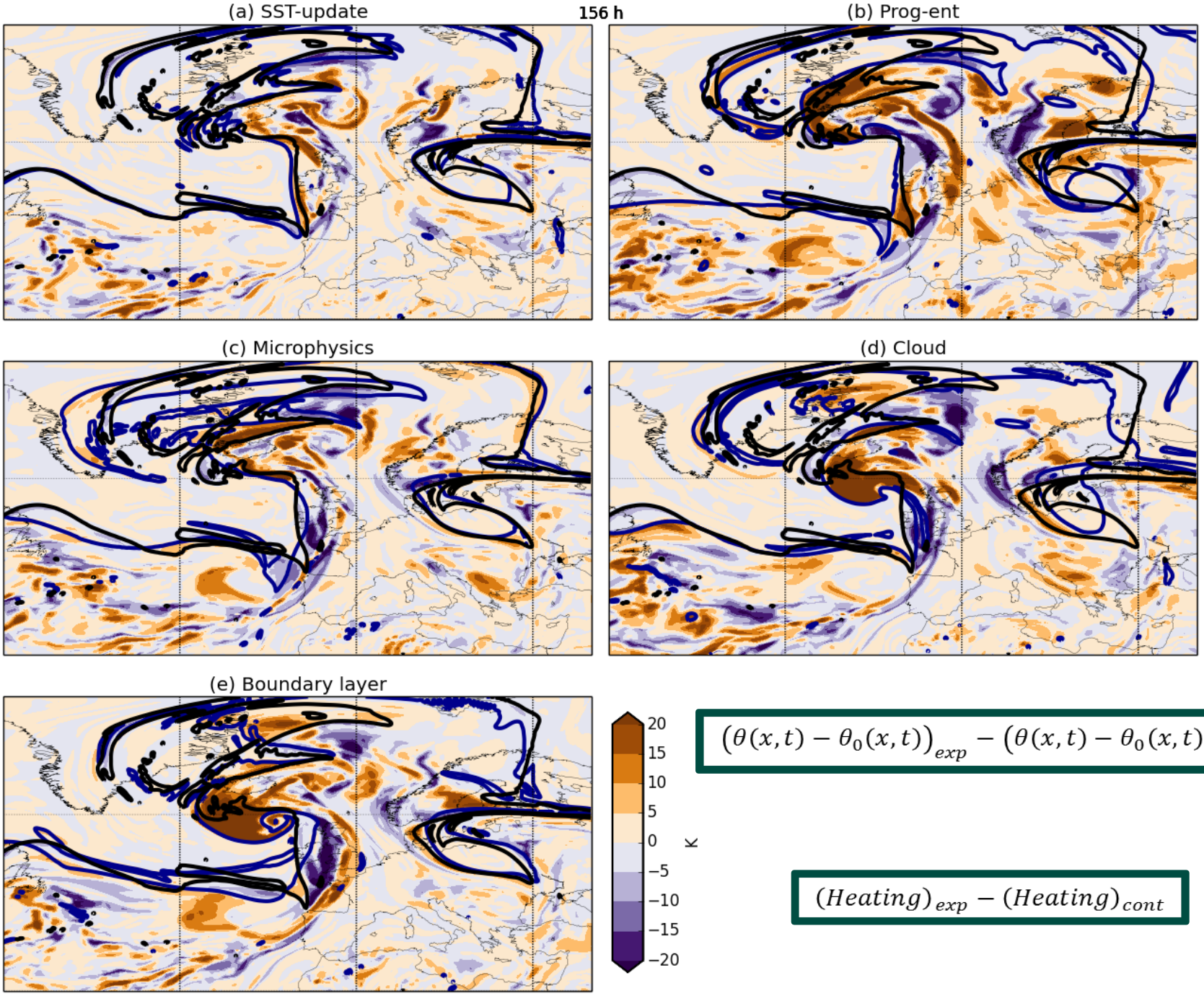

(a) SST-update
138 h
(b) Prog-ent
(c) Microphysics
(d) Cloud
(e) Boundary layer
20
15
10
5
0
−5
−10
−15
−20
K
$\left(\theta(x,t)-\theta_0(x,t)\right)_{exp}-\left(\theta(x,t)-\theta_0(x,t)\right)_{cont}$
$(Heating)_{exp}-(Heating)_{cont}$


144 h
(a) SST-update
(b) Prog-ent
(c) Microphysics
(d) Cloud
(e) Boundary layer
20
15
10
5
0
−5
−10
−15
−20
K
$\left(\theta(x,t)-\theta_0(x,t)\right)_{exp}-\left(\theta(x,t)-\theta_0(x,t)\right)_{cont}$
$(Heating)_{exp}-(Heating)_{cont}$



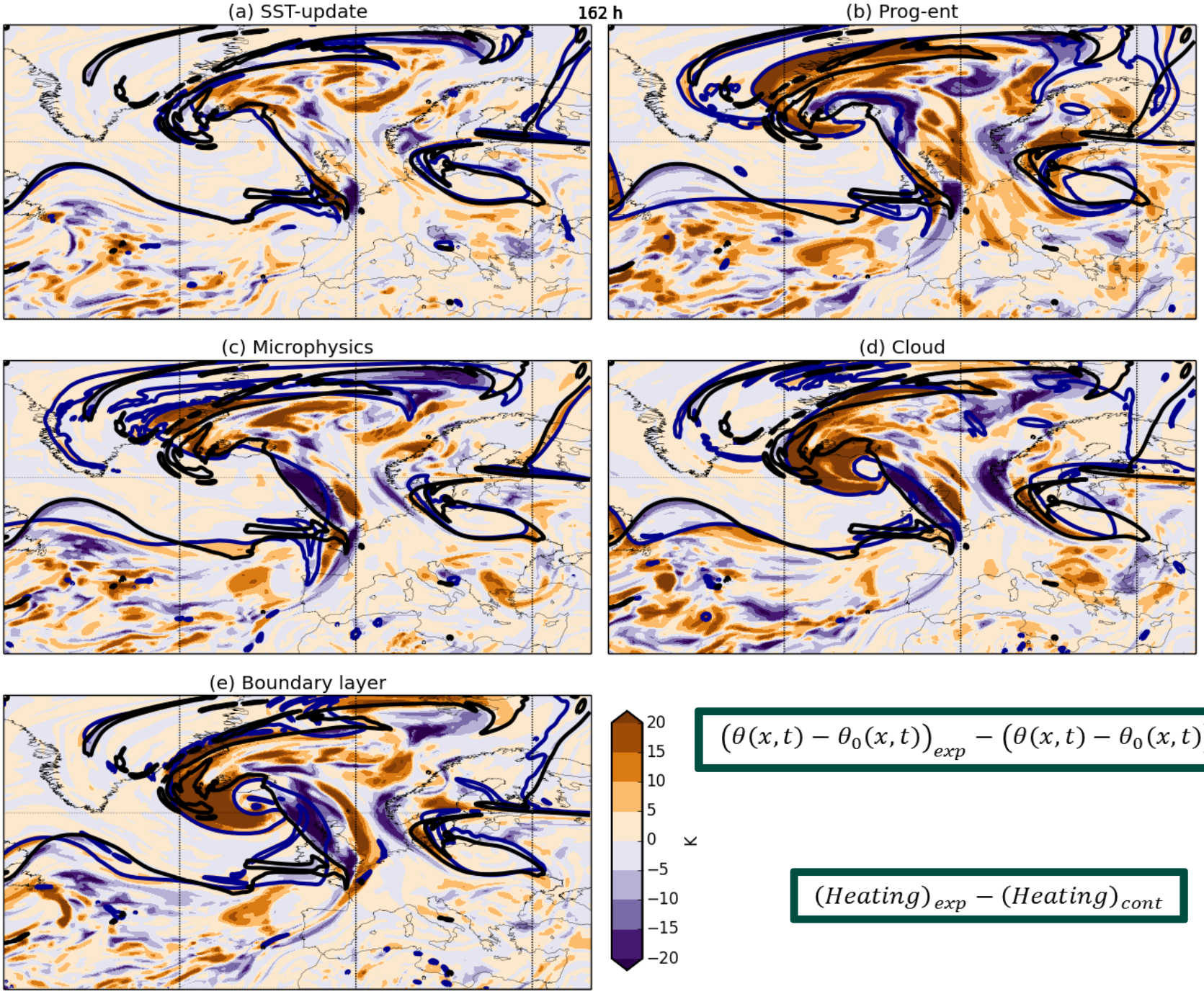
$$\left(\theta(x,t) - \theta_0(x,t)\right)_{exp} - \left(\theta(x,t) - \theta_0(x,t)\right)_{cont}$$

$$(Heating)_{exp} - (Heating)_{cont}$$



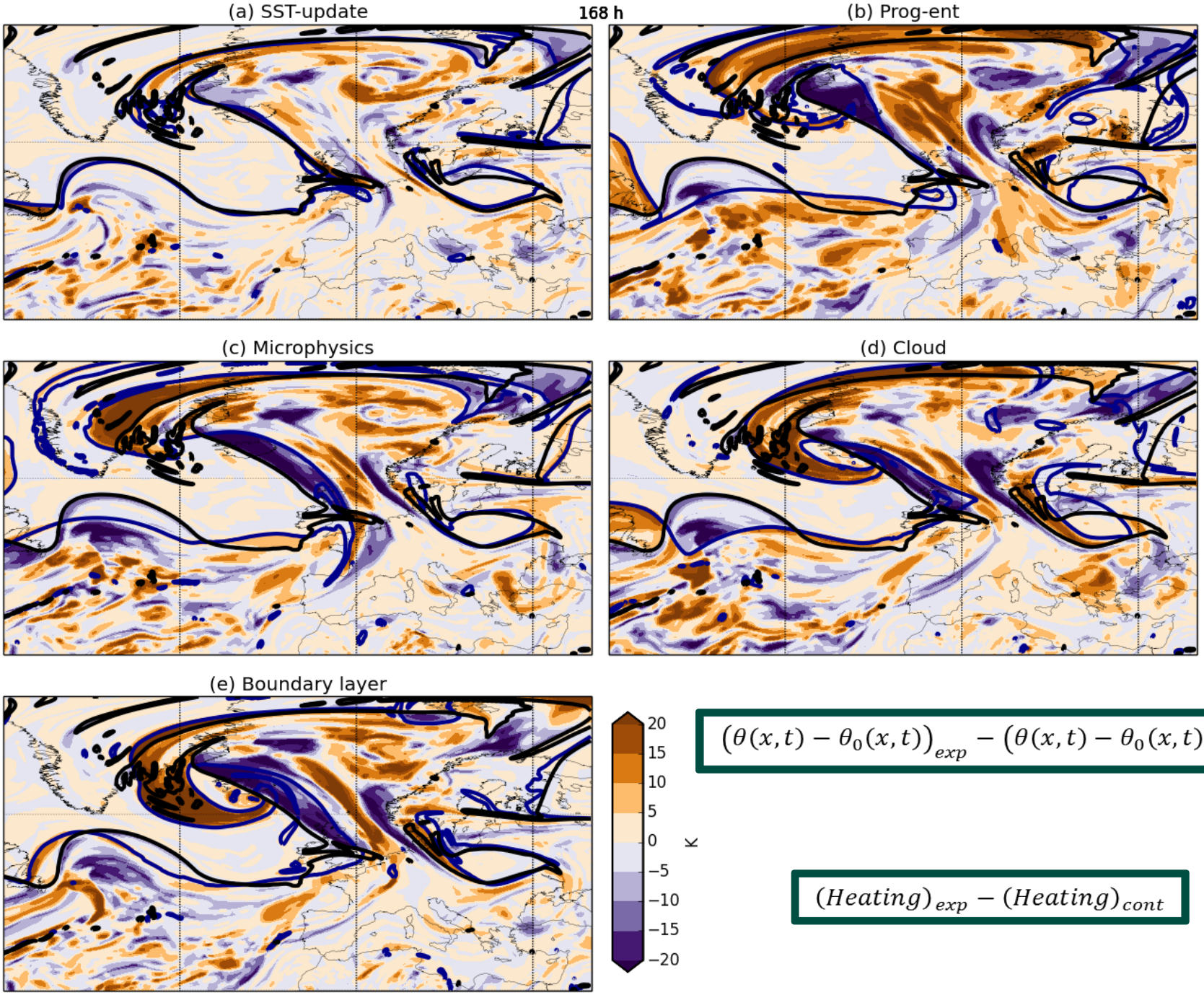
$$\left(\theta(x,t) - \theta_0(x,t)\right)_{exp} - \left(\theta(x,t) - \theta_0(x,t)\right)_{cont}$$

$$(Heating)_{exp} - (Heating)_{cont}$$



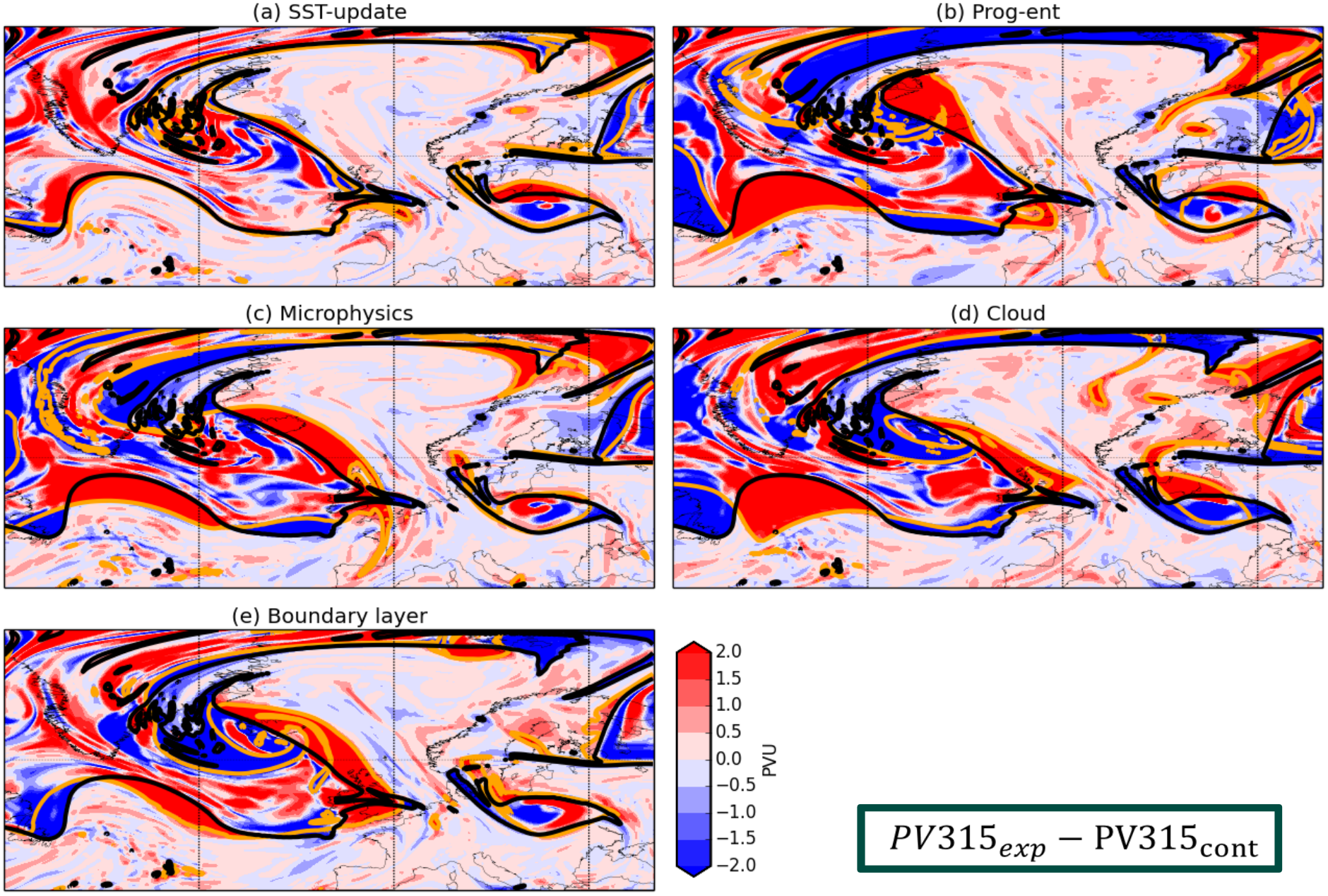
$$\left(\theta(x,t) - \theta_0(x,t)\right)_{exp} - \left(\theta(x,t) - \theta_0(x,t)\right)_{cont}$$

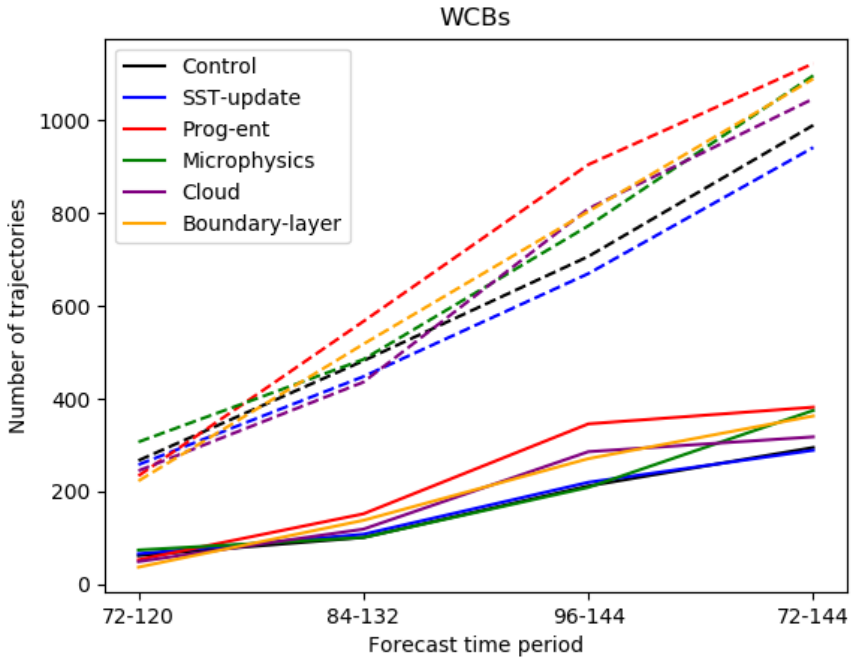
$$(Heating)_{exp} - (Heating)_{cont}$$

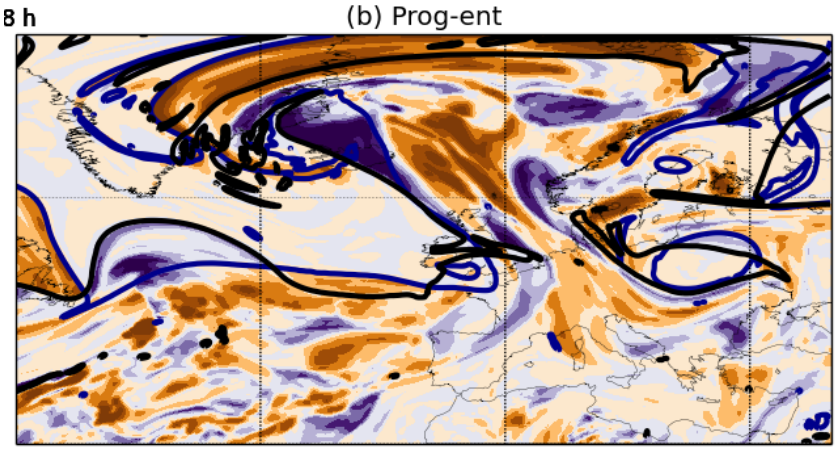


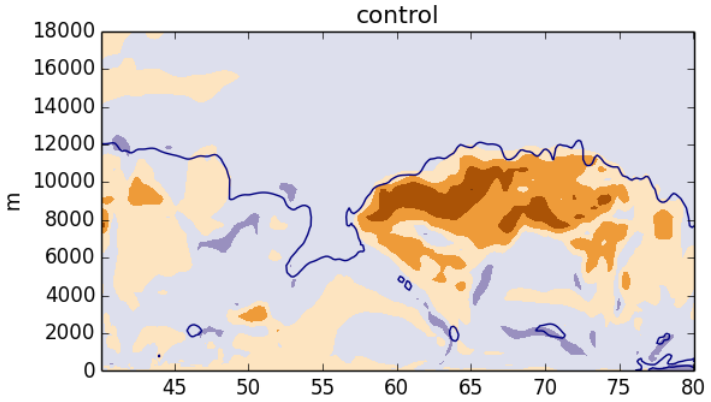
$$\left(\theta(x,t) - \theta_0(x,t)\right)_{exp} - \left(\theta(x,t) - \theta_0(x,t)\right)_{cont}$$

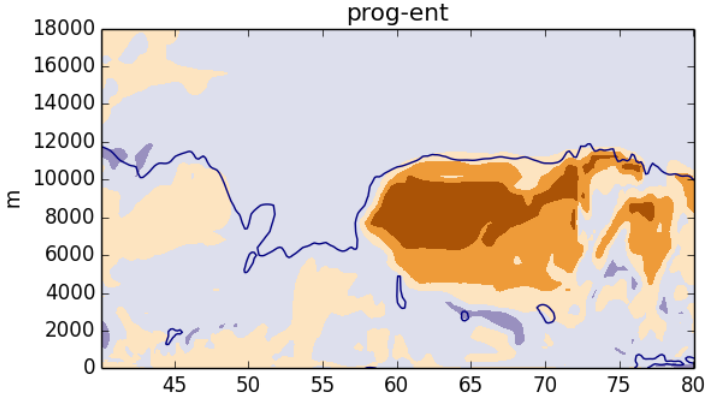
$$(Heating)_{exp} - (Heating)_{cont}$$


(a) SST-update
(b) Prog-ent
(c) Microphysics
(d) Cloud
(e) Boundary layer
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
PVU
$PV315_{exp} - \mathrm{PV315_{cont}}$









Stronger WCB

↓

Increased heating

↓

Bigger ridge

Systematic impacts

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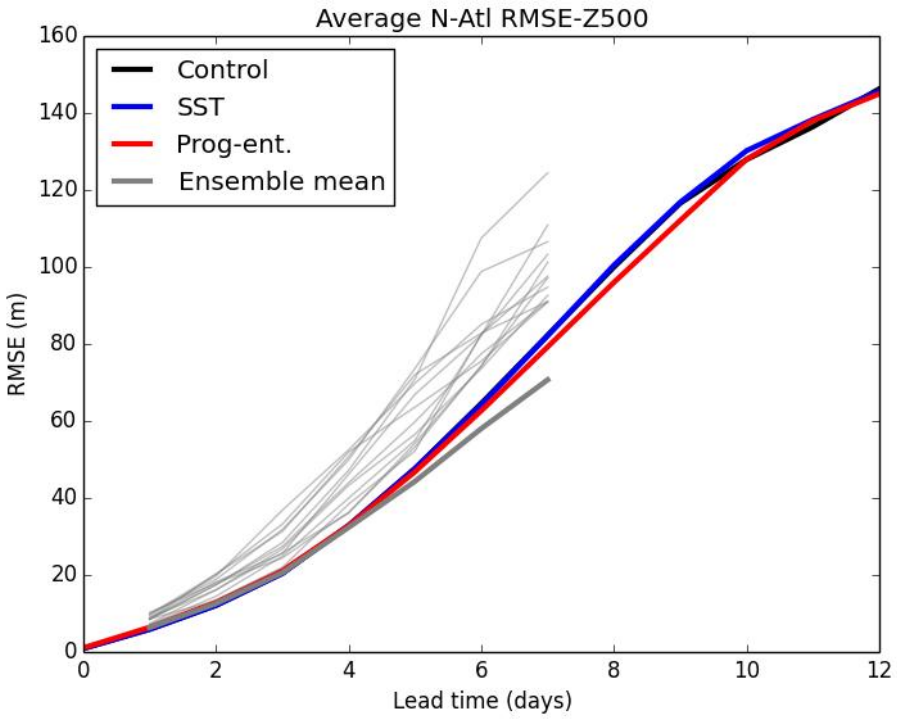
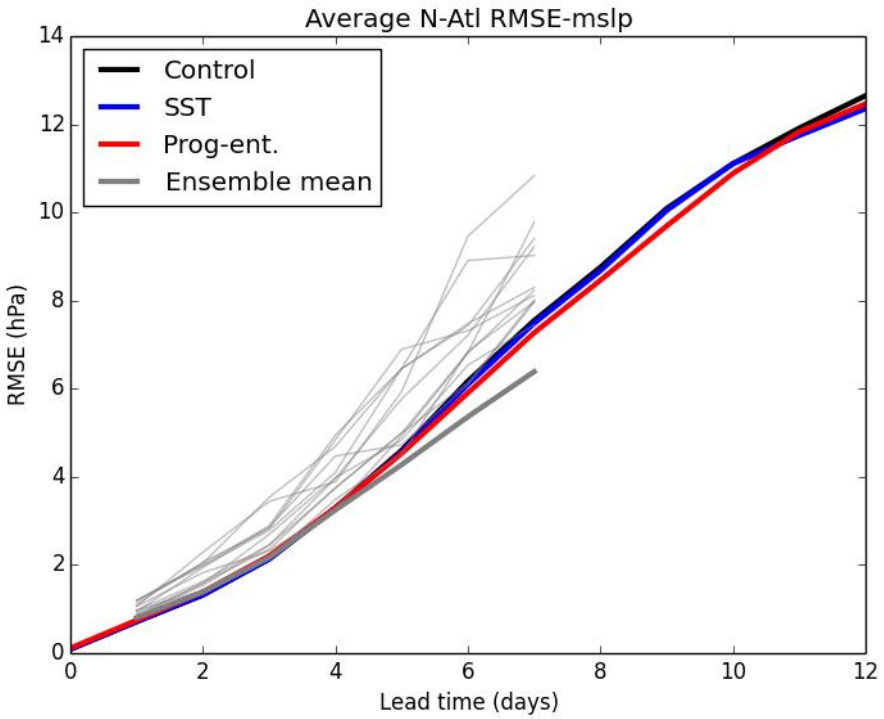
- Did the prognostic entrainment or SST-update experiments have a systematic effect for forecasts during NAWDEX?

Have 54 forecasts (run 00,12 between 20 September and 16 October)

NAWDEX period





- On average no forecast skill improvement (or reduction) in SST-update experiment
- Slight improvement in forecasts with lead time >7 days when using Prognostic entrainment (not so slight from an operational perspective!)

Conclusions

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- Block onset following the Stalactite cyclone was unpredictable; correct evolution missed in operational and physics ensemble
- Initial condition uncertainty dominates over model physics uncertainty at early (<7 days) lead times
- Changes in block (ridge) development due to physical parameterisation upgrades is large at later lead times
- Modifying parameterisations (particularly convection and cloud) changed the heating at upper-levels associated with the Stalactite cyclone
- Experiments with increased heating and larger ridges had stronger WCBs, i.e. changing cyclone structure led to change in block development
- Representation of diabatic processes important in block forecast

- "Poor man's coupling" not systematically better or worse than operational forecast
- Convection scheme with memory (Prog-ent) shows slight improvement in skill on average