Response of cirrus clouds to idealised perturbations from aviation

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Supplementary information

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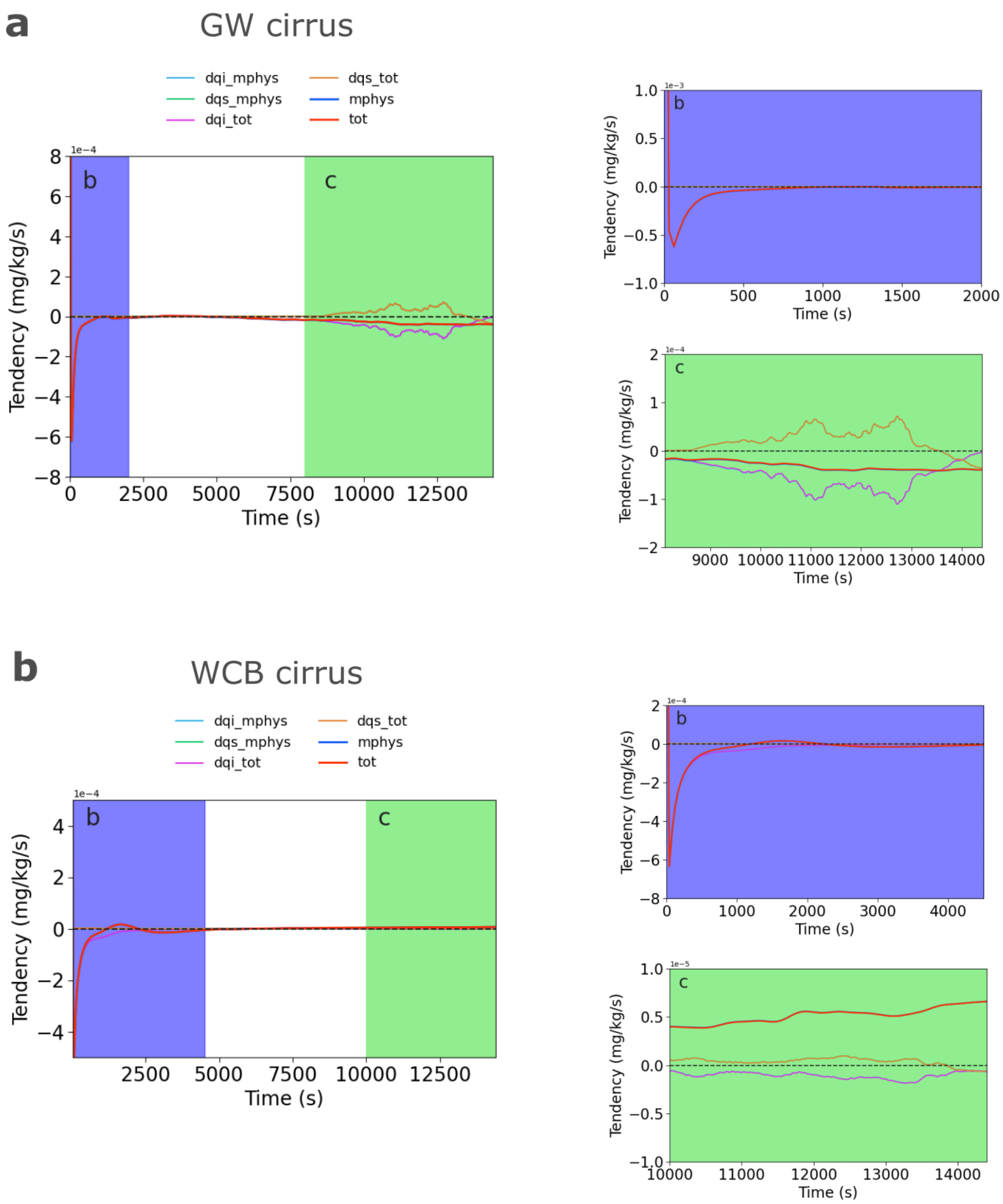

Figure S1. Time series of mean tendencies during the a) GW and b) WCB outflow simulations. Inset panels show the spin-up phase (indicated in blue and with the letter 'b') and dissipation phase (green, letter 'c')

Table S1. Mean process rate values in the stable and dissipation phases of the GW and WCB outflow cases. All values are reported in mg kg^{-1} s^{-1}.

Microphysical process	**GW**		**WCB**	
	Stable	**Dissipation**	**Stable**	**Dissipation**
Nucleation	0	0	0	0
Vapour deposition (ice)	3.79	0.44	0.25	7.50×10^{-2}
Vapour deposition (snow/graupel)	3.3×10^{-2}	1.08	6.31×10^{-2}	0.28
Accretion	1.47×10^{-5}	3.08×10^{-5}	$7.23 \text{ x } 10^{-7}$	$4.8 \text{ x } 10^{-7}$
Auto-conversion (ice to snow)*	1.15	1.15	0.23	0.12
Sublimation (ice)	3.3	0.24	3.6×10^{-2}	$6.0 \text{ x } 10^{-3}$
Sublimation (snow/graupel)	0.72	2.3	0.20	0.41
Sedimentation (ice)	-0.15	-2.5×10^{-2}	-1.2×10^{-2}	-3.0×10^{-3}
Sedimentation (snow/graupel)	-0.02	-0.18	-1.2×10^{-2}	-3.9×10^{-2}

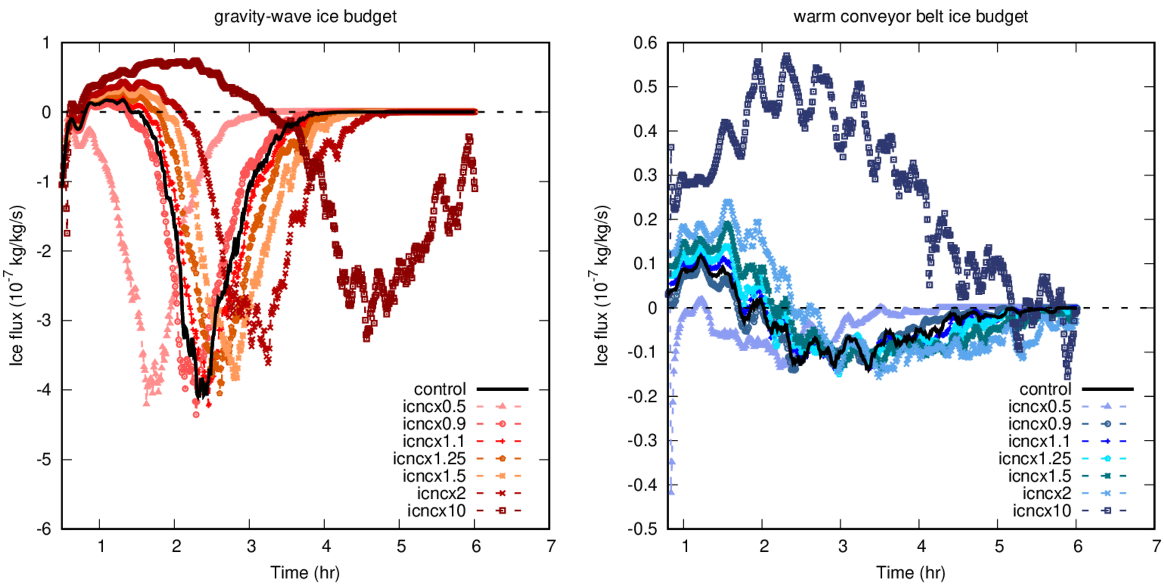

Figure S2. Time series of ice budget for the gravity wave (left) and warm conveyor belt outflow (right) cases, expressed as net total ice mass flux in kg[ice] (kg[dry air] $^{-1}$ s^{-1}. Net ice mass flux is calculated as the difference between microphysical processes that increase mass flux (homogenous freezing, heterogeneous ice nucleation, water vapour deposition and ice accretion from water) and processes that decrease mass flux (ice sublimation, ice sedimentation, ice melting, snow accretion from ice and auto-conversion to snow). The equilibrium line of 0 kg kg^{-1} s^{-1} is shown in both panels as a dashed black line. The control simulation is shown in solid black while colours indicate ICNC perturbation experiments (red for gravity wave, blue for warm conveyor belt).

Text S1 - Calculation of the response phase

The ‘response phase’ of the GW and WCB outflow cases are calculated as described in section 3.7 by finding the difference in IWC between the control and perturbed simulations at 30 and 45 minutes after the ICNC perturbation is applied.

For the GW case, the response phase lasts from approximately 3000-5000 s, while for the WCB outflow, it lasts from 3000-6000 s. Note that this response time interval is based on the control simulation and the phase where the net ice mass flux is positive lengthens when increasing ICNC and shortens or disappears when decreasing ICNC.

The ICNC×0.1 perturbation does not have a response phase because its cloud dissipates quickly, so that case is not included in the analysis. The ICNC×0.5 experiment has differing response phases between the two cases. For the GW case, the net ice mass flux remains slightly negative during the period when all other experiments exceed 0 kg kg^{-1} s^{-1}, but values stay close to equilibrium from 2000-3000 seconds (Figure S2). Meanwhile, for the WCB outflow case, the net ice mass flux is briefly positive at 4000-4600 seconds.

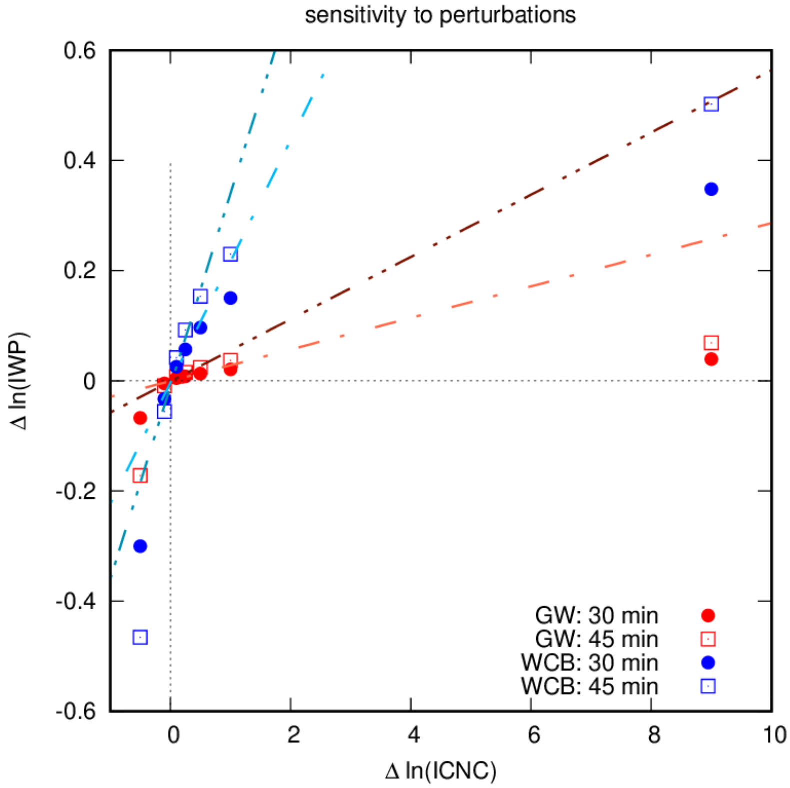

Figure S3. As in Figure 9 (main text) but including the ICNCx10 perturbation experiment.