Influence of model parameterization on the representation of Arctic cloud variability

Patrick C. Taylor, Robyn C. Boeke, Alejandro Bodas-Salcdo

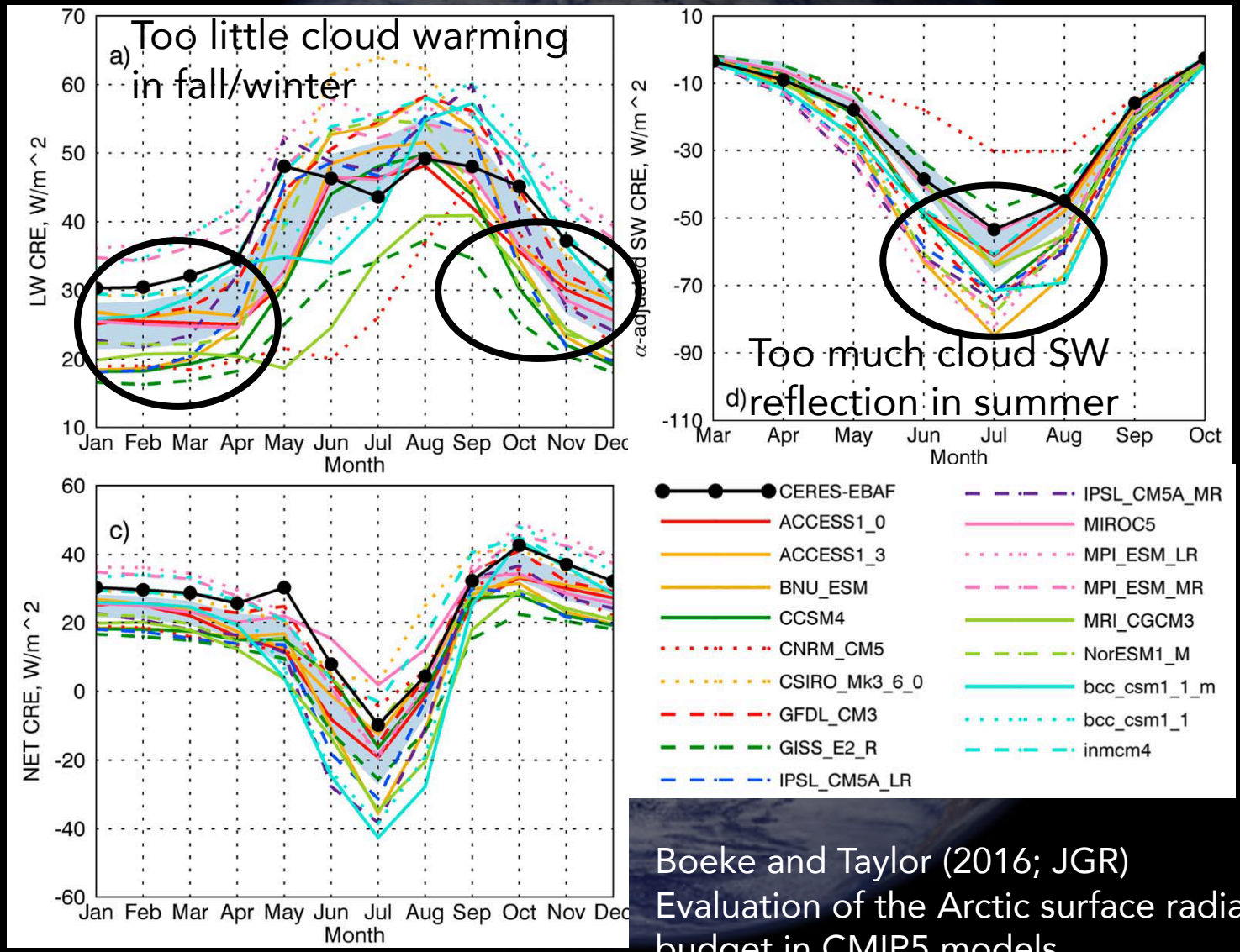
Science Directorate

NASA Langley Research Center

September 16, 2020

patrick.c.taylor@nasa.gov

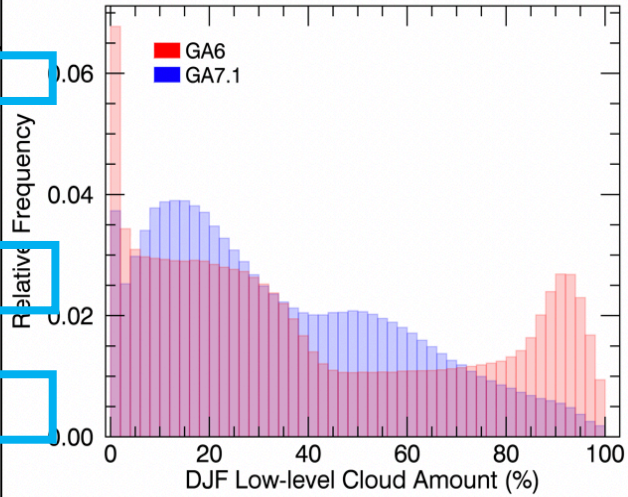
Climate models struggle to simulate the surface cloud radiative effect annual cycle

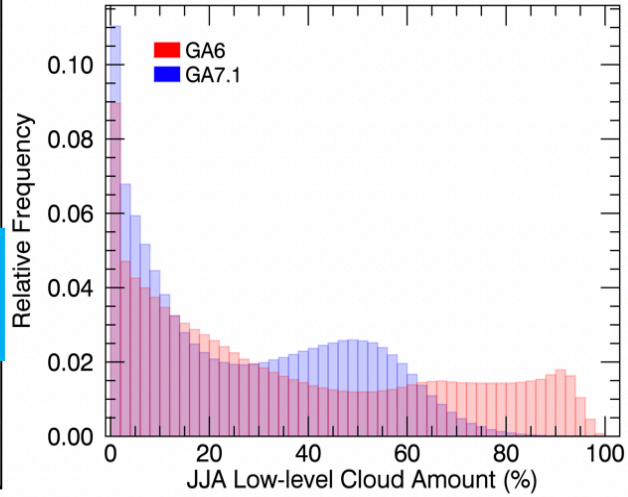


Boeke and Taylor (2016; JGR)
Evaluation of the Arctic surface radiation budget in CMIP5 models

Seasonal average differences: GA6 vs. GA7.1

	DJF		JJA	
	GA6	GA7.1	GA6	GA7.1
Low CA (%)	40.91	34.60	36.36	26.55
Low CLI (g/kg)	0.00679	0.01040	0.00501	0.00589
Low CLW (g/kg)	0.00149	0.00258	0.01350	0.01810
CLIVI (g/m^2)	42.64	62.10	40.00	49.10
CLWVI (g/m^2)	50.50	74.70	91.25	105.70
LWP (g/m^2)	7.89	12.57	51.24	56.51
RLDS (W/m^2)	191.62	193.58	300.84	299.51
RLDSCS (W/m^2)	161.21	160.81	249.91	250.14
RSDS (W/m^2)	n/a	n/a	208.98	208.20
RSDSCS (W/m^2)	n/a	n/a	310.62	303.86
Clr-Sky Albedo	n/a	n/a	0.43	0.42
LW CRE (W/m^2)	30.40	32.76	50.92	49.32
SW CRE (W/m^2)	n/a	n/a	-61.25	-57.23
HFLS (W/m^2)	11.33	12.22	23.52	25.02
HFSS (W/m^2)	5.15	5.58	7.61	8.39



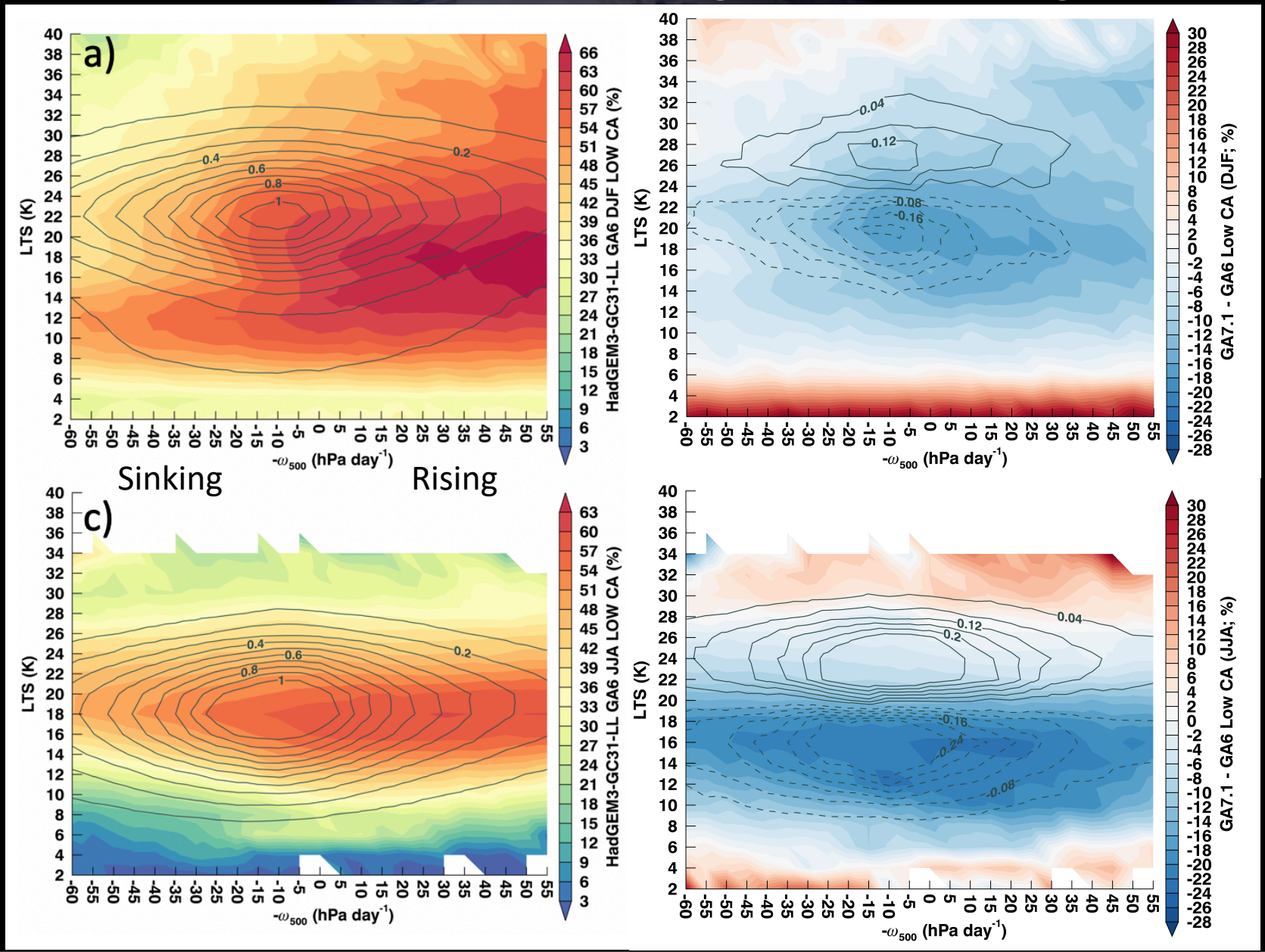


Regime Decomposition: Low cloud amount

GA6 | GA7.1 minus GA6

DJF

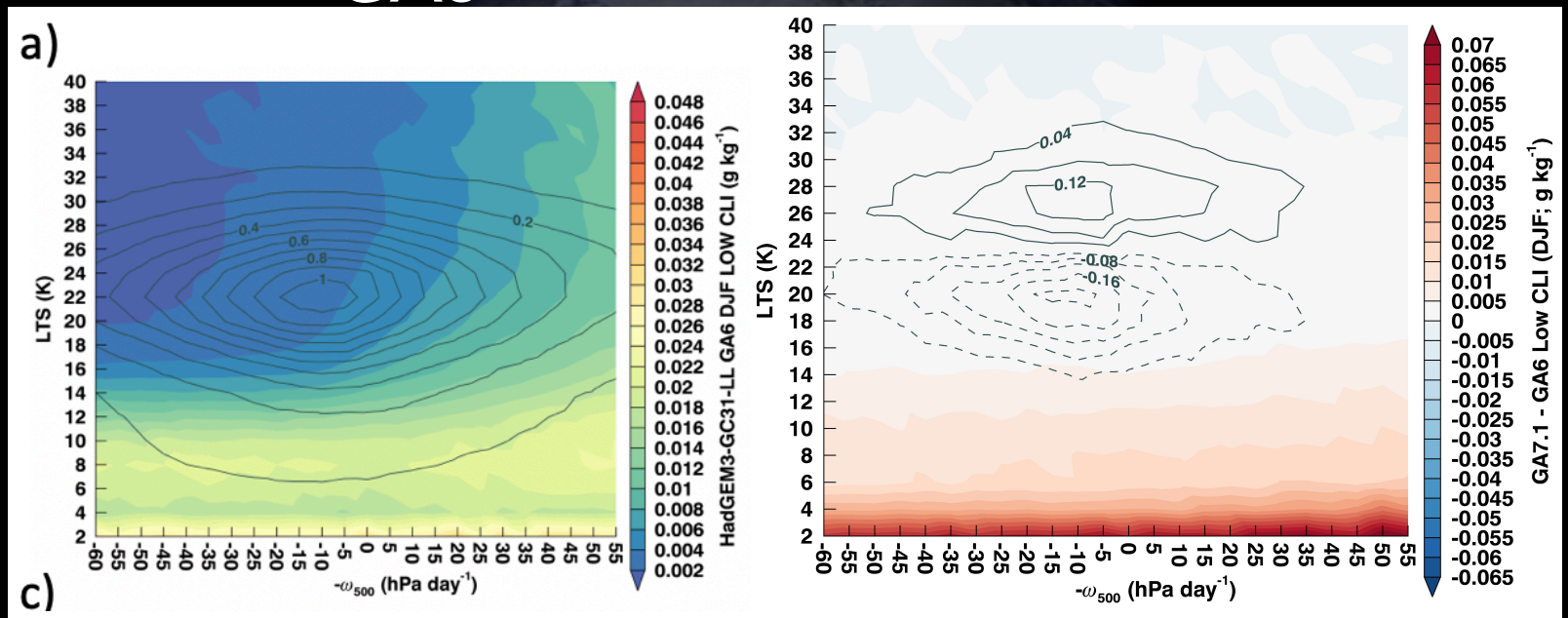
JJA



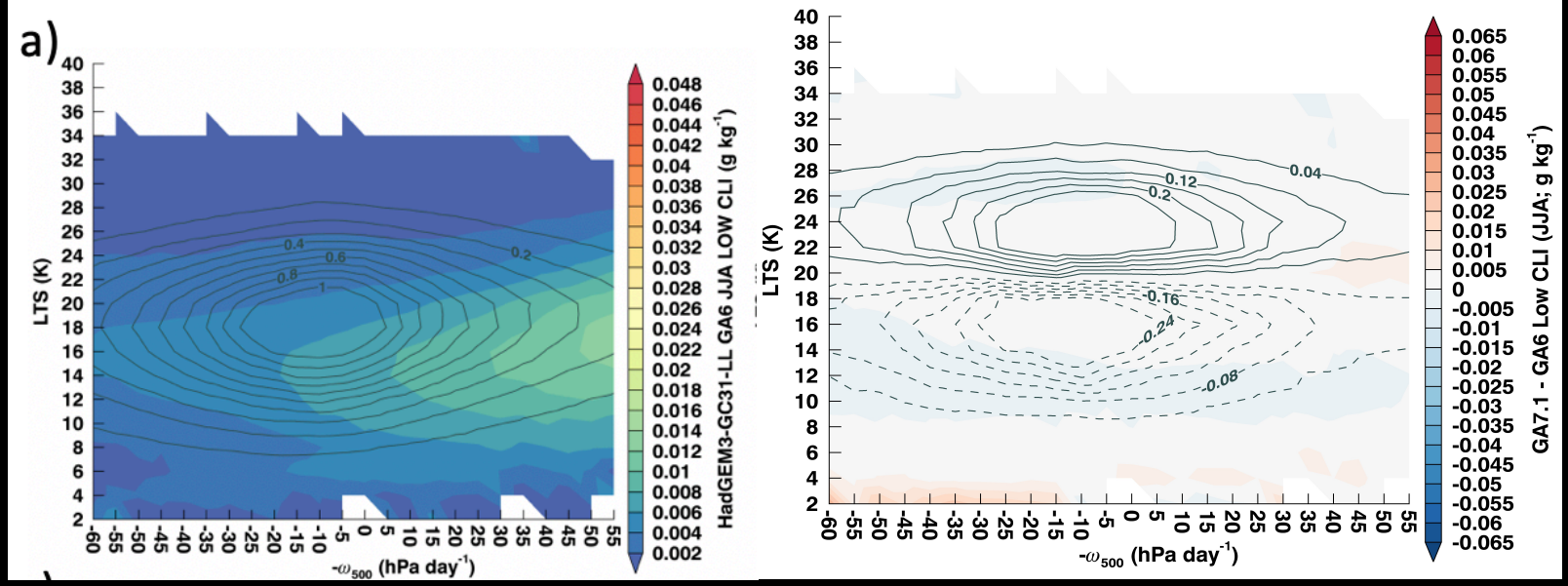
Regime Decomposition: Low cloud CLI

GA6 | GA7.1 minus GA6

DJF



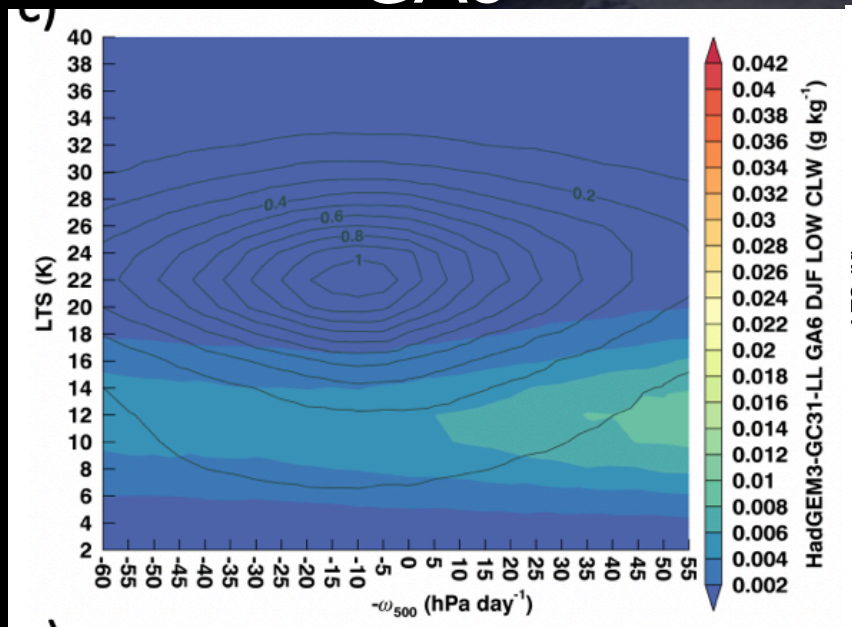
JJA

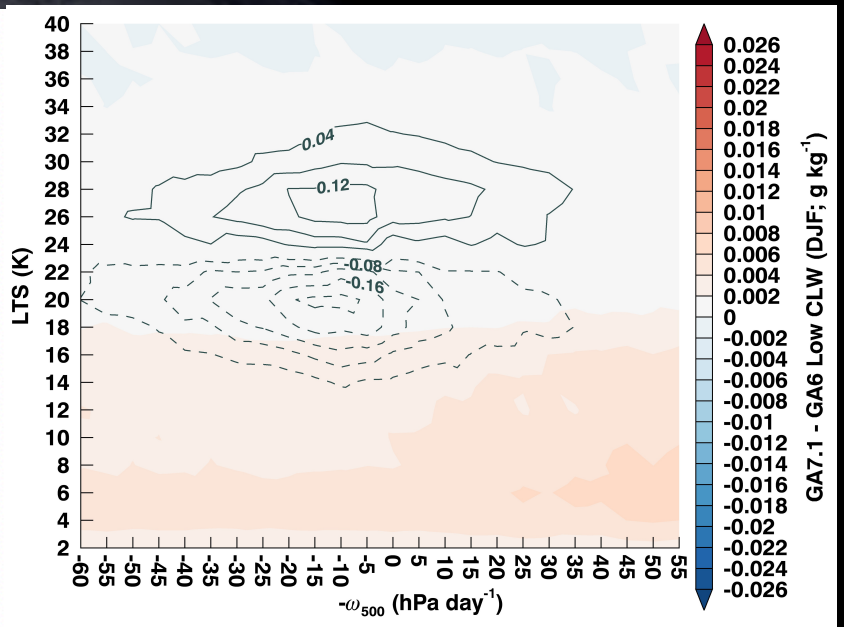


Regime Decomposition: Low cloud CLW

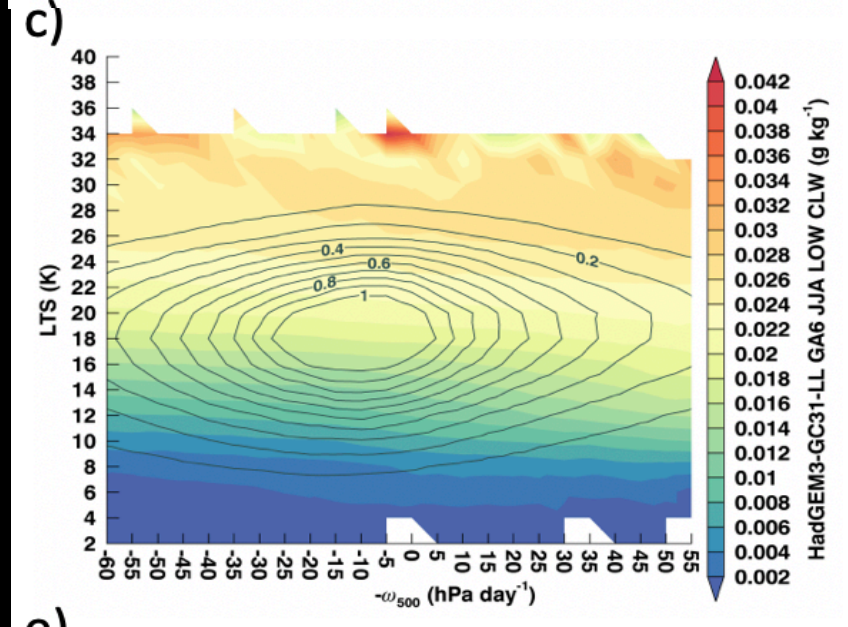
GA6 | GA7.1 minus GA6

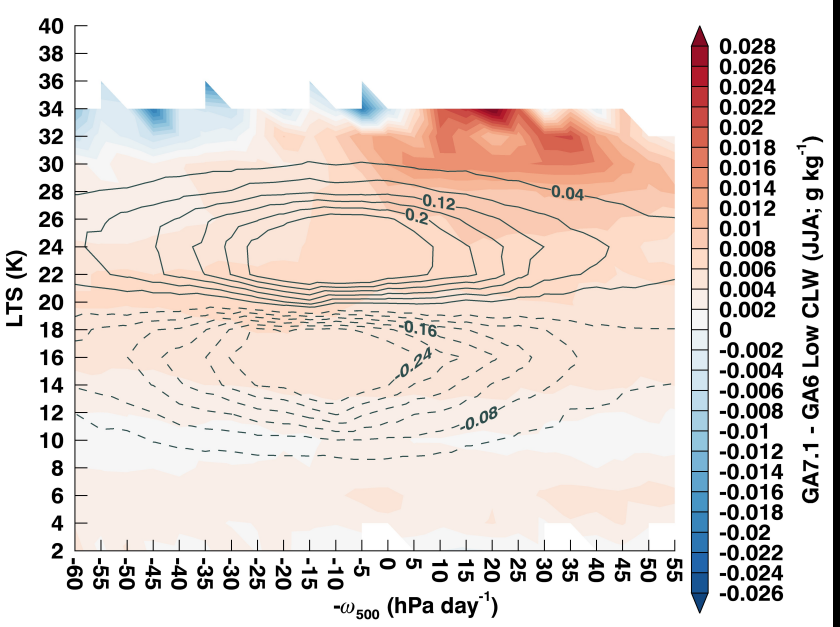
DJF





JJA

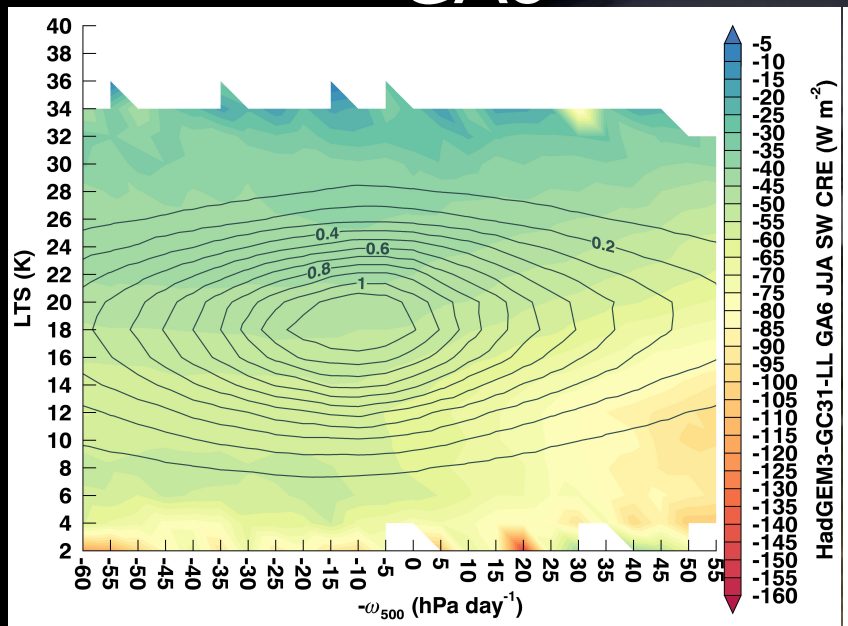


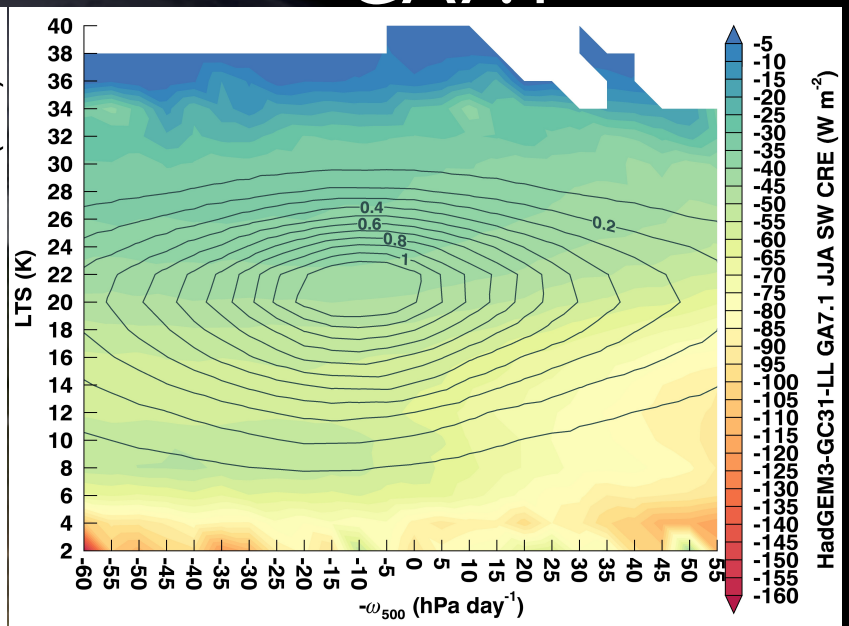


Regime Decomposition: SFC SW CRE

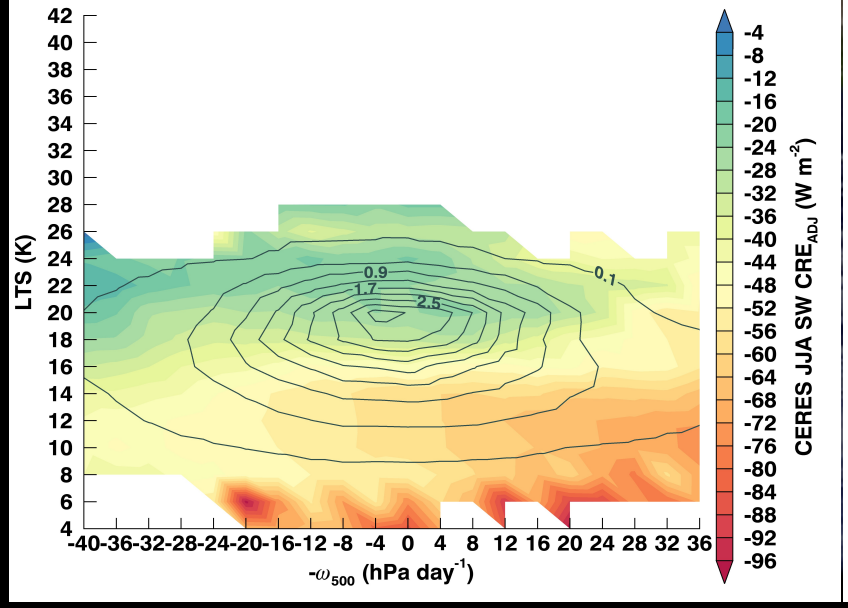
GA6

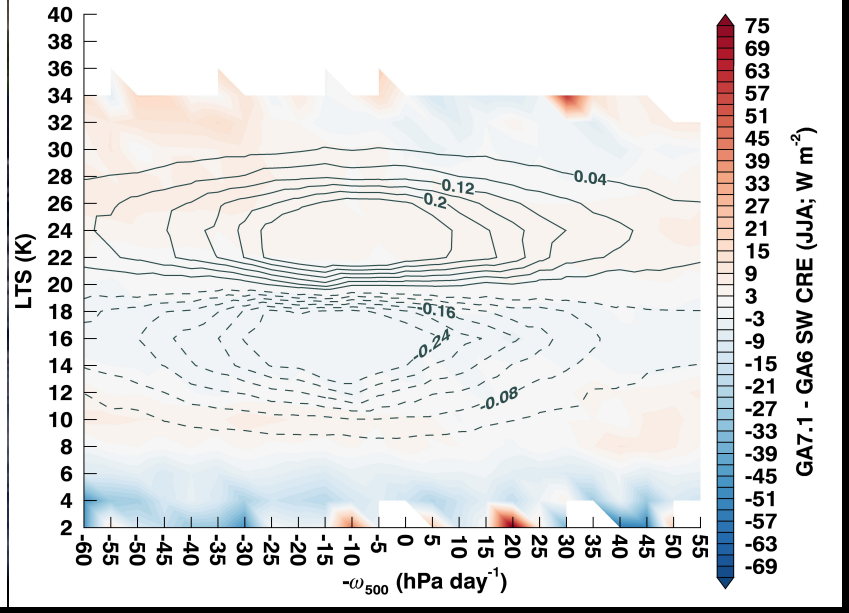
GA7.1





CERES



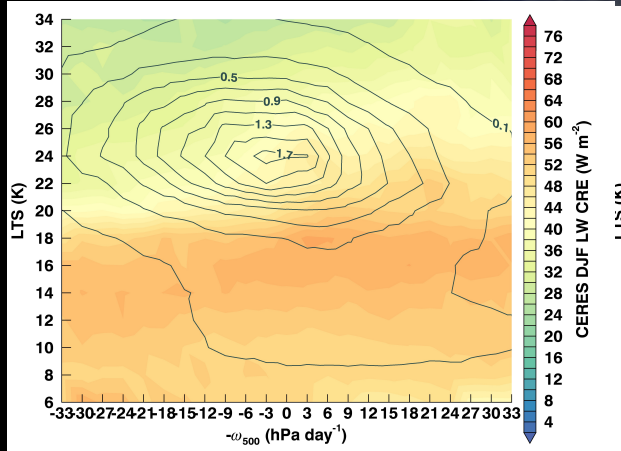


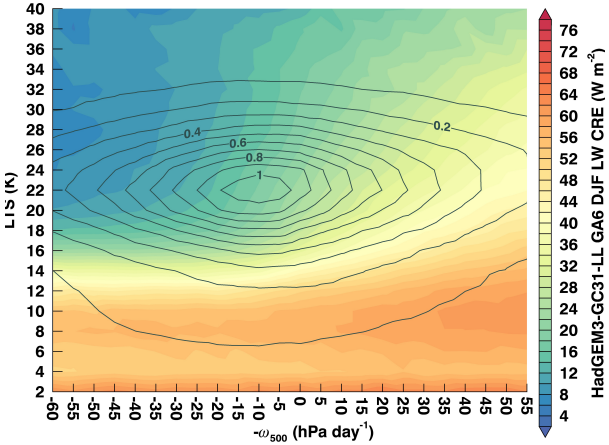
GA7.1 minus GA6

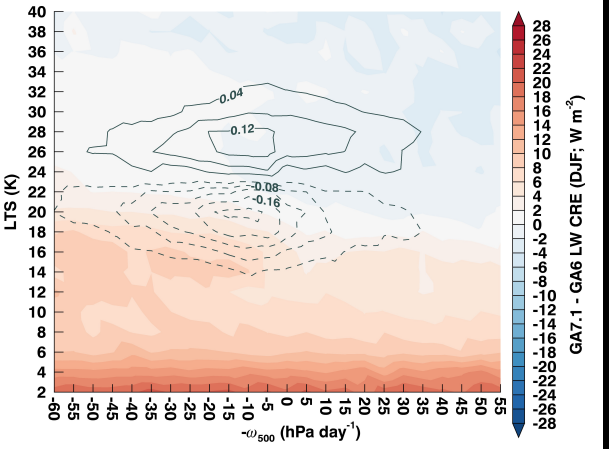
LW CRE: CERES vs. GA6 and GA7.1

CERES | GA6 | GA7.1 minus GA6

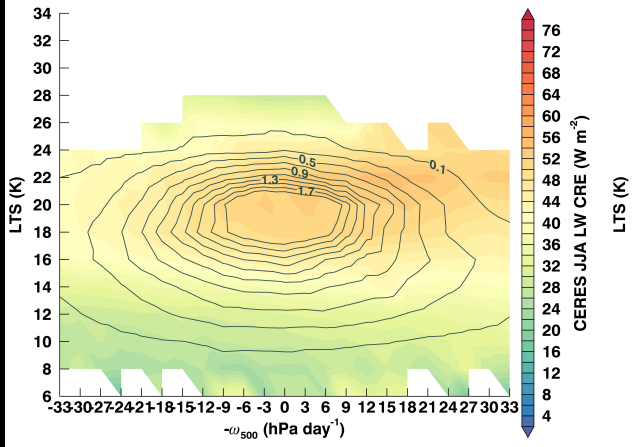
DJF

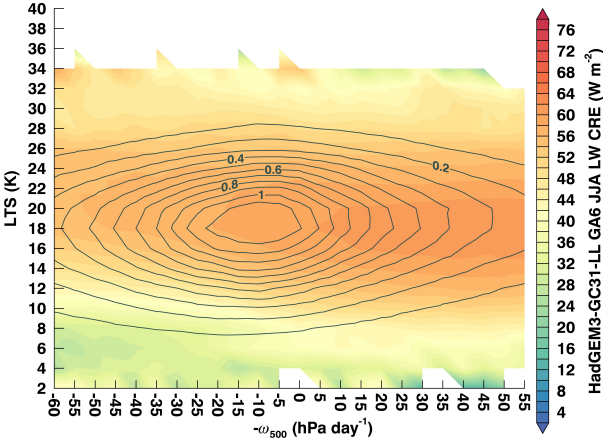


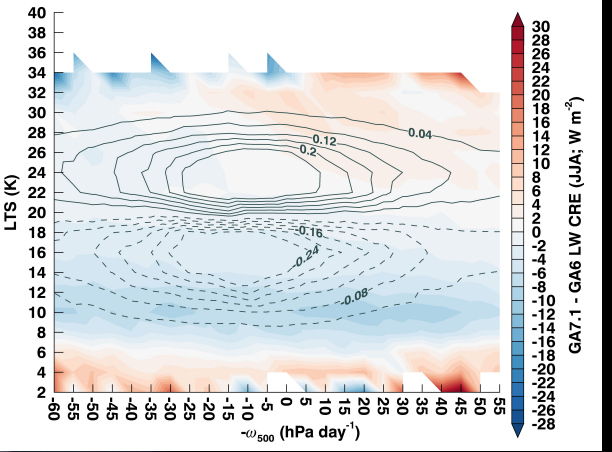




JJA







Model experiments

From Bodas-Salcedo (2019)

Table 1
List of Model Changes Between GA6.0 and GA7.1 Grouped Into Packages

Name	Package	Ticket numbers/reference
Cnv	Convection	64,84,145
Rad	Radiation	11,16,17
Mic	Microphysics and large-scale precipitation	15, 52, 120
Cld	Large-scale cloud	44,58,89,98,134
Bdl	Boundary layer	13, 83, 162
Dyn	Dynamics	135,146,153,161
Gwd	Gravity wave drag	87,138,151,165
Aer	Aerosols	60
Erf	Effective radiative forcing	Mulcahy et al. (2018)
Sto	Stochastic physics	117
Lnd	Land surface	141,GL tickets: 4,30,31,38,43,45,56

Note. Ticket numbers identify individual model changes, as detailed in Walters et al. (2019). All the tickets are GA tickets, except for the GL tickets in the *Lnd* package. The *Erf* package is documented in Mulcahy et al. (2018).

We use a subset of model experiments to understand the influence of specific parameterizations on Arctic cloud properties and radiative effects.

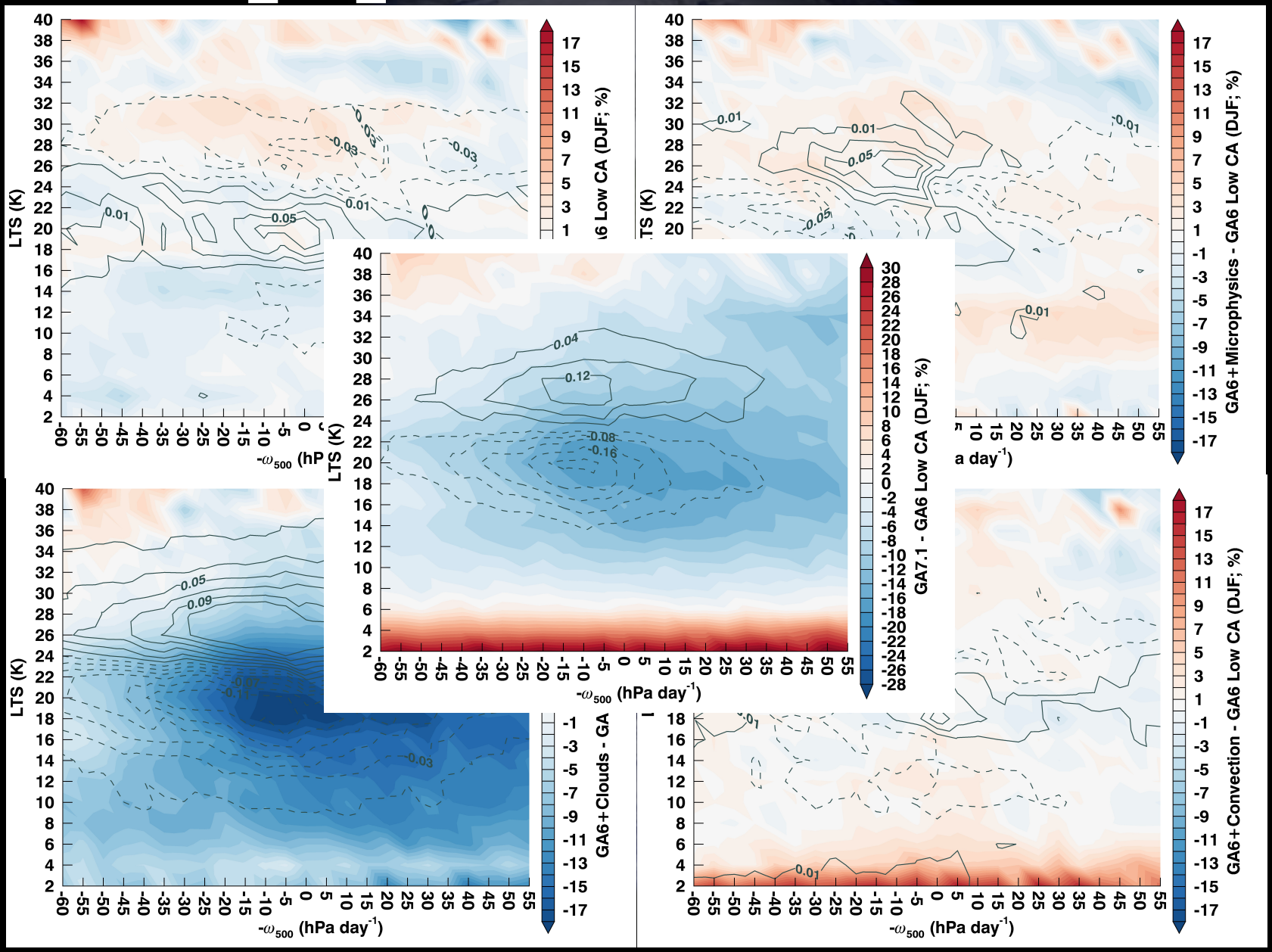
Winter Low cloud amount: parameterization impacts

GA6_aer_on

GA6_Mic_on

GA6_cld_on

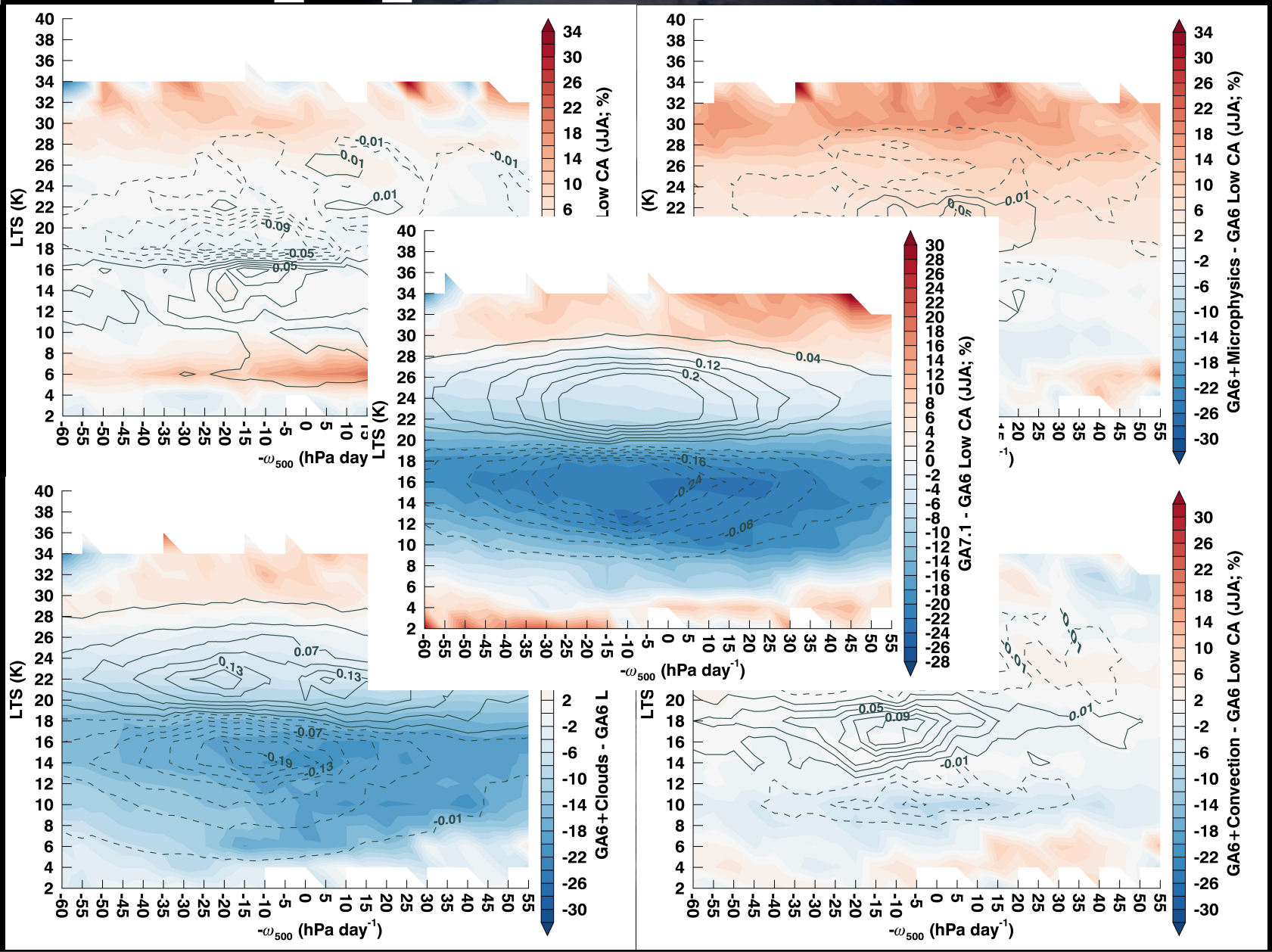
GA6_conv_on



Summer Low cloud amount: parameterization impacts

GA6_aer_on

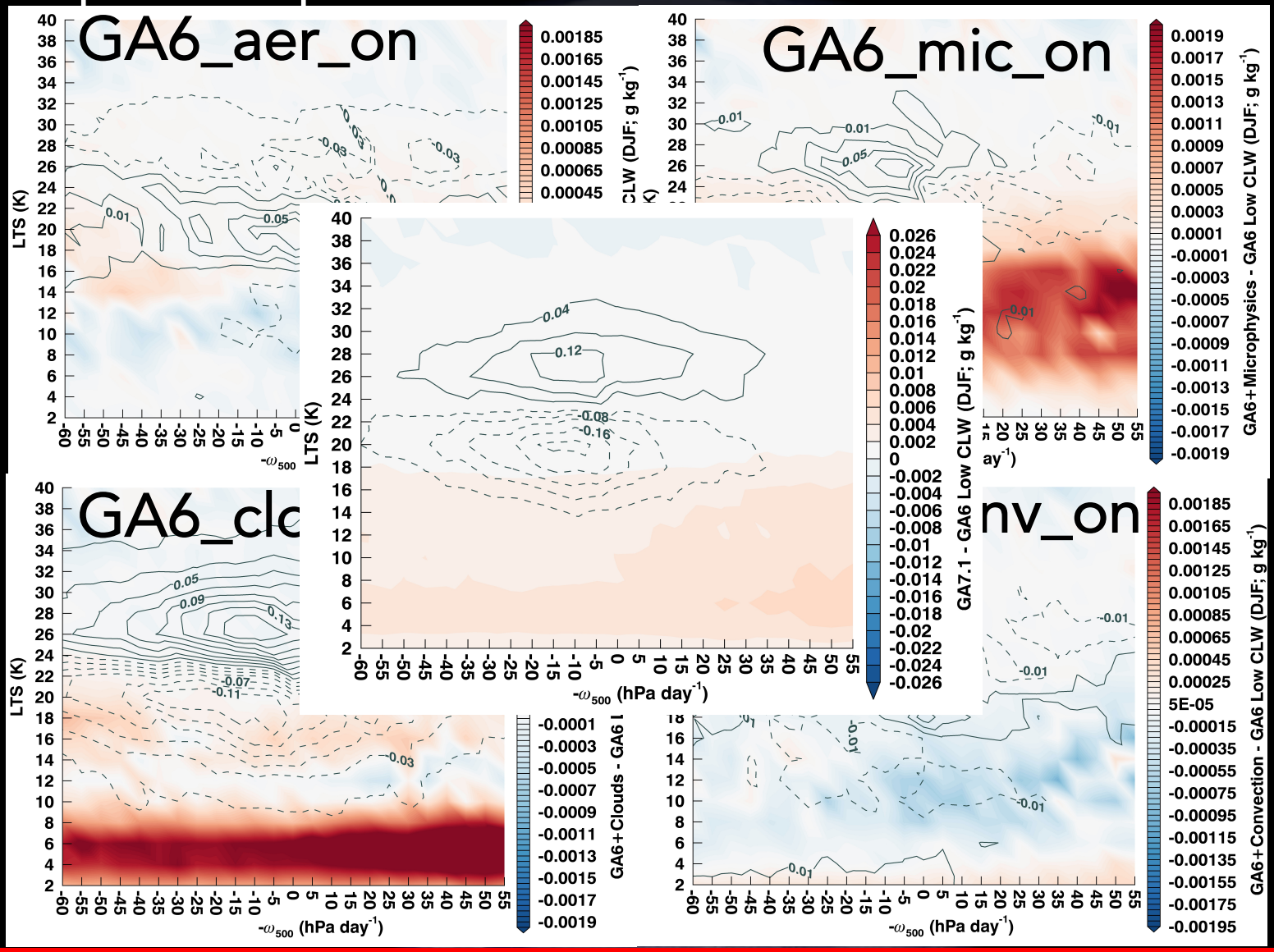
GA6_Mic_on



GA6_cld_on

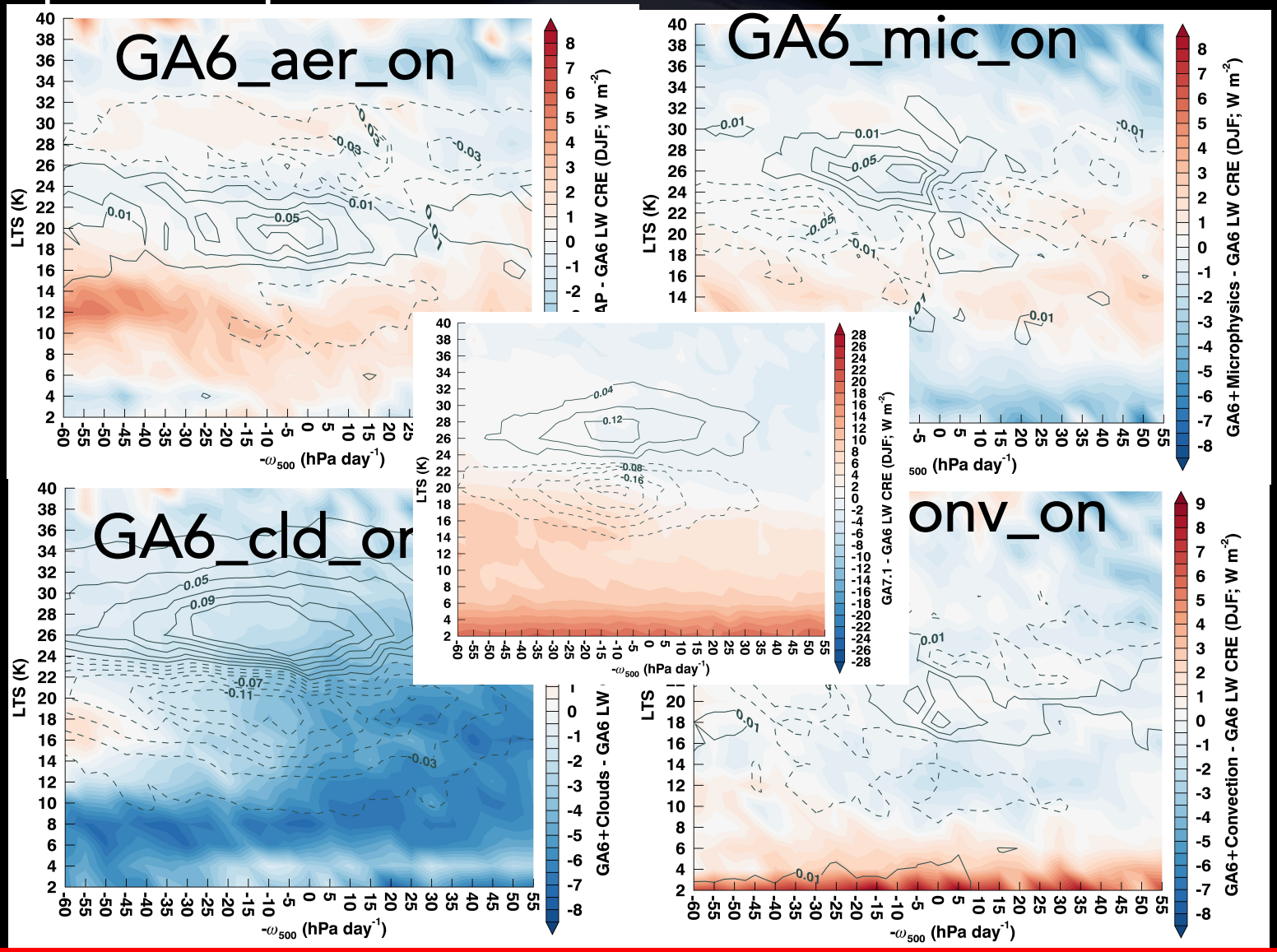
GA6_conv_on

GA6 plus experiments: Winter CLW



The large-scale cloud and microphysics scheme shows the largest effects on the low cloud liquid water mixing ratio.

GA6 plus experiments: Winter LW CRE



The cloud microphysics scheme shows the largest effects on the low cloud liquid water mixing ratio.

Takeaways…

- The regime decomposition approach shows the contributions from different meteorological conditions to differences and is useful for model evaluation against observations and when trying to understand changes between model versions.

- The regime approach highlights the fact that domain averaged changes in cloud properties are often the results of compensating contributions from differently by meteorological regimes.

- Our work indicates, that the effect of a changes in a model parameterization can strongly depend upon meteorological regime and often have compensating effects.

- Lastly, the regime approach also points to important compensating effects between changes in meteorology frequency of occurrence and cloud property changes resulting from the parameterizations. This means that processes that do not directly influence the cloud properties, but influence the regime frequency of occurrence, can influence the domain average cloud properties and model biases.