Met Office

Use of short-range forecasts to evaluate fast physics processes relevant for climate sensitivity

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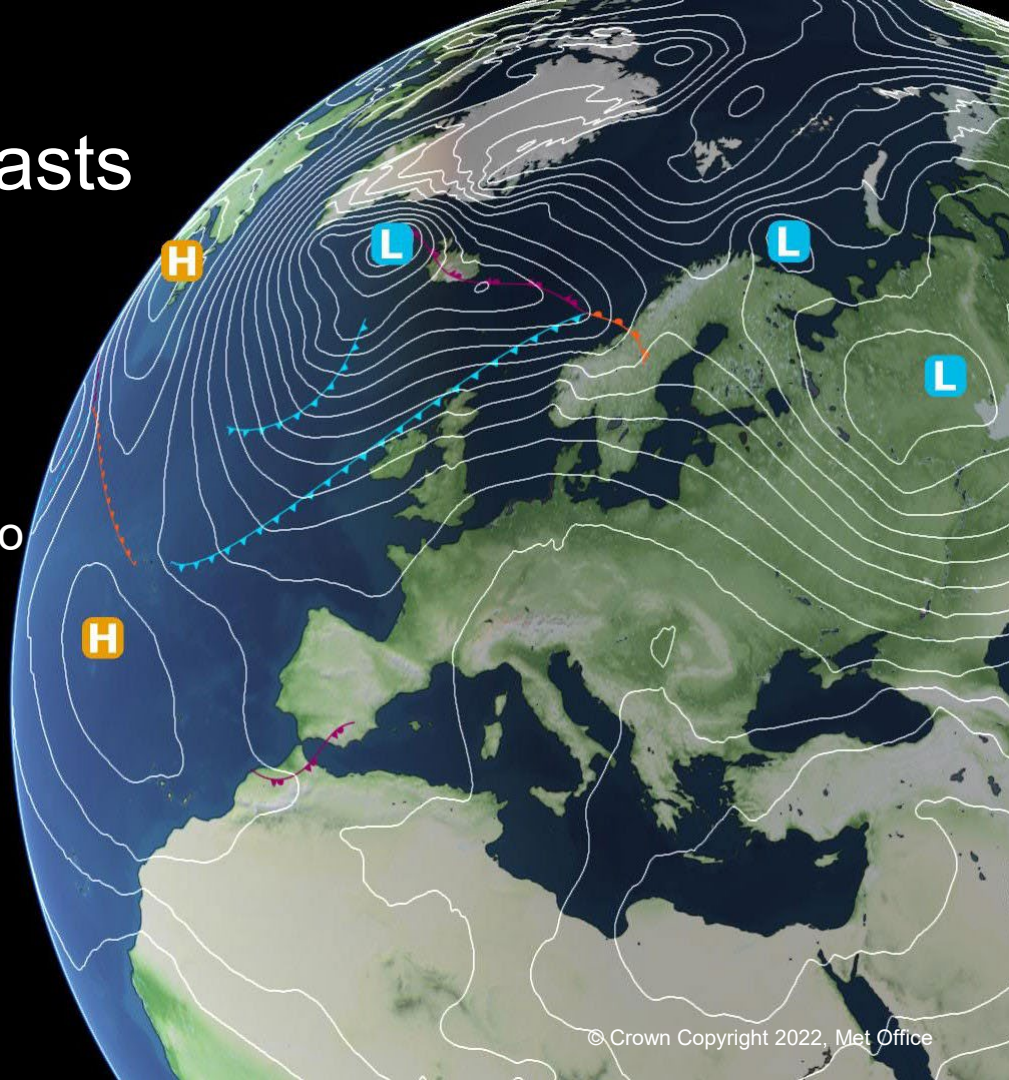
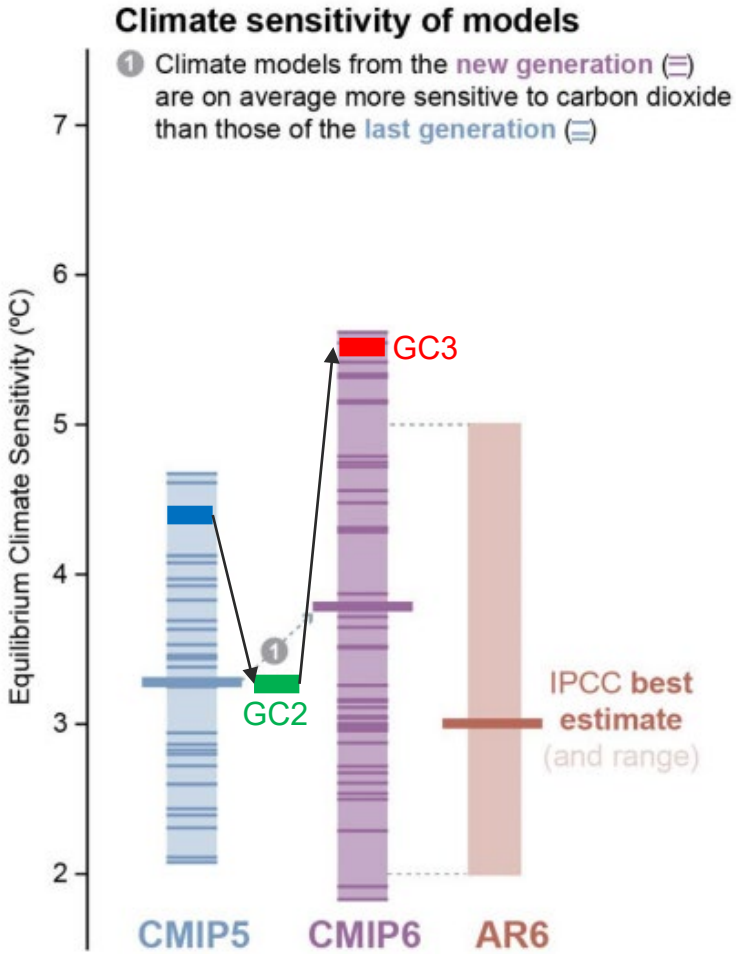
WGNE Systematic Errors Workshop, Nov 2022



Met Office Hadley Centre



Met Office model	EffCS (K)	
HadGEM2	4.4	CMIP5
HadGEM3-GC2	3.2	
HadGEM3-GC3	5.5	CMIP6

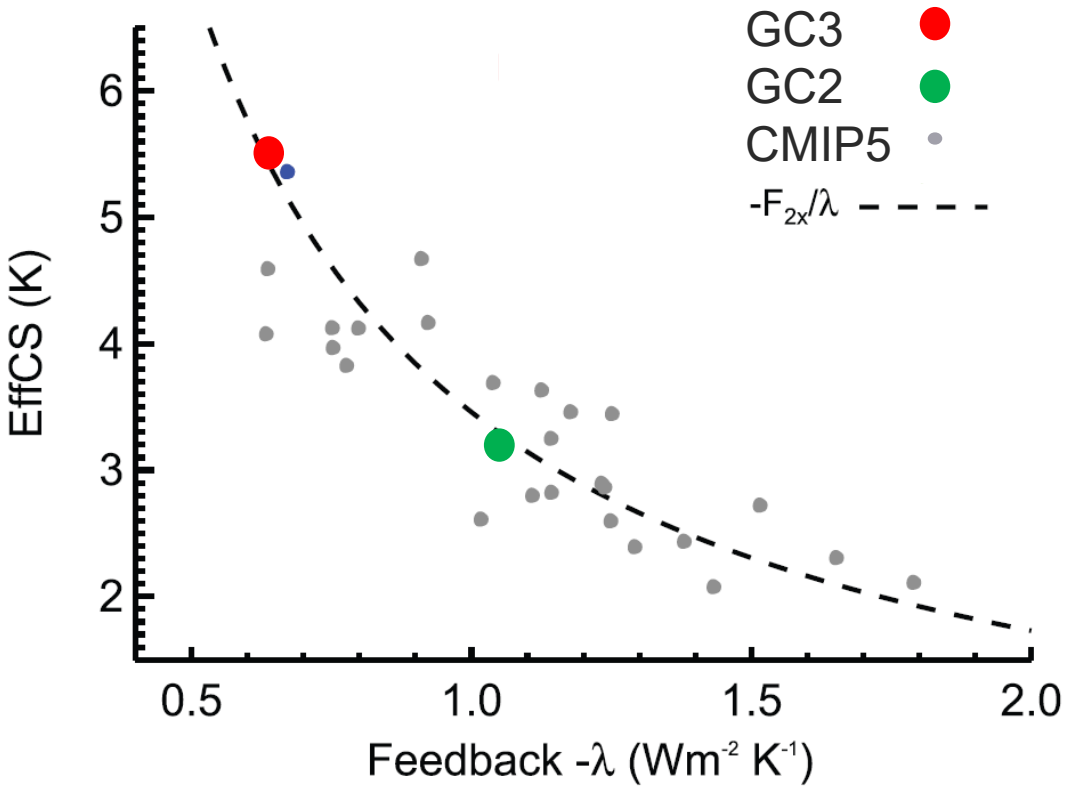
Very likely range:
2.0 – 5.0K

Climate sensitivity of new Met Office model (GC3) is considerably higher than the previous one (GC2)

GC3 has a climate sensitivity which IPCC consider 'very unlikely'

(IPCC AR6, 2021)

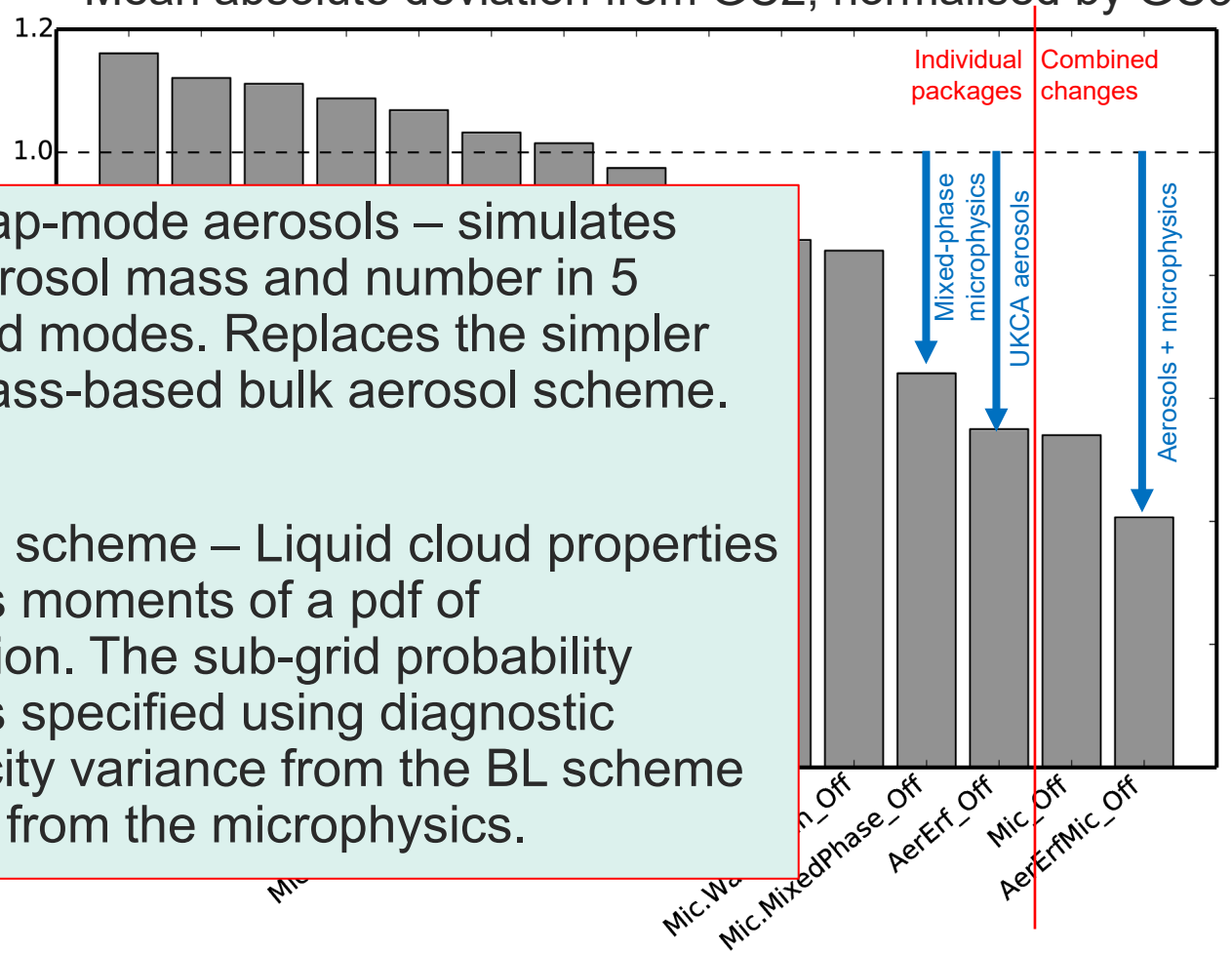
Relationship between feedback strength and climate sensitivity



(Andrews et al., 2019)

Met Office Hadley Centre

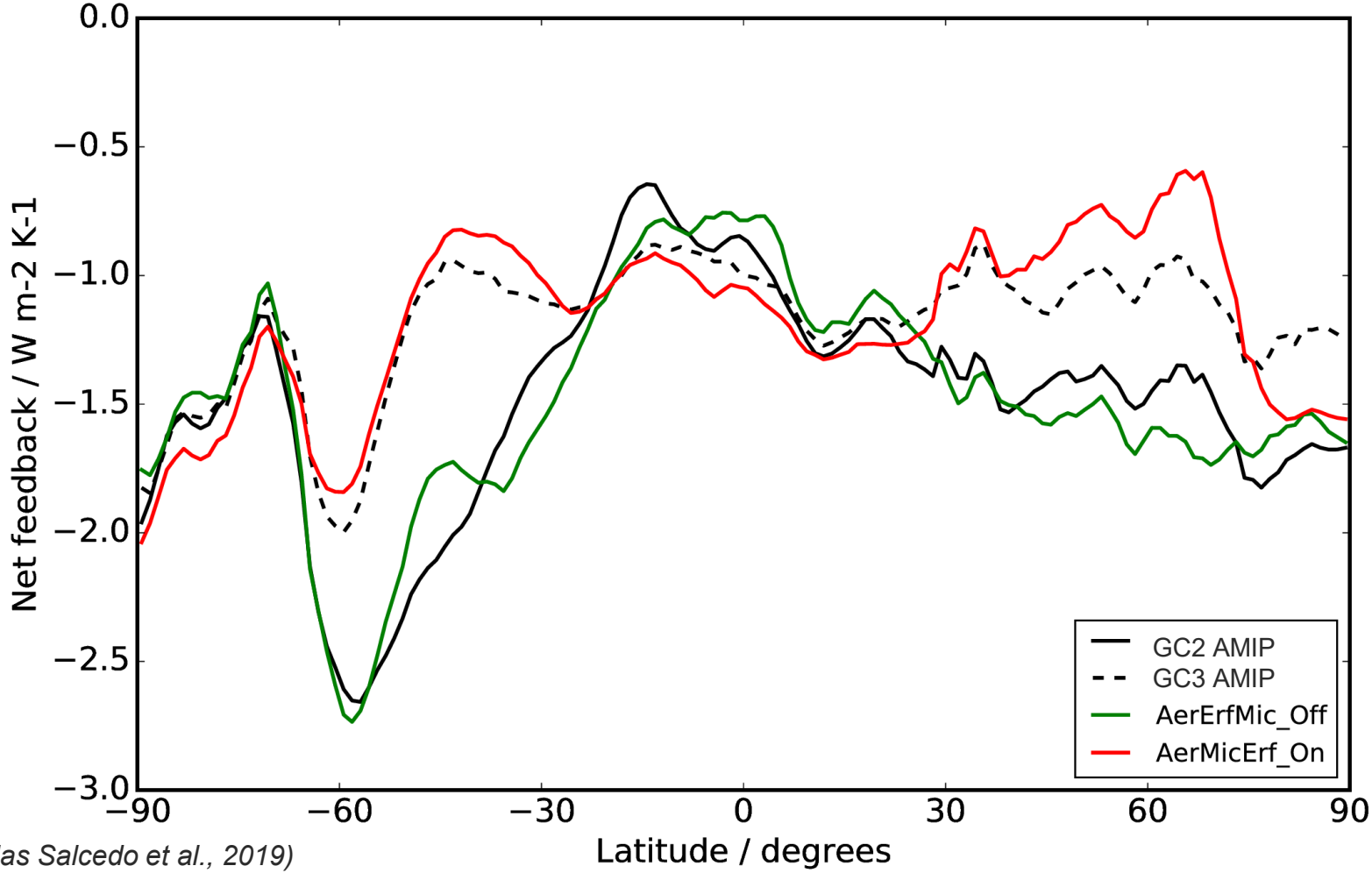
Mean absolute deviation from GC2, normalised by GC3



- UKCA Glomap-mode aerosols – simulates speciated aerosol mass and number in 5 variable-sized modes. Replaces the simpler CLASSIC mass-based bulk aerosol scheme.

- Mixed-phase scheme – Liquid cloud properties calculated as moments of a pdf of supersaturation. The sub-grid probability distribution is specified using diagnostic vertical velocity variance from the BL scheme and ice PSD from the microphysics.

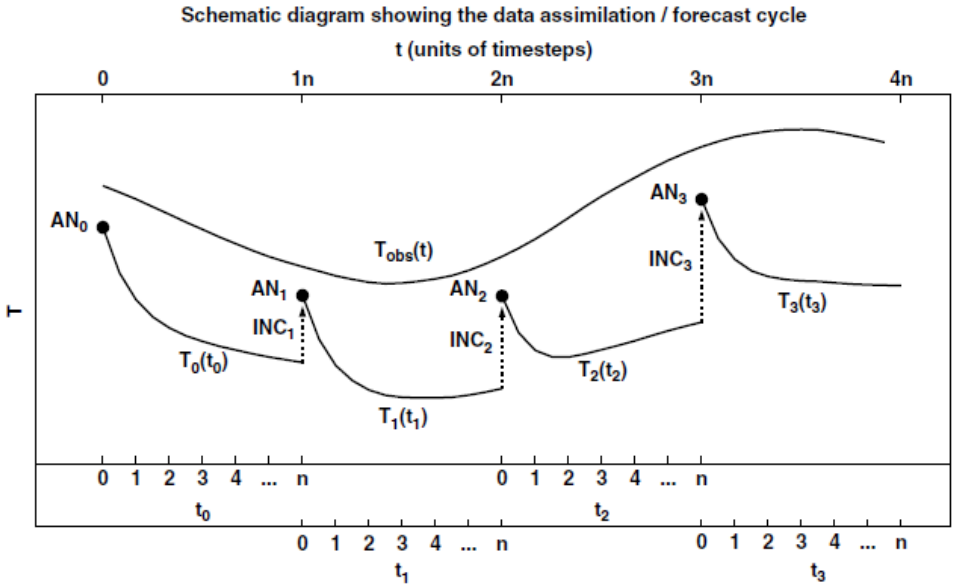
(Bodas Salcedo et al., 2019)



(Bodas Salcedo et al., 2019)

Can we benefit from a seamless approach? - initial tendencies

Based on Klinker and Sardeshmukh (1992) and Rodwell and Palmer (2007)

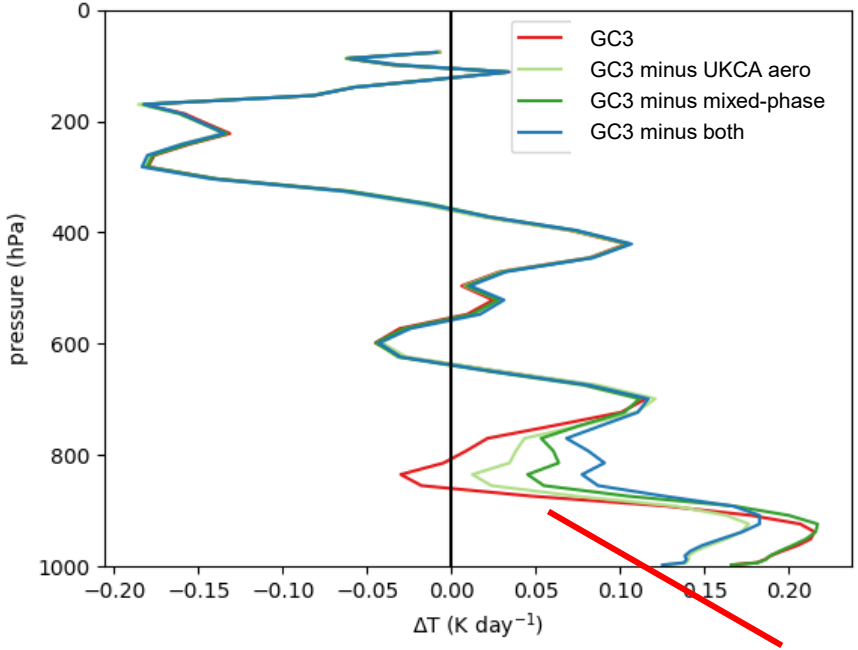


(Rodwell and Palmer, 2007)

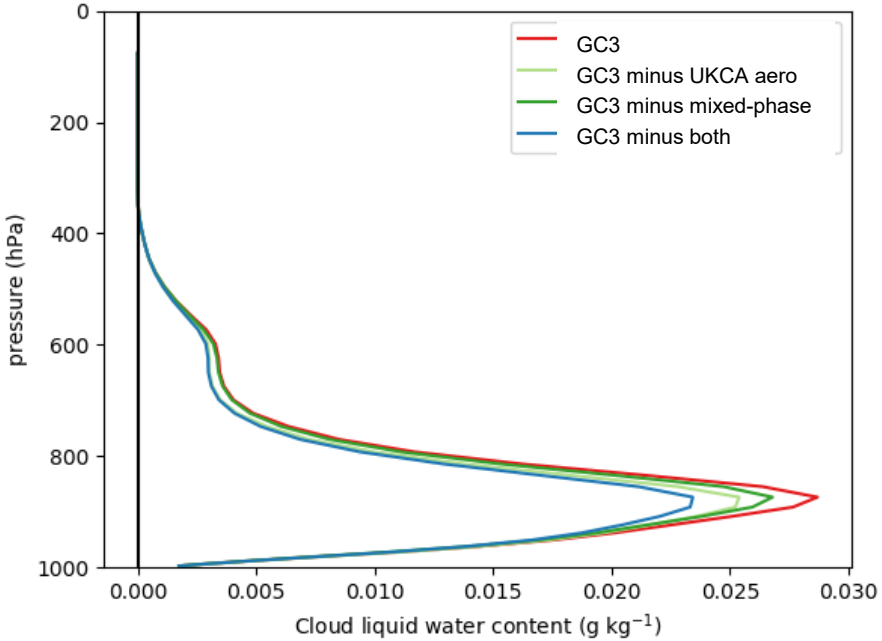
- If the model has a bias, then it will start to develop over the first few timesteps. Each data assimilation cycle will have an analysis increment aimed at correcting this.
- Over a large number of forecasts, the initial tendency in the forecast between data assimilation cycles should be the negative of the analysis increment and reveal the systematic error.
- By examining modelled process tendencies ("initial tendencies"), it may be possible to identify the source of errors before significant feedbacks take place.

DJF NWP trial with cycling DA (atmosphere-only) – Southern Ocean

Initial T tendency
(first 6 hours of forecast)

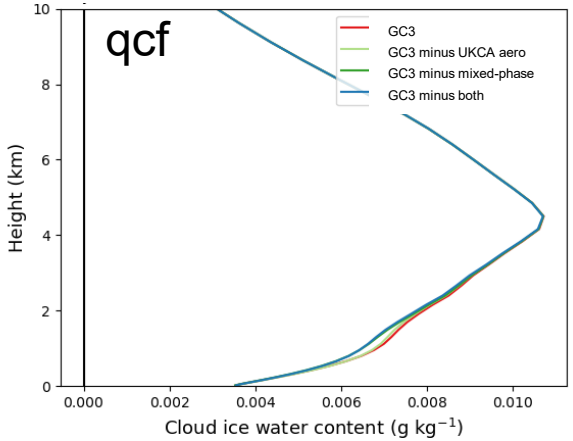


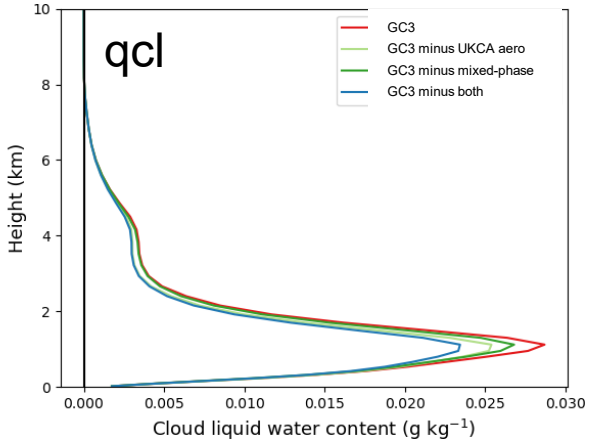
Cloud liquid water content



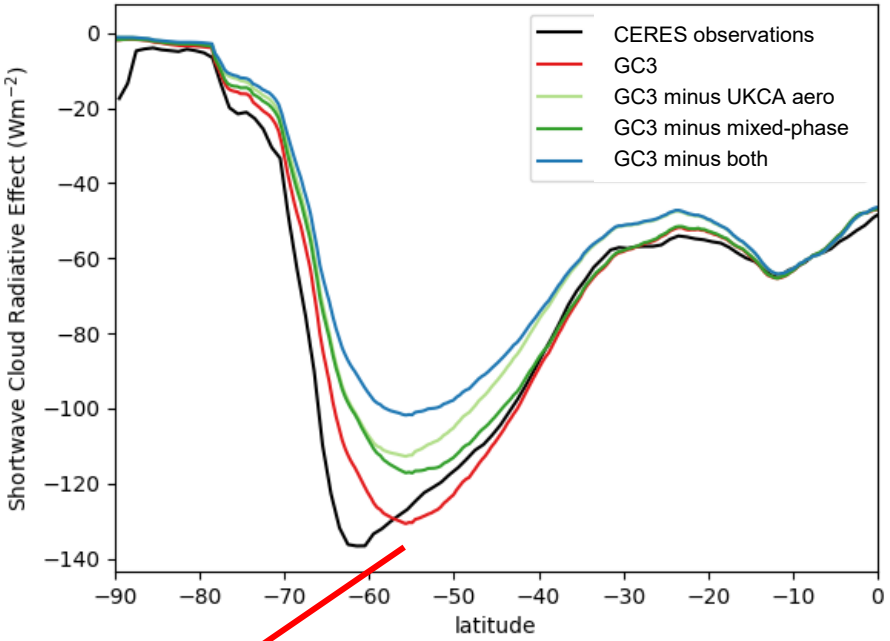
Erroneous warming tendency associated with too little cloud top cooling is reduced in GC3 when these schemes are included

DJF NWP trial with cycling DA (atmosphere-only) – Southern Ocean





SW cloud forcing in NWP trial



Higher qcl in GC3 is associated with improved cloud forcing

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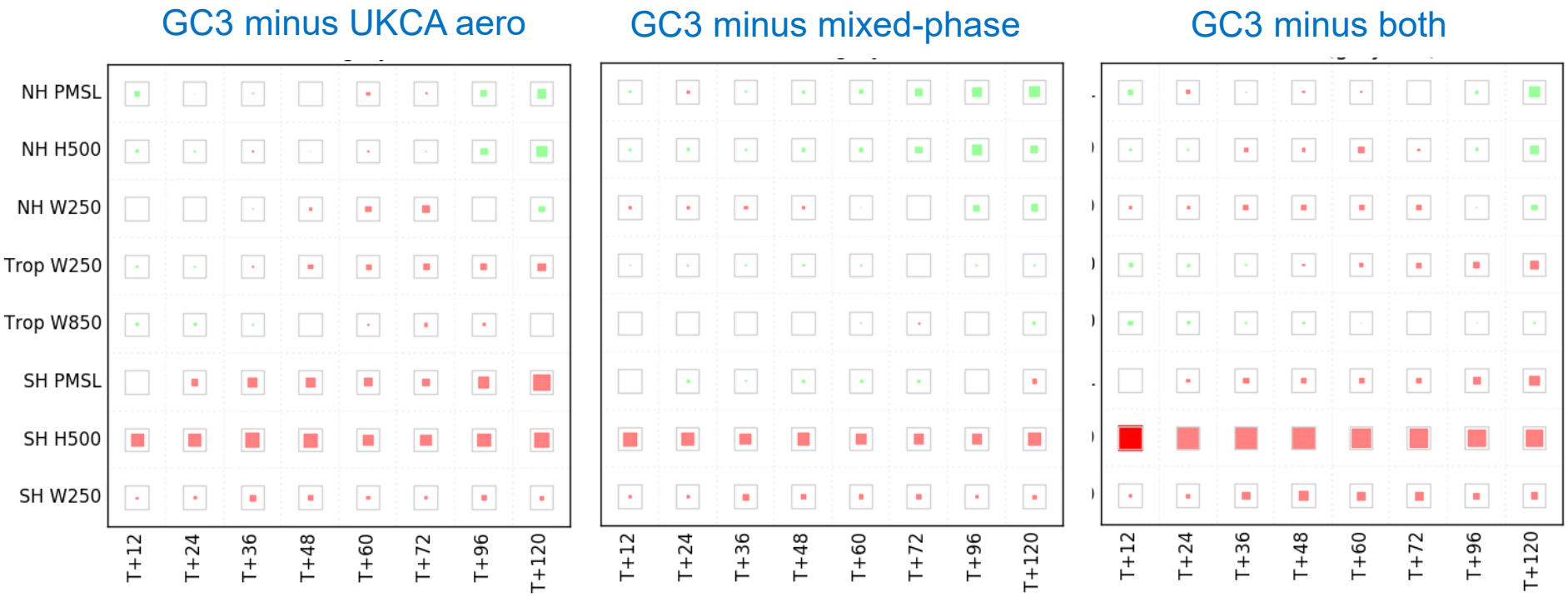
NWP ‘Scorecards’ removing these components of GC3 (DJF)



Removing these components degrades the southern hemisphere performance

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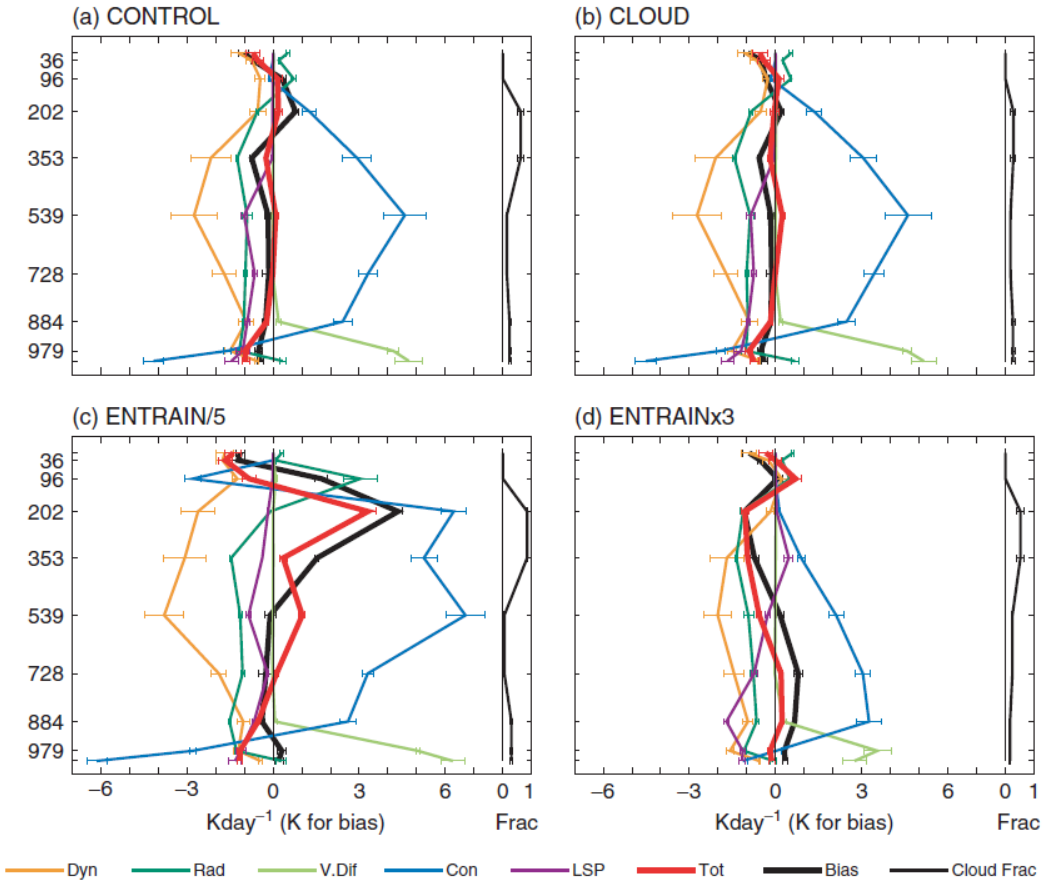
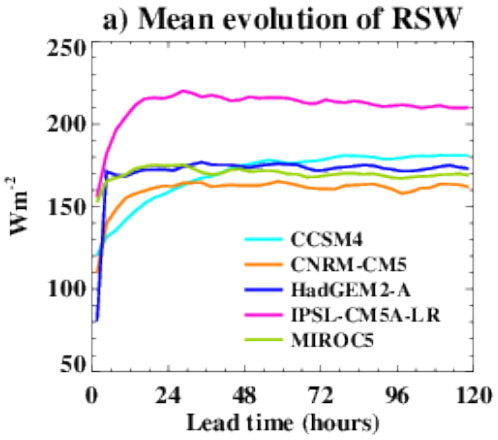
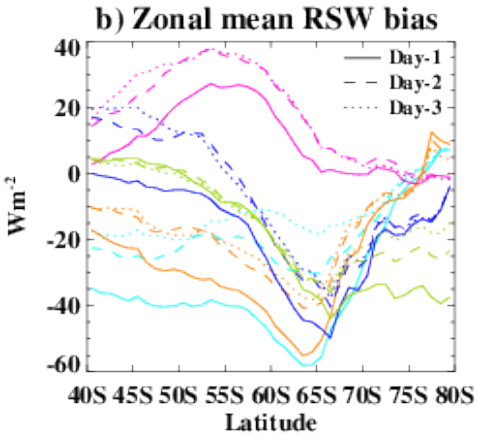
The same method could explore causes of errors using initial tendencies from model physics components

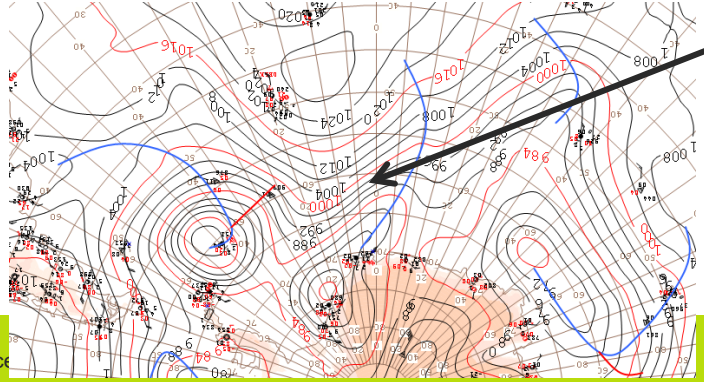


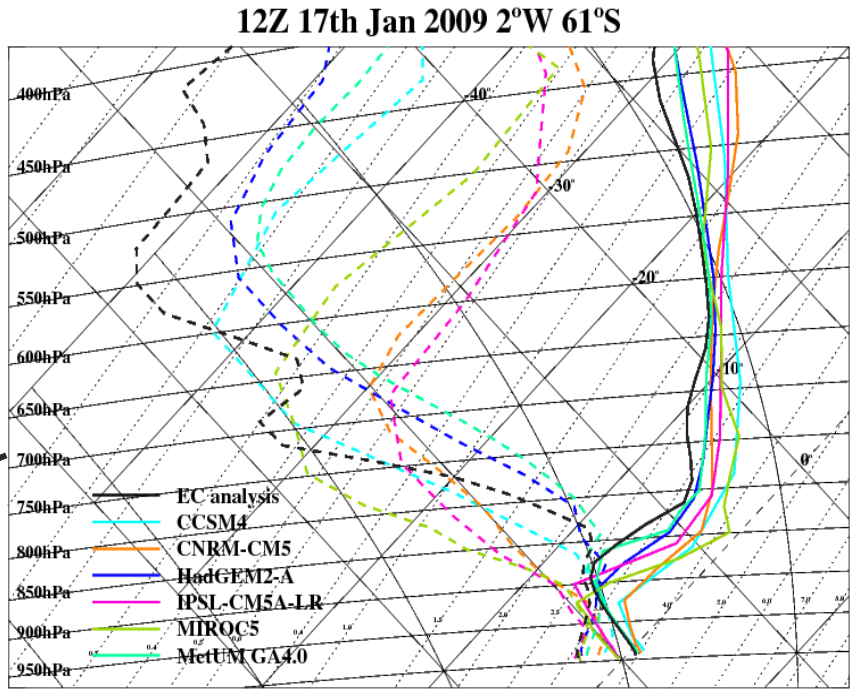
Rodwell and Palmer (2007)

Q: What if my model doesn't have a DA system?
A: There's still the WGNE Transpose-AMIP approach









Williams et al. (2013)

Conclusions

- Microphysics developments can significantly affect climate sensitivity (hence the importance of double-moment CASIM planned for future global model configurations)
- Using an NWP initial tendency approach, we have shown the changes which increase climate sensitivity are improvements – they reduce the correction DA needs to apply to model state variables.
- In turn, these can be traced through to improved cloud processes and radiative effects associated with the change in feedback.
- This increases our confidence in the physical basis of these changes.
- Whilst this does not prove the high climate sensitivity is correct, if the climate sensitivity is too high, it is more likely to be due to existing processes in the model which are in error rather than the recent changes.
- The initial tendency approach (and failing that, the Transpose-AMIP approach) offers potential for understanding the cause of model error.