University of Reading

Relationships between clouds and circulation in reanalysis and climate models

Peter Hill & Chris Holloway

EGU 2022

Advancing understanding of the coupling between clouds, convection and circulation

May 2022

Motivation

University of Reading

- Binning cloud radiative effect by vertical velocity first suggested by Bony et al 2004.
- Used for evaluating models (e.g. Cronin and Wing, 2017) and understanding cloud feedback processes (e.g. Byrne and Schneider, 2016, Mackie and Byrne, 2021)
- Limited observational analysis of these relationships (Yuan et al 2007) at relatively low resolution. Are the relationships between vertical velocity and cloud sufficiently linear to be accurately captured by these resolutions?
- How accurately can we characterise these relationships? Are they consistent across different reanalyses?
- How are these relationship affected by season, ENSO phase, SST?
- How well do climate models capture these relationships?

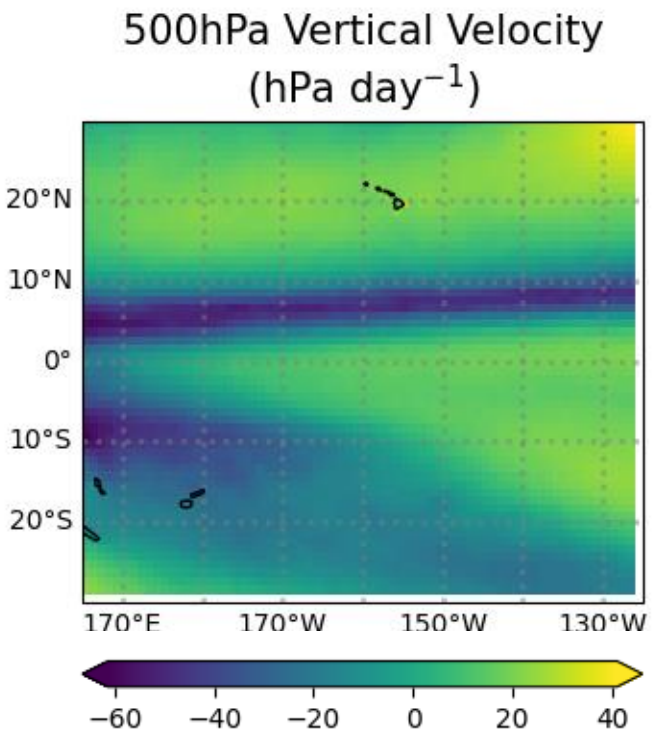
Data

- Instantaneous vertical velocity at 500 hPa in hPa s-1 from 3 different reanalyses, ERA5 (0.25°, hourly), MERRA2 (°, hourly), JRA55 (°, 6 hourly). MERRA2 and JRA55 regridded to 0.5° grid.
- Radiation and cloud properties from CERES-SYN merged satellite data at hourly 1° resolution.
- Vertical velocity and radiation variables matched at CERES-SYN resolution before averaging.
- Vertical velocity bin width of 2 hPa day-1
- 20 years (2001-2020 inclusive) based on availability of CERES data.
- Focus on topical Pacific to minimise variability due to surface/topography.

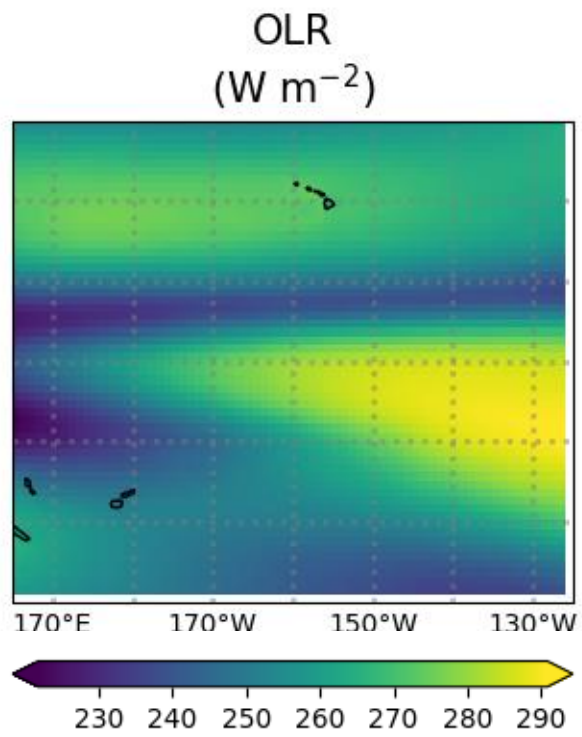
Tropical Pacific Domain

University of Reading

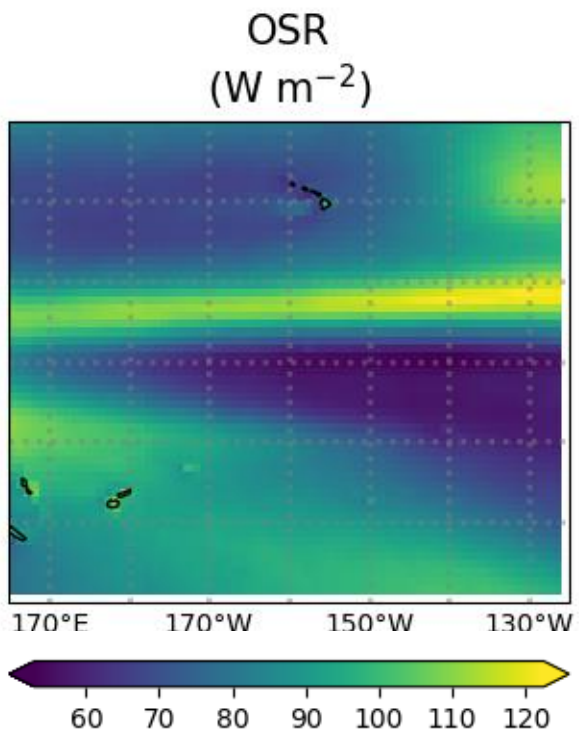
ERA5 mean 2001-2020



CERES-SYN mean 2001-2020

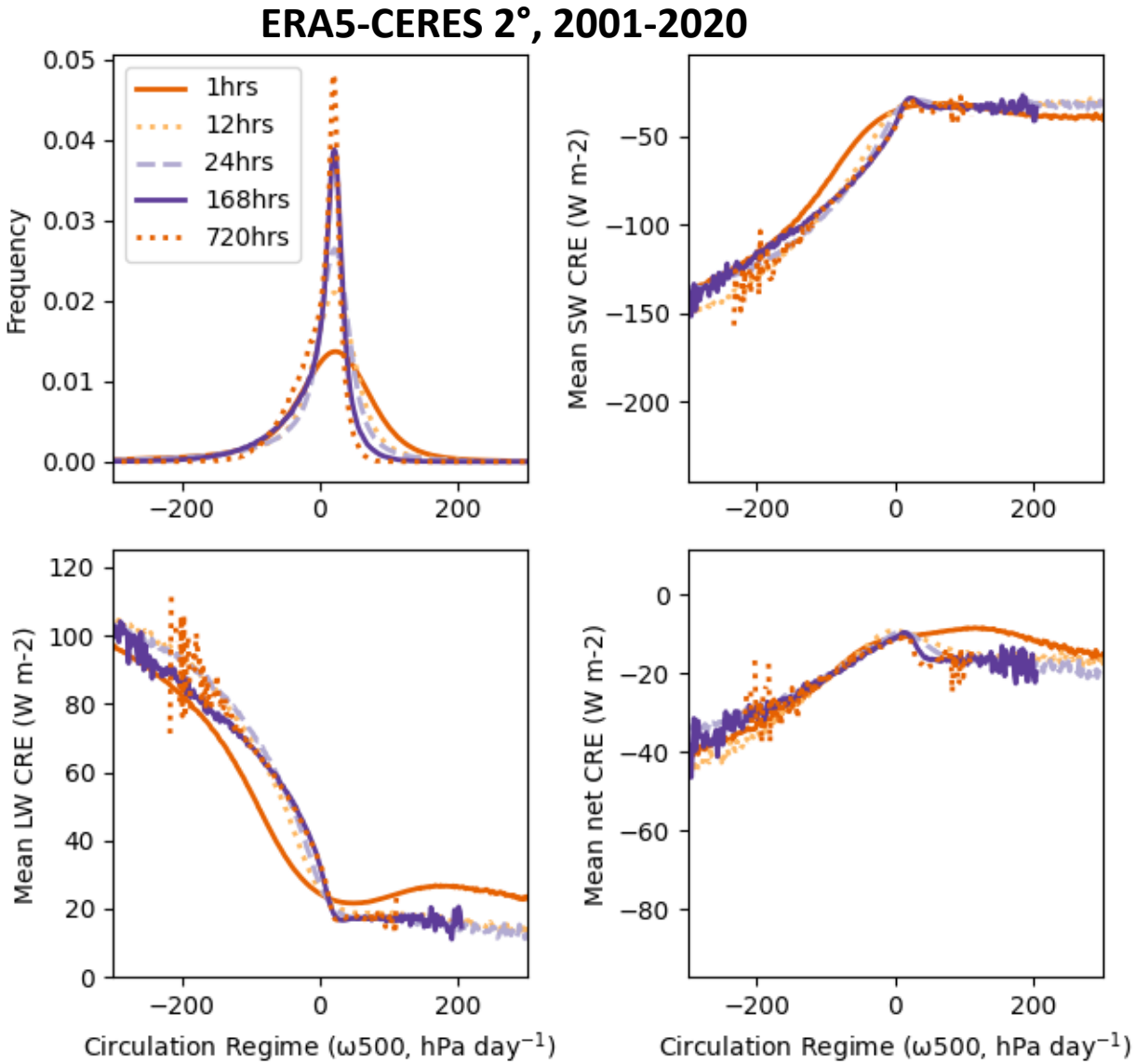


CERES-SYN mean 2001-2020



- Focus on topical Pacific to minimise variability due to surface/topography.
- Region dominated by ITCZ and SPCZ. Some stratocumulus to NE.

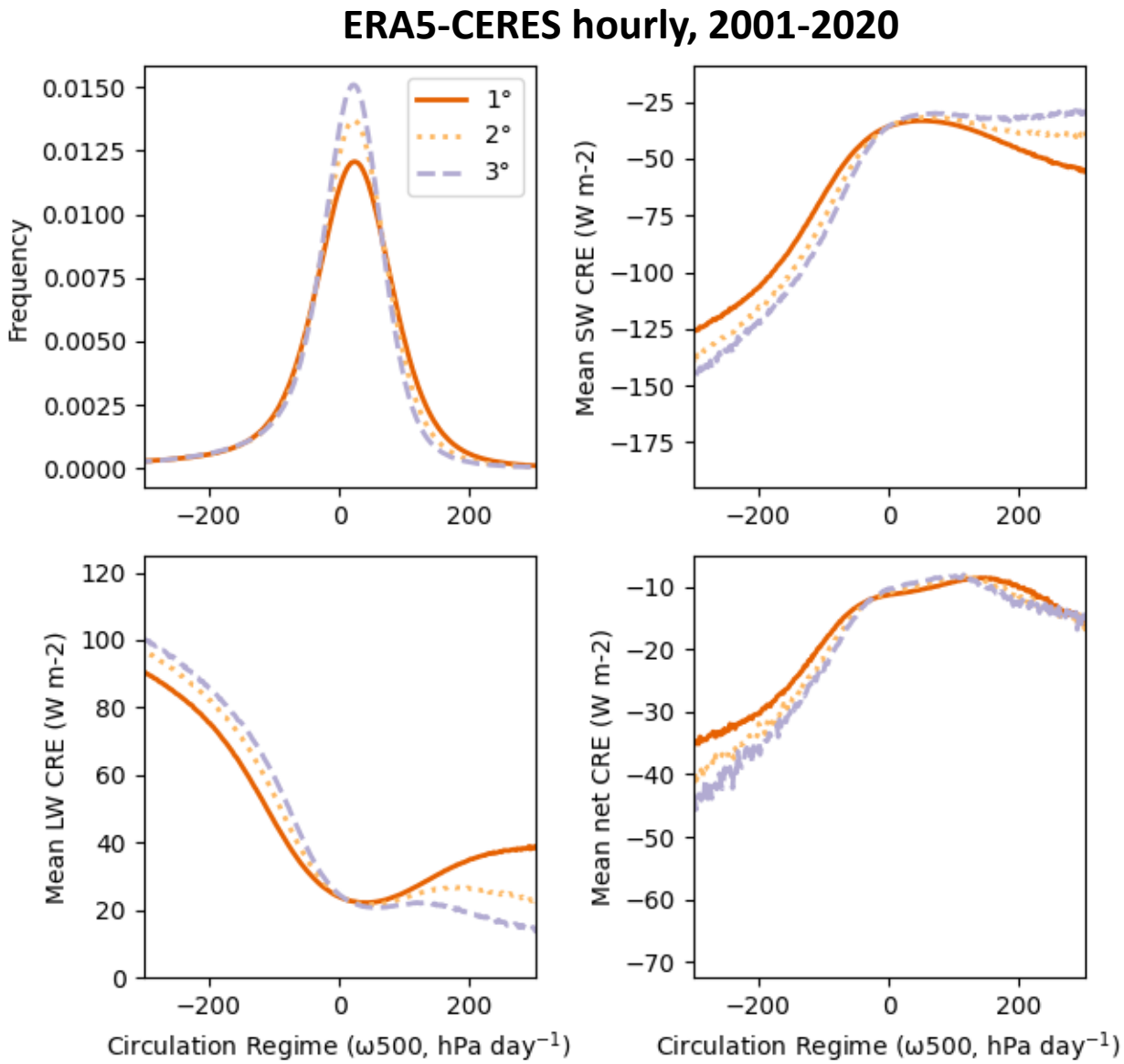
Temporal scales



- Narrower distribution of circulation regimes with increased averaging.
- Relationship between circulation and CRE changes with scale.
- Small dynamical contribution to cloud feedback attributed to linear relationship between CRE and ω500 (Byrne & Schneider, 2016). Degree of non-linearity changes with scale, so dynamical contribution may depend on scales used?
- ERA5, JRA55, MERRA2 reanalyses converge for daily averages.

Spatial scales

University of Reading



- Narrower distribution of circulation regimes with increased averaging.
- Relationship between circulation and CRE changes with scale.
- Small dynamical contribution to cloud feedback attributed to linear relationship between CRE and ω500 (Byrne & Schneider, 2016). Degree of non-linearity changes with scale, so dynamical contribution may depend on scales used?
- ERA5, JRA55, MERRA2 reanalyses converge for daily averages.

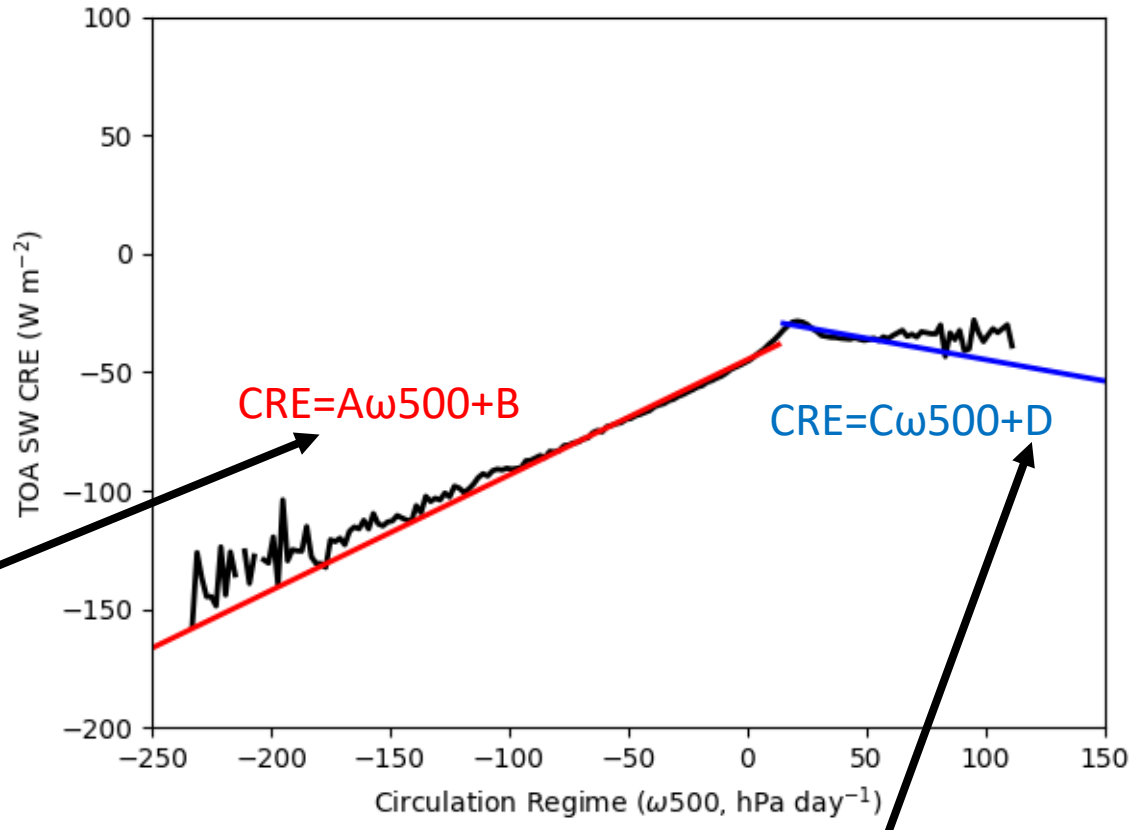
Simple quantification of cloud-circulation relationships

University of Reading

- Simple linear fits to relationship at low resolution result in 4 parameters.
  - Easy to interpret.
  - Facilitates quantitative evaluation of models.
  - Facilitates analysis of impact of other variables on the ω500-CRE relationship (e.g. see further slides online).

A,C represent changes in CRE dependence on strength of circulation.

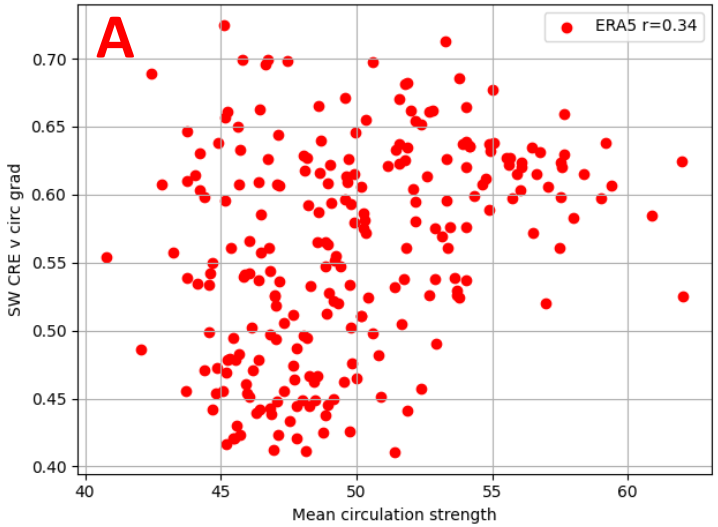
Example of fit to ERA5-CERES 2° monthly data

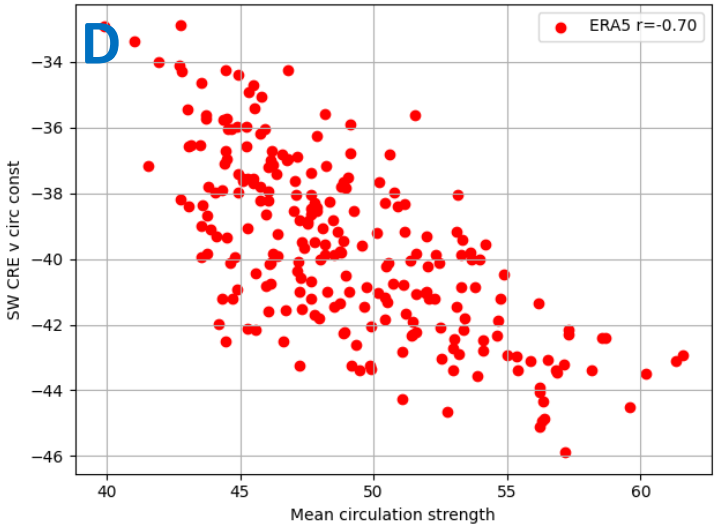


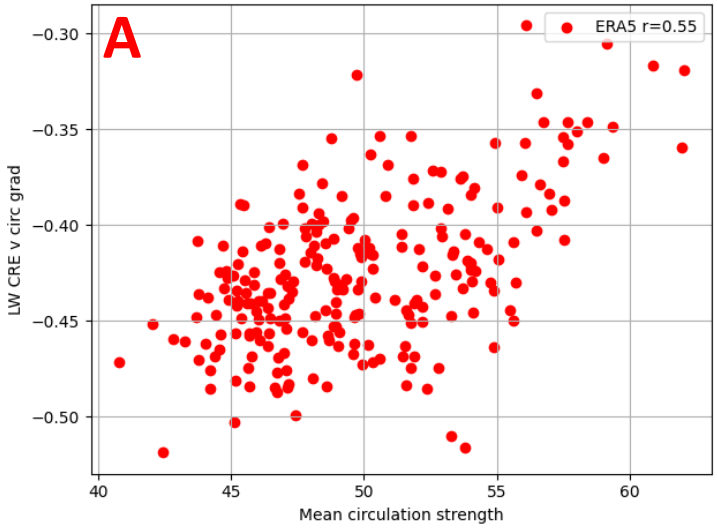
Changes in B,D represent changes in CRE independent of local circulation.

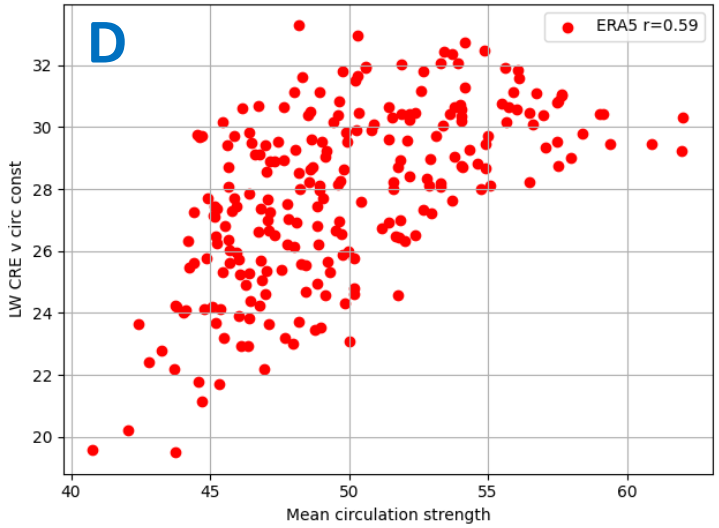
CRE – circulation relationship depends on circulation strength

- Relationships between CRE and circulation derived at 1° daily scale for ERA5 combined with CERES-SYN.
- Parameters estimated for bimonthly data.

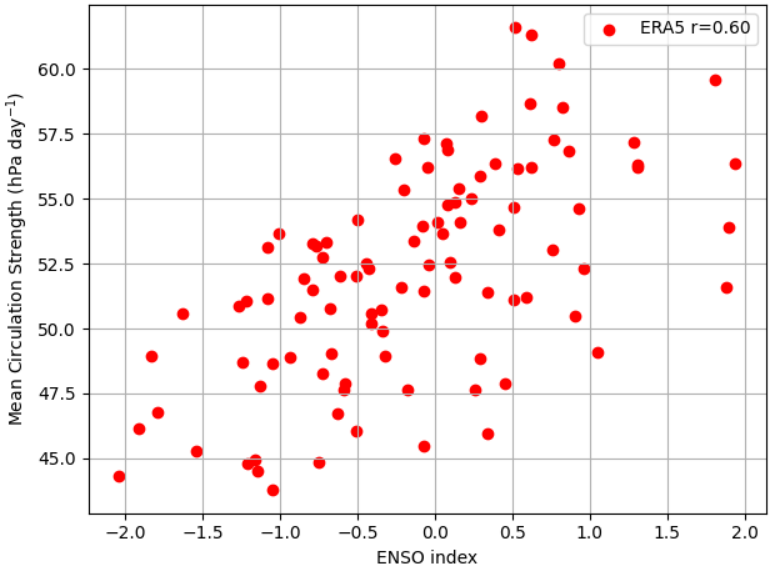


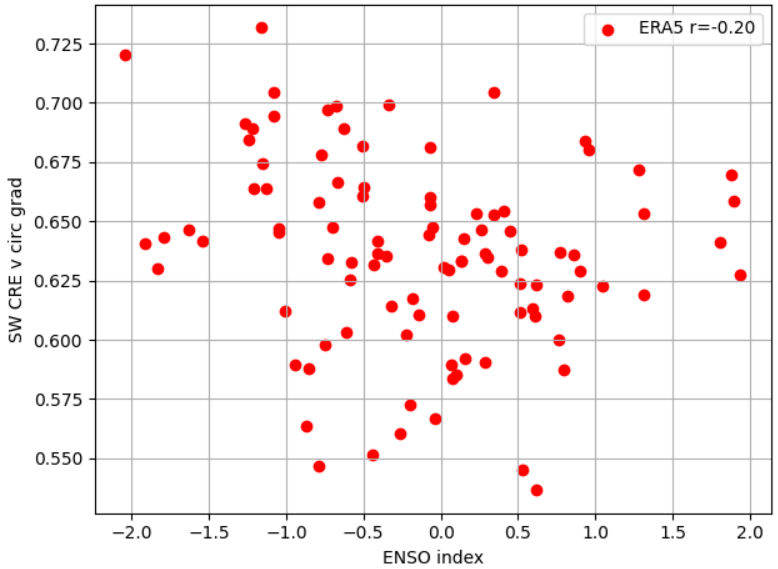


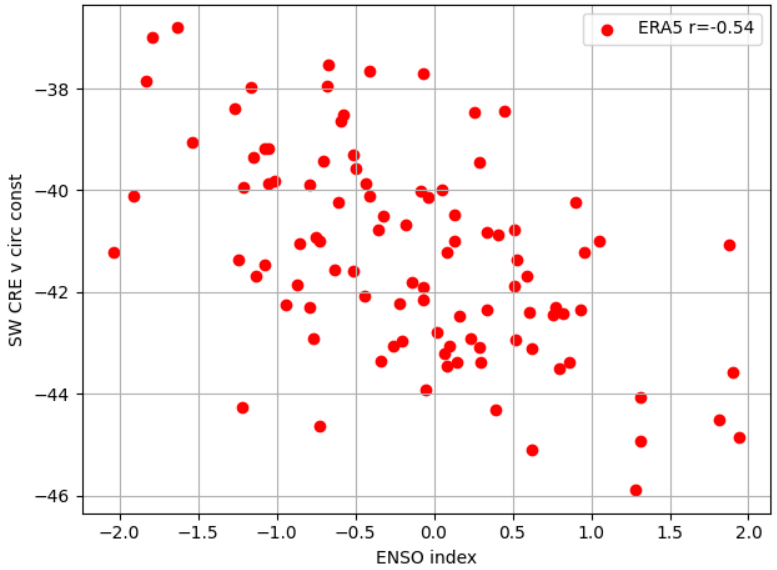




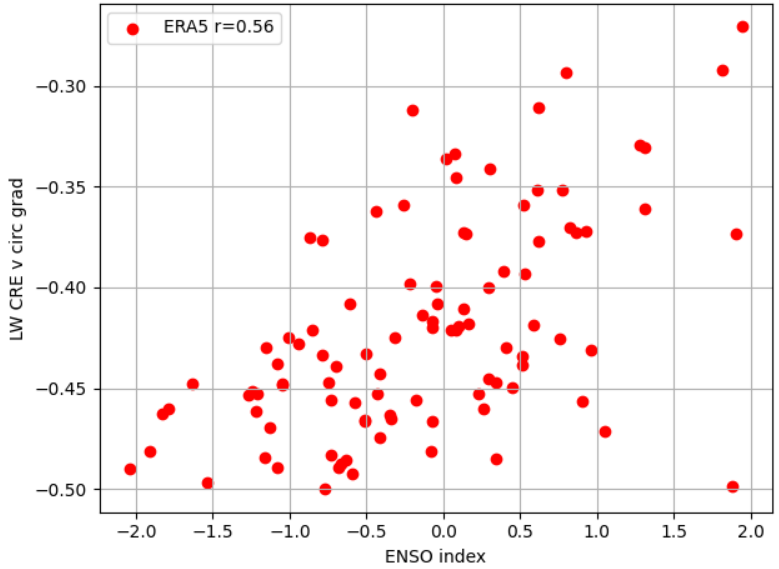
Circulation intensity depends on Oct-Mar ENSO phase

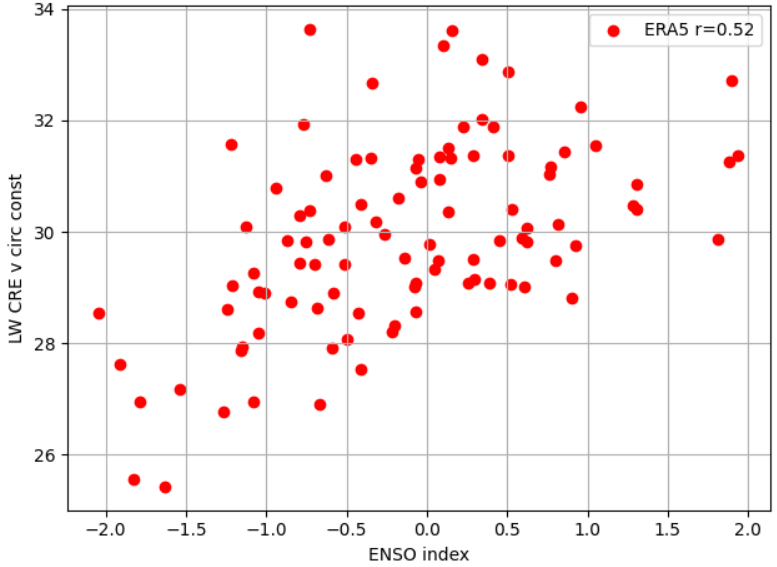




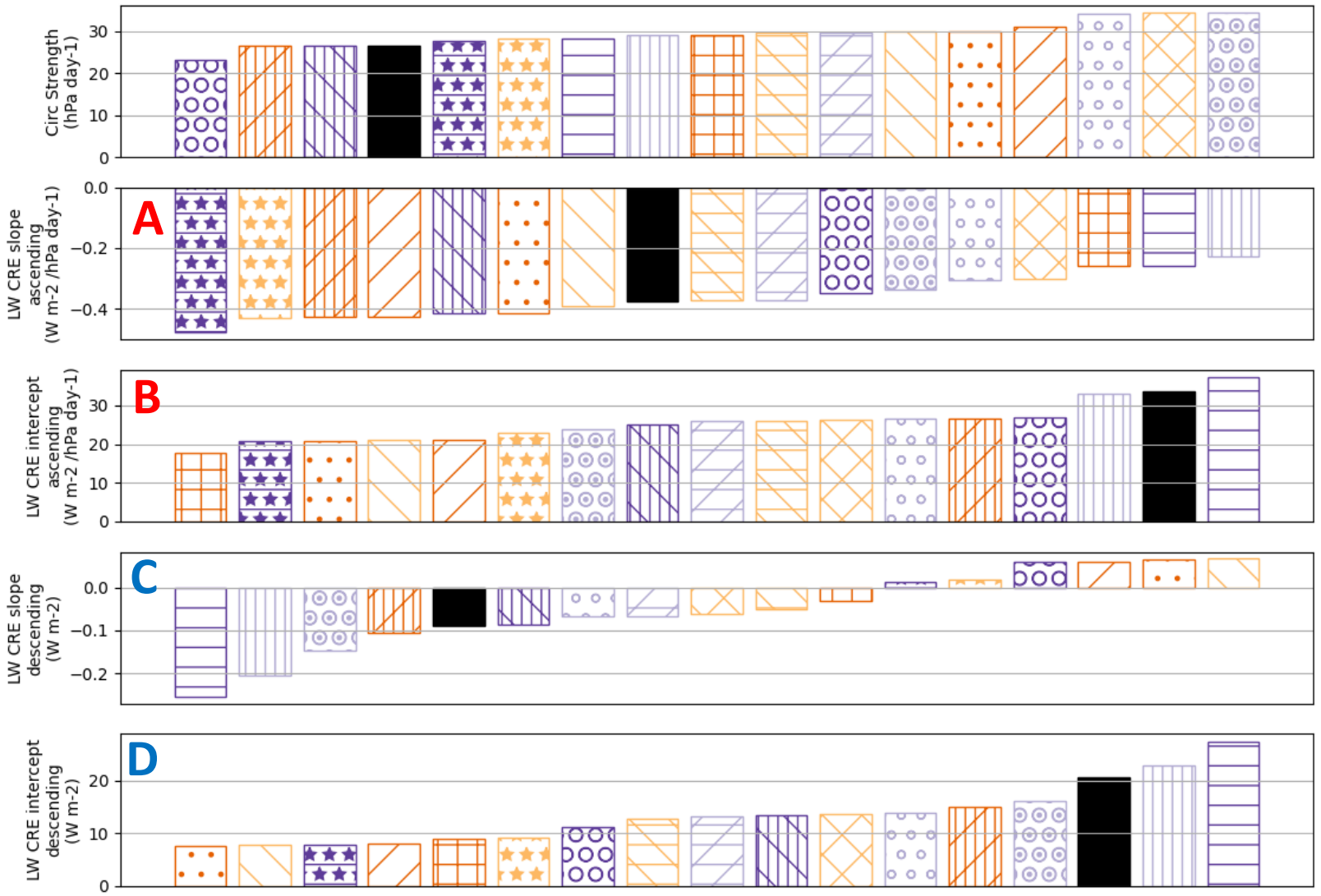


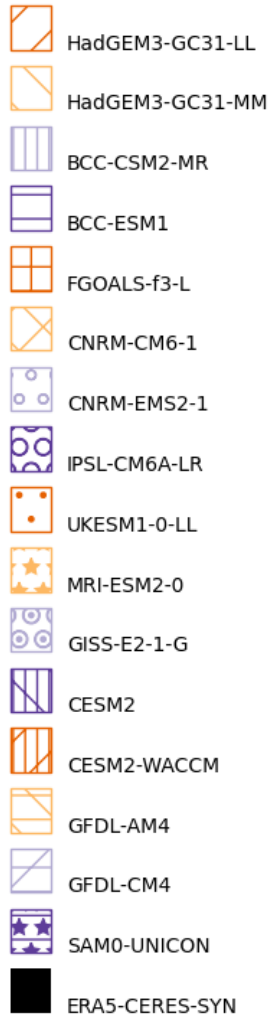
- Relationships between CRE and circulation derived at 1° daily scale for ERA5 combined with CERES-SYN.
- Parameters estimated for bimonthly data.





LW Cloud-circulation relationships in AMIP



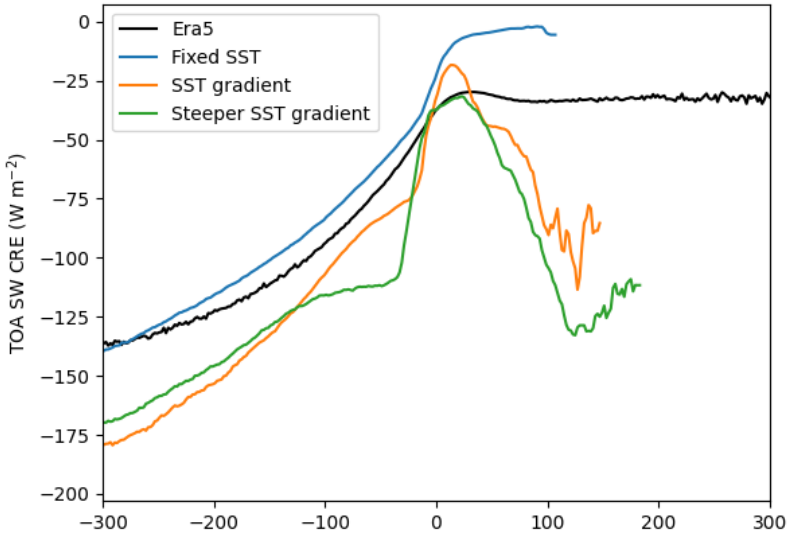


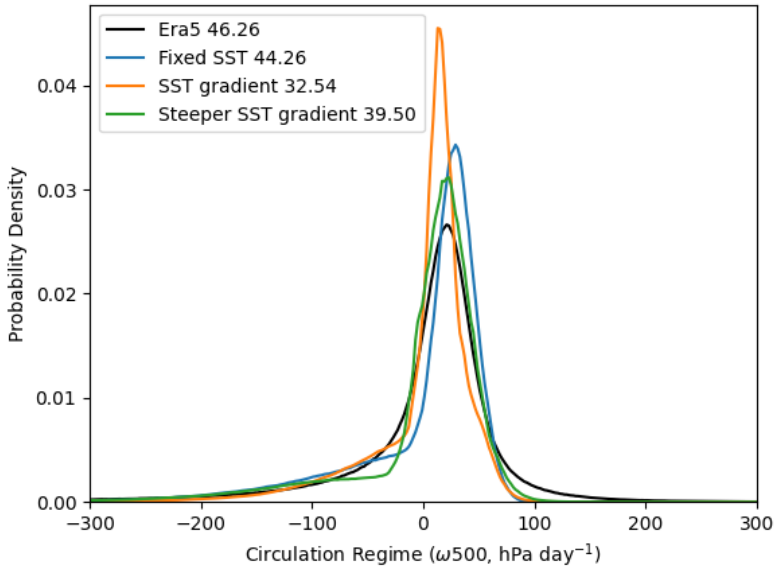
- 2° monthly means from AMIP6 models compared to ERA5-CERES-SYN.
- Circulation strength defined as the mean absolute value of the circulation.
- ERA5-CERES-SYN parameter values are within range of climate models, but this is at least partly due to large spread in climate model parameters.

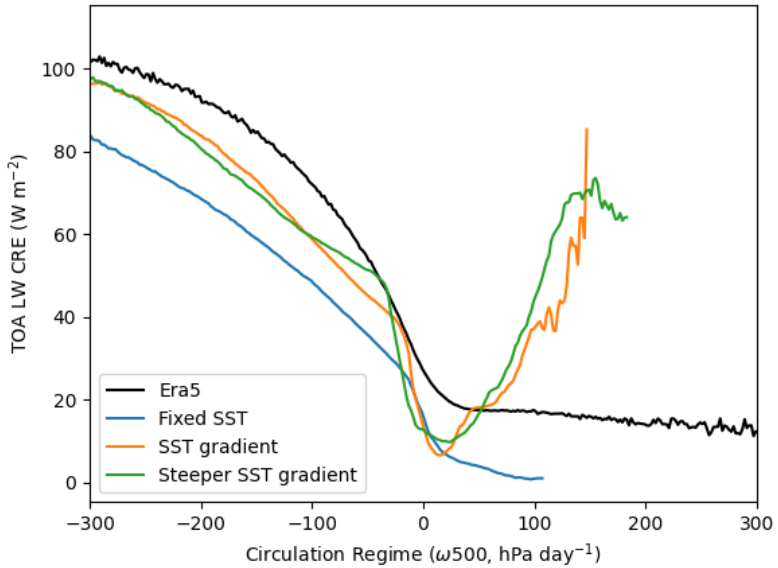
Cloud-circulation relationships in idealised simulations

University of Reading

- Idealised simulations designed for studying cloud-circulation relationships have weaker circulation than reanalyses.
- Increase in CRE with increasingly strong ascent is captured.
- But also show increase in CRE with increasingly strong descent.







Summary and Future work

University of Reading

- Looking at how cloud radiative effects vary with circulation regime in “observations” and models over tropical Pacific.
- CRE-ω500 relationship strongly depends on temporal/spatial scales.
- Fitting simple functions to the CRE-ω500 curves results in easily interpretable parameters that describe the relationship and facilitates analysis of how these relationships depend on other variables.
- Large variability in CRE-ω500 relationship amongst climate models.
- Future work: are climate models able to reproduce observed dependence of CRE-circulation relationship on other variables?

- Further slides available through links on EGU webpage for this session.