Parameter Sensitivities and Variance Connections in CAM4 and CAM5

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Uncertainty Quantification Ensembles of CAM4 and CAM5

CAM4

- **LLNL's *Uncertainty Quantification Strategic Initiative* (LDRD)**
- R. Klein (PI), D. Lucas (co-PI), C. Covey (climate), J. Tannahill (climate), Y. Zhang (climate), G. Johannesson (UQ methods), S. Brandon (UQ software), D. Domyancic (UQ software), and many more.

CAM5

- **DOE/BER's *Climate Science for a Sustainable Energy Future***
- D. Bader (PI), S. Klein (atmos. lead), D. Lucas (atmos. UQ), C. Covey (atmos. UQ), J. Tannahill (atmos. UQ), A. Kupresanin (UQ methods), G. Johannesson (UQ methods), and coordination with lots of people at PNNL and SNL

Q: What are the most important parameters in CAM4 and CAM5?

Q: Are CAM5 parameters more 'connected' than those in CAM4?

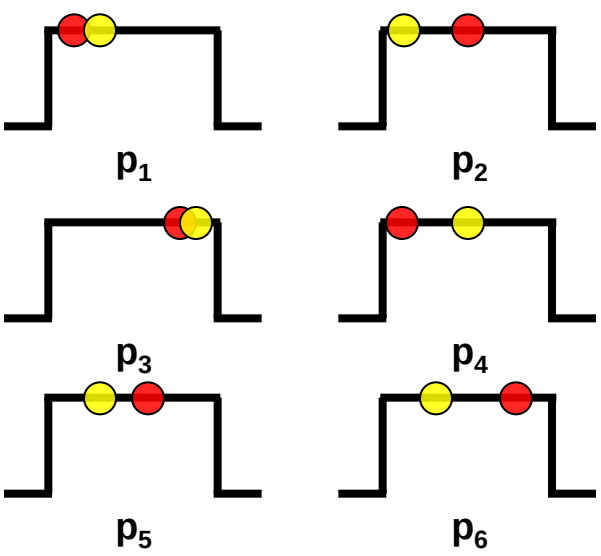
Q: Are there similarities between the old physics in CAM4 and the new physics in CAM5?

Configurations for CAM4 and CAM5 UQ Ensembles

	CAM4	CAM5	
Dynamics	Finite volume	Finite volume	O
Resolution	1.9 x 2.8 deg, L26	1.9 x 2.8 deg, L26	O
Boundary layer	Holtslag & Boville (1993)	UW TKE, Park et al. (2009)	X
Shallow convection	Hack (1994)	UW TKE, Park et al. (2009)	X
Deep convection	Zhang-McFarlane (1995)	Zhang-McFarlane (1995)	O
Microphysics	Rasch & Kristjansson (1998)	Morrison & Gettleman (2008)	X
Macrophysics	Rasch & Kristjansson (1998)	Park et al. (2011)	X
Aerosols	Bulk aerosols	Modal, Ghan et al. (2010)	X
Simulations	AMIP, 1993-2005	AMIP, 2000-2005	O = same
# of parameters	28 (between 21 and 29)	22 (out of 40)	X = differ
# of simulations	~1,300	660	

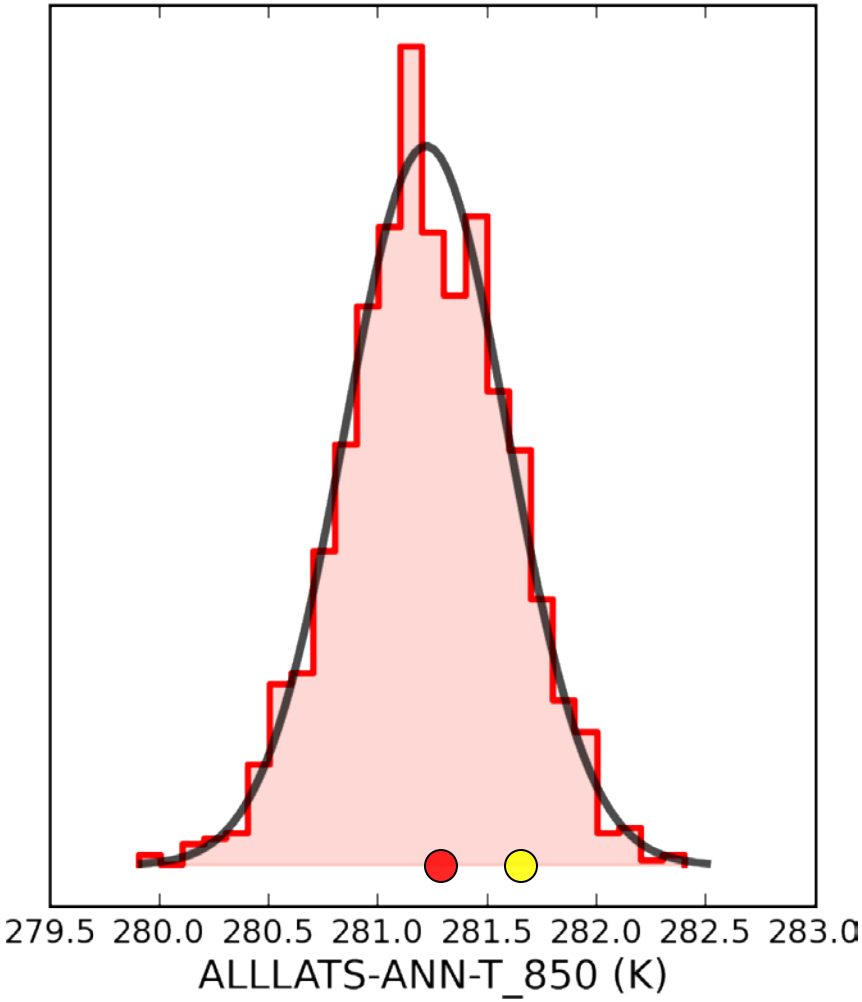
Parameter Sensitivity and Variance Studies in CAM4 and CAM5

- **Parameters are uniform/loguniform PDFs**
- **Sample using space-filling design (e.g. Latin hypercube, Morris method, …)**
- **Perform variance decomposition**



And more …
(up to 29 in CAM4, 22 in CAM5)

Repeat 100's to 1000's of times



Parameter Sensitivity and Variance Studies in CAM4 and CAM5

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Total variance is decomposed:

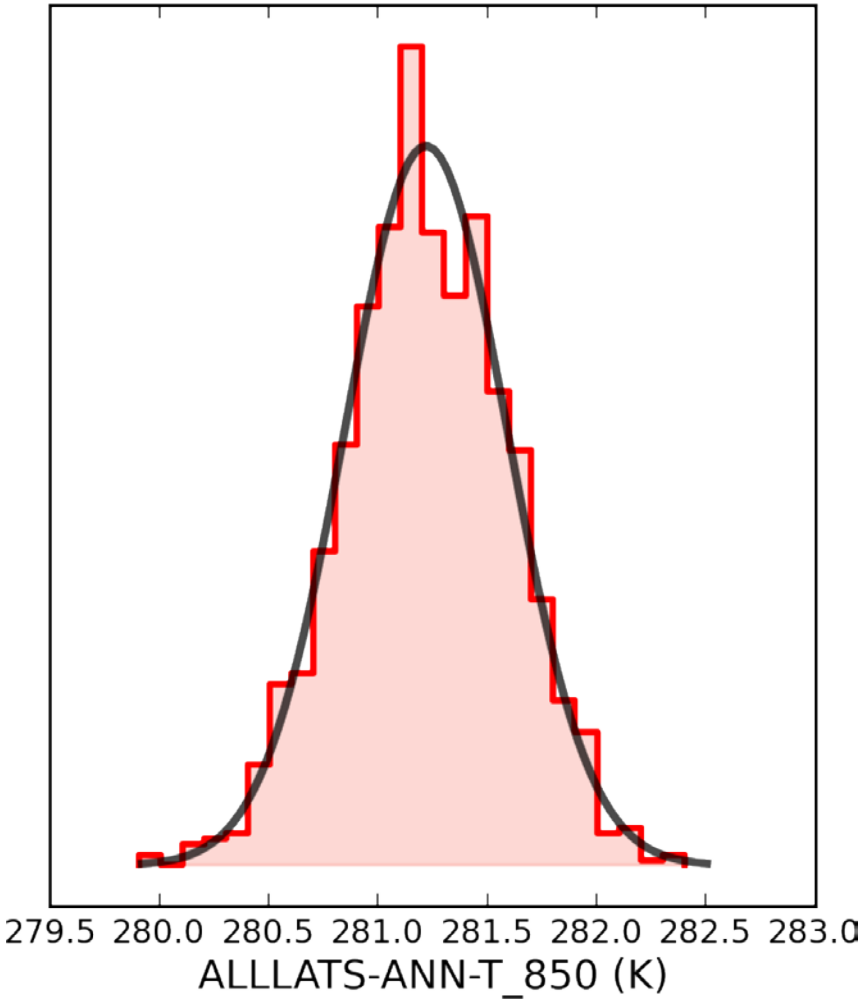
$$v_t = \Sigma v_i + \Sigma v_{ij} + \Sigma v_{ijk} + \ldots,$$

σ^2

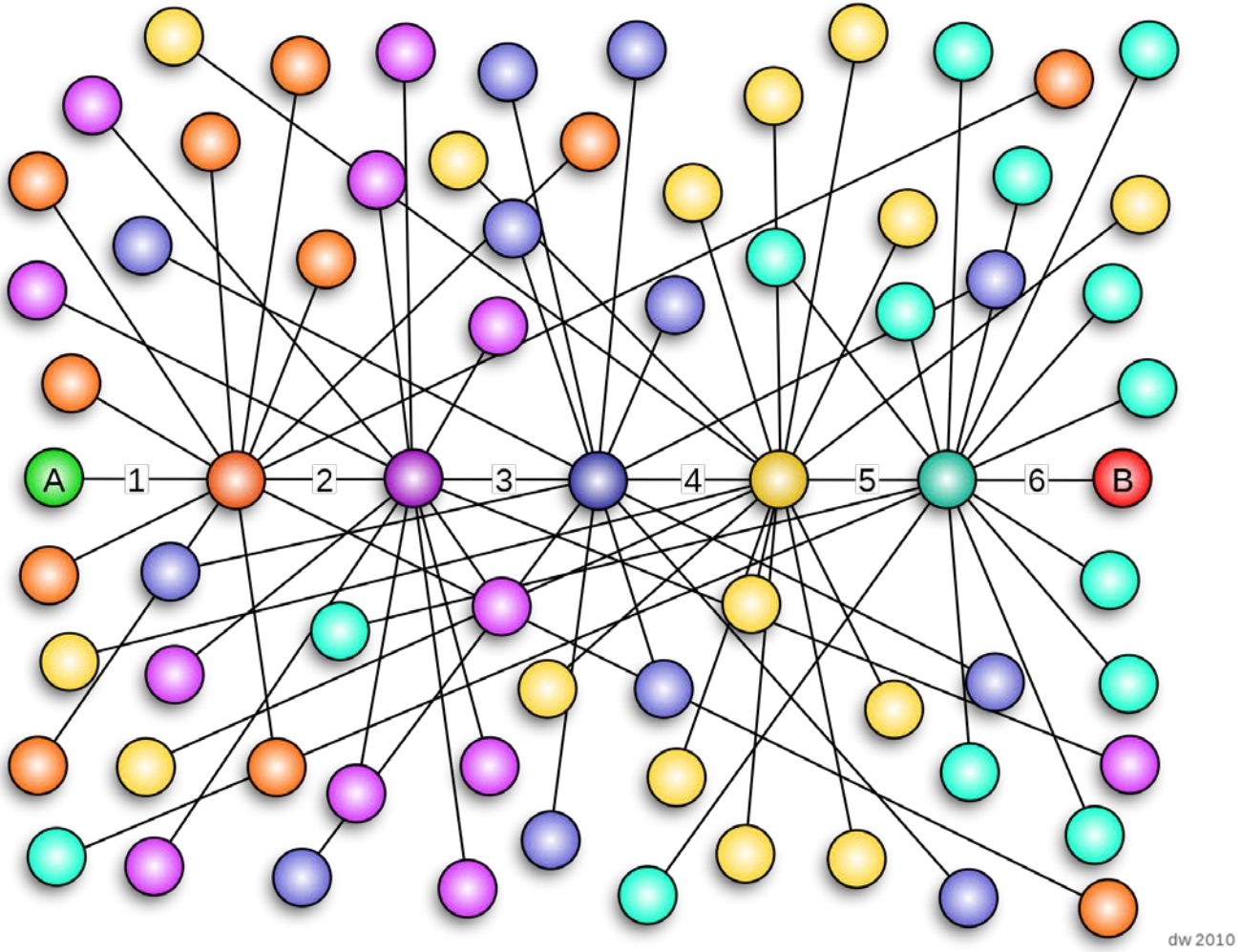
where

v_i = variations from parameter *i*

v_{ij} = co-variations from parameters *i* and *j*



Network Graphs Show Complex Relationships



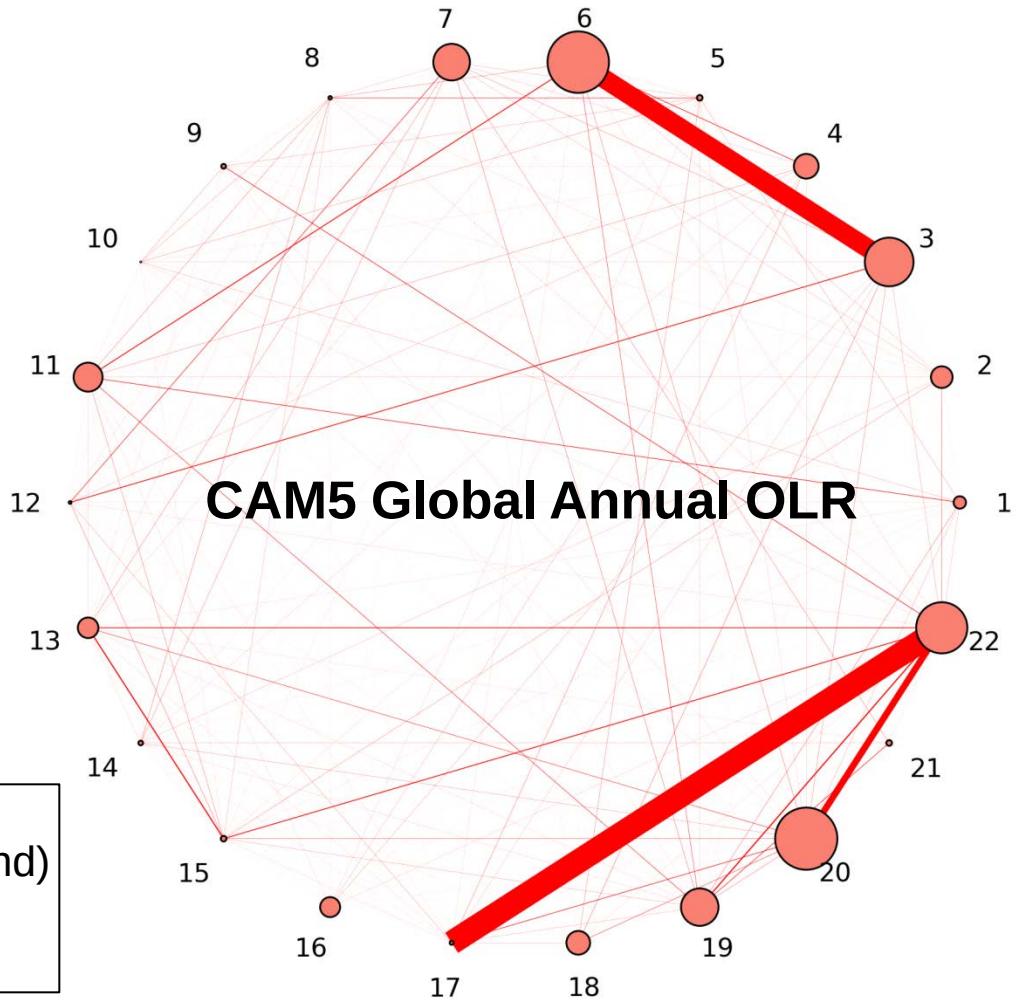
Example of a social network

- Nodes are people
- Connectors are people who know each other
- There are 6 degrees of separation between Persons A and B

Network Graph to Visualize the Variance Decomposition (Sobol Indicies)

- node diameter $\propto v_i / v_t$ (main effects)
- edge width $\propto v_{ij} / v_t$ (interactions)

(only two-way interactions shown, but higher orders can also be displayed on the same graph)



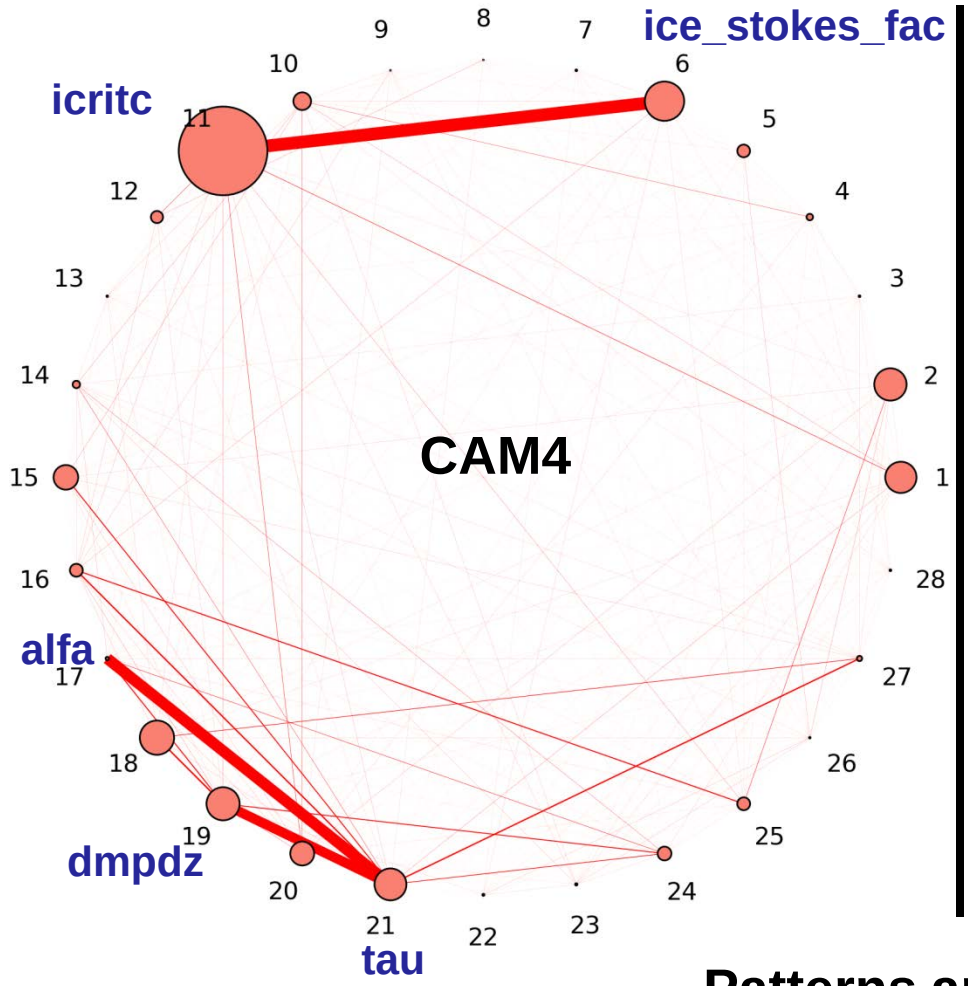
new

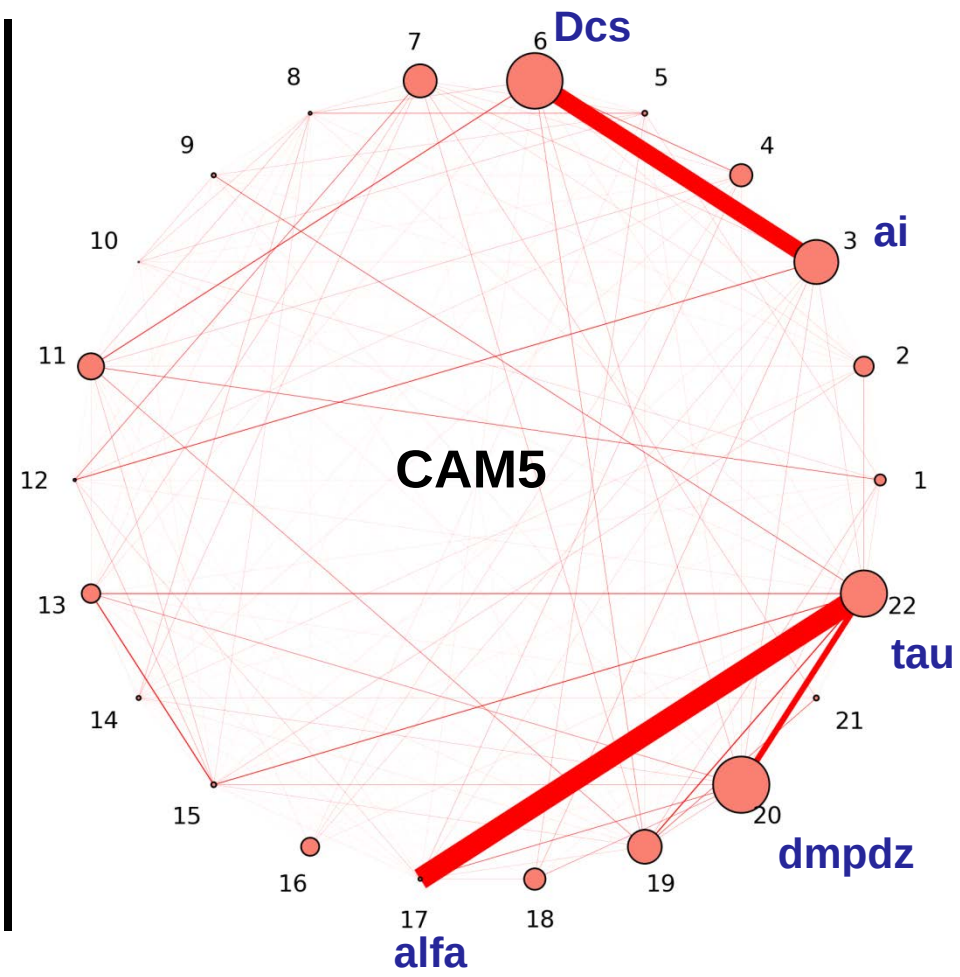
- p_3 = ai (cloud ice fall speed)
- p_6 = Dcs (ice to snow autoconversion)
- p_7 = eii (ice aggregation efficiency)

old

- p_{17} = alfa (downdraft mass flux)
- p_{19} = c0_land (precip efficiency over land)
- p_{20} = dmpdz (mass entrainment rate)
- p_{22} = tau (convective time scale)

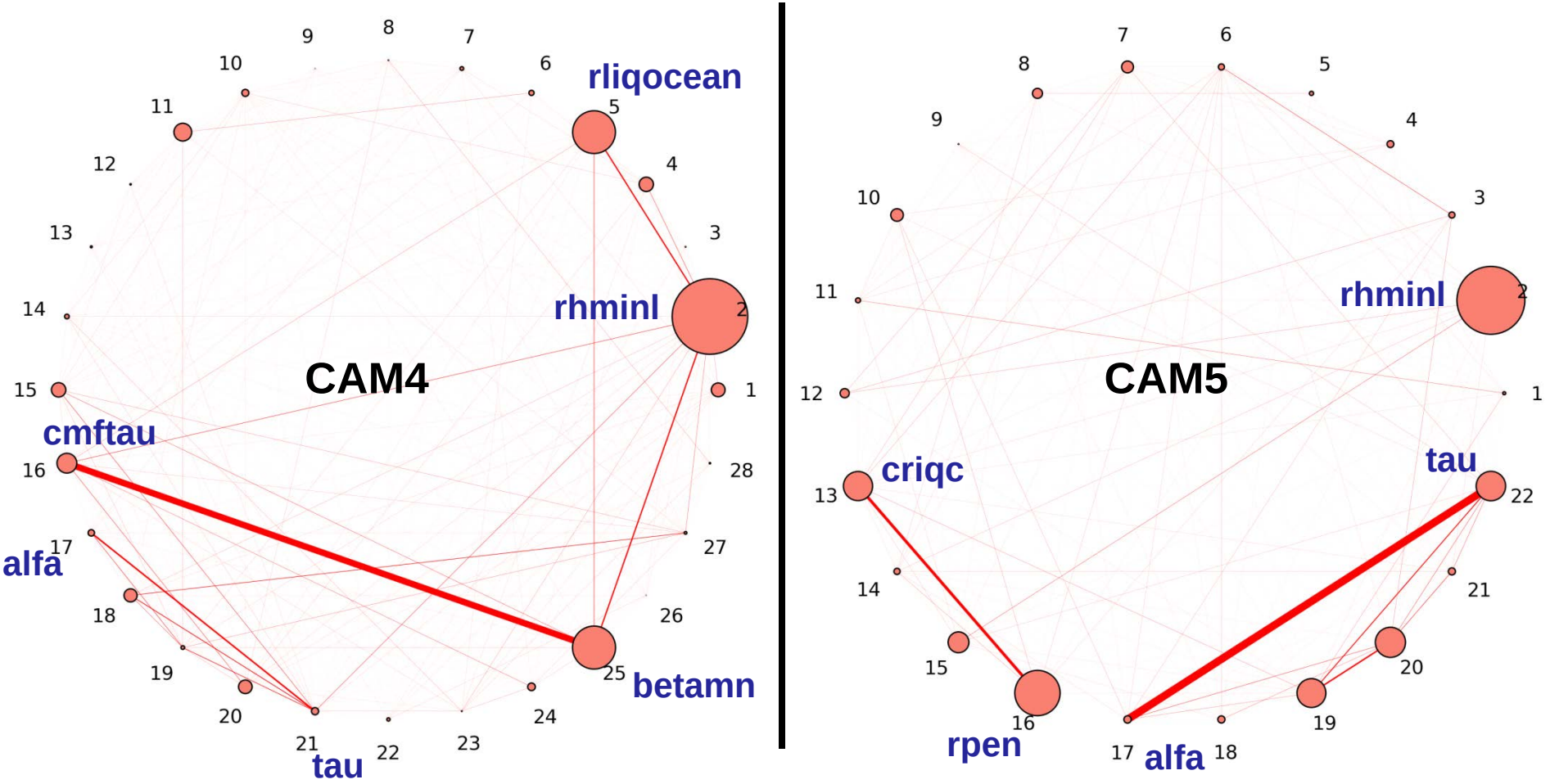
Variance Connections of Outgoing Longwave Radiation





Patterns are similar

Variance Connections of Shortwave Cloud Forcing



rhminl is the dominant factor in CAM4/5; cmftau-betamn in CAM4 replaced by criqc-rpen in CAM5

Summary

- **Ran UQ ensembles sampling uncertain physics parameters in CAM4 and CAM5**
- **Calculated parameter sensitivities and variance decompositions for CAM4 and CAM5**
- **Identified some important parameters.**

CAM4	rhminl, icritc, tau, dmpdz, rliqocean, betamn, fak, …
CAM5	rhminl, Dcs, rpen, criqc, tau, dmpdz, …

- **Although the physics packages in CAM5 are tightly coupled, the parameter interactions in CAM5 do not appear to be more extensive than those in CAM4.**
- **Identified similar interactions in CAM4 and CAM5.**

CAM4	icritc + ice_stokes_fac	cmftau + betamn	more?
CAM5	Dcs + ai	rpen + criqc