Arctic sea-ice change tied to its mean state through thermodynamic processes

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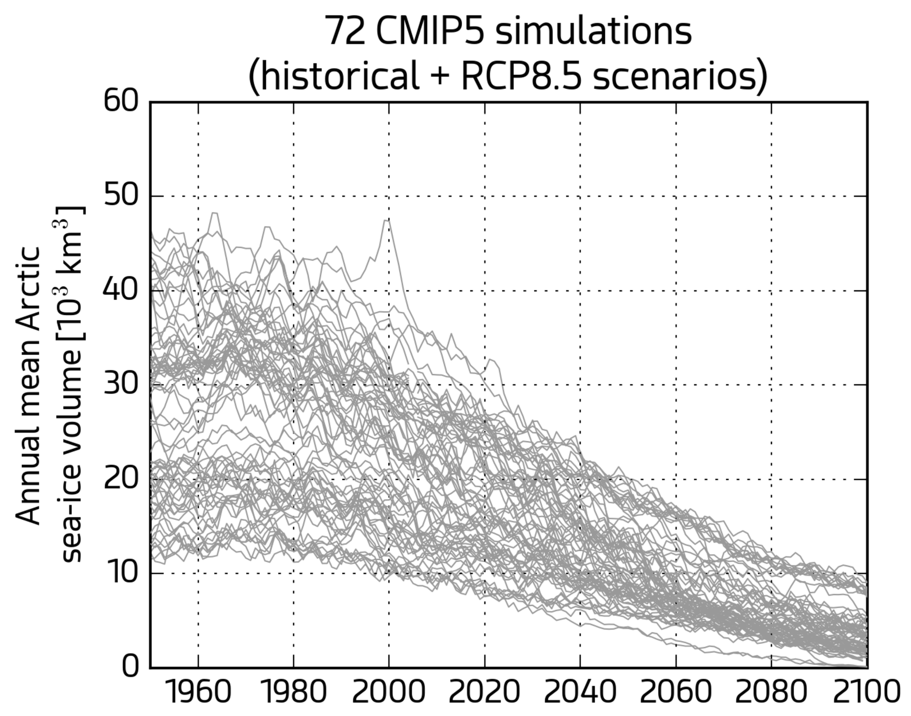
Scientific question(s)

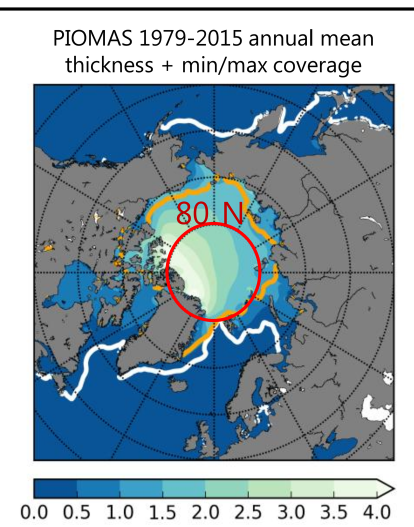
Arctic sea ice has shrunk at dramatic rates since the late 1970s. Besides the well-documented **reductions in area**, in-situ and remote-sensing observations have also revealed a **significant thinning** of sea ice. Further reductions in area and thickness are projected by state-of-the-art General Circulation Models, but **substantial spread** exists in these projections.

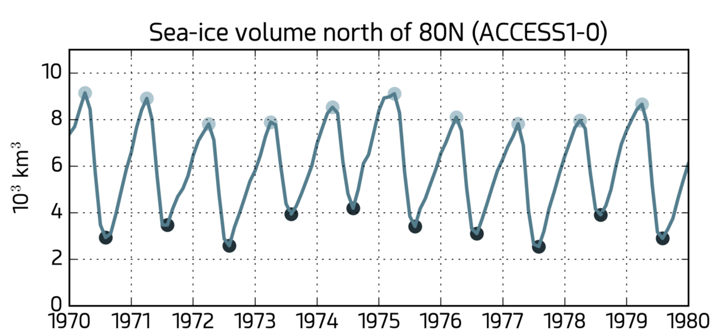


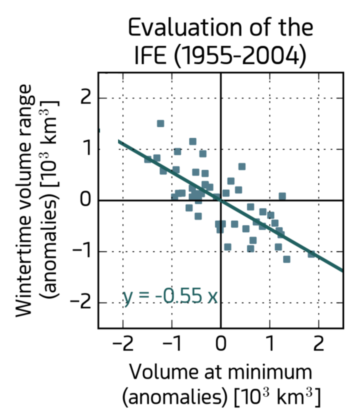
1. What are the **physical origins** of such spread?
2. Has the **representation of sea-ice thermodynamics** an influence on projected volume reductions?
3. Will sea-ice volume **seasonality, variability and persistence change** as the ice continues thinning?

Measuring sea-ice growth and melt processes

Processes of sea-ice growth and melt are diagnosed directly from model output (no dedicated experiments are required). We investigate the domain north of 80 N: large enough to smooth out dynamic effects and relatively sheltered from heat advected by the ocean from the south.

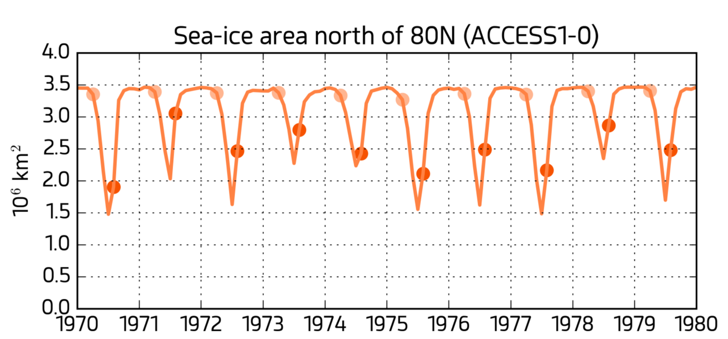


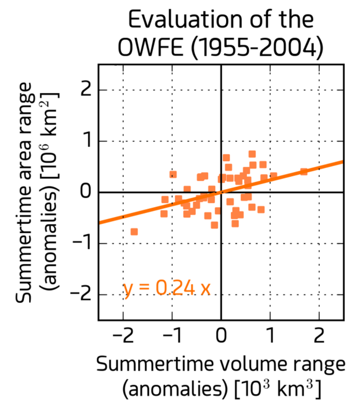




Measuring growth

The **Ice Formation Efficiency** (IFE, unitless) measures the ability of sea-ice volume to recover from summer anomalies



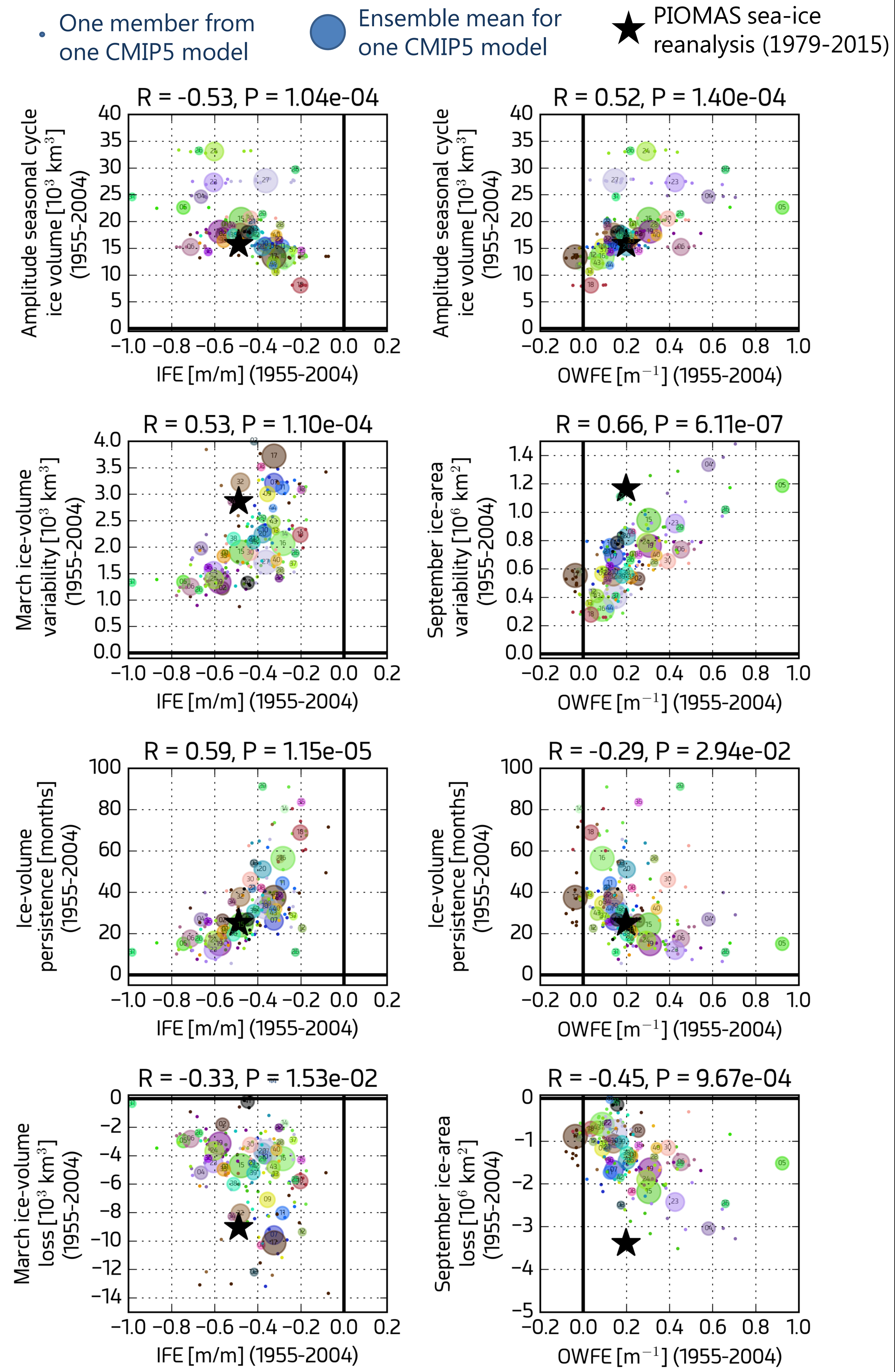


Measuring melt

The Open Water Formation Efficiency (OWFE, m^{-1}) measures the ability to create open water for a given volume reduction (first introduced by Holland et al., 2006)

OWFE: Holland, M. M., Bitz, C. M. & Tremblay, B. Future abrupt reductions in the summer Arctic sea ice. *Geophys. Res. Lett.* **33**, L23503 (2006)
PIOMAS: Schweiger, A., Lindsay, R., Zhang, J., Steele, M., Stern, H. Uncertainty in modeled Arctic sea ice volume. *J. Geophys. Res.* **116**, C00D06 (2011)

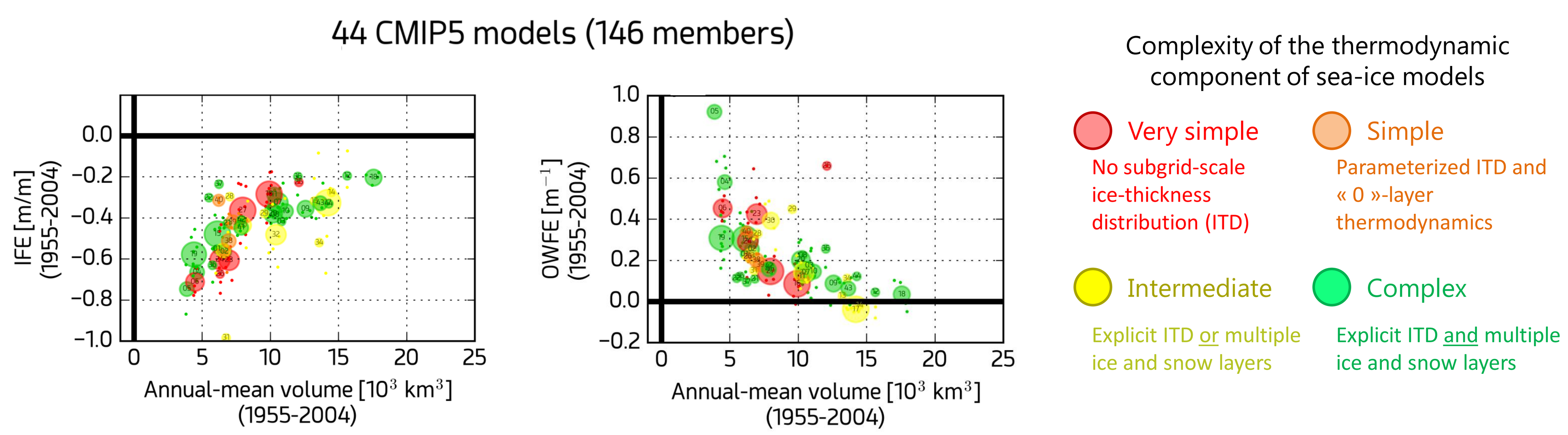
Seasonal processes of thermodynamic sea-ice growth and melt are proxies for longer term sea-ice variability



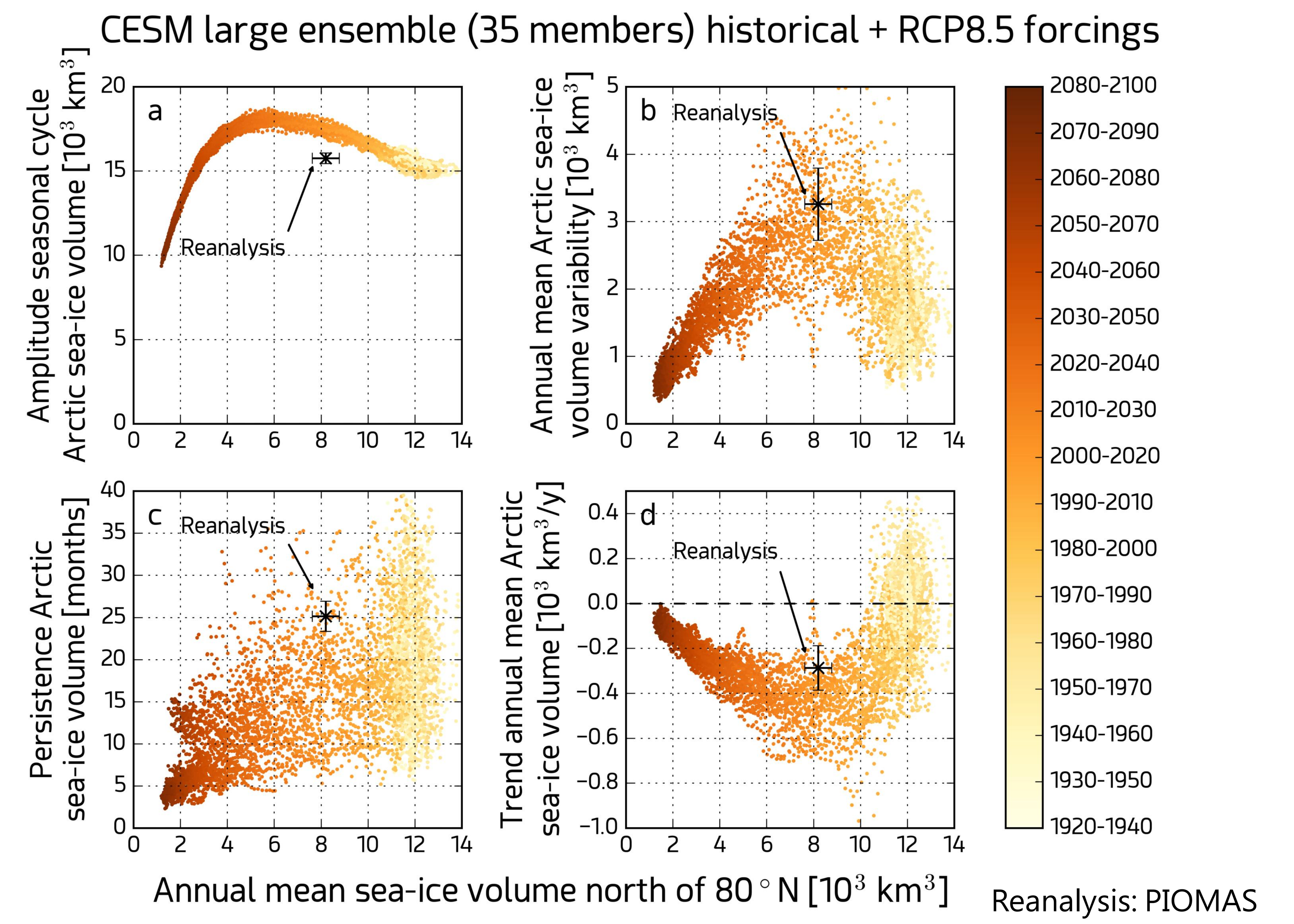
Relationship between the IFE and OWFE (x-axis) and various indices of sea-ice variability evaluated over the whole Arctic: (top row) amplitude of sea-ice volume seasonal cycle; (2nd row) standard deviation of sea-ice volume or area anomalies; (3rd row) persistence of sea-ice volume anomalies, defined as their *e*-folding time scale; (4th row) linear change in sea-ice volume or area. R and P refer to the correlations and P-values for the clouds of points, respectively.

CMIP5 legend | 1. ACCESS1-0 | 2. ACCESS1-3 | 3. BNU-ESM | 4. bcc-csm1-1 | 5. bcc-csm1-1-m | 6. CanESM2 | 7. CCSM4 | 8. CESM1-BGC | 9. CESM1-CAM5-1-FV2 | 10. CESM1-CAM5 | 11. CESM1-FASTCHEM | 12. CESM1-WACCM | 13. CMCC-CMS | 14. CMCC-CM | 15. CNRM-CM5 | 16. CSIRO-Mk3-6-0 | 17. EC-EARTH | 18. FGOALS-g2 | 19. GFDL-CM2p1 | 20. GFDL-CM3 | 21. GFDL-ESM2G | 22. GFDL-ESM2M | 23. GISS-E2-H | 24. GISS-E2-R | 25. GISS-E2-H-CC | 26. GISS-E2-R-CC | 27. HadCM3 | 28. HadGEM2-AO | 29. HadGEM2-CC | 30. HadGEM2-ES | 31. inmcm4 | 32. IPSL-CM5A-LR | 33. IPSL-CM5A-MR | 34. IPSL-CM5B-LR | 35. MIROC5 | 36. MIROC-ESM | 37. MIROC-ESM-CHEM | 38. MPI-ESM-LR | 39. MPI-ESM-MR | 40. MPI-ESM-P | 41. MRI-CGCM3 | 42. MRI-ESM1 | 43. NorESM1-M | 44. NorESM1-ME

Baseline volume is the primary driver of growth and melt processes, while model sophistication is not obviously related to them



Implications: sea-ice volume seasonality, variability, persistence and trend are slaved to the mean sea-ice state



Reanalysis: PIOMAS

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