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Time of emergence of trends in ocean biogeochemistry

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The detection of forced trends in biogeochemical cycles and ecosystems is a challenge. A major issue is the presence of natural variability which has the potential to enhance or mask trends over decadal timescales. The successful detection of trend signals is thus a signal-to-noise (S/N) problem, i.e., the signal has to be of a magnitude that durably exceeds the envelope of background variability. One possible measure to estimate this is the time of emergence (ToE) of a signal, that is, the point in time at which the ratio S/N exceeds a certain threshold. We use historical simulations from 17 Earth System Models to investigate the ToE of trends in surface ocean biogeochemistry. For maximum comparability with the available observations, we focus on dissolved inorganic carbon (DIC), pCO_2 and pH, and sea-surface temperature (SST). We find that signals in ocean biogeochemical variables emerge on much shorter timescales than the physical variable SST. The ToE patterns of pCO_2 and pH are spatially very similar to DIC, yet the trends emerge much faster – after roughly 12 years for the majority of the global ocean area, compared to between 10-30 years for DIC and 45-90 years for SST. In general, the background noise is of higher importance in determining ToE than the strength of the trend signal. In areas with high natural variability, even strong trends both in the physical climate and carbon cycle system are masked by variability over decadal timescales. In contrast to the trend, natural variability is affected by the seasonal cycle. This has important implications for observations, since it implies that intra-annual variability could question the representativeness of irregularly seasonal sampled measurements for the entire year and, thus, the interpretation of observed trends.