Autoregressive Models

• What are they?
• Why are they useful/important?

Reading:

Optional:
Acclimation: step function

\[ \tau = 5 \]
Photoacclimation: step function

Fig. 6. Time-course of photoadaptation of the parameters of the P-I curves in Fig. 4 and 5

Lewis et al. (1984)
Photoacclimation: step function

Fig. 6. Time-course of photoadaptation of the parameters of the P-I curves in Fig. 4 and 5

Lewis et al. (1984)
Same $\tau$, different forcing

\[ \tau = 2 \]
Same forcing, different $\tau$
Double Integration Hypothesis

- **A**: Aleutian Low
- **B**: Integrated Aleutian Low
- **C**: Integrated PDO Index

\[
\frac{d\phi(t)}{dt} = f(t) - \frac{\phi(t)}{\tau_{ocean}},
\]

\[
\frac{d\beta(t)}{dt} = \phi(t) - \frac{\beta(t)}{\tau_{bio}},
\]

Di Lorenzo and Ohman (2013)
SSH index. The PDO and SSH indices are used as proxies of changes in the atmosphere (red line). Ekman currents differ from geostrophic currents in that they do not alter population growth rates. The variability in upwelling is altered by changes in Ekman currents, which are a direct result of changes in the atmosphere and thus thought to be related to changes in local upwelling, which modulates food availability (e.g., via phytoplankton blooms) and thus controls food web dynamics. Weekly-to-annual variations in upwelling (red line) are captured by the PDO index (blue line), whereas changes in the oceanic response to upwelling are captured by the SSH index (blue line).

Figure 4. As an example, we explore the variability of another krill species in the California Current, because they capture the upwelling response to climate forcing: (A) Integrated PDO index (red line) with PDO index (red line) and (B) Integrated SSH index (red line) with SSH index (red line).

Figure 5. Schematic of impacts of environmental forcing on zooplankton. (A) Monthly data. (B) One-year low-pass filter. (C) Integrated PDO index. (D) Integrated SSH index. Types of ecosystem response to climate forcing:

- **No integration** (B): Changes in phytoplankton (Phytoplankton) are forced with the raw SSH index (i.e., the ocean red-noise forcing). Although the results for Euphausia pacifica (E) are consistent with a single integration of atmospheric forcing, (D) exhibiting double-integration effects.
- **1 x integration** (C): Changes in horizontal geostrophic transport are obtained by low-pass filtering the PDO (red line) with different cutoff time scales in the model. This model skill is compared with the skill obtained by low-pass filtering the SSH index with different cutoff time scales in the model. The resulting correlation is 0.65, suggesting that this zooplankton time series is forced with the raw SSH index (i.e., the ocean red-noise forcing). These characteristics suggest that organisms respond to both local and remote forcing (the latter including sources of oceanic red-noise forcing).

Figure 3. Comparison of zooplankton time series in the California Current. We now compare the SSH index with the PDO index. Ekman currents do not alter population growth rates, but they do modulate food availability (e.g., via phytoplankton blooms) and thus control food web dynamics. Weekly-to-annual variations in upwelling are captured by the PDO index, whereas changes in the oceanic response to upwelling are captured by the SSH index. The correlation between the PDO index and the SSH index is 0.65.

Figure 2. Double-integration effects. (A) Nyctiphanes simplex (N. simplex). (B) Lowpass PDO index. (C) Integrated PDO index. (D) Euphausia pacifica (E. pacifica). (E) Lowpass SSH index. (F) Integrated SSH index.

Table 1. Summary of model skill. The model skill is compared with the skill obtained by low-pass filtering the SSH index with different cutoff time scales in the model. The resulting correlation is 0.65, suggesting that this zooplankton time series is forced with the raw SSH index (i.e., the ocean red-noise forcing). These characteristics suggest that organisms respond to both local and remote forcing (the latter including sources of oceanic red-noise forcing).