#### Title: Ocean Surface Currents - Papa Trajectory Index

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**Description of indicator:** The Papa Trajectory Index (PTI) provides an annual index of near-surface water movement variability, based on the trajectory of a simulated surface drifter released at Ocean Station Papa (50oN, 145oW; Figure 1). The simulation for each year is conducted using the “Ocean Surface CURrent Simulator” (OSCURS; <http://oceanview.pfeg.noaa.gov/oscurs>). Using daily gridded atmospheric pressure fields, OSCURS calculates the speed and direction of water movement at the ocean’s surface at the location of a simulated surface drifter. It uses this information to update the position of the simulated drifter on a daily basis over a specified time period. For the index presented here, OSCURS was run for 90 days to simulate a surface drifter released at Ocean Station Papa on December 1 for each year from 1901 to 2022 (trajectory endpoints years1902 to 2023).

FIGURE 1 (MAP) GOES HERE

Figure 1: Simulated surface drifter trajectories for winters 1968-2023 (endpoint year). End points of 90-day trajectories for simulated surface drifters released on Dec. 1 of the previous year at Ocean Station Papa are labeled with the year of the endpoint (50oN, 145oW). In grey: trajectories prior to 2012/13; in colour: trajectories ending in 2013/14-2022/23; in black: 2022/23 (most recent).

**Status and trends:** In general, the trajectories fan out northeastward toward the North American continent (Figure 1); the 2021/22 was among the relatively few that initially moved strongly to the southeast and ended south of Ocean Station PAPA while the trajectory for 2022/23 was fairly typical among the time series. In this respect, the 2022/23 trajectory represented a return to more “average” winter atmospheric conditions. The 2022/23 trajectory was influenced in December by high sea level pressure (SLP) anomalies centered over the Alaska mainland north of the central Gulf of Alaska that initially gave rise to weak southwesterly wind anomalies east of Ocean Station PAPA. The wind anomalies dropped in strength in January and shifted direction to the north, then increased again in February while shifting more directly eastward as a second high pressure system centered to the west of the California coast moved eastward. As a result, the ending latitude for the 2022/23 trajectory, and thus its PTI value, was closer to the longterm mean than any year since 2017/18.

FIGURE 2 (TIME ) GOES HERE

Figure 2: Annual, long-term mean (blue line) and 5-year running mean (orange line and squares) of the Papa Trajectory Index time-series end-point latitudes (dotted green line and points) for 1902-2022 winters.

The PTI time series (Figure 2, black dotted line and points) indicates high interannual variation in the north/south component of drifter trajectories, with an average between-year change of >4o and a maximum change of greater than 13o (between 1968/69-1969/70). The change in the PTI between 2015/16 and 2016/17 was the largest since 1968/69-1969/70, while the changes between 2010/11 and 2011/12, and between 2020/21 and 2021/22, represent reversals with slightly less, but diminishing, magnitude. Such swings, however, were not uncommon over the entire time series. The 2021/22 value returned below the mean after an excursion above it in 2020/21; the 2022/23 value also remained below (although closer to) the long term mean, with the result that the trajectories in six of the last seven years have ended below the mean.

Over the past century, the filtered (5-year running average) PTI has undergone five complete oscillations with distinct crossings of the mean, although the durations of the oscillations are not identical: 26 years (1904-1930), 17 years (1930-1947), 17 years (1947-1964), 41 years (1964-2005), and 10 years (2005-2015). The filtered index indicates that a shift occurred in the mid 2000s to predominantly southerly anomalous flow following a ~25 year period of predominantly northerly anomalous flow. This was indicative of a return to conditions (at least in terms of surface drift) similar to those prior to the 1977 environmental regime shift, although this cycle ended rather quickly, as the filtered PTI crossed the mean in the opposite direction in 2011. A similar shift back to anomalous southerly flow appears to have occurred in 2016. Since 2005, the PTI appears to be fluctuating on a much shorter time scale (~10 years per mean crossing) than previously.

**Factors influencing observed trends:** Individual trajectories reflect interannual variability in regional (northeast Pacific) wind patterns which drive short term changes in ocean surface currents, as well as longer term changes in atmospheric forcing that influence oceanic current patterns on decadal time scales.

**Implications:** The year-to-year variability in near-surface water movements in the North Pacific Ocean has been shown to have important effects on the survival of walleye pollock (*Theragra chalcogramma*) by affecting its spatial overlap with predators (Wespestad2000), as well as to influence recruitment success of winter spawning flatfish in the eastern Bering Sea (EBS; Wilderbuer2002). Filtered PTI values greater than the long-term mean are indicative of increased transport and/or a northerly shift in the Alaska Current, which transports warm water northward along the west coast of Canada and southeast Alaska from the south and consequently plays a major role in the Gulf of Alaska’s heat budget. Interdecadal changes in the PTI reflect changes in ocean climate that appear to have widespread impacts on biological variability at multiple trophic levels (King2005). There is strong evidence that the productivity and possibly the carrying capacity of the Alaska Gyre and of the continental shelf were enhanced during the “warm” regime that began in 1977. Zooplankton production was positively affected after the 1977 regime shift (Brodeur1992), as were recruitment and survival of salmon and demersal fish species. Recruitment of rockfish (Pacific ocean perch) and flatfish (arrowtooth flounder, halibut, and flathead sole) also increased. However, shrimp and forage fish such as capelin were negatively affected by the 1977 shift (Anderson2003). The reduced availability of forage fish may have contributed to the decline in marine mammal and seabird populations observed after the 1977 shift (Piatt1996).