The state of the eastern North Pacific entering spring 2004

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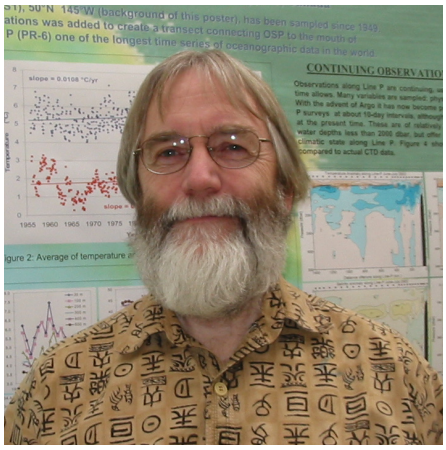

Frank A. Whitney has led the Line P program for the past 12 years, carrying out repeat oceanographic sections for WOCE (1991-97) and hosting the Canadian JGOFS program (1992-97) on these cruises. Through this time, his main research interest has been in understanding processes which control nutrient supply to the upper ocean. He has also surveyed meso-scale eddies several times in an attempt to estimate offshore transport of coastal waters in the Gulf of Alaska. Frank has been working in oceanography on the British Columbia coast since 1969.

Our most recent Line P survey in February 2004 shows that surface water in the Gulf of Alaska is warmer than our 1956-1991 climatology, and that a cool layer persists below it (Fig. 1). This figure also shows a warm body of water situated 270 km along Line P that is more saline than surrounding waters, suggesting that it is of a southern origin (rather than being a meso-scale eddy).

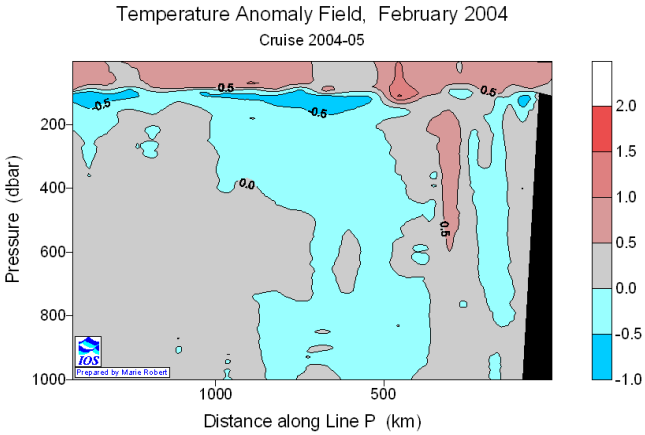

Fig. 1 Temperature anomaly along Line P from the coast of southern British Columbia to Ocean Station Papa (OSP - 50°N, 145°W).

The warm surface anomaly is a persistent feature of the mixed layer (ML) over most of the past decade, whereas the cool layer appeared in the past few years. The combination of these water masses has created stronger than normal stratification and a shallower winter mixed layer over the past couple of winters. In 2003, the 75 m-deep winter ML was the shallowest yet recorded at OSP, and in 2004, the mixed layer was again shallow (90 m) compared to an average of 112 m from 1977-2002.

The subsurface layer at OSP has shown huge variability over the past decade. Recent work (Whitney *et al.*, 1998. *Mar. Ecol. Progr. Ser.*, 170) described a 2˚C warming in waters between 125 and 200 m at OSP between 1988 and 1995. A feature of the warm water mass was low nutrient concentrations. As cool waters returned into the pycnocline, nutrient concentrations increased by ~50% (*e.g.* from 25 to 36 uM nitrate and from 40 to 67 uM silicate between 1995 and 1998, Fig. 2). High nutrient concentrations in these waters have persisted over the past few years.

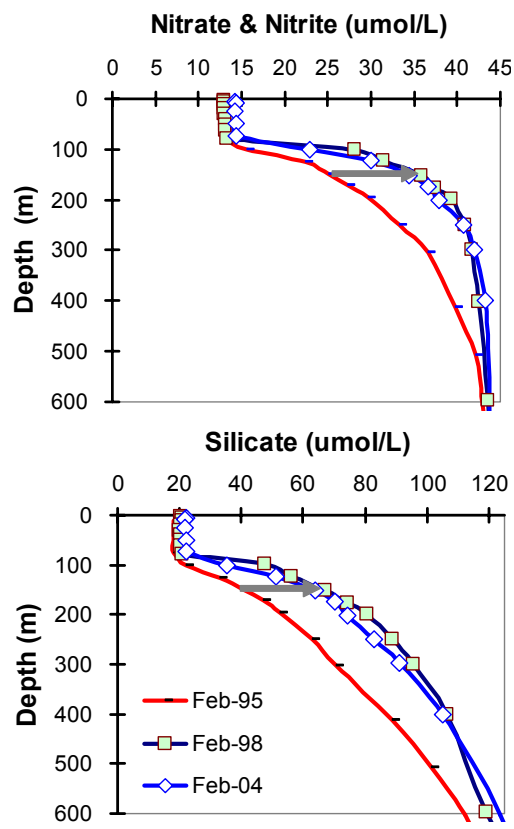

Fig. 2 Nutrient profiles at OSP during periods when subsurface waters were warm in 1995, and cool in 1998 and 2004.

By focusing on winter data, we are likely sampling pycnocline waters that have been produced during winter mixing, and advected from the south or north under the fresh surface layer of the subarctic Pacific. There is little open ocean evidence that shows us the speed or direction of subsurface currents in this region. However, the extreme upwelling event of summer 2002 is an example of subarctic waters being transported onto the continental shelf of Oregon from a great distance (Huyer, 2003. *Geophys. Res. Lett.*, 30).

At OSP, we can describe a "decadal" oscillation which sees the source of pycnocline waters switch from subarctic in 1989, to subtropical in 1995, and back to subarctic for the period from 1998 to 2004 (Fig. 3). Over the past several years, subsurface waters have cooled by ~2˚C to return to 1989 levels. The large changes in subsurface temperature observed at OSP suggest that there are processes in the subarctic ocean that are capable of exporting either warm or cold waters away from the atmosphere (winter ventilation or subduction) and storing it for several years. Known sources of pycnocline waters that are active in the NE Pacific include cold Alaska Gyre waters which are upwelled during winter, and California Undercurrent waters that are transported northward, especially during strong El Niño events. One large question in my mind is

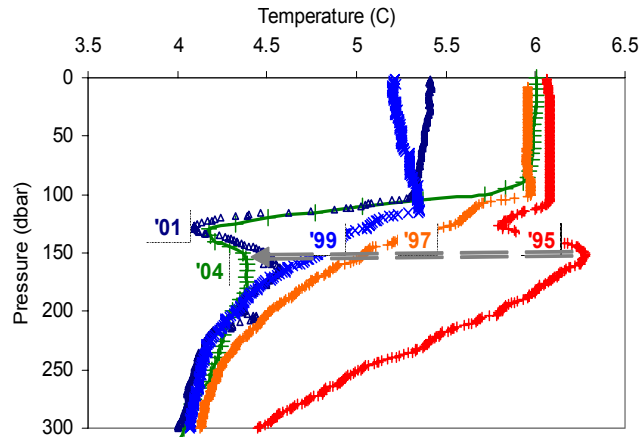

Fig. 3 Temperature in mixed layer and pycnocline waters at Ocean Station Papa.

how the recent "decadal" (actually ~14 yr) oscillation seen at OSP is forced. I anticipate that the many Argo profilers currently deployed in the North Pacific are going to provide the data necessary to trace sources of pycnocline waters in the eastern subarctic Pacific, and will hopefully also be able to identify routes by which waters spread from open ocean to coast (subarctic), and from coastal margins into the ocean (subtropical).