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Physical Forcing of an Antarctic Marine Ecosystem: the Ocean-Ice Environment in the PAL LTER Region

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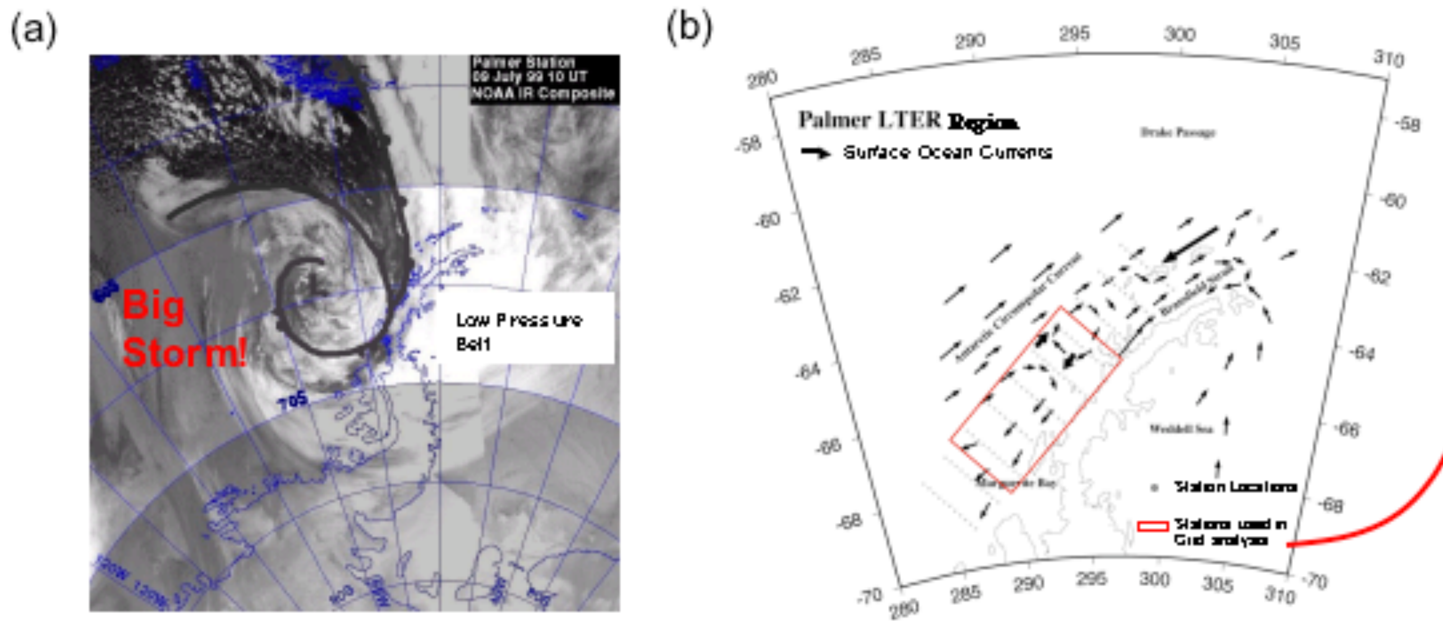
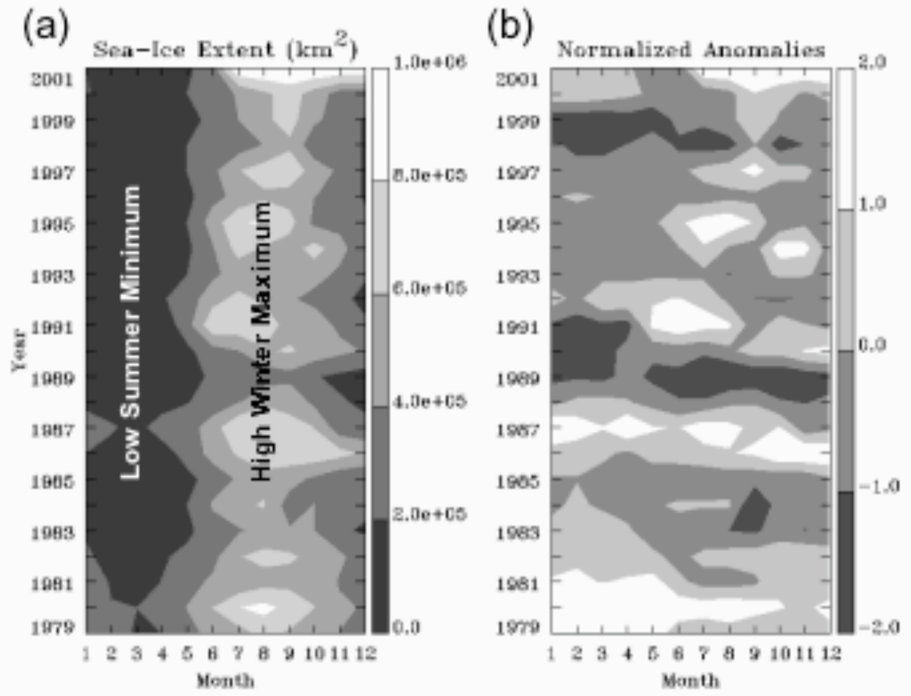
1. Geographic Setting of the PAL LTER



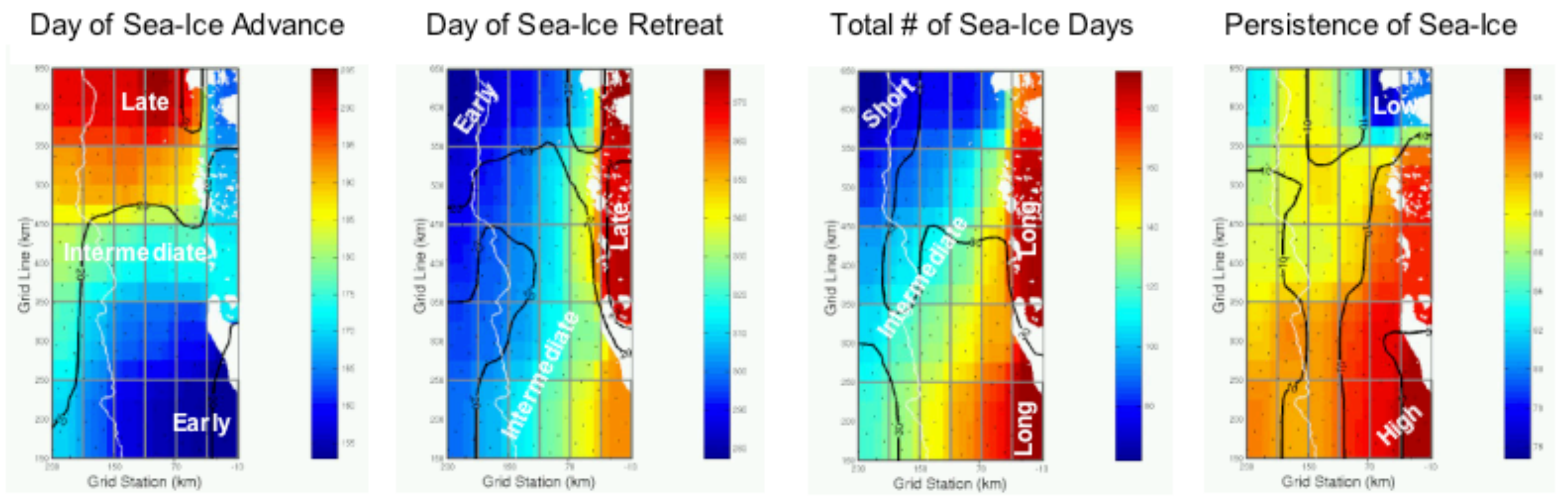
- Direct exposure to prevailing westerlies and storm forcing (Fig 1a)
- Relatively close to the frontal boundaries of the Antarctic Circumpolar Current and the corresponding Circumpolar Deep Water (Fig 1b)
- The confluence of subtropical and polar air masses and water types creates *an ocean-atmosphere-ice (OAI) system that is sensitive to climate variability*

2. Central Tenet of the PAL LTER



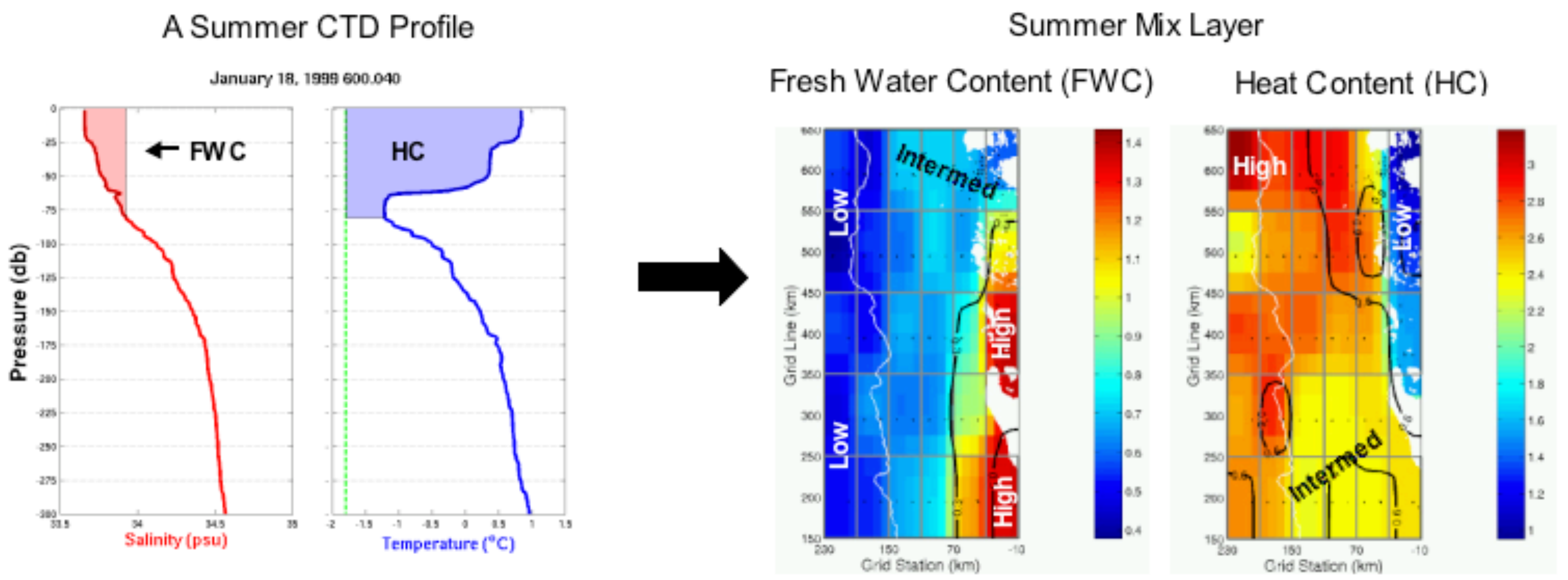
- Seasonal and interannual variability of sea ice affects (Fig 2) all trophic levels: from the timing and magnitude of seasonal primary production to the breeding success and survival of apex predators (*Smith et al*., 1995; *Ross et al*., 1996)
- In contrast to terrestrial ecosystems, *external* physical forcing plays a more dominant role in causing variability in marine ecosystems than *internal* biological mechanisms (*Steele*, 1991)
- Variable external forcing includes high variability in the timing of sea-ice advance and retreat from year-to-year (Fig 2a), and the changing persistence of monthly anomalies (from >1yr to <1yr) between the 1980s and 1990s (Fig 2b)

3. Sea-Ice Seasonal Climatologies


Day of Sea-Ice Advance | Day of Sea-Ice Retreat | Total # of Sea-Ice Days | Persistence of Sea-Ice

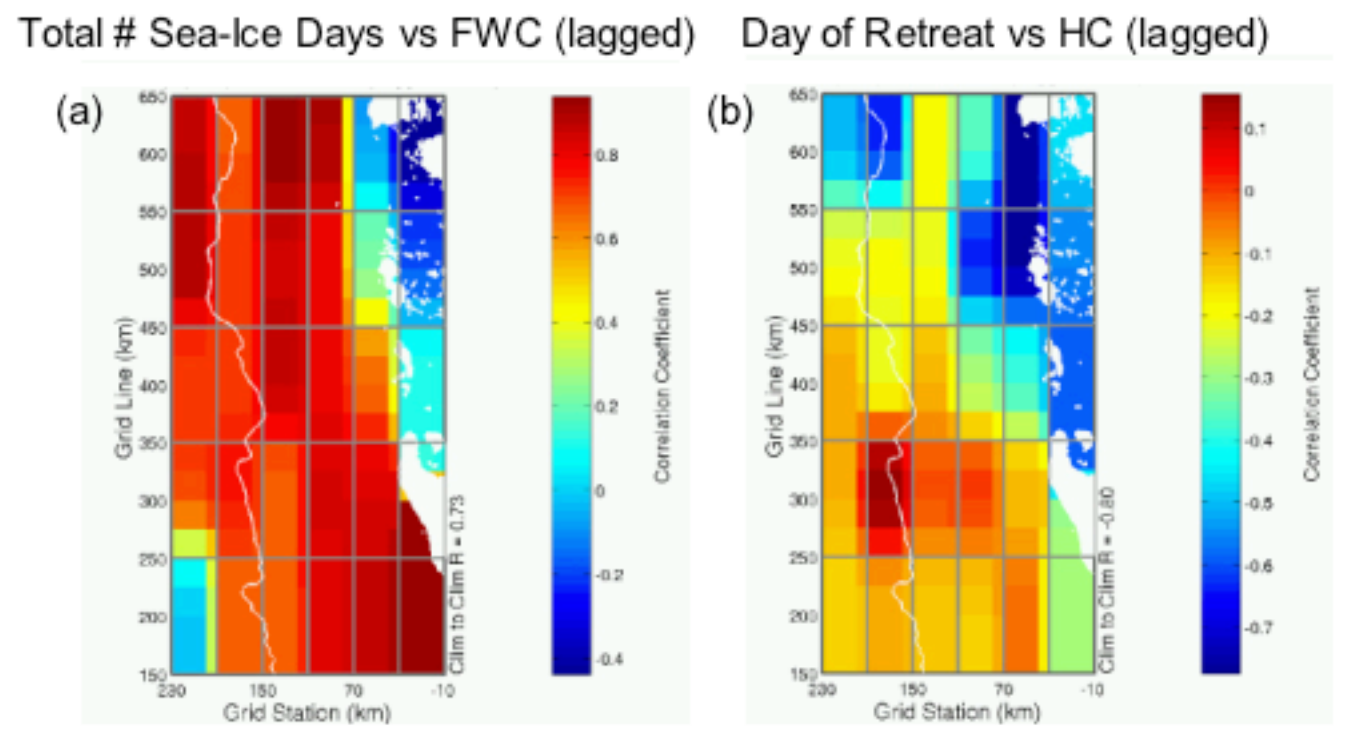
- Sea-ice indices were determined from daily SSM/I (1992 to 2001) satellite derived sea-ice concentrations (Comiso, 2003); land is white, and contours of standard deviation and 1500 m slope-shelf break are black and white, respectively
- Offshore North: short ice cover duration (late advance, early retreat), openings occur ~15% of time
- Offshore South: intermediate ice cover duration (early advance, intermediate retreat), openings occur ~10% of time
- Onshore North: long ice cover duration (intermediate advance, very late retreat), openings occur ~15-20% of time
- Onshore South: very long ice cover duration (early advance, late retreat), openings occur ~5% of time

4. Upper Ocean Summer Climatologies


A Summer CTD Profile | Summer Mix Layer: Fresh Water Content (FWC) | Heat Content (HC)

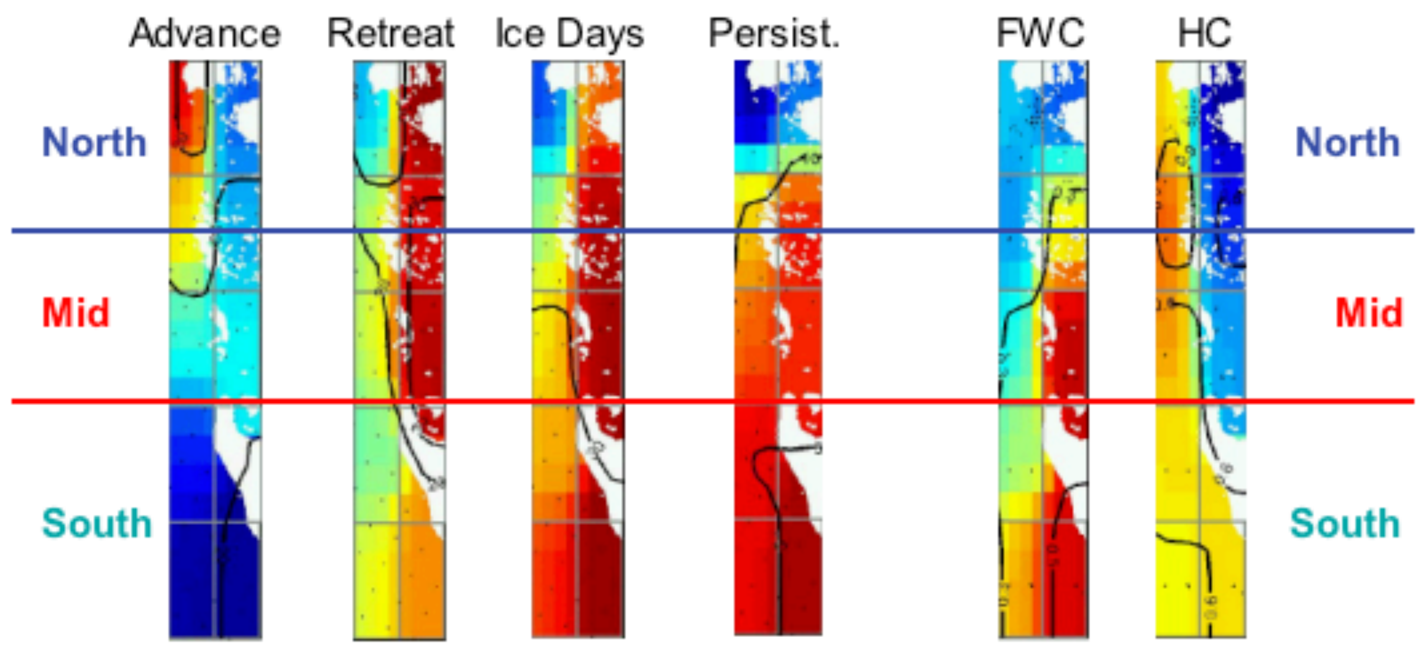
- Fresh water content (FWC) and heat content (HC) are derived from *summer* CTD profiles (1993-2001) by vertically integrating salinity and temperature, respectively, over the summer surface mix layer (*Martinson and Iannuzzi*, 1998); FWC and HC are essentially removed by the growth of sea-ice in the coming winter and have been normalized into equivalent units of effective sea-ice thickness
- Offshore North: low FWC and high HC (salty, warm, and very deep surface layer)
- Offshore South: low FWC and intermediate HC (salty, warm, and deep surface layer)
- Onshore North: low to intermediate FWC and low HC (very fresh, cold, and very shallow surface layer)
- Onshore South: high FWC and intermediate HC (very fresh, cold, and moderately deep surface layer)

5. Sea-Ice and Upper Ocean Co-Variability


Total # Sea-Ice Days vs FWC (lagged) | Day of Retreat vs HC (lagged)

- Total # of sea-ice days *during the previous winter* is ***positively*** correlated in time against *summer* surface fresh water content (Fig 5a) for most of the grid except
  - the mid and north coastal regions (where glacier meltwater input dominates the fresh water budget)
  - the south shelf break region (where intrusion of salty circumpolar deep water also contributes to the fresh water budget)
- Day of sea-ice retreat *during the previous winter* is ***negatively*** correlated in time against *summer* surface heat content (Fig 5b), particularly for the coastal regions
  - and for the rest of the grid, noting that in general sea-ice extent and surface air temperature (SAT) are negatively correlated (*Smith et al*, 1996)
  - but when this is not the case (as for the late 1990s), then SAT is the dominate influence on HC

6. Three Distinct Coastal Regions



- The **North**, **Mid**, and **South** coastal regions are distinct in their geography and ice-ocean coupling:
  - **North**: location of Palmer Deep; typically low sea-ice concentration and frequent opening/closing of the ice cover create variable upper ocean light environment; glacier meltwater run-off dominates freshwater budget
  - **Mid**: dotted by numerous archipelagos that trap both sea-ice and freshwater ice; typially high ice concentration and long ice covered period; glacier meltwater run-off is low relative to freshwater input from ice melting *in situ*
  - **South**: mouth of Marguerite Bay; typically high sea-ice concentration and long ice covered period; freshwater input is dominated by large volumes of sea-ice melting *in situ*

7. Summary

- External physical forcing of the Antarctic marine ecosystem in the PAL LTER study area includes high ***temporal and spatial*** variability of sea-ice (Figs 2 and 3) and its affect on ocean-ice co-variability
- Climatologies of seasonal sea-ice indices and summer upper ocean parameters show that ***spatially*** there are distinctly different physical environments within the PAL LTER study area (Figs 3 and 4)
- The freshwater content of the summer mix layer is highly correlated (***temporally***) with the previous winter's sea-ice duration throughout most of the PAL LTER study area, inferring that the freshwater contribution from sea-ice melting *in situ* is the dominant influence on the freshwater budget (Fig 5)
- The exceptions are the coastal regions which show distinctly different ice-ocean coupling and therefore distinctly different physical forcing of the marine ecosystem (Fig 6)

8. References

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