Wind stress curl forcing (Sverdrup balance)
N. Pacific subtropical gyre
  Kuroshio
N. Pacific subpolar gyre
  Oyashio
S. Pacific subtropical gyre
  East Australian Current

READING:
  DPO: 10.1, 10.2,
    10.3.1.1-10.3.1.4, 10.4
    (intro, skim rest)
Pacific Ocean: mid-latitude wind-driven circulation features

- **N. Pacific subtropical gyre**
  - Kuroshio and Kuroshio Extension (WBC)
  - North Pacific Current (eastward flow on north side of gyre)
  - California Current (southward flow on east side)
  - North Equatorial Current (westward flow on south side)

- **N. Pacific subpolar gyre**
  - Oyashio and East Kamchatka Currents (WBC)
  - Subarctic Current/North Pacific Current (eastward flow)
  - Alaska Current and Alaskan Stream (northward and westward flow)
  - Subarctic Front (separating subtropical and subpolar gyres)

- **S. Pacific subtropical gyre**
  - East Australian Current (WBC)
  - South Pacific Current, Peru-Chile Current, South Equatorial Current
Mean kinetic energy

Kinetic energy: $\frac{1}{2} \rho v^2$

Notice correspondence of high energy with major currents on previous slide

Sudre et al. (Limnology and Oceanography, 2013)
Forcing: Pacific wind stress and wind stress curl (mean)

- Wind stress (vectors)
- Wind stress curl (multiplied by sign of latitude) (shading).
- Blue: Ekman pumping (downwelling)
- Yellow-red: Ekman suction (upwelling)
**Pacific wind-driven circulation: winds (mean)**

- **Sverdrup transport**
  - Blue: southward
  - Yellow-red: northward

![Subpolar gyre](image)

Subpolar gyre

Subtropical gyre

Subtropical gyre

---

**Talley SIO 210 (2016)**

DPO Fig. S10.2

10/25/16
Surface circulation

**WBCs:**
- Kuroshio
- Oyashio
- East Australian Current

**EBCs:**
- California Current System
- Peru-Chile Current System

*Talley SIO 210 (2016)*

DPO Fig. 10.1
Pacific surface height, which is associated with its geostrophic surface circulation.

Surface height (cm), from Niiler et al., 2003

(DPO Fig. S10.1)
Sverdrup transport and surface gyres
N. Pacific surface steric height

(Kuroshio and K. Extension, North Pacific Current, California Current, Recirculation, C-shape, North Equatorial Current)

(DPO FIGURE 10.2, Flow 0 db)

Talley SIO 210 (2016)
N. Pacific steric height: 0, 500, 1000 dbar

Shift in subtropical gyre with increasing depth:

Gyre shrinks towards northern side and towards west

C-shape disappears

At 1000 dbar, even Kuroshio not clear (but see next slide)

Reid (1997)
N. Pacific 2000 dbar steric height (Reid, 1997)
N. Pacific 5000 dbar steric height (Reid, 1997)
The subtropical gyre circulation is a geostrophic flow (with many eddies)

From WHP Pacific Atlas (Talley, 2007)
http://www-pord.ucsd.edu/whp_atlas
Talley SIO 210 (2016)
Kuroshio and Kuroshio Extension

Features that are similar to all subtropical western boundary currents:

1. Kuroshio has very high velocities at surface > 100 cm/sec
2. Kuroshio extends to the bottom (weak velocity)
3. Kuroshio ‘separates’ from western boundary
4. Kuroshio extends far eastward into the gyre (“Kuroshio Extension”), not just at western boundary
5. Kuroshio meanders (time dependence)
6. Kuroshio has “recirculations” in opposite direction on both sides of the current. Biggest “recirculation” is on south side of Kuroshio Extension - “C - shape” of gyre.

Special feature of Kuroshio, not similar to other WBCs:

Large meander state of Kuroshio
Kuroshio nomenclature
(Kawai, 1972)

Separation point
Kuroshio as a western boundary current;
Special feature: Large and small meander states

Kuroshio along western boundary with transports (Sv)

Kuroshio large meander and small meander

DPO Figs. 10.4 and 10.5
Kuroshio at western boundary: velocity sections (Bingham and Talley, 1991)
Kuroshio Extension meandering

Mean

Mizuno and White (1983)

Variability (rms temperature)

Individual Kuroshio tracks

Normal meanders

“Large meander” (before separation point)
Kuroshio Extension observations

Deep mean velocities (vectors): mostly westward
Pathway of deep overturning circulation: inflow of deep water that upwells in the N. Pacific

Niiler, Schmitz and Lee (1985)
Density structure across the Kurosho: geostrophic shear
Kuroshio Extension, farther east

Kuroshio Extension (eastward - red) extends to the ocean bottom

Westward recirculations on both sides

Yoshikawa et al. (2004)
North Pacific Subpolar gyre

Ekman upwelling (suction): northward interior flow, southward western boundary current = Oyashio and East Kamchatka Current

Subarctic Front (or “Subpolar Front”): sharp demarcation all across the North Pacific from west to east, marking boundary between the subtropical and subpolar gyres.

North of the Subarctic Front, upwelling and nutrient rich surface waters, productive fisheries

South of Subarctic Front, downwelling, nutrient-poor surface waters.
N. Pacific surface steric height (Reid, 1997)
Old, interesting subpolar gyre schematic

Favorite et al. (1976)  
DPO Fig. S10.4

Talley SIO 210 (2016)  10/25/16
Subpolar and subtropical frontal zones

- Transition between subtropical and subpolar regimes (downwelling to upwelling) is abrupt - a FRONT.
- Two frontal zones: subtropical (at Ekman downwelling maximum in ST gyre) and subpolar or subarctic (at downwelling-upwelling boundary)

Talley SIO 210 (2016)

DPO Fig. S10.3
Subpolar gyre as a geostrophic flow

Isopycnals slope down towards east across the gyre (northward flow)
South Pacific subtropical gyre
S. Pacific surface steric height (Reid, 1997)

East Australian Current          South Equatorial Current      Peru Curr

South Pacific Current

Talley SIO 210 (2016)
S. Pacific steric height: 0, 500 dbar

Shift in subtropical gyre with increasing depth:

Gyre shrinks towards southern side and towards west

Reid (1997)
South Pacific subtropical gyre: western boundary currents

South Equatorial Current    East Australian Current (WBC)

Tasman Front

East Auckland Current (WBC)

Ridgway and Dunn (2003)