so, where would you predict the highest primary productivity?

along continental margins, especially in coastal waters

Why?

low productivity in the low latitude open ocean; subtropical gyres are "biological deserts" Why?

cooler sea surface temperatures = higher productivity

cooler sea surface temperatures = weaker thermocline

What relationship, if any, do you see between chlorophyll abundance (top panel) and sea surface temperature (bottom panel)?

Northern Hemisphere summer

Georges Bank
"north wall" of the Gulf Stream

subtropical gyre "Sargasso Sea"
**Seasonality**

- seasonal factors that influence primary production across latitude
  - the presence or absence of a strong thermocline (including the development of a **seasonal thermocline** in the mid-latitudes)
  - **seasonal changes in solar radiation** (angle of incidence)
  - think of the thermocline as a "density doorway"

**High Latitudes (Polar)**

- productivity is **not** limited by nutrients; "density doorway" is open
- productivity is limited by available solar radiation
  - angle of solar incidence too low for much of the year
- **short-lived episode of productivity** when solar radiation is available 24 hours/day

**Mid-Latitudes (Temperate)**

- **winter**: nutrients are available (doorway open), but not enough solar radiation
- **spring**: nutrients and solar radiation are available = high productivity ("spring bloom")
- **summer**: solar radiation available, but nutrients cut-off by seasonal thermocline (doorway closed)
- **fall**: break-down of thermocline = renewed productivity
Low Latitudes (Tropics)

- always enough solar radiation, but nutrients cut-off from below by the strong thermocline ("density doorway" closed tight)
  - except where upwelling occurs (coastal & near equator)
- coral reefs are an exception – despite very low nutrients in the water, high productivity is driven by highly efficient nutrient recycling

Mid-latitude seasonal cycle

Angle of solar radiation controls the development of the seasonal thermocline and the depth of light penetration for photosynthesis.

Nutrient Cycling

- organic matter in the ocean:
  - rain of organic matter from the surface waters
  - terrigenous organic matter from the continents
- heterotrophic bacteria break down the organic matter
  - nutrients are recycled back to the useable inorganic form
- these regenerated nutrients become “trapped” in the deep waters below the pycnocline (thermocline)
  - except where upwelling occurs
- upwelling provides a mechanism to deliver nutrients back to the sunlit surface waters.
Overview of nutrient distribution

Marine life is concentrated in sunlit surface waters where photosynthesis occurs; however, vast areas of the surface ocean are depleted in nutrients required for photosynthesis due to the presence of a pycnocline (thermocline) except where upwelling occurs.

The subtropical gyres are "biological deserts" very little dissolved nutrients make it out into the open ocean surface waters.

Note: the scarcity of nutrients where surface waters are warm and well stratified (the thermocline is a barrier to nutrient diffusion to surface waters).

Annual mean phosphate at the surface

Annual mean nitrate at the surface