INTERNATIONAL POLAR YEAR

Sea Ice

Sea ice, the thin layer of ice that covers most of the Arctic Ocean and surrounds most of the Antarctic continent, represents a distinctive feature of our planet. Sea ice spreads and retreats seasonally. It drifts and packs under the influence of wind and currents. It isolates the atmosphere from the ocean and produces the coldest saltiest ocean waters. It restricts the movement of ships but supports the traverses of bears. Sea ice contains unique organisms that sustain under-ice ecosystems. Poised where slight warming converts ice to water, sea ice has an exquisite sensitivity to climate. Its disappearance from any region, at any season, will represent a profound planetary change. Understanding sea ice and predicting its future represents a crucial challenge for IPY.

Sea Ice Formation

A clear 3-cm layer of ice on a lake will support a person. The same person could push a finger through 3 cm of sea ice. The formation of sea ice draws pure water into ice crystals, leaving behind a saltier brine. The brine accumulates in pockets and channels, which prevent the formation of continuous ice crystals. Air temperatures, wind, tides, currents, remnant ice, river flows, and the presence of surface debris or oceanic microorganisms all influence freezing and the structure of new ice. English words - nilas ice, frazzle ice, grease ice, pancake ice - demonstrate the complexity of the freezing process. Inuit languages convey a deep understanding of sea ice and of its suitability for travel and hunting. Sea ice often survives for several years, and the surfaces of multi-year ice record a complicated history of temperature, compression, fracture, melting, snowfall, dust collection, and wind erosion. Out of sight to most observers, the underside of sea ice presents an equally complex and fascinating appearance.

Sea Ice and Climate

Above sea ice, air masses cut off from direct contact with the relatively warm ocean lose substantial heat to space, especially during winter darkness. This cooling process, which can produce surface air as cold as -30°C, represents an important 'refrigeration' process for the planet. Meanwhile, the ocean below the ice increases in saltiness as brine excluded during ice formation mixes downward. Additional salt makes these cold ocean waters very dense - they become deep ocean waters that move slowly around the planet. At the surface, drifting sea ice transfers cold fresh water toward the equator. When sea ice disappears, solar energy reflected by the ice instead warms the upper ocean. A warmer ocean leads to less ice, which exposes more ocean, and so on - a positive (warming) feedback.

Sea Ice Movement

Sea ice can drift back and forth across a basin, it can pile into multiple layers on a windward coast, or, as in the Arctic, it can undertake a somewhat

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predictable journey, from formation, thickening, and accumulation to discharge, lasting two to three years. Nations occasionally install research bases on sea ice (often including aircraft runways) but every structure built on sea ice eventually moves. A variety of birds and animals travel on sea ice and use it to hunt, to give birth, and to take refuge. Often, fractures in sea ice expose areas of ocean, called leads and polynyas, that play important roles in heat exchange and cloudiness and often serve as zones of rich biological activity. An important facet of sea ice, one that exerts strong influence on movement and longevity, remains very difficult to measure - ice thickness.

Sea Ice Biology

Light can penetrate through several meters of sea ice. Pockets and channels on the underside of the ice become habitats for an interesting array of microorganisms. Adapted to cold salty micro-habitats, and protected within the ice matrix, these microorganisms can 'improve' (sculpt) their habitats and grow abundant enough to give the underside of sea ice a brownish green colour. The ice microorganisms stimulate and attract other organisms adapted to the ice environment. Antarctic krill, for example, use specialized structures to scrape food from the underside of ice, and juvenile crustaceans and fish take refuge in the ice structure. Materials sinking from the under-ice communities stimulate biological activity on the sea floor. The sea-ice sea-floor connections can represent substantial components of local ecosystem productivity. In summer, under-ice and ice-edge environments provide favourable conditions for many fish, birds, seals and whales.

Seasonal Sea Ice Patterns

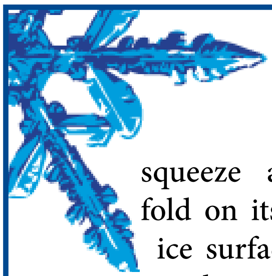
Sea ice extends and retreats in pronounced seasonal patterns. From summer minimum to winter maximum, the area of Antarctic sea ice changes by approximately 15 million square kilometers, an area twice as large as Australia. On average, Arctic Ocean sea ice varies by 7 million square kilometers, an area larger than the combined area of EU nations. These substantial changes in the planet's surface influence local and hemispheric weather patterns, local and hemispheric populations of many migratory species, and commercial activities such as marine shipping or fishing.

Sea Ice Monitoring

The unambiguous retreat of summer sea ice in the Arctic since 1979 provides a compelling example of the use of satellites to monitor sea ice. At present, however, space and airborne sensors provide information on extent or, occasionally, on ice freeboard (height above the ocean surface), but not on ice thickness. A full assessment of ice thickness, including snow cover, will require a sustained program of satellite, airborne, ship-borne, and underwater upward-looking fixed and mobile measurements. To obtain longer records of ice variations, researchers drill through sea ice into ocean sediments to find the alternating signals of ice cover and open ocean.

Sea Ice Prediction

Understanding and monitoring sea ice should enable predictions of future sea ice conditions, but modeling sea ice remains a very complicated challenge. What precise temperature and mixing conditions, at the atmosphere-ocean interface, allow ice to form? Does ice grow by freezing and accumulation or by compression and packing? When does ice move as rigid plates, and when does it



squeeze and flex and fold on itself? How do ice surfaces, with hard multiyear ice, fresh and old snow, melt ponds, frost flowers, and deposited dust and soot, actually absorb or reflect sunlight? What happens when melting sea ice and its load of organisms and nutrients form shallow freshwater layers in the adjacent ocean? These urgent questions, covering processes as small as crystal formation and as large as ocean basins, emphasize the critical need to better understand sea ice.

Find these and other educational materials in: Kaiser, 2010, Polar Science and Global Climate, An International Resource for Eduation and Outreach, ISBN 978 1 84959 593 3, www.pearson.co.uk.

www.ipy.org

Sea Ice Activity: What Happens When It Melts?

Materials (for two students working together):

- Two blue ice cubes made with tap water and food colouring.
- One glass container with tap water at room temperature
- One glass container with tap water saturated with salt, also at room temperature.

Directions:

1. Discussion: Draw what you think will happen when the ice cubes are placed in each container.
2. Have students place one ice cube in each container.
3. Do not disturb the containers while the ice cubes melt.
4. Observe and watch carefully for at least 10 minutes, or until the ice has melted.
5. Record your observations, and draw the results.
6. Measure temperatures at the top and bottom of the containers.

Concepts:

- Different densities as a result of temperature and salinity cause ocean currents which circulate throughout the world's oceans.
- In the tap water container, cold water from the ice cube is more dense than the warmer container water, so cold blue water sinks to the bottom. It mixes with the warmer water as it sinks so as it reaches the bottom it may begin to rise.
- In the saltwater container, the cold water from the ice cube sits in a band on top of the warmer salt water. Even though it is cold, it is still less dense than the underlying saline water.

Extend this experiment:

- Make two large ice cubes, one of tap water and one of salt water (3.5 g of salt per 100 ml of water). Once frozen, place these cubes in shallow dishes.
- Mix blue food color with a small amount of alcohol. (Alcohol will prevent the dye from freezing on the ice cubes).
- Place a drop of the blue dye on top of each ice cube.
- Most of the dye will run off of the tap water ice cube, but most of it will permeate the salt water ice cube. Now you have demonstrated sea ice porosity!

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