GEF 2610
ON F/F TRYGVE BRAARUD
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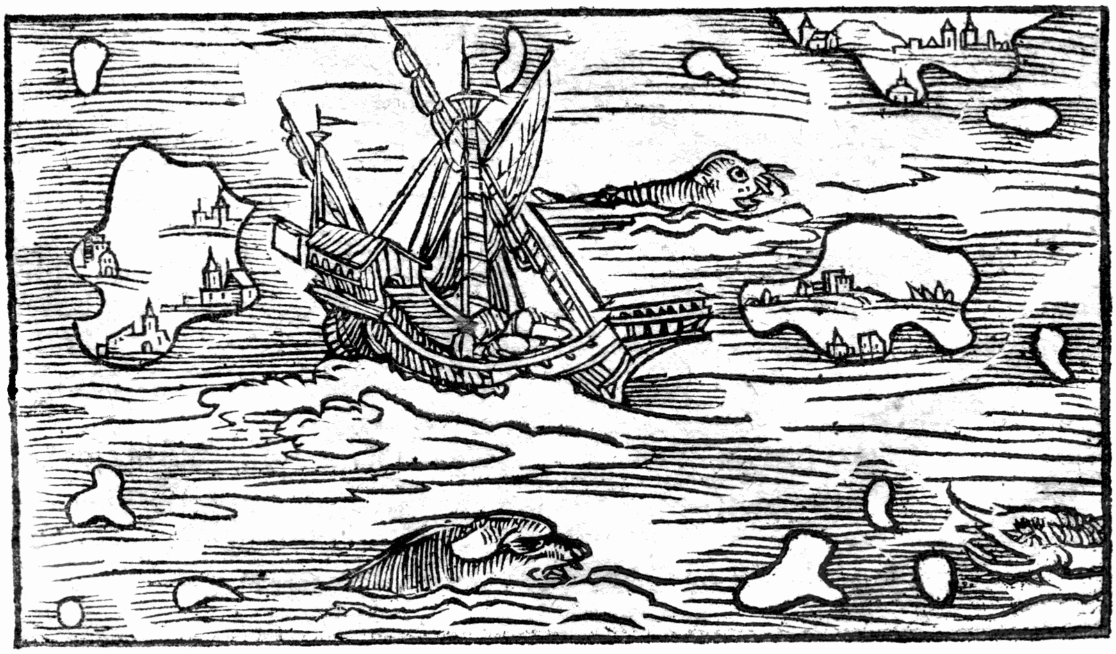
Program, analysis and presentation of results



Program for the day

The purpose of the cruise is to make the students acquainted with some basic observational techniques and to learn some more about air-sea fluxes and fjord circulation and hydrography from their own measurements.

We will collect hydrographic measurements (salinity, temperature, pressure) at three different stations, likely at *Malmøykalven* (in Bekkelagsbassenget), *Oksvaldflua* (close to Nesodden) and *Geitholmen* (in Lysakerfjorden). The hydrography will be collected with the ship's *conductivity, temperature and depth (CTD)* sensor. The lowering of the CTD will be done by the ship's crew, but students will be involved with the data collection.

We will also make estimates of some air-sea energy (“heat”) fluxes. For this we will need to collect: air and sea surface temperature, air humidity, incident irradiance, cloudiness and wind speed. Wave height, and general weather conditions will also be noted. Some of these quantities are displayed on the bridge and on the screen in the laboratory.

The downward penetration of shortwave radiation into the water will be measured with a quanta irradiance meter. Simultaneous irradiance measurements on deck (an irradiance meter mounted above the bridge) will be used as a reference—to compensate for variations in e.g. the cloud cover while we measure in the sea. The measurement depths will be: air, 1, 2, 5, 10, 15, and 20 meters. The Secchi disk depth will also be observed and noted for comparison.

Analysis and reporting

Each student will make his/her own cruise report. The report shall contain:

- A brief repetition of the purpose of the cruise and measurement program.
- A brief description of the vessel, the equipment used and the sampling procedure we used.
- A description of stations visited, including exact position and time.
- Analysis/calculations.
- A brief discussion of the results, including an assessment of possible errors.

Specific observations and analyses

1) Hydrography

The CTD measurements from all stations shall be presented in graphs as vertical profiles and as TS diagrams. The observations shall then be discussed, both individually (What characterizes the vertical stratification? Does the stratification give sign of what is expected from an estuary?) and in relation to the other stations (To what extent do we observe contrasting conditions?). If one station is repeated you should compare and discuss the time evolution of hydrography at that station.

Calculate from the CTD recordings the hydrostatic pressure at 30 m depth at *both* of the stations Malmøykalven and Geitholmen. Estimate the total density as 1000 + *sigma-t* [kg m^{-3}], where *sigma-t* is taken from the CTD data. Use g = 9.81 m s^{-2}. If we assume *hydrostatic balance*, what is the pressure difference at 30 m depth? If the sea surface itself is completely horizontal, which way will the current flow? In order to compensate for the pressure difference at 30 m depth, so that there is no pressure difference at depth, what would the sea level difference have to be between the two stations?

2) Air-sea heat fluxes
In our study here we will make estimates of air-sea heat fluxes from 1) shortwave and 2) longwave radiation and, in addition, from 3) heat conduction (sensible heat fluxes).

Shortwave radiation
The quanta irradiance, or photosynthecially active radiation (PAR), is measured as the number of light quanta per unit time per area, and for our instrument this is reported in units of [μmol s^{-1} m^{-2}]. When we want to calculate the heat effect of the irradiance, it is better to express it in energy flux units, i.e. in [W m^{-2}]. The incident shortwave irradiance Q_s in energy flux units just beneath the surface can be obtained from the PAR value Q_q by multiplying it with the empirical factor

$$0.5\ (W\ m^{-2})/(\mu mol\ m^{-2}\ s^{-1}).$$

Observe shortwave radiation at the sea surface and report this in W m^{-2}

Longwave radiation
Stefan-Boltzmann's formula for longwave radiation (the one involving temperature to the fourth power) is seldom used in practice. Instead, a *practical* formula for the *net received* longwave (infrared) radiation at the surface of the sea is

$$Q_b \approx -\left(143 - 0.9\ T_w - 0.46\ e_a\right)\left(1 - 0.1\ C\right)\left[W\ m^{-2}\right]$$

where T_w is the sea surface temperature measured in ºC, e_a is the relative humidity of the air measured in %, and C is the cloudiness measured in the unit of oktas. Usually Q_b will be negative and thus represent a *loss*.

What is Q_b at the time of observation? How many Joules are lost diurnally from one square meter of water surface, based on the sea surface temperature, the relative air humidity and the cloudiness, provided these quantities remain constant?

Turbulent sensible heat flux
The heat gain of the sea due to heat conduction can be approximated by

$$Q_h \approx -1.88\ V\ \left(T_w - T_a\right)\left[W\ m^{-2}\right]$$

where V is wind velocity in m s^{-1}, T_w is again the sea surface temperature in ºC, and T_a is the air temperature in ºC. If $T_w > T_a$, Q_h will be negative and represent a loss.

What is Q_h at the time of observation?

Heat budget
Using your measured heat fluxes and assuming that other heat transport terms (what are these?) are small, assess whether the surface waters in the fjord are warmed or cooled during our cruise. If one station is repeated (e.g. Oksvaldflua), you should average the heat budget made for those two sets of observations and then compare the result with the measured temperature difference (from the CTD data) between observation 1 and 2.

3) Vertical penetration of shortwave radiation

The total irradiance incident at the surface of the sea has a spectrum from about 300 to 3000 nm. The shortwave part of this may be wavelengths less than 750 nm, and the longwave or infrared part wavelengths above 750 nm. The energy within the spectral range of the quanta irradiance meter (400-700 nm) will practically correspond to the energy of the shortwave spectrum. In air and just beneath the surface the shortwave radiation will contain about half of the energy of the total irradiance, implying that when we are at the 1% depth of the quanta irradiance (let's call this *z(1%)*) we are also at the 0.5% depth of the total irradiance. This means that practically all incident radiation is absorbed in the layer above *z(1%)*.

A rather crude rule of thumb states that net photosynthesis/primary production will exist down to the depth *z(1%)* where the quanta irradiance is reduced to 1% of its surface value (just beneath the surface). The quanta irradiance is often termed PAR (Photosynthetically Available Radiation), and it is usually assumed that the spectral range 400-700 nm contributes to the photosynthesis. The layer where a net photosynthesis occurs is termed *the euphotic zone* (the zone with good light).

All irradiance readings shall be normalized to the same deck value. This value should be representative for the whole recording. If the recording Q_q in water was obtained with a deck value of Q_{deck}, and if $Q_{deck,ref}$ has been chosen as the reference deck value, then the normalized irradiance value in water becomes $Q_{q,norm}=Q_q \cdot Q_{deck,ref}/Q_{deck}$. The surface value of the irradiance (just beneath the surface) is obtained from the value in air by multiplying it with a transmittance value for the air-water interface, taken to be approximately 0.9.

The quanta irradiance should be presented in a semilogarithmic graph as a function of depth (irradiance along the logarithmic axis and depth along the linear axis), and the depth *z(1%)* should be determined.

It is easier to measure the Secchi disk depth *D* than *z(1%)*, and a statistical analysis of earlier results from the inner Oslofjord has shown that

$$z(1\%) \approx 2.0\ D$$

$$\Delta z \approx 0.7\ D$$

where Δz is the average error of *z*(1%) estimated from *D*. What is *z*(1%) according to your Secchi disk depth? How does it fit with your irradiance measurements?

Instruments

-The CTD is manufactured by Sea-Bird Electronics and the model is SBE911*plus*.
-The quanta irradiance meter is LI-COR quantum (PAR) sensor model LI-185B for the underwater measurements, and model LI-189 for the recordings in air.
-The Secchi disk is a standard disk of unknown origin.