



BALLOON DATA VS ATMOSPHERE MODEL

Task Box: The Sun-Earth Connexion

Summary

This exercise uses data obtained from the release of a meteorological balloon to analyse the main physical parameters of the atmosphere and compare with the standard atmosphere model.



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Overview

Purpose	Gain understanding of the use of balloon data in science. Gain experience in using scientific data processing tools.
Duration	Two hours
Location	Classroom
Equipment	Computer with internet connexion.
Safety issues	None
Background	Basic knowledge about Balloons and PTU radiosondes
Literature	Included
Software	MATLAB and script provided

Learning objectives

Gain increasing knowledge about:

- using the scientific methodology
- using scientific data processing tools
- the physical characteristics of the atmosphere
- the stability in gases and how to recognise local instabilities in the atmosphere
- the planetary boundary layer and its connexion with the troposphere

21st Century skills:

- Work in international groups using English as communication language
- Problem solving skills
- Critical thinking
- Collaboration
- Communication
- Information and media literacy

Introduction

This task can be completed in the local schools having the data and software needed. However, it is designed to be completed during the gathering in Andøya. In this case, before proceeding with the tasks, the students attach a PTU (Pressure Temperature Humidity) radiosonde to a meteorological and release the meteorological balloon by themselves. Therefore, they will use their own data. This will be ready after around 1.5 hours, which is the typical time the balloon is ascending until it explodes. In this exercise, an analysis of a Northern Light event that happened on February 2014 will be done. To carry it out, we will make a historical tour that will allow us to discover why the Northern Lights are produced. Later, we can generalize to other past events and we will learn to know how the northern lights are currently predicted.

The main objective of this task is to describe characteristics of the atmosphere using the data obtained from the PTU radiosonde, compare with the International Atmosphere Model and search for areas of instabilities. But for understanding these objectives it is important to first introduce some important concepts.

The International Standard Atmosphere

The *International Standard Atmosphere* is an atmospheric model or convention which is used as reference when actual atmospheric conditions are to be described.

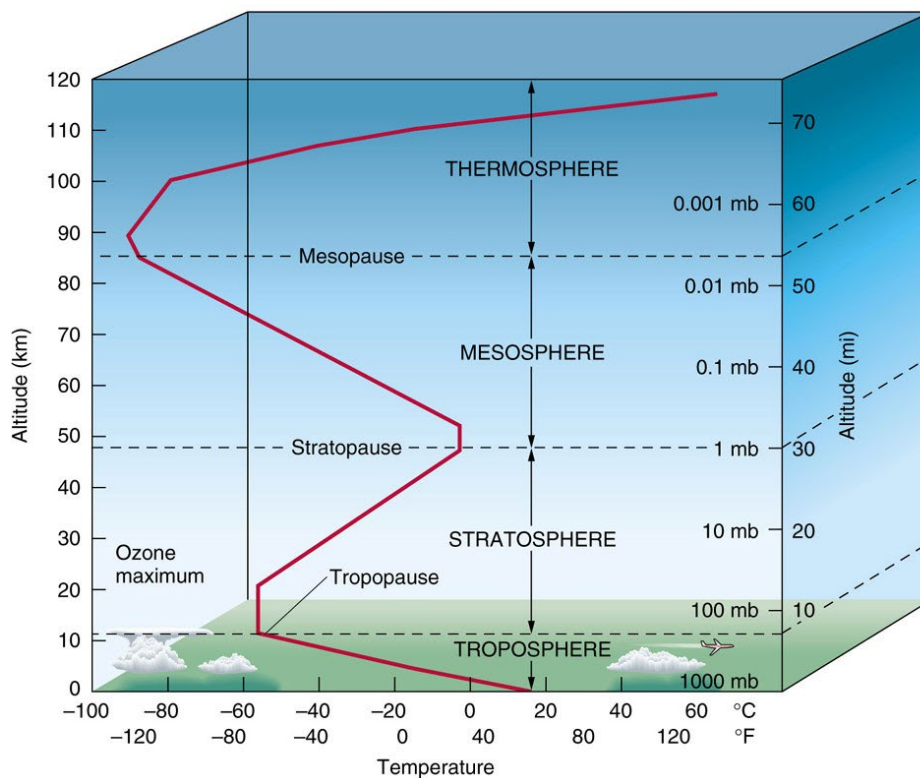


Figure 1: Standard atmosphere layers.

Variables used for such a description are e.g. pressure, temperature or the number density of the air molecules. Most significantly, the convention divides the atmosphere into different layers based on the temperature gradient (see Fig. 1). The table below shows this layering in more detail:

Level	Name	Altitude [km]	Lapse rate [°C/km]	Base temp. [°C]	Static base pressure [Pa]
0	Troposphere	0	-6.5	+15.0	101325
1	Tropopause	11.019	0.0	-56.5	22632
2	Stratosphere	20.063	+1.0	-56.5	5474.9
3	Stratosphere	32.162	+2.8	-44.5	868.02
4	Stratopause	47.350	0.0	-2.5	110.91
5	Mesosphere	51.413	-2.8	-2.5	66.939
6	Mesosphere	71.802	-2.0	-58.5	3.9564
7	Mesopause	86.000	-	-86.2	0.3734

There are more than one “reference atmospheres”. The International Standard Atmosphere above is originally the US Standard Atmosphere from 1976 which includes all layers up to the mesopause but neglects the thermosphere.

Stability in a gas

Stability as a concept in physics is easy to understand: A body which is displaced from one (of maybe several) equilibrium position(s) either moves away further (instability), moves back (stability) or does not move at all if another equilibrium position is found.

A gas is no body in the sense the term is used above. It is, however, possible to define the term “body” as a volume of gas, a so-called “parcel of air”¹.

Assume that such a parcel of air is located in the troposphere. In equilibrium it has a certain pressure p_{eq} and temperature T_{eq} . Assume further that the parcel is pushed upwards until it has pressure p_1 and temperature T_1 . Based upon what we know about the troposphere we would expect that $p_1 < p_{eq}$ and $T_1 < T_{eq}$ since both pressure and temperature are supposed to decrease with increasing altitude. In a stable atmosphere this means that the parcel of air cools such that it eventually will sink again until it has p_{eq} and T_{eq} .

But what if $p_1 > p_{eq}$ or $T_1 > T_{eq}$, i.e. if the parcel gains energy from its surroundings while it ascends? This may e.g. happen when a gravity wave propagates through the parcel. Then the parcel of air will be lifted even higher and moves away from its equilibrium position. The movement of the parcel may become unstable. In such a case one uses the term locally unstable atmosphere.

¹ This is akin to (but of course not exactly the same) as defining light pulses to be made of particles (photons) in order to be able to calculate certain things about electromagnetic radiation more easily.

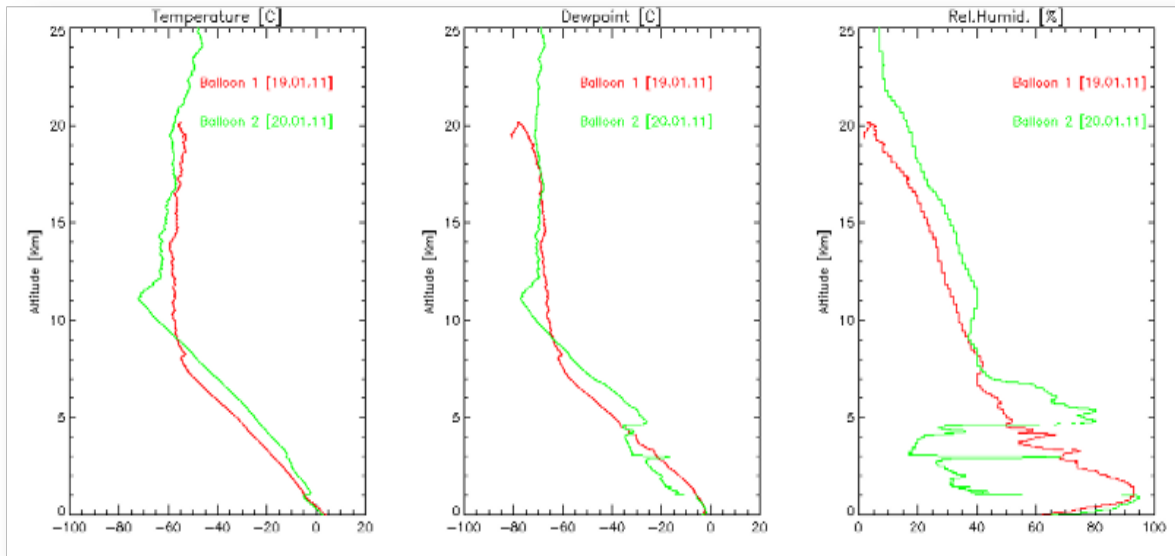


Figure 2: Balloon data examples. In the plot to the left the temperature graph for balloon 2 shows an increase in temperature at around 1 km height. This cannot be turbulence since we observe a cloud layer at the same height in the plot to the right. Low-altitude clouds/humidity layers cannot exist in an unstable atmosphere. Thus, the temperature increase shows the top of the planetary boundary layer.

How to recognize a local instability in the atmosphere

A different way of looking at atmospheric stability is to say that a stable atmosphere resists vertical air motion while an unstable atmosphere does not. Here is the idea:

We define the dry adiabatic lapse rate as the temperature gradient a dry parcel of air would experience while rising and cooling adiabatically. The wet adiabatic lapse rate is then the analogue for a parcel of air which is saturated with water vapour.

Stability arises from energy transfer to the parcel of air, i.e. temperature evolution as the parcel rises is no longer adiabatic. Thus, we can define for any parcel of air that the atmosphere is (1) absolutely stable when the actual temperature gradient or environmental lapse rate is lower than the wet adiabatic lapse rate, (2) absolutely unstable if the temperature gradient is larger than the dry adiabatic lapse rate and (3) conditionally stable if the temperature gradient is larger than the wet but smaller than the dry adiabatic lapse rate.

Planetary Boundary Layer

Atmospheric stability is of major importance in the so-called Planetary Boundary Layer (*PBL*) which is the atmospheric layer closest the ground. Here, both friction between air motion and the Earth's surface as well as infrared radiation from the Earth's surface have such a great degree of influence on the energy balance in the atmosphere that turbulent motion can occur quite often.

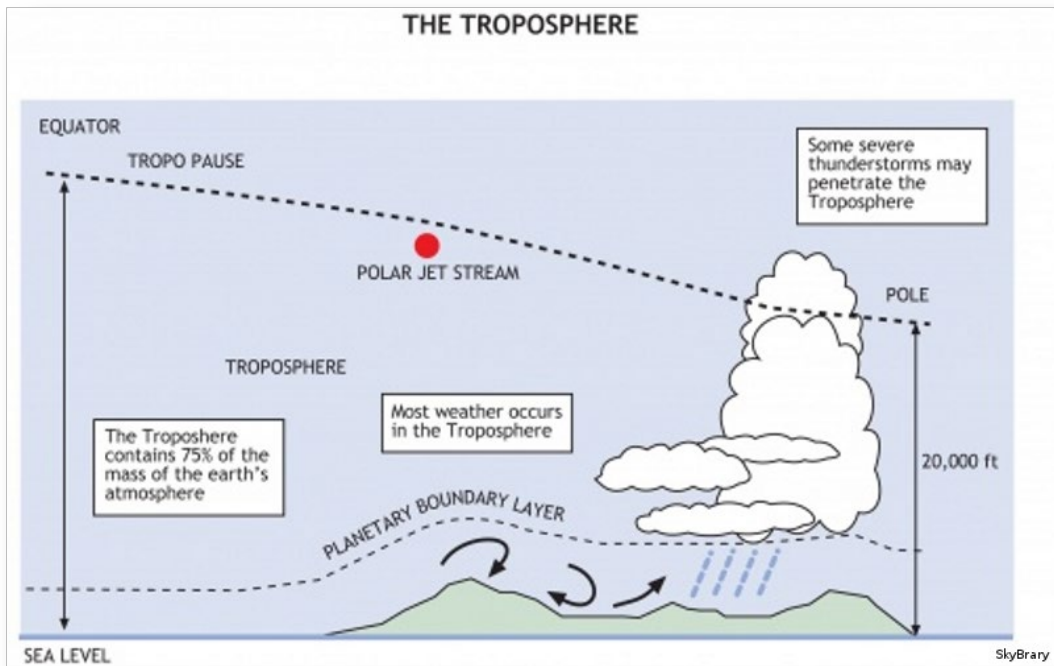


Figure 3: The Planetary Boundary Layer within the troposphere. Note, how “topography”, i.e. a mountain, can produce turbulence on the lee side.

Fig. 3 shows a schematic of the PBL. As is the case with the tropopause (and for mostly the same reason), the thickness of the PBL is variable with latitude. For even if frictional forces due to “topography” are dependent on local conditions and can therefore be assumed to be constant here, the amount of energy absorbed and converted into thermal radiation is not. At the equator a lot more of the Sun’s radiation reaches the Earth’s surface, such that the PBL and the troposphere are much thicker than at the poles.

Activity 1: Predict the route the balloon will follow

The objective of this activity is to predict the route it will follow and where it will hit the ground, making use of websites that shows the wind direction at different altitudes.

Use the following link:

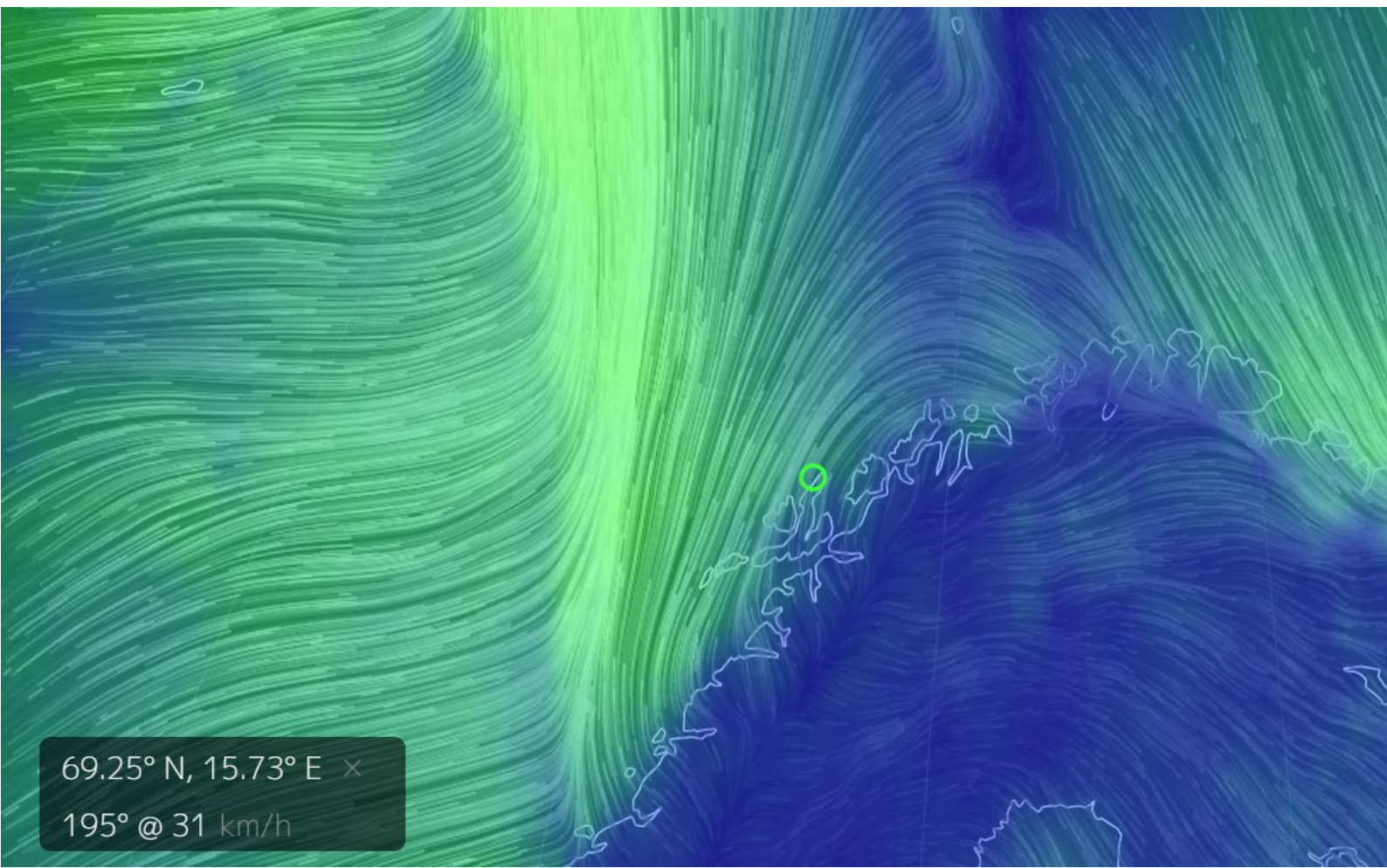
<https://earth.nullschool.net/#current/wind/surface/level/orthographic=-343.62.68.87.3000/loc=15.732.69.248> .

You will see a map of the wind directions and magnitudes at surface level around Andøya. Study the map closely. You can choose higher altitudes. Use the button “Earth” and select different “Heights”. Note: Height are given in hPa. Take into account that 1 meter has 0.1268 hPa. The maximum altitude you can check is 1000 hPa, around 7890 meters.

Now go to the link: http://maarsy.rocketrange.no/MAARSY/tropo_plots.htm

This is showing Maarsy data. Maarsy is an important instrument located in ASC. It can provide different measurements. In this case we are interested in the wind velocity. This link shows 4 graphs. Click in the graph that appears at the lower right of the screen. This shows the Zonal and Meridional (directions) wind velocities up to 20 km. Look in internet the meaning of these terms: Zonal and Meridional wind components.

Discuss in groups: taking into account the wind at different altitudes, and that the balloon ascends for around 1.5 hours until it reaches around 25000 meters before exploding, where do you think the balloon will explode? Mark your expectations in Google Earth?





Now use the following link: <http://habhub.org/predict/>

Find the coordinates of Andøya Space Center and write them in the Latitude/Longitude fields. Choose “5” for Launch altitude, “5” for Ascent rate, and “27000” for Burst altitude. Click on “Run Prediction”. When the prediction run is complete, click on “KML” in the upper right corner in order to save the data.

Import the data into Google Earth and compare with your own prediction. How do the two predictions measure up compared to each other? Write a few sentences about your expectations versus the result of the simulation.

Activity 2: Analysis of PTU radiosonde data

This activity makes use of MATLAB. Open and run the script “balloon_2_o.m”. When asked for a data file, choose the one from your flight («<flight identifier>_ARS.rts»). Eventually, 8 graphs will appear on screen.

Before you take a look at those, load the kml-file in the sub-directory \plot\kml into Google Earth. This contains the GPS balloon data showing the actual path it has follow. Compare it with the two previous predictions.

Now, take a look to the graphs. Discuss in groups what information the different graphs present. Do you notice something unexpected? Explain

Answer the following questions:

1. Now, onto the data: Where is the tropopause? Which graph/s are you using to locate the tropopause? Explain.

2. Does your findings about the tropopause fits with the International Standard Atmosphere (see Fig 1). Describe the similarities/differences you have found.
3. Planetary Boundary Layer. If we want to look for indications about the PBL, which are the best graph to use and why? In our data, is it possible to make statements about the height of the Planetary Boundary Layer? Explain.
4. Compare in general the measurements to the International Standard Atmosphere. Calculate and compare the temperature lapse rate (temperature gradient with altitude)?
5. Stratosphere: Can we make statements about the Temperature in the stratosphere? Explain. Would you have expected the results? If yes, why - if not, why not?
6. Are there altitudes where the atmosphere could be unstable? Which graphs are the more appropriate to use for finding instabilities? Why?
7. Analyse the conditions at the respective altitudes and argue for why the atmosphere is or is not stable.
8. If you did not find unstable atmosphere in point 7. Discuss with your colleagues whether one can actually expect turbulent air motion over Andøya and what would be the main factors that could create such instabilities. Consider first what you know about the energy budget in the atmosphere. What may have happened at the relevant altitudes?