Bernd Richter Marine Meteorology

2022/23 Klausur/Test (H) 90 Min 08.03.2023 13:00 – 14:30 Hörsaal 200

Questions and examples of answers **sufficient for full score**

1. 8 Points: Which physical variables describe the humidity of air?

    a. Give examples of humidity parameters (4 P)
    Temperature/Dewpoint, Absolute Humidity (g/m^3), Specific Humidity (g/kg), Relative Humidity 100*(Spec.Hum.@actual/Spec.Hum.@saturation)

    b. Give a typical humidity problem with the best suited parameter (4 P)
    Forming of Radiative Fog: Radiative Cooling down to Dewpoint: Forming of Fog!
    The answer above is sufficient for full score!

    Another Example: Appartment air exchange in winter:
    Outside Air Condition: T=0°C, Td=0°C, abs.Hum. 5g/m^3, rel.Hum.=100%
    Room after Exchange: T=0°C, Td=0°C, abs.Hum. 5g/m^3, rel.Hum.=100%
    Room after Heating: T=20°, Td=0°C, abs.Hum. 5g/m^3, rel.Hum.= 25%
    Desired value for Health: rel.Hum. =50%
    Required Humidification: rel.Hum. =50%, abs.Hum.10g/m^3, T=20°, Td=15°C

    I did not expect this example to be given with these values!!

2. 6 Points: Which types of fog do you know? Describe the typical process of forming. (6 P)
    - Radiative Fog: Near surface radiative cooling down to Dewpoint: Forming of Fog.
    - Advective Fog: Advection of moist, warm air over cold surface: Forming of Fog.
    - Mixing Fog: Mixing of two air masses, each below saturation, results in mixed air mass above saturation: Forming of Fog.

3. 2 Points: How can you define the meteorological visibility? (2 P)
    - Contrast between white and black visual target goes below a threshold, e.g. 5%

4. 10 Points: What determines the layer thickness 500 over 1000 hPa (rel. topography)? (2 P)
    - The average temperature of the air column – this and only this!

    a. What is the consequence for the thickness of this layer extending over an area of different vertical average temperature? (4 P)

    - The thickness will adjust to the average temperature of the air column at each position.

    b. What results for the 500 hPa layer height (absolute topography), if the MSL pressure is constant? (4 P)

    - If the air column is warmer, the 500 hPa layer rises. If it is colder, it sinks, the geopotential decreases, i.e. upper cold air advection helps to intensify upper air troughs.

5. 15 Points: The dynamic consequence of an air pressure field with areas of higher and lower pressure (pressure gradient) is wind. Answer the following questions

a. Which forces change a pressure field with a pressure difference on the rotating Earth? (3 P)
   - Pressure gradient force, Coriolis force (**full score**)

b. How does the curvature of isobars affect the windspeed? (3 P)
   - Anticyclonic curvature increases, cyclonic curvature reduces the windspeed (**full score**)

c. How does friction affect the windspeed and -direction? (3 P)
   - It reduces the windspeed and turns it towards lower pressure

d. What are the synoptic consequences of friction in a low pressure area? (3 P)
   - Lows (specially hurricanes) are weakening, filling up, surface pressure rises or falls less.

e. What is super-geostrophic wind? (3 P)
   - Windspeed is higher than geostrophic due to anticyclonic curvature

6. 26 Points: The temperature T normally decreases with height (vertical T-gradient)

   a. Give a typical value for the vertical T-gradient in the dry atmosphere? (2P)
      - 1 °C/100m

   b. How does the vertical T-gradient change for moist air and condensation? (2P)
      - 0.6 °C/100m due to heat release during condensation processes.

   c. How does the vertical T-gradient change for different stability conditions. (3 P)
      - Stable conditions: Vertical T-gradient is less or even positive
      - Unstable conditions: Vertical T-gradient is greater

   d. Name the cloud types that result from different vertical T-gradients? (3 P)
      - Stratification stable: stratiform clouds
      - Stratification unstable: cumuliform clouds

   e. Which consequences result for the character of the wind? (2 P)
      - Stable: steady wind, unstable: gusty wind (reason: vertical exchange)

   f. Give basic types of clouds and their typical vertical extent. (6 P)
      - (Alto-, Cirro-)-Stratus, (Alto-, Cirro-)-Cumulus, Stratocumulus, Cumulonimbus
        Answer above **sufficient for full score**

      - 0 – 3 km Stratus, Cumulus, Stratocumumlus
      - 3 – 5 km Altostratus, Altocumulus
      - 5 – Tropopause Cirrus, Cirrostratus, Cirrocumulus
      - 0 – Tropopause Cumulonimbus, Nimbostratus

   g. Give examples for abnormal vertical temperature profiles. (2 P)
      - Inversions

h. Describe three different types of inversion and the physical process behind (6 P)
   - Radiative inversion due to radiative cooling at surface
   - Advective inversion due to advection of warm air (e.g. warmfront)
   - Subsidence inversion due to adiabatic warming by subsidence of air in Highs

7. 7 Points: What is the height of the tropopause?

   a. Give typical values for the polar, mid-latitude and tropical region. (3 P)
      - 6km, 12km, 18km

   b. Which are the physical characteristics of the tropopause with respect to temperature and humidity? (4 P)
      - Temperature constant above (isothermal), water vapor of no importance (dry), therefore commonly said: …above the weather (except severe 'hot towers' of thunderstorms)

8. 20 Points: The General Global Circulation

   a. What drives the Global Circulation? (4P)
      - Curvature of the Earth, therefore less radiative energy amount per area at higher latitudes with a resulting meridional (N-S-) temperature gradient.

   b. Describe its circulation cells and the resulting wind regimes. (4P)
      - Hadley Cell: Rising air in the tropics, upper level poleward winds, subsidence in subtropical latitudes, surface winds towards equator (Tradewinds)
      - Ferrell Cell: Near-surface SW-winds towards polar frontal zone, cyclogenesis
      - Polar Cell: Near-surface NW-winds towards polar frontal zone, cyclogenesis

   c. What is the reason for the forming of a Jetstream? (4P)
      - Air from equator (earth rotational velocity 40.000 km/24hrs equal 1600 km/hr) moves poleward to areas with earth rotational velocity 1200 km/hr) results in forming of a jetstream due to 'the excessive windspeed relative to the vicinity'.

   d. What do the wavenumbers of the Global Circulation describe (500 hPa)? (4 P)
      - Number of full sinus-like ridge-trough-ridge-patterns around the earth

   e. What is the relation between wavenumber and propagation speed of the wave? (4P)
      - The higher the wavenumber, the shorter the wavelength of the pattern, the faster its eastward propagation

9. 6 Points: Which dynamic and oceanographic conditions are necessary (not sufficient, though) for the development of tropical storms / hurricanes? (6P)
   - Latitude > 5° N/S, Water temperature > 27°C

10. 2 Points: What is the main season of tropical storms on the northern hemisphere? (2P)
   - Late summer

11. 6 Points: What is the basic idea behind the 1-2-3 rule for the forecast of hurricanes? (6P)
    - Cover the 'Avoid' area of estimated winds > 34kt/Bft8 after 24, 48, 72 hours

12. 6 Points: Describe the qualitative physics and processes behind the Foehn-Effect. (6P)
    - Forced lifting and dry-adiabatic cooling of air when moving towards mountains. Condensation and rain fallout, ongoing lifting, now wet-adiabatic lapse-rate. After crossing of mountains, subsidence of air, dry-adiabatic warming, air very warm and dry at surface.

13. 6 Points: How does a sea-breeze develop? (6P)
    - Diurnal warming of shore, therefore lifting of air, rising of pressure layers, forming of a pressure gradient force towards sea at 1500m. Forming of a closed cell due to continuity reasons.

14. 6 Points: What is the basic idea of Numerical Weather Prediction (NWP)? (6P)
    - NWP is an initial state problem for 6 variables with 6 equations (Basic Laws, Thermodynamics, Newton etc., some time-dependent). Integration of these equations into the future.

15. 8 Points: How can spot forecasts of the NWP Direct Model Output (DMO) be improved? (4P)

    a. Describe the main DMO improvement principles for spot forecasts. (4P)
    - Statistical post-processing combining DMO and …
    - MOS Model Output Statistics: … and past observations
    - PP Perfect Prog: … and past analyses

16. 4 Points: What is the idea behind Ensemble Forecast Technology? (4P)

    - As an initial state problem, NWP is very sensitive against the initial state. Ensemble Forecasts compute 50 runs (of lower resolution) of the model with slight variations (slightly modified observations) and compares these 'ensemble forecasts' thus allowing forecasts of probability.

17. 4 Points: Why and where does the global oceanic conveyor belt start to form? (4P)
    - Between Greenland and Iceland: During sea ice forming, salt brine (water of high salinity and accordingly high density) sinks down. Sea ice is not salty, melting of sea ice results in fresh water, important for 'the real' Whisky on the rocks!

18. 4 Points: What is the reason for coastal upwelling / downwelling? (4P)
    - Wind-driven transport of surface water away from or towards the coast and resulting compensation by upwelling/downwelling near the coast.

19. 4 Which phenomenon is typically associated with up-/downwelling and has global climatological feedback effects? (4P)
    - El Nino/La Nina

20. 3 Points: Give typical values of salinity for Baltic Sea, other Oceans and for the Dead Sea. (3P)
    - Baltic Sea 3 o/ooo, Oceans typically 30 o/ooo equal to 3 %, Dead Sea 30 %

21. 4 Points: How is the characteristic wave height defined? (4P)
    - The average value of the highest third of observed wave heights.

22. 6 Points: Name the main factors to form wave heights specific for the Beaufort Force? (6P)
    - Wind force, sufficient duration, sufficient fetch (length of wind acting on the sea)

23. 2 Points: What is the difference between sea and swell? (3P)
    - Sea result of current wind field, swell generated in the past by another wind field at another location

24. 2 Points: Describe typical satellite orbits and their properties. (3P)
    - Polar orbit, geostationary orbit (**sufficient for full score**)
    - Polar orbit: altitude 800 km, period 90 min
    - Geostationary orbit: altitude 36.000 km, satellite at fixed position

25. 2 Points: What does the IR Greyscale of satellite images represent? (3P)
    - Temperature scale: black is warm (e.g. surface), white is cold (e.g. cloud tops)

170 Total Points