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Anomalous propagation: Examination of ducting conditions and anaprop events in SW-Germany

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Anomalous propagation (Anaprop) of electromagnetic rays

- In the atmosphere propagation described by refractivity N:

$$N = (n-1)\cdot 10^6 = 77.6\cdot\frac{p}{T} + 3.732\cdot 10^5\frac{e}{T^2}$$

where p: total atmospheric pressure (hPa), T: Temperature (K) and e: water vapor partial pressure (hPa) (Bean and Dutton, 1968)

→ bending of the radar beam by decrease of p, increase of T and decrease of e with height

→ dry warm air over wet cold air

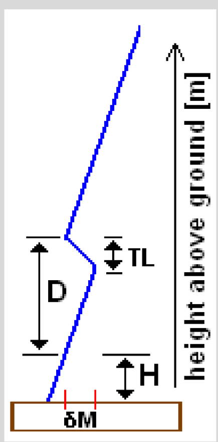
For practical purpose use of a modified refractivity M:

$$M := N + \frac{h\cdot 10^6}{R_e}$$

where h: height above ground and R_e: earth's radius

→ ducting conditions described by decrease of M, profile of M, resp. (Turton et al., 1988) with:

- duct height H [m]
- duct thickness D [m]
- duct strength δM [M-units]
- Trapping Layer TL



Calculation of the propagation

from Fermat's principle, the optical way of the beam has to be minimal

→ nonlinear second-order ordinary differential equation (Hartree et al. **1946**):

$$\frac{d^2h}{ds^2} - \left(\frac{1}{n}\frac{dn}{dh} + \frac{2}{R_e+h}\right)\left(\frac{dh}{ds}\right)^2 - \left(\frac{R_e+h}{R_e}\right)^2\left(\frac{1}{n}\frac{dn}{dh} + \frac{1}{R_e+h}\right) = 0$$

where n is the index of refractivity, s the arc element on the earth's sfc

Boundary conditions:

$$h(s=0) = h_0$$

$$\frac{dh}{ds}(s=0) = \frac{R_e+h_0}{R_e}\tan\varepsilon$$

where h_0 height of the radar, ε the elevation of the beam

Short 3 year ducting climatology of SW-Germany

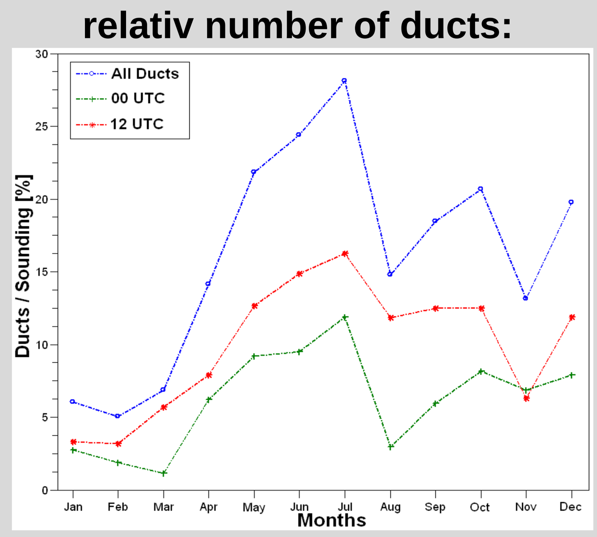
- **Data set:** operational radiosonde data from rawinsonde station Stuttgart-Schnarrenberg (WMO-ID: 10739)
- 00 UTC and 12 UTC soundings of 2004, 2005 and 2006
- „records":
  - largest duct thickness: 327.4 m (with Duct Height of 2010 m on 11.07.06, 00 UTC)
  - greatest duct strength: 27 M-units (at Duct Height of 1025 m on 11.08.05, 12 UTC)
- But high elevated ducts don't affect beam propagation (beam strikes ducting layer too steep)

→ additional criteria for finding relevant ducts: duct height ≤ 500 m

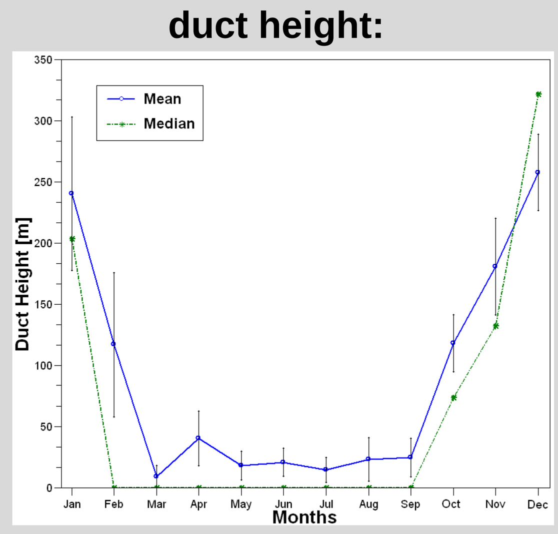
Total: 332 relevant ducts in 2067 soundings (16.1 %)

All ducts in the course of the year

relativ number of ducts:

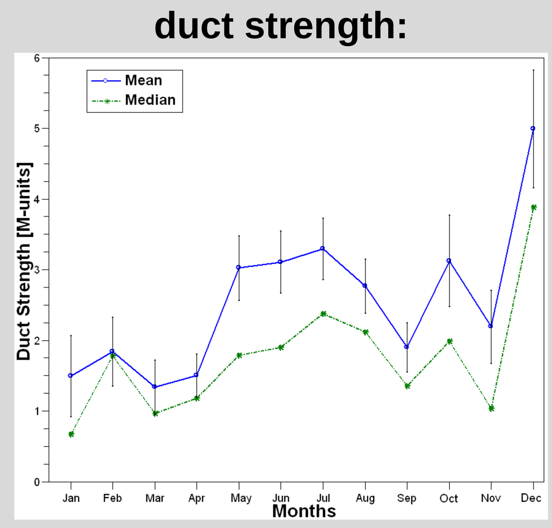


duct height:

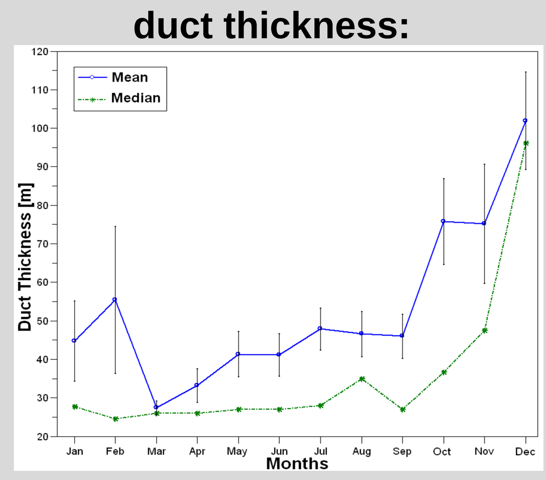


- more ducts in summer, october and december
- less ducts from january to march
- low ducts from march to september (median of duct height from february to september even at 0 m agl)
- strong ducts in summer, october and esp. in december
- large duct thickness esp. in december

duct strength:



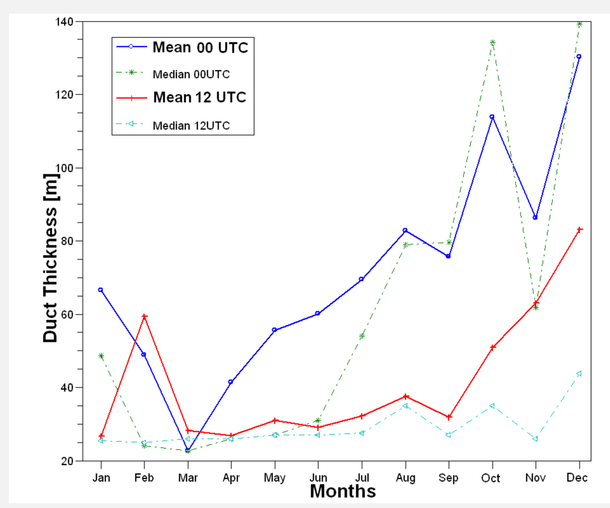
duct thickness:



meteorological interpretation

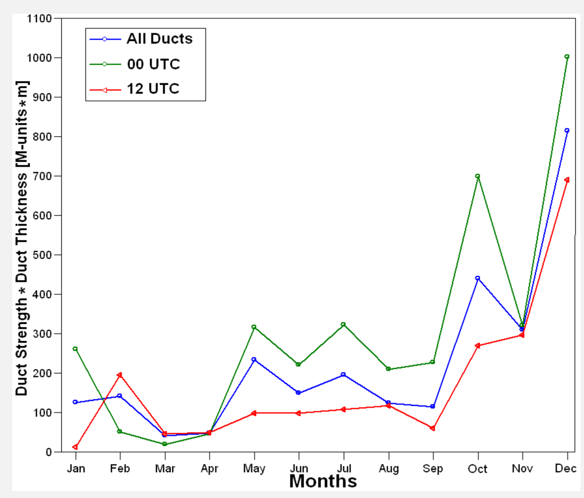
- In summer often persistent high pressure systems with temperature- and (more important) humidity inversions at the surface present.
- From october to december also frequent presence of persistant low level inversions.
- Duct-"poverty" from january to march based on frequent cyclonic-weather pattern, which provides for mixing and thus more standard conditions.

00 and 12 UTC difference



duct thickness

- Except of the „duct-poor" february march, duct thickness is larger at 00 UTC (night) than at 12 UTC (day)
  → beam stays „longer" in the ducting layer and thus can be bended „longer".
- Product of duct strength and duct thickness show - consistent with experience - that stronger ducting is to be anticipated during the night.
- High values of the product for october and december at both times show the persistant inversions during these months, which are also difficult to break during the day.



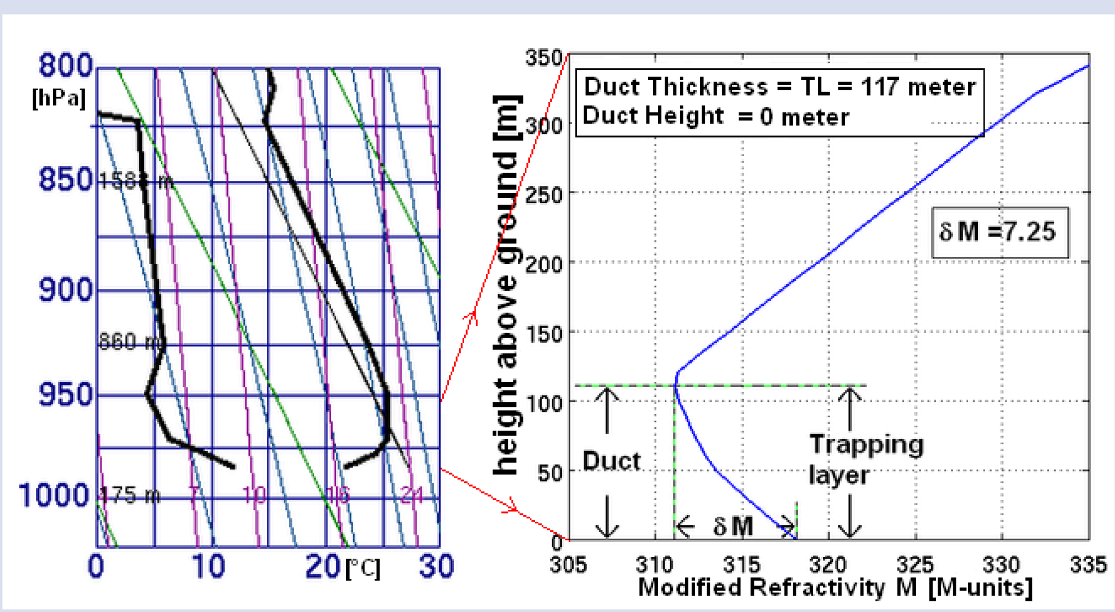
duct strength x duct thickness

Case study (19.07.2006)

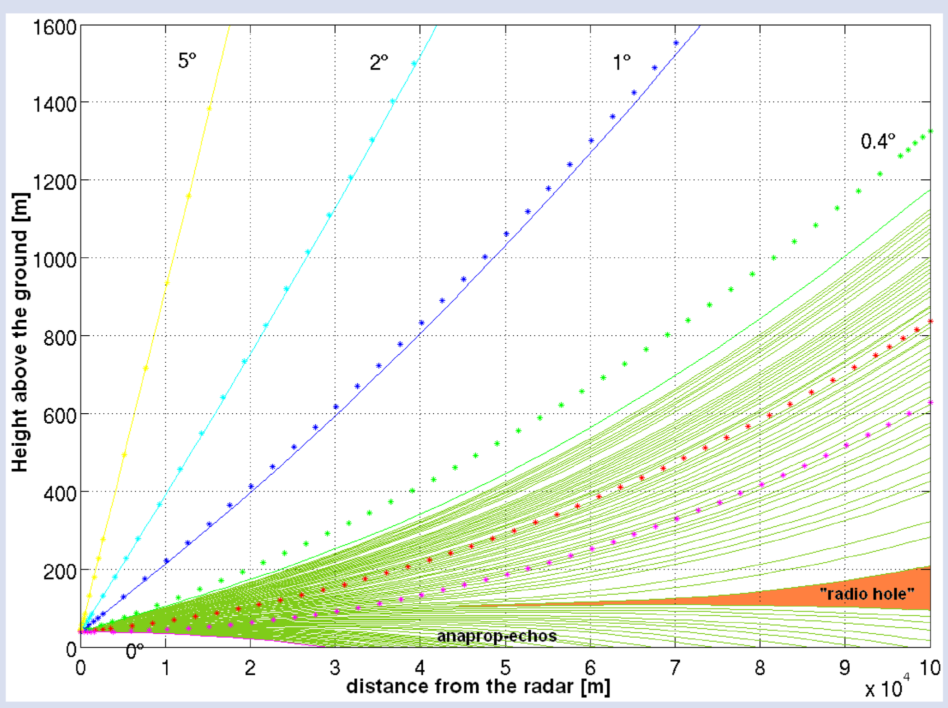
Synoptic background:

- marked blocking anticyclone present over Central Europe with large scale subsidence and warm subtropic air (maximum temperatures of the day over 30°C)
- During the night - besides an elevated subsidence inversion – formation of a marked radiation inversion

Vertical profiles:



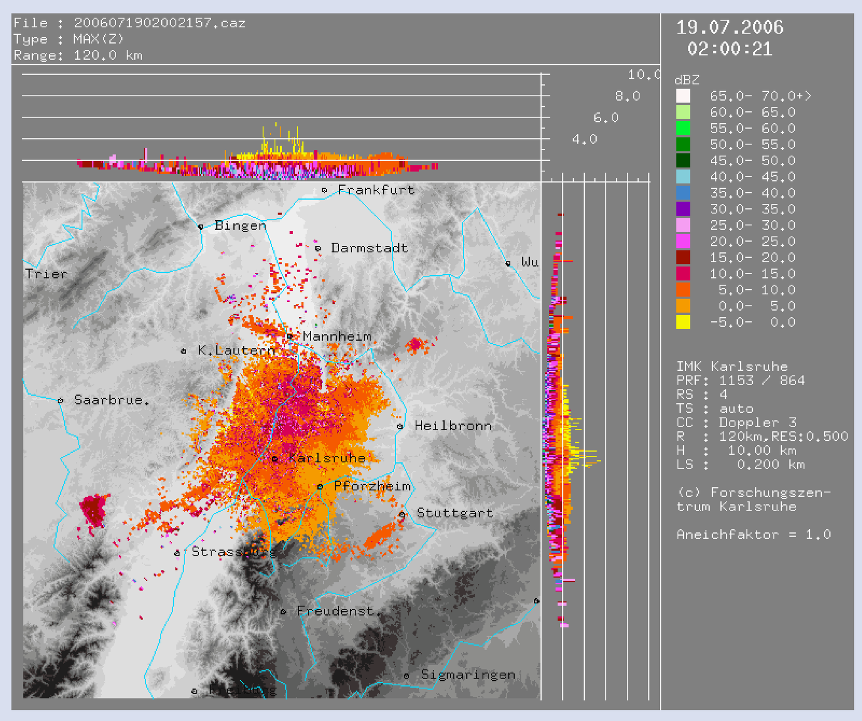
Calculated beam propagation:



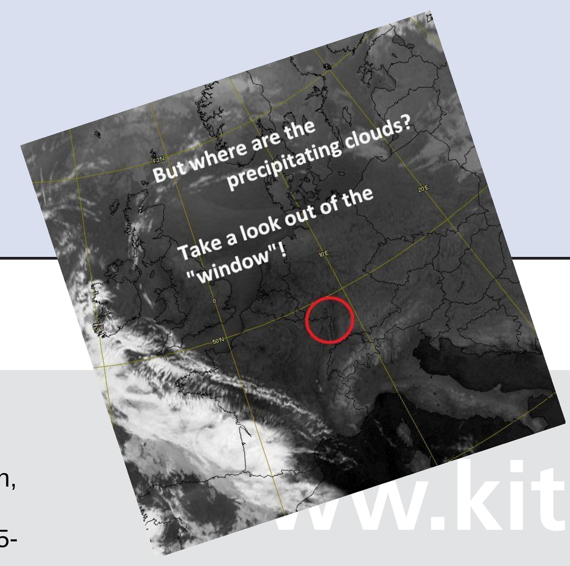
solid lines propagation based on the measured radiosonde profile, stars represent standard propagation for marked elevations

→ Anaprop echoes possible for lower elevations, especially from the side lobes.

Radar picture:



Even after applying a Doppler filter, some distinct echoes remain – SRIs (not shown) reach values of 0.3 to 0.5 mm/h, later on even of 1.0 mm/h.
8 h „Anaprop" - rainfall amounts up to 4.1 mm



References:

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