Die Dynamik tropischer Wirbelstürme

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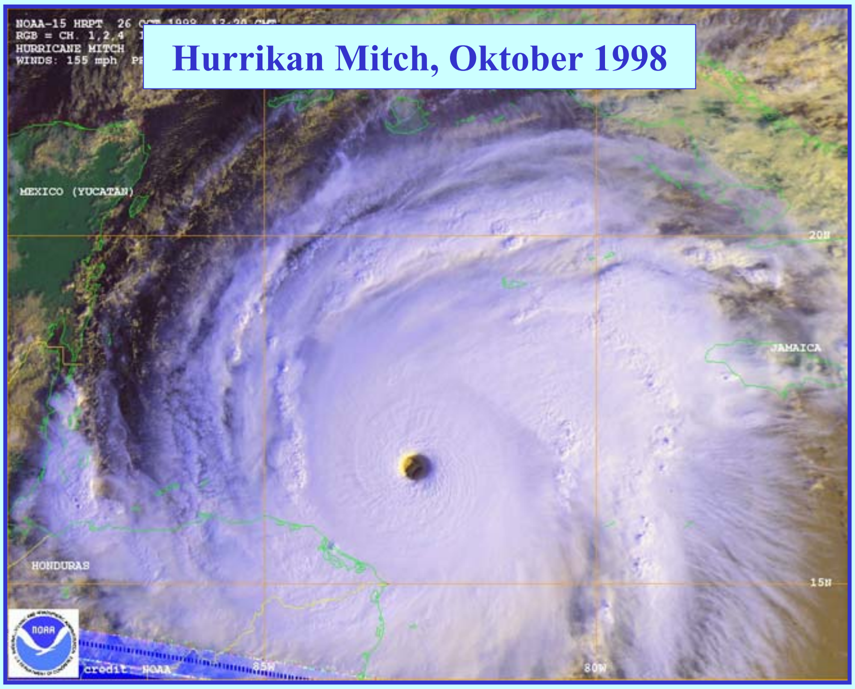
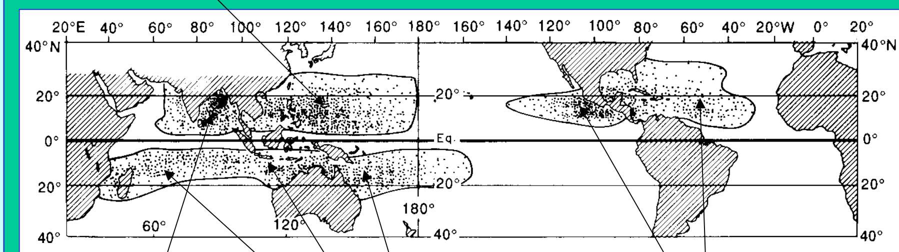
Hurrikan Mitch, Oktober 1998



Entstehungsgebiete

Taifune



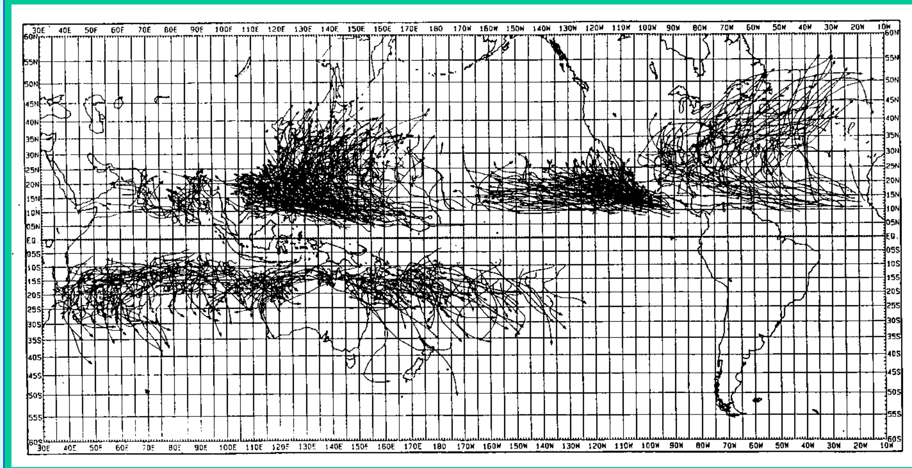
Zyklone

Tropische Zyklone

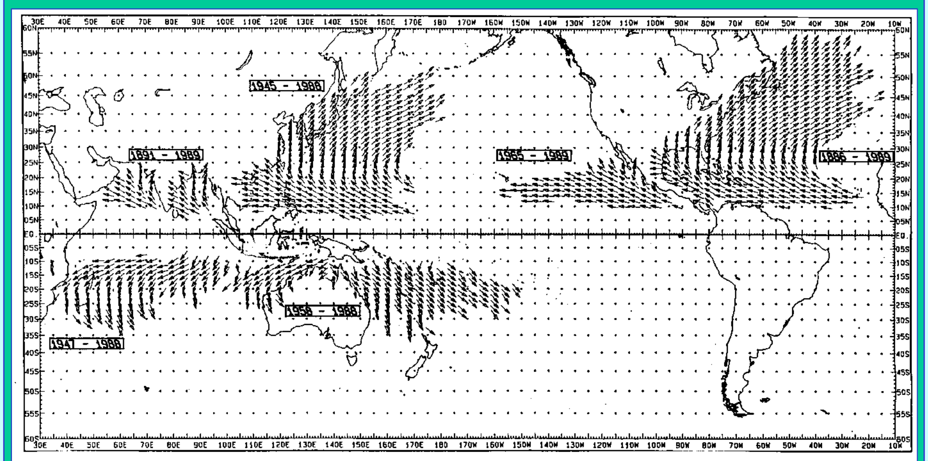
Hurrikane

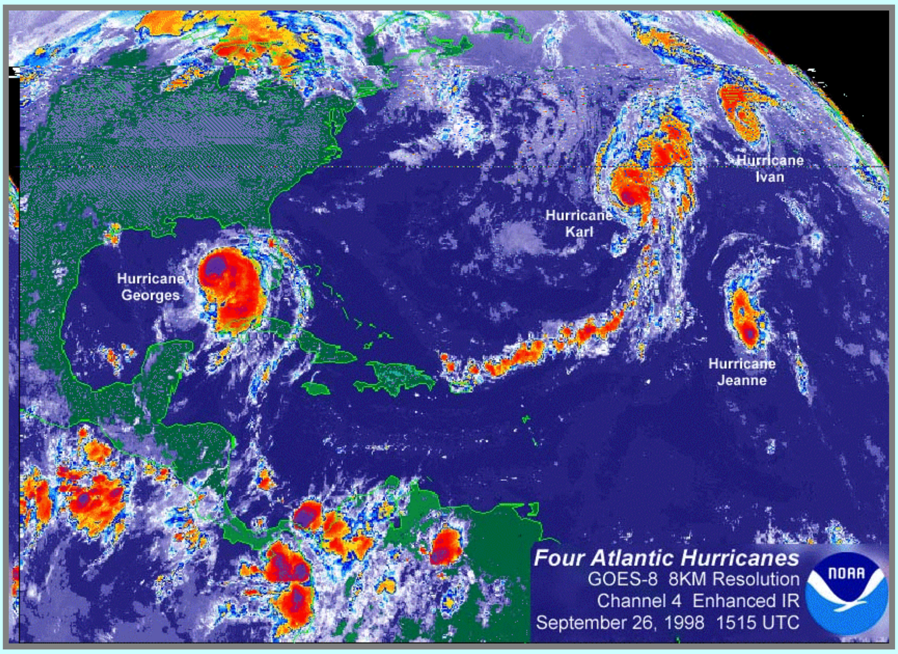
Tropische Zyklogenese benötigt eine Wassertemperatur von über 26.5 Grad C

Bahnen tropischer Wirbelstürme (1979-1988)

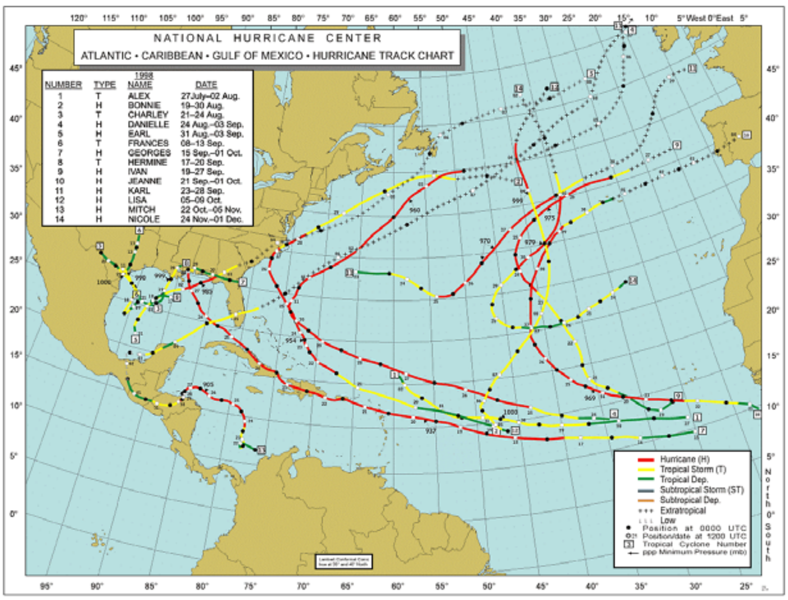


Gemittelte Bahnen tropischer Wirbelstürme

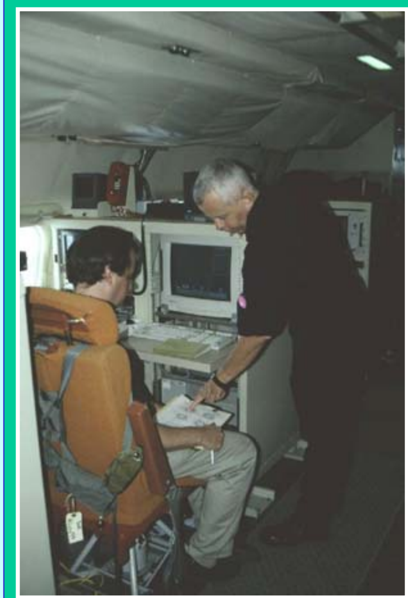




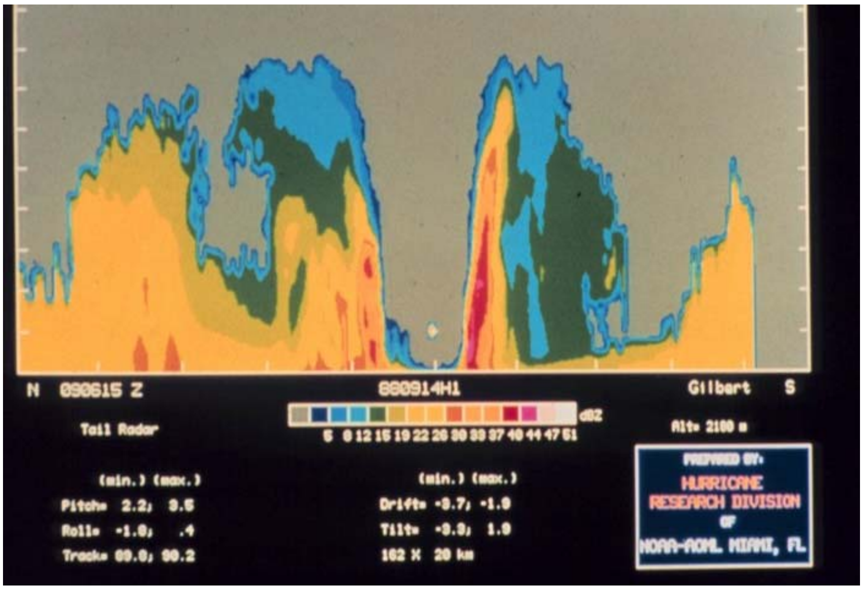
Zugbahnen der Hurrikane 1998



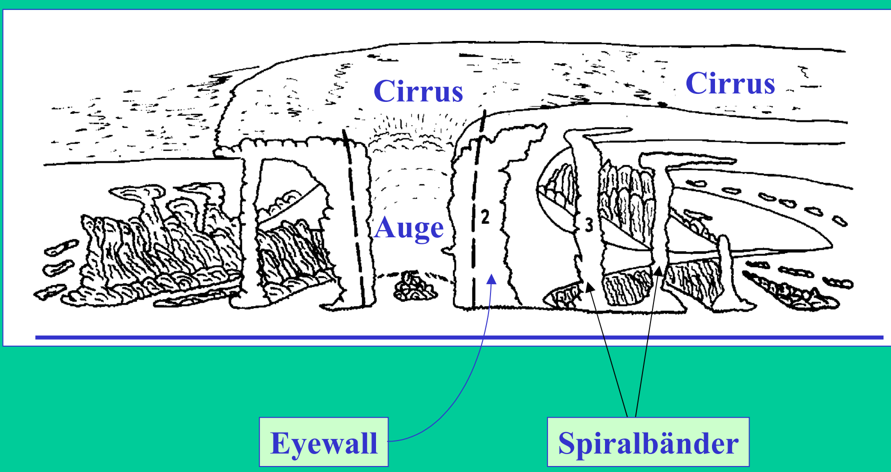
Hurrikan Forschungsflugzeug NOAA WD-P3



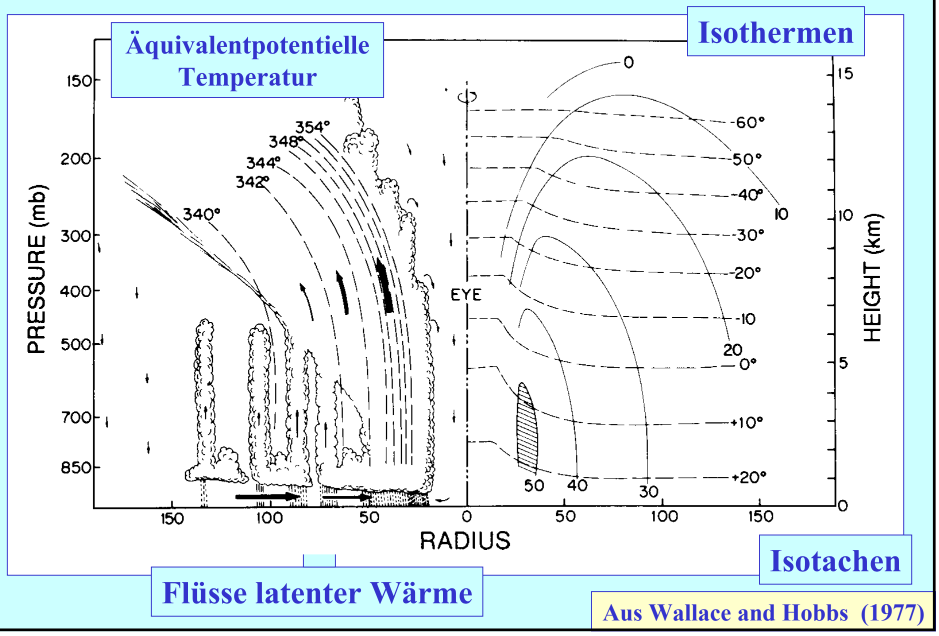
Radarbild vom Heckradar



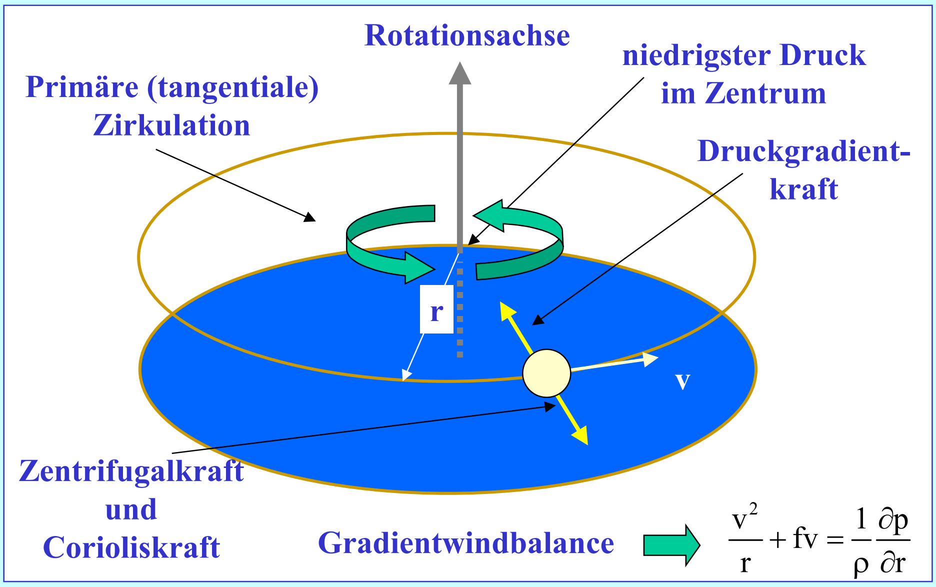
Schematischer Querschnitt durch einen Hurrikan



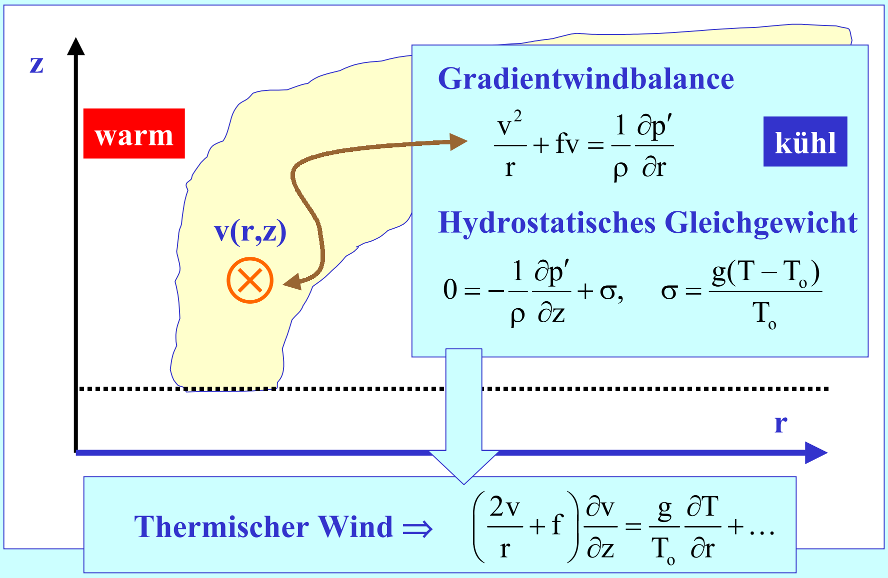
Vertikal-radialer Schnitt durch einen Hurrikan



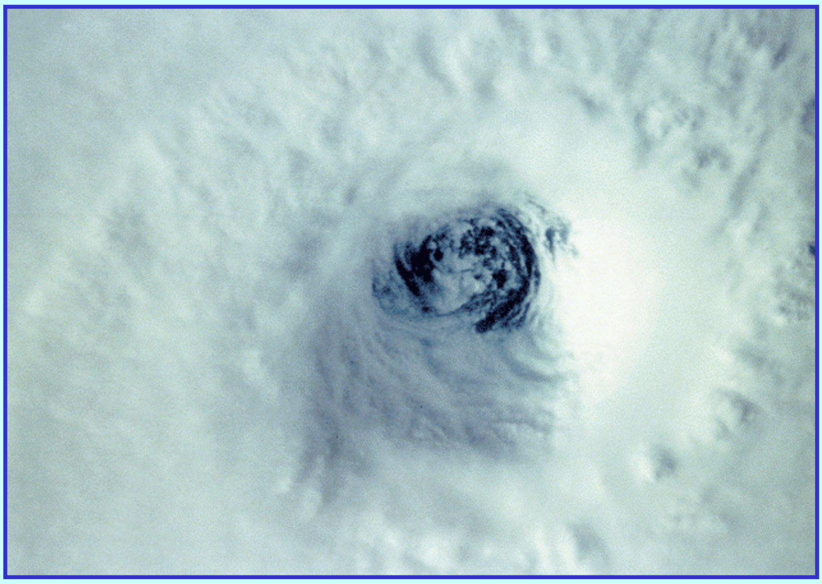
Kräftebilanz in einem Wirbel

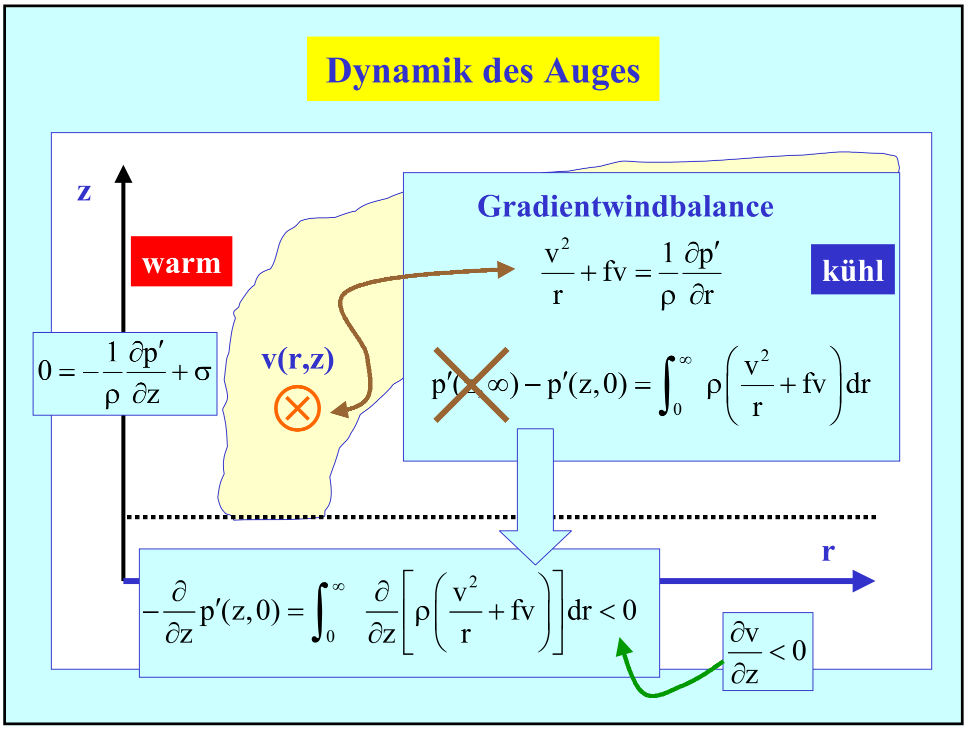


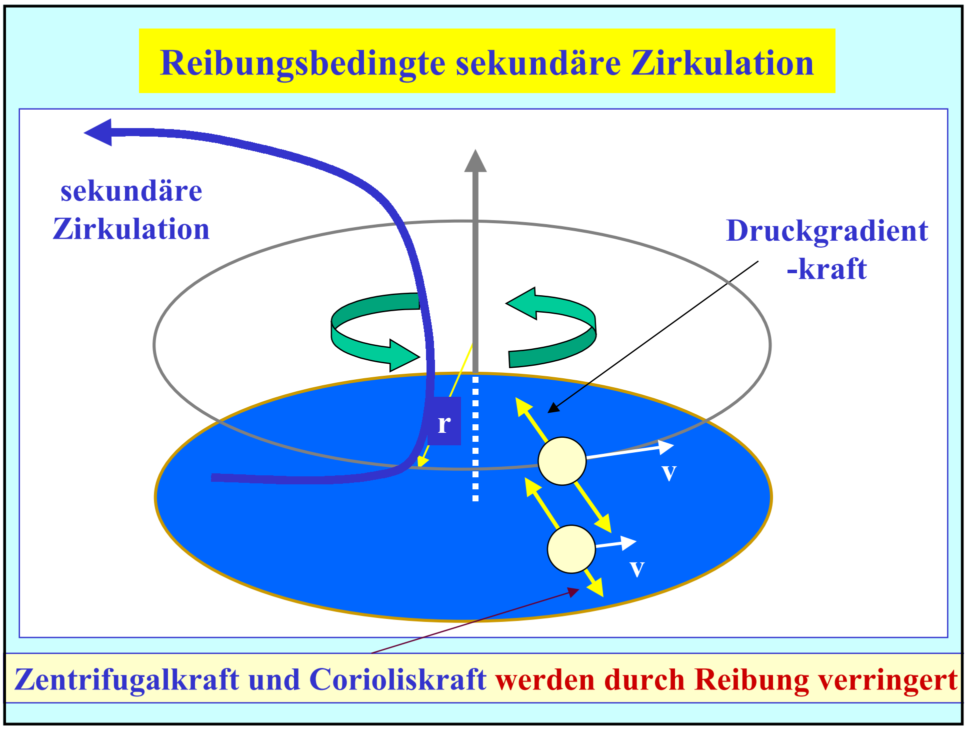
Primäre (tangentiale) Zirkulation



Grossaufnahme des Auges

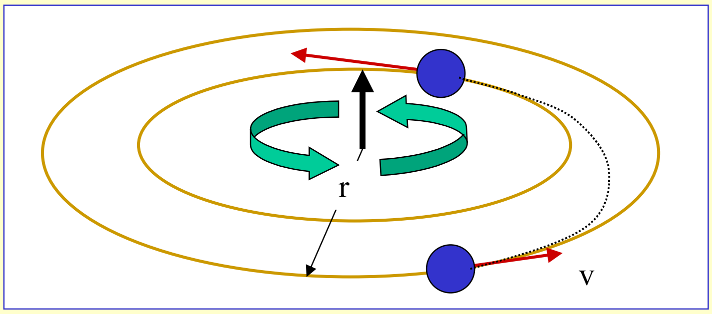



Dynamik des Auges
z
warm
$0 = -\frac{1}{\rho}\frac{\partial p'}{\partial z} + \sigma$
v(r,z)
Gradientwindbalance
$\frac{v^2}{r} + fv = \frac{1}{\rho}\frac{\partial p'}{\partial r}$
kühl
$p'(\infty) - p'(z,0) = \int_0^\infty \rho\left(\frac{v^2}{r} + fv\right)dr$
r
$-\frac{\partial}{\partial z}p'(z,0) = \int_0^\infty \frac{\partial}{\partial z}\left[\rho\left(\frac{v^2}{r} + fv\right)\right]dr < 0$
$\frac{\partial v}{\partial z} < 0$


Reibungsbedingte sekundäre Zirkulation
sekundäre
Zirkulation
Druckgradient
-kraft
r
v
v
Zentrifugalkraft und Corioliskraft werden durch Reibung verringert

Dynamik des Spinups von Wirbeln

- **Basisprinzip:**
  - **Erhaltung des absoluten Drehimpulses:** $M = rv + r^2 f/2$

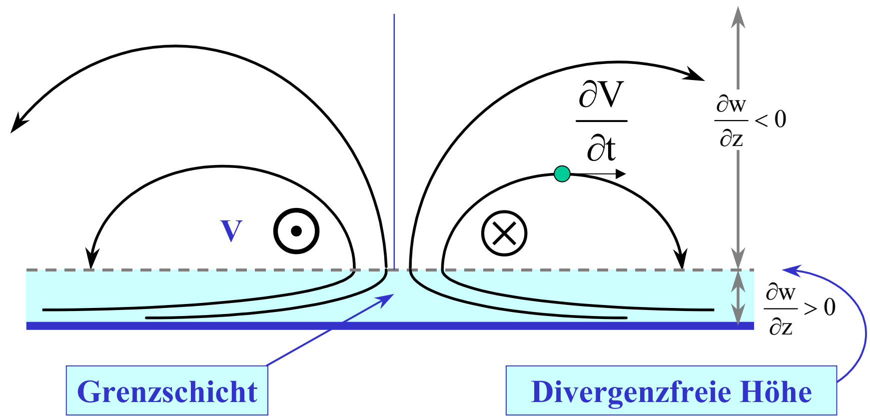


$v = M/r - rf/2$ ⇨ **Wenn r abnimmt, nimmt v zu!**

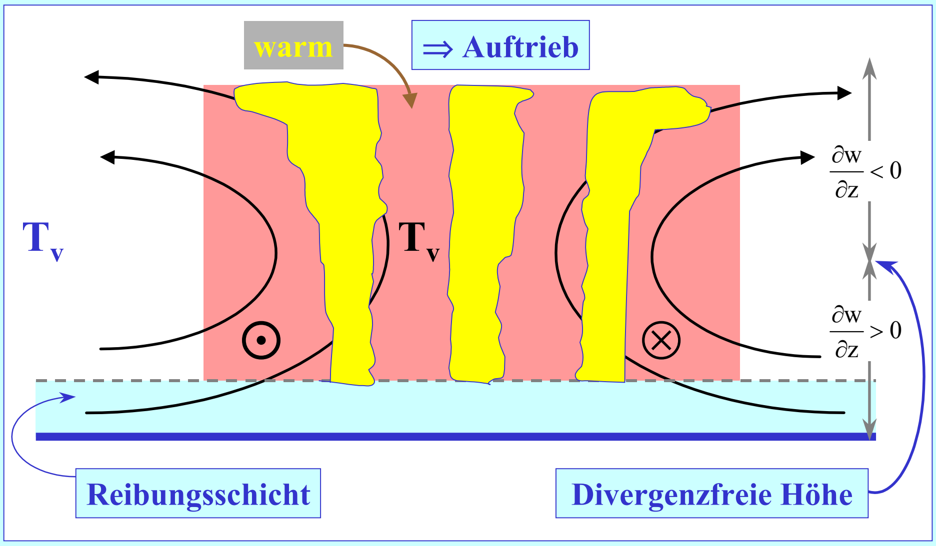
⇨ **Spinup benötigt radiale Konvergenz**

Dynamik des Spindowns von Wirbeln

Vertikaler Schnitt

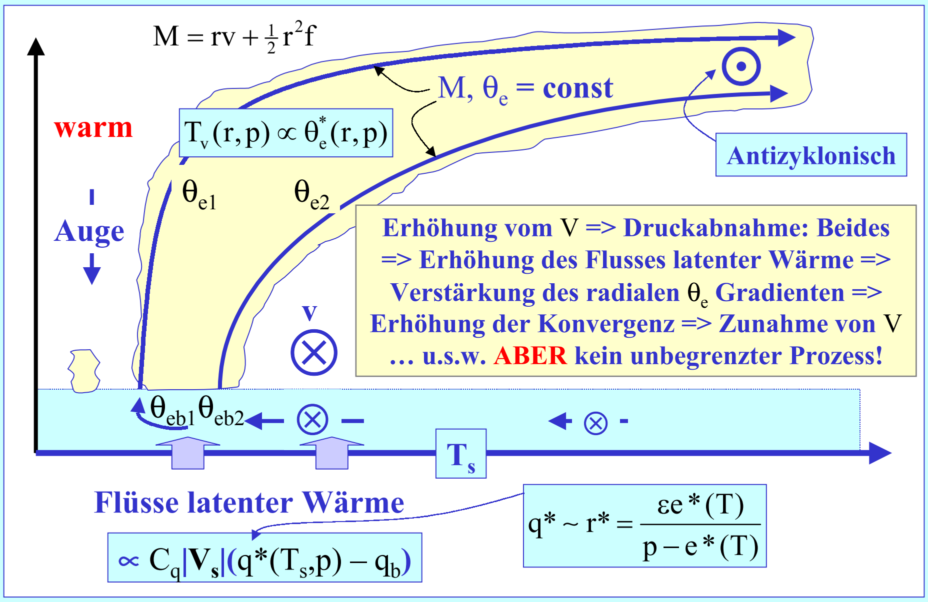


Auftrieb in einem Wirbel



Auftriebskraft ∝ horizontaler (virtueller) Temperaturunterschied

Theorie des "Wind-induced Surface Heat Exchange" (WISHE)



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A Minimal Three-Dimensional Tropical Cyclone Model

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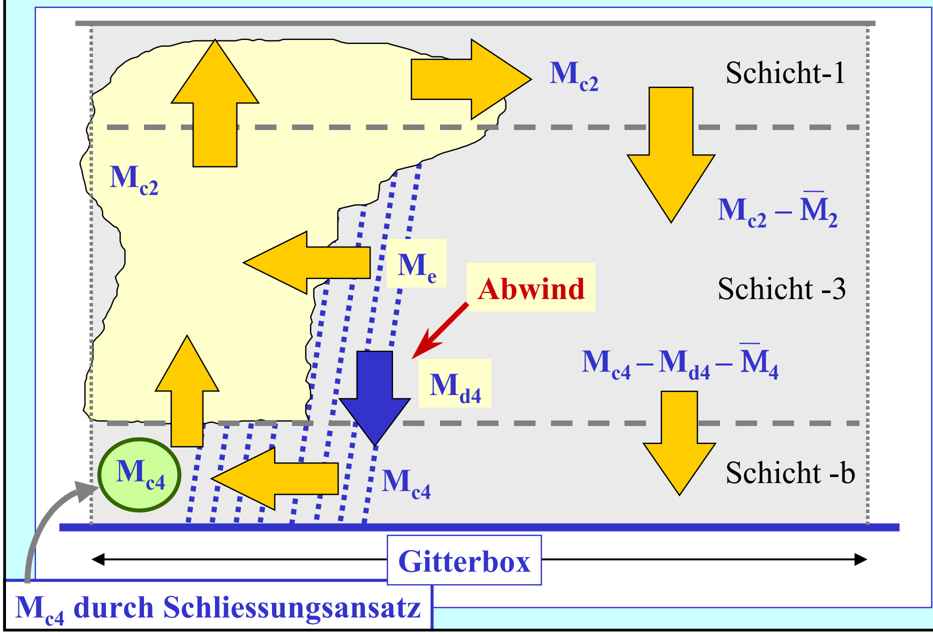
ABSTRACT

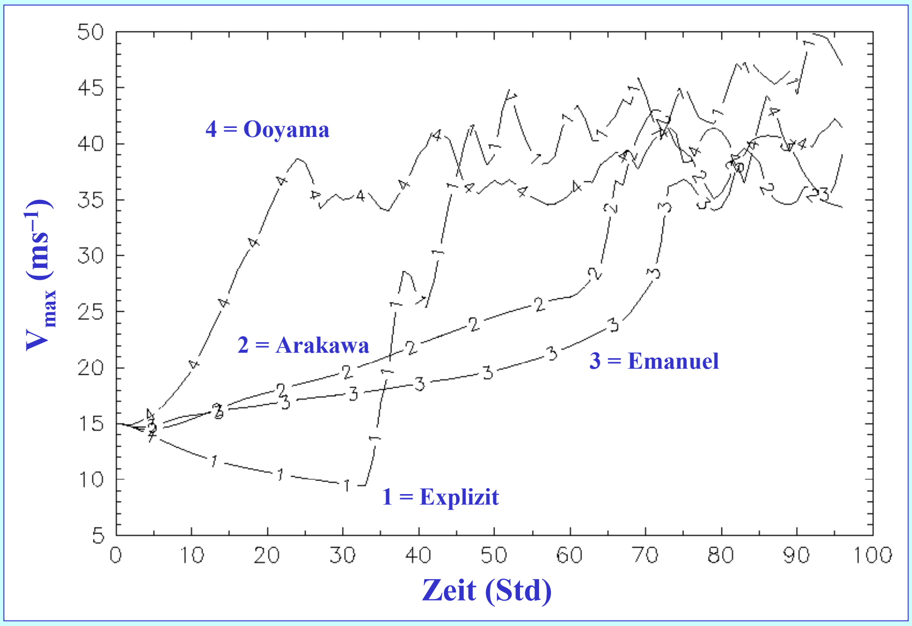
A minimal 3D numerical model designed for basic studies of tropical cyclone behavior is described. The model is formulated in σ coordinates on an f or β plane and has three vertical levels, one characterizing a shallow boundary layer and the other two representing the upper and lower troposphere, respectively. It has three options for treating cumulus convection on the subgrid scale and a simple scheme for the explicit release of latent heat on the grid scale. The subgrid-scale schemes are based on the mass-flux models suggested by Arakawa and Ooyama in the late 1960s, but modified to include the effects of precipitation-cooled downdrafts. They differ from one another in the closure that determines the cloud-base mass flux. One closure is based on the assumption of boundary layer quasi-equilibrium proposed by Raymond and Emanuel.

It is shown that a realistic hurricane-like vortex develops from a moderate strength initial vortex, even when the initial environment is slightly stable to deep convection. This is true for all three cumulus schemes as well as in the case where only the explicit release of latent heat is included. In all cases there is a period of gestation during which the boundary layer moisture in the inner core region increases on account of surface moisture fluxes, followed by a period of rapid deepening. Precipitation from the convection scheme dominates the explicit precipitation in the early stages of development, but this situation is reversed as the vortex matures. These findings are similar to those of Baik et al., who used the Betts–Miller parameterization scheme in an axisymmetric model with 11 levels in the vertical. The most striking difference between the model results using different convection schemes is the length of the gestation period, whereas the maximum intensity attained is similar for the three schemes. The calculations suggest the hypothesis that the period of rapid development in tropical cyclones is accompanied by a change in the character of deep convection in the inner core region from buoyantly driven, predominantly upright convection to slantwise forced moist ascent.

Die Parameterisierung hochreichender Konvektion



Maximale tangentiale Windgeschwindigkeit in der mittleren Schicht



Einige offene Fragen und Probleme

- Wie verhalten sich komplexe Modelle?
- Asymmetrische Spinup-Mechanismen
- Wechselwirkung mit Trögen in der oberen Atmosphäre
- Scherung des Horizontalwindes mit der Höhe
- Einfluss des Bodens: z.B. Ozeanoberfläche, das Verhalten des Austauschkoeffizienten in Bodennähe bei starkem Wind (> 20 m/s)
- Starkniederschläge
- Initialisierung von Vorhersagemodellen
- Umwandlung tropischer Zyklone im extratropische Systeme