

Changing tropical water vapour transports in high resolution atmospheric data

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My Background

- ▶ Polar Lows (regional scale Arctic Storms)

PhD in Hamburg with Hans von Storch
resulted in a series of papers (e.g.
GRL [*Zahn and von Storch(2008)*],
Nature [*Zahn and von Storch(2010)*])

- ▶ Hydrological Cycle/ Moisture Transports

Post Doc with Richard Allan and Lennart Bengtsson
one paper so far (JGR [*Zahn and Allan(2011)*])
one about to be submitted

high resolution instantaneous data

- ▶ in space and time ($\approx 0.5^\circ$, ≈ 30 vertical levels, $6h$)
- ▶ reanalysis (ERAint) 1989 -2008
- ▶ model (ECHAM5)
C20: 1960-1989, A1B: 2070-2100
- ▶ ω , \mathbf{U} and \mathbf{V} , q , pressure information

Method, two steps

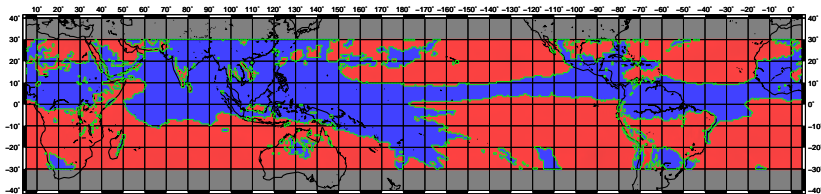
1. define ASC and DESC regions

- ▶ based on monthly mean and instantaneous ω
- ▶ $4 * 365 * 20 = 29200$ ASC/DESC masks

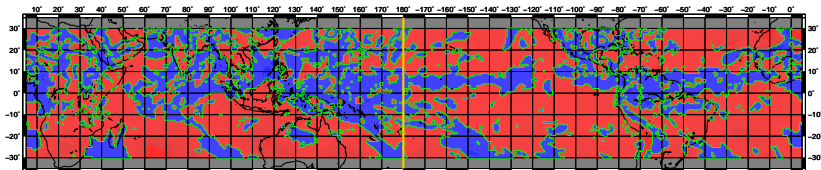
2. calculate moisture transport across boundary

- ▶ linking wind vectors with water content
- ▶ along all boundary segments (horizontally and vertically)
- ▶ monthly mean and instantaneous

Examples of monthly mean and instantaneous ω fields

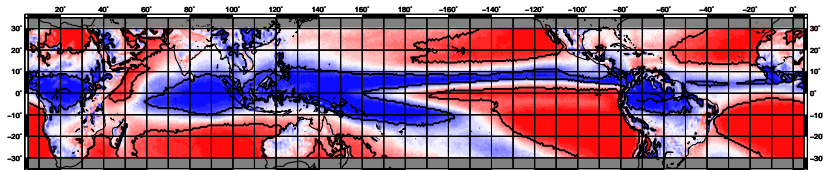


Jun 2008

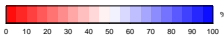
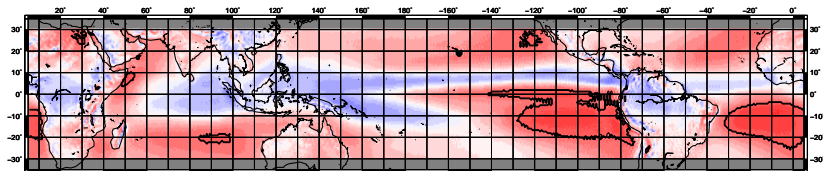


22 Jun 2008, 0:00

Frequency distribution of ASC (1989-2008)

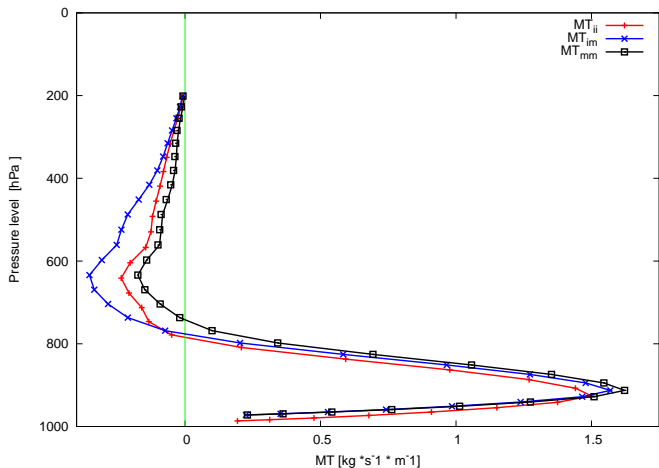


from monthly mean ω fields



from instantaneous ω fields

Vertical Profile of MT (1989-2008)



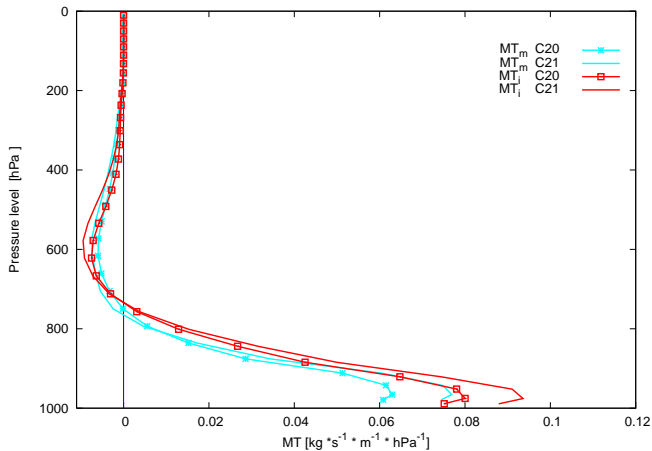
- ▶ lower level MT similar
- ▶ mid-level MT different

implication for the budget !

mean and trend for MT in different experiments

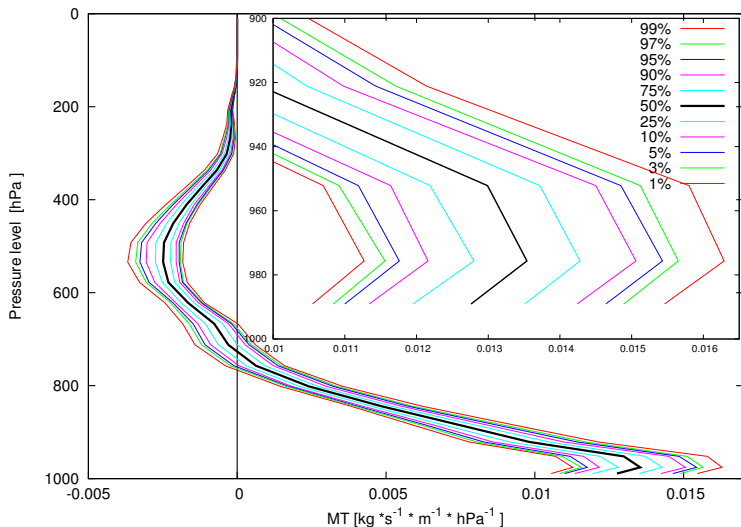
acronym	mean [$km^3 \cdot day^{-1}$]	trend [per year]
MT_{ij}	651.1	0.612
MT_{im}	320.3	0.236
MT_{mm}	404.6	0.514
P-E in ASC_m	320.0	0.274

Vertical Profile of MT C20/C21



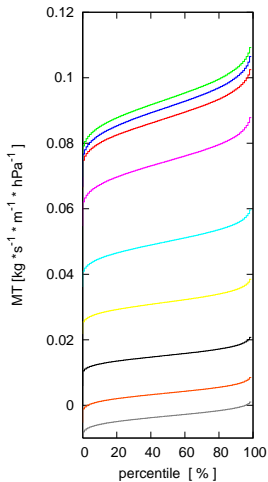
- ▶ lower level MT strengthened
- ▶ mid-level MT strengthened

MT_{ii} percentiles (C21 - C20)

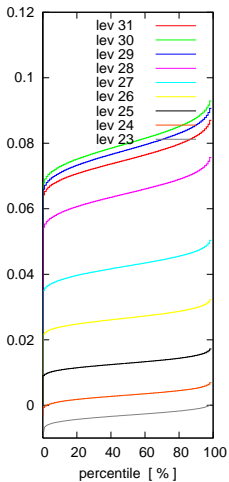


C21 - C20

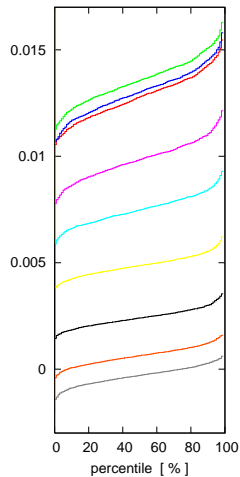
MT_{ii} percentiles at lower levels (C21 - C20)



(a) C21

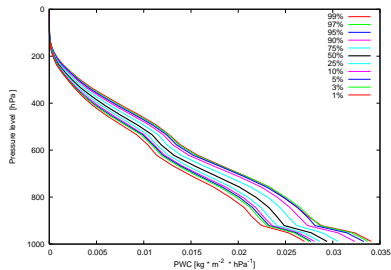


(b) C20

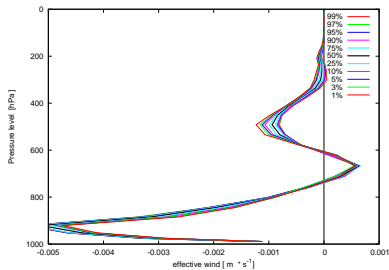


(c) C21 - C20

Changes of wind and humidity

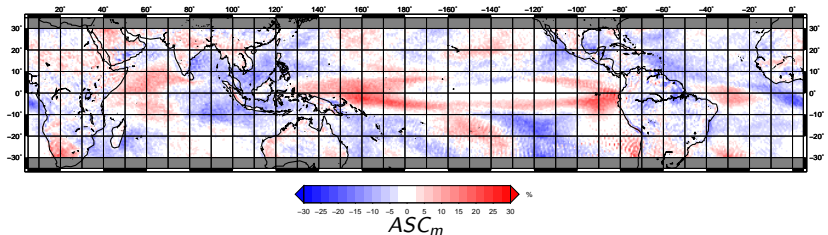
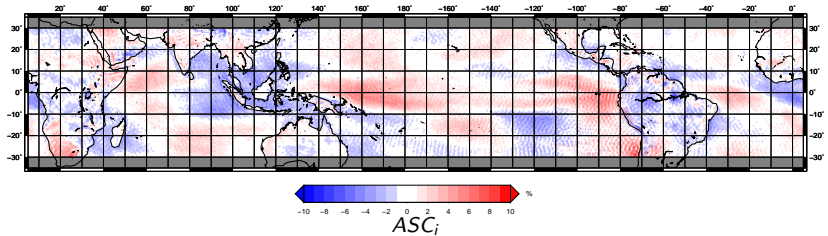


(d) PWC



(e) effective wind[Sohn and Park(2010)]

Tropical Circulation pattern. Changing frequency of ASC (C21 - C20)







Results

1. MT should be calculated instantaneously
 - ▶ definition of ASC/DESC region
 - ▶ mid level outward MT underestimated otherwise
2. MT projected to intensify with warming
 - ▶ especially at higher percentiles
 - ▶ due to higher humidity
3. (Changes of tropical circulation less distinct if based on instantaneous ω)
 - ▶ to be investigated in more detail ...

Thank you very much for your attention

<http://www.nerc-essc.ac.uk/maz/>

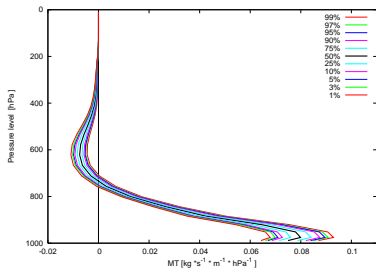
References

-  Sohn, B. J., and S.-C. Park, Strengthened tropical circulations in past three decades inferred from water vapor transport, *J. Geophys. Res.*, *11*, 2010.
-  Zahn, M., and R. P. Allan, Changes in water vapor transports of the ascending branch of the tropical circulation, *J. Geophys. Res.*, *116*, 2011.
-  Zahn, M., and H. von Storch, A long-term climatology of North Atlantic polar lows, *Geophys. Res. Lett.*, *35*, 2008.
-  Zahn, M., and H. von Storch, Decreased frequency of north atlantic polar lows associated

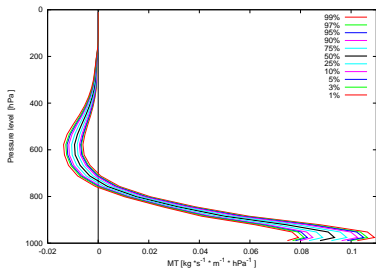
Bonus material

<http://www.nerc-essc.ac.uk/maz/>

Vertical structure of percentiles



(f) C20



(g) C21

Method

define ASC and DESC regions

- ▶ based on monthly mean and instantaneous ω
- ▶ $4 * 365 * 20 = 29200$ ASC/DESC masks

calculate moisture transport across boundary

$$MT_t = \sum_b^{n_b} \sum_l^{n_l} W_{bl} \cdot PWC_{bl} \quad (1)$$

MT: moisture transport

W: wind vector (positive towards ASC)

PWC : precipitable water content

t: time, b: boundary segment, l: level

PWC along boundaries C21 relative to C20.

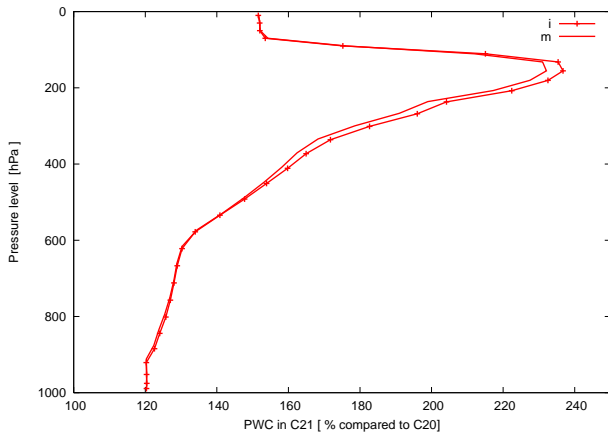
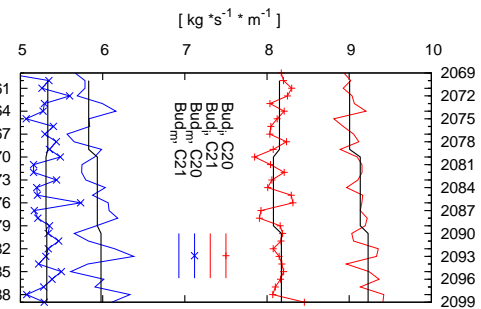
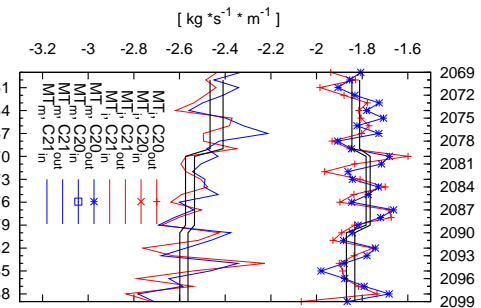
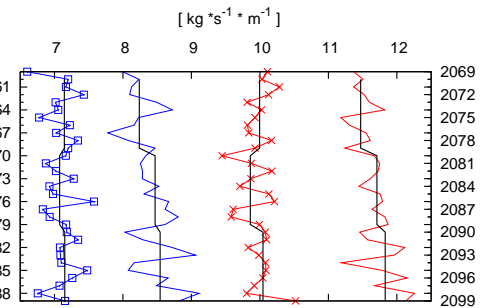


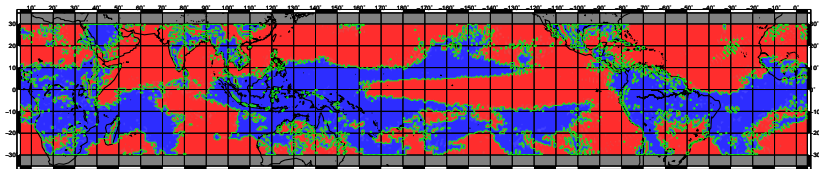
Figure: Percentage of precipitable water content along ASC/DESC boundary of ASC_i and ASC_m in C21 relative to C20. Unit of transport is mass of water [kg] per time [s] and area [$hPa * m$]. Note that the vertical unit of the area is given in pressure [hPa].

Time series of MT above and below RL

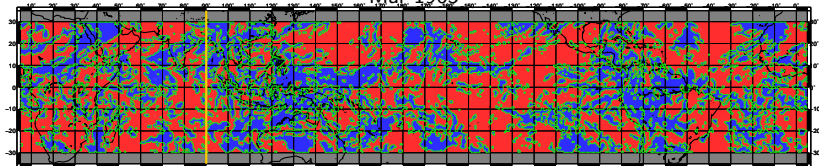
Temporal evolution of moisture transport into the ascending region.



Examples of monthly mean and instantaneous ω fields, ECHAM5 C20

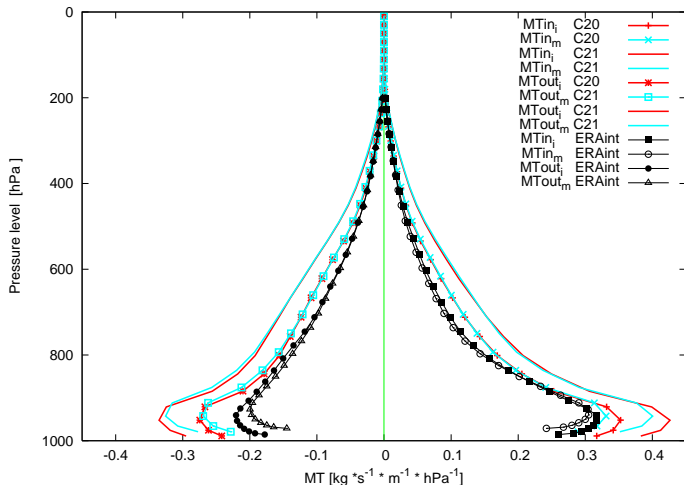


Mar 1965



22 Mar 1965, 6:00

Vertical profile of in an outflows, separately



MT outwards also strongest at low levels, Hadley pattern only exists in theory, average