Variability of intensification mechanisms of extra-tropical cyclones analysing ERA20C reanalysis

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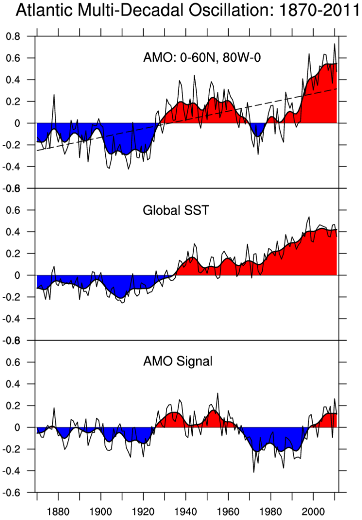
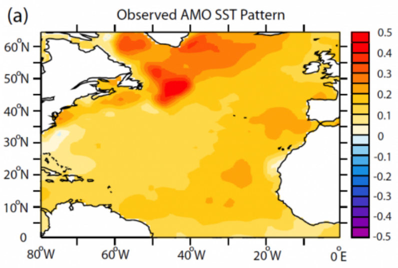
Motivation



[Trenberth and Shea, 2006]

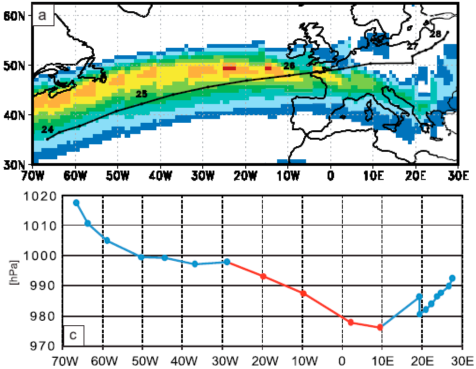


Trenberth et al.: The Climate Data Guide: Atlantic Multi-decadal Oscillation (AMO).

- decadal variability of SSTs
- decadal variability of mechanisms for development (pressure fall) of cyclones?

Introduction

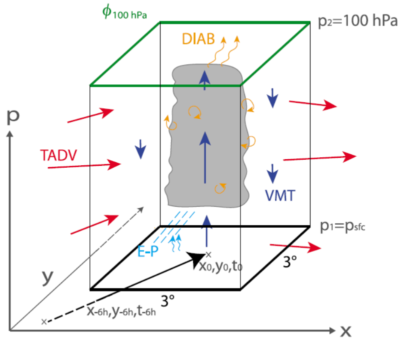
Lothar: between 24 and 28 December 1999



(upper panel) cyclone track and wind speed
(lower panel) core pressure
[Fink et al., 2012]

- red curve: explosive deepening
- change of core pressure
- $\Rightarrow$ pressure tendency equation

Pressure tendency equation (PTE) [Fink et al., 2012]



p_{sfc} : surface pressure

ρ_{sfc} : surface air density

ϕ_{p_2} : geopotential at $p_2 = 100\text{hPa}$

E, P : Evaporation, Precipitation

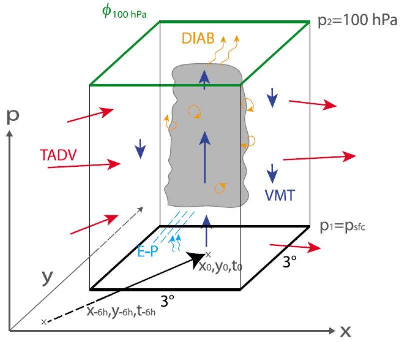
g : gravitational accelaration

R_d : gas constant

T_v : virtual temperature

$$\frac{\partial p_{sfc}}{\partial t} = \rho_{sfc}\frac{\partial \phi_{p_2}}{\partial t} + g\,(E - P) + \underbrace{\rho_{sfc} R_d \int_{sfc}^{p_2} \frac{\partial T_v}{\partial t} d \ln p}_{ITT} + RES_{PTE}$$

Integrated Temperature Tendency (ITT) [Fink et al., 2012]



ρ_{sfc} : surface air density

R_d : gas constant

$\vec{v}$: horizontal wind vector

T_v : virtual temperature

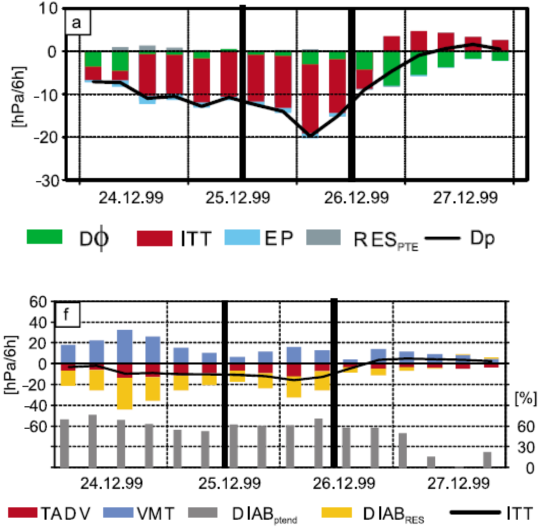
c_p : specific heat capacity

Q : diabatic heating rate

$$ITT = \rho_{sfc} R_d \int_{sfc}^{p_2} d\ln p \left[\underbrace{-\vec{v}\cdot\vec{\nabla} T_v}_{TADV} + \underbrace{\left(\frac{R_d T_v}{c_p p} - \frac{\partial T_v}{\partial p} \right)\omega}_{VMT} + \underbrace{\frac{T_v Q}{c_p T}}_{DIAB} \right]$$

$$+ RES_{ITT}$$

Example Lothar



[Fink et al., 2012]

in the following: analysis of TADV and DIAB in a 50 year dataset

Data and methods

ERA20C reanalysis (1.125°) between 1960 and 2008 [Poli et al., 2016]

Pressure tendency equation (PTE)

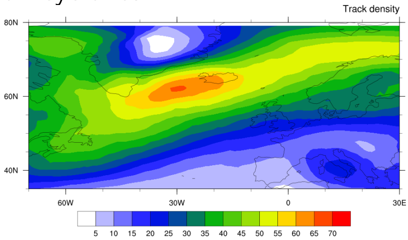
- Fink et al. [2012]
- 6hourly model level data
- interpolated to 10hPa pressure levels

Cyclone identification and tracking

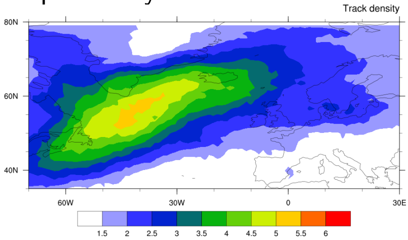
- Murray and Simmonds [1991], Pinto et al. [2005]
- 6hourly sea level pressure

Cyclone track density

all cyclones



explosive cyclones



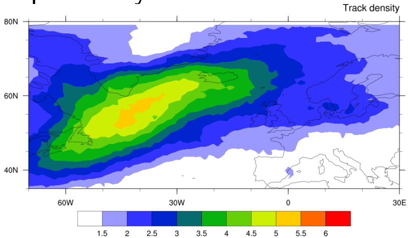
- cyclone track density on a 2.5°grid
  - density of tracks which pass a grid point within R=500km
- track density of explosive development ("bombs")

calculation of density of pressure tendency components (TADV, DIAB)

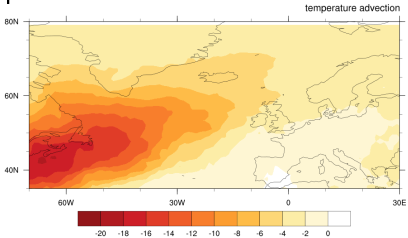
- for each track in a circle (R=150km) around cyclone core

Pressure tendency components (explosive cyclones)

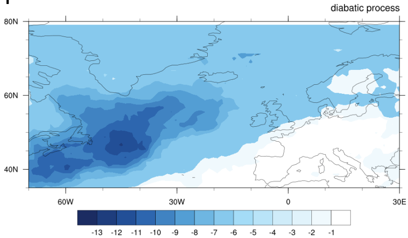
explosive cyclones



pressure fall due to TADV



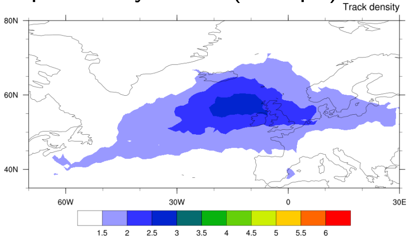
pressure fall due to DIAB



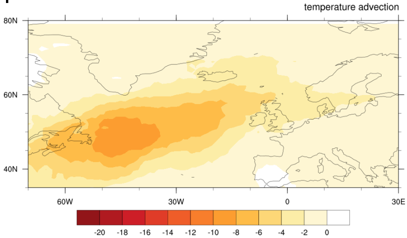
- Maximum of TADV is located near New Foundland where meridional temperature gradients are largest
- Maximum of DIAB agrees with maximum track density

Pressure tendency components (explosive cyclones EU)

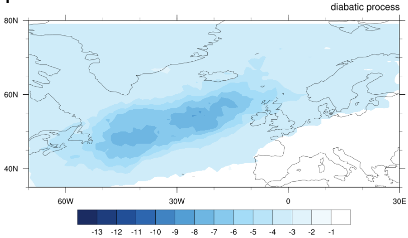
explosive cyclones (Europe)



pressure fall due to TADV



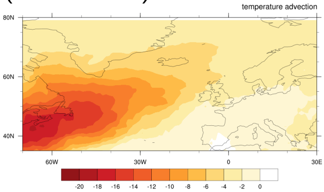
pressure fall due to DIAB



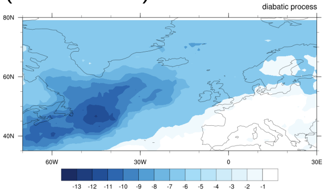
- Maximum of TADV is located East of New Foundland
- Maximum of DIAB in central North Atlantic

Timeseries PTE components (explosive cyclones)

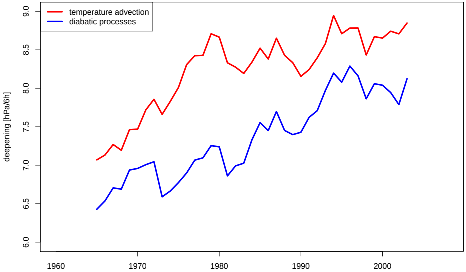
pressure fall due to TADV (1960-2008)



pressure fall due to DIAB (1960-2008)



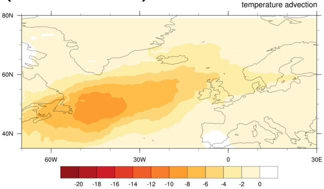
timeseries of spatial average
(11y running mean)



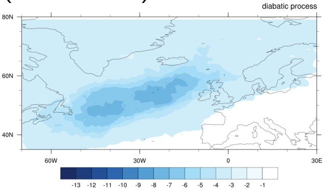
- TADV strongly increases from 1960 to 1980 and remains at high, stable levels afterwards
- DIAB contribution shows a positive trend during the whole analysis period

Timeseries PTE components (explosive EU cyclones)

pressure fall due to TADV (1960-2008)



pressure fall due to DIAB (1960-2008)



timeseries of spatial average
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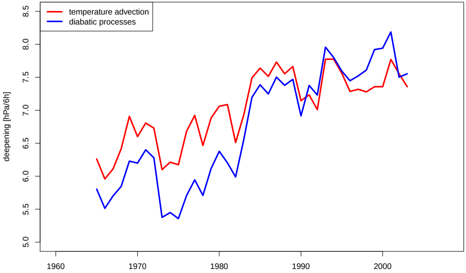

- TADV contribution shows a positive trend during the whole analysis period
- DIAB strongly increases between 1980 and 1990

Conclusion

- diagnosis of the PTE for extra-tropical cyclones [Fink et al., 2012] could be applied to ERA20C between 1960 and 2008

explosive cyclones

- a strong increase of the temperature advection component between 1960 and 1980 and no trend between 1980 and 2008
- maximum of TADV is located near New Foundland where meridional temperature gradients are largest

explosive cyclones reaching Europe

- maximum of TADV and DIAB is shifted towards central NA
- DIAB strongly increases between 1980 and 1990
- increase can be understood with temperature variability in the NA

possibility to analyze variability of intensification mechanisms

References

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