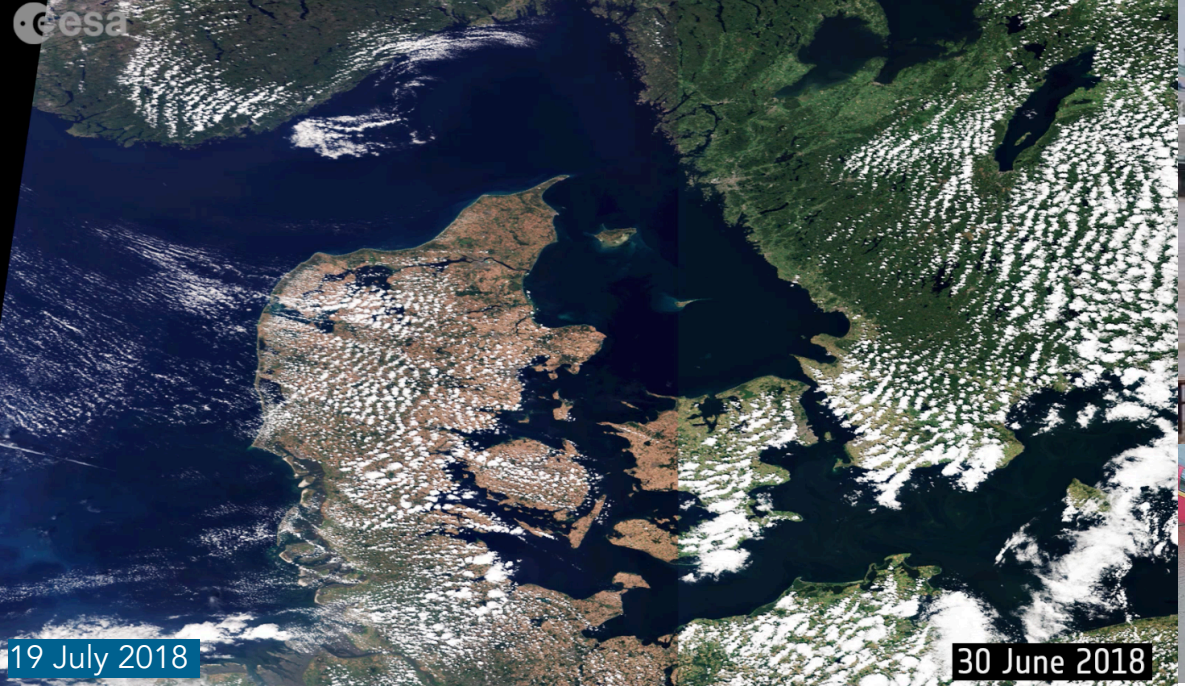

CMSAF Workshop 2019

Water transport diagnostics: satellite, model, and reanalysis based

Amelie Krug[1], Bodo Ahrens[1], Marc Schröder[2]

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Deutscher Wetterdienst
Wetter und Klima aus einer Hand
DWD

satellite image: https://www.esa.int/spaceinvideos/Videos/2018/07/ Dresden, Aug 2002: http://www.die-sachsen-kommen.de/shtm/hochwasser.htm

Outline

1. Data basis: satellite, reanalysis and model data

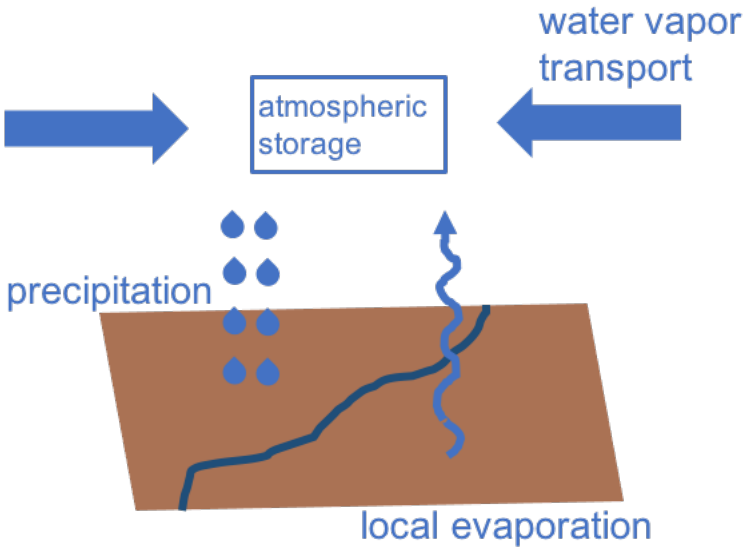
2. Water vapor transport diagnostics

3. Applications
    - Global Climatology (11/1987 – 12/2014)
    - Extreme Floods in Europe
    - Atacama desert (Böhm, C. et al.)

Data basis

- HOAPS-4.0 satellite data (Andersson et al., 2017):
  - evaporation, precipitation, integrated water vapor
  - ocean without sea-ice
  - 1987—2014, https://doi.org/10.5676/EUM_SAF_CM/HOAPS/V002
- ERA-Interim Reanalysis data (Dee et al., 2011):
  - specific humidity, horizontal wind fields
  - since 1979
- ERA-20C Reanalysis data (Poli et al. 2016):
  - integrated water vapor
  - 1900--2010
- COSMO-CLM simulation data (Naveed Akhtar, IAU, now at HZG)
  - uncoupled setup driven by ERA-Interim
  - coupled with regional ocean model NEMO (North- and Baltic Sea, Mediterranean Sea), driven by ERA-Interim

How did we calculate the water vapor transport?



horizontal water vapor transport $\vec{Q}$:

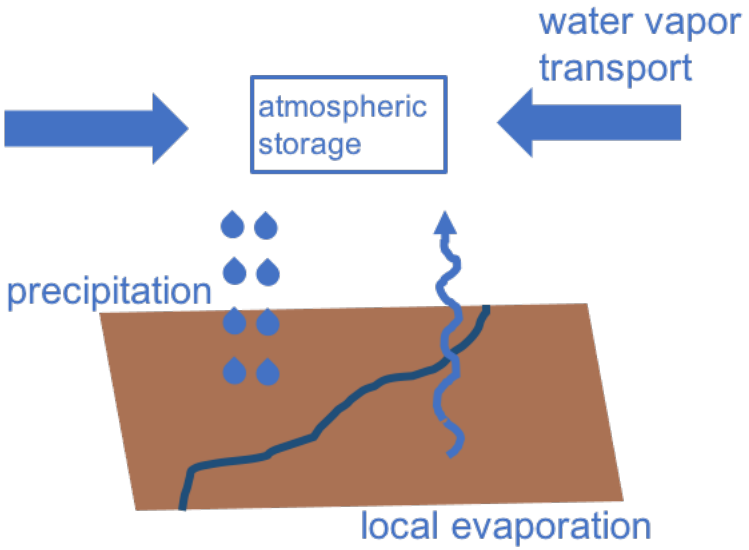
$$\vec{Q} = \frac{1}{g} \int_0^1 q \, \vec{V} \, \frac{\partial p}{\partial \eta} \mathrm{d}\eta,$$

with gravity acceleration g, specific humidity q, and horizontal wind $\vec{V}$ (and the vertical hybrid model coordinate η).

→ **high resolution vertical profiles of specific humidity and horizontal wind**

→ **reanalysis and model data**

How did we calculate the water vapor transport?



water balance equation:

$$\frac{\partial (W + W_c)}{\partial t} + \mathrm{div}(\vec{Q} + \vec{Q}_c) = E - P,$$

with evaporation E, precipitation P, and the column-integrated total water content $W+W_c$ and the divergence of the horizontal water vapor flux vector $\vec{Q}$.

→ **indirect calculation (Sohn et al., 2004)**

→ **satellite data can be used!**

→ HOAPS-4.0

Climatology in satellite & ERAint data (Dez. 1987 – Nov. 2014)

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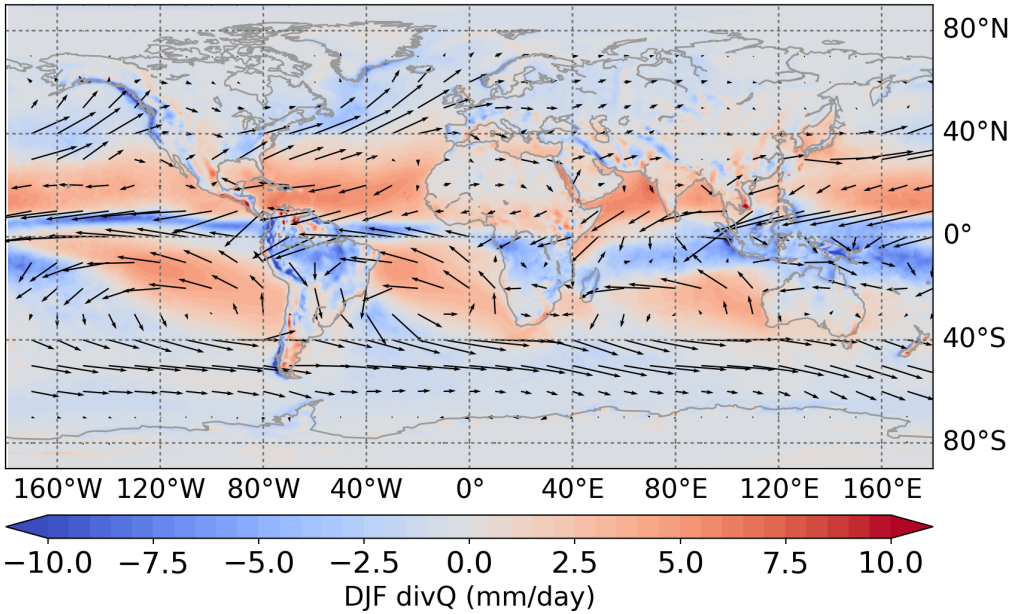
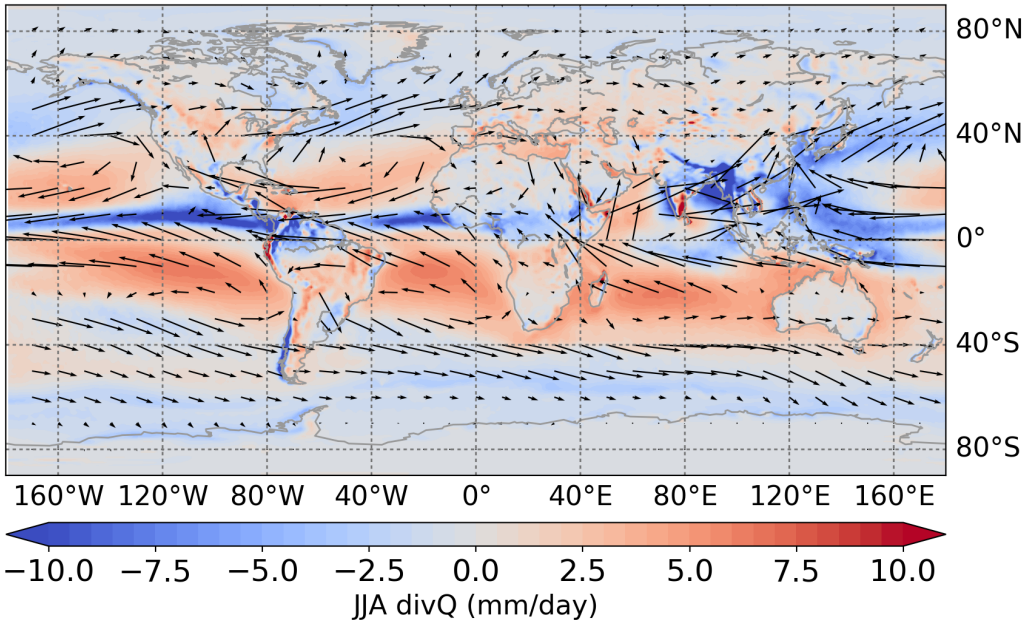
winter (DJF)



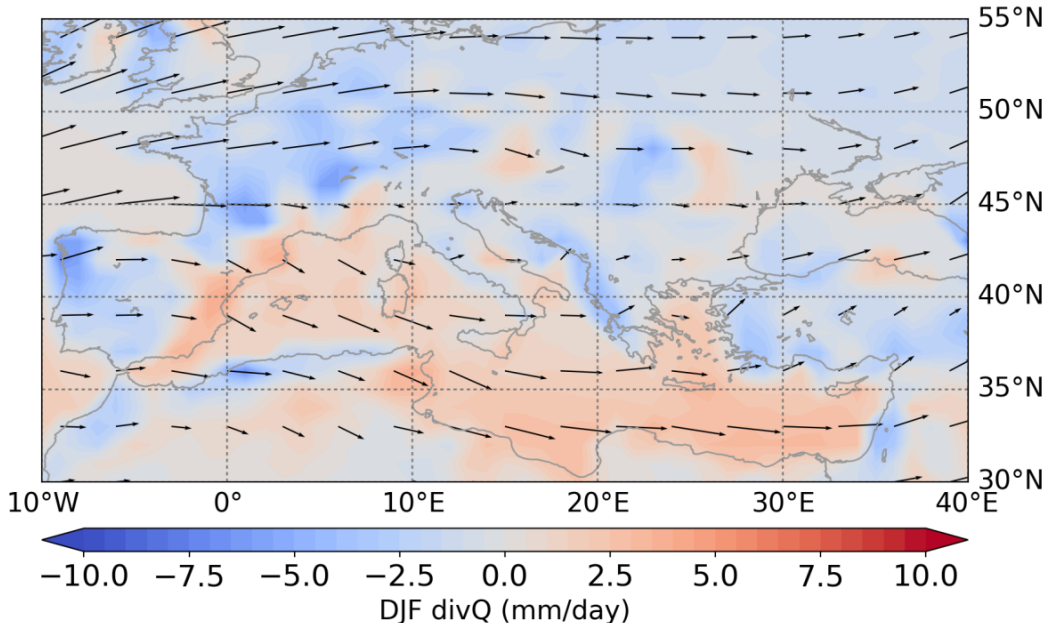
summer (JJA)



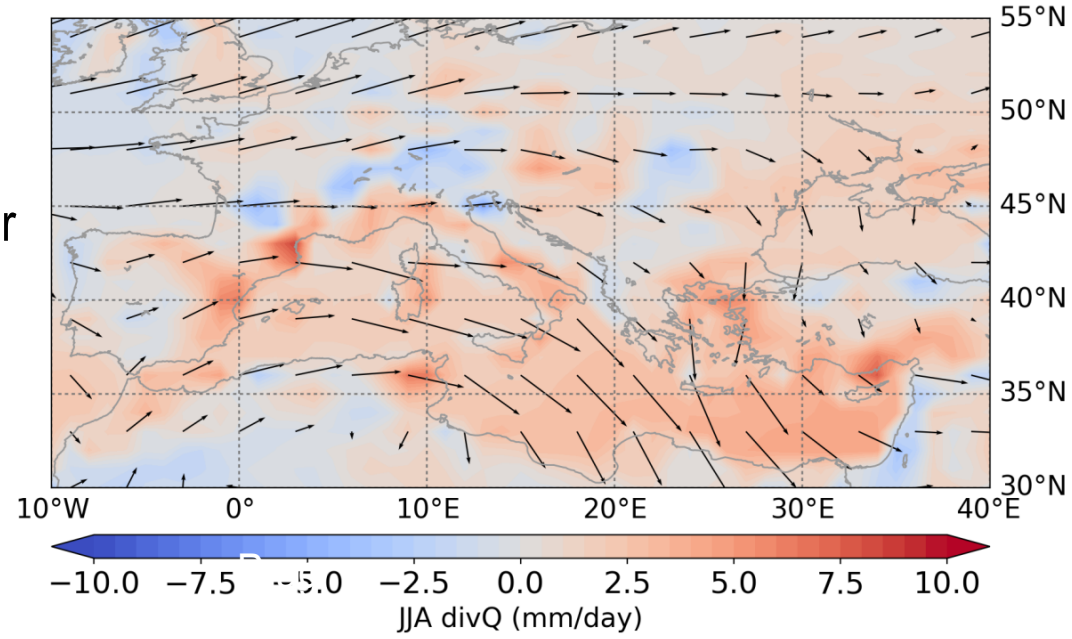
vector field: water vapor transport $\vec{Q}$ (m/s)

Climatology in satellite & ERAint data (Dez. 1987 – Nov. 2014)

winter (DJF)



summer (JJA)

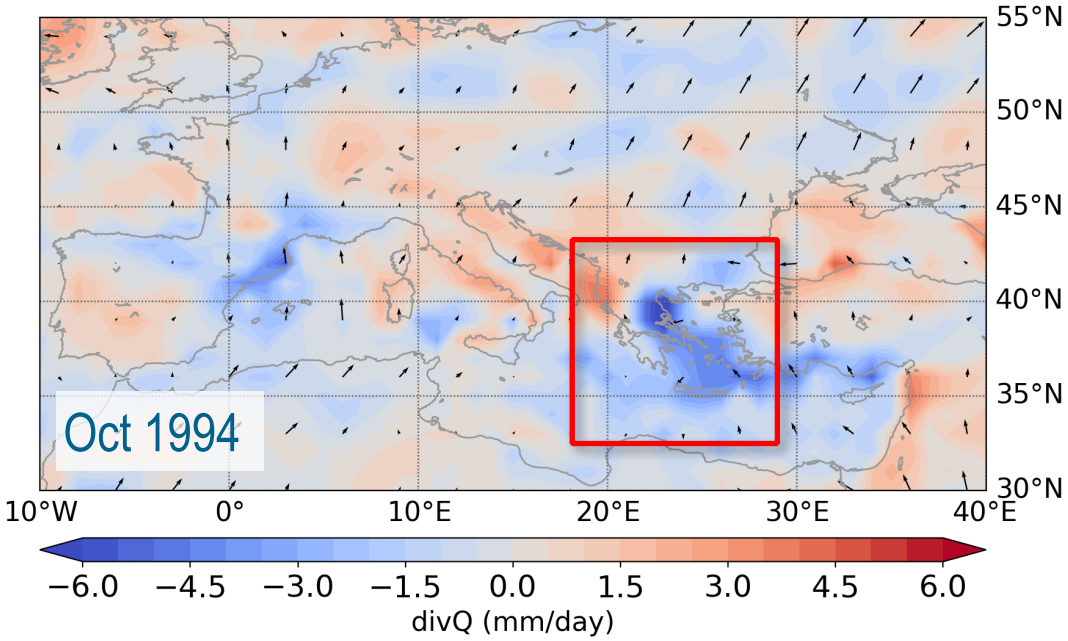


vector field: water vapor transport $\vec{Q}$ (m/s)

Extreme Floods in Europe: October 1994

- HOAPS-satellite & ERAint data

deviation from the climatology (1987-2014)



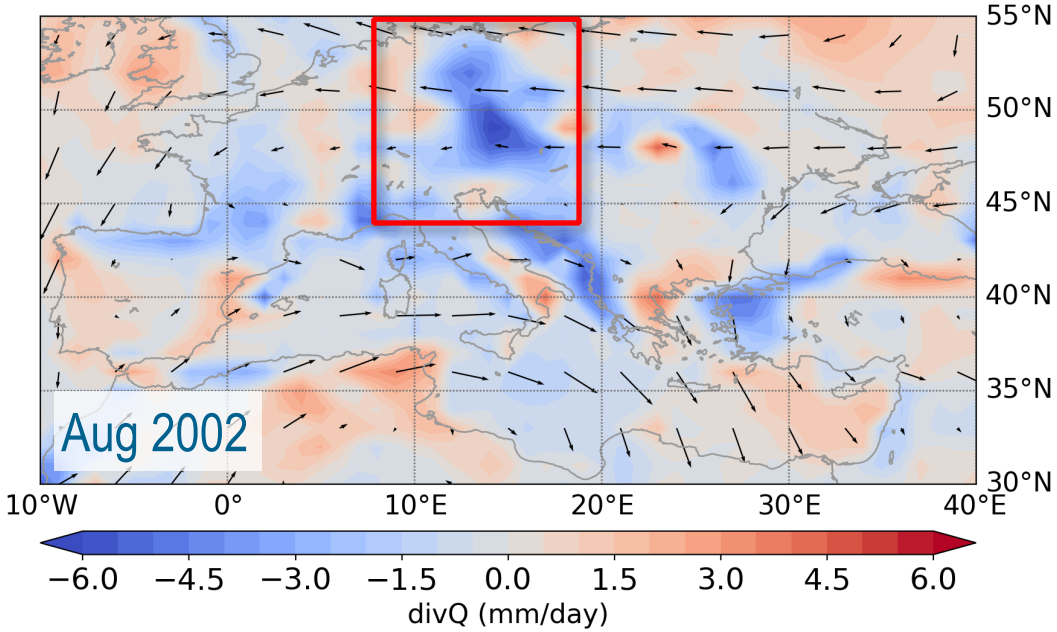
→ 21-22 October 1994: one of the most severe flash floods in Greece during the past decades

figs: Mimikou, M. & Koutsoyiannis, D. 1995: Extreme floods in Greece: The case of 1994

Extreme Floods in Europe: August 2002

- HOAPS-satellite & ERAint data

deviation from the climatology (1987-2014)



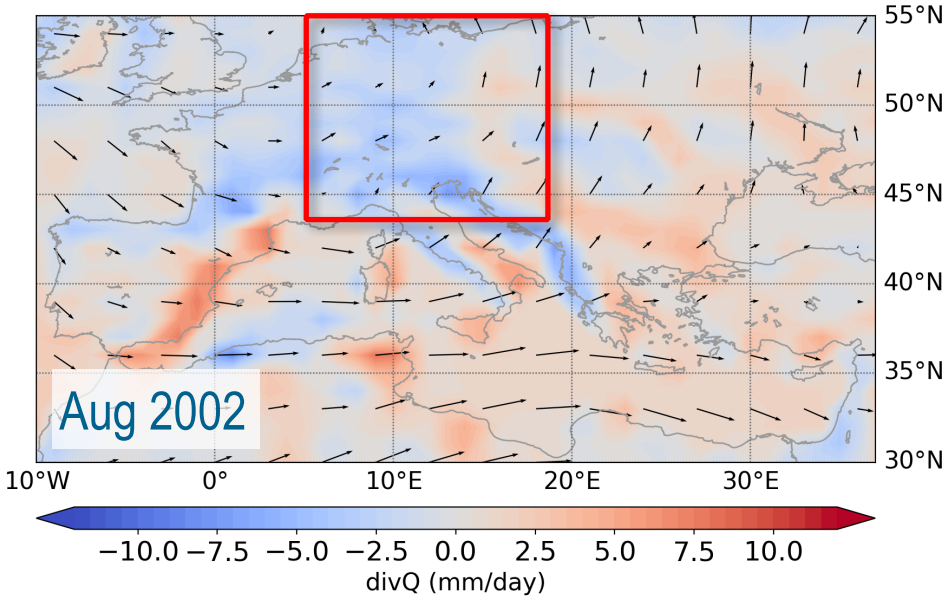
→ August 2002: Elbe flooding (Vb-cyclone)

Photos: http://www.die-sachsen-kommen.de/shtm/hochwasser.htm

Extreme Floods in Europe: August 2002

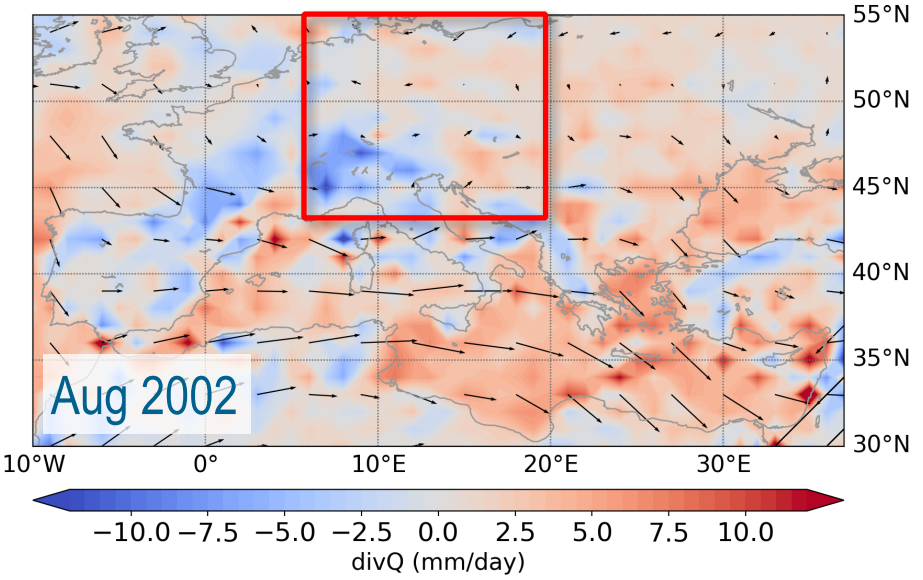
- HOAPS-satellite & ERAint data

monthy mean water vapor transport



- COSMO-CLM simulation; driven by ERAint

monthy mean water vapor transport

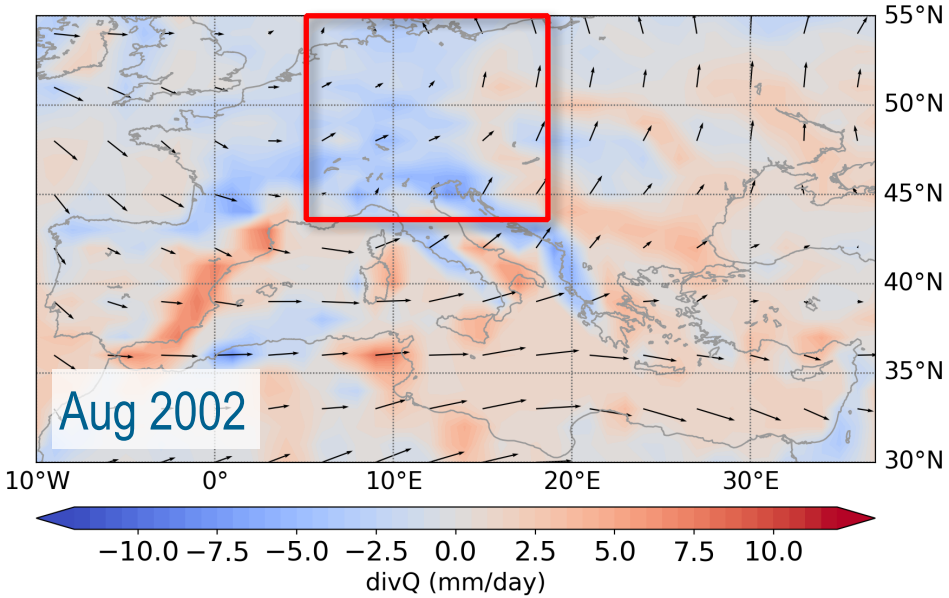


→ August 2002: Elbe flooding (Vb-cyclone)

Extreme Floods in Europe: August 2002

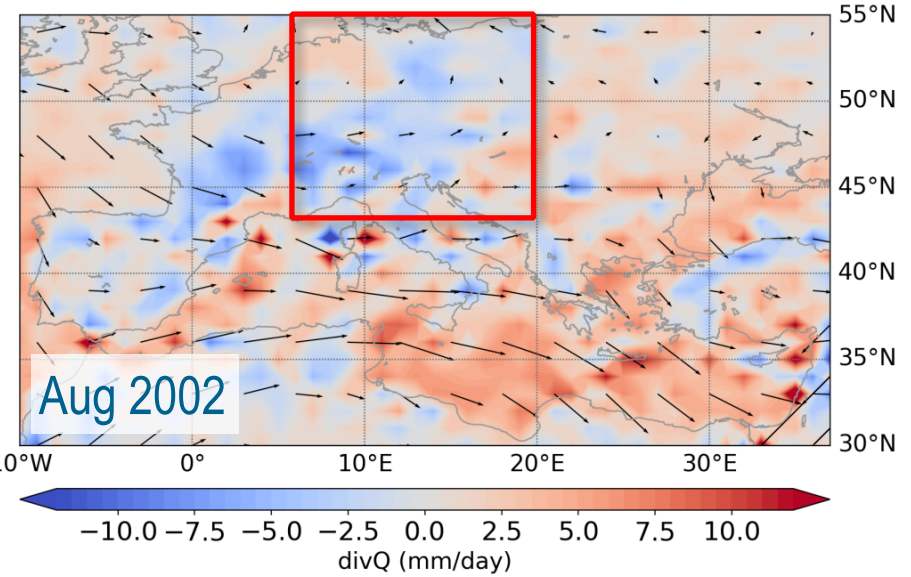
- HOAPS-satellite & ERAint data

monthy mean water vapor transport

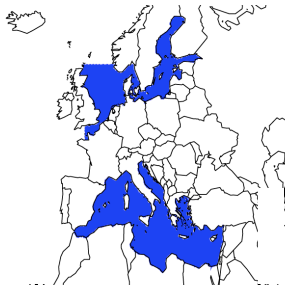


- COSMO-CLM, **coupled** with the **regional ocean model NEMO**; driven by ERAint

monthy mean water vapor transport



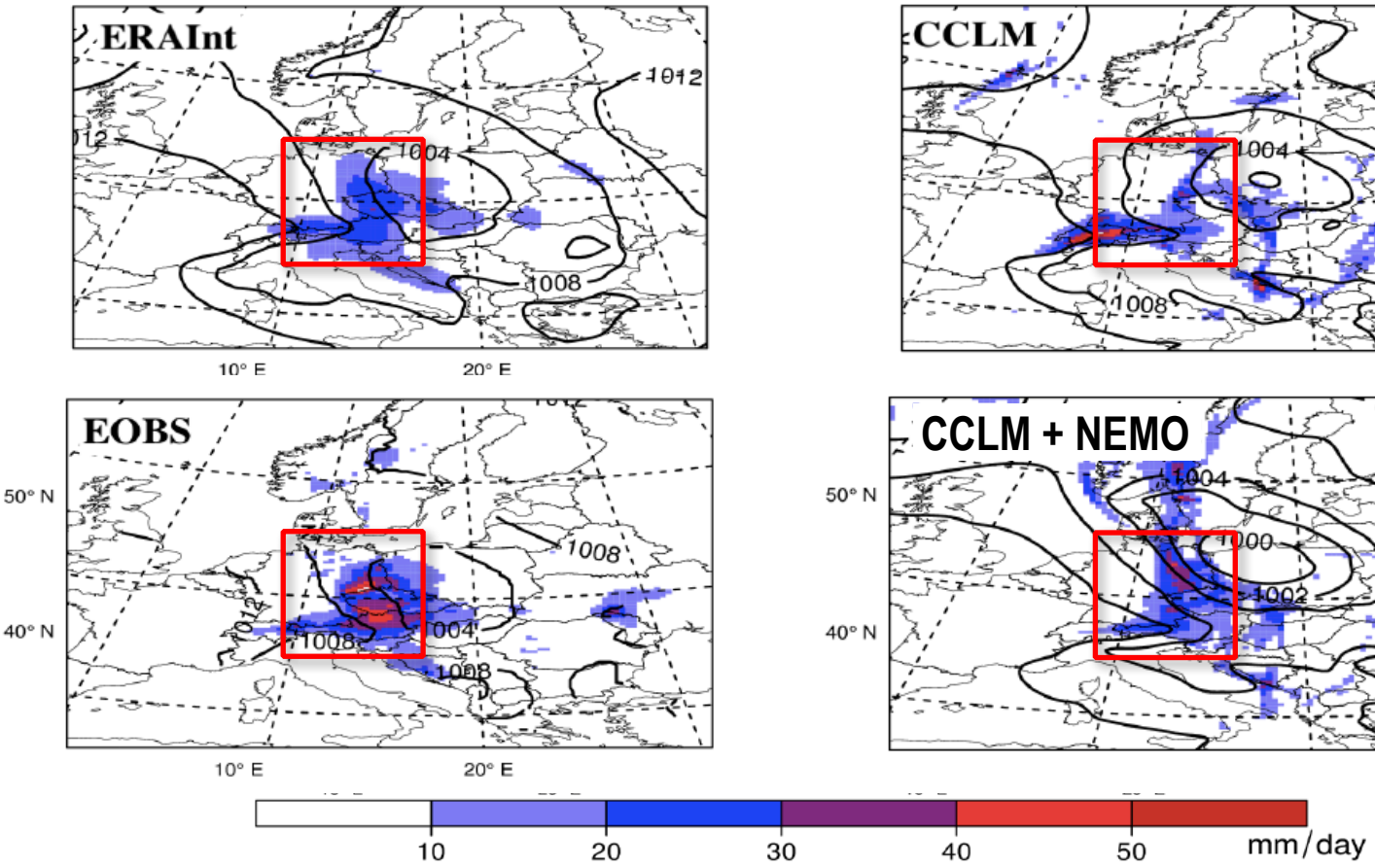
→ August 2002: Elbe flooding (Vb-cyclone)



NEMO: North- and Baltic Sea, Mediterranean Sea

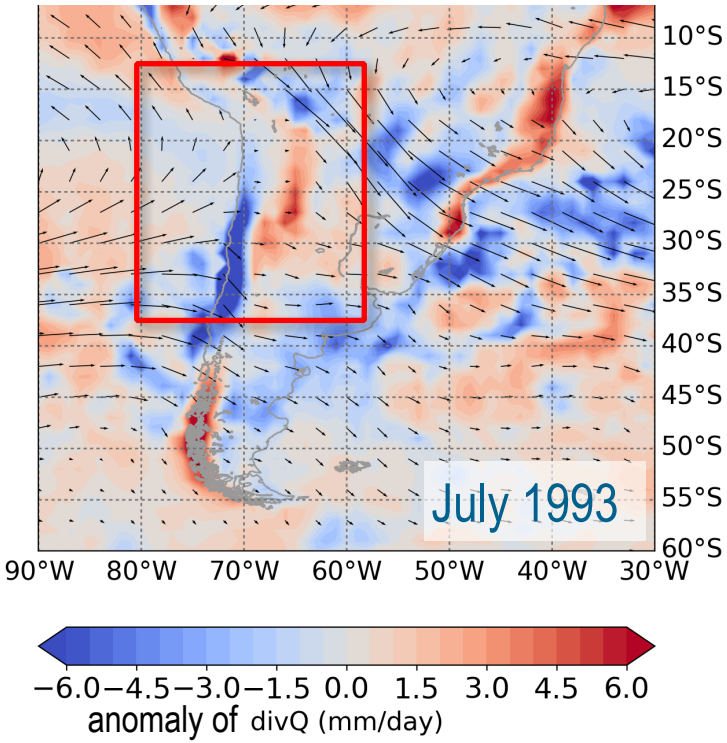
Extreme Floods in Europe: August 2002

11-13 August 2002: average total precipitation/day



Akhtar, N., A. Krug, J. Brauch, T. Arsouze, C. Dieterich, *B. Ahrens* (2018) **European Marginal Seas in a regional atmosphere-ocean coupled model and their impact on Vb-cyclones and associated precipitation**. Subm. to Clim. Dyn.

Atacama desert (Böhm, C. et al.)



Atacama Desert in Bloom
Photo: P. Pardo Ávalos/ESO

Atacama Desert:

- extremely dry regions
- water vapor transport influenced by ocean-atmosphere coupling, orography, ...
- only few operational measurements available

How well can we describe the atmospheric water cycle components in the Atacama desert over the last 100 years?

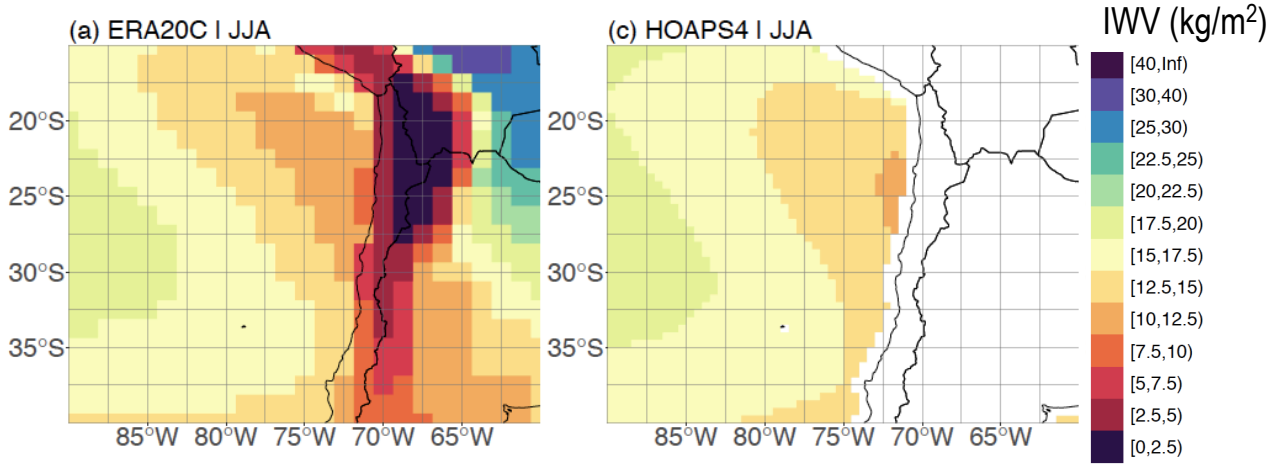
10 April 2019

Christoph Böhm, Mark Reyers, Jan Schween, Ulrich Löhnert, Susanne Crewell

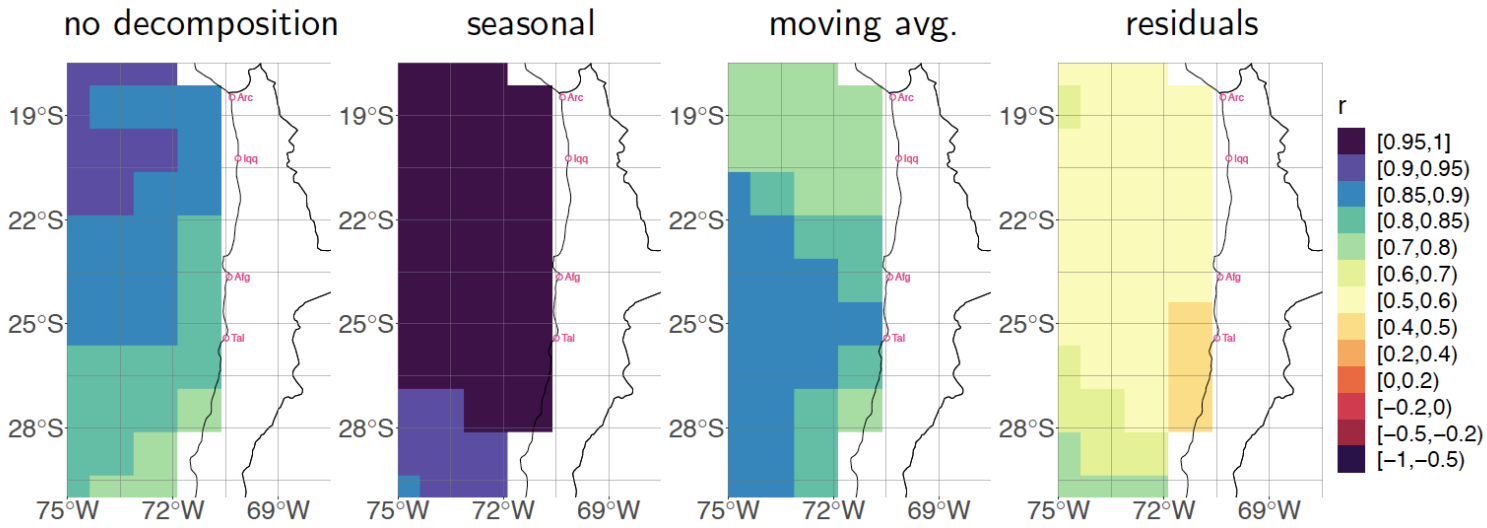
Atacama desert (Böhm, C. et al.)

University of Cologne

Integrated Water Vapor (IWV) comparison (HOAPS vs ERA-20C)



- dry bias in ERA-20C
- seasonal and interannual variability of IWV well represented
- ERA-20C suitable for studying IWV variability during the past century



correlation HOAPS vs ERA-20C

Conclusion

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Wetter und Klima aus einer Hand

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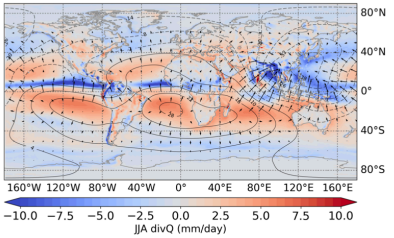
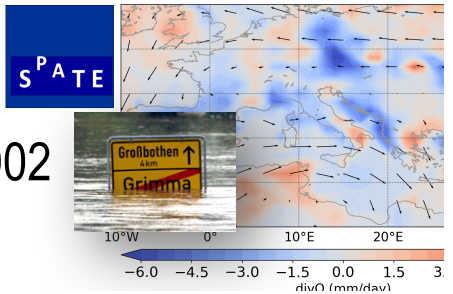
1. Water vapor transport diagnostics:

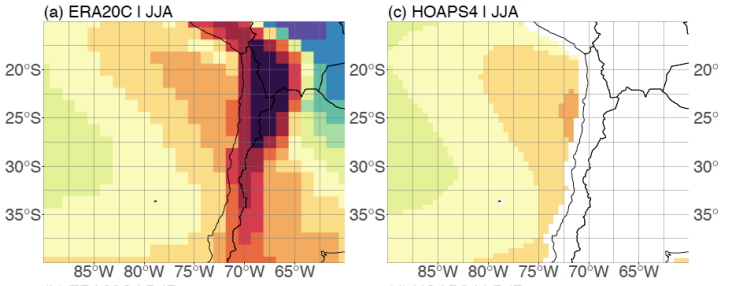
$$\frac{\partial (W + W_c)}{\partial t} + \mathrm{div}(\vec{Q} + \vec{Q}_c) = E - P,$$

$$\vec{Q} = \frac{1}{g} \int_0^1 q \, \vec{V} \, \frac{\partial p}{\partial \eta} \mathrm{d}\eta,$$

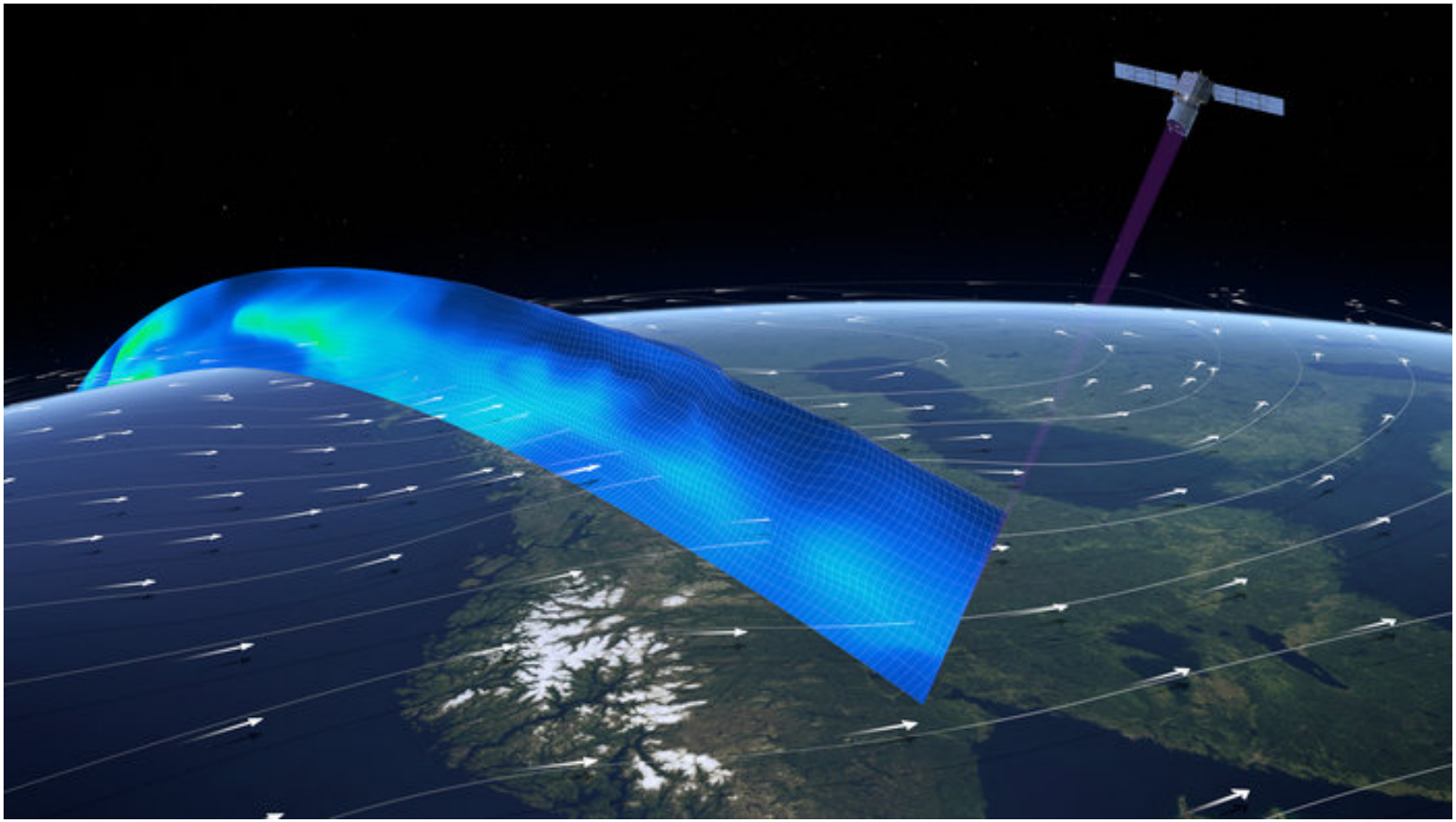
2. Applications
   - Global Climatology (11/1987 – 12/2014)
     → based on HOAPS-4.0 satellite & ERAint reanalysis data
   - Extreme Floods in Europe
     → high convergences in the water vapor transport associated with flooding, e.g. August 2002
   - Atacama desert (Böhm, C. et al)
     → extremely dry region
     → atmospheric water supply?







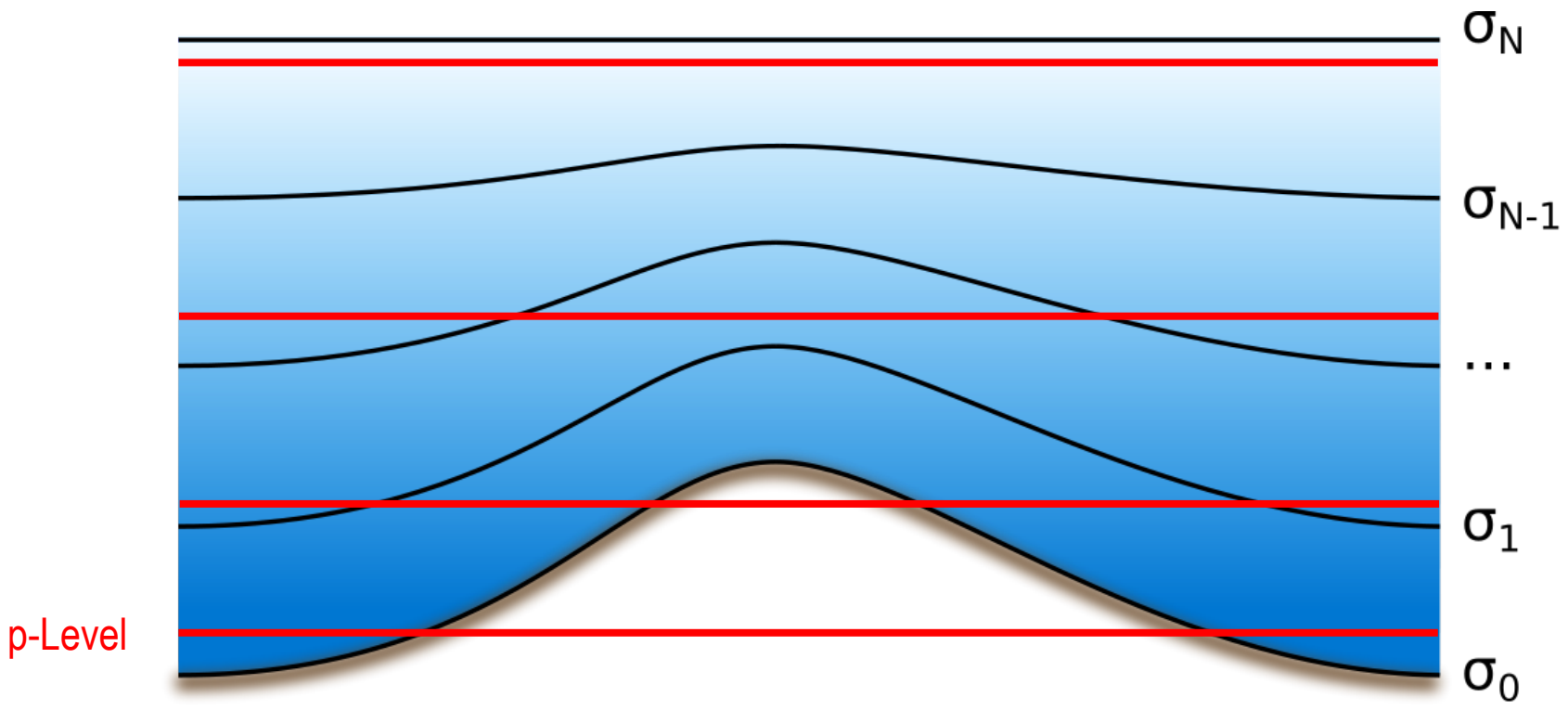
ESA´s Earth Explorer Aeolus satellite



- first wind lidar in space
- profiles of wind, aerosols and clouds (lowermost 30 km)

http://www.esa.int/spaceinimages/Images/2016/07/Profiling_the_world_s_winds

Anhang


σ_N
σ_{N-1}
...
σ_1
σ_0
p-Level

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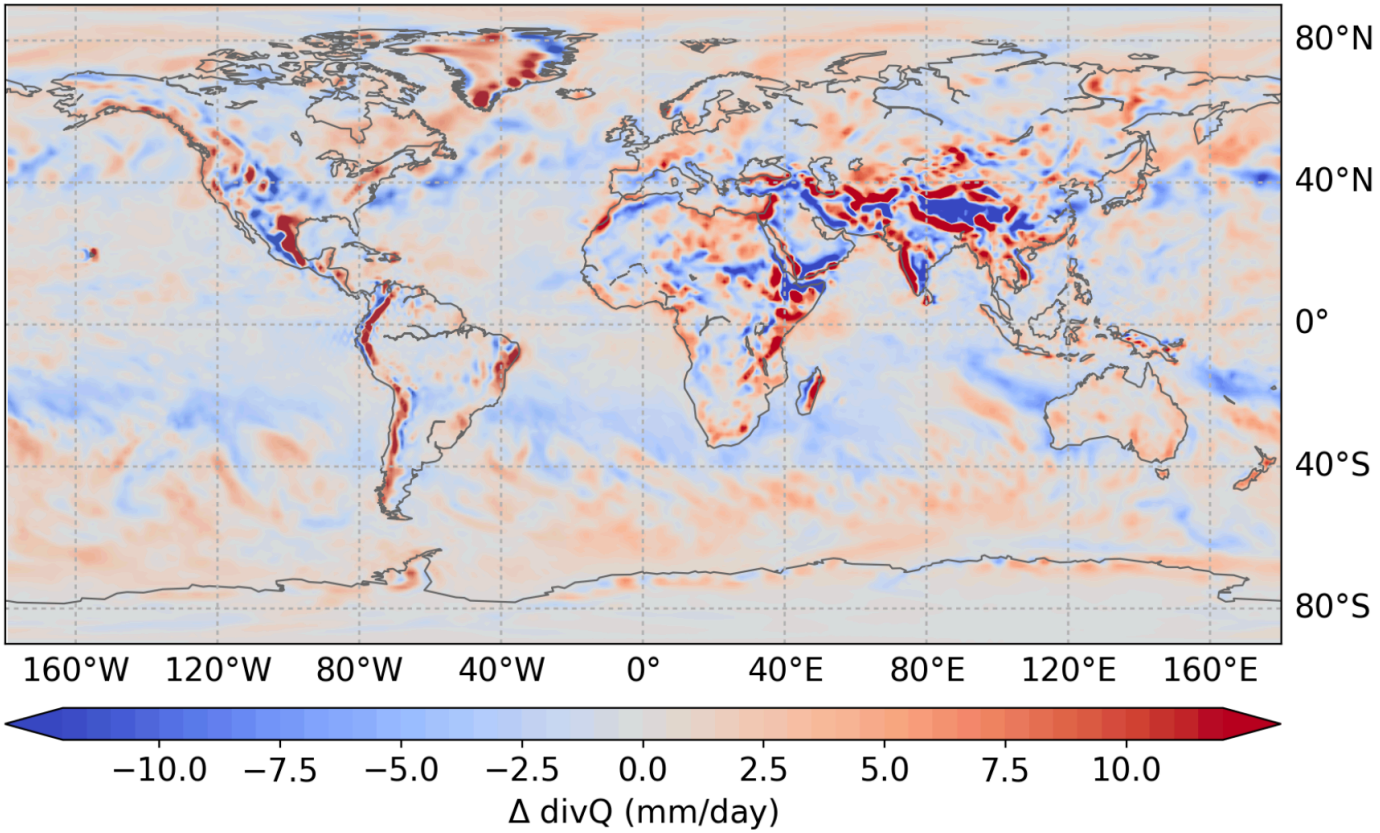
Juli 1996



with $$\vec{Q} = \frac{1}{g}\int_0^{p_s} q\,\vec{V}\,\mathrm{d}p$$

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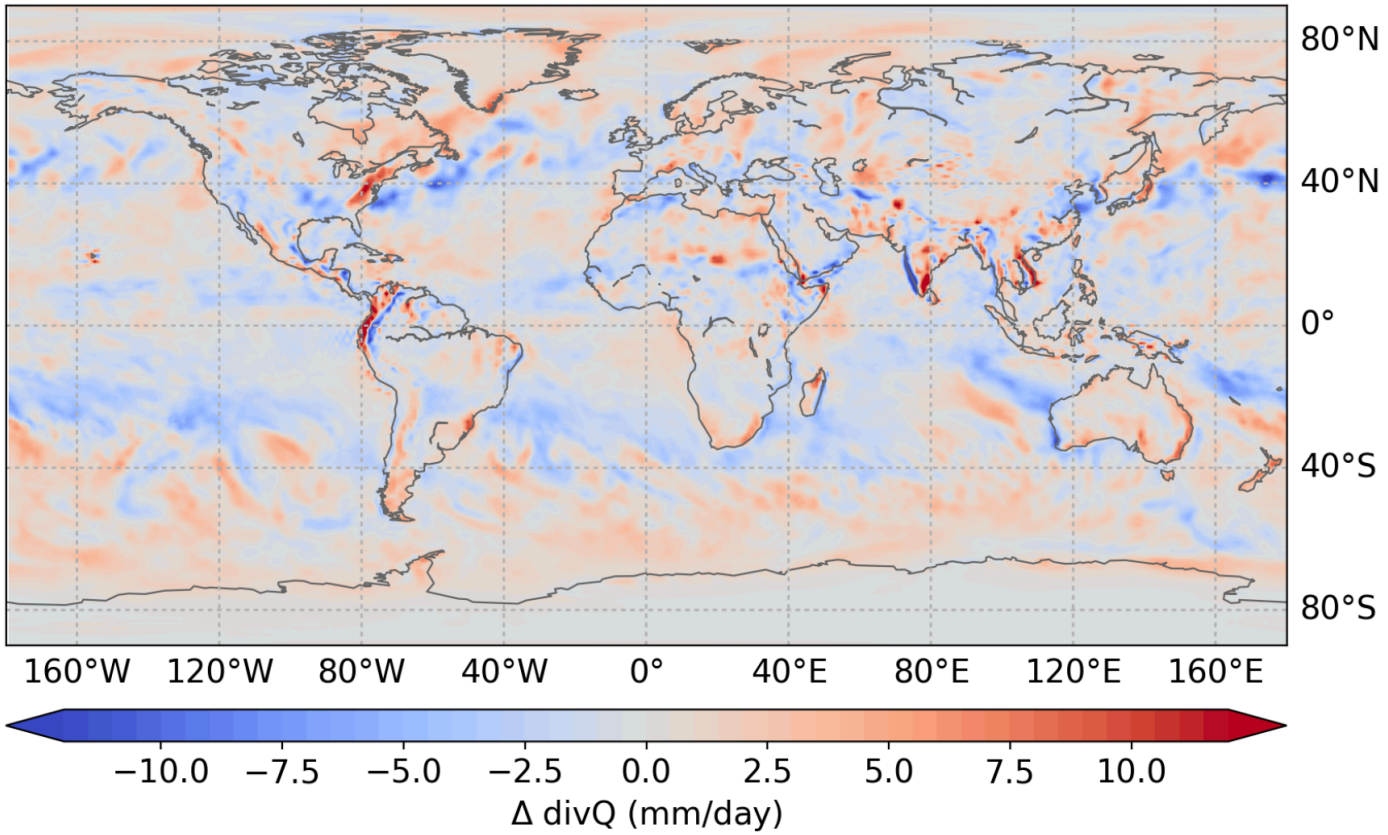
Juli 1996



with $$\vec{Q} = \frac{1}{g}\int_0^1 q\,\vec{V}\frac{\partial \eta}{\partial p}\mathrm{d}\eta$$

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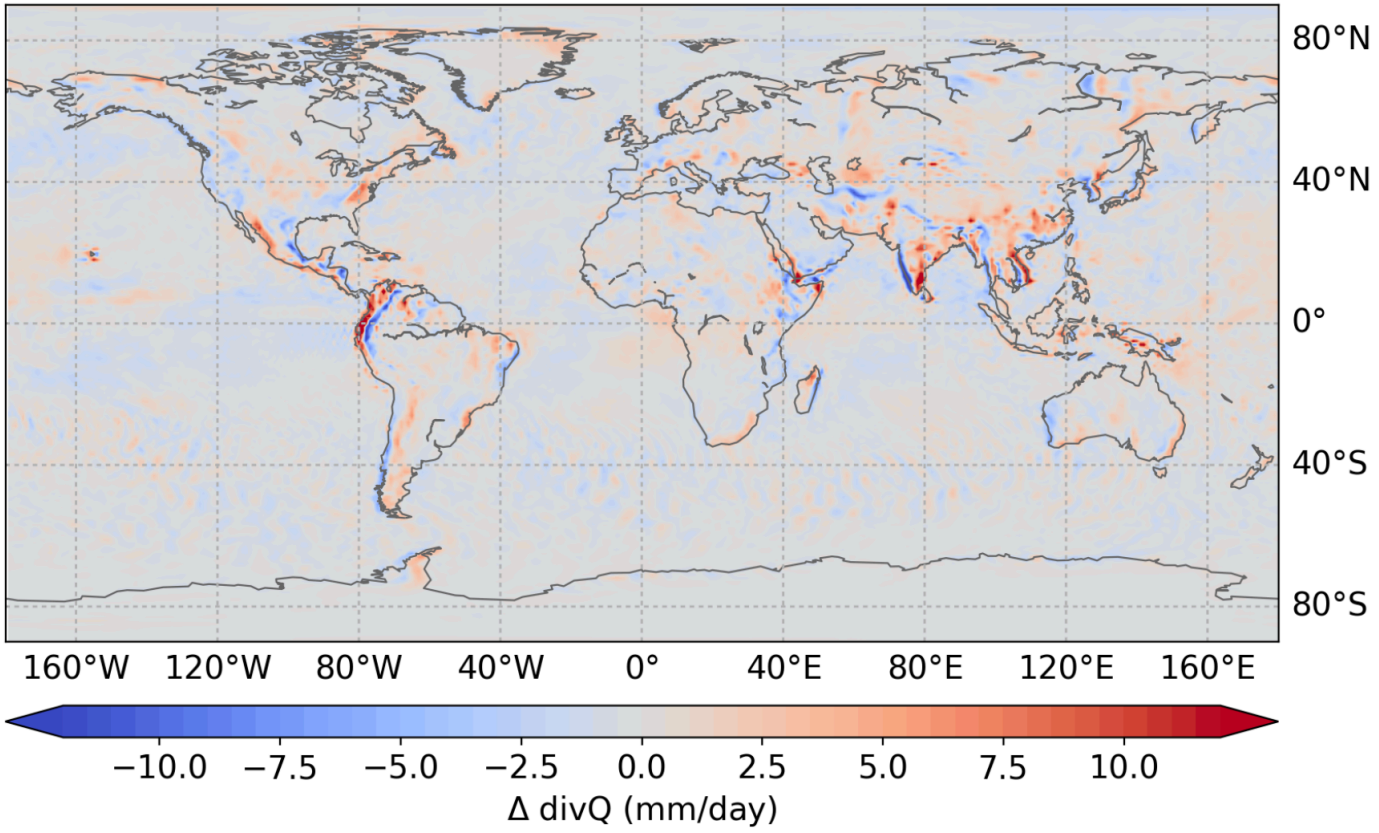
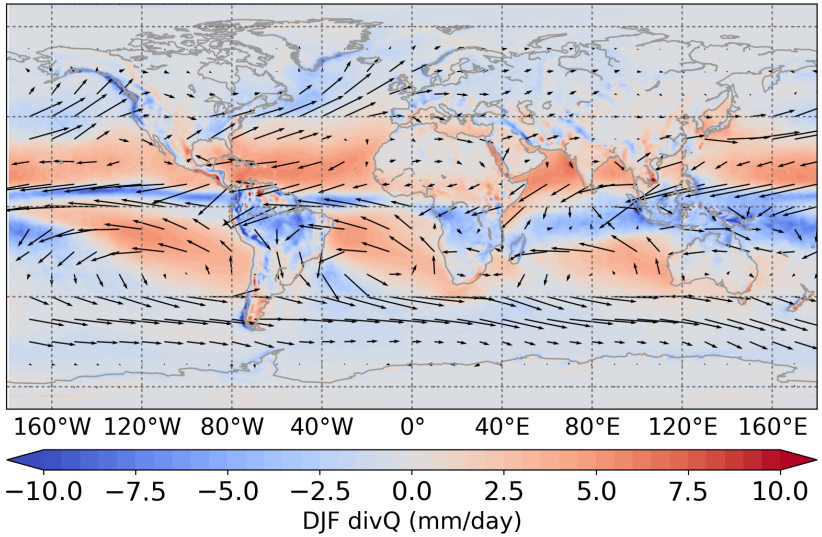
Juli 1996

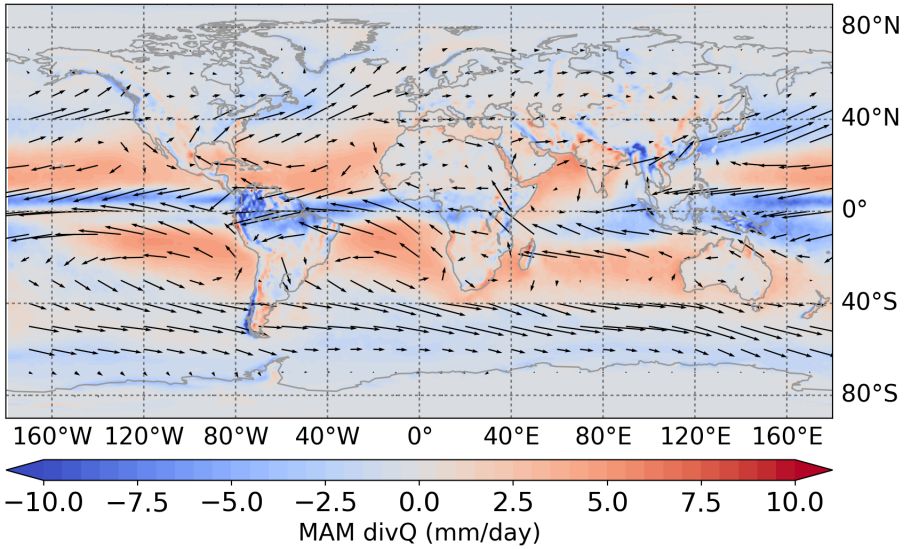


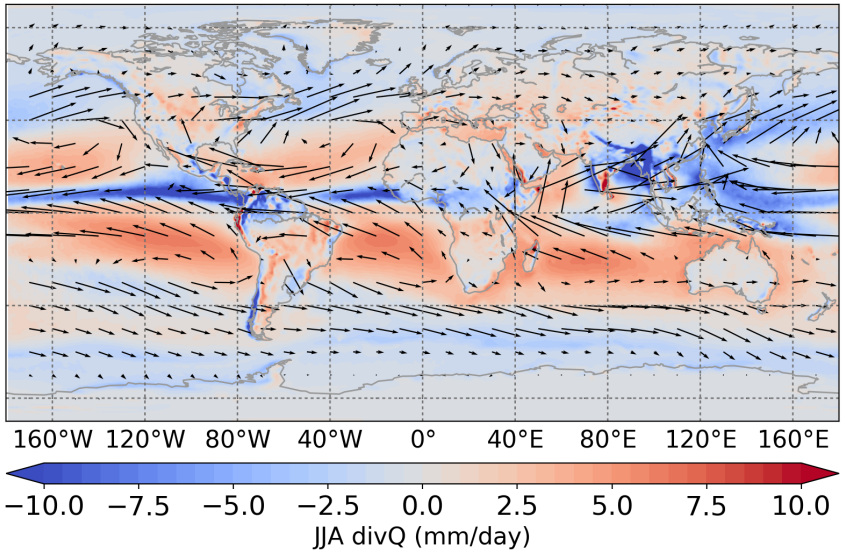
with $\vec{Q} = \frac{1}{g}\int_0^1 q\,\vec{V}\,\frac{\partial \eta}{\partial p}\mathrm{d}\eta$

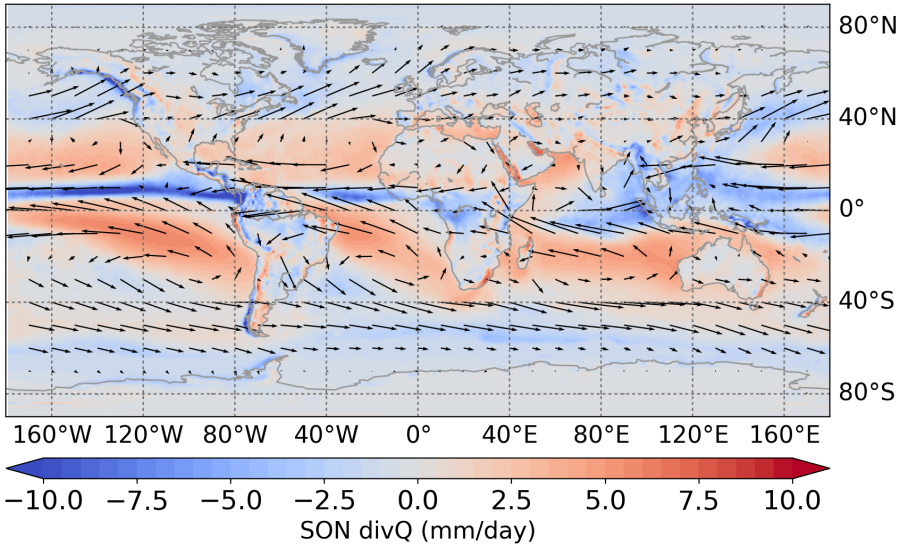
6h resolution

Climatology in satellite & ERAint data (Dez. 1987 – Nov. 2014)





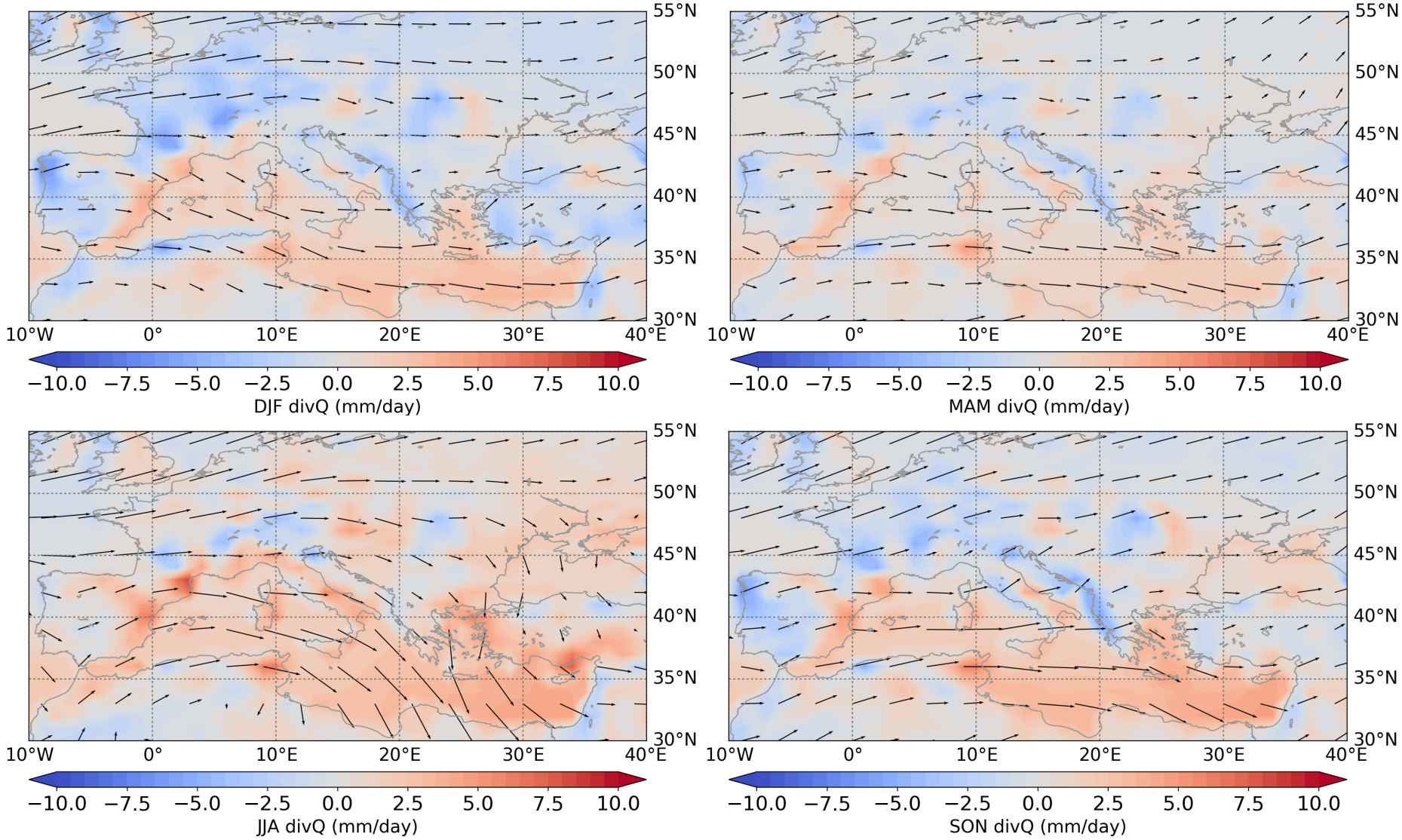




countour lines: potential field of water vapor transport Φ (x 10^7kg/s)

vector field: divergent component of water vapor transport $\vec{Q}_D$(m/s)

Climatology in satellite & ERAint data (Dez. 1987 – Nov. 2014)



countour lines: potential field of water vapor transport Φ (x 10^7kg/s)

vector field: horizontal water vapor transport $\vec{Q}$ (m/s)