The residence time of water in the atmosphere revisited

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Research questions

- What is the global average residence time of water in the atmosphere?
- What is the spatial picture of residence in the atmosphere?
- Do different perspectives (i.e., precipitation, evaporation, age) lead to different pictures of residence time?
- What is the influence of seasons on residence time?
- What is the probability distribution function of residence time?

Previous findings

- Global average residence time of water in the atmosphere (or turn-over time, definitions not always used consistently) is non-controversially estimated at 8-10 days in many textbooks
- Spatial pictures of depletion on replenishment times provided by Trenberth (1998) and Van der Ent and Savenije (2011), but these are not equal to residence times
- Van der Ent et al. (2014) estimated atmospheric residence time of land precipitation to be 9.7 days, that of land evaporation to be 8.7 days, and that of recycled land precipitation to be 6.4 days based on atmospheric moisture tracking
- Läderach and Sodemann (2016) provided a global spatial picture of precipitation residence time in the atmosphere, but with an extremely low average estimate of 4-5 days

Why the global average residence time is 8-10 days

- Considering mass balance, the average residence time equals

$$\text{Residence time} = \text{average mass} / \text{average flux} \qquad (1)$$

- The only way Eq. (1) does not hold is when some mass does not participate in the hydrological cycle. However, this does not seem to be the case in the atmosphere:
  a) Bosilovich and Schubert (2002) found that 97% of moisture is removed from the atmosphere within 30 days.
  b) The troposphere holds 99% of the water (ERA-Interim data)
  c) Even the tiny bit of water in the stratosphere participates with residence times of >1 year (Kristiansen et al., 2016)
- Counterexamples of Läderach and Sodemann (2016) violate mass balance (see Van der Ent and Tuinenburg, 2017, Supplement)

References

- Van der Ent, R. J. and Tuinenburg, O. A.: The residence time of water in the atmosphere revisited, Hydrol. Earth Syst. Sci., 21, 779–790, doi:10.5194/hess-2016-431, 2017.
- Also see this paper for other references mentioned on this poster

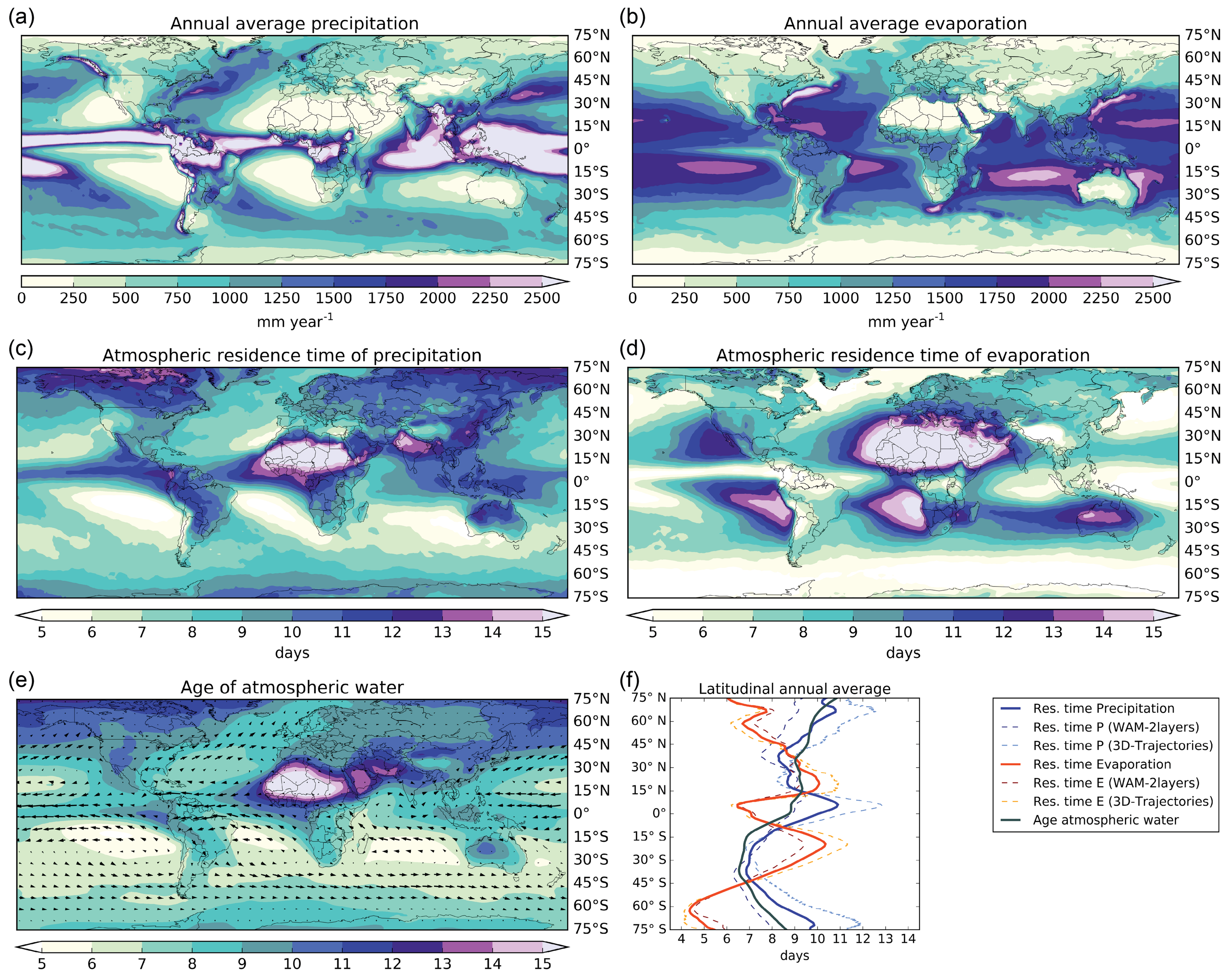

Fig. 1. Spatial estimates of hydrological cycle, residence times an age

Results are a combined estimate of moisture tracking with WAM2-layers (Van der Ent, 2014, 2016) and 3D-T (Tuinenburg, 2013; based on Dirmeyer and Brubaker, 1999), forced with ERA-Interim data

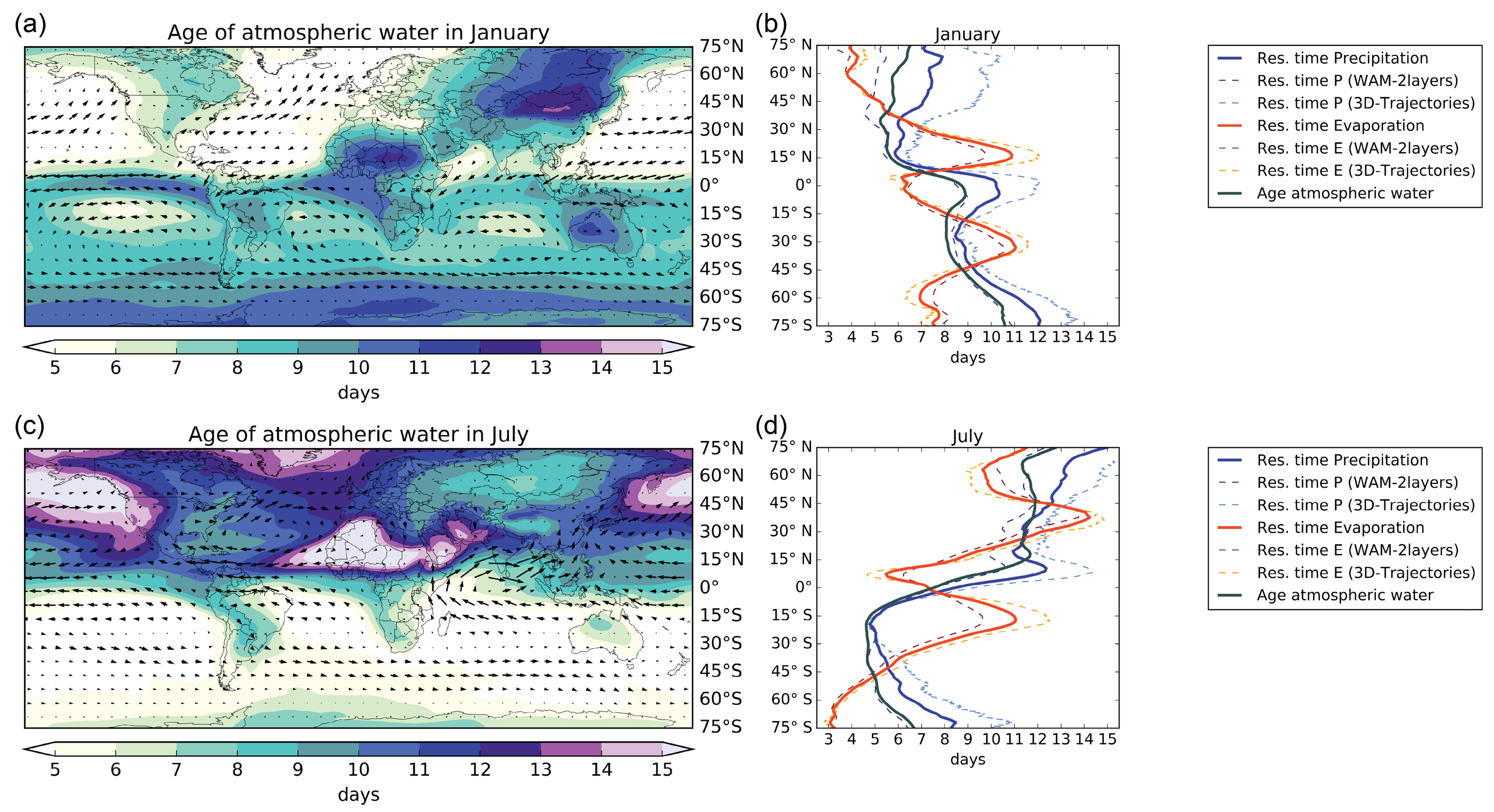

Fig. 2. Age of atmospheric water in January vs. July

Differences in January and July can be explained by the ratio of atmospheric water content to evaporation and the temperature contrasts between land and ocean

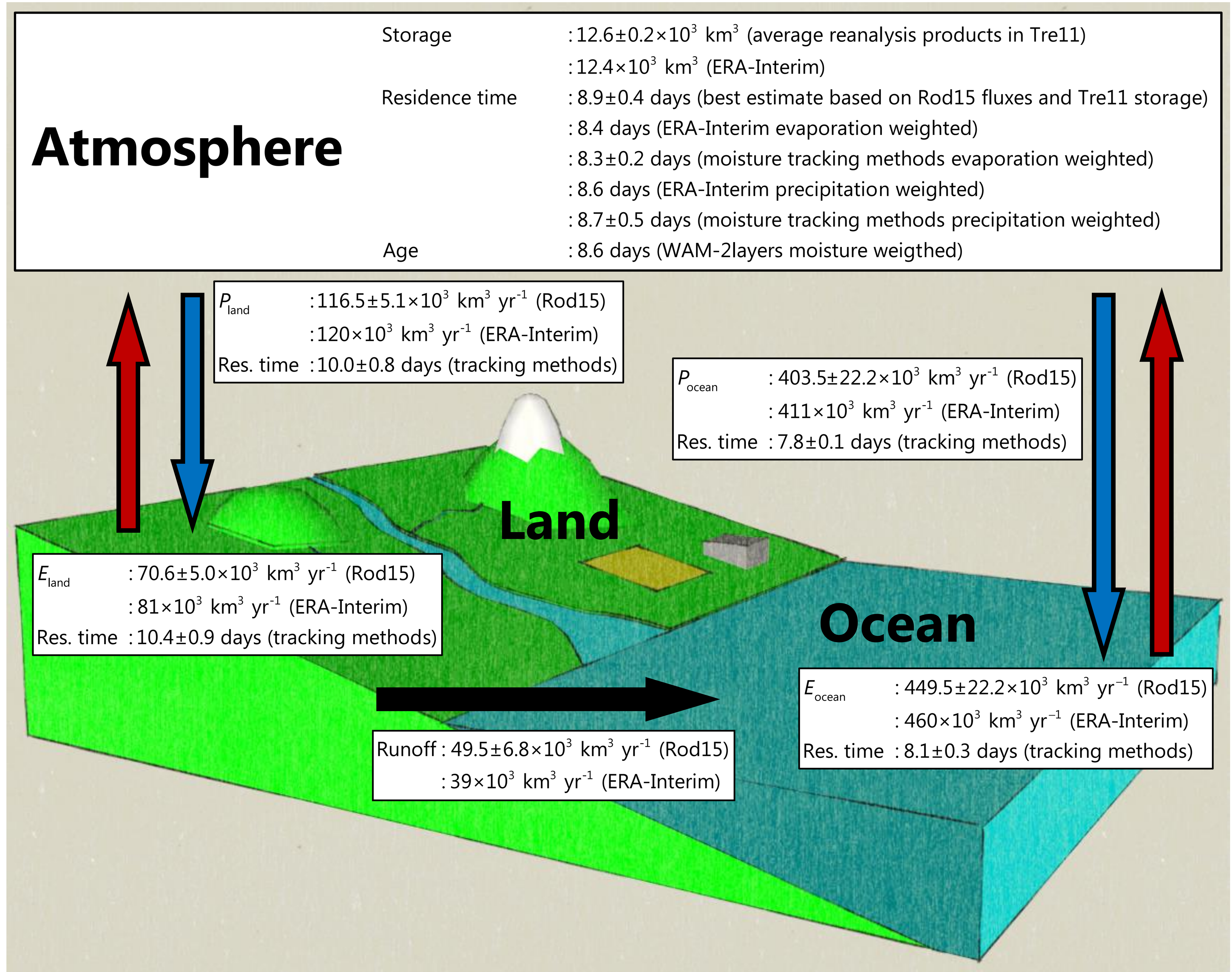

Fig. 3. Earth's hydrological cycle with residence times

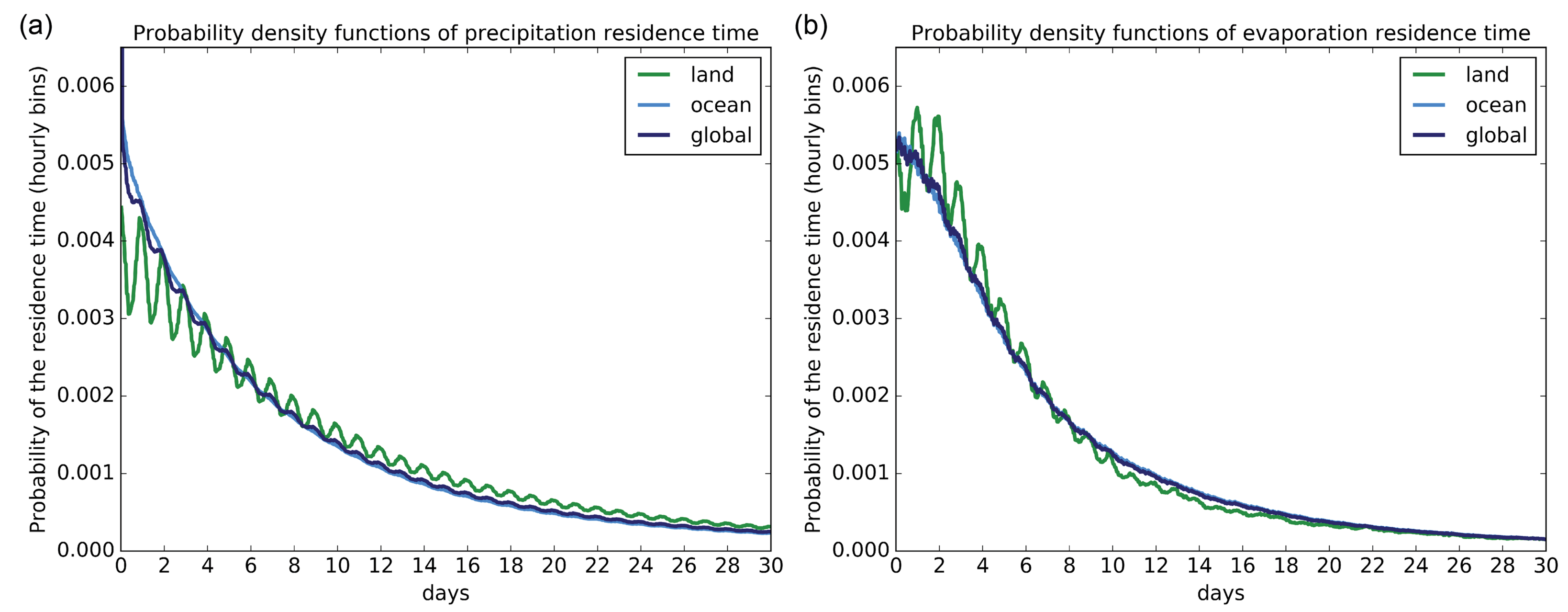

Fig. 4. Probability density functions residence times

Conclusions and implications

- "Best" estimate global average residence time of atmospheric water is 8.9 ± 0.4 days (uncertainty indicated by one standard deviation)
- Residence time of evaporation often corresponds with a travel distance of towards area of high precipitation
- Age of atmospheric water generally lower in winter
- Probability density functions have long tails and a median around 5 days
- Climate models need hydrologically more realistic land surface schemes for weather predications on weekly scales. See poster A.223 Friday