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Combined event-based tritium and air mass back-trajectory analysis of Mediterranean precipitation events

Tobias Juhlke*, Jürgen Sültenfuß, Katja Trachte, Frédéric Huneau, Emilie Garel, Sébastien Santoni, Johannes A. C. Barth, Robert van Geldern **

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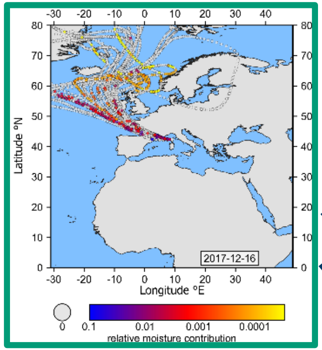
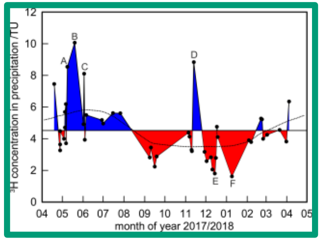
Event based precipitation sampling for tritium (^3H) analysis
Corsica (France), April 2017 to April 2018

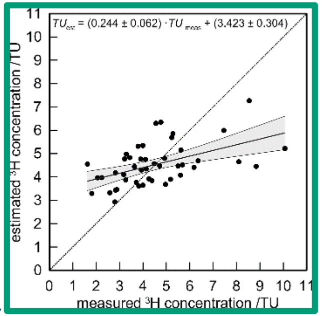
HYPLSIT trajectory runs for all sampled hours of precipitation



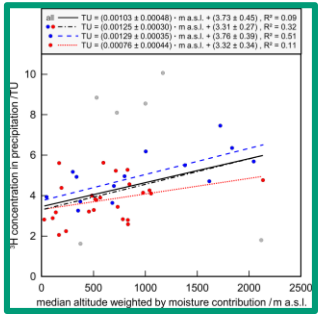
^3H seasonality in precipitation



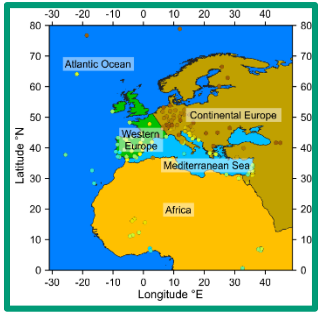
Model performance of forward calculation for ^3H event values



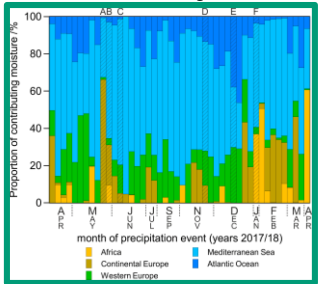
^3H vs average altitude of moisture contribution



^3H source regions delineated by GNIP station 3H records and land-sea differences



Event-based moisture uptake in ^3H source regions



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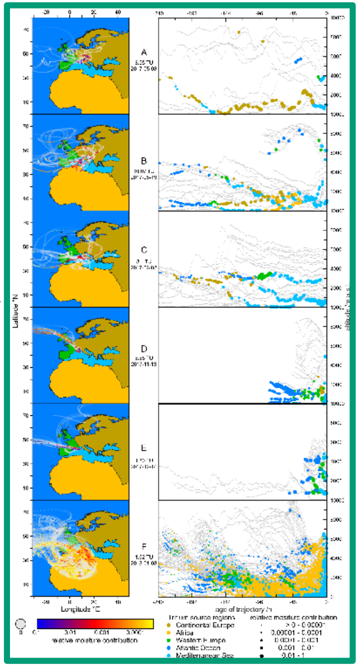
HYSPLIT trajecories and their altitude history for ^3H outlier events



Conclusions

- Moisture originating from the Atlantic Ocean and Continental Europe result in predominantly low and high ^3H concentrations in precipitation, respectively.
- Air mass history altitude is good predictor of ^3H concentration in precipitation, especially during the „tropopause leak“
- Extreme ^3H events hint on possible recycled continental moisture as source of ^3H to precipitation

For more information feel free to read the published, full-length, open access article:

Juhlke, T. R., et al. (2020). "Tritium as a hydrological tracer in Mediterranean precipitation events." Atmospheric Chemistry and Physics **20**(6): 3555-3568, https://doi.org/10.5194/acp-20-3555-2020.

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HYSPLIT back-trajectory modelling

HYSPLIT model generates backward tracks of air mass movement

Event based precipitation sampling for ^3H analysis

Input parameters and data:

- Start location
  - LAT
  - LON

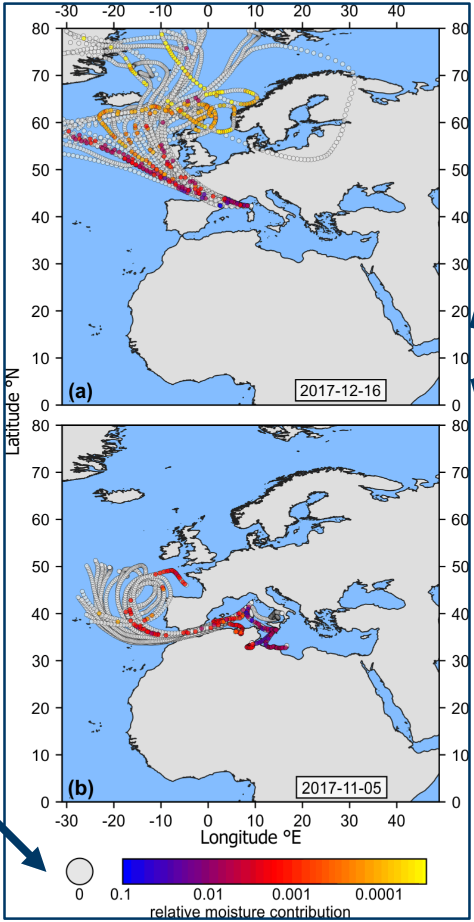
  } sampling site at Corte (Corsica), France

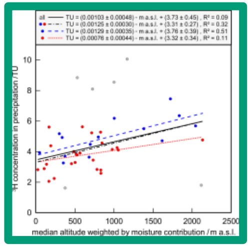
  - Altitude: 12 starting altitudes from 0 to 6000 m a.g.l.
- Start time (date and hour): full hours of sampled precipitation events
- 3D grid of meteorological background data: ERA5 meteorological grid dataset[1]

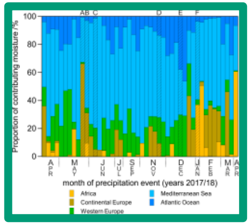
HYSPLIT output: hourly spaced points with attached information

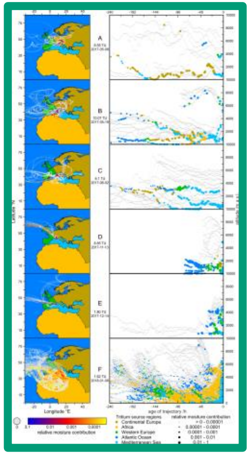
- Position (LAT, LON, altitude)
- Meteorological parameters (e.g. specific humidity)

Calculation of origin of mositure uptake for air mass at starting location









Source regions of similar ^3H content

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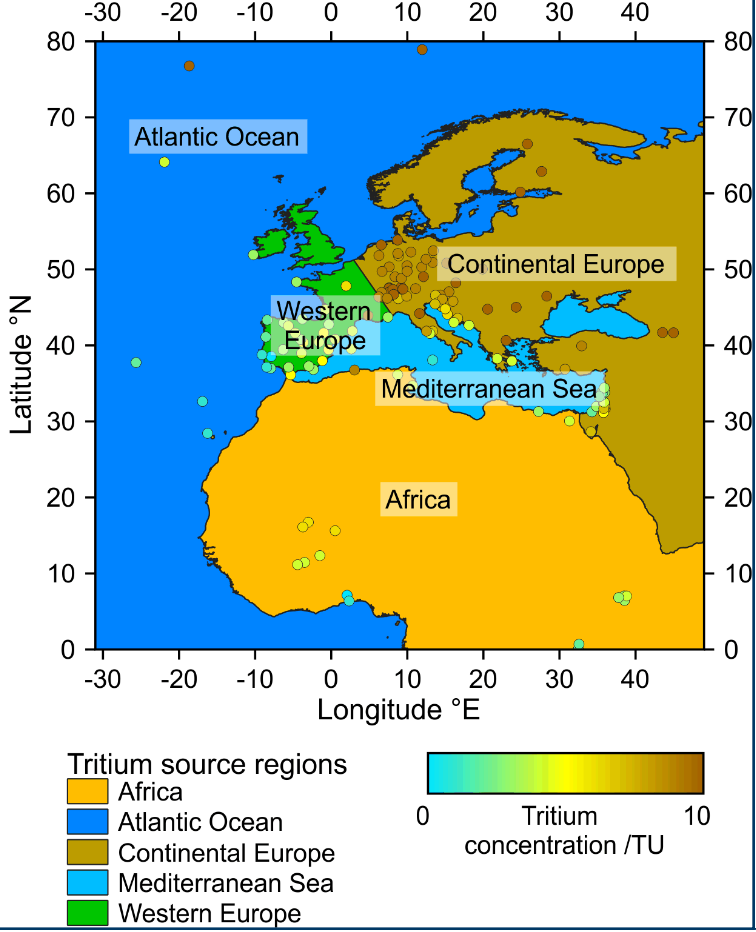
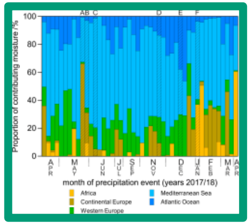
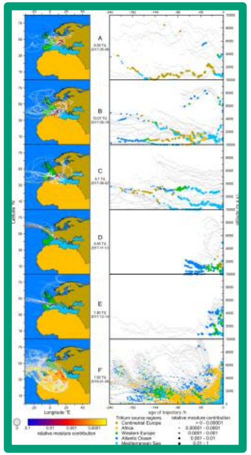
General assumptions about ^3H distribution (e.g. land-sea difference, continental gradient)

Average ^3H concentration in precipitation at GNIP[2] stations between 2000 and 2016

Subdivision of working area (~±40° around sampling site) into five ^3H source regions of expected similar ^3H concentrations







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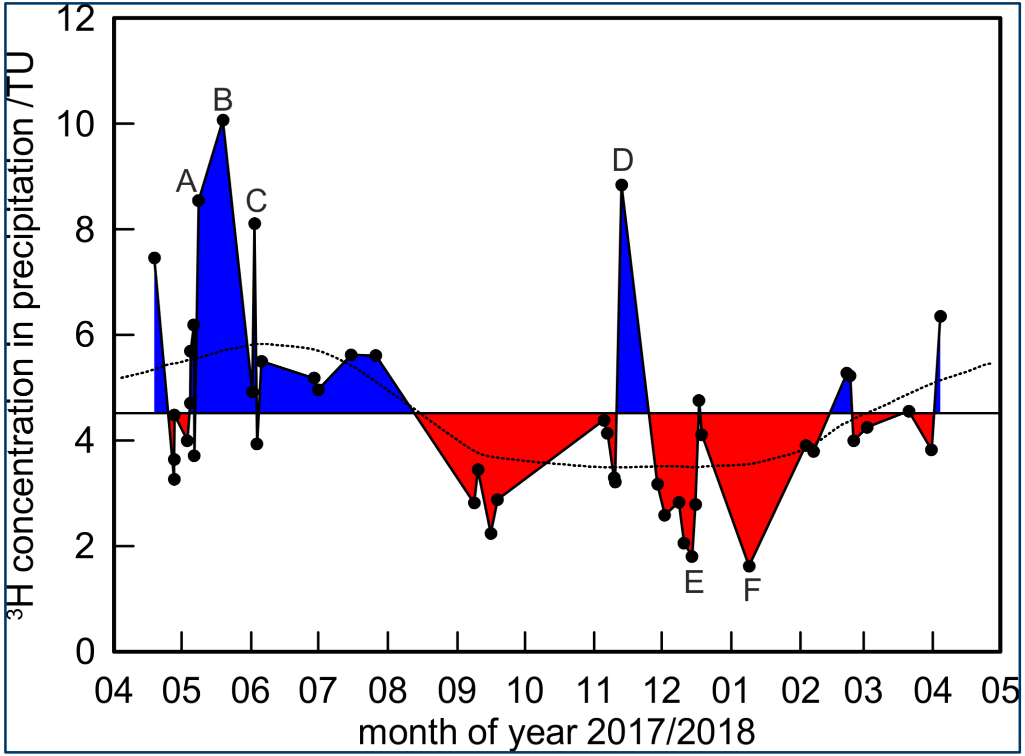
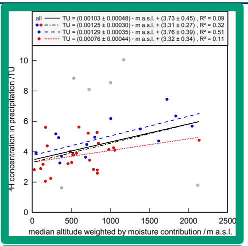
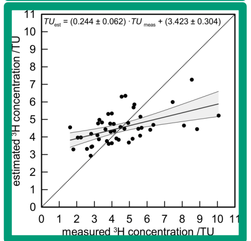
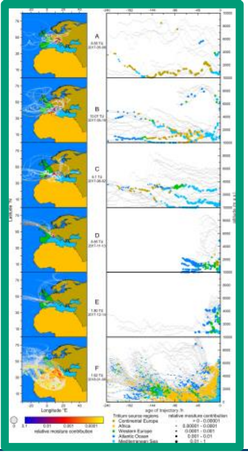
Seasonality of ^{3}H in precipitation events

Event based precipitation sampling for ^{3}H analysis









Expectation

Spring & early summer:
Increased moisture exchange from stratosphere to troposphere („tropopause leak“)[3]

→ ^{3}H of stratospheric origin influences ^{3}H concentration in precipitation

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Observation

Spring & early summer:
Increased 3H concentration

Autumn & winter:
Decreased 3H concentration

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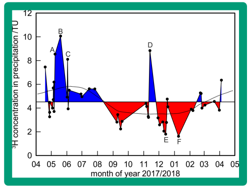
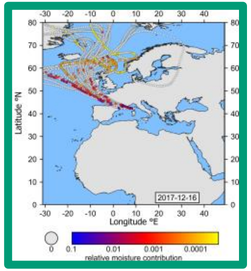
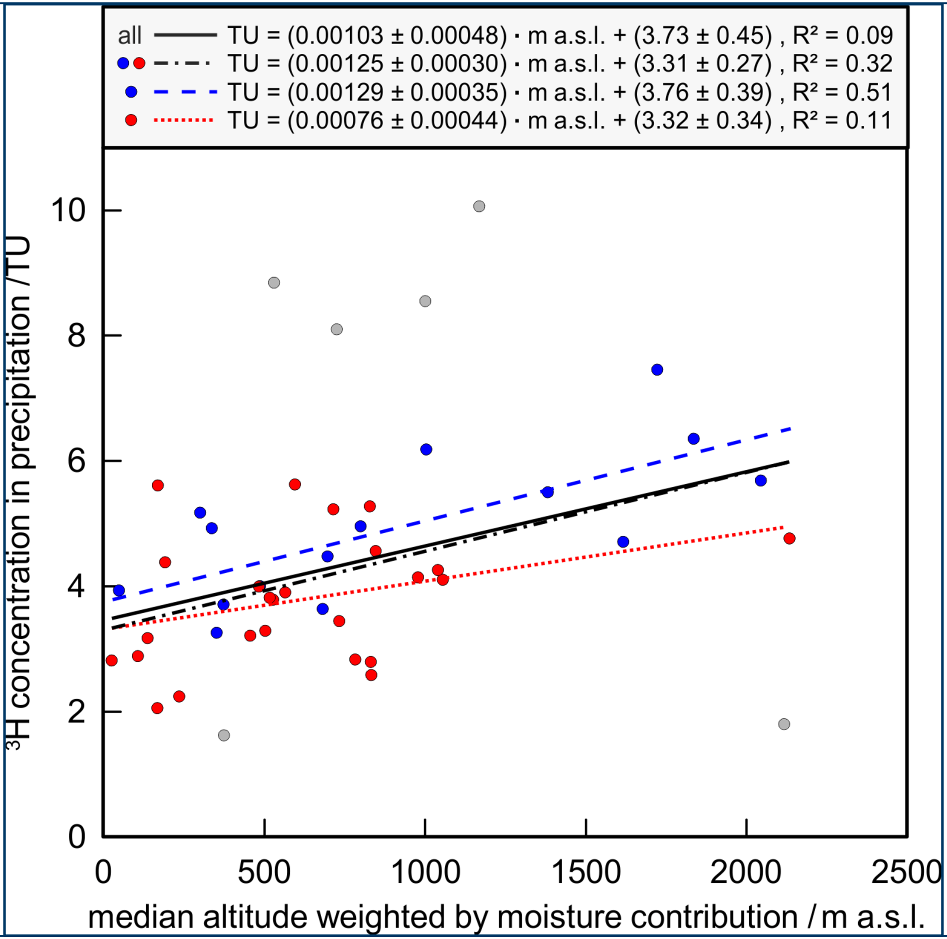
^{3}H and the average altitude of moisture contribution







Observations

- ^{3}H increase per altitude (slope) is similar for all sample subsets
- Quality of the regression line (R^2) increases when
    - outlier values are excluded
    - only samples from the „troposphere leak“ season (here April to July, blue) are considered

→ Altitude of air mass history can be a predictor of ^{3}H concentrations in precipitation, especially in spring and summer

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Event-based regional moisture origin

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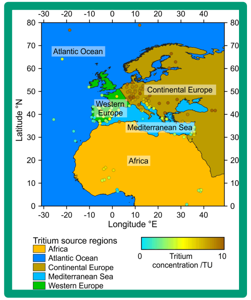

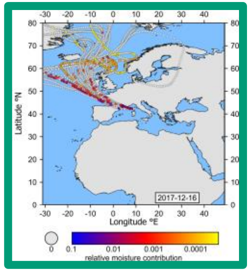

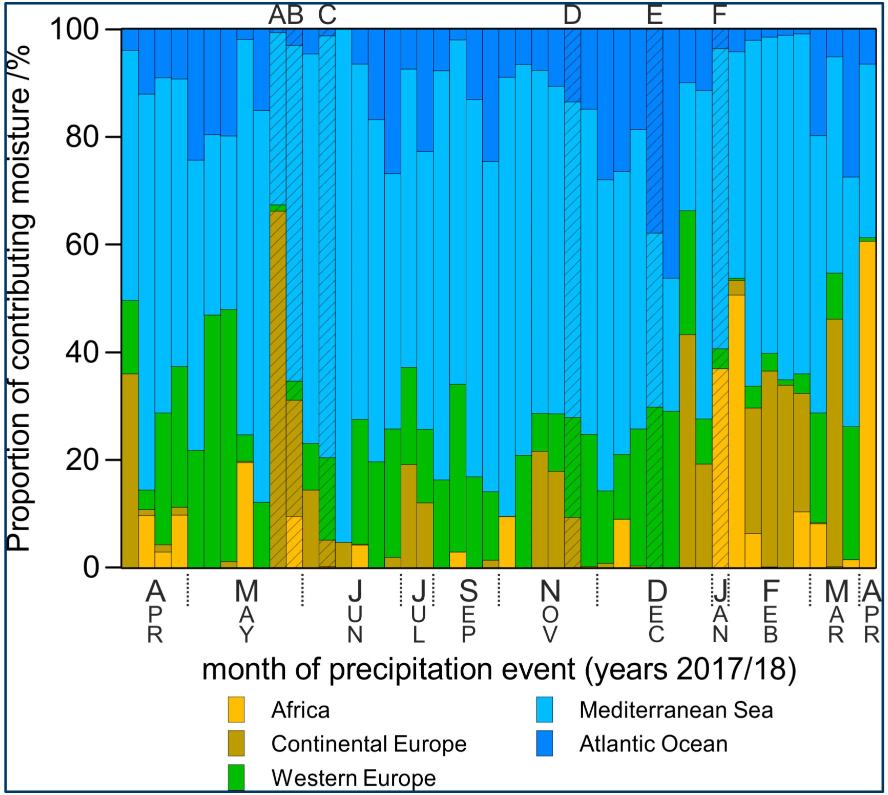

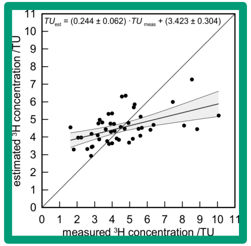

^3H source region	Mean …	Median …
	… moisture contribution to precipitation events [%]	
Africa	5	0
Atlantic Ocean	12	9
Continental Europe	10	1
Mediterranean Sea	57	60
Western Europe	15	14

- Mediterranean Sea & Western Europe: most significant moisture contributors on average
- Continental Europe & Africa: high event contributions possible, but small influence on average

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Model of ^3H source region concentration

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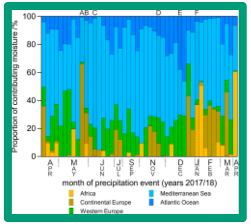
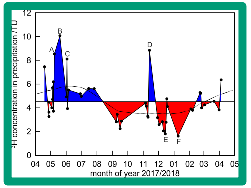
46 precipitation events



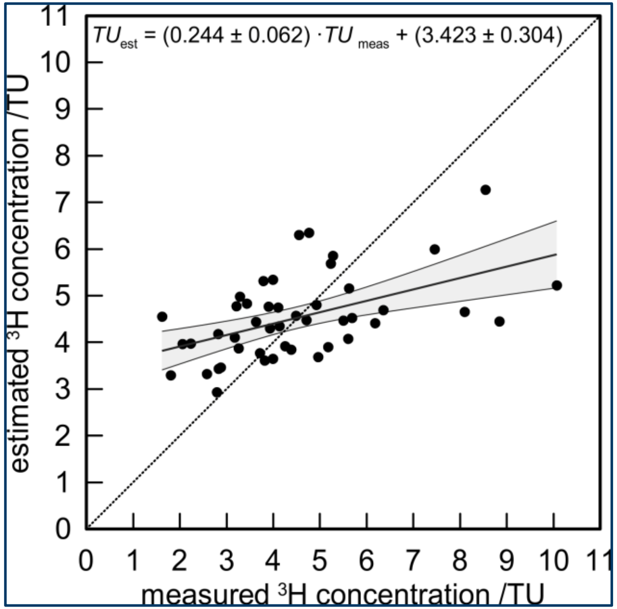


Simplifying assumptions for ^3H model:
^3H content of precipitation event is linear related to average ^3H content of the 5 source regions and their moisture contribution

$$TU_{event} = \sum_{n=1}^{5} (TU_n \cdot w_{s\,n})$$

Slope = 0.24
→ Model can represent around a quarter of measured ^3H variability
Probable errors: seasonal differences in stratosphere-troposphere exchange

Model forward run to estimate model accuracy



^3H source region	Estimate of ^3H concentration [TU]	Explanation/discussion
Africa	5.5	Higher than Mediterranean Sea, but high uncertainty due to rare moisture contribution
Atlantic Ocean	(-1.2)	Negative value indicates tendency to 0, minor 3H contribution from the open ocean matches low 3H values in ocean water
Continental Europe	8.8	High estimate matches expected trend of increased 3H concentration over continent
Mediterranean Sea	4.1	High value for marine environment, near to average of all measured events, because of highest moisture contribution
Western Europe	7.3	Unexpectedly high values for marine incluenced lanmasses, maybe anthropogenic influences?

Events with extremely low and high ^{3}H concentrations

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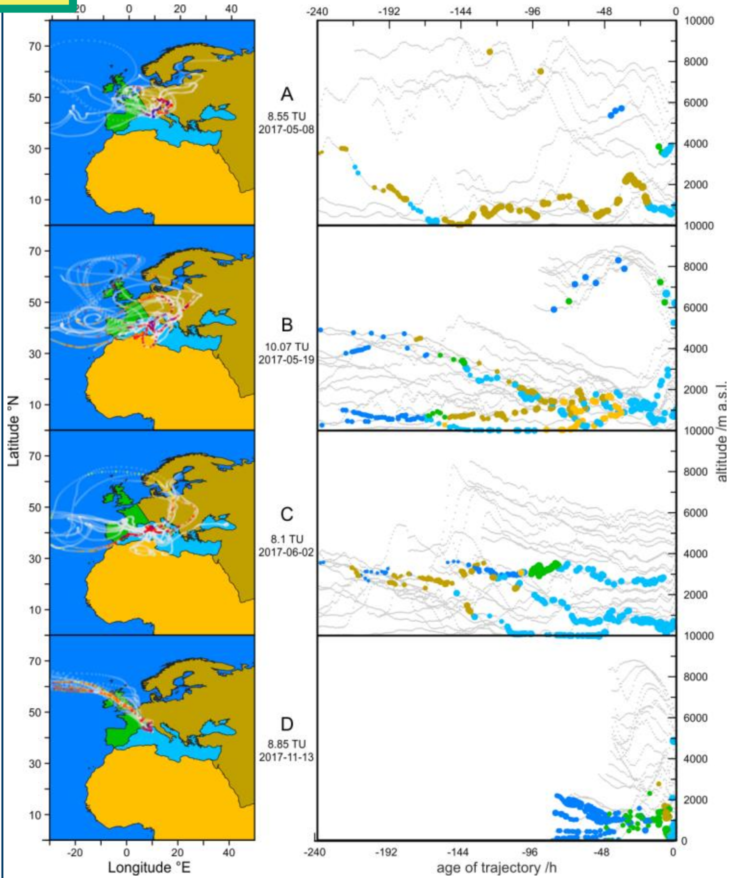
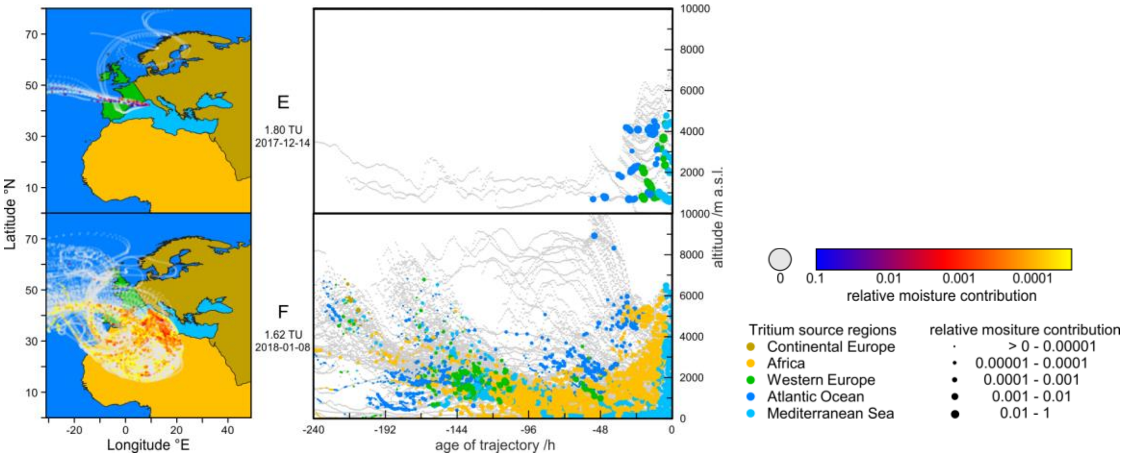


Event	Observation	Explanation/discussion
A	High TU, low altitude air-mass, main origin: Continental Europe	Probably recycled moisture from continental sources
B	High TU, mainly low altitude air-mass, Continental Europe and Mediterranean Sea	Probably recycled moisture from continental sources
C	High TU, some higher altitiudes (>3000 m a.s.l.)	Minor influences of high altitude moisture (maybe stratospheric origin)
D	High TU, lower altitudes, fast air masses, not during tropopause leak	Possible anthropogenic influences from nuclear facilities and their surroundings
E	Low TU, not during tropopause leak, Atlantic origin	Low ^{3}H uptake over Atlantic Ocean water
F	Low TU, origin: Africa & Atlantic Ocean	No clear time frame, analysis compromised



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Affiliations and references

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[1] Copernicus Climate Change Service (C3S): ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate, Copernicus Climate Change Service Climate Data Store (CDS), available at: https://cds.climate.copernicus.eu/cdsapp#!/home, 2017.
[2] IAEA/WMO: Global Network of Isotopes in Precipitation, The GNIP Database, available at: https://nucleus.iaea.org/wiser, 2019.
[3] Martell, E. A.: Atmospheric Aspects of Strontium-90 Fallout: Fallout evidence indicates short stratospheric holdup time for middle-latitude atomic tests, Science, 129, 1197–1206, https://doi.org/10.1126/science.129.3357.1197, 1959.

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