High-resolution precipitation reanalysis over France through offline data assimilation in a downscalled ensemble meteorological reconstruction

Alexandre Devers, Jean-Philippe Vidal, Claire Lauvernet, B. Graff

High-resolution precipitation reanalysis over France through offline data assimilation in a downscaled ensemble meteorological reconstruction

Alexandre Devers[1], Jean-Philippe Vidal[1], Claire Lauvernet[1], Benjamin Graff[2]

[1] Irstea, UR RiverLy, Villeurbanne, France
[2] CNR (Compagnie Nationale du Rhône), Lyon, France
alexandre.devers@irstea.fr

This study considers an "offline" data assimilation method using the Ensemble Kalman Filter to build a precipitation reanalysis over France. The method is here applied for reconstructing the 2009-2012 period, using past observation density of 1871, 1900 and 1950. The methodology allows taking two main features of precipitation into account: (1) an anisotropic localization matrix based on the climatological background information, (2) a Gaussian transformation applied to daily precipitation. Results show a reduced error and a reduced uncertainty compared to background reconstructions, even with few observations, thus demonstrating the added value of data assimilation.

Research question

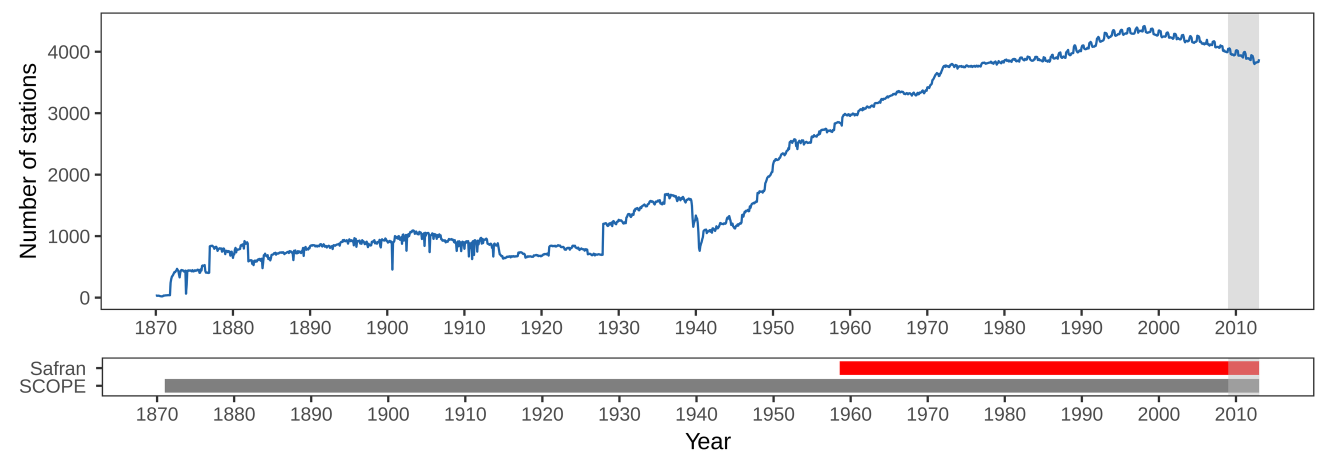
How to produce a 150-year high-resolution precipitation reanalysis over France ?

→ Through data assimilation of observations of precipitation into with available downscaled ensemble

→ This work:

- Evaluation of the methodology on the 2009-2012 period
- Sensitivity of the analysis to the network density

Data



Data available over the 1871-2012 period.

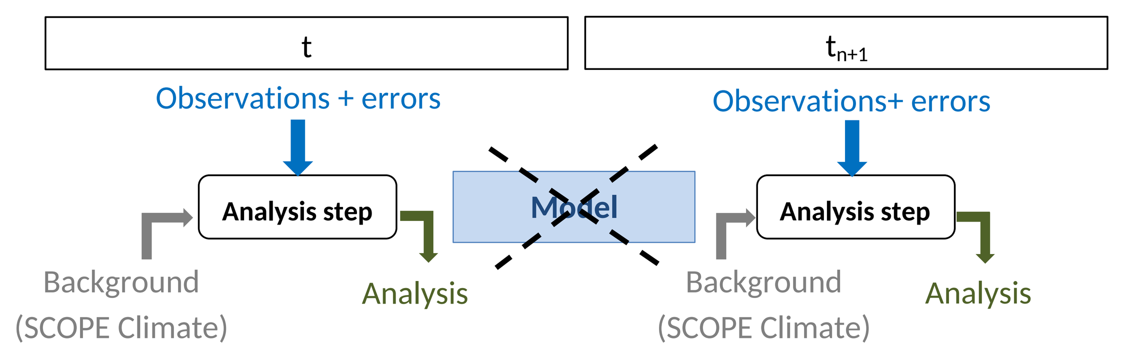
▶ Observations : Daily precipitation over France for the 1871-2012 period with associated measurement metadata

▶ Safran [Vidal et al., 2010] : Deterministic reanalysis of meteorological variables / Daily on the 1958-2012 period / 8 x 8 km grid over France (8602 cells)

▶ SCOPE Climate [Caillouet et al., 2016, 2017] : Ensemble reconstructions (25 members) of meteorological variables / Daily on the 1871-2012 period / 8 x 8 km grid over France (8602 cells)

Methods

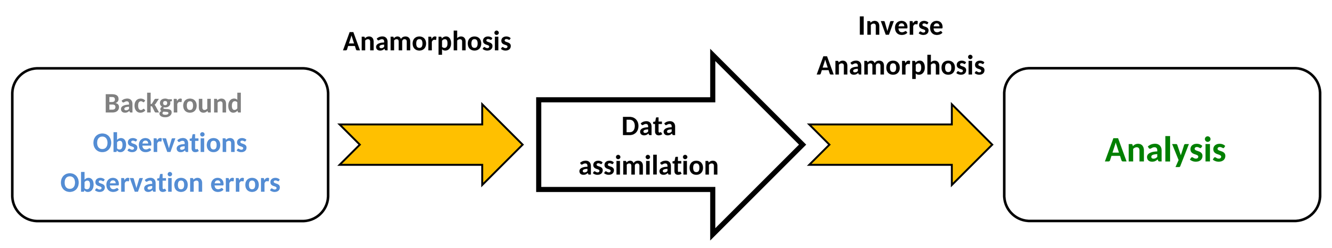
▶ Offline data assimilation scheme



Offline assimilation scheme.

- No model / Analysis step of the Ensemble Kalman Filter [Evensen, 2003]
- Observation error covariance matrix: diagonal with σ_{obs} defined by metadata
- Background error covariance matrix: defined by the 25 members of SCOPE Climate

▶ Gaussian anamorphosis

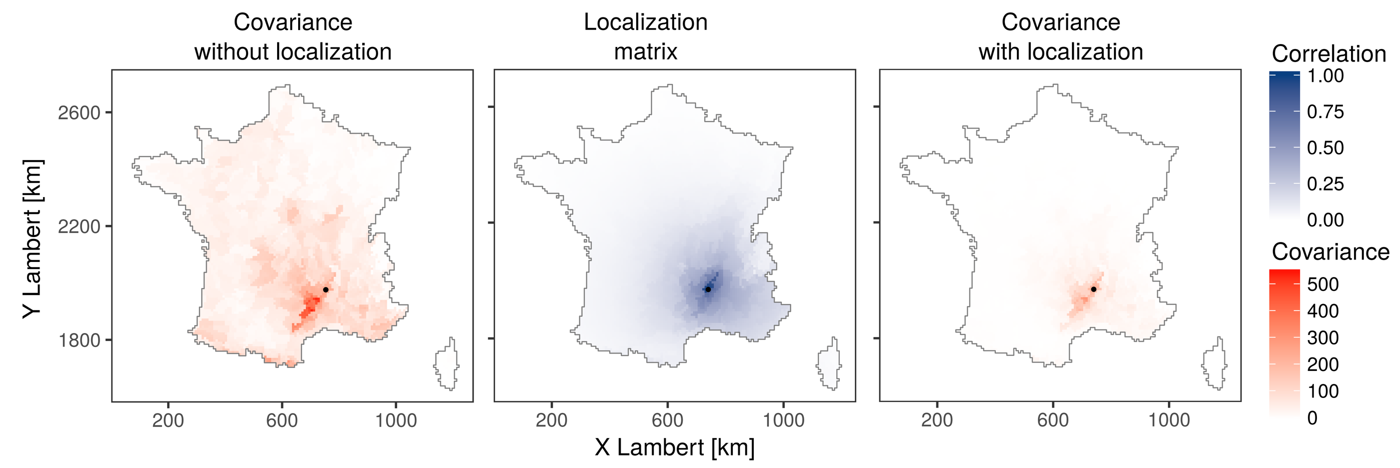


Gaussian anamorphosis scheme.

- Gaussian transformation [Lien et al., 2013] defined on each cell with SCOPE Climate using 1958-2008 period as reference
- Allows a more Gaussian distribution except for non-null precipitation

Methods

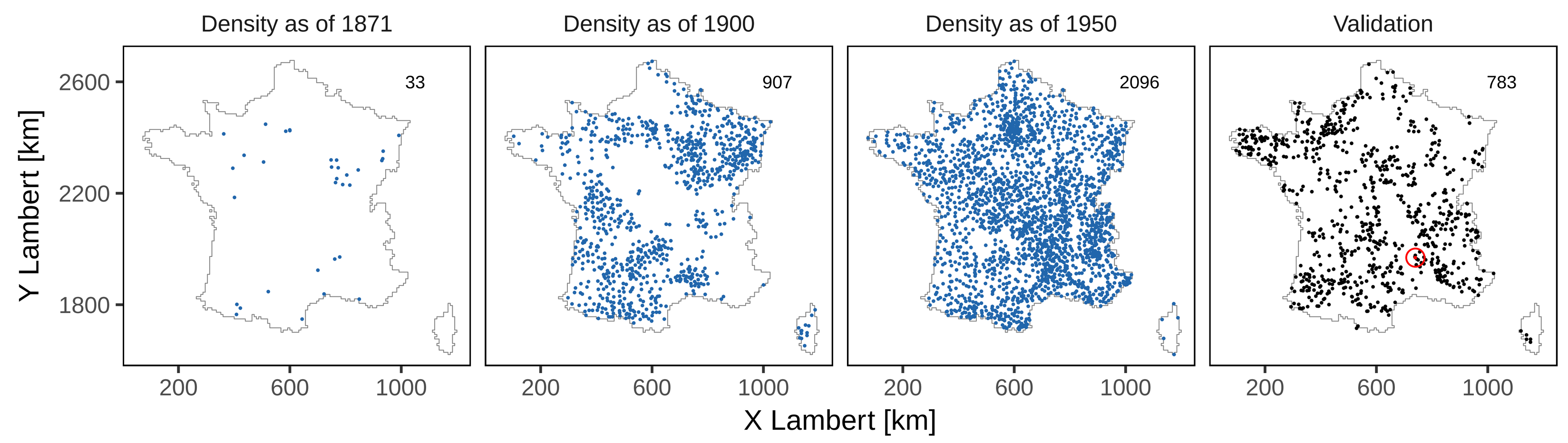
▶ Localization of background error covariance matrix



Example of localization for the case study cell (black square) during the extreme event of 3 november 2011.

- Construction of localization matrix based on spatial correlation of SCOPE Climate over the 1958-2008 period
- Localization matrix is strongly anisotropic

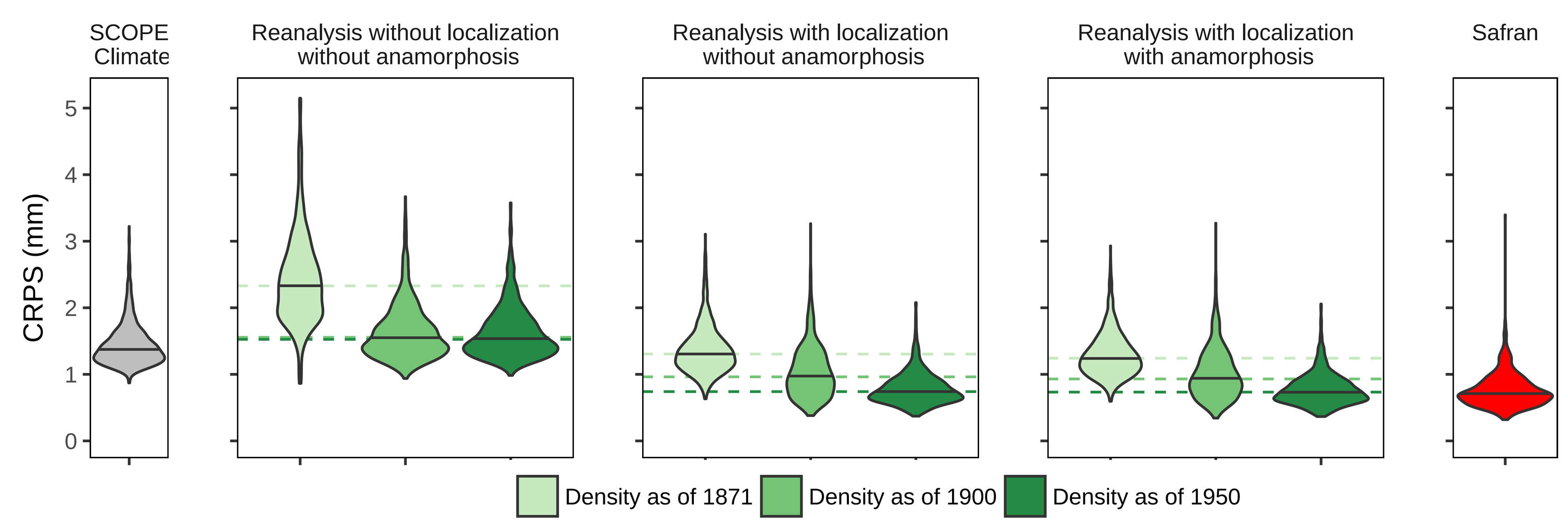
▶ Set-up and Validation



Stations used for simulating different densities and stations used for validation. The red square highlights the case study cell.

- Daily reanalysis over the 2009-2012 period
- Density simulated as of 1871, 1900 and 1950 / A set of 783 stations is used for validation
- Validation using the Continuous Ranked Probability Score (CRPS) between each perturbed observation and the corresponding grid cell value from SCOPE Climate / the reanalysis

(1) Results: added value of localization & anamorphosis



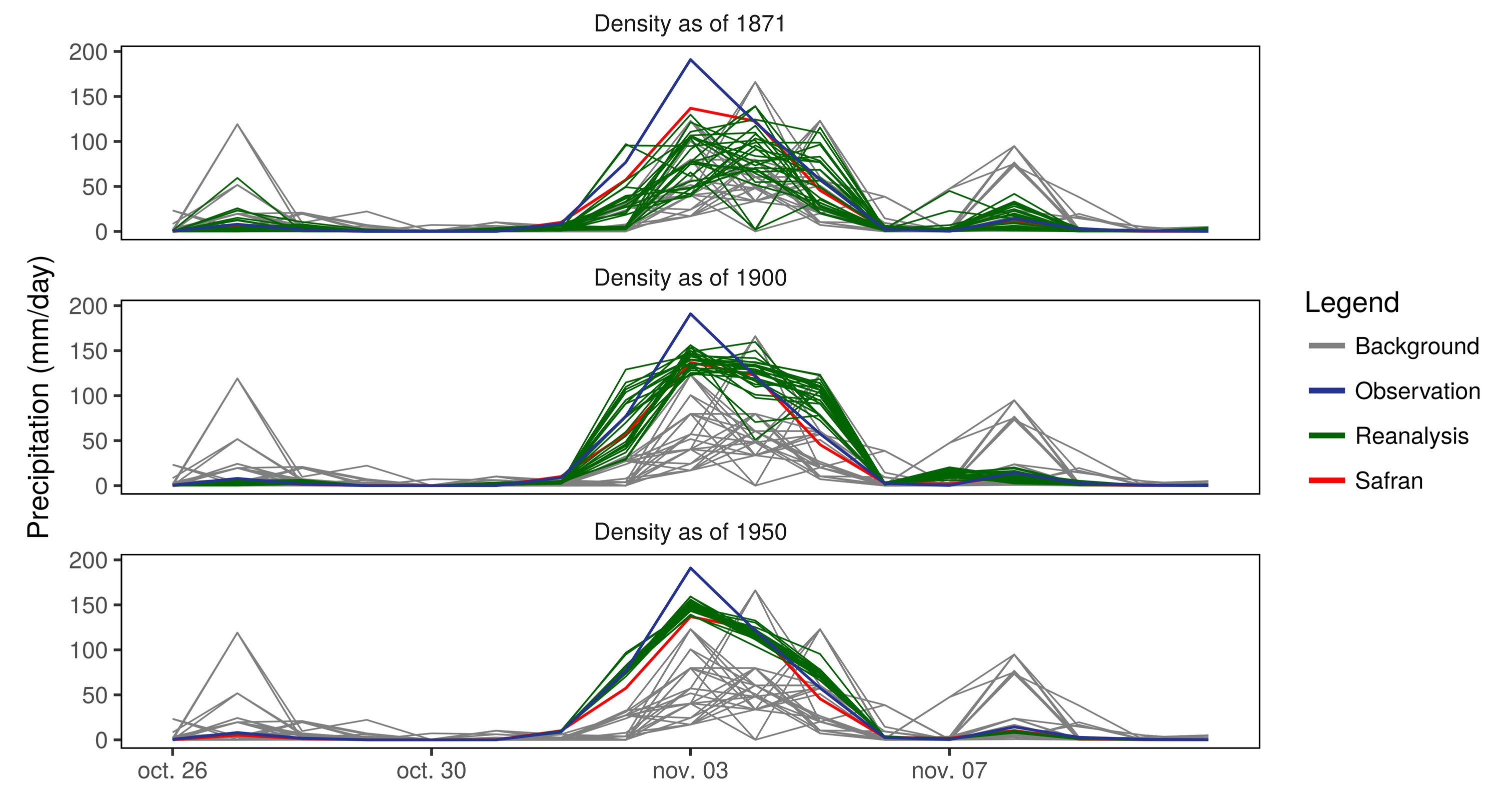
Error as a function of density and uses of localization and anamorphosis.

- Localization:
  Without: error of the reanalysis higher than for the background
  With: error of the reanalysis lower than for the background
- Anamorphosis: overall improvement with anamorphosis
- Localization / Anamorphosis: Improvement strongly dependent on the density

(2) Results: extreme event of November 2011

- Intense rainfall event that led to 14 casualties in the South of France [MunichRE, 2012]

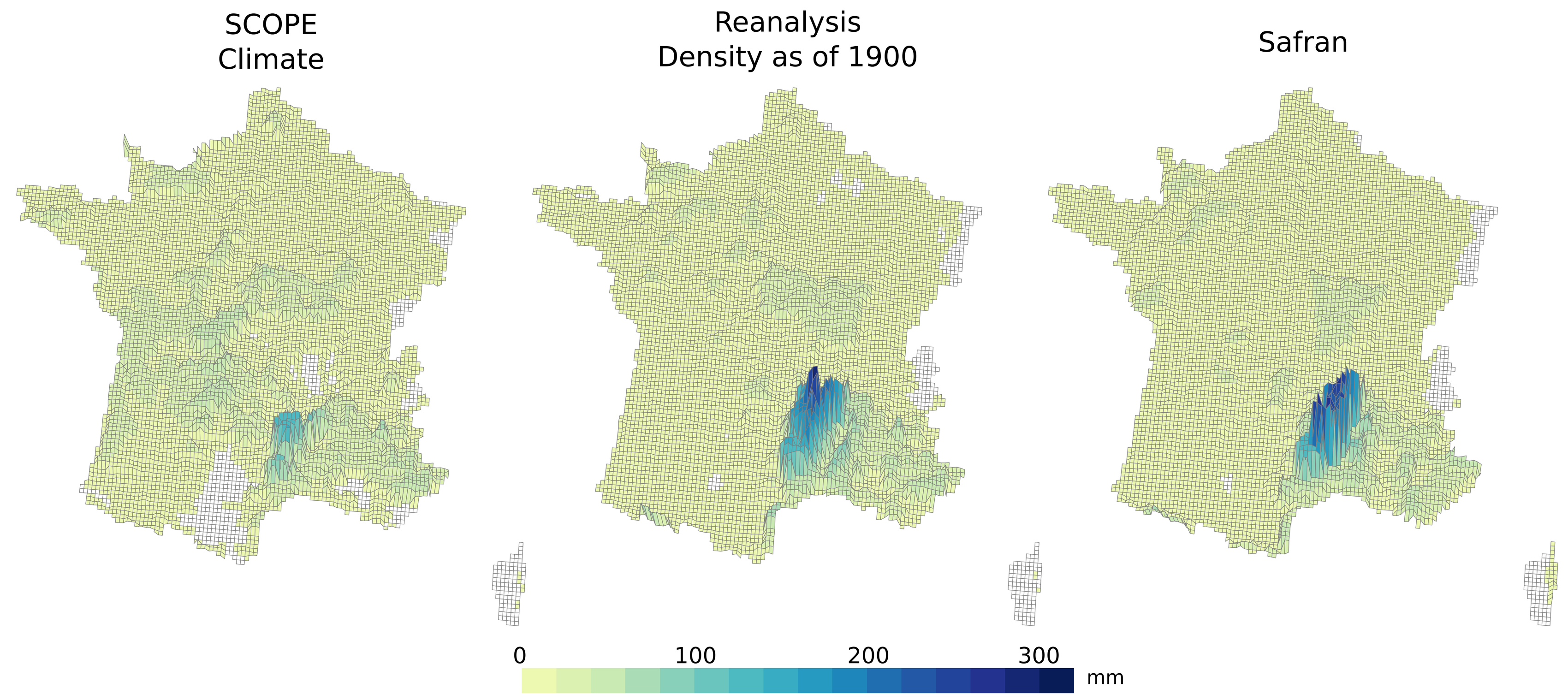
▶ Temporal perspective



Daily precipitation time series for the case study cell during the extreme event of November 2011.

- Reduction of uncertainty / Improves autocorrelation and coherence between members
- Improvement strongly dependent on the density

▶ Spatial perspective



Precipitation over France for the 3 november 2011: member #3 of background and reanalysis together with Safran as reference

- High values (South-East) / small precipitation (West) well reproduced
- Smoother small-scale pattern than Safran

Future work

- Meteorological reanalysis of the full 1871-2012 period for both temperature and precipitation
- Hydrological modeling over France for the 1871-2012 period using the meteorological reanalysis produced for improving current hydrological reconstructions SCOPE Hydro [Caillouet et al., 2017]

References

Caillouet, L., Vidal, J.-P., Sauquet, E., and Graff, B. (2016). Probabilistic precipitation and temperature downscaling of the Twentieth Century Reanalysis over France. Climate of the Past, 12(3):635–662. doi:10.5194/cp-12-635-2016

Caillouet, L., Vidal, J.-P., Sauquet, E., Devers, A., and Graff, B. (2017). Ensemble reconstruction of spatio-temporal extreme low-flow events in France since 1871. Hydrology and Earth System Sciences, 21:2923–2951. doi:10.5194/hess-21-2923-2017

Evensen, G. (2003).The Ensemble Kalman Filter: theoretical formulation and practical implementation. Ocean Dynamics, 53(4):343–367. doi:10.1007/s10236-003-0036-9

Lien, G.-Y., Kalnay, E., and Myoshi, T. (2013), Effective assimilation of global precipitation: Simulation experiments. Tellus A, 65.doi:10.3402/tellusa.v65i0.19915

Vidal, J.-P., Martin, E., Franchistéguy, L., Baillon, M., and Soubeyroux,J.-M. (2010).A 50-year high-resolution atmospheric reanalysis over France with the Safran system. International Journal of Climatology, 30(11):1627–1644. doi:10.1002/joc.2003

MunichRE. (2012). Natural catastrophes 2011. Analyses, assessments, positions. Topics GEO, 302-07226, 62 p