Figure S1. Comparisons of the monthly means (2010-2020) of integrated precipitable water (PRW, in cm) simulated by ALADIN in hindcast mode (green lines) with coincident photometric measurements (black lines) for the six AERONET measurement sites located in the BNF region.
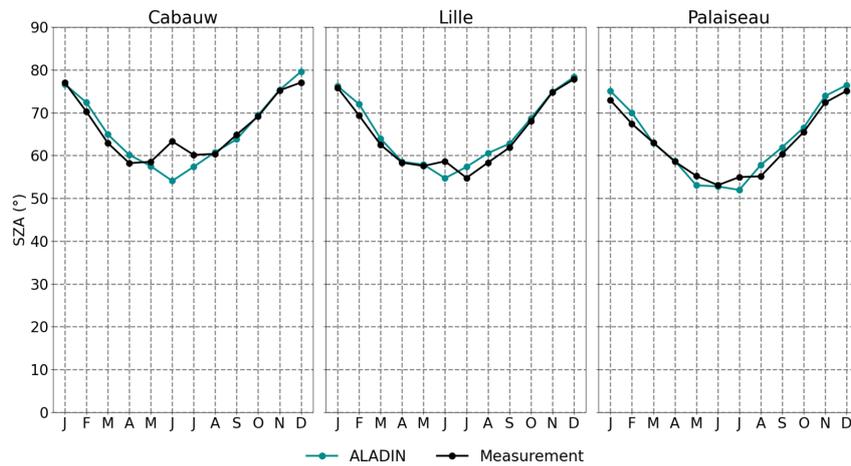
Figure S2. Comparisons of the monthly means (2010-2020) of measured (black lines) and simulated in hindcast mode (green lines) daytime average solar zenith angle under clear-sky (in degrees) conditions for the three irradiance measurements stations located within the BNF region.
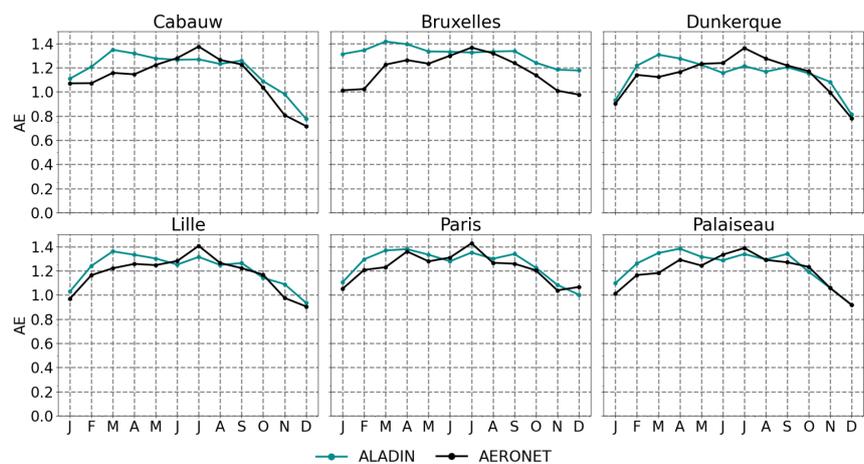
Figure S3. Comparisons of the monthly means (2010-2020) of Ångström exponent between 440 and 870 nm simulated by ALADIN in hindcast mode (green lines) with coincident photometric measurements (black lines) for the six AERONET measurement sites located in the BNF region.
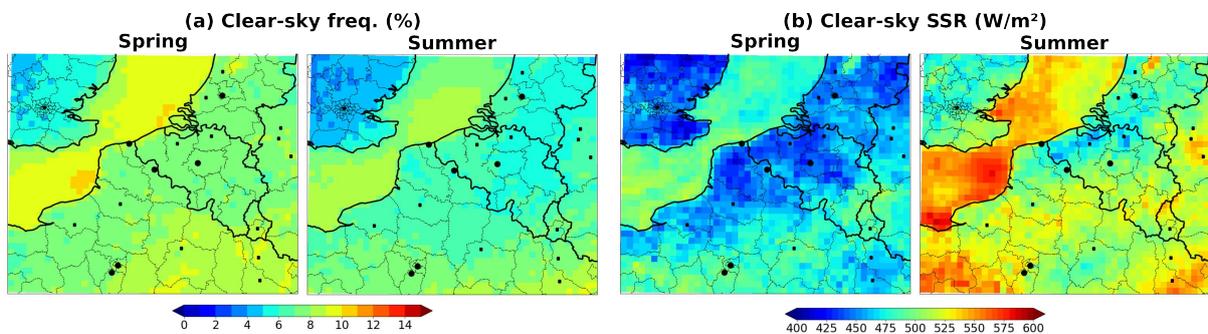
Figure S4. Seasonal averages over the period 2010-2020 of ALADIN daytime hourly hindcast simulations of clear-sky (a) frequency and (b) SSR in spring and summer.
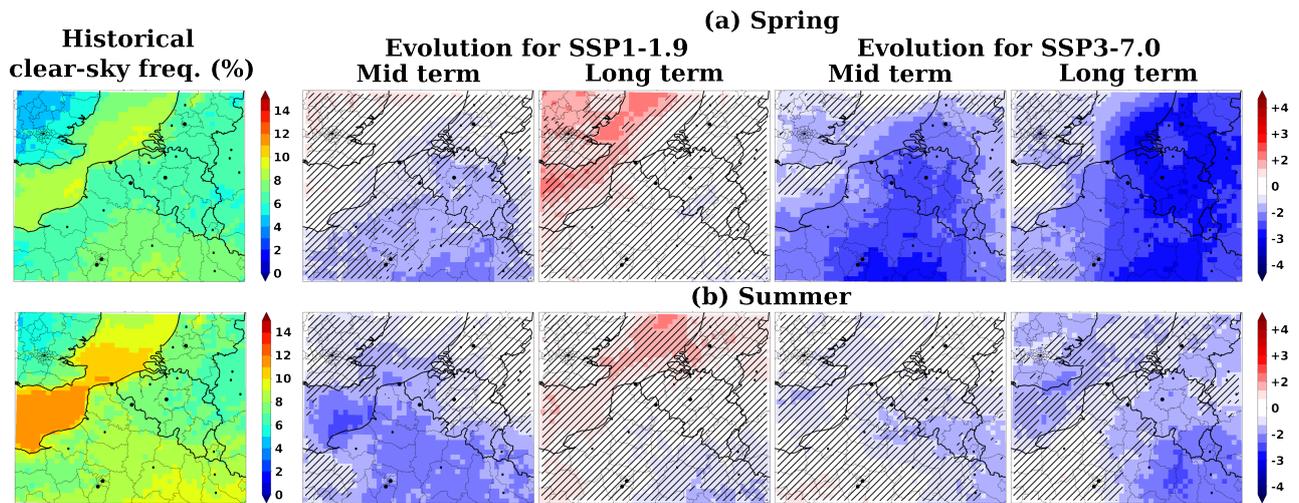
Figure S5. Future evolutions for CMIP6 scenarios SSP1-1.9 and SSP3-7.0 of the daytime clear-sky frequency (%) estimated from ALADIN simulations compared to the reference climate simulations over the period 2005-2014 (left panels) in (a) spring and (b) summer. Hatched areas correspond to areas characterized by a non-significant changes relative to a Student t-test with a significance level of 10%.
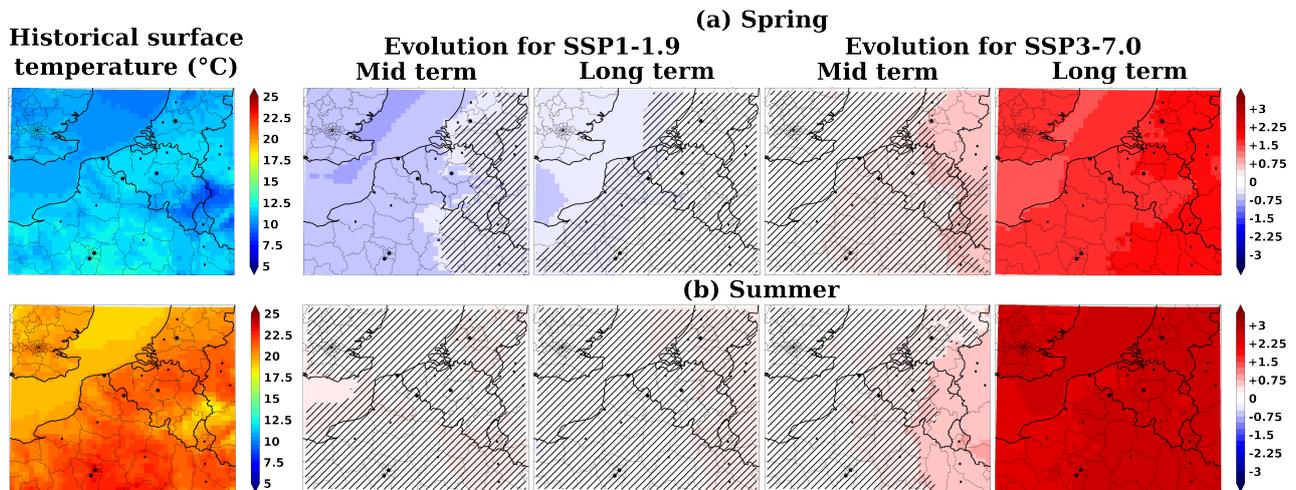
Figure S6. Future evolutions for CMIP6 scenarios SSP1-1.9 and SSP3-7.0 of the daytime surface temperature (°C) simulated by ALADIN compared to the reference climate simulations over the period 2005-2014 (left panels) in (a) spring and (b) summer. Hatched areas correspond to areas characterized by a non-significant changes relative to a Student t-test with a significance level of 10%.

	Sulfate		Nitrate		Ammonium		Organic		Black carbon		Total PM$_1$ concentration ($\mu g.m^{-3}$)	
	Model	ATOLL	Model	ATOLL	Model	ATOLL	Model	ATOLL	Model	ATOLL	Model	ATOLL
Winter	0.7	1.5	2.6	5.1	0.8	2.2	1.3	5.7	0.5	1.4	**5.8**	**15.9**
Spring	0.8	1.1	6.8	5.2	2.0	2.1	1.1	4.1	0.4	0.7	**11.0**	**13.3**
Summer	0.8	1.2	3.8	2.1	1.1	1.3	1.0	4.8	0.4	0.7	**7.1**	**10.1**
Autumn	0.8	1.2	2.8	3.6	0.8	1.6	1.3	4.8	0.5	1.1	**6.1**	**12.2**
Overall	**0.8**	**1.2**	**4.0**	**4.0**	**1.2**	**1.8**	**1.2**	**4.9**	**0.4**	**1.0**	**7.5**	**12.9**

Table S1. Mean daytime PM_1 surface concentrations (in $\mu g.m^{-3}$), per season and on average over the period 2016-2020, of the different aerosol types simulated by ALADIN or measured by the ACSM and aethalometer from the ATOLL platform.

Mean aerosol optical depth at 550 nm

		Total	Sulfate	Nitrate	Ammonium	Organic matter	Black carbon	Sea salt	Desert dust
HINDCAST	2010-2020	0.19	13.6	51.0	13.7	4.6	1.8	14.1	1.2
Historical	2005-2014	0.17	16.7	46.5	12.5	3.9	1.9	16.2	2.3
SSP1-1.9	2045-2054	0.14	6.4	56.3	15.3	2.2	0.3	18.1	1.3
SSP1-1.9	2091-2100	0.13	4.9	56.6	12.3	4.7	0.1	19.6	1.7
SSP3-7.0	2045-2054	0.20	8.4	55.0	15.0	3.0	0.9	15.7	1.9
SSP3-7.0	2091-2100	0.19	7.0	56.0	15.3	2.3	0.6	17.0	1.8

(a) Spring

Mean aerosol optical depth at 550 nm

		Total	Sulfate	Nitrate	Ammonium	Organic matter	Black carbon	Sea salt	Desert dust
HINDCAST	2010-2020	0.14	18.4	44.1	11.8	6.1	2.2	15.4	2.2
Historical	2005-2014	0.13	22.6	41.6	11.0	6.3	2.6	14.6	1.4
SSP1-1.9	2045-2054	0.11	7.8	54.3	14.7	4.7	0.5	16.6	1.4
SSP1-1.9	2091-2100	0.10	6.1	55.7	15.1	4.3	0.3	17.0	1.6
SSP3-7.0	2045-2054	0.15	10.5	53.7	14.6	5.6	1.3	12.9	1.3
SSP3-7.0	2091-2100	0.15	8.9	55.8	15.3	4.9	1.0	13.0	1.1

(b) Summer

Table S2. Mean AOD at 550 nm over the BNF region and corresponding contributions (in %) of the different aerosol types simulated by ALADIN for *HINDCAST*, *HIST*, *SSP119* and *SSP370* datasets in (a) spring and (b) summer.

Δ AOD [550 nm]	-0.05	-0.04	-0.03	-0.02	-0.01	+0.01	+0.02	+0.03	+0.04	+0.05	+0.06
Δ PRW (cm)	-0.5	-0.4	-0.3	-0.2	-0.1	+0.1	+0.2	+0.3	+0.4	+0.5	+0.6
Associated $\Delta \mathrm{SSR_{cf}}$ (W/m^2)	+8.5	+6.8	+5.1	+3.4	+1.7	-1.7	-3.4	-5.1	-6.8	-8.5	-10.2

Table S3. Sensitivity of the surface solar irradiance, in W/m^2, relative to changes in aerosol optical depth and precipitable water under clear-sky conditions. Results based on radiative transfer simulations presented in Chesnoiu et al. (2024b) for typical values of atmospheric parameters observed in Lille over the period 2010-2022.