DustClim WP3
Solar & Aviation products

Athanasios Votsis & the DustClim Team

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ERA4CS European Research Area for Climate Services
DustClim
BSC
AEMet Agencia Estatal de Meteorología
cnrs

I. Solar energy

Soiling index

Sunshine hours

Optimal cleaning frequency

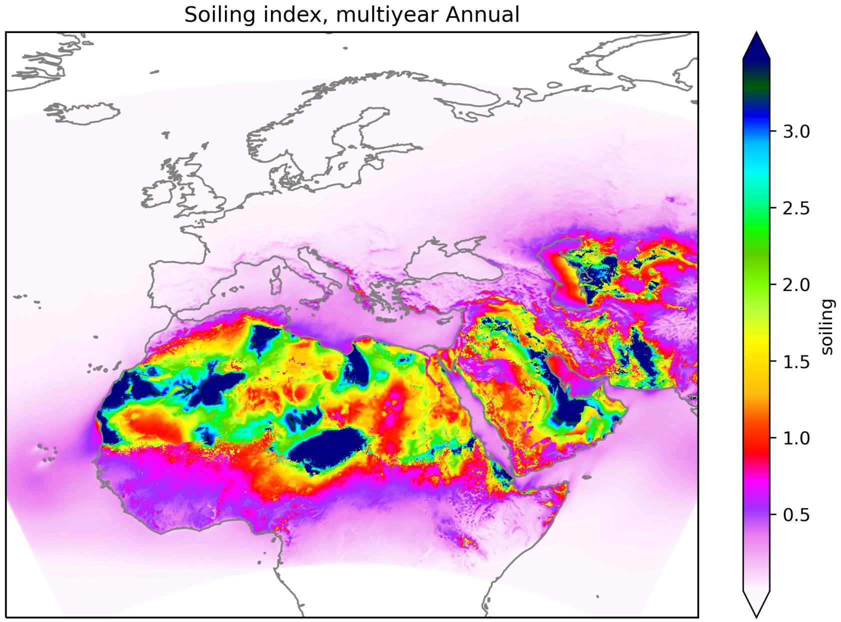
Soiling index [% of transmittance reduction]

- Bergin et al. (2017), adapted in D3.1 and Rautio et al. (in preparation).

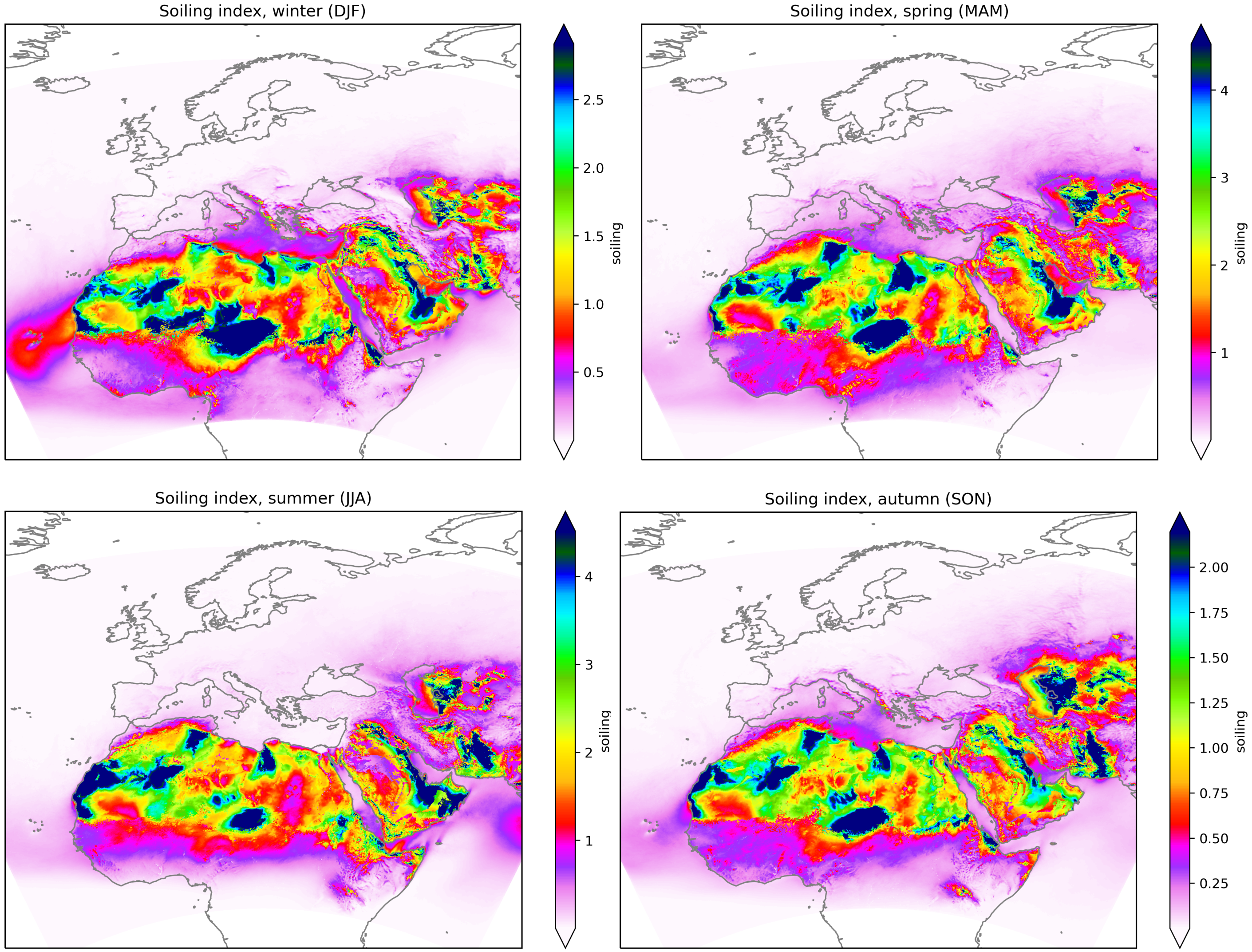
- $\Delta T = -(E_{abs} + \beta E_{scat})*(dep_{dry} + dep_{wet})$
- For dust particles, $E_{abs} = 0.02$, $\beta = 0.02$, $E_{scat} = 1$
- Soiling Index = $0.04*(dep_{dry} + dep_{wet})*100$

- Simple approximation, does not take into account other performance reduction factors (e.g. salt deposition, self cleaning from wet deposition). Assumes a horizontal fixed solar PV panel. Assumes that change in transmittance is linearly related to the mass loading of particulate matter (dust only).

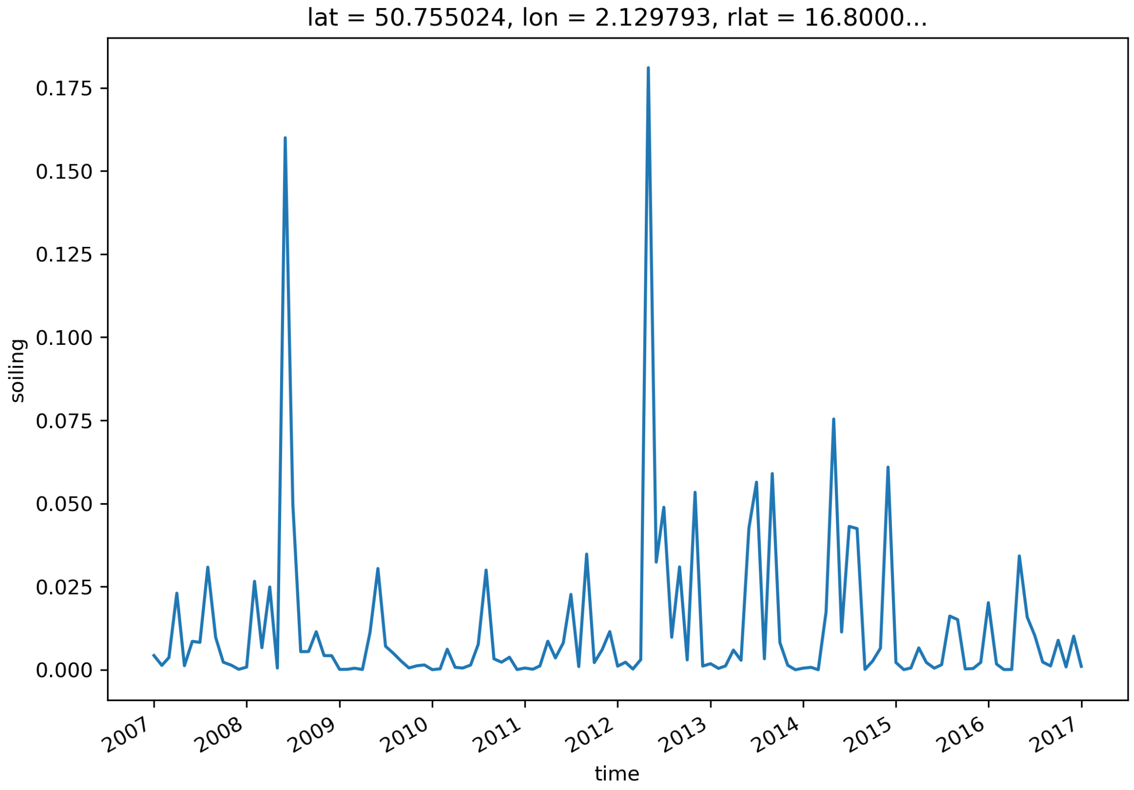
Climatology of soiling index (2007-2016)

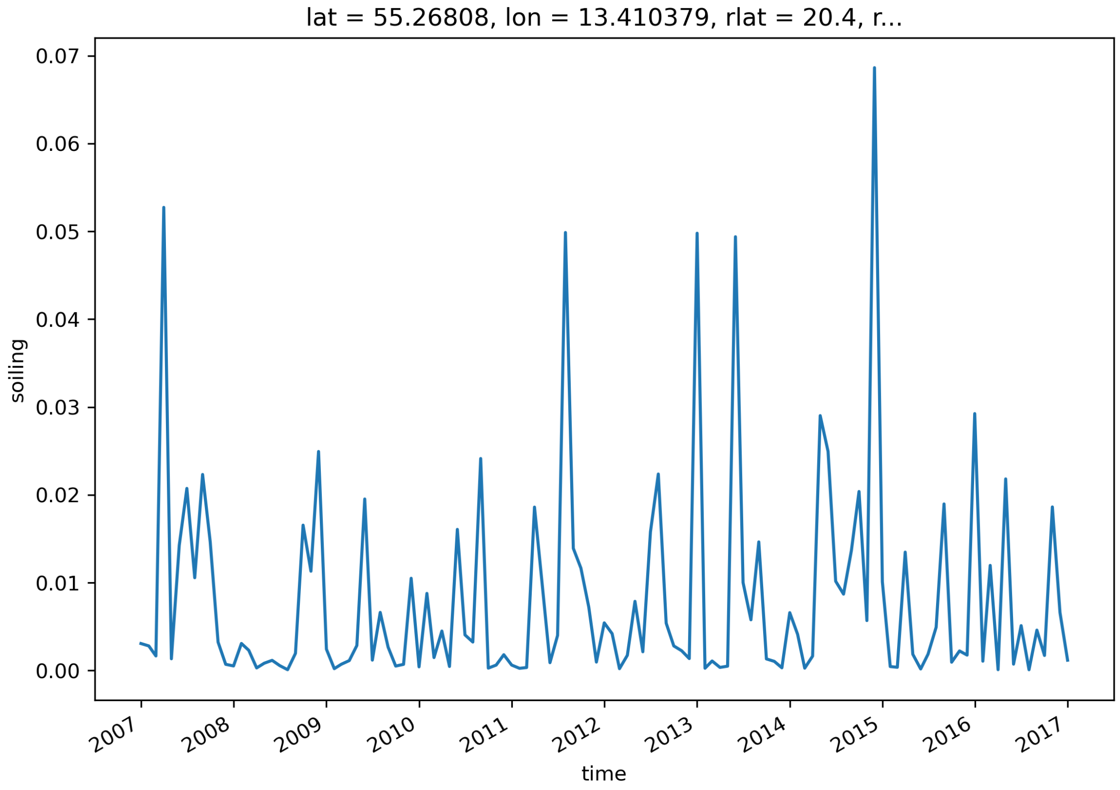


	ANN	DJF	MAM	JJA	SON
mean	0.6	0.5	0.7	0.7	0.4
std. dev.	1.1	1.3	1.5	1.3	0.7
min	0.0	0.0	0.0	0.0	0.0
25%	0.02	0.01	0.02	0.01	0.01
50%	0.2	0.1	0.17	0.1	0.1
75%	0.6	0.5	0.8	0.8	0.4
max	25.8	41.1	40.2	45.9	23.7



Time series examples (Barcelona vs Berlin pixels)



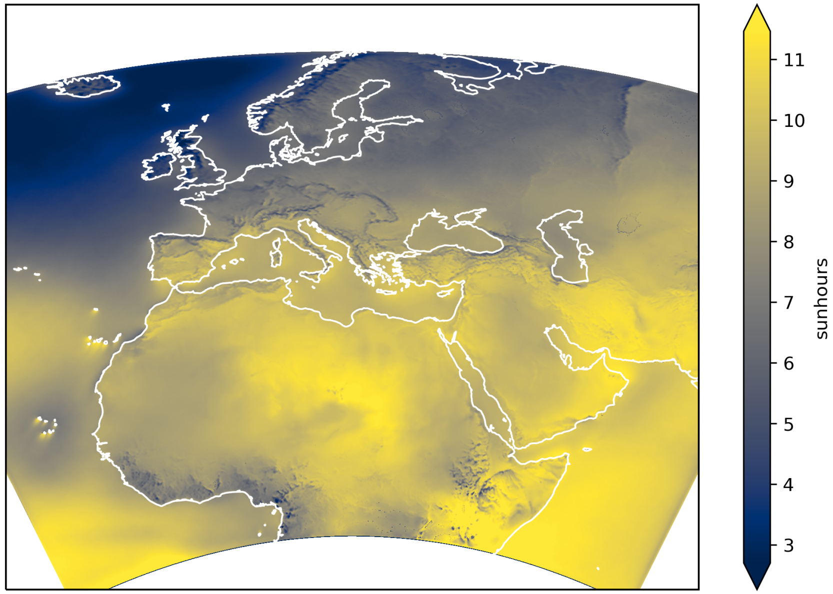


Sunshine duration [hours]

- WMO (2018)
- Derived from the count of 3-hour segments with DNI > 120 Wm^{-2}
- Provides the potential maximum sun hours, corrected with the presence of dust.

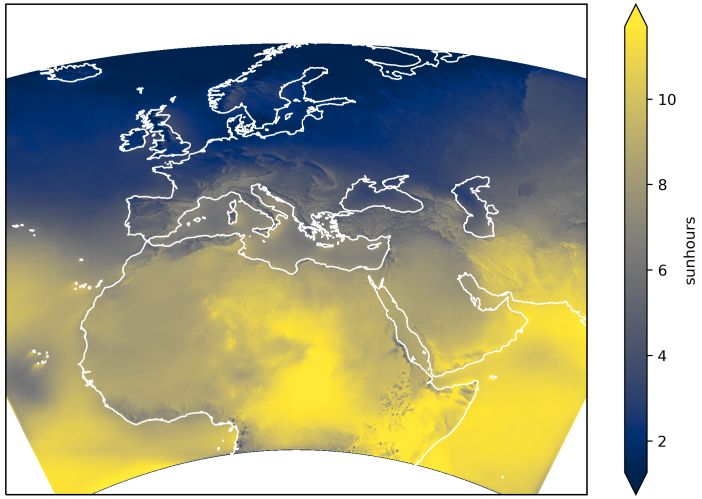
Climatology of sunhours (2007-2016)

Potential maximum sunshine hours, multiyear Annual

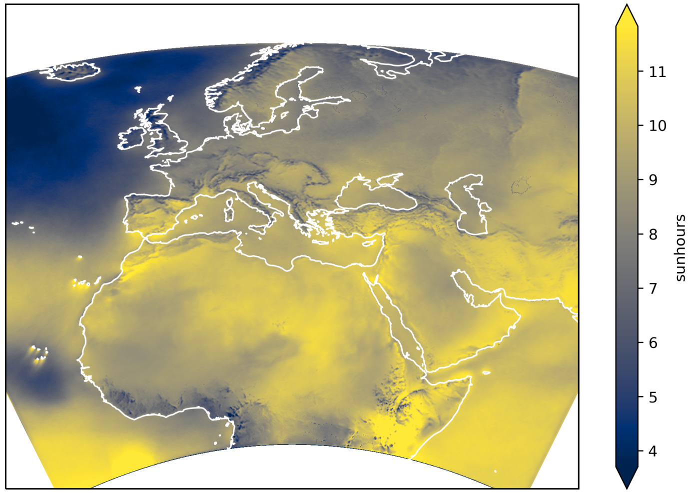


	ANN	DJF	MAM	JJA	SON
mean	8.6	7.3	9.0	9.9	8.2
std. dev.	2.3	3.3	2.1	2.6	2.8
min	0	0	0	0	0
25%	7.4	4.2	8.1	8.6	6.5
50%	9.2	8.2	9.6	10.4	9.0
75%	10.3	10.0	10.6	11.7	10.3
max	13.7	13.5	15.0	16.0	14.3

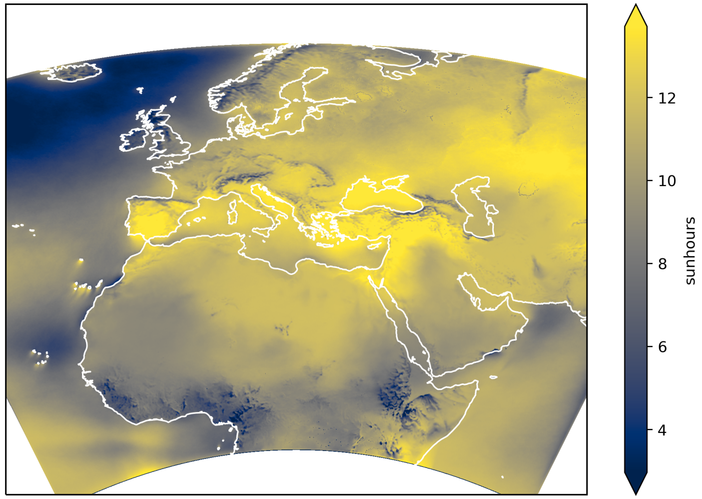
Potential maximum sunshine hours, winter (DJF)



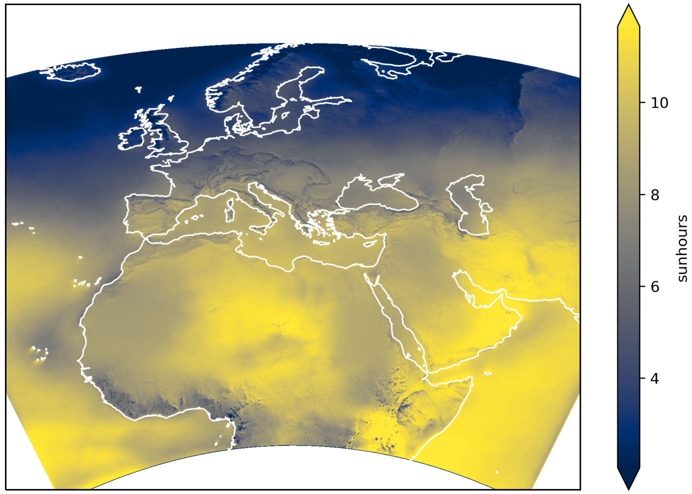
Potential maximum sunshine hours, spring (MAM)



Potential maximum sunshine hours, summer (JJA)



Potential maximum sunshine hours, autumn (SON)



Optimal cleaning frequency [days]

- After Abu-Naser (2017). After how many days a panel should be cleaned to operate with profit, given cleaning cost, electricity selling price, capacity *[constants]*, **sunshine hours**, and **retrospective average soiling index of past month** *[reanalysis]*.

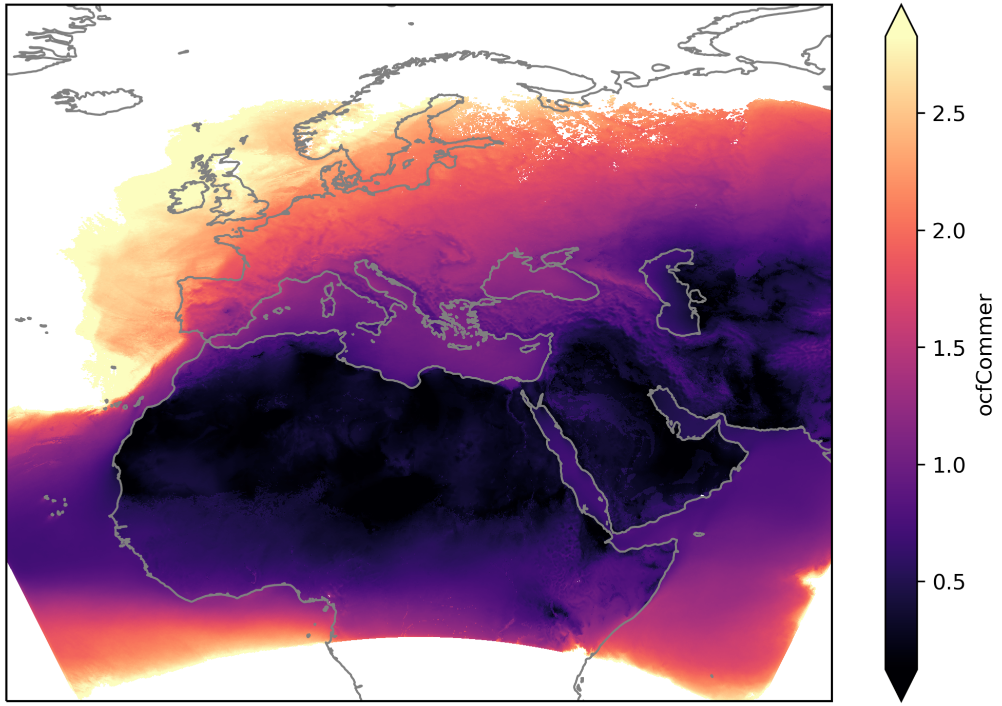
- OCF = sqrt(2ic / αsiβ),

  where *OCF* is the optimal number of days between cleaning cycles, *α* the average daily losses in solar conversion efficiency due to dust deposition, *s* the average sun hours per day, *i* the kW capacity of the installed panel, *c* is the cleaning cost per kW size, and *β* the selling price of one kWh of electricity.

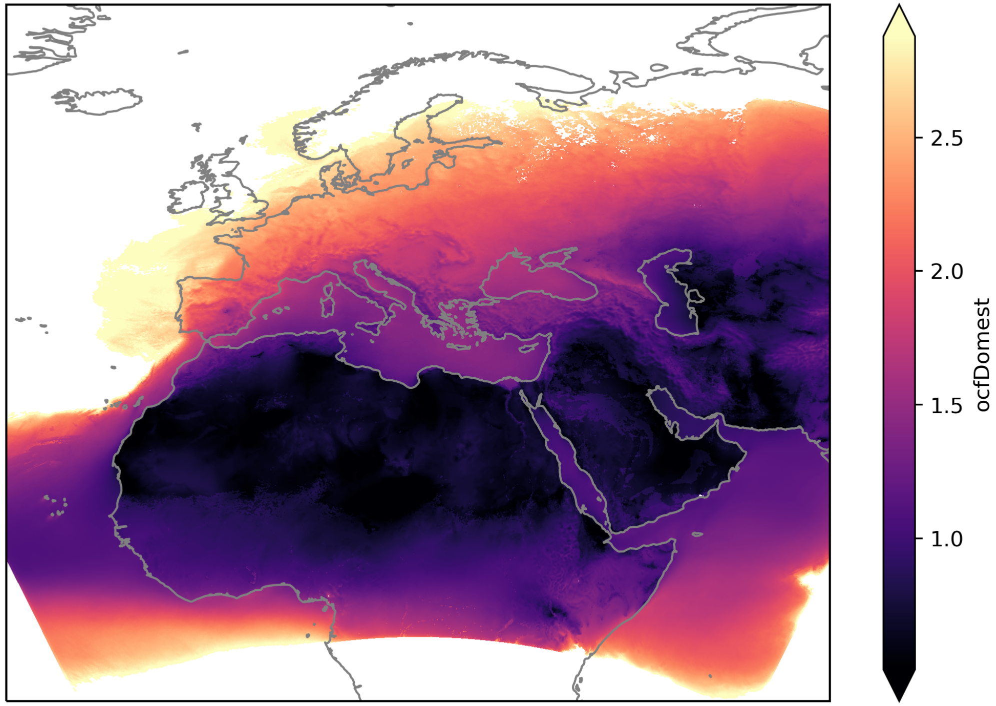
Climatology of OCF for indicative commercial and domestic solar PV panels (2007-2016)

	commercial	**domestic**
i **(size, kW)**	100000	6
c **(unit cost of cleaning, $/kW)**	0.032 (machine)	0.19 (manual)
β **(electricity price, $)**	0.13	0.13
s **(mean daily sunlight, hours)**	location and time specific; see Section 3.3	
α **(mean daily loss of output, ratio 0-1)**	location and time specific; see Section 3.2	

log10 Optimal Cleaning Frequency (days, Commercial), multiyear Annual



log10 Optimal Cleaning Frequency (days, Domestic), multiyear Annual



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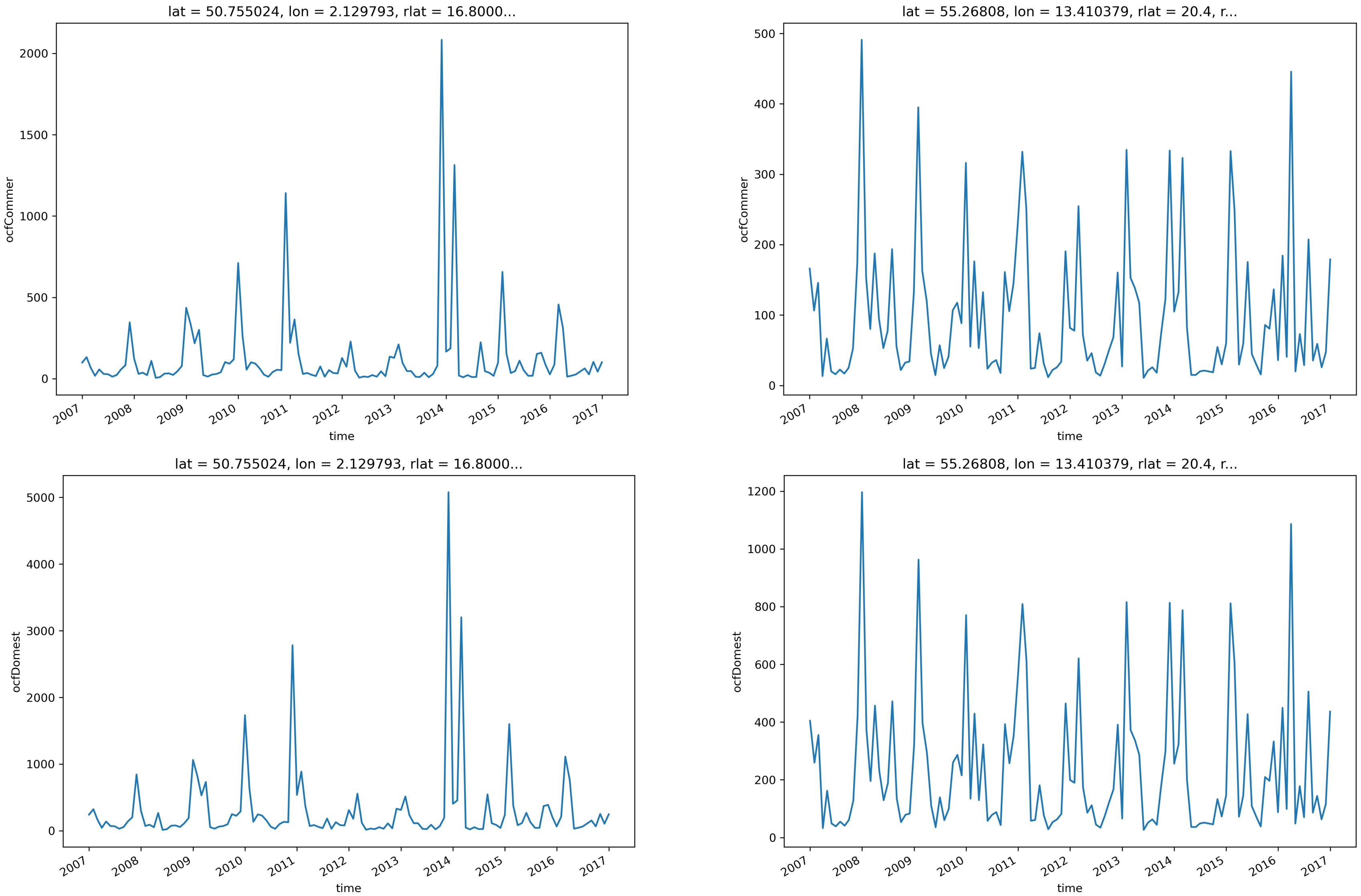
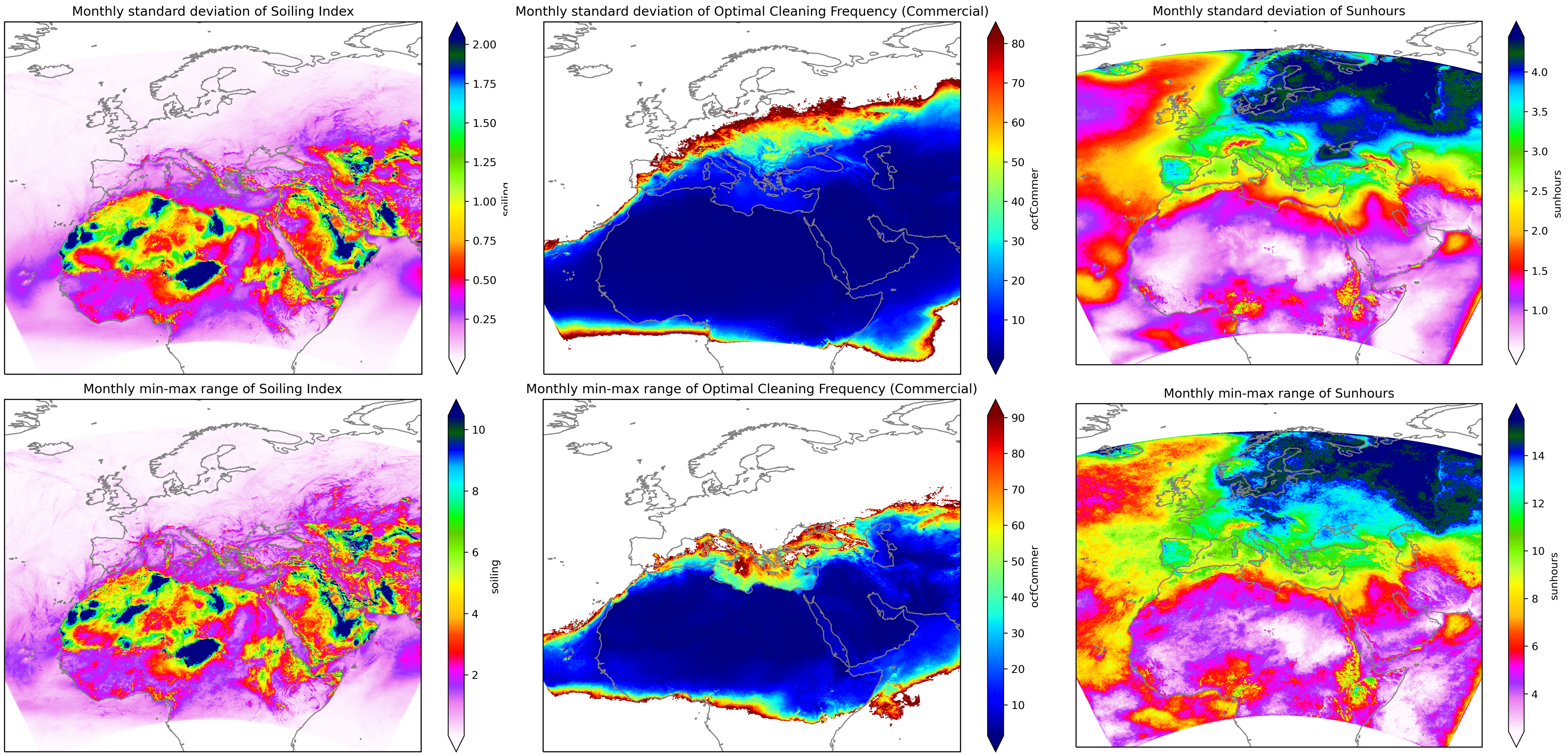
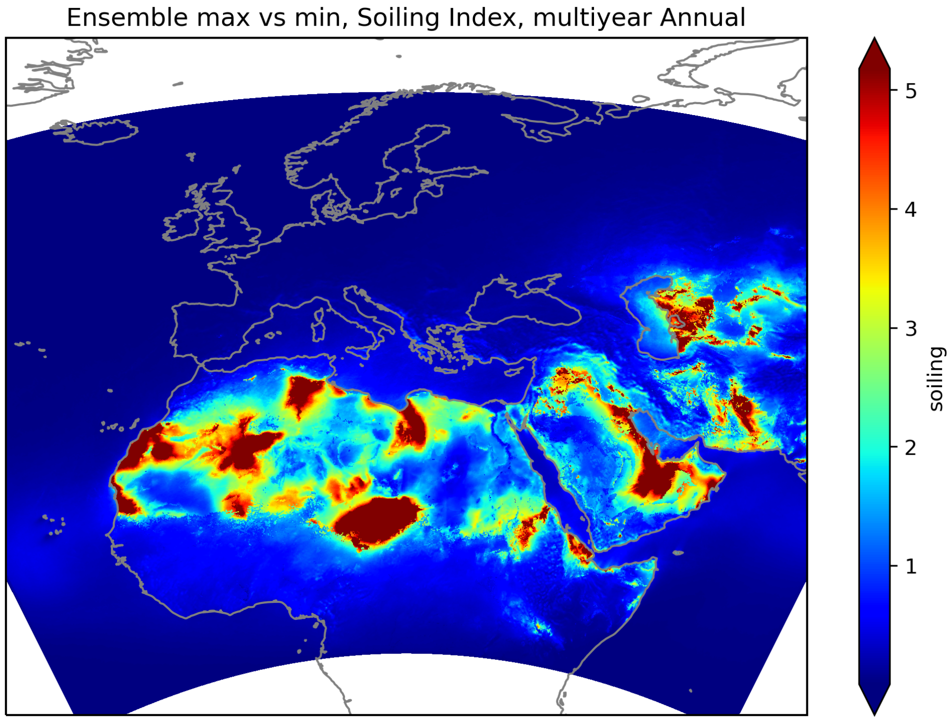
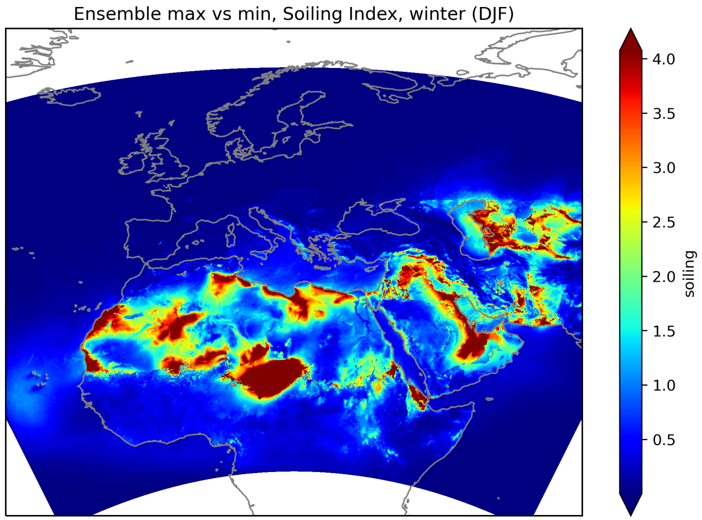


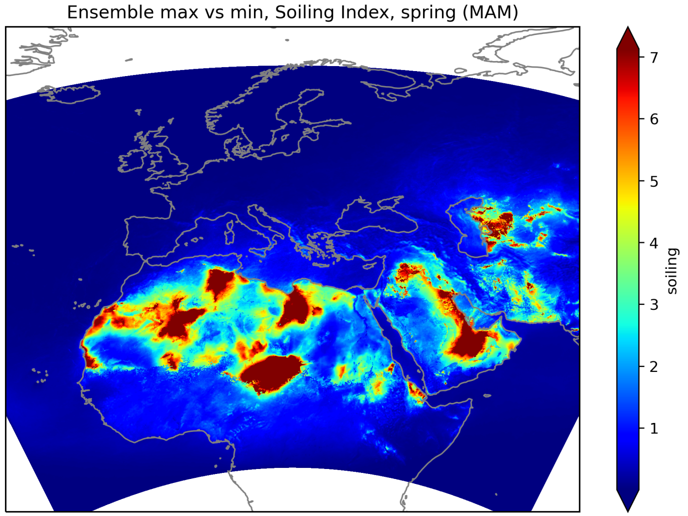
Investment & operational risk: Climatological variability

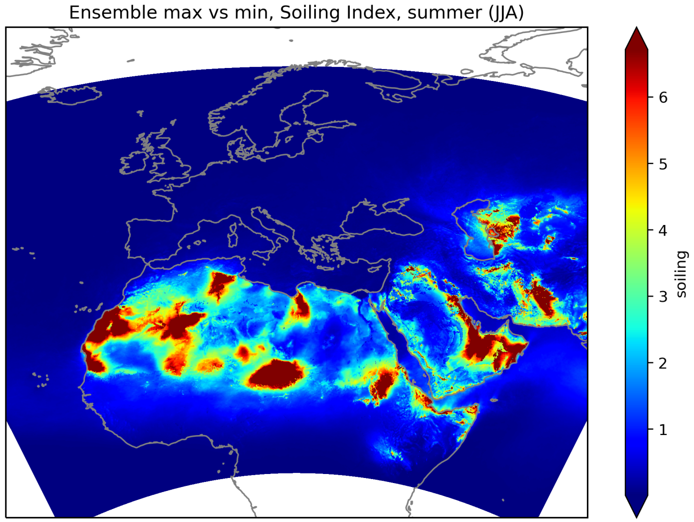


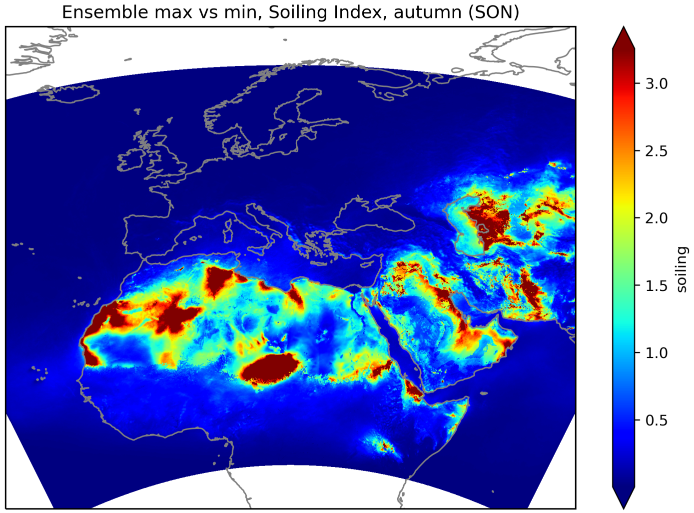
Investment & operational risk: Ensemble avg vs max, Soiling index



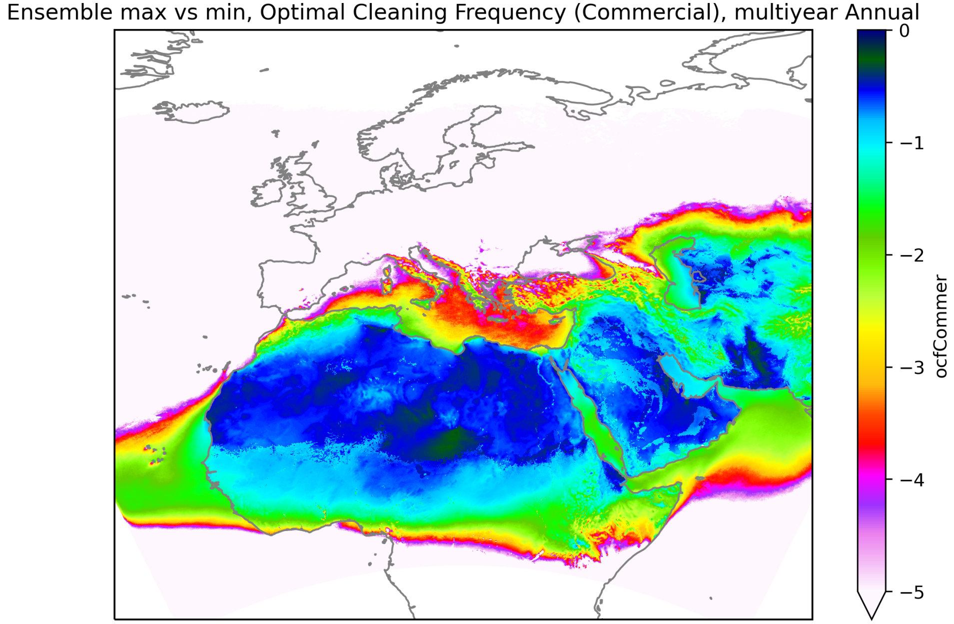


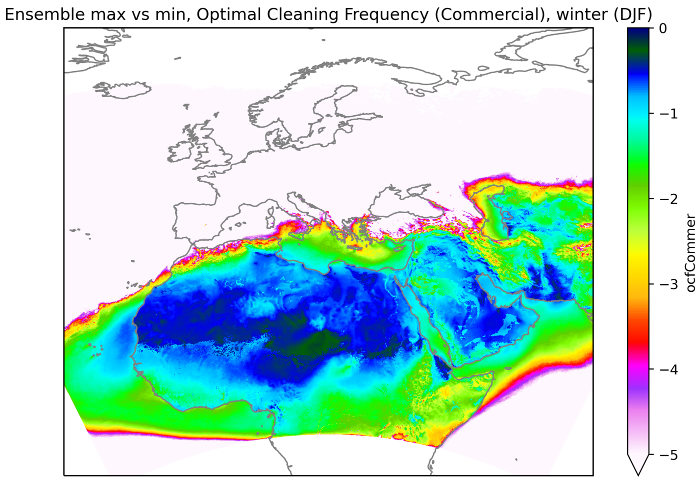


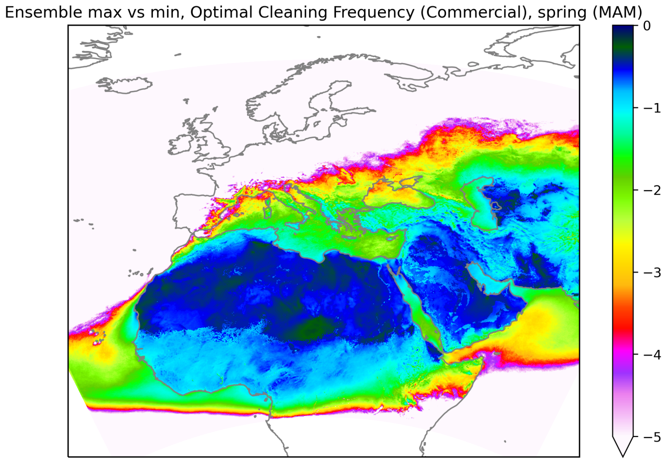


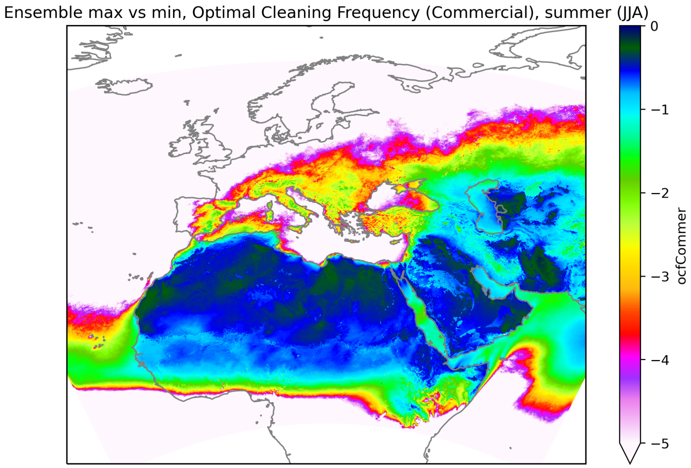


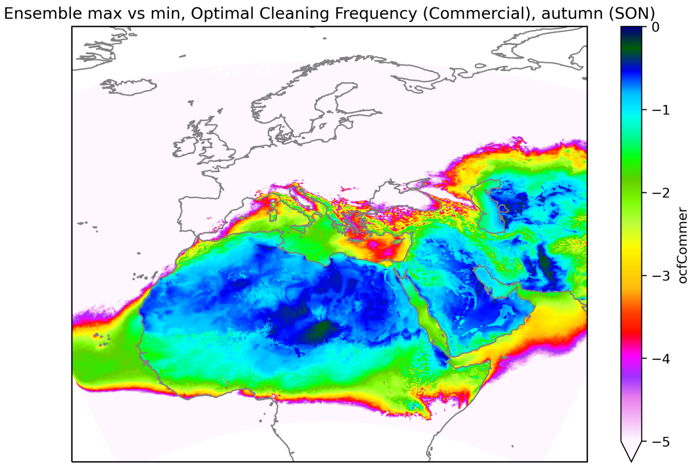
Investment & operational risk: Ensemble avg vs max, Optimal cleaning frequency for commercial SPV panels











Societal benefits: SWOT analysis

South Europe Solar Energy SWOT

Strenghts

- Europe is leading in installed capacity
- PV is still seen as a secure investment for investors with secure rates of return
- Technical potential of PV is several times more than energy consumpiton in certain regions

Weaknesses

- Debate of reducing support tariffs
- Uncertainty of policy support
- Uncertainties reduce investors' confidence in the markets
- Uncertainties in forecasting PV energy production

internal

Opportunities

- Government-supported tariffs have remained high
- System prices decrease rapidly
- Development of Climate Services improve PV energy forecasts

Threaths

- Growth of PV has concentrated only in few countries
- Economic potential of PV is strongly dependent on international climate policy and national energy policies

external

Africa Solar Energy SWOT

Strenghts

- Potential for Solar Energy
- Energy security
- Low political risk
- Political and economical support
- PV energy is unlimited and carbon free

Weaknesses

- Storaging energy
- SDS storms
- Technical inefficiency
- System costs
- Possible extra costs (repairs)

internal

Opportunities

- Rural areas lack acces to power grid
- Grid systems are generally unreliable
- Solar Energy meets international commitments for renewable energy
- Energy demand
- Sustainable growth & SD goals
- Reduces poverty through electicity access

Threaths

- Technical and expertise lag
- Societal practises
- Political instability
- Loan interest rates

external

Middle East Solar Energy SWOT

Strenghts

- Large potential due to climatology
- PV systems help to achieve RE targets
- Solar Energy has more potential than wind
- Transition towards environmentally friendly policies (Saudi Arabia)

Weaknesses

- SDS storms
- Inefficient energy use
- High dependency on fossil fuels
- Critical infrastructure is affected directly or indirectly by conflicts

internal

Opportunities

- Feed in tariffs
- High energy consumption per capita
- Underused energy production capacity
- Decreasing capital costs of PV systems

Threaths

- Political instability
- Conflicts
- High reserves of oil and natural gas
- Inadequate share of renewable energy

external

A way to correspond the solar products to the current strengths-weaknesses-opportunities-threats of the solar energy sector in the NAMEE region.

Therefore, systematizing how these products address the identified strategic situation in these regions for the energy sector.

II. Aviation

Ground visibility

Flight route exposure

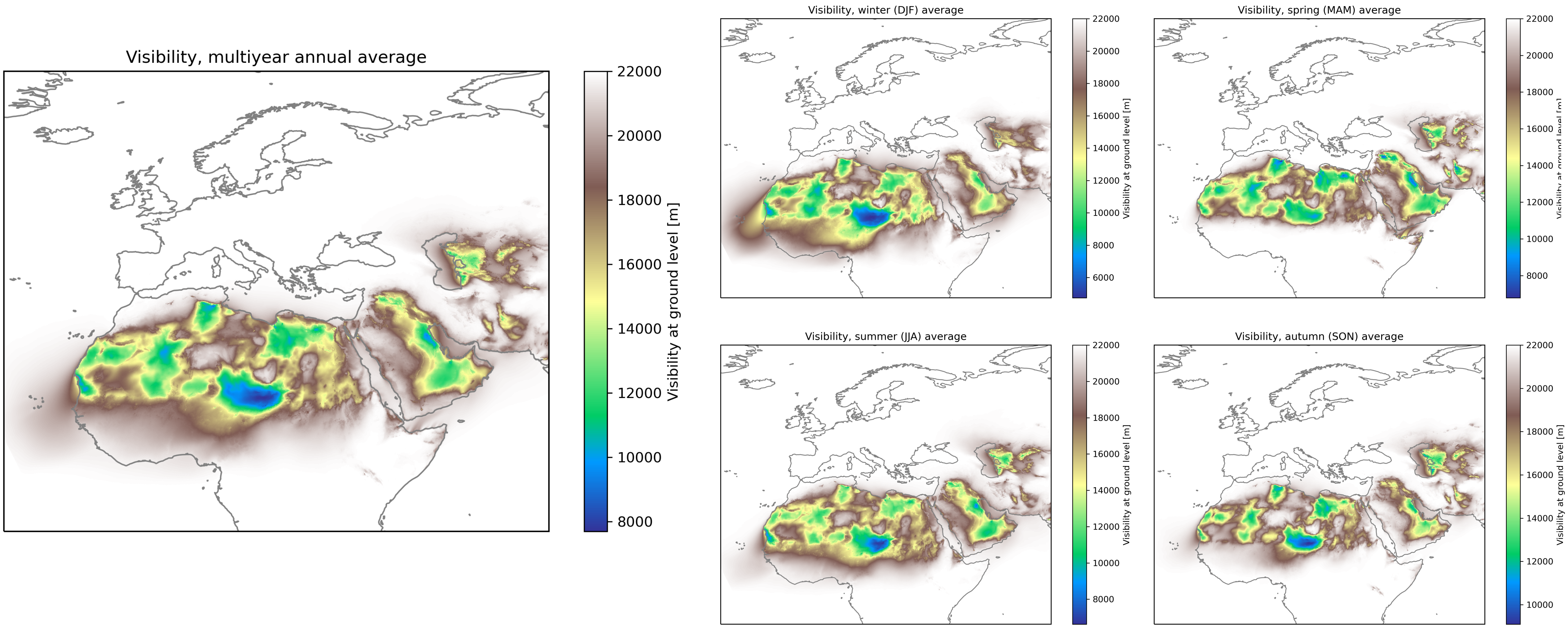
Visibility

Visibility threshold (meters)	Limit/Range	Procedure
Visual Flight Rules (VFR)		
10000+	over	
10000	below	
8000	below	
5000	below	
3000	below	
1500	below	
Instrument Flight Rules (IFR) according to ICAO/FAA thresholds		
800+	over	CAT I
800–350	between	CAT II
350–200	between	CAT III A
200–50	between	CAT III B
50–0	between	CAT III C
Low Visibility Procedures (LVP)		
550	below	Restricted ground operations
end-user specified values	below	Restricted ground operations

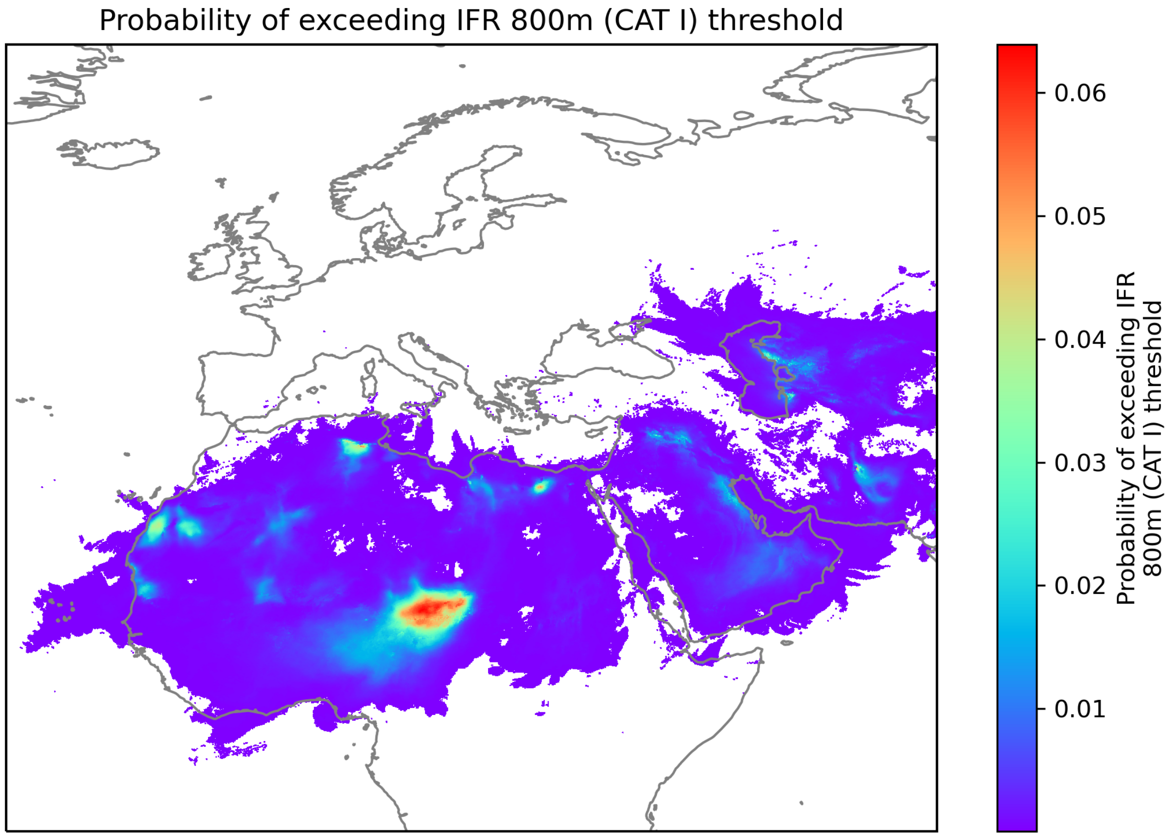
Koschmieder formula (Goldish 1997) corrected by a 0.5 factor (Konstantina's MSc thesis 2020):

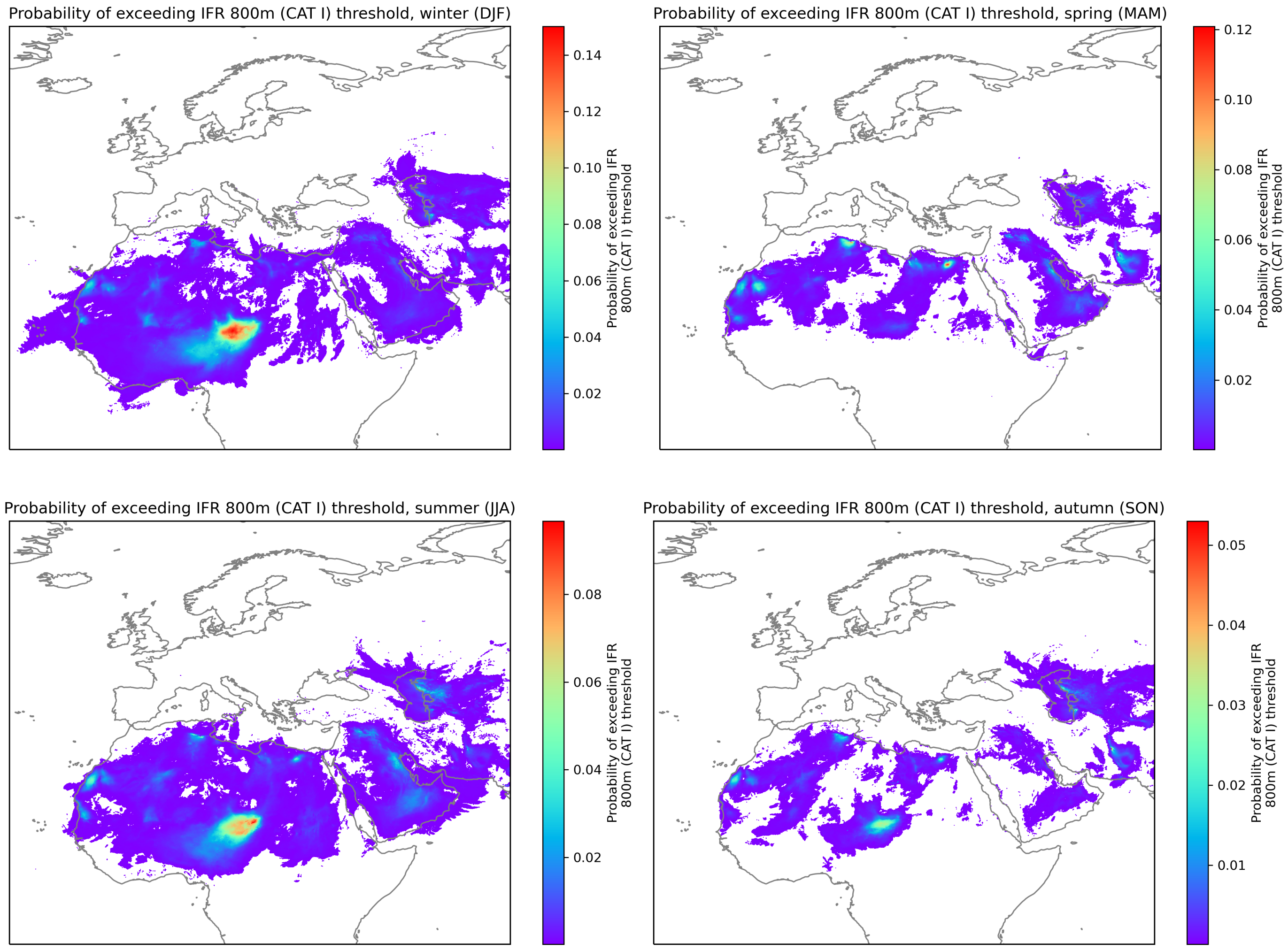
- **VIS = 1.96/sec550du** [VIS_{max} = 22000 m].
- **Number of exceedances** of each of the 12 regulatory thresholds.
- **Probability of exceeding** each of the 12 regulatory thresholds.
- Gridded output + extraction for coordinates of NAMEE airports.

Climatology of visibility, 2007-2016



Climatology of P(ILS CAT I), 2007-2016





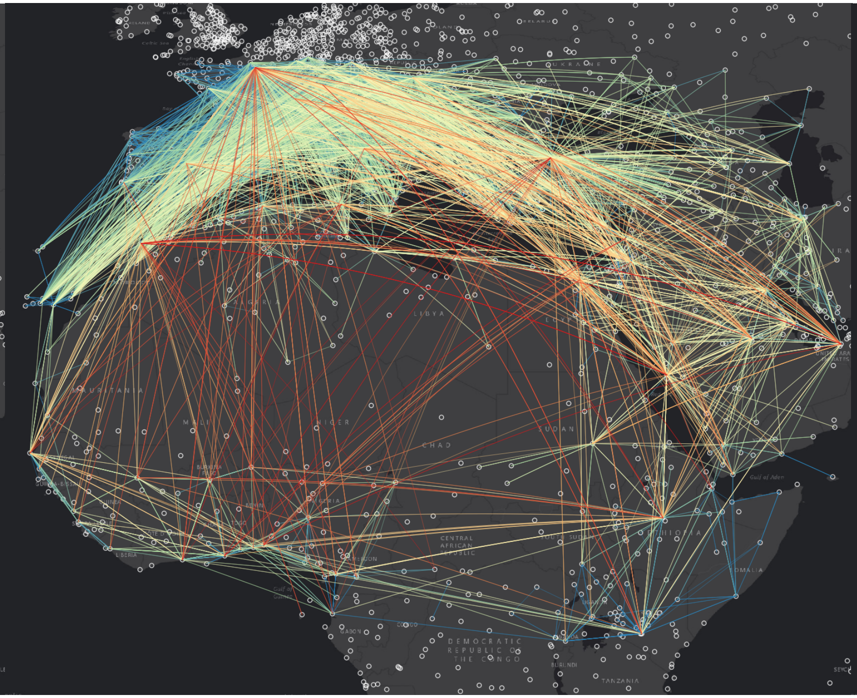
Flight route exposure

hPa	Flight Level	Critical flight stages
1000	**FL000 (ground)**	take off, landing, taxying
975	**FL010**	min. alt. for light aircraft
850	**FL050**	initial climb/min WAFS/WAFC
750	**FL080**	
700	**FL100**	decent
600	**FL140**	climb
500	**FL180**	
400	**FL240**	climb/initial decent
350	**FL270**	
300	**FL300**	
250	**FL340**	
175	**FL410**	cruise
150	**FL450**	
100	**FL530**	max WAFS/WAFC

- **Spatial join operation**: vectorized hard-coded interpolation of total concentration (Thiessen polygons) *U* geodetic flight routes in NAMEE.
- **For 11 Flight Levels** (975-100 hPa) following the convention for gridded aviation weather forecasts.
- Accumulation of particle exposure per flight path (with option to compute average exposure per route).

Climatology of exposure at 3 critical Flight Levels

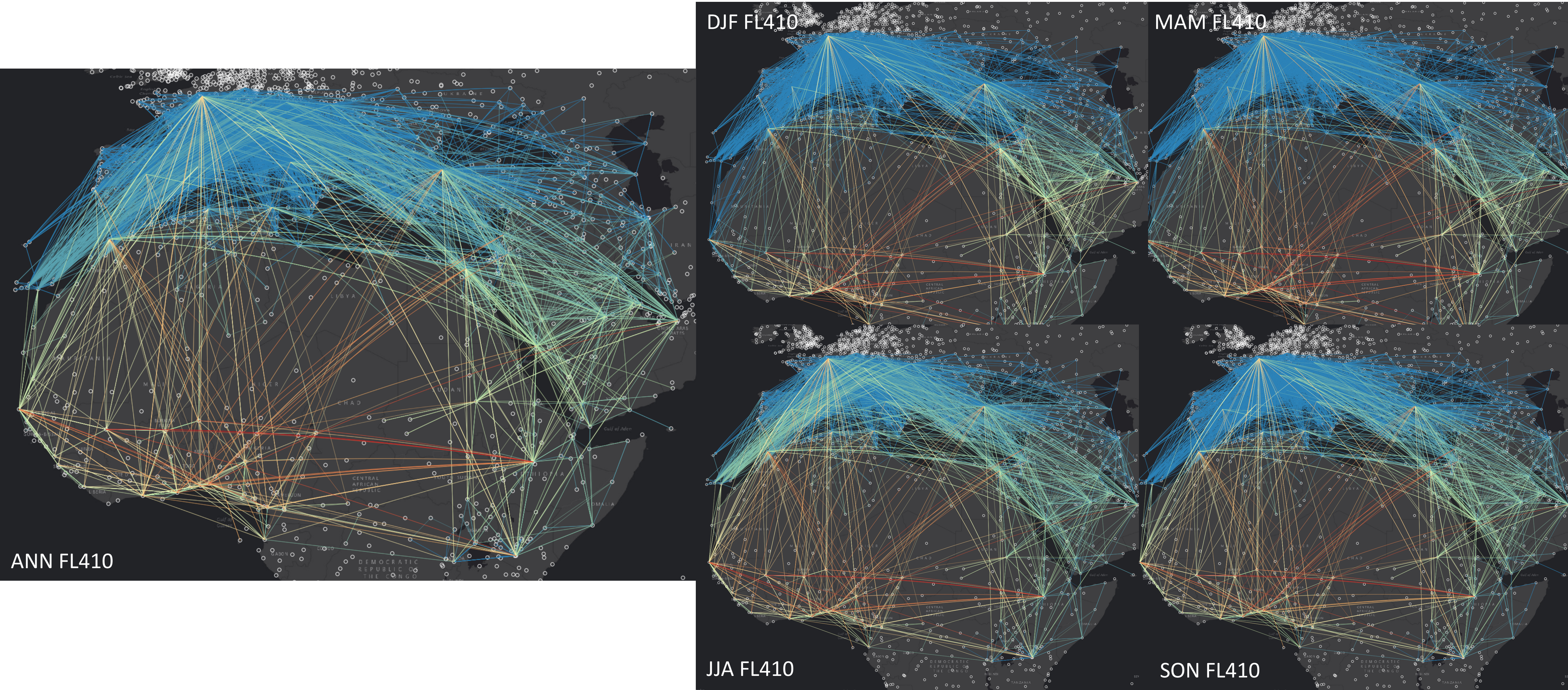
Initial climb [FL050/850hPa]



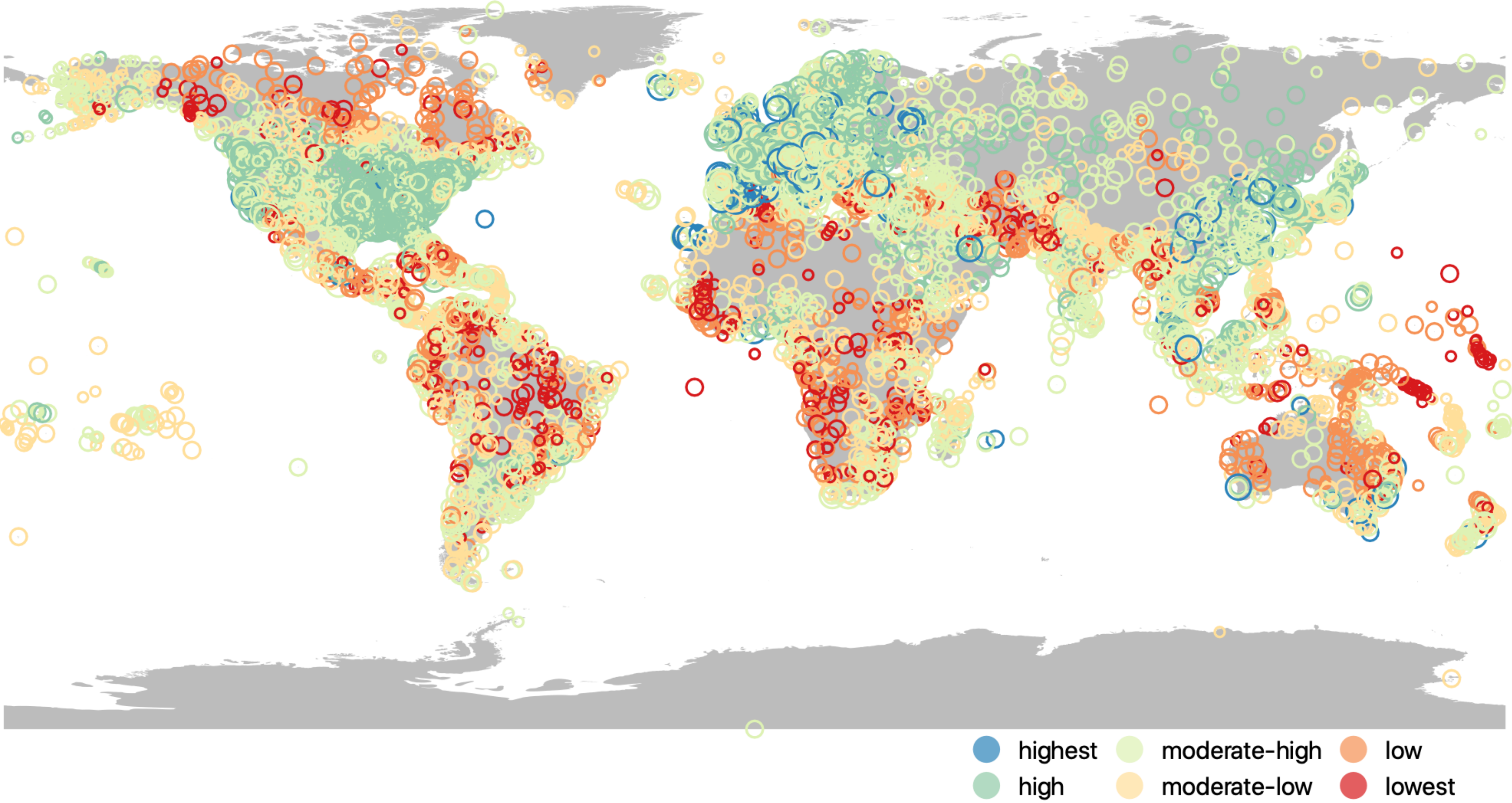
Climb [FL240/400hPa]

Cruise [FL410/175hPa]

Climatology of exposure at cruise (FL410/175hPa)



Airport resilience



A novel classification that accounts for:

- Landing support instrumentation.
- Ability to cope with excessive demand.
- Proximity to alternative airports.
- Visibility climatology.
- Flight route exposure climatology.