SOLAR FORCING ON THE NORTHERN HEMISPHERE WEATHER AND CLIMATE EXTREMES DURING SUMMER

Norel Rimbu, Monica Ionita and Gerrit Lohmann (Norel.Rimbu@awi.de)

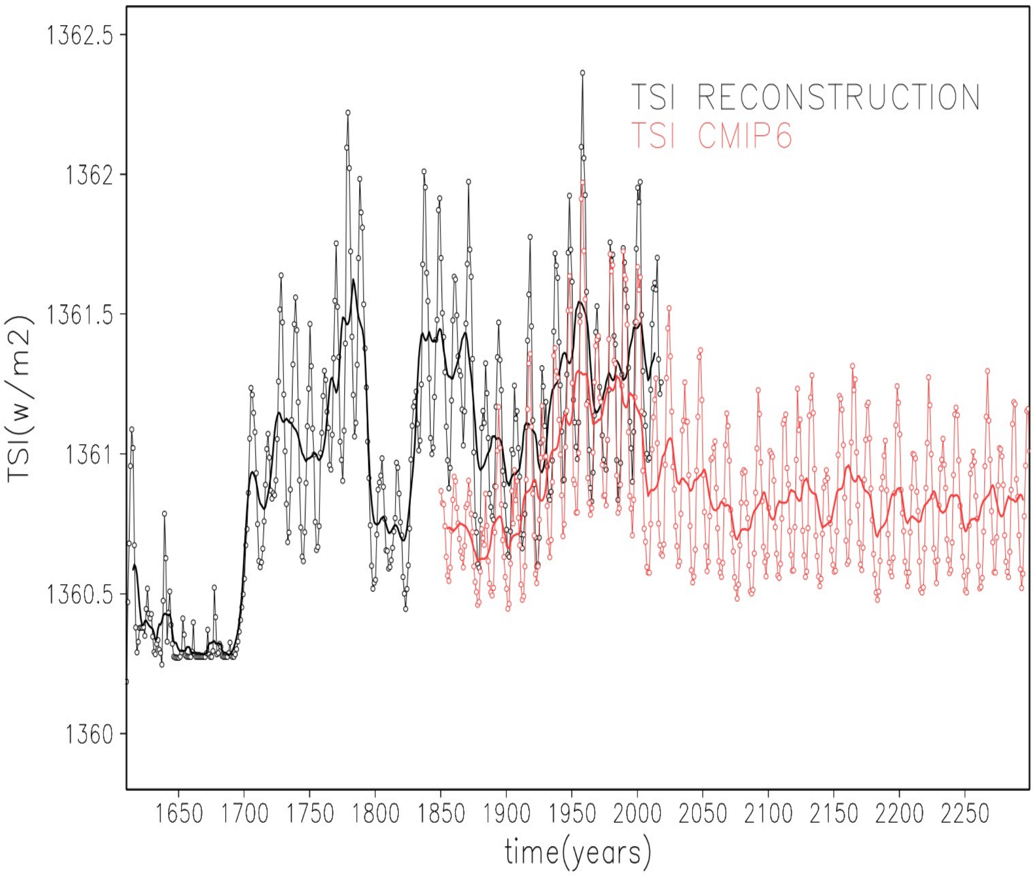
Alfred Wegener Institute Helmholtz Center for Polar and Marine Research, Paleoclimate Dynamics , Bremerhaven, Germany

SOLAR IRRADIANCE FORCING

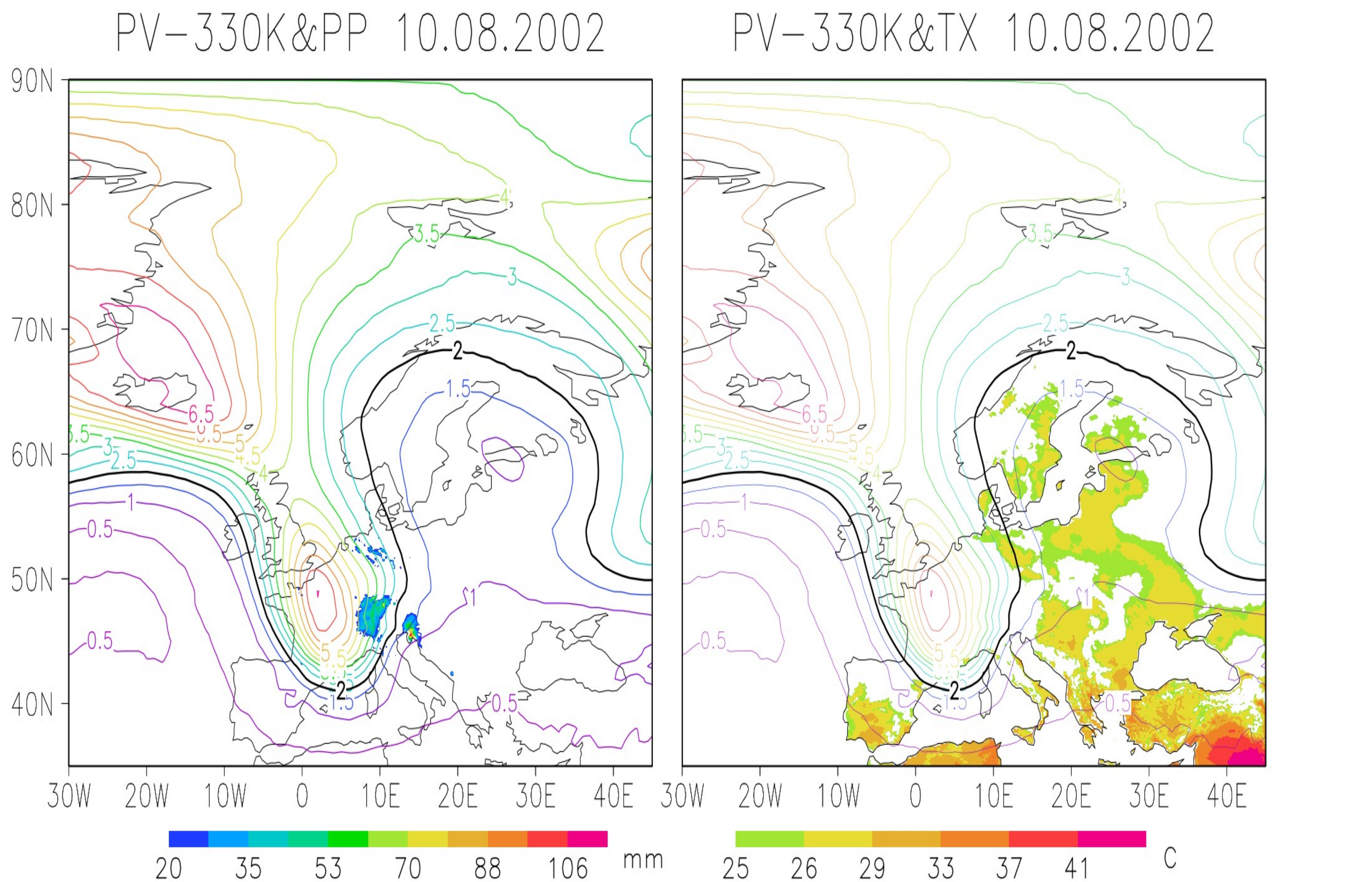
Research on solar influence on the Earth´s climate variability focus on:
-changes in the average of different climatic variables (temperature, precipitation, sea level pressure, etc.)
-winter season

Solar activity:
-prominent minima in TSI during the past (Mounder and Dalton)
-present maximum
-possible a prominent minimum in the second half of 21st century

Research question:
-What are the large-scale patterns of surface temperature and precipitation extremes associated with solar irradiance forcing during summer?



TSI-total solar irradiance; Reconstruction:1610-2018;CMIP6:1850-2299; thick-11 year running mean



Upper level PV anomalies-forcing for surface precipitation and temperature extremes

PV-potential vorticity on 330K surface;**PP**-daily precipitation amount;**TX**-maximum daily temperature; contour: PV in PVU; color-precipitation (**PP**) and maximum temperature(**TX**); Time: 10.08.2002.

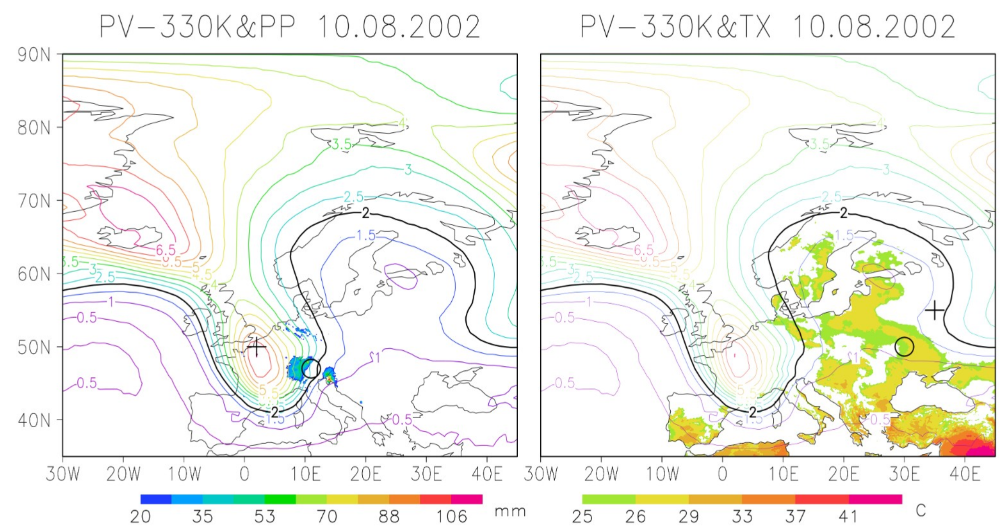
POTENTIAL VORTICITY INDICES

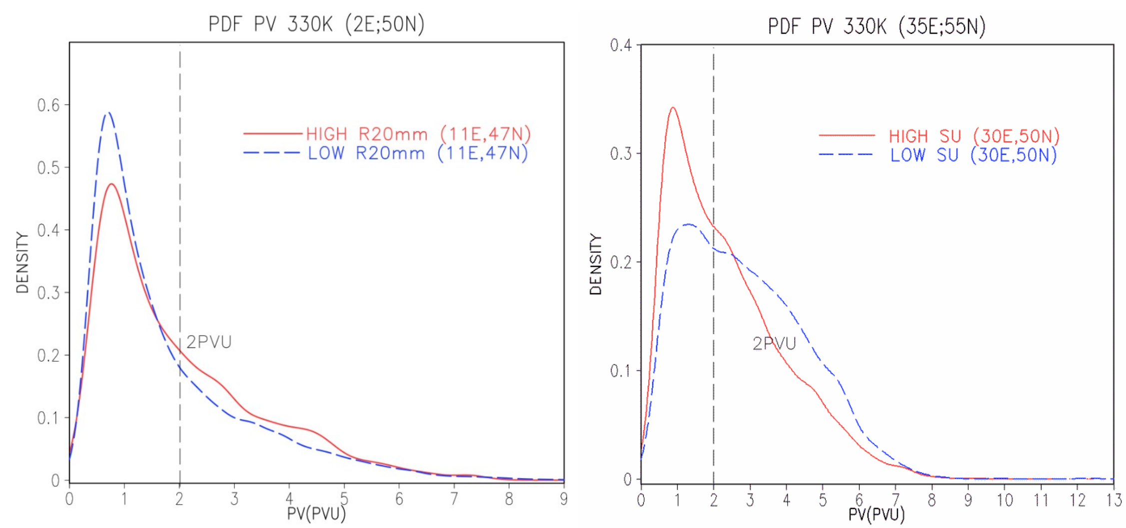
-**PV2**-frequency of days with PV>2PVU

-**PV90p**-frequency of days with PV>the 90th local percentile

-**PV10p**-frqency of days with PV<the 10th local percentile

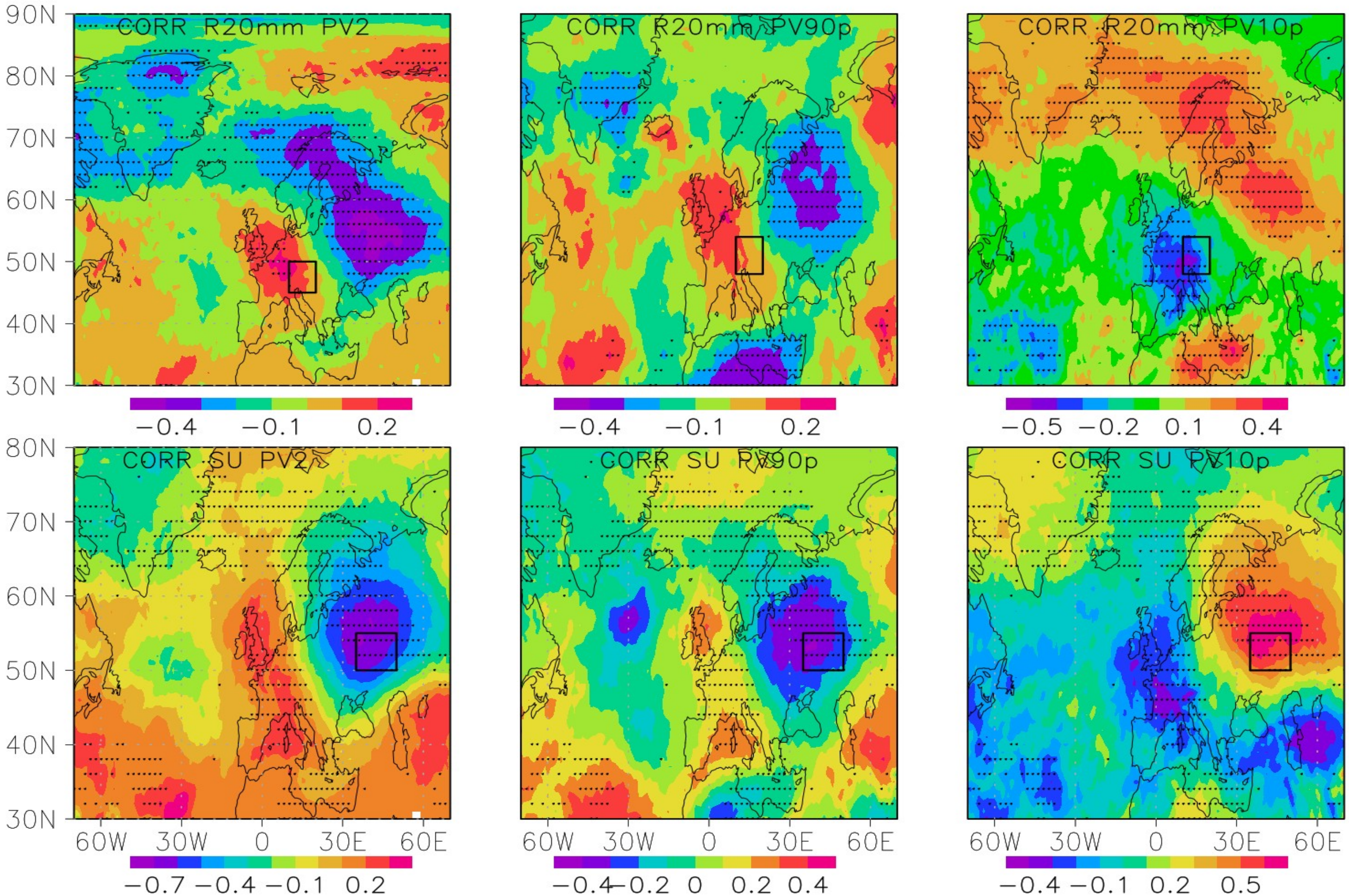
Units:days





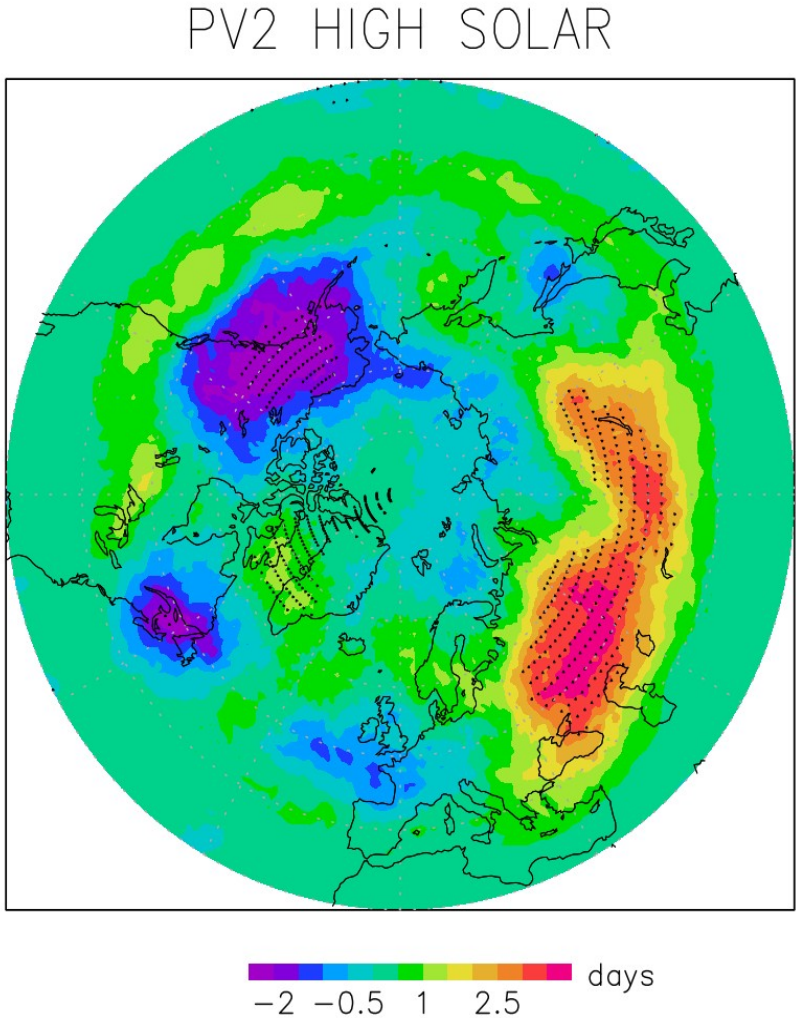
Frequency of surface extremes linked to frequency of upper level high PV events

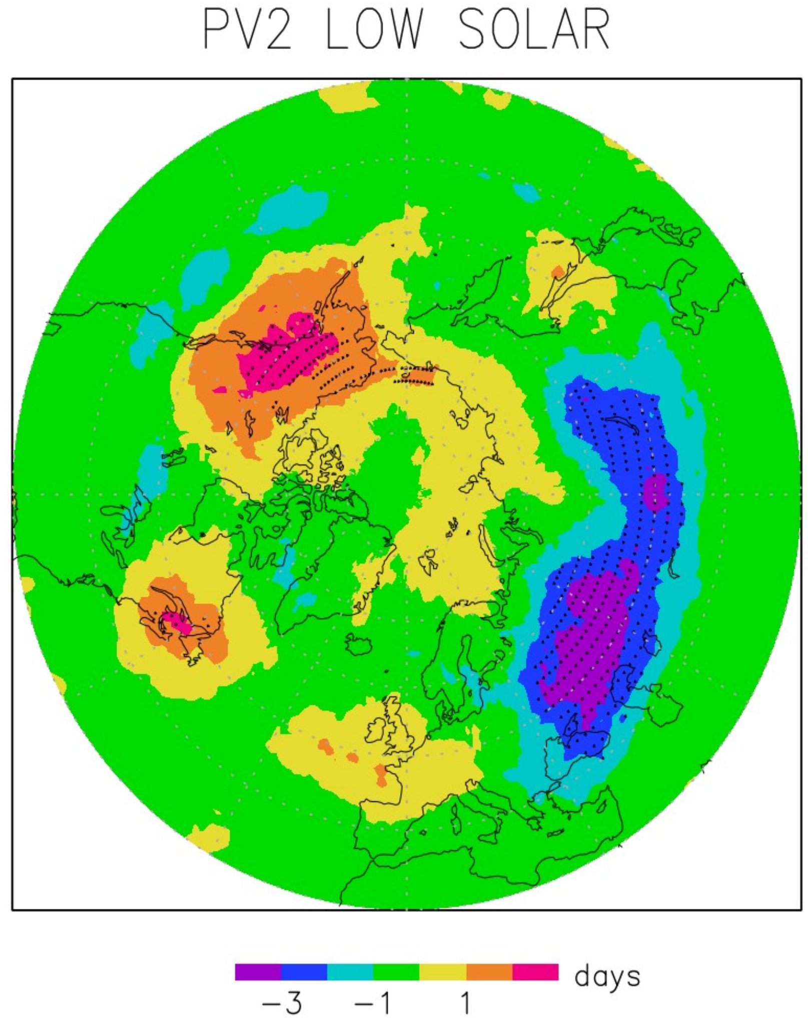
PDF-probability density functions of daily PV; (**+**) selected grid points for daily PV; **PVU**-potential vorticity unit;Period:1901-2015; Season-JJA**;R20mm**-frequency of heavy rain days (rr>20mm);**SU**-frequency of summer days (TX>25°C); (**0**)-selected grid points for R20mm and SU.



PV indices-proxies for surface temperature and precipitation extremes

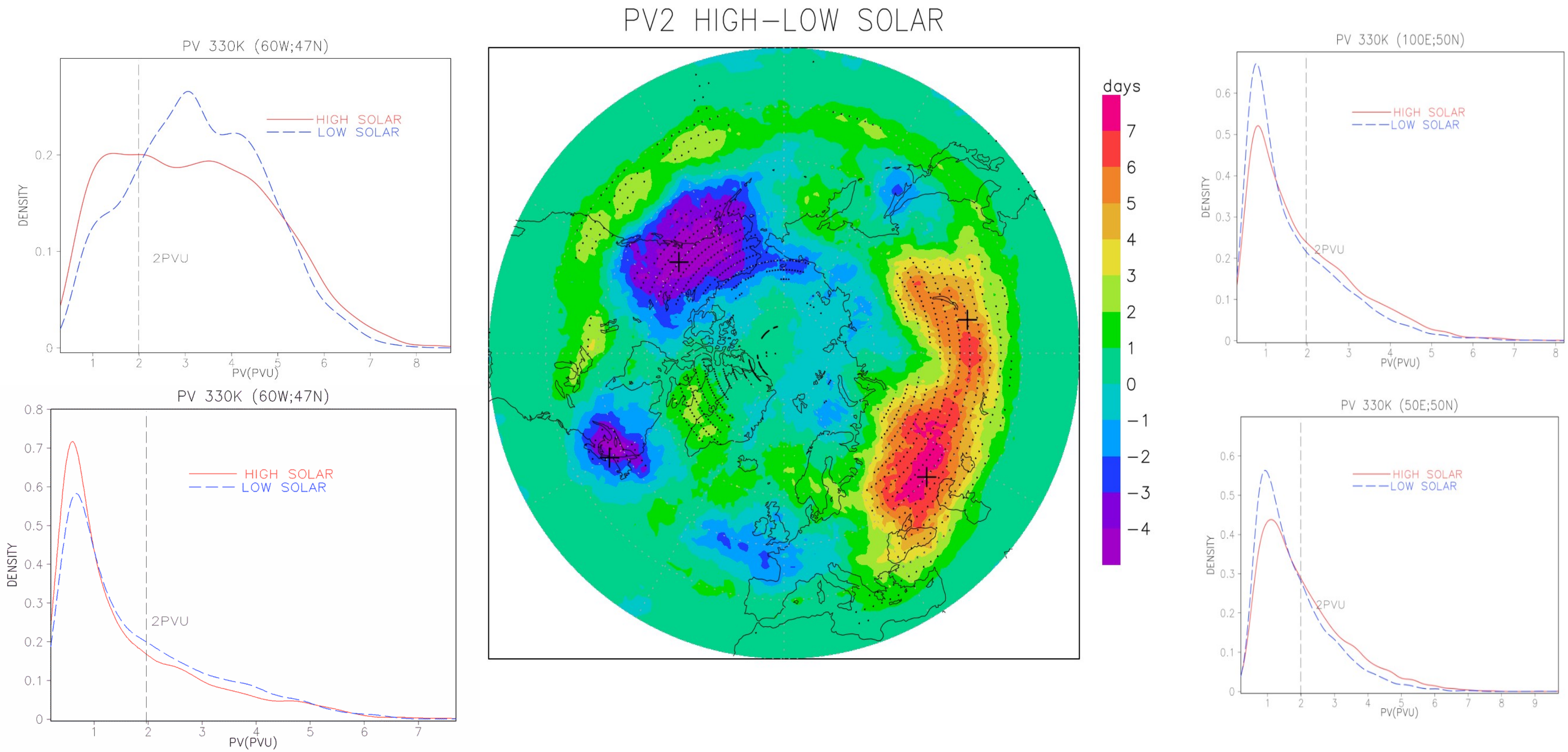
CORR-correlation between extreme indices (R20mm or SU averaged within rectangle boxes) and PV2,PV90P and PV10p fields; **R20mm**-frequency of very heavy rain days (rr>20mm);**SU**-frequency of summer days (TX>25°C);dotted-the 90th significance level;period:1950-2015





-Large scale PV2 anomaly patterns associated with solar irradiance forcing during summer
-Strong solar signal over Asia and northwestern North America

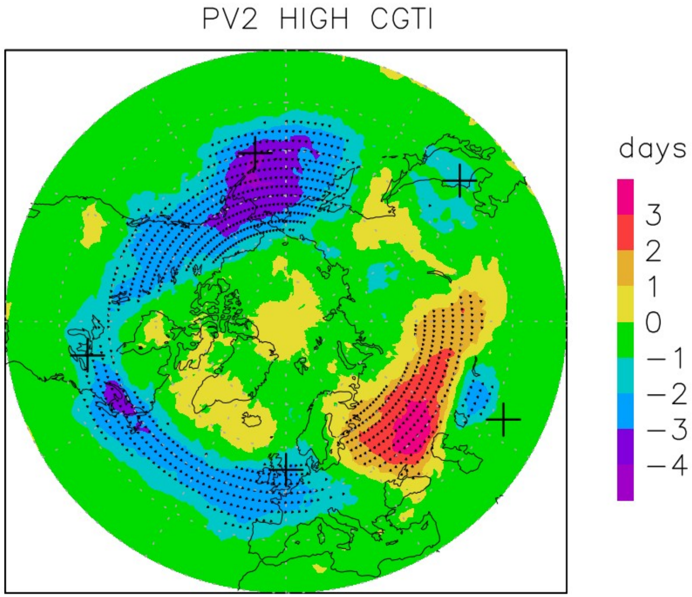
PV2-frequency of days with PV on 330K higher than 2PVU; **high(low) solar**-years with positive (negative) solar irradiance index (open solar flux); season:JJA; period: 1901-2015; dotted-the 90th significance level

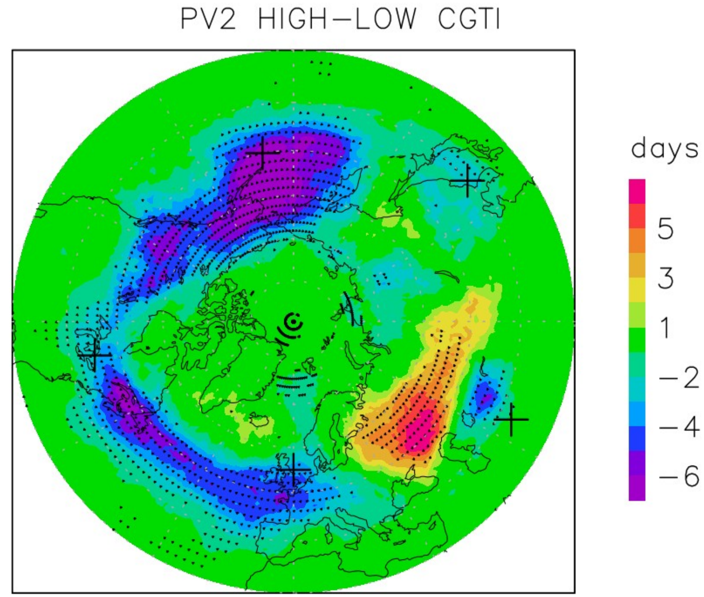


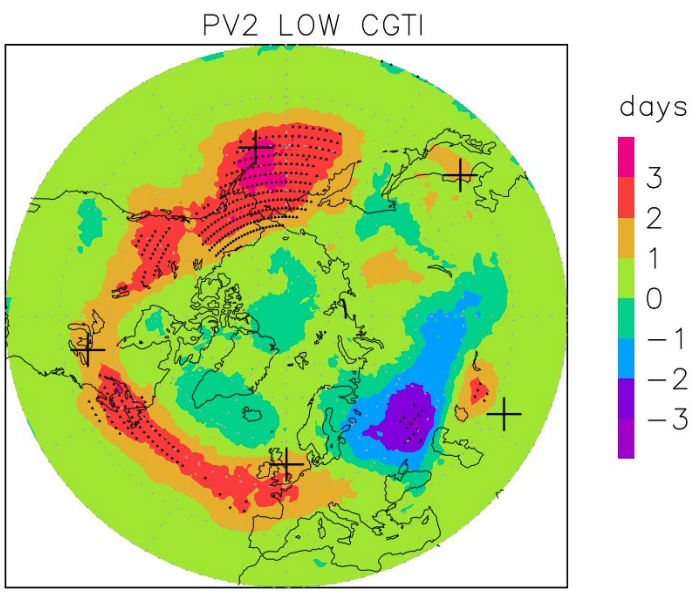
Right tail PV PDFs - strong sensitivity to solar forcing

PV2-frequency of days with PV on 330K higher than 2PVU; **high(low) solar**-years with positive (negative) solar irradiance index (open solar flux); season:JJA; period: 1901-2015; dotted-the 90th significance ;(**+**) selected grid points

POSSIBLE MECHANISM





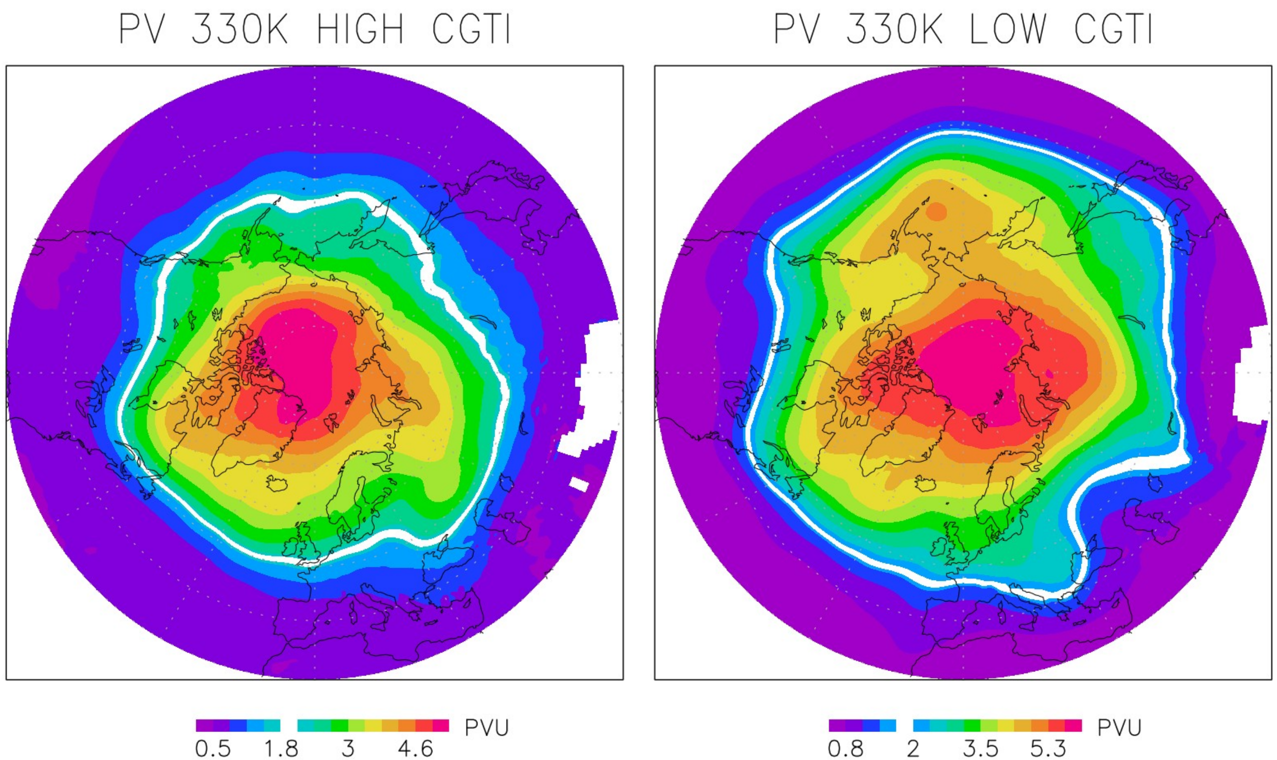


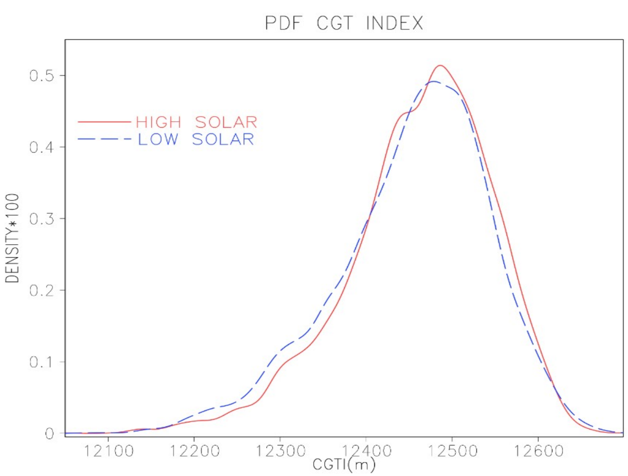
-Solar irradiance forcing (TSI) modulates the impact of Asian Summer Monsoon (ASM),including Indian Summer Monsoon (ISM), on Circumglobal Teleconnection Pattern (CGT)

-High TSI→strong ASM(ISM)→positive phase of CGT→increased frequency of upper level high PV southward intrusions over Asia due to CGT anticyclonic centers (enhanced RWB activity)→increased frequency of surface heavy precipitation

CGTI-CGT index (average of Z200 within (35°N-40°N;60°E-70°E);RWB-Rossby Wave Breaking;
TSI:Total Solar Irradiance; (**+**) anticyclonic centers of CGT
Period: 1901-2015; season-summer(JJA);dotted-the 90% significance

SENSITIVITY OF DAILY CGTI TO SOLAR FORCING

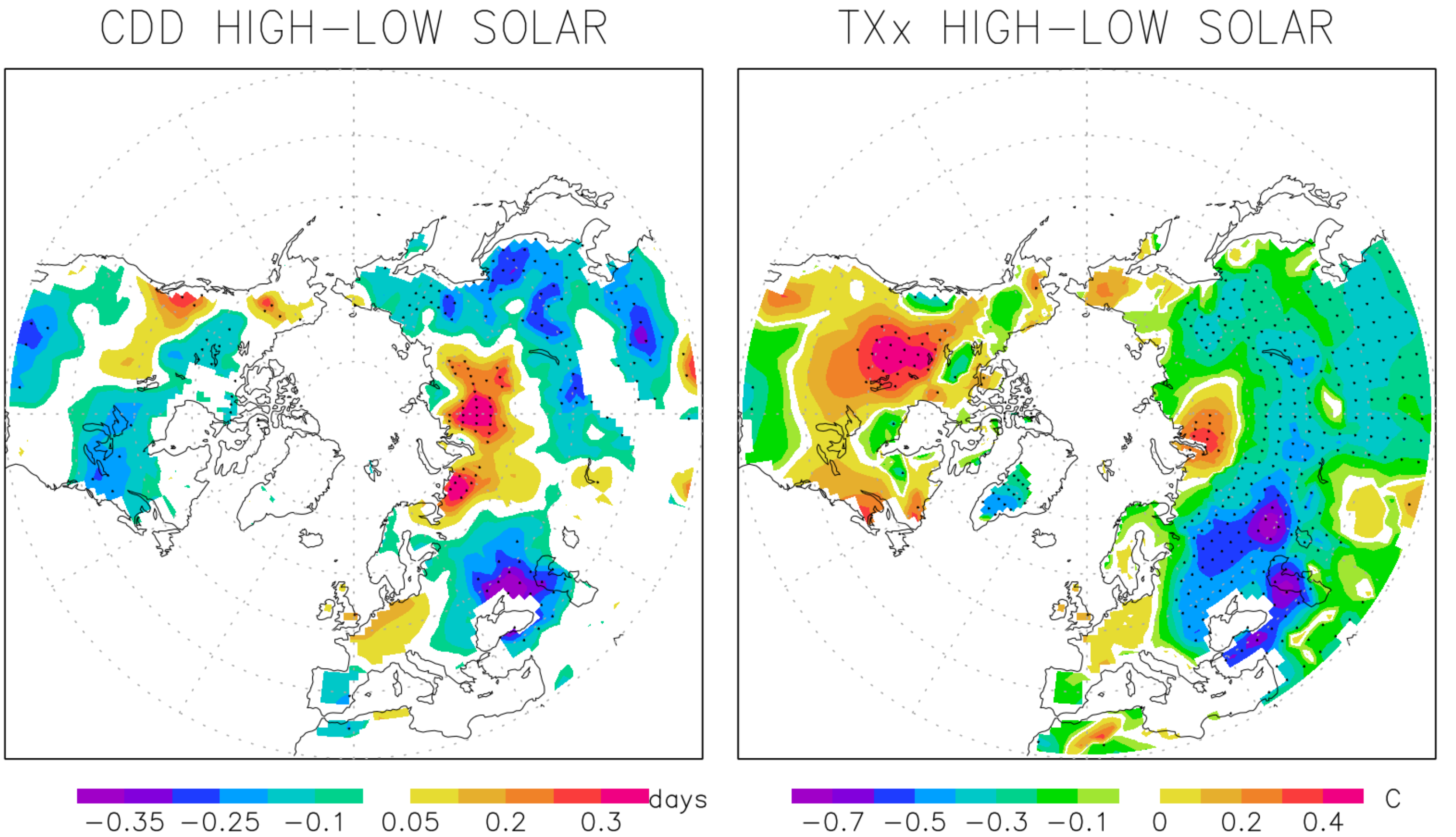




-Hemispheric PV patterns associated with daily CGTI are consistent with corresponding seasonal patterns

-The left tail of the CGTI PDF is more sensitive to solar forcing than the right tail

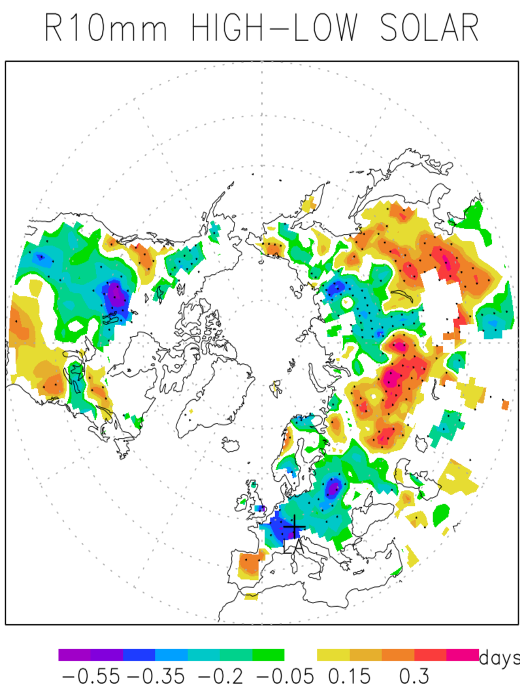
NORTHERN HEMISPHERE EXTREME PATTERNS

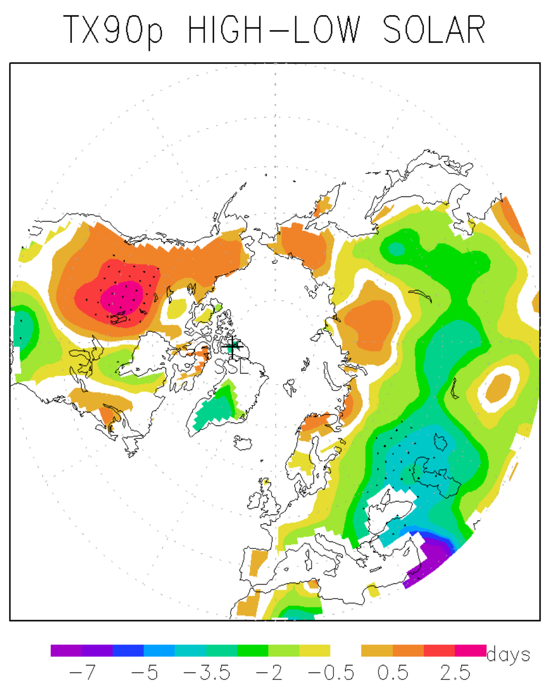


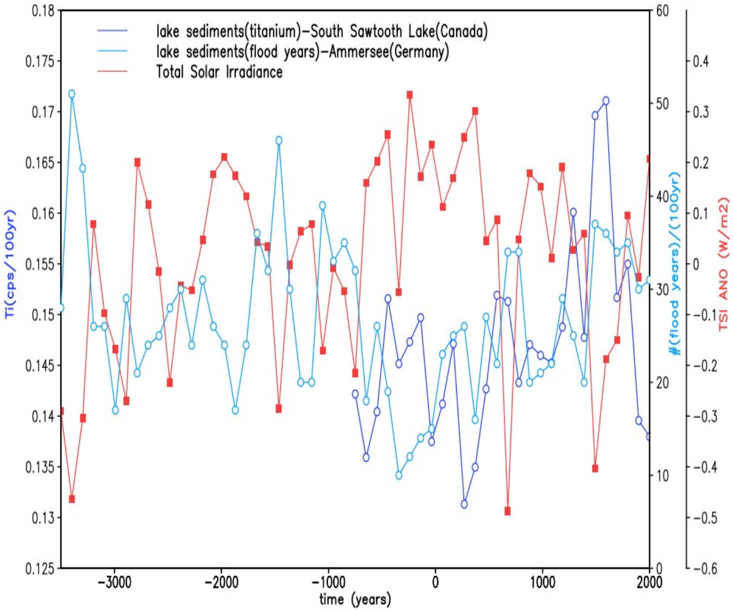
-Shorter dry spells and lower maximum daily temperatures over much part of Asia during high relative to low solar irradiance summers

TXx-maximum of maximum daily temperature; **CDD**-continous dry days;Period: 1901-2015; season-summer ;dotted-the 90% significance

PALEOCLIMATE PERSPECTIVE







-Lake sediments from southern Germany (proxy for heavy precipitation frequency)&lake sediments from northern Canada (proxy for temperature and precipitation frequency) – out of phase with TSI at centennial to millennial time scales

LA-Lake Ammer (11°E;48°N); **SSL**-South Sawtooth Lake(79°W;83°N); **TSI**-total solar irradiance anomaly;(**+**) location of the LA and SSL

SUMMARY & CONCLUSIONS

- Strong sensitivity of the frequency of upper level PV events to solar irradiance forcing

- Large scale upper level PV anomalies associated with solar forcing related to large scale patterns of surface precipitation and temperature extremes

-Possible “bottom-up” mechanism for solar impact on the Northern Hemisphere summer extremes: high TSI→strong Asian Summer Monsoon→positive phase of Circumglobal Teleconnection Pattern-enhanced RWB activity over Asia (increased frequency of high PV southward intrusions) →more (less) frequent extreme precipitation over Asia (Europe)

-Proxy data suggest that solar related extreme patterns are qualitatively the same for interannual to millennial time scales

- Solar related patterns of extremes are useful for understanding not only the past and present, but also the future extreme weather and climate variability (a prominent minimum in solar activity is expected in the near future)

REFERENCES & DATA

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-Lapointe et al. (2020) Annually resolved Atlantic sea surface temperature variability over the past 2,900 years. PNAS,doi.org/10.1073/pnas.2014166117.

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-Rimbu, N. et al. (2021) Interannual to millennial scale variability of River Ammer floods and its relationship with solar forcing, Int. J. Climatol, 41,E644-655. https://doi.org/10.1002/joc.6715

Data

-Solar irradiance index (open solar flux): https://climexp.knmi.nl/data/iosf_merged.dat

-Holocene total solar irradiane (TSI): ftp://ftp.ncdc.noaa.gov/pub/data/paleo/climate_forcing/solar_variability/steinhilber2009tsi.txt

-Climate extreme indices-Europe: https://surfobs.climate.copernicus.eu/dataaccess/access_eobs_indices.php

-Meteorological data (including PV): https://psl.noaa.gov/data/gridded/data.20thC_ReanV3.html

-Climate extreme indices-Northern Hemisphere: https://www.metoffice.gov.uk/hadobs/hadex3/

-Flood layer (LA) record for the last 5500 years: https://doi.pangaea.de/10.1594/PANGAEA.803368

-Lake sediments (SSL) record for the last 2900 years: https://www.ncdc.noaa.gov/paleo-search/study/31353