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The Impact of Trends in the Large Scale Atmospheric Circulation on Mediterranean Surface Turbulent Heat Fluxes

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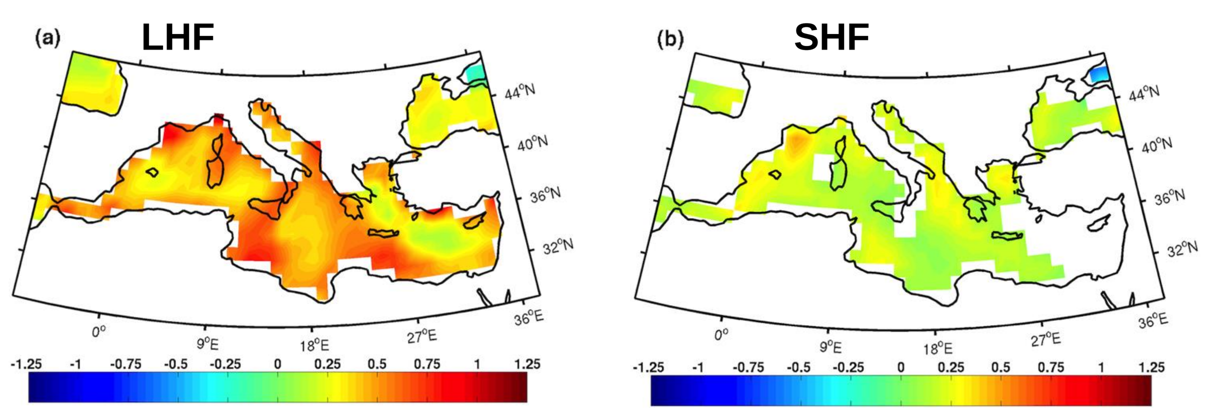
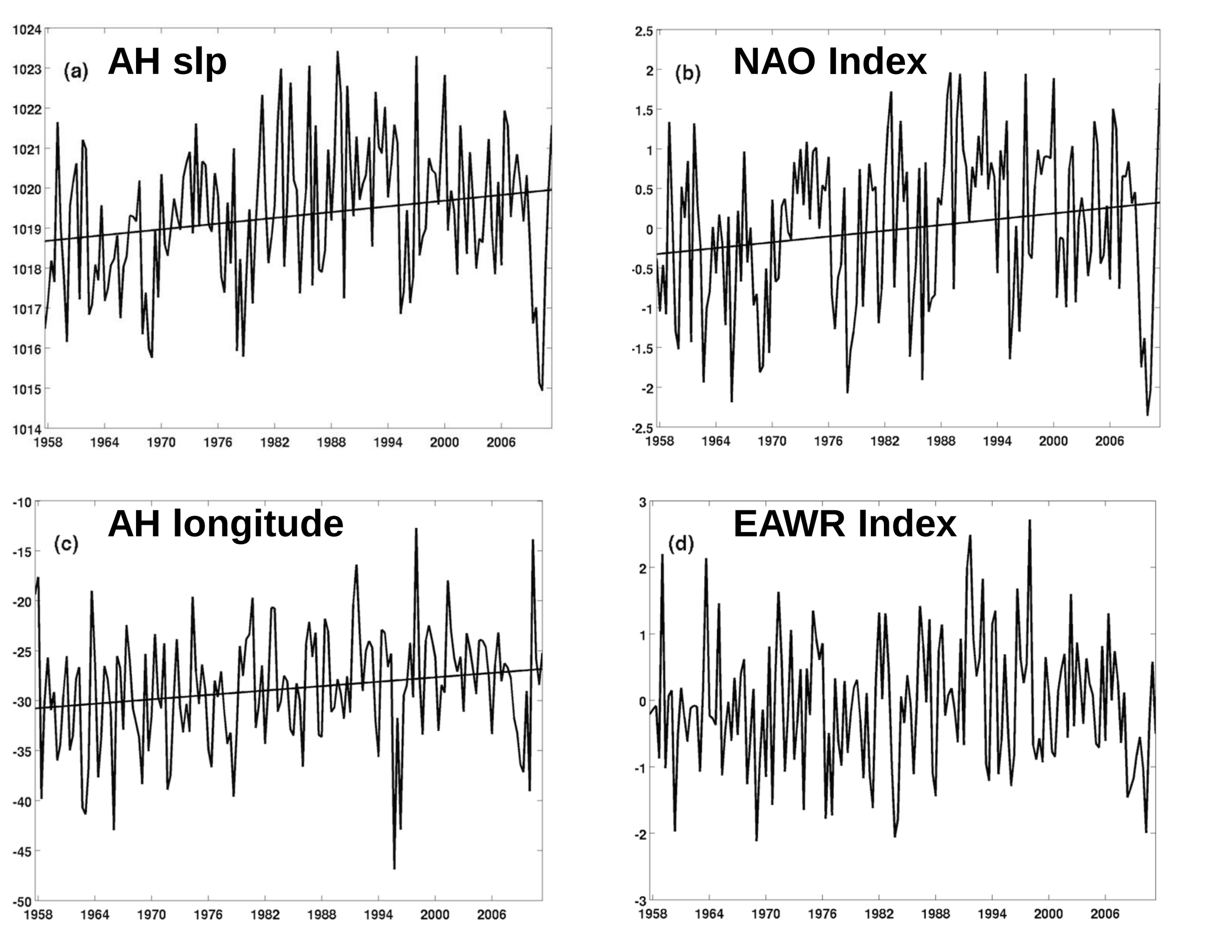
Abstract

Interannual variations of latent heat fluxes (LHF) and sensible heat fluxes (SHF) over the Mediterranean for the boreal winter season (DJF) show positive trends during 1958-2011. Comparison of correlations between the heat fluxes and the intensity and location of the Azores High (AH), and the NAO and East Atlantic-West Russia (EAWR) teleconnections, along with analysis of composites of surface temperature, humidity and wind fields for different teleconnection states, demonstrates that variations of the AH are found to explain the heat flux changes more successfully than the NAO and the EAWR. Trends in sea level pressure and longitude of the Azores High during DJF show a strengthening, and an eastward shift. DJF Azores High pressure and longitude are shown to co-vary such that variability of the Azores High occurs along an axis defined by lower pressure and westward location at one extreme, and higher pressure and eastward location at the other extreme. The shift of the Azores High from predominance of the low/west state to the high/east state induces trends in Mediterranean Sea surface winds, temperature and moisture. These, combined with sea surface warming trends, produce trends in wintertime Mediterranean Sea sensible and latent heat fluxes.

Trends in DJF Heat Fluxes and Circulation Patterns



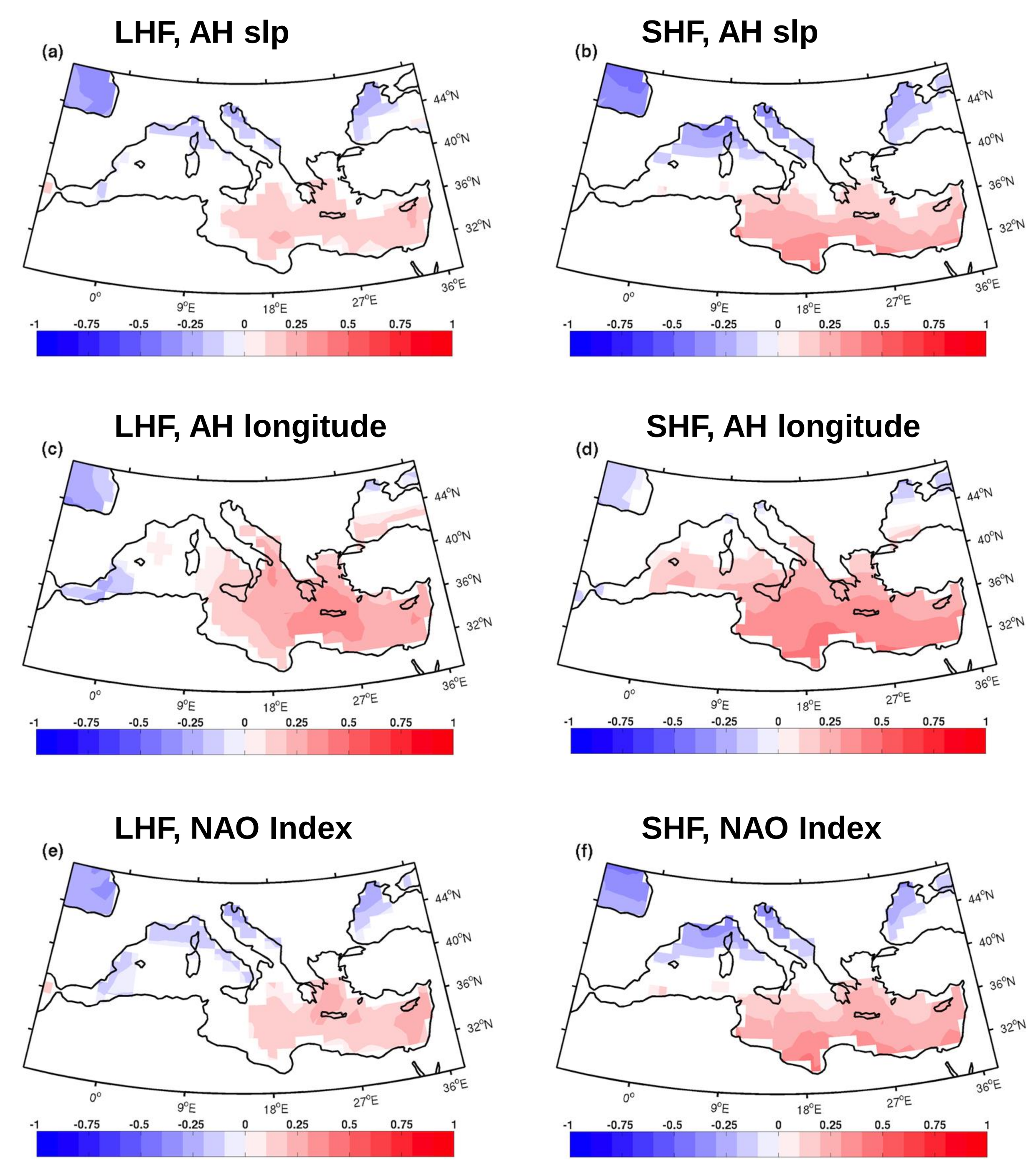
(a) Trends in DJF mean latent heat flux, 1958-2011 (Wm-2/yr); (b) Trends in DJF mean sensible heat flux, 1958-2011 (Wm-2/yr). Only trends which are significant at p = 0.05 are shown.



(a) Monthly mean Azores High sea level pressure and trend (mb), DJF 1958-2011; (b) monthly mean NAO index and trend, DJF 1958-2011, (c) monthly mean Azores High longitude (degrees east) and trend, DJF 1958-2011; (d) monthly mean EAWR index, DJF 1958-2011. Only trends which are significant at p = 0.05 are shown.

- **Significant trends in Mediterranean heat fluxes, AH pressure and longitude, and NAO index, but not in EAWR during DJF 1958-2011**

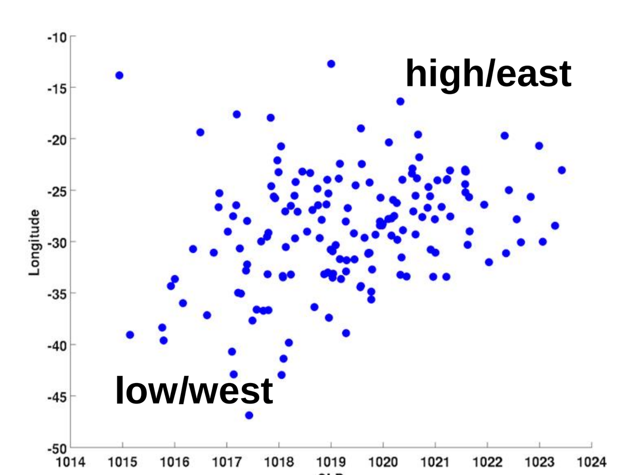
Correlations on monthly time scales



(a), (c) and (e) Correlations between detrended monthly mean latent heat flux and detrended Azores High sea level pressure, Azores High longitude, and NAO index; (b), (d) and (f) correlations between detrended monthly mean sensible heat flux and detrended Azores High sea level pressure, Azores High longitude, and NAO index, DJF 1958-2011. Only correlations which are significant at p = 0.05 are shown.

- **Mediterranean heat fluxes mostly positively correlated with circulation patterns on monthly time scales, except northern Mediterranean**
- **Correlations strongest with Azores High longitude**

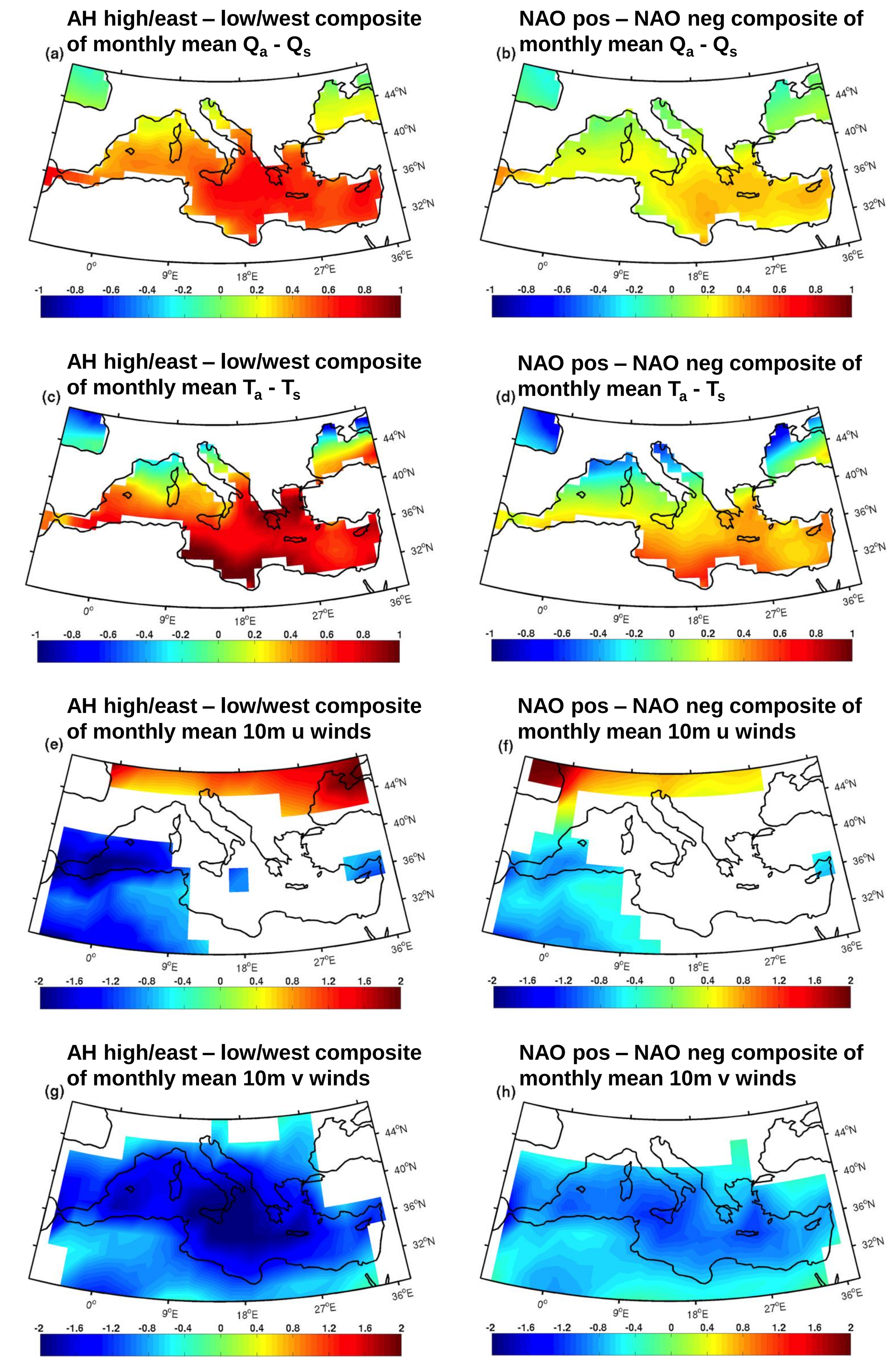
AH pressure, longitude covariability



Monthly mean Azores High pressure (mb) and longitude (degrees east) for DJF 1958- 2011.

- **DJF AH tends to vary along axis from high/east to low/west**
- **Trend toward more frequent occurrence of high/east state**

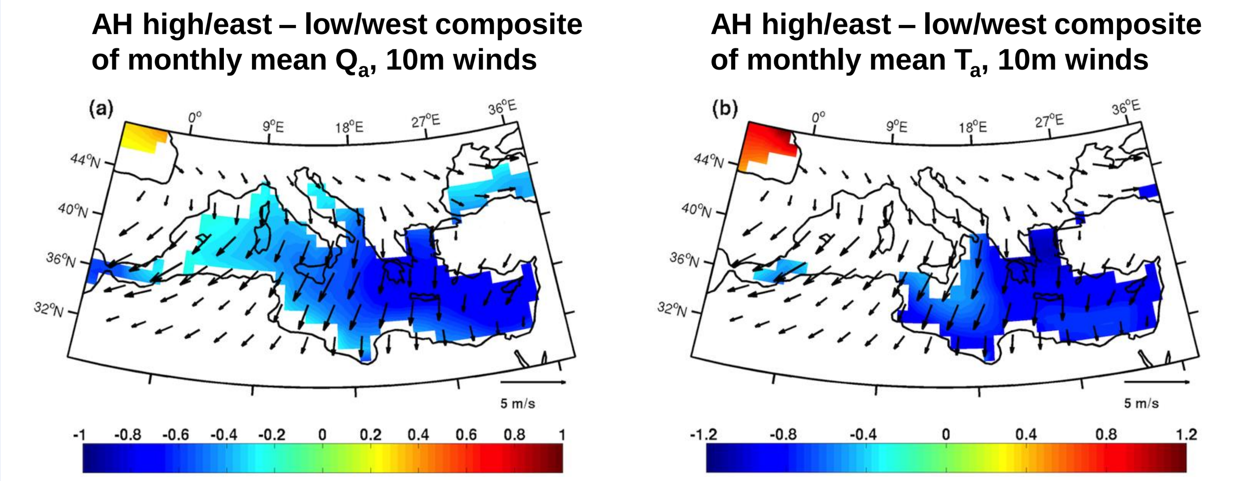
Effect of AH state on air-sea gradients, winds



a), (c), (e) and (g) AH high/east composite – AH low/west composite of monthly mean Qa-Qs (g/kg), Ta-Ts (C), u (m/s), and v (m/s); (b), (d), (f) and (h) NAO+ composites – NAO- composite of monthly mean Qa-Qs (g/kg), Ta-Ts (C), u (m/s) and v (m/s), DJF 1958-2011. Only differences which are significant at p = 0.05 are shown.

- **Change in AH state has larger effect than NAO on air-sea T, q gradients and wind components**
- **AH high/east – low/west patterns similar to NAO, as expected, since AH slp is a component of NAO, but…**
- **AH high/east – low/west spatial pattern of air-sea T, q gradients, when scaled by wind components, more closely resemble trends in LHF, SHF than NAO spatial patterns**
- **Correspondence is not perfect - could be due to effect of coastal topography on local winds, influence of other teleconnections**

How does AH state influence air-sea gradients?



a) AH high/east composite – AH low/west composite of monthly mean Qa (g/kg) overlaid with AH high/east composite – AH low/west composite of monthly mean near surface winds (m/s), DJF 1958-2011; (b) AH high/east composite – AH low/west composite of monthly mean Ta (C) overlaid with AH high/east composite – AH low/west composite of monthly mean near surface winds (m/s), DJF 1958-2011. Only differences which are significant at p = 0.05 are shown.

- **Colder, drier conditions associated with high/east AH state**
- **Eastward shift of anticyclonic wind field strengthens northerly winds over Mediterranean, especially eastern basin**
- **Advection of cold, dry continental air by enhanced northerly winds leads to larger air-sea T, q gradients over Mediterranean**

Conclusions

- **Positive trends in DJF LHF and SHF over Mediterranean, with substantial spatial variability**
- **Positive trend in Azores High slp and eastward displacement, as well as positive trend in NAO index over same period**
- **Compared to NAO, trends in AH slp and eastward displacement best account for spatial pattern of air-sea T, q gradients and wind velocity components associated with observed trends in LHF and SHF**
- **Trends in Mediterranean LHF and SHF best explained by the shift toward more frequent AH high/east states**
- **Anomalous anticyclonic circulation associated with AH high/east shift causes stronger, more northerly winds over Mediterranean basin, advecting colder, drier air, producing larger air-sea T, q gradients**

Datasets

AH slp and longitude indices are computed from NCEP/NCAR monthly mean slp, monthly mean NAO and EAWR indices are from the NOAA/NWS Climate Prediction Center. Monthly mean turbulent fluxes (lhf and shf) and the quantities they are derived from (wind speed, near surface air temperature and humidity, and SST) are from the Woods Hole Oceanographic Institution Objectively Analyzed Air-Sea Flux (OAFlux) dataset. Q_s is computed using the Coupled Ocean Atmosphere Response Experiment (COARE) v2.5b algorithm. Daily mean 10m u and v winds are from the NCEP/NCAR Reanalysis I.

Romanski, J. and S. Hameed, "The Impact of Trends in the Large Scale Atmospheric Circulation on Mediterranean Surface Turbulent Heat Fluxes," Advances in Meteorology, 2015. doi:10.1155/2015/519593., contact: Joy Romanski, joy.n.romanski@nasa.gov