Atmospheric forcing of the Eastern Mediterranean Transient by midlatitude cyclones

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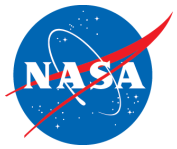

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The Eastern Mediterranean Transient (EMT)

- Shift of deep water production from Adriatic to Aegean in late 1980s/early 1990s. Peak production during winters of 1991/1992 and 1992/1993 (the "enhanced EMT winters").

  (Beuvier et al. 2010, Bozec et al. 2006, Josey et al. 2003, Roether et al., 1996, Rubino and Hainbucher, 2007, Samuel et al. 1999, Theocharis et al. 2002)

- Hydrological changes in Eastern Med enhanced density of Aegean – increased salinity due to reduced freshwater input and circulation changes – preconditioned for deep convection.

  (Beuvier et al. 2010, Civitarese et al., 2010, Malanotte-Rizzoli et al. 1999, Sayin and Besiktepe, 2010, Samuel et al. 1999, Velaoras and Lascaratos, 2005)

- Strong convection during 1991/1992 and 1992/1993 winters triggered by unusually strong atmospheric forcing – anomalously strong turbulent fluxes of heat and moisture from Aegean caused by unusually cold and windy conditions.

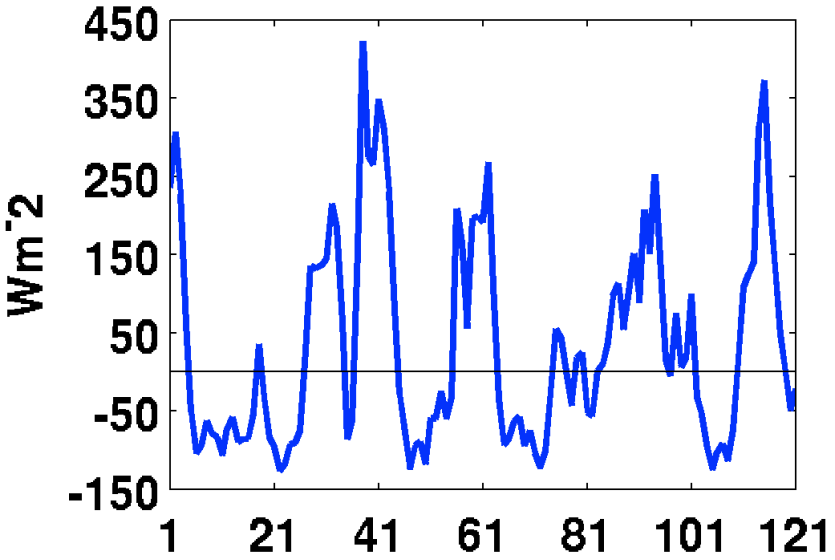
  (Beuvier et al. 2010, Bozec et al. 2006, Josey, 2003, Samuel et al. 1999, Theocharis et al. 2002)

Datasets

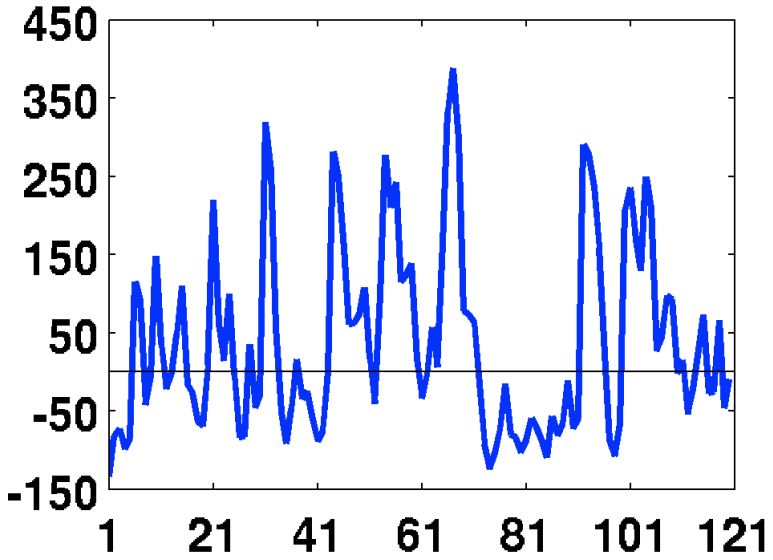
- OAFlux latent and sensible heat fluxes
  - Merged satellite and reanalysis product, 1°, daily resolution
- ECMWF Interim Reanalysis (ERA Interim) 10m meridional winds and 2m air temperatures
  - ~ 0.7°, 6-hourly resolution
- NASA's Modeling, Analysis, and Prediction (MAP) Climatology of Mid-latitude Storminess (MCMS) cyclone centers and tracks
  - Derived from 1.5°, 6-hourly resolution ERA Interim sea level pressure
- Winters NDJF 1989/1990 through 2008/2009

Anomalous Turbulent Heat Fluxes from the Aegean during the EMT

NDJF 1991/1992



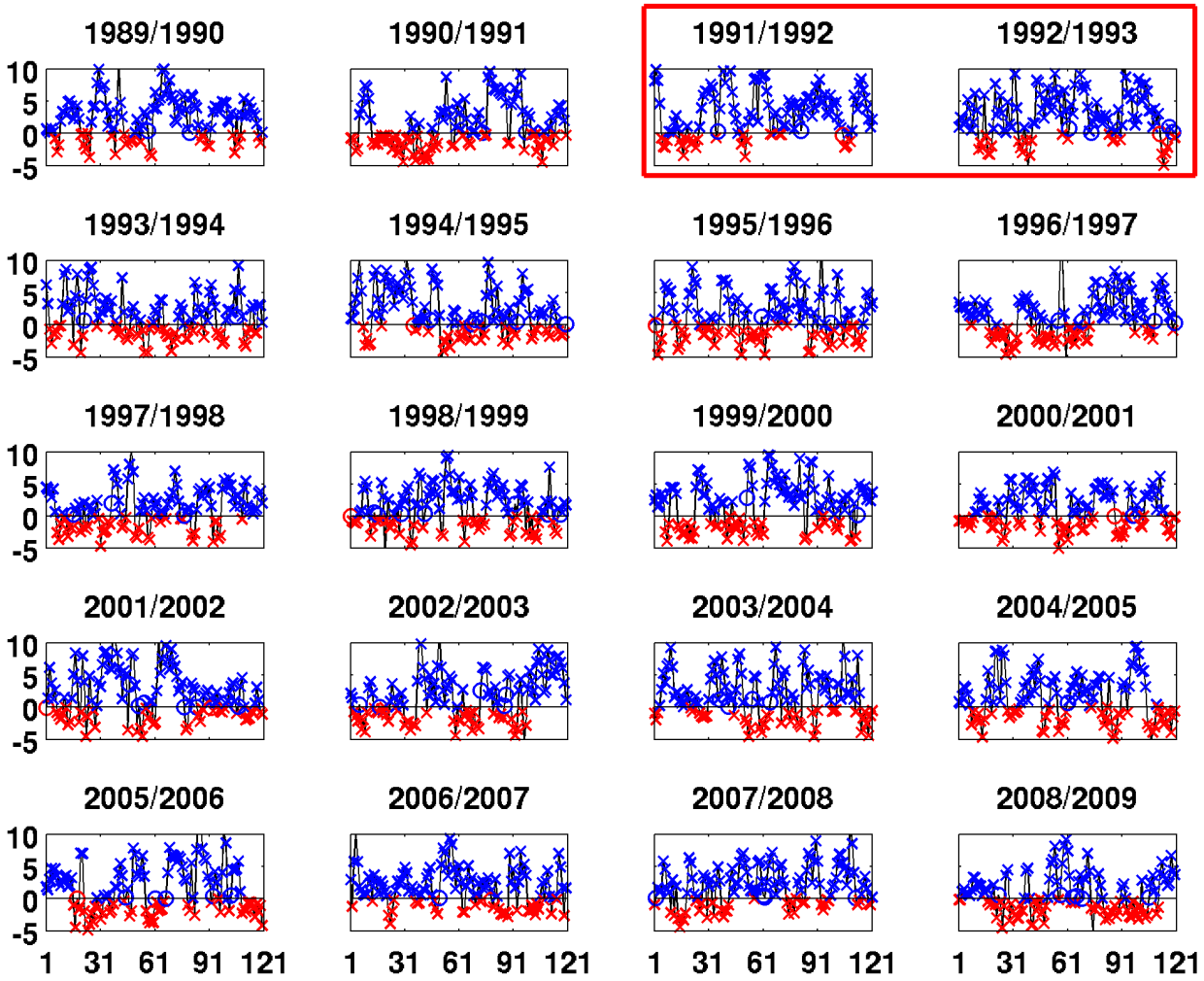
NDJF 1992/1993



Net flux highly correlated **on synoptic time scales** with wind, air temperature and air humidity

	Wind	Air Temp	Humidity
Net Flux	0.89	– 0.85	– 0.79

Heat Advection over the Aegean by the Meridional Wind (vdT/dy)



In NH winter,
dT/dy < 0

North wind:
v < 0; vdT/dy > 0;

South wind:
v > 0; vdT/dy < 0;
warm advection

Decomposition of vdT/dy

$$A = \overline{[A]} + [A'] + \overline{A}^{*} + A^{*\prime}$$

$[\ ]$ = zonal mean

* = deviation from zonal mean (eddy)

$\overline{\ }$ = temporal mean (stationary)

$'$ = deviation from temporal mean (transient)

A comprises:

$\overline{[A]}$, the time mean zonal mean, e.g., latitudinal temp gradient

$[A']$, the time varying zonal mean, e.g., subseasonal variation of the latitudinal temp gradient

$\overline{A}^{*}$, the time mean spatial eddies, e.g., standing waves

$A^{*\prime}$, the time varying spatial eddies, e.g., storms

Decomposition of vdT/dy

$$A = \overline{[A]} + [A'] + \overline{A}^{*} + A^{*\prime}$$

substitute v and dT/dy for A, multiply

select largest terms

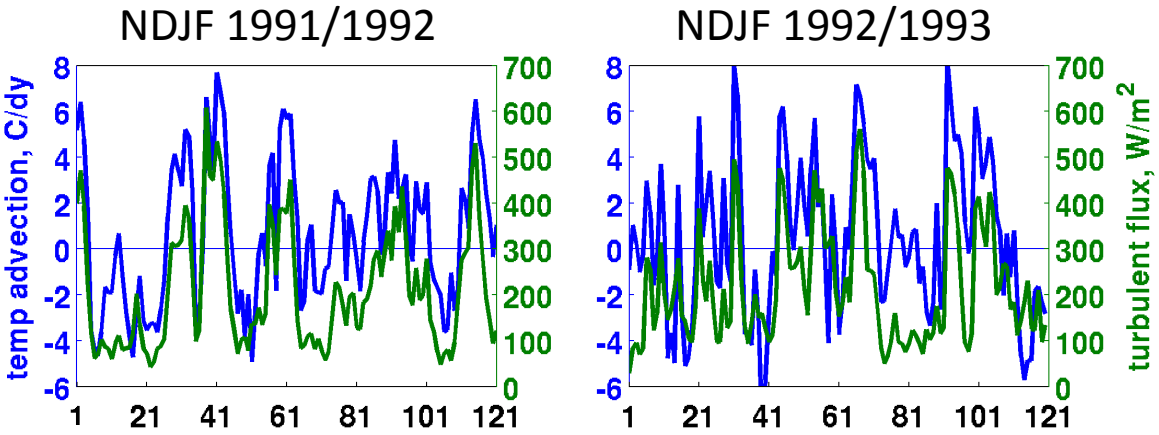
storms

$v^{*\prime}\overline{[dT/dy]}$	advection of mean temperature gradient by transient eddy meridional winds (storms)
$v^{*\prime}\overline{dT/dy}^{*}$	advection of stationary eddy temperature gradient by transient eddy meridional winds
$v^{*\prime}\,dT/dy^{*\prime}$	advection of transient eddy temperature gradient by transient eddy meridional winds

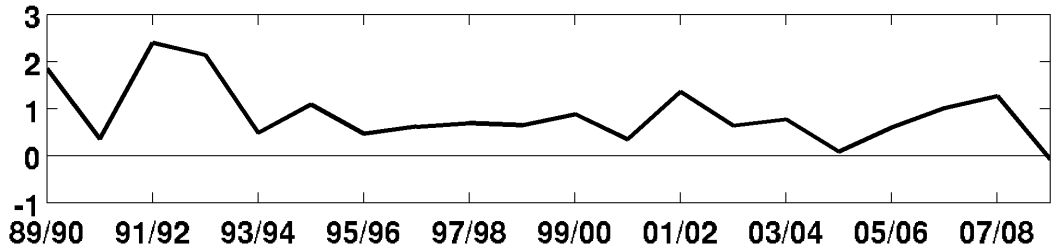
stationary features

$\overline{v}^{*}\overline{[dT/dy]}$	advection of mean temperature gradient by stationary eddy meridional winds
$\overline{v}^{*}\overline{dT/dy}^{*}$	advection of stationary eddy temperature gradient by stationary eddy meridional winds

Aegean Sea Turbulent Fluxes and Heat Advection



heat advection by storms strongly correlated with turbulent flux, especially during the enhanced EMT winters (0.9 vs. 0.7)

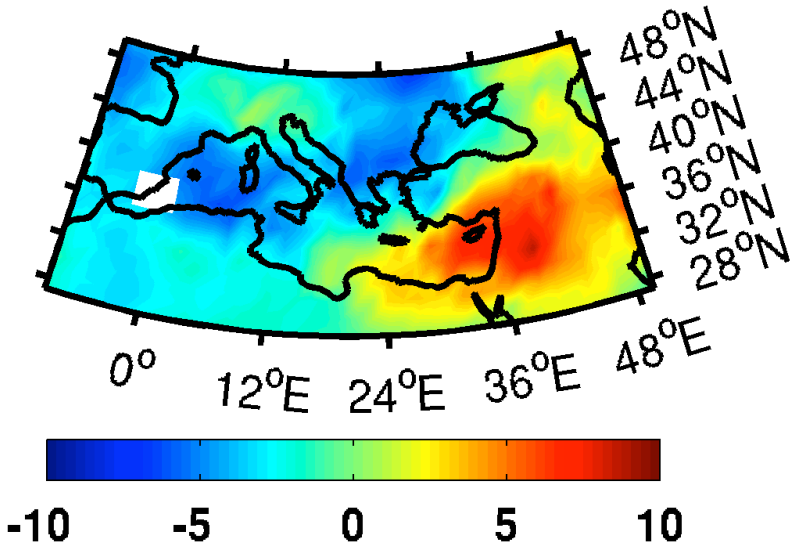


interannual variability of vdT/dy controlled by stationary eddy winds (correlation = 0.97)

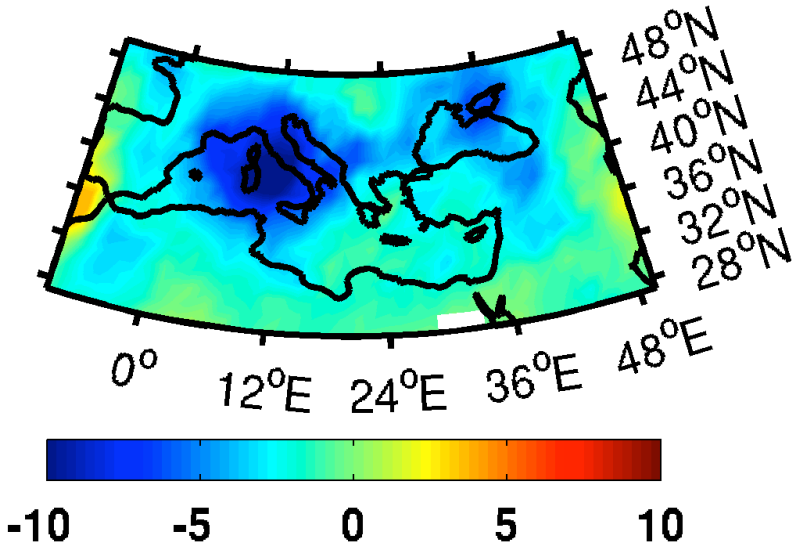
- day-to-day flux variability controlled by advection of mean temperature field by storms, especially during 1991/1992 and 1992/1993 winters
- fewer warm events during 1991/1992 and 1992/1993 winters
- cold advection due to stationary eddy wind field larger during 1991/1992 and 1992/1993 winters

Cyclone Frequency Anomalies during EMT

NDJF 1991/1992

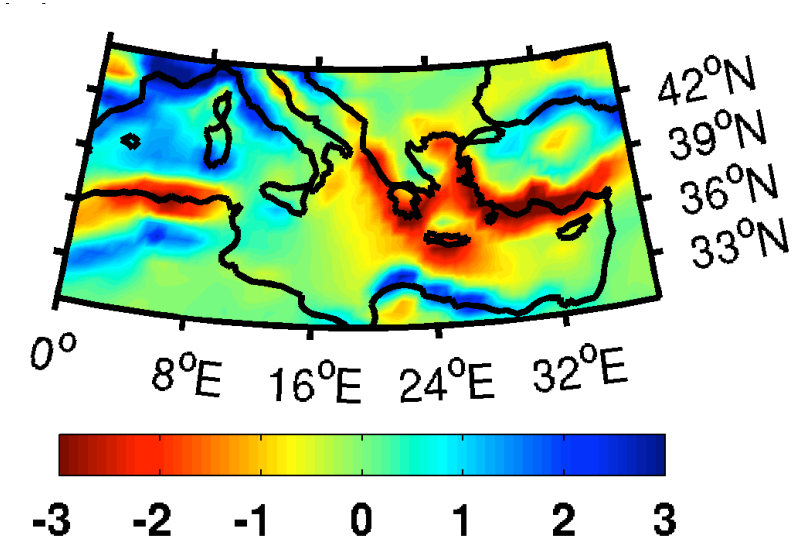


NDJF 1992/1993

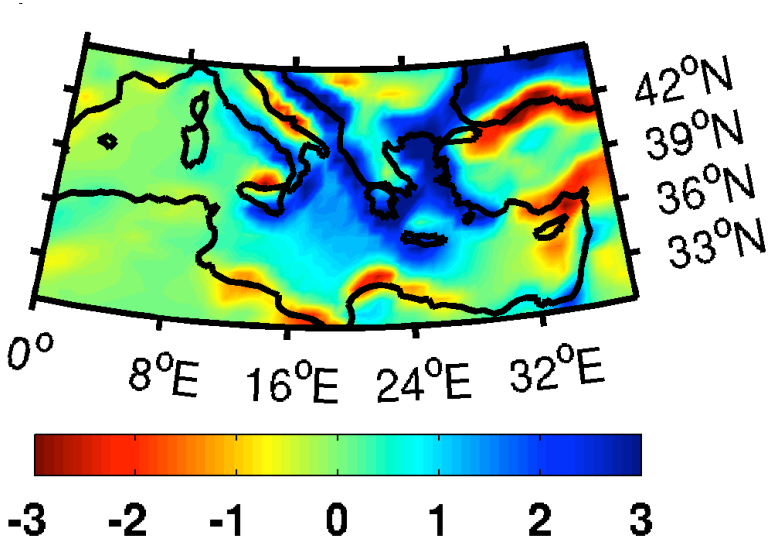


- Dipole pattern in both years – fewer storms in central Mediterranean compared to eastern Mediterranean
- Produces reduced warm advection (fewer central Med storms) and enhanced cold advection (more eastern Med storms) over Aegean Sea

Storm-related anomalous heat advection



vdT/dy anomaly when there is a storm in the Central Mediterranean (defined as 10-15E, 38-40N and 15-20E, 30-40N), NDJF 1989/1990 – 2008/2009



vdT/dy anomaly when there is a storm in the Eastern Mediterranean (defined as 25-37E, 32-37N), NDJF 1989/1990 – 2008/2009

- Fewer central Med storms lead to reduced warm advection over Aegean
- More eastern Med storms lead to enhanced cold advection over Aegean
- Both enhance turbulent heat loss from Aegean

Conclusions

- Atmospheric forcing during most intense portion of EMT was due to altered cyclone activity
- Reduced frequency of central Med storms led to fewer warm advection events
- Increased frequency of eastern Med storms led to more cold advection events

Further Questions

- Relationship with large scale oscillations?
  - No correlation between Aegean flux and NAO, in agreement with *Josey, 2003*
  - Relationship with NCP/EAWR pattern – correlation of 0.60 between monthly mean NCP and Aegean turbulent fluxes
- Will there be more frequent EMT-like cyclone patterns in the future?
  - Poleward storm track shift could lead to fewer central Med storms
  - Higher resolution climate models/nested modeling techniques may be able to help

Thank you!

Romanski, J., A. Romanou, M. Bauer, and G. Tselioudis (2012), Atmospheric Forcing of the Eastern Mediterranean Transient by midlatitude cyclones, *Geophys. Res. Lett.*, 39, L03703, doi:10.1029/2011GL050298

For more information on the NASA Modeling, Analysis, and Prediction Program Climatology of Mid-latitude Storminess dataset, please contact George Tselioudis or Michael Bauer at NASA GISS.

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