Climatology of dry air intrusions and their relation to strong surface winds in extratropical cyclones

....and intro to synoptic and meso-scale cyclone dynamics

Shira Raveh-Rubin and Heini Wernli

Institute for Atmospheric and Climate Science (IACETH), ETH Zurich

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Impact of cyclones – what?

- strong damaging surface winds
- extended heavy precipitation
- hail, thunderstorm...

... damage, fatalities, floods, landslides, storm surge, economic losses
Impact of cyclones – where and when?

MODIS on Terra satellite, NASA, 12 February 2014
Impact of cyclones – where and when?

cloud head

dry slot

1000 km
Impact of cyclones – where and when?
Impact of cyclones – where and when?

N. Atlantic composite (~400 cyclones)

Surface wind velocity

Precipitation rate

Field and Wood 2007 (J Climate)
Storm track and max. wind gust speed

Born et al., 2012 (Tellus)

Impact of cyclones – wind footprint
Wernli and Schwierz 2006 (JAS)
Precipitation in intense Mediterranean cyclones

Flaounas et al., 2015 (Clim Dyn)
Co-occurrence of precipitation and gust extremes in Mediterranean

On average: gust maximum \(~12\text{h}\) after precipitation maximum

Raveh-Rubin and Wernli 2015 (*QJ*)
Impact of cyclones – associated features

- warm conveyor belt (WCB)
- cold conveyor belt (CCB)
- dry air intrusion (DAI)
- sting jets (SJ)
- fronts
- convection
Warm conveyor belts (WCBs)

Lagrangian definition and climatology:
Madonna et al., 2014 (*J Climate*)

≠ convection

Lagrangian definition and climatology:
Madonna et al., 2014 (*J Climate*)
composite of 500 explosively intensifying cyclones associated with a strong WCB

> 600 hPa ascent in 48 h
WCBs and extreme precipitation

Pfahl et al., 2014 (J Climate)
Cold conveyor belt (CCB) and sting jet (SJ)

Review CCB: Schultz 2001 (MWR)
Cold conveyor belt (CCB) and sting jet (SJ)
Cold conveyor belt (CCB) and sting jet (SJ)

Gray et al., 2011 (QJ)
Dry air intrusions (DAIs)
Dry air intrusions (DAIs)

Browning 1997 (*Meteorol. Appl.*)
DAI and extreme surface wind

Browning and Reynolds 1994 (*QJ*)
Extreme large-scale wind and precipitation

Case study: 21-23 October 2007 Mediterranean cyclone

2 PVU on 330 K

SLP

WV (Dundee satellite receiving station)

12 UTC 22/10/2007
Total wind and precipitation

ERA Interim

Maximum 10-m gust

Total precipitation

Convective precipitation
Total wind and precipitation

Maximum 10-m gust

ERA Interim

COSMO 7

Total precipitation

Convective precipitation

[m/s]

[mm /4 days]
Temporal evolution

ERA Interim

- SLP
- Gust
- Total prec.
- Convective prec.

Peak time
Peak wind / precipitation and Lagrangian airstreams

Ascending trajectories  Descending trajectories  Trajectories reaching max. gust
500-hPa ascent in 48 h  400-hPa descent in 96 h  Gust > 22 m/s
Total 6-h precipitation  Maximum 6-h gust (at 10 m)  P > 900 hPa
Peak wind / precipitation and Lagrangian airstreams

Ascending trajectories

500-hPa ascent in 48 h

Total 6-h precipitation

Descending trajectories

400-hPa descent in 96 h

Maximum 6-h gust (at 10 m)

Trajectories reaching max. gust

Gust > 22 m/s

P>900 hPa

12 UTC, 22 October 2007
COSMO 7
12 UTC, 22 October 2007

- PV > 2 pvu
- Wind vel. > 20 m/s
- θe

- RH [%]
- Total precip.
- Convective precip.
- SLP
- Gust

Map showing RH [%], Total precipitation, Convective precipitation, and 10-m gust.
COSMO trajectories reaching high gust
COSMO 7
12 UTC, 22 October 2007

PV>2 pvu
Wind vel. > 20 m/s
θe
COSMO trajectories which descend strongly 400 hPa in 24 h
Observation of shallow convection

Channel 10 - IR
11.00-13.00 µm

Channel 5 - WV
5.35-7.15 µm

Dundee satellite receiving station
Case study - summary

- Large-scale and persistent non-convective precipitation associated with WCB trajectories
- Large-scale high gust associated with CCB and instability
- At the cold front environment – shallow convection and destabilization by a DAI – important for co-location of strong wind and precipitation
- Strong wind and precipitation are otherwise separated
Dry air intrusions – Lagrangian definition

- ERA Interim
- LAGRANTO (Sprenger and Wernli 2015, *Geosci. Model Dev.*)
- Start forward trajectories every 6 h, 80 km, above 600-hPa level
Dry air intrusions – Lagrangian definition

400-hPa descent in 48 h

Start at 19921121_06
Dry air intrusions climatology

DJF

0 h

+48 h

# / (6h deg²)
Dry air intrusions climatology

JJA

0 h  +48 h

# / (6h deg²)
Dry air intrusions climatology

DJF

0 h

+48 h

Pacific

Atlantic

# / (6h deg²)
Atlantic / DJF

Temporal evolution

- **P [hPa]**
- **θ [K]**
- **q [g kg\(^{-1}\)]**
- **PV [pvu]**
- **RH [%]**

Time [hr]
Temporal evolution

Pacific / DJF

- $P$ [hPa]
- $\theta$ [K]
- $q$ [g kg$^{-1}$]
- $PV$ [pvu]
- $RH$ [%]

Time [hr]
Dry air intrusions – outlook

- How do DAIs interact with cyclones?
- What is the origin of DAIs?
- What initiates DAIs?
- What is the impact of DAIs on extreme weather at the surface?
Thank you!