Lecture 1
Compound weather and climate events:

What are they? Why do we care?

Bart van den Hurk (Deltares)

with contributions from
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A "typical univariate" extreme event

In 2012, a flash flooding in Krymsk (Russia) killed more than 170 people due to an unprecedented amount of rain.

But not all flooding are "univariate", many are caused by a combination of hazards/drivers.
On 6th Feb 2015, along Ravenna’s coast, river discharges were partially obstructed from draining into the sea by the storm surge, causing a compound flooding (CF).
Near-flooding event 2012: a compound event
Computing infrastructure requirements

What about correlation characteristics between drivers?

Statistics of time evolution of internal water fluctuations at short and long time scales
The concept of compound events

All precipitation events → highest 10%

all storm surge events →

joint probability: 1%

← All precipitation events →
The concept of compound events

All precipitation events → highest 10%

All storm surge events → joint probability: >1%

← All precipitation events →
← all storm surge events →

Image source: Douglas Merriam/Science Advances
Analysis of compound events

› A regional climate model (RACMO2)
  – @12km
  – 1950 – 2000, 16 members = 800 yrs
  – precipitation averaged over target domain
  – storm surge derived from wind + astronomical tide

› Local precipitation observations
  – for statistical bias correction

› Hydrological model of Noorderzijlvest water system
  – including water management
  – to generate time series of inland water level
Compounding occurrence of storm surge and intense precipitation

Effect of compounding events

99% of all shuffled data (where correlation is removed) within this contour

99% of all data within this contour
Local water level at Lauwersmeer

With compound events

Without compound events

1/50 yr

1/200 yr
The concept of risk
Compound events

Compound weather/climate events refer to the **combination** of **multiple** drivers and/or hazards that contributes to societal or environmental **risk**.

Future climate risk from compound events

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Floods, wildfires, heatwaves and droughts often result from a combination of interacting physical processes across multiple spatial and temporal scales. The combination of processes (climate drivers and hazards) leading to a significant impact is referred to as a ‘compound event’. Traditional risk assessment methods typically only consider one driver and/or hazard at a time, potentially leading to underestimation of risk, as the processes that cause extreme events often interact and are spatially and/or temporally dependent. Here we show how a better understanding of compound events may improve projections of potential high-impact events, and can provide a bridge between climate scientists, engineers, social scientists, impact modellers and decision-makers, who need to work closely together to understand these complex events.

Zscheischler et al, NCC 2018
Impact varies with combination of drivers
Examples

- Drought
  - Precipitation, evapotranspiration, historic evolution of soil moisture, temperature
- Heat stress
  - Diurnal cycle of temperature, humidity
- Fire risk
  - Temperature, precipitation, relative humidity, wind, lightning
- Coastal flooding
  - Storm surge, precipitation, discharge
- Concurrent phenomena
  - Wind, precipitation, temperature, air pollution, ...
Elements of a compound event

Climate change

Compound weather/climate events refer to the combination of multiple drivers and/or hazards that contributes to societal or environmental risk.
Four types of compound events

1. Preconditioning
2. Concurrent events
3. Temporally compounding
4. Spatially compounding
1. Preconditioning
“False” spring

Regularly causing large-scale damage to natural vegetation and crops in temperate regions.

Warm late winter: creates precondition
Frost in early spring: hazard

Damaged sugar maple trees

Rain on snow events

Important flood-producing events in the high latitudes and mountainous areas.

Snow-covered surface: precondition
Rain: hazard

2. Concurrent events

Driver 1 — Hazard 1 — Hazard 2 — Impact

Driver 1 — Hazard n — Impact
Compound flooding

Common driver: storms, tropical cyclones, atmospheric rivers, etc.

See 2nd lecture on CE’s (Thursday)
Various types of dependence

Zheng et al. (2013) *J. of Hydrology*

Van den Hurk et al. (2015) *ERL*
Correlation is highly variable in space

Ward et al. (2018) ERL
Separate the drivers – Compositing

Events at Devonport, UK

Surge-only events
- No. of events: 41
- Years of overlapping data: 23

Joint-occurrence events
- No. of events: 11

River-only events
- No. of events: 37
Concurrent drought and heat
Drought-heat feedbacks

Combined high temperature-low precipitation

- Correlation between summer temperature and precipitation (CMIP5)

Change in dependence

- Change in correlation 1870-1969 and 2001-2100 (RCP8.5)

Likelihood of concurrent hot and dry summers

› How much more likely is the combination of 10% highest temperature and 10% lowest precipitation?
3. Temporally compounding

Modulator → Driver 1 → Hazard 1 → Hazard 2 → Hazard n → Fixed geographical area → Impact

Time
Sequence of heatwaves

Baldwin et al. (2019) GRL
Cluster of tropical cyclones

Katia, Irma, Jose in 2017

Precipitation clustering and lake flooding

Barton et al. (2016) MWR
4. Spatially compounding

Modulator \(\rightarrow\) Driver 1 \(\rightarrow\) Hazard 1 \(\rightarrow\) Driver 2 \(\rightarrow\) Hazard 2 \(\rightarrow\) Driver n \(\rightarrow\) Hazard n \(\rightarrow\) Impact

space
Global Famine 1876-78

Estimated fatalities: > 50.000.000

Concurrent impacts of El Niño on crop yields

Conclusions

› Many events have compounding drivers

› Impacts are important starting point for compound event definition

› Typology of compound events exist, each requiring a specific analysis method