Dynamics of sting-jet storm "Egon" over continental Europe

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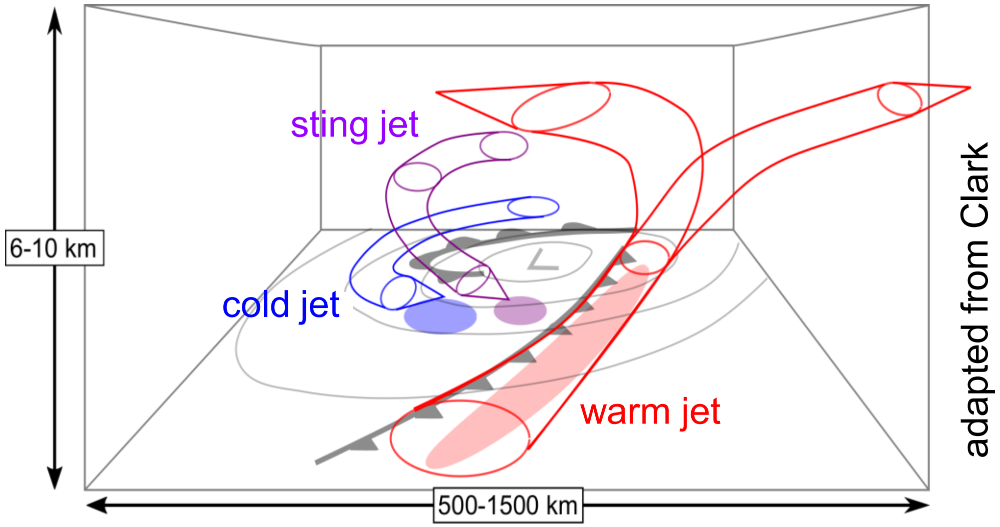
Motivation

- Strong winds in extratropical cyclones are often associated with the **warm** and **cold** jets
- Another cause is the **sting jet**, which still requires more research for full understanding
- Sting-jet case studies from previous literature over the North Atlantic and British Isles mostly
- Simulations showed a strong sensitivity towards horizontal and vertical resolution



adapted from Clark and Gray (2018), Fig. 7

→*Do sting jets develop over continental Europe?*

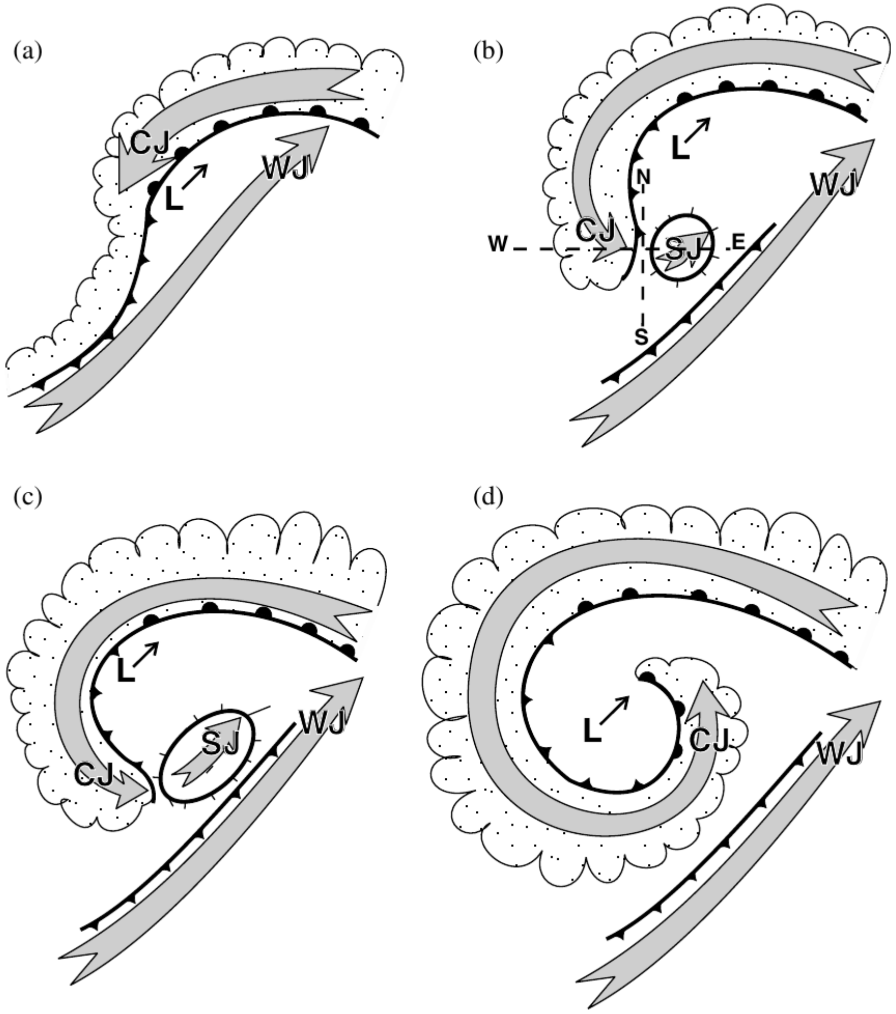
→*What is the impact of topography? (orography, land surface)*

→*Are there benefits of running models at km-scale resolution?*

What is a sting jet?

“[…] coherent air flow that ***descends*** *from mid-levels inside the* ***cloud head*** *into the* ***frontal-fracture*** *region of a Shapiro-Keyser cyclone over a period of a* ***few hours*** *leading to a* ***distinct*** *region of near-surface* ***stronger winds****.”*

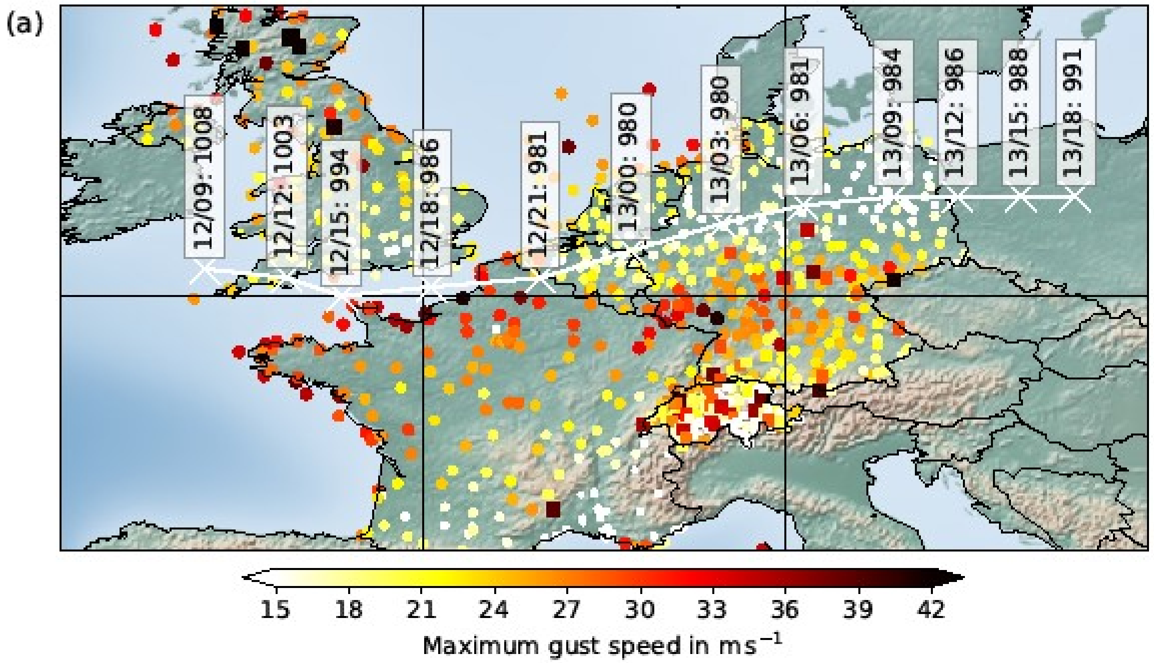
Clark and Gray (2018)

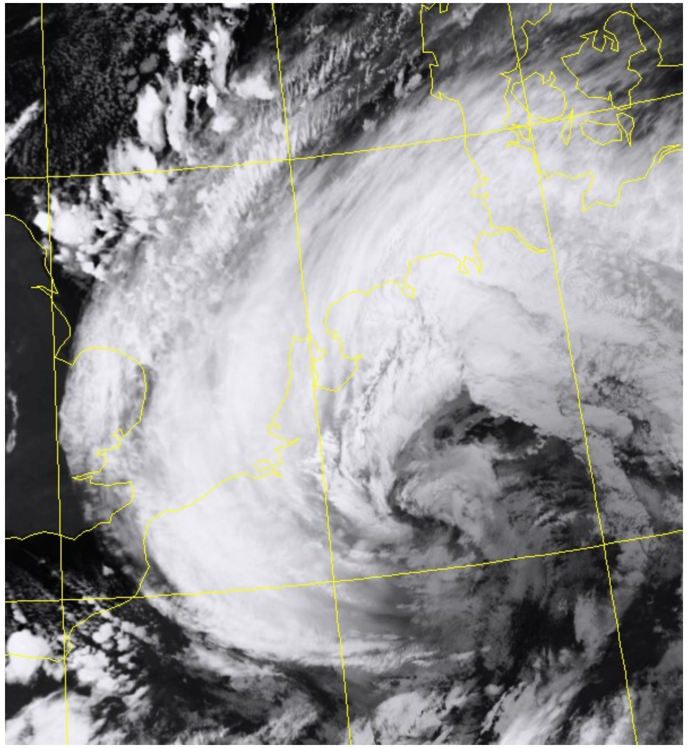


Clark et. al. (2005), Fig. 17

Case study: windstorm “Egon”

- Recorded gusts up to ~150 km/h on 12-13 January 2017
- Explosive cyclogenesis over English Channel (28 hPa in 15 h)
- Insured damage in Germany and France ~275 M€ (www.perils.org)

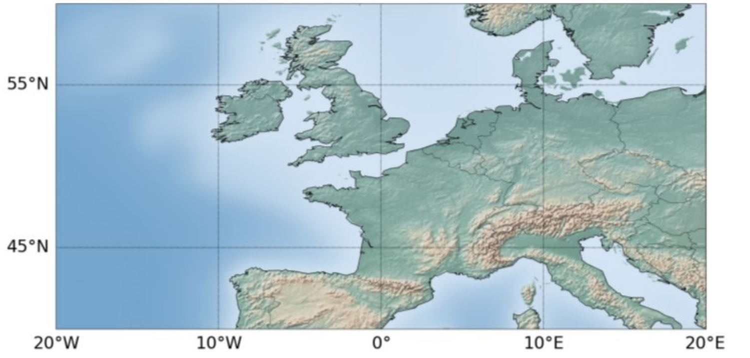




VIIRS 13 Jan 2017 at 00:46 UTC, www.sat.dundee.ac.uk

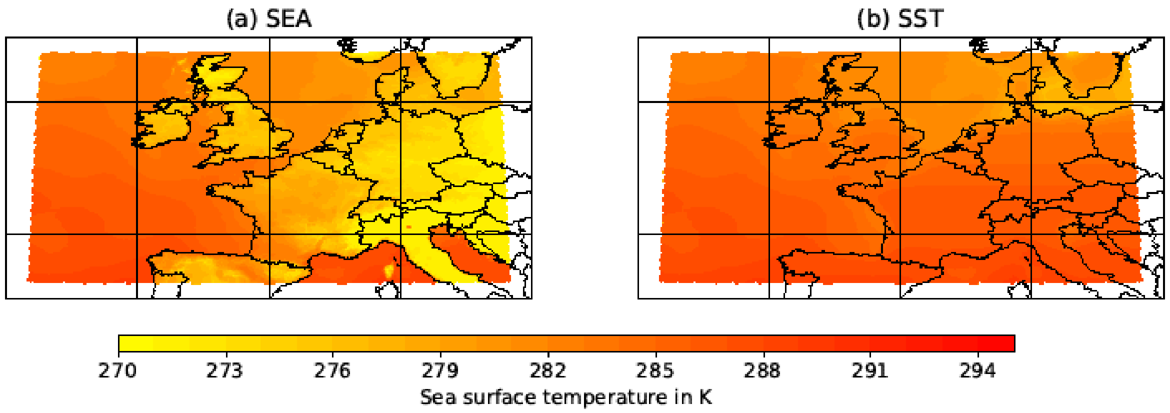
Model simulations using ICON-LAM

- Time period: 00 UTC 12-14 January 2017 (48 h)
- Initial and lateral boundary conditions ICON Δt = 3 h
- **REF: dx = 3.3 km**, convection parametrisation turned **on**

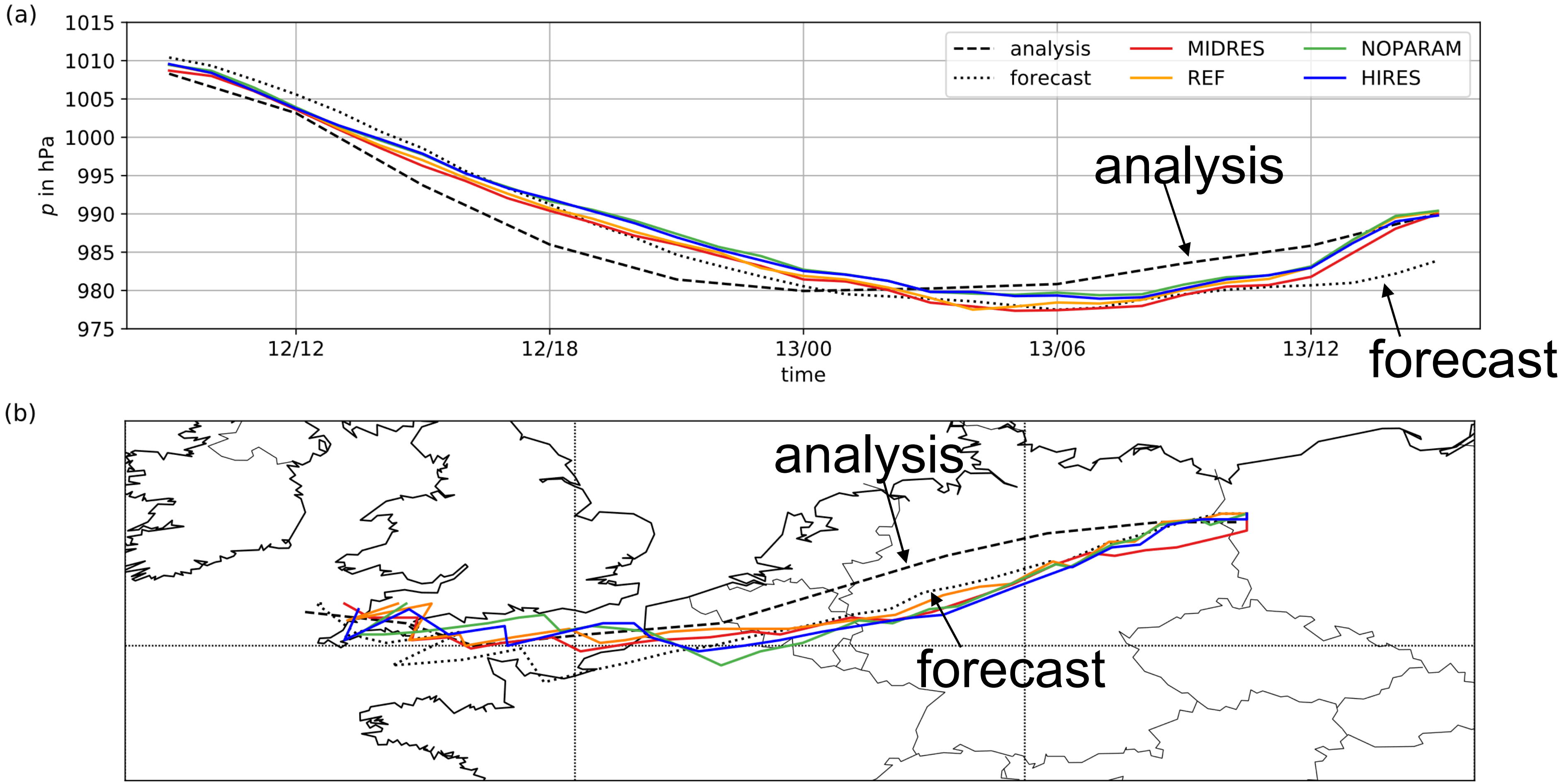


- Sensitivity to horizontal resolution
  - **MIDRES: 6.5 km**, convection parametrisation turned **on**
  - **HIRES: 1.6 km**, convection parametrisation turned **off**
  - **NOPARAM: 3.3 km**, convection parametrisation turned **off**

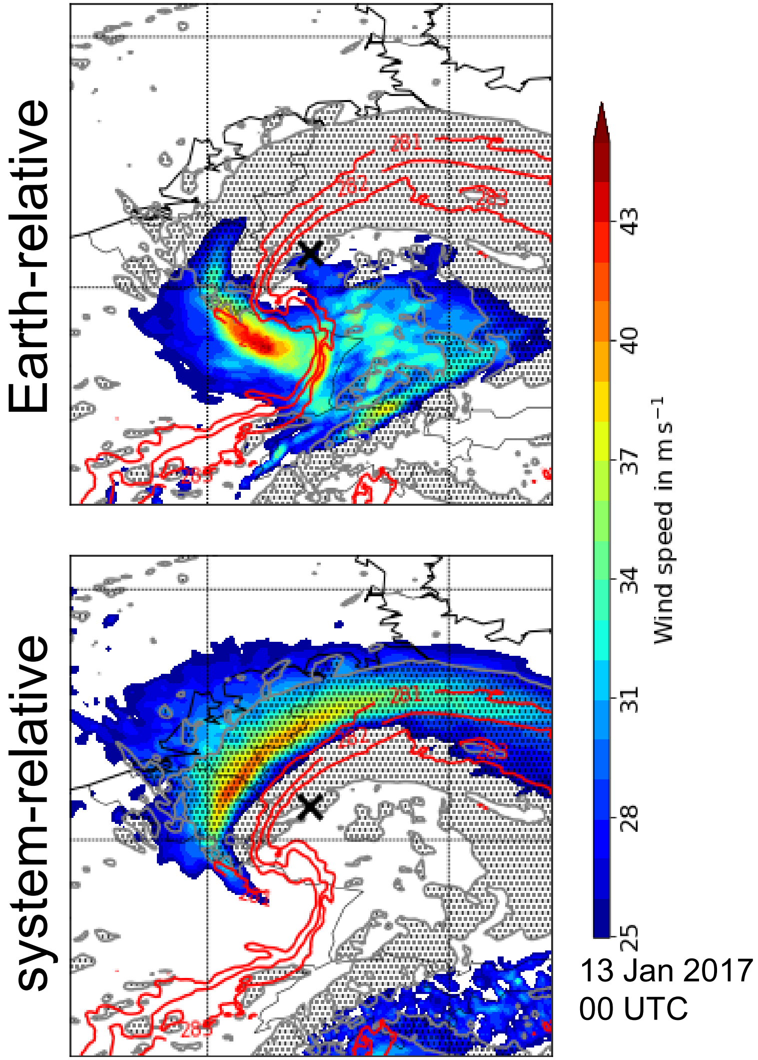
- Impact of surface properties
  - **FLAT:** deleted orography
  - **SEA:** FLAT + land replaced by sea
  - **SST:** SEA + warmer sea



Cyclone evolution in simulations



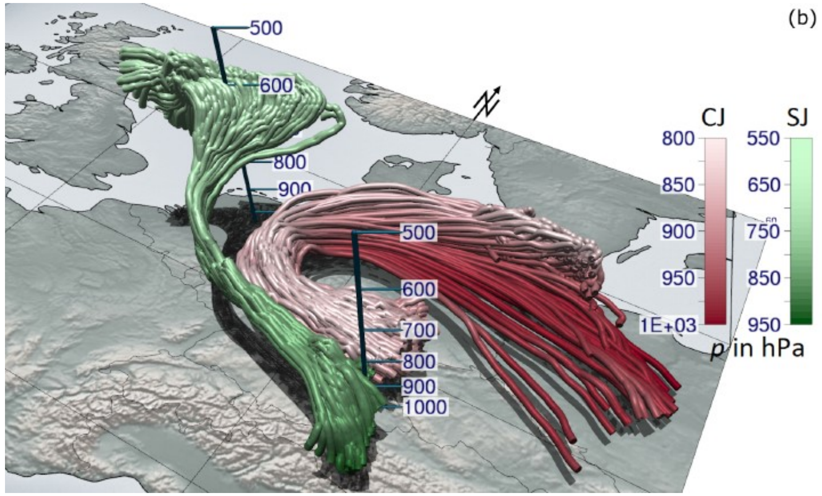
Did Egon involve a sting jet?



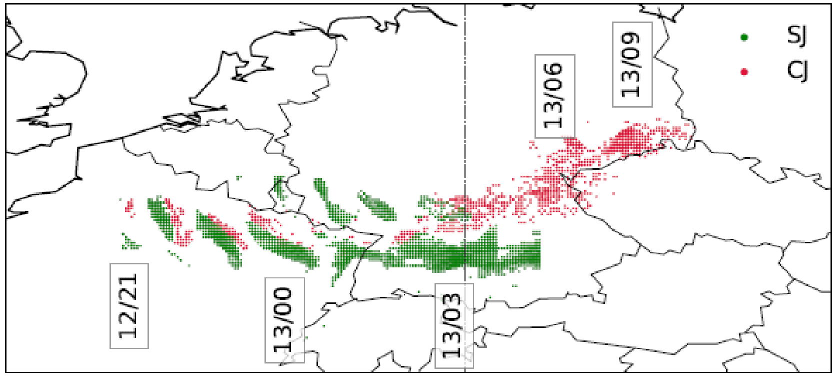
Lagrangian trajectories using LAGRANTO tool

(Wernli & Davies, 1997; Sprenger & Wernli, 2015)

- Backward (12-15 h) and forward trajectories (3-6 h) starting from time and location of max 850 hPa wind
- Criteria for **sting jet**: $v > 37$ m s^{-1} and $\Delta p > 150$ hPa in 8 h
- Criteria for **cold jet**: $v > 37$ m s^{-1} and $p > 800$ hPa



Visualization using Met.3D



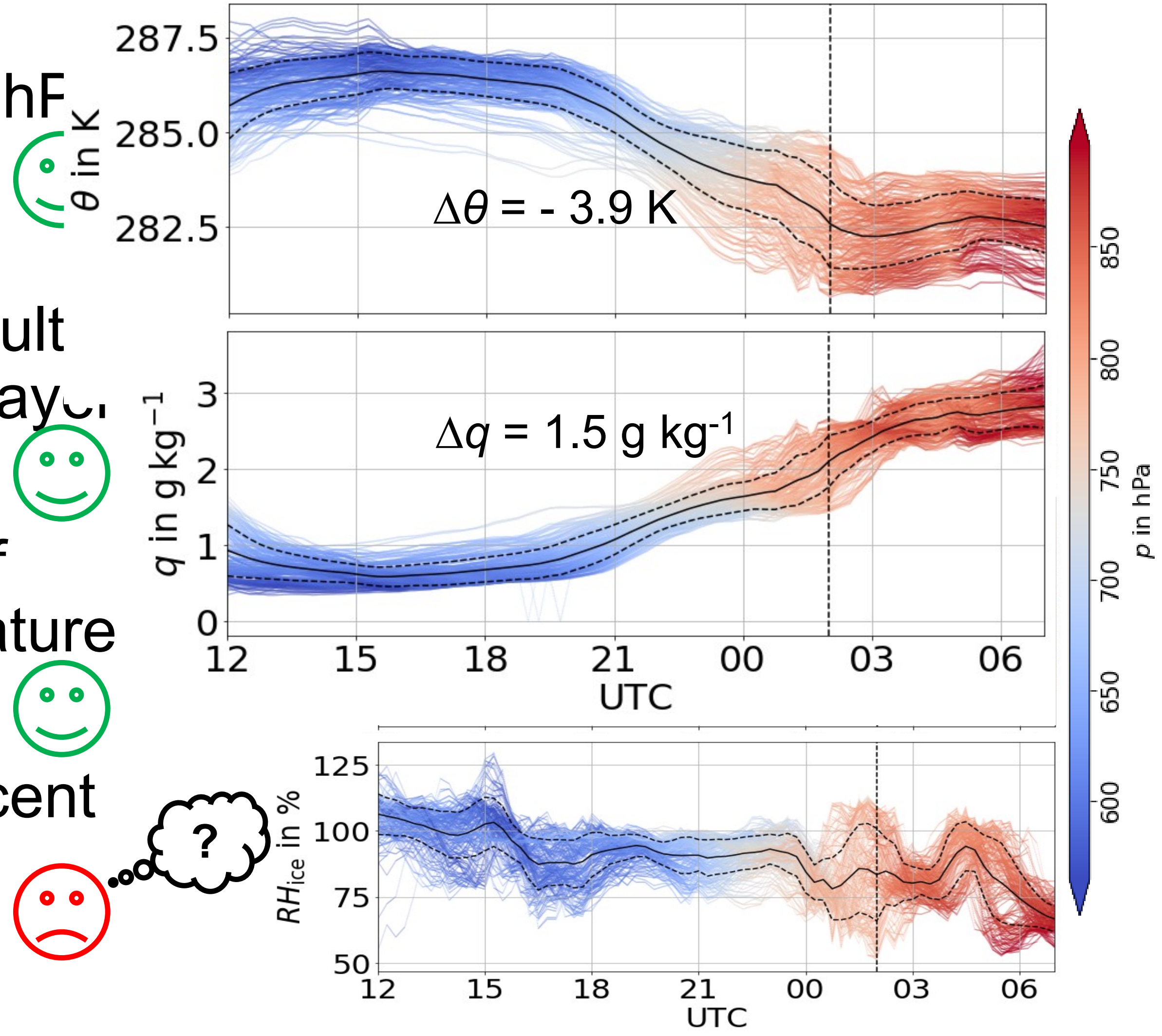
Starting points of trajectories

Sting jet characteristics

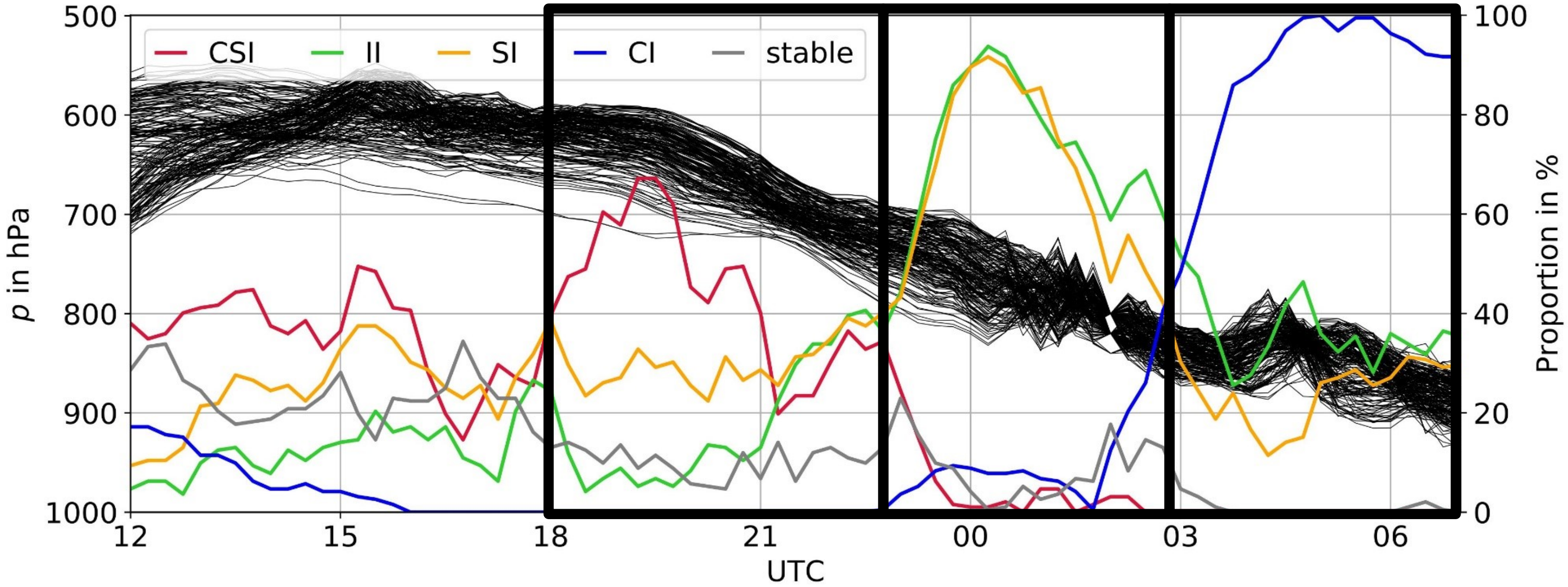
Previous studies (e.g. Baker et al. 2014)

- Originates at mid levels (600 – 800 hF
within cloud head
- Accelerates during descent and result
strong winds near top of boundary lay
- Descends along sloping surfaces of
constant wet-bulb potential temperature
- Relative humidity drops during descent
→ Evaporative cooling!

Our model simulations



Mesoscale instabilities

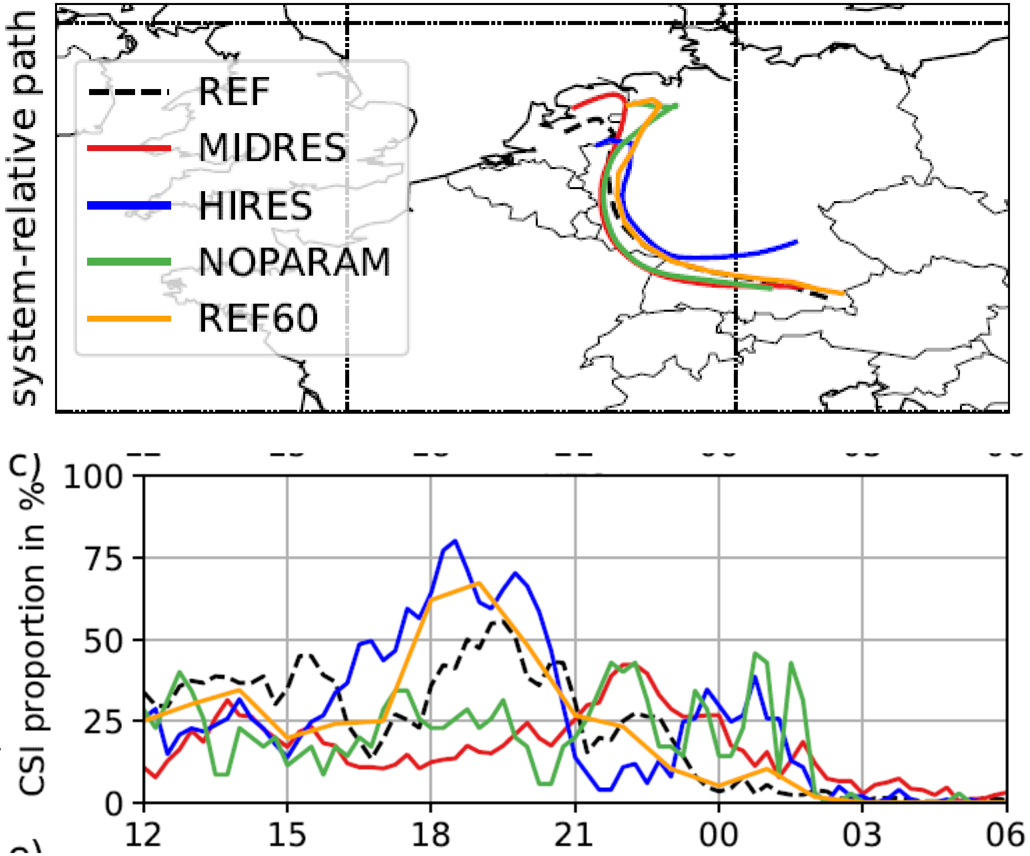


- Part I: conditional symmetric instability (CSI) appears to trigger descent
- Part II: symmetric (SI) / inertial instability (II) contribute during descent
- Part III: conditional instability (CI) may support BL mixing of strong winds

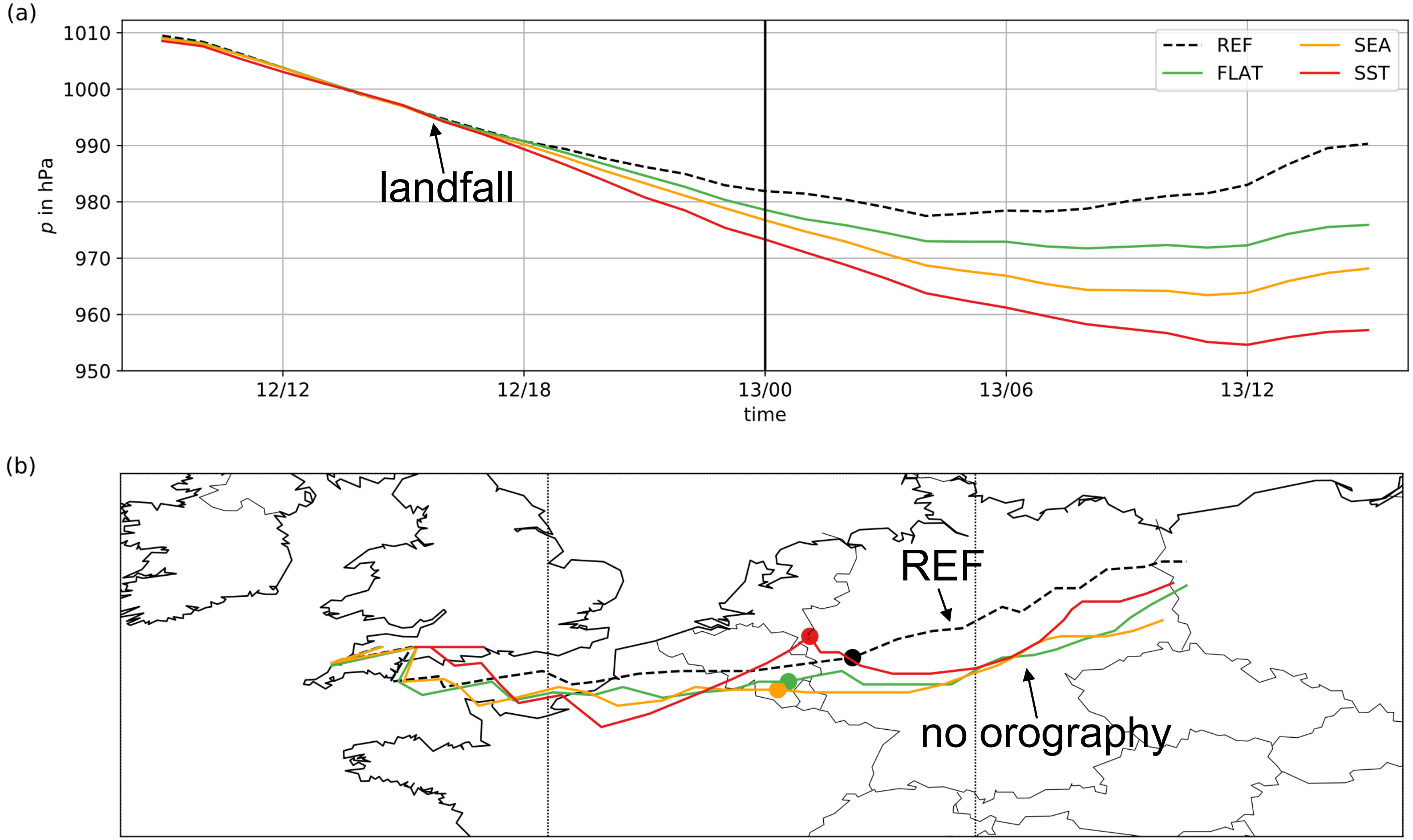
Sensitivity to model resolution

- SJ trajectories found in all simulations
  - 292 in **REF** (dx=3.3km, param. convection)
  - 258 in **MIDRES** (dx=6.5km, param. convection)
  - 101 in **HIRES** (dx=1.6km, explicit convection)
  - 35 in **NOPARAM** (dx=3.3km, explicit convection)
- CSI in all simulations: **HIRES**>**REF**>**MIDRES**
- Also impact on descent & evaporative cooling
- Also sensitive to SJ criteria & output frequency

→ *Robust SJ and CSI but uncertainty in numbers*



Impact of surface properties



REF

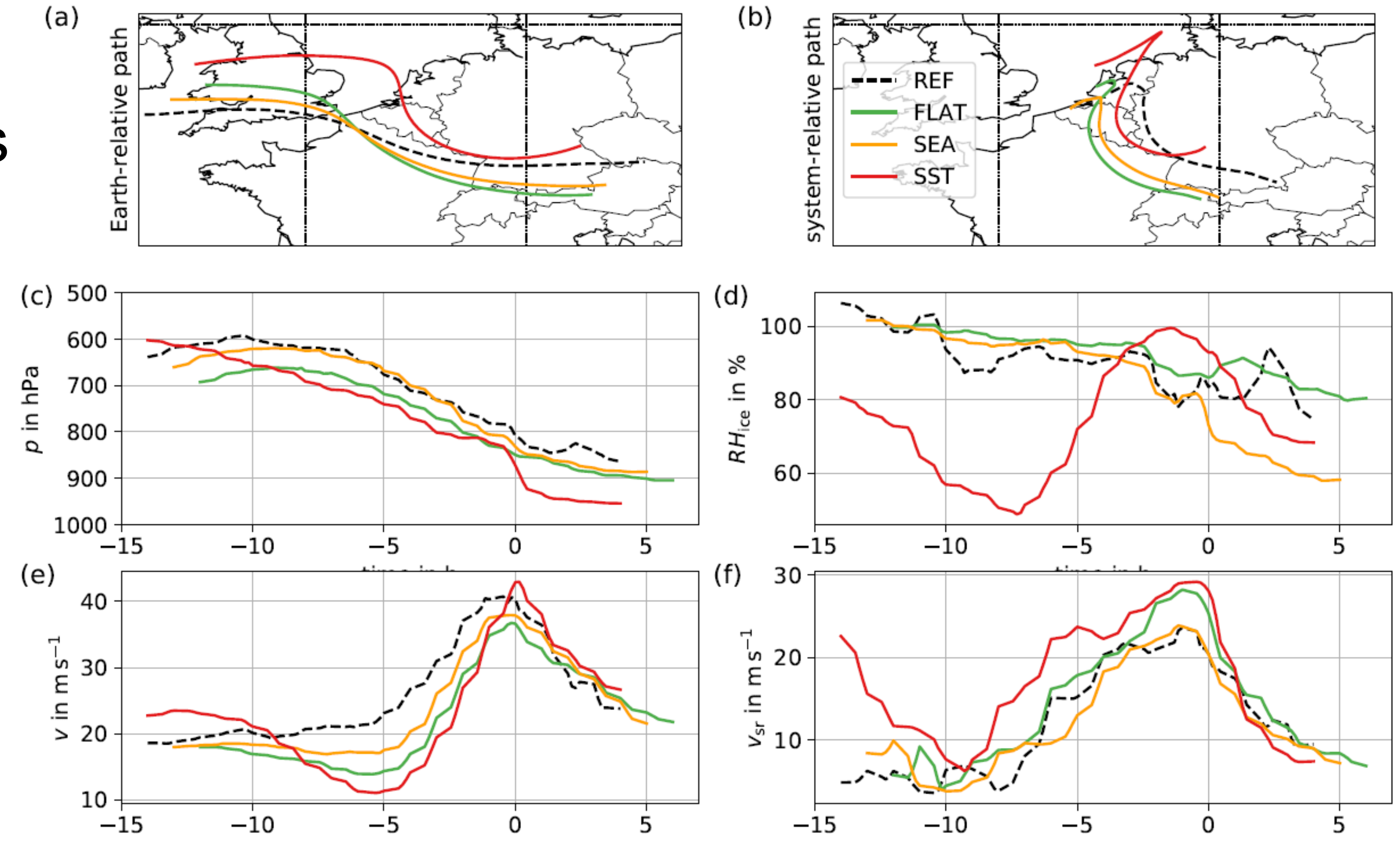
FLAT = removed orography

SEA = removed land

SST = warmer sea

Moderate impact on SJ dynamics

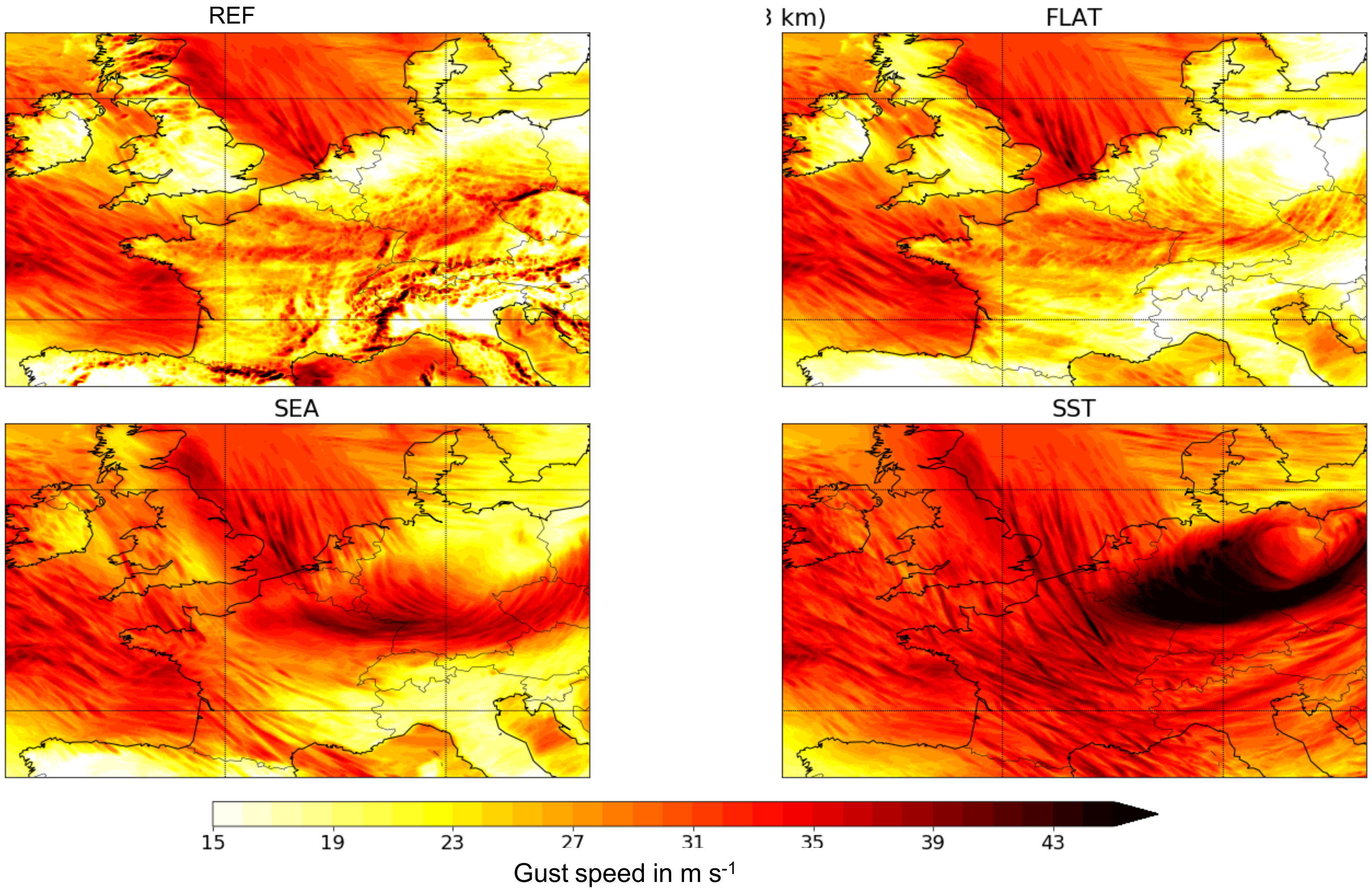
- Sting jet present in all simulations
- **FLAT** and **SEA** similar to **REF**
- Different evolution in **SST**



Dramatic impact on gust footprint

REF

FLAT
removed orography
→no signature of mountains



SEA
removed land
→reduced friction

SST
warmer sea
→increased mixing

Conclusions

Windstorm Egon 12-13 January 2017 over continental Europe

- ICON-LAM simulations satisfactorily reproduce cyclone dynamics
- Lagrangian trajectories **confirm presence of sting jet**
  → Contribution of **mesoscale instabilities** consistent with previous cases
  → **Evaporative cooling** prevents drying, stronger than in previous cases
- Sensitivity tests to horizontal resolution (dx=1.6-6.5 km) and convection param.
  → Weak impact on cyclone dynamics but **strong impact on SJ characteristics**
- Sensitivity tests to surface properties (orography, land/sea, SST)
  → Each result in **deeper cyclone and stronger gusts** but mixed impact on SJ

Eisenstein, L., Pantillon, F. and Knippertz, P. (2019): *Dynamics of sting-jet storm "Egon" over continental Europe: impact of surface properties and model resolution*. **Q. J. R. Meteorol. Soc**. DOI: 10.1002/qj.3666