



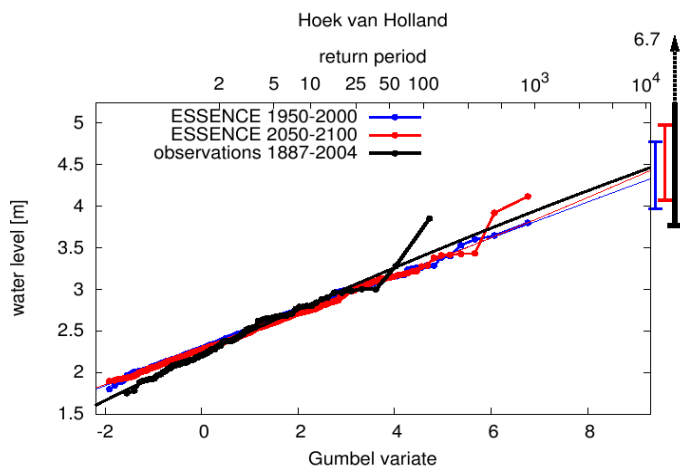
## Dynamics of extra-tropical transition of tropical cyclones hitting western Europe in a warmer climate

Rein Haarsma, Michiel Baatsen and Hylke de Vries

KNMI, The Netherlands



How will extreme winds in NW Europe change in the future?

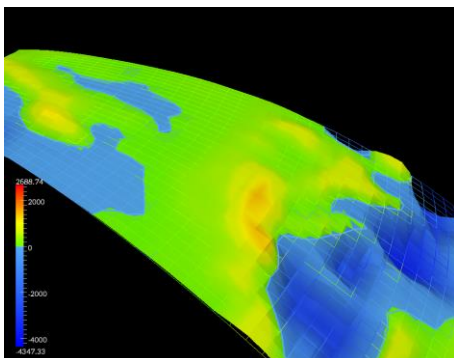


Sterl et al 2009

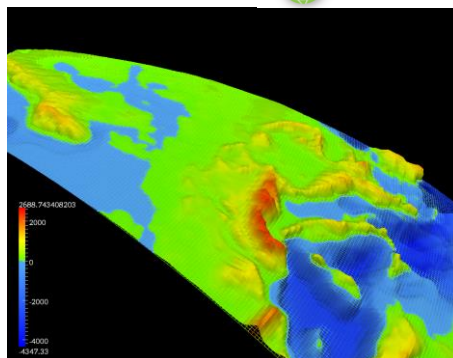


## 'Future Weather' simulations

- High resolution (T799, ~ 20km)
  - Atmosphere-only (EC-Earth: ECMWFs IFS cycle31r1+)
  - 6 member ensemble of 5-year
- 
- Present 2002-2006. Observed SST at 0.25° (NOAA)
  - Near-Future 2030-2034  $\Delta$ SST from ECHAM5/OM (SRESA1B)
  - Future 2094-2098.  $\Delta$ SST from ECHAM5/OM (SRESA1B)



EC-EARTH T159  
~ 150 km

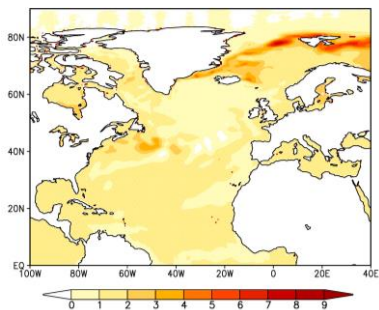


EC-EARTH T799  
~ 20 km

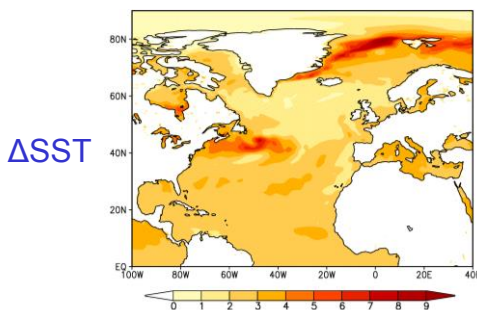


### Analysis severe autumn storms

Near Future (2030-2034)



Future (2094-2098)

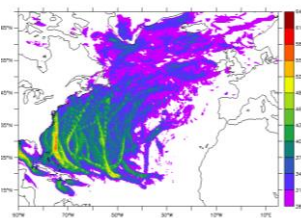


3 hrly surface data  
6 hrly pressure level data

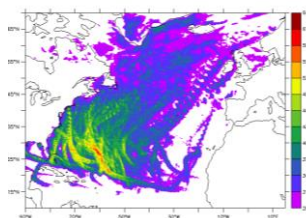


### Maximum wind speed Aug.-Nov.

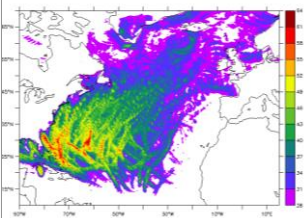
Present



Near Future



Future



More storms of > Bft11 in Western Europe  
in Near Future and Future

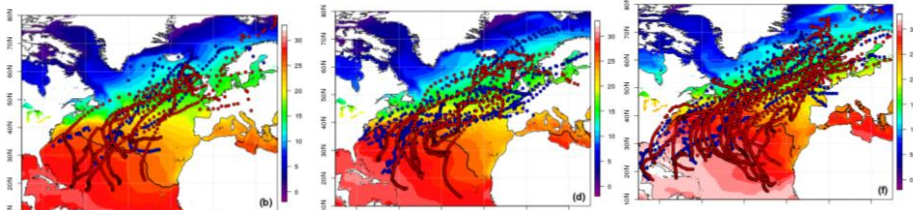


## Tropical systems that reach Europe with Bft 11

Present

Near Future

Future



15 storms (5,10)

23 storms (13,10)

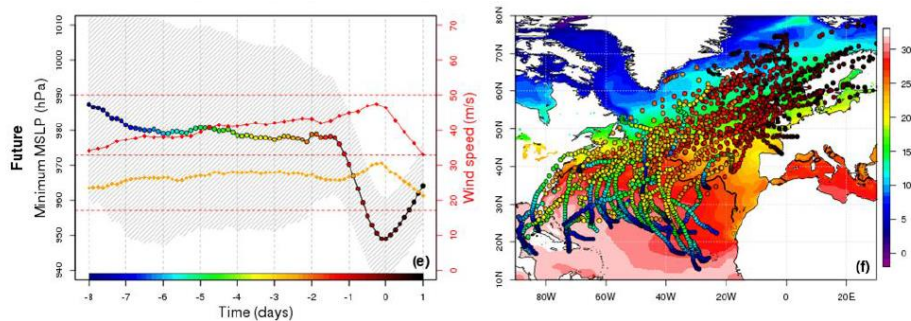
37 storms (15,22)

Red: Fully developed hurricanes, full warm core

Blue: Weak tropical systems, shallow warm core

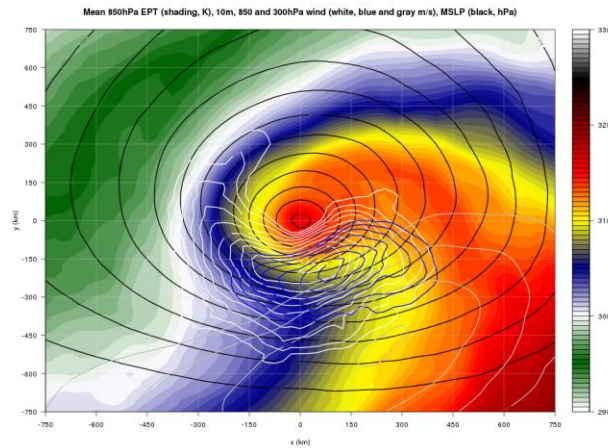


## Development of all extreme autumn storms

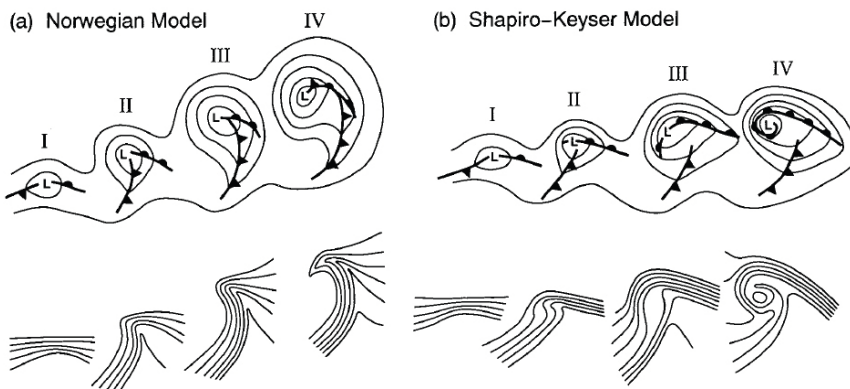


## All these storms form warm seclusions

Composite of storms that make extra-tropical transition



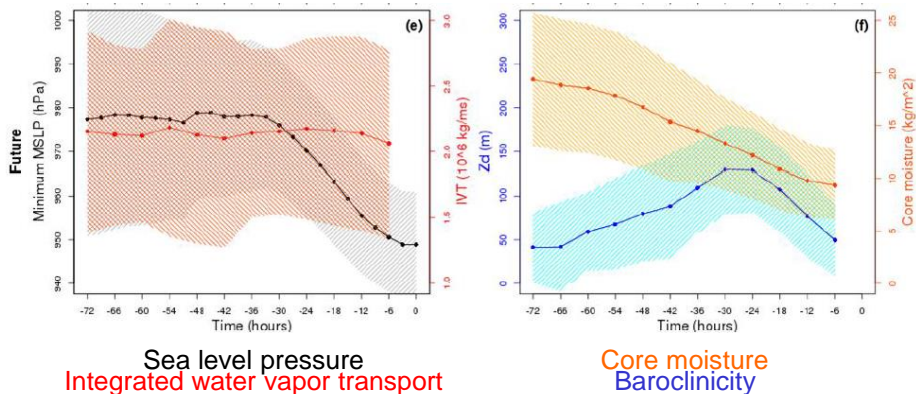
## Synoptic structure of warm seclusion storms



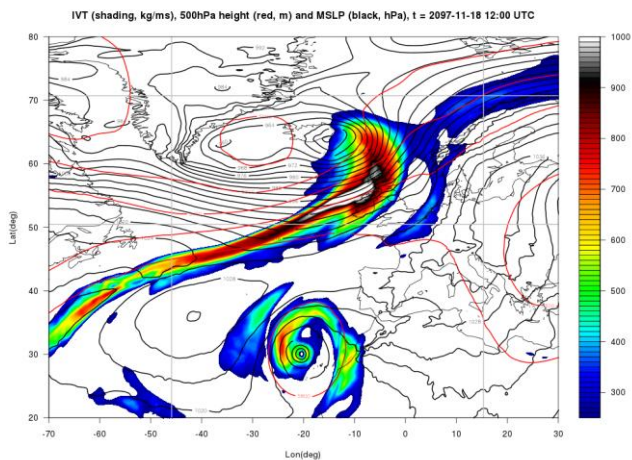
Highest gradient on cold front vs highest gradient on warm front  
(detached, t-bone structure: warm seclusion; Maue 2010)



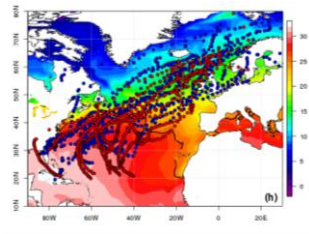
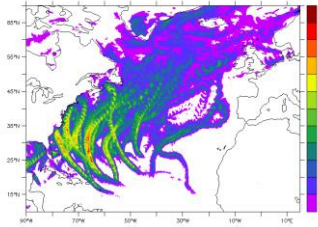
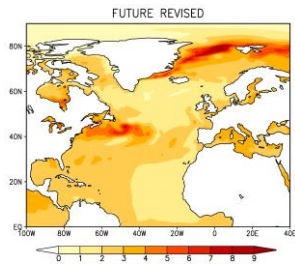
## Mean evolution of BF11+ storms hitting Western Europe AND that make a tropical-extratropical transition



## Atmospheric rivers: integrated vapor transport



## Sensitivity to eastern tropical Atlantic warming

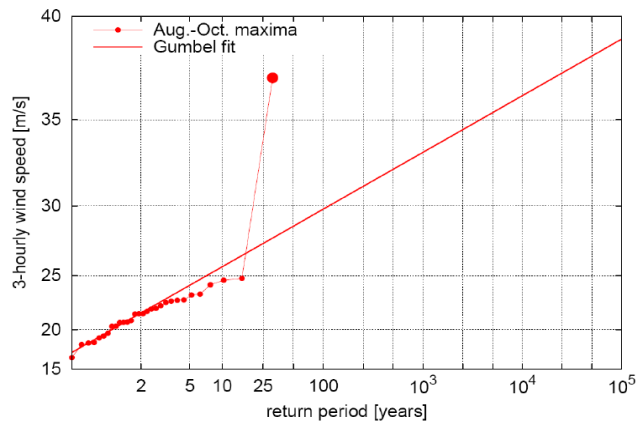


Smaller eastern tropical Atlantic warming reduces amount of **fully developed hurricanes** that reach Europe.

**Weak tropical systems** are not affected.

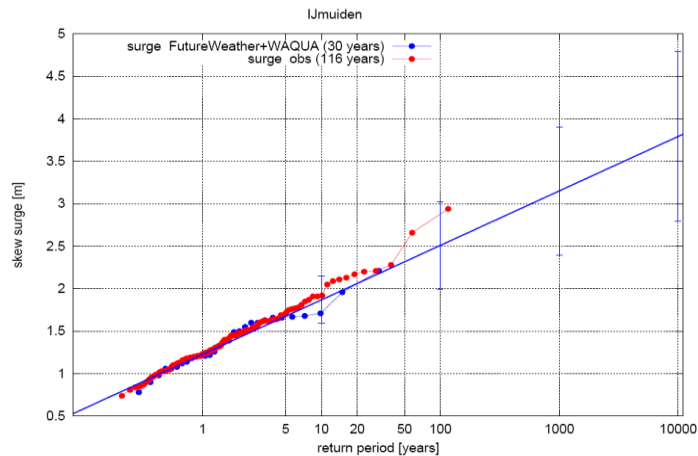


## Extreme value distribution winds North Sea





## No effect on storm surges in future



## Conclusions



**Global warming can lead to an increase of severe storms in Western Europe.  
Signal already visible in near future.**

**Severe storms have a tropical origin and reintensify when entering baroclinic zone.**

**Warm seclusion structure and often associated atmospheric rivers.**

**Caveats: prescribed SST, small sample (30 years), model dependency, still coarse resolution**

HighResMip: CMIP6 initiative to assess robustness of this type of results: [haarsma@knmi.nl](mailto:haarsma@knmi.nl) or [malcom.roberts@metoffice.gov.uk](mailto:malcom.roberts@metoffice.gov.uk)

Haarsma, R.J et al. More hurricanes to hit Western Europe due to global warming  
Geophys. Res. Lett., 2013.

Baatsen, M. et al. Severe Autumn Storms in Future Western Europe with a Warmer Atlantic Ocean. accepted, Clim. Dyn., 2014.