Department of Meteorology

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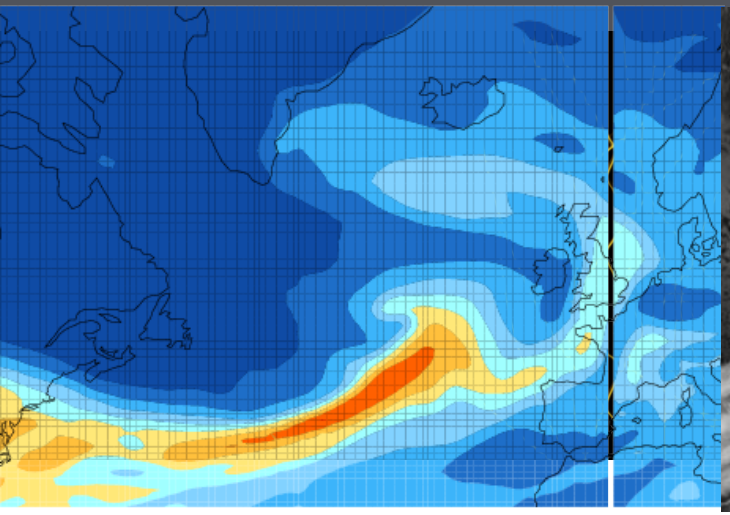
LINKING WARM CONVEYOR BELTS AND ATMOSPHERIC RIVERS



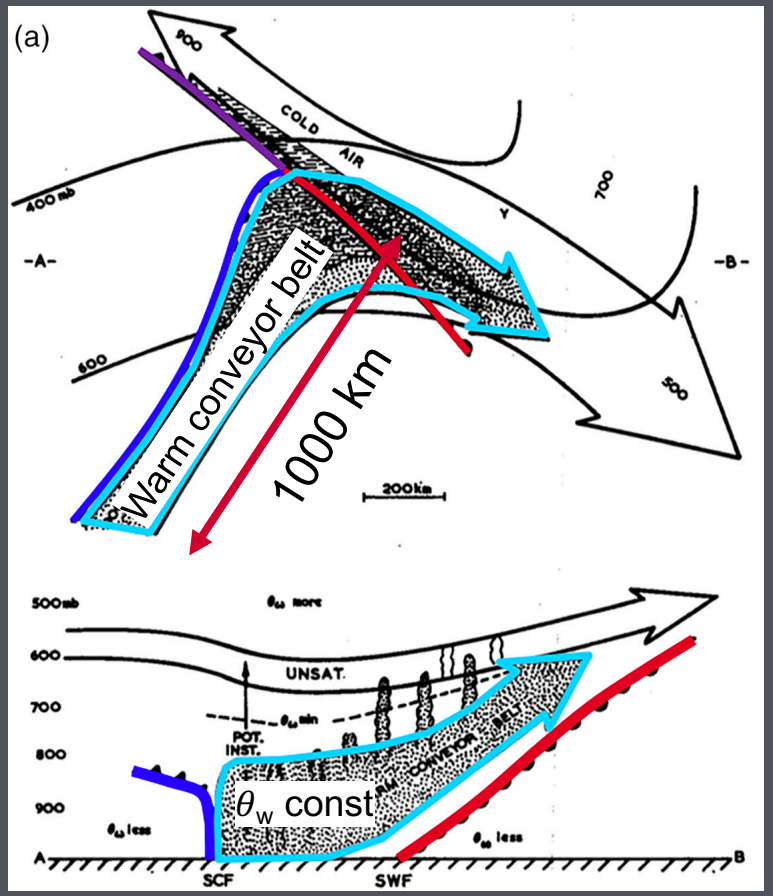
'What's the difference between a warm conveyor belt and an atmospheric river'?

Helen Dacre[1], Oscar Martinez-Alvarado[1], Cheikh Mbengue[2]

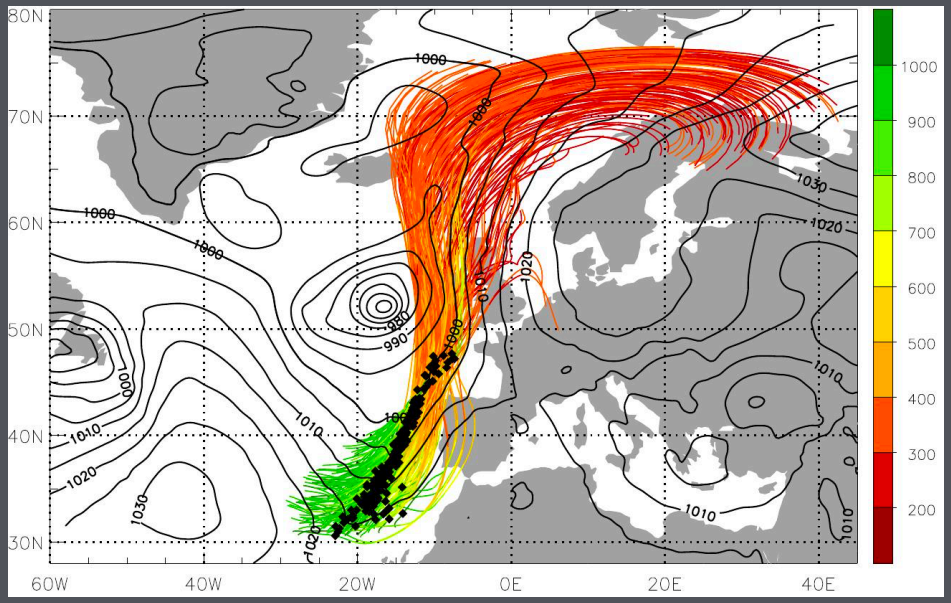
1. University of Reading, 2. University of Oxford

WARM CONVEYOR BELTS

- Cyclone-relative airflows that ascend from within the boundary layer of an extratropical cyclone warm sector to the upper troposphere



Cyclone-relative streamlines on a sloping isentropic surface (Browning, 1971)



Air parcels in the vicinity of cyclones ascending at least 600 hPa within 48 hours (Wernli, 1997)

ATMOSPHERIC RIVERS

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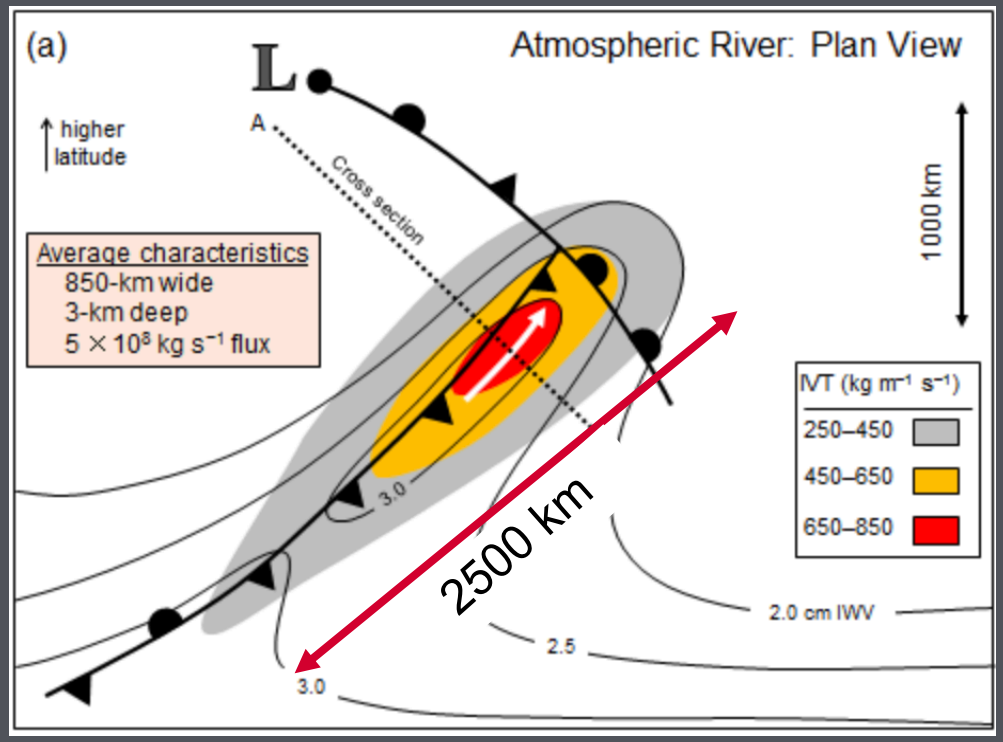
- 2D filaments of strong horizontal water vapour flux typically associated with the low-level jet ahead of the cold front of an extratropical cyclone *(Newell et al. 1992)*

- ARs structure (WMO):
  - shallow (3 km deep)
  - broad (850 km wide)
  - elongated (> 2000 km in length)
  - Threshold water vapour flux (> 250 kg/m/s)



How are warm conveyor belts and atmospheric rivers linked?

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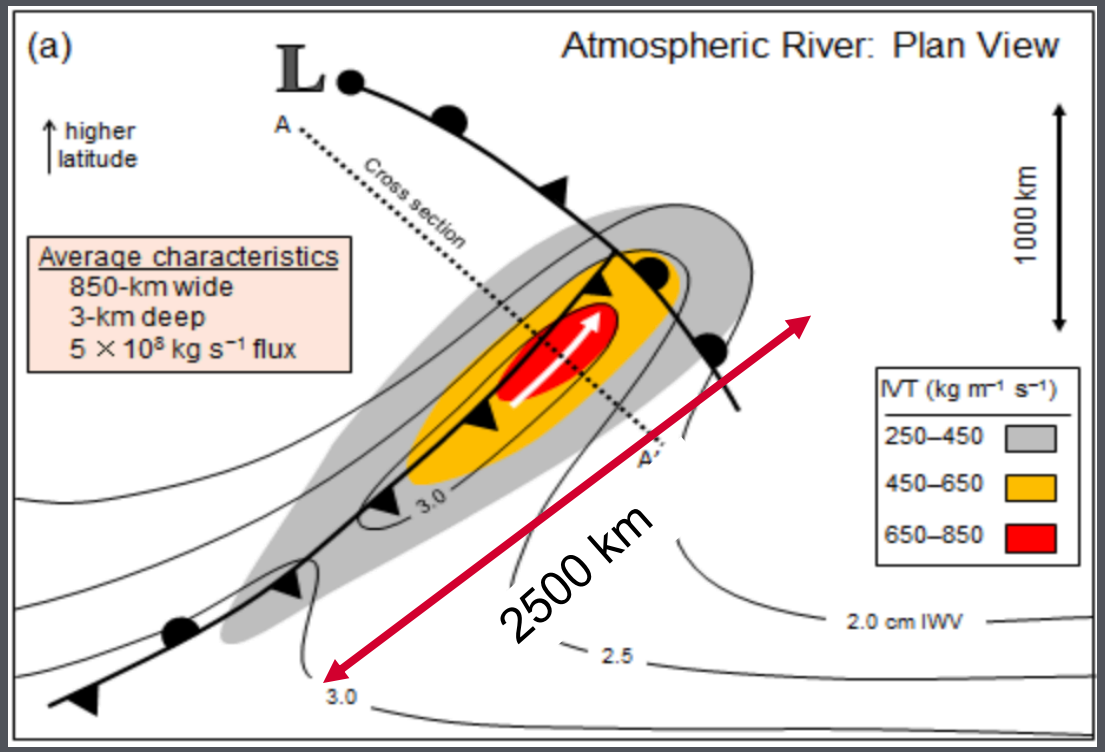
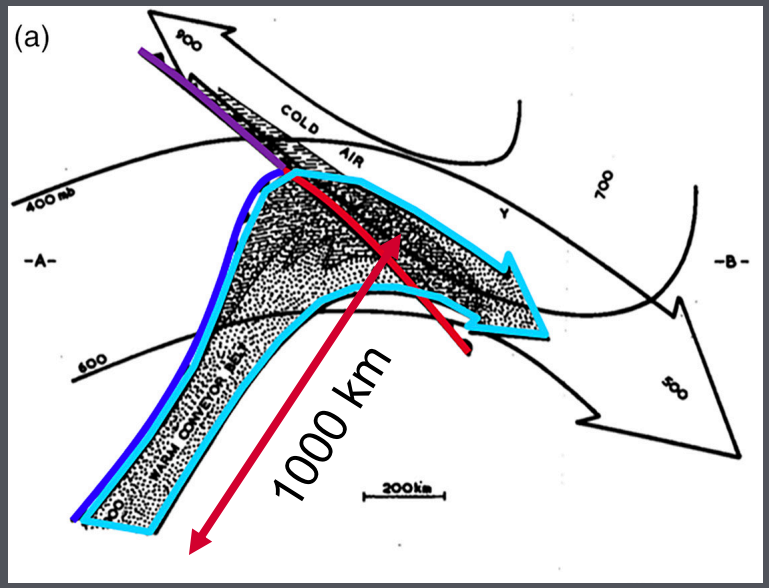
Schematic of an atmospheric river airstream



Schematic of a warm conveyor belt airstream



RESEARCH QUESTION

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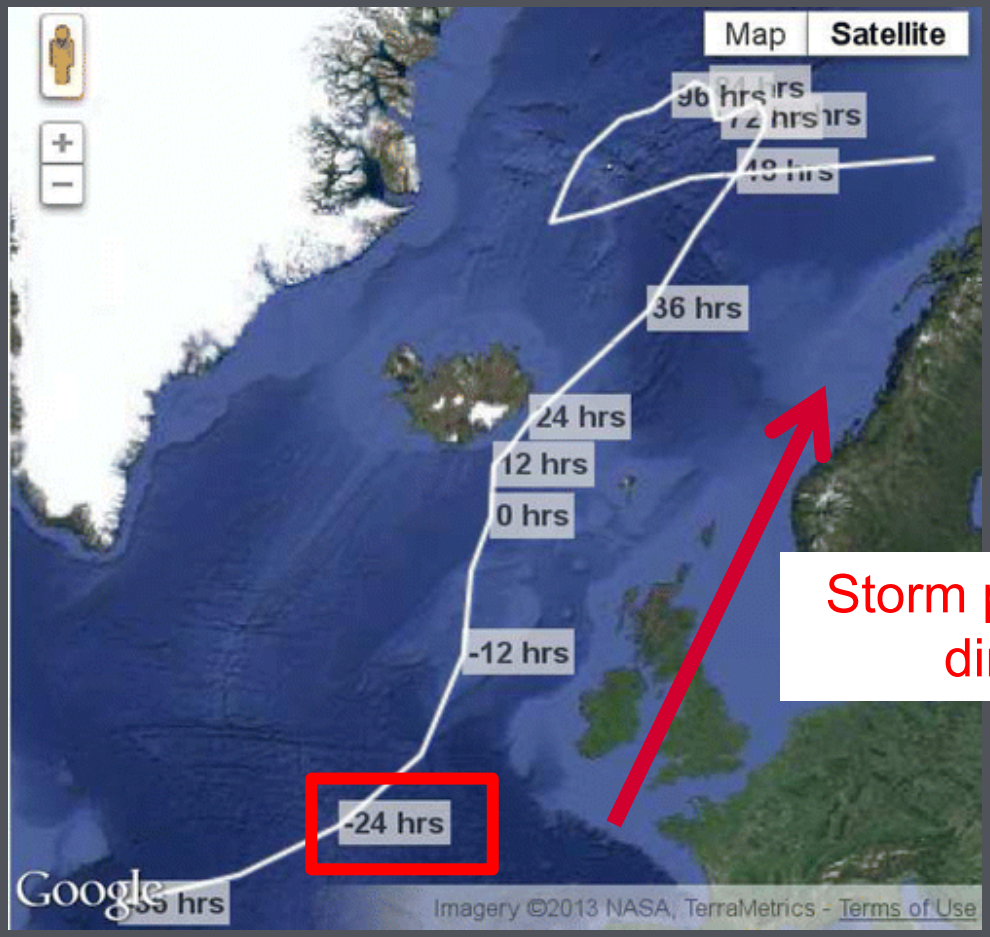
Q. *How are WCBs and atmospheric rivers linked ?*

- Introduction to cyclone airflows – case study
- Composite cyclone structure and airflows – the feeder airstream
- What controls cyclone precipitation and moisture transport?

CASE STUDY: 31 JAN 2002

Track of storm and position relative to maximum intensity



Dacre et al. (2015), BAMS

BAND OF HIGH TCWV EXTENDING FROM SUBTROPICS TO THE UK

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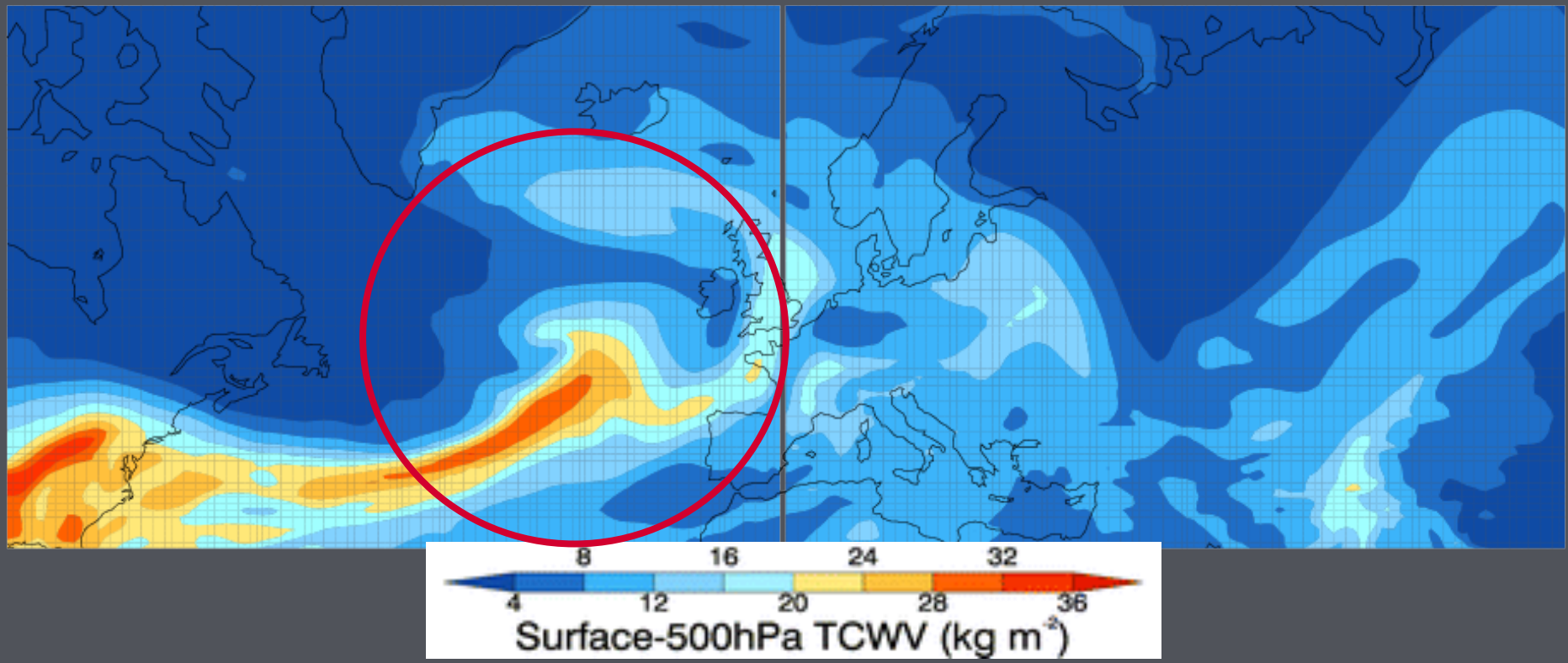
ERA-Interim Total Column Water Vapour (TCWV)
18UTC 31 Jan 2002



HIGH TCWV FOUND AHEAD OF COLD FRONT IN THE WARM SECTOR

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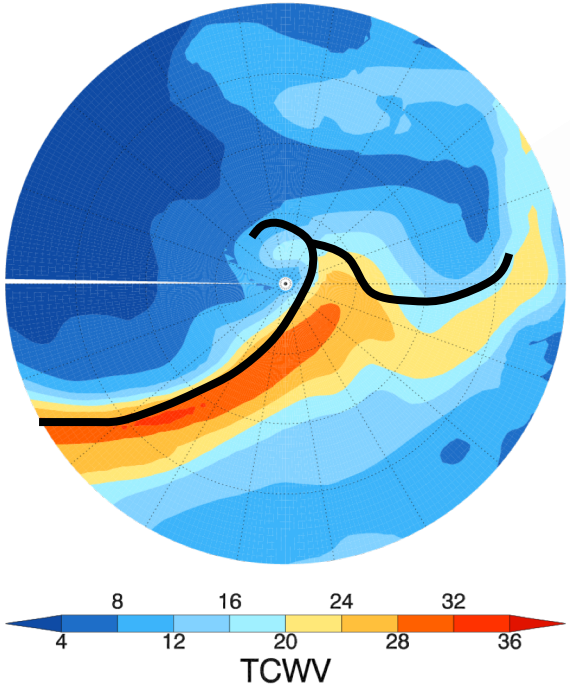
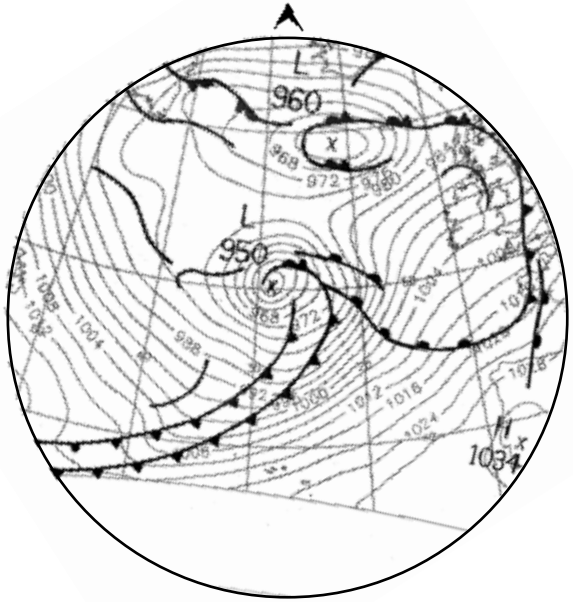
Total column water vapour



Synoptic analysis



IR satellite

www.met.rdg.ac.uk/~storms

Dacre et al. (2012), BAMS

ATMOSPHERIC RIVER ASSOCIATED WITH CYCLONE

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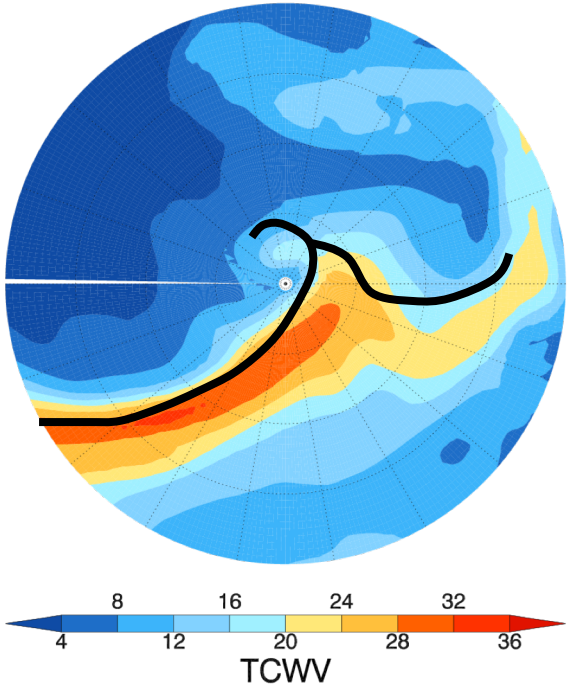
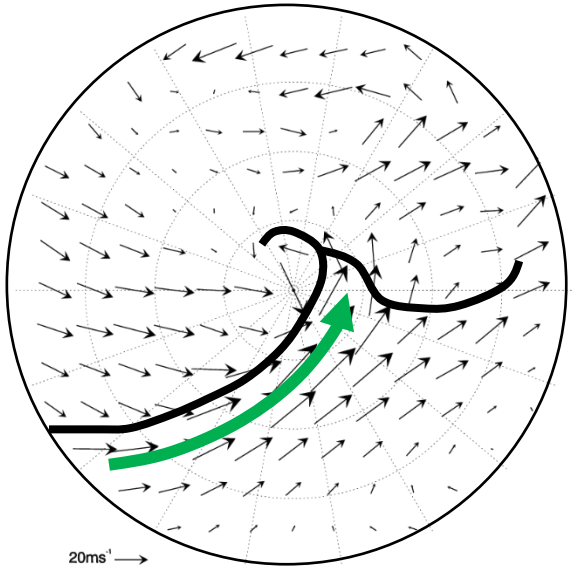
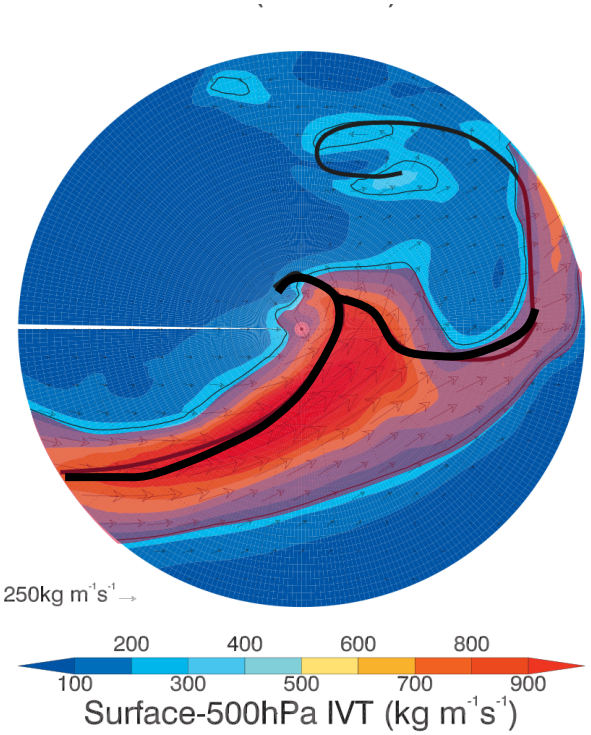
Total column water vapour



925hPa earth-relative wind





Dacre et al. (2015), BAMS

- ERA-Interim TCWV and 925hPa winds
- Atmospheric river (IVT > 250 kg/m/s) associated with cyclone

CYCLONE AIRFLOWS AT 925HPA

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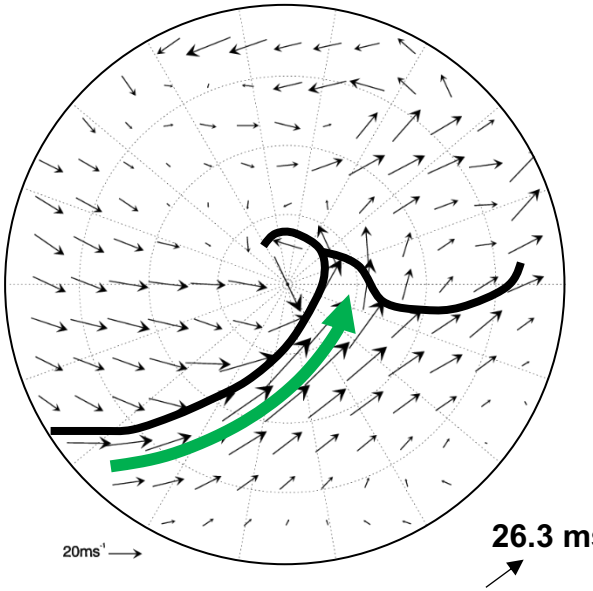
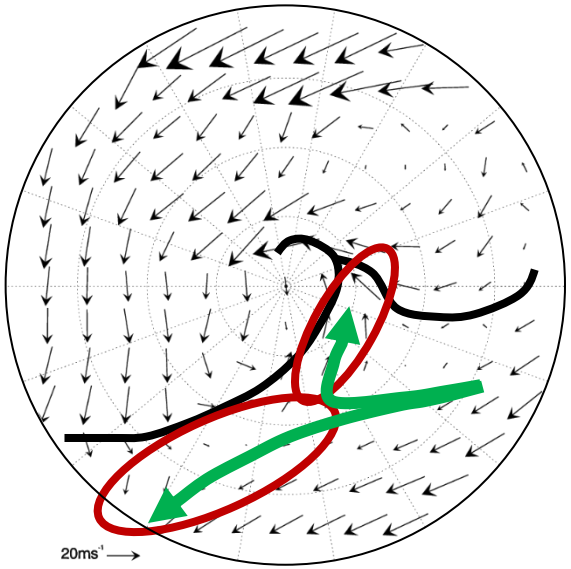
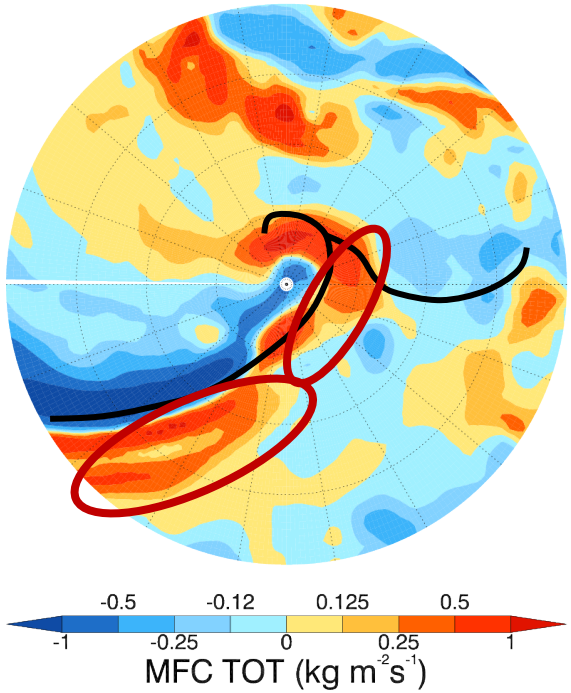
925hPa Earth-relative winds

925hPa cyclone-relative winds

Total moisture flux convergence







- Cyclone airflow within warm sector is towards the cold front
- Cold front sweeps up water vapour leading to accumulation
- Moisture exported from cyclone leaving a footprint of TCWV

CYCLONE TRACKS IN THE NORTH ATLANTIC VARY IN ORIENTATION

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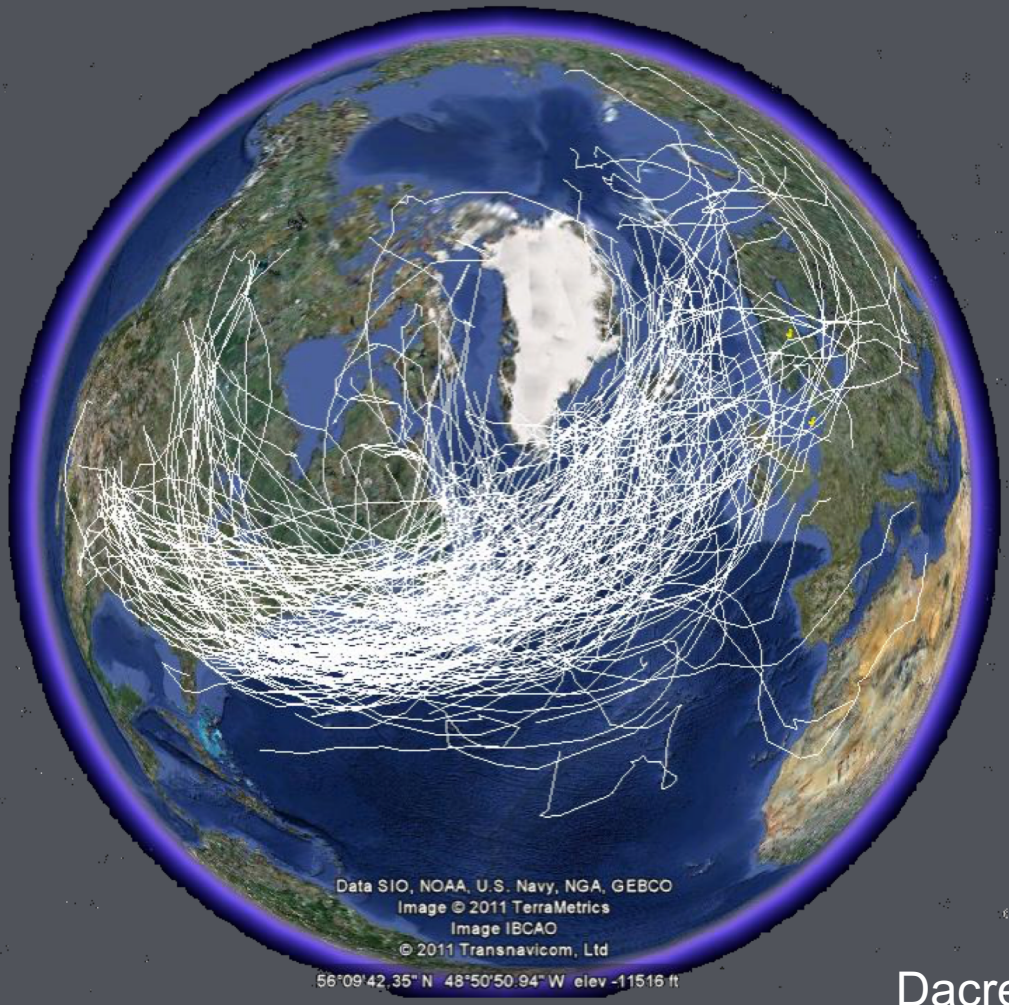
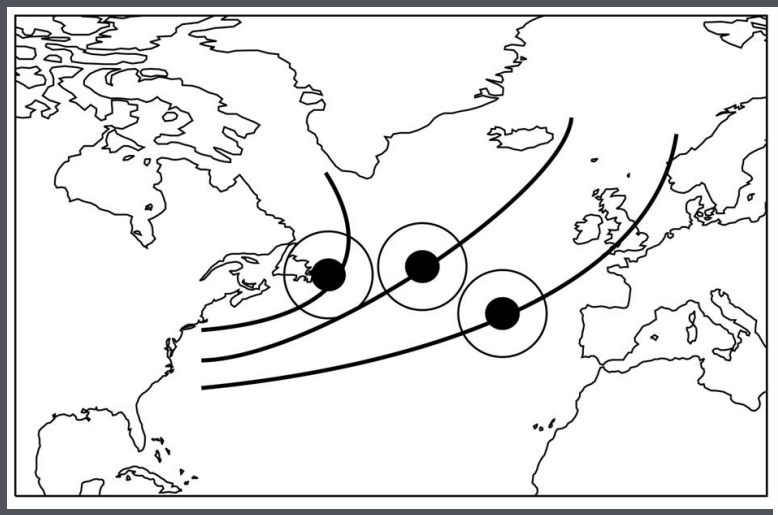
Tracks of 200 intense cyclones in 1990-2008 DJF

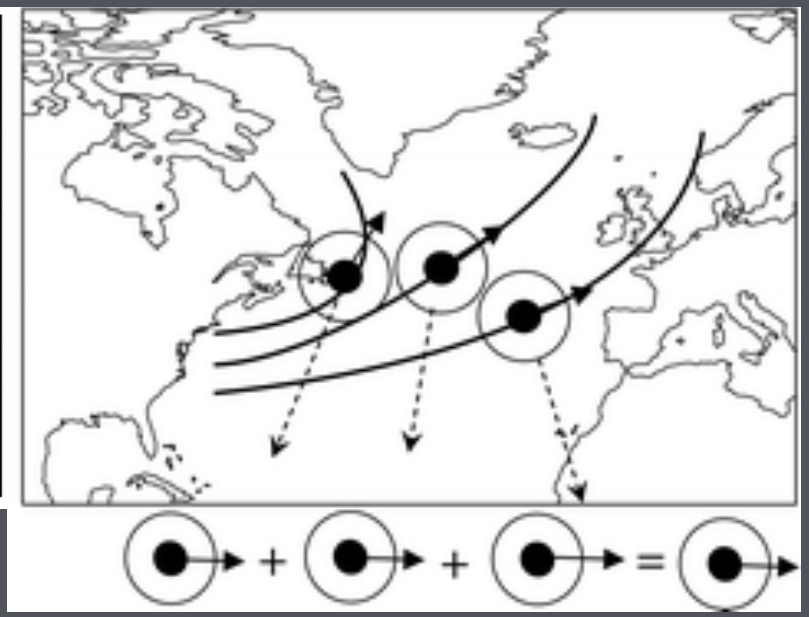


Dacre et al. (2012), BAMS

CYCLONE COMPOSITING IS USED TO EXAMINE CYCLONE CHARACTERISTICS



Catto et al. (2010)



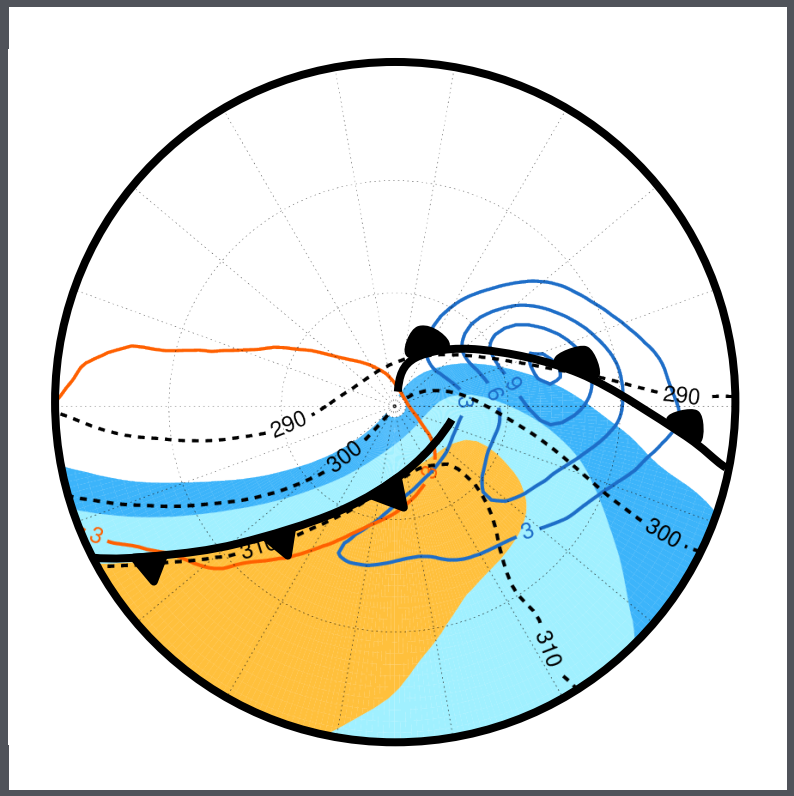
1. Extract fields from ERA-I along cyclone tracks within 1500km radius surrounding the identified cyclone position
2. Rotate cyclone centred fields so direction of travel is left to right
3. Composite 200 most intense cyclones at times relative to max intensity

A BAND OF HIGH TCWV IS LOCATED AHEAD OF THE COLD FRONT

Composite cyclone-centred fields 24 hours prior to time of maximum intensity

3000km

Cyclone propagation



TCWV (filled contours, kg m^{-2}), 6-hr Precipitation (blue, mm), 6-hr Evaporation (orange, mm), 925 hPa θ_e (black dashed)

3D CYCLONE RELATIVE AIRFLOWS ARE IDENTIFIED ON ISENTROPIC SURFACES

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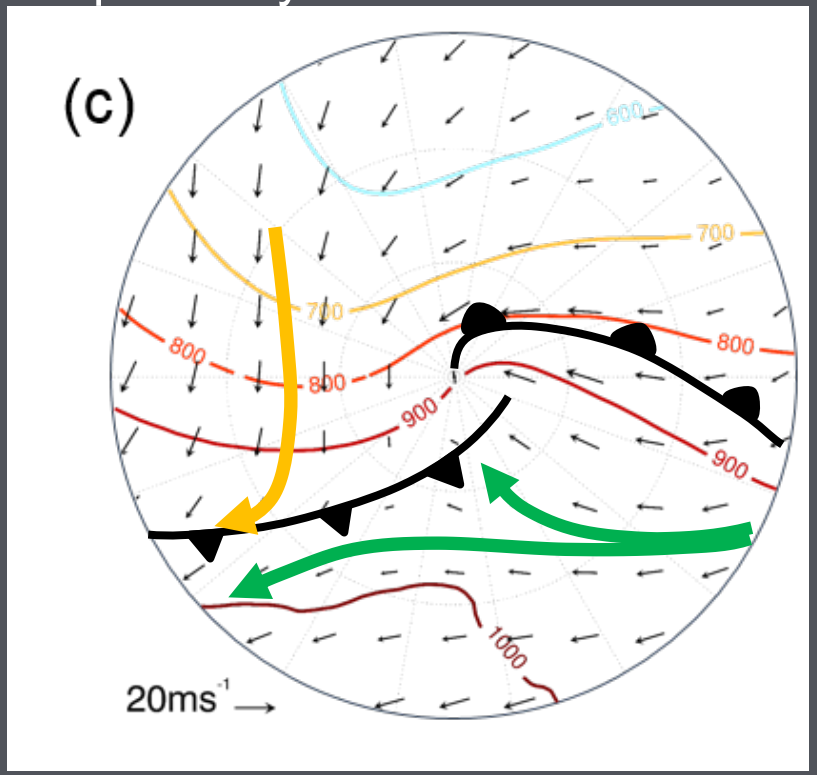
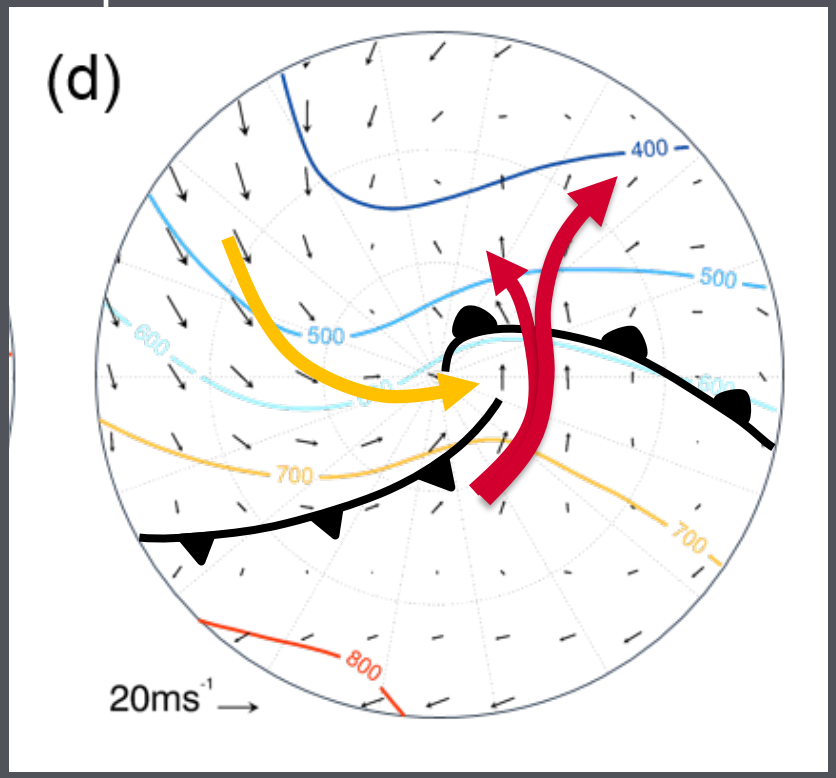
Composite cyclone-centred fields 24 hours prior to time of maximum intensity



Pressure in hPa (contours) and cyclone-relative winds on 285 K θ surface



Pressure in hPa (contours) and cyclone-relative winds on 300 K θ surface

Dacre et al. (2019), JHM

THE FEEDER AIRSTREAM TRANSPORTS AIR TOWARDS THE COLD FRONT

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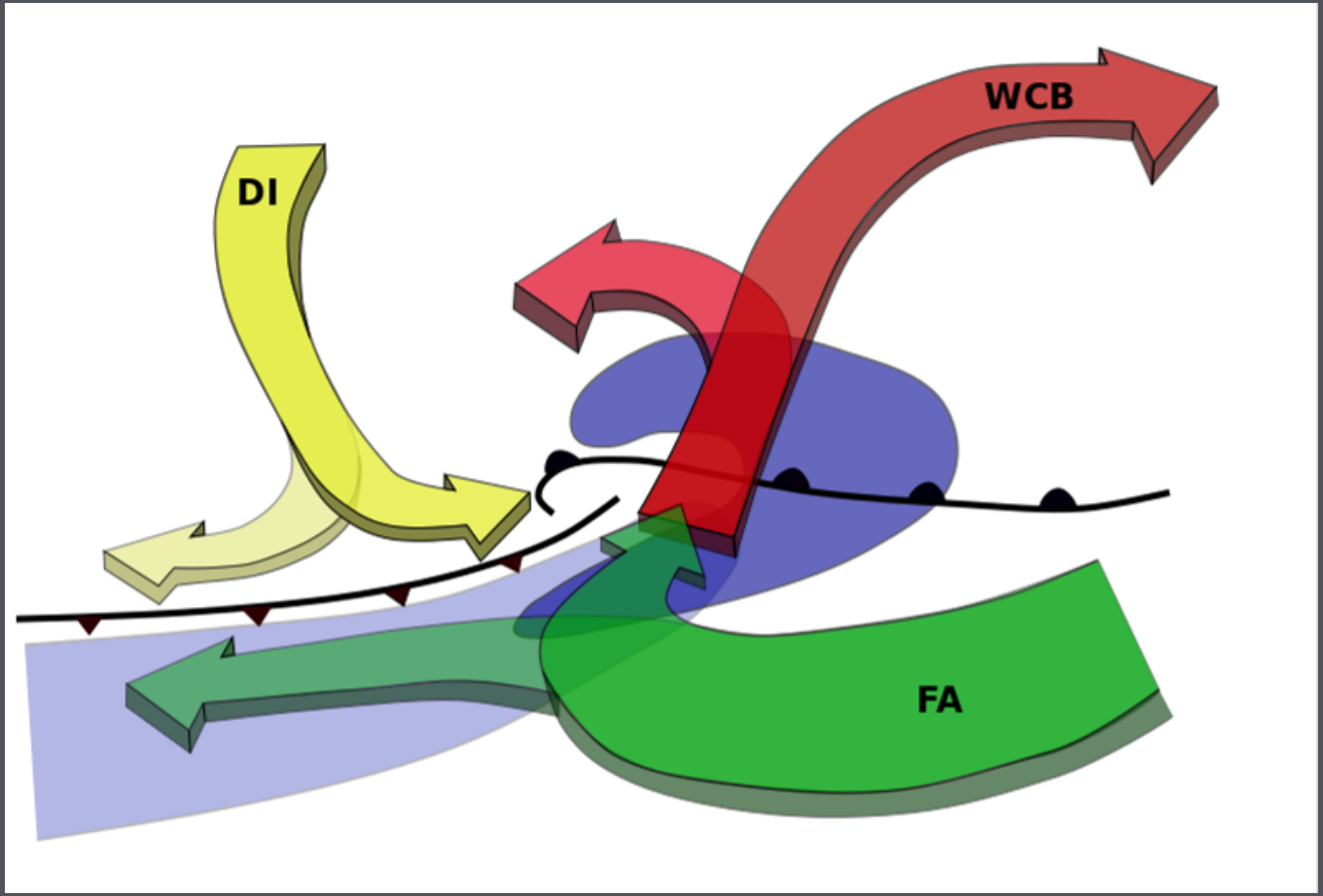
Schematic of cyclone-relative airflows overlaid on surface features



Dacre et al. (2019), JHM

Precipitation (dark blue), high TCWV (light blue), Warm conveyor belt (red),
Dry intrusion (yellow), Feeder airstream (green)

BETWEEN PRECIPITATION AND TCWV 24HRS EARLIER

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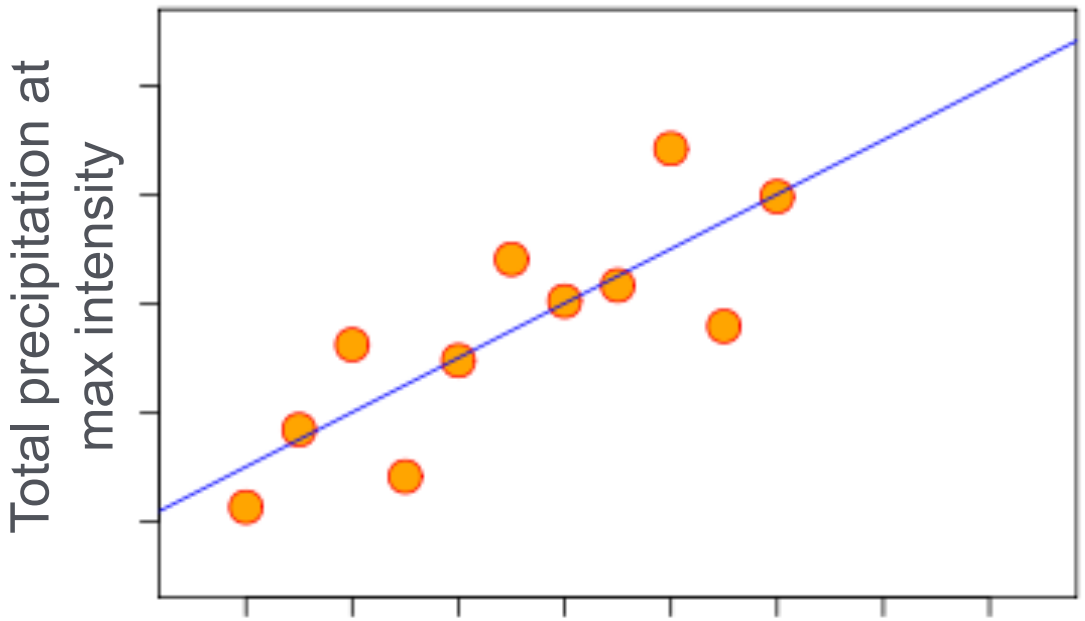
$$\frac{\partial(TP)_{T+0}}{\partial(TCWV_{i,j})_{T-24}} \times \sigma_{TCWV_{i,j}} = S_{i,j}$$



Dacre and Gray (2013), GRL

CYCLONE PRECIPITATION IS RELATED TO DOWNSTREAM TCWV 24HRS EARLIER

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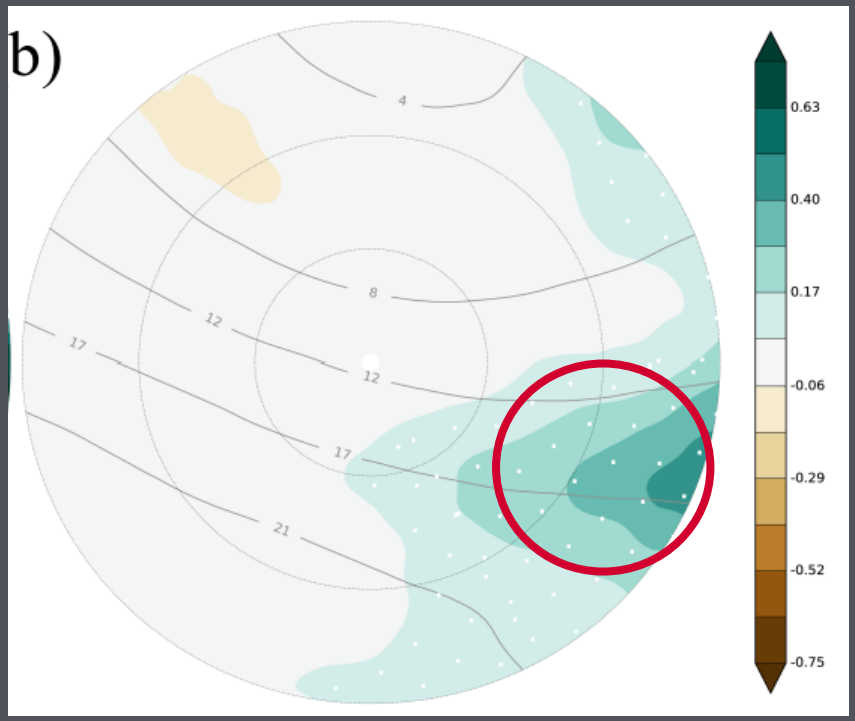
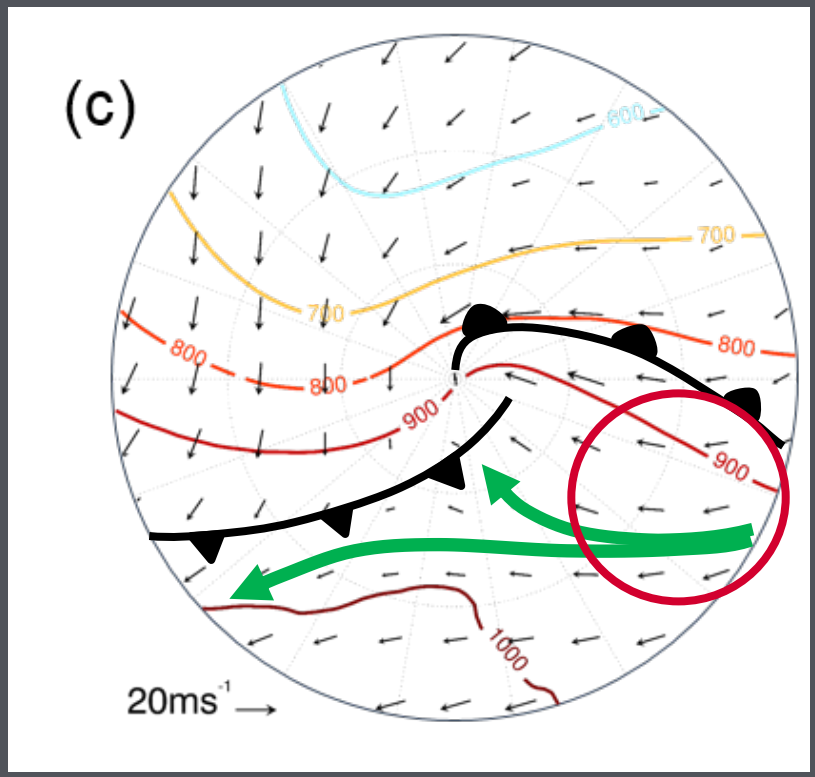
Lagged linear regression between precipitation and TCWV 24 hours earlier



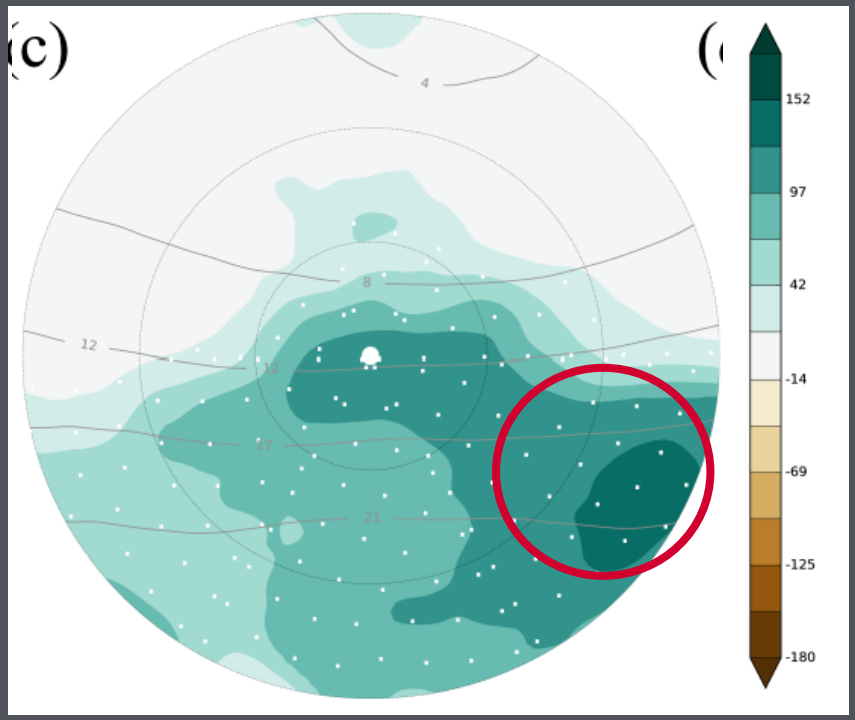
Composite 10-day filtered TCWV at T-24 (contours) and sensitivity of precipitation (kg m^{-2}) at max intensity to TCWV 24 hrs earlier



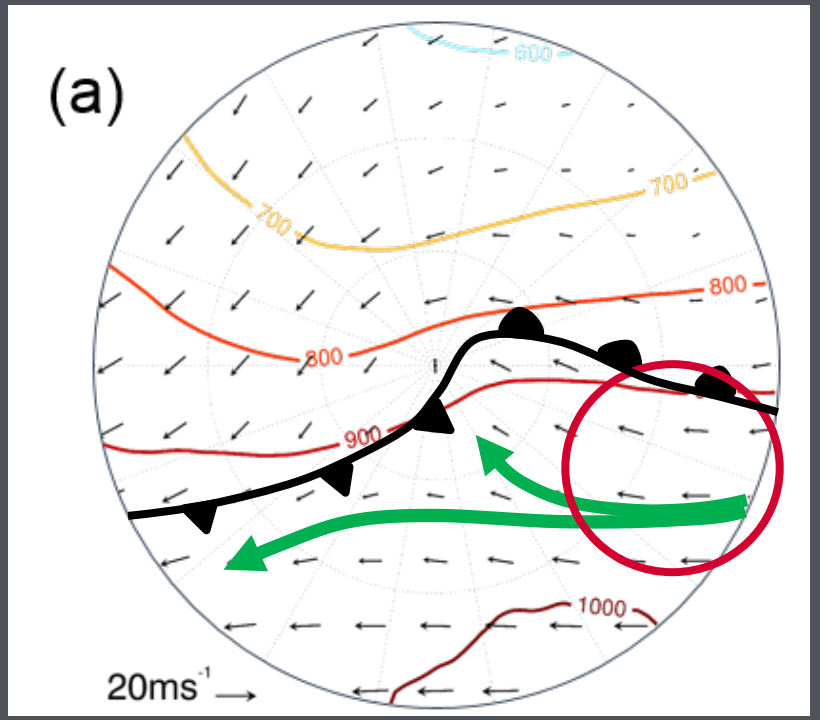
Pressure in hPa (contours) and cyclone-relative winds (vectors) on 285 K θ surface at T-24

CYCLONE IVT IS RELATED TO DOWNSTREAM TCWV 24HRS EARLIER

Lagged linear regression between integrated vapour transport (IVT) and TCWV 24 hours earlier

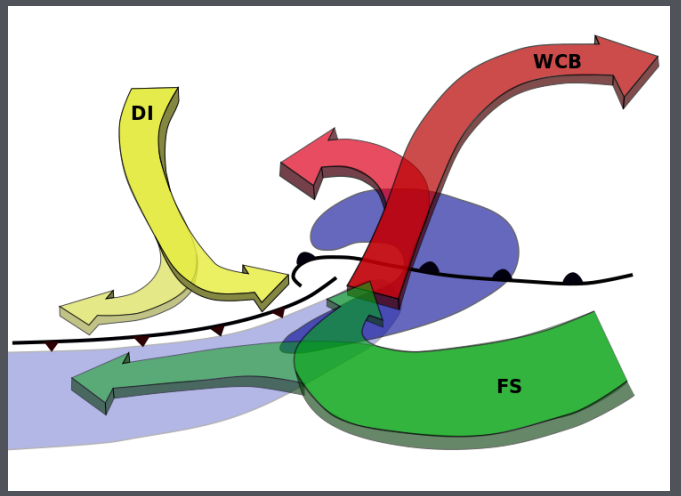


Composite 10-day filtered TCWV at T-48 (contours) and sensitivity of IVT (kg m^{-1} s^{-1}) at T-24 to TCWV 24 hours earlier



Pressure in hPa (contours) and cyclone-relative winds (vectors) on 285 K θ surface at T-48

SUMMARY



Q. What's the difference between a WCB and an atmospheric river?

- WCB is a cyclone-relative airflow and atmospheric river is an Earth-relative airflow

Q. How are atmospheric rivers formed?

- Cyclone sweeps up water vapour in the atmosphere causing a band of high TCWV to form ahead of the cold front

Q. How are WCBs and atmospheric rivers related?

- They are linked via a common source of moisture at the entrance to the feeder airstream
- Feeder airstream transports moisture to the base of the WCB where it then ascends leading to precipitation
- Feeder airstream exports moisture from the cyclone creating a long quasi-stationary filament of high IVT (tail of atmospheric river)

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References and

EXTRA SLIDES

REFERENCES

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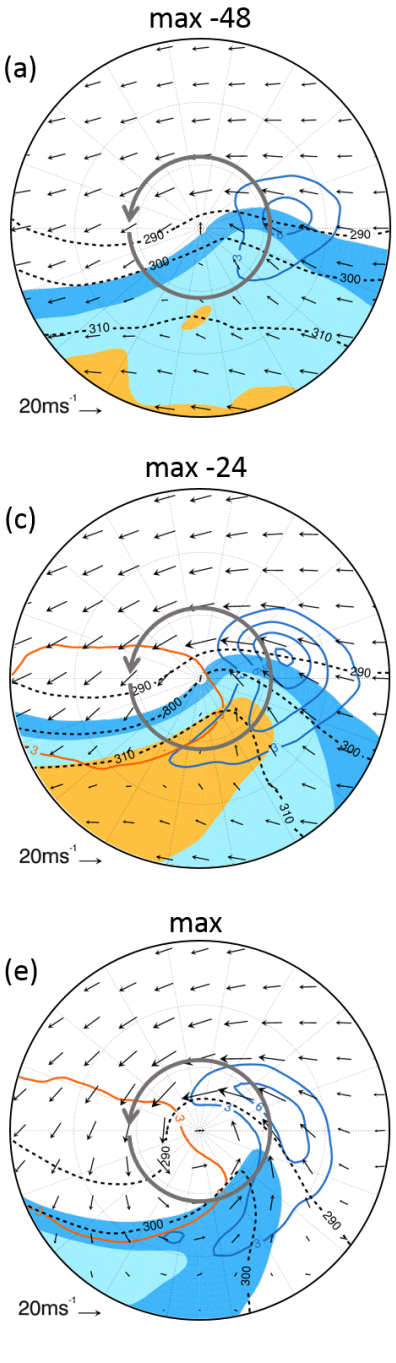
- Dacre, H.F., Martinez-Alvarado, O. and Mbengue, C.O., 2019. Linking atmospheric rivers and warm conveyor belt airflows. *Journal of Hydrometeorology*, *20*(6), pp.1183-1196
- Dacre, H.F., Clark, P.A., Martinez-Alvarado, O., Stringer, M.A. and Lavers, D.A., 2015. How do atmospheric rivers form?. *Bulletin of the American Meteorological Society*, *96*(8), pp.1243-1255.
- Dacre, H.F. and Gray, S.L., 2013. Quantifying the climatological relationship between extratropical cyclone intensity and atmospheric precursors. *Geophysical Research Letters*, *40*(10), pp.2322-2327.
- Dacre, H.F., Hawcroft, M.K., Stringer, M.A. and Hodges, K.I., 2012. An extratropical cyclone atlas: A tool for illustrating cyclone structure and evolution characteristics. *Bulletin of the American Meteorological Society*, *93*(10), pp.1497-1502.


max -48
(a)
20ms-1
(b)
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400hPa
500hPa
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700hPa
800hPa
900hPa
Pressure (hPa)
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Angle (degrees)
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400hPa
500hPa
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800hPa
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Pressure (hPa)
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Angle (degrees)
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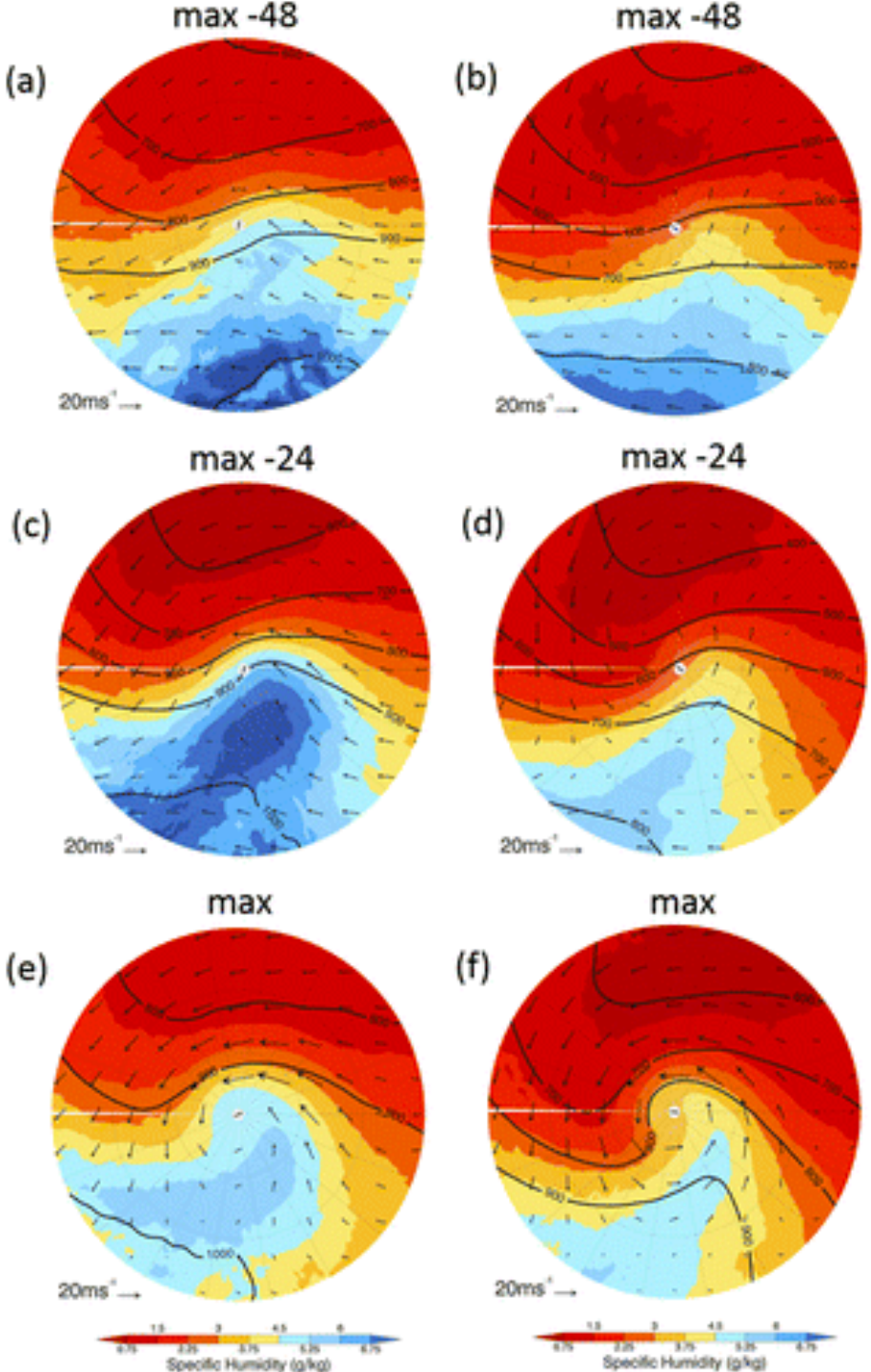
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20ms⁻¹
Specific Humidity (g/kg)
Specific Humidity (g/kg)