A case study of intense moisture transport and precipitation over the East Antarctic ice sheet and Southern Ocean

Annick Terpstra[1] & Irina Gorodetskaya[1]

[1] Centre for Environment and Marine studies (CESAM), University of Aveiro, Portugal

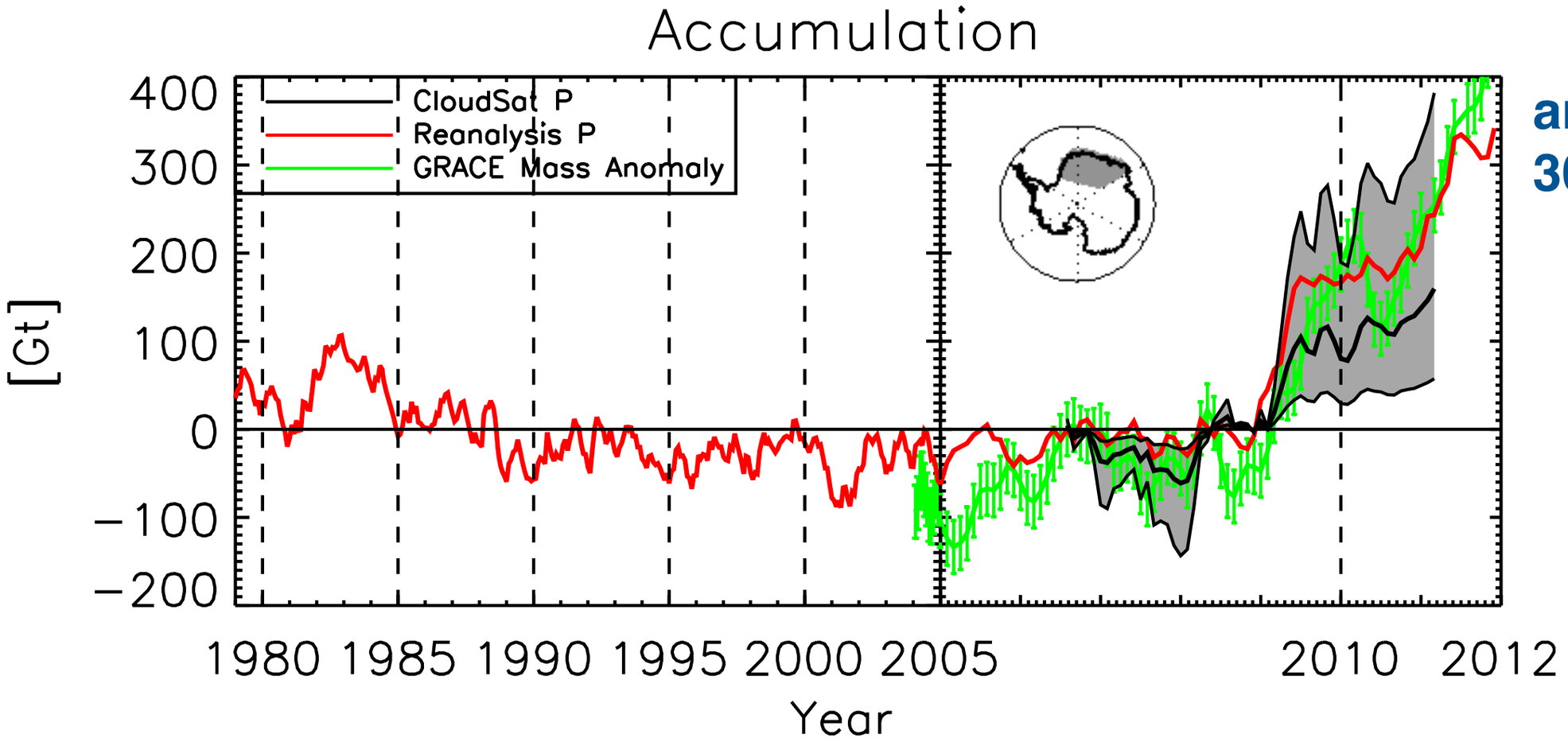
cesam
universidade de aveiro
centro de estudos do ambiente
e do mar

12th Workshop on Antarctic Meteorology and Climate

26-28 June 2017, Boulder, Colorado

Motivation: Accumulation

A few strong snowfall events over Dronning Maud Land (DML) in 2009 and 2011 have been responsible for an anomalously high mass load over the East Antarctica counterbalancing the negative total mass trend over the Antarctic ice sheet (Boening et al. 2012, King et al. 2012).



Boening et al. 2012

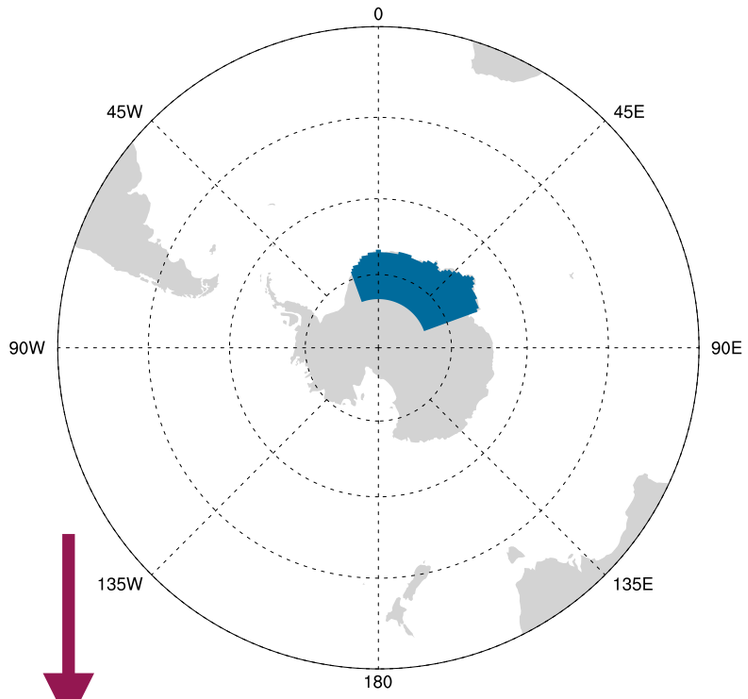
area (DML): 30W&60E; 65S-80S

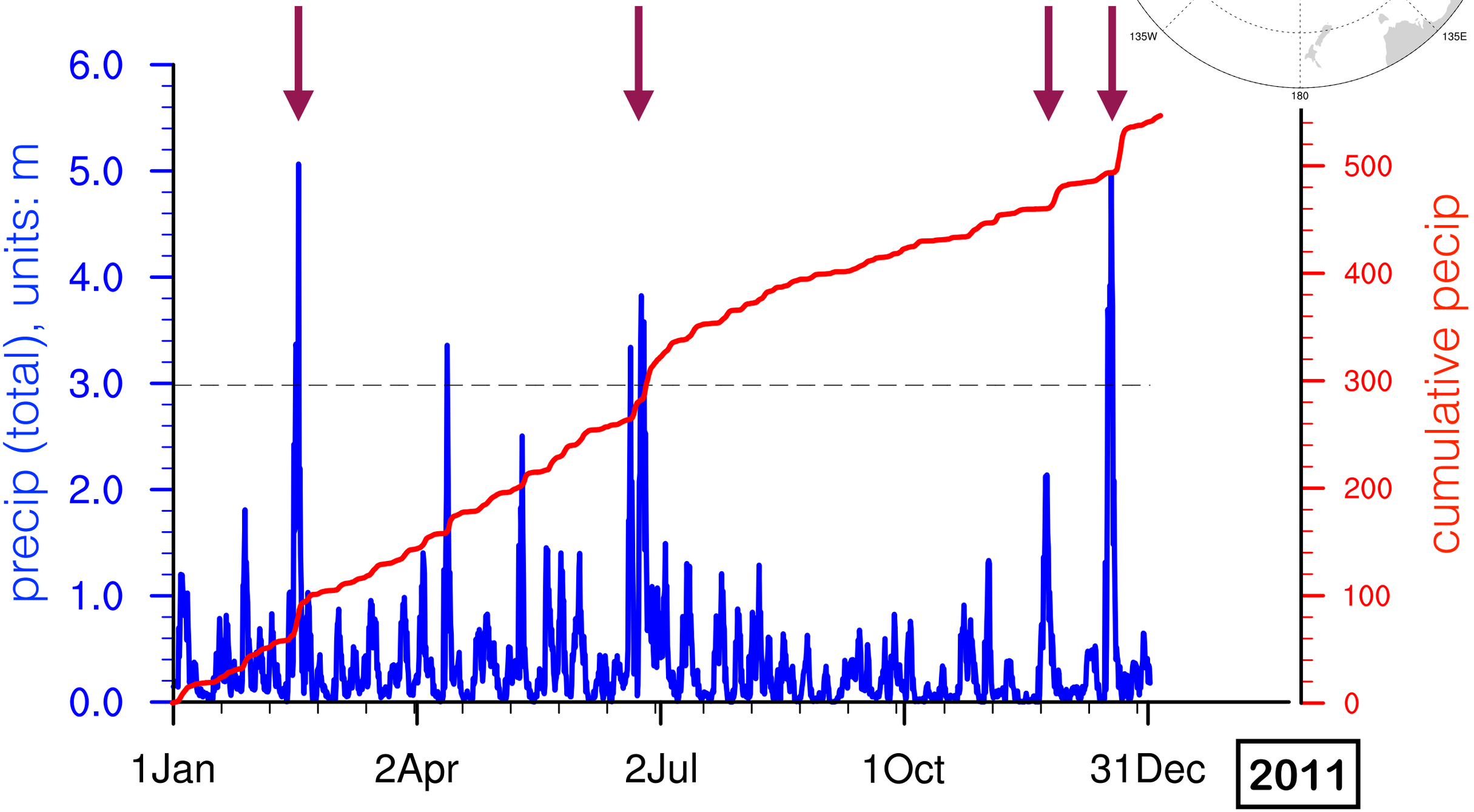
GRACE Mass Anomaly
ERA-I integrated net precip
CloudSat precip

critical to understand underlying dynamical pathways, including moisture transport & sources

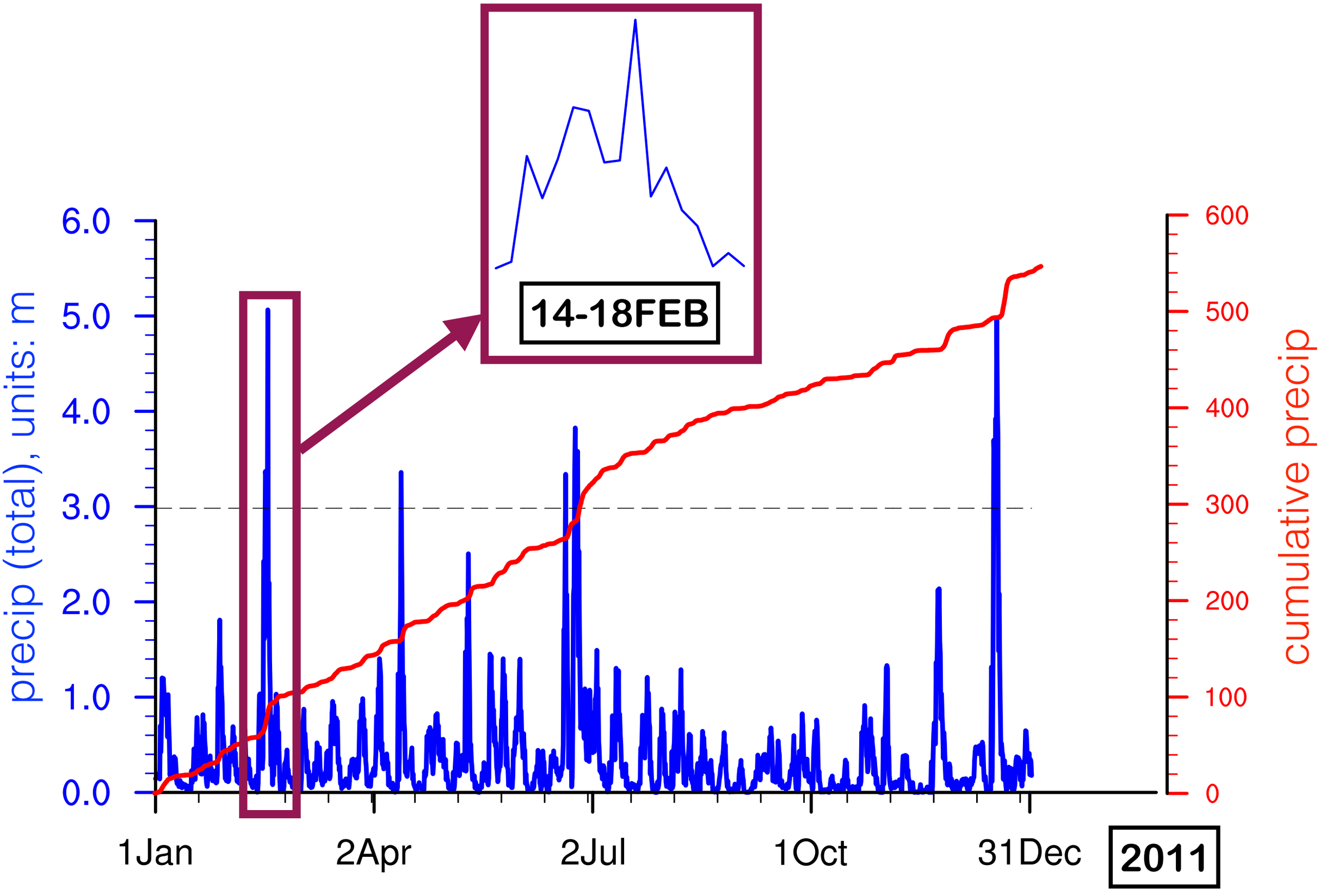
Dronning Maud Land (East Antarctica)

total ice-sheet accumulation:
~80% during episodic events associated with ARs
(Gorodetskaya et.al.2014)





Dronning Maud Land (East Antarctica)



Case study moisture transport

“Atmospheric river”

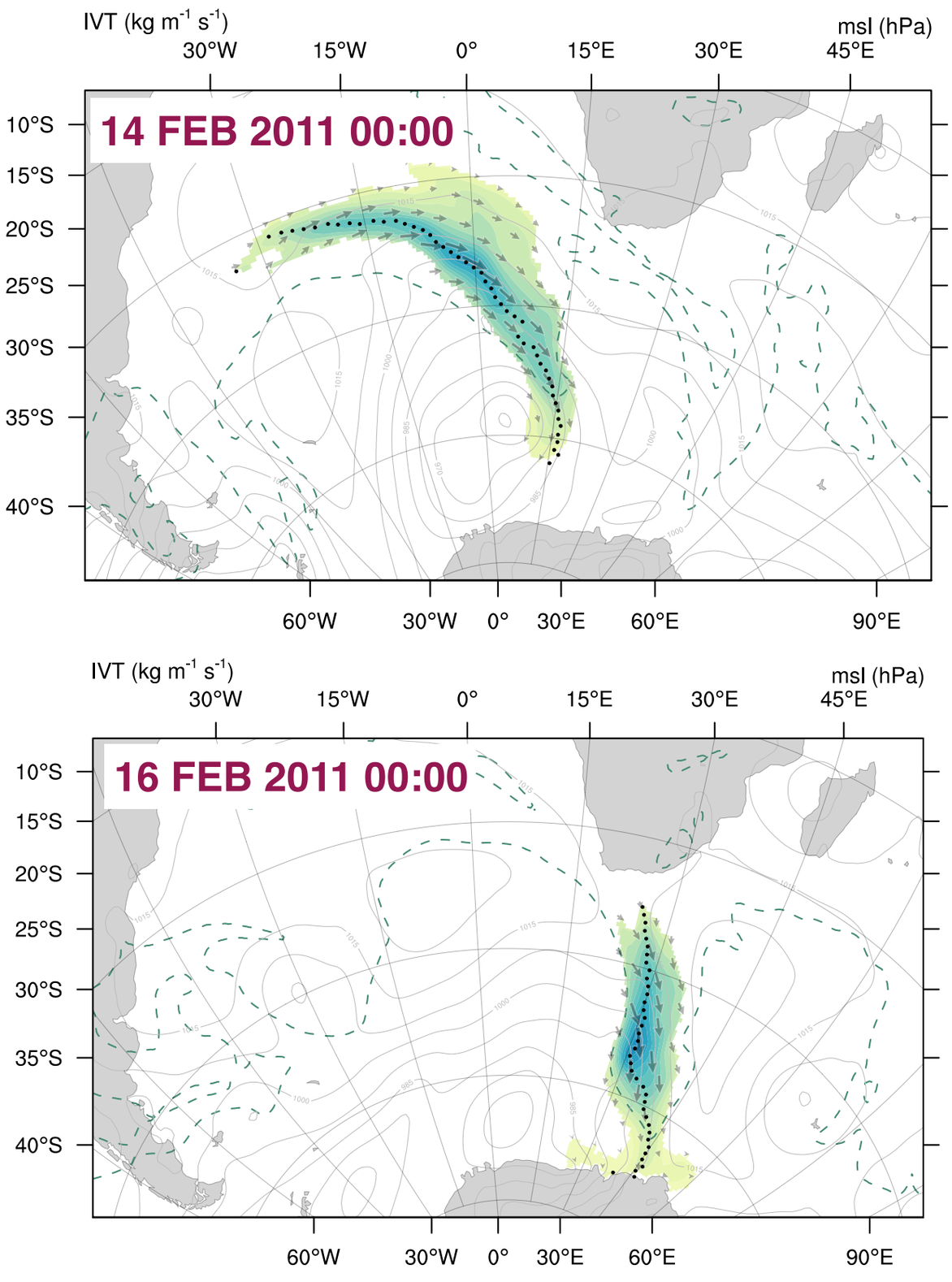
Zhu&Newell (1998): “… the majority of the middle-latitude moisture flux occurs in the filamentary features, the rivers, …”

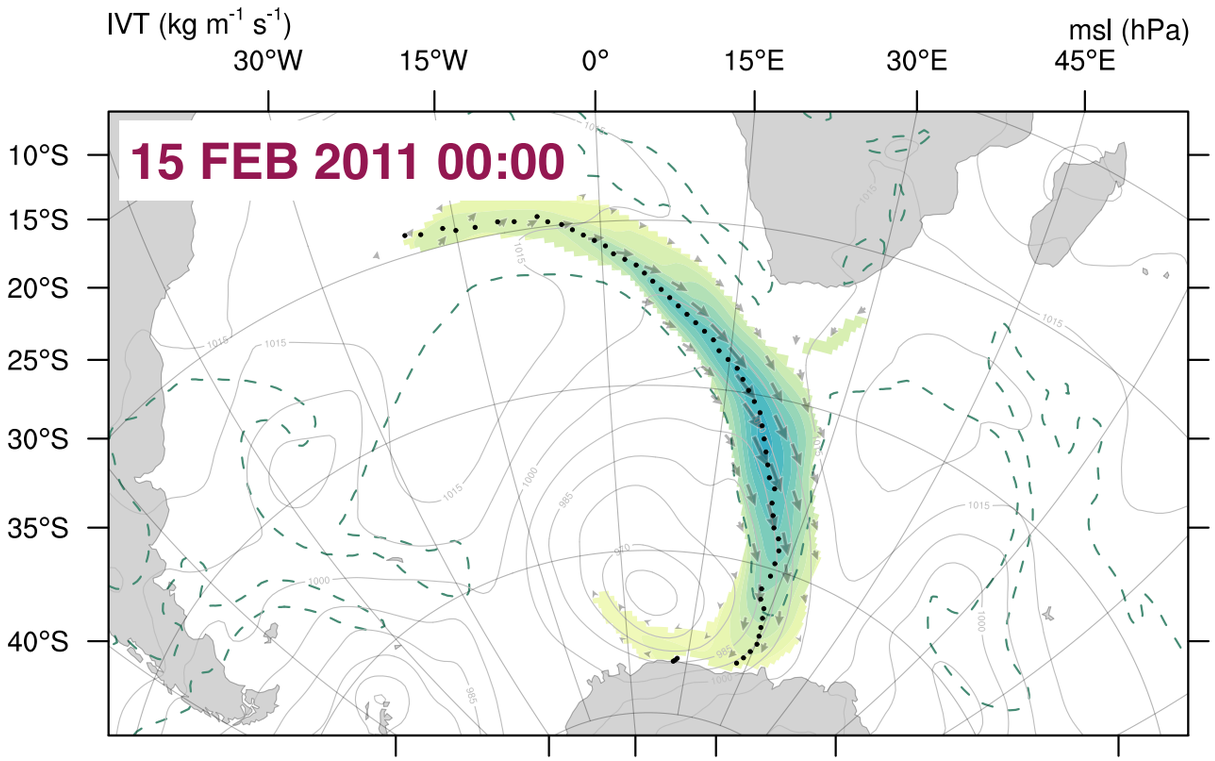
$$IVT = \frac{1}{g}\int_{p_{sfc}}^{p_{top}} q\vec{v}_h dp$$

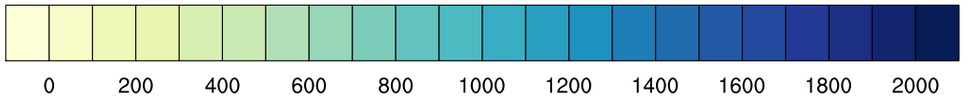
Detection (following Guan&Waliser,2015):

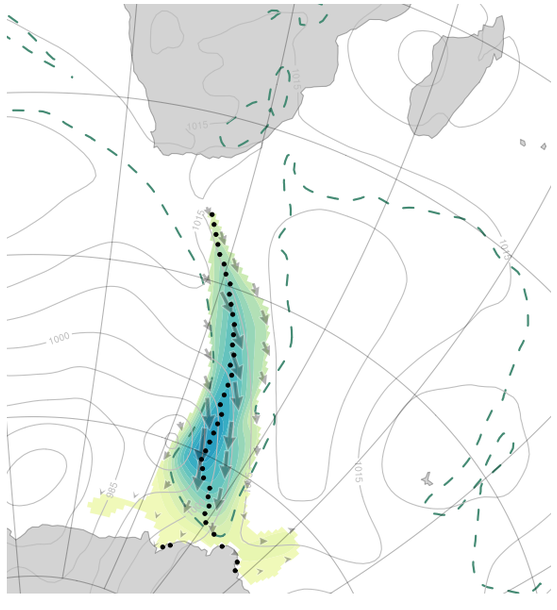
- IVT > 85th percentile of monthly mean IVT
- IVT > 100 kg m^{-1} s^{-1}
- exclude land areas

Case study anomalous moisture transport

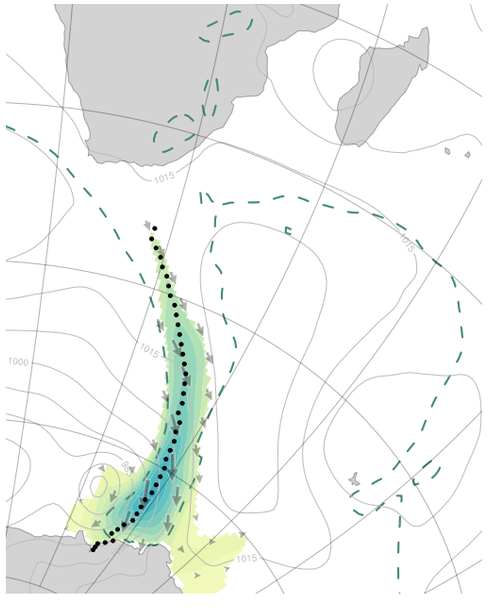








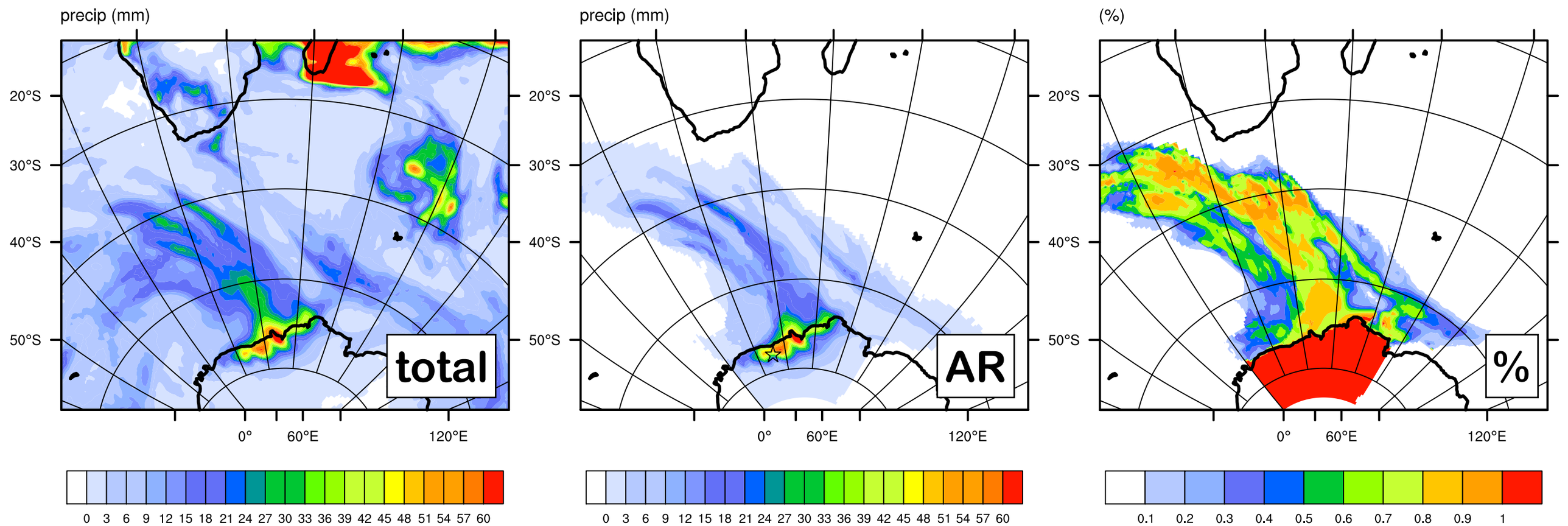
16 FEB 2011 06:00



16 FEB 2011 12:00

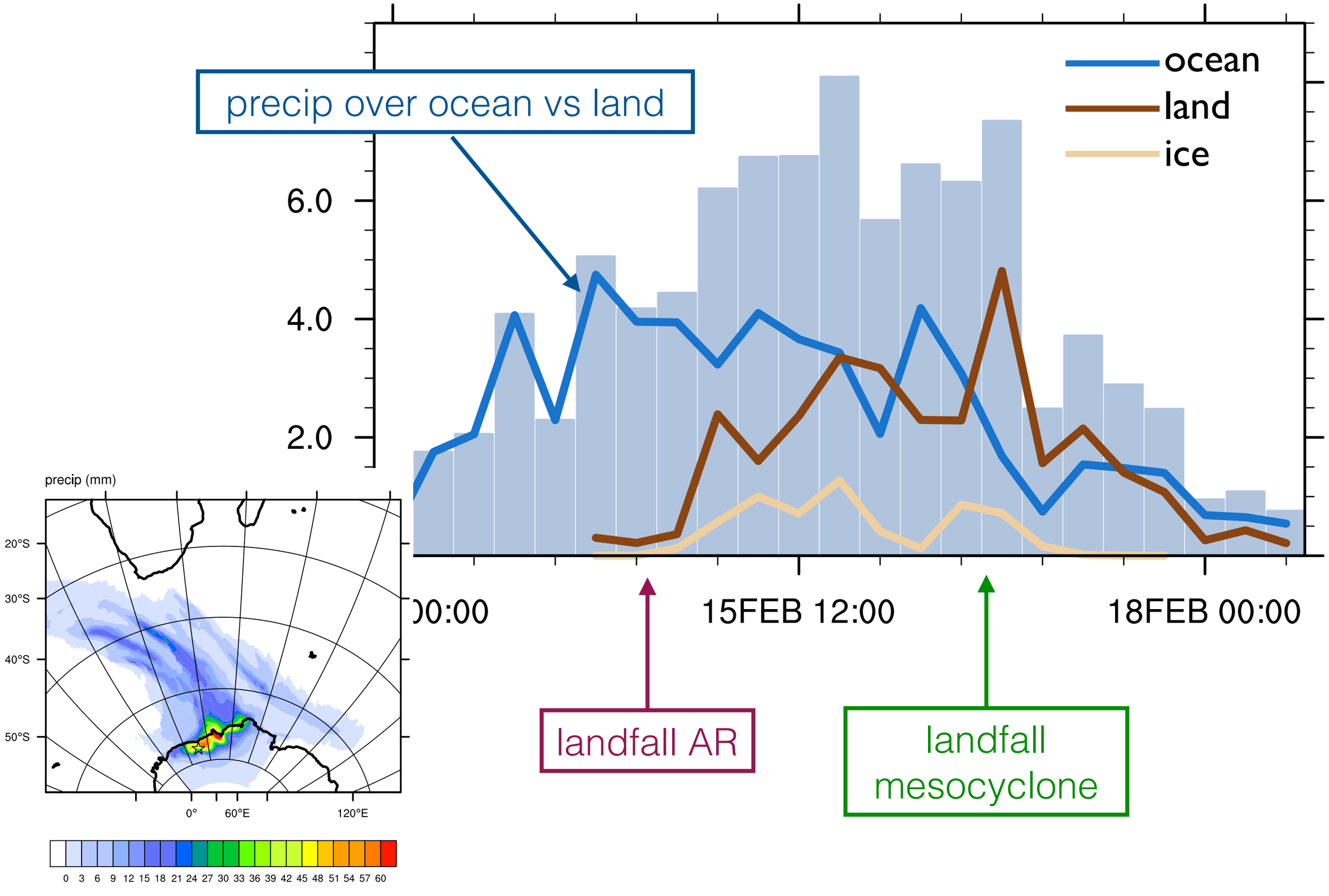
Case study precip associated with AR-event

14-18FEB



max. ~ 75 mm (AR accumulated)

Case study precip associated with AR-event



Case study

PART I

AR is associated with snowfall/
ice-sheet accumulation

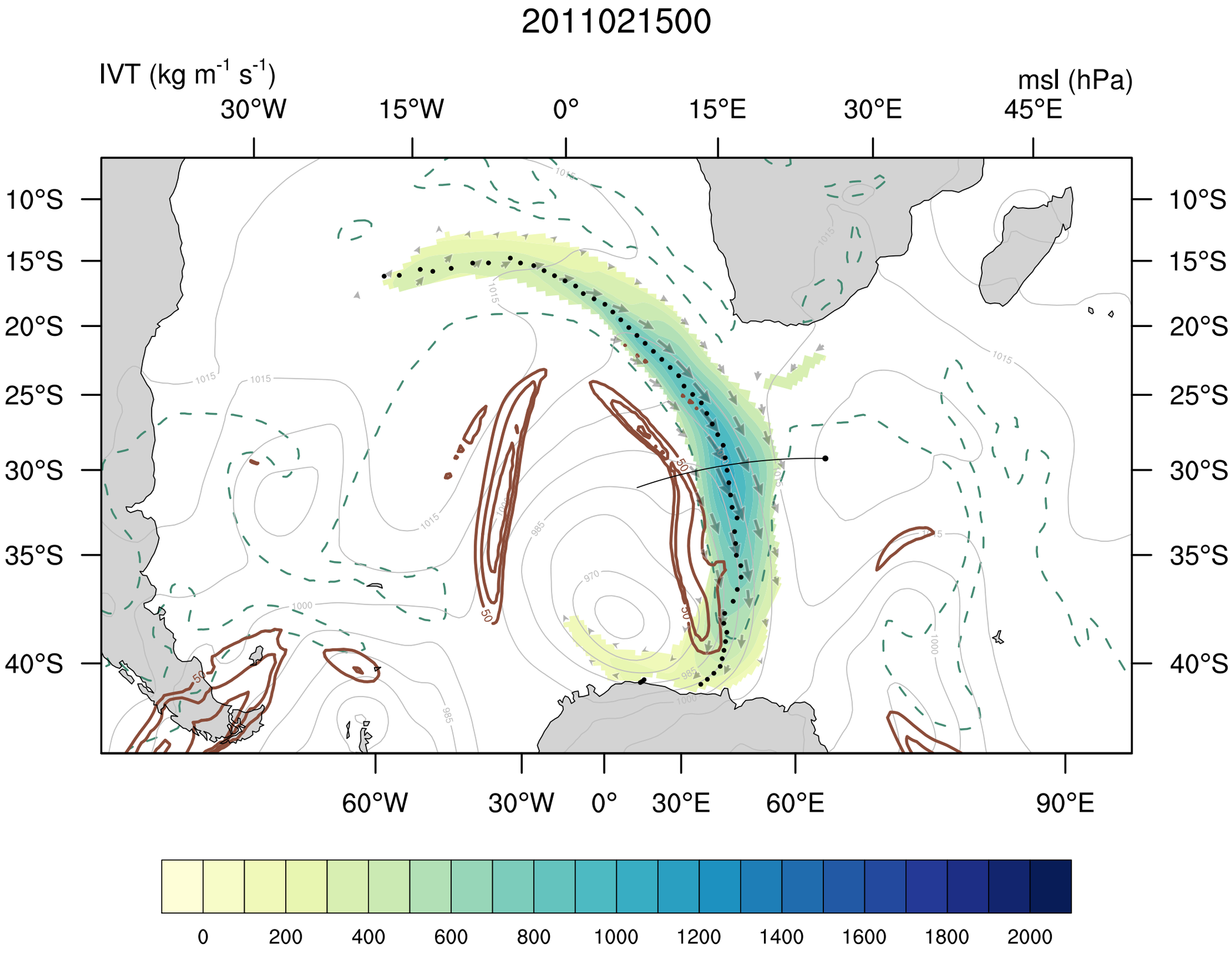
PART II

1. What is the moisture source?

- local evaporation?
- local convergence?
- long-range transport?

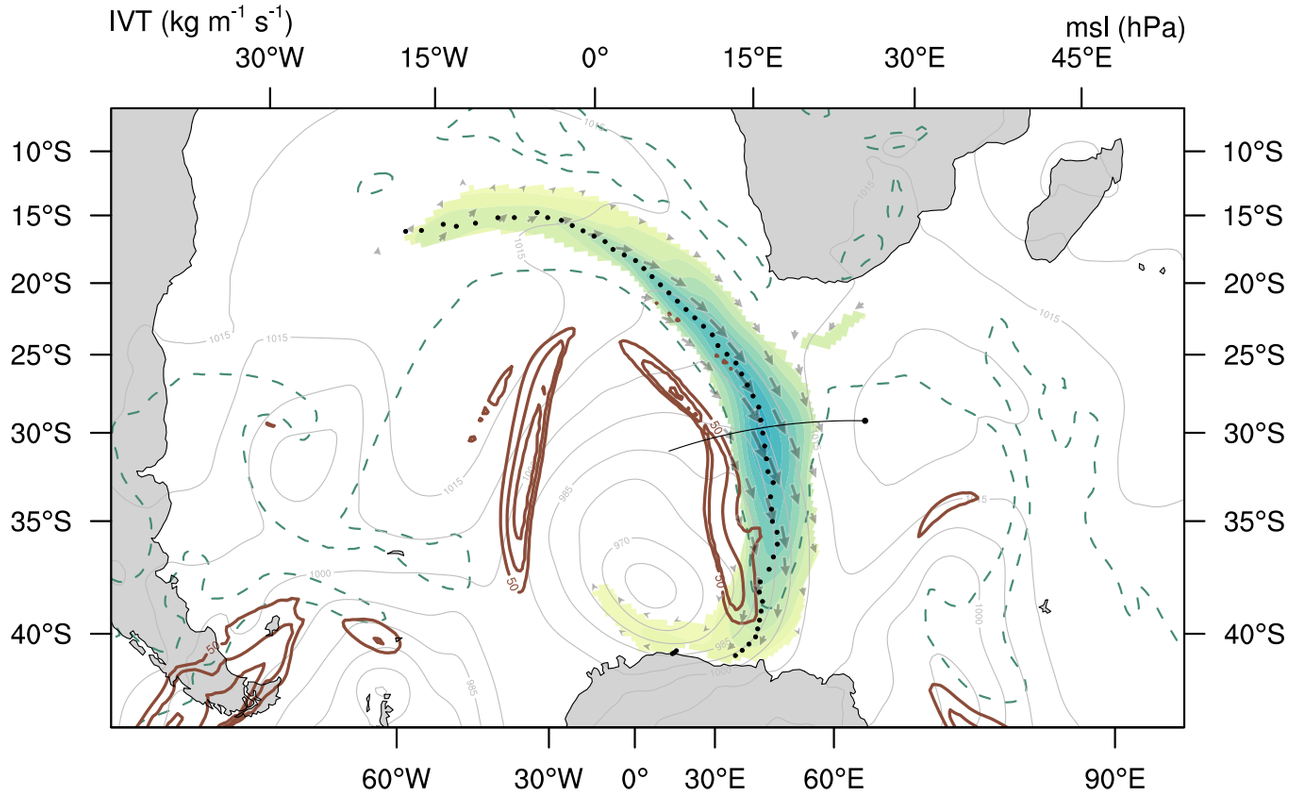
2. What is this AR-thing?

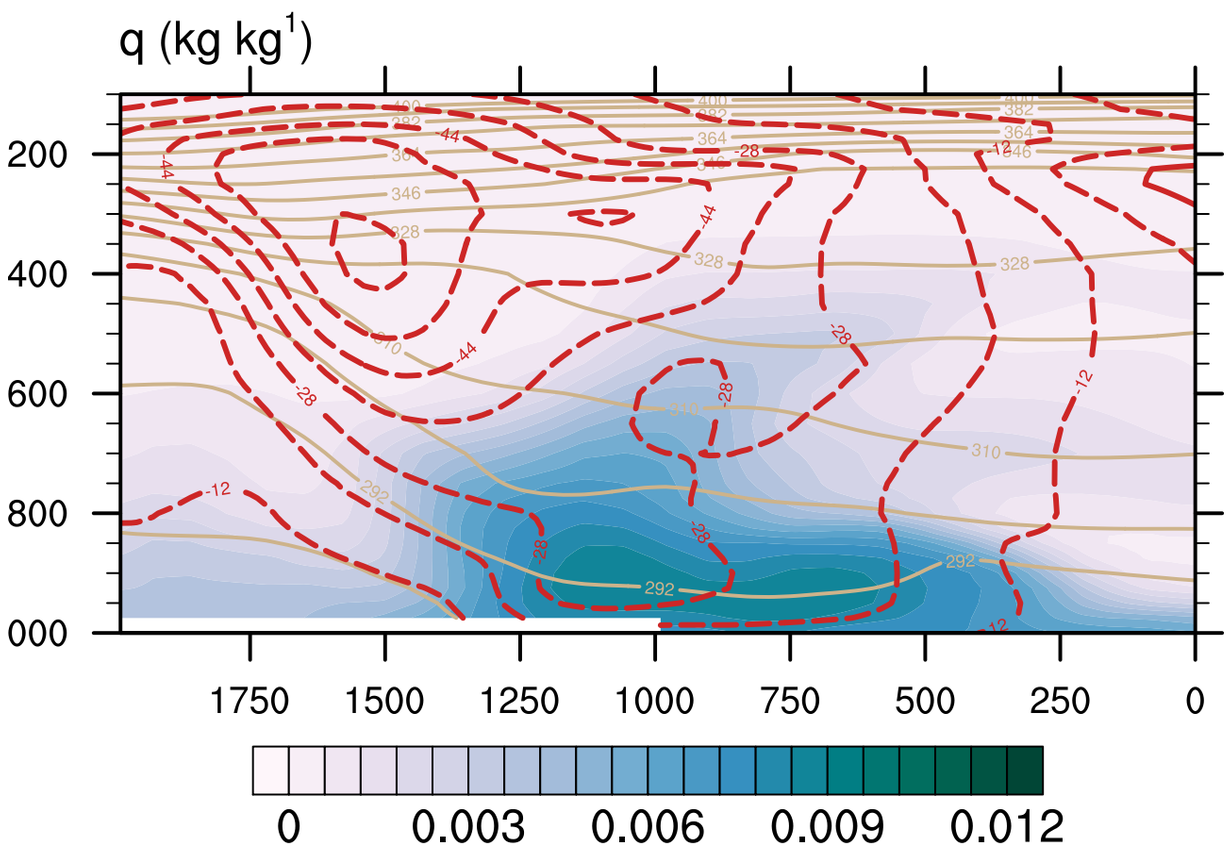
Case study

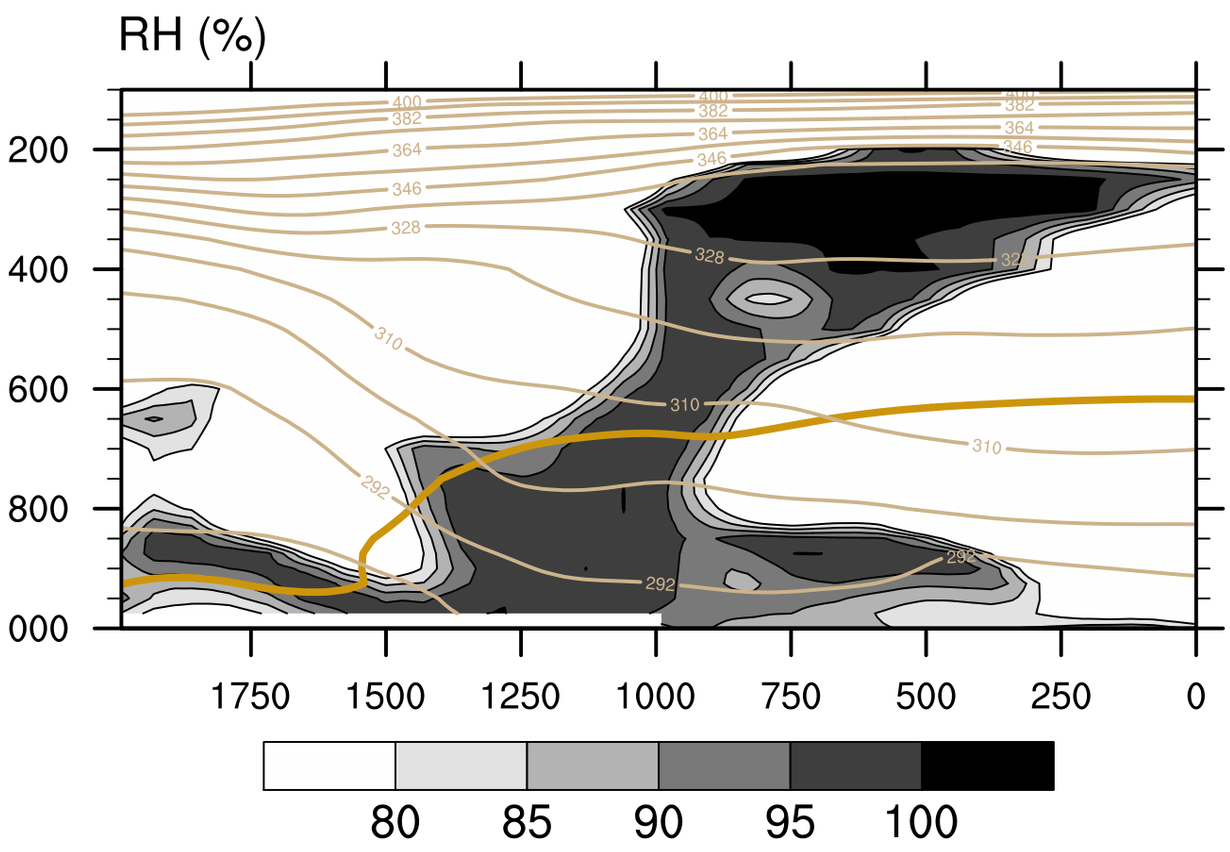

2011021500
IVT (kg m-1 s-1)
msl (hPa)
30°W
15°W
0°
15°E
30°E
45°E
10°S
15°S
20°S
25°S
30°S
35°S
40°S
60°W
30°W
0°
30°E
60°E
90°E
1015
1000
985
970
50
0
200
400
600
800
1000
1200
1400
1600
1800
2000

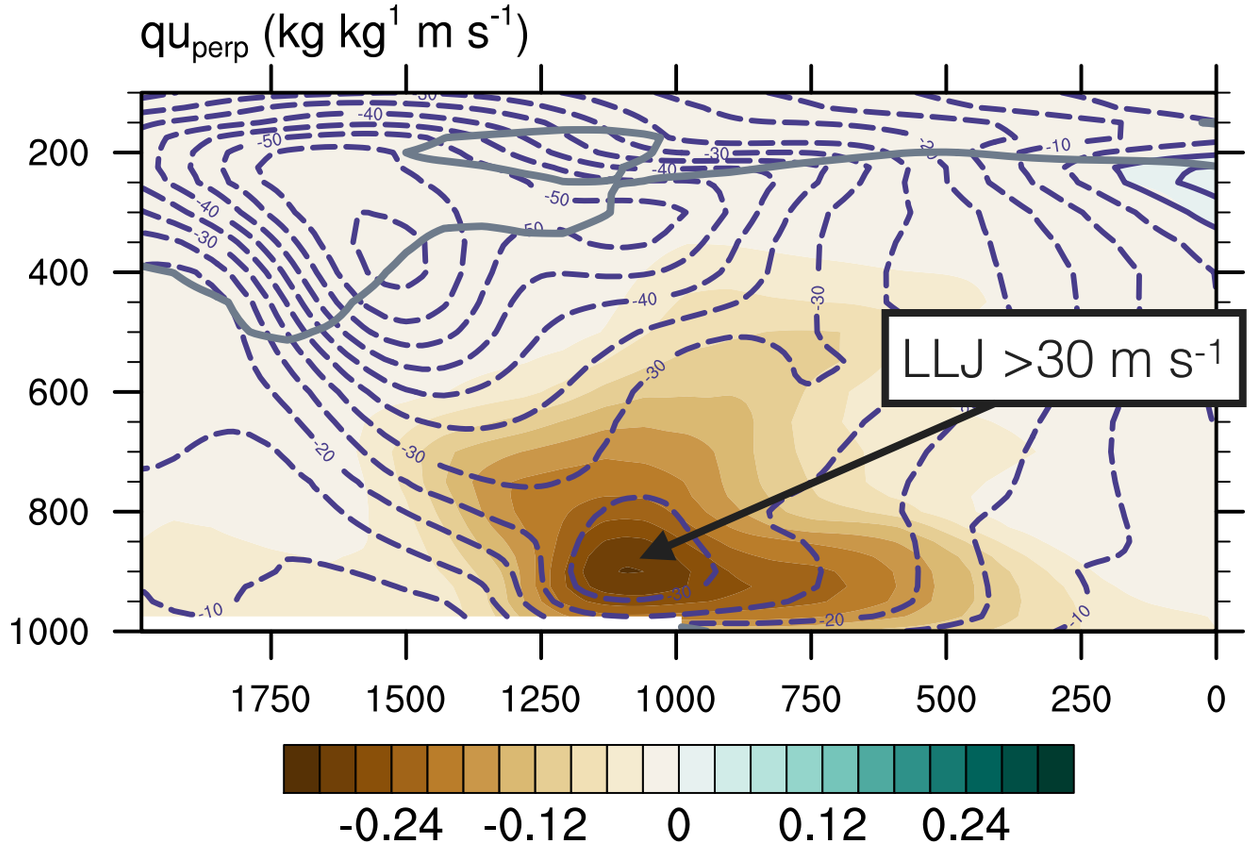
Case study

vertical structure



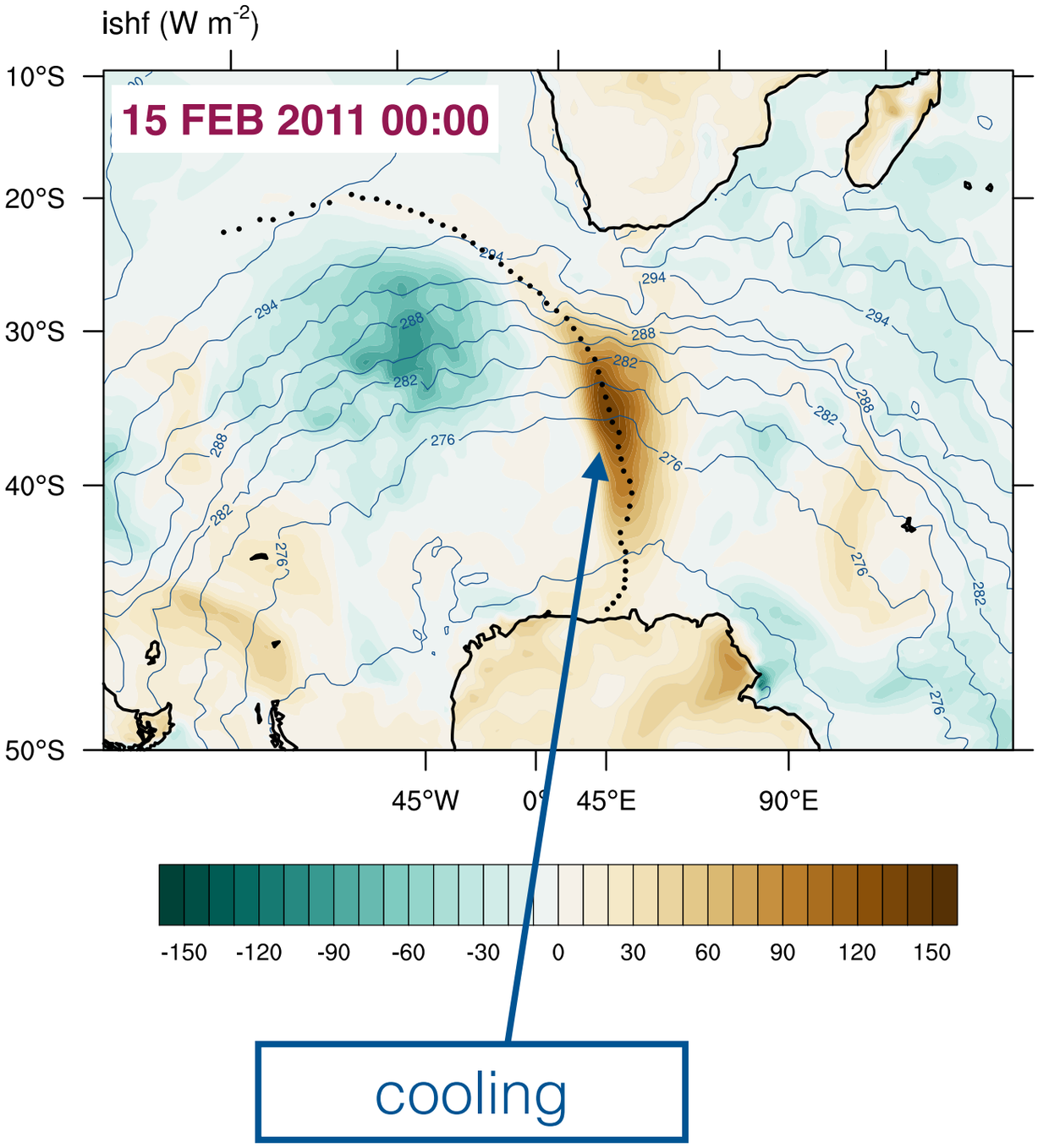




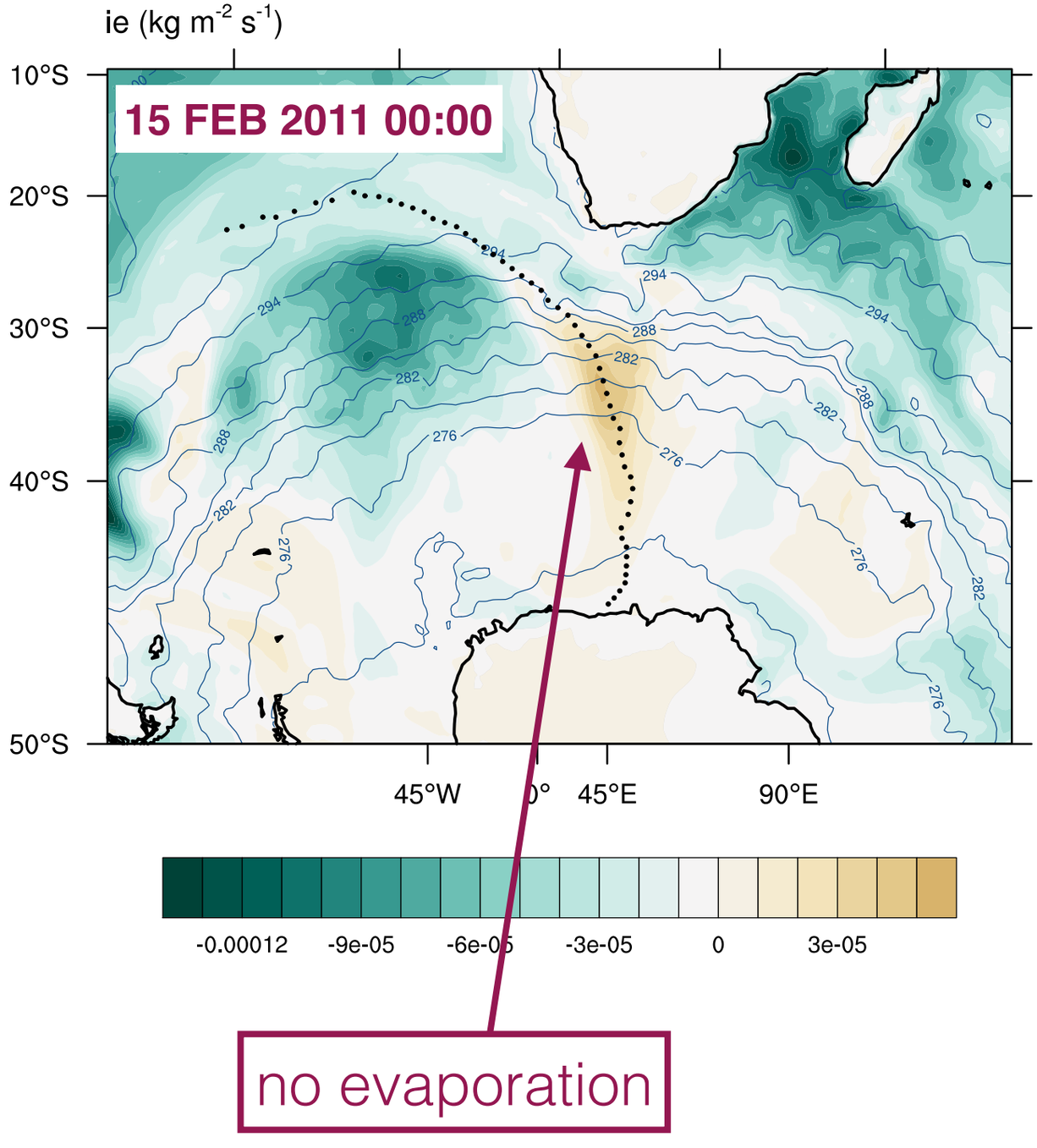


Case study air-sea exchange along AR

sensible heat flux



latent heat flux

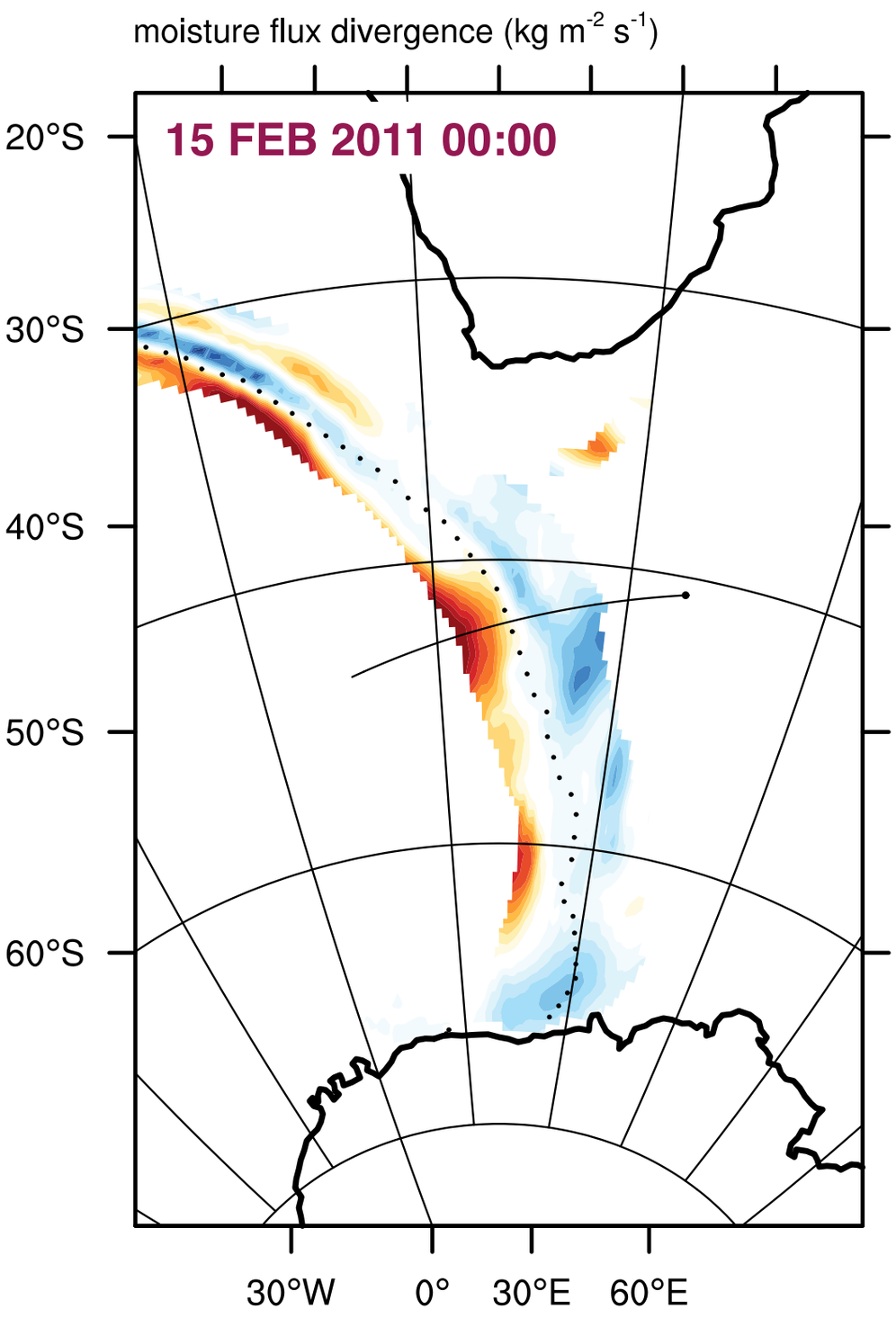


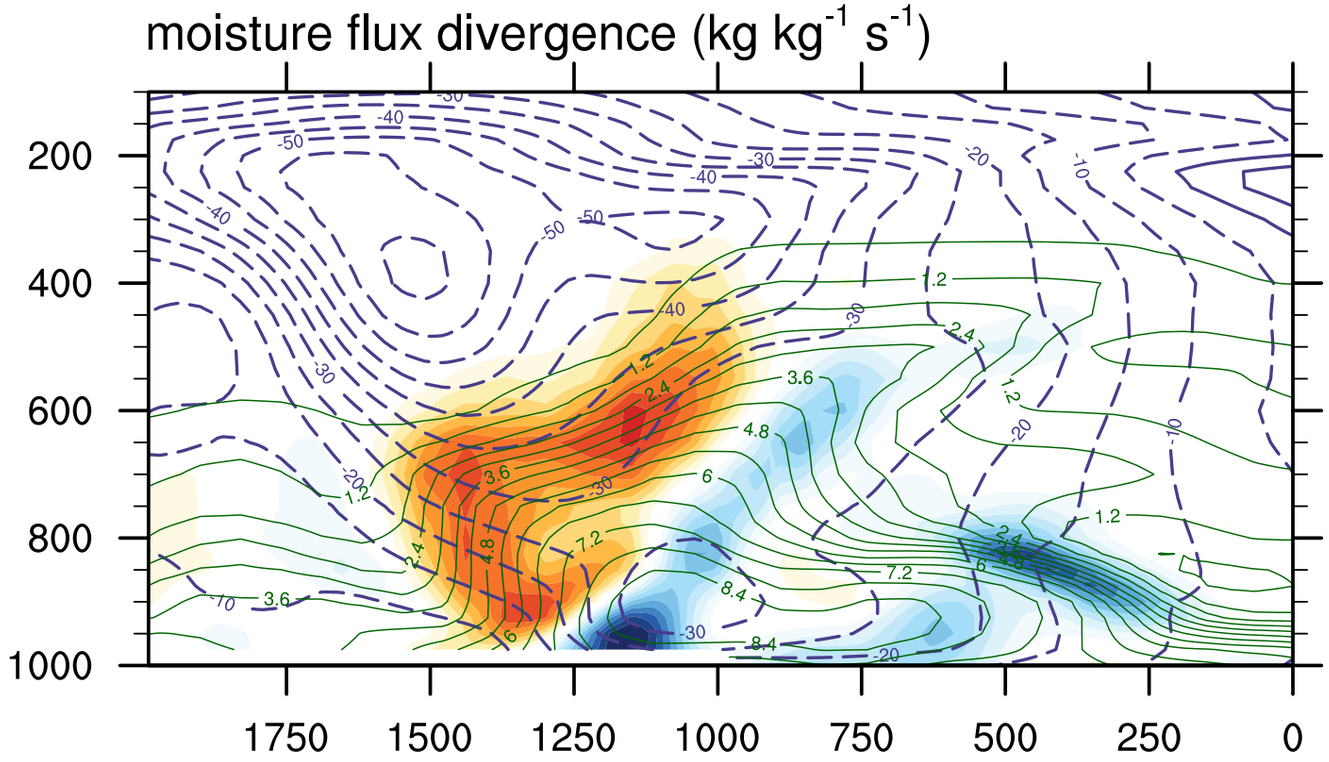
downward fluxes are positive

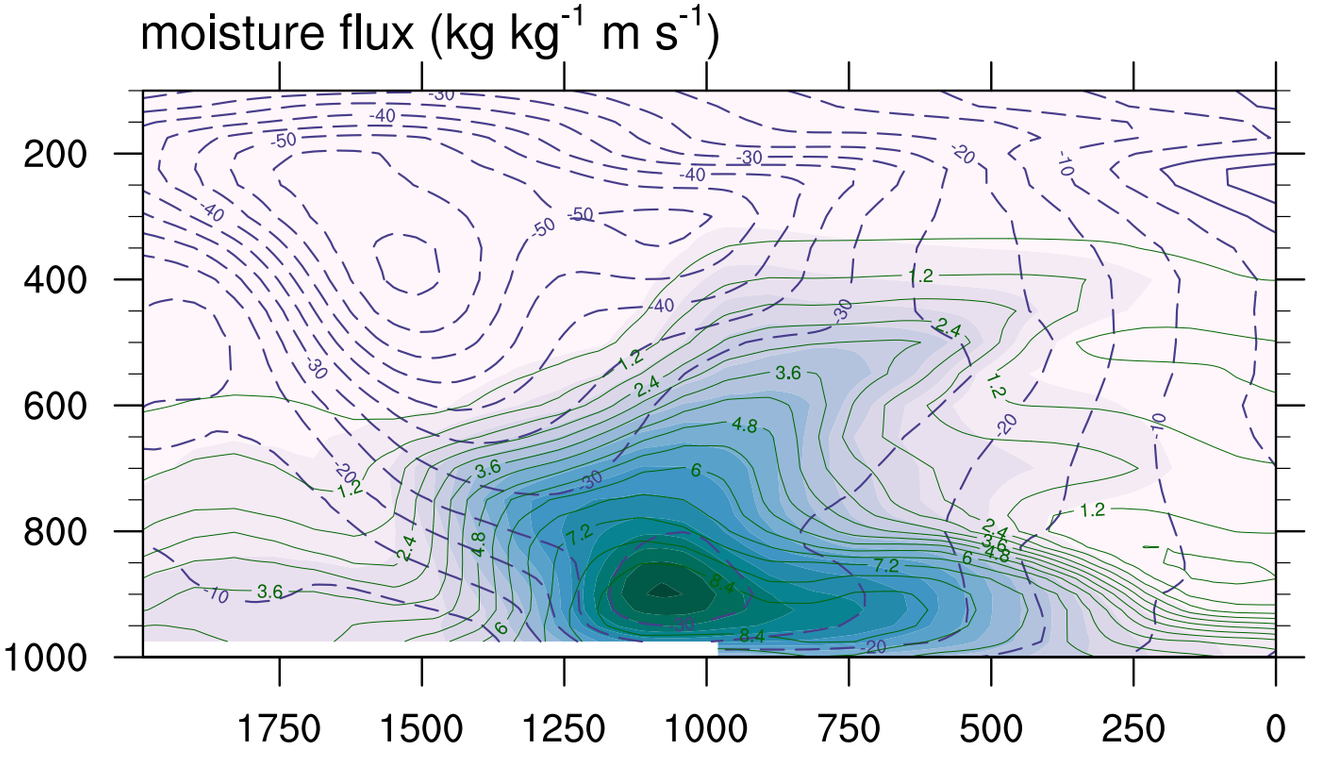
Case study

moisture flux divergence

$$\nabla \cdot q\vec{v}_h$$



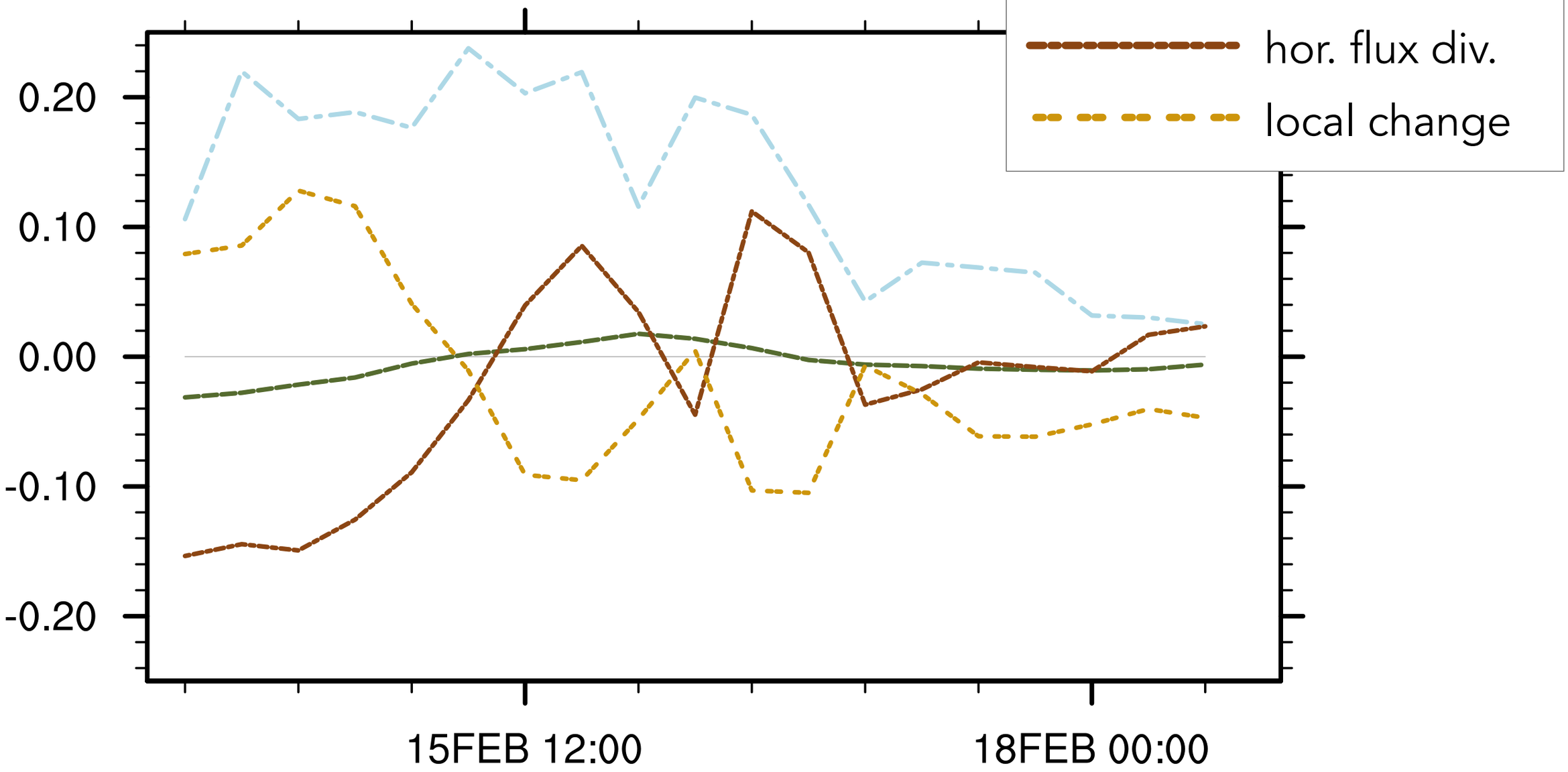




Case study

moisture budget

$$\frac{1}{g}\int_{p_{top}}^{p_{sfc}}\left(\frac{\partial q}{\partial t}+\nabla\cdot(q\vec{v}_h)+\frac{\partial \omega q}{\partial p}\right)dp = E - P$$

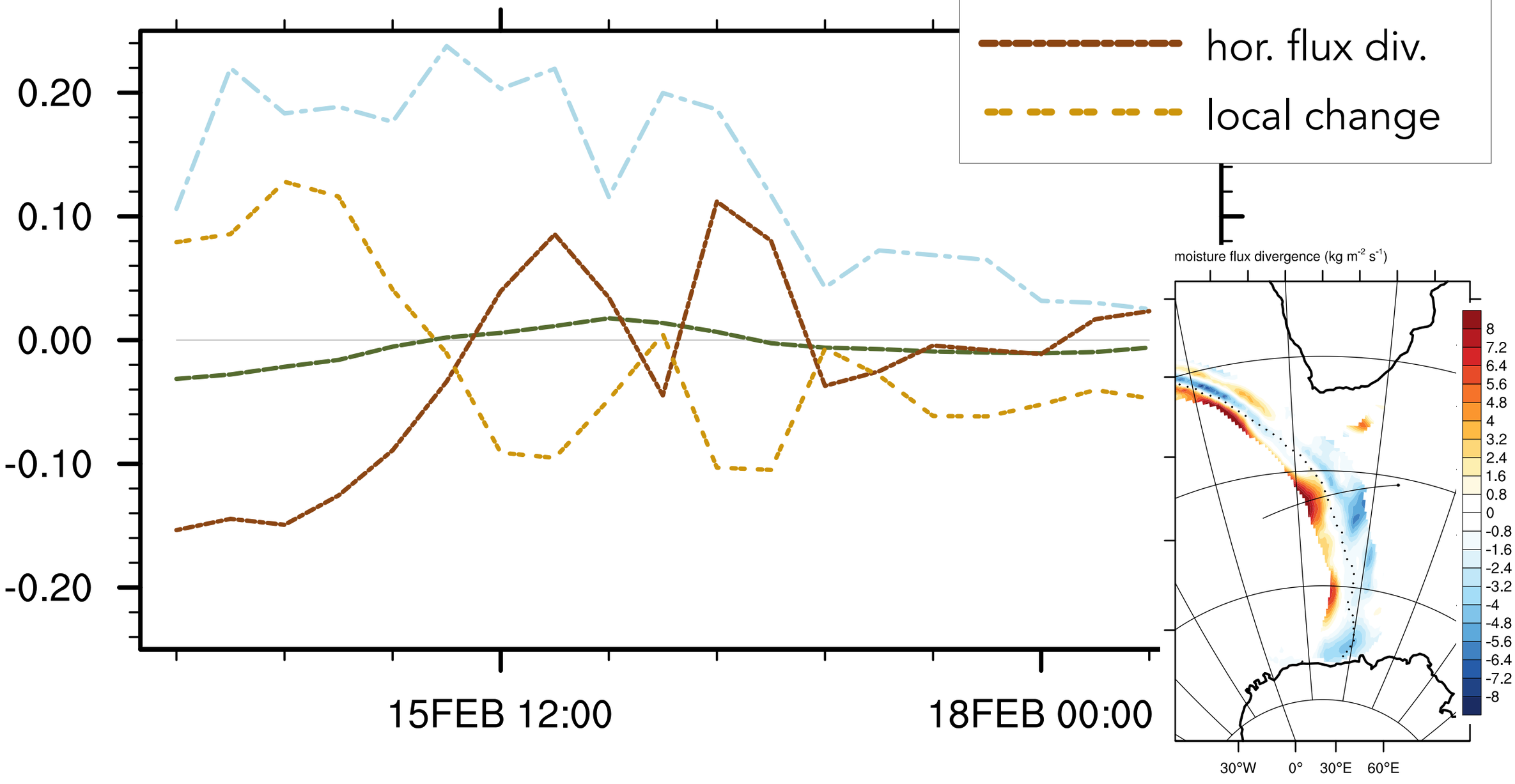


Case study

moisture budget

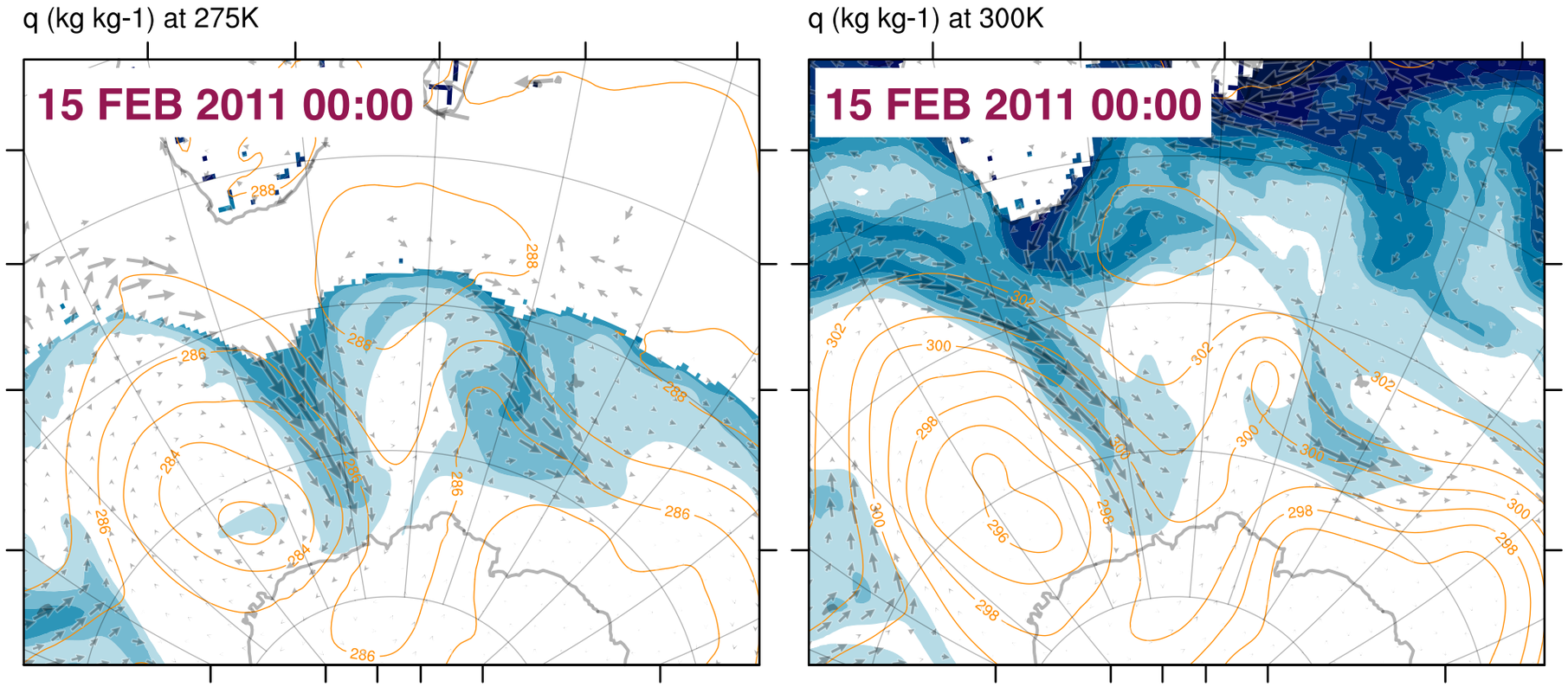
? dipole

$$\frac{1}{g}\int_{p_{top}}^{p_{sfc}}\left(\frac{\partial q}{\partial t}+\nabla\cdot(q\vec{v}_h)+\frac{\partial \omega q}{\partial p}\right)dp = E - P$$



Case study long range transport: isentropic view

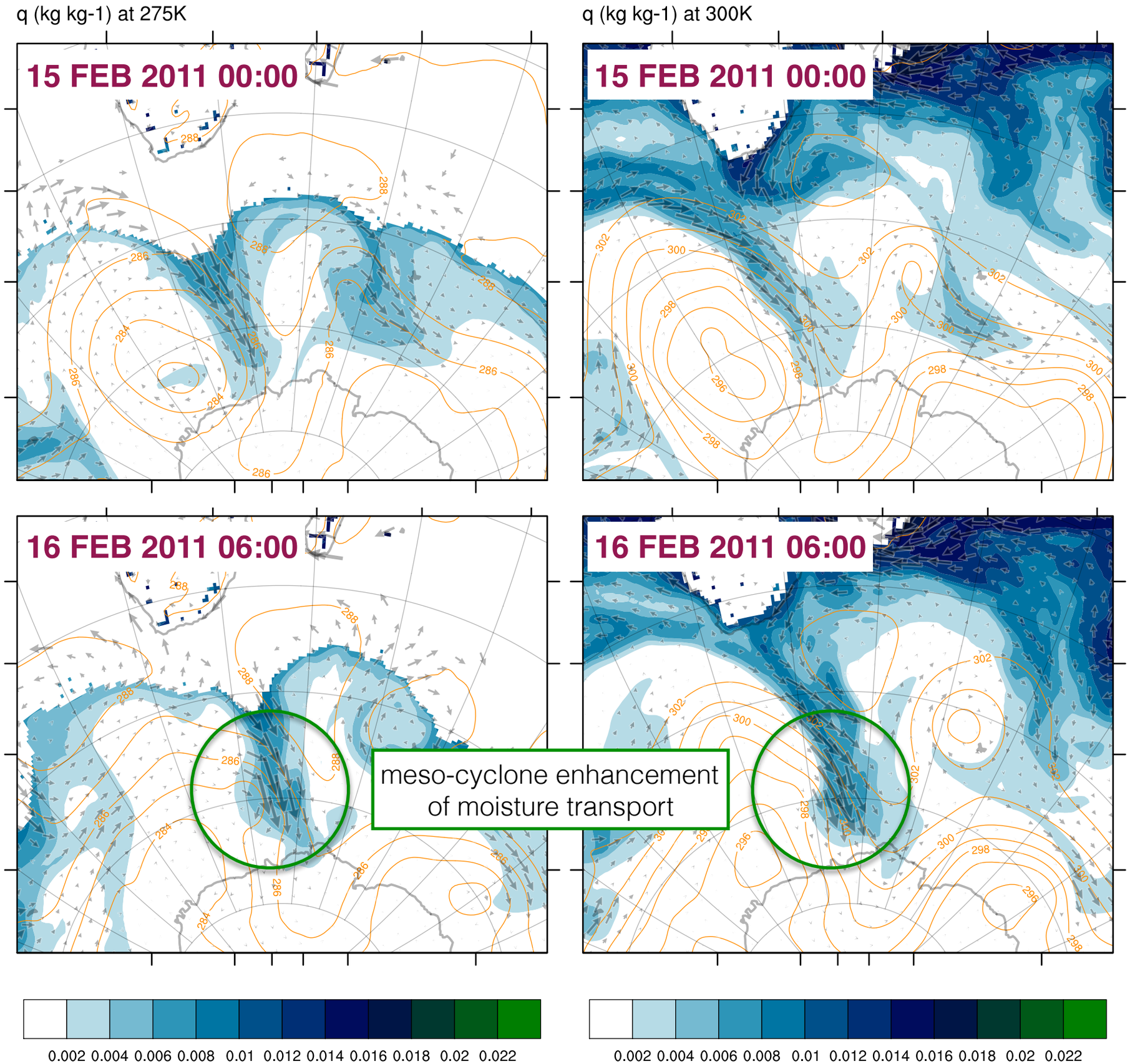
$$M = gz + c_p T$$



Case study long range transport: isentropic view

$$M = gz + c_p T$$

moisture transport //
isentropic heights contours

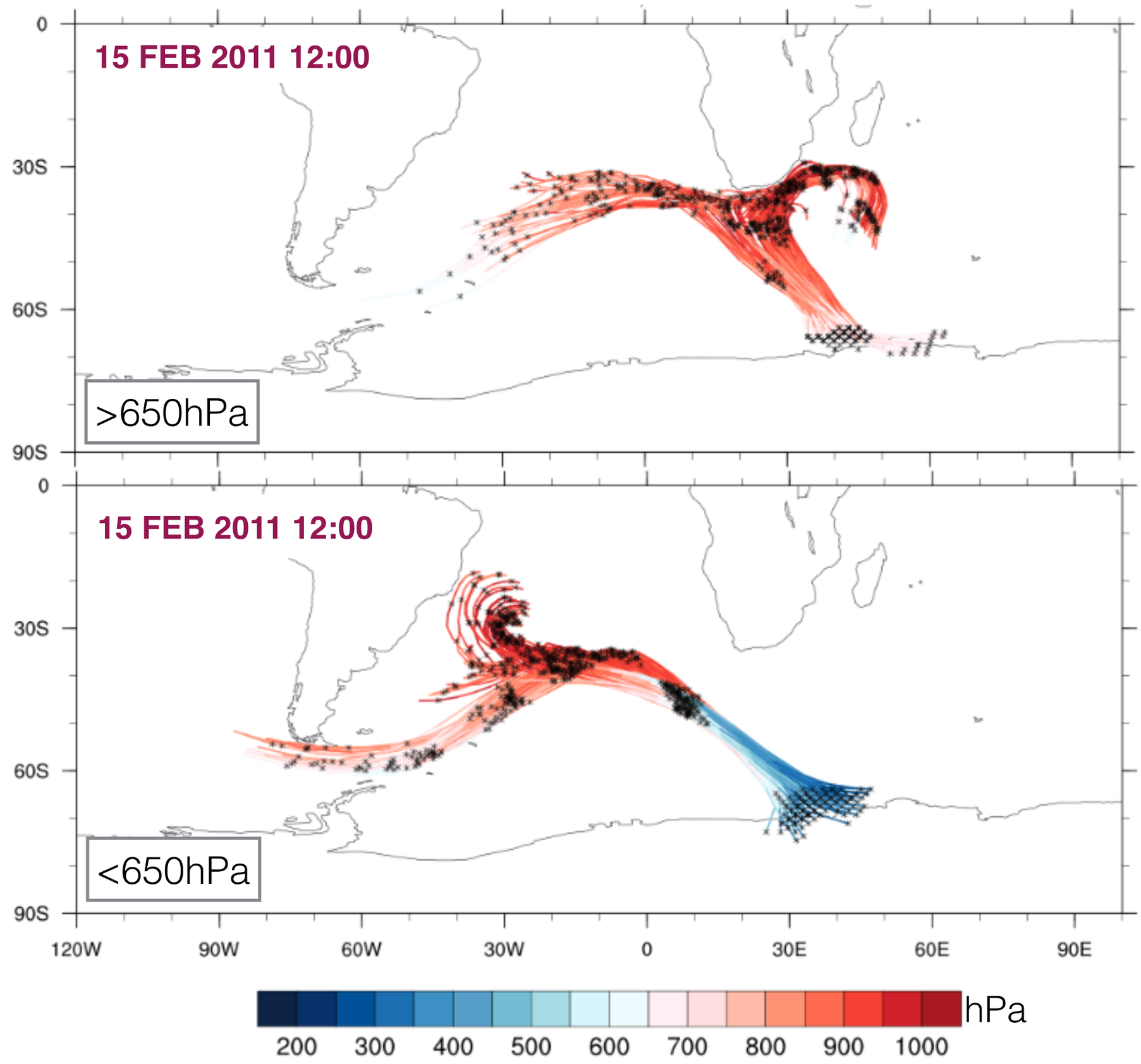


Case study long range transport: trajectories

criteria:

MF>250 gr kg^{-1} m s^{-1}

area: 0E-70E, 63S-78S



Summary

(global) hydrological context:

*** ARs provide large scale, atmospheric link between oceanic evaporation and Antarctic ice-sheet growth

*** ARs are actors in mid-high latitude interactions

(event) atmospheric science context:

*** evaporation along the AR is virtually absent: indication of long-distance moisture transport

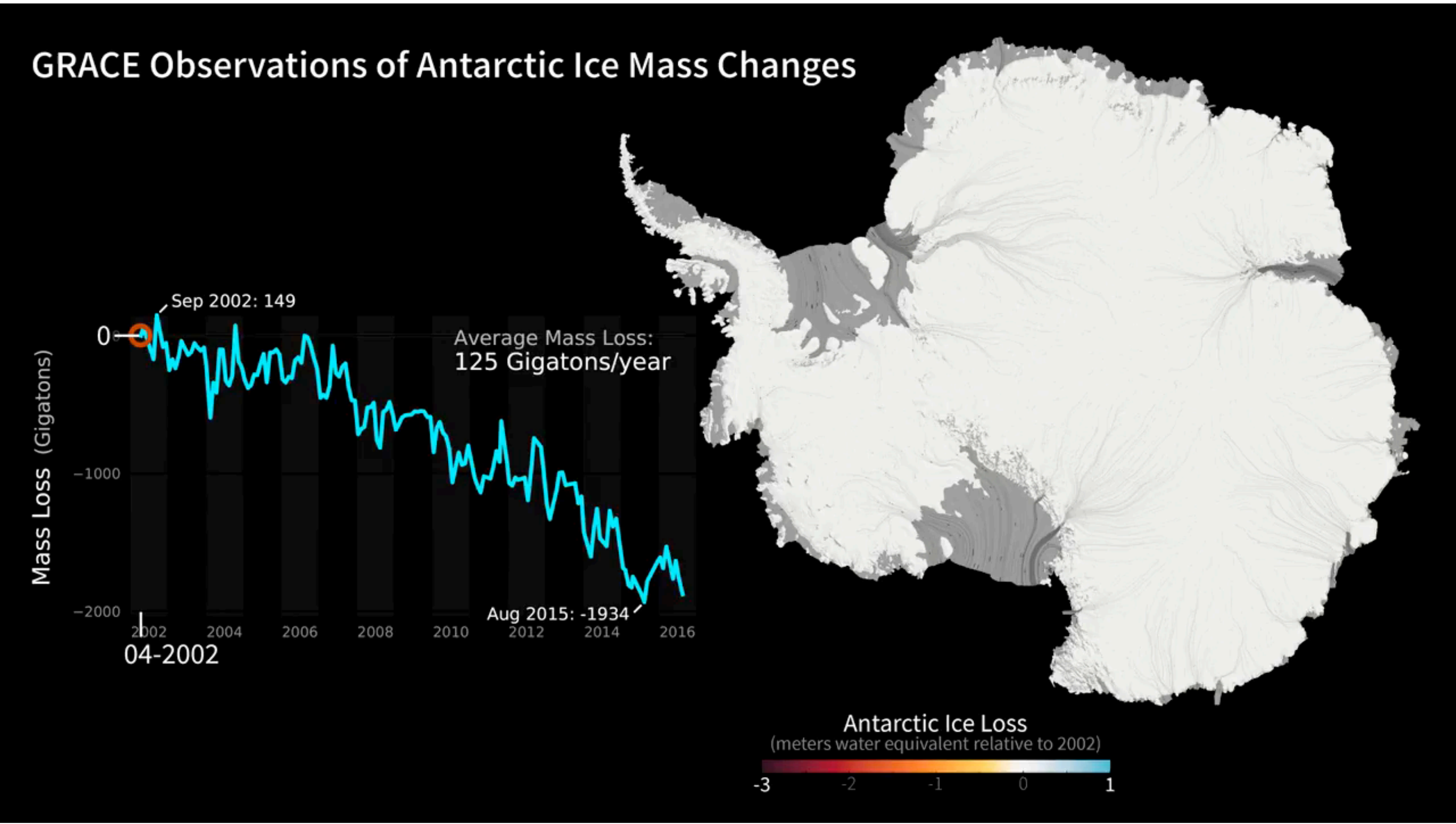
*** mesoscale cyclone enhances moisture transport

*** isentropic moisture transport —> direction determined by isentropic height contours

contact: annick.terpstra@uib.no

Motivation

surface mass balance: net balance between **accumulation** and ablation



Motivation

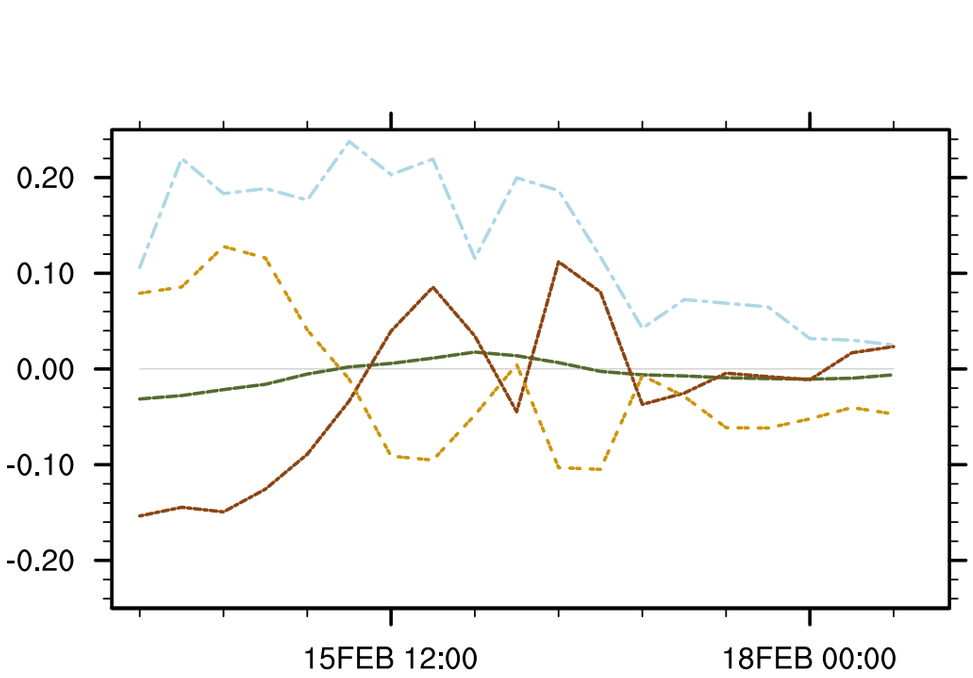
Accumulation:

- precip is only significant source term in mass budget of Antarctic ice-sheet
- local sources ~non-existing
- futurology perspective: large uncertainties

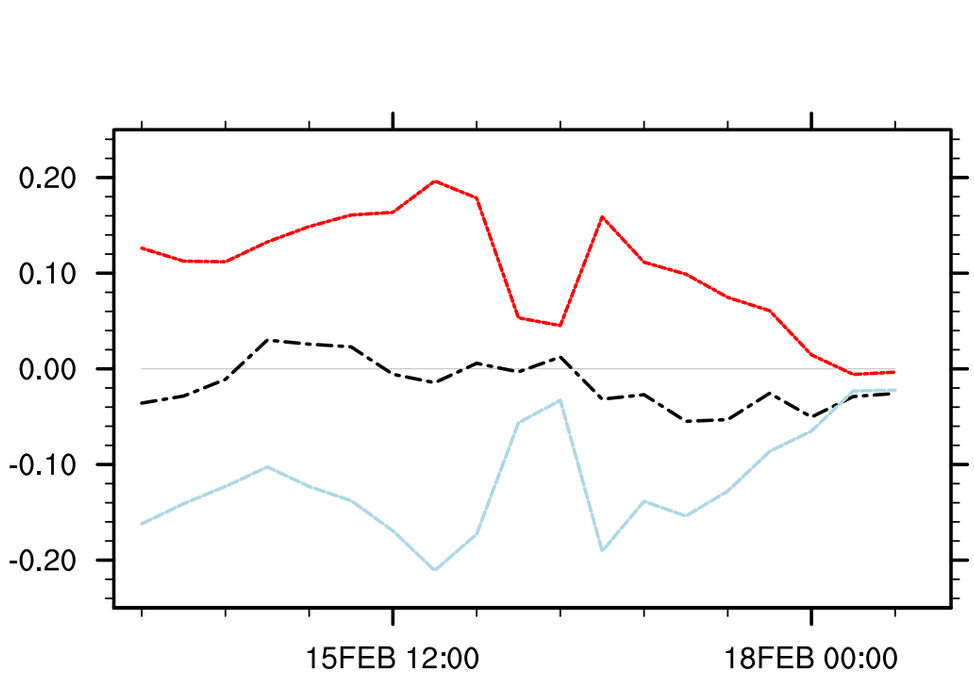
critical to understand dynamical mechanisms resulting in accumulation, including moisture transport & sources

Impact:

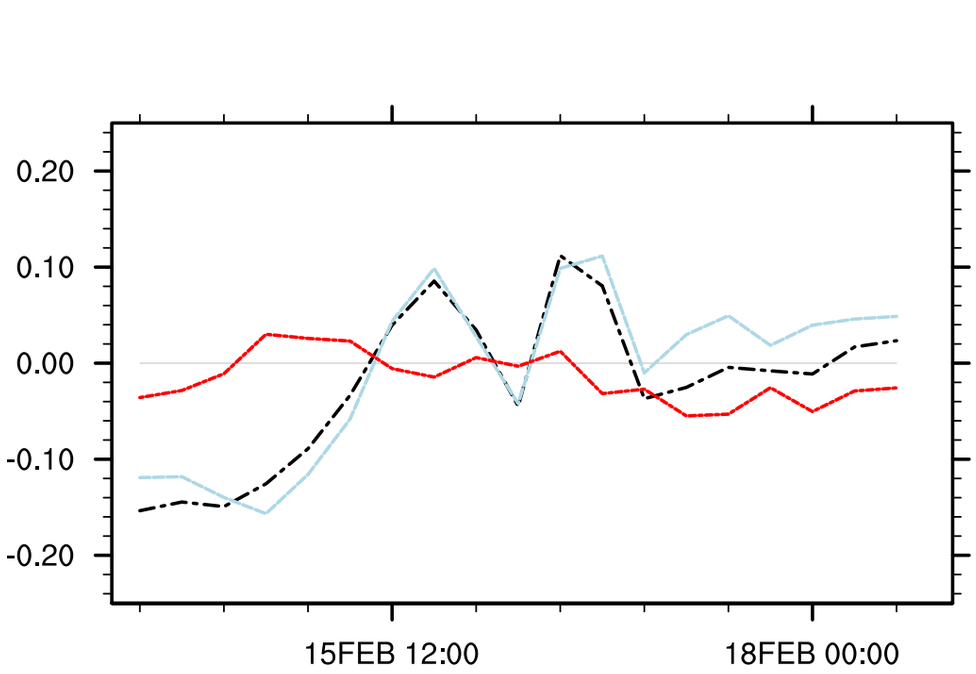
- ice-sheet growth/decline: global impact on sea-level rise
- freshwater-budget over Southern ocean
- cloud-radiative forcing

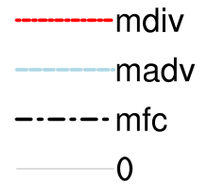

0.20
0.10
0.00
-0.10
-0.20
15FEB 12:00
18FEB 00:00

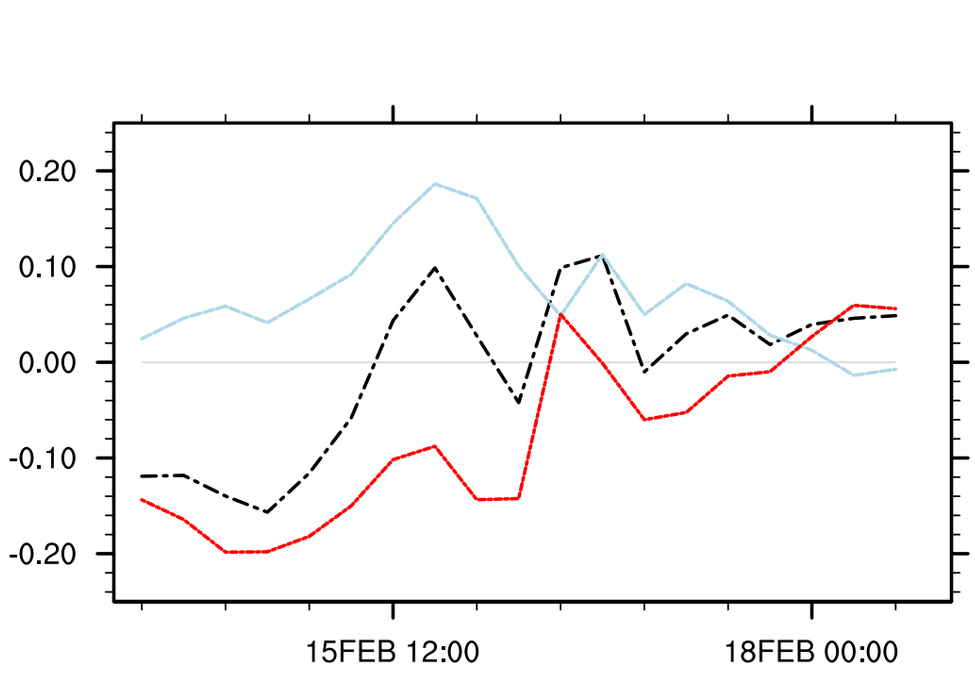

dS
mfc
evap
precip
0

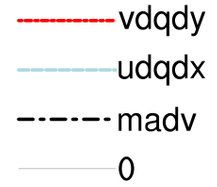

0.20
0.10
0.00
-0.10
-0.20
15FEB 12:00
18FEB 00:00


qdvdy
qdudx
mdiv
0

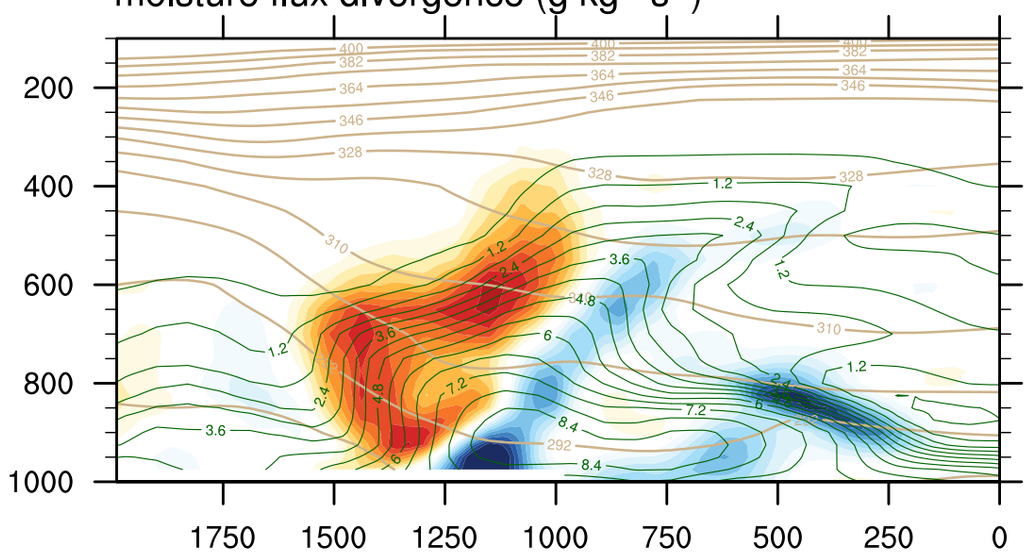

0.20
0.10
0.00
-0.10
-0.20
15FEB 12:00
18FEB 00:00


mdiv
madv
mfc
0

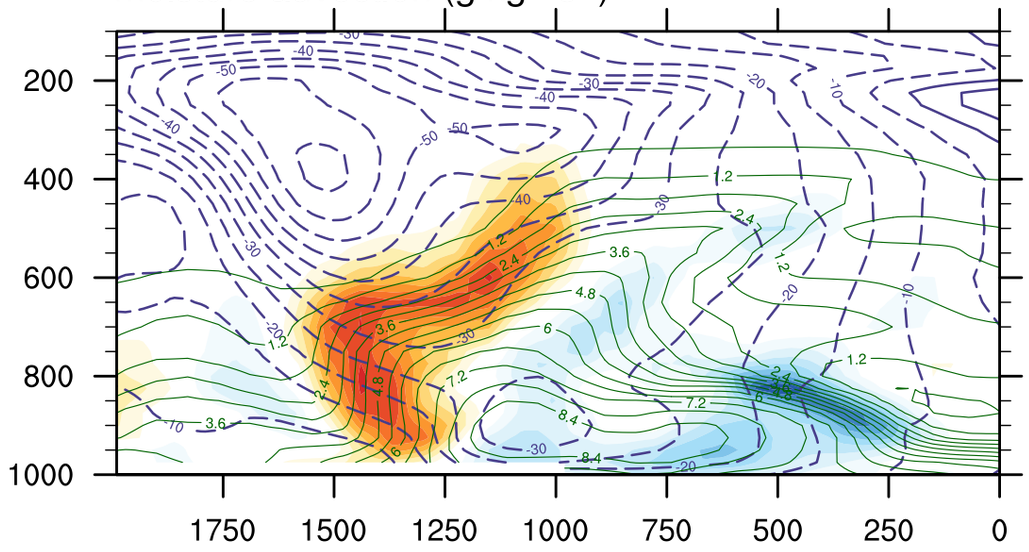

0.20
0.10
0.00
-0.10
-0.20
15FEB 12:00
18FEB 00:00


vdqdy
udqdx
madv
0

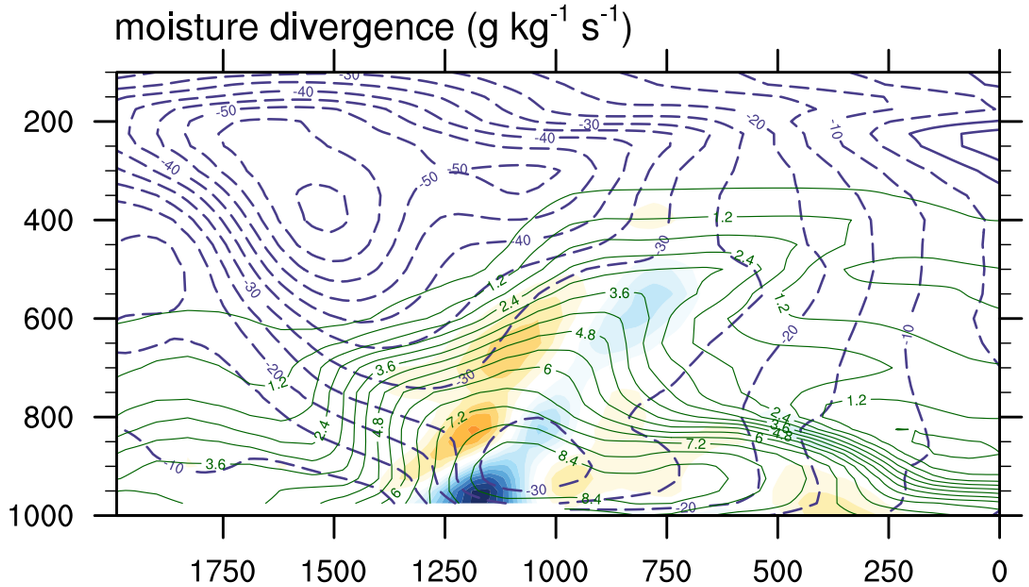
moisture flux divergence ($g\ kg^{-1}\ s^{-1}$)

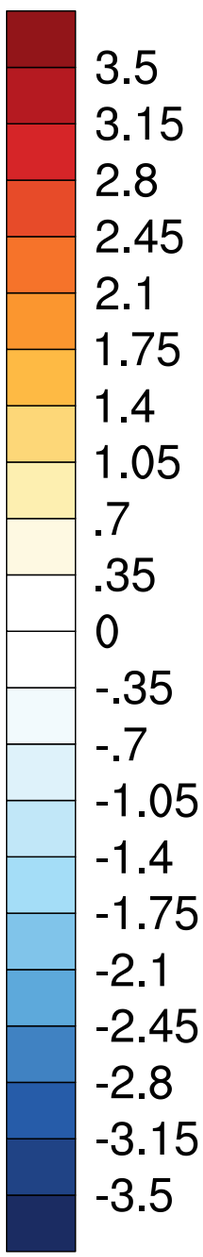


moisture advection ($g\ kg^{-1}\ s^{-1}$)



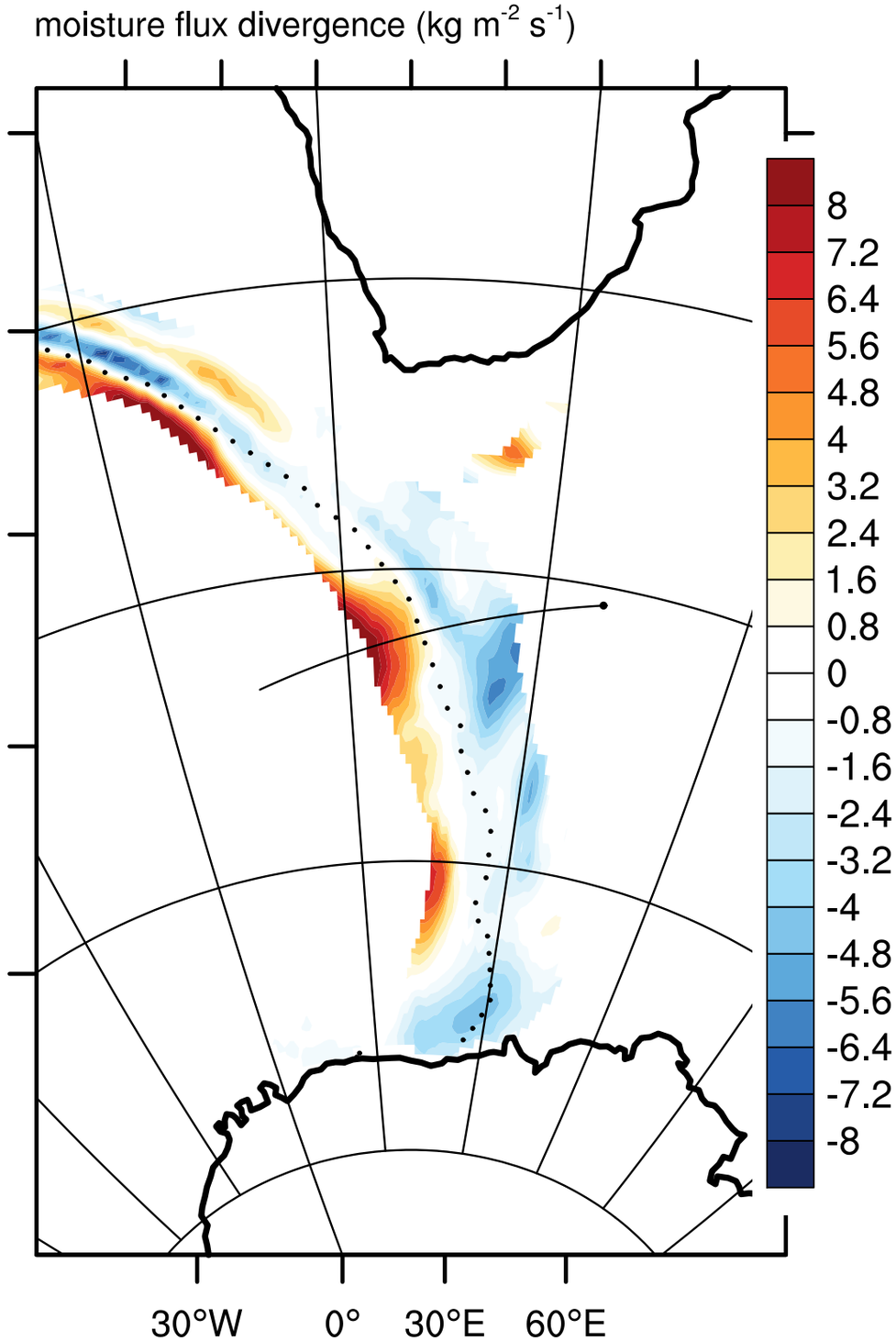
moisture divergence ($g\ kg^{-1}\ s^{-1}$)



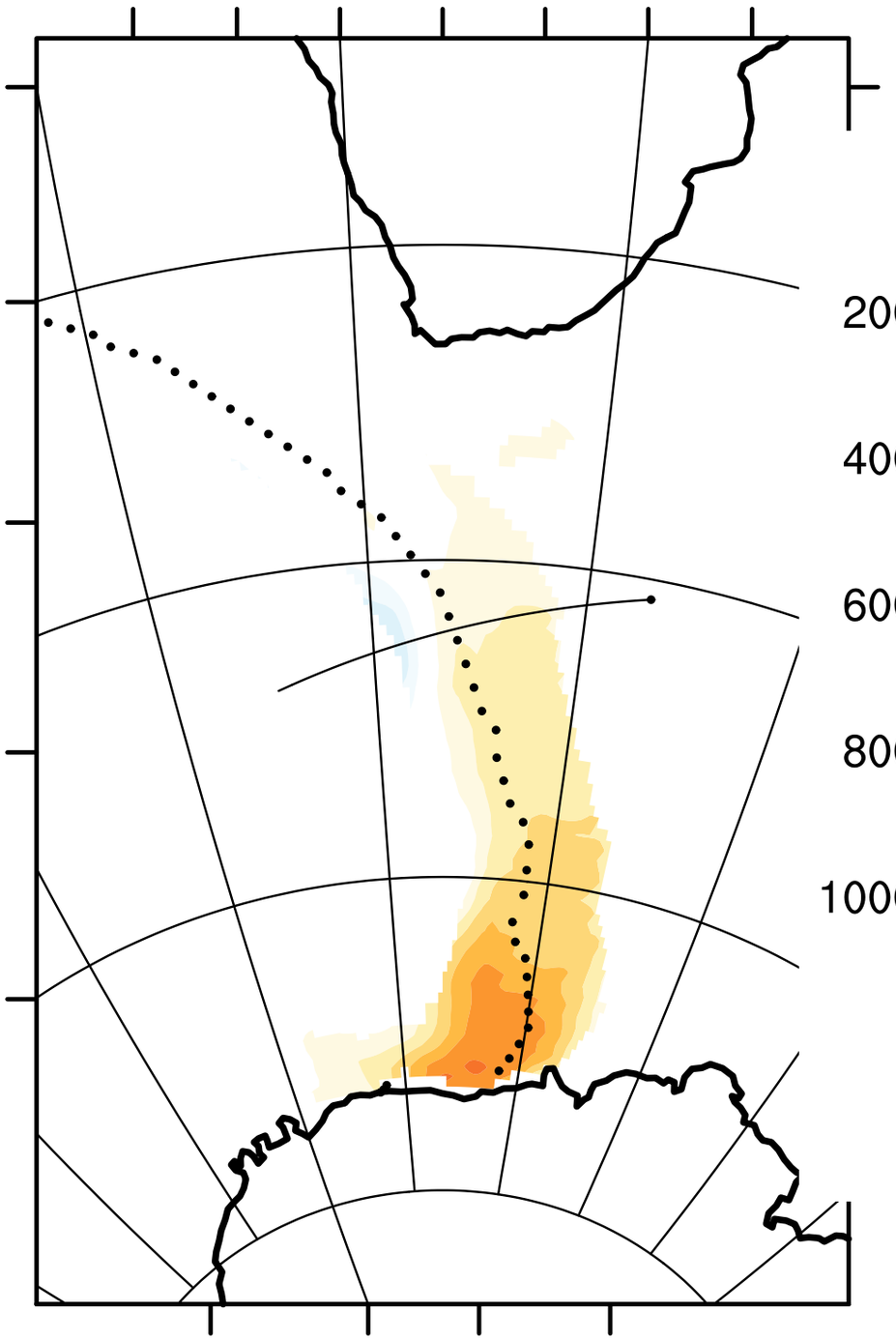


$$\nabla \cdot q\vec{v}_h = \vec{v}_h \cdot \nabla q + q\left(\nabla \cdot \vec{v}_h\right)$$

moisture flux divergence ($kg\ m^{-2}\ s^{-1}$)



temperature advection (K s^{-1})



temperature advection (K s^{-1})