Supplementary Material: Lagrangian Detection of Moisture Sources for the Southern Patagonia Icefield

1 THE EL-NIÑO SOUTHERN OSCILLATION (ENSO)

1.1 SOI, ONI and Precipitation Anomalies

A period of at least five consecutive overlapping 3-month seasons must exceed (deceed) an ONI threshold of 0.5 (-0.5) in order to be classified as a full-fledge El-Niño (La-Niña) episode (National Oceanic and Atmospheric Administration, 2017). Considering these definitions the ERA-Interim data contains 126 El-Niño and 90 La-Niña months. Figure S1 illustrates the chronology of the El-Niño months (red) and the La-Niña months (blue). The Ocean Niño Index (ONI) provides a good estimation for the strength of an event. For example, an exceptionally strong El-Niño occurred during the years 1982 to 1983, 1997 to 1998 and 2015 to 2016. The corresponding Southern Oscillation Index (SOI) of all months shows Figure S2.

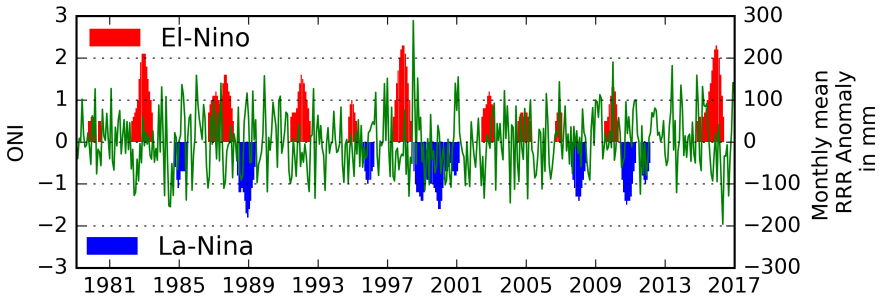

Figure S1: Ocean Niño Index (ONI) (red and blue bars) and monthly mean precipitation anomaly in the target region (green line) over a timeline from January 1979 to January 2017.

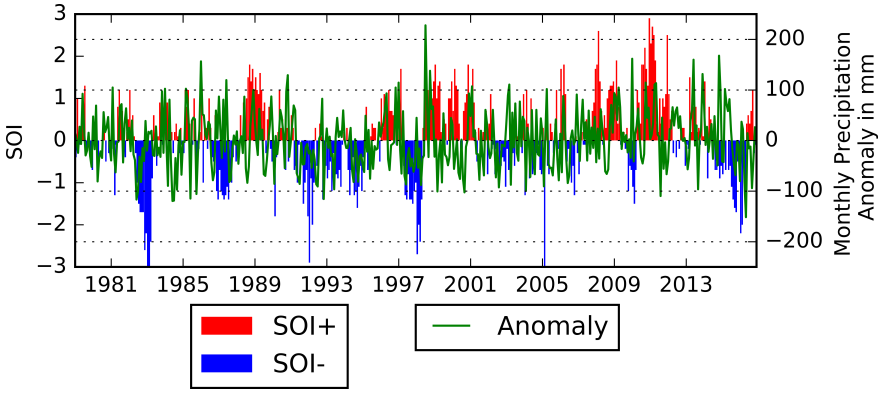

Figure S2: Southern Oscillation Index (SOI) (red and blue bars) and monthly mean precipitation anomaly in the target region (green line) over a timeline from January 1979 to January 2017.

1.2 Sea Surface Temperature Anomalies

Figure S3 shows the averaged SST anomalies in and the mean sea level preasure anomalies in for the full-fledged El-Niño months.

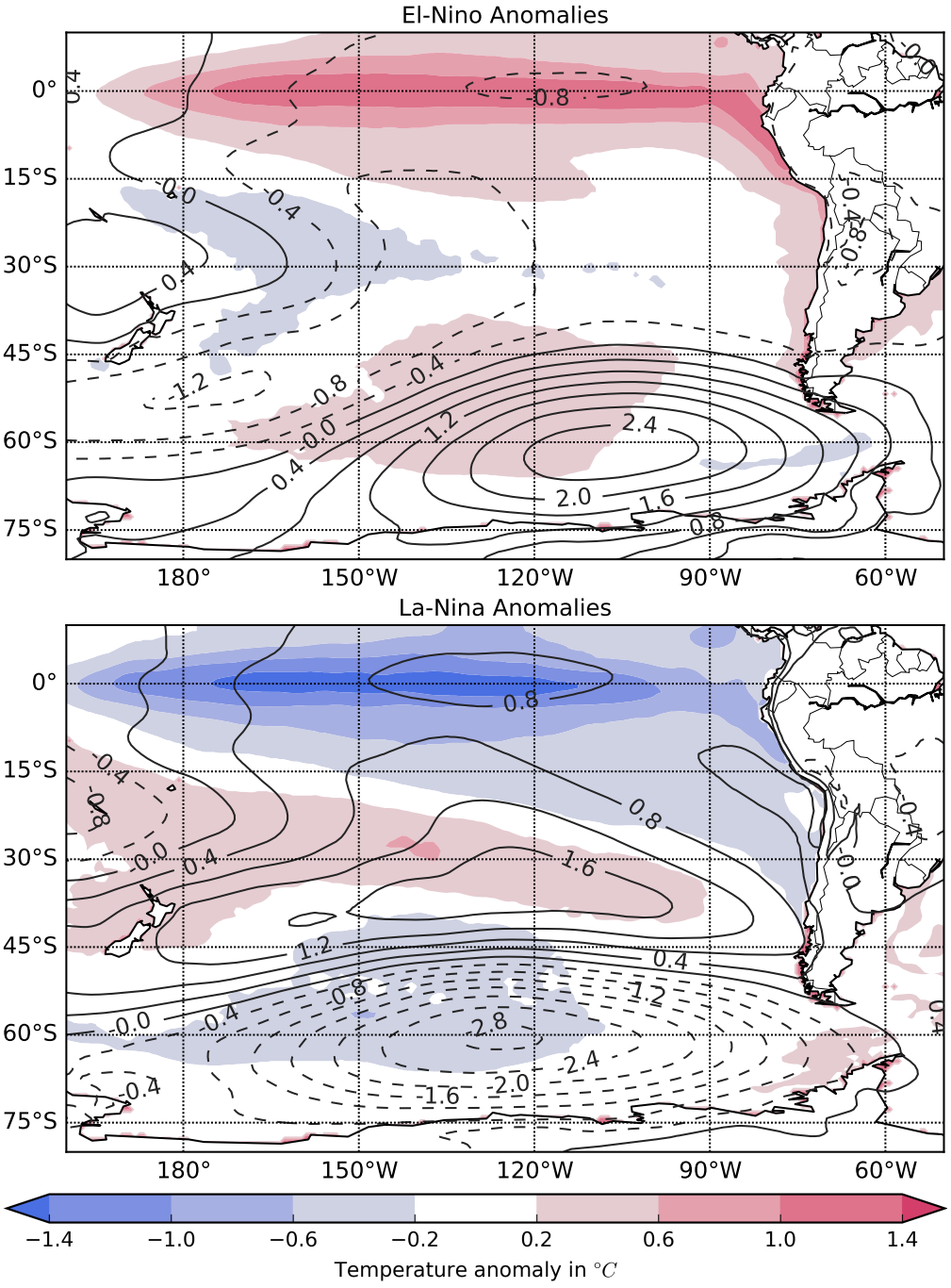

Figure S3: a) El-Niño and b) La-Niña mean sea level pressure (contours, 0.4 h Pa interval) and sea surface temperature (colors) anomalies obtained from ERA-Interim.

2 800-HPA GEOPOTENTIAL FIELD

Figure S4 shows the 800 h Pa geopotential height and wind velocity during extreme precipitation months and El-Niño and La-Niña months.

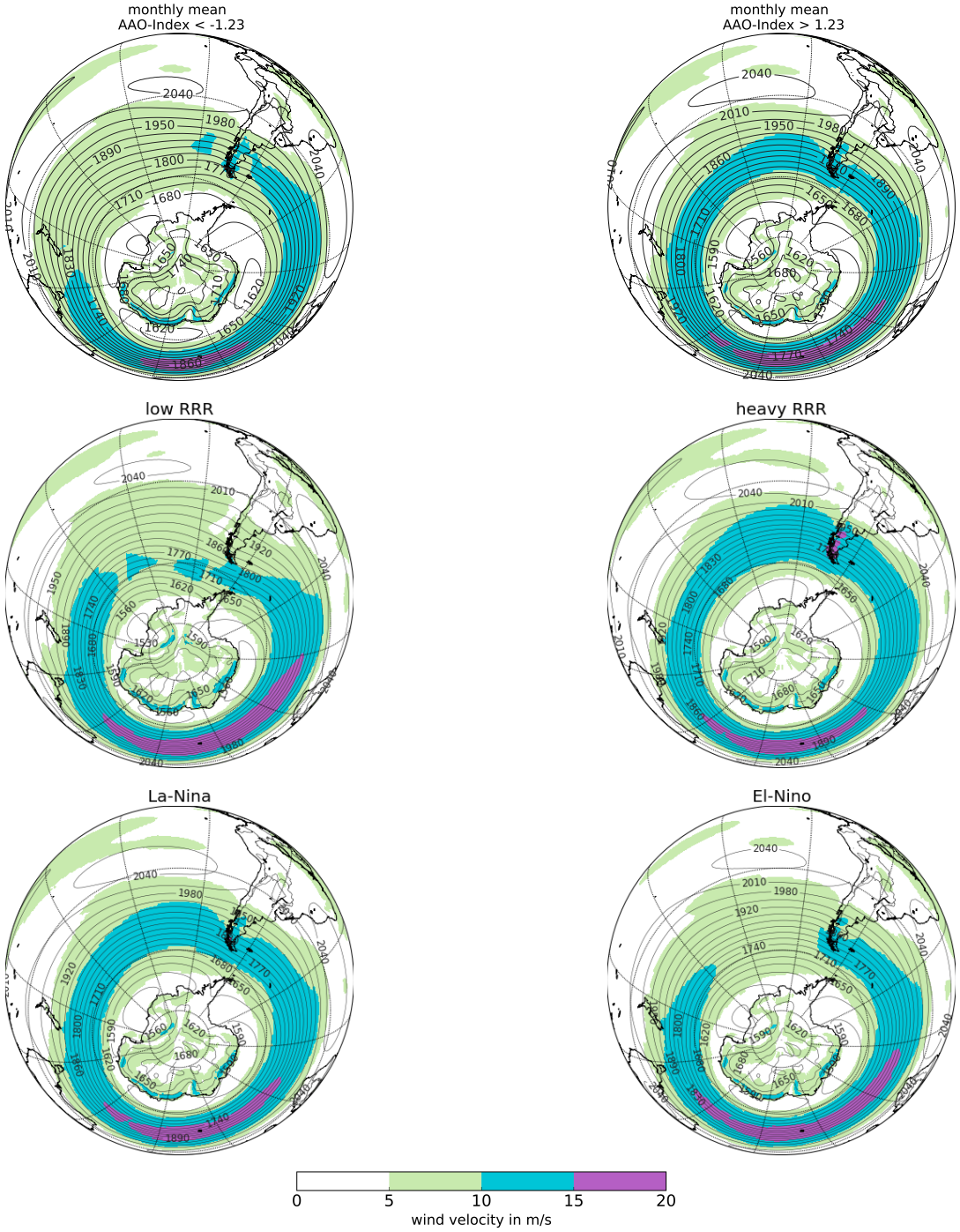

Figure S4: 800 h Pa pressure level of the ERA-Interim data. Contour lines show the geopotential height in meter. Color indicates the wind velocity. The values are averages of the corresponding selection. The interval of the meridians and parallels is 30°.

3 MOISTURE SOURCES

In the following we show the moisture sources for the corresponding anomaly discussed in the manuscript. For interpretation issues of the plots in Figure S5, Figure S6, Figure S7 and Figure S8, we refer to the Section 4.1 in the manuscript.

3.1 Seasons

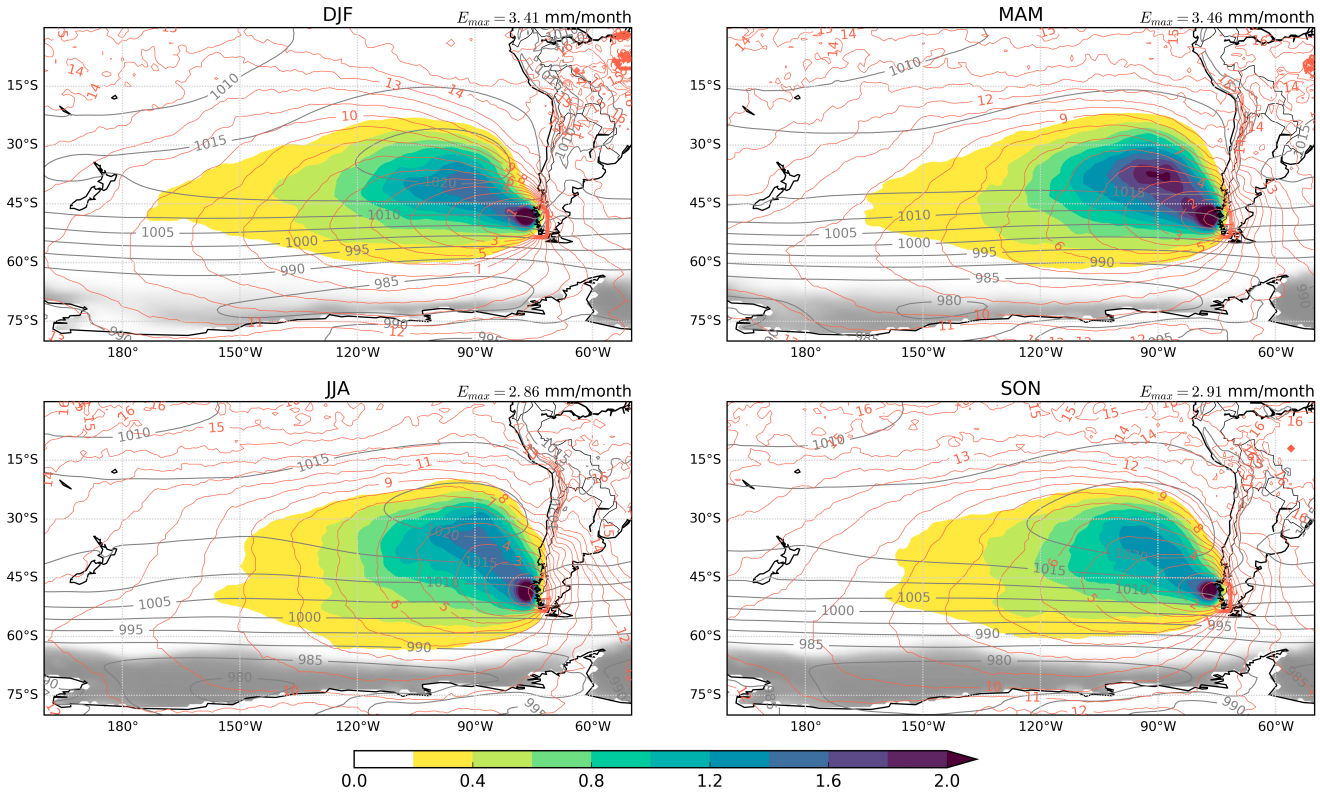

Figure S5: Seasonal monthly mean moisture sources of the SPI (colored area) in mm/month. The maximal moisture uptake is written above the figure. The mean transport time of the moisture towards the SPI indicate the red lines in days before arrival. The averaged mean sea level pressure (gray lines) and sea ice cover (gray shaded area) are depicted as well.

3.2 Moisture Sources of La-Niña and El-Niño Events

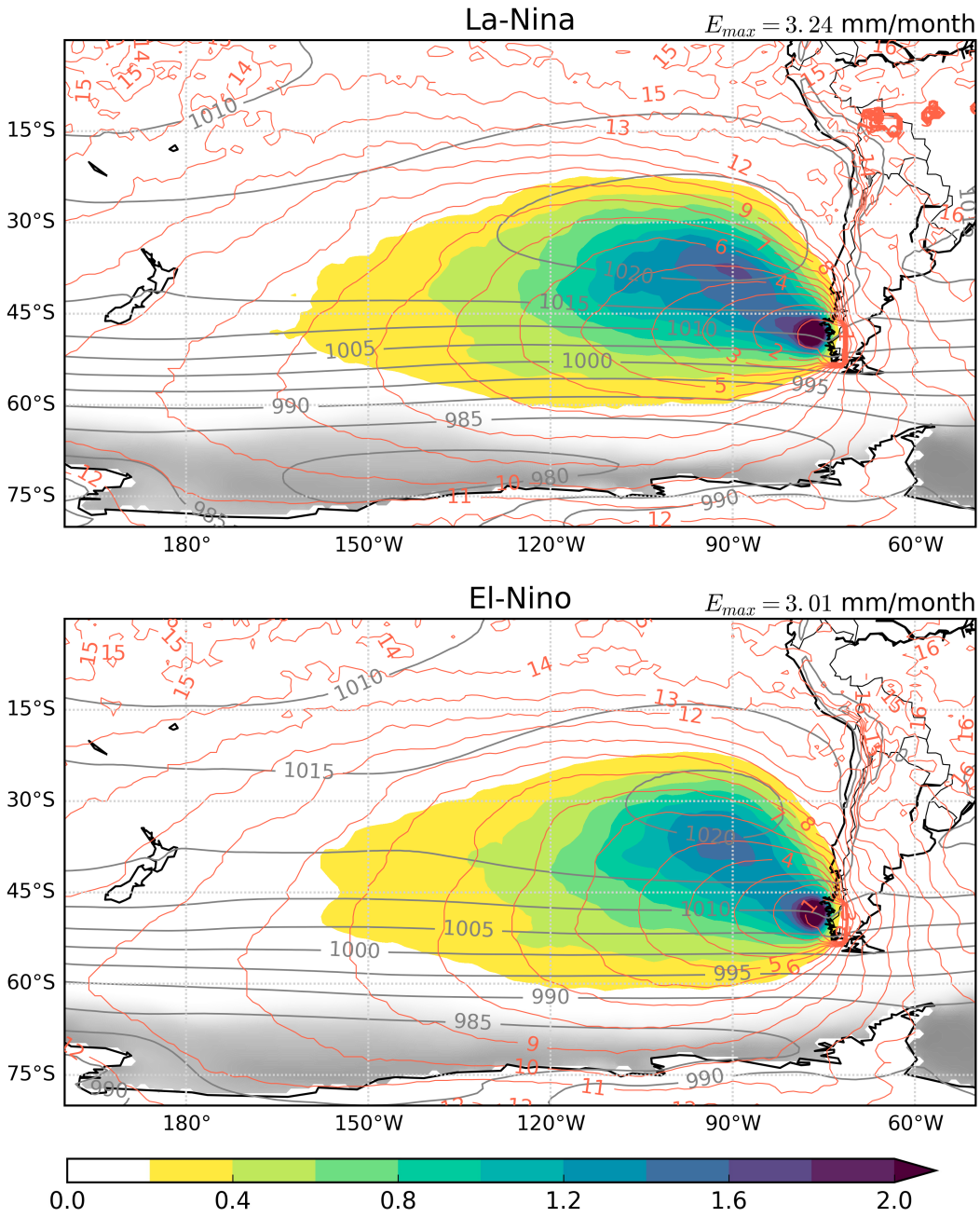

Figure S6: Monthly mean moisture sources of the SPI during La-Niña and El-Niño (colored area) in mm/month. The maximal moisture uptake is written above the figure. The mean transport time of the moisture towards the SPI indicate the red lines in days before arrival. The averaged mean sea level pressure (gray lines) and sea ice cover (gray shaded area) are depicted as well.

3.3 Moisture Sources of Extreme Precipitation Events

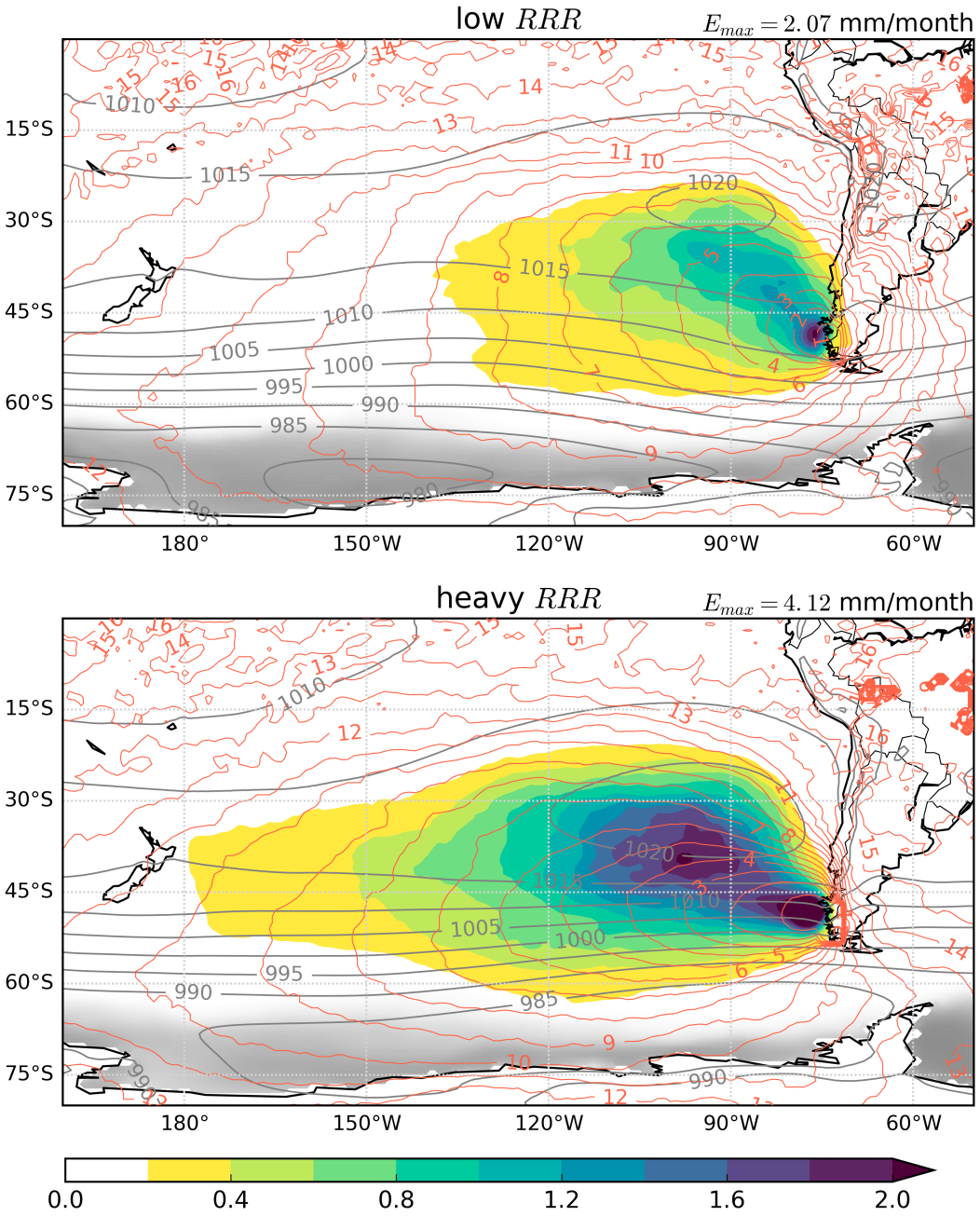

Figure S7: Monthly mean moisture sources of the SPI during low and heavy precipitation months (colored area) in mm/month. The maximal moisture uptake is written above the figure. The mean transport time of the moisture towards the SPI indicate the red lines in days before arrival. The averaged mean sea level pressure (gray lines) and sea ice cover (gray shaded area) are depicted as well

3.4 Moisture Sources of strong negative (10 percentile) and strong positive (90 percentile) AOI months

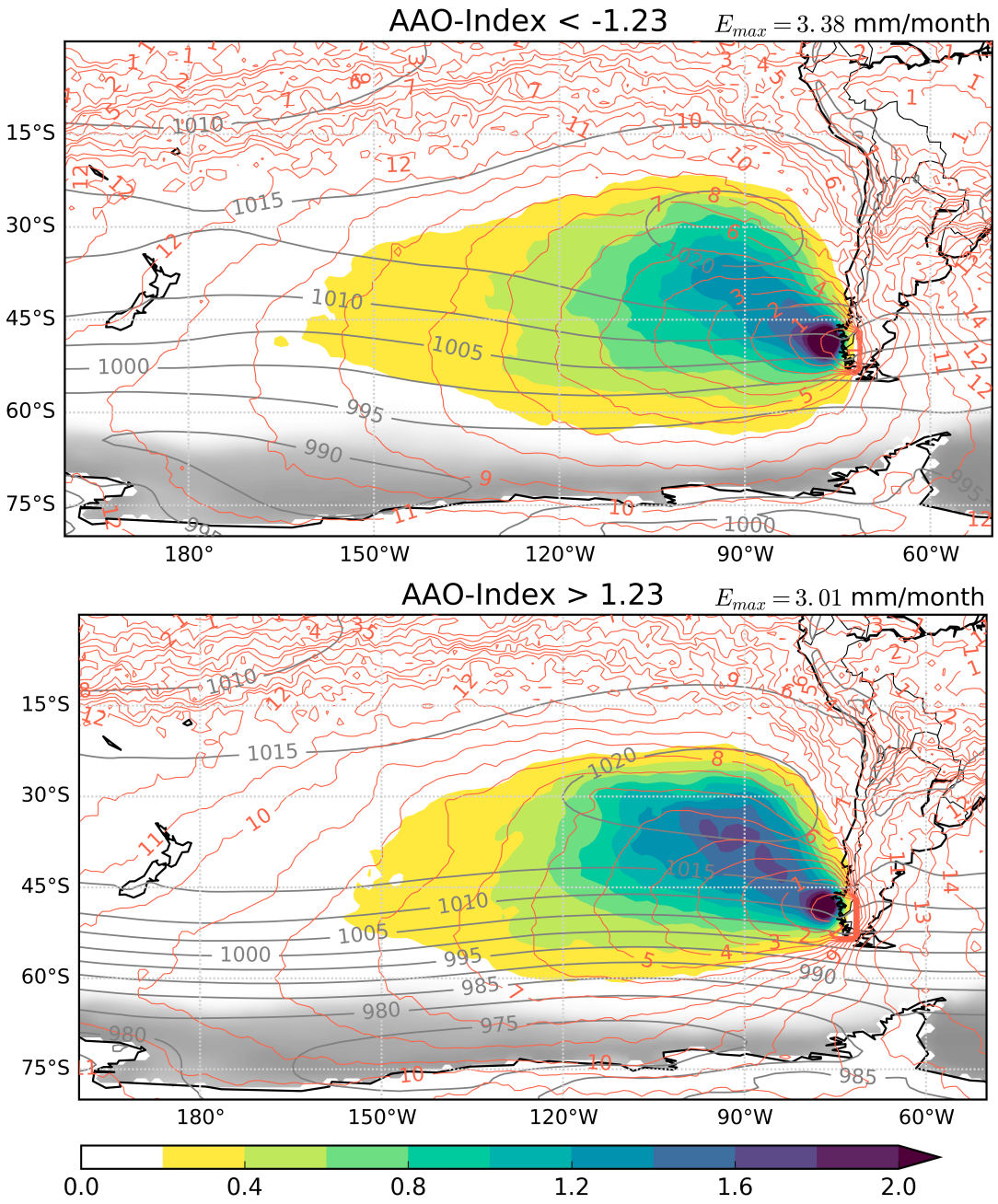

Figure S8: Monthly mean moisture sources of the SPI during low and heavy precipitation months (colored area) in mm/month. The maximal moisture uptake is written above the figure. The mean transport time of the moisture towards the SPI indicate the red lines in days before arrival. The averaged mean sea level pressure (gray lines) and sea ice cover (gray shaded area) are depicted as well

4 MAY 2016 - EN ROUTE PRECIPITATION

Section 5.3 in the original manuscript analyzed the trajectories from May 2016. Figure S9 shows the same subset of trajectories as in Figure 11. It illustrates the en route precipitation upstream (east) of the Andes cordillera and the moisture uptake in the south-west South Atlantic.

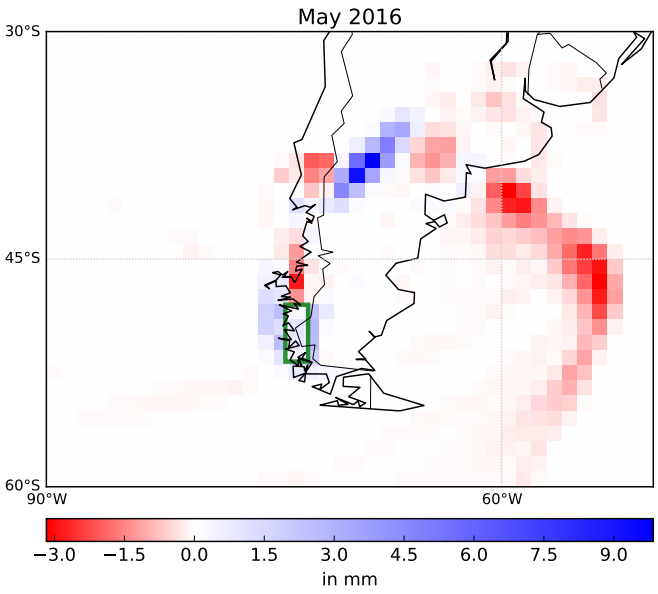

Figure S9: Sample of trajectories with moisture uptake in the south-west South Atlantic during May 2016. Red contours denotes evaporation and blue contours en route precipitation in mm along the trajectory. The green rectangle demarcate the trajectory starting position.

5 DETECTION EFFICIENCY

Table S1 summarizes the informations about the moisture source detection efficiency. The number of trajectories gives the fraction of trajectories, which satisfies the selection criteria. The number of trajectories correlates positive with the monthly mean precipitation.

	number of trajectories in %	f in %	e in %	d in %
1979-2017	27.1	71.4	25.1	3.5
DJF	27.9	64.8	29.1	6.1
MAM	28.9	71.3	25.2	3.5
JJA	26.1	76.5	21.6	1.8
SON	26.4	72.8	24.5	2.7
low RRR	20.6	71.9	25.1	3.0
heavy RRR	32.5	69.6	26.4	4.0
AOI < -1.23	26.8	72.5	23.9	3.6
AOI > 1.23	26.4	71.5	25.5	3.0
El-Niño	25.3	69.9	27.3	3.8
La-Niña	28.7	69.9	25.7	2.6
February 1983	30.9	62.2	31.5	6.3
February 2016	26.7	64.0	31.1	4.9
May 2016	12.7	50.1	46.9	3.0

Table S1. Summary of all investigated cases. Number of trajectory indicates the fraction of trajectories which satisfy the selection criteria from all 198 staring positions. f fraction of moisture sources within the scaled planetary boundary layer (PBL), e above scaled PBL moisture uptake fraction and d fraction of unknown moisture source.

REFERENCES

[Dataset] National Oceanic and Atmospheric Administration (2017). ENSO: Recent Evolution, Current Status and Predictions. `http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf`. Accessed March 10, 2017