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Supplement of

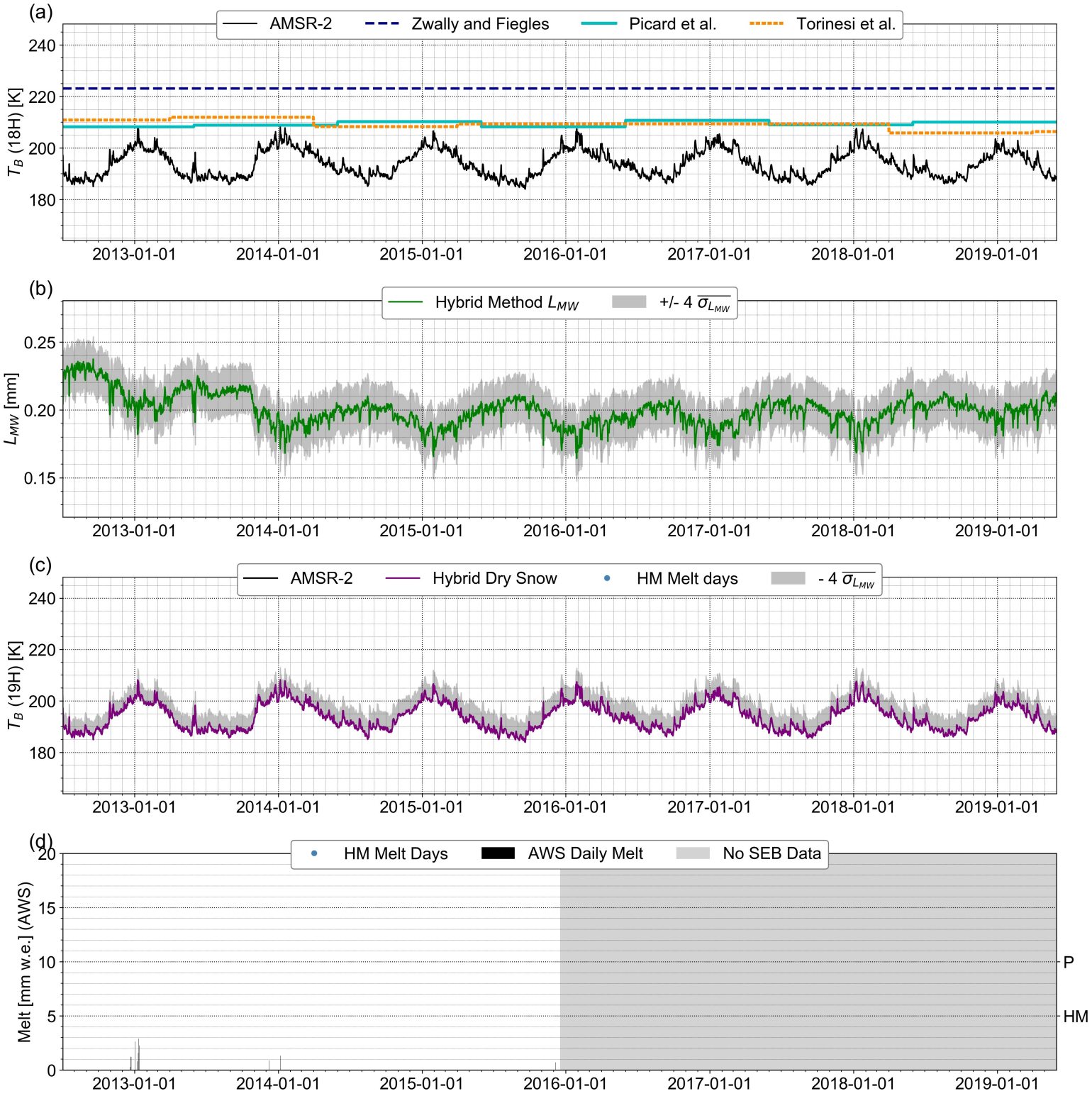
A physics-based Antarctic melt detection technique: combining Advanced Microwave Scanning Radiometer 2, radiative-transfer modeling, and firn modeling

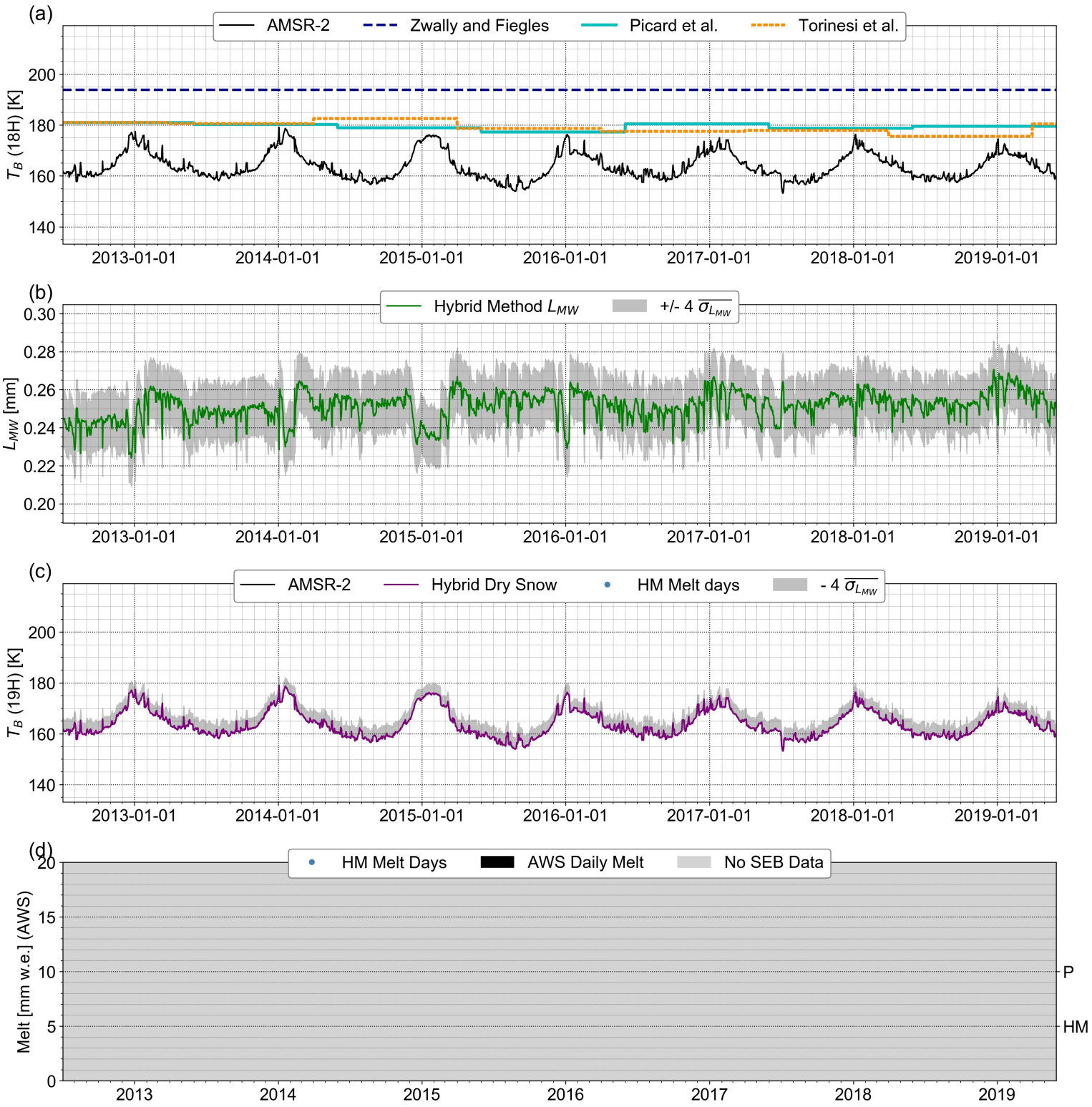
Marissa E. Dattler et al.

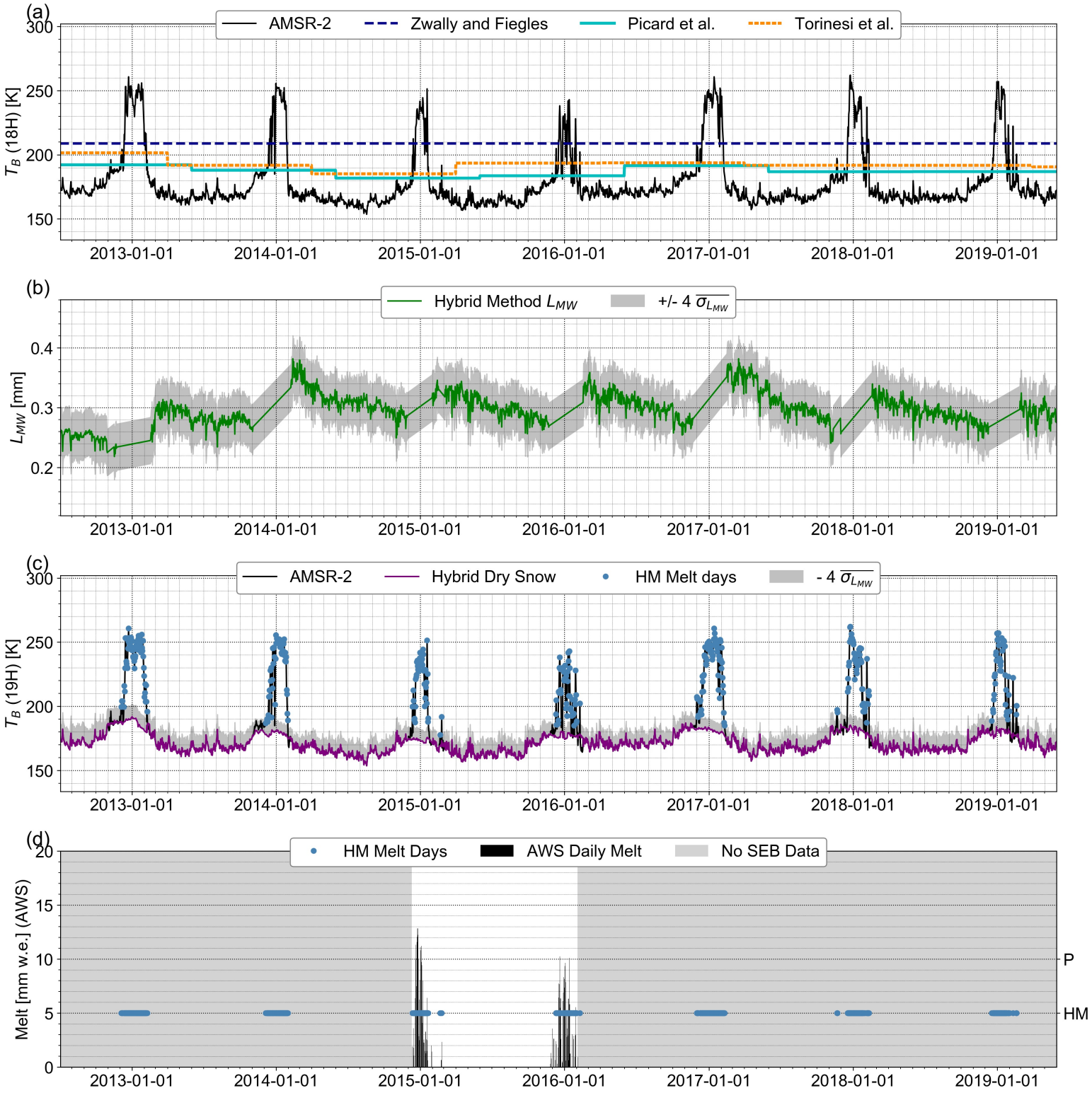
Correspondence to: Marissa E. Dattler (marissa.e.dattler@nasa.gov)

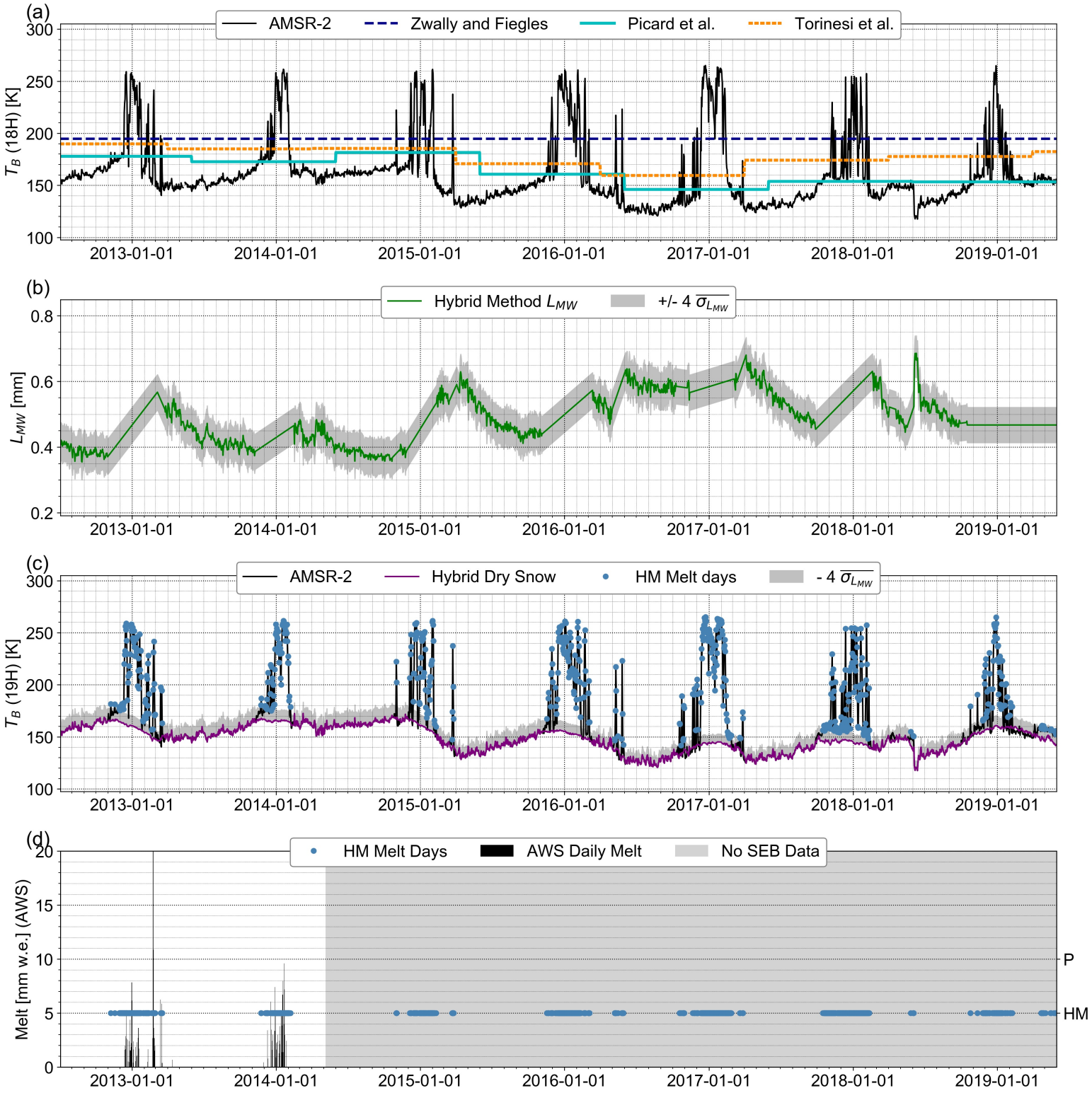
Figure S1-S15: Melt detection for fifteen sites. (a) Brightness temperature from 19H from AMSR-2 (black line) with thresholding techniques from Zwally and Fiegles (1994; dashed dark blue line), Torinesi et al. (2003; dotted orange line), and Picard et al. (2022a; solid cyan line). (b) Microwave grain size computed from the Hybrid Method (19H; green line) along with +/- 4$\overline{\sigma_{L_{MW}}}$ bounds. (c) AMSR-2 brightness temperature (19H; black line). Hybrid Method dry snow brightness temperature (19H; purple line) with propagated -4$\overline{\sigma_{L_{MW}}}$ (grey bounds). Melt days detected by Hybrid Method (blue dots). (d) Melt days detected by Hybrid Method (blue dots). These represent melt days versus non-melt days in a binary fashion and do not reflect a specific melt volume. AWS surface energy balance melt data (black bars). Grey area represents time period where AWS-derived data are unavailable.

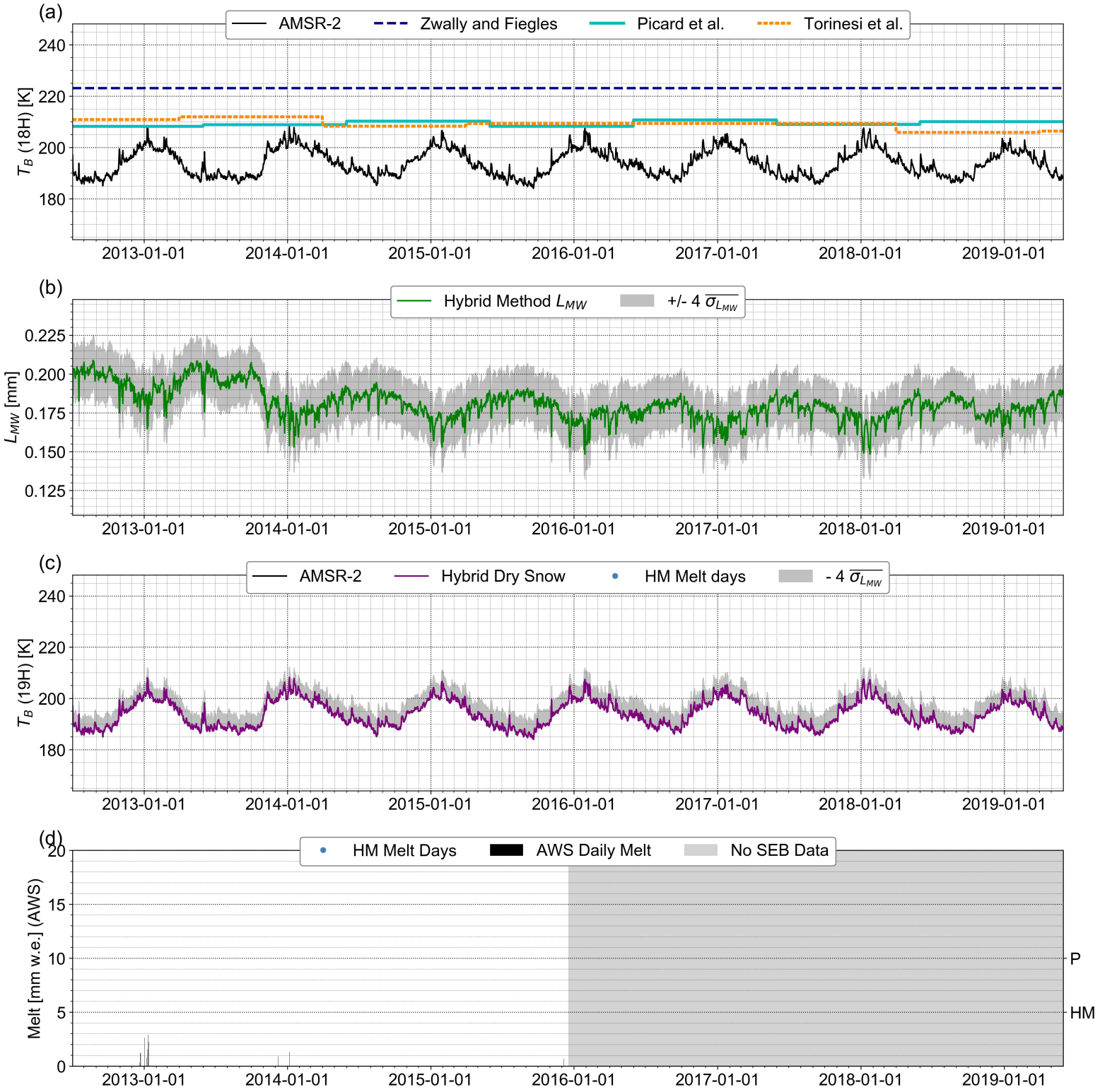
Figure S16-S30: Microwave grain size for fifteen sites. (a) Brightness temperature from 19H from AMSR-2 (black line) with thresholding techniques from Zwally and Fiegles (1994; dashed dark blue line), Torinesi et al. (2003; dotted orange line), and Picard et al. (2022a; solid cyan line). (b) Microwave grain size computed from the Hybrid Method (19V; green line) along with +/- 4$\overline{\sigma_{L_{MW}}}$ bounds.


Site: AWS16 (Bias Corrected), Channel: 18H
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
240
220
200
180
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.25
0.20
0.15
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(c)
AMSR-2
Hybrid Dry Snow
HM Melt days
- 4 $\overline{\sigma_{L_{MW}}}$
T_B (19H) [K]
240
220
200
180
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(d)
HM Melt Days
AWS Daily Melt
No SEB Data
Melt [mm w.e.] (AWS)
20
15
10
5
0
P
HM
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01

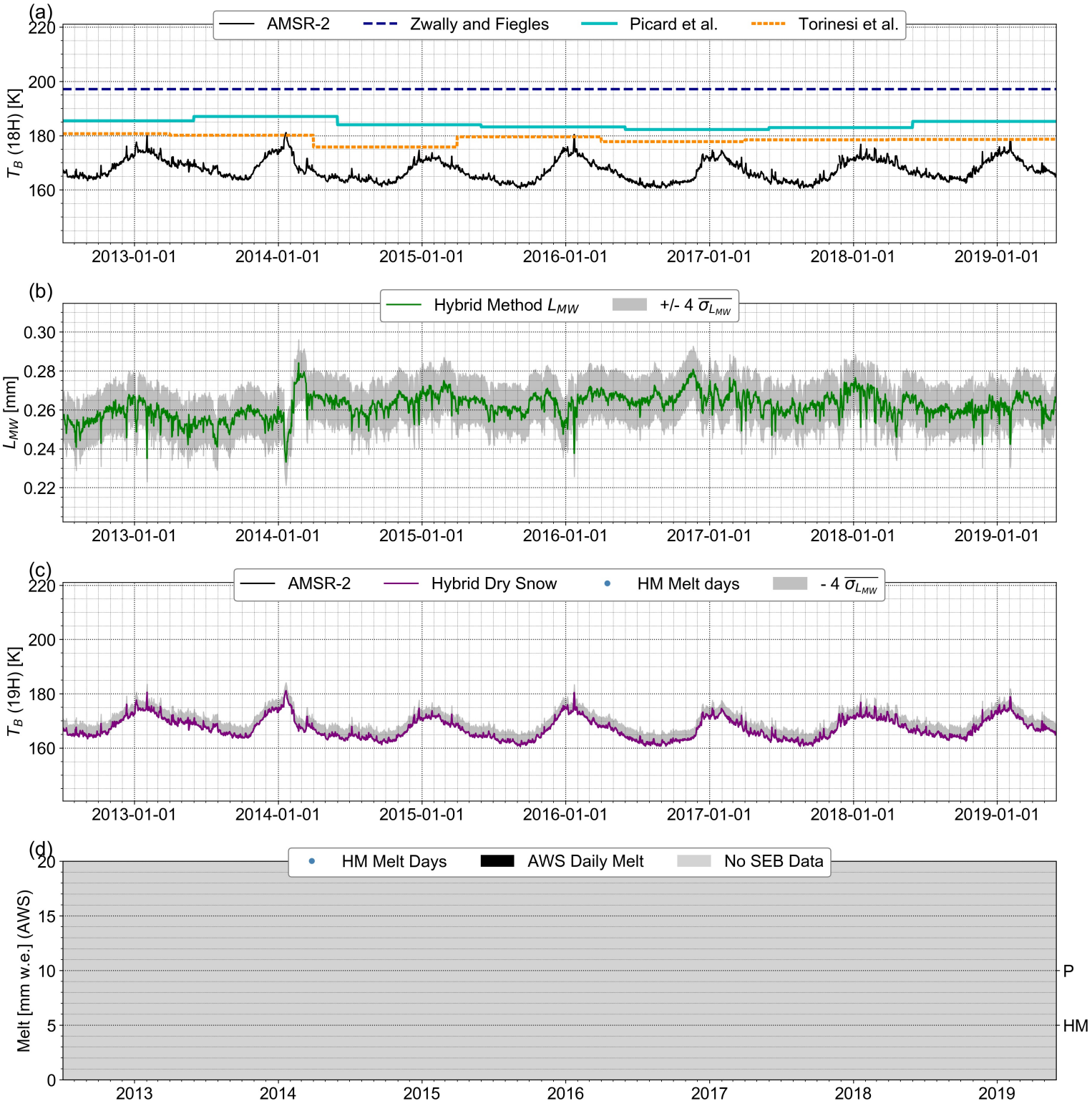

Site: Dome C (Bias Corrected), Channel: 18H
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
200
180
160
140
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.30
0.28
0.26
0.24
0.22
0.20
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(c)
AMSR-2
Hybrid Dry Snow
HM Melt days
- 4 $\overline{\sigma_{L_{MW}}}$
T_B (19H) [K]
200
180
160
140
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(d)
HM Melt Days
AWS Daily Melt
No SEB Data
Melt [mm w.e.] (AWS)
20
15
10
5
0
P
HM
2013
2014
2015
2016
2017
2018
2019

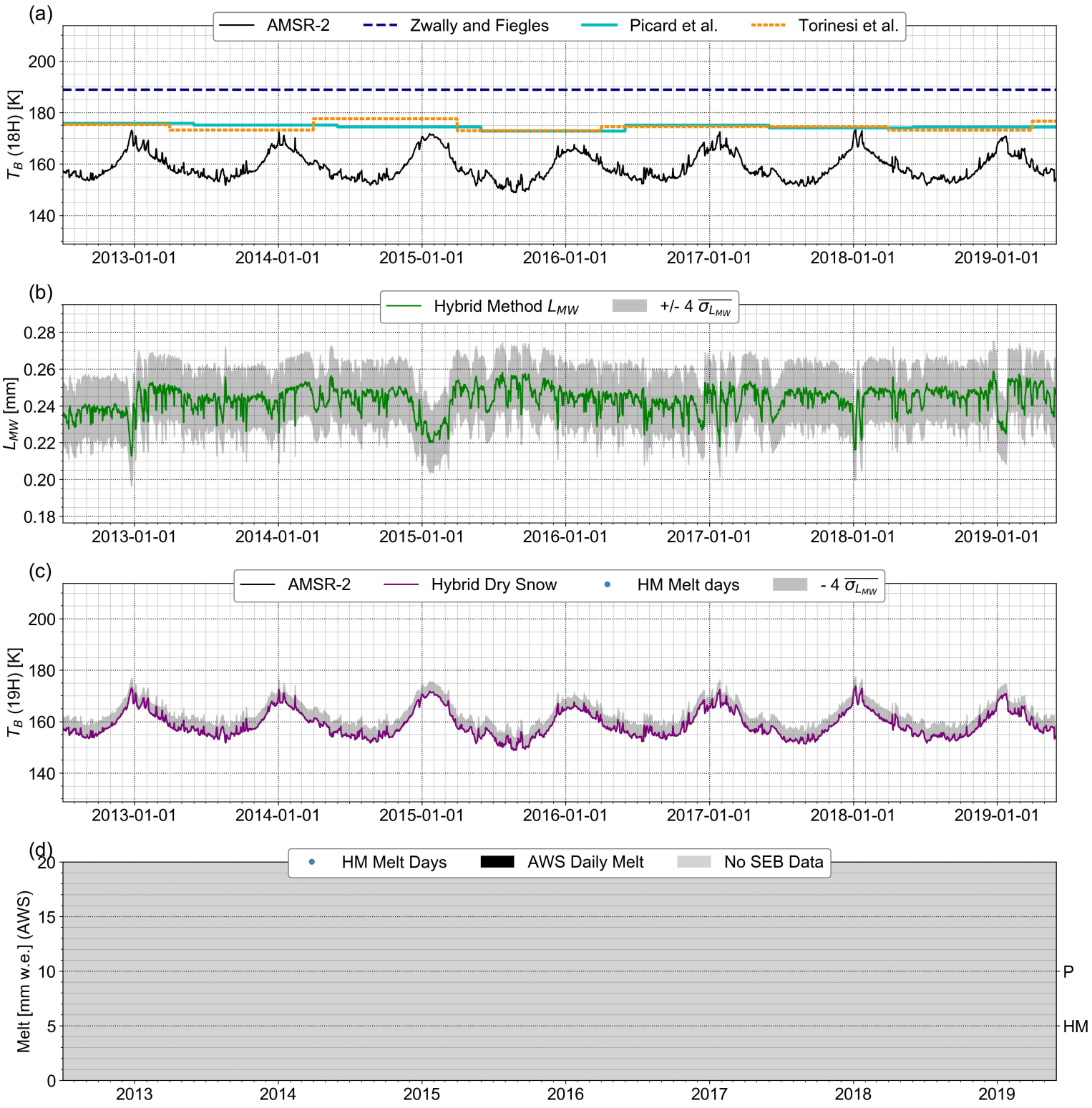

Site: AWS 19, Channel: 18H
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
300
250
200
150
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.4
0.3
0.2
(c)
AMSR-2
Hybrid Dry Snow
HM Melt days
- 4 $\overline{\sigma_{L_{MW}}}$
T_B (19H) [K]
(d)
HM Melt Days
AWS Daily Melt
No SEB Data
Melt [mm w.e.] (AWS)
20
15
10
5
0
P
HM


Site: AWS 15, Channel: 18H
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
300
250
200
150
100
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.8
0.6
0.4
0.2
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(c)
AMSR-2
Hybrid Dry Snow
HM Melt days
- 4 $\overline{\sigma_{L_{MW}}}$
T_B (19H) [K]
300
250
200
150
100
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(d)
HM Melt Days
AWS Daily Melt
No SEB Data
Melt [mm w.e.] (AWS)
20
15
10
5
0
P
HM
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01

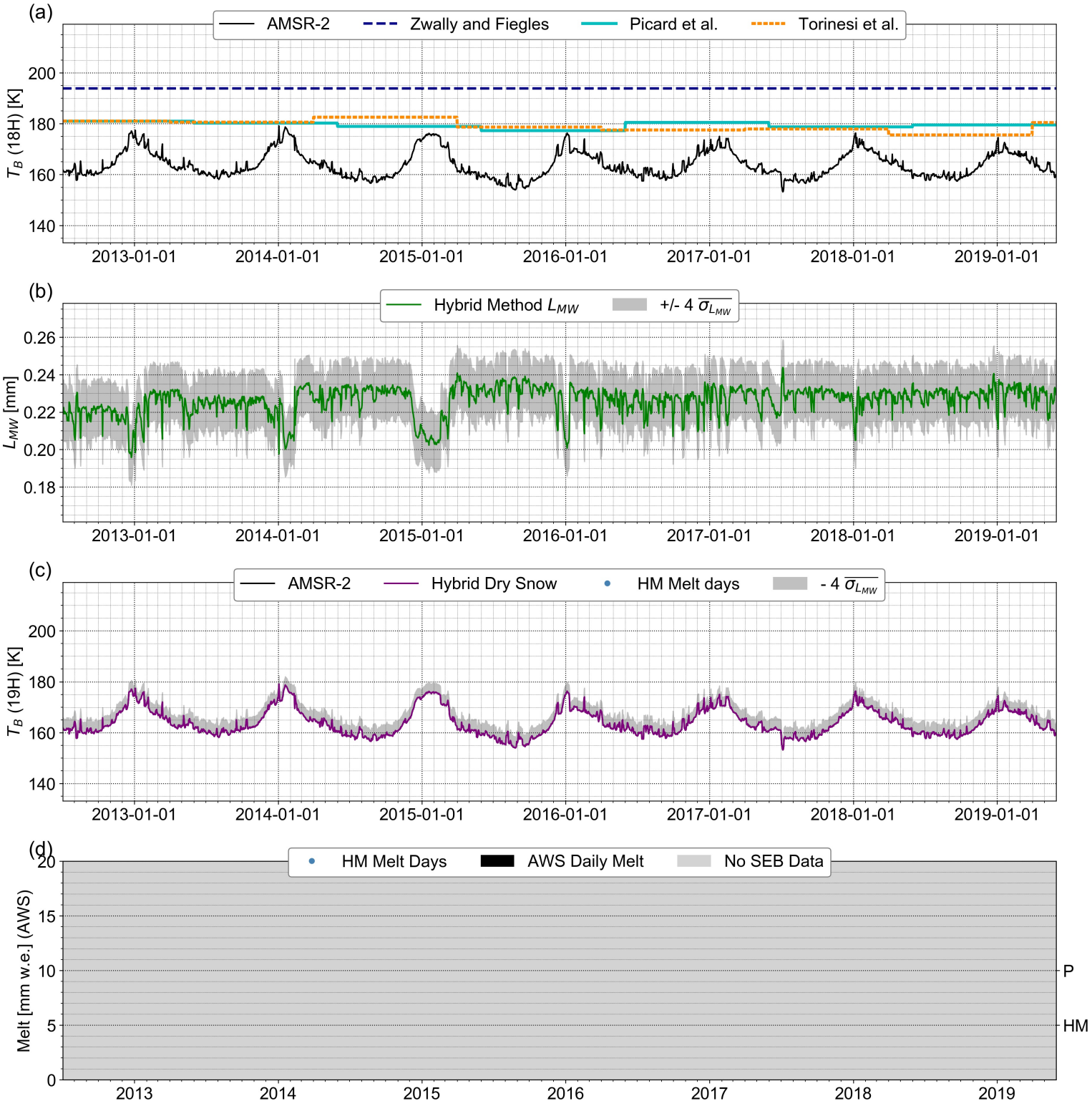

Site: AWS 16, Channel: 18H
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
240
220
200
180
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.225
0.200
0.175
0.150
0.125
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(c)
AMSR-2
Hybrid Dry Snow
HM Melt days
- 4 $\overline{\sigma_{L_{MW}}}$
T_B (19H) [K]
240
220
200
180
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(d)
HM Melt Days
AWS Daily Melt
No SEB Data
Melt [mm w.e.] (AWS)
20
15
10
5
0
P
HM
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01

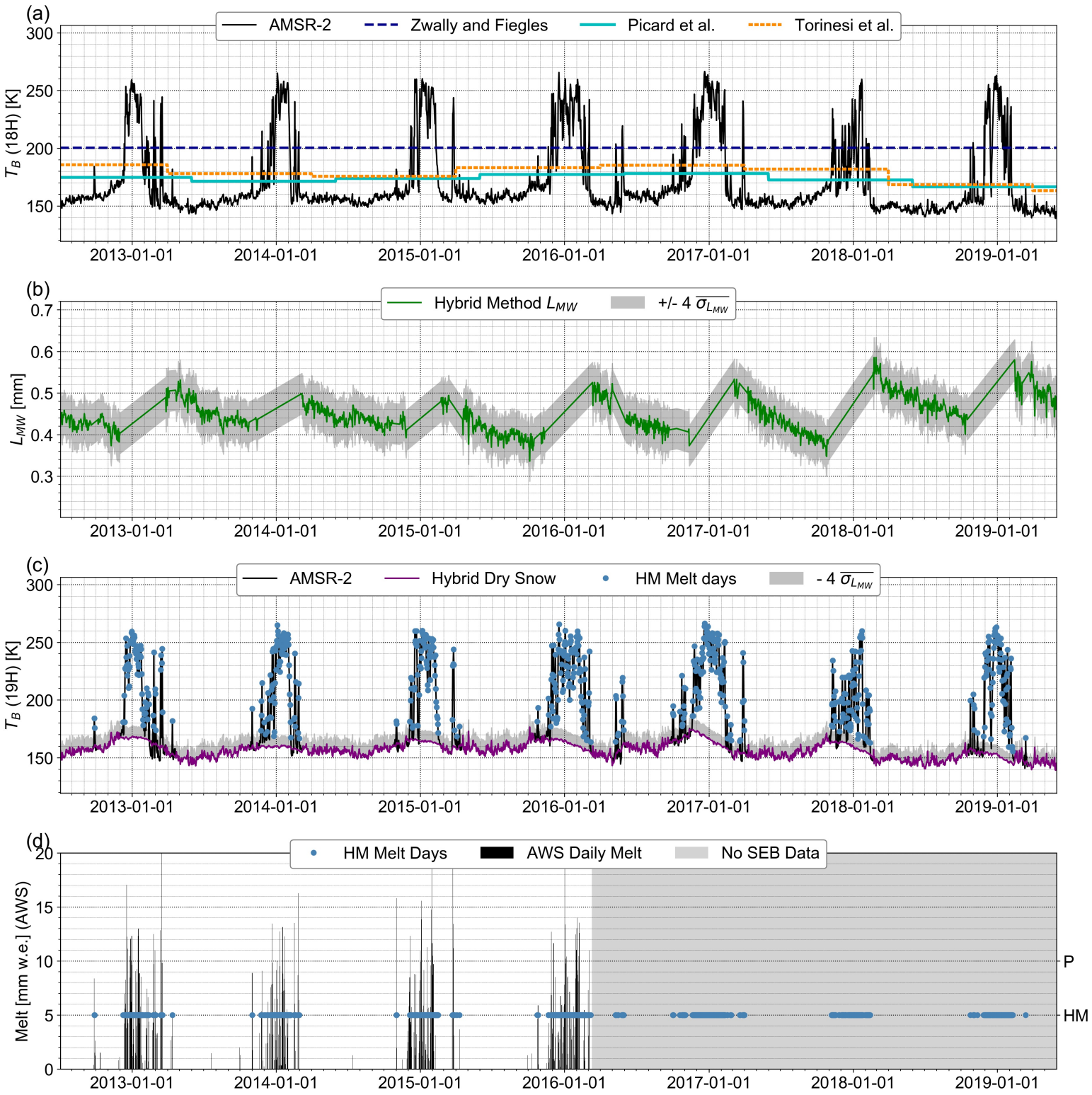
Site: Kohnen, Channel: 18H

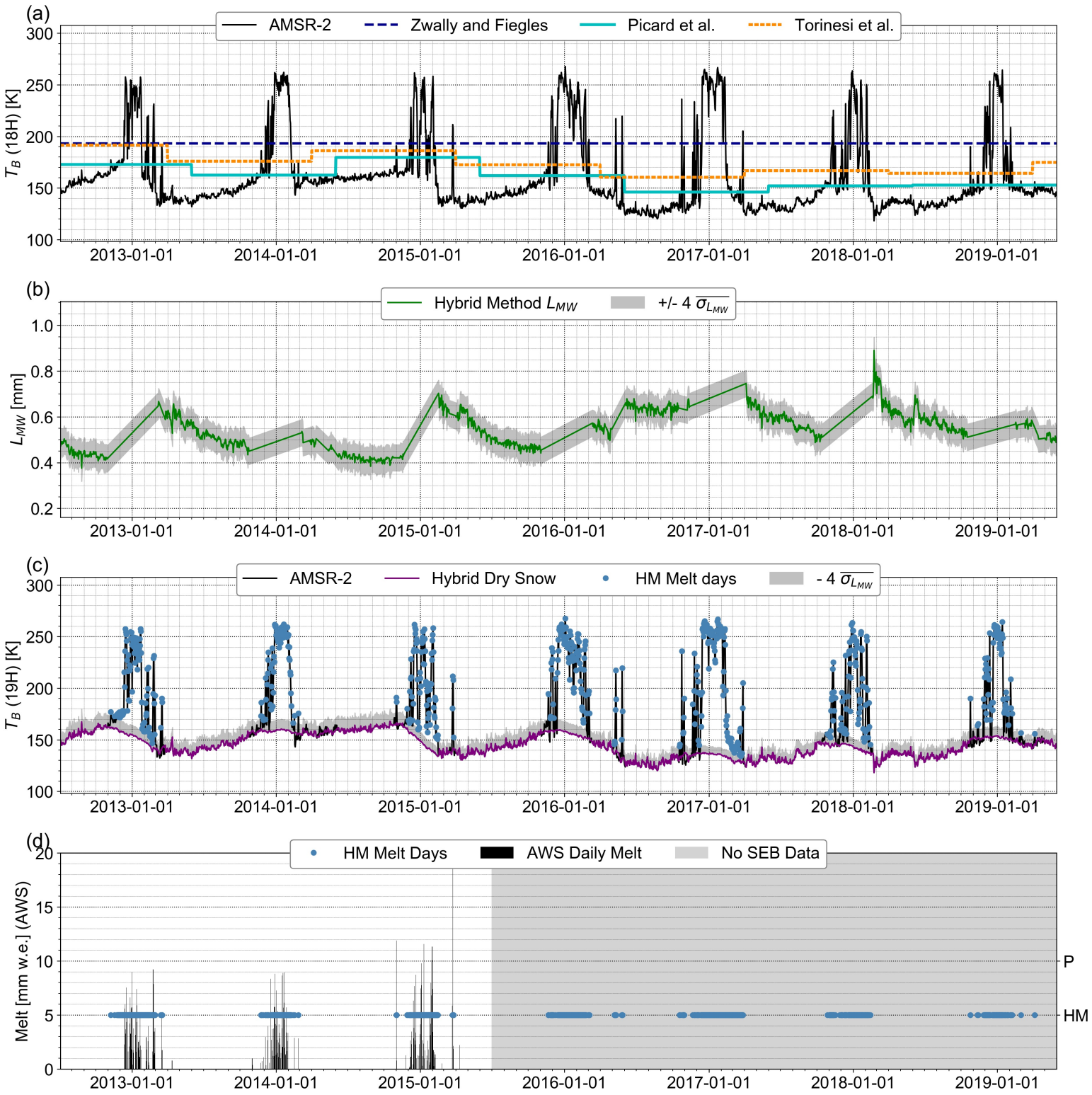


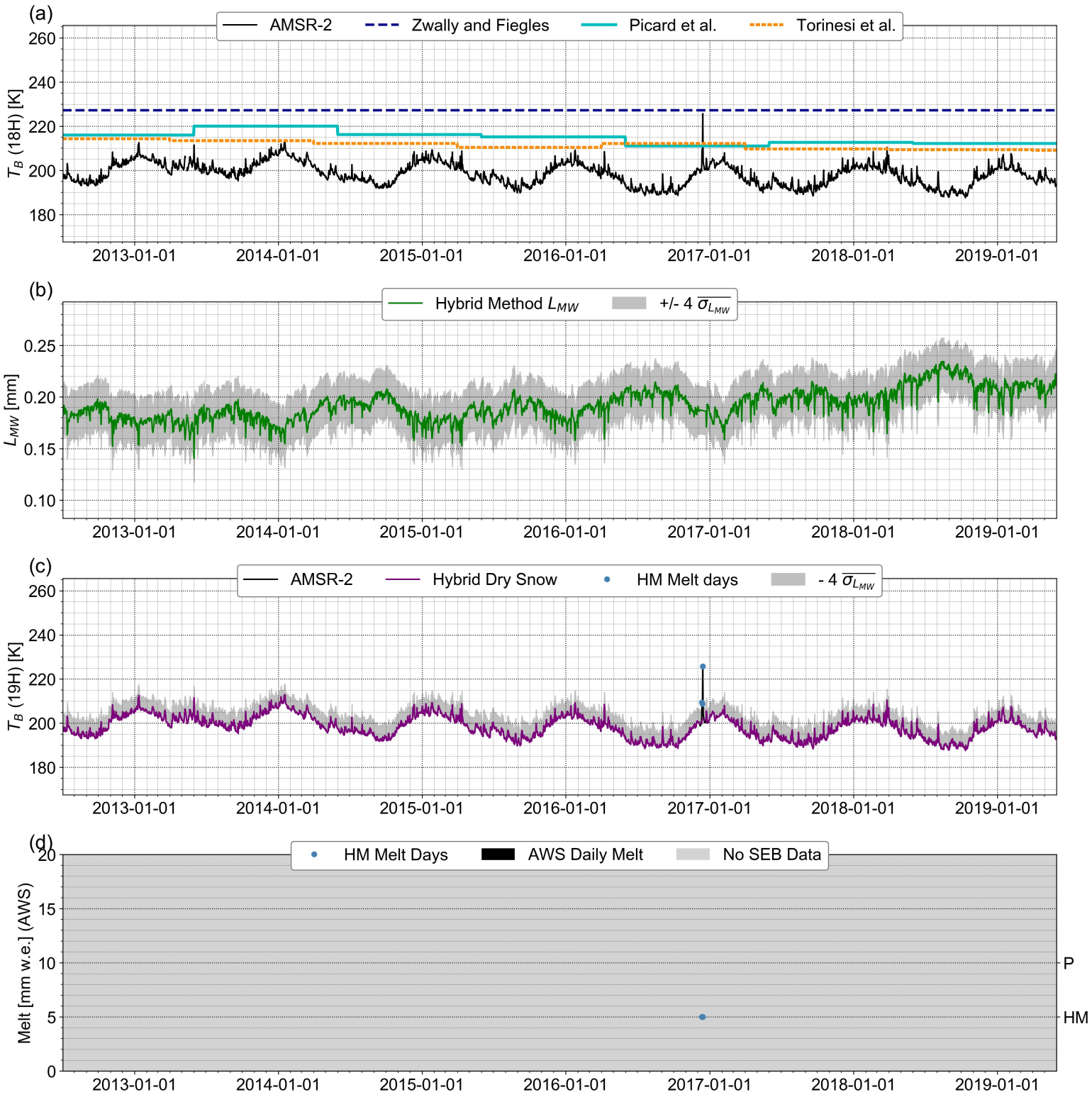

Site: Point Barnola, Channel: 18H
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
200
180
160
140
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.28
0.26
0.24
0.22
0.20
0.18
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(c)
AMSR-2
Hybrid Dry Snow
HM Melt days
- 4 $\overline{\sigma_{L_{MW}}}$
T_B (19H) [K]
200
180
160
140
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(d)
HM Melt Days
AWS Daily Melt
No SEB Data
Melt [mm w.e.] (AWS)
20
15
10
5
0
P
HM
2013
2014
2015
2016
2017
2018
2019

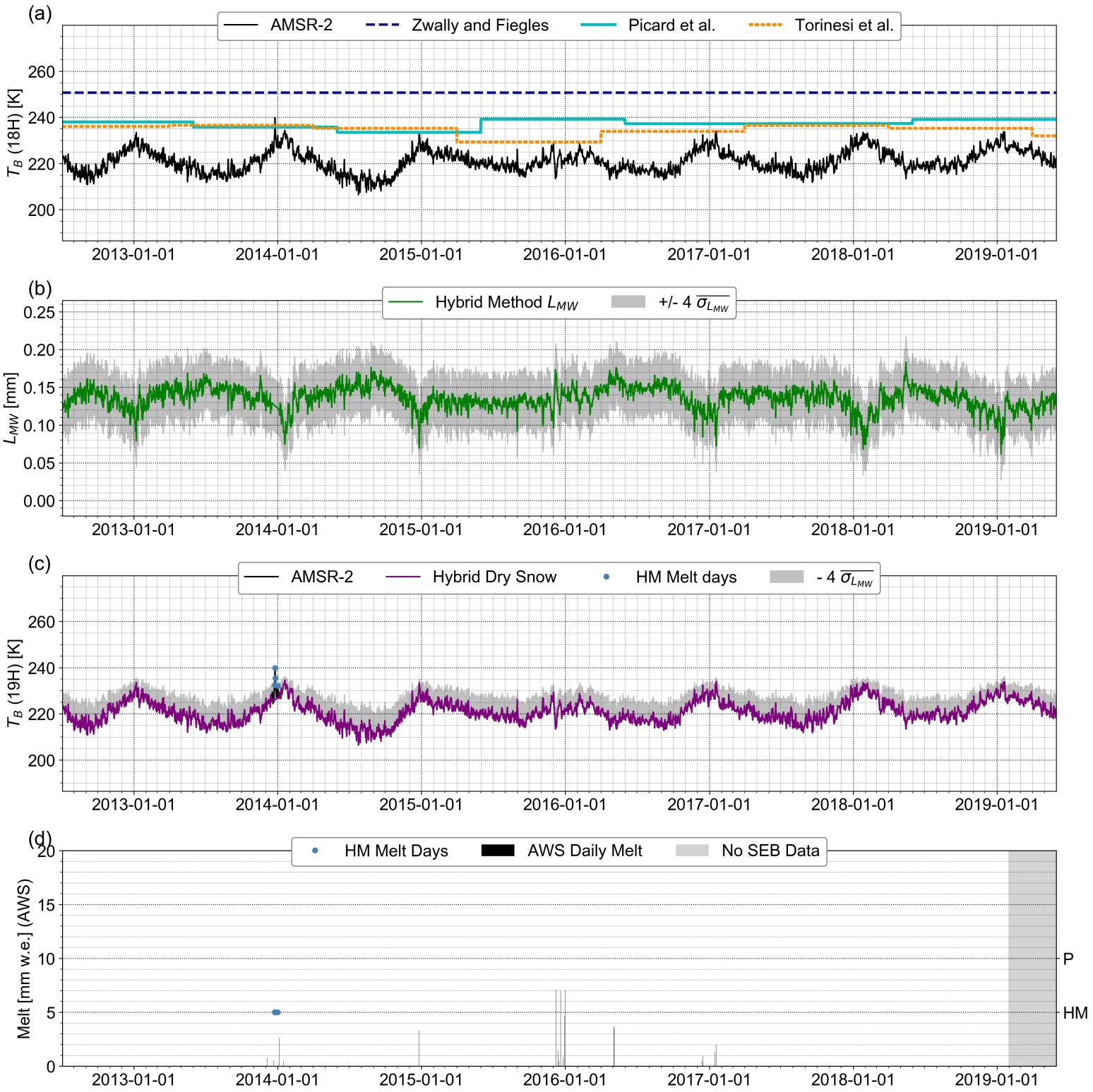
Site: Dome C, Channel: 18H

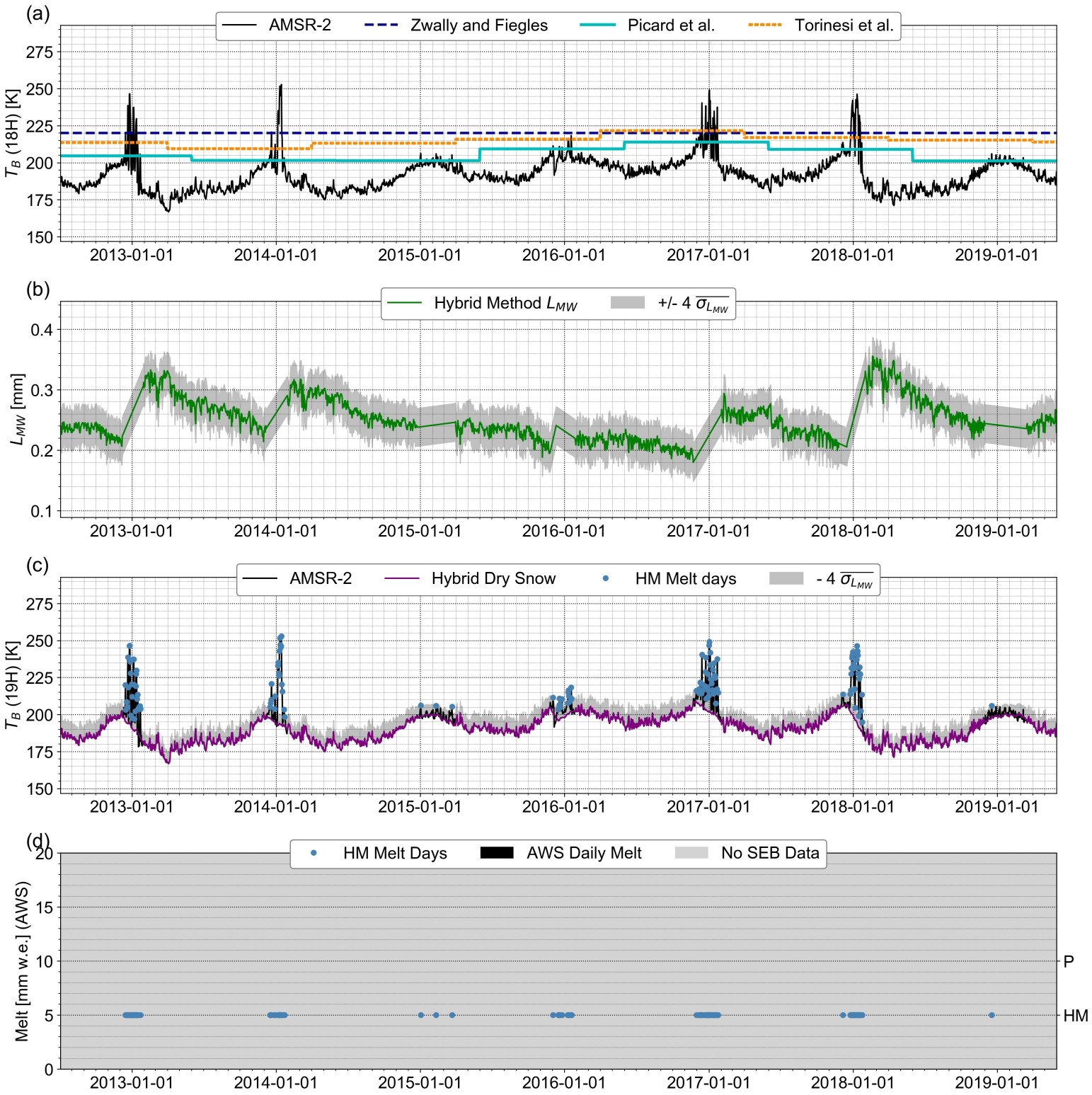


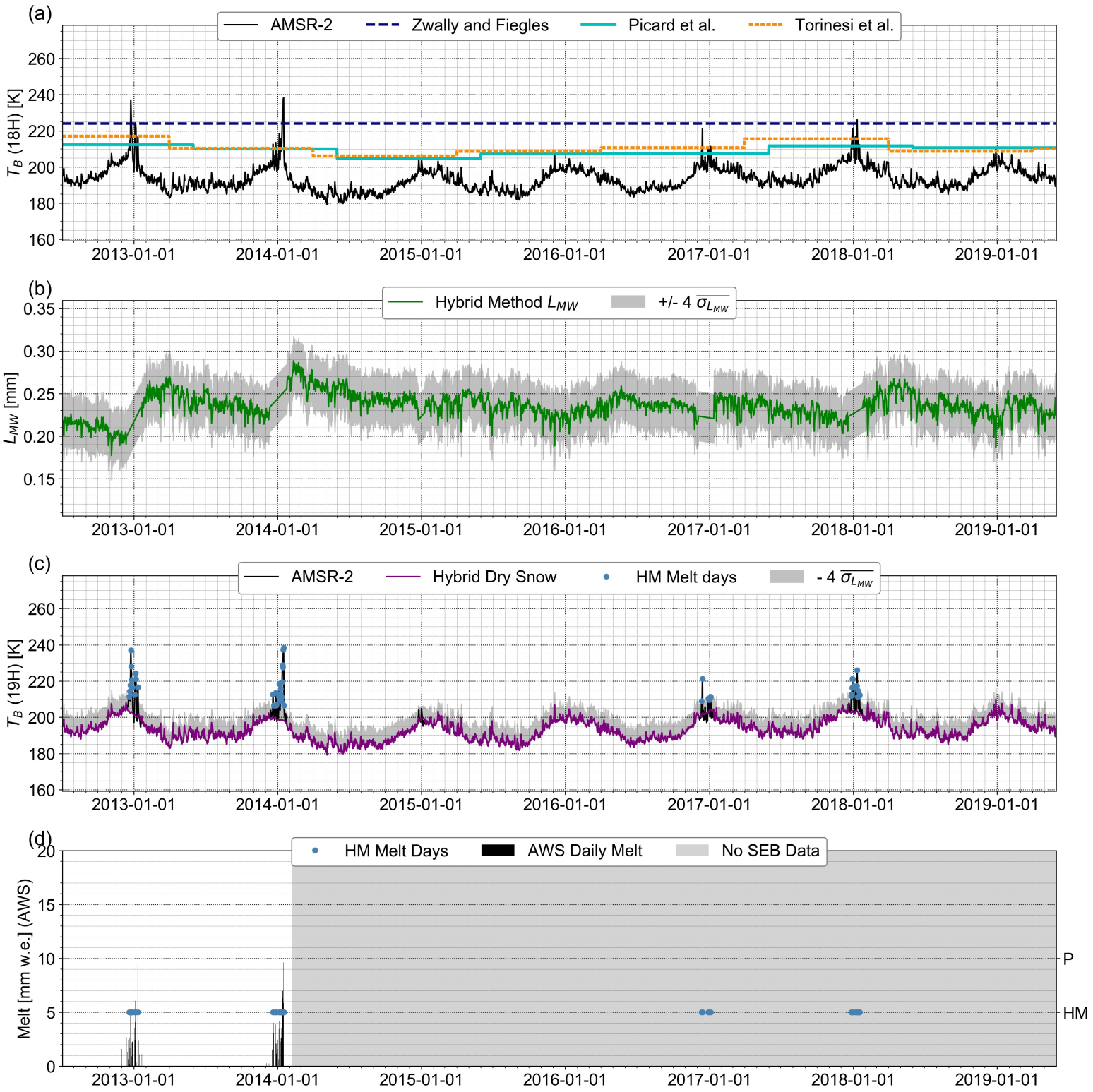

Site: AWS 17, Channel: 18H
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
300
250
200
150
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.7
0.6
0.5
0.4
0.3
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(c)
AMSR-2
Hybrid Dry Snow
HM Melt days
- 4 $\overline{\sigma_{L_{MW}}}$
T_B (19H) [K]
300
250
200
150
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(d)
HM Melt Days
AWS Daily Melt
No SEB Data
Melt [mm w.e.] (AWS)
20
15
10
5
0
P
HM
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01

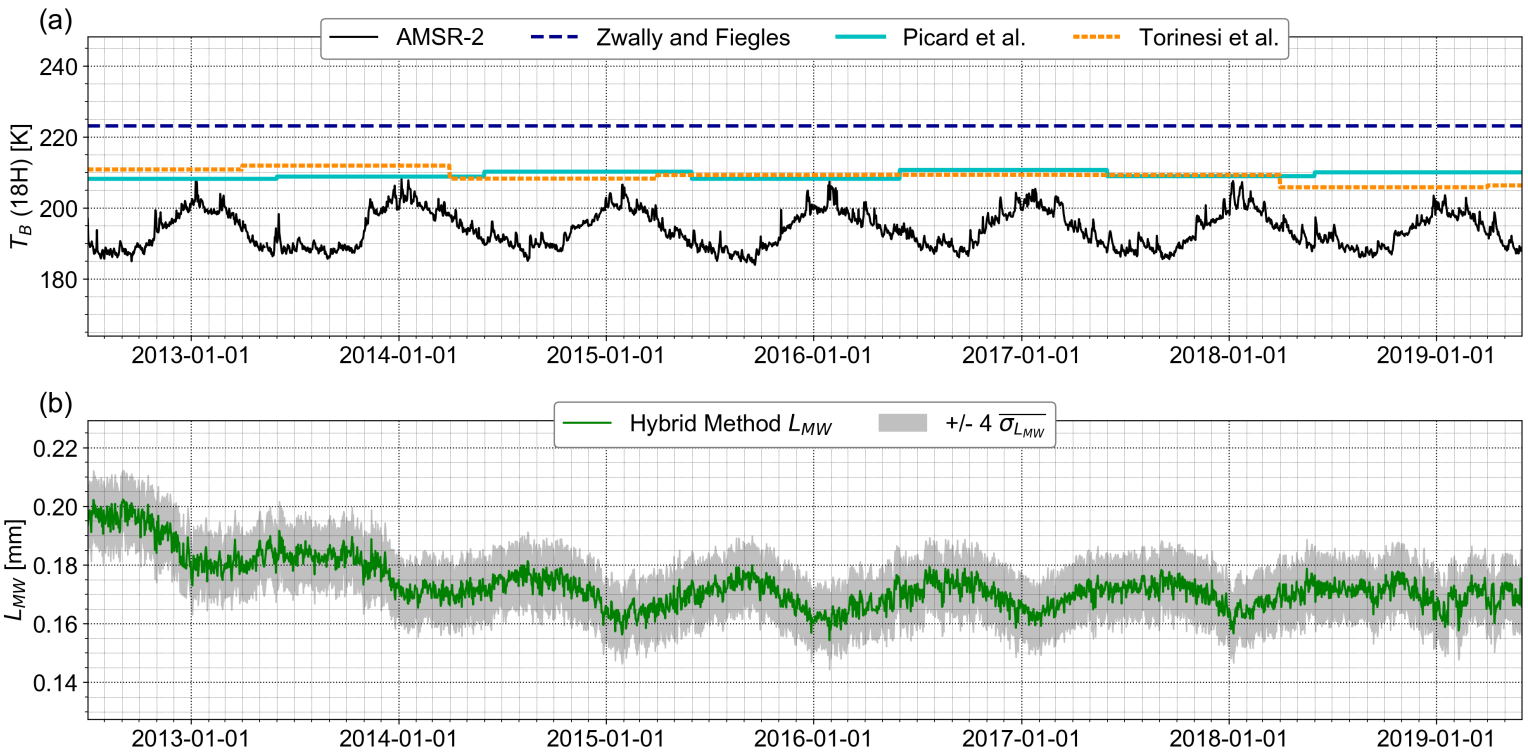

Site: AWS 14, Channel: 18H
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
300
250
200
150
100
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
1.0
0.8
0.6
0.4
0.2
(c)
AMSR-2
Hybrid Dry Snow
HM Melt days
- 4 $\overline{\sigma_{L_{MW}}}$
T_B (19H) [K]
(d)
HM Melt Days
AWS Daily Melt
No SEB Data
Melt [mm w.e.] (AWS)
20
15
10
5
0
P
HM

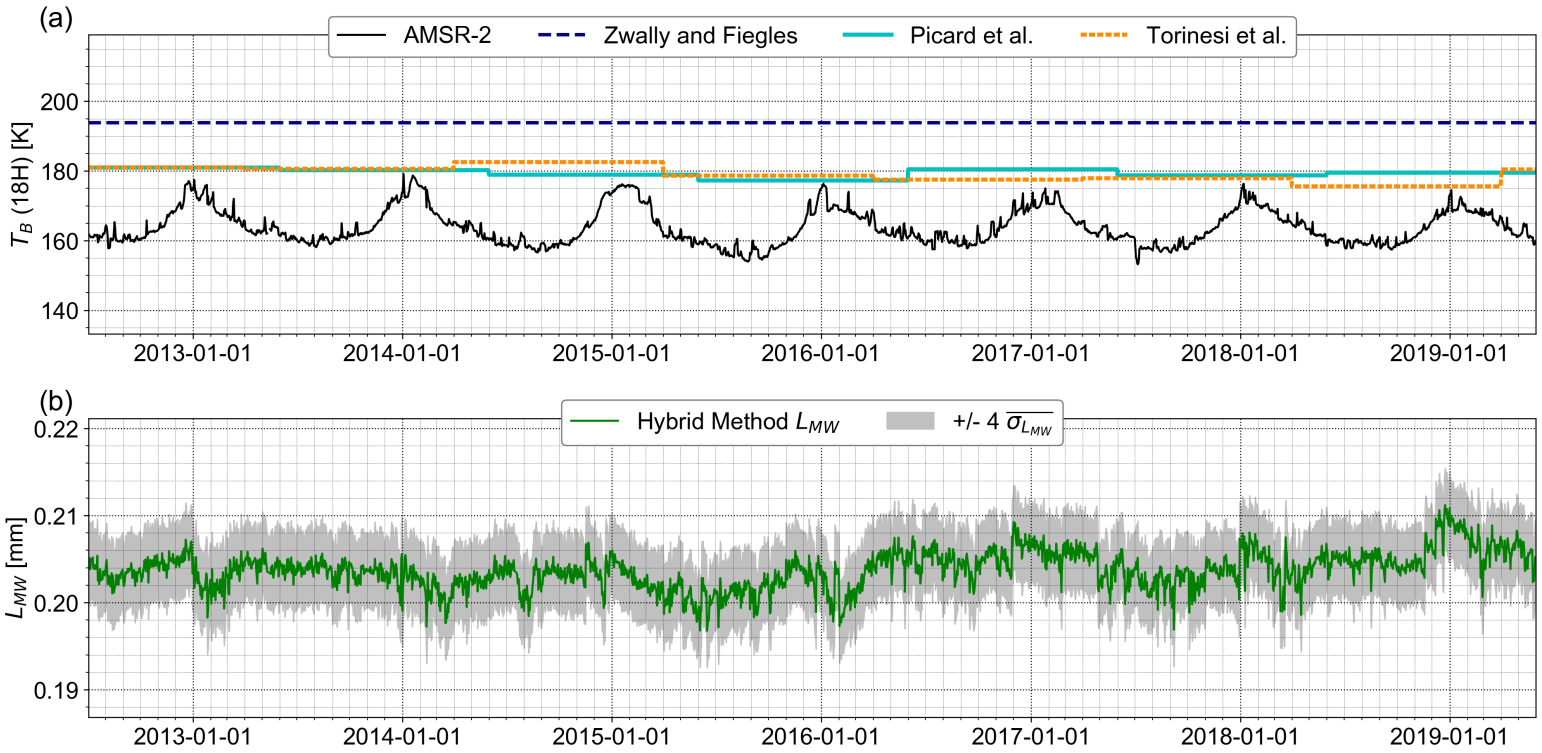

Site: AWS 6, Channel: 18H
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
260
240
220
200
180
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.25
0.20
0.15
0.10
(c)
AMSR-2
Hybrid Dry Snow
HM Melt days
- 4 $\overline{\sigma_{L_{MW}}}$
T_B (19H) [K]
(d)
HM Melt Days
AWS Daily Melt
No SEB Data
Melt [mm w.e.] (AWS)
20
15
10
5
0
P
HM


Site: AWS 11, Channel: 18H
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
260
240
220
200
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.25
0.20
0.15
0.10
0.05
0.00
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(c)
AMSR-2
Hybrid Dry Snow
HM Melt days
- 4 $\overline{\sigma_{L_{MW}}}$
T_B (19H) [K]
260
240
220
200
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(d)
HM Melt Days
AWS Daily Melt
No SEB Data
Melt [mm w.e.] (AWS)
20
15
10
5
0
P
HM
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01

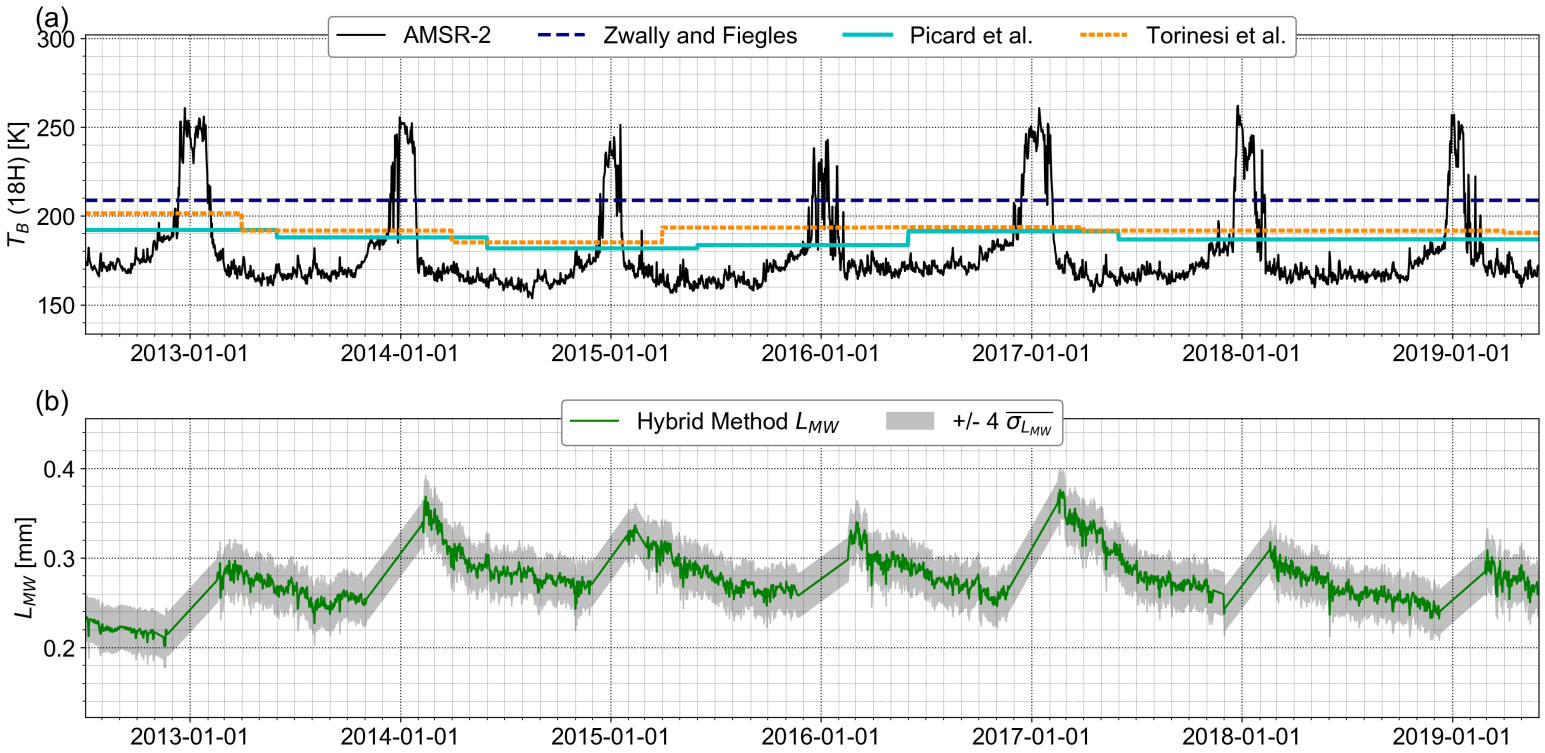

Site: AWS 4, Channel: 18H
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
(c)
AMSR-2
Hybrid Dry Snow
HM Melt days
- 4 $\overline{\sigma_{L_{MW}}}$
T_B (19H) [K]
(d)
HM Melt Days
AWS Daily Melt
No SEB Data
Melt [mm w.e.] (AWS)
P
HM
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01


Site: AWS 5, Channel: 18H
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
(c)
AMSR-2
Hybrid Dry Snow
HM Melt days
- 4 $\overline{\sigma_{L_{MW}}}$
T_B (19H) [K]
(d)
HM Melt Days
AWS Daily Melt
No SEB Data
Melt [mm w.e.] (AWS)
P
HM
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01

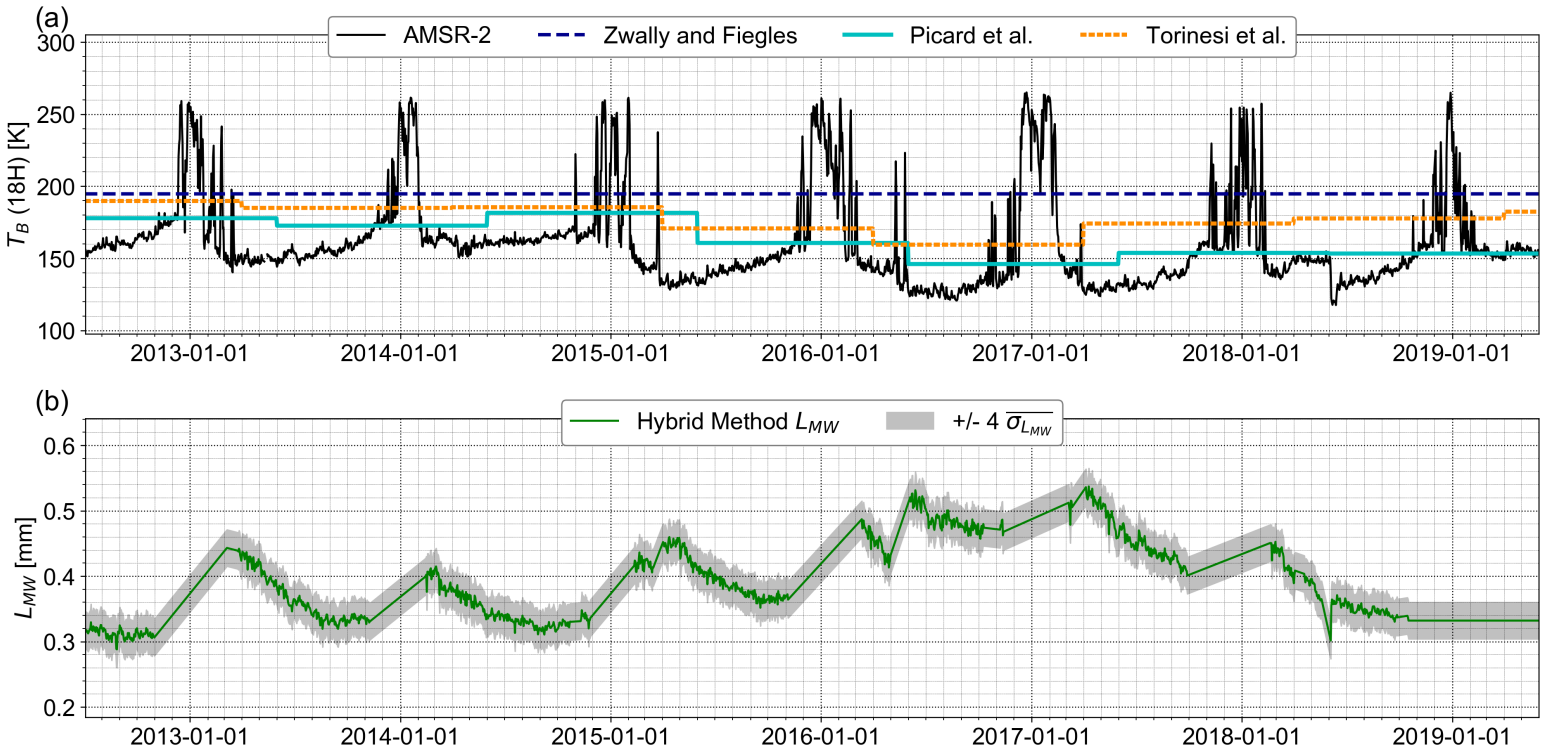

Site: AWS16 (Bias Corrected), Channel: 18V
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
240
220
200
180
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.22
0.20
0.18
0.16
0.14
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01


Site: Dome C (Bias Corrected), Channel: 18V
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
200
180
160
140
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.22
0.21
0.20
0.19
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01

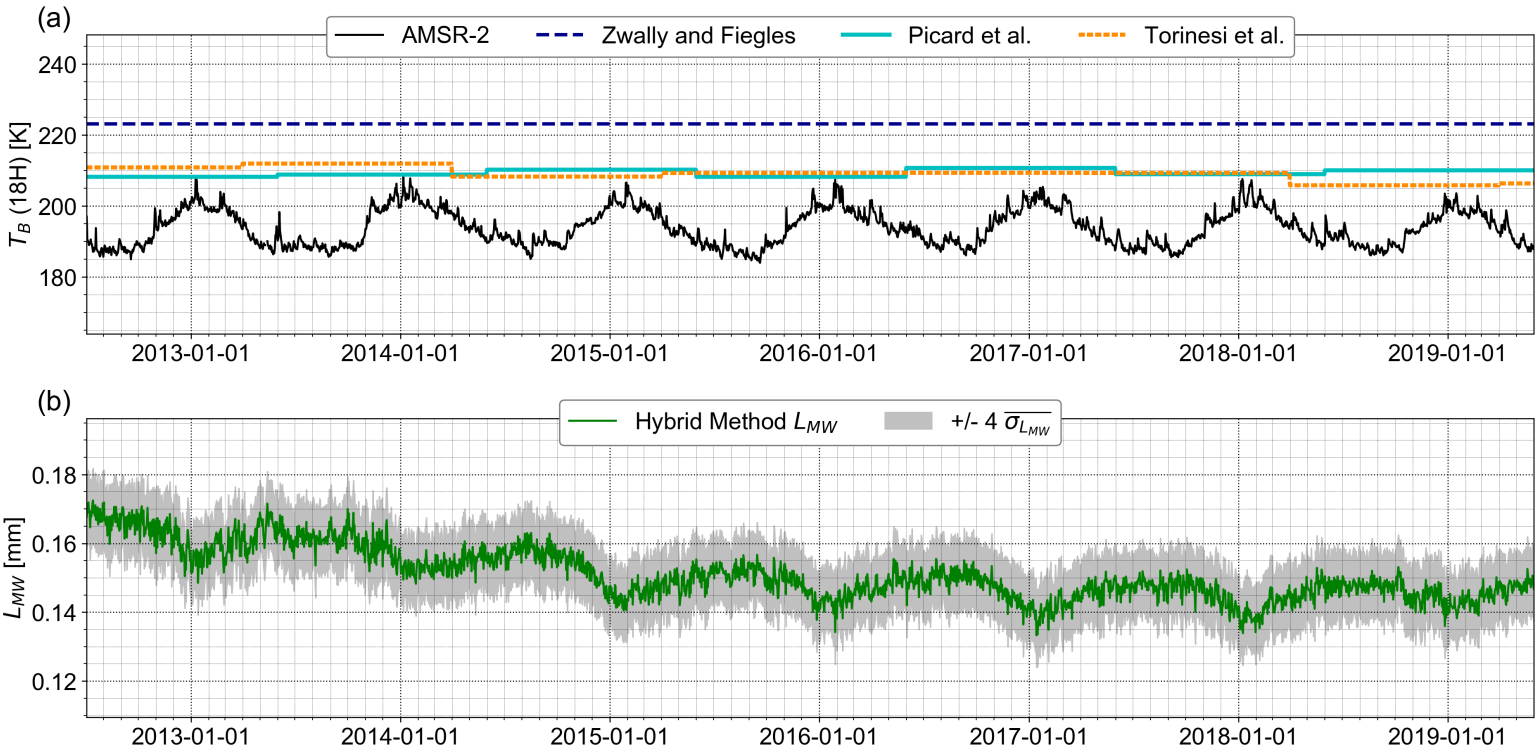
Site: AWS 19, Channel: 18V



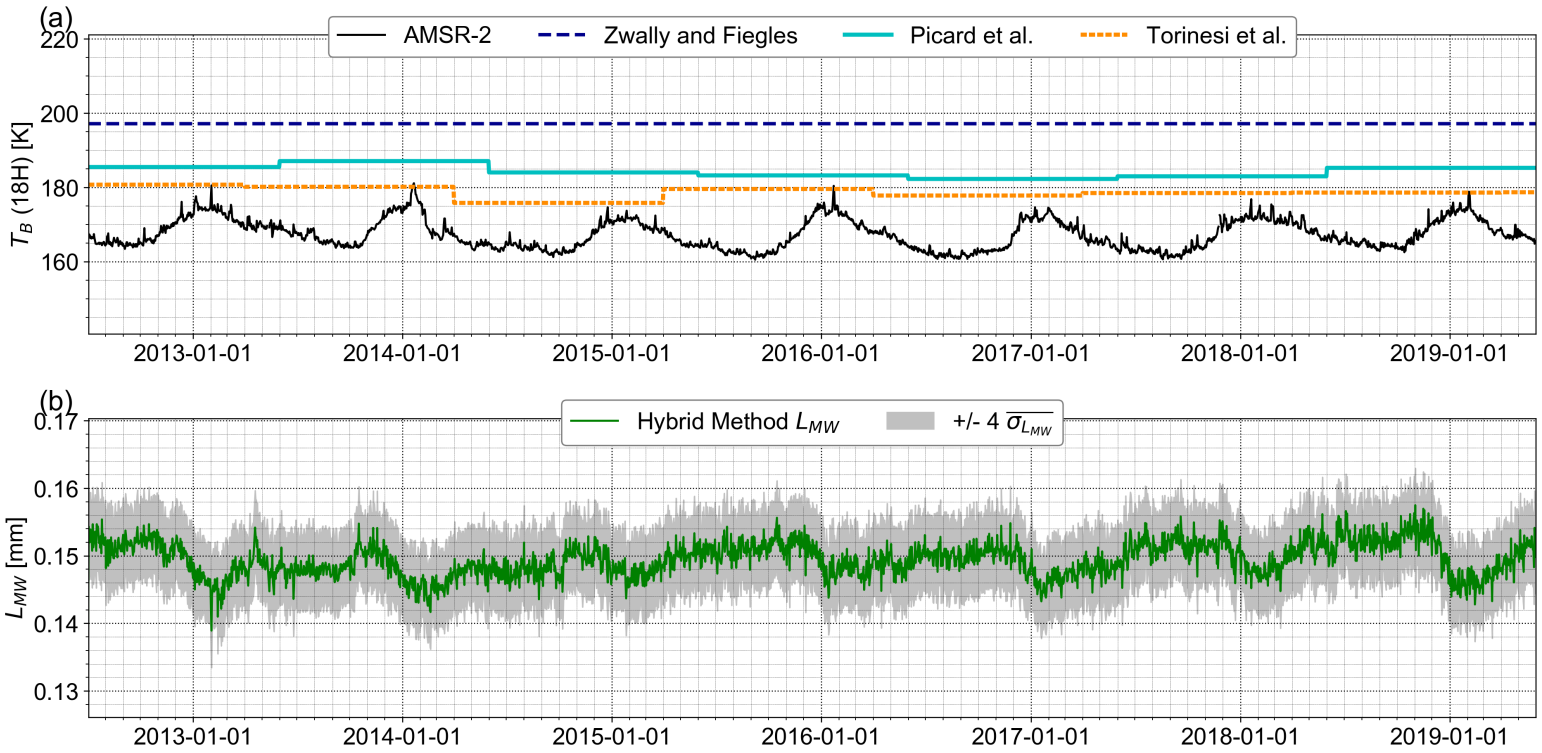
Site: AWS 15, Channel: 18V



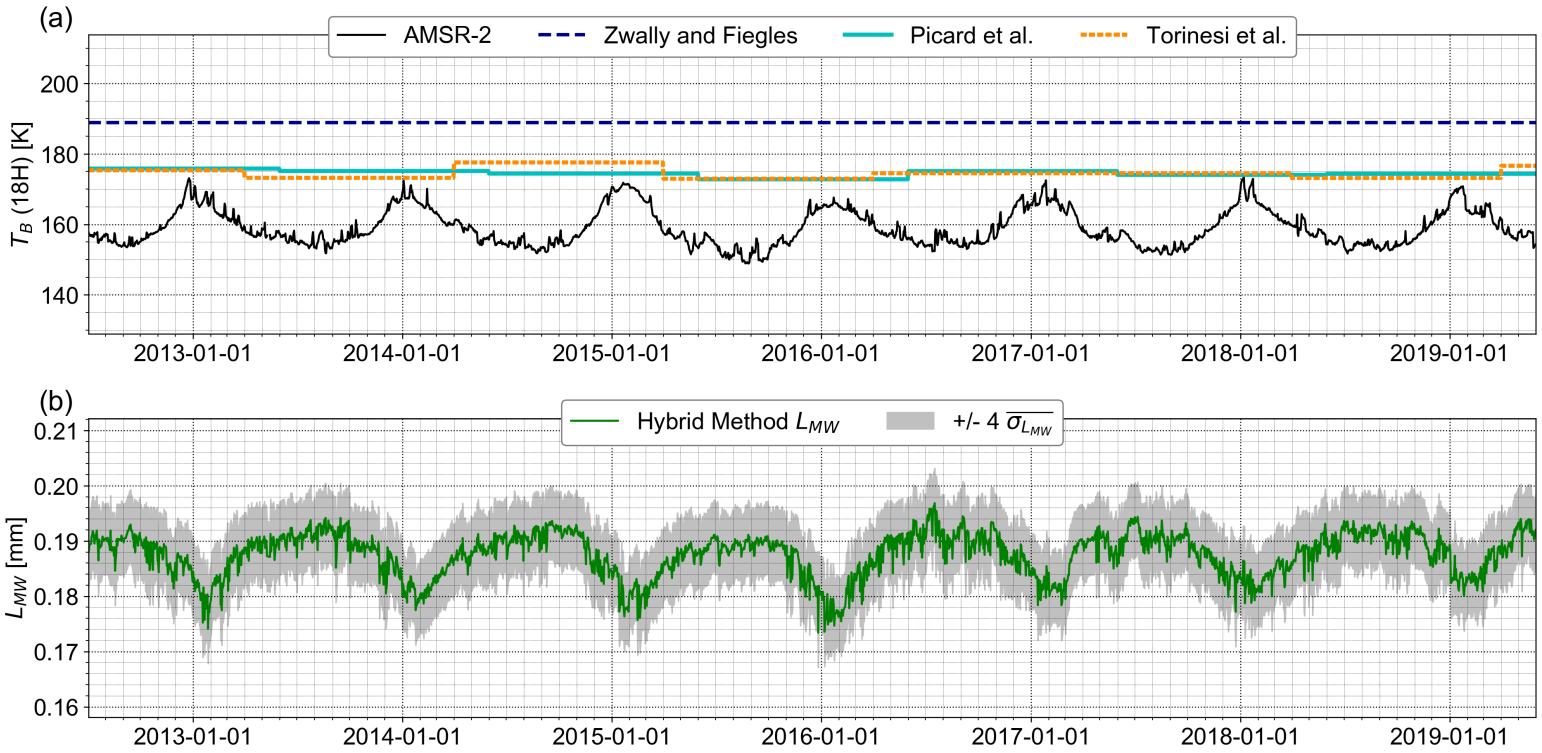
Site: AWS 16, Channel: 18V



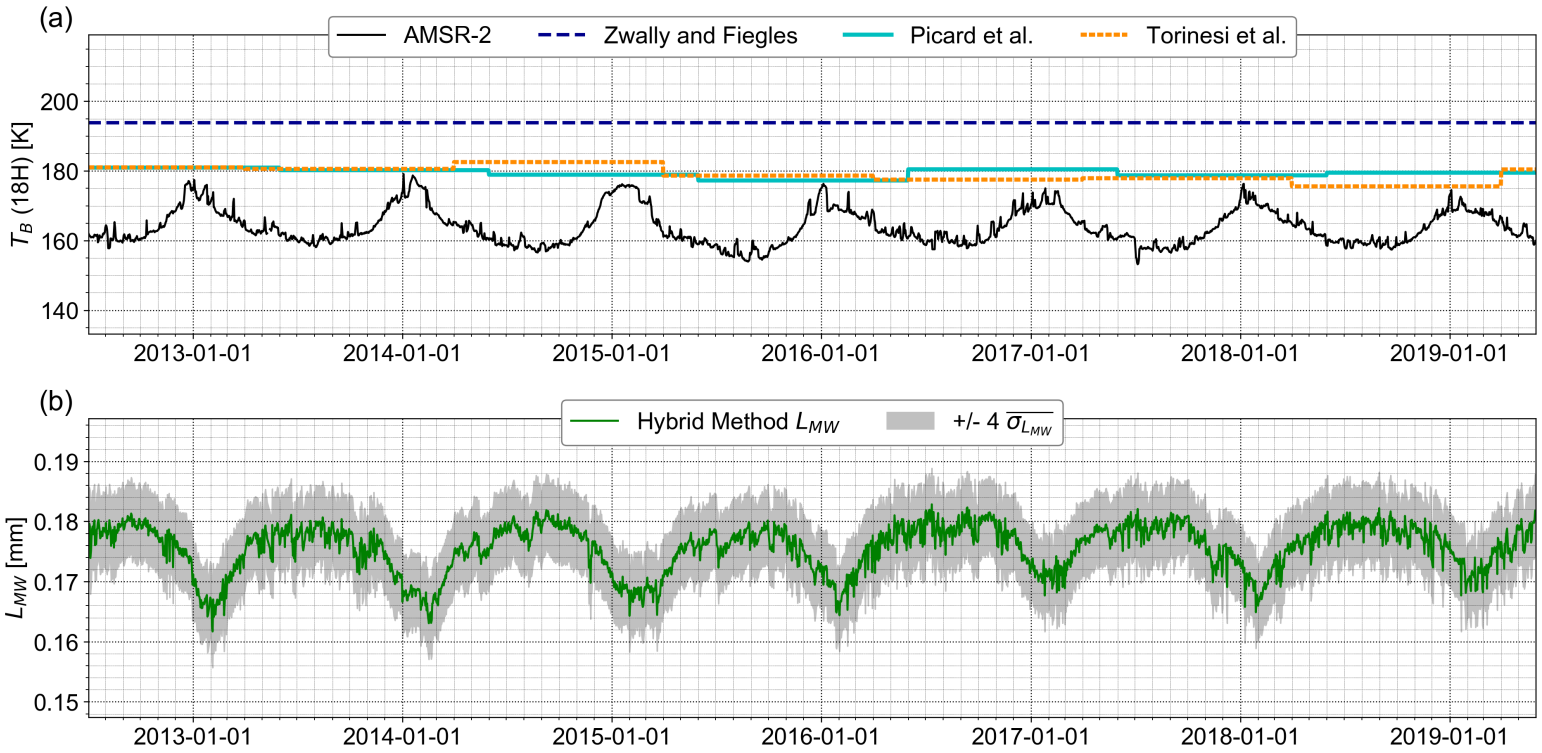
Site: Kohnen, Channel: 18V

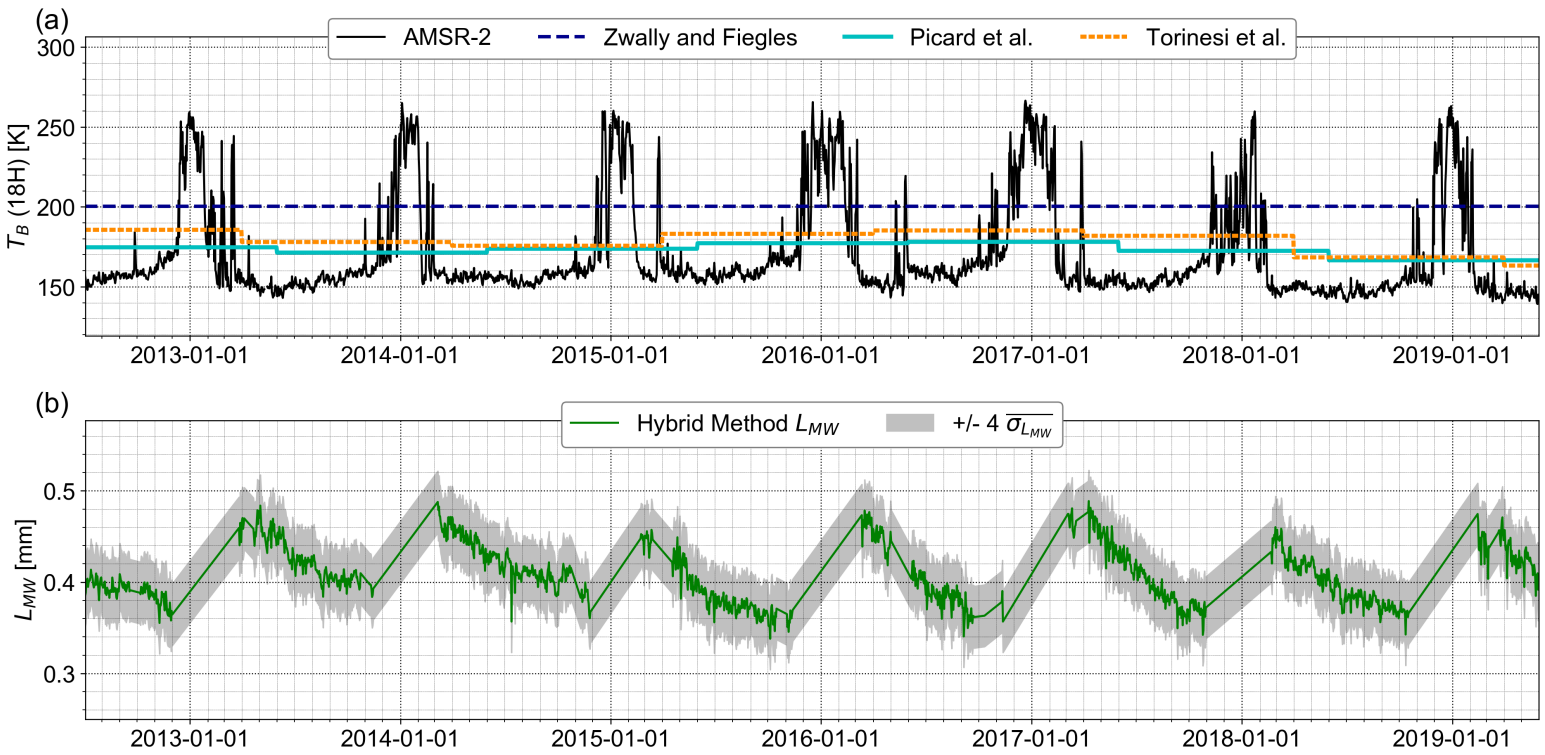


Site: Point Barnola, Channel: 18V

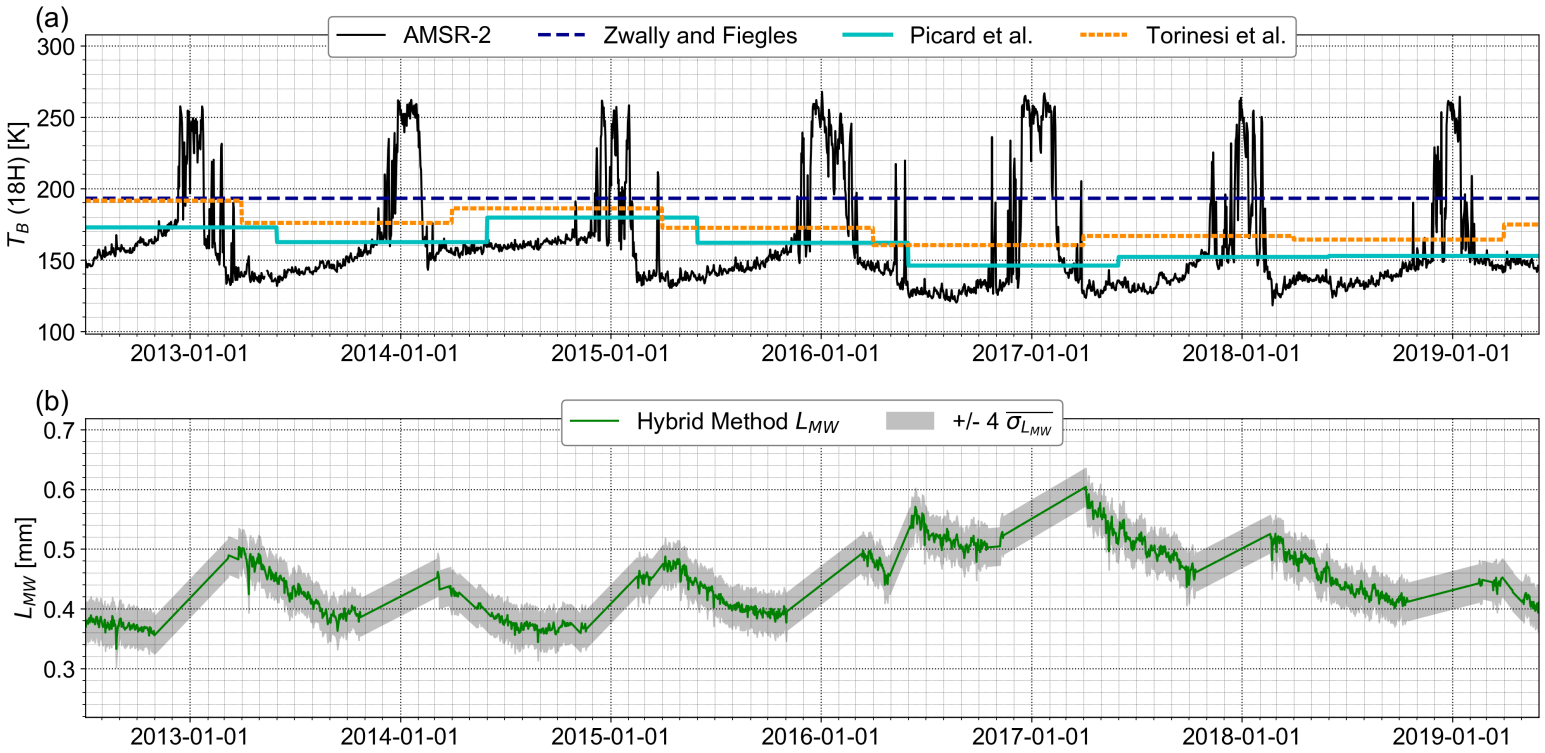


Site: Dome C, Channel: 18V

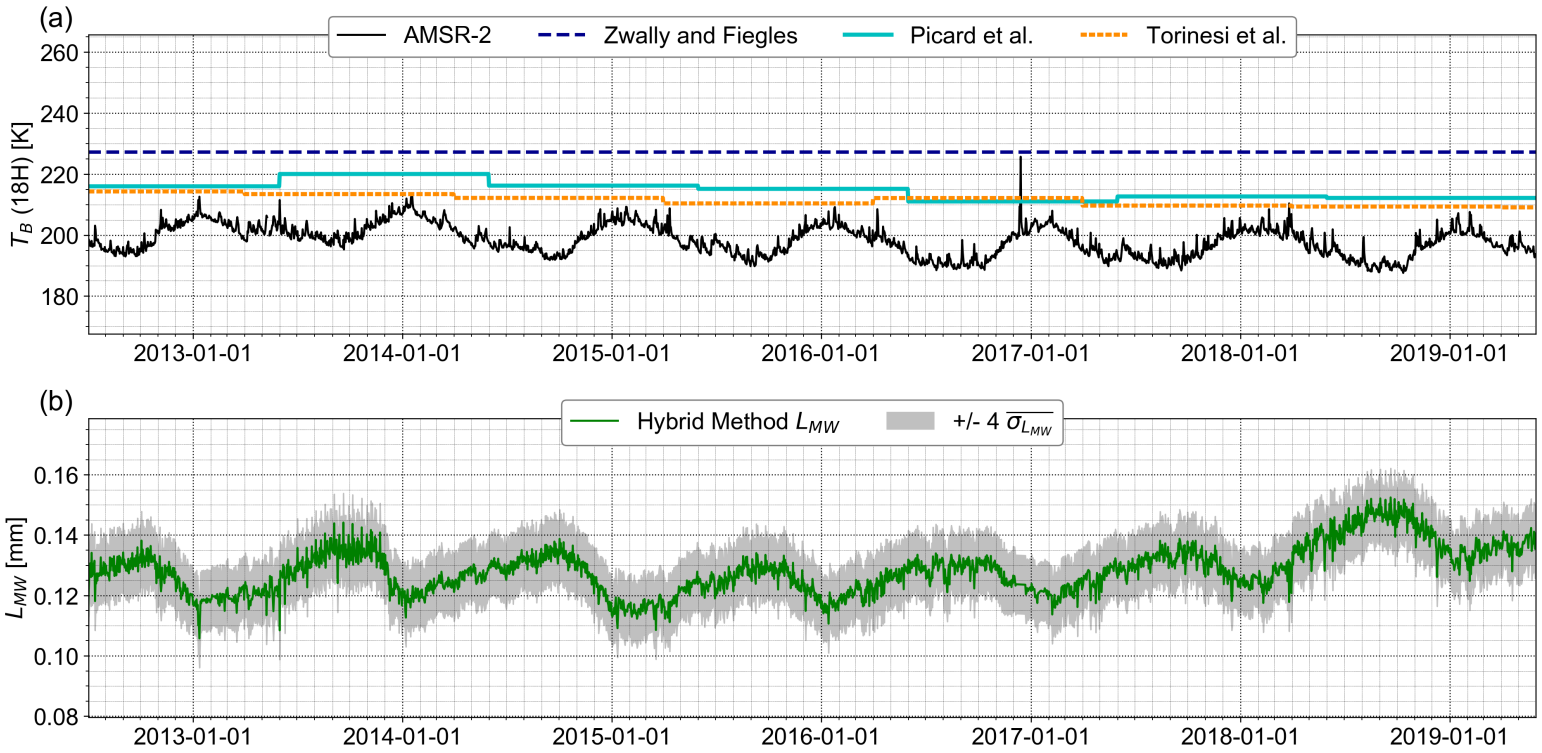



Site: AWS 17, Channel: 18V
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
300
250
200
150
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.5
0.4
0.3
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01

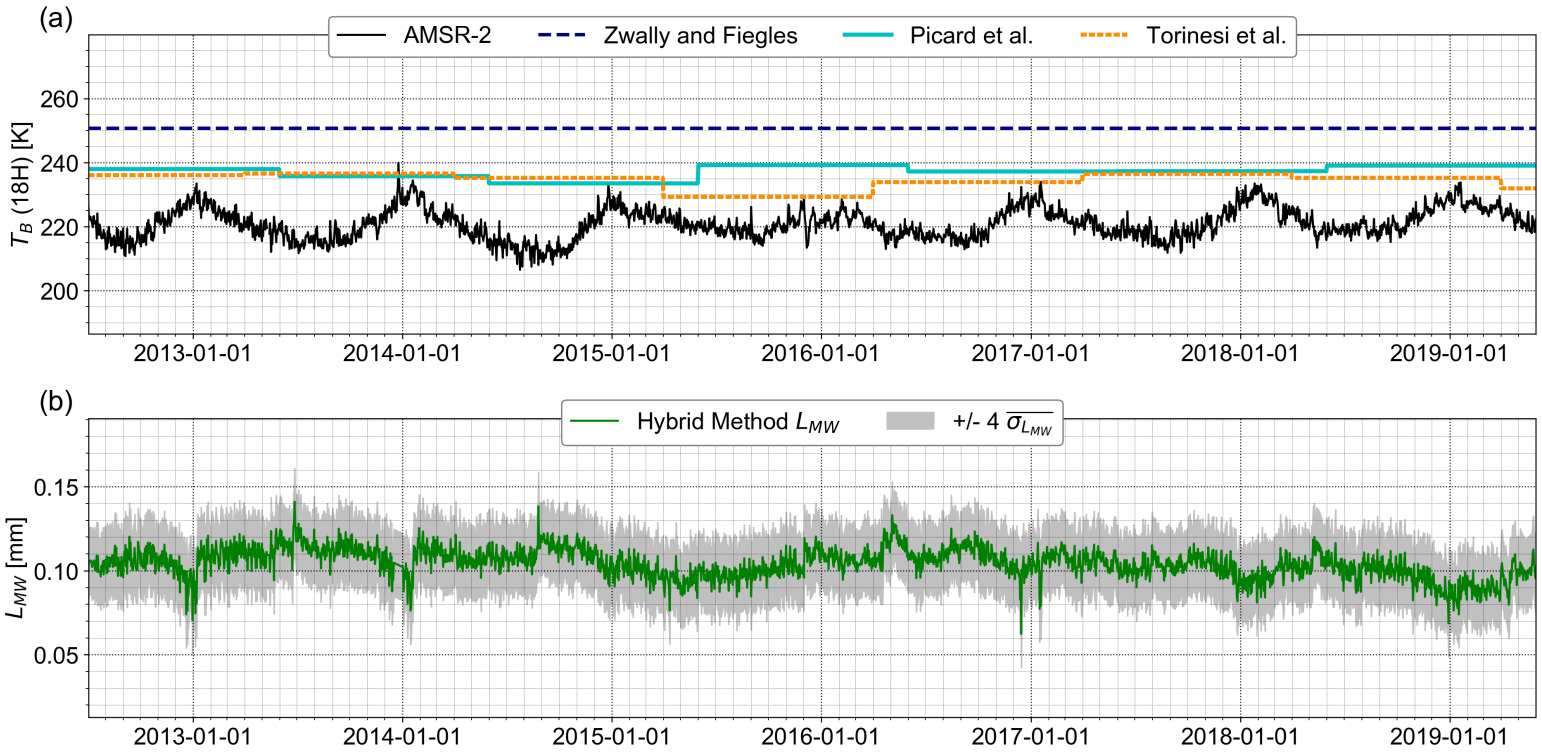
Site: AWS 14, Channel: 18V

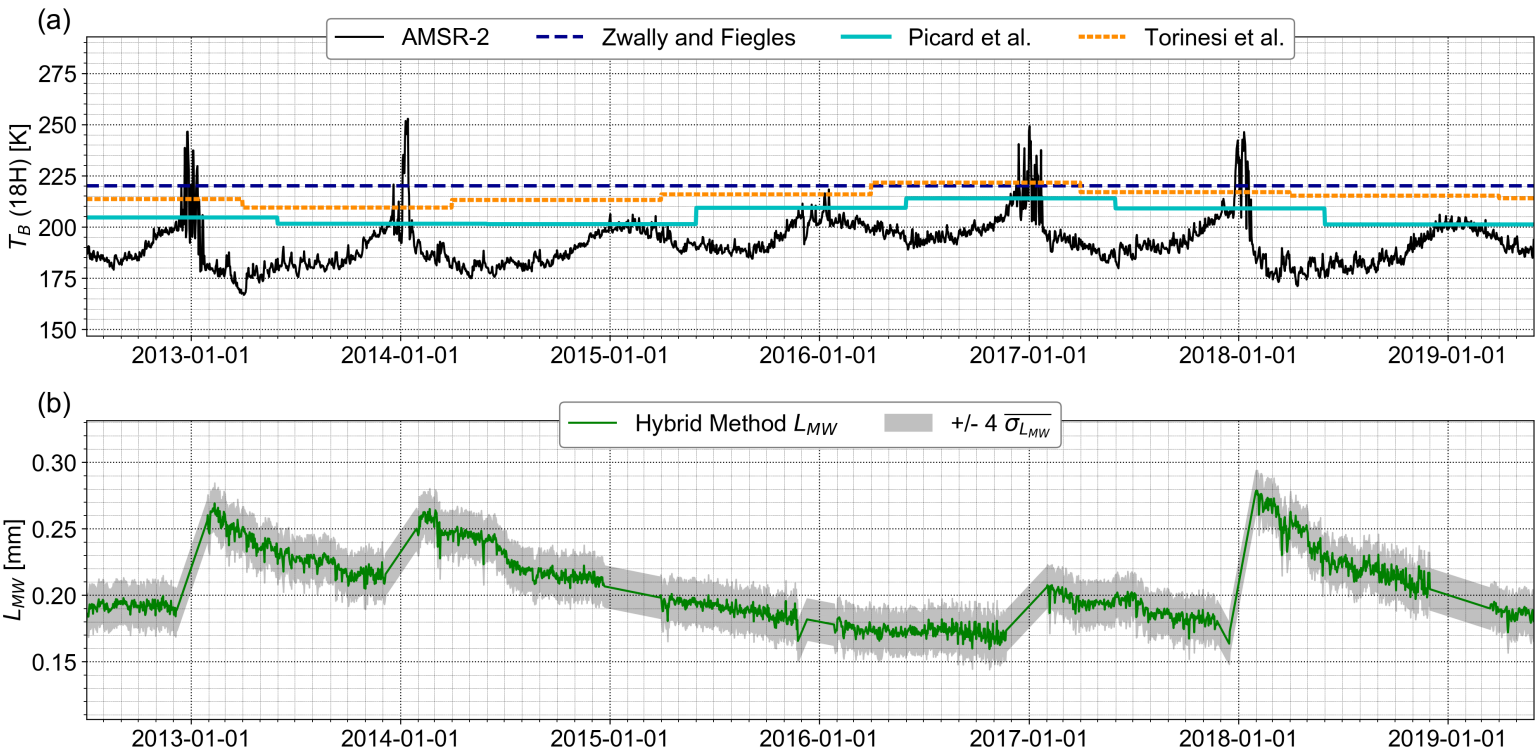


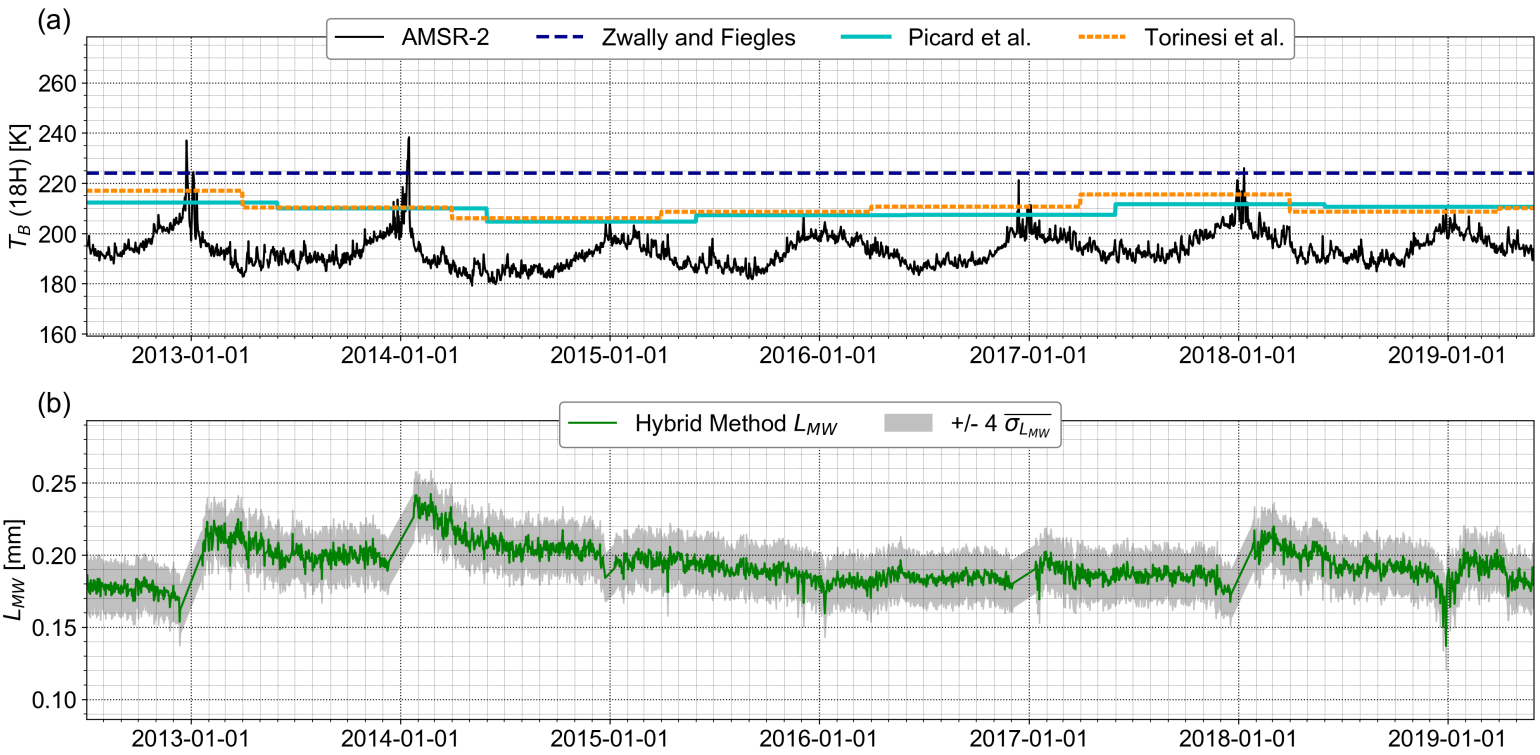
Site: AWS 6, Channel: 18V



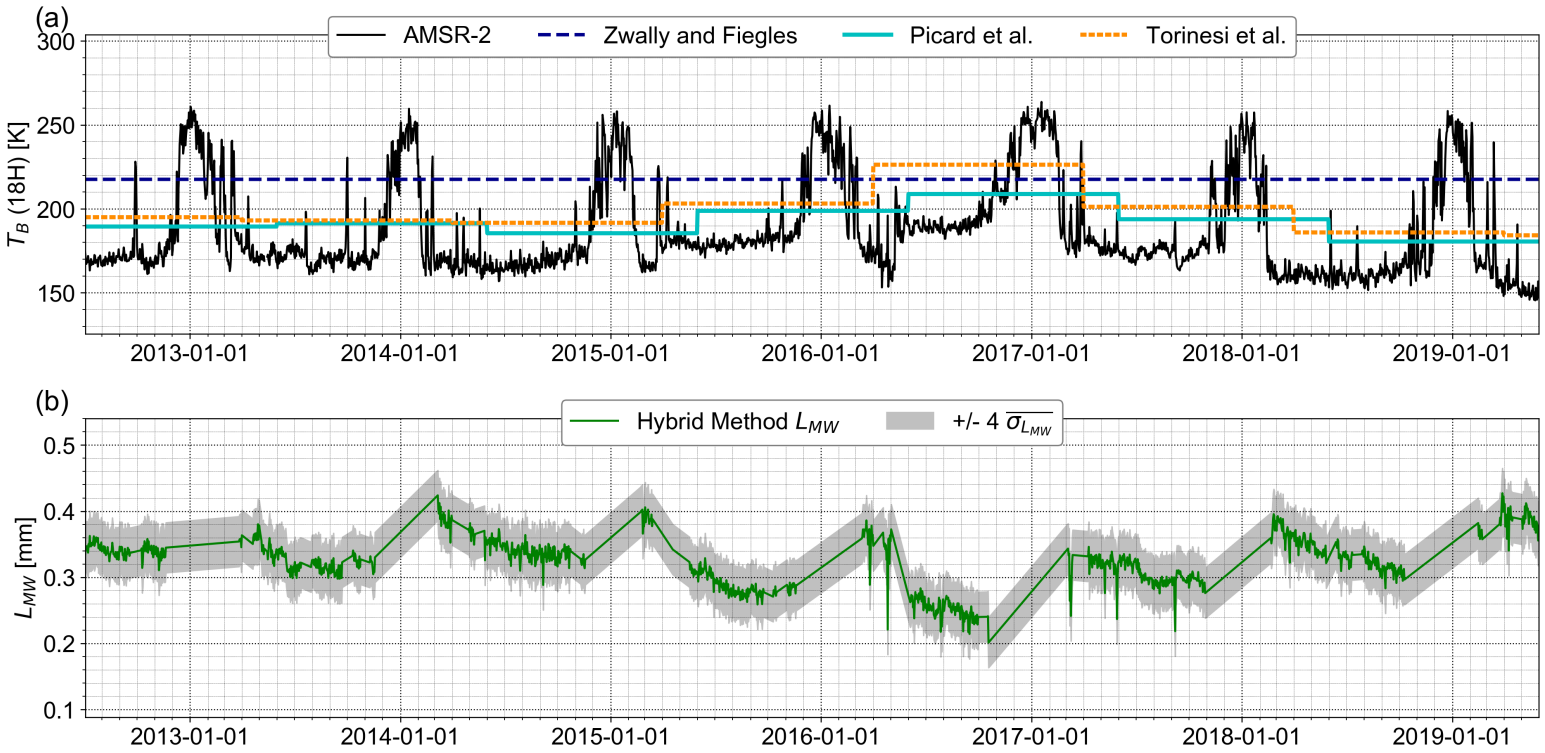
Site: AWS 11, Channel: 18V



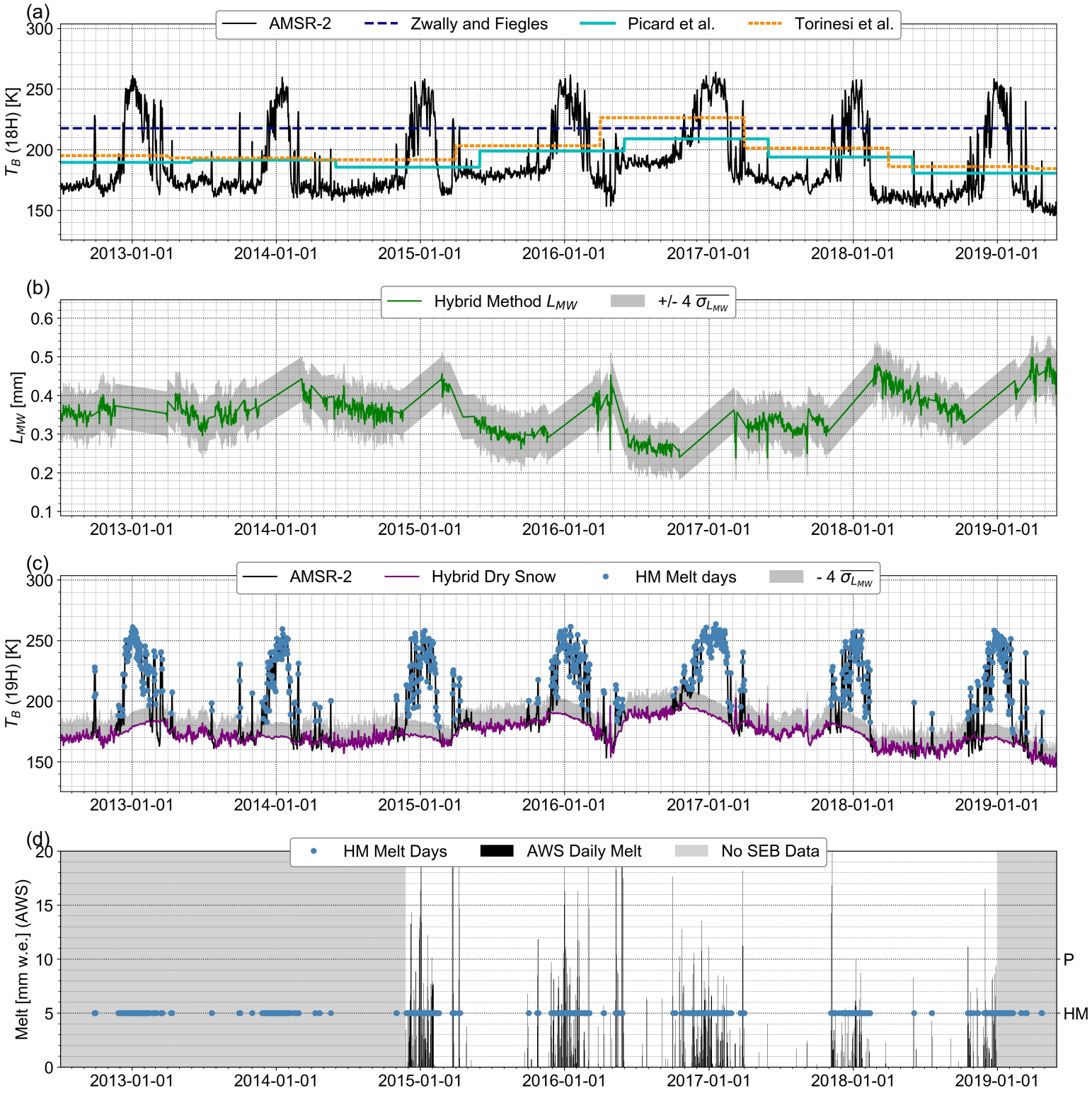

Site: AWS 4, Channel: 18V
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
275
250
225
200
175
150
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.30
0.25
0.20
0.15
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01

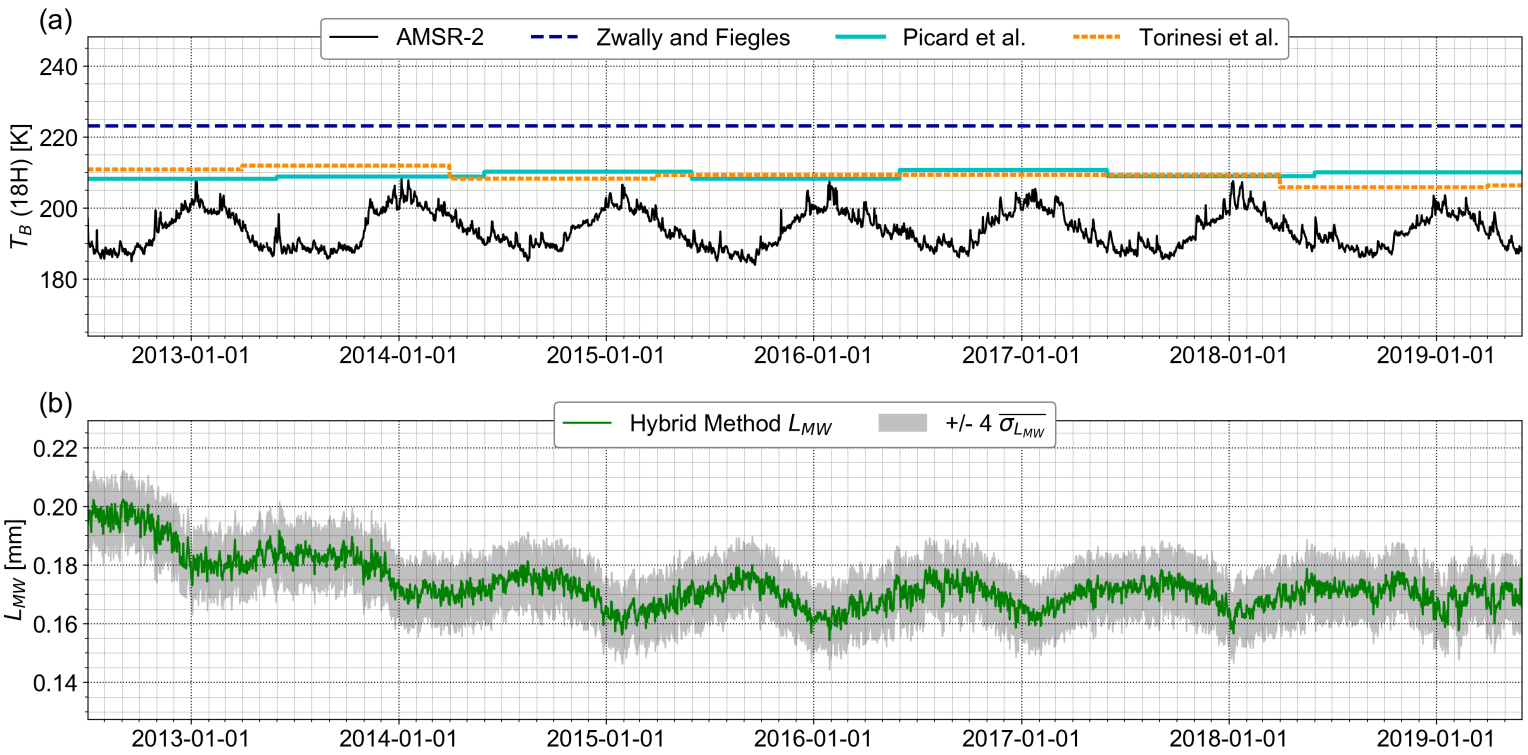

Site: AWS 5, Channel: 18V
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
260
240
220
200
180
160
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.25
0.20
0.15
0.10
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01

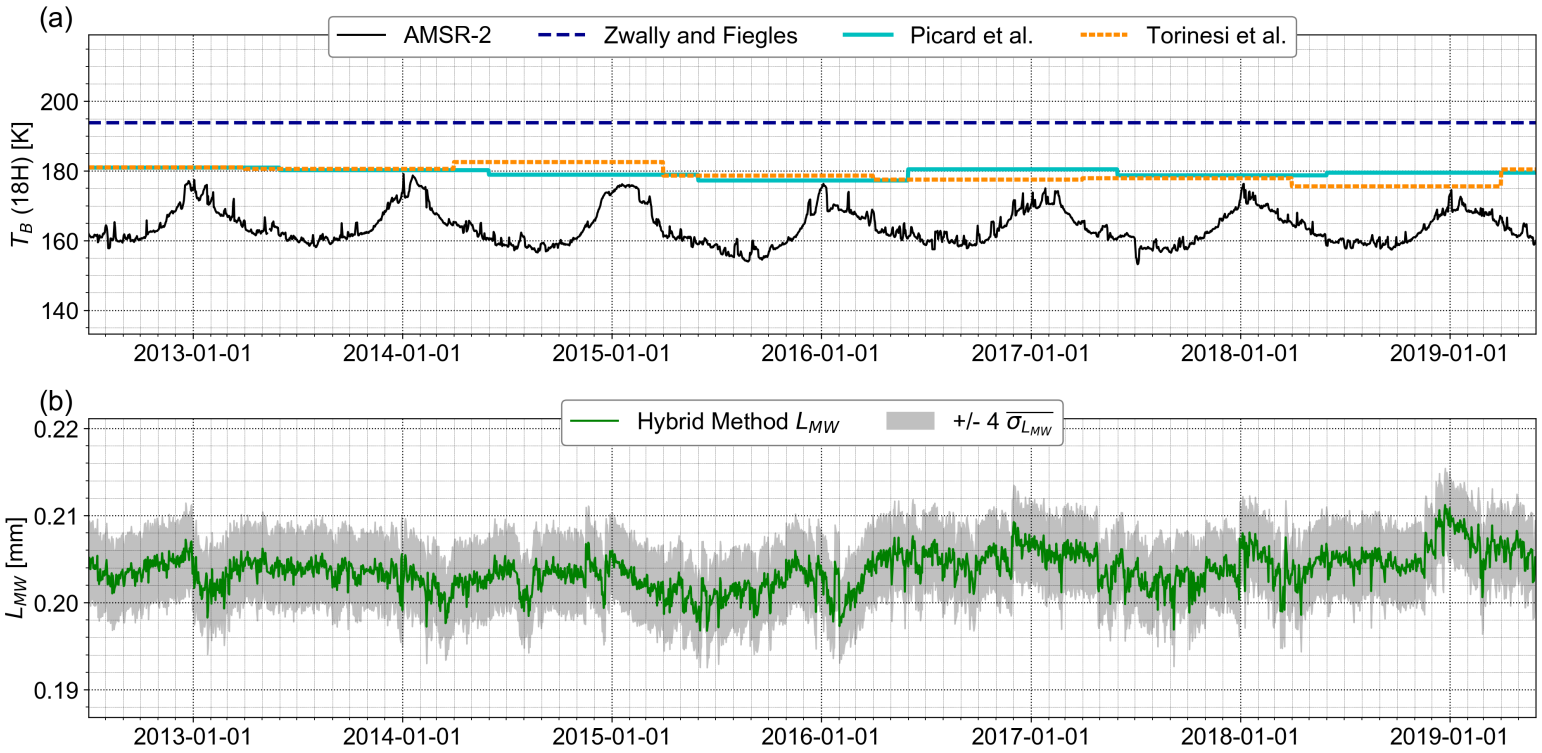
Site: AWS 18, Channel: 18V



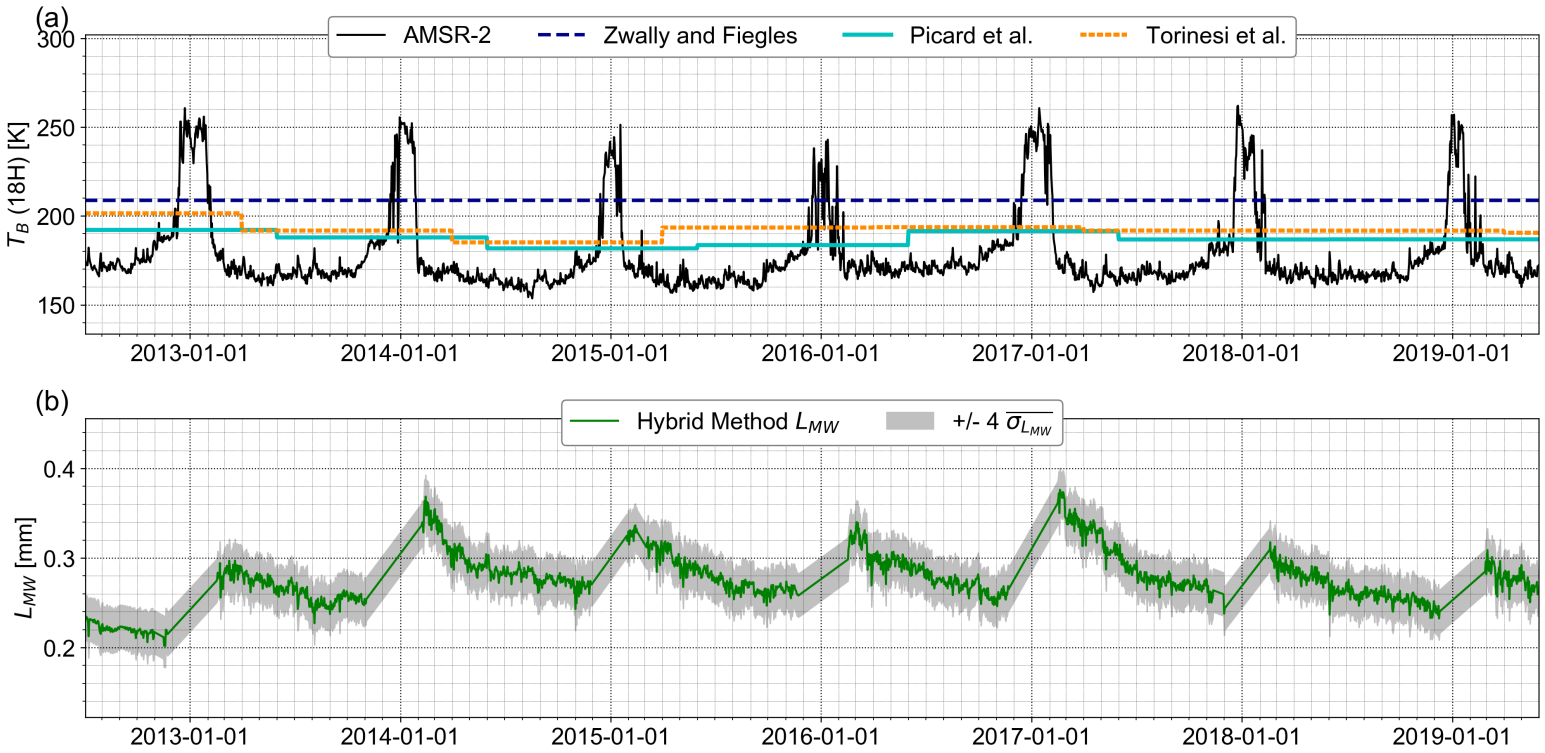
Site: AWS 18, Channel: 18H



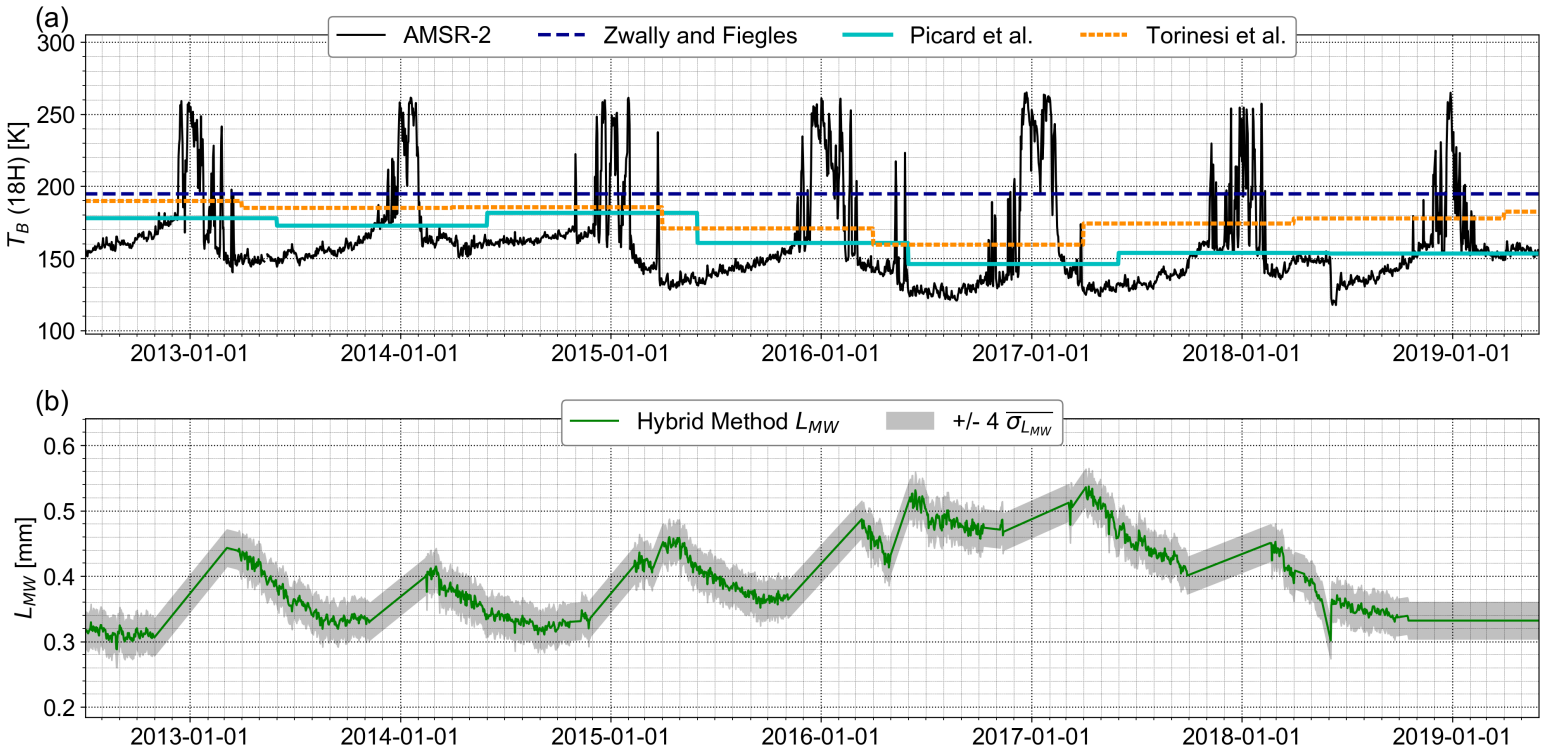

Site: AWS16 (Bias Corrected), Channel: 18V
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
240
220
200
180
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.22
0.20
0.18
0.16
0.14
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01


Site: Dome C (Bias Corrected), Channel: 18V
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
200
180
160
140
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.22
0.21
0.20
0.19
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01

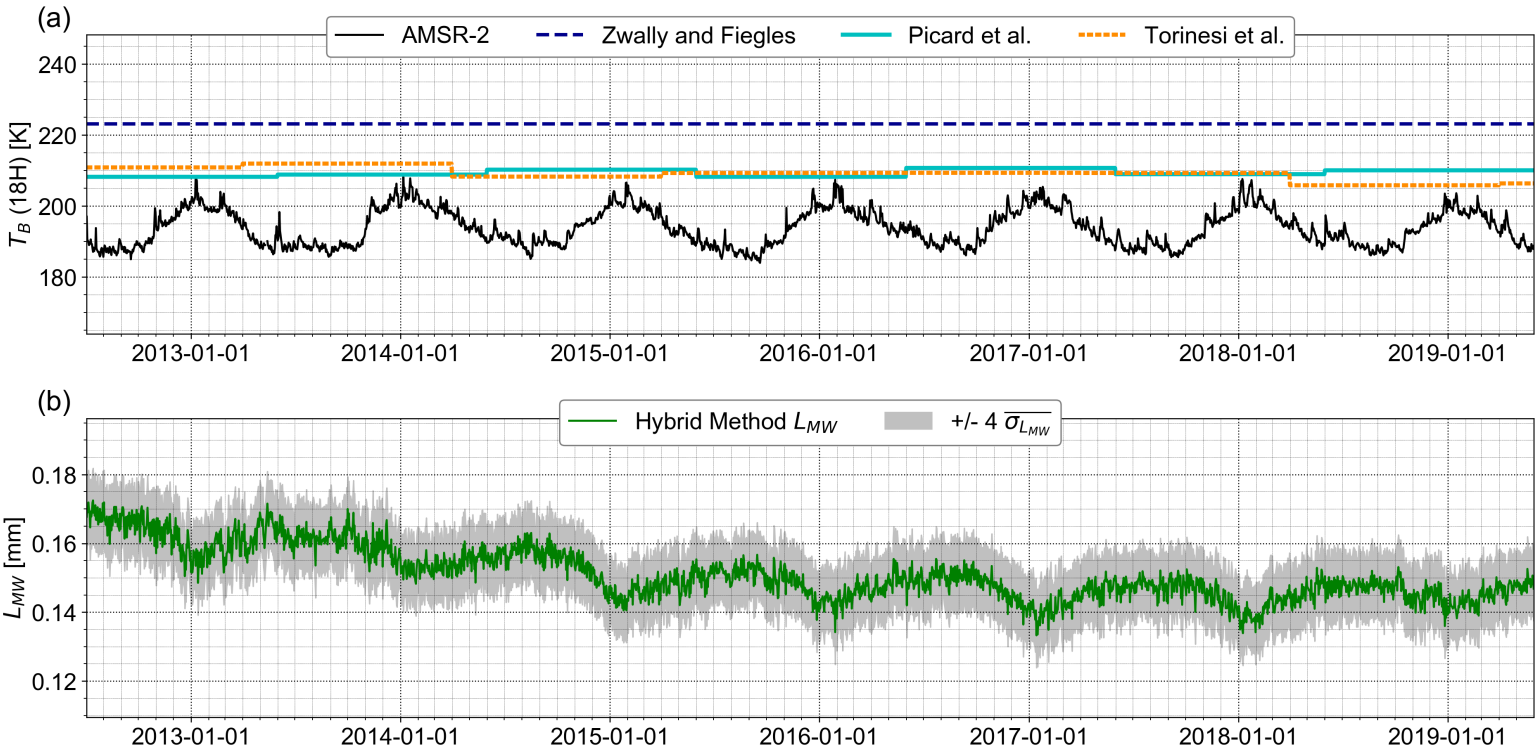
Site: AWS 19, Channel: 18V



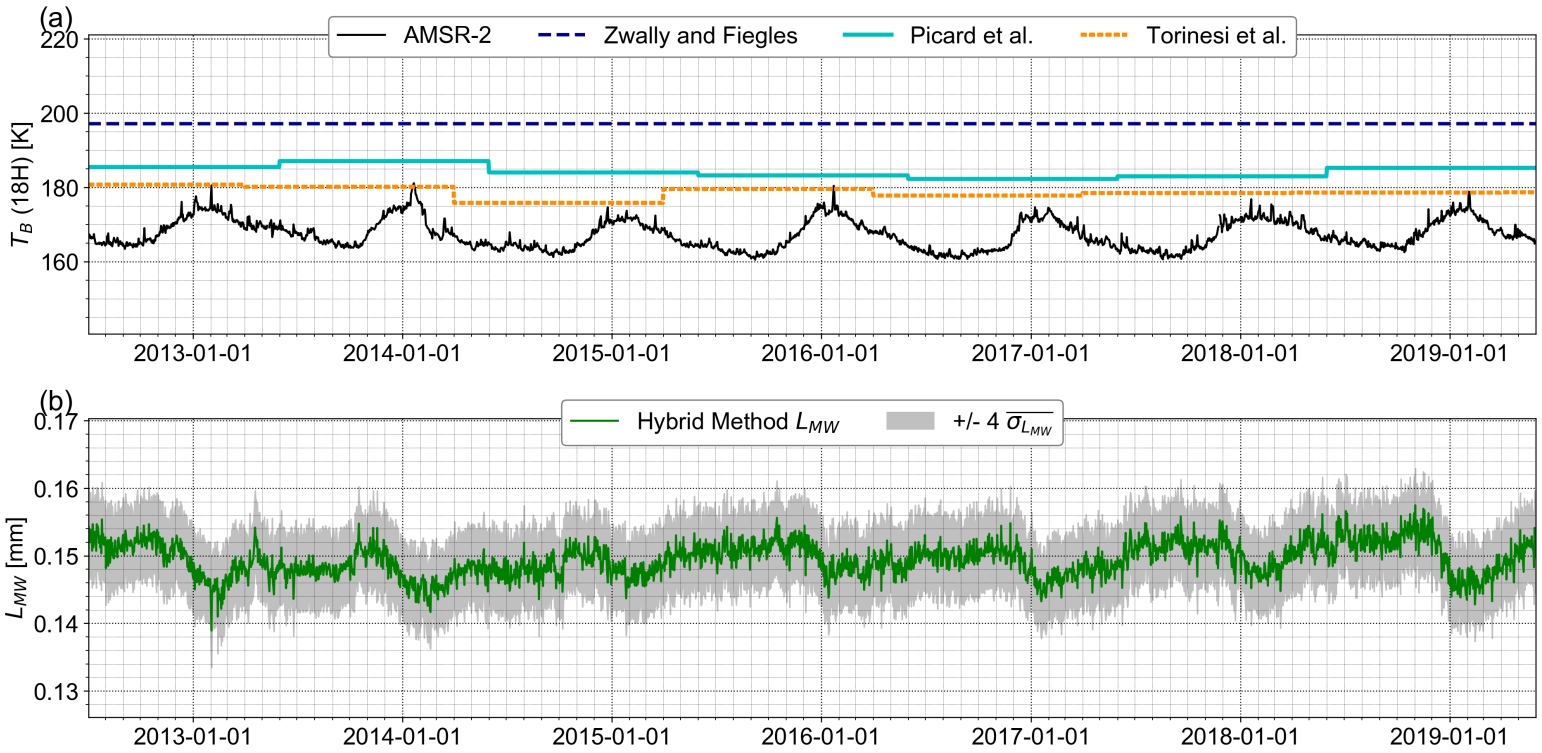
Site: AWS 15, Channel: 18V



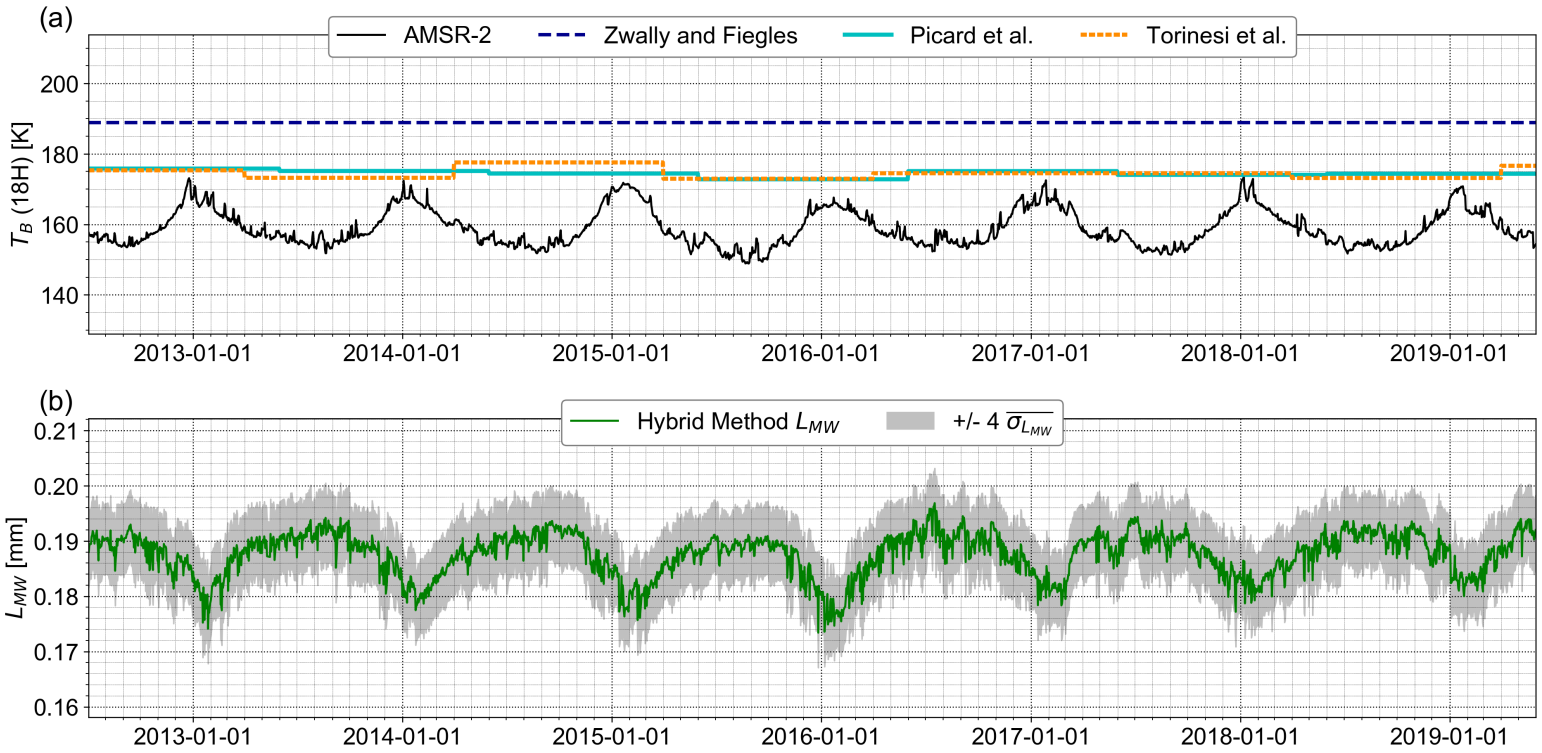
Site: AWS 16, Channel: 18V



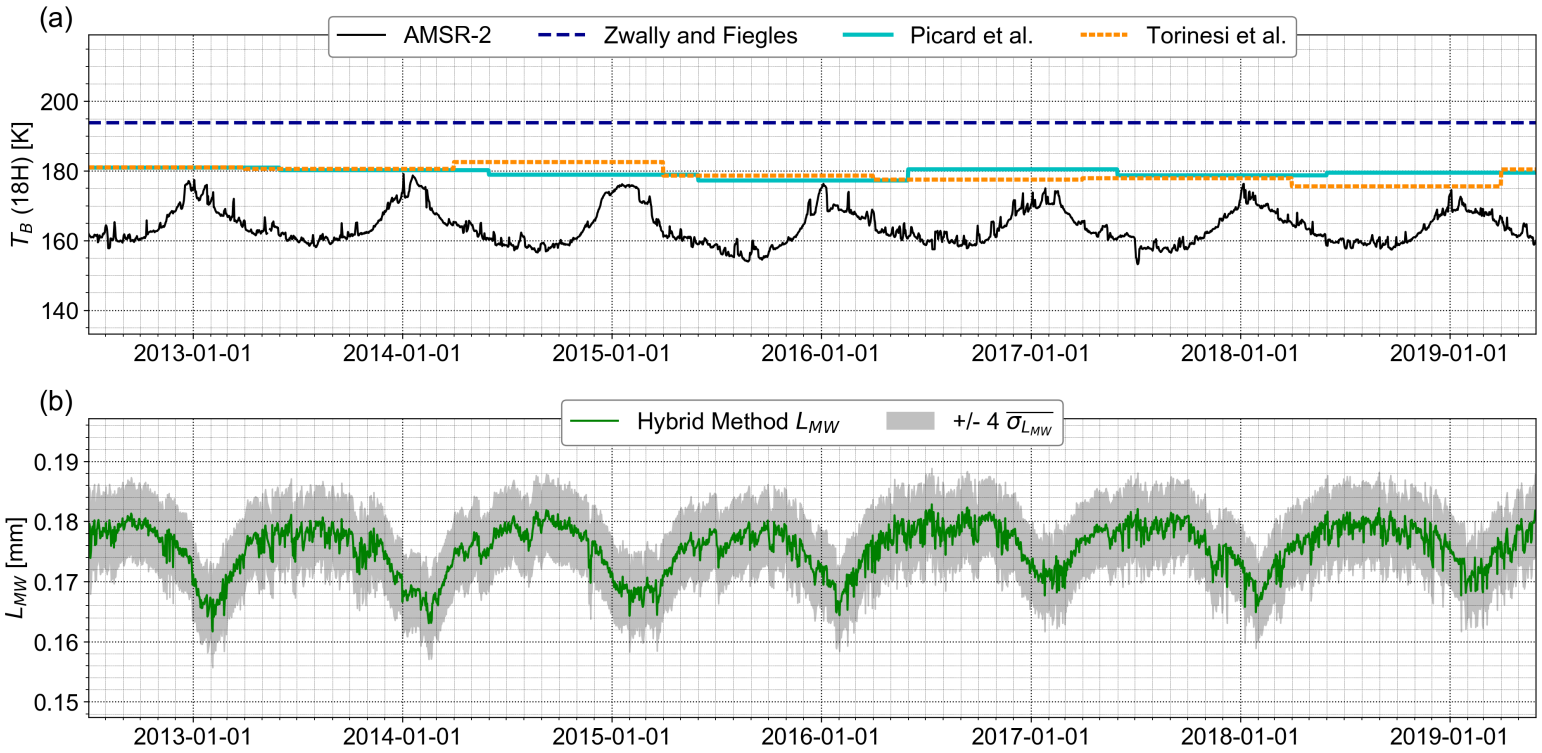
Site: Kohnen, Channel: 18V

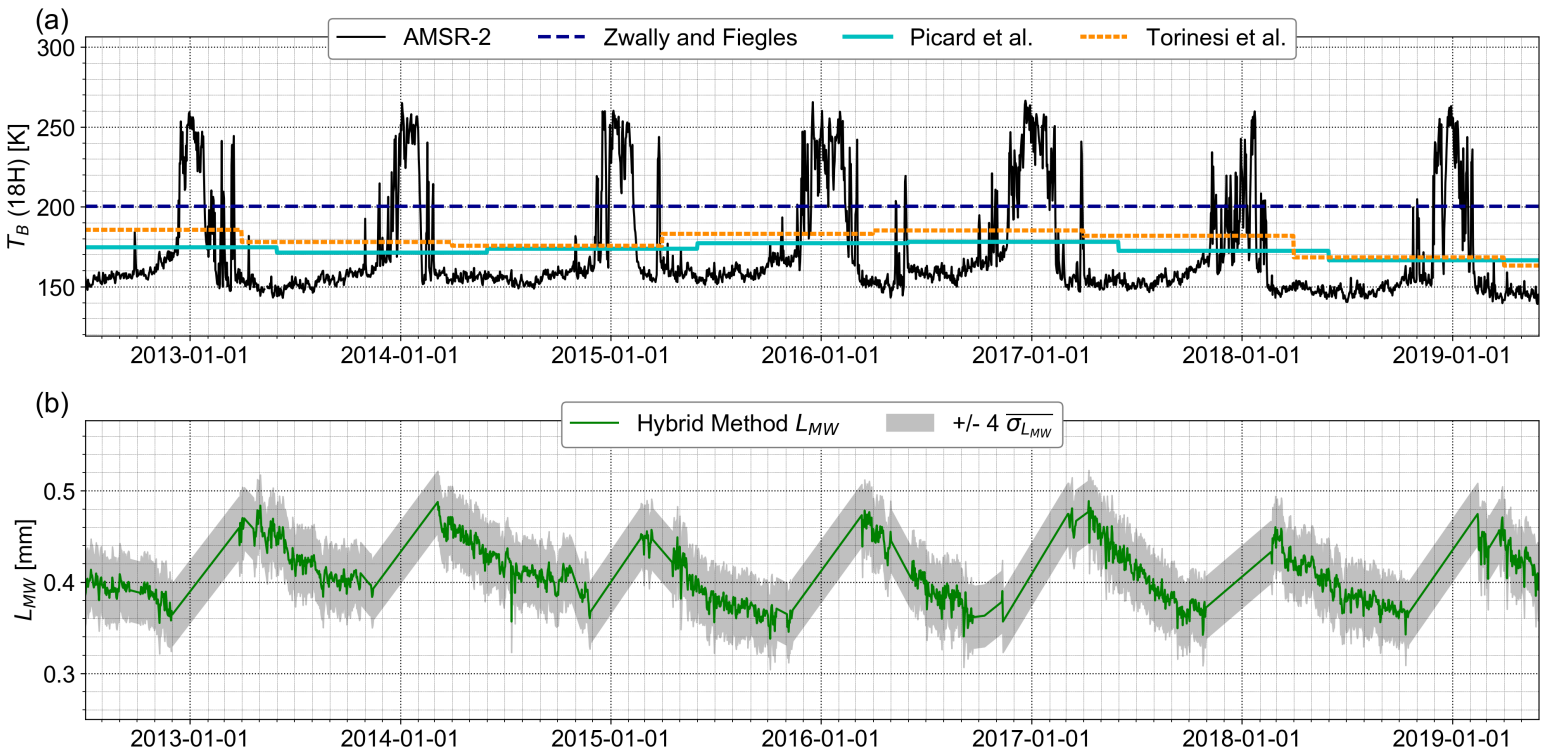


Site: Point Barnola, Channel: 18V

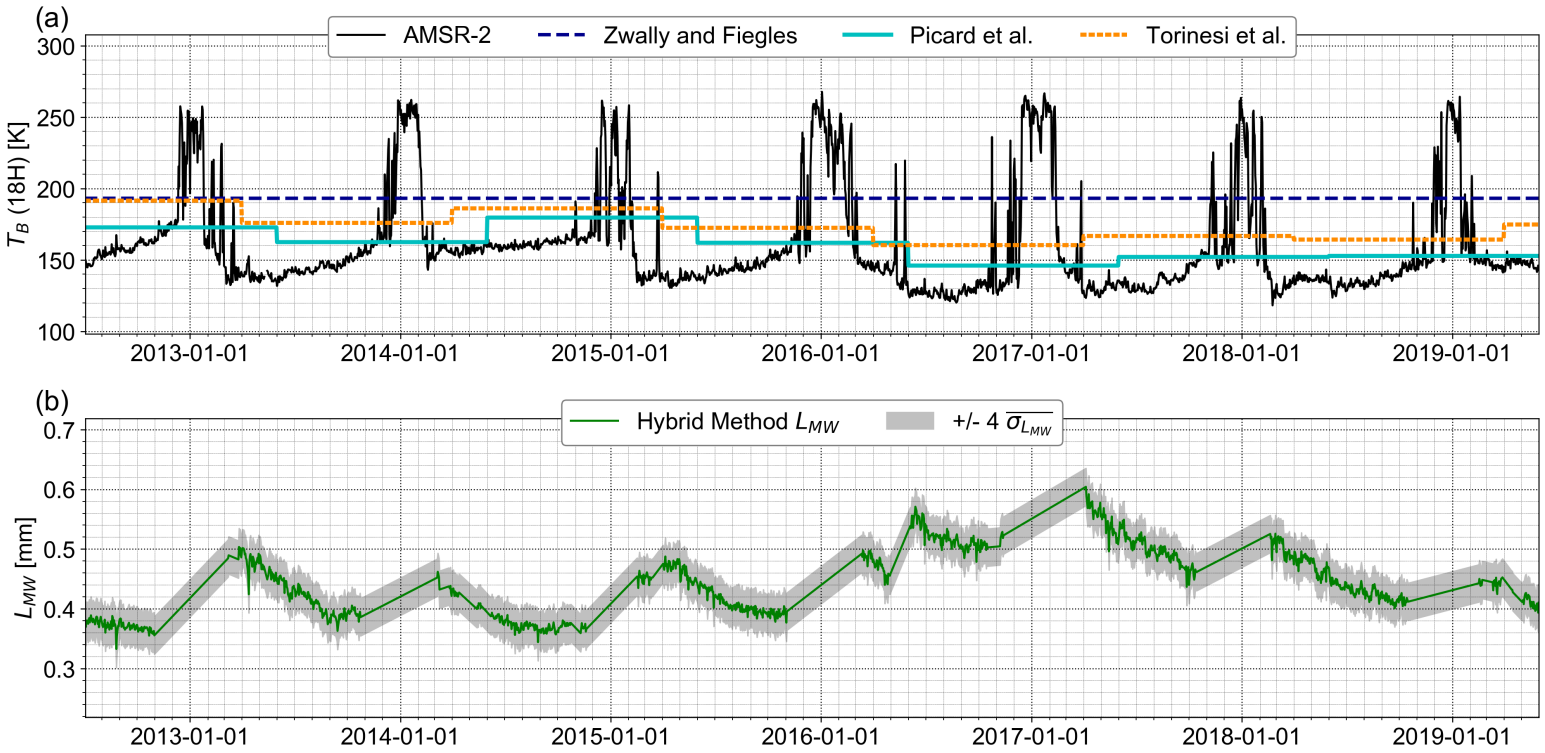


Site: Dome C, Channel: 18V

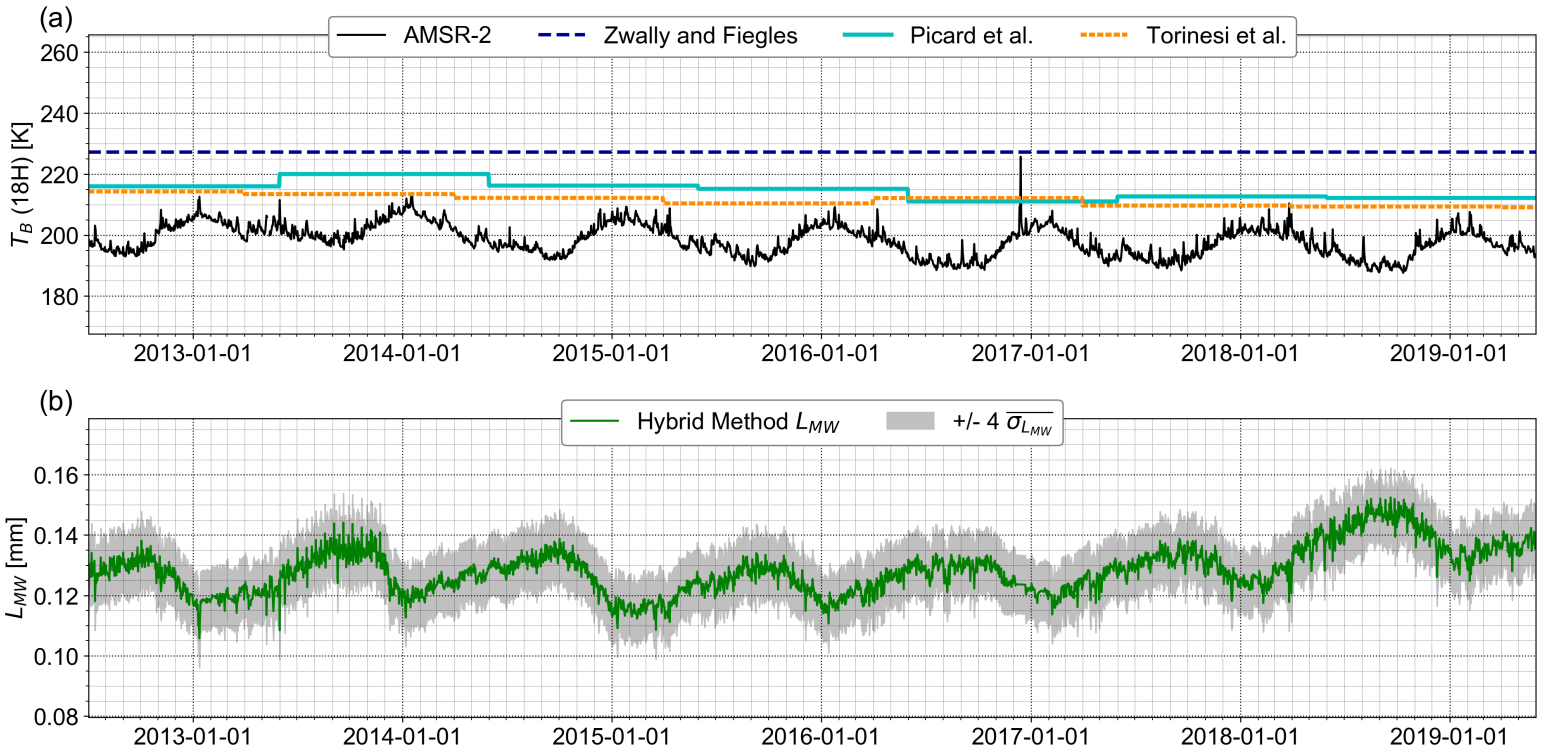



Site: AWS 17, Channel: 18V
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
300
250
200
150
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.5
0.4
0.3
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01

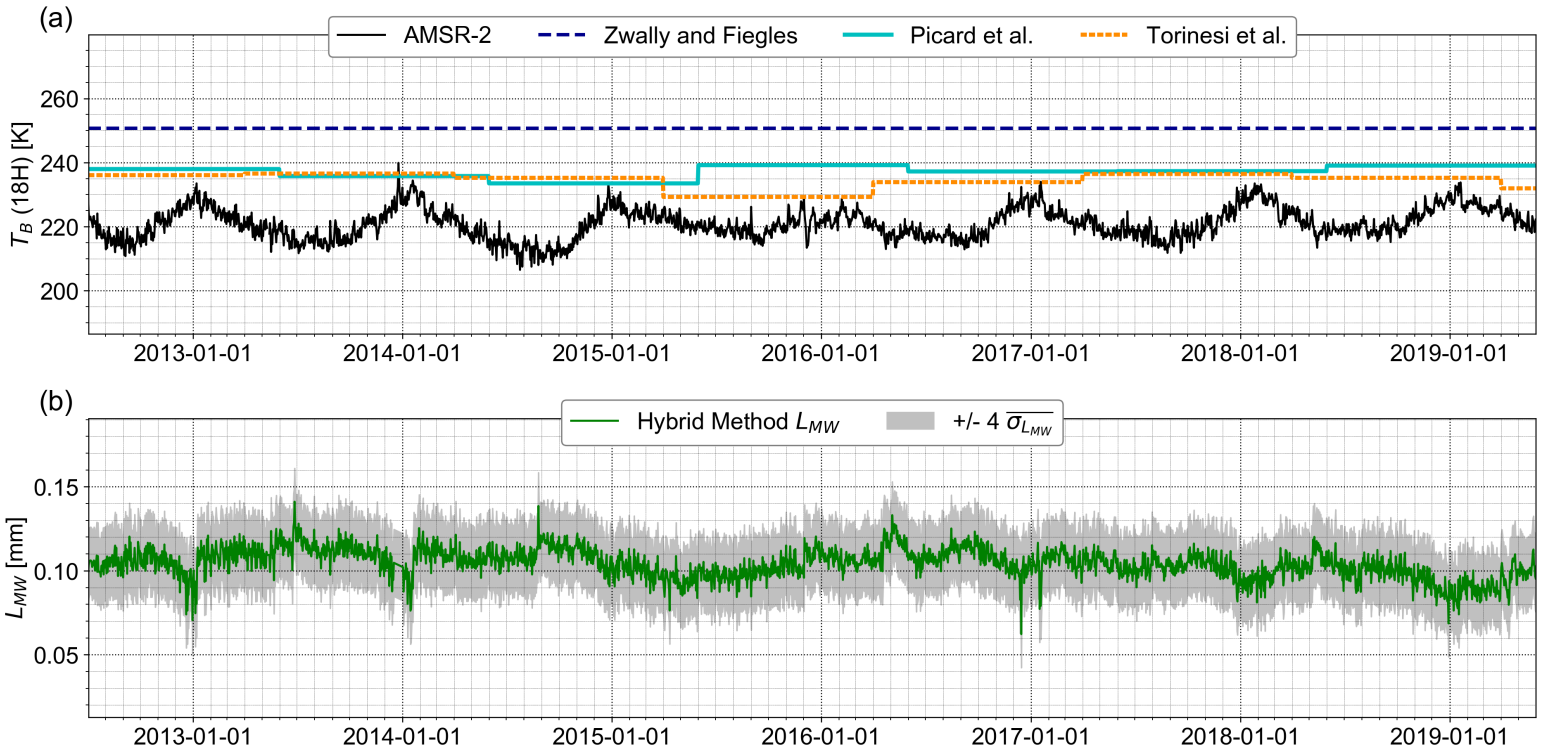
Site: AWS 14, Channel: 18V

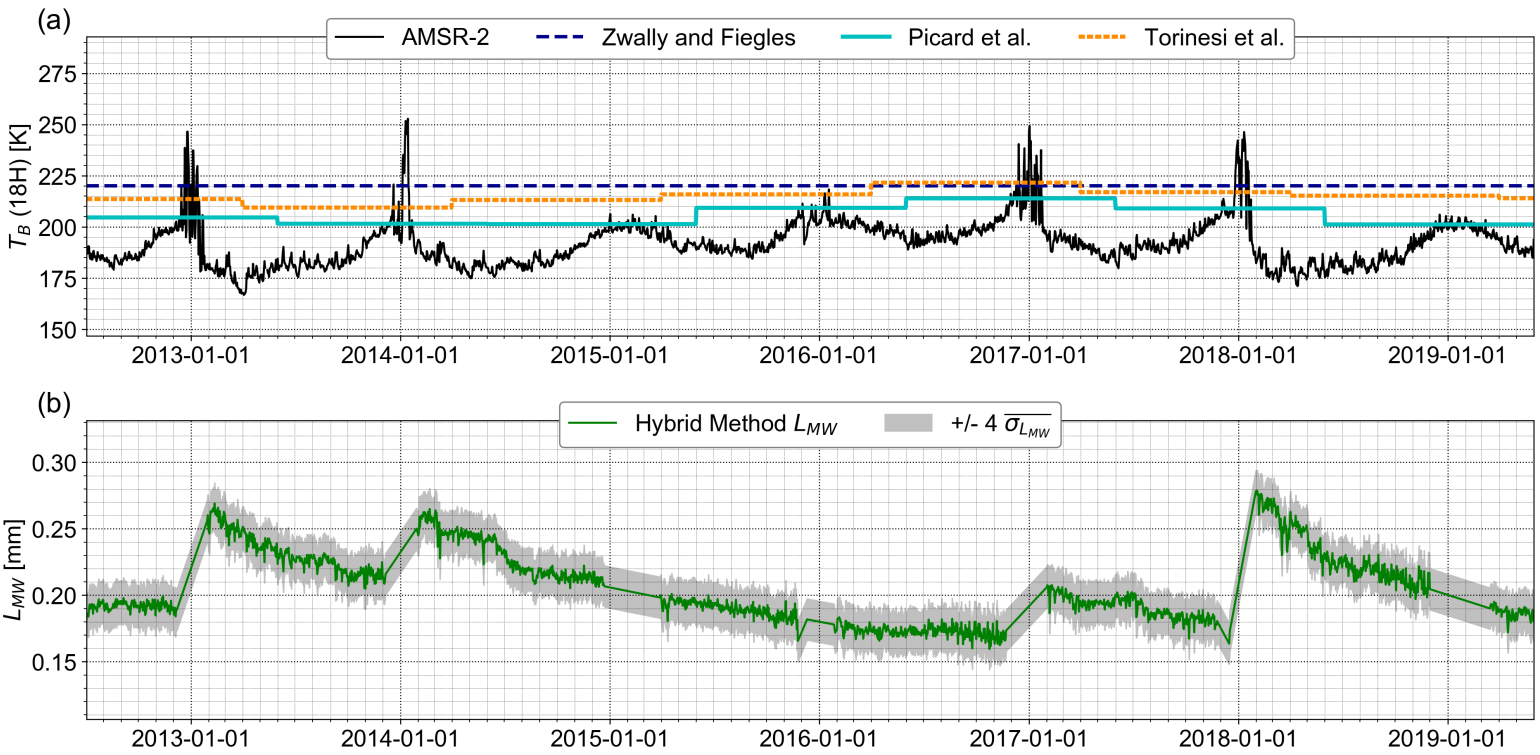


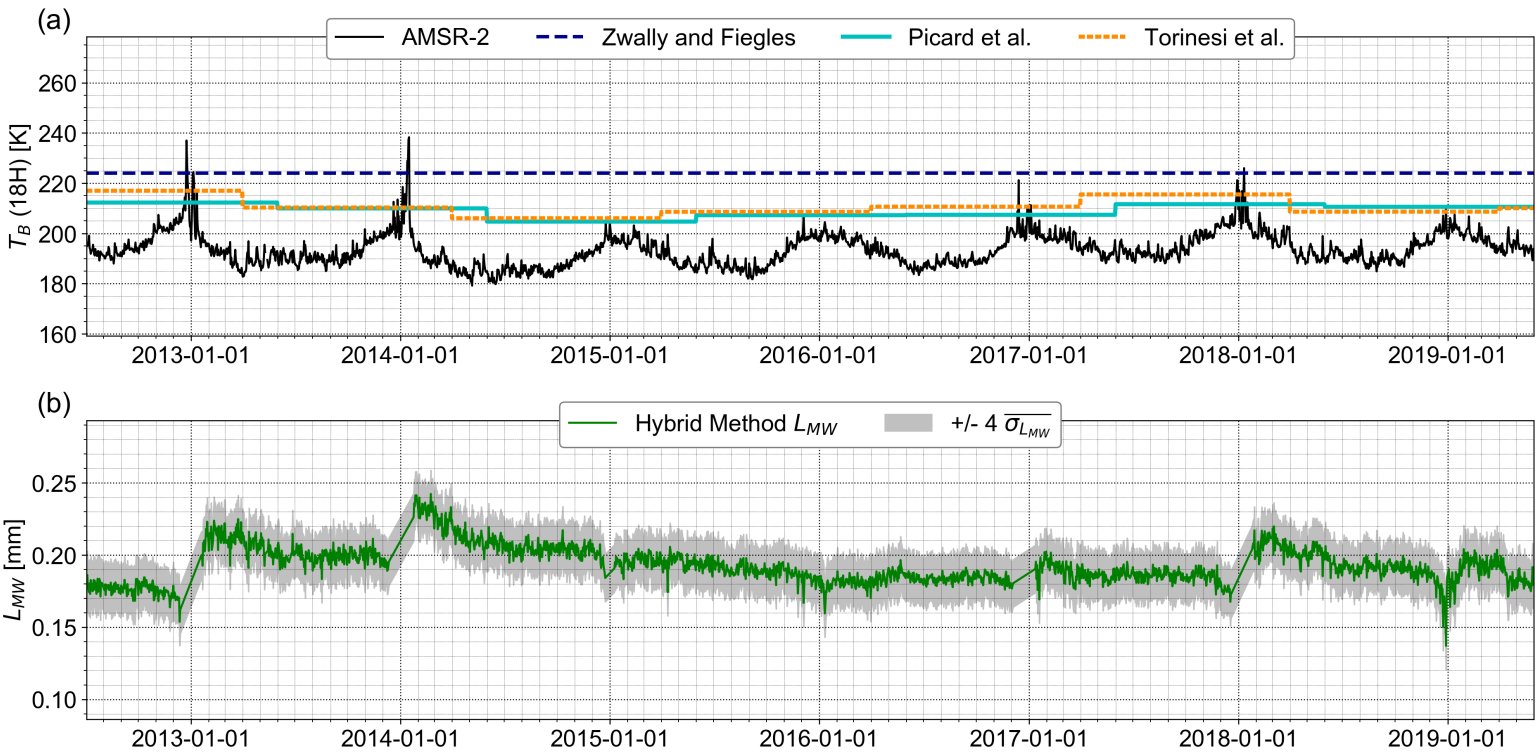
Site: AWS 6, Channel: 18V



Site: AWS 11, Channel: 18V




Site: AWS 4, Channel: 18V
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
275
250
225
200
175
150
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.30
0.25
0.20
0.15
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01


Site: AWS 5, Channel: 18V
(a)
AMSR-2
Zwally and Fiegles
Picard et al.
Torinesi et al.
T_B (18H) [K]
260
240
220
200
180
160
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
(b)
Hybrid Method L_{MW}
+/- 4 $\overline{\sigma_{L_{MW}}}$
L_{MW} [mm]
0.25
0.20
0.15
0.10
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01

Site: AWS 18, Channel: 18V