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Semidiurnal tidal signatures in microbarom infrasound array measurements

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Session AS1.21
Infrasound, acoustic-gravity waves, & atmospheric dynamics

Friday, 8 May 2020, 16:15 – 18:00

Semidiurnal tidal signatures in microbarom infrasound array measurements

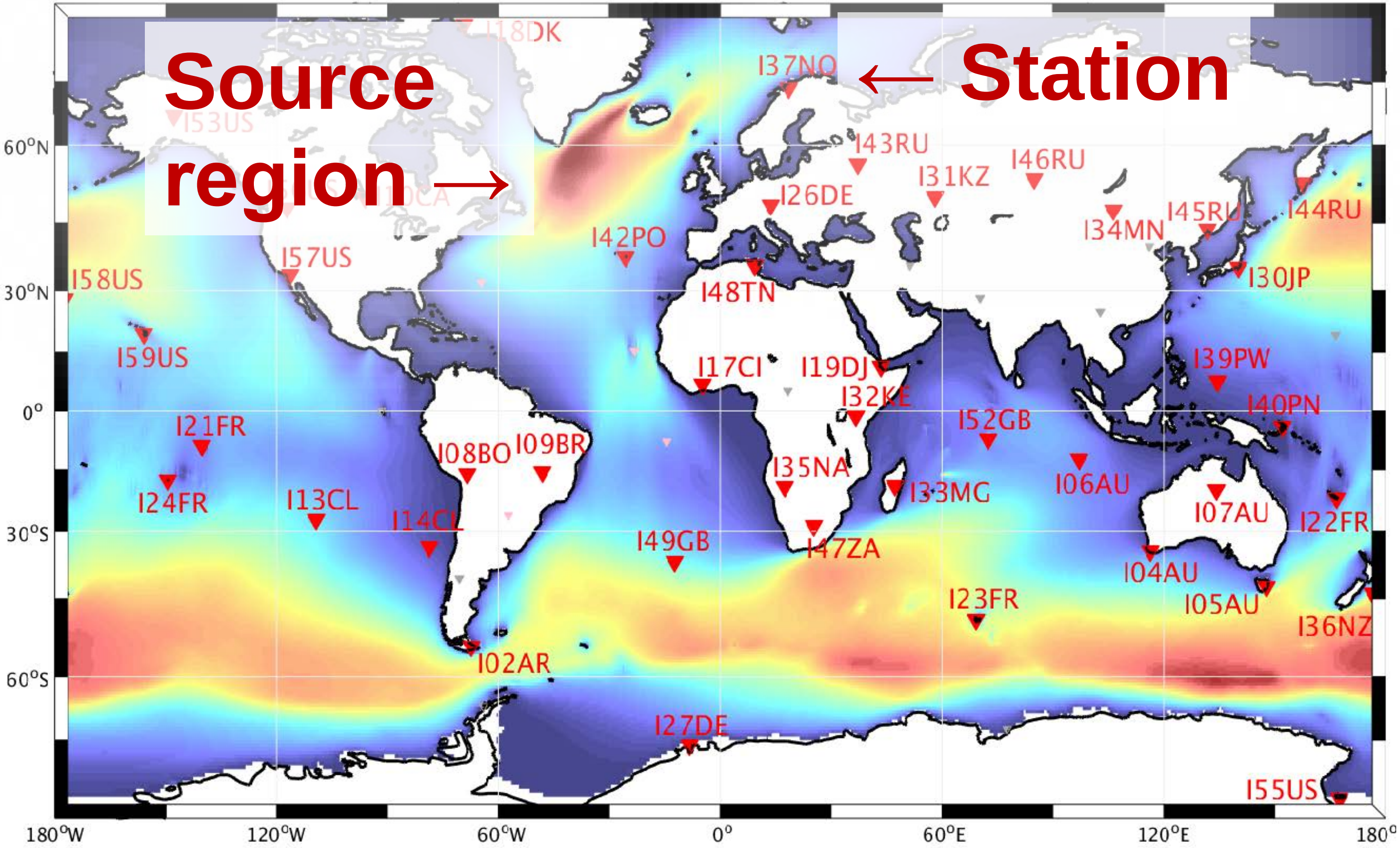
Recent studies on infrasonic signatures related to atmospheric tides are mostly focused on stratospherically ducted infrasound or on tidal signatures in recorded infrasound signal power.

In the current work, we address microbarom infrasound ducted by mesosphere-lower thermosphere (MLT) waveguides and the associated infrasound apparent velocity (trace velocity) of arrivals at a ground-based array station in northern Norway.

A hypothesis is that the infrasound apparent velocity – which is related to the incidence angle of the wavefront impinging the station – is linked to the altitude of the final refraction of the infrasound waves. This altitude would be affected by the regional MLT tidal pattern.

We apply specialized beamforming and filtering recipes to highlight the MLT-ducted microbarom arrivals and we find semidiurnal patterns in the infrasound apparent velocity measurements.

Array site & microbarom source



Wave-front & array measurements

Pressure amplitude

[Donn & Rind 1971 ++; Smets & Evers 2014; Smets, Assink & Evers 2019]

– Along-track wind & *T* sensitivity

– Challenges:

Sensitive to source strength variations; Long-distance propagation over multiple tide phases

Celerity / traveltime

– Along-track wind & *T* sensitivity

– Challenge:

Continuous-wave microbaroms without “origin time”

Backazimuth direction-of-arrival

– Cross-wind sensitivity

– Challenges:

Long-distance propagation over multiple tide phases, as well as vertical integration effects ?

Inclination direction-of-arrival

– Along-track wind & *T* sensitivity

– Prospective advantage:

Information about **final return path**, with less long-distance averaging over multiple tide phases ?

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Domains

– **Apparent velocity** (trace velocity):

$$v_{app} \in [\, c_{0ground},\ \infty\,]$$

– **Inclination:**

$$\arcsin(c_{0ground} / v_{app}) \in [\, 0,\ 90\,]\ \text{deg.}$$

More favorable for fitting to sinusoids

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Tide-related signatures in infrasound ambient noise recordings ?

Tidal characteristics of the middle atmosphere

- Semidiurnal (12h) period would dominate above stratopause
- Diurnal (24h) period would dominate in the stratosphere

But we’re at high latitudes:

Tidal patterns are complex (“tidal weather”):

Non-linear interactions between tidal components (migrating & non-migrating) and between planetary waves and tides, and time-varying sources

Altitude-regime particular interest
(less studied for infrasound)

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Mesosphere-lower thermosphere (MLT) tidal signatures

Requires:

Data processing to isolate the “thermospheric microbarom arrival”, having penetrated the MLT

Approaches:

- Temporal filtering & window-length settings
- Spatial filtering (adaptive or conventional beamforming)
- Rejecting data-points which obviously are not MLT arrivals

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Season of particular interest at high latitudes:

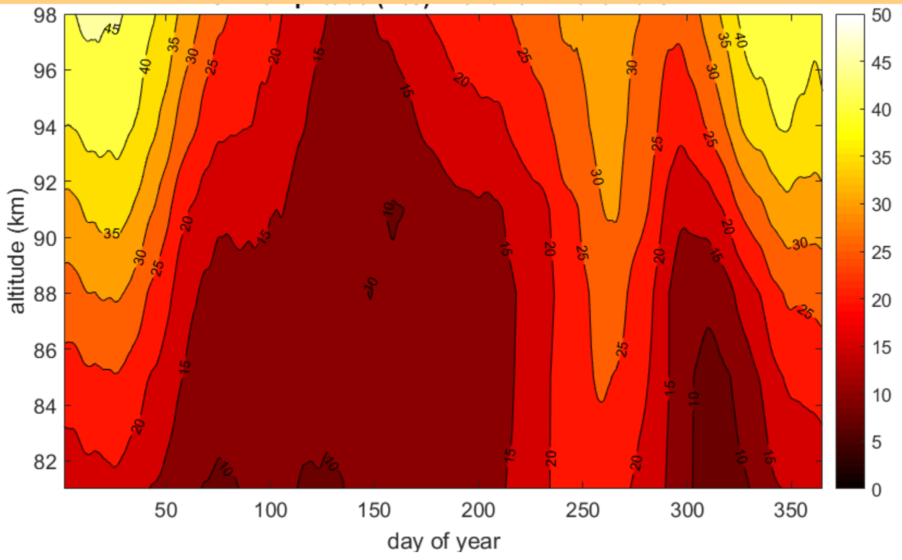
Late summer MLT semidiurnal tides

Radar observations:

Late summer peak in semidiurnal tide

- Trondheim meteor radar climatology (Norway) - see figure. Also previously observed over ESRANGE (Sweden) [Mitchell et al., 2002] and Andenes (Norway, close to I37NO) [Riggin, et al., 2003]

- Maximises around early September primarily due to the migrating SW2 tide but with contributions from non-migrating modes [Hibbins et al., 2019]



Climatology of semidiurnal tides in Trondheim meteor radar zonal wind amplitude [m/s]

Pinpointing thermospheric microbarom infrasound

Processing pipeline, I37NO data

- Temporal filtering: 0.1 – 0.2 Hz

  Allows for "focusing" onto microbarom hotspot close to Greenland/Iceland

- Long time window, to accommodate for continuous-wave microbarom arrivals
- Find location of slowness space peak with highest coherence ⇒ wave-front parameters (backazimuth & apparent velocity)
- Reject too low array coherence (but stay very tolerant)
- Reject backazimuth outside of relevant sector

⇒ ***Irregularly sampled time-series of apparent-velocity (inclination angle) estimates***

Generalized Lomb-Scargle periodogram

– **Fit our irregularly sampled inclination angle series to:**

$$y(t; f, \vec{\theta}) = \theta_0 + \sum_{n=1}^{\texttt{nterms}} \left[\theta_{2n-1} \sin(2\pi n f t) + \theta_{2n} \cos(2\pi n f t)\right]$$

Floating-mean method: θ_0 compensate for biased average estimate

N_{terms} = 2 means including 1st harmonic. [We first set N_{terms} = 1]

– **Moving time-window, calculate L-S periodogram for 5-day chunks**

⇒ **Pseudo-spectrogram** showing tidal peaks as function of day

Normalize each periodogram to its max, before packing to pseudo-spectrogram

Resulting semidiurnal signatures

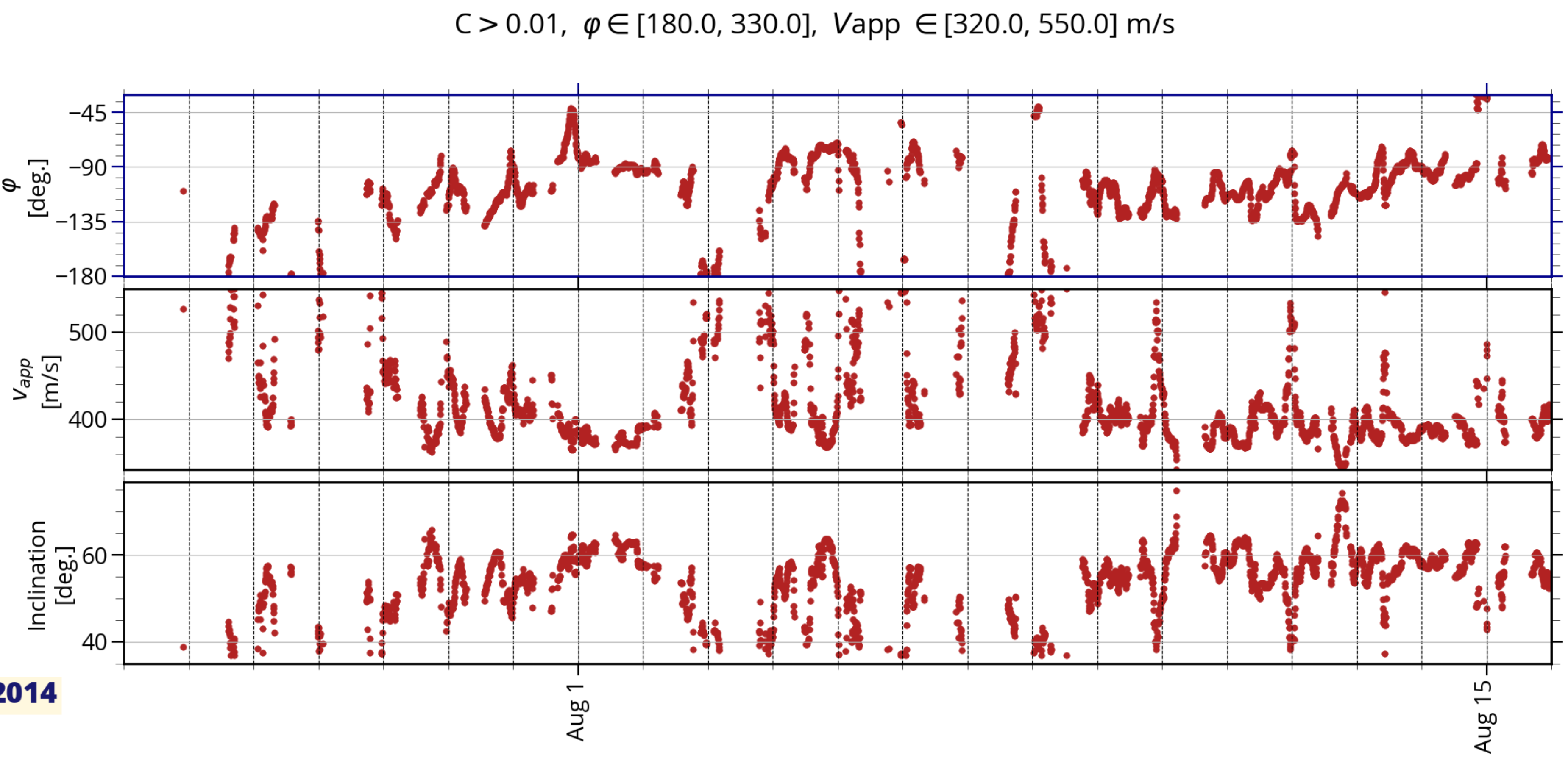
Eastward stratospheric winter vortex

⇒

- In winter, stratospheric arrivals dominate in microbaroms from “Iceland / Greenland hot-spot” at I37NO

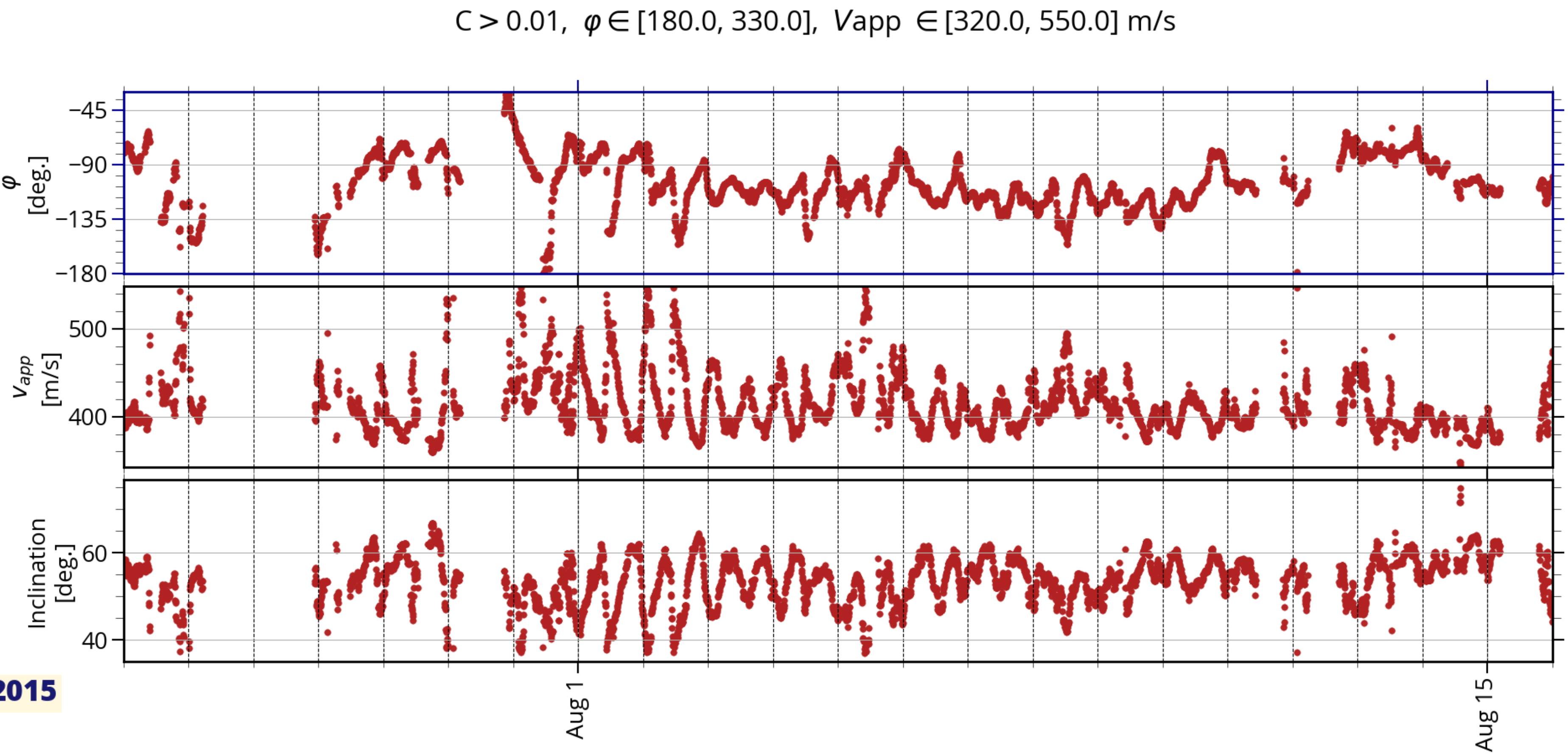
- In summer, MLT arrivals can dominate, but only if signal processing removes stratospheric arrivals from other directions (Pacific / Barents, etc.)

Five late summers, data piped to pseudo-spectrogram



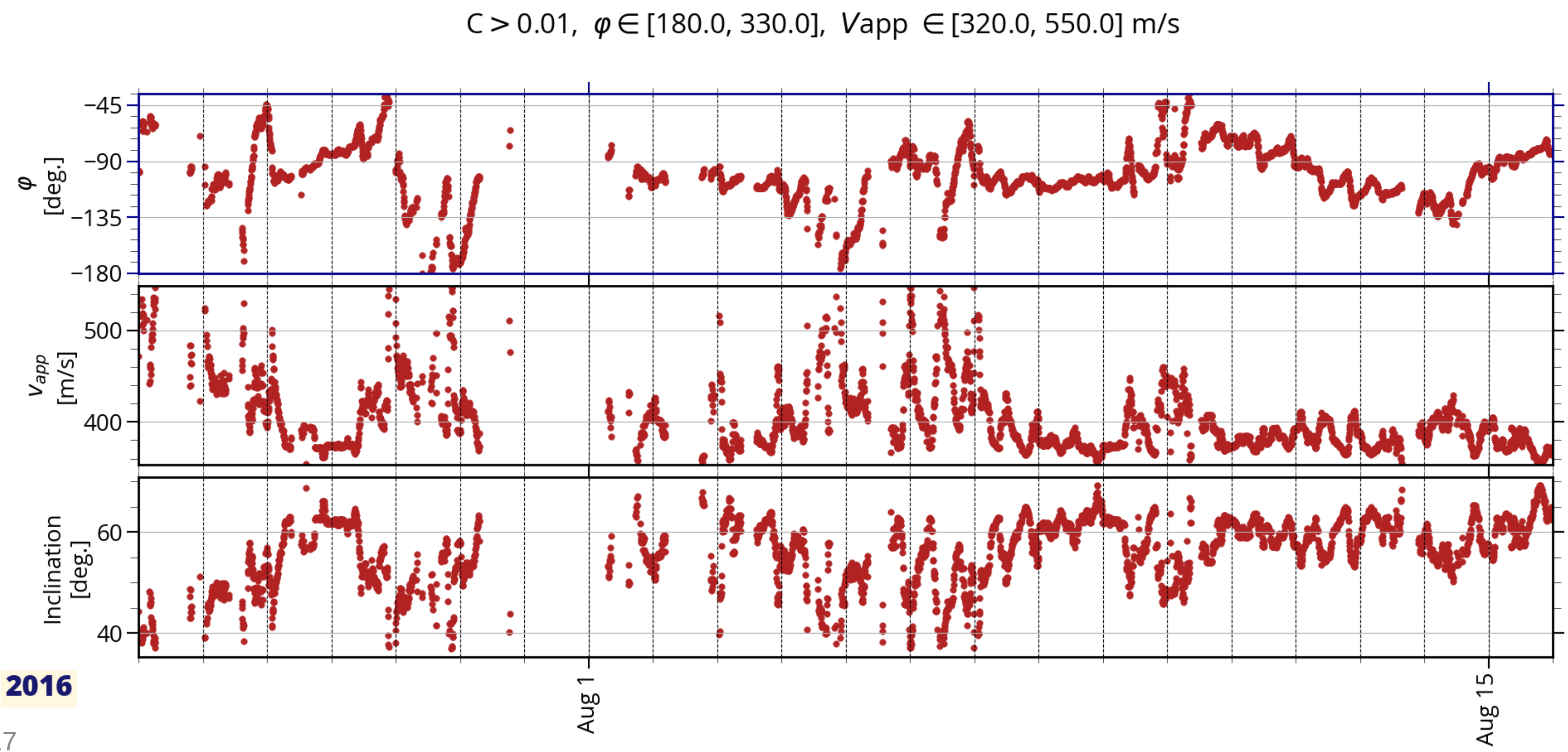
2014

Five late summers, data piped to pseudo-spectrogram



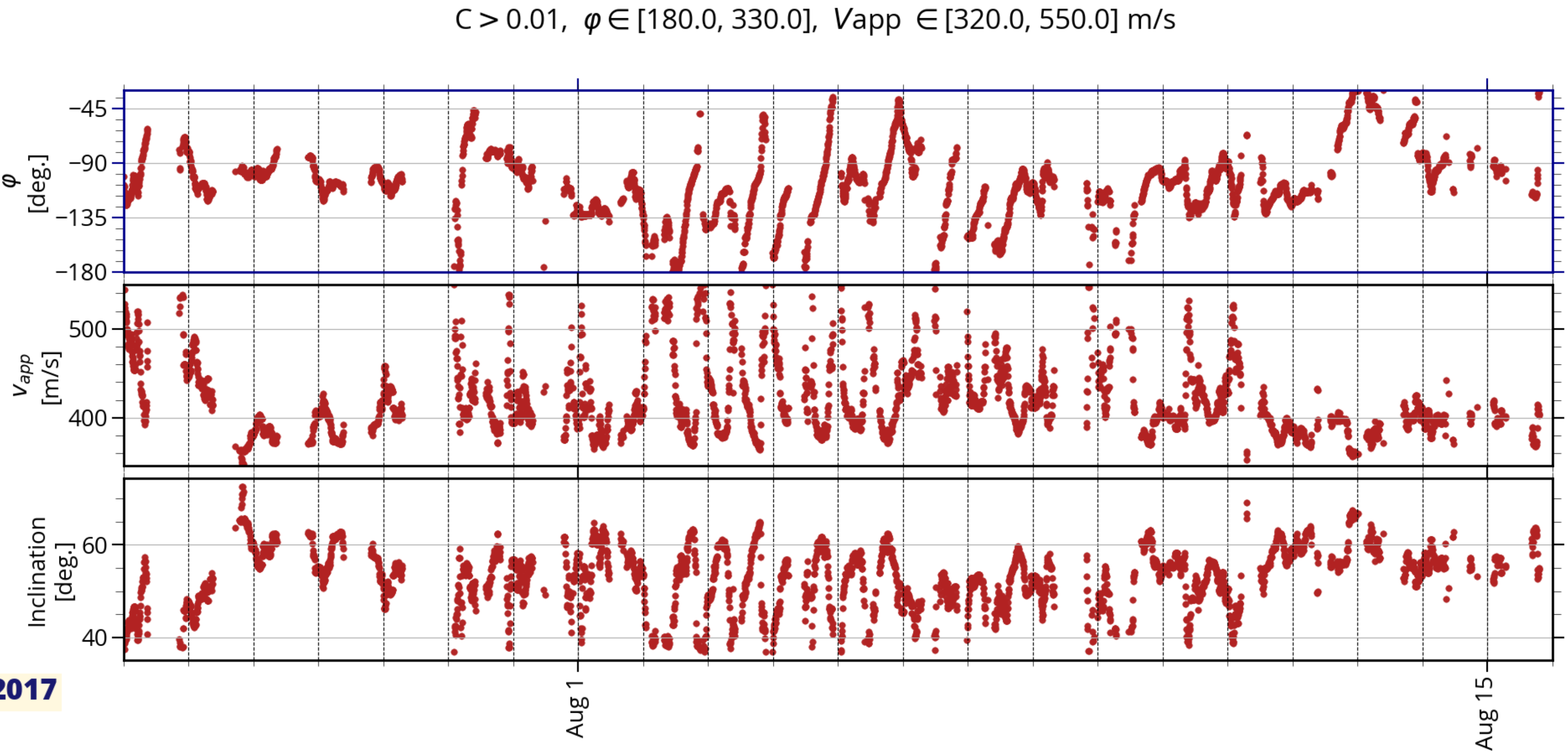
2015

Five late summers, data piped to pseudo-spectrogram



2016

Five late summers, data piped to pseudo-spectrogram



2017

Five late summers, data piped to pseudo-spectrogram

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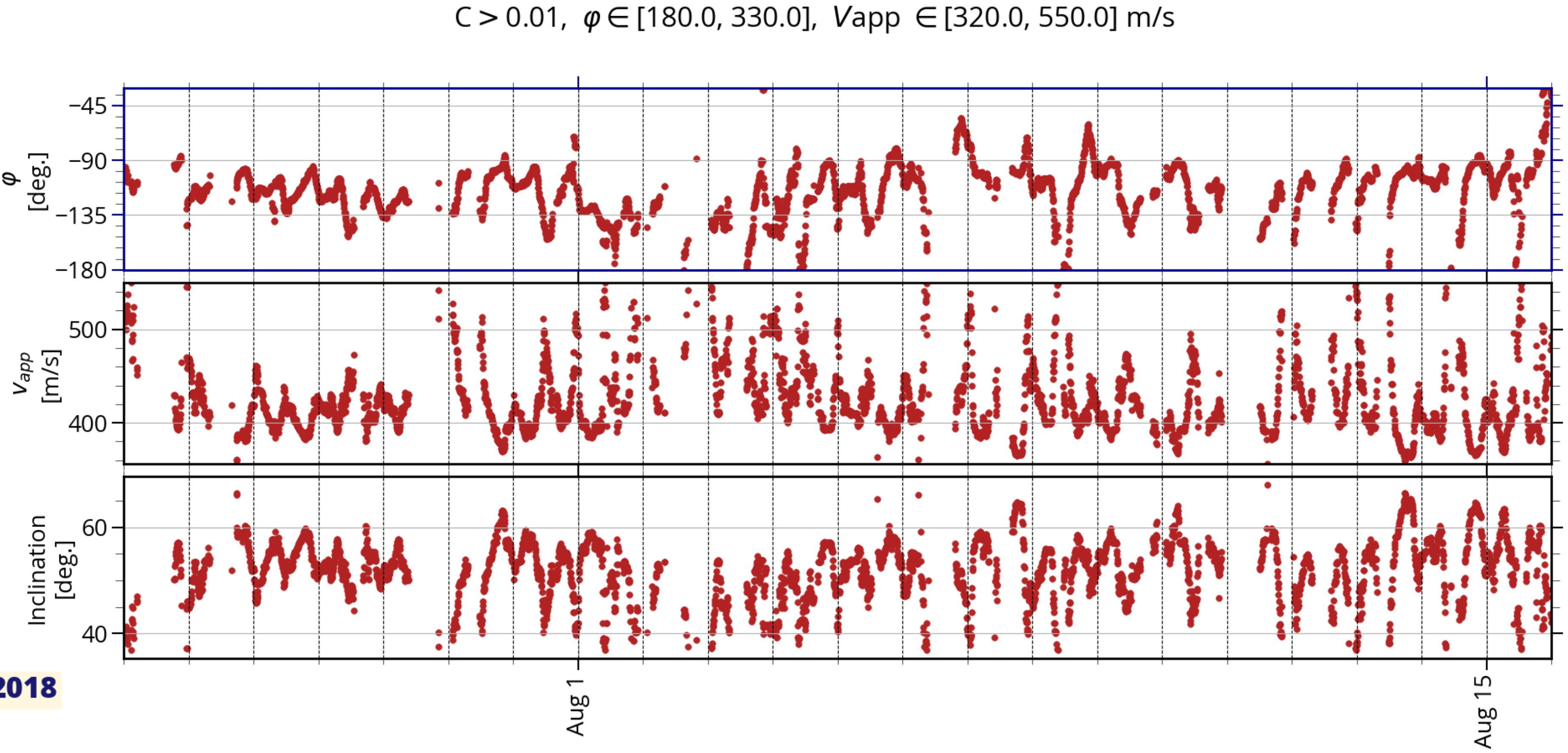
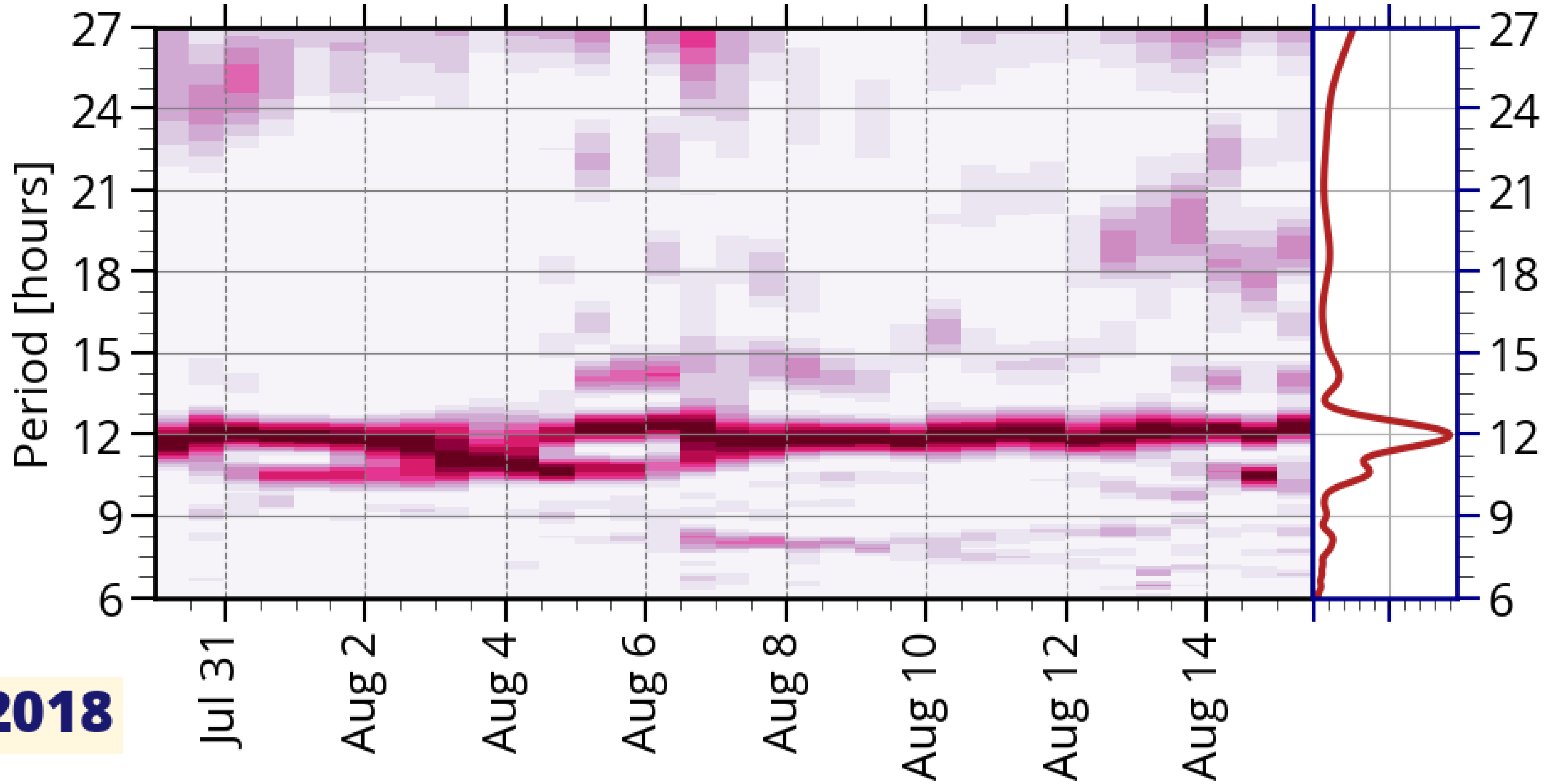


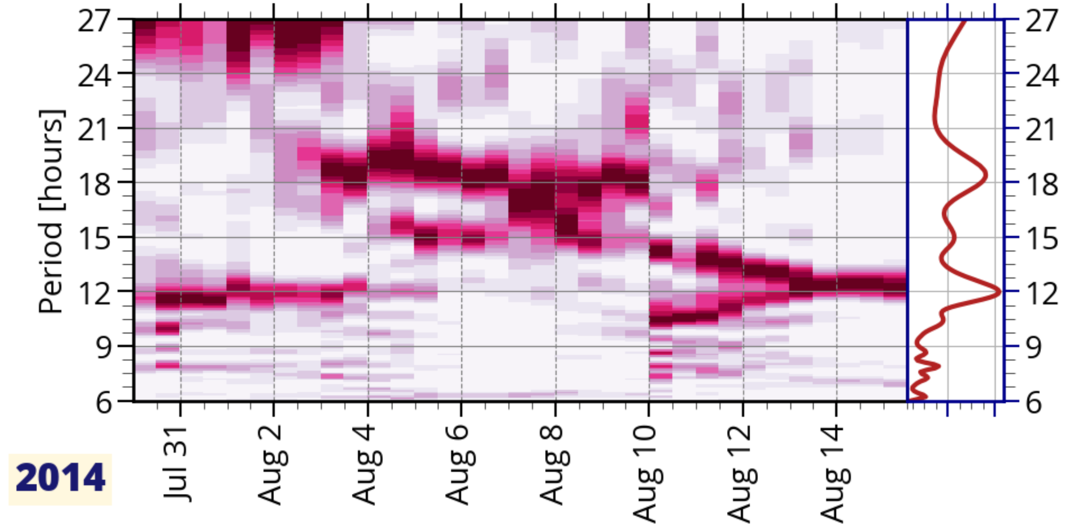
2018

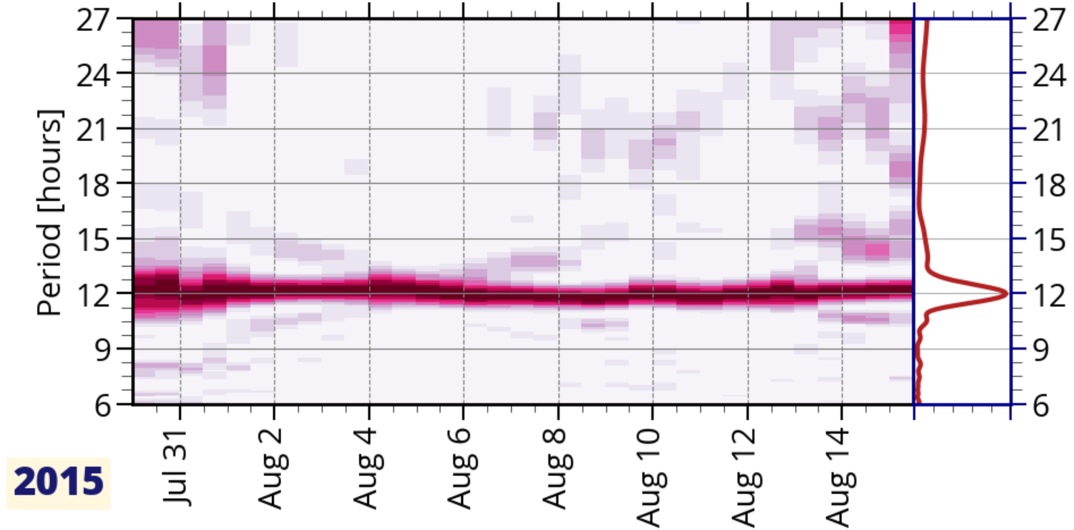
Late summer pseudo-spectrogram from inclination angle



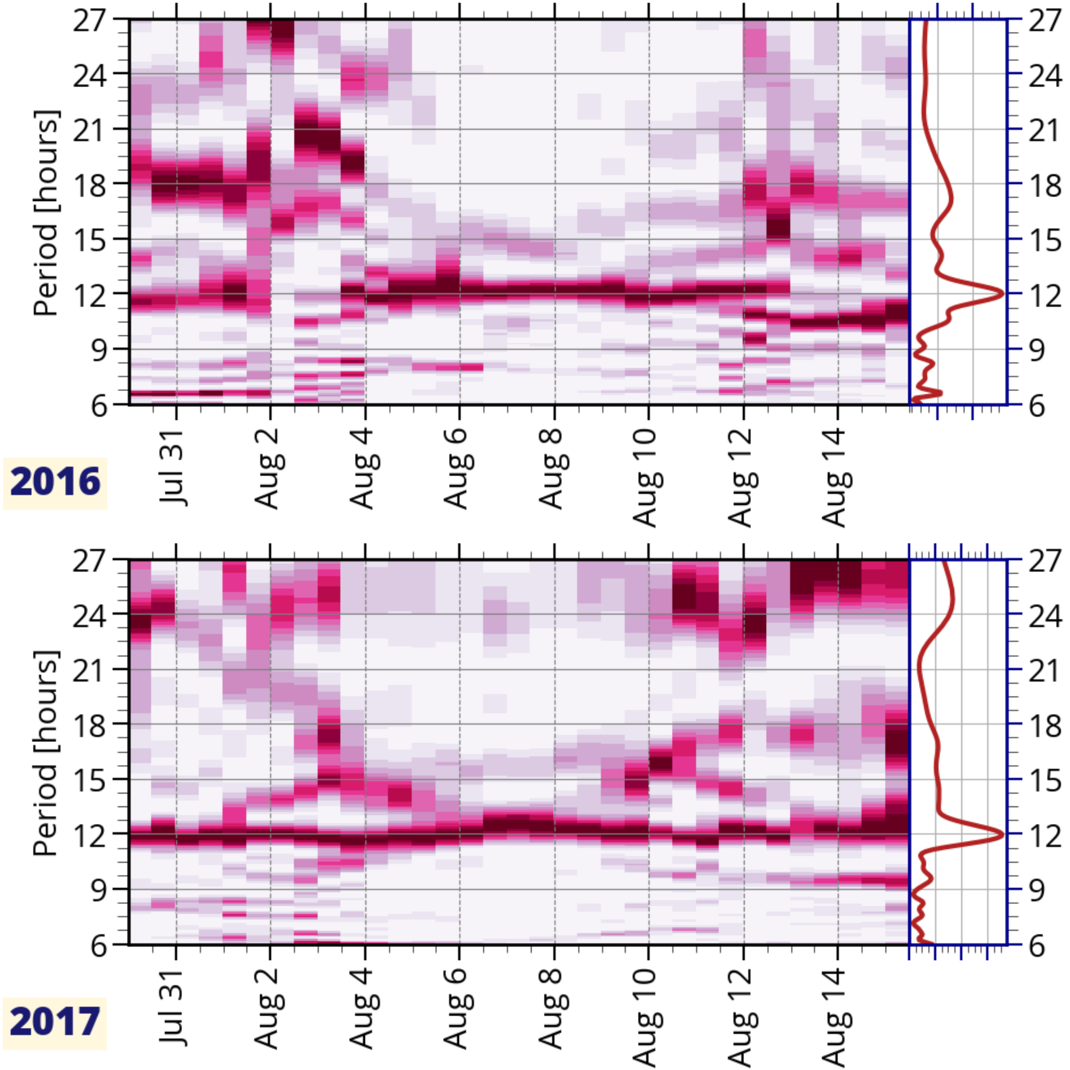
2018

Pseudo-spectrograms
from inclination angle

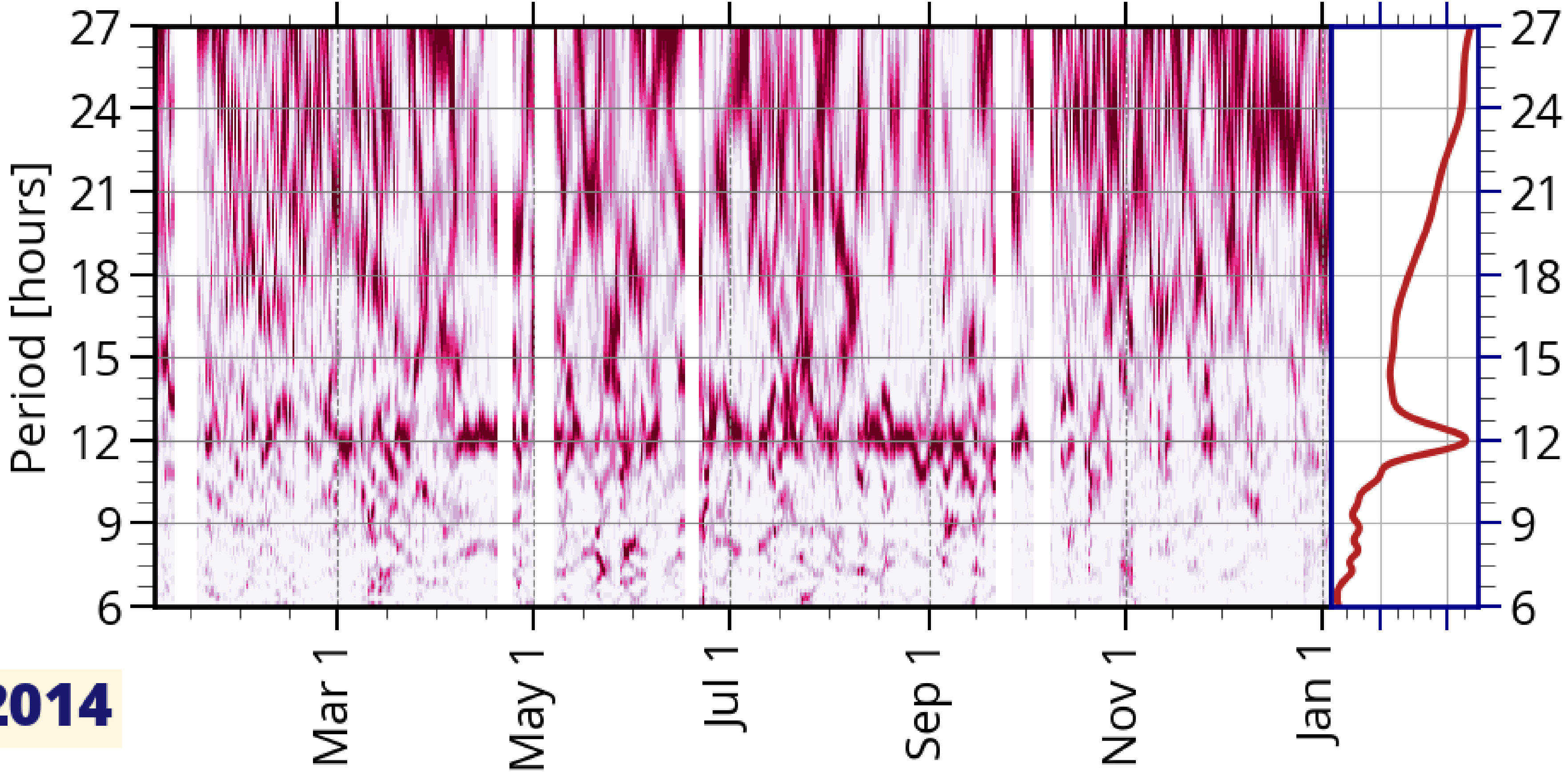




Pseudo-spectrograms
from inclination angle

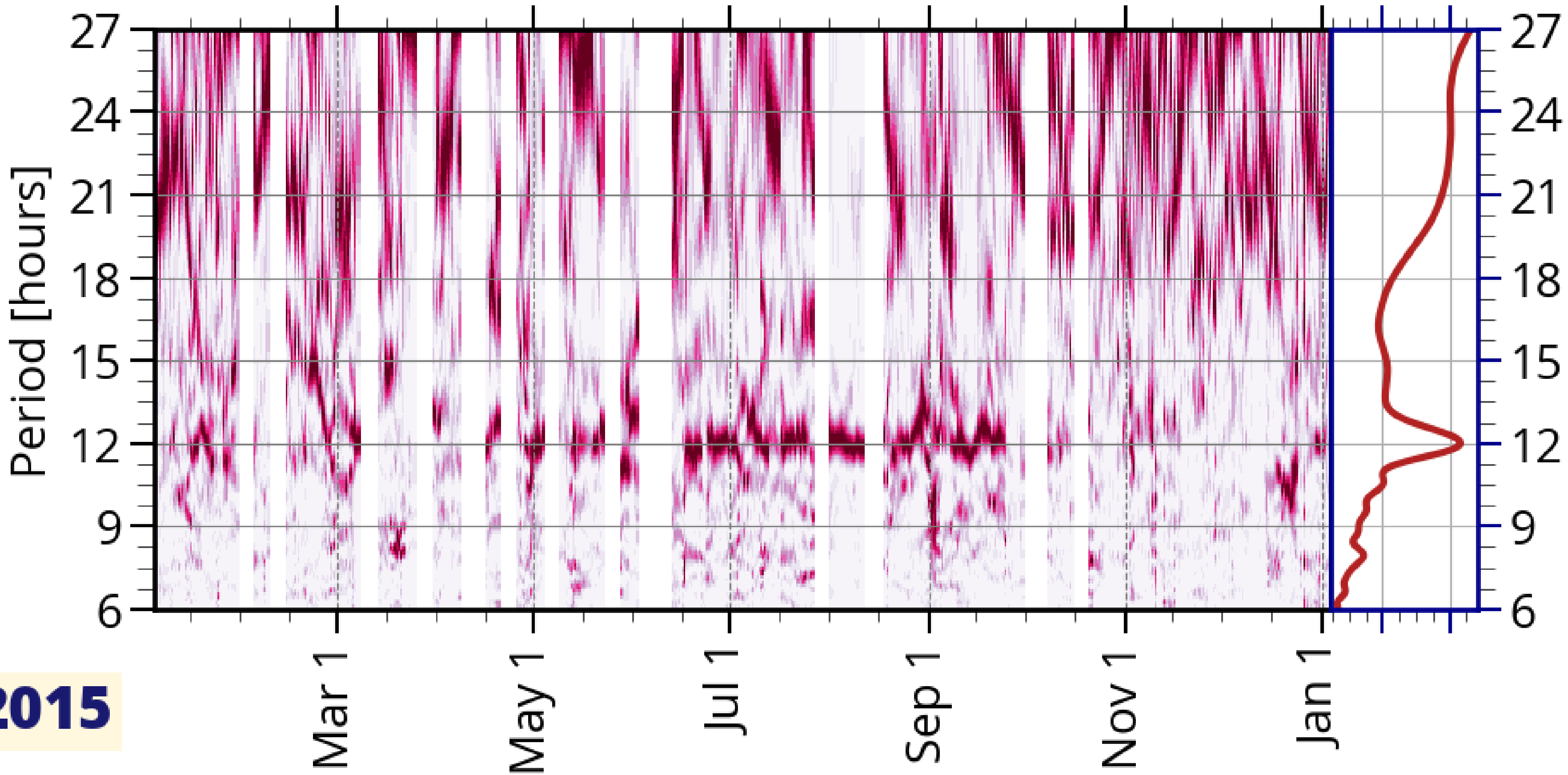


Whole-year pseudo-spectrograms from inclination angle



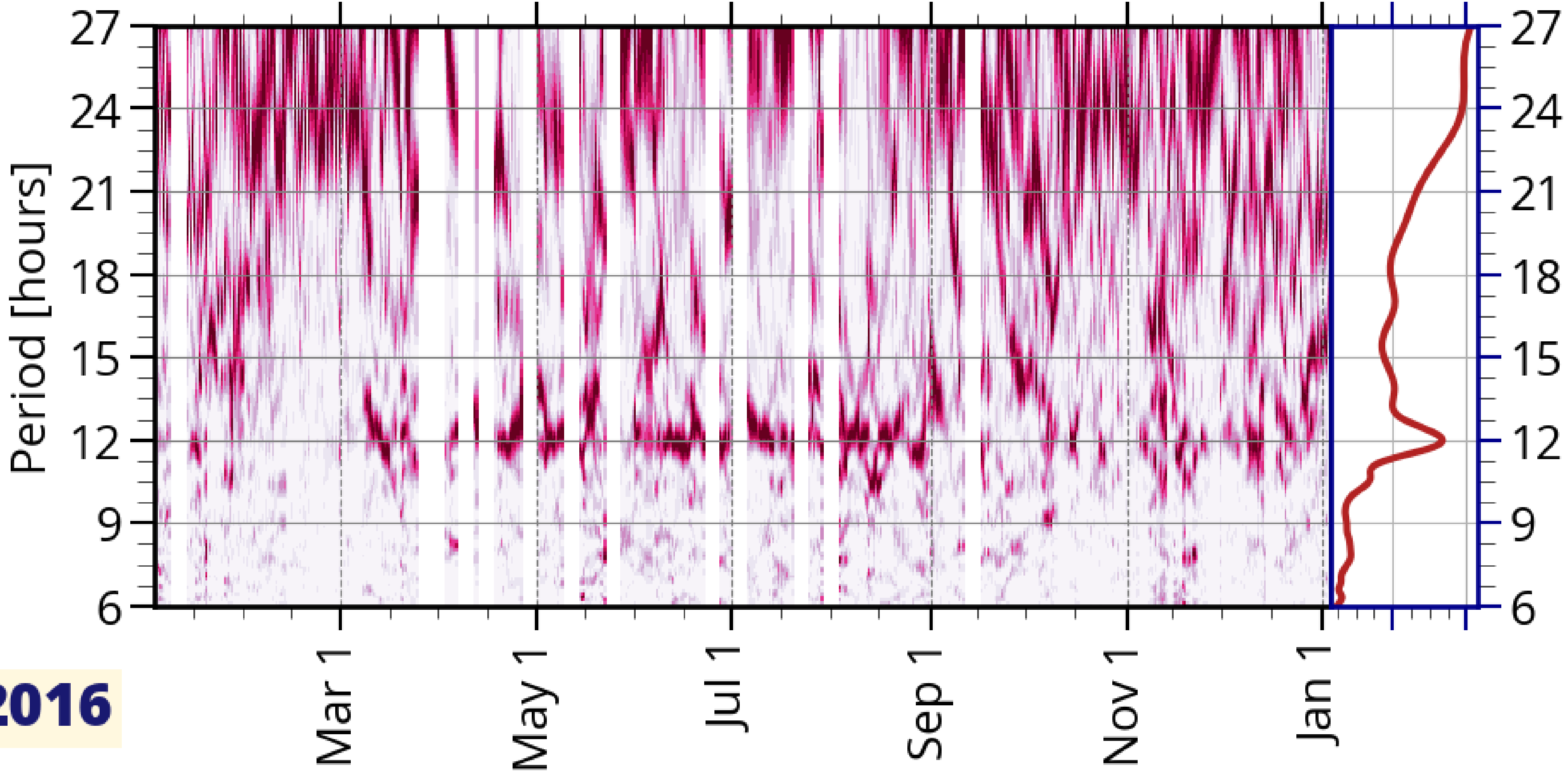
2014

Whole-year pseudo-spectrograms from inclination angle



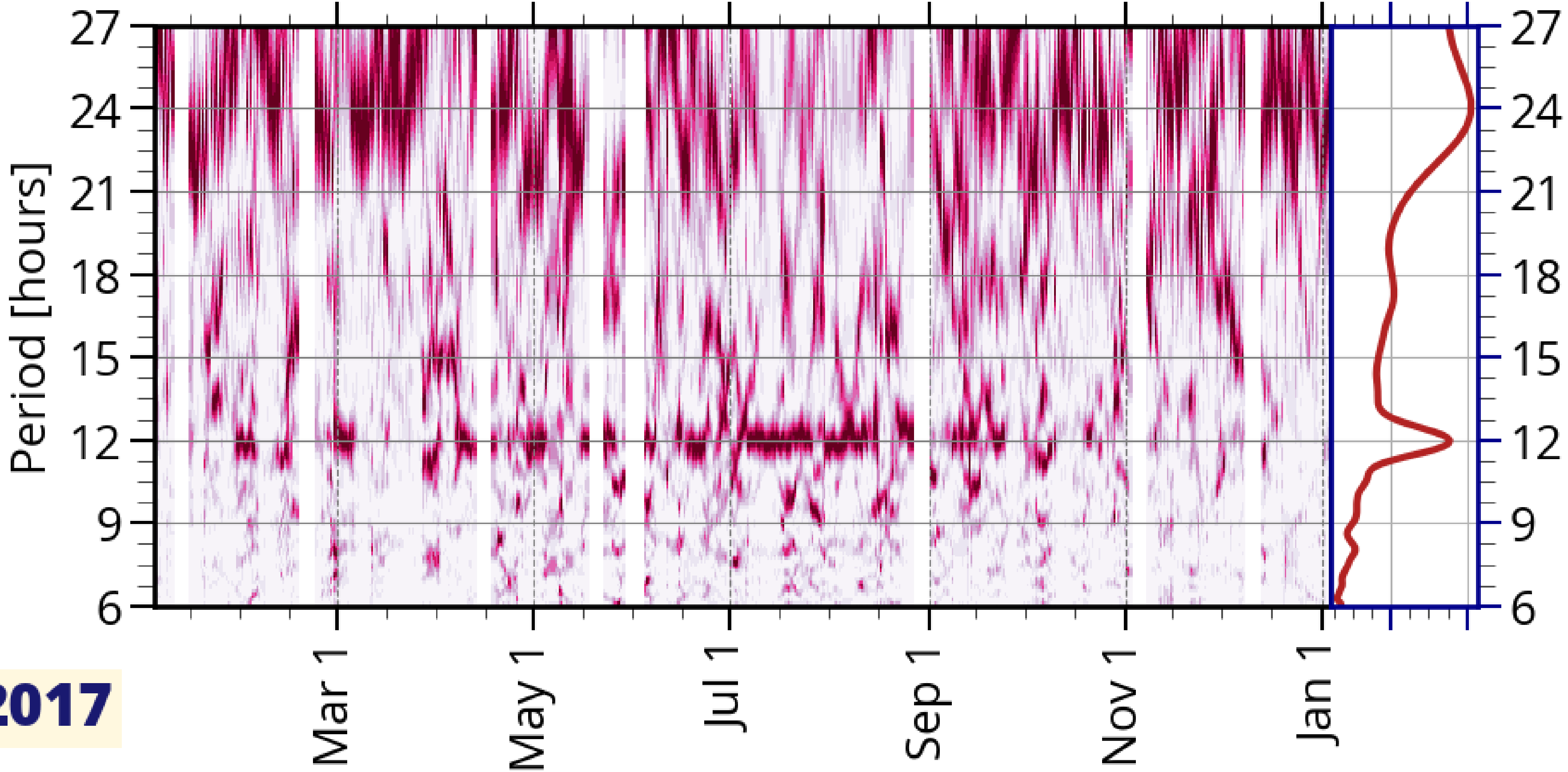
2015

Whole-year pseudo-spectrograms from inclination angle



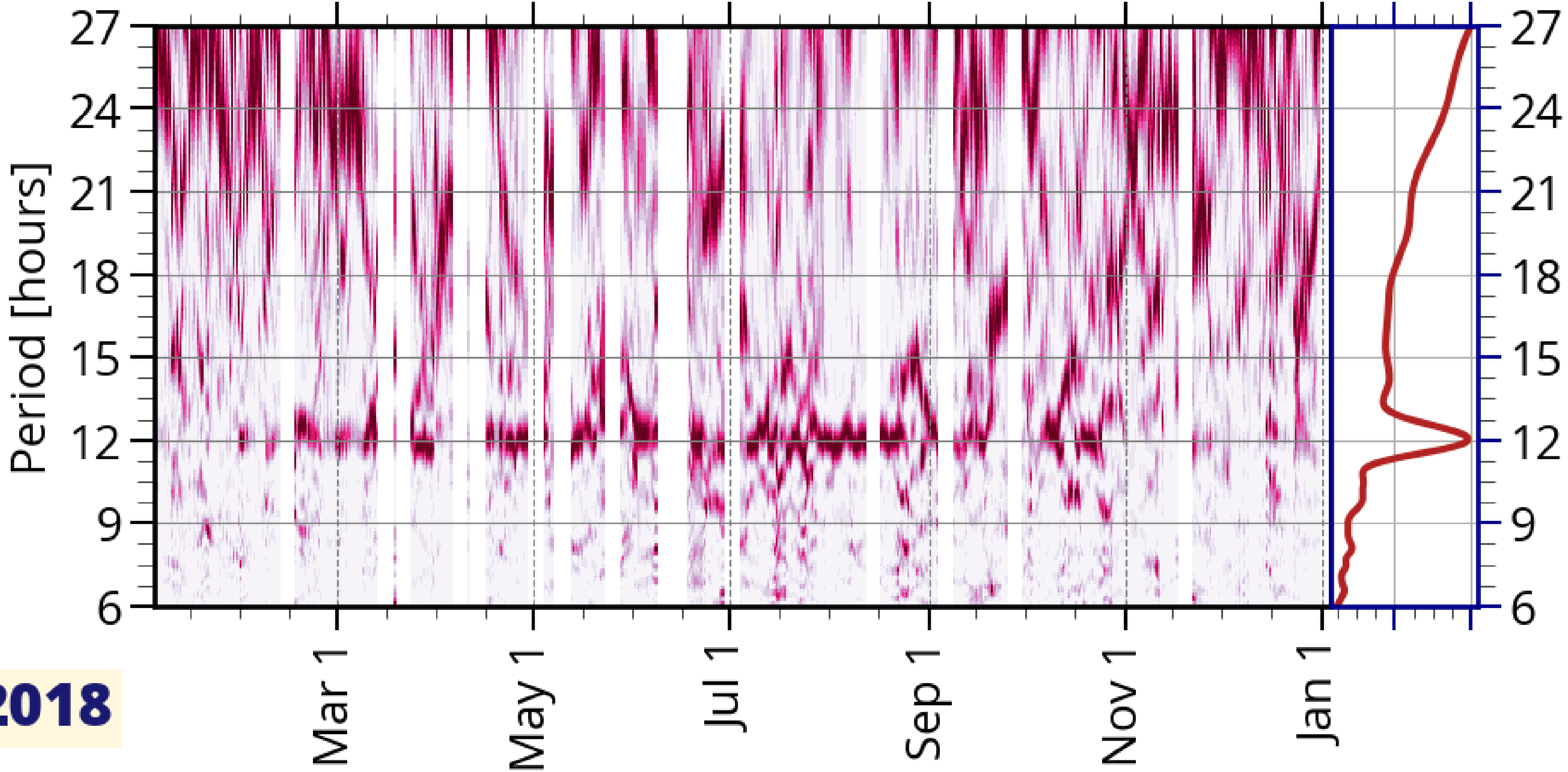
2016

Whole-year pseudo-spectrograms from inclination angle



2017

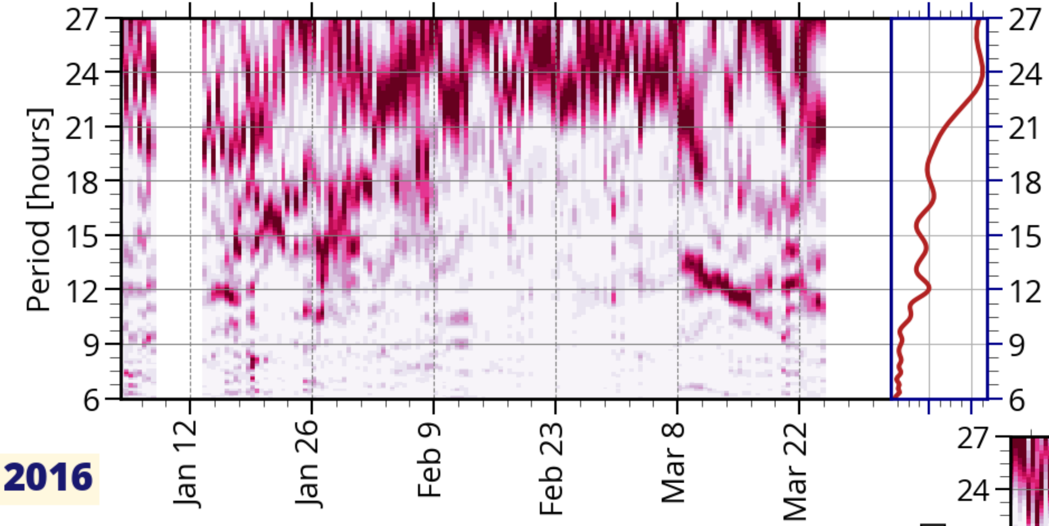
Whole-year pseudo-spectrograms from inclination angle



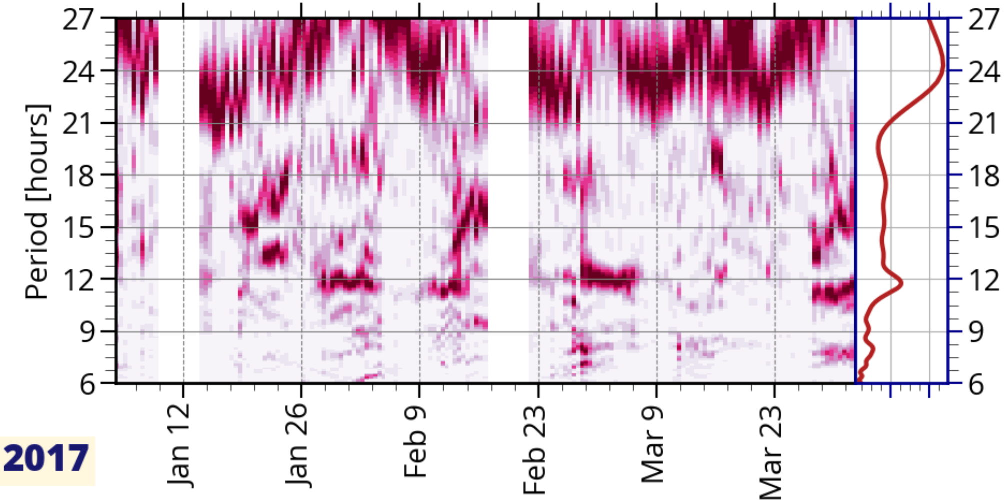
2018

Winter examples: “less semidiurnal”

Pseudo-spectrograms from inclination angle



2016



2017

Reflections

Current study

Focus on *identifying* semidiurnal variations in microbarom data

What's next ?

- Benchmarking against models & other data ?
- Apply similar method to other infrasound parameter time-series ?
- Evaluate time-of-delay (phase) evolution of the L-S pseudo-spectrogram ?
- Evaluate prospective added-value to atmospheric probing of the MLT ?
- Infrasound-based wind estimates would be great of great value

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References

Donn W.L., Rind D. (1971) Natural infrasound as an atmospheric probe. Geophys J R Astron Soc 26:111–133

Hibbins, R. E., Espy, P. J., Orsolini, Y. J., Limpasuvan, V., & Barnes, R. J. (2019). SuperDARN observations of semidiurnal tidal variability in the MLT and the response to sudden stratospheric warming events. Journal of Geophysical Research: Atmospheres, 124(9), 4862-4872.

Mitchell, N. J., Pancheva, D., Middleton, H. R., Hagan, M., (2002). Mean winds and tides in the Arctic mesosphere and lower thermosphere, *J. Geophys. Res.*, 107(A1), doi: 10.1029/2001JA900127.

Riggin, D. M., Meyer, C. K., Fritts, D. C., Jarvis, M. J., Murayama, Y., Singer, W., Vincent, R. A. & Murphy, D. J. (2003). MF radar observations of seasonal variability of semidiurnal motions in the mesosphere at high northern and southern latitudes. Journal of Atmospheric and Solar-Terrestrial Physics, 65(4), 483-493.

Smets, P. S. M., & Evers, L. G. (2014). The life cycle of a sudden stratospheric warming from infrasonic ambient noise observations. *Journal of Geophysical Research: Atmospheres*, *119*(21), 12-084.

Smets, P., Assink, J., & Evers, L. (2019). The study of sudden stratospheric warmings using infrasound. In *Infrasound Monitoring for Atmospheric Studies* (pp. 723-755). Springer, Cham.

VanderPlas, J. T., & Ivezic, Ž. (2015). Periodograms for multiband astronomical time series. *The Astrophysical Journal*, *812*(1), 18.

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  Middle Atmosphere Dynamics: Exploiting Infrasound Using a Multidisciplinary Approach at High Latitudes (MADEIRA)

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Appendix A:

Comparison with *backazimuth* pseudo-spectrograms

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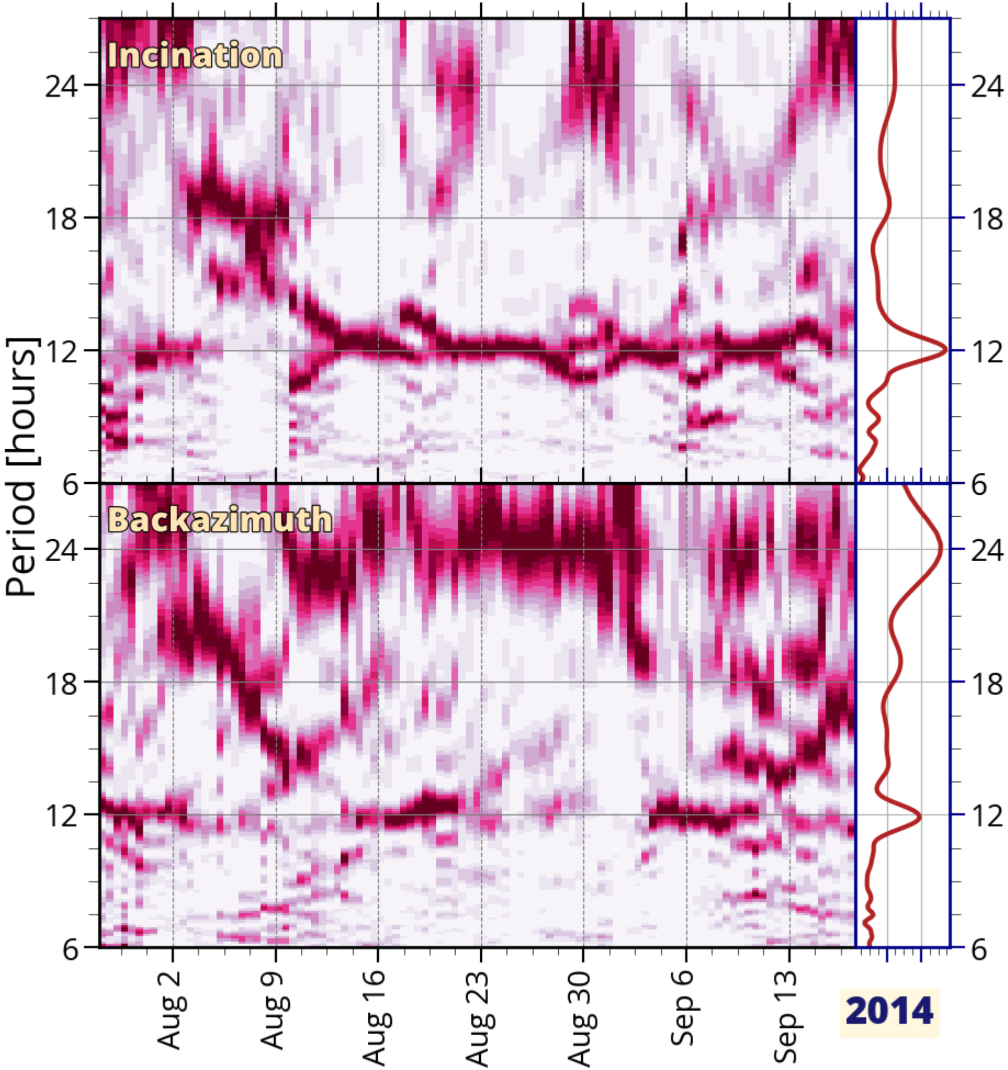
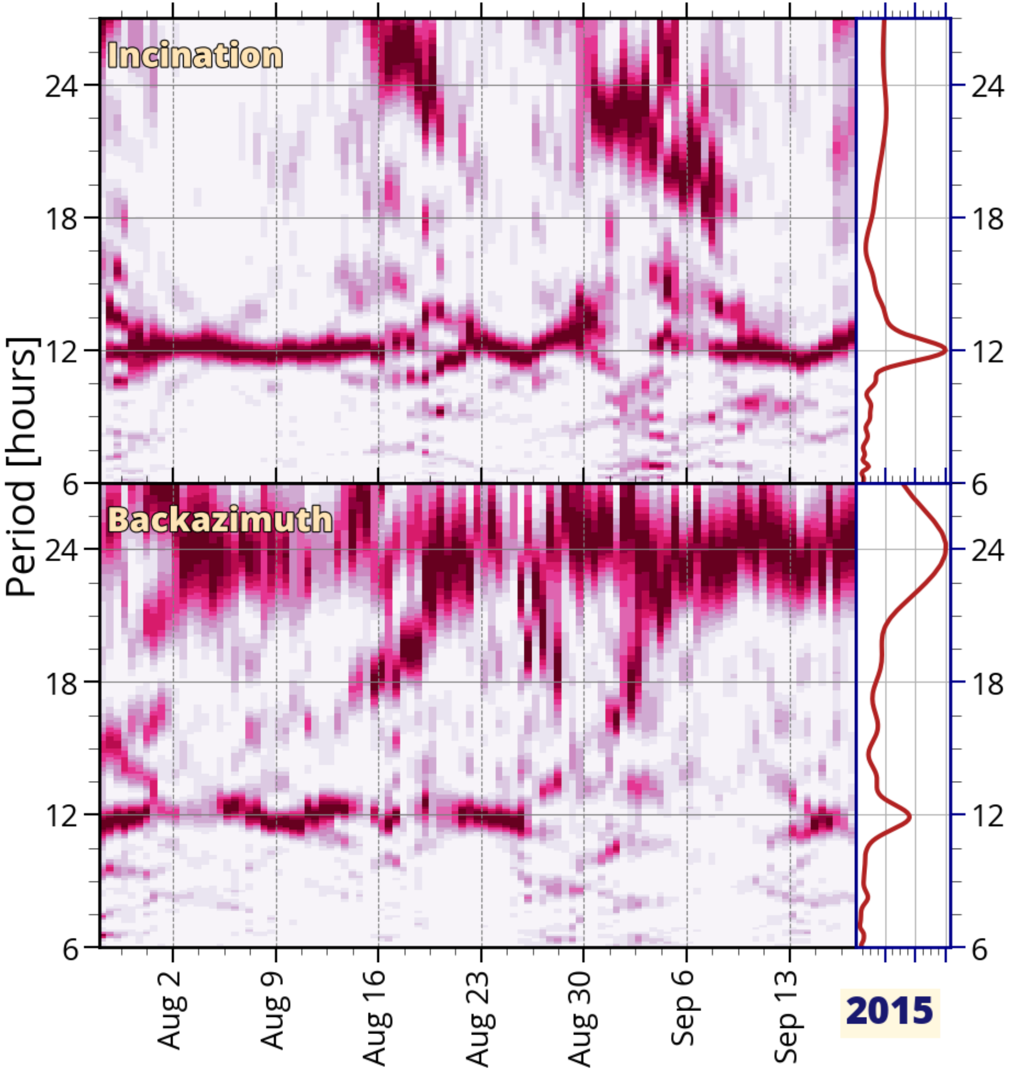
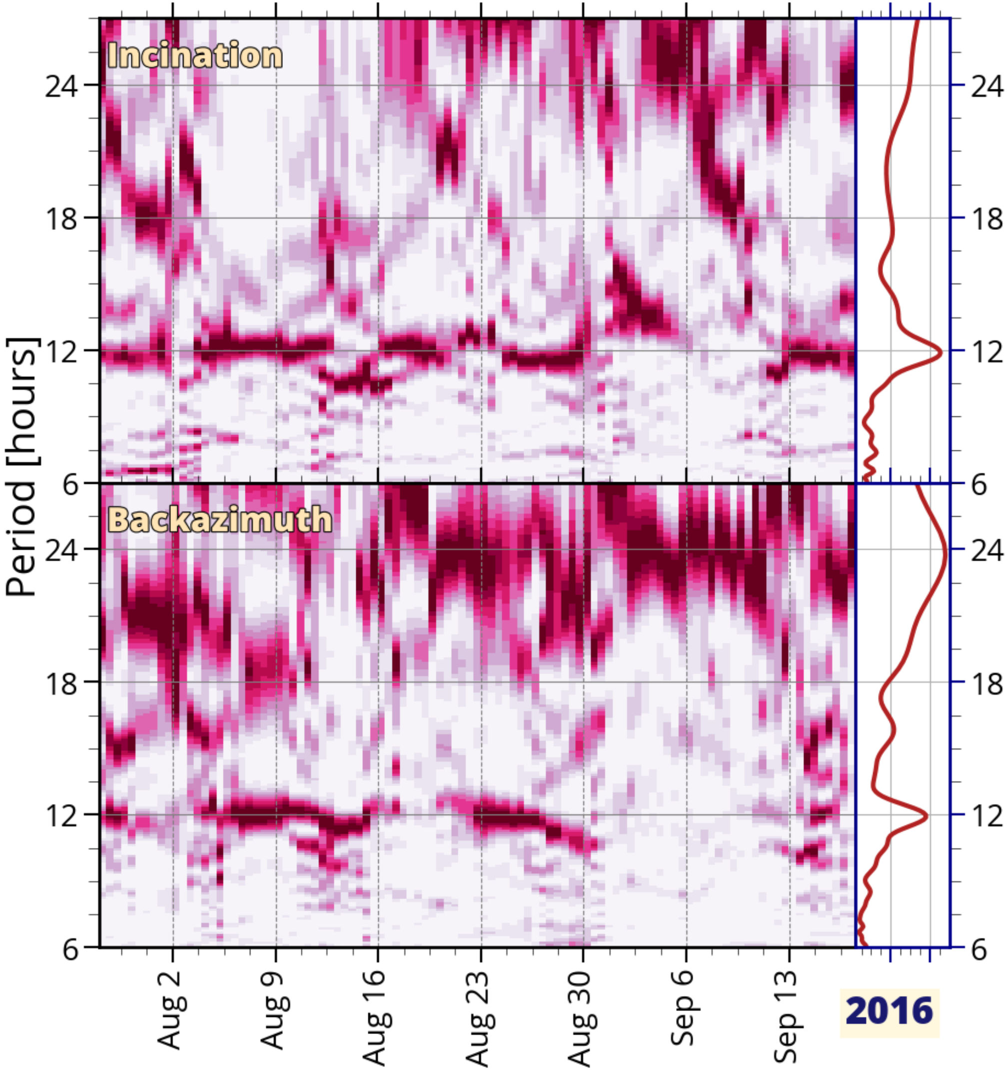
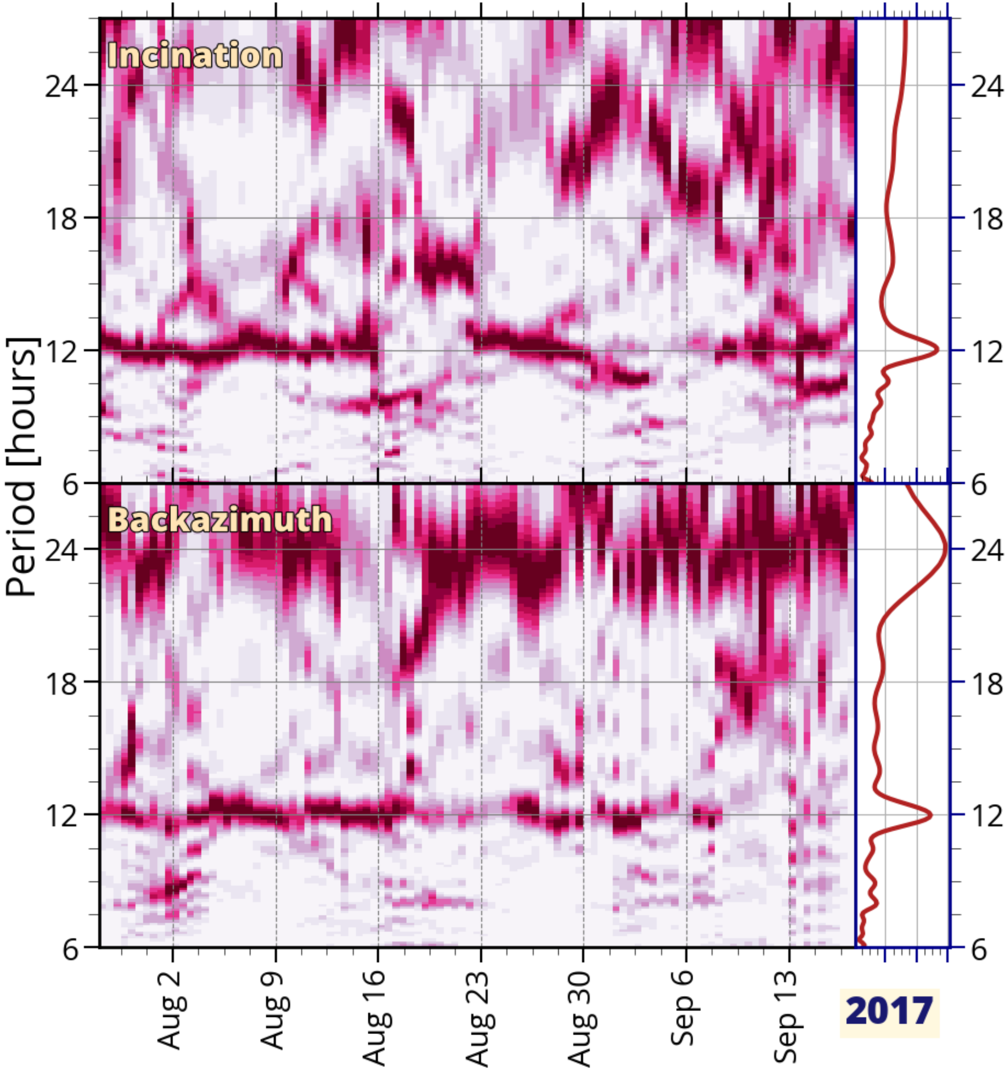


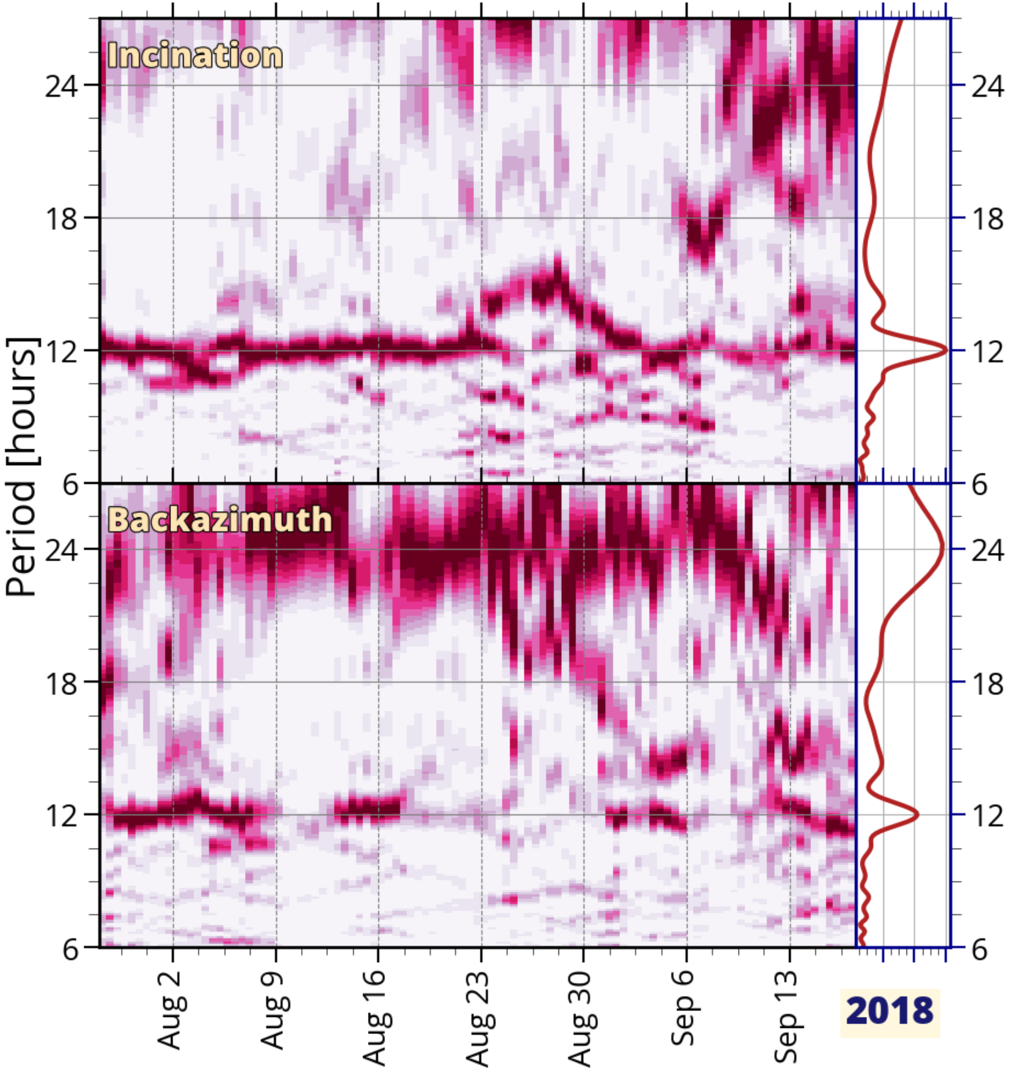
Incination
Backazimuth
Period [hours]
24
18
12
6
Aug 2
Aug 9
Aug 16
Aug 23
Aug 30
Sep 6
Sep 13
2014



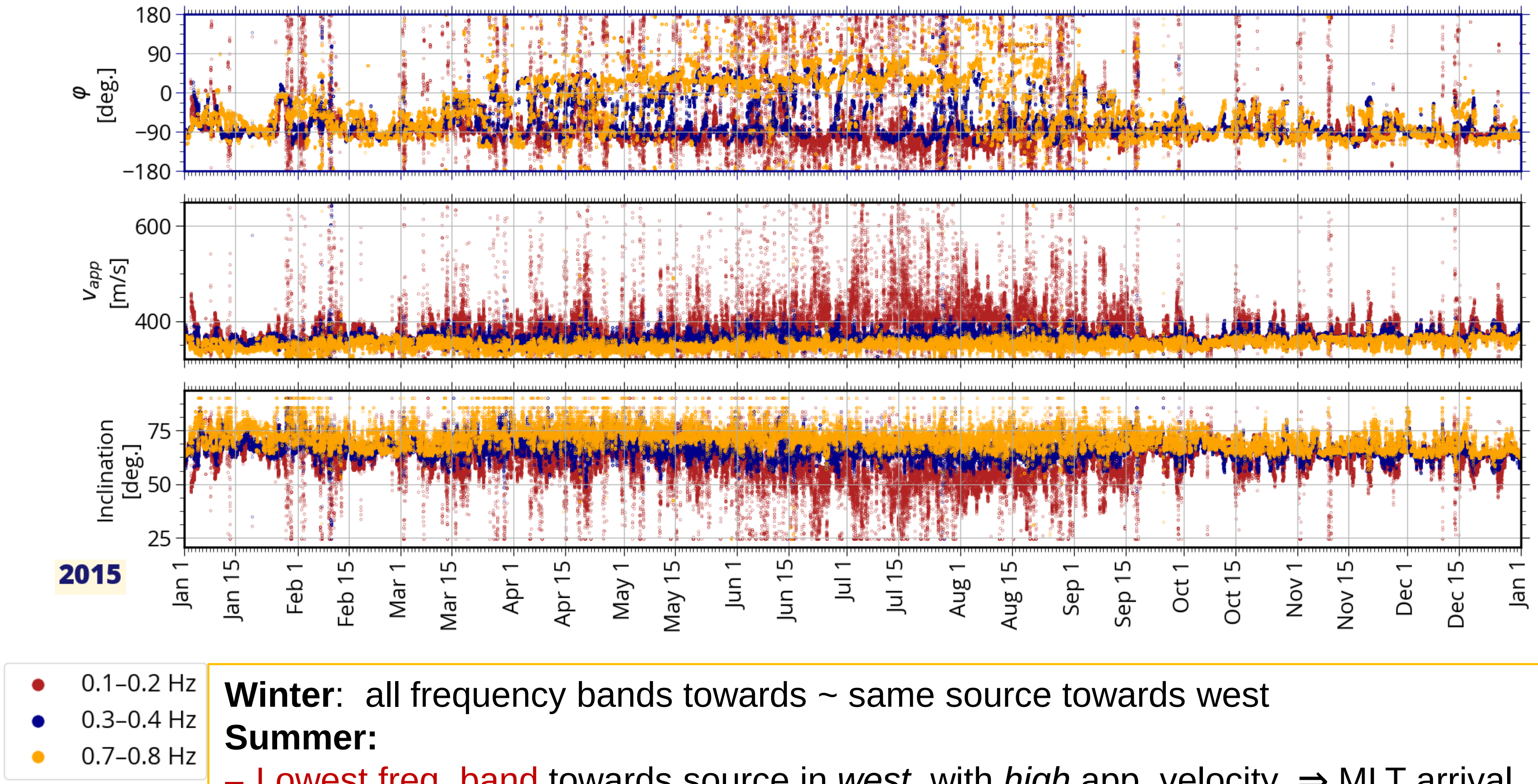
Incination
Backazimuth
Period [hours]
24
18
12
6
Aug 2
Aug 9
Aug 16
Aug 23
Aug 30
Sep 6
Sep 13
2015


Incination
Backazimuth
Period [hours]
24
18
12
6
Aug 2
Aug 9
Aug 16
Aug 23
Aug 30
Sep 6
Sep 13
2016


Incination
Backazimuth
Period [hours]
24
18
12
6
Aug 2
Aug 9
Aug 16
Aug 23
Aug 30
Sep 6
Sep 13
2017


Incination
Backazimuth
Period [hours]
24
18
12
6
Aug 2
Aug 9
Aug 16
Aug 23
Aug 30
Sep 6
Sep 13
2018

Appendix B: data point sifting demo

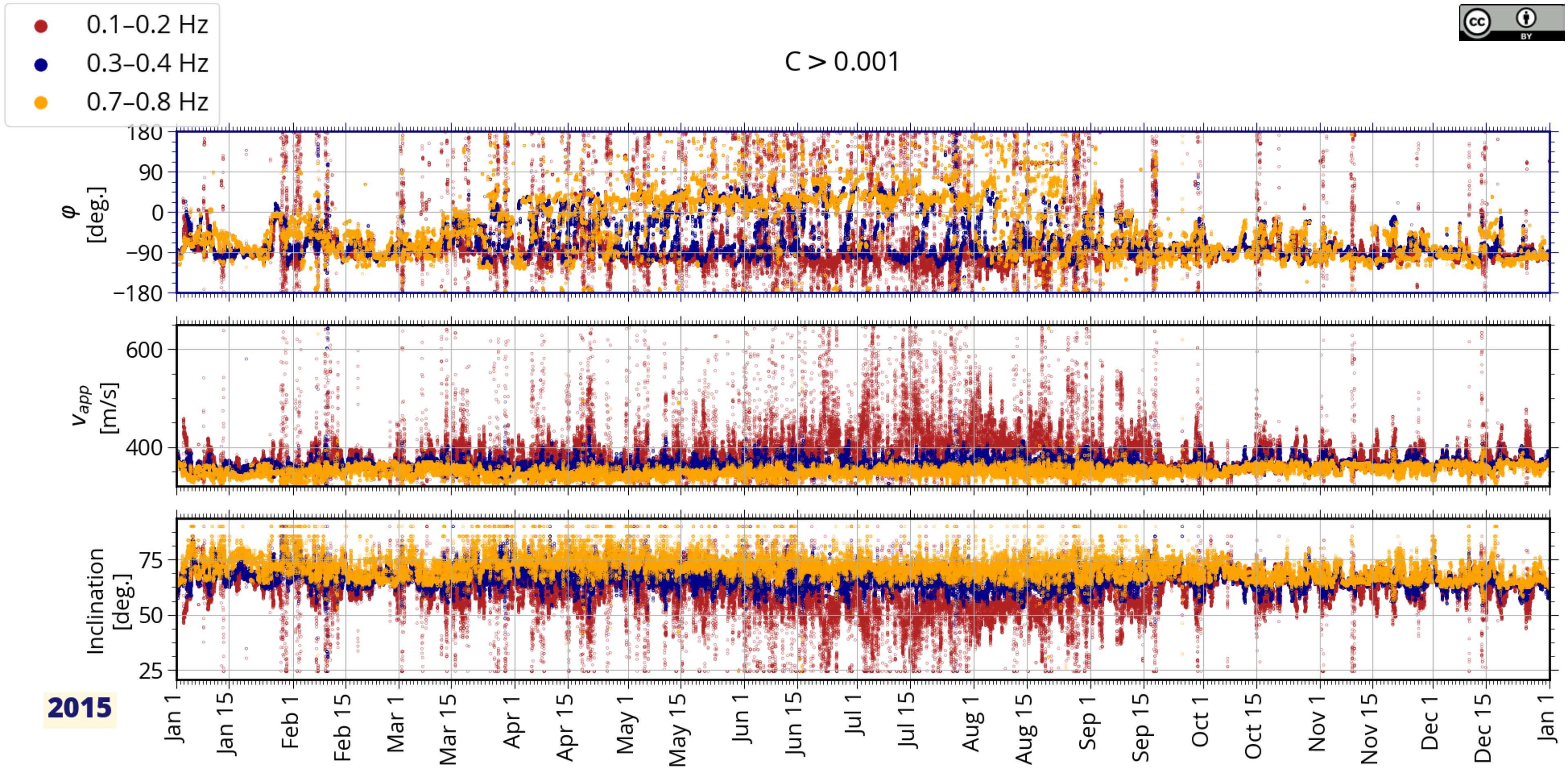


Winter: all frequency bands towards ~ same source towards west

Summer:

– Lowest freq. band towards source in *west*, with *high* app. velocity ⇒ MLT arrival

– Highest freq. band varying direction, with *lower* app. velocity ⇒ Stratospheric arrival



0.1–0.2 Hz
0.3–0.4 Hz
0.7–0.8 Hz
C > 0.001
φ [deg.]
180
90
0
−90
−180
v_{app} [m/s]
600
400
Inclination [deg.]
75
50
25
2015
Jan 1
Jan 15
Feb 1
Feb 15
Mar 1
Mar 15
Apr 1
Apr 15
May 1
May 15
Jun 1
Jun 15
Jul 1
Jul 15
Aug 1
Aug 15
Sep 1
Sep 15
Oct 1
Oct 15
Nov 1
Nov 15
Dec 1
Dec 15
Jan 1

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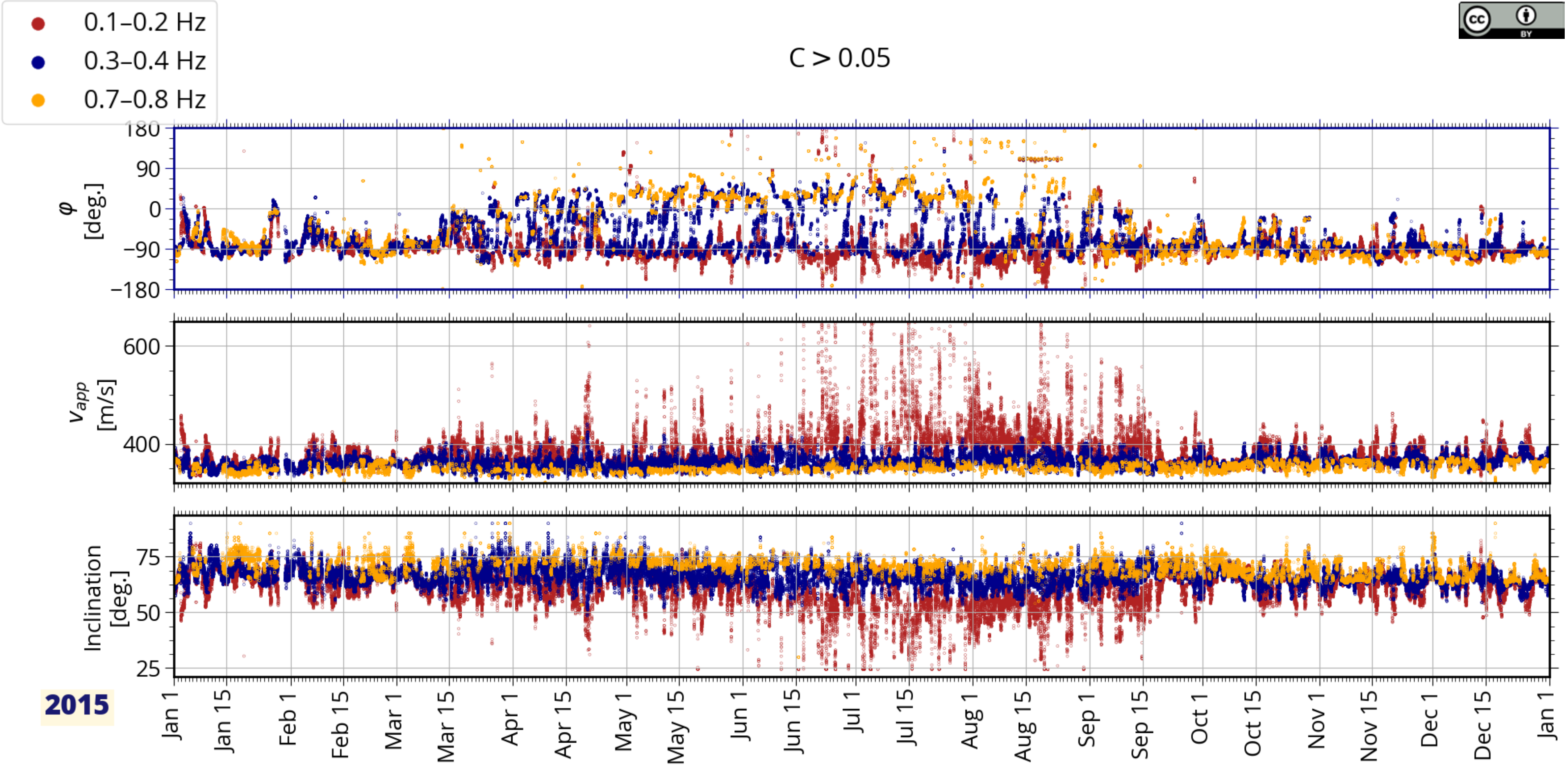
0.1–0.2 Hz
0.3–0.4 Hz
0.7–0.8 Hz
C > 0.05
φ [deg.]
180
90
0
−90
−180
v_{app} [m/s]
600
400
Inclination [deg.]
75
50
25
2015
Jan 1
Jan 15
Feb 1
Feb 15
Mar 1
Mar 15
Apr 1
Apr 15
May 1
May 15
Jun 1
Jun 15
Jul 1
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Aug 1
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Sep 15
Oct 1
Oct 15
Nov 1
Nov 15
Dec 1
Dec 15
Jan 1

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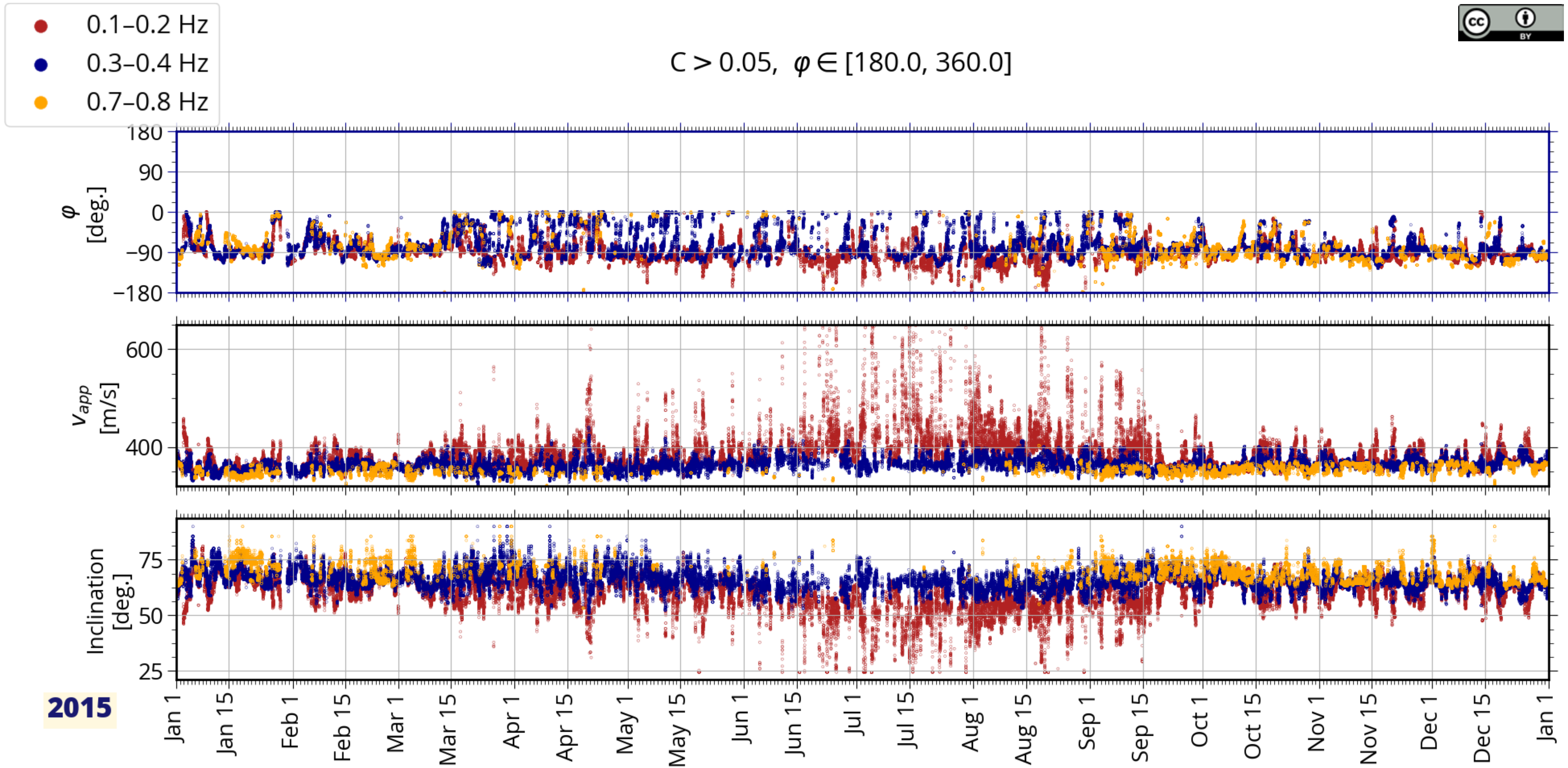
0.1–0.2 Hz
0.3–0.4 Hz
0.7–0.8 Hz
C > 0.05, φ ∈ [180.0, 360.0]
φ [deg.]
180
90
0
−90
−180
v_{app} [m/s]
600
400
Inclination [deg.]
75
50
25
2015
Jan 1
Jan 15
Feb 1
Feb 15
Mar 1
Mar 15
Apr 1
Apr 15
May 1
May 15
Jun 1
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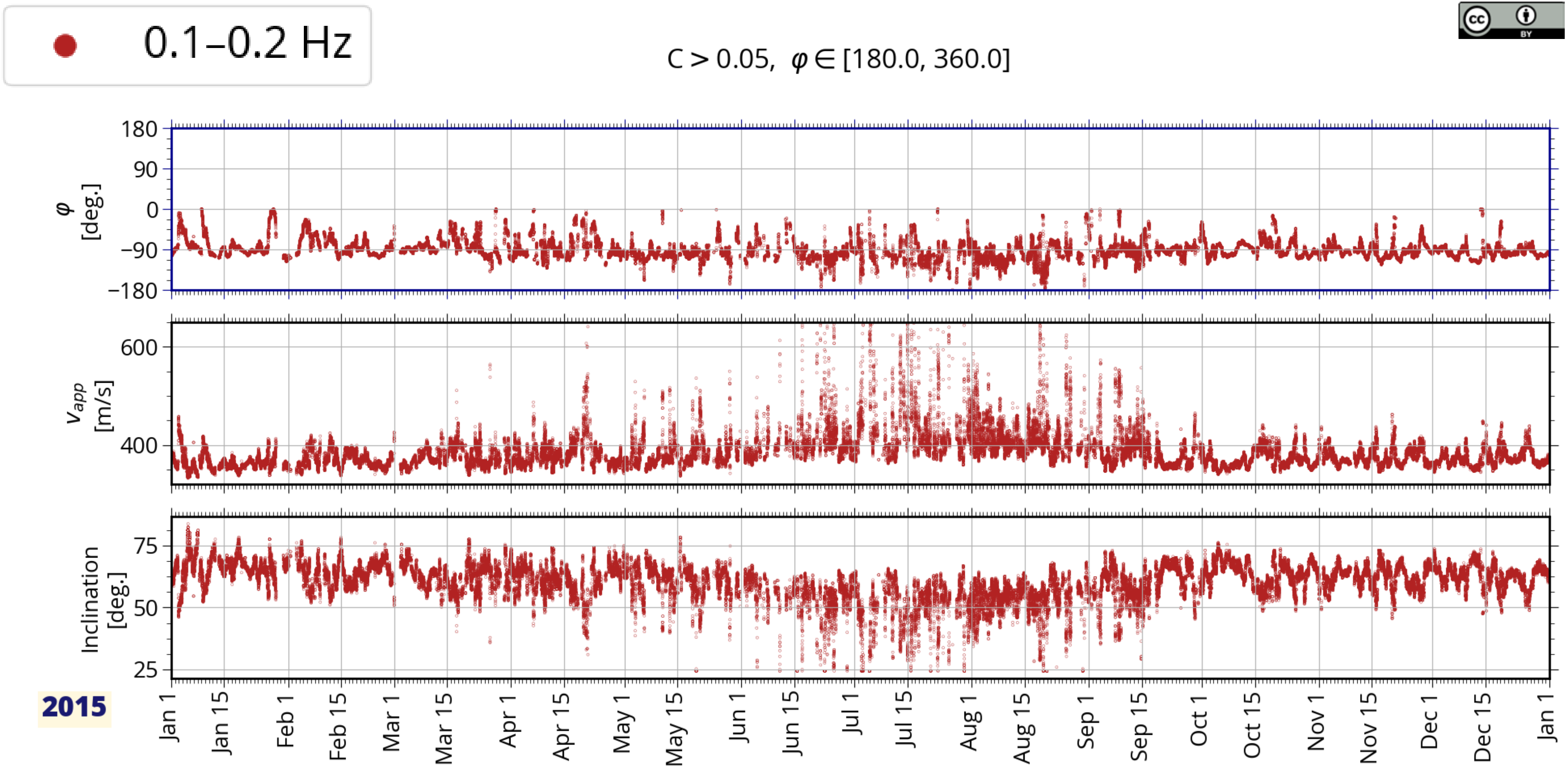
Nov 15
Dec 1
Dec 15
Jan 1


0.1–0.2 Hz
C > 0.05, φ ∈ [180.0, 360.0]
180
90
0
−90
−180
φ [deg.]
600
400
v_{app} [m/s]
75
50
25
Inclination [deg.]
2015
Jan 1
Jan 15
Feb 1
Feb 15
Mar 1
Mar 15
Apr 1
Apr 15
May 1
May 15
Jun 1
Jun 15
Jul 1
Jul 15
Aug 1
Aug 15
Sep 1
Sep 15
Oct 1
Oct 15
Nov 1
Nov 15
Dec 1
Dec 15
Jan 1

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0.1–0.2 Hz

$C > 0.05$, $\varphi \in [180.0, 360.0]$, $V_{app} \in [320.0, 550.0]$ m/s

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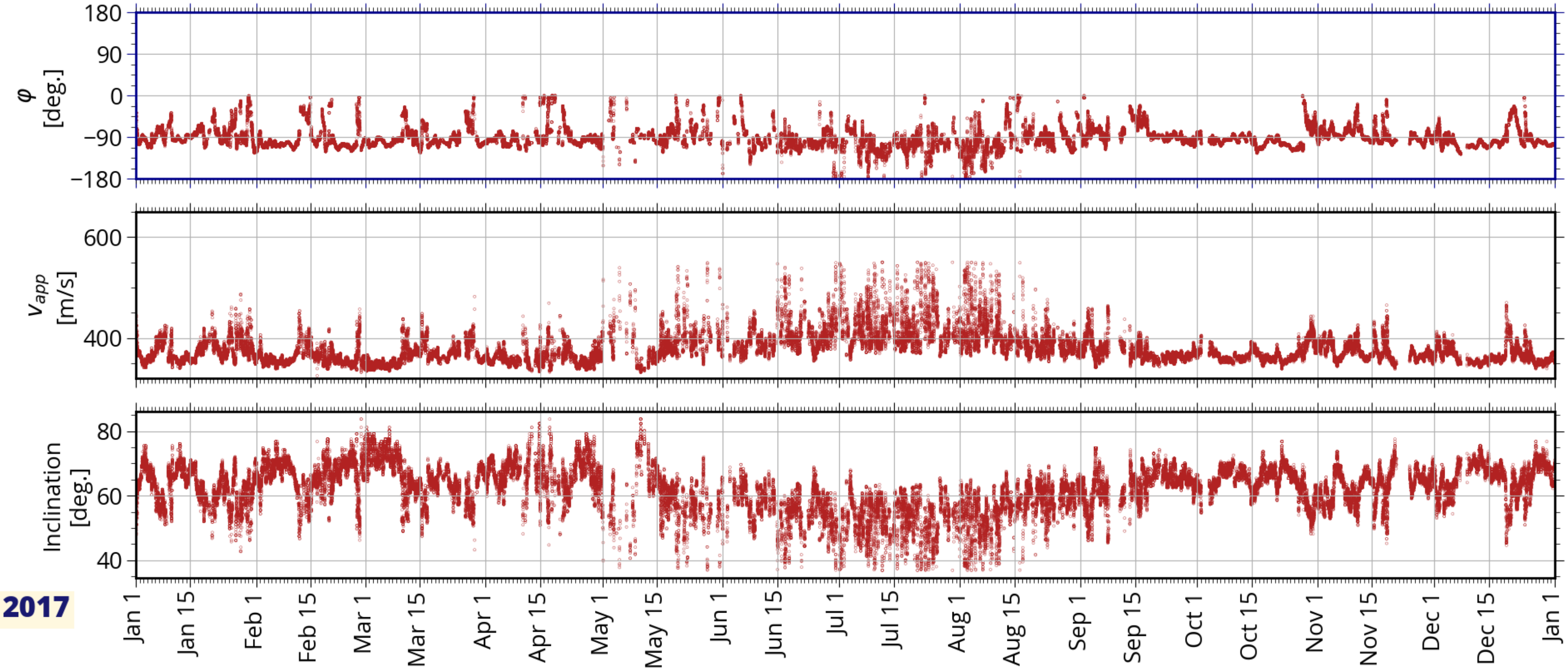

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