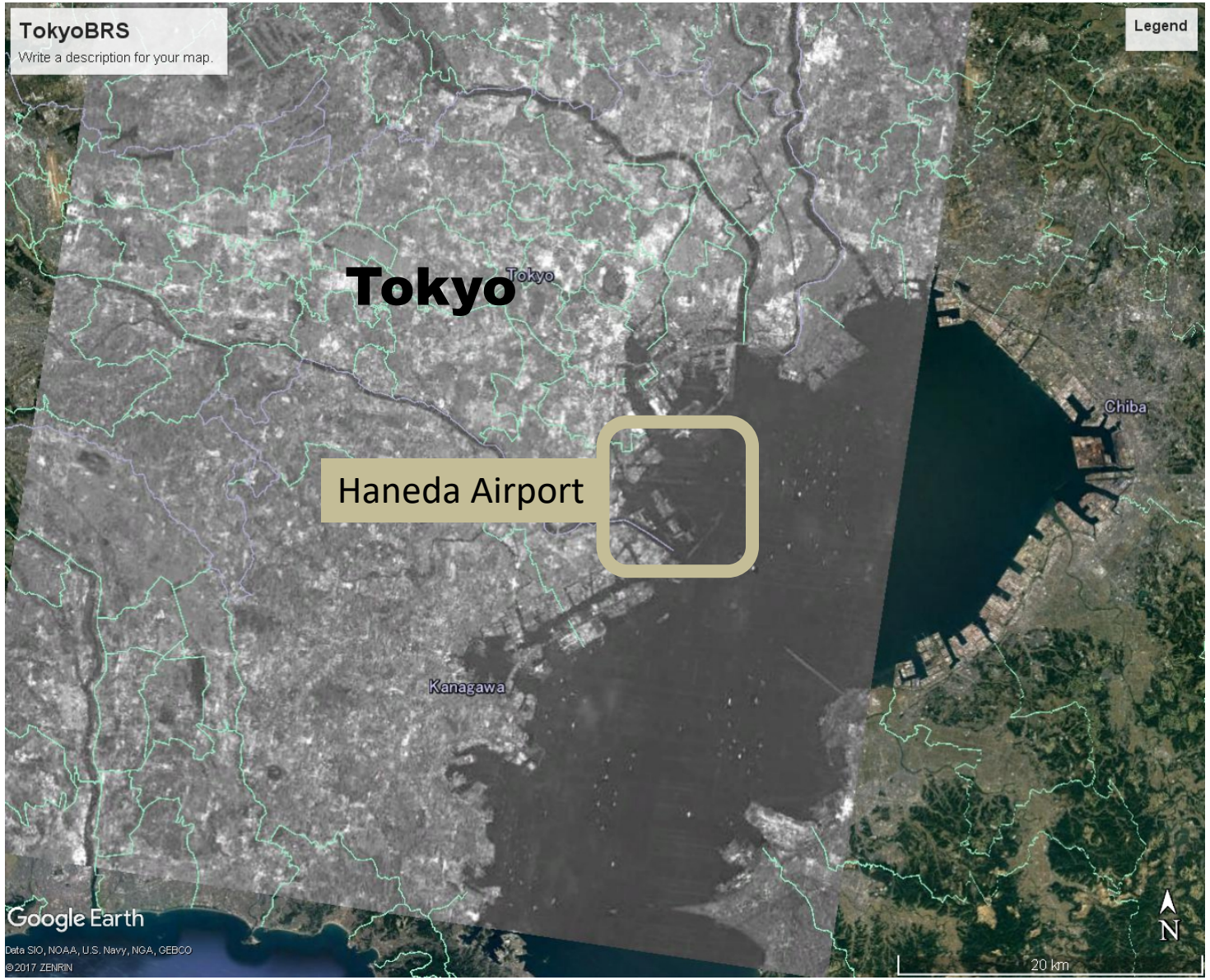
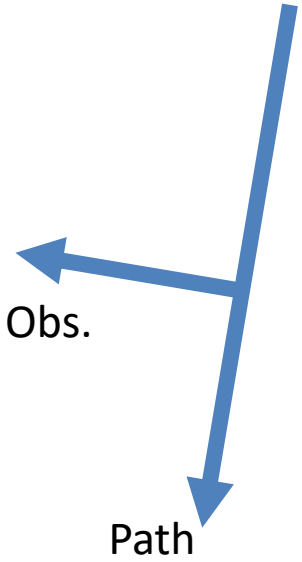
Temporally coherent radio frequency interference in ALOS-2 PALSAR-2 image

Ryo Natsuaki and Akira Hirose
The University of Tokyo

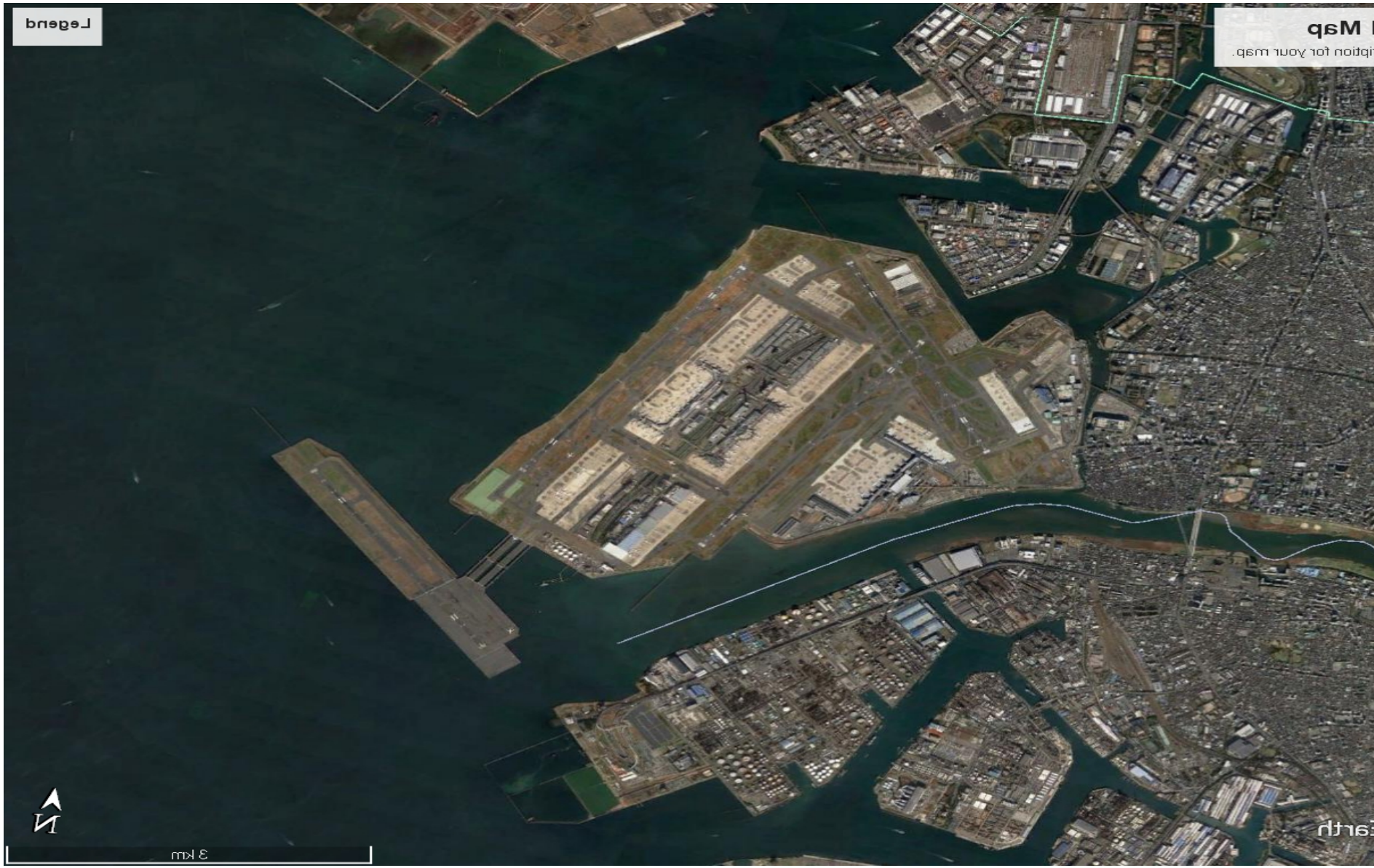
Sample area (Path 16, Frame 2910)

Path 16
Frame 2910
HH-Pol.
Obs. date
Nov. 9, 2015
Nov. 23, 2015



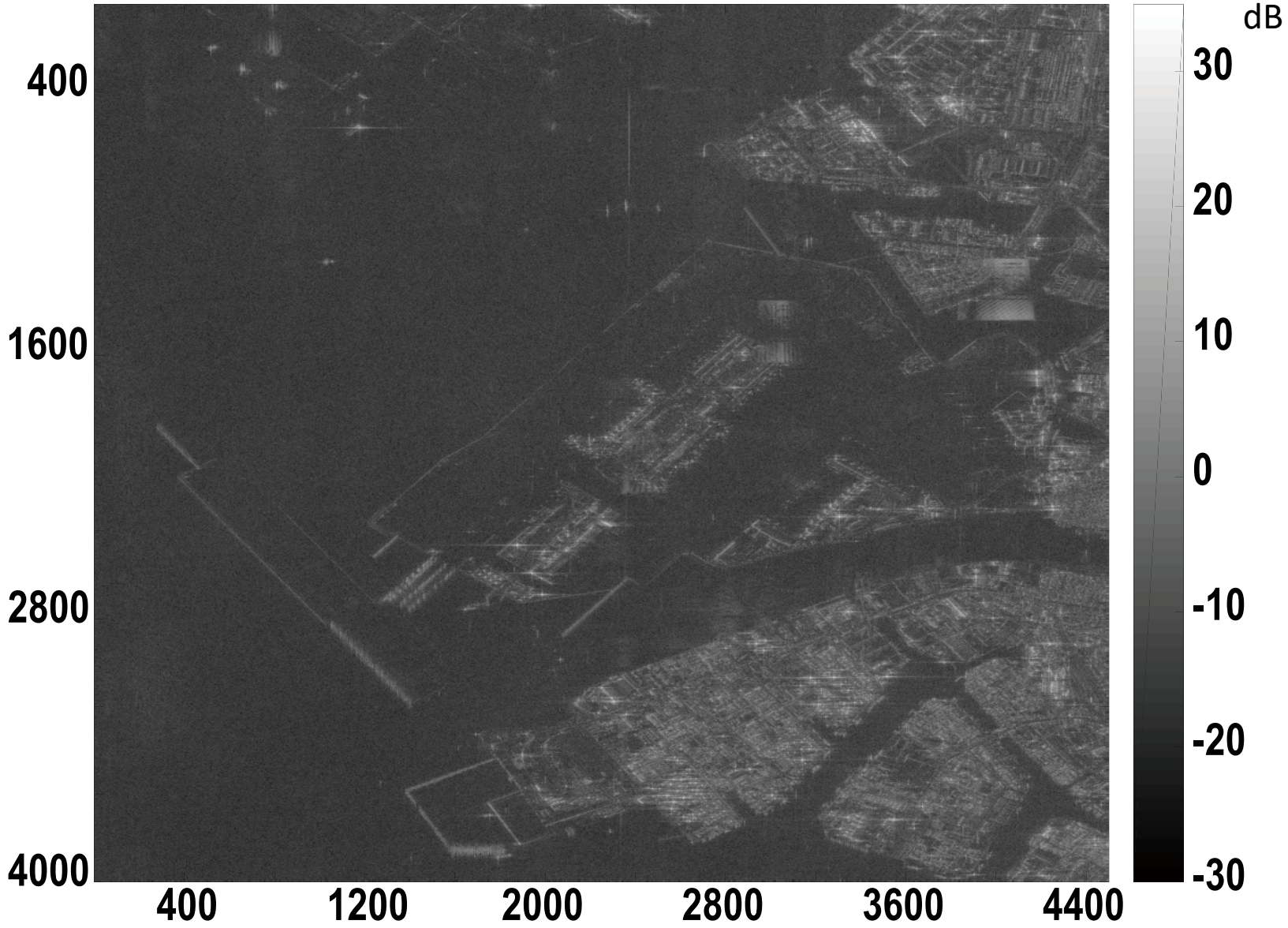


Optical image (Flipped to slant range of SAR)

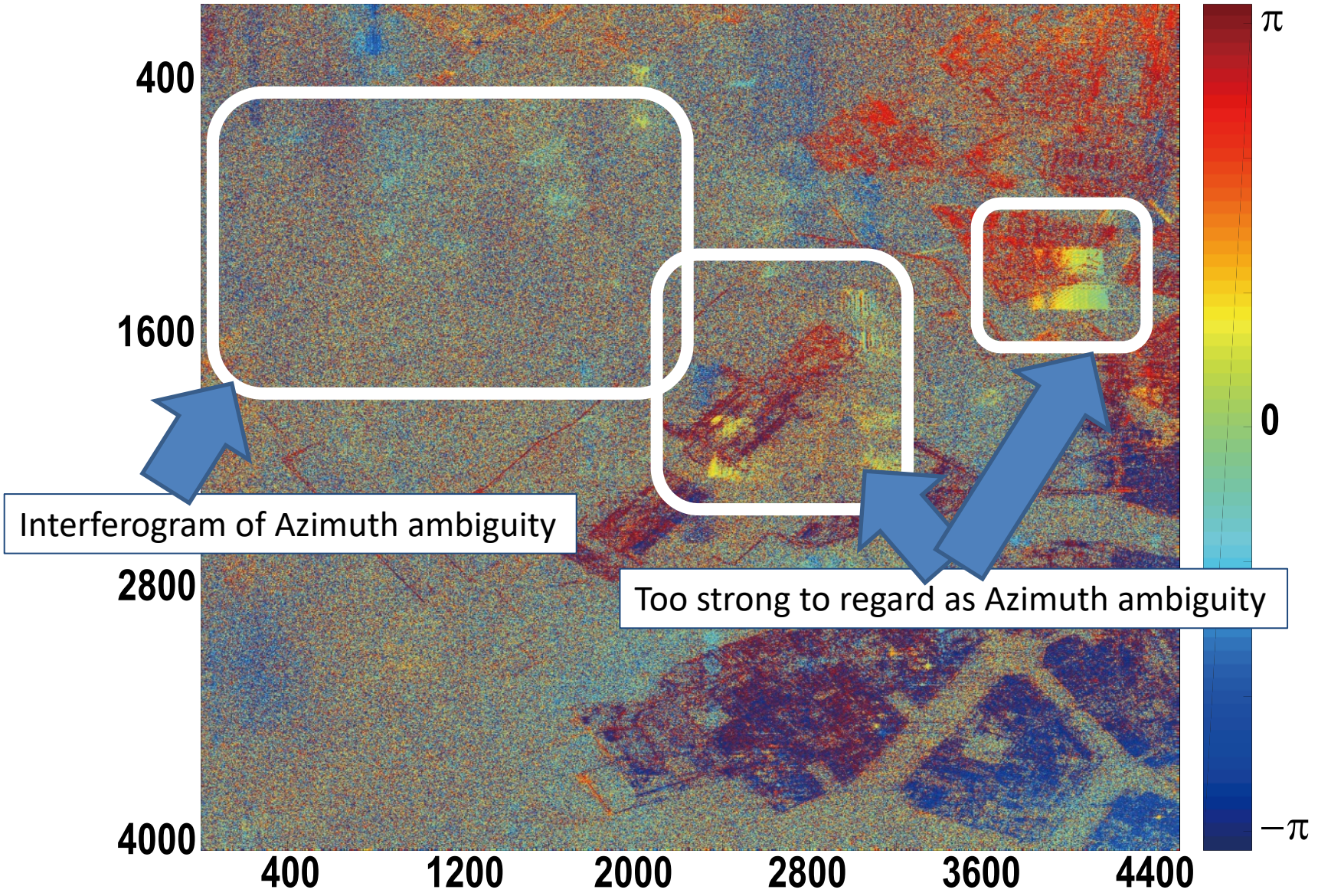


HH Nov. 23, 2015

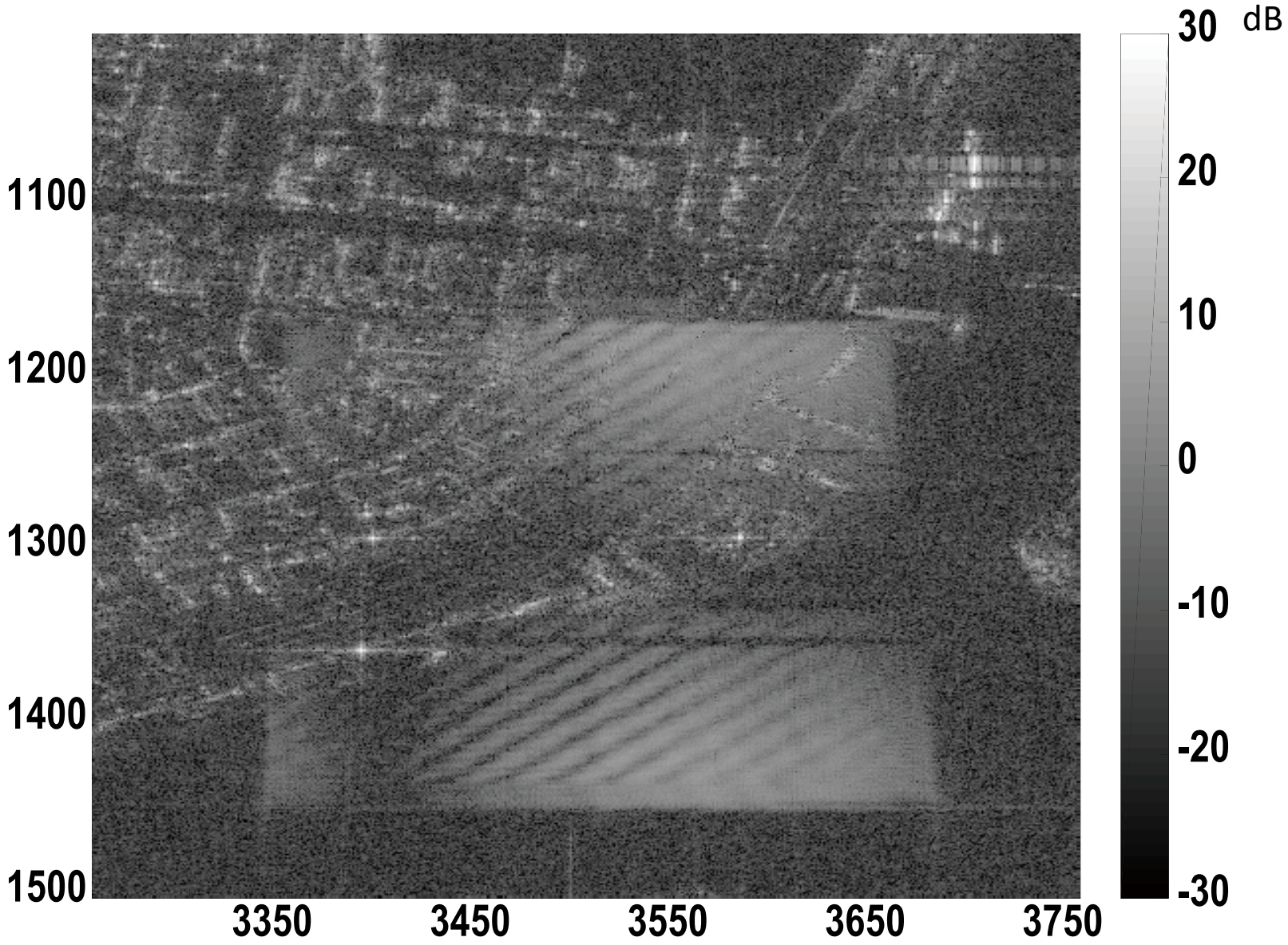
HH Nov. 9, 2015



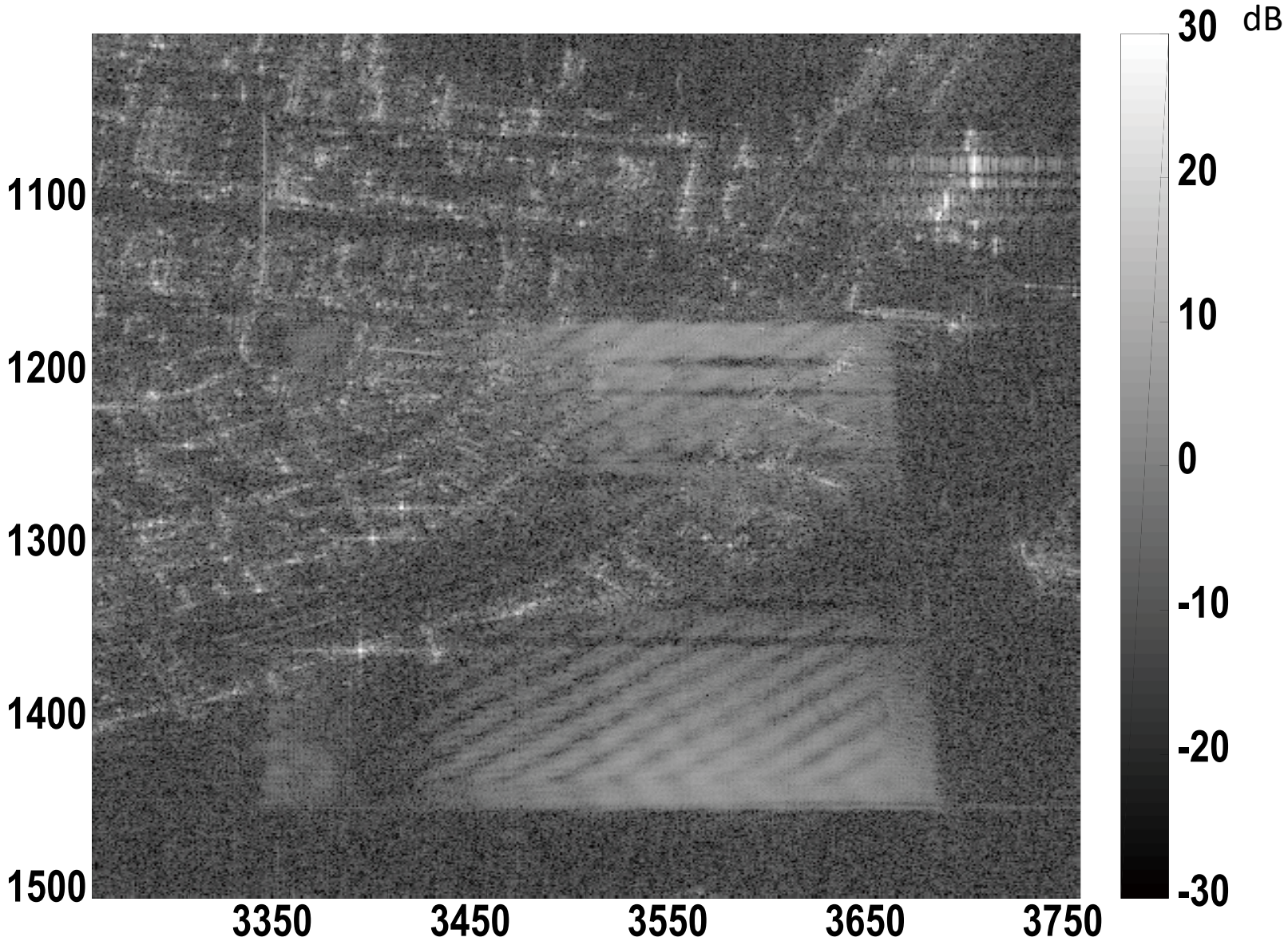
Interferogram Nov. 9 – Nov. 23, 2015



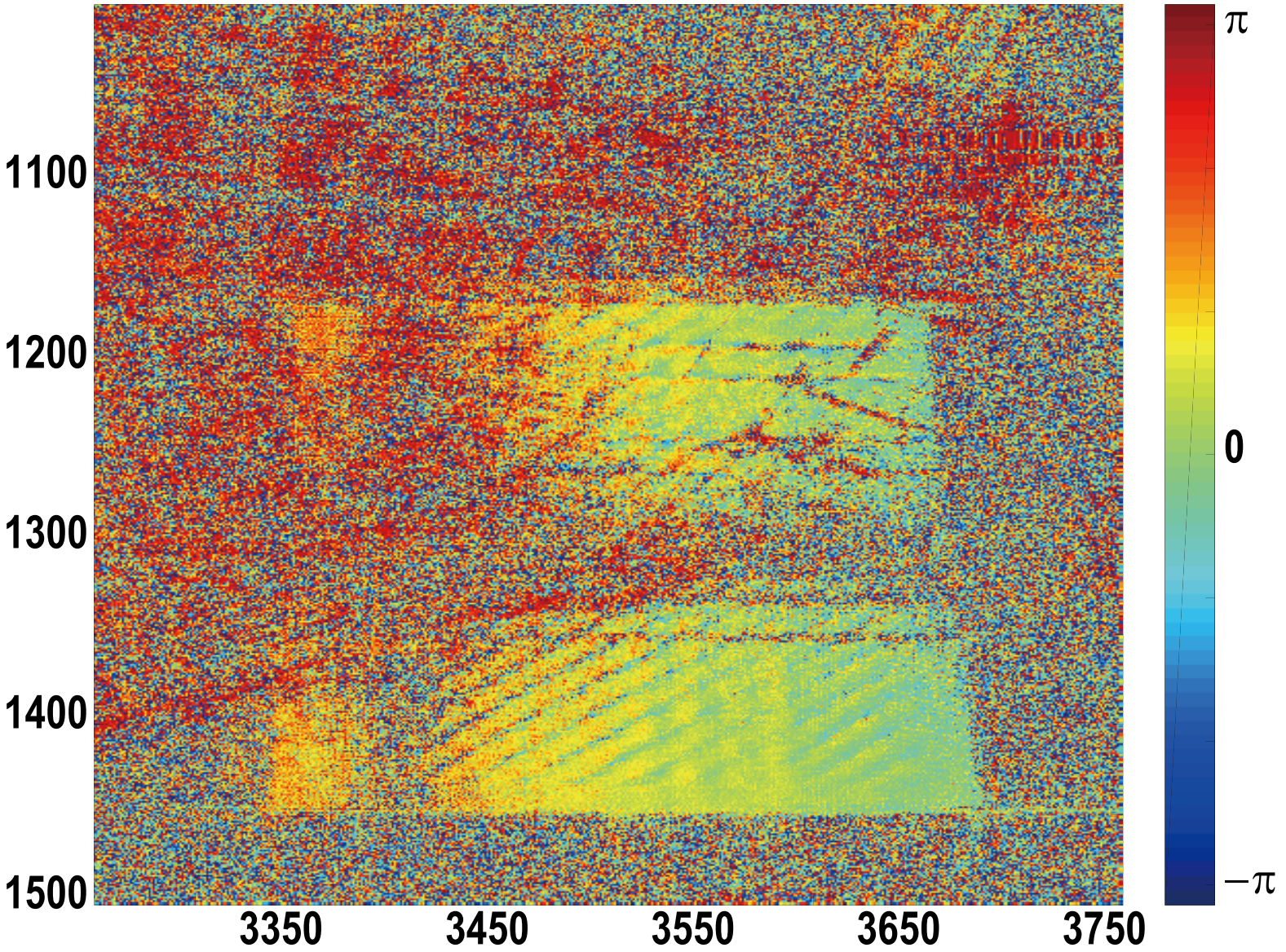
Closed up, Nov. 23, 2015



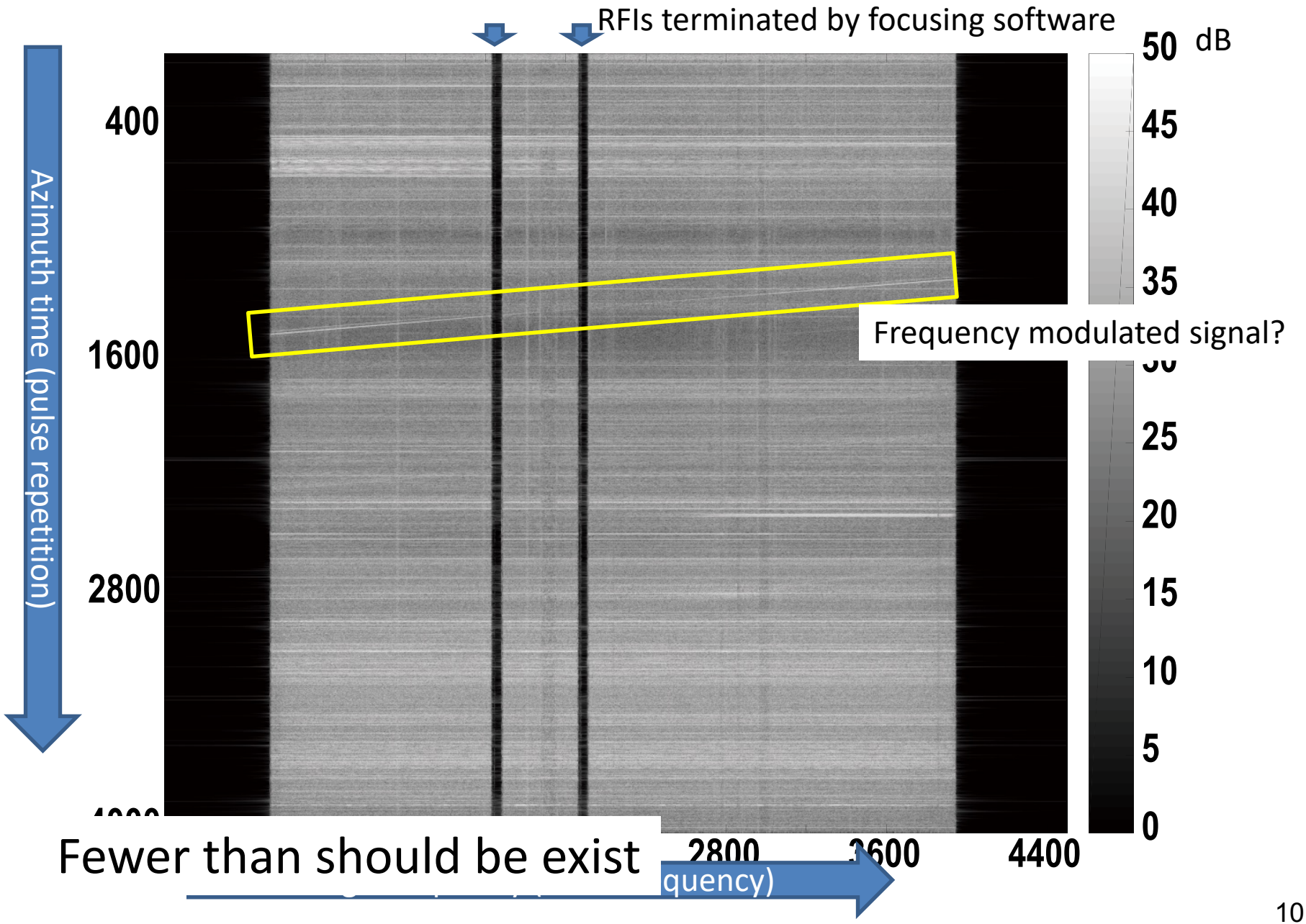
Closed up, Nov. 9, 2015



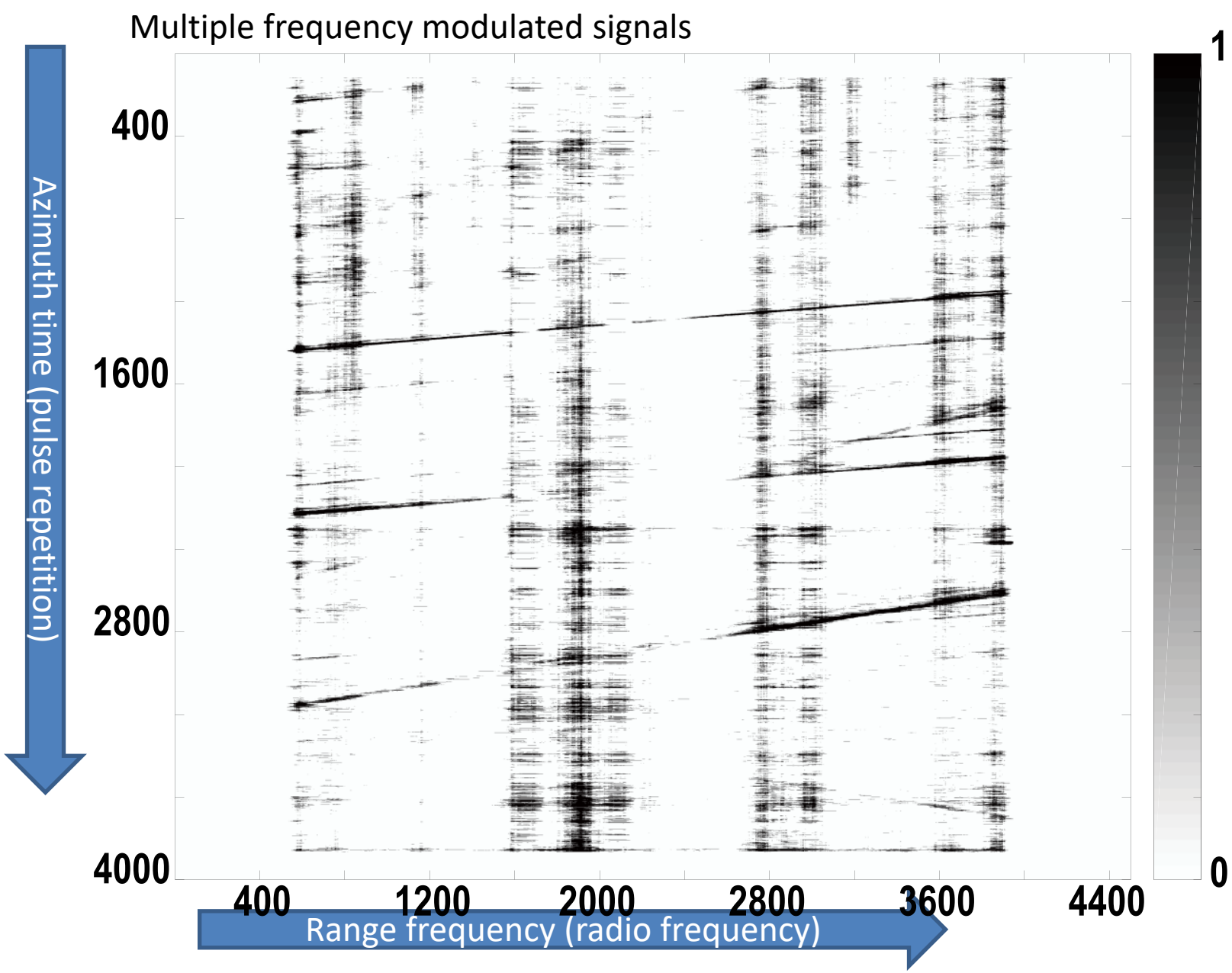
Closed up interferogram



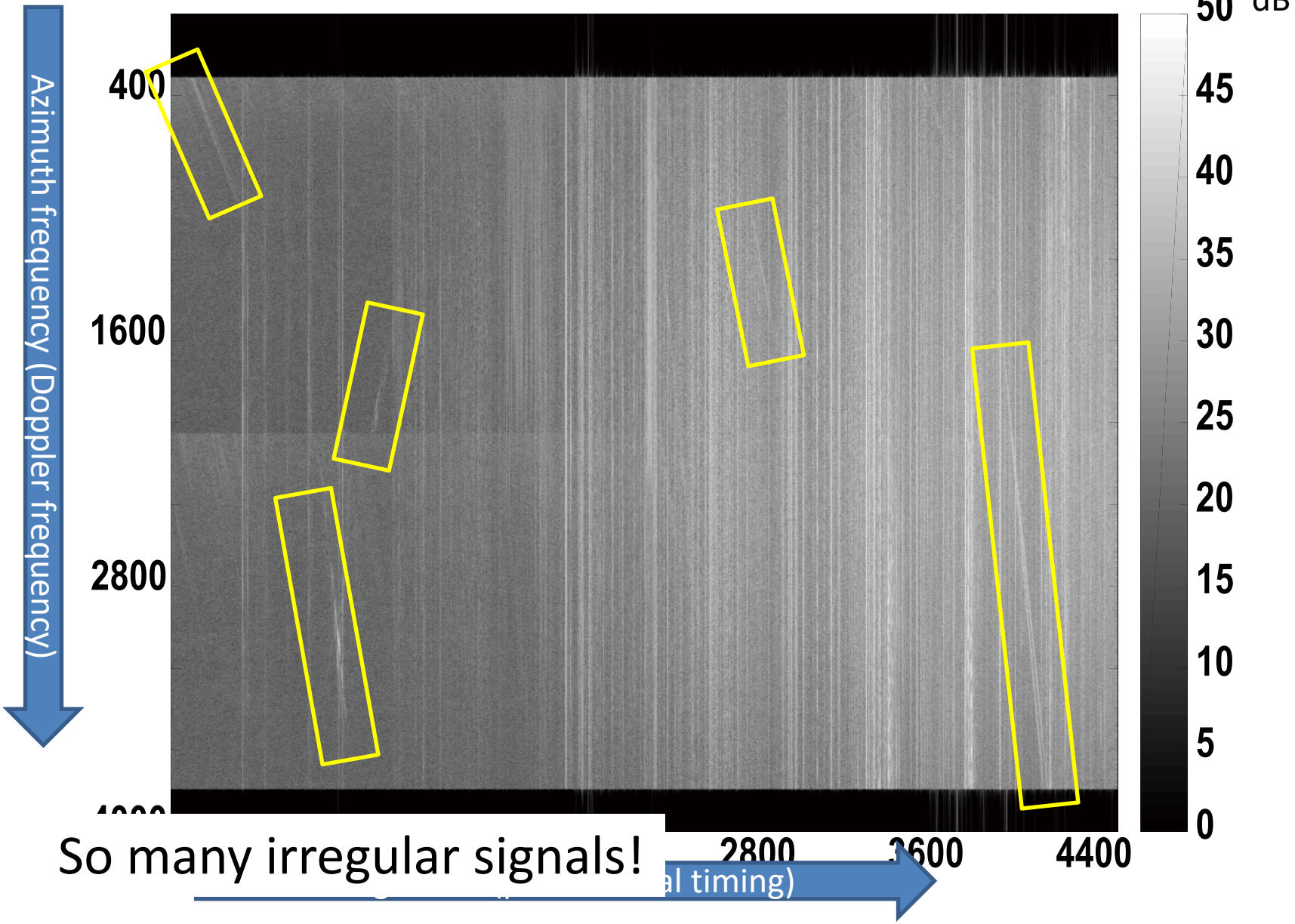
Range freq. domain (radio frequency domain)



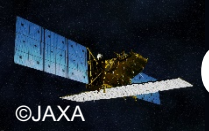
Detection result (spectrum based)



Azimuth freq. domain (Doppler domain)



So many irregular signals!



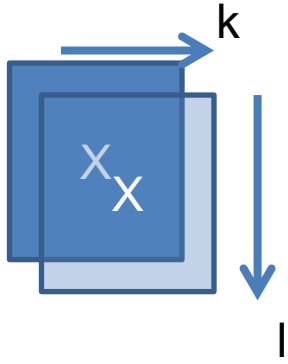
Candidates of artifacts

Reason	High temp. coherency	Radio freq. modulation	Dopp. freq. variance	Notes
Azimuth ambiguity	✔	-	?	No candidate scatter Too strong?
Range ambiguity	✔	-	?	No candidate scatter
Moving target	-	-	✔	Appears in all interferometric pairs
Ionospheric effect	-	-	?	Appears in all interferometric pairs
Tropospheric effect	-	-	?	Appears in all interferometric pairs
Hardware error	-	✔	✔	Fixed location
Software error	-	✔	✔	Appear with multiple software
Wideband RFI Incl. transponder, IF of something	✔	✔	✔	Unknown source

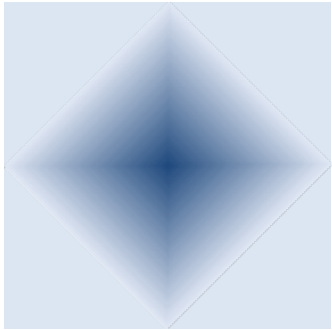
Autocorrelation based RFI detection

- Focused SAR signal aligns to Range and Azimuth direction. Irregular signal does not.
- Make an autocorrelation map in Rg. Time / Az. Freq. and Rg. Freq. / Az. Time domain

$$C_{(x,y)}(k,l) = \frac{\sum_{m=x-M/2}^{x+M/2-1} \sum_{n=y-M/2}^{y+M/2-1} X(m,n) * \overline{X(m+k,n+l)}}{\sum_{m=x-M/2}^{x+M/2-1} \sum_{n=y-M/2}^{y+M/2-1} X(m,n) * \overline{X(m,n)}} \quad (1)$$



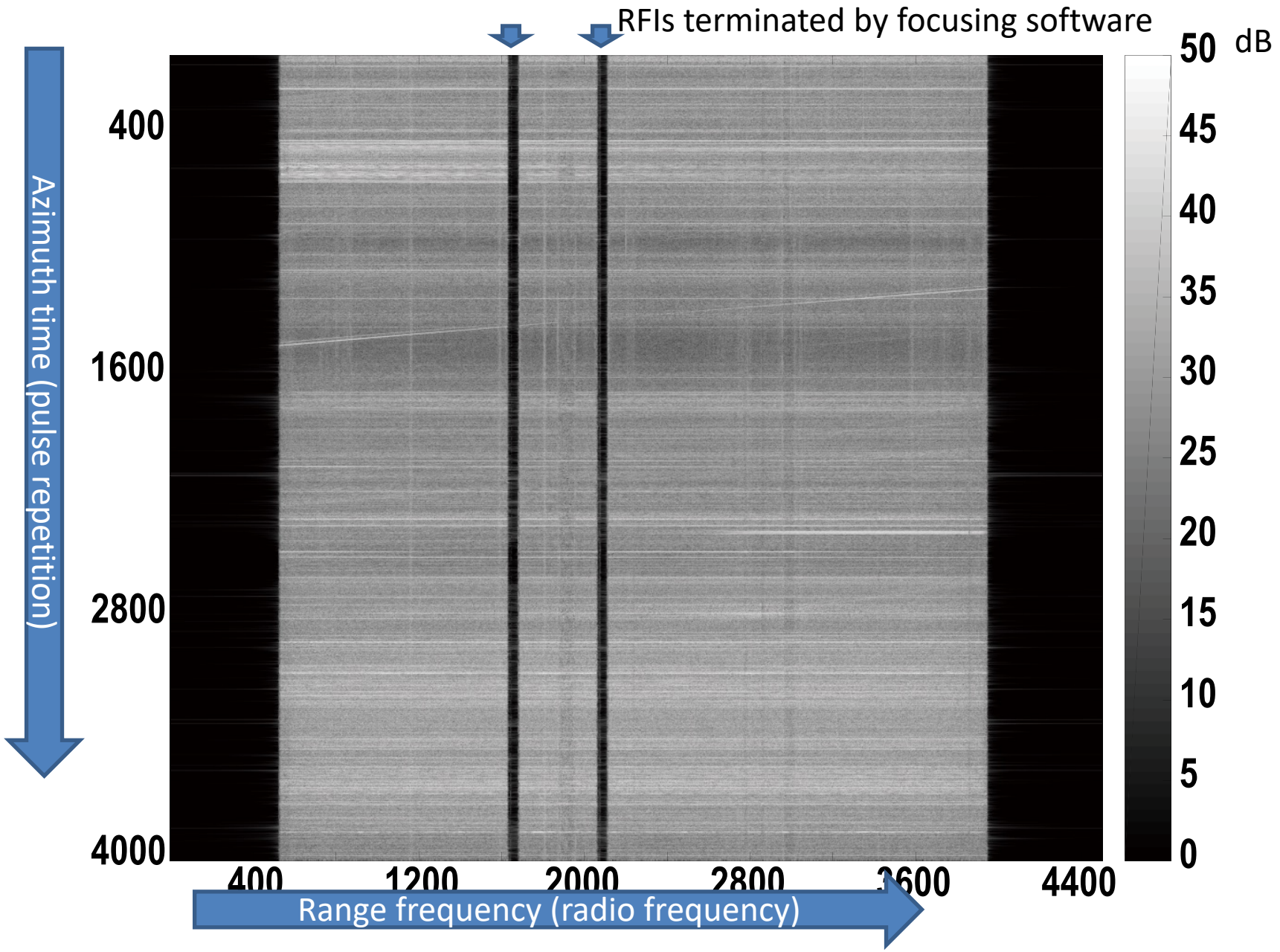
- If SAR signal, C(0,0)=1 and other part becomes low correlation.
  Rg. and Az. direction have high correlation.
- Irregular signal has high correlation in different direction



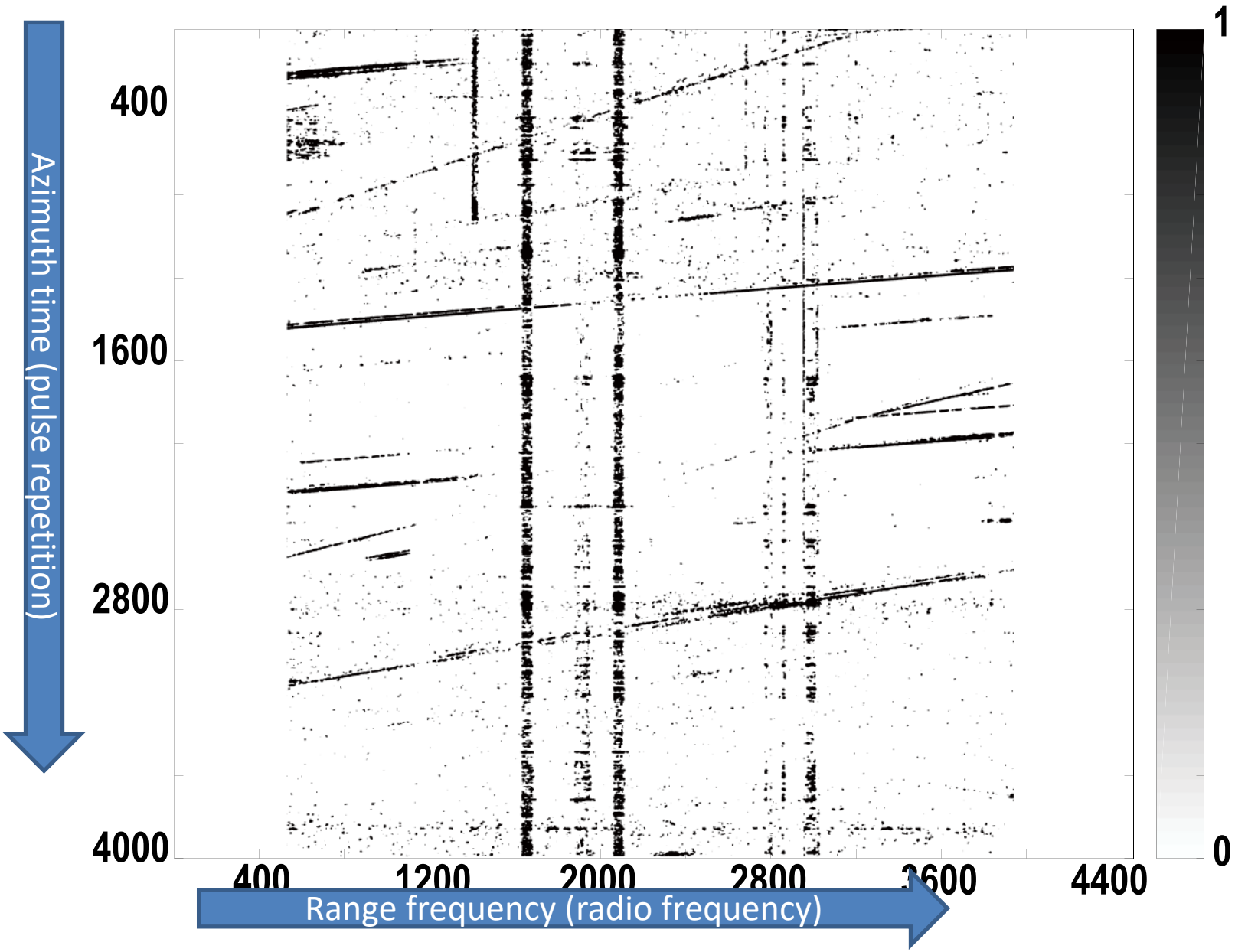
Expected correlation map

Ryo Natsuaki, et al., IEEE JSTARS accepted

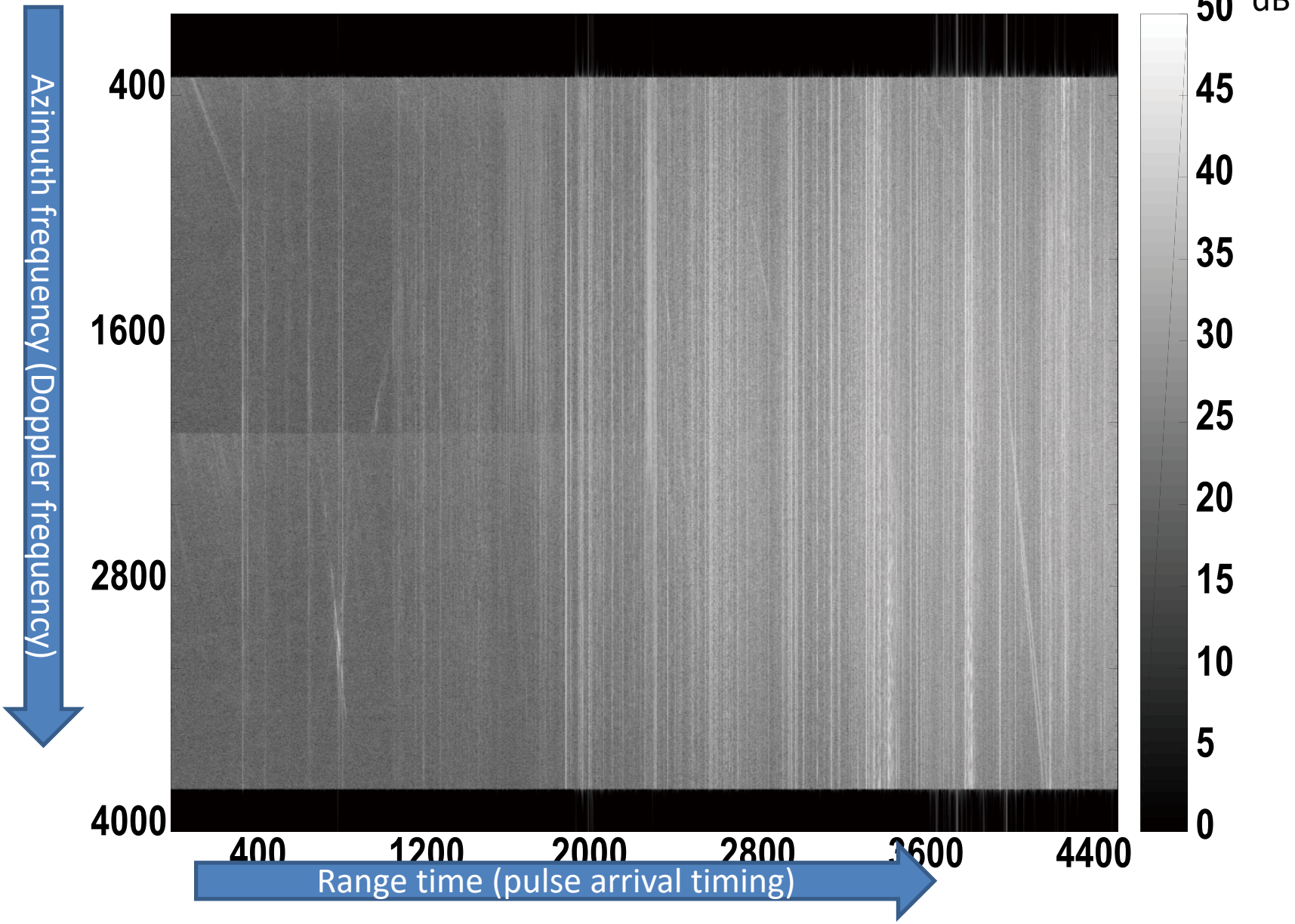
Range freq. domain (radio frequency domain)



Detection result (autocorrelation based)

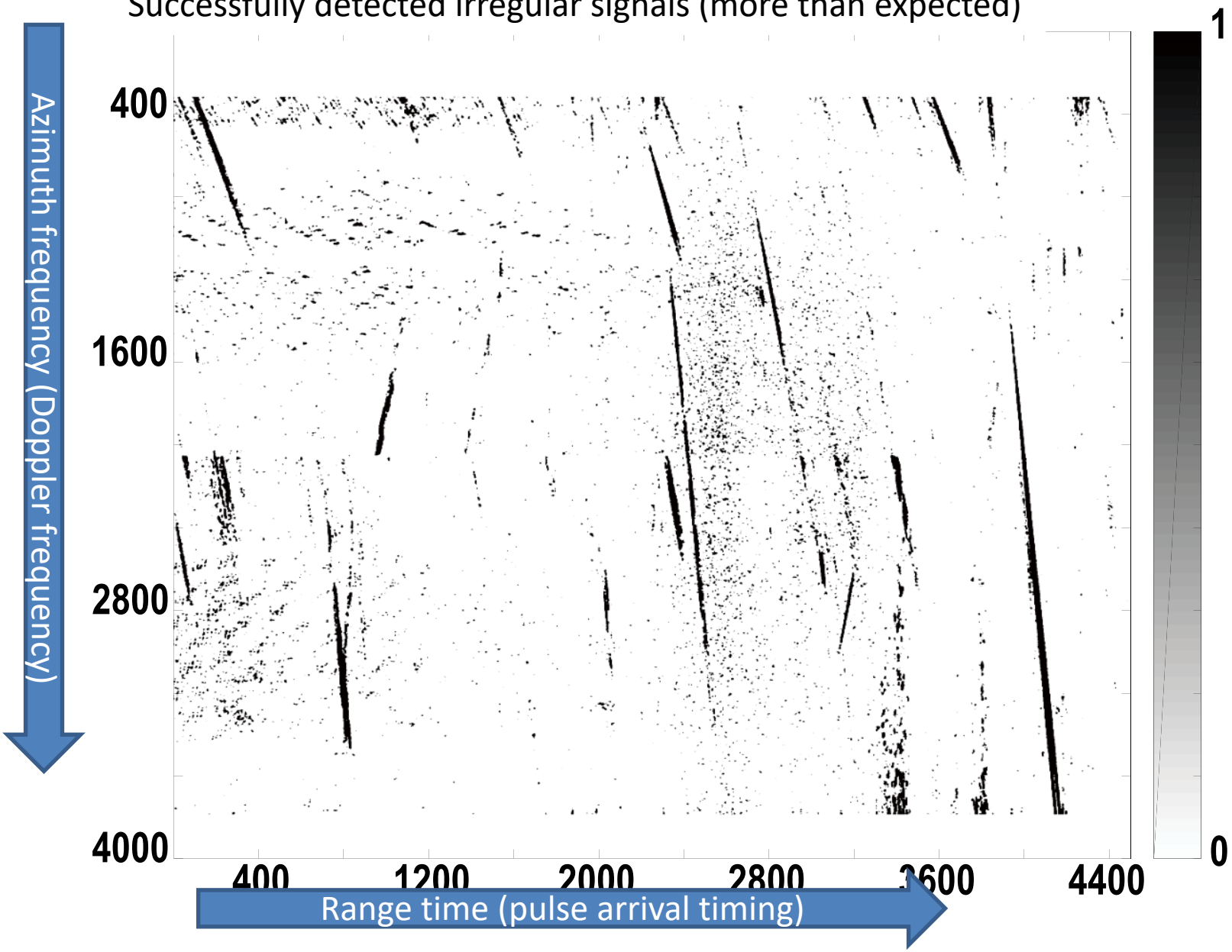


Azimuth freq. domain (Doppler domain)



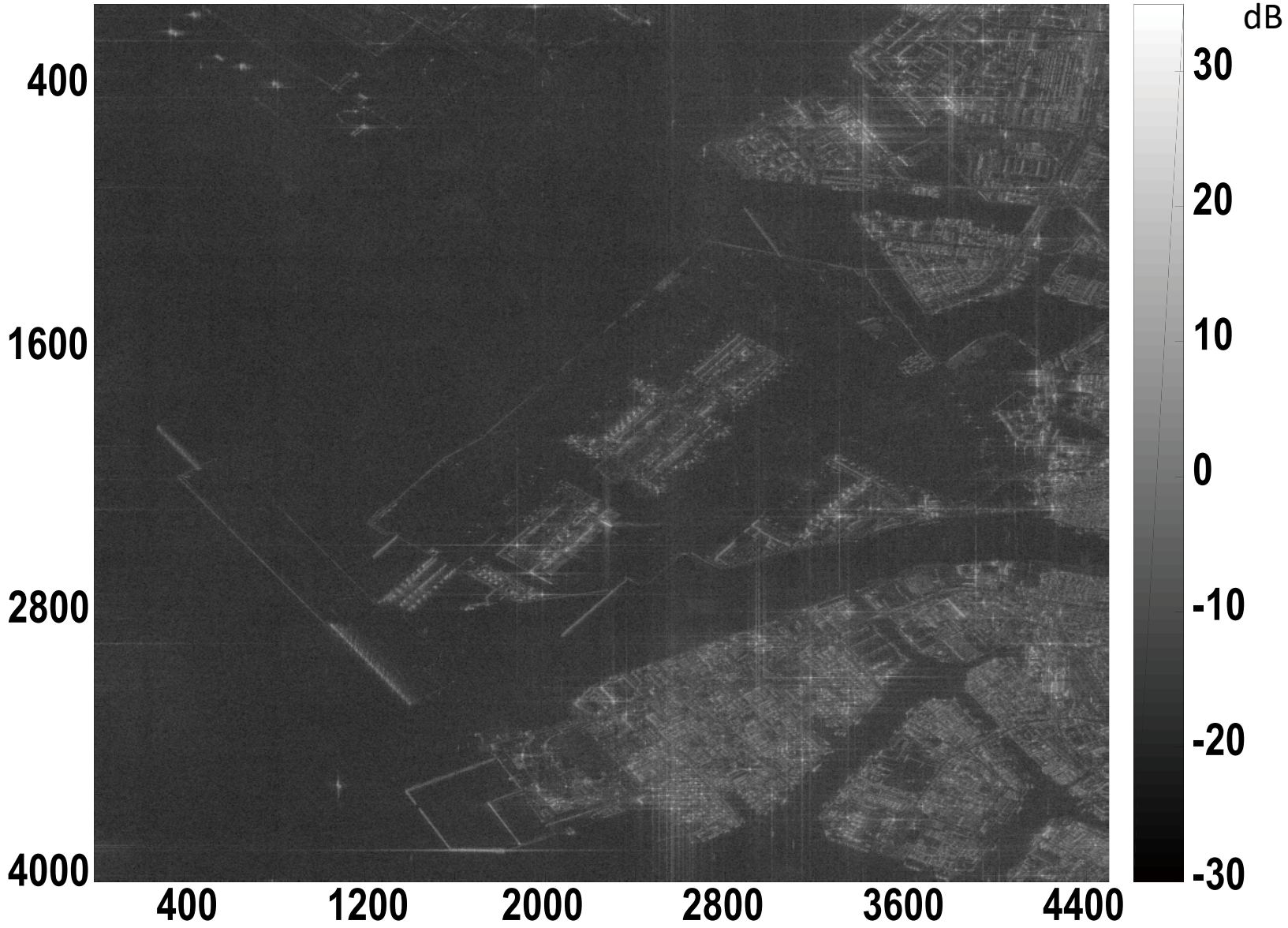
Detection result (autocorrelation based)

Successfully detected irregular signals (more than expected)

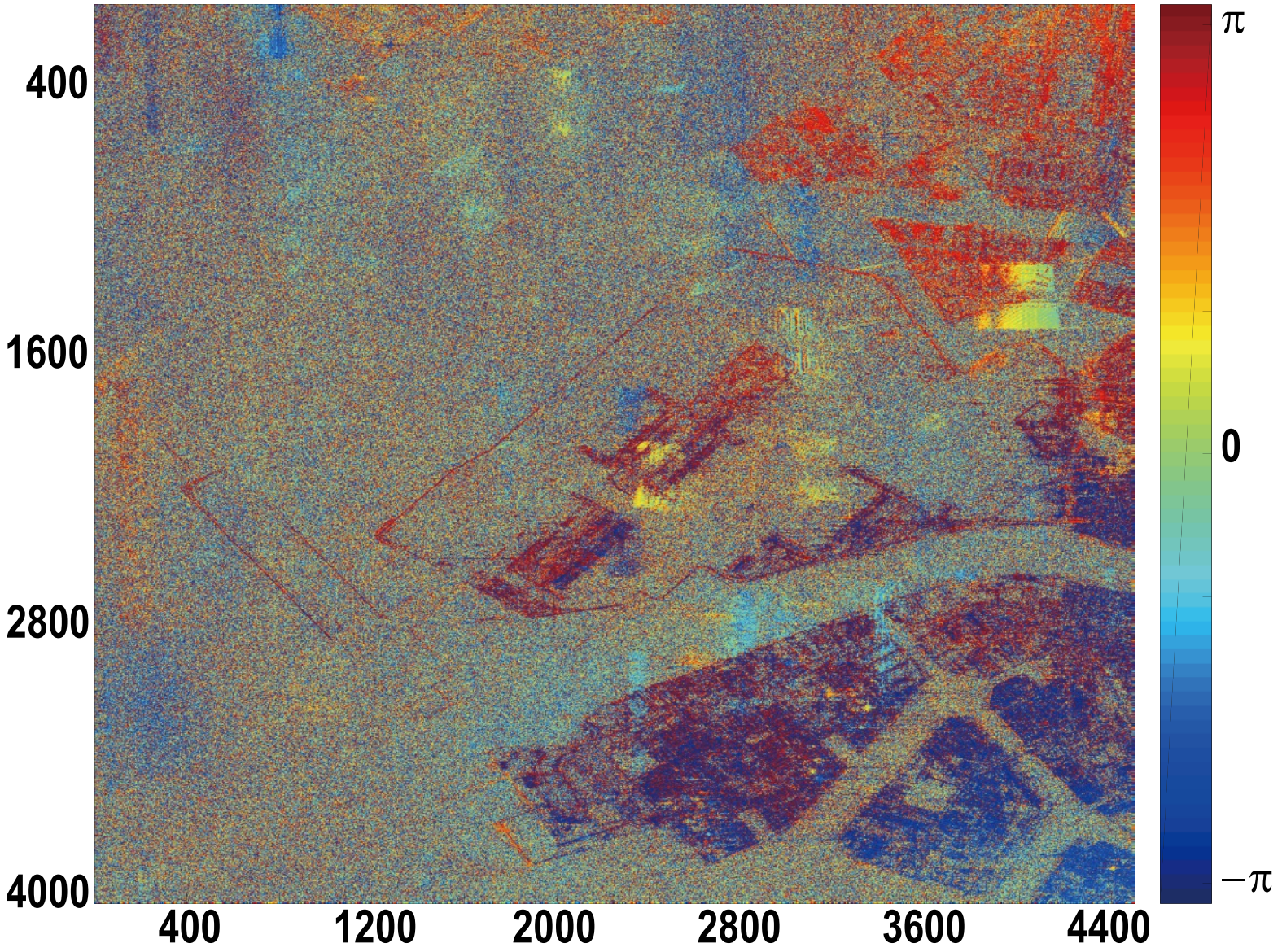


RFI contaminated (Nov. 23, 2015)

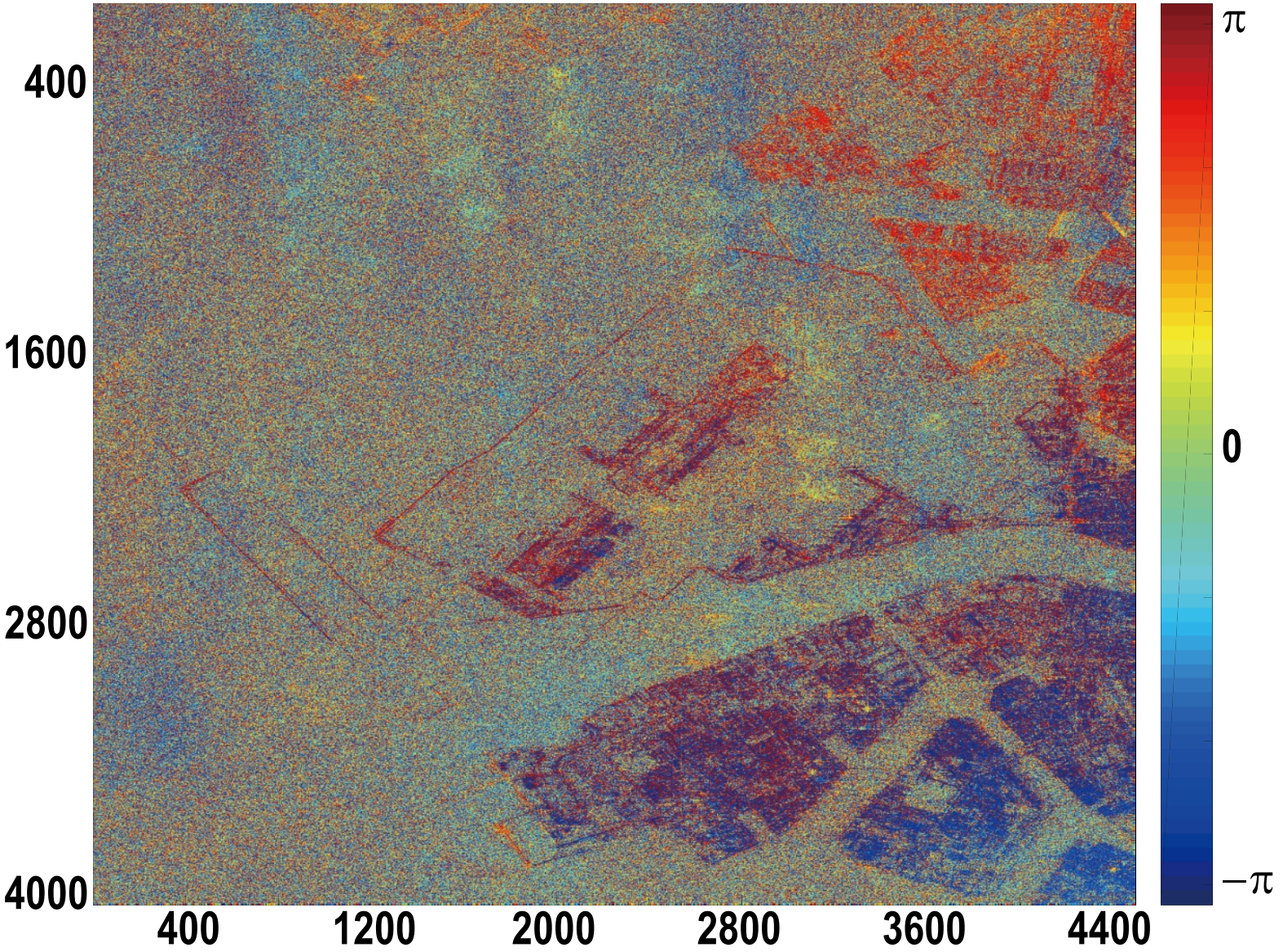
RFI removed (Nov. 23, 2015)



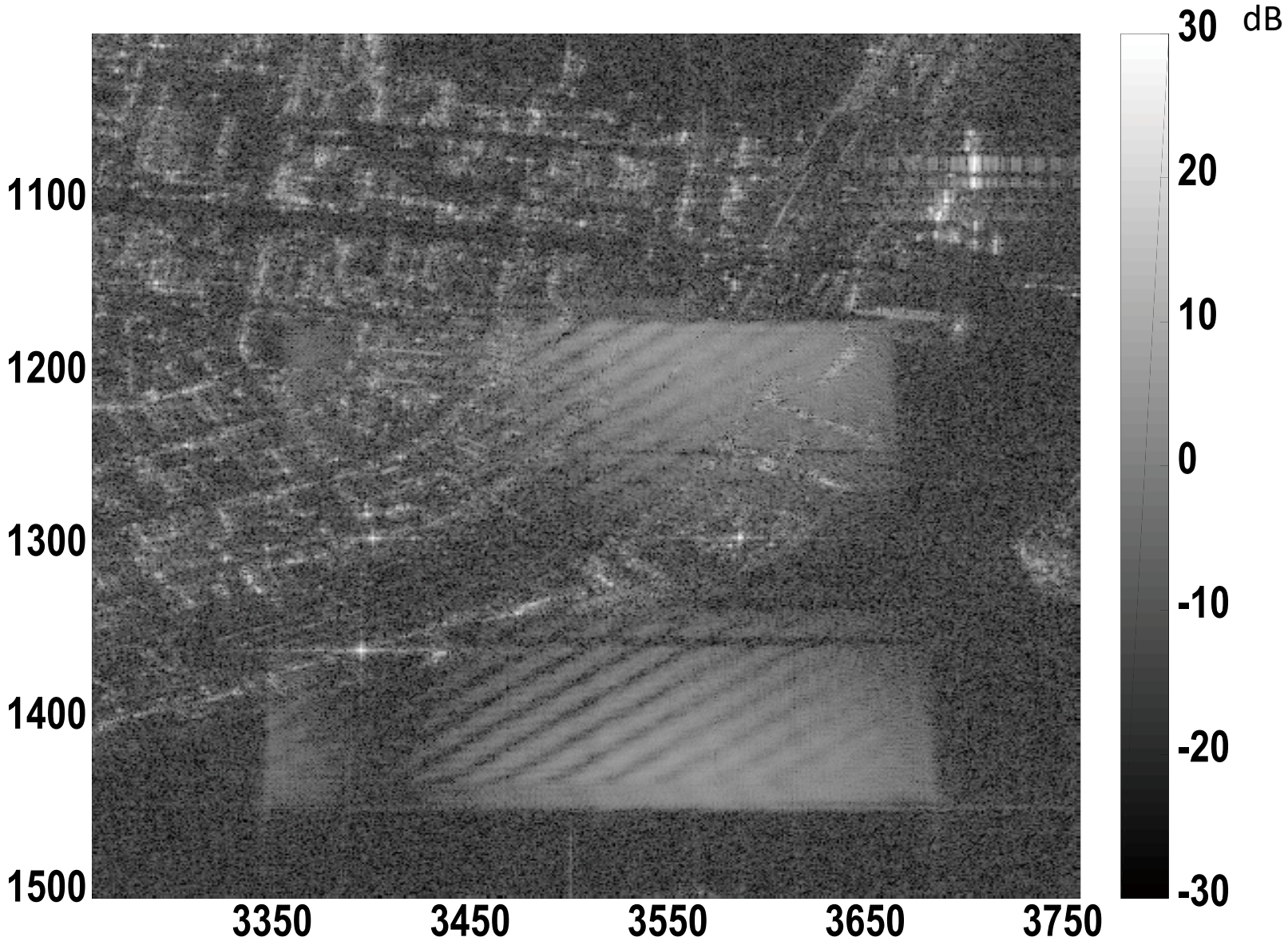
RFI contaminated interferogram



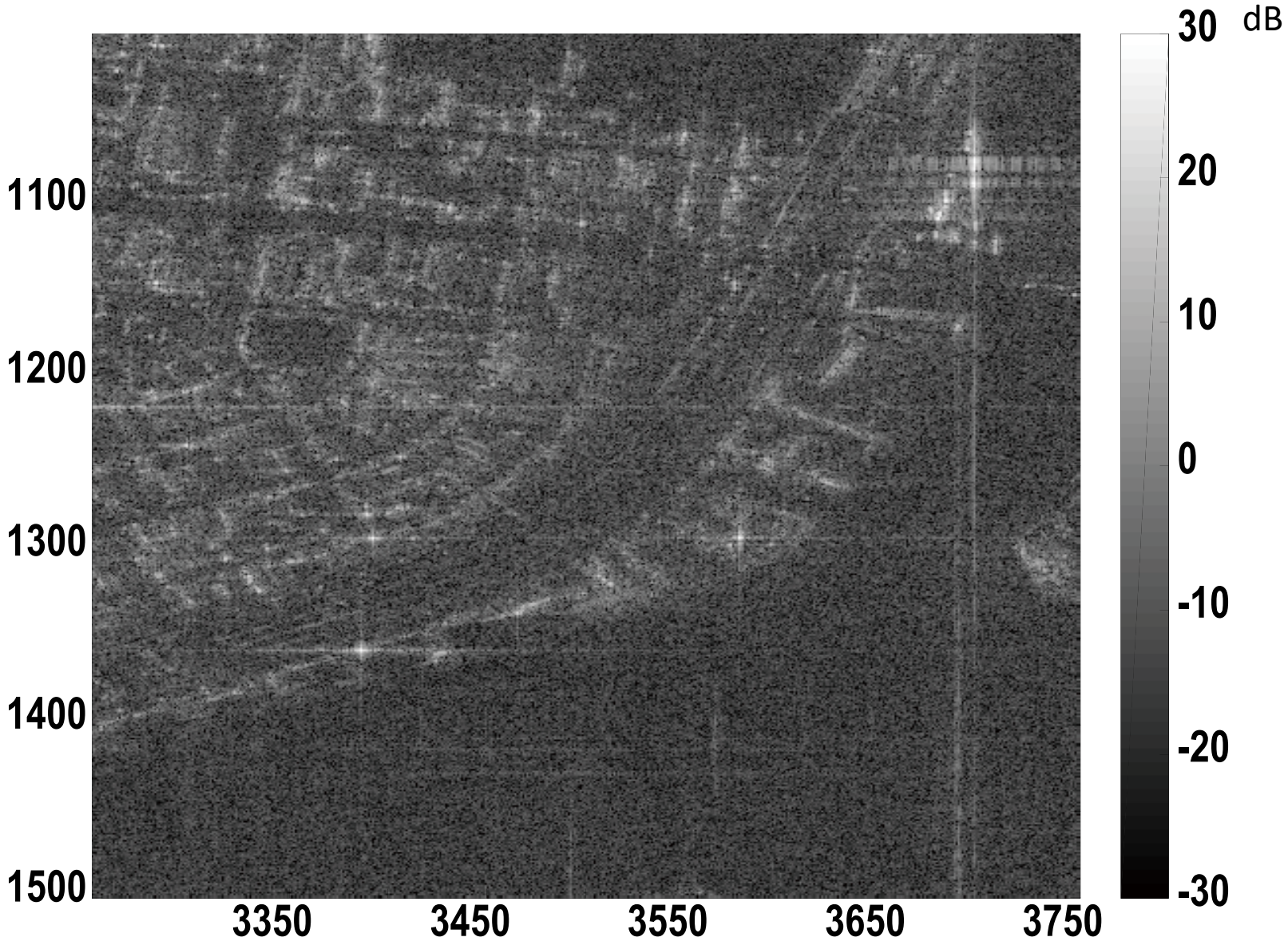
RFI removed interferogram



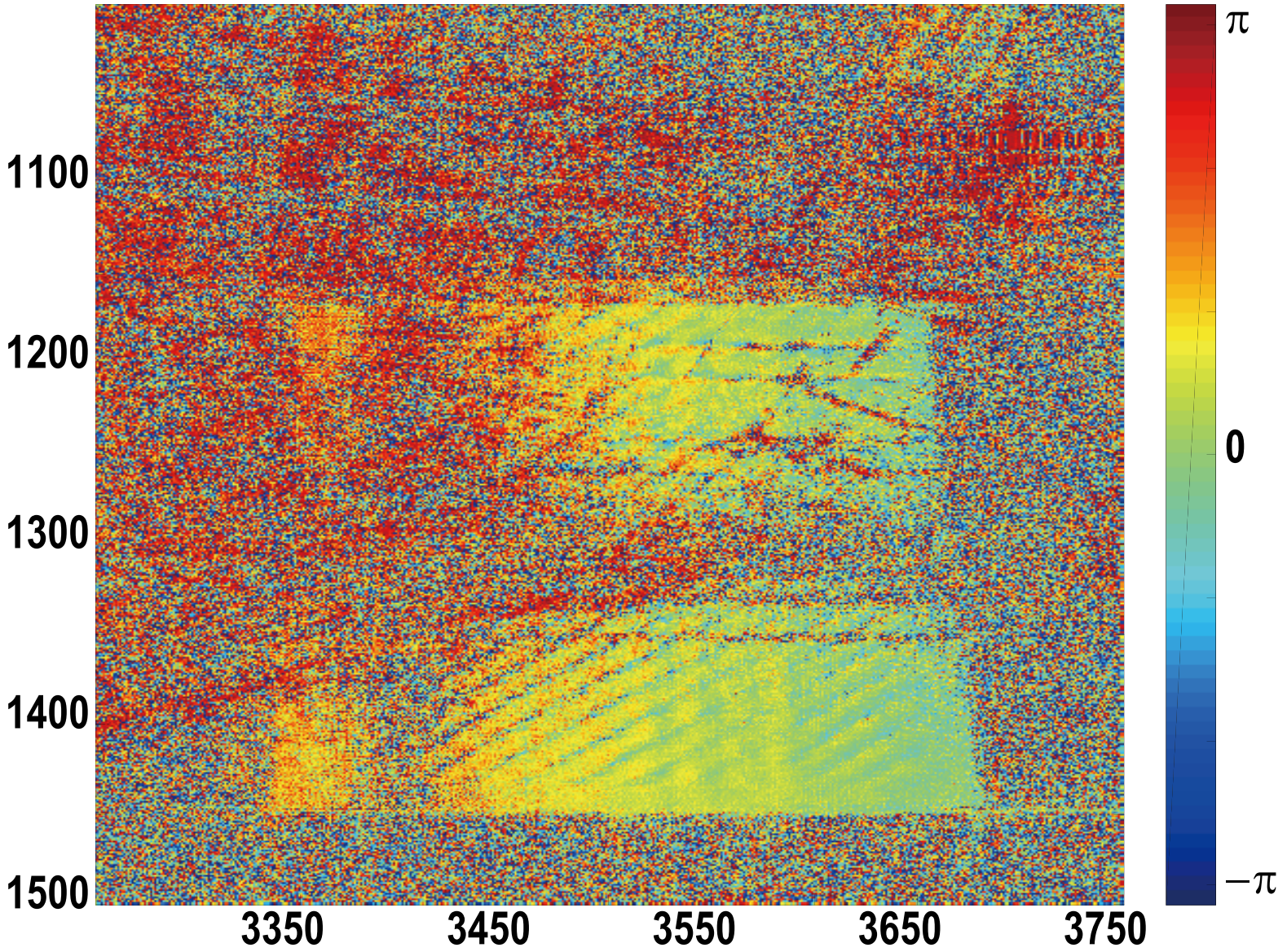
RFI contaminated (closed up, Nov. 23, 2015)



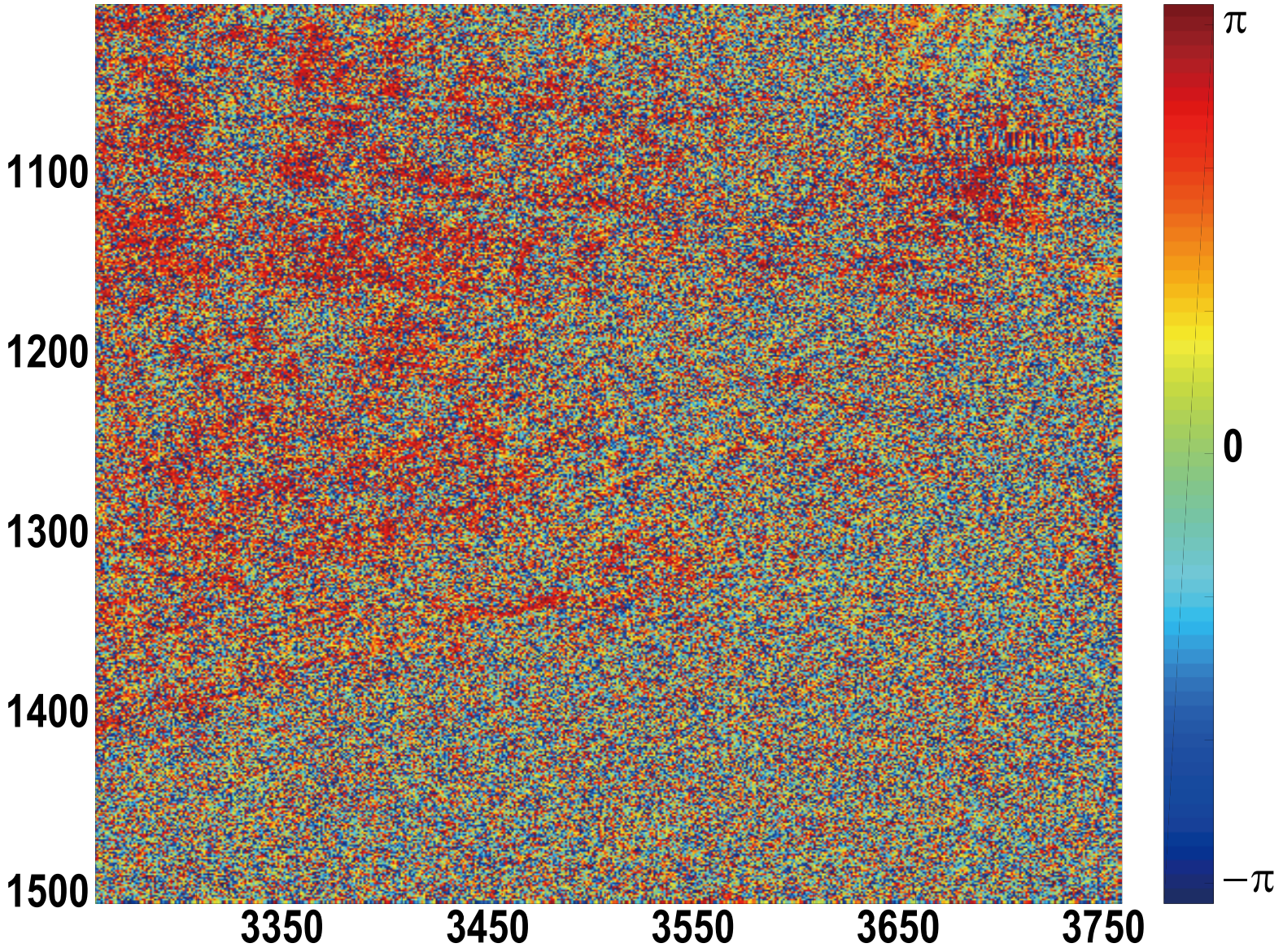
Autocorrelation based method (closed up)



RFI contaminated interferogram (closed up)



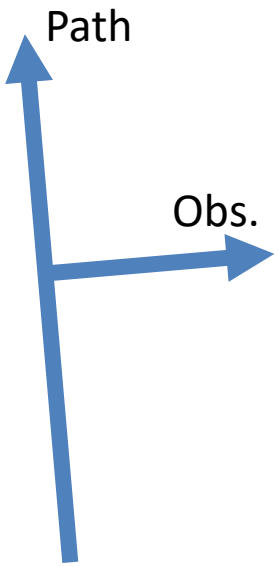
Autocorrelation based method (closed up)

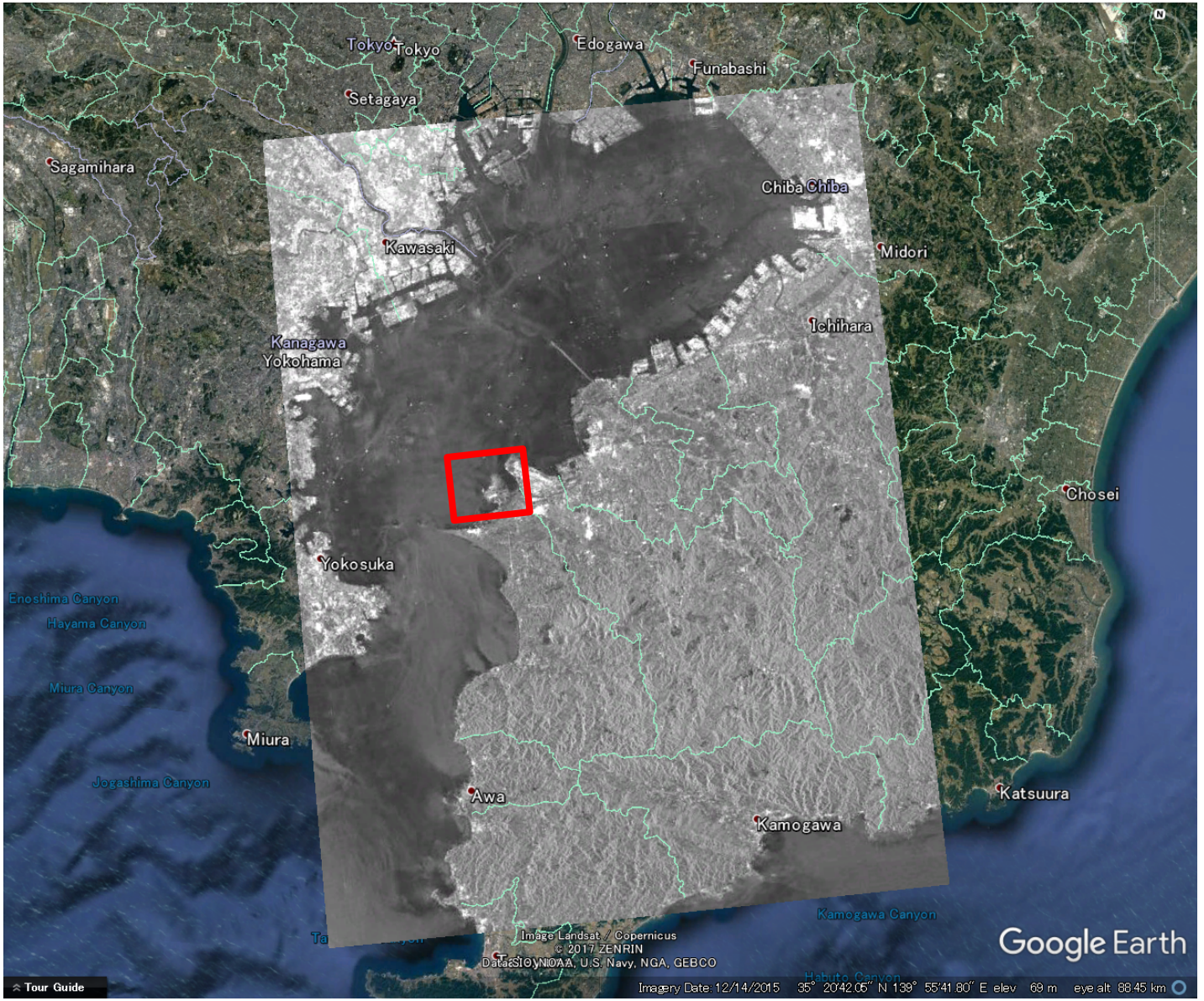


Full Pol. observation case

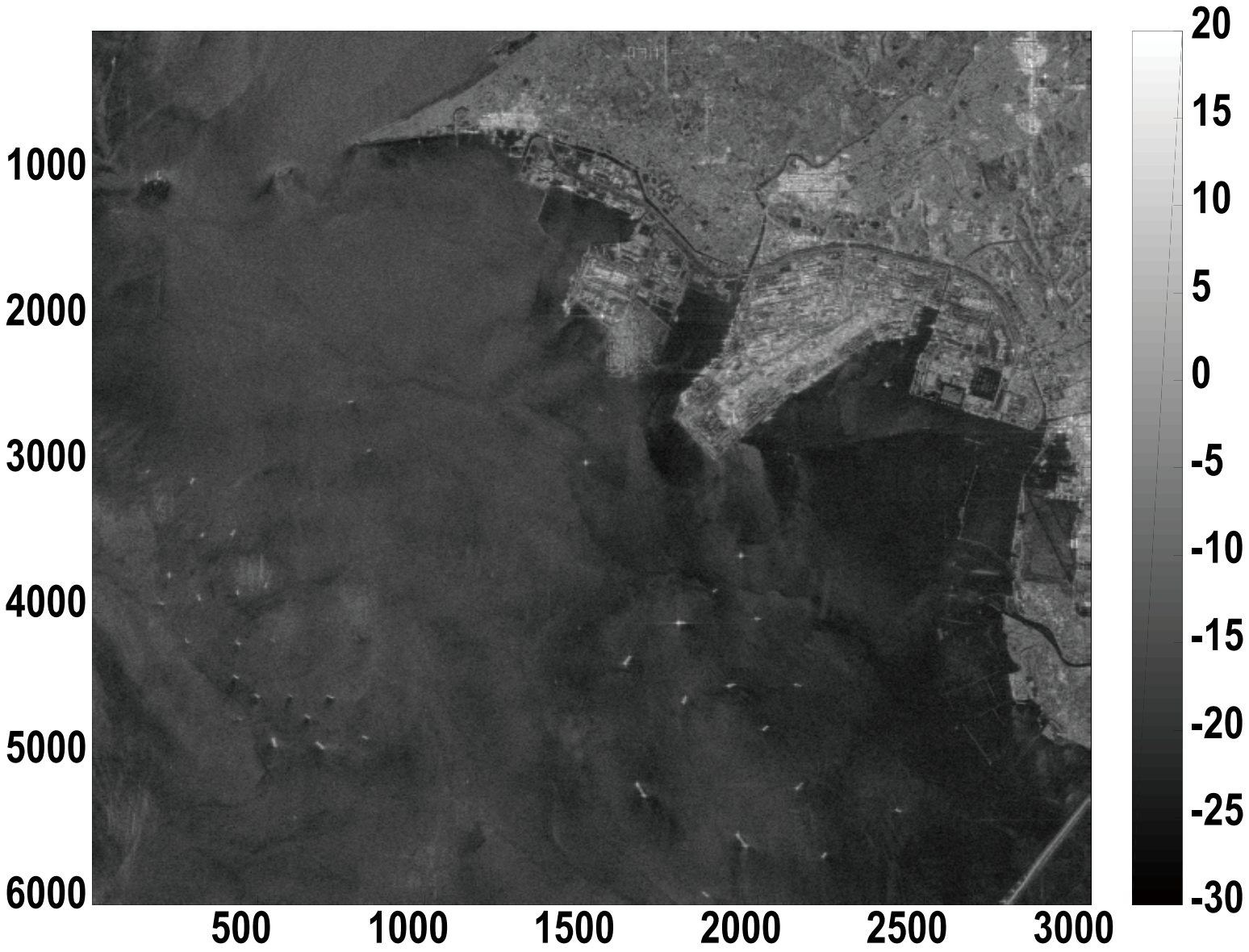
©JAXA

Path 124 Frame 700
Full-Pol.
Obs. date
Aug. 11, 2015
Aug. 8, 2017

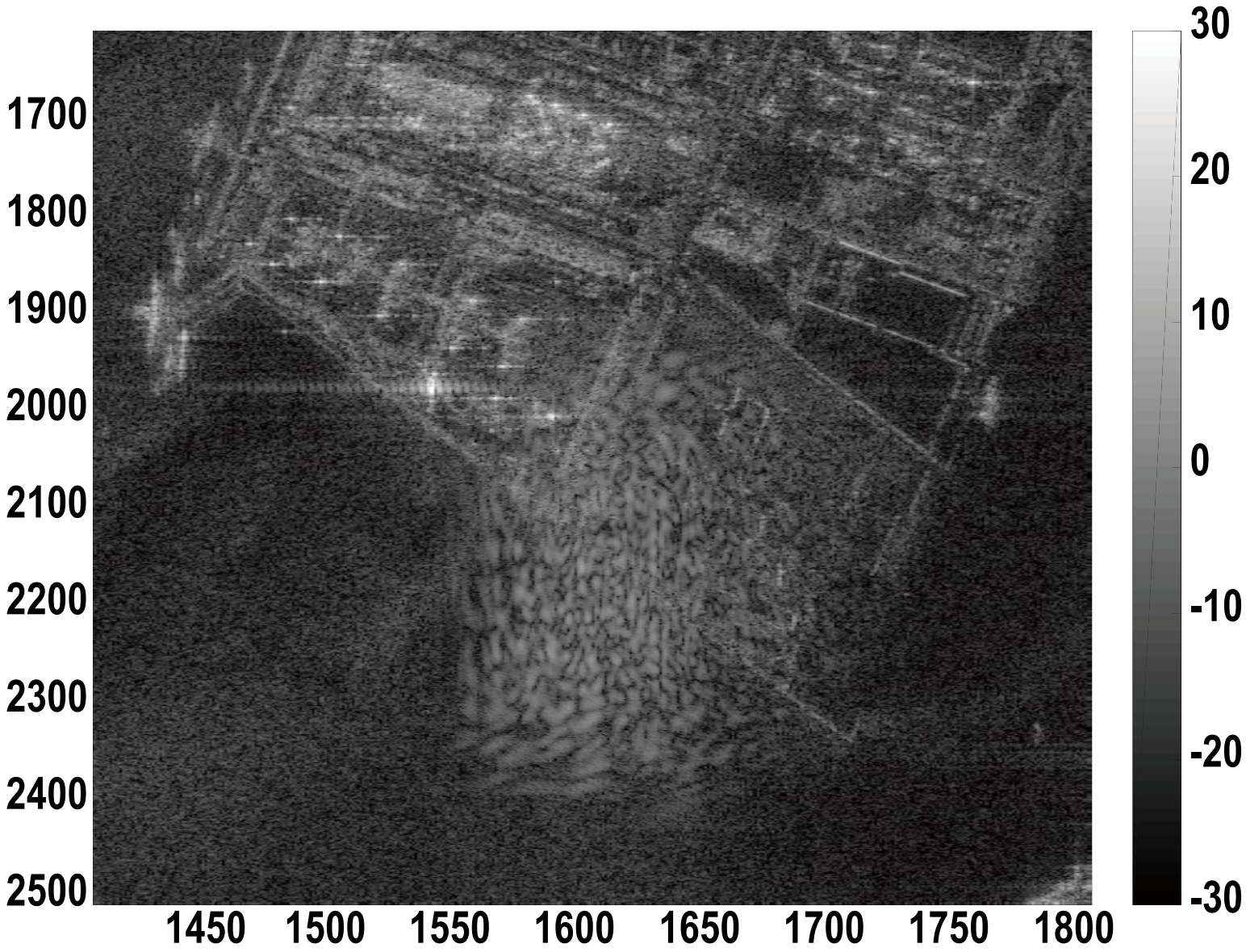




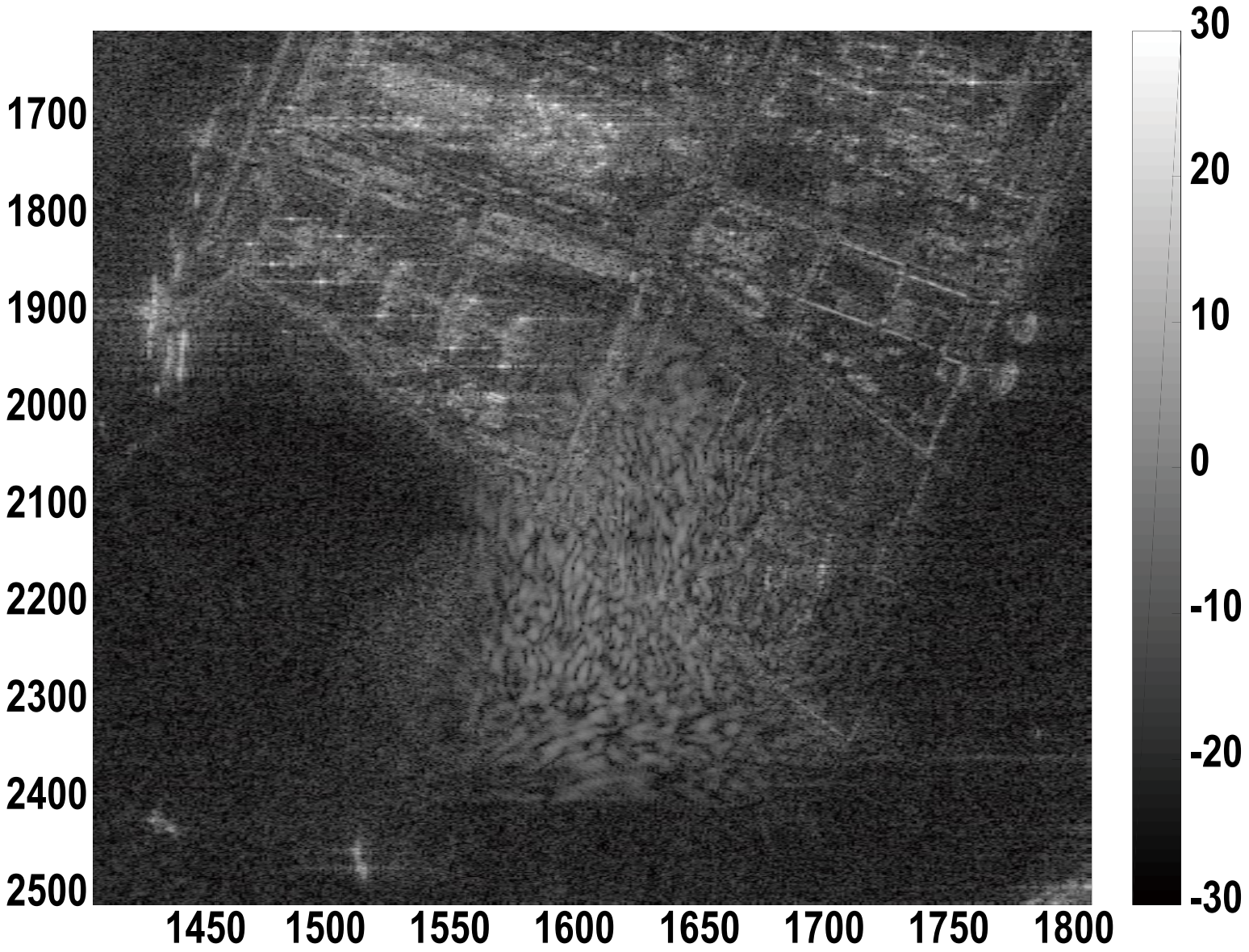
HH Aug. 8, 2017



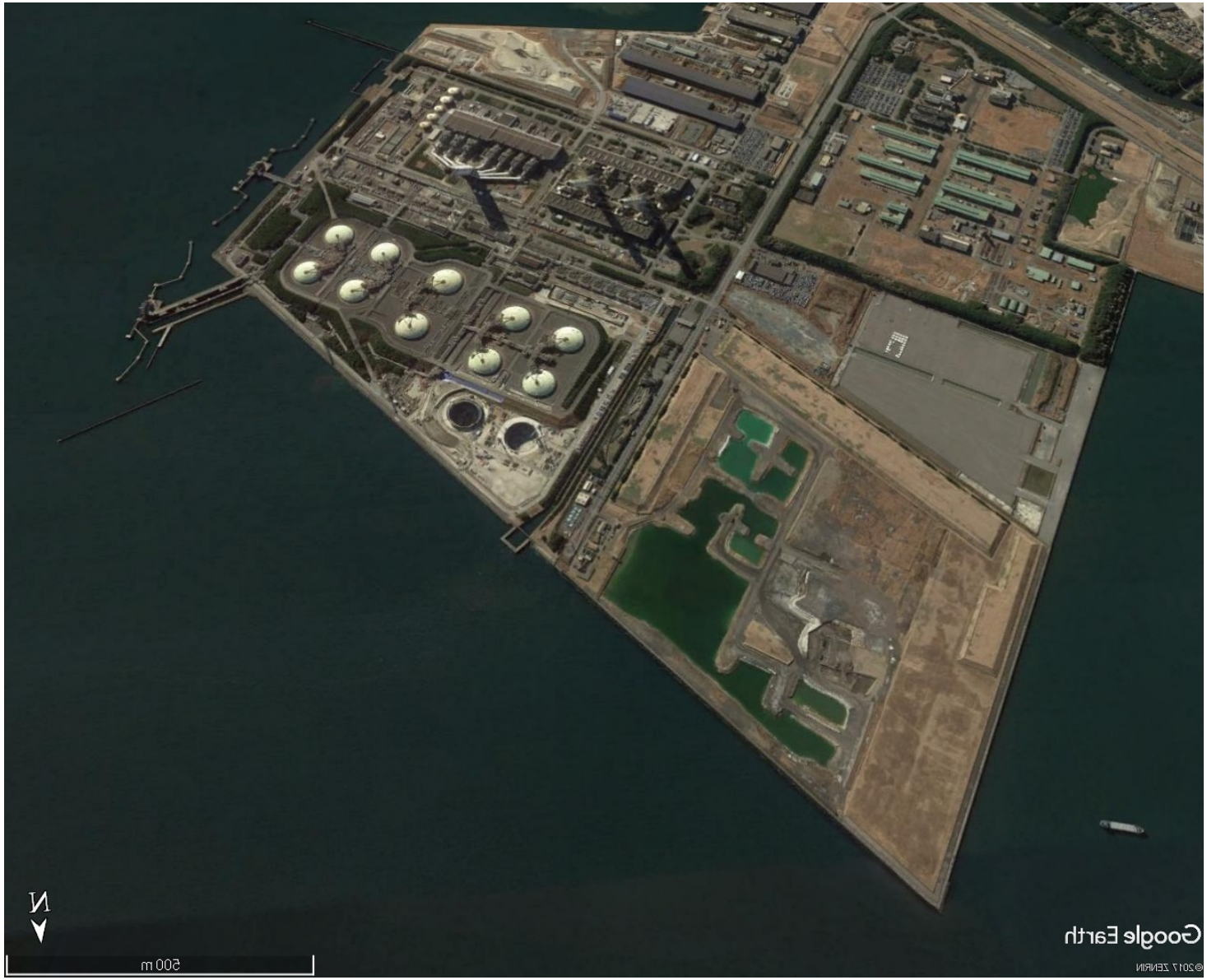
HH Aug. 8, 2017



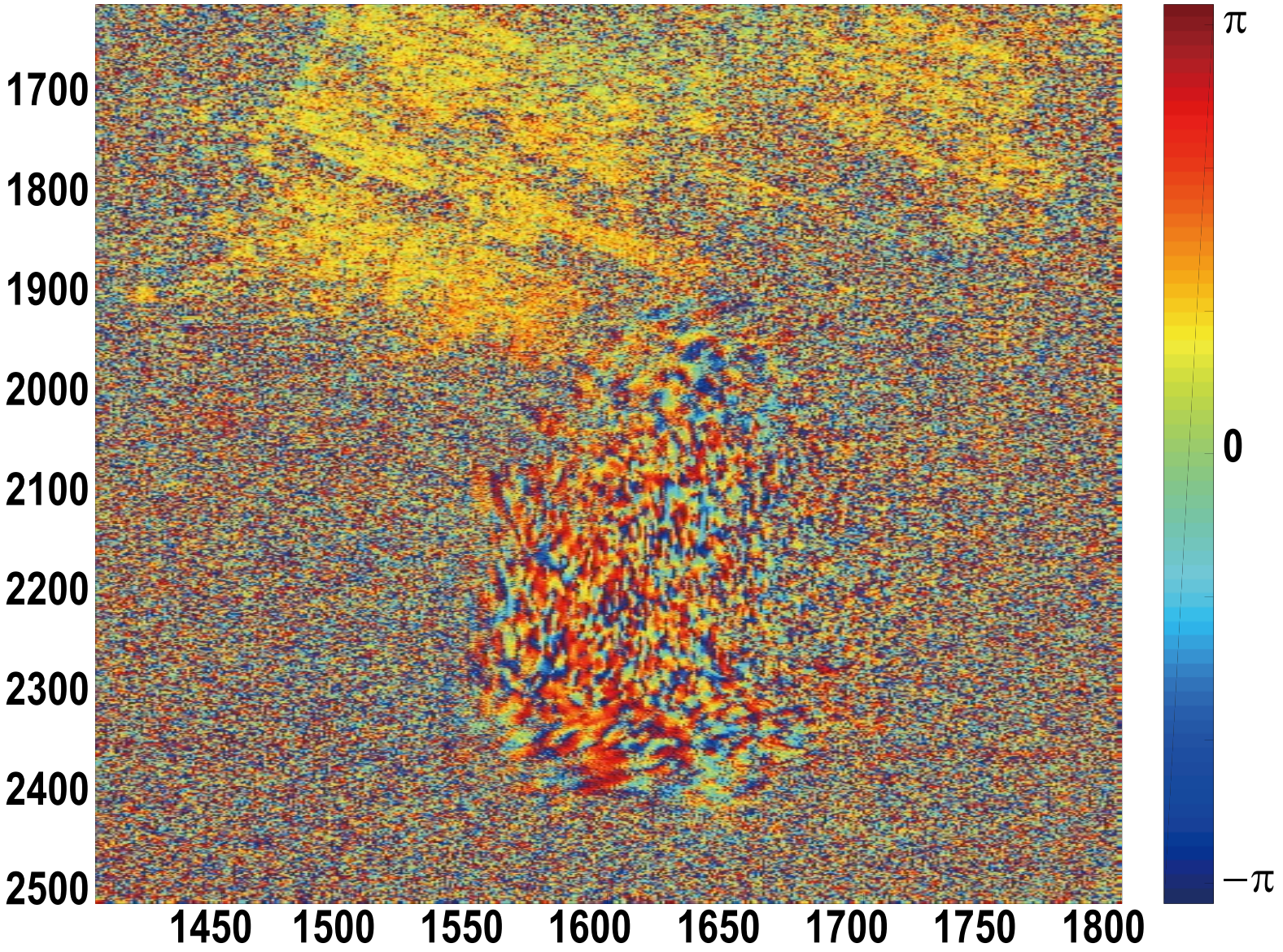
HH Aug. 11, 2015



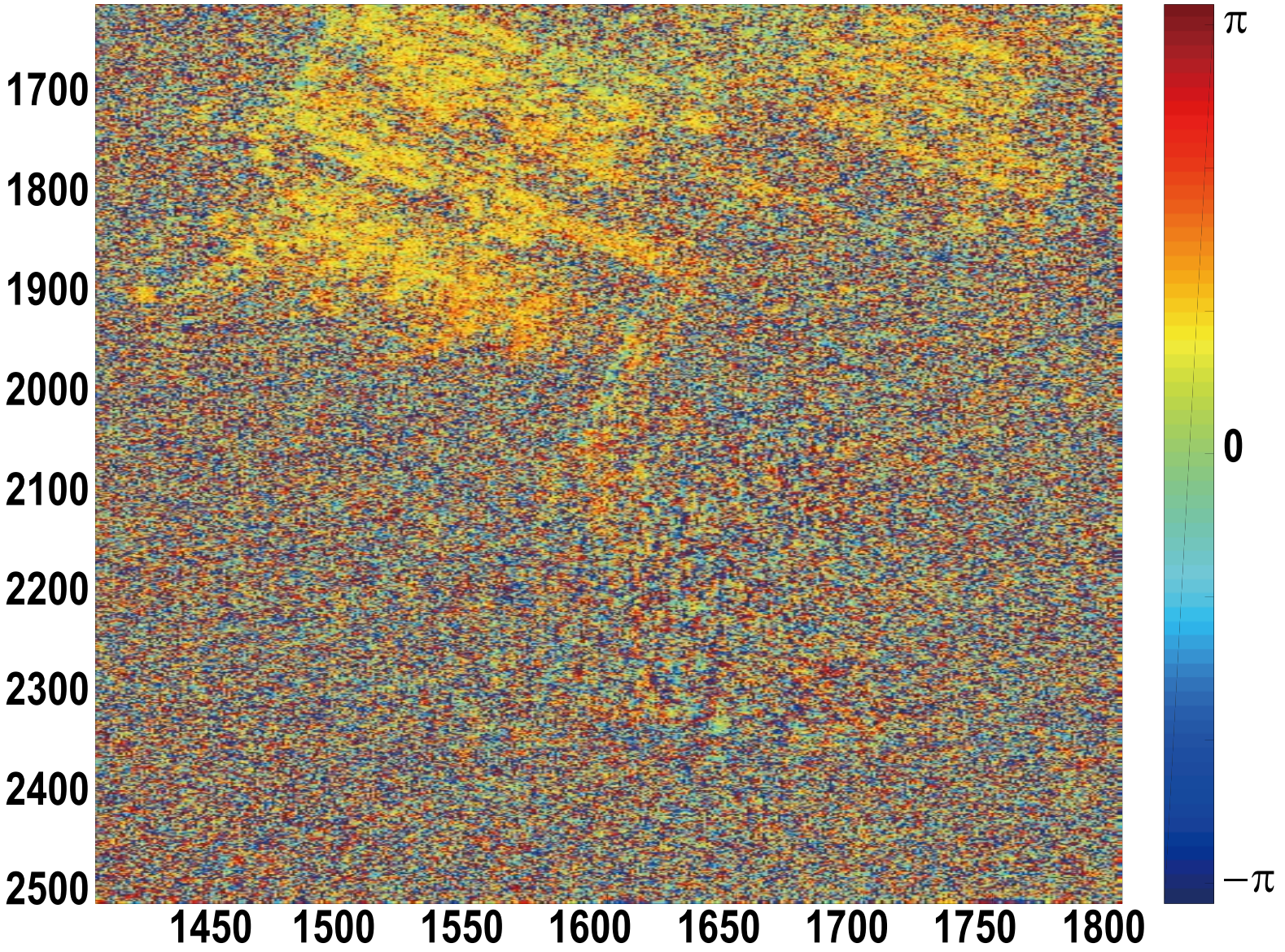
Google Earth image (Jan. 17, 2017)



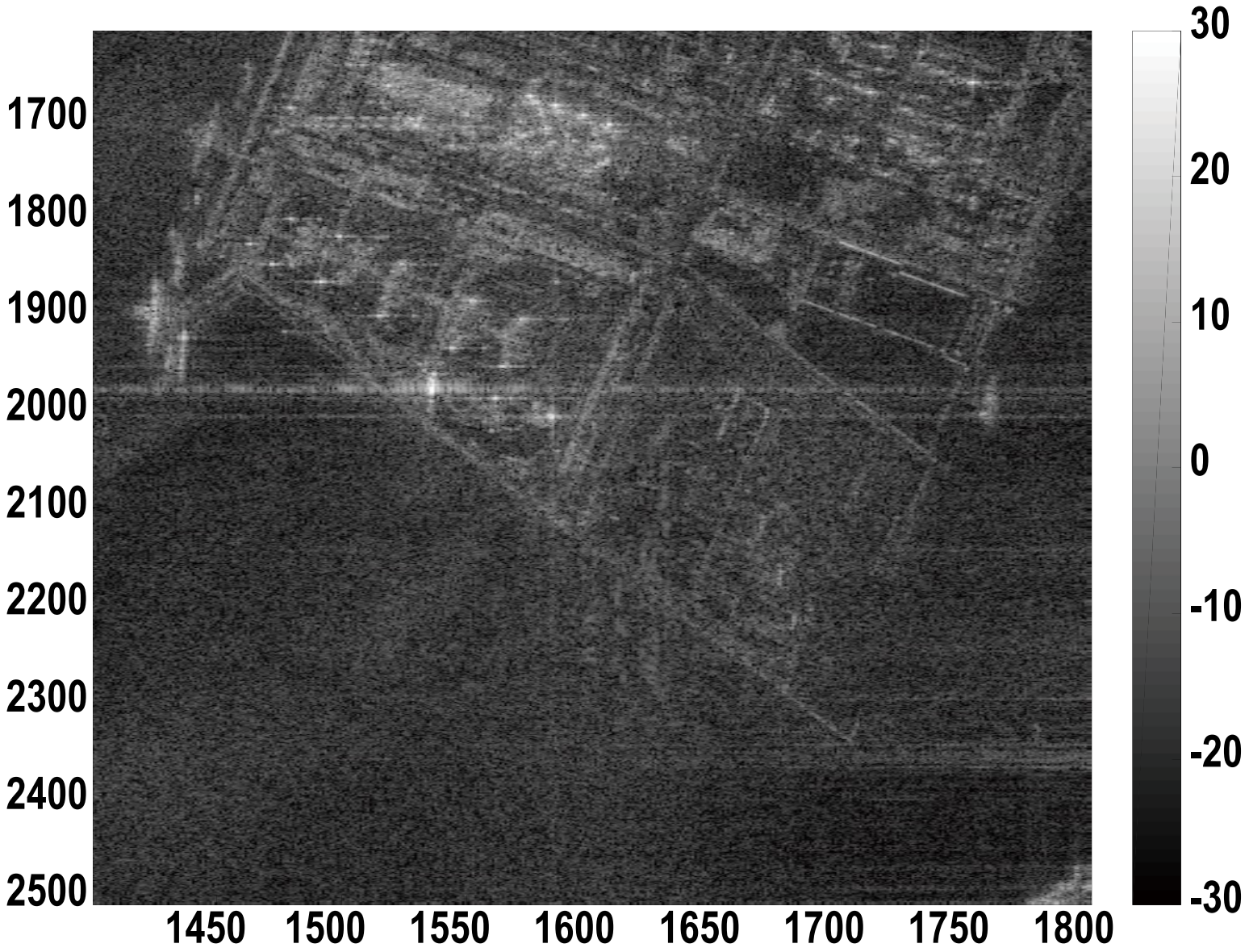
HH interferogram Aug. 8, 2017 – Aug. 11, 2016



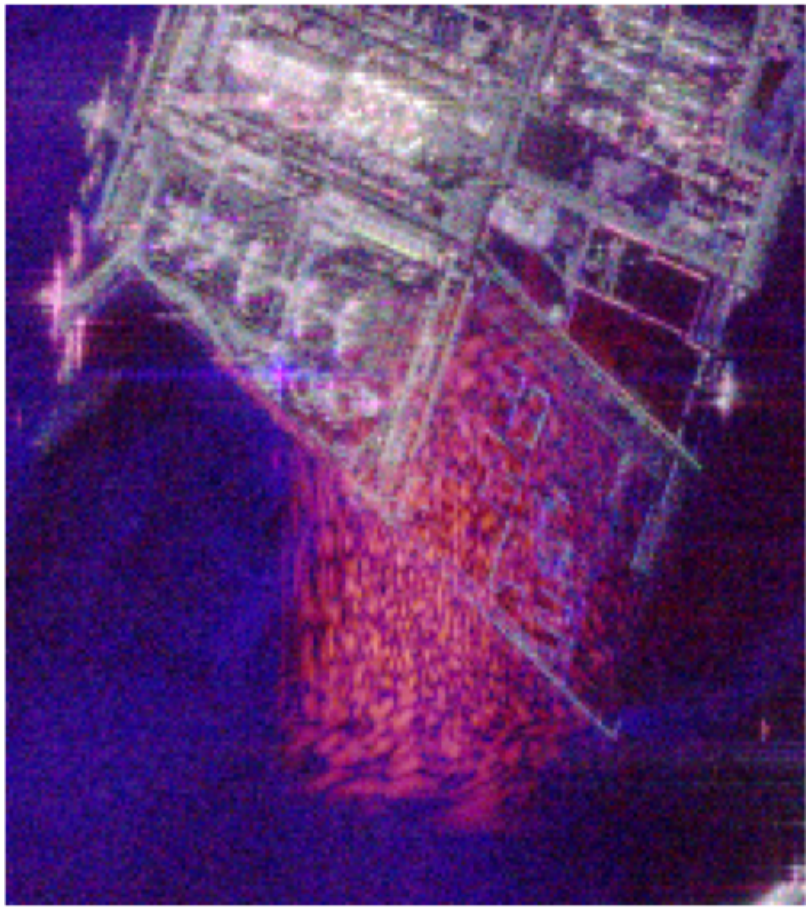
After RFI removal



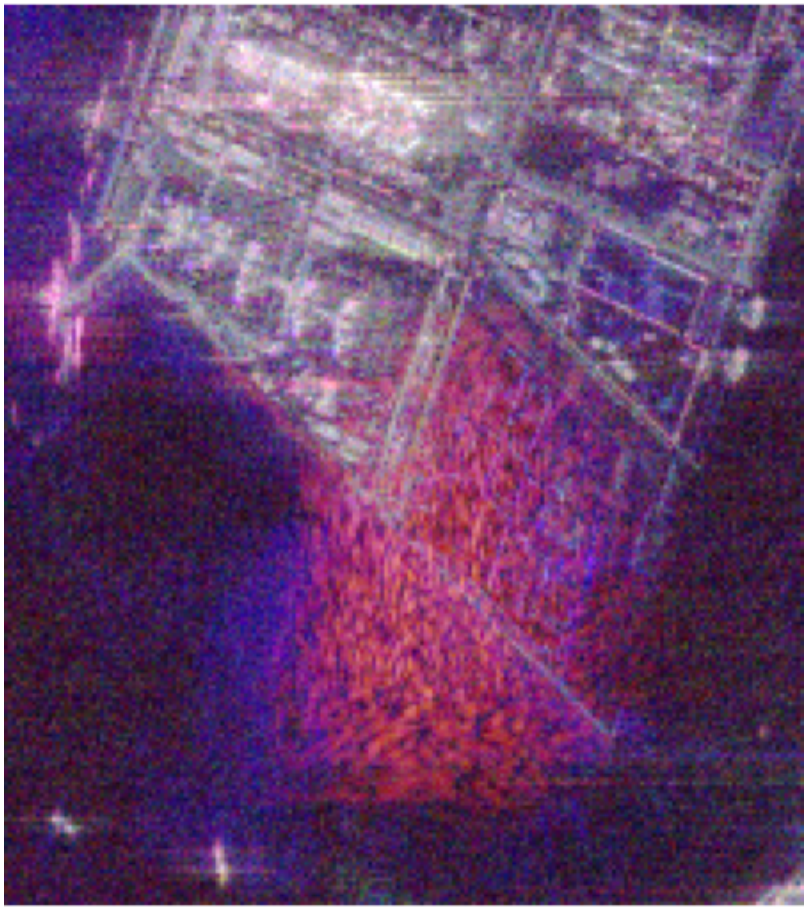
After RFI removal



Pauli decomposition before removal

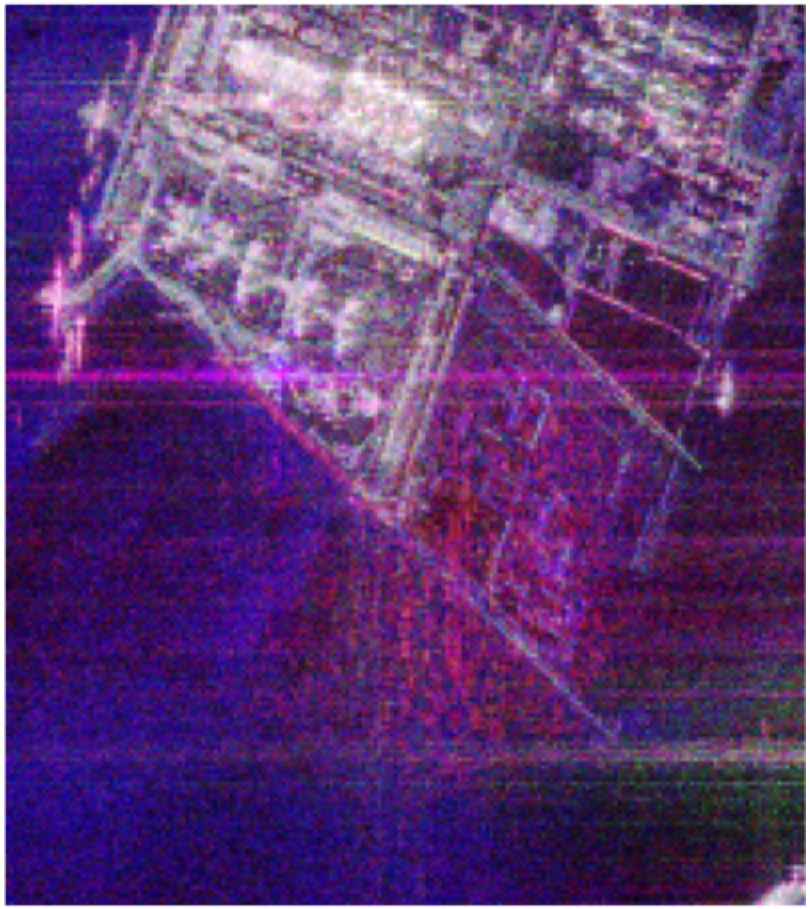


Aug. 8, 2017

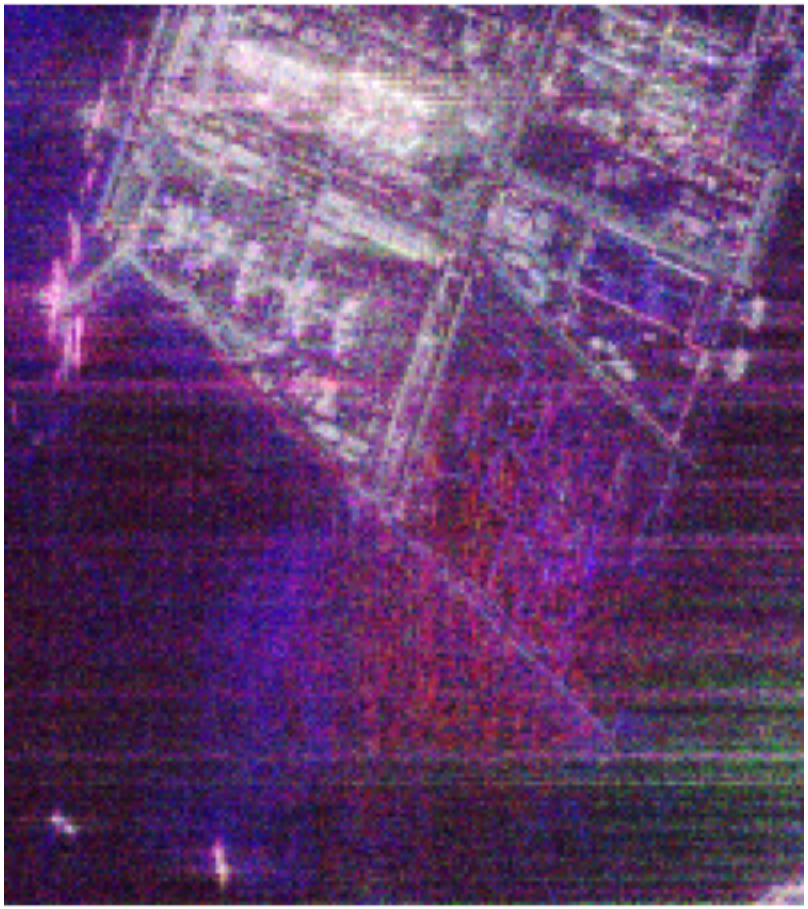


Aug. 11, 2015

Pauli decomposition after removal

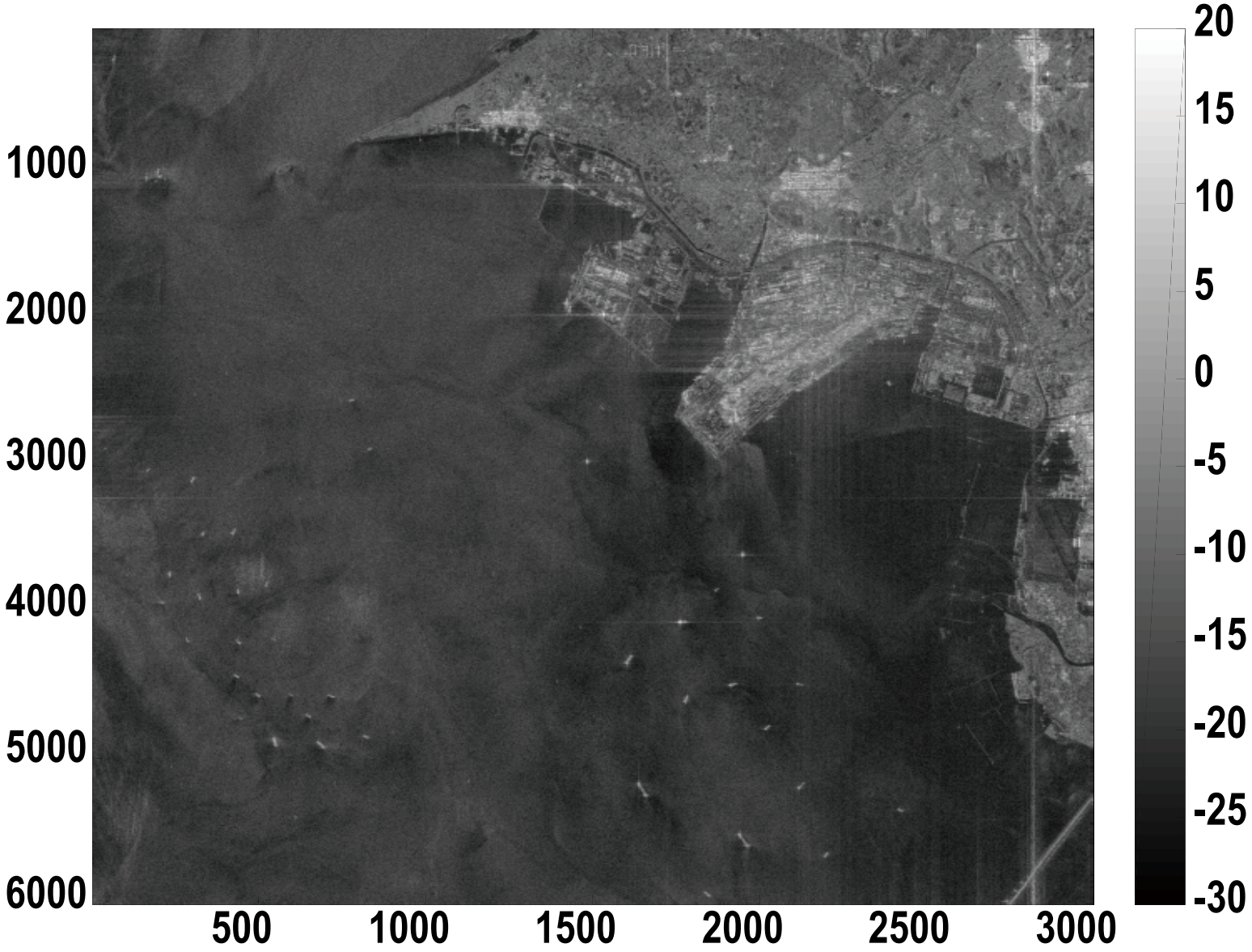


Aug. 8, 2017

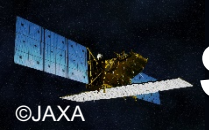


Aug. 11, 2015

HH Aug. 8, 2017 after RFI removal



Must be improved (too many false alarms for bright targets)



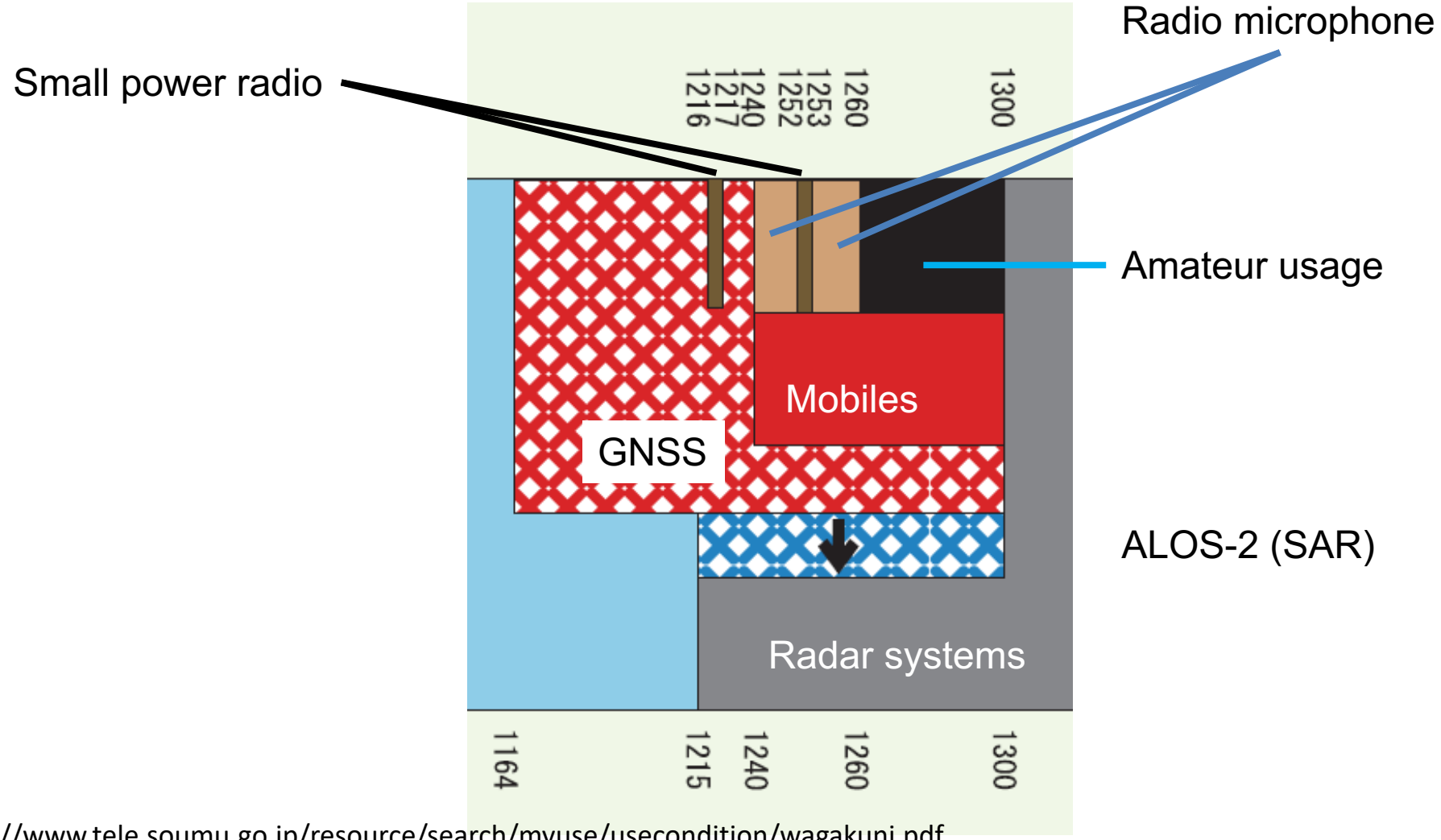
Summary

- Found irregular signals (probably RFI)
- High temporal coherency, overwrite ground targets
  -> Disturb interferometric analysis
- Multiple polarizations
  -> Disturb polarimetric analysis
- Do not appear at same place if track is different.
- Proposed autocorrelation based RFI detection method
- Further improvements are required
  -> Distinguish strong backscattered signal from RFI
  -> Finding RFI source
- How to evaluate numerically?
  -> Strong, high temporal coherency


©JAXA

Radio Frequency Interference (RFI)

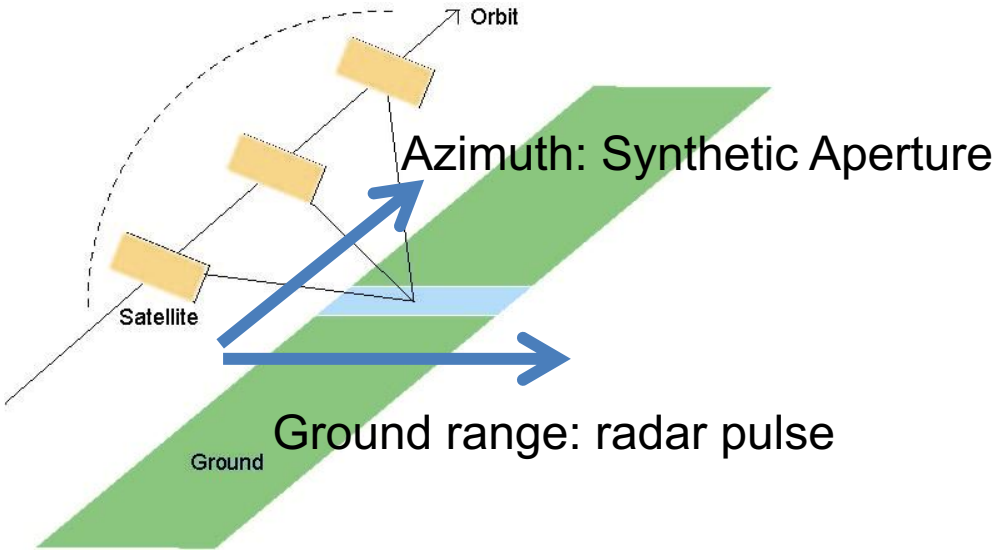
- Cross talk between multiple systems

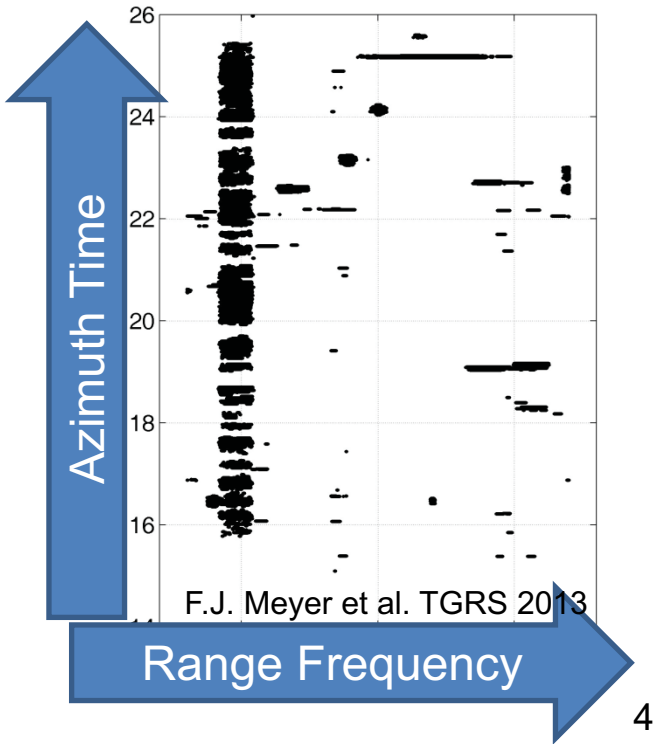


http://www.tele.soumu.go.jp/resource/search/myuse/usecondition/wagakuni.pdf

RFI detection in SAR system

- Time Stationary Narrow Band (E.g., GNSS)
- Time Varying Wide Band (E.g., Communication, Radar）
- Integration in time / frequency domain for RFI detection
- “SAR system consumes the widest bandwidth”
- Detection by spectrum-based methods.





F.J. Meyer et al. TGRS 2013

Intermittently transmitted (ITWB) RFI

- High temporal coherence
  -> Arrives simultaneously in multiple observation dates
- Difficult to find in range freq. domain
  -> Frequency modulated
  -> Bandwidth is close to (or wider than) SAR
- Appear in azimuth freq. domain
  -> Doppler frequency shifts differently from backscatter

Declined sources

- Moving target (blurred appearance)
  -> Must be temporally incoherent
- Ambiguity (sidelobe)
  -> Can expect the signal source
  -> Higher coherency than normal ambiguity