Singularity-Spreading Phase Unwrapping

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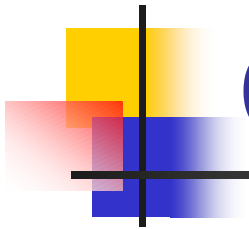
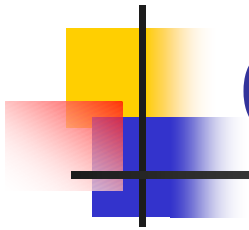


Outline

1. Introduction
2. Singularity-Spreading Phase Unwrapping : SSPU
3. Weighted SSPU Utilizing Amplitude Data
4. Evaluation with Real Terrain Height Data
5. Reduction in Calculation Time
6. Conclusion



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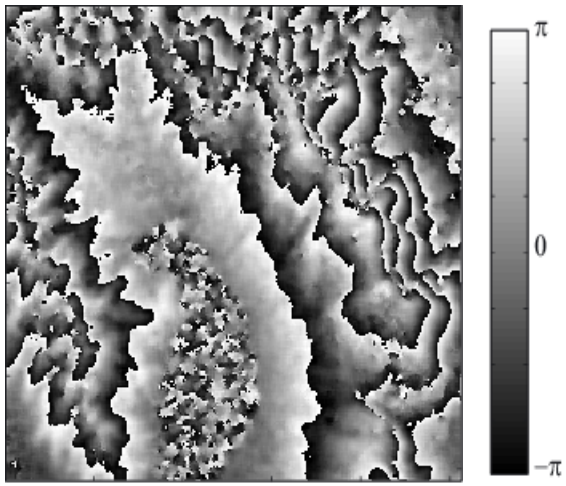
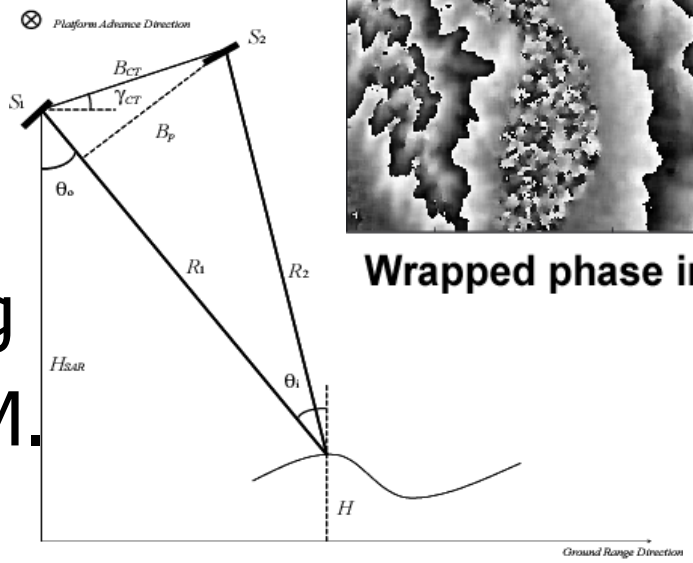
Introduction

- Interferometric Synthetic Aperture Radar (InSAR) system generates interferograms which represent the landscape.

- Phase Unwrapping:
  Observed phase value
  is wrapped into $(-\pi,\pi]$.
  Need to unwrap for making
  Digital Elevation Map : DEM.



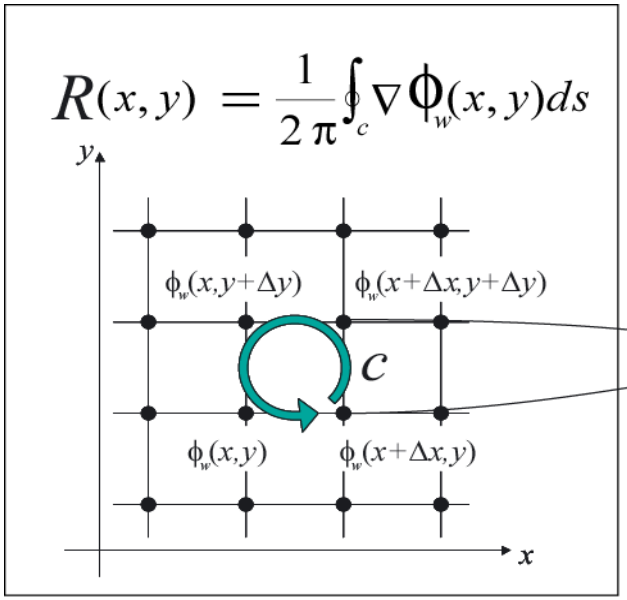
Wrapped phase image

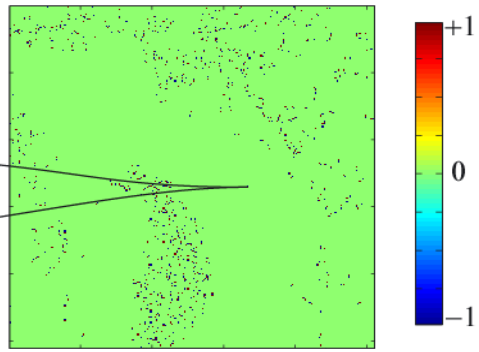


Introduction

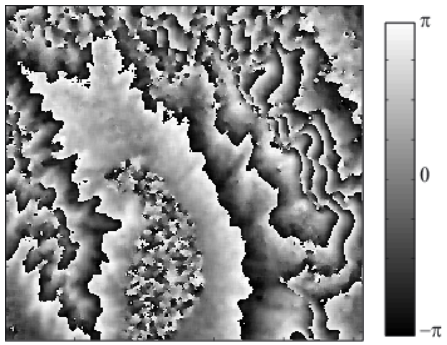
- Singular Point (SP):

  where phase rotation has a non-zero value (+1 or-1). SPs cause phase inconsistency.





SP map



Wrapped phase image

Introduction

- Minimum Cost Network Flow (MCNF) Method

  Mario Costantini, 1998

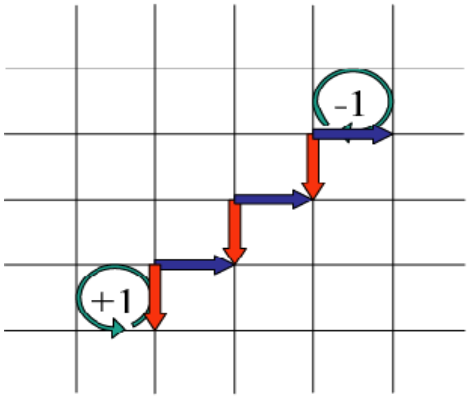
  An efficient method for 2D-PU

  Paring +1 and –1 SPs with discrete 2nπ's

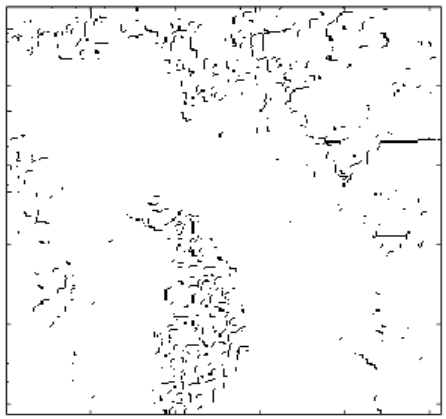
  (Placing optimum branch-cuts)

Problems:

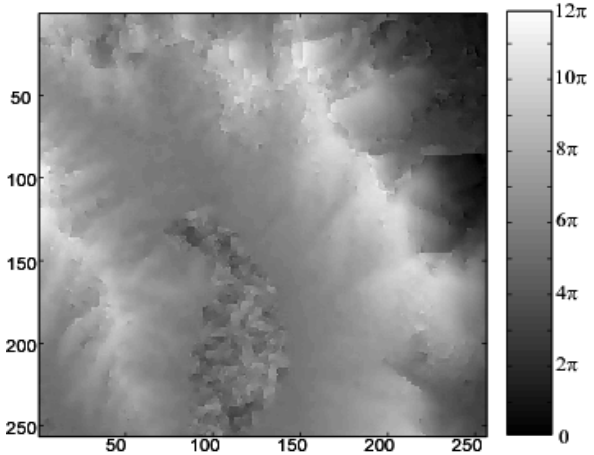
1. Dense SPs generate spikes.
2. Isolated SPs cause unnatural cliffs.
3. Optimization requires a high calculation cost.



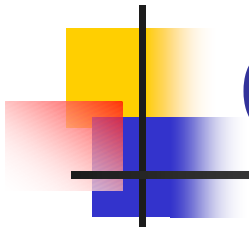
Pairing SPs



Branch-Cuts



Unwrapped phase image



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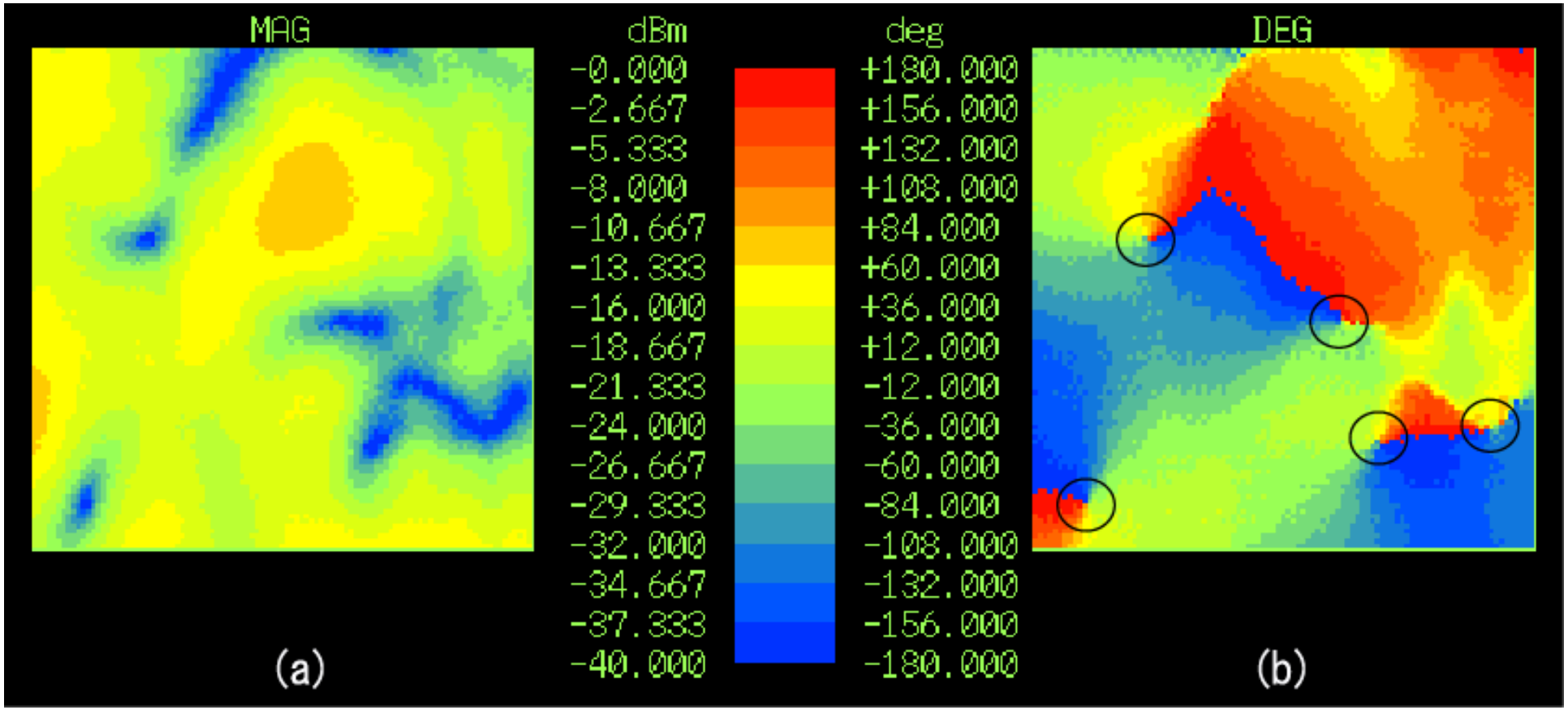
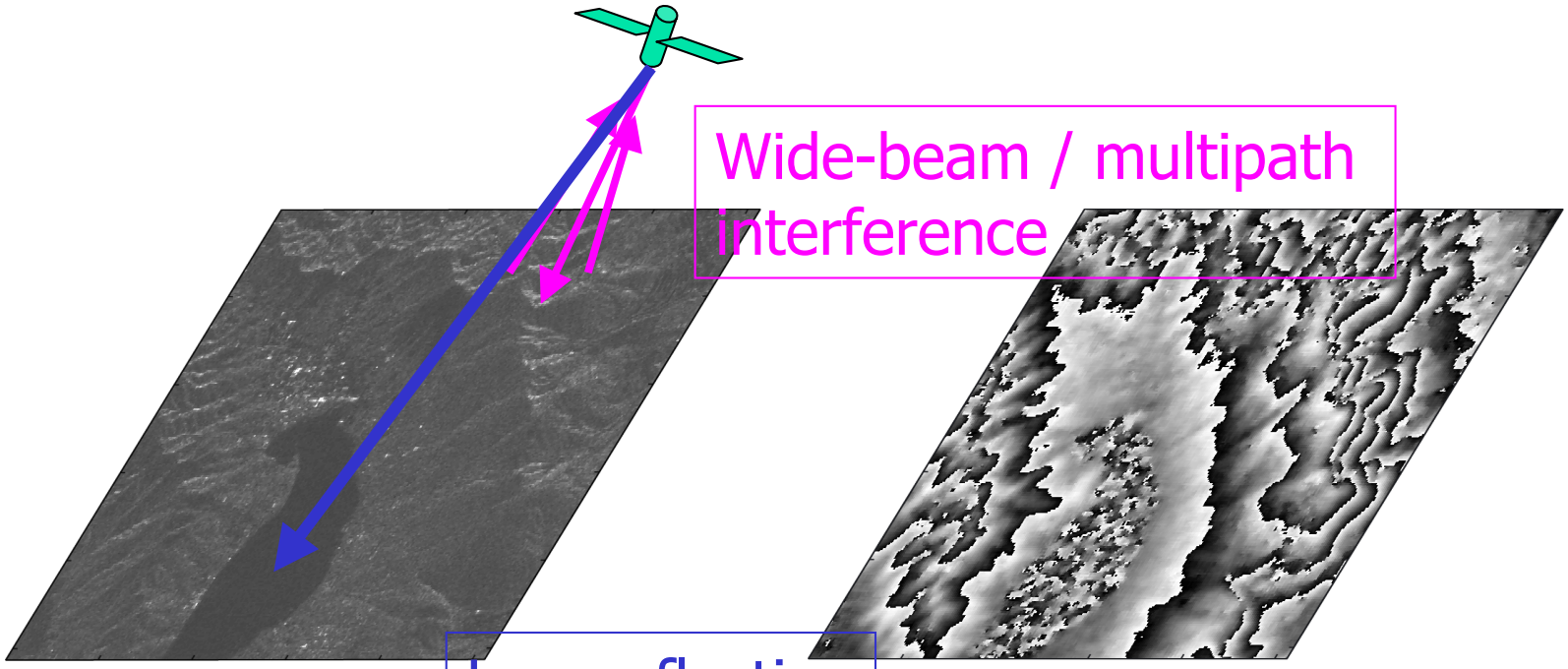
Introduction



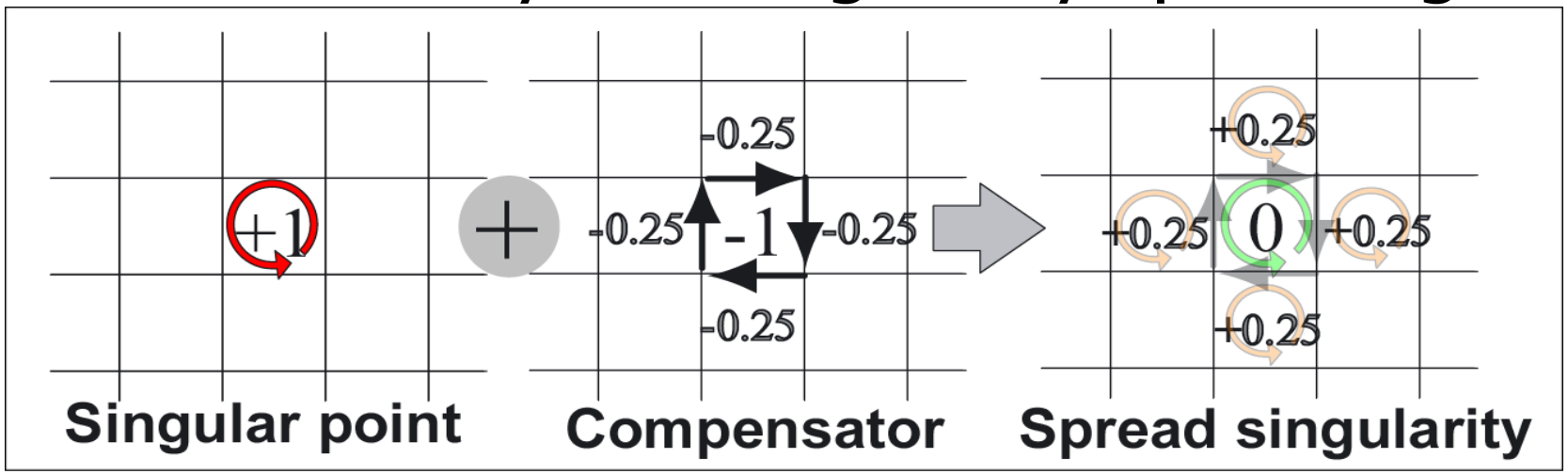
Singularity-Spreading Phase Unwrapping

- Phase values are distorted in EM-wave propagation causes SPs.



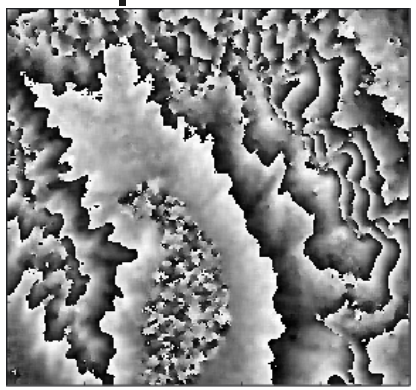
Singularity-Spreading Phase Unwrapping

- SPs should be compensated in **a continuous manner** together with their vicinity. -->Singularity spreading

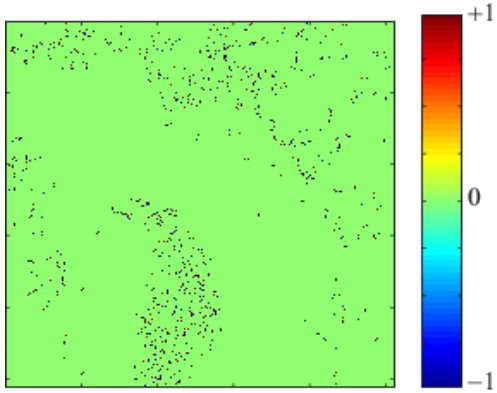


Iteration over the whole image

Singularity-Spreading Phase Unwrapping



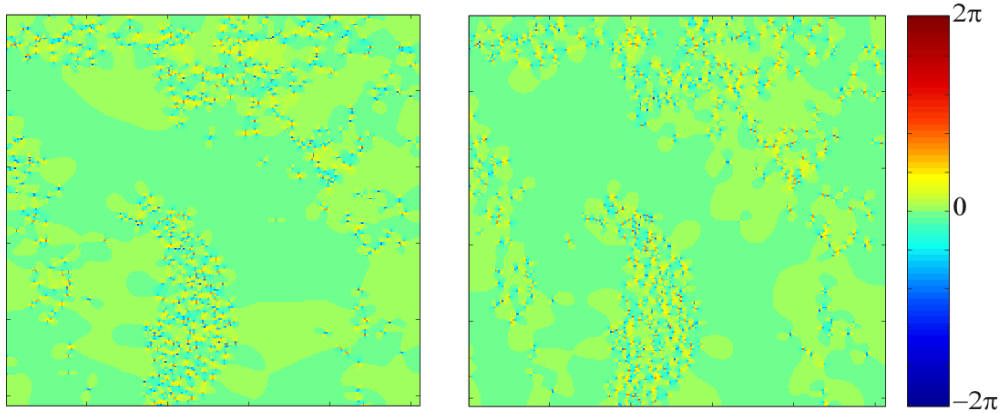
Wrapped phase image



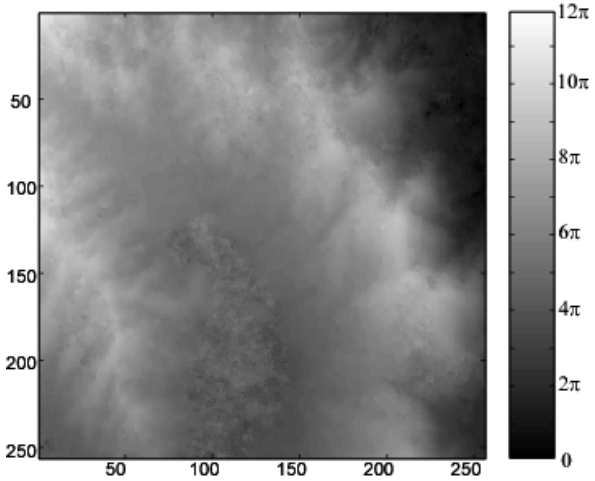
SP map

In the SSPU, compensators combine +1 and −1 SPs gently, and diffuse isolated ones.

--> SPs are removed.

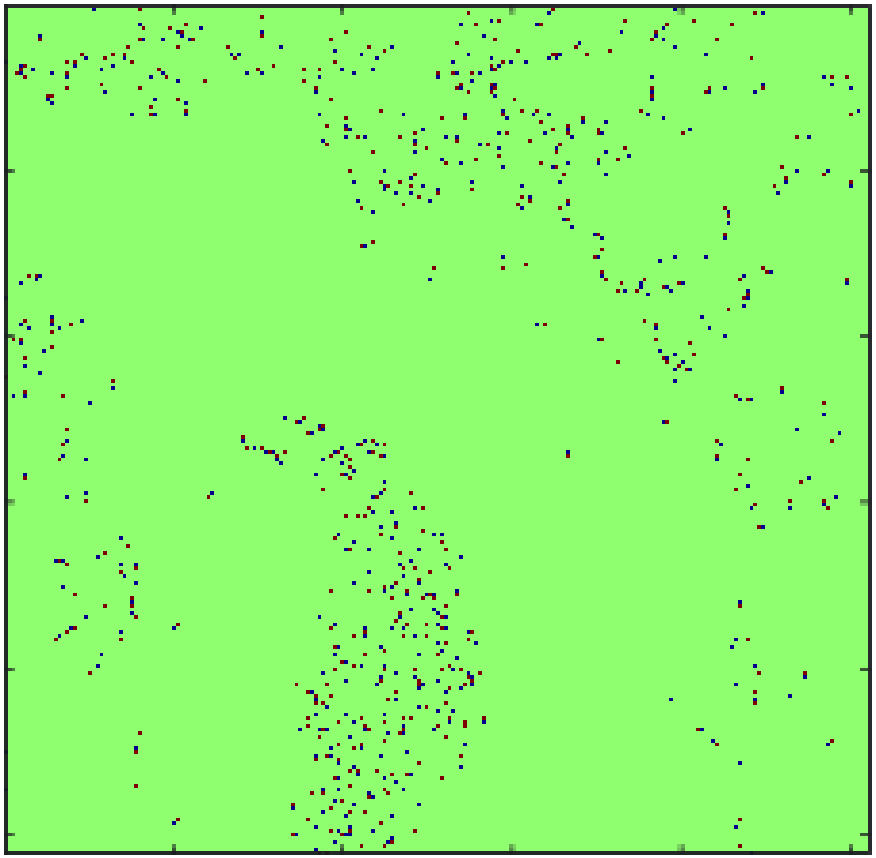


x and y directional compensators



Unwrapped phase image

Singularity-Spreading Phase Unwrapping



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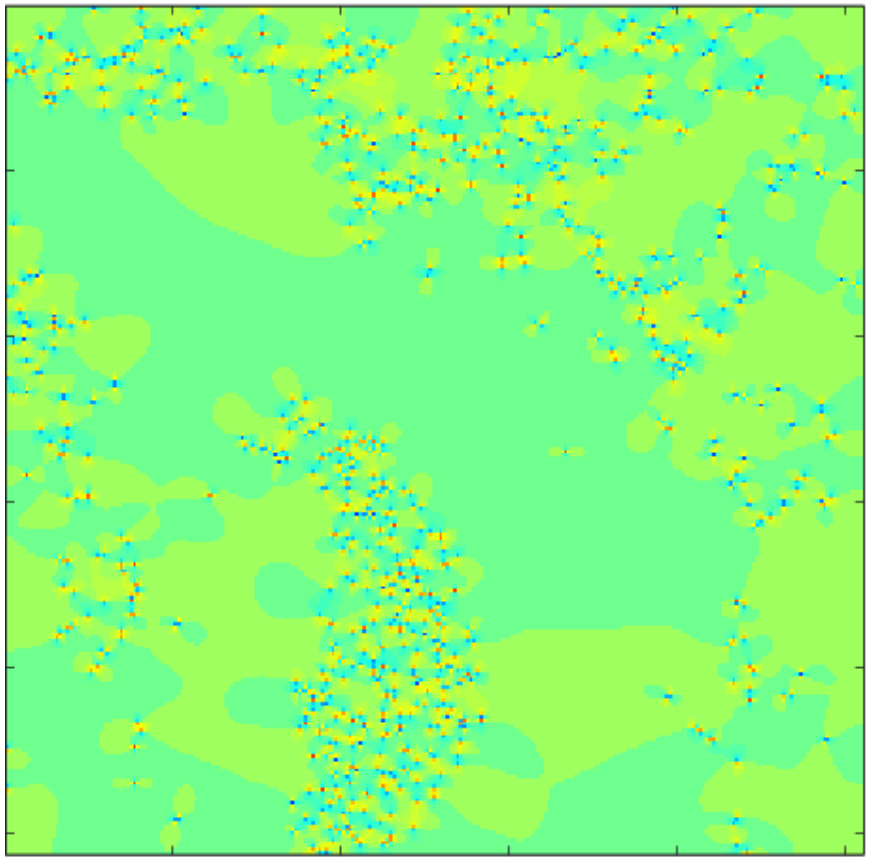

x directional compensators

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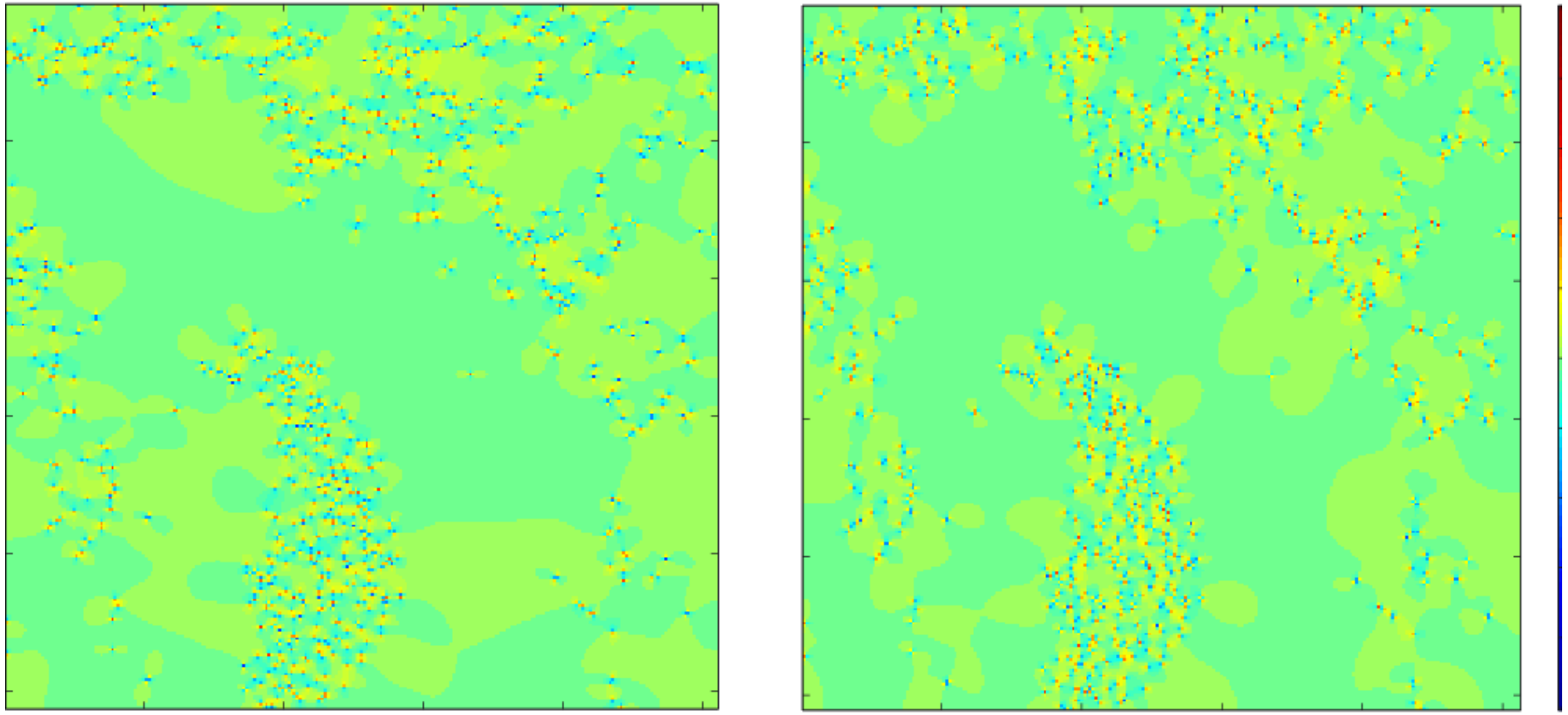
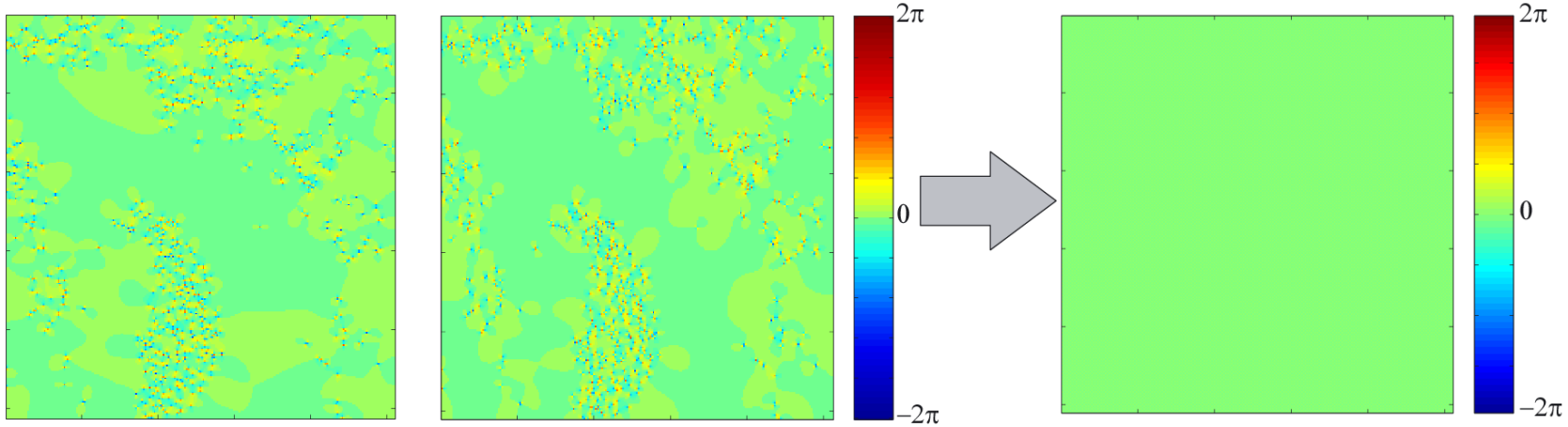


x and y directional compensators

Singularity-Spreading Phase Unwrapping

In the SSPU, compensators combine +1 and –1 SPs gently. Then, the inconsistency cancels out.

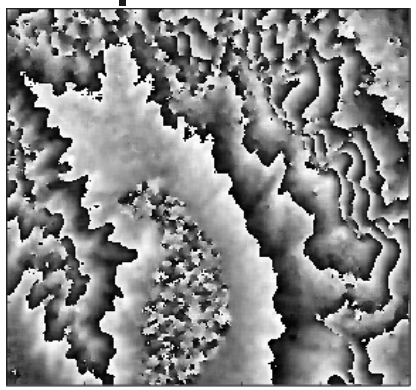
Isolated SPs are also erased without yielding unnatural cliffs.



(L) x- and (R) y- directional compensators

Cancelled inconsistency

Singularity-Spreading Phase Unwrapping



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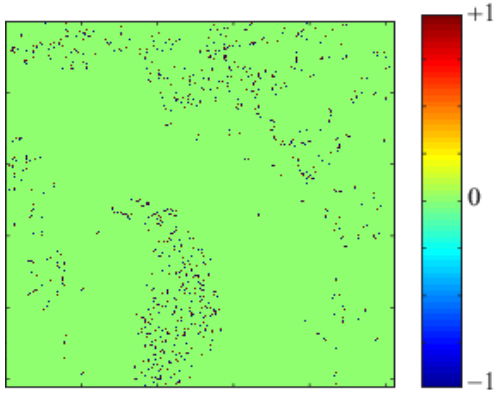

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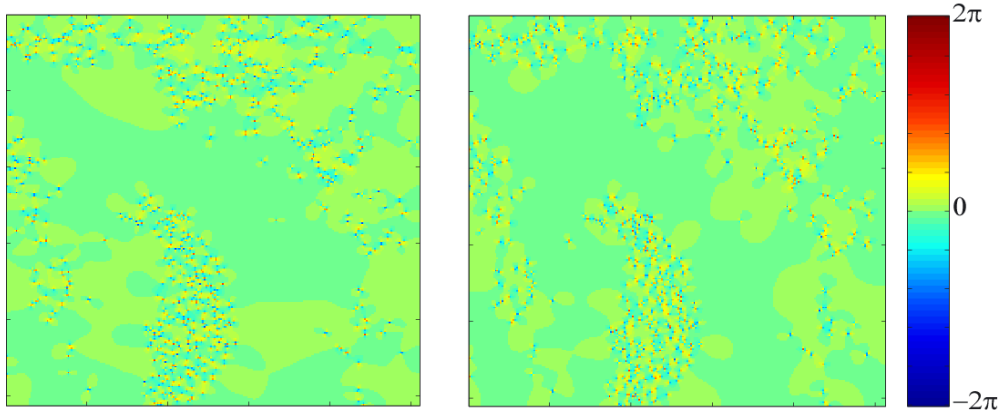
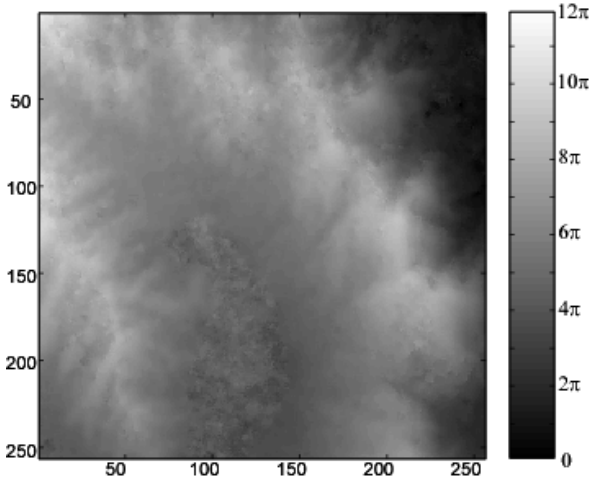


x and y directional compensators



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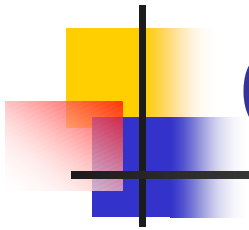

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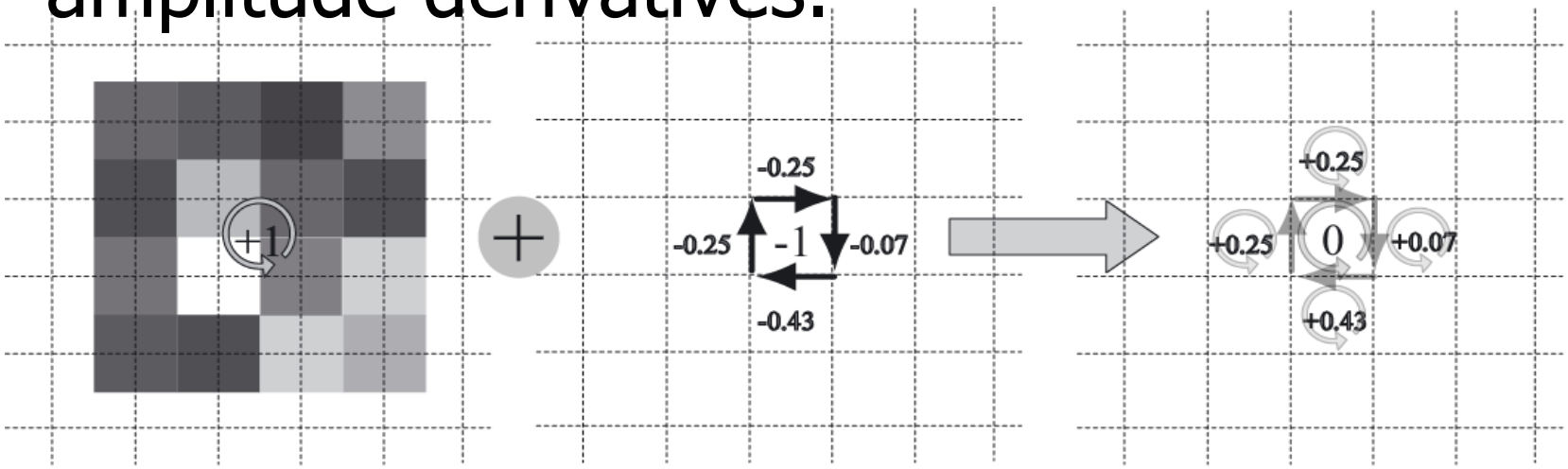
Weighted SSPU Utilizing Amplitude Data

Weight the fractions of the inverse rotation depending on the absolute values of the amplitude derivatives.



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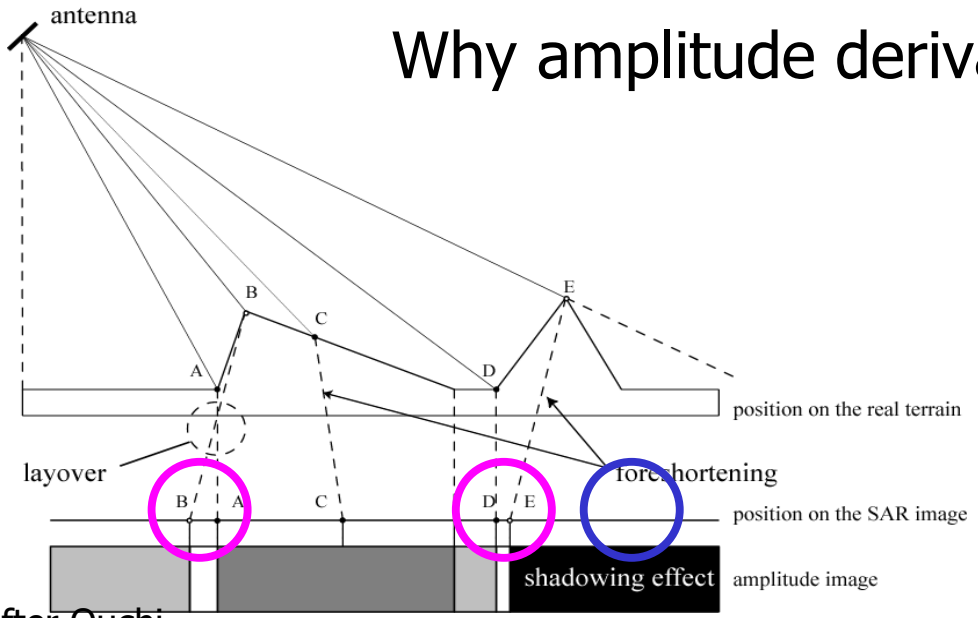
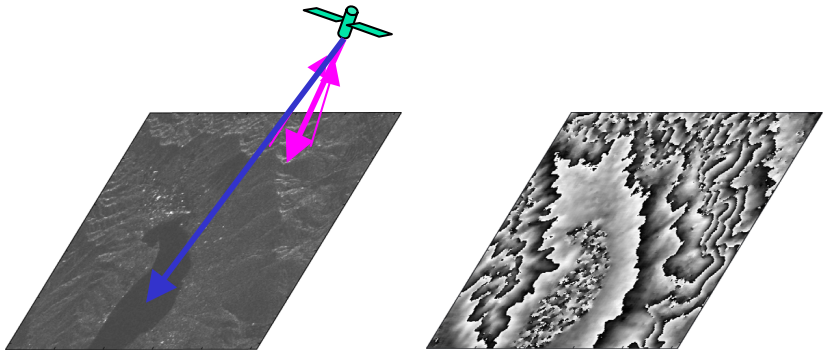


After Ouchi

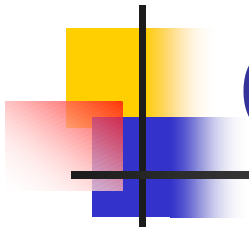
Why amplitude derivative?

Wide-beam / multipath interference



Low reflection

	Amplitude	Phase	Compensator
Layover area	higher than its vicinity	distorted by interference	locally distributed
Shadowed area	almost zero	random noise	uniform (statistically)



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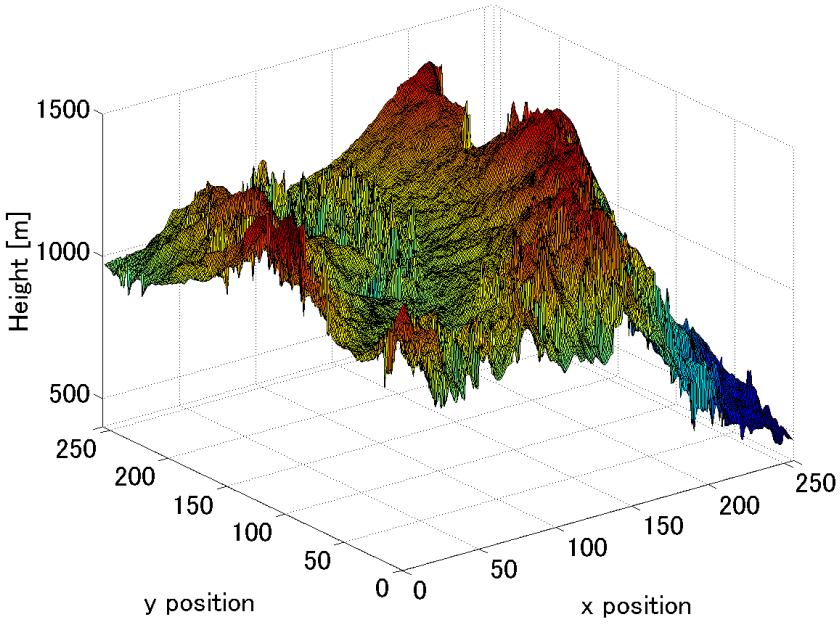
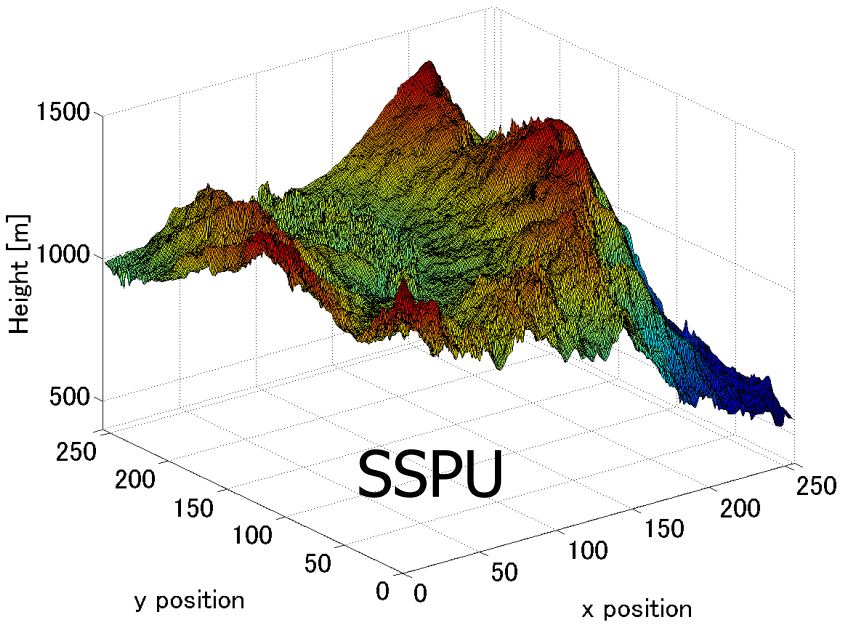
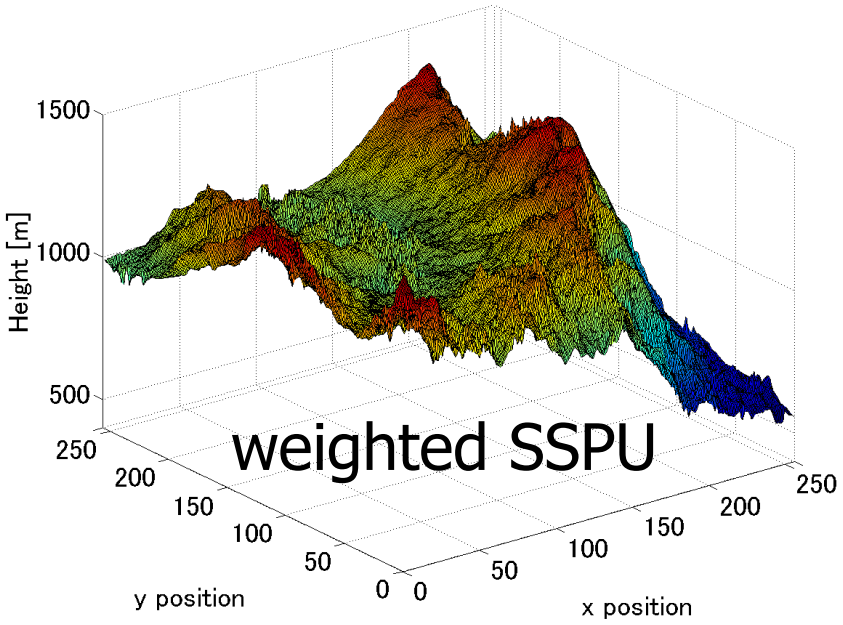
Evaluation wit Height Data

Generated DEMs



Min.Cost NF method





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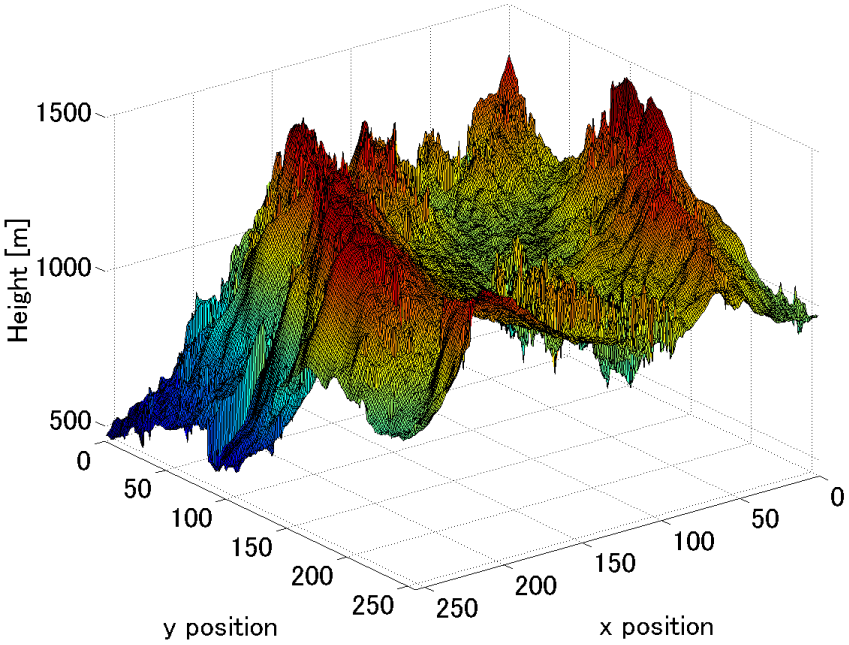

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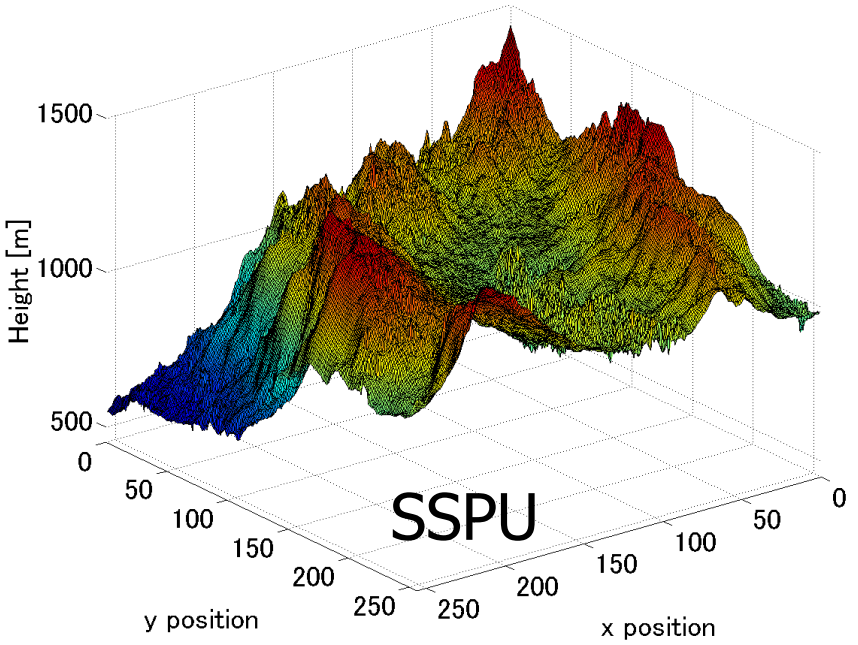
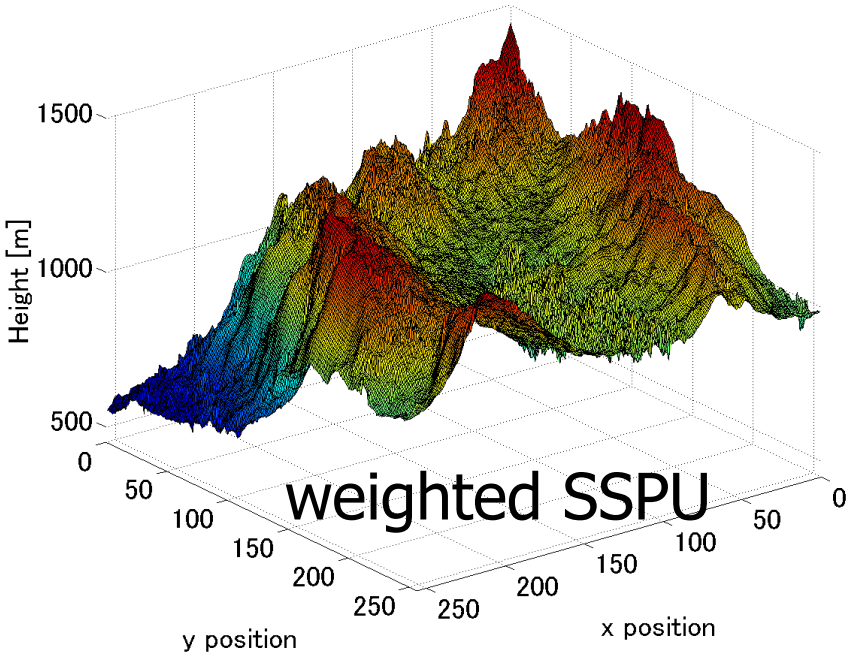




Evaluation with Real Terrain Height Data

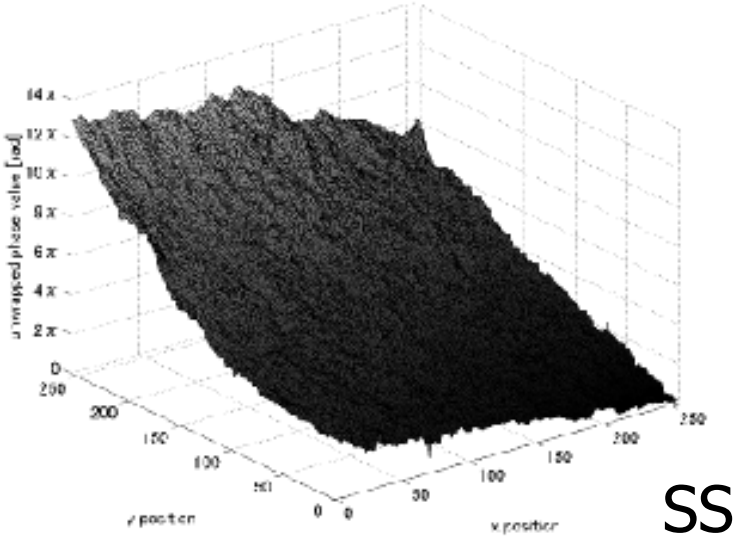
Method	MSE	MSNR	PSE	PNSNR
	MSE	$10\log_{10}\frac{SHR}{MSE}$	PSE	$10\log_{10}\frac{SHR}{PSE}$
	$\times 10^3[m^2]$	[dB]	$\times 10^3[m^2]$	[dB]
MCNF	3.32	24.3	121.2	8.63
Simple SSPU	2.93	24.8	83.4	10.26
Weighted SSPU	2.59	25.3	95.4	9.67

$$MSE = \frac{1}{S}\sum_x\sum_y\{\hat{H}(x,y) - H(x,y)\}^2 \quad [\mathrm{m}^2]$$

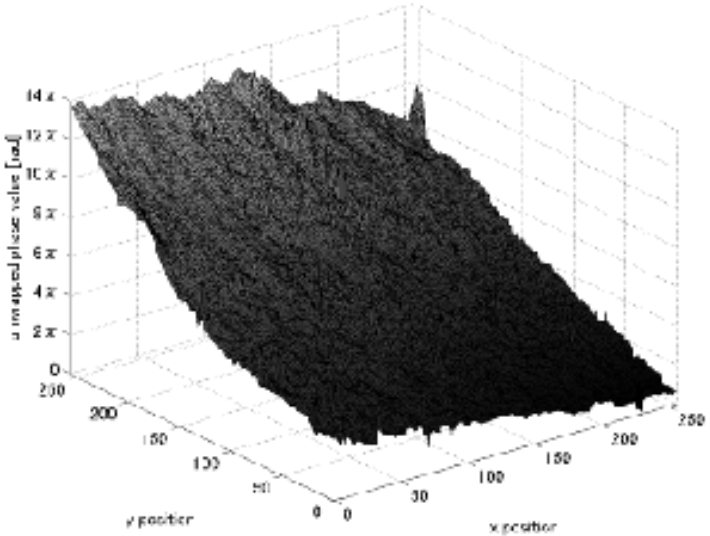
$$PSE = \max[\{\hat{H}(x,y) - H(x,y)\}^2] \quad [\mathrm{m}^2]$$

Evaluation with Real Terrain Height Data

Generated DEMs



SSPU



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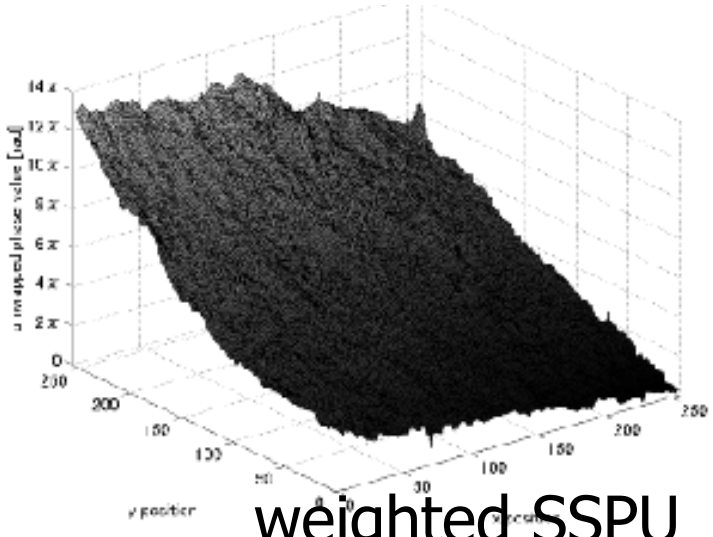
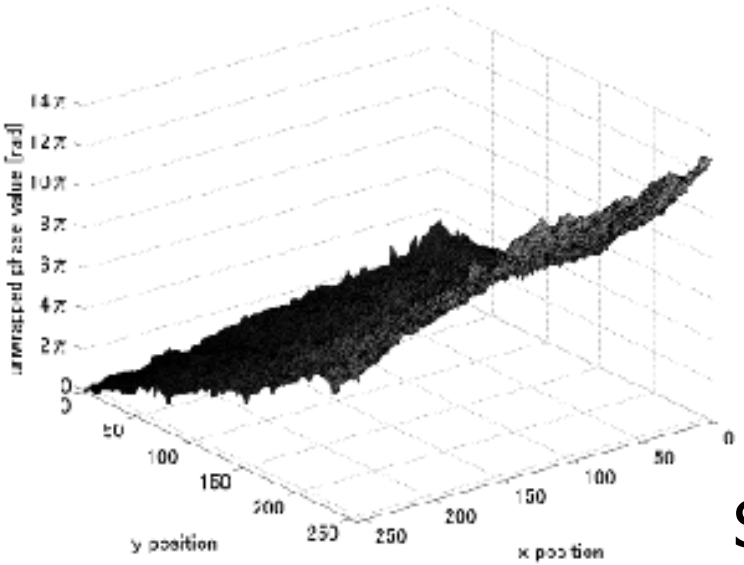


weighted SSPU

Evaluation with Real Terrain Height Data

Generated DEMs



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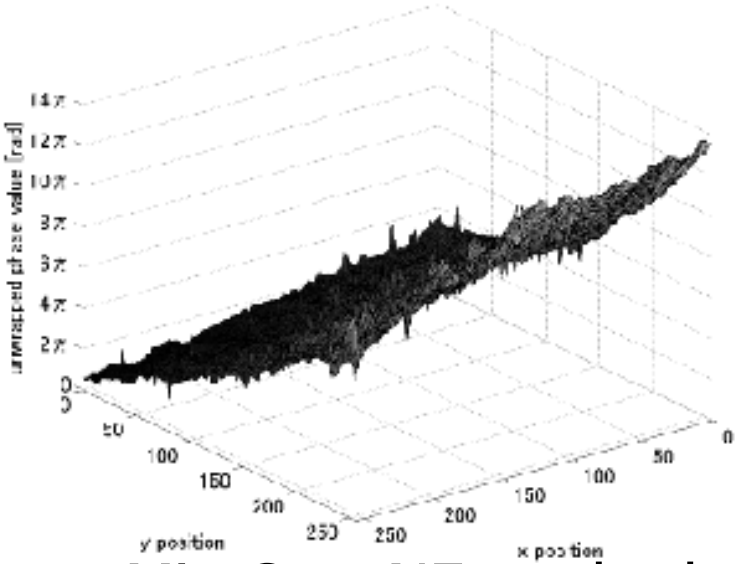

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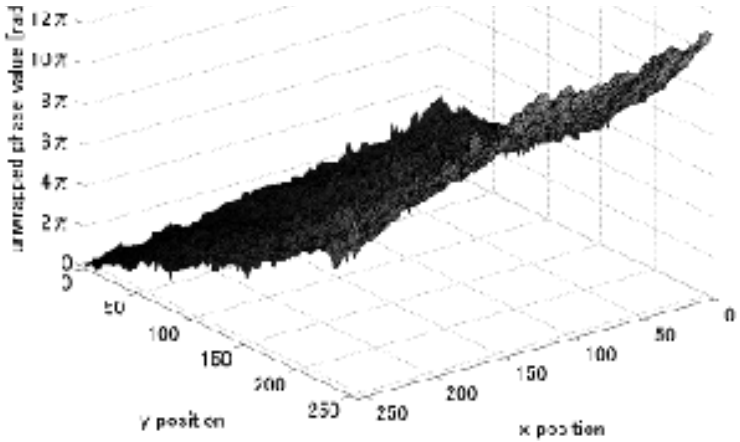


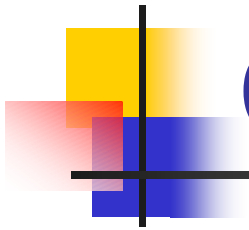
weighted SSPU

Evaluation with Real Terrain Height Data

Method	MSE	MSNR	PSE	PNSNR
	MSE	$10\log_{10}\frac{SHR}{MSE}$	PSE	$10\log_{10}\frac{SHR}{PSE}$
	$\times 10[m^2]$	[dB]	$\times 10^3[m^2]$	[dB]
MCNF	17.2	37.5	26.0	15.7
Simple SSPU	15.2	38.0	6.0	22.1
Weighted SSPU	15.5	38.0	6.0	22.1

$$MSE = \frac{1}{S}\sum_x\sum_y\{\hat{H}(x,y) - H(x,y)\}^2 \quad [\mathrm{m}^2]$$

$$PSE = \max[\{\hat{H}(x,y) - H(x,y)\}^2] \quad [\mathrm{m}^2]$$



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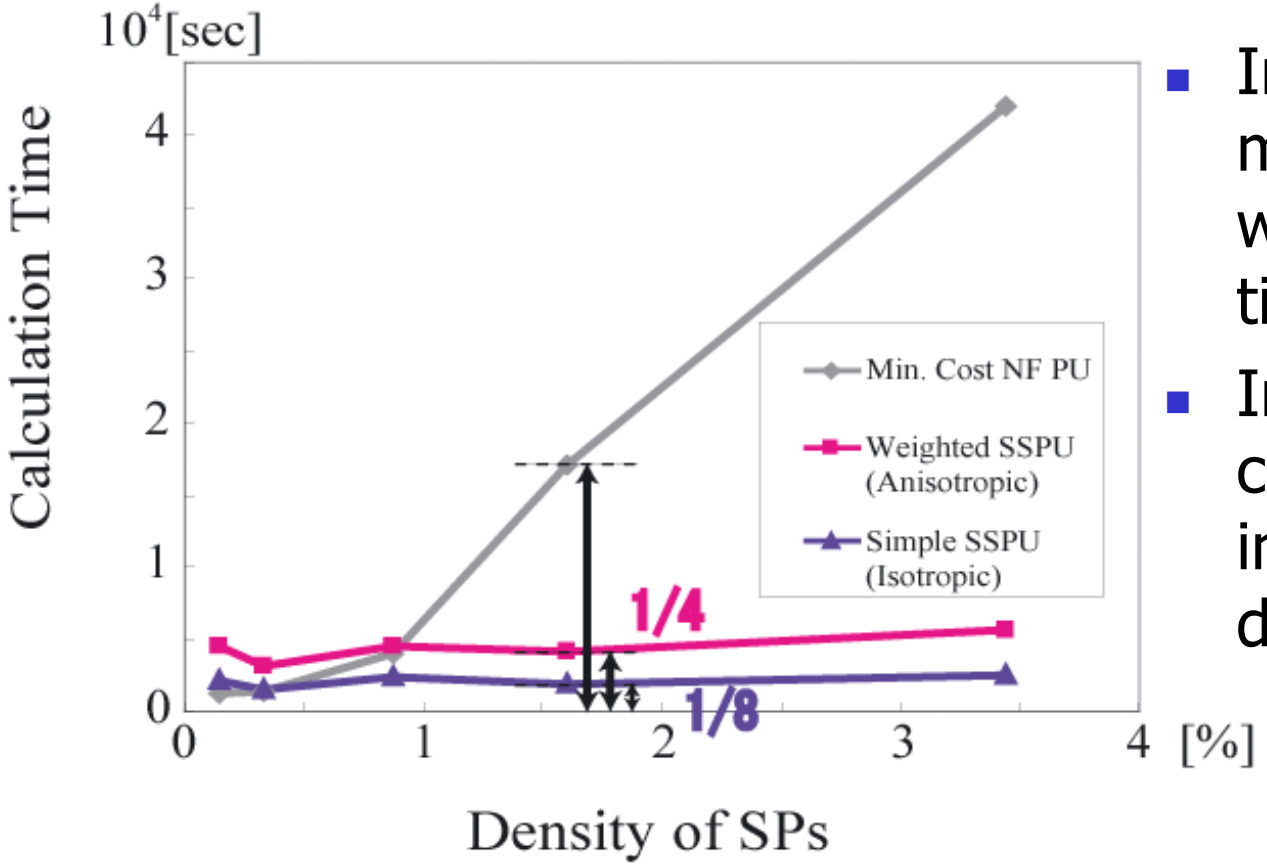
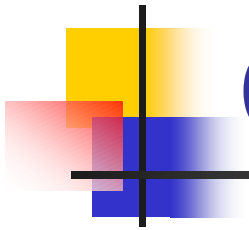
Reduction in Calculation Time



- In the conventional method, the more SPs we have, the more time is required.
- In SSPU, calculation costs are very low and independent of the density of SPs.



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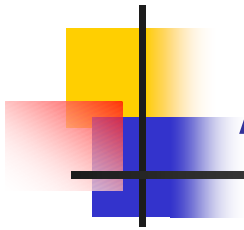
Conclusion

- We have proposed the simple SSPU method / weighted SSPU method by utilizing amplitude information.
- More precise DEMs can be generated in the weighted SSPU method as compared to the conventional method.
- Calculation times are reduced.



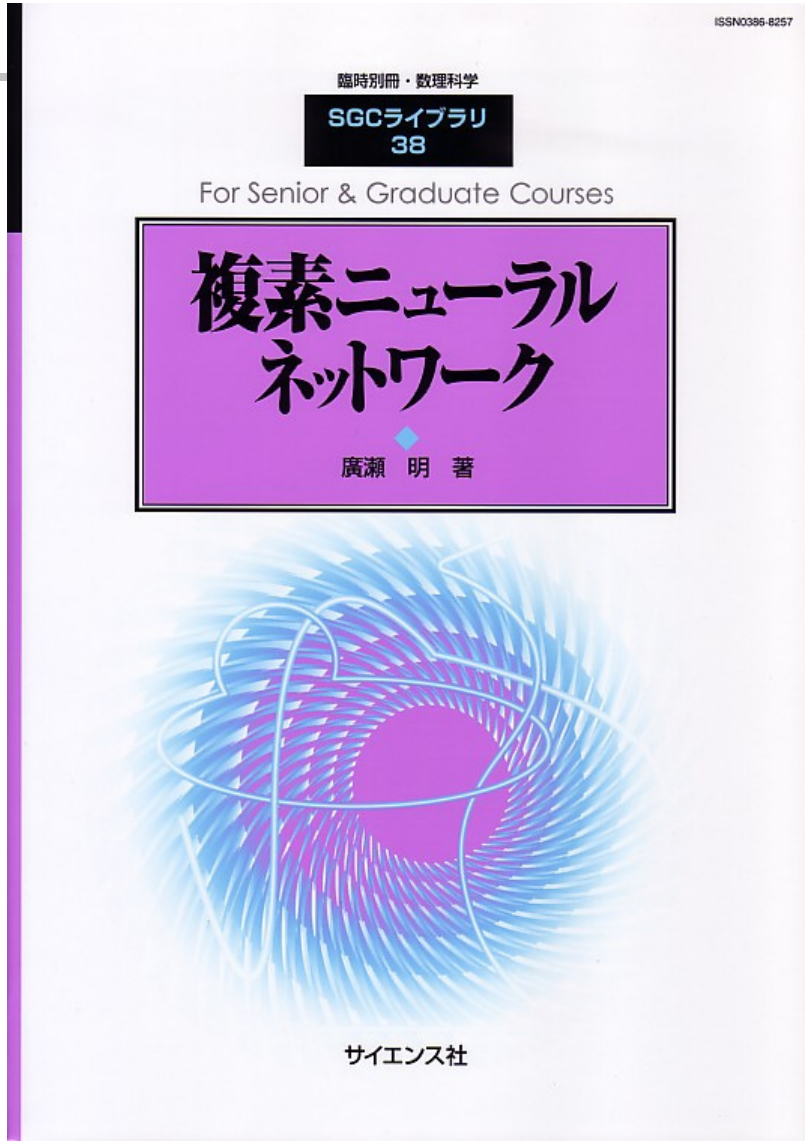
Acknowledgment

- We thank Dr. M. Shimada of EROC/JAXA for supplying the data.

「複素ニューラルネットワーク」

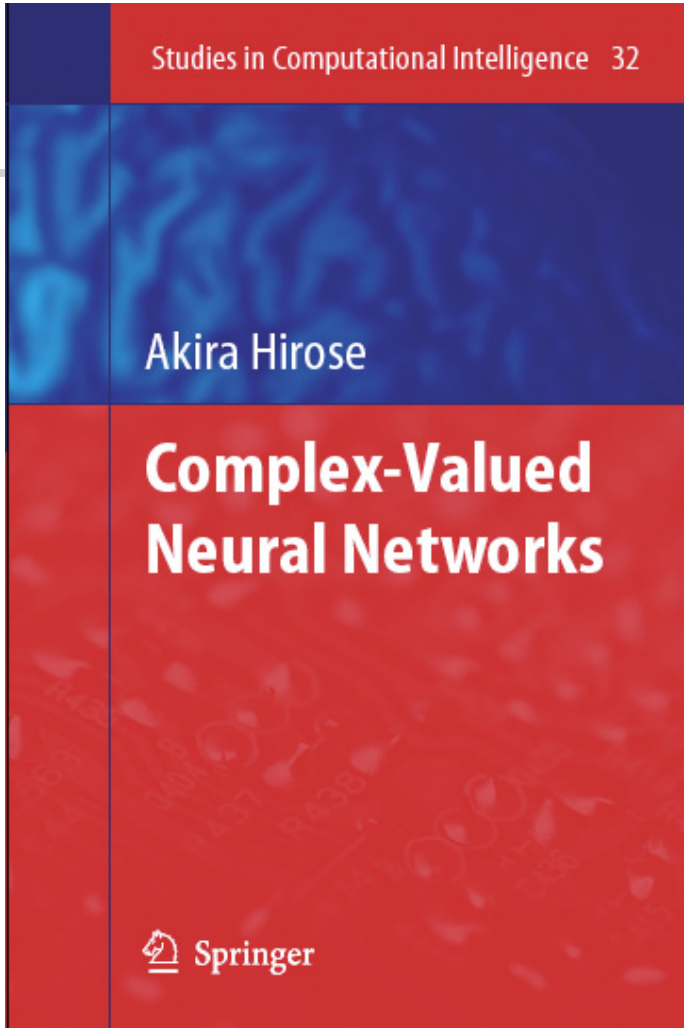
サイエンス社、
SGCライブラリ
（2005年3月刊）

InSARデータなどの
位相を含む信号の
適応的処理について
解説しています。



Complex-valued neural networks

Phase-sensitive
neural networks
= *a Super Brain*
that could be
brought up
if we had
phase-sensitive eyes



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