MULTIFREQUENCY COHERENCE TOMOGRAPHY IN FORESTS

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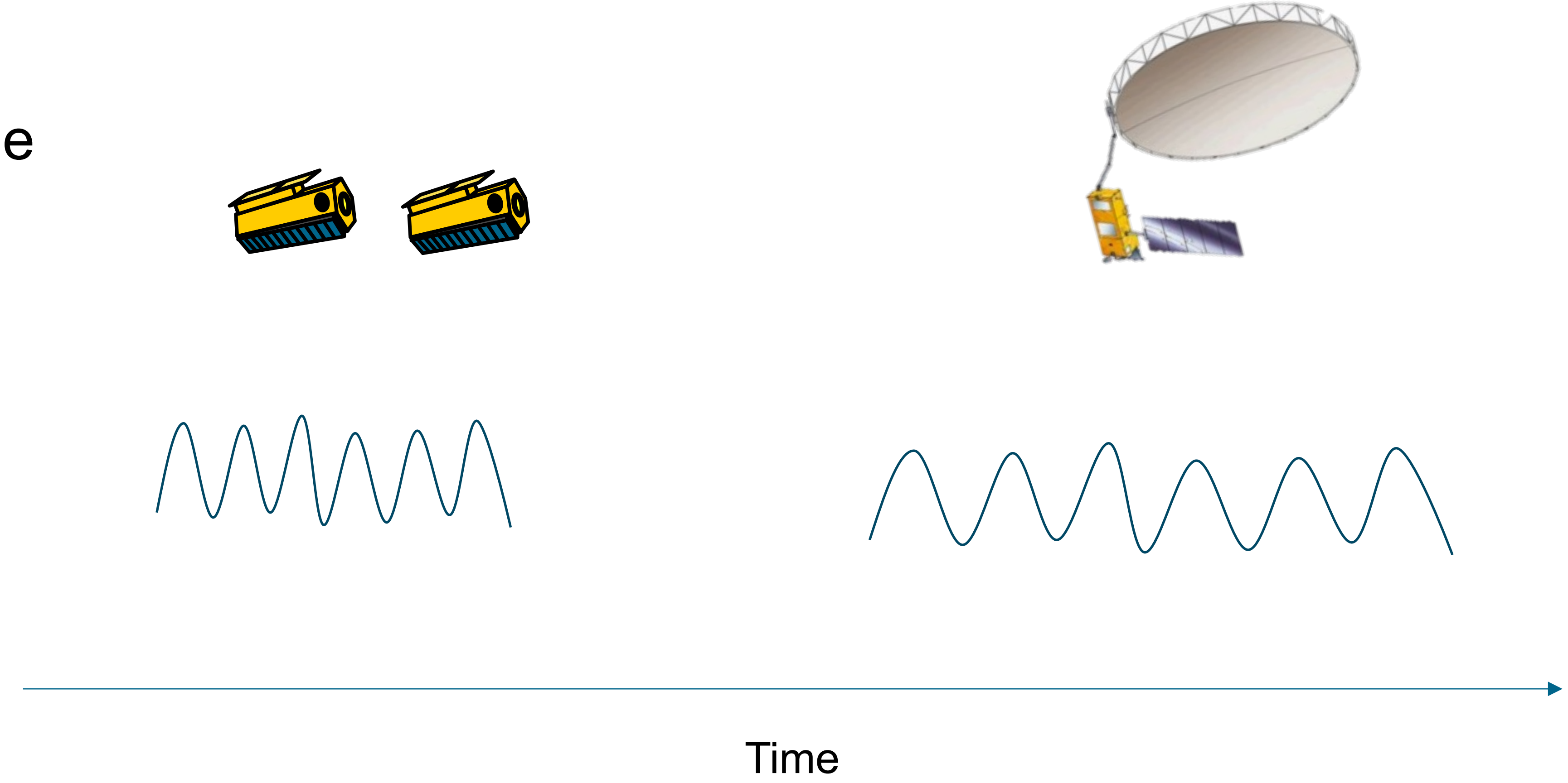
DLR

Multifrequency data

- Different sensors
- Frequencies
- Acquisition time



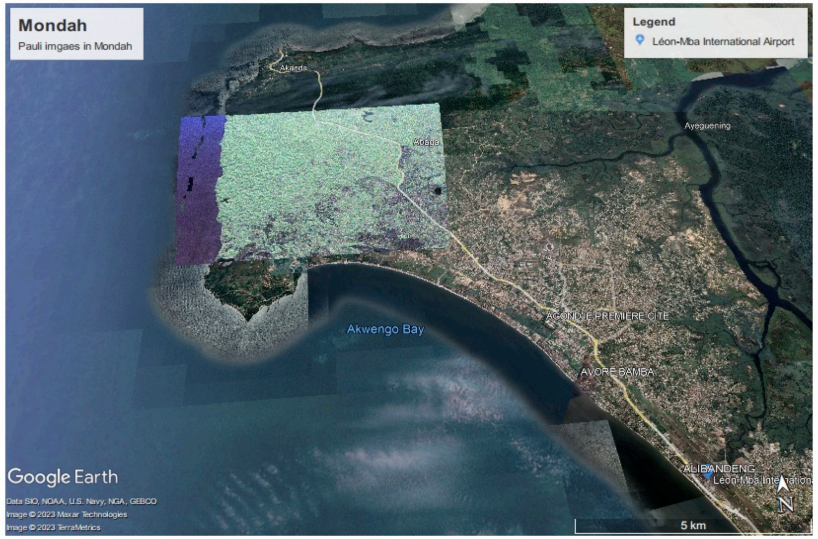
AFRISAR 2016 and GABONX 2023

Image credit: Ralf Horn

Do 228, FSAR

AFRISAR 2016 and GABONX 2023

- L-, P- bands
- 12 tomographic acquisitions



AFRISAR 2016 and GABONX 2023

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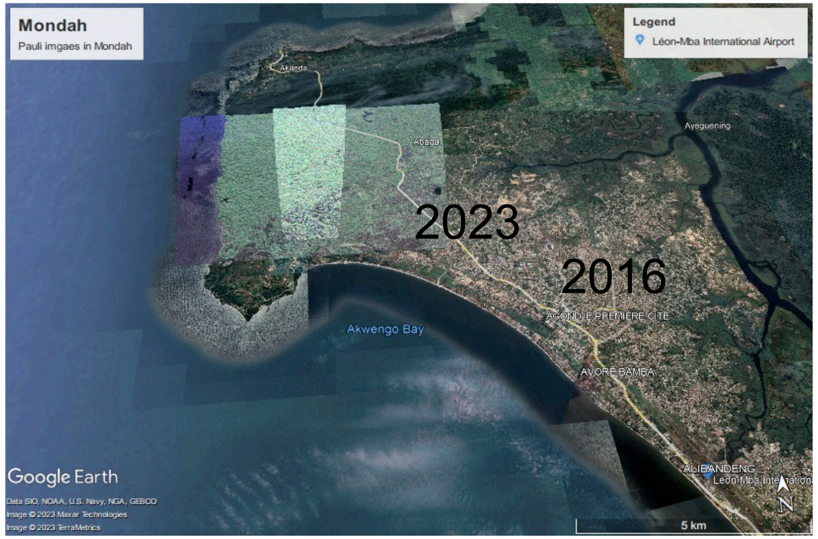
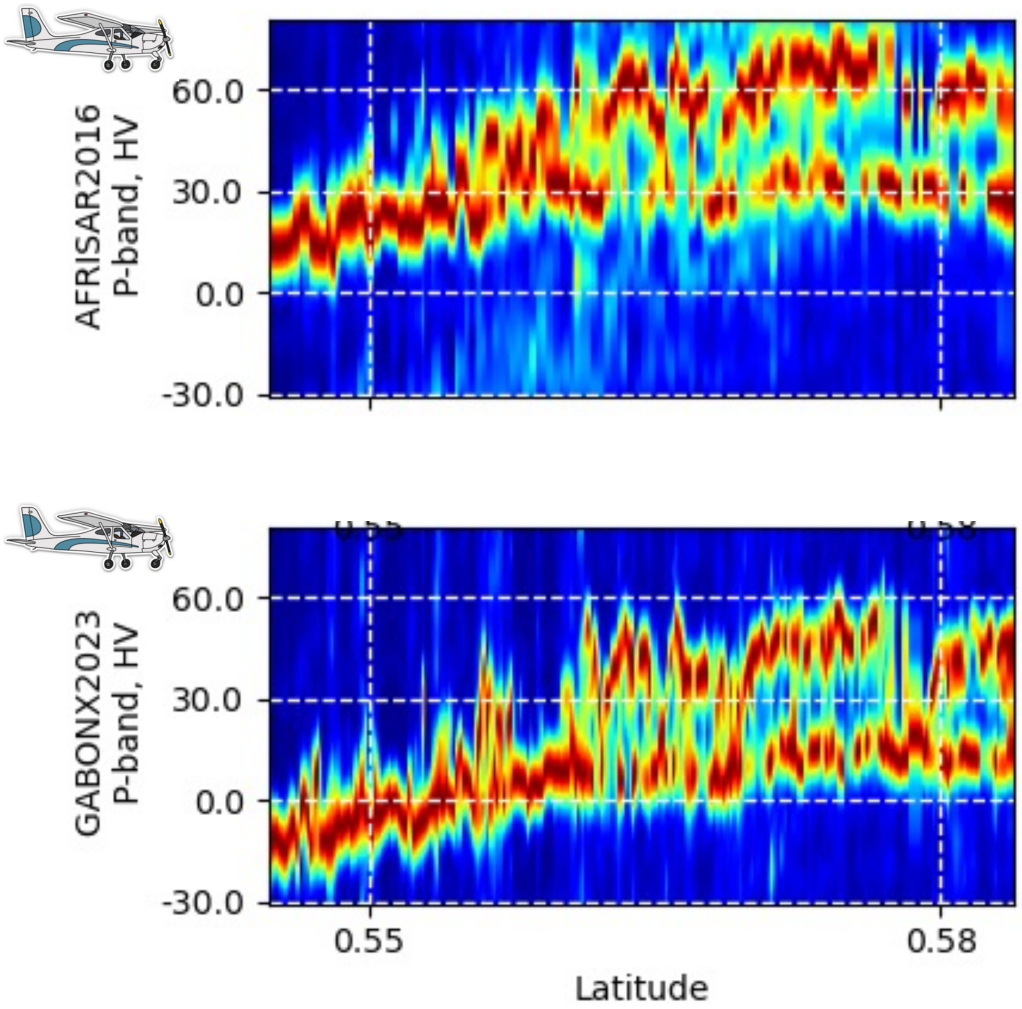
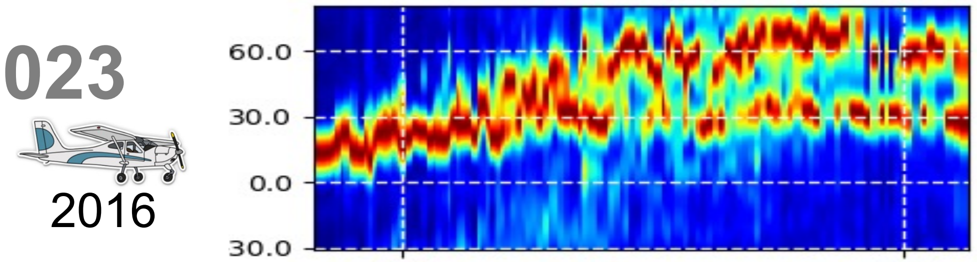


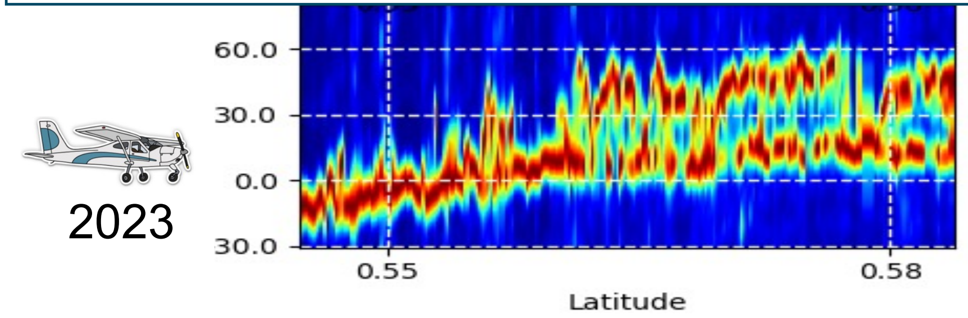
Beamforming profiles P-band, AFRISAR 2016 and GABONX2023



Detecting Change between 2016 and 2023



- Need info between 2016/2023
- TanDEM-X filling
- But no tomographic acquisitions
- Using Coherency Tomography



Coherence Tomography

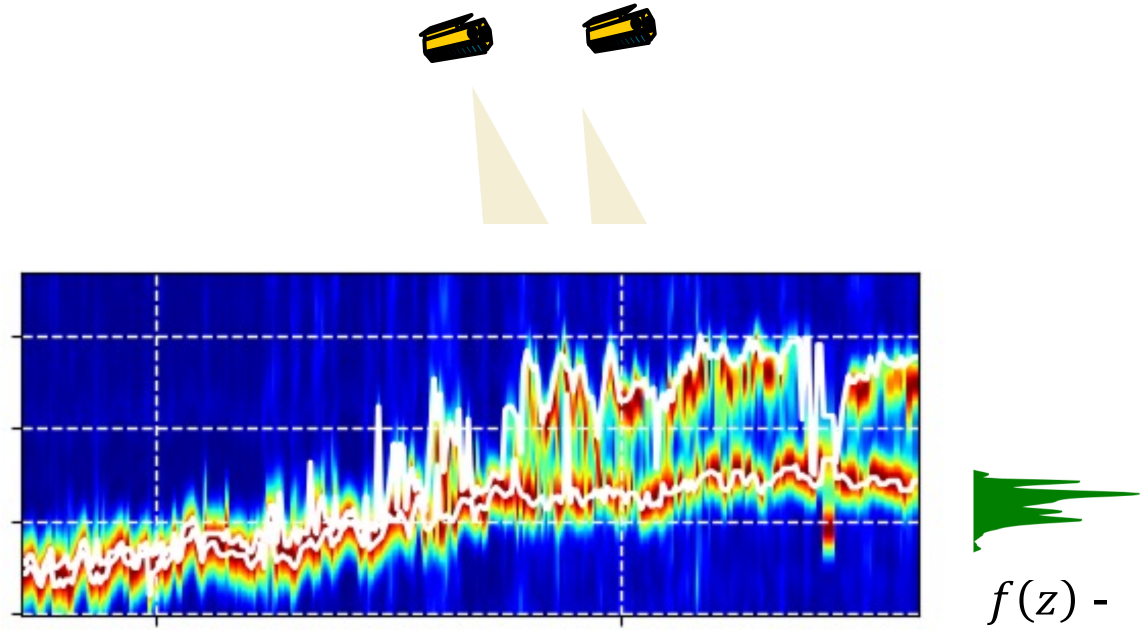
$$\gamma_v = e^{i\phi_0} \frac{\int_0^{h_v} f(z)\, e^{ik_z z} dz}{\int_0^{h_v} f(z)\, dz}$$

$$f(z) \approx f_0(z) + A_1 f_1(z) + A_2 f_2(z)$$

$$\gamma_v = e^{i\phi_0} \frac{\int_0^{h_v} [f_0(z) + A_1 f_1(z) + A_2 f_2(z)]\, e^{ik_z z} dz}{\int_0^{h_v} [f_0(z) + A_1 f_1(z) + A_2 f_2(z)]\, dz}$$

2 linear equations => find A_1 and A_2

$$A_n = \int_0^{h_v} f_n(z)\, f(z) dz$$



$f_n(z)$ - basis

$f(z)$ - vertical reflectivity

ϕ_0 and h_v can be derived from P band tomography

S. Cloude „Polarization Coherence Tomography“ , 2006

Deriving the basis for Coherence Tomography

N_P = number of reflectivity profiles

F = [||||| … |||]

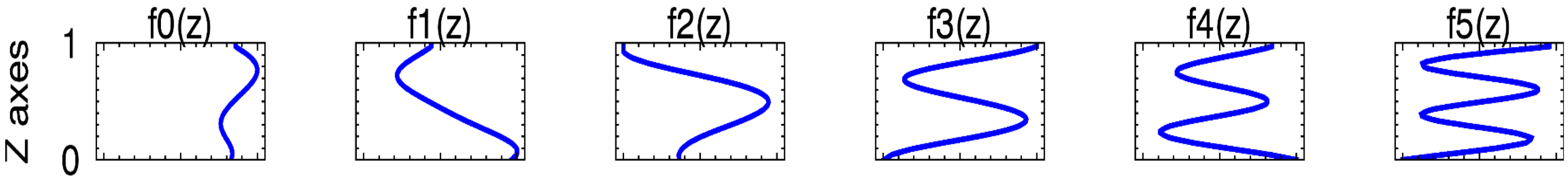
N_H = Number of height samples

Profile covariance matrix :

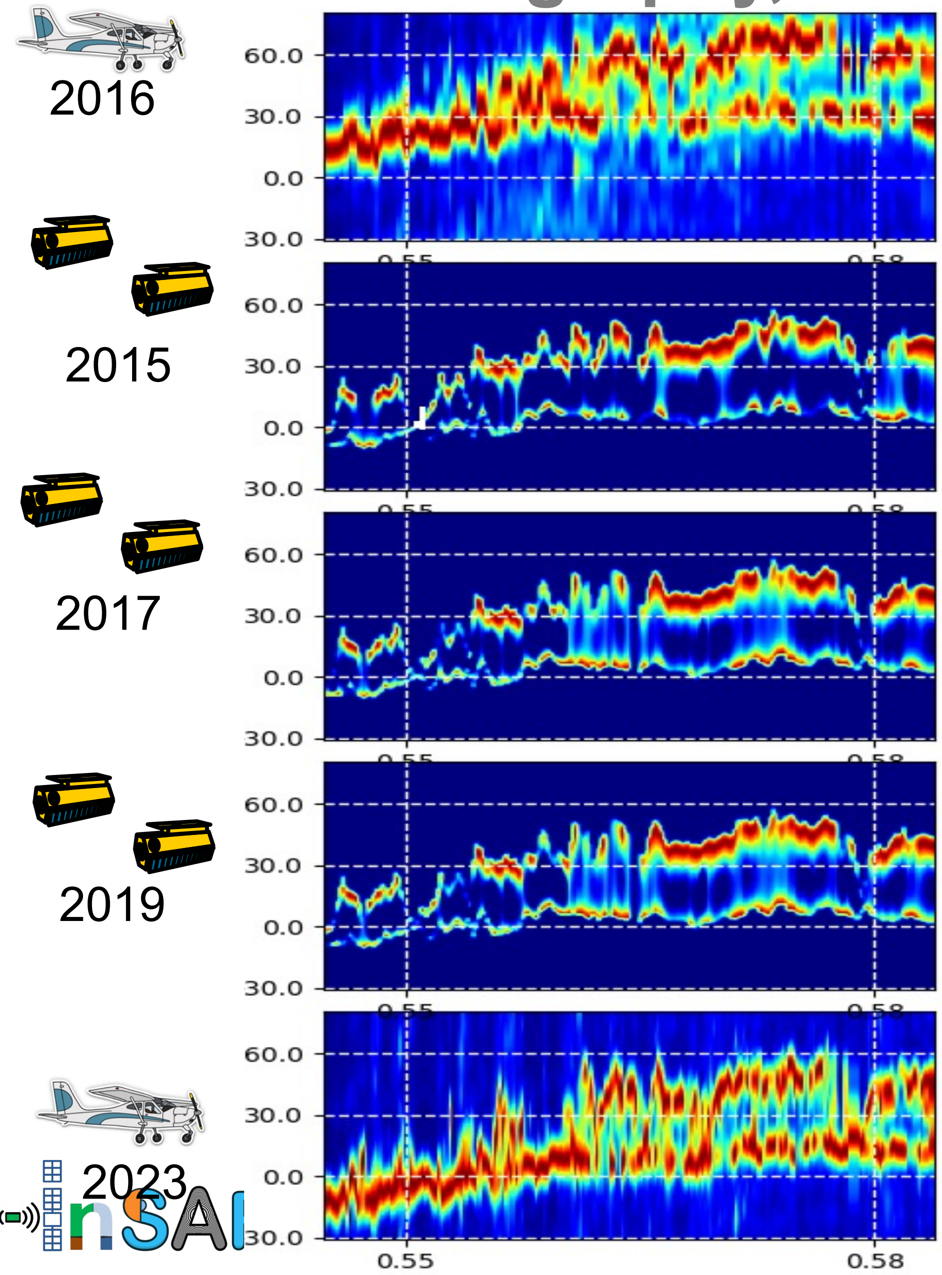
C = F F^T **=** [… c_{ij} …] N_H

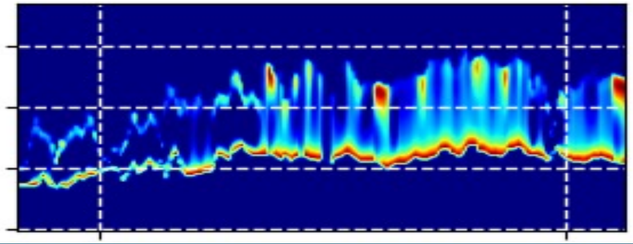
$$c_{ij} = \frac{1}{N_p} \sum_{s=1}^{N_p} F_{is} F_{js}$$

P band basis

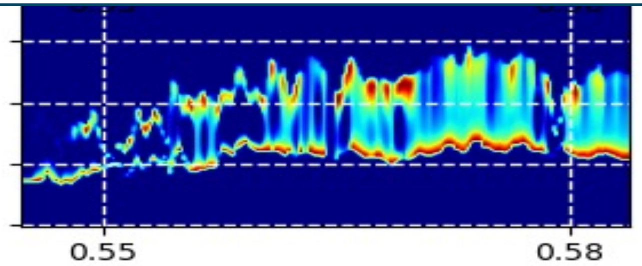


Coherence Tomography, P band

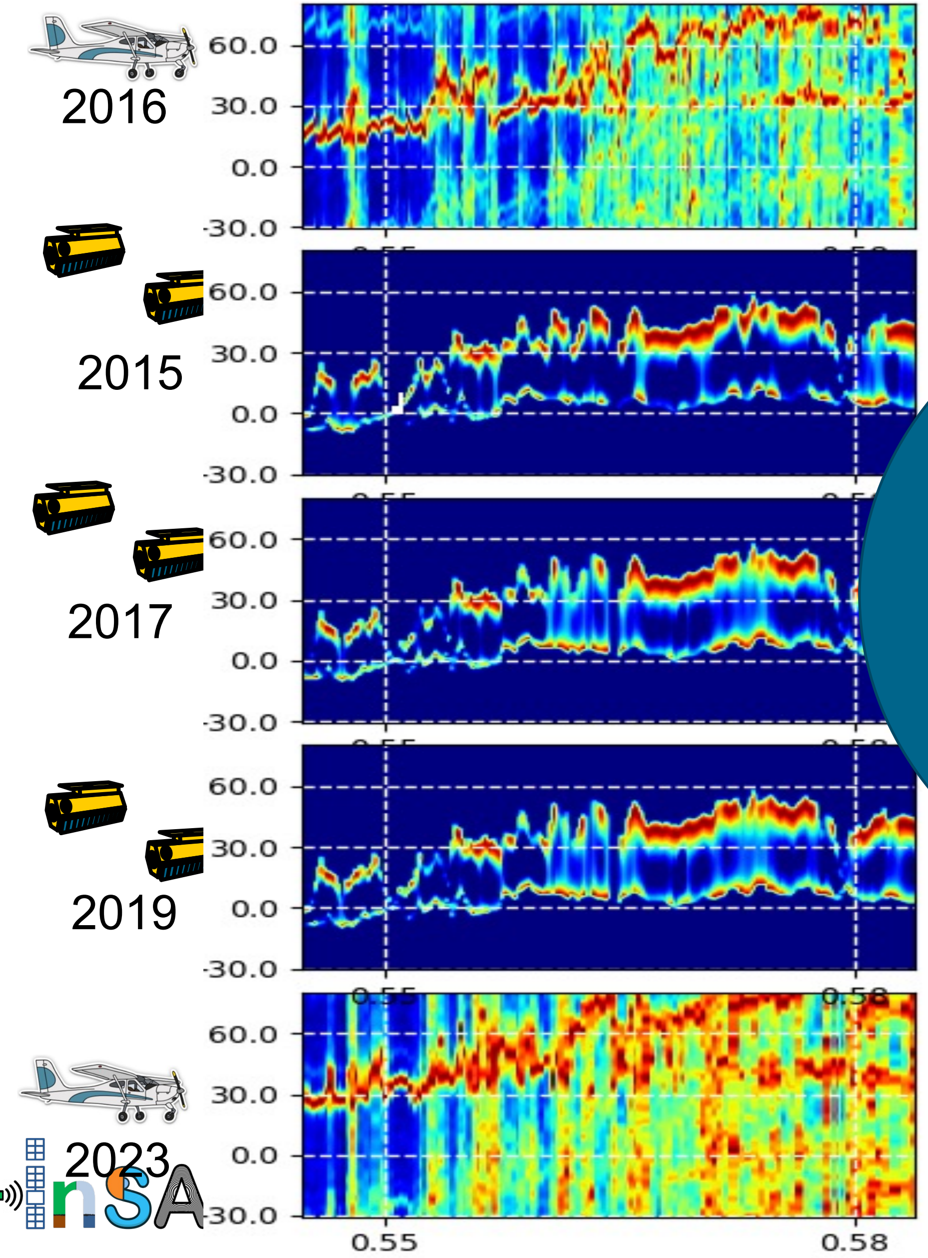


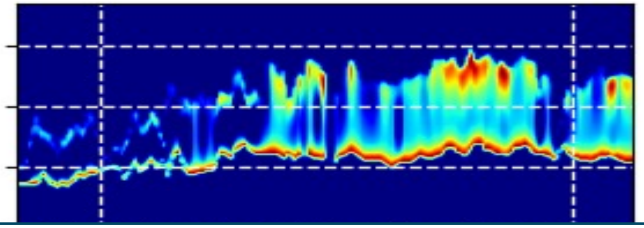


Both P- and X-band
Coherence Tomography
profiles



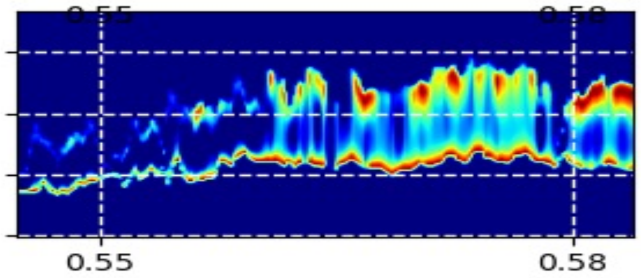
L band





Same P band basis across frequencies!

L- and X-band
erence tomography
es

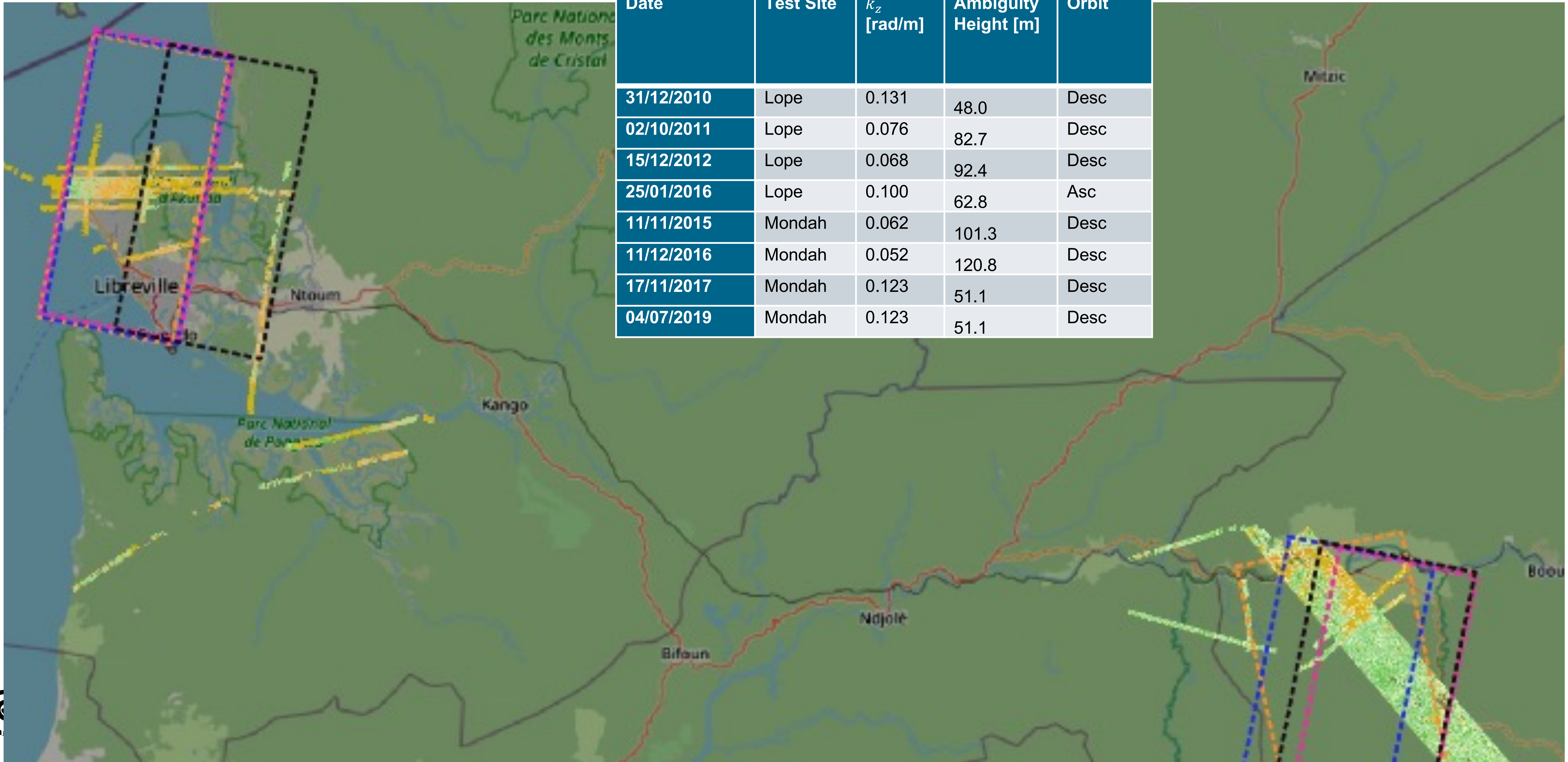


Caveats

- Method suffers from temporal decorrelations
- Ground phase errors
- Depends on the used basis
- Can produce negative profiles

Need quantitative assessment

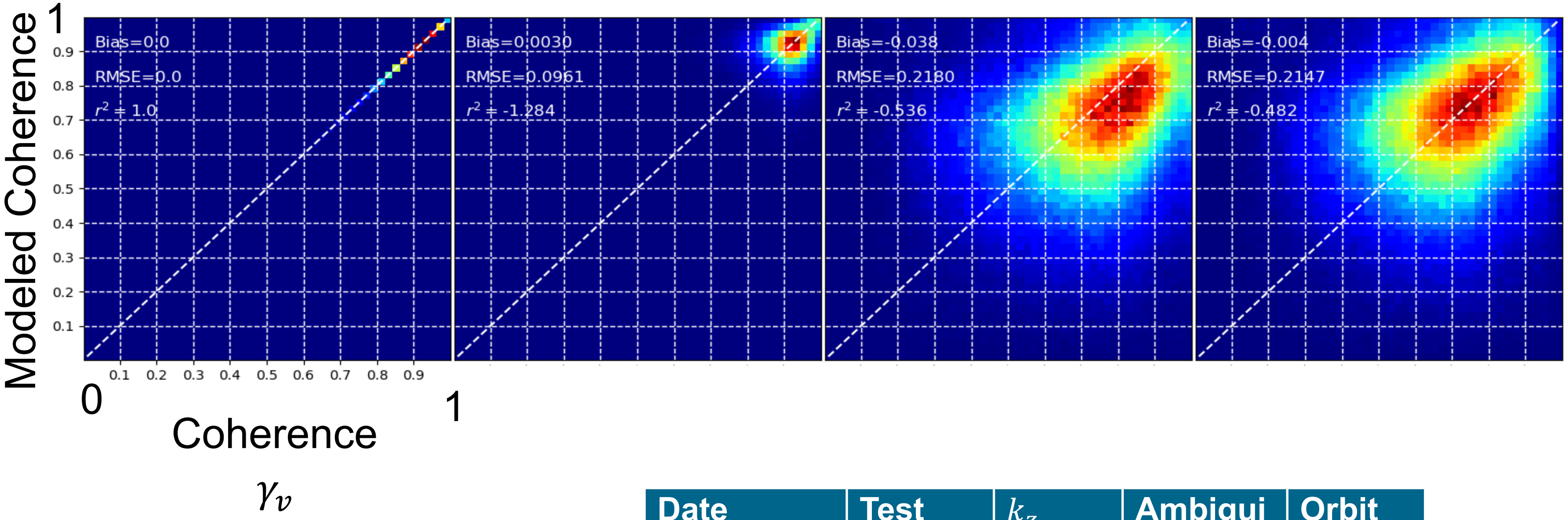
TanDEM-X acqusitions



Date	Test Site	k_z [rad/m]	Ambiguity Height [m]	Orbit
31/12/2010	Lope	0.131	48.0	Desc
02/10/2011	Lope	0.076	82.7	Desc
15/12/2012	Lope	0.068	92.4	Desc
25/01/2016	Lope	0.100	62.8	Asc
11/11/2015	Mondah	0.062	101.3	Desc
11/12/2016	Mondah	0.052	120.8	Desc
17/11/2017	Mondah	0.123	51.1	Desc
04/07/2019	Mondah	0.123	51.1	Desc

Quality assessment

$$\gamma_v^{mod}(\kappa_z) = \frac{\int_0^1 f_{PCT}(z) exp(i\kappa_z h_v^{ref} z) dz}{\int_0^1 f_{PCT}(z)\, dz}$$



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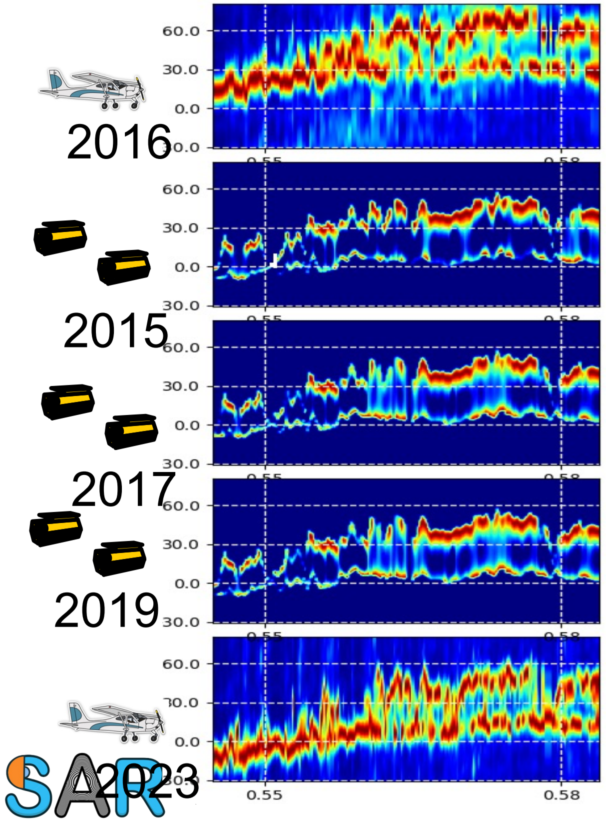
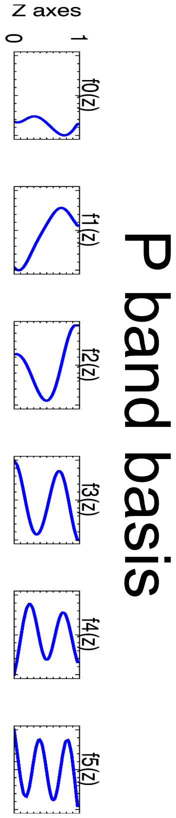
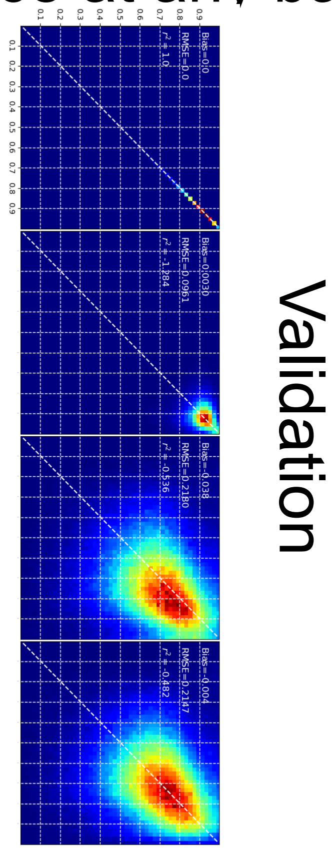
Summary

- The InSAR profiles (Coherence Tomography) can facilitate the interpretation of changes between TomoSAR profiles separated in time
- Same basis for different frequencies can be applied
- Correct CT profile should correctly model the coherence at any baseline





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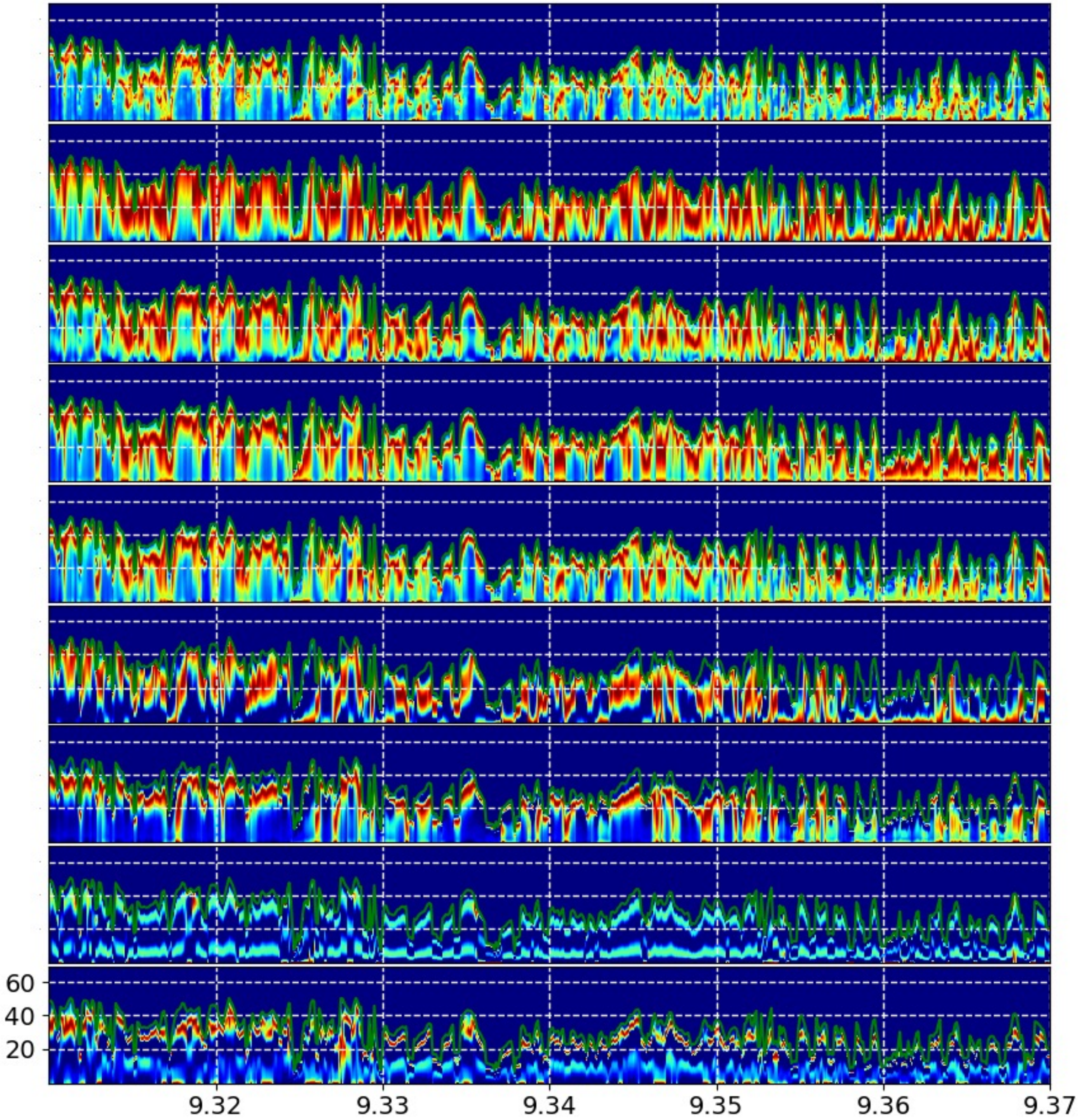
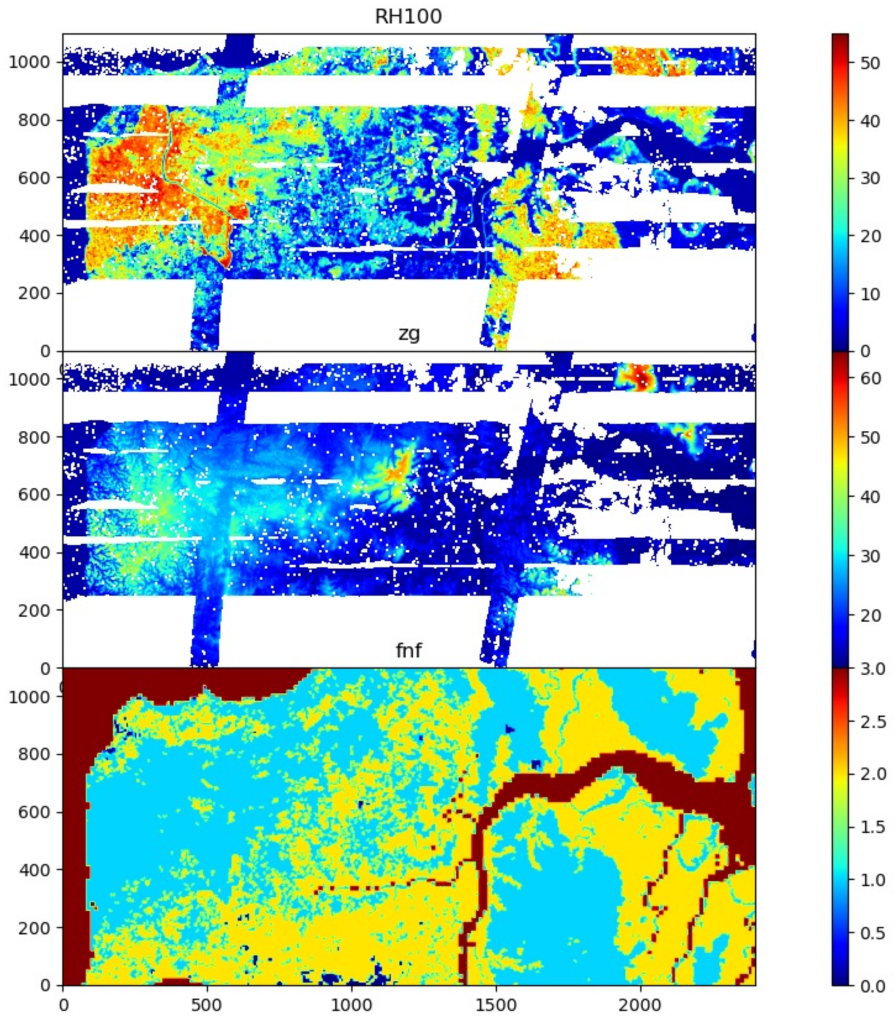
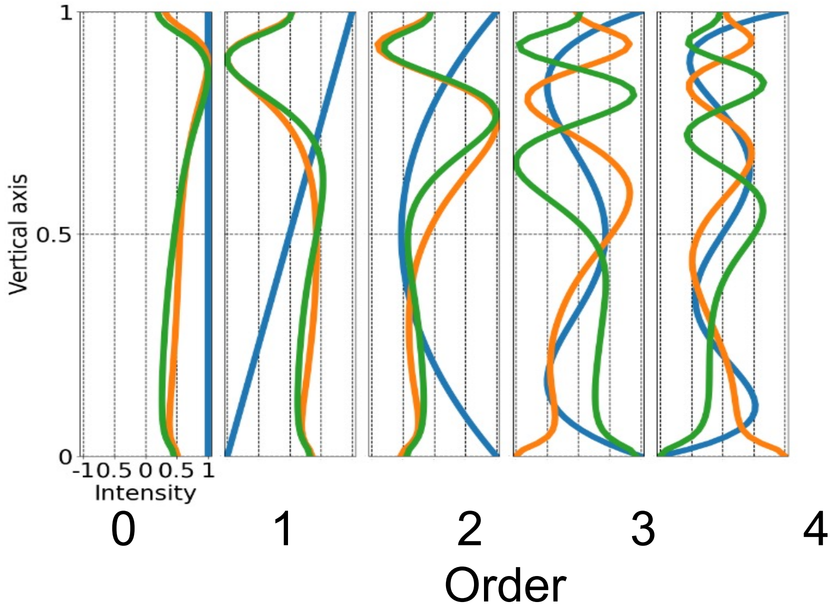
- Lidar profile
- Lidar profile, decomposed on 3 coef. of Legendre
- Lidar profile, decomposed on 3 coef. of Eigenbasis
- Lidar profile, decomposed on 5 coef. of Legendre
- Lidar profile, decomposed on 5 coef. of Eigenbasis
- Single baseline, X-band on Legendre
- Single baseline, X-band on Eigenbasis
- Dual baseline, X-band on Legendre
- Dual baseline, X-band on Eigenbasis



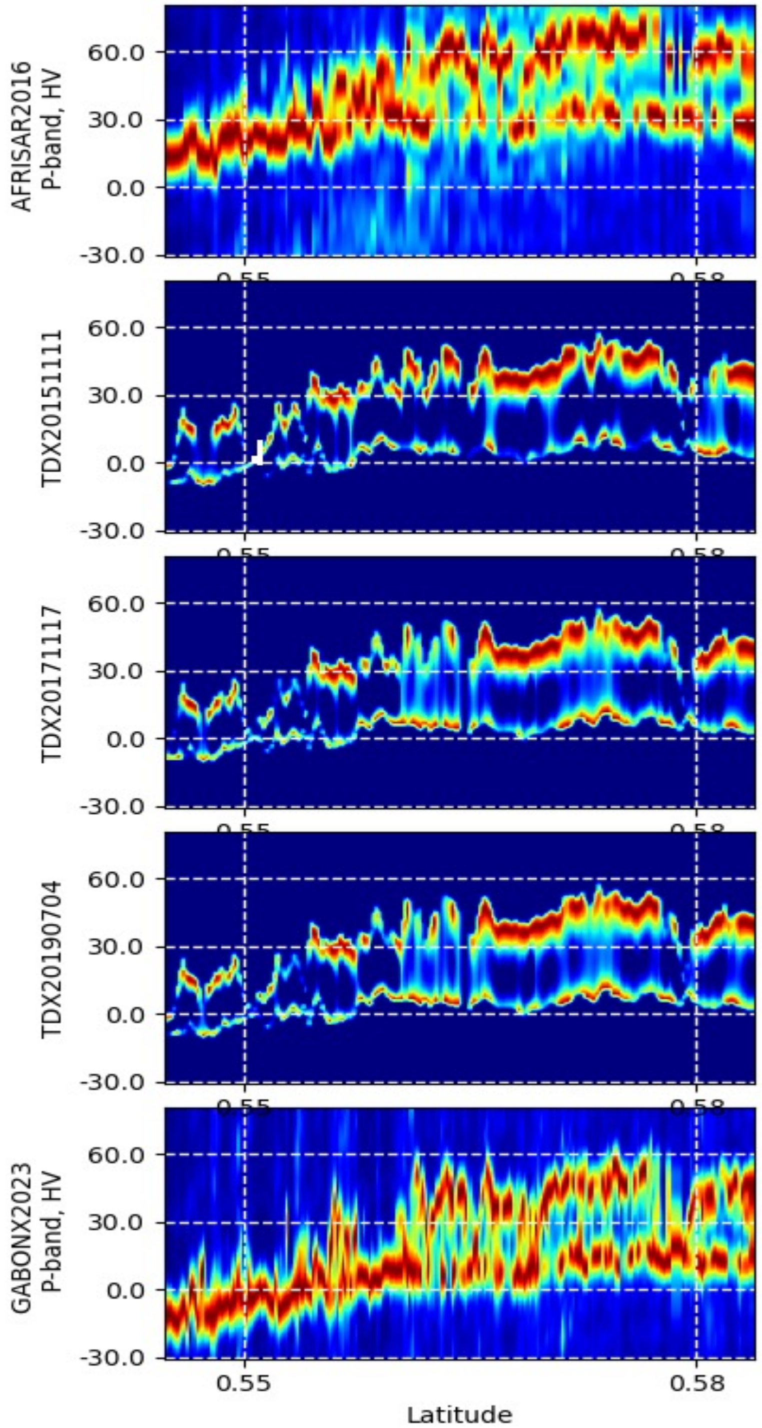
Lidar data



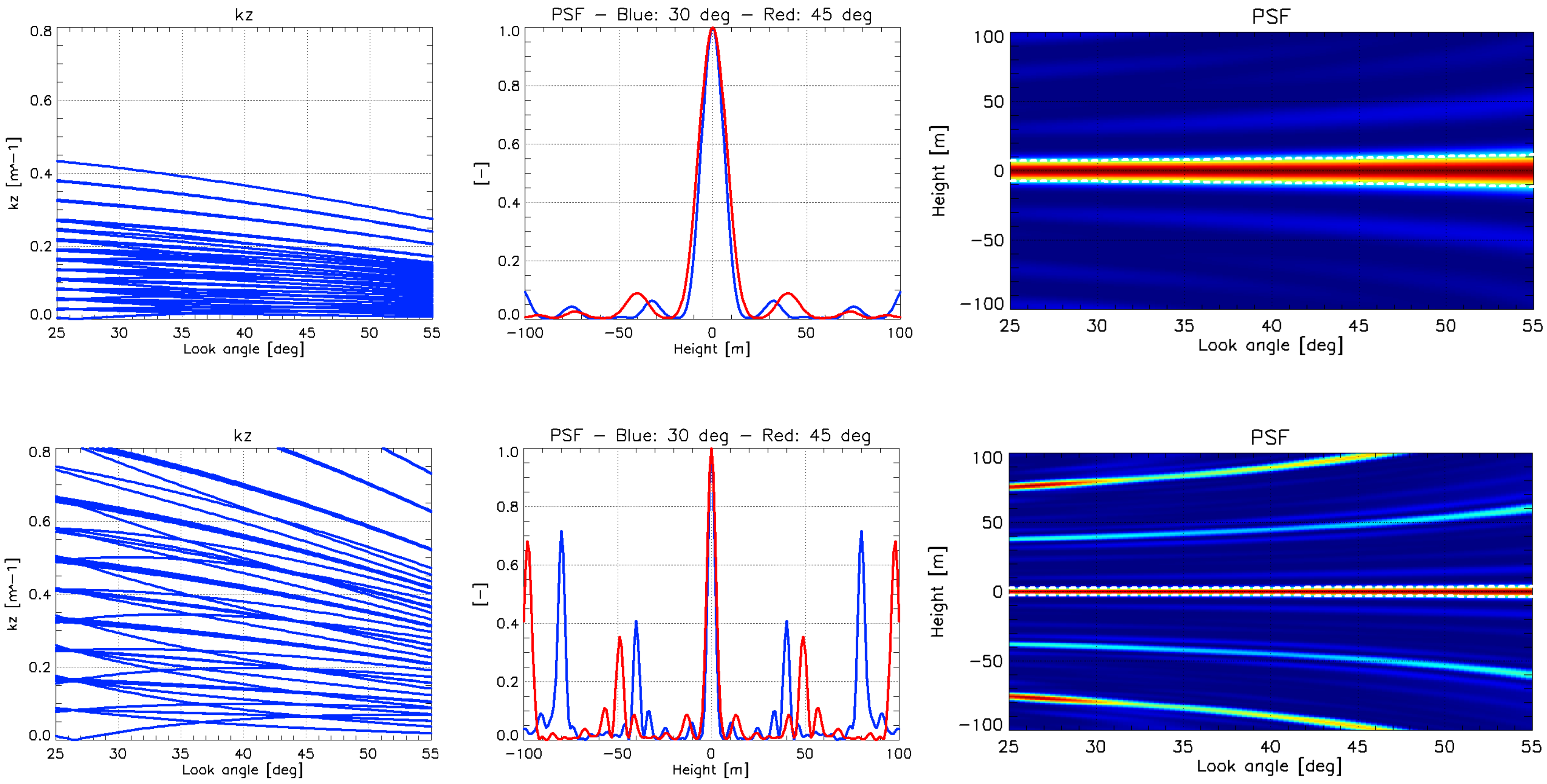


$f_n(z)$ - basis

Profile propagation across frequencies and time



Tomographic baseline distribution



General form of linear system

$$FA = B$$

$$F = \begin{bmatrix} \dots & \dots & \dots \\ \dots & Im\{F_n(k_z^k h_v) - \gamma_v^k F_n'\} & \dots \\ \dots & Re\{F_n(k_z^k h_v) - \gamma_v^k F_n'\} & \dots \\ \dots & \dots & \dots \end{bmatrix}$$

$$B = \begin{bmatrix} \dots \\ Im\{\gamma_v^k F_0' - F_0(k_z^k h_v)\} \\ Re\{\gamma_v^k F_0' - F_0(k_z^k h_v)\} \\ \dots \end{bmatrix}$$

$$A = \begin{bmatrix} \dots \\ A_n \\ \dots \end{bmatrix}$$

$$F \in \mathbb{R}(2K \times N)$$
$$B \in \mathbb{R}(2K)$$
$$A \in \mathbb{R}(N)$$

$$\gamma_v^k = \frac{\int_0^1 [f_0(z) + \cdots A_n f_n(z) + \cdots]\, e^{ik_z^k h_v z} dz}{\int_0^1 [f_0(z) + \cdots A_n f_n(z) + \dots]\, dz}$$

K – number of baselines k_z^k with γ_v^k
N - number of basis coefficients

$$F_n(k_z^k h_v) = \int_0^1 e^{i\kappa_z h_v z} f_n(z) dz$$

$$F_n' = \int_0^1 f_n(z) dz$$

$$A = F^{-1} B$$

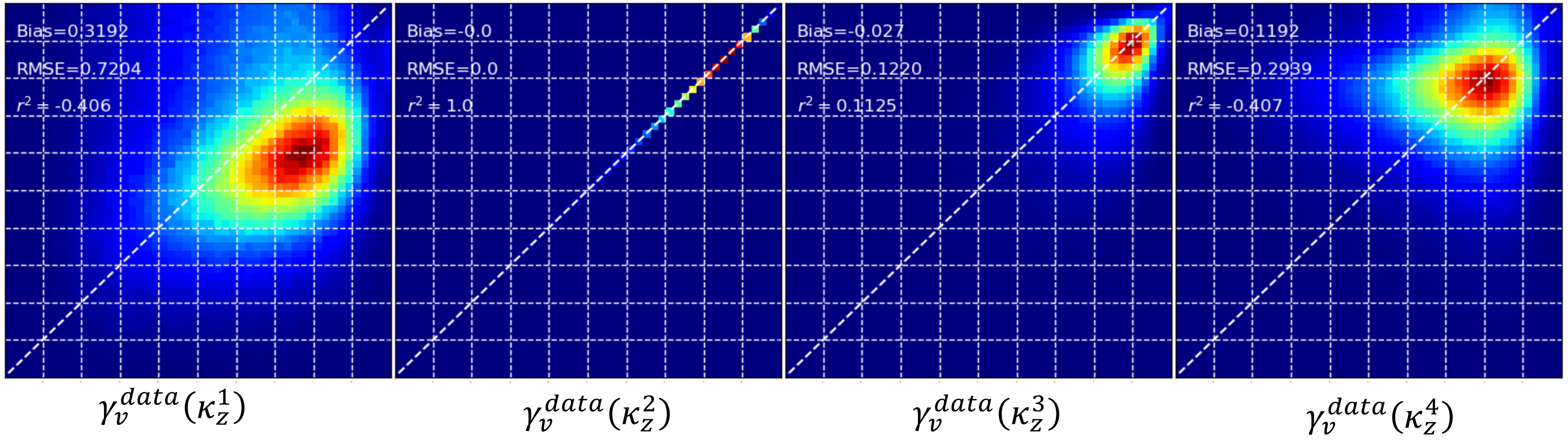
SVD solution:

$$F = U \Sigma V^T$$
$$A = V^T \Sigma U \quad B$$

Single baseline, Lope

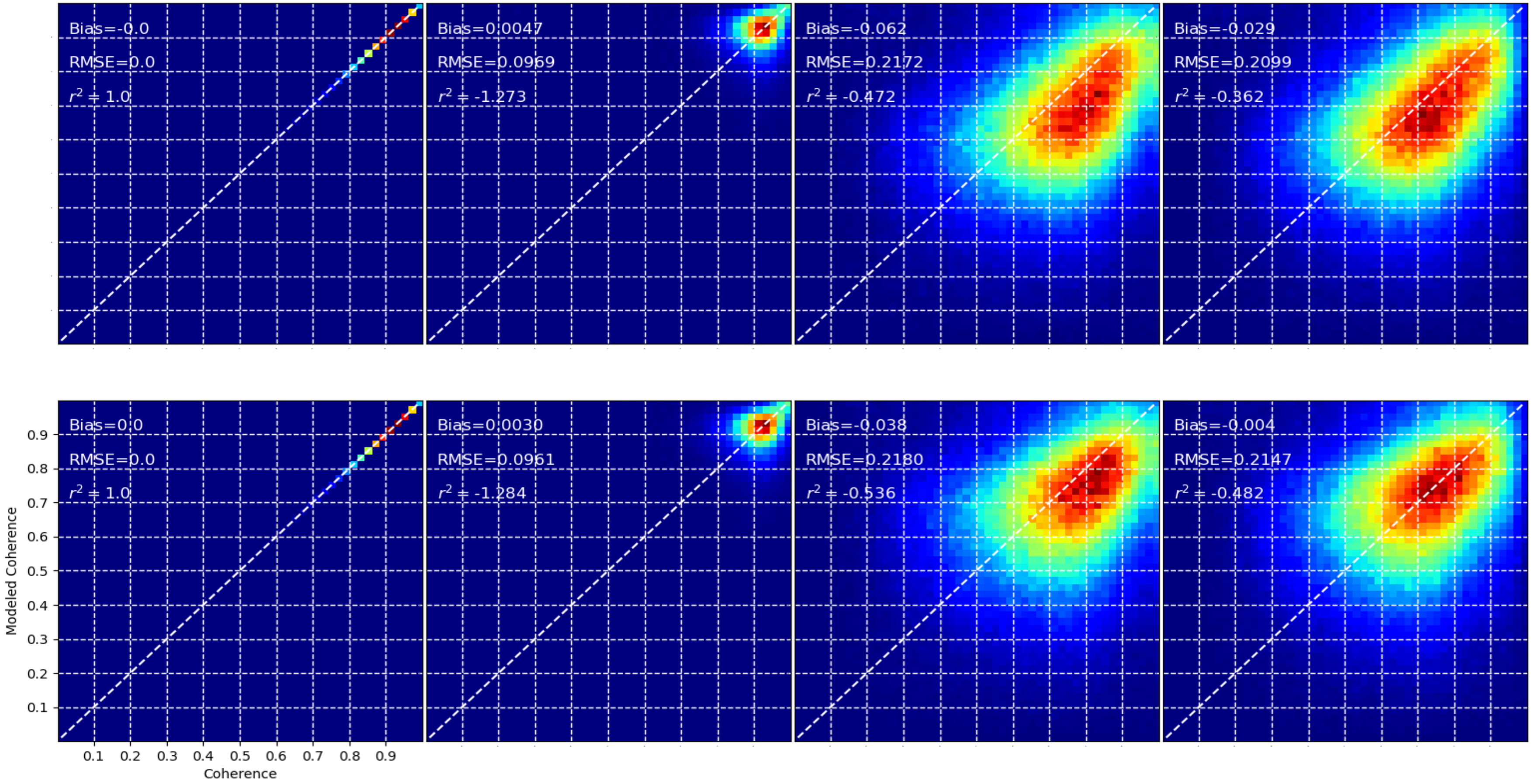
- Legendre

$$\gamma_v^{mod}(\kappa_z) = \frac{\int_0^1 f_{PCT}(z) exp(i\kappa_Z h_v^{ref} z) dz}{\int_0^1 f_{PCT}(z)\, dz}$$



Single baseline - Mondah

- Legendre
- Eigenbasis



Dual baseli

- Legendre
- Eigenbasis