22. EVGA Meeting, Azores, Portugal

Augmenting the stochastic model in VLBI data analysis by correlations from atmospheric turbulence models

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Motivation

[www.apod.nasa.gov, last access on 12 May 2015]

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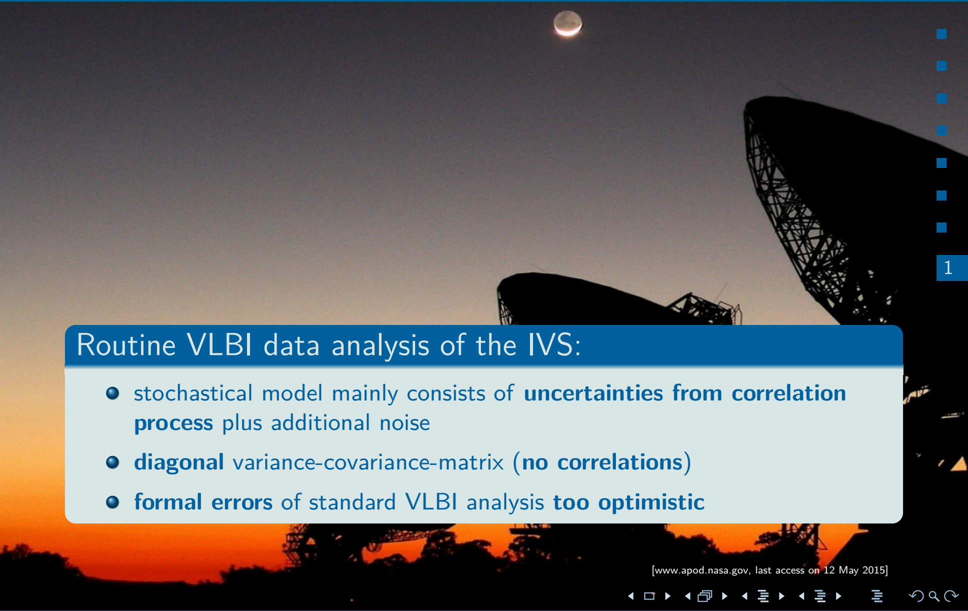


Routine VLBI data analysis of the IVS:

- stochastical model mainly consists of **uncertainties from correlation process** plus additional noise
- **diagonal** variance-covariance-matrix (**no correlations**)
- **formal errors** of standard VLBI analysis **too optimistic**

[www.apod.nasa.gov, last access on 12 May 2015]

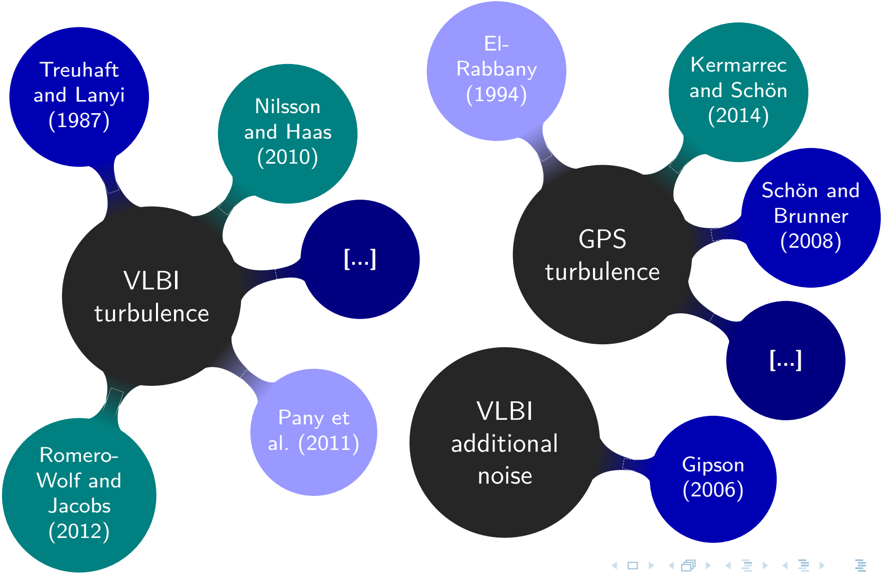
Motivation

this study:

- **augmenting the stochastic model by correlations due to dynamic processes in the atmosphere**
- concerning small-scale fluctuations (**stochastic description**)
- **fully populated** variance-covariance matrix based on turbulence modeling

[www.telegraph.co.uk; www.apod.nasa.gov, last access on 12 May 2015]

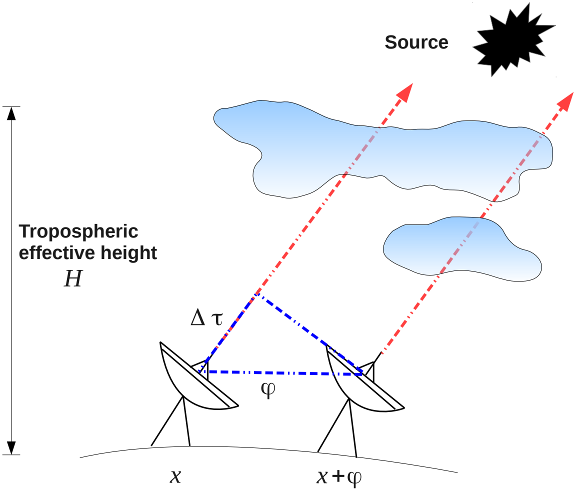
state of research



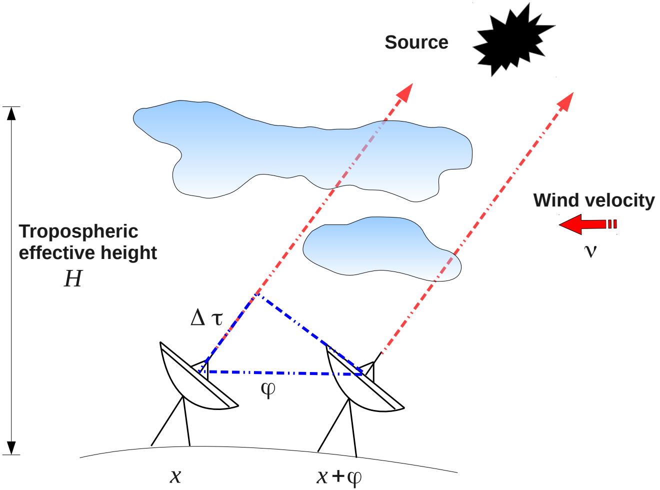
ciritcal discussion

- **neither anisotropy nor inhomogeneity is taken into account** (except for Brunner and Schön, 2008)
- considering anisotropy (Brunner and Schön, 2008) some **numerical instabilities** due to the double integral occour
- most models based on a **double integral** which can only be solved numerically, necessitating a **large computational effort**

Kolmogorov Turbulence Theory



Kolmogorov Turbulence Theory



Refractivity (co-) variance expression

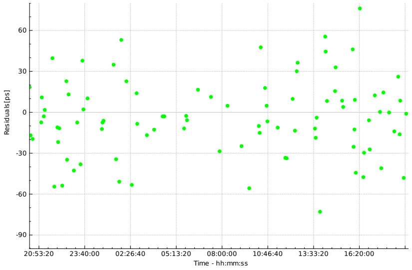
$$\boldsymbol{C}(t,t) = 0.782 \frac{k^2 H C_n^2 c \kappa_0^{-\frac{3}{5}}}{\sin^2(\epsilon_i(t))}$$

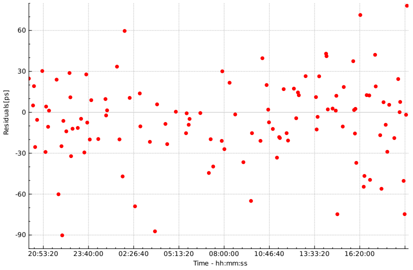
$$\boldsymbol{C}(t,t+\tau) = 0.7772 \frac{k^2 H C_n^2 c \kappa_0^{-\frac{3}{5}}}{\sin(\epsilon_i(t)) \sin(\epsilon_j(t+\tau))} \times \left(\frac{\kappa_0 u \tau}{a}\right)^{\frac{5}{6}} K_{\frac{5}{6}} \left(\frac{\kappa_0 u \tau}{a}\right)$$

Variable	Description	Variable	Description
$\boldsymbol{C}(t,t+\tau)$	**variance-covariance matrix**	ϵ^i, ϵ^i	elevation angle for stations i and j
C_n^2	Structure constant	K	modified Bessel function of second kind
H	Integration height	$\frac{1}{\alpha}$	Matern correlation time
k	electromagentic wavenumber	c	stretched parameters for the
κ	wavenumber vector		outer scale length

[Kermarrec and Schön, J Geod 2014]

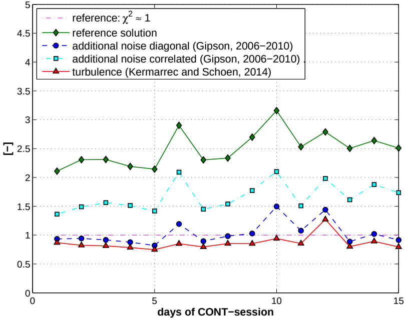
Residuals vs outliers





solution type	KOKEE-NYALES20	ONSALA60
Reference solution (const. additional noise)	31 (≈ 24.8%)	240 (≈ 21.3%)
additional noise, diagonal (Gipson, 2006-2010)	9 (≈ 7.2%)	184 (≈ 16.3%)
turbulence model (Kermarrec and Schön, 2014)	2 (≈ 1.6%)	67 (≈ 6.0%)
overall:	125	1127

χ^2

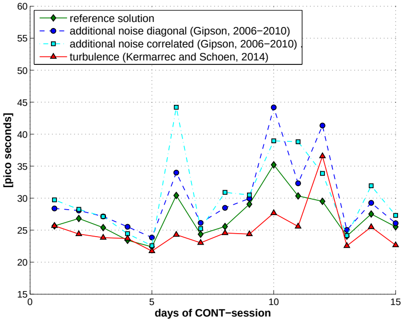


solution type	χ^2 [-]
Reference solution (const. additional noise)	2.50
additional noise, diagonal (Gipson, 2006-2010)	1.13
additional noise, correlated (Gipson, 2006-2010)	1.67
turbulence model (Kermarrec and Schön, 2014)	0.87

CONT02 session: 12.-26.08.2002

WRMS of post fit residuals

WRMS

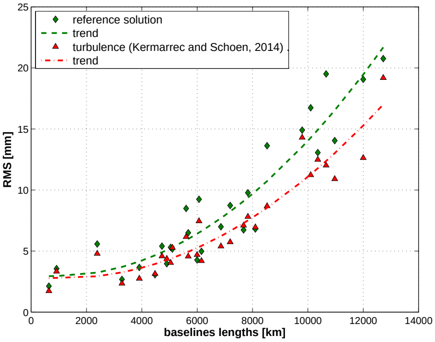


solution type	WRMS [ps]
Reference solution (const. additional noise)	25.67
additional noise, diagonal (Gipson, 2006-2010)	28.40
additional noise, correlated (Gipson, 2006-2010)	29.73
turbulence model (Kermarrec and Schön, 2014)	24.38

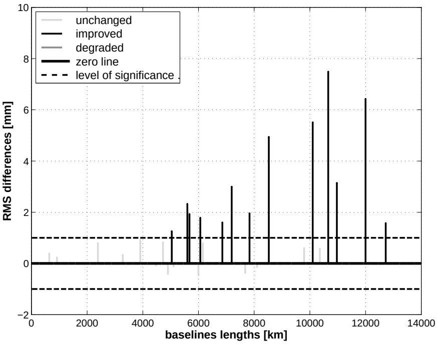
CONT02 session: 12.-26.08.2002

Baseline lengths repeatabilities

baseline repeatabilites

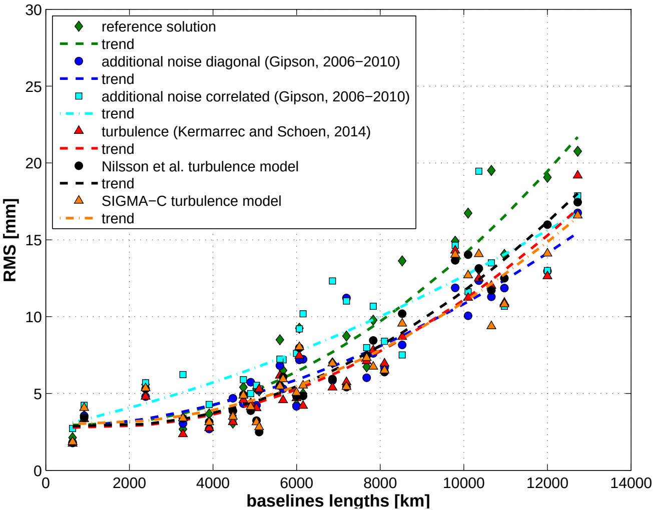


Differences



Improvement: 46.4%, Unchanged: 53.6%, Degradation: 0.0%

Baseline lengths repeatabilities



CONT02 session: 12.-26.08.2002

Conclusion

- stochastic model augmented by correlations due to atmospheric turbulence
- $\chi^2 \approx 1$ for the solutions with additional noise and correlations due to turbulent effects (slightly to small)
- WRMS and RMS decrease slightly
- **improvement of baseline lengths repeatabilites** (≈ 50 % for CONT02 sessions)

Conclusion

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- WRMS and RMS decrease slightly
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further work

- further investigations of small baseline lengths
- parameterization of wind speed, structure constant, integration height, maximal baseline lengths for spatial correlation ...
- other error sources should possibly be used in the stochastic model

Thank you
for your attention!

[www.apod.nasa.gov, last access on 12 May 2015]

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