Some aspects of inversions of radio occultation signals

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2nd IROWG Workshop, Estes Park, CO, Mar.28 - Apr.3 2012

1. Lower troposphere inversions

- calculation of wave optics transform & truncation

- use of L1CA and L2C signals

2. Stratosphere inversions

- reduction of noise in BA caused by ionospheric scintillation

These approaches currently are under testing
(not implemented in the processing yet)

Wave Optics transform of RO signal (Phase Matching [Jensen et al., 2004]**)**

$u = A\exp(i\Phi)$ $\qquad$ $v(a) = B(a)\exp[i\Psi(a)] = \int A(\theta)\exp[i\Phi(\theta) - ikS(a,\theta)]d\theta$

$$S(a,\theta) = a\theta + \sqrt{r_1^2(\theta) - a^2} + \sqrt{r_2^2(\theta) - a^2} - a[\arccos(a/r_1(\theta)) + \arccos(a/r_2(\theta))]$$

$\alpha(a) = k^{-1}d\Psi/da$ - bending angle

Phase model: frequency matches the frequency of a sub-signal with given impact parameter; main input in the integral is around the stationary point; location of the stat. point = arrival time of the sub-signal with that imp. par.

Assumption: spherical symmetry; only one ray with given impact parameter; for each impact parameter only one stationary point; transformed signal is quasi-monochromatic

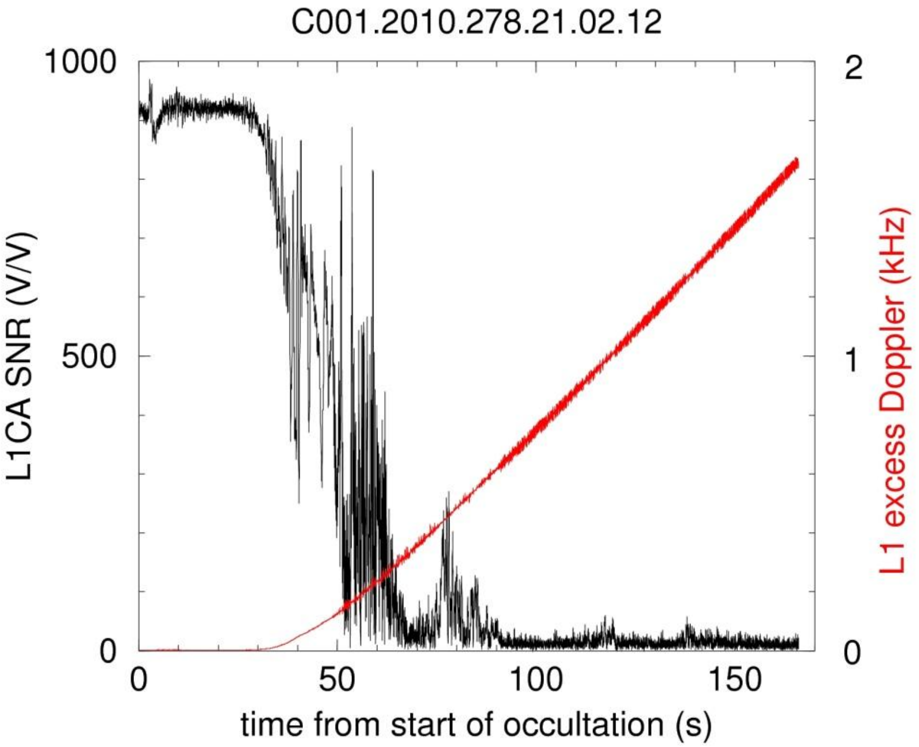
Reduction to FFT: CT, FSI, CT2 (requires additional transf./approximations)

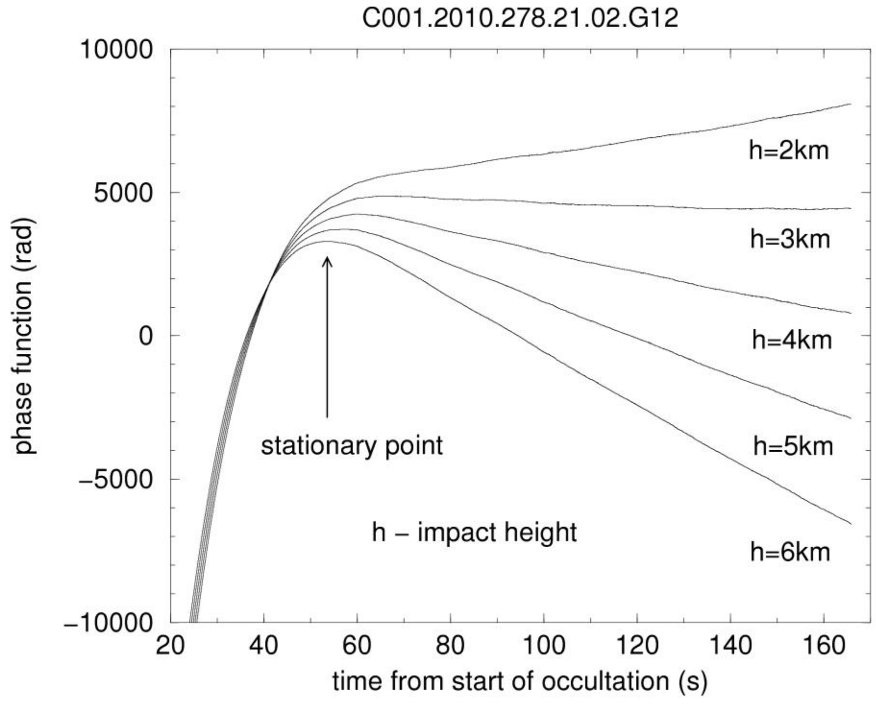
Direct calculation of WO transform allows analysis of the phase function

More computationally expensive than FFT, doable for LT, can be optimized

Wave optics transform (cont.), an example: tropical occultation

Stationary point:
- exists for impact heights > 3 km,
- not well pronounced around ~ 3 km,
- disappears for impact heights < 3 km

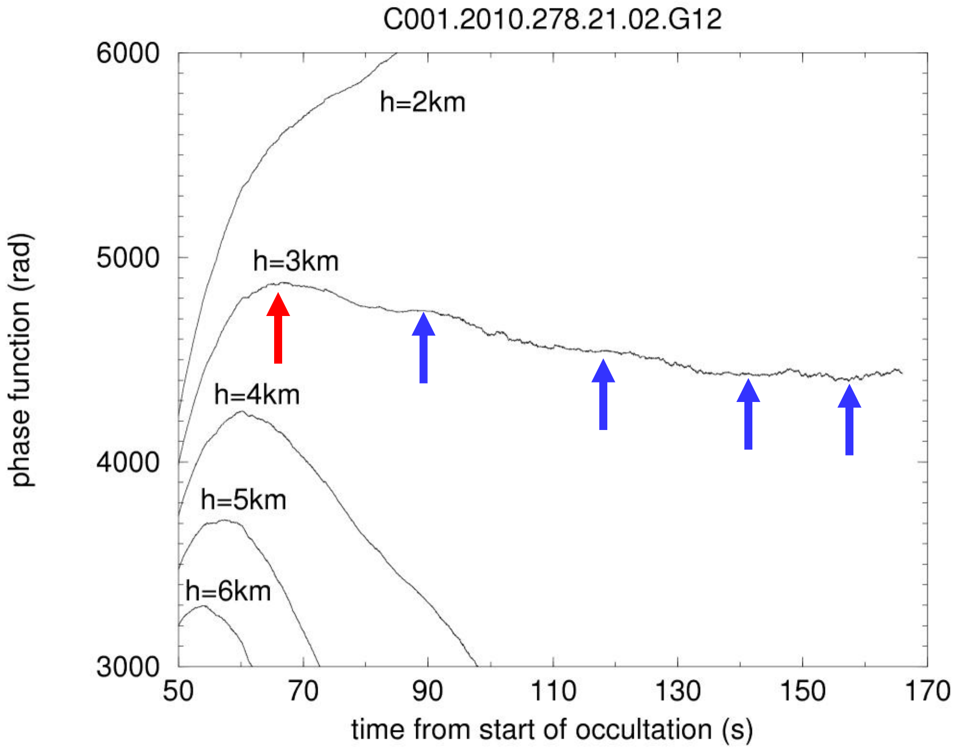


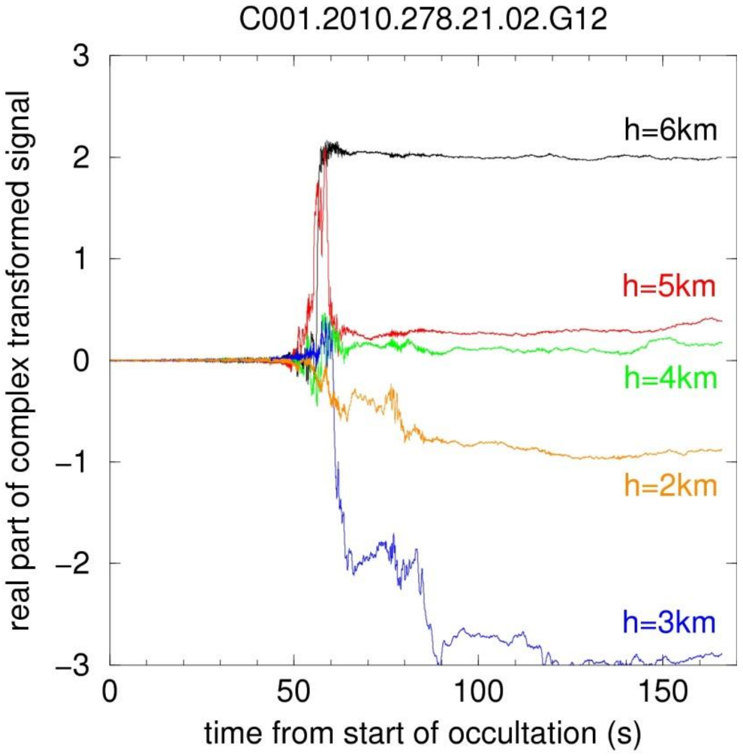


Wave optics transform (cont.)

Analysis shows:

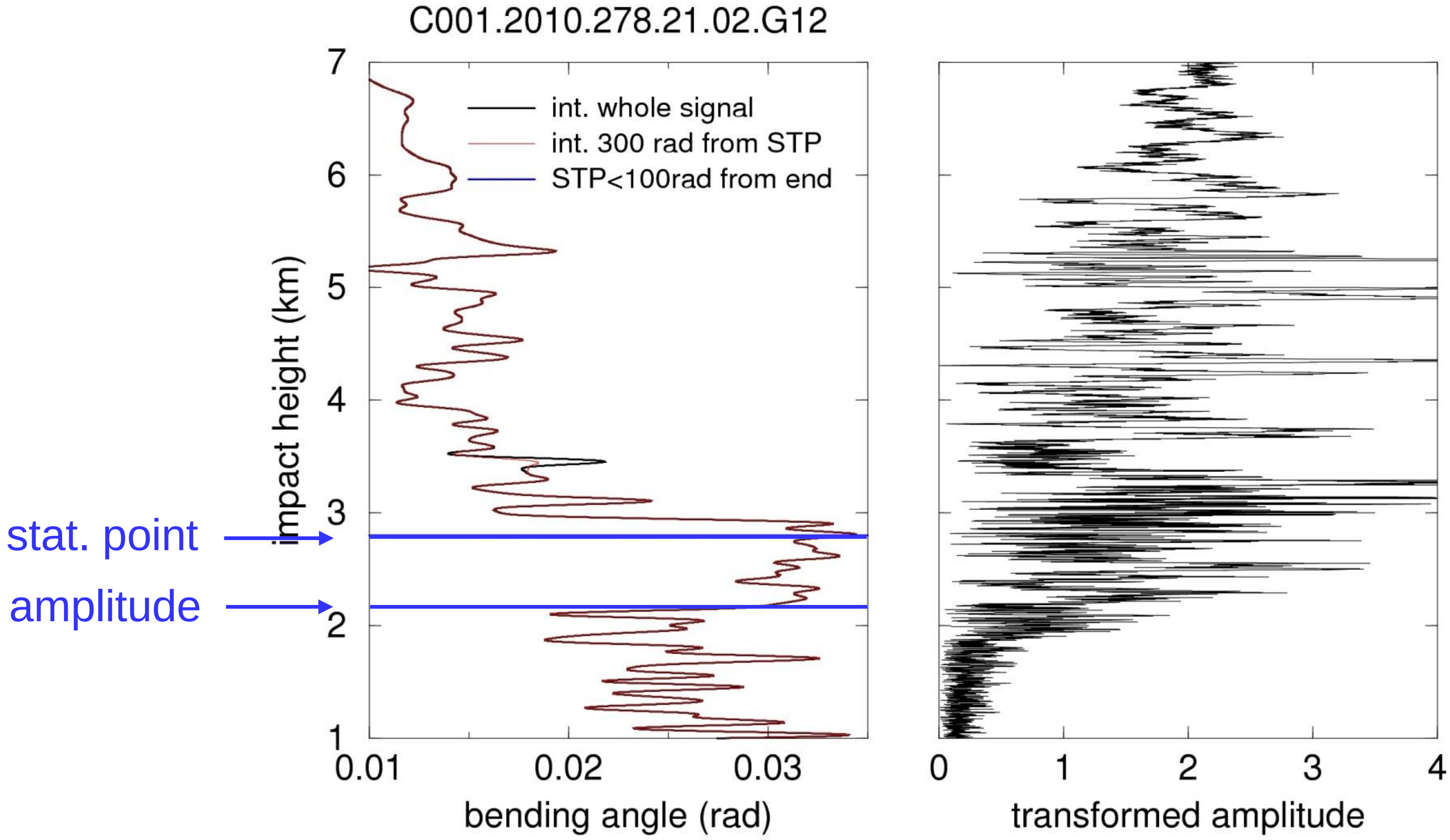
- main impact in the transform: about 100 rad around stat. point
- sufficient to integrate in limited interval around the stat. point
- integration interval expands in case of strong de-focusing
- no need to truncate RO signal before applying WO transform





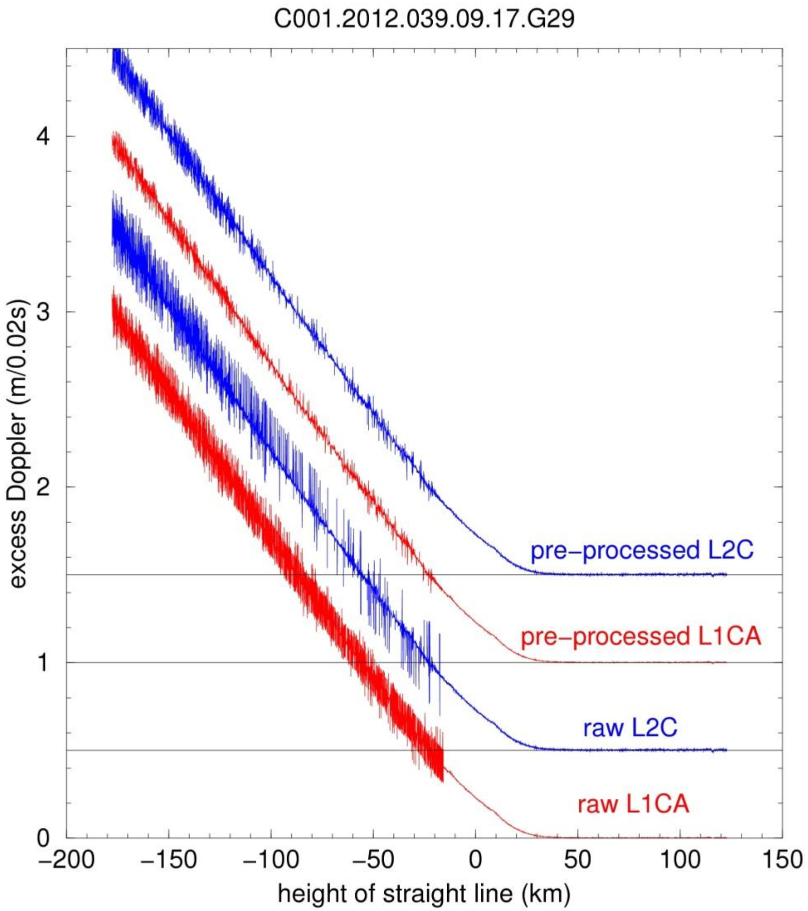
Wave optics transform (cont.)

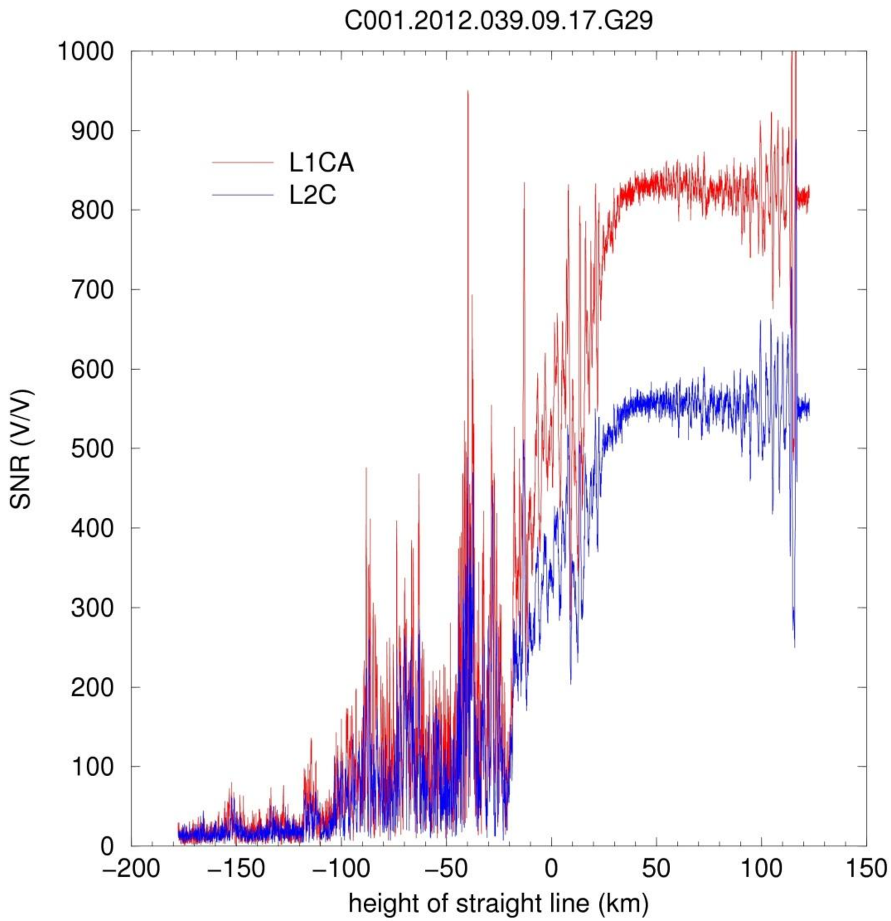
- truncation of retrieved BA profile based on existence of stationary point + 100 rad, generally, is higher than based on amplitude
- below: larger structural uncertainty
- may replace two truncations (or raw signal and retrieved profile)



JPL modified COSMIC receiver FW to track L2C in PLL and OL modes
Acquisition of L2C started in 2012

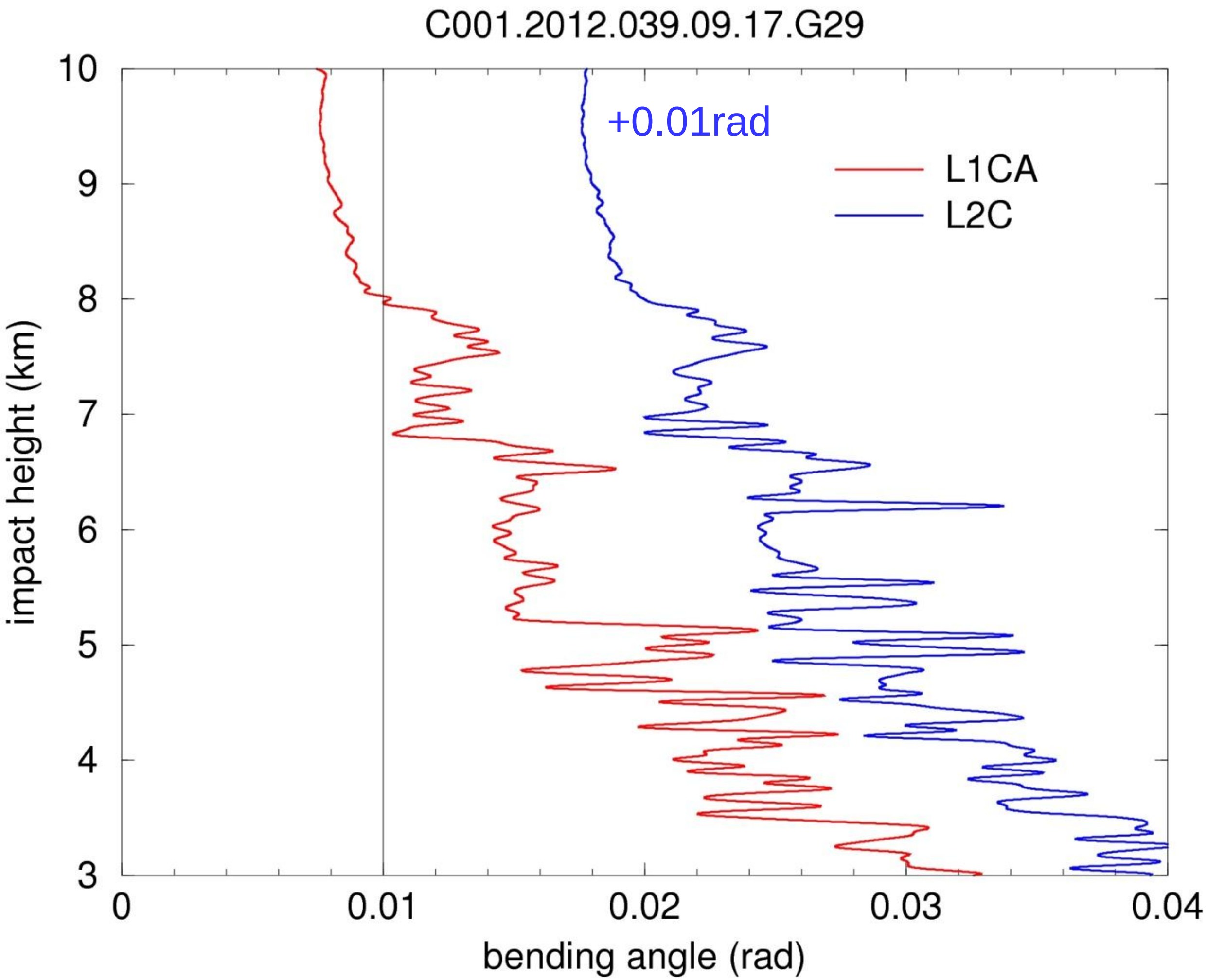
- reduction of BA noise in the stratosphere
- use of L2 down to lower heights for the ionospheric correction
- how to make use of L2C in LT ?





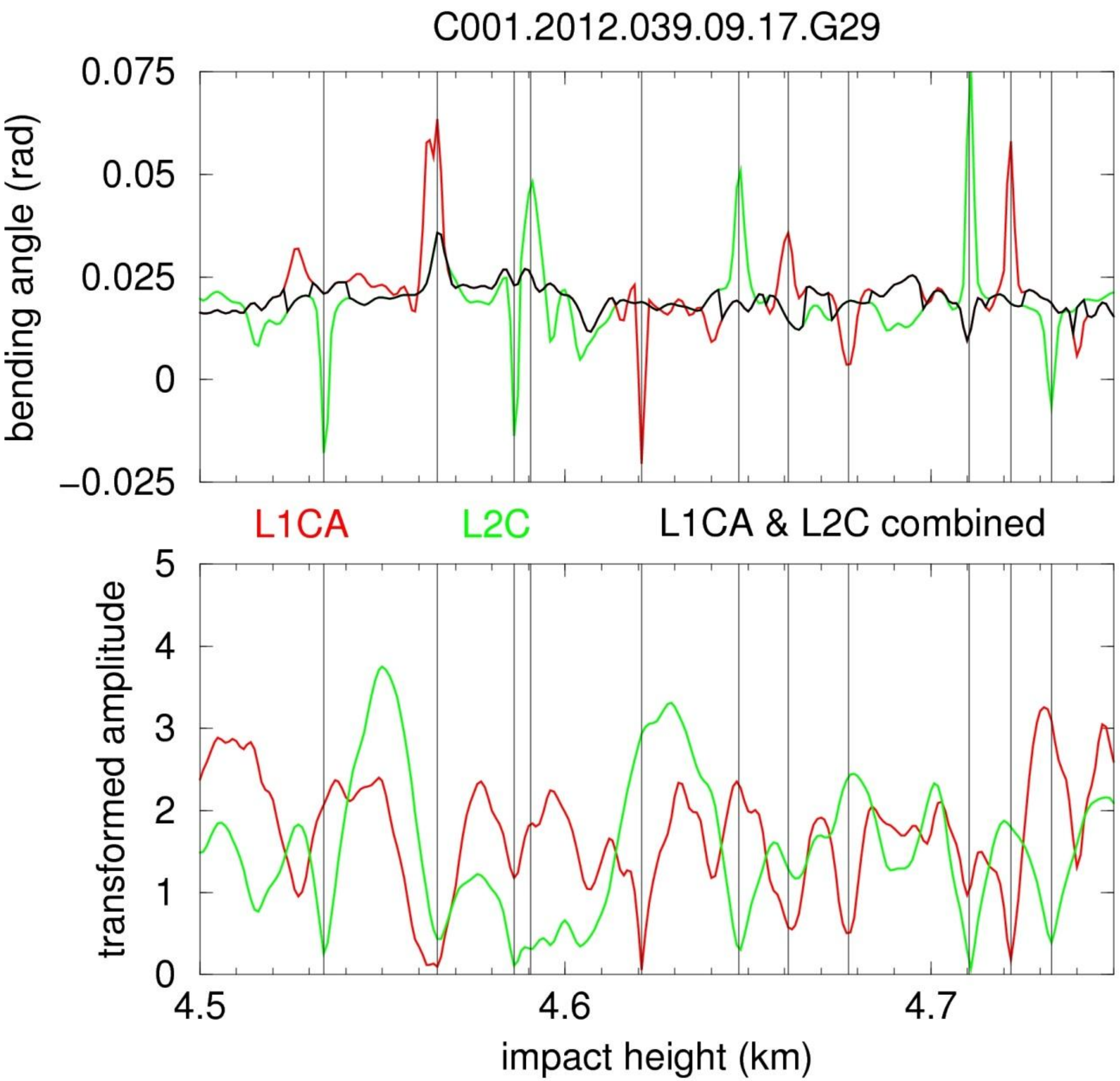
BA profiles retrieved by WO from L1CA and L2C in tropical troposphere

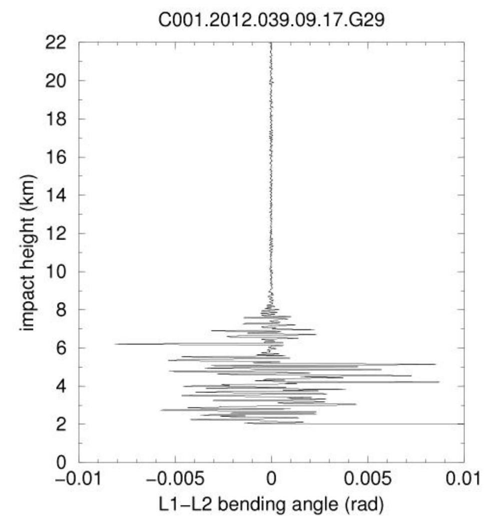
- L2C BA more noisy than L1CA BA
- L2C BA more susceptible to additional noise (larger struct. uncert.)
- summing L1CA and L2C BA increases noisiness and sensitivity to noise



Combining L1CA and L2C BA in the lower troposphere by use of the amplitude of WO transform

- largest BA spikes correspond to regions of small amplitude





BAC =

BA1+C1*<BA1-BA2>

if

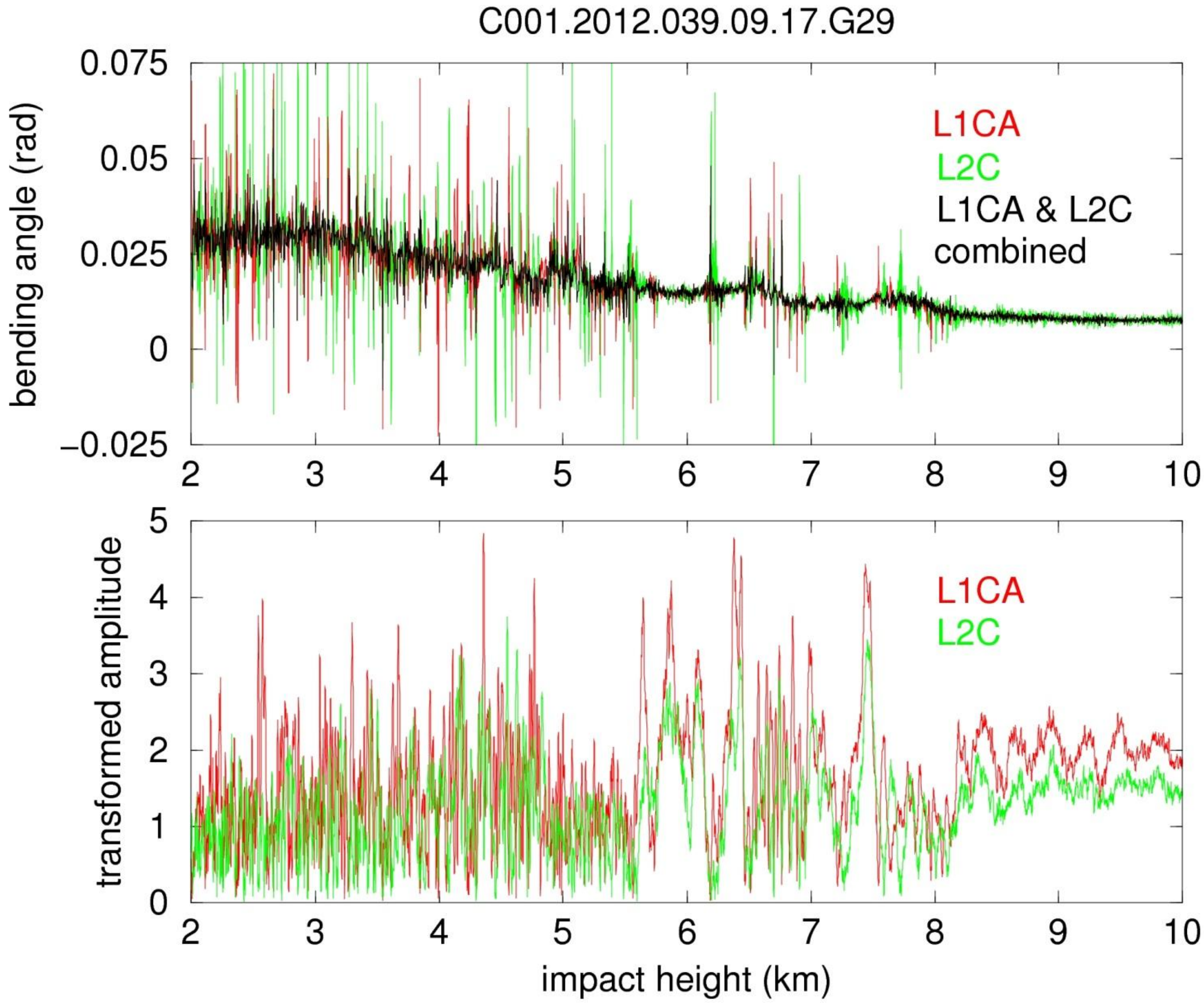
WO amp.1 > WO amp.2

BA2+C2*<BA1-BA2>

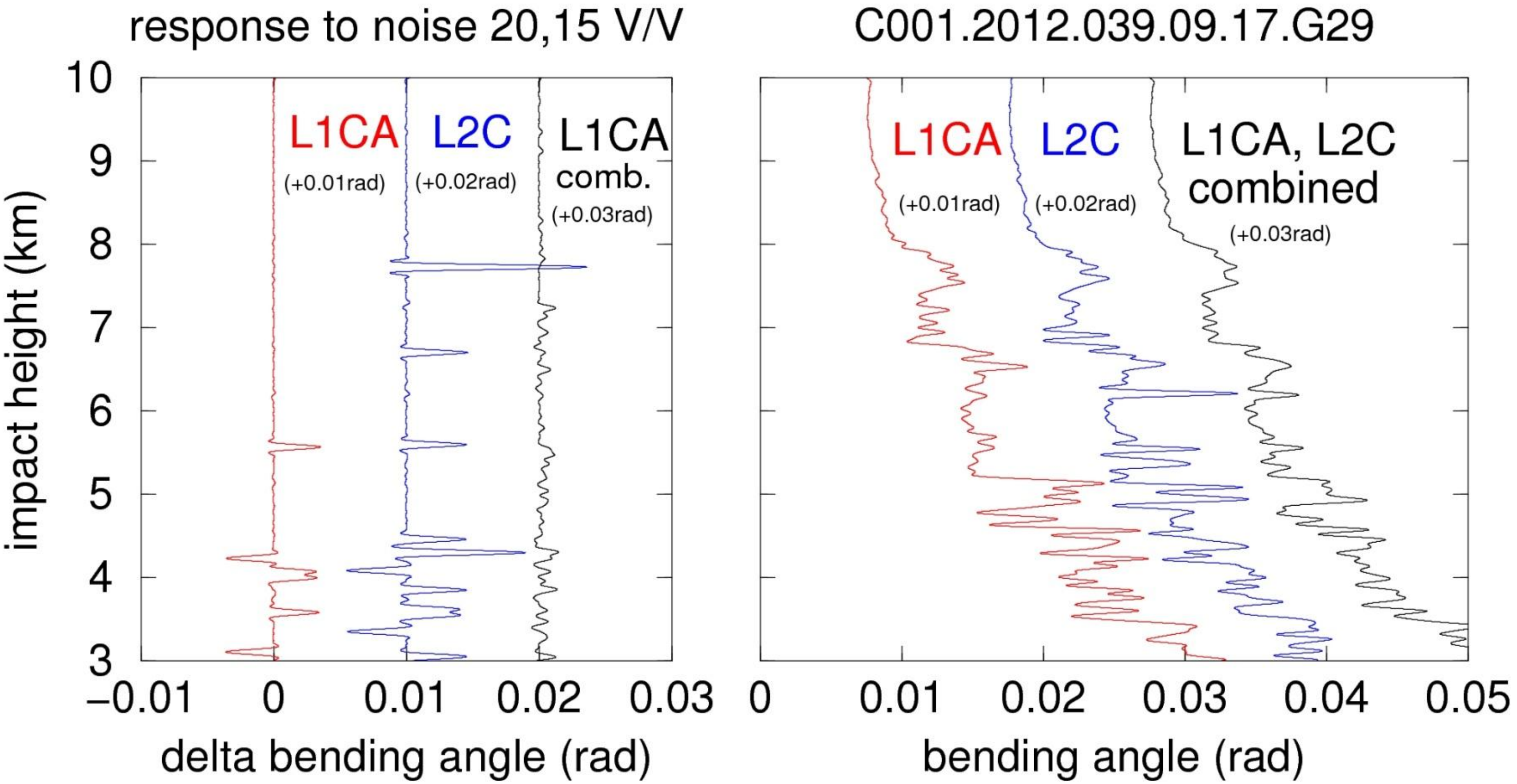
if

WO amp.2 > WO amp.1

Combined BA is less noisy than any of L1CA and L2C BA



Combined BA is less sensitive to additive noise on RO signal than any of L1CA and L2C

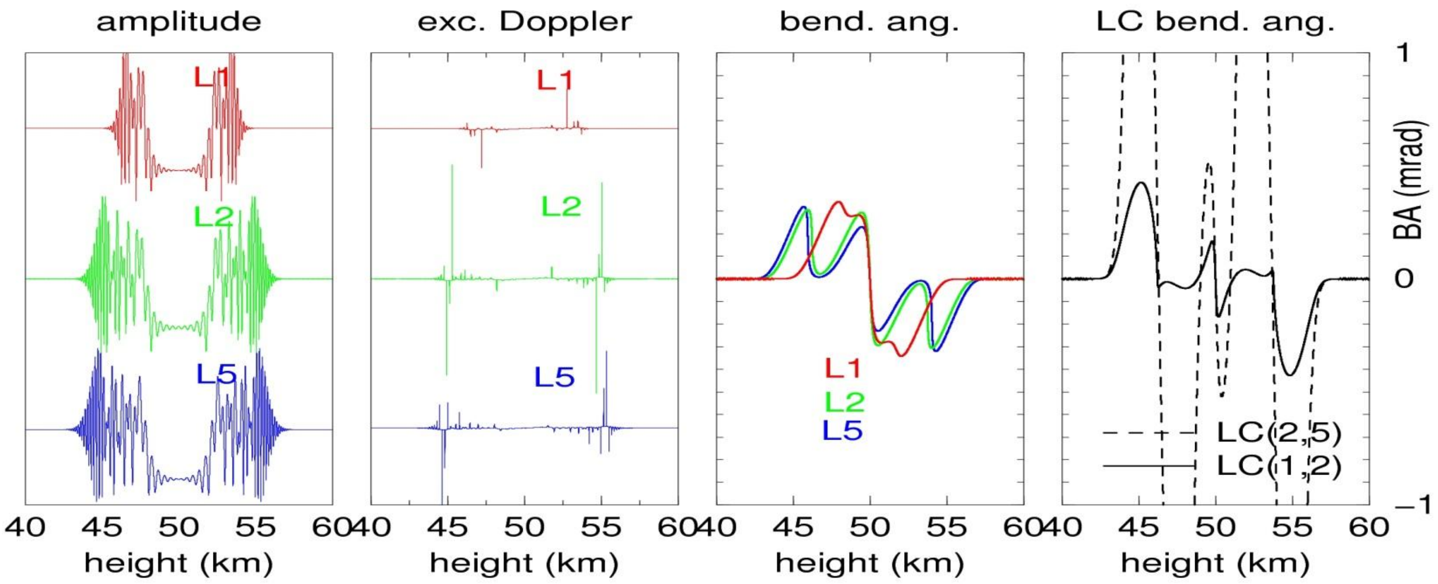


Error sources of the ionospheric correction:

- amplification of noise by linear combination
- diffractional effects
- higher order terms of dependence of N on frequency
- ray separation

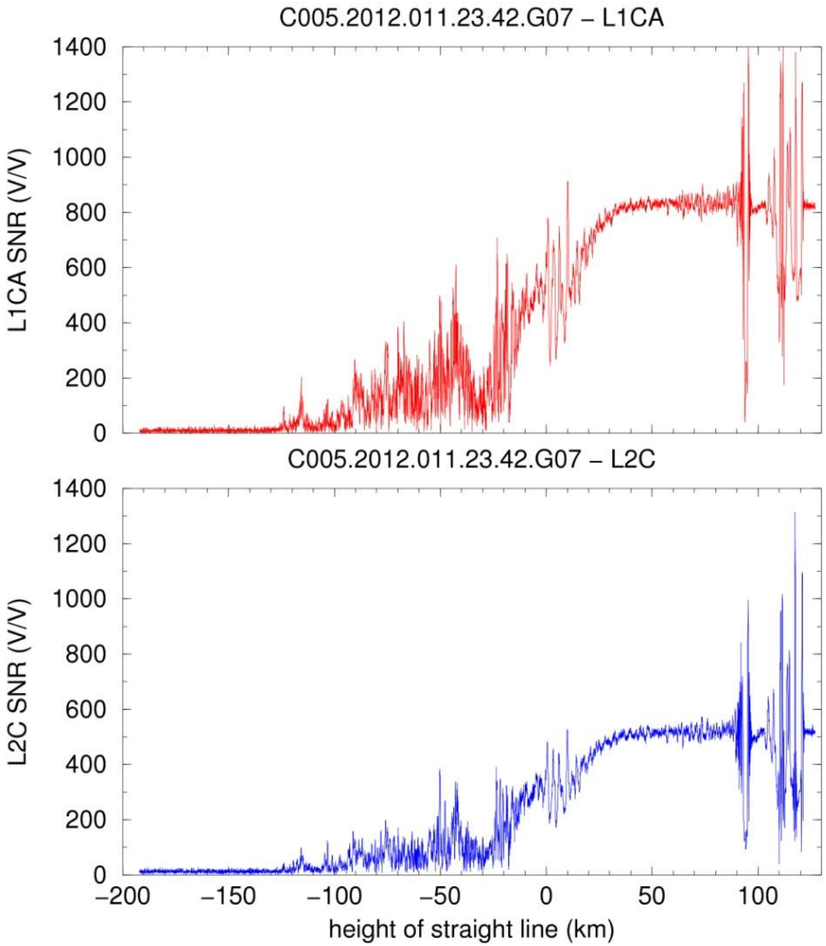
- the use of L2C allows reduction of BA noise (compared to L2P) after the ionospheric correction for all occultations

- additionally, L2C allows reduction of the errors due to diffractional effects for occultations affected by the ionospheric scintillation

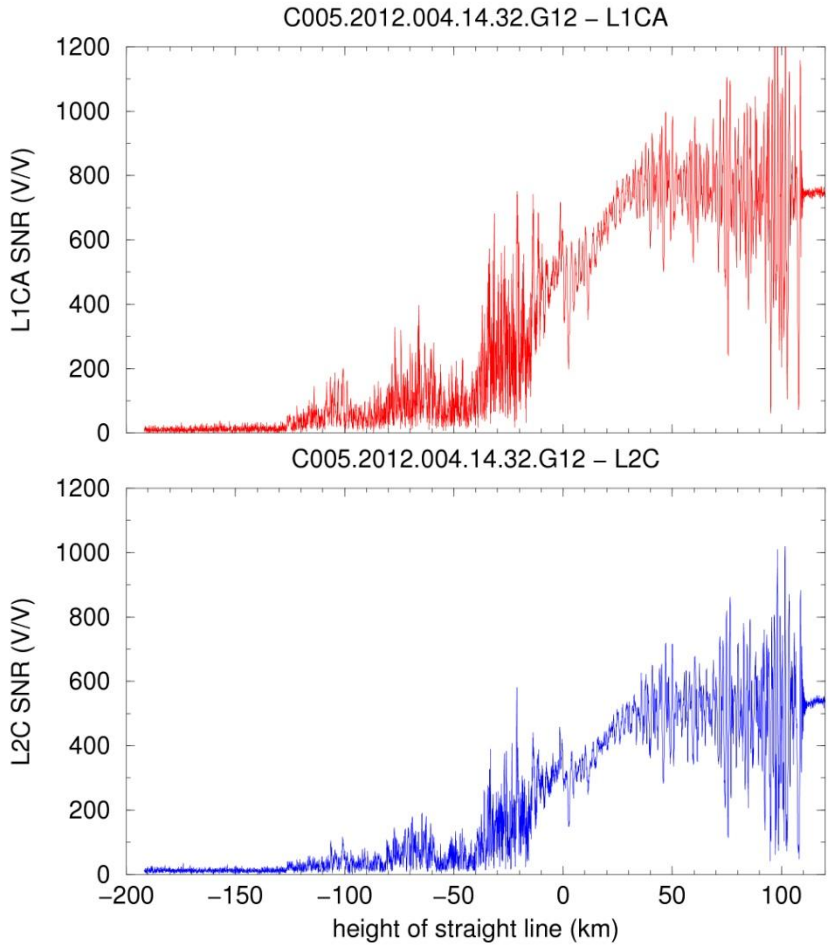


Examples of the ionospheric scintillation on L1CA and L2C signals

Es scintillation

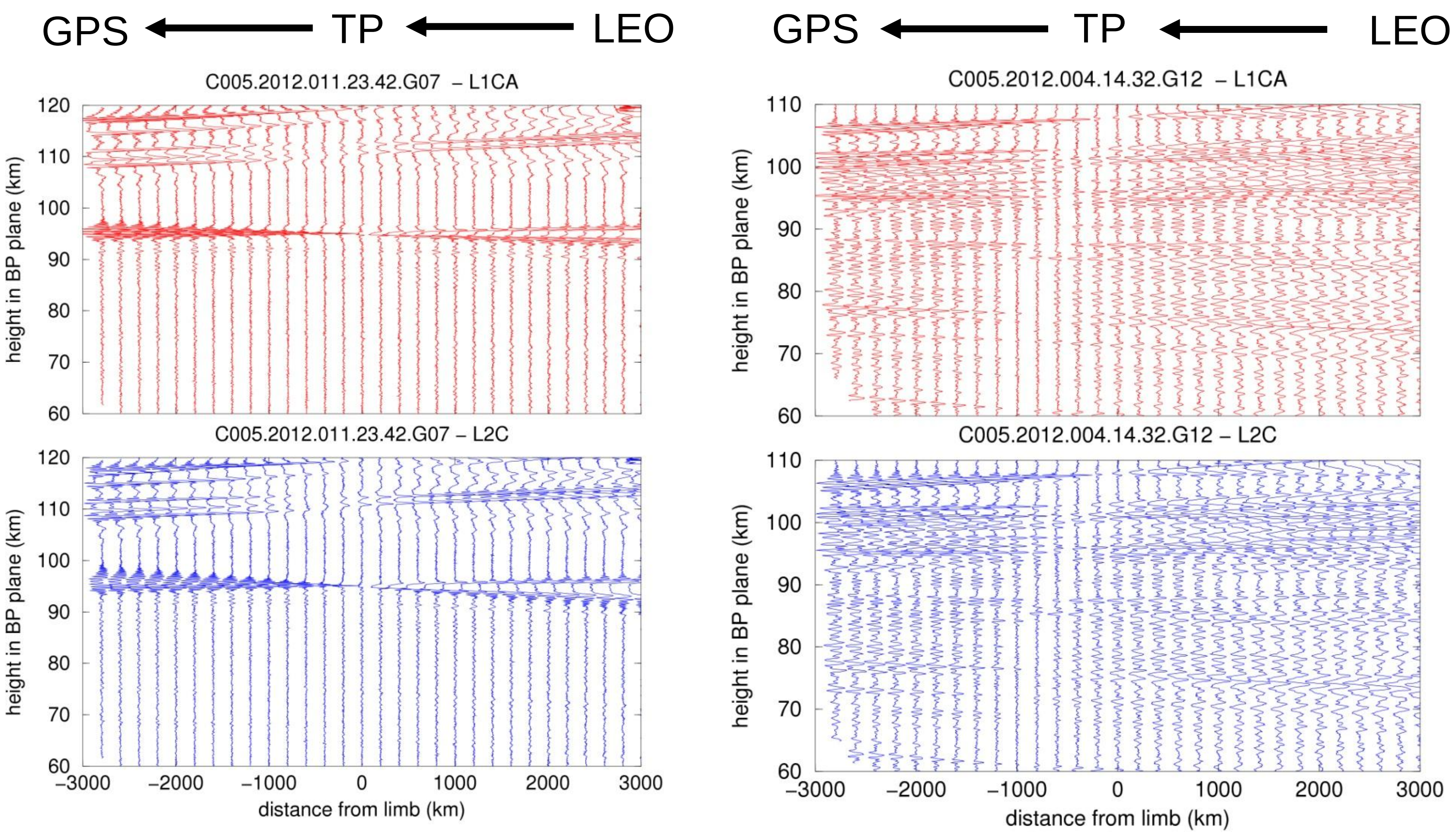


F scintillation



Back propagation of RO signals

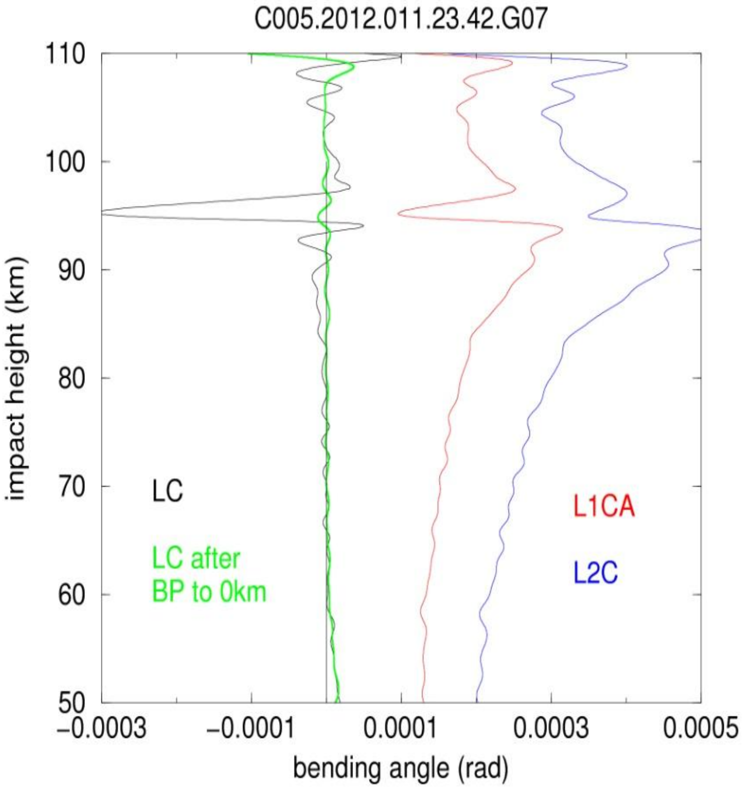
In case of localized ionospheric irregularities, the regions with minimum fluctuation of BP amplitude correspond to the regions with minimum difractional effects on complex signals. Ionosphere-free BA calculated from BP signals in these regions are less noisy.



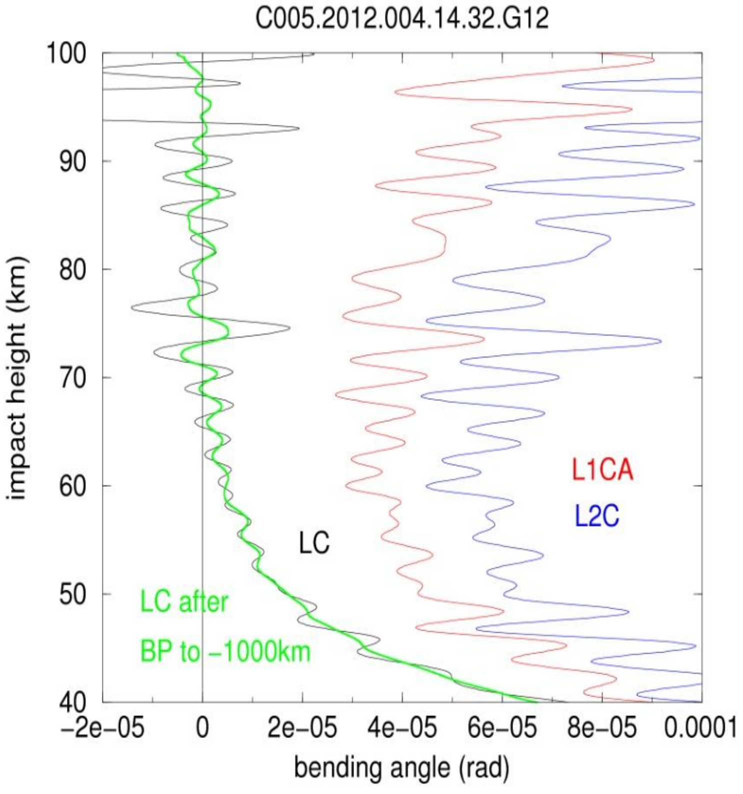
BA calculated from RO signals directly and after back propagation of complex signals to the regions of minimum fluctuation of amplitude

- location close to TP (Es layer): WO yields ionosphere-free BA similar to BP+GO
- location far away from TP (F layer): WO yields noisier BA than BP+GO and even GO

Es scintillation



F scintillation



Summary

- wave optics transform (phase matching) can be calculated in limited interval around stationary point: this makes it more computationally efficient and replaces two truncations: of observed RO signal and retrieved BA profile

- combining of BA retrieved by wave optics transform from L1CA and L2C complex signals in lower troposphere based on transformed amplitude reduces the noise and structural uncertainty of BA profile

- back propagation of L1CA and L2C complex signals in the stratosphere to the region of minimal fluctuation of amplitude reduces diffractional effects and the noise of BA after the ionospheric correction