



## Regional Infrasound Propagation

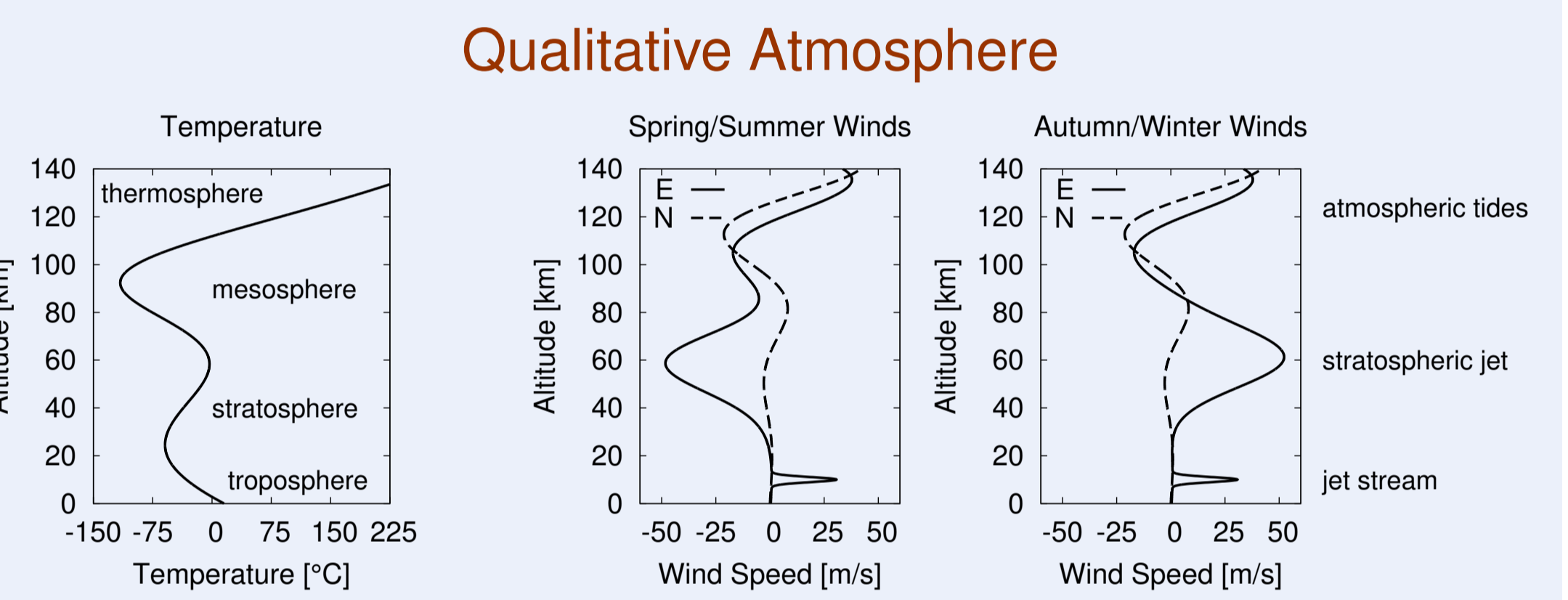
The "Classical Shadow Zone" is Frequently Ensonified

The "Standard Atmosphere" and the circumpolar vortex

- The classical stratospheric duct is stratopause plus circumpolar vortex
  - Tropospheric structures were generally considered less significant
  - The CTBTO IMS design was based on a stratospheric duct
- The pure stratospheric duct has a shadow zone about 200 km deep
  - Signal is often detected in the stratospheric shadow zone

Mechanisms for ensonification at regional distances

- Scattering from turbulence (Kulichkov, Chunchuzov *et al*)
  - Returns from all altitudes
- The jet stream
  - Returns from about 10 km
- Mountain and sea/land induced flow
  - Creates a ducts in the lower few kilometers
- Nocturnal inversions
  - Effectively creates a surface wave
- Low altitude wind jets
  - Nocturnal jets and other winds
  - A few hundred meters high



Effective sound speed

- $c(z) + \text{wind speed in prop direction}$

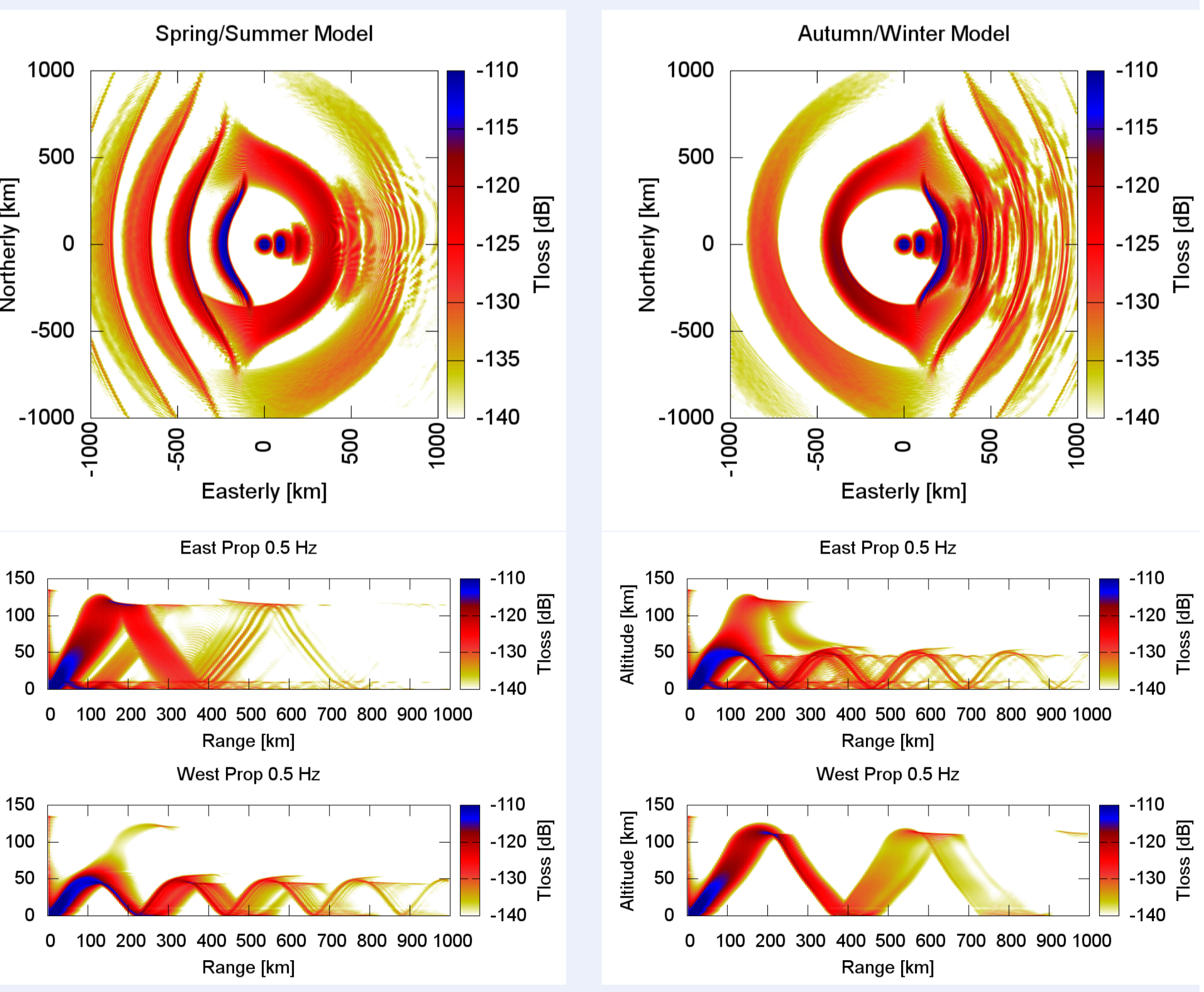
Approx ground return criterion:

- Eff. sound speed > Gnd sound speed

Wind is needed for the lower ducts

- Stratospheric
- Tropospheric

## Qualitative Signal Propagation



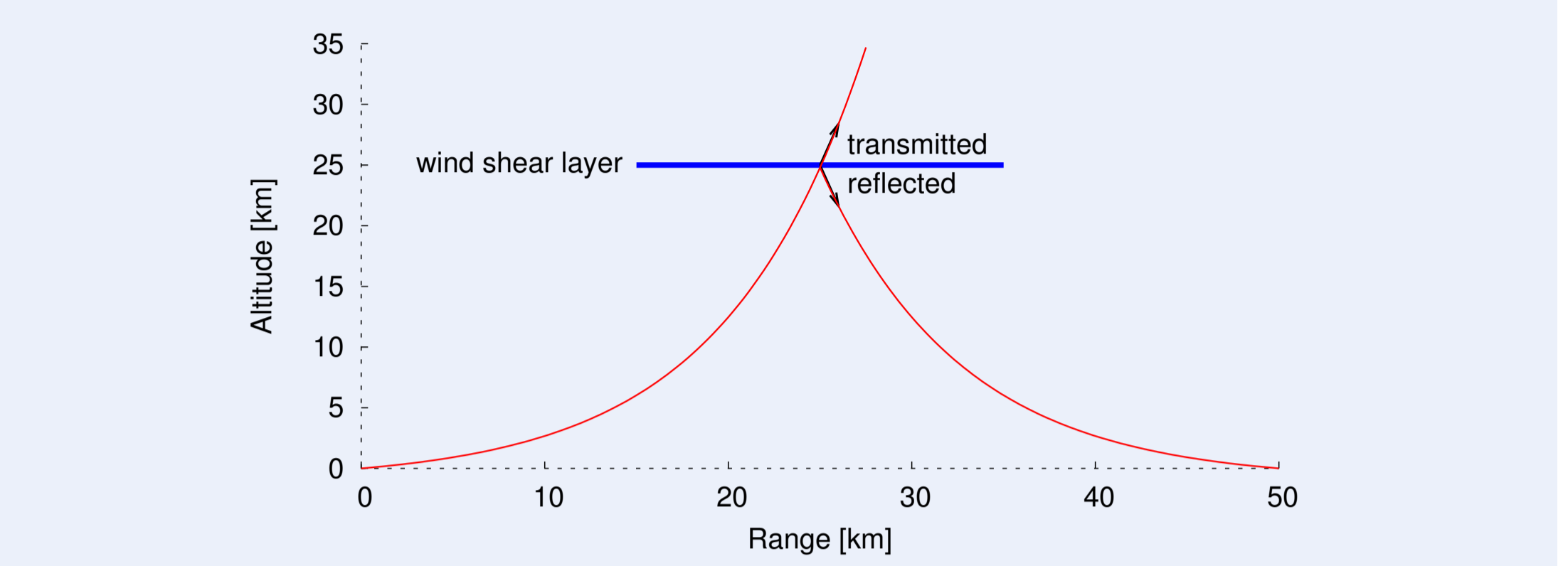
## Scattering into the Transition Zone (Kulichkov et al)

Diffracted direct arrival

- if there is a low altitude wind jet

Followed by signal scattered from wind shear in the atmosphere

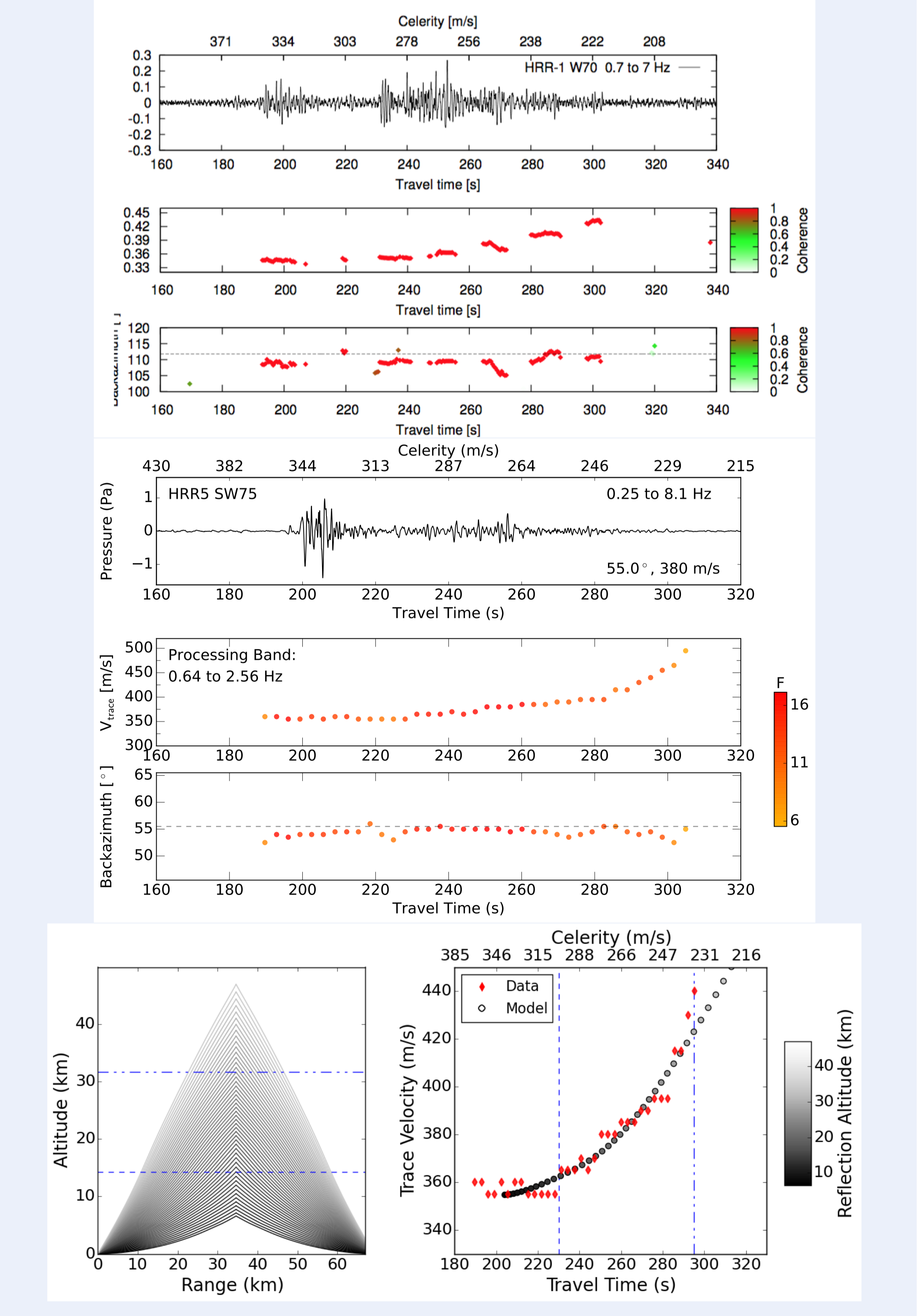
- similar to seismic coda, but not stationary
- produces high trace velocity, low celerity, signals
- trace velocity should increase with time along the signal trace



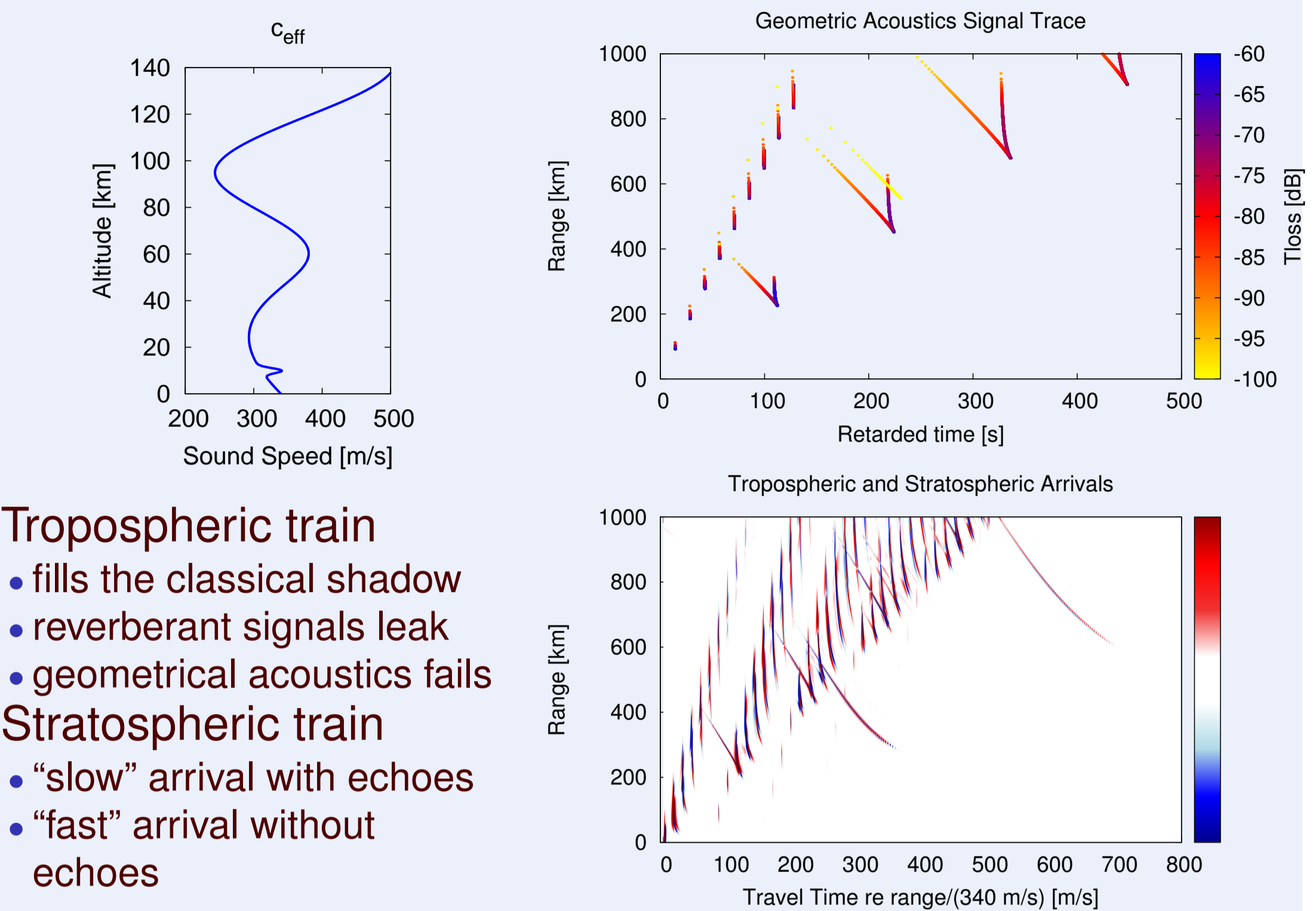
## Examples from Humming Roadrunner (Green et al JGI 2018)

Six large chemical explosions

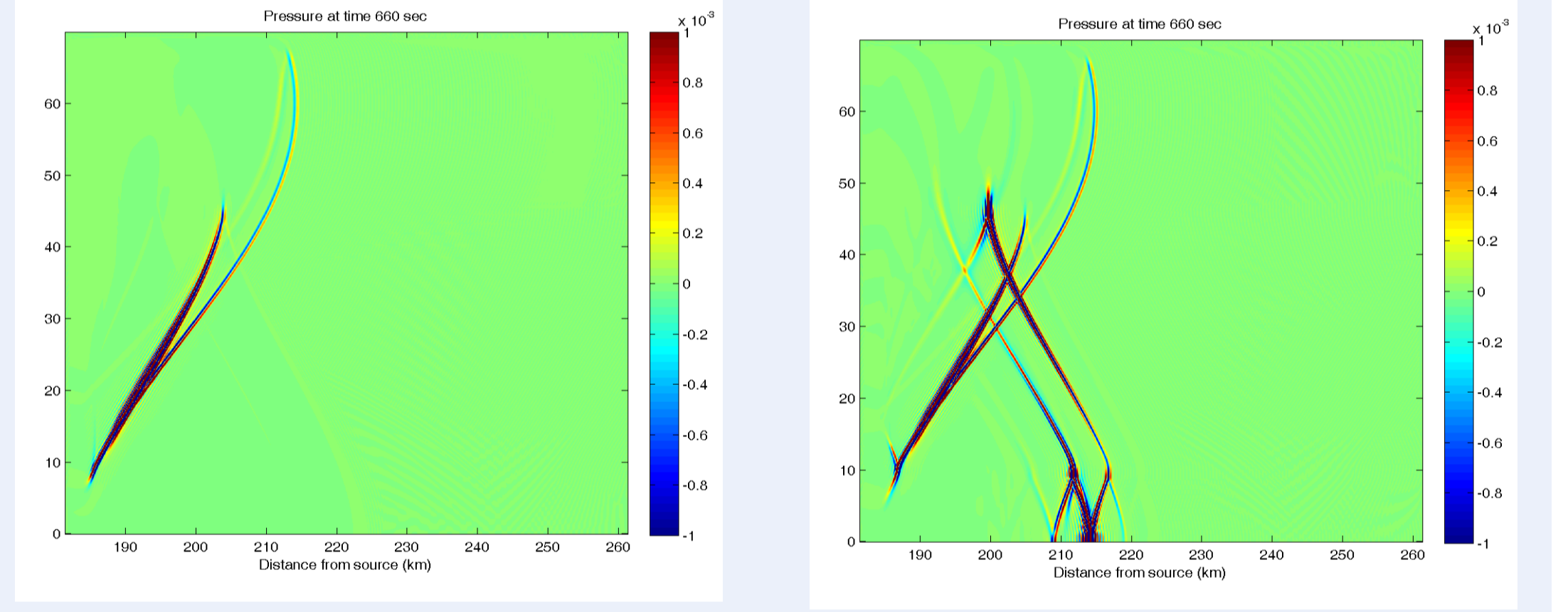
- near, regional, and far field field signal captures
- Deployment at transitional ranges
  - 50 to 90 km from source in the three principle directions



## Leaky Tropospheric Ducts



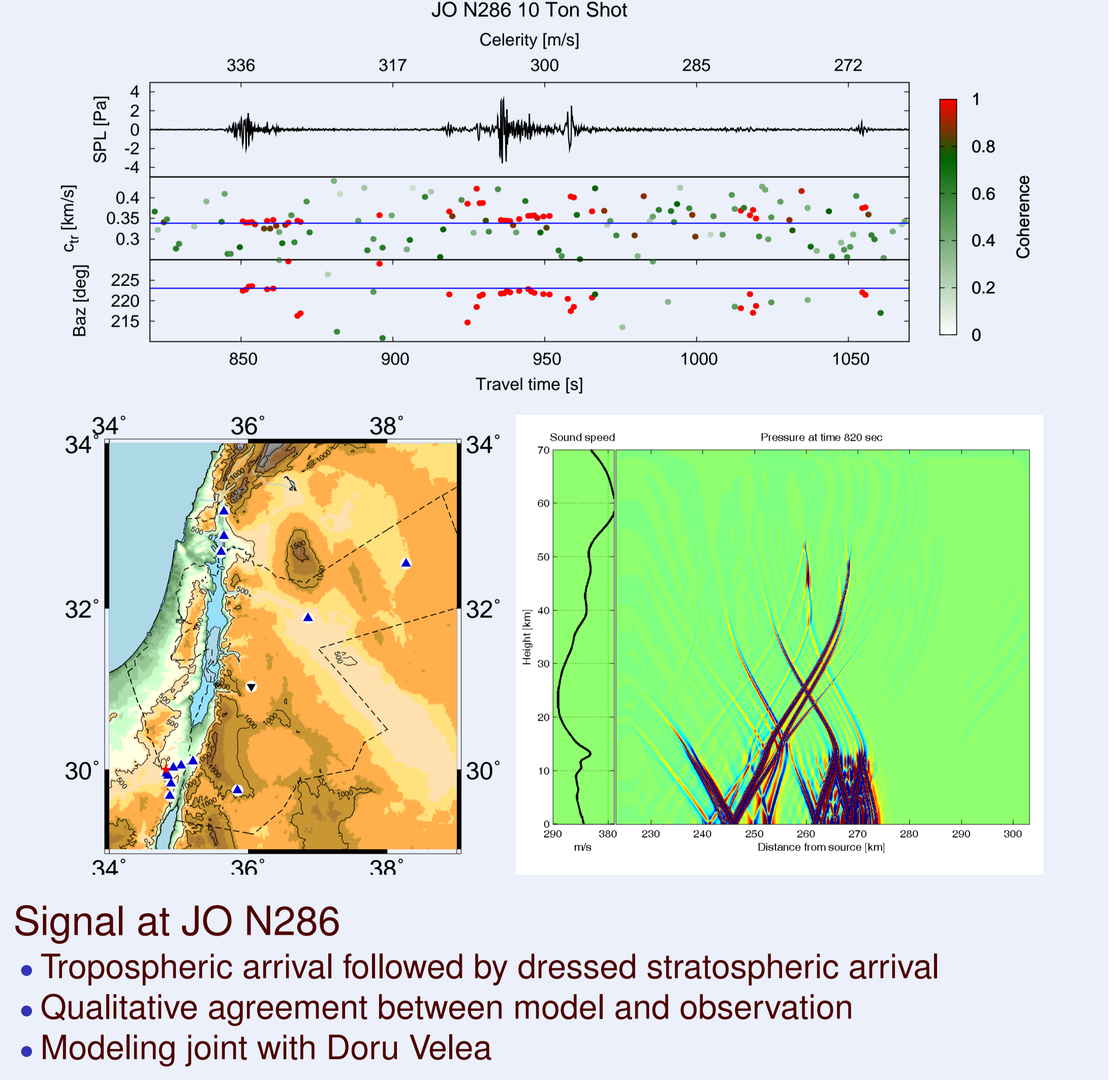
## Without Jet Stream vs With Jet Stream



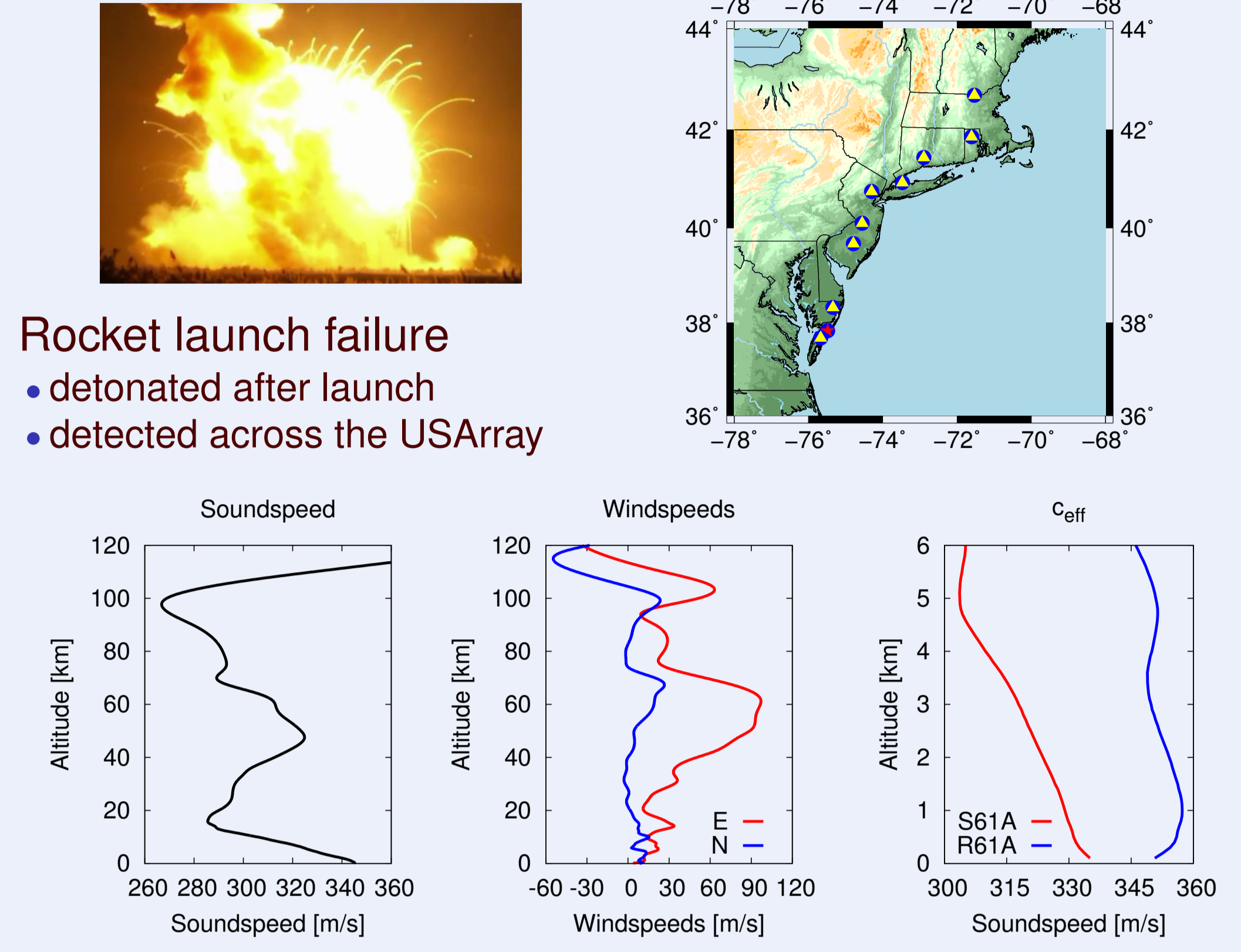
The leaked echoes retain persistently large amplitudes

- their phase speeds are tuned to minimize geometric spreading

## Sayarim 2011 10 ton: Tropospheric Detection in Jordan



## Wallops Island Rocket Explosion



## Low altitude tropospheric duct

- Nocturnal temperature inversion and a low altitude east-northeast jet
- solid easterly jet stream and E-NE stratospheric jet E-NE
- Upward refraction to the south and west

