



# ENVIRONMENTAL MONITORING AND PIPELINE EROSION DETECTION

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## Outline

- Introduction
- Sensing technology: Optical Fiber Distributed Sensing
- Soil-atmosphere thermal interaction
- Application to the PLNG natural gas transport system
  - Erosion detection, localization and quantification
  - El Nino 2014-2016 Episode
- Conclusions



## Introduction: The Peru LNG Pipeline

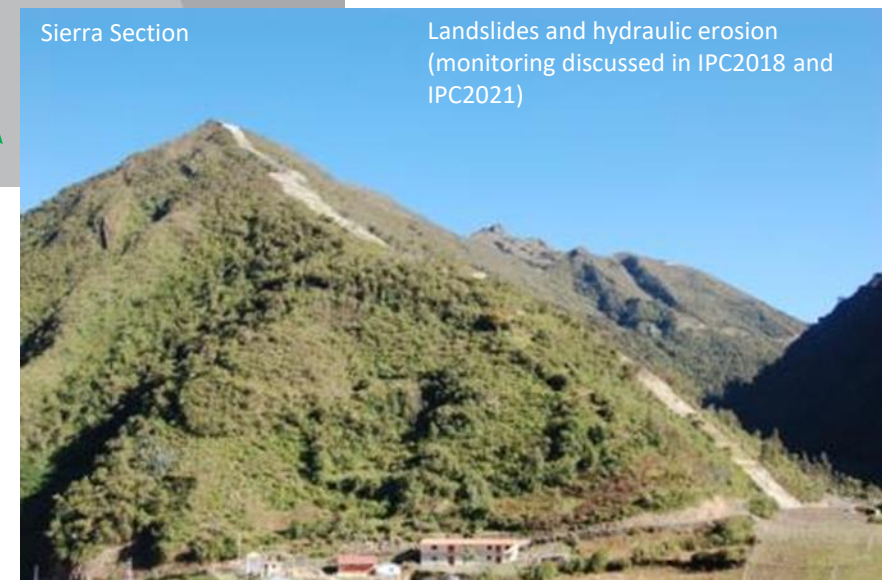
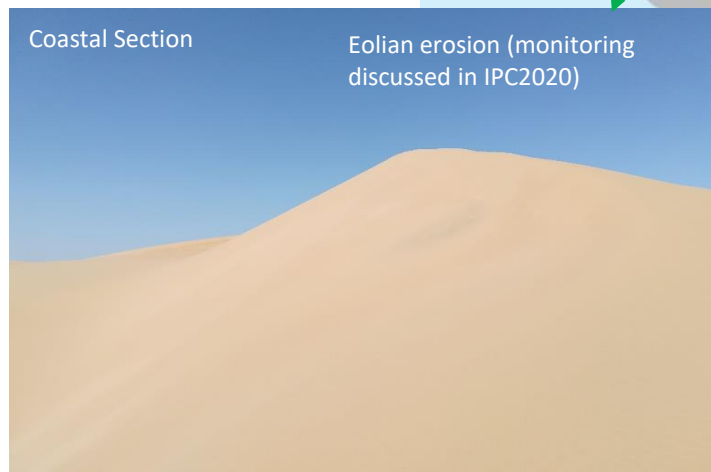


### • Quick facts

- 34" high pressure natural gas pipeline
- Connects to TGP in Chiquintirca
- 408 km long
- Ends in Pampa Melchorita, LNG plant on the coast of Peru
- Record breaking altitude of 4901 m



## Introduction: The Peru LNG Pipeline

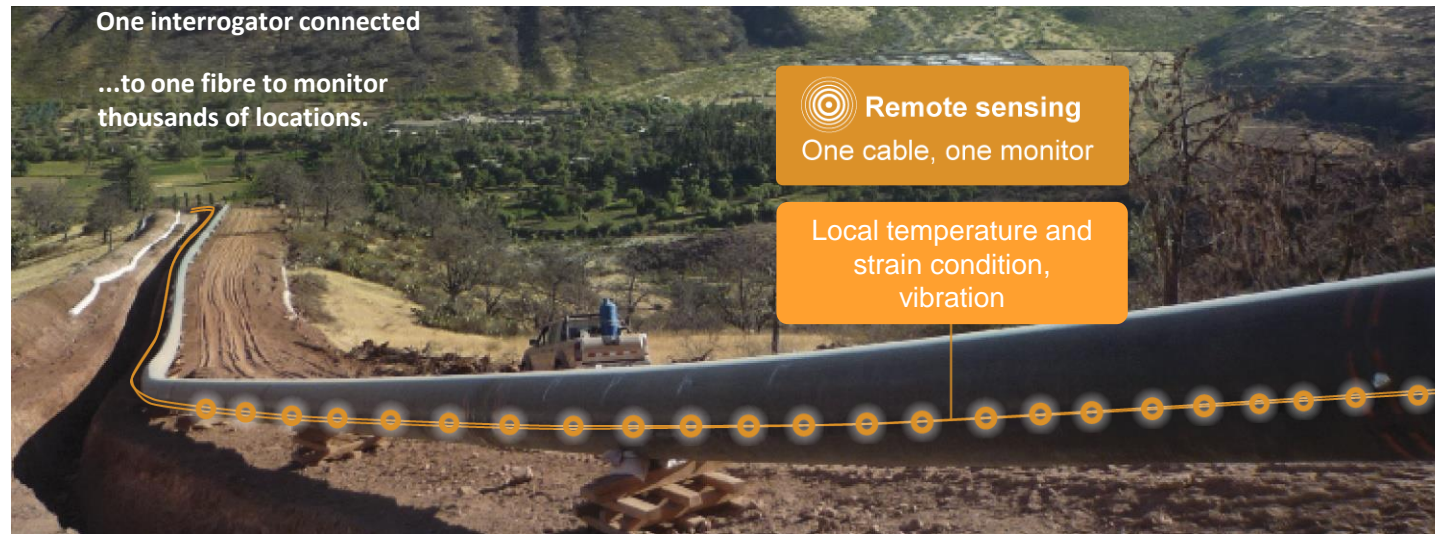




## Distributed Sensing – The Concept



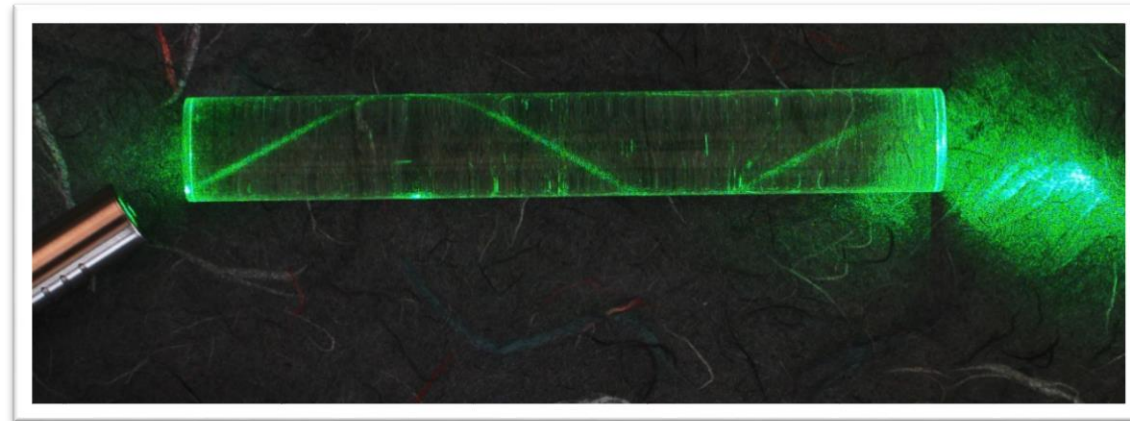
- Turning optical fibers into a fully distributed sensor





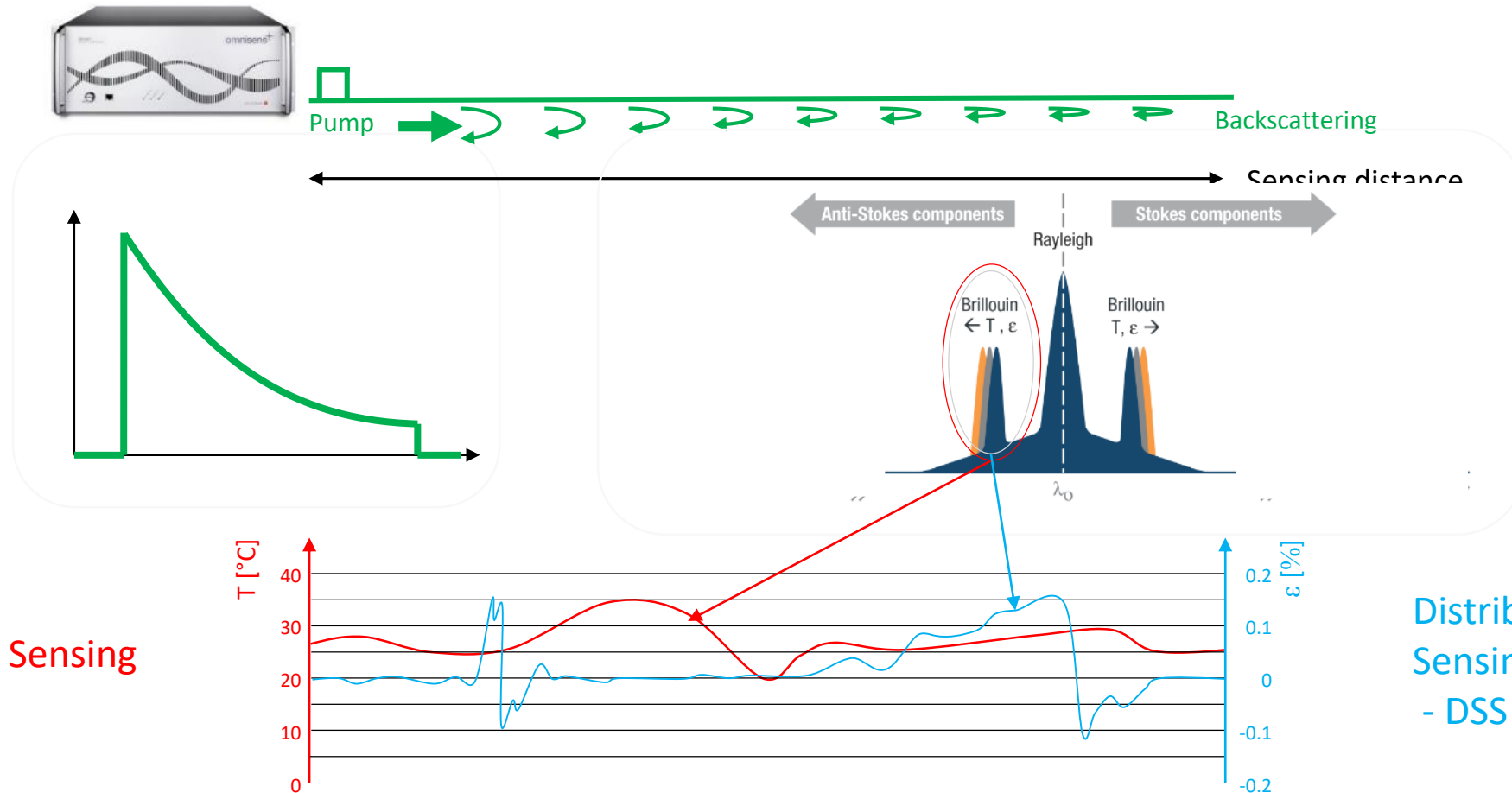
## Optical Fiber Distributed Sensing

- Distributed sensing uses light scattering
- Scattering originates from inhomogeneities in silica





# Optical Fiber Distributed Sensing

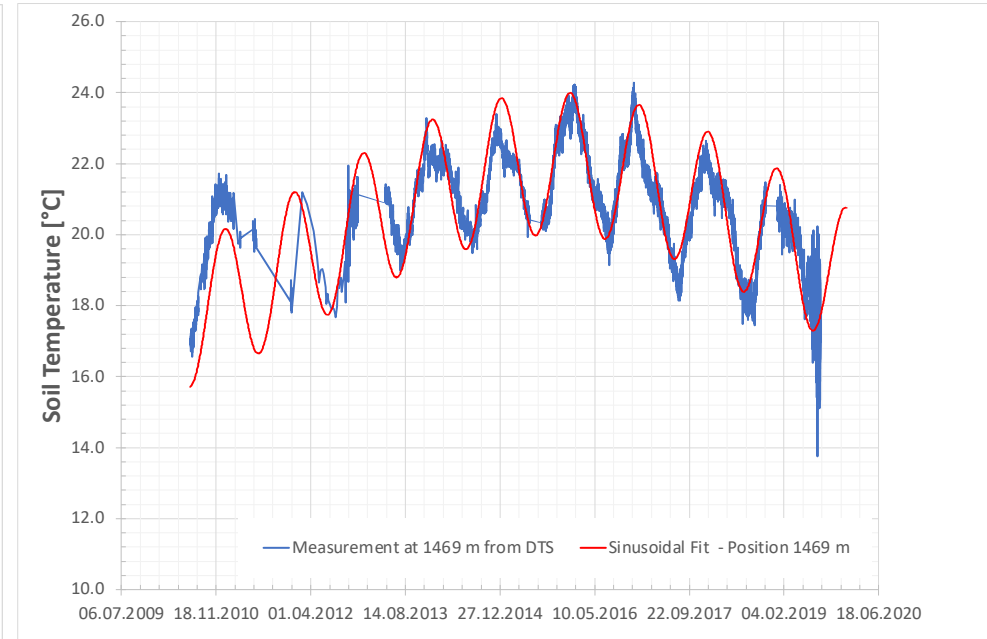
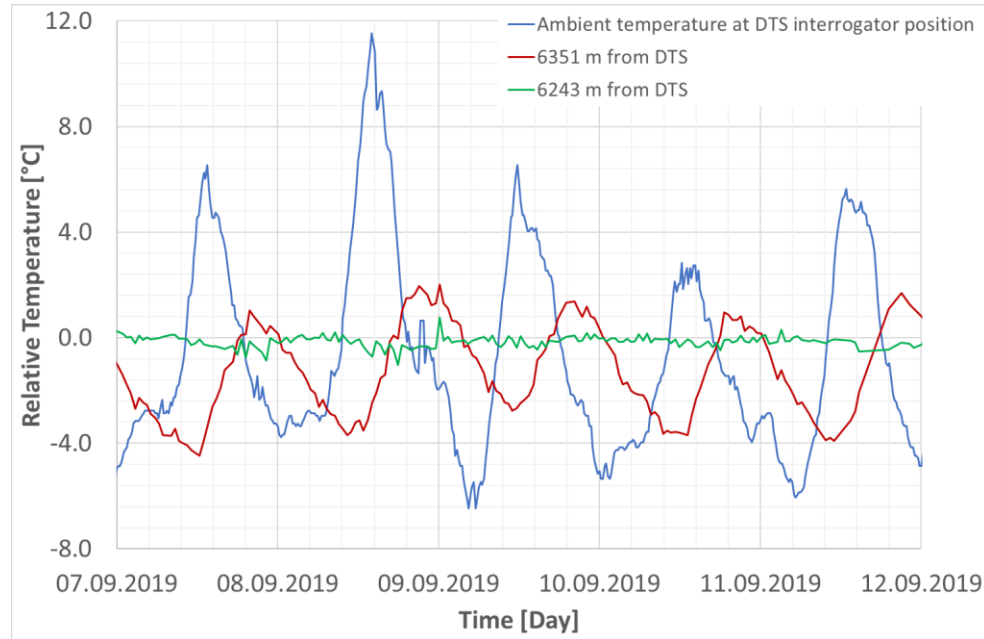


Distributed  
Temperature Sensing  
- DTS

Distributed Strain  
Sensing  
- DSS



## Soil-Atmosphere Thermal Interaction



- **Daily Change**

- Variation not perceptible for depth larger than 50cm
- Down to 50 cm, amplitude of variation decreases and phase difference increases

- **Yearly Change**

- Temperature is constant at depths larger than 10m
- At pipeline depth ( $\approx 1\text{m}$ ), only seasonal change can be observed



## Application of DTS to Erosion Monitoring

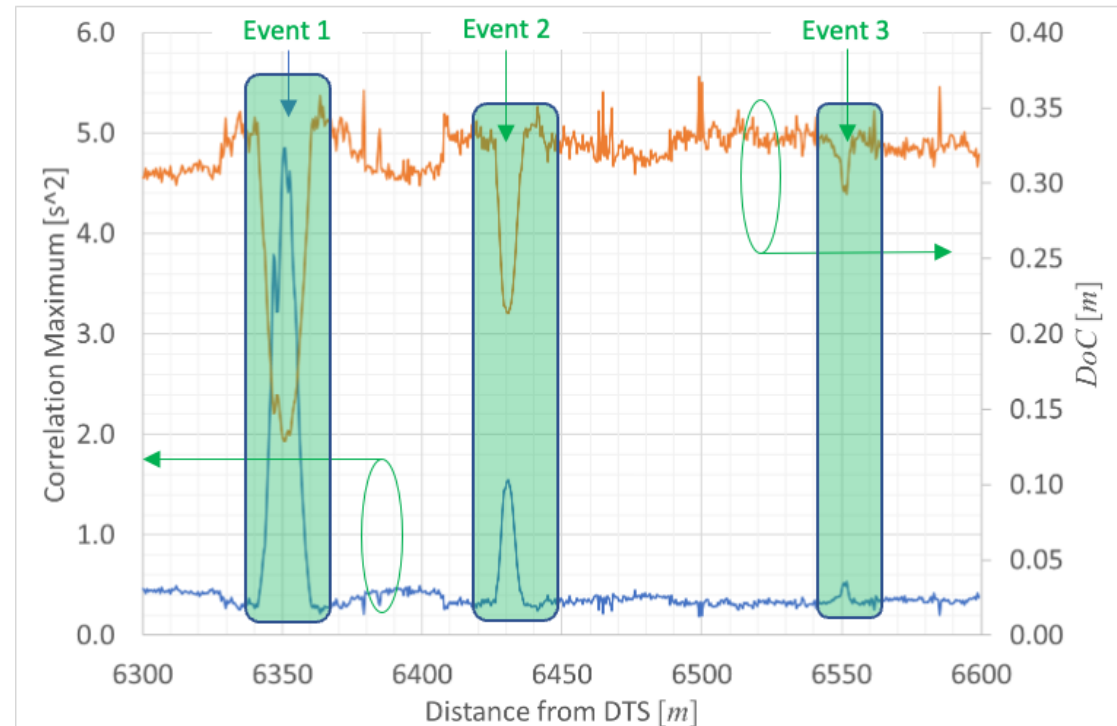
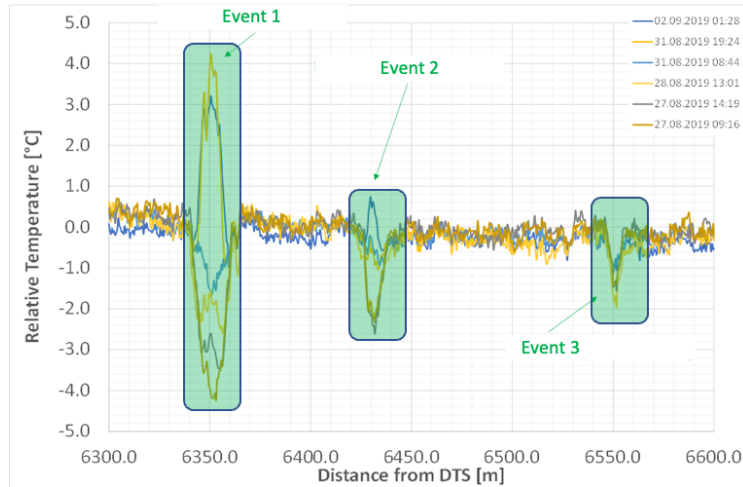
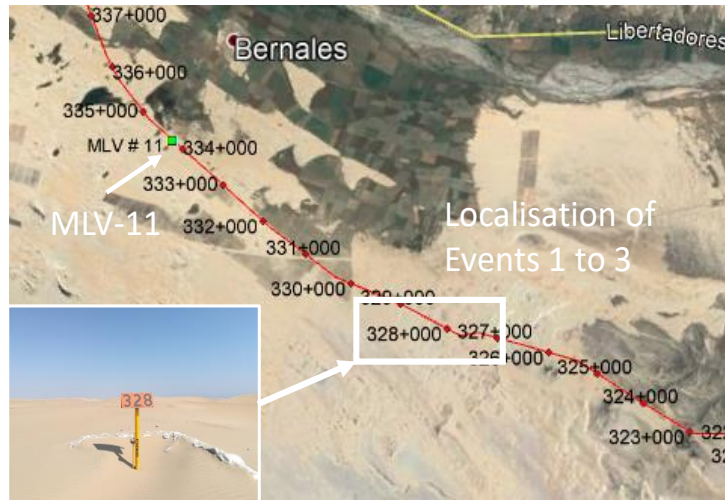
- Profiling temperature along the fiber
  - Erosion detection
  - Erosion localization
  - Erosion quantification: Depth-of-Cover computation ( $DoC$ )
- $DoC$  is calculated from the computation of the Cross-correlation between the ambient temperature variation and the DTS profile which gives the delay ( $\tau$ ) and the

$$X(x, \tau) = \frac{\omega_d}{2\pi} \int_0^{2\pi/\omega_d} T_{weather}(t + \tau) T_{DTS}(x, t) dt$$

$$DoC(x) \equiv \tau \sqrt{2D\omega_d} = \sqrt{\frac{2D}{\omega_d}} \ln \left[ \frac{1}{2} \frac{T_{weather,max}^2}{X_{max}(x)} \right]$$

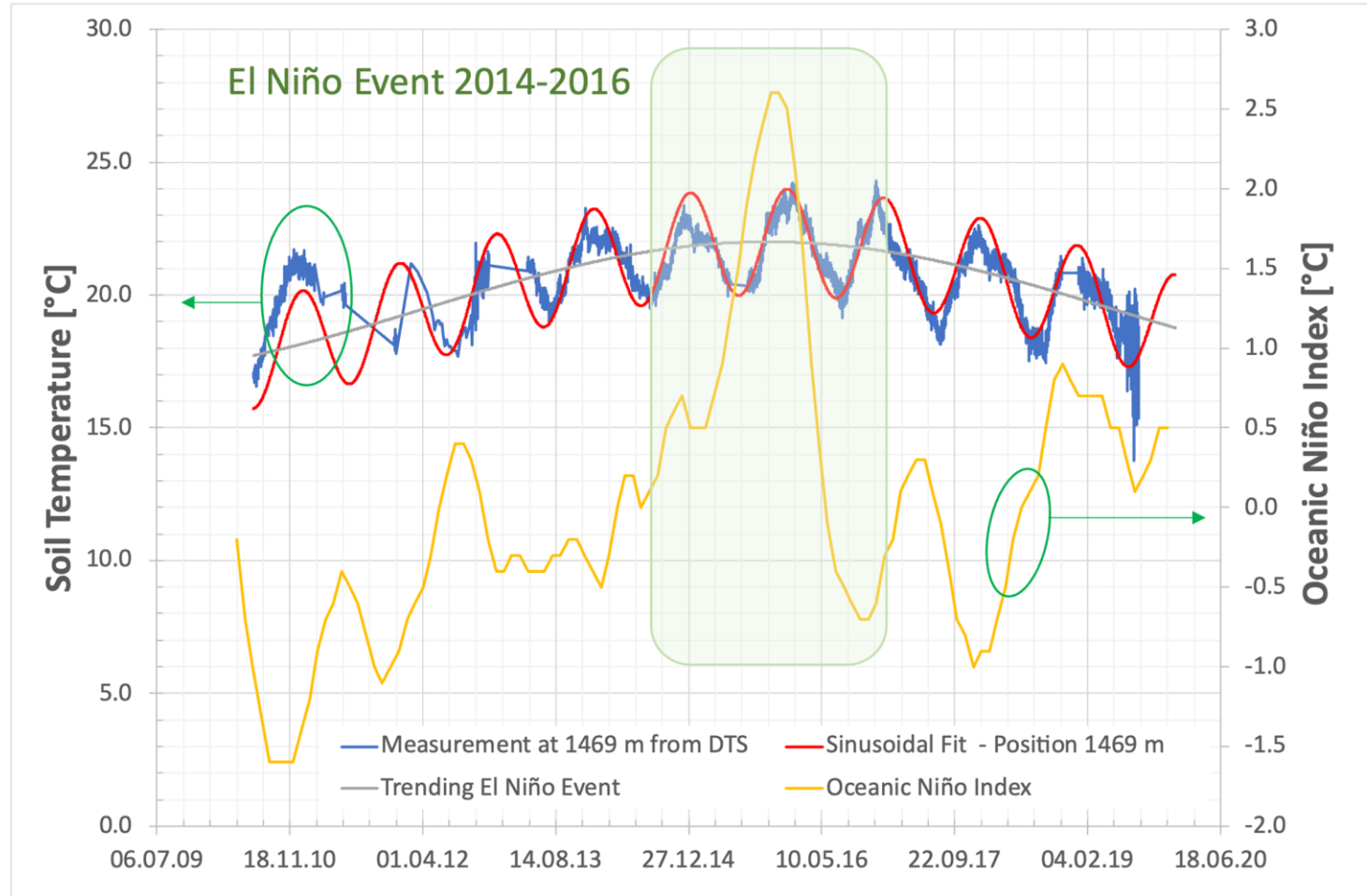


## Sand Dune Section: Events near KP328





## El Niño 2014-2015 Episode





## Conclusions

- Unattended and real-time measurements of temperature along pipeline using Communication OFC and DTS
- Localization of erosion and estimation of DoC
- Improves and rationalizes maintenance activities by increasing the periodicity of the visits and confirms completion of the remedial works
- Improves integrity of FOC based communication systems



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