National Physical Laboratory

Field validation of open path techniques and support of CEN/TC 264/WG 38
CEM 2016

IMPRESS workshop
NPL May 2017

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Work Package 3: Remote Sensing of Area Source Emissions

- Focus on three different types of optical remote sensing techniques that can be applied to area source emissions:
  - single-ended, range-resolved measurements using DIAL, aiming to fully characterise the emission measurement uncertainties;
  - double-ended, path-integrated measurements using tuneable diode laser absorption spectrometry, where the main challenge is the derivation of emission data from the path-integrated concentration measurements;
  - optical imaging of emissions using infrared camera, where moving from visualisation to quantification of emissions requires significant research.
  - SOF validation and protocol development
- Developing field test and validation facilities and demonstration during field campaigns at industrial area emission sites.

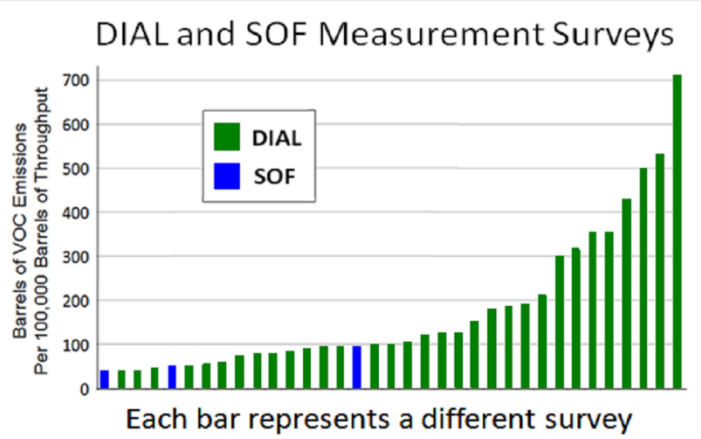
What are fugitive/diffuse emissions?

- Emissions from known sources can be measured reasonably well.
- However, there can be, and are, significant fugitive emissions from other parts of a plant – leaks, storage tanks, waste treatment, etc
- Definitions

  Fugitive emissions – leaks from contained systems

  Diffuse emissions – uncontrolled emissions from area and distributed sources

  Pragmatic definition is those emissions from a site that are not controlled and monitored point source emissions



European regulations

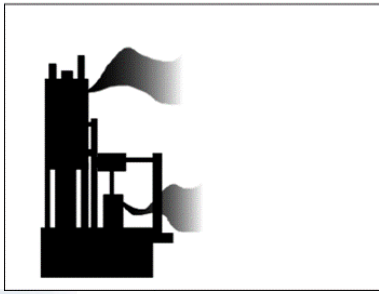
- European Directives define emission limits and monitoring requirements – Industrial Emissions Directive
- Best Available Technique Reference (BREF) documents define sector specific BAT
- Refining BREF includes fugitive emissions
- BAT conclusions (legal summary) published end 2014
- REF BREF released 2015, 4 years to comply.
- Fugitive emissions of VOCs are included (BAT 6)

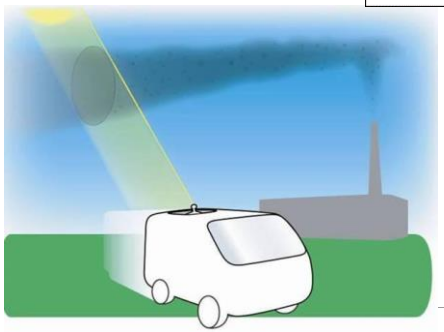
Techniques in the REF BREF

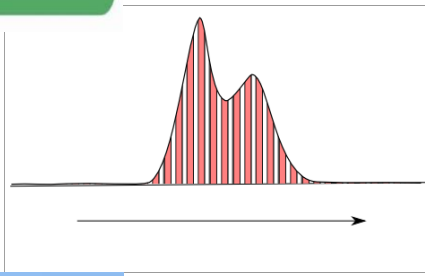
- Leak detection and repair (LDAR) – VOC sniffing and correlation factors. European standard exists – EN 15446
- Optical Gas Imaging (OGI) - IR Camera to image VOC plumes
- Solar Occultation Flux (SOF) - mobile measurement through plume using the sun as the light source
- Differential Absorption Lidar (DIAL) - remote sensing using lasers to scan through plumes

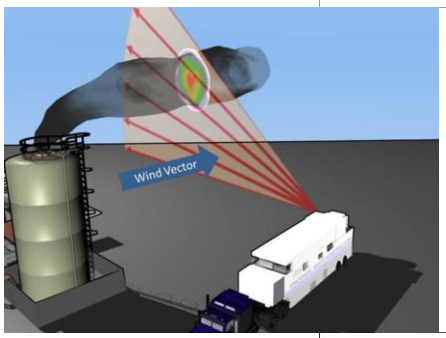
Flux box for water treatment ponds.

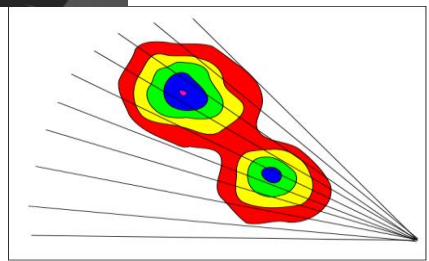
Also added in Tracer techniques (Release a tracer and measure VOC and tracer downwind) and reverse dispersion modelling.











BAT Conclusions

- **BAT 6. BAT is to monitor diffuse VOC emissions to air from the entire site by using all of the following techniques:**

- i. sniffing methods associated with correlation curves for key equipment;
- ii. optical gas imaging techniques;
- iii. calculations of chronic emissions based on emissions factors periodically (e.g. once every two years) **validated by measurements**.

The screening and quantification of site emissions by periodic campaigns with optical absorption-based techniques, such as differential absorption light detection and ranging (DIAL) or solar occultation flux (SOF) is a useful complementary technique.

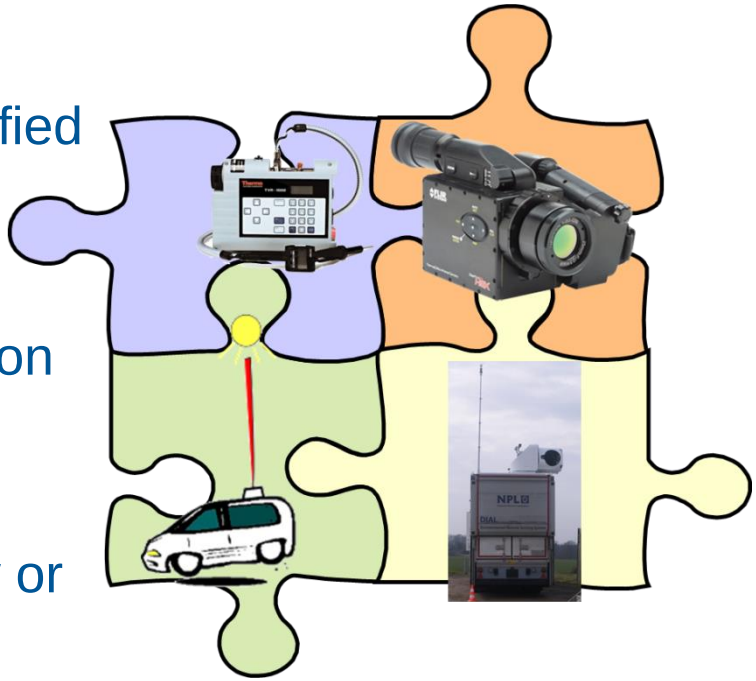
- Full screening and quantification of site emissions can be undertaken with an appropriate combination of complementary methods, e.g. Solar occultation flux (SOF) or differential absorption lidar (DIAL) campaigns. These results can be used for trend evaluation in time, cross checking and updating/validation of the ongoing LDAR programme.

European Standard Development

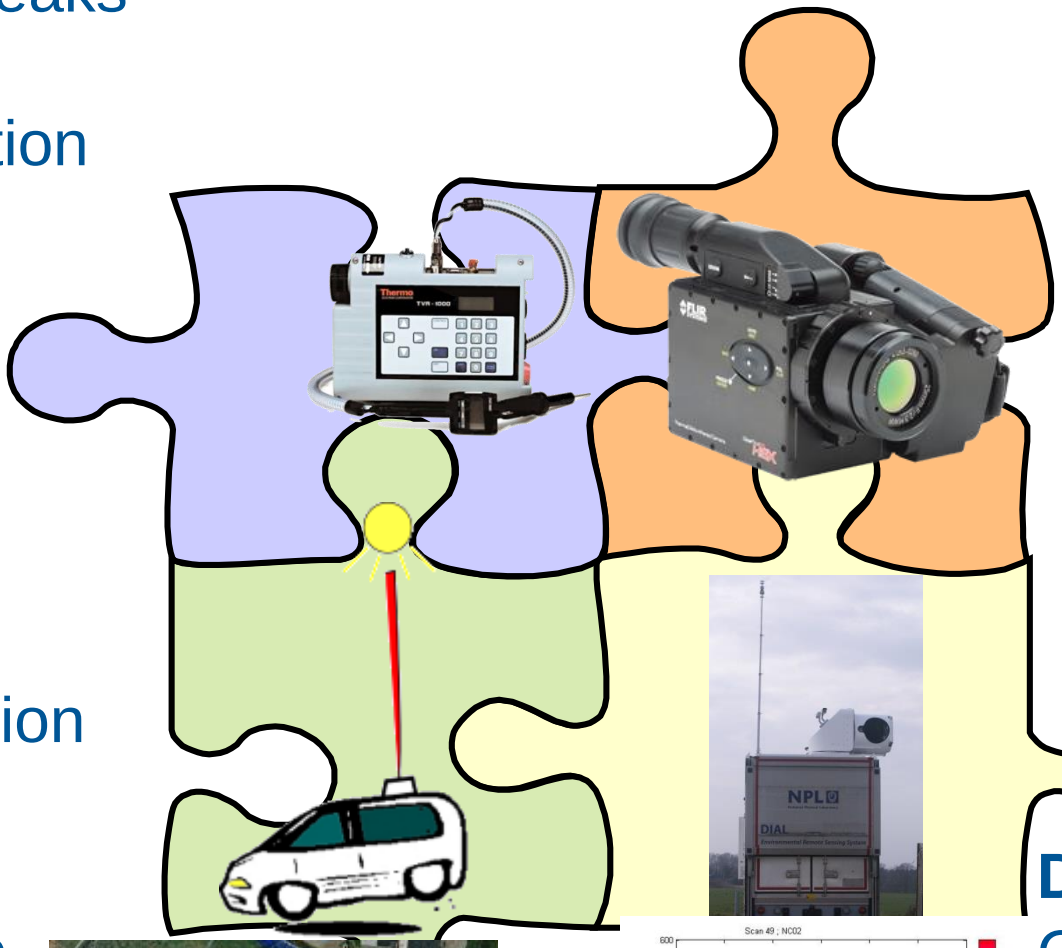
- Development of European standard to cover methods in refinery BREF
  - Focussed on industrial VOCs but applicable to methane
- Determine Fugitive and Diffuse emissions
  - DIAL, SOF, OGI, Tracer, Sniffing (EN 15446), Flux box, Calculations
- Standard currently being developed
  - TC 264, WG38
- Validate the standard with 2 field campaigns – funded by EU
  - One used the CRF
- Structure is a framework enabling user to select correct measurement methods
  - Role and capabilities of each technique – they do different things
  - Performance characteristics and requirements
  - QA/QC to carry out each technique

Concept of the standard

- Toolbox of techniques
  - Strengths of different techniques
  - Framework in which they can be used
  - Whole site emissions covered and quantified
  - Main sources identified
- Concept
  - Identification, localisation and quantification
  - Different scales
    - sniffing / OGI – equipment leak level identification and quantification (hi flow or tracer correlation)
    - DIAL – area/unit level building up to full site
      - spatially resolved concentration + emission rate
    - SOF – whole site flux focussing in on areas
      - cover wide area quickly

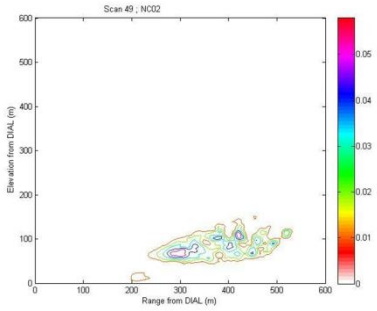


Sniffing
Identifies leaks
'Quantify'
by correlation
Or hi-flow
sampler



OGI
Identifies leaks
Visualisation
No direct
quantification

SOF
Concentration
in vertical
column
Cover wide
area very
quickly



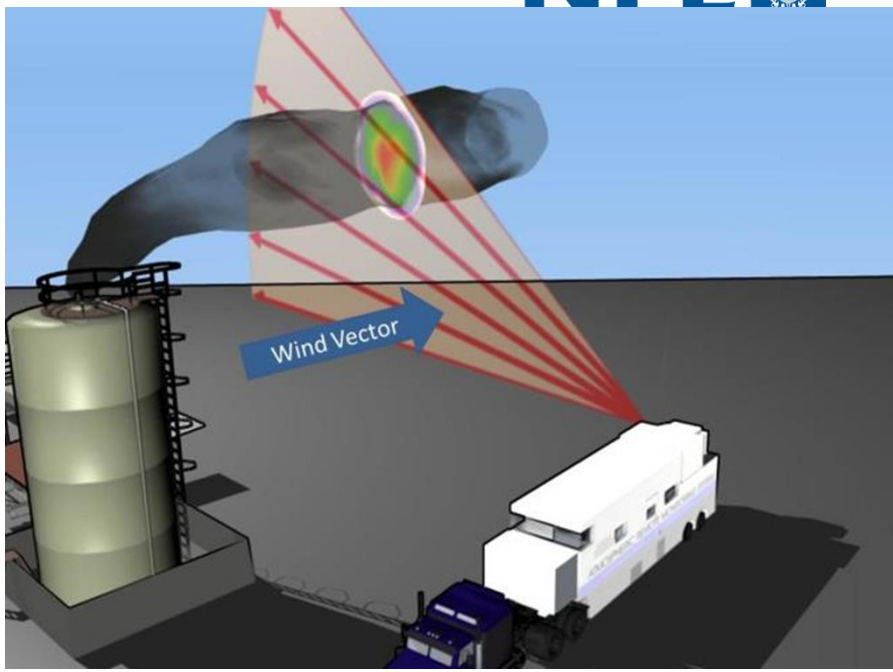
DIAL
Concentration
spatially resolved
Plume location and
quantification

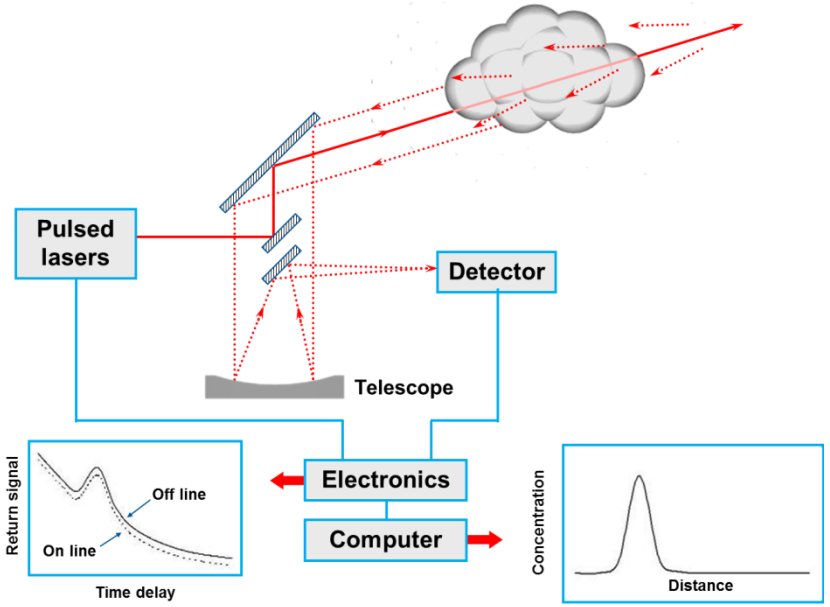
Contents of standard

- Minimum performance requirements
- Protocols for using DIAL/SOF
  - Measurement planning
  - System configuration/set up
  - Measurement strategy
  - Measurement method
- Quality control
  - Calibration
  - Spectroscopy
  - Meteorological instruments
- Data analysis
- Reporting
- Uncertainty

DIAL technique

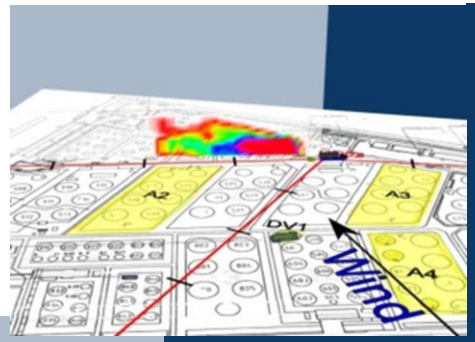
- Differential Absorption Lidar
- Laser Radar system targeted on gas measurements.
- Gives range-resolved concentration along optical path.
- Measurement beam can be scanned to map concentration distribution.
- Able to measure wide range of species :
  - VOCs including methane, ethene, methanol, and general hydrocarbons
  - SO_2, NO_2, NO, Hg, HCl
  - Benzene, Toluene, Xylenes
- Spatial resolution <8 metres
- Range typically 300-800m in IR, UV > 1km

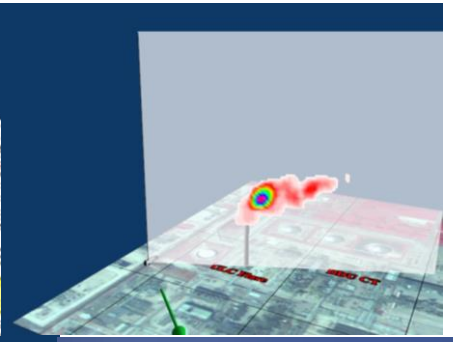


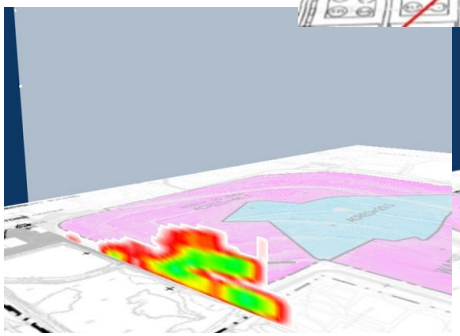


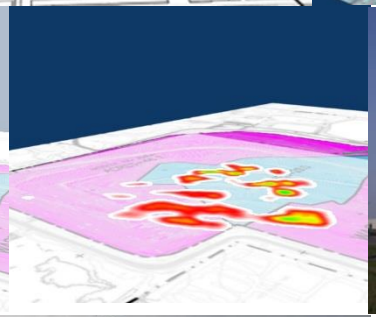
DIAL measurements

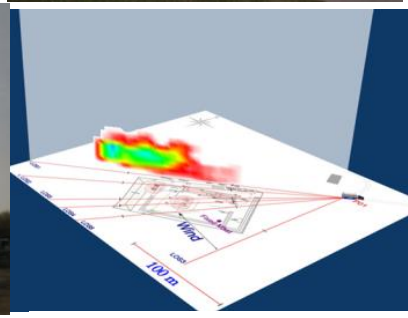
- DIAL has been used for measuring emission rates from a range of sources for over 25 years
- Refineries
- Flares, tanks,
- Landfills
- Onshore oil production
- Emission plumes
- Gas stations
- Lots of previous validation

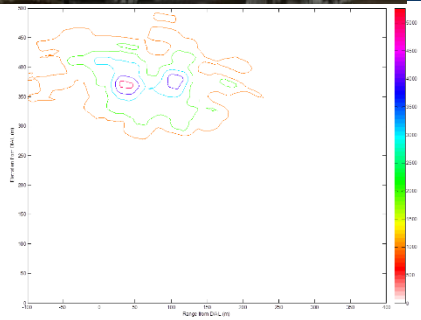


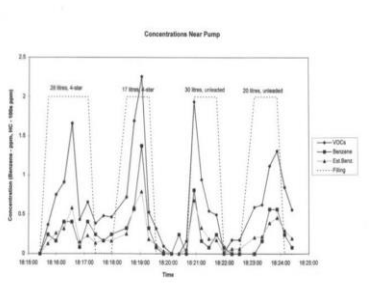








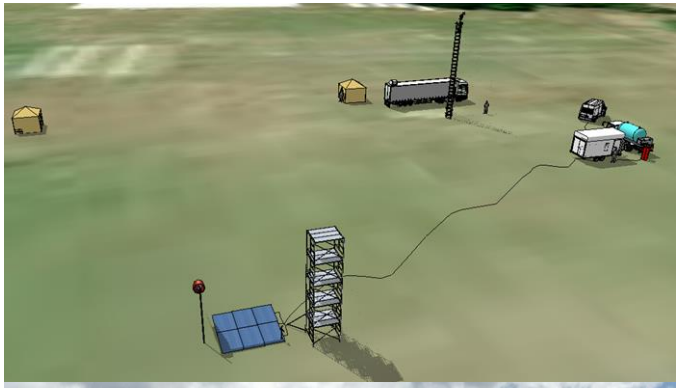


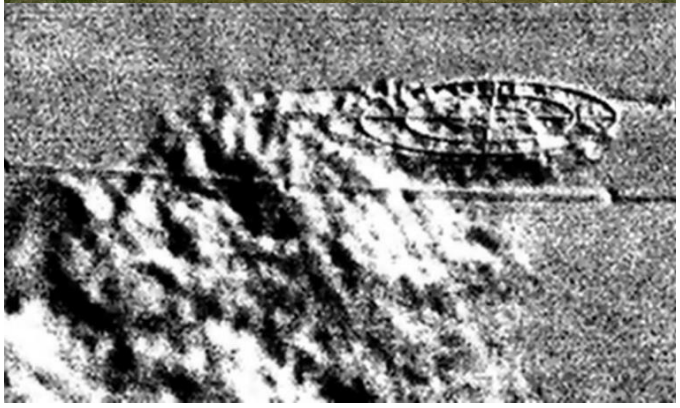


"Infrared Differential Absorption Lidar (DIAL) measurements of hydrocarbon emissions" J. Environ. Monit. 2011.13.2213. Rod Robinson, Tom Gardiner, Fabrizio Innocenti, Peter Woods and Marc Coleman.

AREA SOURCE EMISSIONS FACILITY

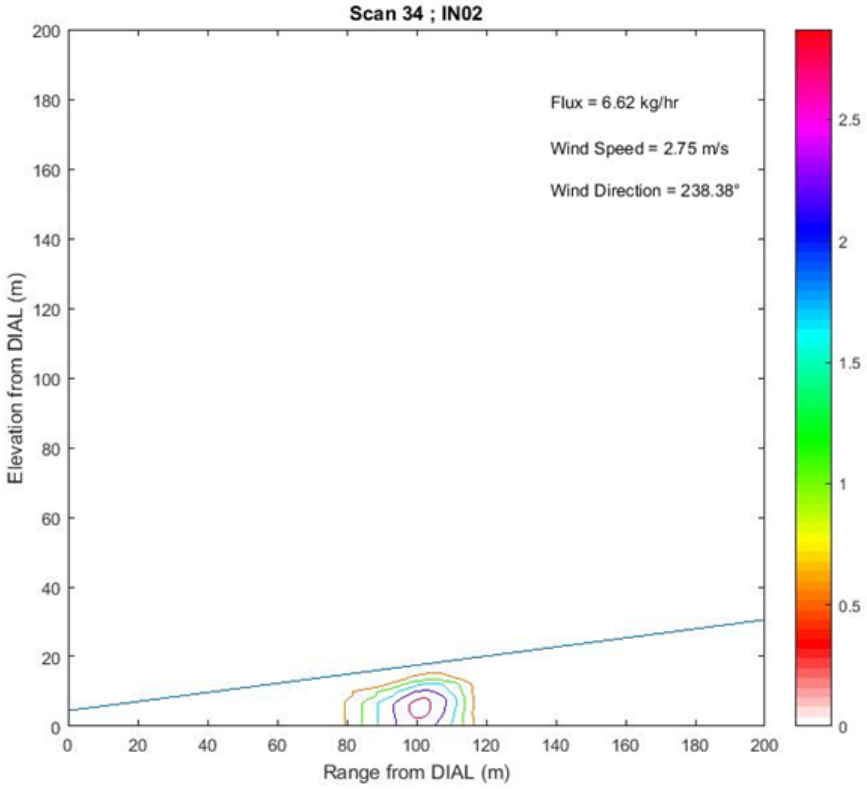
- A high flow gas blending system was constructed that allows gas species to be released at controlled rates comparable to small-medium industrial emissions: (1.1 – 55 kg.h^{-1} for C_3H_8; 0.7 – 36 kg.h^{-1} for CH_4; and 2 – 99 kg.h^{-1} for CO_2).
- The system is entirely computer controlled, and is operated remotely via an umbilical cable.
- The system is housed within a 3.5 tonne trailer making it easily transportable.
- Gas dispersion from nodes has been validated using several techniques including DIAL and Optical Gas Imaging (OGI) technology.
- The system has been successfully utilised in a number of campaigns to date, including replicating emission sources from shale gas processing equipment.
- Work is continuing to develop larger diffusive emission nodes.

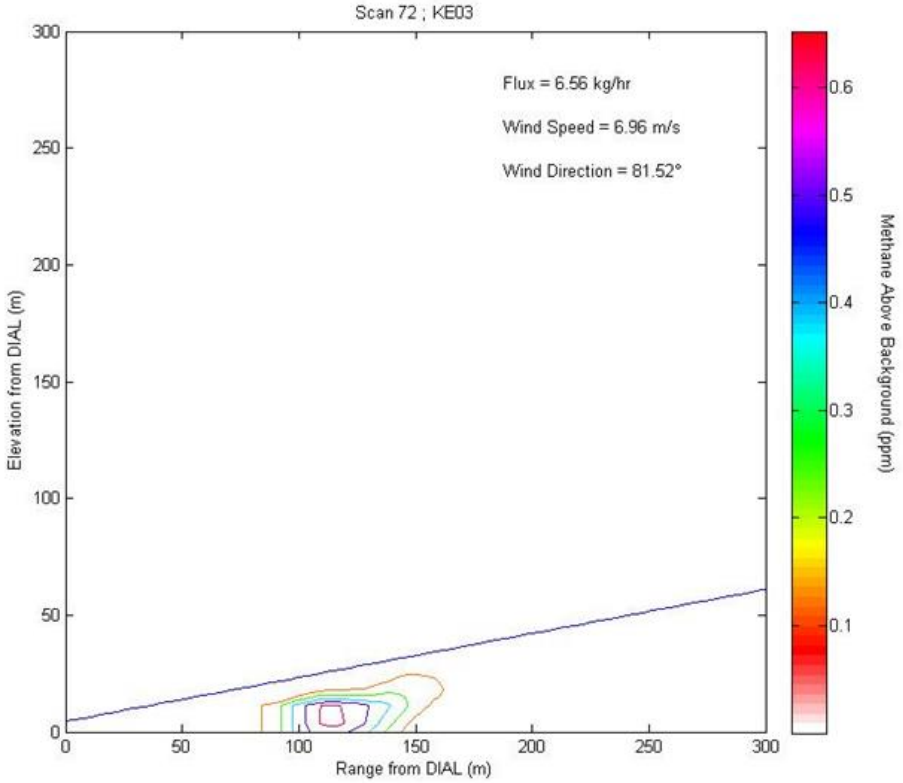





NPL
DIAL

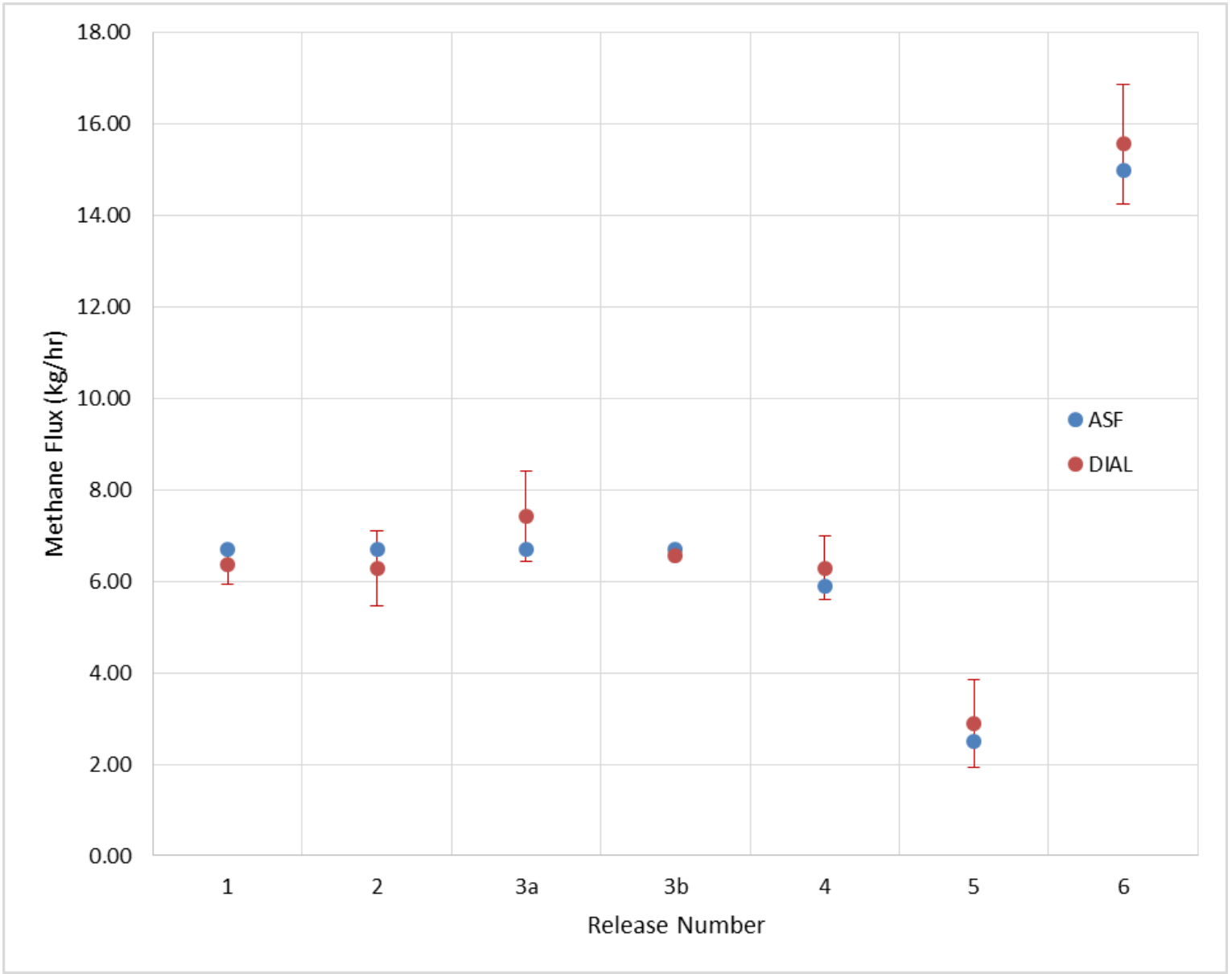
ASF release





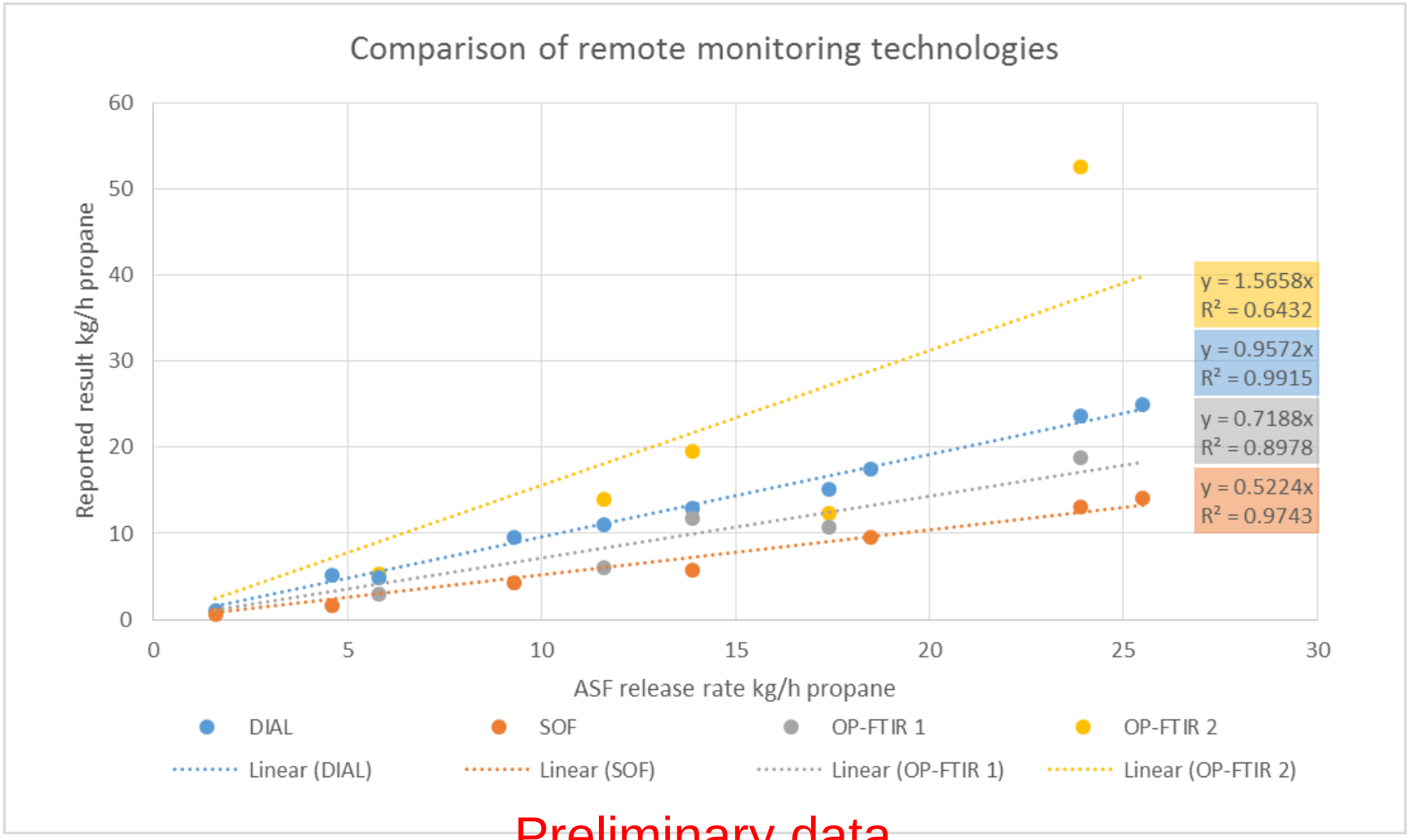
Real world site

DIAL results compared to controlled release (ASF)



Los Angeles, October 2015

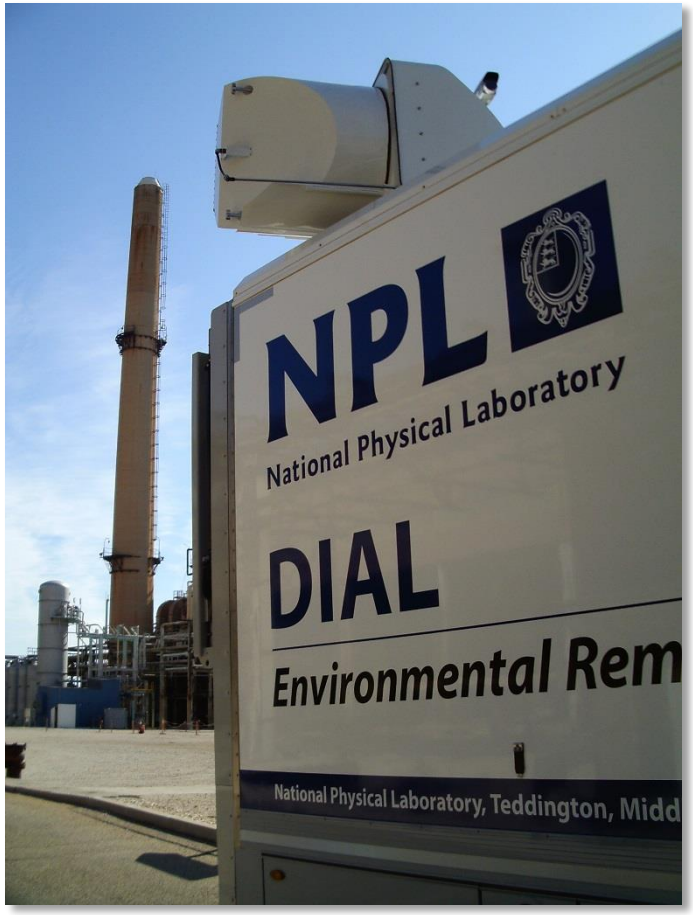
Elevated C_3H_8 release to replicate petrochemical plant emissions. DIAL, SOF and OP-FTIR compared.



Preliminary data

Validation campaign

- Intercomparison of remote sensing technologies measuring VOCs –DIAL, SOF, N_2O Tracer correlation; and an inverse dispersion model.
- CRF source nodes released propane gas while embedded within the structure of a cracking/reforming plant.




TOTAL

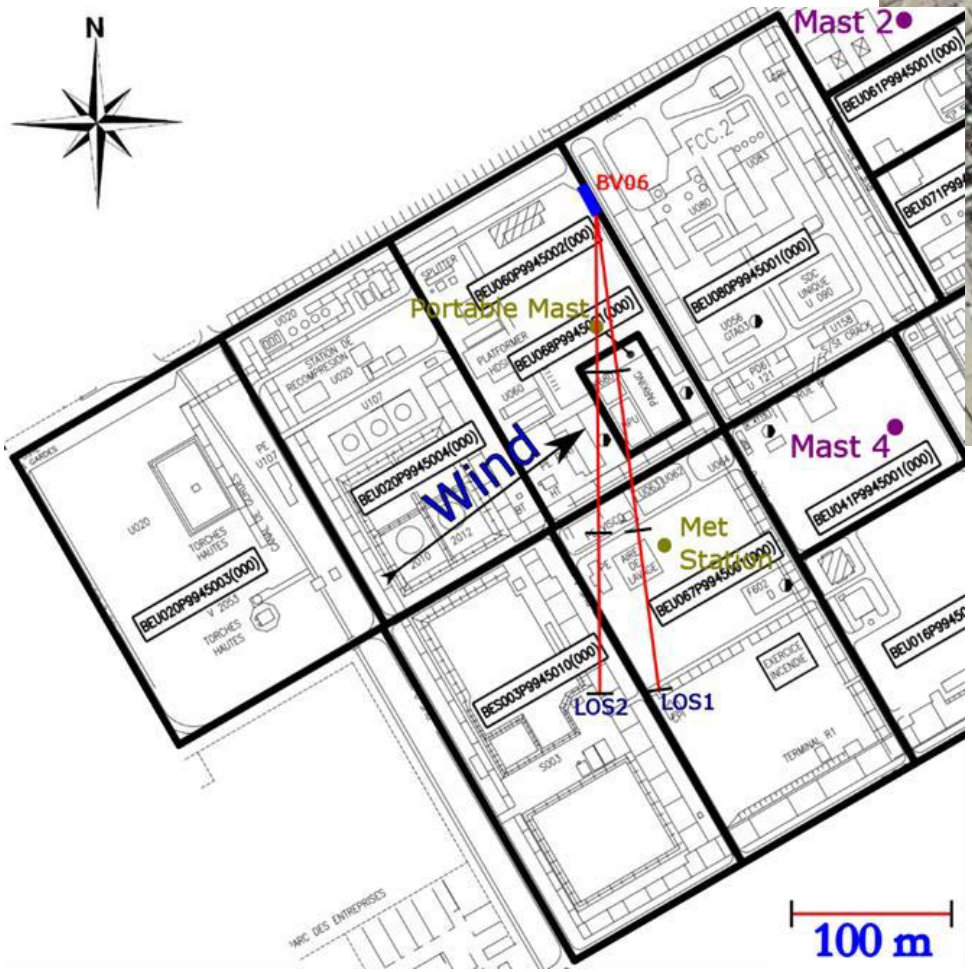

NRM 696

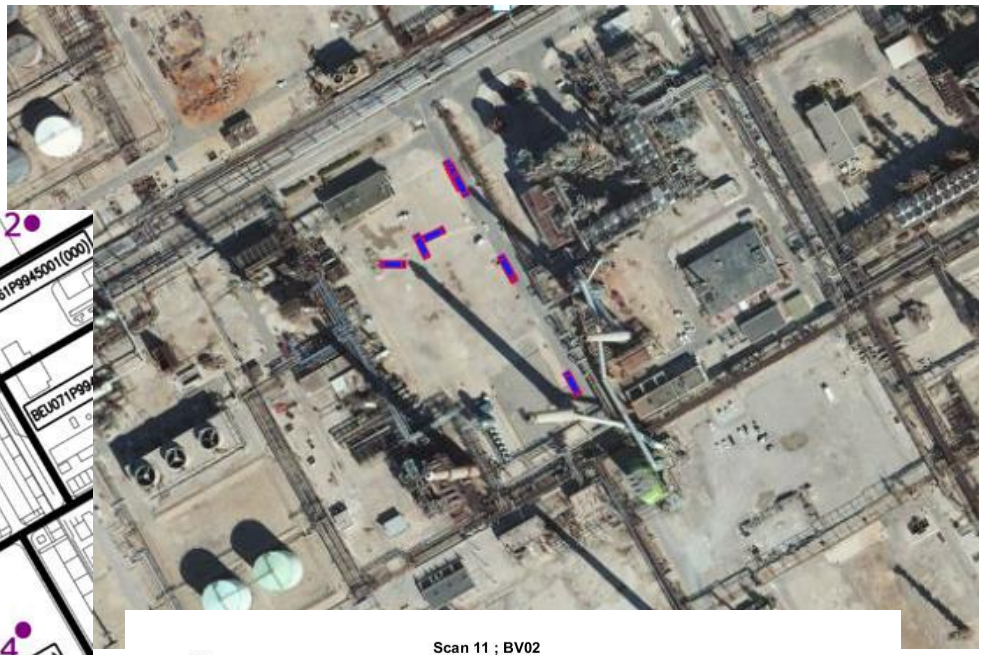

NPL
National Physical Laboratory
DIAL
differential absorption lidar
Environmental Remote Sensing System
National Physical Laboratory, Teddington, Middlesex, TW11 0LW, UK | Switchboard: +44 20 8977 3222 | www.npl.co.uk
Laser
VOLVO

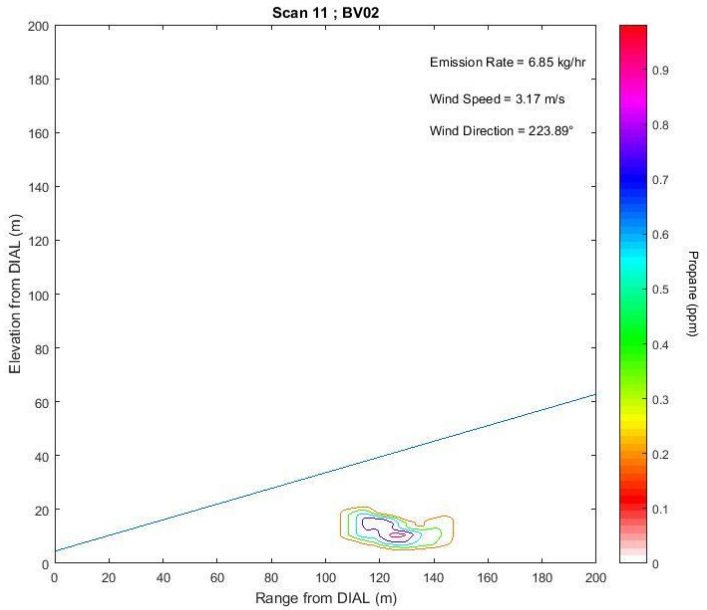

PROTECTION
AUDITIVE
OBLIGATOIRE


INERIS

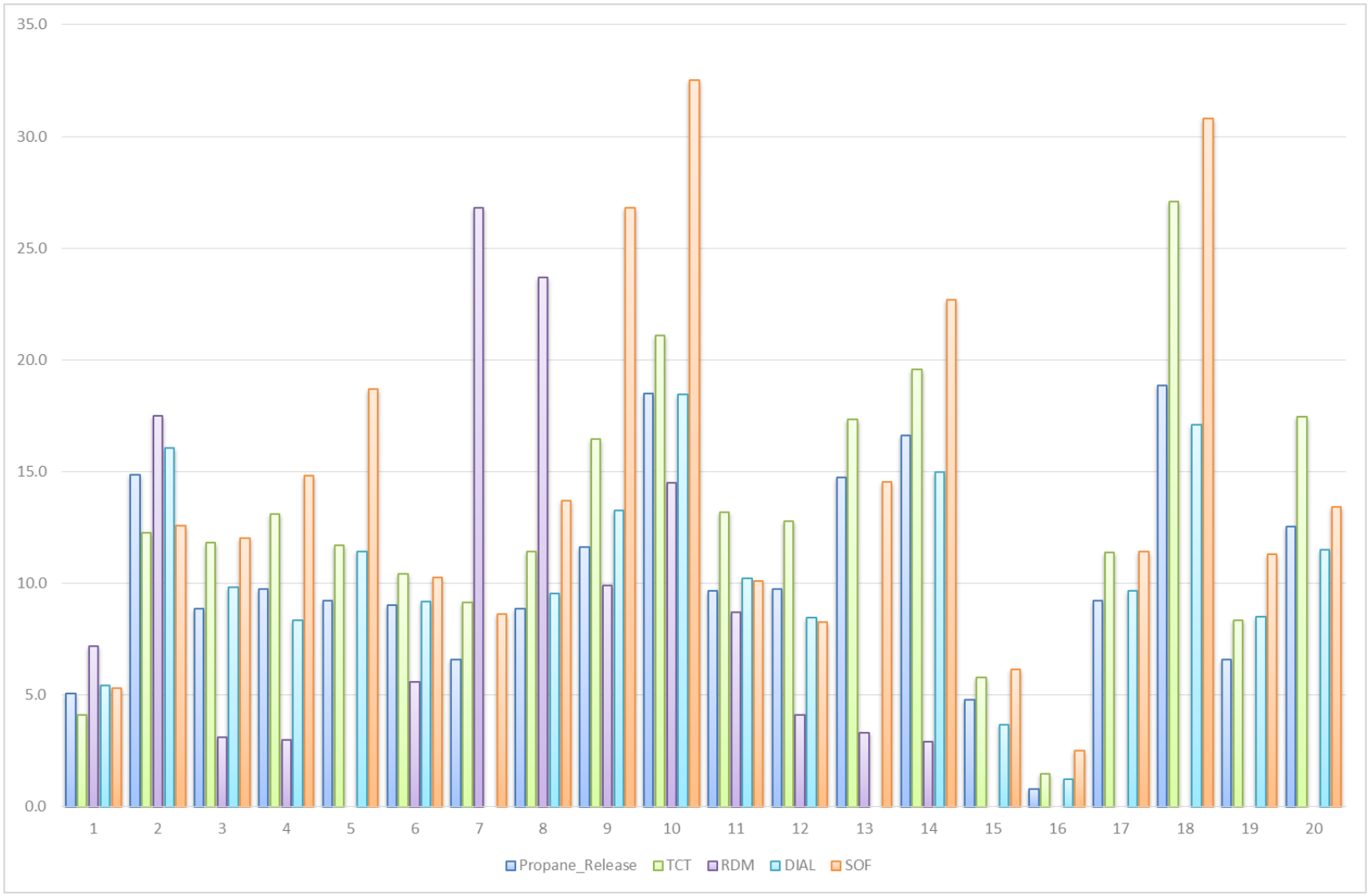
Example DIAL measurement







Initial results from field campaign



IMPRESS

- Provided protocols for SOF and DIAL as input into standardisation process
- Provided data on performance of DIAL
- Provided controlled release facility for validation
- Provided additional field validation

Thank you
Any Questions ?