Parameter Trade Studies For Coherent Lidar
Wind Measurements of Wind from Space

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Hybrid Doppler Lidar Concept

Complementary Lidars Together Lower Total Mass, Power, Cost, Risk

**Green** represents percentage of sampled volumes when coherent subsystem provides the most accurate LOS measurement; **Yellow** is for direct detection; **Gray** is when neither system provides an observation that meets data requirements.

When two perspectives are possible

**Green:** both perspectives from coherent system

**Yellow:** both perspectives from direct molecular

**Blue:** one perspective coherent, one perspective direct
GWOS Mission Study

- Hybrid Doppler lidar
- 400 km, 45 deg nadir, 4 azimuth angles
- Coherent lidar:
  - 0.25 J, 5 Hz, 2.053 microns, 180 ns
  - 0.5 m receiver diameter
  - 60 shot accumulation attempted; 12 s; 85.2 km
  - Pattern repeat = 4 x (12 + 1.5) = 54 s = 390 km
- 1 m/s design 1-σ wind turbulence (broadens sig. spectrum)
- 0.5 m/s 1-s laser difference frequency knowledge error
- No vertical shear of horizontal wind velocity (always aligned with beam: broadens signal spectrum)
- Sampling/representativeness error = 0.62 m/s (85 km line in 100 km box)
Specific GWOS Operating Point
For Trade Studies

- 5 km altitude wind measurement height
- Enhanced aerosol levels; $\beta = 2.75 \times 10^{-8} \text{ m}^{-1}\text{sr}^{-1}$
- Vertical resolution = 2000 m
- $\varphi = 4.5$ (# coherent photoelectrons per range gate per shot)
- 60 shots accumulation attempt
- $\Pr\{\text{good}\} = 0.95$
- Lidar LOS velocity error = 1.5 m/s
- Lidar horizontal velocity error = 2.0 m/s
- With sampling error, total horizontal velocity error = 2.1 m/s
Pulse Energy vs. PRF

- Hold $Pr\{\text{good}\} = 0.95$
- Velocity error does not change

Favors higher PRF?

nominal operating point
Laser Power vs. PRF

- Hold $P_{\text{good}} = 0.95$
- Velocity error does not change
- Laser Power = Energy $\times$ PRF

Favors lower PRF?
Relative LDA Lifetime vs. PRF

- Hold \( Pr\{\text{good}\} = 0.95 \)
- Velocity error does not change
- LDA lifetime probably reflects laser lifetime

Favors higher PRF?
PRF vs. LDA Lifetime

• Hold \( \text{Pr\{good\}} = 0.95 \)
• Velocity error does not change
• Lifetime in **seconds** more important than lifetime in shots
  (seconds = shots/PRF)

Favors lower PRF?
Pulse Energy vs. Pulse Duration

- Hold Pr{good} = 0.95
- Velocity error fairly constant above 180 ns (5% bad estimates dominating)

Outside the validated parameter range of the performance parameterization
Pulse Energy vs. Telescope Diameter

- Assume scanner does not reduce collection area
- Assume $1-\sigma$ transmit/receive misalignment angle fixed at 3.082 $\mu$rad
- Hold $\text{Pr}\{\text{good}\} = 0.95$ and velocity accuracy constant

- Larger diameters have more SNR loss for fixed misalignment angle
Pulse Energy vs. Nadir Angle

- Hold $P_r\{\text{good}\} = 0.95$
- Above 70 degrees misses the earth

- Spherical earth steepens the slope
Velocity Error vs. Nadir Angle

- Hold Pr\{good\} = 0.95
- Above 70 degrees misses the earth

- Laser beam more horizontal at larger nadir angles
Velocity Error x Pulse Energy vs. Nadir Angle

- Hold Pr{good} = 0.95
- Above 70 degrees misses the earth

- Broad optimum from 25 – 45 degrees
• Hold $P_{\text{good}} = 0.95$
• Above 70 degrees misses the earth

• Broader optimum; what other figures of merit are there?
Pulse Energy vs. Vertical Resolution

• Hold Pr\{good\} = 0.95

1/SQRT(RES)

• Wind shear increases required pulse energy
Wind shear greatly increases velocity error
Dilemma: pulse energy and velocity error favor oppositely
(Energy x Error)$^{-1}$ vs. Vertical Resolution

- Wind shear case has optimum vertical resolution
Pulse Energy vs. Velocity Search Bandwidth

- Full search bandwidth in horizontal direction for last pass through the data
- Hold Pr{good} = 0.95

- Significant effect on pulse energy
Velocity Accuracy vs. Velocity Search Bandwidth

- Full search bandwidth in horizontal direction for last pass through the data
- Hold Pr\{good\} = 0.95

- Large effect on velocity error
- Bad wind estimates dominate error
Summary and Conclusions

• NASA LaRC computer simulation of global wind profiling coherent-detection Doppler lidar uses latest published theory
• Simulation permits parametric trade studies with choice of parameters held constant
• Tool should prove useful in mission design and guide to parameter goals for technology under development
• There are many more possible trades than are shown here
• Desire to incorporate optic component aberrations, laser beam intensity and phase description, and misalignment rigorously into theory
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