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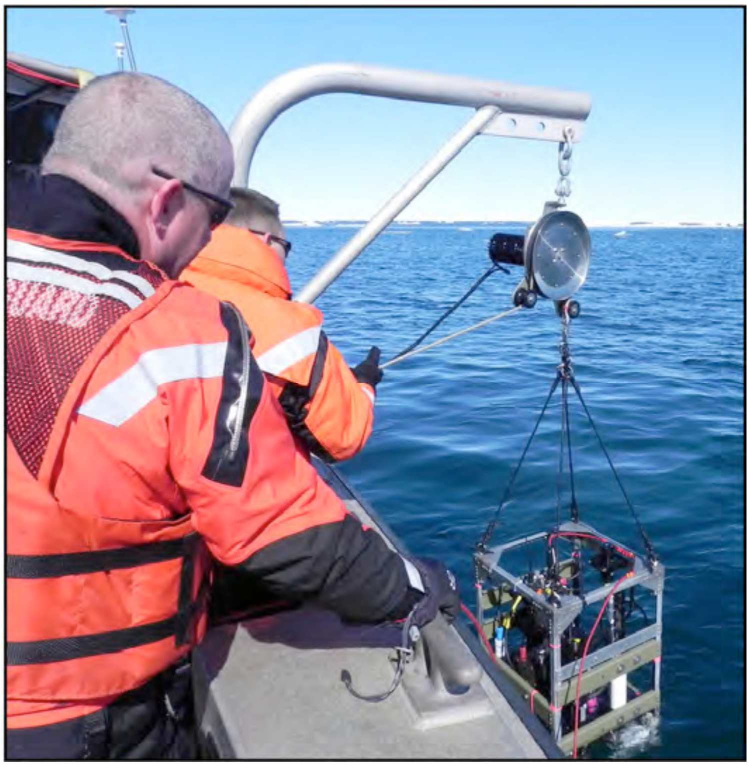

The Cable Hauler for Optical In Situ *Technologies (C-HOIST)*

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Chapter 8

The Cable Hauler for Optical *In Situ* Technologies (C-HOIST)

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Abstract

Because of their large size and weight, IOP instruments are usually mounted inside a large metallic frame and require significant resources to deploy over the side of a ship, e.g., a hydraulic winch and an A-frame. In comparison, modern free-fall AOP profilers, like C-OPS, are sufficiently small in size and weight to be deployed by hand. For small boat operations, AOP instruments are easily accommodated, but IOP sensors usually are not. Most small boats are equipped with a davit for deploying small packages into the water, which, when combined with a COTS system used by the commercial fishing industry, provides a solution to the IOP instrument frame problem. The capabilities of this new deployment system, called the Cable Hauler for Optical *In Situ* Technologies (C-HOIST), is presented along with results from the field commissioning of the prototype. The significant advantages of C-HOIST are as follows: a) the power head uses 12 VDC power, which is available on most small boats; b) there is no need for hydraulics; c) the payload can be raised or lowered very slowly; and d) it can be used with standard synthetic line of any length—there is no need for an integral drum of cable.

8.1 Introduction

For most field campaigns, it is desirable to collect contemporaneous IOP measurements during, or in close temporal proximity to, AOP observations (many U.S. research vessels do not permit more than one *wire* over the side at once). For small-boat operations, like those described earlier during Malina and ICESCAPE (Sect. 7.2), the difficulty is in dealing with the large size and weight of IOP instruments in comparison to the smaller and lighter modern AOP profilers. This distinction is best summarized by the fact that IOP instruments usually require a winch and A-frame for deployment, whereas AOP instruments are routinely deployed by hand.

IOP sensors are usually mounted inside a large frame, and even if the frame is built from lightweight materials, the total weight of all the equipment needed for IOP observations can be on the order of 40 kg or more. It is not unusual for IOP systems to be so heavy—wheels are attached to the bottom of the frame to make it easier to move around on deck. Part of the reason for the large size and weight is the larger diversity in IOP variables (and, thus, instruments) than AOP light-field components, coupled with the desire to have more information about water column properties to interpret those variables, but there are also simply more components for each instrument (some, for example, require external pumps).

The net effect of the rather large and heavy instruments mounted inside a bulky frame is a requirement for some significant ship resources for safe deployment, that is, a hydraulic winch and an A-frame are needed. This is a rather difficult requirement for many small boats. The vessels launched from the icebreakers used during the Malina and ICESCAPE field campaigns, for example, did not have A-frames and they did not have hydraulic winches. Instead, they had small davits (or J-frames) and electrical winches with small-diameter stainless steel cables that were not very long in length (40 m or less).

The small-diameter cable is a concern, because it is hard to handle by hand, and many aspects of deploying or recovering a frame from a small boat require handling by the scientists or crew. A more desirable situation is to be able to use standard synthetic line with an outer diameter more in keeping with normal at-sea practices (e.g., 3/8 or 1/2 in). For a normal electromechanical winch, the larger the diameter of the line, however, the larger the size of the winch drum and, thus, the size of the winch. The amount of line that can be wound on the winch decreases as the line diameter increases, so a limiting size quickly emerges if the winch size is going to be kept small.

Adding to the difficulty of obtaining a small winch is the desire to run the winch on 12 VDC, because it is the most practical power source on small boats. There is also the problem of being able to lead the line from the winch through a pulley on the davit. In most situations for deploying with a davit, the davit is rotated to facilitate deploying and recovering the instrument package over the side of the boat. Any needed movement of the davit adds to the complexity of leading the line from the winch to the davit; therefore, a solution that easily accommodates this requirement is substantially more useful than one that does not.

8.2 Description

For small research vessels that do not have a winch and an A-frame that can lift and deploy a heavy instrument frame, but do have a davit (which is a common piece of equipment on small boats), the only practical solution is to either a) create two or more smaller subunits that can be deployed by hand, or b) bring a device that can fulfill the task. With the former, simultaneity of observations is lost, plus it is not easy to smoothly control the descent and ascent of the package by hand, except for very small instruments, so the vertical resolution of the sampling is not very uniform.

The solution adopted by the CVO was to work with BSI to modify an existing capability to solve the IOP deployment problem. The solution is based on what is called a *pot puller*, which is used by the commercial fishing industry for raising and lowering shrimp pots, or lobster and crab traps, over the side of small boats. Any of these can be quite heavy, so pot pullers with a 300 lb capacity are common.

Fishermen want to get their work done quickly, because every hour at sea is costly and reduces profitability, so pot pullers are designed to pull line in at a high velocity. Scientists making IOP measurements, on the other hand, prefer slower line speeds, so the vertical sampling resolution can be as high as possible—particularly in shallow, optically complex waters, like the coastal zone. Consequently, part of the design problem for using a commercial pot puller as the basis for C-HOIST was producing a speed control capability.

8.3 Design

The pot puller is a light-duty COTS model that is used extensively by commercial fisherman. It is equipped with a stainless steel self-grip sheave, 2.1 HP 12 VDC electric power head, 8 AWG wiring harness, 80 A circuit breaker, and has a 300 lb capacity. The gearbox assembly, which is part of the power head unit, is a *differential planetary* design that is an extremely strong and reliable unit. The gear ratio is 159:1, which means the motor turns 159 revolutions for every revolution of the sheave. The reduction unit is sealed with a life-time lubrication grease (a high pressure, EP-2 rated, lithium-based grease).

The motor assembly is O-ring sealed to prevent saltwater intrusion from spray or wash down after use at sea. Metal components are either stainless steel or powder coated for corrosion resistance. The electric motor draws 30–80 A during normal operations. If operated using a 90 A hr lead-acid (sealed) battery, approximately 25 casts lasting 6 min each can be performed before the battery needs recharging.

The sheave design eliminates the need to thread the line through complicated idler wheels and pulleys. The line is simply laid into the sheave and around the idler wheels. A light downward pull seats the line between the rubber lined sheave, which grips the line for both paying out and hauling in line. The sheave line capacity is 0.25–0.75 in. Because the line is not wound onto a drum by the power head, the line can be as long or as short as desired. There is no line length limit, and the pot puller will pull line as long as the power source is available. For the ICESCAPE campaign, the pot puller was wired into the small boat 12 VDC power system.

To provide a range of slower deployment options, the STP-2100 was mated to a deck box control unit built by BSI. The principal purpose of the deck box was to provide a speed control capability and modular power connection, that is, power from the small boat was the input to the deck box and the output was the regulated power for the pot puller. For making IOP casts, slow ascents and slow descents are equally important. In the Arctic, melt water and riverine sources can produce a thin surface layer of water with significantly different optical properties than the water below. Consequently, there was also the need to be able to sample the near surface layer(s) very slowly and then to speed up to save time.

The variable speed control of the deck box was based on a regenerative DC-to-DC drive. Most nonregenerative variable-speed DC drives control current flow to a motor in only one direction. The direction of the current flow is the same direction as motor rotation (if a motor is reversible, there are two control options). Regenerative drives can also provide motor torque in the opposite direction of motor rotation. This allows a regenerative drive to reverse motor direction without contacts or switches to control an overhauling load, and to decelerate a load faster than it would take to coast to a lower speed.

The specific regenerative drive used with C-HOIST accepts an input voltage of 10–32 VDC, provides speed regulation to within 1%, and has a maximum (peak) armature current of 120 A (250 A). The electronic control board is sufficiently compact, about $7 \times 5\,\mathrm{in}^2$, to fit inside the same small waterproof case used by BSI for their standard instrument deck boxes. Speed adjustment for paying out or hauling in line is set using a potentiometer, which is manipulated using a knob mounted on the top of the deck box.

There are three other switches on the deck box, which provide the rest of the operational controls:

- The *Hoist Enable* switch turns the power to the power head on and off.
- The *Brake* switch enables motor torque to keep the sheave stationery.
- The *Direction* switch toggles the direction the motor is turning.

The power head is connected to the davit with a swivel, so the direction for paying out or hauling in line is arbitrary and is set by the orientation of the entire assembly on the davit. Consequently, direction control simply reverses whatever is the present setting (which can be initially set or changed before line is threaded through the sheave by rotating the entire pot puller).

8.4 Operation

A picture of the prototype C-HOIST unit being used during an ICESCAPE station is shown in Fig. 75. The pot puller is hanging immediately below the end of the curved davit. The large silver disc is the self-grip sheave. To the left of the sheave is the black power head, and below the sheave are the two black idler wheels. The line attached to the IOP frame threads to the left of the idler wheel immediately below the sheave, around the sheave, and then to the right of the idler wheel below and to the left of the sheave. Not shown in the picture is the person operating the deck box to control the ascent and descent of the frame.

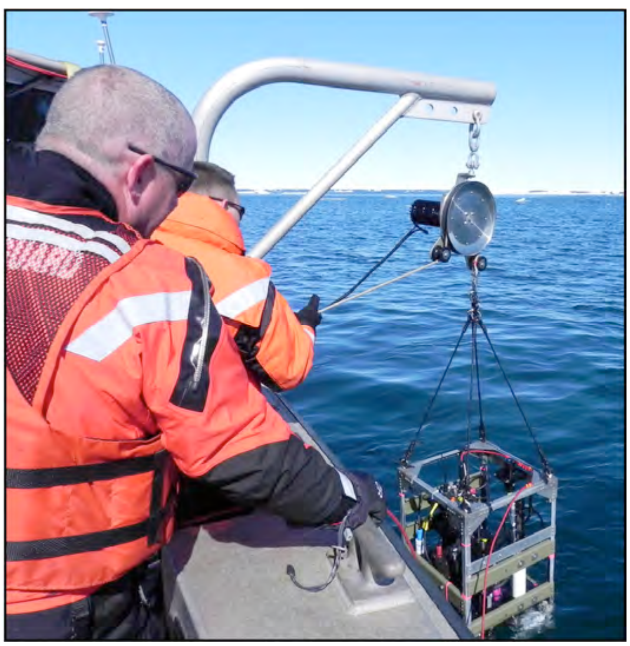

Fig. 75. The prototype C-HOIST unit being used during the ICESCAPE campaign from the davit on the small boat launched from the icebreaker USCGC *Healy.*

8.5 Testing

The C-HOIST power head is a COTS device for light-duty commercial crab fishing, but the motor drive and deck box are assembled by BSI. The 80 A system is rated for 300 lb dead-weight lifting. The revised cruise schedule for the ICESCAPE field campaign did not permit extensive testing or local field deployment of the prototype. In-house testing consisted of attaching the power head to an overhead steel beam and testing the main functions when powered by a 12 VDC lead-acid marine battery. This testing included retention of a large (100 kg) weight in both unpowered and dynamic hold (*brake*) states, very slow and maximum retrieve speed testing with a large (100 kg) weight, and idle testing with the deck box power turned on for hours. The temperature of the drive controller and head was monitored during all testing, and overheating was never observed under any conditions.

Field commissioning of the prototype C-HOIST during the ICESCAPE cruise consisted of more than 30 profiles of the NASA IOP frame in a variety of sea states. Unfortunately, the prototype suffered an unknown failure during the recovery of the frame on cast number 33, under light-to-moderate conditions. Disassembly of the power head aboard ship did not reveal the cause of failure and field testing was terminated.

A post-mortem conducted by BSI on the deck box confirmed it was functioning correctly and had no fault conditions. The power head was returned to the manufacturer where no mechanical or motor failure was discerned. Given the information available, the most likely candidate for the field failure is the system circuit breaker, which consisted of two 40 A thermal breakers operating in parallel. The breakers are of the type featuring automatic reset and no trip indicator. The circuit breakers have been respecified for single 80 A operation with trip indication and manual reset.

8.6 Summary

The C-HOIST device is a COTS electrical fishing winch with custom speed and direction control that can be operated from a small davit to aid deployment and retrieval of lightweight (less than 100 kg) instrument packages from almost any size boat. The system is designed to be transportable, and can be operated from any 12 VDC source with sufficiently high current capacity, including a single marine battery. The sheave on C-HOIST is designed to accept line or cable diameters up to 0.5 in, but unlike a winch, the line or cable used with C-HOIST is not spooled on the assembly, and any convenient length can be used (assuming appropriate caution is used when the remaining line on deck is reduced to a short length). The system requires two operators; one to operate the power head controls attached to the deck box, and one to control and feed the line out to the instrument package.

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Glossary

3GμR Three-Gain Microradiometer

A/D Analog-to-Digital
ADC Analog-to-Digital Converter
AERONET Aerosol Robotic Network
AOI Angle of Incidence
AOPs Apparent Optical Properties
ASCII American Standard Code for Information Interchange
AWG American Wire Gauge

BATS Bermuda Atlantic Time Series
BioGPS Biospherical Global Positioning System
BioOPS Biospherical Optical Profiling System
BioPRO Biospherical Profiler
BioSHADE Biospherical Shadowband Accessory for Diffuse Irradiance
BioSOPE Biogeochemistry and Optics South Pacific Experiment
BioSORS Biospherical Surface Ocean Reflectance System
BOUSSOLE *Bouée pour l'acquisition de Séries Optiques à Long Terme* (literally translated from French as the "buoy for the acquisition of a long-term optical series.")

CCGS Canadian Coast Guard Ship
CCW Counterclockwise
CDR Climate-quality Data Record
CERBERUS Compact Environmental Radiometer Buoyancy Enhancements for Rate-Adjusted Underwater Sampling
C-HOIST Cable Hauler for Optical *In Situ* Technologies
C-OPS Compact-Optical Profiling System
COTS Commercial Off-The-Shelf
CSTARS Center For Southeastern Tropical Advanced Remote Sensing
CVO Calibration and Validation Office
CW Clockwise

DARR-94 The first SeaWiFS Data Analysis Round Robin
DARR-00 The second SeaWiFS Data Analysis Round Robin

EOS Earth Observing System
EPIC Enhanced Performance Instrument Class

FAFOV Full-Angle Field of View
FEL Not an acronym, but a lamp designator.
FPA Filter-Photodetector Assemblies
FOV Field of View
FWHM Full Width at Half Maximum

GPS Global Positioning System
GSFC Goddard Space Flight Center

HD Housing Diameter

ICESCAPE Impacts of Climate on Ecosystems and Chemistry of the Arctic Pacific Environment
IOPs Inherent Optical Properties
IR Infrared

LCD Liquid Crystal Display
LED Light Emitting Diode
LoCNESS Low-Cost NASA Environmental Sampling System
LOV *Laboratoire d'Océanographie de Villefranche*

MERIS Medium Resolution Imaging Spectrometer
microSAS micro-Surface Acquisition System
microSD Microsecure Digital (card)
microNESS micro-NASA Environmental Sampling System
miniNESS miniature NASA Environmental Sampling System
MMS Multiple Microradiometer System
MOBY Marine Optical Buoy
MODIS Moderate Resolution Imaging Spectroradiometer
MODIS-A Moderate Resolution Imaging Spectroradiometer-Aqua
MODIS-T Moderate Resolution Imaging Spectroradiometer-Terra

NASA National Aeronautics and Space Administration
NEI Noise Equivalent Irradiance
NER Noise Equivalent Radiance
NIR Near Infrared
NIST National Institute of Standards and Technology
NMEA National Marine Electronics Association
NPT National Pipe Tapered

OBB Ocean Biology and Biogeochemistry
OCTS Ocean Color and Temperature Scanner
OSPREy Optical Sensors for Planetary Radiant Energy
OXR OSPREy Transfer Radiometer

PAR Photosynthetically Available Radiation
PCA Printed Circuit Assembly
PE Polyethylene
PGA Programmable Gate Array
POLDER Polarization and Directionality of the Earth's Reflectance
PP Polypropylene
PRR Profiling Reflectance Radiometer
psia Pressure per Square Inch Absolute
PU Polyurethane
PURLS Portable Universal Radiometer Light Source

QA Quality Assurance

RPD Relative Percent Difference
RSMAS Rosenstiel School of Marine and Atmospheric Science
RTD Resistance Temperature Detector
R/V Research Vessel

SAS Surface Acquisition System
SBIR Small Business Innovation Research
SeaBASS SeaWiFS Bio-optical Archive and Storage System
SeaFALLS SeaWiFS Free-Falling Advanced Light Level Sensors
SeaPRISM SeaWiFS Photometer Revision for Incident-Surface Measurements
SeaSAS SeaWiFS Surface Acquisition System
SeaWiFS Sea-viewing Wide Field-of-view Sensor
SHALLO Scalable Hydro-optical Applications for Light-Limited Oceanography
SIRREX SeaWiFS Intercalibration Round-Robin Experiment
SPI Serial Peripheral Interface
SPMR SeaWiFS Profiling Multichannel Radiometer
SQM SeaWiFS Quality Monitor
SS Stainless Steel
STAR Standardized Technologies for Applied Radimetry
SuBOPS Submersible Biospherical Optical Profiling System
SUnSAS SeaWiFS Underway Surface Acquisition System
SWIR Short-Wave Infrared
SZA Solar Zenith Angle

T-MAST Telescoping Mount for Advanced Solar Technologies

UAV Unmanned Aerial Vehicle
UPD Unbiased Percent Difference
USB Universal Serial Bus
USCGC United States Coast Guard Cutter
UTC Universal Time Coordinated
UV Ultraviolet

XTRA Expandable Technologies for Radiometric Applications

Symbols

C_a Chlorophyll a concentration.
$c_b(\lambda)$ The angular response error of the solar reference.
$C_c(\lambda)$ The spectral calibration coefficient.
$c_d(\lambda)$ The angular response error of the solar reference when measuring global irradiance.
$c_i(\lambda)$ The angular response error of the solar reference when exposed to isotropic radiation.
d The distance between the lamp and the diffuser faceplate.
$\bar{D}(\lambda)$ The average bias or dark voltage.
$E(\lambda)$ Spectral irradiance.
$E(z,\lambda)$ Spectral irradiance at a depth z.
$E(0^+,\lambda)$ The in-air spectral irradiance just above the sea surface.
$E(0^-,\lambda)$ The in-water spectral irradiance at null depth ($z = 0^-$).
$E_0(\lambda)$ The direct-normal spectral irradiance outside the Earth's atmosphere (irradiance on a plane perpendicular to the detector–Sun direction).
$E_a(0^+,\lambda)$ The spectral irradiance at the solar reference when the centers of the solar disk, shadowband, and diffuser are aligned and direct sunlight is completely occluded (at time t_v).
$E_b(0^+,\lambda)$ The direct-horizontal spectral irradiance (irradiance on a horizontal plane from direct solar illumination).
$E_{\mathrm{cal}}(\lambda,t_i)$ The spectral calibrated irradiance.
$E_d(z,\lambda)$ The in-water spectral downward irradiance profile.
$E_d(0^+,\lambda)$ The spectral global solar irradiance (from the Sun and sky on a horizontal plane).
$E_d^B(0^+,\lambda)$ The global solar irradiance measured by a bow sensor.
$E_d^S(0^+,\lambda)$ The global solar irradiance measured by a stern sensor.
$E_i(0^+\lambda)$ The spectral diffuse (sky) irradiance (irradiance from the sky on a horizontal plane).
$E_k(0^+,\lambda)$ The hypothetical spectral irradiance at the solar reference for the segment of the sky that is shaded by the shadowband when the band is at time t_v and the shadowband is at angle v.
$E_n(0^+,\lambda)$ The direct-normal spectral irradiance (irradiance on a plane perpendicular to the detector–Sun direction).
$E_p(0^+,\lambda)$ The spectral irradiance at the solar reference at time t_v when the band is at shadowband angle v and not blocking direct sunlight.
$E'_{p_B}(0^+,\lambda)$ An extrapolated spectral irradiance (at the solar reference) at time t_M using an interval denoted B.
$E'_{p_E}(0^+,\lambda)$ An extrapolated spectral irradiance (at the solar reference) at time t_M using an interval denoted E.
E_s A solar reference sensor.
$I_f(\lambda)$ The spectral immersion factor.
$K(\lambda)$ The spectral diffuse attenuation coefficient.
$K_d(\lambda)$ The spectral diffuse attenuation coefficient computed from $E_d(z,\lambda)$.
$L_i(0^+,\lambda)$ The spectral indirect (or sky) radiance reaching the sea surface.
$L_p(0^+,\lambda)$ The radiance of the plaque.
$L_T(0^+,\lambda)$ The (total) radiance above the sea surface.
$L_u(\lambda)$ The upwelled spectral radiance.
$L_u(z,\lambda)$ The upwelled spectral radiance at depth z.
$L_W(\lambda)$ The spectral radiance leaving the sea surface from below (the water-leaving radiance).
$\hat{L}_W(\lambda)$ The spectral water-leaving radiance derived from an above-water sampling method.
$\tilde{L}_W(\lambda)$ The spectral water-leaving radiance derived from an in-water sampling method.
$[L_W(\lambda)]_{\mathrm{N}}$ The spectral normalized water-leaving radiance.
M The point (in time) when the centers of the Sun, shadowband, and collector are all aligned.
$m(\theta)$ The relative optical airmass.
N_P The number of photodetectors.
$n_w(\lambda)$ The spectral refractive index of water, which is also a function of S and T.
$\mathfrak{P}$ The in-water radiometric quantities in physical units (L_u, E_d, or E_u).
P_e The packing efficiency of microradiometers into a cylinder.
$\mathfrak{P}(z,\lambda,t_0)$ A radiometric parameter (L_u, E_d, or E_u) as it would have been recorded at all depths z at the same time t_0.
$\mathfrak{P}(0^-,\lambda)$ A subsurface radiometric quantity (L_u, E_d, or E_u) at null depth $z = 0^-$.
Q_n Nadir-viewing measurements.

R_d Radius of the diffuser.
$R_{\rm rs}$ Remote sensing reflectance.
$\Re$ The effects of reflection and refraction.
$\Re_0$ The $\Re$ term evaluated at nadir, i.e., $\theta' = 0$
S Salinity.
t Time.
T Water temperature.
t_0 A reference time (generally chosen to coincide with the start of a measurement sequence).
t_i A specific time.
$T_s(\lambda)$ The spectral transmittance of the water surface to downward irradiance.
t_υ The time when the shadowband is at angle υ.
$V(\lambda, t_i)$ Spectral digitized voltages (in counts).
W Wind speed.
x The horizontal axis (abscissa).
X An arbitrary reference measurement.
Y An arbitrary measurement to be investigated.
z The vertical (depth) coordinate, where the depth is the height of water above the cosine collectors.
z_c The critical depth.
θ Solar zenith angle.
θ' The above-water viewing angle (ϑ) refracted by the air–sea interface.
ϑ The radiometer pointing angle with respect to the vertical axis, z.
ϑ' The angle ϑ measured with respect to the zenith.
λ Wavelength.
ρ The surface reflectance factor.
$\tau(\lambda)$ The spectral optical depths of all scatters and absorbers in the atmosphere.
$\tau_A(\lambda)$ The aerosol optical depth.
$\tau_R(\lambda)$ The Rayleigh optical depth.
$\tau_X(\lambda)$ Other scatters and absorbers at optical depth.
ϕ The solar azimuth angle.
φ The perturbations (or tilts) in vertical alignment, which can change the pointing angles.
ϕ' An angle away from the Sun (here either 90° or 135°).
ϕ^- An angle 90° counterclockwise away from the Sun.
ϕ^+ An angle 90° clockwise away from the Sun.
ψ The RPD value.

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