PACE Postlaunch Airborne eXperiment: PACE-PAX

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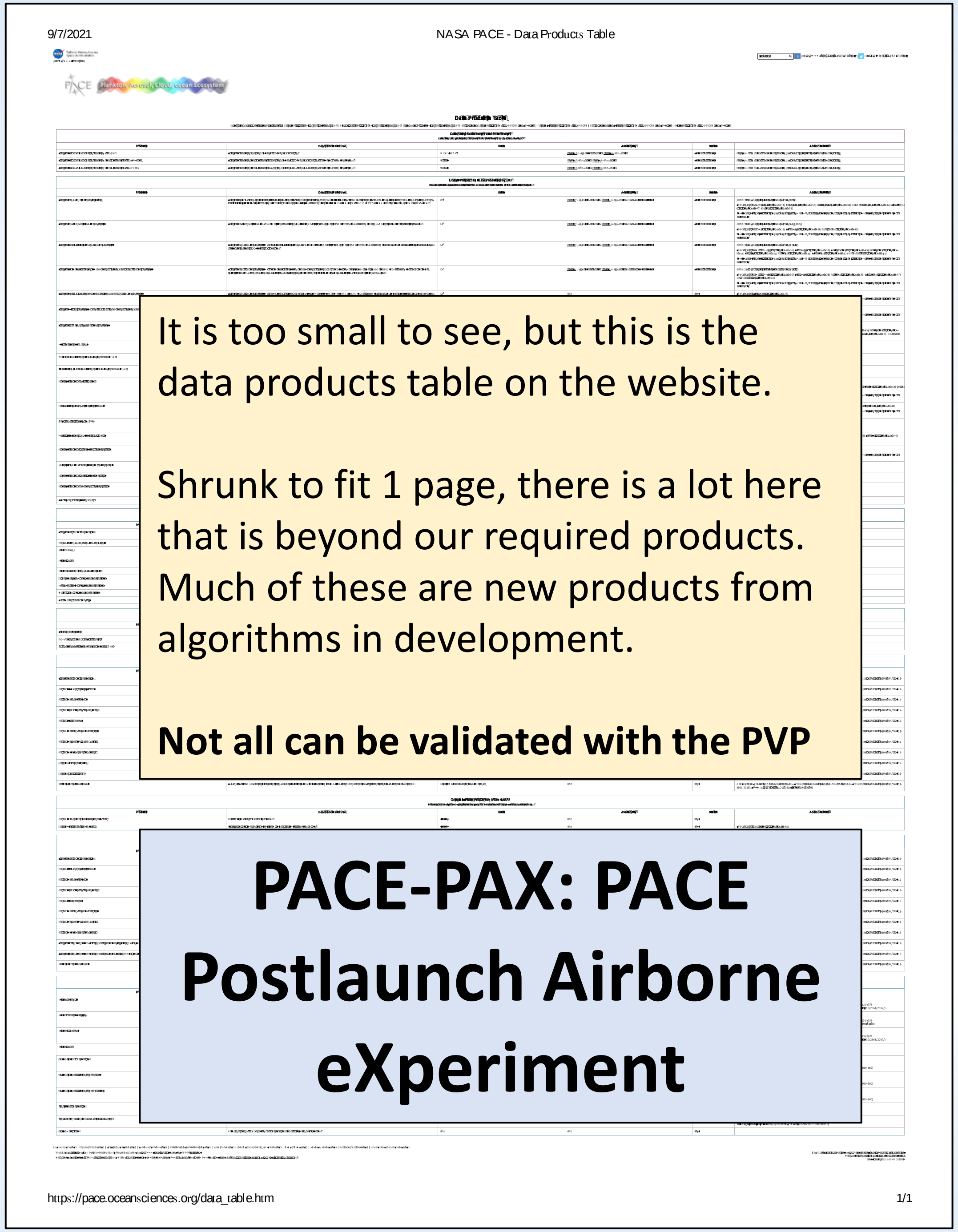
PACE SAT meeting
October 8, 2021


9/7/2021 NASA PACE - Data Products Table

https://pace.oceansciences.org/data_table.htm 1/1

It is too small to see, but this is the data products table on the website.

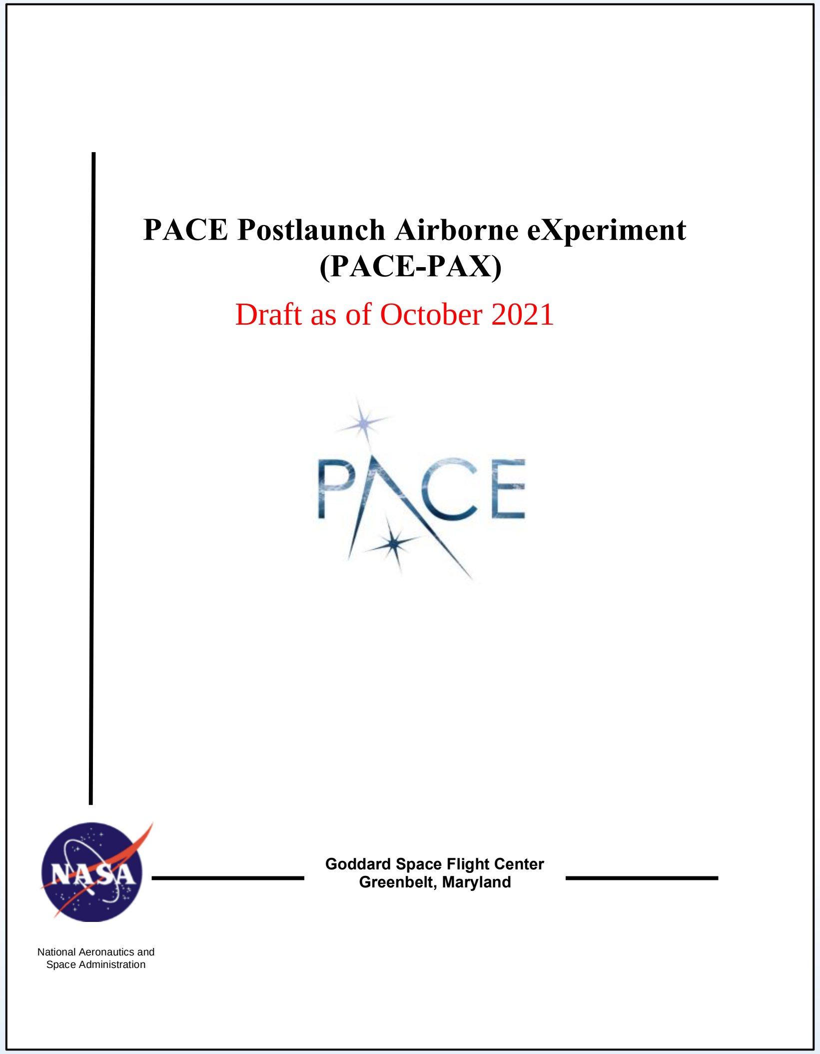
Shrunk to fit 1 page, there is a lot here that is beyond our required products. Much of these are new products from algorithms in development.

Not all can be validated with the PVP

PACE-PAX: PACE Postlaunch Airborne eXperiment

PACE-PAX field campaign white paper

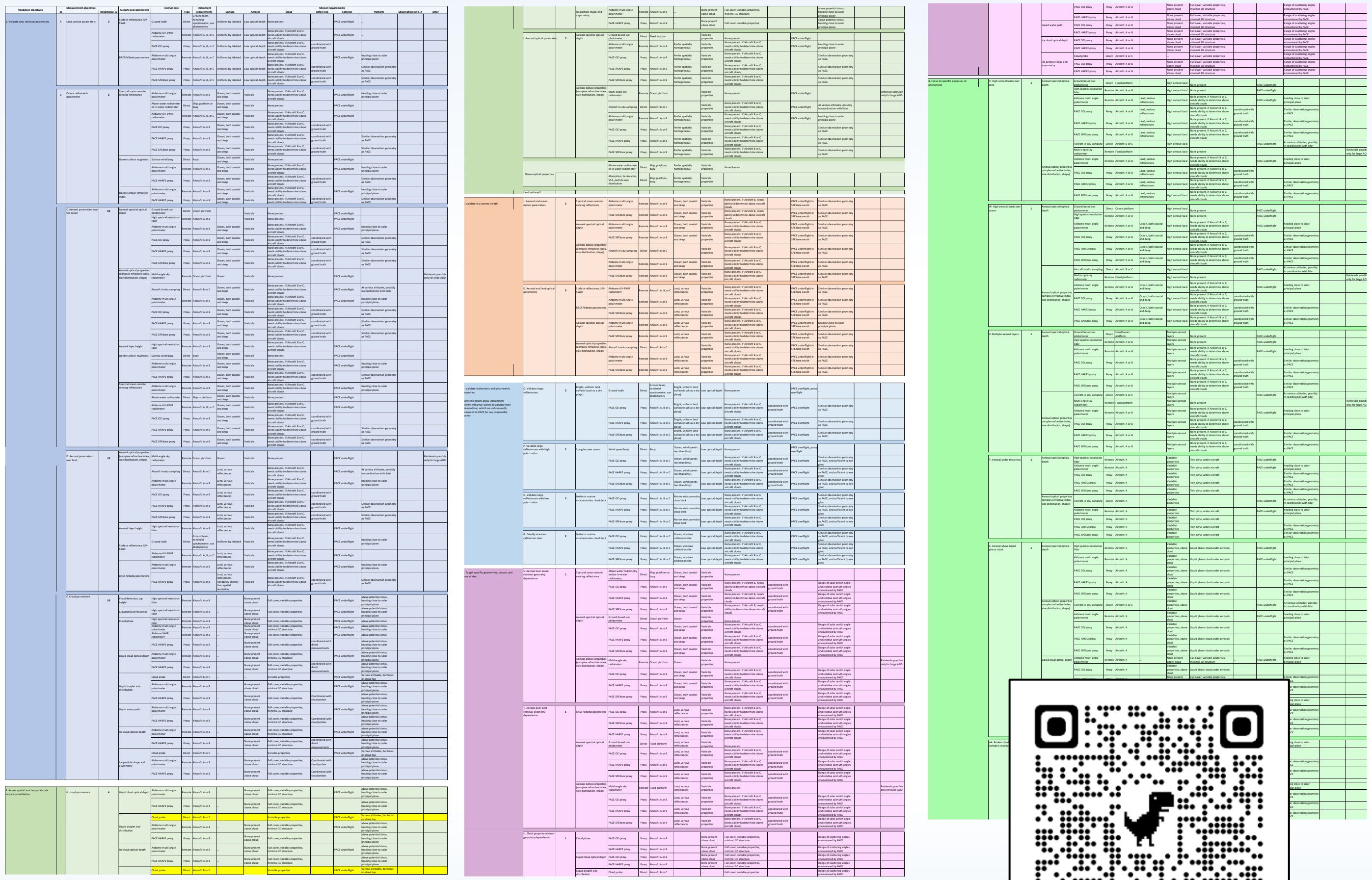
"**Planning for PACE relevant field campaigns**" white paper and Validation Traceability Matrix (VTM)


PACE Postlaunch Airborne eXperiment (PACE-PAX)

Draft as of October 2021

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration



These documents are available now:
https://pacesat.marinesciences.uconn.edu/october-2021-team-meeting/

PACE-PAX planning

How do we perform trade studies?

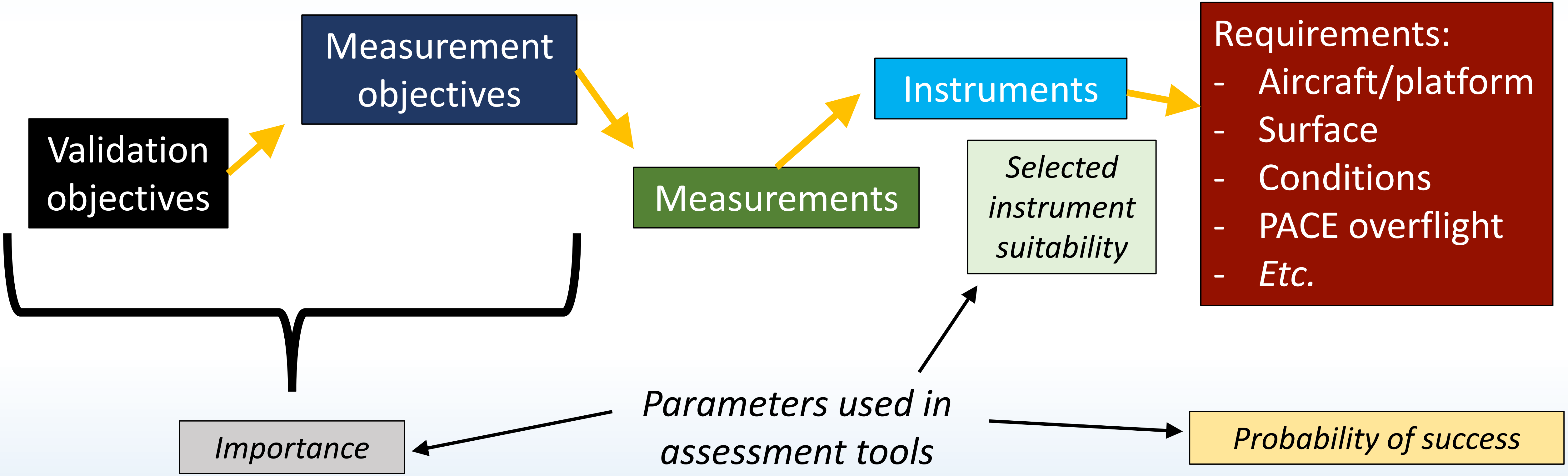
How do we design a campaign from just a list of goals?

How do we manage conflicting needs & mission creep?

What is the mission scope and relationship to PACE Validation Plan?

Validation Traceability Matrix (VTM)

Our main tool – similar to a Science Traceability Matrix (STM), but based on validation objectives



PACE-PAX VTM

Validation objectives	Measurement objectives	
		Importance, w
1. Validate new retrieval parameters	A. Land surface properties	2

Subjective assessment, higher is better but no specific meaning besides that.

Validation objectives	Measurement objecti	Im	ellite	Platform	*Observation time, h*	other
1. Validate new retrieval parameters	A. Land surface properties		rflight	...		
			rflight	...		
			rflight	heading close to solar principal plane		
				Similar observation geometry as PACE		
				Similar observation geometry as PACE		

PACE-PAX VTM

w	Measurement requirements	Instruments	Type	Instrument requirements	
	Surface reflectance, UV-SWIR	Ground truth	Direct	Ground team, handheld spectrometer, sun photometers	Ur
		Airborne UV-SWIR radiometer	Remote	Aircraft: A, B, or C	Ur
		PACE OCI proxy	Proxy	Aircraft: A, B, or C	Ur
	BRDF/albedo parameters	Airborne multi angle polarimeter	Remote	Aircraft: A, B, or C	Ur
		PACE HARP2 proxy	Proxy	Aircraft: A, B, or C	Ur
		PACE SPEXone proxy	Proxy	Aircraft: A, B, or C	Ur

Va

1. Validate n

Aeroso

optical

optical

optical

optical depth	None present. If Aircraft B or C, needs ability to determine above	coordinated with ground truth	PACE underflight	heading close to solar principal plane

optical

optical

Instrument type definition	
Proxy	Proxy validation is the use of airborne remote sensing instruments similar to those on PACE, and possibly utilizing the same retrieval algorithms.
Remote	Remotely sensed validation uses retrievals of validation parameters from instruments dissimilar to those on PACE.
Direct	Direct validation is the use of *In situ* sampling of atmospheric, ground or ocean properties.

Aircraft category definition	
Type A	High altitude, sufficient to overfly aerosols and clouds, e.g. ER-2, WB-57
Type B	Large payload mid-altitude aircraft, e.g. P-3, DC-8. Includes ability to determine if aerosols or clouds are above current flight path, an capability to fly above if needed.
Type C	Small payload low to mid-altitude aircraft, e.g. B-200, Twin Otter

PACE-PAX VTM

				Mission requirements			
Type	Surface	Aerosol	Cloud	Other inst.	Satellite	Platform	*Observation time, h*
Direct	Uniform dry lakebed	Low optical depth	None present	…	PACE underflight	…	
Remote	Uniform dry lakebed	Low optical depth	None present. If Aircraft B or C, needs ability to determine above aircraft clouds		PACE underflight	…	
Proxy	Uniform dry lakebed	Low optical depth	None present. If Aircraft B or C, needs ability to determine above aircraft clouds	coordinated with ground truth			
Remote	Uniform dry lakebed	Low optical depth	None present. If Aircraft B or C, needs ability to determine above aircraft clouds		PACE underflight	heading close to solar principal plane	
Proxy	Uniform dry lakebed	Low optical depth	None present. If Aircraft B or C, needs ability to determine above aircraft clouds	coordinated with ground truth		Similar observation geometry as PACE	
Proxy	Uniform dry lakebed	Low optical depth	None present. If Aircraft B or C, needs ability to determine above aircraft clouds	coordinated with ground truth		Similar observation geometry as PACE	

Assessment of time required to satisfy objective

Objectives

Validation objectives	ID	Measurement objectives	Importance, w	Objective total
1. Validate new retrieval properties	A	Land surface parameters	2	34
	B	Ocean radiometric parameters	2	
	C	Aerosol parameters over the ocean	10	
	D	Aerosol parameters over land	10	
	E	Cloud parameters	10	
2. Assess spatial and temporal scale impact on validation	F	Cloud parameters	4	6
	G	Aerosol parameters	2	
3. Validate in a narrow swath	H	Aerosol parameters over the ocean	10	20
	I	Aerosol parameters over land	10	
4. Validate radiometric and polarimetric properties	J	Validate large reflectances	2	8
	K	Validate large reflectances with high polarization	2	
	L	Validate large reflectances with low polarization	2	
	M	Overfly vicarious calibration sites	2	
5. Target specific geometries, season, and time of day	N	Aerosol over ocean retrieval geometry dependence	1	3
	O	Aerosol over land retrieval geometry dependence	1	
	P	Cloud property retrieval geometry dependence	1	
6. Focus on specific processes or phenomena	Q	High aerosol loads over land	1	10
	R	High aerosol loads over ocean	1	
	S	Multiple aerosol layers	1	
	T	Aerosol under thin cirrus	1	
	U	Aerosol above liquid phase cloud	1	
	V	Broken clouds with complex structure	1	
	W	Dust aerosols over ocean	1	
	X	Aerosol and ocean parameters over turbid waters	1	
	Y	Aerosol and ocean parameters over biologically productive waters	1	
	Z	Aerosol and ocean parameters with and without reflected sunglint	1	

These objectives are a draft and subject to further refinement, more so for objective weights.

Larger weights denote higher importance, weighted by total.

We want your input!

Here's some details on the two most important validation objectives

Objectives

Validation objectives	ID	Measurement objectives	Importance, w	Objective total
1. Validate new retrieval properties	A	Land surface parameters	2	34
	B	Ocean radiometric parameters	2	
	C	Aerosol parameters over the ocean	10	
	D	Aerosol parameters over land	10	
	E	Cloud parameters	10	

Objective 1: Validate new retrieval parameters.

- Primary focus: **moving new products from provisional to validated status**
- We limit our scope to radiometric and polarimetric products, with a focus on observations from aircraft
- Airborne proxies are important. With these proxies, algorithms can be tested in controlled (or at least known) environments, without the need for concurrent PACE measurements.
- Validation requires simultaneous observation of multiple parameters in order to meet this objective.

Example: Aerosol single scattering albedo (SSA) ratio of scattering to total extinction by aerosols. Not a required product for OCI but is a climatologically important parameter that could be produced from OCI or MAPs. Algorithms (in development) retrieve multiple parameters and cannot be fully validated as part of the PVP. A specific field effort must therefore be made to validate SSA, and similar products, from PACE.

Objectives

Validation objectives	ID	Measurement objectives	Importance, w	Objective total
3. Validate in a narrow swath	H	Aerosol parameters over the ocean	10	20
	I	Aerosol parameters over land	10	

Objective 3: Validate in a narrow swath. While the OCI and HARP2 instruments have a wide swath with 1 to 2 day global coverage, SPEXone has a much narrower (~100km at nadir) swath, resulting in an approximately 30 day global coverage. This means that comparisons of SPEXone to fixed ground locations (such as AERONET) will be infrequent.

As an example: # of AOD MODIS-Aqua to AERONET-OC validation matchups in SeaBASS (2012-2015):

- 1,164 matchups using OCI swath
- 916 matchups using HARP2 swath
- 80 matchups using SPEXone swath

This has been a successful approach for other narrow swath instrumentation, such as for CALIPSO.

Objectives

Validation objectives	ID	Measurement objectives	Importance, w	Objective total
1. Validate new retrieval properties	A	Land surface parameters	2	34
	B	Ocean radiometric parameters	2	
	C	Aerosol parameters over the ocean	10	
	D	Aerosol parameters over land	10	
	E	Cloud parameters	10	
2. Assess spatial and temporal scale impact on validation	F	Cloud parameters	4	6
	G	Aerosol parameters	2	
3. Validate in a narrow swath	H	Aerosol parameters over the ocean	10	20
	I	Aerosol parameters over land	10	
4. Validate radiometric and polarimetric properties	J	Validate large reflectances	2	8
	K	Validate large reflectances with high polarization	2	
	L	Validate large reflectances with low polarization	2	
	M	Overfly vicarious calibration sites	2	
5. Target specific geometries, season, and time of day	N	Aerosol over ocean retrieval geometry dependence	1	3
	O	Aerosol over land retrieval geometry dependence	1	
	P	Cloud property retrieval geometry dependence	1	
6. Focus on specific processes or phenomena	Q	High aerosol loads over land	1	10
	R	High aerosol loads over ocean	1	
	S	Multiple aerosol layers	1	
	T	Aerosol under thin cirrus	1	
	U	Aerosol above liquid phase cloud	1	
	V	Broken clouds with complex structure	1	
	W	Dust aerosols over ocean	1	
	X	Aerosol and ocean parameters over turbid waters	1	
	Y	Aerosol and ocean parameters over biologically productive waters	1	
	Z	Aerosol and ocean parameters with and without reflected sunglint	1	

To show how all this is used, we will assess the ACEPOL field campaign's ability to meet PACE-PAX objectives

Using validation instrument potential, *V:*

$$V = \frac{\sum_{i=1}^{n} w_i c_i}{\sum_{i=1}^{n} w_i}$$

- *w* : weights assigned to each objective
- *c:* 'completeness' of measurements satisfying those objectives
- 0 < V < 1, higher is better

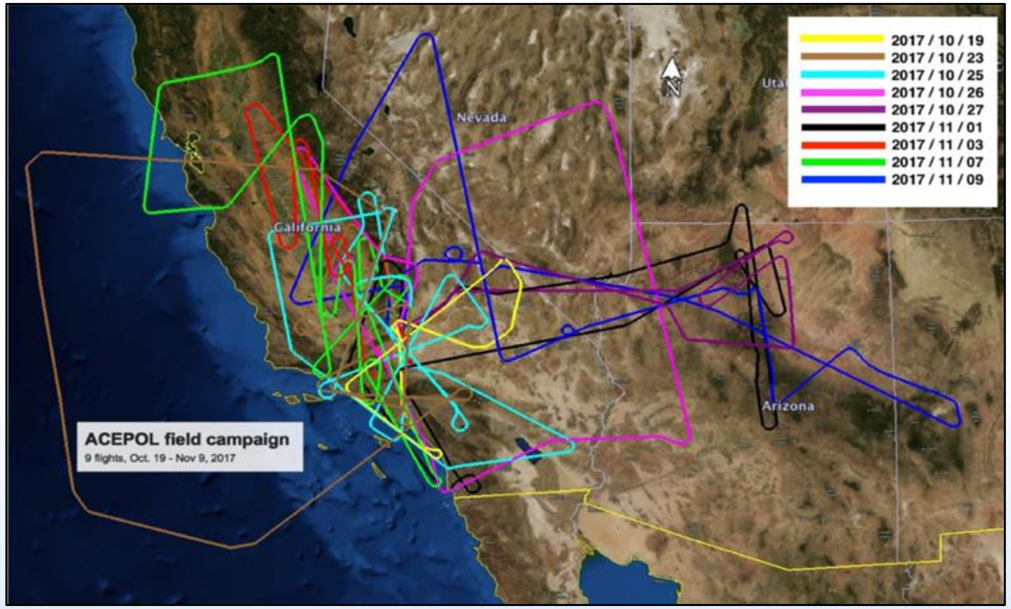
Example: ACEPOL VTM assessment

ACEPOL had a focused, prioritized list of target objectives

Target	Description	Achieved?	Dates (2017)
1a	Calibration over ocean with no clouds or aerosols	Yes	10/23, 10/25, 11/07
1b	Calibration over land with no clouds or aerosols	Yes	10/25
1c	Calibration over spatially uniform cloud deck	Partially	11/01
1d	Geolocation using coastlines with no clouds	Yes	10/23, 10/25, 10/26, 11/07
1e	Coordinated CALIOP/CALIPSO or CATS underflight	Yes	10/19, 10/26, 11/07, 11/09
2a	Validation with AERONET with medium to high aerosol loading	Yes	10/23, 10/25, 10/26, 11/01, 11/07, 11/09
2b	Validation with AERONET with low aerosol loading	Yes	10/23, 10/25, 10/26, 11/01, 11/07, 11/09
2c	Validation against CASPER field campaign	No	None, but one overlap with an AJAX flight on 11/09
3a	Satellite intercomparison for aerosol retrievals	Yes	10/23, 10/27, 11/01
3b	Satellite intercomparison for cloud retrievals	Partially	11/09
4a	Targets of opportunity: high aerosol loads over ocean	No	-
4b	Target of opportunity: high aerosol loads over land	Yes	10/27, 11/01, 11/07
4c	Targets of opportunity: multiple aerosol layers	No	-
5	Targets of opportunity: aerosol above cloud	No	-
6	Targets of opportunity: high aerosol loads over urban surfaces	No	-
7	Targets of opportunity: marine stratocumulus clouds far from land	No	-
8	Targets of opportunity: broken clouds far from land	No	-
9	Targets of opportunity: low clouds over land	Yes	11/01, 11/03
10	Targets of opportunity: Cirrus clouds	Yes	10/19, 10/23, 11/03, 11/07, 11/09

← Data description paper
DOI: 10.5194/essd-12-2183-2020
Data archive @ ASDC DAAC →

ACEPOL had 4 multi-angle polarimeters & 2 lidars, flew in a wide variety of conditions



ACEPOL VTM assessment

Validation objectives	ID	Measurement objectives	Importance, w	Measurement completeness, c	w x c
1. Validation of new retrieval properties	A	Land surface parameters	2	0.75	1.500
	B	Ocean radiometric parameters	2	0.75	1.500
	C	Aerosol parameters over the ocean	10	0.75	7.500
	D	Aerosol parameters over land	10	0.75	7.500
	E	Cloud parameters	10	0.50	5.000
2. Assessment spatial and temporal scale impact on	F	Cloud parameters	4	0.50	2.000
	G	Aerosol parameters	2	0.50	1.000
3. Validate in a swath	H	Aerosol parameters over the ocean	10	1.00	10.000
	I	Aerosol parameters over land	10	1.00	10.000
4. Validate radiometric and polarimetric properties	J	Validate large reflectances	2	1.00	2.000
	K	Validate large reflectances with high polarization	2	0.75	1.500
	L	Validate large reflectances with low polarization	2	0.50	1.000
	M	Overfly vicarious calibration sites	2	0.00	0.000
5. Target specific geometries, season, time of day	N	Aerosol over ocean retrieval geometry dependence	1	0.50	0.500
	O	Aerosol over land retrieval geometry dependence	1	0.50	0.500
	P	Cloud property retrieval geometry dependence	1	0.50	0.500
6. Focus on specific processes or phenomena	Q	High aerosol loads over land	1	0.75	0.750
	R	High aerosol loads over ocean	1	0.00	0.000
	S	Multiple aerosol layers	1	0.00	0.000
	T	Aerosol under thin cirrus	1	0.50	0.500
	U	Aerosol above liquid phase cloud	1	0.00	0.000
	V	Broken clouds with complex structure	1	0.00	0.000
	W	Dust aerosols over ocean	1	0.00	0.000
	X	Aerosol and ocean parameters over turbid waters	1	0.00	0.000
	Y	Aerosol and ocean parameters over biologically productive waters	1	0.00	0.000
	Z	Aerosol and ocean parameters with and without reflected sunglint	1	0.75	0.750
		total:	81	**total:**	54.000
				V_I:	0.667

ACEPOL validation instrument potential, based on our VTM, is V=0.667 out of 1.0

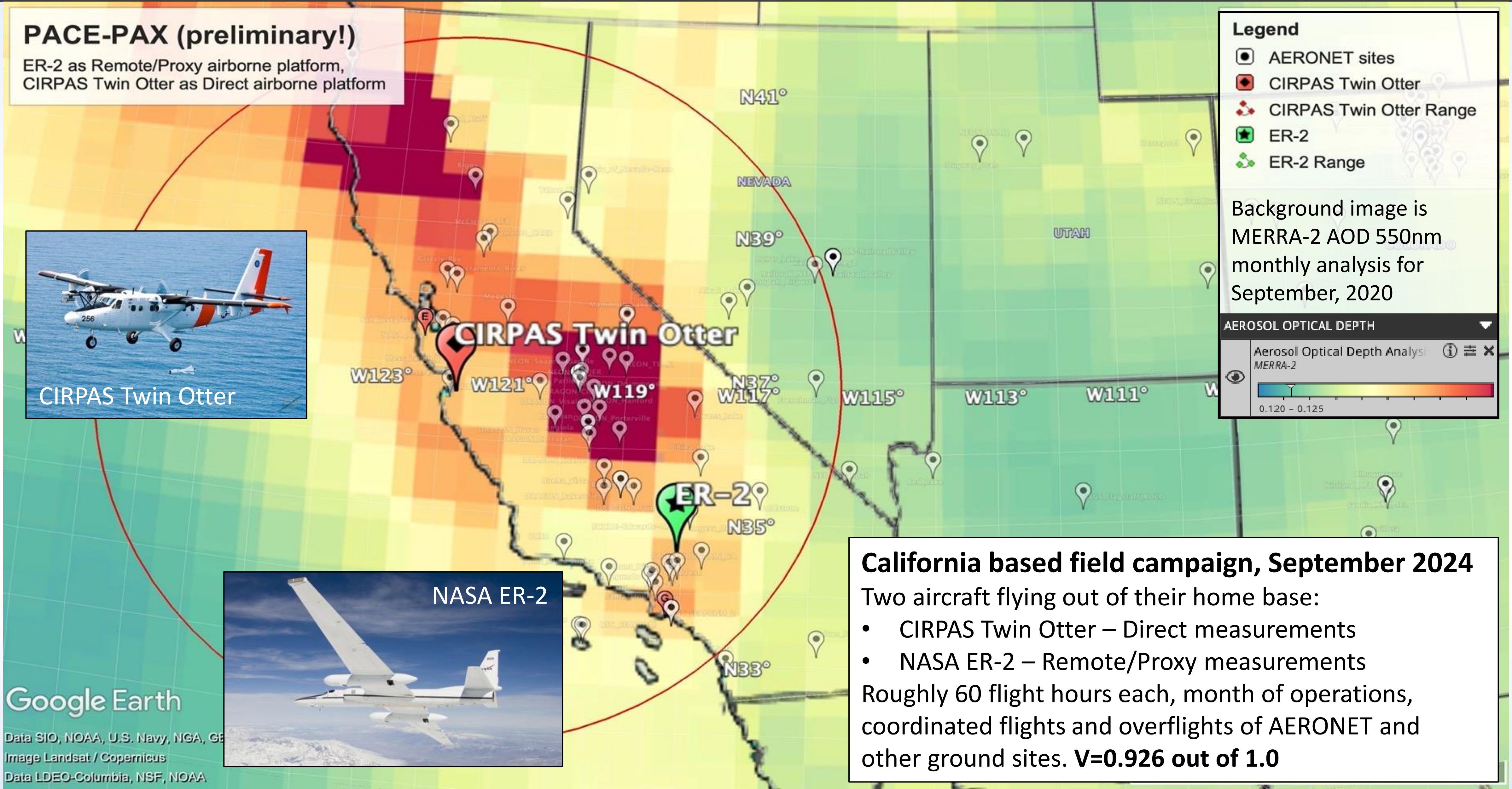
- Including a UV-SWIR OCI proxy: V + 0.019
- More complete Rrs data*: V + 0.056
- More heavy aerosol loads: V + 0.049
- More observations of liquid phase clouds: V + 0.117
- Add Direct aerosol/cloud observations: V + 0.157
- Add all of above: V + 0.299
- *Descope to remove High Spectral Resolution Lidar: V – 0.085*

*ocean surface remote sensing reflectance, more than existing AERONET-OC

This is an overall metric unconnected to required # flight hours or probability of success. It is appropriate for post-campaign assessment, or pre-campaign trade studies when flight hours are unknown

Initial PACE-PAX plan

Initial PACE-PAX plan



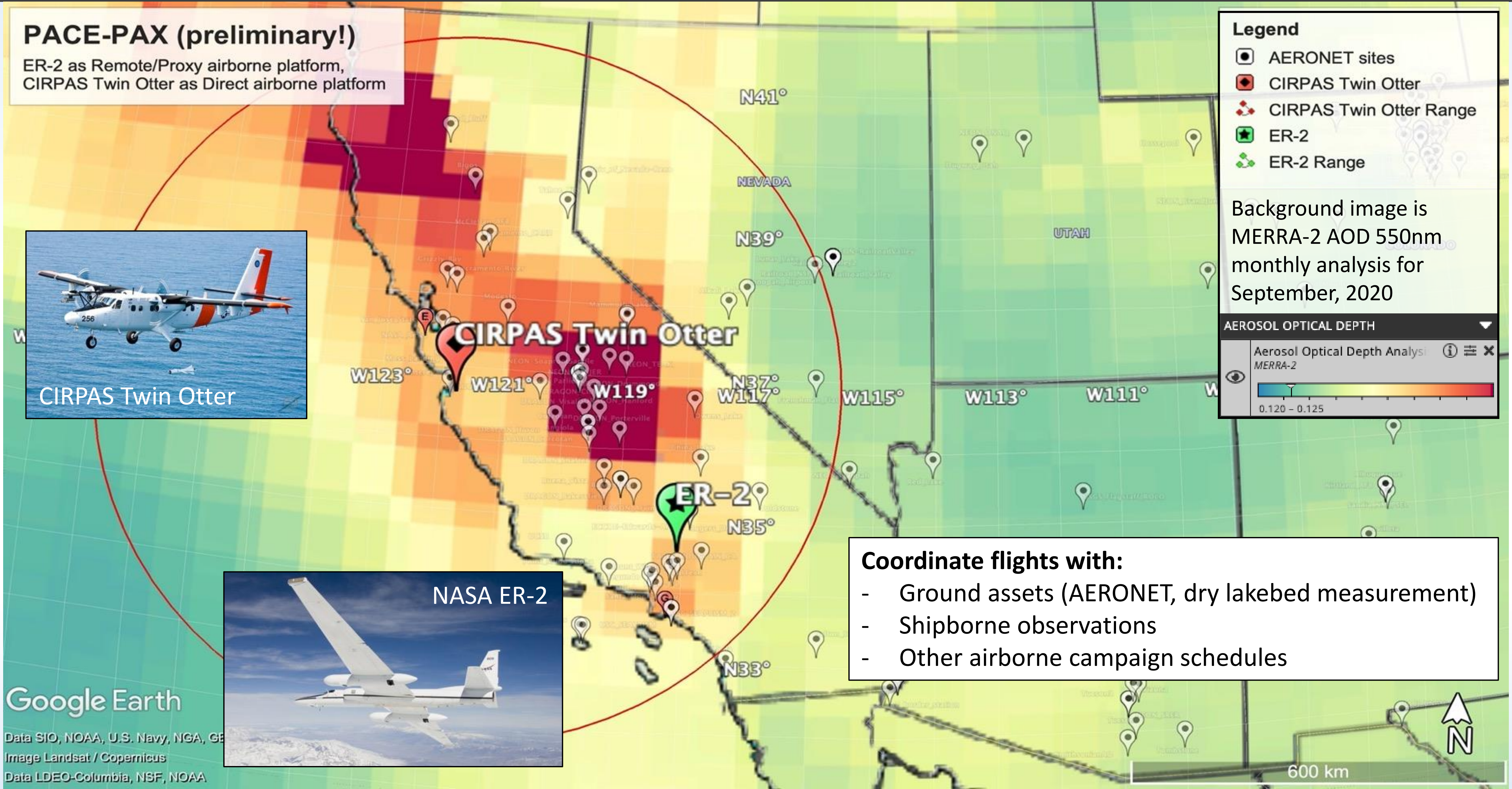
California based field campaign, September 2024

Two aircraft flying out of their home base:

- CIRPAS Twin Otter – Direct measurements
- NASA ER-2 – Remote/Proxy measurements

Roughly 60 flight hours each, month of operations, coordinated flights and overflights of AERONET and other ground sites. **V=0.926 out of 1.0**

Initial PACE-PAX plan



CIRPAS Twin Otter

NASA ER-2

Coordinate flights with:

- Ground assets (AERONET, dry lakebed measurement)
- Shipborne observations
- Other airborne campaign schedules

Team and management structure

PACE-PAX mission scientist (MS): will have an overall responsibility for the field campaign, will lead the PACE-PAX team, and will be the interface between the team and PACE Project Science, NASA HQ, the PACE Validation Science Team (to be competed at a later date), and others. She/he is responsible for defining and meeting the validation objectives, their scope, and implementation. *Kirk Knobelspiesse*

PACE-PAX deputy mission scientists (DMS): will assist the PACE-PAX mission scientist and serve in her/his place should when the MS is unavailable for meetings or other activities. Ensures timely communication between multiple locations and aircraft / ship. *Brian Cairns and Ivona Cetinić*

PACE-PAX project manager (PM): will provide guidance on management aspects to the MS. She/he will work with the aircraft managers, instrument scientists and other members of the team regarding shipping, deployment of personnel, and other matters pertaining to logistics. She/he will maintain the budget and schedule, and works with the Aircraft Manager(s) to ensure risk management and safety. TBD

PACE-PAX instrument scientists (IS): are responsible for integration, deployment and operations for individual scientific instruments (not competed).

PACE-PAX Aircraft Manager(s) (AM): Will serve as the point of contact between the PACE-PAX team and the aircraft personnel, including responsibility for instrument integration, planning and operations. TBD

PACE-PAX weather forecasting (WF): will provide forecasts or climatologies of weather and geophysical parameters during planning and operations of PACE-PAX. Both will be connected to the previously described decision algorithm and BST. TBD

PACE-PAX data manager (DM): will ensure that data collected during the campaign will be archived in accordance with NASA policies in the identified repository. TBD

+ overall guidance from HQ

Schedule

Now: Prepare PACE-PAX white paper, VTM, notational plan

October, 2021: Present white paper and VTM at PACE SAT meeting. Acceptable feedback:

1. input on *structure* of VTM and plan, ie should we include other things or weight differently?
2. Requests for specific instruments, etc., must come with traceability to the VTM and justification in that context.

Dec 10, 2021: Close feedback period

Fall, 2024: PACE-PAX field campaign

We need your feedback!

Please take our survey

https://www.surveymonkey.com/r/5ZWT5N6

PACE-PAX feedback form

- **I would like to suggest changes to the VTM**

Validation/Measurement objective to change/add ______

Importance/weighting change ______________________

Justification _____________________________________

____

____

____

____

- **I have other suggestions**

Validation/Measurement objective affected __________

Suggestions ______________________________________

____

____

____

____

Thank you!

What are your questions?

Please take our survey
https://www.surveymonkey.com/r/5ZWT5N6

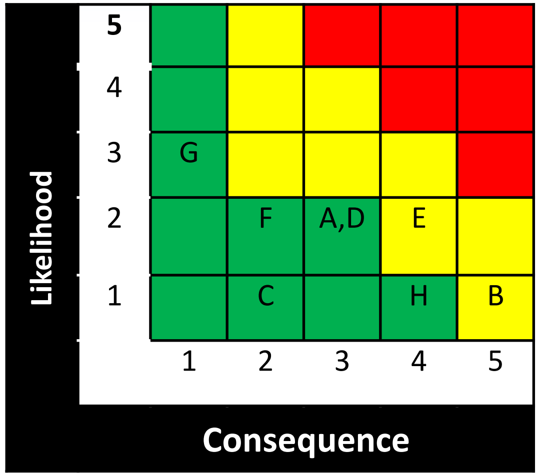
PACE-PAX
documents

https://pacesat.marinesciences.uconn.edu/october-2021-team-meeting/

Backup material…

PACE-PAX risks

#	Risk	Background	Response / Mitigation	Like-lihood	Consequence
A	PACE launch delay	PACE may launch later than expected.	Delay	2	3 Aircraft or instruments may not be available with delayed schedule. Optimal observation conditions may be missed.
B	PACE spacecraft failure	Full launch or spacecraft failure of the PACE mission.	Cancellation	1	5
C	Individual PACE instrument failure	Full individual instrument failure upon successful launch.	Descope of PACE-PAX	1	2 Fully planned validation mission would be descoped as described in previous sections, keeping the timeline so the optimal observation condition are captured.
D	PACE instrument data delivery delay	Fully calibrated data not available at the planned time point	Delay	2	3 Aircraft or instruments may not be available with delayed schedule. Optimal observation conditions may be missed.
E	Aircraft failure	Aircraft failure close to beginning or during PACE-PAX	Delay	2	4 (New) aircraft or instruments may not be available with delayed schedule. Optimal observation conditions may be missed.
F	Individual PACE-PAX instrument failure	An aircraft instrument in PACE-PAX fails to operate prior to or during the mission	Select instruments that have established successful heritage. Redundant observations.	2	2
G	Optimal observation conditions are not encountered	Measurement conditions required in the VTM are not encountered (for example, insufficient aerosol loads)	Based on climatological assessments, estimate and provide sufficient margin on schedule and flight hours	3	1 VTM is organized for multiple objectives that rely on measurement conditions
H	Unexpected extreme weather event(s)	Extreme environmental conditions along planned flight path or at BOP (e.g, hurricane, earthquake) result in extended suspension of flight operations	Modify/delay PACE-PAX plan	1	4



Objectives

Validation objectives	ID	Measurement objectives	Importance, w	Objective total
2. Assess spatial and temporal scale impact on validation	**F**	Cloud parameters	4	6
	G	Aerosol parameters	2	

***Objective 2: Assess spatial and temporal scale impact on validation*.**

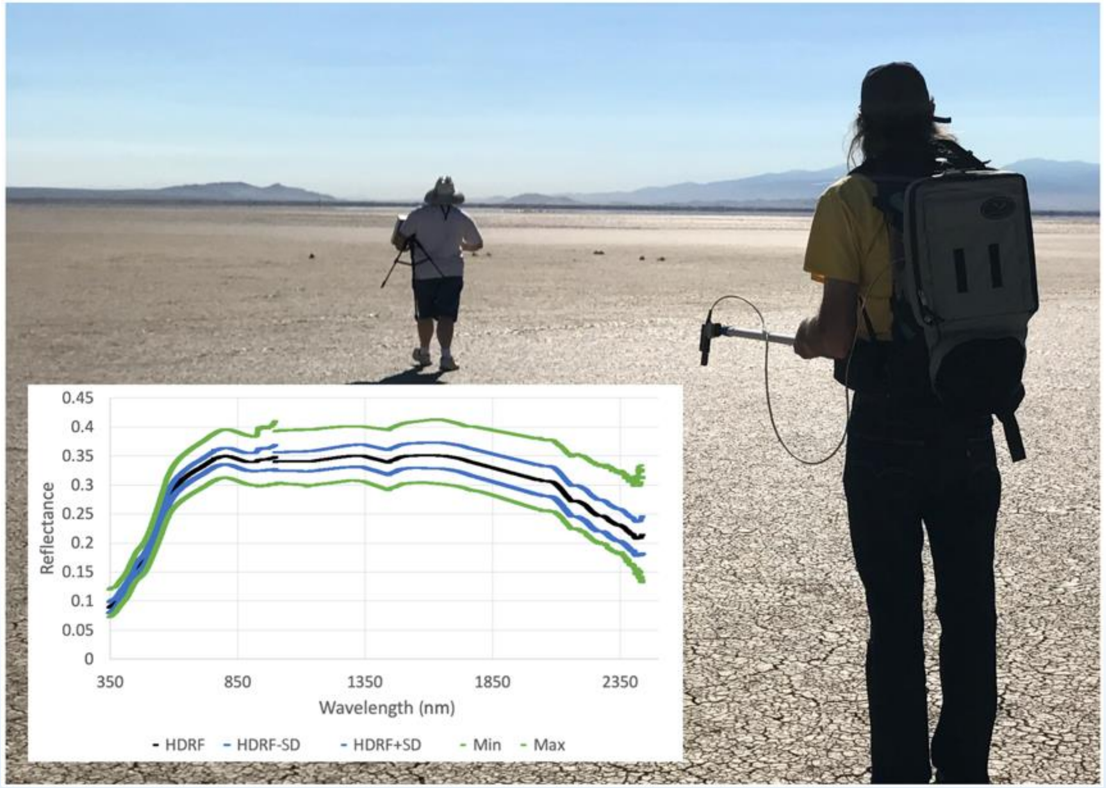
- This is important to link ground, aircraft and satellite observations.
- To complicate matters, this spatial and temporal variability differs among geophysical parameters and conditions (Sayer, 2020).
- We must determine appropriate validation scales, by the use of spatial or temporal surveys. Remote sensing measurements, at a higher spatial (or temporal) resolution than PACE, are best suited for this purpose, as are extended measurements under conditions of known variability.

Objectives

Validation objectives	ID	Measurement objectives	Importance, w	Objective total
4. Validate radiometric and polarimetric properties	**J**	Validate large reflectances	2	8
	K	Validate large reflectances with high polarization	2	
	L	Validate large reflectances with low polarization	2	
	M	Overfly vicarious calibration sites	2	

Objective 4: Validate radiometric and polarimetric parameters prior to their use for retrieval of geophysical parameters with instrument proxies

This activity supports PACE in-flight calibration activities. For example, during the ACEPOL field campaign, a team characterized the reflectance of Rosamond Dry Lake in California, providing a bright surface calibration reference.



Objectives

Validation objectives	ID	Measurement objectives	Importance, w	Objective total
5. Target specific geometries, season, and time of day	**N**	Aerosol over ocean retrieval geometry dependence	1	3
	O	Aerosol over land retrieval geometry dependence	1	
	P	Cloud property retrieval geometry dependence	1	

Objective 5: Target specific geometries, season, and time of day. Retrieval capability depends on observation geometry (the solar and sensor zenith and azimuth angles). This is especially the case for the MAP instruments.

Furthermore, a field campaign can be used to investigate the influence that geometry has on retrieval success.

Objectives

Validation objectives	ID	Measurement objectives	Importance, w	Objective total
6. Focus on specific processes or phenomena	**Q**	High aerosol loads over land	1	10
	R	High aerosol loads over ocean	1	
	S	Multiple aerosol layers	1	
	T	Aerosol under thin cirrus	1	
	U	Aerosol above liquid phase cloud	1	
	V	Broken clouds with complex structure	1	
	W	Dust aerosols over ocean	1	
	X	Aerosol and ocean parameters over turbid waters	1	
	Y	Aerosol and ocean parameters over biologically productive waters	1	
	Z	Aerosol and ocean parameters with and without reflected sunglint	1	

Objective 6: Focus on specific processes or phenomena to verify they are properly accounted for in the satellite retrieval scheme. A variety of atmospheric, ocean, and land surface parameters will be retrieved from PACE observations, and data processing must have the capability to identify when the appropriate algorithms are to be used. Furthermore, those algorithms must be robust for the range of possible conditions that are to be observed. Dedicated field campaigns can seek to observe specific geophysical conditions and ensure retrieval success.

ACEPOL VTM assessment: success function

Success function incorporates needed measurement time, probability of success

Validation assessment metrics for theoretical field campaign **Alpha**. V=0.78.

Measurement objective	Measurement objective weight, *w*	Observation time required, *h*	Measurement completeness, *c*	Probability of success, *p*
A	4	20	1.0	0.5
B	2	10	1.0	0.5
C	2	15	0.0	0.1
D	1	5	1.0	0.1

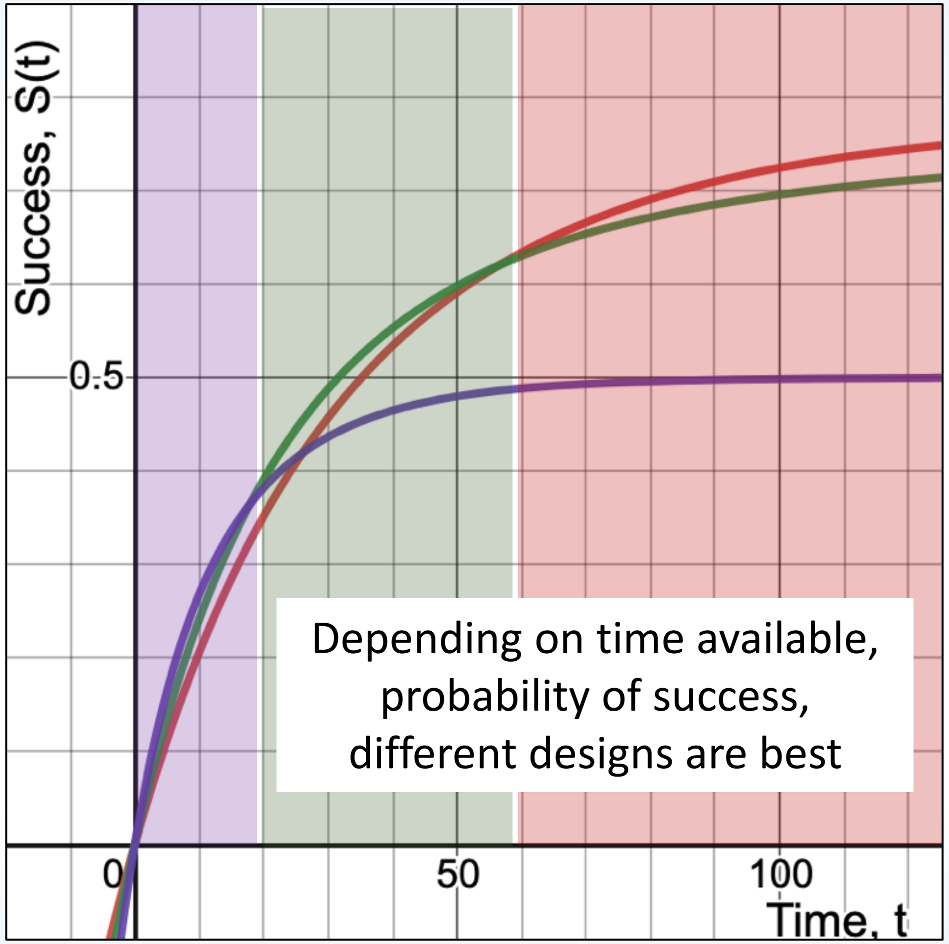
Validation assessment metrics for theoretical field campaign **Beta**. V=0.75

Measurement objective	Measurement objective weight, *w*	Observation time required, *h*	Measurement completeness, *c*	Probability of success, *p*
A	4	20	0.75	0.75
B	2	10	0.75	0.75
C	2	15	0.75	0.2
D	1	5	0.75	0.2

Validation assessment metrics for theoretical field campaign **Gamma**. V=0.5

Measurement objective	Measurement objective weight, *w*	Observation time required, *h*	Measurement completeness, *c*	Probability of success, *p*
A	4	20	0.25	0.9
B	2	10	0.25	0.9
C	2	15	1.0	0.95
D	1	5	1.0	0.75

Figure 2 Success functions (equation 5) for field campaign Alpha (red), Beta (green), and Gamma (purple).



This metric asymptotes to validation instrument potential, but incorporates flight hours and success probability

How to use the VTM

This can also be used to help decision making while the field campaign is underway

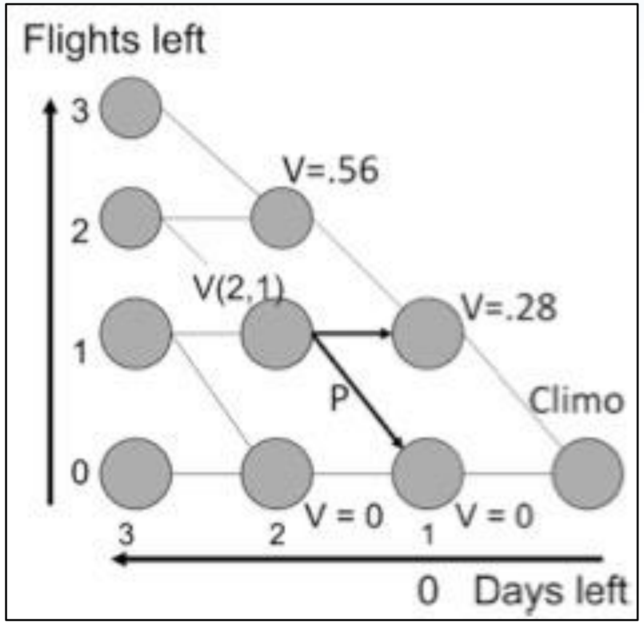


FIG. 1. A graphical representation of the decision algorithm. When there are 2 days remaining in the field season, and only 1 flight remaining in the project budget, the investigator chooses either to fly, or not. If the decision to fly is taken, the investigator has success with probability P, which is estimated based on a forecast of the next day's atmospheric conditions, and then drops to state $d = 1, f = 0$. Alternatively, the investigator can hold the remaining flight in reserve until the last day, when the project will be in state $d = 1, f = 1$. The remaining flight is then used with certainty, yielding success with a probability equal to the long-run climatological average frequency of encountering good conditions (here, 28%). State (2, 1) is more valuable than state (1, 1) exactly because the extra day gives the investigator the option to fly only in case the forecast probability exceeds the average climatological probability. Given knowledge of the long-run distribution of forecasts, the likelihood that the option will be exercised can be computed in advance, prior to the start of the field season.

This isn't something we're going to work through completely at this point, but having a VTM enables this approach

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The Cloud Hunter's Problem: An Automated Decision Algorithm to Improve the Productivity of Scientific Data Collection in Stochastic Environments

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ABSTRACT

A decision algorithm is presented that improves the productivity of data collection activities in stochastic environments. The algorithm was developed in the context of an aircraft field campaign organized to collect data in situ from boundary layer clouds. Required lead times implied that aircraft deployments had to be scheduled in advance, based on imperfect forecasts regarding the presence of conditions meeting specified requirements. Given an overall cap on the number of flights, daily fly/no-fly decisions were taken traditionally using a discussion-intensive process involving heuristic analysis of weather forecasts by a group of skilled human investigators. An alternative automated decision process uses self-organizing maps to convert weather forecasts into quantified probabilities of suitable conditions, together with a dynamic programming procedure to compute the opportunity costs of using up scarce flights from the limited budget. Applied to conditions prevailing during the 2009 Routine ARM Aerial Facility (AAF) Clouds with Low Optical Water Depths (CLOWD) Optical Radiative Observations (RACORO) campaign of the U.S. Department of Energy's Atmospheric Radiation Measurement Program, the algorithm shows a 21% increase in data yield and a 66% improvement in skill over the heuristic decision process used traditionally. The algorithmic approach promises to free up investigators' cognitive resources, reduce stress on flight crews, and increase productivity in a range of data collection applications.

1. Introduction

This paper presents a decision algorithm developed to improve the efficiency of scientific data collection in stochastic environments. The Atmospheric Radiation Measurement (ARM) Program within the climate science programs of the U.S. Department of Energy has objectives involving the routine collection of data in situ from particular cloud formations by means of specially equipped aircraft (more information available online at http://www.atmos.uiuc.edu/~mcfarq/aavp.whitepaperoverview.pdf). Each day during a field campaign, investigators must decide whether or not to deploy the aircraft on the following day. Investigators traditionally have made these fly/no-fly decisions through a process involving heuristic analysis by experienced human investigators of forecasts of atmospheric conditions. Since budgeted flight hours are limited and expensive, and since available forecasts of suitable conditions are imperfect, investigators view the deployment decisions as having high stakes. In these decisions, two considerations must be balanced: the uncertain data value of the immediate opportunity and the cost associated with using up, from the fixed budget, flight hours that might otherwise be held back for use at a later date. The forecasts provide some information about the estimated value of the immediate prospect. Regarding

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