Requirements for processing data from an AmeriFlux site using ONEFlux

AMP webinar series
October 19th, 2020

What to expect

- Logistics
  - About 45 minutes of content, 1 hour total
  - A few stop points through the presentation for quick questions
  - Longer Q&A at the end
  - Live streaming (and recording/slides available at ameriflux.lbl.gov)
- This *is not*:
  - How to run ONEFlux
  - How to use AmeriFlux / FLUXNET data products
- This *is*:
  - What is needed to create data products with ONEFlux for an AmeriFlux site
- Familiarity with AmeriFlux data upload process helps (not required)

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Danielle Christianson

Housen Chu

Gilberto Pastorello

Dario Papale

Agenda

- ONEFlux overview
- Workflow of a ONEFlux run
- Metadata collection for ONEFlux processing
- Data QA/QC for AmeriFlux BASE data and impacts on ONEFlux runs
- FLUXNET data products created with ONEFlux
- Future of FLUXNET regional and global data products

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Gilberto
Pastorello

FLUXNET Datasets

- Marconi 2000: 38 sites / 97 site-years
  - Data contributed by attendees of workshop
  - Access limited to attendees
- LaThuile 2007: 252 sites / 965 site-years
  - Data contributed by many site PIs
  - Start of uniform code base and processing for comparable data products
  - Data access/usage opened to other users, with some restrictions (three tiers)
  - Over 500 unique users downloaded data
- FLUXNET2015: 212 sites / 1532 site-years
  - Standardized code base (developed in collaboration among networks)
  - Extensive QA/QC of data (data more comparable and usable, but fewer sites)
  - Data access to anyone, usage has fewer restrictions (two tiers) – tools to keep track of usage
  - Over 3000 unique users downloaded data
  - *NEW (Feb 2020):* **206 sites following data policy based on CC-BY-4.0**

Eddy Covariance Data Processing

- High-frequency data
  - Alteddy (ALTERRA),
  - EddyPro (LI-COR),
  - eddy4R (NEON)
  - EdiRE (U. Edinburgh),
  - Custom codes
- Data products from fluxes
  USTAR filtering, met/flux gap-filling, flux partitioning,
  uncertainty estimates, etc.
  - REddyProc (MPI),
 - **ONEFlux (AMP/EUDB/ICOS-ETC)**
  - Custom codes

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  - Custom codes

Why one more software?

ONEFlux is a <u>package</u> *of eddy covariance data processing codes*

- *Extensive validation on many site characteristics*
- *Focus on creating network-level data products; standardized for synthesis studies and cross-site comparisons*

ONEFlux

ONEFlux is a package of eddy covariance data processing codes

Reference paper:
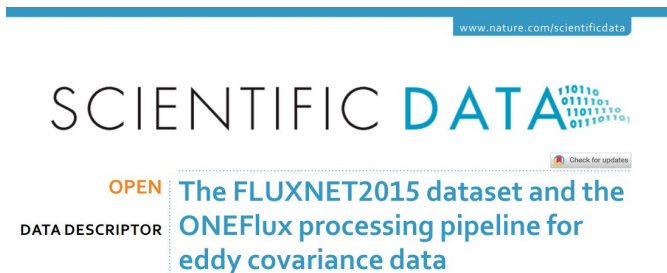
Code available:

https://github.com/FLUXNET/ONEFlux

Pastorello, G., Trotta, C., Canfora, E. *et al. (287 co-authors). **The FLUXNET2015 dataset and the ONEFlux processing pipeline for eddy covariance data.** Scientific Data* **7,** 225 (2020). https://doi.org/10.1038/s41597-020-0534-3
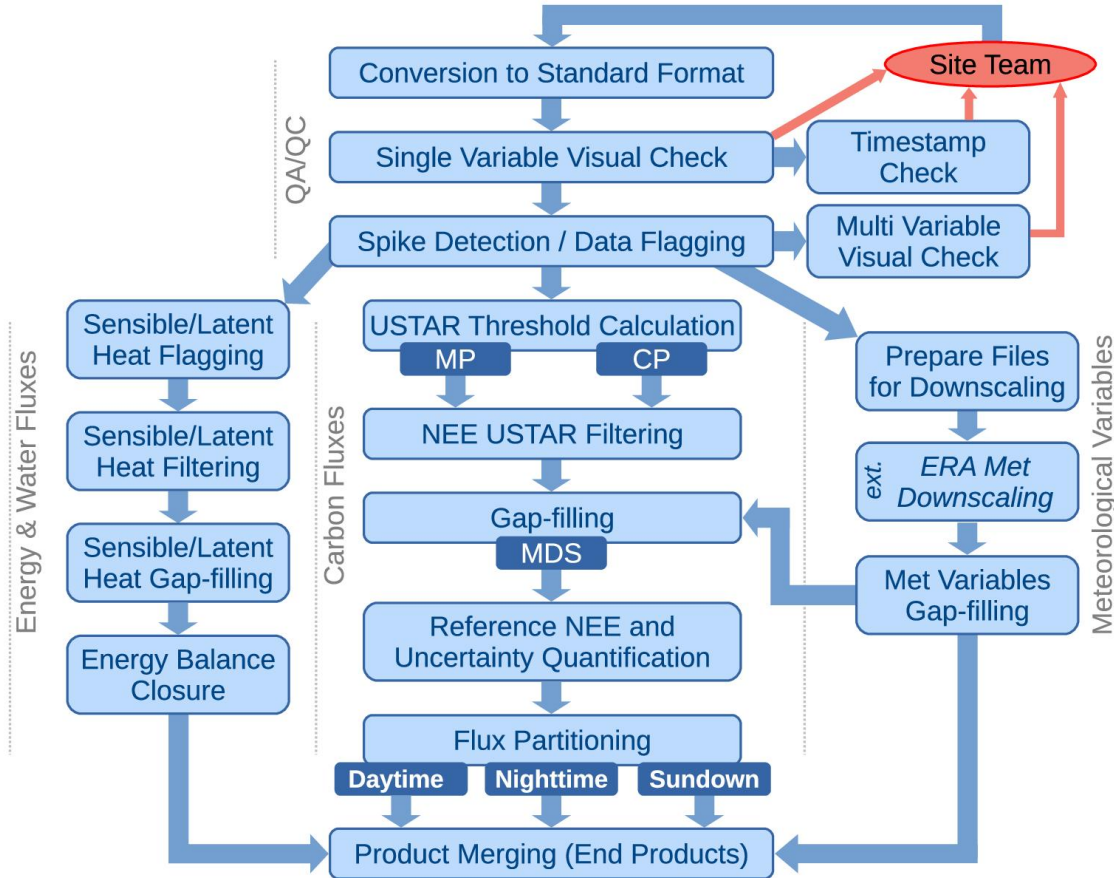
ONEFlux Steps
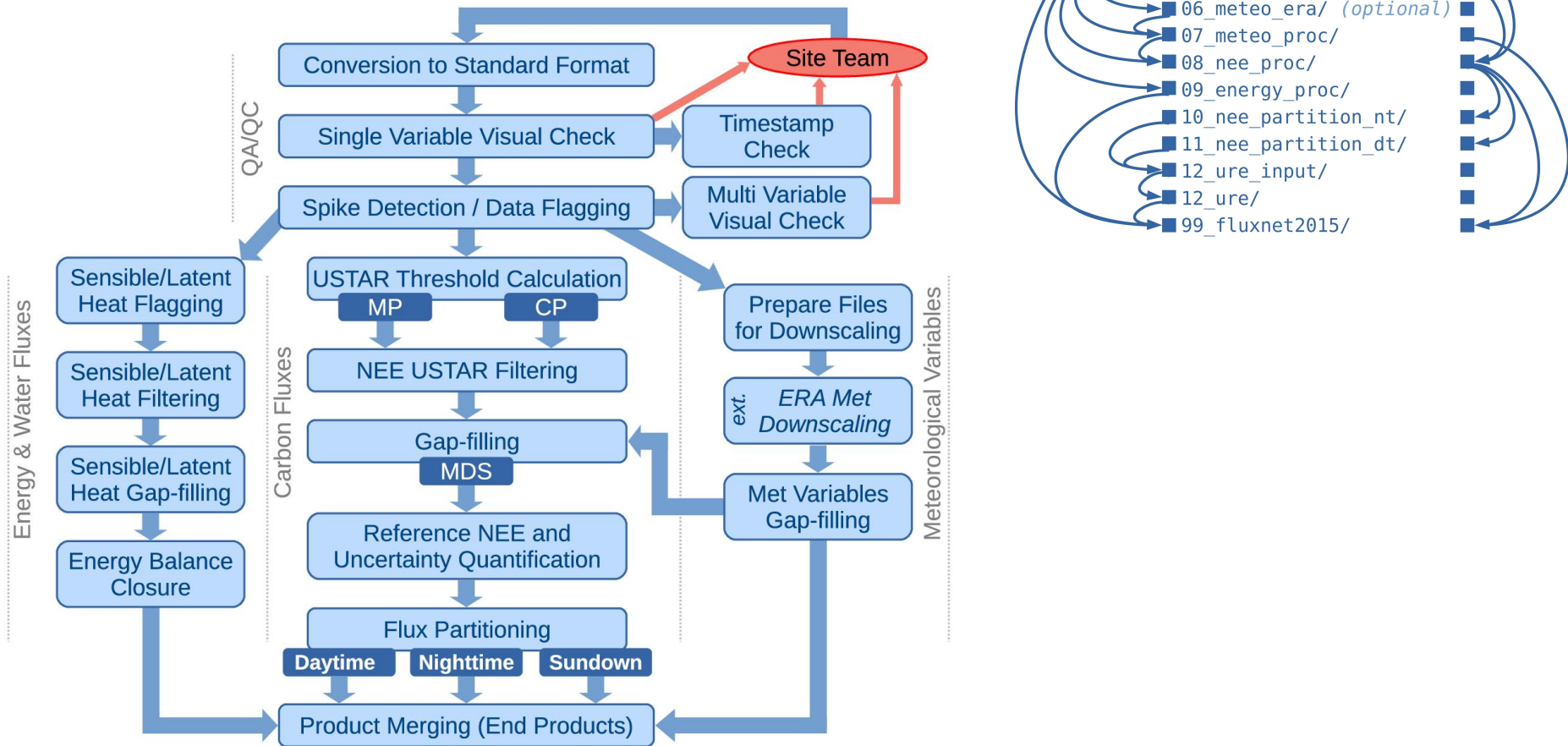
ONEFlux Steps

ONEFlux Steps
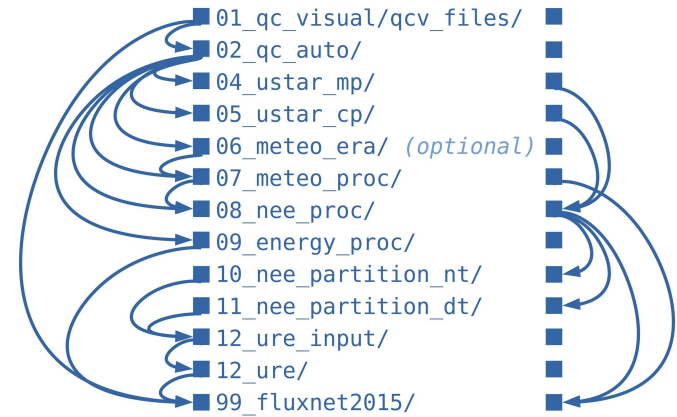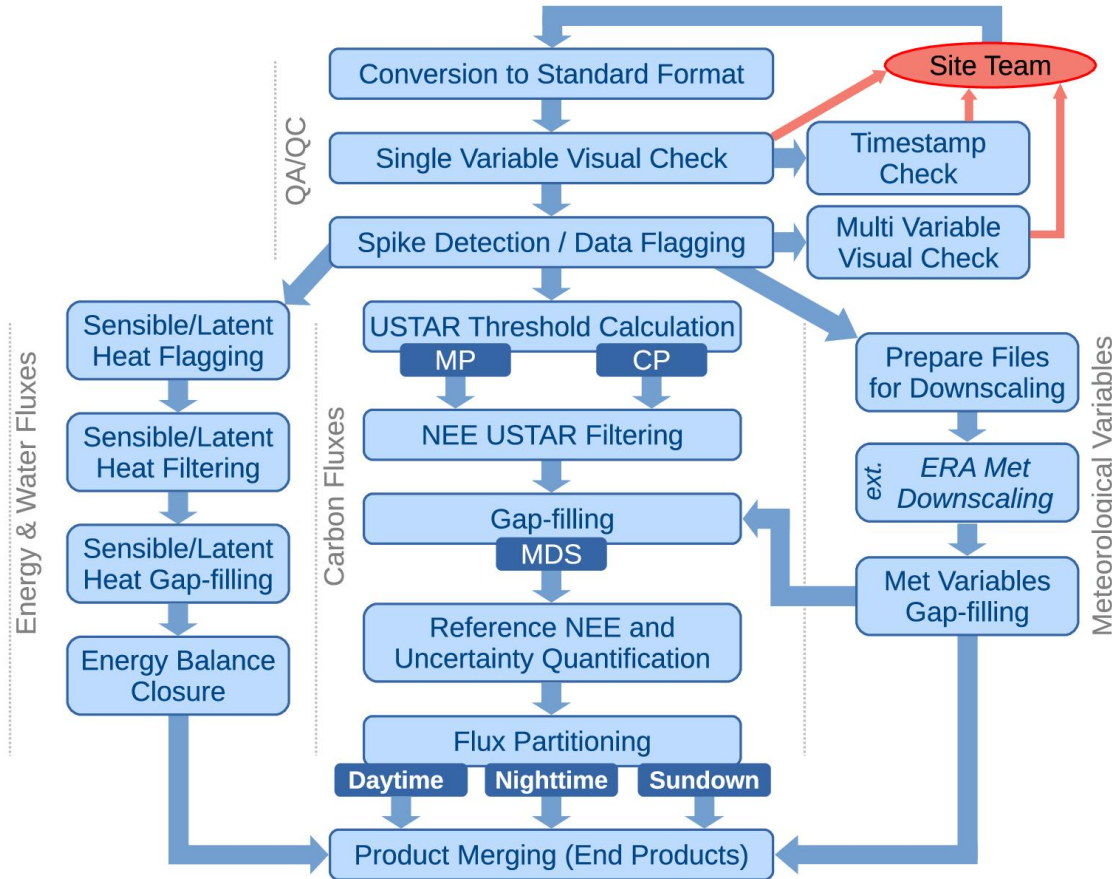
01: input (not-quite FP-Standard)
02: flagging/filtering
04: USTAR threshold method 1 (unc.)
05: USTAR threshold method 2 (unc.)
06: downscaling for met gapfilling
07: met gapfilling (MDS + downscaling)
08: NEE filter/storage/unc./ref/gapfilling
09: H & LE corr. factors/gapfilling/unc.
10: NEE partitioning (nighttime method)
11: NEE partitioning (daytime method)
12 (i): create input for 12
12: unc. from multiple USTAR thresholds
99: merge into FP-Standard compliant output

US-UMB
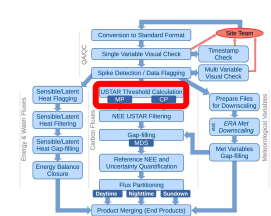
Distribution of USTAR Threshold values

USTAR Threshold (m s^{-1})

Legend:
- Papale et al. 2006 (modified)
- Barr et al. 2013
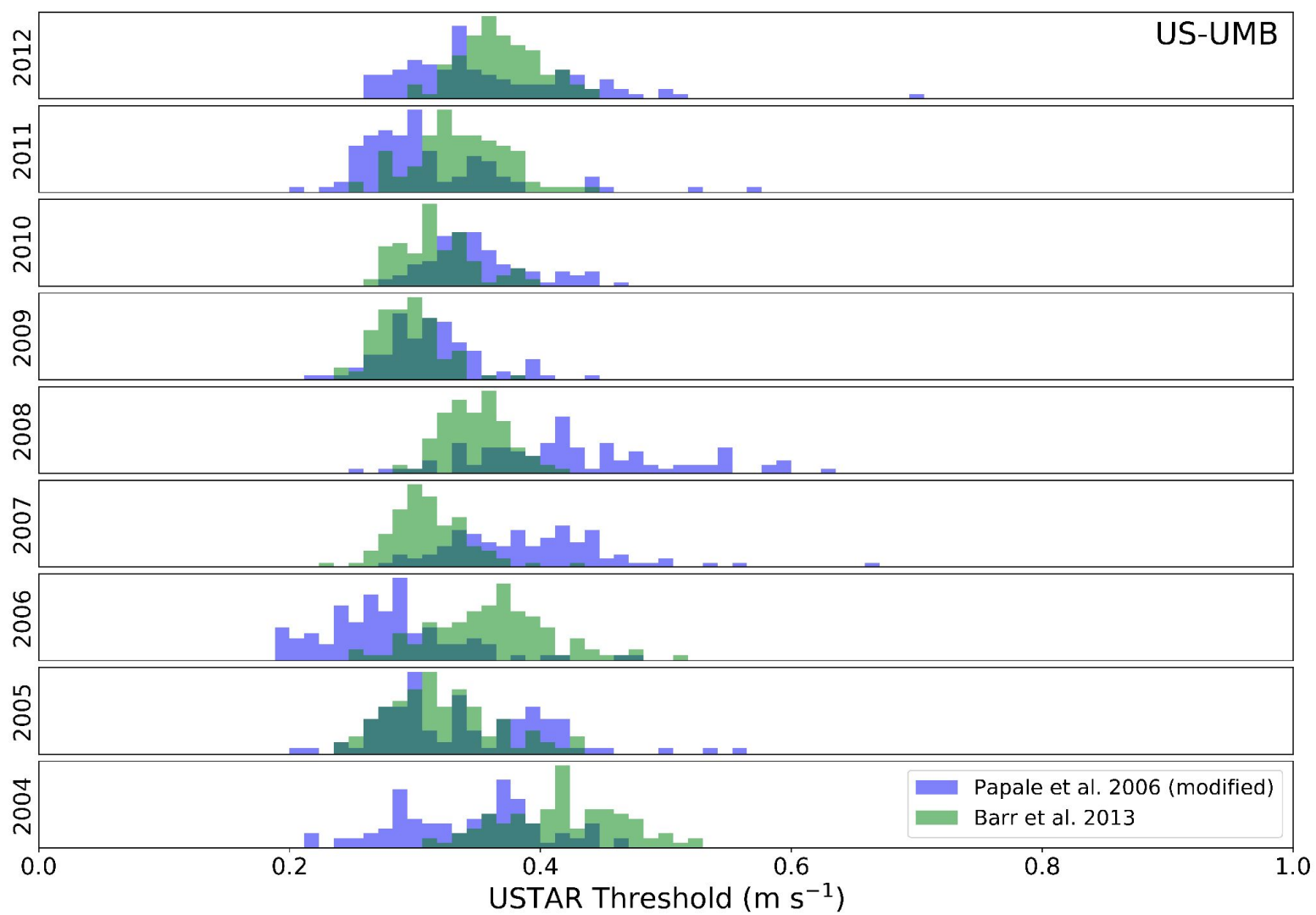
n.b.

- Key uncertainty estimate
- USTAR should not be pre-filtered

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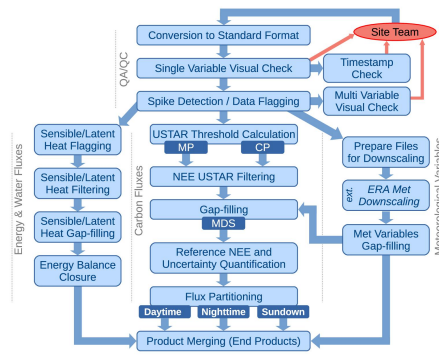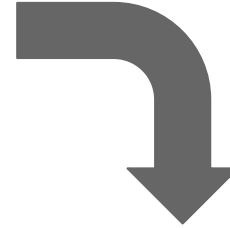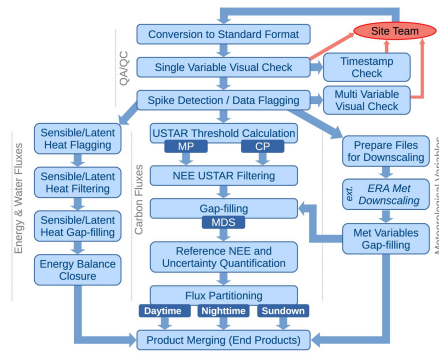- Future of FLUXNET regional and global data products

Gilberto
Pastorello

Workflow of a ONEFlux run
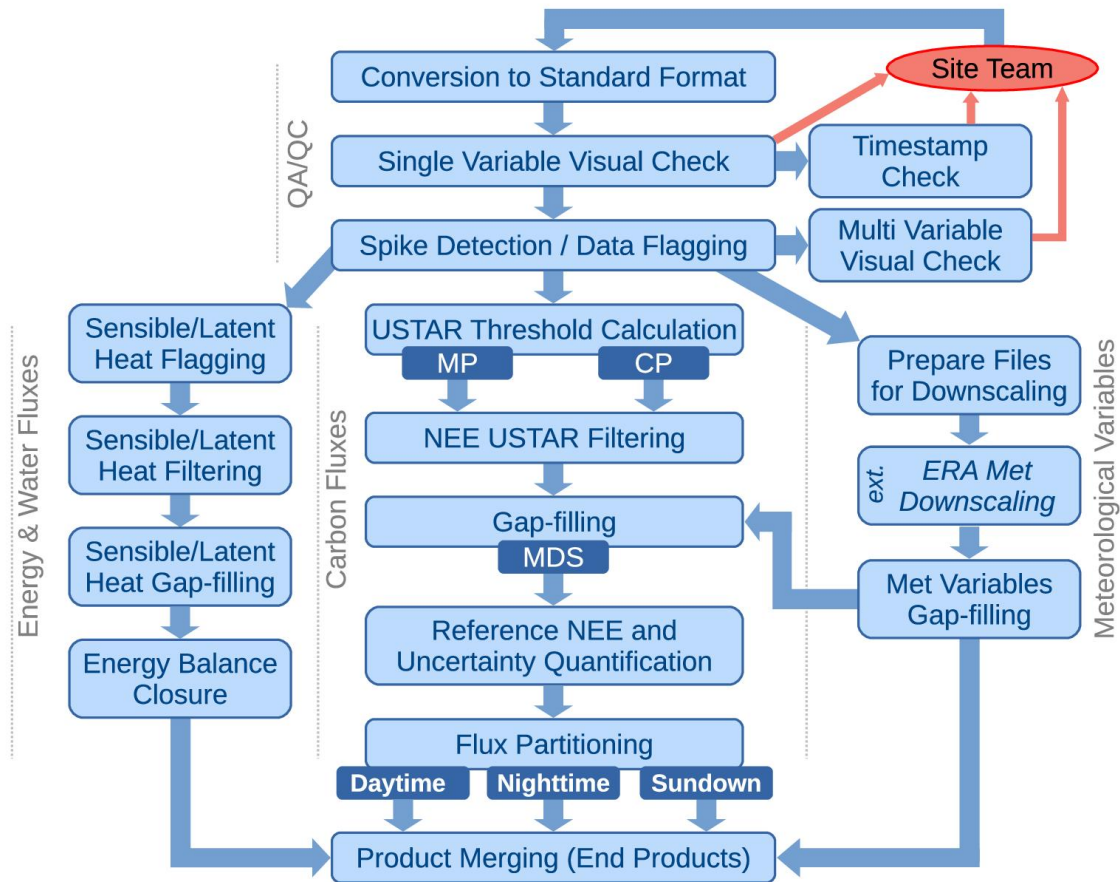
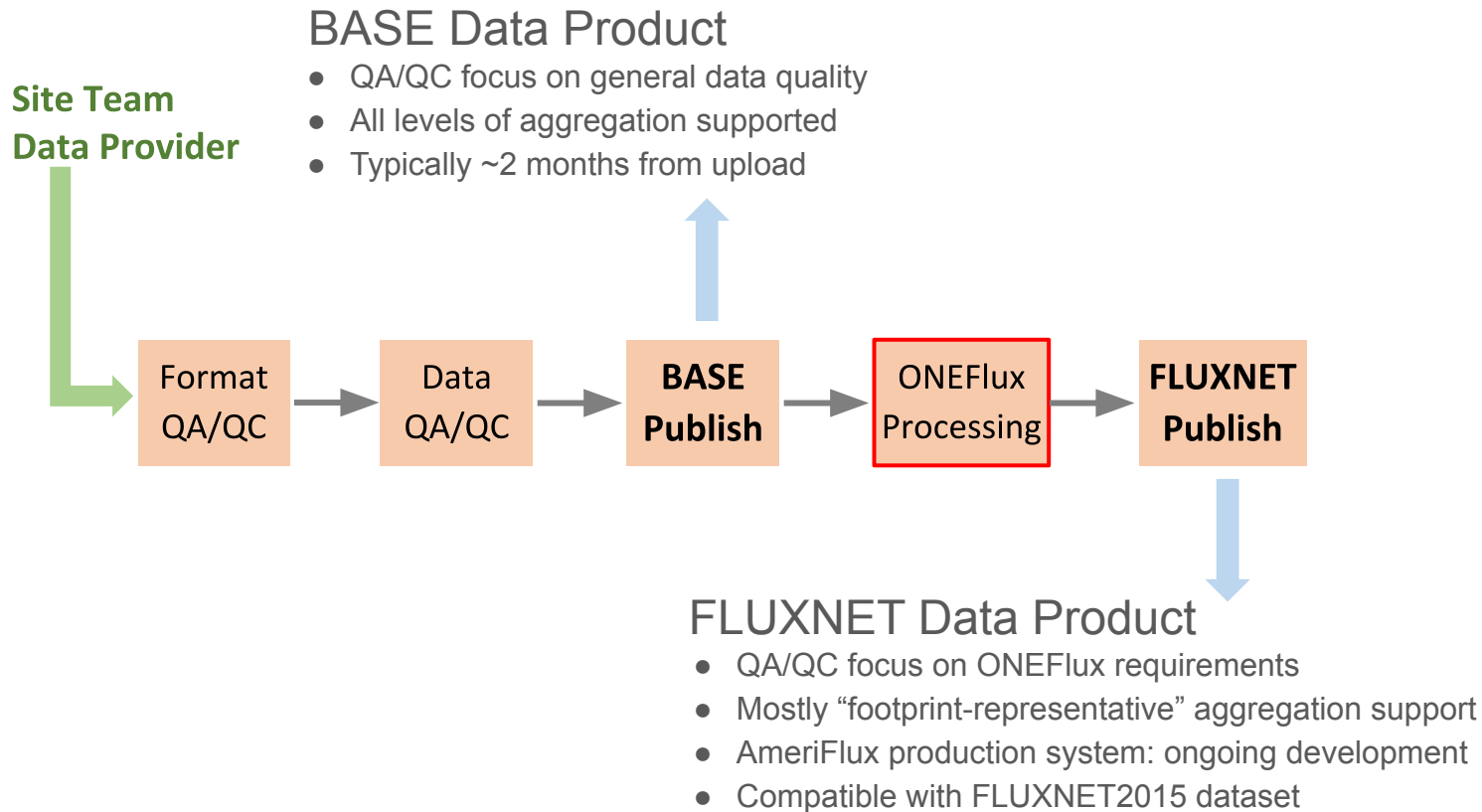# Workflow of a ONEFlux run

Workflow of a ONEFlux run

ONEFlux
Processing
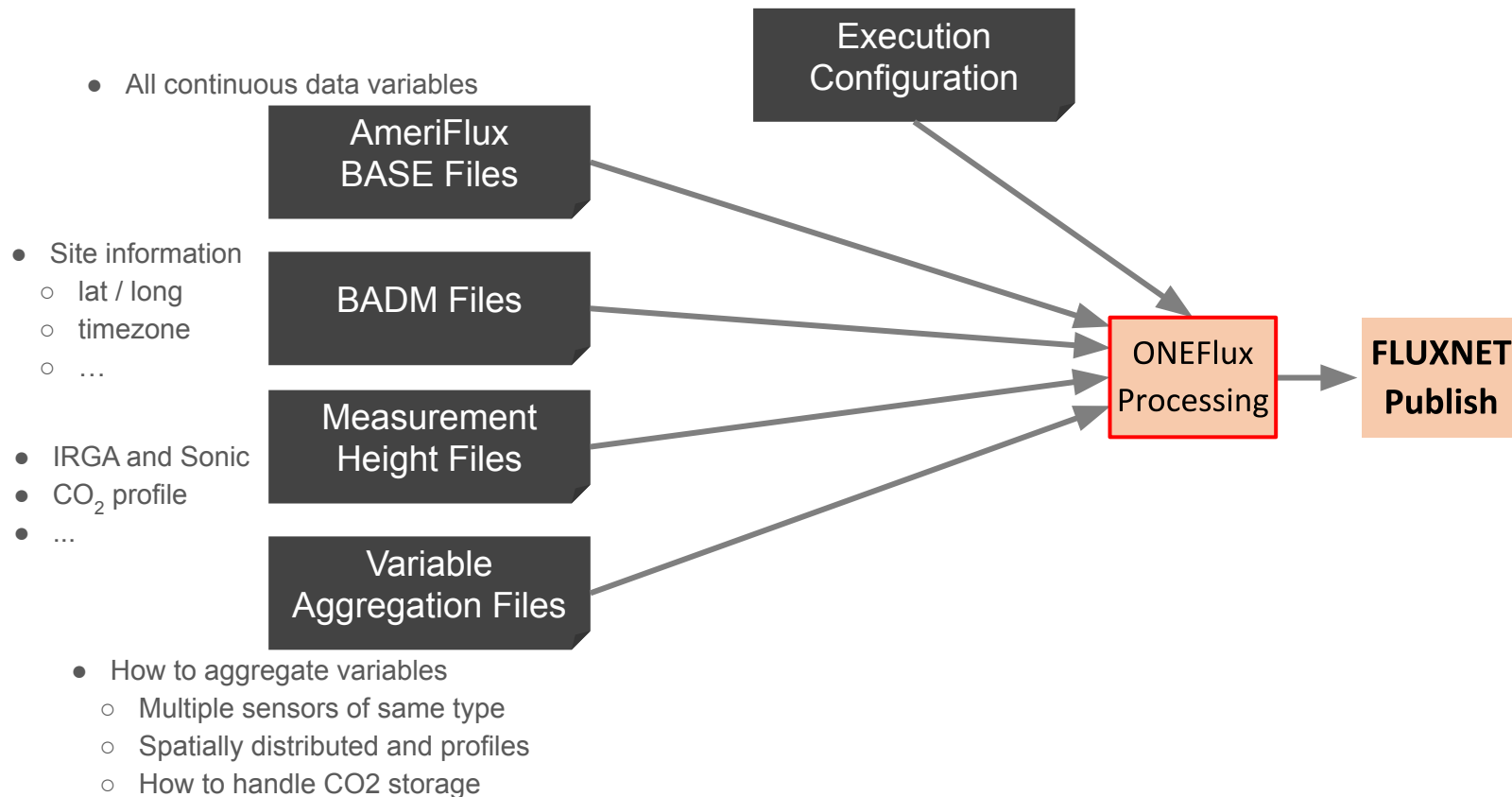
Workflow of a ONEFlux run
(within AmeriFlux Data Processing)
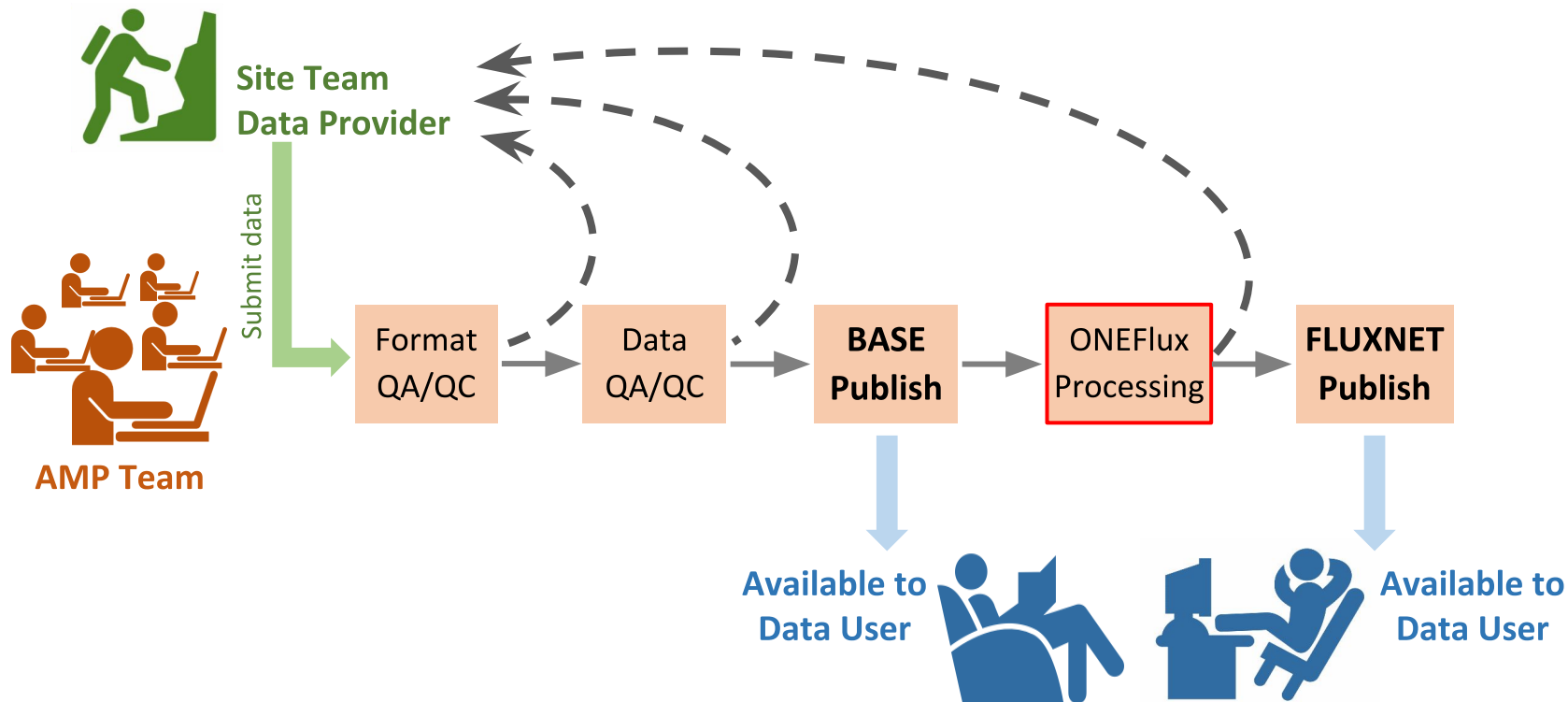
Workflow of a ONEFlux run: **Data Products**

Site Team Data Provider

BASE Data Product
- QA/QC focus on general data quality
- All levels of aggregation supported
- Typically ~2 months from upload

Format QA/QC → Data QA/QC → **BASE Publish** → ONEFlux Processing → **FLUXNET Publish**

FLUXNET Data Product
- QA/QC focus on ONEFlux requirements
- Mostly "footprint-representative" aggregation support
- AmeriFlux production system: ongoing development
- Compatible with FLUXNET2015 dataset

Workflow of a ONEFlux run: **Required Inputs**

- All continuous data variables

- Site information
  - lat / long
  - timezone
  - …

- IRGA and Sonic
- CO_2 profile
- ...

- How to aggregate variables
  - Multiple sensors of same type
  - Spatially distributed and profiles
  - How to handle CO2 storage

Critical data variables for ONEFlux

Required

- **CO2** (*μmolCO2 mol−1*): Carbon Dioxide (CO2) mole fraction in moist air
- **FC** (*μmolCO2 m−2 s−1*): Carbon Dioxide (CO2) turbulent flux (without storage component)
- **SC** (*μmolCO2 m−2 s−1*): Carbon Dioxide (CO2) storage flux measured with a vertical profile system, optional if tower shorter than 3 m
- **H** (*W m−2*): sensible heat turbulent flux, without storage correction
- **LE** (*W m−2*): latent heat turbulent flux, without storage correction
- **WS** (*m s−1*): horizontal wind speed
- **USTAR** (*m s−1*): friction velocity
- **TA** (*deg C*): air temperature
- **RH** (*%*): relative humidity (range 0–100%)
- **PA** (*kPa*): atmospheric pressure
- **SW_IN** (*W m−2*): incoming shortwave radiation

Recommended

- **G** (*W m−2*): ground heat flux, not mandatory, but needed for the energy balance closure calculations
- **NETRAD** (*W m−2*): net radiation, not mandatory, but needed for the energy balance closure calculations
- **SW_IN_POT** (*W m−2*): potential incoming shortwave radiation (top of atmosphere theoretical maximum radiation), calculated based on the site coordinates

Suggested

- **PPFD_IN** (*μmolPhotons m−2 s−1*): incoming photosynthetic photon flux density
- **P** (*mm*): precipitation total of each 30 or 60 minute period
- **LW_IN** (*W m−2*): incoming (down-welling) longwave radiation
- **SWC** (*%*): soil water content (volumetric), range 0–100%
- **TS** (*deg C*): soil temperature

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VPD computed from TA and RH; if provided, used for validation in QA/QC

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Support for multiple layers of soil variables (SWC & TS)

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Metadata collection for ONEFlux processing

BADM = Biological, Ancillary, Disturbance, and Metadata

- Variable Information
- Variable Aggregation (and Representation)

Metadata collection for flux-met data variables

Metadata collection for flux-met data variables
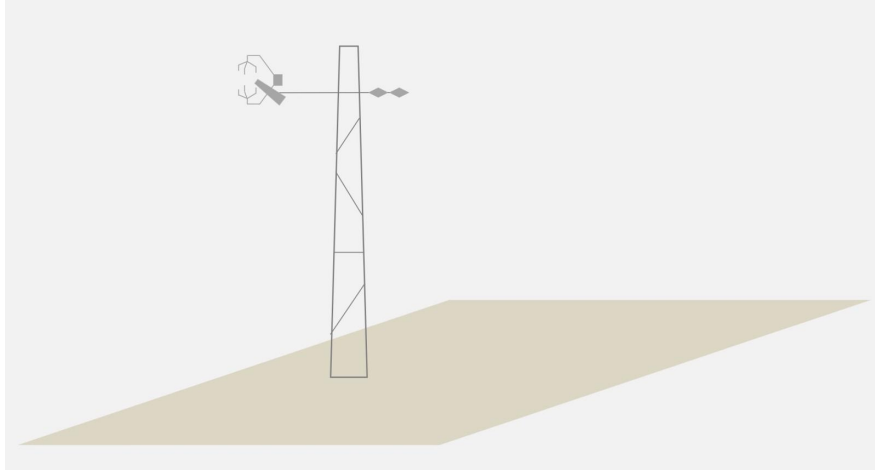
https://ameriflux.lbl.gov/data/data-variable-qualifier-examples/
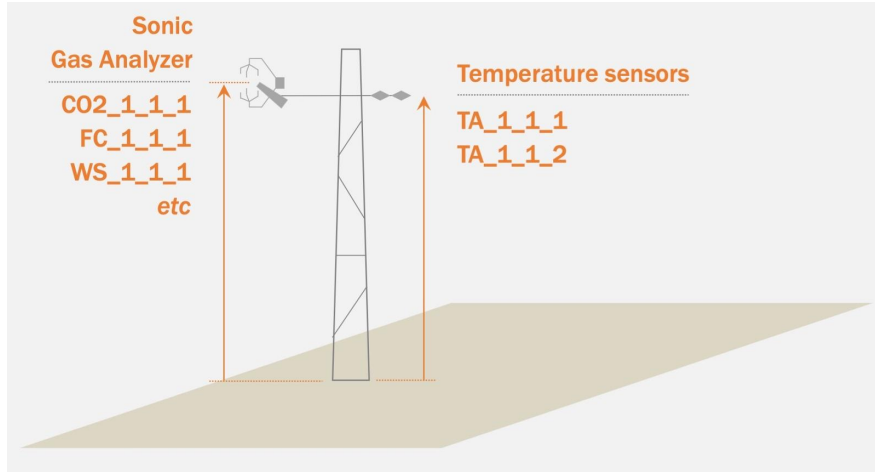
Variable Information: Height and Sensor Info

https://ameriflux.lbl.gov/sites/variable-information/

All sites are different!

AMP needs to know which variables are representative and/or should be aggregated.
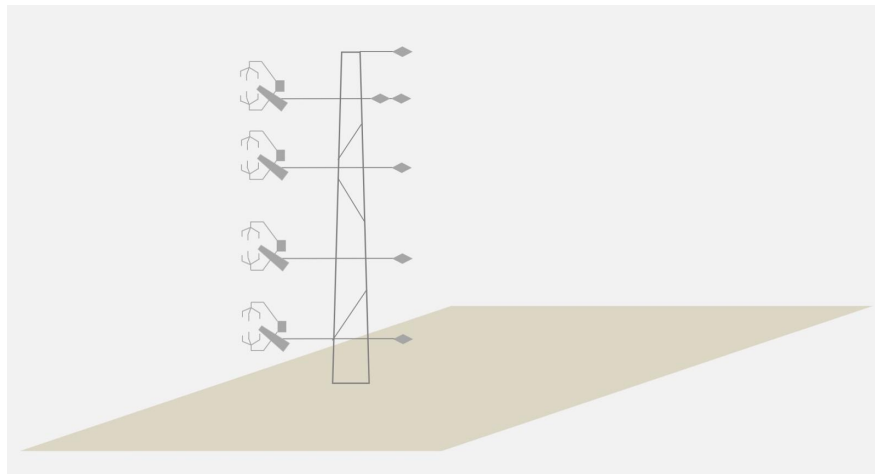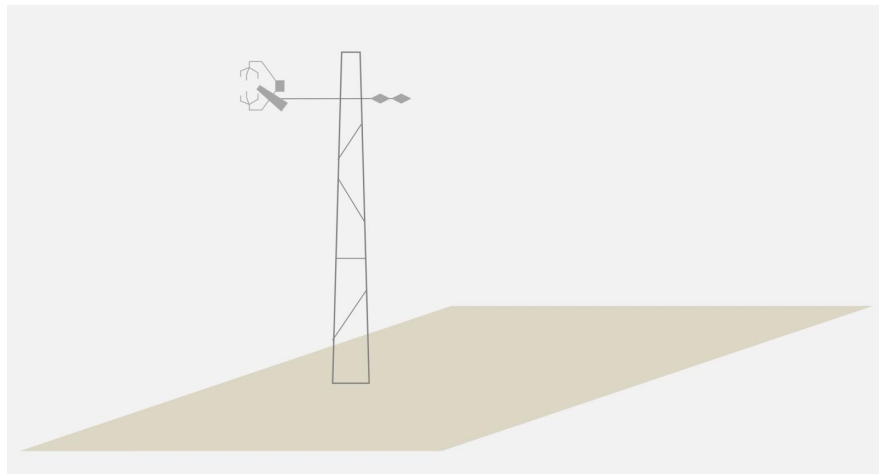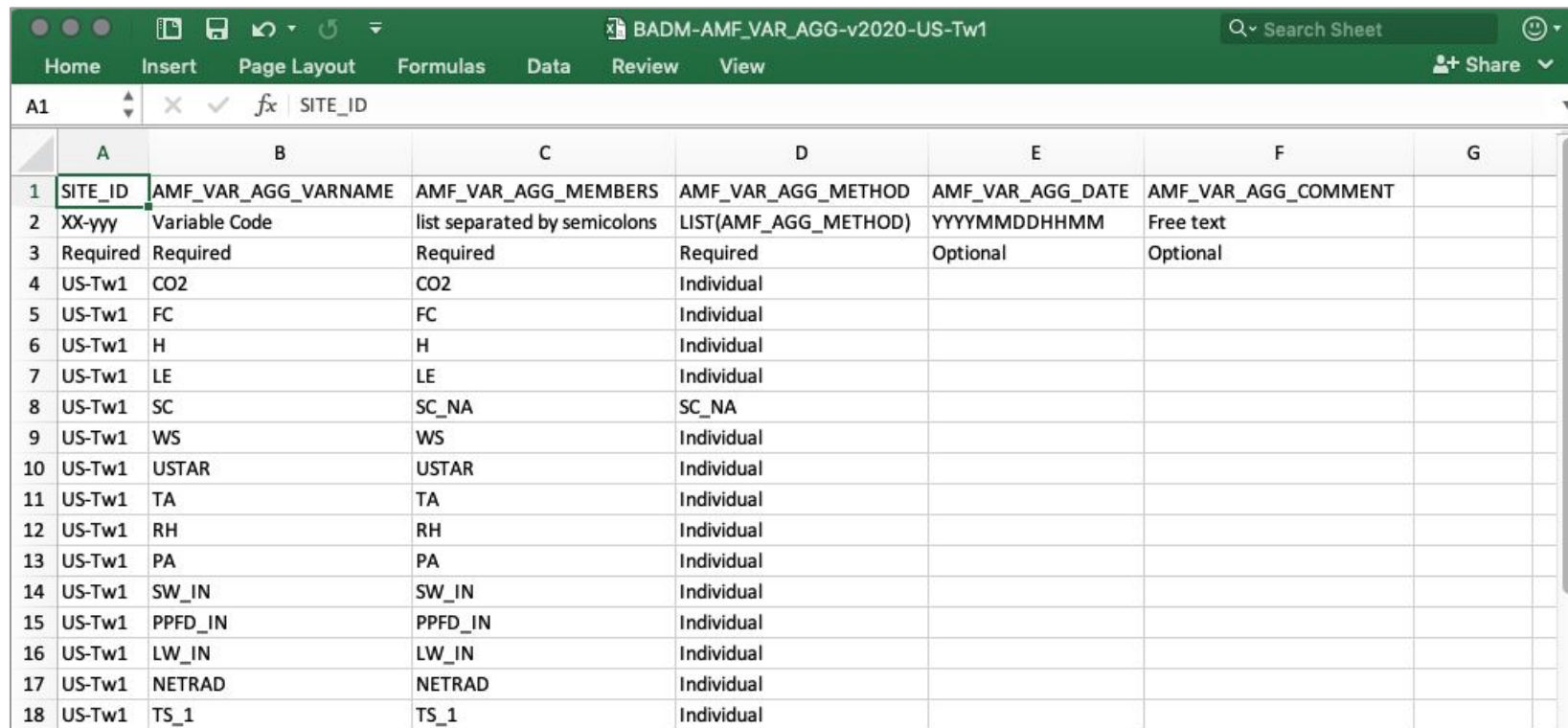
Submitting Variable Aggregation (AMF_VAR_AGG) BADM

1. AMP will contact you requesting submission via email

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2. AMP provides a pre-filled csv file (based on Variable Information and BADM database)

	A	B	C	D	E	F	G
1	SITE_ID	AMF_VAR_AGG_VARNAME	AMF_VAR_AGG_MEMBERS	AMF_VAR_AGG_METHOD	AMF_VAR_AGG_DATE	AMF_VAR_AGG_COMMENT	
2	XX-yyy	Variable Code	list separated by semicolons	LIST(AMF_AGG_METHOD)	YYYYMMDDHHMM	Free text	
3	Required	Required	Required	Required	Optional	Optional	
4	US-Tw1	CO2	CO2	Individual			
5	US-Tw1	FC	FC	Individual			
6	US-Tw1	H	H	Individual			
7	US-Tw1	LE	LE	Individual			
8	US-Tw1	SC	SC_NA	SC_NA			
9	US-Tw1	WS	WS	Individual			
10	US-Tw1	USTAR	USTAR	Individual			
11	US-Tw1	TA	TA	Individual			
12	US-Tw1	RH	RH	Individual			
13	US-Tw1	PA	PA	Individual			
14	US-Tw1	SW_IN	SW_IN	Individual			
15	US-Tw1	PPFD_IN	PPFD_IN	Individual			
16	US-Tw1	LW_IN	LW_IN	Individual			
17	US-Tw1	NETRAD	NETRAD	Individual			
18	US-Tw1	TS_1	TS_1	Individual			

BADM-AMF_VAR_AGG-v2020-US-Tw1

Submitting Variable Aggregation (AMF_VAR_AGG) BADM

1. AMP will contact you requesting submission via email
2. AMP provides a pre-filled csv file (based on Variable Information and BADM database)
3. AMP provides instructions in the email

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1. AMP will contact you requesting submission via email
2. AMP provides a pre-filled csv file (based on Variable Information and BADM database)
3. AMP provides instructions in the email
4. Site Teams review, update if needed, and upload the csv file

https://ameriflux.lbl.gov/data/upload-data/ > Choose BADM

Review Variable Aggregation (AMF_VAR_AGG) csv file

AMF_ ... _VARNAME	AMF_ ... _MEMBERS	AMF_ ... _METHOD	AMF_ ... _DATE	AMF_ ... _COMMENT
Variable Code	list separated by semicolons	LIST(AMF_AGG_METHOD)	YYYYMMDDHHMM	Free text
Required	Required	Required	Optional	Optional
CO2	CO2_1_1_1	Individual		
FC	FC_1_1_1	Individual		
SC	SC_NA	SC_NA		
TA	TA_1_1_1	Individual		
TA	TA_1_1_1;TA_2_1_1	Mean	201504121200	
WS	WS_1_1_1	Individual		
G_1	G_1_1_1;G_2_1_1;G_3_1_1;G_4_1_1	Mean		
SWC_1	SWC_1_1_1;SWC_2_1_1;SWC_2_1_2	Mean		AMP: No depth info; please double check

Review Variable Aggregation (AMF_VAR_AGG) csv file

Varname

Variable to be used in ONEFlux processing.

MEMBERS

MEMBERS variable(s) must match variables in the site's BASE data product.

AMF_..._VARNAME	AMF_..._MEMBERS	AMF_..._METHOD	AMF_..._DATE	AMF_..._COMMENT
Variable Code	list separated by semicolons	LIST(AMF_AGG_METHOD)	YYYYMMDDHHMM	Free text
Required	Required	Required	Optional	Optional
CO2	CO2_1_1_1	Individual		
FC	FC_1_1_1	Individual		
SC	SC_NA	SC_NA		
TA	TA_1_1_1	Individual		
TA	TA_1_1_1;TA_2_1_1	Mean	201504121200	
WS	WS_1_1_1	Individual		
G_1	G_1_1_1;G_2_1_1;G_3_1_1;G_4_1_1	Mean		
SWC_1	SWC_1_1_1;SWC_2_1_1;SWC_2_1_2	Mean		AMP: No depth info; please double check

METHOD Options

- Individual
- Mean
- SC_NA (use only with SC_NA in MEMBERS)

Review Variable Aggregation (AMF_VAR_AGG) csv file

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Variable to be used in ONEFlux processing.

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MEMBERS variable(s) must match variables in the site's BASE data product.

AMF_ ... _VARNAME	AMF_ ... _MEMBERS	AMF_ ... _METHOD	AMF_ ... _DATE	AMF_ ... _COMMENT
Variable Code	list separated by semicolons	LIST(AMF_AGG_METHOD)	YYYYMMDDHHMM	Free text
Required	Required	Required	Optional	Optional
CO2	CO2_1_1_1	Individual		
FC	FC_1_1_1	Individual		
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SWC_1	SWC_1_1_1;SWC_2_1_1;SWC_2_1_2	Mean		AMP: No depth info; please double check

DATE

- No DATE = info starts at beginning of data record.
- Provide DATE when info changes within data record.

METHOD Options

- Individual
- Mean
- SC_NA (use only with SC_NA in MEMBERS)

Review Variable Aggregation (AMF_VAR_AGG) csv file

Varname

Variable to be used in ONEFlux processing.

MEMBERS

MEMBERS variable(s) must match variables in the site's BASE data product.

Indicate storage with VARNAME = SC

Options for MEMBERS:
- Enter SC variable(s) calculated by site team
- Enter CO2 variable to use for estimating SC (typically the highest CO2 observation)
- Storage is negligible. Enter SC_NA.

See details below for more info.

AMF_ ... _VARNAME	AMF_ ... _MEMBERS	AMF_ ... _METHOD	AMF_ ... _DATE	AMF_ ... _COMMENT
Variable Code	list separated by semicolons	LIST(AMF_AGG_METHOD)	YYYYMMDDHHMM	Free text
Required	Required	Required	Optional	Optional
CO2	CO2_1_1_1	Individual		
FC	FC_1_1_1	Individual		
SC	SC_NA	SC_NA		
TA	TA_1_1_1	Individual		
TA	TA_1_1_1;TA_2_1_1	Mean	201504121200	
WS	WS_1_1_1	Individual		
G_1	G_1_1_1;G_2_1_1;G_3_1_1;G_4_1_1	Mean		
SWC_1	SWC_1_1_1;SWC_2_1_1;SWC_2_1_2	Mean		AMP: No depth info; please double check

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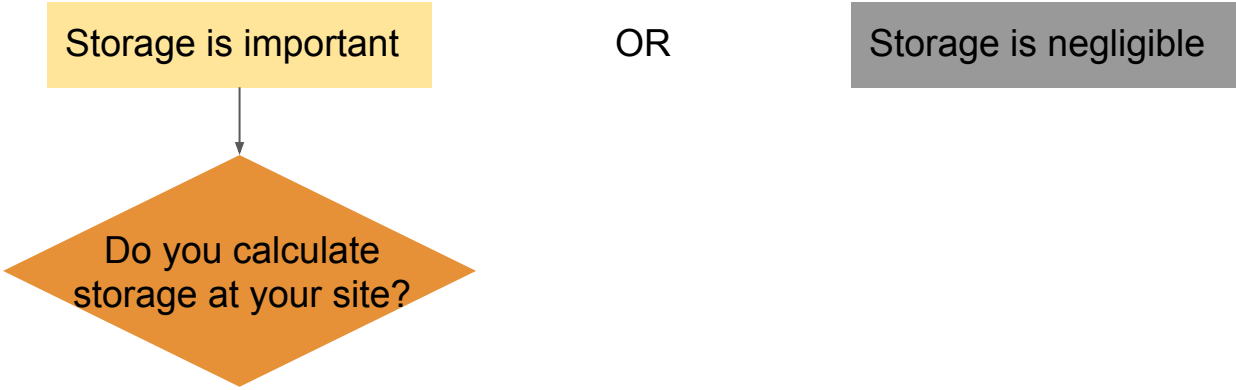# Reporting carbon storage (VARNAME = SC)

Storage is important   OR   Storage is negligible

Reporting carbon storage (VARNAME = SC)
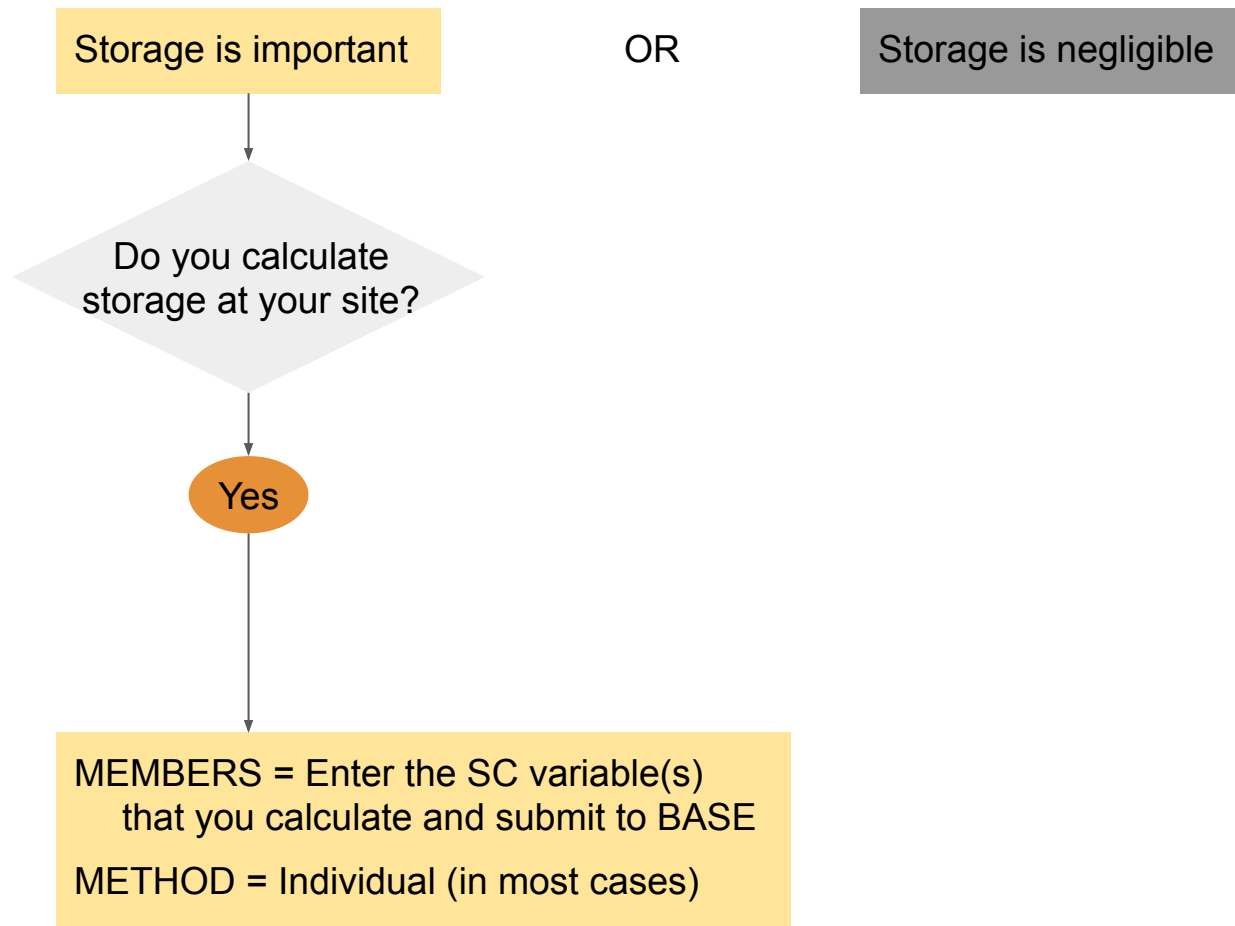
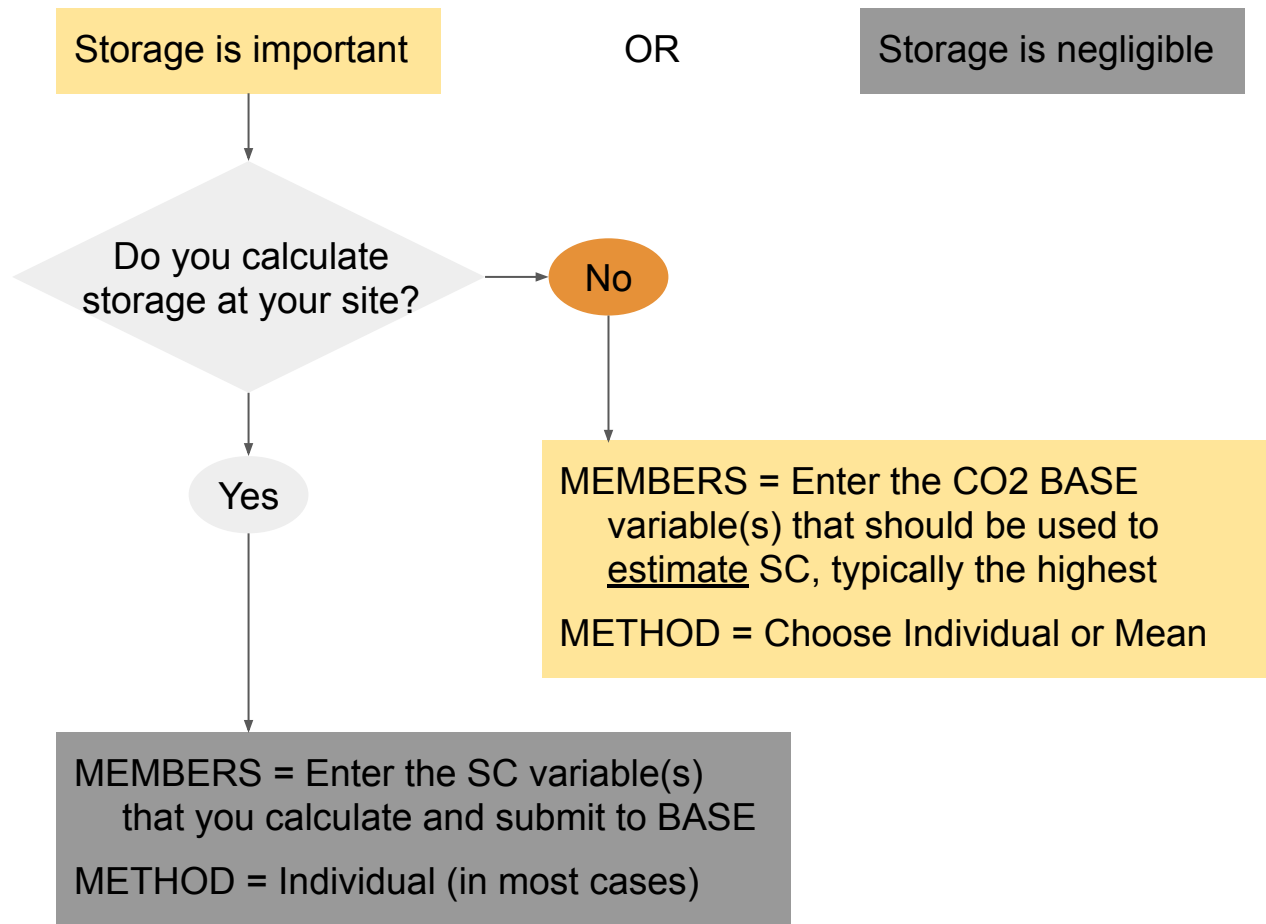Storage is important   OR   Storage is negligible

Do you calculate storage at your site?

Reporting carbon storage (VARNAME = SC)

Storage is important   OR   Storage is negligible

Do you calculate storage at your site?

Yes

MEMBERS = Enter the SC variable(s) that you calculate and submit to BASE

METHOD = Individual (in most cases)

Reporting carbon storage (VARNAME = SC)

Storage is important   OR   Storage is negligible

Do you calculate storage at your site?

No

Yes

MEMBERS = Enter the CO_2 BASE variable(s) that should be used to <u>estimate</u> SC, typically the highest

METHOD = Choose Individual or Mean

MEMBERS = Enter the SC variable(s) that you calculate and submit to BASE

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Reporting carbon storage (VARNAME = SC)

Storage is important   OR   Storage is negligible

Do you calculate storage at your site?

No

Yes

MEMBERS = SC_NA

METHOD = SC_NA

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AmeriFlux Data Pipeline
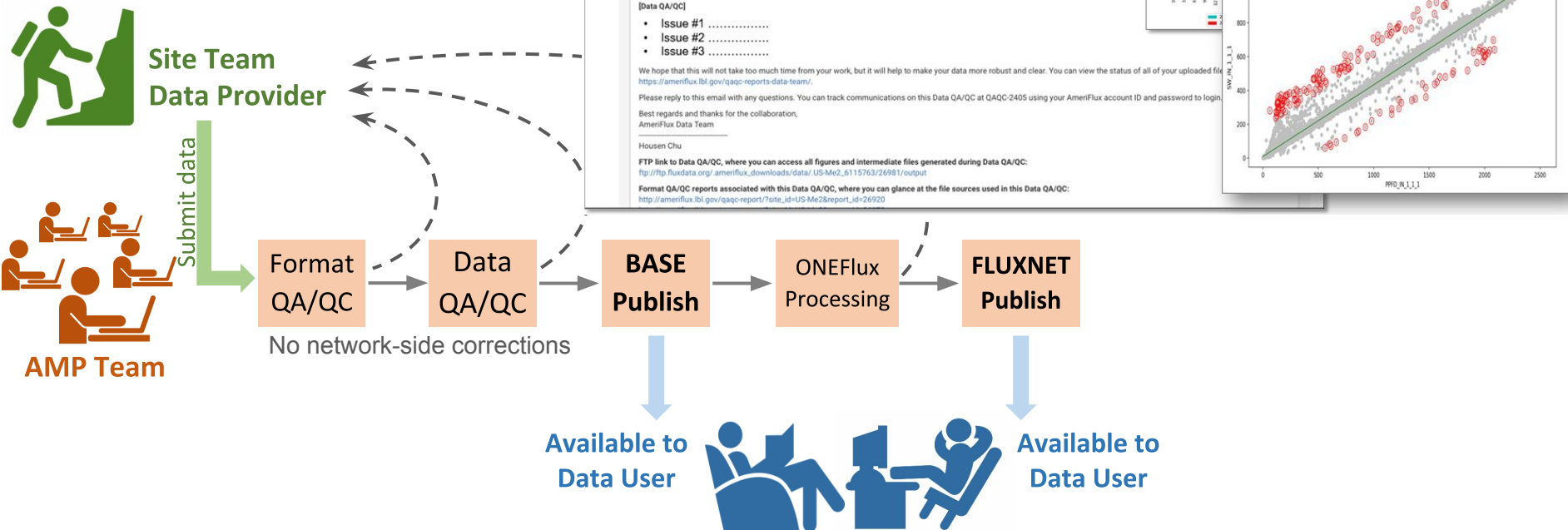
Observational data patterns for time series data quality assessment

Pastorello, G. et al., 2014., Proc. 10th IEEE International Conference on e-Science, Sao Paulo, pp. 271-278, doi: 10.1109/eScience.2014.45

Issues	Descriptions	Sources	Corrections
Windowed varying maximums	levels of values at higher end varies more than expected for natural variability	sensor malfunction or dirt accumulation; poor filtering for noise and spikes	correct calibration; redo despiking from original data
Trend in minimums	noticeable increasing or decreasing trend in lower end of vales within a time window	sensor deg	
Trend in maximums	noticeable increasing or decreasing trend in higher end of vales within a time window	sensor deg	
Measurement interval filter	data filtered for one or more ranges of values (e.g., values between x and y are removed)	incorrect fi ing process	
Measurement cutoff filter	data at points higher (or lower) than a threshold are removed (e.g., values larger than x are removed)	incorrect fi ing process	
Inconsistent noise levels	time series has different levels of noise that are not usually explained by sensor, measurement, or processing variability, especially very low noise periods	indirect est based gap-processing filtering	
Repeating pattern	repetition of exact pattern throughout short or long time windows	indirect est based gap-processing	
Physically unlikely ranges	range of values for a period within available data has unlikely values (either because it's out of physically possible values or because it grossly mismatches general trend)	sensor ma sensor; wr efficient ap filtering ap	

different levels for maximums and minimums
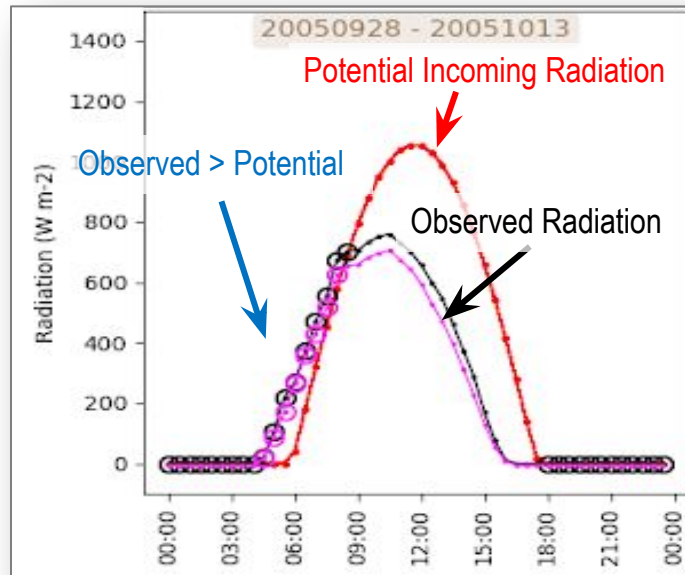
Current Implemented Checks

- Timestamp shift check
- Physical range check
- Diurnal & Seasonal pattern
- Multivariate comparison
- USTAR filtering check
- Variable availability

Current Implemented Checks

o Timestamp shift

- Timestamp shift
- Daylight saving time
- Data stream not synchronized
- Time zone specification
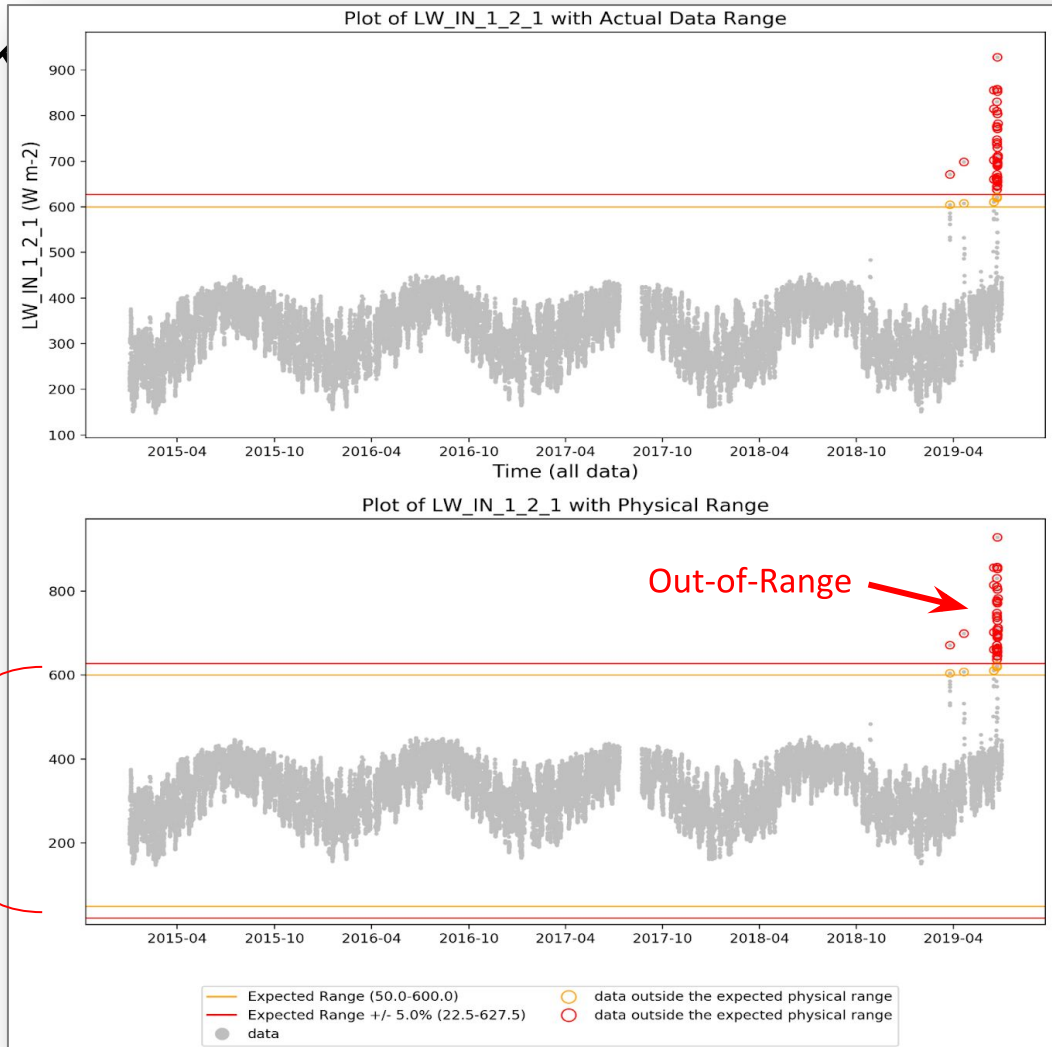

Max Diurnal Pattern

Potential Incoming Radiation

Observed > Potential

Observed Radiation

Radiation Timeshift Analysis for year 2005
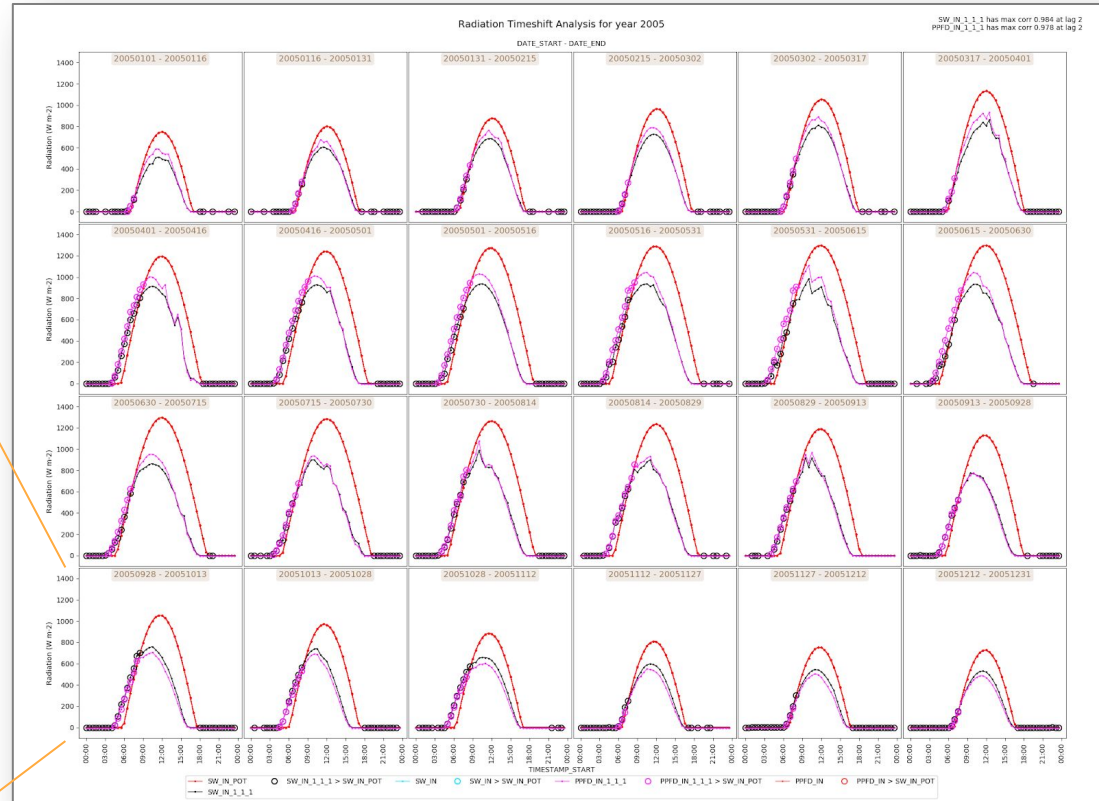
Current Implemented Check

o Physical range check

- Physically unlikely values
- Outlier
- Inconsistent noise levels / filtering
- Trend
- Step change in full range
- Change of resolution
- Repeating patterns / constants
- Long gaps
- Measurement cutoff filter
- Other unrecognized pattern

Physically plausible range
Network-wise historical range

Out-of-Range

Current Implemented Checks

o Diurnal & Seasonal pattern

- Physically unlikely values
- Outlier
- Sign convention
- Step change in full range

Mean Diurnal Pattern

Historical Mean + Quantiles

Observed Mean
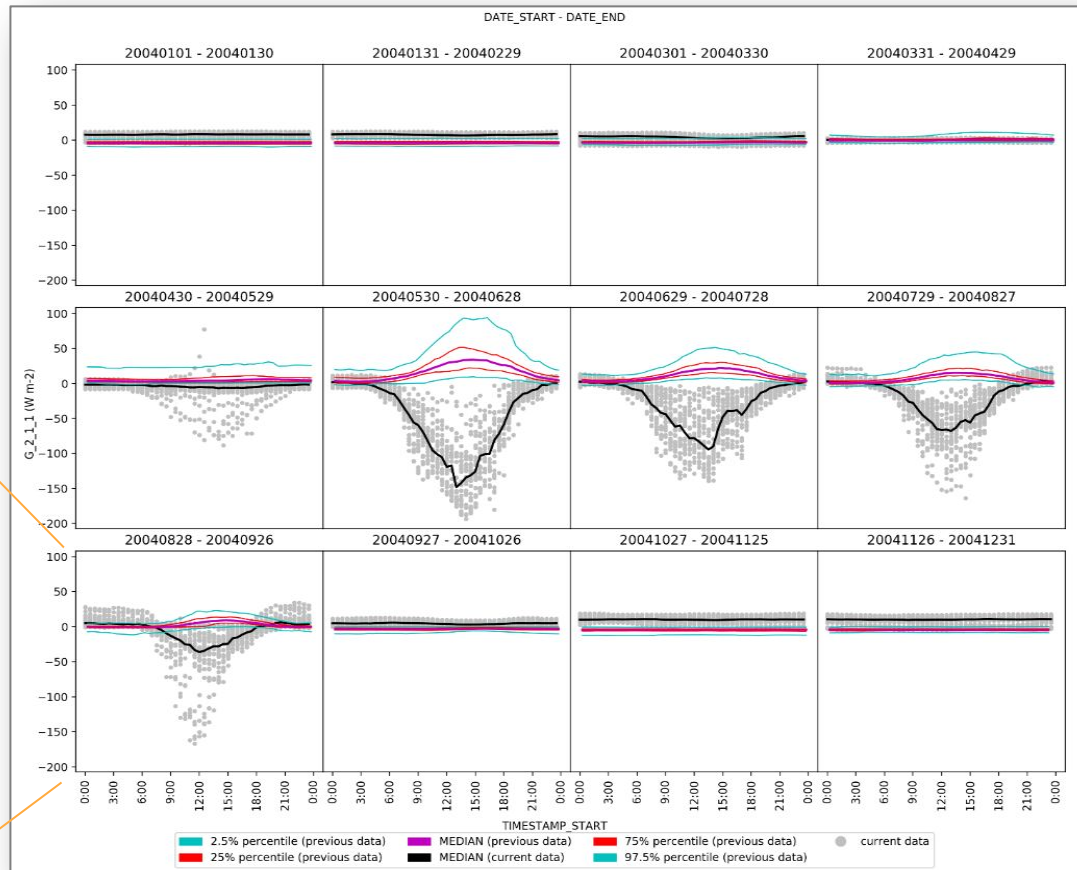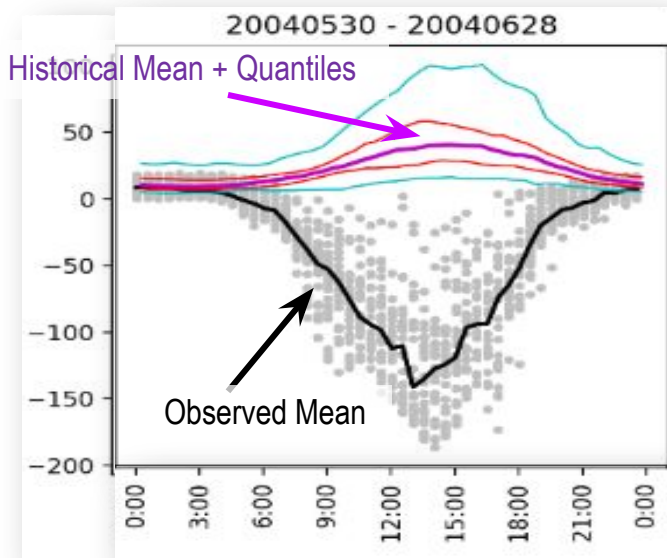
Current Implemented Checks

o Multivariate comparison

- Outlier
- Variables not synchronized in time
- Step change in full range
- Trend
- Shaded radiation
- Derived one from other

- Cross-variable:
  - PPFD_IN vs SW_IN
  - TA vs T_SONIC
  - WS vs USTAR

- Cross-level:
  - TA profile
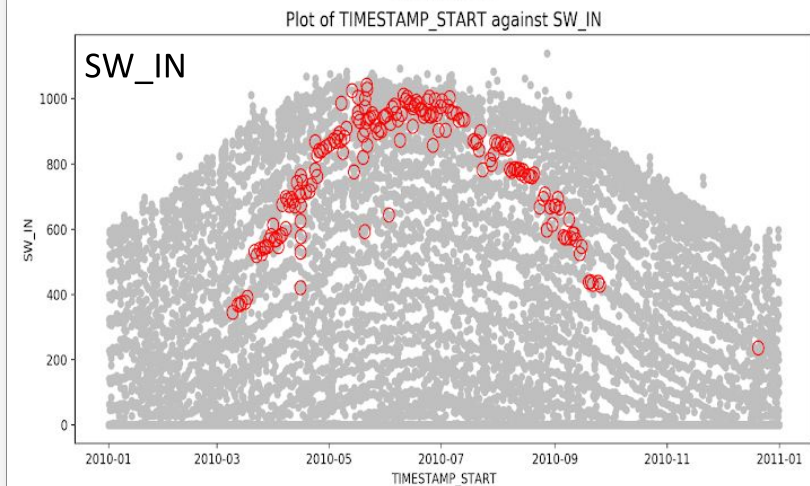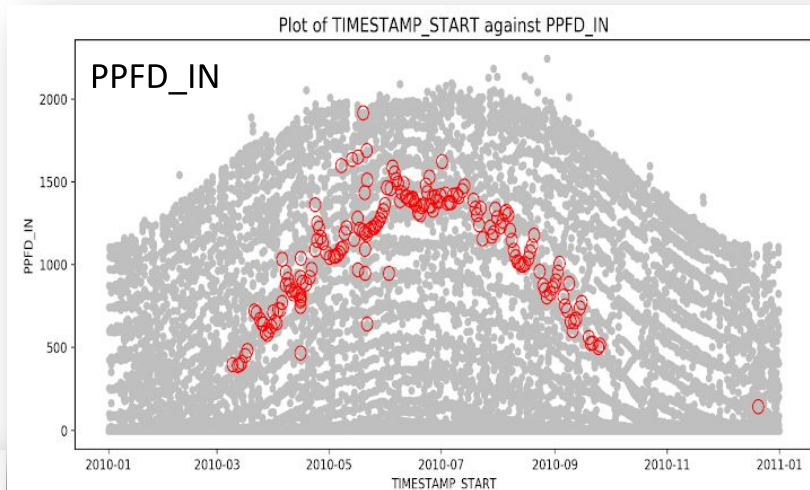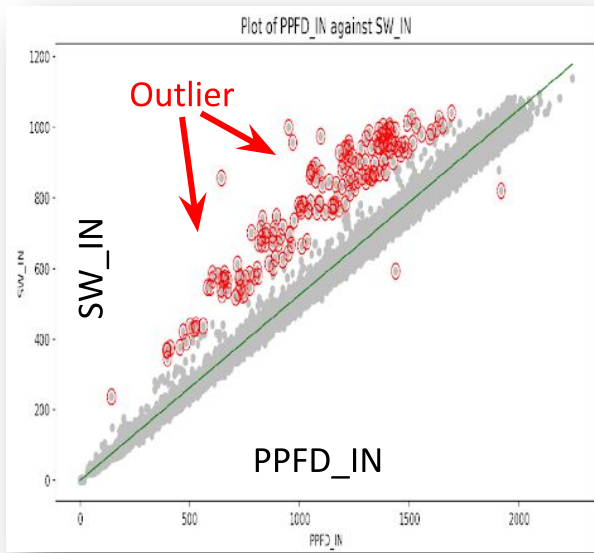
Current Implemented Checks

o FC-USTAR filtering check

USTAR when FC not missing

USTAR when FC missing
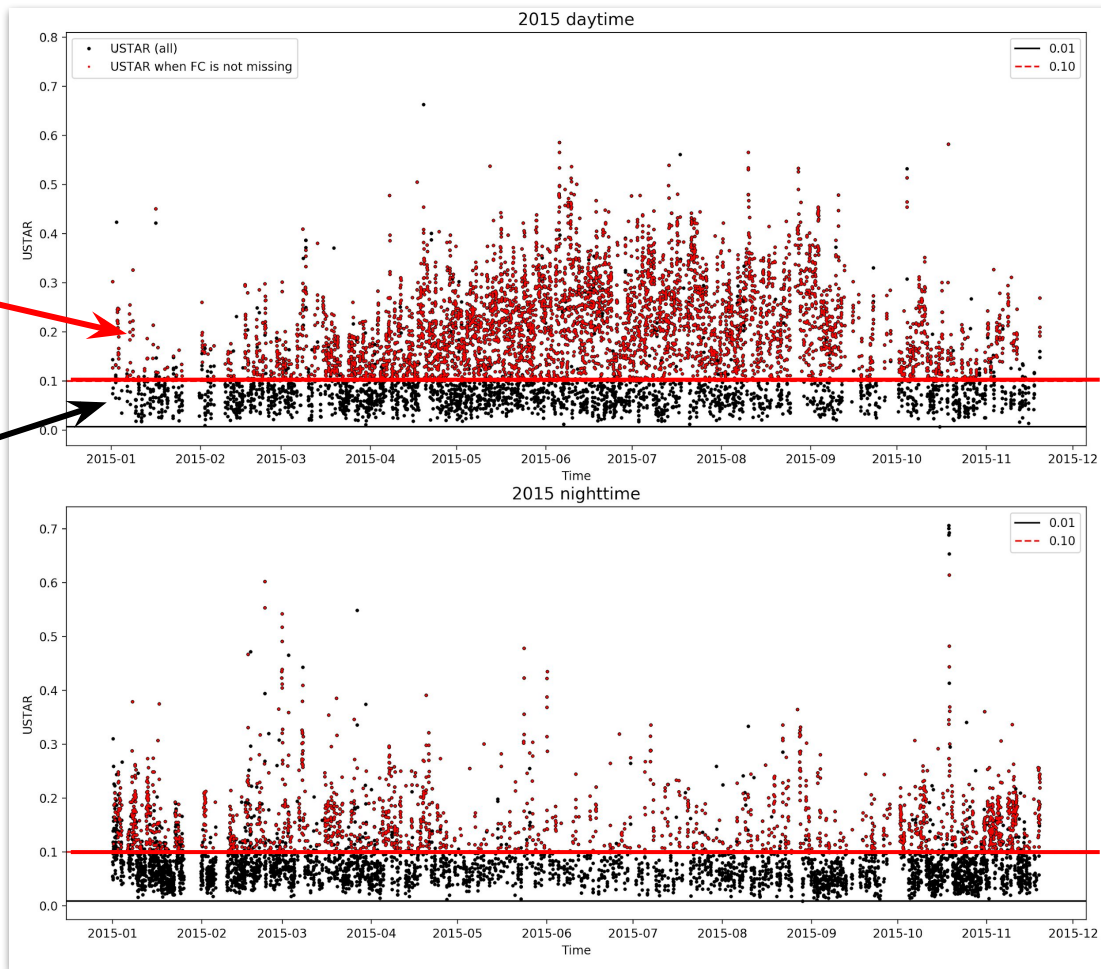
Current Implemented Checks

o Variable availability
  - Long gaps
  - Missing mandatory variables
  - Inconsistent variable naming / qualifier / aggregation

No measurement

Variables not provided
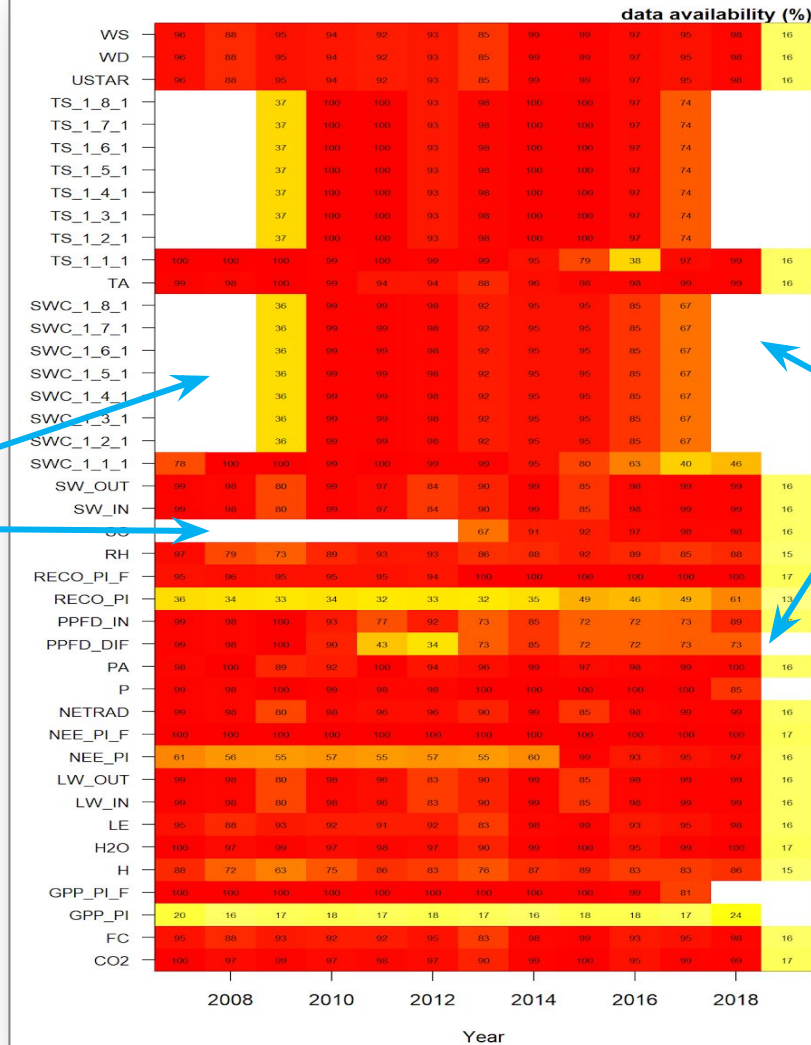
Data QA/QC for ONEFlux

- Important variables

Required	Recommended	Suggested
FC	NETRAD	WD
CO2	G	P
SC		PPFD_IN
USTAR		SW_OUT
WS		LW_IN
SW_IN		LW_OUT
TA		SWC ...
RH		TS ...
LE		
H		
PA		

Plot of TIMESTAMP_START against PPFD_IN

Plot of TIMESTAMP_START against SW_IN

- Critical issues affecting processing
  - Timestamp shifts
  - Flux variables being filtered using USTAR thresholds
  - Trend or step change in radiation variables
  - Large outliers, esp in flux variables
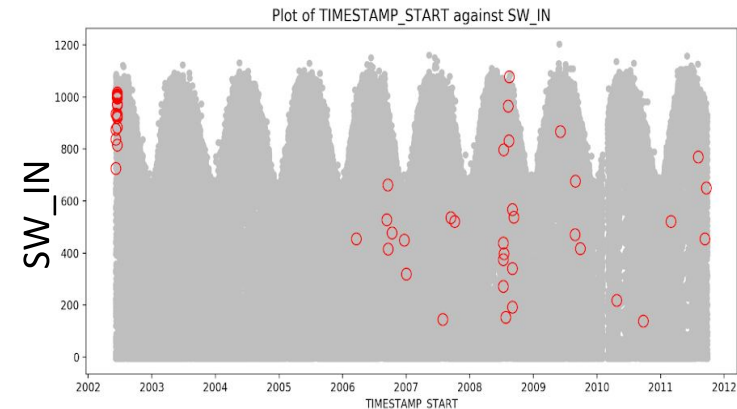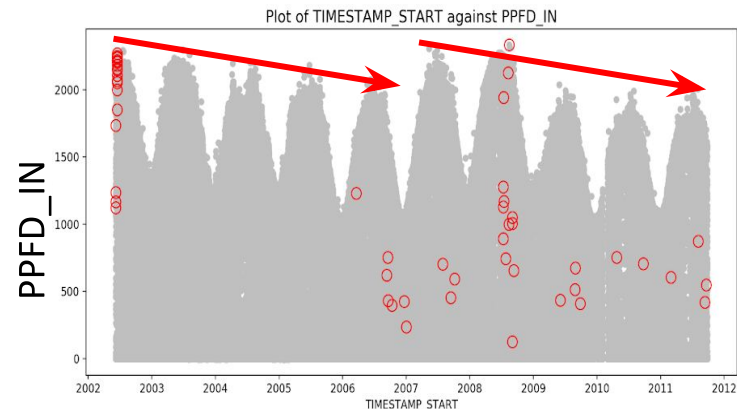
Agenda

- ONEFlux overview
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- Future of FLUXNET regional and global data products

Gilberto
Pastorello

FLUXNET data products created with ONEFlux
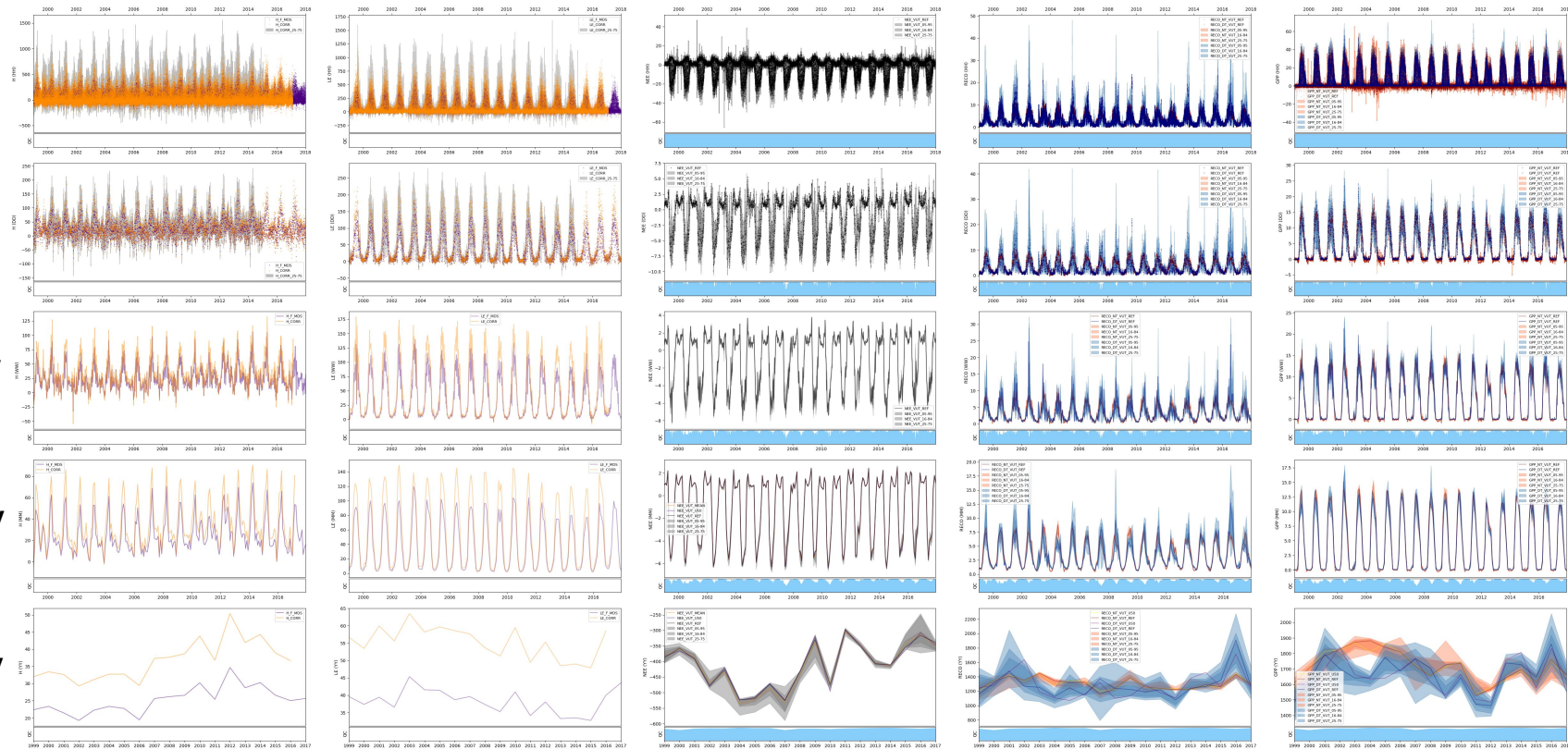
NEE (μmolCO2 m-2 s-1), hourly

US-MMS

NEE (μmolCO2 m-2 s-1)
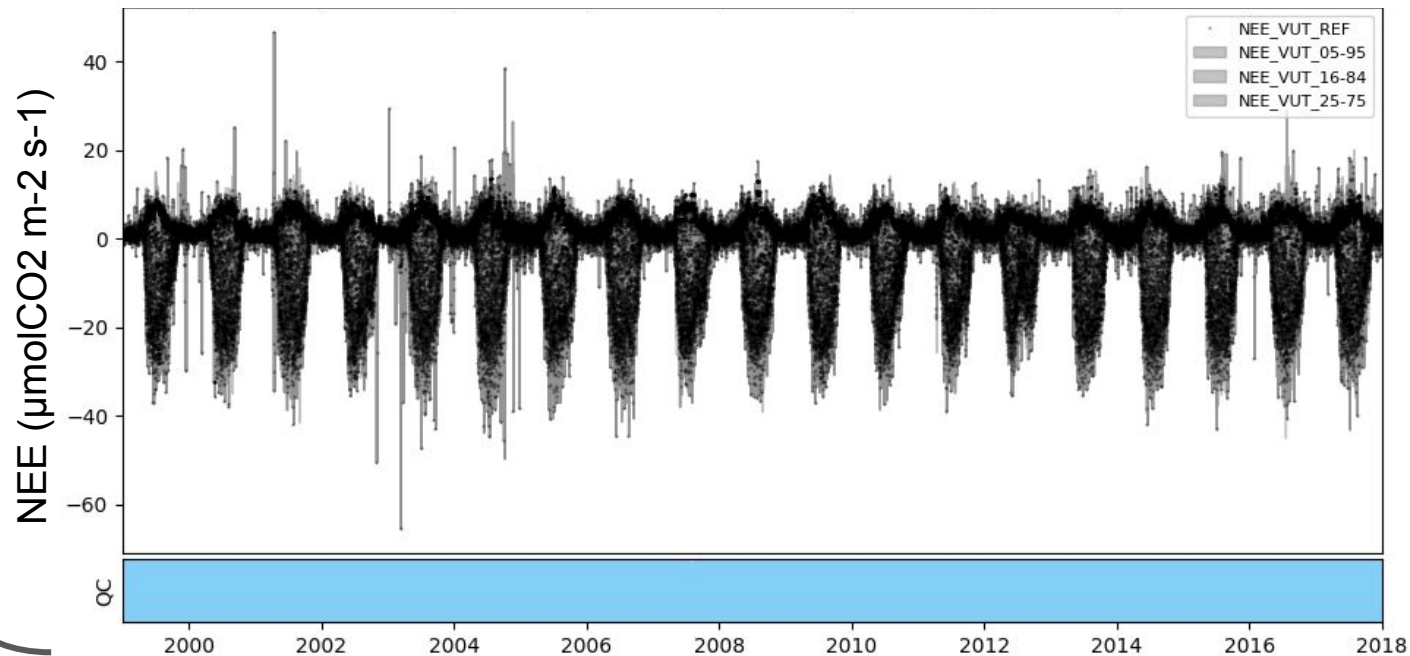
NEE (gC m-2 y-1), yearly

US-MMS

GPP (gC m-2 y-1), yearly

US-MMS
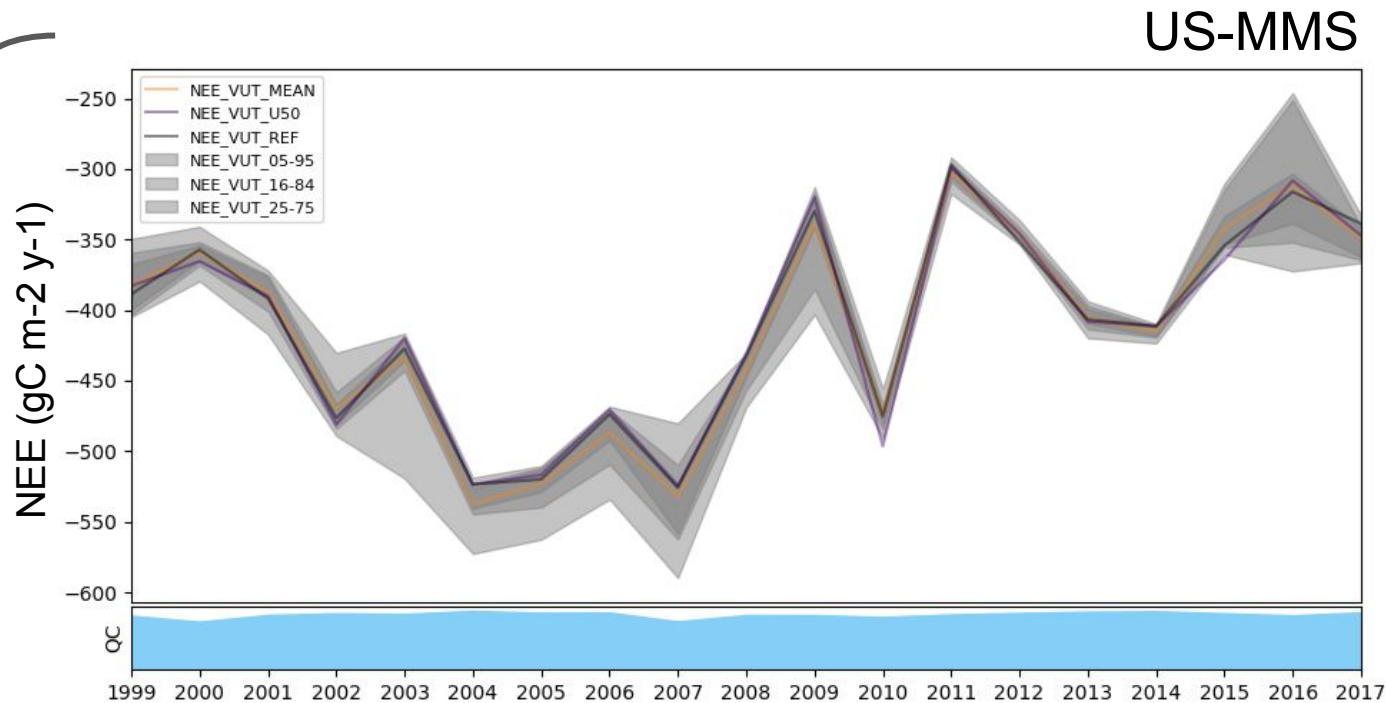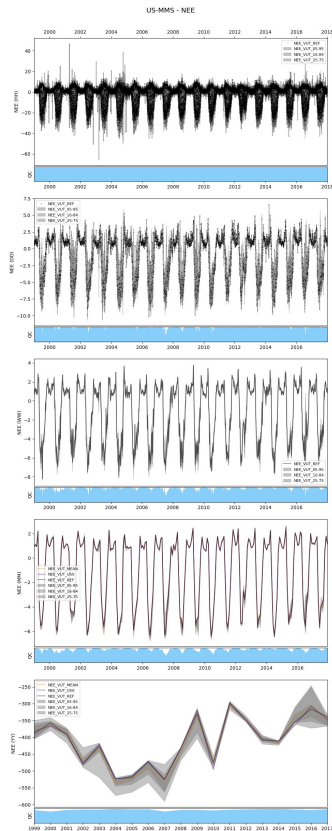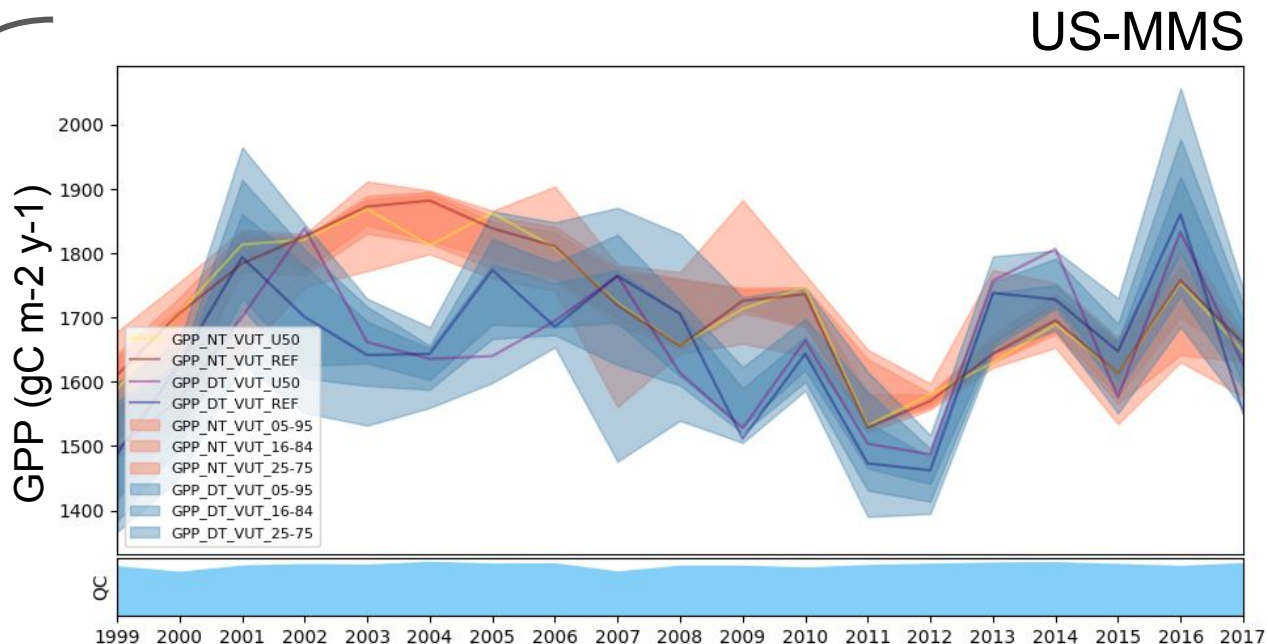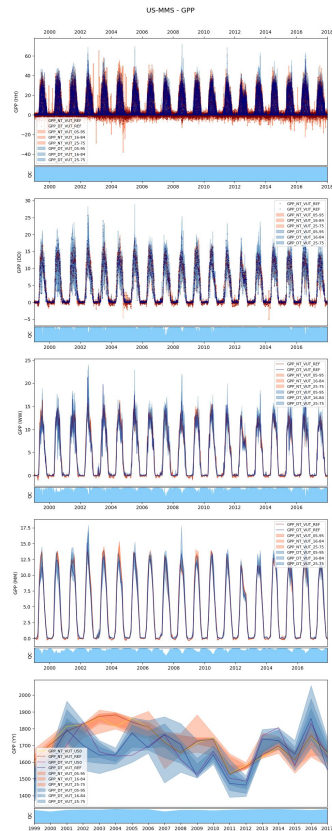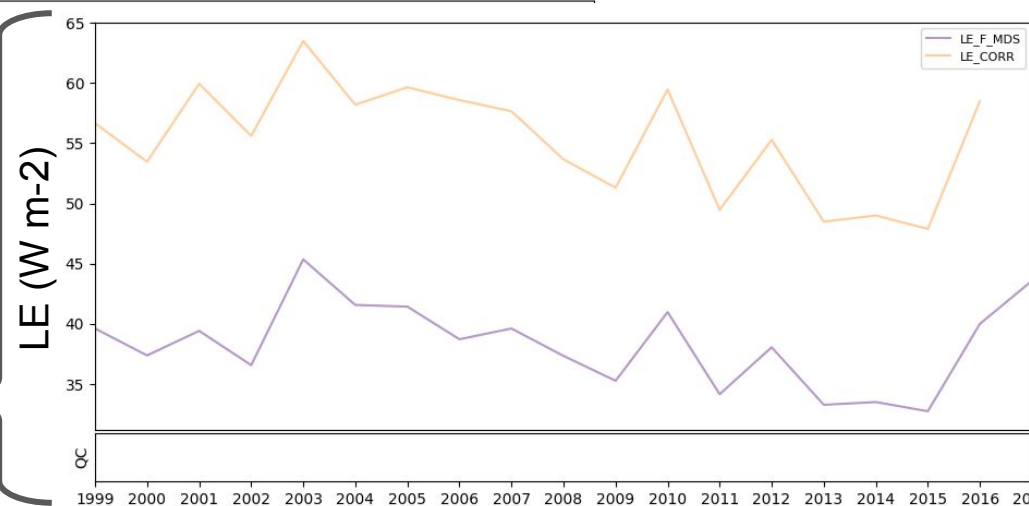
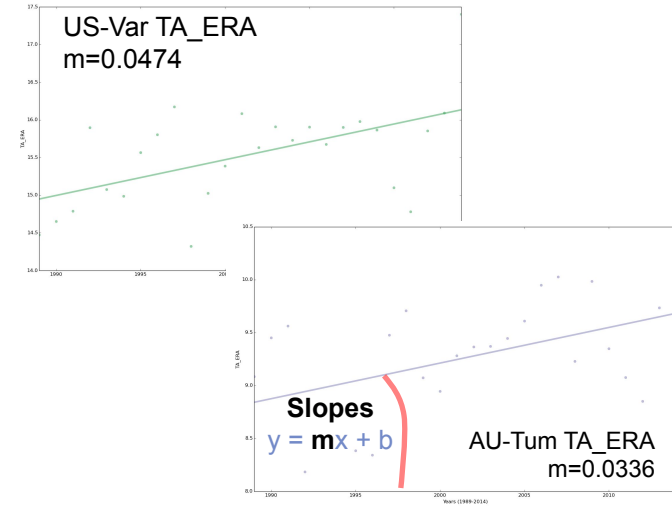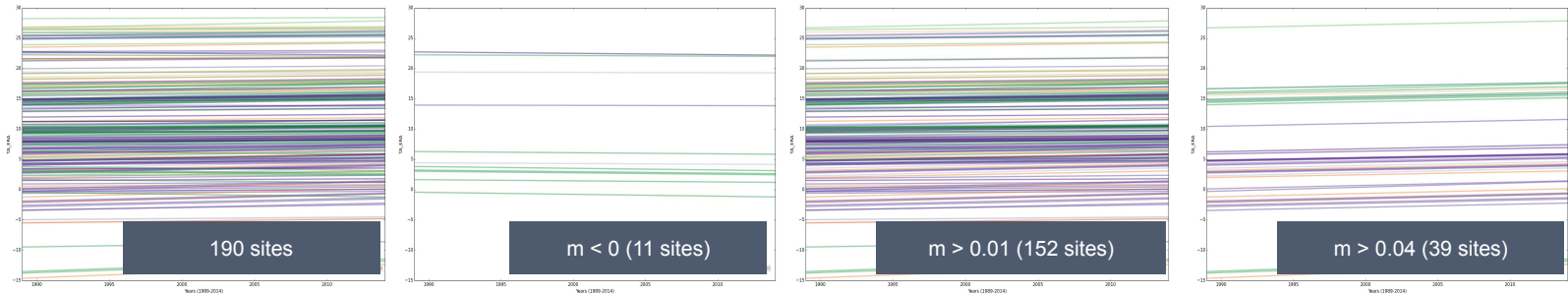# NEE (gC m-2 y-1), yearly
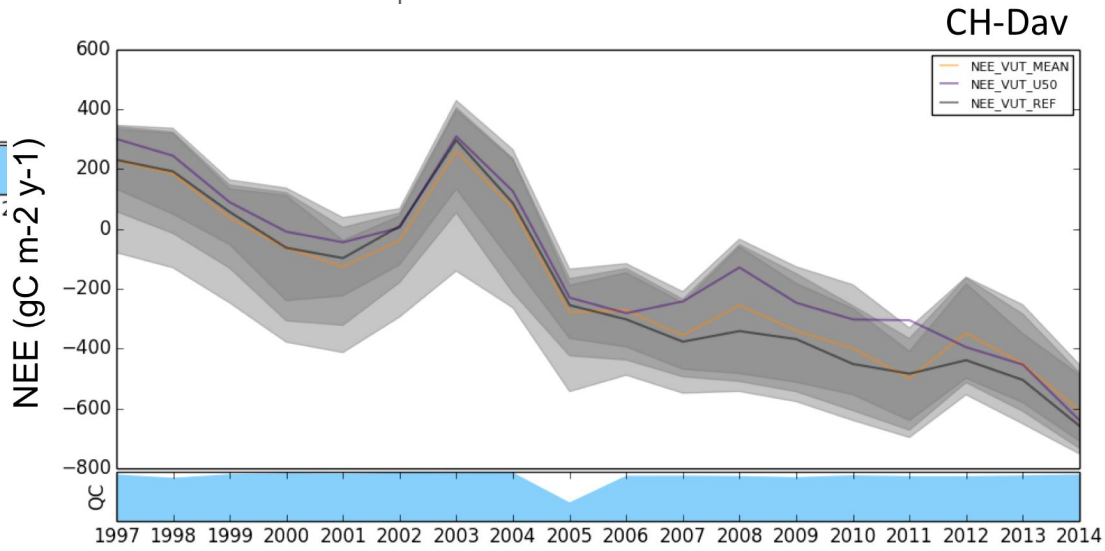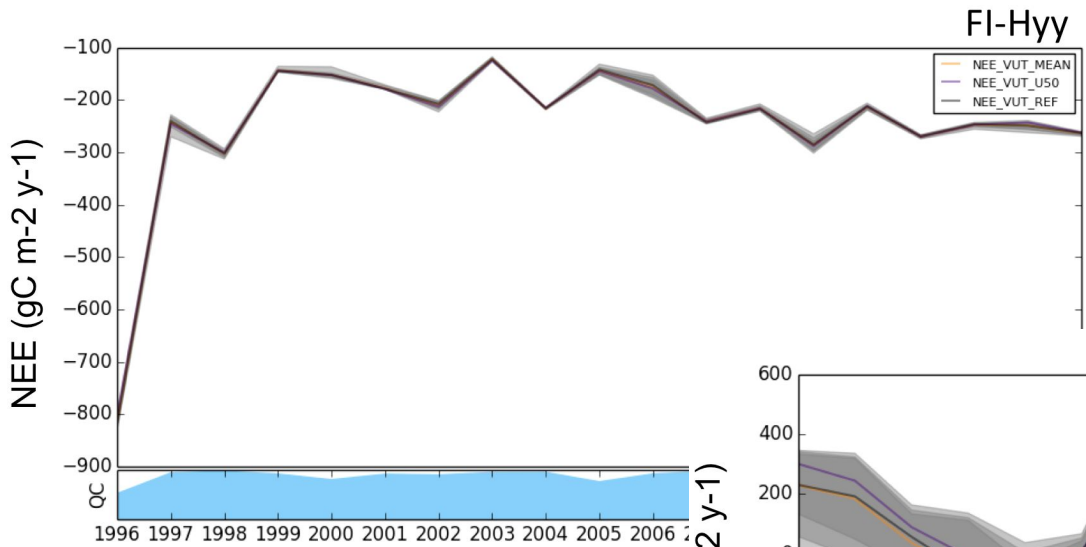
RECO (gC m-2 y-1), yearly
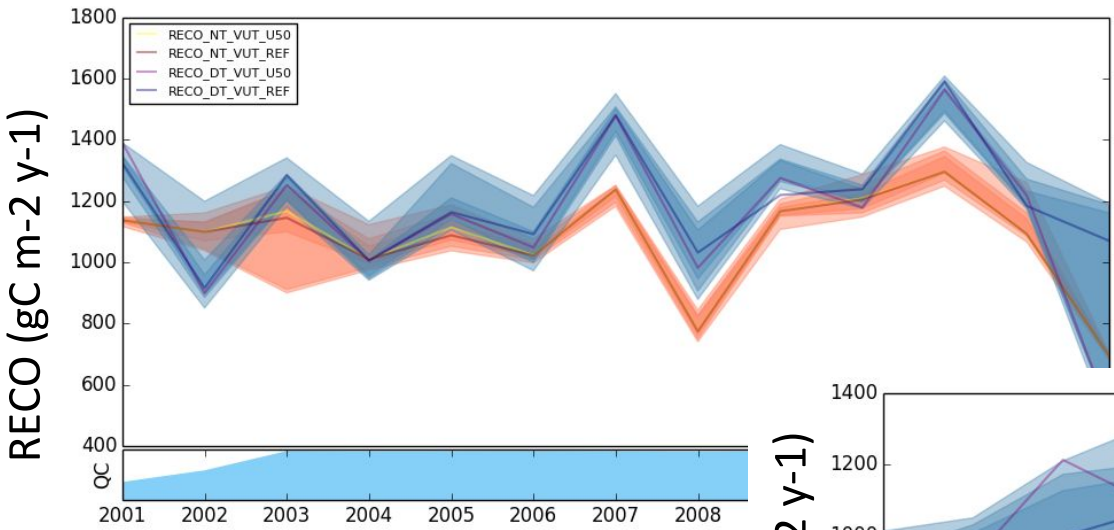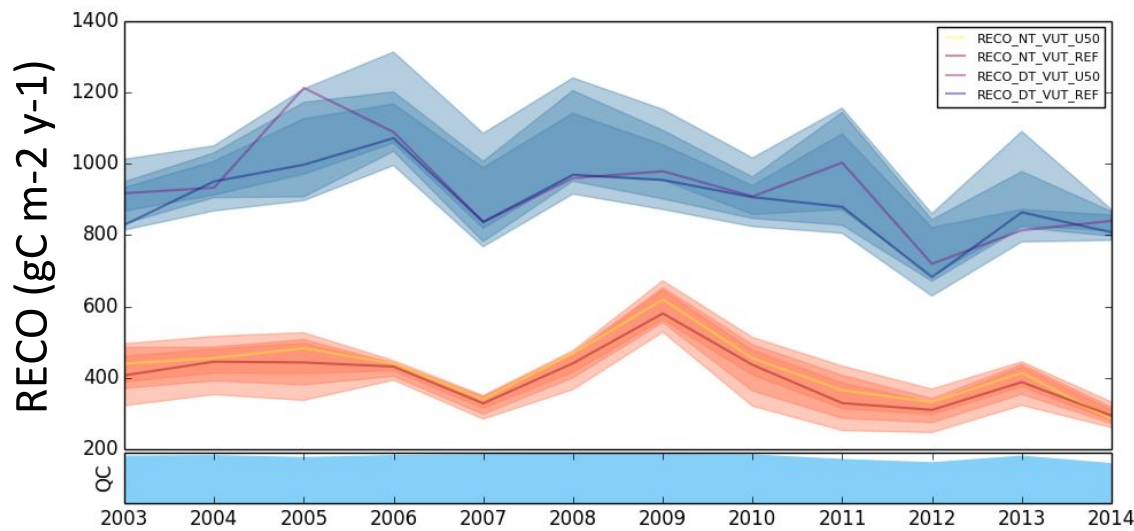
LE (W m-2), hourly and yearly

US-MMS

ERA Downscaling
(ERA-I) 1989-2019→(ERA5) 1979-Now

US-Var TA_ERA
m=0.0474

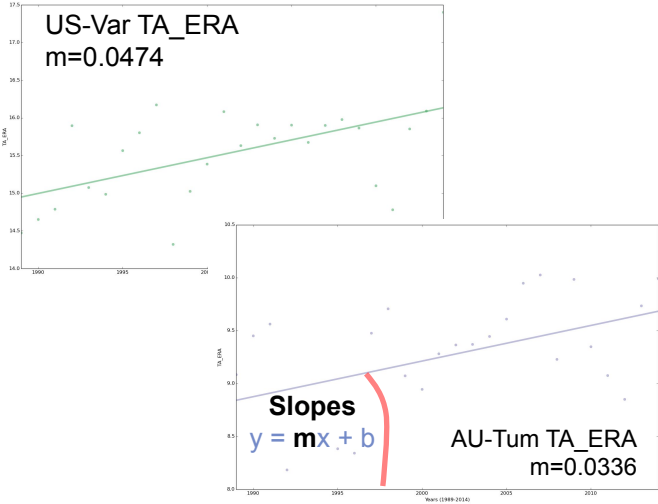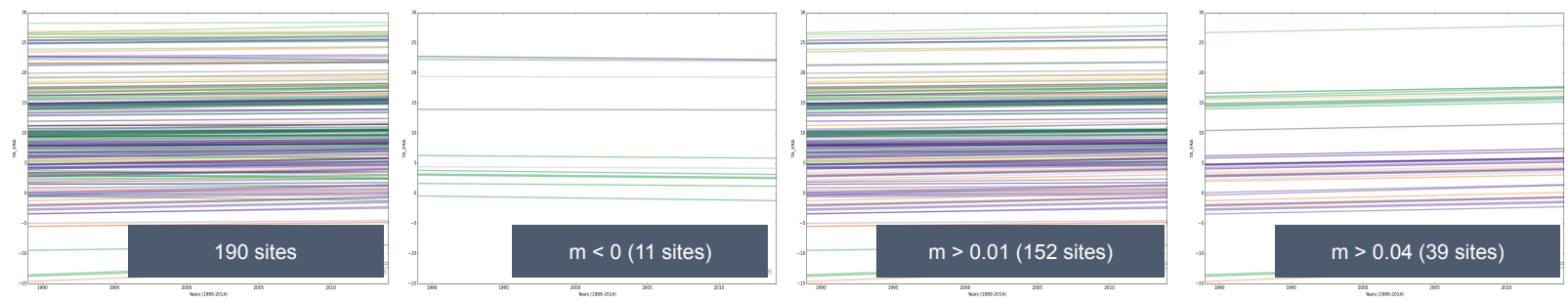AU-Tum TA_ERA
m=0.0336

Slopes
y = **m**x + b
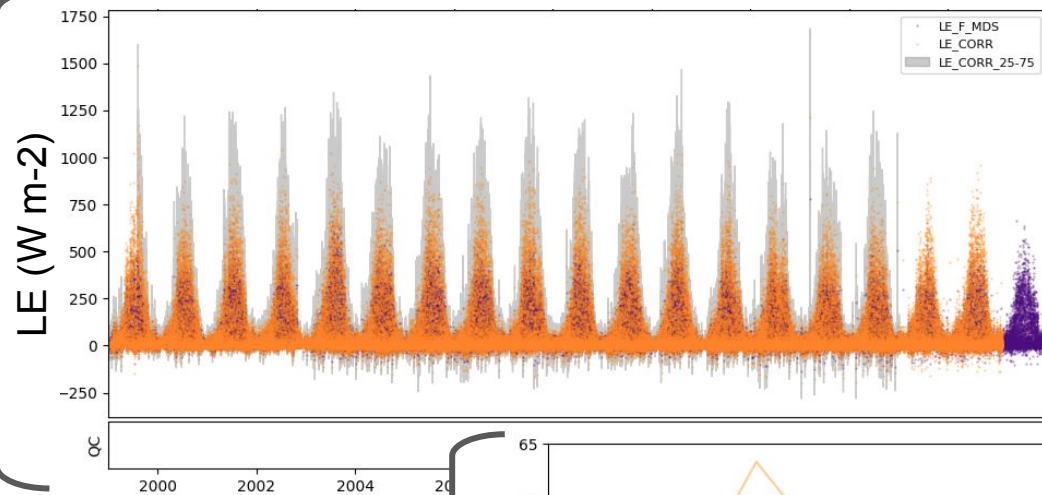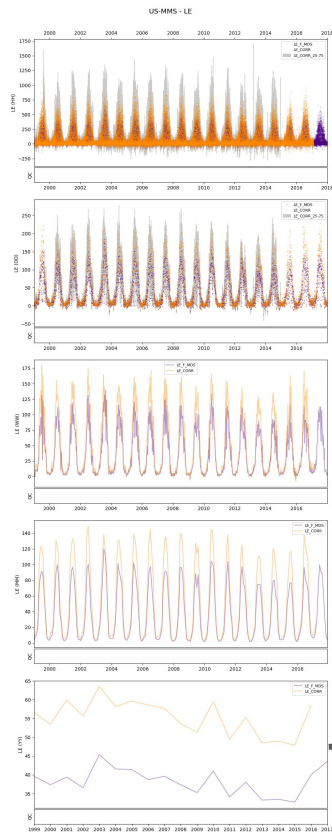
ERA Downscaling

(ERA-I) 1989-2019→(ERA5) 1979-Now

ERA Downscaling

(ERA-I) 1989-2019→(ERA5) 1979-Now
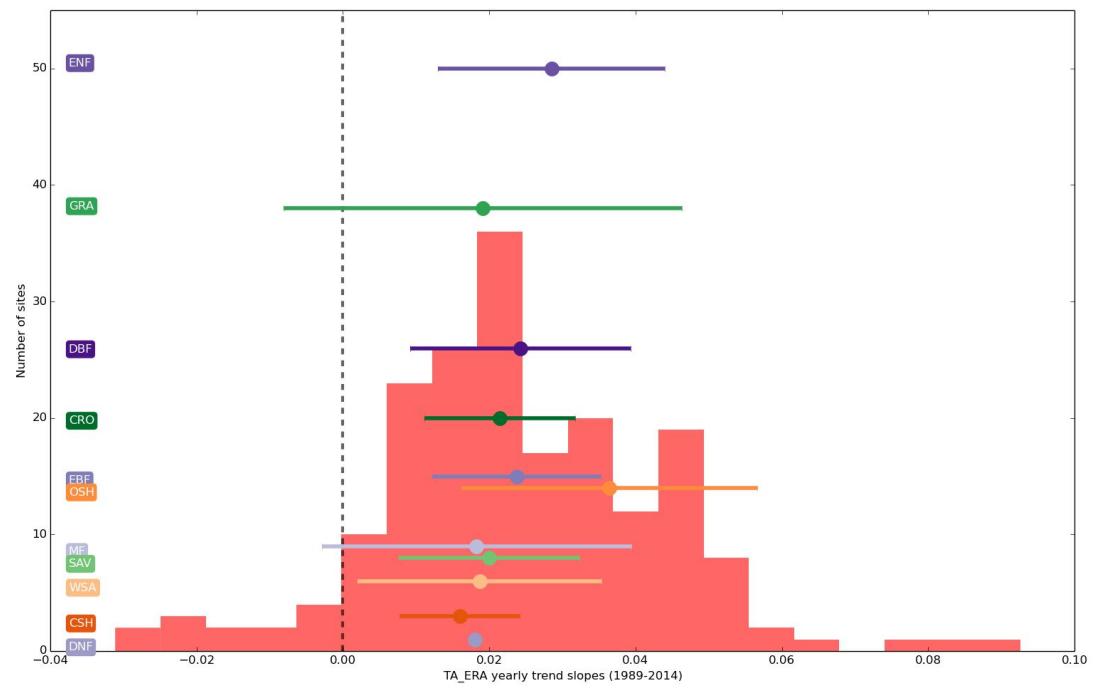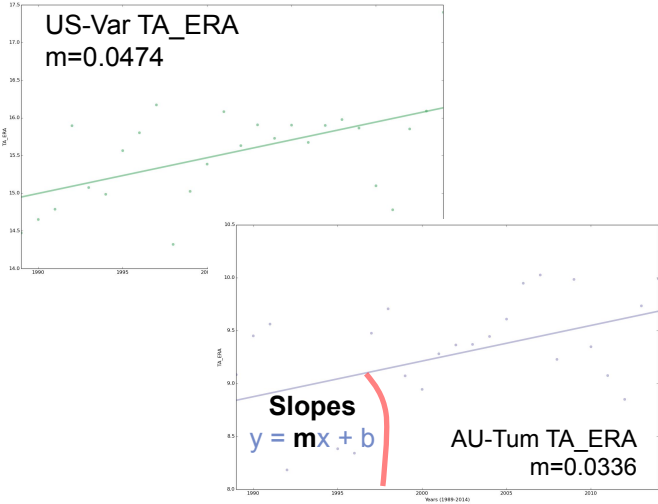
US-Var TA_ERA
m=0.0474

Slopes
y = **m**x + b

AU-Tum TA_ERA
m=0.0336

190 sites

m < 0 (11 sites)

m > 0.01 (152 sites)

m > 0.04 (39 sites)

Examples using
FLUXNET2015 dataset

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Dario Papale

Future of FLUXNET regional and global data products

Papale 2020, Biogeosciences.
https://doi.org/10.5194/bg-2020-211
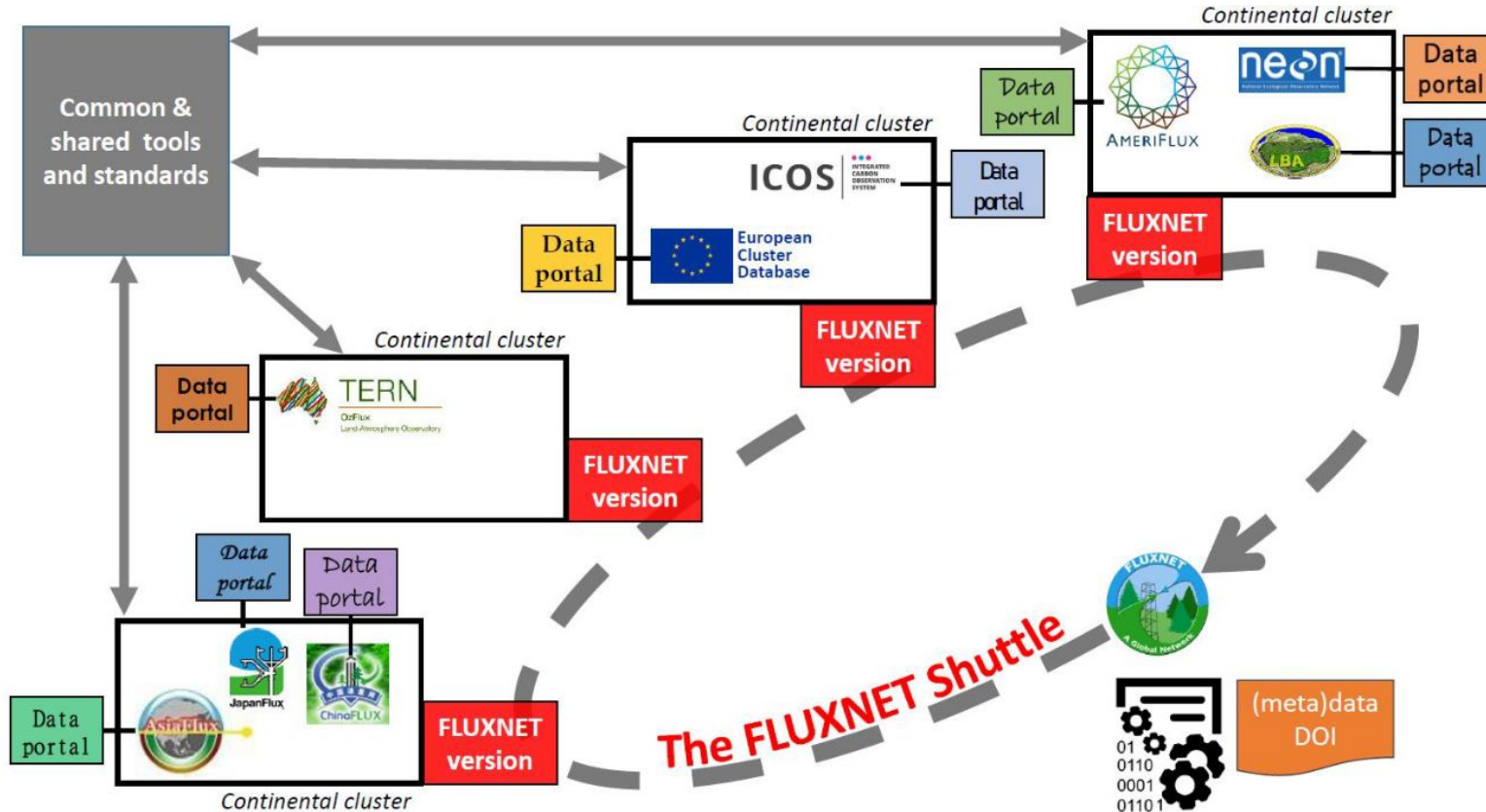
Q&A

Thank you!

Questions?

AMERIFLUX

Reference paper:

Pastorello, G., Trotta, C., Canfora, E. *et al.* *(287 co-authors).* **The FLUXNET2015 dataset and the ONEFlux processing pipeline for eddy covariance data.** *Scientific Data* **7,** 225 (2020). https://doi.org/10.1038/s41597-020-0534-3

Code available:

https://github.com/FLUXNET/ONEFlux

Contact us: ameriflux-support@lbl.gov