oceanflux ghg
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An ensemble approach to gas flux climatology

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Overview

- Introduction
- Classifying Uncertainty
- Measurement Uncertainty
- Uncertainty in Systems
- An Ensemble “brute force” Approach
- Errors in Differences
- Examples from OceanFlux
- Whose Ensemble?

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How do we arrive at realistic estimates of uncertainty?

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Classifying Uncertainty I

Random Error and Systematic Bias

Level

- Statistical
- Scenario
- Qualitative
- Recognised Ignorance

Location

- Where in modelling/processing system

Nature

- Epistemic
- Natural Variability
- Ambiguity

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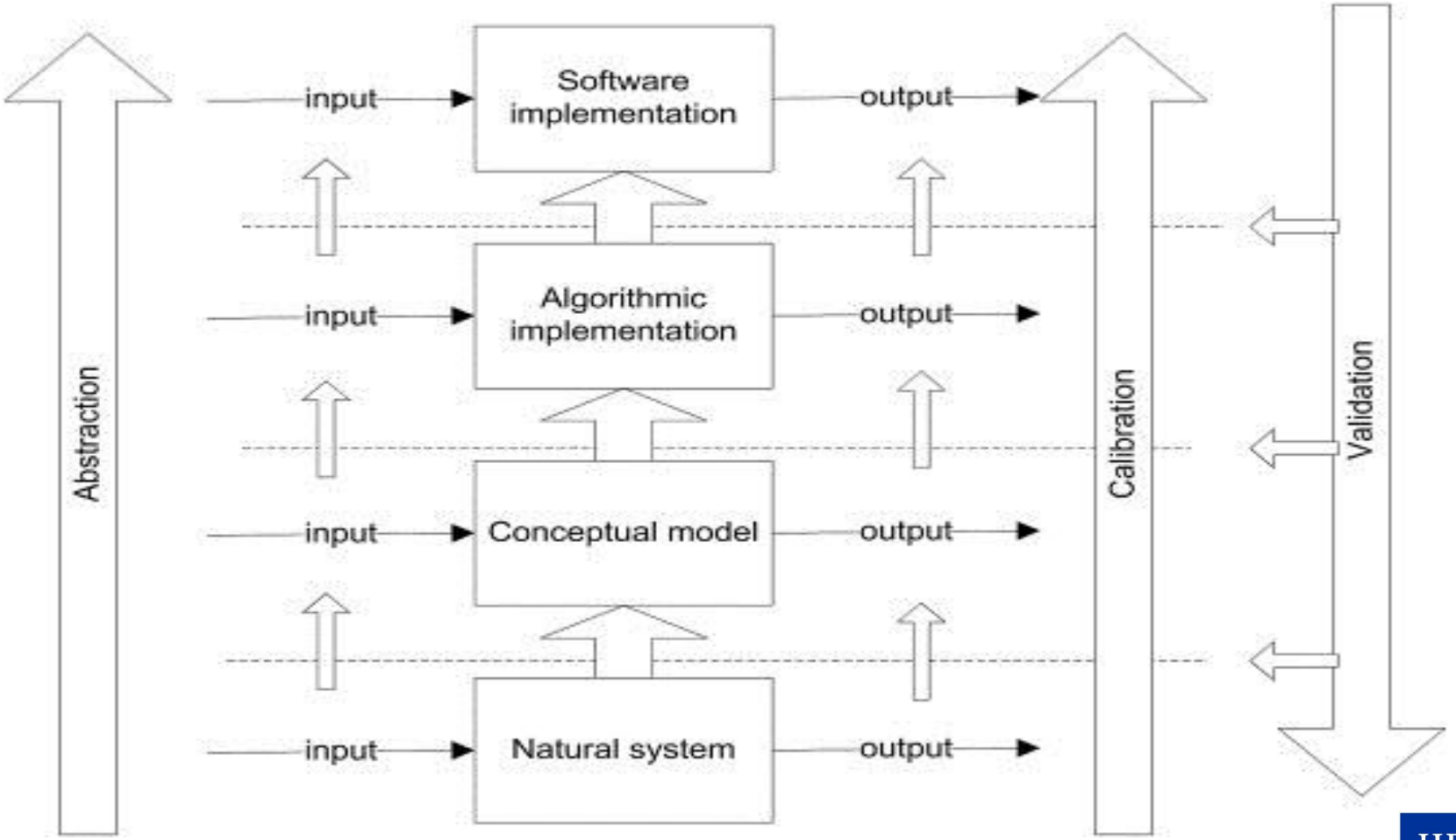
Location. Where?



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What and where?

e.g. parametrization of k

Parameter e.g. “a_2” in “$k = a_2 U^2$”

Structural e.g. “$a_2 U^2$” *vs* “$a_0 + a_3 U^3$”

Separate and distinct

Propagation characteristics differ

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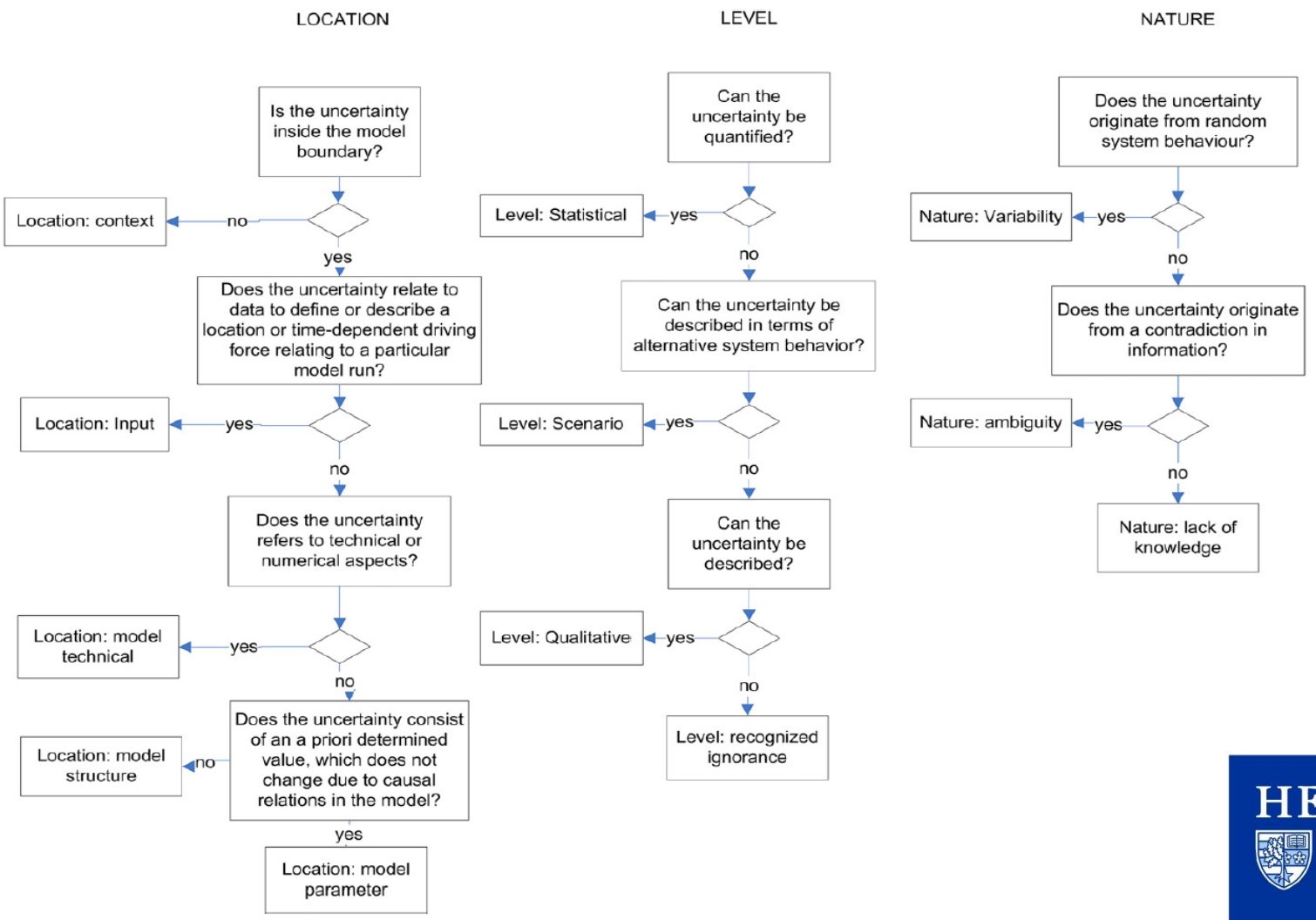
Classifying Uncertainty II



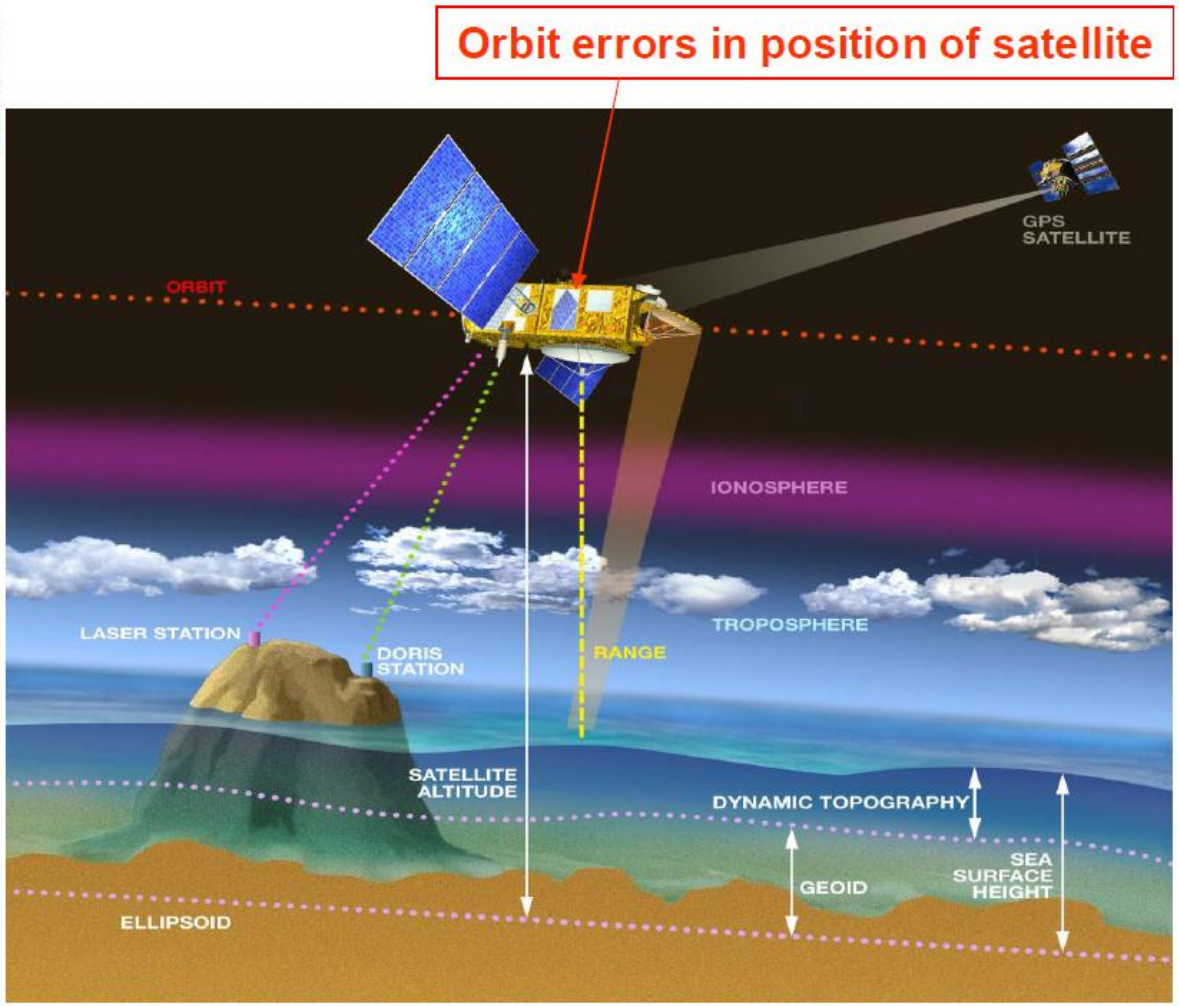
An example of a “simple” error budget:
Sea surface height, P-Y Le Traon, 2007

Sea Surface Height (SSH) (relative to an earth ellipsoid)= Orbit height – Range

SSH = Orbit – Range – Σ Corr

Precision of the SSH :

- **Orbit error**
- **Errors on the range**
  - **Instrumental noise**
  - **Various instrument errors**
  - **Various geophysical errors (e.g., atmospheric attenuation, tides, inverse barometer effects, …)**



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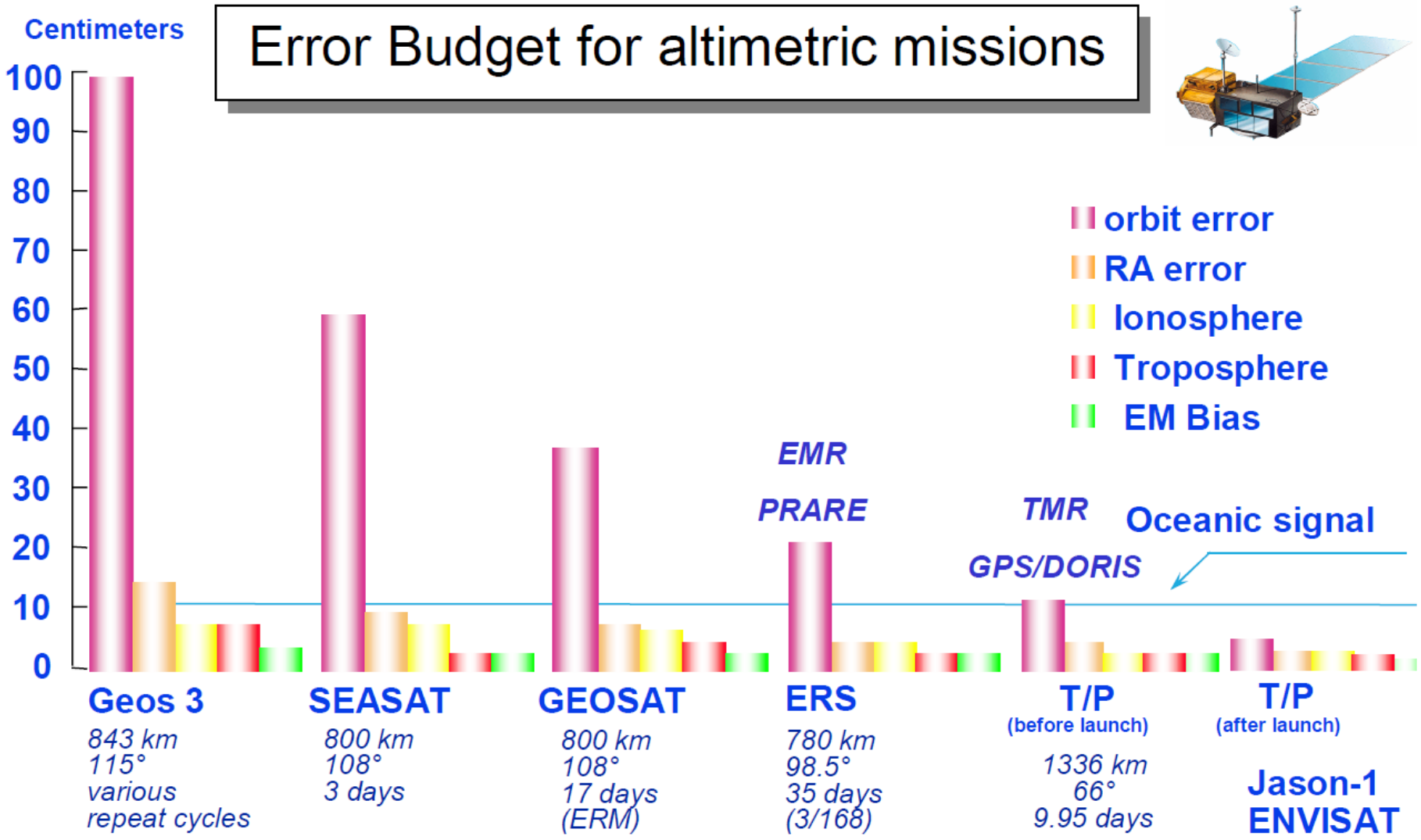
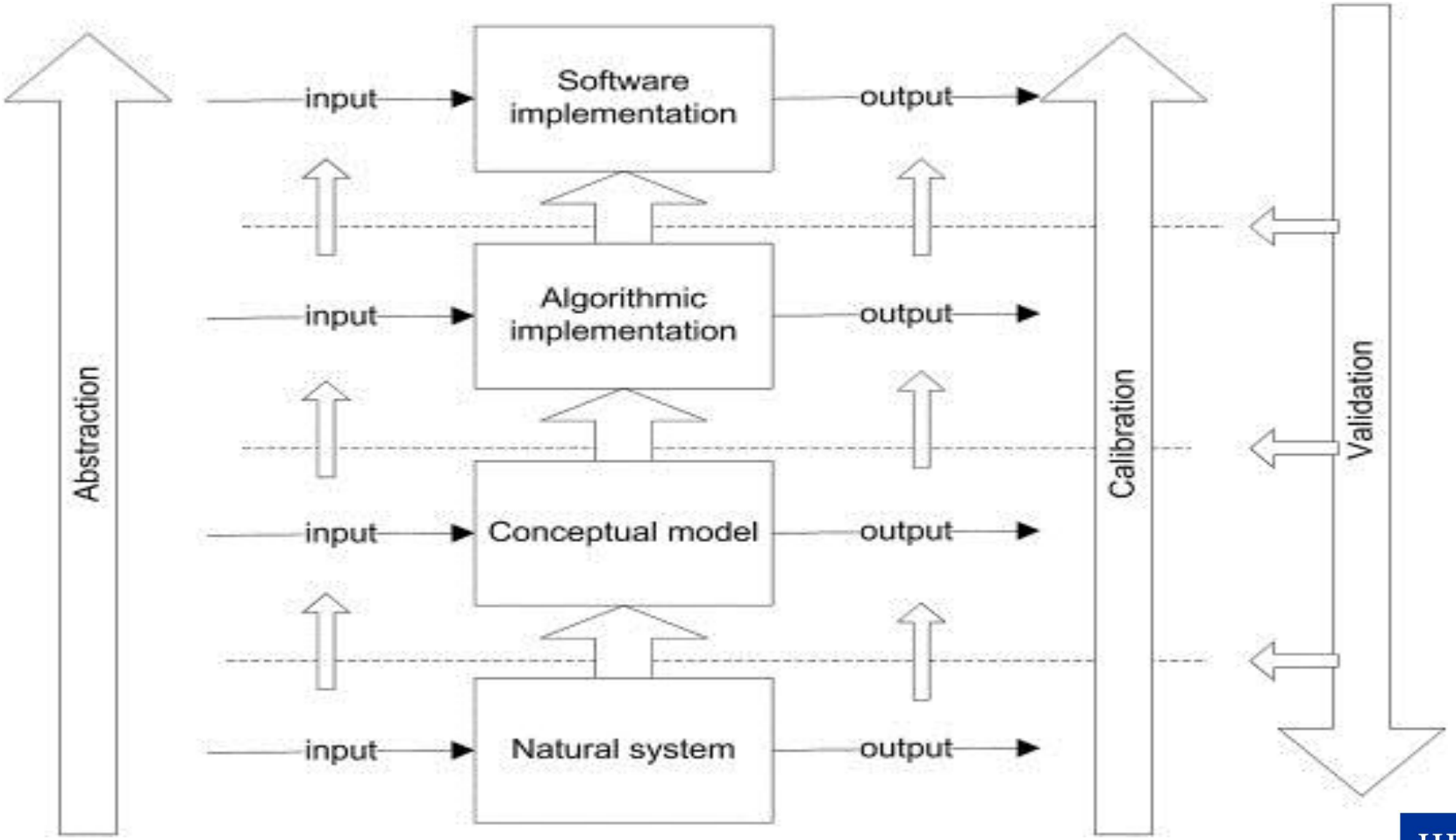


a, *likely to be minor errors at global level, but much more important locally*

Identification of sources of error within the flux calculation and tentative estimates of the uncertainty that they contribute to the gross and net fluxes.

Identifier	Location	Level	Nature	Randomness	Uncertainty in Gross Flux	Uncertainty in Net Flux
k kerfuffle	Model structure	Scenario	Ambiguity	Bias	50%	>100%
k parameter	Parameter	Statistical or scenario	Epistemic	Bias	20%	50%
Wind speed (products)	Input	Statistical or scenario	Epistemic	Bias	10%	10%
Wind speed (sampling)	Input	Statistical	Natural Variability	Random	<5%, a	<5%
Cool skin and warm layers	Model structure	Statistical or scenario	Epistemic	Bias	<5%, a	25%
Temperature (products)	Input	Statistical or scenario	Epistemic	Bias	<5%, a	<5%
Temperature (sampling)	Input	Statistical	Natural Variability	Random	<5%, a	<5%
Temperature – wind speed covariance (sampling)	Input	Statistical	Natural Variability	Random	<5%, a	<5%
Temperature – wind speed covariance	Model Structure	Statistical or scenario	Natural Variability	Random	<5%, a	<5%
pCO2 (bias)	Input	Statistical or scenario	Epistemic	Bias	<5%, a	25%
pCO2 (random)	Input	Statistical	Epistemic	Random	<5%, a	<5%
Asymmetry	Model Structure	Statistical or scenario	Epistemic	Bias	<5%	25%

Uncertainty in a Modelling System



Ensemble Calculations

- + bias
- + random error
- Bootstrapping (by cruise)
- Parallel data
- Parallel Theories (ambiguity)

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Ensemble Calculations II

- Core (project controlled)
- User
  - Moderated
  - Uncensored
- Expert Group
  - Censored

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Errors in Differences

- Globally for CO_2, net flux is ~2% of gross exchange
- Propagation varies:
  - Acting on gross and net equally (e.g. *k* parameter)
  - Acting on upward or downward separately
    - e.g. thermal and haline effects
    - 1% in gross corresponds to 50% in net
  - Complicated (e.g. *k* structural)

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Examples from OceanFlux net global CO_2

- Largest (>1 PgC/y)
- Large (>0.5 PgC/y)

- Substantial (0.1-0.5PgC/y

- *k* ambiguity
- SOCAT vs Takahashi

- Tskin, Tsubskin
- Secular trend
- k structural and parameter
- Data censoring (e.g. equilibrator temp)
- fugacity bias
- bootstrap

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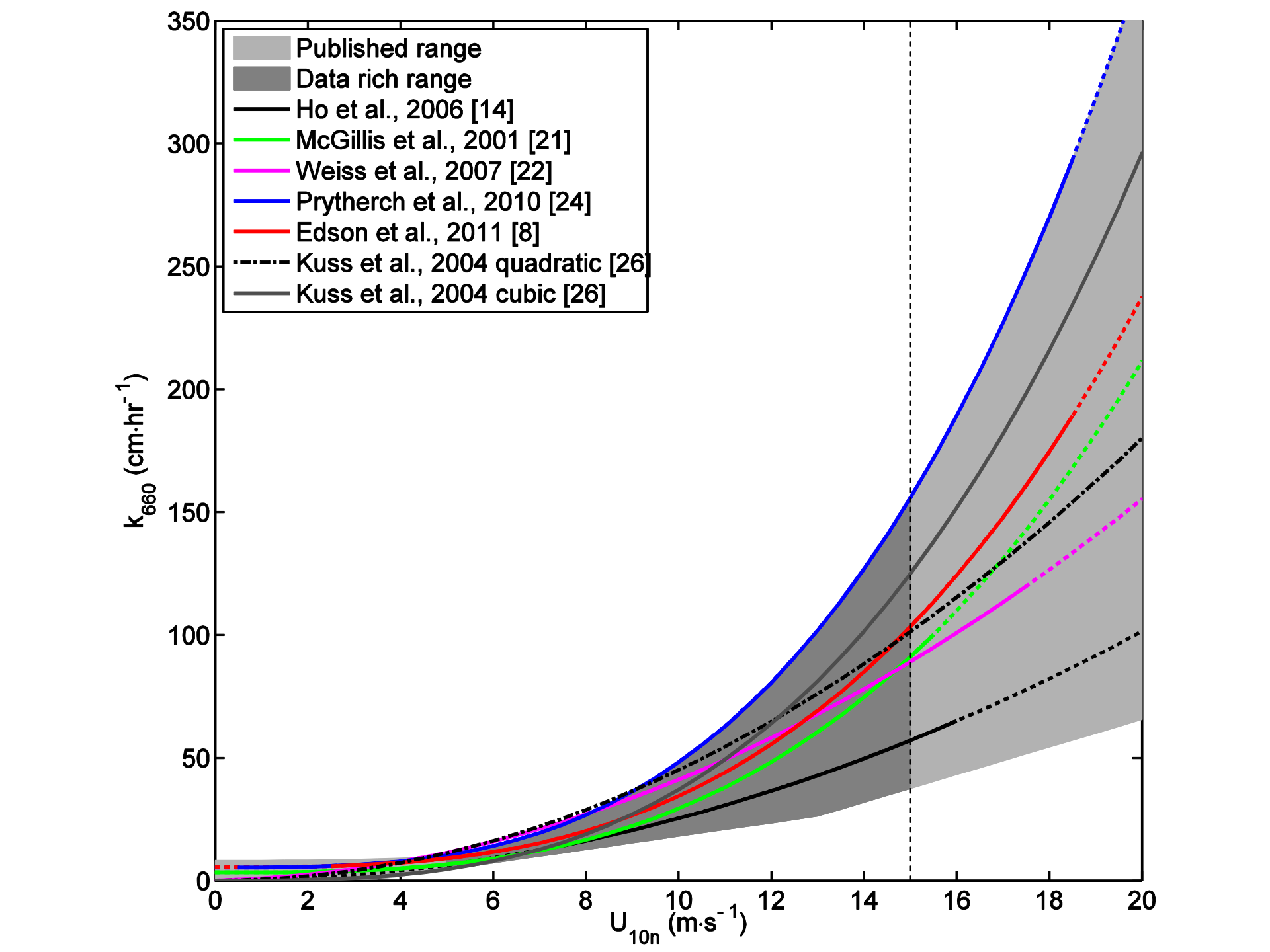
Published range
Data rich range
Ho et al., 2006 [14]
McGillis et al., 2001 [21]
Weiss et al., 2007 [22]
Prytherch et al., 2010 [24]
Edson et al., 2011 [8]
Kuss et al., 2004 quadratic [26]
Kuss et al., 2004 cubic [26]
k_{660} (cm·hr^{-1})
U_{10n} (m·s^{-1})
0
50
100
150
200
250
300
350
0
2
4
6
8
10
12
14
16
18
20

How would you define uncertainty on climatologies?

How can we agree what is and what is not credible?

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