Part III
Uncertainties of Atmospheric Correction in Complex Environments

Uncertainties in Ocean Colour Remote Sensing

Key findings

of the IOCCG Working Group

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Working Group Terms of Reference:

- ***analyse factors which determine uncertainties for various water types;***
- ***analyse the problem of uncertainties for different product types;***
- ***analyse the problem of uncertainty propagation in L3 and merged products;***
- ***review, analyze and document methods, which allow to determine out-of-scope conditions and uncertainties including flagging;***
- ***recommend procedures to be implemented in ground processors and formats to present errors / uncertainties in data products;***
- ***summarize the results and recommendations in the form of an IOCCG report.***

http://ioccg.org/group/uncertainties/

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Outline

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2. Terminology and Main Principles
3. Sources of Uncertainties
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5. Representation and Distribution of Uncertainties
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DEFINITIONS

Measurement error:

Measured quantity value minus the true value / a reference value

Measurement uncertainty :

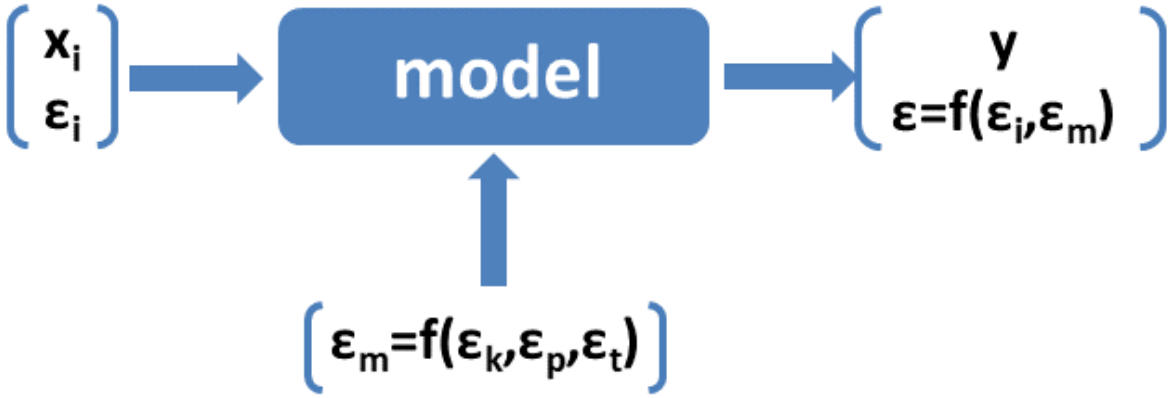
Non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand

BIPM: Bureau International des Poids et Mesures
International Bureau for Weights and Measures
https://www.bipm.org

GUM: Guide to the expression of Uncertainty in Measurements (not for EO)

VIM: Vocabulaire International de Métrologie
International Vocabulary of Metrology

Sources of Uncertainties



$$\varepsilon = f(\varepsilon_i, \varepsilon_k, \varepsilon_p, \varepsilon_t) + \varepsilon_e$$

inherent/ stochastic

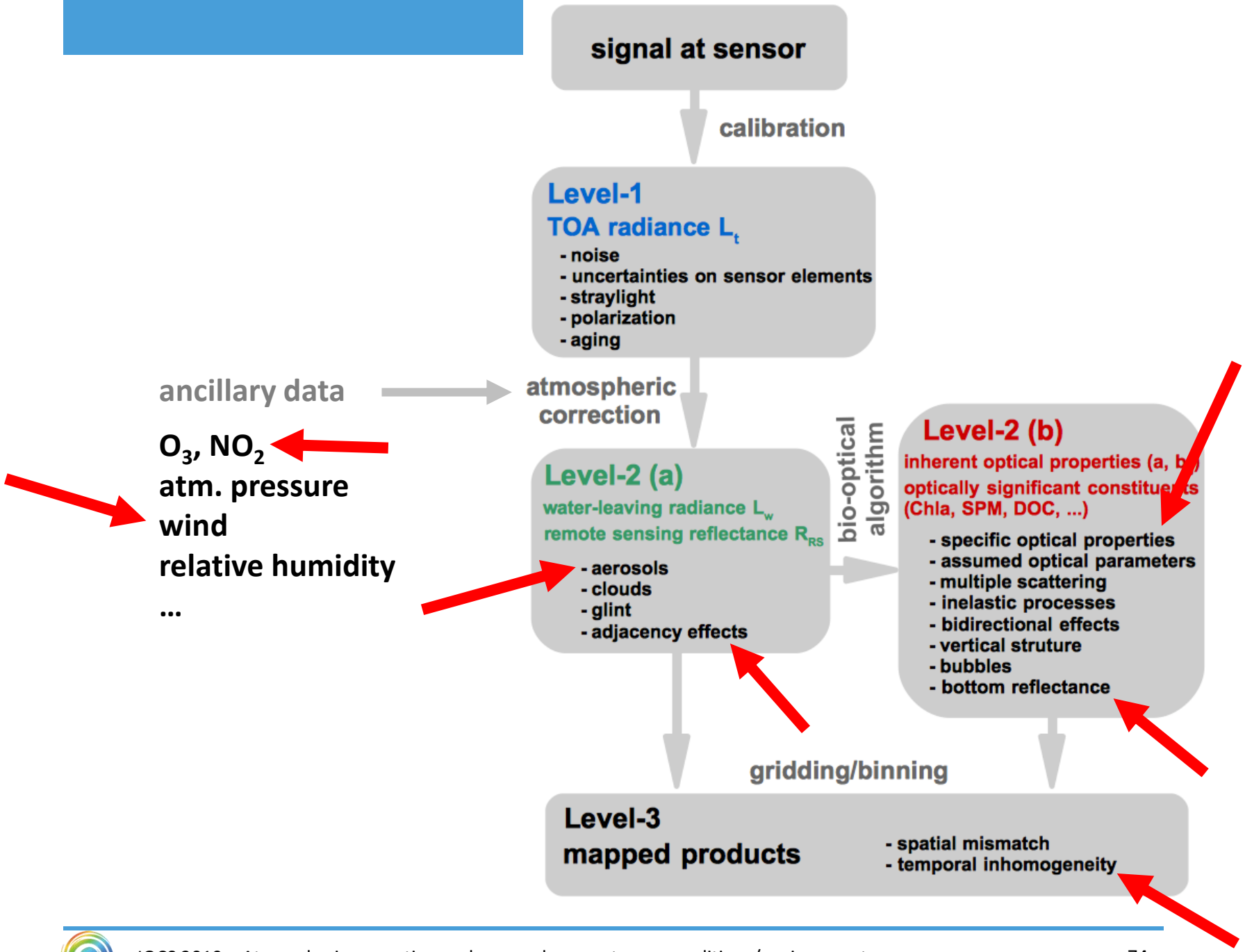
model structure

model parameters

technical/ numerical

structural/epistemic

editing


signal at sensor
calibration
Level-1
TOA radiance L_t
- noise
- uncertainties on sensor elements
- straylight
- polarization
- aging
ancillary data
O_3, NO_2
atm. pressure
wind
relative humidity
…
atmospheric correction
Level-2 (a)
water-leaving radiance L_w
remote sensing reflectance R_{RS}
- aerosols
- clouds
- glint
- adjacency effects
bio-optical algorithm
Level-2 (b)
inherent optical properties (a, b)
optically significant constituents (Chla, SPM, DOC, …)
- specific optical properties
- assumed optical parameters
- multiple scattering
- inelastic processes
- bidirectional effects
- vertical struture
- bubbles
- bottom reflectance
gridding/binning
Level-3
mapped products
- spatial mismatch
- temporal inhomogeneity

Methods for identifying out-of-scope conditions and estimating uncertainties

- Identification of out-of-scope conditions
- Assessment from algorithm construction
- Use of simulated data
- Clear-water approach
- Approach based on optical water types
- Outputs on non-linear inversion methods
- Uncertainty propagation using expansion-based methods
- Uncertainty propagation using Monte-Carlo approaches
- Bayesian approach
- Use of Cramer-Rao bounds
- Comparison of satellite products
- Co-location techniques
- Role of biogeochemical models

None of the methods presented includes a full uncertainty budget !!

What about validation?
(i.e., comparison between satellite and field data)

Issues:

- Definitional uncertainty
- Spatial representativeness
- Uncertainties of the field data

Nonetheless, most of what we know about uncertainties historically come from validation statistics

Validation results for atmospheric corrections:

Residuals distributions:

- **vary by site/atmospheric/water type (when expressed both in relative and absolute terms)**

For a site:

- **are fairly Gaussian**
- **show spectral correlation**
- **are fairly consistent across missions**
- **show cross-mission correlation (when processed with the same code)**

Discussion: recommendation about uncertainties in complex environments

1. **How should requirements be formulated?**

   Given in radiometric units? What about error covariance?

2. **How is the role of field data to be (re-)considered?**

   What about their uncertainties? What about the issue of representativeness (scale)? Role as the main independent source of verification of uncertainties estimates?

3. **Are there favored approaches to obtain and present comprehensive, traceable, uncertainty estimates?**

   Comprehensive uncertainty propagation? Role of class/pattern recognition for detection of out-of-scope conditions and for easier calculation of uncertainty estimates? Comparison of outputs from different methods?

Part IV
Final discussion