Ocean Colour Climate Change Initiative

European Space Agency

CMUG Questions

1. Is your URD consistent with the needs of Climate Research Groups (CRG) in the context of CMUG needs and GCOS requirements, including source traceability? Yes

2. How are your product specifications developing to meet the needs of your individual Climate Research Group (will the CRG use the proposed products in their applications)? User requirement key to development of product specifications

3. How will you address the integrated perspective for consistency between the ECVs including identification of gaps? Through related WG developed at co-location meeting

4. How will you deal with uncertainties in products? Multiple approaches, error specification to some extent depend on algorithm selection

5. What are your data needs for ECMWF reanalysis data? Details identified

Ocean Colour and Ocean Models for Climate Research

Ocean-colour observations are a valuable adjunct to models of the marine ecosystem, biogeochemistry and fisheries, serving to test model outputs; providing data to initialise models; contributing to data assimilation to constrain model parameters or to improve predictions

Climate Research Group:

- Corinne Lequéré – Dynamic Green Ocean Models; Input requirements
- Icarus Allen, Stefano Ciavatta – Model skill assment, EC FP7 MEECE
- Laurent Bertino – Data Assimilation; Input requirements; Arctic
- Watson Gregg – General Circulation model, Data Assimilation
- Hans von Storch – Time Series, Trend Analysis
- Takafumi Hirata – Global and North Pacific Modelling

User Requirements Document Preparation

Three parts:

1. **Consultation Meeting**

   Contributors: Shubha Sathyendranath, Corinne Lequéré, Stephanie Hensen, Takafumi Hirata, Laurent Bertino, Stefano Ciavatta, Momme Butenschön, John Swinton, George White III, Victor Martinez Vicente, Trevor Platt, Rosa Barciela

2. **User Consultation Survey**

   Based on GCOS requirements; CMUG Survey: SST-CCI Survey; discussions at co-location mtg

   Contributors: Victor Martinez Vicente, Shubha Sathyendranath, Trevor Platt

   Plus some 100 or so respondents to the questionnaire

3. **Discussions and Invitation to Review**

   Discussion with CMUG at Plymouth

   All OC-CCI Team, all contributors, IOCCG, CMUG

Consultation Meeting Report: Highlights

- Requirements vary according to type of model. For example:
  - spatial resolution: 1º deg (global models); 4 – 25 km (regional models)
  - temporal resolution: 1 month (global models); 1 day – 1 week (regional models)
  - timeline: not important (regional and global models); 1 day (operational models)

- Error in products
  - error specification is important for all users
  - error reduction is desirable, but unclear what might be feasible in the near term (3-5 y)
  - precision less important than accuracy (this contradicts with results from survey)

- Direct use of ocean-colour data in climate studies
  - trend analysis: stability is most important, but what it should be is unknown
  - phenology: high frequency is important
  - ecological provinces: requirements vary with method, but precision could be important

- General considerations
  - long-term, reliable, quality-controlled, stable products over long term is important
  - desirable to have algorithms that work seamlessly across Case 1 and Case 2 algorithms
  - great interest in additional products (over and above chlorophyll and inherent optical properties

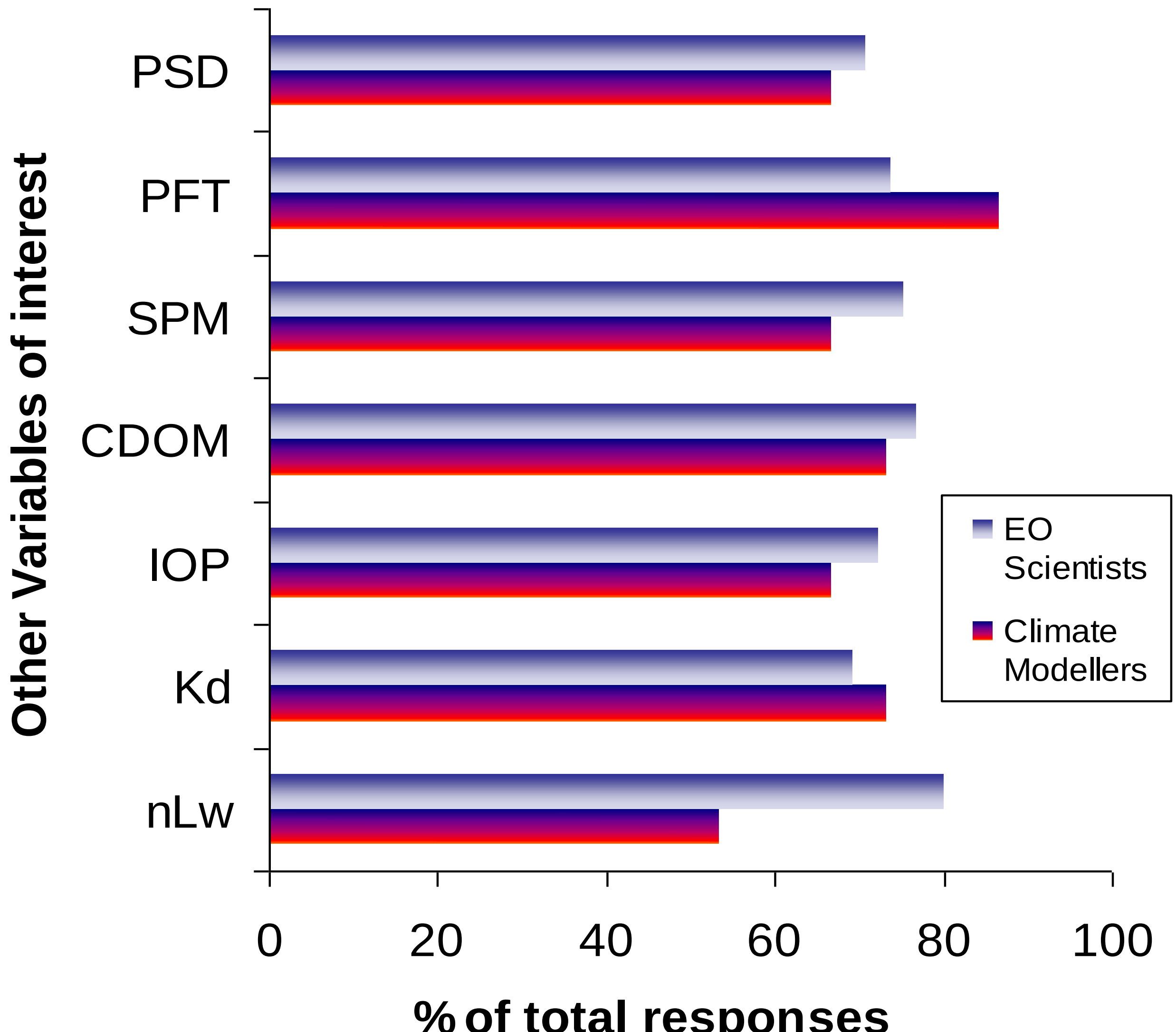
Chlorophyll-a

G = Goal, B = Break-through, T = Threshold

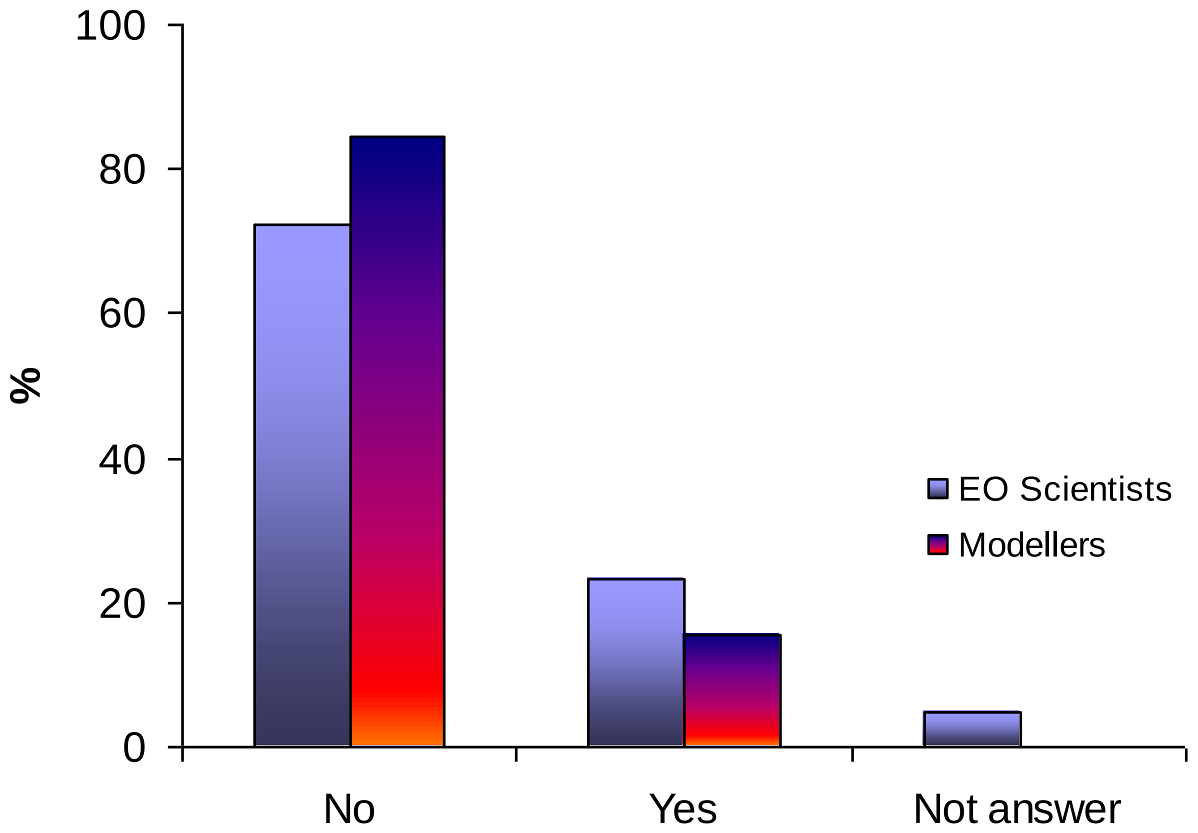
	Horizontal Resolution (Km)			Observing cycle (day)			Accuracy (%)			Precision (%)			Stability (over 10-years) (%)		
Source of requirement	G	B	T	G	B	T	G	B	T	G	B	T	G	B	T
Requirement from GCOS/WMO	1	5	100	1	1.5	3	5 max	8.5 max	25 max						
Requirement from CMUG		4			1			30			30				
Requirement from CCI – Modellers	0.1 -1	1 - 10	1 - 10	1	7	30	< 10	10 – 25	10 – 25	< 10	< 10	10 - 25	1	1	10
Requirement from CCI – EO scientists	0.1 -1	0.1 - 1	1 - 10	1	7	30	< 10	10 – 25	25 – 50	< 10	10 - 25	25 - 50	1	1-2	5
Suggested Product specification	1			1			25-30			10-25			~1		

PML | Plymouth Marine Laboratory

Percentage of other variables of interest to EO and Climate modellers (besides Chl-a)



The use of CZCS in climate studies



Overall, according to users, CZCS could be a useful tool for phenology or fisheries studies if careful processing is made.

Traceability of data and algorithms

User Requirements Traceability: Product specification document refers back to the URD.

A means of tracing the source data and algorithm versions used will be incorporated into each dataset.

The method is to be determined by the CCI Software Engineering or the Data Standards working group, but the two main suggestions are:

- Embed all relevant versioning information in the metadata (source data versions, algorithm versions, processing log, etc)

- Tag each data file with an unique identifier (UUID) and store the matching version information in a (web accessible) database

The main difference between the two is the ease of updating following release of data.

Recommendations for Product Specification

- Make highest resolution data available, along with subsampling, binning, mapping tools
- Important to provide normalised water-leaving radiances at full spectral (and temporal) resolution, along with online tools for generating products according to different algorithms
- For all OC-CCI products, associate each product with error specification, along with details of how the errors are estimated
- Ensure long-term, stable and sustained delivery of products to ensure user base
- Move towards algorithms that have the potential to merge Case 1 and Case 2 waters in a seamless manner
- Product selection should bear in mind down-stream applications in climate studies: this would imply a preference for algorithms that rely on multi-spectral optical signatures, over purely empirical or indirect algorithms
- If the above consideration conflicts with the need for algorithms with minimal errors, some difficult choices will have to be made (offer more than one product?)
- If CZCS data are included, provide information on limitations of product, even for the most promising of applications, such as phenology

Consistency between the ECVs

High level coordination is addressed by:
- CCI Data Standards group
- CCI Software Engineering Working Group

The aim of these groups is to produce data that are consistent across the CCIs (particularly data format, metadata, standards, input data).

Gaps:

- OC-CCI intends to process the complete time series of available satellite data (MODIS, MERIS, SeaWiFS and maybe CZCS)

- As such, there should not be any gaps (excepting sensor outages / input data unavailability)

Error Characterisation, Reduction

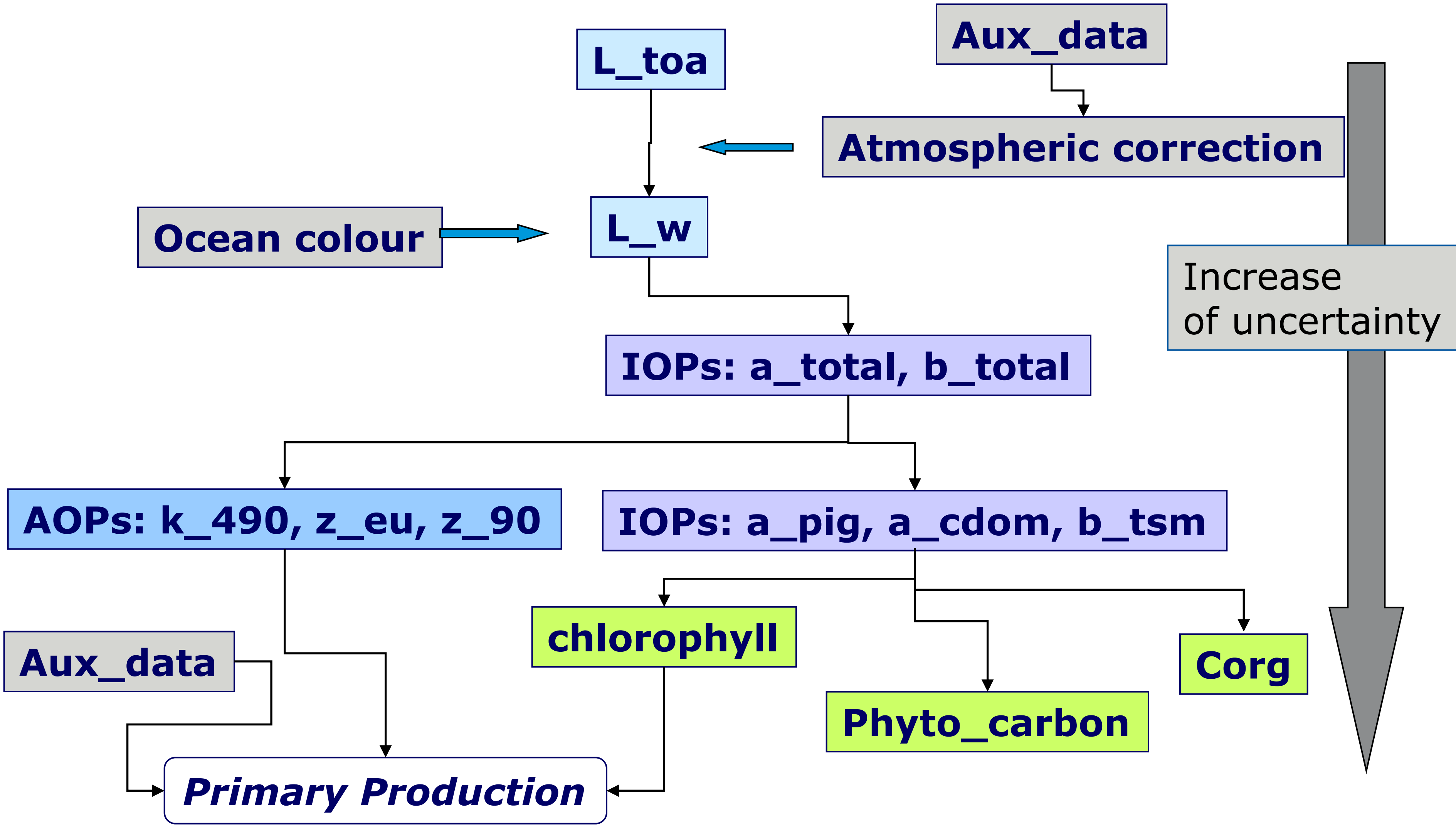
Requires meticulous analyses of the various sources of error in ocean-colour products:

1. instrument specifications
2. instrument calibration procedure
3. atmospheric correction
4. in-water algorithms

Approaches to error characterisation include:

1. Neural Network
2. Formal error analysis
3. Fuzzy logic

Hierachical system of variables



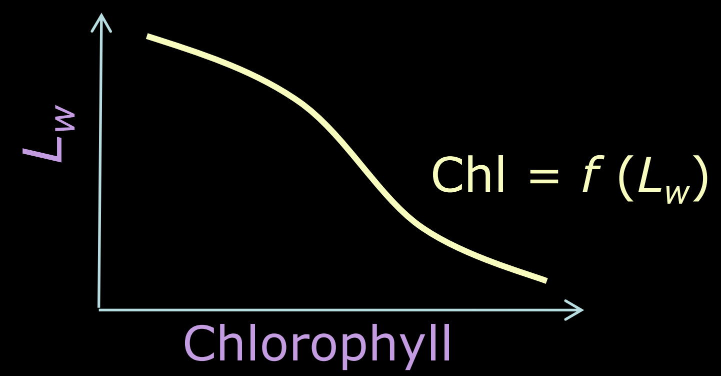
In-water algorithms

Spectral Water-leaving Radiance (L_w)

Analytic Approaches:

- Link radiance to reflectance
- Link reflectance to inherent optical properties of all in-water constituents through radiative transfer models
- Retrieve inherent optical properties of all constituents from spectral water-leaving radiances
- Relate inherent optical properties to concentrations of constituents (eg. chlorophyll)
- Provides theoretical basis for ocean-colour algorithms
- Accounts for factors other than chlorophyll that modify L_w
- Algorithms of choice?
- Less validated and tested than empirical algorithms

Empirical Approaches:



Highly successful (eg. NASA algorithm)

Algorithms of choice?

What affects f (L_w) other than chlorophyll?

- Phytoplankton community structure
- Coloured dissolved organic material
- Scattering by non-phytoplanktonic particles

Algorithm stable in a changing climate?

Neural Network Approach to Estimating Uncertainties (Doerffer)

Training requires information on

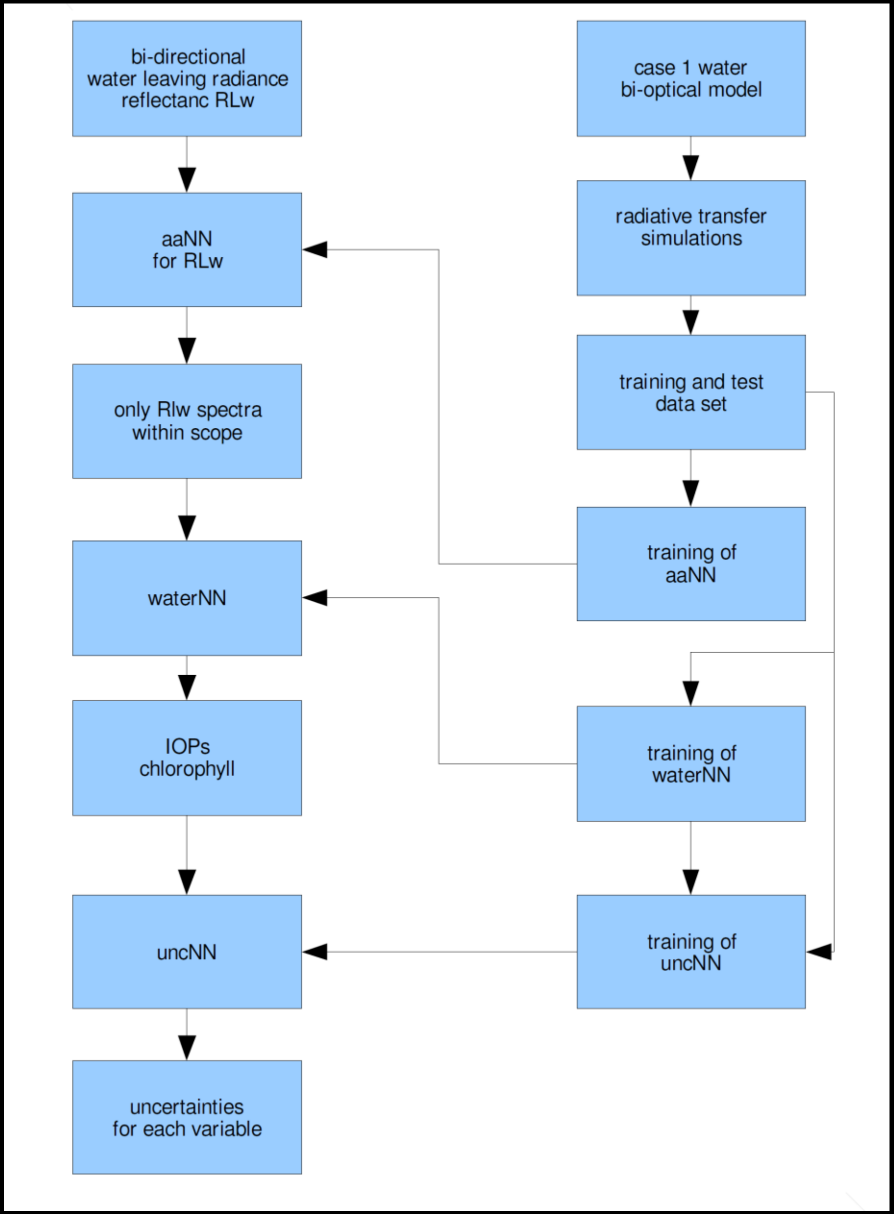
- Bio-optical properties
- Radiative transfer model
- Geometric considerations

Contains three elements:

- retrieving water-leaving radiances
- retrieve IOPs and chlorophyll
- estimate uncertainties

Uncertainties based on differences between observation and training set.

Rigorous, based on first principles. Potential limitation is gaps in our knowledge of the system we are exploring.



Quasi-Analytic Algorithm (Zhongping Lee)

Bio-optical model constructed using simple relationship between reflectance and inherent optical properties: $R = f\ (a,\ b_b)$

Solution obtained analytically, using simplifying relationships to solve for unknowns.

Model tested using a combination of in situ and simulated datasets

Errors in various steps of algorithm (Δxi) are established, and total error Δz is computed as:

$$\Delta z = \sqrt{\sum_{i=1}^{N} \left(\frac{\partial z}{\partial x_i} \Delta x_i \right)^2}$$

Out of scope and uncertainties

- **Conditions out of scope of the algorithm / model**
  - **Clouds**
  - **Low sun elevation**
  - **High concentrations of aerosols or exceptional types**
  - **Foam / white caps or other surface material**
  - **Bottom reflection**
  - **Vertical distribution**
  - **Bio-optical model does not apply**
- **Uncertainties**
  - **Variabilities in optical properties**
  - **Concentration level**
  - **Impact of other substances**
  - **Conversion factors**

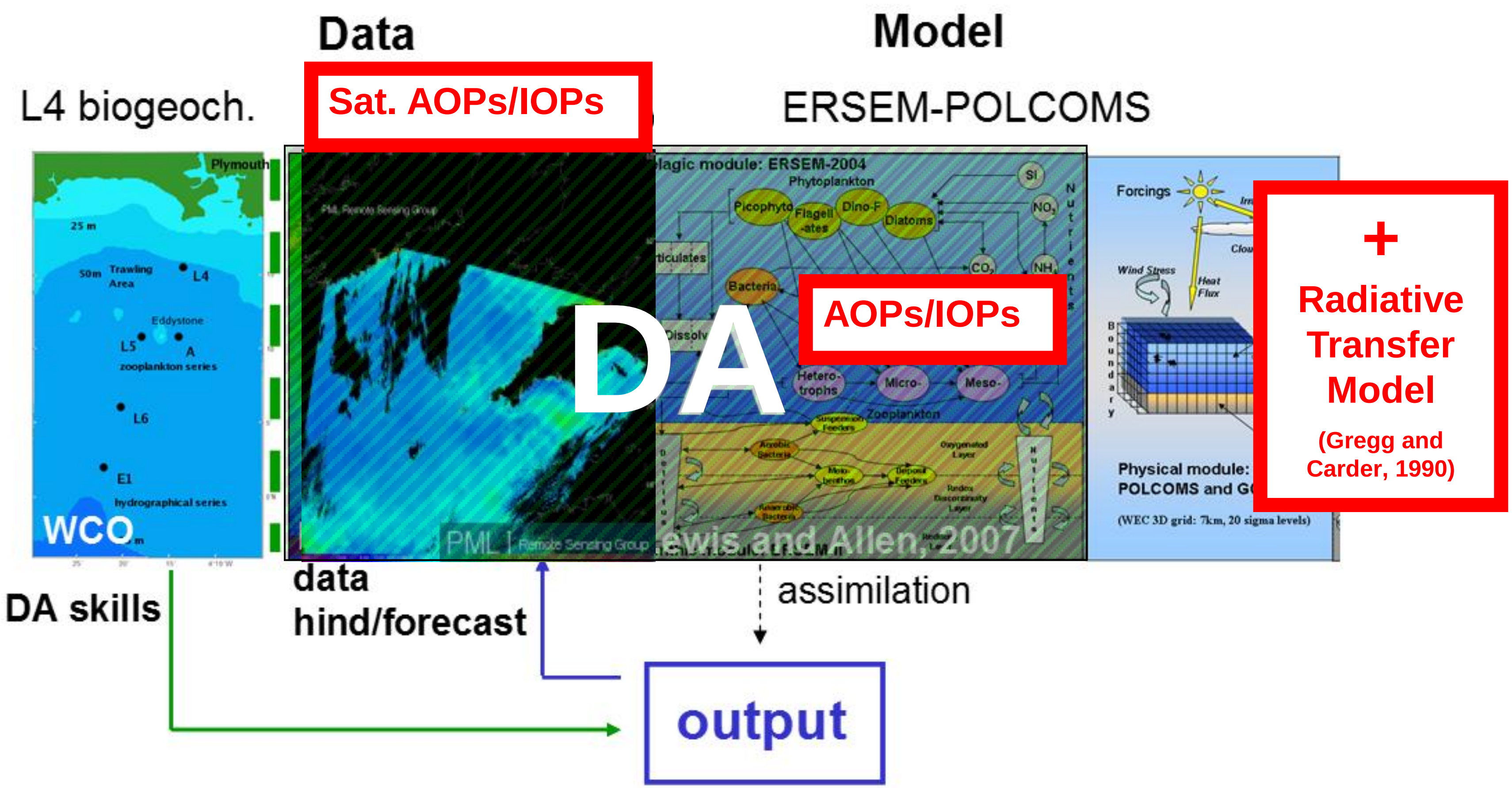
Time series

- **OC records are not homogenous in time**
    - **Atmosphere, incl. clouds**
    - **Surface effects**
    - **Vertical distribution of phytoplankton**
    - **Different satellite instruments**
- **Define selection criteria for homogenous conditions**
- **Data base shrinks if criteria are too strict**
- **Define other variables than concentrations**
    - **e.g. start of spring bloom**

ECMWF Code	Output field	Abbreviation	Units	Analysis or Forecast	Model levels	Model Grid		Needed for
						ERA40	interim	
34	Sea surface temperature	SSTK	K	Analysis (+ Forecast)	Surface	N80	N128	Water quality
137	Total column water vapour	TCWV	kg m^{-2}	Analysis (+Forecast)	Column	N80	N128	Gaseous absorption
151	Mean sea level pressure	MSL	Pa	Analysis (+ Forecast)	Surface	N80	N128	Rayleigh scattering
165	10m east wind component	10U	m s^{-1}	Analysis (+ Forecast)	Surface	N80	N128	Whitecaps, scatter, sun glint.
166	10m north wind component	10V	m s^{-1}	Analysis (+ Forecast)	Surface	N80	N128	Whitecaps, scatter. Sun glint.
206	Total column ozone	TCO3	kg m^{-2}	Analysis (+ Forecast)	Column	N80	N128	Gaseous absorption.

Table 1: Summary of ERA-interim data required for OC_CCI project.

Ongoing work: assimilation of optical properties (OP)



Can the modelling and assimilation of Apparent and Inherent OP enhance biogeochemical hindcasts in shelf-seas?