

# Electrical Resistance Tomography for Milk Powder Processing Monitoring and Control



*Brent Young and Mohadeseh Sharifi*

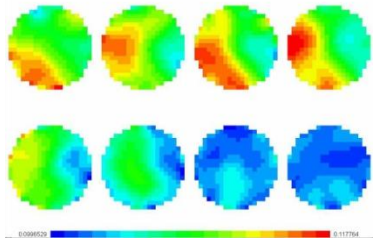
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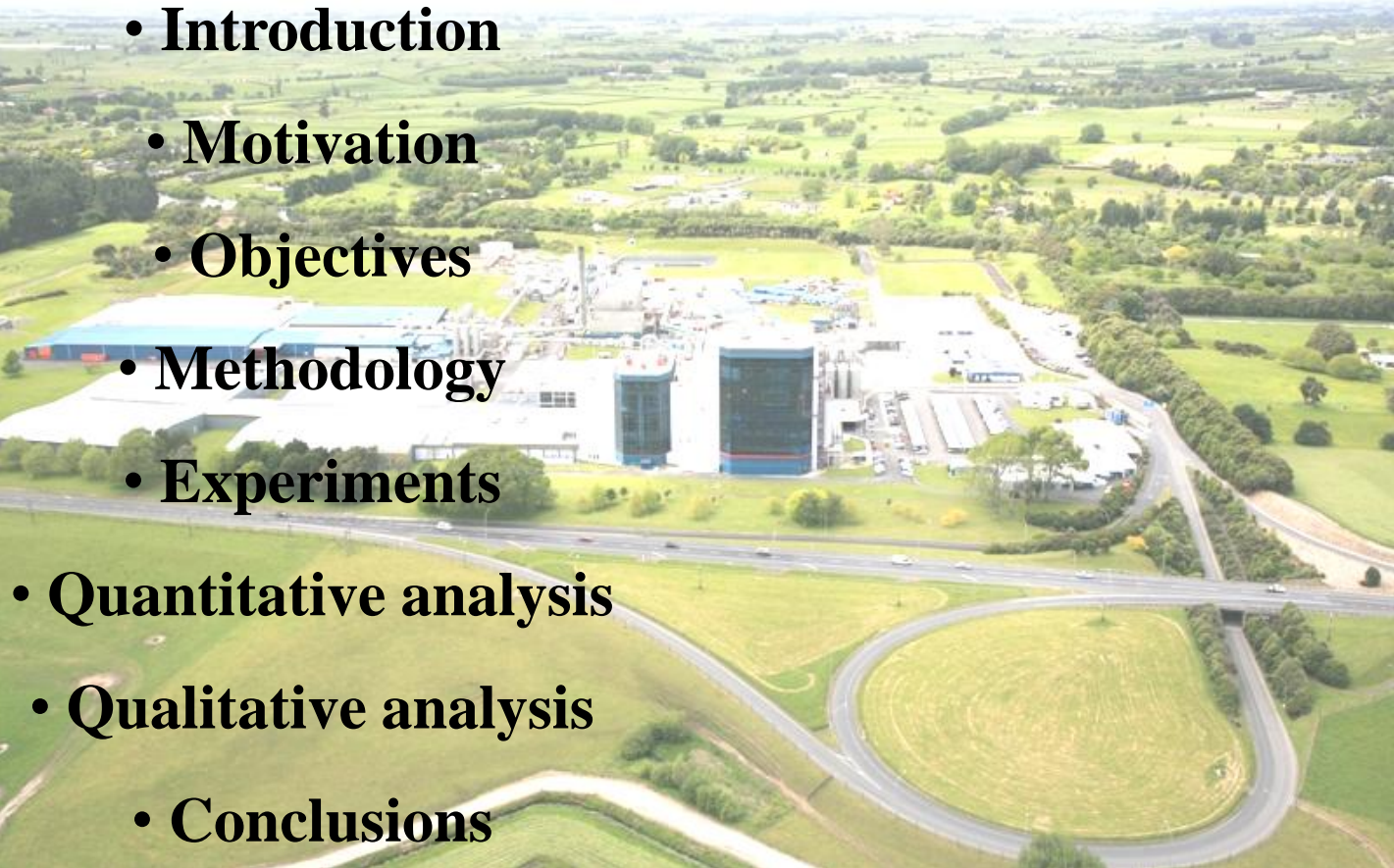
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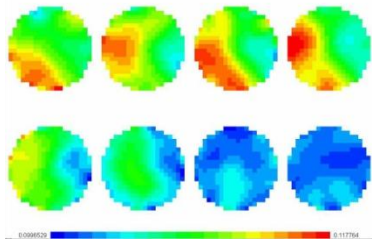


# *Presentation Outline*



- **Introduction**
- **Motivation**
- **Objectives**
- **Methodology**
- **Experiments**
- **Quantitative analysis**
- **Qualitative analysis**
- **Conclusions**

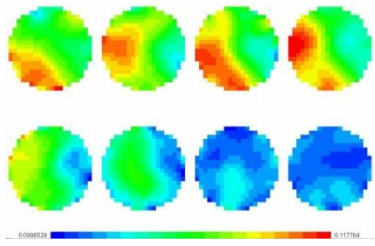
Fonterra Dairy Factory-Te Rapa, New Zealand



# *Introduction:*



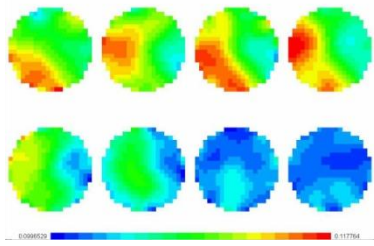
Fonterra Dairy Factory-Te Rapa, New Zealand



## *Motivation:*

- Existence of strict regulations on monitoring and control of milk characteristics to assure satisfactory final product
- Lack of online concentration monitoring sensors
- ERT => Continuous spatially distributed information => Process control
- Visual inaccessibility to internal state of opaque vessels
- Electrical Resistance Tomography:
  - Simplicity, Strong construction, High speed potential, Low cost
- Dairy plant potential situations:
  - \* Raw milk silo tanks
  - \* Standardization process
  - \* homogenization process or homogenizing mixers
  - \* On the feed pipe of the atomizer



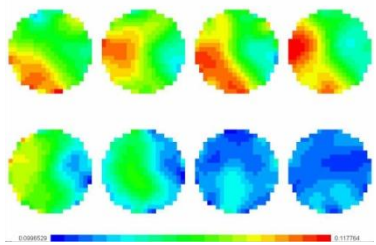


## *Objective:*



=> To develop and validate Electrical Resistance Tomography for applications in the milk processing industry:

- 1- To develop a methodology which would produce accurate measurements of concentration
- 2- Application for qualitative detection of an operating variation in a milk mixing tank
- 3- Quantitative analysis of an incomplete milk mixing situation

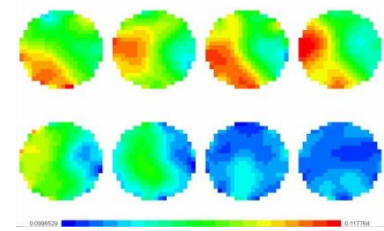


## *Methodology:*



- i. Validation of the ERT instrument (ITS P2000) for monitoring milk
  - a. Examining the application on simple tap water to understand the instrument techniques and principles
  - b. Propose a methodology for the application of the instrument on milk
  - c. Run tests to validate the “new methodology”
- ii. Monitor a milk mixing tank situation





# Preliminary Milk Experiments



## •Sample milk solution:

- Conductivity measurement => <3% error
- Concentration measurement => >98% error

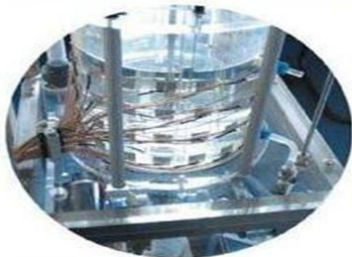


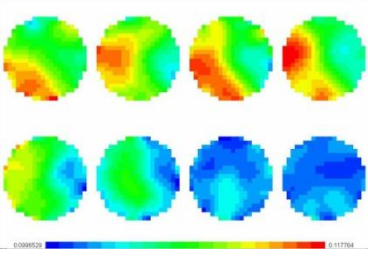
## •Similar saline solution:

- Conductivity measurement => <5% error
- Concentration measurement => <10% error

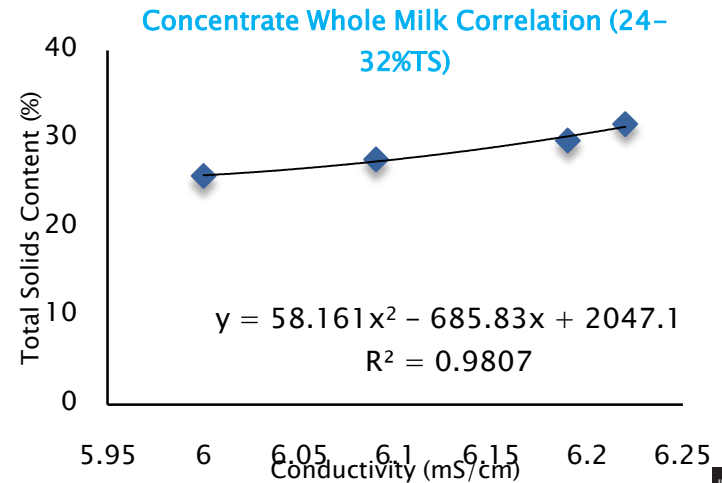
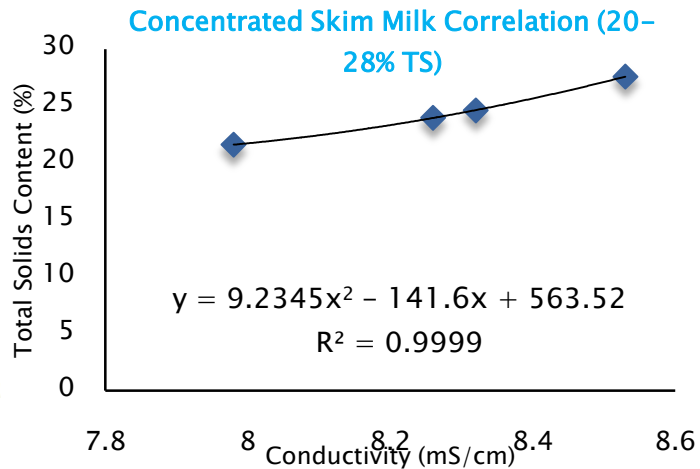
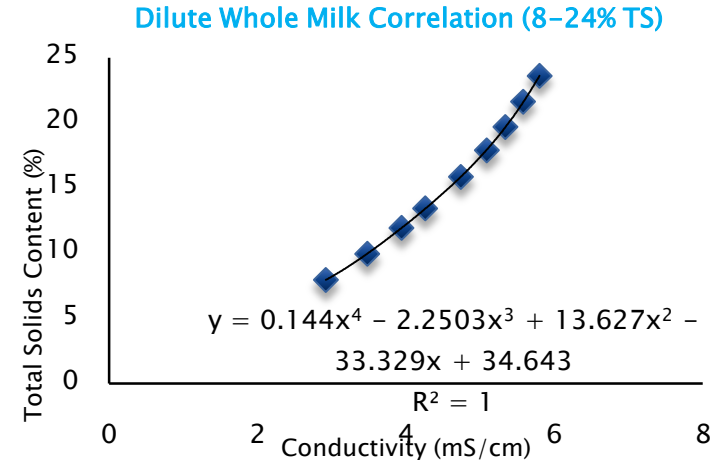
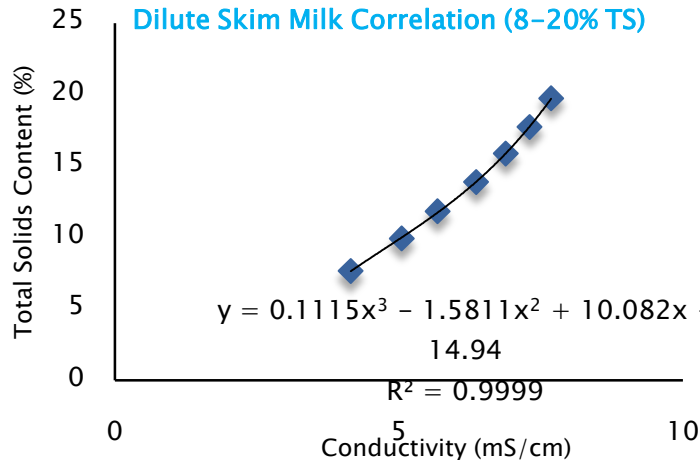


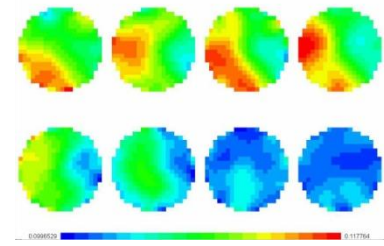
**Unsuitable conductivity-concentration conversion**





# Conductivity-Total Solids Content Correlation:

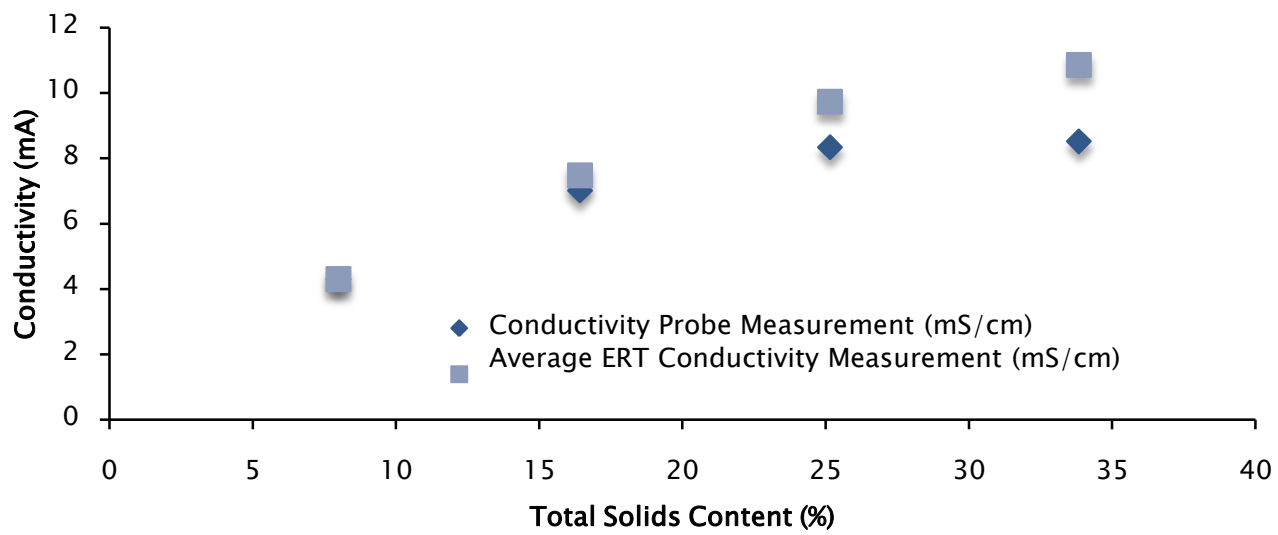




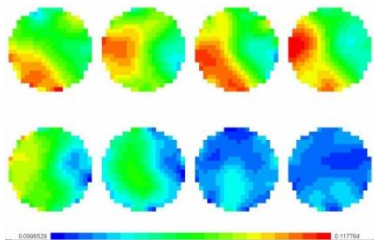
# *Increasing Conductivity Measurement Error*



Various concentration skim milk samples measured using an arbitrary reference solution and its optimum current injection



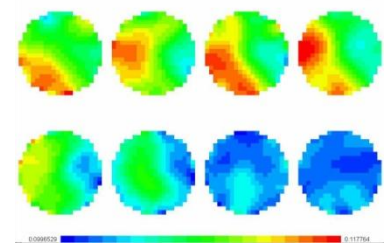
**Selection of separate reference solution and optimum current injections for each milk type and category**



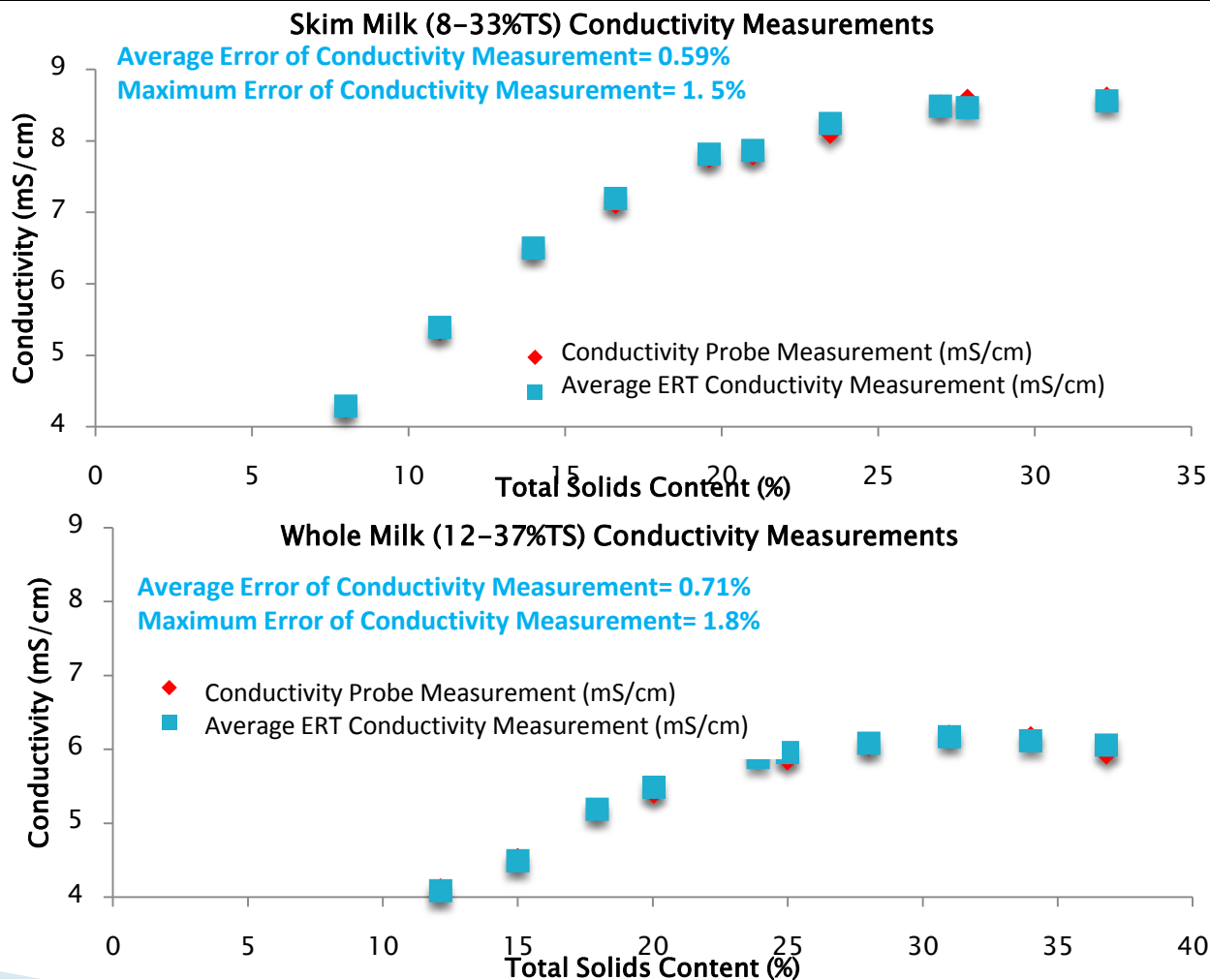
# *Defining Separate Reference Sample & Current Injections for Each Milk Category*

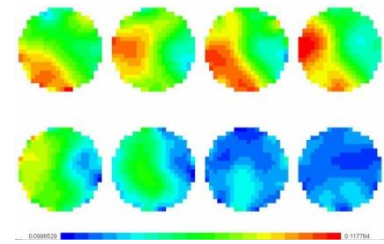


<b>Milk Type &amp; Category</b>	<b>Concentration Range</b>	<b>Reference Sample Concentration</b>
Dilute Skim Milk	8% - 20%	14%
Concentrated Skim Milk	21% - 33%	27%
Dilute Whole Milk	12% - 24%	18%
Concentrated Whole Milk	25% - 37%	31%

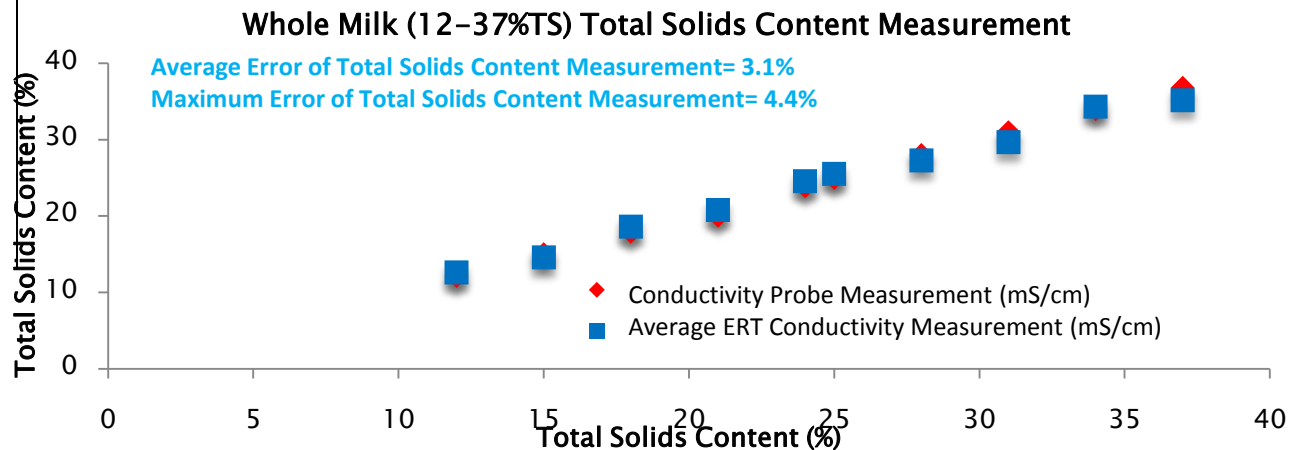
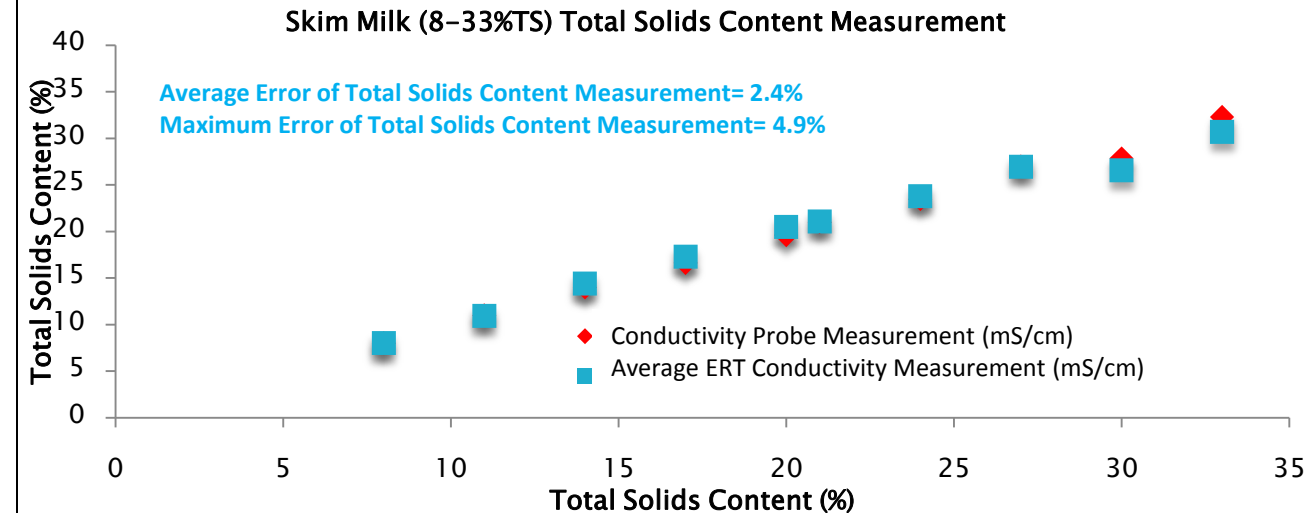


# Sample Conductivity Measurements

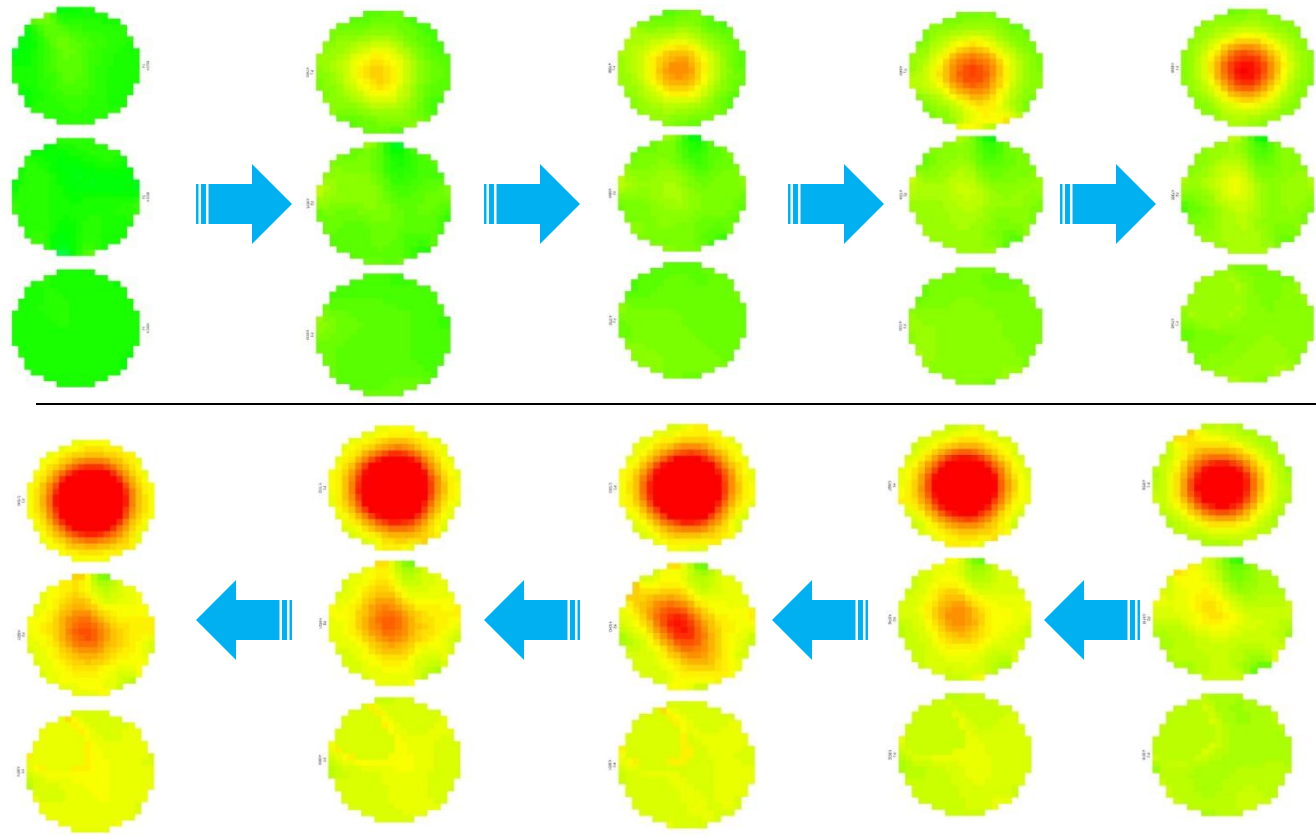
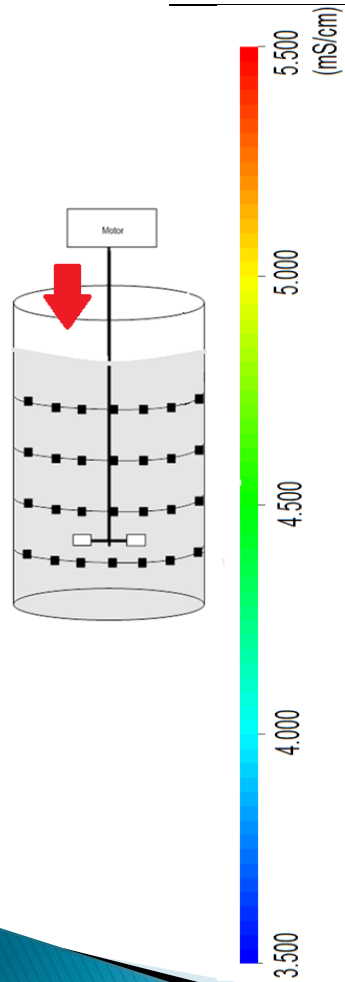
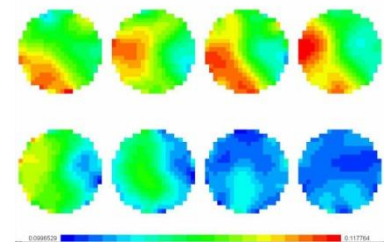




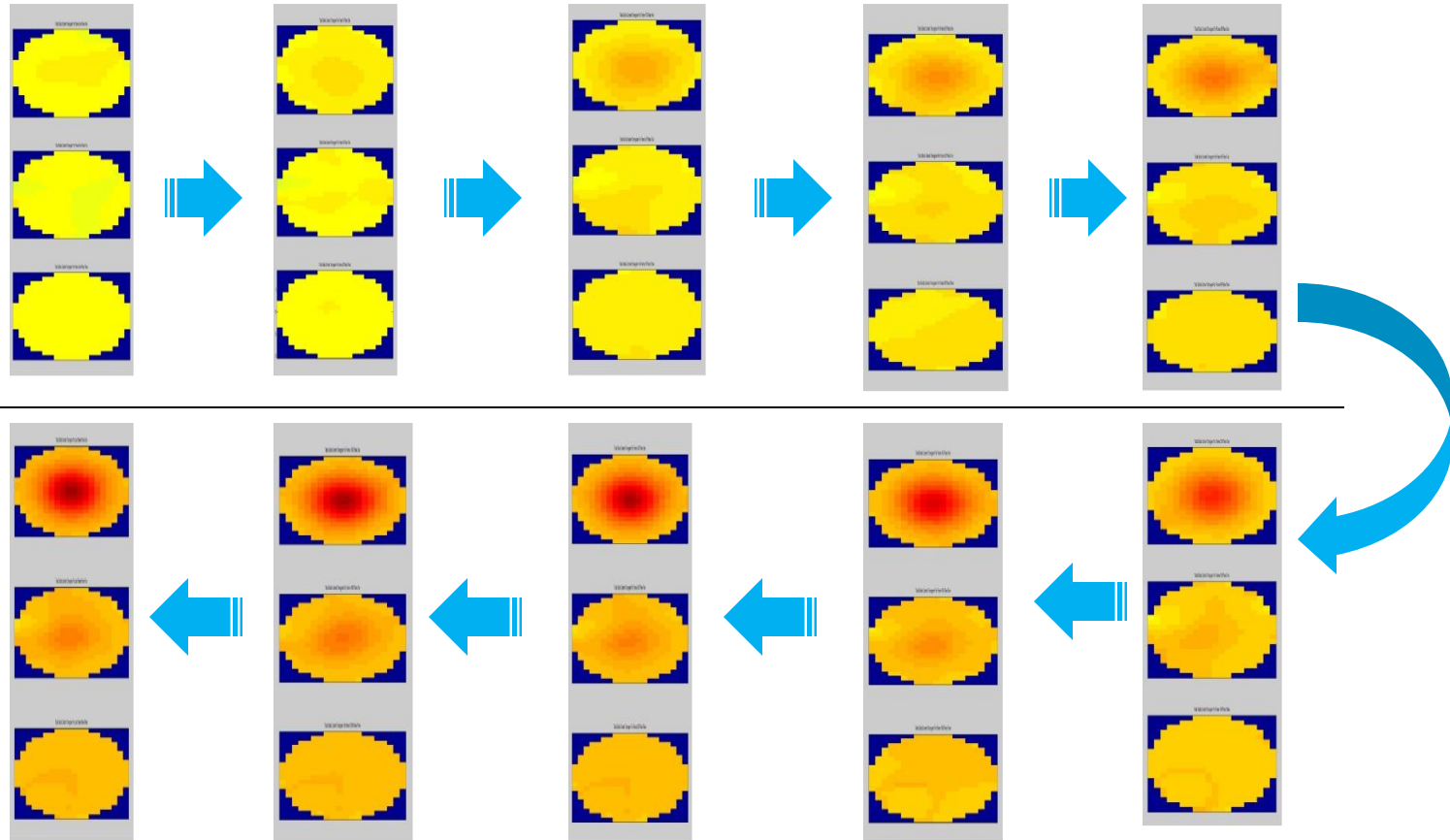
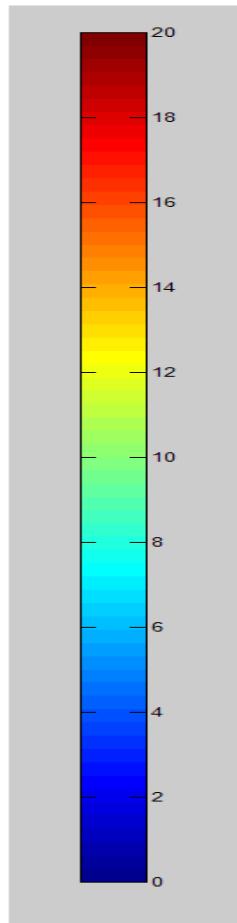
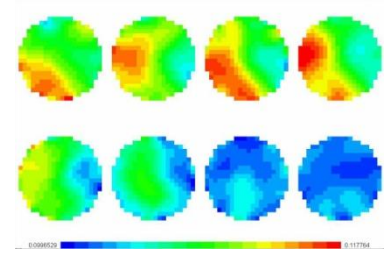
# Sample Total Solids Content Measurements



# Miscible mixing qualitative visualization: Conductivity Tomograms



# Miscible mixing qualitative visualization: Total Solids Content Tomograms



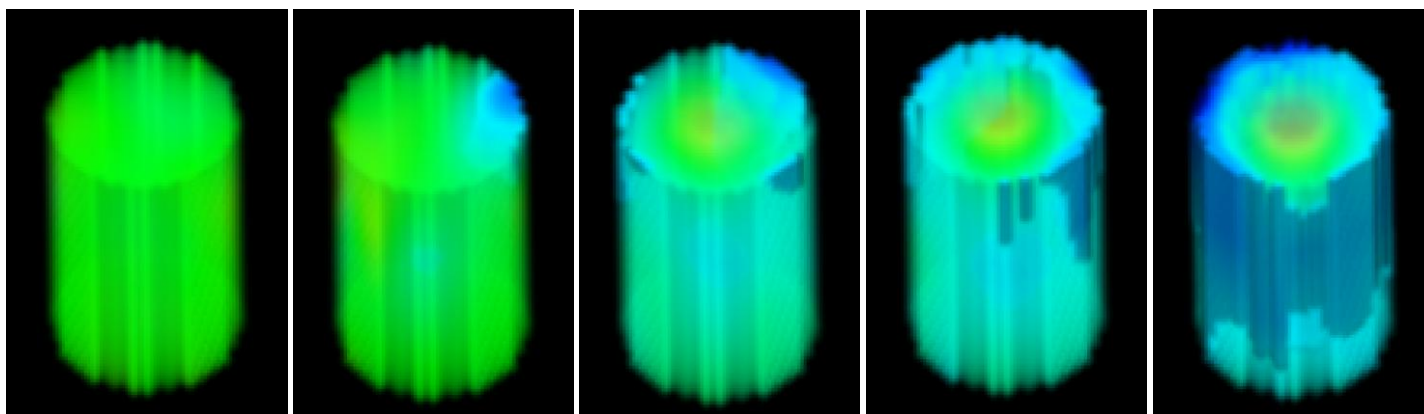


Figure 1: Addition of water to a homogenous whole milk solution

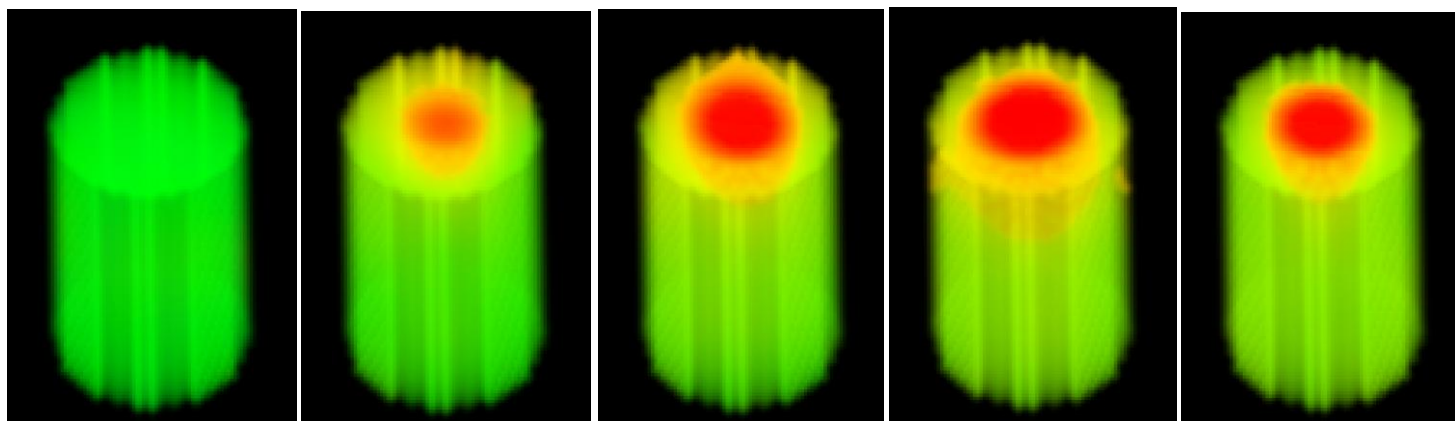
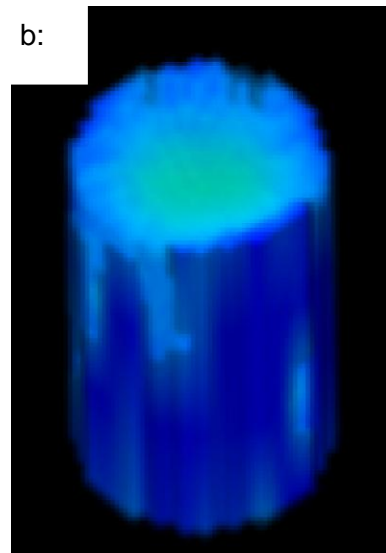
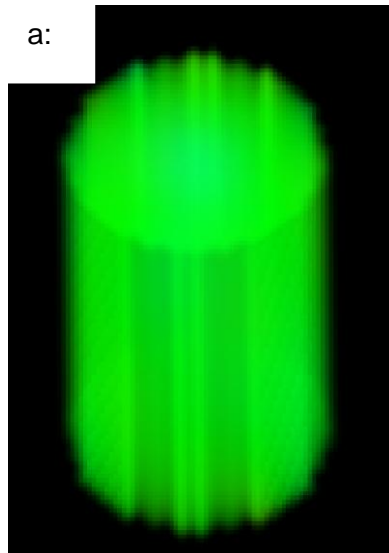


Figure 2: Addition of a higher concentration solution to a homogenous whole milk solution

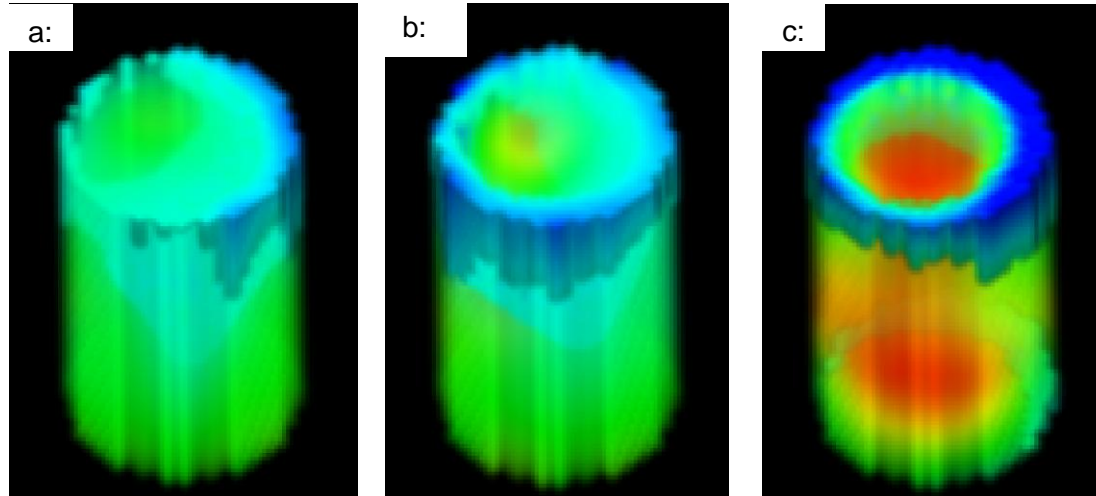
# Adulteration Visualization for a skim milk solution

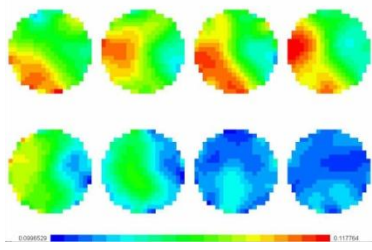
a: Desired state with no adulteration

b: After water addition

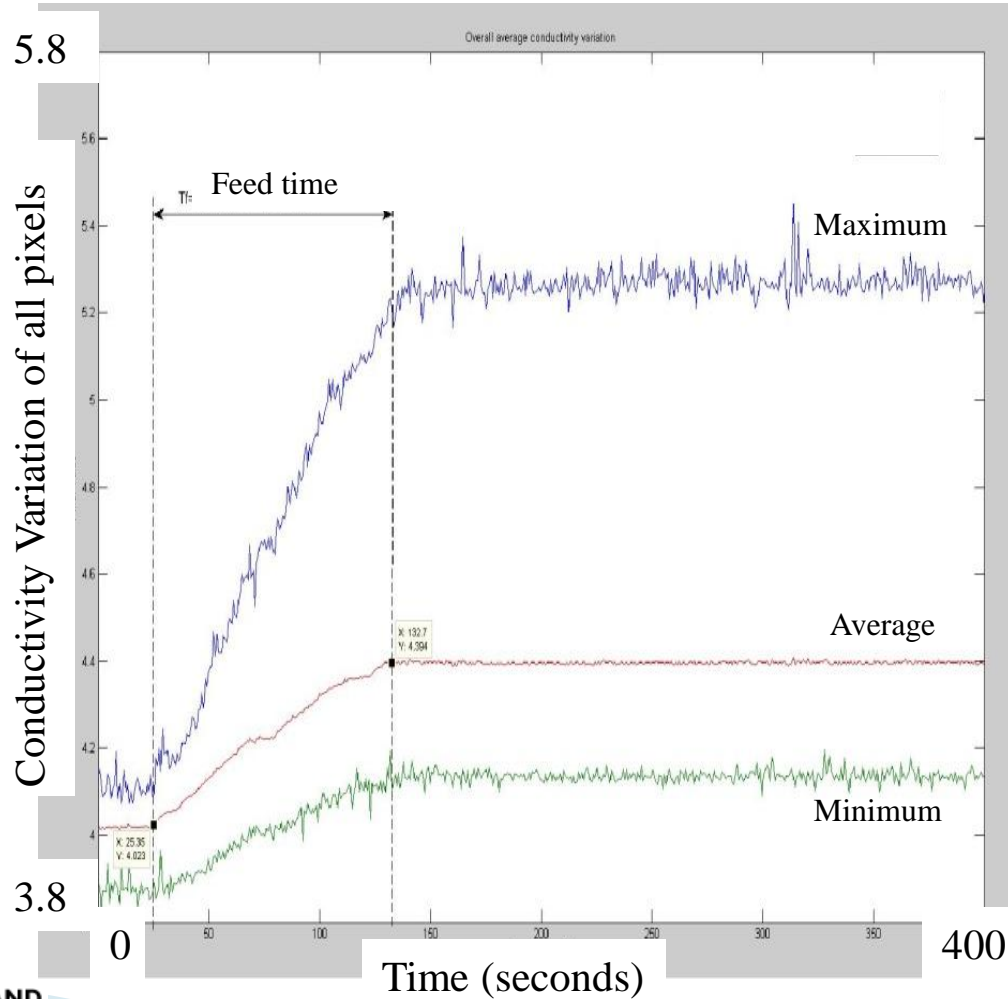


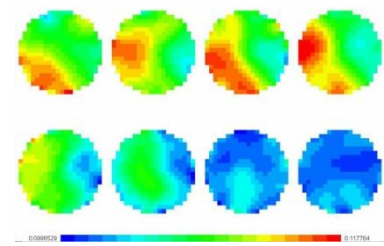
Overnight cream separation for whole milk solutions of  
a: 12.7% , b: 30% and c: 50% total solids content





# Miscible mixing quantitative visualization:





# Miscible mixing quantitative visualization:

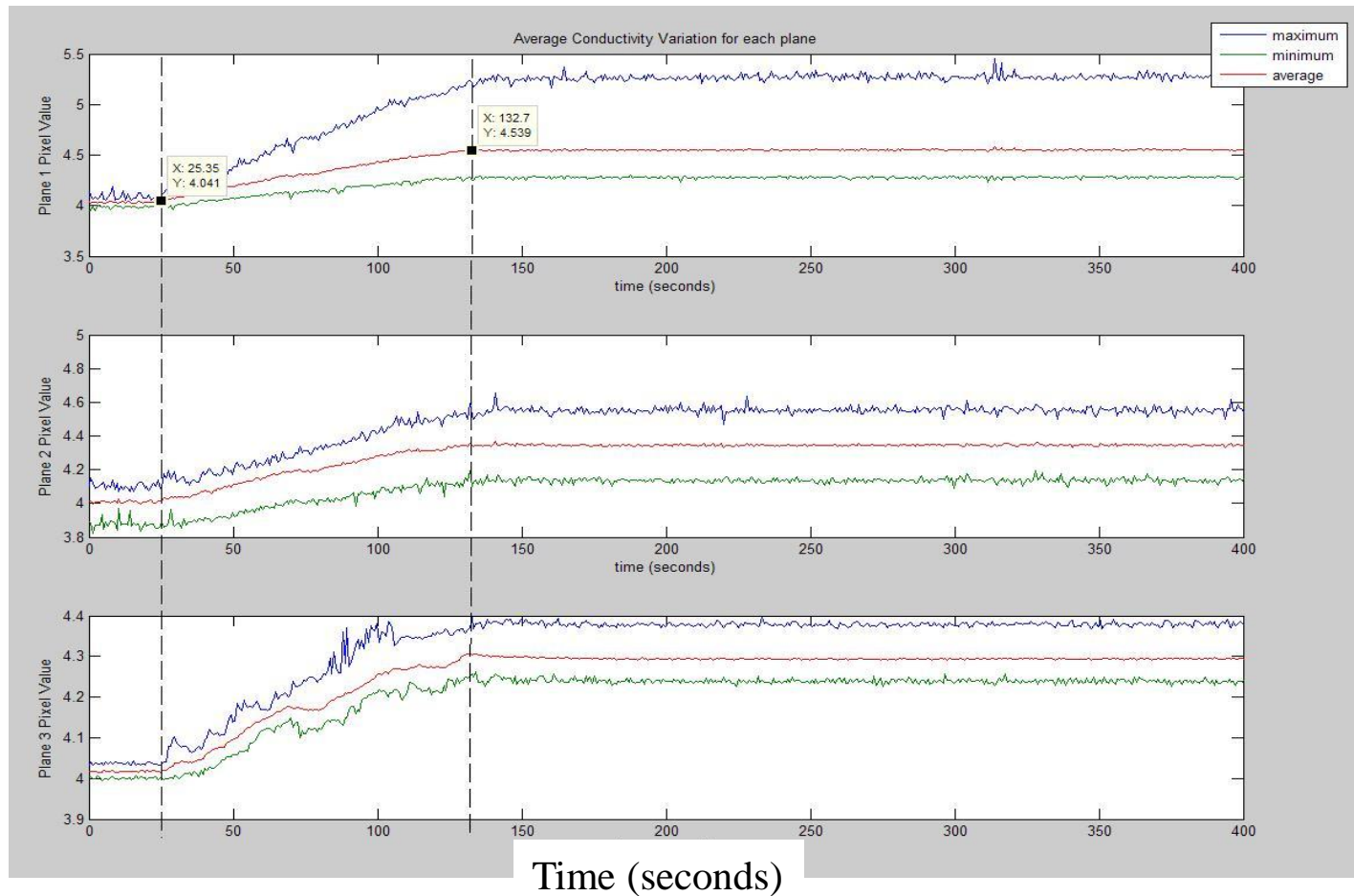


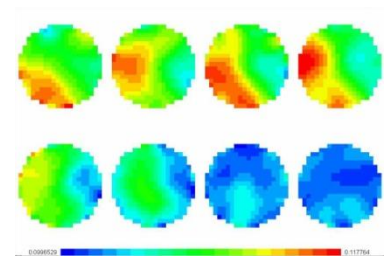
Conductivity Variation per plane

Plane 1

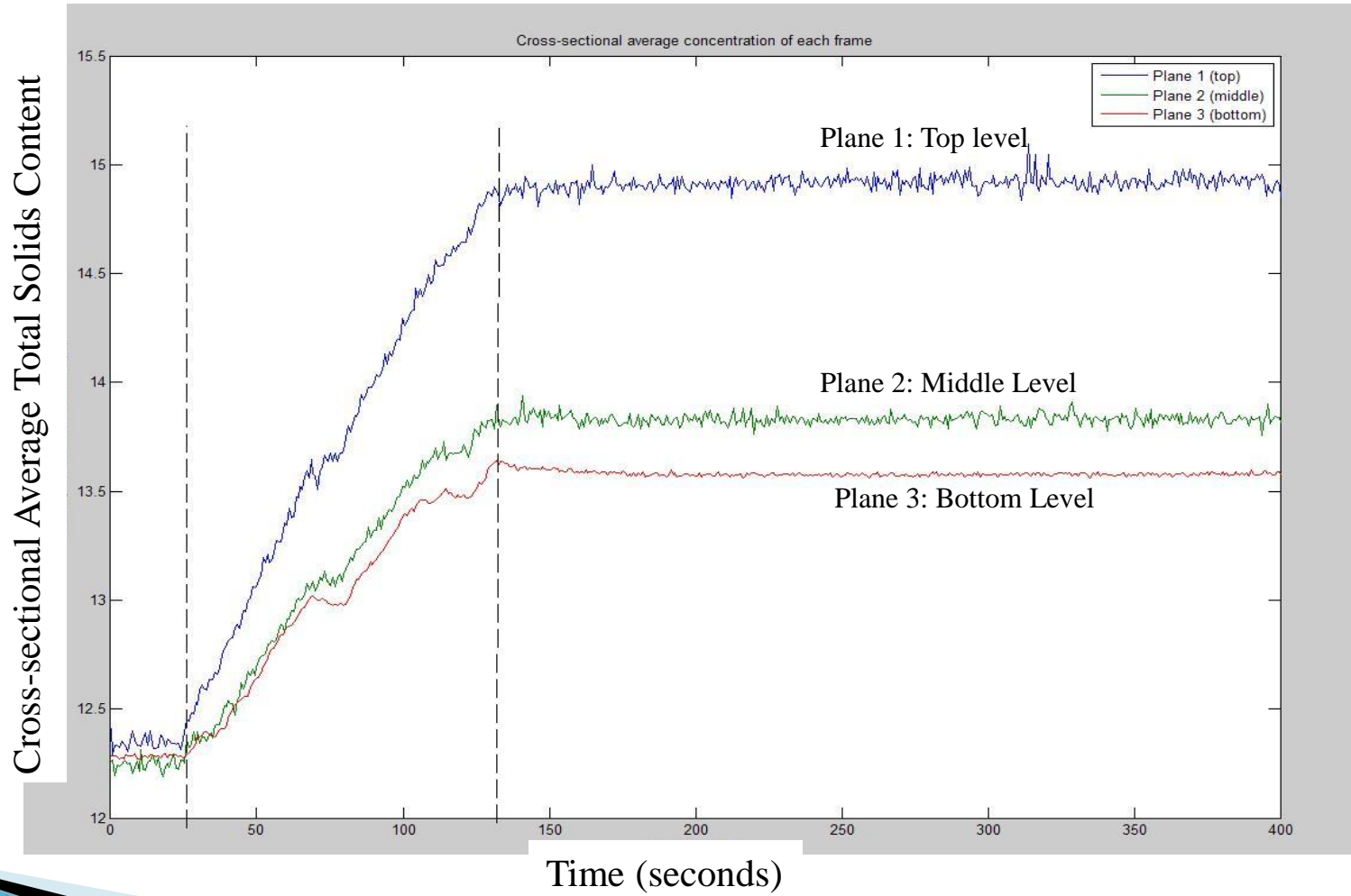
Plane 2

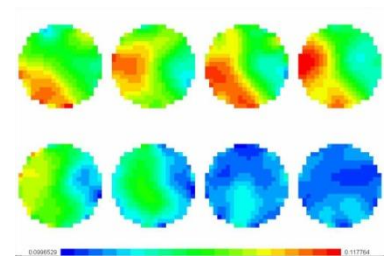
Plane 3



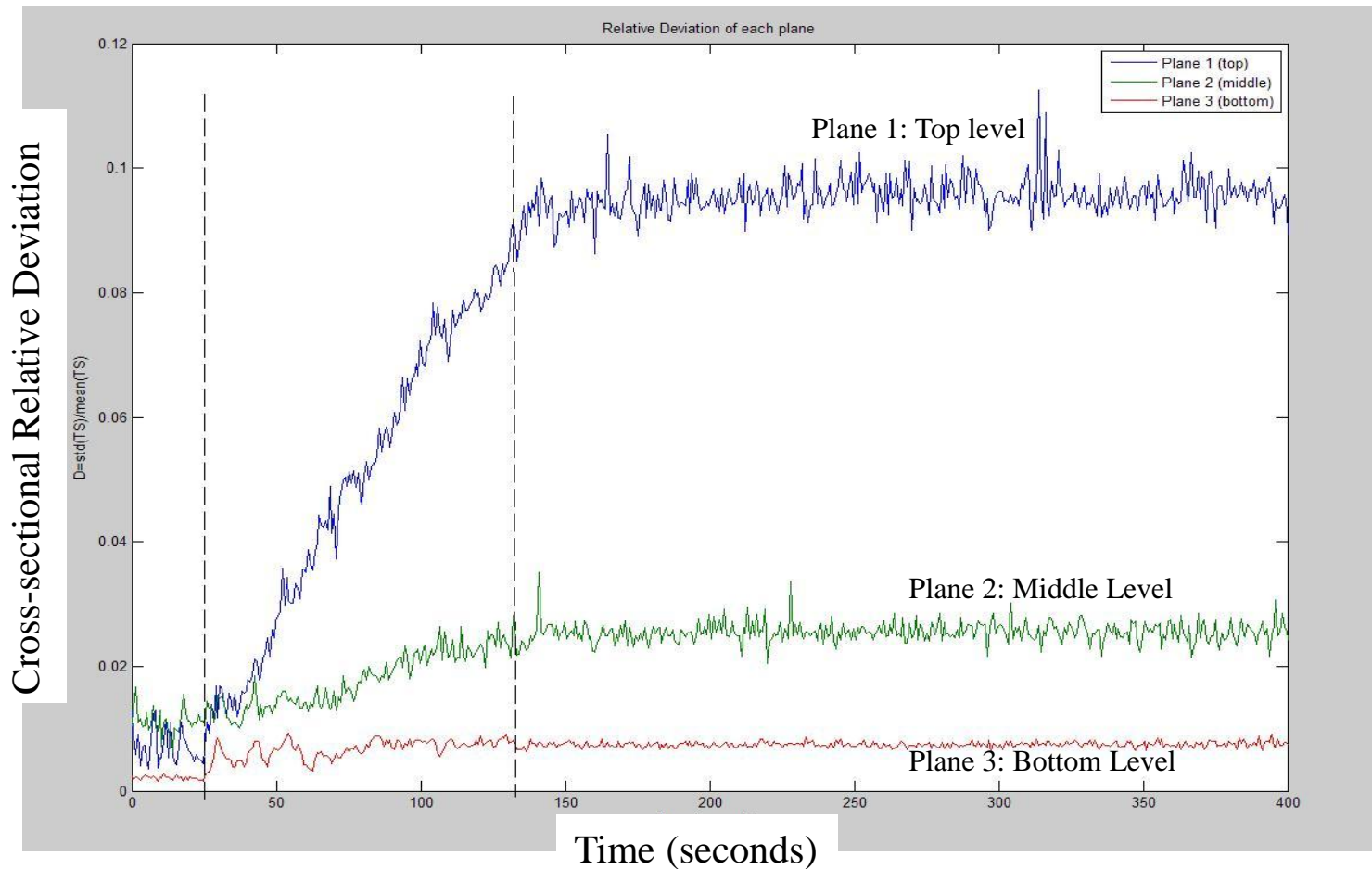


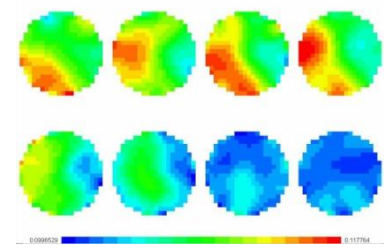
# Miscible mixing quantitative visualization:





# Miscible mixing quantitative visualization:





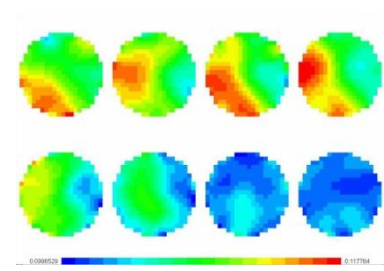
## *Conclusions :*



⇒ 1- Validation of ERT for monitoring milk

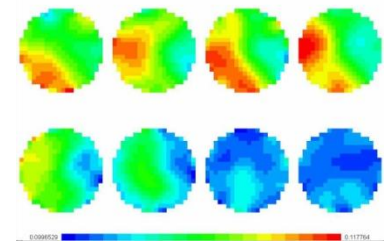
⇒ 2- Remote internal inspection into the mixing process of a milk sample extracting valuable information such as:

- Qualitative images of the milk conductivity / concentration profile
- Quantitative evaluation of the milk mixing process, e.g. feed time, mixing time, degree of homogeneity
- Average milk concentration measurement
- The ability of detecting mixing operating variations such as a nonhomogenous tank due to imperfect mixing



## *Future Work:*

- Application of ERT to higher milk concentrations commensurate to the feed fluid of the spray dryer system.
- Application of ERT to extract compositional information, e.g. fat and protein content.
- Application of ERT to a milk pipe flow-line extracting flow and velocity profile.
- Integration of ERT measurements for an industrial monitoring and control system.
- Consideration of the application for simulated potential situations.

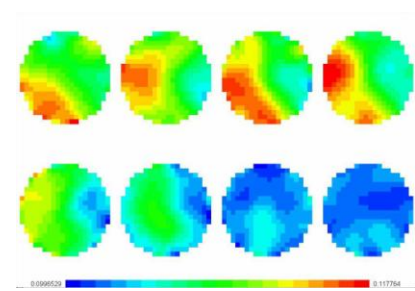


# *Acknowledgments*



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